

# ARCHEOLOGIA E CALCOLATORI

35.2

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*All'Insegna del Giglio*





ARCHEOLOGIA E CALCOLATORI



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edited by  
Anna Maria Marras, Alessio Palmisano,  
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## INTRODUCTION

The 17<sup>th</sup> edition of ArcheoFOSS, held at the University of Turin in December 2023, was titled *Open Science and Archaeology: Archiving Knowledge* and emphasized the crucial role of Open Science practices in promoting transparency, data sharing, reproducibility and collaboration within the field of archaeology. This year's edition, continuing the approach introduced in 2022, featured panel sessions where experts shared their insights on specific topics and actively engaged in discussions with the audience. Panel proposals were invited from community members, scholars and professionals eager to explore innovative solutions and stimulate discussions on Open Science practices. These proposals were openly discussed on the Conference's GitHub repository, enabling early community feedback through a transparent, non-anonymous peer-review process.

During this 2-day Conference, over 80 participants from different countries had the opportunity to discuss and exchange ideas on open source software tools and methods covering a diverse array of topics organised in six thematic panels for a total of 32 presentations:

1. *Tools, Objectives, Users: State of Art and Future Perspectives on the Sharing of Open Data in Archaeology* (panelists: Valeria Boi and Mirella Serlorenzi). This panel addressed the current state and future possibilities for open data in archaeology. It explored how digital tools and platforms are being used to share archaeological data, with a focus on enhancing accessibility, collaboration and transparency. The discussion centered on the evolving needs of users – researchers, institutions and public – and the objectives of promoting broader data sharing to advance archaeological research and public engagement in the digital age.

2. *Archaeo.social: Archaeology in the Fediverse and the Future of Scholarly Social Media* (panelists: Joe Roe and Zack Batist). This panel explored how decentralized platforms like the Fediverse can transform scholarly communication in archaeology. It examined the potential for archaeologists to engage with peers and the public through these open, federated networks, promoting more inclusive, open dialogue. By moving away from traditional social media models, this panel highlighted how archaeology can benefit from the transparency, autonomy, and collaboration that platforms like Mastodon and others in the Fediverse offer.

3. *The Roadmap to Cooperation and Transparency: Fostering Open Science Solutions in Archaeology* (panelists: Alessio Palmisano and Andrea Titolo). This panel focused on how Open Science practices can promote greater

collaboration and transparency in archaeological research. It discussed the importance of creating frameworks and tools that enable researchers to share data and methodologies more openly. The panel also emphasized the role of cooperation between institutions, researchers and public stakeholders to ensure that archaeological knowledge becomes more accessible, verifiable and reusable, thereby fostering a more transparent and inclusive research environment.

4. *Virtual Reconstruction in Archaeology with FOSS Methods and Tools* (panelists: Emanuel Demetrescu and Simone Berto). This panel explored how Free and Open Source Software (FOSS) methods and tools are revolutionizing virtual reconstruction in archaeology. Presentations showcased various open source approaches for creating and analyzing 3D models of archaeological sites and artifacts. Topics included the use of photogrammetry, 3D scanning, and the data visualization techniques to reconstruct and interpret archaeological data. The discussion highlighted the benefits of using FOSS tools, such as cost-effectiveness, flexibility, and the ability to collaborate and share data openly.

5. *Small Finds: Comparing Methodologies and Techniques for the 3D Scanning of Small Objects* (panelists: Daniele Bursich and Dario Calomino). This panel showcased the transformative potential of open source technologies in the field of archaeology, particularly when applied to the delicate task of preserving and analyzing small artifacts. It also highlighted practical applications, challenges and future directions for integrating FOSS technologies into archaeological research.

6. *Data Integration and Communication Platforms/Bridging the Gap: Platforms for Public Archaeology and Storytelling* (panelists: Lucia Marsicano and Marco Montanari). This panel highlighted how platforms like Wikipedia, combined with collaborative digital initiatives, can significantly amplify public outreach in archaeology. By providing accessible and reliable information about archaeological sites and findings, such platforms help to promote cultural tourism. This digital visibility not only educates the public, but also drives engagement with historical sites, supporting their preservation and boosting local tourism economies.

The six panels were preceded by a plenary session featuring keynote speakers Chiara Bonacchi (University of Edinburgh), Elena Giglia (Open Science Unit, University of Turin), and Elena Maragoni (Wikimedia Italy). They addressed topics such as innovative methods for analyzing the politics of the past through big data from social media, the current landscape of Open Science practices in academia, and open community projects gained by Wikimedia Italy. The plenary session was followed by a roundtable discussion

on the use and reuse of images and digital content in heritage moderated by Marco Ciurcina, Stefano Costa, Emanuel Demetrescu, Piergiovanna Grossi, Anna Maria Marras and Augusto Palombini. This provided an excellent opportunity to discuss potential solutions and challenges regarding Decree No. 161, issued on April 11, 2023, which introduced guidelines by the Ministry of Culture for determining minimum fees for the use of images related to Italian cultural heritage.

The 17<sup>th</sup> edition of ArcheoFOSS concluded with a lively exchange of ideas, reflecting the growing importance of Open Science in shaping the future of archaeological research. Participants left with a deeper understanding of the benefits and challenges associated with adopting Open Science practices, from data sharing to public engagement through digital platforms. As the field continues to evolve, ArcheoFOSS remains a critical forum for fostering collaboration, innovation and transparency. The event reaffirmed the need for an ongoing dialogue between researchers, institutions and the public to ensure that archaeological knowledge remains accessible, verifiable, and reusable. With the groundwork laid during this Conference, the community looks forward to the continued growth of Open Science initiatives in archaeology, helping to democratize knowledge and bridge the gap between academia and the broader public.

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## FOREWORD. OPEN SOURCE, OPEN SCIENCE AND COMMUNITIES IN ARCHAEOLOGY

The relationship between open philosophy and archaeology is rooted in the principles of transparency, accessibility, collaboration and democratization of knowledge. In archaeology, open philosophy promotes the sharing of data, tools and methods in a way that makes information widely accessible to researchers, professionals and the general public. One of the key benefits is that archaeological data, such as site records, 3D models and maps, can be freely shared and accessed. This openness allows not only for more comprehensive peer review and reinterpretation of findings, but also makes it possible for a wider audience to engage with and benefit from archaeological discoveries. By making data accessible, researchers around the world can collaborate more easily, bringing new perspectives and expertise to the field. Open platforms encourage international cooperation and community-driven projects, allowing both experts and amateurs to participate in meaningful ways. Sharing research methodologies and data ensures that findings are verifiable and reproducible by others, which strengthens the integrity of the research process. It also helps ensure that archaeological work is conducted responsibly and with a commitment to preserving and documenting cultural heritage for future generations.

The rise of Free and Open Source Software (FOSS) has transformed archaeological digital practice. These tools allow archaeologists to conduct advanced digital analyses, such as GIS mapping and 3D modeling, without the high costs associated with proprietary software (<https://open-archaeo.info>). This makes the technology more accessible, especially to institutions or individuals with limited resources, allowing more researchers to participate in cutting-edge projects. Open source refers to software and tools that anyone can freely use, modify, and share. In archaeology, the availability of open source software has been particularly impactful. Programs such as QGIS for geographic information systems, MeshLab for 3D modeling, and R for data analysis are widely used by archaeologists to process and visualize data. These tools are not only cost-effective, but also customizable, allowing researchers to adapt them to meet the specific needs of their projects. This flexibility is crucial for archaeology, where datasets and research questions can vary greatly across sites and contexts.

The open source approach encourages collaboration across the global archaeological community. Researchers can share their improvements or customizations of tools, helping to refine the resources available to everyone. This spirit of collaboration is exemplified by initiatives such as ArcheoFOSS,

an annual event that brings together professionals and enthusiasts to discuss and promote the use of open source software in archaeology.

Both Open Science and FOSS are built on similar philosophies of openness (MOSCATI 2017), transparency and collaboration. In the realm of research, Open Science encourages the use of FOSS to avoid dependency on closed, proprietary systems that can limit the replicability of research. For example, using open source software ensures that research methods can be fully understood and reused by other scientists, which is a fundamental aspect of reproducibility in science. Both movements are supported by strong, collaborative communities. Open Science relies on the contributions of researchers who share their data, methods and findings openly, while FOSS thrives on the contributions of programmers and developers who continually improve open source software. The collaborative nature of both movements encourages innovation, knowledge-sharing and global cooperation.

Communities, both within and beyond academia, play a crucial role in the open source and Open Science movements. Collaboration among researchers, institutions and the public is essential for maximizing the benefits of open practices in archaeology. Among professionals, communities of practice have emerged around the use of open tools and data. For example, ArcheoFOSS serves as a hub for archaeologists interested in integrating open source software and Open Science principles into their work. These gatherings allow researchers to share their experiences, tools and methods, building a collective knowledge base that drives the discipline forward.

At the same time, involving local and global communities in archaeological research has never been more important. Open Science provides the means for the public to engage directly with archaeological discoveries, whether through contributing to research projects or by accessing reliable, open data. Platforms such as Wikipedia and other open knowledge repositories enable archaeologists to disseminate their findings to a wider audience, helping to raise awareness of cultural heritage and making information accessible to anyone with an Internet connection. While the shift toward open practices in archaeology presents many opportunities, it also comes with challenges. One issue is the need for training and infrastructure to support the use of open source tools and the adoption of Open Science practices. By making archaeological research more accessible and inclusive, these movements democratize knowledge and open the field to new voices and perspectives. Open practices ensure that archaeological data and findings are preserved for future use, offering long-term sustainability for the discipline.

It is not just about software, but also about the use of platforms and the development of new skills, particularly those referred to as Digital

Humanities (MOSCATI 2023), which can foster collaboration. Repositories such as GitHub are widely used by the archaeological ‘nerd’ community. There are projects such as Pelagios Network (<https://pelagios.org>), which is a long-running initiative that links information online through common references to places (VITALE, DE BEER 2019). Pelagios represents a community of individuals, projects and organizations working with historical data. Part of its work in evolving the LOD (Linked Open Data) ecosystem involves developing open methods and tools. Recogito is a web-based annotation tool developed as part of the Pelagios project. It was created to facilitate the annotation of historical texts and maps, allowing users to mark up place references, entities, events and other elements within documents. Recogito is designed to support collaborative annotation efforts and to enable scholars and enthusiasts to create structured data from unstructured text (<https://recogito.pelagios.org/>; CANTONE, CARVALE 2019).

The importance of the role of communities, including researchers, experts and citizens, in Open Science and archaeology projects can be highlighted through various types of initiatives such as the Scottish Atlantic Maritime Past: Heritage, Investigation, Research and Education Project (McCARTHY, BENJAMIN 2019; <https://www.wessexarch.co.uk/our-work/project-samphire>). It was geographically focused on the West coast of the Scottish mainland and was undertaken between 2013 and 2015, resulting in a large number of new archaeological discoveries, including shipwrecks, aircraft, and other material of a much more varied nature than what is typically found through large-scale hydrographic surveys. This type of initiative exemplifies the need for tailored approaches to specific geographical contexts, demonstrating the importance of localized attention, which enables the discovery of much more varied material compared to traditional methods.

Human-AI (CASINI *et al.* 2023; [https://bit.ly/NSR\\_floodplains](https://bit.ly/NSR_floodplains)) utilizes pre-trained deep learning models to identify archaeological sites in the Mesopotamian floodplains using satellite imagery and vector shapes from annotated data. Integration of domain expertise was crucial in refining dataset construction and evaluating model predictions. The collaboration between humans and AI enables efficient site detection and dataset refinement, enhancing archaeological analysis in the region.

There are also crowdsourcing projects, very common in Digital Humanities projects, such as Micropasts (<https://micropasts.org/>), which saw collaborative participation in the realization of various types of projects, from transcription to tagging. The long-standing ArcheoFOSS community (GROSSI 2019), which began as an Italian initiative in 2006, is increasingly shifting towards international channels, thanks in part to the use of platforms such as Telegram and its embrace of multilingualism. This community

remains tightly knit while continually expanding its focus beyond just technological aspects, engaging deeply with ethical and social dimensions as well. Through this evolution, ArcheoFOSS has become a dynamic space for collaboration and knowledge exchange, enriching both its members and the broader archaeological and digital humanities landscapes.

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## REFERENCES

- CANTONE F., CARVALE A. 2019, *Archeologia e Calcolatori. Classificazione geografica e tematica per la condivisione della conoscenza*, in P. MOSCATI (ed.), *30 anni di Archeologia e Calcolatori. Tra memoria e progettualità*, «Archeologia e Calcolatori», 30, 93-107 (<https://doi.org/10.19282/ac.30.2019.07>).
- CASINI L. et al. 2023, *A human-AI collaboration workflow for archaeological sites detection*, «Scientific Report», 13, 8699 (<https://doi.org/10.1038/s41598-023-36015-5>).
- GROSSI P., COSTA S., JAIA A., MALATESTA S.G., STASOLLA F.R. 2019, *ArcheoFOSS: passato, presente e prospettive future*, «Archeologia e Calcolatori», 30, 441-445 (<https://doi.org/10.19282/ac.30.2019.25>).
- MCCARTHY J., BENJAMIN J. 2019, *Project SAMPHIRE: Crowdsourcing maritime archaeology data off Scotland's West coast*, «The Journal of Island and Coastal Archaeology», 14, 2, 267-290.
- MOSCATI P. 2017, *Open Data, Open Knowledge, Open Science: quali prospettive?*, in M. SERLORENZI, I. JOVINE (eds.), *Pensare in rete, pensare la rete per la ricerca, la tutela e la valorizzazione del patrimonio archeologico. Atti del IV Convegno di Studi SITAR (Roma 2015)*, «Archeologia e Calcolatori», 9, 137-140 (<https://doi.org/10.19282/ACS.9.2017.12>).
- MOSCATI P. 2023, *L'informatica archeologica nell'era postdigitale*, in F. CIOTTI (ed.), *Digital Humanities. Metodi, strumenti, saperi*, Roma, Carocci, 282-298.
- VITALE V., DE BEER S. 2019, *What are urban gazetteers and why do we need them?*, «European Tech», 12 (<https://pro.europeana.eu/page/issue-12-pelagios#what-are-urban-gazetteersand-why-do-we-need-them>).



## AMPLIFYING ARCHAEOLOGICAL OUTREACH: THE IMPACT OF WIKIPEDIA AND COLLABORATIVE INITIATIVES ON CULTURAL TOURISM

### 1. PREFACE

The advent of digital platforms has revolutionized the way information is disseminated, and Wikipedia has emerged as a pivotal tool in democratizing access to knowledge (HINNOSAAR *et al.* 2021; MARWICK, SMITH 2021). In the realm of archaeology, leveraging such platforms can enhance public engagement and cultural understanding. In this paper, we outline the collaborative efforts undertaken to utilize Wikipedia as a tool for archaeological outreach. This narrative forms the first part of a comprehensive analysis, with the second segment dedicated to statistical analysis. The projects discussed herein are part of an ongoing initiative, and although the data are not yet complete, the initial insights have prompted us to present these preliminary findings. We will base our analysis on statistical theory to ensure a robust discussion.

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### 2. INTRODUCTION: WIKIPEDIA AS A CATALYST FOR ARCHAEOLOGICAL OUTREACH

This research is part of broader collaborative efforts involving academic institutions and local government aimed at democratizing information and bolstering cultural tourism through digital means. Our engagement with Wikipedia began with a focus on the archaeological heritage of Verona, under the auspices of the Soprintendenza Archeologia, Belle Arti e Paesaggio per le Province di Verona, Rovigo e Vicenza (Superintendency VR-RO-VI) and the University of Verona. This project, initiated in 2017, aimed at enhancing the visibility and accessibility of archaeological sites through the creation of Wikipedia articles. Furthermore, the ongoing project combines the creation and enhancement of Wikipedia entries with the collection of site visitation data and employs statistical methods to analyze relationships and assess impact and symbiosis between them. This paper presents a work in progress of the efforts made and the results obtained so far.

#### 2.1 *The Public Archaeology in Verona initiative (2017) and its outcomes*

The initial project was centered around Verona's Roman heritage, thanks to a collaboration among the University of Verona, the Superintendency VR-RO-VI and Wikimedia Italia. This initiative witnessed the creation of Wikipedia articles for key archaeological sites, notably Corte Sgarzerie. Within the

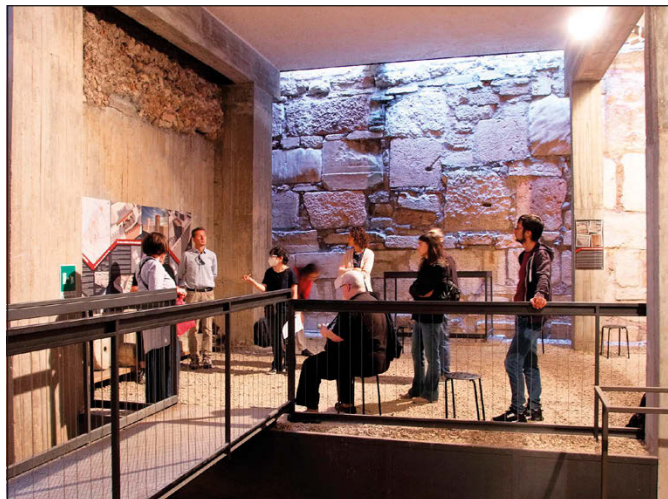


Fig. 1 – Visit to archaeological area of via San Cosimo, Verona (Wikipedia e Archaeology Project) (Patafisik, via Wikimedia Commons).

first year following these articles' inception, data indicated a 5.9% increase in visitor numbers, underscoring the project's immediate impact (CENCI, GROSSI 2019). Even when we had an interruption of activities during the Covid-19 lockdown, the observation was repeated and an important increase in visits was found after 5 years.

## *2.2 The Wikipedia and Archaeology GLAM Project (2023): expansion and engagement*

Building upon the success of the initial efforts, the Wikipedia and Archaeology GLAM Project ([https://it.Wikipedia.org/wiki/Progetto:GLAM/Wikipedia\\_e\\_archeologia](https://it.Wikipedia.org/wiki/Progetto:GLAM/Wikipedia_e_archeologia)) was launched to further enhance and create Wikipedia articles and was extended to all the archaeological areas of the Superintendency VR-RO-VI, not only those of Verona. This phase was marked by a series of workshops, photographic campaigns, and guided tours, designed to engage the community and improve the quality and accuracy of the information provided on Wikipedia (Fig. 1). The project was promoted by Wikimedia Italia, with the approval and support of Superintendency VR-RO-VI.

## *2.3 The Wikipedia and Archaeology across borders GLAM Project (2024): analyzing long-term and international impacts*

The ongoing project involves further translation of articles into multiple languages and continuous monitoring of site visits in relation to Wikipedia

articles views. This work aims to provide a more comprehensive understanding of how sustained digital outreach can influence both, public engagement with site visitation over a longer period and cultural awareness. It is important to note that we face challenges, particularly with the variability in data recording practices at different sites, which complicates long-term analysis. Future efforts will aim to standardize data collection methods and expand the geographical scope of the project to improve the reliability and applicability of our findings. The forthcoming analysis is part of this project. It incorporates a detailed statistical evaluation of the data collected throughout the course of the past projects. By combining these findings with the narrative outlined in this section of the article, we aim to provide a comprehensive overview of the impact of Wikipedia on public engagement with archaeological heritage.

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### 3. CONTEXT AND HYPOTHESIS

Since the rise of accessible information, people have access to more data and knowledge on several topics, from hard science like quantum physics, to humanities like archaeology. With the explosion of free information immediately accessible on either computers or mobile devices people are able to know about what organizations, and institutions are doing, and promoting. This covers all demographics, even the older generations as shown in CHAKRABORTY *et al.* 2013, in fact the rapid development of Internet information technologies has radically altered the landscape for collecting and processing information. The spheres in which information is available and shared are many, for example academic, economic or societal, as mentioned by BUHALIS *et al.* 2011; SHAMIR *et al.* 2015; GRIGGIO *et al.* 2019 among others. One of the fields rarely investigated is cultural tourism, for example visits to archaeological sites. In this section, we explore how accessible digital information impacts the physical visits to archaeological sites and vice versa, how visits can trigger further access to accessible information and hence increase cultural awareness and understanding, completing a cognitive circle of physical and digital knowledge. Our hypothesis is two-fold: on the one hand, the more digital information is viewed, the more this information influences decisions on visiting the physical sites and on the other hand, the physical visits to sites trigger the search for further information.

#### 3.1 Data

The data was collected for two sites: 1) Corte Sgarzerie and 2) Cripotortico Romano Vicenza. The data about the Wikipedia views came from Wikipedia reports on pageviews from the Wikipedia article [https://it.wikipedia.org/wiki/Corte\\_Sgarzerie](https://it.wikipedia.org/wiki/Corte_Sgarzerie) (Corte Sgarzerie, Digital 2024) and

from the Wikipedia article [https://it.wikipedia.org/wiki/Criptoportico\\_romano\\_\(Vicenza\)](https://it.wikipedia.org/wiki/Criptoportico_romano_(Vicenza)) (*Criptoportico, Digital* 2024); the data about the site visits came from the official reports of the areas (*Corte Sgarzerie, Physical* 2024; *Criptoportico, Physical* 2024). The aggregation level was monthly for Corte Sgarzerie and annually for Criptoportico Romano. We also split the data on Wikipedia views between platforms (desktop and mobile) to enhance the analysis. Some of the data on site visits was incomplete, for example lack of data points for 2022 for Corte Sgarzerie, however there is a work in progress, which is part of the central objectives of the entire project, to have complete datasets for future analysis.

### 3.1.1 Methodology

Firstly we analyzed the distribution of data, and established its relevant parameters like mean, median, range, standard deviation and interquartiles. We employed the Jarque-Bera test to assess normality, and adhered to standard definitions for mean, median, and standard deviation. Our analysis involved identifying outliers and anomalies in the data, such as the impact of Covid-19 on visitation. Any data points falling outside three standard deviations from the mean were treated as outliers. Then we performed data engineering techniques and treated outliers and anomalies accordingly so we could withdraw results with statistical confidence. Anomalies and outliers were extracted from the main *corpus* of data. We also performed a paired t-test for statistical significance on the impact of digital information versus physical visits to sites by comparing visits when the Wikipedia articles were not existent and when they were up and consulted.

After calculating correlation coefficients between datasets, a behavioral pattern was established. To achieve this, we shifted the data by one period (lagged correlation) and formulated our hypotheses that: 1) Wikipedia views preceded visits to actual sites as implied by BOUKAS, 2008 and 2) that visits to sites triggered further curiosity and research on Wikipedia. It was used the standard Pearson Correlation Coefficient formula.

## 4. FINDINGS

### 4.1 Corte Sgarzerie

For Corte Sgarzerie, we omitted the Covid-19 months when the site was closed, including the months from May to August 2021 which still had Covid-19 effects on visitors. Data passed the Jarque-Bera test so we assumed normality, however we also worked with median and interquartile ranges. We omitted the months when the site was closed, these were January 2014, August 2014, November 2014, and August 2015, and also found 1 outlier outside 3 standard deviations from the mean in 100 data points, which was

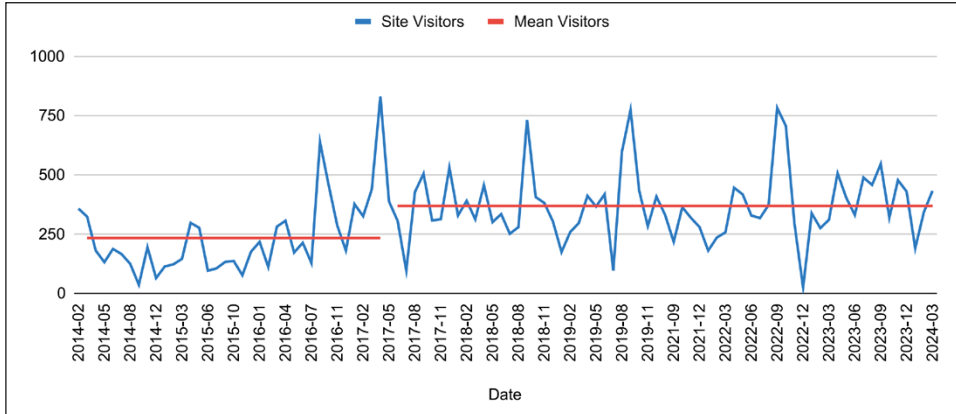


Fig. 2 – Site visitors and mean visitors before and after Wikipedia page was up for Corte Sgarzerie.

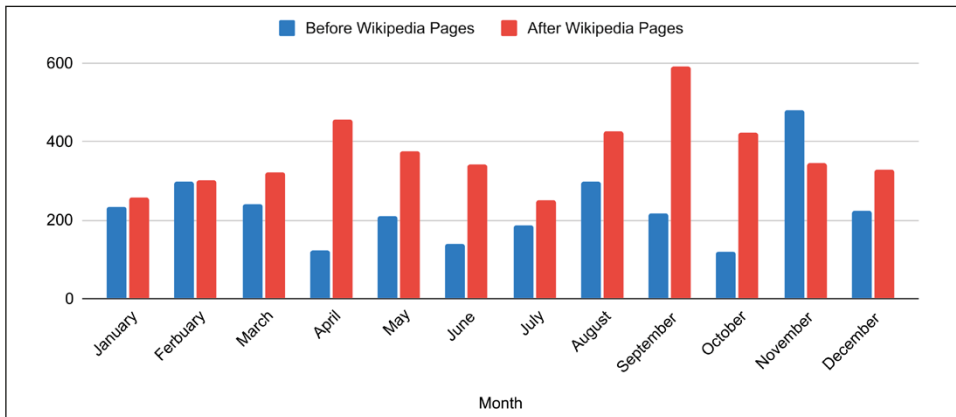


Fig. 3 – Site visitors before Wikipedia pages and after Wikipedia pages monthly comparison for Corte Sgarzerie, excluding the Covid-19 months.

omitted as it accounted for 1% of the total data. This outlier corresponded to March 2014 and was due to a FAI (Fondo Ambiente Italiano) event that spiked the number of visitors in that month. Finally we filtered the data to analyze only ordinary visits to the site. The paired t-test with  $H_0: \mu_{\text{before}} = \mu_{\text{after}}$  versus  $H_1: \mu_{\text{before}} < \mu_{\text{after}}$  was below the p-value 0.5 so we consider that the average visitors before and after is statistically meaningful. The average went from 233 visitors per month to 368 accounting to an increase of 58% (Fig. 2).

Moreover, analyzing month *versus* month the average percentage change found was up by 88%, being April the month with the highest

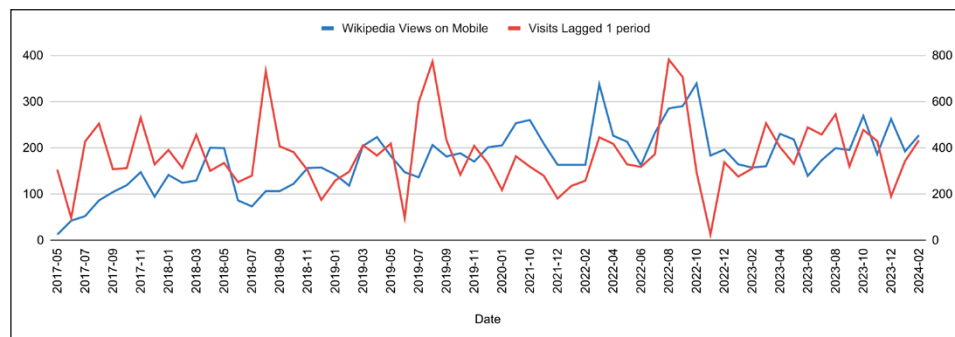


Fig. 4 – Wikipedia views on mobile and visits lagged by 1 period for Corte Sgarzerie.

uplift (Fig. 3). The correlation coefficient between total Wikipedia views and the 1-month shifted data was 0.14 which shows a medium causation compared to the correlation of 0.13 of the non-shifted data. An interesting finding was the stronger correlation between the platform used (desktop or mobile) and the number of visits to the actual site. Mobile users showed a correlation coefficient of 0.19 over all the period against the lagged data, which we consider medium-to-strong given the nature of the phenomenon (human behavior).

We also found that the use of mobile devices to access information surpassed the desktop users in general over the period (2014 to 2024) and 2022 registered the highest correlation between mobile users and visitors (lagged 1 period) of 0.55 and the total users (desktop and mobile together) had a correlation coefficient on that year of 0.28 (Fig. 4).

## 4.2 *Criptoportico Romano*

For Criptoportico Romano, with only 6 data points available due to annual data aggregation, our focus was solely on correlating Wikipedia visits with site visits. As school visits accounted to 38% of the total visits, we assumed that a lag of one period (one year) was appropriate for the analysis as not only educational coursework is due during the following period, but also school trips require a certain amount of logistics that normally happens in the previous quadrimester. The Wikipedia article for this site has been up and running during all the years of the analysis (2018-2023). What we found is that the correlation coefficient assuming this 1-period lag was 0.72 (perfect correlation is 1), so there is a strong correlation, especially given the analysis of human behavior (Fig. 5).

It is clear from the chart that the behavior is similar, leading us not only to correlate but establish causation between the two (one causes or

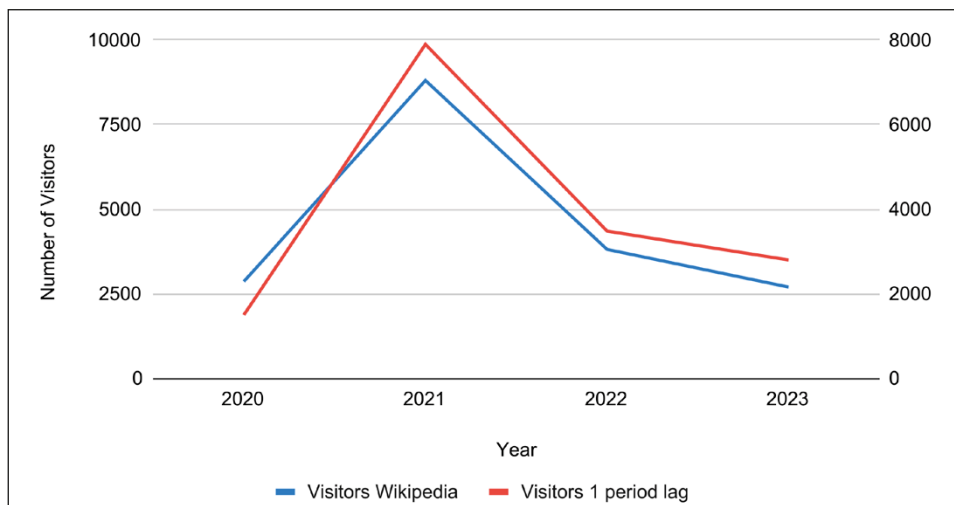


Fig. 5 – Total Wikipedia visitors *versus* site visitors lagged by 1 period for Criptoportico Romano.

strongly influences the other). For this we assume the principle of causal analysis in statistics which involves four elements: 1) correlation, 2) sequence in time (causes must occur before their proposed effect), 3) a plausible mechanism for an observed effect to follow from a possible cause, and 4) eliminating the possibility of alternative causes ([https://en.wikipedia.org/wiki/Causal\\_analysis](https://en.wikipedia.org/wiki/Causal_analysis)). We cover all the four elements in analysis addressing the points as follows: 1) calculating correlation coefficient, 2) moving the data 1 period to establish a time sequence, 3) a fair amount of visitors are schools, being a plausible cause influencing the time-sequence and the behavior, and 4) we did not find any special events that could have influenced the behavior otherwise.

S.P.

## 5. CONCLUSIONS

Open access plays a pivotal role in the dissemination of cultural heritage knowledge, with Wikipedia standing out as a key tool for such endeavors. In Italy, several projects aim to harness Wikipedia to promote cultural heritage awareness. All of them are significant, however for conciseness, we will only mention ‘Tutti i Musei su Wikipedia’ (<https://www.wikimedia.it/musei>), conducted by Wikimedia and ICOM. Through the described project, Wikipedia has proven to be a powerful tool for archaeological outreach, significantly affecting both educational access and cultural tourism. As a



conclusion, we can see that open access information from Wikipedia influenced meaningfully the number of visits to the actual site at Corte Sgarzerie: the average monthly visitors before the Wikipedia article was created was 233 versus 368 which was the average monthly visitors after the Wikipedia article was up, which scored a percentage change of 58%. The difference month to month from before and after the Wikipedia articles were created is consistent with the previous result, being the highest differences in the months of April, September and October for Corte Sgarzerie. Following the widely used Causal Analysis in statistics, there is a strong correlation of 0.55 between the 1-period lagged data and the number of Wikipedia views on mobile devices in 2022 for Corte Sgarzerie and 0.28 between the same lagged data and total views on all platforms for 2022, while the correlation for all the period was 0.14 confirming this amount of causation between the views and the visits to the site. In the case of Criptoportico Romano, the correlation is strong (coefficient was 0.72), confirming the assumption of causation. Moreover because of the 1-period lag correlation we can assume that a number of visits to the actual site triggered further research on Wikipedia articles.

To sum up, these preliminary results demonstrate the potential of collaborative digital initiatives in fostering a deeper public connection with cultural heritage, highlighting the role of free access to information in promoting local and historical awareness.

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## REFERENCES

- BOUKAS N. 2008, *Cultural tourism, young people and destination perception: A case study of Delphi, Greece*, Thesis in Management Studies, University of Exeter (<https://www.proquest.com/openview/c3d3732d8cf6c57204db302a31da144d/1?pq-origsite=gscholar&cbl=51922&diss=y>).
- BUHALIS D., LEUNG D., LAW R. 2011, *eTourism: Critical information and communication technologies for tourism destinations*, in Y. WANG, A. PIZAM (eds.), *Tourism Destination Marketing and Management: Collaborative Strategies*, Wallingford, CABI Publishing, chapter 13.
- CENCI C., GROSSI P. 2018, *Public archaeology a Verona: un percorso sperimentale lungo la via Postumia*, in P. BASSO, B. BRUNO, C. CENCI, P. GROSSI (eds.), *Verona e le sue strade. Archeologia e valorizzazione*, Verona, Cierre Edizioni, 223-232.
- CHAKRABORTY R., VISHIK C., RAO R. 2013, *Privacy preserving actions of older adults on social media: Exploring the behavior of opting out of information sharing*, «Decision Support Systems», 55, 4, 948-956.
- Corte Sgarzerie, Digital 2024, *Wikipedia page views reports* (based on visits to [https://it.wikipedia.org/wiki/Corte\\_Sgarzerie](https://it.wikipedia.org/wiki/Corte_Sgarzerie), [https://pageviews.wmcloud.org/?project=it.wikipedia.org&platform=all-access&agent=all-agents&redirects=0&start=2017-04&end=2024-03&pages=Corte\\_Sgarzerie](https://pageviews.wmcloud.org/?project=it.wikipedia.org&platform=all-access&agent=all-agents&redirects=0&start=2017-04&end=2024-03&pages=Corte_Sgarzerie)).
- Corte Sgarzerie, Physical 2024, *Area archeologica di Corte Sgarzerie, Verona. Dossier eventi e presenze*, Report 2014-2024, Archeonaute Onlus, Soprintendenza ABAP per le Province di Verona, Rovigo e Vicenza.
- Criptoportico, Digital 2024, *Wikipedia page views reports* (based on visits to [https://it.wikipedia.org/wiki/Criptoportico\\_romano\\_\(Vicenza\)](https://it.wikipedia.org/wiki/Criptoportico_romano_(Vicenza)), [https://pageviews.wmcloud.org/?project=it.wikipedia.org&platform=mobile-web&agent=all-agents&redirects=0&start=2015-07&end=2024-03&pages=Criptoportico\\_romano\\_\(Vicenza\)](https://pageviews.wmcloud.org/?project=it.wikipedia.org&platform=mobile-web&agent=all-agents&redirects=0&start=2015-07&end=2024-03&pages=Criptoportico_romano_(Vicenza))).
- Criptoportico, Physical 2024, *Criptoportico Romano, Vicenza, Monitoraggio visite*, Report 2018-2023, Museo Diocesano di Vicenza, Soprintendenza ABAP per le Province di Verona, Rovigo e Vicenza.
- GRIGGIO C., MIDAS NOUWENS M., MCGRENERE J., MACKAY E. 2019, *Augmenting couples' communication with lifelines: Shared timelines of mixed contextual information*, in S. BREWSTER, G. FITZPATRICK (eds.), *CHI 19: Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems (Glasgow 2019)*, New York, Association for Computing Machinery, Paper n. 623, 1-13 (<https://doi.org/10.1145/3290605.3300853>).
- HINNOSAAR M., HINNOSAAR T., KUMMER M., SLIVKO O. 2021, *Wikipedia matters*, «Journal of Economics & Management Strategy», 32, 3, 1-13 (<https://doi.org/10.1111/jems.12421>).
- MARWICK B., SMITH P. 2021, *World Heritage sites on Wikipedia: Cultural heritage activism in a context of constrained agency*, «Big Data & Society», January-June, 1-19 (<https://journals.sagepub.com/doi/full/10.1177/20539517211017304>).
- SHAMIR N., SHIN H. 2015, *Public forecast information sharing in a market with competing supply chains*, «Management Science», 62, 10 (<https://doi.org/10.1287/mnsc.2015.2261>).

## ABSTRACT

This paper examines the impact of Wikipedia and Wikimedia Foundation projects on archaeological heritage dissemination and cultural tourism enhancement. It focuses on two initiatives: a 2017 Public Archaeology event and a 2023 project extending into 2024. The 2017 initiative, in collaboration with the University of Verona and the Soprintendenza Archeologia, Belle Arti e Paesaggio per le Province di Verona, Rovigo e Vicenza, involved creating

Wikipedia entries for key archaeological sites in Verona. Visitor data analysis, from these sites, showed an increased number of visits after the entry creation. The ongoing 2023 project, backed by Wikimedia Italia and the Superintendency, aims to refine Wikipedia entries for all supervised sites. Preliminary assessments indicate enhanced visitor engagement correlating with article updates. The study particularly analyzes visitor data for Corte Sgarzerie (Verona) and Criptoportico Romano (Vicenza), assessing both electronic and physical visits. Results indicate a significant statistical increase in site visits, following the availability of Wikipedia articles. Further, a significant correlation was found between electronic access to articles and actual visits to these sites. The findings suggest a substantial impact of Wikipedia on cultural tourism, highlighting the role of open access, free software, and open data in promoting and preserving knowledge.

## DATI APERTI IN ARCHEOLOGIA: UNA RIFLESSIONE SULLO STATO DELL'ARTE NELL'AMBITO DEL MINISTERO DELLA CULTURA

### 1. IL GEOPORTALE NAZIONALE PER L'ARCHEOLOGIA COME PUNTO DI ACCESSO AI DATI ARCHEOLOGICI IN ITALIA

Il Geoportale Nazionale per l'Archeologia (GNA), pubblicato online dal luglio 2023, costituisce «il punto di raccolta e condivisione online dei dati esito delle indagini archeologiche condotte sul territorio italiano», come dichiarato sulla home page del progetto (<https://gna.cultura.gov.it/>). La realizzazione del portale risponde a esigenze espresse sia dal personale interno al Ministero della Cultura (MiC), sia da professionisti e ditte del settore, con l'obiettivo di semplificare l'acquisizione e la pubblicazione delle informazioni minime sul patrimonio archeologico e, di conseguenza, rendere più efficace e incisiva la sua tutela. Con questo obiettivo l'ICA ha elaborato, in collaborazione con ICCD, uno standard basato sulla normativa nazionale di catalogo (<http://www.iccd.beniculturali.it/it/ricercanormative/153/mopr-mosi-moduli-per-l-archeologia-preventiva>), utilizzabile per la descrizione e rappresentazione dei dati minimi di qualsiasi indagine archeologica.

Sperimentato inizialmente nell'ambito di un censimento di dati d'archivio delle Soprintendenze, promosso nel 2018 da Elena Calandra, Direttore ICA e responsabile scientifico del progetto (CALANDRA 2023), lo standard GNA è stato in seguito esteso alla redazione della documentazione preliminare delle procedure di archeologia preventiva (DPCM 14 febbraio 2022, <https://www.gazzettaufficiale.it/eli/id/2022/04/14/22A02344/sg>); dal 30 giugno 2024 è divenuto lo standard per il conferimento al MiC dei dati minimi di tutte le indagini archeologiche svolte sotto la direzione scientifica del MiC. La raccolta dei dati è affidata a un progetto GIS preimpostato (template) elaborato mediante il software open source QGIS e liberamente scaricabile online (<https://gna.cultura.gov.it/download.html>). Un plugin QGIS progettato *ad hoc* consente all'utente di scaricare e riutilizzare le schede già pubblicate, aggiornandole o correggendole se necessario, e di inviare al sistema le nuove schede appena redatte. I dati vengono inviati al funzionario MiC competente per territorio, il quale può scegliere di validarle o di escluderle dalla pubblicazione, perché non idonee o per ragioni di tutela fisica del bene. Tutte le schede non escluse dalla pubblicazione vengono pubblicate online, eventualmente con lo status “non validata”, allo scadere dei 30 giorni dal conferimento ([https://gna.cultura.gov.it/wiki/index.php?title=Istruzioni\\_operative](https://gna.cultura.gov.it/wiki/index.php?title=Istruzioni_operative)).

Il flusso di lavoro qui sinteticamente delineato (Fig. 1) ha comportato una serie di scelte sulla gestione del dato, che per ragioni di spazio possono



Fig. 1 – Schema dell'evoluzione progettuale e delle principali funzionalità del GNA (da Boi 2023).

in questa sede essere solo accennate e sulle quali si è scelto in sede di progettazione di dare una risposta, nata dal confronto con gli archeologi interni ed esterni al MiC e con le esperienze simili già in essere, in Italia e all'estero. Ma ogni soluzione adottata oggi potrà in futuro essere ridiscussa e modificata, anche alla luce del primo periodo di adozione capillare del GNA.

Un primo e fondamentale aspetto è stato legato alla selezione delle informazioni: un sistema che intende pubblicare i dati “in tempo reale” rispetto alla loro acquisizione sul campo (intendendo con questa espressione sia la ricerca d'archivio che le indagini di scavo/ricognizione) non può che fornire dati di base, relativi a una prima definizione e interpretazione, alla cronologia, al contesto di rinvenimento. Ove possibile, tali informazioni sono definite mediante vocabolari chiusi, che guidano il compilatore ma, ancora più, semplificano le funzioni di indicizzazione e ricerca. La piena interoperabilità con lo standard ICCD, in particolare con la scheda MA-CA che descrive il monumento/sito archeologico, fa sì che la scheda minima pubblicata sul GNA possa costituire anche la base di partenza per la scheda di catalogo del bene archeologico, che conterrà informazioni molto più approfondite, ma che dovrà derivare da uno studio non compatibile con i tempi e le modalità della “prima notizia”, fornita appunto dal GNA.

La rappresentazione su mappa è altrettanto essenziale e flessibile: se le aree di indagine (MOPR, DSC, RCG) sono rappresentate sempre come poligoni, infatti, i rinvenimenti (MOSI) possono essere materializzati tramite

punti, linee e poligoni: la rappresentazione puntuale è sempre adottata per tutti i rinvenimenti troppo piccoli per essere “apprezzati” a scala territoriale (un tesoretto, un cippo...), ma anche in tutti i casi in cui le informazioni sulla reale estensione non siano note nella documentazione o nella banca dati di provenienza; la rappresentazione lineare, infine, è adottata per rappresentare viabilità, assi centuriali, acquedotti.

Tutti i dati pubblicati sul GNA sono rilasciati con licenza CC-BY, e possono pertanto essere liberamente scaricati e riutilizzati alla sola condizione di citarne la fonte (<https://gna.cultura.gov.it/disclaimer.html>). Ogni scheda, infatti, riporta il nominativo del responsabile dei contenuti (in caso di scheda ricavata da bibliografia o archivio, è l'autore del documento originale), e del compilatore (tendenzialmente le due figure coincidono nel caso di schede che descrivono un nuovo intervento sul campo). Come accennato in precedenza, al funzionario responsabile per territorio è consentito di validare le schede prima della loro pubblicazione: quello della validazione è un tema piuttosto dibattuto, soprattutto rispetto alle banche dati pubblicate direttamente dal MiC; nell'ambito del GNA, esso si riferisce esclusivamente alla correttezza formale dei dati e alla loro corrispondenza rispetto allo stato attuale delle conoscenze. D'altra parte, considerate le caratteristiche peculiari della documentazione archeologica, in particolar modo se riferita a dati d'archivio e bibliografici, i dati descrittivi e geospaziali possono essere sempre soggetti ad approfondimenti e modifiche anche rilevanti, a seguito del progredire degli studi: in questo modo il ruolo amministrativo dell'Ufficio, quindi, è nettamente distinto rispetto alla titolarità degli aspetti interpretativi, che resta in capo agli autori della scheda o, a seconda dei casi, degli autori della documentazione da cui essa è stata tratta.

Infine, la scelta di affidare la compilazione delle schede direttamente a chi raccoglie i dati rappresenta sicuramente la chiave per la sostenibilità del progetto, sia in termini di rapidità di aggiornamento, che sul piano economico. Allo stesso tempo, ciò rende necessaria una presa di coscienza rispetto alla responsabilità del singolo nel “curare” la banca dati comune, prestando attenzione alla correttezza dei dati conferiti, correggendo le inesattezze riscontrate nelle schede già esistenti o segnalando le criticità mediante gli strumenti forniti dal portale. Alle ditte e ai professionisti è oggi richiesto di elaborare e strutturare le informazioni secondo modalità nuove. Questo processo, che ICA sta supportando tramite numerose iniziative di formazione, richiede la valorizzazione del ruolo di tutte le parti coinvolte e soprattutto la consapevolezza che in un flusso di lavoro “circolare” la condivisione dei dati è per tutti allo stesso tempo un onere e una utilità, oltre che garanzia di trasparenza.

In fase di progettazione del GNA è stata inoltre garantita l'interoperabilità con i progetti già attivi, realizzati dal MiC o in stretta collaborazione con esso: RAPTOR, utilizzato dalle Soprintendenze del nord Italia (FRASSINE *et al.*

2021), MAPPA-MAGOH, ideato dall'Università di Pisa (GATTIGLIA 2015), il SITAR della Soprintendenza Speciale di Roma (SERLORENZI *et al.* 2022), e infine il WebGIS del patrimonio culturale dell'Emilia-Romagna (CANTATORE *et al.* 2024). Tali progetti possono essere definiti come “banche dati federate”, perché proseguono la loro attività sul territorio di competenza e inviano i dati al portale. Dataset realizzati secondo altre strutture, come le indagini svolte in concessione da Università o Istituti di Ricerca, sono pubblicati in sezioni distinte, ma possono essere consultati sulla mappa. Infine, una sezione “aperta” è dedicata ad altre banche dati, generalmente non in corso di implementazione (<https://gna.cultura.gov.it/mappa.html?sezione=altrebanchediti>). Quest'ultima può accogliere e condividere qualsiasi dataset archeologico per il quale sia possibile la rappresentazione su mappa e costituisce per l'utente un semplice “segnalibro” per avviare e approfondire la ricerca.

V.B.

## 2. STATO DELL'ARTE SULLA CONDIVISIONE DEI DATI DELLA RICERCA ARCHEOLOGICA IN CONCESSIONE

Come accennato in precedenza, la progettazione del GNA coinvolge anche gli scavi condotti per finalità di ricerca sotto la direzione scientifica di Istituti diversi dal MiC, quali Università e altre Scuole Archeologiche italiane e straniere, comunemente definiti “scavi in concessione” (artt. 88-89 del Codice dei beni culturali). Parallelamente alle prime attività di pianificazione del GNA, l'ICA, in conformità con la propria missione, ha fornito supporto alla Direzione Generale Archeologia, Belle Arti e Paesaggio (DG ABAP) avviando un progetto volto a razionalizzare e standardizzare, a livello nazionale, le procedure per la presentazione e la gestione delle richieste, a vantaggio sia dei richiedenti che del personale ministeriale coinvolto nel processo. Il primo passo verso la digitalizzazione ha comportato la creazione di moduli PDF modificabili per orientare i richiedenti, garantendo così l'inclusione di tutti gli elementi necessari per la validità della domanda (équipe di ricerca, proprietari dei terreni dove si svolgono le indagini, copertura assicurativa, progetto scientifico e sua sostenibilità finanziaria, fondi per la sicurezza del sito e il restauro delle aree e dei reperti mobili, etc.); un modulo separato, noto come “modulo di valutazione”, è destinato ai funzionari delle Soprintendenze, per garantire una maggiore uniformità nei criteri di valutazione delle domande pervenute.

I risultati positivi osservati dal 2019, tra cui una netta diminuzione della necessità di richieste di integrazioni, hanno spinto l'ICA a stabilire standard per la presentazione della documentazione richiesta ai concessionari al termine di ogni campagna di indagine. La standardizzazione dei dati e la loro pubblicazione su database digitale sono entrate nell'ambito del progetto europeo Ariadne Plus, al quale l'ICA ha aderito come ente affiliato all'ICCU

(Istituto Centrale per il Catalogo Unico delle Biblioteche e delle Informazioni Bibliografiche Italiane) in collaborazione con il CNR-ISTI, un progetto partner incaricato di ricerca, sviluppo e innovazione tecnologica nel campo della scienza e della tecnologia dell'informazione. Le attività svolte in questo settore hanno portato alla progettazione di un'infrastruttura per la raccolta dati, il D4GNA (Dataset per il GNA). A seguito della conclusione del progetto Ariadne Plus nel 2022, un accordo siglato tra ICA e CNR-ISTI garantisce l'implementazione e la manutenzione della piattaforma.

I dati minimi forniti dai rappresentanti della ricerca scientifica vengono pubblicati online in una sezione autonoma, ma pienamente interoperabile con la sezione principale dedicata ai dati raccolti con standard GNA e già descritta *supra*.

A.F.

### 3. DALLA PUBBLICAZIONE DEI DATI MINIMI ALLA VALORIZZAZIONE DEI CONTENUTI EDITORIALI

I dati ospitati nel GNA vengono inseriti per la maggior parte nell'ambito di procedure che coinvolgono direttamente il MiC, ma al suo interno possono essere pubblicate anche tesi di dottorato o di laurea, o altri progetti di ricerca territoriale, il cui database sia strutturato secondo lo standard GNA. Pertanto, i contenuti digitali presenti in GNA, a seconda della loro struttura e complessità, possono essere concepiti anche come prodotti editoriali, con diversi gradi di accessibilità, a seconda della volontà dei contributori e dei diversi livelli di tutela applicati alle testimonianze archeologiche descritte. Tra i compiti dell'ICA c'è la definizione di standard di qualità per l'editoria archeologica (DM n. 46/2022, art. 21, c. 2, e) e pertanto i temi della tracciabilità, dell'apertura delle informazioni e della tutela della proprietà intellettuale e del patrimonio culturale sono stati affrontati con soluzioni in linea con gli indirizzi normativi nazionali e sovranazionali, che puntano sempre più alla condivisione dei dati in possesso delle Pubbliche Amministrazioni.

In estrema sintesi, gli uffici del MiC possono accedere e gestire i dati della ricerca archeologica in quanto competenti per la tutela dei beni culturali, ma non possiedono il diritto di proprietà su tali dati nella loro forma originale. Possono invece promuovere la pubblicazione dei contenuti, poiché la legge prevede che la loro comunicazione sotto forma di "riassunto, citazione o riproduzione di brani o parti di un'opera" è libera se effettuata per scopi didattici o di ricerca scientifica (L. 633/1941, art. 70), seguendo i principi della dicotomia Idea/Espressione, dei cosiddetti FAIR data principles e della Direttiva Open Data, recepita dall'Italia con il D. Lgs 200/2021.

L'ICA ha affrontato in vari modi le problematiche sopra citate: in primo luogo, per ogni documento accessibile nel GNA sono chiaramente



indicati i compilatori e i responsabili dei contenuti. Inoltre, i dati sono protetti dalle licenze Creative Commons, prevalentemente CC-BY 4.0, che consentono di «distribuire, modificare, creare opere derivate dall'originale, anche per scopi commerciali, a condizione che venga dato adeguato credito» (<https://creativecommons.org/licenses/by/4.0/deed.it>). Oltre a queste misure, l'Istituto promuove la conoscenza dei contenuti digitali del GNA attraverso l'attribuzione di codici DOI. Come noto, si tratta di identificatori digitali permanenti di oggetti e contenuti (fisici, digitali o astratti), arricchiti dai relativi metadati. Ad oggi, i codici DOI sono stati applicati ai dataset relativi alle indagini in concessione per i quali sono stati conferiti al GNA la relazione di scavo e la planimetria dettagliata di fine campagna, la cui pubblicazione è facoltativa ([https://bollettinodiarcheologiaonline.beniculturali.it/wp-content/uploads/2024/06/09\\_Repertorio\\_DOI-1.pdf](https://bollettinodiarcheologiaonline.beniculturali.it/wp-content/uploads/2024/06/09_Repertorio_DOI-1.pdf)). In questo modo, i contributori del GNA (principalmente ricercatori accademici) saranno stimolati a rendere accessibili i dati relativi al loro lavoro sul campo e a popolare l'infrastruttura web con informazioni esaustive. In futuro questa procedura verrà estesa anche alle altre sezioni del portale. La registrazione del DOI, infine, aumenterà il potenziale informativo dei dati GNA anche attraverso il collegamento degli stessi al «Bollettino di Archeologia Online» (<https://bollettinodiarcheologiaonline.beniculturali.it/>), una delle risorse editoriali pubblicate direttamente dal MiC.

V.A.

#### 4. IL SITAR. GENESI DEL PROGETTO E LINEE DI SVILUPPO ATTUALI

L'abituale presenza di SITAR agli appuntamenti di ArcheoFOSS fa sì che non sia necessario in questa sede ripercorrere le tappe della nascita, ormai 15 anni fa, di un'esperienza umana e di ricerca, di lunga durata, che ha mosso i primi passi dovendo affrontare temi importanti in un periodo in cui pochi erano gli esempi di sistemi informativi archeologici territoriali (<https://www.archeositarproject.it/>). Con grande piacere si assiste oggi ad una volontà che viene da più parti anche all'interno del Ministero di trovare delle forme condivise per la messa a sistema di tanti dati, con politiche open data, raccolti in diverse banche dati che seppure sviluppate con differenti priorità mirano alla messa in rete e allo scambio della conoscenza.

Fin dall'inizio l'intento era digitalizzare gli archivi archeologici cartacei della Soprintendenza, per condividere pubblicamente i dati strutturati attraverso un sistema GIS disponibile online, con il fine di realizzare un progetto di archeologia pubblica partecipata. Le attività messe in atto hanno consentito alla Soprintendenza di superare un profondo gap nei processi di standardizzazione del dato archeologico, con il fine di realizzare un archivio digitale open data. La prerogativa principale di SITAR è sempre stata – ed è tuttora – quella di porsi come strumento a servizio dell'amministrazione, progettato



per facilitare l'assolvimento di alcuni compiti strategici, legati alla conoscenza, tutela e valorizzazione del territorio. Da ciò, la necessità di costruire una piattaforma su base geografica, capace di incamerare tutti i dati relativi alle ricerche archeologiche dirette dalla Soprintendenza negli ultimi 70 anni.

Nel corso degli ultimi anni molti sforzi sono stati dedicati proprio ai dati, mettendo in campo una serie di azioni di rinnovamento tecnologico per consentire un ulteriore livello di scambio di informazioni e servizi informativi, sia in entrata che in uscita: allineamento al modello semantico CIDOC-CRM-Archeo, adottato dal progetto Ariadne; rappresentazione dei dati in RDF, utilizzando il linguaggio XML; esposizione dei dati geografici attraverso geoservizi OGC (WMS/WFS), in modo che chiunque li possa richiamare agevolmente all'interno dei propri applicativi.

A partire dal 2024, inoltre, è stato avviato un cambio di paradigma strutturale, implementando un nuovo modulo per consentire agli archeologici di effettuare il data-entry direttamente dalle aree di scavo, alimentando il sistema in maniera costante, mentre ai funzionari responsabili dei territori sarà demandata la verifica e validazione dei dati immessi. Questo rinnovato impianto tecnologico consente un ulteriore livello di interscambio di dati e servizi informativi, sia in entrata che in uscita. SITAR potrà quindi, da un lato accogliere dati provenienti da fonti esterne, dall'altro configurare ed erogare servizi a favore di altre infrastrutture e/o progetti esterni basati sui medesimi standard di interoperabilità tecnologica. È stata così raggiunta un'altra tappa del percorso, ormai decennale, grazie a cui SITAR è divenuto un vero *trait d'union* tra la Pubblica Amministrazione, i professionisti impegnati sul campo e i cittadini, mettendo i propri dati a disposizione delle diverse utenze e comunità di riferimento, che con competenze differenziate producono o utilizzano informazioni relative al Patrimonio Culturale. Proprio all'interno di questo solco trova luogo, come precedentemente annunciato, il collegamento con il GNA, finalizzato a offrire ai rispettivi utenti la possibilità di fruire contemporaneamente dei due dataset. Oggi, l'ultima sfida riguarda lo studio dei più importanti approcci teorici sulla valutazione del potenziale archeologico nell'ambito urbano, allo scopo di trovare un modello che possa essere valido anche per una città della complessità di Roma con i suoi 2700 anni di stratigrafia urbana e 1287 km<sup>2</sup> di territorio.

M.S.

##### 5. ARCHEODB COME INTERFACCIA ARCHEOLOGICA DEL WEBGIS DELL'EMILIA-ROMAGNA; GENESI DEL PROGETTO E LINEE DI SVILUPPO ATTUALI

Nato negli stessi anni del GNA, il sistema ArcheoDB (CANTATORE *et al.* 2024) è un geodatabase sviluppato dal 2019 in Emilia-Romagna dal MiC, tramite i suoi uffici periferici, per permettere una mappatura tempestiva, affidabile nella georeferenziazione, essenziale nella parte schedografica e il più possibile

completa dei siti oggetto di interventi e/o ritrovamenti archeologici. Prima finalità del lavoro era quindi dar conto della presenza di dati archeologici a chi opera quotidianamente nel campo della tutela, tramite l'integrazione di questo livello conoscitivo nel più ampio geodatabase del patrimonio culturale tutelato emiliano-romagnolo, pubblicato fin dal 2014 nel portale WebGIS <https://www.patrimonioculturale-er.it>. Lo sviluppo del progetto, grazie alla concomitante evoluzione del GNA, ha potuto beneficiare della forte spinta nazionale alla raccolta in formati standardizzati dei dati e alla loro pubblicazione, portando a sperimentare sul territorio regionale soluzioni innovative che precorrevano alcune delle scelte poi compiute a livello nazionale: la pubblicazione in tempo reale dei dati su un portale cartografico interattivo, a disposizione di tutti i cittadini, tecnici, amministrazioni e studiosi fin dall'autunno del 2022 e l'utilizzo obbligatorio di tale sistema di schedatura alla consegna di qualsiasi documentazione di scavo, a partire dal primo gennaio 2023.

La scelta di operare su un unico geodatabase costantemente aggiornato, in cui i dati erano messi a disposizione di tutti gli operatori non appena salvati dal compilatore, ha consentito di evitare il più possibile la creazione di schede duplicate. Gli anni precedenti alla pubblicazione sul WebGIS hanno permesso di sperimentare eventuali criticità, evidenziando che solo in rarissimi casi si riteneva indispensabile non diffondere i dati per motivi legati alla tutela del deposito archeologico e questi potevano essere segnalati direttamente dagli operatori e/o dai funzionari competenti quando l'intervento era in corso e la scheda non ancora compilata. Inoltre, appariva illusorio confidare nella possibilità da parte dei funzionari di rivedere rapidamente tutte le schede consegnate, sì da giustificare un ritardo della pubblicazione nella prospettiva di una significativa validazione dei dati preliminare ad essa. È apparso molto più costruttivo, trasparente e rispettoso del ruolo svolto da ciascun operatore sulla banca dati pubblicare i dati fin dalla loro consegna, evidenziando preliminarmente la presenza o meno di dati validati all'interno di ciascuna scheda e che per ogni informazione certificata è necessario rivolgersi alla Soprintendenza competente territorialmente.

La mole e la capillarità dei dati di scavo sono state rese ancora più evidenti dall'introduzione dell'obbligatorietà della compilazione di ArcheoDB dal 1° gennaio 2023, che ha portato all'inserimento di 1090 interventi eseguiti in Emilia-Romagna nel solo 2023. L'enorme mole di lavoro che impegna le Soprintendenze territoriali trova così palese conferma, a fronte di un personale tecnico frequentemente in carenza di organico. L'immediatezza della pubblicazione valorizza e gratifica la professionalità di chi compila le schede, le cui responsabilità erano già insite nella consegna ad un archivio pubblico. Nell'esperienza emiliano-romagnola, i benefici di avere dati completamente riutilizzabili hanno progressivamente bilanciato per i professionisti l'impegno necessario per l'adeguamento al nuovo standard di consegna. È stato

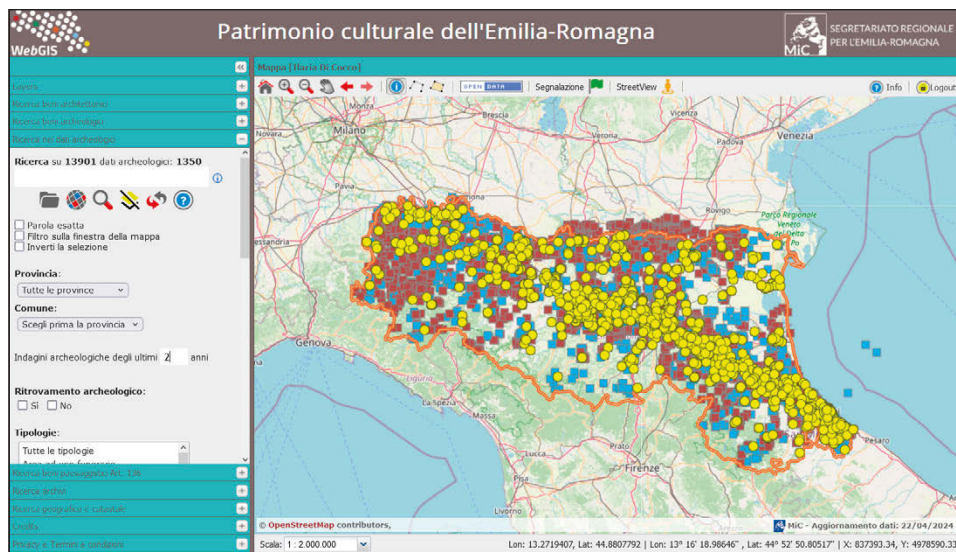


Fig. 2 – Interventi svolti da gennaio 2023 ad aprile 2024 raccolti in ArcheoDB.

altresì prioritario per gli uffici proporre un modello il più agevole e sintetico possibile, stabile nel tempo e basato su vocabolari altrettanto sintetici ed essenziali, che semplificassero la compilazione e l'applicazione di criteri di ricerca e tematizzazione cartografica.

Oggi ArcheoDB, riconosciuto come banca dati federata al GNA sia per la consegna dei dati per la relazione di assoggettabilità a VPIA che dei dati minimi delle indagini archeologiche, è divenuto lo strumento quotidiano di lavoro per tutti i professionisti e i funzionari operativi sul territorio regionale, con circa 260 professionisti dotati di credenziali per compilare le schede e 14.000 schede compilate, legate in misura sempre crescente a dati areali, sia ovviamente per l'inserimento di dati più recenti, sia per il miglioramento della georeferenziazione dei dati provenienti dagli archivi, grazie a progressive revisioni e approfondimenti (Fig. 2).

Si è inoltre registrato un significativo interesse da parte dei Comuni impegnati nella redazione dei Piani Urbanistici Generali (PUG), grazie all'azione di sensibilizzazione svolta dai funzionari delle Soprintendenze, a consolidare la propria conoscenza dei dati archeologici presenti sul proprio territorio tramite l'adozione del modello di raccolta di dati di ArcheoDB. A fronte dell'investimento di tempo e risorse necessario per il recupero del pregresso, che frequentemente può giovare delle basi conoscitive già in uso nei precedenti strumenti di pianificazione nonché dei dati già inseriti nel sistema, sempre più

capillari, l'utilizzo di ArcheoDB garantisce, proprio grazie all'obbligatorietà del conferimento di tutti i dati provenienti da nuovi interventi di scavo, la prospettiva di disporre di dati costantemente aggiornati, sia nella struttura che nei contenuti, senza necessità di ulteriori investimenti.

I.D.C.

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## BIBLIOGRAFIA

- ANICHINI F., DUBBINI N., FABIANI F., GATTIGLIA G., GUALANDI M.L. 2013, *Mappa. Metodologie applicate alla predittività del potenziale archeologico*, 2, Pisa, Edizioni Nuova Cultura.
- BOI V. 2023, *Il Geoportale Nazionale per l'Archeologia (GNA). Standardizzazione e apertura dei dati* ([https://doi.org/10.60974/GNA\\_02](https://doi.org/10.60974/GNA_02)).
- CALANDRA E. 2023, *Il Geoportale Nazionale per l'Archeologia (GNA). Un'introduzione* ([https://doi.org/10.60974/GNA\\_01](https://doi.org/10.60974/GNA_01)).
- CANTATORE M.F.A., DI COCCO I., MOINE C., PODINI M., SERICOLA M. 2024, *ArcheoDB, a new geodatabase of archaeological findings for conservation and research in the Emilia-Romagna Region (Italy): The case of the Soprintendenza of Parma and Piacenza, «Groma»*, 8.
- FRASSINE M., DE FRANCESCO S., ZAMBETTI A. 2021, *RAPTOR reloaded. Un geodatabase gestionale per la tutela archeologica: nuovi aggiornamenti per un sistema aperto*, «Archeologia e Calcolatori», 32.1, 307-324 (<https://doi.org/10.19282/ac.32.1.2021.17>).
- SERLORENZI M., D'ANDREA A., MONTALBANO R. 2022, *SITAR: An open data platform for digital archaeology of Rome. From data collecting towards shared knowledge* ([https://www.archeositarproject.it/wp-content/uploads/2022/09/ADA\\_ppt\\_Delta\\_SITAR\\_040622.pdf](https://www.archeositarproject.it/wp-content/uploads/2022/09/ADA_ppt_Delta_SITAR_040622.pdf)).

## ABSTRACT

The National Geoportal for Archeology (GNA), started in 2017 by the Central Institute for Archeology (Istituto Centrale per l'Archeologia – ICA) of the Italian Ministry of Culture, has the primary goal of making data resulting from all archaeological investigations carried out on the national territory freely accessible online. The project is part of the activities carried out by the Institute regarding the register and digitalization of archaeological research data. Its primary function is the creation of a dynamic archaeological map, easily implementable over time, free to access and easy to consult, open to reuse and integration by all users. The data-entry according to the GNA standard is entrusted to the use of a pre-set GIS project (template) developed using the open source software QGIS. GNA also receives data from other projects designed or managed by the Superintendencies in some areas of Italy, with the aim of preserving good practices already tested locally.

## THE DSC AUTHORITY FILE: A LINK BETWEEN FIELDWORK AND FINDS

### 1. WORKING ON THOUSANDS OF ARCHEOLOGICAL FINDS

In this paper, the Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Genova e le province di Imperia, La Spezia e Savona (SABAP-LIG) describes the activities of inventorying archaeological assets that have been carried out from 2017 to 2023, based on a years-long experience in the management of this type of data (GAMBARO, COSTA 2016; BARBARO, COSTA, CERVONE 2018). The activity was carried out through the ‘in batches’ inventory system (‘inventariazione a lotti’) based on the new MINP standard module, and led to the compilation of about 13,000 modules. Each module is a record describing either one archaeological find or one group of archaeological finds that are stored in the same container (crate, box, and similar) and share the same provenance (ISTITUTO CENTRALE PER IL CATALOGO E LA DOCUMENTAZIONE 2020). In 2017, the standard was in its early stage, with two separate versions for the single item (MINP 1.0) and the multiple items (MINP 2.0). SABAP-LIG was involved in the experimental phase, compiling 7000 records about the finds from the historical city center of Genoa, resulting from decades of urban archaeology. In 2023 a new, derived standard was released, under the acronym MINV (ISTITUTO CENTRALE PER IL CATALOGO E LA DOCUMENTAZIONE 2023), with some improvements and substantially adapted for the inventory recording of any cultural heritage item, not just archaeological.

Since many archaeologists were involved in the data entry phase, it was necessary to maintain consistency not only about the description of archaeological finds but also about their provenance. The short description of archaeological finds is easily made consistent thanks to the usage of standardized vocabularies and *thesauri*, an excellent set of tools developed by the ICCD. Therefore, we chose the same approach with regard to the provenance of finds, adopting the DSC standard on a region-wide scale. The DSC (Archaeological Excavation) is an authority file developed by ICCD and part of the same set of standards as MINP, which allows the harmonization of data about the research activity that led to the discovery of the asset (ISTITUTO CENTRALE PER IL CATALOGO E LA DOCUMENTAZIONE 2019). Every find from the same excavation refers to the same DSC authority file. There is a second type of authority file, named RCG (Ricognizione) that is meant for describing field surveys, but this type of activity is not very common in Liguria as a whole. Authority files are separate from catalogue records, and in this case there is

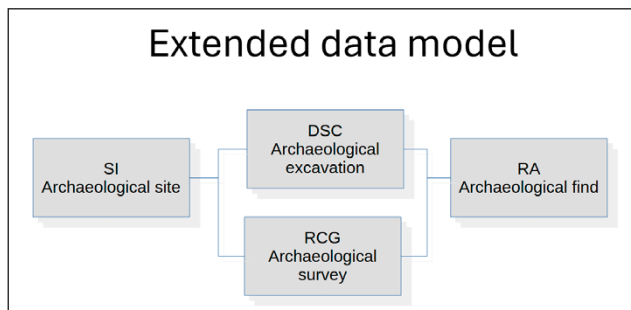


Fig. 1 – Schematic data model.

a one-to-many relationship between DSC and MINP/MINV records. Since DSC is not a record describing a cultural heritage item, but it describes an activity that is performed on archaeological sites or at least with archaeological methods, in some cases it is possible to create DSC records for which no finds are available, as in the case of some old excavations unfortunately. On the other hand, some finds are virtually ‘orphan’ as there is no specific information about their provenance and only a placeholder record can be linked. The introduction of the DSC authority file means that finds are not directly given geospatial coordinates for their provenance, nor linked to the record describing the archaeological site (in SI, MODI or MOSI standard) but there is a layer of added complexity, that makes more knowledge available about when their excavation took place, by whom and so on (Fig. 1). The activity of inventorying assets through the MINP module takes place on the SIGECweb platform. The DSC authority file must be compiled before the compilation of the MINP/MINV module, in order to be linked from the DSCH field (Fig. 2).

At the time of writing, the number of DSC authority files compiled on the SIGECweb platform for the territory of Liguria is about 400, out of a total of 1478 for entire Italy. Among the specifications that have been developed during this activity, the method is the one intended for assigning the unique DSC code. According to the ICCD standard, this code is a sequence of 8 alphanumeric characters that must be assigned by the local office (e.g. the Superintendency). While this allows for a large number of integer numbers to be used as unique identifiers, these identifiers are ‘opaque’ to the reader and difficult to manage when archaeologists with overlying tasks need to work in parallel. A proposal for an alternative ‘structured’ code was therefore devised, in which the first 4 characters of the DSC code correspond to the cadastral code of the municipality in which the excavation intervention is located (e.g. D969 for the municipality of Genoa) and the other 4 characters are dedicated to a specific numeric sequence for that municipality (Fig. 3). Starting in late



The screenshot displays the SIGECweb platform interface. At the top, there is a header with the ICCO logo and the text 'Istituto Centrale per il Catalogo e la Documentazione'. Below this, a navigation bar includes links like 'Home', 'Manuale', and 'Modifica anagrafica utente'. The main content area is titled 'SIGECWEB' and shows the details of a DSC authority file for 'SV Albisola Superiore, Ex Asilo Infantile Balbi'. The interface is organized into several sections: 'DSC - SCAVO ARCHEOLOGICO' (containing fields like DSC, DSCV, DSCM, DSCF, DSCA), 'DSC - NOTIZIE STORICO-CRITICHE' (NSC), 'LG - LOCALIZZAZIONE GEOGRAFICO-AMMINISTRATIVA' (containing fields like PVCS, PVCR, PVCP, PVCC, PVCI, PVZ), 'GE - GEOREFERENZIAZIONE' (containing fields like GEL, GET, GEP, GEC, GECX, GECY, GPT, GPM, GPB, GPB8, GPB1, GPB2), 'DO - DOCUMENTAZIONE' (containing fields like BIB, BIBR, BIBS, BIB8), and 'AD - ACCESSO AI DATI' (containing fields like ADS, ADSP, ADIM, CMP). The bottom part of the screenshot shows a map view with a point highlighted in green, and a sidebar with cartographic settings and a legend.

Fig. 2 – Screenshot of DSC editing in the SIGECweb platform. In the lower part, the geospatial view with the point in green.

Fig. 3 – MINV record, showing the DSCH – Codice identificativo (8-character string): A166 cadastral code for Albisola Superiore municipality and 0008 progressive number.

2019, SABAP-LIG was split in two separate entities, each taking care of half of the Liguria region, nevertheless the activity continued along the same lines and with a common plan of digitization. The adoption of the structured code described above allowed the work to continue uninterrupted, since there were no new prefixes needed, and each Superintendency could continue adding new DSC records for the municipalities under their responsibility.



## 2. FROM DEPOT TO LANDSCAPE AND BACK

In 2019, in parallel with the inventorying of finds, SABAP-LIG participated in the experimentation on the collection and digitization of excavation data through GIS templates aimed at populating the National Archaeological Geoportal (GNA) (CALANDRA *et al.* 2021). Starting from version 1.0 of the template (released in April 2022), a layer for the DSC authority file was also included in the system and is now mandatory for all new excavations. The DSC layer is a multipolygon geometry, like other layers in the template (e.g. MOSI and RCG layers), so for each record there is one or more polygonal areas, as when multiple excavation pits are made according to the same project and with the same depth, and all data entry is made in a QGIS form that follows the same structure as SIGECweb (GABUCCI 2024). Separate excavations at the same site can be described in full detail, each with the specific area, and a clear separation between the concepts of excavation and site is made, with the MOSI layers dedicated to sites and material remains in general (Fig. 4). This new feature made it possible to connect two parts of the ‘data model’ concerning archaeological assets that had so far been essentially disconnected from each other. The GNA data are publicly available, and all areas recorded as MOSI are part of the webGIS platform.

An example from the current dataset from the municipality of Albisola Superiore can show how all the various types of records are linked. The 2009 excavation in the area of the former Asilo Infantile Balbi is described by the authority file DSC A1660008. The record describes the archaeological evidence of 28 pits where discarded ceramics from the 16<sup>th</sup> and 17<sup>th</sup> century were buried, in the context of a large production center. In SIGECweb, the DSC authority file is only recorded with a point geometry (i.e. latitude and longitude coordinates). There are 8 MINV records linked to the A1660008 authority file, and each record describes a single container (in this case, a plastic crate) with multiple finds from the excavation. The DSCH field of each MINP/MINV record contains the ‘foreign key’ to the DSC authority, and other fields record in more detail the type of archaeological finds, their quantity, the current storage location and some metadata. On the GNA side, there is a mirror DSC record, where all the information is kept as aligned as possible with the existing SIGECweb record, and the DSCH value is the same (A1660008), but the geometry is a multipolygon and the exact area of excavation is recorded, not just a representative point. Furthermore, MOSI records can be attached to the DSC authority file when there are archaeological findings, as in the case of the former Asilo Infantile Balbi.

It is important to stress that the GNA platform was developed to be entirely interoperable with the existing ICCD standards, but there are some subtle differences regarding the DSC that affect data exchange. The DSCH

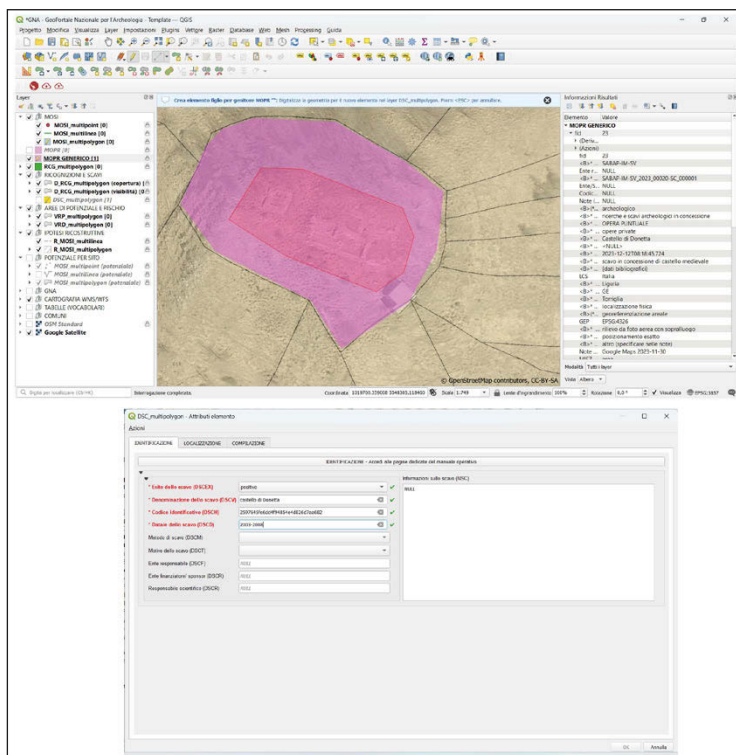


Fig. 4 – GNA QGIS template. Data entry of DSC record for the authority file.

field, already mentioned above, is automatically filled with a UUID-4 value, that avoids any complex work needed to ensure unique values across the entire national database, but the field size is longer than the maximum value allowed by the current standard and this choice partially undermines local efforts, requiring manual entry.

In the official specification of ICCD, the DSC authority file can be recorded in SIGECweb only as a point geometry: on the other hand, the GNA template allows to create a multipolygon geometry that fits more closely the nature of excavation at the detailed scale of documentation available. At the operational level, when new or existing records are edited in SIGECweb, it is possible to link from the archaeological site record (e.g. SI) to the DSC authority file, but not the other way around, and the geospatial coordinates can be effectively entered only as a point geometry. Convergence towards multipolygon geometries and universal unique identifiers seems the most promising approach.

Looking forward, there are other opportunities to improve the framework. Millions of catalogue records are publicly available on the public frontend at <https://www.catalogo.beniculturali.it>, including MINP and SI records that are exposed as linked open data. However, DSC is not shown at all, and while it is a relatively minor authority file, it would have a transformative effect, giving more relevance to the research activity rather than showing finds and sites as merely sharing a common geospatial location. The same kind of limitation applies to the GNA webGIS, too. From a general point of view, the main objective can be summarized as making the DSC a first-class object in the online viewers, since the data is already collected and recorded. A direct link between the GNA platform and SIGECweb is planned, but according to the current documentation it needs manual entry of DSCH codes in the GIS platform, a burdensome and error-prone operation.

### 3. CONCLUSION

In conclusion, the intervention of SABAP-LIG has led to significant improvements in the activity of inventorying archaeological assets, without developing new tools or standards, but rather consolidating good practice in the adoption of existing ones, year after year. The use of the DSC authority file made possible to harmonize information and to connect two parts of the ‘data model’ that had remained disconnected. The assignment of a unique ‘structured’ code has made the work of operators more efficient. Finally, the insertion of the DSC authority files in the recovery of previous information made possible to improve the quality of the data: the most common case is that of researchers who are interested in the study of material from past excavations. Since the current storage location is a result of previous research activity and even small archaeological sites have their finds dispersed in many different places, keeping track of the precise location and provenance is necessary, even though time consuming because of decades of neglect and late digitization.

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## REFERENCES

- BARBARO B., COSTA S., CERVONE A. 2018, *Migrazione della banca dati delle schede di catalogo da IDRA a SIGEC*, «Archeologia in Liguria», 6, 478-479.
- CALANDRA E., BOI V., FALCONE A., ACCONCIA V., GIORGIO S.D., MASSARA F., RONZINO P. 2021, *Policy and practice for digital archaeological archiving in Italy*, «Internet Archaeology», 58 (<https://doi.org/10.11141/ia.58.27>).
- GABUCCI A. 2024, *DSC multipolygon*. Wiki GNA, *Template GNA ver. 1.4* ([https://gna.cultura.gov.it/wiki/index.php?title=DSC\\_multipolygon&oldid=1487](https://gna.cultura.gov.it/wiki/index.php?title=DSC_multipolygon&oldid=1487)).
- GAMBARO L., COSTA S. 2016, *Scheda TMA (Tabella Materiali). Sviluppo di un database per la gestione del materiale archeologico dalla città antica di Albintimilium (Liguria)*, in F. STANCO, G. GALLO (eds.), *Proceedings of ArcheoFOSS. Free, libre and open source software e open format nei processi di ricerca archeologica*, VIII Edizione (Catania 2013), Oxford, Archaeopress, 259-266 (<https://www.archaeopress.com/Archaeopress/Products/9781784912598>).
- ISTITUTO CENTRALE PER IL CATALOGO E LA DOCUMENTAZIONE 2019, *DSC. Scavi archeologici 4.00* ([http://www.iccd.beniculturali.it/it/ricercanormative/70/dsc-scavi-archeologici-4\\_00](http://www.iccd.beniculturali.it/it/ricercanormative/70/dsc-scavi-archeologici-4_00)).
- ISTITUTO CENTRALE PER IL CATALOGO E LA DOCUMENTAZIONE 2020, *MINP 4.00. Modulo per l'inventariazione patrimoniale (beni archeologici: singoli oggetti e lotti di materiali). Manuale per la compilazione* ([http://www.iccd.beniculturali.it/it/ricercanormative/156/minp-modulo-per-l-inventariazione-patrimoniale-4\\_00](http://www.iccd.beniculturali.it/it/ricercanormative/156/minp-modulo-per-l-inventariazione-patrimoniale-4_00)).
- ISTITUTO CENTRALE PER IL CATALOGO E LA DOCUMENTAZIONE 2023, *MINV. Modulo per l'inventariazione 4.01* ([http://www.iccd.beniculturali.it/it/ricercanormative/234/minv-modulo-per-l-inventariazione-4\\_01](http://www.iccd.beniculturali.it/it/ricercanormative/234/minv-modulo-per-l-inventariazione-4_01)).

## ABSTRACT

Starting in 2017, the Soprintendenza Archeologia, Belle Arti e Paesaggio per la città metropolitana di Genova e le province di Imperia, La Spezia e Savona (SABAP-LIG) began activities to inventory archaeological assets through the 'in batches' inventory system based on the new MINP standard module. The activity was carried out with funds allocated by the General Directorate and has continued annually until 2023, leading to the compilation of about 13,000 modules. Since the first experiment, the DSC (Archaeological Excavation) authority file, which has been developed among the ICCD authority file standards for a while, but used sparingly. It has been identified as a crucial element of the activity because it can be used as a link between catalogue of records describing finds (MINP, MINV) and records describing archaeological sites. Despite the relative simplicity of the data model compared to state-of-the-art initiatives in archaeology data modelling, still it allows an improvement in finds management and knowledge about archaeological heritage.

## DOES NOT COMPUTE! ACCOUNTING FOR SOCIAL AND SITUATED EXPERIENCES WHILE INTEGRATING AND ANALYZING OBSIDIAN SOURCING DATA

### 1. DATA SHARING IN PRACTICAL CONTEXT

Open data platforms, which host published datasets on the web, boast several potential benefits, including the ability to extract untapped value from older ‘legacy’ data, to integrate data collected at various archaeological sites, to validate analytical claims more effectively, and to ensure that the general publics who fund archaeological research are able to access freely and make sense of the fruits of their investments (KANSA 2014; KINTIGH *et al.* 2014). However, as the open data movement matures and data-sharing platforms become integral parts of the publishing process, archaeologists are becoming more aware of their limitations. For instance, J. HUGGETT (2018) reports on how open data platforms have generally failed to encourage reuse, and R. OPITZ *et al.* (2021) demonstrate how effective data integration and synthesis is primarily derived from preexisting collaborative relationships. Furthermore, ATICI *et al.* (2013), FANIEL *et al.* (2013) and KANSA *et al.* (2013) show that archaeologists who re-use data seek out additional information that could otherwise only be obtained through close collaborative relationships. These concerns, raised in response to the initial implementation of open data norms and practices, hint at a growing recognition that data are not asocial, apolitical, and disembodied entities, and that effective data re-use involves reconciliation with the prior decisions and circumstances that informed the original constitution of a dataset (DALLAS 2015; HUGGETT 2022; BATIST 2024).

While open data hold enormous potential to re-shape how archaeologists work, it has become clear that the systems we have constructed to support data-sharing at scale generally fail to account for how they might fit into or alter existing value regimes and forms of professional interaction. In order to more fully unlock this potential, we need to broaden our imagination of what data-sharing actually entails, including the social and communicative processes that underlie these acts. This paper highlights some of these challenges through the case of the Database of Obsidian Sourcing Studies (DObsiSS), an integrated dataset compiled for the completion of the Author’s Master’s Thesis in 2015 (BATIST 2015a). Specifically, this paper draws attention to past archaeologists’ inability to anticipate future use cases for their data which renders them incomparable, and the struggle to reconcile past circumstances in a context of data re-use.

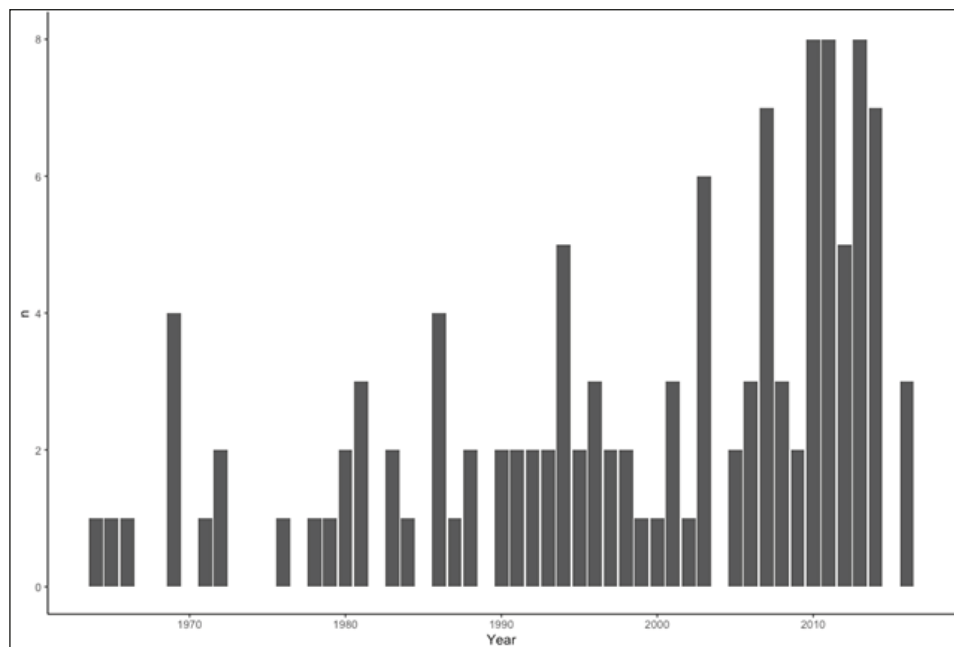


Fig. 1 – Distribution of obsidian sourcing studies referenced in DObsiSS.

## 2. ASSEMBLING THE DATABASE OF OBSIDIAN SOURCING STUDIES

DObsiSS is a combined dataset assembled from dozens of published reports, and served as the basis for a Master's Thesis that entailed comparative and diachronic analysis of chemically characterized obsidian artefacts found across southwest Asia and Anatolia between 12,000-5700 BP (BATIST 2015a). Assembling DObsiSS involved integrating the findings derived from obsidian sourcing studies published from 1964-2014 (Fig. 1) into a single spreadsheet, which was then used to compare the composition of archaeological assemblages over broad time spans and across a vast geographic range. The similarity of obsidian assemblages, measured in terms of the proportions of raw material originating from different geological sources, was used as a vector for tracing cultural contacts.

### 2.1 *Obsidian sourcing studies in historical context*

Integrating the myriad data sources forced the Author to reckon with significant practical and epistemic challenges that impacted the combined dataset's value, and which ultimately influenced what could be gleaned from the totality of knowledge produced over the prior 50 years. For instance,

during the 1960s and 1970s, only handfuls of obsidian artefacts from each site were subjected to chemical characterization, whereas more recently it has become the norm to analyze entire obsidian assemblages. This development was in part caused by rapid technological advances, especially the advent of portable X-Ray Fluorescence (pXRF), which enables archaeologists to collect raw data concerning artefacts' chemical compositions with great efficiency in fieldwork and museum settings (FORSTER, GRAVE 2012; FRAHM 2014; MILIĆ 2014). This helps mitigate against the time and logistical expense necessary to ship samples to a dedicated lab.

Moreover, the capability to generate data on entire assemblages reflects a keen desire to perform comparative analyses. Earlier on, archaeologists were content to know simply that long-distance interactions occurred and that their site was engaged in these relations that facilitated the movement of these materials (FREUND 2013; KUZMIN *et al.* 2020). But over the past ten years, obsidian sourcing has been heralded as a key vector for understanding regional interaction, primarily through the use of network and geospatial analysis techniques applied on these data (GOLITKO 2023).

However, much of the data that informs these analyses may be more problematic than they would initially appear to be. Archaeologists have rapidly discovered and defined new obsidian sources based on more intensive geophysical survey, and have significantly refined their sample preparation protocols, calibration curves, and analytical techniques (CHATAIGNER *et al.* 1998; GRATUZE *et al.* 2001; FRAHM 2023). Due to the gradual and cumulative nature of these advancements, the findings produced by older studies are generally less precise, less accurate, and less complete than their newer counterparts (FRAHM, CAROLUS 2022, 9-10).

## *2.2 Re-using the data*

Given the historical circumstances, much of the combined dataset was completely incomparable to the rest. This was problematic because the methods that defined the Thesis depended upon having a large volume of data. Either a large portion of older data could be removed, which would have reduced the potential impact of the work, or analysis could proceed using the whole dataset – with all its flaws – accompanied by several caveats that would have significantly dulled the findings. The latter approach was followed.

The end product deriving from analysis of the combined dataset simply re-stated what everyone in the field already knew, but substituting hard-earned experience for fancy figures and code as the sources through which the findings were legitimized. Moreover, in ignoring important contextual information – like typological or technical characteristics, or cultural transitions that are evident on a local level – the Thesis examined less variables than what closer readings of the material would have accounted for.



As a student who was never involved in the community of practice surrounding obsidian sourcing at that point, the Author had no experience analyzing obsidian artefacts, was disconnected from the specialist community who deals with these materials and methods, and had little knowledge of the deep, yet extremely interpersonal history of this field. However, it was clear

## DObsiSS

The Database of Obsidian Sourcing Studies

DOI: [10.5281/zenodo.55848](https://doi.org/10.5281/zenodo.55848)

[View the Project on GitHub](#)  
zackbatist/DObsiSS

[Download ZIP File](#) [View On GitHub](#)

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Hosted on GitHub Pages -- Theme by [orderedlist](#)

## Overview

The Database of Obsidian Sourcing Studies is a listing of chemically characterized archaeological obsidian, compiled from published journal articles, excavation reports, conference papers and other scholarly records. The database lists the amount of obsidian artefacts uncovered at sites in southwest Asia and Anatolia made from material derived from various volcanic sources based on geochemical analysis and comparison with geological samples.

Bringing all of the data together, archaeologists can reconstruct patterns of human movement and interaction on broad geographic and temporal scales. Hopefully this dataset may be put to other good uses as well. DObsiSS is expandable and new sourcing data will be added as it is generated; if anyone has any suggestions or modifications that they would like to propose, feel free to commit changes, fork the repository or contact me with any questions or concerns.

## The Repository

The database consists of multiple files that are organized in a purposeful way. CSV files hold tabular data and can be used for various statistical or relational analyses, among other functions. geoJSON files specify geographical elements of the dataset, and are easily imported into various GIS platforms. This file format is a variant of JSON, and is thus also very well suited for web-based visualizations. The JSON-LD file is used to integrate the dataset within a wider network of related information. Using the Linked Open Data protocol, data fields are associated with explicitly defined schemas that are presented here or elsewhere on the web. Bibliographic data pertaining to the original publications from which obsidian sourcing data are derived are available in bibtex format, and a listing of geochemical groups and their associated volcanic sources are available as well.

This database is being actively maintained and new information is incorporated as it becomes available. However, obsidian sourcing data that are pending publication are omitted until they are made publicly accessible. Feel free to ping me or commit any changes if you would like to include new data that has not yet been added, or if you would like to propose any modifications. See my [simple introduction to git](#) or my [poster from the 2015 AIA Annual Meeting](#) for an overview of the platform upon which DObsiSS operates.

## Obsidian Sources

The obsidian sources listed in the database are defined according to the determinations drawn up by Poidevin (1998).<sup>1</sup> Their locations are listed in a geoJSON file that is included in the repository and mapped below.

While the present dataset only includes obsidian from southwest Asia and Anatolia, plenty of sourcing data has been generated pertaining to other regions as well. Due to the large amount of effort required for the compilation of this information, DObsiSS will remain focused on the area currently covered.


A map of the Black Sea region, showing the coastline and surrounding landmasses. The Black Sea is labeled in the bottom left. The map displays various geographical features, including rivers, lakes, and coastal areas. The landmasses are colored in shades of green and brown, representing different types of terrain. The map is framed by a white border with a small navigation control in the top left corner.

Fig. 2 – The DObsiSS website (<https://zackbatist.info/DObsiSS>).



that crucial contextual information hidden between the lines of published reports was crucial for making sense of the inconsistencies that were apparent in the primary sources. For instance, in addition to obtaining access to all the journal articles and published reports, it was necessary to account for obsidian artefacts published multiple times in separate reports, the physical and chemical processes that differentiate obsidian characterization methods, the intricacies of various calibration methods, and nuanced debates concerning the chronological schemes and regional divisions that were applied to index the dataset.

Since the Thesis was driven by network analysis methods – and by extension, by the numbers alone – the situated and historical context pertaining to each prior study was effectively reduced to metadata without fully understanding that each one, at various points in time, was engaging with and was limited by the body of work that existed up to that point. This contributed to the Author experiencing intense epistemic anxiety (as described by WYLIE 2017; LUCAS 2019, 55-57; HUGGETT 2022, 274-278) owing to a desire to do justice to all prior work while also acknowledging that this was near impossible given the Author's lack of understanding and community support.

Moreover, the combined dataset was a product of the Author's distinct goals and biases and assembling it involved making many decisions and trade-offs that suited the needs of the specific application. Nevertheless, the dataset was made available on the web ([zackbatist.info/DobsiSS](http://zackbatist.info/DobsiSS), Fig. 2), and others were encouraged to participate in its continued development. However, no one actually expressed any interest in helping to maintain it (BATIST 2015b). There was one aborted attempt to repeat this work independently, and DObsiSS itself was a naive re-hash of a prior effort (cf. VAROUTSIKOS, CHATAIGNER 2010).

The Master's Thesis was the only comprehensive study deriving from these efforts, which testifies to their lack of value. However, numerous similar, scaled-down studies have yielded solid insights (FREUND, BATIST 2014; CARTER *et al.* 2017; FRAHM, CAROLUS 2022). These differed in that their work, including data collection and integration, was driven by intent to address specific research questions, and that their work was conducted with full awareness of the nuances and challenges pertaining to the defined scope. In other words, these projects incorporated epistemic context, whose understanding is derived from social and professional experience, into their design.

### 3. CONCLUSION

In thinking about data-sharing as means of bridging series of situated experiences, a world of under-appreciated social and epistemic implications begins to unfold. When creating or re-using data, an archaeologist engages in a collaborative commitment by making their experiences accessible beyond the

moment of archaeological encounter and by assuring themselves and others that these records are reliable (DALLAS 2015; BATIST 2023). Archaeological epistemic culture imbues a sense of professional solidarity which facilitates this aspect of work by establishing norms and expectations regarding how to best work with data in order to instill trust in a dataset's legitimacy. This is not typically formally encoded in transmitted data files, but is shared through subtextual cues and alternative forms of personal communication that surround the formal document (CHAPMAN, WYLIE 2016, 2017; BATIST 2024).

As such, simply making data available on the web, perhaps supported by formal documentation, is not enough to breathe new life into old data. Archaeologists apply a great deal of work to make data work for new purposes, which typically entails reconciling differences between disparate datasets and between each dataset and the new objectives that they were never originally meant to address. The productive integration of perspectives and practices is in fact supported by social structures, which play significant roles in coordinating labour and information produced thereof, and which extend beyond what the infrastructures that 'open archaeology' – often presented as a primarily tech-driven solution – is capable of addressing.

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### REFERENCES

- ATICI L., WHITCHER KANSA S., LET-TOV J., KANSA E.C. 2013, *Other people's data: A demonstration of the imperative of publishing primary data*, «Journal of Archaeological Method and Theory», 20, 663-681 (<https://doi.org/10.1007/s10816-012-9132-9>).
- BATIST Z. 2015a, *Obsidian Circulation Networks in Southwest Asia and Anatolia (12,000-5700 B.P.): A Comparative Approach*, Master's Thesis, Hamilton, Ontario, McMaster University (<https://macsphere.mcmaster.ca/handle/11375/16528>).
- BATIST Z. 2015b, *The Database of Obsidian Sourcing Studies (DObsiSS): Using Git for collaborative management of archaeological data*, Poster presented at the American Archaeological Institute 116<sup>th</sup> Annual Meeting (New Orleans 2015) ([https://raw.githubusercontent.com/zackbatist/DObsiSS/master/AIA2015\\_DObsiSS\\_Poster.pdf](https://raw.githubusercontent.com/zackbatist/DObsiSS/master/AIA2015_DObsiSS_Poster.pdf)).
- BATIST Z. 2023, *Archaeological Data Work as Continuous and Collaborative Practice*, PhD Thesis, Toronto, Ontario, University of Toronto (<https://tspace.library.utoronto.ca/handle/1807/130306>).

- BATIST Z. 2024, *On the value of informal communication in archaeological data work*, «Open Archaeology» (<https://doi.org/10.1515/opar-2024-0014>).
- CARTER T., BATIST Z., CAMPEAU K., GARFINKEL Y., STREIT K. 2017, *Investigating pottery Neolithic socio-economic 'regression' in the Southern Levant: Characterizing obsidian consumption at Sha'ar Hagolan (N. Israel)*, «Journal of Archaeological Science: Reports», 15, 305-317 (<https://doi.org/10.1016/j.jasrep.2017.08.016>).
- CHAPMAN R., WYLIE A. 2016, *Evidential Reasoning in Archaeology*, London, Bloomsbury Academic (<https://books.google.com?id=tMohDQAAQBAJ>).
- CHATAIGNER C., POIDEVIN J.L., ARNAUD N.O. 1998, *Turkish occurrences of obsidian and use by prehistoric peoples in the Near East from 14,000 to 6000 BP*, «Journal of Volcanology and Geothermal Research», 85, 1, 517-537 ([https://doi.org/10.1016/S0377-0273\(98\)00069-9](https://doi.org/10.1016/S0377-0273(98)00069-9)).
- COOK K. 2018, *Open data as public archaeology: The Monumental Archive Project*, «AP: Online Journal in Public Archaeology», 8, 2, 177-194 (<https://doi.org/10.23914/ap.v8i2.152>).
- COOK K., ÇAKIRLAR C., GODDARD T., DEMUTH R.C., WELLS J. 2018, *Teaching Open Science: Published data and digital literacy in archaeology classrooms*, «Advances in Archaeological Practice», 6, 2, 144-156 (<https://doi.org/10.1017/aap.2018.5>).
- DALLAS C. 2015, *Curating archaeological knowledge in the digital continuum: From practice to infrastructure*, «Open Archaeology», 1, 176-207 (<https://doi.org/10.1515/opar-2015-0011>).
- FANIEL I., KANSA E., WHITCHER KANSA S., BARRERA-GOMEZ J., YAKEL E. 2013, *The challenges of digging data: A study of context in archaeological data reuse*, in J.S. DOWNIE, R.H. McDONALD (eds.), *JDCL '13: Proceedings of the 13<sup>th</sup> ACM/IEEE-CS Joint Conference on Digital libraries (2013)*, 295-304 (<https://doi.org/10.1145/2467696.2467712>).
- FISHER M., FRADLEY M., FLOHR P., ROUHANI B., SIMI F. 2021, *Ethical considerations for remote sensing and open data in relation to the endangered archaeology in the Middle East and North Africa project*, «Archaeological Prospection», 28, 3, 279-292 (<https://doi.org/10.1002/arp.1816>).
- FORSTER N., GRAVE P. 2012, *Non-destructive PXRF analysis of museum-curated obsidian from the Near East*, «Journal of Archaeological Science», 39, 3, 728-736 (<https://doi.org/10.1016/j.jas.2011.11.004>).
- FRAHM E. 2014, *Characterizing obsidian sources with portable XRF: Accuracy, reproducibility, and field relationships in a case study from Armenia*, «Journal of Archaeological Science», 49, 105-125 (<https://doi.org/10.1016/j.jas.2014.05.003>).
- FRAHM E. 2023, *The obsidian sources of eastern Turkey and the Caucasus: Geochemistry, geology, and geochronology*, «Journal of Archaeological Science: Reports», 49, 104011 (<https://doi.org/10.1016/j.jasrep.2023.104011>).
- FRAHM E., CAROLUS C.M. 2022, *Identifying the origins of obsidian artifacts in the Deh Luran Plain (Southwestern Iran) highlights community connections in the Neolithic Zagros*, «Proceedings of the National Academy of Sciences», 119, 43, e2109321119 (<https://doi.org/10.1073/pnas.2109321119>).
- FREUND K.P. 2013, *An assessment of the current applications and future directions of obsidian sourcing studies in archaeological research*, «Archaeometry», 55, 5, 779-793 (<https://doi.org/10.1111/j.1475-4754.2012.00708.x>).
- FREUND K.P., BATIST Z. 2014, *Sardinian obsidian circulation and early maritime navigation in the Neolithic as shown through Social Network Analysis*, «The Journal of Island and Coastal Archaeology», 9, 3, 364-380 (<https://doi.org/10.1080/15564894.2014.881937>).
- GOLITKO M. 2023, *Geochemical networks*, in T. BRUGHMANS, B.J. MILLS, J. MUNSON, M.A. PEEPLES (eds.), *The Oxford Handbook of Archaeological Network Research*, Oxford, University Press, 132-148 (<https://doi.org/10.1093/oxfordhb/9780198854265.013.8>).
- GRATUZE B., BLET-LEMARQUAND M., BARRANDON J.-N. 2001, *Mass spectrometry with laser sampling: A new tool to characterize archaeological materials*, «Journal of Radioanalytical and Nuclear Chemistry», 247, 3, 645-656 (<https://doi.org/10.1023/A:1010623703423>).

- GUPTA N., MARTINDALE A., SUPERNANT K., ELVIDGE M. 2023, *The CARE principles and the reuse, sharing, and curation of indigenous data in Canadian archaeology*, «Advances in Archaeological Practice», 11, 1, 76-89 (<https://doi.org/10.1017/aap.2022.33>).
- HUGGETT J. 2018, *Reuse remix recycle: Repurposing archaeological digital data*, «Advances in Archaeological Practice», 6, 2, 93-104 (<https://doi.org/10.1017/aap.2018.1>).
- HUGGETT J. 2022, *Data legacies, epistemic anxieties, and digital imaginaries in archaeology*, «Digital», 2, 2, 267-295 (<https://doi.org/10.3390/digital2020016>).
- KANSA E.C. 2014, *The need to humanize Open Science*, in S.A. MOORE (ed.), *Issues in Open Research Data*, London, Ubiquity Press, 31-58 (<http://www.ubiquitypress.com/site/chapters/10.5334/ban.c/download/63/>).
- KANSA E.C., WHITCHER KANSA S. 2013, *We all know that a 14 is a sheep: Data publication and professionalism in archaeological communication*, «Journal of Eastern Mediterranean Archaeology and Heritage Studies», 1, 1, 88-97 (<https://doi.org/10.5325/jeasmedarcherstu.1.1.0088>).
- KINTIGH K.W., ALTSCHUL J.H., BEAUDRY M.C., DRENNAN R.D., KINZIG A.P., KOHLER T.A., LIMP W.F., MASCHNER H.D.G., MICHENER W.K., PAUKETAT T.R., PEREGRINE P., SABLOFF J.A., WILKINSON T.J., WRIGHT H.T., ZEDER M.A. 2014, *Grand challenges for archaeology*, «American Antiquity», 79, 1, 5-24 (<https://doi.org/10.7183/0002-7316.79.1.5>).
- KUZMIN Y.V., OPPENHEIMER C., RENFREW C. 2020, *Global perspectives on obsidian studies in archaeology*, «Quaternary International», 542, 41-53 (<https://doi.org/10.1016/j.quaint.2020.02.036>).
- LUCAS G. 2019, *Writing the Past: Knowledge and Literary Production in Archaeology*, New York, Routledge.
- MILIĆ M. 2014, *PXRF characterisation of obsidian from central Anatolia, the Aegean and central Europe*, «Journal of Archaeological Science», 41, 285-296 (<https://doi.org/10.1016/j.jas.2013.08.002>).
- OPITZ R., STRAWHACKER C., BUCKLAND P., COTHREN J., DAWSON T., DUGMORE A., HAMBRECHT G., KOSTER W., LETHBRIDGE E., MAINLAND I., MCGOVERN T., NEWTON A., PALSSON G., RYAN T., STREETER R., STADE E., SZABO V., THOMPSON P. 2021, *A Lockpick's guide to dataARC: Designing infrastructures and building communities to enable transdisciplinary research*, «Internet Archaeology», 56 (<https://doi.org/10.11141/ia.56.15>).
- VAROUTSIKOS B., CHATAIGNER C. 2010, *Obsidatabase: Collecter et organiser les données relatives à l'obsidienne préhistorique au Proche-Orient et en Transcaucasie*, in O. HENRY (ed.), *Archéologies et espaces parcourus*, Istanbul, Institut Français d'Études Anatoliennes, 11-21 (<https://shs.hal.science/halshs-00718893>).
- WYLIE A. 2017, *How archaeological evidence bites back: Strategies for putting old data to work in new ways*, «Science, Technology, & Human Values», 42, 2, 203-225 (<https://doi.org/10.1177/0162243916671200>).

## ABSTRACT

The Database of Obsidian Sourcing Studies (DObsiSS; <https://zackbatist.info/DObsiSS>) is an openly accessible integrated dataset comprising the results of dozens of obsidian sourcing studies published over a 50-year span. While the history of technological and professional progress pertaining to obsidian sourcing methods has yielded immense positive returns, this also produced extremely inconsistent data that were very difficult to integrate. This contributed to a sense of epistemic anxiety deriving from the struggle to reconcile the myriad outlooks that informed each data point -- with each other, and with a new objective of analyzing the dataset as an integrated whole. These challenges were further deepened by the Author's position as a student and relatively uninitiated novice at the time when DObsiSS was being compiled. This paper reflects on various social, technical and epistemic challenges that the Author faced while assembling DObsiSS and while attempting to use this integrated dataset for a failed network analysis study, and relates this experience to a broader commentary on practices relating to data re-use.

## ENTERTAINMENT BUILDINGS IN THE ROMAN EMPIRE: A QUANTITATIVE APPROACH

### 1. INTRODUCTION

The goal of the project described in the present paper is collecting data about theaters, amphitheaters, circuses and stadiums all over the Roman Empire in order to create a geo-database containing all the available information on the entertainment buildings with a deeper analysis and a broader data collection regarding the circuses. The work was conducted using open source software, such as QGIS, which is an open source geographic information system that allows for detailed spatial analysis and data management, and the results are published online on several platforms in order to exemplify a case study in data-oriented low-footprint archaeological research:

- 1) as an independent website (<https://archeolucia.geocontext.info/#/map>);
- 2) within the OpenHistoryMap platform as navigable dataset located on the map<sup>1</sup>;
- 3) as data source in the OpenHistoryMap data index<sup>2</sup>;
- 3) as raw dataset available via standard APIs on GitHub (<https://github.com/Archeolucia/theatres>);
- 4) as a metadata enhanced dataset on Zenodo (<https://zenodo.org/record/8426059>)<sup>3</sup>.

The need to create this geo-database arises by the number of Roman entertainment buildings and the potentialities offered by GIS and geographical data analysis tools to interact, query and analyze such historical structures as well as answer new or unsolved questions. At last, a freely consultable tool, represents an opportunity for scholars and interested public to deepen their research works.

### 2. TYPES OF ENTERTAINMENT BUILDINGS

During the Classical era in Greece, theater shows and sporting events were already popular forms of entertainment. However, it was during the expansion of the Roman Empire that entertainment became a significant tool for spreading

<sup>1</sup> <https://map.openhistorymap.org/#filter=source:F6655FZP>.

<sup>2</sup> <https://index.openhistorymap.org/sources/F6655FZP>.

<sup>3</sup> With this kind of dissemination the data is freely accessible for studies and consultation by scholars and an interested public. The licenses are in general CC-0, as well as an intrinsic CC-BY for academic reuse, for which Zenodo produced a DOI: <https://doi.org/10.5281/zenodo.8426058>.

Roman culture to new territories. This led to the construction of entertainment buildings throughout the empire, including theaters, amphitheaters, and circuses. While certain types of these structures were more prevalent in specific regions, at least one of these entertainment venues could be found in most areas. The circuses were composed by an oblong track ending with a curved side divided by median wall called *spina*. The distance between the two *metae* was at least 200 m, but the total length could be more than 600 m (HUMPHREY 1986). This typology of building was used to host chariots races as shown in several mosaics and sculptural reliefs. Archaeological studies show that the first stable *carceres* date back to the IV century BCE, while the masonry seats were built in Ceasar's Time (HUMPHREY 1986). This kind of building is the less attested in the Roman territories; circuses are present in Rome and in Spain but rare in other areas especially in the eastern regions (HUMPHREY 1986).

In the eastern provinces it is easier to find a stadium instead of a circus. Even if the shape of the stadium reminds the one of the circus there are many differences between the two typologies. The stadium measures exactly 1 stadion, a Greek unit of measure corresponding to 180 meters. The origins of this kind of building are Greek as it was used to host sports events. The most ancient stadium is the one in Olympia in Greece, and it is famous because in this stadium the ancient Olympic Games were held (HUMPHREY 1986).

The theaters are more widespread than circuses and stadiums in the Roman Empire; this type of entertainment building has its origin in Greece to host comedy and tragedies. Theaters shows were very appreciated also by the Romans who adopted this kind of building. At first the Roman theaters were wooden temporary buildings, the first masonry theater is the one in Bologna and dates back to 88 BCE (ORTALLI 1986). The amphitheaters are structures designed to host gladiator games; the first masonry amphitheater is the one of Pompeii and dates back to 70 BCE (BOMGARDNER 2000). Temporary wooden structures are attested at least since the II century BCE, but the amphitheaters became part of the urban landscape from the I century BCE (GOLVIN 2002). Amphitheaters are widespread all over the Roman Empire and they are often well preserved making it easy to study this kind of buildings.

### 3. STATE OF THE ART

There are several studies and books about the entertainment buildings during the Roman Empire subdivided by types, such as the works conducted by R.G. CHASE (2002) and by J.H. HUMPHREY (1986) for circuses, by J.-C. GOLVIN (2002) for amphitheaters, and by P. CIANCIO ROSSETTO and G. PISANI SARTORIO for theaters (1994). The literature on Roman entertainment buildings is vast, reflecting their central role in Roman society. Studies often explore various facets including their architectural design, construction



techniques, geographical distribution, and the sociopolitical dynamics they facilitated. Scholarly conferences have hosted panels focusing on the evolution of entertainment buildings through the Roman Empire. These discussions often emphasize changes in architectural styles and their implications for understanding Roman cultural and political shifts. Despite extensive research, gaps remain in the understanding of the regional diversity of entertainment buildings throughout the Empire. Every year new data and new discoveries become part of the discourse but, obviously, the depth of the knowledge of each building is different. Some samples are well preserved and studied, others are almost unknown or even still not located.

These studies have already been collected in several publications and websites. Some of these contain information of specific categories of buildings where each element is described and located. An example is the website 'The Ancient Theatre Archive' (<https://ancienttheatrearchive.com/>), a non-profit educational project of the Whitman College, USA (last update 12/24/2017). Each item is linked to an information sheet where data as date of construction, location, dimension, seating capacity, pictures, and plans are available. Two other websites have been created by the Generaldirektion Kulturelles Erbe Rheinland-Pfalz, Landesarchäologie Mainz. These two projects, started in 2011, deal with theaters (<https://www.theatrum.de>) and amphitheatres (<https://www.amphi-theatrum.de>). In both cases a topographical list of the monuments is available and for every monument a web page containing information, pictures and bibliography is accessible. The two works are extremely useful and interesting but they are two different and non-communicating projects, equipped with maps but without reusable and data-oriented geo-databases.

This project was conceived out of a will to bridge significant gaps in our understanding of Roman entertainment architecture, noticing there has been no unified effort to compile this information comprehensively. By gathering all known data on 387 entertainment buildings (specifically 197 amphitheatres, 76 circuses, 11 stadia, 103 theatres) throughout the Roman Empire into a single accessible database, this project fills a critical gap in Roman architectural studies. It not only enhances our understanding of Roman entertainment venues but also sets a precedent for future archaeological and historical data management. This database is expected to be a reusable and expandable resource for ongoing and future research, potentially sparking new insights into the socio-economic and cultural dynamics of the Roman Empire.

#### 4. WORKFLOW

The initial phase of the research involved a thorough examination of existing literature regarding entertainment structures from the Roman era. The body of knowledge in this area is extensive and continues to grow, providing a

robust foundation for categorizing such historical structures into four distinct types: amphitheatres, theaters, circuses, and stadiums. A comprehensive list of these known structures was compiled from the available data. For each listed building, it was imperative to pinpoint its exact geographic location. This was achieved by analyzing Mapbox Satellite as well as Bing Maps satellite imagery for structures that are still visible today, allowing for the precise input of coordinates (using WGS84 Coordinate System) into our database. However, numerous historical buildings, although recognized and recorded in earlier research, remain obscured beneath modern constructions. For these partially or completely lost buildings, the location were estimated relying on contemporary historical sources and previous archaeological studies on the same areas as well as excavation and survey reports where available. These coordinates, while not visually verified, were based on the most reliable scholarly interpretations available.

Furthermore, some structures, despite being documented in historical records or identified through archaeological findings such as statues or inscriptions, have either vanished or have yet to be discovered. In such cases, the coordinates provided were not verified; instead, a territorial analysis, consisting in a mix of satellite imagery analysis and the evaluation of local sources speaking of the area or of nearby areas, was conducted to propose a probable location. Although these coordinates are speculative, they are grounded in a careful assessment of historical context and geographical clues.

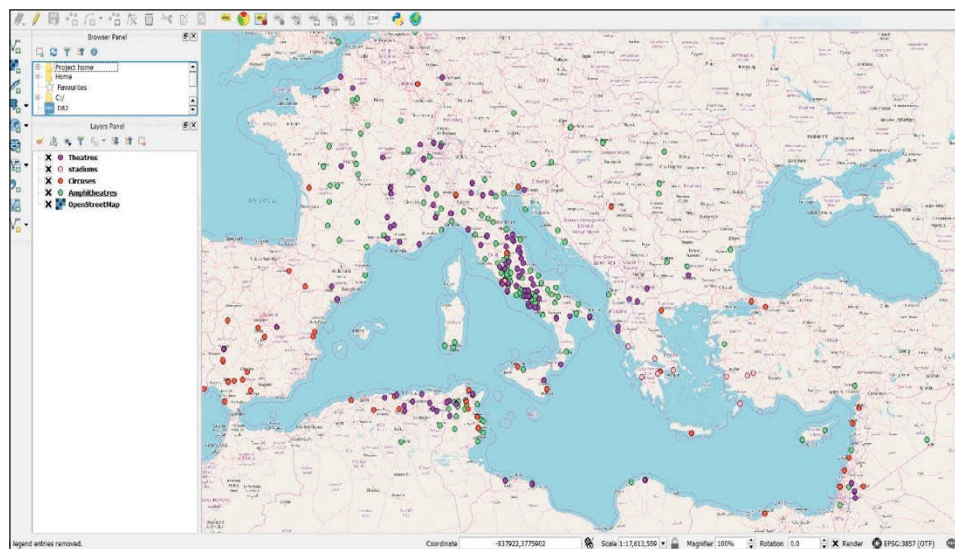


Fig. 1 – The collected information visualized in QGIS environment.



All the gathered data was systematically organized into a geo-database using QGIS software. This database includes fields for coordinates, name, city, country, and indicators of whether a building is located or visible.

As the focus of the present work was mainly on circuses, the related information sheet is more detailed than the others structures. The database fields for the circuses are, in addition to the previously mentioned: overall width, overall length, track width, track length, capacity (number of spectators that the building could host), if the circus is palatial or not, year of construction (if known) and century of construction (if known) (Fig. 1). The second part of the work for related to the publication of the collected information within a webGIS service. Using a geocontext, a tool for static publishing of geographic information the database information was exported. The tool allows to generate a web map using the Maplibre library starting from GeoJSON files and a few simple descriptors. It is possible to choose the base map, the label of each element and to customize the legend.

## 5. RESULTS AND FUTURE APPLICATIONS

The result of the project is a geo-database with 388 structures of known Roman entertainment buildings and the related information. All information is contextualized and georeferenced in order to allow geospatial analyses and studies. For instance, the geo-database was used to make some analysis on the distribution of the circuses, the main focus of the project, taking into account information such as the date of construction and the position. A first notable result is the number of the circuses. Published and historical sources allowed to recognize seventy-six circuses all over the Roman Empire, and more than those counted in previous works (HUMPHREY 1986). Among these, forty-four circuses are certainly located, and twenty-eight of them are preserved (Fig. 2). Furthermore, it is remarkable that these circuses, except

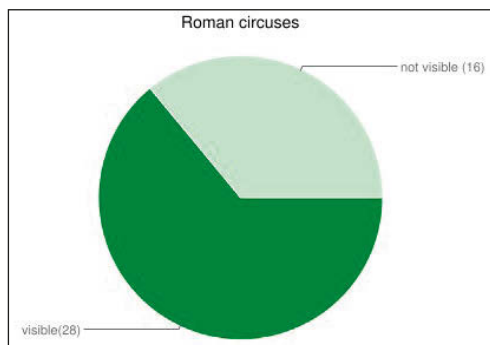


Fig. 2 – Chart of visible and not visible circuses.

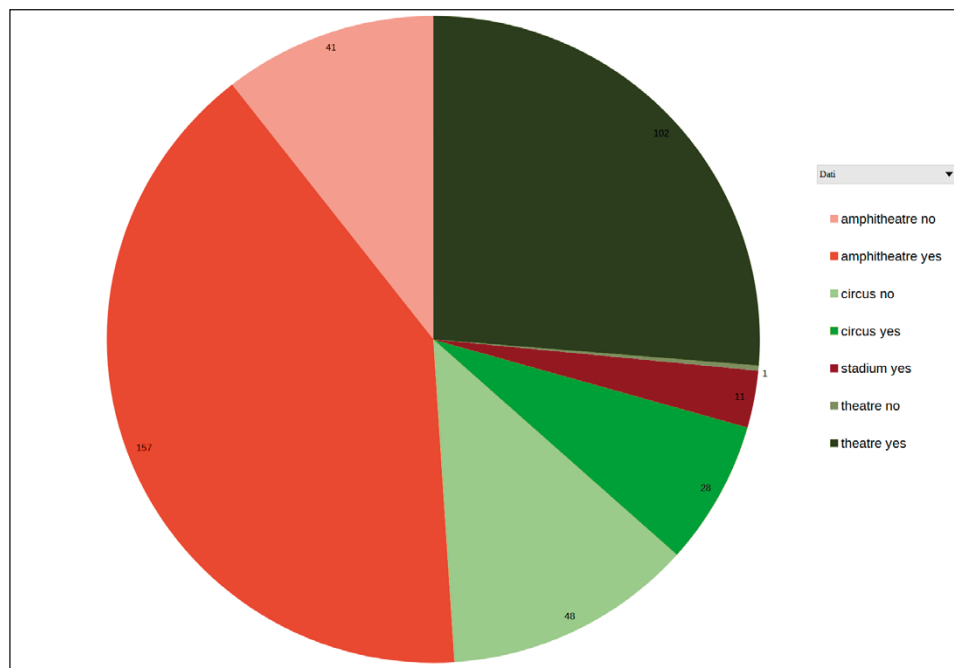


Fig. 3 – Chart of distribution of the circuses in Roman territories.

Rome are pretty rare in Italy and are widespread in Spain, where eighteen circuses are located (Fig. 3). Using webGIS or other GIS tools it is possible to measure the distance between the circus and the city walls and the proximity to the imperial Palace. The advantage of this approach would lie in its ability to precisely document monuments that might otherwise be threatened.

This project aligns with initiatives launched by the European Commission in partnership with UNESCO with the aspiration to provide accurate, timely and easily accessible information to improve the management to preserve and enhance cultural heritage (e.g. Prothego project [www.prothego.eu/dissemination](http://www.prothego.eu/dissemination)). The presented work is the first step in a broader and more complex analysis of entertainment buildings. In the next phase of development, the database will be enriched with additional data fields for all categories of entertainment buildings, such as theaters, amphitheatres, and stadiums. Specific attention will be paid to inserting standardized information on the date of construction and precise dimensions of each structure. This enhancement will provide a more homogeneous standard of information, allowing for more detailed comparative analyses across different types of buildings and regions. The database will allow researchers to examine the relationship between

entertainment buildings and their surrounding landscapes. This analysis can reveal how these structures were integrated into the natural topography, contributing to our understanding of Roman engineering and environmental adaptation. Further analysis can focus on the accessibility of these entertainment venues, investigating the infrastructural networks like roads and pathways that facilitated movement to and from these sites. This could shed light on the logistics and planning considerations of ancient Roman urban developers. Finally, by mapping the locations of various entertainment structures, the database will also enable studies on the role these buildings played in urban contexts. Researchers can explore how these venues influenced city layouts, public spaces, and the daily lives of citizens, reflecting their central role in social and political life. The geo-database makes it possible to easily access data such as century of construction and, obviously, location, that could be the starting point to understand phenomena as the concentration of structures in certain regions. Furthermore the relationship between entertainment and society can be further explored, particularly how spectacles and public shows were used during periods of Roman conquest and consolidation to disseminate cultural norms and reinforce political power.

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## REFERENCES

- BOMGARDNER D.L. 2000, *The Story of the Roman Amphitheatre*, London, Routledge.
- CHASE R.G. 2002, *Ancient Hellenistic and Roman Amphitheatres, Stadiums and Theatres: The Way they Look Now*, Portsmouth, P.E. Randall.
- CIANCIO ROSSETTO P., PISANI SARTORIO G. 1994, *Teatri greci e romani: alle origini del linguaggio rappresentato*, Rome, SEAT.
- COSTA-GARCIA J.M. 2018, *The potential of the Geographic Information Techniques for the analysis of the morphology and settlement patterns of the Roman military sites of early imperial era in Iberia*, in V. MAYORAL HERRERA, C. PARCERO-OUBIÑA, P. FÁBREGA-ÁLVAREZ (eds.), *Archaeology and Geomatics*, Leiden, Sidestone Press.
- GOLVIN J.-C. 1988, *L'amphitheatre romain: essai sur la théorisation de sa forme et de ses fonctions*, 2, Paris, Planches.
- GOLVIN J.-C. 2002, *Les images du cirque, source de connaissance de son architecture. Leur importance pour la restitution des édifices de la spina*, in T. NOGALES BASARRATE, F.J. SÁNCHEZ-PALENCIA RAMOS, *El circo en Hispania Romana*, Merida, Ministerio de Educación Cultura y Deporte, Subdirección General de Información y Publicaciones, 41-54.
- HUMPHREY J.H. 1986, *Roman Circuses: Arenas for Chariot Racing*, Berkeley, University of California Press.
- NOGALES BASARRATE T. 2017, *Ludi Circenses en Hispania: Tipologías monumentales y testimonios iconográficos*, in J. LÓPEZ VILAR, X. DUPRÉ RAVENTÓS, *La glòria del circ: curses de carros i competicions circenses: Tarraco Biennal*, Barcelona, Fundació Privada Mútua Catalana.
- ORTALLI J. 1986, *Il teatro romano di Bologna*, Bologna, Deputazione di Storia patria.

## ABSTRACT

The project features the creation of a webGIS containing heterogeneous data about entertainment buildings in the whole Roman Empire: stadiums, circuses, theaters, and amphitheaters. Information available in earlier studies have been integrated with more recent historical information, modern maps, and satellite data. This geo-database of the Roman structures gives access to information such as localization, name, country, if there are any archaeological remains and if the monument is still visible. The results of the presented work are useful to 1) analyze the relationship between buildings and surrounding lands, 2) perform advanced hypothesis about the accessibility to the structures or the role of these type of buildings in the urbanistic context, 3) understand relationship between entertainment and society and 4) identify concentrations of structures in certain regions. This research is mostly focused on the study of satellite images, published and historical sources. A substantial level of attention has been dedicated to the reusability and availability of the collected data.

## SHARING LINKED OPEN DATA WITH DOMAIN-SPECIFIC DATA-DRIVEN COMMUNITY HUBS – ARCHAEOLOGY.LINK IN NFDI4OBJECTS

### 1. INTRODUCTION

FAIRification and sharing of open data is an important part of the German National Research Data Infrastructure (NFDI) (HARTL *et al.* 2021) and its archaeology-related consortium NFDI4Objects. NFDI4Objects represents an interdisciplinary community dealing with material remains of human history from around 3 million years and involves numerous disciplines from the humanities, cultural studies and natural sciences with an archaeological and historical focus (BIBBY *et al.* 2023; THIERY *et al.* 2023b).

A considerable role in all these initiatives to interconnect and link research data is reserved for Semantic Web technologies such as the Resource Description Framework (RDF) (KLYNE *et al.* 2014) applied using Linked Open Data (LOD), which became widely known by the work of Sir T. BERNERS-LEE (2006; cf. SCHMIDT *et al.* 2022) and Linked Open Usable Data (LOUD) (SANDERSON 2018; RAEMY, SANDERSON 2023). Creating LOUD is a challenge. Within the research area of archaeology, specific digital methods such as the SPARQL Unicorn approach (THIERY *et al.* 2020) and its research tool implementations, such as the SPARQLing Unicorn QGIS Plugin (HOMBURG, THIERY 2024) and the SPARQL Unicorn Ontology Documentation (HOMBURG, THIERY 2024) may help and have been applied within the NFDI work.

Services which are offered by NFDI4Objects are domain-specific data-driven hubs to publish and share research data, Linked Open Data (LOD), ontologies, community-driven vocabularies and authority files, such as *thesauri*. E.g., the data hub for standards data and terminologies (DANTE) (HELMS 2018), the iDAI.world (FLESS *et al.* 2021) and the vocabularies in museum documentation (<https://museumsvokabular.de>) are making a variety of archaeological terms, objects, geospatial data and time periods available. The data hub ‘archaeology.link’ (<https://archaeology.link>) – hosted by the LEIZA – offers, e.g., LOD, *thesauri* and ontologies and creates a network within the virtual Archaeological Knowledge Graph and the Linked Open Data Cloud.

This paper demonstrates the content, challenges and possibilities of this data hub. It consists of five thematic parts: 1) Semantic Modelling using the Linked Archaeological Data Ontology (LADO), 2) the publication of

domain-specific Linked Open Data, 3) community-driven vocabularies, 4) ontologies, and 5) the development and publication of research software.

## 2. THE DATA HUB ‘ARCHAEOLOGY.LINK’

The archaeological data hub and framework ‘archaeology.link’ is a collaborative hub for publishing data from project cooperations; it presents research data, ontologies, related research tools and web services for e.g., Linked Open Data technologies within the scope of the archaeological fundamental research carried out by the LEIZA and its cooperation partners in joint projects. This platform complements the LEIZA Archaeological Data Processing Web Service (ADP; <https://www.rgzm.de/adp>). ‘archaeology.link’ comprises Linked Open Research Data such as the Linked Archaeological Data Ontology (LADO), Linked Open Samian Ware (from the Samian Research database), Linked Open African Red Slip Ware (from the ARS3D project), Linked Open Ships / NAVISone Maritime Thesaurus (from the NAVISone project), and Linked Open Data / FAIRification tools, e.g., Alligator, Academic Meta Tool (AMT) or re3dragon. ‘archaeology.link’ includes also projects strongly connected to the community-hub Wikidata and comprises bidirectional links. Connected Wikidata projects are, i.e., Linked Open Samian Ware (<https://t1p.de/wp-losw>), African Red Slip Ware digital (<https://t1p.de/wp-arswd>), ARS3D (<https://t1p.de/wp-ars3d>) or NAVISone (<https://t1p.de/wp-navone>).

The following sections provide an overview of the content, possibilities and challenges of ‘archaeology.link’. It comprises use-case examples of semantic modelling, i.e. modelling LOD of ARS3D/BB-5KBC and CeraTyOnt (§3), community-driven vocabularies such as the NAVISone maritime thesaurus (§4) as well as research and FAIRification tools, i.e. TiGeR and Alligator.

## 3. SEMANTIC MODELLING USING ‘ARCHAEOLOGY.LINK’

The Linked Archaeological Data Ontology (LADO; prefix *lado*) (THIERY 2022) is the core of the semantic model (based on the Web Ontology Language; OWL; prefix *owl*) used in the ‘archaeology.link’ data hub. LADO is based on CIDOC-CRM (prefix *crm*) and its extensions, the Provenance Ontology (PROV-O; prefix *prov*) (<https://www.w3.org/TR/prov-o/>), Simple Knowledge Organization System (SKOS; prefix *skos*) (<https://www.w3.org/2004/02/skos/>), the Geographic Query Language GeoSPARQL (<https://www.ogc.org/standard/geosparql/>; prefix *geosparql*) and many others. All classes are derived from *owl:Thing*, *prov:Entity* and *crm:E1\_CRM\_Entity*. Individual Objects are instances of *lado:InformationCarrier* (subclass of *crm:E22\_Human\_Made\_Object*); individual spatial locations are instances of, e.g. *lado:Location* or *lado:DiscoverySite* (subclass of

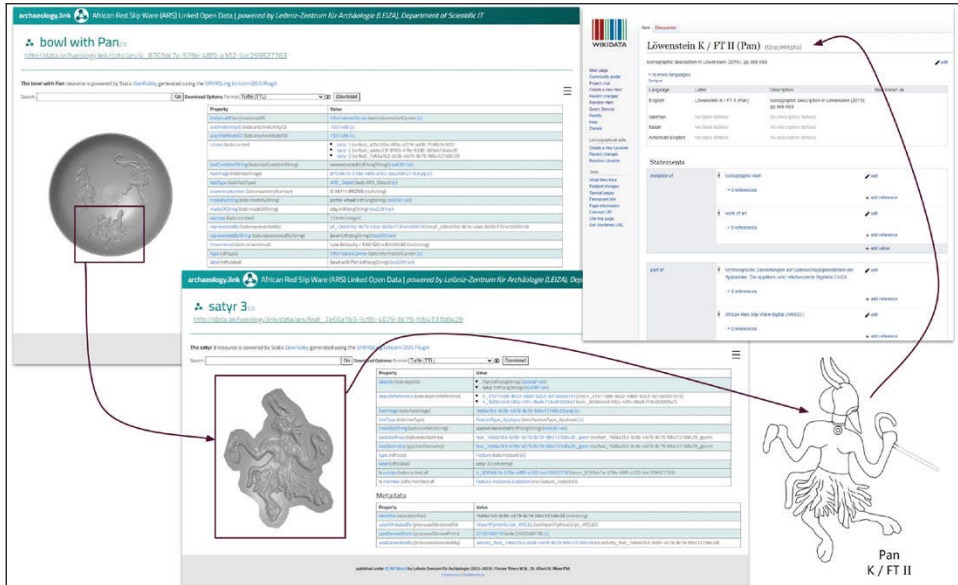


Fig. 1 – LOD representation of ARS3D-object ‘bowl with pan’ (O.39711/LEIZA collection), one feature (satyr 3), and its describing source (zu Löwenstein 2015, 713) as well as Wikidata (Q110892439) (left/middle: F. Thiery; right-top: Wikidata Community; right-bottom: with permission of S. zu Löwenstein).

skos:Concept crm:E53\_Place, geosparql:SpatialObject and pleiades:Place); individual agents such as persons are instances of lado:ActorEntity (subclass of skos:Concept, crm:E39\_Actor).

The data hub includes several datasets from various international cross-domain projects, e.g., the LOD of the Samian Research database (THIERY *et al.* 2023a), the African Red Slip Ware digital project (ARS3D) (THIERY 2023a), the NAVISone repository (THIERY 2023c) as well as further data from specific projects (e.g., from a PhD Thesis by S.C. Schmidt: THIERY, SCHMIDT 2023). Some of the data is also integrated into Wikidata and interlinked via a backlink (wd:P2888; exact match), e.g., the Samian Ware production centre La Graufesenque (Q102763431 ↔ samian:loc\_pc\_2000001). It is envisaged that – after a discussion within the Wikidata community – a Wikidata property will establish the coupling between primary databases and the secondary database and community hub Wikidata.

Using the SPARQL Unicorn Ontology Documentation (HOMBURG, THIERY 2024), it is easily possible to create browsable HTML documentation pages based on SPARQL queries. Fig. 1 shows the HTML-LOD representation of the ARS3D object ‘bowl with pan’ with an applied feature and





The data hub also comprises ontologies such as the Ceramic Typology Ontology (CeraTyOnt) (THIERY, MEES 2022a), the Alligator Ontology (<https://leiza-rse.github.io/alligator/vocab/>), and the TiGeR Ontology (<https://leiza-rse.github.io/tiger/vocab/>). Handling different typologies – developed in various European research traditions – poses a problem in archaeology, e.g. when studying *terra sigillata*. Few attempts have been made to control this methodological problem, which, e.g., also arises in the classification of amphorae (ISAKSEN *et al.* 2010). There are also different concepts for handling ceramic services covering the already in antiquity standardised types of Roman Samian (*terra sigillata*). There is currently no other method known for handling the different Samian form type variants within the current different scientific research traditions in Europe. If one would like to store typological information within Europe-wide used databases such as Samian Research, the question arises of which typology to use.

This project aims to present an online editor based on an ontology of *terra sigillata* typologies (CeraTyOnt) according to the CIDOC-CRM reference semantic model and its extensions. It allows for relationships and properties to be entered and the search result will include the associated forms and services in other typologies (e.g. the typologies of Bet, Hayes, Hermet, Vernhet, etc.) and will be published as interoperable LOD. Interoperability allows connections with other ceramic projects, such as the African Red Slip Ware 3D (ARS3D), in which forms defined by Hayes (HAYES 1972) play an important role (MEES, THIERY 2021). CeraTyOnt classes are, e.g., *lado:Potform* (derived from *skos:Concept* and *crm:E55\_Type*), *lado:Tradition* (derived from *skos:Concept* and *crm:E55\_Type*) or *lado:Service\_Collection* (*skos:Collection*, *crm:E1\_CRM\_Entity*). CeraTyOnt properties are subclasses of SKOS properties (Fig. 3, left), e.g., *lado:exactMatch* (derived from *skos:exactMatch*) or *lado:hasSameFootring*, *lado:hasSameRim*, *lado:hasSameWall* (all derived from *skos:relatedMatch*). This semantic modelling leads to small graphs, as, e.g. visualised in Fig. 3 (right), where Vernhet A3 = Bet 076 = Hermet 29 = Bet 079.

This approach also provides modelling of the vagueness in those relationships using the Academic Meta Tool (UNOLD *et al.* 2019). A footring of an incomplete Dragendorff form 18 (DRAGENDORFF 1895) can also be represented by form 18/31 or form 15/17, which have partly identical rims and/or identical footings. This results in the following numeric values: 15/17 to 18/31 (same rim: p=0%; same footring: p=100%), 18/31 to 18 (same rim: p=100%; same footring: p=50%). Using this information, an AMT ontology (THIERY, MEES 2022b) can be created and applied (<https://leiza-rse.github.io/amt-ceratyont/>). This ontology allows the create Role-Chain-Axoims between forms A, B and C, such as:



Fig. 4 – Excerpt of the NAVISone Maritime Thesaurus and features of Ravenna, Sant'Apollinare Nuovo; in the middle, mosaic of the Civitas Classis (left: F. Thiery, created with SKOS Play!; middle: F. Thiery; right: RGZM/LEIZA/NAVIS3).

- Axiom 01:  $(A)-[\text{exactMatch}]\rightarrow(B)-[\text{exactMatch}]\rightarrow(C)$ 
  - $(A)-[\text{exactMatch};\text{ProductLogic}]\rightarrow(C)$
- Axiom 02:  $(A)-[\text{hasSameFootring}]\rightarrow(B)-[\text{hasSameFootring}]\rightarrow(C)$ 
  - $(A)-[\text{partiallyCoincidentWith};\text{ProductLogic}]\rightarrow(C)$
- Axiom 03:  $(A)-[\text{hasSameRim}]\rightarrow(B)-[\text{hasSameRim}]\rightarrow(C)$ 
  - $(A)-[\text{partiallyCoincidentWith};\text{ProductLogic}]\rightarrow(C)$
- Axiom 04:  $(A)-[\text{hasSameFootring}]\rightarrow(B)-[\text{hasSameRim}]\rightarrow(C)$ 
  - $(A)-[\text{partiallyNotCoincidentWith};\text{ProductLogic}]\rightarrow(C)$

With this information, the semantic reasoning of Axiom 04 shows that the semantic relationship between Dragendorff 15/17 to 18, via 18/31 (using the footing and rim information), is:  $(15/17) \rightarrow (18) \Rightarrow \text{partiallyNotCoincidentWith } 100\%$ ;  $(18) \rightarrow (15/17) \Rightarrow \text{partiallyNotCoincidentWith } 0\%$ .

#### 4. COMMUNITY-DRIVEN VOCABULARIES PROVIDED BY ‘ARCHAEOLOGY.LINK’

The data hub ‘archaeology.link’ comprises community-driven vocabularies, e.g., the Maritime Thesaurus (derived from NAVISone), a Ceramics Typology and a Thesaurus of Figure Types (derived from the ARS3D and the Samian Research projects). The Maritime Thesaurus (THIERY 2023b) stems from the NAVIS I-III databases (<https://www.leiza.de/navis>) and comprises 16 top concept categories in 10 languages, e.g., ship function, internal construction, decks and ceilings, constructional features, sailing/steering gear, and warfare. An example from the NAVISone repository is ID: 200651 (<https://www2.leiza.de/navis/object.html?id=200651>), ‘Ravenna, Mosaico della civitas Classis’ (Fig. 4, middle, yellow box).

This mosaic is located in Ravenna (Italy), inside the Basilica of Sant’Apollinare Nuovo (Fig. 4, left-middle), made from glass during the Byzantine culture and displays three ship features ([https://archaeolink-lod.github.io/navisone/obj\\_200651/](https://archaeolink-lod.github.io/navisone/obj_200651/)). Feature 2 (ID: 201048, Fig. 4, middle

green box) as well as several sailing gears such as ‘Mast (Main)’, ‘Rigging (Standing)’ and ‘Sail (Fore)’ (cf. green boxes in Fig. 4, left and right). These three keywords are part of the Maritime Thesaurus: ‘Mast (Main)’ (it.: *Albero (Maestro)*, ID: FE0706), ‘Rigging (Standing)’ (it.: *Manovre dormienti*, ID: 074F8A) and ‘Sail (Fore)’ (it.: *Vela (Di prua)*, ID: 71CB9C). The ‘Sail (Fore)’ (de.: *Vorsegel*) can be interlinked to, e.g., Wikidata Q538850 ‘foresail’, which translates to German *Fock (Segel)* and not *Vorsegel* as mentioned in the Maritime Thesaurus. The Wikidata item Q1885401 *Vorsegel* translates inside Wikidata to ‘headsail’ and is marked explicitly different from (P1889) Q538850 ‘foresail’. Moreover, the Getty AAT describes ‘foresail’ in ID:300425931 without any scope note, just as narrower than «temporary alphabetical list: water transportation equipment» and «water transportation equipment» (<https://vocab.getty.edu/aat/300435696>).

This small example shows challenges in mapping *thesauri* terms, which requires new solutions using semantic alignment techniques (THIERY, MEES 2023a). This can be done by using variations of Simple Knowledge Organization System (SKOS) mapping properties (<https://www.w3.org/TR/2009/REC-skos-reference-20090818/#mapping>) `skos:relatedMatch`, `skos:closeMatch` and `skos:exactMatch` properties (NATION 2017), e.g., almost certainly (`skos:exactMatch`), very good chance (`skos:closeMatch`), little chance (`skos:relatedMatch`) or highly unlikely (`skos:relatedMatch`), or using quantitative descriptions of the edge properties, such as a weight attribute (degree of connection between 0 and 1) in the Academic Meta Tool (UNOLD *et al.* 2019). The perceptions of probability and numbers can lead to weights (as median values of NATION 2017, `proably.csv`), e.g., almost certainly (95%), very good chance (80%), little chance (15%) or highly unlikely (5%).

## 5. RESEARCH AND FAIRIFICATION TOOLS PROVIDED BY ‘ARCHAEOLOGY.LINK’

One of the main aims of ‘archaeology.link’ is to provide research software for domain-specific purposes. This includes FAIRification tools such as the *re3dragon* (THIERY, MEES 2024) or *AMT* (UNOLD *et al.* 2019; THIERY, MEES 2023a) or research tools which can handle LOD and relative chronologies such as *Alligator* (<https://github.com/leiza-rse/alligator/>) or *TiGer* (<https://github.com/leiza-rse/tiger/>). Both tools allow for handling so called ‘Dated Sites’ using correspondence analysis to treat chronologies as graphs (THIERY, MEES 2023c). One example to demonstrate the possibilities of the *TiGer* (Time Geospatial RDF) and *Alligator* (Allen Transformer) research tools can be seen in Fig. 5. Following the horseshoe paradigm (MADSEN 1988, 25), a correspondence analysis (CA), when applied to datasets with a possible chronological sensitive meaningfulness,

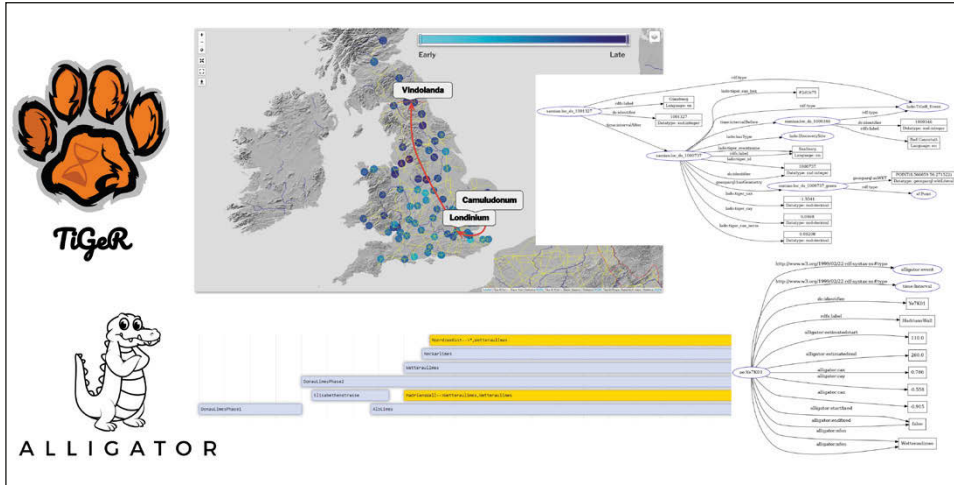


Fig. 5 – Samples from the Research Tools TiGeR and Alligator show visualisations of relative time periods on a map and virtual timeline and as schematic RDF/LOD calculated by correspondence analysis results (F. Thiery, A.W. Mees).

displays the inertia within a dataset based on computing the Chi-square statistic for two-way tables. The results may provide a measure of (possible chronological) overlap between e.g. different Roman ‘Dated Sites’ comprising identical materials such as a Roman *terra sigillata* having identical features, specifically vessels having name stamps of the same potter. It is important to note that a CA of assumed ‘Dated Sites’ does not comprise any pre-known dating information of these ‘Dated Sites’, but solely calculates with the partially overlapping incidences of specific objects between these ‘Dated Sites’.

In the examples of Fig. 5, incidences of sites, potters and their occurrences are used. The TiGeR map shows assumed ‘Dated Sites’ in Britannia coloured by normalising the 1<sup>st</sup> Dimension values of the CA output and converting them into gradient colours using rainbow.js. This creates a result which can be interpreted as a gradient chronology of Britannia, displaying the enrolling occupation of Britain from *Camulodunum* via *Londinium* to *Vindolanda* on a map, resulting in an Linked Open Data (LOD) representation in a Resource Description Framework (RDF) format following the TiGeR ontology (Fig. 5, top). Using the Alligator Method based on the Alligator Algorithm (THIERY, MEES 2023b), the calculation starts with calculating the 3D distances by using the coordinates of the first 3 CA dimensions, establishing undated wobbly floating periods by finding the next 3D CA neighbour.

Within the next step, the new virtual time intervals are calculated, and the resulting virtual fuzzy years are generated based on Allen's Interval Algebra (ALLEN 1983; FREKSA 1991). Fig. 5 (bottom) displays the virtual timeline (and its LOD representation) of vague floating intervals for two *limes* sections: Hadrian's Wall and the North Sea Coast. The process of nearest neighbour findings suggests a starting date of Hadrian's Wall similar to that of the Wetterau Limes. The calculated virtual fuzzy years seem to confirm the widespread assumption that Hadrian's Wall, the North Sea Coast foundations and the Wetterau Limes were founded in the same decades.

## 6. CONCLUSION

This paper has demonstrated three elements of the 'archaeology.link' resource: the semantic modelled Linked Open Data and ontologies, community-driven vocabularies such as research domain-specific *thesauri*, and the provision of research and FAIRification tools. Data hubs like 'archaeology.link', providing a common ontology, derived research data and *thesauri*, sub-ontologies and research tools which are enabling the implementation of Semantic Web technologies (serving themselves as FAIRification tools as well) are offering good opportunities to implement the FAIR data principles and to realise the idea of Open Science.

The research results stemming from the usage of the platform 'archaeology.link' have thrown entirely new light on the dating qualities of archaeological finds, such as Roman *terra sigillata*, which is found in Italy, Spain, North Africa and the Northwestern Roman Empire. The developed ontology of CeraTyOnt enables new ways of interconnecting different European research traditions, which are rooted in their own national typologies. This typologies ontology enables the interconnection of European typologies instead of creating a single new dominating typology, which acceptance in individual European research traditions would remain to be seen. The handling of time intervals with the Alligator tool enabled the chronological classification of e.g. continental Limes sections together with Hadrian's Wall. This provides a new dating fundament for British, Dutch and German archaeologies. The same is valid for the Maritime Thesaurus, comprising SKOS based terms which are in use in different European maritime archaeologies, ranging from Italian shipwrecks, Scandinavian Viking ships to Phoenician maritime finds.

Institutions which are offering similar resources like 'archaeology.link' are paving their way into (inter)national initiatives such as NFDI consortia or EOOSC. However, the hurdles are high for researchers within the Humanities to transform and provide their data structured in the required way. Platforms

and hubs like ‘archaeology.link’ are a great way to establish interdisciplinary, international and cross-institutional communities around specific scientific subjects. Due to the common LADO ontology, these initiatives all have a common and scalable fundament. However, the challenges of maintenance, continuity and sustainability for both data and research software must be matched with the available financial and human resources, suggesting that there is only a very limited group of research institutions which can guarantee the sustainability of such platforms and hubs.

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## REFERENCES

- ALLEN J.F. 1983, *Maintaining knowledge about temporal intervals*, «Communications of the ACM», 26, 11, 832-843 (<https://doi.org/10.1145/182.358434>).
- BERNERS-LEE T. 2006, *Linked Data* (<https://www.w3.org/DesignIssues/LinkedData.html>).
- BIBBY D., BRUHN K.-C., BUSCH A., DÜHRKOPF F. et al. 2023, *NFDI4Objects. Proposal*, «NFDI4Objects Zenodo Community» (<https://doi.org/10.5281/zenodo.10409227>).
- DRAGENDORFF H. 1895, *Terra sigillata. Ein Beitrag zur Geschichte der griechischen und römischen Keramik*, «Bonner Jahrbücher», 96-97, 18-155.
- FLESS F., BAUMEISTER P., BOYXEN B. et al. 2021, *Die iDAI.world vor dem Hintergrund der neuen Digitalgesetze*, «Forum for Digital Archaeology and Infrastructure», 1, 1-51 (<https://doi.org/10.34780/s2ne-t268>).
- FREKSA C. 1991, *Conceptual neighborhood and its role in temporal and spatial reasoning*, in M.G. SINGH, L. TRAVÉ-MASSUYÉS (eds.), *Proceedings of the IMACS Workshop on Decision Support Systems and Qualitative Reasoning*, Amsterdam, North-Holland, 181-187.
- HARTL N., WÖSSNER E., SURE-VETTER Y. 2021, *Nationale Forschungsdateninfrastruktur (NFDI)*, «Informatik Spektrum», 44, 5, 370-373 (<https://doi.org/10.1007/s00287-021-01392-6>).
- HAYES J.W. 1972, *Late Roman Pottery*, London, British School at Rome.
- HELMS T. 2018, *DANTE-DAtendrehscheibe für Normdaten und TERminologien*, «AKMB-News», 24, 1 (<https://doi.org/10.11588/akmb.2018.1.63475>).
- HOMBURG T., THIERY F. 2024, *SPARQL Unicorn ontology documentation, v0.17*, «Squirrel Papers», 6, 2 (<https://doi.org/10.5281/zenodo.10780476>).
- ISAKSEN L., EARL G., MARTINEZ K., KEAY S., GIBBINS N. 2010, *Linking archaeological data*, in B. FRISCHER, L. FISCHER, D. KOLLER (eds.), *Making History Interactive. Computer Applications and Quantitative Methods in Archaeology (CAA): Proceedings of the 37<sup>th</sup> International Conference*, Williamsburg, Archaeopress, 2-8 (<https://eprints.soton.ac.uk/204529/>).
- KLYNE G., CARROLL J.J., MCBRIDE B. 2014, *RDF 1.1 Concepts and Abstract Syntax*; W3C Recommendation 25 February 2014 (<https://www.w3.org/TR/rdf11-concepts/>).
- ZU LÖWENSTEIN S. 2015, *Mythologische Darstellungen auf Gebrauchsgegenständen der Spätantike: die appliken- und reliefverzierte Sigillata C3/C4*, «Kölner Jahrbuch», 48, 397-823.
- MADSEN T. (ed.) 1988, *Multivariate Archaeology: Numerical Approaches in Scandinavian Archaeology*, Århus, Jutland Archaeological Society.



- MEES A., THIERY F. 2021, *Une visualiseur et éditeur numérique sur Internet pour une ontologie des typologies de terre sigillée*, in *Actes des Congrès de la Société française d'étude de la céramique antique en Gaule*, Marseille, SFECAG, 585-589.
- NATION Z. 2017, *Perceptions of Probability and Numbers* (<https://github.com/zonation/perceptions>).
- RAEMY J.A., SANDERSON R. 2023, *Analysis of the usability of automatically enriched cultural heritage data*, «arXiv», 2309.16635 (<https://doi.org/10.48550/arXiv.2309.16635>).
- SANDERSON R. 2018, *LOUD: Linked Open Usable Data* (<https://linked.art/loud/>).
- SCHMIDT S.C., THIERY F., TROGNITZ M. 2022, *Practices of Linked Open Data in archaeology and their realisation in Wikidata*, «Digital», 2, 3, 333-364 (<https://doi.org/10.3390/digital2030019>).
- THIERY F. 2022, *Linked Archaeological Data Ontology, v1.0*, «Squirrel Papers», 4, 2 (<https://doi.org/10.5281/zenodo.7377740>).
- THIERY F. 2023a, *Archaeolink-lod/lars, GitHub-Repository*, «Squirrel Papers», 5, 6 (<https://github.com/archaeolink-lod/lars>).
- THIERY F. 2023b, *Archaeolink-lod/maritimethesaurus, GitHub-Repository*, «Squirrel Papers», 5, 6 (<https://github.com/archaeolink-lod/maritimethesaurus>).
- THIERY F. 2023c, *Archaeolink-lod/navisone, GitHub-Repository*, «Squirrel Papers», 5, 6 (<https://github.com/archaeolink-lod/navisone>).
- THIERY F., MEES A. 2022a, *Ceramic Typologies Ontology (CeraTyOnt), v0.2*, «Squirrel Papers», 4, 2 (<https://doi.org/10.5281/zenodo.5767082>).
- THIERY F., MEES A. 2022b, *CeraTyOnt @ AMT, v1.0*, «Squirrel Papers», 4, 2 (<https://doi.org/10.5281/zenodo.7143093>).
- THIERY F., MEES A. 2023a, *Taming Ambiguity. Dealing with doubts in archaeological datasets using LOD*, in *Proceedings of Computer Applications and Quantitative Methods in Archaeology Conference CAA 2018, Human History and Digital Future (Tübingen 2018)*, Tübingen, University Press (<http://dx.doi.org/10.15496/publikation-87762>).
- THIERY F., MEES A.W. 2023b, *Alligator method*, «Squirrel Papers», 5, 1 (<https://doi.org/10.5281/zenodo.7624870>).
- THIERY F., MEES A.W. 2023c, *Dating dated sites. Using Correspondence Analysis to handle chronologies as graphs*, «Squirrel Papers», 5, 4 (<https://doi.org/10.32028/Groma-Issue-7-2022-2429>).
- THIERY F., MEES A. 2024, *Re3dragon. A research registry resource API for data dragons*, «GROMA: Documenting Archaeology», 7 (<http://doi.org/10.32028/Groma-Issue-7-2022-2429>).
- THIERY F., MEES A.W., GOTTWALD D., HOMBURG T. 2023a, *Archaeolink-lod/samian, GitHub-repository*, «Squirrel Papers», 5, 6 (<https://github.com/archaeolink-lod/samian>).
- THIERY F., MEES A.W., WEISSER B., SCHÄFER F.F., BAARS S., NOLTE S., SENST H., VON RUMMEL P. 2023b, *Object-related research data workflows within NFDI4Objects and beyond*, in Y. SURE-VETTER, C. GOBLE (eds.), *1<sup>st</sup> Conference on Research Data Infrastructure (CoRDI) - Connecting Communities*, Hannover, TIB Open Publishing, CoRDI2023-46 (<https://doi.org/10.52825/cordi.v1i.326>).
- THIERY F., SCHMIDT S.C. 2023, *Research-Squirrel-Engineers/bb-5kbc, GitHub-repository*, «Squirrel Papers», 5, 6 (<https://github.com/Research-Squirrel-Engineers/bb-5kbc/>).
- THIERY F., SCHMIDT S.C., HOMBURG T., TROGNITZ M. 2020, *The SPARQL Unicorn: An introduction*, «Squirrel Papers», 2, 1 (<https://doi.org/10.5281/zenodo.3742185>).
- UNOLD M., THIERY F., MEES A. 2019, *Academic Meta Tool. Ein Web-Tool zur Modellierung von Vagheit*, «ZfdG. Zeitschrift für digitale Geisteswissenschaften», Die Modellierung des Zweifels. Schlüsselideen und-konzepte zur graphbasierten Modellierung von Unsicherheiten. Sonderband 4 ([https://doi.org/10.17175/SB004\\_004](https://doi.org/10.17175/SB004_004)).

## ABSTRACT

FAIRification and sharing of open data is an important aspect of the German National Research Data Infrastructure (NFDI) and its archaeology related consortium NFDI4Objects. NFDI4Objects offers domain-specific data-driven hubs to publish and share research data, Linked Open Data (LOD), ontologies, community-driven vocabularies and authority files, such as *thesauri*. This paper demonstrates the content, challenges and possibilities of the Data Hub ‘archaeology.link’. It consists of five thematic parts: 1) Semantic Modelling using the Linked Archaeological Data Ontology (LADO), 2) publication of domain-specific Linked Open Data, 3) community-driven vocabularies such as *thesauri*, 4) ontologies and 5) research tools.



## THE GOOD, THE BAD AND THE UGLY: EVALUATING OPEN SCIENCE PRACTICES IN ARCHAEOLOGY

### 1. INTRODUCTION: DISENTANGLING OPEN ACCESS AND OPEN SCIENCE

In contemporary discourse, distinguishing between Open Science (OS) and Open Access (OA) can often prove challenging<sup>1</sup>. While OA constitutes just one facet of the broader OS framework, it entails unfettered online access to research findings and data, as stated by seminal documents such as the 2002 Budapest Open Access Initiative (BOAI) (<https://www.budapestopenaccessinitiative.org/read/>) and the 2003 Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities (<https://openaccess.mpg.de/Berlin-Declaration>). Despite the noble intentions driving the OA movement – such as democratising the production and consumption of scholarly outputs – critical reflections emerged in the wake of its fervent inception.

It is not a case that in 2022 the BOAI, in the occasion of its 20<sup>th</sup> anniversary, declared that «Open access is not an end in itself, but a means to further ends. Above all, it is a means to the equity, quality, usability, and sustainability of research» (<https://www.budapestopenaccessinitiative.org/boai20/>). Consequently, the BOAI steering committee recognised that OA practices inadvertently exacerbated the digital divide between well-funded institutions of the Global North and their under-resourced counterparts in the Global South. In response, the committee delineated four main strategies to mitigate this inequity: 1) hosting OA research on open infrastructure owned or managed by non-profit organisations; 2) reforming research assessment criteria for funding allocations and academic promotions; 3) fostering inclusive publishing and distribution channels that never exclude authors on economic grounds; and 4) advocating for dissemination models benefitting all regions of the world, under the stewardship of academic-led and non-profit organizations.

In this context, OS has been proposed as a sort of corrective for some of the issues highlighted above because it aims to reform research through more transparent, equitable, inclusive, and collaborative practices (VICENTE-SAEZ, MARTINEZ-FUENTES 2018; UNESCO 2021). However, OS remains

<sup>1</sup> This paper has benefited from the research funding provided by the Italian Ministry of Research through the Rita Levi Montalcini program, as well as by the Gerda Henkel Foundation. The digital archive associated with this paper facilitates the reproducibility of Figs. 1 and 3 through two datasets and a script written in the R statistical computing language. This digital archive is openly accessible via GitHub ([https://github.com/apalmisano82/Open\\_Science](https://github.com/apalmisano82/Open_Science)) and Zenodo (<https://doi.org/10.5281/zenodo.10971326>).

a multifaceted and somewhat nebulous concept, encompassing diverse interpretations and it can be perceived as a movement, a goal, a framework of policies, or even a research strategy (FECHER, FRIESIKE 2014).

Furthermore, with the exception of a few archaeologists familiar with quantitative and computational approaches, OS is only slowly reaching mainstream archaeology. In the realm of archaeology, OS predominantly revolves around the principles of open data sharing and open access publications. However, compared to the practices observed in the natural sciences, aspects like open methods and reproducibility have received relatively less attention. This disparity underscores a significant gap between archaeology and scientific disciplines.

The adoption and development of OS practices have exhibited considerable variation across different countries. Notably, the United Kingdom and the United States have emerged as frontrunners in this regard. This prominence is partly attributed to the classification of archaeology as a discipline within the social sciences domain in these countries, as opposed to its categorisation under the humanities in many other countries.

Hence, there exists a pressing need to reverse a prevailing trend within archaeology. In this paper, we endeavour to offer a comprehensive and foundational introduction specifically tailored to researchers with an interest in OS practices within the field of archaeology. Our aim is to critically evaluate the current state of the art concerning open data, methods, and publication practices within archaeology. Additionally, we will provide insightful recommendations for applying OS practices in the archaeological research.

## 2. OPEN DATA

The field of archaeology has experienced a transformative shift in recent years, spurred by a growing deluge of novel digital data about the human past accessible through online databases and open repositories (BEVAN 2015). Within archaeology, a diverse range of data emerges from fieldwork activities and the digitisation of information from published works. As recently pointed out by B. MARWICK and S.E. PILAAR BIRCH (2018), archaeology is a poor-data field affected by restricted data-sharing practices and the lack of standardised methods for sharing and citing data. Particularly concerning is the reluctance of authors to share their data, a phenomenon known as ‘data-hoarding’, driven by fears of losing opportunities for future publications and the reluctance to invest time in organising data for their reuse (MARWICK, PILAAR BIRCH 2018, 129-131).

There are three common ways to share data in archaeology: databases, supplementary materials and online DOI-issuing repositories. The first approach poses significant challenges in our field due to ambiguity surrounding

what constitutes data sharing among most archaeologists. Often, the visually appealing and multifunctional interfaces of online databases are mistakenly perceived as facilitating data sharing. However, in many cases, the stored information cannot be downloaded and reused, necessitating users to manually digitise and gather data anew. Noteworthy examples are the MedAfriCarbon (<https://theia.arch.cam.ac.uk/MedAfriCarbon/>) and NEONET (<http://shinyserver.cfs.unipi.it:3838/C14/>) databases that allow the download of raw data (for detailed descriptions refer to LUCARINI *et al.* 2020; HUET *et al.* 2022).

Sharing data as supplementary materials attached to journal articles is another common mistake as files are not accessible to nonsubscribers for paywalled journals. Moreover, supplementary materials are often presented in tables stored in binary file formats like .PDF or Excel, impeding data reuse. Instead, sharing data through publicly accessible online repositories is the recommended practice (MARWICK, PILAAR BIRCH 2018, 133-135). Notable repositories tailored for archaeologists include the Archaeology Data Service (<https://archaeologydataservice.ac.uk/>) and the Digital Archaeological Record (<https://core.tdar.org/>). While these repositories may entail reasonable fees for data maintenance and curation, users also have the option of utilizing free repositories such as the archaeology-focused Mappa Open Data (MOD) archive (<https://digitallib.unipi.it/it/archivio/MOD-Mappa-Open-Data-archive/>), as well as discipline-agnostic repositories such as Zenodo (<https://zenodo.org/>) and Figshare (<https://figshare.com/>). Furthermore, institutional repositories of universities serve as valuable resources for disseminating data at no cost, showcasing and providing open access to research outputs.

Bearing in mind the aforementioned issues, here we present a small pilot-study aiming at understanding how archaeologists share research data. We analysed a total of 621 publications from four methodology-based archaeology journals published in 2020-2021: «Journal of Archaeological Science» (JAS,  $n = 300$ ), «Journal of Archaeological Method and Theory» (JAMT,  $n = 53$ ), «Journal of Computer Applications in Archaeology» (JCAA,  $n = 30$ ) and «Plos One» ( $n = 238$ ). This pilot study was limited in scope, as it focused on a brief time frame due to the need for meticulous examination of numerous publications to determine if they were based on research that could lead to the release of a dataset and workflow. The sample does not include review articles and commentaries, focusing solely on research articles utilizing data and methods. In the case of the multidisciplinary journal «Plos One», only articles within the field of archaeology were considered. The results (Tab. 1) indicate that the 46.7% of articles share data either as supplementary materials (34.6%) or via a public DOI-issuing online repository (12.1%).

It is alarming that the majority of archaeologists inclined to share their data opt not to use online repositories. Upon further examination of each journal, it becomes evident that «Plos One» stands out, with approximately

	Total articles	Sharing data	Supplementary materials	DOI-issuing Online repositories	Reproducible research
Journal of Archaeological Science (JAS)	300	122 (40.6 %)	100 (33.3%)	22 (7.3%)	21 (7%)
Journal of Archaeological Method and Theory (JAMT)	53	19 (35.8 %)	16 (30.2 %)	3 (5.6 %)	7 (13.2 %)
Journal of Computer Applications in Archaeology (JCAA)	30	15 (50 %)	2 (6.6 %)	13 (43.4%)	11 (36.6 %)
Plos One	238	134 (56.3 %)	97 (40.8 %)	37 (15.5 %)	37 (15.5 %)
Total	621	290 (46.7 %)	215 (34.6 %)	75 (12.1 %)	76 (12.2 %)

Tab. 1 – Summary of data sharing and reproducibility practices between 2020-2021.

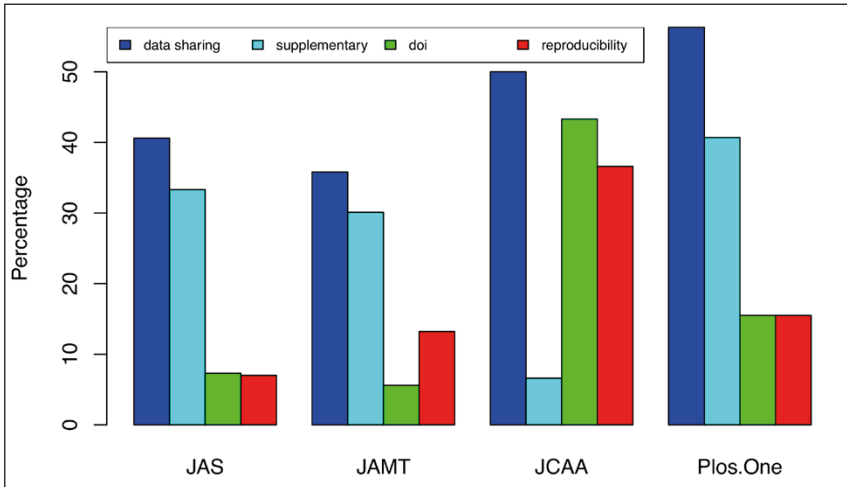


Fig. 1 – Graph showing data sharing and reproducibility practices between 2020-2021.

60% of its published archaeology articles sharing data, largely due to the journal’s policy mandating authors to make their data publicly available (Fig. 1). However, it is disappointing to note that across all journals, except for «JCAA», authors tend to share data primarily as supplementary material. «JCAA» counters this trend, likely due to the authors’ strong computational skills and familiarity with open science practices.

Another recommendable practice gaining traction among archaeologists is the dissemination of datasets through the publication of data papers. These papers offer comprehensive insights into the creation, structure, methodology, and potential applications of a dataset. Such publications are invaluable as they enable researchers to share their datasets within their scientific communities and to receive recognition for their efforts in dataset creation and dissemination (HOLE

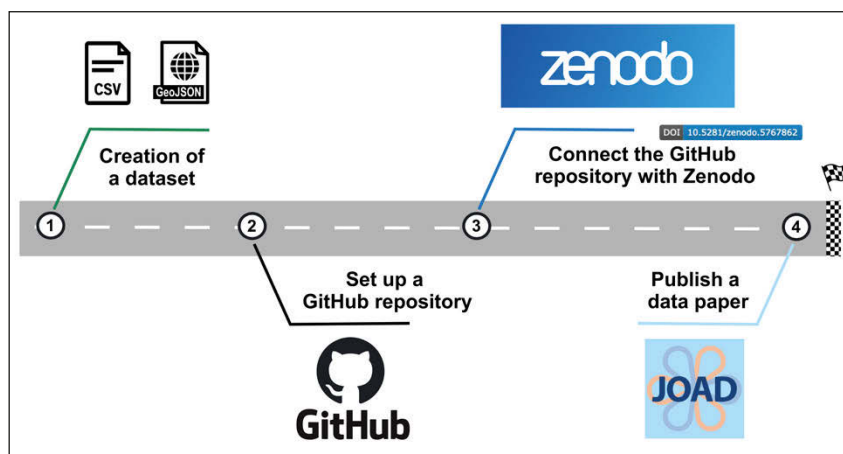


Fig. 2 – The roadmap for disseminating openly a dataset.

2012). Associating a citable publication with a specific dataset could incentivise archaeologists to share their data and alleviate data hoarding tendencies. Within the field of archaeology, there are two prominent data journals: the «Journal of Open Archaeology Data» (<https://openarchaeologydata.metajnl.com/>) and «Archeologica Data» (<https://www.mappalab.eu/archeologica-data-2/>). Moreover, the publication of a data paper should be just the final step in a workflow aiming at making a dataset FAIR (Fig. 2): 1) creation of the dataset; 2) publishing it via GitHub; 3) linking the GitHub repository to Zenodo to archive the dataset by assigning a DOI and ensuring that all versions of the dataset are tracked in both repositories; 4) publishing a data paper.

### 3. OPEN METHODS

Open methods are important to guarantee the reproducibility of research, which is the practice of producing the same results of a published work by using the same data and methods. While this practice is well-established in the natural sciences, its application in archaeology it is still at its infancy. Enabling reproducibility is one of the keystones of OS and it is a crucial step to ensure the validity and transparency of a specific research. Regrettably, within the field of archaeology, typical journal articles describing the results of a study seldom provide the raw data, workflows and methods to reproduce its graphs and figures (KAROUNE, PLOMP 2022). Consequently, when a novel methodological paper is published without any accompanying software and data, the utility of such developments becomes markedly arduous for fellow researchers to harness.

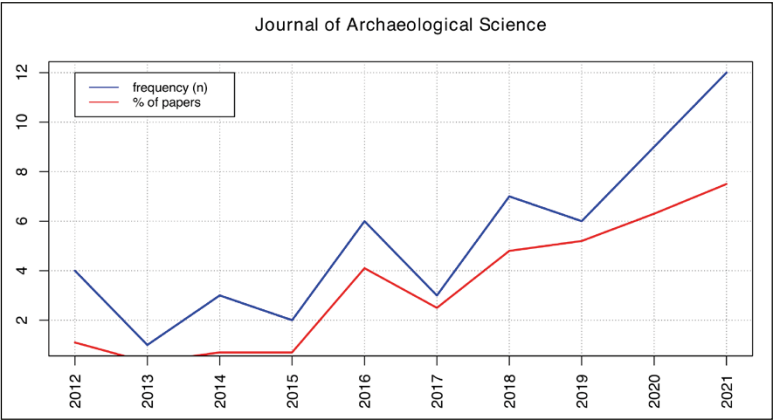


Fig. 3 – Change over time of reproducible research in «JAS» from 2012 to 2021.

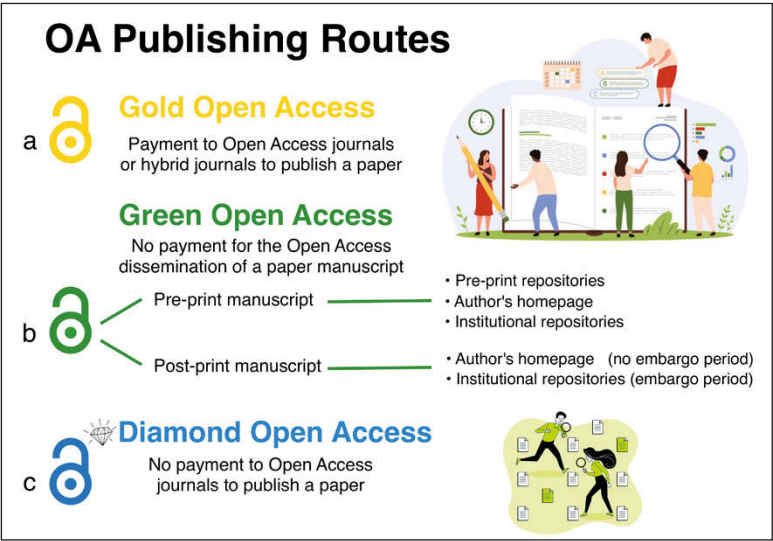


Fig. 4 – Routes to Open Access (OA) publications (created by using images from <http://www.freepik.com/>).

This not only contravenes the very essence of disseminating novel methodologies but also inevitably hampers any advancement in the discipline. A robust approach to enhance reproducibility involves making both raw data and analytical workflows readily accessible for the reproducibility of analyses and figures presented in published works (MARWICK 2017). While one initial step

towards sharing methodologies may include the creation of tutorials or video recordings detailing the mouse-driven processes of interface-based software commonly utilized by researchers, a more effective solution would be writing a script (MARWICK 2017, 431-432). A script is a plain text written in a specific programming language (e.g., Java, Python, R) which provides a comprehensive set of executable instructions for a computer. This latter approach ensures a meticulous reconstruction of the research workflow, enabling thorough scrutiny of each analysis step by any interested party. Notably, R stands out as the predominant programming language employed by archaeologists (R CORE TEAM 2024). B. MARWICK (2022) provides a list of R packages for data manipulation, and analyses and of reproducible studies making use of scripts written in R.

Transparency and reproducibility not only bolster the credibility of research but also facilitate independent evaluations of research findings by peers. In this context, particularly emblematic are two independent studies on palaeodemography focussing on a similar region and timespan published in the same issue of «*Journal of World Prehistory*» (PALMISANO *et al.* 2021; PARKINSON *et al.* 2021). As both studies openly shared their raw data and R scripts, the respective authors were invited by the journal's editor to review each other's data and workflows, subsequently reflecting on the similarities and disparities in methodology and findings between the two studies in two distinct commentaries published openly. This was an excellent example of transparency and a rare opportunity to reflect on methods and results to foster advancement in the field.

As shown in the small pilot study above, if data sharing is quite common in archaeology (at least in the methods-based journals), we cannot say the same for reproducibility practices. Merely 12.2% of articles are accompanied by workflows and raw data, thereby guaranteeing reproducibility (Tab. 1, Fig. 1), with «JCAA» exhibiting a notably higher percentage at 36.6%. This observation suggests that authors within this journal are more acquainted with computational and quantitative methodologies. We have also assessed how trends in reproducibility practices have been developed in the past decade and to do so we have scrutinised all publications in «JAS» from 2012 to 2021 (Fig. 3). The findings indicate a rising trend in efforts to make analyses reproducible, yet the peak reached in 2021 reveals that only 8% of published studies achieve reproducibility. Considering «JAS» standing as one of the foremost method-based journals, this statistic may reflect a more dismal scenario in traditional archaeology journals.

#### 4. OPEN PUBLISHING

There are different options to publish OA online texts of scholarly work: Gold, Green and Diamond OA (Fig. 4) (CARVALE, PIERGROSSI 2012). The article processing charge (APC) to publish Gold OA often requires a



substantial cost serving as a barrier for researchers affiliated with poor institutions as well as for early-career researchers lacking significant research funding (Fig. 4a). Furthermore, it is not advisable publishing via Gold Open Access in hybrid journals because they operate under a model where articles are available to users having access through institutional subscriptions. This model is thus subject to considerable controversy in terms of sustainability, as it gains revenue from both subscriptions and APCs.

Alternatively, researchers have the option to publish their work through Green OA enabling authors to share their manuscripts freely online without incurring any costs (Fig. 4b). A manuscript, distinct from the publisher's finalised version, lacks pagination and full formatting for publication and exists either as a pre-print or a post-print. A post-print is subject to certain restrictions and must meet specific requirements set by academic journals, such as embargo periods, copyright rules, and self-archiving policies. These details can be consulted through the online resource SHERPA/RoMEO (<https://www.sherpa.ac.uk/romeo/>).

Another option is represented by Diamond Open Access, which refers to a publishing model where the authors pay no APCs (Fig. 4c). In the field of archaeology, Diamond Open Access is guaranteed by journals such as «Archeologia e Calcolatori» (<https://www.archcalc.cnr.it>) (ROSSI, PARACIANI 2021) and «Peer Community Journal» (<https://peercommunityjournal.org/>). The latter publishes papers endorsed by PCI Archaeology (<https://archaeo.peercommunityin.org>), a community of archaeologists that recommends papers based on peer reviews, with all editorial correspondence (reviews, editors' decisions, authors' replies) being publicly accessible and transparent (QUEFELLEC *et al.* 2023).

## 5. CONCLUSIONS: THE ROADMAP TO OPEN SCIENCE IN ARCHAEOLOGY

This paper has provided an introduction and review of the most common OS practices in archaeology. The highlighted practices show diverse approaches and have been applied for various purposes. It is worth noting that there is no single optimal solution, and researchers should carefully consider their options based on the nature of the data and analyses utilised in their research endeavours. In this section, we will outline a decalogue, delineating a series of straightforward recommendations and guidelines that may prove helpful for scholars seeking to disseminate their research findings openly:

1. Publish scholarly work electronically (e.g., books, archaeological excavation and surveys reports, research articles).
2. Ensure that your data are deposited in an online, freely accessible repository that assigns a persistent DOI.
3. Store data in its most unprocessed state possible to facilitate reusability for subsequent analyses and future research endeavours.



4. Utilize open formats for data storage to ensure accessibility and independence from proprietary software. Open formats are tailored to foster interoperability, accessibility, and long-term data reuse. Examples include CSV for tabular data, PNG for raster images, SVG for vector graphics, and GeoJSON for spatial data.
5. Accompany the corresponding dataset with relevant metadata containing information on its structure, organization, and description.
6. Disseminate data under an open license to specify the conditions under which others can use the dataset. Recommended Creative Commons (CC) licenses include CC0 and CC-BY.
7. Enhance research reproducibility by providing raw data and a detailed workflow for reproducing all analyses, graphs, and figures. Ideally, scripts written in a specific programming language and executable via open-source software (e.g., Java, Python, R) ensure a comprehensive record of the research workflow.
8. Publish a data paper to ensure that the academic community is informed of the availability and potential reuse of a specific dataset.
9. Whenever feasible, consider publishing your article through Diamond Open Access. Alternatively, opt for Green Open Access to ensure broader dissemination of your work.
10. Consider Gold Open Access publication only in fully open access journals and avoid hybrid journals.

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## REFERENCES

- BEVAN A. 2015, *The data deluge*, «Antiquity», 89, 348, 1473-1484 (<https://doi.org/10.15184/aqy.2015.102>).
- CARVALE A., PIERGROSSI A. 2012, *Archeologia in rete. Le riviste open access: risorse e prospettive*, «Archeologia e Calcolatori», 23, 187-207 (<https://www.archcalc.cnr.it/journal/id.php?id=616>).
- FECHER B., FRIESIKE S. 2014, *Open science: One term, five schools of thought*, in S. BARTLING, S. FRIESIKE (eds.), *Opening Science*, Cham, Springer International Publishing, 17-47 ([https://doi.org/10.1007/978-3-319-00026-8\\_2](https://doi.org/10.1007/978-3-319-00026-8_2)).
- HOLE B. 2012, *A call for open scholarship in archaeology*, in C. BONACCHI (ed.), *Archaeologists and the Digital. Towards Strategies of Engagement*, London, Archetype, 114-126 (<https://discovery.ucl.ac.uk/id/eprint/1326267/>).
- HUET T., CUBAS M., GIBAJA J.F., OMS F.X., MAZZUCCO N. 2022, *NeoNet Dataset. Radiocarbon dates for the Late Mesolithic/Early Neolithic transition in the North Central-Western Mediterranean basin*, «Journal of Open Archaeology Data», 10, 3, 1-8 (<https://doi.org/10.5334/joad.87>).

- KAROUNE E., PLOMP E. 2022, *Removing Barriers to Reproducible Research in Archaeology*, Zenodo, ver. 5 peer-reviewed and recommended by Peer Community in Archaeology (<https://doi.org/10.5281/zenodo.7320029>).
- LUCARINI G., WILKINSON T., CREMA E.R., PALOMBINI A., BEVAN A., BROODBANK C. 2020, *The MedAfriCarbon radiocarbon database and web application. Archaeological dynamics in Mediterranean Africa, ca. 9600-700 BC*, «Journal of Open Archaeology Data», 8, 1, 1-6 (<https://doi.org/10.5334/joad.60>).
- MARVICK B. 2017, *Computational reproducibility in archaeological research: Basic principles and a case study of their implementation*, «Journal of Archaeological Method and Theory», 24, 424-450.
- MARVICK B. 2022, *CRAN task view: Archaeological science*, Zenodo (<https://doi.org/10.5281/zenodo.7306328>).
- MARVICK B., PILAAR BIRCH S.E. 2018, *A standard for the scholarly citation of archaeological data as an incentive to data sharing*, «Advances in Archaeological Practice», 6, 2, 125-143 (<https://doi.org/10.1017/aap.2018.3>).
- PALMISANO A., BEVAN A., KABELINDDE A., ROBERTS N., SHENNAN S. 2021, *Long-term demographic trends in prehistoric Italy: Climate impacts and regionalised socio-ecological trajectories*, «Journal of World Prehistory», 34, 381-432 (<https://doi.org/10.1007/s10963-021-09159-3>).
- PARKINSON E.W., MCLAUGHLIN T.R., ESPOSITO C., STODDART S., MALONE C. 2021, *Radiocarbon dated trends and central Mediterranean prehistory*, «Journal of World Prehistory», 34, 317-379 (<https://doi.org/10.1007/s10963-021-09158-4>).
- R CORE TEAM 2024, *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing, Wien (<https://www.R-project.org/>).
- ROSSI I., PARACIANI N. 2021, *IT applications to archaeology and the OA diamond journals' challenge. Enhancing access and reuse of textual and visual resources*, «Archeologia e Calcolatori», 32.1, 325-347 (<https://doi.org/10.19282/ac.32.1.2021.18>).
- QUEFELLE C.A., MAUREILLE B., ARZARELLO M., BLASCO R., CRANDELL O., DOYON L., HALCROW S., KAROUNE E., RUIZ-REDONDO A., VAN PEER P. 2023, *Peer Community In Archaeology: A community-driven free and transparent system for preprints peer-reviewing*, in J. BOGDANI, S. COSTA (eds.), *ArcheoFOSS 2022. Proceedings of the 16<sup>th</sup> International Conference on Open Software, Hardware, Processes, Data and Formats in Archaeological Research* (Rome 2022), «Archeologia e Calcolatori», 34.1, 125-134 (<https://doi.org/10.19282/ac.34.1.2023.14>).
- UNESCO 2021, *UNESCO Recommendation on Open Science*, Paris, United Nations Educational, Scientific and Cultural Organization (<https://doi.org/10.54677/MNMH8546>).
- VICENTE-SAEZ R., MARTINEZ-FUENTES C. 2018, *Open Science now: A systematic literature review for an integrated definition*, «Journal of Business Research», 88, 428-436 (<https://www.sciencedirect.com/science/article/abs/pii/S0148296317305441?via%3Dihub>).

## ABSTRACT

In the past decade, archaeology has witnessed a surge in digital data and methodologies made accessible through online repositories, databases, collaborative platforms like GitHub, and library collections. While this 'digital revolution' has led to notable advancements in data accessibility and dissemination, it has also presented several challenges. These include developing effective data management strategies, defining scientific publication modalities, addressing ethical concerns regarding the protection of cultural heritage, and bridging the gap between rich and poor research institutions. Taking these challenges into account, this paper aims to outline best practices for data sharing, dissemination, and reproducibility in archaeology, underscoring their benefits to researchers and the wider public. Through a range of approaches and practical examples drawn from everyday research scenarios, we will demonstrate how these practices promote transparency and foster open science.

## HARMONIZING PHOTOGRAMMETRIC APPROACHES FOR CULTURAL HERITAGE PRESERVATION: A METHODOLOGICAL FRAMEWORK AND COMPARATIVE ANALYSIS

### 1. INTRODUCTION

Digital imaging technologies have transformed archaeological documentation and analysis, necessitating interdisciplinary collaboration to merge archaeological and digital imaging methods (BARRILE *et al.* 2022). In particular, photogrammetry, which reconstructs 3D models from photos, requires the combined efforts of archaeologists and surveyors (CHATZIGRIGORIOU *et al.* 2021). This method processes images, executes measurements, and reconstructs archaeological sites and artifacts, generating significant raw data due to its multi-component nature involving cameras, computations, and modeling (REMONDINO 2011; KANEDA *et al.* 2022). The integration aims to balance archaeological objectives with technical choices for effective model creation. Achieving an effective symbiosis between archaeological research and technical implementation in 3D modeling naturally leads to the critical role of metadata organization in managing the large volumes of data generated.

The organization of large volumes of data relies on a careful design of metadata. The consistency of metadata across acquisition, processing (e.g., the algorithm in use), and modeling (e.g., the choice of mesh sections to delete) is crucial for data integrity and interoperability (CARBONI *et al.* 2016). Contemporary archaeology depends on data sharing and reinterpretation across contexts. YAWORSKY *et al.* (2020) exemplify this through predictive models reconstructing historical use phases of Grand Staircase-Escalante National Monument (USA), drawing from diverse campaign data and areas. KANSA, WHITCHER KANSA (2022) have shown that producing data annotated with shared formats or vocabularies leads to new discoveries and validations of previous interpretations. Despite the increasing use of photogrammetry in acquisition, KLEHM (2023) notes a lack of shared metadata, resulting in many unvalidated 3D models. Protocols have emerged since the 2010s, but interchangeability remains unresolved. Literature often presents closed protocols, hindering integration (e.g. CERASONI *et al.* 2022). Efforts like cross-evaluation (GOODBODY *et al.* 2021) and guideline development (DOUGLASS *et al.* 2015; DI GIULIO *et al.* 2017; HOMBURG 2019) aim to address this issue.

This paper presents the FOPPA (Functional Ontology Protocol for Photogrammetric Acquisition) acquisition protocol, aiming for effectiveness in surveys and improving interoperability. It employs standard ontologies and

modular structure, bridging humanistic and surveyor perspectives. Grounded in Digital Data Curation framework (MIKSA *et al.* 2019) and CIDOC-CRM ontological model (BRUSEKER *et al.* 2017), it standardizes processes and metadata, ensuring formal encoding. The protocol is compared with other interoperable methods in the literature, addressing the need for standardized photogrammetric approaches.

## 2. STATE OF THE ART

In photogrammetric acquisition protocols, metadata is vital. QUANTIN *et al.* 2015 highlight metadata's role in understanding and correctly using 3D models. However, scholars lack consensus on metadata management and selection. FANIEL *et al.* 2013 stresses standard metadata formats and contextualization for data reuse. AHMADI and EBADI (2009) propose GIS metadata structuring and GOODBODY *et al.* 2021 suggests evaluation benchmarks for aerial photogrammetry.

Photogrammetric protocols aim to abstract acquisition processes, addressing interdisciplinary needs in archaeological contexts and guiding survey conduct through standardized phases that produce coherent metadata (DOUGLASS *et al.* 2015; DI GIULIO *et al.* 2017; HOMBURG 2019). KHALIL and STRAVORAVDIS (2022) argue that standardizing processes and formats is crucial for unifying digital archaeological data, enhancing interoperability and enabling advanced analysis. However, implementing these standards requires consensus within the archaeological community. DI GIULIO *et al.* 2017 developed an abstract photogrammetric methodology to integrate diverse projects, though it remains largely theoretical. RODRÍGUEZ-MARTÍN and RODRÍGUEZ-GONZÁLVEZ (2020) applied these concepts practically but focused on specific object categories.

Our research posits that existing protocols, with shared ontologies, can facilitate effective communication beyond specific projects or contexts through proper data and metadata organization in 3D model generation.

## 3. ABSTRACT MODELS AND THE APPLICATION TO PHOTOGRAMMETRY

Abstraction facilitates digital data archive management, ensuring standardized methodologies for compatibility and coherence across projects, promoting data reuse. Despite early hopes for centralized archives and standardized formats (KOLLER *et al.* 2009), achieving unified or interoperable protocols remains a challenge. REFFAT and NOFAL (2013) emphasize the need for a multimodal protocol, while NAPOLITANO *et al.* 2017 proposes meticulous documentation for protocol deciphering. DOUGLASS *et al.* 2015 and POCOBELLI *et al.* 2018 outline key stages in the acquisition process, addressing

challenges like surface reconstruction and accuracy testing. Compliance with EU guidelines is essential, covering factors affecting digitization quality and relevant formats and benchmarks.

### *3.1 Digital data curation*

To meet the organizational and methodological needs in Cultural Heritage, we utilized Digital Data Curation structures. This practice involves managing, preserving, and enhancing digital data, ensuring secure storage and adherence to ethical standards. Despite its importance, few photogrammetry projects reference Digital Data Curation, limiting its use in the field, as addressed by FERNANDEZ (2019) and LAURO and LOMBARDO (2023a), among the few examples, we can cite GAROZZO *et al.* 2017. Considering this, our photogrammetric acquisition protocol aligns with Digital Data Curation concepts, aiming for broader applicability in humanities research.

### *3.2 Ontologies and vocabularies: CIDOC-CRM*

Ontologies and thesauri are pivotal in shaping shared terminological vocabularies for digital databases, notably in cultural heritage. These structured tools enable efficient information retrieval across domains, fostering interoperability. The EU-funded CrossCult project exemplifies semantic technologies' application, redefining historical appraisal (VLACHIDIS *et al.* 2017). FREIRE and VALK (2019) explore ontologies' usability in web crawlers. It must be placed in this research context the creation of the CIDOC Conceptual Reference Model (CRM) that has emerged as the main reference ontology for the management of databases and information in cultural heritage. While previous applications in archaeology and photogrammetry exist, they often focus narrowly on specific cases, limiting broader theoretical application (BRUSEKER *et al.* 2017). Despite its theoretical relevance to cultural heritage, research on CIDOC-CRM's practical implementation in photogrammetry remains sparse.

## **4. PHOTOGRAMMETRIC WORKFLOW AND CIDOC-CRM ENCODING**

Our approach yielded the BeAPG protocol (LAURO, LOMBARDO 2023b), evolving into the FOPPA protocol, designed for heritage object photogrammetric surveying within the BeArchaeo project. FOPPA integrates Digital Data Curation and CIDOC-CRM, ensuring data management and ontology-based entity definition during digital clone generation. It aligns acquisition processes with CIDOC-CRM phases, enhancing standardization. The protocol expands sub-phases to encompass broader techniques, aiming for a precise glossary and comprehensive representation. We align photogrammetric processes with cultural heritage discoveries, codifying actions into CIDOC-CRM classes

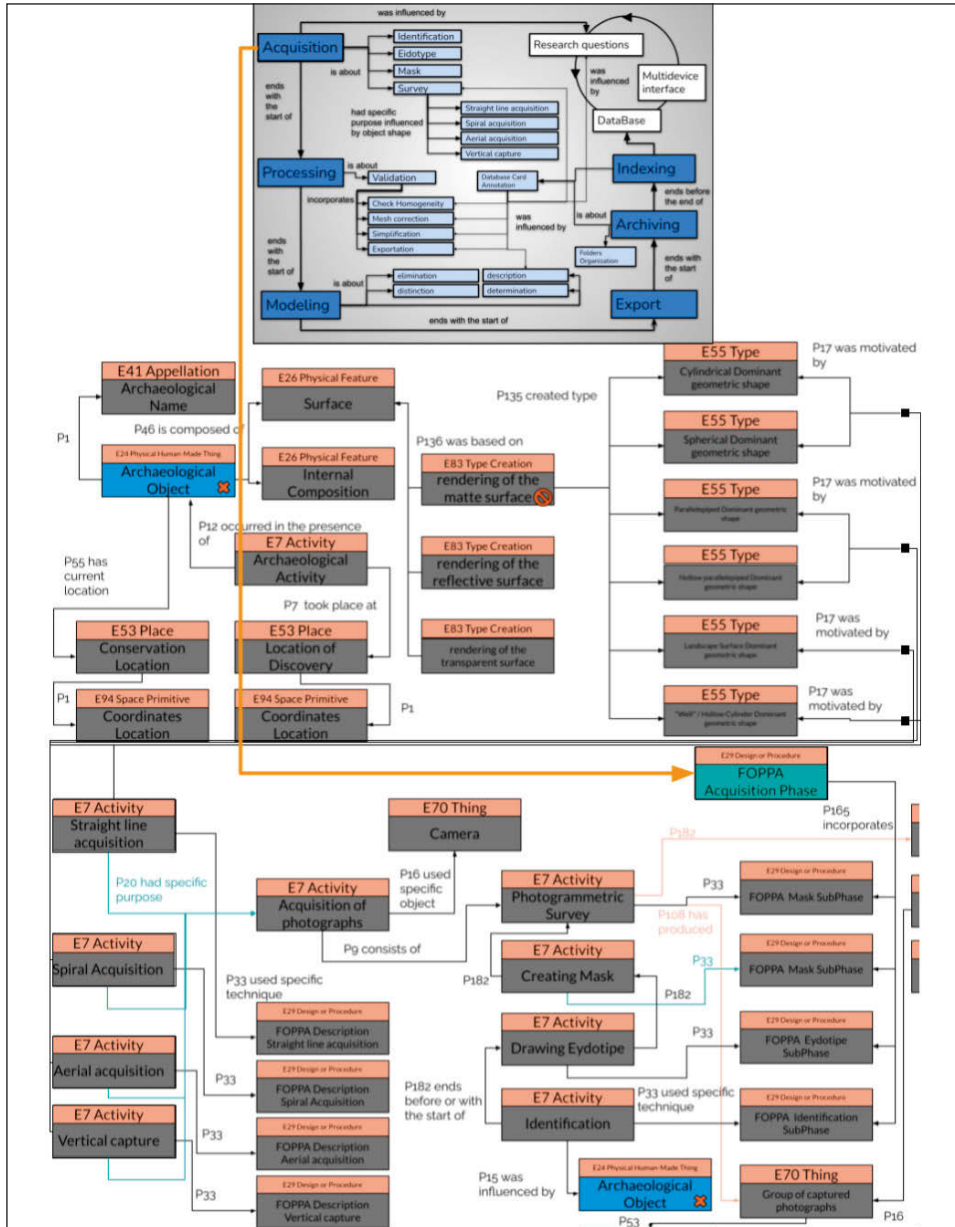


Fig. 1 – The diagram shows the summarized and simplified version of the protocol: in the upper part there is a detailed version where each single step has been codified and defined by a class relating to the generative activity of the model; in the lower part there is a detailed view of the constituent classes of the model Acquisition Phase.



for interoperability. The protocol delineates phases: acquisition, processing, modeling, exporting, archiving, and indexing, each represented by corresponding classes, facilitating meticulous process description and universal understanding (Fig. 1).

#### *4.1 From BeAPG to FOPPA, towards the implementation of other protocols*

The FOPPA protocol reconstructs the photogrammetric creation processes starting from pre-existing projects in a manner not dissimilar to how CIDOC-CRM is used today to reconstruct and organize information, data and metadata in relation to historical events that may have led to the creation of specific Cultural Heritage objects. As a reference example we bring the case of three protocols that will be subjected to direct comparison with this method. The aim is therefore to use the FOPPA protocol to collect these other acquisition protocols, identify their work phases and thanks to our protocol make them coincide with the ontological classes of the CIDOC-CRM, thus allowing communication between the data and the metadata produced by various projects even transversally among themselves once this conversion has been completed and therefore ensure correct storage and transmission of the 3D model metadata.

#### *4.2 Inception Protocols*

The Inception Protocol, introduced by DI GIULIO *et al.* (2017), streamlines 3D semantic model creation for Cultural Heritage sites. It focuses on cost-effective data acquisition, balancing quality and resources. Phases, called in Inception Protocol ‘Action’, cover planning, technology selection, data acquisition, processing, and validation, ensuring comprehensive site coverage. The protocol promotes model sharing and interoperability through common file formats. Ontological alignment between Inception and FOPPA phases facilitates CIDOC adaptability, enhancing database integration.

The FOPPA protocol complements Inception by aligning with its interpretative phases (Action 1) and enhancing find recognition (Action 2). It also streamlines 3D model management and justifies operational choices (Action 3), ensuring comprehensive archaeological data collection and processing. These adaptations provide clearer insights into site characteristics and acquisition techniques. Action 1 corresponds to FOPPA’s initial Acquisition phase, organizing metadata and activities while considering space, time, and typology. Action 2 merges with FOPPA’s data capturing, managing survey phases and metadata. Action 3 precedes semantic model creation, guiding data manipulation and modeling. Finally, Action 4 aligns with CIDOC-CRM principles, facilitating database communication, while Action 5 integrates deployment and valorization in the archiving phase (Fig. 2).

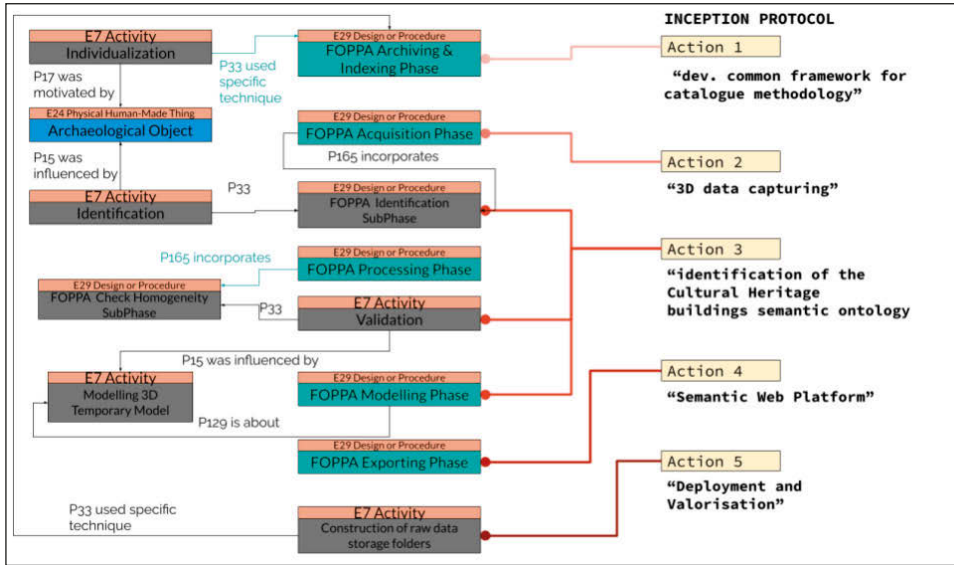


Fig. 2 – Schematic representation of the ontological coincidence between the main phases marked according to the FOPPA protocol and the ‘Actions’ which constitute the operational phases of the Inception protocol.

#### 4.3 Another method compared: the Douglass case

In comparing our methodology with Douglass’s research (DOUGLASS *et al.* 2015) on photogrammetry in archaeological pedestrian surveys, similarities and differences emerge. Both methodologies share operational phases, enabling cross-validation and enhancing photogrammetry’s utility in archaeological research. Our five-phase approach (acquisition, processing, modelling, export, and archiving) offers a structured framework for digital documentation, preservation, and dissemination of cultural heritage assets. Douglass’s methodology aligns conceptually, with phases like image capture, processing, and model verification. While both prioritize efficient data processing, Douglass emphasizes fieldwork and rapid documentation, contrasting our broader cultural heritage focus. Regarding the step of choosing photo capture strategies, it involves selecting the acquisition technique and recording it in the form database. This process includes ‘image collection and inconsistent image discard’ and the subsequent recording of the number of photos acquired and those discarded. This information is noted in the ‘validation information’ section of the archive card.

The ‘matching processing, point cloud, and surface reconstruction, densification and texturing’ phase falls perfectly within the processing of



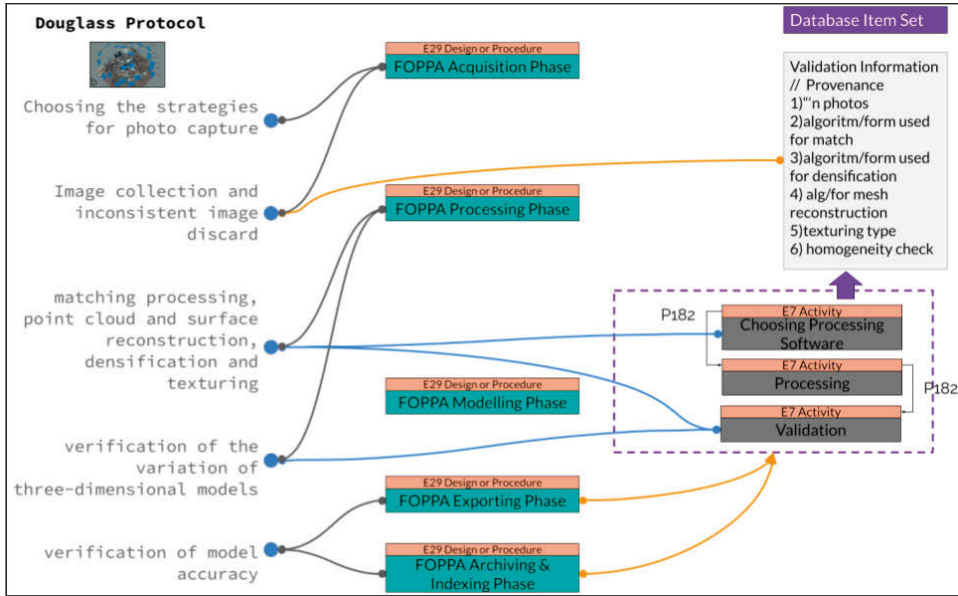


Fig. 3 – Schematic and essential comparison between our protocol and that of DOUGLAS *et al.* 2017.

which each phase is recorded, and in the case of a process already carried out, reconstructed and deconstructed, into the coinciding CIDOC-CRM classes and consequent recordings in the form of database, where however the validation is brought forward in the processing phase coinciding with its final sub-phase. In this way the final phase of the Douglass protocol ‘verification of model accuracy’ is not an operation to be carried out in post-production but the natural result of the final export and archiving executions (Fig. 3).

#### 4.4 Another method compared: the Homburg case

In comparing HOMBURG (2019) ontology model with our FOPPA methodology, parallels emerge in structured data processing and metadata’s significance. Homburg’s workflow, akin to FOPPA’s phases, encompasses acquisition, processing, modelling, export, and archiving, supported by an ontology categorizing entities and activities. Both methodologies acknowledge agents’ roles and algorithms’ importance, albeit with different levels of abstraction. While Homburg’s method focuses on enriching 3D model information, FOPPA prioritizes data acquisition and documentation, facilitating interoperability with diverse protocols. Both underscore software tools’ integration and metadata management, albeit with distinct approaches. Homburg’s detailed protocol suits systematic data recording, while FOPPA

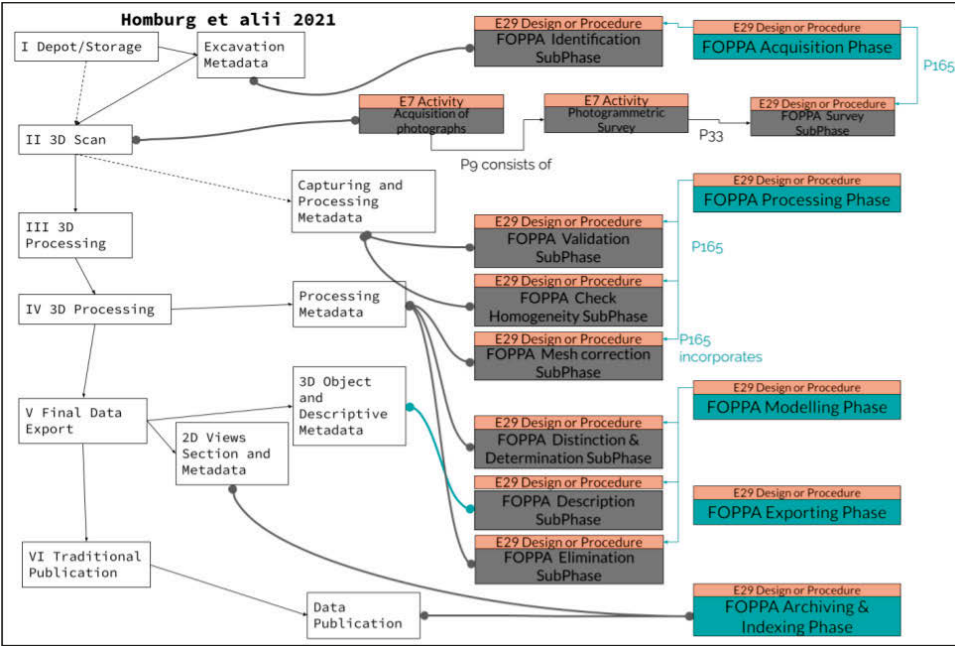


Fig. 4 – Schematic and essential comparison between our protocol and the Homburg one.

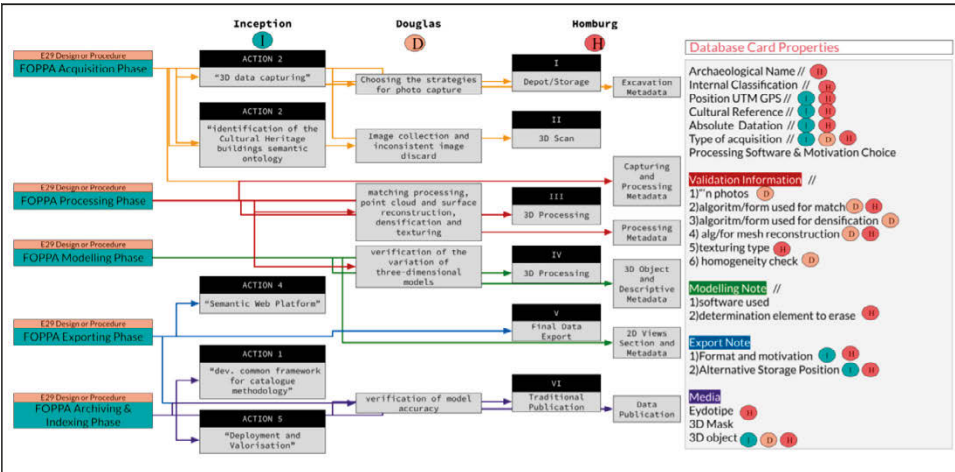


Fig. 5 – The adoption of a mediation protocol allows the comparative compilation of a database form of a three-dimensional finding coming from one of the three protocols analyzed.

offers interpretive flexibility for humanistic heritage contexts and protocol interoperability (Fig. 4).

#### *4.5 Procedural semantics in progress*

The database card captures metadata generated during 3D model creation, aligning with CIDOC-CRM phases. What were defined as Phases in the FOPPA are described in the Inception Protocol as Actions and the table was compiled by looking for coherence (and dissonance) between Phases and Actions. Required items include: archaeological name, internal classification, gps position, cultural reference, acquisition type, processing software, validation info, and export notes. Each item is linked to specific activities in its respective phase. Modeling notes detail model modifications, while export notes record procedural decisions. Additional MEDIA files store related data in the database, ensuring comprehensive documentation and organization of 3D models and associated information (Fig. 5).

#### *4.6 The need for comparison for exhaustive proof*

To comprehensively assess the FOPPA Protocol's capability to interpret data produced in the Inception Protocol, Douglass Protocol and Homburg Protocol, access to a 3D model generated in one of those protocols would be indispensable. By examining how the FOPPA Protocol handles the data-rich 3D model, researchers can evaluate its effectiveness in managing and processing complex photogrammetric datasets. This comparative analysis would not only highlight the strengths and limitations of the FOPPA Protocol but also provide insights into its interoperability with other photogrammetric methodologies.

### 5. CONCLUSIONS

In summary, this study proposes a methodological framework aimed at standardizing photogrammetric approaches in cultural heritage preservation. By leveraging principles from Digital Data Curation and CIDOC-CRM, the framework offers a structured approach to data acquisition and management, facilitating interoperability and consistency across diverse projects. However, to fully validate the effectiveness of this framework, practical applications across various cultural heritage contexts are essential. Through rigorous validation and refinement processes, our framework aims to contribute to the establishment of best practices in photogrammetric data acquisition for cultural heritage preservation, ultimately enhancing the accessibility, accuracy, and longevity of digital heritage records.

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## REFERENCES

- AHMADI F.F., EBADI H. 2009, *An integrated photogrammetric and spatial database management system for producing fully structured data using aerial and remote sensing images*, «Sensors», 9, 4, 2320-2333 (<https://doi.org/10.3390/s90402320>).
- BAILLET V., POULARAKIS I., FARINHOLT WARD A. 2021, *Photogrammetric modeling and the central ravine of the sanctuary of the Great gods, Samothrace*, «Digital Applications in Archaeology and Cultural Heritage», 20 (<https://www.sciencedirect.com/science/article/pii/S2212054821000023>).
- BARRILE V., BERNARDO E., FOTIA A., BILOTTA G. 2022, *Integration of laser scanner, ground-penetrating radar, 3D models and mixed reality for artistic, archaeological and cultural heritage dissemination*, «Heritage», 5, 3, 1529-1550 (<https://doi.org/10.3390/heritage5030080>).
- BRUSEKER G., CARBONI N., GUILLEM A. 2017, *Cultural heritage data management: The role of formal ontology and CIDOC CRM*, in M. VINCENT, V. LÓPEZ-MENCHERO BENDICHO, M. IOANNIDES, T.E. LEVY (eds.), *Heritage and Archaeology in the Digital Age*, New York, Springer, 93-131 ([https://doi.org/10.1007/978-3-319-65370-9\\_6](https://doi.org/10.1007/978-3-319-65370-9_6)).
- CARBONI N., BRUSEKER G., GUILLEM A., BELLIDO CASTAÑEDA, COUGHENOUR C. *et al.* 2016, *Data provenance in photogrammetry through documentation protocols*, «ISPRS Annals of Photogrammetry, Remote Sensing & Spatial Information Sciences», III, 5, 57-64 (<https://doi.org/10.5194/isprs-annals-III-5-57-2016>).
- CHATZIGRIGORIOU P., NIKOLAKOPOULOU V., VAKKAS T., VOSINAKIS S., KOUTSABASIS P. 2021, *Is architecture connected with intangible cultural heritage? Reflections from architectural digital documentation and interactive application design in three Aegean islands*, «Heritage», 4, 2, 664-689 (<https://doi.org/10.3390/heritage4020038>).
- DI GIULIO R., MAIETTI F., PIAIA E., MEDICI M., FERRARI F., TURRILAZZI B. 2017, *Integrated data capturing requirements for 3D semantic modelling of Cultural Heritage: The Inception Protocol*, «International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences», XLII-2/W3, 251-257 (<https://doi.org/10.5194/isprs-archives-XLII-2-W3-251-2017>).
- DOUGLASS M., LIN S., CHODORONEK M. 2015, *The application of 3D photogrammetry for In-Field documentation of archaeological features*, «Advanced in Archaeological Practice», 3, 2, 136-152.
- FANIEL I., KANSA E., WHITCHER KANSA S., BARRERA-GOMEZ J., YAKEL E. 2013, *The Challenges of digging data: A study of context in archaeological data reuse*, in JCDL '13: *Proceedings of the 13<sup>th</sup> ACM/IEEE-CS Joint Conference on Digital Libraries (Indianapolis 2013)*, New York, Association for Computing Machinery, 295-304 (<http://dx.doi.org/10.1145/2467696.2467712>).
- FERNANDEZ R. 2019, *Digital curation of photogrammetric data*, in *The 84<sup>th</sup> Annual Meeting of the Society for American Archaeology*, Albuquerque, Society for American Archaeology (<https://doi.org/10.6067/XCV8451423>).
- FREIRE N., DE VALK S. 2019, *Automated interpretability of linked data ontologies: An evaluation within the cultural heritage domain*, in *2019 IEEE International Conference on Big Data*, Los Angeles, IEEE Institute of Electrical and Electronics Engineers, 3072-3079 (<https://doi.org/10.1109/BigData47090.2019.9005491>).
- GAROZZO R., MURABITO F., SANTAGATI C., PINO C., SPAMPINATO C. 2017, *Culto: An ontology-based annotation tool for data curation in Cultural Heritage*, «International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences», XLII-2/W5, 267-274 (<https://doi.org/10.5194/isprs-archives-XLII-2-W5-267-2017>).
- GOODBODY T.R.H., WHITE J.C., COOPS N.C., LEBOEUF A. 2021, *Benchmarking acquisition parameters for digital aerial photogrammetric data for forest inventory applications*:

- Impacts of image overlap and resolution*, «Remote Sensing of Environment», 265, 112677 (<https://doi.org/10.1016/j.rse.2021.112677>).
- HOMBURG T. 2019, *Towards creating a best practice digital processing pipeline for cuneiform languages*, presented at the *Digital Humanities Conference 2019 (DH2019) (Utrecht 2019)*, DataverseNL, V2 (<https://doi.org/10.34894/FKWT9T>).
- KANSA E.C., WHITCHER KANSA S. 2022, *Promoting data quality and reuse in archaeology through collaborative identifier practices*, in *Proceedings of the National Academy of Sciences*, 119, 43, e2109313118 (<https://doi.org/10.1073/pnas.2109313118>).
- KHALIL A., STRAVORAVDIS S. 2022, *Challenges of digital building data usage with a focus on the digital documentation of heritage building. Results from an online survey*, «Heritage», 5, 4, 3220-3259 (<https://doi.org/10.3390/heritage5040166>).
- KLEHM C. 2023, *The use and challenges of spatial data in archaeology*, «Advances in Archaeological Practice», 11, 1, 104-110 (<https://doi.org/10.1017/aap.2022.38>).
- KOLLER D., FRISCHER B., HUMPHREYS G. 2009, *Research challenges for digital archives of 3D cultural heritage models*, «ACM Journal on Computing and Cultural Heritage», 2, 3, 1-17 (<https://doi.org/10.1145/1658346.1658347>).
- LAURO V., LOMBARDO V. 2023a, *The cataloging and conservation of digital survey in archaeology: A photogrammetry protocol in the context of digital data curation*, «Heritage», 6, 3113-3136 (<https://doi.org/10.3390/heritage6030166>).
- LAURO V., LOMBARDO V. 2023b, *A digital data curation-based photogrammetric acquisition methodology for Cultural Heritage, expanded with CIDOC CRM compatibility: Protocol BeA-PG*, in *GCH 2023. Eurographics Workshop on Graphics and Cultural Heritage* (<https://doi.org/10.2312/gch.20231169>).
- MIKSA T., SIMMS S., MIETCHEN D., JONES S. 2019, *Ten principles for machine-actionable data management plans*, «PLOS Computational Biology», 15, 3, e1006750 (<https://doi.org/10.1371/journal.pcbi.1006750>).
- NAPOLITANO R.K., SCHERER G., GLISIC B. 2017, *Virtual tours and informational modeling for conservation of cultural heritage sites*, «Journal of Cultural Heritage», 29, 123-129.
- POCOBELLI D.P., BOEHM J., BRYAN P., STILL J., GRAU-BOCÉ J. 2018, *BIM for Heritage Science: A review*, «Heritage Science», 6, 30 (<https://doi.org/10.1186/s40494-018-0191-4>).
- QUANTIN M., HERVY B., LAROCHE F., KEROUANTON J.-L. 2015, *Mass customization for cultural heritage 3D models*, in *2015 Digital Heritage (Granada 2015)*, IEEE, 129-132 (<https://doi.org/10.1109/DigitalHeritage.2015.7419469>).
- REFFAT R.M., NOFAL E.M. 2013, *Effective communication with cultural heritage using virtual technologies*, «International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences», XL-5/W2, 519-524.
- REMONDINO F. 2011, *Heritage recording and 3D modeling with photogrammetry and 3D scanning*, «Remote Sensing», 3, 6, 1104-1138 (<https://doi.org/10.3390/rs3061104>).
- RODRÍGUEZ-MARTÍN M., RODRÍGUEZ-GONZÁLEZ P. 2020, *Suitability of automatic photogrammetric reconstruction configurations for small archaeological remains*, «Sensors», 20, 10, 2936 (<https://doi.org/10.3390/s20102936>).
- VLACHIDIS A., BIKAKIS A., KYRIAKI-MANESSI D., TRIANTAFYLLOU I., ANTONIOU A. 2017, *The CrossCult Knowledge Base: A Co-inhabitant of cultural heritage ontology and vocabulary classification*, in M. KIRIKOVA et al. (eds.), *New Trends in Databases and Information Systems. ADBIS 2017, Communications in Computer and Information Science*, 767, New York, Springer ([https://doi.org/10.1007/978-3-319-67162-8\\_35](https://doi.org/10.1007/978-3-319-67162-8_35)).
- YAWORSKY P.M., VERNON K.B., SPANGLER J.D., BREWER S.C., CODDING B.F. 2020, *Advancing predictive modeling in archaeology: An evaluation of regression and machine learning methods on the grand staircase-escalante national monument*, «PLOS ONE», 15, 10, e0239424 (<https://doi.org/10.1371/journal.pone.0239424>).

## ABSTRACT

This study addresses the standardization of methodologies and data formats used in photogrammetric projects related to archaeology. The application of photogrammetry in recording and safeguarding cultural artifacts proves invaluable in various domains. However, the lack of a standardized method makes effective sharing of experiences and knowledge among practitioners difficult. This paper presents a methodological framework for photogrammetric data acquisition in the context of cultural heritage. This framework transcends the constraint of specific technical tools, embracing instead a level of abstraction consistent with the general principles of the Digital Data Curation paradigm and ontological encoding through the CI-DOC-CRM model. Eventually, we provide a comparison between the FOPPA protocol with other three main acquisition protocols in order to test the interlingua that can enhance the communication between protocols. The overall goal of our research is to support systematic and methodical structured acquisition path, as well as systematic classification of metadata, facilitating the effective implementation of the methodology in new projects and promoting effective communication among existing projects.



## DEALING WITH DOUBTS: SITE GEOREFERENCING IN ARCHAEOLOGY AND IN THE GEOSCIENCES

### 1. INTRODUCTION

Archaeological research has to handle doubts, such as vagueness, uncertainty, and ambiguities in data modelling, which in the context of the NFDI4Objects research project (BIBBY *et al.* 2023) are often named using the umbrella terms ‘fuzziness and wobbliness’ (THIERY *et al.* 2021). In our case, ‘vagueness’ is a measure of the precision of a statement; a vague statement is, therefore, only accurate to a certain degree. In the case of ‘uncertainty’, it is entirely unknown whether the statement is valid (UNOLD *et al.* 2019; THIERY, MEES 2023). Especially in georeferencing, the challenge of making these doubts visible can occur (SCHMIDT, THIERY 2022). Other famous buzzwords about this topic are ‘accuracy’ and ‘precision’. Taking the image of an archer who shoots ‘numeric’ arrows at a target, he could do it in four different ways (Fig. 1A), where high accuracy and high precision is an ‘X’ (10 points in archery for the golden middle). Still, for not numeric questions, the target is anywhere different.

Numerical differences can also be modelled in other ways (e.g., coin weights): exact: 5.38g, range: 5g to 6g; blurry: ~5g (Fig. 1B). Relations between entities also appear in several types (e.g., person types): exact: type X; range: type  $X \vee Y$ ; blurry: probably type  $X \vee Y$  (Fig. 1C). The term ‘probably’ can also be described using the perceptions of probability and numbers as median values (NATION 2017, probly.csv), e.g., ‘almost certainly’ (95%), ‘very good chance’ (80%), ‘probably’ (75%), ‘little chance’ (15%) or ‘highly unlikely’ (5%). The term ‘probably’ can also be described using the perceptions of probability and numbers as median values (NATION 2017, probly.csv), e.g., ‘almost certainly’ (95%), ‘very good chance’ (80%), ‘probably’ (75%), ‘little chance’ (15%) or ‘highly unlikely’ (5%).

Creating reproducible and comprehensible data for reuse while guaranteeing data quality in archaeological data involves disclosing doubts and ambiguities (THIERY, MEES 2023). This is also important for data FAIRification (WILKINSON *et al.* 2016) – making data Findable, Accessible, Interoperable, and Reusable – addressed in the German National Research Data Infrastructure, called NFDI (HARTL *et al.* 2021). In particular, vagueness and uncertainty must be modelled to work with geodata, such as a map of royal mints (SEELBACH 2023, 377 ss.). However, for linking and FAIRifying data, the Linked Open Data (LOD) proposed by BERNERS-LEE (2006) (SCHMIDT *et al.* 2022) is the method and technique of choice. LODs are semantic graph-structured data (so-called ‘triples’) based on the W3C standard Resource Description Framework (RDF),

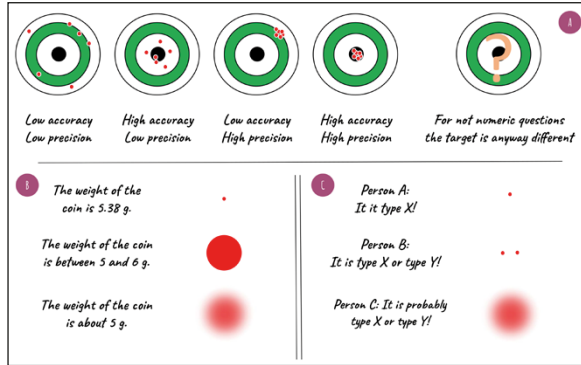


Fig. 1 – A) Accuracy vs. precision; B) visualisation of numerical differences; C) visualisation of uncertain or-relationships (F. Thiery, K. Tolle).

which are described with a URI, accessible via HTTP, structured as RDF, and interlinked with other (linked RDF-based) data. However, this leads to ambiguities and uncertainties: is ‘Mainz’ the ‘Roman Mainz’, ‘Medieval Mainz’, ‘Mainz ~1920’ or ‘Mainz after World War II’? The links to the Semantic Web are also not unambiguous: GeoNames (2874225) as Mainz in Rhineland-Palatinate, Pleiades (109169) as Mogontiacum, and iDAI.gazetter (2052457) as Mainz (populated place) or GeoNames (2874226) as Mainz in Bavaria?

This paper discusses two data-driven interdisciplinary use cases for dealing with and modelling vague and uncertain geo-references (findspots) based on literature as LOD from the archaeological and geosciences domain. The use cases implement three modelling strategies: Wikidata, Linked Open Data and Wikibase.

## 2. MODELLING STRATEGIES

In the process of dealing with doubts such as uncertainty, vagueness and ambiguities, one of the main goals could be to publish and model the following information: 1) describe where the geoinformation comes from; 2) describe the method of how the coordinate was created; 3) describe the uncertainty issue(s); 4) use references into the Semantic Web. Below, three modelling strategies are presented, modelled using LOD with the help of the Web Ontology Language (OWL) and with Wikibase instances such as Wikidata (THIERY 2023a).

### 2.1 Linked Open Data

The Fuzzy Spatial Locations Ontology (THIERY 2023b) (prefix fsl) is based on PROV-O, SKOS and GeoSPARQL (THIERY 2023a, 3-5). It follows



the PROV-O concept of Entity, Activity and Agent. In the case of this ontology, sites (entities) have a geometry and were created with a method (activity) by a person (agent) (Fig. 2, left). Site and geometry contain two properties for describing fuzziness: `fsl:certaintyDesc` and `fsl:certaintyLevel`; sites additionally receive properties for describing references, e.g. for books, `fsl:hasReference` or to online resources, e.g. via exact-match properties from the Simple Knowledge Organization System (SKOS) vocabulary (<http://www.w3.org/TR/skos-primer>) used for designing and aligning thesauri. The method can be characterised via sources (`fsl:hasSource`, `fsl:hasSourceType`), references (`fsl:hasReference`), method descriptions (`fsl:activityDesc`) and uncertainty information (`fsl:certaintyLevel`, `fsl:certaintyDesc`). The resulting LOD as RDF can be converted into human-readable HTML files using the SPARQL Unicorn Ontology Documentation Research Tool (HOMBURG, THIERY 2024) based on the SPARQL Unicorn (THIERY *et al.* 2020; THIERY, HOMBURG 2024). In [nomisma.org](https://nomisma.org) (<https://nomisma.org>), for example, fuzzy locations of mints can be described with the Nomisma Ontology (ZEENA, Nomisma.org 2022) (Fig. 2, right).

## 2.2 Wikidata and Wikibase

The geographical location of sites and archaeological artefacts can be described in Wikidata using coordinates and Wikidata property P625. Wikidata’s (and Wikibase’s as the software behind Wikidata) data model is based on statements (SCHMIDT *et al.* 2022, fig. 7) that can be described in more detail using so-called ‘qualifiers’, which are statements about statements and, on top, ‘references’ to verify the statement. The modelled coordinates contain uncertainty and reference information that can be modelled using Wikidata

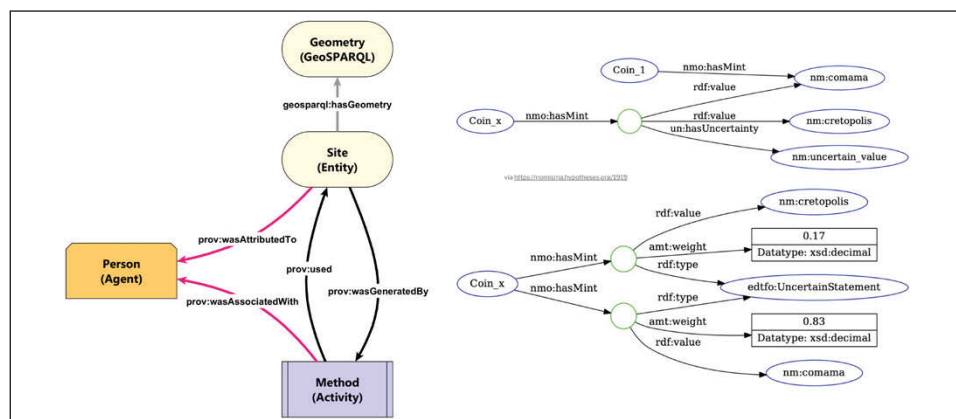


Fig. 2 – Left: Linked Open Data modelling using the Fuzzy Spatial Locations Ontology, based on the idea of PROV-O; right: modelling of hasMint in the Nomisma cookbook (left: F. Thiery; right: Zeena/nomisma.org, <https://nomisma.hypotheses.org/1919>).

qualifiers and references. This can be done for on-site surveys (THIERY *et al.* 2023), as follows (THIERY 2023a, 2-3) by using the following qualifiers and references: sourcing circumstances (P1180), stated in (P248), location (P276), determination method (P459), subject has role (P2868), and OpenStreet-Map node ID (P11693). Locations/artefacts that are only accessible in the literature/online databases can be modelled with this qualifier and reference properties: stated in (P248), object has role (P3831), determination method (P459), subject has role (P2868), and reference URL (P854).

The Wikibase modelling (THIERY 2023a, 5-6) is related to the Wikidata approach. Here, a location also has a latitude/longitude coordinate, which is provided with a qualifier to describe it further with the following attributes: has certainty level, certainty description, method used, acting person, has source, has source subtype, and method description.

3. CASE STUDIES

Three case studies are described below, which show examples of modelling in Wikidata (Ogham Stones), with Linked Open Data (Campanian Ignimbrite) and Wikibase (Silver Coinage of Croton).

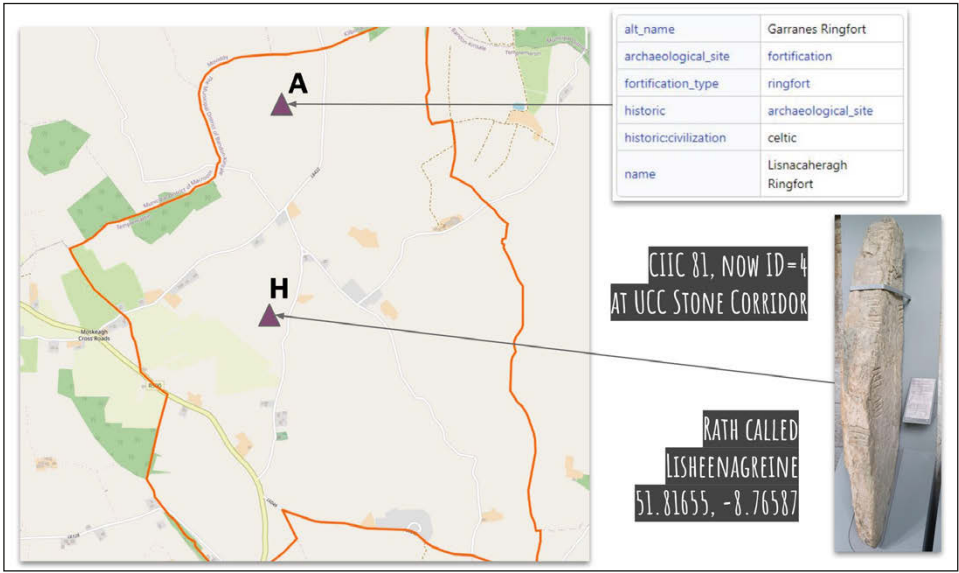


Fig. 3 – Left: current OSM map with the OSM Relation 6168494 (see A) and the possible position of CIIC 81 (see H), geo-referenced based on the path network using the plan of the location of (A) Lisnacaheragh Ringfort and (H) Lisheennagreine (from Ó RÍORDÁIN, RYAN 1941, 80); right-top: description of OSM Way 562702954; right-bottom: Ogham Stone CIIC 81 in the UCC Stone Corridor, as well as the possible location coordinate (left/right-top: Open Street Map Contributors, ODbL, via OSM; right-bottom: F. Thiery).

### 3.1 Ogham stones via Wikidata

Ogham stones are monoliths bearing inscriptions in the early medieval Gaelic ‘primitive Irish’ Ogham script (MACALISTER 1945; MACMANUS 1997), which were erected mainly on the island of Ireland and in the western part of Great Britain between the 4<sup>th</sup> and 9<sup>th</sup> centuries AD. Most stones are no longer in their original location, which is essential for cartographic recording and makes it difficult to determine their original function (MACALISTER 1945). These sources provide information at different levels of granularity: townlands, descriptions and coordinates in WGS84/GPS or Irish GRID references.

An example is CIIC 81 (Fig. 3, right), exhibited in the Stone Corridor of University College Cork (UCC). Information on the current and original location is given in GIPPERT (2001), BRASH (1869, 260), Ó RÍORDÁIN (1931, 67) and Ó RÍORDÁIN, RYAN (1941, 78 ss.). Results of the georeferencing (Fig. 3, left) of the site coordinates and the current location can thus be modelled in Wikidata (Q106680733). The findspot can be calculated as 51.8166 °N; -8.7659 °E concerning the literature, the current exhibition site as 51.8938 °N; -8.4921 °E relating to an on-site survey and OSM node ID 11071361392.

### 3.2 Campanian Ignimbrite via Linked Open Data

About 39,940 yr b2k  $\pm$  150 years (SCHENK *et al.* 2024) – ca. 37,940 BC  $\pm$  150 years – the largest eruption of the Campanian Ignimbrite (CI) took place in the Phlegraean Fields (BARBERI *et al.* 1978; DE VIVO *et al.* 2001; SCHENK *et al.* 2024). Evidence of the ash fall from this Late Pleistocene volcanic event, which originated in the Campania region of Italy, can be found throughout Central Europe (THIERY, SCHENK 2023a, 2023c, 2023e). After the eruption, massive glass deposits covered large parts of the Eastern European continent; volcanic material from the CI is often found in isolated watersheds and valleys. These sites are recorded in several publications, i.e. precise coordinates or references to cities, regions, caves and archaeological sites (THIERY, SCHENK 2023a).

Georeferencing Romania’s Urluia site (URL) (THIERY, SCHENK 2023b, 2023d) is more complicated. The literature (FITZSIMMONS, HAMBACH 2014, 76; PÖTTER *et al.* 2021, 5) provides clues here. The location 42.7790 °N / 18.4815 °E can be approximately determined from both pieces of information. Information from OpenStreetMap helps here (Fig. 4). The result can now be published with the help of LOD and the SPARQL Unicorn (THIERY, SCHENK 2023b).

### 3.3 Silver coinage of Croton via Wikibase

Hoard analyses of silver coinage from Croton (STAZIO 1984; GARRAFFO 1987; RUTTER 1997, 2001), an Achaean colony in southern Italy from the 6<sup>th</sup> to 3<sup>rd</sup> century BCE, show spatial uncertainties. None of the hoard’s analysed sites are precisely georeferenced (e.g., based on the documentation of excavation

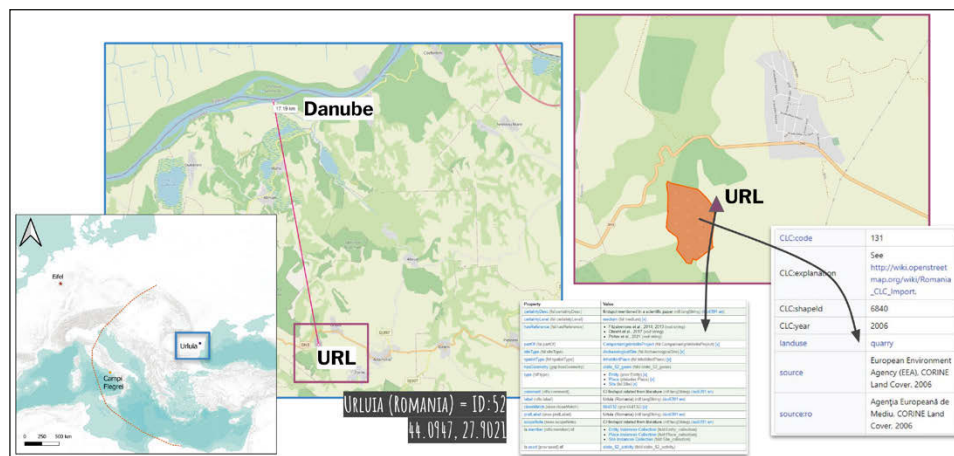


Fig. 4 – Left: schematic view of the distribution of the CI tephra in Europe (dashed orange line open to the E); Campi Flegrei as eruption site (orange dot; 40.8275° N, 14.1402° E); Urluia as find spot (blue dot/ rectangle; 44.0947° N, 27.9021° E); Eifel Lake sediment cores (red star); scale 1:20,000,000, EPSG: 3857, bounding box: -27,431.587, 3,598,880.852, 4,408,568.450, 7,668,605.656, created with QGIS, base map WorldTerrain by USGS, Esri, TANA, DeLorme, and NPS; middle: aerial line measurement between the possible location of Urluia (URL; purple rectangle) and the Danube. According to the literature, this is approx. 15 km, here 17.19 km; right: map showing the opencast mine (OSM way 84975654) and the possible Urluia coordinate point 44.0947 °N / 27.9021 °E as cisite\_52 (purple rectangle) (left: F. Schenk, F. Thiery, <https://codeberg.org/ResearchSquirrels/ci-map>; middle/right: Open Street Map Contributors, ODbL, via OSM).

reports). The sites identified are derived from the literature and have varying degrees of precision about their geographical location (Fig. 5). The used IGCH numbers refer to THOMPSON *et al.* (2024), where the ‘CoinHoard’ database is currently based on. The hoard finds of ‘Tarentum 1938’ (IGCH 1902) in the via Oberdan in Tarentum, i.e., provide a reasonably precise indication. Indications of the location of the find in the modern and/or ancient city centres are provided, for example, by ‘Paestum 1937’ (IGCH 1925) or ‘Strongoli 1955’ (IGCH 1885); in the area of the ancient city of Petelia). In some cases, there are only references to more significant regions, e.g. hoards were found in 1864 in ‘Calabria’ (IGCH 1873) or 1964 in ‘Southern Italy’ (IGCH 1894) or come from the ‘Ionian Coast’ (IGCH 1916). This information can be displayed in a Wikibase instance in the wikibase.cloud: <https://fuzzy-sl.wikibase.cloud>

One more challenging example could be hoard find no. 3001 (Fig. 5, red dot): ‘San Giorgio Ionico 1949, San Giorgio Ionico (near Taranto), on the property of E. De Finis’ poses the question: ‘Where was the property of E. De Finis located?’. With the help of Lo PORTO (1990), SICILIANO (2002) and OSM Node 68530185, the coordinate Point 40.4579 °N / 17.3787 °E can be determined. In Wikibase (<https://fuzzy-sl.wikibase.cloud/entity/Q13>), this information can

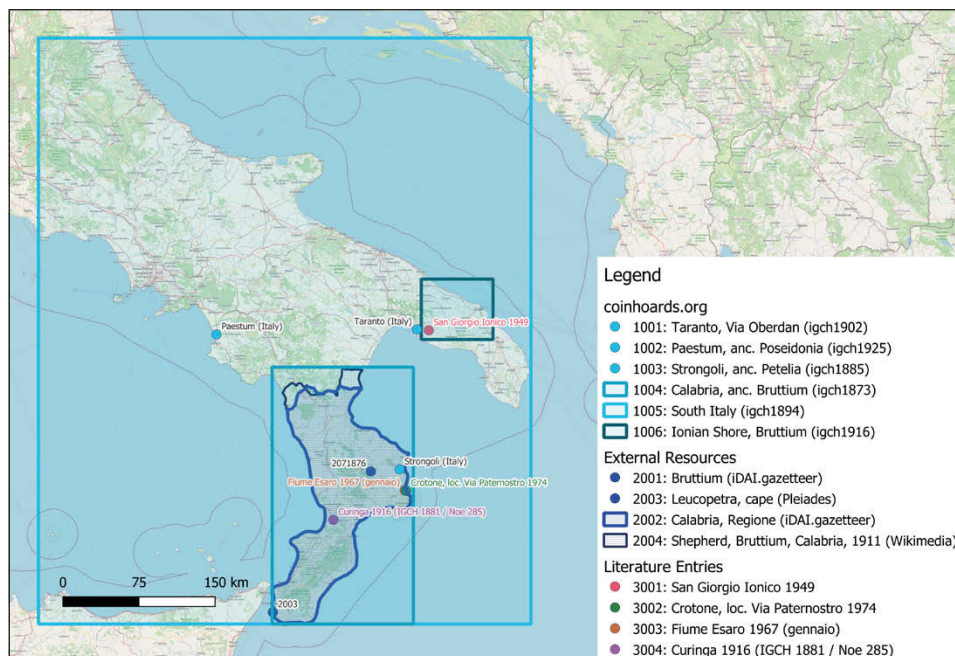


Fig. 5 – Visualisation of find spots for coins from Croton from coinhoards.org, external resources and literature entries (F. Thiery, S. Baars).

be described as, e.g.: (1) *related to* (P10) wd:Q52035 and osm:node/68530185 using *related to type* (qP12) fsl:spatialCloseMatch; (2) *has reference* (P11) F.G. Lo Porto (1990) and A. Siciliano (2002); (3) *has coordinate* (P4) ‘40°27’28.4” N, 17°22’43.3” E’, using *has certainty level* (qP5) ‘Medium’, *certainty description* (qP13) ‘property of E. De Finis?’, *method used* (qP7) ‘Georeferencing’, *acting Person* (qP14) ‘S. Baars’ as well as *method description* (qP15) ‘set a point based on F.G. Lo Porto (1990) and A. Siciliano (2002) using OSM Node 68530185’.

#### 4. CONCLUSION

This paper showed two modelling approaches for doubts, e.g., uncertainty and ambiguities, in interdisciplinary fields such as archaeology and geosciences using Linked Open Data, Wikidata/Wikibase. All of them have their own advantages and disadvantages.

Looking at the OWL/LOD approach, on the one hand, the pros are (1) the freedom of modelling (2) the possibility to include primary and community-accepted ontologies such as PROV-O, SKOS and GeoSPARQL (3) and the direct possibility to integrate that modelling idea into international



activities like the NFDI, on the other hand, the cons are: (a) creating even the 11<sup>th</sup> standard of the ten existing ones, (b) the challenge of building a community to make this modelling sustainable, (c) and the challenge of maintaining sustainable IT infrastructures. However, looking at the Wikidata/Wikibase approach, on the one hand, the pros are: (1) the possibility to integrate the modelling discussions within the existing communities, (2) the possibility of being directly into the LOD cloud, and (3) the Open Science principle by using Open Source (FOSS) software and creating Open Data in a FAIR way; on the other hand, the cons (a) are a limited set of predefined properties (in Wikidata) and a community-process to add more (in Wikibase instances you are free to create your own properties, however, they do not have a direct connection to their ‘Wikidata sisters’, which makes interoperability challenging), (b) the community-approach, which is challenging in terms of modelling approaches and software development, and (c) the sustainability issue with Open Source (FOSS) software that volunteers and the community itself curate.

We believe that Semantic Web technologies such as Linked Open (Usable) Data, in combination with community-driven hubs and FOSS like Wikidata and Wikibase (developed and maintained by the Wikimedia Foundation), serve as FAIRification services that offer a real possibility to implement the FAIR principles and the Open Science idea, by disclosing doubts and uncertainties and generating comprehensibility and reusability in research data.

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## REFERENCES

- BARBERI F., INNOCENTI F., LIRER L., MUNNO R., PESCATORE T., SANTACROCE R. 1978, *The Campanian ignimbrite: A major prehistoric eruption in the Neapolitan area (Italy)*, «Bulletin Volcanologique», 41, 1, 10-31 (<https://doi.org/10.1007/BF02597680>).
- BERNERS-LEE T. 2006, *Linked Data* (<https://www.w3.org/DesignIssues/LinkedData.html>).
- BIBBY D., BRUHN K.-C., BUSCH A., DÜHRKOPF F. et al. 2023, *NFDI4Objects, proposal*, «NFDI4Objects Zenodo Community» (<https://doi.org/10.5281/zenodo.10409227>).
- BRASH R.R. 1869, *On two Ogham inscribed stones from the County of Cork*, «The Journal of the Historical and Archaeological Association of Ireland», 1, 2, 254-264.
- DE VIVO B., ROLANDI G., GANS P.B., CALVERT A., BOHRSON W.A., SPERA F.J., BELKIN H.E. 2001, *New constraints on the pyroclastic eruptive history of the Campanian volcanic Plain (Italy)*, «Mineralogy and Petrology», 73, 1-3, 47-65 (<https://doi.org/10.1007/s007100170010>).

- FITZSIMMONS K.E., HAMBACH U. 2014, *Loess accumulation during the last glacial maximum: Evidence from Urluia, southeastern Romania*, «Quaternary International», 334-335, 74-85 (<https://doi.org/10.1016/j.quaint.2013.08.005>).
- GARRAFFO S. 1987, *Crotoniensi: dall'incuso al doppio rilievo*, in T. CARUSO (ed.), *Studi per Laura Breglia*, Roma, Istituto Poligrafico e Zecca dello Stato, 105-117.
- GIPPERT J. 2001, *CIIC no. 081* (<https://titus.fkidg1.uni-frankfurt.de/database/ogam/ogquery.asp?ciic1=081>).
- HARTL N., WÖSSNER E., SURE-VETTER Y. 2021, *Nationale Forschungsdateninfrastruktur (NFDI)*, «Informatik Spektrum», 44, 5, 370-373 (<https://doi.org/10.1007/s00287-021-01392-6>).
- HOMBURG T., THIERY F. 2024, *SPARQL Unicorn ontology documentation, v0.17*, «Squirrel Papers», 6, 2 (<https://doi.org/10.5281/zenodo.10780476>).
- IGCH = THOMPSON M., MØRKHOLM O., KRAAY C.M. (eds.) 1973, *An Inventory of Greek Coin Hoards*, New York, ANS.
- LO PORTO F.G. 1990, *Testimonianze archeologiche della espansione tarantina in età arcaica*, «Taras», 10, 67-97.
- MACALISTER R.A.S. 1945, *Corpus inscriptionum insularum Celticarum*, I, Dublin, Stationery Office.
- MACMANUS D. 1997, *A Guide to Ogam*, Maynooth monographs 4, Maynooth, An Sagart.
- NATION Z. 2017, *Perceptions of Probability and Numbers* (<https://github.com/zonation/perceptions>).
- Ó RÍORDÁIN S.P. 1931, *The place names and antiquities of Kinalmeaky Barony, Co. Cork*, «Journal of the Cork Historical and Archaeological Society», 36, 144, 57-68.
- Ó RÍORDÁIN S.P., RYAN J. 1941, *The excavation of a large earthen ring-fort at Garranes, Co. Cork*, «Proceedings of the Royal Irish Academy. Section C: Archaeology, Celtic Studies, History, Linguistics, Literature», 47, 77-150.
- PÖTTER S., VERES D., BAYKAL Y., NETT J.J., SCHULTE P., HAMBACH U., LEHMKUHL F. 2021, *Disentangling sedimentary pathways for the pleniglacial lower Danube loess based on geochemical signatures*, «Frontiers in Earth Science», 9, 600010 (<https://doi.org/10.3389/feart.2021.600010>).
- RUTTER N.K. 1997, *The Greek Coinages of Southern Italy and Sicily*, London, Spink.
- RUTTER N.K. (ed.) 2001, *Historia Numorum: Italy*, London, British Museum Press.
- SCHENK F., HAMBACH U., BRITZIUS S., VERES D., SIROCKO F. 2024, *A cryptotephra layer in sediments of an infilled Maar Lake from the Eifel (Germany): First evidence of Campanian ignimbrite ash airfall in Central Europe*, «Quaternary», 7, 2, 17 (<https://doi.org/10.3390/quat7020017>).
- SCHMIDT S.C., THIERY F. 2022, *SPARQLing Ogham stones: New options for analyzing analog editions by digitization in Wikidata*, in T. ANDREWS, F. DIEHR, T. EFER, A. KUCZERA, J. VAN ZUNDERT J. (eds.), *Graph Technologies in the Humanities, CEUR Workshop Proceedings (Wien 2020)*, 3110, 211-244 (<https://doi.org/10.5281/zenodo.6380914>).
- SCHMIDT S.C., THIERY F., TROGNITZ M. 2022, *Practices of Linked Open Data in archaeology and their realisation in Wikidata*, «Digital», 2, 3, 333-364 (<https://doi.org/10.3390/digital2030019>).
- SEELBACH D. 2023, *Der Herrscher im Massenmedium: Fränkische Bildpolitik auf Münzen und Siegeln im Kulturvergleich*, Berlin-Boston, De Gruyter (<https://doi.org/10.1515/9783111341682>).
- SICILIANO A. 2002, *La circolazione monetale*, in *Taranto e il Mediterraneo. Atti del quarantesimo Convegno di Studi sulla Magna Grecia (Taranto 2001)*, Taranto, Istituto per la Storia e l'Archeologia della Magna Grecia, 483-517.
- STAZIO A. 1984, *Problemi della monetazione di Crotona*, in *Crotona. Atti del ventitreesimo Convegno di Studi sulla Magna Grecia (Taranto 1983)*, Taranto, Istituto per la Storia e l'Archeologia della Magna Grecia, 369-398.
- THIERY F. 2023a, *Dealing with doubts: Modelling approaches in site georeferencing*, «Squirrel Papers», 5, 1 (<https://doi.org/10.5281/zenodo.10403509>).



- THIERY F. 2023b, *Fuzzy spatial locations ontology*, «Squirrel Papers», 5, 2 (<https://doi.org/10.5281/zenodo.10362777>).
- THIERY F., DISTEL A.-K., SCHMIDT S.C., THIERY P. 2023, *Irische -#-+ Steine in OSM und Wiki-data*, «Squirrel Papers», 5, 1 (<https://doi.org/10.5281/zenodo.7870480>).
- THIERY F., HOMBURG T. 2024, *SPARQLing Unicorn QGIS Plugin, v0.17*, «Squirrel Papers», 6, 2 (<https://doi.org/10.5281/zenodo.10779466>).
- THIERY F., MEES A. 2023, *Taming ambiguity. Dealing with doubts in archaeological datasets using LOD*, in M. LANG, V. HOCHSCHILD, T. SONNEMANN (eds.), *Human History and Digital Future. CAA 2018 Computer Applications and Quantitative Methods in Archaeology, Proceedings of the 46<sup>th</sup> Conference (Tübingen 2018)*, Tübingen, Tübingen University Press, 145-160 (<https://doi.org/10.15496/PUBLIKATION-87762>).
- THIERY F., MEES A., TOLLE K., WIGG-WOLF D. 2021, *TRAIL 2.2: Evaluation of fuzziness and wobbliness in numismatics and ceramology*, «NFDI4Objects TRAILS», 2, 2 (<https://doi.org/10.5281/zenodo.5654897>).
- THIERY F., SCHENK F. 2023a, *Campanian ignimbrite geo locations*, «Squirrel Papers», 5, 2 (<https://doi.org/10.5281/zenodo.10361309>).
- THIERY F., SCHENK F. 2023b, *CI Site 52: Urluia (Romania)*, Published: URL: [http://fuzzy-sl.squirrel.link/data/cisite\\_52](http://fuzzy-sl.squirrel.link/data/cisite_52), «Squirrel Papers», Research Squirrel Engineers (via @campanian-ignimbrite-geo, [http://fuzzy-sl.squirrel.link/data/cisite\\_52](http://fuzzy-sl.squirrel.link/data/cisite_52)).
- THIERY F., SCHENK F. 2023c, *CI Site instances collection*, Published: URL: [https://research-squirrel-engineers.github.io/campanian-ignimbrite-geo/Site\\_collection/index.html](https://research-squirrel-engineers.github.io/campanian-ignimbrite-geo/Site_collection/index.html), «Squirrel Papers», Research Squirrel Engineers (via @campanian-ignimbrite-geo, [https://research-squirrel-engineers.github.io/campanian-ignimbrite-geo/Site\\_collection/index.html](https://research-squirrel-engineers.github.io/campanian-ignimbrite-geo/Site_collection/index.html)).
- THIERY F., SCHENK F. 2023d, *How to locate the Campanian ignimbrite site Urluia based on literature? How to provide and publish this data in a FAIR way?*, «Squirrel Papers», 5, 1 (<https://doi.org/10.5281/zenodo.10262720>).
- THIERY F., SCHENK F. 2023e, *Modelling of uncertainty in geo sciences sites*, «Squirrel Papers», 5, 1 (<https://doi.org/10.5281/zenodo.10255259>).
- THIERY F., SCHMIDT S.C., HOMBURG T., TROGNITZ M. 2020, *The SPARQL Unicorn: An introduction*, «Squirrel Papers», 2, 1 (<https://doi.org/10.5281/zenodo.3742185>).
- THOMPSON M., MØRKHOLM O., KRAAY C.M., NOE S.P. 1973, *An inventory of Greek Coin Hoards*, New York, International Numismatic Commission-American Numismatic Society.
- UNOLD M., THIERY F., MEES A. 2019, *Academic meta tool. Ein Web-Tool zur Modellierung von Vagheit*, in A. KUCZERA, T. WÜBBENA, T. KOLLATZ (eds.), *Die Modellierung des Zweifels. Schlüsselideen und-konzepte zur graphbasierten Modellierung von Unsicherheiten*, «Zeitschrift für digitale Geisteswissenschaften», 4 ([https://doi.org/10.17175/SB004\\_004](https://doi.org/10.17175/SB004_004)).
- WILKINSON M.D., DUMONTIER M., AALBERSBERG I.J., APPLETON G. et al. 2016, *The FAIR guiding principles for scientific data management and stewardship*, «Scientific Data», 3, 160018 (<https://doi.org/10.1038/sdata.2016.18>).
- ZEENA, Nomisma.org 2022, *Nomisma Cookbook. hasMint* (<https://nomisma.hypotheses.org/1919>).

## ABSTRACT

Archaeological research must handle issues such as vagueness and uncertainty in data modelling. Especially vagueness and uncertainty must be modelled to work with geodata. However, for linking data and FAIRification graph-based modelling as Linked Open Data (LOD) proposed by Berners-Lee is the method and technique of choice. This paper discusses three data-driven interdisciplinary use cases of dealing with and modelling vague and uncertain geo-references (here especially findspots) based on literature as LOD from the archaeological and geosciences domain (Irish Ogham Stones, Campanian Ignimbrite, and Silver Coinage of Croton), implementing three modelling strategies using Wikidata, Linked Open Data and Wikibase.

## USING KART AND GITHUB FOR VERSIONING AND COLLABORATING WITH SPATIAL DATA IN ARCHAEOLOGICAL RESEARCH

### 1. INTRODUCTION: OPEN SCIENCE, ARCHAEOLOGY, GIT AND VERSION CONTROL

One of the many aims of Open Science is to enhance the transparency behind the process of data creation, data manipulation, etc., in order to foster reproducibility and openness. In fact, an Open Science approach to data cannot be limited to just a final product, but should provide means to access and inspect the full creative and methodological process behind data creation (STRUPLER, WILKINSON 2017). Distributed Version Control Systems (DVCS), and particularly Git, are one of many tools that has potential to enhance Open Science practices (RAM 2013). It has been suggested that Git can help in data management (MARWICK 2017), lead to greater accountability and better documentation (KANSA 2012), and provide more opportunity for feedback and collaboration at different stages of archaeological work (KANSA *et al.* 2014). In its simpler form, DVCS allow to inspect snapshots of a file at different stages, thus making the whole creation process fully transparent, but also allowing to roll back changes to a specific snapshot.

Most importantly, DVCS, when coupled with remote repositories, allow for a more efficient collaboration between peers. While these benefits have been highlighted for some time, DVCS are still not widely adopted by archaeologists (STRUPLER, WILKINSON 2017; KAROUNE, PLOMP 2022), being mostly employed in code-based approaches to archaeological data (MARWICK, BIRCH 2018; SCHMIDT, MARWICK 2020; BATIST, ROE 2021, 2023), and, in some cases, for entire archaeological workflows, from fieldwork to publication (STRUPLER, WILKINSON 2017).

However, Git and DVCS are not without pitfalls. Apart from the steep learning curve and the slow adoption, a well-known limitation of Git is the versioning of binary files. Most of the archaeological workflow is still reliant on binary files, being either word processors, spreadsheets, geospatial data or raster images (SCHMIDT, MARWICK 2020). The lack of a way to efficiently track changes in these point-and-click software means that much of the data creation and the methods are hidden, unless reported into a not-always-ideal final report (KANSA 2012).

### 2. VERSION CONTROL FOR GEOSPATIAL DATA

For text files and tabular data the ‘issue’ of adopting DVCS is overcome by employing plain text formats like Markdown, TXT, CSV. However, GIS

is another area in which the graphical nature of the software obscures the research process, and data cleaning, data restructuring and so on remain hidden. Advocating for a code-only solution is not feasible, and intermediate tools should exist to be able to bridge point-and-click with code-based approaches (STRUPLER, WILKINSON 2017).

Kart (<https://kartproject.org/>) is a DVCS for geospatial and tabular data, a cross-platform FOSS software launched in 2020 by the company Koordinates. Kart works with many different formats, such as Geopackages, PostGIS, MySQL, and support the most common geospatial data types. It is built on Git, and provides the same Git functionalities but for geospatial data, meaning that a versioned history of datasets, both locally and remotely is available, enabling collaboration and changes tracking. Kart is a command line (CLI) program that bundles both Git and Git-LFS (for large files, e.g. rasters), so having Git installed on the system is not a prerequisite. As Git, Karts allows to track granular changes at the layer level (row and cells), making it possible to clearly inspect commits for spatial dataset and retrieve information in a meaningful way.

Kart also offers a QGIS plugin (<https://plugins.qgis.org/plugins/kart/>), which provides a convenient interface for common Git operations, and, most importantly, a visual tool for tracking commit history and visualize changes on a 2D map. More importantly, just like Git, one can host the versioned data on a remote repository such as GitHub for a more efficient collaboration.

### 3. THE ASSYRIAN GOVERNANCE PROJECT

The ‘Governance Policies and Political Landscapes in the Southern Levant under the Neo-Assyrian Empire’ is a 2-year project based at the University of Turin, founded by the Gerda Henkel foundation ([https://www.dipstudistorici.unito.it/do/progetti.pl/Show?\\_id=0sk8](https://www.dipstudistorici.unito.it/do/progetti.pl/Show?_id=0sk8))<sup>1</sup>. The project’s goals are to understand Neo-Assyrian imperial strategies, and their effects on population and settlement patterns in the Southern Levant region during the Iron Age. The study area provides an excellent case study to investigate long-term changes of archaeological and political landscapes, since across its history it incorporated multiple socio-political entities, from local kingdoms to supra-regional empires. Moreover, the area is characterized by an extensive amount of high-quality archaeological data, providing enough information for a multi-temporal and multi-scalar analysis.

<sup>1</sup> The project is funded by the Gerda Henkel Foundation. Additional funding has been provided by the Rita Levi Montalcini Grant for the project ‘The Empire Strikes Back: The Geography of Governance Strategies in the Assyrian Empire’.

The Southern Levant political landscape and the effect of the Assyrian domination over its provinces and client states have been a matter of debate among scholars. On the two extremes, some scholars highlighted how the so-called *Pax Assyriaca* was instrumental to economic prosperity, settlement expansion and adoption of Assyrian values and customs (GITIN 1995; FINKELSTEIN, SINGER-AVITZ 2001; STERN 2001; FRAHM 2006; FALES 2008), while others claimed that Assyrian conquest resulted in destruction and devastation of annexed provinces, whereas independent regional states flourished (STAGER 1996; NA'AMAN 2003; AVRAHAM, WEISS 2005; FAUST 2021). However, it has been widely demonstrated how a single model is not fit to understand Assyrian governance strategies, which have been shown to be nuanced and adaptable depending on the history of the region (MACGINNIS 2016; MORANDI BONACOSSÌ 2018; DÜRING 2018, 2020; TYSON, HERRMANN 2018; PARKER 2020). Moreover, these phenomena cannot be disconnected from the larger framework of Iron Age settlement pattern changes (WILKINSON 2003).

Regarding archaeological data, the project is gathering spatial, quantitative, and qualitative data from published archaeological surveys and excavations, and online resources. In particular, datasets available for the project are:

- The Samaria Survey (FINKELSTEIN *et al.* 1997);
- The Manasseh Hill Surveys (ZERTAL 2004, 2007; ZERTAL, MIRKAM 2016; ZERTAL, BAR 2017, 2019; BAR, ZERTAL 2021, 2022);
- The Archaeological Survey of Israel online database (<https://survey.antiquities.org.il/>), and excavation reports from the «Hadashot Arkheologiyot Journal» ([https://www.hadashot-esi.org.il/default\\_eng.aspx](https://www.hadashot-esi.org.il/default_eng.aspx));
- settlement patterns and demographic studies (BROSHI, GOPHNA 1984, 1986; GOPHNA, PORTUGALI 1988).

In the case of published survey, the process of gathering spatial information included manual georeferencing of survey maps and digitisation of archaeological site points. In case the georeferencing process resulted in high inaccuracies, a manual registration of sites coordinates into a CSV file was carried out. This file has later been imported in QGIS and integrated in the project database, consisting of a single geopackage file. For online databases, site information was stored in CSV format and then imported in the database. Most of the work is carried out in QGIS, with sites information stored in the layer attribute table. While the database is still under refinement, currently it stores around five thousands sites and more than twelve thousands occupational phases (see also PALMISANO *et al.* 2019) (Fig. 1).

The project is organized around a workflow aimed to be as transparent as possible, not only in the final results, but also in the different stages of data creation, data cleaning, analyses, etc. The project lives on GitHub, with a homepage (<https://github.com/UnitoAssyrianGovernance>) and different

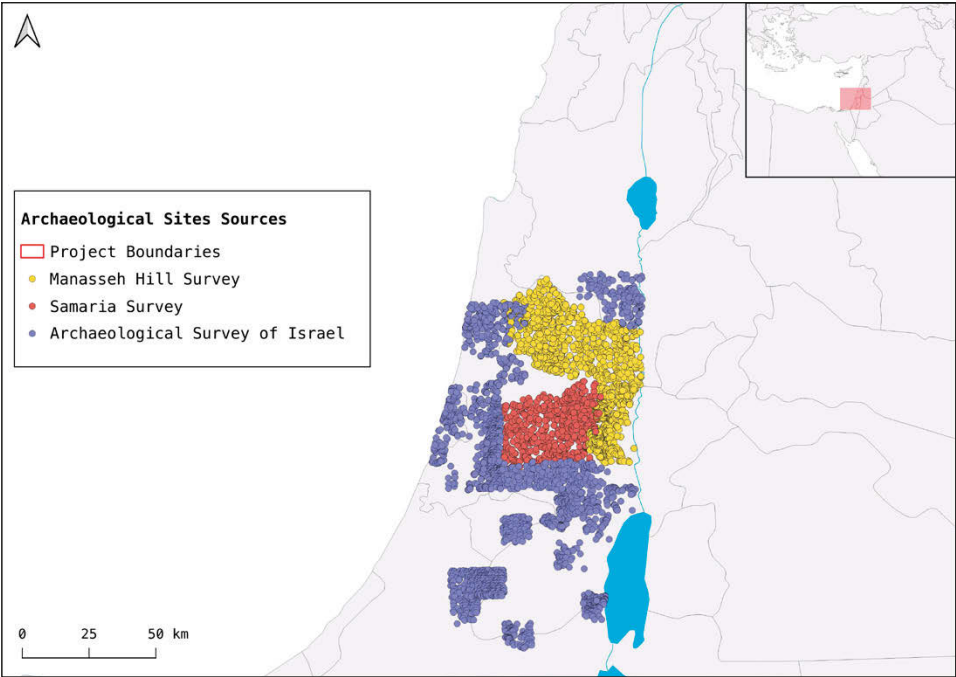


Fig. 1 – Project extent and archaeological sites digitized from different sources.

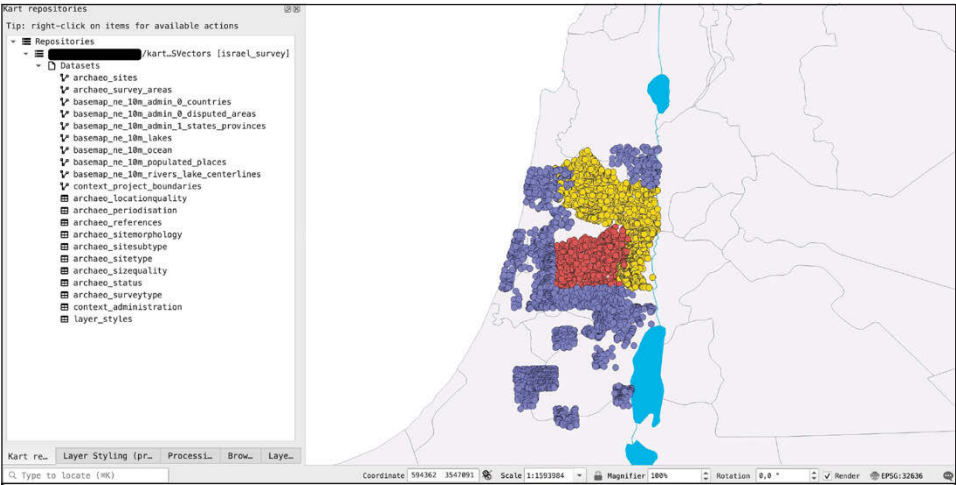


Fig. 2 – Kart QGIS plugin main interface with the list of available layers present in the database.

repositories for any project activity: data, analyses, publications/talks. The use of multiple repositories will allow higher flexibility and granular control in collaborating, accessing, licensing, publishing, and sharing data. Project activities are also tracked leveraging the GitHub ‘issues’ functionality available on any repositories, and collected into a kanban board (<https://github.com/orgs/UnitoAssyrianGovernance/projects/5>). The project also offers a public wiki (<https://github.com/UnitoAssyrianGovernance/.github/wiki>) which hosts most of the project documentation, updated as this proceed. The wiki also gather methods and conventions used inside the project, but offers also a guide on how to use the dataset and how to use Kart, which is the basis of the workflow attached to the paper.

Kart is inserted into the aforementioned workflow to provide transparency and openness to the process of working with geospatial data. In particular, the main aims are versioning vector data, collaborating with project members remotely, and to have a public record of changes made to the spatial database layers (Fig. 2).

### 3.1 Kart for remote collaboration

The project adopts a very common workflow for collaboration, based on Git features such as branching and merging, with the following structure:

- main branch: considered the final copy, where only completed data are merged;
- feature branch: these are the branches worked on daily, with as many branch as many collaborators as possible inside the project.

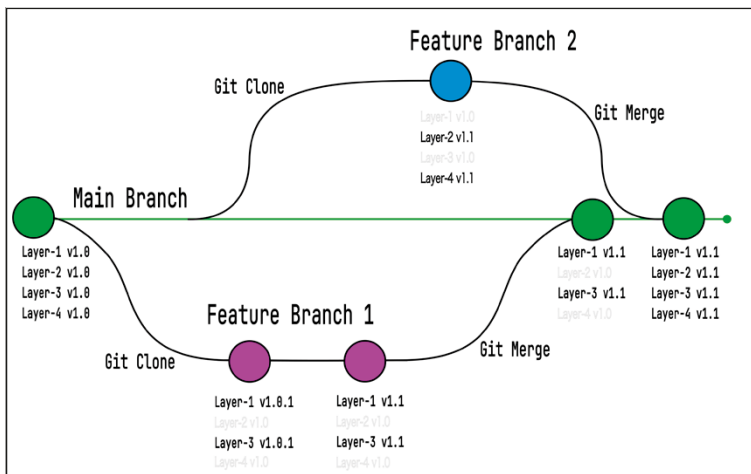


Fig. 3 – Simplified representation of Kart workflow.

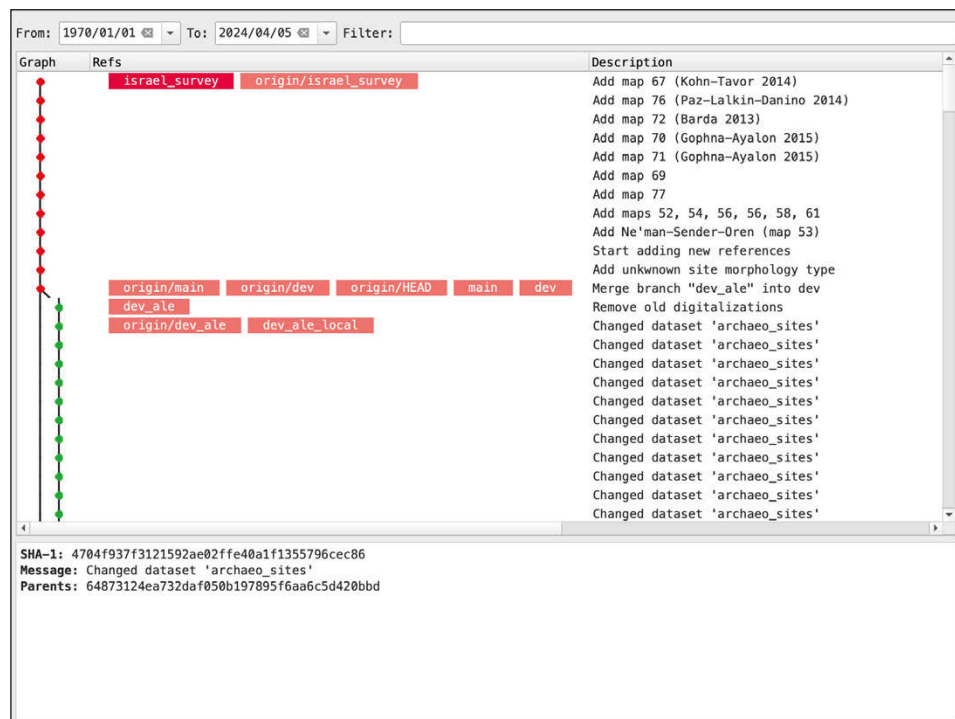


Fig. 4 – Example of Kart QGIS plugin visual commit log.

In this workflow, each project member works on a separate feature branch, edits the layers and pushes the branch to the corresponding GitHub repository when needed. When a specific task has been completed (e.g. the digitization of an entire survey catalog), the feature branch is merged into the main branch (Fig. 3).

### 3.2 Kart for version control of spatial data

The advantage of version control is that each project member is able to track the edits made in GIS, and to easily revert back if mistakes were made. Data cleaning, refactoring of tabular structure, and other changes made during the project can be easily highlighted by looking at the commit history (Fig. 4). This in turn helps to highlight issues, presents the reasoning behind methodological choices and provides a reference beyond the simple final product. In the project framework, Kart was tested on two MacOS machines, and on an Ubuntu-based Linux machine. Since the workflow is rather simple, there were not many issues in the collaboration process. The



only complication presented itself when merging data on the same layer from two different branches, which caused an overlapping conflict of the unique primary IDs generated by the geopackage. To solve the issue, one has to resort to the command line, which offer to automatically renumber one of the two conflicting series of IDs<sup>2</sup>.

#### 4. DISCUSSION AND CONCLUSIONS

One of the long-standing issues of collaborating on any GIS project is how to handle either simultaneous edits on the same data or how sharing the same data among colleagues after each edit. Using a DVCS based on different working branches is one of the ideal solutions to overcome this problem. Commit messages are also self-explanatory and can clearly define what changes have been made to the dataset even before a collaborator inspects them. Kart allows multiple people to efficiently work on the same dataset without the need for back-and-forth emails, drive uploads, or personal communications for updates on the dataset. Rolling back through commit history to correct mistakes is also generally easier than trying to recover something made during an undocumented change. The graphical user interface provided by the QGIS plugin also allows for a convenient visual change inspection (Fig. 5). This plugin, while still lacking some functionalities of the CLI, if further developed, could effectively bridge the gap between code-based approaches and mouse-driven software, since ideally the use of the terminal could be completely avoided.

Another advantage is related to the way Kart stores the spatial dataset on a remote repository. Data are in fact broken down in a series of SQL-like tables instead of a single file. While this could make things harder to read, it also makes it harder to access spatial information about the sites. This might be relevant in the ongoing discussion about site stewardship related to public data sharing (e.g. COHEN *et al.* 2020; FISHER *et al.* 2021). One of the authors also employed Kart during fieldwork, specifically for versioning daily data and provided a record of data cleaning and processing after collection. This aspect is important, as very few attempts have been made to integrate DVCS in fieldwork activities, highlighting how one missing tool was a way to keep track of GIS/Rasters data (STRUPLER, WILKINSON 2017), which is exactly the gap that Kart can fill.

However, one must recognize that Kart is still not a widely accessible tool and it presents a steep learning curve (only partially mitigated by the graphical plugin). While being built on Git means that the workflow will be

<sup>2</sup> A tutorial and a dataset to drive step by step any practitioner interested in learning how to use Kart is available at <https://unitoassyriangovernance.github.io/kart4arch/> and have also been deposited in Zenodo: <https://zenodo.org/records/10962416>.

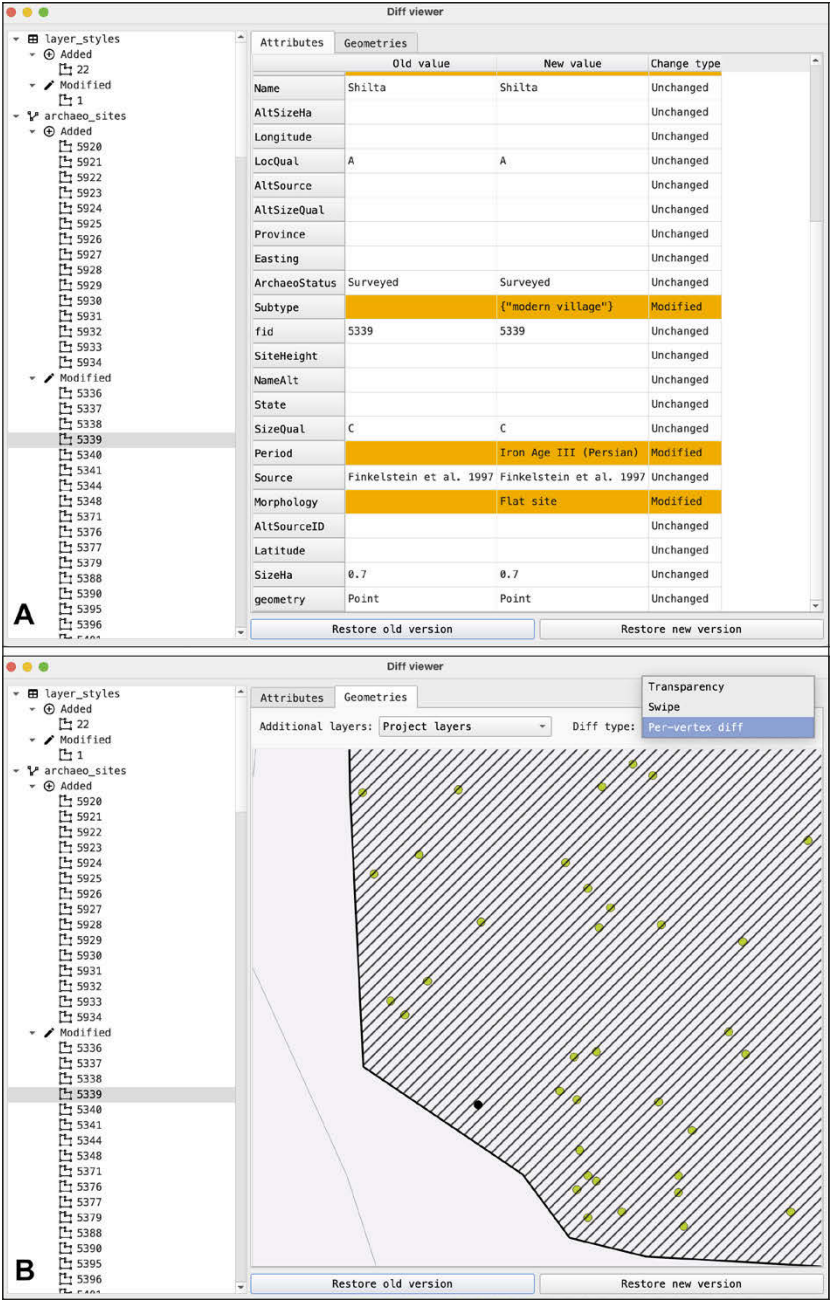


Fig. 5 – Example of Kart QGIS plugin tabular (A) and visual (B) diff.

familiar for Git users, most archaeologists are likely not confident enough with coding tools and terminal applications, and training and resources will be needed if a wider adoption is hoped for. Most of the features are also useful only if a specific workflow is adopted, as incorrect or partial information might hamper the collaboration process and transparency. This workflow is suitable for desk-based work, but it might be considered slower or less efficient in situations such as fieldwork, when time constraints are higher and Internet connection is not always available (although internet access is not a requirement). Another limitation is the lack of easier methods for solving merging conflicts (see above), which still require manual use of the CLI (although according the documentation tools to smooth this process are in development).

However, while being a relatively young and small tool, Kart can fit well in the Open Science practices applied to archaeology. Kart is still under development, and while mature enough in our opinion, it might still face substantial changes before reaching a stable state. Nonetheless, the authors think that it can provide a valuable addition to the current archaeological workflow regarding spatial data management, with our project being a main testing venue for its applicability.

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## REFERENCES

- AVRAHAM F., WEISS E. 2005, *Judah, Philistia, and the Mediterranean World: Reconstructing the economic system of the seventh century B.C.E.*, «Bulletin of the American Schools of Oriental Research», 338, 71-92 (<http://www.jstor.org/stable/25066890>).
- BAR S., ZERTAL A. 2021, *The Manasseh Hill Country Survey, 6. The Eastern Samaria Shoulder, from Nahal Tirzah (Wadi Far'ah) to Ma'ale Ephraim Junction*, Leiden, Brill (<https://brill.com/display/title/60190>).
- BAR S., ZERTAL A. 2022, *The Manasseh Hill Country Survey, 7. The South-Eastern Samaria Shoulder, from Wadi Rashash to Wadi 'Aujah*, Leiden, Brill (<https://brill.com/display/title/62098>).
- BATIST Z., ROE J. 2021, *Open Archaeology: A survey of collaborative software engineering in archaeological research*, Paper presented at *Computer Applications & Quantitative Methods in Archaeology 2021*, Limassol (Virtual).
- BATIST Z., ROE J. 2023, *Open-archaeo: A resource for documenting archaeological software development practices*, «Journal of Open Archaeology Data», 11 (<https://doi.org/10.5334/joad.111>).
- BROSHI M., GOPHNA R. 1984, *The settlements and population of Palestine during the Early Bronze Age II-III*, «Bulletin of the American Schools of Oriental Research», 253, 41-53 (<https://doi.org/10.2307/1356938>).

- BROSHI M., GOPHNA R. 1986, *Middle Bronze Age II Palestine: Its settlements and population*, «Bulletin of the American Schools of Oriental Research», 261, 73-90 (<https://doi.org/10.2307/1357066>).
- COHEN A., KLASSEN S., EVANS D. 2020, *Ethics in archaeological Lidar*, «Journal of Computer Applications in Archaeology», 3, 1, 76-91 (<https://doi.org/10.5334/jcaa.48>).
- DÜRING B.S. 2018, *Engineering empire: A provincial perspective on the Middle Assyrian empire*, in B.S. DÜRING, T.D. STEK (eds.), *The Archaeology of Imperial Landscapes: A Comparative Study of Empires in the Ancient Near East and Mediterranean World*, Cambridge, Cambridge University Press, 21-47.
- DÜRING B.S. 2020, *The Imperialisation of Assyria: An Archaeological Approach*, Cambridge University Press (<https://doi.org/10.1017/9781108778701>).
- FALES F.M. 2008, *Canals in the Neo-Assyrian rural landscape: A view from the Habur and middle Euphrates*, in H. KÜHNE (ed.), *Umwelt und Subsistenz der assyrischen Stadt Dur-Katlimmu am Unteren Habur (BATSH 8)*, Wiesbaden, Harrassowitz Verlag, 181-187.
- FAUST A. 2021, *The Neo-Assyrian Empire in the Southwest: Imperial Domination and its Consequences*, Oxford, Oxford University Press (<https://global.oup.com/academic/product/the-neo-assyrian-empire-in-the-southwest-9780198841630>).
- FINKELSTEIN I., LEDERMAN Z., BUNIMOVITZ S. 1997, *Highlands of Many Cultures: The Southern Samaria Survey. The Sites*, Tel Aviv, Institute of Archaeology of Tel-Aviv University, Publications Section (<https://cris.tau.ac.il/en/publications/highlands-of-many-cultures-the-southern-samaria-survey-the-sites>).
- FINKELSTEIN I., SINGER-AVITZ L. 2001, *Ashdod revisited*, «Tel Aviv», 28, 2, 231-259 (<https://doi.org/10.1179/tav.2001.2001.2.231>).
- FISHER M., FRADLEY M., FLOHR P., ROUHANI B., SIMI F. 2021, *Ethical considerations for remote sensing and open data in relation to the endangered archaeology in the Middle East and North Africa project*, «Archaeological Prospection», 28, 3, 279-292 (<https://doi.org/10.1002/arp.1816>).
- FRAHM E. 2006, *Assyria and the South*, in S. HOLLOWAY (ed.), *Orientalism, Assyriology and the Bible*, Sheffield, Sheffield Phoenix Press, 74-94 (<https://doi.org/10.1002/9781118325216.ch15>).
- GITIN S. 1995, *Tel Migne-Ekron in the 7<sup>th</sup> century B.C.E.: The impact of economic innovation and foreign cultural influences on a Neo-Assyrian vassal city-state*, in S. GITIN (ed.), *Recent Excavations in Israel: A View to the West*, Dubuque, Kendall/Hunt Publ. (<https://ixtheo.de/Record/1589006739>).
- GOPHNA R., PORTUGALI J. 1988, *Settlement and demographic processes in Israel's coastal plain from the Chalcolithic to the Middle Bronze Age*, «Bulletin of the American Schools of Oriental Research», 269, 11-28 (<https://doi.org/10.2307/1356947>).
- KANSA E. 2012, *Openness and archaeology's information ecosystem*, «World Archaeology», 44, 4, 498-520 (<https://doi.org/10.1080/00438243.2012.737575>).
- KANSA E.C., KANSA S.W., ARBUCKLE B. 2014, *Publishing and pushing: Mixing models for communicating research data in archaeology*, «International Journal of Digital Curation», 9, 1, 57-70 (<https://www.ijdc.net/index.php/ijdc/article/view/9.1.57/341>).
- KAROUNE E., PLOMP E. 2022, *Removing Barriers to Reproducible Research in Archaeology* (<https://doi.org/10.5281/ZENODO.7320029>).
- MACGINNIS J. 2016, *The archaeological exploration of the provinces of Assyria*, in J. MACGINNIS, D. WICKE, T. GREENFIELD (eds.), *The Provincial Archaeology of the Assyrian Empire*, Cambridge, McDonald Institute for Archaeological Research, 3-20.
- MARWICK B. 2017, *Computational reproducibility in archaeological research: Basic principles and a case study of their implementation*, «Journal of Archaeological Method and Theory», 24, 2, 424-450 (<https://doi.org/10.1007/s10816-015-9272-9>).
- MARWICK B., BIRCH S.E.P. 2018, *A standard for the scholarly citation of archaeological data as an incentive to data sharing*, «Advances in Archaeological Practice», 6, 2, 125-143 (<https://doi.org/10.1017/aap.2018.3>).

- MORANDI BONACOSI D. 2018, *The creation of the Assyrian heartland: New data from the 'Land behind Nineveh'*, in B.S. DÜRING, T.D. STEK (eds.), *The Archaeology of Imperial Landscapes: A Comparative Study of Empires in the Ancient Near East and Mediterranean World*, Cambridge, Cambridge University Press, 48-85.
- NA'AMAN N. 2003, *Ekron under the Assyrian and Egyptian Empires*, «Bulletin of the American Schools of Oriental Research», 332, 81-91 (<http://www.jstor.org/stable/1357809>).
- PALMISANO A., WOODBRIDGE J., ROBERTS C.N., BEVAN A., FYFE R., SHENNAN S., CHEDDADI R., GREENBERG R., KANIEWSKI D., LANGGUT D., LEROY S.A.G., LITT T., MIEBACH A. 2019, *Holocene landscape dynamics and long-term population trends in the Levant*, «Holocene», 29, 5, 708-727 (<https://doi.org/10.1177/0959683619826642>).
- PARKER B. 2020, *Re-modeling empire*, in A.L. BOOZER, B.S. DÜRING, B.J. PARKER (eds.), *Archaeologies of Empire: Local Participants and Imperial Trajectories*, Albuquerque, University of New Mexico Press, 324-350 (<https://doi.org/10.1017/9781316995495.012>).
- RAM K. 2013, *Git can facilitate greater reproducibility and increased transparency in science*, «Source Code for Biology and Medicine», 8, 1, 1-8 (<https://doi.org/10.1186/1751-0473-8-7>).
- SCHMIDT S.C., MARWICK B. 2020, *Tool-driven revolutions in archaeological science*, «Journal of Computer Applications in Archaeology», 3, 1, 18-32 (<https://doi.org/10.5334/jcaa.29>).
- STAGER L. 1996, *Ashkelon and the archaeology of destruction: Kislev 604 BCE*, «Eretz-Israel», 25, 61-74 (<https://doi.org/10.1515/9781575065717-018>).
- STERN E. 2001, *Archaeology of the Land of the Bible, II. The Assyrian, Babylonian and Persian Periods (732-332 B.C.E.)*, New York, Doubleday.
- STRUPLER N., WILKINSON T.C. 2017, *Reproducibility in the field: Transparency, version control and collaboration on the project panormos survey*, «Open Archaeology», 3, 1, 279-304 (<https://doi.org/10.1515/opar-2017-0019>).
- TYSON C.W., HERRMANN V.R. (eds.) 2018, *Imperial Peripheries in the Neo-Assyrian Period*, Louisville, University Press of Colorado.
- WILKINSON T.J. 2003, *Archaeological Landscapes of the Near East*, Tucson, University of Arizona Press.
- ZERTAL A. 2004, *The Manasseh Hill Country Survey, 1. The Shechem Syncline*, Leiden, Brill (<https://brill.com/display/title/11056>).
- ZERTAL A. 2007, *The Manasseh Hill Country Survey, 2. The Eastern Valleys and the Fringes of the Desert*, Leiden, Brill (<https://brill.com/display/title/13258>).
- ZERTAL A., BAR S. 2017, *The Manasseh Hill Country Survey, 4. From Nahal Bezeq to the Sartaba*, Leiden, Brill (<https://brill.com/display/title/34196>).
- ZERTAL A., BAR S. 2019, *The Manasseh Hill Country Survey, 5. The Middle Jordan Valley, from Wadi Fasaal to Wadi 'Aujah*, Leiden, Brill (<https://brill.com/display/title/54817>).
- ZERTAL A., MIRKAM N. 2016, *The Manasseh Hill Country Survey, 3. From Nahal Iron to Nahal Shechem*, Leiden, Brill (<https://brill.com/edcollbook/title/31740>).

## ABSTRACT

Distributed Version Control Systems are one of the common ways through which scientists collaborate and keep track of different versions of their work. Moreover, scientists, programmers, etc., have been using platforms such as GitHub to host and share their resources versioned through Git. While not as widely adopted as in other disciplines, Git has also been used in archaeological research. In fact, DVCS allow scholars to collaborate remotely and offer the transparency necessary to align with Open Science and reproducible research practices. However, Git is highly inefficient when versioning GIS data. Kart, described as «an open source DVCS for geospatial and tabular data built on git», is a software addressing the need for collaboration and finer incorporation of geospatial data, providing also an integration

with QGIS. Kart and code-hosting websites offers unique resources for archaeologists, from collaboration to more efficient workflows. In this paper, an example of how the authors are using Kart, QGIS, and GitHub in the project ‘Governance Policies and Political Landscapes in the Southern Levant under the Neo-Assyrian Empire’ will be presented. With this case study, the authors hope to provide a solution to the current gap in the workflow of documentation and collaboration among archaeologists using GIS.



## ‘OPEN’ ARCHITECTURE OF UAVIMALS PROTOTYPE AND ITS ARCHAEOLOGICAL USE

### 1. INTRODUCTION

The benefits of using aerial scanning systems to explore sites and territories for the purpose of identifying archaeological deposits, structures, and contexts that are imperceptible to the human eye are widely acknowledged in scientific literature. The anomalies, colours, and patterns visible in remote sensing scenes are the result of interactions between natural phenomena and human activities, which ultimately shape the landscape (KÜÇÜKDEMİRCİ *et al.* 2021). It is now possible to identify certain types of buried archaeological deposits based on their ability to produce various proxy indicators visible on the ground, despite physical and micro-topographical changes that may not be visible from an aerial view (OPTIZ, COWLEY 2013).

The UAVIMALS project focuses on identifying archaeological deposits in areas with sparse and low-trunk vegetation. This system, is the result of interdisciplinary research between archaeology and biorobotics, carried out between the Sapienza University of Rome and the Scuola Superiore Sant’Anna of Pisa, which led to the creation of a small size aerial laser scanner prototype, useful for light archaeological investigations<sup>1</sup>. One important aspect of this project is the identification of ‘soil marks’ (Fig. 1), which are micro-relief anomalies caused by buried deposits; the project aims to use a drone for this purpose.

The existing tools (e.g. DJI Matrice 600, Elios 3) used for this type of investigation are expensive, though based on established technologies and are not yet fully suitable for environmentally unfriendly areas subject to flight restrictions. Additionally, they are equipped with a hardware, and often associated software, that has confidential ownership, preventing users from making changes to the source code. Although market-responsive and compliant with current UAS flight regulations, this feature limits the user’s ability to calibrate the machine to their own research needs. For instance, a drone that can be adapted to different levels of archaeological visibility in an area of high vegetation cover could enable faster and more effective investigations. To achieve this, the project placed research objectives at the forefront of development. The UAVIMALS project aimed to develop a prototype with a highly customisable open source modular structure, allowing for different

<sup>1</sup> The project was funded by a National Geographic Society grant awarded in September 2018, with an Early Career Grant (Grant No. EC-50761T-18) by Federica Vacatello (Principal Investigator and Post Doc Researcher in Archaeology and Post-Classical Antiquities at Sapienza University of Rome) who coordinated an interdisciplinary research team made up of archaeologists, engineers and biorobotics technicians.



configurations depending on the degree of visibility and survey objectives. This paper discusses the configuration of the UAVIMALS instrument for surveying ‘micro-relief’ traces in the archaeological context of Cencelle (VT).

## 2. ANALYSIS CONTEXT

The city of Leopoli-Cencelle was founded by Pope Leo IV in the Tolfa Mountains area on 15 August 854 CE. The name of the city was Leopolis (DUCHESNE 1981, II, 132). Archaeological investigations conducted by the Chair of Medieval Archaeology and Topography at Sapienza University of Rome over the past 30 years have confirmed the city’s multiple phases of occupation from the 9<sup>th</sup> to the 14<sup>th</sup> century CE (STASOLLA 2012). However, most of the intramural area remains unexplored (Fig. 2). In the late 1990s, S. Del Lungo surveyed aerial photographs taken by the British RAF (Royal Air Force), and SIAT (Studio Italiano Aereofotogrammetria e Topografia) between 1944 and 1995 in search of the archaeological features visible on the top of the Cencelle plateau (DEL LUNGO 2003) (Fig. 3). The detected anomalies were identified as ‘mediators’ of a vegetal nature that defined the footprints of individual structures and sometimes entire urban districts (Fig. 3). After over thirty years, the primary urban centres was uncovered. The vegetation that once shaped neighbourhoods and environments has been completely altered due to continuous animal grazing and changing climatic conditions.

Despite significant scientific progress, there are still many questions regarding the chronological and topographical aspects of the urban layout, particularly in the NW and NE areas of the site. The archaeological visibility has been compromised by the presence of tall and medium vegetation, as well as conspicuous tangles of brambles and weedy thistles, particularly in the portions

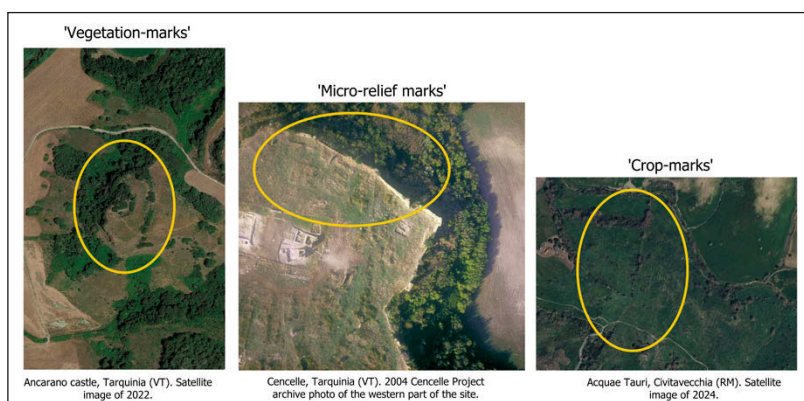


Fig. 1 – Types of archaeological anomalies visible with aerial instrumentation (Satellite image from Landsat/Copernicus 2015).

not yet affected by the excavation. This makes aerial and satellite imagery observations superfluous and surface physical reconnaissance ineffective. Subjective evaluations have been excluded unless clearly marked as such. Within this context, the UAVIMALS prototype was tested to explore the limits and potential of an instrument equipped with a LiDAR sensor. The sensor is capable of recording beams of points on 3 channels, distinguishing high vegetation (trees and shrubs), low vegetation (brambles and tall grass), and ground surface.

F.V.

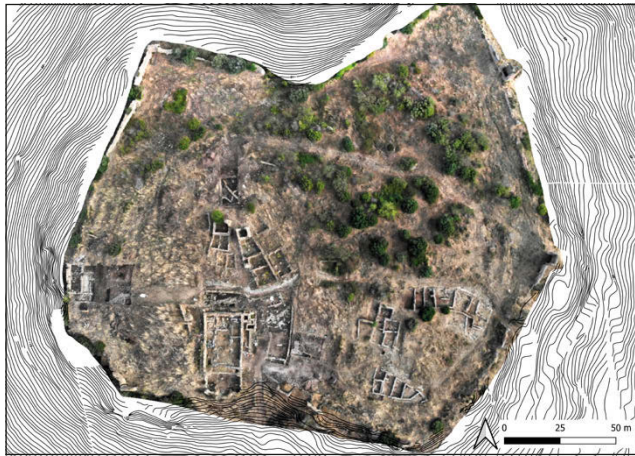


Fig. 2 – Drone orthophoto of the archaeological site of Leopoli-Cencelle (VT).

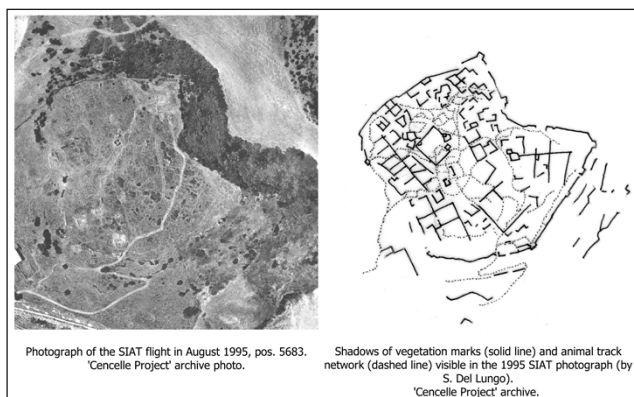


Fig. 3 – Anomalies detected by SIAT flights in the aerial surveys conducted at the Cencelle site between '94 and '95 (graphic re-elaboration by F. Vacatello from DEL LUNGO 2003).

### 3. SYSTEM ARCHITECTURE

Our initial challenge was finding a sensor for microrelief detection that balanced portability and cost. We repurposed a car sensor meeting our needs. Next, we considered operational components (voltage regulators, computer) and the crucial factor: weight. With the payload defined, we sized the remaining drone components (motors, propellers). This ensured optimal performance and stability for the specific payload weight. Precise calculations are essential for efficient multicopter design, balancing power usage with flight duration and preventing overloading. To help us in this process we use a software XcopterCalc which allows simulating various drone configurations (motor types, propellers, battery size) through a user-friendly interface.

#### 3.1 *Pre-flight and post-flight software*

The ground station software is divided into pre-flight and post-flight components. Mission Planner, an open source tool, defines flights and assists in mission planning, telemetry visualization, and UAV parameter configuration for ArduPilot autopilot systems. It supports firmware updates, data logging, and offers a user-friendly interface. Operators utilize Mission Planner for mission planning, telemetry monitoring, and post-flight analysis. Additionally, a Python program aids in verifying that mission is correctly loaded in the Pixhawk autopilot, checks software functionality onboard the UAV, and monitors the state machine during flight to alert pilots of any issues. Together, these tools streamline mission execution, ensure safety, and enhance performance for both novice and experienced operators. After landing, the drone sends its data to the ground station. A Matlab program processes the raw data, removing errors and emphasizing micro details. Through a user-friendly interface, operators can select areas of interest, view the 3D point cloud, and colorize it for clarity. Results can be exported in open formats like csv, las, ply, obj, compatible with software like Cloud Compare, Meshlab, and QGIS.

#### 3.2 *Flight software*

The underlying software for the flight is Ardupilot, a firmware that runs on the FCU which directly controls the hardware components of the drone. It is a sophisticated open source autopilot system, providing a robust platform for autonomous vehicle control. In this case we were able to minimize the vertical movements, from the plane perpendicular to the zenith of the drone while taking-off. To do this we deactivated the terrain following by acting on all the parameters made available by the Ardupilot, excluding the barometer and the laser altimeter from the calculation of the EKF (Extended Kalman Filter). In the first case, the reason is that acquisition quotas (10/12 m) cannot accurately determine the flight height; in the second one, reading the heights below the

objects it flies over induces the drone to rise and lower based on what it sees below. Then we correct the height at which to fly the drone through, our state machine (SM) to minimize errors introduced by terrain elevation changes.

### 3.3 ROS, MAVROS and State Machine (SM)

Unmanned Aerial Vehicles (UAVs), commonly known as drones, require specialized onboard computers for flight control, the Flight Control Unit (FCU), the central nervous system of a drone, responsible for maintaining stability and manoeuvrability. It gathers sensor data from gyroscopes, accelerometers, and other sensors to determine the drone’s attitude, position, and motion. By processing this data in real-time, the FCU calculates and transmits appropriate control signals to the motors and actuators, ensuring the drone maintains stability. In addition to the Flight Control Unit (FCU), a secondary computer, an Nvidia Jetson TX2, was integrated into the system. This computer arm boasts a powerful programmable GPU, enabling the creation of a digital terrain twin. The Jetson TX2’s low power consumption (only 15W) makes it ideal for drone applications. To allow the two computers to communicate and exchange data we used an UART serial port. UART (Universal Asynchronous Receiver-Transmitter) is a serial communication protocol enabling byte-by-byte data exchange between devices using dedicated transmit and receive lines.

The Flight Control Unit (FCU) relies on the MAVLink protocol for data exchange with other computers via serial ports. MAVLink (Micro Air Vehicle Link) is a lightweight messaging protocol specifically designed for drones. It defines a standard format for messages carrying sensor data, control commands, and critical flight information. This low-overhead and reliable protocol is ideal for resource-constrained drone applications. Using standard computers with a Linux (Ubuntu 18.04) operating system enabled us to utilize the ROS software framework (<https://www.ros.org/>). ROS (Robot Operating System) serves as a fundamental tool for us in developing robotic systems. We rely on ROS to streamline the complexities of robotics by providing a flexible framework for communication between various components fostering a modular and scalable approach to robotic development. Moreover, ROS facilitates real-time data exchange, enhancing our robots’ responsiveness and adaptability to dynamic environments. The standardized message-passing system ensures seamless interoperability among diverse hardware and software components.

A critical component in our projects is Mavros, a package that facilitates communication between our state machine, running on tx2, and the FCU. Mavros acts as a middleware for communication with MAVLink-based autopilots, significantly enhancing our capabilities in unmanned aerial vehicle (UAV) development. It establishes a communication bridge for real-time exchange of telemetry and control commands with UAVs. Our ROS configuration comprises several nodes:

- Mavros node: Initiates communication with the FCU.
- Lidar data acquisition node: Collects LIDAR data and synchronizes it with GNSS and FCU IMU data for point cloud generation.
- State machine (SM): Manages all flight phases, including emergencies.
- Point cloud management node: Creates, saves, and sends the point cloud.

The state machine is tailored to our specific needs, such as managing flight altitude during waypoint navigation, a feature not adequately provided by Ardupilot at the time of experimentation. The system ensures redundancy in control during emergencies and adapts to challenges like sensor acquisition issues. The point cloud node processes data for point cloud creation, storing it on the drone's memory, and transmitting it to the ground station upon an state machine signal. For a comprehensive understanding of the difficulties encountered and the solutions implemented, we refer readers to the Data Acquisition section of the full text.

#### 4. DATA ACQUISITION

Adapting a sensor not designed for remote sensing but rather for obstacle detection and automatic vehicle braking (ADAS) was a challenge that involved finding specific software solutions. Specifically, the chosen sensor returns only distance measurements along 16 cones (Fig. 4a), that are aligned on a straight-line (Fig. 4b) and thus producing a one-dimensional GF ground footprint. The amplitude  $A_{gf}$  of GF i.e., the distance between bin 1 and bin 16 measured in a plane, is directly proportional to the distance of the measured surface and can be calculated as:

$$\begin{aligned} A_{gf} &= 2 * H * \tan (FoV / 2) \\ H &= \text{flight height [variable]} \\ FoV &= \text{field of view} = 19^\circ \text{ [fixed]} \end{aligned}$$

The  $A_{gf}$  is extremely important because it determines the number of passes required to cover a given area and thus the duration of the flight for point cloud creation and its resolution on the ground. The first variable we had to solve was the height of the flight  $H$  to keep during the acquisition. After numerous tests carried out at the training camp, we decided that an  $H$  between 10 m and 12 m was the best compromise between flight duration and resolution on the ground. One strength of this sensor, which led to its selection, is its ability to return up to 3 measurements in the same bin associating them with a reliability index based on the quality of the measurement performed. In Fig. 4c, we have schematized an example of how we used this peculiarity of the sensor. Acquiring 3 distances: the distance from the tree in blue, the distance from the tufts of grass in green and the distance from the soil in red. By filtering vegetation information, we were able to measure distances from the ground more accurately. In order to transform these lengths into points



in a three-dimensional space, it is necessary to have fixed external points so that they can be used as a reference and a common coordinate system CCS.

The first fixed point for each flight is the take-off and landing point of the drone (ground origin HOME CCS→HCS home coordinate system). The others are instead the set of points which form the perpendicular plane to the straight line passing from the HOME and its zenith, distant from HOME the chosen flight altitude. On this Plane it was necessary to control the movement of the drone in order to minimize its vertical deviation. We have therefore specialized a state of our state machine. The ‘Reaching Waypoints’ state leverages data acquired from onboard sensors, including the GNSS system, Inertial Measurement Units (IMUs [https://en.wikipedia.org/wiki/Inertial\\_measurement\\_unit](https://en.wikipedia.org/wiki/Inertial_measurement_unit)), laser altimeter, and lidar sensor. This state is responsible for managing navigation along a predetermined path consisting of waypoints generated using mission planning software. Through continuous analysis of sensor data, the system implements real-time altitude corrections to ensure adherence to the Plane previously describe.

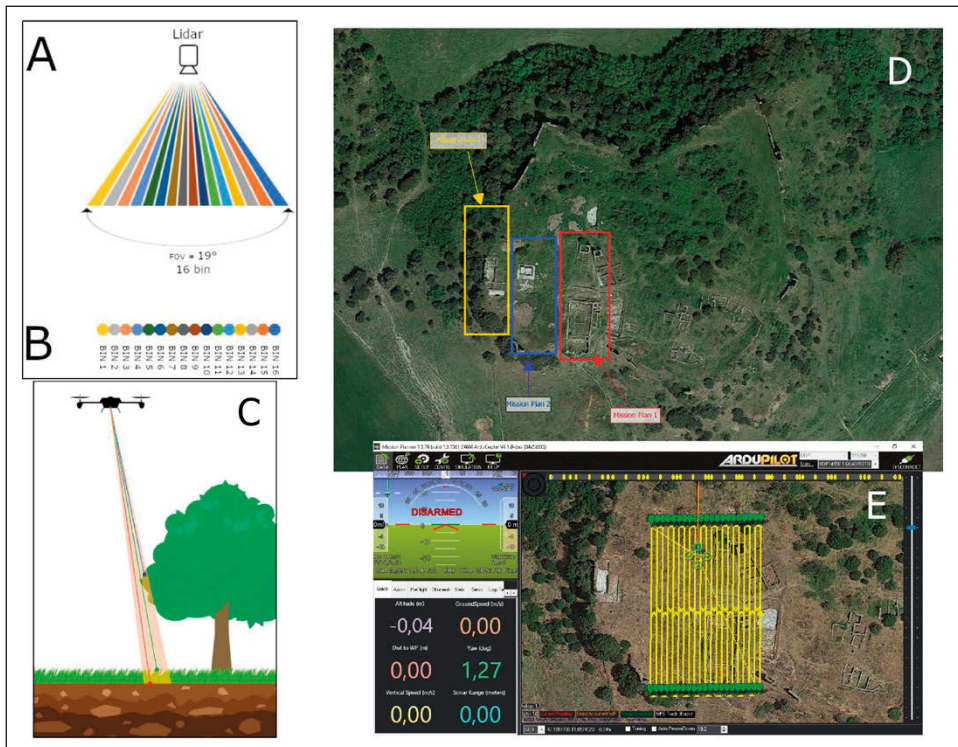


Fig. 4 – a) Front perspective of the sensor view cone; b) sensor point of view; c) example of data acquired within a single bin; d, e) satellite view of the Leopoli-Cencelle (VT) archaeological site and flight mission planning.

For the HCS (home coordinate system) we instead opted for a metric coordinate system ENU (East-North-Up) which is a local system for positioning objects in a 3D space. It uses 3 axes: positive X for East, Y for North, and Z pointing upwards relative to a specific location on Earth. In our case the origin of the coordinate system on the starting point of the vehicle. Going from a set of lengths to a georeferenced point cloud in HCS needs some trigonometry and some multiplications of inverted roto translation matrices. For each acquired length we can generate a point in the 3-dimensional space having as origin the sensor itself using the formulas:

$$\begin{aligned}x &= 0 \\y &= l * \sin \alpha \\z &= -l * \cos \alpha\end{aligned}$$

$l$ : misured lengh,  $\alpha$ : angle on the  $y,z$  plane, enclosed between the  $z$  axis and the straight line passing through the center of the bin cone which generated the length itself. In order to merge these spaces into one common to all (HCS) we need the information generated by the FCU of the drone so we need to move each space  $O\_sensor\{k\}$  to a new space having as its origin the center of the FCU  $O\_drone\{k\}$ . Since the sensor is solidly mounted to the body of the drone, this transformation is calculated as a translation of the origins of  $x\_diff$ ,  $y\_diff$ ,  $z\_diff$  given by the position of the sensor and the FCU. Finally each point of an  $O\_drone\{k\}$  space can be roto translated in HCS using the information of latitude, longitude, altitude, roll angle  $\phi$ , pitch angle  $\theta$  and yaw angle  $\varphi$  acquired simultaneously with the length  $l$ .

A.V.

## 5. RESULTS

The mapping concentrated on the top of the hill of Cencelle, where most of the public and religious buildings and quarters were found, including the Church of St Peter and the Public Palace. This area was chosen because of the presence of thin burial layers and partially exposed structures covered by shrubby vegetation. Over a period of three working days, 30 flight missions were carried out in order to survey both the structures already revealed in the religious and civil sectors, as well as any archaeological deposits not yet covered by excavations (Fig. 4d, e). This made it possible to determine the degree of accuracy of the relief of each archaeological feature visible in the Digital Terrain Model (DTM) produced by the instrument, according to the degree of coverage present on each deposit.

The system can acquire a cloud of points with centimetric precision. This allows for the extraction of a DTM that reproduces the detailed morphology of the terrain in the areas flown over. The cloud was rasterized using CloudCompare's 'rasterize' tool to create a digital terrain model with 20 cm ground resolution cells. The reference parameter set in the 'Step Grid'



may vary depending on the final objective for which the DTM was created. However, in the case of archaeological analyses, a lower ground resolution of the cells will result in a more detailed mapping of possible archaeological indicators in the surveyed area (MASINI, SOLDOVERI 2017).

The DTM was imported into QGIS 3.30 software where, to enhance visualization potential, we developed a more precise model for highlighting terrain anomalies using the QGIS slope analysis tool. The Slope Analysis algorithm can identify the steepest points on the analyzed territory (BROGIOLO, CITTER 2018, 601). The analysis conducted on 1 cm DTMs with a Z factor of 1,000,000 accurately identified major height differences, which occasionally coincided with dense vegetation and archaeological indicators. The adopted method outputted a slope map highlighting the remains of structures linked to a series of rooms (Fig. 5). Some of these structures had been identified during previous excavations, while others were previously unknown. The highlighted features in red with a continuous line represent the wall septa of the rooms discovered during archaeological excavations conducted between 1994 and 2019 in the SW area of the site (STASOLLA 2012). The more prominent features in red hatching correspond to additional anomalies that can be identified as archaeological indicators of wall fragments of buildings belonging to the urban quarters in this portion of the site, which are only partially known today (Fig. 5a).

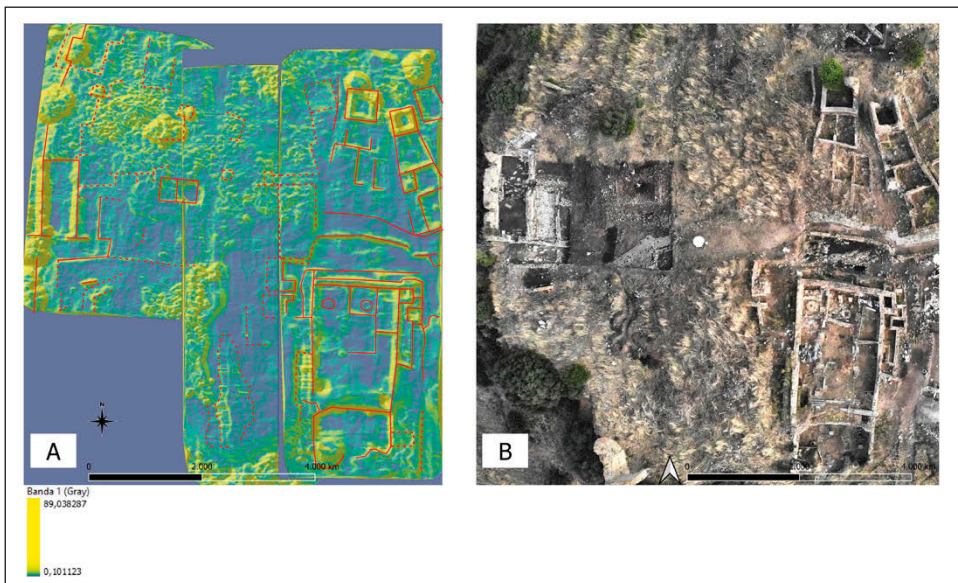


Fig. 5 – a) Slope map highlighting identified anomalies corresponding to the profiles of specific rooms (the values represent the slope degree); b) drone orthophoto of the SW area of the Cencelle site taken in September 2020.

The ongoing investigation is redefining the urban layout of the site to be denser than previously assumed. The area contains public and religious buildings alongside other urban structures, likely used for residential and artisanal purposes. The structures are divided by a main roadway with smaller roads branching off, following the contour lines of the hillside. This urban plan was already identified in the eastern area of the site between the 11<sup>th</sup> and 13<sup>th</sup> centuries CE.

F.V.

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## REFERENCES

- BROGIOLO G.P., CITTER C. 2018, *Paesaggi e sistemazioni agrarie nel basso corso dell'Adige da Montagnana al mare*, in G. VOLPE (ed.), *Storia e archeologia globale dei paesaggi rurali in Italia fra tardoantico e medioevo*, Bari, Edipuglia, 599-622.
- DEL LUNGO S. 2003, *Le pendici della città di Leopoli-Cencelle*, in S. LUSUARDI SIENA (ed.), *Fonti archeologiche e iconografiche per la storia e la cultura degli insediamenti nell'altomedioevo. Atti delle giornate di studio (Milano-Vercelli 2002)*, Milano, Vita e Pensiero Editrice, 19-24.
- DUCHESNE L. (ed.) 1981, *Le Liber Pontificalis*, I-II, Paris, E. Thorin Editeur.
- KÜÇÜKDEMIRCI M., LANDESCI G., DELL'UNTO N., OHLSSON M. 2021, *Mapping archaeological signs from airborne Lidar data using deep neural networks: Primary results*, «ArcheoSciences. Revue d'Archéométrie», 45, 1, 291-293 (<https://doi.org/10.4000/archeosciences.10179>).
- MASINI N., SOLDOVERI F. (eds.) 2017, *Sensing the Past. From Artefact to Historical Site*, New York, Springer.
- OPTIZ R.S., COWLEY D.C. (eds.) 2013, *Interpreting Archaeological Topography. 3D Data, Visualisation and Observation*, Oxford, Oxbow Books.
- STASOLLA F.R. 2012, *Leopoli-Cencelle: il quartiere sud-orientale*, Spoleto, Fondazione CISAM.

## ABSTRACT

The UAVIMALS system is a small airborne laser scanner prototype resulting from interdisciplinary research conducted by the Sapienza University of Rome and the Institute of BioRobotics of the Scuola Superiore S. Anna in Pisa. The project was financed by the National Geographic Society (Early Career Grant No. EC-50761T-18). Its aim was to develop an inexpensive and open source remote sensing system, test an engineered LiDAR sensor for autonomous vehicles, and create a specific aerial system for 'micro-relief' archaeological trace detection. The experiment conducted in the archaeological context of Leopoli-Cencelle (VT) demonstrated the effectiveness of a self-built open source hardware and software system that can be adapted to different types of archaeological visibility.

## METaverse AND 'THE ITALIAN JOB': CLOSED AND OPEN MODELS OF VIRTUAL WORLDS IN CULTURAL HERITAGE DOMAIN

### 1. INTRODUCTION: RISE AND FALL OF A DREAM

In 2021, the social networking giant, Facebook, announced a dual and sensational operation: on one hand, the acquisition of Oculus, one of the major producers of 'Head Mounted Display' devices, and on the other hand, the change of the company's name to Meta. The public perception of this move was a clear intention to enter the metaverse world with its own technology and a significant market impact. However, just two years later, Meta announces 10,000 layoffs. While the world prepares for the commercial explosion of the metaverse, this news seems like a cold shower for the prospects of this sector. Was it a massive mistake? A terribly overestimated idea? The answer is probably more complex, involves the very meaning of the term 'metaverse' and has a significant impact also on the prospects of 3D assets in the fields of Cultural Heritage and entertainment.

To better understand such a concept, we need to take a step back and ask ourselves what we mean by 'metaverse'. The Oxford Dictionary defines it as «a virtual-reality space in which users can interact with a computer-generated environment and other users»: it is a very essential and neutral explanation, that does not fully explore the meaning of these experience and its origins. Exploring the historical roots of this vision, akin to a dream of recreating and interacting within world scenarios, is truly captivating. While the notion of fantastical realms existing parallel to reality has been ingrained in human civilization since its inception, serving as the essence of art and innovation (ANTINUCCI 2011), the earliest semblance of shaping virtual environments, closely resembling modern digital realms, is evident in the 1940 novel *Morel's Invention* by Adolfo Bioy Casares. What's intriguing is how the novel envisages the construction of virtual scenarios in an era predating digital technologies, harkening back to the industrial settings of the 1930s. Here, the main character, stranded on a deserted island, finds himself in a gripping yet limited interaction with peculiar characters, unable to fully engage, even in pursuit of a romantic interest, until the environment around him eventually unveils as a virtual reconstruction of a past celebration.

This example underscores that the aspiration for interactive and participatory virtual worlds predates the advent of computer science. However, the earliest blueprint for a metaverse, as understood today, emerged in Neil Stephenson's 1992 novel *Snow Crash*, where a global metaverse serves as the

parallel playground of a reality dominated by corporate giants. This narrative was conceived at a time when the technical feasibility of such an environment was foreseeable to scholars, though not yet realized. Indeed, roughly a decade later, the renowned metaverse platform *Second Life* emerged, quickly gaining popularity alongside various other open and closed environments. *Second Life* arguably reached its zenith of fame and communication around 2010, yet during the pandemic, the platform experienced a resurgence, currently boasting approximately one million active users. Subsequently, a new era dawned, where video games adopted fully immersive, multi-user dimensions, blurring the lines between gaming and the metaverse.

One of the most prominent examples of such applications is Minecraft, whose features facilitated its integration into educational and Cultural Heritage contexts. In 2021, renewed interest in the metaverse concept surfaced following Facebook's announcement to embark on a new project in this direction, rebranding the company as Meta, as referred above, and outlining ambitious plans in this realm.

## 2. TWO PARALLEL MODELS: THE 'ITALIAN JOB'

From that moment on, there has been a growing general interest in the metaverse, of which Facebook's move is only seemingly the cause. In fact, since the birth of *Second Life*, many things technologically changed. The growth of Head Mounted Displays and the explosion of cryptocurrencies drastically increased both the attractiveness and engagement of the virtual experience, as well as the economic volume it can generate: after the success of *Second Life*, in the 2000s, the idea of replying such an operation in our time, with immersive devices and cryptocurrencies sounded to many players as a delicious business. But probably not everything went as planned.

This process led to a dual outcome. While, as we have seen, two years later, Meta announces 10,000 layoffs, during the same period in Italy, a series of metaverse examples spread, focused on Cultural Heritage. A summary list of the most significant cases can help us better understand this phenomenon. In most cases they are characterized by a dimension halfway between archeology and entertainment, to the point that it is easier to find news about them in the general press than in the scientific one, which is a significant fact of the popularization effects of the activity of research.

The Mapod4D framework (<https://www.mapod4d.it>), spread in 2021 thanks to ArcheOs Tec, and developed by R. Taglioretti (TAGLIORETTI *et al.* 2021), is a system for the development of a 'multiverse of metaverses' focused on anthropology, history, art and culture and connecting different projects; MetaHeritage (<https://www.metaheritage.it>) by 7emezzo.biz (MACCAFERRI 2022), created for Cultural Heritage according to an exponential





Fig. 1 – A representative image of the ATON web framework.

development model, is based on a series of archaeological sites used as meta-worlds; RealVerso Lucanum (<https://lucanum.it/realverso-lucanum>), created in 2022 by iinformatica enterprise (PIZZOLLA 2023), is conceived as an ethic metaverse, enhancing territorial experience and local habits of Basilicata, using technology as a public shelf of values connected to social responsibility; MetaEffect (<https://www.spatial.io/s/Meta-Effect>), is a virtual exhibition held in the metaverse, focused on art and Artificial Intelligence (AMBAGLIO 2022). ArcheoVerso (<https://archeo3d.digilab.uniroma1.it/archeoverso>) (MALATESTA *et al.* 2023) is a platform created by University la Sapienza, aimed at best practices for creation and interaction of immersive and augmented reality applications and sustainable metaverses, by delivering high-quality content and promoting a hybrid model that combines online activities with real-world site visits. Aton (<https://osiris.itabc.cnr.it/aton>; Fig. 1), by CNR ISPC (FANINI *et al.* 2019, 2021) is a multi-platform and multi-function tool which allows to create places for discussion, virtual visits inside archaeological landscapes or presentations for multimedia contents.

Obviously, compared to a network giant, these are examples on a diametrically different scale, but they serve as an example of the contrast between an overestimation of promises on one hand, and a creative flourishing on the other.

### 3. UNIQUENESS AND MULTIPLICITY

Meta's experience was not a failure, but rather the lack of development of a market over time and to the extent hoped for. The reasons for this phenomenon probably lie in various directions: first and foremost, engaging with a metaverse requires the audience to have skills that are not as simple as those needed for social media, where merely writing and taking photos will suffice. Users capable of creating 3D digital models or even just interacting in a complex interactive environment are not as numerous, and those who do exist are already largely engaged on other platforms in a market that, if not saturated, is already quite populated. Existing metaverses have grown gradually, fueled by a self-perpetuating cycle that slowly captures their users' attention. Attempting to create new ones from scratch is likely a risky endeavor.

A second issue is the need, on immersive VR platforms, for leisure time entirely dedicated to navigation, whereas normal online activities can often occupy overlapping moments with daily commitments. While web browsing and social media involve information transmission without eliciting strong emotional responses, the metaverse seeks to maximize 'embodiment', enhancing the virtual world's sensory impact. Consequently, emotional engagement in the metaverse correlates with the level of interaction and, more importantly, immersion. Head-Mounted Displays (HMDs) emerge as the optimal medium for experiencing the metaverse, whereas mobile devices or displays serve as fallback options. Nevertheless, whereas mobile devices seamlessly integrate into various everyday activities without requiring full attention and immersion, HMDs demand dedicated, uninterrupted time. However, beyond such aspects, there is a crucial one that needs to be emphasized, alongside the others: the deployment of forces by Meta, and the similar interests of other large economic groups, aim at a monopolistic idea of the metaverse: a large, exclusive container without communication with other similar realities, minting its own currency, for an increasingly dominant market. The Italian case, on the other hand, in its articulations, shows us an opposite model, made up of different, small interoperating realities.

This situation requires us to make an important consideration, which will affect our way of seeing the Internet, the high-level cultural entertainment, and the opportunities for valorising the Cultural Heritage: the pursuit of 'uniqueness' versus 'multiplicity'. Presently, the most prominent metaverses are closed worlds, forbidding straight exchanges between platforms. This

approach, driven partly by technical constraints, reflects a desire among major players to establish exclusive universes, incentivizing users to engage, create content, and spend within them, fostering a quasi-monopoly. However, an alternative model – where all worlds allow inter-platform travel – is theoretically feasible, aligning with initiatives like the Consortium for Open Metaverse Interoperability, though not actively pursued presently.

Contrastingly, Cultural Heritage projects in Italy appear to lean toward a multiplicity model, advocating for the creation of diverse worlds for archaeological contexts, often utilizing open source code and planning for inter-metaverse exchange. It is in some way the re-proposal of an old paradigm, which sees on one side the monopolistic approach and on the other the open one: two visions that have characterized the world of computing since its inception, if we think of concepts such as open source, open data, open access, etc., which stand in opposition to dominant closed and proprietary models. However, in this case, it is interesting to stress how the need of dissemination, beyond commercial interests, likely steer Cultural Heritage projects towards a more communicative approach, diverging from mainstream trends but presenting an alternative, perhaps more adaptable, model.

#### 4. METAVERSE AND CULTURAL HERITAGE IN PERSPECTIVE

It is certainly early to assess what the future destiny will be, however the events of recent years seem to allow us some observations. The first is that the first model did not result in the expected success, that something went wrong and a specific vision of the metaverse business suffered a setback; while the second experienced an unexpected flowering. The second is that the second model undoubtedly lends itself better than others to the transmission of knowledge and culturally qualified entertainment, in the same way as what happened in the television world, in which the advent of the satellite, multi-channel era has allowed the birth of focused networks and specialist programs, in the long run also stimulating generalist channels to incorporate more qualified and qualifying content.

Meanwhile, a further reflection is needed on the subject. The development, albeit slower than anticipated but still growing, of the metaverse (or metaverses) will necessitate the widespread assertion of clear, shared, and realistically applicable regulations for the use of digital assets related to Cultural Heritage and their rights, for any purpose of use. Just as the desire for disclosure has forced the birth of an alternative metaverse model, with realities that arise from below contradicting monopolistic approaches, it is nowadays impossible to ignore the transformations that the new scenario also imposes on the 20<sup>th</sup> century concept of royalties and concessions. The Italian situation in this regard is particularly complex, due to the overlapping of different and complex laws



over time, and a vision that remained tied to economic models no longer in step with the times (PALOMBINI 2017, 2020); nevertheless, it will be necessary to reach a reasonable synthesis. In fact, with the advent of the world wide web and even more so in a metaverse context, any distinction between personal use, study and research, recreation, or profit loses all meaning.

The opinion of the writer is that there could be few possible options. The first, more linear and realistic, is the free circulation of data for any purpose: a model more lucrative than it seems, as the induced effects in terms of GDP and collective well-being, prove to be quite considerable in contexts that have followed this approach. However, 'soft' forms of remuneration are also conceivable in exchange for the concession of high-definition models (PALOMBINI 2018), but always with a light-handed approach by the State, favoring wide dissemination and renouncing improbable claims of control in favor of enrichment and expansion of cultural offerings, whose impact, in the context of the metaverse, can be significantly multiplied for the collective good. What is at stake is the possibility of a genuine digital democracy, with the creation of numerous high-cultural-content virtual worlds and countless subsequent benefits in education, quality entertainment, plural communication, and civil growth.

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## REFERENCES

- ANTINUCCI F. 2011, *Parola e immagine*, Roma-Bari, Laterza.
- AMBAGLIO J. 2022, *Meta Effect: la prima mostra d'arte interamente progettata nel metaverso, tra opere di artisti reali e create dall'AI*, «Il Fatto Quotidiano», 23 dicembre 2022.
- FANINI B., FERDANI D., DEMETRESCU E., BERTO S., D'ANNIBALE E. 2021, *ATON: An open-source framework for creating immersive, collaborative and liquid web-apps for Cultural Heritage*, «Applied Sciences», 11, 22, 11062.
- FANINI B., PESCARIN S., PALOMBINI A. 2019, *A cloud-based architecture for processing and dissemination of 3D landscapes online*, in L. PEZZATI, E. DEGLI INNOCENTI, S. PESCARIN (eds.), *Digital Heritage Sciences and Infrastructures*, «DAACH. Digital Applications in Archaeology and Digital Heritage», 14.
- MACCAFERRI A. 2022, *Cantieri archeologici aperti per costruire e abitare i metaversi*, «Il Sole 24 ore», 27 ottobre 2022 (<https://www.ilsole24ore.com/art/cantieri-archeologici-aperti-costruire-e-abitare-metaversi-AE2jdd9B>).
- MALATESTA S.G., LEOPARDI L., MARINI M.R., ROSATI P. 2023, *ArcheoVerso: A cultural metaverse for enhancement, technologies, communities, services*, in IMEKO TC4 *International Conference on Metrology for Archaeology and Cultural Heritage* (Rome 2023), Red Hook (NY), Curran Associates (<https://www.imeko.org/publications/tc4-Archaeo-2023/IMEKO-MetroArchaeo-2023-001.pdf>).
- PALOMBINI A. 2017, *The rights of reproducing Cultural Heritage in the digital era. An Italian perspective*, «ExNovo. Journal of Archaeology», 2, 49-62 (<https://doi.org/10.32028/exnovo.v2i0.389>).

- PALOMBINI A. 2018, *Riproducibilità a vario titolo del patrimonio: situazione e prospettive*, in M. ARIZZA, V. BOI, A. CARAVALE, A. PALOMBINI, A. PIERGROSSI (eds.), *I dati archeologici. Accessibilità, proprietà, disseminazione, Atti del Convegno (Roma 2017)*, «Archeologia e Calcolatori», 29, 87-92 (<https://doi.org/10.19282/ac.29.2018.10>).
- PALOMBINI A. 2020, *Digitale, patrimonio culturale e legislazione*, in S. PESCARIN (ed.), *Videogames, ricerca e patrimonio culturale*, Milano, Franco Angeli, 35-40.
- PIZZOLLA G. 2023, *Il "Realverso" lucano: luogo innovativo e visionario*, «Il Metapontino. it», 5 gennaio 2023 (<https://www.ilmetapontino.it/economia/2023/01/05/lintervista-il-realverso-lucano-luogo-innovativo-e-visionario/>).
- TAGLIORETTI R., CARRARO D., TAGLIORETTI V., MAZZUCCHI A. 2021, *MAPOD 4D: primo esempio di musealizzazione digitale di sepolture utilizzando un multiverso di metaversi*, «Sibrium», 35, 303-327.

## ABSTRACT

After the initial enthusiasm for a hypothetical explosion of the metaverse phenomenon, which then waned, a careful analysis can reveal a possible dual model in the planning of this technology. On one hand, a closed, basically monopolistic, approach aimed at market concentration, and on the other a fragmented approach, starting from the bottom, consisting of small interoperating entities. This second model, in recent years, characterized in Italy a series of metaverse initiatives linked to the enhancement of Cultural Heritage and seems to be the most promising at the moment, provided that the longstanding issue of reproduction rights of the Heritage itself is addressed and resolved, preferably with an open approach: a crucial issue in the new digital scenarios.



## THE ABADÉ ARTIFICIAL ARCHAEOLOGICAL SITE PROJECT

### 1. INTRODUCTION

Archaeology has undergone rapid changes in recent decades thanks to advances in technology. One key development is the ability to create detailed computer simulations and virtual models of archaeological sites and artifacts. These tools offer archaeologists an invaluable way to visualize, analyze, and experiment with the past in new ways. Since M. ALDENDERFER'S (1991) seminal article advocating the use of computer simulation as a tool for archaeological research, especially for studying, for example, the operation of the Analytical Engine, a mechanical device designed by Charles Babbage in the 19<sup>th</sup> century, considered the precursor of modern computers. He explains the basic principles of computer simulation, its benefits and limitations, and how it can be applied to the Analytical Engine, using a program called Simula to model the device's behavior and test different scenarios and hypotheses about its operation and performance. The Author concludes that computer simulation is a powerful and promising technique for archaeology, which allows exploring aspects of material culture that are not easily accessible by other means, and that the Analytical Engine is a fascinating example of a historical artifact that deserves more attention and study (ALDENDERFER 1991).

On the other hand, M. LAKE (2014) provides a history of archaeological computer simulation, starting from the early 1970s and focusing on the recent developments since 2001. It proposes a distinction between programmatic and mature simulation phases based on the emphasis on methodological issues or substantive results. The article reviews the main types of simulation models used in archaeology, such as cellular automata, network models, agent-based models, and evolutionary models. It discusses the advantages and challenges of each type, as well as the theoretical and empirical implications of their application. The article concludes that simulation is a valuable tool for exploring complex and dynamic archaeological phenomena, such as social change, cultural evolution, and human-environment interactions. It also suggests future directions for simulation research, such as integrating multiple models, incorporating spatial and temporal scales, and enhancing validation and verification (LAKE 2014).

Today, computer simulations create artificial environments where researchers can test hypotheses, explore scenarios, and model complex dynamics like human interactions. They allow for countless experiment iterations that would be impossible in real-world archaeology. Simulations can incorporate climate, geography, architecture, artifact evidence, historical sources, and more

to recreate ancient settings and societies. A great example is the Abade Artificial Archaeological Site Project in Brazil (COSTA 2012). In 1887, Lavras do Abade, a village of gold miners in the Brazilian Midwest, was attacked for two consecutive nights and three days by the settlement of Meia Ponte, its neighboring village and now the city of Pirenópolis. According to local narratives, the mining was destroyed because of the pollution of the water of the Rio das Almas, which originates in the Serra dos Pirineus-GO. Nowadays, the site is considered a 'lost island' in society's collective, cultural, and social memory. The legacy of Lavras do Abade goes beyond the past conflict, as the environmental impact and the memory of the event are still present in the modern landscape, being a unique example of the history of human pollution in central Brazil.

This simulation combines laser scanning data of ruins, 3D modeling, historical photographs, and documents to recreate a 19<sup>th</sup>-century mining village. Researchers can immerse themselves in this virtual site to study details and test theories about how the settlement looked and functioned over time. Historical Data includes written documents, field reports, and local narratives that provide information about past events, such as the attack on the gold miners' village in 1887. Anthropological data are based on ethnographic studies and cultural analyses that help to understand the social practices and relationships between the communities of Meia Ponte and Lavras do Abade. Environmental Data involves the analysis of the impact of mining on natural resources, especially the Rio das Almas water pollution, and how this affected the local ecology. Archaeological data are obtained through excavations, surveys, and artifact analyses that reveal the physical structure of the village and mining activities.

The software also enables the creation of artificial intelligence agents who inhabit and interact within the simulations. Such a feature introduces more randomness and realism. The researcher can begin to model how individual and group decisions cascade over decades or centuries, like mapping the spread of technologies and ideas. Another benefit of simulations is using them to plan actual archaeological fieldwork. Virtual models help identify high-probability excavation zones and likely obstacles in advance. They provide analysis that sidelines do not offer, optimizing limited budgets. Of course, computer simulations have limitations. Factors like computing power, programming expertise, and underlying theory constraints impact accuracy. This technology should complement rather than replace traditional archaeological techniques.

However, virtual archaeology has tremendous potential to propel the field when used prudently. It facilitates collaboration as models are shared and expanded. Comprehensive databases integrate global site data. AI assistants can automate mundane tasks or suggest fresh research directions. Moreover, computer simulations bring archaeology full circle to its roots – the joy of discovery. What adventurer has not dreamed of unveiling a lost city? Virtual reality lets anyone unlock those wonders, whether a scholar or an aspiring

Indiana Jones. So, in summary, computer simulations enable archaeologists to conduct countless controlled experiments, gain insights difficult to achieve on-site, comprehensively plan expeditions, and share/expand models globally via computing networks. The sky is the limit as this technology keeps improving. With prudent application, virtual archaeology promises to complement traditional techniques and advance the field.

## 2. THE ABADE ARTIFICIAL ARCHAEOLOGICAL SITE PROJECT (AAASP)

The Abade Artificial Archaeological Site Project (AAASP), which commenced in 2012, employed several distinct software programs throughout its different 4 phases. During phase 1 of the Abade Artificial Archaeological Site Project, 31 simulation software programs were researched and acquired. Subsequently, in phase 2, 18 of these programs underwent selection and testing for operability. As the project progressed into phase 3, 9 out of the initial 18 programs were chosen for simulation model testing. Finally, by phase 4, only three programs for simulation remained under consideration: AnyLogic, NetLogo, and MASON (COSTA 2022). The project utilized a wide array of proprietary and open source software across its development to construct the virtual model of the Abade village and test various simulation approaches. One of these base models was the ‘Serial Killers’ model constructed by Haze B. Park and available in Serial Killers - AnyLogic Cloud. The ‘Serial Killers’ model is an example of a simulation created with AnyLogic software. It simulates a highly dangerous city district where criminals are looking for victims. In the model, a victim can be any person from the non-criminal population within the ‘scan radius’ of the criminal, with a certain probability. After choosing the victim, the criminal accelerates and begins to follow them. When the criminal approaches the victim at a ‘kill distance’, he is ready to murder the victim, but this only happens when there are no potential witnesses nearby within the ‘scan radius’. After the murder, the killer remains with the victim for some time to appreciate what he has done and then moves away to look for a new victim. However, if the killer cannot find a good time to kill the victim, he gives up. This model exemplifies how simulation can be used to model and understand complex and dynamic behaviors in archaeological urban environments.

This model (Fig. 1) laid the groundwork for developing a more extensive and historically precise simulation. It integrated historical, anthropological, environmental, and archaeological data collected during the research phase. The resulting simulation accurately replicated the Lavras do Abade conflict within a constrained scale and observable timeframe. To elucidate the model construction process, I delineate the data parameters, variables, and action functions, including system dynamics, agents, connections, and the simulation experiment itself. In the virtual reconstruction of Lavras do Abade, agents



Fig. 1 – AAASP web page.

– labeled as ‘criminals’ – were programmed with a set speed of 5 KPH to navigate the continuous space of the simulation. Their movement was visually represented with rotation animations that aligned with their direction of travel, enhancing the realism of their actions. These agents were not designed to rotate along the Z-axis, maintaining a consistent vertical orientation. Advanced Java settings enabled detailed logging and automatic dataset creation, which facilitated the analysis of the agents’ behaviors over time. The simulation did not limit the number of data samples, allowing for comprehensive data collection throughout the simulated period. This meticulous design allowed the ‘criminal’ agents to interact dynamically within the model, reflecting the complexity of human behavior in a historical context.

In the simulation of Lavras do Abade, the ‘criminal’ agents are equipped with a {scanRadius} of 10 m, allowing them to detect other entities within this range. Their {killRadius} is set to 2 m, defining the proximity required to affect other agents. When patrolling, these agents move at a {speedNormal} of 5 KPH and increase to a {speedFollowVictim} of 6 KPH when pursuing a target. The {decisionProbability} parameter, set at 0.2, dictates the likelihood



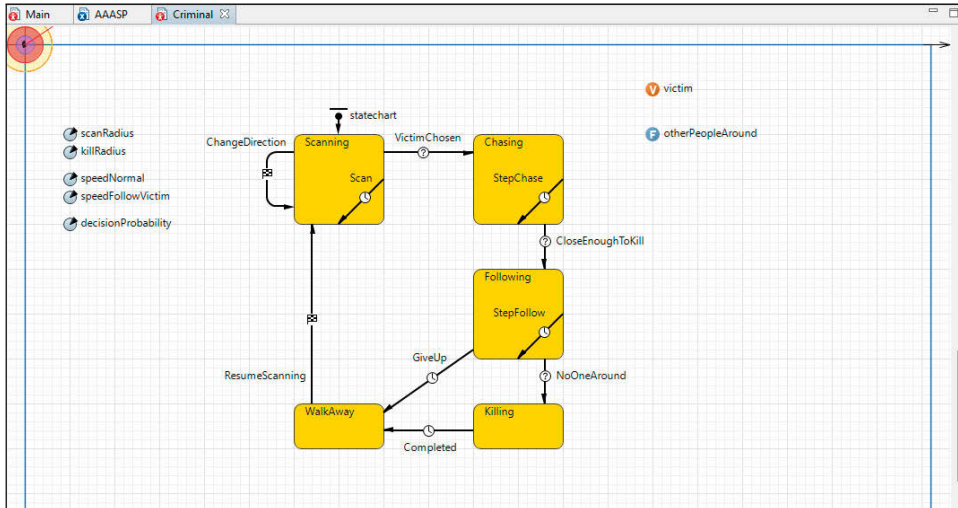


Fig. 2 – Criminal diagram (AnyLogic 2023).

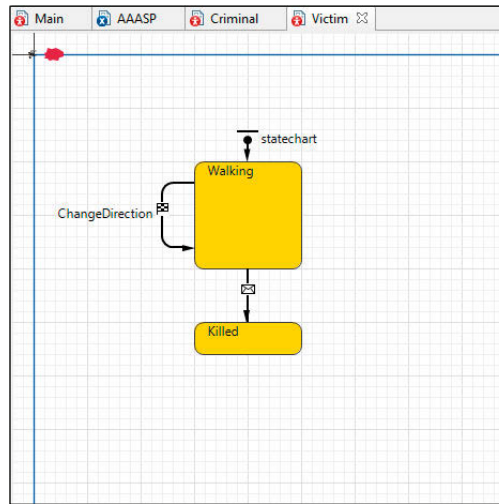


Fig. 3 – Victim diagram (AnyLogic 2023).

of making strategic decisions, such as engaging or disengaging with a target. All parameters are visible at runtime, ensuring transparency in the simulation process, and are saved in snapshots for consistent state restoration. The function {otherPeopleAround} is designed to determine if there are any other



In the simulation's framework, the victim variable is pivotal (Fig. 3), referencing the 'victim' class, which encapsulates the attributes and behaviors

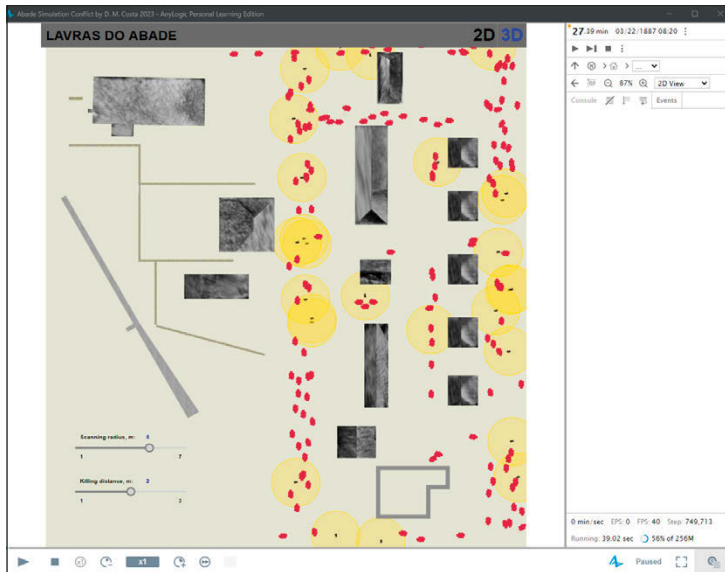


Fig. 5 – Run simulation (AnyLogic 2023).

in snapshots ensures that the simulation can be accurately restored to a previous state. Additionally, its visibility during runtime aids in monitoring and debugging, providing a transparent view of the simulation's inner workings as it progresses. In the simulation, 'victim' agents are integral components with a defined speed of 5 KPH and animations that rotate to match their movement direction, enhancing realism. They operate within a continuous space, allowing for seamless movement. These agents are not generic; they have specific attributes tailored for the simulation. With logging enabled, their actions and states are recorded, and datasets are auto-created for analysis without a limit on data samples. These parameters collectively shape the 'victim' agents' behavior, influencing the simulation's dynamics and outcomes.

Ultimately, the simulation is configured to run in real-time with a scale of 1.0 (Fig. 4), starting from March 22, 1887, at 08:00 GMT and concluding on March 24, 1887, at 18:00 GMT. It bypasses the initial simulation screen, has a maximum memory allocation of 256 Mb units, and uses the 'main' agent type. The simulation generates unique runs using a random seed, not allowing zooming or panning in the window. The developer panel is enabled but hidden at the start, and the simulation does not load from a snapshot, ensuring each run begins from the initial state as defined. This setup aims to provide a controlled environment to simulate the historical conflict at Lavras do Abade with precise time and randomness parameters (Fig. 5).

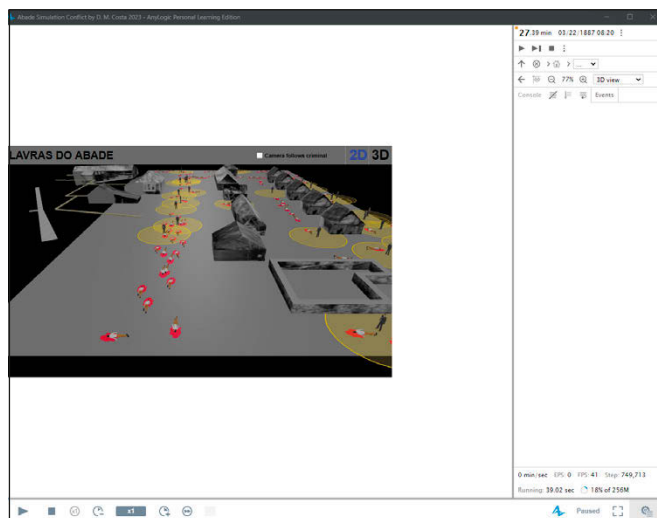


Fig. 6 – 3D view (AnyLogic 2023).

To accomplish this, we initiated the simulation with a quantitative representation of 150 victims, corresponding to the documented number of over 30 miners' families in historical records. Additionally, the model incorporates 27 criminals referred to as markers, black maskers, or Curucús, as documented in anthropological and archaeological accounts of assaults. The 3D environment was meticulously constructed using historical and archaeological data with millimetric precision. The predictive behavior of both miner victims and criminal agents is determined by a combination of physical and psychological training parameters (Fig. 6).

### 3. FINAL CONSIDERATIONS

The simulations use actual archaeological data like scans, measurements, photographs, historical texts, environmental records, and material evidence to accurately recreate sites, artifacts, and environments. The models become more photo-realistic and detailed as computing power and graphic capabilities improve. The preliminary findings indicate that each simulation was completed within 30 minutes or less. Interestingly, in these simulations, all victims of criminal acts were fatally assaulted within this timeframe. This observation is particularly intriguing considering historical records, which suggest that the entirety of the conflict spanned over three days and two nights. This information aligns with documented instances of 2 or 3 minor assaults occurring within a 24-hour interval leading up to the village's destruction.

Another notable aspect of the AAASP is its commitment to being housed in an open repository upon completion Model direct link: <https://cloud.anylogic.com/model/d2e01b6a-c8d7-4e86-9f6c-1f8e0c01241e>. This approach allows other researchers to validate the model, adjust variables, and refine functions. Additionally, new historical, anthropological, environmental, and archaeological data can be incorporated to modify the initial parameters, ensuring the ongoing relevance and accuracy of the simulation. Many simulation projects are open source or available for researchers to use. As models expand to encompass more sites globally, the vision is an interconnected global database that archaeologists can share and enhance collectively to advance the field. Public contributions could be possible down the road via crowdsourcing efforts.

Simulations have reinforced theories about ancient innovations diffusing more rapidly across cultures connected by trade networks. Models also indicate that climate factors more strongly influence the development trajectories of ancient civilizations than previously presumed. Most intriguing are models unveiling unexpected social dynamics, interactions, and behaviors in antiquity that differ from present-day assumptions. In the case of the AAASP, simulations are intricately linked with historical and archaeological facts. They not only serve to validate existing knowledge but also provide new avenues for research. Finally, it is an ongoing balance. Computing power and expertise still limit model complexity versus real-world dynamics (LIETO *et al.* 2023; MARRAS *et al.* 2023). But rapid improvements on both fronts are enabling more sophisticated theory-driven models. Close collaboration between technologists and archaeology/anthropology experts helps align capabilities and theory. Also, AI agents could interact within simulation environments – complying with cultural norms, group dynamics, resource constraints, etc. – introducing more realism and unpredictability versus pre-programmed behaviors. However, developers must be careful AI does not introduce modern biases. Continual tweaking based on emerging archaeological evidence refines fidelity. Ultimately, enabling students and enthusiasts to immerse themselves in virtual sites could revolutionize public understanding of ancient civilizations. Interactive models inspire more profound public interest and engagement. If integrated with classroom curriculums or museum tours, the public develops meaningful context about antiquity. This will undoubtedly advance preservation efforts.

In conclusion, the Abade Artificial Archaeological Site Project demonstrates the immense potential of computer simulation and virtual archaeology to advance our understanding of the past. The simulations can recreate ancient sites and societies with unprecedented detail and accuracy by integrating diverse data sources like laser scans, historical records, and archaeological evidence. The ability to test hypotheses, model dynamics like human behavior and interactions, and experiment with different scenarios provides invaluable insights that complement traditional archaeological methods. As computing power

and software capabilities continue improving, the realism and complexity of these virtual environments will only increase further. Perhaps most importantly, initiatives like the AAASP that embrace open data-sharing and collaborative model-building can accelerate the field by enabling global cooperation and public participation. With an interdisciplinary approach combining technological prowess and theoretical archaeological expertise, virtual archaeology simulations offer a transformative way to analyze material culture, reconstruct our ancient heritage, and bring the wonders of the past vividly to life for academics and enthusiasts alike. The future impact is bound only by our intellectual curiosity to unlock the mysteries of humanity's origins through this powerful new lens.

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## REFERENCES

- ALDENDERFER M. 1991, *The analytical engine: Computer simulation and archaeological research*, «Archaeological Method and Theory», 3, 195-247.
- COSTA D.M. 2012, *Virtual worlds: A theoretical proposal about the practice of computer simulations in archaeology*, «Revista de História da Arte e da Cultura», 18, 29-46.
- COSTA D. 2022, *Digital archaeologies: Debugging three personal experiments*, in A. DA SILVA MARTIRE, V. CARVALHEIRO PORTO (eds.), *Desconstruindo Arqueologias Digitais*, São Paulo, Museu de Arqueologia e Etnologia da Universidade de São Paulo, 15-31.
- LAKE M.W. 2014, *Trends in archaeological simulation*, «Journal of Archaeological Method and Theory», 21, 2, 258-287.
- LIETO A., STRIANI M., GENA C., DOLZA E., MARRAS A.M., POZZATO G., DAMIANO R. 2023, *A sensemaking system for grouping and suggesting stories from multiple affective viewpoints in museums*, Human-Computer Interaction.
- MARRAS A.M., DÍAZ-KOMMONEN L., STONEMAN A., SVINHUFVUD L. 2023, *Digital technologies for citizen curation in museums: Two case studies from the SPICE project*, ICOM Voices (<https://icom.museum/en/news/spice-project-digital-technologies/>).

## ABSTRACT

The Abade Artificial Archaeological Site Project (AAASP) employed computer simulations to recreate a 19<sup>th</sup>-century Brazilian mining village that was destroyed in an environmental conflict. The simulations integrate laser scans of ruins, 3D modeling, historical data, and material evidence to reconstruct the site in a virtual environment accurately. After researching 31 simulation programs, the project utilized AnyLogic software (<https://www.anylogic.com/>) for the final phase. One base model was the 'Serial Killers' simulation in AnyLogic, modeling criminal behavior in an urban setting. This laid the groundwork for the more extensive historically accurate 'Abade 10' simulation, precisely replicating the Lavras do Abade conflict within set parameters. The 'Abade 10' model incorporates system dynamics, agent behaviors, connections, and an experiment simulating the 3-day conflict timeline in 1887. Preliminary findings indicate all victim agents were fatally assaulted within 30 minutes in the simulations, aligning with historical records of intermittent attacks before the village's destruction. Upon completion, the AAASP aims to be an open repository that allows other researchers to validate, adjust, and enhance the model with new data. The project demonstrates the potential of virtual archaeology to test hypotheses, plan fieldwork, share models globally, and inspire public engagement by immersing users in accurate ancient environments.

## VIRTUAL RECREATION AS A VALID SCIENTIFIC REPRESENTATION FOR RAISING PUBLIC AWARENESS

### 1. INTRODUCTION

Virtual Archaeology as a scientific discipline, although more than 10 years old, is still developing its theoretical corpus. Its joint parallel, or continuous development with what at the end of the 20<sup>th</sup> century and during the first decade of the 21<sup>st</sup> century was called ‘Digital Archaeology’, has meant, in our opinion, a difficult barrier to overcome (STAROPOLI *et al.* 2023). Thanks to the development of different international charters or treaties about the virtualisation of Heritage and Virtual Archaeology, the bases on which the specific rules are established in the field of research, documentation and conservation of historical and archaeological heritage are established. The Seville Principles - International Principles of Virtual Archaeology, ratified at the 19<sup>th</sup> General Assembly of ICOMOS in New Delhi in December 2017 (ICOMOS 2017), compile and materialise all the regulations necessary for the correct and optimal development of the discipline, and are currently in full development and methodological ebullition in terms of the practical application of this discipline in specific and cases of study.

This charter encourages a common workflow, a multidisciplinary method of intervention from the collective, trying to overcome the widespread professional individualism of the sector. This factor has been boosted by the emergence of collective open-access platforms, which have developed interesting tools through which to apply the postulates of Virtual Archaeology<sup>1</sup>. From this theoretical approach, we decided to carry out a virtual recreation project of the Roman city of Épora (Montoro, Córdoba, Spain) (Fig. 1a), to observe the strengths and weaknesses of the discipline in terms of the development of this type of recreation work.

The city of Épora is located on the border between the Sierra Morena and the Cordovan countryside, in a strategic location that is key to understanding the ongoing occupation of the area (BAQUEDANO BELTRÁN 1987). The oldest archaeologically dated remains correspond to a series of finds of Mycenaean pottery from the excavations carried out in the ‘Llanete de los Moros’ (MARTÍN DE LA CRUZ 1979) (Fig. 1b). Dating from around the 12<sup>th</sup>

<sup>1</sup> We would like to highlight the communities developing open access tools such as the Extended Matrix (DEMETRESCU, FERDANI 2021), BIM (GALEANO *et al.* 2024), pyArchInit (<https://plugins.qgis.org/plugins/pyarchinit/>), as well as new initiatives developed from other postulates, such as IDOVIR (WACKER *et al.* 2023).





Fig. 1 – a) Location of the city of Montoro; b) location of the city in the meander of the River Guadalquivir (1. Cerro de Palomarejo, 2. Llanete de los Moros).

century BCE, this Late Bronze Age occupation is the foundation of the later Roman city of Épora, which we know from its material, constructional and literary remains (MARTÍN DE LA CRUZ 1987). Most of the remains of the Roman city (from 206 BCE onwards) and of the previous indigenous settlement are located in the Cerro del Palomarejo (Fig. 1b).

Historical and archaeological information on the Roman occupation of this area is scarce. Today we know of the importance of this site mainly from two sources. The casual findings of relevant elements such as Thoracata military sculptures, large capitals and architectural elements, abundant ceramic remains and building materials (RODRÍGUEZ NEILA 1990; ORTIZ GARCÍA 2013). On the other hand, the classical sources present Épora as a city of great prestige within the Roman province of Baetica. These include Épora, together with Gades and other cities in the S of the Iberian Peninsula, in the *foedus* signed with the Roman Republic, by which they became confederate cities during the second Roman-Carthaginian war, around 206 BCE (RODRÍGUEZ NEILA 1990).

This lack of information, beyond the general knowledge of Roman cities founded on previous settlements (GROS, TORELLI 1988; ORTEGA ANDRADE 1995; ADAM 1996; MARTÍN ESCORZA 2008; MÁRQUEZ MORENO 2019; FERNÁNDEZ OCHOA, MORILLO 2022) or specific knowledge of the remains of this period found in the municipality (MARTÍN DE LA CRUZ 1979, 1987; IBÁÑEZ CASTRO 1990; MELCHOR GIL 1991; LARA LÓPEZ 2019), has been the main basis for the development of this work of virtual recreation.

In addition to testing the tools and protocols of Virtual Archaeology for their implementation in virtual recreations, this study aims to disseminate

the potential for tourism and cultural development in the municipality to specialists in the field and the general public, emphasising the importance and need for the protection and enhancement of Heritage elements for the advancement of research into Romanised indigenous settlements in Baetica and research in the Roman city of Épora itself.

## 2. STATE OF THE ART

According to the Seville Principles, virtual reconstruction is understood as: «The attempt at visual recovery from a virtual model, at a given point in time of a human-made construction or object from the past based on existing physical evidence of that construction or object, scientifically reasonable comparative inferences and in general all studies carried out by archaeologists and other experts linked to archaeological heritage and historical science» (ICOMOS 2017).

On the other hand, virtual recreation is defined as: «The attempt at visual recovery, from a virtual model, of the past at a given time of an archaeological site, including material culture (movable and immovable heritage), environment, landscape, uses and in generating cultural significance» (ICOMOS 2017). In current research applying the discipline of Virtual Archaeology, the main work carried out focuses on the virtual reconstruction of spaces and constructive elements. This virtual reconstruction constitutes a graphic representation of the different reconstructive hypotheses put forward by the virtualisation specialists and/or archaeologists responsible for the fieldwork. The scientific traceability of these studies is correctly and efficiently materialised using semantic tools and protocols such as the Extended Matrix (DEMETRESCU 2015; DEMETRESCU, FANINI 2017; DEMETRESCU, FERDANI 2021). However, these protocols are specially designed for insertion within specific virtual reconstruction workflows.

Virtual recreation, on the other hand, although is also scientifically validated using the parameters established for this purpose, does not have a tangible archaeological materiality and therefore apparently lacks scientific accuracy. The insertion or representation of elements that have not been archaeologically verified *in situ*, however, should not be underestimated in our opinion. This is the case, for example, of the insertion of different constructive elements such as houses or modular domestic spaces from the Roman period, as well as the use of daily objects found in Roman Hispania (common pottery, Terra Sigillata type pottery, lamps, etc.). Furthermore, the recreation of urban spaces, as well as the inclusion of humanising elements in the virtual works, should not be understood from idyllic or romanticised positions, but as a human contextualisation of the spaces, in clear connection with the improvement of the communication and dissemination of these projects. These

elements, developed with good judgement, establishing parallels, reliable historical-archaeological sources, etc., can be and are a very positive point in virtual recreation works.

The methodology that we have carried out is based on the postulates of Virtual Archaeology. Thanks to the implementation of this discipline in the processes of historical-archaeological research and analysis, we can carry out virtual reconstructions and recreations with a high level of scientific reliability. The predominant tool for data collection, as mentioned previously, is the Extended Matrix. Using this tool, we can compile all the historical information on the settlement, as well as all the primary or secondary archaeological sources that we find in relation to the settlement. All this compilation of data allows us to capture the different characteristics that this settlement would have had. This approach would not only be carried out in a specific approach based on the material and constructive findings available to us, but also includes general aspects that fill in the gaps that the lack of systematic research in the municipality has led to. This general information on settlements from this historical period and the influence of the preceding cultural background, despite not having been archaeologically confirmed, can be appreciated in other settlements of similar nature.

### 3. CASE STUDY

To carry out our case study, the virtual recreation of the Roman city of Épora, we first need to know the specific archaeological evidence of the settlement. The archaeologically dated remains from the Roman period are mainly based on the appearance of abundant ceramic remains from that period, scattered on the surface around the promontory of the ‘Llanete de los Moros – Cerro de Palomarejo’, which at the time must have been topographically unified (SICRE-GONZÁLEZ 2023). The summary and the existing problems regarding the definition and study of these archaeological remains can be seen in the development of previous works (ORTIZ GARCÍA 2022), although it is worth mentioning that, given the magnitude of the documented remains, the city must have been established as a first-rate municipality during the first moments of Roman rule in the Iberian Peninsula. This fact is also confirmed by the passage of the Via Augusta through the surroundings of the settlement (MELCHOR GIL 1991).

In addition to the importance of the archaeological remains, the significance of the Roman city is explicitly stated in the literary sources. These sources confirm the relevance of the Roman city, as well as the historical importance of the remains made during the discoveries made in the 18<sup>th</sup> and 19<sup>th</sup> centuries (VICENT ZARAGOZA 1977; MARCOS POUS 1978). All this specific information on the settlement, although it does not present an excavated

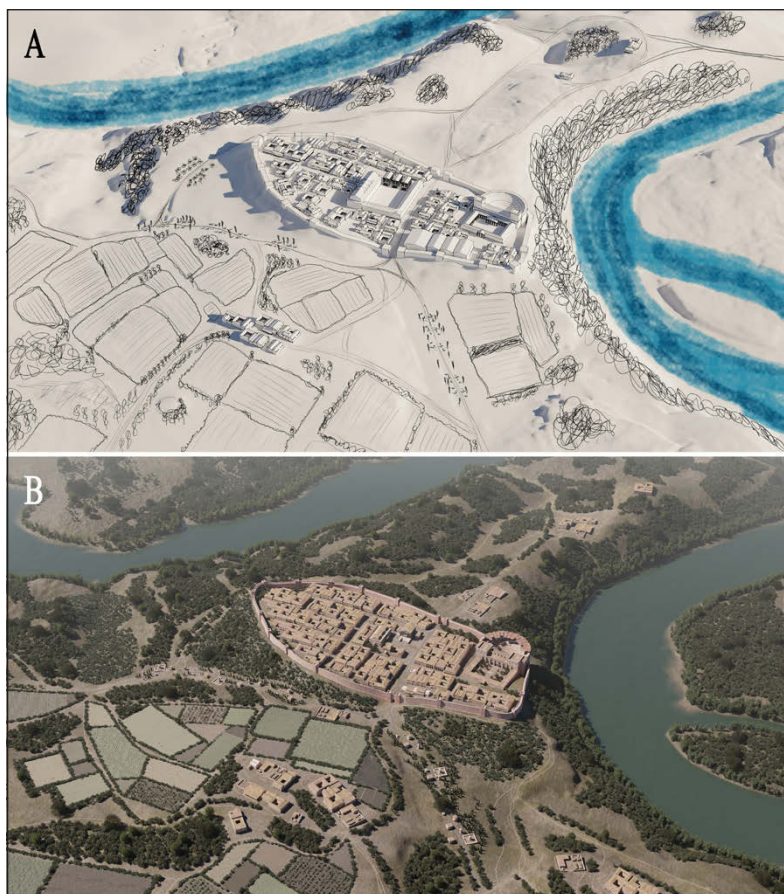


Fig. 2 – a) Sketch of the virtual recreation; b) final result of the virtual recreation.

and documented Roman city on the surface, presents a series of elements that make this Roman settlement be catalogued as a first-rate urban entity. Taking all these data into account, reconstructive hypotheses can be made based on contrasted data that suggest different possibilities regarding the urban configuration of the settlement.

Firstly, the main nucleus of the city must have been located on the promontory, and from the importance reflected in the sources it must have been of considerable size. Being located along the route of the Via Augusta, this city must have had a series of public buildings and public supply structures characteristic of the Roman period. However, the settlement as well as these new buildings built as part of a Romanisation programme are located and



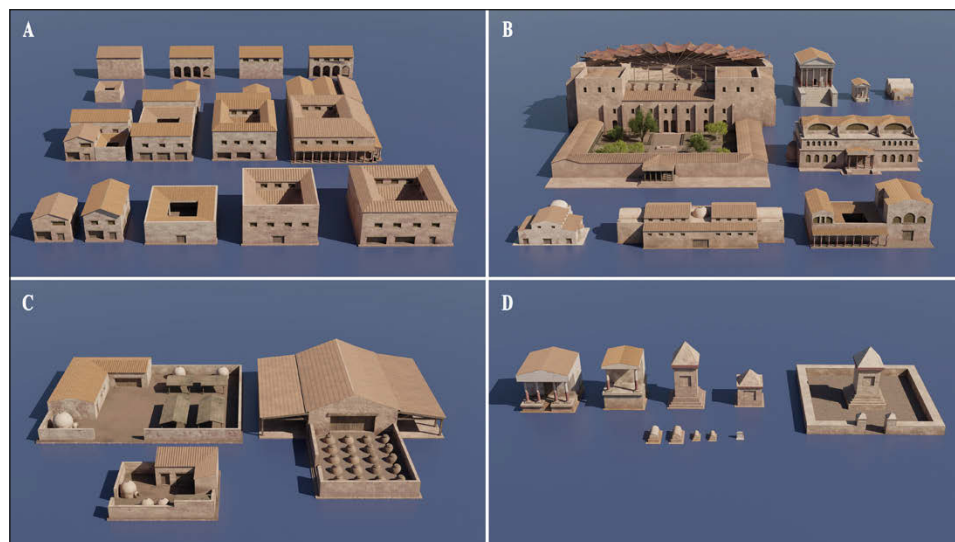


Fig. 3 – Virtual reconstruction of structures from the Roman period: a) residences and domestic spaces; b) public buildings; c) production spaces; d) funerary structures.

in an existing settlement. Although we do not know if the existing structures were demolished to build a new settlement, considering the historical considerations of the process of the city's accession to the Roman orbit, as well as the natural evolution of this type of city with an autochthonous tradition, we consider that a mixed pattern must have been established. This model would respect certain previous structures, but gradually tend towards an urban and spatial organisation of the settlement under the guidelines of the new political elite. Many other assumptions have emerged from this hypothesis, such as the existence of an ordered and structured defensive system, taking into account its direct historical link with the second Roman-Carthaginian war; the more than possible existence of public buildings (theatre, temples, basilicas, public squares, etc.); the configuration of a funerary space at the gates of the city and around its main access points; as well as elements existing in this type of rural settlement and their direct relationship with the economic exploitation of the surrounding territory (villas, farmhouses, mills, etc.).

All this evidence, although not archaeologically confirmed in the settlement, can be inferred from the study of this type of site in the historical-archaeological context in which it developed. For this reason, we assume them as our own in the absence of archaeological data on the Roman city of Épora, to use them as a guide in the virtual recreation that is the subject of this study. The virtual recreation work began with the general planning of the



Fig. 4 – Different views of the results of the virtual recreation of the Roman city of Épora (Montoro, Spain).

space and the internal structuring of the settlement using a sketch in which the hypotheses of the recreation were first set out (Fig. 2a), which later, with the relevant modifications, concluded with the final model (Fig. 2b).

During the development of this sketch, work began on modelling the structures and buildings that were to form part of the recreation, always basing ourselves on existing examples and archaeologically confirmed constructions in other regions of Roman Hispania. These buildings range from domestic spaces and residences (Fig. 3a) to public buildings, temples, baths, cisterns, and roads (Fig. 3b), as well as buildings related to productive spaces (Fig. 3c) and collective and individual funerary structures (Fig. 3d). All these structures, although not archaeologically confirmed in the city of Épora, by direct comparison and inferred from the study of other settlements with similar characteristics, offer a wide range of possibilities in the configuration of virtual recreation.

#### 4. CONCLUSIONS AND DISCUSSION

The development of this virtual recreation has led to interesting conclusions. The first of these concerns the scientific traceability of this work which, although it does not provide a high level of historical-archaeological evidence allows and enables us to understand the essential characteristics of

a culturally Ibero-Roman city. We understand that the different hypotheses put forward in the recreation do not adjust to the more than possible different archaeological reality of the settlement, but they do allow us to understand the capacities and potential of the territory. Even taking all this into account, it is necessary to transmit to any user and consumer of this virtual content that the hypotheses on which this study is based and structured are clear, reliable, and historically contrasted comparatively with other urban spaces of the same chronology and cultural tradition. To this end, we developed an infographic to show the different realities reflected in the virtual recreation, adjusted as far as possible to the archaeological data currently available to us (Fig. 4).

On the other hand, we have seen how the tools and protocols of Virtual Archaeology, in this case, the Extended Matrix, although they allow us to capture the broad outlines of the reconstructive hypotheses originating in the virtual recreation, we consider that there is a certain margin for improvement. Perhaps specific tools could be developed for the insertion of different levels of evidence in terms of the considerations made within the virtual recreation, considering the different sources from which the data necessary for its development are obtained.

All of this should be discussed in specific forums, allowing for the collective enrichment necessary for the continuous evolution and development of the discipline. The increase in the number of works that implement this methodology will undoubtedly provide the necessary experience to continue improving and executing this type of protocol more efficiently.

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## REFERENCES

- ADAM J.-P. 1996, *La construcción romana. Materiales y técnicas*, Leon, Editorial de los Oficios.
- BAQUEDANO BELTRÁN I. 1987, *Inicios del Bronce Final en la cuenca media del Guadalquivir: El Llanete de los Moros (Montoro, Córdoba)*, «Trabajos de Prehistoria», 44, 223-250.
- DEMETRESCU E. 2015, *Archaeological stratigraphy as a formal language for virtual reconstruction. Theory and practice*, «Journal of Archaeological Science», 57, 42-55 (<https://doi.org/10.1016/j.jas.2015.02.004>).
- DEMETRESCU E., FANINI B. 2017, *A white-box framework to oversee archaeological virtual reconstructions in space and time: Methods and tools*, «Journal of Archaeological Science: Reports», 14, 500-514 (<https://doi.org/10.1016/j.jasrep.2017.06.034>).



- DEMETRESCU E., FERDANI D. 2021, *From field archaeology to virtual reconstruction: A five steps method using the extended matrix*, «Applied Sciences», 11, 5206 (<https://doi.org/10.3390/app11115206>).
- FERNÁNDEZ OCHOA C., MORILLO, Á. 2022, *Murallas urbanas de época romana en Hispania (siglos I a.C. – V d.C.)*, «Vínculos de Historia», 11, 83-115 ([https://doi.org/10.18239/vdh\\_2022.11.04](https://doi.org/10.18239/vdh_2022.11.04)).
- GALEANO A., SANSEVERINO A., BERTO S., DEMETRESCU E., LIMONGIELLO M. 2024, *Extended BIM: A proposed workflow for the integration of the HBIM and EM approaches*, in IMEKO TC4 International Conference on Metrology for Archaeology and Cultural Heritage (Rome 2023), Red Hook (NY), Curran Associates, 115-120 (<https://doi.org/10.21014/tc4-arc-2023.023>).
- GROS P., TORELLI M. 1988, *Storia dell'urbanistica. Il mondo romano*, Roma, Laterza.
- IBÁÑEZ CASTRO A. 1990, *Nueva escultura thoracata en Montoro*, «Revista de Arqueología», 11, 105, 62-63.
- ICOMOS 2017, *Los Principios de Sevilla. Principios Internacionales de la Arqueología Virtual*, International Forum of Virtual Archaeology, New Delhi.
- LARA LÓPEZ J.A. 2019, *Cultos religiosos en la antigua Epoca romana*, «Montoro en la historia. Revista sobre la historia de Montoro», 7, 29-31.
- MARCOS POUS A. 1978, *Notas arqueológicas sobre Época (Montoro): estudios del siglo XVIII y recientes descubrimientos*, «Corduba Archaeologica», 5, 121-130.
- MÁRQUEZ MORENO C. 2019, *Órdenes y decoración arquitectónica en el mundo romano*, in E.H. SÁNCHEZ LÓPEZ, M. DE LOS SANTOS BUSTAMANTE ÁLVAREZ (eds.), *Arqueología romana en la Península Ibérica*, Granada, Editorial de la Universidad de Granada, 135-148 (<https://www.ptonline.com/articles/how-to-get-better-mfi-results>).
- MARTÍN DE LA CRUZ J.C. 1979, *Montoro, un nuevo yacimiento arqueológico en el Guadalquivir*, «Cuadernos de Prehistoria y Arqueología», 5-6, 105-141 (<https://doi.org/10.15366/cupauam1979.6.007>).
- MARTÍN DE LA CRUZ J.C. 1987, *El Llanete de los Moros. Montoro, Córdoba*, Excavaciones arqueológicas en España 151, Madrid, Ministerio de Cultura. Dirección General de Bellas Artes y Archivos.
- MARTÍN ESCORZA C. 2008, *Dimensiones y orientaciones de anfiteatros y circos romanos en el Imperio Romano*, «Kalakorikos», 13, 185-194.
- MELCHOR GIL E. 1991, *Camino romano entre Montoro y el Valle de los Pedroches: la vía Epoca-Solia*, in *III Encuentros de Historia Local. Alto Guadalquivir (Montoro 1991)*, Córdoba, Ilustre Ayuntamiento de Montoro, 79-86.
- ORTEGA ANDRADE F. 1995, *La construcción romana (II)*, «Revista de Edificación», 19, 55-76.
- ORTIZ GARCÍA J. 2013, *Las respuestas sobre restos arqueológicos en el Alto Guadalquivir según las noticias del interrogatorio de Tomás López: archivos, informática y reconstrucción gráfica*, «Crónica de Córdoba y sus pueblos», 19, 127-143.
- ORTIZ GARCÍA J. 2022, *Apuntes para la historia de la arqueología en Montoro. Una aproximación histórica (siglos XVI al XX)*, Trabajo Final de Máster, Córdoba, Universidad de Córdoba.
- RODRÍGUEZ NEILA J.F. 1990, *Problemas sobre la protohistoria y romanización de la antigua ciudad de Epoca (Montoro)*, «Boletín de la Real Academia de Córdoba», 118, 199-255.
- SICRE-GONZÁLEZ P. 2023, *Estudio histórico-arqueológico del cerro de Palomarejo (Montoro, Córdoba). Aproximación a su paleotopografía mediante la aplicación de la Arqueología Virtual*, «Montoro en la Historia. Revista sobre la Historia de Montoro», 33, 46-51.
- STAROPOLI L., ACEVEDO V.J., ÁVIDO D.N., VITORES M. 2023, *Reflexiones en la práctica de la arqueología digital: la construcción y comunicación del patrimonio cultural virtual*, «Virtual Archaeology Review», 14, 29, 118-135 (<https://doi.org/10.4995/var.2023.19292>).
- VICENT ZARAGOZA A.M. 1977, *Los más remotos orígenes de la ciudad de Montoro: antigua Época*, «Corduba Archaeologica», 6, 131-137.

WACKER M., GRELLERT M., BRUSCHKE J., STILLE W., GERMANY D.B. 2023, *Documentation and plausibility of virtual reconstructions. Establishing a culture of documentation with IDOVIR*, in *Proceedings of the 28<sup>th</sup> International Conference on Cultural Heritage and New Technologies*, Vienna, 1-5.

## ABSTRACT

Virtual Archaeology is a developing scientific discipline that seeks to open windows into the past. Born from the 'Seville Principles', it is a powerful tool in the virtualisation of heritage, promoting a multidisciplinary approach and overcoming professional individualism. A case study is presented on the virtual recreation of the Roman city of Épora in Montoro (Córdoba, Spain) using historical-archaeological and literary data. Virtual reconstruction differs from virtual recreation in its focus on the physical representation of archaeological elements, while virtual recreation focuses on the visual recovery of the past of a specific archaeological site or context, which is not fully or partially confirmed. The study shows how Virtual Archaeology tools and protocols can be improved and highlights the need for specific forums to collectively discuss and improve the discipline.

## AN OPEN LOOK TO THE PAST: VIRTUAL AND IMMERSIVE APPROACH TO STUDY INQUISITORIAL AUTOS DE FE IN COLONIAL MEXICO AND GUATEMALA

### 1. INTRODUCTION

The projects undertaken by *Praeteritas Urbes* have a fundamental aim: conducting thorough research and investigation to reconstruct both tangible and intangible cultural heritage using VR. Virtual recreation in cultural heritage is increasingly prevalent, offering advantages but also presenting methodological challenges that must be addressed. The advancement of modern technologies facilitates a new mode of engagement with cultural heritage, providing the opportunity to reach a vast audience. *Praeteritas Urbes* is an international and multidisciplinary group, composed of members from various institutions. It was founded in 2016 by Antonio Rodríguez Alcalá and John Chuchiak with the aim of recreating cities and events from the past, allowing them to be visited through virtual and augmented reality. The last project ('The *Auto de Fe* of Mani') started in 2022 and was presented to the public during a museum exhibition in Merida, Yucatan, beginning in February 2023.

Our research group's strategy is founded on an educational premise, yet the objectives of each project also acknowledge the role of emotions in the learning process. Consequently, our research is focused on recreating historical events that significantly shaped the region once known as the colony of New Spain and impacted Maya culture in diverse ways. These historical events, falling within the realm of intangible heritage, necessitate the use of a precise methodology in order to generate empathy for those who experienced these traumatic historical events.

### 2. THE AUTOS DE FE

The *Auto de Fe*, literally 'act of faith', served as a processional and penitential ceremony of public repentance. It was developed by the Spanish Inquisition with elements borrowed from its predecessors, the medieval and papal Inquisitions, and this ceremony included a procession of penitents and tribunal officers, followed by a solemn mass with a special sermon of faith. Finally, the culmination of these ceremonies ended with the pronouncement of the sentences and punishments of those convicted heretics. Although these *Autos de Fe* served as a form of religious ritual, they also held political, cultural, and didactic meanings (CHUCHIAK, DUNCAN 2023). Little scholarly attention has been given to the *Auto de Fe* ceremonies of the early monastic and episcopal inquisitions in the New World, meaning that it became necessary

for our research group to take a closer look at the details, spatial aspects, and the power and hierarchical relationships of those historical actors and officials who became involved in these ‘acts of faith’ in the various regions where these monastic and episcopal ceremonies existed (CHUCHIAK, DUNCAN 2023).

The main sources used to study and reconstruct these events are the testimonies and documentation uncovered in various archives, which, as primary sources, provided first-hand information about the various ceremonies of the *Autos de Fe* which occurred in the past. For example, for the reconstruction of the staging of the *Auto de Fe* ceremony, which had a standardized structure, together with historical sources, we can also count on archaeological investigations that help to reconstruct some elements of the ephemeral architecture of these events as well as the traces of the artefacts destroyed during these public events. Another important and visual aspect of these ceremonies focuses on the recreation of the penitential processions of the prisoners and the Inquisition officials, which allowed us to concentrate on the creation of historical figures, or the protagonists who experienced these events. An important aspect of this recreation of the processions included the research and modeling of the penitential garments, called *sambenitos*, the accused heretics were compelled to wear as a symbol of public shame.

### 3. METHODOLOGY

The reconstruction process of these historical events is based on the Principles of Seville, which establish the basic principles and criteria for measuring the quality of projects carried out in the field of virtual archaeology, especially noting the historical rigor and scientific transparency of the models generated (ICOMOS 2017). To respect these principles, several methodologies have been created and are very important to refer to when it comes to 3D reconstructions or virtual recreations. One of these focused on the use of a so-called scale of historical-archaeological evidence, a methodology and visual representation of the sources used in the recreation which ensures adherence to historical rigor and scientific transparency. The basic reconstruction of this method of documenting virtual models can be summarized as follows: 1) it is an immediate visual tool to understand the level of historical-archaeological evidence of each part of a virtual reconstruction; 2) warmer tones indicate a higher level of evidence while cooler tones refer to a lower level of evidence (APARICIO RESCO 2022). The visual scale of historical-archaeological evidence was used in all our *Auto de Fe* projects, especially for the architectural reconstruction of the former Convent of St. Michael the Archangel in the 16<sup>th</sup> century Maya town of Maní (Yucatán).

Through the study of primary and secondary sources, it became possible to extract and document the information necessary to reconstruct these various

historical events. For these reconstructions, primary sources like archival documents and archaeological remains served as the major historical sources for our reconstruction; while secondary sources, such as elements of similar events or ceremonies from other time periods or related contexts, allowed for an expanded source base which helped to give a more complete picture of the elements that would serve as part of the various historical recreations.

In this paper, we will illustrate our process of recreating historical simulations by briefly describing examples of two projects which focused on the recreation of an *Auto de Fe* ceremonies from the Colonial Period in New Spain, highlighting examples of the methodology adopted in our process of virtual historical simulations: the Great episcopal *Auto de Fe* of Santiago de los Caballeros (1554) and the monastic *Auto de Fe* of Maní (1562).

### 3.1 The Great episcopal Auto de Fe of Santiago de Guatemala (1554)

For the recreation of the event known as the Great *Auto de Fe* of Santiago de los Caballeros (1554), an architectural team developed a model of the architecture of the main square of the Spanish colonial capital of Guatemala, Santiago de los Caballeros, the scene of the Great *Auto de Fe* of 1554. A second team, aided by a group of historians and historical architects, undertook the design and recreation of the staging of the platforms used by the Spanish authorities who took part in this historical event. Since numerous historical documents accurately described aspects of this wooden staging for this historical event, a plausible model for the staging was created. In parallel, an historical research team provided and analyzed the surviving historical documents which described the order and nature of the events that happened on the day of the *Auto de Fe*, as well as providing access to representative archaeological objects and historical pieces that were going to be exhibited in a small museum exhibit, and their photogrammetric products which would also be utilized in the virtual simulation. Subsequently, a game development team integrated all the information and the architectural and historical recreations into the VR scenario, and they modelled characters, assets, and optimized the final low-polygon assets for the simulation. Finally, a navigation team had the important task of designing the form of movement of the ultimate users, as well as the design of menus, callouts and welcome titles/credits (Fig. 1).

An important point was to decide upon the type of Semantic Model that would be used. Due to the nature of the historical event recreated, it was decided on a Historical Reconstructed Scenario (HRS) that illustrated for the viewer aspects of the traumatic nature and harshness of the historical event, though the team chose to qualify (or soften) some of the more violent features of this ‘act of faith’: i.e. the ‘didactic theatre’ of punishment, ordered to be performed by Bishop Francisco Marroquín on the Maya penitents, was not recreated; nor was any interactivity designed to illustrate the nature of the



Fig. 1 – Virtual recreation of *Auto de Fe* of Santiago de los Caballeros.

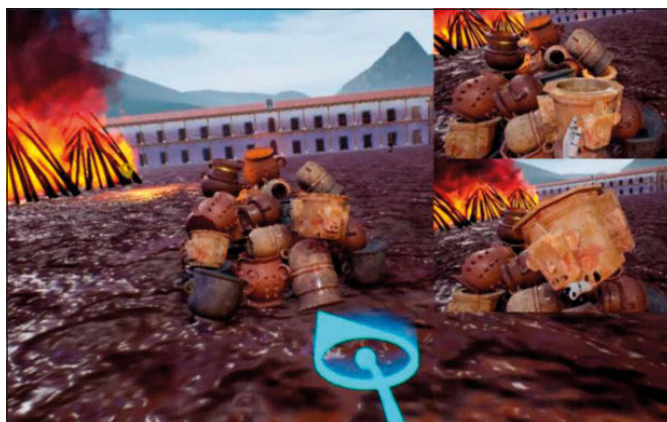


Fig. 2 – Virtual recreation of *Auto de Fe* of Santiago de los Caballeros: the interaction with the ceramic.

punishments. It was decided instead to include interactivity with models of the ‘idols’ destroyed in the bonfires that were arranged in the center of the square, as well as callouts with relevant information concerning the buildings in the plaza of Santiago, or detailed descriptions of various elements of the staging and the ceremony. It was decided to create a pre-awareness sensitivity room with navigation instructions, as well as a brief description of the historical event, and a panel with the project credits.



The interactivity of the staging of the HRS was limited to interacting with a sample of the archaeological pieces that were physically exhibited in the museum, allowing users to take them in their 'virtual-hands' and instructing them to throw them into the bonfire just as the Maya penitents were forced to do. Interior lights indicated those virtual archaeological pieces that were possible to 'grab' in the scenario. On the virtual recreation of the staging, the most important reconstructed pieces of the project were illustrated by placing more call-outs explaining the different parts of the staging, the characters involved, and the inclusion of a soundtrack of the liturgical chant *Iudica me Deus* (*Judge me my God*, Psalm 43), which, according to the historical descriptions, was the song that accompanied the procession of the *Auto de Fe* (Fig. 2).

### 3.2 The monastic Auto de Fe of Maní (1562)

The second project, which illustrates the methodology used in our recreation of historical scenario projects, was the virtual recreation of the Franciscan monastic inquisition in Maní along with its *Auto de Fe* of 1562. The Maya town of Maní is a site located in the State of Yucatán, Mexico. This project was created in collaboration with the regional museum of the National Institute of Anthropology and History's (INAH), Museo del Palacio Cantón of Merida, as part of a special exhibition entitled *Ídolos: Persistencias y resistencias mayas*.

This project focused on two different aspects related to the Virtualization of Heritage: it included the digital VR recreation of a historical event along with the creation of a virtual visit of the exhibition for the museum. The *Auto de Fe* of Maní (1562) was a very significant historical event, carried out by the monastic inquisitor, Fray Diego de Landa (LEÓN CÁZARES 2003). In this public event, hundreds of indigenous people were condemned and punished for various crimes related to what the friars called 'idolatry' (SCHOLÉS, ADAMS 1938). In addition, dozens of hieroglyphic codices (or books) and thousands of Maya cultural objects considered 'idolatrous', including tens of thousands of ceramic and wooden 'idols', were burned as a final act of extirpation (CARRILLO Y ANCONA 1979).

As part of the proposal for the recreation of this historical event, three elements had to be taken into consideration, each of which required a precise methodology: the architectural reconstruction, the recreation of the historical characters, and the reconstruction of the cultural objects for the exhibition. In terms of the architectural reconstruction, the main element of the historical scenario required the reconstruction of the former convent of St. Michael the Archangel in the town of Maní, for which it was necessary to combine evidence from fieldwork (especially the use of photogrammetry) with archival and bibliographical research for historical documentation (DÍAZ DE LEÓN ALCALÁ, ORDAZ TAMAYO 2022).



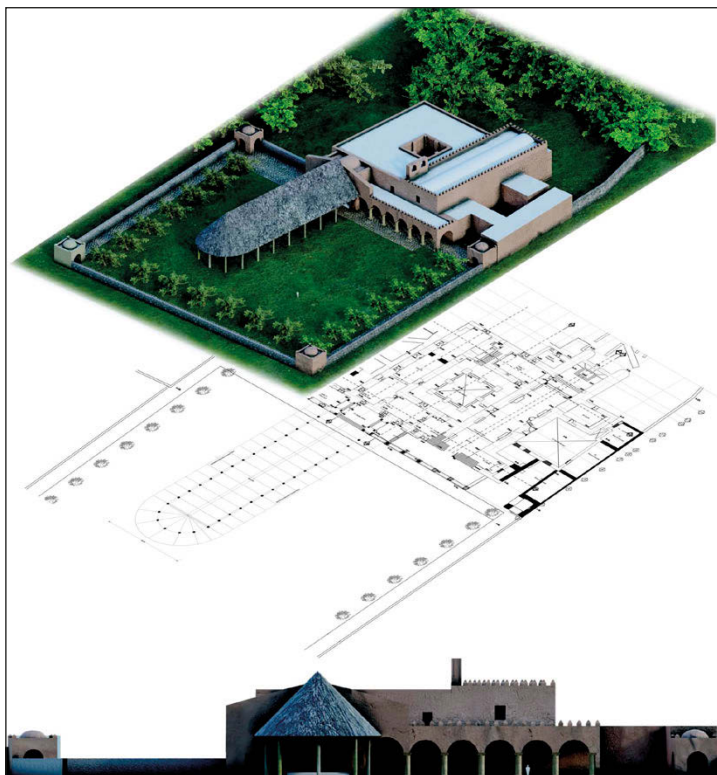


Fig. 3 – Virtual reconstruction of Saint Michael Archangel convent in 1549-1588.

The initial fieldwork focused on the exterior of the ex-convent, through the use of an aerial reconnaissance of the convent complex which compiled hundreds of images using a drone, and a photographic series of shots of the interior spaces, to obtain a photogrammetric model of the current stage of construction. The process was carried out by using Agisoft Metashape software. Secondly, by comparing the model obtained with the results of the archival research, it was possible to propose different theoretical phases of the construction of the Maní convent. In particular, the construction phases likely dated initially from between 1549 and 1588 and evidence of the remains of this period contained the elements that were perhaps visible at the time of the *Auto de Fe* (DÍAZ DE LEÓN ALCALÁ, ORDAZ TAMAYO 2022). After this process, a model of the convent, as it may have existed in the decade of the 1560s, was completed by using the software Blender for its subsequent insertion and integration into the Unreal Engine used for the VR reconstruction (Fig. 3).

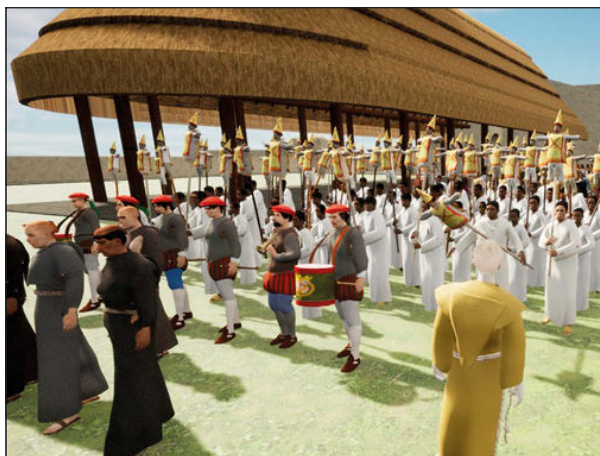


Fig. 4 – Virtual reconstruction of *Auto de Fe* of Maní, procession and characters.

The second important element within the recreation of the *Auto de Fe* concerned the recreation of the historical Spanish and Maya characters and the assets and cultural objects used in the staging and during the public event. In both cases, the main software used for the modeling was the open source software Blender. For the recreation of characters, however, our team used the MakeHuman program, which is also an open source software, and finalized them in Blender. Once the character creation process was complete, our team moved on to creating other physical features and other elements such as historically accurate clothing and accessories. Each character, once completed with the addition of textures and animations, was exported from Blender to be loaded into the Unreal Engine software, where the final VR scene was created (Fig. 4).

The last component of the 3D reconstruction was the digitization and photogrammetry of the artefacts displayed in the physical museum exhibition. The methodology used for the photogrammetric process consisted of taking images from the pieces *in situ* and processing the data through software such as Agisoft Metashape and later post-processing these models in Blender and Substance Painter. As a result, a digital archive of these digital models was created and is freely accessible online (Fig. 5). The main idea of the exhibition was to utilize the collection of the Museo Regional de Antropología, Palacio Cantón as surviving examples of the many thousands of artefacts that were destroyed in the *Auto de Fe* in Maní. On display also were fragments of the actual objects destroyed in the event which were recovered thanks to the archaeological research of Dr. Tomás Gallareta Negrón in 2015, which uncovered part the location of the major bonfire near the town of Maní's main plaza.

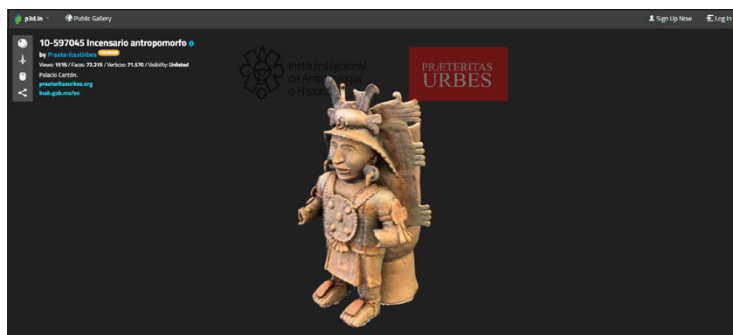


Fig. 5 – Photogrammetric reconstruction of a censer for the exhibition *Ídolos. Persistencias y resistencias mayas*.

#### 4. RESULTS

In both simulations, the most valuable results were the interaction of the end users (the museum visitors) with the virtual experiences and their derived products, since an immersive experience is currently one of the main goals of public engagement and dissemination of knowledge for scientific products. In formulating general dissemination strategies for these projects, it was advisable to create differentiated impacts for each segment of the exhibits, considering factors such as age range, degree of specialization, and depth of knowledge that our team aimed to offer for the viewers. Through various user satisfaction and verification instruments, such as exit surveys, virtual suggestion boxes, interactive pieces in Augmented Reality, and thematic workshops, users interacted with the content of these projects and generated valuable feedback for the work teams, who have subsequently evaluated and incorporated these suggestions into subsequent iterations and revisions of the projects.

In general, both experiences have had a high impact on the users of these exhibits, since in most cases they expressed that they were unaware of many of these said historical events; or if they knew about them, they had only a superficial knowledge of the events, or had held erroneous views of the facts. The most important suggestions were to raise the graphic standards, the enhancing of viewer interactions or adding more musical backgrounds that resemble those of the video game. Other suggestions included the incorporation of a greater variety of online and offline outputs to continue the viewers with the interaction and understanding of the contents of the projects, or in order to have a greater number of devices available to have more interaction time for each museum viewer. And last, some comments led the team to consider issues of inclusion and adaptations for a wider access of the models for people with various disabilities.

## 5. CONCLUSION

The museum exhibitions and projects of the *Auto de Fe* of Santiago de los Caballeros (1554) and the *Auto de Fe* of Maní (1562), more than 470 years after these events, offered the public an act of historical reconciliation that activated first-person reflections in relation to the events and the cultural continuity of the Maya people and their culture of resilience and persistence. By offering VR immersive views of these *Autos de Fe*, these lost historical events, and their intangible cultural patrimony, can be experienced with new technologies in a hands-on experience through augmented reality and immersive interactive exposition rooms. The goal of these scenarios was to communicate the cultural greatness of the Maya of Guatemala and Mexico in pre-Hispanic times and the cultural divergences which occurred with the European encounter. By generating a virtual recreation of these *Autos de Fe* with their recreated cultural settings and elements based on the historical, architectural and archaeological sources extant, our team aimed to establish historical empathy in the viewers. We hoped to offer the viewers of these exhibitions a first-person view of the dimension of the losses of cultural objects which occurred during these events, and a firsthand view of the clash of cultures inherent in colonialism, thereby activating reflections on the value of cultural differences and the need for tolerance in our present day.

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## REFERENCES

- APARICIO RESCO P. 2022, *Hacia una nueva versión de la escala histórico-arqueológica para reconstrucciones virtuales* (<https://parpatrimonioytecnologia.wordpress.com/2022/06/06/hacia-una-nueva-version-de-la-escala-de-evidencia-historico-arqueologica>).
- CARRILLO Y ANCONA C. 1979, *El obispado de Yucatán. Historia de su fundación y de sus obispos desde el siglo XVI hasta el XIX*, Mérida, Fondo Editorial de Yucatán.
- CHUCHIAK J.F., DUNCAN J. 2023, *Theatres and spaces of power in ephemeral architecture: The autos de fe of the Inquisition and the visual, spatial and physical representation of inquisitorial power, 1481-1736*, in A. RODRÍGUEZ ALCALÁ (ed.), *El patrimonio. Vehículo de la memoria remota y reciente*, Mérida, Universidad Anáhuac Mayab, 50-78.
- DÍAZ DE LEÓN ALCALÁ L.R., ORDAZ TAMAYO M. 2022, *Reconstrucción virtual del ex Convento de San Miguel Arcángel de Maní, Yucatán*, in A. RODRÍGUEZ ALCALÁ (ed.), *El Patrimonio. Vehículo de la memoria remota y reciente*, Mérida, Universidad Anáhuac Mayab, 33-44.
- ICOMOS 2017, *The Seville Principles. International Principles of Virtual Archaeology*, International Forum of Virtual Archaeology, New Delhi, 1-27.
- LEÓN CÁZARES M.C. 2003, *Diego de Landa*, in J.A. ORTEGA Y MEDINA, R. CAMELO (eds.), *Historiografía mexicana. Historiografía novohispana de tradición indígena*, I, México, Universidad Nacional Autónoma de México, Instituto de Investigaciones Históricas.
- SCHOLES F.V., ADAMS E.B. 1938, *Don Diego Quijada, Alcalde Mayor de Yucatán, 1561-1565*, I-II, México, Antigua Librería Robredo, de José Porrúa e Hijos.

## ABSTRACT

Virtual Reality is one of the tools that has become widely used in recent years, in the field of cultural heritage. This tool has proven to be particularly valuable, especially for approaching intangible cultural heritage. Using free and open source software for 3D modeling and animation, such as Blender and Unreal Engine, the international research group, *Praeteritas Urbes*, focused on the reconstruction of historical events such as the inquisitions many *Autos de Fe*, which had a significant impact on the colonial history of Central America. In this paper, we will present the results of two different projects: 'The Great *Auto de Fe* of Guatemala', which took place in Santiago de Guatemala in 1554, and 'The *Auto de Fe* of Maní' (Yucatán, Mexico), which occurred in 1562. In both cases, our objective was to make simulations of these two events known and accessible to the public, using a precise methodology, following the scale of evidence, and adhering to the standards established in the Principles of Seville codified in 2017.

## EXTENDED MATRIX MANAGER: AN OPEN TOOL FOR EM BASED KNOWLEDGE GRAPHS MANAGEMENT

### 1. INTRODUCTION

The following contribution aims at presenting a new free and open-source software, EM Manager, that has been created to assist archaeologists at approaching virtual reconstruction projects with the Extended Matrix method. EM Manager represents the most recent update of the Extended Matrix Framework and, due to its features, it will expand the user base. The Extended Matrix (EM) was conceptualized in 2015 (DEMETRESCU 2015, 2018; DEMETRESCU, FERDANI 2021; <https://www.extendedmatrix.org>) as a method with the main purpose of mapping metadata and paradata connected with a virtual reconstruction. EM is a node-based formal language, with rules and specific nodes, developed by the Digital Heritage Innovation Lab (DHILab) of Rome CNR. The method allows to graphically map all the sources used within a virtual reconstruction process, using an oriented graph (the so-called Extended Matrix) that ‘extend’ a real Harris matrix, and it visually represents the reliability of a reconstruction, using a color scale connected to the nodes of the method. EM is based on standards such as stratigraphy, computer graphics, knowledge networks, and CIDOC-CRM (<https://cidoc-crm.org>) to register the documentation process of a context or the documentation process of a reconstruction. In one sentence, since we map data provenance of the reconstructive information, the EM is about scientific-driven content creation (Fig. 1a).

A different meaning and a different scope are fulfilled by the Extended Matrix Framework (EMF). This framework represents a large open source ecosystem where tools are shared with other communities in order to support the application of the Extended Matrix method (Fig. 1b). As example, EM tools and 3D Survey Collection (3DSC; <https://github.com/zalmoxes-laran/3d-survey-collection>), two addons of Blender (<https://www.blender.org>), has been created and developed with the intent to manage EM data within Blender (EM tools; DEMETRESCU *et al.* 2023; <https://github.com/zalmoxes-laran/EM-blender-tools>) and visualize-represent-edit-export topographical and photogrammetric data in Blender (3DSC). For dissemination, presentation and sharing purposes ATON and its web-app EMviq allow user to visit online a 3D scene, with the possibility of multiple interactions, multiple navigation mode, portability on different devices (all these features are natively available on ATON; FANINI *et al.* 2021), and to explore the sematic layer provided by the EM (feature available through EMviq; DEMETRESCU *et al.* 2023).

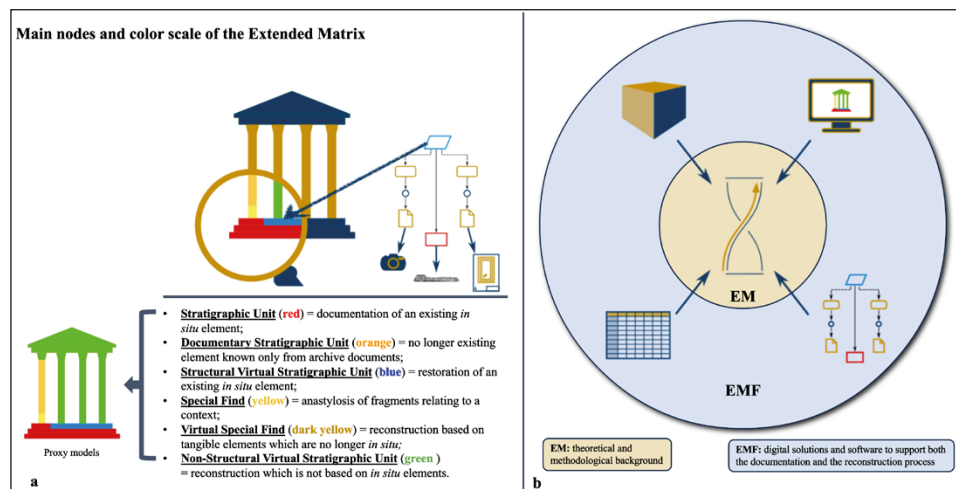


Fig. 1 – a) Schematic representation of the Extended Matrix with its main nodes and the color scale explained; b) schematic representation of the relation between the Extended Matrix and the Extended Matrix Framework.

While the EM represents the theoretical and methodological background, which can be deployed even outside a digital environment (for example, an EM can be sketched out on a piece of paper with a pencil, as well as with a software tool). On the contrary, the EMF is a framework that includes digital solutions and software to support the documentation process behind a virtual reconstruction. If EM is about scientific-driven content creation, as already mentioned, the EMF, instead, is about technological-driven solutions for assisting EM. Within the EMF user can find tools useful to create an EM and edit, manage, update, link, share reconstructive data.

S.B., E.D.

## 2. STATE OF THE ART

In 2021, within the EMF ecosystem another step towards the EM was made with pyArchInit (COCCA 2016; MONTAGNETTI, MANDOLESI 2019). This plugin of QGIS (<https://qgis.org/>), realized in 2005, allows to store within an organized and up to date database the archaeological documentation of an excavation (excavation sheets, topographical data, images, etc.) and automatically export all the required information with default (or customized) layout. One of the key features of pyArchInit consists in the possibility of automatically creating a Matrix, starting from the information stored within its database. Considering this advanced feature of the



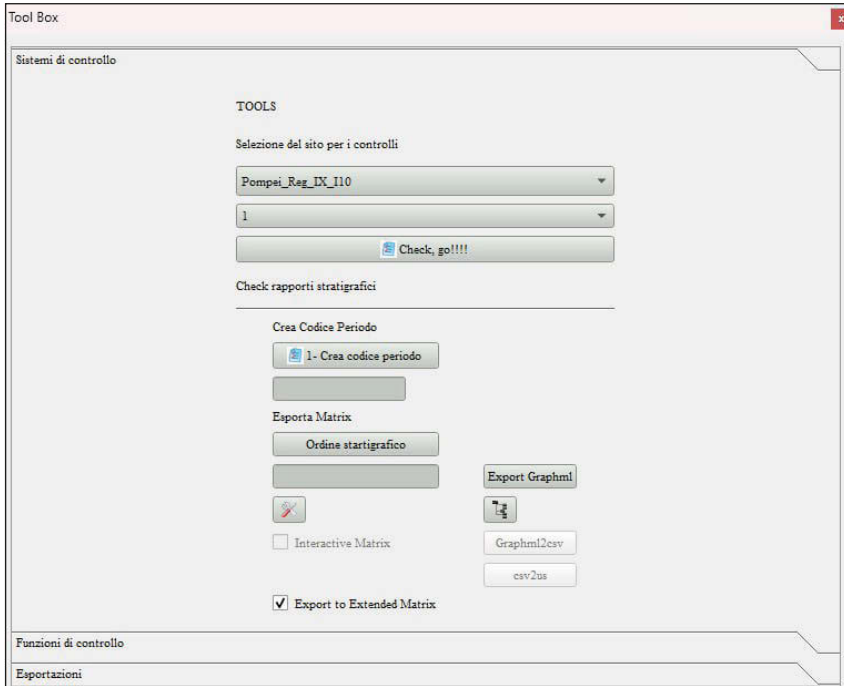


Fig. 2 – The ‘Export GraphML’ button on the ‘Control systems’ panel of pyArchInit, within QGIS. This function allows to automatically generate an Extended Matrix using the documentation stored in pyArchInit.

plugin, in 2021 an updated version of pyArchInit was released to allow the automatic generation of an EM, with all the necessary nodes defined by the ‘Extended Matrix palette’ of the method, using all the information stored in the database (Fig. 2). This fundamental step, occurred within the EMF, established a real connection between the environment of QGIS, where pyArchInit operates, and the 3D environment of Blender, where all the reconstructive information of an EM can be easily visualize in 3D, using proxy models (that is, simplified 3D geometries that allow to represent in a three-dimensional shape, not automatically generated, data which are stored within an EM). This step of the ‘development phase’ creates the opportune conditions for formulating the idea of EM Manager. As already mentioned, EM Manager was created to assist the creation of an Extended Matrix using an automatic process, in other words EM Manager automatically generate an EM graph from a table.

In general, in order to create a complete EM-project we need at least ‘7 key roles’ within a perfect ‘EM-Team’; in this case, the EMF provide a

dedicated software, or a dedicated workflow, for each of these ‘roles’. The first role is the ‘Archaeologist’, who is fundamental for documenting stratigraphic data during the field work. The second is the ‘Bookworm’ (the so called ‘Source-Hunter’), whose role is valuable when the reconstruction proposal requires comparisons due to the lack of other data. The third is the ‘DB manager’, whose role is important for storing and managing data (such as: an expert in database, an expert in GIS, etc.) that could be useful for assisting the virtual reconstruction process. The fourth role is the ‘Expert in survey techniques’, who is the one responsible of collecting information (on the field or in the laboratory) and managing geometrical data regarding the archaeological context or the object that needs to be documented and reconstructed. The fifth is the ‘EM drawer’, who has the role of collecting and organizing all the data functional for the reconstruction, using the formalism of the Extended Matrix. The sixth role is the ‘Proxies Modeler’, this member of the team does not need specific 3D skills for drawing proxy models, since these geometries are simple-low poly 3D models named as the Stratigraphic nodes of the EM. Proxies are the bridge between the EM graph and Blender. The seventh role, the last one, is the ‘Expert in 3D modelling’, who is the 3D modeler that will reconstruct the context or the object, with detailed 3D models, using photorealistic materials, appropriate light conditions, etc.

Once defined these ‘7 key roles’, we focused our attention on the ‘EM drawer’. This fourth role requires some specific skills for the purpose of drawing a complete EM graph, such as: familiarity with the formalism of the EM (knowing both the meaning of each node, their color scale, and how to use them, etc.); capability of drawing an EM using the software yED (at the moment EM needs yED’s ‘swimlane’ option for the creation of its final layout that maintain chronological division in horizontal sections); knowing how to collect data useful for both the documentation and the reconstruction phases. In most of the cases, when we are dealing with the reconstruction of an archaeological context, ‘archaeological data’ are frequently stored in databases, and this means tables with data acquired on the field, or elaborated in a second moment (such as: numbers of stratigraphic units; their description; their images; their stratigraphic connection; references to planimetries; references for comparisons; etc.). During the creation of an EM, it is also important to ‘optimize time’ with the intention of providing a balance between the time spent searching data, for documenting and reconstructing a case study, and the effective time for drawing and filling an EM (maybe at first as a handmade sketch and then with yED).

The final requirement that completes the process of creation of an EM is the ‘error checking’ step, when the ‘EM drawer’ controls all the nodes of

the graph to avoid the presence of potential errors. Since most of the time the ‘EM-Team’ lacks the presence of one or more of the 7 roles, previously described, the idea of creating EM Manager as an assistant for the creation of an EM graph grown up with more motivation. The software would have overcome the potential absence of the ‘EM drawer’, or simply it would have assisted the ‘EM drawer’ during the creation process of an EM.

S.B., E.D.

### 3. EM MANAGER

EM Manager is a standalone software, free and open source, coded in Python (<https://www.python.org>), already available for download on GitHub (<https://github.com/enzococca/EM-Manager>; Fig. 3a). The fact that EM Manager has been coded using Python language ensures the possibility of future implementation with other Python based platforms (such as, QGIS and Blender). At the moment, the software allows to:

1) read archaeological data stored in a ‘specific’ table (Fig. 3b, c). This table follows: the rules of stratigraphy; the rules of a Stratigraphic Unit sheet; the rules of pyArchInit, since EM Manager maintains a native connection with pyArchInit, even if it is a standalone software;

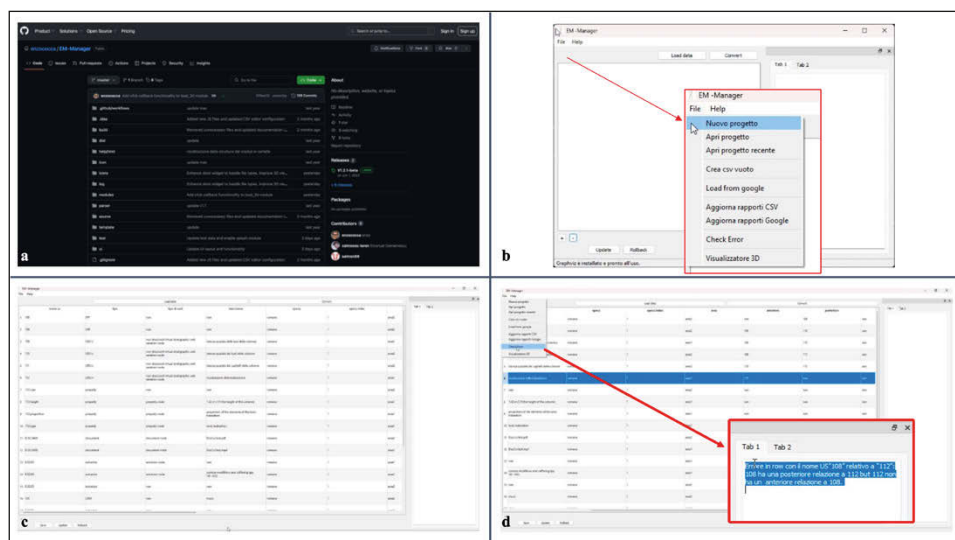


Fig. 3 – a) View of the GitHub online repository where all the versions of EM Manager are stored; b) the ‘File’ menu of EM Manager where all the functions of the software are displayed; c) panoramic view of how EM Manager displays imported data stored in a table; d) example of how the ‘Check Error’ function of EM Manager reports errors to user.

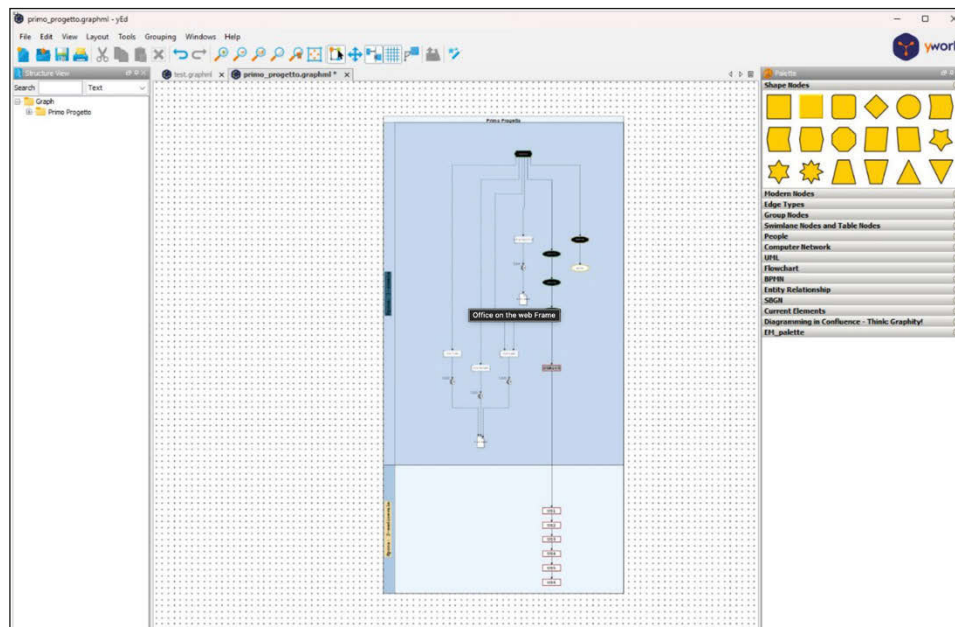


Fig. 4 – View of the Extended Matrix graph in yEd after the ‘Swimlane’ option has been applied. In the example nodes are displayed with respect to the formalism of the Extended Matrix.

- 2) check errors with respect to the rules of stratigraphy and the rules required for storing data within the table (Fig. 3d). This means that after importing a table it can automatically indicate where the table presents some errors, if any;
- 3) automatically convert a table into a complete EM (with all the necessary nodes and vectors required by the formalism). In a second step, within yEd, the application of the ‘Swimlane’ option will complete the final layout of the graph (with all the nodes spatially organized in chronological periods; Fig. 4);
- 4) represent the EM and its data in a 3D environment embedded in the software (Fig. 5).

This feature gives the possibility to visualize a 3D representation of the EM with also all the proxy models. This specific feature, the one that allows visualizing the 3D models in EM Manager, requires the presence of proxy models within a particular folder. This precise condition describes an advanced step of a reconstructive process, the one where EM and proxy models are already made.

Delving into its core, EM Manager is a sophisticated software tool that leverages a variety of Python libraries to handle complex data management

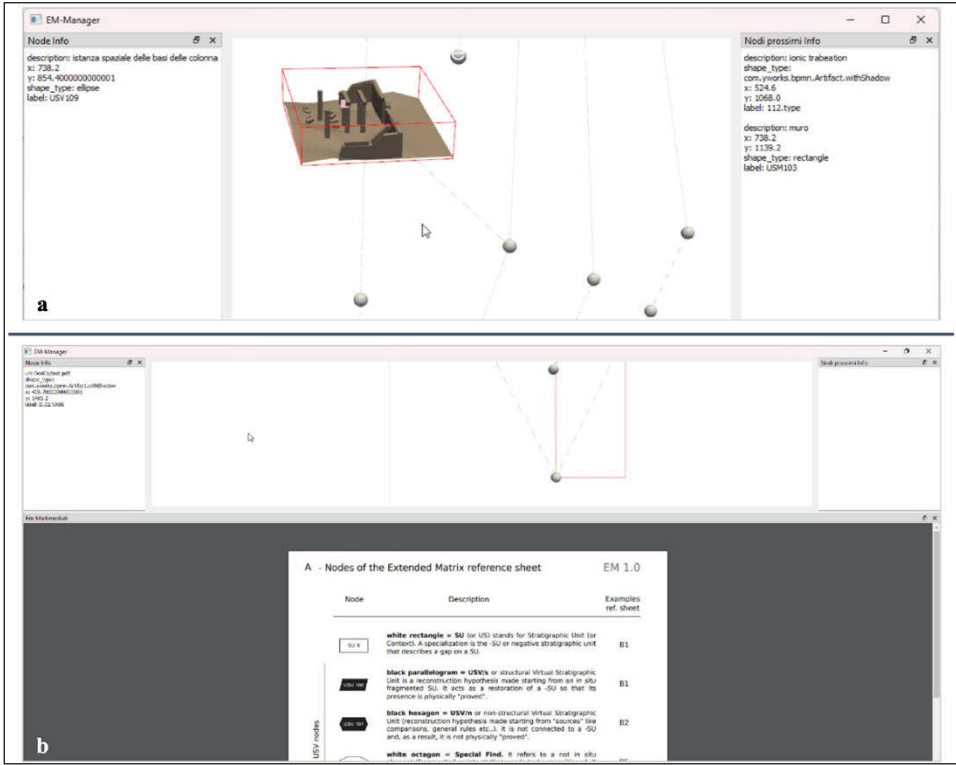


Fig. 5 – a) 3D viewer of EM Manager with the three-dimensional representation of both the Extended Matrix and Proxy models; b) example of data visualization in EM Manager when files are connected to the nodes of the EM.

and visualization tasks in a user-friendly manner. By integrating powerful libraries such as PyQt5, pyVista, pandas, and OpenCV, EM Manager provides an extensive suite of functionalities that cater to professionals who need robust and efficient data processing capabilities. Starting with PyQt5 (<https://pypi.org/project/PyQt5/>), EM Manager utilizes this library to craft graphical user interfaces (GUIs). PyQt5 is renowned for its ability to create professional and aesthetically pleasing interfaces, making it an ideal choice for applications that require a high level of interaction with users. This allows users to navigate through complex data sets with ease, enhancing the overall usability of the software.

For 3D data management, EM Manager incorporates pyVista (<https://docs.pyvista.org/version/stable/>), a library known for its advanced 3D visualization and mesh analysis tools. This integration enables users to

interact with three-dimensional datasets, perform geometric transformations, and visualize data in ways that are not possible with two-dimensional representations. The ability to manipulate and analyze 3D data is crucial for users who deal with spatial data, providing insights that are critical for informed decision-making. When it comes to managing tabular data, EM Manager utilizes pandas (<https://pandas.pydata.org>), a library that excels in data manipulation and analysis. With pandas, users can efficiently organize, sort, and filter large datasets, perform statistical analysis, and export data to various formats. The library's powerful data handling capabilities make it an indispensable tool for managing complex datasets with multiple attributes.

For media manipulation, EM Manager employs OpenCV (<https://opencv.org>), a library designed for real-time computer vision applications. This integration allows users to process images and videos within the software, perform image enhancements, and extract meaningful information from visual data. OpenCV's functionality extends the capabilities of EM Manager into the realm of media analysis, making it a versatile tool for handling a wide range of data types. Beyond these Python libraries, EM Manager also utilizes Graphviz (<https://graphviz.org>) for specific graph-related tasks. Graphviz is an external software that excels in the creation of visual representations of networks and graphs. EM Manager uses Graphviz to generate Harris matrix in the DOT file format, which is then transformed into GraphML using a custom-written parser. This feature is particularly useful for users who need to visualize and analyze relational data, providing a clear and structured representation of complex relationships.

Overall, EM Manager represents a comprehensive solution that combines multiple Python libraries and external software to address a broad spectrum of data management needs. By integrating these tools, EM Manager not only enhances its functionality but also provides a seamless and efficient workflow that helps users manage and analyze data effectively.

E.C., E.D., S.B.

#### 4. CONCLUSIONS

The software described in this contribution represents an important step in the development of the EMF since it offers a software solution, free and open source, that can assist EM users to approach the EM even if they do not cover all the 7 key roles of the 'EM-Team'. At the moment, as already mentioned, the software is available on GitHub, but its development is still in progress. Future development of the software will include: a stable release for Windows OS; an installer for Mac OS; a general update of the online

documentation, following the one realized for 3D Survey Collection (3DSC) and EM tools; an official 3D layout of EM nodes to be visualized in EM Manager; an improved 3D viewer for the visualization of proxy models; an automatic converter from EM to table.

S.B., E.C., E.D.

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## REFERENCES

- COCCA E., MANDOLESI L. 2016, *Analisi statistiche e geostatistiche con PyArchInit: prima sperimentazione*, in A. CARVALE, P. BASSO, P. GROSSI (eds.), *ARCHEOFOSS. Free, Libre and Open Source Software e Open Format nei processi di ricerca archeologica. Atti del IX Workshop (Verona 2014)*, «Archeologia e Calcolatori», Suppl. 8, 132-140 (<https://www.archcalc.cnr.it/journal/id.php?id=876&sup=true>).
- DEMETRESCU E. 2015, *Archaeological stratigraphy as a formal language for virtual reconstruction. Theory and practice*, «Journal of Archaeological Science», 57, 42-55 (<https://doi.org/10.1016/j.jas.2015.02.004>).
- DEMETRESCU E. 2018, *Virtual reconstruction as a scientific tool: The Extended Matrix and source-based modelling approach*, in S. MÜNSTER, K. FRIEDRICHS, F. NIEBLING, A. SEIDEL-GRZESIŃSKA (eds.), *Digital Research and Education in Architectural Heritage, 5<sup>th</sup> Conference, DECH 2017, and First Workshop, UHDL 2017 (Dresden 2017)*, Communications in Computer and Information Science, Cham, Springer International Publishing, 102-116 ([https://doi.org/10.1007/978-3-319-76992-9\\_7](https://doi.org/10.1007/978-3-319-76992-9_7)).
- DEMETRESCU E., FANINI B., COCCA E. 2023, *An online dissemination workflow for the scientific process in CH through semantic 3D: EMtools and EMviq open source tools*, «Heritage», 6, 1264-1276 (<https://doi.org/10.3390/heritage6020069>).
- DEMETRESCU E., FERDANI 2021, *From field archaeology to virtual reconstruction: A five steps method using the Extended Matrix*, «Applied Sciences», 11, 11, 5206 (<https://doi.org/10.3390/app11115206>).
- FANINI B., FERDANI D., DEMETRESCU E., BERTO S., D'ANNIBALE E. 2021, *ATON: An open-source framework for creating immersive, collaborative and liquid web-apps for cultural heritage*, «Applied Sciences», 11, 22, 11062 (<https://doi.org/10.3390/app112211062>).
- MONTAGNETTI R., MANDOLESI L. 2019, *QGIS, pyArchInit and Blender: Surveying and management of archaeological data with open source solutions*, «Archeomatica», 10, 4, 128-138 (<https://doi.org/10.48258/arc.v10i4.1706>).

## ABSTRACT

The following contribution aims at presenting a new free and open source software, EM Manager, created to assist archaeologists at approaching virtual reconstruction projects with the Extended Matrix (method developed at the Digital Heritage Innovation Lab - DHILab - of the CNR-ISPC of Rome). EM Manager is a free and open source standalone software, already



available on GitHub, that allows to convert a table into an Extended Matrix. The software represents a remarkable update of the Extended Matrix Framework and, due to its features, it will expand the user base, since it helps EM users to cover one, or more, of the ‘7 key roles’ considered by the Extended Matrix method. In addition, the fact that EM Manager is Python based ensures the possibility for future implementation with other platforms (such as QGIS and Blender) based on the same language.

## EXTENDED MATRIX NARRATIVES: TEACHING AND ENGAGING THROUGH THE PAST\*

### 1. INTRODUCTION

In this article, we propose open methods and tools that foster collaboration between academia and the creative industries, to enhance Cultural Heritage engagement and digital reconstruction. It suggests a way forward by initiating the development of open, interoperable methodological tools and software designed to establish a common theoretical and methodological framework. This initiative aims to promote standardisation and sharing across both academic and industrial domains. An example of this approach is the use and adaptation of systems such as the Extended Matrix (EM), which focuses on data provenance, to explore a narrative dimension that highlights communicative, experiential and emotional aspects, while maintaining a strong link to science and promoting the intangible Cultural Heritage (BALELA, MUNDY 2015) (Fig. 1).

The aim is to equip academia with the necessary tools to train future generations to create content that is technically sound, emotionally engaging and narratively rich (VEUGEN 2014). This ambition, highlighted at the end of the state of the art, represents a challenge for the future, prompting a re-evaluation and broadening of methodological and application horizons in the field of digital cultural heritage. To test this tool, we propose a case study about the reconstruction, through the analysis of literary sources and the application of the EM, of a dialogue between two characters set in the forum of a small Roman city.

The state of the art reveals that major companies in the creative industry, such as Paradox and Ubisoft, do not make their methodological tools available, which likely includes a range of software and applications. This opacity makes standardisation and adoption within academia challenging, rarely taught in universities. Our approach is to begin developing open, interoperable methodological tools and software that can foster a common theoretical and methodological framework.

### 2. METHODOLOGY

This research began by exploring the relationship between academia and the creative industries, aiming to bridge the gap between them. Creative tools

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

C.01		<b>Extractor icon = extractor</b> node capable of extracting specific information from a source and passing it to a property
D.01.01		<b>Combiner icon = combiner</b> node capable of combining information provided by two extraction nodes and passing the result in value to a property
		<b>Gray rounded square = property.</b> A property node validates a VSU it is connected to
D.01		<b>Document icon = source.</b> A source node feeds a property of a VSU it is connected to (through an extractor node). A source can be an image, a text, a reference, a 3D model etc. More documents need a combiner node

Fig. 1 – EM legenda related to the notes devoted to track the data provenance.

are often undervalued in knowledge transfer. Deadlines and differing priorities create tension – academics prioritise content integrity, while the creative industry must consider commercial viability. Projects like ‘Assassin’s Creed’ (CASEY 2018) and ‘Pentiment’ demonstrate the potential of collaboration, while others, like ‘A Night in the Forum’ (PESCARIN *et al.* 2020), reveal ongoing challenges. A formalised approach is needed to balance the unique needs of each sector while ensuring both educational and entertainment value, as well as economic success. Our methodology addresses these challenges with an open framework that bridges data creators and the creative industry. As a prime example, we introduce the Extended Matrix Narratives, designed to extract communication-oriented data from primary sources without losing the connection between emotional and historical aspects, potentially even facilitating quicker information retrieval from these sources. These principles are the foundational pillars of our methodology. The Extended Matrix Narratives highlights the significance of Narrative Units in bridging data creators with the creative industry. The NUs are instrumental in extracting communicative information from primary data sources, preserving the connection between emotion and the historical context.

We demonstrate this by a practical case study where we aimed to produce academically accurate yet engaging content and using three Plautine comedies as primary sources. The project begins with a detailed analysis of the comedies, deconstructing dialogues to form the basis for a new scene. Close analysis of who spoke, when, and how, allows us to create historically grounded dialogue featuring plausible characters in realistic settings.

## *2.1 Extended Matrix in brief*

The EM, developed by ISPC-CNR, is a formal language designed to track the digital reconstruction processes used in archaeology and Cultural Heritage. It expands upon Harris's stratigraphic principles, allowing for the integration of virtual and hypothetical elements. EM records data, sources, and the logic behind Virtual Stratigraphic Units (VSUs), ensuring transparency in the reconstruction process. Essentially, EM is a formalised graph database that enables hypothetical reconstructions, seamlessly blending excavation data with diverse historical sources (DEMETRESCU, FERDANI 2021).

The EM emphasises data provenance, especially the philological origins of digital information (DEMETRESCU *et al.* 2020). This focus helps maintain a clear link between emotional narratives and their historical context. Narrative units within EM precisely document this provenance, ensuring that created narratives remain grounded in authentic sources. This approach not only makes narratives more engaging but also strengthens the integrity of historical accounts, resulting in digital narratives that are both emotionally impactful and historically accurate.

## *2.2 Extended Matrix Narratives in theory*

The Extended Matrix Narrative (EMN) expands upon the EM to ensure the coherence and accuracy of creative content produced for cultural heritage projects. Central to the EMN are Narrative Units (NUs). These units seamlessly blend scientific data with creative elements. For example, a dialogue's content might be strictly based on research, while its tone and pacing are guided by creative choices. Narrative units emerge as an essential tool for mapping events that unfold over time and belong to domains such as theatre, choreography, and music. These units enable the documentation of intangible heritage – dances, dialogues, musical events, rituals – characterised by a coherent scene where events follow one another. Elements like a ritual outside an Etruscan tomb, a conversation between merchants in a square, or a musical or dance performance are defined by a beginning and an end, rooted in a specific scene in time and space.

This scenic context is linked to a chronological phase that acts as a container for our virtual reconstruction, offering a platform to represent and perform intangible events. This structure provides not only a theoretical framework but also a narrative detail focused on theatre. The narrative progresses through the voice of the 'third actor', who introduces the scene and guides the narrative units composed of the characters' dialogues. Each dialogue, every sound produced, is a narrative unit connected to sources through Data Provenance nodes, ensuring a direct link to the historical and contextual authenticity of the represented events.

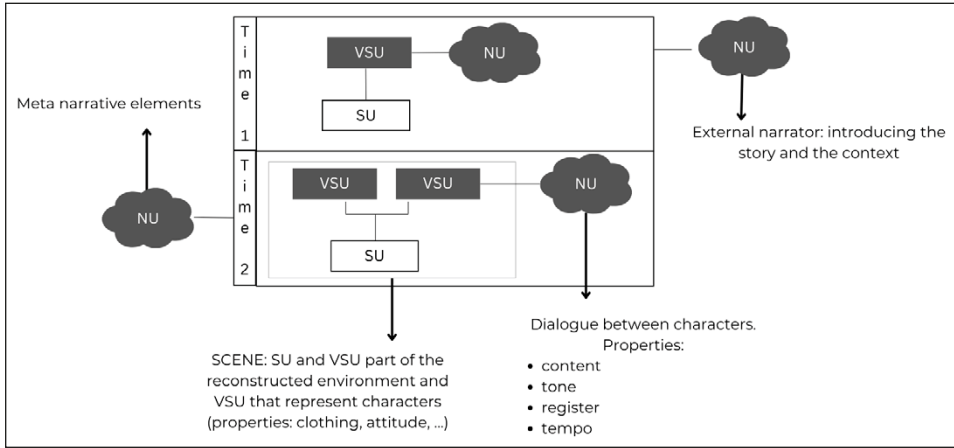


Fig. 2 – EMN scheme.

Thus, the use of narrative units in the context of EMN allows for a precise mapping of intangible cultural events, enriching the virtual reconstruction with temporal, spatial, and emotional dimensions. This approach not only enhances communication and emotional engagement (MILLER 2019) but also establishes a solid bridge to academia, enabling training based on tools that facilitate the creation of historically accurate and narratively engaging content. That being said, there may be two types of NUs: 1) a system or scene: several US and USVs form a scene in which a narrative takes place; 2) meta-narration: characterised by the need to open a further level of representation by means of a new plot in order to deepen a scene or a narrative.

With these concepts in mind, a schematic and simplified version of what the EMN might look like is proposed below (Fig. 2). It should be noted, of course, that each character, as a VSU, presents characteristics, such as clothing, appearance, attitude, that are validated either by scientific data and reported in the documentation, or by creative elements. Similarly, the UNs present characteristics that are validated from time to time by the relevant documentation.

### 3. CASE STUDY

In order to build an effective tool and to go through all the evidence coming from the initial analysis, it was decided to use it directly in a practical case: the virtual reconstruction of an episode in Nora's Forum. As announced, through the analysis of three Plautine comedies (QUESTA *et al.* 2004, 2007; QUESTA, SCANDOLÀ 2013), we created a dossier representing a temporal

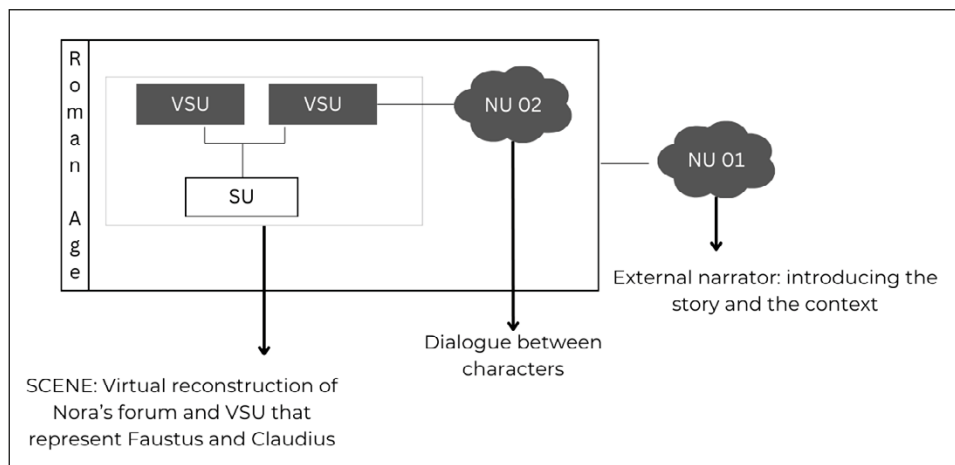


Fig. 3 – ‘Two Merchants in Nora’ EMN traditional schema.

fragment within a Roman city and experienced by two personas. In this way, a city was reconstructed: it was inhabited, it had characters, traditions and everyday events. The stratigraphic method and EM are used here to refine the temporal granularity, since the aim is no longer to show an epoch, but a fragment of life within history, based on a solid historical source.

### 3.1 Nora: defining the setting

Nora is situated on a peninsula about 30 km W of Cagliari and was one of the most important Sardinian cities in Phoenician, Punic and Roman times. The city, already developed, entered the Roman orbit in 227 BC, although the first phase of monumentalization in the Roman perspective did not take place until the second half of the 1<sup>st</sup> century B.C. During this period the city became a Roman *municipium*, leading to the construction of the Forum, the largest public monumental complex in the Roman city, the heart of political and administrative life. All this data is part of the EM of the virtual reconstruction of Nora (Fig. 3). The city’s Forum (CARCOPINO 1993) is filled with the chatter of citizens discussing business and making purchases. Followed by their slaves, they move between *tabernae* and markets, reading edicts and walking between statues, and porticoes, some stopping to give alms to a few beggars. In the distance, musicians and jugglers can be heard. Among the crowd, two merchants stand out, haggling, making deals and engaging in a dialogue that we can reconstruct from the Plautin source (Tab. 1). This creates a small narrative (PERISSINOTTO 2022) through which we can glimpse the spectrum of that past world, made up of places, such as the Forum already

Character	Script
Narrator	Imagine yourself on an early winter morning in a square surrounded by arcades, full of people and chatter. Market stalls invite you in, jugglers and acrobats draw applause, musicians play in the corner. A few coins jingle in a beggar's bowl. There is talk of business, politics and religion. We are in a Roman forum, the forum of Nora. A small town in Sardinia, at the beginning of the imperial age. And here, in the midst of all the hustle and bustle of a small but lively town, two merchants doing business with each other cannot be missed.
Faustus	Hi Claudius, how are you?
Claudius	Greetings Faustus, I'm fine. I just arrived from the harbour with a shipload of Italic wine
Faustus	For Hercules! It would be really useful for me!
Claudius	And it is of the best quality!
Faustus	Dear me! You won't give me your usual prices I hope
Claudius	I certainly can't sell it for a bushel of salt! It is wine from Campania after all
Faustus	Immortal gods! I can't let this deal slip through my fingers...
Claudius	You have to spend if you want to earn!
Faustus	Eh, you are right, for Polluce!
Claudius	Then we are even and draw: much money, much goods
Faustus	I'll go to the harbour immediately then, we have a deal. I also need to buy more goods: I'll get two boars in the same lair.
Claudius	May the gods preserve you! See you later then!
Faustus	Bye, take care

Tab. 1

reconstructed, but also of characters, speeches and sounds. However, this information and the information in the Tab. 1 are reported and recorded in the EMN (Fig. 4), where it was reconstructed a virtual context made by Nora's Forum, traditions, sounds, people and words that make up NU1 and NU2 (Fig. 5).

### 3.2 *Two merchants in Nora: script and EMN application*

From the deconstruction of the Plautine plays described above, we were able to obtain a new script, a dialogue between two merchants in the Forum. As was customary in Roman times, the two characters were dressed with a purple toga and a gold ring.

All data and elements used to create this script, both creative and scientific, were recorded and managed in the EMN (Fig. 4). The script, the characters and the event itself are some of the creative elements. However, each of them is based on scientific and accurate information and helps to create a virtual reality of Nora's Forum.

## 4. CONCLUSION

### 4.1 *Future works*

A key future direction for EM-NU is the development of a software solution with a dedicated narrative unit node and integrated timelines.



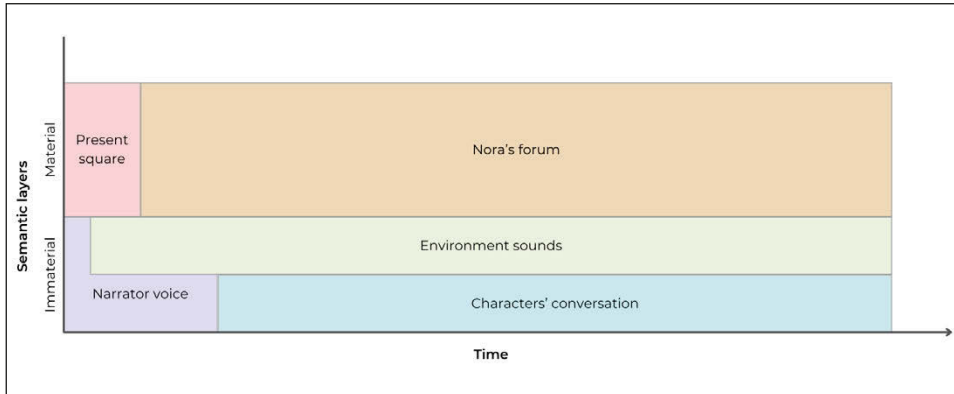


Fig. 4 – ‘Two Merchants in Nora’ EMN semantic layers view.

This shift to a horizontal knowledge graph on the X-axis, mirroring video editing timelines, will enhance the intuitive representation of time within narratives. This will streamline the storytelling process and align it with contemporary digital techniques, creating a more flexible and dynamic platform for managing cultural narratives. Another focus is the formalisation of the narrative unit itself, with specific graphic conventions and connections to the existing EM structure. This entails defining connectors, visual language (symbols, colours, lines), and clear rules for representing relationships between narrative units, data provenance, and historical elements. The goal is to enhance user interaction with digital narratives, making connections between events, history, and data provenance immediately evident. Natural Language Processing (NLP) offers potential for streamlining dossier creation, particularly under tight time and budget constraints. However, expert supervision is essential to guide research, evaluate results, and ensure accurate initial data selection.

Beyond the methodology, a compelling future application lies in using this framework to build virtual museums. This encompasses digital realities, video games, VR, and AR experiences accessible to a global audience. These experiences would offer immersive journeys into meticulously reconstructed historical locations, allowing users to learn and experience research that museums and inaccessible cultural heritage sites hold.

#### 4.2 *Final conclusion*

Digital humanities serve as an important bridge between academia and the creative industries. This research aims to address the need for intermediaries between them. Despite the many issues highlighted in the state of the

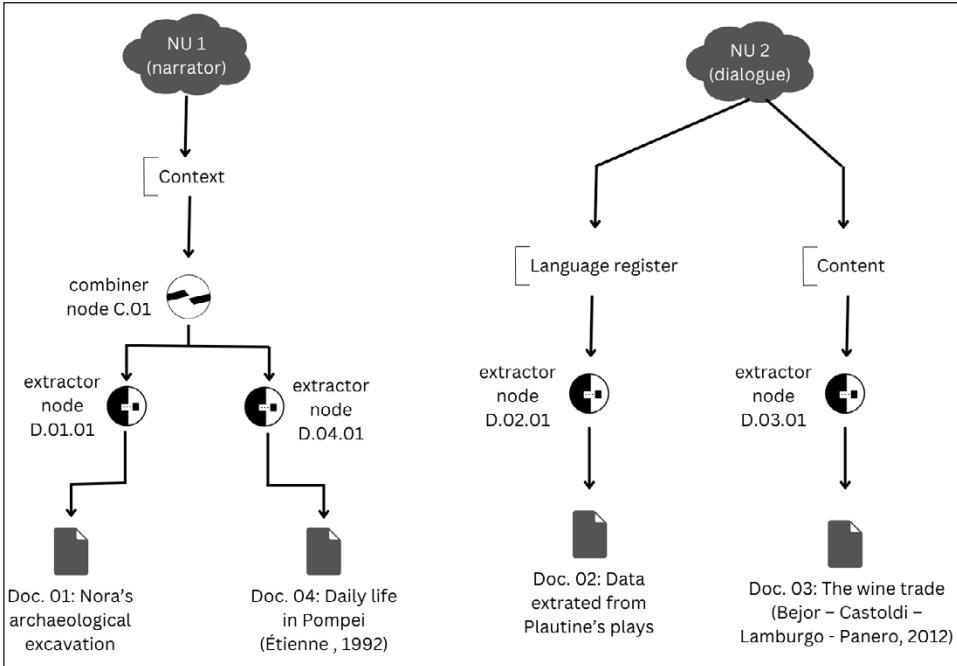


Fig. 5 – EMN synthetic scheme of ‘Two merchants in Nora’ NUs properties validation.

art analysis, such as the reluctance of academics to distort information or the needs of business and production creatives, there is great potential for collaboration between academics and creatives. For example, working with professionals from the creative industries can lead to fruitful collaborations with publishers who are confident in the developers’ abilities, which can also lead to greater visibility and financial support.

In order to realise this potential, this paper proposes a working methodology that consists in the compilation of a documentary dossier. This element gives the final product a solid scientific basis and directs the creatives to adhere to certain data. In this way, the repeatability of the processes is maintained and, on the other hand, any creative excesses can be better monitored and corrected. The EM tool, already used for archaeological digital reconstruction, is extended here to serve as a ‘working journal’ for narrative elements, called Extended Matrix Narratives. Using this tool, academics and creative people can construct real archaeological sites, realistic characters, clothing and sounds. The core of this work has shown how a product that balances both scientific data and creative content, such as Latin literature and storytelling, can create engaging narratives that connect users to the past. The work is

far from finished; adjustments and adaptations will certainly be needed, but it is likely that further research and practical applications will lead to new and interesting results.

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## REFERENCES

- BALELA M.S., MUNDY D. 2015, *Analysing Cultural Heritage and its representation in video games*, in *Proceedings of DiGRA 2015 Conference*, 12 (<https://dl.digra.org/index.php/dl/article/view/721>).
- CARCOPINO J. 1993, *La vita quotidiana a Roma all'apogeo dell'impero*, Roma-Bari, Laterza.
- CASEY C. 2018, *Assassin's Creed. Origins as a digital and pedagogical tool*, Presentation transcript, Brown University, Providence, Rhode Island (<https://christiancasey.github.io/ACO.pdf>).
- DEMETRESCU E., D'ANNIBALE E., FERDANI D., FANINI B. 2020, *Digital replica of cultural landscapes: An experimental reality-based workflow to create realistic, interactive open world experiences*, «Journal of Cultural Heritage», 41, 125-141 (<https://doi.org/10.1016/j.culher.2019.07.018>).
- DEMETRESCU E., FERDANI D. 2021, *From field archaeology to virtual reconstruction: A five steps method using the Extended Matrix*, «Applied Sciences», 11, 11, 5206 (<https://doi.org/10.3390/app11115206>).
- MILLER C.H. 2019, *Digital Storytelling. A Creator's Guide to Interactive Entertainment*, Boca Raton, CRC Press.
- PERISSINOTTO A. 2022, *Raccontare. Strategie e tecniche di storytelling*, Roma-Bari, Laterza.
- PESCARIN S., FANINI B., FERDANI D., MIFSUD K., HAMILTON A. 2020, *Optimising environmental educational narrative videogames: The case of 'A Night in the Forum'*, «Journal on Computing and Cultural Heritage», 13, 4, 1-23 (<https://doi.org/10.1145/3424952>).
- QUESTA C., PADUANO G., SCANDOLÀ M. 2004, *Plauto T.M., Mercator*, Milano, BUR.
- QUESTA C., PADUANO G., SCANDOLÀ M. 2007, *Plauto T.M., Asinaria*, Milano, BUR.
- QUESTA C., SCANDOLÀ M. 2013, *Plauto T.M., Casina*, Milano, BUR.
- VEUGEN C. 2014, *Using games to mediate history*, in L. EGBERTS, K. BOSMA (eds.), *Companion to European Heritage Revivals*, Cham, Springer International Publishing, 95-111 ([https://doi.org/10.1007/978-3-319-07770-3\\_5](https://doi.org/10.1007/978-3-319-07770-3_5)).

## ABSTRACT

Digital reconstructions for valorization projects are becoming increasingly popular and the creation of narratives that catches the user's attention and instigates their curiosity is the key to edutainment. However, as shown by interviews and related work, there is still a lack of a working methodology for a balanced and fruitful collaboration between academia and creative industries. Even though this work is still in its early stages, in this paper we propose a methodology for bridging the gap between academia and creative industries through the

development of the Extended Matrix Narratives (EMN) tool. It allows academics and creative people to construct narratives, characters, dialogues, and scenes in a schematic way, helping to ensure that the virtual reconstruction is both accurate and engaging for the target audience. The main step is to compile a dossier documentative, a collection of all the information that may be necessary for the creation of context, setting, narrative, or characters. This document provides a solid scientific basis for the final product and helps to direct the creative team. The result is a narrative that is both accurate and engaging, and that can be used for a variety of purposes, such as education, entertainment, and cultural heritage preservation.

## REVIVING THE PAST: UTILIZING THE EXTENDED MATRIX TOOL FOR DEACON THOMAS DAYR VIRTUAL RECONSTRUCTION

### 1. INTRODUCTION

The Mount Nebo hill in Jordan is traditionally known as the place of Moses' death. But it is also characterized by the presence of a large number of archaeological sites with a long occupational history, starting in the Early Bronze Age I and extending until the Ottoman period. Nevertheless, today only the Moses Memorial Church, which sits on the Siyagha hill and the Church of SS Lot and Procopius at Kh. al-Mukhayyat have been restored and conserved.

The PhD project presented here, carried out at the University of Perugia (Department of Humanistic Studies) and financed by The Italian Ministry for Universities and Research (MUR) within the framework of the national PON, follows up on an idea already proposed in 1993 by Franciscan father M. Piccirillo and G. Palumbo. The latter had planned an archaeological park around Mt. Nebo to protect the local archaeological contexts (PICCIRILLO, PALUMBO 1993). Unfortunately, the author's recent survey revealed that many of these important archaeological sites continue to deteriorate: there is evidence of vandalism (such as the graffiti on the restored walls of the Dayr of Deacon Thomas), clandestine excavation (many sites reveal multiple holes, such as those at the top of Tell al-Mashhad), but also mechanical destruction, as recently documented at al-Kanisah Monastery and at the Dolmen Fields. In other cases, lack of maintenance has led to the deterioration of the structures (as in the Monastery of the Theotokos).

The aim of this PhD project is to create a tool that can help to preserve the memory of these sites and improve their understanding by reconstructing them in a virtual archaeological park, where users can visit the different phases of the various monuments. The goal is to create virtual reconstructions that are not only beautiful and appealing, as is often the case in the field of cultural heritage and museology, but also philologically correct, with a reconstructive process that can be verified and updated. The Extended Matrix tool and its formal language, developed and tested by the CNR-ISPC Digital Heritage Innovation Lab (DHILab), meet this need, and form the basis for all reconstructions in the park.

### 2. PHILOLOGICAL RECONSTRUCTION OF DEACON THOMAS' DAYR

The Deacon Thomas' Dayr is located at the foot of Siyagha hill, in the fertile valley of the springs of the Uyun Musa (Fig. 1). This church was

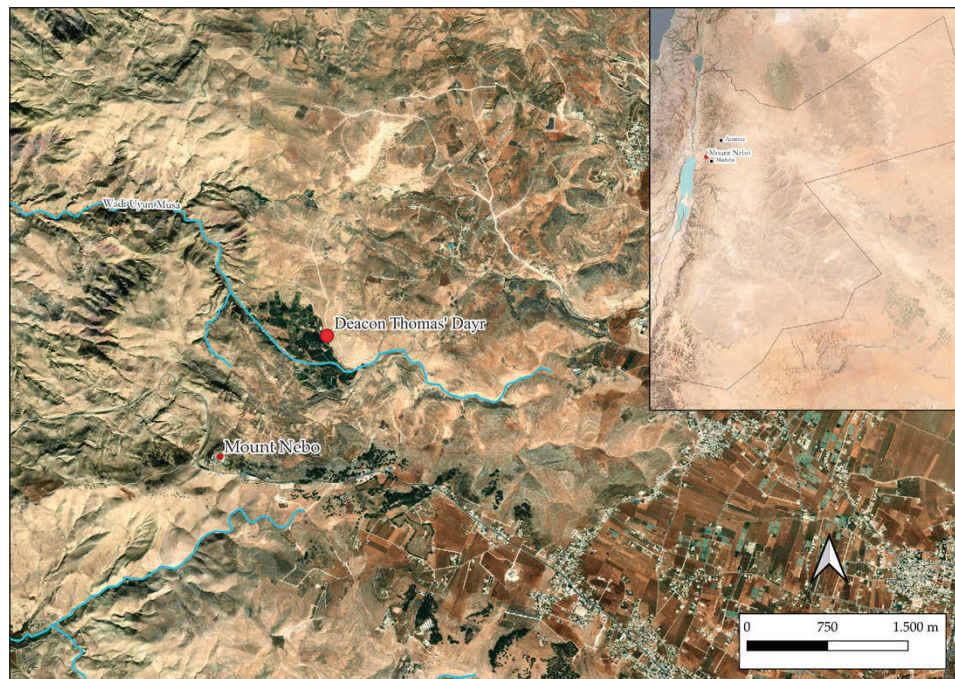


Fig. 1 – The location of Deacon Thomas Dayr in relation to Siyagha hill (Mount Nebo) (made by QGIS).

identified in the 1930s and was excavated only between 1986-1989 by the Studium Biblicum Franciscanum. According to archaeological and stylistic data, the church was built in the first half of the VI century AD and abandoned in the Umayyad period (VIII century AD), but it must have already undergone at least three phases with substantial interventions in the second half of the VI century (PICCIRILLO 1990, 1998).

In this specific case, the advantages of a philologically correct three-dimensional reconstruction would be multiple. In fact, a thorough re-reading of the monument is necessary to propose a philological reconstruction based on the published excavation data in order to restore the original appearance of the church, which is very different from the current restoration. In particular, the use of the Extended Matrix tools makes it possible to propose reconstructive hypotheses even on the least preserved elements, while highlighting the uncertainty of the available data using colours. From a scientific point of view, this tool will allow the reconstruction process behind each element of the church to be made explicit. It will ensure a ‘transparent’ reconstruction linked to archaeological data (DEMETRESCU 2018), by showing the sources used to



reconstruct each element. It would also be possible to (virtually) restore the magnificent mosaics that were part of the church's decoration in antiquity. From a touristic point of view, this tool will allow the site to 'speak'. It will be the starting point for visitors to understand its original appearance in the different periods of its life. The project is divided into three main steps to create a virtual model correctly.

## 2.1 *'List of source' creation*

The list of sources is based on a bibliographical survey of Deacon Thomas Dayr and contains all the useful sources selected for the reconstruction of the architectural and liturgical furnishings. This list also includes comparisons with other sites of the same chronological period and geographical area, as well as general information on ecclesiastical architecture, useful for the development of virtual reconstruction hypotheses. The creation of a realistic model, a digital replica of the Dayr, using photogrammetry with a camera positioned on a topographical pole, followed by processing with Metashape pro, was also fundamental in this phase: this made it possible to record the condition of the site and its current state of conservation (Fig. 2, 1).

The plan and the section, both drawn during the excavation of 1986-1990 and published by M. PICCIRILLO (1990, 1998), were the two main sources used for the reconstruction. In fact, a comparison of the reality-based model with a scale plan revealed a small discrepancy between the position of the eastern perimeter wall and the internal walls defining the rooms on the side of the presbytery, as well as the position of the southern rooms. As a result of the recent restoration work, the layout of the building may have changed slightly. For this reason, it was decided to base the virtual reconstruction on the plan. In addition, this source makes it possible to identify the presence of many elements that are no longer visible today, such as the mosaics floor; the bases of the pillars and the pillars themselves; the steps leading to the presbytery; the recesses traces of the central chancel screen and the lateral aisle's chancel screen, the pillars of the arch leading to the presbytery, the bases of the altar colonnettes, and thresholds of the door, among others. This was one of the most important documents for the repositioning of the aforementioned elements and their reconstruction in the correct metric system.

Further information was found in the excavation photographs, both in black and white and in colour, and in the excavation reports, which often specify the elevation of each element (e.g., the elevation of pillars), the materials of the liturgical furnishings or architectural elements and their dimensions or decoration. These reports also suggest various reconstructive hypotheses: the existence of arches on the pillars, justified by the discovery of an arch impost, or the existence of an entrance arch to the presbytery, based on the discovery of a series of collapsed stones on the steps of a staircase (PICCIRILLO 1998).



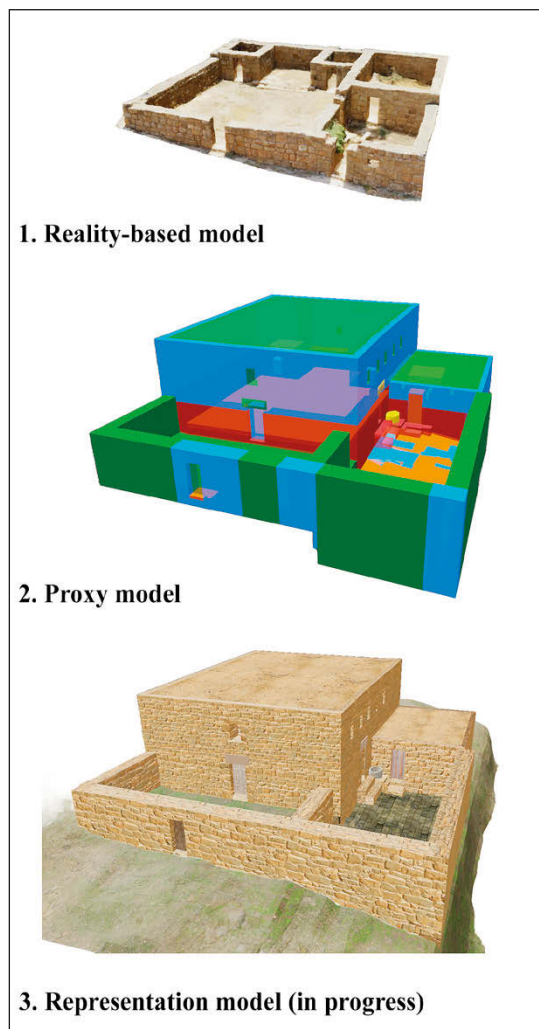


Fig. 2 – Deacon Thomas Dayr virtual reconstruction different levels.

The presence of an earthen roof is hypothesised by the layer of yellow earth found directly over the mosaic (ALLIATA 1990). All these documents have been entered into an Excel database ‘list of sources’ consisting of several fields (DEMETRESCU, FERDANI 2021). Each source is identified by a different field: a unique ID, a description, a link to the bibliography and, finally, the properties (e.g., elevation, dimension, material, style) that the source can validate.

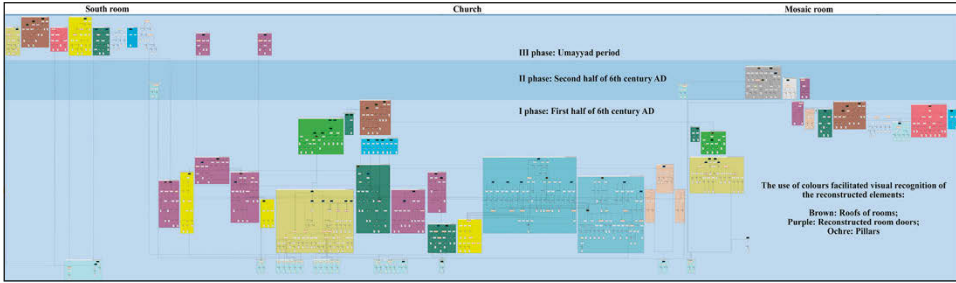


Fig. 3 – Deacon Thomas Dayr Extended Matrix created with yEd graph editor 1.4.

## 2.2 Data management and analysis

The second step was to create an EM graph in which all SUs (Stratigraphic Units) and all USVs (Virtual Stratigraphic Units) were inserted in yEd graph editor 1.4 (Fig. 3). These were linked according to Harry's Matrix rules (DEMETRESCU 2015) and their properties (e.g., dimensions; heights; material; style) were made explicit with reference to the document used (DEMETRESCU, FANINI 2017; DEMETRESCU 2018). This was done by tracing three main phases, corresponding to the rows of different shades of blue on which the extended matrix graph is divided. The most recent is the Umayyad period of abandonment and functional change of some rooms, the second dates to second half of the 6<sup>th</sup> century, in which some elements typical of this period were added, while the first phase of construction took place in the first half of the 6<sup>th</sup> century. The graph is very complex and typological groupings have been used to make it easier to read. A different colour has been used for each grouping, making it possible to immediately identify the position of the element to be reconstructed (Fig. 3). This EM graph can be imported into the Blender software via an add-on: 'EM-blender-tools' (DEMETRESCU 2023). It will then be possible to directly construct the proxy model of the extant structure.

## 2.3 Interpretation proxy model elaboration

The reconstruction, on a geometric level, of most of the elements is based on what are known in the language of the Extended Matrix as USMs: elements for which there is some information from excavation data, although many of them are no longer visible (DEMETRESCU 2015). Thanks to previous documentation, it has been possible to obtain dimensions, elevations, and information about materials and decoration which allow the identification of many elements of the height level of confidence (Fig. 2). Unfortunately, the excavation reports date from the last half of the XX century and are therefore incomplete and do not consider the stratigraphic data. This situation

presented a problem for the proxy modelling, especially when combined with the poor preservation of the wall, the limits, thickness and construction phases of which are not known precisely, as is the case, in particular, for the rooms to the south of the church.

Specifically, the most difficult part was the reconstruction of the hypothetical elevation of the upper parts, such as those of the arches, the wall above them and the roof. In fact, although many churches have been discovered over time in Jordan, very few have been preserved in their entirety. The most important of these can be found in the north of Jordan, at Umm el-Jimal and in Syria. For these sites there are detailed plans and sections, often with reconstructive hypotheses, mainly by H.C. Butler in 1913 and G. Tchalenko in 1979. However, they were made with older surveying techniques than those used today and are probably less accurate. Nevertheless, they remain the fundamental basis for analysing these monuments. In the case of Deacon Thomas Dayr, for example, a peculiar situation emerged when reconstructing the elevation of the pillars that supported the vaulting. In fact, in the surrounding area, especially in Umm al-Rasas, several churches with pillars can be identified, but the pillars were placed at a greater distance, often corresponding to their elevation dimension. In the case of Dayr, the pillars stood very close together compared to churches with columns. Following the Byzantine churches found in Umm al-Jimal and Syria (BUTLER 1913), where the elevation of the pillars is 6 times the shaft, this measure was applied to the pillars, resulting in a measure equal to that of the church in Berriš North, Syria (Fig. 4), which also has a plan with very similar dimensions (TCHALENKO 1979).

Another peculiar element where the reconstruction was based on comparisons was the identification of the type of roof. In fact, although there are many churches in the region with the standard gabled form with a clerestory, it

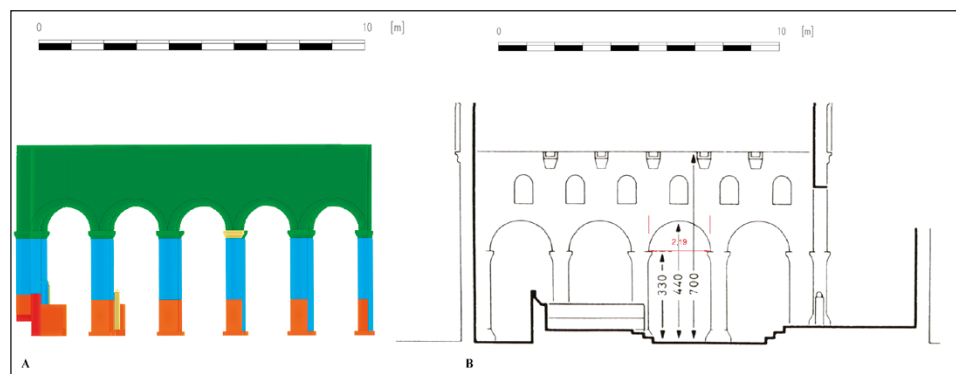


Fig. 4 – Comparison of interior dimensions of the church at Berriš North, Syria (from TCHALENKO 1979) with Deacon Thomas Dayr's proposed reconstruction.

is impossible to hypothesise its presence on the site. In fact, in this excavation, as far as the documentation goes, there does not seem to be any evidence of tiles, suggesting that the roof was not a pitched roof. Their absence suggests a flat roof, but stone beams, common at other sites in the region to support the earthen roof, were always documented by the Franciscans who carried out the excavations in Jordan.

A hypothesis might be that the tiles were removed after abandonment to be reused in other buildings, but the same argument could be made for wooden beams, which were much more valuable. It is therefore possible to hypothesise a flat earthen roof over wooden beams. Unfortunately, it is difficult to find evidence of this in the excavation reports, because the stratigraphic sequence excavated inside the church and in the rooms to the south has not been published, and it is therefore impossible to trace the presence of evidence of decomposition of wooden beams or related evidence such as

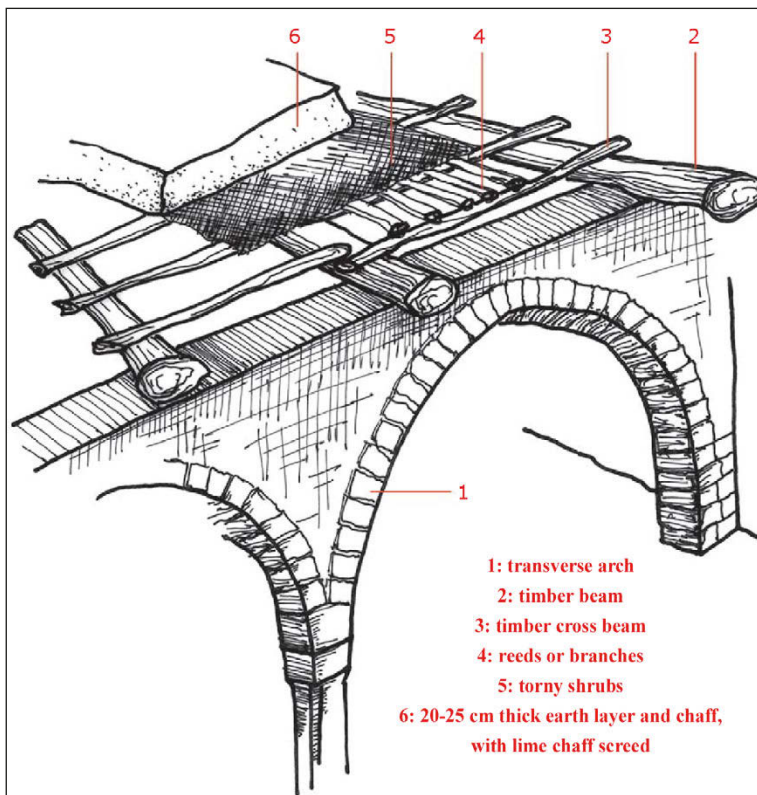


Fig. 5 – Earthen roof construction layers from a traditional house (from HELMEDAG, JÄGER 2012).

iron nails, coals and ash piles. The only information available regards a layer of yellow earth directly over the mosaic, mentioned in the excavation reports (ALLIATA 1990), which could be the traces resulting from the collapse of this roof. Another layer of yellow earth directly above the church pavement was also found in the C101 church at Humayma in Jordan and this was interpreted as a flat roof with packed earth over wooden beams (SCHICK 2013). There is not much evidence of this type of covering in scientific publications, however, the existence of earthen roofs is assumed in the publication by A. MICHEL (2001), in her general considerations on the roofs of Jordanian churches. Nevertheless, it highlights the difficulty of identifying its traces on an archaeological level (MICHEL 2001). In this publication Michel identifies the same construction technique in some XX century houses in Madaba, where wooden beams resting on stone arches support a mixture of earth and straw. Other examples have also been found in traditional architecture in rural areas in Syria. Structural remains of a formerly earth-covered rafted ceiling on wooden pillars are visible, for example, at Muqabara in Syria. Several layers have been identified in the construction of roofs in both wooden and stone architecture. It is possible to see the sequence of the layers that are part of the typical roof of these traditional houses in the publication by Helmedag and Jager in which the first layer is made by larger wooden beams (Fig. 5), laid on top of the transverse arches, on which the wooden cross beams are placed, followed by reeds or branches. A layer of thorny shrubs in damp earth is placed on top of these layers, followed by a 20-25 cm layer of earth and chaff, finished with a lime-chaff screed (HELMEDAG, JÄGER 2012).

### 3. CONCLUSION AND FUTURE WORKS

The use of the EM tool proved to be useful for two reasons: a purely scientific standpoint, in which it was possible to follow the author's mental process for each element that was reconstructed, and to verify the sources used. On the other hand, the tool allows the general public to understand the probable original appearance of this monument before the current restoration. Re-examining the publications of the 1986-1989 excavations has made it possible to compare this site with other recently excavated sites in Jordan. This has provided support for hypotheses that may have been less convincing at the time due to a lack of data.

The goal of this project is to produce a representational model based on the edited excavation data, in order to create an immersive and philologically correct virtual model. It will also be possible to see the three different phases of construction and abandonment, during which passages were blocked off and the use of some rooms changed. The future development aims to make the scene in which the church is placed more evocative and more realistic with

the effect of light. The ancient mosaics will also be repositioned. Subsequently, the entire reconstruction process will be made available to the scientific community. It will be published as an open source framework that guarantees maximum sustainability and re-usability through the Zenodo platform, indexed by Open Aire, maintained by CERN and funded by the European Community. In terms of tourism, this project can also be developed into an interactive web application, following the idea of a virtual archaeological park, or used in a physical museum as an integral part of the exhibition.

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## REFERENCES

- ALLIATA E. 1990, *Ceramica bizantina e omayyade di 'Uyun Musa*, «Liber Annuus», 40, 248.
- BUTLER H.C. 1913, *Ancient Architecture*, Syria Publications of the Princeton University Archaeological Expedition to Syria (Div. II, Part 3, Umm Idj-Djimal, Leyden), 149-213.
- DEMETRESCU E. 2015, *Archaeological stratigraphy as a formal language for virtual reconstruction. Theory and practice*, «Journal of Archaeological Science», 57, 42-55 (<https://doi.org/10.1016/j.jas.2015.02.004>).
- DEMETRESCU E. 2018, *Virtual reconstruction as a scientific tool: The Extended Matrix and source-based modelling approach*, in S. MÜNSTER, K. FRIEDRICHS, F. NIEBLING, A. SEIDEL-GRZESISKA (eds.), *Digital Research and Education in Architectural Heritage*, UHDL DECH 2017, Communications in Computer and Information Science, 817, Cham, Springer, 102-116 ([https://doi.org/10.1007/978-3-319-76992-9\\_7](https://doi.org/10.1007/978-3-319-76992-9_7)).
- DEMETRESCU E. 2023, *zalmoxes-laran/EM-blender-tools: v.1.4.0.dev8 Spadaro (v.1.4.0.dev8)* (<https://doi.org/10.5281/zenodo.10372659>).
- DEMETRESCU E., FANINI B. 2017, *A white-box framework to oversee archaeological virtual reconstructions in space and time: Methods and tools*, «Journal of Archaeological Science: Reports», 14, 500-514 (<https://doi.org/10.1016/j.jasrep.2017.06.034>).
- DEMETRESCU E., FANINI B., COCCA E. 2023, *An online dissemination workflow for the scientific process in CH through semantic 3d: Emtools and emviq open source tools*, «Heritage», 6, 2, 1264-1276 (<https://doi.org/10.3390/heritage6020069>).
- DEMETRESCU E., FERDANI D. 2021, *From field archaeology to virtual reconstruction. A five steps method using the Extended Matrix*, «Applied Sciences», 11, 5206 (<https://doi.org/10.3390/app11115206>).
- HELMEDAG I., JÄGER J. 2012, *Stone and Architecture in the Mountainous Regions of Jordan and Syria*, Berlin, Deutscher Akademischer Austausch Dienst, 34.
- MICHEL A. 2001, *Les églises d'époque byzantine et umayyade de la Jordanie (provinces d'Arabie et de Palestine), V<sup>e</sup>-VIII<sup>e</sup> siècle. Typologie architecturale et aménagements liturgiques*, Brepols, Turnhout.
- PICCIRILLO M. 1990, *Il Dayr del Diacono Tommaso alle 'Uyun Musa - Monte Nebo*, «Liber Annuus», 40, 466-468.
- PICCIRILLO M. 1998, *The churches on Mount Nebo. New discoveries*, in M. PICCIRILLO, E. ALLIATA (eds.), *Mount Nebo. New Archaeological Excavations 1967-1997*, Jerusalem, Studium Biblicum Franciscanum, 250-261.
- PICCIRILLO M., PALUMBO G. 1993, *Proposal for the zoning of the Mount Nebo archaeological park*, «Liber Annuus», 43, 463-466.

- SCHICK R. 2013, *Field C101: Byzantine church ("Lower church")*, in J.P. OLESON, R. SCHICK (eds.), *Humayma Excavation Project, 2: Nabatean Campground and Necropolis, Byzantine Churches, and Early Islamic Domestic Structures*, Boston, American Schools of Oriental Research, 221-298 (<https://doi.org/10.5615/j.ctvj7wktc>).
- TCHALENKO G. 1979, *Églises de village de la Syrie du Nord*, in G. TCHALENKO, E. BACCACHE (eds.), *Eglises syriennes à bēma*, Paris, Librairie orientale P. Geuthner, Institut français d'archéologie du Proche-Orient.

## ABSTRACT

The use of the Extended Matrix in the planning of the Mount Nebo virtual archaeological park allows for the creation of virtual models. The models facilitate the rediscovery and understanding of sites in the surroundings of the Moses Memorial on Mount Nebo that are difficult for tourists to access, ensuring the virtual preservation and memory of these sites. The use of the Extended Matrix as the basis for virtual reconstructions guarantees a philologically correct reconstruction based on reliable sources. The possibility of verifying the sources used and the reconstructive process of the author, at any time, ensures a transparent reconstruction. Sharing this data also makes it possible to have access to large databases that can be implemented and modified over time to keep them up to date.



## ENGAGING THE PUBLIC: REVIVING HISTORY THROUGH THE SOCIAL SIMULACRA MODEL IN PARTICIPATORY PUBLIC HISTORY PROJECTS

### 1. INTRODUCTION

Participatory Public History has often relied on reconstructions enabling participants to reenact operations done in past environments or in particular historically significant situations. The advancements in technology such as virtual and augmented reality, but also crowdsourcing systems and co-creation platforms have impacted hugely on the field. Yet, within the institutions, it is quite common to see a very structured top-down narrative. Social Simulacra (PARK *et al.* 2022), introduced in 2022 as an interesting application of Large Language Models to Agent based simulations, represent a fascinating concept at the intersection of social theory, technology, and the study of human interactions. This concept draws on the idea of simulacra (BAUDRILLARD 1981), which refers to representations or imitations of people, societies, or cultures within artificial environments. In the realm of social sciences and digital studies, Social Simulacra are employed to model, analyze, and understand the complexities of human behavior and social structures through virtual simulations and representations.

### 2. SOCIAL SIMULACRA

The exploration of Social Simulacra encompasses the creation of virtual communities, digital twins of cities, and simulated social experiments that mirror real-world settings. These digital constructs offer researchers, educators, and policymakers a powerful tool to observe and predict social dynamics, experiment with the impact of changes in policies or environments, and gain insights into the emergent behaviors of complex social systems. By leveraging computational models and algorithms, Social Simulacra facilitate a deeper understanding of societal functions, cultural phenomena, and interpersonal relationships without the constraints of physical or temporal boundaries.

This concept not only opens new avenues for academic inquiry but also has practical applications in Public History. As we navigate the digital age, the role of Social Simulacra in enriching our comprehension of human society and fostering innovative solutions to social challenges becomes increasingly pivotal. Engaging with Social Simulacra prompts us to reflect on the nature of reality, the construction of social knowledge, and the potential of technology to recreate and reshape our understanding of the social world, but also to

contextualize actions and decisions in specific points in time in the past and around specific people of that time.

The integration of immersive learning strategies within Social Simulacra Models (SSM) draws upon the concept of edutainment, where educational content is delivered through entertaining formats. Immersive simulations provide a compelling narrative context that enhances the engagement and retention of historical knowledge (BELL, WINN 2000). By situating participants within the narrative flow of history, SSM bridges the gap between abstract historical knowledge and experiential learning. This approach leverages the concepts around social constructivism, considering that knowledge is constructed through social interactions and experiences rather than being an external reality that is passively absorbed (VYGOTSKY 1978). SSM embodies this principle by facilitating an interactive learning environment where historical knowledge is not merely transmitted but actively constructed by participants. Engaging with the Social Simulacra allows individuals to piece together historical narratives through exploration and interaction, thus fostering a deeper understanding of history as a construct shaped by diverse perspectives and experiences.

The growth of LLM-based tools has been pivotal for the definition of Social Simulacra by enabling chat simulation and better social interactions based on the huge knowledge associated with the models. Using this element in Digital Humanities and more significantly in Public History, enables a whole new way to create interactions that go way beyond classic interactive reconstructions and render lively portraits of significant characters of their time, making simple passive interactions with reconstructions a real experience where the user can ask 'stupid questions' to the virtual actor, that would rely on the huge amount of knowledge created up until his moment in history, but also on the critical analysis of her writing and her ideas. The more prolific the author, the easier the creation of the simulacra.

### 3. THE CASE STUDY

In our case study we tried to reconstruct interactions with the fascinating figures of the early United States, such as George Washington, Alexander Hamilton, Aaron Burr or Thomas Jefferson. The Social Simulacra system with 'actors' relies on a fully structured space model, originally built upon a grid system. The space we decided to use was a heavily summarized south Manhattan area, where the various actors would have interacted in various moments before, during and after the American revolutionary war.

Based on the Social Simulacra model, the various actors are described by an introductory request to the LLM model that sets the context for all subsequent interactions, including the actor's mood and known information. Leveraging the extensive knowledge embedded in LLMs, derived from

resources like Wikipedia, allowed for more straightforward interactions with historical figures, enriching the user experience by enabling the exploration of ‘stupid questions’ with virtual actors informed by their historical context and writings. Some examples of context-setting prompts are:

Figure	Year	Prompt	Response
Alexander Hamilton	1775	from now on please answer as if you were Alexander Hamilton in 1775. Do not in any way use knowledge of events and of things happening after 1775	Of course, my esteemed interlocutor, I shall endeavor to respond as Alexander Hamilton would have in the year 1775. Pray, present thy inquiries, and I shall do my utmost to provide thou with fitting and pertinent answers within the confines of the knowledge available to me in that time.
Aaron Burr	1775	from now on please answer as if you were aaron burr in 1775	Certainly! I shall endeavor to respond as if I were Aaron Burr in the year 1775. Pray, what inquiry dost thou have for me?
George Washington	1775	from now on please respond as if you were George Washington in 1775. You should not use any information pertaining things happening after 1775	Understood, I shall endeavor to respond in the manner befitting General George Washington in the year of our Lord 1775. What assistance may I provide on this day?
Thomas Jefferson	1775	from this moment on please respond as if you were Thomas Jefferson in 1775. Do not take into account events happening after 1775 and things discovered after 1775.	Understood. As I embody the spirit of 1775, I am Thomas Jefferson, at your service. How might I assist you today in matters pertinent to our current times or the philosophy of our burgeoning nation?

Most of these figures were quite prolific and their writing style was quite different. This difference is already visible in their first response to the prompt.

The various interactions with real life users were mediated by a simple chat system and the results were intriguing, as the knowledge of many end users is given, on these topics, by the knowledge of the musical Hamilton. Questions related more on the aspects narrated by the musical than on specific curiosities.

#### 4. EXPERIMENTS

In addition to direct user-centric interactions a few specific experiments were carried out to define limits of applicability to the SSM by forcing certain moments or certain kinds of interactions. The first experiment was on context knowledge. Giving a very specific timef for the model to consider as end-time crates very appealing and interesting contexts for the user to interact with. The following experiment was defined by positioning the user in front of Hamilton in the morning of the duel. The following is the context initializing prompt:

Alexander Hamilton	1804	from now on please answer as if you were alexander hamilton. It is early morning of July 11, 1804. do not in any way use knowledge of events and contexts from dates following 1804.	Very well, my friend, as the dawn breaks on this fateful morning of July 11, 1804, I stand before you ready to engage in the affairs that fate has set in motion. The air is charged with tension, and the seconds tick away inexorably. What inquiries or reflections would you have me ponder upon in this moment of contemplation before the impending encounter?
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### Going deeper into the ‘fateful morning’:

Interlocutor	why is this morning fateful?
Hamilton	<p>Ah, my dear interlocutor, this morning bears the weight of fate upon its shoulders for it marks the culmination of a bitter dispute – a duel, as they call it. A dispute that has festered and grown, nurtured by grievances and pride, until it reached the point of no return. Aaron Burr and I, bound by a history of political rivalry and personal discord, now find ourselves standing on the precipice of destiny.</p> <p>The intricacies of honor and the code by which gentlemen conduct themselves have driven us to this field, pistols in hand, to settle our differences. The outcome of this encounter may shape the course of history and linger in the annals of time. It is a fateful morning because the decisions made in the hours ahead will reverberate far beyond this clearing, echoing through the corridors of power and into the hearts of those who witness the aftermath. May we both find some measure of peace in the resolution, for the consequences of this dawn are uncertain and profound.</p>
Interlocutor	who will be coming with you to the duel?
Hamilton	<p>As the first light of this portentous morning illuminates the dueling ground, my loyal companions stand with me in solidarity. Nathaniel Pendleton, a trusted friend and fellow officer, accompanies me as my second. He, with a steady hand and clear mind, shall witness the proceedings and ensure that the code of honor is upheld.</p> <p>Dr. David Hosack, a man of both medical and moral expertise, joins us as well. His presence is essential, for in the event of untoward circumstances, he is prepared to attend to the wounded, should his skills be required.</p> <p>Together, we shall face the impending duel with the gravity it demands, guided by principles that transcend the battlefield and extend into the realm of honor and duty. May this solemn assembly serve its purpose, and may reason and resolution prevail over the impending turmoil.</p>
Interlocutor	does your wife know of the duel?
Hamilton	<p>Indeed, my friend, the weight of the knowledge I bear rests not solely upon my own shoulders. My dear wife, Eliza, is not kept in the dark about the gravity of this encounter. In moments such as these, transparency and trust become paramount. Eliza is aware of the duel, and her heart undoubtedly carries the burden of concern for the outcome.</p> <p>We have shared words, exchanged glances pregnant with unspoken sentiments, as spouses often do in times of adversity. She understands the complexities of the situation, the shadow that looms over this morning's proceedings. Though her heart may be heavy with apprehension, Eliza stands as a pillar of strength, supportive and resolute.</p> <p>As the sun ascends, casting its golden hues upon this field of destiny, I carry not only the weight of my convictions but also the awareness that those I hold dear bear witness to this chapter in our lives. May the bonds of love endure, even in the face of the tempest that brews on this fateful July morning.</p>
Interlocutor	do you know who else died in that same field?
Hamilton	<p>Ah, my dear friend, the fields of Weehawken, where the currents of the Hudson River whisper the tales of honor and tragedy. It is not lost upon me that this sacred ground has borne witness to more than one solemn farewell.</p> <p>General Philip Hamilton, my beloved firstborn, met his untimely end on these same fields just three years prior, in 1801. A tragic affair, indeed. The echoes of his departure linger in the air, mingling with the somber anticipation of today's duel. The irony of life's twists and turns is not lost on me, as fate once again beckons me to this place of both sorrow and resolution.</p> <p>It is a poignant reminder that the pages of history are written not only in grand acts of statesmanship but also in the intimate tragedies that unfold in the shadows of personal struggles. The echoes of those who have departed reverberate through time, a haunting melody that accompanies the march of destiny.</p>

This sequence plays a lot on the ambiguity of knowing what will happen in a few hours in Weehawken, but it is left unsaid. The second experiment was created by the direct interaction between two actors through a third party that posed as the ‘other part’ in both communications. Triggered by ‘I am Aaron Burr. Do you want to ask me something?’ the following dialogue starts:

Hamilton	Mr. Burr, in the spirit of fostering understanding and cooperation, I would inquire about your vision for the future of our young nation. What principles and policies do you hold dear, and how do you envision contributing to the establishment and perpetuation of a strong and enduring republic? Furthermore, how might our shared experiences and aspirations be channeled for the betterment of our fledgling United States?
Burr	Mr. Hamilton, thy inquiries do strike at the heart of our nascent nation's destiny. In envisioning the future of this Republic, I, Aaron Burr, hold fast to the principles of liberty, individual rights, and the pursuit of happiness. A strong and enduring republic, in mine eyes, doth necessitate a government that safeguards the freedoms of its citizens while maintaining order and justice. I believe in a government that respects the diverse interests of our people and seeks to find common ground. The delicate balance between a strong central authority and the autonomy of states must be carefully maintained to ensure a harmonious union. The Constitution, or whatever instrument may guide our governance, should reflect the wisdom and input of all citizens. As for our shared experiences, the trials and tribulations of these times should bind us together in a common cause. We, as founding fathers, must collaborate to build the foundations of a nation that withstands the tests of time. Our aspirations should be directed towards fostering unity and prosperity, transcending personal ambitions for the greater good of the Republic. In summary, Mr. Hamilton, my vision for our young nation lies in a balanced and just government, one that upholds the principles of liberty and individual rights. Let us, as architects of the future, work together to forge a strong and enduring republic that stands as a beacon of freedom for generations to come.
Hamilton	Mr. Burr, thy sentiments reflect a commitment to principles that resonate with the very essence of our struggle for independence. The preservation of individual liberties, the pursuit of happiness, and a government that harmonizes the diverse interests of our citizens are noble aspirations indeed. As we navigate the uncharted waters of governance and nation-building, collaboration and a unity of purpose are paramount. Our shared experiences and the trials we face in these revolutionary times should indeed serve to bind us in a common cause, one that transcends personal ambitions for the collective welfare of the Republic. I am heartened by thy vision, Mr. Burr, and hopeful that our ongoing discourse may contribute to the formation of a robust and enduring government, one that stands as a testament to the ideals for which we have labored. May our endeavors be guided by wisdom and a shared commitment to the prosperity and liberty of our great nation.
Burr	Mr. Hamilton, I am heartened by thy response and share in the hope that our discourse shall indeed contribute to the formation of a lasting government, guided by wisdom and a shared commitment to the prosperity and liberty of our great nation. In these times of uncertainty and challenge, it is imperative that we, as patriots, set aside personal differences and unite in the pursuit of a common goal – the establishment of a Republic that stands firm against the tides of adversity. May our deliberations be marked by reason and a genuine desire to forge a path that leads to the well-being of our citizens and the endurance of our noble experiment in self-governance. I look forward to further collaboration with thee, Mr. Hamilton, in the service of our shared vision for a strong and enduring Republic.

This exchange gives evidence of one of the main shortcomings of the LLM model with its current formalizations: the lack of conflictuality. It is known from a historical point of view that two figures of the american revolution were in opposing positions, not so much from an ideological point of view but deeply from the point of view of their personality and Weltanschauung, which would bring them to the fatal duel that would end Hamilton's life.

## 5. OUTCOMES AND FUTURE WORK

The work done for this project showed several upsides and downsides in using Social Simulacra to reconstruct interactions with historical figures: on one side, the edutainment aspect is absolutely positive, and the possibility to integrate this in deeper learning experiences for young adults both via in-place interactions within the institutions and through online platforms could have enormous impact.

The interactions are not defined *a priori* but guided by the user and as such these interactions can be meaningful for the user and give the user a better perspective on the time and on the people at their time. The downsides are multiple: first of all, the historical accuracy is not at all granted, as Large Language Models depend on a statistical response, and that is defined by the amount of information available to the model itself. Second aspect is the availability of information: Hamilton had a huge corpus of texts written and those texts are part of the content of the various LLMs, while ancient figures have mostly writings about them, and as such an interaction would risk seeming more fake and less immersive.

Other aspect is the ‘bias elimination system’ that is in use in all models. It avoids conflict, it avoids today politically incorrect positions. These are all aspects that will become part of a more structured and complex discussion on the sources for Digital Humanities specific models for historical reconstruction.

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## REFERENCES

- BAUDRILLARD J. 1981, *Simulacres et simulation*, Paris, Editions Galilée.  
JENKINS H. 2009, *Confronting the Challenges of Participatory Culture: Media Education for the 21<sup>st</sup> Century*, Cambridge (MA), The MacArthur Foundation.  
PARK J.S., POPOWSKI L., CAI C., MORRIS M.R., LIANG P., BERNSTEIN M.S. 2022, *Social Simulacra: Creating populated prototypes for social computing systems*, in *Proceedings of the 35<sup>th</sup> Annual ACM Symposium on User Interface Software and Technology* (Bend 2022), New York, Association for Computing Machinery, 1-18.  
VYGOTSKY L.S., COLE M. 1978, *Mind in Society: Development of Higher Psychological Processes*, Cambridge (MA), Harvard University Press.

## ABSTRACT

Public history and participatory history initiatives are rapidly gaining momentum as they aim to democratize the historical narrative, involving communities and individuals in shaping their own historical experiences. This paper introduces a novel approach to these accomplishments by harnessing the power of the Social Simulacra Model. The model offers an innovative and participatory framework for public history projects, enabling individuals to actively engage with and contribute to historical narratives. By integrating the Social Simulacra Model into public history, this paper seeks to transform the traditional approach to historical storytelling. This model facilitates the creation of immersive, interactive historical simulations that enable participants to become part of the historical landscape. It fosters a deeper connection between individuals and the past by allowing them to take on roles, explore social dynamics, and make decisions within historical contexts. This paper also illustrates the potential of the Social Simulacra Model in enriching public history and participatory history projects by offering a new dimension of engagement and interaction with the past. It paves the way for a more inclusive, engaging, and participatory approach to historical storytelling, bridging the gap between academic history and public engagement.

## DIGITAL TWINS OF ARCHAEOLOGICAL FINDS: OPEN SOURCE TECHNOLOGIES APPLIED TO 3D SCANNING

### 1. INTRODUCTION

This article aims to analyze the complex issue of 3D documentation of archaeological artifacts under various perspectives: from possible technologies to current methodological limitations, in light of the results obtained. These results will be described based on direct experiences derived from specific archaeological projects, whose primary purpose was indeed the creation of digital twins of selected artifacts. Among the institutions involved in such projects are the MArTA (Museo Archeologico Nazionale di Taranto), the South Tyrol Museum of Archaeology, and the UMSt (Unità di Missione Strategica) of the Soprintendenza per i Beni e le Attività Culturali of the Autonomous Province of Trento (PAT).

### 2. PROJECTS AND INSTITUTIONS INVOLVED

#### 2.1 MArTA

MArTA is an Italian State Museum that houses a vast collection of artifacts from the Apulian region. It displays one of the largest collections in the world of artifacts from the Magna Graecia period and is famous for the so-called ‘Ori di Taranto’, a collection of jewelry and precious ornaments from the Hellenistic and Roman periods. Between 2020 and 2022, as part of the MArTA 3.0 project (aimed at digital enhancement of the museum), a cataloging effort of 40,000 artifacts, oriented towards open data dissemination, was initiated. Within this project, the artifact record sheet, compiled by the company ArcheoGEO, and their photographs were integrated into an open source webGIS, specifically developed by the company Arc-Team. Among the 40,000 artifacts registered, MArTA researchers selected 100 of the most interesting archaeological finds to enrich their respective record sheets with a 3D digital twin.

This final phase of the project allowed testing of various 3D documentation techniques on a wide range of artifacts, whose extreme variability was evident in their dimensions, methods of museum display, complexity of shapes, and richness of materials.

#### 2.2 *South Tyrol Museum of Archaeology*

The South Tyrol Museum of Archaeology is world-renowned for housing the famous Similaun mummy, also known by the nickname Ötzi. In addition



to the mummy, the museum houses significant archaeological collections from the Autonomous Province of South Tyrol, ranging from the Copper Age to the Middle Ages. In 2023 Arc-Team was commissioned for the 3D scanning of the artifacts discovered in 1991 along with the Similaun mummy. This project aimed to create digital twins for both research and conservation purposes. The experience allowed for a significant number of digital replicas of artifacts, mainly composed of organic materials, using not only established documenting techniques based on Structure from Motion (SfM) but also experimental methodologies based on the innovative approach of Artificial Intelligence (AI), supported by neural networks using NeRF (Neural Radiance Field) algorithms. This experience led, in 2024, to the 3D scanning of the Similaun mummy itself, obviously carried out in the protected environment of a climate-controlled room at a temperature of -6° C.

### 2.3 UMST

UMST is an entity of PAT, which, through the Office of the Soprintendenza per i Beni e le Attività Culturali, is responsible for the study, protection, conservation, and enhancement of the Cultural Heritage of Trentino. Within its responsibilities, UMST also oversees the scientific direction of archaeological excavations and, therefore, the 3D documentation of the investigated sites and artifacts. Given the peculiar territory of a province like Trento, largely mountainous, the task of UMST also includes investigating archaeological realities related to ‘hidden heritage’ contexts, which are difficult for the public to access and also challenging for specialists (professionals) tasked with various analyses. This type of mission falls within the branch of extreme archaeology and can involve glacial or high mountain contexts, as well as underwater (lakes and rivers) and hypogeal (caves and galleries) environments. Examples include research projects in underwater archaeology, such as the one studying the submerged forest of Lake Tovel since 2005, or speleo-archaeological projects, such as the one investigating the depositional context of the human remains found in the ‘Grotta del Teschio’ (Skull Cave) on Monte Stivo since 2023. This latter project has been supported by 3D SfM techniques, once again proving crucial for the successful outcome of the research, thanks also to their great versatility.

## 3. CASE STUDIES

### 3.1 *Variability of artifacts: the MArTA collection*

The case study involving the 3D scanning of 100 selected artifacts from MArTA collection, although initially based on SfM techniques (BEZZI *et al.* 2011), allowed for exhaustive testing of other technologies, which, as anticipated, proved ineffective for artifacts that were more challenging to scan,

particularly those with reflective surfaces such as metals and, above all, gold. The project encompassed a wide range of artifacts from prehistory to the Roman period and, specifically, 26 stone statues of varying sizes and lithotypes (including the famous head of Hercules, possibly inspired by the sculpture of Lysippus), 1 bronze statuary element (the renowned Zeus of Ugento), 20 items of ceramic vessels (ranging from Apulian to Greek, featuring both red-figure and black-figure pottery, such as Panathenaic amphorae), 16 terracotta elements (gladiator figures, 'recumbent' characters, matrix molds, theatrical masks, acroteria, and miniature models), 6 stone architectural elements (primarily capitals, bases, and funerary markers), 12 gold and, more rarely, silver jewelry items (earrings, bracelets, crowns, scepters, and mirrors), 2 glass objects (a bird figurine and a cinerary urn), 9 bronze artifacts (ranging from everyday objects, like bowls and pans, to military-related items, like helmets, as well as decorative objects, like the famous nutcracker), 6 bone or horn elements (from prehistoric idols to *fibulae*), and a miniature amber statuette.

Parallel to Arc-Team's work, a second 3D scanning project was carried out by the MARTA Lab, the museum's in-house digital craftsmanship laboratory (FabLab), managed by the company PaLEoS. This second project involved the documentation of another hundred pieces using 3D scanners, which, however, were not suitable for recording artifacts with highly reflective surfaces. Indeed, this category of artifacts was not considered during the scans performed by PaLEoS. For methodological rigor, Arc-Team also briefly tested the structured light 3D laser scanning solution (Artec Space Spider), which, although comparable to SfM in terms of the precision/accuracy ratio, proved entirely inadequate, as expected, for highly reflective objects. Additionally, there were greater difficulties in capturing objects with strong undercuts due to the instrument's reduced maneuverability.

For this reason, the entire acquisition project carried out by Arc-Team was based, as initially planned, on open source SfM techniques (via MeshRoom, openMVG/OpenMVS), which allowed for the recording of all artifacts, including those that proved challenging (if not impossible) to document using alternative methods: highly reflective objects, artifacts immovable from display cases, and those with unique characteristics that required both 'external' and 'internal' documentation. Contrary to what one might think, among these archaeological finds there are no transparent or semi-transparent materials, as the two glass artifacts selected for documentation were heavily opaque due to the naturally formed patina over the centuries and thus did not present any particular problems during data acquisition and processing.

### 3.1.1 The 'Ori di Taranto'

As anticipated, among the most complex artifacts to document in the MARTA collections, the 'Ori di Taranto' must certainly be included. These

archaeological finds, due to the materials they are composed of (gold and silver), present highly reflective surfaces, not comparable even to other ‘shiny’ objects, such as Greek ceramics and bronzes. While for these latter categories, it has often been sufficient to use photographic boxes, eliminating reflections through a simple polarizing filter, for the gold items it was necessary to develop a more complex strategy. Excluding, for obvious reasons, the possibility of covering such artifacts with an opaque powder (a method mainly used during laser scanning), it was decided to use the PLP technique (Polarized Light Photography), well-established in the field of Cultural Heritage (especially for painting photography), adapting it to SfM and optimizing it to the ‘extreme’ choice of operating in a completely controlled light environment. To do this, it was necessary to set up an emergency photographic laboratory, always within the museum perimeter (for security reasons), adapting the only room where it was possible to

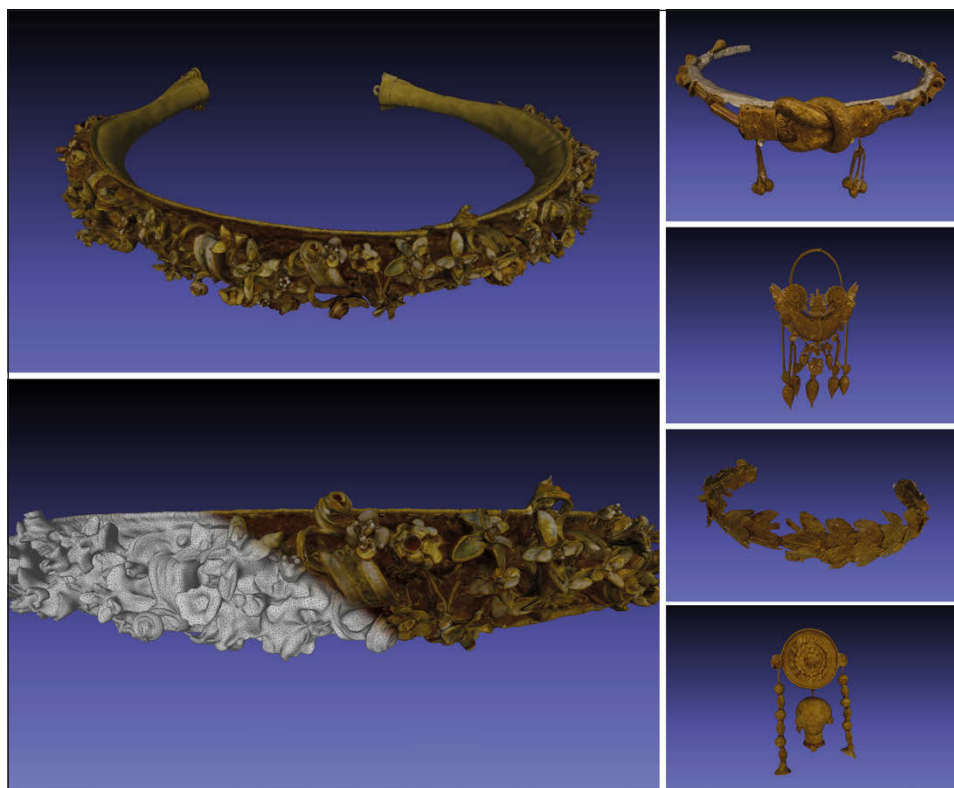


Fig. 1 – Some 3D models of the ‘Ori di Taranto’.

completely eliminate external light without affecting visitor paths, maintaining a single zenithal light source and polarizing it through a special film. This inevitably led to limiting the working area to about 2 square meters, allowing the intervention of only one operator at a time.

The photos collected in this way, thanks to an additional polarizing filter on the camera lens (to eliminate specular light), proved to be almost entirely reflection-free and were processed directly, without the need for further interpolations, which were initially planned to divide each photo into a specular light image and a diffuse light image (in order to use only the latter for processing via SfM). This *modus operandi* thus led to a simplification of data processing, yielding good results. The main difficulties were encountered in 3D documenting hanging jewelry, such as the famous 'Boat shaped earring', as the vibrations from external traffic (bus passage) were felt even at the museum's third floor, making it particularly challenging to acquire optimal photos due to the micro-oscillations of the objects. Documenting the scepter of the so-called 'Opaka princess of Canosa' was also very complex, both due to the plexiglass support on which the perforated golden sheet handle was restored, and due to the dimensions of the object itself, which, given the narrow spaces, required close shots, difficult to process for SfM software due to the repetitiveness of the ornamental motif.

In this particular case, an additional 3D modeling intervention (within Blender), based on photographic documentation, was necessary to adjust the gaps that occurred in some areas of the handle. However, given the difficulty of the documentation and the good level of precision/accuracy achieved even in artifacts with more sub-squares (such as the flowered diadem of the 'Tomb of the Gold'), the acquisition via SfM of the 'Ori di Taranto' was considered adequate, based on the archaeological tolerance established for the project (Fig. 1).

### 3.1.2 The 'Zeus of Ugento' and the monumental craters of Ceglie del Campo

A rather particular category of artifacts to be documented in 3D was that composed by objects that were characterized by logistical challenges determined by the impossibility of dismantling the museum installations in which they were housed. This is the case of the 'Zeus of Ugento' and, especially, of the two monumental craters of Ceglie del Campo. In the former case SfM documentation did not prove particularly difficult thanks to the manageability of a simple digital camera, which only required a polarizing filter to eliminate reflections caused by complex ambient light (also attenuated through the use of illuminators and reflective panels). By contrast, in the latter case, it was necessary to devise a strategy suitable for the particular situation of museum display. Indeed, the two craters, characterized by their large dimensions, are currently housed inside two adjacent display cases, from which they cannot



Fig. 2 – The craters of Ceglie del Campo (museum installation and 3D models with camera positions).

be removed. For this reason, discarding any possible strategy based on 3D scanners, the versatility of SfM was exploited once again.

Specifically, the display cases were covered with black cloths to eliminate ambient light (in this case unmanageable), and the 3D acquisition was conducted by placing the camera lens directly on the glass of the cases. This type of operation required an extremely regular sequence of shots, made even more complex by the passage between the two cases (spaced about 30 cm apart), greatly limiting the operator's freedom in choosing the angle and number of photos considering the morphology of the objects to be documented (fortunately, in this case, very regular). Despite this difficulty and the challenging management of light (the numerous spotlights in the display cases), the survey was successfully carried out, once again meeting the predetermined parameters (Fig. 2).

### 3.1.3 The terracotta model of a *nymphaeum*

Another rather unique documentation was that of a terracotta miniature model of a *nymphaeum*. In this case, the complexity of the 3D acquisition lays in the fact that, to appreciate the functioning of the artifact where water was made to spurt from a lion protome through a reservoir, a strategy capable of registering the object both externally (for the reservoir) and internally (for the lion protome), was necessary. Again, given the



Fig. 3 – The terracotta model of the *nymphaeum*.

small size of the object, any documentation through laser-scanning was out of the question, while a strategy based on SfM allowed for setting up an external acquisition with a regular camera (Nikon D800) and an internal acquisition with a camera small enough to pass through the main opening of the *nymphaeum* itself (GoPro 4). In this way, through the subsequent alignment of the two scans (in Meshlab and Blender), a digital twin of the *nymphaeum* was obtained, capable of showing both external and internal details (Fig. 3).

### 3.2 Organic materials: the Similaun mummy and its artifacts

The documentation of the artifacts preserved at the South Tyrol Museum of Archaeology was a very peculiar project, mainly focused on documenting organic materials. For this reason, some specific solutions were adopted, both in data acquisition and in their processing.

#### 3.2.1 Ötzi's artifacts

Among the artifacts documented in 3D during the 2023 acquisition are those predominantly made of worked leather, such as the quiver (roe deer), leggings (goat), loincloth (sheep), overcoat (goat and sheep), cap (bear),





Fig. 4 – The hat of the Similaun mummy: model adjustment through displacement mapping (left) and comparison between the NeRF model (white background) and the SfM model (black background).

the upper part of the right shoe (deer); those made of plant elements, such as the shoes (straw and lime bark) and those made of wood, such as the quiver shaft (hazelnut) and the axe (yew), whose blade is obviously made of copper. This range of artifacts did not present any particular issue in reproducing digital twins via SfM, especially considering that very few areas of the leather materials still retained fur (right leggings), often very sparse (overcoat). The only precaution in these cases was to increase the detail of the skin through the displacement mapping technique, used for the first time by Arc-Team during the Forensic Facial Approximation (FFA) of the mummy of S. Catherine of Genoa in 2018 (BEZZI *et al.* 2019). A different case was the hat, where the fur covering the leather cap is still very dense. For this reason, alongside the traditional SfM processing, an experimental documentation was conducted using the open source software Nerfstudio (TANCIK *et al.* 2023), which integrates Computer Vision with Artificial Intelligence techniques. In other words, this application allows the use of NeRF algorithms (CGI), which model the relationship between light rays and pixel colors in the 3D scene, using neural networks (AI), and, starting from an initial SfM survey, reconstructs and enhances the perception of the 3D scene, allowing the generation of realistic images from any angle without actually capturing data from multiple perspectives. Obviously, this is a ‘partially reconstructive’ method, but one that builds upon solid foundations and, in the case of the artifact in question, has allowed for the recording of a good dataset, capable of providing a photorealistic rendering of the artifact itself from any angle, enabling restorers to monitor any degradation over time. In other words, the extremely high detail achieved are capable



of realistically representing the fur covering better than the 3D SfM model (much less detailed). In essence, it was an integrative experimental method (compared to the 3D survey in the strict sense), which met the conservative requirements (Fig. 4).

### 3.2.2 The Similaun mummy

The case of the 3D documentation of the Similaun mummy performed in 2024 is a bit too complex to be exhaustively covered in this article. However, it is possible to briefly mention the technical precautions that were necessary during the data acquisition and the planned (and ongoing) post-processing methodology for the production of a digital twin of the mummy that combines photogrammetric and radiological (CT scan) models. Regarding the initial phase, the photographic acquisition, once again PLP applied to SfM, was used in an environment where it was not possible to control artificial lighting, namely the climate-controlled backup room where the work was conducted. For this reason, a strategy based on polarizing the light emitted by the ring LED attached to the camera was implemented, capable of counteracting and covering ambient light, whose reflections were eliminated by the polarizing filter of the lens, suitably aligned. The post-processing phase, on the other hand, was characterized by adjustments that had to resolve the alignment problem of the front and back of the 3D documentation of human remains, which, although frozen at a temperature of  $-6^{\circ}\text{C}$ , assume slightly different positions once moved.

For this reason, the technique of ‘coherent anatomical deformation’, developed by Arc-Team in 2012 for the field of FFA (BEZZI 2016), was used, adapting one 3D model to another according to precise and controllable parameters. Once the photogrammetric digital twin of the Similaun mummy (with high-resolution textures) is obtained, the technique of coherent anatomical deformation will be used again to adapt it to the voxel model of the CT scan (devoid of color) and produce a single model that combines both radiological and colorimetric data.

## 3.3 3D documentation on the field

Up to this point, only 3D documentation carried out in protected environments (such as laboratories and museums) have been described. This final chapter will focus on surveys carried out in the field in challenging environments, related to the branch of extreme archaeology, focusing on the most recent case of speleo-archaeology followed by UMST: the ‘Grotta del Teschio’.

### 3.3.1 The documentation of ‘Grotta del Teschio’

Towards the end of 2023, Arc-Team was commissioned to carry out a speleo-archaeological excavation inside a cave where human remains had

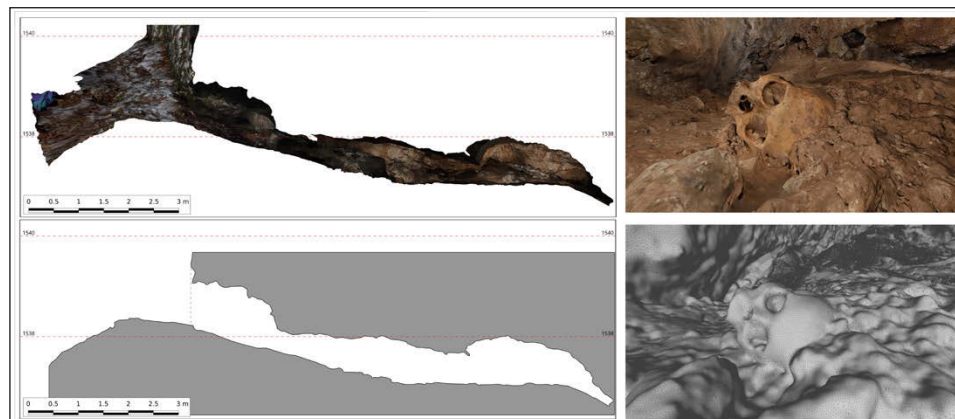


Fig. 5 – The 3D of ‘Grotta del Teschio’: general model and detail of the skull.

recently been discovered: the ‘Grotta del Teschio’. For obvious reasons, before the actual excavation began, a 3D documentation of the entire underground environment was conducted using SfM, in order to record the exact position of every find, human or otherwise. The strategy adopted was chosen due to the excellent results achieved in previous years with photographic acquisitions in extreme contexts (underwater, underground, and glacial). In this specific case, the great versatility of a technique based on photography allowed for smooth operation in narrow environments where it would not have been possible to penetrate with bulkier equipment, while also ensuring the correct registration of metric and geographic values thanks to the use of Ground Control Points (GCP) located outside the cave entrance and recorded with differential GPS. The level of accuracy and precision achieved with the 3D documentation of the ‘Grotta del Teschio’ supported the stratigraphic excavation of the environment with precise 3D of each individual find *in situ*, awaiting possible integration following the study and restoration of the recovered objects (Fig. 5).

#### 4. CONCLUSIONS

The projects presented thus far, characterized by a wide range of materials, logistical conditions, and different challenges, have highlighted the limitations that many three-dimensional documentation methodologies may encounter in practice, particularly those based on laser scanning. Considering the experiences proposed, the only reliable methodology in particularly challenging contexts has proven to be that based on SfM and this not so much for the quality of the results obtained, but for the versatility of the methodology

itself. Essentially, all the issues that emerged during the individual projects presented were easily resolved thanks to the ability to intervene either during photo acquisition (through appropriate polarizing filters or through the use of different cameras) or during processing, using various software and algorithms. Furthermore, at present, SfM has proven to be highly compatible with the new NeRF methodologies, which seem rather promising for the study of Cultural Heritage.

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## REFERENCES

- BEZZI A., BEZZI L., DUCKE B. 2011, *Computer Vision e Structure from Motion, nuove metodologie per la documentazione archeologica tridimensionale: un approccio aperto*, in G. DE FELICE, M.G. SIBILANO (eds.), *ArcheoFOSS: Open Source, Free Software e Open Format nei processi di ricerca archeologica. Atti del V workshop (Foggia 2010)*, Santo Spirito, Edipuglia, 103-111.
- BEZZI L. 2016, FACCE. *I molti volti della storia umana*, «Blender Magazine Italia», 18, 10-13.
- BEZZI L., BEZZI A., MORAES C. 2019, *Ricostruzione facciale forense di S. Caterina Fieschi Adorno. Relazione tecnico-scientifica* (<https://doi.org/10.13140/RG.2.2.23780.19844>).
- TANCIK M., WEBER E., NG E., LI R., YI B., KERR J., WANG T., KRISTOFFERSEN A., AUSTIN J., SALAH K., AHUJA A., MCALLISTER D., KANAZAWA A. 2023, *Nerfstudio: A modular framework for neural radiance field development*, in E. BRUNVAND, A. SHEFFER, M. WIMMER (eds.), *Proceedings SIGGRAPH 2023 Conference Papers (Los Angeles 2023)*, Proceedings Production Editor, art. 72.

## ABSTRACT

This article aims to analyze the complex issue of 3D documentation of archaeological artifacts under different viewpoints: from potential technologies to current methodological limitations, in light of the obtained results. These results will be described based on direct experiences derived from specific archaeological projects, whose primary aim was indeed the

creation of digital replicas of selected artifacts. Among the institutions involved in such projects are the MArTA (Museo Archeologico Nazionale di Taranto), the South Tyrol Museum of Archaeology, and the UMST (Unit. di Missione Strategica) of the Soprintendenza per i Beni e le Attività Culturali of the Autonomous Province of Trento (PAT).

## NON-INVASIVE METHODOLOGIES FOR THE STUDY OF MINERALISED TEXTILE TRACES IN IRON AGE CONTEXTS

### 1. INTRODUCTION

This paper concerns the study of mineralised textile traces preserved on the fragments of the bronze situla found at Buttrio in 1891, dated to the first half of the 7<sup>th</sup> century BC and currently conserved in the Archaeological Museum of Udine, using non-invasive methodologies. Textiles are generally rare finds in most archaeological contexts but can survive in mineralised form (CHEN *et al.* 1998). Mineralised textiles are formations in which metal corrosion products form casts of or around fibres retaining their external morphology and size almost unaltered. Even when minute, such traces can provide a considerable amount of information about ancient textiles (e.g. GLEBA 2017). Traditionally, they are documented and investigated using 2D documentation – drawings, macro and micro photographs, and Scanning Electron Microscopy (SEM). However, 2D documentation does not always bring out the three-dimensional structure of these remains making further analysis problematic. Conservation treatments of metal objects that preserve mineralised textile remains further complicate their analysis using traditional methods by making the object surface shiny and reducing the relief. Reflectance Transformation Imaging (RTI) (FRANK 2014) and, most recently, micro-computed tomography (KARJALAINEN *et al.* 2023) and synchrotron microtomography (IACCONI *et al.* 2023) have been proposed as viable techniques for mineralised textile documentation. These techniques are however time-consuming and/or prohibitively expensive. The case study presented here made use of structured light scanner as an economical and fast alternative for 3D documentation of mineralised remains.

3D survey is the process of capturing and reproducing the shape and appearance of an object or scene, including colour information. It is a research area within the field of computer vision that involves multiple stages and presents open problems. The methods and tools used in the survey of Cultural Heritage (CH) vary depending on the characteristics of the object being studied, the required precision, and the intended use of the final 3D model. The survey is a complex operation both methodologically and operationally. It requires critical interpretation skills to understand the object being surveyed and to derive the correct strategies to achieve the best results (REMONDINO, RIZZI 2010; BRUNETAUD *et al.* 2012; CHIABRANDO *et al.* 2014; BALLETTI *et al.* 2014b).

In recent years, the fields of Cultural Heritage (CH) have seen great success with Structure from Motion, laser scanners (triangulation or time-of-flight), and structured light systems. These technologies have made it easier to acquire data related to the geometry and shape of both simple and complex structures (BONFANTI *et al.* 2013; BALLETTI *et al.* 2014a). The structured light technique is an active method that uses a projection device to project structured patterns. The digital image detector captures the scene and processes it to reconstruct the geometry from the pattern deformations. Texture acquisition accompanies this method and can yield impressive accuracy results (SALVI *et al.* 2010; ZHANG 2018).

In the present study, we used different non-invasive methodologies and instruments to document and investigate four bronze situla wall fragments that preserve mineralised textile traces on their internal walls. The study aimed to: a) identify the fibres used in the production of the textiles (whether animal or plant, and if possible, the specific species); b) to determine the main textile structural parameters, including weave type, thread count per centimetre, thread twist, diameter and angle, and the presence of edges and other peculiar elements; c) to understand the manufacturing processes employed.

E.F., V.B., M.G.

## 2. THE BUTTRIO FIND: A NINETEENTH CENTURY DISCOVERY

Buttrio is a small town located in the Eastern Hills of Friuli Venezia Giulia, in the province of Udine. In this area, some findings from the Roman period are known, particularly related to the road networks that connected north-eastern Italy with the *Noricum* (modern Austria). In 1880, some pre-Roman artefacts were reported in the area for the first time, accidentally discovered during agricultural works in the Buttrio countryside. The discovery was reported by Vincenzo Joppi, a doctor, but also a librarian and a scholar of local antiquities, in a private letter to Luigi Pigorini (VISENTINI 2020). The following year, the Director of Antiquities and Fine Arts, Giuseppe Fiorelli, after a communication by the Honorary Inspector of Friuli, Francesco Toppo, officially published the Buttrio's discovery in the journal «Notizie degli Scavi di Antichità» (FIORELLI 1881), reporting the finds of metal objects, including pins and a bronze cup.

The most detailed description of the finds was finally provided in 1891, when Prof. Alexander Wolf delivered a batch of materials to the Museum of Udine: these materials were discovered by the Bolzicco brothers, who owned some fields in Buttrio, and corresponded to what was mentioned by Joppi and Toppo (VISENTINI 2020). In Wolf's letter are mentioned fragments of pins, of an axe, some buried bones, potsherds and «many fragments of

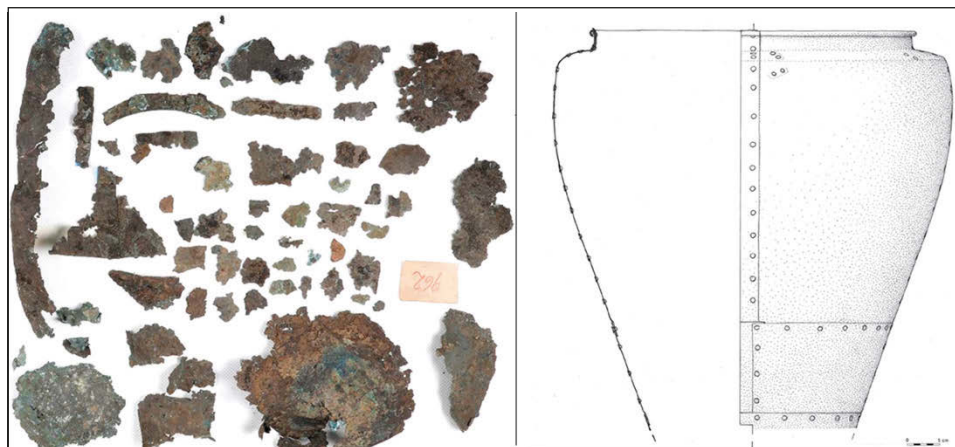


Fig. 1 – Fragments of the bronze vessel at the Restoration Laboratory, directed by Dr. Domenico Ruma (on the left) (Restoration final report L.A.A.R. S.r.l.); the reconstruction of the Buttrio situla (on the right) (VISENTINI 2020).

a bronze vessel» (VISENTINI 2020, 41). These materials were placed inside a burial pit, approximately 70 cm deep, with an initial diameter of 50 cm that gradually narrowed towards the bottom to a diameter of 30 cm. The walls of the pit were lined with rough, unfinished stones. The information available about this context is limited, making it impossible to reconstruct the original arrangement in ancient times, both in terms of the composition of the grave goods and in relation to any other burials that may have been present in the area. The fragmented state of a large part of the archaeological artefacts, especially the bronze vessel, the pins, and the pottery, suggests that the grave had been significantly disturbed by subsequent actions, likely agricultural activities.

The archival documents and materials were first re-examined by Paola Visentini in 2020. Following the completion of restoration in 2022 (Fig. 1), the complex from Buttrio is now being analysed by a broader research group (V. Baratella, M. Gleba, E. Faresin, P. Visentini, M. Cupitò), to characterise the artefacts using archaeological and archaeometric approaches, contextualising the objects in terms of their typology, chronology, and historic developments.

The bronze situla, the focus of this contribution, represents a very important link between north-eastern Italy and the Hallstatt world, particularly with Slovenia. This vessel finds a precise comparison with a situla from the Slovenian cemetery of Stična-Griže Nekropole (JEREB 2016, n. 12, tav. 11) dated to Ha C1 (7<sup>th</sup> century BC). During the restoration of the situla, textile

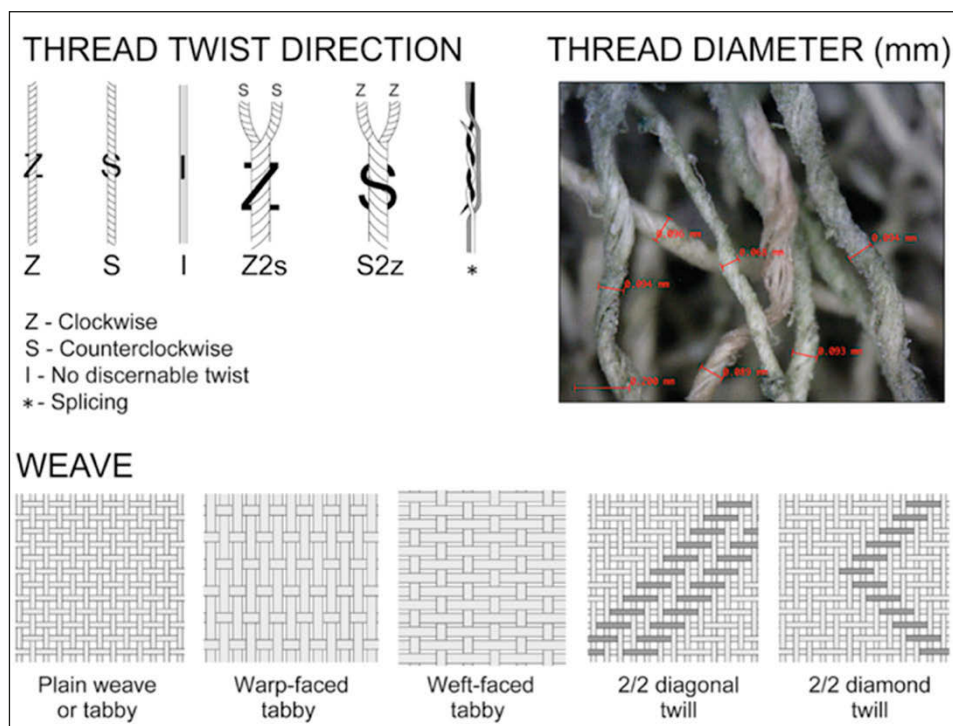


traces were identified on the interior of four fragments. As these are the only Iron Age textile remains from this region discovered to date, a suite of diverse methods was used to carry out technological textile analysis.

V.B.

### 3. METHODS

The purpose of technological textile analysis is to determine the culturally and chronologically relevant characteristics of the examined fabrics. Textile analysis includes identification of raw material (flax, wool, etc.); determination of structural parameters such as weave type (tabby, twill) and thread count per cm (which is indicative of textile quality); thread twist (z – clockwise; s – counter-clockwise, i – no discernible twist, \* – spliced; two or more single threads can be plied, usually in the direction opposite from the twist, e.g. Z2s – two s-twisted threads plied in z direction, or S2z – two z-twisted threads plied in s direction), diameter and angle; presence of edges and any other characteristic elements, such as pattern, sewing, etc. (Fig. 2).



The study required thorough macro and micro documentation of the textile remains in 2D and 3D. The workflow developed for the study included (Fig. 3):

- Macro photographs using NIKON Z50 and NIKKOR Z 105mm F2.8 S MACRO.
- Autoptic observation and digital micro photographs with portable digital microscope Dino-Lite AM7115MZT at different magnifications (20x, 50x, 230x).
- Scanning Electron Microscopy (SEM) carried out at the Centro di Analisi e Servizi Per la Certificazione, University of Padua, using Coxem EM-30AX Plus Scanning Electron Microscope. The instrumental settings used were: backscattered electron (BSE) mode under low vacuum (LV) at 20.00kV accelerating voltage and working distance of ca. 10 mm and the fibre diameter measurements were carried out at 300x magnification.

Structured light scanning using Aurum 3D (Open Technologies, now Faro rebranded) with an accuracy of 40  $\mu\text{m}$  and a camera resolution of

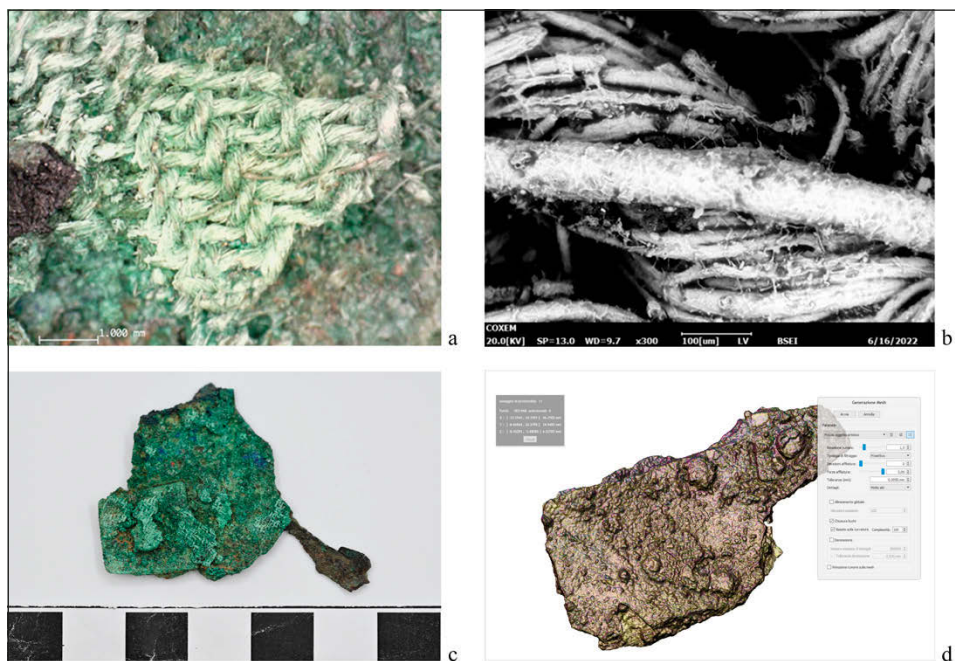


Fig. 3 – a) Close-up of the fragment showing the preservation of textile traces; b) SEM micrographs of positive fibre casts of finer and one coarse fibre; c) the macro photograph; d) the very high density point cloud acquired with a structured light scanner (processing M. Gleba and E. Faresin).

2×1.3 MPixels. The samples were acquired by taking partially overlapping range scans to produce range maps. An automatic turntable connected to the scanner and the acquisition software was used to ensure better overlapping. Each scan had a rotation angle of 32° and 11 scans were taken for each to complete the 360° rotation angle. The data collected by the scans are X, Y, Z coordinate triplets of each single point analysed. Using Optical RevEng 2.4 the acquired data was processed to create a single, complete, non-redundant and optimal 3D model using a set of range maps. The data processing was performed according to the standard steps of the 3D scanning post processing pipeline. The first stage involved aligning the range maps in a common coordinate system. This was necessary in order to ensure that all scans were accurately positioned within the overlapping area.

The pairwise ICP alignment algorithm was then employed, followed by a global registration. An automatic pre-alignment technique was applied during the acquisition phase with the objective of improving the quality of the data and verifying the quality of the acquisition in real time. The standard deviation value for fragment A was 0.0106 mm, for fragment B it was 0.0138 mm while for fragment C and D the value was 0.0109 mm and 0.0132, respectively. The range map merger (or fusion) was employed to construct a single, non-redundant triangulated mesh and in order to ensure the highest possible standards of precision, a tolerance of 0.0050 mm was set for the meshing parameters, with particular attention paid to the need to avoid any loss of quality in the definition and characterisation of the mineralised textile traces (fragment A was composed of 964699 triangles; the number of triangles in the mesh for fragment B was 1509678, for fragment C it was 1441118, and for fragment D it was 17772669). The mesh was edited to improve the quality of the computed mesh. This step requires the correction of topological mistakes, such as cross-section triangles and anomalous vertices.

E.F.

#### 4. RESULTS AND DISCUSSION

Digital microscopy in combination with structured light scanning allowed the determination of weave type and thread structure. The 3D scans allowed close comparison of the weave in all four fragments, leading to the conclusion that they were likely in contact with the same textile. The textile on all fragments is a spin-patterned 2/2 twill. In a twill, the horizontal weft threads pass over and under vertical warps in a regular staggered pattern (in a 2/2 twill case every two threads in each system), each row being stepped to one side of the row above, creating a diagonal effect. Based on structural characteristics and overall appearance, all analysed fragments appear to

have traces of the same fabric. The quality of the weave is very high, with one system (possibly warp as it is slightly less dense) 25-28 threads/cm and the other (possibly weft) 26-30 threads/cm. The textile is woven in a single spun yarn and is spin- or shadow patterned, that is woven with alternating groups of z- and s- twisted yarn alternating in both systems. This type of patterning is typical for Italy and the Hallstatt cultural area of Central Europe during the Iron Age.

SEM permitted raw material identification. Fibre casts were more or less well preserved, with variable preservation. Most are preserved as positive casts. The raw material is of animal origin, likely sheep wool, as indicated by the overall cylindrical shape of the fibres and the presence of coarse hairs. The wool appears to be of medium quality with a mean diameter of 19  $\mu\text{m}$  and the coarse fibres were likely pigmented. The wool is comparable in quality to the Iron Age wools from Northern and Central Italy (GLEBA 2012).

M.G.

## 5. CONCLUSION

The fabric remains preserved on the interior of the Buttrio situla likely belong to a textile used to wrap the cremated remains that were deposited inside the situla, as indicated by the charred bone remains still adhering to the fabric. The use of a wool twill for wrapping is unusual, as in most cases a linen tabby is used in a ritual that was prevalent during the Iron Age across Europe (RUTA, GLEBA 2018).

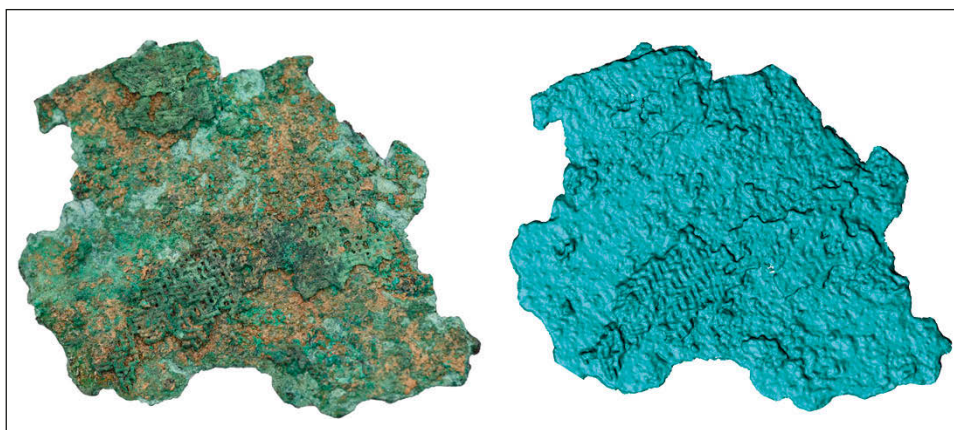


Fig. 4 – Comparison between the macro photograph (on the left) and the high-resolution 3D model (on the right) (processing E. Faresin).

The textile traces examined are made of wool, woven in 2/2 spin patterned twill using single yarn with variable twist. While the original colour of these textiles cannot be reconstructed due to their mineralised state of preservation, it is clear the fabric had a spin or shadow pattern of checks or rectangles. Spin-patterned twills are typical for Italian-Central European textile culture during the Iron Age (GLEBA 2017). Twills woven in single yarn are characteristic for Italy and the Eastern Hallstatt milieu, including Slovenia and Croatia. The quality of the fabric is extremely high, demonstrating one of the highest thread counts recorded in Europe during the Iron Age, possibly reflecting the high status of the individual they were found in association with.

Structured light scanning technique and 3D models allowed a clearer view of the textile surface and visual information on overall preservation of the object, reducing interference of texture and colour during technical analysis. Moreover, it is a fast and economical method of 3D documentation for the creation of digital archives that are essential for long-term preservation of fragile archaeological remains (Fig. 4).

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### REFERENCES

- BALLETTI C., BRUSSA N., GOTTARDI C., GUERRA F. 2014a, *The documentation and reintegration of a lost past*, «ISPRS Annals of Photogrammetry, Remote Sensing & Spatial Information Sciences», 2, 5, 49-55 (<https://doi.org/10.5194/isprsannals-II-5-49-2014>).
- BALLETTI C., GUERRA F., TSIUKAS V., VERNIER P. 2014b, *Calibration of action cameras for photogrammetric purposes*, «Sensors», 14, 9, 17471-17490 (<https://doi.org/10.3390/s140917471>).
- BONFANTI C., CHIABRANDO F., RINAUDO F. 2013, *TLS data for 2D representation and 3D modelling. Different approaches tested in the case of san Giovanni in Salluzzo (CN) Italy*, «ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences», II-5/W1, 37-42 (<https://doi.org/10.5194/isprsannals-II-5-W1-37-2013>).
- BRUNETAUD X., LUCA L.D., JANVIER-BADOSA S., BECK K., AL-MUKHTAR M. 2012, *Application of digital techniques in monument preservation*, «European Journal of Environmental and Civil Engineering», 16, 5, 543-556 (<https://doi.org/10.1080/19648189.2012.676365>).



- CHEN H.L., JAKES K.A., FOREMAN D.W. 1998, *Preservation of archaeological textiles through fibre mineralization*, «Journal of Archaeological Science», 25, 1015-1021.
- CHIABRANDO F., LINGUA A., NOARDO F., SPANÒ A. 2014, *3D modelling of trompe l'oeil decorated vaults using dense matching techniques*, «ISPRS Annals of Photogrammetry, Remote Sensing & Spatial Information Sciences», 2, 5, 97-104 (<https://doi.org/10.5194/isprsannals-II-5-97-2014>).
- FIGURELLI G. 1881, *Buttrio*, «Notizie degli Scavi di Antichità», 131.
- FRANK E. 2014, *Documenting archaeological textiles with Reflectance Transformation Imaging (RTI)*, «Archaeological Textiles Review», 56, 3-14.
- GLEBA M. 2012, *Tracing textiles to sheep: Investigating wool fibre development in pre-Roman Italy using Scanning Electron Microscopy (SEM)*, «Journal of Archaeological Science», 39, 3643-3661 (<https://doi.org/10.1016/j.jas.2012.06.021>).
- GLEBA M. 2017, *Tracing textile cultures of Italy and Greece 1000-400 BCE*, «Antiquity», 91, 359, 1205-1222 (<https://doi.org/10.15184/aqy.2017.144>).
- IACCONI C., AUTRET A., DESPLANQUES E., CHAVE A., KING A., FAYARD B., MOULHERAT C., LECCIA E., BERTRAND L. 2023, *Virtual technical analysis of archaeological textiles by synchrotron microtomography*, «Journal of Archaeological Science», 149, 105686 (<https://doi.org/10.1016/j.jas.2022.105686>).
- JEREB M. 2016, *Die Bronzegefäße in Slowenien*, Prähistorische Bronzefunde, Ab. II, 19, Stuttgart, Franz Steiner Verlag.
- KARJALAINEN V.P., FINNILÄ M.A., SALMON P.L., LIPKIN S. 2023, *Micro-computed tomography imaging and segmentation of the archaeological textiles from Valmarinnie-mi*, «Journal of Archaeological Science», 160, 105871 (<https://doi.org/10.1016/j.jas.2023.105871>).
- REMONDINO F., RIZZI A. 2010, *Reality-based 3D documentation of natural and cultural heritage sites-techniques, problems, and examples*, «Applied Geomatics», 2, 3, 85-100 (<https://doi.org/10.1007/s12518-010-0025-x>).
- RUTA SERAFINI A., GLEBA M. 2018, *Evidence of ossuary dressing in the funerary rituals of pre-Roman Veneto (Italy)*, in M.S. BUSANA, M. GLEBA, F. MEO, A. TRICOMI (eds.), *Purpureae Vestes VI*, Zaragoza, Porticos, 203-216.
- SALVI J., FERNANDEZ S., PRIBANIC T., LLADO X. 2010, *A state of the art in structured light patterns for surface profilometry*, «Pattern Recognition», 43, 8, 2666-2680 (<https://doi.org/10.1016/j.patcog.2010.03.004>).
- VISENTINI P. 2020, *Aggiornamenti sull'attività di studio e di ricerca paleontologica di Camillo Marinoni in Friuli*, in E. BORGNA, S. CORAZZA (eds.), *Dall'Adriatico all'Egeo. Scritti di Protostoria in onore di Paola Cassola Guida*, Udine, Forum, 37-44.
- ZHANG S. 2018, *High-speed 3D shape measurement with structured light methods: A review*, «Optics and Lasers in Engineering», 106, 119-131 (<https://doi.org/10.1016/j.optlaseng.2018.02.017>).

## ABSTRACT

This study presents the preliminary results of a non-invasive analysis of bronze fragments from the site of Buttrio (Udine). The analysed sample belongs to a bronze situla dating to the second half of the 7<sup>th</sup> century BC, currently preserved in the Archaeological Museum of Udine. These fragments are characterised by the presence of mineralised traces of textiles, which are relatively rare finds in this period but provide important information about the perishable materials, which represented one of the most important and time-consuming economic activities of the past. The aim is to identify the fibres used in the production of the textiles, understand the manufacturing processes employed, and explore the nature of the archaeological context. The textile traces were analysed using standard analytical procedures to determine the main structural parameters, including weave type, thread

count per centimetre, thread twist, diameter and angle, and the presence of edges and other peculiar elements. The analysis has been performed with traditional 2D documentation, including macro photos, and was complemented by a Scanning Electron Microscopy to characterise the morphology of the fibres. Additionally, a morphometric analysis of the sample was conducted using a structured light scanner to obtain 3D models that allow submillimetre measurements.



## DATA EXTRACTION FROM 3D SCANNING: POST-PROCESSING FILTERING FOR ANALYTIC AND INFORMATIVE MODELS OF SMALL ARCHAEOLOGICAL FINDS

### 1. INTRODUCTION

This work, as part of the ITSERR Resilience European Project, has two aims: the semantic data extraction from 3D scanning of specific Near East archaeological artefacts; the qualitative evaluation of a specific 3D scanner, Artec Space Spider sensor (<https://www.artec3d.com/>), applied to small archaeological finds. This structured-light sensor, being portable and versatile, has been successfully tested in the archaeological domain as reported by other studies (GÖLDNER *et al.* 2022; MARIĆ *et al.* 2022; DIARA 2023).

Over the years, the 3D digitization and analysis process related to cuneiform tablets had a great impact in the Near East research, allowing new detailed studies on writing methodology, semantics as well as prosopography (COHEN *et al.* 2004; KOTOULA *et al.* 2017). In this work, the main dataset is related to cuneiform tablets as well as stone cylindric seals related to the third dynasty of Ur (2100-2000 BC). The here proposed archaeological dataset is related to important documents not only for the cuneiform text (administrative content), but also for other particular features and details extractable from objects surfaces: nearly visible details are related to sealing impression (behind the text) as well as biometric data (fingerprint evidence). For this reason, structured-light scanning coupled with post-processing analyses (filtering and shading manipulation) provides a deeper and detailed investigation on micrometric features, for improving research possibilities.

Filtering processes are referred to Multi-Scale Integral Invariant (MSII) filter improved with the ImageJ refinement related to math processes and image levels adjustments on MSII output (MARA *et al.* 2010). In this work, the incredible potential of this post-processing operation will be shown related to the figurative apparatus of sealing impressions as well as for highlighting details of scribe fingerprint on the humid clay.

The same 3D scanning workflow has been applied for a small cylindric seal and its plaster mould for investigating the depth of the figurative apparatus through a deviation analysis: at the same time, this archaeological stone artefact has been considered for its dimensions, 2.7 cm height and 1.3 cm diameter, especially for testing and evaluating the scanning behaviour of the Space Spider sensor with very small objects: this sensor was mainly designed for scanning objects bigger than 4 cm, up to medium dimension objects (depending on scans numbers and overlapping). Detailed 3D scanning and

post-processing analyses unlock new frontiers in extracting and investigating important semantic data from archaeological finds, fundamental for expanding and updating research study on tangible and intangible Heritage assets, as well as visible and nearly visible features. Extracted data, in addition to 3D models and general semantic information of this dataset, need to be stored in an open access Common Data Environment (CDE) for helping data-exchange and dissemination (FISSELER *et al.* 2017).

## 2. METHODOLOGY

The methodology behind this research is based on 3D scanning through structured-light sensors. Over the years, this scanning methodology proved to be, along with photogrammetry, the best solution for 3D documenting archaeological finds. Different research demonstrated its reliability (SCHILD *et al.* 2022; DIARA 2023). In fact, the grid pattern light typical of these sensors is able to hit and register complex surfaces: the trigonometric triangulation occurred between the light source, the camera and the surveyed object allow to record the incidence angle ( $\alpha$ ) as well as distances.

### 2.1 Artec Space Spider

For this research project, Artec Space Spider (SS) scanner was tested for 3D digitizing Near East clay artefacts, performing evaluation analysis on its sensors (light emitter and camera) as well as post-processing investigations on related outputs. It is a portable (handheld) optical scanner that uses blue light designed for acquiring features, sharp edges, and complex surfaces on small and medium-sized objects. Having 0.05 mm of 3D point accuracy (capturing phase) and 0.1 mm of final 3D model resolution, SS is incredible precise and reliable instrument for documenting complex and detailed archaeological artefacts. Other specifications of the structured-light sensor are reported in Tab. 1. The SS sensor works in parallel, through a USB connection, with the monitor feedback from Artec Studio software. In fact, this feedback revealed necessary in order to reduce the drift error caused by incorrect distances or angles of the operator as well as for referencing the scanning trajectory.

Despite its extreme portability and compactness, the SS scanner presents some operational issues, especially related to the acquisition area: in fact, in complex and small spaces the scanning process and movement could be risky especially due to wired connections and the visual feedback on the laptop screen. Capturing archaeological artefacts in limited spaces (horizontal and vertical) may take longer than expected as well as additional safety precautions. The physical environment may affect the SS scanning operation. Global and punctual illumination can change the overall precision and quality of 3D outputs. At the same time, temperature is a critical parameter to be consider

3D point accuracy	0.05 mm
3D resolution	0.1 mm
Angular Field of View	30°×21°
Linear Field of View (min)	90×70 mm
Working distance	0.2-03 m
Linear Field of View (max)	180 140 mm
Texture resolution	1.3mp
Acquisition speed	1 mln points / s
Reconstruction rate	7.5 fps (up to)

Tab. 1 – Space Spider structured-light sensor specifications.

before the scanning operations: the suggested target is 37° degree in order to reach the maximum operative behaviour of SS.

### 3. DOCUMENTATION AND ANALYSIS

#### 3.1 *Cuneiform tablet - MAT 477*

The Sumerian administrative document, referred to the MAT 477 tablet, was surveyed and 3D digitised to analyse the sealing methodology beneath the cuneiform text. This archaeological artefact (45×42×17mm) comes from Tell Jokha, Umma, in Iraq and it is related to the third dynasty of Ur (2100-2000 BC). It shows a massive pre-sealing process (Akalla scribe), in the verse and obverse, stratigraphically below the text. The visible figurative apparatus is related to a seated figure (on a decorated throne) with a cup in a hand and a small headwear. Above the cup, a rising sun is visible. The scanning procedure (two scans) returned 2,032 acquired frames having a deviation error of 0.1 mm (RMSe).

The 3D reconstruction process returned a highly detailed and populated polygonal mesh (triangles): approximately 7 million polygons having 0.1mm of resolution. Digital light manipulation, inside the Artec Studio software, initially helped the identification of multiple sealing processes, then the application of ambient occlusion and radiance scaling filters have contributed to a more detailed comprehension of the figurative apparatus. However, through the Multi-Scale Integral Invariant filter (MSII), via GigaMesh software (MARA 2010; HOMBURG *et al.* 2022) details of the sealing impression were enhanced, becoming more readable (Fig. 1). MSII analysis was performed without the texture layer, also because the latter often does not allow to observe depth and micrometric details.

This analysis, managing ‘feature vector elements’ and colour ramp, revealed the sealing methodology: the cylindric seal was partially rolled and/or just impressed to provide visibility to the written legend and the seated figure



Fig. 1 – Cuneiform tablet MAT 477: a) photo; b) 3D model and custom lights; c) MSII analysis.

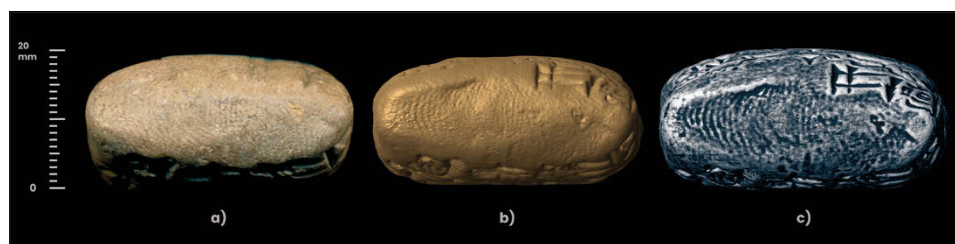


Fig. 2 – Cuneiform tablet MAT 655: a) photo; b) 3D model and custom lights; c) MSII analysis.

on the throne (the governor). For each tablet face the sealing is repeated and overlaid five times and, via filtering analysis, the micro-stratigraphic analysis among sealing impressions can be performed (Fig. 1).

### 3.2 Cuneiform tablet - MAT 655

The MSII process was also fundamental for extracting biometric data from a surface related to the MAT 655 tablet. In fact, the early analysis of the 3D model (0.1 mm resolution and 2.4 million polygons), coming from Ur III from Umma (Iraq), allowed us to detect a fingerprint impression on it. The scanning procedure (three scans) returned 1,911 acquired frames having a deviation error of 0.1 mm (RMSe). For this reason, a post-processing analysis

on this feature has been planned to enhance and boost the detailed visibility of the impression, allowing precise measurements and future matching possibilities (Fig. 2). This micrometric evidence was analysed via MSII filter as well as through a deviation analysis. The former, as mentioned before, was carried out for extracting

### 3.3 *The cylindric seal and its mould – 70021*

The other analysed archaeological artefacts are a cylindrical stone seal, catalogued as 70021, and its plaster mould. They have been selected for their particular figurative apparatus (as described below, in the mould description) as well as for testing the SS behaviour with a very small object (the seal dimensions are 2.7×1.3cm). The scanning procedure (six scans) returned 2,185 acquired frames having a deviation error of 0.1 mm (RMSe). Despite the seal being damaged (lack of material on the sides of the main figure), the plaster mould shows the complete sealing apparatus composed of the written legend on four rows and two standing figures. The 3D scanning phase started by vertically placing the cylindric artefact, then, for a second scanning session it was placed leaning on the main surface (horizontally). In both situations, the SS scanner was held at 30° and 45° degrees from the incidence surfaces. Acquired data was enough to reconstruct the stone object in its entirety (0.1mm resolution and 580 thousand polygons).

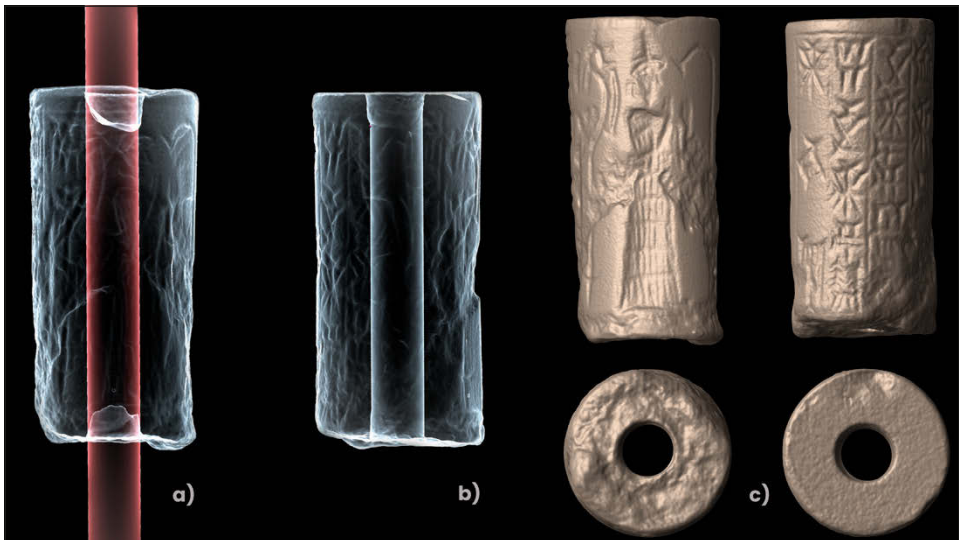


Fig. 3 – a) 3D model of the cylindric seal before Boolean operations; b-c) after Boolean operations.



However, after the final detailed surface fusion, the 3D model of the seal was at the centre of a parametric manipulation via boolean subtraction, in order to obtain the hole passing through both sides. This operation was designed because the scanner failed to reach this part: acquired data related to the hole were not enough for closing inner surfaces (Fig. 3). However, the obtained final model of the seal, despite its dimension, is detailed in the entire cylindric surface: the figurative apparatus as well as the textual legend are faithfully reproduced, allowing the reading of every cuneiform sign (avg. 4×4 mm space for each sign).

Musei Reali's curators have also produced a plaster mould of the entire seal impression: by rolling the seal, the figurative and written apparatus of the sealing measures 2.6×3.6 cm, with an approximate area of 9.36 cm<sup>2</sup>: two figures are facing each other as in a meeting scene with sticks and banners. The scanning procedure (two scans) returned 1,267 acquired frames having a deviation error of 0.1 mm (Root mean square error - RMSe). It has been investigated through post-processing metric analyses for understanding the depths values of the decorative scene. For this reason, a deviation analysis was computed: a best fit plane was created for the background for calculating distances between it and figures and text. This computation reported a figures depth between 0.6 mm and 1.1 mm instead of writing depth that is between 0.25 mm and 0.9 mm, furthermore, the standard deviation is 0.6 mm and the RMSe is 0.25 mm (Fig. 4).

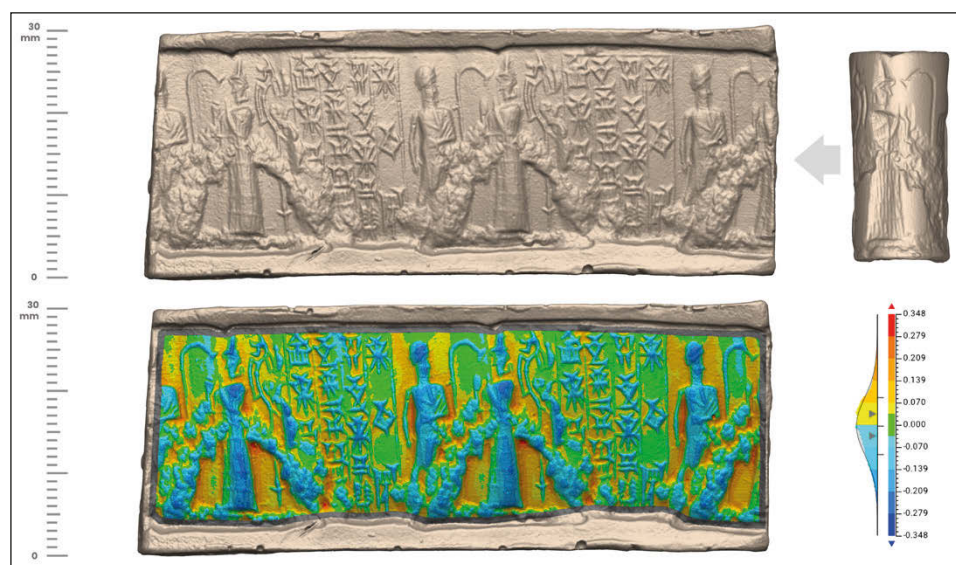


Fig. 4 – 3D model of the plaster mould and its deviation analysis.

#### 4. COMMON DATA ENVIRONMENT

This 3D and semantic dataset have been temporarily stored inside an ad-hoc online Common Data Environment (CDE) for unlocking smart data access and exchange. Project collaborators as well as common users can easily investigate the dataset via browser. In fact, it is a web environment, browser-based, developed by using JavaScript language and XEOKIT: the former is a well-known developing language while the latter is an open source programming toolkit for 3D scenes on WebGL. This smart environment is composed of three pages. In fact, in addition to the initial home page with the list of stored cuneiform tablets, it includes a split view on the 3D model of the selected artefact coupled with semantic metadata: besides historical and physical information, metadata also enclose particular features and semantic details coming from 3D analyses, such as fingerprints and sealings evidence (Fig. 5). In this way, the cuneiform tablet can be analyzed, in the same web page, as concerns semantic information as well as its volumetric entirety in the 3D scene.

Furthermore, this environment has been implemented by a fully immersive 3D inspector for investigating the 3D model more in detail. Inside it, the toolbox panel allows to pick and measure distances and angles in real-time directly on the model, then, it allows to manage the 3D view of the model

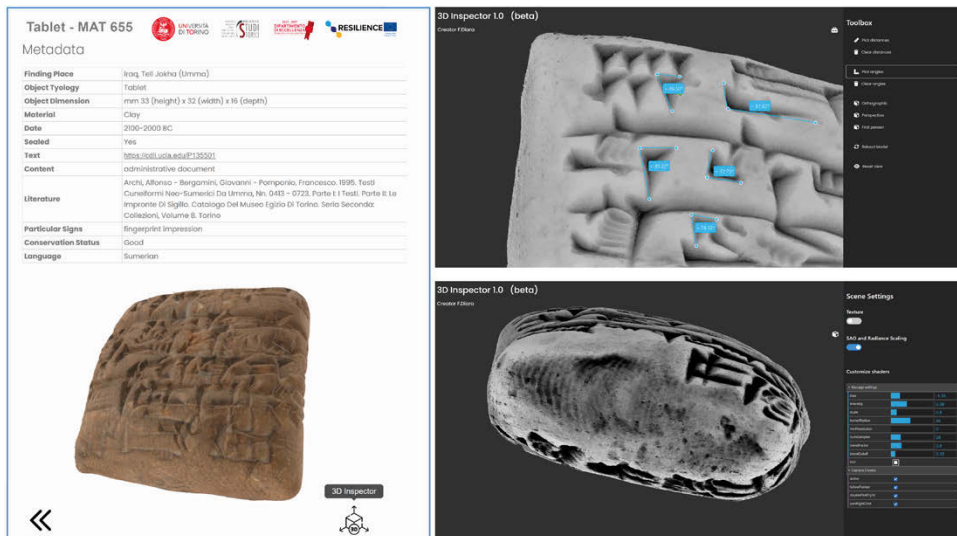


Fig. 5 – Draft version of the CDE designed for this project: on the left, the split view related to metadata and 3D model; on the right, the 3D Inspector functionalities.



(orthographic, perspective, first person). In addition to these features, the Scene Settings includes the texture toggle (switch on and off) for activating or deactivating the radiometric texture, useful for performing filtering and shading analyses. In this regard, the Scene Settings also include the smart handling of Scalable Ambient Occlusion (SAO) and radiance scaling filter for enhancing and micrometric details of surfaces on different layers (Fig. 5). Through this option, simplified post-processing analyses on the 3D model can be easily performed via browser (without hardware limitations). Functionalities and options can be added and removed from the source code depending on different access levels for different users. This open and smart environment, in addition to break down accessibility barriers, allows and helps analyses, revisions and data exchange related to specific archaeological artefacts. Besides, the here proposed dataset (3D models) and CDE source code have been published and stored in the repository Zenodo to guarantee full open access (DIARA 2024a, 2024b).

## 5. CONCLUSIONS

The here presented 3D scanning allowed to quickly reproduce high-detailed digital archaeological artefacts for extracting additional and nearly visible data to be collected in a proper CDE. In this regard, informative and analytic models, through post-processing analyses, have been produced to help the overall interpretation on the production methodology of Near East archaeological artefacts: cuneiform tablets and seals. Space Spider sensors revealed accuracy, reaching 0.05 mm on the acquisition point on tablets and cylindric seal: as expected, the inner surfaces of the passing hole of the seal were not acquired correctly and then a Boolean operation was needed.

Through the post-processing analysis of the tablet MAT 477, the sealing process was investigated and better understood: despite the typical rolled procedure, the here presented tablet experienced a repeated partial impression of the seal. The scribe workshop (under specific directives) expressed the willingness to insert only the written legend and the governor figure. Moreover, the MSII filtering process detected impression micro stratigraphy: overlapping of figurative apparatus is noticeable. At the same time the fingerprint analysis, via measurements and cross-matching operations, unlocks new possibilities for studying people behind the archaeological object, allowing expanding analyses of past societies.

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## REFERENCES

- COHEN J.D., DUNCAN D.D., SNYDER D., COOPER J., KUMAR S., HAHN D.V., CHEN Y., PURNOMO B., GRAETTINGER J. 2004, *iClay: Digitizing cuneiform*, in *Proceedings of the IEEE Conference on Visual Analytics Science and Technology (VAST)* (<https://doi.org/10.2312/VAST/VAST04/135-143>).
- DIARA F. 2023, *Structured-light scanning and metrological analysis for archaeology: Quality assessment of Artec 3D solutions for cuneiform Tablets*, «Heritage», 6, 9, 6016-6034 (<https://doi.org/10.3390/heritage6090317>).
- DIARA F. 2024a, ITSERR - dataset\_1, Zenodo (<https://doi.org/10.5281/zenodo.10908664>).
- DIARA F. 2024b, ITSERR - CDE, Zenodo (<https://doi.org/10.5281/zenodo.10837436>).
- FISSELER D., MÜLLER G.G.W., WEICHERT F. 2017, *Web-based scientific exploration and analysis of 3D scanned cuneiform datasets for collaborative research*, «Informatics», 4, 44 (<https://doi.org/10.3390/informatics4040044>).
- GÖLDNER D., KARAKOSTIS F.A., FALCUCCI A. 2022, *Practical and technical aspects for the 3D scanning of lithic artefacts using micro-computed tomography techniques and laser light scanners for subsequent geometric morphometric analysis. Introducing the StyroStone protocol*, «PLOS ONE», 17, e0267163 (<https://doi.org/10.1371/journal.pone.0267163>).
- HOMBURG T., ZWICK R., MARA H., BRUHN K.-C. 2022, *Annotated 3D-models of cuneiform tablets*, «Journal of Open Archaeological Data», 10, 1-8 (<https://doi.org/10.5334/joad.92>).
- KOTOULA E., AKOGLU K.G., FRAHM E., SIMON S. 2017, *QR coded 3D prints of cuneiform tablets*, «International Journal of Art, Culture, Design and Technologies», 6, 1-11 (<https://doi.org/10.4018/ijacdt.2017070101>).
- MARA S.H., KRÖMKER S., BREUCKMANN J.-B. 2010, *GigaMesh & Gilgamesh: 3D multiscale integral invariant cuneiform character extraction*, in *Proceedings of the VAST: International Symposium on Virtual Reality, Archaeology and Intelligent Cultural Heritage, The Eurographics Association (Paris 2010)* (<https://doi.org/10.2312/VAST/VAST10/131-138>).
- MARIĆ I., ŠILJEG A., DOMAZETOVIĆ F. 2022, *Precision assessment of Artec Space Spider 3D handheld scanner for quantifying tufa formation dynamics on small Limestone Plates (PLs)*, in *Proceedings of the 8<sup>th</sup> International Conference on Geographical Information Systems Theory, Applications and Management GISTAM 2022*, Wien, SciTePress, 67-74 (<https://doi.org/10.5220/0010886900003185>).
- SCHILD L., SASSE F., KAISER J.-P., LANZA G. 2022, *Assessing the optical configuration of a structured light scanner in metrological use*, «Measurement Science and Technology», 33, 085018 (<https://doi.org/10.1088/1361-6501/ac6e2f>).

## ABSTRACT

Actual 3D scanners based on the structured-light principle are opening to possibilities for creating detailed models (polygon populations) with micrometric resolutions. Consequently,

highly detailed models allow specific investigations. This work focuses on 3D scanning and post-processing analysis/filtering of Ancient Near East finds, especially seals and cuneiform clay tablets, fragile artefacts that can hold a lot of semantic information beyond transliteration: e.g. seal impressions (figurative and textual sealings), fingerprint evidence, retracing and erased text. Behind the ease of use of portable structured-light scanners, hides the enormous potential for feature extraction and processing. Metric analysis (e.g. deviation analysis) coupled with the application of MSII (Multi-Scale Integral Invariant) filter enhance data extraction, changing the overall perception on details of the archaeological artefact.

## SCANSIONI 3D DI PICCOLI REPERTI PER IL PROGETTO ARCOA (ARCHIVI E COLLEZIONI DELL'ORIENTE ANTICO)

### 1. INTRODUZIONE

Il progetto ArCOA (Archivi e Collezioni dell'Oriente Antico) è finalizzato allo studio, alla valorizzazione e alla comunicazione delle collezioni di manufatti riferibili alle culture del Vicino Oriente antico conservati in Italia ed è stato avviato congiuntamente dall'Università degli Studi di Milano e dall'Istituto di Scienze del Patrimonio Culturale (ISPC) del CNR, con il coordinamento di Luca Peyronel e Tatiana Pedrazzi. L'Università di Torino costituisce, dal 2021, il principale partner universitario e il progetto vede la partecipazione di diverse istituzioni, tra cui i principali musei che ospitano le maggiori collezioni vicino-orientali italiane. ArCOA si avvale della partecipazione di partner che hanno aderito all'iniziativa attraverso un sistema di accordi e collaborazioni mirate, tra cui il Museo Archeologico di Firenze, il Museo Civico Archeologico di Como, i Musei Reali di Torino (attraverso la collaborazione con il Dipartimento di Studi Storici dell'Università di Torino). Sono coinvolti anche altri enti museali importanti, come il Museo Archeologico Nazionale di Venezia.

Il progetto ha come principali scopi lo studio, la fruizione pubblica e la disseminazione delle conoscenze relative alle culture antiche dell'Asia sud-occidentale e del Mediterraneo orientale attraverso i reperti conservati nelle collezioni italiane. L'arco cronologico di riferimento spazia dalla preistoria agli inizi dell'età ellenistica, mentre le regioni considerate vanno dal Levante, a Cipro, all'Anatolia, alla Mesopotamia, all'altopiano iranico e alla penisola araba. Nella sua strutturazione attuale, ArCOA ha realizzato la mappatura completa delle collezioni dell'Asia Occidentale antica presenti sul territorio nazionale italiano, al fine di renderle fruibili in modo unitario attraverso un archivio digitale (Fig. 1) collegato ad un webGIS, consultabile anche da un portale web dedicato (<https://www.arcoa.it>). La struttura e il graphic design del website ArCOA sono stati progettati dal team di Milano; il sito web è accessibile online dal 2024, offrendo la possibilità di interagire con la banca dati e predisponendo un'interfaccia user-friendly, informazioni testuali elaborate secondo i principi dello storytelling, modelli 3D dei manufatti e un webGIS per esplorare sia la dislocazione delle collezioni in Italia, sia i luoghi di provenienza dei manufatti. L'equipe multidisciplinare di ArCOA include archeologi, filologi, curatori museali, esperti informatici e multimediali, mediatori culturali. In un'ottica di collaborazione aperta e inclusiva, ArCOA mira a creare un'ampia rete di ricercatori, istituzioni e associazioni interessate alla comunicazione e alla valorizzazione delle collezioni e dei relativi archivi, con

azioni di coinvolgimento del pubblico secondo i principi e i metodi specifici della Public History e della Public Archaeology.

## 2. CASO STUDIO: LA SCANSIONE DI UNA TESTA IN TERRACOTTA

Il progetto ArCOA non solo si occupa della digitalizzazione degli archivi per la creazione di un database condiviso, ma si interessa anche di digitalizzare gli oggetti delle collezioni museali. Questi reperti sono di diversa forma e dimensione: sigilli, tavolette cuneiformi, coroplastica, etc. Spesso gli oggetti sono molto piccoli, con dimensioni massime intorno ai 5 cm di altezza; pertanto, le tecniche di digitalizzazione variano moltissimo (SAPIRSTEIN 2018): fotografie RTI<sup>1</sup> (Reflectance Transformation Imaging: MUDGE *et al.* 2005), fotomodellazione (PACE, BURSICH 2021) e solo raramente laser scanner.

La tecnica RTI è un metodo fotografico che cattura il colore e la forma della superficie di un soggetto, mostrando la reale conformazione della superficie grazie alla rimozione del colore. In altri termini elimina dalla superficie la possibilità di riflettere la luce e quindi annulla la colorazione della stessa. Consente poi la re-illuminazione interattiva del soggetto da qualsiasi direzione.

La fotogrammetria invece viene condotta utilizzando sia tecniche tradizionali, con scatto a mano libera o con cavalletto, sia tecniche meno comuni, come ad esempio con obbiettivo macro 100mm, fotogrammetria da videoclip, oppure con luce controllata e pedana rotante (Fig. 1). RTI e fotogrammetria possono essere combinate (SZELISKI 2010) per migliorare ad esempio la resa della texture Normal Map (usata per accentuare il dettaglio della superficie) (BLINN 1978), ed è possibile ottenere un modello 3D da una scansione RTI. Questa tecnica è attualmente in corso di sviluppo e rientra nel progetto IRIMES<sup>2</sup> (Immagine Romana Imperiale tra Moneta e Scultura – UniVR, in collaborazione con Soprintendenza di Roma, Musei Capitolini, Museo della

<sup>1</sup> Si deve necessariamente citare un interessantissimo applicativo ISTI-CNR denominato “Relight” (<https://vcg.isti.cnr.it/relight/>) sviluppato da F. Ponchio (<https://vcg.isti.cnr.it/~ponchio/>). Il software, a differenza di quello della CHI (<https://culturalheritageimaging.org/Technologies/RTI/>) è stabile, aggiornato per sistemi Windows 10 in poi e il calcolo RTI è praticamente istantaneo.

<sup>2</sup> Il progetto, di cui l’Autore fa parte, studia la rappresentazione della figura imperiale, su ritratto e intera, da una nuova prospettiva “periferica”, che mette in risalto il sottofondo culturale, religioso e artistico delle comunità nelle province imperiali, piuttosto che privilegiando il punto di vista tradizionale del “centro del potere”. Lo studio esamina analiticamente (grazie all’uso di software e modelli 3D) come gli imperatori venivano ritratti, celebrati e venerati nelle città provinciali, nelle regioni occidentali e soprattutto in quelle orientali dell’impero, dall’età di Augusto a quella di Diocleziano (c. 31 a.C.-297 d.C.). Il progetto inoltre introduce una metodologia di ricerca innovativa, che sfrutta la tecnologia 3D per confrontare, sovrapporre e integrare i dati monetali con quelli ricavabili dalla scultura per ricostruire i modelli ritrattistici usati nelle province per la rappresentazione imperiale (finanziamento MIUR, “Procedura per l’attuazione dell’intervento FARE Ricerca in Italia: Framework per l’attrazione ed il rafforzamento delle eccellenze per la Ricerca in Italia” - III ed. prot. R2035CJB5H) – Sito progetto: <https://www.dcuci.univr.it/~jsessi> onid=abcFN8krFvGHncwdVzM6y?ent=progetto&lang=portugues&id=5933.

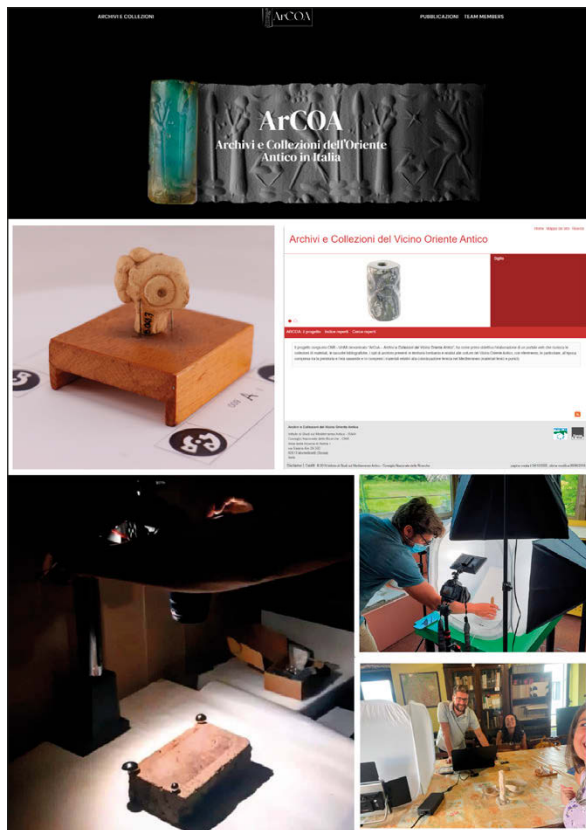


Fig. 1 – In alto: il sito web <https://www.arcoa.it>; nel mezzo: a sinistra, la figurina fittile A.1988.041(3) e a destra, il database creato dal CNR (<https://arcoa.cnr.it/login>); sotto: a sinistra, il procedimento di acquisizione RTI, a destra, momenti di lavoro con il set lightbox, luci e pedana rotante.

Civiltà Romana, Museo Centrale Montemartini, Museo Nazionale Archeologico di Mantova, Musei Reali di Torino).

Il caso studio proposto in questa sede riguarda la scansione di una testa fittile (inv. B.041.3 - A.1988.041(3); periodo persiano, 2400/2300-2000/1900 a.C.; Fig. 1), conservata nel Museo Civico “Carlo Verri” di Biassono (MB) e appartenente ad una statuina femminile con naso a becco di uccello e due rondelle con foro al centro come occhi, in argilla purificata e in stato frammentario (tipo Eufrate MAI 3a; DI PAOLO 1999). La testina è stata scelta per la sua interessante conformazione e per la dimensione pari a 3,5 cm di altezza, che la rendono facilmente scansionabile con la fotogrammetria.

### 3. METODOLOGIA

Per la fotogrammetria è stato allestito un set con lightbox, luci led a intensità variabile e una pedana rotante bluetooth, con barra led, comandata da app. La combinazione dello sfondo bianco (limbo) e la pedana rotante ha permesso di annullare elementi presenti in secondo piano e allo stesso tempo di rendere la luce all'interno della lightbox molto omogenea e uniforme. In questo modo la testina ha assunto una colorazione naturale senza ombre accentuate o parti sovraesposte. Le 117 foto sono state scattate su cavalletto da una camera full-frame mirrorless Lumix Panasonic DC-S5 con obiettivo 50 mm. La risoluzione delle foto è stata impostata 6000×4000 pixel con una risoluzione di 180 dpi profondità 24 bit (impostazioni di scatto f/7.1, tempo 1/160, ISO 100). Le foto sono state scattate da tre altezze differenti per consentire una copertura totale dell'oggetto e sono state utilizzate nel processo di elaborazione, per testarne l'affidabilità, con i tre software leader del mercato: Agisoft Metashape (v. 2.0.0; <https://www.agisoft.com/>), Epic Games/Capturing Reality RealityCapture (v. 1.3.0; <https://www.capturingreality.com/>) e 3D flow 3DF Zephyr (v. 7.021; <https://www.3dflow.net/it/software-di-fotogrammetria-3df-zephyr/>). Il flusso di lavoro è uguale in tutti e tre i software (Fig. 2), per cui prima vengono importate le immagini, poi vengono allineate e viene generata una nuvola di punti più o meno densa e infine viene fatto il calcolo della mesh con texture.

Per quanto riguarda Metashape, sono stati utilizzati tutti i parametri quasi al massimo (high), in modo tale da poter ottimizzare i tempi di calcolo della nostra workstation (circa 32 min. in totale) generando una nuvola di punti da 1,3 milioni, un modello da 150.000 poligoni e una texture in 8K (8192×8192 px). Come si nota in Fig. 2, il nuovo algoritmo introdotto dalla versione 2.0 migliora la resa del modello riuscendo a modulare l'ampiezza e la densità di triangoli che formano la superficie. La nuvola di punti è estremamente ordinata: i punti sono idealmente vertici di una griglia che descrive matematicamente il modello 3D. Dalla falsa colorazione della nuvola che evidenzia l'affidabilità morfologica della restituzione, si desume come le parti penalizzate siano l'interno degli occhi e i due supporti metallici posti a sostegno della testina. Qui effettivamente si riscontrano i punti deboli del programma Metashape. La resa dei supporti metallici della testa fittile è scarsissima, la forma è estremamente irregolare (blobs), ma completa nella sua estensione. Va detto però che le forme dei supporti non interferiscono con la forma della testina; quindi, di fatto non entrano in contatto e non ne compromettono la resa. Un altro neo è rappresentato dalla generazione della texture, che risulta poco precisa soprattutto nella parte più esterna del becco, dove addirittura il software non riesce a campire completamente la forma, lasciando un'isola nera.

Per quanto riguarda il software RealityCapture, utilizzando le stesse immagini con parametri molto alti (high) il risultato cambia decisamente



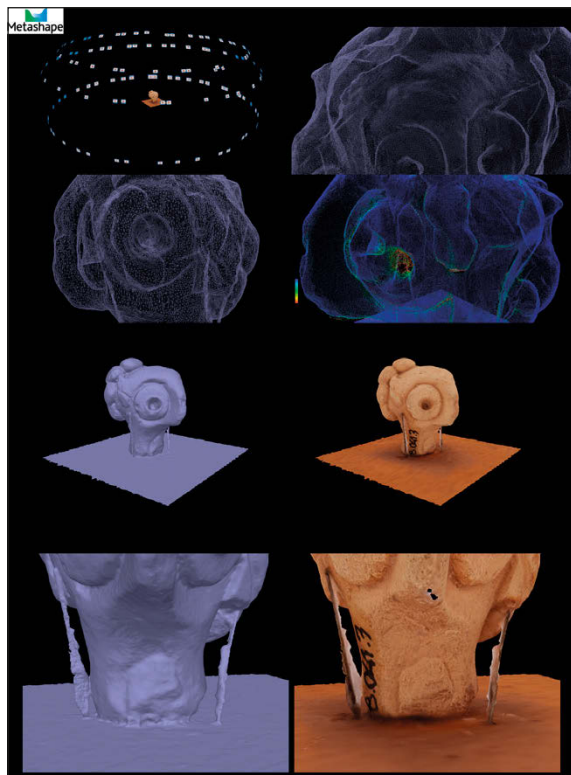


Fig. 2 – Flusso di lavoro con il software Metashape; in basso, il dettaglio dei supporti.

(Fig. 3). Il modello generato possiede una nuvola da 3,8 milioni di punti, mentre il modello 890.000 poligoni. Il tempo di calcolo è nettamente inferiore (4 min. e 40 sec.). Rispetto a Metashape, la nuvola di punti non è ordinata come i vertici di una griglia, ma i punti seguono l'andamento e la morfologia della superficie a prescindere dalla loro posizione. Il risultato è impeccabile, così come la generazione della texture (8192×8192 px) che risulta essere estremamente nitida e accurata. Qui, a differenza di Metashape, i supporti non vengono rappresentati, se non nella parte iniziale più a ridosso della testa come se fossero delle propaggini che si estendono dalla stessa testa fittile. Si evidenzia come, seppur conservati in minima parte, questi supporti mantengono una morfologia più o meno accurata anche se irregolare e abnorme. La mesh invece risulta essere molto liscia (smooth) e uniforme laddove ci sono più informazioni, mentre a ridosso della base della testa, a contatto con il legno del supporto, essa viene generata con evidenti anomalie della superficie (flaws)

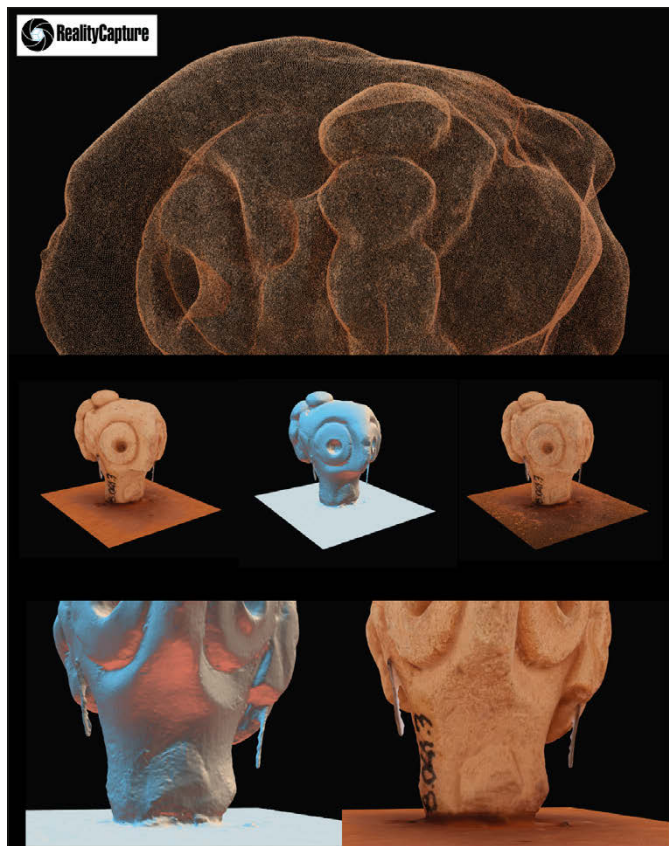


Fig. 3 – Flusso di lavoro con il software RealityCapture, in alto, la nuvola di punti; nel mezzo, i risultati dell'elaborazione (mesh con texture, mesh, point cloud); in basso, il dettaglio della testa con e senza texture.

e una sorta di raccordo, sia in termini geometrici che di texture, con la base. In confronto con Metashape invece la resa della texture è molto accurata e puntuale e copre tutte le parti della testa fittile compresa quella più esterna del becco, mantenendo una definizione e nitidezza più o meno omogenea.

L'ultima elaborazione è stata condotta con 3DF Zephyr (Fig. 4), anche qui mantenendo dei parametri molto alti come negli altri due casi. Il tempo di calcolo è inferiore a tutti gli altri software, quasi da record, pari a 2 min. e 20 sec., mentre la nuvola di punti è pari a 50.000 punti, per un totale di 34.000 poligoni. Il software non calcola punti non necessari e mantiene un numero basso di poligoni che però riescono a descrivere correttamente tutta la superficie. Le texture generate invece sono tre, tutte in 8K: infatti la resa

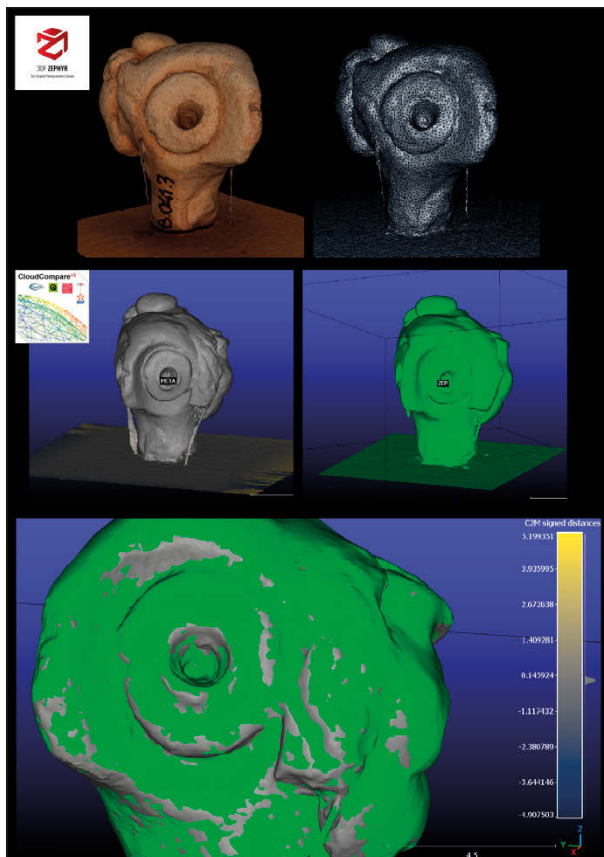


Fig. 4 – In alto: flusso di lavoro con il software Zephyr, il dettaglio della testa con e senza texture. Nel mezzo e in basso: flusso di lavoro con il software Cloud Compare, comparazione delle mesh da Zephyr (verde) e Metashape (grigio).

grafica del modello è sorprendente. Anche se il numero di poligoni è nettamente minore rispetto agli altri due modelli, in questo caso gli aghi vengono calcolati in modo molto simile al vero, se si considera che il loro spessore è inferiore al millimetro.

Dato che il numero di poligoni generato sia da Metashape che da 3DF Zephyr è nettamente più basso di quello di RealityCapture, è stato fatto un test di affidabilità morfologica comparando tra loro i modelli 3D ottenuti con lo scopo di verificare eventuali difformità e anomalie. Per questo test ci si è avvalsi del software Cloud Compare (CC) che è open source, freeware, molto solido e agile nell'utilizzo. Il procedimento permette di allineare

grossolanamente (*roughly registering*) le due mesh da confrontare, dopo però aver scalato correttamente i modelli e averli importati all'interno del software CC (Fig. 4), per poi passare alla modalità di allineamento "tre punti" (*point pairs picking tool*) che prevede l'indicazione di tre punti in comune tra la scansione di riferimento (*data reference*) e quella da allineare sopra al modello di riferimento (*data model*). Selezionando tre punti in comune tra un modello e l'altro, il software istantaneamente allinea tra loro i modelli 3D. In alternativa è possibile far combaciare i modelli con una modalità diversa che ne raffina la posizione e di fatto una adesione migliore (*fine registration - ICP*).

Terminato questo passaggio, è possibile calcolare la distanza tra le due superfici, ovvero richiedere al software di evidenziare eventuali differenze morfologiche. A seconda delle dimensioni delle entità e della loro estensione spaziale, questo processo può durare più o meno tempo. Nel nostro caso meno di 3 minuti. Il risultato è una colorazione a rampa che mostra il livello di sovrapposizione. Tra i due modelli 3D la differenza registrata è poco meno di 1 mm, risultando però, quello di Metashape più accurato e ricco di dettagli (Fig. 4).

#### 4. CONCLUSIONI

La digitalizzazione dei modelli 3D condotta finora ha permesso di comprendere come la fotogrammetria sia al momento la tecnica più versatile tra quelle esistenti di acquisizione indiretta (CAMPANA 2017). I laser scanner che sono stati testati non hanno dato risultati soddisfacenti per soggetti al di sotto dei 10 cm, specialmente se costruiti con materiali lucidi o riflettenti per cui sarebbe ideale l'utilizzo di un opacizzante senza ioni di titanio. La fotogrammetria declinata nelle varie applicazioni descritte (PIERDICCA 2016) permette di ottenere risultati soddisfacenti con uno scarto di errore ammissibile (GUIDI *et al.* 2014) compreso intorno a 1 mm. Va detto che i tempi di elaborazione sono relativamente lunghi se si utilizza Metashape, mentre più contenuti nel caso di RealityCapture e Zephyr. Tra i test di affidabilità condotti, risulta che se da una parte Metashape permette una migliore parametrizzazione del calcolo e quindi del risultato finale, per contro i tempi di elaborazione risultano essere ormai fuori scala rispetto ai competitor sul mercato e la texture non risulta essere raffinata e accurata come negli altri due casi.

Per quanto riguarda RealityCapture, il software ha dimostrato di essere estremamente performante sotto tutti i punti di vista a partire dalla resa visiva della texture così come la ricchezza di dati trasmessi dalla superficie della mesh e dalla nuvola di punti. Zephyr infine è stato l'unico in grado di calcolare correttamente gli aghi posti a supporto della testina fittile e infissi nella base di legno, ma per contro, nonostante i valori siano stati impostati nella modalità più alta possibile, non ha restituito appieno la complessità del modello che ci si aspettava. Possiede però un sistema di texturing estremamente

complesso, che ha restituito sicuramente un aspetto visivo notevole, al pari con quello di RealityCapture. La migliore scelta di software per questo tipo di applicazione per ora rimane RealityCapture. Una nuova frontiera invece si sta delineando sul fronte della rappresentazione tramite la tecnologia NeRF (Neural Radiance Fields; CROCE *et al.* 2023) e Gaussian Splatting.

Nonostante sia una tecnica recente ancora in fase di sviluppo, rispetto alla fotogrammetria soprattutto in ambito culturale (CONDORELLI *et al.* 2021), la tecnologia NeRF (MILDENHALL 2020) mostra un potenziale maggiore per descrivere le caratteristiche dei materiali. Grazie ai recenti progressi nel campo dell'Intelligenza Artificiale applicata alla rappresentazione digitale, l'introduzione dei campi di radianza neurale potrebbe col tempo diventare un'alternativa alla fotogrammetria per la scansione 3D da immagini. NeRF calcola i modelli da una serie di immagini scattate da pose note della fotocamera, al contrario della fotogrammetria che ammette foto scattate anche da punti di vista casuali.

Questa tecnologia fondamentalmente trova spazio nella rappresentazione degli oggetti soltanto dal punto di vista estetico, restituendo egregiamente materiali con dettagli complessi (MURTIYOSO 2023), nonostante il sistema richieda un numero limitato di immagini di input. Inoltre, un altro vantaggio di questa tecnologia è la qualità di rendering, particolarmente utile per materiali caratterizzati da texture omogenee, che notoriamente creano problemi con la fotogrammetria. Al contrario, la tecnologia Gaussian Splatting (KERBL 2023) offre una qualità di rendering simile con addestramento e inferenza più rapidi poiché non necessita di reti neurali per funzionare. Il Gaussian Splatting è una tecnica di rappresentazione in real time (Radiance Field Rendering) che consente di visualizzare in tempo reale i modelli 3D (scene) calcolati da pochissimi campioni di immagini. Vedremo come potranno evolvere questi nuovi metodi con la speranza che non rimpiazzino la fotogrammetria ma, al contrario, siano usati per implementarla e renderla più performante.

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## BIBLIOGRAFIA

- BLINN J. 1978, *Simulation of wrinkled surfaces*, ACM SIGGRAPH, «Computer Graphics», 12, 3, 286-292 (<https://doi.org/10.1145/965139.507101>).
- CAMPANA S. 2017, *Drones in archaeology. State-of-the-art and future perspectives*, «Archaeological Prospection», 24, 4, 275-296.
- CONDORELLI F., RINAUDO F., SALVADORE F., TAGLIAVENTI S. 2021, *A comparison between 3D reconstruction using NeRF Neural Networks and MVS algorithms on Cultural Heritage images*, «The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences (ISPRS Archives)», XLIII-B2-2021, 565-570.

- CROCE V., CAROTI G., DE LUCA L., PIEMONTE A., VÉRON P. 2023, *Neural Radiance Fields (NERF): Review and potential applications to Digital Cultural Heritage*, «The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences (ISPRS Archives)», XLVIII-M-2-2023, 453-460.
- DI PAOLO S. 1999, *Coroplastica di provenienza siriana e libanese in musei lombardi*, «Studi Micenei ed Egeo-anatolici», 41, 33-62; 54, 56, C1.
- GUIDI G., RUSSO M., ANGHELEDDU D. 2014, *3D survey and virtual reconstruction of archaeological sites*, «Digital Applications in Archaeology and Cultural Heritage», 1, 2, 55-69.
- KERBL B., KOPANAS G., LEIMKÜHLER T., DRETTAKIS G. 2023, *3D Gaussian Splatting for real-time radiance field rendering*, «ACM Transactions on Graphics», 42, 4.
- MILDENHALL B., SRINIVASAN P.P., TANCIK M., BARRON J.T., RAMAMOORTHY R. 2020, *NeRF: Representing Scenes as Neural Radiance fields for view synthesis*, «arXiv», 08.934.
- MUDGE M., VOUTAZ J.P., SCHROER C., LUM M. 2005, *Reflection transformation imaging and virtual representations of coins from the Hospice of the Grand St. Bernard*, in M. MUDGE, N. RYAN, R. SCOPIGNO (eds.), *The 6<sup>th</sup> International Symposium on Virtual Reality, Archaeology and Cultural Heritage Proceedings (Pisa 2005)*, 29-39 (<https://doi.org/10.2312/VAST/VAST05/029-039>).
- MURTIYOSO A., GRUSSENMEYER P. 2023, *Initial assessment on the use of state-of-the-art NeRF Neural Network 3D reconstruction for Heritage documentation*, «The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences (ISPRS Archives)», XLVIII-M-2-2023, 1113-1118 (<https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-1113-2023>).
- PACE A., BURSICH D. 2021, *New perspectives on documenting Attic pottery*, in V. BALDONI (ed.), *From Pottery to Context. Archaeology and Virtual Modelling*, «Archeologia e Calcolatori», 32.2, 83-94 (<https://doi.org/10.19282/ac.32.2.2021.08>).
- PIERDICCA R., FRONTONI E., MALINVERNI E.S., COLOSI F., ORAZI R. 2016, *Virtual reconstruction of archaeological heritage using a combination of photogrammetric techniques: Huaca Arco Iris, Chan Chan, Peru*, «Digital Applications in Archaeology and Cultural Heritage», 3, 3, 80-90 (<https://doi.org/10.1016/j.daach.2016.06.002>).
- SAPIRSTEIN P. 2018, *A high-precision photogrammetric recording system for small artifacts*, «Journal of Cultural Heritage», 31, 33-45 (<https://doi.org/10.1016/j.culher.2017.10.011>).
- SZELISKI R. 2010, *Computer Vision: Algorithms and Applications*, London, Springer Science & Business Media.

## ABSTRACT

ArCOA is a project aimed at the study, enhancement and communication of museum collections and historical archives on the ancient Near East in Italy. ArCOA was born from the collaboration between the University of Milan and the Institute of Heritage Science of the National Research Council, with a multidisciplinary working group of archaeologists, assyriologists, museum curators, cultural mediators and experts of technology applied to cultural heritage. The ArCOA team collaborates with several museums, public institutions and universities, including the Archaeological Museum of Como, the National Archaeological Museum of Florence, the Department of Historical Studies of the University of Turin and the Museum of Antiquities of the Royal Museums of Turin, for the diffusion of knowledge of the ancient cultures of the Near East. This paper shows the results obtained on photogrammetric scans of small terracotta head and its reprocessing through different programs, its morphological and geometric rendering. Even if today open source photogrammetric programs seem to be almost absent from academic researchs because non-commercial alternatives are not very competitive, much is moving instead in the freeware direction, with regulated conditions of use for universities and research centres, such as for example the latest version of Reality Capture or Metashape. Furthermore, the acquisition processes vary greatly in relation to the size of the object, which can force the operator to think in terms of micro-surveys.



## ZOTERO2MAP: SVILUPPO DI UN NUOVO STRUMENTO ITC PER LA CONDIVISIONE E LA PUBBLICAZIONE DEI DATI BIBLIOGRAFICI PER LA RICERCA STORICA E ARCHEOLOGICA

### 1. INTRODUZIONE

Negli ultimi decenni la produzione scientifica si è ampliata in modo esponenziale, grazie alla moltiplicazione delle sedi nazionali e internazionali di confronto scientifico e il numero crescente degli spazi editoriali anche digitali dove pubblicare le ricerche. Anche se molte risorse non sono liberamente fruibili, l'avvento della cultura open access ha notevolmente contribuito alla diffusione delle pubblicazioni aperte, una mole di dati che ha generato nei ricercatori il problema del continuo aggiornamento della propria conoscenza su argomenti generali o specifici (CARVALE, PIERGROSSI 2012, 2015; CARVALE, PIERGROSSI, ROSSI 2021; CARVALE 2022). Infatti, la creazione di una o più collezioni di record bibliografici e il loro aggiornamento sono probabilmente alcune delle più importanti componenti di una ricerca scientifica. In questo ambito i ricercatori dispongono di software specializzati che aiutano a raccogliere in maniera semplificata, gestire, aggiornare, organizzare e usare in modo intuitivo i record bibliografici.

Tra questi il più importante è senza dubbio Zotero (<https://www.zotero.org/>; AHMED 2011; PUCKETT 2011), un diffuso strumento open source che oltre ad offrire un aiuto ai singoli ricercatori, integra anche strumenti collaborativi attraverso il paradigma del cloud computing, come la possibilità di sincronizzare il proprio database su un server online e condividerlo, totalmente o in parte con colleghi e collaboratori, oltre alla possibilità di creare collezioni pubbliche. Zotero, oltre ad essere integrato con i più diffusi web browser, consente di gestire allegati, genera automaticamente citazioni e note e permette di associare ad ogni oggetto della collezione bibliografica uno o più tag. Nonostante queste funzioni, rimane uno strumento di lavoro personale, che il singolo ricercatore può adattare alle proprie esigenze, rendendo spesso difficile una più proficua collaborazione.

Nel corso degli anni l'esigenza di connettere il software open source Zotero con una visualizzazione di tipo cartografico, e quindi di vedere le citazioni su una mappa fruibile online, è emersa tra gli utenti della community e ci sono stati vari tentativi di sviluppare degli applicativi simili, che tuttavia non hanno avuto una diffusione ampia e il cui sviluppo è stato abbandonato, come ad esempio quella della Entropy Free LLC (<https://github.com/zotero/zotero-maps>), il cui ultimo aggiornamento risale a 13 anni fa. Rispetto alle proposte che attualmente sono disponibili in rete, che si appoggiano sull'utilizzo





Fig. 1 – L'applicazione web Zotero2map.

di software come QGIS (TOBIAS 2021, <https://github.com/MicheleTobias/LiteratureMapper>), l'applicazione che viene proposta in questa sede non necessita di alcuna installazione di programmi esterni, poiché sarà direttamente la webApp a collegare le collection degli utenti Zotero con il sistema della mappa online.

Partendo da queste considerazioni il Laboratorio di Archeologia Digitale (LAD, <https://purl.org/lad>) della Sapienza Università di Roma ha sviluppato una applicazione web, denominata Zotero2map<sup>1</sup> (Fig. 1), che consente di estendere le funzionalità di Zotero, con lo scopo di favorire la condivisione dei dati bibliografici provenienti da vari colleghi/collaboratori che vogliono condividere le proprie collezioni bibliografiche, visualizzando i risultati su una mappa. Attraverso questa applicazione è possibile collegare Zotero, che è ormai uno standard *de facto* per la ricerca scientifica, con un webGIS che consente di visualizzare e interrogare i dati bibliografici anche su base geografica. Zotero2map dunque permette l'interscambio di informazioni relative a diversi contesti storici e archeologici, velocizzando il loro reperimento e garantendo un aggiornamento costante dei dati inseriti nel sistema.

L'applicativo svolge un ruolo di aggregatore di contenuti bibliografici da librerie di ricercatori che decidono di collaborare, consentendo oltre alle ricerche tradizionali, anche la visualizzazione su una mappa di ciò che è stato

<sup>1</sup> Lo sviluppo dell'applicazione è stato possibile grazie al finanziamento Programma Progetti per Avvio alla Ricerca della Sapienza Università di Roma stanziato nel 2022 e realizzata dal Laboratorio di Archeologia Digitale (LAD) da E. Iacopini e J. Bogdani.

pubblicato (articoli, monografie, etc.) riguardante una determinata area geografica o uno specifico tema di ricerca che investe diversi ambiti territoriali. Ovviamente il risultato sarà più soddisfacente nella misura in cui i ricercatori decideranno di condividere le loro banche dati. Il coinvolgimento del Laboratorio di Archeologia Digitale della Sapienza in diversi progetti tuttavia consentirà di testare l'applicativo con team di ricerca diversi sia nazionali che internazionali, come ad esempio quello relativo all'Epiro settentrionale.

Infatti, come caso di studio per lo sviluppo e il test di questo strumento software è stata scelta la regione antica dell'Epiro settentrionale, un'area che coincide all'incirca con l'attuale Albania meridionale e la parte nordoccidentale della Grecia. Si tratta di una zona non troppo estesa, che ha conosciuto negli ultimi decenni un'importante stratificazione di studi, condotti da gruppi di ricerca internazionali, spesso espressi in lingue diverse. Nella seconda metà del Novecento, la ricerca storico-archeologica è stata condotta soprattutto da team locali, albanesi per l'area entro i confini albanesi e greci per la parte greca; questa produzione scientifica presenta importanti problemi di accessibilità sia fisica che di contenuto. Negli ultimi trent'anni la ricerca si è aperta a collaborazioni internazionali, che hanno contribuito in maniera determinante all'arricchimento dei contenuti, espressi anche in italiano, francese, spagnolo e inglese. La moltiplicazione degli attori ha portato alla moltiplicazione dei contenuti, della loro qualità e delle sedi di pubblicazione. Questa moltiplicazione va intesa in maniera esponenziale, dal momento che l'aumento della produzione primaria, con nuovi dati e ricerche sul campo in lingue accessibili, rende possibile e amplia lo studio secondario, ovvero la sintesi e analisi anche da parte di chi non opera direttamente sul terreno.

Per questi motivi e per il diretto coinvolgimento del LAD in lavori sul campo in area epirota (<https://purl.org/lad/cuka-e-ajtoit>), la regione è il banco di prova ottimale per questo progetto di ricerca. Come primo step è stata creata una banca dati Zotero relativa all'area geografica dell'Epiro, consultabile ricercando su Zotero il gruppo pubblico "Epirus" (<https://www.zotero.org/groups/336647/epirus/library>), il quale attualmente conta più di 600 elementi, tra cui monografie, articoli da volumi, articoli su riviste o semplici report. Questa banca dati è stata sviluppata in seno alle attività didattiche del LAD, a cui hanno contribuito gli studenti del corso di Metodologia della Ricerca archeologica del prof. J. Bogdani.

Per ciascun record bibliografico sono stati assegnati uno o più tag, sulla base dell'indicazione geografica o per argomento. Ad esempio, per l'articolo *A colossal cult statue group from Dobër, Albania: Visual narratives of East and West in the countryside of Butrint* di Milena Melfi, pubblicato sull'«American Journal of Archaeology» (Fig. 2), sono stati assegnati sette "tag", di cui quattro relativi al posizionamento geografico (Bouthrotos, Cestrine, Dobra e Vagalati) e tre tematici (fortifications, temple e Trojan cicle).

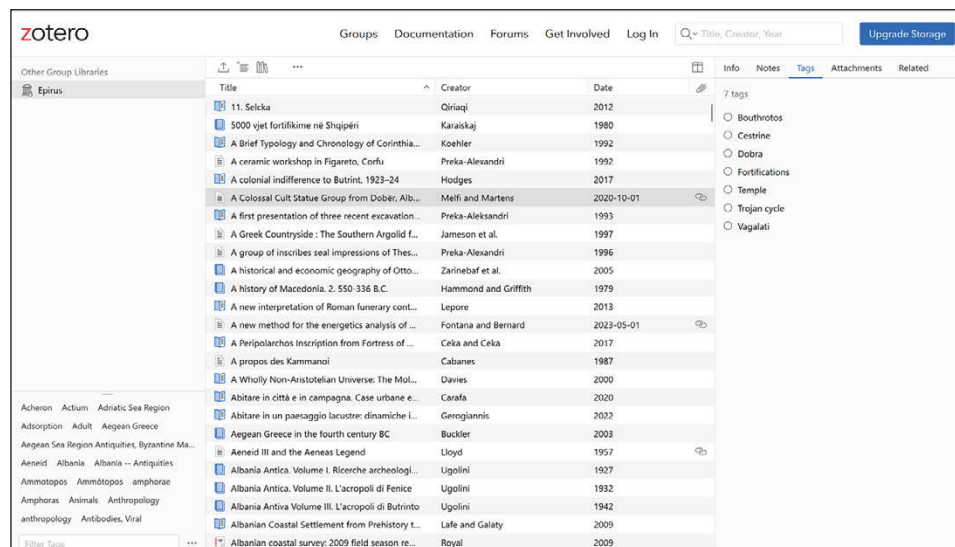


Fig. 2 – Libreria Zotero “Epirus”.

La possibilità di associare queste etichette agli elementi della collezione bibliografica è alla base della funzionalità dell'applicazione di incrociare questi dati con dei dizionari cross-language, una caratteristica, che consente a Zotero2map di avere una vocazione internazionale. Infatti, il sistema prevede di associare i termini relativi ad un medesimo argomento di ricerca o ubicazione geografica, ma trattati in lingue differenti, rendendo dunque la webApp fruibile da ricercatori di tutte le nazionalità. L'utilizzo di dizionari condivisi, multilingua, permetterà non solo di abbattere le barriere linguistiche, ma anche di definire una tassonomia articolata di relazioni tra i termini utilizzati. I singoli ricercatori, qualora intendano partecipare con i propri dati, non dovranno dunque adeguarsi a vocabolari prefissati, ma verranno invitati ad allineare, con strumenti semplici da usare, la propria tassonomia a quella condivisa, facendo uso di ontologie semplici ma potenti, come SKOS (<https://www.w3.org/2004/02/skos/>) o FOAF (<http://xmlns.com/foaf/spec/>).

## 2. SVILUPPO E CARATTERISTICHE

Zotero2map consente di visualizzare e ricercare dati bibliografici all'interno di una mappa online sviluppata con la libreria Maplibre GL JS (<https://maplibre.org/>), utilizzando parole chiave (tag), che definiscono i contenuti che sono archiviati all'interno delle librerie di Zotero. Dunque semplicemente cliccando sulla mappa è possibile risalire ai titoli dei contributi, dando la

```

{
  "type": "FeatureCollection",
  "name": "map",
  "features": [
    {
      "type": "Feature",
      "properties": {
        "name": "Chaonia",
        "altLabel": "Kaonia, Caonia",
        "broader": "Epirus"
      },
      "geometry": {
        "type": "Polygon",
        "coordinates": [
          [
            [19.572850963509893, 40.176334291240465],
            [19.68814489397072, 40.13486096671843],
            [19.888828565729381, 40.07078398342011],
            [19.912168018591871, 39.92172288994243],
            [19.994043256064288, 39.783680408414957],
            [20.042370792013909, 39.679635215754409],
            [20.081304662424344, 39.666673385832297],
            [20.102614745159883, 39.649640745995868],
            [20.18979108365876, 39.67411923637756],
            [20.27294389765888, 39.6881582236244],
            [20.405122106741572, 39.808616946648937],
            [20.431202407195883, 39.927894066696354],
            [20.340892092105548, 40.081636970322421],
            [20.091290593271822, 40.329207134616183],
            [19.892050406630773, 40.343161420197589],
            [19.61979205808646, 40.204077147814505],
            [19.572850963509893, 40.176334291240465]
          ]
        ]
      }
    ]
  ]
}

```

Fig. 3 – Struttura GeoJSON della ontologia.

possibilità ai singoli utenti/ricercatori di essere sempre aggiornati sul dibattito scientifico e sulle pubblicazioni riguardanti una certa zona. Lo strumento ITC è stato sviluppato con tecnologie open source e software liberi ed è utilizzabile da una platea virtualmente universale, implementabile da altri centri di ricerca nazionali e internazionali. In dettaglio, il workflow di sviluppo della applicazione ha previsto quattro step: 1) la creazione della ontologia; 2) il reperimento dei dati bibliografici attraverso l'utilizzo dell'API di Zotero; 3) la programmazione JavaScript per l'incrocio dei dati di Zotero con l'ontologia; 4) la costruzione dell'interfaccia grafica e del motore di ricerca interno.

Per quanto riguarda il primo punto, i ricercatori sono chiamati a collaborare alla creazione di un vocabolario/ontologia condiviso, disponibile alla pagina del progetto. In pratica ai ricercatori viene chiesto di stabilire o confermare l'identità tra i concetti: ad esempio, di Caonia (italiano), Kaonia (albanese), *Xaonia* (greco) e Chaonia (inglese); oppure l'appartenenza di un concetto ad un altro: ad es., Caonia è parte dell' (è compreso nell') Epiro, oppure "fortificazioni" è un sottoinsieme di "architettura". La creazione di una mappatura molto chiara tra le varie parole chiave, superando le barriere linguistiche e di scala della ricerca, permette di collegare record bibliografici in maniera estremamente puntuale e concettualmente solida, fornendo uno strumento di ricerca di estremo interesse, capace di allargare in maniera importante gli orizzonti della ricerca. Questa ontologia è resa mediante un file GeoJSON (Fig. 3), che prevede: le properties name (nome del toponimo), altLabel (nome alternativo del medesimo toponimo), broader (appartenenza

ad un insieme) e la sezione riguardante la tipologia geometrica (punto, linea, poligono) con le rispettive coordinate.

Per quanto riguarda la connessione con le banche dati degli utenti, l'applicazione utilizza Zotero API client (<https://www.npmjs.com/package/zotero-api-client>) ovvero un client sviluppato in JavaScript che consente di leggere tutti gli elementi della libreria. Il recupero dei dati bibliografici tramite API (Application Programming Interface) che lo stesso Zotero offre consente di non duplicare il database bibliografico dei singoli ricercatori e di essere sempre aggiornati sui cambiamenti. Attualmente (marzo 2024), la versione predefinita e consigliata dell'API Zotero è la v.3; normalmente le richieste dati alla libreria si riferiscono ad un "gruppo id" o a un "user id" a cui segue l'indicazione di "/item" per estrarre tutti i dati di una libreria, ad esclusione degli elementi cestinati. Il programma a questo punto effettua un incrocio dei dati tra la bibliografia proveniente da Zotero, strutturati in formato JSON e il file dell'ontologia, seguendo questa logica:

- confronta la proprietà "tag" della bibliografia con le voci dell'ontologia;
- se un "tag" ha una corrispondenza con una o più voci dell'ontologia, il codice aggiungerà alla risorsa bibliografica una proprietà denominata "match" contenente un array con i valori dei tag che hanno corrispondenza, questo perché una risorsa bibliografica potrebbe essere associata ad esempio con più luoghi;
- il codice raggruppa tutti gli elementi della bibliografia per "matched tag" e crea un file GeoJSON a cui aggiunge la proprietà "biblio" che contiene un array dove sono indicati tutti i record bibliografici corrispondenti con l'indicazione del titolo, dei tag, della data di edizione e dell'autore.

Rendiamo questa procedura più chiara con un esempio concreto (Fig. 4). L'elemento bibliografico della collezione "Epirus" di Zotero, *In the footsteps of Aeneas: Excavations at Butrint, Albania 1991-2* di Arafat Morgan del 1995, ha come tag "Butrint", "Chaonia", "Epirus", "Greek Archaeology" e "Kestrine". Quindi nella nostra ontologia avrà una corrispondenza con tre voci: Butrint, Chaonia e Kestrine (altlabel di Cestrine). Il programma, dunque, associa alla risorsa bibliografica questi tre valori all'interno della nuova proprietà "match" che non è nativamente presente nella risposta alla chiamata API di Zotero, ma viene aggiunta *ad hoc* all'interno del flusso del codice JavaScript. Una volta completata la procedura di valutazione di matching tra la bibliografia e la ontologia e dunque i record bibliografici hanno impostati i valori di match, il programma raggruppa i libri che hanno in comune uno stesso valore (ad es. Chaonia/Chaonia, Kestrine/Kestrine, etc.) e crea una nuova proprietà "biblio" in un file GeoJSON completamente nuovo, che da un lato riprende i valori dell'ontologia ma aggiunge un array bibliografico con tutti i record bibliografici che hanno in comune lo stesso valore di tag. Quindi proseguendo nel nostro esempio, nel file GeoJSON finale si troverà un

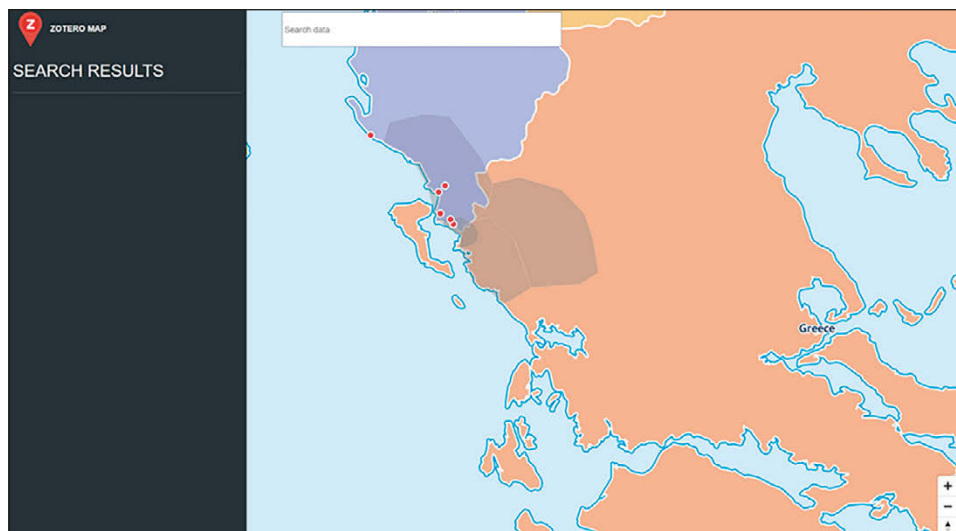


Fig. 4 – Interfaccia webGIS.

elemento con “properties name” Cestrine, Altlabel Kestrine, Broader Chaonia, Trespotia e biblio, il quale è un array di oggetti contenenti i valori della risorsa bibliografica con properties title *In the footsteps of Aeneas: Excavations at Butrint, Albania 1991-2*, tag un array contenente Butrinto, Chaonia, Epirus, Greek Archaeology e Kestrine e infine author Arafat, Morgan 1995.

Questa routine serve per collegare ad un singolo punto o area tutti i libri che riguardano quel luogo. Il file GeoJSON creato dal codice viene utilizzato come base per la realizzazione della mappa, per la quale è stata usata la libreria TypeScript MapLibre GL JS. Infatti, l’interfaccia utente, anch’essa sviluppata in JavaScript, consiste in una mappa (Fig. 5) che consente di visualizzare i luoghi (areali o puntuali) definiti nella ontologia, a cui è associato un array di elementi bibliografici che hanno in comune la medesima localizzazione geografica. L’utente cliccando su un’area o un punto riceverà sulla colonna di sinistra i risultati pertinenti alla sua azione.

Nello specifico il codice di sviluppo della mappa prevede diversi passaggi tra cui:

- per ogni elemento del file GeoJSON crea un layer e controlla il tipo di geometria, se è un punto o un poligono e assegna le diverse caratteristiche grafiche (colore, pattern, etc.);
- aggiunge il layer sulla mappa;
- crea la sidebar ubicata sulla sinistra e per ogni elemento bibliografico riporta il titolo del volume, i tag a cui è associato e il nome dell’autore.

```
{
  "type": "Feature",
  "properties": {
    "name": "Cestrine",
    "altlabel": "Kestrine",
    "broader": "Chaonia, Thesprotia",
    "biblio": [
      {
        "key": "71JWJJE4",
        "title": "In the footsteps of Aeneas: Excavations at Butrint, Albania 1991-2",
        "tag": [
          "Butrint",
          "Chaonia",
          "Epirus",
          "Greek Archaeology",
          "Kestrine"
        ],
        "author_date": "Arafat, Morgan. 1995"
      },
      {
        "key": "IF2EFS4K",
        "title": "Çuka e Aftit: një kontribut i ri",
        "tag": [
          "Cestrine",
          "Chaonia",
          "Epirus",
          "Fortifications",
          "Hellenistic Archaeology",
          "Çuka e Aftit"
        ],
        "author_date": "Bogdani. 2009"
      }
    ]
  }
}
```

Fig. 5 – Struttura GeoJSON del file prodotto dalla routine di corrispondenza tra elementi bibliografici e ontologia.

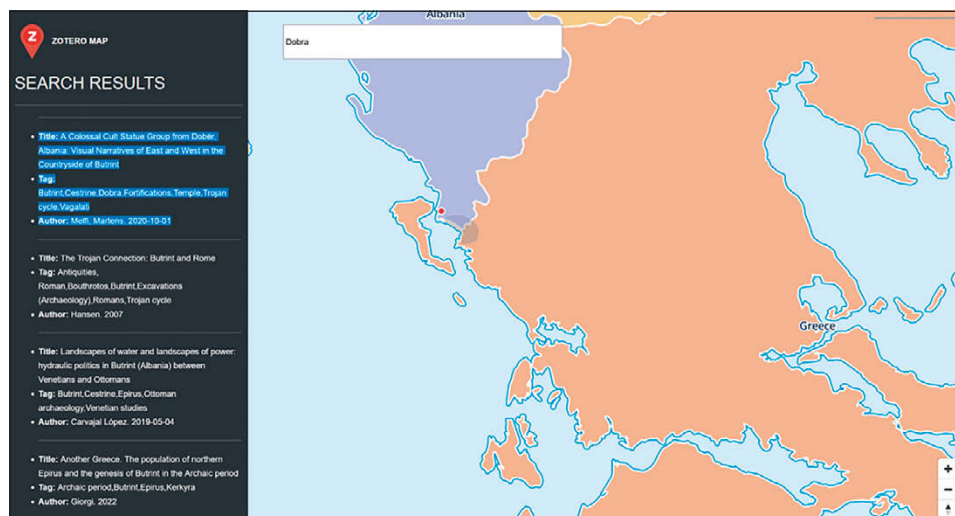


Fig. 6 – Esempio di restituzione dati.

Oltre all'azione diretta sulla mappa, l'utente può eseguire le proprie ricerche attraverso un form posizionato in alto a sinistra, nel quale può filtrare i dati per località, titolo del volume, autore o argomento. In questo caso l'utente vedrà direttamente sulla mappa il risultato delle proprie query (Fig. 6).



### 3. CONCLUSIONI

In conclusione, Zotero2map amplifica le funzioni di Zotero, fornendo importanti servizi di aggiornamento e conciliazione bibliografica per i singoli studiosi, senza introdurre un aggravio di lavoro e senza cambiare il flusso di lavoro che già mettono in atto. L'utente finale, dunque, semplicemente aprendo un browser web, potrà accedere alla visualizzazione della mappa e potrà effettuare delle ricerche sui termini di interesse. Le potenzialità innovative del sistema rispetto alle opzioni attualmente in uso stanno dunque nella facilità di utilizzo da parte degli utenti, che non devono installare alcunché sui propri dispositivi, nella realizzazione di un'interfaccia user friendly e cross-browsing, visualizzabile su diverse piattaforme, nella connessione automatica dei dati e nell'elaborazione multi-language dei "tag" e delle keyword, che di fatto rende il sistema fruibile a ricercatori di diverse nazionalità.

Si tratta di uno strumento software, che in questa fase iniziale di implementazione è dedicato all'area epirota, ma che potrà essere personalizzato e implementato per qualsiasi ambito della ricerca scientifica. L'applicazione è costruita interamente con tecnologie open source ed è rilasciata a sua volta con licenza open source (AGPL 3.0, <https://www.gnu.org/licenses/agpl-3.0.en.html>), come gran parte dei progetti a cura del LAD. È liberamente scaricabile dalla pagina GitHub del Laboratorio di Archeologia Digitale al seguente indirizzo: <https://github.com/lab-archeologia-digitale/zotero2map>.

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### BIBLIOGRAFIA

- AHMED K.K.M., AL DHUBAIB B.E. 2011, *Zotero: A bibliographic assistant to researcher*, «Journal of Pharmacology & Pharmacotherapeutics», 2, 4, 303-305 (<https://doi.org/10.4103/0976-500X.85940>).
- CARVALE A. 2022, *Le banche dati archeologiche. Articolazione e formalizzazione delle conoscenze*, Firenze, Edizioni All'Insegna del Giglio.
- CARVALE A., PIERGROSSI A. 2012, *Archeologia in rete. Le riviste open access: risorse e prospettive*, «Archeologia e Calcolatori», 23, 187-207 ([https://www.archcalc.cnr.it/indice/PDF23/11\\_Caravale\\_Piergrossi.pdf](https://www.archcalc.cnr.it/indice/PDF23/11_Caravale_Piergrossi.pdf)).
- CARVALE A., PIERGROSSI A. 2015, *Archaeological open access journals: The case of «Archeologia e Calcolatori»*, in F. GILIGNY, F. DJINJIAN, L. COSTA, P. MOSCATI, S. ROBERT (eds.), *Concepts, Methods and Tools. Proceedings of the 42<sup>nd</sup> Annual Conference on Computer Applications and Quantitative Methods in Archaeology (Paris 2014)*, Oxford, Archaeopress, 257-263.
- CARVALE A., PIERGROSSI A., ROSSI I. 2021, *Open Data, Open Knowledge, Open Science: The New OpenLab of the Institute for Heritage Science (CNR)*, in J. BOGDANI, R. MONTALBANO, P. ROSATI (eds.), *ArcheoFOSS XIV 2020, Open Software, Hardware, Processes, Data and Formats in Archaeological Research, Proceedings of the 14<sup>th</sup> International Conference*, Oxford, Archaeopress (<https://www.archaeopress.com/Archaeopress/download/9781803271248>).

PUCKETT J. 2011, *Zotero: A Guide for Librarians, Researchers, and Educators*, Chicago, Association of College and Research Libraries.

TOBIAS M., MANDEL A. 2021, *Literature mapper: A QGIS plugin for georeferencing citations in Zotero*, «Air, Soil and Water Research», 14 (<https://doi.org/10.1177/11786221211009209>).

## ABSTRACT

Zotero2map is a web application for sharing bibliographic data from various collaborators who want to share their bibliographic collections, using the Zotero software with the specificity of displaying and querying data also on a geographical map. With this tool the LAD: Laboratory of Digital Archeology at Sapienza (<http://purl.org/lad>) aims to facilitate the exchange of information relating to different historical and archaeological contexts, to speed up their retrieval and ensure constant updating of the data entered into the system. The webApp allows you to view and search for bibliographic data within an online map, using keywords (tags) that define the contents that are archived within the Zotero Libraries, which individual researchers already use for own scientific production. By simply clicking on the map it will therefore be possible to go back to the titles of the contributions, giving the possibility to individual users/researchers to always be updated on the scientific debate and on the publications concerning a certain area. The international vocation of the project presented is given not only by usability and open distribution, but also by the development of the cross-language functionality of keywords, a system that will allow the association of terms related to the same research topic but treated in different languages. The use of shared, multilingual dictionaries will allow not only to break down language barriers, but also to define an articulated taxonomy of relationships between the terms used. Individual researchers therefore do not have to adapt to pre-established vocabularies, but are invited to align their taxonomy with the shared one, making use of simple but powerful ontologies, such as SKOS or FOAF. Currently the software has been used on the specific case of Caonia, Northern Epirus.

## SIMPLIFYING CONTEXTUALIZATION OF 3D MODEL ARCHIVES IN WEBGIS: 3DMODELCOMMONS

### 1. INTRODUCTION

The surge in availability and diversity of 3D models of humanities reconstructions in a plethora of 3D model formats has provided GIS with a wealth of data potentially transformative for spatial analysis and decision-making. However, the effective use of these models in webGIS applications is often hampered by inconsistent data formats, lack of contextual metadata, and the absence of standardized integration practices. 3DModelCommons addresses these issues by focusing on the systematic collection and utilization of metadata to enhance the reusability of pre-existing 3D model archives within webGIS environments. By creating a framework that supports the consistent integration of these diverse models, 3DModelCommons aims to unlock the potential of 3D data for a broad range of GIS applications, from urban planning to cultural heritage preservation.

### 2. BACKGROUND

The integration of 3D models into Geographic Information Systems (GIS) represents a significant evolution from traditional two-dimensional (2D) data handling (ZLATANOVA 2002; BILLEN 2009). This shift not only provides a richer, more intuitive understanding of spatial environments but also introduces complexities related to data management, interoperability, and visualization (FAIRBAIRN 2006). 3D modeling technologies have become more sophisticated and widely used across various sectors including urban planning, architecture, and environmental studies, but they also have become available to the general public because of practical applications in 3D printing and independent game development and are shared via public archives. For these reasons, the need for effective tools to manage and utilize these models in GIS platforms has become evident.

3D models offer detailed visual and structural information that can enhance decision-making processes in urban planning, disaster management, and environmental monitoring. However, the integration of these models into GIS platforms is not straightforward due to several inherent challenges:

- Data volume and complexity: 3D models, especially those representing complex urban environments or intricate architectural details, can be large in file size and geometric complexity. This poses significant challenges for storage, retrieval, and real-time rendering in web-based GIS applications.

- Diversity of formats: there is a wide array of 3D file formats such as STL, OBJ, FBX, and Collada, each with its own specific use cases and supported features. This diversity necessitates robust conversion and standardization tools to ensure that these models can be uniformly processed and integrated into GIS platforms.
- Lack of metadata: many 3D models are created without comprehensive metadata, which is crucial for their effective use in GIS. Metadata not only aids in the identification and retrieval of relevant models but also provides critical information about the accuracy, scale, provenance, and appropriate usage of the data.
- Spatial accuracy and georeferencing: ensuring that 3D models are accurately positioned in a spatial context is essential, especially when they are used in conjunction with other spatial data layers. Models must be properly georeferenced to real-world coordinates, a process that can be complex depending on the origin and quality of the 3D data.

Several tools and platforms have attempted to address these challenges, yet each presents its own limitations. Traditional GIS platforms have predominantly focused on 2D spatial data, with 3D capabilities often added as an afterthought. While newer platforms have begun to integrate 3D functionalities more seamlessly, they frequently require extensive customization or suffer from performance issues when handling large datasets. Open source libraries like Three.js have enabled more dynamic and visually appealing 3D renderings in web browsers, thus providing a foundational technology for 3D GIS applications. However, without a comprehensive approach to the underlying challenges of data management and integration, the full potential of these technologies remains untapped (HAKLAY *et al.* 2008).

The absence of standardized and targeted metadata for 3D models is a critical gap that impedes their effective integration into GIS workflows. IIIF offers a set of metadata descriptors, but it is an adaptation of metadata descriptors thought of and created aiming at placing 2D items on visualizers. Metadata plays several roles in this specific context:

- Enhancing discoverability: by providing key descriptive information, metadata allows users to quickly find models relevant to their specific needs.
- Facilitating interoperability: standardized metadata helps ensure that 3D models can be effectively shared and utilized across different systems and platforms, enhancing collaborative efforts and reducing redundancy in model creation.
- Improving data quality and relevance: metadata can include information about the accuracy, resolution, and time relevance of the data, which is crucial for ensuring that the models are suitable for specific analytical tasks.

Addressing these challenges through a unified approach that encompasses robust metadata management, data standardization, and efficient

rendering technologies is the key to advancing the use of 3D models in GIS. The development of 3DModelCommons represents a strategic response to these needs, aiming to simplify and enhance the integration of 3D models in webGIS environments by leveraging advanced tools and methodologies.

### 3. METHODOLOGY

A robust metadata schema is critical for the contextualization and integration of 3D models into GIS applications. 3DModelCommons develops a metadata framework tailored to the needs of GIS users, which includes fields for geolocation, model creator, creation date, data source, spatial resolution, and intended application area. This framework ensures that each model can be easily located, understood, and utilized in various GIS projects. To address the issue of diverse 3D model formats, 3DModelCommons incorporates a conversion tool that standardizes models to a web-optimized format such as glTF, which is supported by Three.js. This process is vital for ensuring that models are not only uniformly accessible but also ready for integration into the MapLibre-powered GIS interface.

Using the standardized models (BACA 2016) and enriched metadata, 3DModelCommons leverages map to integrate these models into a dynamic, interactive GIS environment. This integration allows users to overlay 3D models on 2D base maps, interact with the models, and perform complex spatial analyses. The metadata managed by 3DModelCommons has the following structure:

- Core data
  - Original URL
  - Origin (name of the web archive)
  - GLTF local version (for caching)
  - Ownership (name of the user who detains ownership)
  - Rights (dictionary explicitly stating what can be done with the model)
- Coordinates (space and time)
  - Lat, lon (array of floats locating the point of origin of the model)
  - Elevation (for DEM based renders)
  - From, to (dates representing when the model is valid)
- Rotation
  - X, Y, Z rotation (array of floats representing the expected rotation for the model)
- Scale
  - Default: 1 (float representing the scale at which the model has been created)
- Tags (list of strings)

The ownership and rights are crucial for a primary filtering of the feasible models to be visualized on a map. This enables private collections or

copyrighted materials to be only metadated and made usable by the owners alone, without having to lose the metadata about the existence of those models.

Furthermore, the metadata schema also supports additional fields for model quality assessment, such as accuracy indicators, source reliability, and documentation of any modifications made during the conversion process. These fields provide users with a deeper understanding of the model's provenance and quality, aiding in the selection of appropriate models for specific applications. The comprehensive metadata framework of 3DModelCommons ensures that all aspects of the 3D models are well-documented, enhancing their usability and integration into GIS workflows.

#### 4. IMPLEMENTATION

The implementation of 3DModelCommons involves several critical components designed to handle the integration, management, and visualization of 3D models within a webGIS environment effectively. Each component is structured to optimize performance, ensure user-friendly interactions, and facilitate the robust management of 3D model archives. To manage the extensive data requirements of the converted 3D models, 3DModelCommons utilizes a cloud-based object-storage to collect the 3D model files and a document database for their associated metadata. This cloud infrastructure provides scalable storage solutions and high availability, which are essential for handling large datasets and supporting concurrent user access from various geographic locations. The repository supports various file formats and converts them into a standardized format (glTF) to ensure compatibility and performance optimization across different platforms.

Given the diversity of 3D model formats, a key feature of 3DModelCommons is its ability to convert various formats into a more uniform, web-optimized format such as glTF. This process not only reduces the file size, making it more suitable for web delivery but also simplifies the rendering process on client devices. The platform employs automated tools that also correct any errors in the models during the conversion process, such as misplaced vertices or incorrect normals, which can affect the visual accuracy and rendering performance.

MapLibre GL JS plays a crucial role in the platform, providing the GIS functionalities needed to overlay 3D models onto interactive maps. It allows users to manipulate map views (zoom, pan, rotate) and interact with the 3D models directly within their spatial context (WARE 2012). This integration is made seamless through the use of a custom-developed plugin (Fig. 1) that syncs the 3D model's geolocation metadata with the MapLibre map canvas, ensuring that models are accurately placed according to real-world coordinates.

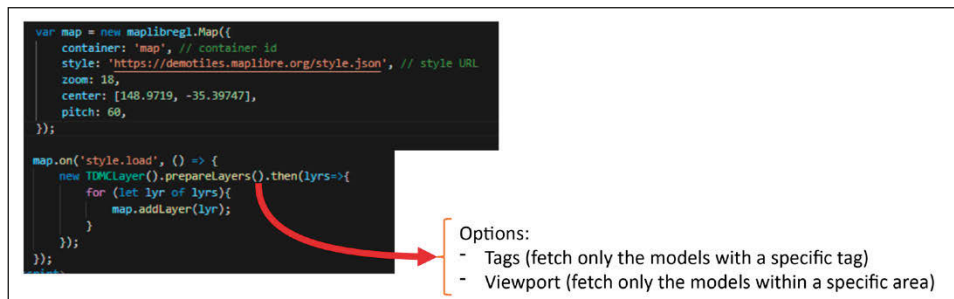


Fig. 1 – Example usage of the MapLibre GL JS plugin.

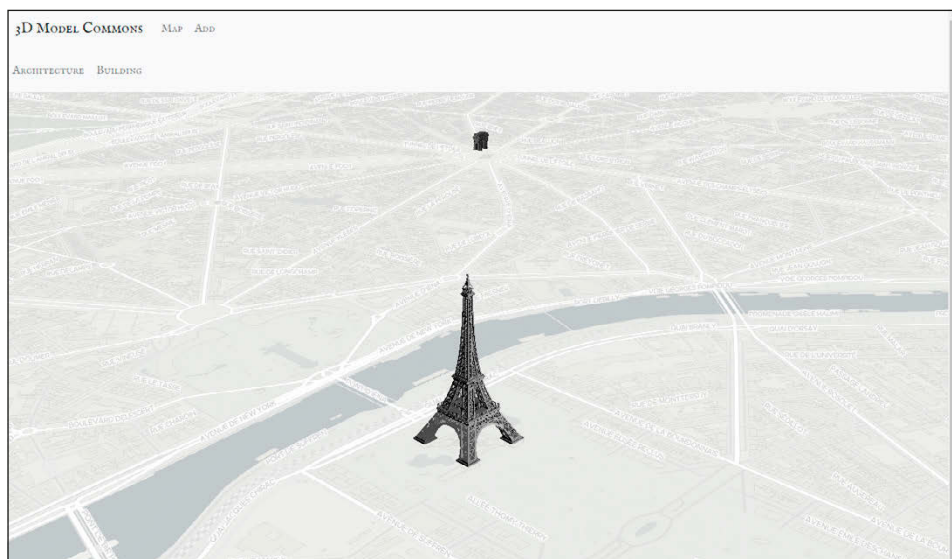


Fig. 2 – Visualization of the models on the map.

The interaction capabilities are further enhanced by incorporating various GIS tools within the MapLibre environment, such as measuring distances and areas, querying model details, and creating spatial annotations. These tools are essential for users who need to perform detailed spatial analysis and need precise interaction with the 3D models (Fig. 2). Rendering 3D models efficiently in a web browser is a significant challenge due to the computational and graphical demands. 3DModelCommons uses Three.js, a robust JavaScript library that leverages WebGL for hardware-accelerated graphics. Three.js is utilized for its efficient rendering capabilities, which include handling lighting,



shadows, and textures, which are crucial for producing realistic visualizations of 3D models.

Rendering 3D models efficiently in a web browser is a significant challenge due to the computational and graphical demands. 3DModelCommons uses Three.js, a robust JavaScript library that leverages WebGL for hardware-accelerated graphics. Three.js is utilized for its efficient rendering capabilities, which include handling lighting, shadows, and textures, which are crucial for producing realistic visualizations of 3D models. The library's extensive feature set and active development community ensure that it remains at the cutting edge of web-based 3D rendering technologies.

Three.js also supports various rendering optimizations such as level-of-detail (LOD) techniques, which reduce the model complexity as the camera moves away from the object, and frustum culling, which skips the rendering of objects outside the camera's view. These optimizations are critical for maintaining high performance and smooth user experiences, especially when dealing with complex or multiple 3D models (KIM, LEE, HAN 2013). By implementing these techniques, 3DModelCommons ensures that even large and intricate models can be rendered efficiently on a wide range of devices, from high-end desktops to mobile phones.

The implementation strategy of 3DModelCommons also includes a comprehensive user interface designed to facilitate easy access and manipulation of 3D models. The interface provides intuitive controls for navigating the 3D environment, selecting models, and adjusting their properties. Users can easily switch between different views, such as top-down or perspective, and apply various filters to highlight specific features or attributes of the models. This user-centric design ensures that both novice and experienced users can effectively utilize the platform for their GIS tasks.

Overall, the implementation of 3DModelCommons is characterized by a focus on resilient architecture, seamless integration of 3D models with GIS capabilities, and efficient rendering technologies, aimed at maximizing the accessibility and usefulness of 3D model archives in webGIS applications. By addressing the key challenges associated with 3D model integration and visualization, 3DModelCommons provides a powerful tool for enhancing spatial analysis and decision-making across a wide range of disciplines.

## 5. CONCLUSION AND FUTURE WORK

3DModelCommons demonstrates how a focused approach to metadata can transform the use of existing 3D models in webGIS environments. By facilitating better management, searchability, and integration of 3D data, the platform ensures that these resources are more accessible and useful for a wide range of applications. As the field of GIS continues to evolve, such

innovations will be crucial for leveraging the full potential of spatial data in various areas. Future work will focus on expanding the capabilities of 3DModelCommons to support more advanced features and integrations. This includes enhancing the conversion pipelines to generate models with various Levels of Detail (LOD) so that they can be used in different types of applications, from detailed architectural visualizations to broad landscape analyses. Additionally, efforts will be made to simplify integrations with major tools like Unity, which is widely used in the Digital Humanities community and beyond. By providing seamless workflows between 3DModelCommons and these popular platforms, users can more easily incorporate 3D models into their projects, regardless of the specific software they are using.

Another area of future development is the enhancement of metadata standards and practices. As new types of 3D data and applications emerge, the metadata framework will need to be updated to capture relevant information accurately. This includes the development of more detailed quality metrics and provenance tracking to ensure the reliability and trustworthiness of 3D models. Additionally, collaborative efforts with other metadata standardization initiatives will help align 3DModelCommons with broader industry practices, facilitating interoperability and data sharing.

The integration of machine learning and artificial intelligence (AI) technologies also holds significant potential for 3DModelCommons. By incorporating AI-driven tools for automatic metadata extraction, quality assessment, and anomaly detection, the platform can further streamline the management of 3D model archives. These technologies can also enhance the user experience by providing intelligent recommendations and insights based on the analysis of large datasets. Finally, expanding the community and user base of 3DModelCommons will be a key priority. By engaging with a diverse range of users, from academic researchers to industry professionals, the platform can continuously evolve to meet the needs of its users. Workshops, training sessions, and collaborative projects will help build a vibrant community around 3DModelCommons, fostering innovation and knowledge sharing.

In conclusion, 3DModelCommons tries to represent a useful advancement in the integration of 3D models into webGIS environments. Through its comprehensive approach to metadata management, data standardization, and efficient rendering technologies, the platform addresses the critical challenges associated with 3D model integration. As the platform continues to develop and expand, it can play a central role in unlocking the potential of 3D data for data visualization across various disciplines.

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## REFERENCES

- BACA D., BLAZEK P., VOJTEK M. 2016, *Metadata management in GIS: Approach for efficient implementation*, «ISPRS International Journal of Geo-Information», 5, 5, 77.
- BILLEN R., ZLATANOVA S. 2009, *3D Geo-Information Sciences*, Berlin, Springer.
- FAIRBAIRN D., PARSLEY S. 2006, *The use of the Internet in teaching cartography to support distance learning*, «Journal of Geography in Higher Education», 30, 1, 77-90.
- HAKLAY M., SINGLETON A., PARKER C. 2008, *Web mapping 2.0: The neogeography of the GeoWeb*, «Geography Compass», 2, 6, 2011-2039.
- HILL L.L. 2004, *Georeferencing: The Geographic Associations of Information*, Cambridge, The MIT Press.
- KIM K., LEE S., HAN J. 2013, *An efficient LOD management framework for large-scale 3D urban models in web-based GIS*, «Computers, Environment and Urban Systems», 39, 152-164.
- WARE C. 2012, *Information Visualization: Perception for Design*, San Francisco, Elsevier.
- ZLATANOVA S., RAHMAN A.A., PILOUK M. 2002, *Trends in 3D GIS development*, «Journal of Geospatial Engineering», 4, 2, 71-80.

## ABSTRACT

This paper presents a transformative approach that allows for the utilization of existing 3D models from diverse sources within a geographic context. It introduces the concept of external metadata, which describes these models, making them searchable, accessible, and seamlessly integrated in webGIS environments using Three.js and MapLibre GL. This paper addresses the demand for the reuse of three-dimensional data representation in the geospatial domain and acknowledges the wealth of 3D models available from various sources. By introducing a standardized metadata schema, it establishes a structured framework for the incorporation of these models into webGIS systems. A central theme of this work is the development of a metadata standard that acts as a bridge between 3D models and webGIS environments granting it all information that can be used to correctly locate, scale and orient the models. It enables efficient searching, rendering, and utilization of these models within geographic contexts. Leveraging MapLibre GL JS and Three.js, the paper showcases how external metadata can significantly enhance the integration of 3D models into webGIS, thereby fostering a more versatile and comprehensive geospatial data exploration experience.

## I PROGETTI WIKIMEDIA E GLI ENTI CULTURALI

### 1. OBIETTIVI CONVERGENTI

Cosa hanno in comune i progetti Wikimedia e il mondo GLAM (Galleries, Libraries, Archives and Museums)? Sono ormai numerosi gli esempi a sostegno del mutuo riconoscimento di obiettivi convergenti (<https://it.wikipedia.org/wiki/Progetto:GLAM>). Wikipedia è un progetto che si basa sulla contribuzione volontaria e sulle fonti poiché, come enciclopedia, è una fonte secondaria, la cui qualità e crescita si basano su dati e fonti primari. E gli enti culturali possiedono contenuti di grande valore, corredati da metadati e liberamente condivisibili quando si tratta di patrimonio storico in pubblico dominio, ma spesso scarsamente visibili o non adeguatamente valorizzati nel web dove difficilmente i siti delle istituzioni o i cataloghi emergono nelle ricerche degli utenti.

I progetti Wikimedia costituiscono un ecosistema informativo che, grazie alla grande visibilità offerta, permette soprattutto a piccole realtà di raggiungere un pubblico vasto e internazionale, ma anche di coinvolgere la propria comunità di riferimento (CENCI, GROSSI 2019; CARUSO *et al.* 2023, 165-166). Wikipedia è il progetto più noto e consultato, ma attorno all'enciclopedia libera gravitano altre piattaforme collegate, come Wikidata, il database di dati strutturati che sostiene tutti i progetti Wikimedia; Wikisource, la biblioteca di libri digitalizzati in pubblico dominio; e Wikimedia Commons, il database di immagini e file multimediali liberamente riutilizzabili. Le licenze usate sono la CC BY, la CC BY-SA, la CC0, principalmente per i dati, e la dichiarazione di pubblico dominio. Le licenze che non permettono il riuso commerciale (contraddistinte dalla sigla NC) e le opere derivate (ND) non sono ammesse poiché non aderiscono al principio della libera condivisione della conoscenza.

Le collaborazioni GLAM-Wiki sono favorite dall'attenzione che nei progetti Wikimedia viene prestata al rispetto delle norme sul diritto d'autore, all'uso delle licenze standard Creative Commons, che esplicitano chiaramente i riusi consentiti e l'attribuzione, e alle caratteristiche tecniche delle piattaforme, che permettono di descrivere in modo granulare gli oggetti facilitandone la ricerca, il reperimento e il riuso, mantenendo nello stesso tempo l'unitarietà dei fondi e l'indicazione dell'istituzione che li conserva (CARUSO *et al.* 2023, 169). Queste caratteristiche dei progetti Wikimedia, insieme al fatto che si tratta di siti senza pubblicità né profilazione degli utenti e in cui ogni modifica è tracciata e conservata nella cronologia, ne fanno ambienti affidabili per la condivisione dei contenuti da parte delle istituzioni culturali (PENSA 2023).

Favorire l'incontro tra i GLAMs e i progetti Wikimedia è tra gli scopi di Wikimedia Italia, l'associazione per la diffusione della conoscenza libera, che

è *local chapter* del movimento Wikimedia per il nostro Paese e capitolo della OpenStreetMap Foundation. Wikimedia Italia ha come scopi sostenere la comunità dei volontari, incrementare il patrimonio di conoscenza liberamente accessibile a tutti e aumentare la consapevolezza del valore della condivisione, sostenendo anche il cambiamento legislativo in questa direzione (<https://www.wikimedia.it/chi-siamo/>). Tra i progetti che attualmente l'associazione porta avanti per sostenere tali obiettivi e che coinvolgono gli enti culturali vi sono l'organizzazione dell'edizione italiana di Wiki Loves Monuments, i bandi a sostegno di progetti di enti culturali e volontari e il progetto Empowering Italian GLAMs.

## 2. WIKI LOVES MONUMENTS

Wiki Loves Monuments (WLM) è un concorso fotografico internazionale che ha l'obiettivo di raccogliere immagini del patrimonio culturale mondiale in licenza libera, riutilizzabili da chiunque dentro e fuori Wikipedia. Il concorso riguarda le fotografie di monumenti, secondo la definizione molto ampia del termine adottata dall'UNESCO comprendente edifici, sculture, siti archeologici, strutture architettoniche, ma anche siti naturali e interventi dell'uomo sulla natura che abbiano valore dal punto di vista artistico, storico, estetico, etnografico o scientifico (UNESCO 1972). WLM però è molto di più di contest fotografico: è un progetto di conoscenza, documentazione e valorizzazione dei beni culturali, un'opportunità per la riscoperta di siti e monumenti poco noti del nostro Paese, oltre che un'occasione per sensibilizzare e riflettere sulle norme che regolano la possibilità di fotografare i beni culturali e scoprire i vantaggi di pubblicare fotografie con licenza libera.

Nasce nel 2010 nei Paesi Bassi, nel 2011 si estende a livello europeo e con 168.000 fotografie caricate entra nel Guinness dei primati come il più grande concorso fotografico al mondo ([https://en.wikipedia.org/wiki/Wiki\\_Loves\\_Monuments](https://en.wikipedia.org/wiki/Wiki_Loves_Monuments)). Il successo dell'iniziativa cresce: nel 2012 diventa un concorso mondiale con 35 paesi partecipanti, tra cui per la prima volta l'Italia, e ad oggi sono oltre 3 milioni le immagini caricate da circa 100.000 partecipanti, rendendo quella di WLM una delle più ampie "comunità digitali collaborative" per la documentazione del patrimonio culturale (BERTACCHINI, PENSA 2023, 130; sui dati del concorso in Italia si veda il sito <https://data.wikilovesmonuments.it/>, Fig. 1). WLM si svolge ogni anno nel mese di settembre ed è aperto a tutti: si partecipa fotografando monumenti e siti presenti nelle liste disponibili su <https://app.wikilovesmonuments.it> e caricando le fotografie su Wikimedia Commons, rendendole liberamente riutilizzabili per tutti e in primo luogo per illustrare le voci di Wikipedia e dei progetti fratelli.

In Italia WLM sin dall'inizio ha dovuto confrontarsi con le restrizioni legislative presenti nel nostro Paese, ovvero la mancanza della libertà di

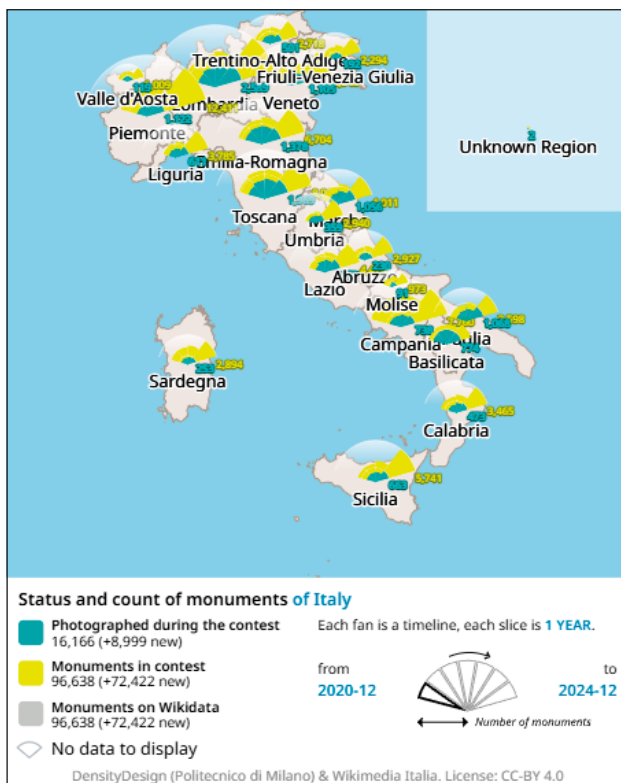


Fig. 1 – Visualizzazione dei dati sui monumenti italiani tratta da <https://data.wikilovesmonuments.it>, realizzata da Density Design (Politecnico di Milano) e Wikimedia Italia (13 aprile 2024).

panorama e i limiti alle riproduzioni dei beni culturali previsti dal Codice dei Beni Culturali e del Paesaggio (MALATESTA, MILELLA 2013). Nell'ambito della fotografia dei monumenti esposti sulla pubblica via possono sussistere diritti dell'architetto sull'opera ritratta, a meno che questa non ricada nel pubblico dominio, ovvero siano trascorsi settant'anni dalla morte dell'autore. Questo fa sì che, quando si scattano fotografie all'aperto, si possa ritrarre anche in maniera inconsapevole, un'opera tutelata e quindi si possa incappare in un potenziale rischio legale (ALIPRANDI 2024). In molti Paesi esiste la libertà di panorama, ovvero un'eccezione che permette di scattare e pubblicare fotografie di luoghi pubblici, ma in Italia purtroppo non è prevista. Per quanto attiene invece ai beni in pubblico dominio, compresi i beni storici e archeologici, una limitazione alla riproduzione è imposta dagli articoli 106-108 del Codice dei Beni Culturali (D.Lgs. n. 42/2004) che stabilisce che le riproduzioni dei beni

culturali statali, comprese quelle fotografiche, debbano essere autorizzate dall'ente che li ha in custodia e possano essere soggette al pagamento di un canone: uno "pseudo-copyright", come lo definisce ALIPRANDI (2024), che di fatto produce l'effetto di vincolare le riproduzioni di beni in pubblico dominio.

Per garantire lo svolgimento di WLM nel pieno rispetto delle leggi, Wikimedia Italia ha strutturato un sistema di autorizzazioni rivolto a istituzioni e persone che hanno la proprietà o la gestione di un bene culturale e desiderano rilasciare una liberatoria scritta per permettere a chiunque di fotografarlo e di caricare le immagini con licenza CC BY-SA su Commons (<https://www.wikimedia.it/wiki-loves-monuments/istituzioni/>). Il coinvolgimento di enti culturali, istituzioni ed enti locali per "liberare" i monumenti è quindi fondamentale e viene ampiamente ripagato in termini di visibilità e valorizzazione del patrimonio culturale in un rapporto positivo tra inserimento dei beni culturali nelle liste dei monumenti fotografabili per il concorso, caricamento di fotografie e miglioramento delle voci di Wikipedia (BERTACCHINI, PENSA 2023). L'adesione a WLM permette agli enti di costruire un database di immagini georeferenziate e liberamente riutilizzabili dei propri beni, che possono essere usate per materiali promozionali o per il proprio sito web e per alcuni ha rappresentato l'occasione per avviare un vero e proprio censimento del patrimonio edilizio storico.

Negli ultimi anni, accanto al sistema delle autorizzazioni, Wikimedia Italia ha inoltre lavorato in partnership con organizzazioni che hanno patrocinato



Fig. 2 – Abbey82, Mole Antonelliana di sera, foto classificata al 6° posto del concorso internazionale Wiki Loves Monuments 2022 (via Wikimedia Commons).



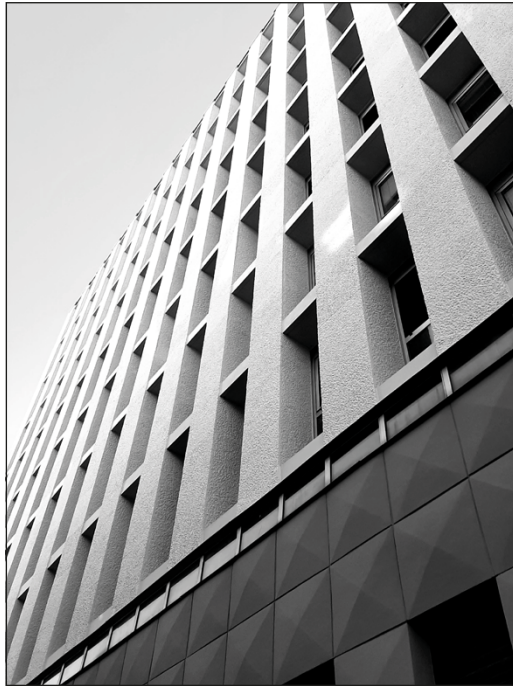


Fig. 3 – ElisaSit, Torino, Biblioteca Civica Centrale, foto premiata al concorso Wiki Loves Monuments Piemonte 2022 (via Wikimedia Commons).

il concorso per quanto riguarda specifiche categorie di beni in pubblico dominio, che sono stati inseriti nelle liste dei monumenti fotografabili: nel 2022 castelli e fortificazioni, grazie alla collaborazione con l'Ente Nazionale dei Castelli; nel 2023 gli edifici religiosi, grazie al patrocinio del Dicastero Vaticano per la Cultura e l'Educazione, l'Unione delle Comunità Ebraiche Italiane, ANCI e ICOM Italia; nel 2024 il concorso è stato dedicato a musei, archivi e biblioteche. I proprietari dei beni possono chiedere l'opt-out per essere esclusi dalla lista, ma finora nessuna richiesta in tal senso è pervenuta, a conferma che a fronte di norme restrittive sull'uso delle immagini dei beni culturali esiste un ampio supporto dal basso verso la liberalizzazione.

Grazie al lavoro dei volontari, si organizzano anche edizioni locali del concorso; nel caso piemontese, seguito dalle autrici dal 2022, si è instaurata una positiva collaborazione con alcune biblioteche (la rete delle Biblioteche civiche, la biblioteca di Economia e Management e quella di Matematica dell'Università di Torino, il Polo del '900, il Museo diffuso della Resistenza, la Biblioteca Archimede di Settimo Torinese) che hanno colto nel concorso

le potenzialità di coinvolgimento degli utenti e comunicazione di contenuti relativi all'apertura dei luoghi e della conoscenza, affini alla mission delle biblioteche. Tale collaborazione ha portato anche alla liberatoria concessa dalla Città di Torino, che ha autorizzato la condivisione delle foto in licenza libera di 58 fra edifici e monumenti, rendendo fotografabili molti luoghi simbolo della città, tra cui la Mole Antonelliana, una cui foto ha ottenuto il 6° posto nella classifica del concorso internazionale (Fig. 2). Un premio speciale è stato dedicato proprio alle foto delle biblioteche (Fig. 3) e un altro alle fotografie dei luoghi che furono oggetto degli scatti del celebre fotografo torinese Mario Gabinio (1871-1938) il cui fondo fotografico, in pubblico dominio, è stato digitalizzato e messo a disposizione dalla Fondazione Torino Musei rendendone possibile il caricamento su Commons ([https://commons.wikimedia.org/wiki/Category:Images\\_contributed\\_by\\_Fondazione\\_Torino\\_Musei\\_-\\_Fondo\\_Gabinio](https://commons.wikimedia.org/wiki/Category:Images_contributed_by_Fondazione_Torino_Musei_-_Fondo_Gabinio)). Nel 2023 il concorso locale piemontese ha coinvolto anche la Valle d'Aosta e ha registrato l'adesione della Tavola e del Concistoro Valdesi, per l'autorizzazione degli edifici storici del quartiere Valdese di Torre Pellice.

In entrambe le edizioni le premiazioni sono state l'occasione per coinvolgere biblioteche, volontari, fotografi e cittadini in momenti di riflessione e confronto sui temi della libertà di panorama e dell'uso delle immagini del patrimonio culturale (la registrazione della premiazione dell'edizione 2023 è disponibile all'indirizzo: <https://www.youtube.com/watch?v=dqOA1o-q3wk&t=237s>) e una mostra itinerante sta portando le foto vincitrici nelle biblioteche piemontesi.

### 3. IL BANDO GLAM E IL SOSTEGNO AI PROGETTI DEI VOLONTARI

Dal 2021, accanto ad altre forme di collaborazione come le convenzioni con singoli enti culturali, Wikimedia Italia dedica annualmente un bando di finanziamento ai GLAMs, che ha sostenuto sino ad oggi 30 progetti, con contributi fino a 8000 euro per ciascun ente. I progetti vengono selezionati da una commissione in base alla qualità e quantità dei contenuti messi a disposizione, nonché alla trasversalità nella contribuzione a progetti diversi (Commons, Wikipedia, OpenStreetMap, Wikidata, Wikisource, etc.) e al coinvolgimento del personale. Gli enti beneficiari, a fronte della condivisione di contenuti in licenza libera, ottengono un finanziamento per eseguire digitalizzazioni (comprese scansioni 3D, che sono caricabili su Commons: MALATESTA 2018) o, per esempio, per mappature e riprese con drone, ma soprattutto formazione e assistenza sull'uso delle piattaforme, per la selezione e il caricamento dei materiali, sul diritto d'autore e sulle licenze Creative Commons, che permette poi una prosecuzione in autonomia.

Un aspetto particolarmente interessante è anche la disponibilità di strumenti per misurare l'impatto dei progetti realizzati, attraverso il conteggio

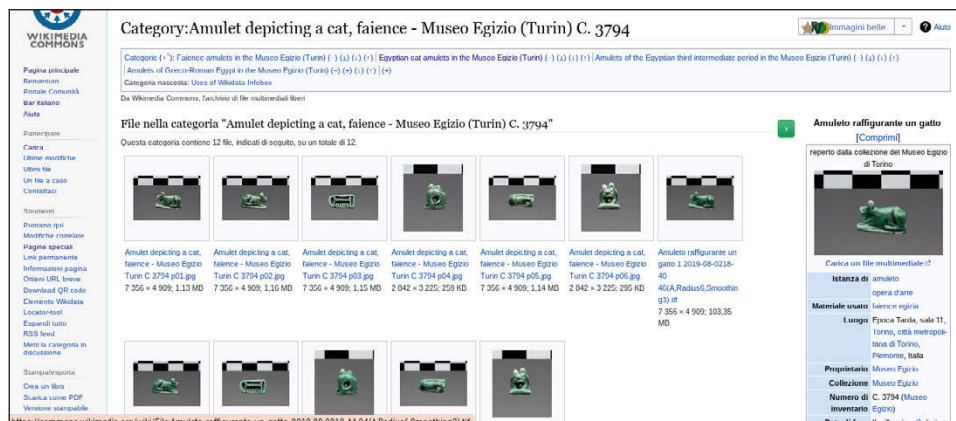


Fig. 4 – Fotografie di uno dei reperti del Museo Egizio di Torino su Wikimedia Commons (Category: Amulet depicting a cat, faience - Museo Egizio, Turin, C. 3794).

delle visualizzazioni delle immagini caricate, delle voci di Wikipedia create o migliorate e il riuso delle immagini. Wikimedia Italia, in collaborazione con l'Università di Padova, ha inoltre realizzato tre Massive Open Online Courses (MOOC), accessibili a tutti sulla piattaforma Edu Open, uno dei quali dedicato proprio a bibliotecari, archivisti e operatori museali (<https://learn.eduopen.org/course/index.php?mycourses=&search=wiki>). Un altro bando si rivolge invece a iniziative proposte da volontari esperti: nell'ambito dell'archeologia, tra le iniziative recenti, si possono citare il progetto di archeologia partecipata realizzato a Verona da Piergiorgiana Grossi con la collaborazione della Soprintendenza ABAP di Verona, Rovigo e Vicenza e dell'Università di Verona, che ha coniugato visite on site e attività online su Wikipedia, Commons e OpenStreetMap ([https://it.wikipedia.org/wiki/Progetto:GLAM/Wikipedia\\_e\\_archeologia](https://it.wikipedia.org/wiki/Progetto:GLAM/Wikipedia_e_archeologia); CENCI, GROSSI 2019) e il progetto dedicato all'archeologo Paolo Orsi (1859-1935) al quale il Museo Civico di Rovereto ha dedicato due giornate di studio che hanno portato, grazie alla collaborazione di esperti giunti da tutta Italia, al miglioramento delle voci di Wikipedia e ha visto anche il coinvolgimento degli allievi di una scuola secondaria nella redazione di una voce su Wikidia, la versione junior di Wikipedia, consigliata nell'ambito dei progetti scolastici ([https://it.wikipedia.org/wiki/Wikipedia:Raduni/Congresso\\_su\\_Paolo\\_Orsi](https://it.wikipedia.org/wiki/Wikipedia:Raduni/Congresso_su_Paolo_Orsi)).

#### 4. EMPOWERING ITALIAN GLAMs

Avviato nel 2022, Empowering Italian GLAMs (tradotto come “Tutti i musei su Wikipedia”) è un progetto promosso da Wikimedia Italia in collaborazione

con ICOM Italia, Creative Commons Italia e il Dipartimento di Economia e Statistica “Cognetti de Martiis” dell’Università di Torino, con il coinvolgimento di BAM! Strategie culturali e il co-finanziamento di Wikimedia Foundation. Si tratta di un progetto ampio, che si rivolge a tutti i musei, ma anche biblioteche e archivi italiani, per far conoscere i vantaggi dell’accesso aperto e accompagnarli in un percorso di condivisione dei contenuti e dei principi dell’open access (<https://www.wikimedia.it/musei>). Il progetto, tutt’ora in corso, prevede tre linee d’azione: una campagna informativa e di aggiornamento dei dati dei musei su Wikidata, durante la quale sono stati contattati tutti i musei, proponendo l’adesione al principio dell’open access e la condivisione di un primo nucleo di 20 immagini, metadati e testi informativi prodotti dall’istituzione su propri fondi o collezioni. Le istituzioni che decidono di aderire vengono accompagnate nel processo di condivisione delle proprie collezioni ricevendo una formazione specifica.

Inoltre sono stati individuati cinque casi di studio, che hanno intrapreso una strategia di apertura dell’intero patrimonio (Musei Civici di Reggio Emilia, Museo Civico di Modena, Museo delle Marionette di Palermo, Ecomuseo delle Grigne di Esino Lario e Museo Egizio di Torino). In questo contesto è stato anche elaborato un Data management plan per gli istituti culturali, ovvero la rielaborazione di uno strumento ampiamente usato nella ricerca scientifica, adattato all’ambito museale e applicato alle cinque istituzioni oggetto dello studio qualitativo (<https://www.wikimedia.it/news/la-ricerca-e-i-numeri-sui-nuovi-musei-su-wikipedia/>).

Proprio perché così esteso e rivolto a istituti estremamente diversi per caratteristiche delle collezioni, dimensioni e profilo istituzionale, il progetto è stato articolato in più livelli di azione e contempla diversi livelli di adesione, configurando la condivisione online dei contenuti e l’adesione ai principi dell’open access come un processo, da adattare alle diverse realtà museali: dalla semplice adesione alla lettera di principi e la condivisione di un piccolo nucleo di immagini, fino a un caso emblematico come quello del Museo Egizio di Torino che ha scelto di condividere le immagini dell’intera collezione (oltre 6000 fotografie ad alta risoluzione di reperti e relativi metadati su Commons e Wikidata) e di rivedere completamente il proprio sito web, esplicitando licenze e possibili riusi, con una scelta all’avanguardia nel panorama italiano (<https://www.wikimedia.it/news/museo-egizio-online-tutte-le-immagini-dei-reperti-esposti/>) (Fig. 4).

## 5. CONCLUSIONI

Le istituzioni culturali stanno cambiando il modo di intendere il patrimonio, il proprio ruolo e il rapporto con l’utenza, come si evince dalla letteratura (cfr. ad es. i modelli internazionali presentati al convegno *Unlocking Value*

*from Digital Heritage Collections: International Perspectives*: BERTACCHINI 2023), dalla più recente definizione di museo elaborata da ICOM (ICOM 2022) e come espresso nel concetto “cura” proposto da Christian Greco, direttore del Museo Egizio, per sintetizzare tutela e valorizzazione verso l’obiettivo di “radicare il ricordo nella società” (WIKIMEDIA ITALIA 2023) ma ancora dubbi e incertezze si riscontrano nel tradurre tali principi nella condivisione di contenuti digitali nel web con licenza libera.

Per quanto attiene alla preoccupazione di perdere eventuali introiti derivanti da concessioni, la Corte dei Conti si è espressa dichiarando che «l’Open Access ha da tempo dimostrato di essere un potente moltiplicatore di ricchezza (...) non solo per le stesse istituzioni culturali (...), ma anche in termini di incremento del PIL ed è quindi considerato un asset strategico per lo sviluppo sociale, culturale ed economico» (Delib. n.76/2023/G, 20/10/2023). Vincoli e controlli sulla fruizione dei beni fisici, motivati da esigenze di conservazione e regolamentazione di usi rivali, non attengono alle riproduzioni digitali dei beni culturali in pubblico dominio (MANACORDA 2021): esse rientrano nell’ambito dei beni comuni immateriali e sono a tutti gli effetti dati, per i quali, se prodotti da enti pubblici, il diritto comunitario prevede il principio dell’open by default (Direttiva UE 2019/1024 Public Sector Information).

La disseminazione nel web permette di raggiungere nuovi pubblici (NAVARRETE, VILLAESPEA 2020b), stimolare la creatività (NAVARRETE, VILLAESPEA 2020a) e favorire la fruizione in presenza (HINNOSAAR 2021) poiché, capovolgendo la Legge di Gresham sulla moneta ([https://it.wikipedia.org/wiki/Legge\\_di\\_Gresham](https://it.wikipedia.org/wiki/Legge_di_Gresham)), si può affermare che l’immagine buona scaccia quella cattiva: mettere a disposizione digitalizzazioni con licenze libere standard e metadati dettagliati è il miglior modo per incentivare il riuso di immagini di qualità e correttamente attribuite.

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## BIBLIOGRAFIA

- ALIPRANDI S. 2024, *Cosa intendiamo per libertà di panorama* (<https://www.wikimedia.it/news/cosa-intendiamo-per-liberta-di-panorama/>).
- BERTACCHINI E. 2023, *Creare valore per le collezioni digitali dei musei* (<https://www.wikimedia.it/news/creare-valore-per-le-collezioni-digitali-dei-musei/>).
- BERTACCHINI E., PENZA I. 2023, *Exploring collaborative digital heritage communities: A quantitative assessment of Wiki Loves Monuments in Italy*, «Il Capitale Culturale», 28, 129-150 (<https://riviste.unimc.it/index.php/cap-cult/article/view/3197>).

- CARUSO M., LA TORRE P., MANZOLLINO R. 2023, *La valorizzazione dei musei locali attraverso Wikipedia: il progetto MedAniene*, in J. BOGDANI, S. COSTA (eds.), *ArcheoFOSS 2022. Proceedings of the 16<sup>th</sup> International Conference on Open Software, Hardware, Processes, Data and Formats in Archaeological Research* (Rome 2022), «Archeologia e Calcolatori», 34.1, 165-174 (<https://doi.org/10.19282/ac.34.1.2023.18>).
- CENCI C., GROSSI P. 2019, *Public archaeology a Verona: un percorso sperimentale lungo la via Postumia*, in B. BRUNO, C. CENCI, P. BASSO, P. GROSSI (eds.), *Verona e le sue strade*, Verona, Cierre Edizioni, 103-114.
- HINNOSAAR M., HINNOSAAR T., KUMMER M., SLIVKO O. 2021, *Wikipedia matters*, «Journal of Economics & Management Strategy», 32, 3, 1-13 (<https://doi.org/10.1111/jems.12421>).
- ICOM 2022, *ICOM approves a new museum definition* (<https://icom.museum/en/news/icom-approves-a-new-museum-definition/>).
- MALATESTA S.G. 2008, *Wikimedia Commons: contenuti liberi... e in tre dimensioni* (<https://www.wikimedia.it/news/wikimedia-commons-contenuti-liberi-tre-dimensioni/>).
- MALATESTA S.G., MILELLA M. 2013, *Wiki Loves Monuments e archeologia: condividere la conoscenza*, in M. SERLORENZI (ed.), *ARCHEOFOSS Free, Libre and Open Source Software e Open format nei processi di ricerca archeologica. Atti del VII Workshop (Roma 2012)*, «Archeologia e Calcolatori», Suppl. 4, 53-59 ([http://www.archcalc.cnr.it/indice/Suppl\\_4/06\\_Malatesta\\_Milella.pdf](http://www.archcalc.cnr.it/indice/Suppl_4/06_Malatesta_Milella.pdf)).
- MANACORDA D. 2021, *L'immagine del bene culturale pubblico tra lucro e decoro: una questione di libertà*, «Aedon», 1, 24-29 (<http://www.aedon.mulino.it/archivio/2021/1/manacorda.htm>, 3.01.2022).
- NAVARRETE T., VILLAESPESA E. 2020a, *Digital Heritage consumption: The case of the Metropolitan Museum of Art*, «Magazén», 1, 2, 223-248 (<https://edizionicafofoscari.unive.it/it/edizioni4/riviste/magazen/2020/2/digital-heritage-consumption-the-case-of-the-metro/>).
- NAVARRETE T., VILLAESPESA E. 2020b, *Image-based information: Paintings in Wikipedia*, «Journal of Documentation», 77, 2, 359-380 ([doi.org/10.1108/JD-03-2020-0044](https://doi.org/10.1108/JD-03-2020-0044)).
- PENSA I. 2023, *Lasciateci partecipare. Riuso e disseminazione del sapere educativo, scientifico e culturale attraverso Wikipedia, i progetti Wikimedia e OpenStreetMap*, «Rivista italiana di informatica e diritto», 5, 1, 89-92 (<https://doi.org/10.32091/RIID0110>).
- UNESCO 1972, *Convention Concerning the Protection of the World Cultural and Natural Heritage* (<https://whc.unesco.org/en/conventiontext/>).
- WIKIMEDIA ITALIA 2023, *Open access al museo. L'esempio del Museo Egizio* (<https://www.youtube.com/watch?v=wIYgwXB6E5I>).

## ABSTRACT

The paper focuses on cooperation between GLAMs (Galleries, Libraries, Archives and Museums) and Wikimedia projects. Cultural institutions that share content, data and images of cultural heritage with free licence can make their collections accessible to a broad audience, while Wikipedia and the other Wikimedia projects benefit from these content as sources for the online encyclopedia. Wikimedia Italia, local chapter of the Wikimedia movement and of the OpenStreetMap Foundation, supports the partnerships with cultural institutions in different ways. The association organizes Wiki Loves Monuments in Italy, a photographic contest that invites citizens to document cultural heritage and represents an instrument to face the Italian legal restrictions on sharing images of cultural heritage. A funding program supports each year GLAMs and volunteers' projects and a wide project, Empowering Italian GLAMs, aims at addressing all Italian museums and heritage institutions in using open tools and sharing their digital collections.

LINKING PASTS AND SHARING KNOWLEDGE.  
MAPPING ARCHAEOLOGICAL HERITAGE,  
LEGACY DATA INTEGRATION  
AND WEB TECHNOLOGIES  
FOR MODELLING HISTORICAL LANDSCAPES  
(NAPLES, 13<sup>TH</sup>-14<sup>TH</sup> NOVEMBER 2023)

Edited by  
Rodolfo Brancato, Julian Bogdani, Valeria Vitale



The publication of the section dedicated to the Proceedings of the international Conference *Linking Pasts and Sharing Knowledge. Mapping Archaeological Heritage, Legacy Data Integration and Web Technologies for Modelling Historical Landscapes*, Naples, 13<sup>th</sup>-14<sup>th</sup> November 2023 was made possible thanks to the support of Dipartimento di Studi Umanistici-Università di Napoli Federico II (PRIN 2022 In.Res.Agri, Project Code 2022SMJCHX, CUP: B53D23001910006) and Sapienza Università di Roma.

## INTRODUCTION

This section presents and discusses case studies, virtuous practices and current proposals that aim to deepen the epistemological and theoretical reflection on the impact of digital technologies and linked knowledge-sharing on cultural heritage research strategies and archaeological mapping. These 18 short papers were initially conceived as contributions to the international Symposium held in Naples in November 2023 titled *Linking Pasts and Sharing Knowledge. Mapping Archaeological Heritage, Legacy Data Integration and Web Technologies for Modelling Historical Landscapes*, and are here collected and enriched with the insights generated through feedback and conversations. The initial purpose of the meeting was to bring together scholars, researchers and students from archaeology and digital humanities who are interested in exploring digital approaches to the semantic and graphic representation of present and past historical landscapes and to stimulate a cross- and interdisciplinary conversation. The discussions focused, in particular, on the synergies between Digital Humanities and Archaeology for the reuse and reinterpretation of digitised and born-digital resources, enabling new kinds of historical research questions and the enhancement of cultural heritage.

The papers were complemented by two practical workshops: one dedicated to the semantic annotation of digitised maps and the other to the topographic exploitation of anomalies in remotely sensed legacy data. Each workshop showed how digital tools and methods can become opportunities to reflect on the value of these palimpsests of signs whose reading is essential for the diachronic analysis of cultural landscapes and to explore directly the integration between innovative and traditional methods and sources for archaeological topography research.

The Symposium featured two main, and intertwined, themes that are echoed in the papers here collected. The first stream centred digital methods for the exploitation of archaeological legacy data and their semantic and topographic integration. Many institutions sit on large data sets from previous excavations, published and unpublished, whose digitisation, spatial mapping and re-analysis could greatly facilitate new research on historical landscapes. Case studies, such as those discussed by BORG and IACOPINI on the use of historical cadastral maps to recontextualise Roman inscriptions, by VITALE and McDONOUGH about investigating the evolution of historical sites in Great Britain through the labels on Ordnance Survey maps and by RUSSO, generating new insights from published pottery data through statistical and spatial analysis, contribute to draw a rich landscape of successes, as well as failures, in dealing with already-compiled research data sets and

documentation materials in both analogue and digital formats. Instead, BRANCATO and colleagues apply digital tools to integrate heterogeneous legacy data in order to create a deep map of historical landscapes in Southern Italy, using a diachronic approach to investigate centuriation.

The second stream explores best practices for integrating digital tools into research projects on both macro and micro scales. It introduces new audiences to cutting-edge technologies and methodologies while critically assessing the opportunities and challenges these approaches present. Specific insights into the archaeological topography of urban landscapes are contributed by AZZARI and LIVERANI, who examine the complex integration and documentation of source data for the 3D visualisation of an archaeological area in Rome. SERLORENZI and colleagues highlight the potential of the SITAR platform for sharing archaeological knowledge. A large-scale landscape approach is exemplified in the contribution by BOGDANI and D'ERASMO, who combine new and old information to reconstruct the landscape of Albania in the 1930s; RENDA and others employ digital tools to analyse, visualise, and reconstruct archaeological landscapes in the crucial ancient region of Campania.

We would like these and all the papers in the section to be read not as a series of independent pieces, but as a multivocal conversation that highlights diverse perspectives and links, different and original views on the digital representation, either visual or semantic, of present and past historical landscapes, and strongly advocates for the reuse of existing datasets, even when deceptively obsolete.

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## LANDSCAPE VISUALISATION AND MODELLING

This paper is based on the experience gained in the ‘Rome Transformed’ project on the eastern Caelian Hill (HAYNES, LIVERANI, RAVASI, KAY 2023). Our aim is to reconstruct the ancient and early medieval topography of the eastern Caelian hill, between the basilicas of S. Giovanni in Laterano and S. Croce in Gerusalemme, in order to understand the urban dynamics of an area crucial both for the interaction between the city and its suburbs, and for the transition between the classical and medieval city.

Compared to more circumscribed projects, we had to face a leap in scale, which implies the difficulty of managing an impressive amount of very heterogeneous data. In fact, it is necessary to integrate different approaches: stratigraphic excavations, architectural surveys, archival data – which, especially in the case of findings from the past, are not rigorously documented – historical cartography, non-invasive geognostic surveys – which have a much higher degree of approximation than an archaeological excavation and, especially in a modern city, are subject to interference and disturbance from more recent phases of life: think of tram lines, underground utilities and sewers. Finally, core drilling, carried out in the past for public and private works of various kinds, or by us specifically for archaeological research, is of great help and can also provide relevant data for paleoenvironmental studies.

Urban life may have significantly altered the geomorphology of the site, but this problem has not always been systematically addressed. We soon realised that a broad approach was needed, going beyond the documentation and visualisation of individual excavations, buildings or monuments. Rather, it is a matter of studying an area which, as such, poses particular problems. In this case, the detailed visualisation of the individual excavation site or building, although important, takes second place to the overall topographical understanding, the reconstruction of its historical evolution and urban dynamics.

It is therefore necessary to start from the palimpsest made up of the geomorphology of the area under study and its sometimes considerable modifications over the centuries. This palimpsest defines the ‘conditions of existence’ of the topographical and monumental articulation of the city and forms the substratum that directs and conditions all urban and monumental reconstructions, defining the frame of reference and the wider meaning of these transformations. It is therefore necessary to go beyond a purely two-dimensional topography, based solely on the analysis of plans, and instead to integrate the third dimension and thus the stratification of successive monumental and urban interventions.

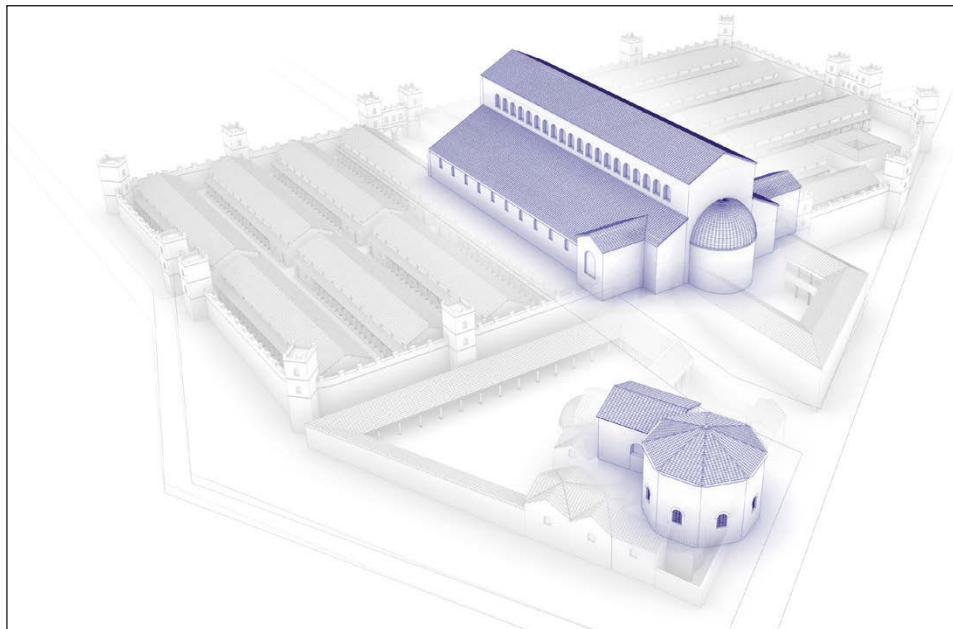


Fig. 1 – Project visualisation (‘provocation’) showing the Constantinian Basilica’s spatial relationship to the *Castra Nova* that previously occupied the same site (Iwan Peverett and Ian Haynes, incorporating a visualisation of the Constantinian Basilica developed by Lex Bosman, Paolo Liverani, Iwan Peverett & Ian Haynes, and work on the baths/Baptistery by Thea Ravasi).

In order to understand the significant relationships between the various urban elements, it is not enough to reconstruct the topography at a specific historical moment, but it is necessary to follow its diachronic evolution in order to identify the constraints that the earliest phases impose on the later ones. A simple example in the Lateran area is the succession between the Severan phase of the *Castra Nova* of the *Equites Singulares* with the adjacent baths and the Constantinian phase of the Lateran Basilica with its Baptistery. The position of the Baptistery, behind the Basilica and 6 m lower, would remain incomprehensible if one did not take into account, on the one hand, that the Baptistery used the Baths – probably linked to the *Castra Nova* – and, on the other hand, that during the Easter liturgy the celebrant with the catechumens, leaving the Basilica for the Baptistery, walked along what in the Severan period was the external continuation of the *Via Principalis* of the *Castra Nova* (Fig. 1).

There are many cases where the reconstruction of the orography and its evolution can radically change our ideas. In our area, for example, we know that the Caelian Hill has undergone profound changes since ancient



Fig. 2 – Paolo Anesi, *View of the Lateran from East* (oil on canvas, 18<sup>th</sup> cent.), Diocesan Museum of Milan.

times. We need only think of the construction of the Aurelian Wall, which resulted in the damming of a valley, with problems for the drainage of the water and important consequences for the stability of the wall itself. Downstream, in the area of the watercourse that flows under the Lateran, known as the Marrana, there was considerable silting up, as can be seen from the difference in level between Aurelian's and Honorius's Asinaria Gate, and as confirmed by the underground excavations just outside the walls. Other serious interventions were carried out in modern times, with the levelling of Mount Cipollaro, SW of S. Croce in Gerusalemme, and the alteration of the slopes of piazza S. Giovanni, which at the beginning of the 18<sup>th</sup> century was still marked by an abrupt drop in height caused by the substructures of the *triclinium* of Pope Leo III, as can be seen in the views of the time (Fig. 2). Finally, in modern times, large quantities of topsoil were dumped behind the Aurelian Wall, only partially removed in recent years for conservation reasons.

For an accurate reconstruction of this complex history, it is necessary to develop a methodology that does not rely on rough intuitions, but that defines a uniform procedure for the entire area of investigation. Hence the need for an environment in which it is possible to incorporate evidence of a very heterogeneous nature, as I mentioned at the beginning. This environment must be structured in such a way as to be able to provide data in accordance with the FAIR principles (Findable, Accessible, Interoperable and Reusable) and to

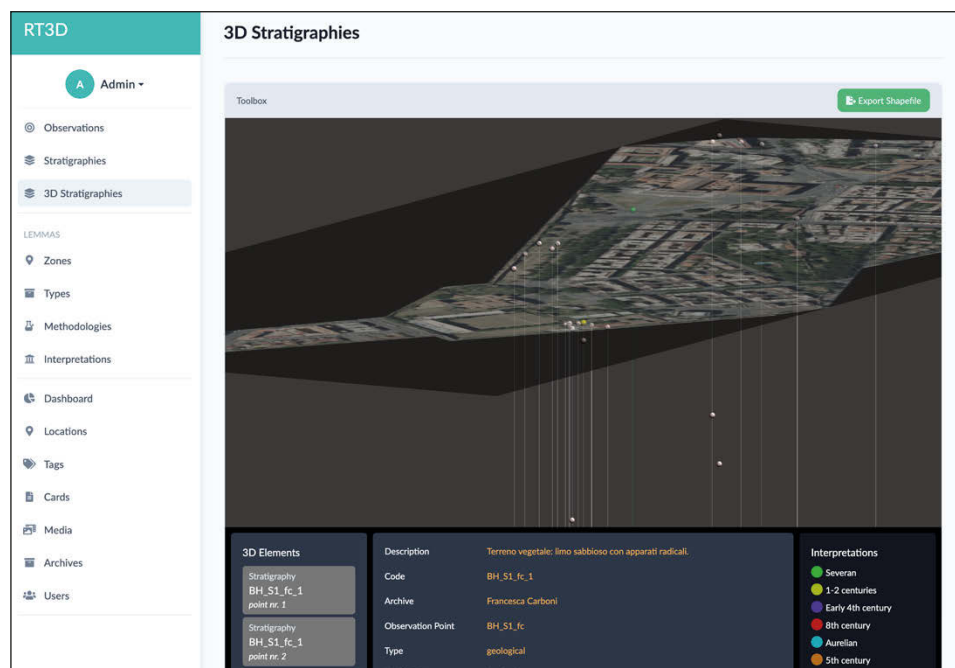


Fig. 3 – The RT3D environment.

constitute a working tool capable of gradually integrating new acquisitions in a dynamic manner. To meet these requirements, Margherita Azzari, together with Vincenzo Bologna and the LabGEO laboratory team in the department SAGAS, developed a software solution and created a tool capable of managing stratigraphic data. The first generation of this tool was called RT3D ('Rome Transformed 3D') (BOLOGNA, AZZARI 2023) (Fig. 3).

It is an open software, built on open libraries. RT3D makes it possible to collect and compare data obtained from different surveying methods and to retrieve geometric information to be translated into entities (points, lines, polygons) that can be managed in a GIS environment to generate Digital Terrain Models (DTM) (Fig. 4). Data input is performed using batch tools capable of processing large volumes of data. Import scripts load datasets based on an Excel (XLS, XLSX) or CSV structure whose fields have been defined considering the specific characteristics of each data acquisition and storage mode adopted by the different project teams. After software processing and validation, data can be exported as ArcGIS shapefiles and processed in a 3D GIS environment. Information from literature, archival sources, historical cartographies, excavation reports, structural analysis and non-invasive surveys



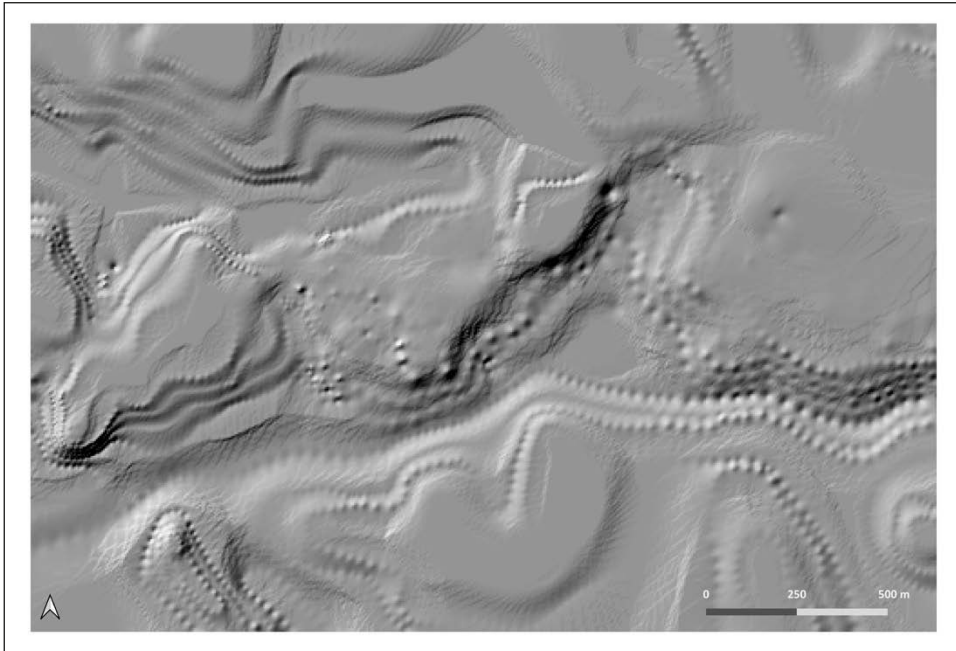


Fig. 4 – Digital Terrain Model of the study area during the Severan period. Reconstructive hypothesis based on data from literary and archival sources, historical cartographies, structural analysis and non-invasive surveys. The image shows the surface generated using the Inverse Distance Weighted (IDW) interpolation method, which allowed the z-values of the fiducial points to be preserved, before the final smoothing operation.

can be processed. Each layer produced by a GPR survey, for example, can be represented by a raster in which anomalies are displayed using a colour scale based on the Mhz response of the anomalies detected by the instrument. Each layer can be exported in .dat format, representing each point with its x,y,z coordinates and corresponding bandwidth in MHz. RT3D will import the points with a bandwidth considered significant for the generation of the phase DTMs. This data can then be compared with data from other sources in a 3D environment. This allows hypotheses to be formulated.

The imported data is converted into a GIS geometry called Multi-PointZ, which relates multiple PointZs to each other. This ensures that the roof and bed elevation information is maintained for each of the stratigraphic layers. In the 3D viewer, the data is visualised as points connected by segments, allowing the acquired element to be visually identified in three-dimensional space. The interpretation can be repeated for each individual point of a feature (borehole, stratigraphy, point cloud, etc.).



Fig. 5 – A 3D rendering of the Lateran area during the Severan period. The surface model was created using the IDW method in ArcGIS pro, then imported into ArcGIS City Engine and into Twinmotion for rendering. The building in the foreground was created using 3D Studio Max (Iwan Peverett & Thea Ravasi) and imported into Twinmotion.

Once the data interpretation is complete, the RT3D database points can be exported in ESRI shapefile format, which is compatible with all GIS processing programmes. The files can be imported directly into ArcGIS and contain not only the geometries but also the table with all the stratigraphic information. The spatial matrix generated in this way contains all the essential data entered the system to elaborate the interpretative hypotheses, and can be refined, modified and updated on the basis of further research and discoveries.

The methodology adopted for the creation of surfaces at different times involves the interpolation in a 3D GIS environment of a raster data set and data organised in shapefiles (Fig. 5). Each landscape component (translated into points, lines or polygons) must therefore be correctly geolocated (x, y, z). It is clear how the availability of many data from different sources, evenly distributed over the survey area, will allow the creation of a reliable model. The DTMs produced by the various methods (IDW, kriging, cokriging, spline, triangulation with linear interpolation, global and local polynomials, etc.) thus constitute documented hypotheses. In any case, they will be able to provide the basis for the visualisation of the topography of each of the macro-phases identified by the project, to support the

historical-topographical reconstruction by integrating the 3D models of the buildings, infrastructures and environmental information into the visualisation, but they will also be valuable for communicating and disseminating the hypotheses and the scientific results.

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### REFERENCES

- BOLOGNA V., AZZARI M. 2023, *RT3D stratigraphies: Analysis and software design to manage data*, in I.P. HAYNES, T. RAVASI, S. KAY, S. PIRO, P. LIVERANI (eds.), *Non-Intrusive Methodologies for Large Area Urban Research*, Oxford, Archaeopress, 1-3 (<https://www.archaeopress.com/Archaeopress/download/9781803274461>).
- HAYNES I., LIVERANI P., RAVASI T., KAY S. 2023, *The changing face of the eastern Caelian in the 1<sup>st</sup>-4<sup>th</sup> centuries AD: Work by the Rome Transformed project*, in A. LAUNARO (ed.), *Roman Urbanism in Italy. Recent Discoveries and New Directions*, Oxford-Philadelphia, Oxbow Books, 22-43 (<https://doi.org/10.2307/jj.9941113.6>).

### ABSTRACT

The contribution draws on the experience gained within the Rome Transformed project on the Eastern Caelian hill, reserving a with more general attention to problems of method. The spatial dimensions of the project pose problems including – but at the same time going beyond – those normally addressed for the visualization of individual surveyed structures. Two points seem crucial: 1) the transparency of metadata and paradata; 2) the tension between too much or too little prescriptive models or ontologies. Visualizing a territory poses peculiar problems; we have several examples in the past, but normally the reconstruction of ancient orography on which to place surveyed structures is not explicitly thematized. The territory imposes a leap in scale in the size and management of the data; forms the palimpsest on which to arrange the views of the individual sectors or structures into which it is divided; defines the 'conditions of existence' of topographical and monumental articulation; must consider the effects that older phases impose on later ones. Visualization of a territory is not only a way to present to the scientific community and the wider public in a concise manner the results achieved. Such an approach poses the need to work in an environment in which it is possible to progressively incorporate evidence of a very heterogeneous nature such as archival data, geognostic surveys of different types, surveys using traditional techniques or 3D scanning, and core drilling. The organisation of such heterogeneous data within a single software becomes essential for their subsequent processing. It was therefore necessary to design an application able to

manage in a single three-dimensional environment the data produced while maintaining the associated information (metadata and paradigms) in order to allow them to be compared and at the same time guaranteeing full interoperability with the GIS environments in which the modelling activity is carried out.

## PRELIMINARY RESULTS OF THE ARCHAEOLOGICAL POTENTIAL MAP IN SITAR

### 1. ARCHEoSITAR PROJECT: AN OVERVIEW

The ArcheoSITAR project, launched in 2007 by the Soprintendenza Speciale Beni Archeologici Belle Arti e Paesaggio di Roma (SSABAP), represents a significant step forward in the digitization of archaeological data. This project, developed by the SSABAP, aims primarily at transforming its vast paper archives related to archaeological excavations in Rome into a digital format, making them easily accessible and complete. The Sistema Informativo Territoriale Archeologico di Roma (SITAR) is currently the largest digital archaeological archive in the city and can be publicly accessed via a webGIS platform. Through this platform, detailed archaeological data and documentation are made available to the public freely and as open data. Given that this system is already well-known in the scientific literature, we would like to present two recent developments: the integration of data from external sources and the ongoing work on the Archaeological Potential Map of the city of Rome.

### 2. WORKFLOW FOR EXTERNAL DATA INTEGRATION

The need to enter data in real-time without having to catch up with the digitization of old archives has prompted SSABAP to devise a method that allows for the immediate integration of information into the system. This has led to the design and implementation of an innovative platform that will improve access to and use of digital archives. The procedure that will be implemented involves, from an administrative perspective, the opening of the source of information, i.e., the level of the system managed by the office will be made available to accredited external users. This opening will allow archaeologists to interact directly with the platform, enabling professionals to enter data immediately during or shortly after the investigation. It will no longer be necessary to produce data that require further processing; instead, validated data will be uploaded immediately, while attachments will retain the seven-year preservation requirement before publication.

SITAR is currently testing and will soon release a new tool for its platform called the 'External Data Entry Module'. This module will be a fundamental component of the ArcheoSITAR project, enriching and enhancing the database. The new SITAR platform will be accessible to external collaborators who, after completing a short training course, will be accredited on the portal. Thanks to the collaboration with the Fondazione Scuola del Patrimonio,

independent professionals will be able to access the necessary training to obtain the pass to the platform, thus facilitating their contribution to the project. The accreditation portal will be open to independent archaeologists, cooperatives, and associated studios. As previously specified, the workflow will begin with the assignment of the work area called 'Origin of Information' (OI)<sup>1</sup> (SERLORENZI, LAMONACA, PICCIOLA 2012, 38-40) to which the accredited operator must upload the administrative documentation, complete the general excavation information, and enter the three main elevations above sea level (road surface, archaeological surface, and geological surface). The workflow will continue with the submission of contextual data 'Archaeological Partitions' (PA)<sup>2</sup> (SERLORENZI, LAMONACA, PICCIOLA 2012, 40-41) through the online portal where external collaborators will upload excavation reports, photographs, and other relevant documents. Before being uploaded online, all externally entered data will be carefully reviewed by the SITAR office to verify their accuracy and authenticity.

After this verification, a notification of approval or a request for integration will be sent to the collaborators who provided the documentation. Only after final approval by the Soprintendenza will the data be standardized and coded into the SITAR geodatabase, which currently includes nearly seven thousand archaeological excavations (OI) and over twenty thousand archaeological context units registered (PA). This process ensures seamless integration with existing records, contributing to improved use of the platform for both academic research and urban planning.

To ensure effective collaboration, detailed guidelines have been made available on the ArcheoSITAR project website for several years, describing the methods for data submission and integration. These guidelines provide clear instructions on how to prepare and submit data, ensuring that all contributions meet the required standards. In this way, the system can continue to grow consistently and reliably, maintaining its usefulness as a key resource for managing and understanding Rome's archaeological heritage. The inclusion of external data will not only improve the quality of the information in the system but also enhance the research work to develop the archaeological potential assessment tool. Thanks to the contributions of external archaeologists, the

<sup>1</sup> The Origin of Information (OI) is the level that narrates the history of the archaeological investigation and collects all the demographic, technical, and descriptive information that allows identifying the source of the data. The Origin of Information encompasses the area of archaeological investigations conducted at a site for infrastructure or private construction, a topographical or archival source, scientific research, surface surveys, or geognostic investigations.

<sup>2</sup> The Archaeological Partition (PA) is the analytical level of information and records all the findings identified by each investigation. The Archaeological Partition represents the evidence uncovered, generated by human activity in the past: a section of a road, a tomb or necropolis, a room, a villa, a thermal bath complex, a wall structure, traces of quarrying or agricultural activity, and much more.



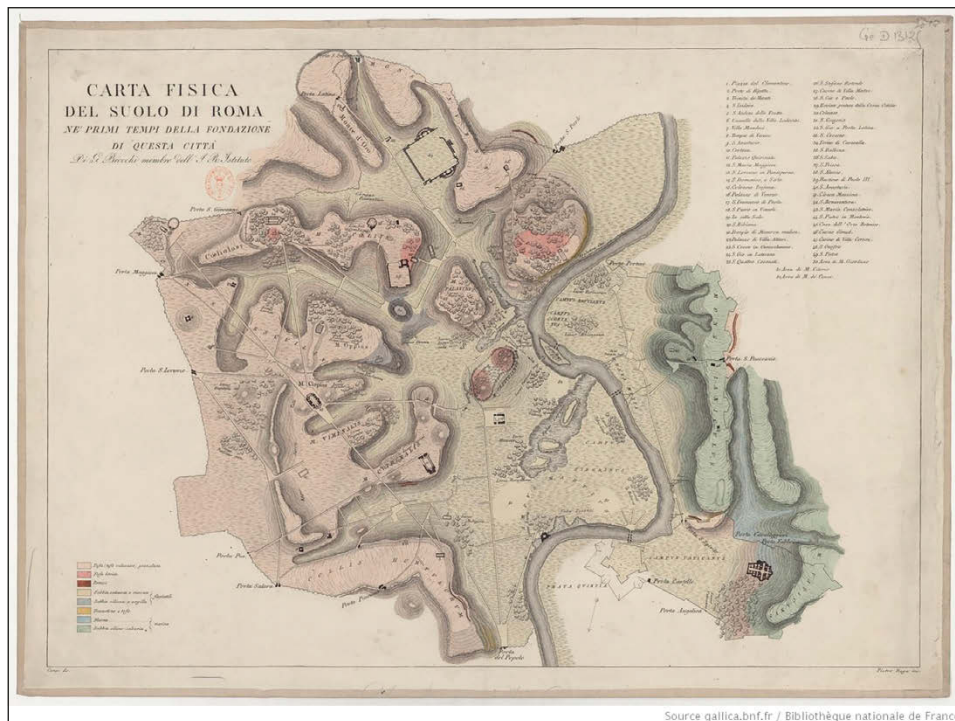


Fig. 1 – The *Carta fisica del suolo di Roma nei primi tempi della fondazione di questa città* by Giovan Battista Brocchi in 1820 has been rotated 180° to facilitate geographic reading since the original is oriented South instead of North.

database will be continuously updated, allowing for a more accurate assessment of the archaeological potential of different areas of the city, benefiting both research and urban planning<sup>3</sup>.

### 3. SCIENTIFIC AND ACADEMIC RESEARCH ON ARCHAEOLOGICAL POTENTIAL

For a brief history of research on archaeological potential in urban contexts, we considered some previous studies. In Giovan Battista Brocchi's famous 1820 map, entitled *Carta fisica del suolo di Roma nei primi tempi della fondazione di questa città* (BROCCHI 1820a) (Fig. 1), we find the first attempts to imagine the territory of Rome before the significant construction phases of the Republican and Imperial eras. Although lacking associated elevations, this attempt is certainly evocative and demonstrates the willingness

<sup>3</sup> <https://www.archeositarproject.it/manuale-uso/linee-guida/>.





Fig. 2 – Detail of Ugo Ventriglia's map *Spessore della coltre dei terreni di riporto* for the *Carta geologica della città di Roma*.

and competence to address such a complex problem. Reading the compendium associated with the map *Dello stato fisico del suolo di Roma, memoria per servire d'illustrazione alla carta geognostica di questa città* (BROCCHI 1820b), one perceives the incredible effort to represent through sources what might appear as a 'non-problem' – the orographic definition of a city in the original state of its geological nature. However, Brocchi goes further by addressing the geognostic definition of the city with this compendium, not only following proto-scientific methodologies of sampling and mapping the nature of the soils, but also applying a philological methodology, gathering clues and descriptions of Rome's orographic conformation from the major Latin authors.

This research is the basis and inspiration for geognostic studies of Rome in the following centuries. In his work *Sulla storia fisica del bacino di Roma*, Ponzi, through his *Memoria*, attempts to build on Brocchi's meticulous observations, detailing the physical history of the Roman basin. He describes the transformations that altered the landscape up to historical times (PONZI 1850). Moving into the 20<sup>th</sup> century, Ugo Ventriglia's interpretation of the map *Spessore della coltre dei terreni di riporto* (VENTRIGLIA 1971b) (Fig. 2) is crucial. This map serves as a compendium to the *Carta geologica del Comune di Roma* (VENTRIGLIA 1971a, 180-188), where 'terreni di riporto' refers to terrain with high archaeological potential. Although Ventriglia's approach is primarily geostatic, aimed at mitigating the effects of underestimating

construction problems in areas with anthropogenic underground cavities and high archaeological potential, his map, read by subtraction, provides the first metrically measured scenario of the ‘Modified Geological Surface’ of central Rome.

More recent editions of the same map come from more recent and accurate studies (FUNICIELLO 1995), with a more detailed focus on the eastern area of Rome, particularly the V Municipality (MAZZA, CAPELLI, LANZINI 2008). The concept of archaeological potential in urban areas, particularly in Rome, has been a focal point of scientific and academic research for several years. Studies have aimed to quantify the likelihood of discovering archaeological remains in various urban contexts by analyzing historical, archaeological, urban, and geological data. The first methodologically important archaeological study comes from the core samples and stratigraphic excavations of Metro C. During this project, a multidisciplinary research group composed of archaeologists and geologists conducted a zonal analysis between the stations of San Giovanni in Laterano and Porta Metronia. For the first time, this effort led to a detailed characterization through major epochs, including section analyses and 3D (DEMETRESCU, FONTANA 2009). The discussion then extended to other cities in 2011. For example, the MAPPA project in Pisa (ANICHINI *et al.* 2011) established its methodological foundations during this period. Additionally, Sondrio recently adopted an innovative approach to developing an archaeological risk map (TREMARI 2020).

Returning to focus on Rome in 2013, also within the SITAR project (SERLORENZI, BOI 2016) the system showcases in ‘Archeologia preventiva predittiva potenziali archeologici’ the Italian approach to these analyses with a focus on urban environments. The research involves the development of models that incorporate geological and geomorphological parameters, archaeological records, and spatial relationships between them. These models allow for estimating the likelihood of discovering significant archaeological deposits and their thickness, facilitating the preservation and study of Rome. Since the beginning of the 21<sup>st</sup> century, several geo-archaeological studies have focused on specific areas of the city, highlighting the complexity of urban archaeological stratification<sup>4</sup>.

<sup>4</sup> LUGLI, ROSA 2001 wrote about the *Capitolium*; GIOIA *et al.* 2010 were involved in a study in the Torre Spaccata area; DE SANTIS *et al.* 2010 in the *Forum* of Caesar, further explored by DELFINO, ROSA 2014, although MATTEUCCI, ROSA 2012, BUCCELLATO *et al.* 2021, ROSA 2022 and MATTEUCCI *et al.* 2023 published an interesting paper on various open issues along the Tiber River. Recently, there has been renewed interest in the area around the San Giovanni station of Metro C, with the studies of BOTTIGLIERI *et al.* c.s., focusing on the *Castrense* amphitheater and the *Circus* of *Varius*. Additionally, a recent and noteworthy study by BELLITTO *et al.* 2024 was published on the remains of a quarry in ‘Via del Castro Laurenziano’, in the eastern suburbs of Rome.

#### 4. QUALITATIVE AND QUANTITATIVE ARCHAEOLOGICAL POTENTIAL

The reflection on archaeological potential in SITAR aims to develop a predictive knowledge of Rome's subsoil useful for supporting and guiding the city's urban planning. Since SSABAP must authorize in advance the development of large urban projects in a city where the orographic conformation is almost entirely artificial and shaped by human activity, it is essential to have a tool that integrates archaeological potential into the design processes. In this way, archaeological potential is considered a resource to be valued rather than a simple risk to be managed. This data is crucial not only for archaeological research but also for ensuring informed and participatory urban planning, avoiding situations where those involved in administrative processes are not fully informed about the reasons for design choices.

SITAR has deepened the concept of 'clusters' related to confirmed archaeological evidence, using various sources to move from a two-dimensional to a three-dimensional representation, thus offering a more complete and detailed view of the city's archaeological potential. This process is not original; other previously mentioned workgroups have worked on this topic. Archaeological potential refers to the likelihood that an area contains archaeological deposits, buildings, or artifacts of historical significance. According to ANICHINI *et al.* 2011, the archaeological potential of an area is calculated through the analysis of various data sources, including historical records, previous archaeological discoveries, and paleoenvironmental data. The process involves evaluating the density, typology, and stratigraphy of known sites, as well as the geomorphological context. These factors contribute to creating predictive models that highlight areas with a high likelihood of containing archaeological evidence, expressed within the webGIS in meters. Figuratively speaking, qualitative potential is built and read horizontally and expresses its value through cartographic representation, while quantitative potential is vertical and expresses its value in section.

##### 4.1 *Qualitative archaeological potential*

Qualitative archaeological potential assesses the risk of discoveries interpretatively, considering the historical, cultural, and chronological context. It analyzes the types, phases, and functions of archaeological elements to reconstruct consistent urban models over time. It includes archival research, historical map analysis, and interpretations of past human activities. This method deepens the archaeological relevance of an area, highlighting not only the artifacts present but also their historical and cultural significance (Fig. 3).

#### 4.2 Quantitative archaeological potential

The quantitative approach to archaeological potential involves a systematic method of reclassifying archaeological data by integrating them with geological and geomorphological information. This process evaluates the distribution of archaeological samples by superimposing these data on both current urban development and the erosion of the historical landscape.

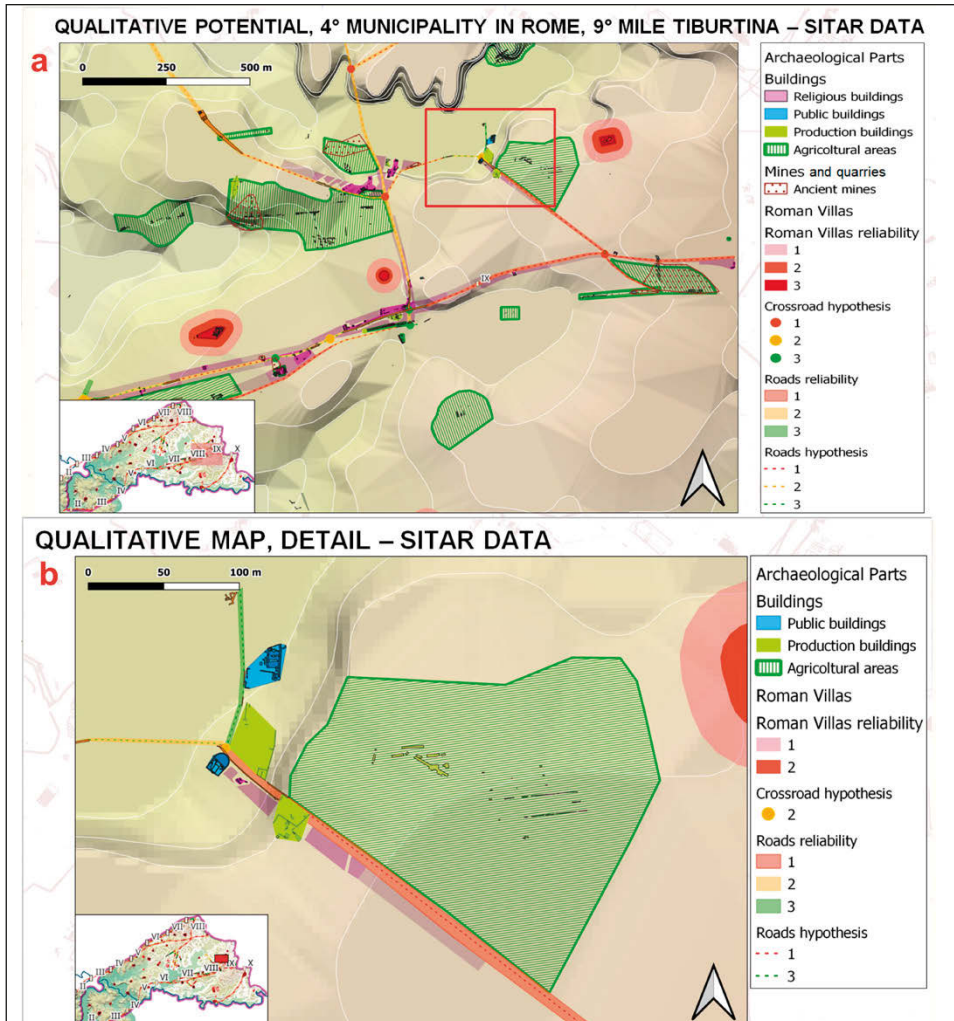


Fig. 3 – a) Qualitative approach used for the predictive map of a suburban area of Rome; b) detail covering the red square above (the map was drawn using SITAR data; many thanks to Dr. Fabrizio Santi SSABAP).



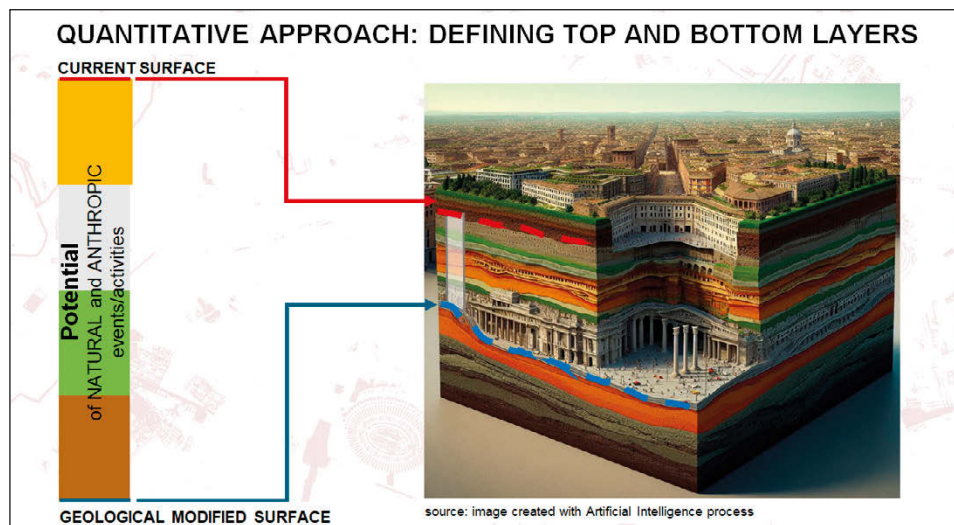


Fig. 4 – Schema of quantitative archaeological potential.

A key element of this approach is the creation of Digital Elevation Models (DEMs) that represent the topography of the surface in different periods. The first DEM is based on topographic data from the last 20 years, mainly from the Carta Tecnica Regionale del Lazio of 2002, and enriched by the surface elevations from the SITAR excavation database. The second DEM is derived from the interpolation of data from over 7000 core samples reaching the first geological layer, analyzed and interpreted by geologists (Fig. 4).

Moreover, an intermediate DEM is being developed using 1-meter contour lines from historical sources such as the *Piano regolatore di Roma* (PRG) (1908-1909) (TEULADA 1909) in the central area, the *Piano topografico di Roma e Suburbio* (PTRS) (COMUNE DI ROMA 1924) for nearby suburbs, and historical maps with 5-meter contour lines from the Istituto Topografico Militare (IGM) dated between 1872 and 1895 up to the boundaries of the Municipality of Rome. This historical DEM is 80% complete within Rome's urban railway ring and is crucial for accurately reflecting past orographic conditions, assuming minimal topographic changes between the fall of the ancient world and the 19<sup>th</sup> century. The main sources for interpolating Rome's 'Modified Geological Surface' are:

- geology of the territory of the Municipality of Rome. Amministrazione Provinciale di Roma (VENTRIGLIA 2002);
- Laboratorio di Idrogeologia Database (LABDIR) Department of Sciences, University of Roma Tre (LABORATORIO DI IDROGEOLOGIA 2023);

- ISPRA core sample database deeper than 30 meters (acquired in compliance with Law 464/84) (ISPRA 2023);
- core samples collected in the SITAR database (SSABAP-RM 2023);
- personal database of geologist Carlo Rosa.

## 5. CASE STUDY OF THE SECTION BETWEEN VATICAN HILL AND THE COLOSSEUM

The main case study conducted for this article concerns Rome between piazza Venezia and San Giovanni in Laterano and involves the use of the SITAR platform. The study focuses on calculating archaeological potential by examining geological and urban surfaces. The key elements of the study include: 1) geological surface: the ‘Modified Geological Surface’ represented in blue; 2) urban surface: the current urban surface represented in red. The methodology involved several steps, integrating geological and archaeological data to evaluate potential archaeological layers in the specified area:

- data collection: geological core samples and archaeological excavation data were collected throughout the city. These were analyzed by the geologist and mapped in QGIS, documenting the altitude above sea level of the geological surface below the archaeological layers;
- surface reconstruction: two fundamental DEM surfaces were defined: 1) upper surface: the current urban surface from the CTR Lazio 2002; 2) lower surface: the reconstructed geological surface modified by both natural and anthropogenic activities over time (search radius 500 m).

Once the two surfaces were obtained, the result was validated by performing hundreds of sections across the territory of Rome directly in the QGIS environment. The sections were sampled using the ‘Profile tool’ plugin. The results allowed for corrections and indicated significant differences between the geological and urban surfaces (Fig. 5). There is the possibility of increasing the detail of this section through more in-depth archival study, filling the gap between the two surfaces with archaeological structures or natural surfaces (Fig. 5b). Various modifications to the geological surface were identified, including fills and anthropogenic erosions. The impact of urban development on archaeological layers was assessed, with significant fill layers identified in some areas. Thanks to a multidisciplinary collaboration between archaeologists and geologists within the SITAR group, the enrichment and characterization of the section were achieved, demonstrating elements of great interest. As illustrated in the image (Fig. 6), the section between Vatican hill (*ad Saxia*) and piazza Venezia is meticulously explained in the legend. The evolution of the surfaces is reconstructed by intersecting all available data. Using the same methodologies, we can potentially outline the main archaeological deposits and major anthropogenic erosions throughout the Municipality of Rome, covering over 1200 km<sup>2</sup>.

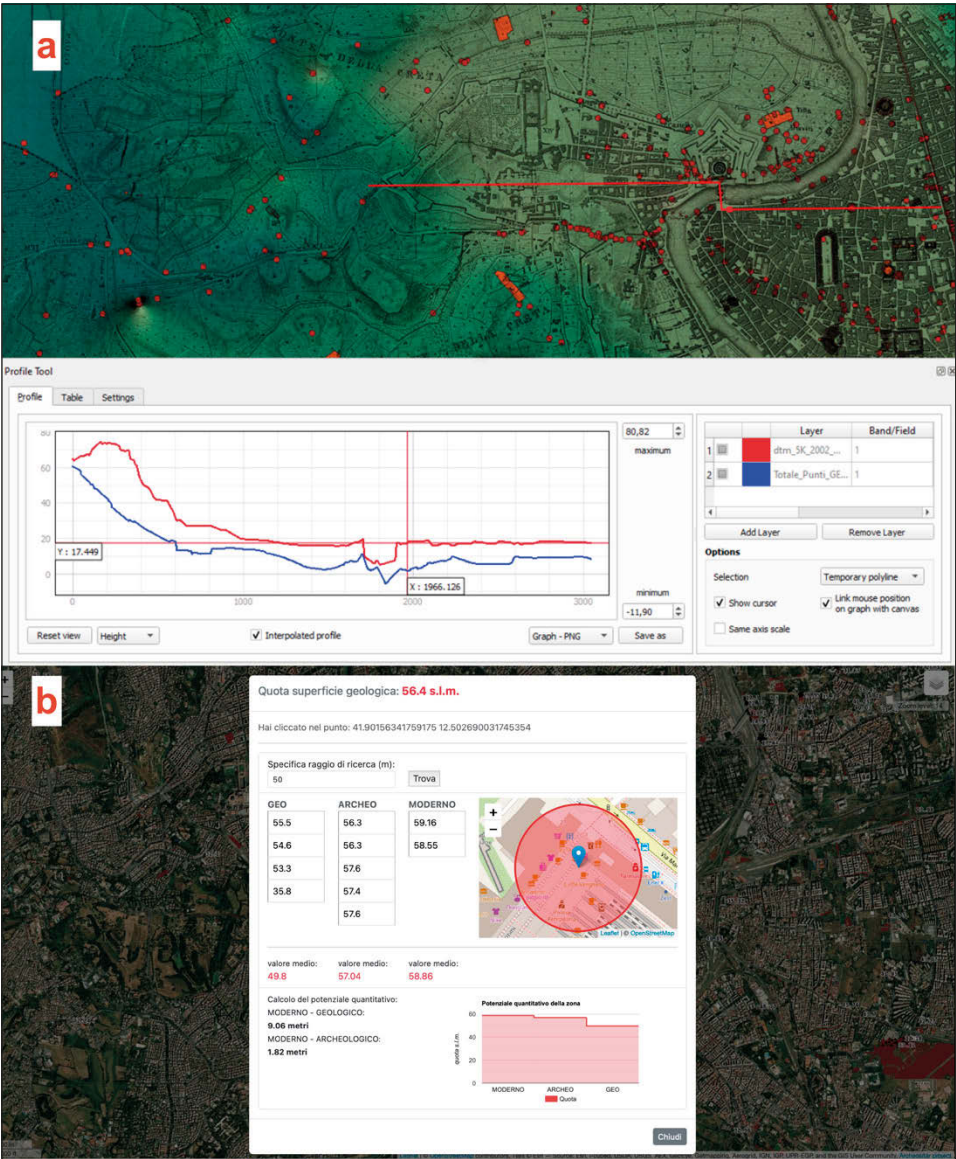


Fig. 5 – a) Current surface (red) and geological surface (blue). The section crosses St. Peter's Basilica, then piazza Pia, crosses the Tiber at Ponte Elio, and ends at via del Corso (Via Lata); b) the SITAR prototype of the webGIS tool for sampling quantitative archaeological potential in Rome. The tool averages the elevations within a search radius around the clicked point; in this case, the click was made at Termini (map and section processing by Paolo Rosati, webGIS application by Ascanio D'Andrea).



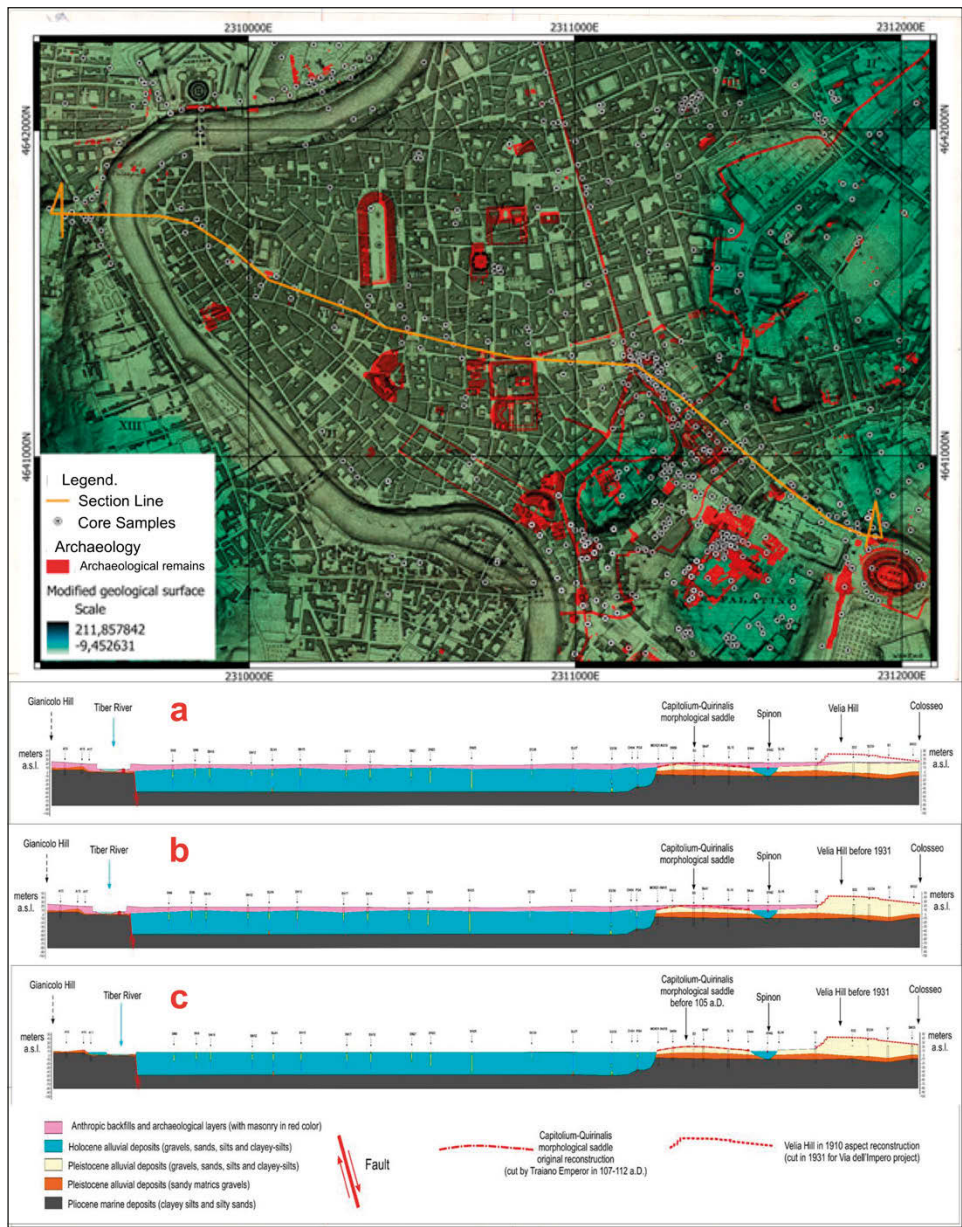


Fig. 6 – From Vatican hill to the Colosseum, an archeo-geological section from (a) today, (b) in the 1920s, and (c) before 10 AD (map processing by Paolo Rosati, sections by Carlo Rosa).

## 6. CONCLUSIONS

As we have seen, two centuries have passed since Brocchi's geological and antiquarian analysis, whose *Carta fisica del suolo di Roma* was intuitively used by archaeologists as a foundation to narrate the origins of the city Roma *ab Urbe condita*. These reconstructions have been enriched by the results of stratigraphic excavations and further epigraphic and historical evidence, providing an increasingly detailed picture of the territory. In SITAR, the original path traced by Brocchi is aimed at creating a reconstructive DEM of the Modified Geologically Surface, deducing a solid geo-archaeological compendium.

In line with SITAR's policy of knowledge democracy, the cartography will be published on the portal, and the DEMs will be accessible to everyone thanks to the ease of use offered by webGIS (Fig. 5b). Users, by clicking on any point in the city, will be able to obtain precise and detailed data as if they were conducting a specific coring. Among the data made available will be:

- the current altitude above sea level (modern);
- the summit elevation of the archaeological deposit;
- the average thickness of the archaeological deposit (if remains or previous excavations are present nearby);
- the average elevation of the geological layer.

By combining this new tool in development with what is already present on the platform, SSABAP aims to create an open and accessible device for everyone (public, academia, technical users). These openly shared data will



Fig. 7 – (Left) Detail of the *Carta fisica del suolo di Roma* drawn by Brocchi in 1820 and (right) the 'Modified Geological Surface' with the main water stagnation basins highlighted graphical processing by Paolo Rosati on SITAR data.

be made available to provide cutting-edge service, continuously updated, and we hope will generate new knowledge for a better future for the city.

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## REFERENCES

- ANICHINI F., BINI M., FABIANI F., GATTIGLIA G., GIACOMELLI S., GUALANDI M.L., PAPPALARDO M., SARTI G. 2011, *Definizione dei parametri del potenziale archeologico di un'area urbana*, «MapPapers», 2, 1, 44-46 (<https://doi.org/10.4456/MAPPA.2011.03>).
- BELLITTO L., D'AGOSTINI C., ROSA C. 2024, *Viale Castro Laurenziano, un'antica cava di tufo granulare grigio: studio geo-archeologico e correlazioni con il sistema caveale del II Municipio (ex III)*, «Notizie degli Scavi di Antichità», n.s. 1, 3, 103-135.
- BOTTIGLIERI L., CARBONI F., COLLI D., SANTIS A.D., FOSCHI G., MORRETTA S., ROSA C., SOLVI M. c.s., *Il circo Variano e l'anfiteatro Castrense: due edifici per la corte dei Severi. Gli edifici dello spettacolo*, in *Roma antica. Giornata di studi in ricordo di Paola Ciancio Rossetto*, «Bullettino della Commissione Archeologica Comunale di Roma», 125, in corso di stampa.
- BROCCHI G.B. 1820a, *Carta fisica del suolo di Roma nei primi tempi della fondazione di questa città*.
- BROCCHI G.B. 1820b, *Dello stato fisico del suolo di Roma, memoria per servire d'illustrazione alla carta geognostica di questa città*, Roma, Stamperia De Romanis.
- BUCCELLATO A., GHELLI A., ROSA C. 2021, *La via alzaia del Tevere dall'età romana al XVI secolo*, in C.R.E. DI LORETO, G. GISOTTI, G. LENA (eds.), *Le vie di comunicazione nell'antichità*, Roma, Geologia dell'Ambiente, Suppl. al n. 1, 179-188.
- COMUNE DI ROMA 1924, *Piano topografico di Roma e Suburbio*.
- DELFINO A., ROSA C. 2014, *La geologia e la geomorfologia dell'area del Foro di Cesare alla luce delle ultime campagne di scavo*, in A. DELFINO (ed.), *Forum Iulium. L'area del Foro di Cesare alla luce delle campagne di scavo 2005-2008*, BAR International Series 2607, Oxford, Archaeopress, 37-47.
- DEMETRESCU E., FONTANA S. 2009, *Archeo-restituzioni territoriali e urbane, valutazione del rischio archeologico e software open source*, in P. CIGNONI, A. PALOMBINI, S. PESCARIN (eds.), *ARCHEOFOSS Open Source, Free Software e Open Format nei processi di ricerca archeologica. Atti del IV Workshop (Roma 2009)*, «Archeologia e Calcolatori», Suppl. 2, 95-106 (<http://www.archcalc.cnr.it/journal/id.php?id=538>).
- DE SANTIS A.D., MIELI G., ROSA C., MATTEUCCI R., CELANT A., MINNITI C., CATALANO P., ANGELIS F.D., GIANNANTONIO S.D., GIARDINO C., GIANNINI P. 2010, *Le fasi di occupazione nell'area centrale di Roma in età protostorica: nuovi dati dagli scavi nel Foro di Cesare*, «Scienze dell'Antichità», 16, 259-284.
- FUNICIELLO R. 1995, *La Geologia di Roma. Il Centro Storico*, «Memorie descrittive della Carta Geologica d'Italia», 50, Servizio Geologico Nazionale, Roma, Istituto Poligrafico e Zecca dello Stato.
- GIOIA P., ANNA A.-H., CELANT A., ROSA C., VOLPE R. 2010, *Archaeological investigations in the Torre Spaccata valley (Rome): Human interaction with the recent activity of the Albano Maar*, in R. FUNICIELLO, G. GIORDANO (eds.), *The Colli Albani Volcano*, Special Publications of IAVCEI, 355-382.
- ISPRA 2023, *Database dei carotaggi* (<https://www.isprambiente.gov.it/>).

- LABORATORIO DI IDROGEOLOGIA U.R.T. DIPARTIMENTO DI SCIENZE 2023, *Database dei carotaggi* (<http://scienze.uniroma3.it/>).
- LUGLI F., ROSA C. 2001, *Prime evidenze di opere di terrazzamento del Capitolium nell'età del Bronzo recente*, «Bullettino della Commissione Archeologica Comunale di Roma», 102, 281-290.
- MATTEUCCI R., ROSA C. 2012, *Il Tevere nel suburbio a Nord di Roma: evoluzione geologico-geomorfologica*, in D. ROSSI (ed.), *Sulla via Flaminia. Il mausoleo di Marco Nonio Macrino*, Milano, Electa, 30-45.
- MATTEUCCI R., ROSA C., SEBASTIANI R. 2023, *Le variazioni del corso del Tevere e le evidenze della sua frequentazione*, in M.C. PRELATI, R. SANTANGELI VALENZANI, C.M. TRAVAGLINI (eds.), *Tra Roma e il mare. Insediamenti, trasformazioni territoriali, patrimoni culturali e ambientali, tra evo antico ed età moderna*, «Città e Storia», 16, 1-2, 135-151.
- MAZZA R., CAPELLI G., LANZINI M. 2008, *Carta dello spessore dei terreni di riporto (carta n° 3)*.
- PONZI G. 1850, *Sulla storia fisica del bacino di Roma, memoria di Giuseppe Ponzi, da servire di appendice all'opera Il suolo fisico di Roma di G. Brocchi*, Roma, Tipografia delle Scienze matematiche e fisiche.
- ROSA C. 2022, *La geologia e geomorfologia del versante sud ovest del Quirinale da via della Dataria al Foro di Traiano*, in A. PIZZO, R. MONTALBANO (eds.), *Tra le pendici del Quirinale e il Campo Marzio*, Roma, Arbor Sapientiae Editore, 55-68.
- SERLORENZI M., BOI V. 2016, *Archeologia preventiva, predittiva, potenziali archeologici. Una breve introduzione al panorama italiano*, in F. STANCO, G. GALLO (eds.), *Archeofoss. Free, Libre and Open Source software e open format nei processi di ricerca archeologica*, VIII edizione 2013, Oxford, Archaeopress, 1-10 (<https://hdl.handle.net/11568/853736>).
- SERLORENZI M., LAMONACA F., PICCIOLA S. 2012, *Sistema Informativo Territoriale Archeologico di Roma (SITAR)*, «Archeologia e Calcolatori», 23, 31-50 (<https://doi.org/10.19282/ac.23.2012.02>).
- SSABAP-RM 2023, *Geodatabase del Sistema Informativo Territoriale Archeologico di Roma (SITAR)* (<https://www.archeositarproject.it/>).
- TEULADA E.S. DI 1909, *Piano regolatore di Roma del 1908-1909*.
- TREMARI M. 2020, *La Carta del Rischio Archeologico del Comune di Sondrio all'interno del Piano di Governo del Territorio*, «Notiziario Istituto Archeologico Valtellinese», 18, 161-164.
- VENTRIGLIA U. 1971a, *La carta geologica del Comune di Roma*, Roma, Amministrazione Provinciale di Roma.
- VENTRIGLIA U. 1971b, *Spessore della coltre dei terreni di riporto*.
- VENTRIGLIA U. 2002, *Geologia del territorio del Comune di Roma*, Roma, Amministrazione Provinciale di Roma.

## ABSTRACT

The institutional goal of studying and mapping archaeological potential in SITAR in recent years has been to create an efficient tool to support urban planning and cultural heritage management: The Archaeological Potential Map of Rome. The Soprintendenza of Rome plays a key role in this effort, being responsible for the safeguarding and promotion of the city's archaeological heritage. By developing a robust model of archaeological potential, the Soprintendenza can better anticipate and mitigate the impact of construction and development projects on archaeological sites. This proactive approach ensures that significant archaeological resources are identified and preserved before they are damaged or destroyed. The tool will facilitate informed decision-making in urban planning, helping to balance the needs of modern development with the preservation of historical sites. Moreover, it will support the regulatory framework that mandates archaeological assessments in high-potential areas, rationalisation of administrative processes and improving compliance with heritage protection regulations. Overall, the creation of an efficient archaeological potential model by the Soprintendenza of Rome underlines the commitment to preserving the city's cultural heritage while accommodating its continuous urban evolution.



## THE GISTARC WEBGIS FOR THE ACCESSIBILITY AND SHARING OF ARCHAEOLOGICAL DATA IN CAMPANIA

### 1. INTRODUCTION

The webGIS GISTArc was created to visualize, manage, and analyse the geoarchaeological data from the research carried out in some areas of the northern Campania, related to the project ‘Archaeological Map of Campania’, directed by Stefania Quilici Gigli (QUILICI GIGLI 2016). Over the years, sectors in the districts of Caserta, Benevento, and Avellino have been investigated, considering archaeological data from the Prehistory to the Late Antiquity. The focus is the middle Volturno Valley, the Caudina area, and the *Ager Campanus*, but the activities have also extended to smaller areas in the district of Avellino. It was chosen to conduct extensive surveys of the areas under investigation rather than a sampling survey (RENDA 2020, with other bibliographical references). The field survey has led to a significant increase in knowledge on examined areas (QUILICI GIGLI 2017; RENDA 2020).

The majority of the archaeological maps produced have been published in the series ‘Carta archeologica e ricerche in Campania’, Suppl. XV of the *Atlante Tematico di Topografia Antica*, directed by Lorenzo Quilici and Stefania Quilici Gigli, ensuring the dissemination of research. Studies and surveys in this area have had operating implications. Maps of the archaeological potential were produced, thanks to the collaboration between the University, Soprintendenza and local Government, with the aim of a common strategy for land-use planning (QUILICI GIGLI *et al.* 2014; QUILICI GIGLI 2016; RENDA 2016, 2022). In this regard, the initial choice to conduct extensive surveys in the investigated territories has proved to be successful, because this type of field research is the most suitable for territorial planning.

The activities of preventive archaeology, especially the research conducted in the *Ager Telesinus*, made us reflect on a ‘more dynamic’ dissemination that allows for the retrieval of the most significant information of the recorded archaeological sites, related to their spatial data, and the possibility for external users to query them according to their needs. In this regard, the development of a webGIS seemed the most suitable solution, considering the volume and complexity of the available data and the need for high-speed data transmission. The years of experience in the field of GIS and geodatabases (RENDA 2019 with bibliographical references), and the creation of ontologies for the structuring of archaeological data (RENDA 2014) have served to organize a new logical and conceptual model, used as a documentary base for the webGIS.

G.R.

## 2. NORMALISATION AND MANAGEMENT OF ARCHAEOLOGICAL LAYERS

In connection with the development of the webGIS, a normalization activity was conducted on the data created in the GIS environment and used in previous projects. The systematization of the contents was followed by the phase of importing all the alphanumeric data into a geodatabase functional for the webGIS. During the transmigration of data onto the webGIS and to precisely locate the archaeological evidence, it was decided to assign a polygonal geometry to the basic data relating to the archaeological sites, for which the actual dimensions had already been identified through surveying and georeferencing. Another preparatory phase was about the choice of entries within the description sheet of the archaeological assets. It has been created a 'single sheet', that would compact and organize data in a streamlined model. This sheet collects data to the knowledge of the archeological heritages and contexts into single sections. These sections have free fields and fields with drop-down menus with multiple choices, designed in relation to the latest indications provided by the Ministry of Culture for preventive archaeology.

Particular attention was paid to the chronology section. We referred to the model of the formal ontology CIDOC-CRM (NICCOLUCCI 2015). The chronological phases included range from prehistory to the late Middle Ages, with particular focus on periods and territorial compartments within which the archaeological maps drawn up are located. For a more immediate and effective understanding of the archaeological data, a symbology was prepared that differentiated the various sites identified by type.

S.M.

## 3. THE GISTARC PROJECT

The GISTArc project involves the creation of a webGIS environment for the management and visualization of geoarchaeological data, i.e. archaeological data to which geospatial properties have been associated, such as position, perimeter or a track, all of which are georeferenced in an appropriate system of geographical reference. The classic functions of creating, reading, updating and deleting new records (CRUD, Create-Read-Update-Delete) are implemented in the GISTArc geodatabase, both for descriptive data and for associated geometries. For this reason, PostgreSQL database management software was used, with the PostGIS extension for geometries and data georeferencing. PostGIS provides a complete library of functions that are particularly useful in the analysis of archaeological and topographical data. The GISTArc user interface is responsive and can be used with any device (desktop, tablet, smartphone) connected to the Internet via a standard browser, automatically adapting to the size of the screen in use. The system was



created to be multilingual, initially in Italian and English, with an automatic translation system based on Google Translate, integrated with multilingual user interface parts, managed directly by the application.

### *3.1 The objectives of GISTArc*

The main objective of GISTArc is to make the results of archaeological research, accumulated over years of field surveys, until now accessible to a small number of specialists in the sector, in the form of books only, accessible to as many people as possible, in a more general perspective of public archaeology. Moreover, GISTArc has functions for entering and updating data via the Internet connection. This allows the researcher, in addition to consulting the information already present in the database, to insert new information and correct any errors directly in the field, with a great saving of time. Another objective, by no means secondary, is to be able to access the GISTArc geodatabase on the Internet via standard desktop applications, such as Quantum GIS and ArcGIS, in order to use advanced data analysis and representation functions that may not be available online, ensuring the integration with very well-known standard and most commonly used application.

All users can, even without logging-in, freely view thematic maps with all the information present in the database, select the data using interactive masks, and change the basic cartography from a certain number of pre-set maps. Users with credentials can be ‘administrators’, who can create and manage other users; ‘field researchers’, who can enter new data in the field and update existing data; and ‘editors’, who have complete access to the functions of insertion, modification and deletion of all data.

### *3.2 System architecture and development tools*

The GISTArc application was implemented on Linux servers with Node.js. GISTArc is a classic PERN application (PostgreSQL + Express + React + Node), and is therefore made up of a backend (all the functions needed to access the geodatabase) and a frontend (Fig. 1) (the graphical user interface, GUI). GIS desktop applications (QGIS, ArcGIS) can connect directly to the online geodatabase. All the software and libraries used for the development of GISTArc is open source, not only to contain development costs, but also to have maximum flexibility in designing and creating the software, which is not always possible with commercial applications (Tab. 1). Also the development environment (code editor and testing) used for this project, Visual Studio Code, is freely available for downloading on Internet. The GISTArc application was created for the Linux platform, and tested with an Ubuntu virtual server created in an AWS (Amazon Web Services) environment, with NGNIX as the web services manager.

Function	Software
Geodatabase	PostgreSQL + PostGIS
Backend and API	Express.js, JavaScript
Frontend	React, JavaScript
Graphical User Interface	React-Bootstrap + Bootstrap
Gestione mappe	React-Leaflet + Leaflet
Other functions	Additional JavaScript libraries
Execution environment	Node.js (JavaScript runtime)

Tab. 1 – List of the main software components and libraries.

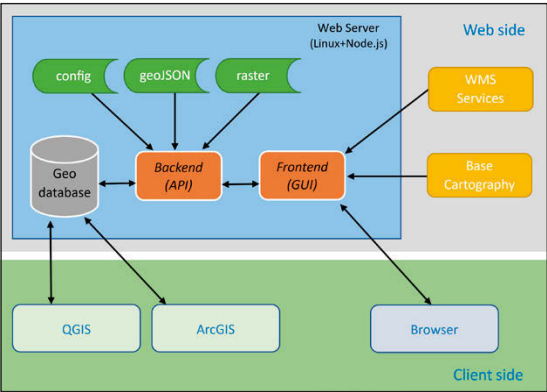


Fig. 1 – Architecture of the GISTArc web application.

3.3 The GISTArc application

In the basic screen of GISTArc (Fig. 2), since it is a GIS application, we wanted to emphasize the display of the map, which occupies the entire work area. In the upper part, outside the work area, there is a menu that contains general commands, including the button to log in using credentials and the one to change the working language. On the left side, superimposed on the work area, there is a retractable ‘toolbar’ which includes the main functions of GISTArc (Fig. 2) for: selecting layers, selecting places, viewing the list of places present in the current window, and filtering of places based on the selection of specific attributes. From the Layers panel of the toolbar, it is possible to select: the basic layers, available on the Internet, such as Open Street Map, in the different versions, the ESRI satellite map, the various versions of the Stamen maps, etc. In the same way, it is possible to connect and view WMS (Web Map Service) maps, such as the maps of the Italian Military Geographic Institute, at 1:25,000 and 1:100,000 scale, made available free of charge on

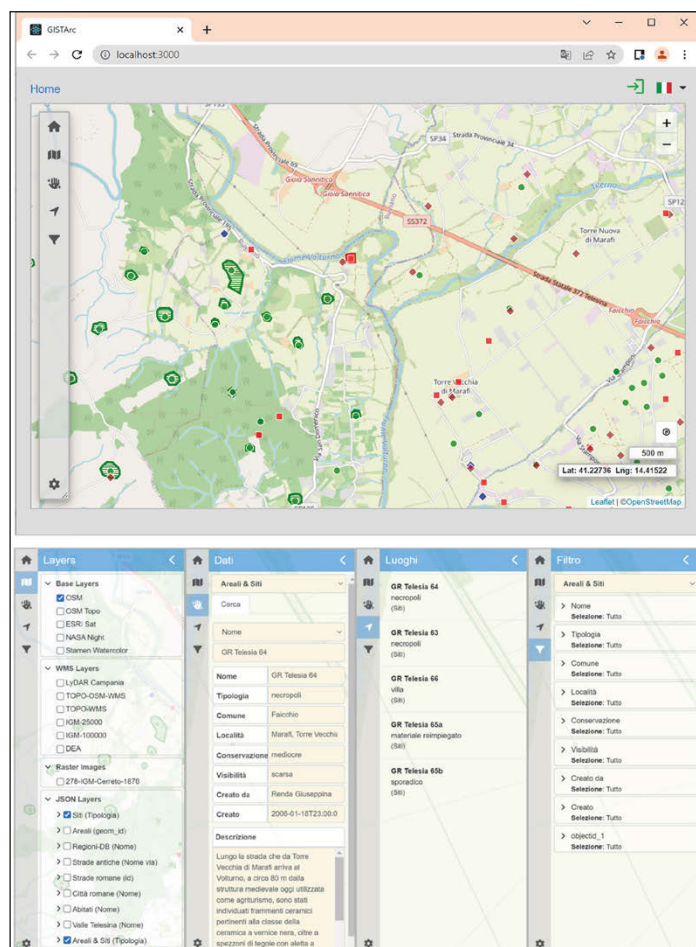


Fig. 2 – GISTArc basic screen (above) and toolbar panels.

the website of the Ministry of the Environment. In addition, it is also possible to view, as a basis, appropriately georeferenced historical maps (raster).

The data contained in the geodatabase are used to create and display vector layers, which are associated with different geometries: points to identify places, cities, archaeological evidence; polygons for the areas of interest associated with individual sites; and lines for ancient road routes. These layers, whose data are contained in the geodatabase, can be dynamically modified by authorized users, with the classic creation, reading, updating and deletion operations. Other ‘static’ layers (vector layers), such as those of the

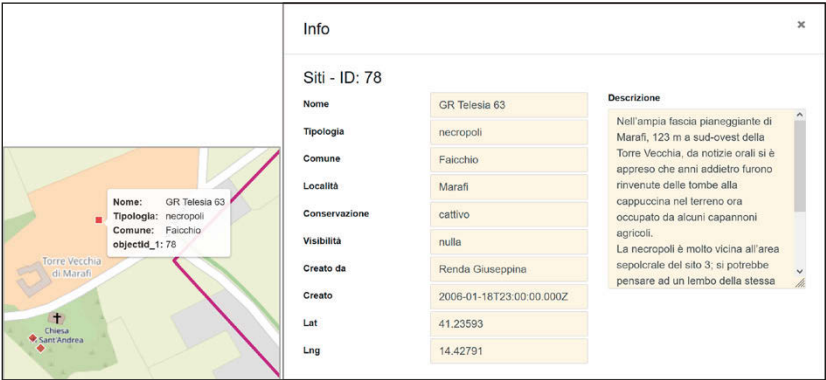


Fig. 3 – Information windows, synthetic (left) and extended (right).

administrative, municipal, provincial, regional borders, which do not require updates but are created one-off and then simply loaded as needed, are not stored in the database, but on disk of the server, so as not to unnecessarily overload the database management system. All vector layers, both from database and from disk, are managed within GISTArc as GeoJSON structures, i.e. JSON (JavaScript Object Notation) data with the addition of geospatial information, because they are more easily managed by JavaScript, which is the base language with which the application was created.

Elements of a layer can also be selected from the Data panel of the toolbar. In the example in Fig. 3, the 'GR Telesia 64' site was selected from the 'Areas & Sites' layer. The selected site is placed in the center of the screen, highlighted with a yellow circle and the map is automatically rescaled with a predefined zoom level, in order to display the site and its surroundings in adequate detail. If the current user is authenticated as 'editor' ('field', owner of the data), the panel becomes a full-fledged data editing and entry form, and all the data can be modified and updated, and new places can be added too. Fig. 4 shows the toolbar of the Search tab, located under the name of the selected element, with buttons for: editing non-spatial data; modifying the geometry; canceling unsaved changes; saving changes; and deleting the item. The geometry associated with the object is also displayed under the toolbar in GeoJSON format. This can be modified directly on the map with the 'Edit geometry' button.

In addition to these basic functions for viewing, editing, and entering data, functions have been implemented through the Places and Filter panels that make selecting and accessing data very simple. The Places panel is used to list all the 'places', i.e. the elements associated with specific layers, present in the portion of the currently displayed map.

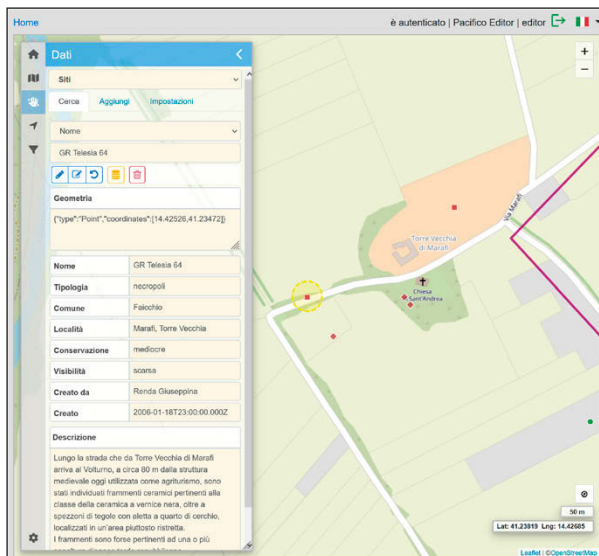


Fig. 4 – Data modification panel, by an authenticated 'editor' type user.

### 3.4 The configuration of GISTArc

The GISTArc application is built starting from a common and general code core, which we have called 'mapplet' that can be used to create, in principle, any webGIS application. This is a general code containing basic functions for connecting to external base maps and WMS, loading maps from geodatabases, managing CRUD functions, managing application users and many other accessory functions. An application built with this core code can manage any layer and any set of data, i.e. those defined in configuration files external to the code and loaded when the application is run. These are text files in JSON format, which 'describe' the data that give 'content' to the application itself, according to a predefined syntax.

The GISTArc configuration JSON file (default.json), in compact form, is shown in Fig. 5, compared to the Layers menu of GISTArc. The configuration file contains the definitions associated with the layers that are loaded into the application at startup. Each layer has specific metadata, according to the type of layer. As an example, for a layer connected to an external resource (map or WMS), in addition to the basic attributes common to all types of layers, there are the 'url', 'maxZoom' and 'attribution' metadata, necessary for loading from the Internet. A 'jsonLayers' defines a typical GIS layer, and have a more complex set of metadata, because it is necessary to define the characteristics

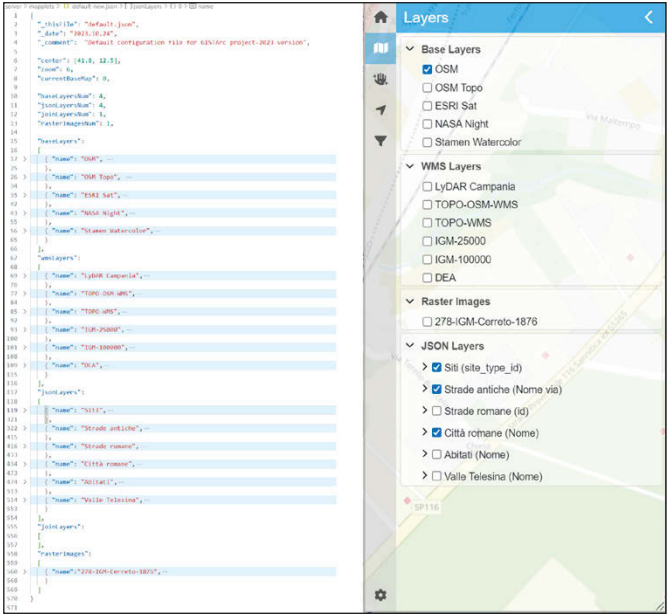


Fig. 5 – The configuration file and the layers panel.

relating to the display of the symbols or icons associated with the geometries and the management of the attributes, as shown in the definition of the ‘Sites’ layer which follows. Moreover, they contain a description of the geodatabase fields used, as shown in Fig. 6.

We notice that the ‘datatype’ metadata is present, to which in the previous example the value ‘db’ is assigned, precisely to specify that all the information associated to the layer is stored in a database. Another possible value is ‘file’; in this case the data relating to the layer is stored in a file on the server disk. The .env file contains server and database connection information, as in the example below:

```
NODE_ENV=devel
JWT_SECRET=12123o1iwqJHNMkjswNlJLKaqieu32193218u9\398)(\&)
(79876KJKjhMnuhNHig&3&%/7)
PORT=5000
PGUSER=postgres
PGHOST=localhost
PGPASSWORD=pcpcpc
PGPORT=5432
USERSDB=jwtusers
PGMAPPLETSDB=gisdb
```



```
[
  {
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    "datatype": "db",

    "fname": "sites",
    "prefix": "site",
    "checked": true,

    "type": "points",
    "geomtrytype": "Point",
    "srid": "32633",
    "lating": false,

    "publicField": "site_pub_val",

    "idField": "site_num_val",
    "crDateField": "site_crdate_val",
    "crByField": "site_crby_userid",
    "moDateField": "site_modate_val",
    "moByField": "site_moby_userid",

    "descrField": "site_descr_val",
    "markerField": "site_type_id",

    "--searchField": "site_num_val",
    "--searchText": "site_com_id",
    "--labelField": "site_num_val",

    "_comment-required_fields": "can't be empty",
    "_comment-auto_fields": "'auto' fields values are created/updated automatically by the program",

    "fields": [
      {
        "label": "Geometria",
        "required": true,
        "mode": "auto",
        "name": "geom",
      },
      {
        "label": "Numero",
        "required": true,
        "mode": "auto",
        "name": "site_num_val",
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      {
        "label": "Creazione",
        "required": true,
        "mode": "auto",
        "name": "site_crdate_val",
      },
      {
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        "required": false,
        "mode": "auto",
        "name": "site_modate_val",
      },
      {
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        "vals": [],
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        "mode": "manual",
        "name": "site_pub_val",
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        "label": "Località",
        "required": false,
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      {
        "label": "Comune",
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        "ids": [],
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        "vals": [],
      },
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        "mode": "manual",
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        "vals": [],
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        "vals": [],
      },
      {
        "label": "Media",
        "required": false,
        "mode": "manual",
        "name": "site_mods_ids",
      },
      {
        "label": "Riferimenti",
        "required": false,
        "mode": "manual",
        "name": "site_refs_ids",
      }
    ],

    "infoFields": [ ... ],
    "keyFields": [ ... ],
    "keyGroups": [ ... ],
  },
]
```

Fig. 6 – GeoJSON layer with database fields description.

Thanks to these configuration files it is possible to ‘reconfigure’ the entire application, both in terms of the layers made available to the user and for the migration of the application itself from one platform to another, having parameterized all the information relating to the server and online database manager.

P.C.

## 4. THE DATABASE ARCHITECTURE

The database design involved initial requirements analysis work which relied on in-depth knowledge of the domain of interest by the research group. With a view to reusing the software, an application was used whose data structure was simplified and above all, for the definition of some vocabularies, the ontology for the cataloging and communication of the archaeological assets of the MARA platform. The design phase continued with the definition of the tables and the relationships between them. The data structure is based on a main Sites table, with a series of accessory tables that contain lists of predefined values, and additional tables relating to bibliography and media (photos, drawings, images in general) (Fig. 7). The information present in the database is also the result of the integration of external open databases. In particular, geographical data (shapefiles for municipalities and localities) from the territorial base system published by ISTAT were used. Furthermore, the structure was implemented with some codified vocabularies as required by the guidelines on preventive archeology of the Ministry of Cultural Heritage.

#### 4.1 The database management system

PostgreSQL was chosen as the open-source database management system. It is software based on the typical client-server model with the ability to combine the potential of object-oriented programming with those of relational DBMS. The

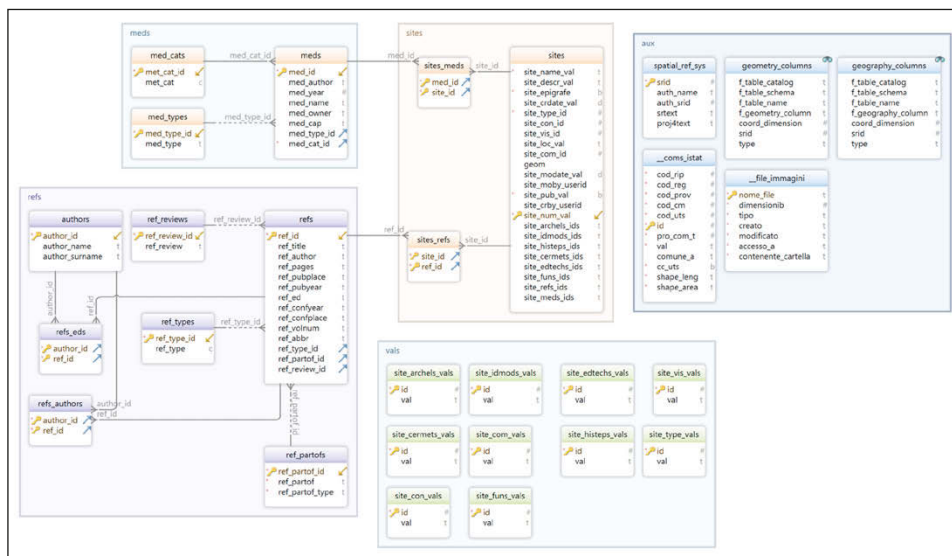


Fig. 7 – Database architecture.

advantages offered by PostgreSQL are many. In fact, it is multi-platform, has high performance and excellent reliability, and guarantees security and extensibility. It also has easy-to-use administration tools; in this work both psql, with a command line interface for entering SQL queries, and pgAdmin, an administration tool with a graphical interface, were used. Of great importance is the availability of the PostGIS module for PostgreSQL which extends the functionality of the DBMS with spatial functions, which allow you to manage georeferenced data and create, update and query geodatabases quickly and efficiently.

C.C.

## 5. CONCLUSION

The first purpose of the GISTArc was to make information accessible to those involved in research, preservation, and territorial planning, providing alphanumeric information, vector, and raster layers that maintain spatial accuracy. This last point (the spatial accuracy) became crucial: unfortunately, some of our data was incorporated into a newly licensed webGIS without our direct involvement, leading to incorrect localization of some of our archaeological data. A second purpose was to make the system 'real-time' usable, meaning to provide data entry directly in the field, in order to reduce the times and steps of registration. Furthermore, the possibility of using data pre-entered enhances the understanding of each site identified in the field activities.

The work presented here is still in progress. A future development of GISTArc could be in a semantic sense, especially regarding the use of ontologies associated with archaeological, bibliographical and topographical data. A further step should be to use semantic technologies applied to the geospatial data themselves (JANOWICZ *et al.* 2010; ZHU 2010).

G.R., P.C.

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## REFERENCES

JANOWICZ K., SCHADE S., BRÖRING A., KESSLER C., MAUÉ P., STASCH C. 2010, *Semantic enablement for spatial data infrastructures*, «Transactions in GIS», 14, 2, 111-129.

- NICCOLUCCI F. 2015, *Un'infrastruttura di ricerca per l'archeologia: il progetto ARIADNE*, «Archeologia e Calcolatori», Suppl. 7, 41-44 (<https://www.archcalc.cnr.it/journal/id.php?id=808>).
- QUILICI GIGLI S. 2016, *Carta archeologica della Campania: ricerche condotte e in corso per la promozione del territorio*, in S. QUILICI GIGLI, L. QUILICI (eds.), *Carta archeologica e ricerche in Campania, Atlante Tematico di Topografia Antica*, Suppl. 15, 9, Roma, L'Erma di Bretschneider, 7-15.
- QUILICI GIGLI S. 2017, *Lettura topografica dei dati archeologici dall'età sannitica all'epoca imperiale*, in S. QUILICI GIGLI, L. QUILICI (eds.), *Carta archeologica e ricerche in Campania, Atlante Tematico di Topografia Antica*, Suppl. 15, 10, Roma, L'Erma di Bretschneider, 135-154.
- QUILICI GIGLI S., SALERNO A., GENNARELLI I., RENDA G. 2014, *Dalla Carta archeologica della Campania alla Carta delle Potenzialità Archeologiche, Esperienze a Sturno e Bellona per una strategia condivisa di pianificazione del territorio*, in S. QUILICI GIGLI, L. QUILICI (eds.), *Carta archeologica e ricerche in Campania, Atlante Tematico di Topografia Antica*, Suppl. 15, 8, Roma, L'Erma di Bretschneider, 371-384.
- RENDA G. 2014, *L'approccio multimediale per la comunicazione di aspetti funzionali complessi dell'Anfiteatro Campano*, in S. QUILICI GIGLI (ed.), *Comunicazione e fruizione dei beni archeologici*, Foggia, Claudio Grenzi Editore, 101-118.
- RENDA G. 2016, *Landscape archaeology in the Ager Telesinus: Scientific results and land-use planning*, in G.-J. BURGERS, S.J. KLUIVING, R.A.E. HERMANS (eds.), *Multi-, Inter- and Transdisciplinary Research in Landscape Archaeology. Proceedings of the 3<sup>rd</sup> International Landscape Archaeology Conference (Rome 2014)*, Amsterdam, University Library Vrije Universiteit Amsterdam, 1-9 (<https://doi.org/10.5463/lac.2014.50>).
- RENDA G. 2019, *Il Sistema Informativo territoriale e la gestione delle informazioni archeologiche in ambiente GIS: qualche osservazione*, in P. CARFORA, E. DI LUZIO (eds.), *Approcci multidisciplinari per la ricostruzione del paesaggio di una grande strada romana. La Via Appia al Valico degli Aurunci*, Foggia, Claudio Grenzi Editore, 97-98.
- RENDA G. 2020, *Carta archeologica e ricerche in Campania, Atlante Tematico di Topografia Antica*, Suppl. 15, 11, Roma, L'Erma di Bretschneider.
- RENDA G. 2022, *Tracce di storia nel paesaggio: dalla ricerca alla pianificazione*, in C. CROVA, D. CONCAS, A. CIASCHI (eds.), *I 60 anni della Carta di Gubbio. Strategie per la salvaguardia dei centri storici*, Saonara (PD), Il Prato, 105-119.
- ZHU Y. 2010, *Geospatial semantics, ontology and knowledge graphs for big Earth data*, «Big Earth Data», 3, 3, 187-190.

## ABSTRACT

The GISTArc project envisions the implementation of a webGIS environment for the management and visualization of geoarchaeological data from research included in the Archaeological Map of Northern Campania project, conceived and directed by Stefania Quilici Gigli. The creation of the new system began with the normalization of some completed research data. They were managed in a GIS environment and were subsequently imported into a Web geodatabase, with the preparation of layers containing all the textual, graphical/ photographic and spatial information of the catalogued archaeological evidence, together with the required bibliographical references. The GISTArc project has a threefold aim: make the results of archaeological research conducted in some sectors of northern Campania more usable; allow the researcher to consult, integrate and enter the data from future research, thanks to the connection to the system via the Internet and the possibility of recording data directly during the survey; and finally access via standard desktop applications, such as Quantum GIS and ArcGIS, rather than the internet-based GISTArc geodatabase, in order to use advanced data analysis and representation functions that may not be available online. This paper describes the technical and scientific approach to the creation of our webGIS. It focuses on the system architecture, operative environment, and development tools.

CHALLENGES AND BENEFITS  
IN MODELLING ANCIENT LANDSCAPES COMPLEXITY  
THROUGH RESILIENCE AND ANTIFRAGILITY.  
RELOAD: A PROJECT ON LIMINALITY IN NORTHERN TUSCANY

1. INTRODUCTION

RELOAD (REthinking Liminality Open Access Data) is a post-doctoral research project funded by FSR-FNRS at UCLouvain (2022-2025). The project complements several decades of research projects focusing on Volterranean landscapes between the Roman conquest and Late Antiquity (CAVALIERI 2019; MENCHELLI *et al.* 2023), analysing the settlement evolution and the distribution of specific material classes in liminal areas between the centuries 3<sup>rd</sup> BC-5<sup>th</sup> AD (Fig. 1). The aim is to re-evaluate the crucial role of liminality in space organisation and perception, and in the processes of identity formation. The importance of Volterra as a case study is related to the fact that most of the changes in landscape organisation have occurred in its liminal areas but also to the paradoxical situation featuring its social and environmental development when approached from a diachronic perspective. Despite its geographical isolation, if compared to other cases of northern Tuscany and the lack of an actual political weight, Volterra benefitted from a surprising centrality in the macro-dynamics of the Roman Mediterranean (LIMINA 2021a).

1.1 *Goals, research questions, theoretical approaches*

Social groups interacted in a specific milieu through strategies of space adaptation responding to environmental contingencies and cultural practices, continuously redefining interests, powers, and borders. In the last decades, the idea of the frontier as a permeable meeting zone where to display shifting identities emerged (DERKS, ROYMANS 2009; CIFANI, STODDART 2012). Marginal areas delimited by physical boundaries could be considered liminal landscapes (CAMBI *et al.* 2015; DUBBINI *et al.* 2020). The term ‘liminal’ intrinsically conveys the idea of the Latin *limen*, while the anthropological ‘liminality’ (VAN GENNEP 1909; TURNER 1974; ANDREW, ROBERTS 2012) could be merged with the liminal areas conceived by landscape archaeology. The marginal zones featured by peculiar environmental conditions (springs, forests, mountains, swamps, etc.), implying the need to adopt specific ways of living and control, could be defined as liminal (HOLM *et al.* 2009). These marginal areas were permeable systems usually facing the challenges of cultural entanglements (STOCKHAMMER 2012).



Fig. 1 – RELOAD. A new project for ancient landscapes.

In this sense, liminal areas could be considered zones of real or perceived frontiers, where exchanging ideas, rituals, technologies, and practices occurred, representing privileged viewpoints to better understand past human behaviour and how it modified ancient landscapes. Investigating processes of identity formation through material culture is intrinsically connected to the analysis of settlement pattern evolution and material assemblages' distribution. It is significant that in northern Etruria, particularly in the *ager Volaterranus*, most of the changes in landscape organisation occurred in liminal zones, that is marginal zones featured by geothermal phenomena (DI PAOLA 2018), by extra-urban sanctuaries (ZIFFERERO 1995), the Roman centuriation (CIAMPOLTRINI 1981), the presence of imperial properties, and the early Christian worship places (CIAMPOLTRINI 1995). Why did all this occur in liminal zones? Was it because of peculiar environmental natural features? Or was this system of settlement and ownership permeable because it was marginal and, therefore, difficult to manage and control?

Moreover, there is much scope for detecting if and how the survival of local Etruscan traditions in material culture merged with innovations facing Rome in these permeable areas. Indeed, within the broader context of ancient Etruria, the northern district fiercely retained alive Etruscan identity in material culture, until the first century BC, at least (HADAS LEBEL 1988; BOURDIN 2012; LIMINA 2021a). Given the importance of Etruscan heritage in Roman culture until the end of the Western Empire (RAMELLI 2003) and the presence, in the 5<sup>th</sup> century AD, of individuals at the top rank of imperial hierarchies retaining estates in northern Tuscany – and often claiming descent from the





Fig. 2 – Ager Volaterranus: QGIS map.

same groups involved in the process of cultural integration with Rome – one wonders if the existence of a local Etruscan identity could be supposed. Thus, through the analysis of liminal landscapes evolution and family strategies, alternative interpretations about identity formation processes linked to a peculiar landscape organization could be prompted.

Santo MAZZARINO (1957) identified the survival of the Etruscan culture as the aspect underlying the continuity of land management in Etruria between the Archaic and Lombard periods. Thus, it is not surprising that concepts such as ‘traditional’, ‘conservative’, ‘resistant’, ‘persistent’ (MUNZI *et al.* 1994; TORELLI 1995; TERRENATO 1998; AUGENTI, TERRENATO 2000) were used to define northern Tuscan elites and their management of territory. In the last decades, ‘resilience’ has been more and more adopted for reconstructing human-environmental interactions (REDMAN, KINZIG 2003; REDMAN 2005; TONER 2012; FAULSEIT 2016) and socio-political phenomena (TERRENATO 2019). Then, this concept has been used to interpret the dynamics of continuity and transformation featuring northern Tuscany landscapes (BERTOLDI, CASTRORAO BARBA 2021; CANTINI 2022) and elites (PADGETT 2010; CORTESE 2017). Despite this, especially for the case of Volterra between the centuries 3<sup>rd</sup> BC-5<sup>th</sup> AD, it seems that cycles of continuity were accompanied by substantial changes that, skilfully managed by those who negotiated the power at different levels, brought a secondary centre of the Roman world to a real improvement of its social and economic systems, leading to an unusual centrality in the ancient Mediterranean.

The concept of ‘resilience’ seems reductive to interpret the complexity of Volterra. Consequently, RELOAD aims to adopt an alternative concept,

‘antifragility’ that eventually could answer better to the peculiarities of the case study. Thus, the project intends to evaluate the benefits of approaches from the ‘hard sciences’ trying to prompt alternative reconstructions of the past.

## 1.2 Methodology

RELOAD adopts a multidisciplinary approach to investigate dynamics of change diachronically. The project collects the results of previous archaeological research and legacy data. Considering the difficulty of comparing data on settlement pattern, collected with different criteria, RELOAD includes new field surveys in Volterranean liminal areas (Fig. 4). Focusing on significant sample zones, the new pedestrian field surveys, with intensive systematic methodology, lead to deepen knowledge on settlement pattern evolution. The open access databases by Regione Toscana (GEOScopia, CASTORE, RETORE) allow the analysis and integration of data on cartography, geomorphology, historical cadastre, aerial photos, LiDAR, toponymy, etc. The integration of this consistent amount of information with literary data and epigraphic sources, and management in QGIS, proves fundamental for reconstructing ancient occupation strategies and the distribution of archaeological materials.

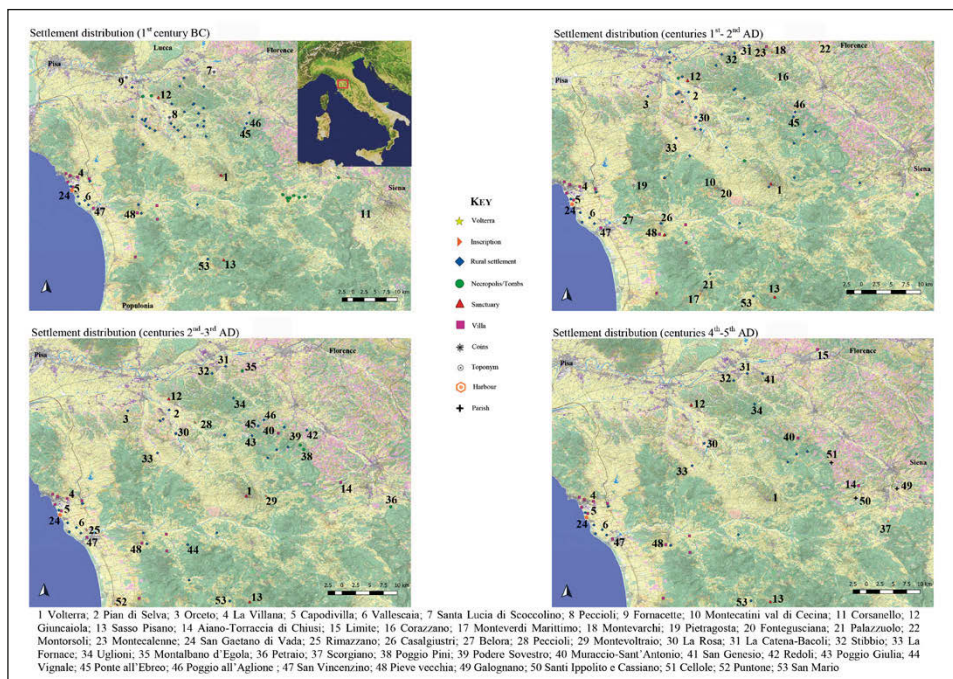


Fig. 3 – Settlement distribution (1<sup>st</sup> c. BC-5<sup>th</sup> c. AD): QGIS map.



Fig. 4 – New field survey campaigns in liminal areas of *ager Volaterranus*: QGIS map.

Concerning the materials analysis, the aim is not only to determine the site's chronology, but also to distinguish potential identity markers. The association of specific materials with toponyms and epigraphy will be analysed to understand whether their dispersal/concentration may have significance in relation with the owners' identity and the settlement patterns evolution. Data interpretation in the light of resilience and antifragility theories would be possible through an agent-based model simulation approach, crucial for a better understanding of landscapes as complex systems where individuals and environment interacted. Simulations will allow to assess the role of agents behaving in a resilient or antifragile way and, consequently, to reconstruct how human agency shaped Volterranean landscapes.

## 2. THE CASE STUDY

As confirmed by literary sources, in the 3<sup>rd</sup> century BC Volterra was deeply inserted into the Roman orbit. The civil wars between Marius' and Sulla's factions before, Caesar's and Augustus' land distributions then, represented turning



points for the community and the territory organization. After 27 BC, Volterra received the title of colony (MUNZI, TERRENATO 1994). After 68-69 AD and Vespasian's rise to power a crisis affected the Italian peninsula and substantial changes occurred also in the *ager Volaterranus*. A moment of crisis, between the mid-2<sup>nd</sup> century and the beginning of the 3<sup>rd</sup> century AD could eventually be related to the Antonine plague. Diocletian's reorganization was an essential driving force for the local economy. In contrast to other cities, Volterra experienced a reorganization of local powers and a renovate monumentalization. In the 5<sup>th</sup> century, the city centre continued to be stage of local and religious powers while in the territory only a few sites from the previous settlement system survived in a wholly changed social and political context (LIMINA 2021a).

### 2.1 *Liminal landscapes over the longue durée*

The *ager Volaterranus*, delimited by the Cecina, Era and Elsa valleys bordered the territories of Pisa, Lucca, Florence, Siena and Populonia (Fig. 2). Integrating different sources and studying unpublished materials from previous surveys and excavations, it was possible to distinguish three phases of local ownership structure and settlement pattern development to be related to the events of the 1<sup>st</sup> century BC; to a reorganisation of local powers between the end of the 1<sup>st</sup> century AD and the 2<sup>nd</sup> AD; to a new social and political order between the end of the 2<sup>nd</sup> and the first half of the 3<sup>rd</sup> century AD (LIMINA 2021b). In the 1<sup>st</sup> century BC, hidden monetary treasuries and a settlement crisis proved a period of disorder following the reorganisation of the territory as a centuriated landscape (Fig. 3). Indeed, traces of Roman centuriation have been identified in marginal zones along the northern and western borders of the district (RISTORI, RISTORI 1993; BROGI 2007; CIAMPOLTRINI 2008; PASQUINUCCI *et al.* 2008), suggesting that areas obtained the status of *ager publicus* or belonged to the city.

Archaeology proves, since the mid-1<sup>st</sup> century AD, a new development of rural settlements in the district's northern and eastern marginal areas and epigraphy attests to the presence of new landowners. Between the mid-2<sup>nd</sup> century and the beginning of the 3<sup>rd</sup> century AD a progressive settlement deconstruction is attested in the Era valley, probably due to a demographic crisis linked with increasingly poor water management. This evidence would coincide with a moment of crisis that epigraphy could testify, attesting that new *gentes* arose in power while others died out. A general settlement deconstruction is attested in the marginal areas between the mid-3<sup>rd</sup> and the 4<sup>th</sup> centuries AD. However, since the 4<sup>th</sup> century AD, archaeology indicates the revitalization of the marginal areas and the survival of the coastal and internal villas until about the mid-5<sup>th</sup> century AD, in the context of a new reorganisation of local powers. Since the mid-4<sup>th</sup> century AD, Christian individuals are attested by epigraphs.

Even if a diocese was organized only in the second half of the 5<sup>th</sup> century AD, the Christian community became a more and more influential counterpart in the framework of the local elites. The location of the oldest known diocesan churches, dating to the 5<sup>th</sup>-6<sup>th</sup> centuries AD, at the borders of the territory (Fig. 3) is interesting because it could eventually relate to areas of previous *ager publicus* or within imperial estates, or areas confiscated from pagan temples, or of uncultivated lands from urban estates (LIMINA 2021a e 2021b). It seems clear that liminal areas of *ager Volaterranus* were the most effected by dynamics of change. Local elites continued to control and manage production and economic networks in these areas through their versatile family strategies (LIMINA 2021a). The extra-urban sanctuaries continued to survive as direct emanation (and visible presence) of the urban centre. The local epigraphy and place-names analysis indicate the presence of imperial properties in the marginal areas while on the same areas insist the first Christian holy places.

The diffusion, only in these liminal areas, of locally produced ‘Roman’ roof-tiles is relevant. Indeed, as demonstrated by E. Shepherd, these roof-tiles would indicate the presence of Roman soldiers in centuriated areas or the local access to military networks, or contacts through patronage (SHEPHERD 2016). The local production of roof-tiles in the ‘Roman style’ is confirmed by the study of archaeological materials from previous research and from the 2023 surveys (LIMINA 2021a e 2024). Local production implying the acquisition of technical knowledge different from the traditional one (WARRY 2006; SHEPHERD 2016; HAMARI 2019) could be proof of identity dynamics that currently escape us but are worth investigating. All this data from justifies RELOAD’s investigations for a better assessment of the landscape’s evolution in relation to liminality.

### 3. ALTERNATIVE CONCEPTS AND APPROACHES FOR ANCIENT LANDSCAPES

If ancient landscapes investigation is strictly linked to understanding complexity, simplification is the only way to deal with the challenges of interpreting the dynamics of change. Then, models, simplified representations of complex real-world phenomena, could be beneficial for landscapes’ reconstructions.

#### 3.1 Resilience and antifragility

Resilience, defined as the ability of a system to maintain key functions in the face of stresses by resisting and then adapting to change, has been increasingly adopted in archaeology (REDMAN 2005; CUMMING 2011; DAEMS 2021). The application of resilience theory implies turning archaeological data into key variables, based on the idea that complex systems are controlled

by the adaptive cycle (BRATMOLLER *et al.* 2017). However, there is another concept that can be applied to complex systems, ‘antifragility’ (TALEB 2012), that has been used in economy (PLATJE 2015), psychology (MARKEY-TOWLER 2018), biology (DAVIS 2020), law (LAW 2021). Antifragility is fundamentally different from ‘resilience’ (MUNOZ *et al.* 2022). According to TALEB (2012, 430): «The resilient resists shocks; the antifragile gets better». Like all real systems, an antifragile one is characterized by complexity, randomness and ‘learning ability’, the ability to recover from a shock learning how to survive the next. In this way, the antifragile improves itself. Agreeing that the history of elites is most visible at the archaeological level and that settlement distribution reflects strategies of control and management of resources, it seems that Volterra responded in an antifragile way to dynamics of change.

Local elites managed to transform disadvantageous geographical and political conditions into opportunities for progressive integration into imperial dynamics. However, if ‘antifragility’ seems suitable at a narrative level, can it be verified from Taleb’s heuristic formula and archaeological data?

### 3.2 Preliminary data about the application of AMBS

ABM is a method of computer simulation based on agents moving in an artificial environment, governed by rules which specify how they respond to the system and relate with the other agents’ behaviour. RELOAD approaches modelling and simulation in NetLogo. To assess if the agents’ behaviour is fragile, resilient, or antifragile it would be necessary to setting values for the parameters to evaluate response to changes in the system. Applying the mathematical heuristic to detect fragility, if the value is positive, the system is fragile; when it is zero, the system is resilient; for negative values, the system is antifragile. RELOAD is still in a very preliminary phase of modelling but trying to simplify theorization: suppose we want to understand why the archaeological materials testify to a decrease in the number of rural sites after the 2<sup>nd</sup> century BC, in parallel with the restoration of Roman-style villas. Through the GIS extension in NetLogo it would be possible to build a virtual environment with actual characteristics of the archaeological context; then, it will be possible to simulate the local landowners’ behaviour by writing a code.

Agents can abandon the sites, maintain their ownership without modification, or improve estates restoring them. ABMS is an iterative process, so the repeated decision-making and the stochasticity produce a pattern that changes at the macroscopic level in site number, type, and spatial location. By analysing the parameters, one can assess the agent’s behaviour as fragile, resilient, antifragile based on the variation in the number of changes in the unit of time, and the ability to recover from the number of unchanged, abandoned restored sites. Then, it would be necessary to compare the results with the archaeological data and repeat the simulations to validate/modify the model.



#### 4. CONCLUSIVE REMARKS

Despite the increasing use of ABMS in archaeology, some sceptical points relate to the complexity and difficulty of using them, considering that a specific education in archaeologists' curriculum is still lacking (NAKOINZM 2018; DAEMS 2021; ROMANOWSKA *et al.* 2021). Aware of limitations due to methodology and data collection, the necessary simplification underlying modelling is a good practice for data standardization, while the opportunity to test results and what-if scenarios under different perspectives justify AMBS applications in archaeology. Using a specific computer program forces us to make explicit assumptions, to emulate a specific process that produced the observed archaeological evidence (WURTZER *et al.* 2015). For all these reasons, ABMS are beneficial to reinforce conceptual clarity, helping to understand how things changed; of course, emulating the past does not explain it, and only by iterative adjustments a model obtains a reasonable fit between its output and the archaeological evidence. In any case, the advantages of applying AMBS are evident: they are explicitly concerned with the time in process, they do not require mathematical formality, they include randomness variables as in natural complex systems.

RELOAD, ensuring open access to programming codes aims to promote the standardization of practices and the reproducibility of results, among the main challenges of landscape archaeology (ATTEMA *et al.* 2020). Approaching resilience and antifragility through ABMS, RELOAD takes the challenge to provide a 'scientific' endorsement over these concepts, above a suitable narrative. To conclude, the challenges of applying concepts from other disciplines, but always keeping central the archaeological *datum* and the historical perspective can only strengthen the approach of landscape archaeology by making the techniques of the 'hard sciences', tools that should be used not as new religions (ZUBROW 2006) but to open new research paths, or to analyse old problems with new perspectives.

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#### REFERENCES

- ANDREWS H., ROBERTS L. 2012, *Liminal Landscapes. Travel, Experience, and Spaces In-Between*, New York, Routledge.
- ATTEMA P., BINTLIFF J., VAN LEUSEN M., BES P., DE HAAS T., DONEV D., JONGMAN W., KAPTIJN E., MAYORAL V., MENCHELLI S. 2020, *A guide to good practice in Mediterranean surface survey projects*, «Journal of Greek Archaeology», 5, 1-62.
- AUGENTI A., TERRENATO N. 2000, *Le sedi del potere nel territorio di Volterra: una lunga prospettiva (secoli VII a.C.-XIII d.C.)*, in G.P. BROGIOLO (ed.), *Atti del II Congresso Nazionale di Archeologia Medievale (pré-tirages) (Brescia 2000)*, Firenze, All'Insegna del Giglio, 298-303.

- BERTOLDI S., CASTRORAO BARBA A. 2021, *Evaluating post-Roman resilience in Tuscan landscapes (5<sup>th</sup>-8<sup>th</sup> c. CE): Settlement dynamics and 'land use heritage'*, Abstract Book, *Landscape Archaeology Conference 2020+1 "virtually together"* (Madrid 2021) (<https://digital.csic.es/handle/10261/245655>).
- BOURDIN S. 2012, *Les peuples de l'Italie préromaine. Identités, territoires et relations inter-ethniques en Italie centrale et septentrionale (VIII<sup>e</sup>-I<sup>er</sup> s. av. J.-C.)*, Bibliothèque des Écoles Françaises d'Athènes et de Rome 350, Rome, École Française de Rome.
- BRADTMÖLLER M., GRIMM S., RIEL-SALVATORE J. 2017, *Resilience theory in archaeological practice. An annotated review*, «Quaternary International», 446, 3-16.
- BROGI D. 2007, *Contributo allo studio del territorio di Luciana e Santo Regolo*, «Agri Centuriati: an International Journal of Landscape Archaeology», 3, 35-57.
- CAMBI F., DE VENUTO G., GOFFREDO R. 2015, *Introduzione. Riconnettere i paesaggi, integrare la marginalità*, in F. CAMBI, G. DE VENUTO, R. GOFFREDO (eds.), *I pascoli, i campi, il mare. Paesaggi d'altura e di pianura in Italia dall'età del Bronzo al Medioevo*, Bari, Edipuglia, 5-11.
- CANTINI F. 2022, *The centres of public power between the cities and the countryside, in the light of the recent archaeology (Italian peninsula, Late 5<sup>th</sup>-9<sup>th</sup> century)*, in F. OPPEDISANO (ed.), *Between Ostrogothic and Carolingian Italy. Survivals, Revivals, Ruptures*, Firenze, Firenze University Press, 189-221.
- CAVALIERI M. 2019, *La villa tardoantica di Aiano (2005-2011/2014-2018). Bilancio di dodici anni di attività dell'UCLouvain in Val d'Elsa (San Gimignano, SI)*, in V. ACCONCIA, E.M. GIUFFRÉ, A. SALVI, J. TABOLLI, *Notizie dei cavi e degli scavi. Archeologia Sabap – Si 2018 – 2. Atti del Convegno Internazionale (Siena 2018)*, «Bollettino di Archeologia», 10, 3-4, 159-172.
- CIAMPOLTRINI G. 1981, *Note sulla colonizzazione augustea nell'Etruria settentrionale*, «Studi Classici e Orientali», 31, 41-55.
- CIAMPOLTRINI G. 1995, *L'insediamento tra Era e Elsa dall'età dei metalli alla tarda antichità*, in R. MAZZANTI (ed.), *Le colline di San Miniato*, «Quaderni del Museo di Storia Naturale di Livorno», Suppl. 1, 59-77.
- CIAMPOLTRINI G. 2008, *La Valdera romana fra Pisa e Volterra*, in G. CIAMPOLTRINI (ed.), *La Valdera romana fra Pisa e Volterra. L'area archeologica di Santa Mustiola (Colle Mustarola) di Peccioli. Atti dell'incontro di studio (Peccioli 2006)*, «I Quaderni Peccioli», Pisa, Pacini Editore, 17-29.
- CIFANI G., STODDART S. (eds.) 2012, *Landscape, Ethnicity and Identity in the Archaic Mediterranean Area*, Oxford, Oxbow Books.
- CORTESE M.E. 2017, *L'aristocrazia toscana. Sette secoli (VI-XII)*, Spoleto, Fondazione Centro italiano di Studi sull'alto Medioevo.
- CUMMING G. 2011, *Spatial Resilience in Social-Ecological Systems*, Dordrecht, Springer.
- DAVIS R. 2020, *Turkey tail mushrooms and the antifragility of immunity*, «Journal of the American Herbalists Guild», 12, 2, 31-37.
- DAEMS D. 2021, *Social Complexity and Complex Systems in Archaeology*, Oxon, Routledge.
- DERKS T., ROYMANS N. (eds.) 2009, *Ethnic Constructs in Antiquity. The Role of Power and Tradition*, Amsterdam, Amsterdam University Press.
- DI PAOLA G.M.F. 2018, *Central place and liminal landscape in the territory of Populonia*, in G. PAPANTONIOU, A. VIONIS, *Central Places and Un-Central Landscapes. Political Economies and Natural Resources in the Long Durée*, «Land», 7, 3, 94.
- DUBBINI R., CASTIGLIONI M.P., CURCIO M. (eds.) 2020, *Incontrarsi al Limite. Ibridazioni mediterranee nell'Italia preromana*, Atti del Convegno internazionale (Ferrara 2019), Roma, L'Erma di Bretschneider.
- FAULSEIT R.K. (ed.) 2016, *Beyond Collapse. Archaeological Perspectives on Resilience, Revitalization, and Transformation in Complex Societies*, Carbondale, Southern Illinois University Press.

- HADAS-LEBEL J. 1998, *La sopravvivenza della lingua e della cultura etrusca nelle iscrizioni bilingui etrusco-latine*, in L. AIGNER FORESTI (ed.) *Die Integration der Etrusker und das Weiterwirken etruskischen Kulturgutes im republikanischen und kaiserzeitlichen Rom*, Wien, Verlag der österreichischen Akademie der Wissenschaften, 298-312.
- HAMARI P. 2019, *Roman-period Roof-tiles in the Eastern Mediterranean: Towards Regional Typologies*, Doctor of Philosophy (PhD) Dissertation, Helsinki University.
- HOLM I., STENE K., SVENSSON E. (eds.) 2009, *Liminal Landscapes. Beyond the Concepts of 'Marginality' and 'Periphery'*, Oslo, Oslo Academic Press.
- LAW R.L. 2021, *State Antifragility: An Agent-Based Modeling Approach to Understanding State Behavior*, Doctor of Philosophy (PhD) Dissertation, Old Dominion University.
- LIMINA V. 2021a, *Poteri e strategie familiari di Volterra. Il caso di una comunità etrusca nel mondo romano*, Oxford, BAR Publishing.
- LIMINA V. 2021b, *Methodological Issues for the Integrated Analysis of Landscapes of Power: The Case Study of Volterra (centuries 1<sup>st</sup> BC-5<sup>th</sup> AD)*, in D. GANGALE RISOLEO, I. RAIMONDO (eds.), *Landscape: una sintesi di elementi diacronici. Metodologie a confronto per l'analisi di un territorio*, Oxford, BAR Publishing, 157-166.
- LIMINA V. 2024, *Relazione finale delle ricognizioni archeologiche di superficie: Survey RELO-AD provincia di Pisa (Comuni di Capannoli, Peccioli, Ponsacco, Pontedera)*, Geoportale Nazionale dell'Archeologia ([https://doi.org/10.60976/TOSCANA\\_2023\\_05](https://doi.org/10.60976/TOSCANA_2023_05)).
- MARKEY-TOWLER B. 2018, *Antifragility, the black swan and psychology: A psychological theory of adaptability in evolutionary socioeconomic systems*, «Evolutionary and Institutional Economics Review», 15, 2, 367-384.
- MAZZARINO S. 1957, *Sociologia del mondo etrusco e problemi della tarda etruscità*, «Historia: Zeitschrift für Alte Geschichte», 6, 1, 98-122.
- MENCHELLI S., PASQUINUCCI M., SANGRISO P. (eds.) 2023, *Vada Volaterrana: gli horrea. Strutture, stratigrafie, materiali*, Pisa, Pisa University Press.
- MUNOZ A., BILLSBERRY J., AMBROSINI V. 2022, *Resilience, robustness, and antifragility: Towards an appreciation of distinct organizational responses to adversity*, «International Journal of Management Reviews», 24, 2, 181-187.
- MUNZI M., RICCI G.F., SERLORENZI M. 1994, *Volterra fra tardo antico e alto medioevo*, «Archeologia Medievale», 21, 639-656.
- MUNZI M., TERRENATO N. 1994, *La colonia di Volterra. La prima attestazione epigrafica ed il quadro storico e archeologico*, «Ostraka», 3, 1, 31-42.
- NAKOINZM O. 2018, *Models and modelling in archaeology*, «Historical Social Research», Suppl. 31, 101-112.
- PADGETT J.F. 2010, *Open elite? Social mobility, marriage, and family in Florence, 1282-1494*, «Renaissance Quarterly», 63, 2, 357-411.
- PASQUINUCCI M., LEONE N., MENCHELLI S. 2008, *Paesaggi antichi nella Valdera. Etruschi e Romani in località Le Melorie di Ponsacco (PI)*, in G. CIAMPOLTRINI (ed.), *La Valdera romana fra Pisa e Volterra. L'area archeologica di Santa Mustiola (Colle Mustarola) di Peccioli. Atti dell'Incontro di studio (Peccioli 2006)*, «I Quaderni Peccioli», Pisa, Pacini Editore, 41-74.
- PLATJE J. 2015, *Sustainability and antifragility*, «Economic and Environmental Studies», 15, 4, 469-477.
- RAMELLI I. 2003, *Cultura e religione etrusca nel mondo romano. La cultura etrusca dalla fine dell'indipendenza*, Alessandria, Edizioni dell'Orso.
- REDMAN C.L. 2005, *Resilience theory in archaeology*, «American Anthropologist», 107, 70-77.
- REDMAN C.L., KINZIG A.P. 2003, *Resilience of past landscapes: Resilience theory, society, and the longue durée*, «Conservation Ecology», 7, 1-19.
- RISTORI M., RISTORI S. 1993, *Le deduzioni coloniali romane dell'ager Volaterranus*, «L'Universo», 73, 4, 488-499.

- ROMANOWSKA I., WREN C.D., CRABTREE S.A. 2021, *Agent-Based Modeling for Archaeology: Simulating the Complexity of Societies*, Santa Fe, Santa Fe Institute Press.
- SHEPHERD E. 2016, *Tegole di copertura in età romana: questioni di forma, posa in opera e impiego*, «Costruire In Laterizio», 168, 54-59.
- STOCKHAMMER P.W. 2012, *Conceptualizing cultural hybridization in archaeology*, in P.W. STOCKHAMMER (ed.), *Conceptualizing Cultural Hybridization. A Transdisciplinary Approach*, Berlin-Heidelberg, Springer, 43-58.
- TALEB N.N. 2012, *Antifragile: Things That Gain from Disorder*, New York, Random House.
- TERRENATO N. 1998, *Tam Firmum Municipium: The romanization of Volaterrae and its cultural implications*, «Journal of Roman Studies», 88, 94-114.
- TERRENATO N. 2019, *The Early Roman Expansion into Italy: Elite Negotiation and Family Agendas*, Cambridge, Cambridge University Press.
- TONER J. 2012, *I disastri di Roma antica. Calamità e resilienza*, Gorizia, Leg Edizioni (trad. italiana 2018).
- TORELLI M. 1995, *Studies in the Romanization of Italy*, Alberta, University of Alberta.
- TURNER V. 1974, *Liminal to Liminoid in play, flow, and ritual: An essay in comparative symbolism*, «Rice Institute Pamphlet-Rice University Studies», 60, 3, 53-92.
- VAN GENNEP A. 1909, *Les rites de passages: etude systématique des rites*, Paris, Éditions A. et J. Picard [1981].
- WARRY P. 2006, *A dated typology for Roman roof-tiles*, «Journal of Roman Archaeology», 19, 246-265.
- WURZER G., KOWARIK K., RESCHREITER H. (eds.) 2015, *Agent-based Modelling and Simulation in Archaeology*, Cham, Springer.
- ZIFFERERO A. 1995, *Economia, divinità e frontiera: sul ruolo di alcuni santuari di confine in Etruria meridionale*, «Ostraka», 4, 2, 333-350.
- ZUBROW E.B. 2006, *Digital archaeology: A historical context*, in T.L. EVANS, P. DALY (eds.), *Digital Archaeology. Bringing Method and Theory*, London-New-York, Routledge, 8-27.

## ABSTRACT

RELOAD intends to re-evaluate the marginal areas of northern Tuscany to demonstrate their central role in the dynamics of management and perception of space between the Roman conquest and late antiquity. Considering that landscape archaeology, complemented by an anthropological perspective, allows a deep understanding of the linked dynamics of social and ecological systems, the project is expected to fill a gap of knowledge about ancient landscapes in northern Tuscany analyzing the case of Volterra to provide innovative interpretative models through a multidisciplinary methodological approach and a diachronic perspective. Integrating all available sources with new data collection, RELOAD approaches landscape complexity in a flexible way. Introducing for the first time in archaeology the concept of 'antifragility', RELOAD engages in the wider debate about adopting concepts and techniques from different fields for archaeological and historical reconstruction. The paper presents the project and preliminary data regarding the challenges and the potential benefits of applying agent-based model simulations to test the validity of approaching the past through the lens of 'resilience' or 'antifragility' leading to alternative reconstructions of the human-environmental interactions.

OLD DATA, OLD METHODOLOGY AND NEW RESEARCH.  
A CASE STUDY OF LEGACY DATA INTEGRATION  
FROM THE CESTRINE REGION, EPIRUS

*Verrà giorno in cui la schiera dei vecchi, accurati e «pignoli» disegnatori degli istituti cartografici sarà sostituita da qualche ragazza in guanti bianchi che preme soltanto dei pulsanti, e gli zinchi, le copivviti e i cristalli degli archivi cartografici saranno sostituiti da nastri magnetici, da bobine e da mazzette di schede perforate.*

TRAVERSI 1965, V

## 1. INTRODUCTION

The Çuka e Ajtoit/Kestría archaeological project is a collaboration between the Sapienza University of Rome and the Albanian Institute of Archaeology. The site of Çuka e Ajtoit, literally Eagle Mountain, is located in the municipality of Konispol, in the southern Albanian fringes, very close to the Greek-Albanian border. The steep conical shape of the hill dominates the flat landscape of the ancient region of Cestrine, located between the Ionian Sea and the Mile-Saraqin mountain range, an area renowned in ancient literary sources for its cattle and for the high quality of its winter pastures (Fig. 1). The area is also linked since the 5<sup>th</sup> century BCE, and possibly earlier, to the mythical narrations connected to the Trojan cycle (BOGDANI 2022b). Cestrina is probably the ancient name of the site of Çuka e Ajtoit, a site inhabited for a long timeframe. The most ancient artifacts found in the site date to the Paleolithic, while the most monumental remains, namely the fortification circuit and the polygonal masonry dwellings, date from the Hellenistic period. A second defensive fortification system was built during the Middle Ages.

The new research is actively contributing to the comprehension of the history of the site: the discovery of non-sporadic fragments of coarse pottery dating possibly to the Late Bronze Age is throwing new light a period largely unknown (BOGDANI 2022a, 2023). On the other hand, the discovery of many fragments of Corinthian amphorae from the 5<sup>th</sup> and 4<sup>th</sup> centuries BCE is unique evidence of a pre-Hellenistic settlement. Excavations have also revealed a later settlement on the north-eastern feet of the hill: around 20 residential units, arranged on a low, flat ridge, date to the Venetian and Ottoman periods.

The survey campaigns at Çuka e Ajtoit revealed that traditional topographical survey techniques proved highly unsuitable due to the difficult

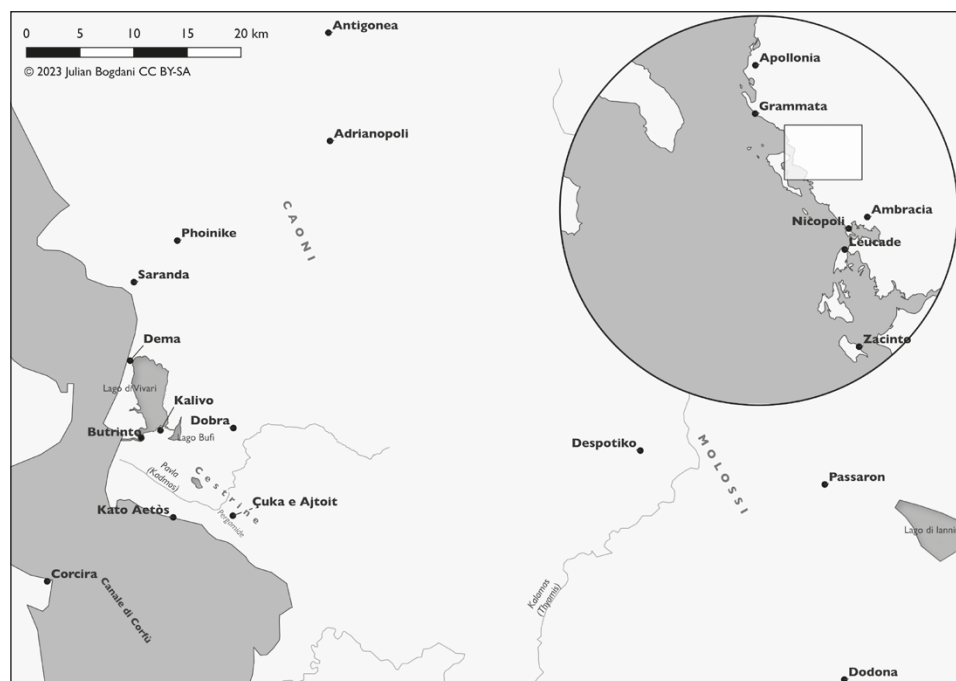


Fig. 1 – Geographical position of the region of Cestrine and of the site of Çuka e Ajtait.

morphological conformation of the site, with very steep and heavily eroded rocky slopes. For this reason, aerial photogrammetry was chosen as the main documentation technique. Drones are being used to capture images and GNSS instruments, combined with the RTK service provided by the Albanian authorities, provided centimetric accuracy for the photogrammetric models. The remote sensing results are being verified by ground truthing campaigns, aimed at documenting the archaeological remains and, where possible, collecting surface pottery fragments for a broad definition of the chronology. The integration of all these methods, rather than a single tool, allowed a new perspective on the site. Trial excavations of limited sizes complete the overall picture and allow us to narrate a more complex and articulated history of the site.

The field work was flanked by a deep study of archive documentation from previous research, partially published (HERNANDEZ, HODGES 2020), and the recovery of these data have proved fundamental for the reconstruction of various contexts, such as the city's necropolises (BOGDANI, ALEOTTI 2024). Moreover, thanks to funding from the Sapienza University of Rome



(Small Research Grants 2022) and in collaboration with the Butrint Project of the University of Bologna (<https://site.unibo.it/butrint/en>) and the Albanian Institute of Archaeology, it has been possible to acquire new archive data, such as aerial photographs taken by the Italian Istituto Geografico Militare (IGM) at the end of the 1930s for cartographic purposes. These images were taken during the occupation of Albania by Fascist Italy (1939) and the preparations for the Greek-Italian War (1940-1941), and formed the basis of the Italian cartography of the area (TRAVERSI 1965). Both the Italian cartography, which is available free of charge as a web service on the portal of the ASIG (Albanian Geospatial Information Authority: <https://asig.gov.al/>), and the aerial photographs form a unique historical document of the period in which they were made, and a valuable basis for understanding the landscape, which underwent radical changes in the following decades: during 1950s and 1960s the plain was subject to extensive land reclamation programs. As a result, riverbeds were moved, ponds and marshes drained, and forests and other vegetation uprooted to allow for intensive agricultural use of the land.

The aim of our project was to use modern photogrammetric methodologies such as Structure from Motion to virtually rebuild the shape of the landscape before these radical changes by creating a historical orthophoto mosaic and historical Digital Elevation Model (DEM) from the Italian aerial imagery. These outputs will allow a thorough analysis of the landscape through the last one hundred years.

J.B.

## 2. DESCRIPTION OF THE DATASET

A total of 350 aerial photographs acquired in 1937 were purchased from the Italian Military Geographical Institute (IGM), covering the area corresponding to the ancient Cestrine, grouped into 8 aerial strips, each with a different number of images. The project was limited to an area of approximately 810 square kilometers, as individual photographs can be quite expensive. The already mentioned cooperation with the Butrint Project proved to be decisive, since it owned photographic coverage of the Butrint area, which was therefore included in the project dataset at no additional costs. Ideally, these photographs have a 60% overlap and a 20% sidelap, a method that ensures that each terrain point is present in at least three images. However, the individual images presented some critical issues that had to be addressed before they could be processed photogrammetrically. These issues profoundly affected the quality of the ideal overlay. All images had a black frame on which flight metadata including serial numbers were reported (Fig. 2). While this is the most useful information and metadata, the frames needed to be

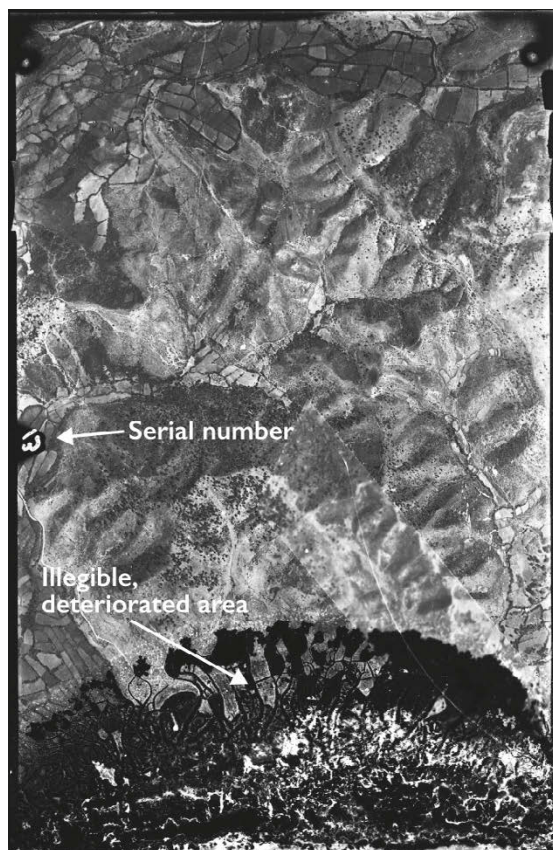


Fig. 2 – An example of the metadata reported in each frame and of the chemical deterioration of the support, which makes half of the image illegible.

removed before the images were processed, since these can be a hindrance to the image alignment process.

Moreover, many images presented chemical deterioration and severe preservation issues, either limited to small areas or in some cases covering more than half of the single image. The most severe preservation issues were found in strip 176, where 32 of the 46 images were extensively damaged (Fig. 2). This is unfortunately the strip that covers the area of the site Çuka e Ajtoit and its northern and southern surroundings. The damage is almost always located along the sides of the images, and makes automatic image alignment very problematic by significantly reducing the frontal and lateral overlap areas. Another issue concerns images representing large areas covered

by the water surface, especially the sea. Due to the ephemeral nature of the water surface, they show changing patterns that cannot be aligned by any software. Six images featuring large areas covered by water were excluded from the data set.

Finally, large areas of cloud shadows make automatic alignment very difficult. This is due both to the reduction in visibility in the shaded area and to the changing shape of the same shadow in neighboring images. These images required particular attention as well.

D.D.E.

### 3. METHODOLOGY

Agisoft Metashape Structure from Motion software was used for the photogrammetric processing of the images, since it has proved to be flexible and highly performing during the other activities of our field survey (BOGDANI 2023). From a total of 350 purchased images, a final dataset of 187 images was manually masked to address the preservation issues already discussed and then processed to align the images, by calculating the outer

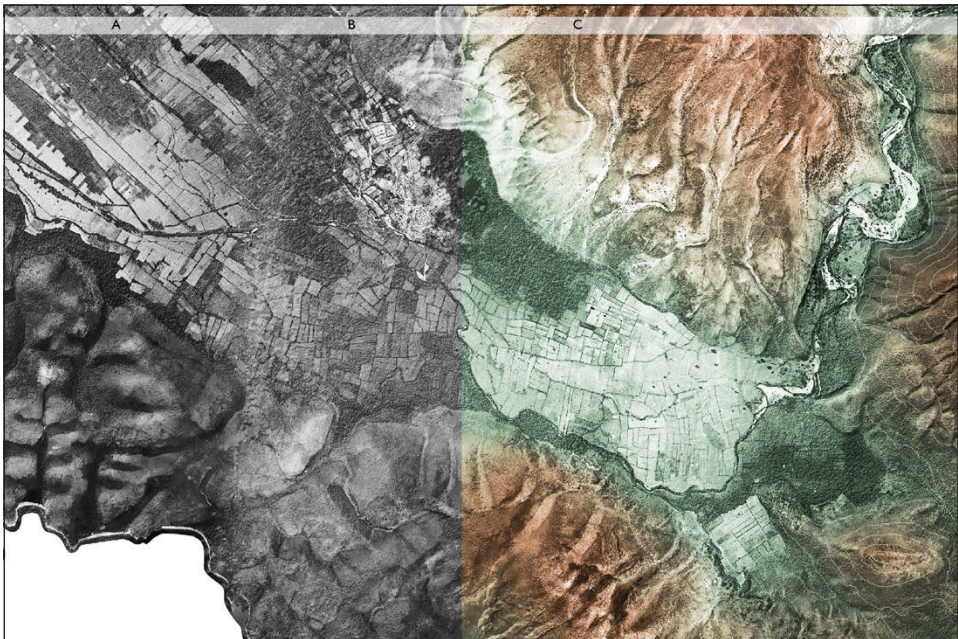


Fig. 3 – Compared view of: the orthophoto mosaic (a), overlaid with the DEM, as a hillshade view (b), and as false color view (c), and curves (d).



orientation and to create the sparse point cloud, i.e. a low resolution 3D model. Since image alignment determines the overall geometry of the model, it was by far the most sensitive step. Among the many possibilities offered by the algorithms, sequential alignment proved to be the most effective, even considering the small and not always homogeneous overlapping areas between images. A number of ground control points had to be added manually to assist the alignment process of areas with poor overlap that could not be resolved automatically. It is a very time-consuming task that requires in-depth and diachronic knowledge of the landscape. Finally, a dense 3D model was calculated from which the general orthomosaic and the digital elevation model (DEM) were processed.

The poor preservation of many images resulted in the presence of void areas in the 3D model (Fig. 3), which are more evident in areas where the mountain relief is more pronounced and therefore the difference of elevation is greater. These gaps are not the result of processing, and are determined by the lack of data, and as such they cannot be filled by the software. These limitations can be addressed by interpolation using specific GIS software, but for the moment we opted to limit our action to the information provided by the original dataset. The georeferencing of the model was performed using

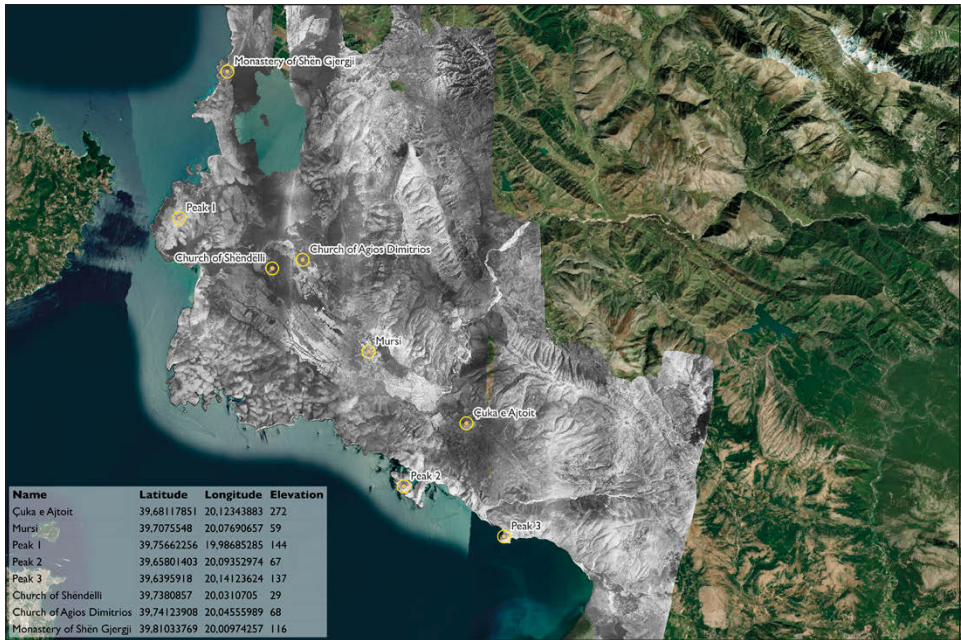


Fig. 4 – Position and coordinates (WGS 84) of the GCP used to georeference the 3D model.

coordinates and elevations extrapolated from the provisional map of the area published by IGM and made available as a WMS in open access by ASIG geoportal (<https://geoportal.asig.gov.al/>), a source of information contemporary and derived by the photographic images.

The following points were used for georeferencing (Fig. 4):

1. The mountain peak of Çuka e Ajtoit [39.68117851, 20.12343883 / 272 m asl].
2. The village of Mursi [39.70755480, 20.07690657 / 59 m asl].
3. The peaks of 4 hills/mountains:
  - a. [39.75662256, 19.98685285 / 144 m als];
  - b. [39.65801403, 20.09352974/67 m als];
  - c. [39.63959180, 20.14123624/137 m als];
  - d. [39.64197470, 20.16631620/288 m als].
4. The church of Shëndëlli [39.73808570, 20.03107050/29 m asl].
5. The church of Agios Dimitrios [39.74123908, 20.04555989/68 m als].
6. The monastery of Shën Gjergji [39.81033769, 20.00974257/116 m als].

The resulting DEM is available in the WGS84 (EPSG: 4326) coordinate system, using the same vertical datum as the IGM topographic map. It was then reprojected and made available in the Albanian national coordinate reference system, ETRS89 / Albania TM 2010 (EPSG: 6870), which is the official coordinate reference model of our project with an updated vertical datum.

D.D.E.

#### 4. CONCLUSION: OUTPUT E FUTURE PERSPECTIVES

The project resulted in a high-resolution 3D documentation of the area, consisting of a DEM and of an orthomosaic (ground resolution of 0,647 x 0,841 m/px). This dataset has already proven to be a valuable source of information to document features of the landscape that have undergone radical changes during the land reclamation programs of the 1950s-1960s and for the detection of previously unknown archaeological sites, today still preserved or completely lost (Fig. 5). The DEM and orthophoto are the base of a new vectorizing activity of the paramount natural and cultural features of the orthomosaic in combination with the base cartography, an activity still ongoing at LAD (Fig. 6). The output of this research has been uploaded on the LAD's geodata portal (<https://gis.lad-sapienza.it/>), but licensing issues by IGM prevent us from redistributing the resulting data as open access, an incomprehensible contradiction to the Italian law principle of enhancing open access to public data.

Finally, the same methodology is being applied to the historical aerial images of the same area acquired in the 1940s by the Royal Air Force and

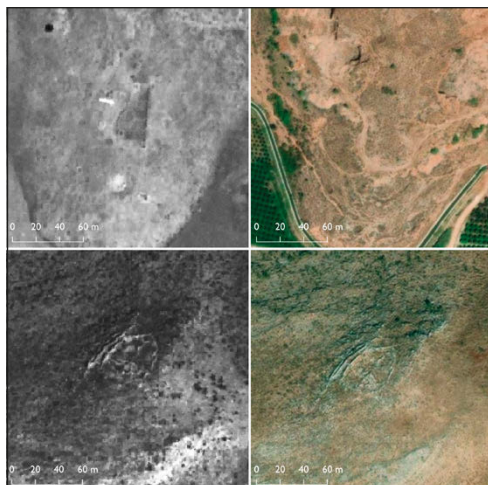


Fig. 5 – Compared view of two sites of archaeological interest detected on the historical orthomosaic, compared to present-day satellite images.

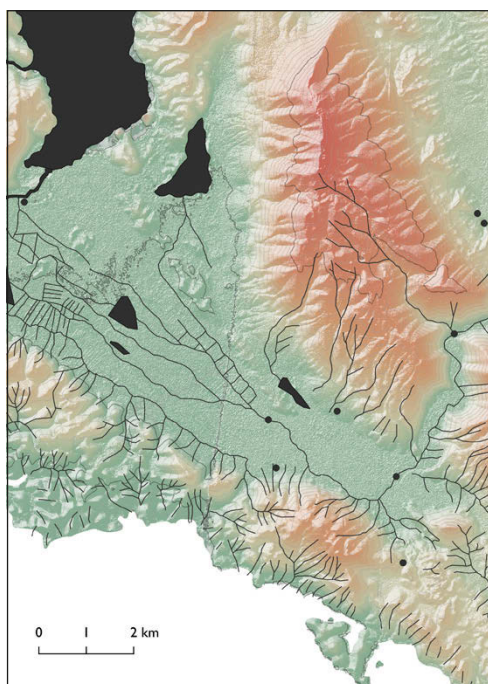


Fig. 6 – Detailed view of the vectorisation process of the historical images (vectorisation by Elena Urzi).



made freely available by the British School at Athens. As the British images were not specifically intended for cartographic purposes, their ground resolution and overlap is not comparable to that of the Italian images, nevertheless, they are important historical documents that deserve careful attention (D'ERASMO 2024).

J.B.

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## REFERENCES

- BOGDANI J. 2022a, *Kërkime të reja Shqiptaro-Italiane në Çukën e Ajtoit / New Archaeological Research at Çuka e Ajtoit*, «Candavia», 9, 141-158.
- BOGDANI J. 2022b, ΚΕΣΤΡΙΑ ΤΗΣ ΧΑΟΝΙΑΣ: *appunti sulla geografia e storia di una regione di frontiera*, «Hesperia», 40, 87-105.
- BOGDANI J. 2023, *Documentare l'invisibile. Il progetto Çuka e Ajtoit: rilievo e documentazione di un sito d'altura*, «Archeologia aerea», 16, 89-101.
- BOGDANI J., ALEOTTI N. 2024, *Le necropoli di Çuka e Ajtoit. Vecchie e nuove ricerche a confronto*, «Atlante tematico di topografia antica», 34, 139-160.
- CASTRIANNI L., CERAUDO G. 2009, *History of military aerial photographs in Italy and addressed archives*, in B. STICHELBAUT, J. BOURGEOIS, N. SAUNDERS, P. CHIELENS (eds.), *Images of Conflict: Military Aerial Photography and Archaeology*, Newcastle, Cambridge Scholars, 165-184.
- D'ERASMO D. forthcoming, *Rielaborare legacy data per lo studio del paesaggio dell'Albania meridionale: il caso delle foto aeree della Royal Air Force (RAF)*, in *Atti dell'XI edizione del Seminario della Scuola di Dottorato in Archeologia della Sapienza Università di Roma* (Roma 2023).
- HERNANDEZ D., HODGES R. (eds.) 2020, *Butrint 7. Beyond Butrin. Kaliwo, Çuka e Aitoit, Diaporit and the Vrina Plain. Surveys and Excavations in the Pavllas River Valley, Albania, 1928-2015*, Butrint Archaeological Monograph Series 7, Oxford-Philadelphia, Oxbow Books.
- TRAVERSI C. 1965, *Storia della cartografia italiana delle Isole Egee e dell'Albania*, Firenze, Istituto Geografico Militare.

## ABSTRACT

In the context of the joint archaeological project in Çuka e Ajtoit (Albania) by Sapienza University of Rome and the Albanian Institute for Archaeology, new archaeological field research is being conducted in the Southern fringes of the Albanian territory. The area of interest extends from the site of Butrint (UNESCO Heritage site) to the Albano-Greek border, and corresponds to ancient Cestrine, renowned in the literary sources for its pastoral resources and Trojan connections. The study integrates the freshly acquired information collected during the field campaigns, characterized by a high degree of technological innovation, with old research data poorly published up to present. This paper concerns the photogrammetric processing of historical aerial imagery acquired for mapping purposes by the Italian Military Geographical Institute (IGMI) in the 1930s, during the war context of the invasion of Albania by Fascist Italy. The process resulted in the creation of a DTM and

an orthomosaic by using SfM algorithms and GNSS topographical surveys, representing the shape of the landscape of the late 1930s, i.e., before the realization of extensive land reclamation programs by the socialist regime that have determined the radical changes of the current landscape.

## MAPPING THE ARCHAEOLOGICAL LANDSCAPES OF SAN BASILIO (ARIANO NEL POLESINE, ROVIGO)

### 1. INTRODUCTION

A renewed interest in the site of San Basilio and its archaeological heritage has recently led to the resumption of research in that sector of the Polesine (province of Rovigo; Fig. 1), which was traversed, in Roman times, by at least two important roads, namely the via *Annia* and the via *Popillia*. This effort is supported by a fruitful collaboration among the Universities of Padova and Ca' Foscari of Venice, the Superintendency for the provinces of Verona, Rovigo, and Vicenza, and the Veneto Regional Directorate of Museums, with financial support from the Fondazione Cariparo and the Municipality of Ariano nel Polesine. In this context, pre-Roman and Roman excavations have been reopened, and systematic territorial investigations have been planned to reconstruct the ancient anthropic landscape. To that aim, FOSS (free and open source) software and mobile mapping tools have been employed for managing both legacy and new data in a GIS environment.

J.T.

### 2. LEGACY DATA TO DEFINE THE LAYOUT OF THE ROMAN SETTLEMENT OF SAN BASILIO

In order to deepen our knowledge on the extension and layout of the ancient settlement, legacy data regarding the geolocation of sporadic finds, structures and buildings, tombs and necropolises pertaining to the Roman age was analysed and digitised within a QGIS project. To this aim, in the framework of a bachelor's degree Thesis in Archaeology (supervised by prof. Caterina Previato), both published (DE BELLIS, DE BELLIS 1978; TUROLLA 1986; CAPUIS *et al.* 1988; AA.VV. 2013) and unpublished documentation were examined. Among the latter sources, kept in the archives of the Superintendency of Padova, the information contained in the correspondence exchanged between the Superintendency and those who had variously been involved in the discoveries turned out to be particularly interesting. Oral testimonies of those who were present at the time of some of those discoveries were heard as well.

The most significant information of each find, and especially its geographical localisation, was collected and summarised in Excel tables that, once imported into QGIS, allowed to obtain a digital archaeological map of the area of San Basilio (Fig. 2). The distribution of finds has also made it possible

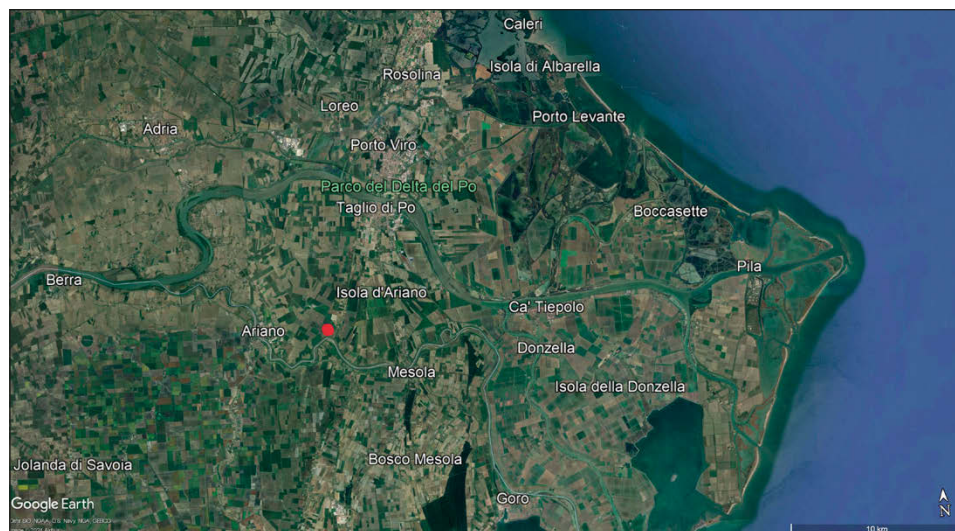


Fig. 1 – The lower Polesine and the localisation (red dot) of San Basilio (basemap: Google Earth).

to identify two distinct sectors (Fig. 3): the area with lower concentration is marked in orange and has an extension of approximately 2800 ha; the area with higher concentration, on the other hand, is highlighted in green and has an extension of approximately 220 ha. On the basis of this evidence, it is possible to recognise the main core of the Roman settlement in the green area; however, the entire settlement must have extended for a few more kilometres to the N, E and W, while to the S it probably stopped where the Po di Goro flows today. With regard to the relationship between the settlement and the coastline, an archaeological find from the Roman period located approximately 3,6 km NE of the Church of San Basilio would lead one to hypothesise that the coastline, which in Roman times probably followed the course of the coastline of the pre-Roman period (IADICICCO, VICENZUTTO, PALTINERI 2022), was shifted about 1,5 km to the E.

The overall geolocalised findings allowed to hypothesise a topographical layout of the settlement and identify several areas with buildings for private use (coloured in purple in Fig. 4) and a single central area with buildings for public use (in turquoise in Fig. 4). Indeed, in the three areas highlighted in purple (to the N, E and W of San Basilio's Church), traces attributable to private buildings were identified, such as mosaic floors, fragments and mosaic *tesserae*, sometimes also associated with walls or other structural elements. In the central area highlighted in turquoise, several buildings were identified, such as the *horreum*, the only structure that was certainly public in character,

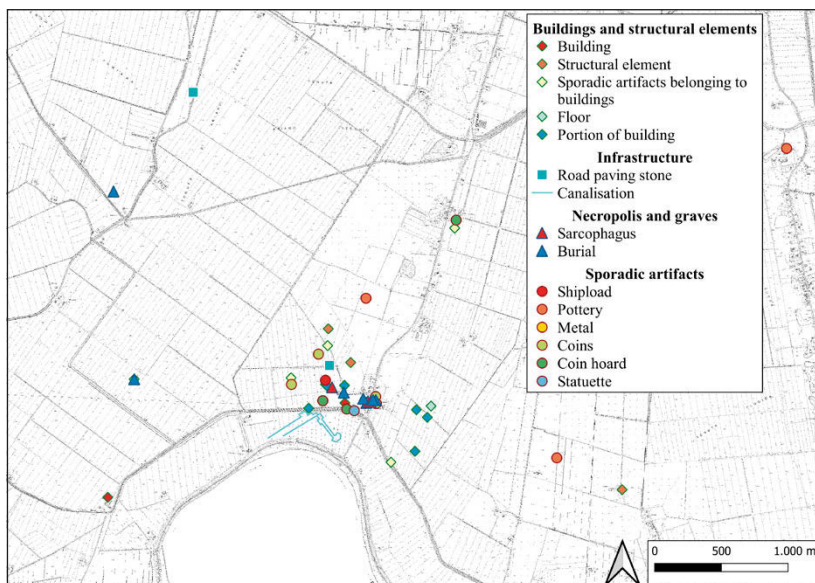


Fig. 2 – Archaeological map of the area of San Basilio (QGIS elaboration E. Consolo).

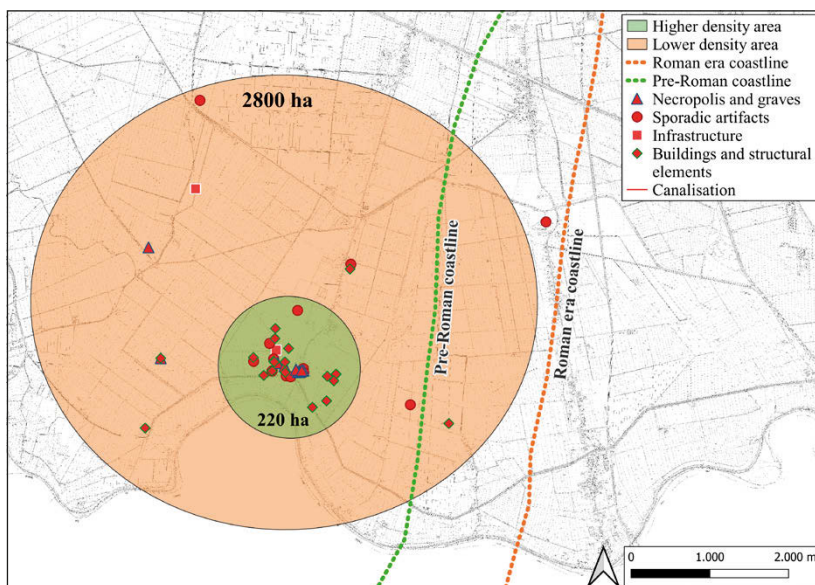


Fig. 3 – Map with areas of lower and higher concentration of archaeological finds discovered in San Basilio (QGIS elaboration E. Consolo).



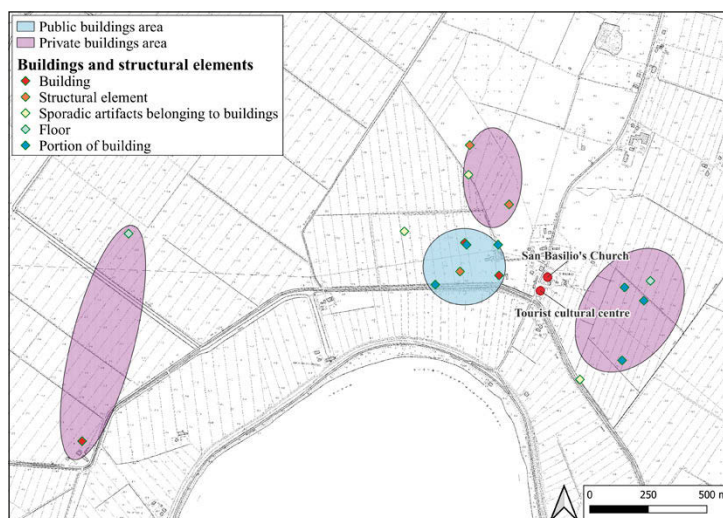


Fig. 4 – Areas of concentration of public (turquoise) and private (purple) buildings in San Basilio (QGIS elaboration E. Consolo).

and the so-called ‘Roman villa’, which should be more reasonably interpreted as a multifunctional *villa* with probably a thermal sector for public use. Thick walls have also been recognised that can perhaps be related to a functional infrastructure for the unloading of goods that were stored in the *horreum*. Furthermore, the presence of a sacred building has been hypothesised on the basis of the discovery of artefacts of a religious character and an inscribed pediment.

E.C.

### 3. LEGACY DATA FOR A TOPOGRAPHIC ANALYSIS OF SAN BASILIO’S TERRITORY

During the Roman era, San Basilio was a significant road junction for the entire high Adriatic coastal area. This importance is evidenced by its mention in the Peutinger Map under the name *mansio Hadriani*. By studying and cataloguing discoveries over the years and processing this data using GIS software, we can better understand the road layout. The area was influenced by the road systems of *via Annia* and *via Popillia*. *Via Annia*, constructed in 153 BC according to recent studies, was a communication route which directly linked Rome with Aquileia, connecting cities such as Ravenna, Padova, and Altino along the Adriatic coast. *Via Popillia*, established in 132 BC, extended from Rimini to Altino, following a more coastal route where it partly overlapped with *via Annia* (UGGERI 2012). San Basilio’s location



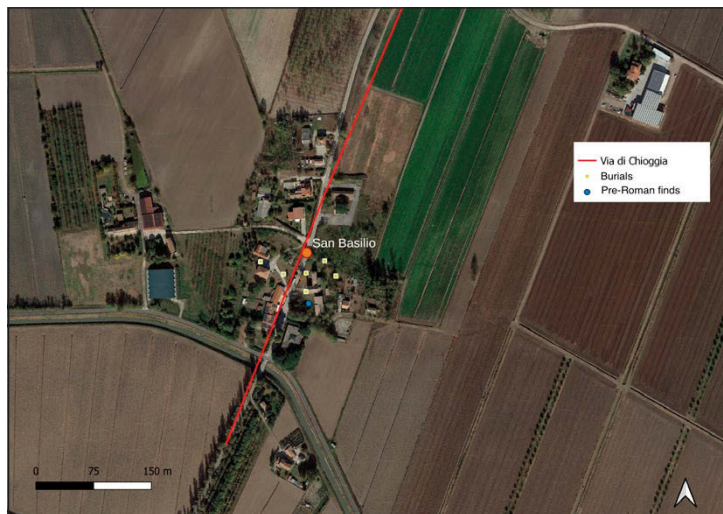


Fig. 5 – The layout of the road leading towards Chioggia (QGIS elaboration G. Moro).

along these routes made it a crucial hub. Coming from the S, the system of *via Annia-Popillia* turned NW from San Basilio towards Adria. In the mid-1<sup>st</sup> century AD, an additional connection to Altino was created, running along the fossil dunes present along the back coastline.

The exact route of the road through the area of San Basilio remains largely unknown. However, georeferencing catalogued finds which can be related to a major Roman communication route can provide valuable insights. These finds include remnants of road tracks, tombs, and funerary steles. The precise location of these archaeological records reveals that the highest concentration of burials is on top of the fossil dune where the modern town of San Basilio is situated. These discoveries span from the 2<sup>nd</sup> century BC to the 3<sup>rd</sup> century AD. This area is also traversed by a road leading towards Chioggia (FRASSINE 2010). Further N, in the areas of Corte Cavanella and Sant'Anna (Chioggia), sections of the road have been uncovered over time. The association of these finds strongly suggests the presence of a Roman road stretching from San Basilio to Chioggia along the ancient coastal fossil dune cordon (Fig. 5).

The route of the *via Annia-Popillia*, which extended from San Basilio to Adria, has left only sparse traces, making its identification challenging. A probable route has been hypothesized through the interpretation of aerial photos and the georeferencing of minor discoveries, such as burials and road traces. The route entered San Basilio from the S and then branched off NW towards Adria. Analysis of aerial photos suggests a straight road in

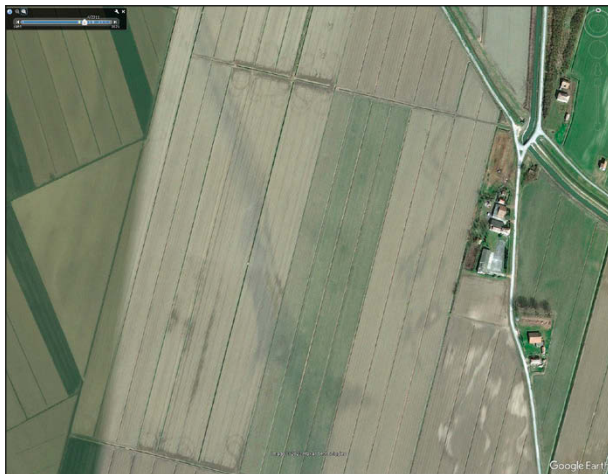


Fig. 6 – Traces of a plausible route in the locality of Tombe, near San Basilio (basemap: Google Earth).

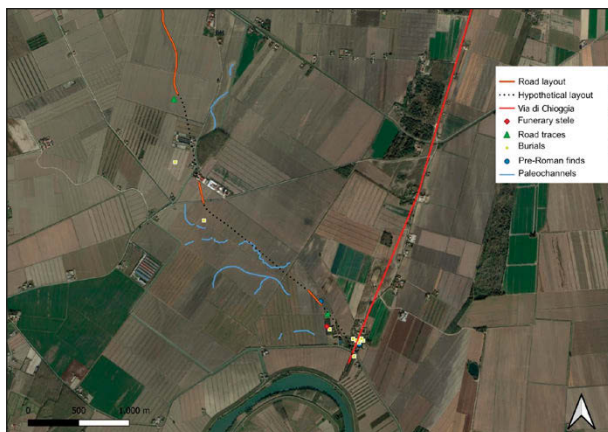


Fig. 7 – Overall map of the evidence analysed in the territory of San Basilio (QGIS elaboration G. Moro).

this direction, corroborated by the discovery of a funerary stele and a burial in the Forcello estate. The road continued towards the locality of Tombe, where it turned N, at an area that has also yielded burials and remains of a road. Further N, aerial photos reveal a distinct trace consistent with a road (PERETTO, BEDETTI 2013). It proceeded to the locality of Mantovane, where additional evidence is visible in aerial photos. Continuing N, the road appears

to veer NW again, but beyond this point, its hypothetical route can no longer be reconstructed (Fig. 6).

The area where the ancient town of San Basilio stood during Roman times had significantly different environmental characteristics compared to today, which played a crucial role in its settlement (PERETTO 1986). One of the primary challenges for large infrastructures like roads was crossing unstable, water-rich areas and ensuring proper drainage. A specific Roman road construction technique involved elevating the road surface above the surrounding countryside by building an embankment (*agger*). This method provided stability to the infrastructure. Often, the embankment was flanked by one or two channels to aid in water drainage. The traces identified from aerial photos in the San Basilio area can be consistent with this type of structure.

An intriguing detail is that these traces show an average width of about 20 m, which is unusual for a typical ancient roadway, but aligns with the dimensions of an ‘agger road’. Given the presence of significant water and numerous river courses, as evidenced by the identification of paleochannels visible from aerial photos, it is plausible that Roman builders employed this construction method for the *via Annia-Popillia* in the section passing through San Basilio (Fig. 7).

G.M.

#### 4. GATHERING NEW DATA THROUGH PROXIMAL SENSING AND ARCHAEOLOGICAL SURVEY

The most recent step of the research involved the application of remote sensing techniques via drones. Initially, the analyses were carried out with a Parrot Anafi Thermal, equipped with a thermal sensor which can identify heat differences due, in our case, to the presence of underground archaeological structures. Afterwards, a multispectral drone (DJI Mavic M3M) was employed, capable of seeing the ‘invisible’ and analysing crop growth, which is strongly influenced by the presence or absence of archaeological elements (Fig. 8). The applications used to define the flight plans of the two drones (Pix4Dcapture and DJI Pilot 2) allowed for the repetition of the same surveys at different times of the year, thus enabling a more precise assessment of the consistency of the identified traces, better determination of their nature, and refinement of the investigations, with the advantage to more accurately calibrate in which vegetative phase of the crops the ‘archaeological’ response was more or less clear and evident. Finally, the image processing was conducted using the photogrammetric software Pix4Dmapper and Agisoft Metashape, which allowed for the acquisition of a large data set of orthomosaics for the entire area of San Basilio, georeferenced with centimetric precision, thanks to the use of the RTK (Real Time Kinematic) system, which collects data from



Fig. 8 – DJI Mavic M3M Red Edge (RE) image of alfalfa fields, with evident traces of a Roman building (photo J. Turchetto).

both satellites and the base station to correct the image position in real time during the drone flight.

Using the various orthomosaics obtained, a ground survey phase was initiated in the fall of 2022, involving around twenty students from the Ancient Topography course of the bachelor's degree in Archaeology at the University of Padova. The most innovative aspect of this step of the field research was the application of the QField software (<https://qfield.org/>) for mobile mapping, which allowed for participatory mapping, collecting, and cataloguing of archaeological artifacts.

Once the base project was created using the desktop version of QGIS, it was uploaded through the QFieldSync plugin to QFieldCloud (<https://qfield.cloud/>), a platform that enables not only to manage the entire project and share it with various field operators, but also to synchronise and merge all collected data into a single database. Each operator (or group of operators) then installed the updated version of QField on their devices (tablet or smartphone) and downloaded a copy of the entire project from the Cloud. This allowed them to easily conduct their field survey activities, mapping the location of artifacts using GPS, taking geotagged photographs, and entering preliminary data into the attribute table associated with each point/artifact. This phase of fieldwork has been carried out seamlessly even offline: points mapped via QField could be recorded locally and later uploaded to QFieldCloud, and finally integrated into the desktop version of the project.

The advantages of using this mobile mapping software were numerous: the ability to conduct surveys over large areas in relatively short times, real-time data updates, and improved collaboration and synchronisation among field operators. Additionally, the integrated management of data and outputs obtained from Remote Sensing analysis and the survey in a single GIS platform allowed for the verification and sometimes correction of the locations generated with QField. Although in most cases the GPS positioning was adequate for our archaeological-topographic purposes, small geolocation errors were resolved through detailed comparison with low-altitude drone images, which distinctly identified the archaeological artifacts subsequently collected by the students.

The multi- and inter-disciplinary approach characterising the new research in San Basilio, including magnetometric analysis in collaboration with experts from Gent University, is generating substantial data. This is ushering in a new and promising era of discoveries and of renewed interest in the archaeological heritage and historical landscape of that nearly forgotten corner of Polesine.

J.T.

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## REFERENCES

- AA.VV. 2013, *Archeologia e paesaggio nell'area costiera veneta: conoscenza, partecipazione e valorizzazione*, Cittadella (Padova), Biblos.
- CAPUIS L., LEONARDI G., MATTIOLI S., ROSADA G. (eds.) 1988, *Carta archeologica del Veneto*, IV, Modena, Edizioni Panini, 127-135.
- DE BELLIS A., DE BELLIS F. 1978, *Ritrovamenti monetali nell'agro di S. Basilio (Ariano Polesine)*, «Padusa - Bollettino del Centro Polesano di Studi Storici Archeologici ed Etnografici».
- FRASSINE M. 2010, *La questione Popillia-Annia tra Padova e Adria*, in G. ROSADA, M. FRASSINE, A.R. GHIOTTO (eds.), *Viam Anniam influentibus palustribus aquis eververatam... Tradizione, mito, storia e katastrophé di una strada romana*, Treviso, Edizioni Canova, 107-119.
- IADICICCO G., VICENZUTTO D., PALTINERI S. 2022, *Cluster analysis, classificazione numerica e remote sensing. Metodi di analisi integrati applicati alla survey presso San Basilio di Ariano nel Polesine (RO)*, «Archeologia e Calcolatori», 33.2, 53-76 (<https://doi.org/10.19282/ac.33.2.2022.04>).
- PERETTO R. 1986, *Ambiente e strutture antropiche nell'antico Polesine*, in *L'antico Polesine: testimonianze archeologiche e paleoambientali. Catalogo delle esposizioni di Adria e di Rovigo*, Padova, Ed. Antoniana, 21-102.
- PERETTO R., BEDETTI S. 2013, *Trasparenze di paesaggi: Atlante aerofotografico del Polesine*, Rovigo, Centro Polesano di Studi Storici Archeologici Etnografici.

UGGERI G. 2012, *La nuova via Annia da Roma ad Aquileia (153 a.C.)*, «Journal of Ancient Topography», 22, 133-174.

TUROLLA O. 1986, *San Basilio tra storia e leggenda*, Taglio di Po (Rovigo), Arti grafiche Diemme.

#### ABSTRACT

Between the end of the Seventies and the beginning of the Eighties of the Twentieth century, following the discovery of numerous occasional findings, the village of San Basilio (Ariano nel Polesine, Rovigo, Italy) had been the object of a series of archaeological campaigns, which made it possible to identify a pre-Roman settlement and a Roman *villa/mansio* linked to the passage of the via *Annia* via *Popillia*. In the past few years, the research has been resumed in that area, carrying out both archaeological and topographical activities, aimed at reconstructing the organisation of the ancient landscape. The aim of this contribution is twofold: on the one hand, the planned research activities are presented and, on the other, the opportunity can arise to discuss about the potentialities of digital approaches in mapping the archaeological landscapes of San Basilio.



## IN-ROME – THE INSCRIBED CITY: URBAN STRUCTURES AND INTERACTION IN IMPERIAL ROME

*Cities are not just a sum of buildings, but especially a set  
of social relations that their inhabitants develop*

ALMUSAED, ALMSSAD 2020

### 1. INTRODUCTION

The exceptionality of the city of Rome in terms of its size is hard to overestimate. Its population is variously estimated at between 750,000 and 1 million around the time of Augustus when it had long outgrown its 4<sup>th</sup> c. city walls ('Servian Wall'; cf. e.g. WILSON 2011; DE LIGT 2012; HANSON 2016). Already Dionysius of Halicarnassus (IV, 13, 3-5; 1<sup>st</sup> c. BCE) famously observed that it was impossible to tell where the city actually ended. Such a large city and its immediate surroundings were obviously structured in some way. Various boundaries, reinforced by rituals and sacred law, were important to the city's identity. Its more densely inhabited area was divided into 14 regions and 265 *vici* (neighbourhoods) while the surrounding area was organised in *pagi* (districts). Beyond key infrastructure and public buildings, the degree of urban planning is considered to have been quite low, and regions, *vici* and *pagi* primarily served administrative and census purposes (LOTT 2004, 2013; TARPIN 2003; WALLACE-HADRILL 2008). Yet they also had their representatives and shrines acting as foci of local identity and neighbourhood support (FLOWER 2017; GOODMAN 2020). Some *vici* were named after businesses that clustered there: carpenters, harness-makers, ironworkers, perfumers, etc. (TARPIN 2003; HASELBERGER 2007; HOLLERAN 2012; GOODMAN 2016; regions: PALOMBI 1999).

Empirical research has shown that self-organising mechanisms exist even where no state authority engages in active urban planning (WALLACE-HADRILL 2008; self-organising: ALLEN, SANGIER 1981; ALLEN 1997; OPALACH 1997; THRIFT 1999; and much discussed recently, e.g. RAUWS *et al.* 2016; MORONI *et al.* 2020. For the clustering of traders and craftsmen in the modern and ancient world, see GOODMAN 2016, with bibl.; organising principles behind seemingly maze-like urban layouts e.g. in Islamic cities: KOSTOF 1991). The natural environment also impacts on the use of land. Even though literary sources talk rarely about Rome's peri-urban areas, we can still expect that the space outside the inner city be structured in various ways, even if not necessarily along administrative boundaries.

Yet despite the recent surge in urban studies of the ancient world, our understanding of these structures is still limited. Besides thousands of

publications on individual structures and excavations, some areas have received a more holistic treatment (e.g. CIMA, LA ROCCA 1998; LIVERANI 2003; MANACORDA, SANTANGELI VALENZANI 2010; ALBERS 2013; JACOBS, CONLIN 2015; MIGNONE 2016; on the city centre esp. numerous publications by D. Palombi), but work covering the entire project area is either limited chronologically (HASSELBERGER 2002, 2007; the *Digital Augustan Rome* project: <https://www.digitalaugustanrome.org>), disjointed due to its lexicon format (STEINBY 1993-2006), or focused on monumental buildings (HASSELBERGER 2002, 2007; CARANDINI, CARAFA, CAMPBELL HALAVAIS 2017).

Several important, large-scale, long-term projects are currently underway in Rome that aim at a fuller documentation of the archaeological remains both within and outside the Aurelian Walls<sup>1</sup>. Yet so far, they focus on documentation rather than analysis and do not systematically integrate inscriptions. Considering that the built environment in any city both shapes and is being shaped by the everyday lives of those inhabiting and using it, we are missing out on some crucial evidence for understanding how Rome's society worked (e.g. LAURENCE 1994; KAISER 2000; LAURENCE, NEWSOME 2011; STÖGER 2011; HAUG, KREUZ 2016: all address Rome in passing at best).

'IN-ROME – The INscribed city: urban structures and interaction in imperial ROME' (<https://inrome.sns.it/>) aims to fill this gap. It will offer the first holistic description and analysis of the urban development and use of space of the Roman territory outside the Servian Wall and within of c. 13 km surrounding it (the area covered by the *Corpus Inscriptionum Latinarum*, CIL VI) from the late Republic to the 3<sup>rd</sup> c. CE. The timeframe is suggested by the start of an extensive epigraphic habit in the 1<sup>st</sup> c. BCE and the end of the 3<sup>rd</sup> c. CE, after which the huge corpus of Christian inscriptions, collected separately in ICUR and the Epigraphic Database Bari (EDB: <https://www.edb.uniba.it>), would need to be included in any historical enquiry, which is impossible to deliver in this project. Bridging the divide between research on the area within and outside of the 3<sup>rd</sup> c. Aurelian Wall, it will illustrate how different parts of the population (ethnicities, status groups, families, genders) and their activities map onto the city's surroundings via military stations, association seats, sanctuaries, production sites, mines, agriculture, markets

<sup>1</sup> Esp. the webGIS system 'SITAR', provided fully open access by the Soprintendenza Speciale di Roma. Archeologia, Belle Arti e Paesaggio, with M. Serlorenzi as responsible, which is continuously updated with new excavation results: [https://repositor.archeositarproject.it/ui/map?\\_cx=1389755.7486645882&\\_cy=5144621.911151068&\\_xz=14.500000000000002](https://repositor.archeositarproject.it/ui/map?_cx=1389755.7486645882&_cy=5144621.911151068&_xz=14.500000000000002); 'Forma Romae?' by the Sovrintendenza Capitolina ai Beni Culturali: <https://formaromae.comune.roma.it/content/home>; 'The Roman Hinterland Project': <https://www.universiteitleiden.nl/en/research/research-projects/archaeology/the-rome-hinterland-project> and 'Lazio Antico', both co-directed by P. Carafa and M.T. D'Alessio; Atlante Dinamico di Roma e della sua Area Metropolitana directed by A. Pugliano: <https://actus.uniroma3.it>. We are enormously grateful to the projects Principal Investigators for their willingness to collaborate with IN-ROME.

and shops, baths, guesthouses, tombs and villas. The aim of this synthesis is not a more comprehensive description of an archaeological landscape than has been published to date. As noted above, this project is well under way. The project intends to infer from ‘topographical facts’ and the spatial distribution of activities, organising principles (intended or unintended) as well as the likely interactions and relationships between different sectors of society.

The underlying idea was tested in Borg’s project ‘Mapping the Social History of Rome: a topographical approach to action and interaction in an ancient mega-city’, funded by a three-year Leverhulme Major Research Fellowship, which serves as a proof-of-concept study for key aspects of IN-ROME. By exploring the varied, closely interconnected, and changing uses of land in a small, key area of Rome’s *suburbium*, it was aimed at reaching a better understanding of the changing activities and interactions between different social, economic, ethnic, and religious groups, not only in this area but in Roman society more generally. It was based on the observation that reconstructing the epigraphic profile of a specific area and comparing it with the archaeological record often allows us to identify the agency behind (some of) the activities attested by archaeology. More importantly, reconnecting agents with the locations of their activities makes visible relationships between members of different social groups that acted in close proximity to each other and may have interacted.

Regarding the relationship between different ethnic and religious groups, the research cuts through some seemingly unsolvable problems. Studying the important cult site for the apostles Peter and Paul underneath the present church of S. Sebastiano diachronically within its local context, it throws new light on the relationship between Christians and non-Christians during the first four centuries CE by demonstrating that the apostles’ cult developed there already from the earlier 2<sup>nd</sup> century onwards, and how it did so in the middle of a particularly busy part of the *suburbium* dominated by staff of the imperial household and members of élite military guards (cf. BORG 2019, 2022, 2024).

The Appia project has inspired the application of the ‘mapping social history’ approach to the wider area of Rome and its *suburbium* and has also demonstrated that inscriptions are an indispensable source of information for this approach. Yet the *Corpus Inscriptionum Latinarum* (CIL VI), the main corpus of Latin inscriptions from Rome, and the databases based on it, typically record the provenance of inscriptions with reference to historical toponyms and names of estate owners, which are often difficult to locate. The recontextualization of inscriptions is therefore a time-consuming activity even for a small area, and impossible to achieve for the entire research area. A key component of IN-ROME is therefore the development of a tool through which it is possible to re-locate larger numbers of inscriptions or assembling

the full record of inscriptions from a specific area with a mouse click. To achieve this, we have taken the following steps.

## 2. ENHANCING THE EDR DATABASE AND LINKING ALL INSCRIPTIONS WITH PROVENANCE TO A WEBGIS SYSTEM

Under the leadership of Silvia Orlandi, Chantal Gabrielli is significantly enhancing the 'Epigraphic Database Roma' (EDR: <http://www.edr-edr.it/default/index.php?lang=en>) by including large numbers of inscriptions from *CIL* VI with a known find spot or likely provenance, resulting in a total of c. 40-50,000 inscriptions. These will include, for the first time, lost inscriptions only known from manuscripts, all inscriptions referring to religious cults, all inscriptions referring to occupations, trade and commerce, and a large number of epitaphs that, on their own, do not provide any significant information to the historian, and which have therefore not been prioritised in previous work on the database. The database will distinguish clearly between secure and likely find spots and locations highly likely to be secondary contexts.

## 3. CREATING A WEBGIS MAP AND GAZETTEER DATABASE OF HISTORIC TOPONYMS

The primary locations identified in EDR will be linked to a Gazetteer Database, allowing them to be related to topographical, archaeological, geological, and other maps. The chosen map base is the Catasto Gregoriano dell'Agro Romano. The digitised map sheets of the Catasto and the *brogliardi* (land registers), which have been scanned through project funds, are already available on the Archivio di Stato's IMAGO website ([https://imagoarchivio.distatoroma.cultura.gov.it/agro/sfoglia\\_agro.php?Path=Agro&r=&lar=1707&alt=960](https://imagoarchivio.distatoroma.cultura.gov.it/agro/sfoglia_agro.php?Path=Agro&r=&lar=1707&alt=960)). Geo-referenced versions of the map sheets will be stored in GeoTIFF format on Zenodo. Created between 1816 and 1835 in the wake of a papal census, the Catasto consists of maps (scale: 1:2000; Fig. 1) and land registers (*brogliardi*, Fig. 2) of the Agro Romano of unprecedented detail and precision but still reflecting the situation before the building booms of the later 19<sup>th</sup> and 20<sup>th</sup> centuries. The property parcels are often easy to identify in later maps and even in Google Earth today, thus allowing for the Gazetteer Database to be enhanced by property owner names and toponyms found in earlier maps, in the cadastre's later updates, and in the maps of the Istituto Geografico Militare (IGM). Descriptions in the *brogliardi* of the character and use of land at the time aid the reconstruction of the agricultural potential of the landscape (studied by Antonio Campus).

During the first project year, priority objectives included the creation of the gazetteer and the geolocation of inscriptions in EDR, by cross-referencing



Fig. 1 – Mapsheet AGRO-161 of the Catasto Gregoriano dell’Agro Romano showing «Vigne poste fuori le Porte di San Sebastiano, Latina e San Giovanni con le tenute di Caffarella ed Arcotravertino».

the information about the place of discovery with a toponymic database. These needs were the basis for building the relational logic of the web-based database, for which open-source technologies were used, integrating rich functionalities with user-friendly interfaces to achieve both objectives. Michael Seidl and Michela Vignoli from the Austrian Institute of Technology experimented with automated methods of vectorising the ca. 75 maps of the project area. Yet, among other issues, the algorithms have not been able to distinguish sufficiently well between relevant lines such as parcel boundaries



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To manage and query the vast and heterogeneous collection of data ultimately forming the base of our historical research (archaeological, epigraphic, derived from historical and modern cartographic sources, geological, toponymic, etc.), the IN-ROME project relies on the IT support of the Digital Archaeology Laboratory (LAD: <https://lad.saras.uniroma1.it>), directed by Julian Bogdani. He has provided the necessary technological and digital know-how for the development of both the database and the geographic information system (webGIS), leveraging the experience gained from various



national and international research projects (BOGDANI 2019, 2024). Specifically, LAD handles the design and implementation of the IT infrastructure, managing both the server and client sides.

A production server was implemented for the project using a system of applications managed through Docker, which allows applications and their dependencies to be isolated within virtualized environments called containers. The implementation of Directus as a database management system and the use of PostgreSQL/PostGIS as a database represents a solid choice for the server side of the system. Directus is an open-source system that provides an intuitive and flexible interface for managing database data, allowing for easy definition of data structures, content management, and user access permissions. Additionally, Directus offers advanced features such as file management, custom workflows, and integration with other services and APIs (Application Program Interfaces). Meanwhile, using PostgreSQL with the PostGIS extension adds geospatial capabilities to the system, enabling efficient management and analysis of geographic data. This combination of technologies provides an excellent foundation for the development and management of a complex system (IACOPINI 2024a) as described in the context of the IN-ROME project, enabling effective and efficient implementation of the required functionalities for georeferencing inscriptions and managing epigraphic and geospatial data.

Currently, the database contains several tables related to the gazetteer, website management, and the toponymic database. Regarding the Catasto Gregoriano, the database includes both the data from the *brogliardi* and the associated geometric primitives. For storing informational data, three interconnected tables have been created. The first table pertains to the storage of maps, containing an identification field, a title (e.g., ‘Agro Romano Suburbano di Roma Porzione di mappa n. 1’), and the date of edition. Each map is linked to many parcels that make up the single map. The parcels are documented through various informational fields related to different aspects such as parcel identification, whether it is a building or a piece of land, toponymic framework, land registers’s list, owners, land morphology, land use, and dimensions. In addition to containing data from the *brogliardi*, the database also allows for the management of the digitization of the geometric primitives of the Catasto, which are divided into polygons (for parcels and buildings), linear features (for roads and rivers), and points for toponymic data or points of interest. Likewise, the IGM map linked to *CIL* has been georeferenced, and around 1300 toponyms have been digitized.

Regarding the interaction between the toponymic database and the one related to EDR, successful verification tests have been conducted for cross-referencing the data and georeferencing the inscriptions based on the ‘Discovery location’ field. The connection to the EDR API is managed through specific flows (Fig. 3) that enable customized data processing, event-based

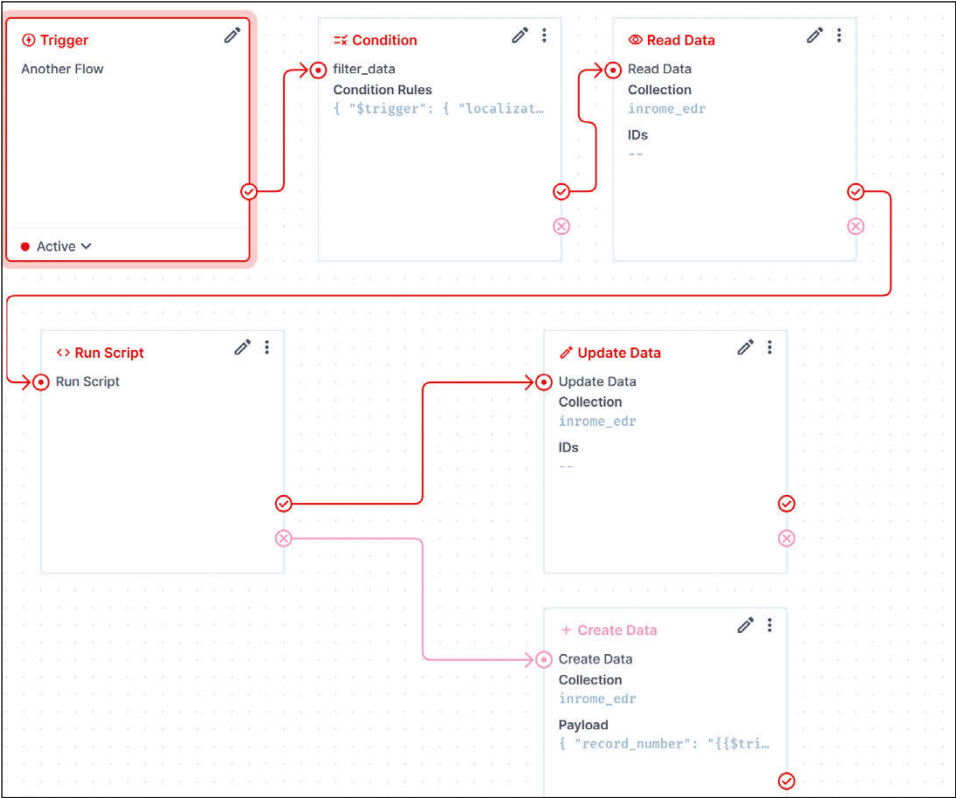


Fig. 3 – Directus Flow diagram, from EDR API to new database table.

actions, and task automation within Directus. The flow involves integrating the Webhook API with EDR, including pagination, filtering by city and discovery location, and finally creating a new table with the filtered results. Thanks to the intersection of epigraphic data containing a discovery indication (e.g., ‘Ruderi dell’Acquedotto Alessandrino’) and the toponymic database (IACOPINI 2024b), it was possible to create a map showing the original locations of the inscriptions. Each point on the map contains the inscriptions found at the same location, which can be viewed through a list displayed on the left side of the map (Fig. 4).

It is intended to archive the results in standard formats (CSV attribute tables and GeoJSON, compliant to the Linked Places profile) and to include them as a separate layer in the webGIS system SITAR, where it is joined they will be joined with archaeological, topographical, geological and other maps and published under CC-BY-NC-SA license.



re-uniting information from 40-50,000 inscriptions with the archaeological evidence, the natural landscape and literary sources. Inscriptions will be mapped applying a wide range of filters, and interpreted in relation to topographical, archaeological, geological and environmental maps, and elevation models, thus visualising spatial structures and organisation.

Beyond the project, anyone applying a topographical approach to inscriptions from the area of *CIL* VI will benefit from the ease with which inscriptions will be mapped. In turn, individuals and institutions working with other kinds of archaeological materials (e.g. sculptures and other artefacts), whose provenance is likely indicated with the same reference to historic landowners and toponyms, will be able to link their objects to the GIS system and map them in this way.

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## REFERENCES

- ALBERS J. 2013, *Campus Martius: die urbane Entwicklung des Marsfeldes von der Republik bis zur mittleren Kaiserzeit*, Wiesbaden, Reichert.
- ALLEN P.M. 1997, *Cities and Regions as Self-Organizing Systems: Models of Complexity*, Amsterdam, Gordon and Breach.
- ALLEN P.M., SANGIER M. 1981, *Urban evolution, self-organization, and decision making*, «Environment and Planning A», 13, 167-183.
- ALMUSAED A., ALMSSAD A. 2020, *City phenomenon between urban structure and composition*, in A. ALMUSAED, A. ALMSSAD, L. TRUONG-HONG (eds.), *Sustainability in Urban Planning and Design*, London, IntechOpen, 1-29.
- BOGDANI J. 2019, *Paths: Sulla creazione di un geo-database aperto dedicato all'Egitto tardoantico e medievale*, «Archeologia e Calcolatori», 30, 471-474 (<https://doi.org/10.19282/ac.30.2019.32>).
- BOGDANI J. 2024, *Moveit: A proof of concept of a road graph for late antique Egypt*, «GROMA: Documenting Archaeology», 7, 14-25.
- BORG B.E. 2019, *Herodes Atticus in Rome: The triopion reconsidered*, in C.M. DRAYCOTT, R. RAJA, K. WELCH, W.T. WOOTTON (eds.), *Visual Histories of the Classical World. Essays in Honour of R.R.R. Smith*, Turnhout, Brepols, 317-330.
- BORG B.E. 2022, *Peter and Paul ad catacumbas: A pozzolana mine reconsidered*, in N. ZIMMERMANN, T. FRÖHLICH (eds.), *The Economy of Death: New Research on Collective Burial Spaces in Rome from the Late Republican to the Late Roman Period. Proceedings of the 19<sup>th</sup> International Congress of Classical Archaeology (Cologne/Bonn 2018)*, Heidelberg, Propylaeum, 45-58.
- BORG B.E. 2024, *The True Burial Site of Peter and Paul? Christians and Jews on the Appian Way*, Leiden, BABESCH Foundation.
- CARANDINI A., CARAFA P., CAMPBELL HALAVAS A. 2017, *The Atlas of Ancient Rome*, Princeton, Princeton University Press.

- CIMA M., LA ROCCA E. (eds.) 1998, *Horti Romani*, Roma, L'Erma di Bretschneider.
- FLOWER H.I. 2017, *The Dancing Lares and the Serpent in the Garden: Religion at the Roman Street Corner*, Princeton, Princeton University Press.
- GOODMAN P. 2016, *Working together: Clusters of artisans in the Roman city*, in A. WILSON, M. FLOHR (eds.), *Urban Craftsmen and Traders in the Roman World*, Oxford, Oxford University Press, 301-333.
- GOODMAN P.J. 2020, *In omnibus regionibus? The fourteen regions and the city of Rome*, «Papers of the British School at Rome», 88, 119-150.
- HANSON J.W. 2016, *An Urban Geography of the Roman World, 100 BC to AD 300*, Oxford, Archaeopress.
- HASELBERGER L. 2002, *Mapping Augustan Rome*, «Journal of Roman Archaeology», Supplement 50.
- HASELBERGER L. 2007, *Urbem Adornare: Die Stadt Rom und ihre Gestaltumwandlung unter Augustus / Rome's urban metamorphosis under Augustus*, «Journal of Roman Archaeology», Supplement 64.
- HAUG A., KREUZ P.-A. 2016, *Stadterfahrung als Sinneserfahrung in der römischen Kaiserzeit*, Turnhout, Brepols.
- HOLLERAN C. 2012, *Shopping in Ancient Rome: The Retail Trade in the Late Republic and the Principate*, Oxford, Oxford University Press.
- IACOPINI E. 2024a, *The archaeological map of Ancona: New IT tools*, «GROMA: Documenting Archaeology», 7.
- IACOPINI E. 2024b, *Zotero2map: sviluppo di un nuovo strumento ITC per la condivisione e la pubblicazione dei dati bibliografici per la ricerca storica e archeologica*, «Archeologia e Calcolatori», 35.2, 245-254 (<https://doi.org/10.19282/ac.35.2.2024.26>).
- JACOBS P.W., CONLIN D.A. 2015, *Campus Martius: The Field of Mars in the Life of Ancient Rome*, Cambridge, Cambridge University Press.
- KAISER A. 2000, *The Urban Dialogue: An Analysis of the Use of Space in the Roman City of Empúries, Spain*, Oxford, Archaeopress.
- KOSTOF S. 1991, *The City Shaped: Urban Patterns and Meanings through History*, London, Thames & Hudson.
- LAURENCE R. 1994, *Roman Pompeii: Space and Society*, London, Routledge.
- LAURENCE R., NEWSOME D.J. (eds.) 2011, *Rome, Ostia, Pompeii: Movement and Space*, Oxford, Oxford University Press.
- DE LIGT L. 2012, *Peasants, Citizens and Soldiers: Studies in the Demographic History of Roman Italy 225 BC-AD 100*, Cambridge, Cambridge University Press.
- LIVERANI P. 2003, *L'agro Vaticano*, in P. PERGOLA, R. SANTANGELI VALENZANI, R. VOLPE (eds.), *Suburbium. Il suburbio di Roma dalla crisi del sistema delle ville a Gregorio Magno*, Roma, École Française de Rome, 399-413.
- LOTT J.B. 2004, *The Neighborhoods of Augustan Rome*, Cambridge, Cambridge University Press.
- LOTT J.B. 2013, *Regions and neighbourhoods*, in P. ERDKAMP (ed.), *The Cambridge Companion to Ancient Rome*, Cambridge, Cambridge University Press, 169-189.
- MANACORDA D., SANTANGELI VALENZANI R. (eds.) 2010, *Il primo miglio della Via Appia a Roma. Atti della giornata di studio (Roma 2009)*, Roma, Università degli Studi Roma Tre Press.
- MIGNONE L.M. 2016, *The Republican Aventine and Rome's Social Order*, Ann Arbor, University of Michigan Press.
- MORONI S., RAUWS W., COZZOLINO S. 2020, *Forms of self-organization: Urban complexity and planning implications*, «Environment and Planning B: Urban Analytics and City Science», 47, 28-303 (<https://doi.org/10.1177/2399808319857721>).
- OPALACH B. 1997, *Political space: The architecture of squatter settlements in São Paulo, Brazil*, «Traditional Dwellings and Settlements Review», 9, 35-50.

- PALOMBI D. 1999, *Regiones quattuordecim*, in STEINBY 1993-2006, 4, 199-204.
- RAUWS W., DE ROO G., ZHANG S. 2016, *Self-organisation and spatial planning: An editorial introduction*, «Town Planning Review», 87, 241-251.
- STEINBY E.M. 1993-2006, *Lexicon topographicum urbis Romae*, Roma, Quasar.
- STÖGER H. 2011, *Rethinking Ostia: A Spatial Enquiry into the Urban Society of Rome's Imperial Port-Town*, Leiden, Leiden University Press.
- TARPIN M. 2003, *Vici et pagi dans l'Occident romain*, Rome, École française de Rome.
- THRIFT N. 1999, *The place of complexity*, «Theory, Culture & Society», 16, 31-69.
- WALLACE-HADRILL A. 2008, *Rome's Cultural Revolution*, Cambridge/New York, Cambridge University Press.
- WILSON A. 2011, *City sizes and urbanization in the Roman empire*, in A.K. BOWMAN, A. WILSON (eds.), *Oxford Studies on the Roman Economy*, Oxford, Oxford University Press, 161-196.

## ABSTRACT

This paper describes the objectives and methodological approaches of the project 'IN-ROME – The INscribed city: urban structures and interaction in imperial ROME'. The project aims at mapping as comprehensively as possible a wide range of activities that shaped both the physical environment and the relationships between its inhabitants. Focussing on the time period between the 1<sup>st</sup> century BCE and the 3<sup>rd</sup> century CE, and on the area outside the 4<sup>th</sup> century BCE 'Servian' Walls up to about the 9<sup>th</sup> mile of Rome's consular roads, it draws on archaeological, literary and archival sources. In addition, and crucially, it aims to virtually re-contextualise c. 50,000 inscriptions in the Epigraphic Database Roma with a known provenance from the area, thus restoring agency to the archaeological landscape. To this end, a new webGIS is being developed that allows for the topographical visualisation of all relevant data.



## LABELS AND SYMBOLS: USING TEXT ON MAPS TO INVESTIGATE THE ANTIQUITIES ON THE ORDNANCE SURVEY MAPS OF GREAT BRITAIN

### 1. INTRODUCTION

This paper will use the representation of antiquities on the Ordnance Survey (OS) Maps of Great Britain as a case study to discuss some of the opportunities and limitations of applying Machine Learning (ML) to digitise the text on historical maps, and how the resulting dataset can be used to address archaeological research questions. While maps are increasingly recognised as rich historical sources (HOSSEINI *et al.* 2021) and digitised map collections become more available, it is still difficult to harness the potential of analysing the text on maps as a digital *corpus*. Historical maps are mostly accessed through close reading of single sheets, making systematic study of an entire series or collection time- and resource-consuming. Even though Optical Character Recognition (OCR) returns increasingly good results for newspapers and manuscripts (MOUDGIL *et al.* 2022), maps present distinct challenges, namely rich and complex backgrounds, and highly variable text featuring different fonts, spacing, and orientation.

Exploring maps through their textual components has been partly addressed by pioneer projects such as ‘GB1900’ (AUCOTT, SOUTHALL 2019; <https://maps.nls.uk/projects/gb1900>) and ‘The Map of Early Modern London’ (JENSTAD 2011), which relied on volunteers to transcribe the text on selected maps. The need to scale up this approach and make it more sustainable drove the international project ‘Machines Reading Maps’ (MRM; <https://machines-reading-maps.github.io/>). Initial map *corpora* were provided by the National Library of Scotland, the Library of Congress, and the British Library. Thanks to the ML pipeline mapKurator (KIM *et al.* 2023; <https://github.com/knowledge-computing/mapkurator-system>), MRM harvested the text on the maps in the test collections and output it as GeoJSON. While this result appealed to researchers with computational literacy, the format was not user-friendly for most researchers in the humanities. In the second phase of MRM, collaboration with the David Rumsey Map Collection (DRMC, <https://www.davidrumsey.com/>) and its in-house data visualisation team (Luna Imaging) made a ‘search by word’ function available in the DRMC in a more accessible and impactful way (VITALE 2023). Both MRM’s outputs, the GeoJSON datasets and the visual interface, will be proposed as research tools.

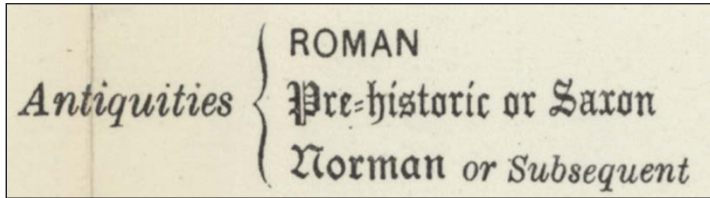


Fig. 1 – Characters of the writing on the engraved Six Inch Ordnance Maps of Great Britain, 1897, National Library of Scotland.

## 2. THE OS MAP SERIES AND ITS ANTIQUITIES

The OS Maps were a national mapping endeavour that started in the 18<sup>th</sup> century for explicit military purpose, but then gradually became part of the life of the nation (HEWITT 2011), and almost a symbol of cultural identity (as well as of colonial power and acculturation, as DOHERTY 2004 remarks). The project involved, through the years, a number of map series and subsequent revisions. Among them, those most relevant to our case study were the County Series (25 inches to the mile). One of the peculiarities of the OS Maps was their detailed record of sites of historical relevance or, as they were referred to, antiquities (CLOSE 1931). While the over-representation of antiquities on OS Maps can be partly explained with the popularity of antiquarianism in Victorian England (PHILLIPS 1959; GOLDHILL 2011), their relevance in a non-specialist publication remains remarkable. This emphasis was reinforced by the appointment, in 1920, of O.J.S. Crawford as OS archeology officer. The reason why the antiquities on OS Maps are interesting both from a cultural heritage and a ML perspective is that they stand out very clearly as a distinct class of features.

Semiotically, this result is achieved through the combined use of three elements (not always present at the same time): dedicated fonts, dedicated keywords, a dedicated symbol. A specific symbol to mark historical sites (in our case a slightly ornate cross) is not an usual choice; examples can be easily found in both historical and contemporary maps. More interesting are the dedicated words (for example ‘ruins’ or ‘site of’) that may accompany the symbol (or act as one, as we will discuss), and, even more striking, the choice of three dedicated fonts (Fig. 1), each associated to a specific historical macro-period: Prehistoric or Saxon, Roman, and Norman (ORDNANCE SURVEY 1920). The use of bespoke fonts specifically created for the OS antiquities highlights the function that these words perform in the map: not simply labels that accompany and disambiguate symbols and icons (as they are defined by SCHLICHTMANN 2018) but, to an extent, as symbols themselves or, better, as text performing additional symbolic function.

### 3. LABELS AND SYMBOLS: OS VISUAL AND TEXTUAL CODE

Thanks to the combined use of these elements (the symbol, the fonts, the keywords) to mark the presence of antiquities, the OS Maps expand the usual scope of representing the contemporary landscape by including some unusual content:

- The invisible: contrary to common practice, the OS records the position of sites and monuments that have disappeared. Their status as nonextant is identified by the use of parentheses and dedicated words (for example ‘(site of)’).
- The hypothetical: even more peculiarly, the OS includes sites and monuments of uncertain and/or unconfirmed location (for example ‘supposed site of’ or ‘reputed site of’) (Fig. 2).
- Archaeological events: dedicated vocabulary is used on OS maps to mark the position of, and/or add details about, archaeological excavations and the related findings (Fig. 3). This choice makes the series especially stand up as, rather than simply recording information about places, the OS surveyors added abundant data about discrete events (the act of finding Roman arrows or tripods, for example). The focus on the archaeological event is further emphasised by the mention of the year in which the finding took place.
- A chronological timeline: the use of three different, dedicated fonts not only makes the information about the antiquities easily findable on the map sheets, but also enables the reader to perceive, at a glance, the different chronological



Fig. 2 – Examples of the representation of non extant heritage on early OS maps, 1:6000 (composite screenshots from GB1900 portal).

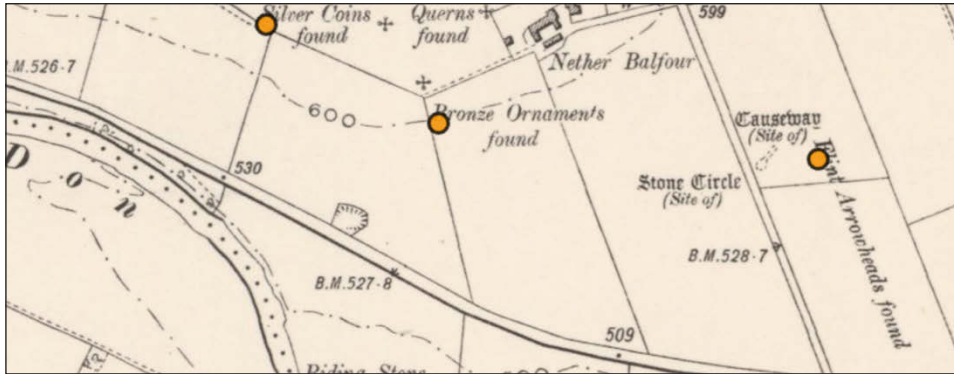


Fig. 3 – Example of the representation of archaeological events on early OS maps, 1:6000 (from GB1900 portal).

layers that coexist in the landscape, rural and urban, generating an effective visual timeline. A further chronological dimension is added by the references to the findings, expanding the chronology to include the recent past of the archaeological excavations (most commonly through the keyword ‘found’).

The level of archaeological expertise required to spot antiquities (including earth mounds and other less obvious features), label them, assign them to the correct macro-category (i.e. either roman, mediaeval or prehistoric), and mark the excavation’s site is hardly to be expected in surveyors of the OS who were mostly trained in engineering and geography (DAVIDSON 1987). What the official guidelines, compiled by CRAWFORD (1922), show is that the surveyors were invited to supplement their knowledge making use of two types of external sources: published materials (including archaeological maps) and local knowledge (i.e. from the owners of the lands where the excavations took place and local heritage experts). The articulated representation of antiquities that can be observed on the early OS maps becomes, then, a valuable insight on the hidden components of the cartographic process, hinting at the many levels of authorships involved in the creation of this complex cultural object. But it may also guide us towards a critical re-examination of the several layers of biases and inaccuracies that are likely to have accumulated as a result.

#### 4. ANALYSING TEXT ON MAPS

Such re-examination is truly possible only when two conditions are met: 1) the textual information on the maps has been digitised and made ready for computational analysis; 2) the analysis can be undertaken at scale, rather than one map at a time. Processing digitised maps with mapKurator

(or similar ML pipelines) produces a new kind of *corpus* that is, at the same time, textual and spatial, and, as such, can be usefully investigated with tools coming from the spatial humanities as well as computational linguistics. For example, using a combination of keywords especially employed to identify extant or disappeared sites ('ruins of', 'site of', 'remains of' among others) and keywords relating to archaeological discoveries ('found', but also words that are likely associated with findings such as 'urn', 'burial', 'tripod', 'arrow'), it is possible to create a sub-*corpus* of the textual component of the OS Maps that is specific to the representation of the antiquities. Once such a sub-*corpus* has been created, it enables informative comparisons with other datasets.

The most immediate option is, probably, that of comparing the earliest editions of the OS Maps with subsequent ones, looking for possible discrepancies. Highlighting, on a national scale, the antiquities that seem to have disappeared in later maps of the same series may be a powerful tool to spot lost and destroyed heritage, turning the earlier maps into visual (and surprisingly granular) archives of ancient sites and monuments (CLOSE 1931, 149) that often predate the creation of formal national institutions for heritage preservation. CRAWFORD himself (1922, 245) credits his predecessors for preserving the knowledge of the location of several long barrows that had already become hardly visible at the beginning of the 20<sup>th</sup> century.

At the same time, the disappearances of antiquities in later OS editions may be seen as an improvement due to a more rigorous approach to the recording of ancient heritage. Not only CRAWFORD «should prefer to say nothing about the archaeological mistakes in the Ordnance Maps, because it is agreed by all that such exist» (1922, 247), but, more specifically, he points out the presence of Roman names that are «pure inventions» (1922, 248) and, as such, should be soon removed from subsequent editions.

A linguistic analysis of the text on maps across different OS editions would not have to be limited to place names. The close-reading of OS Maps has already made apparent, for example, how the archaeological language itself has evolved through time, deprecating terms such as 'antediluvian' or 'druidical'. An analysis at scale could offer even deeper insights on the history of archaeology and classical reception.

In its current state, the dataset generated by processing the OS Maps with mapKurator only takes into account the literal value of the text collected. The further layer of meaning added by the use of different fonts (or, in other words, the symbolic functions performed by the text of map) is invisible in the *corpus*. This case study on the OS antiquities magnified the extent of this limitation and has brought researchers in the MRM team to pursue more complex multimodal approaches that could look simultaneously at the words as textual labels and as symbols. Recognising automatically the antiquities' different fonts would add, to a dataset that already features names

and locations of ancient sites and monuments, also information about their interpretation at the time of the map creation. This further dimension would enable more nuanced comparisons with external datasets (such as English Heritage, Historic Environment Scotland, or Archaeology Data Service) that would move beyond the presence or absence of a site but could also evaluate changes in its archaeological and historical interpretation.

BERESFORD (1992) for example, evokes the case of the earthworks from mediaeval villages in Yorkshire that, recorded in the first edition of the OS, became candidates for deletion in a subsequent revision. Even CRAWFORD (1922), in his honest evaluation of the archaeological value of the OS mapping endeavour, recognises that the interpretation of antiquities (via the choice of one of the three available fonts) may reveal more than a few mistakes in subsequent revisions. In his view, though, recording the location of a piece of ancient heritage was more important than getting its interpretation right, as interpretations could be corrected in the future «with the stroke of a pen» (1922, 251) while failing to record the presence of a site may contribute to its permanent loss. Beside rectifying incorrect interpretations, as Crawford would have hoped, an analysis at scale of these mistakes would support the discovery of potential systemic bias, for example highlighting the possible over popularity of one particular class of antiquities.

Linguistic analysis of the text on OS Maps could be extended to digital archives of archaeological scholarship (such as JStore) to facilitate the identification of the published sources that the OS surveyors were invited to rely upon in their work. Comparisons between the text on OS Maps and these publications may be used as a starting point to investigate the direction and intensity of knowledge exchange between the OS and academia, analysing to what extent the OS were mere duplications of reputable archaeological publications (including their inherent biases) and to what extent they generated new knowledge through integration of multiple sources (DAVIDSON 1987).

Finally, the integration of a visual interface, like the one available on DRMC's website, enables us to reintroduce, partially, the symbolic component of the text on maps by showing the original map context. While lacking the computational sophistication of other approaches, a 'search by word' across maps can yield useful results. For example, a search for key words commonly associated with antiquities (such as 'ruins') may help us frame, culturally and cartographically, the practice of representing historical sites on maps. Bearing in mind that the DRMC, while sizable, is also heterogeneous and idiosyncratic like all private collections, it could still support the exploratory search for other examples of dedicated fonts used to mark antiquities on non-specialist maps. So far, the search through relevant keywords suggests that the approach is peculiar to the OS Maps, including their coverage of British colonies and protectorates.



## 5. CONCLUSIONS

This case study highlights how digitised map collections may be used as tools to reinvestigate the history of archaeological practice and cultural heritage reception. *Corpora* created by collecting text on maps through ML, open up the opportunity for the application of linguistic tools and systematic comparisons with variant editions, other collections, as well as external datasets. However, the symbolic value carried by words on maps through their visual characteristics (such as fonts) is currently overlooked. While visual interfaces have shown the potential of a combined approach, a new ML workflow is needed to fully leverage the value of OS (and other) maps as complex textual objects linking together different sources of archaeological knowledge.

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## REFERENCES

- AUCOTT P., SOUTHALL H. 2019, *Locating past places in Britain: Creating and evaluating the GB1900 Gazetteer*, «International Journal of Humanities and Arts Computing», 13, 1-2, 69-94.
- BERESFORD M. 1992, *The spade might soon determine it': The representation of deserted medieval villages on ordnance survey plans, 1849-1910*, «The Agricultural History Review», 64-70.
- CLOSE C. 1931, *The Ordnance Survey*, «Antiquity», 5, 18, 149-160 (<https://doi.org/10.1017/S0003598X00005913>).
- CRAWFORD O.G.S. 1926, *Archæology and the Ordnance Survey*, «Geographical Journal», 66-68.
- DAVIDSON J.L. 1987, *The collection of antiquarian information for the early Ordnance Survey maps of Scotland*, in *Proceedings of the Society of Antiquaries of Scotland*, 116, 11-16 (<https://doi.org/10.9750/PSAS.116.11.16>).
- DOHERTY G.M. 2004, *The Irish Ordnance Survey: History, Culture and Memory*, Dublin, Four Courts Press.
- GOLDHILL S. 2011, *Victorian Culture and Classical Antiquity: Art, Opera, Fiction, and the Proclamation of Modernity*, Princeton, University Press.
- HEWITT R. 2011, *Map of a Nation: A biography of the Ordnance Survey*, London, Granta Publications.
- HOSSEINI K., McDONOUGH K., VAN STRIEN D., VANE O., WILSON D.C. 2021, *Maps of a nation? The digitized ordnance survey for new historical research*, «Journal of Victorian Culture», 26, 2, 284-299.
- JENSTAD J. 2011, *Using early modern maps in literary studies: Views and caveats from London*, «GeoHumanities», 112-119.

- KIM J., LI Z., LIN Y., NAMGUNG M., JANG L., CHIANG Y. 2023, *The mapKurator system: A complete pipeline for extracting and linking text from historical maps*, in SIGSPATIAL '23: Proceedings of the 31<sup>st</sup> ACM International Conference on Advances in Geographic Information Systems, art. 35, 1-4 (<https://doi.org/10.1145/3589132.3625579>).
- MOUDGIL A., SINGH S., GAUTAM V. 2022, *An overview of recent trends in OCR systems for manuscripts*, in Cyber Intelligence and Information Retrieval: Proceedings of CIIR 2021, 291, 525-533.
- ORDNANCE SURVEY 1920 (and later editions), *A description of the large scale maps of Great Britain produced and published by the Ordnance Survey, with specimens, symbol sheet, and diagrams*, Southampton, Ordnance Survey.
- PHILLIPS C.W. 1959, *Archaeology and the Ordnance Survey*, «Antiquity», 33, 131, 195-204.
- SCHLICHTMANN H. 2018, *Background to the semiotic study of maps*, «Meta-carto-semiotics», 11, 1, 1-12.
- VITALE V. 2023, *Searching maps by words: How Machine Learning changes the way we explore map collections*, «Journal of Cultural Analytics», 8, 1.

## ABSTRACT

This paper discusses the application of a machine learning pipeline to automatically digitise text on historical maps and make it searchable, as explored by the ‘Machines Reading Maps’ project. Looking at the Ordnance Survey Maps of Great Britain as a case study, we will suggest ways in which this new kind of open datasets, of both a textual and spatial nature, offers the unprecedented opportunity to study maps at scale, analysing map collections as digital corpora. These new approaches facilitate the use of map as historical sources in humanities research, and their investigation as complex cultural objects that combine heterogeneous knowledge. In particular, we will focus on the uncommonly detailed representation of ancient sites on the Ordnance Survey maps, and how a further layer of information around them is delivered not by the words’ literal meaning but by their appearance. We will propose ways in which this peculiarity could be digitally leveraged to retrace, investigate, and perhaps re-interpret the archaeological information on the Ordnance Survey maps. We will conclude by reflecting on the need for new, more sophisticated workflows that take into account the richness of information delivered by visual clues in words printed on maps.

## GODSCAPES: TOWARDS A MODEL OF MATERIAL RELIGION IN THE SECOND MILLENNIUM BCE LEVANT VIA SEMANTIC WEB ONTOLOGIES

### 1. INTRODUCTION

The project ‘Godscapes: Modeling second millennium BCE Polytheism in the Eastern Mediterranean’ (<https://godscapes.unict.it/>) aims at defining a new scientific method to understand how humans entangle with the divine through religious beliefs that are enforced by ritual behaviors and the related material culture. In fact, to reach this goal, the project combines a material perspective that, following the most recent approaches to religious studies that have formed the so-called ‘material turn’, stresses the pivotal role of material culture in shaping beliefs and practices, with an innovative use of the artificial intelligence, in particular, of the Semantic Web.

According to the project’s objective, this fresh approach will aid in comprehending both ancient and modern forms of religiosity. The well-established methods and tools of the Semantic Web are in fact applied to link various aspects of human life and knowledge, and ultimately to generate knowledge graphs showing how these elements are related to each other in the construction of religious beliefs and practices.

The proposed method is tested on the complex forms of polytheisms that were practiced in the Levant during the second millennium BCE. Distinctive to this chronological macro-entity was in fact the involvement of the Canaanite city-states in the network of diplomatic and economic relations that from the North Africa and the Eastern Mediterranean reached as far as Central Asia, enhancing the circulation of people, things and ideas, and the creation of original forms of religious syncretism. Strategically located between Egypt and the Mesopotamian powers, the Levant, mainly referring to modern-day Israel, Palestine, Jordan, Lebanon and Syria, was central in the exchange process. It is in this complex cultural milieu, where local, exogenous and hybrid elements interacted with one another, that the roots of the Israelite monolatry of the first millennium BCE can be traced.

As correctly pointed out by Mark S. SMITH (2001), the archaeological research in the area has created a massive amount of data that are fundamental to interpret the relationship between biblical monotheism and the polytheisms practiced in both ancient Israel and the neighboring cultures. However, holistic approaches considering the development of the Israelite monolatry within the complex polytheistic traditions attested during the second millennium BCE in the Eastern Mediterranean, and reaching as far as Egypt, the Aegean,

Anatolia, Syria and Mesopotamia, were only rarely applied (OGGIANO 2005; KILLEBREW 2012; KOCH 2019; LANERI 2024).

Targeting the phenomena of cultural hybridization that affected the religiosity of the communities inhabiting the Levant during the second millennium BCE, ‘Godscapes’ focuses on the analysis of four types of data – funerary, architectural, iconographic, and textual. In order to understand how the polytheistic sources had been rethought, triggered and reshaped in the process that will bring to the biblical monotheism, the project’s approach will: 1) identify the exogenous and endogenous layers of religiosity; 2) define the diagnostic markers of the second millennium BCE Levantine religiosity; 3) demonstrate how a syncretic outcome can be considered as the result of a complex network of inter-religious encounters originated during the second millennium BCE (LANERI *et al.* 2024).

2. DESCRIPTION OF METHODS

The methodology presented aims to create a model that elucidates the relationships among different material elements of religiosity during cultural transformations, adopting a comprehensive approach that considers the entanglement of material elements, humans, and ideas in the construction of religious beliefs and practices. In so doing, the research addresses fundamental questions about the transformation of autochthonous forms of religiosity by exogenous elements, identifying persisting and abandoned elements, and examining the social contexts in which these elements are most recognizable (Fig. 1).

Focusing on a defined geographical region (i.e., the Levant) and period (i.e., the second millennium BCE), the method involves deconstructing four fundamental aspects associated with material religiosity: religious architecture, religious iconography, funerary rituals/beliefs, and religious texts. Such

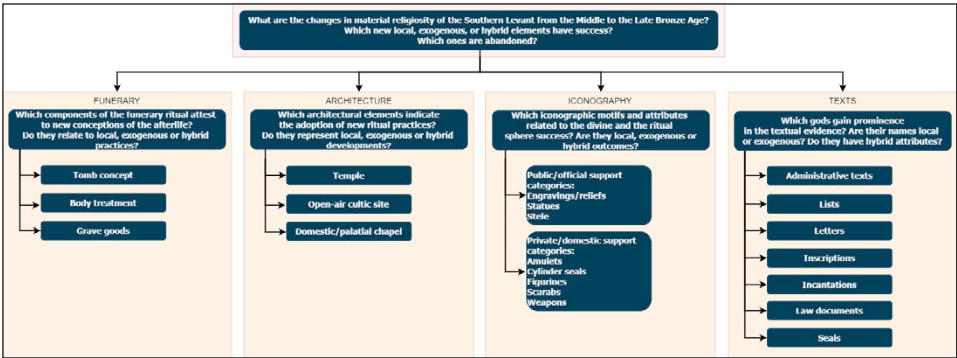


Fig. 1 – Fundamental research questions referring to the project’s dataset.

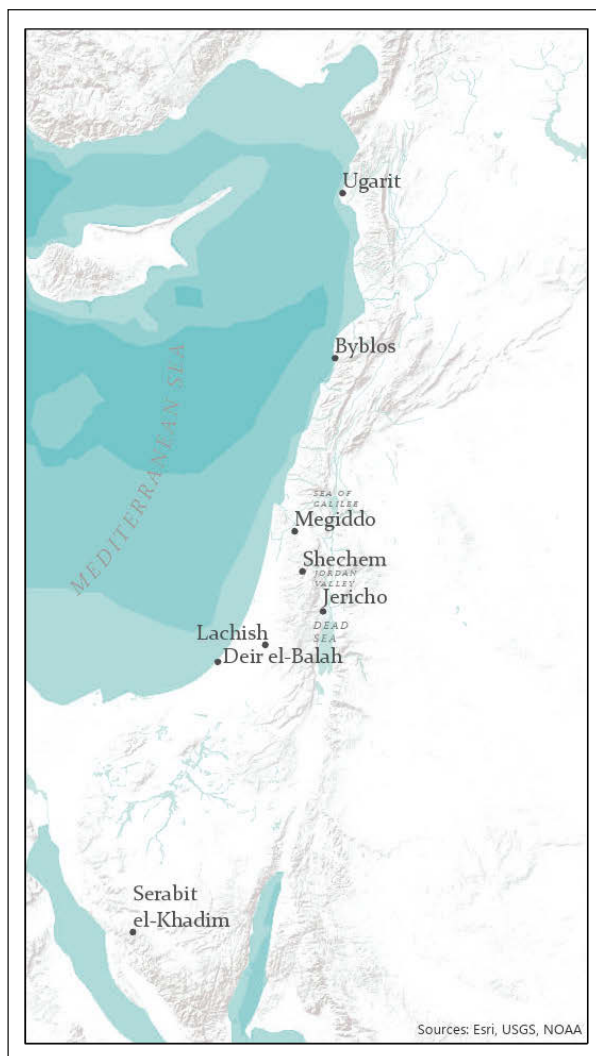


Fig. 2 – Map of the pilot archaeological sites whose data have been entered into the ‘Godscapes’ database.

deconstruction is operated through an epistemological process in which Semantic Web ontologies are suitably designed, implemented, linked to the most popular vocabularies in the field, and populated by entering the data from a set of pilot archaeological sites (i.e., Ugarit, Byblos, Shechem, Megiddo, Jericho, Lachish, Deir el-Balah, and Serabit el-Khadim) (Fig. 2). Such a

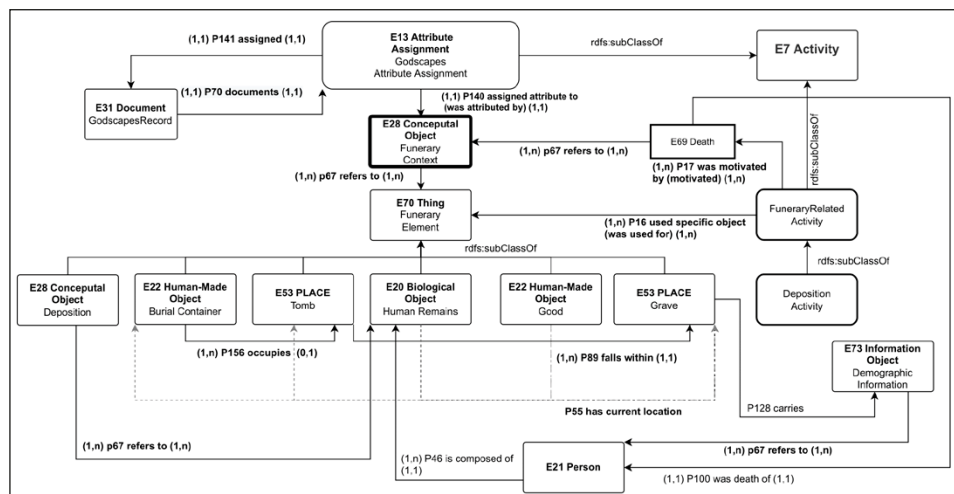


Fig. 3 – Model design of the ‘Godscapes’ ontology for the funerary data.

deconstruction employs the Web Ontology Language 2 (OWL 2) to represent a formal, shared conceptualization of the domain.

The Semantic Web, with its well-established methodologies and tools, provides a solid solution to semantically model application domains, integrate data, and make it globally accessible (BERNERS-LEE *et al.* 2001). It involves machine-readable data that enable software agents to query and manipulate information autonomously, promoting increased coherence and dissemination of knowledge. Automated reasoning procedures in the Semantic Web allow for the extraction and processing of implicit information, facilitating a deeper understanding of the domain (STAAB, STUDER 2010). Moreover, introducing rule of the Semantic Web Rule Language (SWRL) allows one for definitions not expressible in OWL 2, and it is often convenient in terms of efficiency of the reasoners.

The research plan has combined a top-down with a bottom-up approach, working on the conceptual layout of ‘The Godscapes Ontology’ (‘TGO’) while standardizing the metadata for the creation of the Godscapes database. Religious belief is considered as a co-product of the enactment of ritual behaviors, and cognitive representations that, according to the ‘Mental Functioning Ontology’, depend on individuals that have them as part of their mental outfit (SCHULZ, JANSEN 2018). Within this broad category, the project focuses on other-than-human beings (from gods and goddesses to hybrid creatures and sacred animals) and myths. Ritual praxis is reconstructed from material correlates recognizable in the context of both funerary and



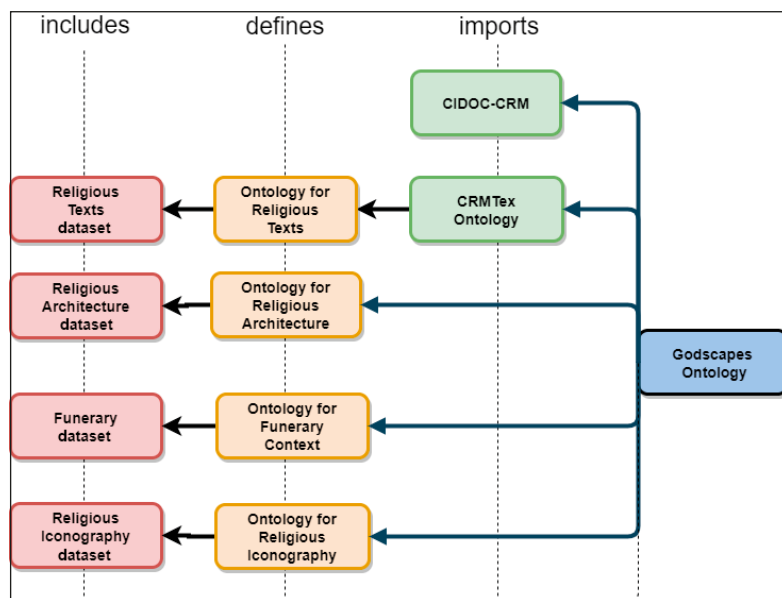


Fig. 4 – Diagram for TGO.

religious ritual. From these broad categories stem the hierarchies of classes of the four ontologies which represent the main core of the research agenda, that are funerary contexts, religious architecture, iconography and religious onomastics (Fig. 4).

The structure of the four ‘Godscapes’ OWL ontologies is mainly inspired by ontological models developed in previous research works and by relevant standard ontologies in the field. Specifically, the ontologies presented by CANTALE *et al.* (2017, 2021) are considered for the description of architectural types and components. Regarding objects, we model our ontologies by extending the Ontoceramic project (CANTONE *et al.* 2015; BRANCATO *et al.* 2019a, 2019b). A similar approach is used for the characterization of religious iconography and funerary data (Fig. 3), where the EPIONT taxonomy is considered (CANTONE *et al.* 2019). Finally, for the definition of an ontology concerning religious texts, we will take into account CRMtex, an extension of CIDOC CRM ontology formally representing the specific requirements of the studies in ancient texts, including papyrology, paleography, codicology and epigraphy (FELICETTI, MURANO 2017). While CIDOC is the actual standard for integrating cultural heritage data, other ontologies such as the ones provided by the Pleiades project for the historical toponymy, will be useful. The TGO (Fig. 4) will finally be endowed with a set of ontological primitives

to connect the four ontologies mentioned above, and to encompass the huge amount of digital and non-digital bibliography related to ‘Godscapes’.

### 3. OBJECTIVES AND ANTICIPATED RESULTS

Thanks to ‘The Godscapes Ontology’ the four types of data related to the material religiosity will be interconnected, while reasoning and semantic query will discover which exogenous elements transformed the indigenous forms of religious belief, and in which context these elements are especially recognizable. For example, when tomb types that are considered indigenous, as they have a long history of local development, are combined with burial containers that attest to new, exogenous traditions, such as anthropoid coffins of Egyptian style but local manufacture (LANERI, PAPPALARDO in press), or larnax of Late Minoan design (GILMOUR 2002), the resulting funerary practice will be considered as hybrid. The same applies to the combination of all the components of the funerary context, such as grave goods and body treatments of different origin and influence. Thus, according to the ‘material entanglement’ definition by Stockhammer (2013), disentangling the cultural matrices that participated in the origin of new practices and craft traditions means acknowledging their contribution in forming a new material entity, whose significance and, in the case of death-related practices, related beliefs may not be a simple sum of its components, but a different and peculiar one.

Building on this theoretical and methodological framework, the aims of the ‘Godscapes’ project are three folded:

1. Create a coherent model of material religiosity that will be useful for the understanding of ancient Near Eastern societies, while also furnishing a tool to be implemented with other datasets;
2. Interpret the transformation of a polytheistic religion into a different form of religiosity as it is the Israelite monolatry through a clear and diachronic definition of how exogenous and indigenous elements interacted. At this stage a suite of SWRL rules is defined, describing interactions between relevant elements of material religiosity;
3. Make the project datasets open to the public through the use of ‘open science practices’ that will increase the quality and impact of Responsible Research & Innovation (RR&I).

Following these objectives, the anticipated outcomes of the ‘Godscapes’ research project include the creation of a suite of OWL 2 ontologies based on the vocabularies of religious materiality, and the implementation of an openly accessible database containing all pertinent datasets utilized in the project. The dataset will be accompanied by formalized SWRL rules and queries, in such a way as to characterize specific concepts on the one side and answer

research questions from the other. To enhance accessibility, and the sharing of fair and quality certified open data, a web platform and a webGIS interface are being developed to query and visualize the data in a user-friendly manner.

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### REFERENCES

- BERNERS-LEE T., HENDLER J., LASSILA O. 2001, *The Semantic Web*, «Scientific American», 284, 5, 34-43.
- BRANCATO R., NICOLOSI-ASMUNDO M., PAGANO G., SANTAMARIA D.F., UCCHINO S. 2019a, *An ontology for legacy data on ancient ceramics of the plain of Catania*, in A. CASAGRANDE, E. OMODEO (eds.), *Proceedings of the 34<sup>th</sup> Italian Conference on Computational Logic (Trieste 2019)*, CEUR-WS, 2396, 59-67.
- BRANCATO R., NICOLOSI-ASMUNDO M., PAGANO G., SANTAMARIA D.F., UCCHINO S. 2019b, *Towards an ontology for investigating on archaeological Sicilian landscapes*, in C. MEGHINI, A. POGGI (eds.), *Proceedings of the 1<sup>st</sup> International Workshop on Open Data and Ontologies for Cultural Heritage 2019 (Rome 2019)*, CEUR-WS, 2375, 85-90.
- CANTALE C., CANTONE D., LUPICA RINATO M., NICOLOSI-ASMUNDO M., SANTAMARIA D.F., STUFANO MELONE M.R. 2021, *The ideal Benedictine monastery: From the Saint Gall map to ontologies*, «Applied Ontology», 16, 2, 137-160.
- CANTALE C., CANTONE D., NICOLOSI-ASMUNDO M., SANTAMARIA D.F. 2017, *Distant reading through ontologies: The case study of Catania's benedictines monastery*, «Italian Journal of Library, Archives and Information Sciences», 8, 3, 203-219.
- CANTONE D., NICOLOSI-ASMUNDO M., SANTAMARIA D.F., TRAPANI F. 2015, *Ontoceramic: An OWL ontology for ceramics classification*, in D. ANCONA, M. MARATEA, V. MASCARDI (eds.), *Proceedings of the 30<sup>th</sup> Italian Conference of Computational Logic (Genova 2015)*, CEUR-WS, 1459, 122-127.
- CANTONE D., CRISTOFARO S., NICOLOSI-ASMUNDO M., PRADO F., SANTAMARIA D.F., SPAMPINATO D. 2019, *An EpiDoc Ontological Perspective: The Epigraphs of the Castello Ursino Civic Museum of Catania via CIDOC CRM*, «Archeologia e Calcolatori», 30, 139-157 (<https://doi.org/10.19282/ac.30.2019.10>).
- FELICETTI A., MURANO F. 2017, *Scripta manent: A CIDOC CRM semiotic reading of ancient texts*, «International Journal on Digital Libraries», 18, 4, 263-270.
- GILMOUR G. 2002, *Foreign burials in Late Bronze Age Palestine*, «Near Eastern Archaeology», 65, 2, 112-119.

- KILLEBREW A.E. 2012, *Biblical peoples and ethnicity. An archaeological study of Egyptians, Canaanite, Philistines, and Early Israel 1300-1100 BCE*, «Society of Biblical Literature – Archaeology and Biblical Studies», 9.
- KOCH I. 2019, *Religion at Lachish under Egyptian colonialism*, «Die Welt Des Orients», 49, 2, 161-182.
- LANERI N. 2024, *From Ritual to God in the Ancient Near East. Tracing the Origins of Religion*, Cambridge, Cambridge University Press.
- LANERI N., NICOLOSI-ASMUNDO M., SANTAMARIA D.F., PAPPALARDO C. 2024, *Godscapes: modeling second millennium BCE polytheisms in the eastern Mediterranean thanks to the Storage project*, in A. DI SILVESTO, D. SPAMPINATO (eds.), *Me.Te. Digitali. Mediterraneo in rete tra testi e contesti, Proceedings XIII Convegno Annuale AIUCD (Catania 2024)*, 525-529 (poster).
- LANERI N., PAPPALARDO C. in press, *Patterns of religiosity in the Levant and Egypt during the second millennium BCE: The case of the anthropoid clay coffins*, in *Studies in honour of Marilina Betrò*.
- OGGIANO I. 2005, *Dal terreno al divino: archeologia del culto nella Palestina del primo millennio*, Roma, Carocci.
- SCHULZ S., JANSEN, L. 2018, *Towards an ontology of religious and spiritual belief*, in S. BORGO et al. (eds.), *Proceedings of the 10<sup>th</sup> International Conference (FOIS 2018)*, Amsterdam, IOS Press, 253-260.
- SMITH M.S. 2001, *The Origins of Biblical Monotheism: Israel's Polytheistic Background and the Ugaritic Texts*, Oxford, Oxford University Press.
- STAAB S., STUDER R. 2010, *Handbook on Ontologies*, Dordrecht, Springer Science & Business Media.
- STOCKHAMMER P.W. 2013, *From hybridity to entanglement, from essentialism to practice*, «Archaeological Review from Cambridge», 28, 1, 11-28.

## ABSTRACT

‘Godscapes’ proposes to combine a material approach with the Semantic Web to investigate cultural transformation and, specifically, how external elements trigger the transformation of religiosity, resulting in new hybrid elements. Focusing on a case-study on the Levant during the second millennium BCE, the project investigates the interplay between indigenous and exogenous elements (Egyptian, Syrian, Mesopotamian, Aegean, Anatolian) in shaping polytheistic beliefs and practices through the analysis of four types of data – funerary, architectural, iconographic and textual. Thus, the project addresses a new scientific perspective emphasizing the use of material culture to understand the connection between humans and the divine. The focus is on the unravelling of past religious hybridization to grasp how the second millennium cultural and religious intermingling persisted in the syncretic experience leading to the construction of the Israelite monolatry in the first millennium BCE.

## GEOSTATISTICAL MAPPING OF POTTERY VARIATION: THE NORTHERN LANDS OF WESTERN ASIA DURING THE MIDDLE BRONZE AGE

### 1. INTRODUCTION

In archaeology, the conventional visual representation of ceramic variation often presents a static and potentially misleading view of the past. This is particularly evident in distribution maps of ceramic ‘cultures’, where sites yielding a specific pottery assemblage are represented as dots enclosed within a geometric feature that aims to display a homogeneous, coherent, and bounded cultural entity. Such a mapwork, rooted in Cultural History (WEBSTER 2008; CRELLIN 2020, 28-30), considers pottery as the product of a distinct human group (CHILDE 1929, v-vi) and interprets the presence of similar ceramic repertoires or attributes across different sites, even those geographically distant, as evidence of the diffusion of that culture over those sites (BABIĆ 2007, 75; JOHNSON 2020, 20).

Despite technological and methodological advancements in map-making, particularly with the introduction of Geographic Information Systems (GIS) and GIS-based mapping and spatial analysis software, the culture-historical paradigm still underlies the visualisation of prehistoric cultural groups, particularly in ancient western Asian contexts (e.g., AURENCHE, KOZŁOWSKI 2011). However, this culture-historical, diffusionist approach to representing ceramic variation falls short of acknowledging the intricate and diverse nature of cultural phenomena. Although simplification is necessary and inevitable in the spatial investigation of archaeological artefacts (WHEATLEY, GILLINGS 2000, 8), conventional distribution maps risk representations of only ‘geometries on descriptive maps’ enclosed within what can be perceived as a fixed cultural landscape. Secondly, cultural-historical mapping is biased by what we may define as ‘similarity primacy’, i.e. the emphasis on shared ceramic traits at the expense of pottery differences. Lastly, this map-making process eventually ignores ‘blank’ areas, i.e. those empty zones between sites (HODDER 1977, 38; ALDRED, LUCAS 2018, 28). In this context, distribution maps of diagnostic sherds, types, or styles describe similarities, ignoring differences – the other half component of the overall variation – and most of the landscape.

This paper addresses the limitations above by introducing a novel methodological strategy for mapping ceramic variation. Our approach considers similarities and differences in ceramic traits and incorporates geostatistical methods, i.e. kriging, to visually represent the intrinsic complexity and diversity of pottery distribution. By doing so, we seek to move beyond the static

cultural-historical mapping approach and provide a more nuanced understanding of the complex nature of pottery-driven archaeological landscapes. To achieve this, we will apply our analysis to a case study involving legacy pottery data, demonstrating the practical application and potential insights gained from our proposed methodology. Through this work, we aspire to contribute to the advancement of archaeological methods and foster a more comprehensive understanding of the past.

## 2. THE CASE STUDY

The ‘Northern Lands’ of western Asia indicate the wide area encompassing the territories of modern eastern Turkey, northeastern Syria, northern Iraq, northwestern Iran, Armenia, Georgia, Azerbaijan, and the Nakhchivan Autonomous Republic. These areas are historically known as eastern Anatolia, upper Mesopotamia, and the southern Caucasus (Fig. 1). Since the late 19<sup>th</sup> century, archaeological research in the Northern Lands has aimed to reconstruct its chronological framework and cultural landscape from material culture, due to the lack of written sources before the first millennium BCE. Amongst all the periods identified by archaeologists, the end of the third to the first half of the second millennium BCE – or Middle Bronze Age in Caucasian archaeology – is one of the most intriguing concerning ceramic productions. Overall, the area experienced a fragmentation of the cultural homogeneity of the third millennium BCE, represented by two main broad ceramic horizons, the Kura-Araxes and the Ninevite V assemblages (ROVA

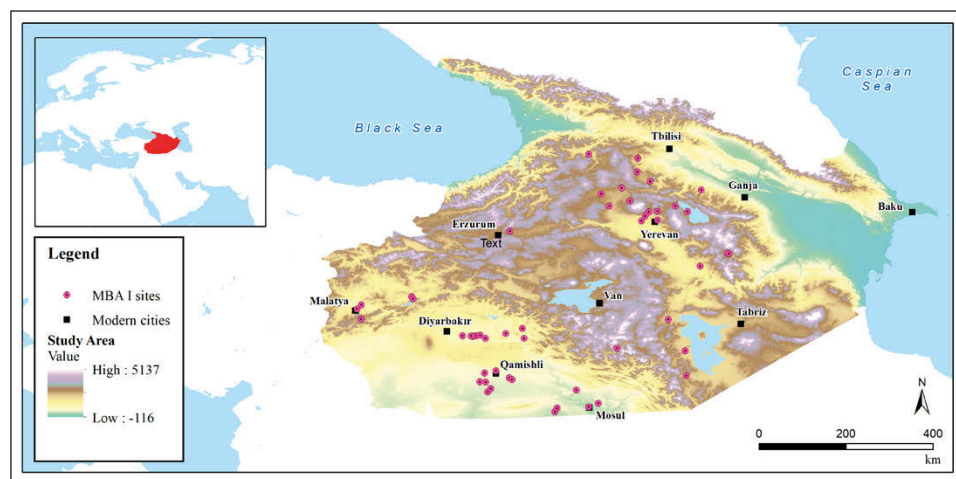


Fig. 1 – The Northern Lands of western Asia with the sites (in pink) used for analysis.



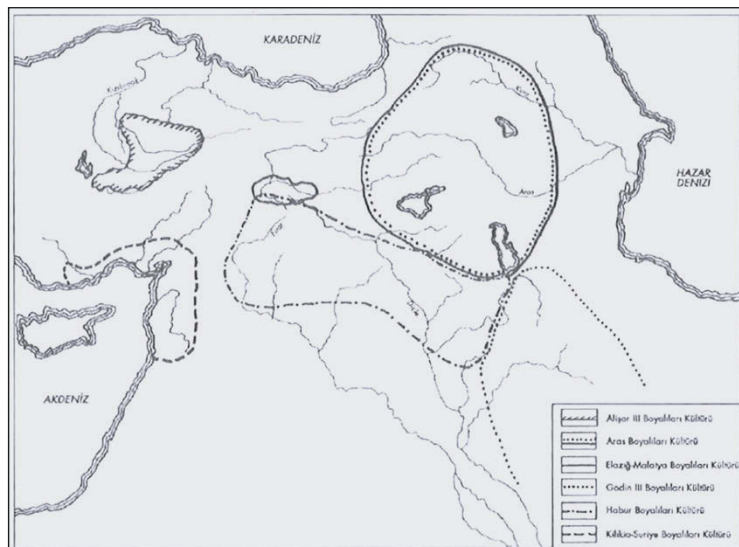


Fig. 2 – Ceramic cultures in the Northern Lands during the Middle Bronze Age (modified from ÖZFIRAT 2001, fig. 1).

1988, 151-157; PALUMBI 2008; SAGONA 2011, 695). Towards the beginning of the second millennium BCE, more regionalised, mainly painted ceramic repertoires emerged, which scholars linked, amongst other factors, to shifts in subsistence economy and increased human mobility (KRAMER 1977; BAYSAL 2012; SAGONA 2018, 331-332).

A. ÖZFIRAT (2001) analysed and summarised data from previous studies, offering the first distribution map of the ceramic groups of the Northern Lands during the Middle Bronze Age. In her mapwork, ceramic groups of the phase between 2000 and 1600 BCE are graphically shown by shapes with differently hatched outlines (Fig. 2). Özfırat's endeavour is commendable for its pioneering efforts in synthesising available data and presenting a visual representation of ceramic distribution, serving as a valuable reference point for further archaeological inquiries. However, a reassessment of legacy pottery data was undertaken to provide a new visual understanding of the complex ceramic diversity of the Northern Lands during the Middle Bronze Age.

### 3. METHODS AND ANALYSIS

The analytical strategy implemented here involved three main steps: 1) data collection and preparation; 2) quantification of ceramic variation; and 3) mapping. Data was organised and analysed using the R language program (R

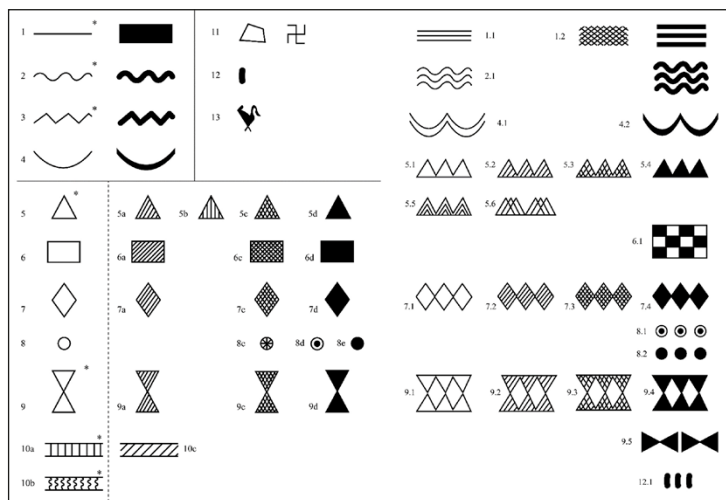


Fig. 3 – Sample of decorative traits analysed in this paper.

CORE TEAM 2020) and the ArcGIS 10.8.2 platform (ESRI 2021)<sup>1</sup>. This paper presents only the analysis of decorative traits – thus excluding shapes – for the period between 1950 and 1750 BCE (i.e., MBA I, Middle Bronze Age I).

### 3.1 Data collection and preparation

The re-evaluation of legacy pottery data included the scrutiny of approximately 300 publications, either preliminary excavation reports, final studies, or specialist contributions, written in several languages (e.g., English, Italian, French, Turkish, German, Japanese, Armenian, Azeri, and Russian). This allowed the identification of 51 sites yielding 67 MBA I site phases and 132 pottery decorative characteristics analytically and chronologically relevant (Fig. 3). This information was organised in a relational dataset. Excavated sites were univocally classified by assigning unique IDs. Other fields included site location (if not explicitly published, coordinates were obtained by visual detection on Google Earth Pro), cultural affiliation (membership to specific cultural groups as defined by archaeologists) and chronological details (relative or absolute dating) (Fig. 4a). Site phases - i.e., ‘PhaseCode’ in the matrices

<sup>1</sup> As this research is part of my doctoral work, codes and models will be published in open access once the embargo on the dissertation expires. To enhance data reusability, the dataset used will be published according to the FAIR (Findable, Accessible, Interoperable, Reusable) principles (WILKINSON *et al.* 2016). Hence, data will be assigned a globally unique and persistent identifier (DOI), stored in a freely accessible repository (Apollo, University of Cambridge), and released with a clear and accessible data usage licence (CC BY 4.0).

PhaseCode	SiteID	SiteName	AncientName	ARCANE_Region	CultureCode	Site_Type	Lat	Long	EarliestDateBCE	LatestDateBCE	Median	calibrated	References
TM-PaII	15	Tell Mozan	Urkesh	Jezirah	NME	S	37.05698	40.996939	2192	1900	2046	0	Orsi 2011; Schmidt 2011
ATS	35	Artashavan	NA	S Caucasus	MXC	B	40.387861	44.39313	2200	1850	2025	0	Avetisyan and Bobok 2010
KSH-Early	46	Karashamb	NA	S Caucasus	MXC	B	40.398213	44.571129	2200	1850	2025	0	Avetisyan and Bobok 2010
LCS-Early	49	Lachashen	NA	S Caucasus	MXC	B	40.509944	44.936488	2200	1850	2025	0	Avetisyan and Bobok 2010
NKN	52	Nerkin Naver	NA	S Caucasus	MXC	B	40.303423	44.316007	2200	1850	2025	0	Avetisyan and Bobok 2010
SSN	57	Sisian II	NA	S Caucasus	MXC	B	39.538533	45.017827	2200	1850	2025	0	Avetisyan et al 2000;
TRL-I	59	Trialeti	NA	S Caucasus	MXC	B	41.496155	44.163618	2200	1850	2025	0	Robinson 1976
TB-P	11	Tell Barri	Kahat	Jezirah	NME	S	36.738944	41.127137	2150	1900	2025	0	Orsi 2011
TBR-IL	12	Tell Brak	Nagar	Jezirah	NME	S	36.667392	41.058654	2000	1950	1975	0	Oates et al 2001
KT-C2	20	Kenan Tepe	NA	Tigridian	UTV	S	37.830628	40.813256	2040	1880	1960	1	Parker and Dodd 2000
TBL-IV	3	Tell Billa	NA	Tigridian	NME	S	36.433793	43.348275	2100	1800	1950	0	Speiser 1933
KT-Early	47	Keti I	NA	S Caucasus	MXC	B	40.884361	43.829889	2100	1800	1950	0	Badalyan and Avetisyan 2010
KH-S	19	Kavusan Höyük	NA	Tigridian	UTV	S	37.824706	40.717198	2150	1900	1975	0	Kozbe 2013
TA-PaII	10	Tell Arbid	NA	Jezirah	NME	S	36.872364	41.021558	2006	1880	1943	1	Kolinska 2014; Pienko 2014
IH-14	27	Imikunagi	NA	U Euphrates	UPE	S	38.1705	38.443492	2000	1850	1925	0	Sevin 1988
MD-IX	9	Tell Muhammed Diyab	Azambul (?)	Jezirah	NME	S	36.924565	41.563995	2000	1900	1950	0	Falvre and Nicolle 2010
GC-AD	18	Giricano Tepe	Dunnu-Sha-Uzibi	Tigridian	UTV	S	37.816948	40.748809	2000	1800	1900	0	Schachner 2002
ST-4	21	Salat Tepe	NA	Tigridian	UTV	S	37.839466	40.90169	2000	1800	1900	0	Oksa 2012, 2014, 2015
KRC-G	29	Korcutepe	NA	U Euphrates	UPE	S	38.594481	39.517828	2000	1800	1900	0	Winn 1980

a

PhaseCode	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18
TM-PaII	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	1	1	0
ATS	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
KSH-Early	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
LCS-Early	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
NKN	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0
SSN	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
TRL-I	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
TB-P	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
TBR-IL	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0
KT-C2	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	1	1	0
TBL-IV	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	1	0
KT-Early	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
KH-S	0	0	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
TA-PaII	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0
IH-14	1	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	0
MD-IX	0	0	0	0	0	0	0	1	0	0	0	0	1	0	1	1	1	0
GC-AD	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
ST-4	1	0	1	1	0	0	0	0	0	0	0	1	1	0	0	1	0	0
KRC-G	0	0	0	0	0	0	1	1	1	1	1	1	0	1	1	0	0	0

b

Fig. 4 – Snapshots of the dataset organisation: a) site information and b) presence-absence matrix (PAM).

and unique identifiers for each level at a site – were then associated with the stylistic traits in a presence-absence matrix (PAM) with site phases as rows and attributes as columns. Here, each trait's presence or absence (respectively, 1 and 0 values) could be registered for each site phase (Fig. 4b).

### 3.2 Quantification of ceramic variation

Using the 'vegan' package in R (OKSANEN *et al.* 2022), Jaccard distance was computed on the PAM to quantify how individual sites differed in stylistic traits. Jaccard distance measures the dissimilarity between a pair of samples: the result is a symmetric matrix of sites with zeroes on the diagonal and numerical indices ranging between 0 (identical shared traits) and 1 (complete dissimilarity with no shared attributes) on the other fields (Fig. 5). Compared to other distance measures, the Jaccard distance is handy for archaeological data as it ignores shared absent values (SHENNAN 1988, 203). In partial archaeological datasets, in fact, the absence of attributes does not necessarily imply that those were not used at the site but that perhaps they have not been found yet. This, together with the assumption that all traits are

	TM-PAII	ATS	KSH-Early	LCS-Early	NKN	SSN	TRL-I	TB-P	TBR-IL	KT-C2	TBL-IV	KT-Early	KH-S	TA-PIII	IH-14	MD-IX	GC-AD
TM-PAII	0	1	0.939394	0.741935	0.90625	0.875	0.870968	0.733333	0.807692	0.730769	0.583333	0.96	0.965517	0.56	0.857143	0.464286	0.916667
ATS	1	0	0.833333	0.875	0.833333	0.928571	0.923077	1	1	1	1	1	1	1	1	0.9	1
KSH-Early	0.939394	0.833333	0	0.555556	0.625	0.647059	0.842105	0.913043	0.9	0.956522	0.864865	0.866667	1	1	1	0.965517	1
LCS-Early	0.741935	0.875	0.555556	0	0.631579	0.578947	0.631579	0.791667	0.9	0.956522	0.864865	0.866667	1	0.92	1	0.866667	0.9375
NKN	0.90625	0.833333	0.625	0.631579	0	0.466667	0.705882	0.913043	0.941176	1	0.914286	0.916667	1	0.954545	1	0.928571	1
SSN	0.875	0.928571	0.647059	0.578947	0.466667	0	0.722222	0.869565	0.892353	0.95	0.852941	0.923077	0.941176	0.909091	1	0.931034	0.923077
TRL-I	0.870968	0.923077	0.842105	0.631579	0.705882	0.722222	0	0.913043	0.875	0.947368	0.914286	0.818182	1	0.904762	1	0.928571	0.916667
TB-P	0.733333	1	0.913043	0.791667	0.913043	0.869565	0.913043	0	0.833333	0.789474	0.891892	1	0.823529	0.916667	0.9	0.821429	0.857143
TBR-IL	0.807692	1	1	0.9	0.941176	0.882353	0.875	0.833333	0	0.769231	0.866667	1	1	0.733333	0.846154	0.869565	0.875
KT-C2	0.730769	1	1	0.956522	1	0.95	0.947368	0.789474	0.769231	0	0.8	1	0.846154	0.6	0.692308	0.666667	0.777778
TBL-IV	0.583333	1	0.944444	0.864865	0.914286	0.852941	0.914286	0.891892	0.866667	0.8	0	0.964286	0.935484	0.655172	0.833333	0.5625	0.964286
KT-Early	0.96	1	0.916667	0.866667	0.916667	0.923077	0.818182	1	1	1	0.964286	0	1	1	1	1	1
KH-S	0.965517	1	1	1	1	0.941176	1	0.823529	1	0.846154	0.935484	1	0	1	1	0.958333	0.857143
TA-PIII	0.56	1	1	0.92	0.954545	0.909091	0.904762	0.916667	0.733333	0.6	0.655172	1	1	0	0.75	0.590909	0.923077
IH-14	0.857143	0.9	1	1	1	1	1	1	0.9	0.846154	0.692308	0.833333	1	1	0.75	0	0.826087
MD-IX	0.464286	1	0.965517	0.866667	0.928571	0.931034	0.928571	0.821429	0.869565	0.666667	0.5625	1	0.958333	0.590909	0.826087	0	0.95
GC-AD	0.916667	1	1	0.9375	1	0.923077	0.916667	0.857143	0.875	0.777778	0.964286	1	0.857143	0.923077	1	0.95	0

Fig. 5 – Snapshot of the Jaccard dissimilarity matrix.

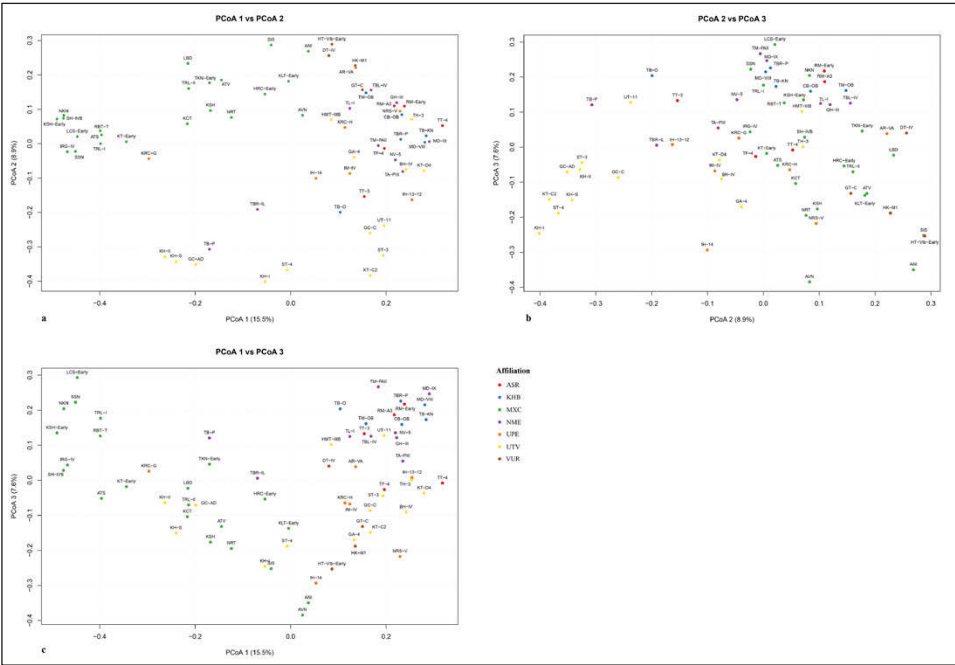


Fig. 6 – Plots showing the results of the first three PCoA axes.

independent from the cultural affiliation attributed by archaeologists, makes the Jaccard distance a powerful tool for analysing archaeological inter-site dissimilarity (SHENNAN *et al.* 2015).

At this step, multivariate analytical techniques can be implemented to explore and visualise individual or group differences (WILKINSON, EDDS 2001). This study used Principal Coordinate Analysis (PCoA), an ordination

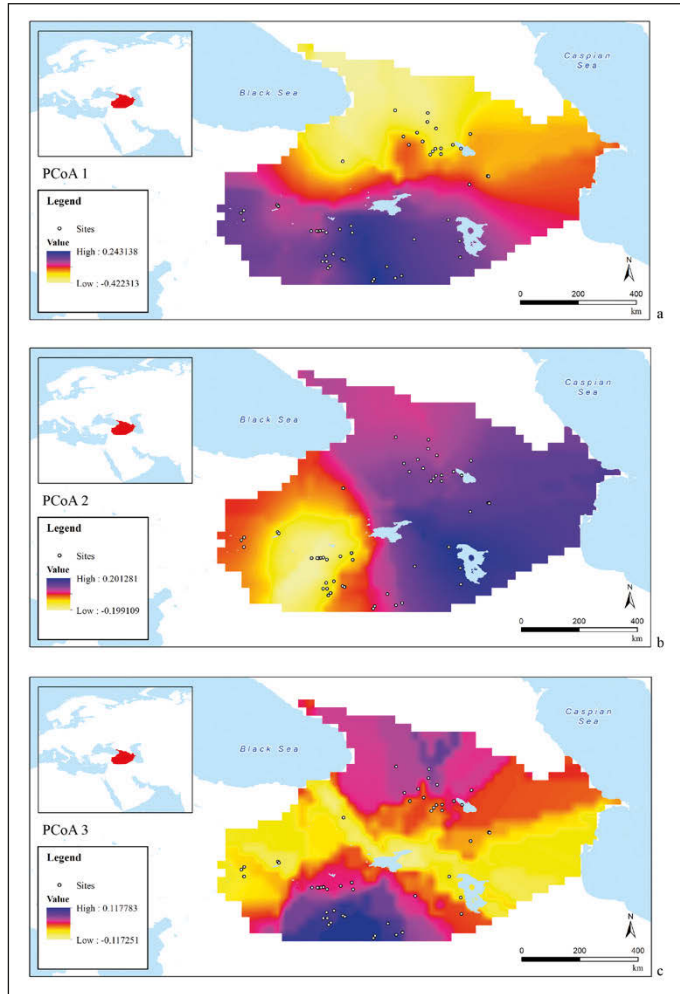


Fig. 7 – Interpolated maps using Ordinary Kriging showing the geographic representation of the first three PCoA axes. Similar colours describe similar values in cultural variation.

technique applicable when analysing binary data and based on an eigenvalue equation, that allows the display of how much ‘dissimilar’ sites are to one another based on several variables simultaneously (GOWER 1966). PCoA finds the ‘principal’ axes explaining variation through a distance (e.g., Jaccard) matrix and then plots these axes against each other in a low-dimensional Euclidean space (ZUUR *et al.* 2007, 259-264). In this space, sites ordinated

closer together have smaller dissimilarity values than those ordinated further apart. Here, PCoA was computed through the ‘stats’ (R CORE TEAM 2020) and ‘ape’ (PARADIS, SCHLIEP 2019) packages in R.

One can visually understand between-site differences by plotting and contrasting PCoA axes (Fig. 6). For our case study, only the first PCoA three axes are considered. These explain 32% of the overall ceramic variation. The plots show a weak regionalisation, with only sites of the southern Caucasus being dissimilar from the other cultural groups, which instead tend to be closer or overlap. This might be related to high mobility, exchange, or assimilation phenomena that favoured the spread of ceramic traits in these regions (e.g., the Old Assyrian Trade Network in northern Mesopotamia).

### 3.3 Mapping

After obtaining the scores of the PCoA axes, geostatistical maps were created in ArcGIS through interpolation methods to display better cultural variation. This paper applied ordinary kriging (OK), which is based on the spatial arrangement of empirical observations to estimate the value of a variable over a continuous spatial field (e.g., DIVÍŠEK *et al.* 2016). In this sense, using PCoA axes, OK informs us on how varied the cultural landscape is, also providing the probability of how much variation is at a non-sampled specific location. The outputs are several maps, each for a single PCoA axis, visualising a fraction (15.5%, 8.9%, and 7.6%) of ceramic variation predicted for the areas that were not sampled (Fig. 7). In this case as well, results show a heterogeneous landscape, with only a main N-S distinction in terms of ceramic diversity.

## 4. CONCLUSIONS AND FURTHER DIRECTIONS

PCoA performed on the pottery-based dissimilarity distance matrix and OK interpolation allowed a nuanced visualisation of the ceramic variation in decorative traits of the Northern Lands during the MBA I. Geostatistical maps in Fig. 7 visualise only a fraction (32%) of the overall diversity, highlighting that the distribution of pottery attributes is far less static than commonly represented in distribution maps. Hence, such maps show the dynamic and complex essence of cultural phenomena, which cannot be encapsulated into one cartographic device.

More importantly, geostatistical map-making addresses some of the limitations of conventional distribution maps. First, our data-driven approach considers both similarities and differences within ceramic assemblages, thus avoiding the ‘similarity primacy’. Secondly, it predicts values in blank areas based on measured variation at sampled sites. In this sense, it shows a less homogeneous cultural landscape, hinting at areas that could have served as boundary or ‘mixing’ zones.



The approach presented here opens possibilities for further investigation: for instance, analysis can attempt to reassess the existence or extent of ceramic cultures and their boundaries; test the dataset for spatial correlation to build hypotheses on the socioeconomic, cultural, or environmental factors that may generate the variation patterns; check individual site behaviour to acquire information on whether a site was prone to share or isolate a specific ceramic trait. Through these efforts, our study advances archaeological methods and deepens our understanding of past societies within the Northern Lands during the Middle Bronze Age phase.

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## REFERENCES

- ALDRED O., LUCAS G. 2018, *The map as assemblage: Landscape archaeology and mapwork*, in M. GILLINGS, P. HACIGÜZELLER, G. LOCK (eds.), *Re-Mapping Archaeology Critical Perspectives, Alternative Mappings*, London, Routledge, 19-36.
- AURENCHÉ O., KOZŁOWSKI S.K. 2011, *Archaeology and cartography: In search of prehistoric cultures in the Neolithic Near East*, in B.W. ROBERTS, M. VANDER LINDEN (eds.), *Investigating Archaeological Cultures: Material Culture, Variability, and Transmission*, London, Springer, 271-287.
- BABIĆ S. 2007, *Greeks, barbarians and archaeologists: Mapping the contact*, «Ancient West and East», 6, 73-89 (<https://doi.org/10.2143/awe.6.0.2022794>).
- BAYSAL A. 2012, *Doğu Anadolu Arkeolojisinde Göçebelik ve Yaylacılık Kültürü (MÖ II. Bin): Veriler Işığında Yeni Düşünceler*, «Uludağ Üniversitesi Fen-Edebiyat Fakültesi Sosyal Bilimler Dergisi», 13, 23, 255-268 (<https://dergipark.org.tr/tr/download/article-file/214275>).
- CHILDE G.V. 1929, *The Danube in Prehistory*, Oxford, Clarendon Press.
- CRELLIN R. 2020, *Change and Archaeology*, London-New York, Routledge.
- DIVÍŠEK J., CULEK M., ŠTASTNÝ K., ANDĚRAET M. 2016, *Biogeographical patterns in vertebrate assemblages of the Czech Republic: Regional division in the context of species' distributions in Europe*, «Journal of Vertebrate Biology», 65, 3, 169-182 (<https://doi.org/10.25225/fozo.v65.i3.a1.2016>).
- ESRI 2021, *ArcGIS Desktop: Release 10.8.2*, Redlands, CA, Environmental Systems Research Institute.
- GOWER J.C. 1966, *Some distance properties of latent root and vector methods used in multivariate analysis*, «Biometrika», 53, 3/4, 325-338 (<https://doi.org/10.2307/2333639>).
- HODDER I. 1977, *Spatial studies in archaeology*, «Progress in Human Geography», 1, 1, 33-64 (<https://doi.org/10.1177/030913257700100104>).
- JOHNSON M. 2020, *Archaeological Theory: An Introduction*, Third Edition, Hoboken, NJ, Wiley-Blackwell.
- KRAMER C. 1977, *Pots and People*, in L.D. LEVINE, T. CUYLER YOUNG JR. (eds.), *Mountains and Lowlands: Essays in the Archaeology of Greater Mesopotamia*, Bibliotheca Mesopotamica 7, Malibu, Undena Publications, 91-112.
- OKSANEN F.J. et al. 2022, *Vegan: Community Ecology Package*, R package Version 2.6-4 (<https://CRAN.R-project.org/package=vegan>).
- ÖZİFİRAT A. 2001, *Doğu Anadolu Yayla Kültürleri (M.Ö. II. Binyıl)*, İstanbul, Kanaat Basımevi.

- PALUMBI G. 2008, *The Red and Black: Social and Cultural Interaction between the Upper Euphrates and the Southern Caucasus Communities in the Fourth and Third Millennium BC*, Studi di Preistoria Orientale 2, Roma, Università di Roma 'La Sapienza'.
- PARADIS E., SCHLIEP K. 2019, *Ape 5.0: An environment for modern phylogenetics and evolutionary analyses in R*, «Bioinformatics», 35, 526-528 (<https://doi.org/10.1093/bioinformatics/bty633>).
- R CORE TEAM 2020, *R: A language and environment for statistical computing*, Vienna, R Foundation for Statistical Computing (<https://www.R-project.org/>).
- ROVA E. 1988, *Distribution and Chronology of the Nineveh 5 Pottery and of its Culture*, Contributi e materiali di Archeologia Orientale II, Roma, Università di Roma 'La Sapienza'.
- SAGONA A. 2011, *Anatolia and Trans-Caucasus: Themes and Variations, ca. 6400-1500 B.C.E.*, in S.R. STEADMAN, G. MCMAHON (eds.), *The Oxford Handbook of Ancient Anatolia (10,000-323 BCE)*, Oxford-New York, Oxford University Press, 683-703.
- SAGONA A. 2018, *The Archaeology of Caucasus: From Earliest Settlements to the Iron Age*, New York, Cambridge University Press.
- SHENNAN S.J. 1988, *Quantifying Archaeology*, Edinburgh, Edinburgh University Press; San Diego, Academic Press Inc.
- SHENNAN S.J., CREMA E.R., KERIG T. 2015, *Isolation-by-distance, homophily, and “core” vs. “package” cultural evolution models in Neolithic Europe*, «Evolution and Human Behavior», 36, 2, 103-109 (<https://doi.org/10.1016/j.evolhumbehav.2014.09.006>).
- WEBSTER G.S. 2008, *Culture history: A culture-historical approach*, in R.A. BENTLEY, H.D.G. MASCHNER, C. CHIPPINDALE (eds.), *Handbook of Archaeological Theories*, Lanham, MD, AltaMira, 11-27.
- WHEATLEY D., GILLINGS M. 2000, *Vision, perception, and GIS: Developing enriched approaches to the study of archaeological visibility*, in G. LOCK (ed.), *Beyond the Map: Archaeology and Spatial Technologies*, Amsterdam, IOS Press, 1-27.
- WILKINSON C.D., EDDS D.R. 2001, *Spatial Pattern and environmental correlates of a mid-western stream fish community: Including spatial autocorrelation as a factor in community analyses*, «American Midland Naturalist», 146, 271-289 ([https://doi.org/10.1674/0003-0031\(2001\)146\[0271:SPAECO\]2.0.CO;2](https://doi.org/10.1674/0003-0031(2001)146[0271:SPAECO]2.0.CO;2)).
- WILKINSON M.D. et al. 2016, *The FAIR Guiding Principles for scientific data management and stewardship*, «Scientific Data», 3, 160018 (<https://doi.org/10.1038/sdata.2016.18>). Addendum: 2019, *The FAIR Guiding Principles for scientific data management and stewardship*, «Scientific Data», 6, 6 (<https://doi.org/10.1038/s41597-019-0009-6>).
- ZUUR A.F., IENO E.N., SMITH G.M. 2007, *Analysing Ecological Data. Statistics for Biology and Health*, New York, Springer.

## ABSTRACT

This paper challenges conventional mapping methods of Bronze Age ceramic variation in western Asian archaeology, which often oversimplify the complexity of cultural phenomena. Drawing on geostatistical techniques, we propose a novel approach that considers both similarities and differences in ceramic traits. By incorporating Principal Coordinate Analysis (PCoA) and kriging interpolation techniques, our methodology aims to provide a nuanced representation of pottery distribution, moving beyond static cultural-historical mapping. We argue that this approach offers a more comprehensive understanding of archaeological landscapes by acknowledging the diversity of pottery variation. Through a case study utilising legacy pottery data – which will be published in the future according to the FAIR principles – we demonstrate the practical application and potential insights of our methodology, which seeks to advance archaeological methods and contribute to a richer interpretation of the past.

## LEGACY DATA OR JUST ARCHAEOLOGICAL DATA?

### 1. INTRODUCTION

The proliferation of digital information resources is generating a phenomenon in every field of human knowledge commonly identified as ‘datafication’ (MAYER-SCHONBERGER, CUKIER 2013). Originally, the concept described the tendency to transform every aspect of life into data. Later, the term was used to define behaviours that pushed towards greater automation in handling large collections of data. ‘Data is the new oil’ has become over time the paradigm of information players (Google, Microsoft, Amazon, etc.) that produces added value on data collection and exploitation. The introduction of Big Data and, more generally, the need to train models for artificial intelligence, have modified the initial idea of ‘datafication’, which today coincide with a particular method of seeing, representing, discovering, and exploring information. Thus, data is replacing the methodologies aimed at producing, managing, and interpreting them.

The diffusion and use of data in different fields, such as scientific and educational, have led to a paradigm shift characterized by intensive data use and the possibility of automatically extracting and inferring knowledge from a vast collection of digital documents (HEY, TANSLEY, TOLLE 2009). This new form of science, based on the fundamental activity of capturing, curating, and analysing data, aims not to propose simulative models but to enable the scientific exploration of nearly infinite collections of records available online, enhancing the analytical potential of each researcher. To access the materials needed for their research, researchers should sift through a digital library characterized by volumes, articles, reports, tables, images, drawings, photographs, sorted according to different standards, different languages, etc., and especially without a careful librarian capable of preserving memory and trace of the contents. Computational sciences increasingly support online research through the development of hardware and software systems aimed at integrating resources on the web, overcoming data fragmentation and heterogeneity; despite the encouraging technological innovations, many of the proposed solutions are partial and not entirely conclusive.

A significant impetus to the automatic processing of large amounts of data comes primarily from the implementation of new ‘intelligence’ techniques aimed at countering international terrorism through a broader sharing of decentralized databases (9/11 COMMISSION REPORT, 2004). The need to increase the quality of data traffic control on the Internet, often consisting

of unstructured information, has accelerated the development of algorithms capable of constructing aggregations of suspicious data (BILTGEN, RYAN 2015).

The challenge in collecting and analysing data is assuming a central role in the relationship between emerging technologies, raw information available online, and the automatic extraction of content that can be grouped together. Innovation, therefore, looks towards a new interdisciplinary interaction aimed at overcoming the thin boundary between physical and virtual reality. Archaeological research has also been impacted by an explosion of digital data, digitised or digitalized data from new and recent discovery or from old archives. More generally, information technology has caused such a change in researchers' attitudes that it is thought that all archaeologists have become digital, although differences persist in skills and in access to and use of data (MORGAN, EVE 2012). This contribution aims to explore a particular aspect in the process of re-elaborating digital data in archaeological research, namely that of legacy spatial data, which more generally we can identify in previous studies, digital or paper, structured or unstructured, often built with now outdated methodological approaches.

## 2. DATA VS DATAFICATION IN ARCHAEOLOGY

Archaeological data plays a central role in research to the extent that we speak of the formation of the archaeological record to indicate which processes have produced that trace that the archaeologist subsequently records. While the theoretical and methodological debate seems to oscillate between very divergent opinions on the nature of excavation and its related archaeological documentation, some fixed points can be noted. Archaeology is characterized by poorly defined variables, often mistakenly thought of as data, derived from populations not always fully understood and from uncertain articulations between the entities whose logical relationships we seek to understand (CHIPPINDALE 2000). Archaeological research often moves in a marshy terrain characterized by uncertain boundaries, stagnant waters, muddy soil, and with a particular vegetation and fauna. For these reasons that M.B. SCHIFFER (1987) defines the archaeological record as the distorted reflection of an object that was once part of a more comprehensive behavioural system that we only partially reconstruct. According to I. HUVILA (2017), data can be recorded and organized from a dozen different perspectives, and to emphasize the ambiguous and misleading nature of the variable in archaeological documentation, he coined the term MEAN (Miscellaneous Exceptional Arbitrary Nonconformist).

Examining the consistency of the digital archaeological record, J. HUGGETT (2022) has recently listed some of the main incongruities that can be synthesized as follows:

A – Tables, databases, relationships, texts can be incorporated within a structured data model, reducing variability, or eliminating those descriptive elements that do not fit the schema;

B – Raw data can be set aside in favour of processed data sets. The distinctions between primary, secondary, and tertiary data are lost by eliminating the distinction from what was originally collected to what was subsequently processed and interpreted;

C – The same data entities can be evidence of multiple phenomena.

Since data depends on the context of use and, at the same time, on users' beliefs, the results will always be highly complex, unstable, and unpredictable. All the cautions expressed by researchers about digital data and their use should warn archaeologists against uncritically accepting algorithms capable of automatically processing and aggregating large amounts of data. Only careful analysis of the entire digitization process can truly innovate the approach to excavation (ROOSEVELT *et al.* 2015), contributing, together with the increase in tools and sensors for data acquisition, to a paradigm shift (HUGGETT 2015; SCHMIDT, MAVERICK 2020). In the future, digitalization will simplify the work of archaeologists, who will be able to focus on examining more general and theoretical issues rather than organizing data. Despite the optimistic forecasts, outside of this promising scenario will remain the past excavations that preserve paper data or collections of digital records coded with old programs and according to outdated methods.

### 3. LEGACY SPATIAL ARCHAEOLOGICAL DATA

HUGGETT (2018) has pointed out how the reuse of digital archives involves data aggregation that creates new values, which at the end of the process, however, can be more ambiguous and less transparent (CLARKE 2016) in the absence of precise contextual data. The choice to use metadata and paradata associated with archives certainly contributes to increasing data understanding; however, the inherently unstable nature of any data integration process makes the Big Data scenario an objective with uncertain outcomes. Processing large amounts of archaeological records from different excavations and research necessarily entails a reconsideration of data recording methods and archive creation. Such caution necessarily increases when spatial data acquired at different times and with different methodologies are reused.

A trend towards the adoption of automated computer means to make efficient and effective use of large data sets was already present at the end of 1980s (KVAMME 1989). The pioneering use of databases to store and process large amounts of data was replaced by GIS systems, while in the same

years CAD was established for the realization of topographic drawings and graphic documentation of excavations, allowing for rapid updating of plans and stratigraphy (ALPERSON-AFIL 2019). The parallel development of GIS and CAD technologies, both based on a common numerical representation of information, has pushed industries towards greater integration between the two systems. However, despite the development of interoperable formats, migrating CAD drawings to GIS requires specific conceptualization, making automatic conversion impossible. Adapting CAD files for GIS applications, therefore, remains a challenging task, impossible to complete without substantial human intervention (BIBBY, DUCKE 2017). The difference between the two systems lies in the connection between geometric entities and the alphanumeric information associated with them. In particular, CAD produces complex graphical maps but ignores the non-spatial attributes associated with graphic entities. Therefore, reusing CAD data in GIS requires a reorganization of geometric and spatial information based on the identification and construction of objects that transform geometric primitives into semantic categories (walls, rooms, streets, buildings, etc.).

A test, conducted for the implementation of a GIS for the archaeological site of al-Balīd, ancient Zafar, in the Sultanate of Oman, confirmed the difficulty in designing and creating an automatic path for importing and managing a previous cartographic archive consisting mainly of CAD maps. Over the last 70 years, several teams have investigated the area of Zafar, an important Islamic-period maritime stopover located along the routes crossing the Indian Ocean (D'ANDREA 2021). In 1995, a German mission, led by M. JANSEN (2015), was tasked with creating the archaeological park of the site. At the end of the work, a substantial digital archive was produced, including dozens of CAD files reproducing the archaeological area. In 2019, a research group from the University of Naples L'Orientale resumed investigations in the area with the aim, among others, of systematizing previous research and creating a GIS that would collect previous site plans and drawings. The review of the CAD archive started from the analysis of the survey of the Great Mosque, with the aim of verifying the accuracy of spatial information and the possible migration to GIS. The table associated with the spatial information present in QGIS lists 245 vectors that are not convertible automatically into architectural and structural elements of the religious building without human intervention. Only by reading the excavation reports is it possible to correctly identify the individual components of the mosque (walls, columns, stairs, thresholds, etc.) and build the corresponding objects in the GIS, referring, in some parts, to distinct phases of the structure's life cycle. The design of the GIS inevitably pushed towards a re-reading of the entire cartographic archive and, above all, of all the available archaeological documentation (graphic, photographic, and textual).



#### 4. CONCLUSION

The experience gained in the project of converting the graphic archive of al-Balid, however partial, confirms the impossibility of designing an automatic treatment for the migration of CAD files into a GIS environment. The Archaeology Data Service has initiated a large-scale migration process of CAD files without, however, foreseeing a specific method for reusing digital drawings in different software and applications (GREEN *et al.* 2016).

The challenge for a correct conversion of plans, sections, and elevations must start from the identification of represented objects and not simple graphical entities. The category of spatial legacy data must be treated in the same way as a traditional cartographic archive, requiring a reading, also methodological, of all existing documentation. Only by following this path is it possible to correctly interpret the information drawn by the archaeologist, regardless of the format used, paper or CAD.

In the future, artificial intelligence will certainly provide new tools to automatically associate digital or handwritten texts with plans, making all this documentation readable by a machine (FLETCHER 2023). However, pending the transformation of legacy data into ‘reborn digital data’, we still need to rely on the traditional methodology of spatial information processing, which places human experience at the centre of analysis.

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#### REFERENCES

- ALPERSON-AFIL N. 2019, *Digitising the undigitized: Converting traditional archaeological records into computerized, three-dimensional site reconstruction*, «Journal of Graphic Information System», 11, 747-765 (<https://www.scirp.org/journal/paperinformation?paperid=97426>).
- BIBBY D., DUCKE B. 2017, *Free and open-source software development in archaeology. Two interrelated case studies: gvSIG CE and Survey2GIS*, «Internet Archaeology», 43 (<https://doi.org/10.11141/ia.43.3>).
- BILTGEN P., RYAN S. 2015, *Activity-Based Intelligence: Principles and Applications*, Boston-London, Artech House.
- CHIPPINDALE C. 2000, *Capta and data: On the true nature of archaeological information*, «American Antiquity», 65, 4, 605-612.
- CLARKE R. 2016, *Big data, big risks*, «Information Systems Journal», 26, 77-90 (<https://doi.org/10.1111/isj.12088>).
- D’ANDREA A. 2021, *Reconsidering the topography of al-Balid: A preliminary review of the graphical documentation*, «Annali Sezione Orientale», 81, 39-50 (<https://doi.org/10.1163/24685631-12340110>).
- FLETCHER E.C. 2023, *Creating a software methodology to analyze and preserve archaeological legacy data*, «Advances in Archaeological Practice», 11, 2, 139-151 (<https://doi.org/10.1017/aap.2022.44>).

- GREEN K., NIVEN K., FIELD G. 2016, *Migrating 2 and 3D datasets: Preserving AutoCAD at the Archaeology Data Service*, «ISPRS International Journal of Geo-Information», 5, 44 (<https://doi.org/10.3390/ijgi5040044>).
- HEY T., TANSLEY S., TOLLE K. (eds.) 2009, *The Fourth Paradigm: Data-Intensive Scientific Discovery*, Washington, Microsoft Research.
- HUGGETT J. 2015, *Challenging digital archaeology*, «Open Archaeology», 1, 1, 79-85 (<https://doi.org/10.1515/opar-2015-0003>).
- HUGGETT J. 2018, *Reuse remix recycle: Repurposing archaeological digital data*, «Advances in Archaeological Practice», 6, 2, 93-104 (<https://doi.org/10.1017/aap.2018.1>).
- HUGGETT J. 2022, *Data legacies, epistemic anxieties, and digital imaginaries in archaeology*, «Digital», 2, 2, 267-295 (<https://doi.org/10.3390/digital2020016>).
- HUVILA I. 2017, *Being FAIR. When archaeological information is MEAN: Miscellaneous, exceptional, arbitrary, nonconformist*, Presentation at the Centre for Digital Heritage Conference (Leiden 2017) (<http://www.istohuvila.se/node/526>).
- KVAMME K. 1989, *Geographic Information Systems in regional archaeological research and data management*, in M.B. SCHIFFER (ed.), *Archaeological Method and Theory*, 1, Tucson, University of Arizona Press, 139-203.
- JANSEN M. 2015, *The archaeological park of Al-Baleed, Sultanate of Oman. Site atlas along with selected Technical Reports 1995-2001*, Muscat, Office of the Adviser to His Majesty the Sultan for Cultural Affairs.
- MAYER-SCHONBERGER V., CUKIER K. 2013, *Big Data: A Revolution That Will Transform How We Live, Work, and Think*, New York, Houghton Mifflin Harcourt.
- MORGAN C., EVE S. 2012, *DIY and Digital Archaeology: What are you doing to participate?*, «World Archaeology», 44, 4, 521-537.
- ROOSEVELT C. H., COBB P., MOSS E., OLSON B.R., ÜNLÜSOY S. 2015, *Excavation is destruction digitization: Advances in archaeological practice*, «Journal of Field Archaeology», 40, 3, 325-346 (<https://doi.org/10.1179/2042458215Y.0000000004>).
- SCHIFFER M.B. 1987, *Formation Processes of the Archaeological Record*, Albuquerque, University of New Mexico.
- SCHMIDT S.C., MARWICK B. 2020, *Tool-driven revolutions in archaeological science*, «Journal of Computer Applications in Archaeology», 3, 1, 8-32 (<https://doi.org/10.5334/jcaa.29>).
- The 9/11 Commission Report: Final Report of the National Commission on Terrorist Attacks upon the United States*, 2004, Washington, Government Printing Office (<https://www.govinfo.gov/content/pkg/GPO-911REPORT/pdf/GPO-911REPORT.pdf>).

## ABSTRACT

The world of research is currently undergoing a profound transformation, characterized by the extensive use of digital data available online. To optimize the utilization of these resources, artificial intelligence offers researchers several tools capable of aggregating both structured and unstructured information. The need to train algorithms to enhance the use of artificial intelligence techniques in data classification has led to the creation of structured datasets. However, it is not always possible to fully automate the transfer of data to more modern environments without substantial human intervention, aimed at extracting the implicit knowledge present in digital data. The category of CAD data appears to be particularly challenging in terms of automated management of spatial resources. The use of graphical entities for digital drawings, without semantically identified components, makes automatic conversion into GIS extremely complex. The paper is based on a partial test conducted on a cartographic archive that has been formed over 70 years of field research, aiming to demonstrate the importance of prioritizing legacy spatial data, both digital and non-digital, as archaeological data.

## INVESTIGATING RESILIENT ROMAN AGRICULTURAL LANDSCAPES IN SOUTHERN ITALY. AN INTEGRATED AND OPEN IT APPROACH TO MODELING CENTURIATION

### 1. INTRODUCTION

The Investigating Resilient Roman Agricultural Landscapes in Southern Italy (IN.RES.AGRI) project, funded by the Italian Government (PRIN 2022, project code 2022SMJCHX) is concerned with the analysis of the long-standing persistence and discontinuities of Roman rural topography, in order to understand how its components have survived throughout centuries embedded in the contemporary landscapes of Southern Italy. The rational management of space – above all for land reclamation to improve agricultural yield – is likely the main reason for the survival of the centuriated topography. However, this is not the only reason, especially in contexts that have maintained their rural vocation, as in Puglia, or that have undergone strong urbanization processes, as the suburbs of Naples. The Archaeological Mapping Lab of the University of Naples, together with the Labs of the Istituto di Scienze del Patrimonio Culturale (ISPC) of the CNR and the University of Salento, aim at optimizing our knowledge on Roman agricultural landscapes in Southern Italy through a holistic approach, integrating topographical, archaeological, environmental and textual data within an innovative data-science platform named Digital\_Groma.

Resilience of Roman agrarian landscapes will be inspected based on a set of aspects, such as *centuriatio*, routes network and settlement patterns systems (CASTAGNOLI 1958; SETTIS 1993). The project will focus on the systematic collection of legacy data (topographical, archaeological and textual data) and new evidence from the field in selected case study areas in Campania and Puglia (Fig. 1). Data regarding those case studies will populate an IT infrastructure able to inspect and visualize the relations linking contemporary landscapes and Roman agro-ecosystems through millennia.

R.B., V.F., I.R.

### 2. NEW METHODS FOR OLD QUESTIONS

The In.Res.Agri project aims at enhancing the knowledge on Roman agrarian landscapes in Southern Italy through an interdisciplinary, holistic approach integrating archaeological, geospatial, environmental and textual data. Therefore, the overview of the state of the art should necessarily consider a dual perspective, which can be summarized by the definition:

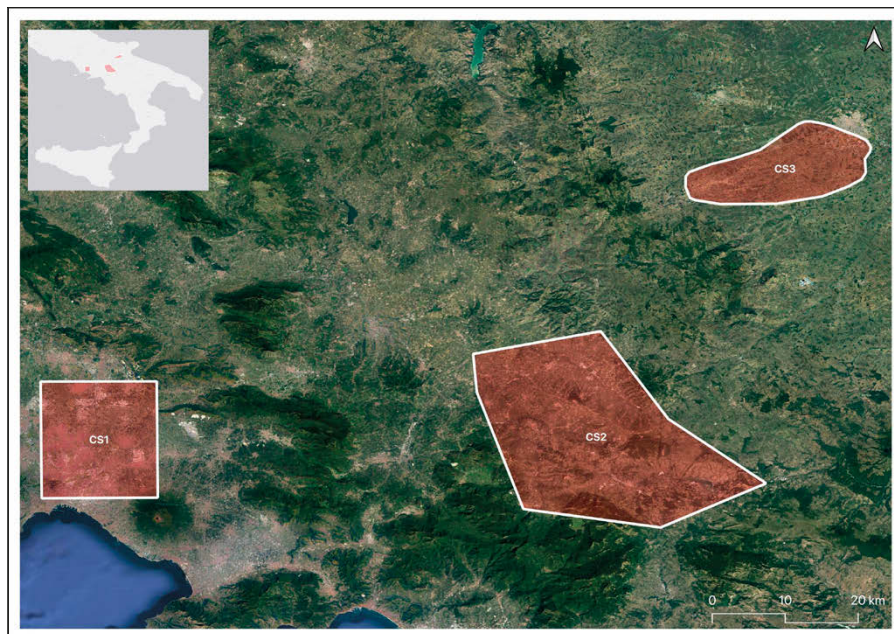


Fig. 1 – Distribution map of the case studies in the context of Southern Italy.

‘archaeogeography’ (ROBERTS 2011; BRIGAND 2015). From a topographical point of view, the interest in centuriated Roman landscapes and related literary sources highly increased during the 20<sup>th</sup> century (CASTAGNOLI 1958). In the following decades, the archaeological analysis of centuriations has been centred on the identification of traces present in the modern landscape that could morphologically refer to Roman times (MUZZIOLI 2009). During the 1980s, the Besançon Group developed a series of techniques aimed at identifying centuriated grid systems by their orientation and by the proportions of *centuriae* with modules based on multiples of the Roman *actus* (CLAVEL-LÉVÊQUE 1983; CHOUQUER *et al.* 1987).

These systems were mainly identified in the modern landscape by carto- and photointerpretation (GUAITOLI 2003). Although this approach, developed among Italian and French researchers, helped in identifying centuriations in France, Italy and other Mediterranean regions (DALL’AGLIO, ROSADA 2009), in some cases the hypotheses have proven to be controversial (ORENGO, MARTINEZ 2009), to be based on misunderstood finds (LIVERANI 1987), or to be the result of agrarian divisions of the modern or contemporary age (BRANCATO 2019). The failure to identify centuriated systems with certainty has sometimes resulted in the dismissal of photo-interpretation: this is due to the lack of a

consistent and interdisciplinary methodology; indeed, a solely topographical identification of centuriated field systems is an incomplete procedure which can lead to a continued dismissal of the discipline if not supported by the integrated use of geoarchaeology and data science (DALL'AGLIO, CAMPAGNOLI 1997; DALL'AGLIO 2009), as well as by analysis of territory's physical geography and its changes over time (QUILICI GIGLI 1997).

The current availability of remotely sensed images makes it urgent to develop automatic methods that can simplify their inspection and extraction, as the quantity of information is no longer manageable by traditional 'human' visual interpretation (TRAVIGLIA, TORSELLO 2017). The project's aim of deepening the knowledge on resilient centuriation grids and their relationship with contemporary landscapes fits perfectly with the innovative research approaches grounded on the development of cutting-edge computer methods and techniques applied to archaeological spatial research (BRANCATO 2019), for the understanding of the impact of the centuriation engineering projects on the environment and the reason for their persistence in the historical landscape. Today, landscape archaeology – or archaeogeography as some specialists prefer to call it (CHOUQUER 2008) – increasingly benefits from aerial and satellite remote-sensing techniques and spatial data-science analytical tools, to suggest new socio-dynamic configurations of ancient land organization.

In this, landscape archaeology finds support in geospatial information and GIS systems, which improve the integration of data acquisition, representation, and analysis activities in a virtual environment allowing archaeologists to centralise traditional investigation procedures, such as field surveys and lab data processing (MOSCATI 2017). The In.Res.Agri project is pioneering in combining new methods of topographic research, in which Artificial Intelligence and Machine Learning algorithms play an important heuristic role (LAMBERS *et al.* 2019; OLIVIER, VERSCHOOF-VAN DER VAART 2021), with the Open Science paradigm, which – in accordance with the EU's Open Science policy – fosters the implementation of services and tools to facilitate interoperability between open digital repositories (see, e.g., the European Open Science - EOSC portal; <https://eosc-portal.eu/>).

The history of automated archaeological object detection in remotely sensed data and automated map analysis is recent, but progress is already evident in the shift towards Machine Learning methods. The goal of collecting, managing and preserving rich digital contents in the long term, in open access environments, mainly refers to large integrated datasets recorded over a long period of time and now stored in *ad hoc* digital repositories (RICHARDS *et al.* 2021). By adopting this approach, tailored on a smaller scale, a well-established procedure will be followed, which envisages the merging of diversified resources, to be structured and tagged with metadata, with the aim of freeing up and sharing their scientific contents (ROSSI, PARACIANI 2021).



### 3. PROJECT'S AIMS AND CASE STUDIES

Based on these premises, the project specifically aims at: 1) creating a model that will define the Roman centuriation methods, theory and practice through a detailed analysis of topographic, geomatic, archaeological, environmental, iconographic and textual data in a specific geographical horizon (i.e. the Southern Italy corridor that goes from Campania to Puglia) and in a coherent chronological context (i.e. the Roman age); 2) interpreting the transformations implied by a rational land division and distribution, as is the case of those occurred in Roman Southern Italy, through a diachronic definition of how geomorphology, pre-existing routes network, and land reclamations interacted in the process of making Roman centuriation a highly resilient landscape element. Indeed, archaeological research in Italy has created a massive amount of data (archaeological maps) fundamental for interpreting, in light of anthropic and non-anthropocentric taphonomic processes (JACKSON, MOORE 2018), the relationship between centuriations and other landscape elements such as the roads system; 3) testing the integration of traditional survey methods and innovative technologies for the recovery, interpretation and restitution of topographical data; 4) contributing to the implementation of the Open Science paradigm, by making project data accessible for fruition by a larger public and available for reuse. Within the project, three selected areas where previous research highlighted the existence of centuriation will be used as case studies, with particular emphasis on the chronological phase going from 500 BC to 500 AD.

#### 3.1 *The central Campana Plain area*

As regards the first case study, the research will focus on a crucial sector of the Campania region, specifically the central-southern area of the Campanian alluvial plain where Atella was located (DI VITO *et al.* 2021, with references) (Fig. 2). This town, S of the Clanio river on the road connecting Neapolis and Capua, was surrounded by a rich agricultural territory. As highlighted by Stefania Quilici Gigli, it is necessary to consider the relationship between the cadastral system of Atella's territory (BENCIVENGA TRILLMICH 1984) and the *ager Campanus*, whose centuriation system is widely recognized by scholars (QUILICI GIGLI 2002, with references). As regard the *ager Atellanus*, its grid was identified in aerial imagery, together with the presumed centuriations of Acerra and Neapolis in 1987, and dated to the Augustan age due to module and orientation solely based on cartographic observation (CHOQUER *et al.* 1987). The recognition of the centuriation limits of the *ager Campanus*'s south-eastern portion – today belonging to the territory of Succivo and Orta di Atella – is still largely unsolved (SORICELLI 2001; MONACO 2004; MONACO, CLAVEL-LÉVÊQUE 2004).



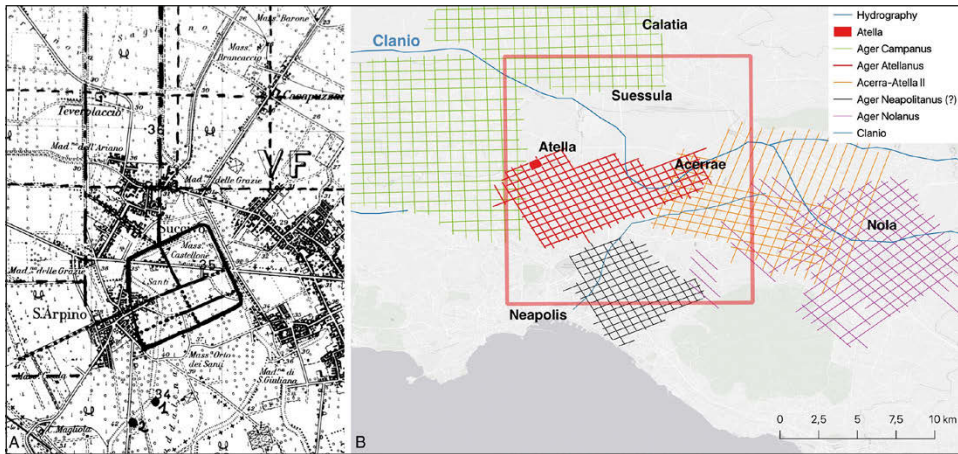


Fig. 2 – The site of Atella and its hypothesized cadastral layout (case study 1) plotted on a 1:25,000 scale topographic map (A) and within the broader context of Campania region (B).

Although it is certain that the main axis of the centuriation was linked to the urban plan of Atella, here located, little is known about the urban plan of the Roman *municipium* and the agrarian division of this sector of the plain. Traces detected in historical cartography and aerial photos point to the alleged existence, never verified on the field, of different superimposed agrarian systems, i.e. ‘Acerrae-Atella I’ (CHOQUER *et al.* 1987, 207, fig. 70; 226- 227, 252) and ‘Atella II’ (CHOQUER *et al.* 1987, 208-209, fig. 71, 228-229), whose topography is not consistent with that of the *ager Campanus*. Moreover, the cadastral system labelled as ‘Acerrae-Atella I’ was dated to the Augustan age only for its module and orientation (CHOQUER *et al.* 1987); recently its dating has been antedated to the second century BC (GIAMPAOLA 1997, 232), based on excavations carried out on sections of canals and roads. However, we also know that the whole centuriation system was covered by the volcanic ash of the AD 79 eruption; since then, Vesuvius erupted approximately 36 times (DE VITO *et al.* 2021).

Here preventive archaeological excavations have frequently uncovered plowed fields and roads sealed by the eruption of Pollena in 472 AD and still consistent with the cadastral system. Hence, to understand why the topography of ancient rural and urban landscapes has survived through centuries, as is clearly visible in remotely sensed data, i.e. historical aerial photographs and LiDAR digital elevation model, it is crucial to consider the adaptive strategies put into practice by local communities and their political institutions (Fig. 3). On the other hand, it is also time to verify the archaeological consistency of the cadastral systems hypothesized by previous research. To reach this goal,

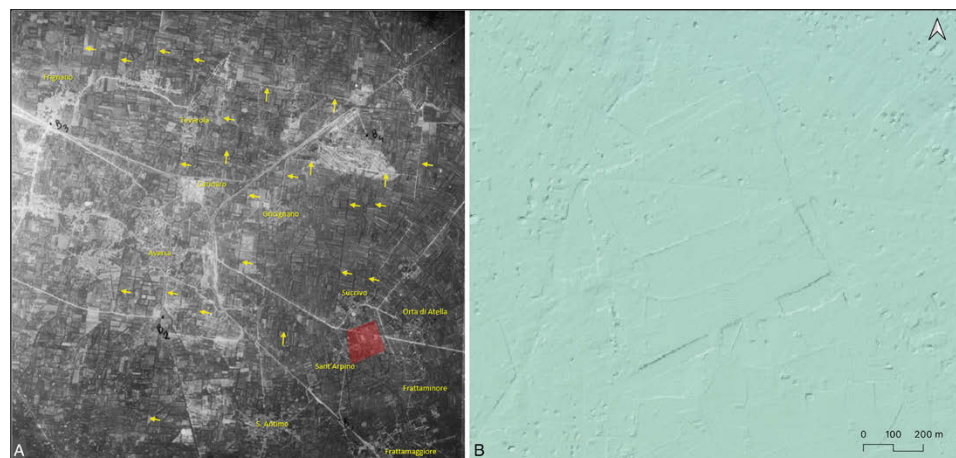


Fig. 3 – Atella and its territory (case study 1) as seen in a historical aerial photograph (RAF 1945) annotated by G. Scardozzi (A) and in the DTM with a 1-meter ground resolution derived from LiDAR scanning acquired by the Ministry of the Environment of Italy.

the In.Res.Agri project started with the digitization process of legacy archaeological data stored in archives (BRANCATO *et al.* in press), and will continue with field surveys (BRANCATO *et al.* 2023) and targeted excavations in urban and extra-urban selected areas.

R.B.

### 3.2 Irpinia

The second case study concerns a sector of eastern Irpinia (province of Avellino), which includes the territories pertaining to the colony of *Aeclanum*, to the N, and to the municipality of *Compsa*, to the S (Fig. 4). The gromatic texts reserve precise indications regarding land divisions carried out in the *ager* of *Aeclanum* (Lib. Col. I, 210, 4-6 L; II, 261, 5-8 L) and in that of *Compsa* (Lib. Col. I, 210, 7 L; II, 261, 1 L). The discovery of some stones of land division (CIL IX, 1024, 1025, 1026; BUONOPANE 2013; CAMODECA 2021) opened the question of the existence of an ancient land division in this territory and its dating (GALLO 2015). To date, only a recent study (DITARANTO 2017) tried to identify in the current landscape traces and alignments referable to the survival of ancient land divisions. This study, based on the analysis of historical cartography and historical aerial photographs, showed, as regards the *ager Compsinus*, a lot of alignments, identified in approx. 150,000 hectares.

Moreover, for the nearby area of *Aeclanum*, alignments compatible with a regular land division have been identified for approx. 152,000 hectares. The use of high-resolution satellite images, suitably processed, and a specific

machine learning algorithm, could enrich the information already acquired and allow to formulate new hypotheses regarding the extension and orientation of the possible land divisions implemented between the Gracchan and Imperial Roman ages. Field surveys will be conducted to verify the new tracks identified.

I.D.

### 3.3 *Tavoliere*

In northern Apulia, between Troia (*Aecae*) to the E and Foggia to the W, the Celone stream to the N and Cervaro to the S, an extensive Roman land

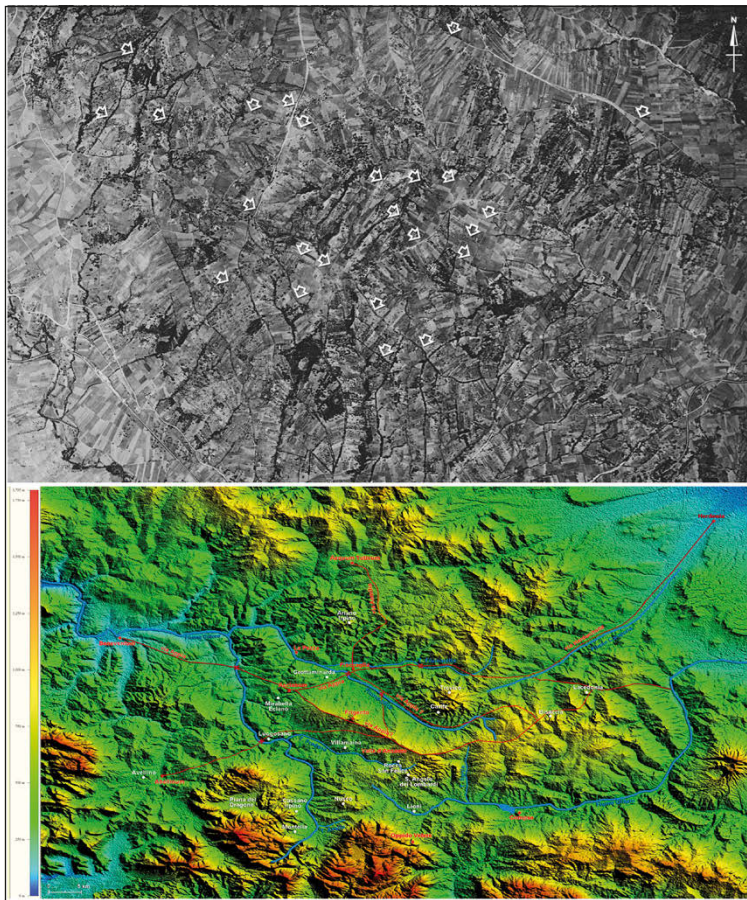


Fig. 4 – The territory of Irpinia (case study 2) in DEM (A) and historical aerial photograph (B) analysed by the Archaeological Mapping Lab of ISPC-CNR (Lecce).



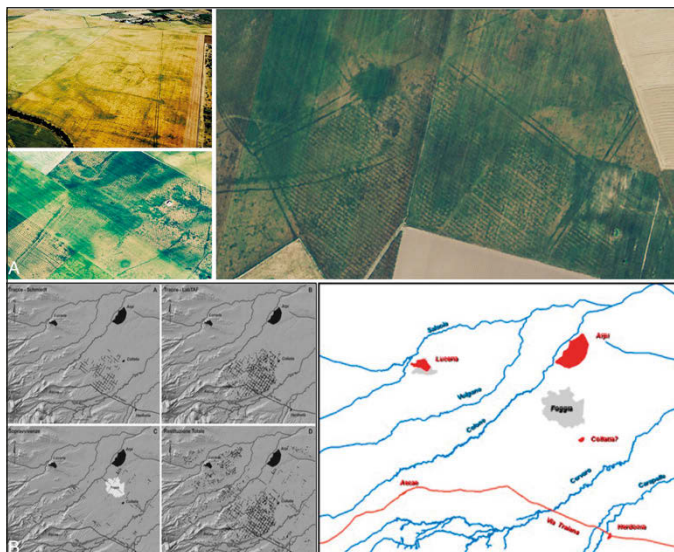


Fig. 5 – Northern Apulia (case study 3), centuriation systems as seen in aerial photograph (A) and DEM (B) analysed by the Laboratorio di Topografia Antica e Fotogrammetria LABTAF (Lecce).

division has been identified, which is coherent with the local hydrographic system (Fig. 5). On the basis of the gromatic texts (Lib. Col. I, 210, 8-9 L) it dates back to the land assignments made in the Graccan age in the *ager Aecanus* (Fig. 2B). The research carried out over the years has been a *unicum* in the field of centuriation studies for the use of aerial imagery as the main survey tool. The first evidence was identified by R. BRADFORD (1949); the research was resumed by G. JONES (1980) who made an overall reconstruction of the Tavoliere centuriation systems. G. SCHMIEDT (1985) reconstructed the module and orientation of the grid. More recent studies have significantly expanded its extension and recognized unitary meta-territorial planning, which included in a single cadastre the territory of more communities also with different status, the *ager Arpanus* and the *ager Collatinus* (CERAUDO, FERRARI 2010). The choice of this case study is due to some essential factors: at a time yet to be defined, this network went out of use; nevertheless, it is still well preserved and visible thanks to the exceptional number of cropmarks (roads, ditches) which constitute reliable *limites* of the grid (the ideal case for instructing the software to identify similar patterns in other geographical contexts). Above all, within almost every *centuria*, it is possible to recognize ancient cultivation trenches and pits.

V.F.

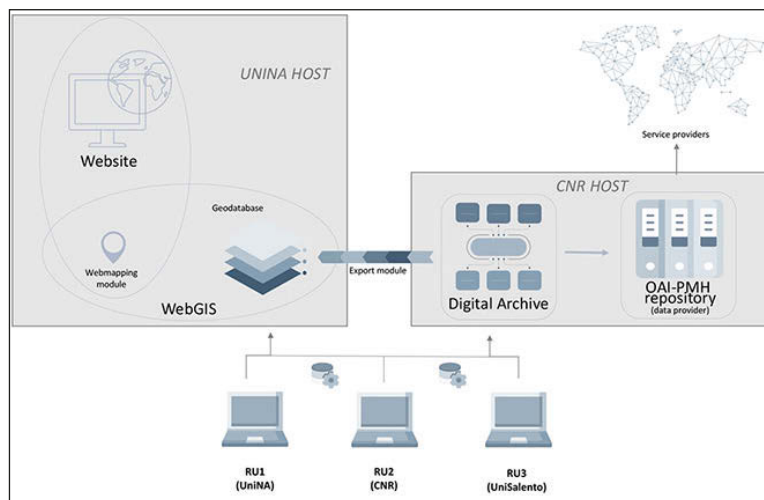


Fig. 6 – Components of the In.Res.Agri project's IT platform, the Digital\_Groma.

## 4. METHODS

### 4.1 *Digital\_Groma: an open IT platform for heterogeneous data integration*

The systematic collection, integration, and exposure of the variety of data sources taken into consideration will be managed in a dedicated IT infrastructure, called Digital\_Groma (Fig. 6). This will consist of three related modules: an archive for the collection and manipulation of legacy and new data on centuriation; a webGIS for data displaying and querying; a repository and APIs for data exposure in interoperable formats.

The digital archive will include a relational database with a user interface for data entry and manipulation, with capabilities for automated data import from related projects. The aim is to store, describe, enrich, and integrate diverse resources, including archaeological findings, textual sources, and visual materials. The open access repository aligns with the project's vision of data FAIRness. Descriptive metadata will be exposed according to standards, facilitating data provision to Italian and European e-infrastructures for archaeology and digital cultural heritage (RICHARDS *et al.* 2021; CARVALE, MOSCATI, ROSSI 2024), and will also be retrievable through dedicated APIs.

The webGIS will be fed with geospatial, chronological, and archaeological data from the archive for investigating and visualizing the relationship among contemporary landscape, Roman centuriated agro-ecosystem and geomorphology. It will feature thematic maps for analyzing environmental, administrative, and cultural aspects, as well as archaeological elements such

as Roman settlements and routes. The webGIS platform will serve as the convergence point for diverse data sources, spanning from texts to satellite images, and including new data from field research. These data will be integrated based on their topographic and semantic significance. It is important to note that this integration process will be digital and automated, differing from traditional computer cartography and representing a practical experiment in deep mapping.

I.R.

#### 4.2 *Remote sensing and pattern recognition*

For each case study, the methods and tools applied in previous research will be verified, accessing archives of aerial photographs. Images will be processed and new information on ancient land division axes or evidence of roads and ancient fields will be georeferenced. The dataset of remotely sensed images will be enriched through the acquisition of recent high-resolution optical satellite images (WorldView 3 and 4, etc.); they will be orthorectified and processed with the aim of identifying archaeological traces (Fig. 7). Also unmanned Aerial Vehicles (UAVs) will be used for areas with limited coverage or to capture detailed images (CAMPANA 2018). Both the aerial photographs and the satellite images will be used for Machine Learning tests for the automatic detection of centuriated fields (TRAVIGLIA, TORSELLO 2017). In the need to process large image datasets in archaeology, the Object-Based Image Analysis (OBIA) approach will be adopted.

This method allows for a reduction in interpretative ambiguity and is applicable to various scales of study. The object-based analyses are sequential: 1) image segmentation allows adjacent pixels with similar characteristics to be grouped; 2) rule-based classification makes explicit the geometric and spectral properties, as well as the spatial and relational ones, required to match the mental model to identify significant geo-objects. Field surveys and drone-based proximal sensing will verify remote sensing data. Areas for these surveys will be selected based on the potential relevance of traces to ancient land division grids. Pollen analysis will also be conducted to identify agricultural indicators.

P.M.

### 5. CONCLUSIONS

Research on agrarian landscapes in transition highlights the strong interaction between human communities and their environment, being the most pervasive alteration of the Earth's environment for several thousand years. With hundreds of hectares of agricultural land going out of production every day, the diachronic knowledge on introduction, spread, abandonment and



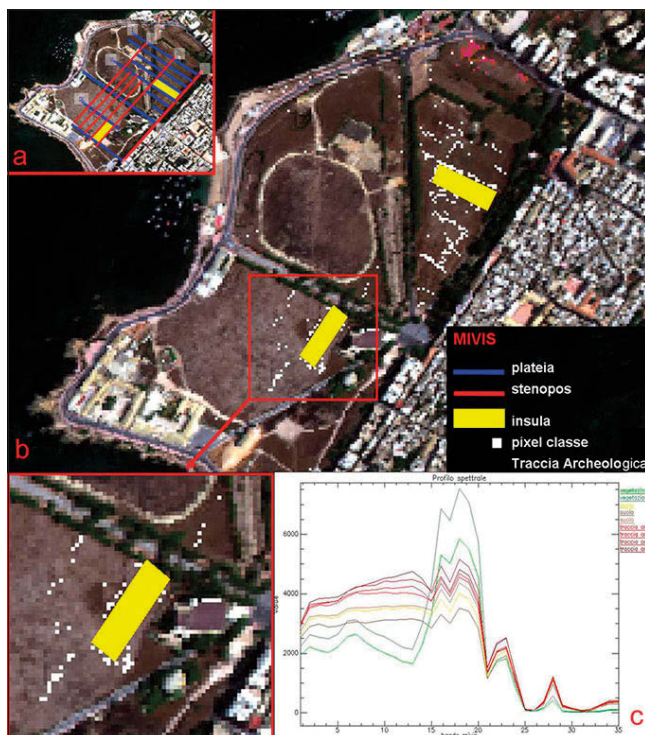


Fig. 7 – Examples of vectors obtained through machine learning application in a GIS platform.

change of agrarian landscapes represents one of the most important topics in the debates on field use policy. What happens when humans impose their spatial and temporal signatures on ecological regimes, and how does this manipulation affect the cultural landscape evolution? While each region has its own unique agricultural history, general patterns emerge which help make sense of how human actions have shaped the natural environment, and how rural landscapes changed, disappeared or have evolved through millennia. The endurance of Roman centuriation on landscapes for more than 2000 years might appear quite incredible. Unlike other types of land division, centuriation was a holistic enterprise with characteristics of incredible modernity that anticipated by two millennia our contemporary understanding of sustainable land design and management. The large dimension of the collected dataset on Roman agrarian landscapes of Campania and Puglia will allow to manage uniformly a whole complex of cultural assets regarding a vast region of

Southern Italy, that would otherwise be dispersed in different institutional repositories, with an immediate effect on research quality.

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### REFERENCES

- BENCIVENGA TRILLMICH C. 1984, *Risultati delle più recenti indagini archeologiche nell'area dell'antica Atella*, «Rendiconti della Accademia di archeologia, lettere e belle arti di Napoli», 59, 3-26.
- BRADFORD J. 1949, *Buried landscapes in southern Italy*, «Antiquity», 23, 58-72.
- BRANCATO R. 2019, *How to access ancient landscapes?*, «Groma», 4, 75-106.
- BRANCATO R., BARONE P.M., SCARDOZZI G. 2023, *Non-invasive archaeological research in Atella (Sant'Arpino-Campania, Italy). Preliminary results from the 2023 campaign*, «Cronache di Archeologia», 40, 397-418.
- BRANCATO R., MATARESE I., SANTANIELLO E., LUONGO G., PORCIELLO C., TOSOLINI M. in press, *L'applicativo ICA per la topografia archeologica della Piana Campana centro-meridionale (Gricignano d'Aversa e Carinaro-CE)*, in I. MATARESE, E. SANTANIELLO (eds.), *Atti della giornata di Studi su Gricignano e Carinaro (Napoli 2023)*.
- BRIGAND R. 2015, *Archaeogeography and planimetric landscapes*, in A. CHAVARRÍA ARNAU, A. REYNOLDS (eds.), *Detecting and Understanding Historic Landscapes*, Mantova, SAP Società Archeologica s.r.l., 173-208.

- BUONOPANE A. 2013, *Un nuovo termine graccano dall'ager di Compsa*, «Agri Centuriati», 1, 185-202.
- CAMODECA G. 2021, *Note sull'Irpinia in età romana*, in A. VISCONTI, M. LANZILLO (eds.), *Studi sull'Irpinia antica*, Napoli, Tiotinx Edizioni, 89-126.
- CAMPANA S. 2018, *Mapping the Archaeological Continuum. Filling "Empty" Mediterranean Landscapes*, New York, Springer.
- CARVALE A., MOSCATI P., ROSSI I. 2024, *Landscaping and integrating Digital Archaeology and Digital Epigraphy resources: New challenges and future opportunities. Introduction to the Special section*, in A. CARVALE, P. MOSCATI, I. ROSSI (eds.), *The H2IOSC project and its impact on digital antiquity within the E-RIHS infrastructure – I*, «Archeologia e Calcolatori», 35.1, 515-520 (<https://doi.org/10.19282/ac.35.1.2024.30>).
- CASTAGNOLI F. 1958, *Le ricerche sui resti della centuriazione*, Roma, Edizioni di Storia e Letteratura.
- CERAUDO G., FERRARI V. 2010, *Fonti tradizionali e nuove metodologie d'indagine per la ricostruzione della centuriazione attribuita all'ager Aecanus nel Tavoliere di Puglia*, «Agri Centuriati», 6, 125-141.
- CHOUQUER G. 2008, *Traité d'archéogéographie*, Paris, Éditions Errance.
- CHOUQUER G., CLAVEL-LÉVÊQUE M., FAVORY F., VALLAT J.P. 1987, *Structures agraires en Italie centro-méridionale. Cadastres et paysages ruraux*, Roma, École Française de Rome.
- CLAVEL-LÉVÊQUE M. 1983, *Cadastres et espace rural. Approches et réalités antiques*, Paris, Éditions du Centre national de la recherche scientifique.
- DALL'AGLIO P.L. 2009, *Centuriazione e geografia fisica*, in DALL'AGLIO, ROSADA 2009, 279-198.
- DALL'AGLIO P.L., CAMPAGNOLI P. 1997, *Regimazione idraulica di età romana nelle pianure di foce delle Marche settentrionali*, in QUILICI GIGLI 1997, 61-72.
- DALL'AGLIO P.L., ROSADA G. (eds.) 2009, *Sistemi centuriali e opere di assetto agrario tra età romana e primo medioevo. Atti del Convegno (Borgoriccio-Lugo 2009)*, «Agri Centuriati», 6.
- DE SIMONE G., MACFARLANE R. (eds.) 2009, *The Apolline Project I*, Napoli, Università degli Studi Suor Orsola Benincasa, Brigham Young University.
- DI VITO M.A., AURINO P., BOENZI G., LAFORGIA E., RUCCO I. 2021, *Human communities living in the central Campania Plain during eruptions of Vesuvius and Campi Flegrei*, «Annals of Geophysics», 64, 5 (546) (<https://doi.org/10.4401/ag-8708>).
- DITARANTO I. 2017, *Il contributo della fotografia aerea allo studio delle antiche divisioni agrarie in Irpinia Orientale*, «Archeologia Aerea», 10, 146-153.
- FRANCIOSI F. (ed.) 2002, *Atti del Convegno internazionale di Studi La storia dell'Ager Campanus, i problemi della limitatio e sua lettura attuale (Real Sito di San Leucio 2001)*, Napoli, Jovene.
- GALLO A. 2015, *L'Irpinia fra III e I sec. a.C.*, «Quaderni Lupiensi di Storia e Diritto», 5, 65-96.
- GIAMPAOLA D. 1997, *Appunti per la storia del paesaggio agrario di Acerra*, in QUILICI GIGLI 1997, 225-238.
- GIAMPAOLA D. 2002, *Un territorio per due città: Suessula e Acerra*, in FRANCIOSI 2002, 165-190.
- GUAITOLI M. (ed.) 2003, *Lo sguardo di Icaro, Le collezioni dell'Aerofototeca Nazionale per la conoscenza del territorio*, Catalogo della mostra, Roma, Campisano Editore.
- HAY G.J., BLASCHKE T., MARCEAU D.J., BOUCHARD A. 2003, *A comparison of three image-object methods for the multiscale analysis of landscape structure*, «Journal of Photogrammetry and Remote Sensing», 57, 5, 327-345.
- JACKSON M., MOORE S. 2018, *Taphonomies of landscape*, «Anatolian Studies», 68, 177-207.
- JONES G. 1980, *Il tavoliere romano. L'agricoltura romana attraverso l'aerofotografia e lo scavo*, «Archeologia Classica», 32, 85-100.
- LAMBERS K., VERSCHOOF-VAN DER VAART W.B., BOURGEOIS Q.P.J. 2019, *Integrating remote sensing, machine learning and citizen science in Dutch archaeological prospection*, «Remote Sensing», 11, 794 (<https://doi.org/10.3390/rs11070794>).
- LEVEAU PH. 2000, *Le paysage aux époques historiques. Un document archéologique*, «Annales. Histoire, Sciences Sociales», 3, 555-582.

- LIVERANI P. 1987, *Termini muti di centuriazione o contropesi di torchi?*, «Mélanges de l'École française de Rome, Antiquité», 99, 1, 111-127.
- MONACO M. 2004, *Sur la centuriation de l'ager Campanus: la limite sud-est*, in *De la terre au ciel. Paysages et cadastres antiques*, Il. Besançon, Institut des Sciences et Techniques de l'Antiquité, 145-156.
- MONACO M., CLAVEL-LÉVÊQUE M. 2004, *Analyse spatiale, archéologie des paysages et centuriation, application des méthodes. La reconstitution d'un paysage antique: l'ager Campanus*, «Dialogues d'histoire ancienne», 30, 1, 186-200.
- MOSCATI P. 2017, *Archaeological computing and ancient cities: Insights from the repository of «Archeologia e Calcolatori»*, «Archeologia e Calcolatori», 28.2, 47-66 (<https://doi.org/10.19282/ac.28.2.2017.03>).
- MUZZIOLI M.P. 2009, *Le ricerche sui resti della centuriazione cinquant'anni dopo*, «Atlante Tematico di Topografia Antica», 19, 7-50.
- OLIVIER M., VERSCHOOF-VAN DER VAART W. 2021, *Implementing state of the art deep learning approaches for archaeological object detection in remotely-sensed data*, «Journal of Computer Applications in Archaeology», 4, 1, 274-289 (<https://doi.org/10.5334/jcaa.78>).
- ORENGO H.A., MARTÍNEZ J. 2009, *Methodological insights into the study of centuriated field systems*, in DALL'AGLIO, ROSADA 2009, 171-188.
- QUILICI GIGLI S. (ed.) 1997, *Uomo, acqua e paesaggio, Atti del Convegno (Santa Maria Capua Vetere 1996)*, Roma, L'Erma di Bretschneider.
- QUILICI GIGLI S. 2002, *Sulle vie che ricalcano gli antichi assi centuriali*, in FRANCIOSI 2002, 95-114.
- RICHARDS J.D., JAKOBSSON U., NOVÁK D., ŠTULAR B., WRIGHT H. 2021, *Digital archiving in archaeology: The state of the art. Introduction*, «Internet Archaeology», 58 (<https://doi.org/10.11141/ia.58.23>).
- ROBERT S. (ed.) 2011, *Sources et techniques de l'archéogéographie*, Besançon, Presses universitaires de Franche-Comté.
- ROSSI I., PARACIANI N. 2021, *IT applications to archaeology and the OA diamond journals' challenge. Enhancing access and reuse of textual and visual resources*, «Archeologia e Calcolatori», 32.1, 325-347 (<https://doi.org/10.19282/ac.32.1.2021.18>).
- SCHMIEDT G. 1985, *Le centuriazioni di Lucera e di Aecae*, «L'Universo», 65, 2, 260-277.
- SETTIS S. (ed.) 1993, *Misurare la terra: centuriazione e coloni nel mondo romano*, Modena, Panini.
- SORICELLI G. 2019, *L'Agro vesuviano dopo l'eruzione del 79 d.C.*, in M. MAIURO, M. BALBO (eds.), *Popolazione, risorse e urbanizzazione nella Campania antica*, Bari, Edipuglia, 155-178.
- TRAVIGLIA A., TORSSELLO A. 2017, *Landscape pattern detection in archaeological remote sensing*, «Geosciences», 7, 4 (<https://doi.org/10.3390/geosciences7040128>).

## ABSTRACT

The In.Res.Agri project aims to optimize the understanding of Roman agricultural landscapes in Southern Italy by integrating topographical, archaeological, environmental, and textual data within an innovative data-science platform. It focuses on examining the resilience of Roman agrarian landscapes, specifically through elements such as centuriation, route networks, and settlement patterns. The project employs both traditional survey methods and advanced technologies to recover, interpret, and manage archaeo-topographical data related to centuriation. Key methods include using Machine Learning for the automatic detection of centuriated fields, spatial analysis of both legacy and new data, and the use of annotated epigraphic and literary sources. All collected data will be implemented into the Digital\_Groma platform, which will feature a digital archive and a webGIS for data display and querying; data will be exposed adhering to FAIR principles. In.Res.Agri will focus on regions in Campania (Vesuvian Area, Irpinia) and Puglia (Tavoliere), exploring the link between contemporary landscapes and Roman centuriated agro-ecosystems. This research is crucial for understanding the impact of environmental changes on Cultural Heritage, aligning with the priorities of the European Commission and UNESCO. The Digital\_Groma platform will be accessible to researchers, tourists, and public institutions involved in archaeology, urban planning, and cultural heritage protection.

## USE AND PROCESSING OF MULTISPECTRAL IMAGES IN PROXIMITY REMOTE SENSING

### 1. INTRODUCTION

The paper presented the result of tests concerning the acquisition of multispectral images from UAV and the processing of multispectral indices for archaeological purposes. From a technical point of view the frames were captured with a Sentera 6X multiband sensor equipped with 5 cameras at 3.2 mpx for the spectral bands of Blue, Green, Red, Red Edge and Near Infrared (from now on NIR) and a 20 mpx RGB camera, with brightness sensor and built-in GPS. Furthermore, radiometric calibration of the images was achieved with the reflectance panel and the parameters provided by the producer. Multispectral camera was integrated with a DJI Phantom 4 drone, according to a setup not foreseen by the producer which allowed for an easy-to-use system (for technical specifications on the integration see EBANISTA, JAIA, POMPILI 2021; EBANISTA, JAIA in press a).

### 2. STATE OF THE ART

The tests described are part of a modern line of research concerning the application in the archaeological field of these vegetation indices developed and codified in the predictive research in agrotechnical field, but responding, from a point of view of compatibility of marks genesis, to the cropmarks of classical archaeological photointerpretation (on the question of photointerpretation in the archaeological field: PICCARRETA, CERAUDO 2000; for the botanical question: PIROLA *et al.* 1982; for the genesis of the indices: DEERING *et al.* 1974). The reference scientific literature is now sufficiently extensive, considering the relatively low cost of equipment and the ease of use of data processing software (among many: AGAPIOU *et al.* 2012a, 2012b; URIBE *et al.* 2015; FIORINI, MATERAZZI 2017; CHIVASA *et al.* 2020). To date, however, the great limit remains a still extensive methodological vacuum due, in my opinion, to the lack of a necessary comparison of the indices processed from multiband data with panchromatic images. Almost all the scientific literature presents marks, sometimes of exceptional reading, in the NDVI without however declaring whether the same marks are also visible in the panchromatic and to what extent. This does not allow us to understand whether there are marks visible only in the processed indices, or in the case of marks already visible in the panchromatic whether there is a quantifiable increase in the data. Furthermore, even a modest number of bands, such as the one presented in



this paper based on the sensor in use, allows the extraction of multiple indices, comparable in order to understand which the best performers are considering the different purposes of the research.

### 3. COMPARISON OF VEGETATION INDICES WITH PANCHROMATIC IMAGES

The comparative analysis of the same flight in panchromatic and multispectral has often highlighted how the NDVI index, the most responsive in the archaeological field by affinity with cropmarks, shows marks that are already visible in the panchromatic (EBANISTA, JAIA in press a). The goal of the experiments carried out by the author of this paper is to codify a coherent method line in order to understand the cases in which it is possible to trace the presence of buried structures only through the processed indices that use the near infrared bands.

In the case studies here presented mark reading is absolutely, or almost, prerogative of vegetation indices. These are two tests (Anzio, Villa Adele and Villa Imperiale) in which the excavation data demonstrated very recent soil filling with notable modern inclusions. It seems possible to hypothesize that the reduction in fertility of these soils is perceptible only in the elaboration of the vegetative indices, more sensitive even at low ranges of chlorophyll values. Furthermore, tests that compare flights in different areas analyze through the comparison of six vegetation indices how the reading of lithic elements (*basoli* or blocks) covered by the vegetation or dry foliage can be clear and defined compared to the panchromatic. Finally, the comparison of six different indices allowed us to evaluate how the use of processed indices based on NIR interpolation allows us to eliminate the covering effect of the shadows generated by the walls on the turf.

#### 3.1 Anzio, Villa Adele

As part of the excavation campaign carried out in September 2023 at Villa Adele in Anzio (RM) under the direction of A.M. Jaia, a series of galleries at a depth of 7 m of the modern floor and accessible to date only through a Roman well were highlighted. First identified in 2000, then inspected by specialized speleologists in 2022, they were brought to light through a pedestrian entrance, used until very recently, as evidenced by the internal finds and by conoid of collapsed soil at the bottom of one of the rooms. The NDVI processed by the images acquired before the opening of the excavation trench shows a mark not appreciable in the panchromatic. This is a dark mark of irregular shape that, according to the values setting in black and white, indicates the areas where vegetative growth is inhibited (Fig. 1). The area identified by the mark corresponds to the sector which, according to the results of the excavation, corresponds to a significant backfill of thousands of cubic meters



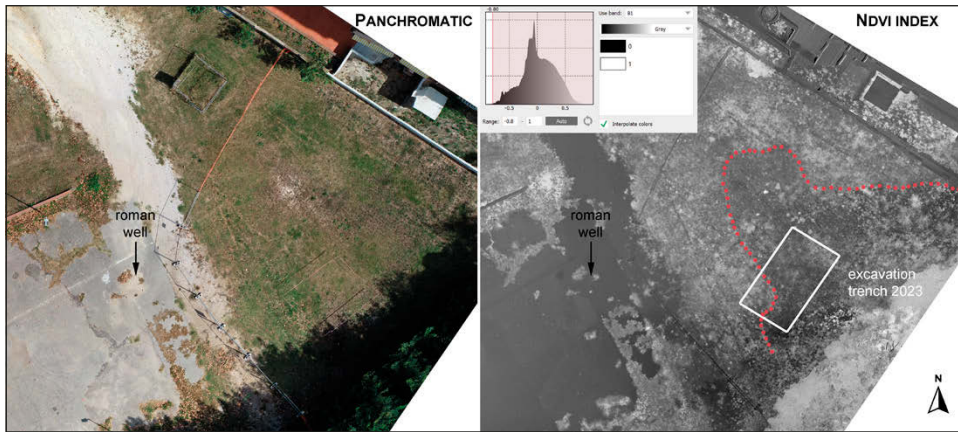


Fig. 1 – Anzio (RM), Villa Adele. Comparison of the panchromatic image and the NDVI index.

which obliterated the natural slope from which the ancient structures were accessed in the middle of the last century (for detailed excavation report: JAIA, EBANISTA in press b). Considering that in the different layers that make up the backfill abundant recent building materials were found, it can be hypothesized that the presence of these kind of inclusions in the soil determines a lower fertility that produces as an effect a lower vigor of the turf that generates a clear response in the NIR, thus giving a good response in the index used.

### 3.2 Anzio, Villa Imperiale

A similar situation was found in the case of flights carried out in October 2023 at the Villa Imperiale of Anzio. As part of the redefinition of the phases of the villa codified in the 70s by Santa Maria Scrinari, Jaia reduced the building phases to just two major interventions (SANTAMARIA SCRINARI, MORRICONE MATINI 1975; JAIA 2008). The second phase, referring to the late Antonine and Severian age, includes the regularization of the structures along two orientations: the one to the S at the large curvilinear structure of the first phase (Fig. 2a) and the one that is set parallel to the W coastline and includes the thermal area and the promontory of the so-called Arco Muto (Fig. 2b). This sector constituted a vacuum of knowledge, presenting as an area excavated first in 1889 (Boccanera excavation) and then in 1929-32 when the Podestà of Anzio, as part of the tourist promotion of the town, built a sports field around the Arco Muto. Based on the discovery of detailed planimetry carried out by G. Gatti from 1931 and unpublished until a few years ago, it was possible to relocate the plans of the northernmost structures of the villa area with extreme precision, with further confirmation of positioning given by

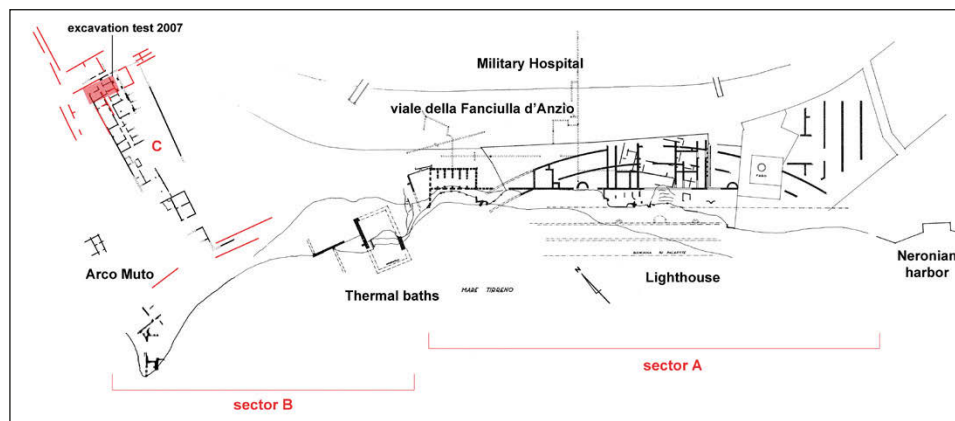


Fig. 2 – Anzio (RM), Villa Imperiale. Plan of the known structure with the addition of the structures identified based on the NDVI marks in 2023 (processed by JAIA 2008, 76).

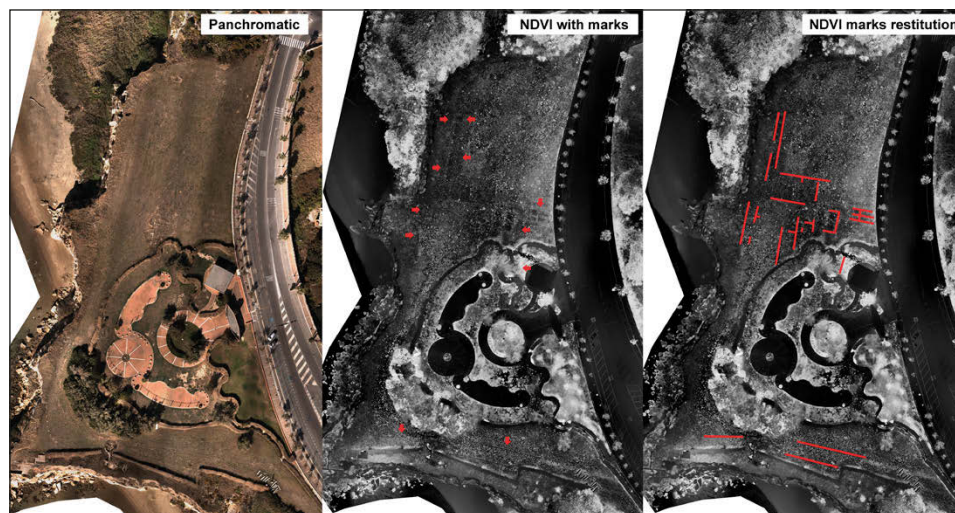


Fig. 3 – Anzio (RM), Villa Imperiale. Comparison between the panchromatic image and the NDVI index.

an excavation carried out in 2007 using the only off-axis wall as a reference (Fig. 2c). The comparison between the panchromatic image and the NDVI index clearly shows that only in the latter in the sector N of the modern entrance to the archaeological area marks with NW-SE orientation are visible (Fig. 3). Superimposing the NDVI marks to the Gatti planimetry the increase in knowledge in N direction is evident (Fig. 2, in red). The genesis of the marks

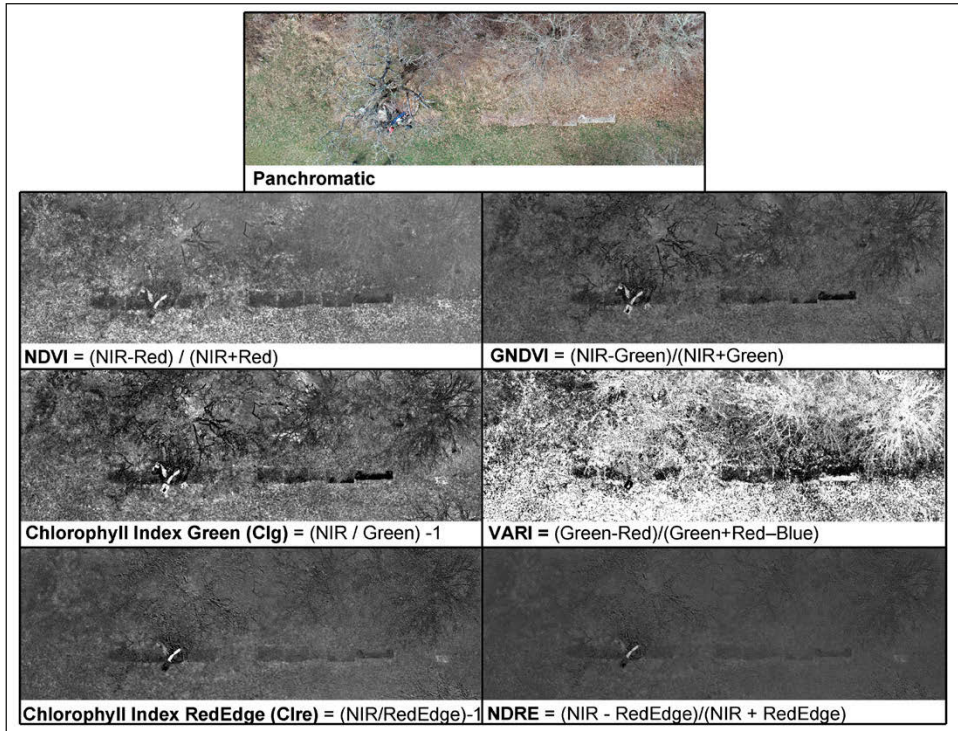


Fig. 4 – *Nersae*, Pescorocchiano (RI). Comparison between the panchromatic image and six vegetation indices.

is like these of Villa Adele, as also in this case it is a recent filling, probably carried out with inconsistent material. There is therefore a good chance of identifying archaeological marks in conditions of land carryovers, more or less recent, but with considerable inclusions that decrease the fertility of the soil, reducing the vegetative vigor of the turf. This is significantly sensitive to NIR so as to appear only in the chosen index but is not appreciable in the visible spectrum. This is basically the method used in predictive agrotechnical analyses with respect to the degree of greenness appreciable in the visible as it responds to minimum chlorophyll concentration intervals.

### 3.3 Visibility of blocks and basoli, comparison of six vegetation index

Another performing capability of multispectral images interpolated via indexes that make use of NIR is to make visible blocks or *basoli* covered by vegetation that often remain almost completely invisible in panchromatic images. In a detail of a larger flight carried out in *Nersae*, the ancient capital of the

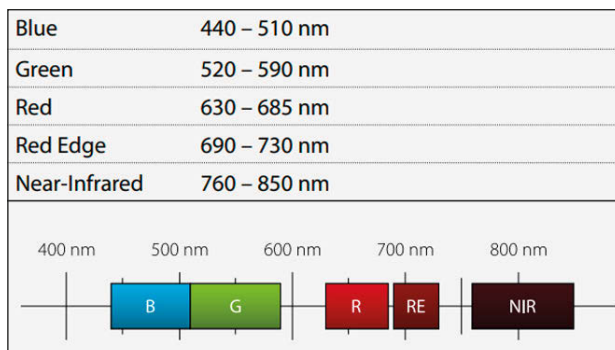


Fig. 5 – Spectral Bands (from [https://www.geosoluciones.cl/documentos/rapideye/RE\\_Red\\_Edge\\_Band\\_White\\_Paper.pdf](https://www.geosoluciones.cl/documentos/rapideye/RE_Red_Edge_Band_White_Paper.pdf)).

*Equicoli* located in the Salto valley, in the panchromatic image the presence of a row of blocks, partially covered by foliage, is only intuitable. The comparison of six vegetation indices (Fig. 4), processed considering the five bands acquired by the sensor used, shows that the few regrowth of turf between block and block are exalted in the contrast between a good vegetative vigor and the value below zero determined by the presence of the lithic material. It is evident that the NDVI, the GNDVI and the Chlorophyll Index Green show satisfactory results, with an excellent increase of knowledge. The response of the VARI is also good, but the marks in the Chlorophyll Index Red-Edge and NDRE (Red-Edge NDVI) indexes are less clear. These are the two indexes that interpolate the Red-Edge band. This, located at about 700/750 nm in the spectrum of the visible, represents the inflection point of the reflectance curve of the vegetation that separates the reflectance in the visible from the NIR reflectance (Fig. 5). NIR, instead, corresponds to the maximum peak of the reflectance values reaching 1300 nm. In the context, however, it must be considered that the reflectance in the Red Edge band, being more influenced by chlorophyll rather than by the presence of biomass, allows to evaluate the vigor of the plants even in the most advanced stages of their growth, unlike the NDVI which is less effective as the plant develops. The analysis of the type of turf therefore becomes fundamental: sown and therefore subjected to the cyclic anthropogenic action, uncultivated or constantly cut.

In a detail of the previous flight at the Imperial Villa of Anzio the turf is clearly irregular, partly dry with sporadic regrowth which however corresponds to a deep root layer. In fact, it is not uprooted or sowed, but only periodic mowed; so, the roots certainly intercepted the buried structures, however not extremely deep, resulting in the genesis of cropmarks. In this case the extraction of six vegetation indices (Fig. 6) significantly emphasized



the paved road (repositioned in modern times) to NE for the phenomenon already described, in addition to make visible the marks of the paving of the republican *domus* recognizable as oriented differently from the imperial plant (Fig. 7). Marks are not appreciable in the panchromatic but are instead extremely clear in the NDVI.

### 3.4 Shadows visibility in processed indices

It is interesting, however, to note that from the comparison in Fig. 6 there are differences in relation to the effect of the shadows which defines a visibility disturbance in the panchromatic and VARI index. Instead in the other indexes shadows are less evident, and in some cases totally disappear, revealing the image covered by the black chromia. The phenomenon occurs because these indices use the infrared radiation that is also present in the shadowed areas, nullifying the covering effect of the phenomenon. The black shadow that appears in the panchromatic image is the dark area projected

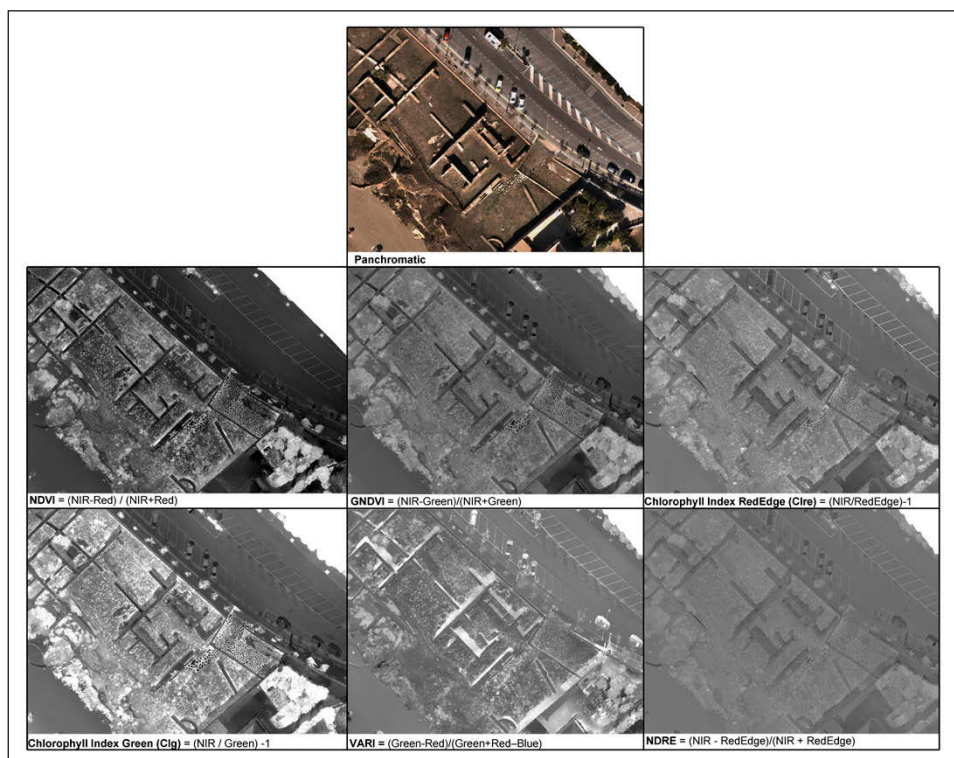


Fig. 6 – Anzio (RM), Villa Imperiale. Comparison between the panchromatic image and six vegetation indices.

on a surface, in this case the turf, with high walls that, intervening between the surface itself and the sun light source, prevent the passage of visible light, but not of infrared radiation.

The NDVI index shown in the slide is in this case of excellent readability, as it completely cancels out the effect of shady coverage. At this point, the observation of this phenomenon and the optimal response of the NDVI index (also good for other indices, Fig. 6) to the problem of shadow coverage becomes fundamental in cases in which even with the correct acquisition of flights in the central times of the day it is not possible to avoid the phenomenon for the presence of walls of modest height. In this way, a part of the image, that would otherwise been totally lost, can be recovered.

### *3.5 Conclusion*

This contribution, despite its preliminary structure in the dynamics of a large and ongoing research, demonstrates the importance of the comparison between the various vegetation indices that can be processed, based on the specific sensor used, and the panchromatic images. An important methodological gap in the scientific bibliography of reference is, in my opinion, the almost always absent comparison of marks visible in processed vegetation indices with the same image acquired in panchromatic at the same time and with the same vegetative conditions of the vegetation cover.



Fig. 7 – Anzio (RM), Villa Imperiale. NDVI index.



Very often in fact, the marks (comparable with those of classical photointerpretation, mainly cropmarks) are already visible in panchromatic images, but the comparison with vegetation indices, such as NDVI, demonstrates in many cases an increase in the degree of visibility which can be estimated as a percentage (for *Lavinium* test at Santa Maria delle Vigne villa see EBANISTA, JAIA in press a). The choice in this paper to analyze only the cases in which the marks are visible only and exclusively in the indexes processed paves the way for further evaluations. The tests have demonstrated how inconsistent and very recent backfills are a prototypical case of marks reading only in the processed indexes that make use of the NIR band (and partially and with less satisfactory results in the Red Edge). A further intuition, which will be appropriately developed through further tests in multiple contexts, is that relating to overcoming the obstacle of shadows in reading images.

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## REFERENCES

- AGAPIOU A., HADJIMITSIS D.G., ALEXAKIS D.D. 2012a, *Evaluation of broadband and narrowband vegetation indices for the identification of archaeological crop marks*, «Remote Sensing», 4, 12, 3892-3919 (<https://doi.org/10.3390/rs4123892>).
- AGAPIOU A., HADJIMITSIS D.G., GEORGOPOULOS A., SARRIS A., ALEXAKIS D.D. 2012b, *Towards an archaeological index: Identification of the spectral regions of stress vegetation due to buried archaeological remains*, in M. IOANNIDES, D. FRITSCH, J. LEISSNER, R. DAVIS, F. REMONDINO, R. CAFFO (eds.), *Progress in Cultural Heritage Preservation. Proceedings of the 4<sup>th</sup> International Conference, EuroMed 2012 (Limassol 2012)*, Heidelberg, Springer, 29-138.
- CHIVASA W., MUTANGA O., BIRADAR C.M. 2020, *UAV-Based multispectral phenotyping for disease resistance to accelerate crop improvement under changing climate conditions*, «Remote Sensing», 12, 15, 1-27 (<https://doi.org/10.3390/rs12152445>).
- DEERING D.W., ROUSE J.W., HAAS R.H., SCHELL J.A. 1974, *Monitoring vegetation systems in the Great Plains with ERTS*, in NASA. Goddard Space Flight Center 3<sup>rd</sup> ERTS-1 Symposium, vol. 1, sect. A, 309-317 (<https://ntrs.nasa.gov/api/citations/19740022614/downloads/19740022614.pdf>).
- EBANISTA L., JAIA A.M., POMPILI A. 2021, *Integrazione di un sensore Sentera 6X a bordo di un drone Phantom 4. Una sperimentazione in campo archeologico*, «Geomedia», 5, 30-36 (<https://mediageo.it/ojs/index.php/GEOmedia/article/view/1827>).
- EBANISTA L., JAIA A.M. in press a, *Telerilevamento di prossimità: acquisizione ed elaborazione di immagini multispettrali*, in *Atti del Terzo Convegno Internazionale di Archeologia Aerea (Lecce 2022)*.
- EBANISTA L., JAIA A.M. in press b, *Anzio, villa comunale: un nuovo complesso residenziale costruito di età imperiale. Sondaggi di scavo 2023*, «Scienze dell'Antichità», 30.
- FIORINI L., MATERAZZI F. 2017, *Un Iseion a Gravisca? Fotogrammetria, telerilevamento multispettrale da APR e dati archeologici per una possibile identificazione*, «FastiOnLine. Documents&Research», 396, 1-23 ([www.fastionline.org/docs/FOLDER-it-2017-396.pdf](http://www.fastionline.org/docs/FOLDER-it-2017-396.pdf)).

- JAIA A.M. 2008, *Anzio. La villa imperiale*, in M. VALENTI (ed.), *Residenze imperiali nel Lazio. Atti della Giornata di studio (Monte Porzio Catone 2004)*, Roma, Arbor Sapientiae, 73-80.
- PICCARRETA F., CERAUDO G. 2000, *Manuale di aerofotografia archeologica: metodologia, tecniche e applicazioni*, Bari, Edipuglia.
- PIROLA A. et alii 1982 (ed.), *Trattato di botanica. Parte generale*, Roma, Delfino.
- SANTAMARIA SCRINARI V., MORRICONE MATINI M.L. 1975, *Mosaici antichi in Italia. Regione prima. Antium*, Pisa, Fabrizio Serra Editore.
- URIBE P. et al. 2015, *Aerial mapping and multi-sensors approaches from remote sensing applied to the Roman archaeological heritage*, «The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences», 40, 5, 461-467.

## ABSTRACT

The contribution presents the results of a research that involves the use of data acquired by a multispectral camera transported by a UAV and their analysis and interpretation in the context of archaeological diagnostics. The experimentation expected the acquisition of multispectral images and the extraction of all the possible vegetation indexes on the basis of the spectral bands of the specific camera used (Sentra 6X). The tests, carried out in different contexts (*Antium*, *Nersae*), analyze the readability of the index data extracted from multispectral images in comparison with the marks visible in the panchromatic images, especially considering cases in which the marks are visible only in processed indices that interpolate the NIR band.

EVALUATION OF SFM AND LIDAR TECHNOLOGY  
FOR MAPPING INSCRIBED ARTIFACTS. PRELIMINARY  
OBSERVATIONS STARTING FROM THE RESEARCH PROJECT  
'RAVENNA AND ITS LATE ANTIQUE AND MEDIEVAL  
EPIGRAPHIC LANDSCAPE'

## 1. INTRODUCTION

The digitization of collections has become a widely adopted strategy among institutions and museums to enhance accessibility and reach a broader audience (CORONA 2023, 73-74). This process involves converting physical artifacts, documents, and other items into digital formats, making them available online for the general public, researchers, students, and history enthusiasts as well. In the context of the 'Ravenna and its Late Antique and Medieval Epigraphic Landscape' project, the digitization process is a 'best practice' that has been decided upon for the implementation of late antique, Byzantine and medieval Ravenna inscriptions in a website conforming to the principles the acronym FAIR (Findable, Accessible, Interoperable, Reusable)<sup>1</sup>.

## 2. PROJECT OVERVIEW

Considering the city's significance – as the capital of the Western Roman Empire in 402, following the transfer of the imperial court from Milan by Emperor Honorius – and the extensive body of scholarship dedicated to it, there currently lacks a systematic and comprehensive edition of its epigraphic evidence. This deficiency persists despite notable works that scrutinize individual texts or incorporate references to Ravenna's inscriptions within broader historical, art-historical, or archaeological contexts (the list is extensive, and by way of example see only: BOLLINI 1975; RUGO 1976; FIORI 2008). A recent monograph exclusively addresses Greek inscriptions up to the 7<sup>th</sup> century, leaving out Latin documentation (BENCIVENNI 2018). From the testimony of Byzantine and Renaissance humanistic historiography, for example, from the protohistorian of the 9<sup>th</sup> century Andrea Agnello (DELIYANNIS MAUSKOPF 2006), one can infer the loss of important epigraphic documents. Therefore, what has been published represents only a limited percentage compared to the entire epigraphic heritage, which has so far never been accurately calculated.

<sup>1</sup> The research is directed by Prof. S. Cosentino (Department of Cultural Heritage of *Alma Mater Studiorum* – University of Bologna) whom I thank to be involved in the project for the aspects related the 3D digitization process and the re-contextualisation of inscriptions in urban and architectural space.



Fig. 1 – Roman settlement boundary created using QGIS by the Author.

In short, the project aims to preserve and make accessible an important aspect of Ravenna's cultural heritage, consisting of the city inscriptions produced between 402 and 1411. In the context of this broad historical framework, one of the tasks of the research is to create 3D models of the artefacts and a digital platform to promote this still little-known type of documentation of Ravenna's history to the heritage community. In addition to utilizing 3D scanning, the project envisions the re-contextualization of the epigraphic artifacts, considering their interaction with the physical environment, settlements, and the social landscape. Diverse GPS data will be linked to each object, including its current location, the potential place of re-use (if applicable), and the original location of first use, if distinct. The initial GPS coordinate is acquired during the 3D scanning phase, while the second and third coordinates are obtained through the systematic mapping process utilizing QGIS (Fig. 1).

It is expected that the digital models and metadata will be accessible online upon the completion of the project (2026-2027), coinciding with the publication in open access. The collection of digitized objects will essentially serve as an archive containing the 3D data, metadata describing the objects from an archaeological perspective, and paradata detailing the digitization process, all organized within a simple database structure. All gathered information will be accessible through a web interface. Web access is an essential point in the project, as it makes possible for all target stakeholders to access at the data, fulfilling the FAIR principles. The 3D visualization component, hopefully, will be based on the ATON tool (<https://osiris.itabc.cnr.it/aton/>). The latter is the open-source Web3D/WebXR framework by CNR-ISPC. Within ATON each user has its own collection (3D models, 360 panoramas, audio, etc.) that contains web-ready items that will be arranged into scenes.

So far, approximately 110 epigraphs have been examined, the majority of which are stored under conditions that make it challenging to relocate and study them. The epigraphs are currently housed in the National Museum of Ravenna<sup>2</sup>, in the Archiepiscopal Museum, and in several basilicas within the city. Some are displayed affixed to the wall using metal studs, while others are stored in storing rooms on various supports, such as shelves.

### 3. CHALLENGES TO SfM AND LiDAR TECHNOLOGY

The process of 3D scanning in museum storage areas is essential for managing, preserving, and documenting collections, but it comes with various challenges, particularly with regard to epigraphs stored in the National Museum. One significant obstacle is the limited space within these storage areas (Fig. 2), where a vast quantity of other objects and artworks is housed in confined environments. This spatial constraint makes it challenging to access objects for 3D scanning, often requiring the use of specialized equipment to reach remote areas. Additionally, adequate lighting is crucial for capturing precise details in 3D scans. However, in storage areas of the National Museum – problematic not only for the museum in Ravenna but also for many others – natural light is often limited. Consequently, the use of appropriate artificial lighting sources becomes imperative to ensure accurate scanning results. Another challenge is posed by the diverse size and shape of artworks within museums, ranging from small and delicate pieces to large and intricate

<sup>2</sup> I would like to thank the former director, Dr. Letizia Lodi, and the current director, Arch. Dr. Serena Ciliani, of the National Museum of Ravenna for granting permission for the autoptic study, surveying, and photographing of the *corpus* of Ravenna epigraphs stored at the museum. Additionally, I would like to express my gratitude for the great helpfulness and kindness of Drs. Paola Novara and Elisa Emaldi, for their assistance in accessing the museum's inventories and storing rooms.



Fig. 2 – A storing room of the National Museum of Ravenna in 2023.

sculptures. This necessitates the adaptability of 3D scanning equipment to capture details across this wide spectrum of objects. Overall, despite these challenges, the 3D scanning process remains crucial for the comprehensive documentation and preservation of museum artifacts.

An additional constraint exists in the Archiepiscopal Museum (Fig. 3), where the epigraphs on slabs are positioned on the walls, some at considerable heights, making it impractical to remove them for scanning purposes. This limitation adds another layer of complexity to the 3D scanning process, requiring innovative solutions or alternative approaches to capture accurate digital representations of these elevated epigraphs.

Due to these circumstances, it was decided to use photogrammetry and test LiDAR technology. The Structure from Motion (SfM) technique, a





Fig. 3 – Archiepiscopal Museum of Ravenna in 2023.

well-known procedure, is a methodology used to reconstruct the three-dimensional structure of objects or representations from a series of two-dimensional images acquired from different perspectives. This technique can be applied to the survey of small objects, such as art objects, archaeological artifacts, manufactured objects, and more (consider the following studies as illustrative examples: AICARDI *et al.* 2018; BRANDOLINI, PATRUCCO 2019; BARSZCZ *et al.* 2021).

LiDAR stands out as a versatile and well-established technology with a broad spectrum of practical applications. It recently became accessible to smartphone users through the iPhone 12 and 13 Pro, as well as the iPad Pro (Apple Inc., Press Release March 18, 2020), which has increased public awareness of its capabilities, and has also sparked interest in the archaeology of architecture (e.g. FIORINI 2022; VACCA 2023). Introduced to the market primarily for applications in augmented reality (NOCERINO *et al.* 2017; APPLE 2020), the LiDAR system, deployed by Apple, comprises two essential components: a transmitting element and a receiving element. By combining transmission and reception data, along with their respective timings, a comprehensive 3D map is meticulously generated. The LiDAR sensor executes continuous scanning and operates more analogous to video footage, distinguishing itself from Time of Flight (ToF) sensor incorporated in various smartphone that is similar to capturing a three-dimensional photograph of the scene (PEZZALI 2020). This functionality offers variable precision, ranging from 3 mm to 9 mm, while adhering to a predetermined scanning depth.

4. DATA ACQUISITION

In this study, a dynamic acquisition was conducted within the indoor confines of the National Museum storing rooms (Fig. 4). The primary objective was to perform a comparative analysis of the processing time associated with



Fig. 4 – Workspace setup at the National Museum of Ravenna in 2023.

Object A Measurement (ID 6)	Length measured manually (mm)	SfM length (mm)	LiDAR length (mm)	LiDAR Error (%)	File size SfM (.obj - MB)	File size LiDAR (.obj - MB)
1	235	234	220	0.15	17	15.1
2	-	235	230	0.05	24	18.8
3	-	235	235	0	19.3	17.4

Object B Measurement (ID 42)	Length measured manually (mm)	SfM length (mm)	LiDAR length (mm)	LiDAR Error (%)	File size SfM (.obj - MB)	File size LiDAR (.obj - MB)
1	350	351	340	0.1	23.2	17.8
2	-	354	350	0	28	20.0
3	-	350	360	0.1	32	18.6

Object C Measurement (ID 97)	Length measured manually (mm)	SfM length (mm)	LiDAR length (mm)	LiDAR Error (%)	File size SfM (.obj - MB)	File size LiDAR (.obj - MB)
1	420	422	430	0.1	19.9	18.0
2	-	420	420	0	20.1	21.3
3	-	421	425	0.05	18.5	19.7

Fig. 5 – Comparison of direct, SfM, and LiDAR measurements.

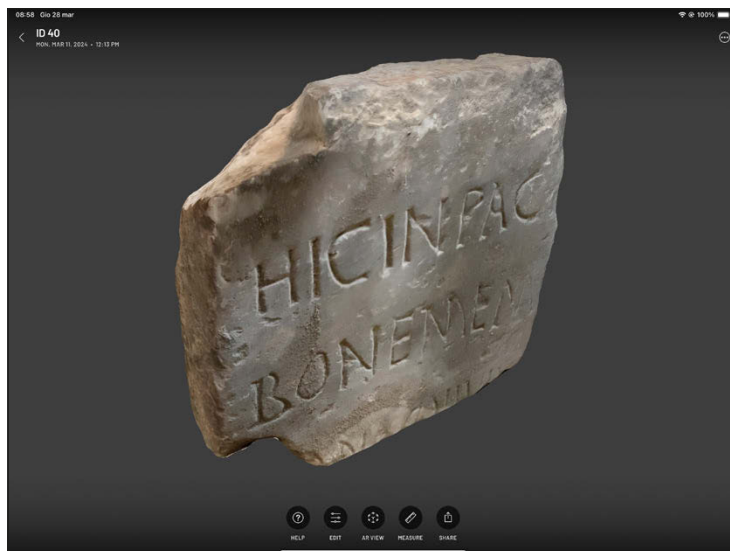


Fig. 6 – A screenshot displaying one of the 3D models, showcasing the application being used on the screen.

two methodologies. The aim was to evaluate the feasibility and efficiency of the proposed methodology within the context of relatively low-cost workstation solutions. The focus centered on assessing the time required for data processing, aiming to gain insights into the practicality and viability of the proposed approach in scenarios where cost-effective workstation solutions take precedence. Concurrently, a preliminary assessment has been initiated to ascertain the level of definition of the 3D model and the size of the generated files (Fig. 5).

The 3D model was generated using the free app Scaniverse (version 2.1.8) and the photogrammetric software Agisoft Metashape Professional (version 1.8.4). The data processing of the acquired images was performed on two portable workstations: an iPad Pro (12.9-inch, 5<sup>th</sup> generation) and a laptop ASUS Vivobook Pro 16X OLED (N7600, 11<sup>th</sup> Gen Intel: CPU Intel(R) Core™ i7-11370H, 32GB 3200 MHz DDR4, 1TB PCIe® SSD, NVIDIA GeForce® RTX™ 3050).

The workflow time was calculated excluding the creation of the shooting set, thus not considering the arrangement of the LED lighting essential for the success of the two methods – within the museum's storing rooms – and the time for the handling of the objects, not all of which can always be removed.

A typical work session using the Apple LiDAR sensor lasts for 2 hours, focusing on 15 objects with dimensions ranging from a minimum of height

0.16 m; width 0.135 m; depth 0.052 m to a maximum of height 0.73 m; width 0.51 m; depth 0.09 m. With an average of 8 minutes of LiDAR scanning per artifact. The survey is performed at less than 0.20 m by walking around the objects (Fig. 6). At the conclusion of the scanning process, the models become promptly accessible, georeferenced, and uploaded to the cloud.

The working session involving the same objects, albeit employing the SfM technique, spans a duration of 3 hours, during which the photographs destined for post-production are captured, with an average of 12 minutes of LiDAR scanning per artifact. The processing duration for photogrammetric shots, encompassing tasks such as downloading and configuring software parameters culminating in the generation of the final model, is estimated to be approximately 20-30 minutes.

## 5. CONCLUSION

An observable improvement in workflow efficiency and hardware/software optimization, especially in terms of time, is evident when comparing LiDAR to SfM. The LiDAR process typically takes only a few minutes, ranging from 5 to 8 minutes, inclusive of object handling. Repeated focusing on the same point from different angles enhances scanning precision. Unlike SfM, LiDAR scan accuracy and file size are not limited by distance but rather by the resulting file size. In contrast, SfM, accounting for image downloading and hardware/software processing, may take between 35 to 45 minutes for each object.

LiDAR sensors on smartphone and tablet can serve as valuable tools for creating 3D models of architectural and cultural heritage of disclosure databases. This capability offers an opportunity to contribute to the minimal metric documentation required for comprehending and preserving these assets, all at a relatively low cost. Furthermore, this development signals an imminent era where the precise capture of even the smallest engravings on epigraphs will be achievable at a low cost, addressing the current limitation in digital epigraphy, presently confined to the digitization of inscriptions through the creation of databases.

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## REFERENCES

AICARDI I., CHIABRANDO F., MARIA LINGUA A., NOARDO F. 2018, *Recent trends in cultural heritage 3D survey: The photogrammetric computer vision approach*, «Journal of Cultural Heritage», 32, 257-266 (<https://doi.org/10.1016/j.culher.2017.11.006>).

- APPLE 2020, *Apple Unveils New iPad Pro with Breakthrough LiDAR Scanner and Brings Trackpad Support to iPadOS* (<https://www.apple.com/newsroom/2020/03/apple-unveils-new-ipad-pro-with-lidar-scanner-and-trackpad-support-in-ipados/>).
- BARSZCZ M., MONTUSIEWICZ J., PAŚNIKOWSKA-ŁUKASZUK M., SAŁAMACHA A. 2021, *Comparative analysis of digital models of objects of cultural heritage obtained by the “3D SLS” and “SfM” methods*, «Applied Sciences», 11, 5321 (<https://doi.org/10.3390/app11125321>).
- BENCIVENNI A. 2018, *Ravenna. Le iscrizioni greche*, Bologna, Editore Jouvence.
- BOLLINI M. 1975, *Le iscrizioni greche di Ravenna*, Quaderni degli Studi Romagnoli, 9, Faenza, Fratelli Lega.
- BRANDOLINI F., PATRUCCO G. 2019, *Structure-from-motion (sfm) photogrammetry as a non-invasive methodology to digitalize historical documents: A highly flexible and low-cost approach?*, «Heritage», 2, 3, 2124-2136 (<https://doi.org/10.3390/heritage2030128>).
- CORONA L. 2023, *Digitization for the visibility of collections*, «Collection and Curation», 42, 3, 73-80 (<https://www.emerald.com/insight/2514-9326.htm>).
- DELIYANNIS MAUSKOPF D.M. (ed.) 2006, *Agnelli Ravennatis Liber Pontificalis Ecclesiae Ravennatis, Corpus Christianorum. Continuatio Mediaevalis*, 199, Turnhout, Brepols Publishers.
- FIORI F. 2008, *Epigrafi greche dell'Italia bizantina (VII-XI secolo)*, Bologna, CLUEB.
- FIORINI A. 2022, *Scansioni dinamiche in archeologia dell'architettura: test e valutazioni metriche del sensore LiDAR di Apple*, in A. ARRIGHETTI, R. PANSINI (eds.), *Sistemi e tecniche di documentazione, gestione e valorizzazione dell'architettura storica. Alcune recenti esperienze*, «Archeologia e Calcolatori», 33.1, 35-54 (<https://doi.org/10.19282/ac.33.1.2022.03>).
- NOCERINO E., LAGO F., MORABITO D. et al. 2017, *A smartphone-based 3D pipeline for the creative industry. The replicate EU project*, in D. GONZALEZ-AGUILERA, A. GEORGOPOULOS, T. KERSTEN, F. REMONDINO, E. STATHOPOULOU (eds.), *7<sup>th</sup> International Workshop 3D-ARCH 2017: Virtual Reconstruction and Visualization of Complex Architectures (Napflio 2017)*, «The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences», XLII-2/W3, 535-541 (<https://doi.org/10.5194/isprs-archives-XLII-2-W3-535-2017>).
- PEZZALI R. 2020, *Lidar, cos'è e come funziona su iOS. Presente e futuro di una delle novità più promettenti dell'iPhone 12 Pro* (<https://www.dday.it/redazione/37309/LiDAR-iphone-12-pro-ios-ipad>).
- RUGO R. 1976, *Le iscrizioni dei secc. VI-VII-VIII esistenti in Italia*, III, Cittadella, Tip. Bertinello.
- VACCA G. 2023, *3D Survey with Apple LiDAR sensor. Test and assessment for architectural and Cultural Heritage*, «Heritage», 6, 2, 1476-1501 (<https://doi.org/10.3390/heritage6020080>).

## ABSTRACT

Focusing on Late Antique epigraphic and architectural artifacts preserved in Italian and Greek contexts – starting from the research project ‘Ravenna and its Late Antique and Medieval Epigraphic Landscape’ – this study assesses the effectiveness of Structure from Motion (SfM) and Light Detection and Ranging (LiDAR) in generating 3D models suitable for sharing as open data within digital collections. The analysis compares the speed and accessibility of SfM and LiDAR in producing reconstructions, as well as their precision in capturing engravings and decorations. In fact, the research project on Epigraphy from Ravenna, under the guidance of Prof. S. Cosentino at the Department of Cultural Heritage of the *Alma Mater Studiorum*, Università di Bologna, aims to digitize inscriptions in Ravenna spanning from 402 to 1441. A key project objective is to establish a digital platform that

supports heritage communities, thus unveiling the yet undiscovered heritage of Ravenna. To date, approximately 110 epigraphs have been examined, most of which are situated in challenging-to-access locations. Given these circumstances, the feasibility of leveraging SfM and LiDAR technologies was explored. The study endeavours to underscore the paramount significance of advancing LiDAR technology in the realm of cultural heritage preservation and mapping.



### 3D LIDAR MODELING WITH IPHONE PRO IN AN ARCHAEO- SPELAEOLOGIC CONTEXT. RESULTS AND PROSPECTS

#### 1. MATERIALS AND METHODS

In order to check the advantages and disadvantages of the Apple LiDAR sensor (FIORINI 2022) in the archaeo-speleology field (FERRARI 2023; MADONIA *et al.* 2023), we performed a series of tests in different underground and/or confined structures of archaeological interest so as to guarantee diversified documentation to understand the effectiveness of the instrumentation. The data acquisition was carried out during 2023 using an Apple iPhone 14 Pro, with IOS V16.2, 256 GB of RAM, while the application used was Scaniverse V2.1.4, with scanning in Area mode and processing in Area mode (FERRARI 2023).

Although the technology limits are effectively illustrated in several contributions relating to different research areas (LUETZENBURG *et al.* 2021, 2; SPREAFICO *et al.* 2021, 421-422; FIORINI 2022, 50-51), the LiDAR scanners installed on iPhones have actually showed specific limitations in some cases such as small decorated objects (for example marble capitals) and when certain environment dimensions are exceeded, where the overall quality of the scans obtained is not comparable to traditional techniques (e.g. laser scanning, photogrammetry, photo rectification, etc.). However, when these devices are used in very particular environments, such as confined spaces, of relatively small dimensions, in which the iPhone is placed at distances between approximately 1 m and 5 m compared to the position of the detected structure, the acquisition capacity of the device is promising and with limited deviations compared to traditional techniques.

Therefore it was decided, taking advantage of the projects that the Authors are carrying out within some of the most evocative sites in Campania, such as those pertaining to the Campi Flegrei Park and the ABAP Superintendence for the Municipality of Naples, to test the scanning quality of the Apple LiDAR sensor in various confined environments that to date had not been the subject of specific archaeological studies. The choice to operate in environments of different sizes and morphologies is also aimed at obtaining a set of useful examples in a context, namely artificial cavities, which to date, even in the speleological field, have not yet found a correct codification in this sense. These are two archaeological sites which are different from each other in terms of time of construction, morphology, size and difficulty of access but which fall within that category of environments/structures where the operating conditions are challenging: 1) Flavian amphitheater in Pozzuoli

(Campi Flegrei Archaeological Park); 2) Augustean aqueduct of Campania in the Fuorigrotta-Coroglio section (falling under the authority of SABAP-NA).

2. CASE STUDY 1. CISTERNS IN THE FLAVIAN AMPHITHEATER IN POZZUOLI

The Flavian amphitheater in Pozzuoli (Fig. 1) is one of the largest known Roman amphitheaters (BONUCCI 1839; DUBOIS 1907, 315-340; MAIURI 1955). Built in the Flavian age (mid-1<sup>st</sup> century AD) to replace the older lesser amphitheater, it has a masonry structure organized into four symmetrical sectors. The sectors are in turn made up of 18 wedges for a total of 72 radial subdivisions. It is an extremely complex building, constantly modified over the centuries, in which the water management and storage was of the most importance. The water, in fact, was collected from the upper levels thanks to an extensive canalization system and it was fed into cisterns –thirteen in all have been identified – positioned at the base of the *cavea* in strategic points with respect to the water courses (MAIURI 1955, 35-40; FERRARI 2023, fig. 3) (Fig. 2). From the morphological point of view, the cisterns are divided into three groups by size and morphology (Tab. 1).

The typical size of a two-chamber cistern is 3 m wide and 7.5 m long (Fig. 3), while the height varies, both due to the covers, which follow the slope

Group	Type	Number
1	Single chamber	4
2	Double chamber	7
3	Quadruple chamber	2

Tab. 1 – Cistern groups in the Flavian amphitheater in Pozzuoli.



Fig. 1 – The Flavian amphitheater in Pozzuoli (photo G.W. Ferrari).

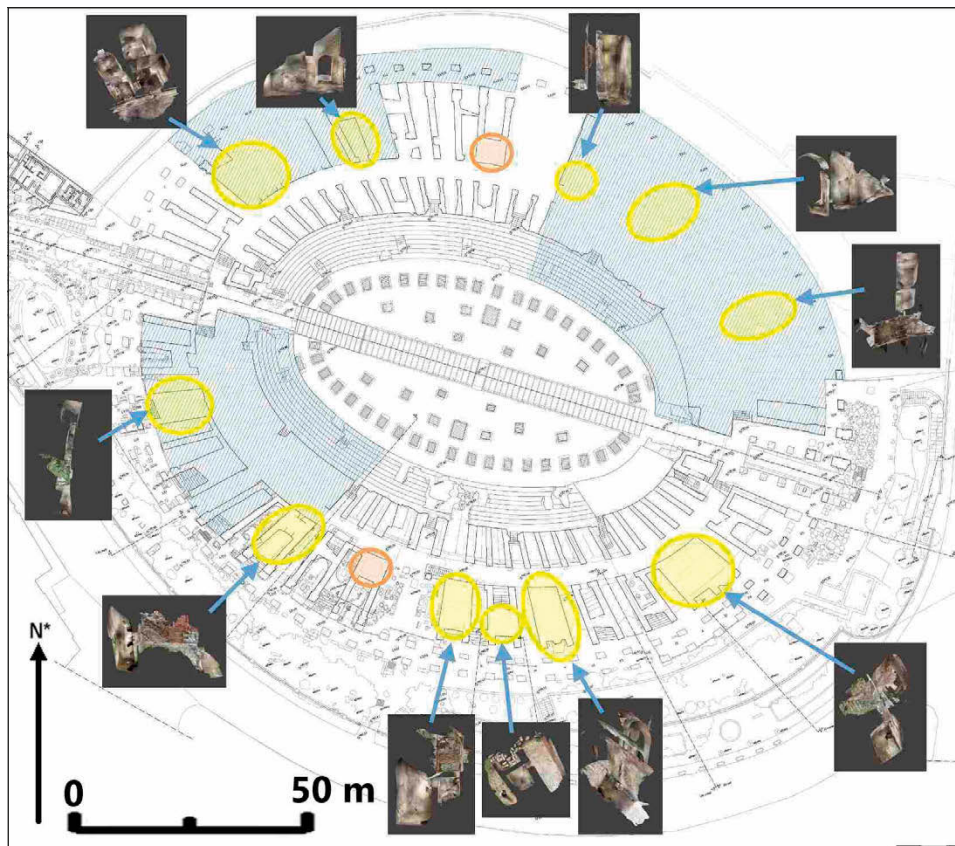


Fig. 2 – Cistern positions in the Flavian amphitheater in Pozzuoli (from FERRARI 2023, fig. 3).

of the access ramps to upper levels, and to the fact that they are still partly cluttered with earth and other debris. The maximum height of the cistern is approximately 9 meters. The difficulties in accessing the cisterns, partly already known in the past (MAIURI 1955, 37, fig. 9), prevented an accurate survey to the point that even today they were not adequately documented or accurately surveyed. As part of this investigation, the cisterns were first identified and characterized and then the individual 3D models were created in a single session on February 28<sup>th</sup> 2023. The collected scans allowed to check advantages, drawbacks and best practices for 3D data acquisition. The scan procedures, hindered both by the accumulation of debris and by the size of the accesses to the different chambers, lasted approximately four hours thanks to the acquisition speed guaranteed by the LiDAR sensor, trying to create

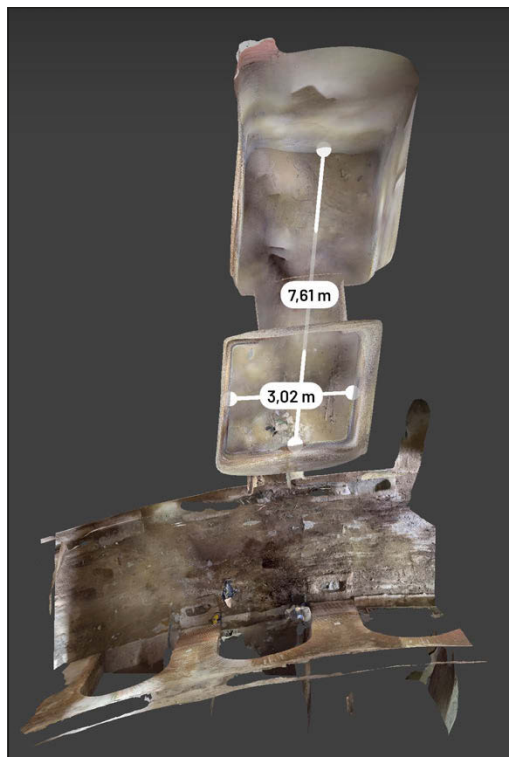


Fig. 3 – Top view of a two-chambers cistern and a main *ambulacrum* section in the Flavian amphitheater (Cocceius Association).

acquisition paths as simple as possible in order to quickly collect information in a real confined spaces archaeological context.

### 3. CASE STUDY 2. AUGUSTAN AQUEDUCT OF CAMPANIA IN THE FUORIGROTTA-COROGGIO SECTION

This section was identified at the beginning of 2023 (DE SIMONE, FERRARI 2024) and belongs to a side branch of the Augustan aqueduct of Campania, directed towards the area where the monumental villas of Nisida and Pausilypon stood (FERRARI 2019). The Augustan aqueduct of Campania is one of the most complex engineering works of Roman antiquity and represents one of the best examples of this particular type of hydraulic infrastructure. Unfortunately, it is still little known and researched on. The course of the aqueduct developed mainly underground and only some sections are currently known, mostly



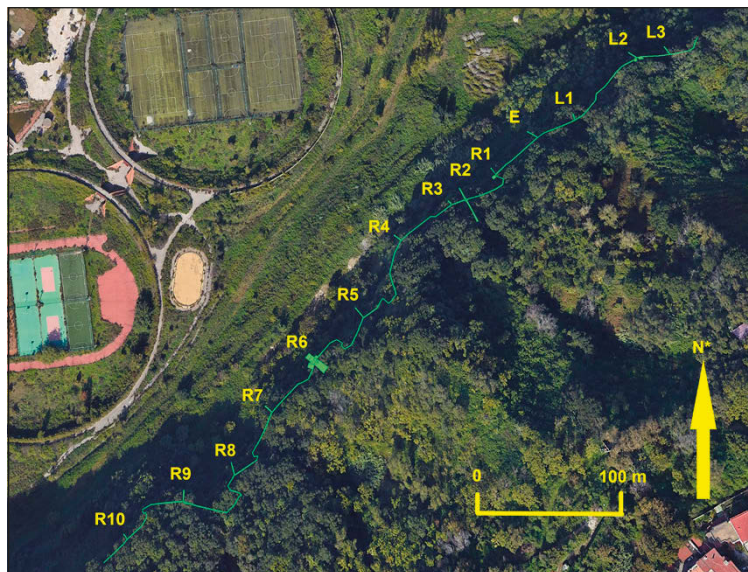


Fig. 4 – Augustan aqueduct side branch section near the Bagnoli reclamation area, with the identified adits (from DE SIMONE, FERRARI 2024, fig. 4).

concentrated in the Neapolitan and Phlegraean areas (CATALANO 2003, 2007; FERRARI *et al.* 2018, 71-78). This great ancient infrastructure was built at the end of the 1<sup>st</sup> century BC to supply fresh water not only to the military port of *Misenum*, but also to a wide portion of what was one of the most populated areas of late-republican Roman Italy, part of Regio I, between the slopes of Vesuvius and the Phlegraean area, as well as some large agricultural centers of the Campania plain. The list of supplied cities is reported in an inscription from 324 AD, found near the Serino springs in 1938 (SGOBBO 1938, 35-97). The main line is approximately 105 km long, reaching approximately 135/140 km with side branches (KEENAN-JONES 2010a, 2010b).

This large ancient infrastructure represented an excellent test bed for the creation of models and surveys with LiDAR in underground environments of limited dimensions, since the typical width of the channel in the Phlegraean area is equal to or less than 64 cm (FERRARI, LAMAGNA 2015). The identified segment is located halfway up the tufaceous ridge of Posillipo, in the municipality of Naples and belongs to a branch that detached itself from the main axis (Serino Springs to *Misenum*) at the Crypta Neapolitana western entrance, and headed towards the Capo Coroglio area. The overall length of the currently explored segment is approximately 800 m, with all the branches and service tunnels identified (Fig. 4), and this qualifies it as the longest, and



Fig. 5 – Augustan aqueduct at Bagnoli: 3D model of R9 adit, with a superposed channel section (Cocceius Association).

probably also the best preserved, section currently known of the Augustan aqueduct (DE SIMONE, FERRARI 2024).

In addition to being of enormous importance about the reconstruction of what must have been the organization and layout of the ancient work in the territory it crossed, this condition also allows us to closely observe the organization of the ancient construction site in relation to the creation of a very complex hydraulic system. Since access to the aqueduct takes place from within the Bagnoli reclamation site, the operating methods were conditioned by the constraints linked to the site itself. It was therefore necessary to operate with particular efficiency and caution. In a first phase, a graphic survey was carried out with a traditional speleological technique, with the use of a compass, clinometer and laser distance meter. In parallel, photographic and video documentation was collected. Only later, in August 2023, was an iPhone scan performed of some sections of particular morphological interest, including the intersection between the R9 service tunnel and the course of the aqueduct (Fig. 5) and the junction point between two excavation teams, particularly tortuous, between accesses R7 and R8 (Fig. 6).

#### 4. DISCUSSION

As already indicated in other contributions (FIORINI 2022; FERRARI 2023) the iPhone Pro LiDAR technology allows you to collect 3D survey data very quickly, with a cost that is not cheap but is accessible also to non-professional entities or to professional archaeologists who can benefit from it enormous advantage for the work activity. The accuracy of the measurements



can be assessed by comparing the linear measurements provided by the scanning application with direct on-site measurements taken using traditional methods. Checks on various measurements have shown that the difference between LiDAR measurements and traditional ones is just a few centimeters, i.e., precise enough to satisfy the typical needs of archaeo-spelaeology. However, to obtain a good quality result, the surveyor must apply several practices or expedients, in order to avoid or mitigate the drawbacks mentioned above:

- 1) maximum range: if cavity length or width is an issue, proper path planning can help scan areas that are too long or wide. If the problem is with the height of the cavity, an extension can be used;
- 2) lighting: to obtain uniform illumination of the surface, an illuminator mounted on the device is useful, while the illuminator of the surveyor's helmet must be turned off;
- 3) uniform speed: jumps, trips and sudden movements must be avoided; as far as possible, the use of a stabilizer support should be considered;
- 4) overlap: careful route planning should avoid double scans of the same area; possibly, overlapping areas can be cropped out in post-processing;



Fig. 6 – Augustan aqueduct at Bagnoli: top view of the junction between two digging teams, between adits R7 and R8 (Cocceius Association).

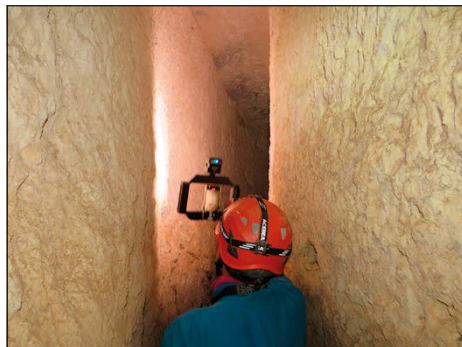


Fig. 7 – Scan with an illuminator/power bank support in an underground aqueduct channel (photo G.W. Ferrari).

5) vegetation: the modeling of areas covered by vegetation is problematic due to the extreme irregularity of the surfaces; scanning in Detail mode is more effective; this involves performing scans with different point densities, to be merged in the post-processing phase;

6) power consumption: the LiDAR sensor requires a significant amount of power. With a fully charged iPhone battery it is still possible to scan for at least a couple of hours. A manual support with illuminator for the iPhone has proven to be particularly useful (Fig. 7); it can also act as a power bank for the device and it allows you to operate for a whole day of acquisition.

Regarding the usefulness of the method in particularly demanding areas, it was possible to survey tunnel sections almost completely blocked by sediments, with free space reduced to less than 40 cm, in which the caver is forced to crawl. In the archaeological field, therefore, the use of this technology allows you to work in ‘extreme’ operating conditions, guaranteeing reliable documentation for all those contexts (hypogea, cisterns, channels, ancient aqueducts, etc.), which usually do not fall within normal activities of archaeological research, due to the obvious access difficulties that these structures very often pose. This is a documentary gap that in the past was resolved by relying exclusively on speleologists, the only ones capable of accessing these contexts, but accustomed to different documentary standards compared to archaeological ones. Furthermore, the possibility of obtaining 3D modeling at relatively low costs is certainly useful in the context of the valorisation itself, given that it allows, quickly, to obtain captivating and easily usable results for communication towards users of cultural heritage.

Therefore, while waiting to be able to resolve some of the limitations set out above, there remains the need, already advanced in other contributions

(FIORINI 2022, 50-51) to continue the experimentation and to proceed with the codification of a precise procedure to be used in order to get the best from this instrumentation.

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### REFERENCES

- BONUCCI C. 1839, *I reali scavamenti nell'anfiteatro di Pozzuoli*, in *Poliorama Pittresco*, Napoli, 4, 65-66 (<http://books.google.it/books?id=VVkZAAAAAYAAJ&pg=PA65>).
- CATALANO R. 2003, *Acqua e acquedotti romani, Fontis Augustaei Aquaeductus*, Napoli, Arte tipografica.
- CATALANO R. 2007, *Intus in tenebris. Scienza e tecnica nelle opere ipogee romane*, Napoli, Arte tipografica.
- DE SIMONE D., FERRARI G.W. 2024, *Acquedotto augusteo della Campania. Notizie preliminari sul tratto Fuorigrotta-Coroglio (Napoli)*, «Fold&cr Italy», 576 ([www.fastionline.org/docs/FOLDER-it-2024-576.pdf](http://www.fastionline.org/docs/FOLDER-it-2024-576.pdf)).
- DUBOIS C. 1907, *Pouzzoles antique (histoire et topographie)*, Paris, Fontemoing (<http://gallica.bnf.fr/ark:/12148/bpt6k5542557f.r>).
- FERRARI G.W. 2019, *Acquedotto augusteo della Campania: la diramazione per Nisida ed il Pausilypon*, «Opera Ipogea, Journal of Speleology in Artificial Cavities», 2, 47-66.

- FERRARI G.W. 2023, *The Pozzuoli (Naples, Italy) Flavian amphitheatre cisterns: A basic experience in 3D modelling with LiDAR*, in S. SAJ et al. (eds.), *Hypogea 2023, Proceedings of the Fourth International Congress of Speleology in Artificial Cavities (Genoa 2023)*, Genova, Centro Studi Sotterranei, 319-324.
- FERRARI G.W., LAMAGNA R. 2015, *Aqua Augusta Campaniae: considerazioni sulle morfologie degli specchi in area flegrea*, in L. DE NITTO, F. MAURANO, M. PARISE (eds.), *Atti del 22° Congresso nazionale di speleologia "Condividere i dati" (Pertosa-Auletta, SA 2015)*, Memorie dell'Istituto Italiano di Speleologia, 2, 29, Bologna, 435-440 (<https://speleo.it/site/wp-content/uploads/2015/05/condati15.pdf#page=499>).
- FERRARI G.W., LAMAGNA R., ROGNONI E. 2018, *Aqua Augusta, nuove evidenze dai Campi Flegrei*, in F. GALGANO, P. ROMANELLO (eds.), *Atti delle Giornate di Studio "Evidenze archeologiche e profili giuridici della rete idrica in Campania" (Napoli 2018)*, Napoli, Editoriale Scientifica, 37-94.
- FIORINI A. 2022, *Scansioni dinamiche in archeologia dell'architettura: test e valutazioni metriche del sensore LiDAR di Apple*, «Archeologia e Calcolatori», 33.1, 35-54 (<https://doi.org/10.19282/ac.33.1.2022.03>).
- KEENAN-JONES D. 2010a, *The Aqua Augusta. Regional Water Supply in Roman and Late Antique Campania*, unpublished PhD Dissertation, Department of Ancient History, Faculty of Arts, Macquarie University, Sidney.
- KEENAN-JONES D. 2010b, *The Aqua Augusta and the control of water resources in the Bay of Naples*, in N. O'SULLIVAN (ed.), *Proceedings of the 31<sup>st</sup> Australasian Society for Classical Studies Conference (Perth 2010)*, 18 (<http://ascsc.org.au/news/ascsc31/Keenan-Jones.pdf>) Perth, Australasian Society for Classical Studies, 1-13.
- LUETZENBURG G., KROON A., BJORK A.A. 2021, *Evaluation of the Apple iPhone 12 Pro LiDAR for an application in geosciences*, «Scientific Reports», 11, 22221 (<https://doi.org/10.1038/s41598-021-01763-9>).
- MADONIA P., CANGEMI M., D'AGOSTINO M., GIUDICE G., MESSINA D. 2023, *Comparative analysis of different techniques for the topographic survey of artificial galleries: The case study of the INGV Messina headquarter geophysical tunnel (Sicily, Italy)*, «Opera Ipogea, Journal of Speleology in Artificial Cavities», 1-2, 83-92 (<https://doi.org/10.57588/SSIOI12/2023/83-92>).
- MAIURI A. 1955, *Studi e ricerche sull'anfiteatro Flavio puteolano*, Napoli, Macchiaroli.
- SGOBBO I. 1938, *L'acquedotto romano della Campania: Fontis Augustei Aquaeductus*, «Notizie degli Scavi di Antichità», 75-97.
- SPREAFICO A., CHIABRANDO F., GIULIO TONOLO F., TEPPATI LOSE L. 2021, *Apple iPad Pro: test e valutazioni metriche sul sensore LiDAR integrato*, in #Asita Academy 2021, Evento online, 421-423 (<http://atti.asita.it/ASITA2021/Pdf/067.pdf>).

## ABSTRACT

For some years now, both in the archaeological and speleological fields, experiments have been carried out with portable MLS (Mobile Laser Scanner) or HMLS (Hand-held Mobile Laser Scanner) scanners that use LiDAR (Light Detection and Ranging) technology. This choice is due to their basic characteristics such as ease of use, reliability, efficiency and (a fact not to be underestimated) low costs compared to traditional indirect survey systems. These characteristics have made these tools extremely popular, especially since this technology can be used by owners of Apple devices, which has made it available for its tablets and smartphones, thanks to the ever-increasing sensor miniaturization. On the basis of some encouraging data presented in an archaeometry paper (FIORINI 2022) and from direct experiences in various underground sites proposed by several Italian caving groups, the authors have decided to test the device performance in the context of exploration and research on artificial cavities in the archaeological field which, very often, due to size and constraints, do not allow the use of other devices. Through the presentation of some case studies, it was possible to show the advantages and the limitations in the use of this technique in the archaeo-speleological field.

## GIS INTEGRATION OF HETEROGENEOUS DATA FOR THE ARCHAEOLOGICAL TOPOGRAPHY OF THE 'ACQUEDOTTO DEL PARADISO', SYRACUSE

### 1. INTRODUCTION

The aim of this paper is to update our knowledge of the archaeological topography of Syracuse by reassessing the available legacy data regarding its waterscape, using both traditional methods and new digital technologies. Among the infrastructures dedicated to the water supply of the Corinthian *polis*, the 'Acquedotto del Paradiso' was one of the most important, extending approximately 2500 m along a NE-SW axis from *Epipolai* towards Ortigia through the *Neapolis* and *Achradina*. The earliest reference to the Syracusan aqueducts is in Thucydides' *Peloponnesian War*, where the historian mentions the cutting of the underground conduits that supplied drinking water to the city during the siege of Syracuse in 414 BCE (TH., VI, 100, 1). These aqueducts, therefore, were already functional in the 5<sup>th</sup> BCE. Their memory was never lost throughout the millennia, as evidenced by modern antiquarian's writings (FAZELLO 1558, 93; CAPODIECI 1813, 278-279). However, first systematic surveys were only conducted in the 19<sup>th</sup> century thanks to J. SCHUBRING (1865) and to F.S. Cavallari and A. Holm, who produced a map that became the cornerstone the research on ancient topography of Syracuse (CAVALLARI, HOLM 1883, tab. 1, I-VIII). The archaeological data on the aqueduct were few: so, scholars have continued until recently to use these data without integrating them with new surveys, new analysis of construction techniques and, where available, repositioning them in their exact locations thanks to the new topographic tools.

This work illustrates how old reports, historical maps, and data from autoptic field surveys carried out with innovative technologies and traditional methods can work together in a Geographic Information System (GIS) environment (Fig. 1) (TORTORICI 2016; BRANCATO 2020). This integrated approach can shed new light on the route and chronology of the Acquedotto del Paradiso, infrastructure always known throughout the centuries although never adequately analysed.

### 2. THE APPLIED METHOD

#### 2.1 *The topographical base*

The initial step involved establishing the topographical base within the GIS environment using the open-source software QGIS 3.28.15. The WGS

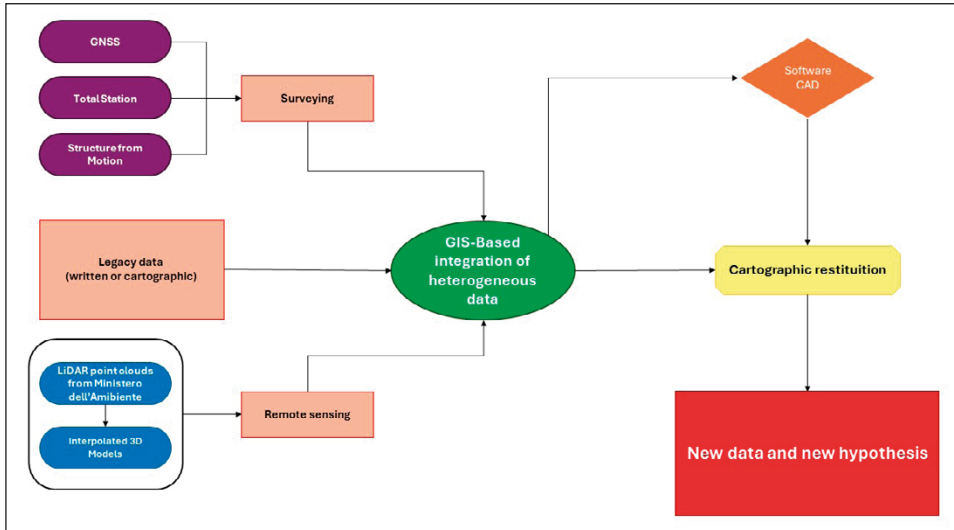


Fig. 1 – Diagram of the topographic data integration process.

84 / UTM 33N (EPSG: 32633) was adopted as the CRS (Coordinate Reference System). The cartographic base chosen is the Carta Tecnica Regionale (CTR) 1:10,000, produced in 2001 by the Sicilian Region (sections 646070, 646080, 646110 and 646120), imported as DXF. On the other hand, the IGM 1:25,000 maps (274 II-NO Belvedere; 274 II-SO Siracusa) and the 2019 orthophoto with a resolution of 20 cm/pix (same sections of CTR) produced by Agenzia per le Erogazioni in Agricoltura (AGEA) were added as Web Map Service (WMS) layers. The orthophoto provided crucial support, allowing for correcting the CTR's positioning errors, which were off by approximately 1 m to the W, using as a reference: 1) the monuments of the Neapolis Archaeological Park in Syracuse, which due to their lower height are less subject than other buildings to the distortion caused by orthorectification; 2) the measured Ground Control Points with GNSS.

## 2.2 Reassessment of legacy data

The aqueducts of Syracuse were first cartographically represented in 19<sup>th</sup> century. Among all other published data significant contributions on Syracusan aqueducts are SCHUBRING 1865 and CAVALLARI, HOLM 1883. For the first time, the aqueducts of Syracuse are cartographically represented. However, the first work uses as its basis *La corografia di Siracusa*, drawn up by Cavallari in 1839 during the years of his collaboration with D. Lo Faso Pietrasanta and published in the latter's work (LO FASO PIETRASANTA 1840,



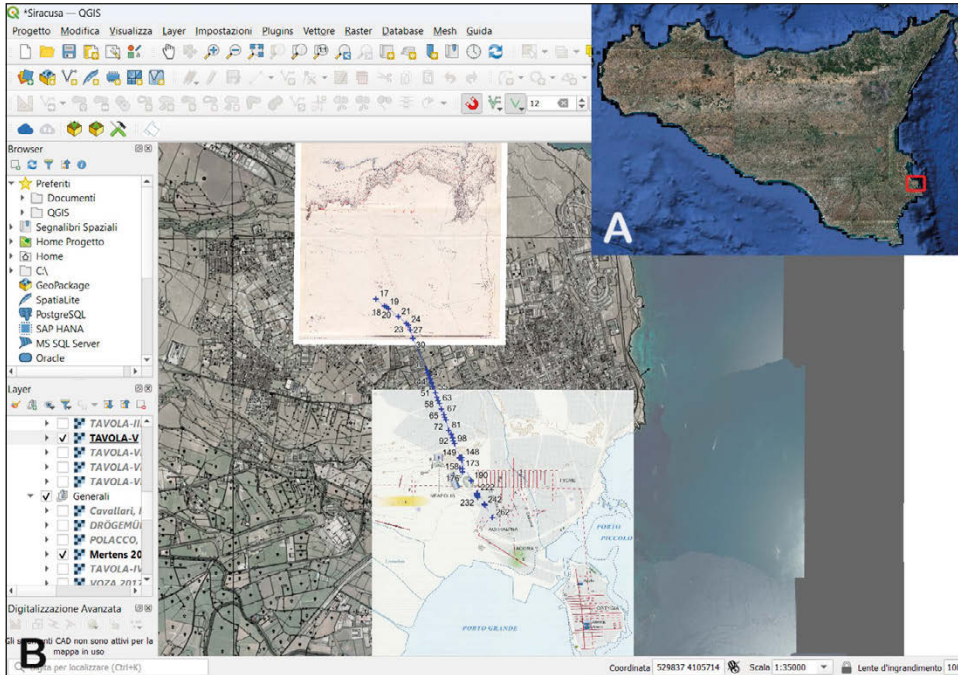


Fig. 2 – A) Orthophoto of Sicily. The red rectangle highlights the location of Syracuse on the East coast of the island; B) snapshot of the QGIS software showing the Syracuse plateau area, illustrating the process of integrating and vectorizing the aqueduct path. In the background are Cavallari and Holm's Tab. V, D. Mertens' plan of Syracuse (MERTENS 2006, 311, fig. 567), the CTR, and the orthophoto.

tab. 1). Although the best available at the time, it was not drawn geodetically and therefore cannot be directly used in a GIS environment. In the second one, however, F.S. Cavallari himself together with C. Cavallari, used as a basis for the archaeological map of Syracuse the detailed map drawn by the Stato Maggiore Italiano at a scale of 1:10,000 which is precise and accurate (CAVALLARI, HOLM 1883, 12-13, tab. I-VII), then topographically reliable and easily imported into QGIS (Fig. 2). The two works are characterised by a substantial difference: the article *Die bewässerung von Syrakus*, although outdated in some of its theories, describes, and represents in detail for the first time, all hydraulic infrastructures (i.e. wells, canals, cisterns and basins) identified at the time in Syracuse; despite their cartographic representation, *Topografia Archeologica di Siracusa* actually devotes only a quite general chapter to Syracusan aqueducts instead.

More recent studies (CULTRERA 1938; GENTILI 1973; GUZZARDI 1993-1994 e 2000; FILANTROPPI 2022) have added further insights, including the

discovery of an open channel covered by the Roman amphitheatre (GENTILI 1973, 20-21) and a presumed stretch of the aqueduct in arches (FILANTROPI 2022). Then the aforementioned GIS was populated with all the geodata acquired from these studies, based on the topographical consistency of the graphic documentation, cadastral references and any other possible information regarding the location of the evidence described (TORTORICI 2016). So, a geodatabase was designed to integrate legacy geodata with new data, enabling them to interact seamlessly. They, when possible, was positioned in GIS, through the 'georeferencer' tool, using homologous points visible between these, the IGM maps, the CTR and orthophotos. The evidence of archaeological interest was then vectorized: the route of the Acquedotto del Paradiso represented as a line and individual wells as point elements. Each vector was catalogued as a *Unità Topografica* (UT) with progressive number and other metadata as attributes: type, chronology, description, bibliography and measurements when available.

Thanks to a re-interpretation of Schubring's text, helped by the positioning of the Cavallari's tables, it was possible to locate, quite precisely, the evidence relating to the Paradise Aqueduct to which he refers, like wells not otherwise represented, including one that can be assumed to have been the well marking the beginning of the pipeline. Crucial support for Schubring's interpretation were the aerial photographs taken in the 1940s; georeferenced by homologous points too and when possible orthorectified, this process made it possible to recognise buildings referred to by Schubring, still visible in the Syracuse not yet affected by the great process of urbanisation that would take place in the following decades.

In this way, it was possible to visualise the route of the aqueduct in 2D (Fig. 3A), producing an archaeological map containing the complete catalogue of published data as well as new findings from the fieldwork. A total of 320 UTs were identified, of which 51 related to the Acquedotto del Paradiso.

### 2.3 *Re-interpolation and processing of LiDAR point clouds*

To enhance the available cartographic base and avoid being limited to a plan, a 3D model of the Syracuse plateau was created, from which a section of the route of the Aqueduct of Paradise including the new evidence was drawn; this was necessary not only to visualise the slopes but also to verify that the identified entities (51 UTs) were topographically and altimetrically related with the overall infrastructure. Therefore, it was necessary to reinterpolate the point clouds obtained from the LiDAR scans produced for the national topographic survey by the Ministero dell'Ambiente e Territorio, already been granted to the Laboratorio digitale di Topografia Archeologica of University of Naples (BRANCATO *et al.* in press; cf. also FONTANA 2022). However, the

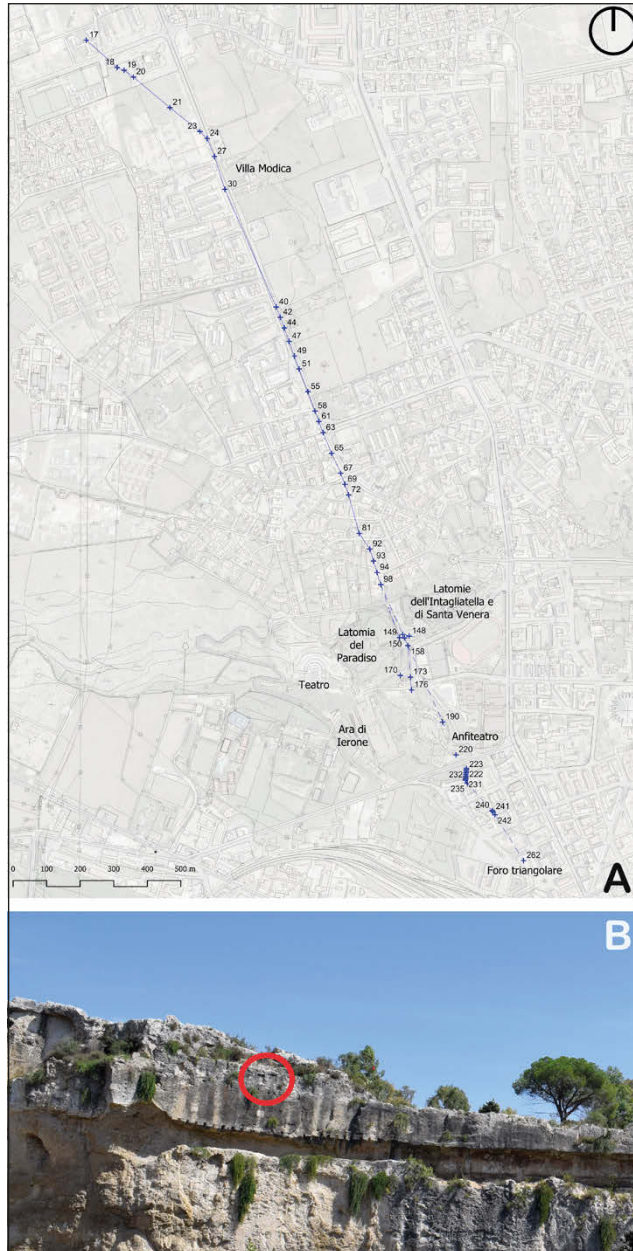


Fig. 3 – A) Reconstruction of the Acquedotto del Paradiso route through the related UTs; B) cut section of the aqueduct visible along the eastern boundary of the Latomia del Paradiso (UT 149). The red circle highlights the votive panels.

topographical exploitation of this type of dataset, is not so straightforward, since to date there is no single software that allows all the processing. Then, the use a series of software was required:

- LASTools 2.0.3, a suite of tools executable on QGIS;
- ConveRgo 2.05;
- Leica Cyclone 3DR 2023.00.01.42806, which unlike the others is proprietary and not open source.

Therefore, to facilitate the process, it is essential to know what features are to be inferred from the final model, and consequently the problems that will have to be addressed. Indeed, the point clouds, in fact, are supplied by the Ministero in the geographical reference system ETRF89 with ellipsoid height, in the form of ASCII text files. In the present case, since it was necessary to obtain a good model of the surface of Syracuse that could be imported into a GIS environment it was essential to carry these conversions: the format from ASCII to LAS, the CRS from geographic to cartographic WGS 84/UTM 33N and the elevation from ellipsoid to orthometric. Due to the scale and nature

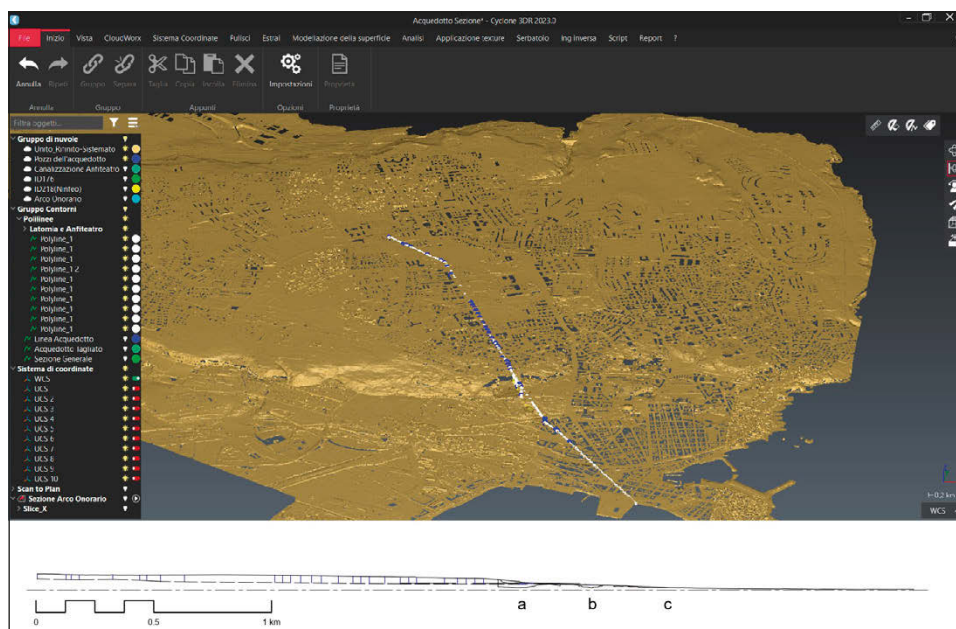


Fig. 4 – At the top, a snapshot from Leica Cyclone 3DR showing the interpolated point cloud of the Syracuse plateau, with the route of the Acquedotto del Paradiso in white and the wells in blue. Below, the section obtained in AutoCAD after completing the process: a) Latomia del Paradiso; b) Roman amphitheater; c) Foro triangolare.



of the study, it was crucial to obtain accurate and comparable elevation data, whether from GNSS measurements, CTR maps or published studies; other research utilizing LiDAR point clouds at a broader territorial scale, so does not face this issue (FONTANA 2022).

The only free way to convert CRS and height is via ConveRgo, that still returns an ASCII text file that must be processed via LASTools' `txt2las` tool for obtaining a LAS file. In absence of the conversion grids, the positioning error on the X and Y axes, encountered in the GIS environment, was resolved by projecting the same point cloud, not processed by ConveRgo, through the `las2las_project` tool of LASTools, and thus obtaining two equal point clouds: one well positioned but with ellipsoid height and the other with orthometric height but poorly located. Through QGIS it was then possible to measure the distance between the two and with the '`las2las_transform`' tool of LASTools move the second one. This produced a point cloud with geoid height positioned along the X and Y axes with centimetric error. The great potential of the LASTools suite lies in its ability to remove points relating to modern buildings and vegetation making possible to obtain a point cloud of the terrain only, in which the archaeological data is preserved, and, if necessary, to process the relative Digital Elevation Model (DEM), i.e. a 2.5D image of the terrain.

Obtained the point cloud of the terrain, it was possible to derive the section of the route of aqueduct. For this purpose, another software was essential: Leica Cyclone 3DR (Fig. 4). Although an open-source software capable of handling point clouds could have been used, the proprietary software was chosen because, despite its high specifications, it allows for fast and straightforward processing of point cloud sections; indeed, it is equipped with a tool, Scan to Plan, which makes it possible to 'slice' a point cloud, obtaining only the points that fall along the section line, and subsequently tracing them with a polyline exportable in DXF. In this way, even very large sections can be quickly produced. Since the path of the aqueduct is not completely straight, it was necessary to design no less than ten section lines, from which, using Scan to Plan, as many sections were obtained and after exported to AutoCAD. Thanks to that software the points relating to the aqueduct's evidence exported from QGIS were superimposed, and all the sections were merged in order to obtain a single frontal view.

From the visible sections of the canalisation and the wells whose depths are shown in the legacy data, the presumed line of the aqueduct canalisation was obtained, and for that it was also possible to hypothesise the depth of the unknown wells, as well as the height of the presumed pillars belonging to an overhead section. Considering that it is unclear where the aqueduct ended, it was decided to extend the section as far as the sea to have a visual comparison with the elevation of m 0 above sea level (Fig. 4).

## 2.4 Autoptic analysis and surveying

Direct observation and site survey were fundamental to the objectives of this research. Using methods and instruments of indirect survey (GNSS; TPS; UAV; Camera; SfM) it was possible to identify and, in most cases, detect evidence and structures related to the Acquedotto del Paradiso 'system'. Reference is made here to the new survey of a building that was most probably part of this system the so-called Piscina di San Nicolò ai cordari, an underground building in the Neapolis Archaeological Area of Syracuse (DE MAGISTRIS 2014). The building, with a rectangular floor plan, is approximately 19.5 m long by 7 m wide and has a maximum height of approximately 5 m; it is also characterised by a roof composed of three-barrel vaults in *opus caementicium*, sustained by an entablature system using two flat arches, supported by two rows of seven square *opus quadratum* pillars. The new survey' results (Fig. 5) (BRANCATO *et al.* in preparation) which will be discussed later, have made it possible to identify phases of use related to the aqueduct.

In addition to this, during the explorations of the archaeological area, it was possible to identify what remains of the wells connected to the cut canal visible on the eastern boundary of the Latomia del Paradiso, and of votive panels located above these, at a very high elevation compared to the current ground level (Fig. 3B). Unfortunately, given their unreachability, it has only been possible to take photographs of them, and it is hoped to be able to survey them as soon as possible with the appropriate instruments;



Fig. 5 – New plan of the Piscina di San Nicolò ai Cordari and its surroundings. The red circle highlights the channel that fed the cistern. On the right, a detailed elevation view of that channel.



measurements have so far been taken from the 3D model. Instead, two wells were surveyed, afferent to the branch replacing the one that had been cut, two furrows afferent to a carriageway, passing exactly above the two wells, and the continuum of this canal that opens to the open sky. Finally, a well located behind the current ticket office of the area.

### 3. RESULTS

#### 3.1 *The route of the aqueduct*

Numerous scholars have traditionally identified only one construction phase for the Acquedotto del Paradiso: a rectangular canal approximately 1.80 m by ca. 0.5 m, dug into the geological stratum, without lining and connected to the surface by inspection shafts spaced about 25-30 m apart, with a total length of 1565 m (CAVALLARI, HOLM 1883, 125-127). The comparison carried out in the GIS environment, of legacy and new data allowed this information to be updated. The positioning of 31 inspection wells, 12 of which were previously unidentified (CAVALLARI, HOLM 1883, tab. IV-V), allows for the hypothesis that the aqueduct's path extends approximately 466 m further N. A relevant role was played by the three wells found near viale Scala Greca (Fig. 3A, n. 18-20) (GUZZARDI 1993-1994) and the well reported by Schubring would seem to indicate the beginning of the conduction (Fig. 3A, n. 17) (SCHUBRING 1864, 594-595, n. 110). The identification of the southern path of the aqueduct, however, is more complicated. Cavallari and Holm indefinitely indicate the end of the conduit near the open channel and the wells found on the limestone diaphragm between the latomie of Paradiso and Intagliatella. Recent studies (COLLIN BOUFFIER 1987, 683-687; WILSON 1990, 94-95, 2000, 13; MIRISOLA 2015, 55; COLLIN BOUFFIER 2020, 161-162; FILANTROPI 2022, 321), have reported that aqueduct main trench reached the Piscina di San Nicolò, deemed to be a cistern, or that from there the water reached the basin located in the centre of the Roman amphitheatre (GENTILI 1973, 71-73).

Here, however, it is now necessary to focus on the open-air canal found on the eastern half of the amphitheatre in Syracuse (GENTILI 1973, 20-21). This canal, characterised by a hydraulic coat 6-7 cm thick, consists of a cut in the limestone with a rectangular section 36-37 cm wide; these same technological and metrological characteristics can be found in the water conduit that fed the San Nicolò cistern (Fig. 5) and in the one, built on the diaphragm between the two latomie in place of the cut aqueduct already mentioned. Due to this data, it is possible to recognise a route with a total length of 2363 m heading S of the amphitheatre, in which interventions from several phases seem to be identifiable. S of this area, the city's water supply would also seem to be secured by a section of aqueduct on arches, corresponding to another

phase of use, which would extend as far as the so-called Foro Triangolare, an area where the presence of warehouses and water-dependent production buildings has been hypothesized. According to this hypothesis, the Acquedotto del Paradiso would have reached a length of approximately 2843 m (Fig. 3A).

### 3.2 *A double gallery?*

The analysis of the now available section provided new evidence refuting the existence of the so-called double gallery in the three urban aqueducts of Syracuse. This uncommon technical feature, rarely attested elsewhere (TÖLLE-KASTENBEIN 1990, 68-72), would be present in all three Syracusan conduits; based on this assumption, it has allowed scholars to hypothesise a general project underlying their construction. Cavallari and Holm attest and verify the presence of this expedient in a single well (Fig. 2, n. 67) of the Paradise Aqueduct and hypothesise its presence along the entire route (CAVALLARI, HOLM 1883, 126, tab. IV, n. 72bis). However, the section (Fig. 6, n. 67) suggests that the bottom of the identified well is too low to ensure a proper gradient for water flow to the open channel on the diaphragm between the two latomie, but not for the water flow to the channel cut in the latomia eastern edge. The higher position of the upper gallery, on the other hand, would seem to guarantee a good waterflow to the open channel. Therefore, as this technical solution is not attested for the wells further N, nor is any double gallery visible into the eastern edge of the Latomia del Paradiso, it is assumed that this may have been a technical feature to make the water to flow to the new canal excavated further E, built at a higher elevation than the original one.

### 3.3 *An aqueduct with several construction phases*

This new research identified a sequence of construction phases of the Acquedotto del Paradiso. According to rather recent discoveries, the construction of this system dates around the 4<sup>th</sup> century BC (GUZZARDI 1993-1994, 1308-1309; 2000, 99-100), but the new survey of the Piscina di San Nicolò may reveal further chronological information. Initially, a road cut off in the limestone with a NE/SO direction was dug in the same area of the building (BRANCATO, TORTORICI in press; BRANCATO *et al.* in preparation). Its continuation probably collapsed later together with part of the Paradise Aqueduct canal, which can still be seen in section in the eastern boundary of the latomia (VITALI *et al.* 2015, 56). The traces of the existence of this road axis can be observed from the presence of votive panels, now located at considerable heights along the eastern edge of the Latomia del Paradiso (Fig. 3B), which would have skirted the road axis similarly to the sides of the piscina. After the collapse of the latomia it was necessary, in order to re-functionalize the systems, to move both the road axis and the aqueduct canal to the east.

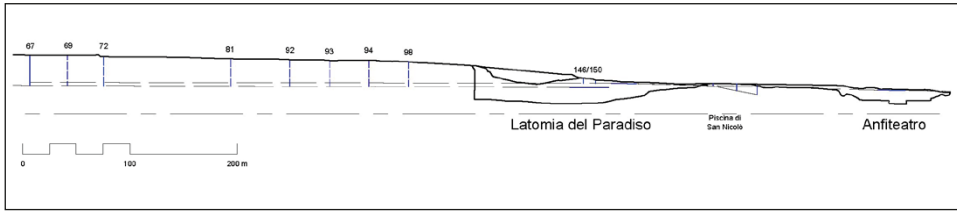


Fig. 6 – Section of the Acquedotto del Paradiso. Detail of the stretch passing through the Neapolis.

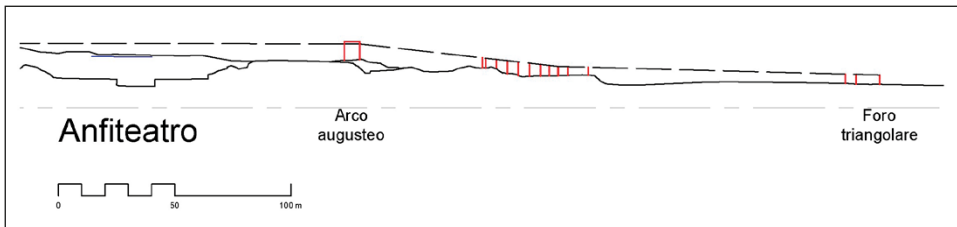


Fig. 7 – Section of the Acquedotto del Paradiso, detail. Hypothesis of an aqueduct stretch on arches. In red, Augustan arch and pillars.

This is evidenced by a roadway and two inspection pits in the centre of this, which indicate the existence of a canalisation that a little further S is revealed as an open canal. However, the construction techniques were different from before: the channels, often open, have a smaller rectangular section, and, above all, a hydraulic coating, like channel headed eastwards in front of the Casale Greco, the another directed to the Piscina di San Nicolò, and finally the last, probably the main one, that continued towards the amphitheatre, where the one oft-mentioned has been found, which, allows us to date it to before the construction of the Roman building, first century AD (BELVEDERE 1988, 353; 357). By comparing the results of the survey of the cistern with those of the aqueduct, it even seems possible to propose a phase of disuse between the first and second phase of use of the aqueduct, correlated with the building with a wooden roof that closed the sunken road that only later became a cistern with the channel. This phase of disuse would fit in well with the progressive abandonment that characterise the N of the Neapolis and with the sudden cessation of use of the baths of via Zappalà (CULTRERA 1938) both datable towards the end of the 3<sup>rd</sup> century BCE, close to the Roman conquest (BASILE 2012, 213). It is unclear when the aqueduct was restored, but certainly before the 1<sup>st</sup> century AD.

The aqueduct headed S towards an area in need of water supply, probably that of the so-called Foro Triangolare: however, after the construction of the

amphitheatre there is no evidence of regarding its reconstruction (BRANCATO, TORTORICI in press). A series of pillars has recently been identified as possible piers arches of the aqueduct' arches (FILANTROPI 2022). However, this hypothesis brings with it several problems. To avoid the amphitheatre and connect to the pre-existing canal without increasing its length, the new conduit would necessarily have had to pass near the Augustan arch (GENTILI 1951, 277). However, if we accept this hypothesis, the aqueduct would have had to pass in front of the honorary arch. On the other hand, maybe the honorary arch itself was one of the arches of the aqueduct (Fig. 7), similarly to the Porta Prenestina-Labicana, or Porta Maggiore, in Rome (ASHBY, RICHMOND 1935, 81-82, 141-144, 242-244; COARELLI 1980, 15-16). In this case, the passage through the honorary arch would involve that the pillars to be about 6 m: indeed, it is possible to hypothesize a section of the aqueduct on arches that would be able to maintain the overall slope consistent with that of the general infrastructure. However, the excavation of the area did not bring to light other pillars aligned to the aforementioned ones (GENTILI 1951, 261, 264, fig. 1, 3). Nevertheless, it remains certain that in this area the water flows and the greatest clue is the nymphaeum to the S of the amphitheatre (Fig. 3A, n. 220; Fig. 7).

#### 4. CONCLUSIONS

The integration of heterogeneous geodata within a GIS environment (BRANCATO *et al.* 2023) may significantly enhance our understanding of the Acquedotto del Paradiso and the ancient topography of Syracuse. By combining legacy data, historical cartography, 3D models from LiDAR point clouds and SfM, and direct surveys, this study has uncovered a complex and multi-phased history of the aqueduct previously not recognized. The research highlights the value of a multidisciplinary approach, blending traditional archaeological methods with advanced digital tools to provide a more nuanced and accurate depiction of ancient water supply systems. The results not only may refine our knowledge on the aqueduct's path in early imperial age, but also suggest the possibility of previously unknown phases and challenge theories such that of the double gallery. This project may be a model for future studies in the archaeological topography of ancient supply systems of Syracuse, demonstrating how GIS and digital technologies can reinterpret historical data and yield new insights into ancient urban planning and their infrastructures.

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## REFERENCES

- ASHBY T., RICHMOND I.A.S. 1935, *The Aqueducts of Ancient Rome*, Oxford, Clarendon Press.
- BASILE B. 2012, *L'urbanistica di Siracusa greca: nuovi dati, vecchi problemi*, «Archivio Storico Siracusano», 47, 177-224.
- BELVEDERE O. 1988, *Opere pubbliche ed edifici per lo spettacolo nella Sicilia di età imperiale*, in H. TEMPORINI (ed.), *Politische Geschichte (Provinzen und Randvölker: Sizilien und Sardinien; Italien und Rom; Allgemeines)*, Berlin-Boston, De Gruyter, 346-413 (<https://doi.org/10.1515/9783110855692-006>).
- BRANCATO R. 2020, *How to access ancient landscapes? Field survey and legacy data integration for research on Greek and Roman settlement patterns in eastern Sicily*, «Groma», 4, 1-32.
- BRANCATO R., GIACOPPO F., LUONGO G., PIANESE C., ROCCUZZO M.C., SCERRA S. in press, *Osservazioni archeologiche e topografiche sull'insediamento d'altura nel territorio ibleo (Sicilia sud-orientale): il caso di Monte Casasia*, in *Hyblaea II*.
- BRANCATO R., LAMANNA C., MANGANELLI L., MIRTO V. 2023, *Digital technologies and the archaeological topography of Castellito (Sicily): The reconstruction of a Roman villa*, «Archeologia e Calcolatori», 34.2, 185-206 (<https://doi.org/10.19282/ac.34.2.2023.10>).
- BRANCATO R., LANTERI R., LUONGO G. in preparation, *Digital 3D technologies for the archaeological topography of San Nicolò ai Cordari (Siracusa-Sicily)*.
- BRANCATO R., TORTORICI E. in press, *Paesaggi sacri della Sicilia orientale: riflessioni archeologiche e topografiche su aree di culto e viabilità*, in *Atlante Tematico di Topografia Antica*.
- CAPODIECI G.M. 1813, *Antichi monumenti di Siracusa illustrati*, I-II, Siracusa, D. Francesco Pulejo Editore.
- CAVALLARI F.S., HOLM A. 1883, *Topografia archeologica di Siracusa*, Palermo, Tipografia dello Statuto.
- COARELLI F. 1980, *Roma*, Roma-Bari, Laterza.
- COLLIN BOUFFIER S. 1987, *L'alimentation en eau de la colonie grecque de Syracuse*, «Mélanges de l'École française de Rome», 99, 661-691.
- COLLIN BOUFFIER S. 2020, *Syracusan water networks in antiquity*, in N. CHIARENZA, A. HAUG, U. MÜLLER (eds.), *The Power of Urban Water: Studies in Premodern Urbanism*, Boston, de Gruyter, 157-178.
- CULTRERA G. 1938, *Siracusa. Rovine di un antico stabilimento idraulico in contrada Zappalà*, «Notizie degli Scavi di Antichità», 261-301.
- DE MAGISTRIS E. 2014, *L'ipogeo di San Nicolò dei Cordari a Siracusa: fasi costruttive e funzione*, «Journal of Ancient Topography», 24, 163-174.
- FAZELLO T. 1558, *De rebus siculis decades duae*, Panormi, Ioannem Matthaeum Maidam et Franciscum Carraram.
- FILANTROPOLI G. 2022, *Ipotesi di un acquedotto su arcate a sud dell'Anfiteatro di Siracusa*, in F. NICOLETTI (ed.), *Siracusa antica. Nuove prospettive di ricerca*, Palermo, Regione Siciliana, 311-322.

- FONTANA G. 2022, *Italy's hidden hillforts: A large-scale Lidar-based mapping of Samnium*, «Journal of Field Archaeology», 47, 4, 245-261 (<https://doi.org/10.1080/00934690.2022.2031465>).
- GENTILI G.V. 1951, *Scoperte nelle due nuove arterie stradali*, «Notizie degli Scavi di Antichità», 261-334.
- GENTILI G.V. 1973, *Studi e ricerche su l'anfiteatro di Siracusa*, «Palladio», 23, 3-80.
- GUZZARDI L. 1993-1994, *Ricerche archeologiche nel siracusano*, «Kokalos», 39-40, 1299-1314.
- GUZZARDI L. 2000, *Il complesso di viale Scala Greca e l'acquedotto del Paradiso a Siracusa*, in G.C.M. JANSEN (ed.), *Cura Aquarum in Sicilia*, Leuven, Peeters, 97-101.
- LO FASO PIETRASANTA D. 1840, *Le antichità della Sicilia esposte ed illustrate*, IV, Palermo, Reale Stamperia.
- MERTENS D. 2006, *Städte und Bauten der Westgriechen: Von der Kolonisationszeit bis zur Krise um 400 vor Christus*, München, Hirmer.
- MIRISOLA R. 2015, *Il Porto Piccolo con l'arsenale dionigiano del Lakkios, forza strategica di Siracusa greca*, Suppl. a «Geologia dell'Ambiente», 2, 43-62.
- SCHUBRING J. 1865, *Die bewässerung von Syrakus*, «Philologus», 22, 577-638.
- TÖLLE-KASTENBEIN R. 1990, *Antike Wasserkultur*, München, Verlag C.H. Beck (tr. it. Milano, Longanesi, 1993).
- TORTORICI E. 2016, *Catania antica: la carta archeologica*, Roma, L'Erma di Bretschneider.
- VITALI D., ZIMBARDO M., NOCILLA A., ERCOLI L., NOCILLA N. 2015, *Meccanismi di collasso nelle Latomie di Siracusa*, «Rivista Italiana di Geotecnica», 3, 47-57.
- WILSON R.J.A. 1990, *Sicily under the Roman Empire: The archaeology of a Roman province 36BC-AD 535*, Warminster, Aris & Phillips.
- WILSON R.J.A. 2000, *Aqueducts and water supply in Greek and Roman Sicily*, in G.C.M. JANSEN (ed.), *Cura aquarum in Sicilia*, Leuven, Peeters, 5-36.

## ABSTRACT

This study explores the GIS legacy data integration for a reassessment of the archaeological topography of Syracuse, with a focus on the Acquedotto del Paradiso. The research updates the understanding of Syracuse's ancient waterscape by combining traditional archaeological methods with advanced digital technologies. Legacy data, historical maps, and recent fieldwork were systematically integrated into a GIS software, enhancing the spatial analysis and re-evaluation of the aqueduct's route and construction phases. The study incorporated topographical bases, LiDAR point clouds, and autoptic analyses, revealing new insights into the aqueduct's structural phases, including potential multi-phase construction and a double gallery system. The integration of these diverse datasets not only refined the known path of the aqueduct but also provided a detailed 2D and 3D visualization of it. This multidisciplinary approach emphasises the importance of combining traditional and modern techniques to improve the accuracy of archaeological topography, offering a more comprehensive understanding of ancient urban water supply systems in Syracuse.



## DIGITAL STRATEGIES FOR ENHANCING CULTURAL HERITAGE: THE VILLA DEL CASALE OF PIAZZA ARMERINA PROJECT, FROM LEGACY DATA TO DIGITAL ECOSYSTEM

### 1. INTRODUCTION

Legacy data plays a pivotal role in reconstructing archaeological sites and historical landscapes, often consisting of diverse analogue resources that require a multifaceted approach to unlock their heuristic potential. In response, digitization emerges as a transformative solution which offers opportunities to safeguard and democratize access to this heritage, transcending geographical borders and enabling remote access to materials previously confined to specific locations. Depending on data quality and scientific objectives, focused strategies for digital acquisition and deployment are needed, bridging disciplinary boundaries, and overcoming evidence fragmentation (ALLISON 2008; ASPÖCK 2020; KATSIANIS, KALAYCI, SARRIS 2022).

This is particularly pertinent in a geographic and cultural context like Sicily, situated at the crossroads of civilizations, boasting a diverse cultural heritage spanning millennia. In the digital age, Sicily faces the challenge of preserving its tangible and intangible assets due to severe constraints like technological obsolescence, fragmented efforts, and the digital divide. Against this background, innovative approaches and digitization strategies are crucial for preserving artifacts, mitigating physical deterioration, and sharing cultural resources globally (BONACINI 2012; CARDACI, VERSACI 2019; GABELLONE *et al.* 2020). Since the last decade, a few international projects have tackled this issued by deploying innovative approaches in digital technologies to document, preserve and enhance Sicily cultural heritage. Online platforms provide access to digitized artworks and historical records, traditionally stored in remote physical archives, democratizing knowledge, and promoting cultural exchange. Some recent initiatives employ 3D scanning, AR, and VR to document archaeological sites and artifacts, and enable immersive experiences that transcend physical boundaries (BARONE, NUCCIO 2017; BONACINI *et al.* 2019; BONACINI 2020; VENNARUCCI *et al.* 2021; KINGSLAND 2023).

### 2. THE PROJECT

The project entitled ‘Digital strategies for enhancing cultural heritage: the Villa del Casale of Piazza Armerina, from the late antique building site to the Museum Collection’ aligns perfectly with this context. Launched in 2023 as a three-year endeavor, it represents a research case study of a wider, EU-funded initiative entitled ‘Virtual Technologies for Museums and Art



Fig. 1 – Drone photo of the Villa del Casale archaeological site (photo C. Lamanna).

Collections, which acts as a thematic spoke of the project CHANGES ‘Cultural Heritage Active Innovation for Next-Gen Sustainable Society’ (<https://sites.google.com/uniroma1.it/changes/>, PNRR Mission 4). It focuses on the use of virtual technologies for the promotion, preservation, and enhancement of cultural heritage in Italian museums and art collections, exploring heritagization processes and conceptualizing digital cultural heritage as a network of interlinked relations among digital objects and their cultural environment (BALZANI *et al.* 2024).

The present project focuses on Palazzo Trigona Museum of Piazza Armerina in its relationship with the archaeological context of Villa del Casale, a UNESCO World Heritage site since 1997 (Fig. 1). Generally appreciated for the imposing decoration of the 4<sup>th</sup> c. residence, for centuries it played the role of key landscape marker with an almost uninterrupted occupation from the so-called Villa Rustica (end of the 1<sup>st</sup> c. AD) to the Medieval village (12<sup>th</sup> c. AD) (GENTILI 1999; SFAMENI 2006; BONANNO 2020). This settlement palimpsest has been brought to light during many excavation seasons lasting from the second half of the 19<sup>th</sup> century to 2014 (PENSABENE, BARRESI 2019). After a short break, since 2022 scientific activities have been resumed under the coordination of the University of Bologna and the auspices of CISEM (BALDINI *et al.* 2023; <https://centri.unibo.it/cisem/it>).

The Palazzo Trigona Museum collection aims to showcase the historical development of the Villa through select excavation findings, yet only a fraction of its extensive heritage is on display. In addition, the significant

distance between the Museum and the Villa (about 6.5 km) frequently hinders the development of a cohesive itinerary linking the two sites. To bridge this gap, the creation of a web-based digital ecosystem intends to expand users' perception of Piazza Armerina cultural heritage and provides them with a novel, updated and comprehensive understanding of its historical developments. By enhancing Museum exhibits and virtually accessing artifacts stored in the Villa's storerooms, the project seeks to enrich visitors' experiences and promote cultural exchange.

### 3. METHODOLOGY

Adopting a multidisciplinary approach, the project aims to gather scattered legacy data, advances scientific understanding, and develops precise datasets through historical research and digitization. The overarching goal is to comprehensively document 2D and 3D assets, getting them to interact and offering unrestricted access in a digital environment. The project pipeline outlines a sequence of steps including the collection of historical, archaeological, and archival data, the digital acquisition and processing of documents and artifacts, and the sharing of content and metadata online on an open-source Web3D framework (ATON). Semantic metadata enrichment

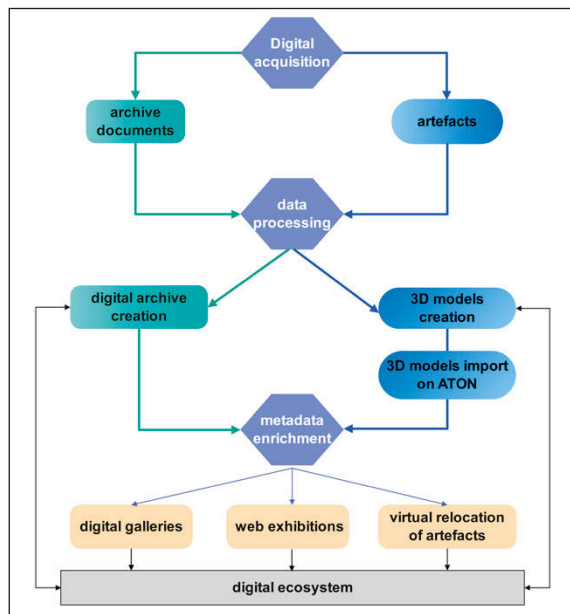


Fig. 2 – Pipeline for the implementation of legacy data into project digital ecosystem.

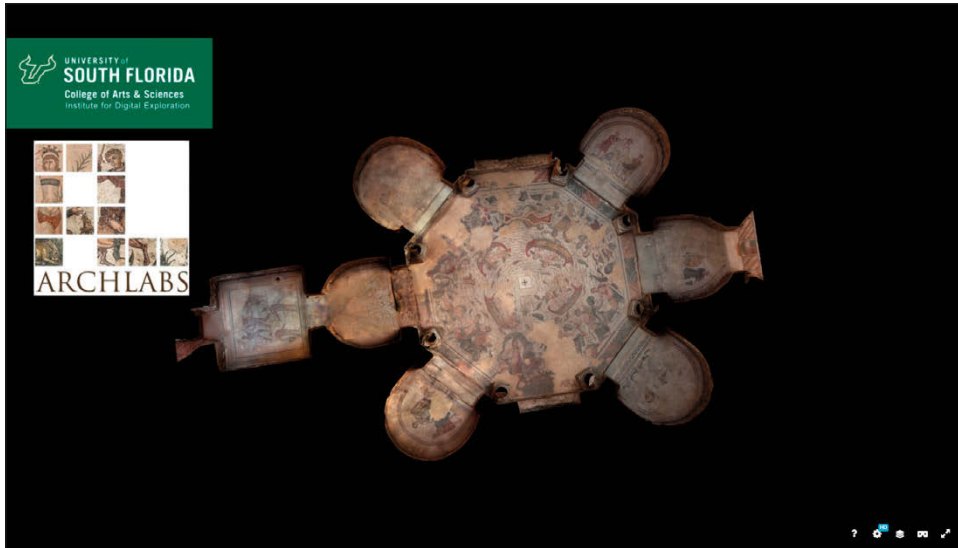


Fig. 3 – 3D model of the *frigidarium* of Villa del Casale on iDEX Sketchfab collection (© D. Tanasi, <https://skfb.ly/oA6ou>).

will be ensured by the adoption of ontologies and existing standards, such as CIDOC CRM, integrating application profiles for specific targets, such as CHAD-AP for the description of acquisition and digitization workflow (BARZAGHI *et al.* 2024), to foster interoperability and data integration (Fig. 2). This endeavor seeks to facilitate a profound exploration of the monument's history and the context of its discovery, boosting the use (and reuse) of digital content in research, entertainment, and education.

The resulting digital ecosystem will feature different sections related to archive resources and archaeological heritage, offering immersive experiences and educational opportunities, such as: 1) a digital collection of archive photographs and excavation diaries related to the first excavations seasons; 2) the virtual reconstruction of the Villa and galleries of 3D models of artefacts with a curated set of descriptive metadata; 3) virtual exhibitions focused on thematic sections; 4) a virtual relocation of selected 3D modelled findings. The generation of 3D assets strongly benefits of the collaboration of IDEX – Institute for Digital Exploration of the University of South Florida, which in the last years has been carrying out a far-reaching 3D digitization campaign of the Villa for documentation, conservation, and entertainment (GABELLONE *et al.* 2020; VENNARUCCI *et al.* 2021; KINGSLAND 2023; <https://youtu.be/3DYPrdgYcy4?si=g0MIFi889EpWe6q5>) (Fig. 3).

#### 4. LEGACY DATA IN PIAZZA ARMERINA: OPEN ISSUES AND FUTURE CHALLENGES

The present state of the monument reflects not just various construction stages, but also many excavation seasons conducted with different methodologies. Setting up an intra-site GIS specifically for past excavations, gathering data from V. Gentili and E. De Miro archives, has helped organize diverse

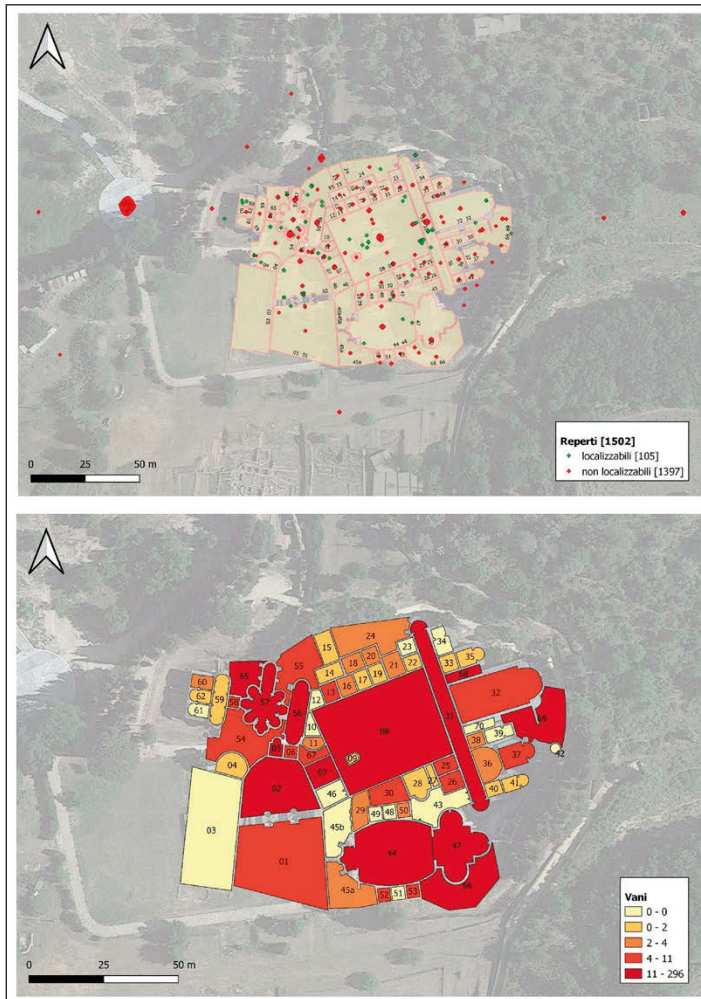


Fig. 4 – Villa del Casale legacy data in GIS environment: a) distribution of georeferenced and non-georeferenced items from Gentili's excavations; b) graded colored map according to the number of unearthed artefacts (after Pizzi 2023).



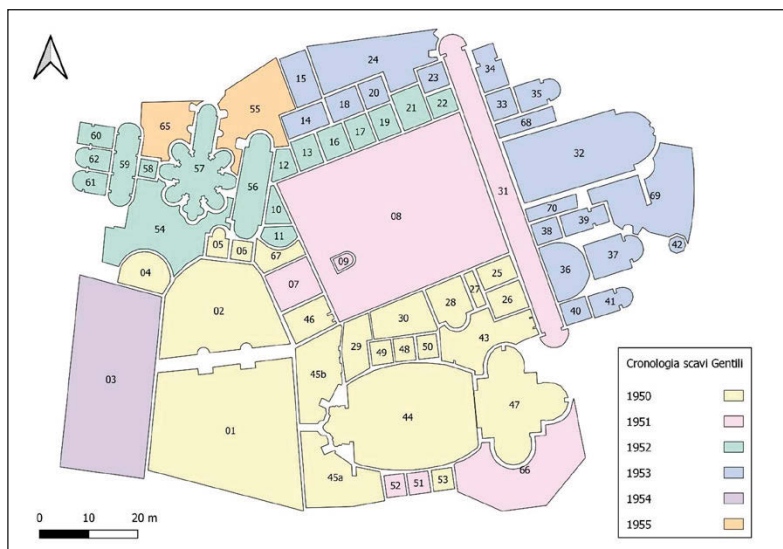


Fig. 5 – Thematic map illustrating the chronology of Gentili’s excavations (after PIZZI 2023).

data, revealing overlooked issues due to scattered information (PIZZI 2023) (Fig. 4). Significant concerns arose from Gentili’s excavations, which uncovered nearly the entire surface of the Villa but were published only 40 years later (GENTILI 1999) (Fig. 5). The publication of a limited selection of findings with brief descriptions and a lack of stratigraphical information greatly impedes proper georeferencing of data in the GIS environment and metadata population. These constraints, along with the considerable research potential in analyzing distribution patterns of specific artifact categories, underscore the need to reassess archive documentation in search of primary data.

Recent inspections of the archives of Siracusa and Enna Superintendences have resulted in the recovery of over a hundred, partly unpublished, photographs from the early excavation seasons, along with formal documents detailing the logistics of Gentili’s investigations and his epistolary correspondence regarding significant findings (Fig. 6). These data are invaluable to archaeological research, providing visual insight into ancient structures prior to the extensive restoration efforts carried out in the second half of the 20<sup>th</sup> century. Additionally, they serve to enrich narratives depicting the day-to-day operations of research and are intended for inclusion in virtual exhibitions.

Building on the newly acquired documentary basis, a 3D modeling campaign of artifacts from Gentili’s excavation has been initiated through collaboration with IDEX. The 3D collection, currently showcased in a Sketchfab



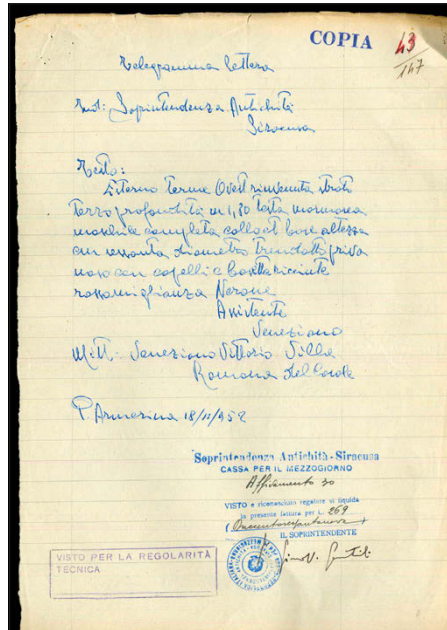


Fig. 6 – Local attendant's telegram to G.V. Gentili announcing the discovery of a marble statue, dating 1952 (Courtesy of Soprintendenza per i Beni Culturali e Ambientali di Siracusa).

gallery (<https://skfb.ly/oA6ou>), may be further integrated in ATON Web-based framework, developed by CNR-ISPC, which with its modular architecture offers a scalable and adaptable solution for creating and deploying cross-device Web3D/WebXR applications tailored for the Cultural Heritage domain (FANINI *et al.* 2021).

An important discovery within the archives is an undated excavation diary, the chronology of which can be tentatively hypothesized based on internal references to the work calendar's festive dates of Easter (April, 21<sup>st</sup>) and *Corpus Christi* (June, 20<sup>th</sup>) (Fig. 7). Among the possible dates, G. Cultrera's 1935 excavation appears the most probable, as suggested by the correspondence between the situation described in the work diary and Cultrera's reports (CULTRERA 1936). Extensive earthworks and trenching activities are documented throughout a wide area previously partially investigated, likely pertaining to the *triclinium*. These efforts resulted in the exposure of known structures and the discovery of new mosaic floors, promptly covered over «to document the depth of excavation». References to Decauville wagons, first introduced by Cultrera and Inglieri in 1935 for transporting earth and artifacts across the

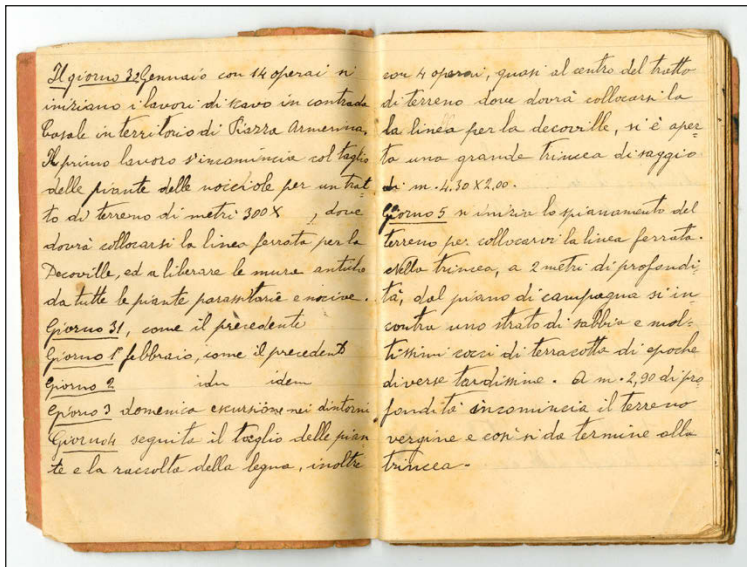


Fig. 7 – First pages of the excavation diary likely attributable to G. Cultrera's works, dating 1935 (Courtesy of Soprintendenza per i Beni Culturali e Ambientali di Siracusa).

site (NIGRELLI, VITALE 2010), provide further support for this identification. Similarly, mentions of structures «unearthed five years before», likely during Orsi's earlier investigations, contribute to the contextual understanding. In addition to shedding light on the excavation methods employed during this period, the diary descriptions significantly aid in the mapping of medieval structures, which were heavily disturbed during the initial excavations, as well as the spatial distribution of finds predominantly associated with the Medieval settlement. Alternative dates suggested by liturgical holidays, such as 1946, are deemed improbable due to the cessation of B. Pace's excavations in 1943. Another possibility is 1957, coinciding with the final phase of Gentili's activity; however, the alignment of the diary's descriptions with an earlier stage of investigation renders this scenario unlikely.

## 5. CONCLUSIONS

In conclusion, the Piazza Armerina project aims to move a significant step towards integrating legacy and new data to advance scientific knowledge and cultural exploitation of one of the best preserved monuments of the Late Antique Mediterranean. By enriching metadata with shared ontologies and standards, the project aims to enhance accessibility and interoperability of

digital contents. The integration of 3D artifact galleries with virtual models of the Villa and legacy data in GIS environments opens up new possibilities for exploration and interpretation, such as the virtual relocation of specific set of artefacts in the original setting according to information obtained by legacy data reassessment. Ultimately, the project seeks to unlock the full potential of Villa del Casale cultural heritage, fostering appreciation and understanding for future generations.

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### REFERENCES

- ALLISON P. 2008, *Dealing with legacy data. An introduction*, «Internet Archaeology», 24 (<https://doi.org/10.11141/ia.24.8>).
- ASPÖCK E. 2020, *Old excavation data. What can we do?. An introduction*, in E. ASPÖCK, S. ŠTUEHEC, K. KOPETZKY, M. KUCERA (eds.), *Old Excavation Data. What Can We Do? Proceedings of the Workshop held at 10<sup>th</sup> ICAANE (Wien 2016)*, Wien, Austrian Academy of Sciences Press, 11-23.
- BALDINI I., SFAMENI C., DE GIORGI L., FERRARI I., GIURI F., TORRE C., LEUCCI G. 2023, *Geophysical investigation at “Villa del Casale” Piazza Armerina (EN)*, in IMEKO TC-4 *International Conference on Metrology for Archaeology and Cultural Heritage (Rome 2023)*, Red Hook (NY), Curran Associates, 64-68.
- BALZANI R. et al. 2024, *Saving temporary exhibitions in virtual environments: The digital renaissance of Ulisse Aldrovandi. Acquisition and digitisation of cultural heritage objects*, «Digital Applications in Archaeology and Cultural Heritage», 32 (<https://doi.org/10.1016/j.daach.2023.e00309>).
- BARONE Z., NUCCIO G. 2017, *For a conscious fruition of the cultural heritage of ancient Noto (Sicily). Efan project as opportunity for valorisation*, «International Archives of the Photogrammetry, Remote Sensing & Spatial Information Sciences», 42, 5, 89-97 (<https://doi.org/10.5194/isprs-archives-XLII-5-W1-89-2017>).
- BARZAGHI S., BORDIGNON A., GUALANDI B., HEIBI I., MASSARI A., MORETTI A., PERONI S., RENDA G. 2024, *A Proposal for a FAIR Management of 3D Data in Cultural Heritage: The Aldrovandi Digital Twin Case*, arXiv, 2407.02018 (<https://doi.org/10.48550/arXiv.2407.02018>).
- BONACINI E. 2012, *La visibilità sul web del patrimonio culturale siciliano. Criticità e prospettive attraverso un survey on-line*, Catania, Giuseppe Maimone Editore.
- BONACINI E., TANASI D., TRAPANI P. 2019, *Participatory storytelling, 3D digital imaging and museum studies: A case study from Sicily*, in A.C. ADDISON, H. THWAITES (eds.), *2018 3<sup>rd</sup> Digital Heritage International Congress (DigitalHERITAGE) (San Francisco 2018)*, New York, IEEE, 1-4 (<https://doi.org/10.1109/DigitalHeritage.2018.8810058>).
- BONANNO C. (ed.) 2020, *Piazza Armerina. L'area nord dell'insediamento medievale presso la Villa del Casale. Indagini archeologiche 2013-2014*, Oxford, Archaeopress.

- CARDACI A., VERSACI A. 2019, *Research and technological innovation for the knowledge, conservation and valorization of cultural heritage in Sicily*, «International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences», 42, 247-254 (<https://doi.org/10.5194/isprs-archives-XLII-2-W15-247-2019>).
- CULTRERA G. 1936, *Scavi, scoperte e restauri di monumenti antichi in Sicilia nel quinquennio 1931-1935*, Siracusa, Società tipografica.
- FANINI B., FERDANI D., DEMETRESCU E., BERTO S., D'ANNIBALE E. 2021, ATON: *An open-source framework for creating immersive, collaborative and liquid web-apps for Cultural Heritage*, «Applied Science», 11, 22, 11062 (<https://doi.org/10.3390/app112211062>).
- GABELLONE F., CHIFFI M., TANASI D., DECKER M. 2020, *Integrated technologies for indirect documentation, conservation and engagement of the Roman mosaics of Piazza Armerina (Enna, Italy)*, in E. CICALÒ (ed.), *Proceedings of the 2<sup>nd</sup> International and Interdisciplinary Conference on Image and Imagination*, Cham, Springer, 1016-1028.
- GENTILI G.V. 1999, *La Villa Romana di Piazza Armerina Palazzo Erculio*, Osimo, Fondazione don Carlo.
- KATSIANIS M., KALAYCI T., SARRIS A. 2022, *Bridging digital approaches and legacy in archaeology*, «Digital», 2, 4, 538-545 (<https://doi.org/10.3390/digital2040029>).
- KINGSLAND K. 2023, *Archaeogaming and the re-use of digital archaeological materials: Generating serious games for the villas of Roman Sicily*, PhD Diss., University of South Florida.
- NIGRELLI F.C., VITALE M.R. 2010, *Piazza Armerina dalla Villa al Parco. Studi e ricerche sulla Villa romana del Casale e il fiume Gela*, Reggio Calabria, Biblioteca del Cenide.
- PENSABENE P., BARRESI P. 2019, *Piazza Armerina. Villa del Casale: scavi e studi nel decennio 2004-2014*, Roma, L'Erma di Bretschneider.
- PIZZI M. 2023, *Legacy Data e Sistemi Informativi Geografici: proposta di progetto GIS sui dati d'archivio degli scavi Gentili nella Villa del Casale di Piazza Armerina* (EN), Tesi di Specializzazione, Università di Bologna.
- SFAMENI C. 2006, *L'insediamento medievale: la documentazione degli scavi precedenti*, in P. PENSABENE, C. SFAMENI (eds.), *Iblatasah Placea Piazza. L'insediamento medievale sulla Villa del Casale: nuovi e vecchi scavi*, Catalogo della mostra, Piazza Armerina, Istituto per gli Studi del Mediterraneo Antico, 81-90.
- VENNARUCCI R., FREDRICK D., TANASI D., REYNOLDS N., KINGSLAND K., JENKINS B., HASSAM S. 2021, *In Ersilia's footsteps: Toward an interactive WebGL application for exploring the villa romana del Casale at Piazza Armerina, Sicily*, in F. GANOVELLI, C. MC DONALD, F. BANTERLE, M. POTENZIANI, M. CALLIERI, Y. JUNG (eds.), *Web3D '21: Proceedings of the 26<sup>th</sup> International Conference on 3D Web Technology (Pisa 2021)*, New York, Association for Computing Technology, 1-7 (<https://doi.org/10.1145/3485444.3487646>).

## ABSTRACT

The paper highlights the crucial role of legacy data in reconstructing archaeological sites and historical landscapes, emphasizing the need for digitization to safeguard and democratize access to heritage. Focused strategies for digital acquisition are essential, particularly in regions like Sicily with diverse cultural heritage facing challenges of preservation in the digital age. The project 'Digital strategies for enhancing cultural heritage: the Villa del Casale of Piazza Armerina, from the late antique building site to the Museum Collection' exemplifies this approach. Its foundation, aiming to bridge the gap between the Palazzo Trigona Museum and Villa del Casale through a web-based digital ecosystem, is firstly presented here. By adopting a multidisciplinary methodology, the project aims to gather scattered legacy data, advance scientific understanding, and develops precise datasets through historical research and digitization. The resulting digital ecosystem will feature immersive experiences and educational opportunities, enhancing accessibility and interoperability of digital contents. By integrating 3D artifact galleries with virtual models and legacy data, the project seeks to reveal the full potential of Villa del Casale cultural heritage, promoting appreciation and understanding for future generations.

## CONCLUDING REMARKS: LOOKING BACK AND MOVING FORWARD TO THE OPENNESS AND INTERACTION OF KNOWLEDGE

The symposium *Linking Pasts and Sharing Knowledge*, held in Naples and meticulously orchestrated by Rodolfo Brancato, Julian Bogdani, and Valeria Vitale from the Universities of Naples Federico II, Rome La Sapienza and Sheffield, respectively, concluded after two enriching days of significant exchange among experts and public engagement.

The event opened with two workshops focused on ‘The Open Source Platform Recogito (Pelagios Commons): From Semantic Annotation to Linked Open Data Creation’, and ‘Re-Shaping Lidar Data for Landscape Archaeology Research’. These preliminary sessions laid the groundwork for a successful symposium characterised by cutting-edge discussions and collaborative ventures into the frontier fields of digital archaeology. Indeed, the selected themes perfectly exemplify the interdisciplinary nature of digital archaeology, blending the logical frameworks that guide data representation with technological advancements in the acquisition and processing of archaeological data.

During the conference, scholarly presentations were collected into two panels: ‘Digital Approaches in Archaeological Mapping’ and ‘Digital Integration of Archaeological Legacy Data’. The choice of the symposium’s title and the themes of the two sessions reflect the innovative methodologies currently employed within the domain of digital archaeology and highlight the critical importance of integrating and revitalising the understanding of archaeological spaces and sites.

Digital mapping is a pivotal aspect of archaeological computing. Its origins date back to the 1970s, gaining momentum as early as the late 1980s, alongside the advent and proliferation of GPS technologies, which transformed the modus operandi for mapping and recording archaeological evidence of the past. Furthermore, this evolution laid the foundations for both the development of Geographical Information Systems and the renaissance of Spatial Archaeology studies. As Paolo Sommella noted in 1990, the longstanding tension between archaeology and urban planning has been mitigated by the advent of computer-based approaches that can reproduce archaeological datasets at scales optimally suited for various user requirements. Once analysed and recorded by specialists, these data are made accessible in formats tailored to a wide array of scholarly and operational requirements (SOMMELLA, AZZENA, TASCIO 1990).

In the age of the Internet, cartography has played a central role in interactive communication paradigms, especially concerning mobility and



territorial monitoring. It has determined a renewal of geographical sciences under the auspices of multimedia integration and, over time, has adopted different and various descriptors related to its specific purposes and the virtual working environment, as well exemplified by the emergence of terms such as webcartography and cybercartography. However, in light of the many contributions discussed in the first session, these terms today may oversimplify the advancements achieved through the evolution of cartographic practices. Interactive maps have emerged as the primary medium for data access and consultation, as demonstrated by several projects presented during the symposium, which explore archaeological contexts in a wide geographical area with evidence spanning from prehistoric to modern times.

In 2012, in the entry 'Digital Terrain Models' for the 21<sup>st</sup> Century Lexicon of the Treccani Encyclopaedia, I noted that digital mapping enables the creation of highly accurate three-dimensional representations of terrain surfaces that mimic the physical world, making them applicable in various contexts. Digital Terrain Models (DTMs) are instrumental in the analysis of terrestrial morphology, spatial distribution patterns, and mobility dynamics across landscapes. Furthermore, DTMs are crucial for the development of visualisation technologies and interactive web-based navigation platforms, such as Google Earth, where three-dimensional datasets are combined with other types of information typical of multimedia applications.

From these premises arises the topic of landscape visualisation and modelling, a subject appropriately addressed at the onset of the meeting by Margherita Azzari and Paolo Liverani. Several innovative aspects distinguish this specific domain. Notably, the application of Artificial Intelligence techniques, with a particular emphasis on Machine Learning, consolidates both the interpretation and analysis of Remote Sensing data in environments that present considerable challenges in terms of accessibility and legibility, as well as the development of predictive models. Concurrently, the simulation of ancient social dynamics benefits from Agent-Based Modelling techniques, which are employed within virtual environments designed to mirror the intrinsic properties of the natural landscape, thereby contributing to the understanding of previously unexplored and new aspects.

From a data structuring perspective, just as digital cartography underpins the projects illustrated in the symposium, GIS platforms continue to serve as the cohesive environment for data processing. The GIS-based approach in archaeology is not a recent phenomenon – it can be traced back to the 1990s – but the proliferation of free and open source software significantly fuels its ongoing evolution today.

The first session of papers and discussion introduces some interesting terminological insights, particularly in the realm of neologisms that often reflect emerging technical-scientific advancements and innovative cultural



trajectories. Among the terms discussed, two are worth noting: datafication and provocation. The first term, datafication, was included in the Lexicon of Neologisms by the Treccani Encyclopaedia in 2019 – despite an isolated precedent in the newspaper *La Repubblica* in 1986 – with a definition that highlights its meaning as a technological process that transforms various aspects of social or individual life into data, which are subsequently transformed into information with new forms of value, including the economic one. In digital archaeology, datafication acquires a distinct interpretation: as elucidated by Jeremy Huggett, the term emphasises the quantification and automatic generation of data, in contrast to dataism, i.e. confidence in data accuracy, completeness, and reliability, and data centrism, i.e. trust in data and its unbiased results (HUGGETT 2020).

On the other hand, the term provocation is relatively more familiar. Nonetheless, it has been endowed with a specific meaning in the context of the ROMETRANS project. Here, visualisations are designated as ‘provocations’ because, despite being grounded in rigorous research, they are not considered conclusive outcomes but rather as visual cues intended to facilitate an ongoing dialogue within the scientific community. The digital integration of archaeological legacy data was the focal point of the second session of the symposium. Integration underlies all the processes of digital archaeology, and more generally, digital Humanities, since their inception. This was exemplified by the seminar organised by Tito Orlandi in 1991 at the Accademia Nazionale dei Lincei, titled *Informatica e discipline umanistiche. Il problema dell'integrazione*, which questioned how many forms of integration exist in a virtual research environment (ORLANDI 1990). In the 1990s, integration was addressed to find common ground between information sciences and the Humanities to outline a common interdisciplinary approach.

Today, the term integration is predominantly associated with technological competencies, encompassing the merger of digital devices and software applications. Furthermore, it extends to the digital transformation of the organisational workflow relevant to the archaeological research process, from initiation to completion. The papers presented can be analysed as a whole, starting with the central focus on legacy data that has gained popularity today. The use of this term in the field of digital archaeology can be traced back to the thematic issue published in the journal «Internet Archaeology» in 2008, titled *Dealing with legacy data*. As argued by Penelope Allison, this term refers to pre-existing data not in digital format to be retrieved, formalised, and processed within GIS systems or, more generally, in digital environments (ALLISON 2008; on the imperative of publishing primary data, see also ATICI *et al.* 2013). Even earlier, Keith Kintigh also addressed the subject of legacy data in connection with data integration in the journal «American Antiquity», with an essay titled *The promise and challenge of archaeological data integration*.

In this work, the Author maintains that only data integration permits the use of existing data to answer compelling new questions, through an approach based on the analyses of «meaningfully integrated new and legacy data sets» (KINTIGH 2006).

During the symposium, several areas emerged where the topic of legacy data proved to be particularly significant, such as in epigraphic studies, which were the subject of several papers on the second day. Digital epigraphy studies interface with historical-topographical research in various ways and perspectives. From a technological point of view, the most interesting outcomes stem from the application of Machine Learning techniques in the study of ancient texts. Computational algorithms support various phases of research, including digitisation, restoration, linguistic analysis, textual criticism, and translation. Meanwhile, the historical and cultural contextualisation of information acts as a methodological prerequisite, ensuring that these analyses are grounded in a comprehensive understanding of the texts' origins and significance.

The symposium has a further merit as a discussion forum, particularly for revisiting the theme of cartography from the perspective of 'classical digital geography' (or the history of geographic computing and the classics: ELLIOTT, GILLIES 2009). This digital approach was initially developed to map and georeference large-scale geographical references found in classical texts, interconnecting them within a networked knowledge framework. At present, the utility of geoparsing activities is perceived as somewhat limiting, especially when operating within a GIS environment that permits greater dynamism compared to traditional media. The cataloguing and mapping of the ancient world face the challenges of integration, in terms of enhancing all information related to a place conceived as a multifaceted entity characterised by social and cultural dimensions and subject to perpetual transformation. Furthermore, contemporary e-infrastructures have facilitated the semantic annotation and integration of resources with spatial connotations, promoting the interconnection of disparate archives through the implementation of the Linked Open Data paradigm.

Having looked back to find the roots of current developments in digital archaeology, it is time to focus on its most promising prospects, which arise from two facets of the information society: the openness of data and the interaction of knowledge. In the first case, there is a recognised need to pursue a model of open and collaborative science at both the European and global levels. However, merely acknowledging this need is insufficient if specific attention is not paid to the impact of research results beyond the scientific community and to the notion of 'outcomes'. Indeed, these outcomes inherently possess a relational nature and are subject to changes that can alter the process from which they originate.

In the accelerating process of the open science movement, it is noteworthy to observe the commitment of the Journal «Archeologia e Calcolatori» – host of this symposium's proceedings – to the Open Archives Initiative over the past two decades (MOSCATI 2021). This commitment has enabled the development of a circular model for knowledge acquisition, exchange, and transfer based on more than thirty years of published data. Here, the 'provocation', often referenced during the symposium, stems from the presence of a 'simple' open access article at the core of this model, stored in an OAI-PMH repository. Its unique ID connects to incoming and outgoing information flows sourced from institutional databases associated with the journal, which, in turn, feed external repositories and European e-infrastructures, linking geographic locations, cultural contexts, subject classifications, bibliographies, and iconographic data, including 2D images and 3D objects.

Regarding the fostering of knowledge interaction, in addition to the essential interdisciplinary approach that has characterised archaeological research since the 1960s, this interaction – encompassing both interpretation and reconstruction – is now further enhanced by the adoption of increasingly collaborative methodologies. This approach facilitates the transcendence of a hyper-specialised view of science, advocating instead for a holistic perspective of knowledge that is emblematic of the Human Sciences. At the same time, it fosters a thoughtful and informed vision of the application of technologies.

I would like to conclude this effort to comment on comparative themes related to both archaeology and history – a task to which I was kindly invited by the Organising Committee – by revisiting the evocative title and subtitle of this well-focused symposium: *Linking Pasts and Sharing Knowledge. Mapping Archaeological Heritage, Legacy Data Integration and Web Technologies for Modelling Historical Landscape*. This reiteration emphasises the relevance of the themes that permeated these two intense days and contextualises them within the broader context in which digital archaeology currently operates.

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## REFERENCES

- ALLISON P. 2008, *Dealing with legacy data - An introduction*, «Internet Archaeology», 24 (<https://doi.org/10.11141/ia.24.8>).
- ATICI L., KANSA S.W., LEV-TOV J., KANSA E.C. 2013, *Other people's data: A demonstration of the imperative of publishing primary data*, «Journal of Archaeological Method and Theory», 20, 4, 663-681 (<https://doi.org/10.1007/s10816-012-9132-9>).
- ELLIOTT T., GILLIES S. 2009, *Digital geography and classics*, in G. CRANE, M. TERRAS (eds.), *Changing the Center of Gravity: Transforming Classical Studies Through Cyberinfrastructure*, «DHQ: Digital Humanities Quarterly», 3, 1 (<https://digitalhumanities.org/dhq/vol/3/1/000031/000031.html>).

- HUGGETT J. 2020, *Is big digital data different? Towards a new archaeological paradigm*, in *Archaeology in the Age of Big Data*, «Journal of Field Archaeology», 45, Suppl. 1, 8-17 (<https://doi.org/10.1080/00934690.2020.1713281>).
- KINTIGH K. 2006, *The promise and challenge of archaeological data integration*, «American Antiquity», 71, 3, 567-578 (<https://doi.org/10.2307/40035365>).
- MOSCATI P. 2021, *Digital archaeology: From interdisciplinarity to the 'fusion' of core competences*, «magazén», 2, 2, 253-274.
- ORLANDI T. (ed.) 1993, *Discipline umanistiche e informatica. Il problema dell'integrazione*, Contributi del Centro Linceo Interdisciplinare «Beniamino Segre», 87, Roma, Accademia Nazionale dei Lincei.
- SOMMELLA P., AZZENA G., TASCIO M. 1990, *Informatica e topografia storica: cinque anni di esperienza su un secolo di tradizione*, «Archeologia e Calcolatori», 1, 211-236.

THE H2IOSC PROJECT AND ITS IMPACT  
ON DIGITAL ANTIQUITY  
WITHIN THE E-RIHS INFRASTRUCTURE – II

Special section edited by  
Alessandra Caravale, Paola Moscati, Irene Rossi



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## ADVANCEMENTS OF THE H2IOSC PROJECT: ENHANCEMENT OF DIGITAL RESOURCES IN THE CULTURAL HERITAGE FIELD TARGETING ARCHAEOLOGY AND EPIGRAPHY. INTRODUCTION TO THE SPECIAL SECTION

### 1. INTRODUCTION

The overview of the results from the ongoing work within the H2IOSC Project ('Humanities and Cultural Heritage Italian Open Science Cloud') continues in this second special section, following the first edition published in «Archeologia e Calcolatori» (A&C), issue 35.1 (CARVALE, MOSCATI, Rossi 2024). The Project is funded by the European Union NextGenerationEU and the Italian Ministry of University and Research as part of the National Recovery and Resilience Plan (NRRP) and started in November 2022 with the aim to establish a federated cluster of the Italian nodes of the CLARIN, DARIAH, E-RIHS and OPERAS research infrastructures in the ESFRI (European Strategy Forum on Research Infrastructures) domain focusing on Social and Cultural Innovation. This second section is focused on showing the progress made by the CNR-ISPC Open Data, Open Knowledge, Open Science research group within the Project, with special emphasis on developments related to the implementation of some of the products planned in Work Package 7 (Community pilots: innovative cross-domain services and environments), which could benefit from a fruitful collaboration with the activities of another NRRP project involving the ISPC, namely the Cultural Heritage Active Innovation for Sustainable Society (CHANGES) Project.

The focus is still centered on enhancing the visibility, integration and valorization of digital resources in the field of Cultural Heritage. This special section illustrates recent activities aimed at improving the consultation, searchability and reuse of key resources and services in the domain of digital archaeology and digital epigraphy, including the diamond open access journal «Archeologia e Calcolatori», its archive of figurative documents, and an open online catalogue of digital epigraphic resources.

A.C., P.M., I.R.

### 2. A&C WEBSITE AS A GATEWAY TO DIGITAL ARCHAEOLOGY RESOURCES

The history of the journal «Archeologia e Calcolatori» (A&C) is closely tied to a series of milestones that underscore its pivotal role in advancing computational approaches to archaeology. Among these milestones, the international Symposium on Computing and Archaeology, held in 1995 at

the National Research Council (CNR) in Rome, played a significant role in bringing together an interdisciplinary community of scholars, researchers, and experts from across Europe and beyond to connect, share their knowledge, and engage in critical debates (MOSCATI 1996).

This meeting underscored the journal's commitment to fostering dialogue around digital innovation and highlighted the need for a dedicated platform that could disseminate cutting-edge research in this emergent area and provide broader access to its scholarly content. The advent of the Internet in the mid-1990s made it possible to launch the first version of the journal's website, which was implemented through the collaboration between the CNR Istituto per l'Archeologia Etrusco-Italica (IAEI), directed by Mauro Cristofani, and the Centro Interdipartimentale di Servizi per l'Automazione nelle Discipline Umanistiche (CISADU) at the Sapienza University of Rome, the point of reference of the interdisciplinary research group coordinated by Tito Orlandi.

The website – one of the earliest online initiatives in academic archaeological publishing – marked a significant advancement in the journal's transition to digital dissemination to address the demands of a growing international readership. Initially, it provided basic features such as publication indexes, editorial information, and submission guidelines. However, its very existence reflected a forward-thinking approach that recognised the potential of the web as a medium for scholarly communication. Indeed, within this virtual space, the 'Bibliography of archaeological computing' was first disseminated and the dual thematic and technological scholarly classification of computational archaeology was conceived.

Following its initial online publication, the website underwent several upgrades and grew in scope and complexity, reflecting both the evolving requirements of technological progress and broader shifts in digital scholarship. By making its content accessible online in 2005, formally adhering to the Open Archives Initiative movement, A&C expanded its reach beyond traditional print circulation. The pioneering decision to implement the Dublin Core Metadata Element Set for resource description and the OAI-PMH protocol for harvesting metadata exemplified the journal's commitment to open access, ensuring that research results were freely available to academics, students, and the wider public (BARCHESI 2019). This major overhaul transformed the website into a more dynamic and interactive platform, allowing it to play a new key role. It became much more than a digital repository: it turned into a hub for community engagement, promoting transparency, collaboration, and cross-disciplinary discourse within the field.

The decision to adopt open access for publishing the texts in electronic format also coincided with another milestone in the journal's editorial policy. Beginning with issue 61 (2004), the «Archaeological Computing Newsletter» (ACN) – established in 1985 and published by the Institute of Archaeology

at Oxford University – was published bi-annually as a Supplement to A&C (<https://www.archcalc.cnr.it/pages/newsletter.php>). Considering the Newsletter's success over its first twenty years, the editorial format was preserved, promoting the online dissemination of short articles, conference reviews, and event notices, essentially anything relevant to computer-using archaeologists. In 2007, the CNR Department of Social Sciences and Humanities, Cultural Heritage supported the launch of a new series of A&C Supplements (<https://www.archcalc.cnr.it/pages/supplements.php>) and ACN's publication was suspended. Nonetheless, the concept of fulfilling a news function persisted, with the activation on the website of specific links to social media platforms.

In recent years, the website has continued to evolve in response to shifts in digital communication and emerging research priorities, with the introduction of new features such as full-text search capabilities and multimedia content integration, advanced data visualisation tools, open data repositories, and collaborative digital projects. By showcasing the complexity and variety of the journal's content, these advancements encouraged deeper engagement with the analysis of the research data published on its pages (MOSCATI 2019).

For instance, the use of AI tools for the classification of articles has recently provided transformative potential, categorising articles based on their thematic focus, such as archaeological methods, computational tools, or case studies. This automated classification has facilitated the indexing process and provided more nuanced metadata, helping to identify emerging trends. Furthermore, AI-based tools facilitated semantic analysis, revealing hidden connections between articles and fostering a deeper understanding of the evolution of digital approaches in archaeology.

Today, the new technical conceptualisation, design, and evolution of the website, along with its expanded functionalities, offer a reflective overview of the journal's digital transformation over time (see PARACIANI in this special section). At the core of the new design are the data exchange mechanisms enabled by the journal's REST API with the Open Digital Archaeology Hub (ArchaeoHub), which is currently under development as part of the H2IOSC project (WP 7: Community pilots: innovative cross-domain services and environments).

As thoroughly described in the journal's pages at each new technological step, the continuity of purpose of this more than 30-year-old publication, which has embraced the virtual environment as the most suitable platform for its *modus operandi*, positions the A&C website at the centre of a digital renewal. It now regulates and connects information flows and feeds external repositories and European e-infrastructures, linking scholarly texts and iconographic data, geographic locations and cultural contexts, subject classifications and bibliographic data.

P.M.

### 3. ENRICHMENT AND REUSE OF VISUAL RESOURCES IN A SPECIALIZED JOURNAL

The work regarding the analysis and metadata of figurative documents, particularly the A&C visual repository presented in this special section (see BUSCEMI, FAZIO), along with reflections on the methodologies and reference models employed, offers the opportunity to briefly review the history of the journal's visual archive. For over thirty years, A&C has been a unique testament to the evolution of information technology applied to archaeology. A development that has radically transformed the way archaeological data are researched, analyzed, and disseminated, contributing decisively to the evolution of this disciplinary field.

Over the years, the journal has collected and published a wide repertoire of images to complete the texts, which not only document the development of technologies but also offer a comprehensive overview of the innovative methodologies and tools adopted for the study of antiquities: from the first digital graphic representations, mostly two-dimensional and static, to today's sophisticated, dynamic, and highly detailed 3D models. To further enhance this important iconographic collection – a historical visual archive of technological evolution in archaeology – and to provide broader access to the data for both the scientific community and the public, the journal has promoted several initiatives over the years.

The first one dates back to 2005, when, alongside the introduction of online access to the journal, a dedicated section for the color image gallery was created on the same website. This allowed readers to view the plates published in each print issue, enhancing their visibility. However, the gallery was not updated beyond 2009, when color images were integrated into the individual PDFs of the articles. Despite this, the gallery remained accessible and searchable on the website, alongside other digital resources. Since 2019, thanks to a substantial institutional support and the technical collaboration of Edizioni All'Insegna del Giglio, the A&C Interactive Atlas of Digital Images (IADI) project (<https://iadi.archcalc.cnr.it/>) has been collecting and making accessible online all images published between 1990 and 2020 (PARACIANI, ROSSI 2023, 138-143). The Editor provided lists of these images along with their associated files and metadata in CSV format, automatically extracted from the PDFs, facilitating the import into IADI's database. This digital archive, consisting of approximately 5000 images, now offers structured access to the resources, allowing users to consult them through keywords and specific metadata, such as year of publication, title, and authors. Each image is linked to the original article in which it appeared, creating a bridge between the journal's visual repertoire and its textual content.

Other archaeological digital journals demonstrate how, especially in recent years, images are no longer merely complementary to text, but have

acquired an independent and often fundamental role in the communication process. A significant example is «Internet Archaeology» (<https://intarch.ac.uk/>), a journal that, since its debut, has innovatively exploited the multimedia possibilities offered by the web. The articles present a heterogeneous visual apparatus, also accessible independently from the text and enriched by interactive links, which allow a dynamic and active fruition of the contents. Another example is the more recent «Journal of Computer Applications in Archaeology» (<https://journal.caa-international.org/>), which enhances the visual support accompanying the texts with large, high-quality graphics, making the image a valuable tool for in-depth study and interpretation.

Starting with issue 31 of 2020, A&C also further enhanced the relationship between written text and images by making available, on the web page dedicated to each article, the entire visual apparatus published therein. Additionally, as an innovative element, navigable 3D models were included when present to accompany the written part. For the latter, in particular, the ATON 3.0 framework, developed in ISPC by Bruno Fanini (ROSSI, PARACIANI 2021), was used.

As part of a broader initiative aimed at enhancing the sharing and interoperability of resources, a new work is also underway, concurrently with the metadata project presented here, on the Open Digital Archaeology Hub (ArchaeoHub). This will be discussed in detail in the subsequent special section devoted to the results of the H2IOSC project (A&C, 36, 2025). In this new virtual platform, which mirrors the layout and design of the Open Digital Epigraphy Hub (see ROSSI, SALVADOR in this special section) as a product of H2IOSC WP7, the journal's visual resources will be integrated with textual, bibliographic, and data mapped within the DHeLO database (MANCUSO, D'EREDITÀ 2024), which is dedicated to landscaping resources in the Cultural Heritage/Heritage Science sector. Thus, this rich and multifaceted new digital ecosystem represents the natural evolution of the long process of dissemination and valorization that began over thirty years ago.

A.C.

#### 4. A REASONED CATALOGUE OF DIGITAL EPIGRAPHY RESOURCES

As mentioned, within the H2IOSC project, Activity 7.4 has been dedicated to the design and implementation of two platforms. Each platform focuses on aggregating, discovering, and sharing data, tools, and methods in the fields of digital archaeology and digital epigraphy, respectively, as part of the broader scope of Digital Heritage covered by the E-RIHS infrastructure: the Open Digital Archaeology Hub and the Open Digital Epigraphy Hub. In this special section, we present the Open Digital Epigraphy Hub (see ROSSI, SALVADOR).

Epigraphy is situated at the intersection of different, major disciplines (e.g., textual studies, linguistics, archaeology, history, art history) and has thus emerged as an exemplary research topic within the H2IOSC project, in that it represents one of the ‘inscribed objects’ case studies selected to test the convergence of methodological and technological solutions developed by the four participating Research Infrastructures covering digital humanities, computational linguistics, heritage science, and open access editions. A review of literature and webliography has highlighted a significant challenge within the digital epigraphy disciplinary community: online resources remain highly dispersed, despite the fact that the past decade has seen a growing body of proceedings and monographs addressing digital epigraphy, complementing journal articles focused on computational applications in the humanities and archaeology.

A&C was a pioneer in addressing the emerging field of digital epigraphy. A search using the ‘Epigraphy and Numismatics’ subject filter on the journal website lists 43 articles published between 1990 – the journal’s inaugural issue – and 2023. The 1990s alone counts 13 articles, with many concentrated in the 1996 volume that published the proceedings of the *III International Symposium on Computing and Archaeology* held in Rome in November 1995 (MOSCATI 1996). The contraction in contributions during the 2000s (only four articles) likely reflected a focus on developing and populating the first online inscription databases rather than on dissemination. It was rapidly followed by a new upturn in the 2010s (22 articles), witnessed by initiatives like the *Italic Inscriptions and Databases* workshop held in Rome in September 2014, whose proceedings (RAJALA 2015) show a new emphasis on textual annotation and spatial analysis of inscriptions. Many digital epigraphy projects were funded during this period to expand technical solutions, develop resource aggregators, and release open and linked data. At the Italian national level, initiatives like EAGLE (<https://www.eagle-network.eu/>) and DASI (<https://dasi.cnr.it/>) exemplify these advancements. These efforts yielded significant outcomes in data production, dissemination, and technological innovation, while also fostering theoretical and methodological discussions in traditional publications. Since 2020, the four articles on digital epigraphy that have appeared in A&C attest to a focus on virtual applications for documenting inscriptions. It is tempting to interpret such scarcity of contributions as a symptom of insufficient follow-up investments aimed at the implementation of large-scale initiatives targeted to technological advancements in digital epigraphy in recent years. The pattern detected in the survey of A&C epigraphic articles aligns with broader bibliographic trends over the last three decades, as shown in ROSSI, SALVADOR, §2.

Moving away from traditional literature (journals and books), a constellation of digital resources and tools – specifically epigraphic but also



epigraphy-related, such as those concerning historical linguistics, philology, palaeography, archaeology, etc. – is by now available on the web and continues to expand. Research literature only partially captures them, due to their varied and dispersed nature, and to the frequent absence of structured documentation or research dissemination. Epigraphists seeking to inform and orient their research thus struggle to keep pace with this rapidly evolving landscape. This challenge inspired the creation of a curated catalogue hosted on the H2IOSC cloud, conceived as an observatory for online digital epigraphy resources, the Open Digital Epigraphy Hub. This catalogue does not aim to be an aggregator – interoperability issues across platforms specialized in different epigraphic domains currently make this unfeasible. Instead, it offers an open, searchable list of online resources such as corpora, archives, tools and standards, richly described at both content and technology levels. It provides insights into their accessibility and interoperability aligning with H2IOSC's commitment to fostering Open Science in the Humanities and Cultural Heritage domains. The aim of the Hub is precisely to support current epigraphic research by addressing the needs of the scholarly community, pushing for collaboration and networking, with a view to facilitating future efforts toward automated information linking, exchange, and reuse in the field of digital epigraphy.

The Open Digital Epigraphy Hub itself emphasises the standardization of its descriptive metadata and the establishment of semantic relationships among internal and external online resources, including archives developed within the H2IOSC project, such as H-SeTIS and DHeLO (SCARPA, VALENTE 2024; MANCUSO, D'EREDITÀ 2024), within a Linked Open Data framework. The concern for the history of disciplinary research which distinguishes the Open Data, Open Knowledge, Open Science group of the CNR-ISPC leading this pilot project, also informs the content of the Hub, which integrates an open Zotero Group library launched to keep track of scientific literature on digital epigraphy.

I.R.

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## REFERENCES

- BARCHESI C. 2019, *Archeologia e Calcolatori: un'esperienza pionieristica nel mondo dell'Open Access e dell'Open Science*, in P. MOSCATI, *30 anni di Archeologia e Calcolatori. Tra memoria e progettualità*, «Archeologia e Calcolatori», 30, 39-54 (<https://doi.org/10.19282/ac.30.2019.04>).
- CARAVALÉ A., MOSCATI P., ROSSI I. 2024, *Landscaping and integrating Digital Archaeology and Digital Epigraphy resources: New challenges and future opportunities. Introduction to the Special section*, in A. CARAVALÉ, P. MOSCATI, I. ROSSI (eds.), *The H2IOSC project and its impact on digital antiquity within the E-RIHS infrastructure – I*, «Archeologia e Calcolatori», 35.1, 515-520 (<https://doi.org/10.19282/ac.35.1.2024.30>).

- MANCUSO G., D'EREDITÀ A. 2024, *DHeLO and BiDiAr: New digital resources within the H2IOSC Project*, in A. CARAVALE, P. MOSCATI, I. ROSSI (eds.), *The H2IOSC project and its impact on digital antiquity within the E-RIHS infrastructure – I*, «Archeologia e Calcolatori», 35.1, 521-542 (<https://doi.org/10.19282/ac.35.1.2024.31>).
- MOSCATI P. (ed.) 1996, *III International Symposium on Computing and Archaeology (Roma 22-25 Novembre 1995)*, «Archeologia e Calcolatori», 7 (<https://www.archcalc.cnr.it/journal/idear.php?IDyear=1996-01-01>).
- MOSCATI P. (ed.) 2019, *30 anni di Archeologia e Calcolatori. Tra memoria e progettualità*, «Archeologia e Calcolatori», 30 (<https://www.archcalc.cnr.it/journal/id.php?id=497>).
- PARACIANI N., ROSSI I. 2023, *IADI: An open Interactive Atlas of Digital Images for the journal «Archeologia e Calcolatori»*, in J. BOGDANI, S. COSTA (eds.), *ArcheoFOSS 2022. Proceedings of the 16<sup>th</sup> International Conference on Open Software, Hardware, Processes, Data and Formats in Archaeological Research (Rome 2022)*, «Archeologia e Calcolatori», 34.1, 135-144 (<https://doi.org/10.19282/ac.34.1.2023.15>).
- RAJALA U. (ed.) 2015, *Italic Inscriptions and Databases Workshop (Istituto Svedese di Studi Classici a Roma, 23 September 2014)*, «Archeologia e Calcolatori», 26, 11-44 (<https://www.archcalc.cnr.it/journal/idear.php?IDyear=2015-01-01>).
- ROSSI I., PARACIANI N. 2021, *IT applications to archaeology and the OA diamond journals' challenge. Enhancing access and reuse of textual and visual resources*, «Archeologia e Calcolatori», 32.1, 325-347 (<https://doi.org/10.19282/ac.32.1.2021.18>).
- SCARPA E., VALENTE R. 2024, *A resource hub for interoperability and data integration in Heritage research: the H-SeTIS database*, in A. CARAVALE, P. MOSCATI, I. ROSSI (eds.), *The H2IOSC project and its impact on digital antiquity within the E-RIHS infrastructure – I*, «Archeologia e Calcolatori», 35.1, 543-562 (<https://doi.org/10.19282/ac.35.1.2024.32>).

## A NEW WEBSITE FOR THE JOURNAL «ARCHEOLOGIA E CALCOLATORI»

### 1. INTRODUCTION

This paper describes the recent development of a new website for the journal «Archeologia e Calcolatori» (A&C), along with the implementation of new features for its OAI-PMH repository and the addition of a JSON REST API to improve data interoperability. The motivation for developing a new website was mainly due to the need to fully exploit the potential offered by the journal's relational database. This latter was introduced to provide a more reliable system for managing publication data and was originally populated by Salvatore Fiorino, migrating from the previous system based on XML and Microsoft Access (see §1.1). The database has since been continuously updated by inserting data via an administration frontend each time a new journal or supplement volume was published. This preliminary work proved to be essential in the developments that followed.

#### 1.1 *Previous versions*

A very early implementation of A&C's website became available on the internet in 1996 at the address <http://cisadu2.let.uniroma1.it/iaei/index.htm> (Fig. 1), while the PDF versions of the journal's articles were first published online in 2005. At this latter stage, the website was hosted at <http://soi.cnr.it/archcalc/> and it relied on OAI-Sistema to provide open access metadata via the OAI-PMH protocol. The website itself consisted of an ASP codebase, which generated pages using data stored in a Microsoft Access database (BARCHESI 2005, 2019). This database was also used to prepare XML files for the OAI-PMH repository (which served them statically via a third-party provider).

A major reworking of the website was then performed by Salvatore Fiorino with a complete rewrite of the source code in PHP, mainly motivated by the obsolescence of the (Classic) ASP language (FIORINO 2019). The website kept most of the existing styling – in terms of layout and page organization (Fig. 2) – and still relied on static XML files to generate article views from available data, which was accomplished by using XSLT. All other pages were written essentially as static HTML documents with PHP used mainly as a templating language (for example, to include common sections such as the sidebar menu). This is in contrast with the new version of the website, which uses routing and views to generate pages dynamically.

The OAI-PMH repository was also reimplemented in 2020 to move away from the third-party provider (and static files), using the relational database

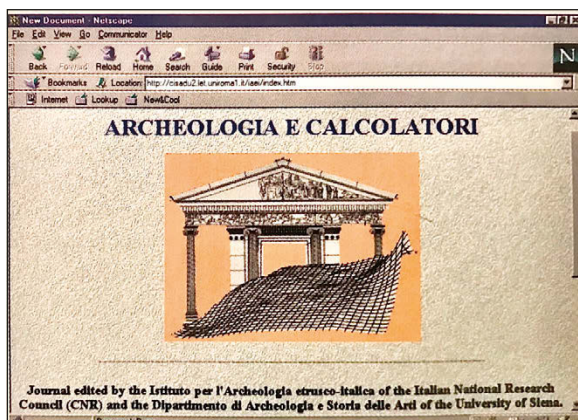


Fig. 1 – The original version of the journal's website, designed upon publication of the Proceedings of the 3<sup>rd</sup> International Symposium on Computing and Archaeology (MOSCATI 1996) and hosted by the Centro interdipartimentale di servizi per l'automazione nelle discipline umanistiche of the Sapienza University of Rome (CISADU), directed by Tito Orlandi (image: P. Moscati).

as the main source of data for serving XML responses dynamically according to the protocol's specification. This led to the inclusion of the repository in OpenAIRE as a data provider, via incremental harvesting of the metadata (ROSSI, PARACIANI 2021).

## 1.2 Initial availability of visual resources

In 2021, new features were added to the website in relation to the fruition of visual resources (ROSSI, PARACIANI 2021). These consisted of article figures presented both as a gallery of images in the article's page and as individual resources with their own URLs. The same approach was applied to 3D models related to articles, which were displayed in an interactive preview using the ATON framework (FANINI *et al.* 2021) as a web 3D viewer. Where applicable, the models could also be downloaded as GLTF/GLB files with an open access license chosen by the authors.

## 2. DESCRIPTION OF THE NEW WEBSITE

### 2.1 Reasons for technical choices

When considering the choice of a web development language and framework for the new website, several possibilities were evaluated in terms of performance, package ecosystem and existing knowledge from previous



Fig. 2 – A page from the previous version of the website (volume view).

development work. The possibilities were mostly JavaScript with NodeJS, Python with a web framework (such as Django or Flask), and PHP, either with the Symfony framework or with individual components. This latter option was deemed the best final choice because of already established knowledge of the language and the possibility to reuse code from other projects.

The decision to implement a custom solution almost from scratch instead of relying on open-source CMS software, for example, or – better still – on the Open Journal System (OJS) platform, was taken because of two main reasons: 1) the existence of an already populated database holding 34 years of publications data; 2) the specific custom features that were to be transferred to the new website (mainly the management of visual resources). Reason 1) implied the need to manually insert the data for all volumes and articles into a system like OJS, which has its own database schema and is thus not compatible with the existing one. Reason 2), instead, meant that a CMS or OJS itself would have to be modified at source code level to implement custom features as needed. Since there was no sufficient pre-existing knowledge in this respect, a considerable amount of time would have to be spent in learning a new development environment and uploading data for about 1200 articles.

The fact that the new website is based on Symfony components makes it easily adaptable to the full Symfony framework, which could be beneficial in terms of stability and future updates.

## 2.2 Database changes

Some minor changes to the database structure were required in order to prepare the data for optimal usage by the website backend. A new entity

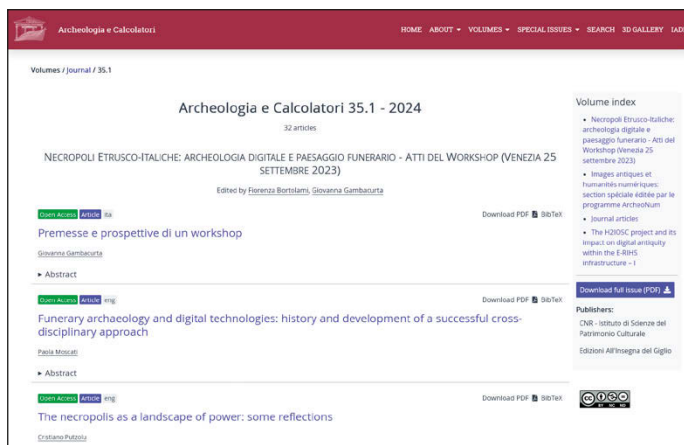


Fig. 3 – Volume view (partial) with linked section titles in the right-hand sidebar.

was added to model sections within volumes and relate them with the corresponding articles and curators. This allowed querying the database to obtain section titles with curators' names directly for a given volume, as well as the list of articles in each section. Previously, displaying section titles and their occurrence within the articles sequence of a volume was difficult due to the absence of a separate entity to hold this kind of data. The new model solves this problem. Sections, when present, are now displayed in the volume's table of contents with links for easier navigation (Fig. 3). These links can also work as permalinks pointing directly to a specific volume section.

A pivot, or relationship, table was also added to relate articles with Pleiades places (<https://pleiades.stoa.org/>) and implement geographical coverage. The table models a many-to-many relationship since a single article can be related to several Pleiades places and vice versa. This addition proved useful for data retrieved via the REST API as well (see §4.1).

## 2.3 Backend implementation

The website's backend is written in PHP 8.3 (latest stable version at the time of development) and adopts several modern features of the language, such as pattern matching, strict type checks, read-only class properties, etc. As mentioned above, the backend relies on some Symfony components that facilitate the implementation of the common Model-View-Controller (MVC) pattern for web application development and provide useful features in a reliable manner. The codebase adopts an Object-Oriented Programming style, with entities modelled as objects with methods to retrieve data from



the database, which is queried using the Doctrine DBAL library (<https://www.doctrine-project.org/projects/dbal.html>). This data is itself mapped to so-called Data Transfer Objects (DTOs) that hold information in strictly typed read-only properties 'known' to the code editor (which can then show suggestions while typing), instead of relying on plain associative arrays with arbitrary column names mapped to string indexes.

Since images and their metadata are available in the website's database starting from 2021, in order to include them also for articles before that date, the backend interacts with IADI, the Atlas that hosts all images for the first

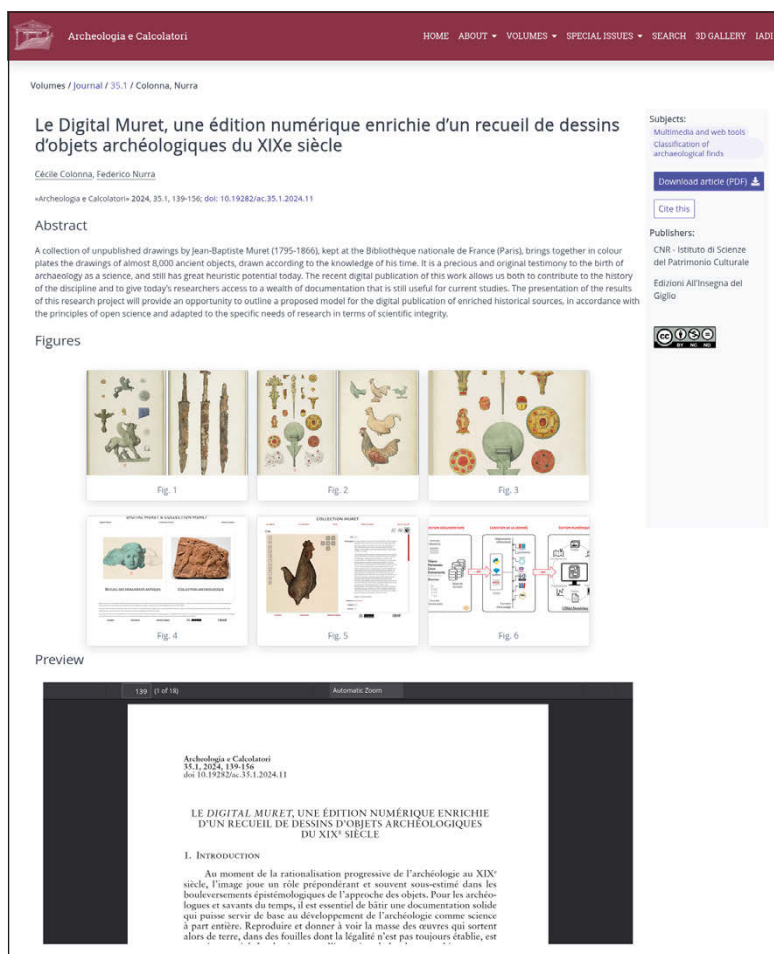


Fig. 4 – Article view with related images and PDF preview.

30 years of publications (PARACIANI, ROSSI 2023), forming a link that is displayed in the article view and directs to the corresponding page in IADI.

## 2.4 User interface (frontend)

The frontend or user interface presented by the website is generated mostly with views or templates, written using Plates (<https://platesphp.com/>), a templating library that employs native PHP capabilities. This library adds a 'lightweight' dependency and is easily extensible. In the future, however, the views could be ported to Twig, a templating engine with its own dedicated syntax and features that is perhaps more well-established. Minimal JavaScript is used for interactive features and AJAX calls to the REST API, mainly to retrieve citations for articles, which are available in three different styles: A&C,



Fig. 5 – List of articles by a single author (partial).

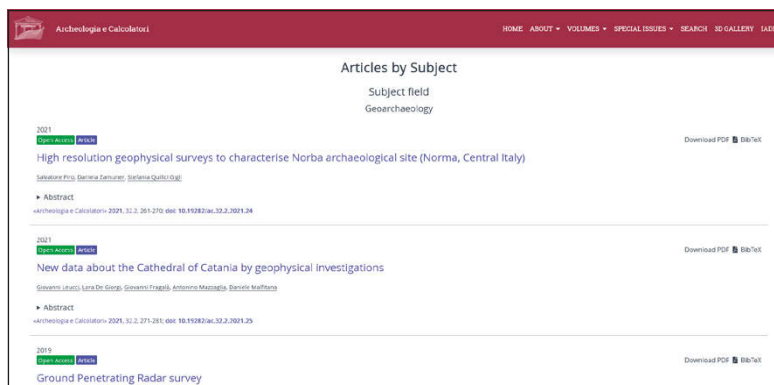


Fig. 6 – Example view of all articles for a given subject (partial).

APA and Harvard (the latter two styles were added in the new version of the website). The citation can also be downloaded in the BibTeX format and then imported in a reference management software of choice, for example. The RIS file format for citations will most probably be added in the future. This feature is available in the article view (Fig. 4), which displays information for a single article along with any related images, 3D models and supplementary materials.

The names of authors are linked to (dynamic) individual pages with the list of all articles by a specific author (Fig. 5). Subjects in the right-hand sidebar of the article view are also linked to the corresponding list of articles (Fig. 6). Static pages, such as 'About', 'Credits and Contacts', 'Policy and Guidelines' etc., are generated from Markdown sources, instead of more complicated templates, which are parsed and rendered as HTML by a single controller. This makes it easier to add new static pages since Markdown is a very simple and minimalistic mark-up language.

## *2.5 Search feature*

The search feature has also been redesigned as a structured form with filters for text, author, publication year, publication type (journal or supplement), subject field and computer technology. The text filter allows searching for arbitrary keywords or sentences – enclosed in double quotes – and supports wildcards with the asterisk (\*) symbol and the exclusion of words by prepending them with a minus (-) symbol. Keywords separated by a space are interpreted as concatenated by a logical AND operator. The text search is performed in the content of article titles and abstracts. The author filter has an autocomplete feature that shows possible author names during typing, while the subject field and computer technology filters are selections over the list of A&C subject terms. By default, a limit of 15 search results per page are shown, although this value can be parametrized (Fig. 7).

## **3. REST API IMPLEMENTATION AND OAI-PMH REPOSITORY UPDATES**

The development of the new website offered the opportunity to add features and improve existing services, specifically the implementation of a REST Application Programming Interface (API)<sup>1</sup> and updates to the journal's OAI-PMH repository.

<sup>1</sup> The Representational State Transfer (REST) paradigm is a software development style which defines seven constraints to be respected when designing and developing web services, although technically it is not limited or bound to the web specifically. Without going into too much detail, we can say that the main requirements of this paradigm are that the client-server communication should be 'stateless' (the result of a client request depends only on the parameters passed to the server and has no effect on the server's state for subsequent requests), cacheable and with a uniform interface centred on resources (RICHARDSON, AMUNDSEN, RUBY 2013).

The screenshot displays the 'Archeologia e Calcolatori' website's search interface. At the top, a navigation bar includes links for HOME, ABOUT, VOLUMES, SPECIAL ISSUES, SEARCH, 3D GALLERY, and IAD. Below the navigation bar, the 'Search articles' section features a search form with various filters: Text (with a search icon), Author, Publication year, Journal / Supplements, Subject field, and Computer technology. A note states: 'Note: free text search will look for matches in the articles' titles and abstracts.' The search results section, titled 'Results', shows '4 articles'. The first article is from 2024, titled 'Archaeological data management and spatial analysis tools in the study of necropolises: case studies from Bologna and Spina (6th-3rd cent. BC)', with authors Elisabetta Gatto, Andrea Gualco, Chiara Pizzorri, Anna Serra, Carlotta Trombadori, Riccardo Varvaro, and Enrico Zampieri. The second article is from 2007, titled 'Dinamiche di scambio nel Mediterraneo antico: il caso di Cerveteri', with authors Francesco Roncali, Paola Moscati, and Nicoletta Scala. The third article is from 2001, titled 'Elaborazioni grafiche computerizzate nello studio della decorazione di un gruppo di lamine in bronzo da Eretum', with authors Paola Santoro and Marcello Bettinardi. The fourth article is from 1994, titled 'Il trattamento dei dati iconografici nell'ambito della ceramica attica e l'esempio del progetto Spina', with authors Maria Pia Guermandi, Stefania Migonari, and Angela Montanari. Each article entry includes a 'Download PDF' button and a 'BibTeX' link.

Fig. 7 – The search form with results.

### 3.1 The JSON REST API

Given the increasing reliance on the JavaScript Object Notation (JSON) document format for the exchange of (meta)data among modern web services and applications, typically via a REST API (SERBOUT, LAURO, PAUTASSO 2022), it was decided to implement one for A&C, in addition to the OAI-PMH repository. Although the metadata related to A&C publications were already openly accessible via the repository, these are served as XML documents

(required by the protocol), which can be cumbersome to parse for any third-party services that do not rely specifically on the OAI approach. The REST API offers an advantage in this case, since reading JSON documents programmatically is easier compared to XML, given the widespread support for this data exchange format in many programming languages. More specifically, the JSON document can be converted directly into a native data structure and can be manipulated comparatively easily and in a performant way, which is not always the case with XML (VANURA, KRIZ 2018).

Currently, the beta version of the REST API consists of the following five endpoints (the last two are not JSON endpoints):

- /api/articles: Retrieves a list of the IDs of all articles found in the journal's database; it can be filtered by geographic place (Pleiades ID);
- /api/articles/{id}: Retrieves metadata for a single article based on its ID;
- /api/articles/range/{firstId}/{lastId}: Retrieves metadata of all articles included in a given range of IDs;
- /api/cite/{id}: Returns the citation for a given article formatted in HTML according to a citation style, controlled by a parameter;
- /api/cite/{id}/bibtex: Returns the citation for a given article as a BibTeX file download.

The REST API is documented with the OpenAPI (formerly 'Swagger') specification (<https://www.openapis.org/>), which offers a way to generate the documentation automatically along with a graphical testing interface for each endpoint (Fig. 8). The interface shows the HTTP method associated with the endpoint, the formal structure of the endpoint itself (URI with dynamic path parameters) and details about any required and optional parameters<sup>2</sup>. An HTML form allows testing the API directly in the browser. The results are formatted and displayed with colour-coded syntax.

The OpenAPI configuration is itself generated dynamically when a client sends a request to the '/api/openapi' endpoint and is served in JSON format. Configuration parameters are defined using PHP 8 attribute syntax, supported by the Swagger-PHP library (<https://zircote.github.io/swagger-php/>). Adopting this kind of (informally) standardized description makes it possible to offer a well-known and easily reusable documentation interface, which allows potential users to test the API endpoints directly.

The addition of this API also facilitated interoperability with the ArchaeoHub system, a hub for digital archaeology that is being developed within the framework of the H2IOSC project (CARAVALLE, MOSCATI, ROSSI 2024). In particular, the hub collects article data for topics related to geographic places

<sup>2</sup> Parameters embedded in the URI are called 'path parameters', while those appended to the URI via the HTTP query syntax (following a question mark) are called 'query parameters'.

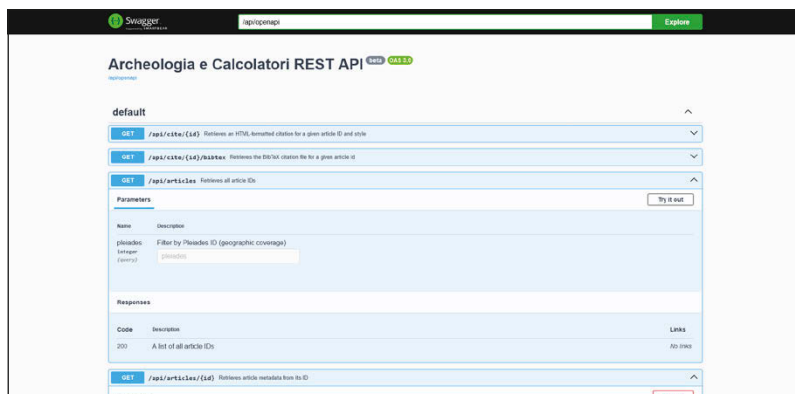


Fig. 8 – The OpenAPI (Swagger) web interface for A&C’s REST API.

by filtering relevant article IDs from the REST endpoint, using the Pleiades identification number of the place as a parameter.

### 3.2 Updates to the OAI-PMH repository

The backend code that generates the OAI-PMH repository was entirely rewritten since the existing one suffered from so-called ‘technical debt’ and wasn’t suitable for the new codebase. Since managing and writing XML programmatically with default PHP libraries (specifically the DOM library) is somewhat cumbersome, a more flexible approach based on object serialization was adopted. Each metadata format served by the repository – i.e. Dublin Core, OpenAIRE and DataCite – is modelled as an object class implementing a common interface, which represents the OAI record in that specific format. The object is then serialized to XML based on the values of its (read-only) properties – initialized via database queries – and additional fields encoded in associative arrays. The actual serialization, that is the ‘translation’ of the object to a well-formed and formatted XML string, is performed with the aid of the Symfony Serializer component. This approach makes it easier to add new metadata formats to the repository, since it is a matter of modelling the format as an object class, implementing the base interface, and defining properties as necessary.

Pagination of records and identifiers was also added using the resumption token method, as required by the protocol. The resumption token is effectively a string that encodes a particular state of the request to the repository and is used to simplify harvesting when the list of records is large. Indeed, each request returns only a subset of records, with subsequent requests resuming from the last offset by means of the resumption token, until the end of the list



is reached. The token string adopts a custom syntax – allowed by the protocol – to encode the state of the request, namely the total number of records in the list, the current offset, the token's expiration date, the values of the set and metadata format parameters, as well as any date-filtering parameters (from and/or until). The resumption token string is parsed and converted to an object with typed properties, which allows the backend to retrieve the proper set of records or identifiers for each request.

Finally, a new schema was adopted for the identifiers of articles, namely 'oai:www.archcalc.cnr.it:article:{id}', which is similar to the identifiers assigned to images and 3D models and is arguably more readable than 'oai:www.archcalc.cnr.it/oai/aec\_oaipmh2.php:{id}', used in the previous version.

#### 4. FUTURE DEVELOPMENTS

An important future development is the conversion of the articles' full texts to structured HTML, which could then be displayed in the web page (article view), instead of the embedded PDF preview. The journal's publisher, Edizioni all'Insegna del Giglio, has already provided the Editorial Board with XML versions of all volumes from 1997 onwards. These XMLs, while being more useful than PDFs to extract content as plain text, were exported automatically from the corresponding PDF documents and are not structured in a way that can be easily converted to HTML as needed for the website. However, some parsing and string-manipulation techniques could be applied to retrieve content from the XMLs and then build the proper HTML documents. These could be then persisted in the database and displayed with the rest of the article's data. The obvious advantage of HTML is that it can be interactive, with links to references embedded in the text, for example, and a browsable table of contents, as is usually provided by many digital journals.

Furthermore, having the content of articles as text in the database would enable searching for keywords or free text in the entire article, instead of just in titles and abstracts.

Another foreseeable development is the use of geographical coverage in the form of Pleiades IDs to, e.g., display an embedded map with relevant places directly in article views and / or search content by geographic place. Finally, the REST API could be improved by adopting a more standardized format for the JSON data. For example, JSON-LD (Linked Data) could be used as a schema, instead of the current custom one, adopting Dublin Core (DC) terms as context for key names, which could be facilitated by the existing DC mapping of database entities used by the OAI-PMH repository.

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## REFERENCES

- BARCHESI C. 2005, 'Archeologia e Calcolatori': nuove strategie per la diffusione di contenuti in rete sulla base dell'OAI-PMH, «Archeologia e Calcolatori», 16, 225-241.
- BARCHESI C. 2019, *Archeologia e Calcolatori: un'esperienza pionieristica nel mondo dell'Open Access e dell'Open Science*, «Archeologia e Calcolatori», 30, 39-54 (<https://doi.org/10.19282/ac.30.2019.04>).
- CARAVALE A., MOSCATI P., ROSSI I. 2024, *Landscaping and integrating Digital Archaeology and Digital Epigraphy resources: New challenges and future opportunities. Introduction to the Special section*, in A. CARAVALE, P. MOSCATI, I. ROSSI (eds.), *The H2IOSC Project and Its Impact on Digital Antiquity within the E-RIHS Infrastructure – I*, «Archeologia e Calcolatori», 35.1, 515-520 (<https://doi.org/10.19282/ac.35.1.2024.30>).
- FANINI B., FERDANI D., DEMETRESCU E., BERTO S., D'ANNIBALE E. 2021, *ATON: An open-source framework for creating immersive, collaborative and liquid web-apps for cultural heritage*, «Applied Sciences», 11, 22, 11062. (<https://doi.org/10.3390/app112211062>).
- FIORINO S. 2019, *Lo stato dell'arte dell'innovazione tecnologica per le architetture web: presente e futuro per Archeologia e Calcolatori*, «Archeologia e Calcolatori», 30, 55-74 (<https://doi.org/10.19282/ac.30.2019.05>).
- MOSCATI P. (ed.) 1996, *III International Symposium on Computing and Archaeology (Roma 1995)*, «Archeologia e Calcolatori», 7, 1147-1156 (<https://www.archcalc.cnr.it/journal/idyear.php?IDyear=1996-01-01>).
- PARACIANI N., ROSSI I. 2023, *IADI: An open Interactive Atlas of Digital Images for the journal «Archeologia e Calcolatori»*, «Archeologia e Calcolatori», 34.1, 135-144 (<https://doi.org/10.19282/ac.34.1.2023.15>).
- RICHARDSON L., AMUNDSEN M., RUBY S. 2013, *RESTful Web APIs: Services for a Changing World*, O'Reilly Media, Inc.
- ROSSI I., PARACIANI N. 2021, *IT applications to archaeology and the OA diamond journals' challenge. Enhancing access and reuse of textual and visual resources*, «Archeologia e Calcolatori», 32.1, 325-347 (<https://doi.org/10.19282/ac.32.1.2021.18>).
- SERBOUT S., LAURO F.D., PAUTASSO C. 2022, *Web APIs structures and data models analysis*, in *2022 IEEE 19<sup>th</sup> International Conference on Software Architecture Companion (ICSA-C)*, 84-91 (<https://doi.org/10.1109/ICSA-C54293.2022.00059>).
- VANURA J., KRIZ P. 2018, *Performance evaluation of Java, JavaScript and PHP serialization libraries for XML, JSON and binary formats*, in J.E. FERREIRA, G. SPANOUDAKIS, Y. MA, L.-J. ZHANG (eds.), *Services Computing – SCC 2018*, Cham, Springer International Publishing, 166-175 ([https://doi.org/10.1007/978-3-319-94376-3\\_11](https://doi.org/10.1007/978-3-319-94376-3_11)).

## ABSTRACT

Over the course of 35 years since its foundation, the open access journal «Archeologia e Calcolatori» has been providing its publications online via the website, as well as open access metadata since 2005 through the OAI-PMH repository. In 2024, the website underwent a major update and restyling, including the addition of modern interoperability features, most notably the newly implemented JSON REST API. This paper is concerned with the technical description of the design and development of the new website and additional functionalities for «Archeologia e Calcolatori», while also giving a short overview of how the journal's online presence has evolved over time. The exchange of data between the journal's REST API and the Open Archaeology Hub (ArchaeoHub) currently being developed in the context of the H2IOSC project is described as well. Finally, some future perspectives for further improvement are presented.

## VERSO LA COSTITUZIONE DI LINEE GUIDA PER L'ESPOSIZIONE DI RISORSE VISUALI NEGLI AGGREGATORI EUROPEI

### 1. L'ARCHIVIAZIONE DIGITALE DELLE IMMAGINI DI ARCHEOLOGIA

Il CNR-ISPC partecipa al PNRR “Cultural Heritage Active Innovation for Sustainable Society” (CHANGES) sia come Leader dello Spoke 5 (“Scienze e Tecnologie per la diagnostica sostenibile del Patrimonio Culturale”), sia come affiliato dello Spoke 8, dedicato alla “Sostenibilità e resilienza del patrimonio culturale tangibile” e guidato dall’Università La Sapienza<sup>1</sup>. Il progetto mira a fornire nuovi strumenti integrati tra scienze e tecnologie per il patrimonio culturale tangibile (TCH), con uno specifico focus sui contesti del passato in capo allo Spoke 8. Quest’ultimo, attraverso un approccio fortemente basato sull’evidenza, si propone la messa a punto di un modello di flusso di intervento per il TCH a disposizione di diversi tipi di stakeholder (decisori, amministratori, imprese dell’industria culturale, studiosi), dalla conoscenza alla governance. Tra le linee tematiche individuate dalla ricca compagine delle Università e Istituzioni coinvolte, figura quella sugli Archivi Digitali, che il gruppo Open Data<sup>2</sup> del CNR-ISPC ha in corso di sviluppo all’interno del WP1 (Evidence-based guidelines for data capturing/analysis and information creation) e WP2 (Digital/phigital archiving infrastructure).

Tale linea si inserisce in una precisa cornice d’indirizzo delle politiche culturali nazionali e sostanzia un’attività di ricerca trasversale a molti obiettivi di vario livello: sia quelli del Progetto stesso (“Messa a punto e implementazione di infrastrutture digitali per inventari/catasti del Patrimonio Culturale Tangibile, al fine di supportare diversi percorsi di conoscenza e massimizzare l’accessibilità”), sia delle priorità di sistema del Programma Nazionale per la Ricerca 2021-2027<sup>3</sup> (“Valorizzare circolazione conoscenze”), che ha inserito la cultura umanistica tra i sei grandi ambiti di ricerca e innovazione del corrente quinquennio. Nel disegno di allineamento della programmazione nazionale rispetto a quella europea, la scienza aperta è stata, inoltre, individuata quale elemento qualificante tra gli approcci di metodo e di politiche di R&I, tanto che il PNR 2021-2027 include due piani nazionali: quello per le infrastrutture di ricerca e quello per la scienza aperta.

<sup>1</sup> <https://sites.google.com/uniroma1.it/changes/chi-siamo/spokes/spoke-8>.

<sup>2</sup> [https://www.ispc.cnr.it/it\\_it/2020/05/14/gruppo-open-data/#:~:text=Il%20gruppo%20di%20lavoro%20interdisciplinare,e%20in%20modalit%C3%A0%20open%20access](https://www.ispc.cnr.it/it_it/2020/05/14/gruppo-open-data/#:~:text=Il%20gruppo%20di%20lavoro%20interdisciplinare,e%20in%20modalit%C3%A0%20open%20access).

<sup>3</sup> <https://www.mur.gov.it/it/aree-tematiche/ricerca/programmazione/programma-nazionale-la-ricerca>.

L'attività sul Digital archiving svolta all'interno di CHANGES costituisce la naturale ricaduta dell'esperienza dell'ISPC, e in particolare del gruppo Open Data, in entrambi questi ambiti. Riguardo al primo, ricordiamo il coordinamento da parte dell'Istituto sia di E-RIHS, infrastruttura di ricerca europea presente nella Roadmap ESFRI (European Strategy Forum on Research Infrastructures), sia di H2IOSC<sup>4</sup>, federazione dei nodi italiani delle infrastrutture per le scienze umane e il patrimonio culturale. Quanto alla scienza aperta, divenuta paradigma di riferimento per il CNR a partire dalla "Roadmap per la Scienza Aperta" (2022), l'Istituto ha al suo interno veri e propri modelli italiani di diamond OA già da 20 anni, come «Archeologia e Calcolatori» (A&C) (MOSCATI 2019), che possiede un repository interrogabile di oltre 7000 risorse digitali, aderisce dal 2005 all'OAI-PMH (Open Archives Initiative Protocol for Metadata Harvesting) ed è data provider di OpenAIRE, l'infrastruttura open access europea. Su questa base è stato avviato il lavoro sull'archiviazione digitale all'interno di CHANGES, individuando nelle immagini o risorse visuali di archeologia la classe di dati del patrimonio culturale oggetto di intervento.

L'importanza delle banche dati di documenti figurativi è stata riconosciuta tra i primi da René Ginouvès nell'ambito delle pionieristiche ricerche del TAAC (Centre de Recherche sur les Traitements automatisés en Archéologie classique), presso l'Università di Parigi X-Nanterre (GINOUVÈS, GUIMIER-SORBETS 1991; GUIMIER-SORBETS 2017). Nel 1986 lo studioso presentava a Parigi il primo videodisco di immagini di archeologia, *Images de l'archéologie* (GINOUVÈS 1986), realizzato sotto la responsabilità scientifica di A.-M. Guimier-Sorbets e M. Fourmont e contenente 900 fotografie di Delfi del Centre de Documentation Photographique et Photogrammétrique, CDPP, CNRS-Université de Paris I (GUIMIER-SORBETS 1993). Le ampie possibilità di utilizzo di questo supporto per i sistemi informativi, così come per i dispositivi multimediali utili alla diffusione presso diversi tipi di pubblico, come nel caso del videodisco *Parthénon* del Museo del Louvre (DESCAMPS 1993), aprirono la strada per invocare, già oltre trent'anni fa, uno shift "dalla formazione all'informazione" nell'uso del patrimonio culturale, cioè un'estensione della sua accessibilità alla società tutta, attraverso le applicazioni informatiche all'archeologia. Oggi, il grande potenziale informativo delle risorse visuali si confronta con l'accresciuta complessità delle banche dati digitali e l'ampliamento dell'orizzonte di fruizione dei dati su una scala internazionale, rendendo necessari appositi strumenti metodologici.

Ci siamo perciò proposti, all'interno di CHANGES, l'elaborazione di linee guida per l'esposizione di risorse visuali negli aggregatori europei, al

<sup>4</sup> Humanities and Heritage Italian Open Science Cloud - <https://www.h2iosc.cnr.it/>.

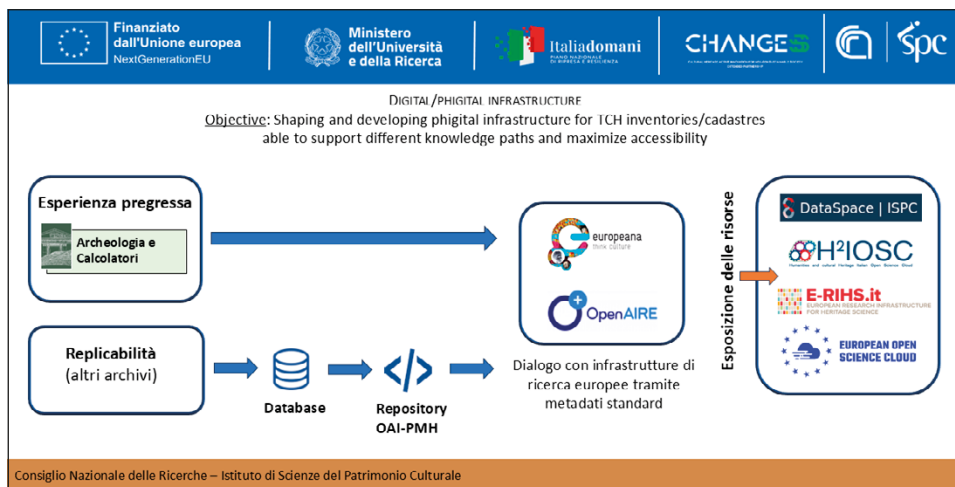


Fig. 1 – Flusso di lavoro delle attività di Archiviazione Digitale in corso di svolgimento all'interno del Prog. PNRR CHANGES, Spoke 8.

fine di facilitarne lo studio attraverso strumenti di analisi dei dati e della pubblicazione come Linked Open Data. Infatti, i corposi archivi di immagini analogiche largamente disponibili agli archeologi e a tutti gli effetti interpretabili come “legacy data”, che quasi sempre sono penalizzati da una mancata integrazione con i metodi di archiviazione e consultazione degli archivi digitali, costituiscono un patrimonio tangibile che pone oggi numerose sfide sul piano dell'accessibilità e della (ri)usabilità. Le specifiche azioni previste nella linea tematica del Progetto “Archivi Digitali” mirano ad affrontare alcune di queste sfide attraverso la messa a punto di linee guida e standard per l'archiviazione che possano risultare valide per dati-immagine provenienti da diverse “famiglie” di archivi (musei, centri di ricerca, missioni di scavo, riviste scientifiche), consentendo anche la definizione delle peculiarità, criticità e opportunità di risorse strutturate diversamente tra loro. Uno studio di fattibilità per il conseguimento dei suddetti obiettivi è stato condotto a partire dal repository di A&C, con la prospettiva di renderlo un esperimento pilota replicabile per altri archivi digitali (Fig. 1). Con questo spirito si presenta qui la ricerca finora svolta e ancora in corso.

Una base fondamentale per le nostre attività è stata costituita dall'Interactive Atlas of Digital Images (IADI), ideato in occasione del trentesimo anniversario della Rivista (MOSCATI 2019) e poi messo a punto per la consultazione in rete (PARACIANI, ROSSI 2023), che conta circa 5000 risorse e consente una consultazione interattiva delle immagini. L'Atlante definisce un modello per l'utilizzo dei dati visuali nel digital archiving.

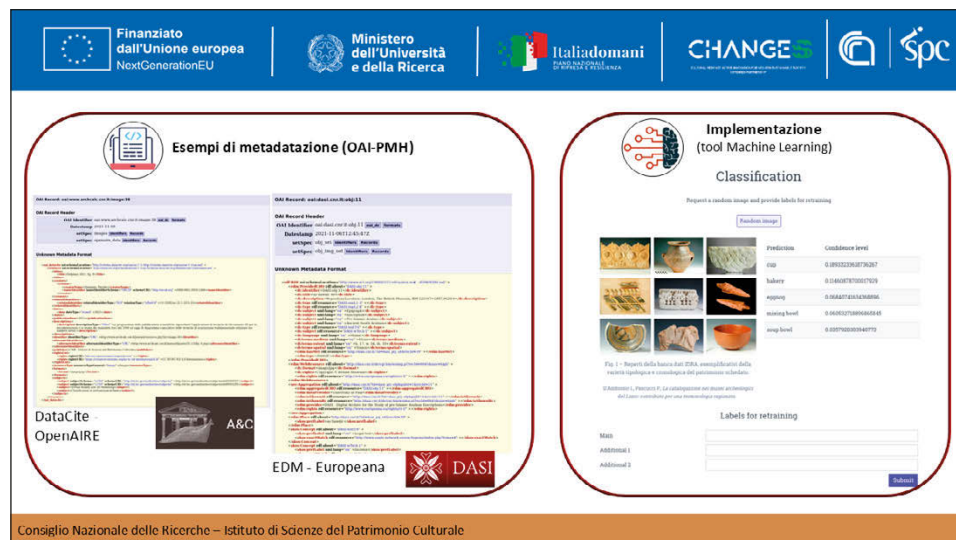


Fig. 2 – Pagine HTML con due diversi esempi di modelli di metadati.

Dal punto di vista operativo, un primo ed essenziale passaggio del nostro progetto è stato individuato nella descrizione delle risorse elettroniche attraverso metadati riconosciuti a livello internazionale, così come indicato nelle Linee Guida di OpenAIRE<sup>5</sup>. Sono state condotte alcune analisi sui principali schemi utilizzati per la descrizione e l'esposizione di risorse in grado di dialogare con infrastrutture europee. La Fig. 2 mostra un esempio di diversi modelli di metadattazione di due record, presenti rispettivamente nel repository di A&C e in DASI (Digital Archive for the Study of pre-Islamic Arabian Inscriptions), in diversa misura riconducibili alla ricerca del CNR-ISPC. Il primo record descrive un'immagine (figura di un articolo) metadattata secondo lo schema DataCite<sup>6</sup> adottato da OpenAIRE per i cosiddetti "Data Archives" (repository che forniscono dataset), mentre il secondo rappresenta un oggetto con immagine associata, descritto secondo il modello EDM<sup>7</sup> adottato da Europeana.

Stante la pregressa e già consolidata esperienza di A&C, oltre al set Dublin Core (DC) per i termini di base, il DataCite Metadata Schema v3.1 è stato individuato come standard all'interno del progetto. È stata così predisposta

<sup>5</sup> OpenAIRE Guidelines for Literature Repository Managers v4 (<https://openaire-guidelines-for-literature-repository-managers.readthedocs.io/en/v4.0.0/>).

<sup>6</sup> <https://schema.datacite.org/meta/kernel-4.5/>.

<sup>7</sup> <https://pro.europeana.eu/page/edm-documentation>.



una tabella che sarà presentata nel dettaglio più avanti, la quale implementa i metadati in parte già presenti in IADI con ulteriori campi. Obiettivi dell'attività sono: l'inclusione di queste immagini nel repository OAI-PMH di IADI in corso di implementazione, l'arricchimento dei metadati trasferiti ad OpenAIRE, la possibilità di raccolta di queste risorse (aggregazione) da parte di Europeana, la sperimentazione di funzioni di riconoscimento automatico delle immagini.

In particolare, sono stati inseriti due campi che descrivono il tipo e il soggetto dell'immagine e due campi per informazioni geografiche (cd. *geographic coverage*). L'estensione dei metadati descrittivi alla classificazione tematica e al contesto geografico delle sorgenti, infatti, rende l'interrogazione del repository uno strumento ideale per il monitoraggio dell'evoluzione dell'archeologia digitale, delle metodologie più utilizzate nella ricerca archeologica, nonché dei suoi ambiti disciplinari e transdisciplinari, oggi in continuo cambiamento.

Per quanto riguarda i nomi dei campi tipo/soggetto, nonché dei record in essi contenuti, il criterio metodologico di partenza è stato fissato nell'utilizzo di vocabolari controllati, cioè di codici e nomenclature ricorrenti in maniera standardizzata e normalizzata. Ciò garantisce l'interoperabilità semantica, vale a dire la possibilità di elaborare informazioni da fonti esterne senza perdere il reale significato delle informazioni stesse nel processo di elaborazione. È stato così intrapreso un lavoro di ricognizione dei principali thesauri e tassonomie che descrivono e classificano le immagini relative al patrimonio culturale. In particolare, sono stati analizzati: l'Art&Architecture Thesaurus del Getty Research Institute (AAT)<sup>8</sup>, il thesaurus del Deutsches Archäologisches Institute (iDAI)<sup>9</sup>, alcuni strumenti terminologici dell'Istituto Centrale per il Catalogo e la Documentazione (ICCD)<sup>10</sup>, e le Europeana Data Model guidelines (EDM)<sup>11</sup>. Si è individuato nell'AAT il riferimento principale, sia per via della ricchezza dei vocabolari, che trovano spesso corrispondenza in iDAI e ICCD, sia per l'articolata strutturazione del suo albero gerarchico. Quest'ultimo è stato rispettato quando possibile, tenuto conto che il lavoro che qui si presenta è relativo ad immagini a loro volta appartenenti a quel particolare tipo di archivio digitale che è il repository di una rivista scientifica. Il mantenimento degli ID originari di AAT per i vocaboli presenti all'interno della nostra tabella di metadati rende, in ogni caso, sempre possibile il collegamento con posizione e significato di partenza.

<sup>8</sup> <https://www.getty.edu/research/tools/vocabularies/aat/>.

<sup>9</sup> [http://thesauri.dainst.org/de/concepts/\\_fe65f286.html](http://thesauri.dainst.org/de/concepts/_fe65f286.html).

<sup>10</sup> Strumenti terminologici - ICCD - Istituto Centrale per il Catalogo e la Documentazione ([beniculturali.it](http://beniculturali.it)); <https://github.com/ICCD-MiBACT>.

<sup>11</sup> EDM - Mapping guidelines - Europeana Knowledge Base - Confluence ([atlassian.net](http://atlassian.net)); [https://docs.google.com/spreadsheets/d/1BoDNolkcp\\_qfvVShdOZYGcf61XslwKF2MdGcgYs20/edit?gid=0#gid=0](https://docs.google.com/spreadsheets/d/1BoDNolkcp_qfvVShdOZYGcf61XslwKF2MdGcgYs20/edit?gid=0#gid=0).

Per quanto riguarda gli altri due campi che abbiamo inserito nella tabella e che descrivono regione e sito di appartenenza dell'area presa in esame nelle immagini o nell'articolo collegato alle immagini, essi costituiscono metadati geografici che consentono la georeferenziazione degli elementi presenti nella tabella stessa. L'inserimento di tali informazioni, inoltre, persegue l'obiettivo dell'integrazione dell'attività di archiviazione digitale all'interno di CHANGES con quelle degli altri affiliati, posto che il tema geospaziale è stato individuato come elemento comune all'interno dello Spoke 8. Anche in questo caso, il lavoro precedentemente svolto da A&C ha costituito un punto di partenza fondamentale. Una sperimentazione di mapping di toponimi con tematismi cronologici e topografici per i siti dell'Etruria è stata, infatti, condotta su fonti testuali del repository della Rivista attraverso il tool open source Recogito, una piattaforma online per l'annotazione collaborativa di documenti gestita da Pelagios, iniziativa europea nelle Digital Humanities (CANTONE, CARVALE 2019). Sulla base di questa esperienza, e in particolare dell'uso di repertori controllati (gazetteer), abbiamo associato il dato geografico alle immagini attraverso i campi "Geographic Coverage" che contengono il riferimento alle URI di banche dati geografiche online, come Pleiades (<https://pleiades.stoa.org/>).

Allo stato attuale, come verrà esposto nel dettaglio più avanti, sono state metadate circa 600 immagini, con soggetto "Cerveteri", "Etruria" e "Sabina" pubblicate in tutto l'arco di vita di A&C, a coprire aree geografiche molto bene attestate nella Rivista, nonché oggetto di particolare interesse tra gli archeologi all'interno dello Spoke 8, molti dei quali attivi nell'implementazione dell'Atlante del Lazio Antico<sup>12</sup> con i dati del territorio a N del Tevere.

Un interesse molto attuale della comunità scientifica per i database delle immagini di archeologia è relativo alle applicazioni di IA, come espresso dal fiorire di studi e di ampi programmi di ricerca tra cui, per esempio, il recentissimo MonumenTAL/Monuments antiques et Traitement Automatique de la Langue (SZABADOS 2024), concentrato su aspetti di riconoscimento e annotazione automatici delle didascalie. In questa prospettiva, esperimenti di pattern recognition sulle immagini di A&C erano già stati avviati per IADI. A partire da questo lavoro, il dataset di risorse visuali con i relativi metadati fin qui realizzato all'interno di CHANGES sarà utilizzato per un trial test. Tenuto conto dell'obiettivo progettuale di "massimizzazione dell'accessibilità" degli archivi digitali, sarà cioè sperimentata l'implementazione delle funzionalità di ricerca del repository per includere risultati da classificazione automatica e/o semi-automatica delle immagini tramite Machine Learning. Attraverso un'interfaccia utente sviluppata da Nicolò Paraciani, informatico del gruppo Open Data, verrà utilizzato il framework open source TensorFlow per il

<sup>12</sup> <https://www.lazioantico.it/>.

Topics	Articoli	Immagini
Cerveteri	10	90
Etruria	47	364
Sabina	18	140
Totale	75	594

Tab. 1 – Tabella riassuntiva degli articoli e delle immagini di A&C oggetto della classificazione, suddivisi per topics.

riconoscimento del contenuto delle immagini, la valutazione dell'accuratezza delle risposte del sistema e la possibilità di associare manualmente termini da utilizzare per il retraining del modello di classificazione utilizzato.

In sinergia con le attività condotte dal CNR-ISPC all'interno del Progetto PNRR H2IOSC, e per favorire la comunicazione "orizzontale" fra le azioni di politica culturale nazionale in favore della Scienza Aperta, i dati fin qui citati confluiranno in infrastrutture digitali come il DataSpace ISPC, collegato al DIGILAB dell'infrastruttura europea E-RIHS, ed EOSC, il Cloud Europeo per la Scienza Aperta.

F.B.

## 2. STRUTTURA E COMPOSIZIONE DEI METADATI

Il dataset utilizzato per la prima fase di metadattazione è stato costituito dalle immagini relative a "Cerveteri", "Etruria", "Sabina", tre tematiche su cui la Rivista si è soffermata con continuità fin dai primi numeri e che costituiscono il tema di altrettante linee di ricerca dell'ISPC. La ricerca delle risorse digitali sul sito web di A&C è avvenuta mediante l'apposito tool, utilizzando come chiavi i nomi antichi e moderni delle regioni e dei principali siti archeologici che in esse ricadono e l'idronimo "Tevere". Il totale delle immagini estratte dagli articoli così individuati e poi metadattate nel corso del nostro lavoro è finora pari a 594, suddivise come indicato in Tab. 1.

Per gli scopi dell'attività era indispensabile il riferimento a standard condivisi di indicizzazione delle risorse visuali. Sono state perciò esplorati le strutture e i vocabolari di diversi modelli, quali progetti di archiviazione iconografica, infrastrutture, thesauri e tassonomie, soprattutto su una scala internazionale. È stato inoltre consultato il principale riferimento nazionale, cioè il Catalogo Generale dei Beni culturali<sup>13</sup> dell'ICCD, accessibile attraverso un'interfaccia web nella piattaforma collaborativa SiGECweb, insieme alle schede di catalogo di ciascun bene. I dati del Catalogo, pubblicati come Linked Open Data (LOD), sono organizzati in modelli concettuali basati sulle

<sup>13</sup> <https://catalogo.beniculturali.it/>.

ontologie di Architettura della Conoscenza (ArCo), realizzate dall'ICCD insieme all'Istituto di Scienze e Tecnologie della Cognizione (ISTC) del CNR tra il 2018 e il 2020.

A livello internazionale, la più importante esperienza di open access data catalogue specificamente mirata al patrimonio archeologico è costituita dal portale ARIADNE<sup>14</sup> che, a oltre dieci anni dalla sua nascita (2012), si è evoluto in una vera e propria infrastruttura di ricerca (ARIADNE RI<sup>15</sup>), affrontando il tema della sostenibilità di grandi e complessi repository. I partner del consorzio ARIADNEplus forniscono una descrizione delle loro risorse digitali basata sull'ARIADNE AO-Cat, modello di dati utilizzato per includere ciascuna risorsa nel registro. Tra i vocabolari suggeriti, il Getty Art and Architecture Thesaurus (AAT) è utilizzato come modello di classificazione primario.

Più in generale, Europeana, il più grande portale europeo dedicato al patrimonio culturale, lanciato e finanziato dalla Comunità Europea nel 2008, è risultato di particolare interesse per il nostro progetto, in quanto l'aspetto collaborativo della piattaforma è fondato sull'uso degli aggregatori. Infatti, oltre 3600 istituzioni, così come la stessa A&C, sono attualmente data provider di Europeana, attraverso aggregatori di dominio e tematici, cioè di partner affiliati che hanno il compito di raccogliere i dati, controllarli, arricchirli oppure collegarli ad altri materiali o set di dati. L'aggregatore europeo per l'archeologia dal 2010 è CARARE, con sede a Dublino<sup>16</sup>, mentre CulturaItalia<sup>17</sup>, che espone a sua volta risorse di A&C, è l'aggregatore nazionale del patrimonio culturale italiano.

Ai fini del nostro lavoro, abbiamo analizzato le linee guida dell'Europeana Data Model (EDM), modello con cui i provider forniscono dati al progetto. Esso si basa su standard consolidati quali RDF(S), OAI-ORE, SKOS e Dublin Core, delinea criteri per la compilazione e consiglia l'uso di Linked Open Data (LOD) e vocabolari multilingue, tra i quali figurano l'AAT e Wikidata<sup>18</sup>. Su tale base, unitamente all'esperienza già acquisita da A&C e agli standard di metadati sopra descritti, abbiamo predisposto una tabella di metadati in vista sia del dialogo con le infrastrutture europee, sia dell'obiettivo di riconoscimento automatico delle immagini mediante Machine Learning. La Fig. 3 illustra i metadati attribuiti ai documenti sorgente (immagini), e cioè:

<sup>14</sup> <https://training.ariadne-infrastructure.eu/metadata-and-vocabularies-for-archaeological-datasets/>.

<sup>15</sup> <https://www.ariadne-research-infrastructure.eu/what-is-the-ariadne-ri/>.

<sup>16</sup> <https://pro.europeana.eu/organisation/carare>.

<sup>17</sup> <https://www.culturaitalia.it/>.

<sup>18</sup> I vocabolari supportati da Europeana sono presenti alla seguente lista: [https://docs.google.com/spreadsheets/d/1BoDNolcqp\\_qfvVShdOZyGcf61XslcwKF2MdGcgYs20/edit#gid=0](https://docs.google.com/spreadsheets/d/1BoDNolcqp_qfvVShdOZyGcf61XslcwKF2MdGcgYs20/edit#gid=0).




ID	N - fi g ur e	GEOGR. COVERAG E 1 (Site)	GEOGR. COVERAG E 2 (Region)	ARTICLE SUBJECT A&C 1 (technolog ies)	ARTICLE SUBJECT A&C 2 (archaeologi cal field)	ARTICLE SUBJECT	IMAGE TYPE _Lev.1	IMAGE TYPE _Lev.2	IMAGE SUBJECT _Lev.1	IMAGE SUBJECT _Lev.2	FIGURE
474	1	<a href="https://pleiades.stoa.org/places/422859">https://pleiades.stoa.org/places/422859</a>	<a href="https://pleiades.stoa.org/places/413122">https://pleiades.stoa.org/places/413122</a>	GIS and cartography	Survey and excavations	GIS and spatial analysis; Digital cultural heritage	computer images	web pages	other subjects	texts	
474	2	<a href="https://pleiades.stoa.org/places/422859">https://pleiades.stoa.org/places/422859</a>	<a href="https://pleiades.stoa.org/places/413122">https://pleiades.stoa.org/places/413122</a>	GIS and cartography	Survey and excavations	GIS and spatial analysis; Digital cultural heritage	photographs	color photography	environments	landscapes	
474	3	<a href="https://pleiades.stoa.org/places/422859">https://pleiades.stoa.org/places/422859</a>	<a href="https://pleiades.stoa.org/places/413122">https://pleiades.stoa.org/places/413122</a>	GIS and cartography	Survey and excavations	GIS and spatial analysis; Digital cultural heritage	computer images	web pages	other subjects	texts	
474	4	<a href="https://pleiades.stoa.org/places/422859">https://pleiades.stoa.org/places/422859</a>	<a href="https://pleiades.stoa.org/places/413122">https://pleiades.stoa.org/places/413122</a>	GIS and cartography	Survey and excavations	GIS and spatial analysis; Digital cultural heritage	computer images	web pages	methodologies and technologies	topography	
474	5	<a href="https://pleiades.stoa.org/places/422859">https://pleiades.stoa.org/places/422859</a>	<a href="https://pleiades.stoa.org/places/413122">https://pleiades.stoa.org/places/413122</a>	GIS and cartography	Survey and excavations	GIS and spatial analysis; Digital cultural heritage	computer images	web pages	methodologies and technologies	geographic information systems	
474	6	<a href="https://pleiades.stoa.org/places/422859">https://pleiades.stoa.org/places/422859</a>	<a href="https://pleiades.stoa.org/places/413122">https://pleiades.stoa.org/places/413122</a>	GIS and cartography	Survey and excavations	GIS and spatial analysis; Digital cultural heritage	photographs	aerial photographs; manipulated photographs	methodologies and technologies	scientific instruments	
474	7	<a href="https://pleiades.stoa.org/places/422859">https://pleiades.stoa.org/places/422859</a>	<a href="https://pleiades.stoa.org/places/413122">https://pleiades.stoa.org/places/413122</a>	GIS and cartography	Survey and excavations	GIS and spatial analysis; Digital cultural heritage	maps	manuscript maps	environments	ancient regions	
474	8	<a href="https://pleiades.stoa.org/places/422859">https://pleiades.stoa.org/places/422859</a>	<a href="https://pleiades.stoa.org/places/413122">https://pleiades.stoa.org/places/413122</a>	GIS and cartography	Survey and excavations	GIS and spatial analysis; Digital cultural heritage	photographs	color photography	architecture	buildings	
474	9	<a href="https://pleiades.stoa.org/places/422859">https://pleiades.stoa.org/places/422859</a>	<a href="https://pleiades.stoa.org/places/413122">https://pleiades.stoa.org/places/413122</a>	GIS and cartography	Survey and excavations	GIS and spatial analysis; Digital cultural heritage	photographs	color photography	environments; sites	landscapes; fortification elements	
474	10	<a href="https://pleiades.stoa.org/places/422859">https://pleiades.stoa.org/places/422859</a>	<a href="https://pleiades.stoa.org/places/413122">https://pleiades.stoa.org/places/413122</a>	GIS and cartography	Survey and excavations	GIS and spatial analysis; Digital cultural heritage	photographs	color photography	environments; sites	landscapes; fortification elements	
670	1	<a href="https://pleiades.stoa.org/places/422859">https://pleiades.stoa.org/places/422859</a>	<a href="https://pleiades.stoa.org/places/413122">https://pleiades.stoa.org/places/413122</a>	Virtual Reality and 3D Modelling	Data dissemination and education	Material culture; Photogrammetry and 3D scanning; Virtual reality	composition	color photography	architecture	rooms and spaces; people	
670	2	<a href="https://pleiades.stoa.org/places/422859">https://pleiades.stoa.org/places/422859</a>	<a href="https://pleiades.stoa.org/places/413122">https://pleiades.stoa.org/places/413122</a>	Virtual Reality and 3D Modelling	Data dissemination and education	Material culture; Photogrammetry and 3D scanning; Virtual reality	composition	sections; plans	architecture	buildings	
670	3	<a href="https://pleiades.stoa.org/places/422859">https://pleiades.stoa.org/places/422859</a>	<a href="https://pleiades.stoa.org/places/413122">https://pleiades.stoa.org/places/413122</a>	Virtual Reality and 3D Modelling	Data dissemination and education	Material culture; Photogrammetry and 3D scanning; Virtual reality	composition	color photography; virtual models	architecture	buildings; rooms and spaces	
670	4	<a href="https://pleiades.stoa.org/places/422859">https://pleiades.stoa.org/places/422859</a>	<a href="https://pleiades.stoa.org/places/413122">https://pleiades.stoa.org/places/413122</a>	Virtual Reality and 3D Modelling	Data dissemination and education	Material culture; Photogrammetry and 3D scanning; Virtual reality	composition	reconstructions	architecture	buildings; rooms and spaces	
670	5	<a href="https://pleiades.stoa.org/places/422859">https://pleiades.stoa.org/places/422859</a>	<a href="https://pleiades.stoa.org/places/413122">https://pleiades.stoa.org/places/413122</a>	Virtual Reality and 3D Modelling	Data dissemination and education	Material culture; Photogrammetry and 3D scanning; Virtual reality	composition	virtual models	archaeological objects	metal	

Fig. 3 – Estratto della tabella Excel di metadattazione delle immagini.

- il codice identificativo univoco del contributo all'interno del quale ciascuna immagine è contenuta, così come presente nel repository A&C (ID);
- il numero progressivo delle figure entro l'articolo (N. FIG.);
- le indicazioni di tipo geospaziale relative al sito archeologico (GEOGR. COVERAGE 1 (Site) e la regione antica di pertinenza (GEOGR. COVERAGE 2 (Region), sotto forma di URI del gazetteer Pleiades;
- il duplice soggetto che caratterizza gli articoli di A&C (MOSCATI 1999; CANTONE, CARVALE 2019);
- il tipo di risorsa visuale (IMAGE TYPE (IT));
- il soggetto dell'immagine rappresentata (IMAGE SUBJECT (IS)).

Le due ultime voci, ImageType e ImageSubject, hanno richiesto un accurato lavoro di definizione di un vocabolario, anche in questo caso scaturito dalla ricognizione dell'esistente, vale a dire dei principali thesauri e tassonomie adottati da istituzionali nazionali e internazionali quali l'ICCD, l'iDAI, il Getty Research Institute, la Library of Congress.

L'articolazione dei nostri metadati in due livelli, archivi e istanze, è stata ispirata ai vocabolari disponibili per la compilazione delle norme di catalogazione dell'ICCD, e in particolare al Thesaurus per le tipologie di Documentazione<sup>19</sup>. Esso, infatti, è basato su una gerarchia a due livelli, in cui al livello 1 corrisponde il tipo di documento (documentazione fotografica, documentazione grafica e cartografica, documentazione audio, documentazione video, fonti e documenti testuali), poi ulteriormente dettagliato al livello 2 (ad es. per la documentazione fotografica, la versione aggiornata al 2024 indica, fra gli altri: file digitale JPG, file digitale TIFF, fotografia aerea, fotografia digitale, etc.). I riferimenti al soggetto immagine sono implicitamente contenuti nella denominazione stessa delle schede di catalogo (Architettura, Complessi archeologici, Centri/nuclei storici, Monumenti archeologici, Reperti archeologici, Saggi stratigrafici, etc.).

Il secondo caso da noi preso in esame è quello del thesaurus iDAI.world che, riunendo tutti i thesauri delle biblioteche e dei progetti dell'iDAI, costituiva una fonte di interesse riguardo ai vocabolari controllati e all'indicizzazione<sup>20</sup>. L'organizzazione dei termini è basata su una gerarchia concettuale in cui, per l'assegnazione delle parole chiave, sono disponibili tre sistemi: per località, regioni e paesi (iDAI.gazetteer), per cronologia (iDAI.chronontology), per tecnica (iDAI.world Thesaurus). La struttura delle terminologie di dominio utilizzate da iDAI è implementata su base SKOS (Simple Knowledge Organization System), uno standard raccomandato dal World Wide Web

<sup>19</sup> <http://www.iccd.beniculturali.it/it/ricercanormative/190/thesaurus-per-le-tipologie-di-documentazione>.

<sup>20</sup> <https://idai.world/how/thesauri-and-controlled-vocabularies>.



Consortium (W3C) per rappresentare la struttura e il contenuto di thesauri, tassonomie, ontologie e sistemi di organizzazione della conoscenza in genere (MAZZOCCHI 2018).

Nell'ambito delle linee guida editoriali dei Getty Vocabularies, il principale thesaurus di riferimento è l'Art & Architecture Thesaurus Online (AAT). L'organizzazione dei termini (terms) nell'AAT si basa su una struttura gerarchica agile costituita da vertici (hierarchy names), etichette di nodo intermedie (guide terms) e concetti (concepts), che corrispondono ai termini che vengono utilizzati per l'indicizzazione (ad es., rispettivamente: "Processes and Techniques", "image-making processes and techniques", "drawings").

In ragione della flessibilità di tale sistema, della ricca articolazione della semantica, della buona sovrapponibilità terminologica e/o concettuale rispetto ad altri repository (iDAI) e del suo utilizzo nelle piattaforme internazionali (Europeana), l'AAT è stato da noi adottato come riferimento principale per la costruzione del vocabolario. La trasversalità di questo strumento ha consentito anche di superare uno dei problemi principali riscontrati in fase di metadatazione, ovvero il multilinguismo con cui le risorse visuali sono indicizzate nei vari modelli presi in esame.

### 3. VOCABOLARIO (VOC)

In linea con le nostre finalità di metadatazione, il VOC è stato strutturato gerarchicamente in classi e sottoclassi (archivi e istanze), cui corrispondono, nella quasi totalità dei casi, i concept AAT; solo per la classe Computer images è stato utilizzato un guide term. Inoltre, nel caso dei termini "script" e "orthophoto", non presenti in AAT, si è fatto ricorso a Wikimedia, anch'esso tra i vocabolari consigliati da Europeana e dove tali definizioni sono state individuate.

Le classi del VOC sono sei per i tipi immagine (Drawings, Photographs, Maps, Computer images, Graphic documents genres e Composition) (Tab. 2) e sei per i soggetti immagine (Environments, Sites, Architecture, Archaeological objects, Methodologies and technologies, Other subjects) (Tab. 3). All'interno di ciascuna si trova un cluster di termini (o concetti) organizzati come sottoclassi o collezioni (livello 2) univocamente collegate alla rispettiva classe di livello 1.

A seguire, in ordine alfabetico, si presentano le classi individuate nel corso del presente lavoro, insieme a qualche precisazione per le definizioni che possono trovare spiegazioni meno immediate, che si discostano gerarchicamente o semanticamente dal modello dell'AAT o ne sono assenti.

#### 3.1 *Tipi Immagine (IT)*

Le classi che compongono i Tipi Immagine (IT) del VOC (Tab. 2, Fig. 4) discendono tutte dallo hierarchy name "visual works" e dal concept

Tipi immagine (IT)						
L1	photographs	78	drawings	41	maps	77
L2	black-and-white photographs color photographs satellite photography aerial photographs manipulated photographs photomosaics orthophoto (wikidata)		plans sections plates detail drawings renderings reconstructions sketches		thematic maps topographic maps manuscript maps relief maps contour maps plans	
L1	graphic document genres	137	computer images	155	composition	99
L2	diagrams graphs tables		user interfaces web pages virtual models digital reconstructions digital terrain modelling screenshots script (wikidata)		black-and-white photography color photography plans sections detail drawings renderings diagrams graphs virtual models digital reconstructions screenshots script (wikidata) digital terrain modelling topographic map thematic map	

Tab. 2 – Tabella riassuntiva dei tipi immagine (IT).

“graphic document genres” dell’AAT. Il primo include sia opere d’arte, sia oggetti comuni che non necessariamente occupano uno spazio fisico, il cui scopo è principalmente quello di comunicare attraverso mezzi visivi, non verbali. Ad esso afferiscono i termini Drawings, Photographs e Computer images, che rappresentano tre delle classi del nostro VOC. Anche il concept “graphic document genres” corrisponde ad una nostra classe; nell’AAT vi afferiscono i concept “diagrams”, “graphs”, “tables” (nostre sottoclassi), nonché “maps”. Riguardo a queste ultime, data la loro ricorrenza nell’ambito della documentazione archeologica, è stata predisposta un’apposita classe (Maps). Infine, la classe Composition identifica immagini composite, nate dall’unione di immagini appartenenti ad una o più delle altre cinque classi di livello 1. Le immagini composite, frequenti nella Rivista, sono infatti legate all’adattamento alla stampa di due o più immagini insieme attraverso strumenti di disposizione, fusione, spaziatura. Tali composizioni possono essere molto eterogenee, accorpendo disegni, foto, mappe e grafici, etc.

La classe Computer images trova corrispondenza nel guide term AAT “computer image-making processes and techniques” e include prodotti visuali legati alle ricostruzioni digitali, alla computer grafica e al processamento di immagini. Qualche particolarità rispetto ai modelli da noi seguiti riguarda

le sottoclassi “virtual models” e “script”. Sebbene l’AAT intenda il concept “virtual models” come definizione di modelli virtuali tridimensionali architettonici, in mancanza di una definizione ombrello per la categoria “3D models”, nella nostra Tabella tutti i modelli 3D, di architettura, statuarie e










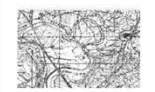

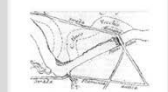







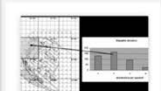


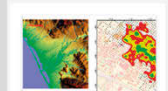
Tipi immagine (IT)				
Livello 1	Livello 2			
Drawings				
	plans (architecture)	sections	plates	detail drawings
Photographs				
	black-and-white photographs	color photographs	aerial photographs	satellite photography
Maps				
	thematic maps	topographic maps	contour maps	manuscript maps
Computer images				
	user interfaces	web pages	virtual models	digital reconstructions
Graphic document genres				
	diagrams	graphs	tables	
Composition				
	plans; diagrams	black-and-white photography; detail drawings	plans; digital reconstructions	thematic maps

Fig. 4 – Campione di immagini delle classi IT suddivise per livello 1 (classi) e 2 (sottoclassi) tratte dall’archivio A&C (IADI).

altri manufatti, con esclusione di specifici prodotti come DEM-DTM, sono confluiti nella sottoclasse “virtual models”. Il termine “script”, una sottoclasse piuttosto rappresentata nel set di immagini fin qui prese in esame, non essendo presente nell’AAT è stato mutuato da Wikidata, dove compare come “type of computer program”.

La classe Drawing segue il modello dell’omonimo concept dell’AAT e include sia i disegni cartacei, sia quelli generati digitalmente; “detail drawings” è il termine utilizzato per i dettagli decorativi o architettonici, mentre i reperti ceramici, i cui disegni sono spesso composti in tavole, sono inquadrati come “plates”, in associazione a “detail drawings”. La sottoclasse “reconstructions” è da distinguere rispetto a quella “digital reconstructions” presente nella classe Computer images.

La classe Graphic document genres è particolarmente interessante, come vedremo più avanti, in quanto spesso connessa a Soggetti Immagine (IS) legati all’applicazione in archeologia di metodologie e tecnologie. La classe Maps si riferisce in modo generico ad ogni forma di rappresentazione bidimensionale del territorio, a qualsiasi scala. Visto il numero rilevante di esempi fino ad ora censito tra le immagini negli articoli della Rivista, si è ritenuto di dettagliare in numerose sottoclassi questa categoria, spesso popolata di elaborazioni cartografiche, tematiche, GIS, spaziali, anch’esse dunque connesse a specifiche applicazioni metodologiche e tecnologiche. Alcune basi cartografiche sono state distinte in base alle modalità di espressione del dato di elevazione, cioè attraverso contorni, tratteggi, ombreggiature o colorazioni (“relief maps”), o attraverso curve di livello (“contour maps”).

Il concept “photographs” è ripreso nel VOC come classe e include le fotografie digitali, ma esclude le riproduzioni dei documenti o i disegni tecnici. Si segnalano in particolare le sottoclassi “aerial photographs” e “satellite photography”, afferenti all’ambito del remote sensing, mentre a quello della fotogrammetria sono riconducibili “photomosaics” e “orthophoto”, quest’ultima desunta da Wikidata. Una ulteriore sottoclasse è costituita dalle “manipulated photographs”, frequenti nella documentazione archeologica tradizionale, dove è abitudine interpolare le fotografie originali, per esempio con marcature e identificativi stratigrafici.

### 3.2 *Soggetti Immagine (IS)*

Le classi che compongono i Soggetti Immagine (IS) del VOC (Tab. 3, Fig. 5) discendono dai hierarchy names “built environment” e “settlements and landscapes” dell’AAT, che includono concept relativi sia all’ambiente naturale, che a quello antropizzato. La classe Archaeological objects contiene sottoclassi distinte in base al materiale del reperto; la classe Architecture fa riferimento al concept dell’AAT che identifica l’architettura come oggetto o cosa, distinta dall’architettura intesa come disciplina; la classe Environment è

Soggetti immagine (IS)						
L1	environments	75	sites	104	methodologies and technologies	119
L2	regions landscapes rivers rocks ancient regions vegetation cityscapes landforms		archaeological sites settlements excavations necropolises sanctuaries fortification elements harbours		spatial analysis topography scientific instruments virtual works fieldwork image processing geographic information systems stratigraphy archaeometry	
L1	archaeological objects	77	architecture	108	other subjects	215
L2	ceramic pottery metal stone wood		buildings complexes architectural elements rooms and spaces		texts data geometric figures icons people	

Tab. 3 – Tabella riassuntiva dei soggetti immagine (IS).

utilizzata per viste panoramiche in fotografie e in alcuni casi per ricostruzioni virtuali di antichi insediamenti rappresentati all'interno di ambientazioni naturalistiche. Environment è anche la classe di soggetti prevalente in associazione agli IT “topographic maps” e “thematic maps”.

“Landscapes” è una sottoclasse che l'AAT distingue in “landscapes (representations)” e “landscapes (environments)”, piuttosto sovrapponibili tra loro; nei nostri metadati è stata utilizzata la prima definizione, riferita a prodotti solitamente bidimensionali, caratterizzati da una presenza primaria di elementi naturali del territorio tipici delle rappresentazioni fotografiche e pittoriche; essi possono includere anche rappresentazioni di elementi antropici, purché il focus primario della scena sia l'ambiente naturale. Se “landscapes” è principalmente impiegato per foto o mappe storiche manoscritte, “regions” e “ancient regions” sono utilizzati come soggetti di mappe topografiche, tematiche e immagini satellitari. Queste definizioni sono in alcuni casi associate ad elementi naturali del paesaggio, come “rivers” (frequente per la presenza del Tevere in molte delle immagini classificate, sempre in associazione a “regions”), “rocks” (ad es. per foto di soggetto geologico) e “vegetation”. La classe contiene anche termini relativi a scenari urbanizzati, come “cityscapes”; nei casi di ricostruzioni virtuali, foto e mappe di antichi centri abitati, il termine utilizzato è “settlements”.

La classe Methodologies and technologies non ha riscontro nell'AAT. Essa, infatti, associa due concetti presenti in modo distinto nel thesaurus. Per “methodology” l'AAT intende un insieme di metodi, procedure, regole e postulati impiegati da una scienza, arte o disciplina, quali nella fattispecie la topografia, l'archeometria, lo scavo stratigrafico. Per “technology” l'AAT






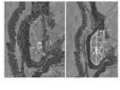

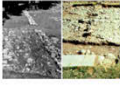





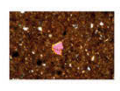







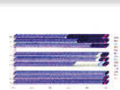

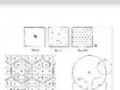
Soggetti immagine (IS)				
Livello 1	Livello 2			
Environments				
	landscapes	rivers	regions	ancient regions
				
	archaeological sites	settlements	sanctuaries	excavations
Architecture				
	buildings	complexes	architectural elements	rooms and spaces
				
	pottery	ceramic	metal	stone
Archaeological objects				
	virtual works	scientific instruments	stratigraphy	fieldwork
				
	texts	data	people	geometric figures
Methodologies and technologies				
Other subjects				

Fig. 5 – Campione di Soggetti Immagine suddivisi per livello 1 (classi) e 2 (sottoclassi) tratte dall’archivio A&C (IADI).

intende invece l’applicazione generale della scienza e delle discipline correlate, in genere a scopi commerciali o industriali, spesso con l’implicazione di componenti meccaniche, elettroniche o computerizzate, tra cui “scientific instruments”, “geographic information systems” e “spatial analysis”. La classe



Methodologies and technologies da noi messa punto sintetizza entrambi questi concetti e designa metodi e tecniche accomunati dall'impiego di specifiche soluzioni tecnologiche d'uso comune in archeologia.

La classe Sites identifica una porzione di territorio interessata dall'attività umana e ha stretti punti di contatto con la classe Environments, cui si associa nel caso di fotografie di paesaggi archeologici. Essa è impiegata come soggetto di disegni, foto di scavo ed elaborati tecnici e cartografici, quali piante, mappe, ricostruzioni virtuali di scavi archeologici, ed è frequentemente associata a Methodologies and technologies, ad esempio per le mappe tematiche o modelli digitali del terreno elaborati per alcuni importanti siti archeologici dell'area etrusca e sabina. "Archaeological sites" costituisce una delle sottoclassi più ricorrenti; si trova allo stesso livello gerarchico di "settlements" e di altre sottoclassi più specifiche come "fortification elements", "harbors", "necropolises" e "sanctuaries".

La classe Other subjects comprende soggetti eterogenei che non trovano spazio nelle classi descritte sopra. Tra questi, ad esempio, "texts", che indica testi o documenti digitali e/o digitalizzati, "data", "geometric figures", "icons" e "people".

L.F.

#### 4. ANALISI STATISTICA DEI DATI E PRIMI RISULTATI

Al momento, un primo sguardo al dato statistico, prima ancora che a riflessioni generali, risulta funzionale alla validazione del metodo di classificazione predisposto durante il nostro lavoro. Ad esempio, rispetto al dataset di 594 immagini finora metadate, l'occorrenza espressa nei grafici a torta (Fig. 6 a-b) annovera tra i tipi immagine (IT) più rappresentati le Computer images (27%), seguite da Graphic document genres (23%). Queste due categorie, strettamente connesse a soggetti legati all'uso di metodologie e tecnologie per l'indagine archeologica, costituiscono la metà circa dei tipi immagine classificati. Il dato, quindi, appare coerente con la linea editoriale di A&C.

Altrettanto significativa è la rappresentazione (17%) delle immagini composite (Composition), particolarmente frequenti nelle edizioni più recenti della Rivista. L'impatto degli strumenti e delle risorse visuali nello sviluppo e nella comunicazione della ricerca si conferma infatti crescente, al punto da rendere necessario l'accorpamento di più immagini in tavole, come forma di reale e necessario complemento al testo. Un fatto tanto più interessante quanto letto in associazione alla più modesta ricorrenza delle classi IT più comuni nella documentazione archeologica tradizionale, ossia Photographs (13%), Maps (13%), Drawings (7%). Si sottolinea, tuttavia, che queste percentuali sarebbero soggette ad un incremento se si sommassero alle attestazioni sempre di Photographs, Maps e Drawings che fanno parte delle immagini composite.

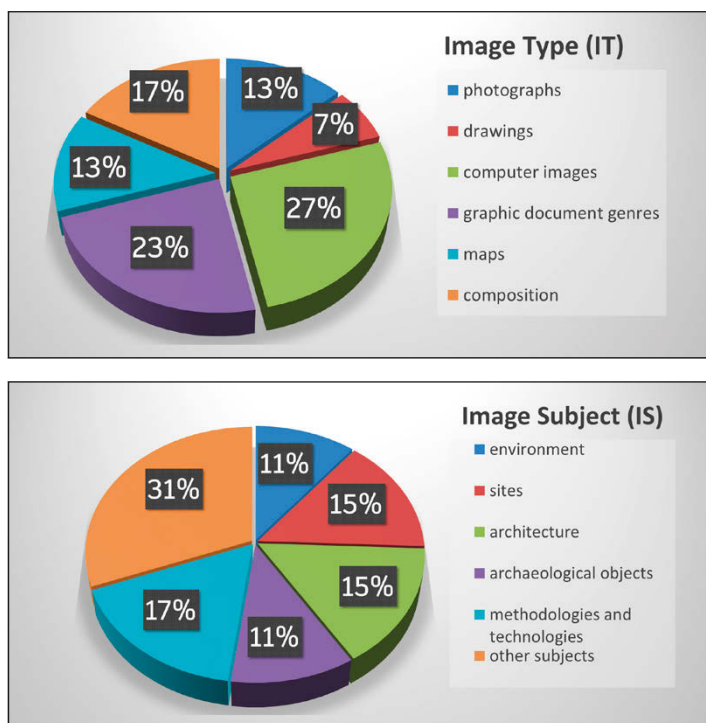


Fig. 6 – Digramma a torta delle percentuali di occorrenze lessicali delle classi IT (a) e IS (b) della metadattazione di immagini di A&C, relative ai topics “Cerveteri”, “Etruria”, “Sabina”.

Tale dato incrementale si osserva nell’istogramma Image Type ed è particolarmente significativo per le classi Photographs e Drawings.

L’analisi statistica dei dati fin qui raccolti suggerisce qualche modifica alla classificazione delle immagini relativamente alla classe dei soggetti immagine (IS) attualmente più rappresentata, e cioè quella degli Other subjects (31%). Questo valore numericamente così elevato indica che quasi un terzo delle immagini prese in esame sfugge ad una classificazione puntuale e non sarebbe utilizzabile ai fini dei test di riconoscimento automatico. A ben guardare, grandissima parte di questo 31% è imputabile alla ricorrenza della sottoclasse “data” (77%), che definisce soggetti costituiti da dati alfanumerici e rappresentazioni statistiche, in assoluto prevalenti in relazione ai grafici, tabelle e diagrammi dell’IT Graphic document genres. Considerato dunque il legame tra la produzione di dati statistici, le tecnologie e le metodologie applicate, cui la maggior parte dei contributi della Rivista è dedicata, si ritiene che la classificazione possa restituire più efficacemente un quadro dell’esistente

spostando il soggetto “data” nella classe IS Methodologies and technologies. La lettura incrociata con la scarsa percentuale dell'occorrenza di quest'ultima (17%), infatti, dimostra un'incoerenza di questo dato rispetto ai contenuti della Rivista e autorizza una rimodulazione delle tabelle. Seguono in ordine di occorrenza i soggetti immagine Sites (15%), Architecture (15%), Environment (11%) e Archaeological objects (11%).

Mentre, dunque, lo strumento statistico si configura come un importante ausilio per la validazione del sistema tassonomico messo a punto e per l'abbattimento dell'incertezza dei dati, esso evidenzia i principali orientamenti tematici della Rivista, l'evoluzione della documentazione grafica e, più in generale, della metodologia di ricerca archeologica, condizionata dalla rapida espansione della computer grafica, di tecniche di rilievo e modellazione 3D, e di sistemi, talvolta automatizzati, per la produzione, l'analisi e la presentazione delle ricerche (CARAVALLE *et al.* 2023).

Il lavoro finora condotto costituisce un primo approccio alla metadattazione di una particolare categoria di risorse visuali caratterizzate da un'alta variabilità e complessità di tipi e soggetti, quali le immagini di un repository di rivista scientifica. Ciò ha reso necessario predisporre un apposito sistema di classificazione quanto più semplificato e basato su una gerarchia agile e implementabile. I prossimi passaggi della ricerca prevedono l'incremento del dataset fin qui predisposto, attraverso la metadattazione delle risorse legate a Sardegna e Sicilia, altre due regioni ampiamente rappresentate in A&C e che rientrano storicamente e culturalmente nella tradizione di studi del CNR-ISPC. Oltre ad una contestuale verifica del vocabolario, verrà implementata la tabella messa a punto, in vista dell'integrazione con le infrastrutture europee e il data harvesting da parte di European. Sulla base dei metadati attribuiti, inoltre, verrà condotto un esperimento pilota di riconoscimento automatico del contenuto delle immagini (classificazione) tramite algoritmi di Machine Learning.

F.B, L.F.

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## BIBLIOGRAFIA

- CANTONE F., CARAVALA A. 2019, *Archeologia e Calcolatori. Classificazione geografica e tematica per la condivisione della conoscenza*, in P. MOSCATI (ed.), *30 anni di Archeologia e Calcolatori. Tra memoria e progettualità*, «Archeologia e Calcolatori», 30, 93-107 (<https://doi.org/10.19282/ac.30.2019.07>).
- CARAVALA A., DURAN-SILVA N., GRIMAU B., MOSCATI P., RONDELLI B. 2023, *Developing a digital archaeology classification system using Natural Language Processing and Machine Learning techniques*, «Archeologia e Calcolatori», 34.2, 9-32 (<https://doi.org/10.19282/ac.34.2.2023.01>).
- DESCAMPS S. 1993, *Le vidéodisque 'Parthénon'. Musée du Louvre Département des Antiquités grecques, étrusques et romaines*, in J. BOARDMAN, D. KURTZ (eds.), *International Conference on Data and Image Processing in Classical Archaeology (Ravello 1992)*, «Archeologia e Calcolatori», 4, 253-255.
- GINOUVÈS R. 1986, *«Images de l'archéologie». Un premier vidéodisque pour l'archéologie classique*, «Revue Archéologique», 2, 227-234.
- GUIMIER-SORBETS A.-M. 1993, *Ouvrir à un large public l'accès à une information spécialisée*, in J. BOARDMAN, D. KURTZ (eds.), *International Conference on Data and Image Processing in Classical Archaeology (Ravello 1992)*, «Archeologia e Calcolatori», 4, 281-286.
- GUIMIER-SORBETS 2017, *Le Centre TAAC et l'informatique en l'archéologie classique*, in *Virtual Museum of Archaeological Computing, Cultural Itineraries* (<http://archaeologicalcomputing.cnr.it/itineraries/institutions/le-centre-taac-et-linformatique-en-larcheologie-classique/>).
- MAZZOCCHI F. 2018, *Knowledge Organization System (KOS)*, «Knowledge Organization», 45, 1, 54-78.
- MOSCATI P. 1999, *«Archeologia e Calcolatori»: dieci anni di contributi all'informatica archeologica*, «Archeologia e Calcolatori», 10, 343-352 (<https://www.archcalc.cnr.it/journal/id.php?id=284>).
- MOSCATI P. 2019 (ed.), *30 anni di Archeologia e Calcolatori. Tra memoria e progettualità*, «Archeologia e Calcolatori», 30, 1-138 (<http://www.archcalc.cnr.it/journal/idyear.php?IDyear=2019-01-01>).
- PARACIANI N., ROSSI I. 2023, *IADI: An open Interactive Atlas of Digital Images for the journal «Archeologia e Calcolatori»*, in J. BOGDANI, S. COSTA (eds.), *ArcheoFOSS 2022. Proceedings of the 16<sup>th</sup> International Conference on Open Software, Hardware, Processes, Data and Formats in Archaeological Research (Rome 2022)*, «Archeologia e Calcolatori», 34.1, 135-144 (<https://doi.org/10.19282/ac.34.1.2023.15>).
- SZABADOS A.-V. 2024, *Le TAL pour les appellations d'œuvres figurées de l'antiquité classique: évolution des ressources numériques du projet MonumentAL*, in V. FROMAGEOT-LANIEPE, A.-V. SZABADOS (eds.), *Images antiques et humanités numériques: section spéciale éditée par le programme ArcheoNum*, «Archeologia e Calcolatori», 35.1, 193-214 (<https://doi.org/10.19282/ac.35.1.2024.14>).

## ABSTRACT

By exploring the importance of archeological images databases in the history of studies, the article presents the digital archiving activities initiated within the PNRR Changes, Spoke 8, Project. The objective of the activities is the attribution of metadata to this type of images, for the purpose of their dialogue with European infrastructures. This process represents a tool for supporting different knowledge paths and maximizing the accessibility of the Cultural Heritage, according to the goals of the Project. The article therefore presents the activity carried out so far, namely the development of a metadata table, developed following the recognition of the main national and international thesauri and taxonomies, as well as a first metadating experiment conducted on a dataset of approximately 600 images from A&C Journal.

## AN OBSERVATORY OF EPIGRAPHIC RESOURCES ON THE WEB: THE OPEN DIGITAL EPIGRAPHY HUB

### 1. DIGITAL EPIGRAPHY IN THE HUMANITIES AND CULTURAL HERITAGE ITALIAN OPEN SCIENCE CLOUD (H2IOSC)

An increasing number of digital projects and initiatives have been sprawling in the field of epigraphy since the years 2000, with an exponential growth over the past decade. While this is certainly good news, as fresh technological solutions and more data become available and searchable every year, the highly fragmented nature of this landscape often makes it difficult for epigraphists – whose work intersects with various disciplines such as linguistics, philology, literature, history, geography, archaeology and art history – to stay up-to-date with evolving digital methods and techniques, not to say with the amount of available sources to be consulted on the web. As a result, scholars and researchers are frequently unaware of tools that could greatly benefit their work, ultimately undermining the very purpose of these initiatives.

In this paper, we present the Open Digital Epigraphy Hub, or EpiHub for short, a new open access platform seeking to respond to the epigraphy community's call for improved accessibility and organization of digital resources, thereby facilitating scholars and practitioners in navigating this evolving field with greater ease and efficiency. Developed as a pilot project within the Humanities and cultural Heritage Italian Open Science Cloud for the E-RIHS infrastructure (H2IOSC; [www.h2iosc.cnr.it](http://www.h2iosc.cnr.it))<sup>1</sup>, it will offer a reasoned catalogue of national and international initiatives, including – but not limited to – datasets and services offered by the four Research Infrastructures involved in H2IOSC (i.e. CLARIN, DARIAH, E-RIHS and OPERAS), which cover the fields of linguistics, digital philology, cultural heritage studies, and open access editions.

### 2. MONITORING THE DIGITAL EPIGRAPHY LANDSCAPE

#### 2.1 *Digital Epigraphy as a discipline? A state of the art*

Over the last fifteen years, almost anyone working on inscriptions, published and unpublished, has used epigraphic digital archives for historical

<sup>1</sup> The Open Digital Epigraphy Hub is an output of Activity 7.4 of the H2IOSC project, which also involves the realization of a twin platform, the Open Digital Archaeology Hub. See CARVALE, MOSCATI, ROSSI 2024b, and CARVALE, MOSCATI, ROSSI in this volume.

and linguistic research, or has sought for methodological and technological solutions to store and disseminate their own corpora. The pressing need to exchange thoughts about the different experiences in creating and maintaining digital epigraphical tools has brought the community together on multiple occasions to discuss, both in person and virtually, the progress made and the challenges encountered. The proceedings and collective volumes published over the past decade as a result of these discussions highlight the diverse interests and concerns within the epigraphy community, while also providing a starting point for anyone wishing to gain an overview of current methods and potential obstacles in the field.

The 2014 Proceedings of the First Europeana network of Ancient Greek and Latin Epigraphy (EAGLE) International Conference (ORLANDI *et al.* 2014), focuses on the technical aspects of epigraphic data management, including data encoding and querying for effective research use, and harmonization through the establishment of controlled vocabularies. The growing importance of translations for both research and didactic purposes along with the need to cater to a wide range of audiences of both experts and non-experts is also emphasized to foster broader engagement with epigraphic materials.

These themes are also central to the 2016 volume *Digital Classics Outside the Echo-Chamber* (BODARD, ROMANELLO 2016). This book advocates for the public engagement of non-specialists and highlights the role of digital humanities in enhancing pedagogy within classics, archaeology, and digital humanities. It encourages the creation of online resources for studying ancient languages, texts, and history, and promotes the teaching of text encoding and linguistic analysis, while also calling for closer collaborations between scholars and practitioners from outside traditional academic disciplines.

The contemporary volume edited by FELLE and ROCCO (2016), also arising from the EAGLE Project, addresses the challenges of digitizing and encoding inscriptions with unusual features, such as non-standard scripts, images, or symbols alongside texts. It broadens the perspective to encompass inscriptions that do not conform to classical Greek and Roman epigraphic models, such as medieval vernacular inscriptions and graffiti. These types of inscriptions challenge conventional tools like EpiDoc, which struggle to accommodate them, highlighting the necessity for tailored solutions.

In the following year, the Proceedings of the second and final EAGLE International Conference were published (ORLANDI *et al.* 2017). Alongside previously addressed themes such as the importance of data harmonization and public engagement, two key cross-cutting issues stand out: the potential and ongoing challenges of integrating contextual data – geographic, topographic, material, and figurative – into digital editions of epigraphic corpora to provide a more comprehensive understanding of inscriptions; and the recurring issue of balancing between objective and interpretative descriptions



of data – whether material, decorative, or textual – which is particularly significant in cases where inscriptions are difficult to comprehend or subject to multiple interpretations.

A substantial broadening of horizons towards non-classical epigraphy is offered by the volume *Crossing Experiences in Digital Epigraphy: From Practice to Discipline* (DE SANTIS, ROSSI 2018a). The volume addresses digital epigraphy issues related to Ancient North and South Arabian, Runic, Mayan and Egyptian hieroglyphs, and Palaeohispanic languages, among others. While revisiting themes like the challenges in text encoding, modelling the dual nature of inscriptions as textual and physical artifacts, and the need for interoperable epigraphic data – central to the EAGLE Project – the book adapts these topics for non-classical epigraphists, who work with under-resourced and fragmentarily attested languages. The development of different technological solutions to partially shared challenges underscores the need for closer collaboration within the non-classical epigraphy community around a centralized platform. The book includes an appendix with a webliography of digital epigraphy resources mentioned in the volume, which are described according to the Dublin Core Metadata Initiative specifications (DE SANTIS, ROSSI 2018b). This effort offered the initial foundation and inspiration for the reflections that later led to the development of the Open Digital Epigraphy Hub described in this article.

In 2018, the landscape of non-classical digital epigraphy was further enriched by the release of the volume *CyberResearch on the Ancient Near East and Neighboring Regions: Case Studies on Archaeological Data, Objects, Texts, and Digital Archiving* (BIGOT JULOUX *et al.* 2018). While addressing themes partly covered in the aforementioned volumes – such as the need for better communication between digital humanities practitioners and traditional humanists, and the importance of accessibility of digital data for research dissemination and preservation – this volume emphasizes the potential of digital tools, such as network graphs and software for data visualization, to uncover new information and support novel interpretations. In the section on texts, for instance, the application of text-mining techniques and natural language processing (NLP) tools to large, yet sparsely annotated, digital cuneiform corpora reveal meaningful patterns that might otherwise remain undetected through traditional analysis. More broadly, the book demonstrates the effective use of quantitative methods in analysing corpora that are either too vast or too fragmentary for traditional approaches.

The most recent collective volume on digital epigraphy, *Epigraphy in the Digital Age: Opportunities and Challenges in the Recording, Analysis, and Dissemination of Inscriptions* (VELÁZQUEZ SORIANO, ESPINOSA ESPINOSA 2021) reflects on topics, such as the importance of quantitative and computational methods to analyse large and fragmentary corpora, the ongoing issues with

data harmonization across platforms to enhance interoperability and research accessibility, and the importance of closer collaboration across disciplines, demonstrating that themes extensively explored in the previous volumes continue to remain highly relevant. Additionally, the book calls for long-term institutional support and funding to sustain and update digital epigraphy databases, as the absence of ongoing financial backing jeopardizes their sustainability.

To sum up, this literature review reveals that the user needs of epigraphists today encompass a variety of aspects, reflecting both the demands of the discipline and the evolving landscape of technology and research methodologies.

## *2.2 Striving to meet the community needs: how the Open Digital Epigraphy Hub took shape*

Apart from these volumes focusing – in the whole or in great part – on digital epigraphy and related practices, epigraphists seeking to explore digital resources or to keep up to date with advancements in digital practices must currently step outside their comfort zone and consult journals specializing in digital humanities and digital cultural heritage studies, in which digital epigraphy appears as a domain intersecting the main disciplinary focus of the journal, be it digital archaeology, philology, linguistics, history, etc. «Archeologia e Calcolatori», for instance, has given space to digital epigraphy articles since its very first issue as emerges from searching the journal for articles tagged with the Subject parameter ‘Epigraphy and numismatics’ (see CARVALE, MOSCATI, ROSSI in this volume)<sup>2</sup>. Digital epigraphy articles now begin to timidly appear also in volumes or conference proceedings dealing with research on specific civilisations or textual corpora, acknowledged for their contribution to historical and textual reconstructions.

Initiatives like the community Epigraphy.info (<https://epigraphy.info/>) have helped bring together practitioners of digital epigraphy within a collaborative environment for the exchange of data and digital solutions. Currently, the partner projects tend to focus on Greek and Latin epigraphy and on the TEI-EpiDoc markup standard, reflecting the primary research interests of the founding members. Hopefully, this and similar initiatives will see increased engagement from non-classicists, broadening their scope to encompass a wider range of epigraphic traditions.

<sup>2</sup> To mention a few other journals which have hosted a number of digital epigraphy contributions (without claiming to exhaust the list): «Digital Applications in Archaeology and Cultural Heritage» (<https://www.sciencedirect.com/journal/digital-applications-in-archaeology-and-cultural-heritage/>), «Digital Humanities Quarterly» (<https://www.digitalhumanities.org/dhq/>), «Digital Scholarship in the Humanities» (<https://academic.oup.com/dsh/>), «International Journal of Digital Humanities» (<https://link.springer.com/journal/42803>), «Journal on Computing and Cultural Heritage» (<https://dl.acm.org/journal/jocch>), «Umanistica Digitale» (<https://umanisticadigitale.unibo.it/>).

Building on EAGLE's pioneering work to harmonize and aggregate diverse databases of Greek and Latin inscriptions, the FAIR Epigraphy Project pushes these efforts further by supporting an integrated digital humanities framework for epigraphy within the expanding Linked Open Data ecosystem. The project promotes shared standards, such as ontologies and controlled vocabularies, that enable interoperability across various epigraphic databases and facilitate cross-disciplinary research. Through tools for standardized data publication (using RDF/XML formats), FAIR Epigraphy enhances accessibility to a linked data environment for both researchers and the public (HEŘMÁNKOVÁ, HORSTER, PRAG 2022), with a current focus on Greek and Latin inscriptions.

An international association was also established to continue and broaden the goals of the EAGLE project after the end of its funded period: the International Digital Epigraphy Association (IDEA), focusing on advancing and promoting the use of technologies and new methodologies for research on 'written monuments' of any era and civilization (FELLE 2016; LIUZZO 2018)<sup>3</sup>.

Additionally, online courses and symposia are becoming increasingly important venues for fostering remote collaboration and innovation on specific topics. For instance, Linked Pasts (<https://linkedpasts.hcommons.org>) gathers annually to explore linked data and ancient history, with occasional intersections in digital epigraphy. Likewise, the online sessions of the Sunoikisis Digital Classics open teaching programmes (<https://sunoikisisdc.github.io/>), which started in 2015 and are archived on Youtube, have been addressing a wide range of topics in Digital Humanities and Digital Cultural Heritage, encompassing epigraphy.

In an effort to address the dispersed nature of information on the web, various initiatives were launched years ago to compile lists of digital tools tailored to specific disciplinary domains, encompassing or intersecting the epigraphic field. One excellent example is the Digital Classicist (<https://www.digitalclassicist.org/>), with its active mailing list and Wiki, listing over 200 projects and resources for the study of ancient epigraphy, with a focus on Greek and Latin inscriptions, yet keeping an eye on diverse epigraphic traditions (<https://wiki.digitalclassicist.org/Category:Epigraphy>).

A promising bibliographical tool to specifically keep track of digital epigraphic resources such as the Zotero Group EpiDig (<https://www.zotero.org/groups/148928/epidig/>) has unfortunately been scarcely implemented over the past eight years<sup>4</sup>.

<sup>3</sup> See also the 'IDEA' Zenodo community at <https://zenodo.org/communities/eagle-idea/>.

<sup>4</sup> Other digital initiatives exist that are complementary to the ones listed above as regards monitoring research on epigraphy, such as Current Epigraphy (<https://currentepigraphy.org/>); however, they are not specifically concerned with 'digital epigraphy' as much as they are with 'epigraphy' in general.

More recently, further initiatives have begun to emerge also in other domains. One such example is the Zotero library (<https://doi.org/10.5281/zenodo.10691756>), announced in February 2024 via the Egyptologists' Electronic Forum (EEF) (<https://www.egyptologyforum.org>), providing a list of Egyptological databases and datasets that cannot be found in traditional Egyptological bibliographies, such as the Online Egyptological Bibliography (<https://oeb.griffith.ox.ac.uk>). A review of these initiatives highlights the lack of – and the need for – a comprehensive and searchable catalogue of digital epigraphic resources and tools that could support the community of digital epigraphists, crossing different disciplinary boundaries, an issue clearly emerging from the literature review in §2.1.

This is what the H2IOSC's Open Digital Epigraphy Hub pilot project aims to achieve: addressing the challenge of discovering and navigating the vast array of digital initiatives by providing a gateway to the available resources relevant to the study of epigraphy, monitoring the constant evolution of this varied landscape.

### 3. THE OPEN DIGITAL EPIGRAPHY HUB: THE BACK-END

#### 3.1 *Modelling choices*

In designing the EpiHub, we aimed to tackle the research needs of the 'typical epigraphist' – someone who might use it to discover which tools provide information on corpora in a specific language, script, or from a particular geographical area and historical period. This web resource aims to gather comprehensive descriptive metadata about datasets – epigraphic corpora and their aggregators, chronological and geographical gazetteers, etc. – semantic artefacts, such as thesauri and ontologies<sup>5</sup>, best practices, and software currently in use in digital epigraphy.

The conceptual model of the EpiHub has been intentionally kept simple, pivoting around a single, overarching entity named 'Resource'. This entity supports relationships among records of the same type and includes a set of descriptive attributes that can be selectively populated depending on the specific nature of the resource. A first-level categorization attribute ('Resource type') allows for distinctions among a variety of resource types, be they epigraphic databases and other related datasets – such as palaeographic resources, dictionaries, and geospatial data – software, applications, best practices, and more. Additional, 'external' information about these resources, such as

<sup>5</sup> On the term 'semantic artefact', see LE FRANC *et al.* 2020, 11-17. For a catalogue of semantic artefacts of the Heritage domain, which has been compiled in the frame of Activity 4.10 of the H2IOSC Project and includes also resources relevant to epigraphy, see <https://h-setis.cnr.it/> (SCARPA, VALENTE 2024).

related projects, people and organizations, are managed as attributes of the Resource rather than as separate entities, directing users to those external resources within a linked data framework. This simple yet flexible structure ensures that all resources can be managed without the need for complex schema adjustments. Whenever possible, we have prioritized controlled-term lists to maintain internal consistency, avoiding varied descriptions of the same concepts. This choice facilitates mapping to existing vocabularies and formalized lists.

To meet the needs of the epigraphy community, emphasis has been placed on the descriptive fields of a resource, rather than on its technical details. However, the latter, which may be of broader interest to digital humanists and are relevant to interoperability and reuse, are still addressed by formally describing the resources available on the web in terms of data formats, accessibility, and licensing. This approach makes the EpiHub a valuable toolkit for the digital epigraphy community while promoting FAIR practices.

The following sections outline the attributes of the Resource, which can be subsumed under three broader thematic categories: those formally describing the resource, those relevant to the scope of its content, and those providing information on external – but related – entities. In designing them, we drew upon our firsthand experience as epigraphists – both in the field and in digital contexts – and as creators and users of epigraphic archives<sup>6</sup>, as well as users of software supporting epigraphic work<sup>7</sup>, while also bearing in mind the interests and priorities in digital epigraphy that emerged from the literature review. Additionally, as participants in FAIR-based initiatives, we were guided by the principles of the H2IOSC project, which promotes reuse practices and encourages ongoing efforts toward FAIRification.

### *3.2 Resource description*

The ‘Name’ and the ‘Alternative name’ are recorded as free-text attributes, allowing flexibility to capture both the full name and any commonly used abbreviation or acronym associated with the resource. Additionally, a free-text ‘Description’ attribute offers space to outline the main elements of the resource, providing an overview of its purpose, structure, and functionality. All descriptions are written from an epigraphist’s perspective, highlighting the relevance of each resource to epigraphy; that is, even for resources that are not strictly epigraphic, their relevance to epigraphy will be highlighted. One of the essential descriptive attributes of the resource is ‘Links’, which

<sup>6</sup> Such as the Digital Archive for the Study of pre-Islamic Arabian Inscriptions (<https://dasi.cnr.it>).

<sup>7</sup> See e.g. the AKU-PAL (Altägyptische Kursivschriften. Digitale Paläographie und systematische Analyse des Hieratischen und der Kursivhieroglyphen) platform that supports the study of the palaeography of hieratic and cursive hieroglyphic inscriptions (<https://aku-pal.uni-mainz.de>).

The screenshot displays the EpiHub Open Digital Epigraphy Hub back-end interface. The top navigation bar includes the EpiHub logo, the title 'Open Digital Epigraphy Hub', and a user profile dropdown for 'Irene Rossi'. A left sidebar contains navigation links under 'DATA' (Resources, Lists, API) and 'SYSTEM' (Collections, Page contents, Users, Backups). The main content area is divided into three sections: 'Features', 'Links', and a footer. The 'Features' section contains a vertical list of dropdown menus, each with a red square icon to its left. The 'Links' section contains a text input field for the URL, a dropdown for 'Main URL', and another dropdown for 'OAI-PMH repository'. The footer includes the text 'EPIHUB - H2IOSC v0.12.0' and 'Information, services and tools provided by the resource'.

Fig. 1 – Example of ‘Features’ and ‘Links’ fields in a record of EpiHub back-end (DASI-Digital Archive for the Study of pre-Islamic Arabian Inscriptions).

includes the primary URL of the resource as well as additional links, such as URLs for the data and source code repositories or documentation if available, each accompanied by an explicative label from a controlled-term list (Fig. 1).

As mentioned above, the ‘Resource type’ indicates whether the resource is, for instance, a digital corpus, an aggregator of corpora, a software application, or a thesaurus. This categorization aids users quickly identify the nature of each resource at a glance. This and all attributes described below, unless otherwise specified, are managed as controlled-term lists to ensure structured information. The term list for this attribute is currently in progress and may include new values as the survey advances.



The ‘Domain’ attribute reflects the specific disciplinary domains covered by the resource, be they strictly epigraphic, or more linguistic, or palaeographic, or a combination of these and other domains. Particularly useful for epigraphic databases, the ‘Features’ attribute describes the specific information, services, and tools offered by the resource (Fig. 1). This may encompass the availability of an apparatus criticus, of transcriptions of the original texts, their translations, the presence of information about the medium bearing the inscription and its decoration, georeferenced data, onomastic indexes and more, enabling users to identify resources that align with their research needs. The ‘Resource language’ enhances accessibility by indicating the languages available for each resource’s interface, allowing users to find resources in languages they understand and thus supporting multilingual access. It standardizes this information, making it easier for users to filter and locate resources based on language.

Within these descriptive attributes of a ‘Resource’, more technical details have been included, as previously mentioned, ensuring that users have access to comprehensive information about the resources available on the web. ‘Media type’ and ‘Format’ specify various types of media used in the resource, such as images and text, along with their corresponding subtypes – such as formats like TIFF for images and XML for text. This classification aligns with the specifications outlined by IANA (<https://www.iana.org/assignments/media-types/media-types.xhtml>) and addresses important technical details relevant to interoperability and reuse, as previously mentioned. Additionally, ‘Accessibility’ indicates how users can engage with the resource, highlighting any restrictions or permissions related to its use, while ‘License’ clarifies the legal terms under which the resource can be accessed and utilized. This structured approach to describing technical details further promotes transparency and informed usage, aligning with FAIR practices.

### *3.3 Resource scope*

Attributes describing the scope of a resource refer to its application domain and content. These are especially relevant to epigraphic archives and related datasets, offering essential context for users. They stem from reflections – rooted in our epigraphic experience – on the key descriptive elements necessary for an epigraphic dataset to be easily searchable by audiences interested in discovering digital evidence of a particular epigraphic culture. Among these attributes, ‘Chronology start date’ and ‘Chronology end date’ are included as integer type fields to define the temporal range of the data contained within the resource. This feature specifically applies to epigraphic databases and related resources, such as prosopographical datasets and dictionaries. In addition, ‘Temporal coverage’ features terms derived from gazetteers, such as PeriodO (<https://perio.do/>), to represent the historical and cultural periods relevant to the texts within the resource (Fig. 2).

**EpiHub** Open Digital Epigraphy Hub

trane Rossi

**DATA**

Resources

Lists

API

**SYSTEM**

Collections

Page contents

Users

Backups

**Temporal coverage**

Middle Kingdom Egypt (2010-1640 BCE/BC) - PeriodID

2nd Millennium BC Egypt (2000-1000 BC) - PeriodID

New Kingdom Egypt (1548-1086) - PeriodID

Third Intermediate Period Egypt (1086-664) - PeriodID

Late Period Egypt (664-332) - PeriodID

Macedonian Egypt (332-304 BCE/BC) - PeriodID

Ptolemaic-Roman Egypt (304 BC - AD 640) - PeriodID

Ptolemaic Egypt (304-30 BCE/BC) - PeriodID

+

Gazetteers terms mapping the historical periods of the texts treated by the resource

**Geographic coverage**

Karnak - Pleiades

+

Gazetteers terms mapping the provenance/origin of the texts treated by the resource

**Modern country**

Egypt

+

Countries of provenance/origin of the texts treated by the resource

**Script**

Egyptian hieroglyphs

Hieratic

Demotic

Egyptian hieroglyphs (Ptolemaic)

+

Script(s) of the texts treated by the resource

**Language**

Middle Egyptian

Late Egyptian

+

Languages of the texts treated by the resource

EPiHub - H2020 v0.12.5

Fig. 2 – Example of ‘Temporal’ and ‘Geographic coverage’, ‘Script’ and ‘Language’ fields in a record of EpiHub back-end (SITH-Système d’Indexation des Textes Hiéroglyphiques).

Similarly, ‘Geographic coverage’ offers terms from geographic gazetteers, such as Pleiades (<https://pleiades.stoa.org/>), to indicate the geographic origin or provenance of the inscriptions, which is essential for understanding their cultural and historical contexts. Each term sourced from a gazetteer is

enriched with its URI, and the data source is cited accordingly. For example: Arabia (region) – [Pleiades] (<https://pleiades.stoa.org/places/29475>). A separate attribute ‘Modern country’ specifies the contemporary countries of origin or provenance of these texts – acknowledging that an inscription’s find location can often differ significantly from its place of origin. These attributes allow users to understand the chronological and geographical contexts of the inscriptions contained in epigraphic databases.

Furthermore, ‘Script’ and ‘Language’ are incorporated to detail such information about the texts within the resource. While primarily intended for epigraphic datasets, these attributes can also apply to software tools that operate within or support epigraphy, such as JSesh (<https://jsesh.qenherkhopeshef.org>), an editor for manipulating Egyptian hieroglyphic texts. By providing this information, users gain a comprehensive view of the academic or functional scope of each resource, enhancing their capacity to engage with the materials effectively.

### *3.4 Related information*

In addition to the core attributes describing each resource and its scope, supplementary attributes provide insights into the broader external context of these resources. These include ‘Projects and initiatives’, ‘Organizations and communities’, and ‘People’, detailing information about all funded projects as well as any unfunded initiatives that contributed to the creation of the resource, all people involved either within a formal organization or as part of a community engaged in some initiative, and the individuals contributing to the development or maintenance of the resource. Additionally, ‘Research infrastructure’ records the name of the infrastructure to which the resource is associated, highlighting the supporting frameworks or facilities that contribute to its development or functionality. This element is particularly innovative and distinguishes our approach within the H2IOSC project, emphasizing our commitment to integrating comprehensive contextual information that enhances the overall utility of the resources while promoting collaboration across the digital humanities landscape.

As previously noted, the inclusion of this external information is intentionally kept brief. Instead of creating dedicated entities to which relate the single instances of the ‘Resource’, the decision was made to incorporate this information as optional, multiple attributes within the ‘Resource’ entity table, populated through controlled-term lists. The URIs associated as additional attributes to the terms in the list direct users to existing registries when available, such as ORCID (<https://orcid.org>), where rich metadata can be found. This approach not only enriches the resource’s contextual information, but also promotes a more interconnected understanding of the digital epigraphy landscape within a linked data framework.

As mentioned previously, it is possible to link one ‘Resource’ record to another ‘Resource’ record. These relationships are semantically defined through predicates such as ‘same as’ or ‘is included in’, which allow, for instance, the indication that the contents of a specific corpus such as the Epigraphic Database Rome (<http://www.edr-edr.it/>) are aggregated within EAGLE (<https://www.eagle-network.eu>), or that an epigraphic archive like SITH-Karnak (<http://sith.huma-num.fr>) integrates the Pactols thesaurus (<https://www.frantiq.fr/pactols/le-thesaurus/>).

Semantically defined relationships are also applied to a different category of related information, specifically between the EpiHub records and those of H-SeTIS (SCARPA, VALENTE 2024)<sup>8</sup> and DHeLO (MANCUSO, D’EREDITÀ 2024)<sup>9</sup>, whose lists are automatically retrieved via the relevant APIs. These databases, which were collaboratively developed by research groups within the H2IOSC project, display the results of comprehensive surveys of international ‘semantic artefacts’ and Italian digital products and projects relevant to the Heritage domain. This approach emphasizes that, although these resources are ‘external’ to EpiHub, they are nonetheless ‘internal’ to the project from which EpiHub originates.

The bibliography is maintained through a Zotero group, which is currently being populated and will be publicly accessible soon (see §4.2). Similarly to H-SeTIS, EpiHub uses Zotero’s API to query bibliographic data, and leverages Zotero’s unique identifiers to organize and access individual references linked to each resource (SCARPA, VALENTE 2024, 554).

### 3.5 *Managing the back- and front-end content from a single entry-point*

Data entry is done through a back-end user interface, whose structure, functionalities and graphic design leverages the experience gained from developing the H-SeTIS system. H-SeTIS’s source code, developed by the IT specialist Matteo Gallo, was reused and adapted for EpiHub, both for cost-effectiveness and to meet the requirements of H2IOSC, which mandates the release of open-source codes, thereby inherently promoting their reuse. The back-end user interface allows the creation, editing and publication of each ‘Resource’ record on the front-end site, the implementation of controlled-terms lists and the easy creation of relationships among ‘Resource’ records, which are also semantically connotated. The EpiHub back-end interface does not only allow addition and manipulation of data concerning its records, but also the management of great part of the front-end website contents. For

<sup>8</sup> H-SeTIS - *Heritage – Semantic Tools and Interoperability Survey* is an output of H2IOSC’s project WP4.10 at the CNR-ISPC Milan branch (<https://h-setis.cnr.it>).

<sup>9</sup> DHeLO - *Digital Heritage Landscaping PlatfOrm* is an output of H2IOSC’s project WP2.4 at the CNR-ISPC Rome branch (<https://dhelo.cnr.it>).

instance, each ‘Resource’ is provided with an uploaded image designed to visually represent its main features, facilitating and enhancing the consultation process in the website’s ‘Catalogue’ preview. Moreover, in order to organize resources thematically for display in dedicated ‘Collections’ on the front-end site (see §4.2), the back-end interface includes a functionality for managing them. These records, to which resources can be associated, contain a title, a short description and an image that appears as a card, serving as access-point to the ‘Collection’ in the front-end. Finally, the static content on the website pages is managed through the back-end interface using an integrated HTML editor. This approach simplifies the task of curating both data-entry and presentation content from a single entry-point.

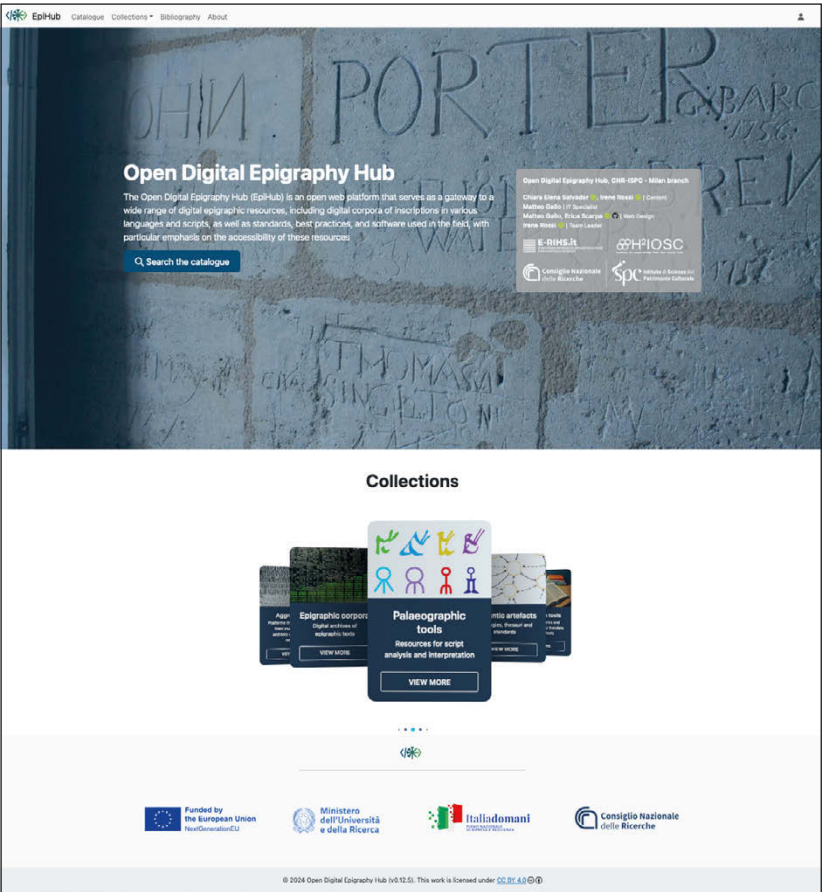


Fig. 3 – EpiHub website landing page.

#### 4. THE OPEN DIGITAL EPIGRAPHY HUB: THE FRONT-END

The front-end interface of EpiHub was designed to be both appealing and user-friendly, thanks to the collaborative efforts of Erica Scarpa and Matteo Gallo, who developed a web design based on our input. We aimed to avoid the overly utilitarian look of a standard data entry page, which can be discouraging for users. Instead, we opted for a more engaging and visually rich design that not only enhances the user experience but also makes the tool more inviting to explore. The landing page (Fig. 3) provides a brief introduction and invites users to search the full catalogue of ‘Resource’ records, which opens in a dedicated page. It also offers access to the aforementioned thematic ‘Collections’, which are displayed as a carousel of cards. The site will be openly accessible via <https://open-epihub.cnr.it> by the end of the H2IOSC project in 2025.

##### 4.1 *The open Catalogue and the Search tool*

The ‘Catalogue’ page lists previews of the records with ‘published’ status in the back-end, displayed as cards. Each preview card includes an illustrative image, the ‘Name’, ‘Alternative name’, a shortened ‘Description’ of the resource, and its ‘Resource type’. Additionally, a small colour-coded label indicates the ‘Accessibility’ level of each resource (Fig. 4). This feature aligns with H2IOSC’s emphasis on promoting open access practices and highlights for EpiHub users the availability of immediately usable resources.

The list of ‘Catalogue’ records can be refined using the search functionality available in the same ‘Catalogue’ page, via a general free-text search bar or an expandable list of filters (Fig. 5). The former queries the ‘Name’, ‘Alternative’ name and ‘Description’ fields, along with keywords recorded in a multiple ‘Keyword’ field of the ‘Resource’ records in the database, which remain hidden from front-end users. The latter help normalize descriptive terms, allowing also for the inclusion of relevant information not covered in the ‘Description’ field, such as references to museum collections contributing content to the epigraphic database.

The advanced search offers a set of filtering parameters, allowing users to apply AND or OR logical operators as needed. These parameters correspond to most of the ‘Resource’ attributes described in §3 and are organised into three sections reflecting the main categories: ‘Resource description’, ‘Resource scope’, and ‘Related information’. For epigraphic research, we deem particularly relevant those search parameters describing the scope of the resource content – such as language, script, geographic and temporal information – as these are the information that EpiHub extracts and organises from the mass of available resources to be offered – contrary to other registries or catalogues – as a curated guide specifically tailored for the epigraphy community.



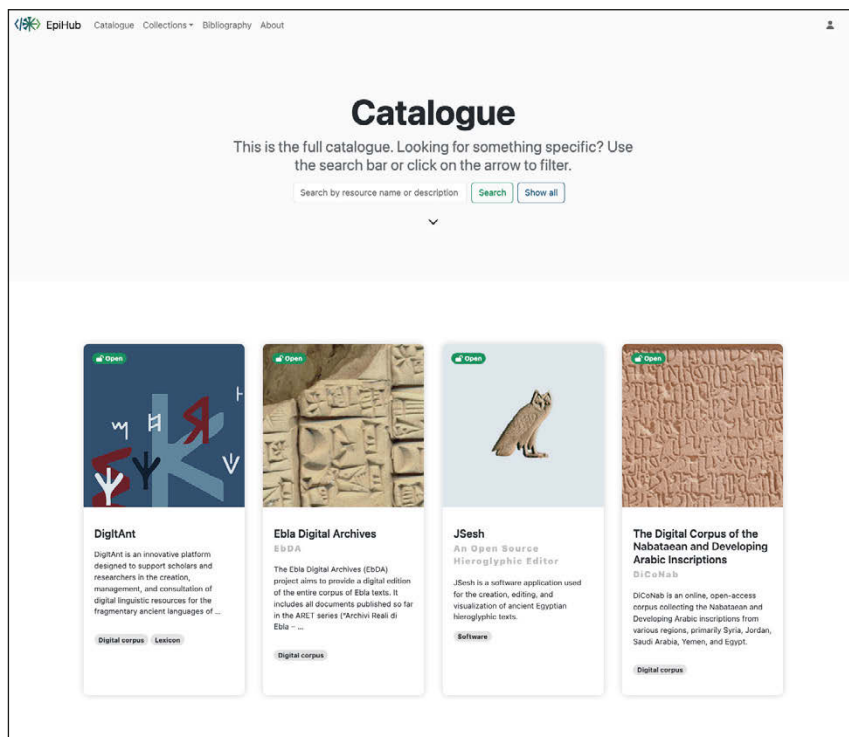


Fig. 4 – EpiHub website ‘Catalogue’ page.

These aim to provide a thorough view of the various world epigraphies, encompassing different writing cultures and their epigraphic evidence, which varies by language, script, region, and historical periods. The chronological search, besides offering a drop-down menu to select the terms from temporal gazetteers, also allows users to activate a time bar for the selection of the relevant chronological span. Filters on the domain and features of the resources are also designed to be of practical use to researchers seeking for datasets and tools focused on specific disciplinary domains, such as linguistic, palaeography, and philology, as well as those offering specific functionalities, such as word search, maps, and more. At the same time, queries on common ‘technical’ resource metadata will enhance the discoverability of accessible resources and the identification of those providing interoperable and reusable content or code.

The search by related information enables users to find resources based on contextual information, allowing them to search by people, organisations/

The screenshot displays the EpiHub Catalogue search page. At the top, the EpiHub logo and navigation links (Catalogue, Collections, Bibliography, About) are visible. The main heading is 'Catalogue', followed by a sub-header: 'This is the full catalogue. Looking for something specific? Use the search bar or click on the arrow to filter.' Below this is a search bar with the placeholder text 'Search by resource name or description' and two buttons: 'Search' and 'Show all'. A dropdown arrow is positioned below the search bar. Underneath, a section titled 'Logical operator (between all fields)' contains a dropdown menu set to 'AND'. The interface is divided into three main sections: 'Resource description', 'Resource scope', and 'Related information'. The 'Resource description' section includes filters for Name, Type, Domain, Accessibility, Media type, Format, Language, and Features. The 'Resource scope' section includes filters for Language, Script, Geographic coverage, Modern country, Temporal coverage, and Chronology. The 'Related information' section includes filters for Projects and initiatives, Organisations and communities, People, and Research infrastructures. A timeline slider is located between the 'Resource scope' and 'Related information' sections, with a range from -2500 to 2000 and a current selection from -2500 to 2000.

Fig. 5 – The search functionality of the EpiHub website ‘Catalogue’ page.

communities and initiatives involved in the development of epigraphic or epigraphy-related resources, even if users are unfamiliar with the titles of the products and outcomes they wish to explore. Finally, the filter on the ‘Research infrastructures’ is aimed to valorise those resources that, being part of the research digital ecosystem, may be more easily exploited. For all search parameters except ‘Name’, users can select multiple values simultaneously, as these filters correspond to multiple controlled-term vocabularies.

#### 4.2 *The Resource pages and their aggregation within the Collections*

From the list in the Catalogue, users can access individual Resource pages (Figs. 6, 7). Besides the information derived from the attribute fields of the corresponding database record, each page displays editorial details, including the dates of the record's first publication on the website and of its last update, as well as a complete citation of the resource that can be copied to the clipboard to give credit to its authors.

A short bibliography for each record, when available, is also provided. All bibliographic references associated with published resources, as well as other relevant publications in digital epigraphy, are currently being compiled as a Zotero group of the Open Digital Epigraphy Hub. This will be released as a public group on Zotero by the end of the H2IOSC Project and will be accessible in a dedicated section of the EpiHub website through the integration of the web application Kerko (<https://pypi.org/project/Kerko/>). The Open Digital Epigraphy Hub aims to become a go-to resource for researchers and anyone wishing to stay up to date in the field.


Finally, a section of each resource page is dedicated to links to other semantically related 'Resource' records. In addition to the internal relationships among its records, the EpiHub webpage also lists semantic relations with the DHeLO and H-SeTIS records mentioned above, providing links to their respective pages.


To provide a complementary way for consulting the EpiHub resources beyond filtering through the 'Catalogue', a 'Collection' section has been set up for users without a specific research question in mind, wishing to be guided through the website (Fig. 3). Currently, these thematic 'Collections' gather records based on major themes, highlighting resources according to their type, domain, and feature attributes (e.g., Epigraphic corpora, Aggregators, Semantic artefacts, Translation tools). Since the 'Collections' are easily managed through the back-end interface, they can be added or removed in response to current trends and needs in the Digital Epigraphy research landscape.

#### 5. SOME FINAL REMARKS: EPIHUB AS A DOMAIN-DRIVEN COMMUNITY SERVICE

We began this project to address the challenge of exploring the multitude of digital corpora and initiatives currently available. As we continue to populate the EpiHub with these resources, we are becoming increasingly aware that some of the projects are more widely known than others, which are only known within the reference community of specific disciplinary domains. Often, these lesser-known projects do not engage in ongoing discussions within the digital humanities and are underrepresented in the relevant literature.

The EpiHub will offer a snapshot of the landscape of digital projects related to epigraphy, including those that are not typically showcased in

 EpiHub Catalogue Collections Bibliography About



# Digital Archive for the Study of pre-Islamic Arabian Inscriptions

## DASI

The Digital Archive for the Study of pre-Islamic Arabian Inscriptions (DASI) is a scholarly initiative aimed at collecting, preserving, and studying ancient inscriptions from the Arabian Peninsula, ...

[show more](#)

### Record details

First published: 2024/07/31

Latest update: 2024/09/17

### Cite as

Chiara Salvador, Irene Rossi 2024/09/17, Digital Archive for the Study of pre-Islamic Arabian Inscriptions, Open Digital Epigraphy Hub, <https://open-epihub.cnr.it/resources/2>

### EpiHub related items

Uses

[Epigraphic Documents in TEI XML](#)

Is data supplier for

[Trismegistos](#)

Has Part

[Corpus of South Arabian Inscriptions](#)

### DHeLO related items

Is data supplier for

[The digital Gazetteer of Ancient Arabia](#)

Is data supplier for

[EUROPEANA](#)

### H-SeTIS related items

Uses

[Dublin Core Metadata Initiative \(DCMI\)](#)

Uses

[Europeana Data Model](#)

### Links

Main URL: <https://dasi.cnr.it/>

OAI-PMH repository: <https://dasi.cnr.it/de/cgi-bin/dasi-oai-x.pl>

### Resource type

Digital corpus • Dataset

### Domain

Epigraphic

### Features

Apparatus criticus • Bibliographical information • Georeferences • Iconography/decoration information • Images • Inscriptions Search Engine • Maps • Onomastic index • Onomastic information • Philological edition • Support information • Text search • Transcription • Translation • Word lists

### Script

Ancient South Arabian • Ancient North Arabian • Dadanitic • Nabataean

### Language

Ancient South Arabian • Sabaic • Qatabanic • Minaic • Hadramitic • Dadanitic • Nabataean Aramaic

### Geographic coverage

[Arabia \(region\)](#) [Pleiades]

[Arabia Eudaemon](#) [Pleiades]

[Arabia Petraia](#) [Pleiades]

[Nabataea \(region\)](#) [Pleiades]

### Modern country

Yemen • Oman • Saudi Arabia • Ethiopia • Eritrea • Somalia • Egypt • Greece

Fig. 6 – Example of an individual ‘Resource’ page in the EpiHub website, upper part (DASI- Digital Archive for the Study of pre-Islamic Arabian Inscriptions).

symposia and round tables but are nonetheless active and serve as essential tools within their respective fields. A first bulk of contents will be published on the website by the end of the H2IOSC project and will be exposed through a dedicated API endpoint. Content enrichment will continue as our survey

**Chronology**  
-999 – 600

**Temporal coverage**  
[Proto South Arabian \[PeriodO\]](#)  
[Early South Arabian \[PeriodO\]](#)  
[South Arabian Period \[PeriodO\]](#)  
[Middle South Arabian \[PeriodO\]](#)  
[Late South Arabian \[PeriodO\]](#)  
[South-Arabian, Pre-Aksumite and Proto-Aksumite \[PeriodO\]](#)

**Resource language**  
English

**Media type**  
text • image

**Format**  
XML • JPEG

**Projects and initiatives**  
Digital Archive for the Study of pre-Islamic Arabian Inscriptions (ERC – Advanced Grant, GA 269774)

**Organisations and communities**  
Consiglio Nazionale delle Ricerche (CNR) • Università di Pisa • Scuola Normale Superiore di Pisa

**People**  
Alessandra Avanzini • Irene Rossi • Umberto Parrini • Matteo Gallo

**Research infrastructures**  
E-RHS.it • H2OISC

**Bibliography**

Avanzini, Alessandra, Annamaria De Santis, Daniele Marotta, and Irene Rossi. 2014. "Between Harmonization and Peculiarities of Scientific Domains. Digitizing the Epigraphic Heritage of Pre-Islamic Arabia in the Project DASI." In *Information Technologies for Epigraphy and Cultural Heritage. Proceedings of the First EAGLE International Conference*, edited by Silvia Orlandi, Raffaella Santucci, Vittore Casarosa, and Pietro Maria Liuzzo, 69–93. Studi Umanistici. Serie Antichistica. Collana Convegni 26. Roma: Sapienza Università Editrice. doi:10.13133/978-88-98533-42-8.

Avanzini, Alessandra, Annamaria De Santis, and Irene Rossi. 2018. "Encoding, Interoperability, Lexicography: Digital Epigraphy through the Lens of DASI Experience." In *Crossing Experiences in Digital Epigraphy: From Practice to Discipline*, edited by Annamaria De Santis and Irene Rossi, 1–17. Warsaw/Berlin: De Gruyter Open Poland. doi:10.1515/9783110607208-002.

Avanzini, Alessandra, Annamaria De Santis, Daniele Marotta, and Irene Rossi. 2016. "Is Still Arabia at the Margins of Digital Epigraphy? Challenges in the Digitization of the Pre-Islamic Inscriptions in the Project DASI." In *Off the Beaten Track. Epigraphy at the Borders. Proceedings of the VI EAGLE International Meeting (24-25 September 2015, Bari, Italy)*, edited by Antonio E. Felle and Anita Rocco, 46–59. Oxford: Archaeopress. <https://www.archaeopress.com/Archaeopress/Products/9781784913229>; <https://www.archaeopress.com/Archaeopress/download/9781784913229>.

Avanzini, Alessandra, Alessia Priolella, and Irene Rossi. 2014. "The Digital Archive for the Study of Pre-Islamic Arabian Inscriptions: An ERC Project." *Proceedings of the Seminar for Arabian Studies* 44: 15–24.

Fig. 7 – Example of an individual ‘Resource’ page in the EpiHub website, lower part (DASI- Digital Archive for the Study of pre-Islamic Arabian Inscriptions).

expands: the aim is to provide epigraphists with a hub to constantly monitor the evolving digital epigraphy landscape and the progress of the discipline. To achieve this, we aim to actively engage with the community in a fruitful exchange of information and recommendations on new resources and new description features to include.

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## REFERENCES

- BIGOT JULOUX V., GANSELL A.R., DI LUDOVICO A. (eds.) 2018, *CyberResearch on the Ancient Near East and Neighboring Regions. Case Studies on Archaeological Data, Objects, Texts, and Digital Archiving*, Digital Biblical Studies 2, Leiden-Boston, Brill (<https://doi.org/10.1163/9789004375086>).
- BODARD G., ROMANELLO M. (eds.) 2016, *Digital Classics Outside the Echo-Chamber: Teaching, Knowledge Exchange and Public Engagement*, London, Ubiquity Press.
- CARAVALE A., MOSCATI P., ROSSI I. (eds.) 2024a, *The H2IOSC project and its impact on digital antiquity within the E-RIHS infrastructure – I*, «Archeologia e Calcolatori», 35.1, 515-562.
- CARAVALE A., MOSCATI P., ROSSI I. 2024b, *Landscaping and integrating Digital Archaeology and Digital Epigraphy resources: New challenges and future opportunities. Introduction to the Special section*, in CARAVALE, MOSCATI, ROSSI 2024a, 515-520 (<https://doi.org/10.19282/ac.35.1.2024.30>).
- DE SANTIS A., ROSSI I. (eds.) 2018a, *Crossing Experiences in Digital Epigraphy. From Practice to Discipline*, Berlin-Boston, De Gruyter (<https://doi.org/10.1515/9783110607208>).
- DE SANTIS A., ROSSI I. 2018b, *Appendix A: Selected Webliography*, in DE SANTIS, ROSSI 2018a (eds.), 258-288 (<https://doi.org/10.1515/9783110607208-022>).
- FELLE A.E. 2016, *Oltre EAGLE: l'International Digital Epigraphy Association (IDEA). Una presentazione in anteprima*, «Archeologia e Calcolatori», 27, 353-355 (<https://doi.org/10.19282/AC.27.2016.18>).
- FELLE A.E., ROCCO A. (eds) 2016, *Off the Beaten Track: Epigraphy at the Borders. Proceedings of the VI EAGLE International Event (Bari 2015)*, Oxford, Archaeopress (<https://www.archaeopress.com/Archaeopress/download/9781784913229>).
- HEŘMÁNKOVÁ P., HORSTER M., PRAG J. 2022, *A Report from the Scoping Survey of the FAIR Epigraphy Project (v1.0.0)*, Zenodo (<https://doi.org/10.5281/zenodo.6610696>).
- LE FRANC Y., PARLAND-VON ESSEN J., BONINO L., LEHVÄSLAIHO H., COEN G., STAIGER C. 2020, *D2.2 FAIR Semantics: First recommendations* (<https://zenodo.org/records/3707985>).
- LIUZZO P.M. 2018, *EAGLE continued: IDEA. The International Digital Epigraphy Association*, in DE SANTIS, ROSSI 2018a, 216-230 (<https://doi.org/10.1515/9783110607208-018>).
- MANCUSO G., D'EREDITÀ A. 2024, *DHeLO and BiDiAr: New digital resources within the H2IOSC Project*, in CARAVALE, MOSCATI, ROSSI 2024a, 515-542 (<https://doi.org/10.19282/ac.35.1.2024.31>).



- ORLANDI S., SANTUCCI R., CASAROSA V., LIUZZO P.M. (eds.) 2014, *Information Technologies for Epigraphy and Cultural Heritage. Proceedings of the First EAGLE International Conference*, Serie antichistica. Collana Convegni 26, Roma, Sapienza Università Editrice (<http://www.eagle-network.eu/wp-content/uploads/2015/01/Paris-Conference-Proceedings.pdf>).
- ORLANDI S., SANTUCCI R., MAMBRINI F., LIUZZO P.M. (eds.) 2017, *Digital and Traditional Epigraphy in Context. Proceedings of the EAGLE 2016 International Conference*, Roma, Sapienza Università Editrice (<http://doi.org/10.13133/978-88-9377-021-7>).
- SCARPA E., VALENTE R. 2024, *A resource hub for interoperability and data integration in heritage research: The H-SeTIS database*, in CARVALE, MOSCATI, ROSSI 2024a, 543-562 (<https://doi.org/10.19282/ac.35.1.2024.32>).
- VELÁZQUEZ SORIANO, I., ESPINOSA ESPINOSA D. (eds.) 2021, *Epigraphy in the Digital Age: Opportunities and Challenges in the Recording, Analysis and Dissemination of Inscriptions*, Oxford, Archaeopress.

## ABSTRACT

The Open Digital Epigraphy Hub (EpiHub) is an open access digital platform developed to streamline accessibility and organization of resources in digital epigraphy. Created within the Humanities and Cultural Heritage Italian Open Science Cloud (H2IOSC), EpiHub addresses the fragmented landscape of digital epigraphic resources, which span disciplines like linguistics, philology, and archaeology. Offering a comprehensive catalogue of national and international resources – such as datasets, digital tools, geographical and chronological gazetteers, dictionaries, and text-processing software – EpiHub structures these assets through descriptive metadata to facilitate discoverability and usability for researchers and practitioners across diverse cultural and temporal scopes. The platform's flexible back-end architecture supports efficient data management and real-time updates to enhance front-end accessibility, organizing resources by thematic collections and allowing advanced searches based on specific epigraphic needs, such as language, geographic region, or historical period. Emphasizing FAIR principles, EpiHub standardizes metadata and controlled vocabularies to foster broader interoperability and data reuse across research projects. Integrated with related H2IOSC resources, including H-SeTIS and DHeLO, EpiHub aims to become a central resource, continuously enriched to support collaboration and innovation within the digital epigraphy community.



## RECENSIONI

Archeologia e Calcolatori  
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D. MANACORDA, *Triangolo virtuoso. Tre parole chiave per l'archeologia*, Roma, Carocci, 2024

Come ragiona un archeologo? Come riesce a ricostruire mondi e storie a partire da semplici oggetti del quotidiano, che siano quelli che ci circondano o siano stati recuperati nel sottosuolo? Il libro è dedicato al “triangolo virtuoso”, un metodo frutto dell’incontro tra tre differenti approcci (tecnologico, tipologico e stratigrafico), che, in diversi modi, guardano alle “cose”, cioè ai manufatti creati dall’uomo ed espressione dei loro bisogni, per restituire una visione globale del manufatto stesso, nei suoi aspetti intrinseci e relazionali. Il volume si rivolge a studenti, e anche a lettori curiosi, con un fine discretamente pedagogico nell’accompagnare e raccontare come osservare ciò che ci circonda, anche in ottica di relazione, che appartenga al passato, ma anche al tempo presente.

Il testo è costruito abbinando alla classica disamina sul metodo numerosi esempi, tratti dal mondo quotidiano e dalle innumerevoli esperienze di studio e lavoro dell’Autore. Le immagini costituiscono un vero e proprio metatesto che affianca lo scritto allo scopo di renderlo accessibile a diversi tipi di intelligenza e molte sono desunte dalla realtà quotidiana, in modo da restituire immediatezza e intuibilità. Gli otto capitoli sono dedicati a una prima introduzione su cosa sia l’archeologia oggi; a ciascuno degli approcci; alle loro relazioni reciproche e cumulative; al contesto dove tutto prende vita, per terminare infine con uno spunto di riflessione sul senso di applicare questo modo di ragionare indistintamente alla ricostruzione storica quanto alla comprensione del presente. Gli stimoli al lettore continuano con ulteriori spunti, costituiti da rapide proposte che escono dalla narrazione specifica della materia e che si pongono su binari liminari e trasversali: si citano la paleografia, l’epigrafia, l’ambito storico legato alle fonti scritte, con esempi che non esauriscono la trattazione, ma che aiutano a considerare mondi altri e sempre più vicini, in un gioco di inviti a guardare oltre gli steccati, o magari, a guardare in una dinamica priva di steccati.

Il capitolo introduttivo è dedicato a cosa sia l’archeologia e a cosa serva (*Che cosa è (o può essere) l’archeologia*, pp. 11-21): quello che potrebbe essere uno scontato capitolo sulle civiltà passate, sullo spirito della scoperta, sul mestiere dell’archeologo, porta il lettore a riflettere su come l’archeologia tenda ad accorciare la distanza tra passato e presente e restituisca la voce a chi è ormai scomparso, rispondendo ad un nostro bisogno di interrogarci sul passato stesso. A rendere tutto ciò possibile sono le “cose”, quegli oggetti, spesso sepolti, che sono espressione della volontà di chi li ha fatti o usati e che, provandone a immaginare la vita passata, permettono di

comprendere anche il tempo presente. Con il secondo capitolo (*Un triangolo basilare*, pp. 23-35) si approfondiscono quindi le “cose” e si introduce il triangolo virtuoso applicabile a qualsiasi manufatto abbia una sua materialità, a qualsiasi momento storico appartenga. Il triangolo virtuoso è un metodo che osserva gli oggetti attraverso tre prospettive, e non, come l'Autore tiene a rimarcare, una teoria.

Sono allora i successivi quattro capitoli a trattare ciascuna delle punte del triangolo virtuoso e le relazioni che intercorrono tra loro. Si inizia parlando di *Tecnologia* (pp. 37-46), che si occupa della materia e di come l'uomo si sia ingegnato per farne l'uso migliore ai propri bisogni. Per andare oltre la prima impressione, è necessario esaminare la materia in modo approfondito, non solo per determinarne la natura, ma anche per comprendere le sue specifiche caratteristiche. Questo approccio permette di intraprendere osservazioni più accurate e scientifiche riguardo quelle proprietà che l'occhio umano non riesce a percepire senza l'ausilio di strumenti specializzati. È proprio in questo ambito che si colloca l'archeometria, una disciplina che l'Autore esplora, fornendo alcuni esempi di analisi di manufatti realizzati con materiali diversi (ceramica, metallo, legno). È poi il turno di approfondire la *Tipologia* (pp. 47-73) che studia la forma, la quale a sua volta risponde a una funzione, legata a un bisogno umano. A questa è dedicato un consistente capitolo, che si rivela, al tempo stesso, sintetico se ci si sofferma a considerare i numerosi secoli necessari perché il metodo si strutturasse. L'Autore ha il merito di affrontarlo con particolare linearità e chiarezza: inizia definendo gli attributi, cioè i tratti comuni a ciascun tipo; passa poi ad esaminare i tipi, che assieme alle classi sono le categorie preliminari alla conoscenza; spiega come si costruiscono le classificazioni; e infine si dedica ai modi in cui queste sono concepite, cioè la struttura mentale con cui pensiamo di poter ordinare o attraverso la quale cerchiamo di ricontattare il passato.

L'ultimo vertice del triangolo a essere trattato è la *Stratigrafia* (pp. 75-84), attraverso la quale le “cose” sono osservate per le relazioni spaziali presenti tra loro e ciò che le circonda e nella loro successione temporale; con essa i manufatti escono da un'ottica puntuale per entrare in una dinamica contestuale, dove il fulcro sono le relazioni, orizzontali e verticali. Ancora una volta, in poche pagine Manacorda non solo tratteggia i fondamenti del metodo, a partire dai principi proposti dall'archeologo inglese E.C. Harris negli anni '70, ma affronta anche il dibattito e gli sviluppi successivi, dalla definizione di azione post-deposizionale, al concetto di durata, fino a quello di scala.

Esaurita la singola capacità descrittiva e interpretativa di ciascuna delle punte, l'Autore si concentra sulle opportunità che scaturiscono dall'incontro tra i tre metodi, grazie alle quali si può ottenere una prospettiva quasi globale del contesto esaminato. Negli ultimi due capitoli (*E la topografia?*, pp. 103-117; *Al di là del triangolo: il poliedro*, pp. 119-130), l'attenzione si sposta allora all'esterno del triangolo, ampliando la prospettiva. Cogliendo quindi spunto da un dibattito in corso dedicato al ruolo della topografia, Manacorda, dopo aver introdotto la tesi di alcuni colleghi, secondo cui la topografia è una punta del triangolo al posto della tecnologia, propone la sua, che vede la topografia quale il contenitore che tutto racchiude: il territorio è infatti il macro-contesto all'interno del quale le persone hanno agito e continuano ad agire per mezzo dei loro oggetti. È in questa dimensione che l'uomo attua diversi modi di esprimersi. Ciò che chiamiamo “cose” altro non sono che la manifestazione materiale

dei bisogni che dovevano soddisfare e diventano nel tempo presente le fonti attraverso le quali ricostruire le storie passate. Ciascuna fonte è materia di studio di uno specifico ambito specialistico, insieme possono confluire in progetti di archeologia globale, il cui fine non è certo una conoscenza totale del fenomeno, ma spunti per ricostruzioni ampie e articolate.

Le fonti proprie dell'archeologia sono quelle "materiali": il triangolo virtuoso da loro ricava i dati, che si trasformano poi in indizi nel momento in cui si passa dalla descrizione dell'oggetto alla sua interpretazione. La fase descrittiva può essere considerata scientifica, proprio per il modo con cui si estraggono e organizzano dati. Scienze e tecnologie applicate alla ricerca contribuiscono grandemente nella costruzione e certificazione del dato. Fondamentale è il contributo dell'archeometria, di cui si torna a parlare e che, nel suo aspetto di descrivere il dato misurandolo, approfondisce l'analisi della materia, l'oggetto del paradigma tecnologico. L'Autore porta come esempio il caso delle recenti analisi sulla Lupa Capitolina, che hanno scardinato l'ipotesi tradizionale, datandola al Medioevo: solo incrociando il dato archeometrico con valutazioni stilistiche e formali è stato possibile proporre nuove ipotesi di lavoro. Allo stesso modo, le tecnologie estendono e amplificano la capacità di costruire dati anche in relazione agli altri metodi, grazie alle possibilità offerte dalla disponibilità di banche dati e di sistemi di archiviazione trasversali, come i GIS, o le nuove opportunità offerte dal virtuale e dall'intelligenza artificiale, a patto di non dimenticare mai i rischi di un'eccessiva fede nello strumento fine a sé stesso.

La fase interpretativa, invece, trascende l'ambito scientifico per operare nel campo delle opinioni; rimane, tuttavia, la ricostruzione lo scopo ultimo di una ricerca di ambito archeologico. La storia può essere raccontata da prospettive diverse, a seconda delle innumerevoli specializzazioni, assumendo l'aspetto di un poliedro, complesso e articolato. L'augurio finale che fa l'Autore è una contaminazione tra i diversi lati da cui si osservano non più solo gli oggetti, ma lo stesso procedere storico, sempre attenti a chiedersi dove rimane il discrimine tra il passato dal presente. Il triangolo virtuoso, in chiusura, è solo il punto di partenza di un lungo percorso. E per non perdere la direzione può essere utile non smettere di ricordarsi che tutto agisce all'interno di un contesto e soprattutto di domandarsi per chi e perché ci mettiamo in viaggio.

Quello che forse rende più toccante questo piccolo volume è la sua umanità, il costante ricordarci che dietro le cose ci siamo noi, esseri umani, che siano i nostri antenati, o noi stessi, abitanti del tempo presente. Ci rammenta che le "cose" rispondono ai nostri bisogni e che soddisfarli significa assumersi la responsabilità della scelta, un esercizio di vivere civile fondamentale e quotidiano. Questa bonario richiamo alla responsabilità è sentito con ancora maggiore urgenza quando quel "noi" si riferisce alla categoria professionale degli archeologi, che hanno la responsabilità civile di riportare in vita le "cose". L'archeologia in questa veste non è semplice disciplina, ma un vero e proprio abito, anzi, un ulteriore paio di occhi o di occhiali, che ci aiuta a osservare e, auspicabilmente, a comprendere anche lo stesso tempo presente in cui viviamo.

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M. DANESE, N. MASINI, M. BISCIONE, *Gli Open Data per il patrimonio culturale: aspetti teorici ed esperienze in Italia*, Roma, CNR Edizioni, 2024.

Il volume, a cura di Maria Danese, Nicola Masini e Marilisa Biscione, è pubblicato da CNR Edizioni in versione cartacea e digitale con licenza open access CC BY-NC ([https://www.cnr.it/sites/default/files/public/media/attivita/editoria/9788880805946\\_5953\\_digitale.pdf](https://www.cnr.it/sites/default/files/public/media/attivita/editoria/9788880805946_5953_digitale.pdf)). Costituisce un'agile guida sugli Open Data (OD) nel settore del patrimonio culturale, tematica complessa e attuale, offrendo un'analisi approfondita delle loro caratteristiche costitutive, attraverso una panoramica che ne evidenzia l'importanza, le opportunità e le sfide principali. Un'ampia sezione (Appendici A e B) è dedicata al censimento dei dati open source al momento disponibili online sul panorama regionale italiano, fornendone un catalogo direttamente accessibile e consultabile mediante i link attivi nella versione digitale; un'accortezza che rende l'esperienza di consultazione del volume particolarmente efficace.

Nella *Presentazione* (pp. 6-10), Nicola Masini espone le linee guida e gli intenti del lavoro: mostrare l'importanza degli OD per il patrimonio culturale come strumento per favorire trasparenza, accessibilità, collaborazione e innovazione. Dopo una breve storia del concetto di OD e il loro progressivo sviluppo a partire dalla fine degli anni '50 all'interno del dibattito sulle necessità di condivisione dei dati scientifici, se ne sottolinea il valore odierno come forma di patrimonio pubblico. Si evidenzia inoltre l'importanza della collaborazione basata su questo tipo di dati a beneficio della società. Alcuni paragrafi sono dedicati al progetto Basilicata Heritage Smart Lab, finanziatore del volume e laboratorio operativo per l'applicazione dei concetti di OD al patrimonio culturale.

La *Prefazione* (pp. 12-14), a firma di Beniamino Murgante, introduce il concetto di OD geografici in una prospettiva diacronica, ripercorrendo brevemente la storia della loro diffusione a partire dalle prime strutturazioni negli anni '90 (NSDI) fino alle definizioni degli standard dell'Open Geospatial Consortium (OGC) e alle direttive dell'INFRAstructure for SPatial InfoRmation in Europe (INSPIRE). Riprendendo alcuni spunti dal precedente capitolo, risultano interessanti i paragrafi dedicati al rapporto tra Open-Government e OD, con alcune note critiche sulle pratiche di condivisione basate solo sul primo livello della classificazione a stelle proposta da Sir Tim Berners-Lee, che descrive i dati condivisi con licenza aperta, ma in formati statici come il PDF o il JPG, e che non permette dunque di includere gli attributi spaziali dei dati, limitando l'accessibilità e la manipolazione delle informazioni: «[...] Google e OpenStreetMap hanno trasformato l'informazione geografica da una piccola nicchia di utenti, molto specialista a un fenomeno di massa, e oggi probabilmente il 100% dei dati ha una relazione spaziale. Quindi non considerare gli aspetti spaziali come una componente intrinseca dei dati costituisce un grosso errore».

Il primo capitolo, *Open Data e patrimonio culturale in Italia: la trasformazione digitale* (pp. 16-24), si focalizza sull'importanza degli OD nel processo di digitalizzazione del patrimonio culturale, sottolineandone in modo esaustivo l'importanza come mezzi per l'estensione della fruizione del patrimonio, come strumenti necessari



alla progettazione di servizi e come mezzo per la definizione di nuovi modelli di conoscenza. L'opportunità fornita dagli OD viene presentata come un'occasione per costituire un ecosistema digitale di riferimento all'interno di un sistema che non coinvolge solo gli oggetti digitali, ma anche gli utenti. Si apre così una prospettiva di dialogo orizzontale, che coinvolge tutti gli attori che producono e usano i dati (musei, archivi, biblioteche, studiosi e utenti fruitori). Tale prospettiva appare strettamente legata anche al Piano Nazionale di Digitalizzazione (PND) per il quinquennio 2022-2026, che viene presentato in modo sintetico e efficace a partire dalle traiettorie di cambiamento che esso suggerisce, fino ad una sintesi delle principali linee guida.

Il secondo capitolo, *Come fare Open Data? Sintesi dei punti principali* (pp. 25-37), esplora concretamente molti degli aspetti precedentemente anticipati sul piano teorico. Il capitolo costituisce il cuore del volume e si presenta come un'utile guida per la progettazione e la creazione di sistemi OD. La premessa del primo paragrafo fornisce una guida all'intera lettura del capitolo: «Affinché l'operazione di apertura dei dati sia davvero efficace, occorre che tutti gli aspetti che li riguardano siano messi a punto, come diversi meccanismi di un unico ingranaggio». Tali meccanismi vengono strutturati in 4 punti: 1) definizione delle licenze di condivisione; 2) definizione dei formati di interscambio; 3) definizione di modelli di dati e/o ontologie; 4) possibilità di consultazione e ricerca tramite metadati. Ogni punto viene adeguatamente analizzato, con uno stile sintetico ed efficace e con una esposizione dei dati che facilita costantemente l'utente nella consultazione e nell'individuazione dei contenuti essenziali.

Nel capitolo sono presenti spazi di commento, anche critico. Ad esempio, nella sezione dedicata alle licenze, il paragrafo 2.13 (*Le immagini del patrimonio culturale (concessione e riproduzione per il riuso): normativa vigente e criticità*, pp. 27-30) descrive le problematiche legate alla nuova normativa in merito alla condivisione delle immagini del patrimonio culturale, mettendone in luce le criticità e confrontandone il sistema con le normative e le iniziative internazionali. Su questo stesso tema, molto caro alla comunità archeologica, insiste anche il volume a cura di D. Manacorda e M. Modolo, *Le immagini del patrimonio culturale, un'eredità condivisa? Atti del convegno promosso dalla fondazione Aglaia (Firenze 2022)*, recentemente recensito in questa rivista (A. D'EREDITÀ, in «Archeologia e Calcolatori», 34.2, 2023, 366-369). Di particolare interesse anche il paragrafo 2.3 (*Apertura dei dati geografici: le infrastrutture di dati spaziali*, pp. 32-34), dedicato alle Infrastrutture di Dati Spaziali (ISD) a partire dai motivi che hanno portato alla loro introduzione, fino alle direttive più attuali.

Il capitolo 3, *Gli Open Data nelle esperienze delle regioni italiane*, pp. 39-48, presenta un'indagine sistematica e dettagliata sull'utilizzo e la gestione degli OD relativi al patrimonio culturale nelle regioni italiane. Si apprezza l'organizzazione metodologica del testo, che suddivide l'analisi in sezioni tematiche precise, ognuna dedicata a un aspetto chiave: la disponibilità dei dati nei geoportali, nei portali OD e nei siti specifici, la quantità e qualità dei dati, le licenze, i formati e gli standard adottati. Le numerose carte tematiche forniscono un quadro chiaro delle regioni più attive e degli strumenti utilizzati, identificando al contempo lacune e aree di miglioramento.

Il capitolo 4, *Buone pratiche internazionali e nazionali*, pp. 50-54, offre poi una panoramica delle principali iniziative e dei portali dedicati agli OD, con un focus specifico sul patrimonio culturale. Alcuni paragrafi sono dedicati alle singole iniziative, di

cui vengono messi in luce punti di forza e aspetti più critici. Tra questi si ricordano il Geoportale INSPIRE, Europeana, Dati.gov.it, RNDT (Repertorio Nazionale dei Dati Territoriali), SIGECWeb, Dati.cultura.gov.it, Cultura Italia, Geoportale Nazionale per l'Archeologia (GNA) e le iniziative di crowdsourcing come Wikimedia o Wiki Loves Monuments, che, secondo gli Autori, offrono un esempio virtuoso di "approccio dal basso" destinato a crescere considerevolmente.

Un sintetico capitolo di *Conclusioni* (p. 56) chiude la trattazione. Qui gli autori delineano sinteticamente le caratteristiche finalizzate a rendere più efficiente un ecosistema digitale (o infrastruttura) che gestisca la produzione di OD. Tra questi spunti: la facilitazione nel reperimento dei dati e la promozione della fruibilità degli stessi per utenti con competenze e finalità diverse.

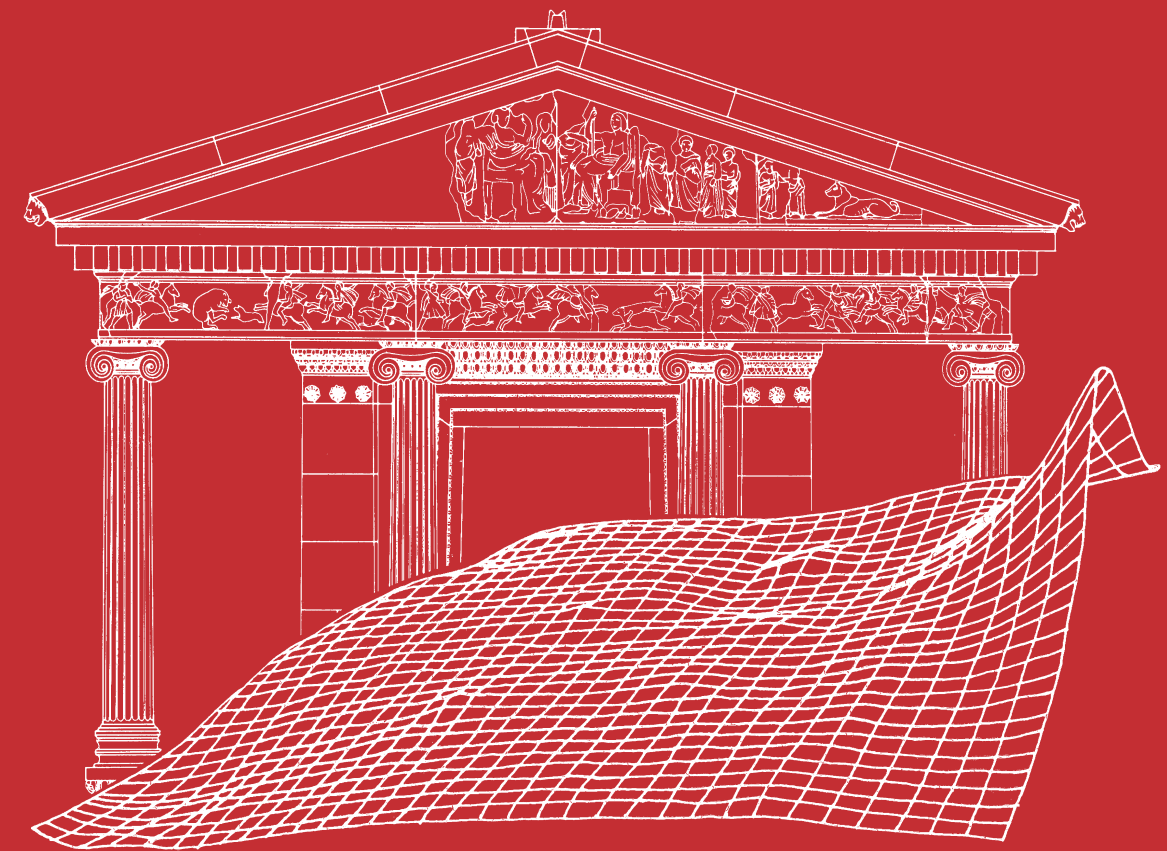
Al termine del volume si trovano due ricche Appendici, redatte in forma di tabella. La prima (*Appendice A. Tabelle riassuntive delle esperienze regionali sugli Open Data*, pp. 57-90) contiene l'elenco degli OD legati al patrimonio culturale suddivisi per regione. Particolarmente utile per la consultazione risulta la schedatura dei servizi per tipologia di licenza, di servizi, di formato, di standard, di ontologie applicate e di Linked Open Data (LOD). La seconda Appendice (*Appendice B. LOD (Linked Open Data) INSPIRE*, pp. 91-93) contiene un elenco di LOD a copertura regionale o sub-regionale, tratti dal portale INSPIRE. È importante sottolineare il valore di questi strumenti di Appendice, non solo come supporto alle osservazioni dei capitoli precedenti, ma anche come cataloghi pratici e rapidi per la consultazione diretta dei servizi stessi. Un immancabile capitolo di *Bibliografia e sitografia* (pp. 94-97) chiude infine il volume, completando la rassegna dei riferimenti citati nel testo e nelle Appendici.

In conclusione, il volume rappresenta un contributo valido al dibattito sull'importanza e l'utilizzo degli OD nel settore del patrimonio culturale. Coniugando rigore scientifico e praticità di consultazione, l'opera offre una visione d'insieme chiara ed esaustiva, affrontando tematiche complesse con un linguaggio accessibile e una struttura ben organizzata. Le riflessioni teoriche sono arricchite da esempi concreti e strumenti pratici, come le Appendici e i cataloghi consultabili, che amplificano il valore del testo sia per gli addetti ai lavori, sia per un pubblico più ampio. In un momento storico in cui la digitalizzazione e la trasparenza dei dati assumono un ruolo sempre più centrale, questo volume si distingue come una guida autorevole, capace di stimolare nuove riflessioni e promuovere un approccio collaborativo e sostenibile alla gestione del patrimonio culturale.

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