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THE VEGETATION FROM THE GUADIX-BAZA (GRANADA, SPAIN) DURING THE COPPER AND BRONZE AGES BASED ON ANTHRACOLOGY

1. INTRODUCTION

Vegetal carbon is present at most archaeological sites, especially from sedentary times and the beginning of agriculture, even in desert and subdesert regions such as the southeastern Iberian Peninsula. Given that in all the periods the primary material for combustion has been wood (other combustible materials have been manure, straw, bamboo, etc.), a woody-plant supply was fundamental to the economy. Almost all the remains of these woody plants, which we have found in the form of vegetal carbon, come from trees and shrubs available in the surroundings of the sites. Inferences, therefore, can be made regarding the palaeo-vegetation of the environment during the time of the occupation.

The identification of botanical remains in archaeological contexts dates from the middle of the 19th Century. In the southeastern Iberian Peninsula the first references concerning vegetal remains are for the Cueva de los Murciélagos (GONGORA 1868), referring to fabrics, poppy seeds (*Papaver somniferum*), items made of esparto (*Stipa tenacissima*), and various objects made of oak (*Quercus* sp.). Later, at Copper- and Bronze-Age sites, the Siret brothers excavated a great number of seeds, vegetal fibers (such as esparto and flax) and remains of wood and carbon (SIRET, SIRET 1890).

In the present century, the recovery of vegetal remains from archaeological excavations on the Iberian Peninsula continues to be meager and without palaeo-ecological inferences. In Spain the identification of wood and vegetal carbon did not begin until the 1980s, although in other parts of Europe the first analyses were made at the end of the last century and the beginning of this: Switzerland (HEER 1866), Germany (PREJAWA 1896), France (BREUIL 1903), and Hungary (HOLLENDONNER 1926).

Not until the 1950s or 60s did interest in vegetal carbon strengthen with the use of ^{14}C radiocarbon dating and with the development of new excavation methods. Afterwards, the development of new techniques for examining carbon (WESTERN 1963, 1971; STIEBER 1967; VERNET 1973), with the abandonment of the thin layers and the use of the reflexion microscope, offered new reliability, speed, and efficiency for studying the numerous samples. Since this time, anthracological studies have proliferated in the United States, the Near East, and the Mediterranean region, including northern Portugal and Spain.

All these studies showed anthracology to be a useful palaeo-ecological discipline, and in fact many researchers insist on such data for a palaeo-ethnobotanical interpretation.

2. METHODS

The appearance and frequency of a specific taxon at archaeological sites depends on various factors: the degree of carbonization, the technique of collecting samples during excavation, the selection of the species by the prehistoric man, the frequency and availability of the different trees and shrubs in nature during ancient times, etc. This last factor is perhaps the most important to evaluate. To address these problems of representation, we have proceeded both in the field and in the laboratory as follows:

2.1 *Method followed at the archaeological site*

The carbon found at archaeological sites may appear in various forms, and therefore in each case the collection of samples required a specific treatment:
a) *Direct collection of materials* – all visible artifacts and vegetal materials were collected and numbered either by piece or by lot.
b) *Screening of sediments* – the soil or mineral sediment recovered in the excavation was screened by sifting with various grid sizes, depending on the materials to be collected.
c) *Flotation* – the carbonizations of organic material reduces the density and thereby encourages flotation, whereas the other materials, having greater density, sink; thus, using the principle of differential density, we submerged samples in water to separate the carbonized elements.

2.2 *Method followed in the laboratory*

a) *Taxon determination.* The study of a fragment of vegetal carbon first requires three planar orientations: transverse, longitudinal-tangential and longitudinal-radial. Each of these orientations allows the identification of particular elements of the internal structure of the wood, where form, size and disposition vary according to the species. The carbon fragments are identified by comparison with various atlases of wood anatomy (e.g. GEGUSS 1959; HUBER, ROUSCHAL 1954; JACQUIOT 1975; JACQUIOT *et al.* 1973; SCHWEINGRUBER 1978) and with a reference collection of present-day carbonized wood. Many Mediterranean woody taxa can be identified to the species level, although in some cases only the genus can be determined, as in *Juniperus, Erica, Cistus* and *Acer* (HEINZ *et al.* 1988).

b) *Determination of the analysis units.* There are two basic analysis units:
– *Determination of the spatial-scale unit:* the ethnological and ecological inferences from the anthracological analysis vary according to the scale used in the study. The studies can be of micro scale (comparing different zones

within a site), of semi-micro scale (comparing results from different sites of the same district) or of macro scale (comparing results from a broad region).
– *Determination of a temporal-comparison unit:* the definition of a temporal unit varies in relation to the questions posed at each site. There is no definite minimum temporal unit which enables us to make simple correlations between the sites. These limits, unclear in many cases, can be defined by radiocarbon dating, especially for recent prehistory, facilitating correlations between the different regional sequences. In the present work, we used ^{14}C data for correlation.

c) *Determination of the units of measurement.* Anthracology has used the number of carbon fragments as the base for the quantitative study, from which the palaeo-ecological data have been inferred. Although this unit of measurement (the fragment) has been questioned by some researchers, who believe vegetal biomass best represents the relative importance of the different species at the same level (CASTELLETTI 1975; KRAUSS-MARGUET 1981; THINON1979), in the present work the fragment has been used as the unit of measurement, or unit of comparison, following the terminology of CHABAL (1991,47).
d) *Determination of the sample.* The great number of carbons at some archaeological sites require making a selection from the total sample, using the following methods:
– *Random division of the sample:* generally, once the sample is divided into four parts, a sample is selected at random (WILCOX 1974), or a handful of carbon samples is gathered, in which there is a range of sizes and forms (MILLER 1985).
– *Systematic study of the first samples or lots:* the present study enabled us to draw taxonomic curves, or using the terminology of CHABAL (1991, 103), the effort-return curve, in which the point of inflexion indicates the number of identifications necessary to find all the taxa of a sample. If the curves of different samples are similar, then the number of fragments identified at the point of inflexion determines the number to study in the remaining samples. The percentage curve is used to find the point at which a population quantitatively stabilizes (BADAL 1988).

2.3 *Botanical studies*

Present-day vegetation has been studied according to the phyto-sociological method of the Zurich-Montpellier school; the bio-climate, biogeography and the vegetal dynamics have been established on the basis of our own studies (VALLE, GÓMEZ-MERCADO 1990) and those of RIVAS MARTINEZ (1987 and 1990) and RIVAS MARTINEZ *et al.* (1992).

2.4 *Correspondence Analysis*

Correspondence analysis is a multi-variant technique of analysing data, which, though originally conceived to study contingency tables, other researchers have applied to wider contexts: complete disjunctive tables, qualitative variables, multi-state qualitative variables, binary tables, etc. (ESCOFIER PAGÉS 1988). The objectives of correspondence analysis are to obtain a typology of units, a typology of variables and to relate both typologies, breaking the link between variables (and between units) in a sum of simple and interpretable tendencies – that is, to obtain information of the "system of associations" (sic.) between the elements belonging to two groups (GREENACRE 1984).

From a mathematical perspective, correspondence analysis extends other multi-variate analyses (Analysis in Principal Components, Multidimensional Scaling) to quantitative data, even when the differences between these are substantial (KRZANOWSKI 1988).

The statistical foundation is the following: let a group of data be defined by two qualitative variables **I** and **J**, and the values $\mathbf{k}_{ij}$, which quantify the number of times that the category **iŒI** and the category **jŒJ** are observed simultaneously in the group. The raw data is transformed into profiles dividing each $\mathbf{k}_{ij}$, of the line i (or column j) by its marginal frequency $\mathbf{f}_{i.}$ (or $\mathbf{f}_{.j}$); in this way, each line (column) of the table is transformed into a profile which can be represented in space $\mathbf{R}^{j}$ (each column in space $\mathbf{R}^{i}$) and, using the statistical chi-square to define a distance between line (column) profiles according to:

$$d_x(\textit{línea, línea } l) = \sum_j \frac{1}{f_{.j}} \left(\frac{f_{ij}}{f_{i.}} - \frac{f_{lj}}{f_{l.}} \right)^2$$

$$dx(\textit{columna } j, \textit{ columna } k) = \sum_j \frac{1}{f_{i.}} \left(\frac{f_{ij}}{f_{.j}} - \frac{f_{ik}}{f_{.k}} \right)^2$$

(BENZECRI 1973).

Given that the distances thus defined have the properties of a Euclidean distance (ESCOFIER, PAGÉS 1988), these give R^{I} and R^{J} a structure of Euclidean space. The following process is already geometric and consists of finding the sub-spaces defined by the principal axes which maximize the inertia between the cloud of points; that is, the spatial variation with respect to the centroids of the file and column profiles (GREENACRE 1984; JAMBU, LEBEAUX 1983), thus obtaining their own values, inertia axes, unit inertias and subject variables at the hyper-plane and each axis, contribution of units and variables subject to the hyper-plane and to each axis, principal planes, groups, etc. These mathematical results, in a overall sense, must be interpreted according to the particular context in order to obtain reliable and rigorous conclusions.

3. THE ARCHAEOLOGICAL SITES AND PRESENT-DAY VEGETATION

3.1 *The archaeological sites*

The sites studied (Table 1) span the second half of the third millennium and virtually all the second millennium BC (2500 to 1400 BC), a period marked in southeastern Spain by the successive development of important cultures: The Los Millares Culture (2500 to 1800 BC), at the sites of El Malagón and the first two phases of Cerro de la Virgen (I-II); and the Argar Culture, within the framework of the Middle Bronze Age (1700 to 1400 BC), at the sites of Castellón Alto, Fuente Amarga, Loma de la Balunca and Terrera del Reloj. Between the two ages, the Early Bronze Age occurred, with chronological variation in the different zones and characteristics of a prelude to the following stage. Thus, in the upper strata of Cerro de la Virgen (III) we found evidence of the acculturation of the populations of the Los Millares Culture, which adopted the rituals and the Argaric typology, although conserving the earlier socio-economic structure.

These sites belong to a natural district within eastern Andalusia, the Guadix-Baza Basin, in the north of the province of Granada. This is one of the basins in High Andalusia forming the so-called Intrabetic trough, running in a rough diagonal between the Sierra Nevada and the Sierra de Baza to the South and southeast, and the Subbetic chains to the northeast and southeast (Fig. 1).

3.2 *The present-day vegetation*

Most of the archaeological sites studied here are at the upper meso-Mediterranean bio-climatic level, with an Ti (thermal index) of 257 to 210, and a semi-arid to dry umbro-climate (P 350-400; P = precipitation); biogeographically, the zone pertains to the Guadiciano-Baztetano sub-sector (Guadiciano-Bacense sector, Betic Province). The dominant vegetation association in the *Rhamno-lycioidis-Querceto cocciferae S.*, which in the Betic zone appears with *Ephedra fragilis*.

At present, the entire Baza Basin shows a high degree of desertification, having a vegetation characteristic of the last stage of regression (Patizal) of the meso-Mediterranean communities, with *Stipa tenacissima, Lygeum spartum* and *Brachypodium ramosum* as representative bio-indicators of the association cited above.

Fig. 2 provides a catena of the vegetation in this region and situates the different sites in their bio-climatic and syn-dynamic contexts. In the centre of the zone, along a band situated on both sides of the Orce-Galera River, the salt and gypsum content is extremely high in some Tertiary loams, and halophilous vegetation is prominent (ESTEVE, VARO 1975).

4. THE APPLICATION OF CORRESPONDENCE ANALYSIS TO THE ANTHRACOLOGICAL STUDY OF THE ARCHAEOLOGICAL SITES OF GUADIX-BAZA

The distribution analysis of the taxa from the sites shows that the information can be summarized by three factors, which carry 43.27%, 25.12% and 11.12%, respectively (79.50% in total); the first two factors are mark-

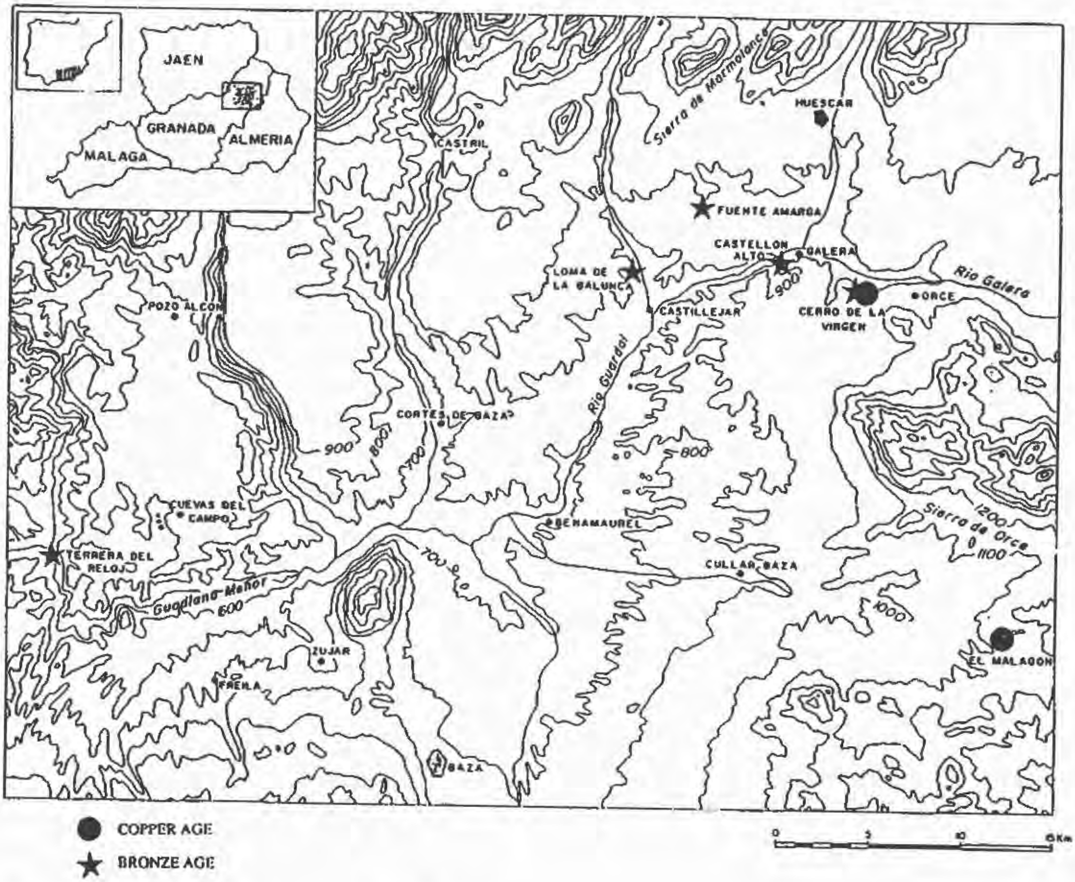


Fig. 1 – Plan of the Depression of Baza showing sites.

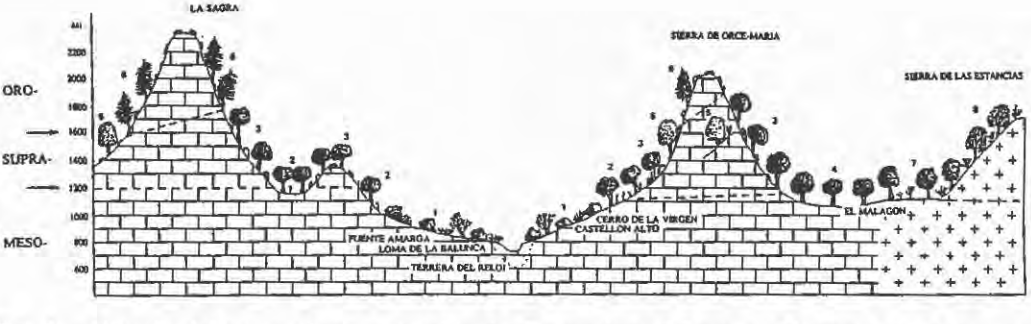


Fig. 2 – Altitudinal Catena of vegetation for the Depression of Baza (1. *Rhamno lycioid-Querceto cocciferae sigmetum*; 2. *Paeonio-Querceto rotundifoliae sigmetum*; 3. *BerbeAdi hispanicae-Querceto rotundifoliae*; 4. *Buplellro-Querceto rotundifolias sigmetum*; 5. *Daphno latifoliae-Acereto granatensis*; 6. *Daphno oleoidi-Pineto sylvestris sigmetum*; 7. *Adenocarpo decorticanti-Querceto rotundifoliaesigmetum*; 8. *Adenacarpo-Querceto pyrenaicae sigmetum*).

CULTURAL SEQUENCE		COPPER AGE				EARLY B. A.		MIDDLE BRONZE AGE							
SITES		**El Malagón**		**C. Virgen I-II**		**C. Virgen III**		**Castellón Alto**		**Fuente Amarga**		**Loma Balunca**		**Terrera Reloj**	
TAXONES		Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%	Nº	%
Pinus halepensis	(PHA)	65	35.44	145	24.81	531	48.09	1840	53.89	281	62.16	558	66.24	848	63.04
Pinus nigra	(PNI)	-	-	-	-	-	-	34	1.00	13	2.87	-	-	1	0.08
Pinus sylvestris	(PSY)	-	-	-		-	-	1	0.05	-	-	-	-	-	-
Pinus nigra-sylvestris	(PNS)	-	-	-		-	-	15	0.14	9	1.99	2	0.24	8	0.59
Pinus sp.	(PSP)	8	0.43	3	0.15	-	-	5	0.16	8	1.77	1	0.12	4	0.29
Juniperus sp.	(JSP)	-	-	-	-	-	-	7	0.23	-	-	-	-	1	0.08
Quercus ilex-coccifera	(QIC)	807	43.73	1111	51.45	349	31.61	338	9.92	87	19.34	84	9.97	64	4.75
Quercus faginea	(QFA)	83	4.49	14	0.64	35	3.17	32	0.94	1	0.23	21	2.49	4	0.29
Quercus suber	(QSU)	7	0.38	-	-	-	-	7	0.23	-	-	1	0.12	1	0.08
Quercus caducifolios	(QHC)	61	3.3	2	0.1	1	0.1	1	0.05	5	1.1	-	-	1	0.08
Acer sp.	(ASP)	-	-	-	-	-	-	-	-	1	0.23	1	0.12	-	-
Atriplex halimus	(ATH)	-	-	-	-	-	-	117	3.14	-	-	-	-	-	-
Cistus sp.	(CIS)	83	4.51	25	1.15	29	2.62	4	0.14	-	-	-	-	1	0.08
Crataegus sp.	(CRS)	-	-	1	0.05	-	-	-	-	-	-	-	-	-	-
Ephedra sp.	(EPS)	-	-	4	0.2	-	-	19	0.56	-	-	-	-	2	0.16
Cf. *Erica* sp.	(ERS)	1	0.06	-	-	-	-	-	-	-	-	-	-	-	-
Juglans regia	(JUR)	-	-	1	0.05	-	-	-	-	-	-	-	-	-	-
Leguminosae	(LEG)	12	0.65	75	3.47	40	3.62	65	1.91	32	7.07	61	7.24	136	10.11
Monocotiledoneae	(MON)	-	-	-	-	-	-	22	0.65	-		-	-	-	-
Phyllirea sp.	(FIS)	-	-	1	0.05	-	-	1	0.05	-	-	-	-	-	-
Pistacia lentiscus	(PIL)	-	-	27	1.25	10	0.9	2	0.08	-	-	-	-	-	-
Rhamnus sp.	(RSP)	-	-	7	0.32	4	0.36	-	-	-	-	-	-	-	-
Rhamnus-Phillyrea	(RPH)	-	-	2	0.1	-	-	-	-	-	-	-	-	-	-
Retama sp.	(RES)	-	-	-	-	-	-	124	3.64	-	-	-	-	-	-
Rosaceae	(ROC)	-	-	2	0.1	-	-	-	-	-	-	-	-	-	-
Rosmarinus officinalis	(ROO)	10	0.54	136	6.29	71	6.43	124	3.64	3	0.67	-	-	16	1.18
Spartium junceum	(SPJ)	-	-	-	-	-	-	1	0.05	-	-	-	-	-	-
Stipa tenacissima	(STT)	-	-	-	-	-	-	8	0.24	-	-	-	-	-	-
Cf. *Alnus* sp.	(ALG)	-	-	-	-	-	-	-	-	-	-	-	-	1	0.08
Fraxinus sp.	(FSP)	1	0.06	15	0.69	3	0.28	8	0.24	-	-	2	0.24	1	0.08
Nerium oleander	(NEO)	-	-	-	-	-	-	-	-	-	-	-	-	1	0.08
Populus sp.	(POS)	42	2.27	2	0.1	-	-	117	3.43	-	-	1	0.12	25	1.85
Salix sp.	(SAS)	7	0.37	1	0.05	1	0.1	18	0.53	3	0.67	101	12	13	0.96
Salix-populus	(SAP)	12	0.65	-	-	-	-	3	0.1	-	-	1	0.12	-	-
Sambucus sp.	(SBS)	2	0.12	3	0.15	-	-	-	-	-	-	-	-	-	-
Tamarix sp.	(TAS)	3	0.18	86	3.98	3	0.28	420	12.31	-	-	1	0.12	198	14.72
Vitis sp.	(VIS)	-	-	-	-	-	-	-	-	1	0.23	-	-	-	-
Undetermined	(IDT)	1	0.06	12	0.55	7	0.63	18	0.53	-	-	-	-	2	0.16
Indeterminable	(IDB)	51	2.76	93	4.3	20	1.81	63	1.85	8	1.77	7	0.83	14	1.04
Nº CHARCOAL FRAGMENTS		1845	100	2159	100	1104	100	3414	100	452	100	842	100	1345	100
Nº OF TAXA		16		21		12		26		12		13		21	

Table 1 – Absolute and relative frequencies of taxa identified at Bronze Ages sites in the Depression of Guadix-Baza with abbreviations used in the text.

edly significant, given that Factor 3 carries only half of the inertia of Factor 2 and a quarter of the inertia of Factor 1 (Table 2c). As a result, the analysis centres both on summarizing the distribution in a tridimensional space which contains 79.50% of the total information, and, in this space, on considering the bidimensional hyper-plane formed by Factor 1 and 2.

With respect to the tridimensional hyper-plane, the sites of Castellón Alto (CA) and Loma de la Balunca (LB) carry the most relative inertia, although Cerro de la Virgen I-II (CVA), El Malagón (MA) and Terrera del Reloj (TR) are also quite important, Cerro de laVirgen III (CVB) offering the least inertia to the

Nº	Var	QLT	WEIG	INR	1•F	COR	CTR	2•F	COR	CTR	3•F	COR	CTR
1	CVIII	499	143	60	340	494	62	-29	4	4	-5	1	7
2	CA	928	143	192	-479	301	120	654	560	366	226	67	110
3	FA	758	143	100	-139	49	12	-260	171	61	-461	537	439
4	LB	977	143	190	-431	248	98	-663	585	377	328	143	225
5	TR	721	143	142	-582	600	176	162	47	25	-203	73	90
6	CVI	755	143	162	668	695	232	188	55	33	-49	4	12
7	MA	669	143	157	620	619	157	-50	5	5	164	44	62

a

	CVIII	CA	FA	LB	TR	CVI	MA
FACTOR 1	-0.378	-0.377	-0.378	-0.378	-0.378	-0.378	-0.378
FACTOR 2	0.260	-0.365	-0.106	-0.329	-0.443	0.510	0.473
FACTOR 3	-0.029	0.654	-0.260	-0.663	0.162	0.188	-0.050

b

	Eigenvalues	% Variance	% Accumulated var.
FACTOR 1	0.246	43.266	43.266
FACTOR 2	0.143	25.120	63.386
FACTOR 3	0.063	11.120	79.506

c

Table 2 –Correspondence analysis of the sites in the Baza Depression: a) contribution of variables; b) eigenvectors; c) eigenvalues and variance.

distribution and being substantially less represented in the tridimensional space.

With regard to the taxa, those most influencing the determination of the tridimensional space are *Tamarix* sp. (TAS), *Salix* (SAS), *Quercus ilex-coccifera* (QIC), and *Pinus halepensis* (PHA) (all together these determine 55.3% of the total inertia). The most significant are *Pinus halepensis* and *Quercus ilex-coccifera*.

4.1 *Factor 1*

This factor, determined by the 43.27% of the total variance (Table 2c), derives from the sites Cerro de la Virgen I-II and E1 Malagón, on the one hand, and, on the other, forming two clearly determined groups (Fig. 3) constituted by:

TR, CA, LB and FA--------------CVIII, MA and CVI

very different from one another in terms of taxa and the appearance frequency of these taxa.

The differentiation between the two groups is based on the predominant types in one group or the other, and even exclusivity in one of the groups; therefore, the type and the frequency of taxon appearance at a site determines the association of the taxon with the group defined by Terrera del Reloj or with the group defined by Cerro de la Virgen I-II and El Malagón.

Within these general groups, it is necessary to specify that Fuente Amarga is associated less with Terrera del Reloj than with Castellón Alto and Loma de la Balunca in terms of Factor 1, due to the fact that over half of the taxa (25) do not appear in the Fuente Amarga group and those which do appear show rather small frequencies in almost all the species except *Pinus halepensis* and, to a lesser degree, *Quercus ilex-coccifera*. Similarly, the association of Cerro de la Virgen III with E1 Malagón is of lesser intensity than that of

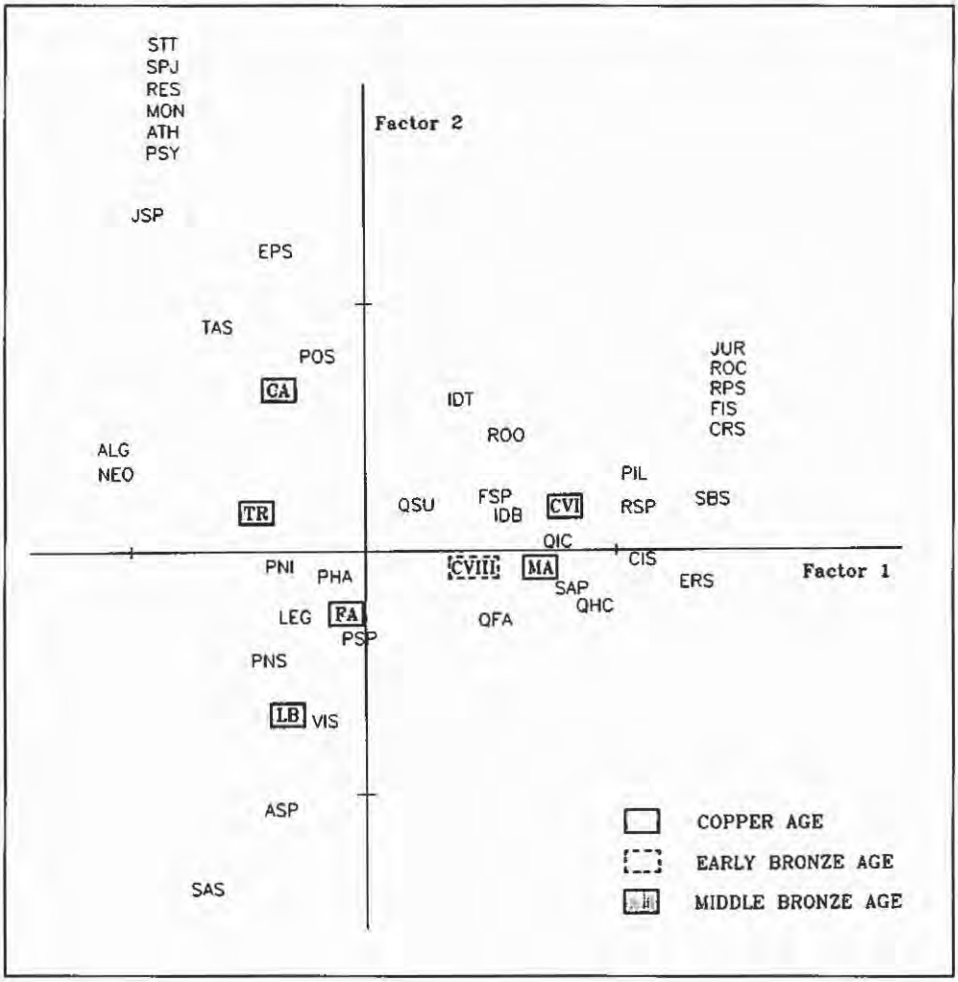
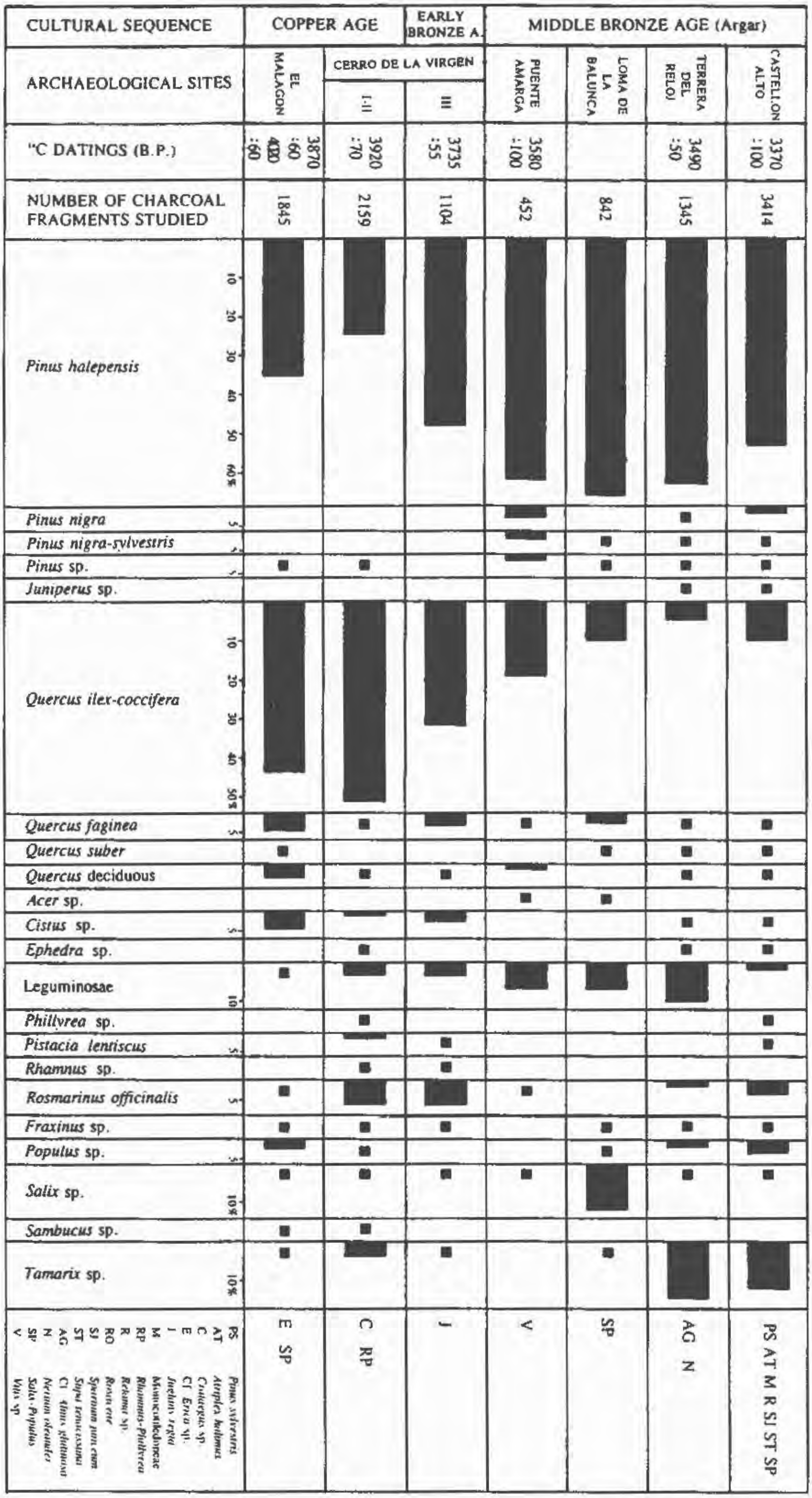


Fig. 3 – Correspondence analysis of the settlements of the Depression of Guadix-Baza. Factors 1 and 3.

Nº	Var	QLT	WEIG	INR	1›F	COR	CTR	2›F	COR	CTR	3›F	COR	CTR
1	PHA	942	506	73	-256	807	126	-98	119	33	-36	16	14
2	PNI	474	6	32	-472	71	7	-53	1	3	-1121	401	92
3	PSY	790	1	1	-967	157	2	1732	499	4	900	135	7
4	PNS	816	5	19	-538	116	7	-437	77	8	-1246	622	86
5	PSP	622	5	14	-121	9	2	-346	65	6	-1003	547	57
6	JSP	963	1	3	-1021	313	4	1396	585	8	459	64	7
7	QIC	982	245	205	682	978	430	34	3	5	4	1	6
8	QFA	664	18	24	422	234	14	-269	95	11	505	335	60
9	QSU	384	2	3	67	4	2	212	34	3	676	345	12
10	QHC	260	7	34	820	242	19	-218	17	5	21	1	6
11	ASP	677	1	3	-482	82	2	-1054	391	7	-758	203	10
12	ATH	790	5	48	-967	156	18	1732	499	86	900	135	50
13	CIS	663	13	38	1031	602	51	6	1	3	322	59	21
14	CRS	353	1	1	1348	304	2	497	42	3	-194	7	6
15	EPS	895	2	5	-500	117	3	1237	714	15	365	63	8
16	ERS	337	1	1	1250	261	2	-132	3	3	654	72	6
17	FIS	353	1	1	1348	304	2	497	42	3	-194	7	6
18	LEG	790	49	36	-411	413	33	-251	154	22	-302	223	60
19	MON	790	1	10	-967	156	5	1732	499	20	900	135	15
20	PIL	471	4	14	998	425	14	310	41	5	-84	4	6
21	RSP	418	1	5	998	397	6	194	15	3	-102	5	6
22	RPS	353	1	2	1348	304	3	497	42	3	-194	7	6
23	RES	790	6	56	-967	156	20	1732	499	99	900	135	57
24	ROC	353	1	2	1348	304	3	497	42	3	-194	7	6
25	ROO	471	27	44	452	223	23	475	247	40	5	1	6
26	JUR	353	1	1	1348	304	2	497	42	3	-194	7	6
27	SPJ	790	1	1	-967	156	2	1732	499	4	900	135	7
28	STT	790	1	4	-967	156	3	1732	499	9	900	135	9
29	ALG	370	1	2	-1174	230	2	429	31	3	-807	109	7
30	FSP	311	3	4	417	197	3	216	53	4	229	60	7
31	NEO	370	1	2	-1174	230	2	429	31	3	-807	109	7
32	POS	471	27	44	-337	84	7	807	478	48	414	126	29
33	SAS	936	21	139	-795	170	52	-1377	509	249	978	257	249
34	SAP	357	2	7	703	158	4	-142	7	3	772	191	15
35	SBS	704	1	2	1305	670	4	218	19	3	183	14	6
36	TAS	837	46	136	-744	326	96	929	509	244	-42	2	7
37	VIS	656	1	4	-280	14	2	-688	80	4	-1835	563	19
38	IDT	547	3	5	284	90	3	624	434	10	139	22	7
39	IDB	803	21	11	436	681	17	182	119	7	-28	3	6

Table 3 – Correspondence analysis of the sites in the Baza Depression: contribution of elements.

Fig. 4 – Anthracological histogram of the settlements from the Copper and Bronze Ages in the Depression of Guadix-Baza (on the opposite page).


CULTURAL SEQUENCE
COPPER AGE
EARLY BRONZE A.
MIDDLE BRONZE AGE (Argar)
ARCHAEOLOGICAL SITES
EL MALAGON
CERRO DE LA VIRGEN
I-II
III
PUENTE AMARGA
LOMA DE LA BALUNCA
TERRERA DEL RELOJ
CASTELLON ALTO
¹⁴C DATINGS (B.P.)
3870 :60 4020 :60
3920 :70
3735 :55
3580 :100
3490 :50
3370 :100
NUMBER OF CHARCOAL FRAGMENTS STUDIED
1845
2159
1104
452
842
1345
3414
Pinus halepensis
10
20
30
40
50
60%
Pinus nigra
5
Pinus nigra-sylvestris
5
Pinus sp.
5
Juniperus sp.
Quercus ilex-coccifera
10
20
30
40
50%
Quercus faginea
5
Quercus suber
Quercus deciduous
Acer sp.
Cistus sp.
5
Ephedra sp.
Leguminosae
10
Phillyrea sp.
Pistacia lentiscus
5
Rhamnus sp.
Rosmarinus officinalis
5
Fraxinus sp.
Populus sp.
5
Salix sp.
10%
Sambucus sp.
Tamarix sp.
10%
PS Pinus sylvestris
AT Atriplex halimus
C Crataegus sp.
E Cf. Erica sp.
J Juglans regia
M Monocotyledoneae
RP Rhamnus-Phillyrea
R Retama sp.
RO Rosa cf.
SJ Spartium junceum
ST Stipa tenacissima
AG Cf. Alnus glutinosa
N Nerium oleander
SP Salix-Populus
V Vitis sp.
E SP
C RP
J
V
SP
AG N
PS AT M R SJ ST SP

Cerro de la Virgen I-II with E1 Malagón, given that over half the taxa (25) do not appear, and those that do show a high frequency in Cerro de la Virgen III but low in El Malagón or vice versa – *Salix* sp., *Tamarix* sp., Undetermined (IDT), *Cistus* sp. (CIS), *Rosmarinus officinalis* (ROO). In addition, there is a certain number of species which appear at E1 Malagón or in Cerro de la Virgen I-II, or in both, but not at Cerro de la Virgen III – *Sambucus* sp. (SBS), *Phillyrea* sp. (FIS), *Crataegus* sp. (CRS), *Juglans regia* (JUR), *Rhamnus-Phillyrea* (RPS), Rosaceae (ROS), *Salix-Pupulus* (SAP), *Quercus suber* sp. (QSU), *Pinus* sp. (PSP), *Populus* sp. (POS) and *Ephedra* sp. (EPS).

The considerations above determine a gradient between the sites, which, maintaining the general format cited earlier, takes the form:

Taxa exclusive or nearly so to TR y CA	Taxa abundant in or exclusive to LB, FA, TR o CA	Taxa very abundant in CVB y CVA o MA	Taxa exclusive to CVA
Alnus glutinosa	*Salix* sp.	Undetermined	*Rhamnus* sp.
Nerium oleander	*Tamarix* sp.	*Fraxinus* sp.	*Erica* sp.
Pinus sylvestris	*Leguminosae*	*Quercus faginea*	*Sambucus* sp.
Spartium junceum	*Populus* sp.	Indeterminable	*Crataegus* sp.
Stipa tenacissima	*Pinus halepensis*	*Rosmarinus officinalis*	*Phillyrea* sp.
Monocotiledoneae	*Pinus* sp.	*Quercus ilex-coccifera*	*Juglans regia*
Atriplex halimus		*Salix-Populus*	*Rhamnus-Philly*
Retama sp.	*Pinus nigra-sylvestris*	*Quercus deciduous*	*Rosaceae*
Juniperus sp.	*Ephedra* sp.	*Pistacia lentiscus*	
	Acer sp.	*Cistus* sp.	
	Pinus nigra		
	Vitis sp.		

The end sites on the gradient (Terrera del Reloj, on the one hand, and Cerro de la Virgen I-II on the other) show a great quantity of taxa, although those which appear at one end do not occur at the other, or the frequency has an opposite sign (taxa with great frequency in one of these sites shows little frequency in the other, and vice versa). The sites of the intermediate zone have substantially fewer taxa than have the previous (approximately half of the taxa do not appear in the zone), but approach the taxonomic characteristics one or the other end, according to the taxa contained (Fig. 5; Table 4).

4.2 *Factor 2*

This factor carries (once the effect of Factor 1 is eliminated) 25.12% of the total inertia (Table 2c) and is determined fundamentally by the sites Castellón Alto and Loma de la Balunca, very well represented in the factor and which provide the greatest part of the inertia (36.6% and 37.7%, respectively) (Table 2a and 2b); the rest of the sites appear with much less significance in relation to Factor 2. In this way, Factor 2 shows a gradient which goes from CA to LB, or vice versa and which is characterized by a clear contrast between the two sites, insisting on the presence of taxa in one and

	TR	CA	LB	FA	CVIII	MA	CVI
ALG	100						
NEO	100						
JSP	25.80	74.20					
PSY		100					
SPJ		100					
STT		100					
MON		100					
ATH		100					
RES		100					
SAS	6.54	3.60	81.70	4.56	0.68	2.52	0.34
TAS	46.60	38.97	0.38		0.88	0.57	12.60
PNS	19.90	4.73	8.11	67.23			
EPS	17.39	60.87					21.74
ASP			34.28	65.71			
PNI	2.02	25.32		72.66			
LEG	29.67	5.60	21.25	20.75	10.62	1.91	10.18
POS	23.81	44.14	1.54			29.21	1.29
VIS				100			
PHA	17.82	15.24	18.73	17.58	13.6	10.02	7.01
PSP	9.93	5.48	4.11	60.62		14.73	5.14
QSU	9.88	28.40	14.81			46.91	
IDT	8.29	27.46			32.64	3.11	28.50
FSP	5.03	15.09	15.09		17.61	3.77	43.40
QFA	2.37	7.67	20.33	1.88	25.88	36.65	5.22
IDB	7.24	12.88	5.78	12.33	12.60	19.22	29.94
ROO	6.29	19.41		3.57	34.29	2.88	33.55
QIC	2.78	5.81	5.84	11.33	18.51	25.61	30.13
SAP		11.49	13.79			74.70	
QHC	1.69	1.06		23.26	2.11	69.77	2.11
RSP					52.94		47.06
PIL		3.59			40.34		56.10
CIS	0.94	1.65			30.82	53.06	13.53
ERS						100	
SBS						44.44	55.56
CRS							100
FIS							100
JUR							100
RPS							100
ROC							100

Table 4 – Sb Taxa in each settlement ordered by Factor 1.

not appearing in the other, or vice versa. From top to bottom, the gradient is determined by the presence of taxa, and on descending the gradient the number of absences increases until reaching FA and LB, which have the greatest quantity of taxa. Together with this fact, the movement along the gradient is defined by taxa which dominate the group formed by CA and TR, and which have low frequencies in FA and LB, and vice versa, with CVA, CVB and MA marking the transition between the two tendencies. One graphic form might be as shown in Fig. 6.

Therefore, with respect to the taxa, this factor, within Groups 1 and 2 defined by Factor 1, makes a distinction between those associated with Castellón Alto and Terrera del Reloj, on the one hand, and those associated with Loma de la Balunca, on the other. This is defined in the following form:

Associated with CA and TR	Associated with LB and FA
Pinus sylvestris	*Salix* sp.
Spartium junceum	*Leguminosae*
Stipa tenacissima	*Pinus halepensis*
Monocotiledoneae	*Pinus nigra-sylvestris*
Atriplex halimus	*Acer* sp.
Retama sp.	*Pinus nigra*
Juniperus sp.	*Vitis* sp.
Tamarix sp.	*Also appearing at El Malagón*
Ephedra sp.	*Quercus faginea*
Alnus glutinosa	*Salix-Populus*
Nerium oleander	*Quercus deciduous*
Populus sp.	

4.3 *Plane 1-2*

The plane formed by Factors 1-2 (Fig. 3) is formed as the hyper-plane which carries the greatest part of the distribution inertia (63.4%), making the results markedly significant.

Plane 1-2 shows a triangular cloud with respect both to the taxa and the sites; that is, it shows a general tendency which is afterwards divided into two clearly determined and opposing branches, both for the taxa and for the sites, summarizing the characteristics shown in Factors 1 and 2 to be evaluated in the following section.

4.4 *Evaluation of the anthraco-analysis using correspondence analysis*

Correspondence analysis has provided a series of groupings of sites and associated taxa (Fig. 3), indicating two important groups of sites:

1. Cerro de la Virgen I-II, El Malagón and Cerro de la Virgen III are close in chronological/cultural attributions, the first two sites attributable to the Middle to Late Copper Age, while the third belongs to the Early Bronze Age of Cerro de la Virgen. At these sites, a group of taxa are associated exclusively

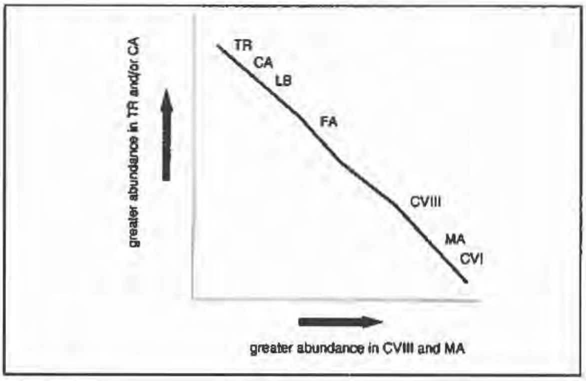


Fig. 5

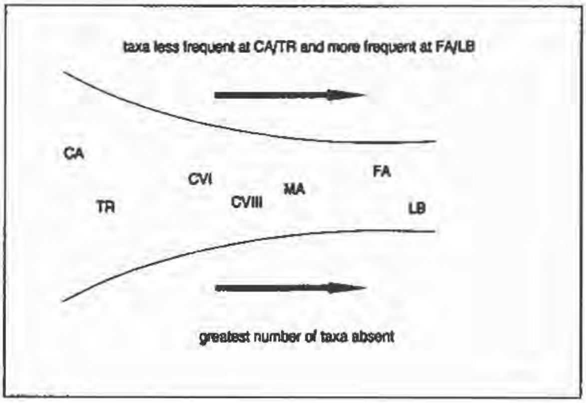


Fig. 6

with certain sites, or the appearance frequency is substantially higher than in the rest (at least in relative terms). Thus there are some taxa specific to Cerro de la Virgen I-II (*Phillyrea* sp., *Juglans regia*, *Rhamnus Phillyrea* and Rosaceae) and to E1 Malagón (*Erica* sp.), or to both (*Sambucus* sp.) and others with greater abundance in the group of the three sites than in the rest (*Cistus* sp., *Pistacia lentiscus*, *Rhamnus* sp., *Quercus* deciduous, *Salix-Populus, Quercus ilex-coccifera, Rosmarinus officinalis, Fraxinus* sp., Indeterminable, Indeterminate and *Quercus faginea*).

This group of taxa includes species of the Mediterranean forest, formed by *Quercus ilex-coccifera, Quercus faginea* and *Quercus* cf. *pyrenaica* as an arboreal layer, these two last indicating greater humidity, and of the shrubby layer are: *Crataegus* sp., *Cistus* sp., *Phillyrea* sp., Rosaceae, *Rhamnus* sp. and *Rosmarinus officinalis*, together with clearly thermophilous species such as: *Phillyrea* sp. and *Pistacia lentiscus*, indicating somewhat higher temperatures than at present. The most notable among the riverbank trees are *Sambucus* sp. and *Fraxinus* sp., which need a high phreatic level, testifying to substantial water courses in this period.

Between Group 1 and 2 is *Quercus suber*, which shows an equilibrium between the two general groups of sites and taxa.

2. This group is formed by Terrera del Reloj, Castellón Alto, Loma de la Balunca and Fuente Amarga, which have similar archaeological records, culturally attributable to the Argar Culture (Middle Bronze Age) and dating from 1700 to 1400 BC. This group contain two subgroups, defined by Factor 2 and distinctly separate and opposite from each other, with taxa and sites associated in terms of appearance frequency of the taxa:

– The group formed by Terrera del Reloj and Castellón Alto show two clearly thermophilous species, such as *Alnus glutinosa* and *Nerium oleander*, and which developed within the thermo-Mediterranean level, in possible relation to the lesser altitude of Terrera del Reloj (600 m. a.s.l.) and which appears to indicate that the thermo-Mediterranean vegetation level was not far away. The group of taxa formed by *Stipa tenacissima*, *Atriplex halimus* and *Ephedra* sp., characteristic of open or saline areas, indicate steppe zones near the sites at this time, though not with the present extension, since taxa such as *Retama* sp. and *Juniperus* sp. indicate shrubby areas of the degrading oak groves mentioned above. As in the previous group, taxa associated with the riverside appear: *Tamarix* sp., *Populus* sp. and, apparently, Monocotyledoneae (possibly *Arundo donax*) although with more xeric implications. The noteworthy member of this group, *Pinus sylvestris* (at present appearing in the Oromediterranean vegetation level; Figs. 1 and 2) occurred in Castellón Alto as construction material. This pine possibly appeared in the Sierra de Orce, Sierra de Baza and La Sagra – a straight-line distance of 10 to 40 km. from Castellón Alto, implying a search expressly for this species.

– In the group formed by Loma de la Balunca and Fuente Amarga, *Pinus halepensis* is prominent, which, together with Leguminosae, indicates a more or less open area where species from the Kermes-oak grove appear sparsely or not at all. In addition, there is a notable presence of *Pinus nigra* and *Pinus nigra-sylvestris*, which, as in the case of *Pinus sylvestris* in the previous group, here occurring nearer the settlements, at some 5 to 10 km. from the southern foothills of La Sagra and Sierra de Castril (Figs. 1 and 2). *Salix* sp. is associated with the Loma de la Balunca, used for constructing ceilings in the huts. The appearance at these sites, of taxa such as Acer sp., *Quercus faginea* and deciduous *Quercus*, with sub-humid umbroclimate demands, could indicate either firewood collection in the same micro-environment, probably in the shade of the valley floors, where there was more wetness than in the rest of the territory, or else the existence of this type of woodland in areas relatively near the sites, such as the Sierra de Segura to the north (VALLE *et al.* 1989).

The nexus of the union between the subgroups Castellón Alto/Terrera del Reloj, on the one hand, and Fuente Amarga/Loma de la Balunca on the other, is determined by such taxa as *Pinus nigra* and *Pinus halepensis*, quite abundant in all the sites and with less frequency in Group 1.

Summarizing, the general form of the gradient in the hyper-plane 1-2 is shown in Fig. 7.

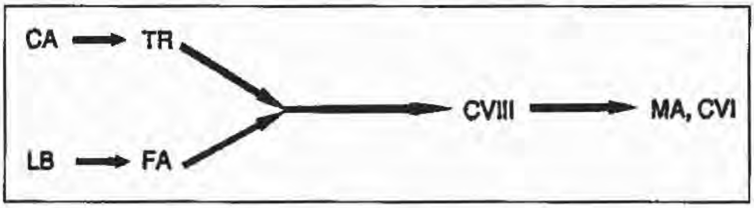


Fig. 7

5. THE PREHISTORIC VEGETATION OF THE BAZA-HUESCAR DEPRESSION

5.1 *The Chalcolithic vegetation (2500 to 1800 BC)*

The data obtained from the two sites studied from this period, El Malagón and Cerro de la Virgen I-II (Fig. 4), offer an image of the vegetation where human impact began to be felt, although each site, having different bio-climatic coordinates (Fig. 2), presents certain peculiarities.

The vegetation of the surroundings of the sites studied, during the Copper Age in the Guadix-Baza Depression, corresponded to an open wooded area of *Quercus coccifera* and *Quercus rotundifolia*, with clearings containing heliophilous shrubbery. The pine grove of *Pinus* HALEPENSIS was relegated to more or less marginal topographic positions. The bases of the massifs surrounding the Hoya de Baza (El Malagón) appears to have been wetter, since, despite the difficulty in differentiating *Quercus coccifera* from *Quercus rotundifolia*. the latter is more abundant, and mesophytic species are highly significant, such as *Quercus faginea*, *Quercus suber* and probably *Quercus pyrenaica*, these latter two taxa over siliceous substrate of the Sierra de las Estancias.

The riverbank vegetation is sparsely represented in the two sites, notable species being *Fraxinus* sp. and *Tarnarix* sp. In addition, there are *Salix* sp., *Populus* sp. and *Sambucus* sp. (Fig. 4). The archaeological and carpological data indicate a vigorous development of agriculture at this time, although not reaching the developmental rate of the following phase. Thus, it might be assumed that around the settlement the land was cultivated in strips, interspersed with natural vegetation.

5.2 *The vegetation of the Early Bronze Age (1800-1600 BC)*

The levels of the Early Bronze Age of the Cerro de la Virgen present a vegetation much more associated with that of the Copper Age than to that of the Middle Bronze Age, although the sharp decrease in the frequency of *Quercus ilex-coccifera*, concomitant with the rise of *Pinus halepensis*, which acquires greater frequencies in the following phase (Fig. 4), indicates that the degradation process of the natural vegetation was progressive and linked to the socio-economic conditions of the inhabitants of this zone.

5.3 *The vegetation of the Bronze Age (1700-1400 BC)*

The results of the anthracological study of the sites of the Bronze Age in the Guadix-Baza Depression indicate the dominance of a pine woodland of *Pinus halepensis*. In addition, all the sites contain shrub-land species typical of degradation, such as Leguminaceae, foremost, and *Rosmarinus officinalis* and *Cistus* sp., next in importance – these reflecting human impact on the environment (Fig. 4). In effect, the ploughing of the oak groves (of which remains are still found together with those of the shrub-lands) for cultivation, together with the expansion of goat and sheep husbandry, entailed the regression of the oaks and advance of the Aleppo pines and legumes. Open-ground species such as *Ephedra* sp. appear in the Terrera del Reloj, while *Atriplex halimus*, characteristic of saline soils, appears in the Castellón Alto site. Finally, *Stipa tenacissima* (esparto), dominating the driest areas, is present at all the sites, used in making cord, footwear, and baskets – these representing important crafts, though still insufficiently studied (FRESNEDA, RODRÍGUEZ-ARIZA 1992).

The Carpological studies of these sites (presently under way) reveal a quantitative and qualitative leap in agriculture at this time, with respect to the Copper Age, contributing, by the ploughing of new terrain, the degradation of the environment near the settlements.

In addition, riparian vegetation is well developed, including *Fraxinus*, *Nerium*, *Salix*, *Populus* and *Tamarix*. Apparently abundant along the rivers, this vegetation was not widely used as a wood source at these sites, except in very specific cases (e.g. for framing the roofs of huts).

The presence of thermophilous elements such as *Pistacia lentiscus*, *Phillyrea* sp., *Quercus suber* and even *Nerium oleander*, as well as mesophytic elements (*Quercus faginea*, *Quercus suber*, *Quercus pyrenaica*) now absent at the sites, suggests that the vegetation corresponded to middle to low meso-Mediterranean and that the climate then differed somewhat from the present-day climate; we postulate that the Ti could have been from 50 to 75 points higher than today, and annual precipitation higher by 100 to 200 mm (dry upper umbroclimate). This dryness is also suggested by the disappearance of species such as *Sambucus* sp. from the riverbanks.

6. CONCLUSION

The Copper Age plant association *Rhamno lycioidis-Querceto cocciferae sigmetum* present at the sites of the Guadix-Baza Basins during the Copper Age, is, based on the edaphic characteristics of the zone (and until we have further studies on the preceding period) considered by us to be potential vegetation. The association evolved in the Bronze Age towards an open shrub-land where *Pinus halepensis* attained a strong presence, favoured by agriculture and animal husbandry. With *Pinus halepensis* more abundant than *Quercus ilex-coccifera*, this plant formation did not resemble a forest, and the progressive degradation gave rise to an open shrub-land dominated by shrubby legumes, as found in the Iberian levels of Fuente Amarga (RODRÍGUEZ-ARIZA, RUIZ 1993).

The sites studied here fit within the last anthracological phase defined by Vernet and Thiébault (1987) for the western Mediterranean, which in southern France is characterized by *garrigues* of *Quercus ilex*, *Quercus coccifera* and *Buxus*, together with a strong presence of *Pinus halepensis*. In the thermo-Mediterranean zones of the Spanish Levante (Cova de Cendres and Recambra) the vegetation is represented by shrub-lands of *Rosmarino-Ericion* (BADAL 1990; BADAL *et al.* en prensa; GRAU 1984), an association represented in the Cueva de Nerja at the Neolithic levels (BADAL 1990). In Los Millares there is the association of *Querco-Lentiscetum*, with a strong presence of *Olea* and *Pistacia*, together with the shrub-lands of *Rosmarino-Ericion* (RODRÍGUEZ-ARIZA, VERNET 1991; RODRÍGUEZ-ARIZA 1992). Meanwhile, in the zones of the meso-Mediterranean level of the region of Murcia, the associations develop from the degradation of the continental Holm-oak groves (*Bupleurum rigidi-Quercetum rotundifoliae sigmetum*), as may be the case with the *Rhamnus lycioidis-Querceto cocciferae sigmetum* (GRAU 1990).

These results suggest a regional similarity in vegetation, with significant change between the Copper and Bronze Ages; in this respect, we find a gradual change at the Cerro de la Virgen. In the western Mediterranean, the beginnings of human impact on the environment differ chronologically between zones. In southern France (VERNET THIÉBAULT 1987) and the eastern Iberian Peninsula (VERNET, BADAL, GRAU 1983, 1987; BADAL 1990) this process begins in the middle Neolithic, whereas in the Ronda Basin the opening of the vegetation does not appear to occur until the beginning of the first millennium (RODRÍGUEZ-ARIZA *et al.* 1991). In view of these chronologies, the changes in the vegetation appear to be associated with different economic strategies, based fundamentally on the raising of crops and animals. Thus, the different degree of development of these activities between human communities inhabiting the different zones produces uneven impact on the vegetation. Therefore, although the influences of climatic change cannot be discarded, and until advances are made in palaeo-ecological studies of our region, we consider these influences minimal compared to human intervention in the environment.

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ABSTRACT

The data from an anthracological study of vegetal carbon from six archaeological sites in the Guadix-Bàza district (Betic province, Guadiciano-Bastetano), dating from 2500 to 1400 BC, have been submitted to Correspondence Analyses in order to define relationships between taxa, to associate taxa with the sites, and to identify patterns of species appearance.

The vegetation identified by anthraco-analysis for the Copper Age is the kermes-oak grove (*Quercus coccifera* association), probably includable in the present-day *Rhamno lycioidis-Quercetum cocciferae* association, with Aleppo-pine groves (*Pinus halepensis* community) occupying the most marginal zones. This pine grove gradually replaced the oak grove during the Bronze Age, for a variety of causes, principally anthropic, such as the cultivation of new lands, farming and the cutting of trees.

Human knowledge of plants is reflected in the uses of certain species for specific functions: construction materials for huts, firewood for the hearth and for metal working, and raw materials for making utensils. The use of materials depended on species availability and the socio-economic organization of the human communities inhabiting the southeastern Iberian Peninsula during the Copper and Bronze Ages.