MODERN CAVE POLLEN IN AN ARID ENVIRONMENT AND ITS APPLICATION TO DESCRIBE PALAEORECORDS

Cristina Navarro, José Sebastián Carrión*, A.R. Prieto**, Manuel Munuera****

RESUMEN.- **Análisis de polen moderno en cuevas con un clima árido y su aplicación para describir los paleoregistros.** *Se presentan los resultados del análisis polínico de sedimentos superficiales de dos cavidades del SE ibérico, región caracterizada por un clima relativamente árido y una vegetación principalmente entomófila. Queda confirmado el valor de la aridez para la preservación polínica en los sedimentos de cavidades kársticas, encontrándose valores elevados de concentración polínica y del número de taxones, así como bajos porcentajes de pólenes indeterminables. Los espectros polínicos de sedimentos de cuevas, aún estando fuertemente influenciados por el transporte biótico, pueden constituir un buen indicador de la vegetación que crece en los alrededores de la cavidad, incluso mejor que la propia lluvia polínica externa.*

ABSTRACT.- *This paper presents pollen-analytical results of surface sediments from two caves in southeastern Spain, a region of particular interest because of its relatively arid climate and entomophilous-dominated flora. The positive role of aridity on pollen preservation in cave sediments is confirmed, and is reflected by samples with high pollen concentration and number of taxa, and low percentages of indeterminable palynomorphs. Pollen spectra from cave sediments, while strongly influenced by biotic transport, may represent the surrounding vegetation acceptably well, even better than the external pollen rain in which is biased by very abundant production and dispersal of wind-pollinated taxa.*

PALABRAS CLAVE: *Análisis polínico, Tafonomía, Sedimento superficial, SE ibérico, Cuevas.*

KEY WORDS: *Pollen analysis, Taphonomy, Surface sediments, Southeastern Spain, Caves.*

1. INTRODUCTION

A major theoretic criticism of cave palynology undertaken to date has been the lack of studies related to the taphonomy of pollen and spores, and modern deposition in cave systems (Bottema 1975; Turner & Hannon 1988; Sánchez-Goñi 1994). This represents a major limitation to the development of cave palynology because it is evident that the models and inferences commonly employed to interpret pollen diagrams from lacustrine sites are inappropriate (Coles *et al.* 1989). In addition, caves systems are poorly known and are affected by distinct taphonomical processes, differing from those of more conventional types of depositional environments mentioned above (Coles & Gilbertson 1994). Some previous studies of modern pollen spectra in cave sites suggested that pollen deposition inside caves can provide a reliable index of the regional and local vegetation, directly comparable to the more conventional spectra derived from open sites. Most of these studies are based on the airfall pollen budget (Burney & Burney 1993; Coles & Gilbertson

* Departamento de Biología Vegetal. Facultad de Biología. Universidad de Murcia. 30100 Campus de Espinardo, Murcia, Spain. Tel: +34 968 364995. Fax: +34 968 364995. E-mail: carrion@um.es

** Laboratorio de Paleoecología y Palinología. Departamento de Biología. Facultad de Ciencias Exactas y Naturales. Universidad Nacional de Mar del Plata. Funes 3250-7600 Mar del Plata, Argentina.

*** Departamento de Producción Agraria. ETS de Ingeniería Agronómica. Universidad Politécnica de Cartagena. 30203 Cartagena, Murcia, Spain.

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1994), while several recent experiments have focused on surface sediment samples (Prieto & Carrión 1999; Navarro 2000; Navarro *et al.* 2000).

The success of cave palynology will rely upon our ability to design adequate experiments in well-selected cave systems. Here we report on pollen analyses of surface sediments from two caves in southeastern Spain. This region is of particular interest because of its relatively arid climate, and entomophilous-dominated flora. Aridity may enhance biotic preservation in cave environment (Davis 1990), and entomophily, while hampering interpretation of conventional pollen diagrams (Leyden 1985), points to biotic transport as source of palaeobiological information. Although, pollen diagrams from regional lagoons (Pantaleón-Cano *et al.* 1996) and offshore cores from the adjacent Alborán Sea (Parra 1994; Carrión *et al.* 2000; Targarona 1997), while retaining palaeoclimatic value, have been unable to provide a picture of Quaternary vegetation in the area. Contrastingly, pollen sequences from caves have provided detailed reconstructions of vegetation composition during several Pleistocene stages, but cannot be utilised to infer palaeoclimatic conditions (Carrión *et al.* 1995a, b).

2. PHYSICAL SETTING AND DESCRIPTION OF THE CAVES

Two caves have been selected with a very different morphology but common biogeographical characteristics (Fig. 1). The territory shows a number of endemics, including Ibero-North African, Mediterranean,

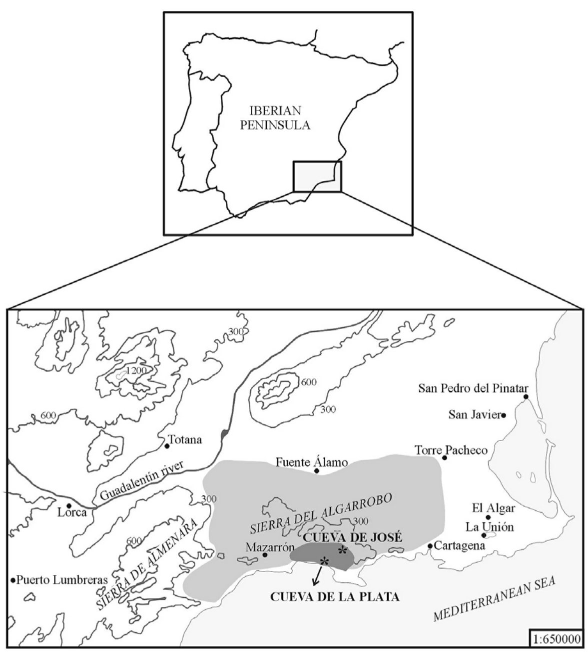

Figure 1.- Location of studied caves in Murcia province, southeastern Spain, with adopted local and regional pollen source areas (Local= dark grey, Regional= light grey).

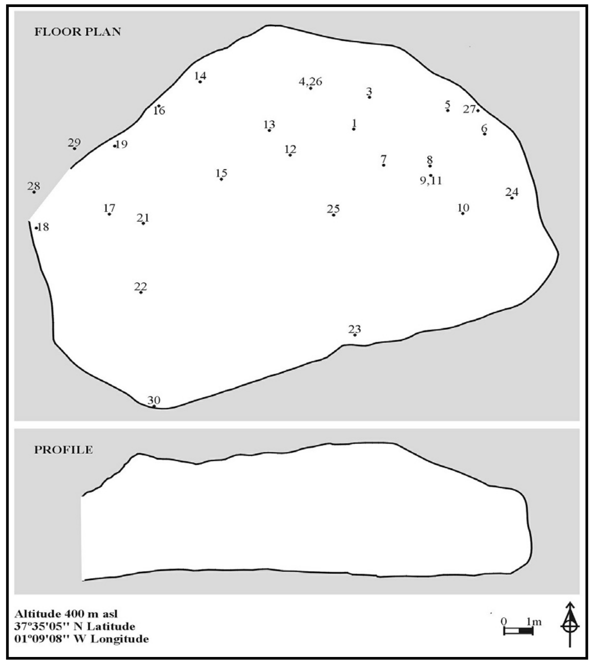

Figure 2.- Longitudinal and vertical sections of Cueva de José, with location of pollen samples.

Irano-Turanian, and southeastern Iberian elements (Sánchez-Gómez *et al.* 1998). Most of these are strictly insect-pollinated species, being eventually dominant in patchy landscapes very similar to the South African fynbos and karoo biomes (Cowling *et al.* 1997). Climate is warm and arid, with mean annual temperatures of 15-18ºC and mean annual precipitation of 190-280 mm.

Cueva de José is located in Cartagena, Murcia province (37º35'05" N, 01º09'08" W) at 400 m asl. The cave is a simple "sac" cavity consisting of a single chamber ca. 17 m deep, 14 m wide, 4 m tall, circular in cross-section (Fig. 2). It has a single circular entrance (5.1 x 4 m), facing northwest. Cave ceiling is 4-5 m tall and shows no stalactites, and the floor is mantled with fine and dry sediments containing abundant goat and boar faeces. Fallen blocks are common and sediments appear to have been removed in particular areas of the cave. Both regional and local vegetation is treeless, and characterised by xero-sclerophyllous scrub of *Pistacia lentiscus*, *Osyris quadripartita*, *Rhamnus oleoides* subsp. *angustifolia*, *Chamaerops humilis*, *Ephedra fragilis*, *Ceratonia siliqua, Olea europaea* var. *sylvestris*, *Asparagus albus,* and a number of Lamiaceae and Cistaceae species.

Cueva de la Plata is located at 116 m asl in the municipality of Mazarrón, Murcia province (37º35' 22" N, 01º12'55" W). The cavity is southeast-facing and three-entranced, with the openings on the upper top, one on the right (1.7 x 1.3 m) and one on the left (1.5 x 1.4 m), and another entrance on the lower floor (0.9 x 1.1 m). All of these entrances are connected with the only main chamber, which is narrowed reaching 30 m deep (Fig. 3). Present-day vegetation near

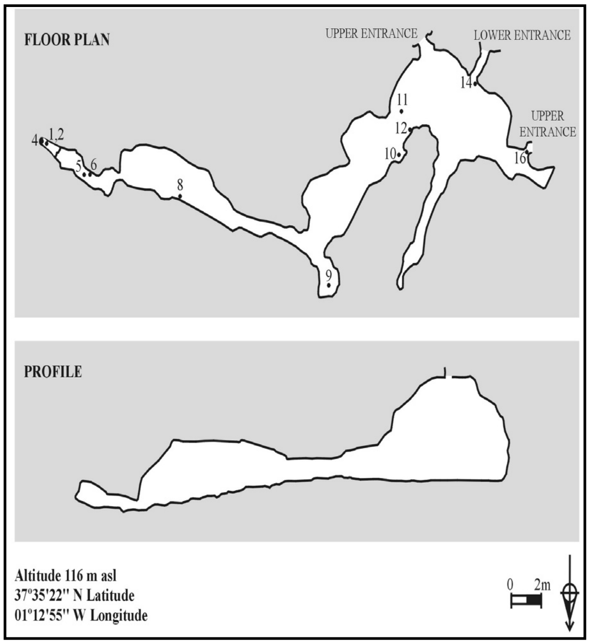

Figure 3.- Longitudinal and vertical sections of Cueva de la Plata, with location of pollen samples.

the cave is characterised by a shrubby formation with *Lavandula dentata*, *L. multifida*, *Launaea arborescens*, *Nerium oleander*, *Thymelaea hirsuta*, *Carthamus arborescens, Periploca angustifolia*, *Lygeum spartum*, *Asparagus albus*, *Euphorbia characias*, *Verbascum sinuatum*, *Artemisia barrelieri*, *Hyparrhenia hirta*, *Eryngium campestre*, *Mercurialis tomentosa*, *Foeniculum vulgare, Thymus hyemalis*, *Teucrium capitatum*, *Andryala ragusina*, *Genista umbellata* and several species of *Helianthemum* and *Fumana*.

3. MATERIALS AND METHODS

Samples of superficial floor sediment (c. uppermost 1 cm) were collected using a spatula and avoiding areas with foot prints. In addition, other kinds of samples were analysed like speleothems, spider's webs, and excrements from different animals. To study "local" pollen rain, a mixture of moss polsters and surface sediments from the vicinity of each cavity was analysed. For the "regional" pollen rain, sub-samples embraced a range of 20 km around the cave site were studied (Fig. 1). A mean weight of 5 to 15 g of dry sediment was processed in the laboratory following Girard & Renault-Miskovsky (1969). At the beginning of the processing, 5 tablets containing a known quantity of *Lycopodium clavatum* spores (12,100 spores/tablet) were added to each sample in order to facilitate concentration calculations (Stockmarr 1972). All microscopic counts used in the analysis ranged between 400 and 600 grains per sample. Identification and counting were performed using the pollen reference collection of the palynological laboratory at University of Murcia. Non-pollen microfossils follow descriptions and illustrations by van Geel *et al.* (1981, 1983, 1986, 1989) and Carrión & van Geel (1999). Pollen diagrams were elaborated using Tilia and Tilia Graph programs (Grimm 1987, 1991), in which samples are ordered according to distance from the entrance. In synthetic diagrams, samples are grouped according to sediment type and ordered according to distance from the entrance. Statistical procedures were applied using MINITAB programs. Spearman correlation coefficients were calculated in order to establish inter-variable relationships. A comparison of external and internal pollen input was made using a regression model. Finally, both were compared with plant cover values estimated from phytosociological tables (Alcaraz & Garre 1987; Alcaraz & de la Torre 1988; Alcaraz *et al.* 1989, 1991).

	Sample No.	Sample type
Interior	7,12,15,16,17,18,19,21,25,26,27	Dry floor sediment
	4,6,8,10,22,23,24	Dry sediment with dung (*)
	9,13,28,29,30	Dry sediment with organic matter (**)
	1	Wet floor sediment
	14	Wet sediment with dung (*)
	11	Bird guano
Local	31,32	Surface sediment
Regional	33,34,35,36	Surface sediment

Table 1.- Samples from Cueva de José.

4. RESULTS

4.1. Cueva de José

Twenty-six samples of floor sediment were studied (Table 1), twenty-three consisting of dry sediment, sometimes with macroscopical evidence of sheep dung (samples 4, 6, 8, 10, 22, 23, and 24), and other macroremains such as leaves, stems and roots (samples 9, 13, 28, 29, and 30). In addition, two samples of wet sediment (samples 1 and 14) and one sample of bird guano (sample 11) from the rearest part of the cavity, were analysed. Dominant pollen types include *Pinus*, *Olea*, *Chamaerops humilis*, Lamiaceae hexacolpate, *Helianthemum croceum* type, Poaceae, *Artemisia*, Chenopodiaceae, and Asteraceae (Figs. 4 and 5). *Coronilla* is also abundant in samples 17 (75%), 18 (45%), and 27 (55%); the two former being located at the entrance and the last at the rear of the cavity (Fig. 2). All 127 palynological types occurring in external pollen spectra are also found in the cave sediment (Table 2). Pollen preservation was excellent and taxonomic resolution to species level was possible for several types such as *Asphodelus fistulosus*, *A. cerasiferus*, and *Coris monspeliensis*. The presence and occasional abundance of Zygnemataceae algal spores in sample 1 (15%), suggests water transport (Fig. 5). Moss and fern spores are well represented inside the cave.

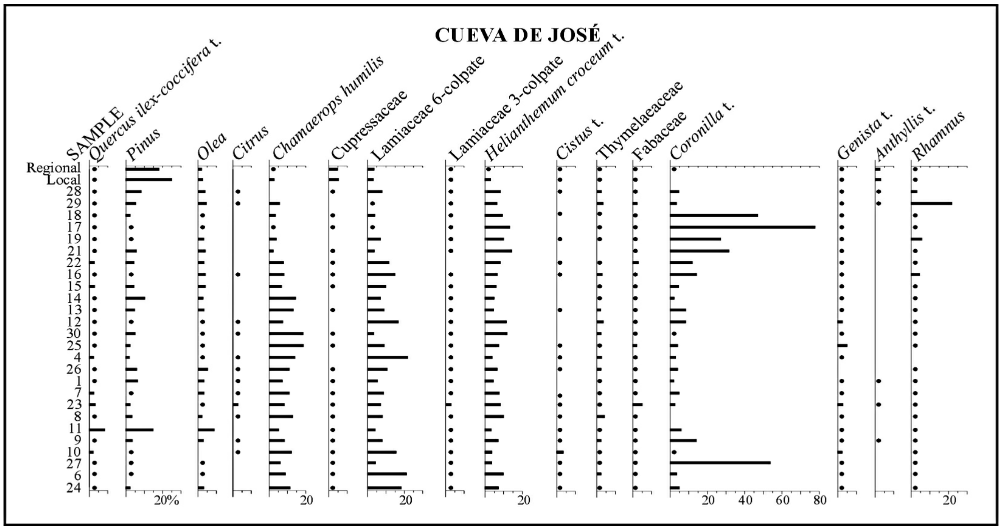

Figure 4.- Percentage pollen diagram from Cueva de José of arboreal taxa. Samples ordered according to distance from the entrance.

A summary pollen diagram of selected types shows high inter-sample similarity (Fig. 6). Indeterminable pollen remains thoroughly below 10%, excepting in samples 9 and 11, both located together at the rear of the chamber, and sample 30, located close to right parietal zone. It is evident that bad conditions for pollen preservation prevail only in these areas. Likewise, Cichorioideae percentages increase sharply in wet sediment samples (1 and 14) suggesting degradation processes are more effective in humid areas of the cave. The highest pollen concentrations are observed in dry sediment (1,116,044 grains/g in sample 17 and 955,824 grains/g in sample 27), and the lowest in wet sediment and bird guano samples (<150,000 grains/g) (Table 3). In general, zoophilous pollen taxa are dominant inside the cave, especially close to the entrance. Anemophilous (wind pollinated) taxa, however, prevail outside the cave (*ca.* 60%), even though external vegetation is dominated by entomophilous species. Spearman coefficients corroborate this trend by showing the existence of an entrance to rear gradient, through which, anemophilous taxa increase and zoophilous taxa diminish (Table 4).

4.2. Cueva de la Plata

Twelve floor samples were analysed, ten corresponding to dry sediment, sometimes including bat guano (samples 5 and 6), one to moss polster (11) and one to speleothem tips (12) (Table 5). Samples from Cueva de la Plata show a high number of palynomorph types (118 in total) (Table 6). Pollen preservation was again excellent. *Pinus*, *Helianthemum croceum* type, Cistaceae, *Anthyllis* type, Genisteae, Lamiaceae hexacolpate, *Olea*, Poaceae, and Asteraceae dominate pollen spectra (Figs. 7 and 8). The gradient for *Olea* in-

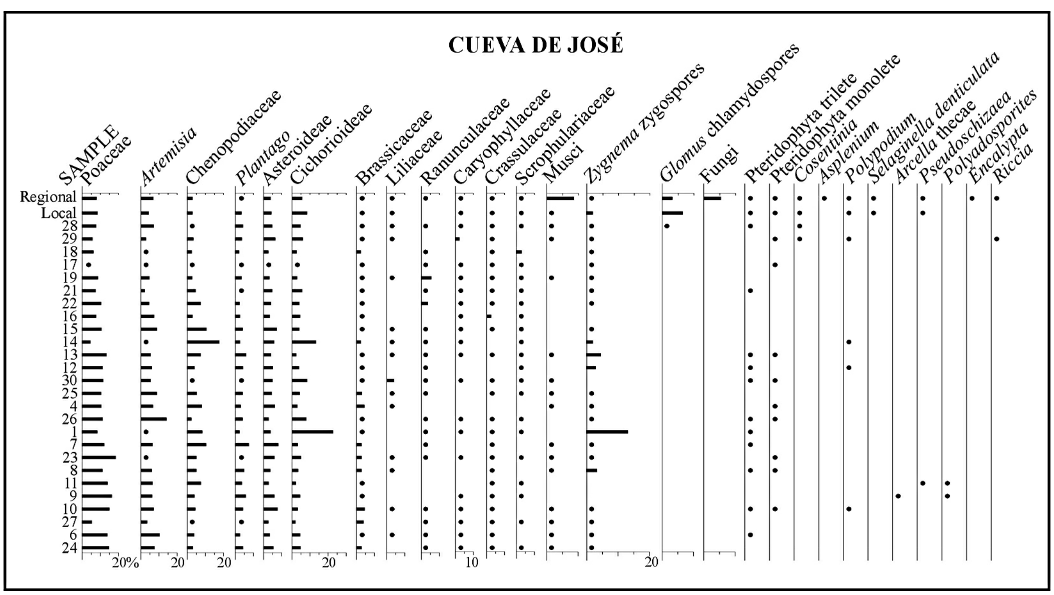

Figure 5.- Percentage pollen diagram from Cueva de José of non-arboreal taxa, spores and non-pollen microfossils. Samples ordered according to distance from the entrance.

Pollen types	R	L	28	29	18	17	19	21	22	16	15	14	13	12	30	25	4	26	1	7	23	8	11	9	10	27	6	24
Quercus faginea t.	+	+	+					+		+						+		+					+				+	
Casuarina	+		+				+		+				+					+									+	
Alnus	+	+	+	+	+				+	+								+			+		+					
Ulmus	+	+																										
Castanea			+																				+					
Palmaceae					+										+											+		
Betula	+							+																				
Populus	+	+	+				+																					
Phillyrea								+		+	+																+	
Salix										+				+							+					+		
Eucalyptus				+	+							+					+				+						+	
Ceratonia	+	+	+																				+	+				
Prunus			+																				+					
Moraceae	+		+		+																					+		
Ficus																							+	+				
Fraxinus ornus t.																								+				
Ephedra fragilis	+	+	+	+	+		+	+		+		+	+	+	+	+			+	+	+	+			+		+	
Ephedra nebrodensis	+	+																										
Pistacia lentiscus	+	+	+					+		+											+	+	+				+	
Teucrium	+	+	+	+	+		+		+	+	+		+	+		+			+	+		+	+				+	+
Sideritis	+	+	+		+			+							+		+				+	+		+	+	+	+	
Fumana thymifolia t.	+																						+	+				
Cistaceae	+																											
Rosaceae			+							+				+				+					+		+		+	+
Rubus	+																											
Asparagus t.	+																											
Opuntia	+																											
Tamarix	+																											
Ericaceae	+	+	+	+		+									+	+	+	+			+		+		+	+		
Myrtus				+																								
Bupleurum	+	+	+		+	+	+	+		+	+		+	+		+			+	+			+	+			+	+
Marrubium																							+	+				
Ononis	+																						+					
Ulex parviflorus t.																								+				
Withania	+	+																										
Smilax		+															+											
Hedera helix	+						+																					
Lycium	+																											
Nicotiana	+																											
Coris monspeliensis			+				+											+										
Calicotome	+			+														+										
Nerium	+	+																				+						
Lithodora	+																											
Mercurialis	+									+													+					
Xanthium			+																									
Sanguisorba	+			+																				+				
Urticaceae	+									+			+				+					+	+			+	+	
Cyperaceae	+	+	+					+			+		+	+				+	+	+	+		+					
Rumex crispus t.	+																						+					
Cerealia																							+	+				
Typha angustifolia			+				+				+	+	+	+			+		+				+					
Centaurea	+	+	+			+	+	+	+	+	+	+		+	+	+		+	+	+	+	+	+	+			+	+
Centranthus			+																									
Reseda	+		+																									
Paronychia t.	+	+	+					+																	+			
Geraniaceae	+	+	+		+	+	+	+		+	+			+	+	+				+		+			+		+	+
Iridaceae	+																											
Allium t.	+																											
Zygophyllum			+																					+				
Lotus t.	+	+	+					+		+	+			+		+	+		+			+	+	+	+		+	
Asphodelus fistulosus	+																											
Asphodelus cerasiferus	+	+	+	+	+	+			+	+				+	+		+	+	+		+	+	+	+			+	+
Lavandula t.	+																											
Verbascum t.	+																											
Portulacaceae	+	+								+																		
Malvaceae																		+							+			
Polygala																+							+		+			
Convolvulus	+						+	+	+	+		+						+				+	+	+	+			
Ecballium	+	+	+																				+	+				
Linum	+	+	+						+					+					+			+	+	+	+			
Apiaceae	+	+	+		+	+		+	+	+	+			+	+		+	+		+	+	+		+	+	+	+	
Spergula arvensis	+		+																		+							
Rubiaceae	+	+	+							+			+		+	+		+		+		+	+	+	+	+		
Hypericum t.	+	+	+																									
Centaurium t.	+																											
Boraginaceae	+	+	+				+	+	+	+			+	+								+			+			
Echium t.	+	+	+																				+	+				
Anagalis arvensis t.			+				+			+	+											+			+			
Papaver	+		+		+	+				+	+		+	+	+	+	+	+	+	+	+	+			+	+	+	+
Sarcocapnos	+		+	+	+										+						+					+		
Digitalis			+																									
Fumaria			+																									
Chaenorrhinum t.	+	+	+	+			+		+						+			+		+	+		+	+		+	+	
Primulaceae																								+				
Ruta	+		+	+		+			+		+		+	+			+					+			+	+	+	
Valeriana					+																							
Solanaceae	+	+	+				+			+								+				+		+			+	
Campanula								+	+	+			+	+					+			+					+	
Polygonaceae	+	+	+			+		+					+			+						+				+		
Osyris	+	+	+					+																				
Euphorbia	+	+							+													+	+					
Plumbaginaceae																						+						
Lemna t.							+											+										

Table 2.- Pollen types with percentage below 2% at Cueva de José.

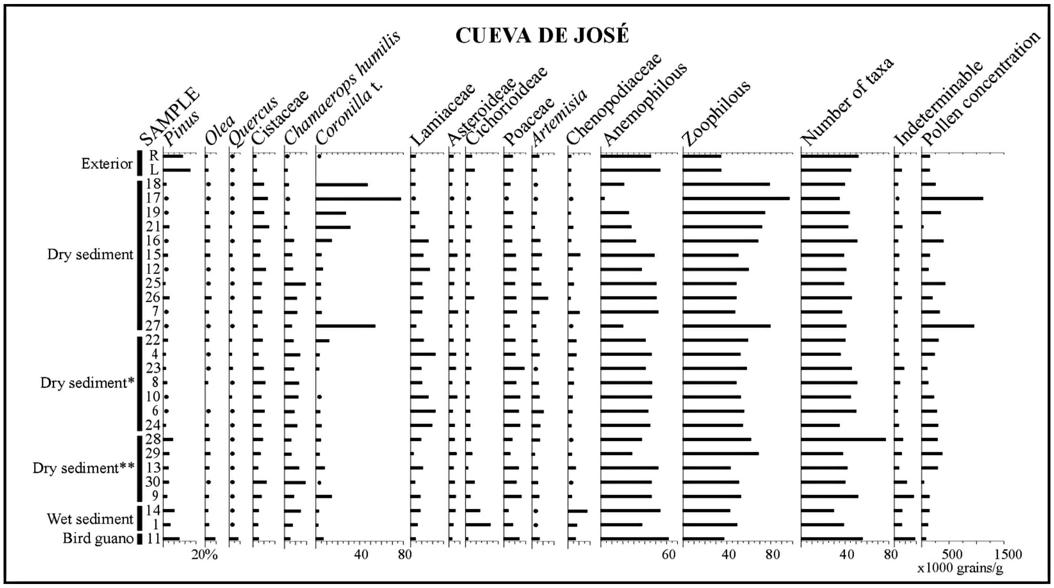

Figure 6.- Synthetic pollen diagram of selected taxa from Cueva de José. Samples grouped according to sediment types and ordered according to distance from the entrance.

creases and that of *Pinus* decreases towards the rear of the cavity. The abundance of *Coronilla* in sample 12, the only sample deriving from speleothem, may be related with water infiltration. Cupressaceae, *Chamaerops humilis*, *Anthyllis* type, Genisteae, Fabaceae, *Teucrium*, and Thymelaeaceae are recorded in all the samples studied including external samples representing local vegetation. Zoophilous taxa are dominant in the cave pollen spectra and indeterminable pollen shows relatively low values (below 10%) in all samples (Fig. 9). Speleothem sample 12 shows high percentage of zoophilous pollen, high number of taxa, and relatively high pollen concentration. Previous studies on speleothems also showed the potential of entrance-facies (Brook *et al.* 1990; Burney & Burney 1993). The number of taxa is relatively high in most samples (34 to 64), and pollen concentration varies greatly from 17,997 grains/g in sample 8 to 434,880 grains/g in sample 4, 353,276 grains/g in sample 12, and 301,219 grains/g in sample 1 (Table 7). Spearman correlation coefficients show a negative gradient for pollen concentration from entrance to rear cave (Table 8). There are negative correlations between distance to the entrance and pollen concentration, and between distance to the entrance and anemophilous. Finally, a positive correlation between distance to the entrance and indeterminable pollen was detected at Cueva de la Plata.

Samples		Number of taxa	Concentration (grains/g)
Dry floor sediment	7	37	326,414
	12	41	124,208
	15	39	149,546
	16	51	396,317
	17	35	1,116,044
	18	40	246,310
	19	44	344,780
	21	43	33,156
	25	39	427,743
	26	46	195,789
	27	41	955,824
Dry sediment with decomposed dung	4	36	234,648
	6	50	274,728
	8	51	118,535
	10	45	224,281
	22	40	304,175
	23	46	100,304
	24	35	296,796
Dry organic sediment	9	52	141,574
	13	42	292,503
	28	77	286,151
	29	38	373,476
	30	40	42,154
Wet floor sediment	1	39	119,099
Wet sediment with dung	14	30	145,009
Bird guano	11	56	74,651
Local	—	45	141,316
Regional	—	52	145,156

Table 3.- Number of taxa and pollen concentration at Cueva de José.

Variables	Coefficients
Distance to the entrance-Anemophilous	+0.387*
Distance to the entrance-Zoophilous	-0.397*
Distance to the entrance-Poaceae	+0.65**
Cichorioideae-Pollen concentration	-0.409*

Table 4.- Spearman correlation coefficients for a set of variables from Cueva de José (level of significance * = 0.05; level of significance ** = 0.01).

Sample No.		Sample type
Interior	1,2,4,8,9,10,14,16	Dry floor sediment
	5,6	Dry sediment with bat guano (*)
	11	Moss polster
	12	Speleothem
Local	17,18	Surface sediment
Regional	19,20,21,22	Surface sediment

Table 5.- Samples from Cueva de la Plata.

Pollen types	R	L	16	14	11	12	10	9	8	6	5	1	2	4
Quercus ilex-coccifera t.	+	+	+	+		+	+	+		+			+	
Quercus faginea t.	+		+											
Casuarina	+	+		+										
Alnus	+	+												
Ulmus	+												+	
Castanea												+		
Schinus molle						+								
Betula	+	+												
Populus	+				+									
Citrus				+	+	+		+						+
Eucalyptus				+			+						+	
Ceratonia	+			+		+			+					
Prunus														
Moraceae	+	+	+	+										
Fraxinus ornus t.				+										
Ephedra fragilis	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Ephedra nebrodensis	+													
Cistus clusii-albidus t.	+	+					+		+			+	+	
Fumana thymifolia t.	+	+												
Calicotome	+	+		+		+			+			+	+	+
Rubus		+		+	+	+							+	
Asparagus t.	+	+												
Opuntia	+	+												
Tamarix	+	+	+	+	+	+	+		+				+	
Ericaceae	+	+		+			+	+						
Myrtus				+			+							
Vitis						+								
Bupleurum	+	+				+	+	+		+				
Ononis	+	+											+	
Withania	+	+					+					+		
Maytenus						+								
Smilax	+													
Phillyrea				+									+	
Hedera helix	+	+			+									
Lycium	+	+				+								
Nicotiana	+	+												
Coris monspeliensis											+	+	+	
Nerium	+	+		+		+	+				+			+
Lithodora	+	+				+		+		+		+		
Periploca								+						
Sanguisorba	+	+			+	+								
Urticaceae	+	+	+	+		+	+				+			+
Cyperaceae	+	+					+							
Rumex crispus t.	+	+		+										
Juncus					+			+						
Thalictrum							+							
Mercurialis	+	+	+	+		+	+	+			+	+	+	+
Centaurea	+	+		+	+			+	+	+	+	+	+	
Reseda	+	+		+						+		+	+	
Paronychia t.	+	+		+				+				+	+	
Geraniaceae	+	+				+		+			+			
Iridaceae	+	+		+	+	+		+						
Ranunculaceae	+	+			+			+	+	+		+		+
Allium t.	+	+			+									
Arisarum t.								+	+					
Oxalis	+	+												
Lotus t.	+					+		+	+		+	+	+	
Psoralea						+								
Dorycnium pentaphyllum								+						+
Trifolium				+		+						+		
Asphodelus fistulosus	+	+	+			+	+	+	+			+		
Asphodelus cerasiferus	+													
Capparis spinosa												+	+	+
Lavandula t.	+	+	+	+	+	+		+						
Polygala						+			+					
Convolvulus	+	+	+			+			+					
Ecballium	+	+												
Linum	+	+		+										
Spergula arvensis	+	+				+								
Rubiaceae	+	+		+				+		+				
Hypericum t.	+										+	+		
Centaurium t.	+	+				+		+				+	+	
Dipsacaceae						+			+			+		
Boraginaceae	+					+								
Echium t.	+	+					+			+		+		
Polygonum aviculare t.	+		+	+		+						+		
Anagalis arvensis t.						+				+				
Papaver	+	+	+		+	+	+							+
Sarcocapnos	+	+												
Ruta	+	+			+	+								+
Osyris		+	+	+		+	+		+			+	+	
Liliaceae	+	+	+		+	+	+				+	+		
Euphorbia	+	+	+	+		+		+						+

Table 6.- Pollen types with percentage below 2% at Cueva de La Plata.

5. DISCUSSION AND CONCLUSIONS

This study demonstrates that arid depositional environment, isodiametric morphology, and entomophilous-dominated flora are desirable characteristics in selecting cave sites for pollen. The contribution of aridity to pollen preservation is confirmed here (Davis 1990). In comparison with previously studied Moro caves (Navarro *et al.* 2000), José and La Plata caves present fewer problems of alteration resulting in higher pollen concentration (average 282,470 grains/g in Cueva de José, and 155,613 grains/g in Cueva de la Plata), higher number of taxa, and lower values of indeterminable pollen (average 5.9 and 5.3% respectively). This was also observed in several Palaeolithic sections of Cueva de la Carihuela (Granada, Spain), whe-

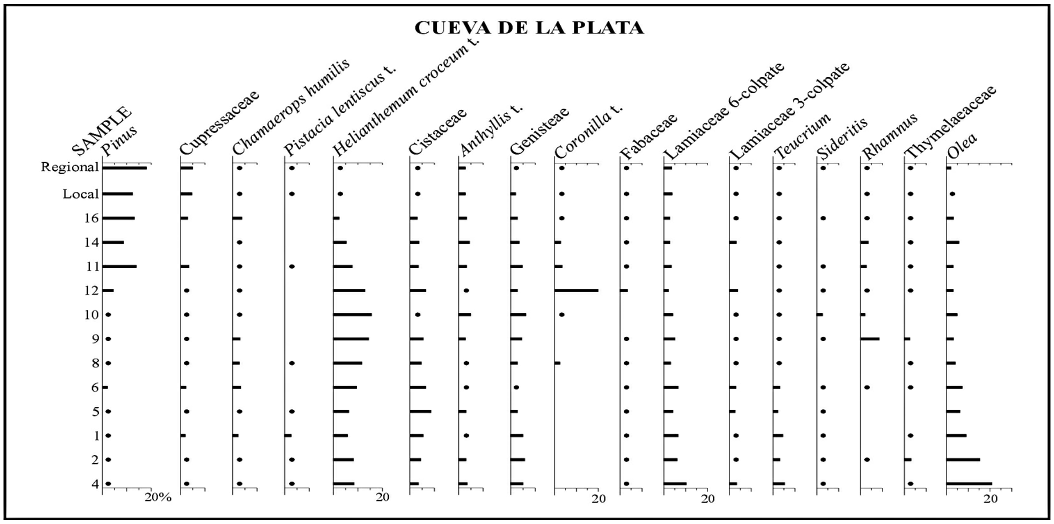

Figure 7.- Percentage pollen diagram from Cueva de la Plata of arboreal taxa. Samples ordered according to distance from the entrance.

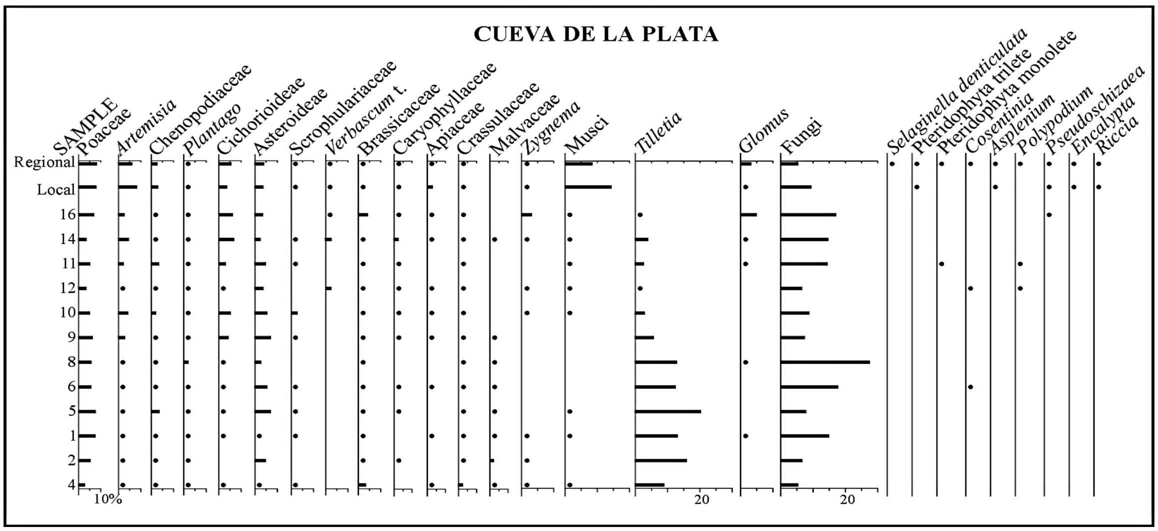

Figure 8.- Percentage pollen diagram from Cueva de la Plata of non-arboreal taxa, spores and non-pollen microfossils. Samples ordered according to distance from the entrance.

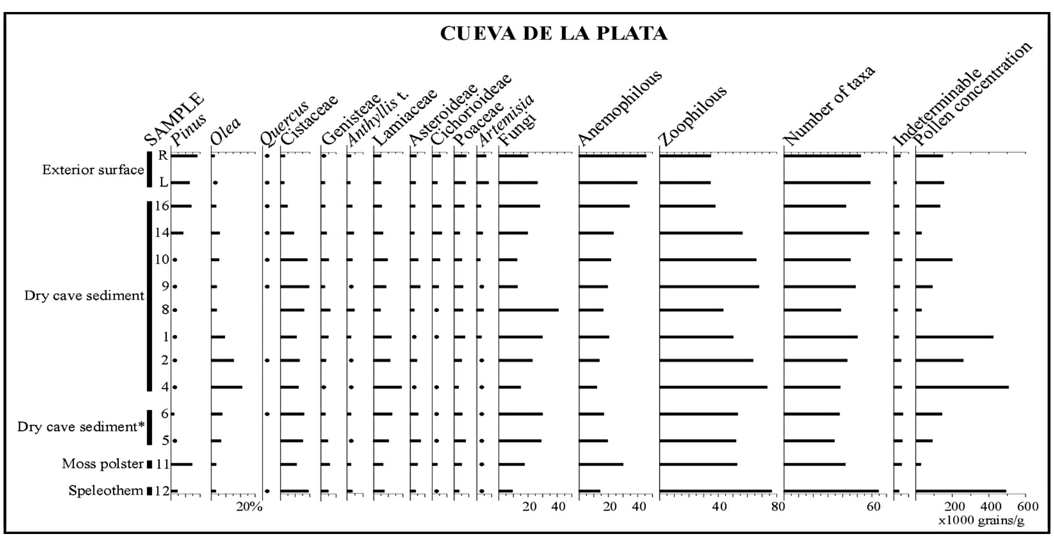

Figure 9.- Synthetic pollen diagram of selected taxa from Cueva de la Plata. Samples grouped according to sediment types and ordered according to distance from the entrance.

Samples		Number of taxa	Concentration (grains/g)
Dry floor sediment	16	42	94,478
	14	58	23,514
	10	45	172,381
	9	49	78,687
	8	39	17,997
	1	50	301,219
	2	43	202,663
	4	38	434,880
Dry sediment with bat guano	6	38	101,519
	5	34	66,180
Moss polster	11	42	20,563
Speleothem	12	64	353,276
Local	—	59	112,959
Regional	—	52	117,113

Table 7.- Number of taxa and pollen concentration at Cueva de la Plata.

re units formed under humid depositional conditions contained no pollen and spores, despite a very rich organic content (Carrión *et al.* 1998). Cueva del Moro I and Cueva del Moro II are located in a wetter climate area and showed poorer pollen spectra with average concentrations of 64,361 grains/g and 461,682 grains/g respectively, and higher number of indeterminable pollen (30 and 18% respectively). Nevertheless, wet sediment surface areas of Cueva de José are probably under the influence of post-depositional processes of pollen degradation, as suggested by relatively high percentage of Cichorioideae, comparatively low pollen concentration values and taxa diversity. The negative correlation between Cichorioideae pollen and pollen concentration at Cueva de la Plata and Cueva de José supports this hypothesis (Tables 4 and 8). Speleothem sample 12 at Cueva de la Plata showed good analytic potential, which contrasts with results at Cuevas del Moro (Navarro *et al.* 2000). There is certainly great variation in the palynological characteristics of modern and fossil speleothem materials (Carrión 1992; Burney & Burney 1993; Carrión & Scott 1999), and it is likely that near-to-entrance speleothems provide the highest pollen concentration and reasonable preservation (Brook *et al.* 1990).

Cave morphology is no less important. Cueva de la Plata, a narrow, small-entranced, long cavity, showed lower pollen concentration (155,613 grains/g) than Cueva de José (282,470 grains/g), an isodiametric, wide-entranced cavity. The same difference was observed between Cueva del Moro I and II (Navarro *et al.* 2000). In addition, Cueva de la Plata, show higher percentages of non-pollen microfossils, which may be eventually indicative of degradation processes. On the other hand, zoophilous taxa, which are dominant in both caves, are more abundant in Cueva de la Plata, plausibly because airborne pollen would find more difficult to reach deep rear cave.

Variables	Coefficients
Distance to the entrance-Anemophilous	-0.729**
Distance to the entrance-*Pinus*	-0.687**
Distance to the entrance-Pollen concentration	-0.557*
Distance to the entrance-Indeterminable	+0.497*
Cichorioideae-Pollen concentration	-0.503*

Table 8.- Spearman correlation coefficients for a set of variables from Cueva de la Plata (level of significance * = 0.05; level of significance ** = 0.01).

Cave	ExpVar (%)	
	Local	Regional
Cueva de José	93.7	91.6
Cueva de la Plata	82.6	92.4

Table 9.- Linear Regression Analysis.

With regard to the ecological reliability of pollen spectra, this study of cave sediments confirms the viewpoint obtained from studies of the airfall pollen budget (Coles & Gilbertson 1994; Burney & Burney 1993), that more frequent use of cave sediments should be made in Quaternary palaeoecology. There is a good reflection of surrounding vegetation (both local and regional) in the pollen spectra obtained from Cueva de José and Cueva de la Plata cave sediments, as

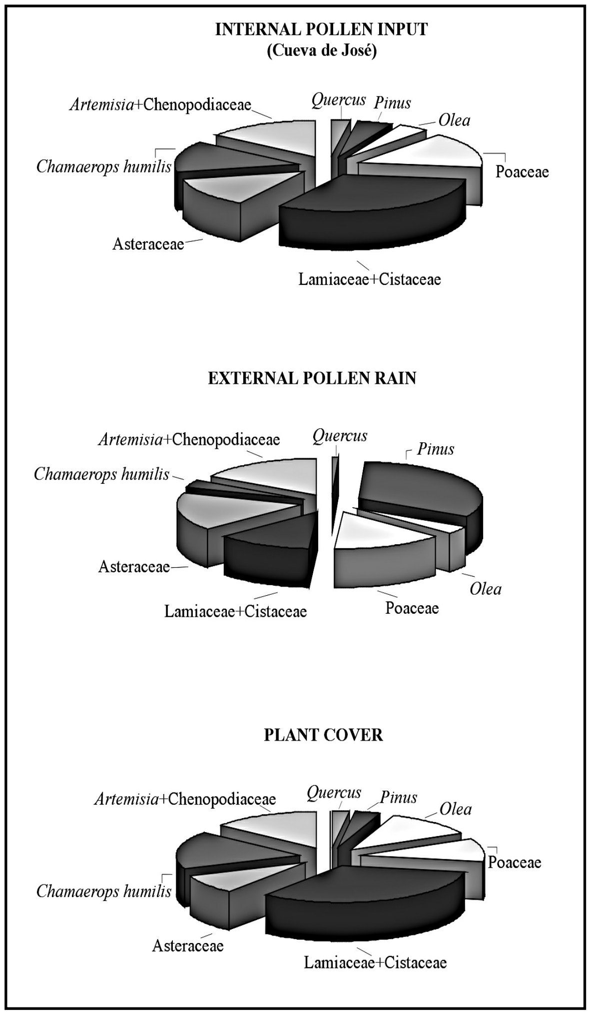

Figure 10.- Percentage comparison between internal pollen input at Cueva de José, external pollen rain and average plant cover.

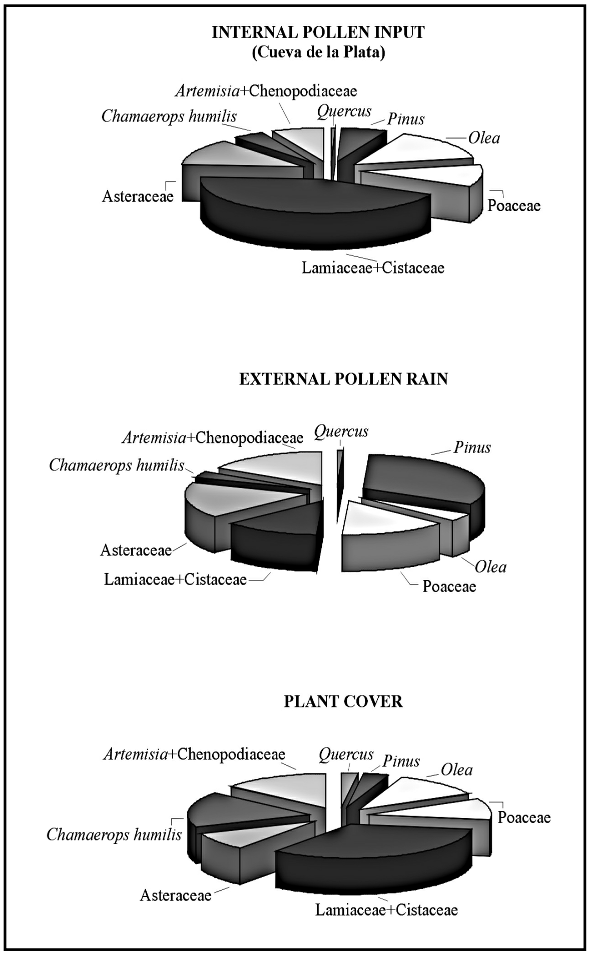

Figure 11.- Percentage comparison between internal pollen input at Cueva de la Plata, external pollen rain and average plant cover.

confirmed from ExtVar percentages obtained through applying the regression model (Table 9). These values quantify the amount of external-samples variability explained by internal-sample values. The representativeness of external vegetation is even better than that obtained from external samples, as demonstrated by a comparison between external pollen rain, internal pollen input and vegetation cover values obtained from phytosociological tables (Figs. 10 and 11). Pollen spectra from cave sediments, while strongly determined by biotic transport may represent entomophilous-dominated floras better than the pollen rain outside the cave correcting the bias produced in the exterior by the very abundant production and dispersal of wind-pollinated taxa.

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