THE EVOLUTION OF ARCHITECTURAL FEATURES AT THE PROTOHISTORIC SETTLEMENT OF ACINIPO (RONDA, ANDALUSIA). FROM ROUNDED HOUSES TO RECTILINEAR STRUCTURES AND ROUNDED AGAIN

1. Introduction

The analysis of architectural constructions provides important information about prehistoric societies, since architecture is a physical manifestation of culture and society. Some researchers affirm that architecture manifests human behaviour in the built environment, and thus architecture that reflects behaviour will necessarily be shaped by it (Rapoport 1990). Other authors point out that architecture reflects social and economic organization and the changes produced in human society, usually increasing the socioeconomic complexity, since «where socioeconomic reorganization is found, it will be noted, a concurrent architectural reorganization is found» (Steadman 2000). Also, the architectural structure and the concepts used in the construction of space are basic to knowing the development of a society because social complexity determines the organization of constructed space (Chapman 1990).

On the other hand, the architectural variability of buildings provides relevant information about the prehistoric societies and the relationships among the prehistoric social groups that built them. Prehistoric builders used specific features such as materials, construction techniques, structural configurations, investment of labour, and geometric designs that cannot be reduced to functional concerns alone (Van Dyke 1999; Esquivel, Navas 2007). Architectural variability can be used to discern the patterning among architectural characteristics and distinguish shared cultural backgrounds between groups (Carr 1995).

A major feature is the architectural design, given that its variability and change are associated with social shifts, diversity among societies, human activities, social structure, etc., and the identification of causal factors that influence the designs for specific structures allows us to infer social structure and cultural changes. Some authors focus on the process of architectural design as concerned with a recurrent set of activities, and the most usual activity sets are production, use, and maintenance of the built environment (McGuire, Schiffer 1983). Architectural design is shaped by human actions and perceptions, and this concept has been employed by archaeologists in the construction of social, functional, and demographic knowledge (Van Dyke

1999). Changes in style have been related to social identity, reflecting social distinction and power relations (Hegmon 1998), structuring of space, and incorporating cosmological and symbolic principles (Parker Pearson, Richards 1994). Architecture is also shaped by human actions and perceptions, reflecting increasing site density, social or economic changes (Van Dyke 1999). Also, geometric design and metric parameters of buildings are a manifestation of the emergence of mathematical thinking and the acquisition of metric and geometric concepts (Esquivel, Navas 2005).

The shape of houses constitutes an important feature of human societies reflecting the social actions and the construction of a social landscape. Several theories have been developed to explain the evolution in the design. In Europe there is a tradition with respect to the design: rounded houses are located in the British Isles and rectangular ones in continental Europe (Hodson 1964). From an architectural point of view, the rounded houses were adopted probably for two major reasons: the complete structure has identical features, and the consideration of houses for death (rounded graves) and houses for life (Harding 2000); but there are other interpretations, such as nomadism (Robbins 1966), social factors such as extended families (Flannery 1972), more economic design, shortage and homogeneity of domestic and symbolic functions, and few associated materials (Ruíz-Zapatero *et al.* 1993). In Spain, rounded houses are associated with a Mediterranean tradition and rectangular designs with European influence (Ruíz-Zapatero *et al.* 1986), whereas in western Andalusia this evolution is associated with a manifestation of discontinuity between the local Bronze Age and Phoenician influence (Belén, Escacena 1993).

Rectangular houses provide the advantage of construction using local building materials, easier construction methods, the possibility of a floor, the best accommodation for domestic life, the differentiation of activity areas, the possibility of adding rooms by the addition of walls, etc. An important reason for building rectilinear houses is also probably intensive agriculture which brings about an increase in production that in turn increases the maintenance costs and duration of settlement (McGuire, Schiffer 1983). The rectangular houses at Acinipo maintain the same metric features as the round ones, probably due to the influence of the Phoenician phase in Andalusia. Moreover, rectilinear constructions show the great acculturation of local populations which may have been due to a transformation in ideological and economic terms (Parker Pearson, Richards 1994).

In prehistory, a major area of interest focuses on analysing the changes in the shape of architectural structures and the transition from rounded shapes to rectangular or sub-rectangular shapes. At the Acinipo settlement, the changes in the geometric design of houses (rounded, rectangular and large houses) from the Early Bronze Age to Phoenician contacts constitute an important feature in the Andalusian protohistoric context.

2. Materials and methods

The settlement of Acinipo is located on a small flat promontory with natural defences near to a great plateau between the city of Ronda (Málaga, Andalusia) and the village of Setenil (Cádiz, Andalusia). This site has an important strategic geographical interest with great agricultural resources and good communications with other areas of the Andalusian region, and this characteristic constitutes an essential factor for the localization of the settlement in prehistoric and protohistoric periods as well as in the Roman period (Fig. 1). The settlement is placed on a great calcareous plateau of tertiary origin (Fig. 2), with a mean altitude of 950 m a.s.l., in an area of great agricultural potential and with good access to other areas of the region.

The oldest discoveries belong to the Neolithic period with an initial occupation belonging to the Copper Age and some remains from the Early Copper Age with no radiocarbon dating, but the first architectural remains belong to the Middle Bronze Age and consist in damaged rounded huts and locally made pottery vessels. Later archaeological levels belong to the Late Bronze Age and protohistoric period, with remains of goods imported by the Phoenicians. Circular houses, rectangular houses, and large rectangular houses with separate rooms were constructed using stones of several sizes and 0.20-0.40 meters average length (Fig. 3).

Afterwards, the Romans settled on the great plateau and built a town with a well-preserved theatre, of which only a small part has been excavated (Aguayo *et al.* 1986).

In this study, we have analysed the architectural design in the different chronological and cultural phases at Acinipo. Metric analyses were performed using digital CAD designs recorded by means of a Cartesian relative coordinate system with an arbitrary point of origin (0,0) determined by the development of the excavations. Using digital CAD designs recorded with great precision (1:20 scale map) by means of (X,Y) relative rectangular coordinates using meters as units and starting from an arbitrary origin (0,0) determined by the development of the excavations, the analyses provide results with a high degree of accuracy (Calter 2000; Eiteljorg 2002).

3. Houses of the first architectural phase

The first phase contains two different types of architectural structures: rounded and rectangular. The earliest houses are two parallel and well preserved structures (UEC40 and UEC46), and the remains of another similar structure (UEC 68) with rounded designs but having differences between them (Fig. 4).

Structure UEC 46 was designed as a circle and the estimation of mathematical parameters was carried out adjusting a theoretical circle to the inner
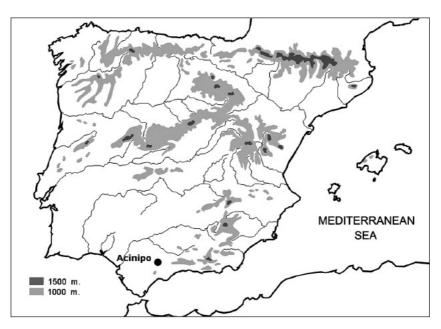
Fig. 1 – Acinipo is located close to the Mediterranean sea and the Guadalquivir river basin.
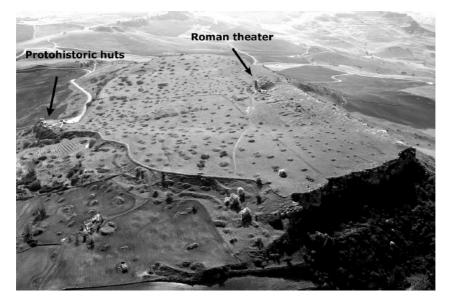

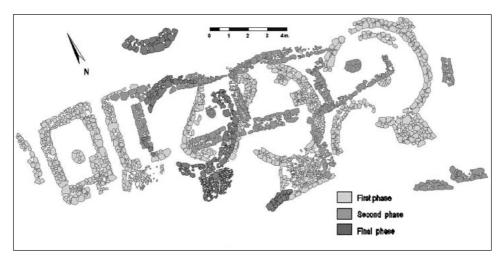Fig. 2 – Location of the protohistoric settlement and the Roman theatre.

Fig. 3 – Architectural structures of each construction phase in the protohistoric period. Structures of each period were built over the previous ones.
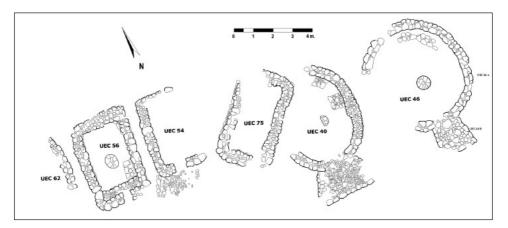

Fig. 4 – Rounded and rectangular huts belonging to the first architectural phase.

and external faces in an independent way in each structure. This procedure allowed us to maintain the maximum fidelity with the archaeological record while minimizing the difference between the estimated and the real structure. The best conserved areas of the structure, with no construction modifications, were used as adjustment elements. The parameters of external C_1 and inner C_2 circles (Table 1) show that the differences between the coordinates of the centres are almost zero ($\Delta X = 0.0104$ m and $\Delta Y = 0.067$ m):

	Coordinates of centers		Radius	Surface
	X	Y		
C_1	28.7128	19.6963	2.87 m	25.87 m^2
C_2	28.7024	19.6293	2.35 m	17.38 m^2

Tab. 1 – Metric and geometric parameters of UEC 46.

The wall was built by means of two rows of stones 30-40 cm average length, and its width was computed by extracting a random sample with 10 points on the wall in the best-preserved areas providing $\bar{x} = 0.508$ m and $\sigma = 0.036$. The estimation of the average width is computed by means of the expression (SOKAL, ROHLF 1982; VENABLES, RIPLEY 2002):

$$m \in \left(\bar{x} - Z_\alpha \frac{\sigma}{\sqrt{n}} , \bar{x} + Z_\alpha \frac{\sigma}{\sqrt{n}} \right)$$

m being the mean of the sample, n the number of elements, σ the standard deviation in the sample, and Z_α the Z-value belonging to the normal distribution N(0,1) that corresponds to the selected level of significance α.

Using a level of significance $\alpha < 0.05$, the mean confidence interval found is $(0.4857, 0.5303)$, indicating the skill of the builders to maintain the same width in the entire construction. This confidence interval includes the theoretical width $W_t = 0.52$ meters with a level of significance at p=0.05, being 7% the coefficient of variation $C.V. = \frac{\sigma}{\bar{x}}$ (SOKAL, ROLF 1982; VENABLES, RIPLEY 2002).

The structure UEC 40 is shaped as an ellipse and the mathematical parameters were estimated by adjusting a theoretical ellipse to the inner and external faces. The best conserved areas of the structure with no building modifications were used as adjustment elements. Differences in the centres of the circles ($\Delta X = 0.045$ m and $\Delta Y = 0.044$ m) are almost zero and indicate the skill and care employed to maintain the elliptical shape. The parameters of external E_1 and inner E_2 ellipses are the following (Table 2):

	Coordinates of centers		Axis major	Axis minor	Surface
	X	Y			
E_1	23.6028	17.5993	5.46 m	4.45 m	20.07 m^2
E_2	23.6477	17.5550	4.56. m	3.44 m	12.50 m^2

Tab. 2 – The metric and geometric parameters of UEC 40.

The wall was constructed by making two parallel rows of stones 15-20 cm long (only one stone 45 cm long is preserved) filled with smaller stones. The width was computed by taking a random sample with 9 points on the wall in the best-preserved areas, providing $\bar{x} = 0.523$ meters, $\sigma = 0.025$, and

the confidence interval of the mean $(0.506, 0.538)$ with a significance level of p=0.05. The value of coefficient of variation (CV=4.7%) was smaller than the circles, revealing the skill used in construction and the previous planning of the structure.

By extracting a random sample of the width from UEC 40 and UEC 46, we used the non-paired two-tailed Student's t-test to compare the results (SOKAL, ROLF 1982; VENABLES, RIPLEY 2002):

$$t_{n_1 + n_2 - 2} = \frac{\overline{x}_1 - \overline{x}_2}{\sqrt{\frac{1}{n_1} + \frac{1}{n_2}} \sqrt{\frac{(n_1 - 1)s_1^2 + (n_2 - 1)s_2^2}{n_1 + n_2 - 2}}}$$

x_1 and x_2 being the means, s_1 and s_2 the standard deviations, and n_1 and n_2 the size of samples. The Levene test showed no differences in the variance between groups (F=1.005, p=0.33), and the Student's t- test shows no statistical significant differences between the mean values of width of UEC 46 and UEC 40 (t=0.980, p=0.341). This result points to the same building feature of both structures.

These two results indicate that the builders took great care in the metric details, perhaps using a stick and rope. Also UEC 46 and UEC 40 were built in a systematic way and designed with great skill and precision.

A porch of almost rectangular shape is linked to UEC 46, presumably to prevent mud in rainy periods. It was constructed using stones that were 20-40 cm long and covered the entire porch with a 1.42×1.80 m^2 surface. A similar trapezoidal porch 3.75 m long is linked to UEC 40 delimited by stones 30-40 cm, and has two smaller sides 2 m long delimited with stones 15-20 cm The angles in vertex measure 68º and 65º. These features are not usual in Andalusian constructions, although settlement such as those at Colina de los Quemados and Cerro Macareno show small floor remains (AGUAYO *et al.* 1986).

Both structures contain a well-constructed central fireplace of baked clay, 0.70 cm in diameter, placed on a layer of lime and constructed a few centimetres over the floor, containing a shallow layer of ashes (Fig. 4). The function was presumably not to contain the fire but to heat flat clay objects for cooking pancakes made of grains or some similar food (AGUAYO *et al.* 1986).

Another ellipsoidal structure (UEC 69) was built over the UEC 46 with a similar construction technique, and had only a short portion of wall. The width was computed by taking a random sample on the wall in the best-preserved areas: $\overline{x} = 0.464$ meters, $\sigma = 0.025$ and the confidence interval of the mean $(0.448, 0.473)$ with α=0.05 level of significance. The ANOVA test rejected the null hypothesis of mean equals (F=11.207 and p<0.001), and the Bonferroni *post hoc* test showed a statistically significant mean difference between the width of UEC 68 and UEC 40 (p<0.001) and UEC 46 (p=0.05) (SOKAL, ROLF 1982; VENABLES, RIPLEY 2002).

The settlement contains three well-preserved rectangular structures (UEC 56, UEC 54 and UEC 75) and the remains of a wall belonging to other similar structures (UEC 62), but their shape may be rectangular or circular. The structures UEC 54 and UEC 56 are situated parallel to each other, but UEC 62 is separated and forms a 36º angle with respect to the previous ones (Fig. 5) and their architectural features also differ.

The parallel structures have similar metric and geometric features, and the measurements were made by the extraction of random samples at each side and the computation of the confidence intervals with $\alpha=0.05$ significance level (Table 3).

		UEC 54	UEC 56 without stair	UEC 56	UEC 75
Major side	Sample parameters	$\bar{x}$ = 4.197 σ = 0.035	$\bar{x}$ = 4.195 σ = 0.040	$\bar{x}$ = 4.663 σ = 0.033	$\bar{x}$ = 5.027 σ = 0.035
	Confidence interval α<0.05	(4.172,4.222)	(4.167,4.219)	(4.643,4.682)	(5.007,5.047)
Minor side	Sample parameters	$\bar{x}$ = 2.536 σ = 0.038	$\bar{x}$ = 2.535 σ = 0.038	$\bar{x}$ = 3.065 σ = 0.067	$\bar{x}$ = 2.868 σ = 0.061
	Confidence interval α<0.05	(2.511,2.561)	(2.510,2.560)	(3.025,3.105)	(2.832,2.904)

Tab. 3 – Longitude of major and minor sides of the rectangular structures.

The ANOVA test rejected the null hypothesis of equal means and the Bonferroni test indicated different means for each structure with respect to the larger and smaller sides, although UEC 54 and UEC 56 have special metric features: mean length of UEC 56 with no internal stair entrance is equal to the mean length of UEC 54 and smaller than the mean length of UEC 75. This result indicates that both structures were constructed following the same pattern and arranged in parallel alignment (the scant remains of UEC 62 seem to follow the same pattern), and rounded houses were built with the same alignment with each other while maintaining this architectural pattern (Fig. 5).

The ANOVA test applied to the width of these structures showed no statistically significant differences in the mean width with $\alpha=0.05$ level of significance (F=0.502, p=0.611), i.e., three structures had an equal width 0.545 meters mean. In each structure the coefficient of variation was very small (CV_{UEC75}=3.9%, CV_{UEC54}=6.3% and CV_{UEC56}=9%).

4. Protohistoric houses

Architecture shows an important change in the protohistoric period, with respect to the previous architectural design: two buildings of different
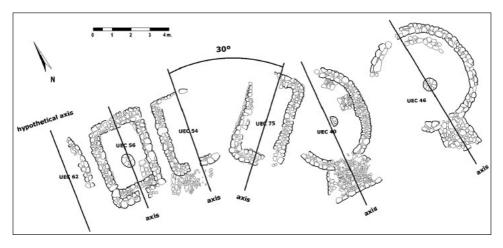
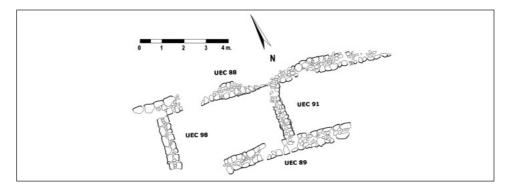Fig. 5 – The N-S axis shows the alignment of the huts.

Fig. 6 – Large linear structures.

sizes and rectilinear and orthogonal walls were built over the previous circular and rectangular structures. The largest structure extends through a great part of the settlement, with only a portion that is 15.54 m long still preserved (Fig. 6), and it is delimited by two large parallel walls (UEC 88 and UEC 89) with two orthogonal walls (UEC 90 and UEC 91) and built by means of two rows of stones 30-40 cm long.

The mean width was computed by taking a random sample in each structure, and the application of the ANOVA test showed that this structure had three well-defined and separate walls (F=512.887, p<0.001):

– The Levene test shows that the variances in width in UEC 88 and UEC 89 are equal, while the Student's t-test shows that the mean width is not statistically different (t=0.351, p=0.731) in the two structures,

being $\overline{x_{UEC88}}$ = 0.7086 , $\overline{\sigma_{UEC88}}$ = 0.0147 and $\overline{x_{UEC89}}$ = 0.7111 , $\overline{\sigma_{UEC89}}$ = 0.0129 . These results give CV_{UEC88} = 2.08% and $\overline{CV_{UEC89}}$ = 1.82% , and the order of differences between the mean the widths is 0.24 cm, showing the skill and care employed by the builders to make walls of the same width.

– UEC 90 differs from UEC 88 and UEC 89 with $\overline{x_{UEC90}}$ = 0.5370 , $\overline{\sigma_{UEC90}}$ = 0.0123 and $\overline{CV_{UEC90}}$ = 2.30% . The skill in construction is similar to that used for UEC 88 and UEC 89, but this wall is almost 17 cm narrower than the previous ones.

– UEC 91 is orthogonal to large walls and parallel to UEC 90 with $\overline{x_{UEC91}}$ = 0.4845 , $\overline{\sigma_{UEC910}}$ = 0.0125 and $\overline{CV_{UEC91}}$ = 2.29% . It is narrower than the previous ones and was constructed with the same skill.

The remains of the other protohistoric building are composed of four walls shaping rectangular rooms (Fig. 7). The ANOVA test rejects the null hypothesis of equal mean width and the Bonferroni *post hoc* test (SOKAL, ROLF 1982; VENABLES, RIPLEY 2002) indicates that the mean widths of UEC 82 and UEC 83 are not statistically different at a significance level of $\alpha < 0.05$ (t=0.258 *post hoc*, p=0.8) demonstrating that these walls have the same metric parameters but differ from the others.

Two new rounded structures were built at the end of the protohistoric phase over the previous rectangular building, similar in its overall shape to the oldest huts, being almost circular and with a porch. Surprisingly, these constructions maintain parallel locations with respect to the oldest rounded huts, but were erected over the largest rectangular building (Fig. 8).

The structure UEC 98 is shaped like an ellipse, and the mathematical parameters were estimated by adjusting a theoretical ellipse to the inner and external sides, giving the mathematical results listed in Table 4; only the shape of UEC 98 was analysed because UEC 99 was almost entirely damaged). Differences between the estimated radius proved to be almost zero ΔX=0.045 m and ΔY=0.044 m, showing that the builders took great care in forming the shape of the rounded dwelling.

	Coordinates of centers		Axis major	Axis minor	Surface
	X	Y			
External	18.9116	17.0509	5.57 m	5.07 m	21.90 m^2
Inner	18.9274	17.0613	4.39 m	3.58 m	13.02 m^2

Tab. 4 – Metric and geometric parameters of UEC 98.

By extracting a random sample of the width, we get $\overline{x_{UEC98}}$ = 0.6702 m, σ_{UEC98} = 0.0178 and CV=2.6%.
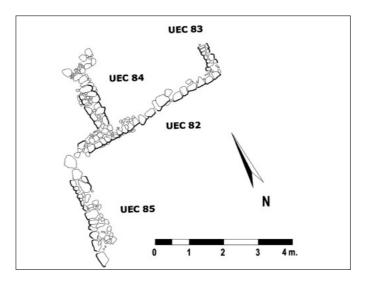
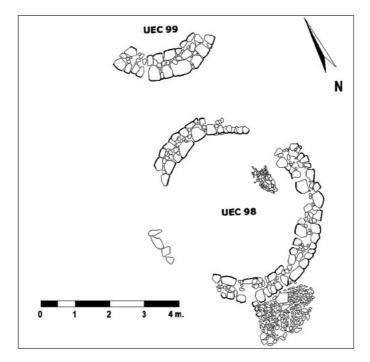Fig. 7 – Ramified walls forming protohistoric rooms.

Fig. 8 – More recent rounded structures built over the previous rectilinear constructions.
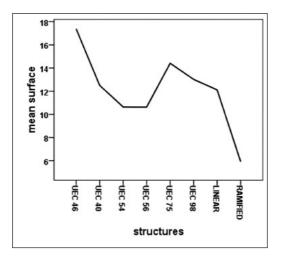
Fig. 9 – Surface of houses.

Taking into account width only, we find that the random sampling from the incomplete rounded structures UEC 68 (belonging to the first construction phase) and UEC 99 (early phase) shows major differences: $\overline{x_{UEC68}}$ = 0.4641 m, σ_{UEC68} = 0.0205, and $\overline{x_{UEC99}}$ = 0.7320 m, σ_{UEC68} = 0.0135, but the coefficients of variation (CV=4.7% and CV=1.8%) confirm the skill of the builders over time.

The ANOVA test applied to the rounded structures indicates that there are significant statistical differences with respect to the mean width (F=199.342, df=45 and p<0.001). The *post hoc* Bonferroni test shows that only UEC 40 and UEC 46 were built with similar width and that the other structures have statistically significant mean differences with p<0.001, perhaps due to a specific pattern.

The quantification of the anamorphic aspect ratio provides 0.9176 for UEC 98 and 0.8053 for UEC 40, indicating an evolution in the form: the most recent rounded structure is similar to the almost circular old structures, but it maintains major differences with respect to the elliptic structure.

The inner surfaces are fairly regular with $\overline{x_{Surf}}$ = 12.96 m^2, σ_{Surf} = 2.26 m^2 and CV=18.2% with the exception of the room on the ramified linear structure that is the smallest (Fig. 9). This result indicates that the living surface of the rooms remained similar through time.

Because the porches were damaged, it was not possible to carry out metric analyses, but the construction technique was similar to the elliptical structure of UEC 40. It was built by means of small stones, as in the case of the porch of UEC 40.

5. Discussion

The archaeological sequence at Acinipo settlement (Table 5) starts in the Neolithic period with a minor occupation, followed by a settlement belonging to the Copper Age and having scarce remains of animal bones left over from meals, polished stone tools, debris, and hand-made pottery including vessels painted with bell-beaker techniques and motifs.

The first architectural remains are linked to a settlement of the Bronze Age spanning from the end of the III Millennium B.C. to the first half of the II Millennium B.C. (radiocarbon dates) with a large quantity of hand-made pottery vessels, plant and animal remains, and cooking tools made with baked clay, polished stones or polished bones. These early constructions were rounded domestic huts built with stone walls and a roof of wood and foliage covered with mud, and were located on staggered terraces built using retaining walls.

The end of the prehistoric sequence contains some not very well-preserved and not very well-known remains of the Late Bronze Age occupation pertaining to the last centuries of the II Millennium B.C., having painted pottery of the "Cogotas" type and buildings designed as rounded huts made with stones and structures of plant material covered with mud. There is no evidence of a relationships between its inhabitants and the Phoenician coastal settlements at this time. The constructions maintain architectural tendencies loke the rounded design and the use of small foundation stones with structures of wood and foliage covered with mud.

The Protohistoric phase has common features with the entire Serranía de Ronda region, and the structure of Acinipo and the Ronda settlement was altered by its inhabitants who were using different building and pottery shapes. The area was flattened to obtain a great plain, and rounded and rectangular huts characterize this first architectural phase. The presence of wheel-made ceramics constitutes an important feature, since it implies evidence of the Phoenician colonization in the Andalusian coastal area and the emergence of relationships with the native inhabitants (Aguayo *et al.* 1986). Three radiocarbon-dating samples from Acinipo belonging to different time periods show human occupation from 920 B.C. to 635 B.C.

This archaeological period contains hand-made ceramics and Phoenician wheel-made amphorae together with red-painted plates, but the percentage of these latter types is smaller than that for the native pottery. Such features as the existence of rounded and rectangular huts, and the remains of the hand-made and wheel-made domestic pottery, are common at many settlements in western Andalusia as well as in the low Guadalete River valley, the lowlands of Huelva, and the low Guadalquivir river valley (Izquierdo 1998). These patterns also appear in areas of central Andalusia

along the Guadalquivir river and the Eastern Béticas regions (GALLARDO 2007), as well as in the Cerro de la Encina (Granada province) and Peñón de la Reina (Almería province) belonging to eastern Andalusia also. In the Málaga province, there are several settlements with similar characteristics like Huertas de Peñarrubia, the Raja del Boquerón and the Castillo of Gobantes (GARCÍA 2008).

18.000/10.000 B.C.	La Pileta cave	P
5400/3500 B.C.	Ronda	N
3000/2200 B.C.	Ronda, Acinipo, Silla del Moro, El Marqués cave	CA
2100/1950 B.C.	Ronda, Acinipo	BA
1300/ 920 B.C.	Acinipo, Ronda	LBA
920/635 B.C.	Ronda, Acinipo	PH
635/450 B.C.	Ronda, Silla del Moro II	PI
450/200 B.C.	Ronda, Acinipo, La Botinera	IB

Tab. 5 – The chronology of settlements and caves in the Acinipo region: P=Palaeolithic, N=Neolithic, CA=Copper Age, BA=Bronze Age, LBA=Later Bronze Age: PH=Protohistoric period, IB=Iberian period. Radiocarbon dates were conducted only on some settlements.

The next archaeological phase has no radiocarbon dates and points to a new change in the city-planning based on the construction of E-W large, wide walls partitioned with thin rectangular walls to create rectangular rooms. The pottery remains are similar to the previous ones; hand-made cooking and small storage pottery are the most frequent, but the percentage of wheel-made ceramics increases. This process is also evident in some settlements of western Andalusia such as Colina de los Quemados (Córdoba), Cerro Macareno, and Montemolín (Sevilla province) (DELGADO 2005), and others in central Andalusia as Huertas de Peñarrubia, Raja del Boquerón, Cerro de la Era and Loma del Aeropuerto in coastal of Málaga (SUÁREZ *et al.* 1996; GALLARDO 2007; GARCÍA 2008), which indicate the existence of structures formed by large walls divided in smaller rooms. Furthermore, this process has been recorded at La Peña Negra settlement (Alicante province), showing that these features do not appear solely in Andalusia.

The final architectural phase at Acinipo occurred from the middle of the 8th century B.C. to the second half of the 7th century B.C., and belongs to the so-called "Orientalizing" period. Architecturally, the major feature of this period is the return to rounded huts. In the period from 635 to 450 B.C., the inhabitants left Acinipo and moved to the present city of Ronda (20 km away), and the next phase in which the site was inhabited belongs to the Iberian period, as is demonstrated by an *oppidum* located in Silla del Moro (AGUAYO *et al.* 1992). The Roman occupation expanded over the entire plateau, where they erected a large city with thermal baths, public buildings, and a theatre.

6. Conclusions

In the protohistoric period, the settlement of Acinipo shows an evolutionary design, it had some important features in common and some differences with respect to others in the Andalusia region. The first architectural phase contains both rounded (circular and elliptical) and rectangular huts with no differentiation in the areas inside except for a central fire, maybe because most tasks were performed outside. The walls were constructed at a constant width throughout the structure (0.52 m mean) but the surface of the circular hut was slightly greater than that of the elliptical one. The porches show similar metric and geometric parameters, maintaining a strong parallel between them as an urban-planning feature. This design of rounded houses is common in western Andalusia, indicating the adscription of Acinipo to this area.

The rectangular huts of this first building phase have similar geometric parameters, maintaining a strong parallelism, except for structure UEC 75, and with respect to another badly preserved one (UEC 62). The width of the walls is the same in all of these structures and narrower than in the rounded huts, and the surface is smaller also, which meant a decrease in the volume of stones and the labour invested to build it. This result indicates that the local inhabitants adopted narrower lineal walls to make rooms with smaller surfaces (10.6 m² mean) and this pattern is not found in other settlements of western Andalusia.

Two linear structures belonging to the second phase show an important change in design: two buildings of different sizes and rectilinear and orthogonal walls built over the structures of the first phase. The older structure is composed of two large and parallel linear walls which are very wide (0.70 m width) and orthogonal walls that are less wide (0.5 m), forming rooms with a surface area similar to that of the huts of the previous period. The second one was built with thicker walls with a ramified design and small rooms (3.29 m average large and 1.80 m average wide). These constructions show an architectural evolution in partitioning the space and they are more similar to the European houses and dwellings in north-eastern Spain, probably associated with similar settlements along the Mediterranean coast (Belén, Escacena 1993).

The remains of two rounded structures belonging to the later phase show a surprising pattern: the design returns to circular structures, but with different metric parameters. The best-preserved structure is an almost circular hut similar to the previous rounded structures of the first phase; it has the greatest surface and greatest average width probably due to a different use. This later building phase provides an evolutionary change to old rounded designs, combining local and foreign construction traditions (there is no in-

dication however that the population was more nomadic). It is possible that the later rounded structures have symbolic and power functions due to the increasing social complexity like a return to ancestral traditions, although the design of these structures maintains the same geometric parameters with porch and central fire also. However, the surface area of the living rooms remained almost constant, perhaps indicating partial Phoenician influence and this metric parameter is similar through time.

An important result concerning the individual rounded structures is the location of huts: the houses are aligned with great perfection in each building phase, no house stands out from the others. This feature implies social equality at least amomg the non-leaders, and it is maintained regardless of the design. This assertion seems strengthened by the small surface of the huts, implying that they would be nuclear family dwellings. Also, the entrances of the huts and the preserved entrances on rectangular structures were oriented to the South, thus avoiding the predominant westerly winds and increasing the microclimatic temperature range, the degree of controllable adjustability and the quantity of tasks performed inside (WILKINS 2009), while the surface of the living rooms remained almost constant. These results probably indicate that the Phoenician influence was not complete and the architectural parameters were similar over time.

In terms of mathematics, the inhabitants of the Acinipo settlement knew some geometric and metric concepts, such as the use of regular geometric figures, the symmetry and the metric features already found in Andalusian prehistory (ESQUIVEL, NAVAS 2005, 2007). Furthermore, at Acinipo complex geometric concepts appear such as the orthogonality in the building of houses and, maybe for the first time, the concept of parallelism used to place the houses on the land as a pattern of urbanism. Therefore, the concept of alignment appears for the first time in the prehistory of Andalusia: this feature is local and not used in other Andalusian constructions, since it is a distinguishing autochthonous characteristic. The architectural evolution at Acinipo settlement is surprising, and new excavations in this area may provide new information to advance in the study of protohistoric architectural design in Andalusia.

The evolution from rounded individual houses points to the colonization by oriental inhabitants probably combining local and foreign building traditions, but the regression to rounded design constitutes a major feature.

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REFERENCES

Aguayo P., Carrilero M., Flores C., De La Torre M.P. 1985, *El yacimiento pre y protohistórico de Acinipo (Ronda, Málaga)*, «Anuario Arqueológico de Andalucía 1985. Actividades Sistemáticas», 2, 33-58.

Aguayo P., Carrilero M., Flores C., De La Torre M.P. 1986, *El yacimiento pre y protohistórico de Acinipo (Ronda, Málaga): un ejemplo de cabañas del Bronce Final y su evolución*, «Arqueología Espacial», 9, 33-58.

Aguayo P. *et al.* 1992, *Excavación arqueológica sistemática en el yacimiento de la Silla del Moro. Primera campaña, 1990*, «Anuario Arqueológico de Andalucía 1985. Actividades Sistemáticas», 2, 33-58.

Belén M., Escacena J.L. 1992, *Las comunidades prerromanas de Andalucía Oriental*, «Complutum», 2-3, 65-88.

Belén M., Escacena J.L. 1993, *Las comunidades prerromanas de Andalucía Occidental*, in M. Almagro, M. and G. Ruiz (eds.), *Paleoetnología de la Península Ibérica*, Madrid, Servicio de Publicaciones de la Universidad Complutense, 65-87.

Calter P. 2000, *Facade measurement by trigonometry*, in C.A. Gorini (ed.), *Geometry at Work, Papers in Applied Geometry, MAA 53*, Washington, Mathematical Association of America, 20-25.

Carr C. 1995, *An unified middle range theory of artefact design*, in C. Carr, J. Neitzel (eds.), *Style, Society, and Person: Archaeological and Ethnological Perspectives*, New York, Plenum Press, 171-258.

Chapman R. 1990, *Emerging Complexity. The Later Prehistory of South-East Spain, Iberia and the West Mediterranean*, Cambridge, Cambridge University Press.

Delgado A. 2005, *La transformació de la arquitectura residencial en Andalucía Occidental durante el orintalizante: Una lectura social*, Anejos de Archivo Español de Arqueología, 35, 1, 585-594.

Eiteljorg H. 2002, *How should we measure an ancient structure?*, «Nexus Network Journal», 4, 2, 1590-1596.

Esquivel J.A., Navas E. 2005, *The geometry and the metric used in the enclosure "Fortín 1" at Copper Age site of Los Millares (Almería, Andalusia)*, «Journal of Archaeological Science», 32 (11), 1577-1586.

Esquivel J.A., Navas E. 2007, *Geometric architectural pattern and constructive energy analysis at Los Millares Copper Age settlement (Santa Fé de Mondújar, Almería, Andalusia)*, «Journal of Archaeological Science», 34 (6), 894-904.

Flannery K.V. 1972, *The origins of the village as a settlement type in Mesoamérica and the Near East: A comparative study*, in P.J. Ucko, R. Tringham, G.W. Dimbley (eds.), *Man, Settlement and Urbanism*, Crescent, NW, Gerald Duckworth and Co. Ltd, 23-54.

Gallardo V. 2007, *Técnicas constructivas prerromanas de las Béticas Occidentales*, «@rqueología y Territorio», 4, 117-139.

García E. 2008, *En la orilla de Tartessos. Indígenas y fenicios en las tierras malagueñas. Siglos XI-VI a.C.*, Málaga, Comunicación y Turismo.

Harding A.F. 2000, *European Societies in the Bronze Age*, Cambridge, Cambridge University Press.

Hegmond M. 1998, *Archaeological research on style*, «Annual Review of Anthropology», 21, 517-536.

Hodder I. 1990, *The Domestication of Europe: Structure and Contingency in Neolithic Societies*, Cambridge, Basil Blackwell.

Hodson F.R. 1964, *Cultural grouping within the British pre-Roman Iron Age*, «Proceedings of the Prehistoric Society», 30, 90-100.

Izquierdo R. 1998, *La cabaña circular en el mundo tartésico. Consideraciones sobre su uso como indicador étnico*, «Zephyrus», 51, 277-288.

Kappraff J. 2002, *Beyond Measure*, Singapore, World Scientific Publishing.

Kent S. 1990, *A cross-cultural study of segmentation architecture and the use of space*, in S. Kent (ed.), *Domestic Architecture and the Use of Space*, Cambridge, Cambridge University Press, 127-152.

McGuire R.H., Schiffer M.B. 1983, *A theory of architectural design*, «Journal of Anthropological Archaeology», 2, 277-303.

O'Connor B. 1980, *Cross-Channel Relations in the Later Bronze Age*, Oxford, BAR International Series 91.

Parker Pearson M., Richards C. 1994, *Architecture and order: Spatial representation and archaeology*, in M. Parker Pearson, C. Richards (eds.), *Architecture and Order. Approaches to Social Space*, London, Rouletdge, 38-72.

Rapoport A. 1990, *Systems of activities and systems of settings*, in S. Kent (ed.), *Domestic Architecture and the Use of Space*, Cambridge, Cambridge University Press, 9-20.

Robbins M. 1966, *House types and settlement patterns: an application of ethnology to archaeological interpretation*, «Minnesota Archaeologist», 28, 3-35.

Ruíz-Zapatero G., Martín-Hernández M., Lorrio-Alvarado A.J. 1986, *Casas redondas y rectangulares de la Edad del Hierro: aproximación a un análisis comparativo del espacio doméstico*, «Arqueología Espacial», 9, 79-101.

Sokal R.R., Rohlf F.J. 1982, *Biometry*, New York, W.H. Freeman, 3rd ed.

Steadman S.R. 2000, *Spatial patterning and social complexity on prehistoric Anatolian tell sites: Models for mounds*, «Journal of Anthropological Archaeology», 19, 164-199.

Suárez *et al.* 1996, *Aproximación a la dinámica de la población del litoral occidental malagueño durante la Antigüedad: Protohistoria*, in F. Wulff, G. Andreotti (eds.), *Historia Antigua de Málaga y su Provincia*, Málaga, Arguval Ed., 177-187.

Van Dyke R.M. 1999, *The Chaco connection: Evaluating Bonito style architecture in outlier communities*, «Journal of Anthropological Archaeology», 18, 471-506.

Venables W.N., Ripley B.D. 2002, *Modern Applied Statistics with S*, New York, Springer.

Wilkins H. 2009, *Transitional change in proto-buildings: A quantitative study of thermal behaviour and its relationship with social functionally*, «Journal of Archaeological Science», 36, 150-156.

ABSTRACT

Architectural design constitutes an important source of information for the study of prehistoric societies. In the protohistoric period, an architectural evolution took place in western Andalusia (Spain): the change from rounded to rectangular huts, and a new evolution to more complex houses formed by rectilinear thick walls and others less thick to shape small rooms. This paper analyses the metric and geometric features of the Acinipo protohistoric settlement (Ronda, Málaga, Andalusia) to determine the main architectural pattern in each construction phase. These analyses emphasize the evolution in the design from rounded huts to rectangular ones, but this type of construction returns to its origins with the more recent circular and elliptical huts. The comparison between these features reflects the similarities and differences arising over time in the settlement. Geometrically, regular shapes such as circles, ellipses and rectangles, as well as the orthogonality and parallelism concepts, were applied to the design and building of dwellings. Therefore, the individual huts were aligned to form a regular structure of the town, maintaining the surface area through time. The results provide evidence that geometry constitutes one of the most important multicultural symbols in the world of the architecture and its evolution shows the evolution of society.