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Quaternary pollen analysis in the Iberian Peninsula: the value of negative results

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Summary

Most unsuccessful palynological work is never published. As a consequence, pollen analysts waste time re-processing sterile sediments, and the available literature exhibits a uniformly positive record of success in pollen extraction. Here we report failures with Quaternary pollen analyses in the Iberian Peninsula; that is, case studies where it was not possible to extract palynomorphs for pollen counting. Both totally sterile and partially sterile sites are considered. Sites and perspectives for future studies are suggested. The majority of the failed studies are open-air archaeological and palaeontological sites, caves and rockshelters, but there are prominent cases of success. Peat bogs have provided positive results, but only with sequences formed under continuous sedimentation processes in marshy environments. Lakes are often successful sites, but a multi-core strategy, following the facies change along a transect from the shore to the depositional centre, is recommended for saline lacustrine deposits, salt marshes and lagoons, especially when there is evidence of temporary desiccation. Cave and rockshelter infills should be considered case-by-case, and these sites definitely require a palyno-taphonomical approach to post-depositional processes. Indurated deposits are sometimes surprising in their high pollen concentration, but one must be prepared for sterility. Coprolites have been insufficiently exploited, and offer a great potential, especially those of Pleistocene Crocuta. This article shows that venturing into sediments assumed *a priori* to be 'difficult', like fluvial terraces, slope deposits, speleothems, cave travertines, and palaeosols, may nevertheless be successful. A

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summary is proposed of the various factors causing sterility, before, during and after sedimentation.

1. Introduction

Reporting failures is not a major concern in science. Research leading to failed or inconclusive results ends up most often unpublished, known only to those who did the work and quickly forgotten even by them. A notable exception is 'The Journal of Negative Results in Biomedicine'. In Quaternary palynology, while it is not unusual that the analyst is unable to extract pollen from sediments, the great bulk of unsuccessful work never sees the light of day and, as a consequence, the available palynological literature exhibits a misleadingly positive impression of success. In an interdisciplinary context, where the results of pollen analysis are often of interest to investigators who are not themselves palaeobotanists, such as archaeologists, palaeoclimatologists, palaeontologists and environmentalists, it is especially important that an understanding of the limitations of pollen analysis is widely disseminated. However, few non-palaeoecologists seem to be sufficiently aware of something as obvious as the fact that not all sediments are suitable for pollen analysis (Bryant and Holloway 1983; Carrión *et al*. 1999a; López-Sáez *et al*. 2003; González-Sampériz 2004a). Often they may require or hope for palaeobotanical information from locations or deposits that are ill-suited to the preservation of pollen, or where the interpretation of the results is complicated by issues of differential preservation and taphonomy. Conversely, palaeobotanists may ignore deposits of potential interest or importance on the grounds that they are unlikely to produce adequate pollen, even though the results could be of great significance at a local scale or in relation to the problems investigated by other disciplines. Even palynologists who concentrate on the 'good' sites are at risk of wasting precious time and resources repeating pollen analyses of unproductive materials, since sites assumed *a priori* to be good sites may turn out to be sterile or partially so, just as sites assumed to be 'bad' may turn out to offer useful information. Applications for Quaternary palaeoecological research projects are often rejected on the grounds that they ignore earlier endeavours, but if the earlier endeavours are not published, everyone is at risk of wasting time and effort reinventing the same wheel and nothing is learned from earlier failures.

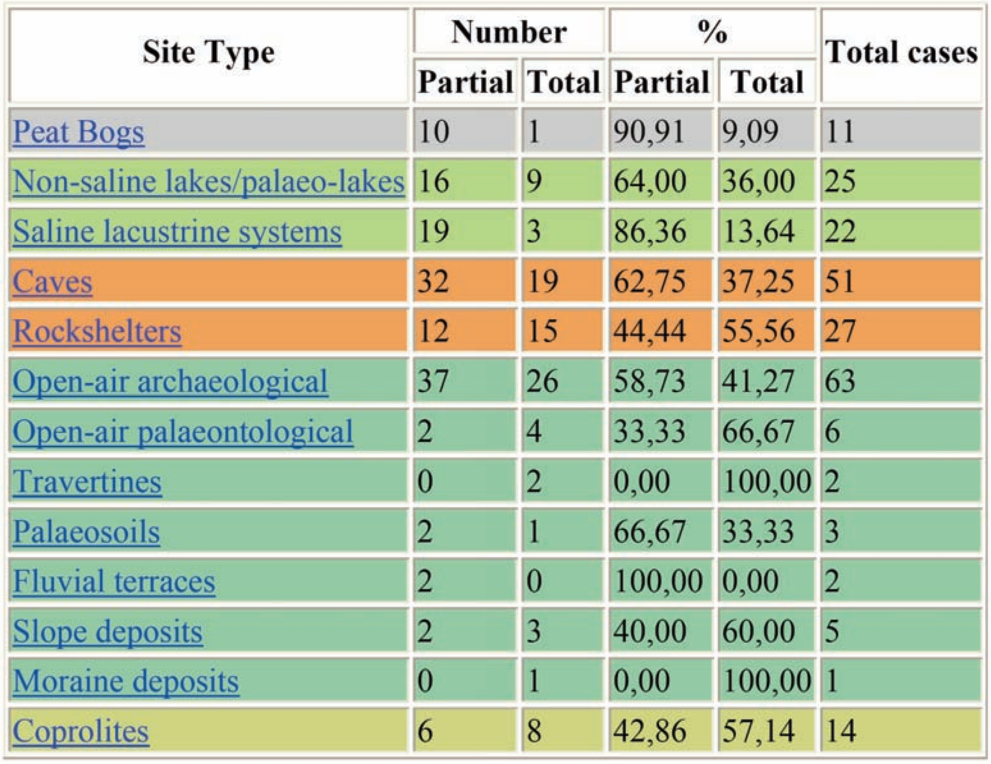
This article originates from an explicit commitment to report failures with pollen analyses for the Quaternary of the Iberian Peninsula. 'Failure' is understood here as the inability or impossibility of obtaining palynomorphs after following the usual extraction methods. A few cases include pollen spectra where the absolute number of pollen recovered from a sample was not sufficient for statistical treatment and interpretation. It is worth emphasising that we do not refer to unexpected or conflicting evidence or to results that are negative in the sense that they do not support hypotheses from designed experiments, nor do we mean those results unable to disprove a null hypothesis. Our viewpoint is that, in spite of the difficulties of interpretation, failed pollen analyses will, sooner or later, be incorporated explicitly into the concepts of the discipline and its research procedures (e.g. Leroy 2008). In fact, a well-designed project should never produce a completely negative result, since there is always the opportunity to learn something. Learning about failures as well as positive results can be instrumental in providing the context for the development of new research strategies and so lead to a better return for public and private funding. Conversely, hearing only about the successes is equivalent to throwing away half of the information, and may give a misleading impression of the opportunities and limitations of pollen analysis. This issue of failure, or the production of unexpected results, is therefore of importance both to the non-specialist consumer of pollen results and the specialist palynologist, and our review is aimed at both types of reader.

2. Methodological Considerations

In addition to a review of the scanty available literature commenting on failures, this article principally uses the information obtained from a questionnaire submitted to Quaternary palynologists who, to our knowledge, have, at any time, been active in palynological work in the Iberian Peninsula. An e-mail list of 46 colleagues was built from directories of the APLE (Spanish-speakers Association of Palynologists), the AEQUA (Spanish Association of Quaternarists), the INQUA (International Union for Quaternary Research), and the IFPS (International Federation of Palynological Societies). We also made telephone calls to people who had been leading projects and initiatives related to Iberian palaeoecology. All the collaborators are named as authors of this article. Eight declared not to have found problems with their own analyses, in these cases exclusively conducted with material from peat bogs and lacustrine sediments. The remaining 23 individuals (50% of the list) to whom the questionnaire was sent did not reply.

Why so many failed to participate is perhaps an interesting matter for sociological research that is outside the scope of this article. Possible causes are: lack of records of failed pollen work; a poor tradition of collaborative research; bad experiences with former database initiatives; perhaps even doubts about the need for this work. Some palynologists may also now be retired or deceased. In any case, it seems logical to consider that the number of sites listed here (221) is surely less than the total. In addition, even if there was a regional distribution among the non-answers, and taking into account that several areas of Iberia, like the humid north-west, have been more intensively explored and studied than others (Carrión *et al*. 2000a; 2008), this article cannot deal with possible geographic trends in sediment sterility. This is unfortunate, because the Iberian Peninsula contains an important physiographical heterogeneity (Vera 2004). Therefore with a more complete dataset, several tendencies might have become detectable.

Table 1. Case studies with total (all samples processed) versus partial sterility in pollen analysis of Iberian sites.



Site Type	Number		%		Total cases
	Partial	Total	Partial	Total	
Peat Bogs	10	1	90,91	9,09	11
Non-saline lakes/palaeo-lakes	16	9	64,00	36,00	25
Saline lacustrine systems	19	3	86,36	13,64	22
Caves	32	19	62,75	37,25	51
Rockshelters	12	15	44,44	55,56	27
Open-air archaeological	37	26	58,73	41,27	63
Open-air palaeontological	2	4	33,33	66,67	6
Travertines	0	2	0,00	100,00	2
Palaeosoils	2	1	66,67	33,33	3
Fluvial terraces	2	0	100,00	0,00	2
Slope deposits	2	3	40,00	60,00	5
Moraine deposits	0	1	0,00	100,00	1
Coprolites	6	8	42,86	57,14	14

The methods of sampling and laboratory analysis declared by contributors are the usual ones. Thus, most drilling in lacustrine and peaty sediments was done using Russian, Hiller, piston and window corers and rotary drilling (Birks 1986; Leroy 1990). Only rarely were open sections sampled in accessible peat bogs (Carrión and van Geel 1999). Cave sediment sampling from stratigraphical sections followed Girard (1975); Burjachs *et al*. (2003), or similar (Dupré 1988). Coprolites were cut open and material from the centre was scraped out to minimise contamination from external surfaces (Carrión *et al*. 2001a). Sometimes, the totality of the coprolites was treated after cleaning the surface with distilled water (González-Sampériz *et al*. 2003b). Independent of the materials, laboratory treatment was performed following the classical HCl, HF and KOH method (e.g. Girard and Renault-Miskovsky 1969; Faegri and Iversen 1975; Moore *et al*. 1991; Bennett and Willis 2001). Mineral separation with heavy liquids (Goeury and de Beaulieu 1979; Dricot and Leroy 1989; Nakagawa *et al*. 1998) was common not only for minerogenic sediments, but also in organic layers of salt marshes, deltas, lagoonal sediments and lacustrine ones. In other cases, sieving was done at 10 microns and also at a coarser mesh (larger than the largest pollen grain). So, even with presumably pollen-rich sediments, Iberian palynologists tend to use complex concentration methods. Could this tradition be related to a long experience of difficulties with extracting pollen and to the diversity of the sediment when available?

Although it is generally not possible to know whether the best analytical procedure was correctly applied, to blame pollen-analysts for failures of pollen extraction seems a little unrealistic. Certainly, macerating larger samples, using sodium pyrophosphate for clays, and gravity separation to enhance pollen concentration, among other protocols, can solve some problems of concentration (Horowitz 1992). But experimental work (Birks and Birks 1980; Havinga 1984; Tipping 1987; Jones *et al*. 2007) suggests that, in a number of cases, the absence of pollen can be attributable to the nature of the depositional environment. Our primary goal is informative, that is, once problems with a site are known, the pollen analyst should be free to repeat the analysis or avoid further trials.

3. Incidence of Failure Discussed by Type of Depositional Site

In this section, sites are presented by type of archive. In the next section, mechanisms are proposed that may account for the sterility.

Compiled failures comprise 221 sites, which are here organised by depositional/sedimentary types, and information is given about their location, magnitude of the sterility (all samples versus only particular levels/samples), age or presumed chronology, and the name and affiliation of the pollen-analyst/s (Tables 1-7, Fig. 2 and Fig. 2). Open-air archaeological sites

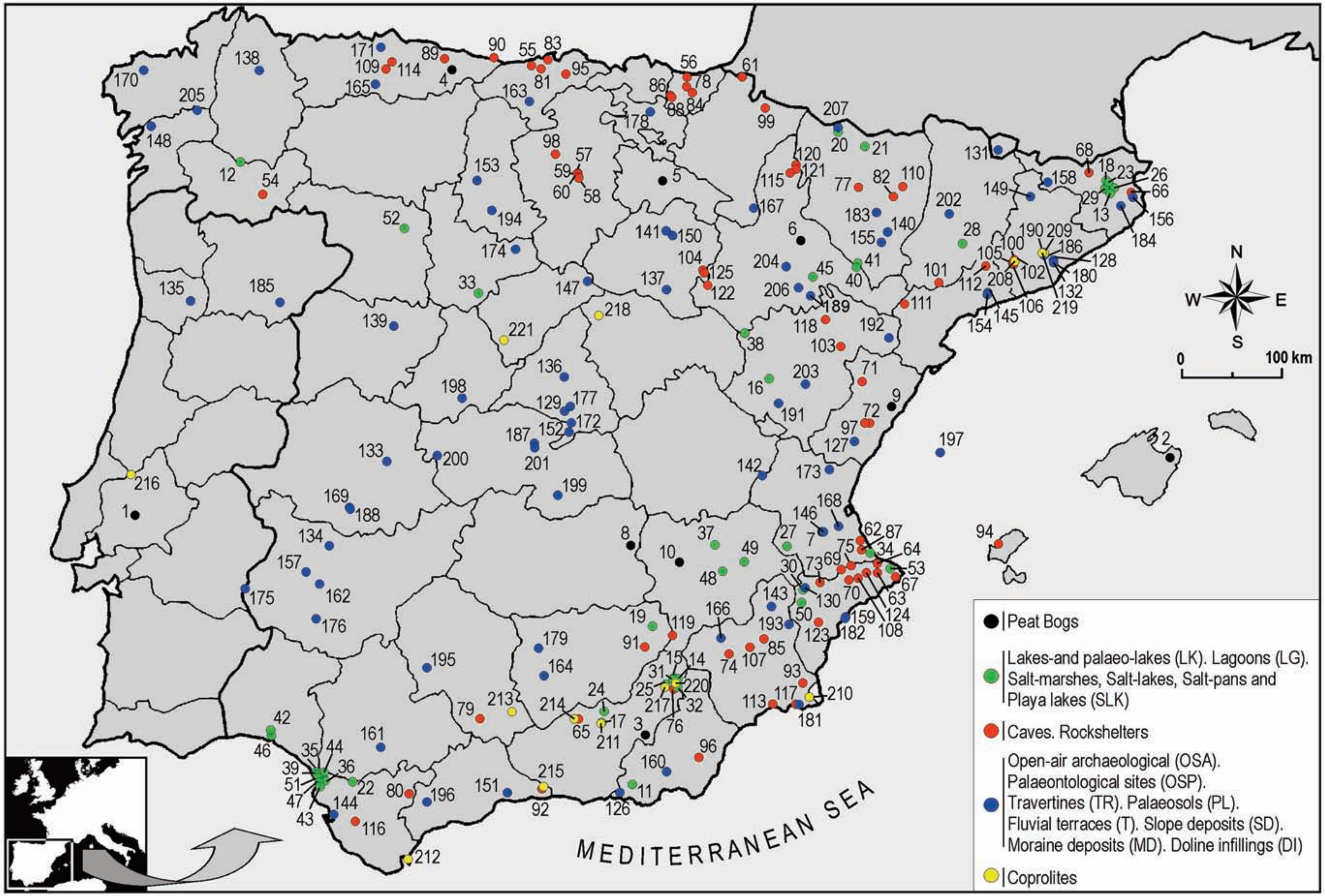


Figure 1. Reported sites with palynological sterility in the Iberian Peninsula. Numbers refer to sites detailed in Tables 3-7

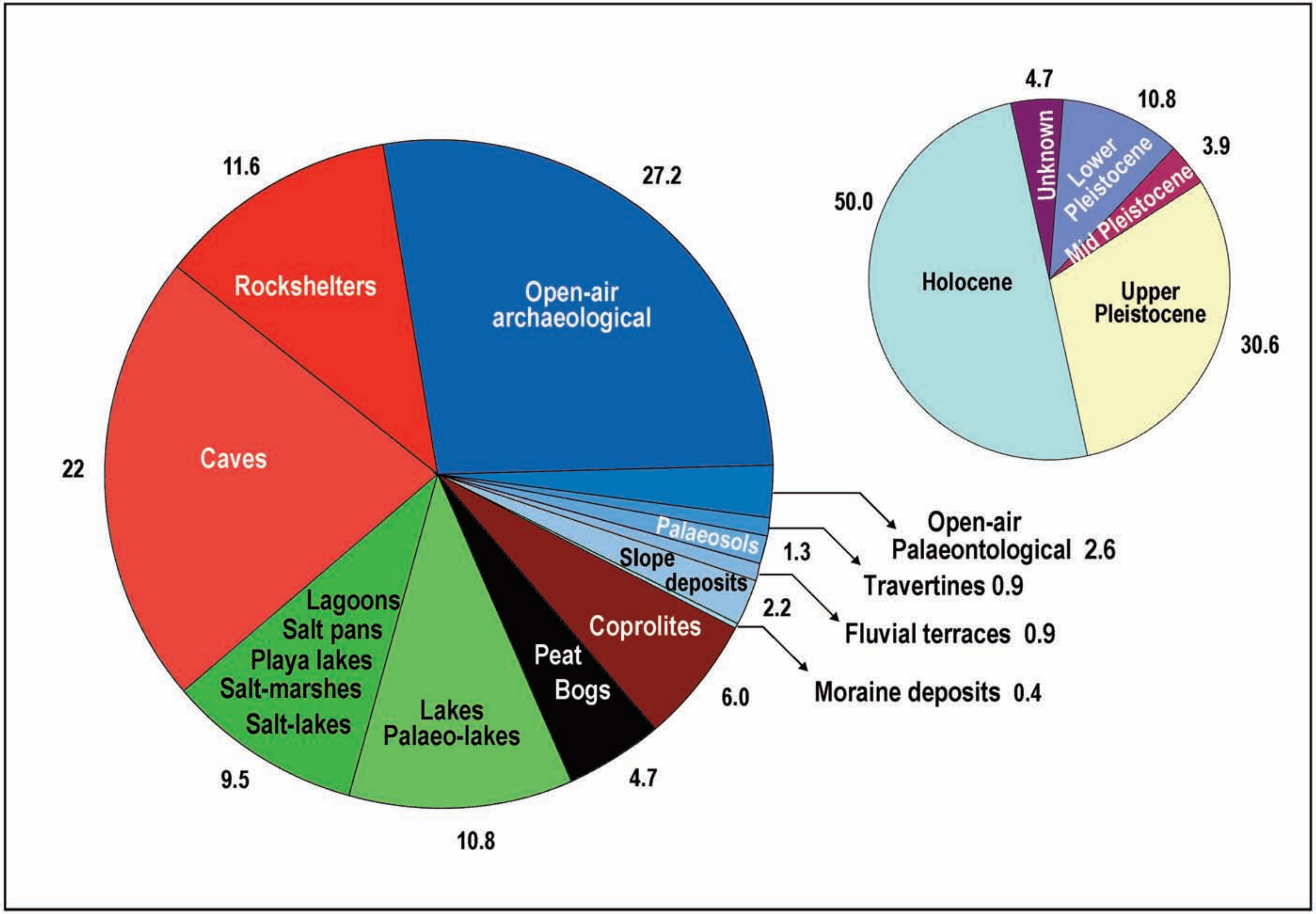


Figure 2. Percentages of reported cases of palynological sterility in the Iberian Peninsula, arranged by depositional type (left) and chronology (right).

Table 2. Abbreviations for the analysts of the pollen-sterile sites (Tables 3-7).

Analyst	Research centre	Abbreviation
AIRA, M.J.	University of Santiago	MJA
ALLUÉ, E.	Catalan Institute of Human Palaeoecology and Social Evolution (IPHES), Tarragona	EA
BOYER-KLEIN, A.	Musée de l'Homme, Paris	BK
BURJACHS, F.	ICREA at Catalan Institute of Human Palaeoecology and Social Evolution (IPHES), Tarragona	FB
CARRIÓN, J.S.	University of Murcia	JC
DAVIS, B.	University of Newcastle	BD
DUPRÉ, M.	University of Valencia	MD
ESTÉBAN, A.	Ajuntament d'Esterri de Cardós	AE
EXPÓSITO, I.	Catalan Institute of Human Palaeoecology and Social Evolution (IPHES), Tarragona	IE
FERNÁNDEZ, S.	University of Murcia	SF
GARCÍA-ANTÓN, M.	Autonomous University of Madrid	MGA
GEURTS, M.	University of Ottawa, Canada	MGU
GIL-GARCÍA, M.J.	University of Alcalá, Madrid	MGG
GIL-ROMERA, G.	University of Wales, Aberystwyth	GR
GONZÁLEZ-SAMPÉRIZ, P.	Instituto Pirenaico de Ecologia, Zaragoza	PGS
IRIARTE, M.J.	University of País Vasco, Bilbao	MJI
JANSSEN, C.	University of Utrecht	CJ
LEROI-GOURHAN , A.	Musée de l'Homme, Paris	ALG
LEROY, S.A.G.	Brunel University, London	SL
LÓPEZ-GARCÍ A.P.	Institute of History, Madrid	PLG
LÓPEZ-SÁEZ, J.A.	Institute of History, Madrid	JLS
MARISCAL, B.	University Complutense, Madrid	BM
MARTÍN-ARROYO, T.	University of Alcalá, Madrid	TMA
MENÉNDEZ-AMOR, J.	University Complutense, Madrid	JMA
MUNUERA, M.	Polytechnic University of Cartagena, Murcia	MM
PARRA, I.	SINKLIM, Almería	IP
PÉREZ-OBIOL, R.	Autonomous University of Barcelona	RPO
RAMIL-REGO, P.	University of Santiago	PRR
RENAULT-MISKOVSKY, J.	Musée de l'Homme, Paris	JRM
RUÍZ-ZAPATA, M.B.	University of Alcalá, Madrid	BRZ
SÁNCHEZ-GOÑI, M.F.	University of Bordeaux 1	MFSG
SANCHIS, A.K.	University of Valencia	AKS
SANTOS, L.	University of Coruña	LS
STEVENSON, A.C.	University of Newcastle, UK	ACS
SUC, J.P.	University of Montpellier	SUC
VAN DER KNAAP, W.O.	University of Bern	VKN
VAN GEEL, B.	University of Amsterdam	VG
VAN LEEUWEN, J.	University of Bern	VLW
VAN MOURIK, J.M.	University of Amsterdam	VMO
YÁÑEZ, C.	University Pablo de Olavide, Sevilla	CY
VOLMAN, K.C.	University of Cantabria, Santander	KV
YLL, R.	Catalan Institute of Human Palaeoecology and Social Evolution (IPHES), Tarragona	RY

(27.2%), caves (22%) and rockshelters (11.6%) represent a majority of the failed case studies (Fig. 2). The proportion of non-saline (10.8%) and saline lacustrine systems (including lagoons, salt pans, playa lakes, salt marshes, and salt lakes) (9.5%) is higher than peat bogs (4.7%). Coprolites (6%) were sterile either individually, or collectively by site (Table 7). Our files also include a few cases with open-air palaeontological sites (2.6%), fluvial terraces (0.9%), slope deposits (2.2%), moraine deposits (0.4%), palaeosols (1.3%), and exposed travertines (0.9%) (Fig. 2, Table 6). Chronologically, 50% of the failed sites are Holocene, 30.6% Upper Pleistocene, 10.8% Lower Pleistocene, and 3.9% Middle Pleistocene. These percentages are likely to be related to the availability of deposits by age. Sites of unknown age average 4.7% of the reported total (Fig. 2).

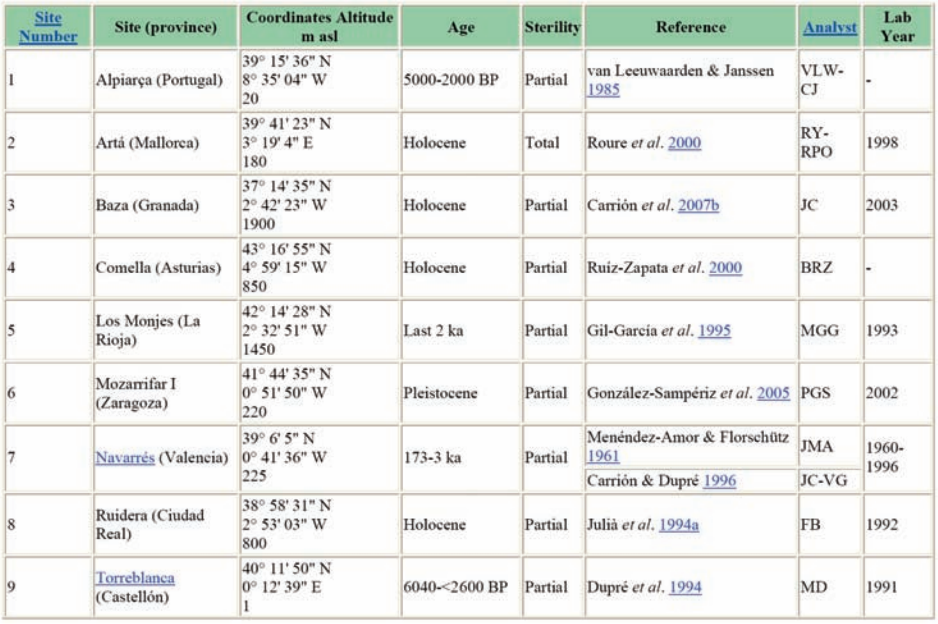
Complete sterility notoriously affects open-air palaeontological sites (67%), and is also relatively high in coprolites (57%), slope deposits (60%), rockshelters (55%), open-air archaeological sites (41%), caves (37%), and non-saline lakes (36%), mostly in cases of palaeolakes (Table 1). Complete sterility is only 9% in peat bogs (Table 1). The few samples of travertines and moraine deposits reported a total absence of pollen. Complete sterility averaged 19% of conventional (lacustrine and peaty) pollen sites. In contrast, it averaged 50% in archaeological sites, including caves, rockshelters, and open-air archaeological or palaeontological excavation sites. Thus, the potential of success at re-studying failed sites is clearly higher in the open-air group.

3.1 Peat bogs

Peat is a classic model for Quaternary pollen analysis (Birks and Birks 1980). However, peat bogs are rare in the Mediterranean region of Iberia, and not particularly numerous in its wetter, Eurosiberian, region (Turner and Hannon 1988; Peñalba 1994; Ramil-Rego *et al*. 1998; González-Sampériz *et al*. 2005). Long pollen sequences (e.g. more than 10m) obtained from Iberian peat deposits like Padul in Andalucía (Florschütz *et al*. 1971; Pons and Reille 1988), Quintanar de la Sierra in the northern Meseta (Peñalba *et al*. 1997), El Portalet in the Pyrenees (González-Sampériz *et al*. 2006), and Area Longa in Galicia (Gómez-Orellana *et al*. 2007) are exceptional.

Given that peats may occur in different wetlands (e.g. peat bogs, fens, swamps, marshes) resulting from a complexity of geomorphological and sedimentary situations, sediments obtained after coring peat deposits are not always peaty throughout. Inorganic layers within mires are problematic for pollen analysis (Moore 1986; Barber and Charman 2003). Several of the records considered here show pollen in sediments formed under continuous sedimentation processes in marshy and shallow lacustrine environments. However, they also show palynologically sterile levels in fluvial and marine depositional environments (Table 3). This could be the situation with the Torreblanca peat bog (Dupré *et al*. 1994), but is demonstrated most clearly with Navarrés (Valencia), a tectonic, flat-bottom valley from which only the uppermost 250cm of a 25m core were polliniferous (Carrión and Dupré 1996; Carrión and van Geel 1999) (Table 2). In particular, this is the section corresponding to the accumulation of peat in a waterlogged context (Dupré *et al*. 1998a). The rest of the Quaternary sequence, starting at *c*. 178,000 years BP, is dominated by high-energy fluvial facies. Samples between 166 and 145cm depth were also palynologically sterile, a hiatus corresponding with the Last Glacial Maximum, during which conditions were not favourable for biotic preservation over large areas of the basin (Carrión and van Geel 1999). A former study including two cores, taken

Table 3. Reported cases of palynological sterility in peat bog sites of the Iberian Peninsula.



Site Number	Site (province)	Coordinates Altitude m asl	Age	Sterility	Reference	Analyst	Lab Year
1	Alpiarça (Portugal)	39° 15' 36" N 8° 35' 04" W 20	5000-2000 BP	Partial	van Leeuwaarden & Janssen 1985	VLW-CJ	-
2	Artá (Mallorca)	39° 41' 23" N 3° 19' 4" E 180	Holocene	Total	Roure *et al*. 2000	RY-RPO	1998
3	Baza (Granada)	37° 14' 35" N 2° 42' 23" W 1900	Holocene	Partial	Carrión *et al*. 2007b	JC	2003
4	Comella (Asturias)	43° 16' 55" N 4° 59' 15" W 850	Holocene	Partial	Ruiz-Zapata *et al*. 2000	BRZ	-
5	Los Monjes (La Rioja)	42° 14' 28" N 2° 32' 51" W 1450	Last 2 ka	Partial	Gil-García *et al*. 1995	MGG	1993
6	Mozarrifar I (Zaragoza)	41° 44' 35" N 0° 51' 50" W 220	Pleistocene	Partial	González-Sampériz *et al*. 2005	PGS	2002
7	Navarrés (Valencia)	39° 6' 5" N 0° 41' 36" W 225	173-3 ka	Partial	Menéndez-Amor & Florschütz 1961 Carrión & Dupré 1996	JMA JC-VG	1960-1996
8	Ruidera (Ciudad Real)	38° 58' 31" N 2° 53' 03" W 800	Holocene	Partial	Julià *et al*. 1994a	FB	1992
9	Torreblanca (Castellón)	40° 11' 50" N 0° 12' 39" E 1	6040-<2600 BP	Partial	Dupré *et al*. 1994	MD	1991

5m apart in another part of the basin, had reported pollen only in the uppermost 180cm (Carrión and Dupré 1996), and the prevailing minerogenic sediments of a Neolithic settlement site in the vicinity were poor in pollen, and totally sterile in sandy sediments (Dupré *et al*. 1985). A similar pattern of pollen occurrence is described in a pioneer study by Menéndez-Amor and Florschütz (1961).

In the Arroyo de los Monjes (La Rioja), a 90cm-depth peaty sand core was fully sterile (Table 3). The 8000-year pollen record from Comella peat bog (Asturias, near Covadonga lakes) was produced from the uppermost 5.7m of peaty sediment, while the underlying detritic, sandy silt section did not contain any pollen (Ruíz-Zapata *et al*. 2002). In the Alpiarça peat bog (Portugal), clayey levels were sterile (van Leeuwaarden and Janssen 1985). In several limnic deposits from Galicia, peats occurring between thick detritic, sterile layers were the only sediments successfully analysed (Ramil-Rego and Gómez-Orellana 1996).

The case of Cañada del Gitano in the Sierra de Baza (Granada) could also be related to the abundance of detritic materials in parts of the peat bog. Two sediment cores were collected from the head of this deposit, and coring stopped at 417 and 378cm on reaching bedrock (Carrión *et al*. 2007b). While the 378cm-deep core was fully polliniferous, the longer 417cm-deep core was discarded because of its poor pollen content, with total sterility in several layers. The polliniferous core was mainly peat and silty peat, while the sterile one consisted of clastic silt.

Alteration of the original sedimentary structure may lead to sterility in peats. This is perhaps what happened to one of the two cores from Villaverde (Albacete), a tufaceous peat deposit overlying a calcreted conglomerate bedrock (Table 3). A sediment core of 550cm depth obtained from the eastern part of the fan was useful for pollen analysis (Carrión *et al*. 2001b). However, another one of *c*. 490cm depth obtained in the northern area was almost completely sterile, showing signs of corrosion in the few pollen grains and spores observed. In this case, the sedimentary context, a detrital marl interbedded with peats and sapropels, was identical for both cores (Carrión *et al*. 2001b). An earlier study by Taylor *et al*. (1998) based on a 600cm-core from the western part of the fan had already pointed to the abundance of inorganic matter and the investigators complained about poor pollen preservation. After reviewing unpublished reports provided by the landowner, we observed that, over the preceding years, the northern and western parts of the basin had been subject to trench excavation for a peat exploitation project requiring drainage.

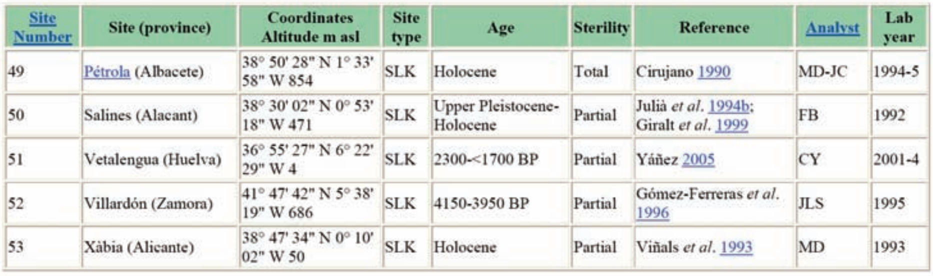
3.2 Lakes, salt marshes, salt pans, playa lakes, and lagoons

With few exceptions (Dupré 1988; Dupré *et al*. 1996; Davis 1994; Leroy 1990; 1997; 2008; Pérez-Obiol and Julià 1994; van der Knaap and van Leeuwen 1994; 1995), lake sediments from the Iberian Peninsula have been extensively explored for pollen only during the last decade (Burjachs *et al*. 1997; Carrión *et al*. 2001c; 2004b; Carrión 2002a; Muñoz-Sobrino *et al*. 2004; Valero-Garcés *et al*. 2006a; González-Sampériz *et al*. 2005; 2008; Morellón *et al*. 2008; Moreno *et al*. in press). In general, karstic lakes with permanent freshwater, and riverine wetlands and floodplains, are valuable for pollen analysis. But there are exceptions (Table 4). Pollen was absent in the less organic sediments of San Benito (Dupré *et al*. 1996) and Beco-

Table 4. Reported cases of palynological sterility in lacustrine sites.

Site Number	Site (province)	Coordinates Altitude m asl	Site type	Age	Sterility	Reference	Analyst	Lab year
11	Balsa del Sabinar (Almeria)	36° 53' 03" N 2° 51' 32" W 1827	LK	-	Partial	Carrión *et al.* 2003a	MD-JC	2000
12	Becorreiras (Ourense)	42° 15' 18" N 7° 22' 46" W 1320	LK	8336-7992 cal BP	Partial	Santos 2004	LS	1991
13	Bòbila Ordis, Lake 1 (Girona)	42° 08' 21" N 2° 44' 5" E 210	LK	Lower Pleistocene	Partial	Løvlie & Leroy 1995; Leroy 2008	SL	1989-2004
14	Conejos (Granada)	37° 43' 18" N 2° 27' 11" W 991	LK OSP	Lower Pleistocene	Total	Gibert *et al.* 1988	SL	Late 1980s
15	Champiñones (Granada)	37° 43' 58" N 2° 23' 16" W 970	LK OSP	Lower Pleistocene	Total	Gibert *et al.* 1988	SL	Late 1980s
16	El Cañizar, Villarquemado (Teruel)	40° 30' 8" N 1° 17' 7" W 987	LK	130-4 ka	Partial	Valero-Garcés *et al.* 2006b	JC-SF	2005-7
17	Fonelas (Granada)	37° 24' 45" N 3° 12' 10" W 800	LK OSP	Plio-Pleistocene	Total	Arribas *et al.* 2004b	JC	2001-5
18	Incarcal-Crespia (Girona)	42° 11' 13" N 2° 47' 59" E 130	LK OSP	Lower Pleistocene	Partial	Geurts 1977; 1979	MGU	1980-90
						Suc 1980	SUC-FB	
						Leroy 1990	SL	
19	Laguna de Orcera (Jaén)	38° 19' 2" N 2° 39' 13" W 900	LK	Holocene	Total	-	JC	2000
20	Lana Mayor (Huesca)	42° 42' 51" N 0° 18' 59" W 1600	LK	-	Total	González-Sampériz 2001	PGS	1999
21	Linás de Broto (Huesca)	42° 36' 19" N 0° 7' 21 " W 1250	LK	>33 ka	Partial	González-Sampériz *et al.* 2005	PGS	1999
22	Los Tollos (Cádiz)	36° 50' 43" N 6° 1' 3" W 54	LK	Pleistocene	Partial	-	SF	2007
23	Mas Miquel (Girona)	42° 10' 52" N 2° 48' 27" E 100	LK	Lower Pleistocene	Partial	Geurts 1977	MGU	1977-90
						Leroy 1990	SL	
24	Mencal (Granada)	37° 29' 38" N 3° 9' 49" W 920	LK OSP	Plio-Pleistocene	Total	Arribas *et al.* 2004b	SF	2007
25	Orce (Granada)	37° 43' 17" N 2° 28' 45" W 940	LK OSP	Lower Pleistocene	Total	Gibert *et al.* 1988; Agusti & Julià 1990	FB-SL-IP	-
26	Pla de l'Estany (Girona)	41° 52' 6" N 2° 6' 48" E 870	LK	Upper Pleistocene-Holocene	Partial	Pérez-Obiol 1988; Burjachs 1994	RPO-FB	1986
27	San Benito (Valencia)	38° 56' 30" N 1° 6' 30" W 671	LK	>41000-1410 BP	Partial	Dupré *et al.* 1996	MD	1995
28	Tornabous (Lleida)	41° 42' 31" N 1° 04' 14" E 299	LK	Holocene	Partial	Yll *et al.* 2008c	RY-FB-IE	2007
29	Tres Pins (Girona)	42° 08' 45" N 2° 43' 5" E 210	LK	Late Pliocene-Lower Pleistocene	Partial	Leroy 1997	SL	1988
30	Villena (Alicante)	38° 37' 11" N 0° 55' 49" W 502	LK	Upper Pleistocene-Holocene	Partial	Yll *et al.* 2003	EY-RPO-MD	2001
31	Yeseras (Granada)	37° 47' 59" N 2° 27' 48" W 1065	LK OSP	Lower Pleistocene	Total	Agusti & Julià 1990	SL	Late 1980s
32	Zagales (Granada)	37° 44' 19" N 2° 26' 5" W 970	LK OSP	Lower Pleistocene	Total	Gibert *et al.* 1988	SL	Late 1980s
33	Almenara de Adaja (Valladolid)	41° 12' 48" N 4° 40' 40" W 780	LG	>2675 BP	Partial	Delibes & Moure 1973	JLS	2003
34	Pego (Valencia)	38° 51' 52" N 0° 3' 11" W 4	LG	8300-7800 BP	Partial	Dupré *et al.* 1998b	MD	1986
37	El Acequión (Albacete)	38° 58' 42" N 1° 53' 22" W 680	SLK	Holocene	Total	Mariscal 1993	MD-JC	1994
38	Gallocanta (Teruel	) 40° 59' 36" N 1° 30' 31" W 995	SLK	*c.* Last 12000 BP	Partial	Burjachs *et al.* 1996	FB	1994
39	Juncabalejo (Huelva)	36° 56' 10" N 6° 22' 56" W 0	SLK	Sub-recent	Partial	Yáñez 2005	CY	2001-4
40	La Playa (Zaragoza)	41° 25' 00" N 0° 11' 10" W 340	SLK	<9900 cal BP	Partial	González-Sampériz *et al.* 2008	PGS	2003-4
41	La Salineta (Zaragoza)	41° 28' 55" N 0° 9' 30" W 340	SLK	<7740 BP	Partial	Valero-Garcés *et al.* 2004	BD, ACS	1994
				Last 2000 BP		González-Sampériz *et al.* 2008	PGS	2003-4
42	Laguna Redonda (Huelva)	37° 12' 13" N 6° 50' 26" W 36	SLK	Holocene	Partial	Stevenson (unpublished)	ACS, BD	-
43	Las Nuevas (Huelva)	36° 50' 30" N 6° 23' 16" W 1	SLK	Upper Pleistocene-Holocene	Partial	-	JC	2007
44	Mari López (Huelva)	37° 1' 4" N 6° 18' 33" W 0	SLK	Last 4000 BP	Partial	Yll *et al.* 2004	RY	2003
45	Mediana de Aragón (Zaragoza)	41° 30' 10" N 0° 44' 00" W 340	SLK	14000-10000 BP	Partial	Valero-Garcés *et al.* 2000a, 2000b	PGS	1996-8
46	Medina (Huelva)	37° 9' 34" N 6° 50' 28" W 10	SLK	Last 9000 BP	Partial	Reed *et al.* 2001	ACS	-
47	Membrillo (Huelva)	36° 53' 10" N 6° 21' 56" W 4	SLK	Sub-recent	Partial	Yáñez 2005	CY	2001-4
48	Ontalafia (Albacete)	38° 44' 59" N 1° 46' 49" W 878	SLK	Holocene	Total	Cirujano 1990	MD-JC	1994

Table 4. Reported cases of palynological sterility in lacustrine sites. *Continuation.*



Site Number	Site (province)	Coordinates Altitude m asl	Site type	Age	Sterility	Reference	Analyst	Lab year
49	Pétrola (Albacete)	38° 50' 28" N 1° 33' 58" W 854	SLK	Holocene	Total	Cirujano 1990	MD-JC	1994-5
50	Salines (Alacant)	38° 30' 02" N 0° 53' 18" W 471	SLK	Upper Pleistocene-Holocene	Partial	Julià *et al*. 1994b; Giralt *et al*. 1999	FB	1992
51	Vetalengua (Huelva)	36° 55' 27" N 6° 22' 29" W 4	SLK	2300-<1700 BP	Partial	Yáñez 2005	CY	2001-4
52	Villardón (Zamora)	41° 47' 42" N 5° 38' 19" W 686	SLK	4150-3950 BP	Partial	Gómez-Ferreras *et al*. 1996	JLS	1995
53	Xàbia (Alicante)	38° 47' 34" N 0° 10' 02" W 50	SLK	Holocene	Partial	Viñals *et al*. 1993	MD	1993

rreiras (Santos *et al*. 2000; Santos 2004), and two metres of organic clay from Laguna de Orcera were fully barren, with characteristics similar to Siles (Carrión 2002a), Cañada de la Cruz (Carrión *et al*. 2001c), and El Sabinar (Carrión *et al*. 2004a), which had provided high-quality pollen data to reconstruct the past vegetation changes in the Segura Mountains since the Last Glacial Maximum (Carrión 2002a). In Sierra de Gádor (Almería), a 150cm-depth core of red clay from Balsa del Sabinar was completely sterile, while a darker, more organic, lacustrine deposit formed under more permanent-water conditions was evenly polliniferous (Carrión *et al*. 2003a).

Palaeo-lakes deserve special attention because they are sometimes associated with palaeontological and palaeoanthropological excavations. Considerable effort, involving up to five trials, has been put into the famous enclaves of the Guadix-Baza depression, without success (Gibert *et al*. 1988; Agustí and Julià 1990; Palmqvist *et al*. 2003) (Table 4). Repeated analyses probably resulted from the suggestion of an early Pleistocene (1.4-1.1 Ma) Eurasian colonisation by humans on the basis of local Oldowan and Acheulean lithics (Oms *et al*. 2000). Excavation sediments, although extremely rich in fauna, were also lacking pollen in the Plio-Pleistocene sites of Fonelas and Mencal, in the same basin. Sediments at these sites are very diverse including clays, silts and sands, occasionally exposing micrite limestone layers formed on the margins of palaeo-lacustrine depositional environments under low-energy water conditions (Arribas *et al*. 2004b). Other palaeolacustrine records, now in an exposed situation, have shown partially polliniferous results, such as Linás in Huesca, where Martí *et al*. (2002) and González-Sampériz *et al*. (2005) have identified evidence of selective pollen corrosion.

Saline lakes, widespread in endorheic depressions of inland Iberia (González-Beserán *et al*. 1991; Casado and Montes 1995) have also presented difficulties, especially when short-lived or seasonal (Table 4, Fig. 2). A notorious case study concerns the Pétrola, El Acequión and Ontalafia lakes in La Mancha Plain of south-central Spain. An international project (PB91-0897, MEC 1992-95) led by M. Dupré, University of Valencia (Table 2), had been specifically designed to link environmental and cultural changes during the Holocene, based on the pollen records expected from these lakes and archaeological reports from adjacent settlement sites (Nájera and Molina 1977; Jordán 1992). Deep sediment cores of 2900, 1010 and 1350cm were extracted from Pétrola, El Acequión, and Ontalafia, respectively. A total of 90 (Pétrola), 53 (Acequión), and 65 (Ontalafia) sediment samples were processed in the palynological laboratories of Valencia (MD) and Murcia (JC), but they all failed to show pollen.

Coastal salt marshes and lagoons, while equally problematic, represent a risk worth taking for pollen analysis (Table 1). A multi-core approach is appropriate here because pollen corrosion and sedimentary and palynological hiatuses may affect the deposit unevenly across the basin (Table 4). Successful cases come from the most arid parts of eastern Spain. Coastal salt marshes of San Rafael, Roquetas de Mar, and Antas (Almería) have yielded pollen records from pleniglacial to late Holocene times (Yll *et al*. 1994; Pantaleón-Cano *et al*. 2003). Northwards in Alicante, the Elx pollen sequence was also obtained from a lagoon (Burjachs *et al*. 2000). Pollen analyses of two coreholes in the Pego-Oliva littoral marsh were less rewarding. Pollen was scarce, poorly preserved, and episodically absent from quite an organic-rich, yet salty, shallow-sea sediment (Table 4).

Pollen analyses carried out in the Doñana marshlands (Abalario Estuaries Complex in the coastal arc of Huelva between the Guadalquivir and Tinto deltas) (Fig. 1) have produced contrasting results. In general, organic-rich layers are polliniferous (Table 4). Some marshy sediments have given pollen records, such as Las Madres (Stevenson 1985), El Acebrón (Stevenson and Moore 1988), Mari López (Yll *et al*. 2003), Laguna Redonda and Línea de la Mediana (Stevenson n.d.), and Las Nuevas. Other 'marisma' deposits have not been as rewarding, such as Carrizosa, Cherri, Juncabalejo, Membrillo, and Vetalengua (Yáñez 2005; Yáñez *et al*. 2006).

3.3 Caves and rockshelters

A number of archaeological caves with excavated profiles show pollen-sterile layers, or sometimes whole sterile sections, even after several trials (Table 5). Well-known sites of the Pleistocene include the Mousterian Cova Negra of Xativa (Fumanal 1986), Cova de les Cendres (Dupré 1988; Badal and Carrión 2001), Cova de El Salt (Fumanal 1986), Cueva de Nerja's

Table 5. Cases of palynological sterility with caves (C), and rockshelters (R).

Site Number	Site	Coordinates Altitude m asl	Site	Age/Industry	Sterility	Reference	Analyst	Lab Year
54	A Valiña (Orense)	43° 2' 27" N 7° 19' 4" W 550	C	Middle-Upper Palaeolithic	Partial	Fernández-Rodriguez *et al.* 1995	PRR	-
55	Altamira (Cantabria)	43° 22' 57" N 4° 06' 58" W 75	C	Magdalenian	Partial	Lasheras and de las Heras 1997	MD JC	1997
56	Amalda (Guipúzcoa)	43° 14' 6" N 2° 13' 37" W 220	C	Mousterian Solutrean Chalcolithic	Partial	Altuna *et al.* 1990	MD	1984
57	Atapuerca Sima Huesos (Burgos)	42° 21' 6" N 3° 31' 12" W 994	C	Middle Pleistocene	Partial	García-Antón 1987	MGA	1984-7
58	Atapuerca Galería (Burgos)	42° 21' 5" N 3° 31' 11" W 999	C	Middle Pleistocene	Partial	García-Antón *et al.* 1990; García-Antón and Sainz-Ollero 1991	MGA	1984-7
59	Atapuerca Gran Dolina (Burgos)	42° 21' 6" N 3° 31' 12" W 994	C	Lower-Middle Pleistocene	Partial	García-Antón 1995; Cattani *et al.* 1994	MGA	1984-7
						Burjachs 2001	FB	
60	Atapuerca Tres Simas (Burgos)	42° 21' 5" N 3° 31' 11" W 999	C	Middle Pleistocene	Total	García-Antón 1989	MGA	1984-7
61	Berroberría (Navarra)	43°16'43.05" N 1°31'34.64" W 160	C	Magdalenian-Neolithic	Partial	Boyer-Klein 1988	BK	-
62	Bolomor (Valencia)	39° 4' 48" N 0° 16' 59" W 22	C (bc, bt)	Mousterian 525-121 ka	Total	Fernández-Peris 2004	MD	1994-5
63	Bolumini (Alicante)	38° 50' 13" N 0° 00' 50" W 170	C	Neolithic	Partial	Sanchís 1992	AKS	1990
64	Calaveres (Alicante)	38° 47' 37" N 0° 1' 43.56" W 180	C (bc)	Mousterian	Partial	Vives 1982	MD	1982
65	Carihuela (Granada)	37° 26' 22" N 3° 26' 13" W 1078	C	Last 120 ka	Partial	Carrión 1992b	JC	1988-1999
66	Cau del Duc d'Ullà (Girona)	42° 3' 51" N 3° 7' 39" E 135	C (bc)	Pleistocene	Total	Guilbaud *et al.* 1993	FB	1978
67	Cendres (Alicante)	38° 41' 10" N 0° 9' 9" E 35	C (bc)	24-6 ka	Partial	Villaverde 2001	MD	1992
68	Cova 120 (Girona)	42° 16' 30" N 2° 36' 42" E 460	C	Middle Palaeolithic	Partial	Burjachs 1988a	FB	1983
69	Cova Beneito (Alicante)	38° 48' 7" N 0° 28' 26" W 650	C	Mousterian-Upper Paleolithic >38-<16 ka	Partial	Carrión 1992a	JC	1989-1996
70	Cova d'En Pardo (Alicante)	38° 44' 04" N 0° 26' 10" W 500	C	Neolithic/Bronze	Partial	Dupré *et al.* 1999; González-Sampériz 1999	MD PGS	1997
71	Cova Fosca (Castellón)	40° 27' 25" N 0° 8' 0" W 1150	C (bt)	Meso-Neolithic	Total	Yll 1988	IP	1980
						Cebrià *et al.* 1988	RY	
72	Cova Matutano (Castellón)	40° 6' 46" N 0° 3' 11" W 324	C	Magdalenian 13960-11410 BP	Total	Yll 1983; Burjachs 1999	FB	1980-86
					Partial	Yll *et al.* 2008d	RY-FB-IE	2007
73	Cova Negra (Alicante)	38° 39' 8" N 0° 44' 21" W 911	C (hrt, bc, bt)	Mousterian *c.* 117-50 ka	Total	Fumanal 1986	MD	1985
74	Cueva del Calor (Murcia)	38° 5' 18 "N 1° 48' 27" W 670	C (bt)	Meso-Neolithic	Partial	López-García 1988	PLG	1986
75	Cova de l'Or (Alicante)	38° 49' 34 "N 0° 23' 04" W 400	C	Neolithic	Partial	Dupré *et al.* 1983	MD	1980
76	Cueva Tomás (Granada)	37° 44' 19" N 2° 26' 5" W 970	C	Lower Pleistocene	Total	Agusti & Julià 1990	SL	Late 1980s
77	Chaves (Huesca)	42° 12' 48" N 0° 8' 30" W 663	C	Upper Palaeolithic-Bronze Age	Partial	Castán & Baldellou 1985	PGS	1998
78	Ekain (Guipúzcoa)	43° 14' 18 "N 2° 16' 09" W 90	C	Magdalenian/Azilian	Partial	Altuna & Merino 1984	MD	1988
79	El Ángel (Córdoba)	37° 24' 31" N 4° 29' 8" W 500	C	Mid-Upper Pleistocene	Total	Botella *et al.* 2006	JC	2004
80	El Arca (Cádiz)	36° 45' 30" N 5° 21' 57" W 850	C	-	Total	Acosta 1968	JLS	1998
81	El Castillo (Cantabria)	43° 17' 55" N 3° 57' 43" W 75	C	Last 120 ka	Total	Bernaldo de Quirós & Cabrera 2000	JLS	1983
82	El Moro de Olvena (Huesca)	42° 6' 48" N 0° 17' 25" E 380	C	Holocene	Total	Alday 1995; Cuchí & Sancho 1995	PGS	1988
83	El Pendo (Cantabria)	43° 24' 17" N 3° 54' 2" W 51	C	Lateglacial-Boreal	Partial	Leroi-Gourhan 1980	ALG	-
84	Erralla (Guipúzcoa)	43° 11' 51 "N 2° 13' 36 W 500	C	Paleolithic	Partial	Altuna *et al.* 1985	BK	1980s
85	La Blanca (Murcia)	38° 9' 27" N 1° 21' 36" W 300	C (sp)	Pleistocene	Total	-	JC	1999
86	Labeko (Guipuzcoa)	43° 3' 36" N 2° 29' 25" W 260	C	Aurignacian-Chatelperronian	Partial	Sánchez-Goñi 1991	MFSG	-
87	Les Malladetes (Valencia)	39° 00' 51" N 0° 17' 41" W 5000	C	Upper Palaeolithic	Partial	Fortea & Jordá 1976	MD	1988
88	Lezetxiki (Guipuzcoa)	43° 4' 51" N 2° 31' 49" W 350	C	Mousterian-Bronze	Partial	Sánchez-Goñi 1991	MFSG	-
89	Los Azules (Asturias)	43° 20' 55" N 5° 7' 37" W 200	C	Azilian 11000-9430 BP	Partial	López-García 1981	PLG	1980

Table 5. Cases of palynological sterility with caves (C), and rockshelters (R). *Continuation.*

Site Number	Site	Coordinates Altitude m asl	Site	Age/Industry	Sterility	Reference	Analyst	Lab Year
90	Mazaculos (Asturias)	43° 23' 22" N 4° 34' 55" W 70	C	9290 BP	Partial	López-García 1986	PLG	1983
				Preboreal-Boreal	Partial	López-García 1986	JLS	1983
				Preboreal-Boreal	Total	González-Morales *et al.* 1980	KV	-
91	Nacimiento (Jaén)	38° 6' 18" N 2° 41' 36" W 1600	C (bt)	Neolithic	Partial	Asquerino & López-García 1981	PLG	1980
92	Nerja (Málaga)	36° 45' 42" N 3° 52' 6" W 110	C (bc, hrt)	Upper Pleistocene-Holocene	Total	Arribas *et al.* 2004a	MD	1986
93	Palomas chasm (Murcia)	37° 47' 54" N 0° 53' 53" E 60	C (bc)	130-120 ka	Total	Carrión *et al.* 2003b	MD-JC	2001
94	Pouàs (Ibiza)	39° 0' 9" N 1° 35' 13" E 5	C	*c.* 100 ka	Partial	Guerrero & Gomés 2000	MGA	1992
95	Rascaño (Cantabria	) 43° 17' 42" N 3° 42' 10" W 200	C	Azilian 10558-10486 BP	Partial	Boyer-Klein 1981	BK	-
96	Sorbas (Almería)	37° 6' 18" N 2° 4' 38" W 330	C (gsp)	Pleistocene	Total	Calaforra & Pulido-Bosch 2003	JC	1999
97	Tossal de la Font (Castelló)	40° 06' 25.14" N 0° 03' 17" W 361	C	Pleistocene	Total	Olària *et al.* 2007	FB-IE	2003
98	Valdegoba (Burgos)	42° 31' 18" N 3° 46' 16" W 890	C	Mousterian	Total	Díez *et al.* 1989	MGA	1989
99	Zatoya (Navarra)	42° 54' 2" N 1° 12' 16" W 1000	C	Epipalaeolithic 8260 BP	Partial	Boyer-Klein 1989	BK	-
100	Abric Agut (Barcelona)	41° 31' 50" N 1° 41' 24" E 305	R (tr)	Upper Pleistocene-Holocene	Partial	Vaquero 2001	FB	1998-9
101	Abric del Filador (Tarragona)	41° 17' 24" N 0° 45' 17" E 437	R	Upper Pleistocene-Holocene	Total	García-Argüelles *et al.* 2005	AE-IP	1983
102	Abric Romaní (Barcelona)	41° 31' 57" N 1° 41' 18" E 314	R (tr)	Upper Pleistocene	Partial	Burjachs & Julià 1994	FB	1998-2004
103	Abrigo de Ángel (Teruel)	40° 44' 31" N 0° 23' 59" W 700 m	R	Holocene	Total	Sebastián & Zozaya 1991	PGS	1997
104	Abrigo Alejandre (Soria)	41° 20' 30" N 1° 58' 18" W 960	R (bc, bt)	Pleistocene	Total	Utrilla *et al.* 2000	PGS	2000
105	Bauma dels Pinyons (Barcelona)	41° 31' 56" N 1° 41' 20" E 310	R (tr)	Upper Pleistocene-Holocene	Partial	Vaquero 2006	FB	1998-9
106	Costa d´En Manel (Barcelona)	41° 32' 2" N 1° 41' 25" E 330	R (tr)	Upper Pleistocene-Holocene	Partial	-	FB	2002
107	Cueva Antón (Murcia)	38° 4' 0" N 1° 29' 33" W 370	R	Mid-Upper Palaeolithic	Total	Martínez-Sánchez 1992	JC	1995
108	El Salt (Alicante)	38° 40' 13" N 0° 21' 52" W 891	R (tr)	Mousterian 60-40 ka	Total	Fumanal 1986	MD	1988
109	Entrefoces (Oviedo)	43° 3' 36" N 2° 29' 25" W 260	R	Paleolithic	Total	González Morales 1990	MD	1980s
110	Forcas I Forcas II (Huesca)	42° 11' 33" N 0° 20' 20" E 550	R	11300-9500 BP	Total	Utrilla & Mazo 2008	PGS	1998
			R (bt)	>8600 BP				
111	La Cativera (Tarragona)	41° 11' 14" N 0° 20' 6" E 82	R	Meso-Neolithic	Partial	Allué & Renault-Miskovsky 1999	EA	1988
112	La Font Voltada (Tarragona)	41° 27' 41" N 1° 17' 58" E 603	R	Upper Pleistocene	Partial	Burjachs & Pérez-Obiol 1989	FB-RPO	1988
113	La Higuera (Murcia)	37° 34' 59" N 1° 12' 56" W 50	R (bt)	Mesolithic	Total	Martínez-Andreu & Sánchez 2006	JC	1989
114	La Viña (Oviedo)	43° 18' 45" N 5° 49' 41" W 220	R	Paleolithic	Total	Fortea 1990	MD	1980s
115	Legunova (Zaragoza)	42° 21' 21" N 0° 56' 45" W 700	R	Azilian Meso-Neolithic	Partial	Montes 2005	PGS	2004
116	Levante (Cádiz)	36° 27' 42" N 5° 55' 42" W 260	R	Upper Pleistocene	Total	Mas *et al.* 1998	JLS	-
117	Los Aviones (Murcia)	37° 35' 12" N 0° 59' 13" W 20	R (bc, bt)	Middle Palaeolithic	Total	Montes 1987	JC	1987
118	Los Baños (Teruel)	41° 2' 5" N 0° 35' 32" W 515	R	<7840 BP	Partial	González-Sampériz 2004b	PGS	2002
119	Molino del Vadico (Albacete)	38° 10' 51" N 2° 26' 58" W 980	R (bt, hrt)	Last 12 ka	Total	Vega-Toscano 1993	JC	1990
120	Paco Pons (Zaragoza)	42° 21' 21" N 0° 56' 45" W 1040	R	Meso-Neolithic	Total	Montes & Domingo 2001	PGS	2000
121	Peña 14 (Zaragoza)	42° 21' 21" N 0° 56' 45" W 760	R	Neolithic	Partial	González-Sampériz *et al.* 2005	PGS	2000-1
122	Peña del Diablo (Zaragoza)	41° 20' 28" N 1° 58' 14" W 700	R	>11080 BP	Partial	Utrilla *et al.* 2000	PGS	1998
123	Ratlla del Bubo (Alicante)	38° 16' 48" N 0° 48' 17" W 200	R (hrt)	Upper Palaeolithic	Total	Badal *et al.* 1990	MD	1991
124	Tossal de la Roca (Alicante)	38° 47' 18" N 0° 15' 11" W 650	R	Lateglacial-Boreal	Partial	Cacho *et al.* 1995	PLG	1995
125	Vergara (Soria)	41° 20' 28" N 1° 58' 14" W 860	R	Pleistocene-Holocene	Partial	Utrilla *et al.* 2000	PGS	1998

Vestíbulo Chamber (Arribas *et al*. 2004a), Cueva de Altamira (Lasheras and De las Heras 1997), Cueva 120 (Agustí *et al*. 1987; Burjachs 1991a), Cueva del Castillo (Bernaldo de Quirós and Cabrera 2000), Cueva del Ángel, Pouás (Guerrero and Gornés 2000), Cueva de Amalda (Dupré 1988; Altuna *et al*. 1990), and noticeably, the mid-Pleistocene (350-120 ka) Cova de Bolomor, where 74 pollen samples from a 7m-deep stratigraphy were sterile (Fernández-Peris 2004).

Many of these cave stratigraphies include hearths, breccias, stalagmitic crusts, calcium-carbonate micelia, and more or less indurated strata, blocks, coarse-grain levels, lithics and other archaeological remains, bone remains, and shells. Hearths may or may not contain pollen. They did not in Civiacas (González-Sampériz 2001), Matutano (Burjachs 1999) and Filador (Burjachs 1999) and the Asturian cave of Los Azules (López-García 1981) (Table 5), but did in other Palaeolithic and Neolithic cave records (Dupré and Renault-Miskovsky 1990; Carrión and Dupré 2002; Carrión *et al*. 1999a; 2004b; 2008; López-Sáez *et al*. 2003; González-Sampériz 1998). The reason for this diversity of results is so far unknown. Cemented sediments coincide with sterility in Cau del Duc d'Ulla, Cueva de Valdegoba, Cova Fosca, Tossal de la Font, Cova Matutano, Bolomor, Cova Negra (Dupré 1988), Sima de las Palomas (Carrión *et al*. 2003b) and Cueva del Ángel (Table 5). In contrast, calcium carbonate deposits of Abric Romaní, Bauma dels Pinyons, Abric Agut and Costa d'En Manel rockshelters have provided pollen records for a major part of the Upper Pleistocene of north-eastern Iberia (Burjachs and Julià 1994; Allué *et al*. 1998; Burjachs 2000b). More general is the expected absence of pollen in sandy layers of cave stratigraphies, as seen in Cuevas de Levante (Cádiz), and Cueva de Chaves (Huesca) (Table 5). Several pollen sequences of the Cantabrian region are interrupted when reaching coarser-grain sediments: notably the caves of Lezetxiki and Labeko (Sánchez-Goñi 1991), Zatoya (Boyer-Klein 1989), and Berroberria (Boyer-Klein 1988).

Pollen analyses in the hominin-bearing Atapuerca (Burgos) have been rather unrewarding (García-Antón 1987; 1995; García-Antón *et al*. 1990; García-Antón and Sainz-Ollero 1991; Cattani *et al*. 1994; García-Antón and Casado 1994). M. García-Antón processed 84 samples from Galería levels TG-12 and TG-3, 87 samples from Gran Dolina levels TD-1 to TD-11, and 12 samples from Boca Norte chasm TN. All of them were palynologically sterile (Table 5). Other analysts, like F. Burjachs, who repeated analyses, have complained about the palynological poverty of Atapuerca.

Carihuela Cave (SE Spain) has proved useful for palaeoecological purposes: there are substantial pollen concentrations and a number of taxa, parallels between the curves of percentages and concentrations, ecological plausibility of the pollen spectra, and possibilities of correlation of pollen spectra from different sections of the same lithological units. Most profiles are, in fact, relatively rich in pollen, including Mousterian (Carrión 1992a), Upper Palaeolithic (Carrión *et al*. 1998) and Neolithic and Bronze Age levels (Fernández *et al*. 2007). However, from the 12 lithostratigraphical units described by Vega-Toscano *et al*. (1988) for chambers CIII and CIV, both the unit XII and the lowermost levels of XI contained no pollen. There was a similar absence in unit VI in chamber CIII and CIV (Carrión *et al*. 1998). Although these deposits are the richest in organic content in the cave, it was clear that they had occasionally experienced repeated fluctuations of water levels (Vega-Toscano *et al*. 1988).

Pollen analyses in Cova Beneito present another interesting case study. This cave contains a continuous record of Middle Palaeolithic and Upper Palaeolithic industries, the latter extending from the Aurignacian to the Solutrean. In the course of excavations during 1990-91, Mousterian strata were polliniferous, but Upper Palaeolithic levels did not provide pollen from the available sections (Carrión 1992b). Later excavations exposed new profiles recording the whole sequence of Upper Palaeolithic industries. Surprisingly, these sediments proved to contain enough palynomorphs to undertake reliable pollen analysis (Carrión and Munuera 1997). Both profiles provided a stratigraphically coherent sequence involving the Middle and Upper Palaeolithic.

Sediments accumulated within rockshelters are prone to palynological sterility, often throughout the whole deposit (Table 1, Fig. 2). A considerable number of the failed records are rockshelters that show signs of burrowing activity by insects, earthworms, rootlets (Cueva de los Aviones, Cueva de la Higuera, Abrigo Alejandre, Abrigo del Molino del Vadico, Forcas II), and/or fluvial transport, flowing water or seepage (Abrigo de Angel, Forcas I, II, Legunova, Abrigo de los Baños de Ariño, Cueva de Antón) (Table 5). Again, sandy sediment is associated with sterility, as in Peña del Diablo, Legunova, Peña 14, and Abrigo del Filador (González-Sampériz 2004a; Utrilla *et al*. 2000; González-Sampériz *et al*. 2003a; 2005; García-Argüelles *et al*. 2005).

3.4 Open-air archaeological and palaeontological sites, slope deposits, terraces, palaeosols and travertines

Given their extraordinary abundance in the Iberian Peninsula since the Plio-Pleistocene, but especially after the Neolithic (Allué and Renault-Miskovsky 1999), the sediments associated with palaeontological, and archaeological open-air sites have traditionally been tested for palynology (Table 6). Reports of pollen occurrence in these sites, predominantly with coarse clasts and high lime concentration, are numerous in Spain (López-García 1991; Mariscal 1991a-c; 1992; Davis and Mariscal 1994; Castro *et al*. 1999; Fuentes *et al*. 2005; 2007; Postigo *et al*. 2007), but because of the high profile of some archaeological excavations, failures are highlighted.

Purely sandy and gravel-based layers are expected to be usually sterile or contain poor, contaminated, or non-significant pollen spectra. This is the case for the Chalcolithic sites of Los Molares (megalithic necropolis), Los Millares (Burjachs

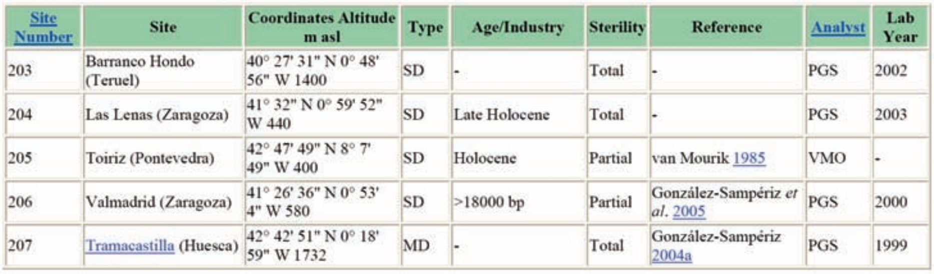
Table 6. Cases of palynological sterility with open-air archaeological sites. (OSA, mainly settlement sites) and palaeontological sites (OSP), exposed travertines (TR), palaeosoils (PL), fluvial terraces (T), slope deposits (SD), and moraine deposits (MD)

Site Number	Site	Coordinates Altitude m asl	Type	Age/Industry	Sterility	Reference	Analyst	Lab Year
126	Adra (Almería)	36° 44' 53" N 3° 1' 21" W 3	OSA	2700-1800 bp	Total	Suárez 1989	JC	1995
127	Alcudia de Veo (Castellón)	39° 55' 01" N 0° 21' 21" W 480	OSA	Holocene	Partial	Butzer *et al*. 1986	MD	1988
128	Bòbila Madurell (Barcelona)	41° 30' 49" N 2° 06' 03" E 157	OSA	Neolithic-Medieval	Partial	Burjachs & Pérez-Obiol 1988	FB-RPO	1987
129	Buzanca I (Madrid)	40° 10' 18" N 3° 39' 17" W 600	OSA	Chalcolithic	Total	López-García 1997	PLG	1994
130	Cabezo Redondo (Alicante)	38° 38' 43" N 0° 53' 34" W 518	OSA	Bronze Age 4000-3900 bp	Total	-	MD-JC	1993
131	Camp Vermell (Andorra)	42° 27' 51" N 1° 29' 30" E 940	OSA	XI-XII centuries	Partial	Yll *et al*. 2007c	RY-FB-IE	2007
132	Can Olivé (Barcelona)	41° 28' 50" N 2° 08' 06" E 118	OSA	Late Iron Age	Partial	Burjachs 1988b	FB	1986
133	Canaleja 1 (Cáceres)	39° 44' 30" N 5° 42' 1" W 410	OSA	Chalcolithic 5000-4300 bp	Partial	López-Sáez and López-Merino 2007	JLS	2006
134	Cáparra (Badajoz)	38° 57' 14" N 6° 19' 35" W 278	OSA	Roman	Total	Castillo *et al*. 1994	PLG	2002
135	Carvalhal (Portugal)	41° 7' 58" N 8° 4' 57" W 380	OSA	Holocene	Total	Cruz 1991	JLS	2001
136	Casa Montero (Madrid)	40° 29' 37" N 3° 41' 21" W 137732	OSA	Early Neolithic	Total	Consuegra *et al*. 2004	JLS	1996
137	Castilmontán (Soria)	41° 11' 37" N 2° 18' 51" W 875	OSA	Celtiberic	Total	Arlegui 1992	PLG	1996
138	Castro de Vigo (Lugo)	43° 12' 17"N 7° 24' 05"W 147	OSA	Late Holocene	Partial	Aira-Rodríguez *et al*. 1988	MJA	-
139	Cerro San Vicente (Salamanca)	40° 57' 41" N 5° 40' 24" W 780	OSA	Early Iron Age	Partial	Yll *et al*. 2007b	RY-FB-IE	2007
140	Civiacas II (Huesca)	41° 49' 36" N 0° 9' 24" E 280	OSA	Bronze Age	Total	González-Sampériz 2001	PGS	1995
141	El Castillejo de Numancia (Soria)	41° 48' 35" N 2° 26' 38" W 1070	OSA	Celtiberic	Partial	López-García 1986	PLG	1996
142	El Molón (Valencia)	39° 38' 52" N 1° 23' 57" W 913	OSA	Iberic	Total	-	JC	1997
143	El Prado (Murcia)	38° 27' 19"N 1° 19' 49"W 470	OSA	Bronze Age	Partial	López-García 1988	PLG	1986
144	El Retamar (Cádiz)	36° 31' 44" N 6° 11' 30" W 10	OSA	Early Neolithic	Total	Lozano *et al*. 1997	PLG	1996
145	El Vinyets (Tarragona)	41° 11' 14" N 1° 20' 6" E 82	OSA	Middle-Upper Palaeolithic	Total	Allué & Renault-Miskovsky 1999	EA	1996
146	Ereta del Pedregal (Valencia)	39° 6' 5" N 0° 41' 36" W 225	OSA	Neolithic-Bronze	Partial	Dupré *et al*. 1985	MD	1983
147	Estebanvela (Segovia)	41° 25' 9" N 3° 22' 26" W 982	OSA	11200-9900 bp	Total	Cacho *et al*. 2003	PLG	2001-4
148	Follente (Pontevedra)	42° 36' 19" N 8° 38' 35" W 24	OSA	Holocene	Total	-	JLS	2001
149	Font del Ros (Barcelona)	42° 06' 04" N 1° 50' 47" E 673	OSA	Meso-Neolithic	Partial	Burjachs 1990	FB	1989
150	Fuentesaúco (Soria)	41° 45' 52" N 2° 20' 11" W 814	OSA	Iron Age 2700-2200 bp	Partial	Mariscal 1994	BM	-
151	Hoyo de La Mina (Málaga)	36° 42' 56" N 4° 16' 31" W 3	OSA	Neolithic	Partial	Cortés and Sanchidrián 1999	PLG	1999
152	Huerta de los Cabreros (Madrid)	40° 1' 43" N 3° 37' 2" W 500	OSA	Chalcolithic 4150-3950 bp	Partial	Mariscal 1996	BM	-
153	La Calzadilla (Palencia)	41° 24' 40" N 4° 50' 31" W 900	OSA	Bronze Age	Partial	-	JLS	2005
154	La Cativera (Tarragona)	41° 11' 14" N 1° 20' 6" E 82	OSA	Meso-Neolithic	Partial	Allué & Renault-Miskovsky 1999	EA-JRM	-
155	La Codera (Huesca)	41° 43' 39" N 0° 7' 20" E 219	OSA	Bronze-Iron Age	Partial	Montón 1998	PGS	2004
156	La Fonollera (Gerona)	42° 2' 51" N 3° 6' 55.73" E 20	OSA	Final Bronze	Total	Pons 1977	FB	1979
157	La Pijotilla (Badajoz)	38° 43' 37" N 6° 32' 7" W 260	OSA	Chalcolithic-Bronze Age	Partial	Hurtado 2007	JLS	1998
158	La Prunera (Girona)	42° 11' 36" N 2° 30' 43" E 424	OSA	Mesolithic	Partial	Burjachs 2000b	FB	1999
159	Las Monjas (Alicante)	38° 20' 41" N 0° 29' 5" W 5	OSA	Middle Age (Muslim)	Total	-	JS	2005
160	Los Millares (Almería)	36° 58' 24" N 2° 31' 32" W 214	OSA	Bronze Age	Total	Burjachs 1991b	FB	1990
161	Los Molares (Sevilla)	37° 9' 21" N 5° 43' 11" W 73	OSA	Chalcolithic	Partial	López-García & López-Sáez 1997	PLG	1990
162	Los Tholos (Badajoz)	38° 41' 5" N 6° 24' 12" W 340	OSA	Chalcolithic	Total	-	PLG	1998
163	Lulióbriga (Cantabria)	42° 59' 0" N 4° 6' 56" W 920	OSA	Roman	Partial	Iglesias-Gil 1997	-	-

Table 6. Cases of palynological sterility with open-air archaeological sites. *Continuation.*

Site Number	Site	Coordinates Altitude m asl	Type	Age/Industry	Sterility	Reference	Analyst	Lab Year
164	Marroquies Bajos (Jaén)	37° 46' 17" N 3° 47' 17" W 548	OSA	Chalcolithic- Iberic	Partial	Zafra *et al.* 1999	PLG	1997
165	Mata el Casare (Oviedo)	43° 09' 07" N 5° 56' 31" W 630	OSA	Holocene	Partial	Dupré 1988	MD	1980s
166	Molinicos (Murcia)	38° 12' 27" N 1° 50' 31" W 460	OSA	Chalcolithic	Partial	López-Garcia 1988	PLG	1986
167	Monte Aguilar (Navarra)	42° 2' 46" N 1° 19' 57" W 300	OSA	Bronze Age	Partial	Iriarte 1992	MJI	-
168	Muntanya Assolada (Valencia)	39° 9' 12" N 0° 22' 52" W 227	OSA	Bronze Age	Total	Martí 1983	MD	1983
169	Necrópolis del Mercadillo (Cáceres)	39° 20' 46" N 6° 4' 19" W 420	OSA	Iron Age	Partial	Hernández & Galán 1992	PLG	1999
170	Pedra Moura (La Coruña)	43° 09' 09" N 8° 36' 01" W 1	OSA	Late Holocene	Partial	Aira-Rodriguez *et al.* 1988	MJA	-
171	Piedrafita (Oviedo)	43° 26' 37" N 5° 59' 51" W 400	OSA	Holocene	Partial	Dupré 1988	MD	1980s
172	Puente Largo del Jarama (Madrid)	40° 5' 8" N 3° 36' 16" W 490	OSA	Iberic 2650 bp	Partial	Mariscal 1996	BM	-
173	Puntal dels Llops (Valencia)	39° 42' 7" N 0° 32' 31" W 370	OSA	Iberic	Total	Bonet *et al.* 1981	MD RM	1988
174	San Bernardo (Valladolid)	41° 37' 53" N 4° 15' 43" W 730	OSA	Final Bronze	Total	-	JLS	2005
175	San Blas (Badajoz)	38° 30' 44" N 7° 16' 52" W 190	OSA	Chalcolithic 5000-4500 bp	Total	Hurtado 2004	JLS	2004
176	San José (Badajoz)	38° 16' 2" N 6° 28' 27" W 495	OSA	Bronze Age	Total	-	PLG	2004
177	San Martin de La Vega (Madrid)	40° 12' 28" N 3° 34' 6" W 510	OSA	Visigothic	Partial	López-Garcia 1983	PLG	1999
178	San Miguel Atxa (Álava)	42° 51' 54" N 2° 42' 29" W 500	OSA	Iron Age	Partial	Iriarte 1994	MJI	-
179	Sevilleja (Jaén)	38° 2' 3" N 3° 51' 44" W 276	OSA	4800-800 bp	Partial	Contreras *et al.* 1985	JLS	1996
180	Sitges de la UAB (Barcelona)	41° 29' 59" N 2° 06' 47" E 127	OSA	Iron Age	Partial	Burjachs 1988b; in press	FB	1986
181	Teatro Romano (Murcia)	37° 35' 58" N 0° 59' 2" W 15	OSA	Roman 5-1 bc	Total	Ramallo *et al.* 2004	MM	1999
182	Torre Roja (Alicante)	38° 20' 41" N 0° 29' 5" W 5	OSA	Late Holocene	Total	-	JC-SF	2006
183	Tozal de Andrés (Huesca)	41° 57' 26" N 0° 3' 28" E 380	OSA	Iberic-Roman	Partial	González-Sampériz & Sopena 2002	PGS	1995
184	Turó de la Bateria (Girona)	41° 59' 40" N 2° 49' 11" E 77	OSA	Upper Pleistocene	Partial	Yll *et al.* 2008b	RY-FB-IE	2007
185	Vale Cerva (Portugal)	41° 7' 7" N 7° 6' 17" W 380	OSA	Holocene	Total	-	JLS	2005
186	Vallparadis (Barcelona)	41° 33' 47" N 2° 01' 09" E 330	OSA	Lower-Upper Pleistocene	Partial	Yll *et al.* 2007a	RY-IE-FB	2007
187	Venta Quemada I (Toledo)	39° 55' 33" N 3° 58' 59" W 593	OSA	Bronze Age	Total	-	PLG	1997
188	Villasviejas de Tamuja (Cáceres)	39° 20' 46" N 6° 4' 19" W 420	OSA	Late Iron Age 2400 bp	Partial	Hernández *et al.* 1989	PLG	1999
189	Almonacid (Zaragoza)	41° 16' 23" N 0° 47' 6" W 500	OSP T	Roman	Total	Pueyo *et al.* 2006	PGS	2002
190	Cal Guardiola (Barcelona)	41° 34' 06" N 2° 00' 40" E 310	OSP T	Middle-Lower Pleistocene	Partial	Postigo *et al.* 2007	FB	1998
191	Cuesta de la Bajada (Teruel)	40° 20' 27" N 1° 6' 37" W 880	OSP T	Middle Pleistocene	Partial	Pérez-González *et al.* 2000	MD	1990s
192	Matarraña (Teruel)	40° 50' 1" N 0° 10' 47" E 560	OSP TR	100-120 ka	Total	Martínez-Tudela 1986	JC	1991
193	Quibas (Murcia)	38° 18' 51" N 1° 4' 41" W 634	OSP TR	1.3-1 Ma	Total	Montoya *et al.* 2001	JC	2004
194	San Quirce (Palencia)	42° 0' 43" N 4° 31' 58" W 738	OSP T	Middle Pleistocene	Total	Arnáiz 1990	MGA	1991
195	Guadalquivir (Córdoba)	37° 49' 53" N 5° 14' 22" W 200	TR	-	Total	-	SF-JC	2006
196	Tajo de Ronda (Málaga)	36° 44' 30" N 5° 9' 59" W 700	TR	-	Total	-	SF-JC	2007
197	Islas Columbretes (Castellón)	39° 53' 39" N 0° 41' 11" E 45	PL	-	Partial	Expósito & Burjachs 2007	IE-FB	2006
198	Pedro Bernardo (Ávila)	40° 15' 4" N 4° 54' 20" W 1095	PL	Holocene	Partial	-	JLS	2004
199	Urda (Toledo)	39° 24' 42N 3° 42' 57" W 770	PL	Holocene	Total	-	JLS	2006
200	Arzobispo (Toledo)	39° 47' 55" N 5° 11' 23" W 320	T	-	Partial	Martín-Arroyo *et al.* 1996a	TMA	-
201	Valdelobos (Toledo)	39° 51' 07" N 4° 01' 04" W 500	T	Pleistocene	Partial	Martín-Arroyo *et al.* 1996b	TMA	-
202	Alós (Lleida)	41° 54' 42" N 0° 57' 42" E 295	SD TR	-	Total	-	PGS	2004

Table 6. Cases of palynological sterility with open-air archaeological sites. *Continuation.*



Site Number	Site	Coordinates Altitude m asl	Type	Age/Industry	Sterility	Reference	Analyst	Lab Year
203	Barranco Hondo (Teruel)	40° 27' 31" N 0° 48' 56" W 1400	SD	-	Total	-	PGS	2002
204	Las Lenas (Zaragoza)	41° 32" N 0° 59' 52" W 440	SD	Late Holocene	Total	-	PGS	2003
205	Toiriz (Pontevedra)	42° 47' 49" N 8° 7' 49" W 400	SD	Holocene	Partial	van Mourik 1985	VMO	-
206	Valmadrid (Zaragoza)	41° 26' 36" N 0° 53' 4" W 580	SD	>18000 bp	Partial	González-Sampériz *et al*. 2005	PGS	2000
207	Tramacastilla (Huesca)	42° 42' 51" N 0° 18' 59" W 1732	MD	-	Total	González-Sampériz 2004a	PGS	1999

1991a), La Pijotilla, Canaleja I (López-García and López-Sáez 1994a; 1994b), Buzanca I and Huerta de los Cabreros (Mariscal 1996), the Bronze Age of Monte Aguilar (Iriarte 1992), San Blas, San José, Venta Quemada I, Sevillejas, San Bernardo, La Calzadilla, El Prado (López-García 1991) and Cabezo Redondo (Fumanal *et al*. 1996), the Iron Age/Iberic sites of El Molón, San Miguel de Atxa (Iriarte 1994), Villasviejas de Tamuja, El Castillejo, Puente Largo del Jarama (Muñoz 2000), Castilmontán, Fuente Saúco (Mariscal 1994), Molinicos (López-García 1991) and Castro Follente (Table 6). Sandy sediments also parallel the lack of pollen in the open-air, historical sites of Castro de Vigo and Pedra Moura in Galicia (Aira-Rodríguez *et al*. 1988), Teatro Romano of Cartagena and Las Monjas and Torrerroja in Alicante. In other cases, sterility is in tandem with gypsum, as in the Neolithic site of Casa Montero, the Bronze Age site of San Bernardo, and the Visigothic site of San Martín de la Vega (López-García 1983).

Sands and red clays are associated with sterile palaeosols in central Spain: Urda in Toledo and Pedro Bernardo in Ávila (Table 6). In wetter climates, old soil horizons associated with settlement sites can, however, contain a lot of pollen and spores (van Geel *et al*. 1983; 2003) which are probably locked up in some form of humic complex (Dimbleby 1985). Slope deposits of Barranco Hondo, Las Lenas, Valmadrid, and the Portuguese Vale da Cerva at Guarda still show partial sterility and evidence of contamination by recent pollen (González-Sampériz *et al*. 2003a; González-Sampériz 2004a; Valero-Garcés *et al*. 2004) (Table 6).

Palaeontological sites can be also associated with doline infills, and fluvial and lakeshore terraces. Polliniferous layers sometimes result from areas that became buried in a general waterlogged phase, such as in the famous hominid site of Florisbad in South Africa (Scott and Nyakale 2002). Similarly, in all the palynological trials in Cal Guardiola (Tarrasa, Barcelona), the darker, more organic layers showed palynomorphs and plant macroremains, including timber (Postigo *et al*. 2007). The remaining layer suffered from oxidation and so lacked pollen (Burjachs 2000a; Peregrina 2003). Other sites were found to be fully sterile, like the mid-Pleistocene San Quince del Río Pisuerga and the early Pleistocene palaeontologically rich doline infilling of Incarcal (Girona) (Villalta and Vicente 1972; Galobart *et al*. 1990; Suc 1980; Geurts 1977; 1979; Leroy 1990) (Table 4).

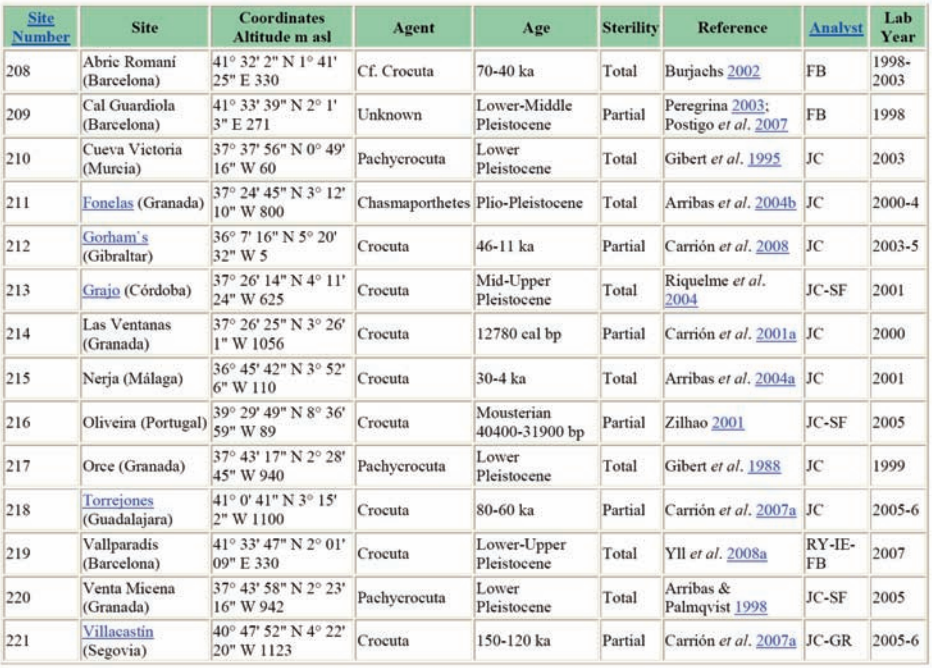
Exposed tufas and travertines of Alós (Lérida), the margins of the Guadalquivir River in Córdoba, Tajo de Ronda (Málaga), the Eemian from Río Matarraña (Beceite, Teruel), and the Lower Pleistocene of Sierra de Quíbas (Murcia) were barren of pollen, despite the presence of preserved macroremains in abundance suitable for detailed palaeobotanical studies (Martínez-Tudela 1986) or palaeontological ones (Montoya *et al*. 2001) (Table 6). Travertines, like breccias, can be polliniferous (Weinstein-Evron 1987; Vermoere *et al*. 1999). When dealing with these deposits, the possibility of contamination by recent or sub-recent pollen has to be kept in mind, as in Sterkfontein and other southern African hominin-bearing sites (Carrión and Scott 1999).

3.5 Coprolites

Dung accumulations, which occur in archaeological and palaeontological sites in caves or under rockshelters, may represent relatively unbiased pollen traps. However, fossil dung deposits are under-represented in the literature of pollen analysis. Carrión (2002b) demonstrated that pollen spectra from biogenic materials of animal origin were the best analogues of local and regional vegetation in the most arid areas of south-eastern Iberia, and still showed the best analytical potential in terms of pollen concentration and taxon diversity. Dung pollen samples are sometimes not influenced by dietary preferences and offer a great potential for palynology, as is shown with bird guano (Horrocks *et al*. 2008), Procavia and Petromus middens (Scott and Cooremans 1992; Carrión *et al*. 1999b; Gil-Romera *et al*. 2007), middens of packrat (Neotoma) and other rodents (Davis and Anderson 1987; Betancourt 2004), cow dung (Carrión *et al*. 2000b), coprolites of extinct caprids (Alcover *et al*. 1999), hyena coprolites (Scott 1987; Scott *et al*. 2003; González-Sampériz *et al*. 2003b; Yll *et al*. 2006), bat guano (Carrión *et al*. 2006b; Leroy and Simms 2006), sheep/goat and human coprolites from old farms (Hunt *et al*. 2001), and canid coprolites (González-Sampériz 2004a). Among these, hyena coprolites have been the most tested in the Iberian Quaternary (Fernández-Rodríguez *et al*. 1995; Carrión *et al*. 2001a; 2007a; González-Sampériz *et al*. 2003b).

The case studies considered here are pertinent to coprolites of three genera of hyaenids, namely Chasmaporthetes, Pachy-

Table 7. Quaternary sites of Iberia with reported sterility in coprolite pollen samples.



Site Number	Site	Coordinates Altitude m asl	Agent	Age	Sterility	Reference	Analyst	Lab Year
208	Abric Romaní (Barcelona)	41° 32' 2" N 1° 41' 25" E 330	Cf. Crocuta	70-40 ka	Total	Burjachs 2002	FB	1998-2003
209	Cal Guardiola (Barcelona)	41° 33' 39" N 2° 1' 3" E 271	Unknown	Lower-Middle Pleistocene	Partial	Peregrina 2003; Postigo *et al*. 2007	FB	1998
210	Cueva Victoria (Murcia)	37° 37' 56" N 0° 49' 16" W 60	Pachycrocuta	Lower Pleistocene	Total	Gibert *et al*. 1995	JC	2003
211	Fonelas (Granada)	37° 24' 45" N 3° 12' 10" W 800	Chasmaporthetes	Plio-Pleistocene	Total	Arribas *et al*. 2004b	JC	2000-4
212	Gorham's (Gibraltar)	36° 7' 16" N 5° 20' 32" W 5	Crocuta	46-11 ka	Partial	Carrión *et al*. 2008	JC	2003-5
213	Grajo (Córdoba)	37° 26' 14" N 4° 11' 24" W 625	Crocuta	Mid-Upper Pleistocene	Total	Riquelme *et al*. 2004	JC-SF	2001
214	Las Ventanas (Granada)	37° 26' 25" N 3° 26' 1" W 1056	Crocuta	12780 cal bp	Partial	Carrión *et al*. 2001a	JC	2000
215	Nerja (Málaga)	36° 45' 42" N 3° 52' 6" W 110	Crocuta	30-4 ka	Total	Arribas *et al*. 2004a	JC	2001
216	Oliveira (Portugal)	39° 29' 49" N 8° 36' 59" W 89	Crocuta	Mousterian 40400-31900 bp	Partial	Zilhao 2001	JC-SF	2005
217	Orce (Granada)	37° 43' 17" N 2° 28' 45" W 940	Pachycrocuta	Lower Pleistocene	Total	Gibert *et al*. 1988	JC	1999
218	Torrejones (Guadalajara)	41° 0' 41" N 3° 15' 2" W 1100	Crocuta	80-60 ka	Partial	Carrión *et al*. 2007a	JC	2005-6
219	Vallparadís (Barcelona)	41° 33' 47" N 2° 01' 09" E 330	Crocuta	Lower-Upper Pleistocene	Total	Yll *et al*. 2008a	RY-IE-FB	2007
220	Venta Micena (Granada)	37° 43' 58" N 2° 23' 16" W 942	Pachycrocuta	Lower Pleistocene	Total	Arribas & Palmqvist 1998	JC-SF	2005
221	Villacastín (Segovia)	40° 47' 52" N 4° 22' 20" W 1123	Crocuta	150-120 ka	Partial	Carrión *et al*. 2007a	JC-GR	2005-6

crocuta and Crocuta (Table 7). Tens of light whitish coprolites, presumably produced by *Chasmaporthetes lunensis*, from the Fonelas sites (Guadix-Baza basin, Granada) were palynologically sterile. These coprolites were stuffed in lutites. Likewise, cases of full sterility come from a few *Pachycrocuta brevirostris* coprolites from the Lower Pleistocene of Cueva Victoria (Murcia), and Venta Micena-Orce (Granada) (Table 7) (Carrión *et al*. 2004c). Although there were items rich in pollen, a number of the analysed coprolites of *Crocuta crocuta* from Villacastín and Torrejones (Carrión *et al*. 2007a), Cueva de las Ventanas (Carrión *et al*. 2001a), Oliveira in Portugal (Zilhao 2001) and Gorham's Cave in Gibraltar (Carrión *et al*. 2008), were sterile. All Crocuta coprolite specimens were sterile in Abric Romaní, Barcelona (Allué *et al*. 1998; Burjachs 2002), while the rockshelter travertine was polliniferous (Burjachs and Julià 1994; 1996). Similarly, there was total sterility in the coprolites of Andalusian Cueva del Grajo and Cueva de Nerja. Potential for work with other hyena species exists because, for instance, *Hyaena brunnea* (brown hyena) has been identified in south-eastern Spain (Arribas *et al*. 2004b). *Hyaena brunnea* coprolites from the southern African sites of Equus Cave (Taung, southern Kalahari) and Oyster Bay (Cape region) were successfully treated for pollen (Scott 1987; Carrión *et al*. 2000c), although total pollen concentrations in the coprolites were lower than those sometimes observed in Crocuta (Scott *et al*. 2003).

4. Mechanisms for the Destruction of Pollen

Although this is not an article on pollen preservation and decay, reasonable speculation about the causes of sterility can be attempted on the basis of the above observations. Peats are mostly polliniferous, but sterile levels of mineral sediment may interrupt the peat sequence. This is the case in Los Monjes, Comella, Mozarrifar, and especially Navarrés (Table 3), with sandy sediment layers suggesting increased processes of erosion of the surroundings, and, in fact, a depositional context favourable for oxidation of pollen (Carrión and van Geel 1999).

Exploitation, drainage, salinisation, contamination and trenching diminish the analytical potential of peats. In Ruidera (Ciudad Real), a barrage tufa wetland (García del Cura *et al*. 2000), peat layers overlying carbonated marls were almost completely sterile (Table 3). It is plausible that a reduction in excessive groundwater altered the polliniferous possibilities of the sediment by changing the original redox conditions (Dorado-Valiño *et al*. 2002). In addition, the lack of less mineralised groundwater inputs has caused an increase in salinisation. In other cases, like Villaverde (Carrión *et al*. 2001b) (Table 3), trenching a peat section resulted in aeration and break-up of the deposit structure, with subsequent oxidation of pollen (Havinga 1984). Trenching and peat extraction on areas of intact peat bog may in part have caused pronounced changes in the hydrological regime, which would in turn have influenced the vegetation and increased peat decomposition. At this point, it is quite possible that the drainage ditches irreversibly influenced the intact part of the bog. A systematic study of the hydrological regime in the Villaverde peat bog is needed to confirm this hypothesis. Eventually, the dams of the ditches should be blocked in order to prevent further desiccation of the area and to bring the hydrological regime more closely into line with the natural regime. Specifically, with tufas there must be some connection between pollen occurrence and depositional morphotypes (e.g. braided, barrage travertine, fluvial barrage, and marsh tufas), timing of inorganic deposition, and types of organically induced facies in travertine formation (Ford and Pedley 1996). No experimental studies have hitherto been devoted to this issue, to our knowledge.

It cannot be stressed enough that human activities may contribute to the irreversible loss of the potential of the few Iberian peats suitable for pollen analysis. The Padul peat bog (Pons and Reille 1988) and other wetlands from the Betic cordilleras, like Sierras de Baza, Filabres, even Sierra Nevada, have been greatly altered during recent decades despite the existence of initiatives for conservation (Casado and Montes 1995; Rodríguez-Sánchez 1998). At their current rate of spread, urban settlements will soon impede any possibility of studying littoral marshlands in Mediterranean Spain (Ortega *et al*. 2004). Old peat lands from Villena and Sax (Alicante), Mazarrón and Calblanque (Murcia), Cueto de Avellanosa (Cantabria), and Saldropo (País Vasco), among others, have now nearly vanished.

As recently as between 1956 and 1987, the area covered by peat in the Doñana National Park was dramatically reduced by almost 90% (Sousa and García-Murillo 1999; Fernández-Zamudio *et al*. 2007. The opportunities for palynology have therefore become more limited. The most saline environments (‘marisma’) are difficult for pollen analyses. In the studies performed on the late Holocene Carrizosa, Cherri, Juncabalejo, Membrillo, and Vetalengua marshlands of Doñana (Rodríguez-Ramírez *et al*. 1996), not only are there a number of palynological hiatuses, but also an extraordinary prevalence of marsh pollen (chenopods, sedges, Alismataceae) as well as thick layers where decomposing fungal activity predominates (Yáñez 2005). Overall in these wetlands, pollen-stratigraphical changes and, indeed, the potential of pollen analysis, are strongly dependent on changing sediment types as a result of geomorphological dynamics. In general, marine sedimentation events coincide with erosion, deposition of sands, destabilisation of the marisma, and palynological sterility (Yáñez *et al*. 2006). The stabilisation of the marisma coincides with colonisation by sedges and pollen deposition. Pollen concentration is low in evolved marisma phases, with long seasonal periods of dryness, and increased decomposing activity.

The situation with saline lacustrine systems is not simple. Failures with the endorheic lakes of La Mancha are worth scrutiny, where it is tempting to look at lithological features (Table 4). The sediments from Pétrola were dark grey to red clays, episodically interweaved with sands, peat, and carbonated crusts. Acequión was a brown marl with grey silts in the uppermost two metres. Ontalafia was light reddish sand with gravels and clays grading upwards to compacted silt. In spite of these differences, carbonates and, especially, signs of oxidation were observed throughout the three cores, and chlorides and sulphates (anhydrite and gypsum) very common in Pétrola, and sparse in the other two sites. Like pyrite in reductive environments, carbonates and sulphates can be frequent in lacustrine basins of semi-arid regions (Horowitz 1992). The same is true for salt pans, where crystal growth (lithification) in and around the pollen grains may be a cause of mechanical damage. Today, water conductivity is very high in the hypersaline Pétrola (16 mS cm^{-1}), and relatively high in Ontalafia (4.85 mS cm^{-1}) (Reed 1998), with abundance of magnesium sulphate in the former and sodium chlorides in the latter (Cirujano 1990). An unpublished sedimentary analysis (M.P. Fumanal) has pointed to long desiccation phases and stationary regimes in the three lakes, probably because of high summer evapotranspiration. Wetting and drying the pollen before burial are a major cause of alteration of the exines (Holloway 1989).

The Salineta lake in Bujaraloz (Zaragoza) adds episodic aeolian deflation (evaporation as a result of wind) to the seasonal character of the water body and saline nature of the sediment as likely factors of pollen decay and/or removal (Moreno *et al*. 2004; Valero-Garcés *et al*. 2004) (Table 4). Very similar are the nearby La Playa and Mediana de Aragón playa-lakes, where sterile layers are clearly associated with the highest concentrations of soluble salts (González-Sampériz *et al*. 2008). In Valsalada (Leciñena, Zaragoza), the absence of pollen parallels gypsum deposition and fluvial inputs (Sancho *et al*. 2007). In Laguna del Villardón in the playa-lake complex of Villafáfila (Zamora), a sandy silt core contained no pollen grains but several types of more resistant non-pollen palynomorphs (Gómez-Ferreras *et al*. 1996). Laguna de Gallocanta (Teruel-Zaragoza), a temporary salt lake with discontinuous sedimentation, shows an alternation of sterile and polliniferous levels, although the latter show low pollen concentrations (Burjachs *et al*. 1996; Julià *et al*. 2000; Rodó *et al*. 2002). Today, both Salineta and Gallocanta exhibit high water conductivity of about 200 mS cm^{-1} and pH between 8 and 9 (Reed 1998).

Salinity measurements cannot yet be used simply to signify a general trend of palynological sterility in salt lakes because, as in other arid regions of the world (Luly 1997; Davis 1998; Scott 1999), they have not always been entirely negative for palynologists. Sites like La Salineta, La Playa, and Mediana de Aragón (Table 4) have eventually been profitable, even considering hiatuses. Smaller saline systems including playa-lakes in north-eastern (Stevenson *et al*. 1991; Valero-Garcés *et al*. 2000a, b; González-Sampériz *et al*. 2008) and south-eastern Spain (Burjachs *et al*. 1997) have also produced satisfactory outcomes (Rodrigo *et al*. 2002). Pollen analysis of pure halite has provided good pollen spectra in the Dead Sea (Heim *et al*. 1997). An interesting case of success in Iberia is Lake Zóñar (Alonso 1998), where detailed palynological studies are being developed with ongoing projects (Valero-Garcés *et al*. 2006a; Martín-Puertas *et al*. 2008). Waters in Zóñar are certainly saline (2.4 g l^{-1}), alkaline (pH between 7.1 y 8.4) and dominated by

(Cl^-)-(SO_4^{2-}) and Na^+ (Valero-Garcés *et al*. 2006a), but a positive factor is most certainly the permanent character of the lake during most of the sequence. In sum, salt deposition is sometimes associated with desiccation and loss of pollen, but the halophilous character of a system should not discourage pollen analysis.

In general, non-saline lake sediments are favourable for pollen preservation, but problems will generally arise in very shallow systems that undergo seasonal periods of dryness and when intense inwash of soils from the surroundings exacerbates sediment dilution by soil that is usually pollen-barren (Table 4). Changes to non-lacustrine facies may still be conducive to sterility. Thus, a marine intrusion is often linked to oxidation both at the beginning and at the end of the phase. In the Pego-Oliva marshland, pollen-sterile intervals correspond with marine sediments and with peaks of detrital sulphates (Dupré *et al*. 1998b).

Palaeo-lakes occasionally may be sterile throughout their whole sequence or include sterile levels (Table 4). In sites like the Lower Pleistocene Mencal, Fonelas and others of the Orce complex (Zagales, Yeseras, Conejos, Champiñones), it is clear that erosion, fast sedimentation, re-sedimentation and water transport have not been favourable to the stabilisation of pollen assemblages. In north-eastern Spain, Mas Miquel, Bòbila Ordis, Incarcal, Tres Pins, and Pla de l'Estany show erosional, oxidised levels lacking pollen (Geurts 1977; Leroy 1990; 1997; 2008; Løvlie and Leroy 1995) and interruption of lacustrine sequences by soils, which are by nature often sterile.

The situation is no different with the so-called open-air archaeological and palaeontological sites, where post-depositional alteration and loss of pollen content is frequent (Table 6). High-energy environments in fluvial, aeolian and open-air contexts are normally to be avoided as oxidation and mechanical factors jointly act to destroy palynomorphs. Clearly for these prehistoric sites, we need experimental studies similar to those of Macphail *et al*. (2004), which deal with the relationships between pollen decay and soil micromorphology and microchemistry.

At first sight, sterility in caves and rockshelters (Table 5) is not surprising given the bad reputation of cave palynology. Sedimentary discontinuities (Campy and Chaline 1993), selective preservation, preferential transport, and contamination by percolating water and bioturbation (Coûteaux 1977; Turner and Hannon 1988) have often been claimed as causing negative results. Certainly, these sites have traditionally suffered from a dearth of experimental data capable of determining the effectiveness of cave pollen spectra in representing source vegetation. But the most worrying factor is not whether the pollen assemblages may or may not reflect the environments of the catchment areas, because we now know that they may do so (Coles *et al*. 1989; Burney and Burney 1993; Coles and Gilbertson 1994), especially in areas with an entomophilous-dominated flora (Navarro *et al*. 2002) and especially if several profiles are studied for the same cave (Carrión *et al*. 1999a). A more serious challenge arises from our current inability to identify characteristics and modes of post-depositional alteration. A high number of Asteraceae and Pteridophyta types can be indicative of this (Bottema and Woldring 1994), but only if coinciding with low pollen concentration and high counts of indeterminable pollen (Carrión 1992a; Sánchez-Goñi 1994). In either case, correlation with conventional pollen sequences demonstrates the usefulness of some cave records (Fernández *et al*. 2007). So, after taking due precautions, the usefulness of depending upon cave sediments in areas where conventional pollen-rich deposits are rare must not be overlooked.

As with peats, sandy layers and clastic strata in cavities usually involve loss of the pollen content (Dupré 1988; González-Sampériz 2004a). But caves are a special case. Most cave and rockshelter stratigraphies show sedimentary features indicative of complex depositional and post-depositional, physical and geochemical processes, several of which lead to alteration of biotic remains, including pollen grains and spores (Table 5). Burrowing, whether by insects, earthworms or rootlets, is a very negative influence. Problems linked to diagenesis appear critical. Red clay beds, associated with the alteration of iron-bearing minerals, often result in sterility, such as in Bolomor (Fernández-Peris 2004), and Calaveres (Vives 1982; Dupré 1988), Cueva del Canuto at Sierra de Grazalema in Cádiz, and El Pendo in the Cantabrian region (Leroi-Gourhan 1980; López-García 1986; Sánchez Goñi 1991) (Table 5). But while reddish colour may suggest oxidation, we generally lack information about whether it took place before or after the incorporation of pollen. So doubt usually persists about the respective timing of pollen deposition and oxidation. In other words, a red colour can indicate erosion of previously red rock formations, not necessarily *in situ* oxidation. The same question arises with manganese oxides characteristic of some occupation layers within caves, as in Mousterian Carihuela Chamber III (Carrión *et al*. 1998). Here, as in Cueva de Chaves (Table 5), the sediments formed under the driest conditions were polliniferous, which substantiates the value of total aridity for biotic preservation and the negative effect of sediment moisture and frequent soil hydration-dehydration cycles (Davis 1990; Navarro *et al*. 2002). In Atapuerca, episodic washing and oxidation of microfossil assemblages dominate the post-depositional environment, resulting in an almost total absence of pollen and phytoliths (Vallverdú *et al*. 2001).

The case of Cova Beneito is notable because no observable difference was noted either texturally or structurally in the polliniferous sediments (Carrión and Munuera 1997) with respect to the sterile sediments (Carrión 1992a). Basically, most levels displayed an angular coarse fraction within a clayey-silt matrix. Measurements of pH showed relatively high values in all sediments, but their variation was insignificant, from 7.7 to 8.3. Pollen was relatively well preserved in samples with high pH values. There is hardly any doubt that the fact that the polliniferous profiles had been freshly exposed served to give better results than samples removed from sections left open on old excavations (Scott 1982; 1995).

Studies of modern pollen deposition suggest that cave morphology can be important for pollen analysis. So there should be a spatial patterning of sediments and pollen influx (Hunt and Rushworth 2005). For example, some caves show a fall-off in pollen concentration with increasing distance from the entrance (Burney and Burney 1993; Navarro *et al*. 2000; 2001). The Cueva de la Plata, a narrow, small-entranced, long cavity in coastal Murcia, showed lower pollen concentrations than the nearby Cueva de José, an isodiametric, wide-entranced cavity (Prieto and Carrión 1999; Navarro *et al*. 2000). The same situation was observed between Cueva del Moro I and II in Alicante (Navarro *et al*. 2000; 2001). However, the fact that a cave displays large chambers and wide entrances seems not to guarantee success with pollen analysis. In the cases of Chaves, El Salt, Cova Negra, Cendres, and Bolomor (Table 5), the successful profiles were located relatively close to the cave opening and some distance away from the cave walls (Fumanal 1986; Fernández-Peris 2004). In several of the caves for which modern pollen deposition was studied, wet sediment and parietal samples, as well as those samples taken from dripping areas, showed biased pollen spectra with low pollen concentration, high percentages of non-pollen microfossils such as fungal spores, and raised percentages and concentration values of Cichorioideae (Prieto and Carrión 1999; Navarro *et al.* 2001). Hence, degradation could occur in this context, and this could explain the aforementioned case of Cova Beneito. It is worth stressing that the two successful new sections studied (5C and 3B) were situated closer to the centre of the cavity (Carrión and Munuera 1997).

The cases of success with cave hearth levels are interesting (Table 5), as is the presence of pollen in burnt cow-dung (Carrión *et al*. 2000b) and bread samples (Williams-Dean 1978). When hearths are poorly compacted, it is difficult to disregard percolation from overlying strata. Hearths usually contain a mixture of ashes and windblown dust, forming a fine-grained, highly organic deposit. Most of the cave infill of Matutano Cave was composed of this type of material, making it very difficult to process for pollen extraction (Burjachs 1999). Supposedly, pollen grains should be burnt out by high-temperature fire, but it is also possible that they are resistant to low-temperature fire and trapped together with fine dust after burning until heat subsides (Horowitz 1992).

Cementation processes of any kind may also cause mechanical degradation of pollen grains (Table 5). However, stalagmitic units were extremely rich in pollen within Carihuela Cave (Carrión *et al*. 1998; Fernández *et al*. 2007), and there are several interesting case studies in the British Isles (McGarry and Caseldine 2004; Caseldine *et al*. 2007) and Africa (Burney *et al*. 1994), showing the enormous potential of speleopalynology including the distinct advantage over other pollen sources that they can be dated by high precision TIMS U-Th dating. Recently, Lartigot (2007) has provided a detailed account of the problems of palynology in cave speleothems from hominin-bearing caves in France and Italy, with low pollen concentration being one of the biggest challenges. In general, as with unconsolidated infills, it seems that entrance facies are more favourable for palynology (Fernández-Cortés *et al*. 2006). This could explain the total absence of pollen in the large speleothems studied from La Blanca (Murcia) and the gypsum speleothems of the Sorbas karst (Almería), both collected in the inner parts of deep karstic caverns. Certainly, other factors are involved, such as speleothem mineralogy, content of organic matter, and distance of the pollen sample from drip points, cave floor/ceiling, and flowstone limbs.

Clearly, cave palynology still needs much experimentally based work before we can predict successful contexts for pollen analysis. The available aforementioned studies indicate a great complexity in the taphonomy of pollen and spores. Both depositional and preservational features of the pollen spectra inside caves are uneven and clearly influenced by the cave morphology and sedimentary types. Stochastic and episodic forms of particle influx, such as transport by animals, periodic flooding and human activities, may also influence pollen deposition inside caves in proportions that are unique to each site. Caves in which the dominant type of pollen transfer from the external environment is airborne will often show a decrease in pollen deposition with increasing distance into the cave. Generally, in these cases, the highest concentrations of pollen and spores are observed in the cave entrance areas, and the lowest at the rear of the cave. Navarro *et al*. (2000; 2001) provide two basic recommendations for the pollen analysis of cave sediments. Firstly, that sampling is undertaken on the basis of a multiple-profile strategy, if possible not very close to parietal and rear areas and avoiding zones of actual moisture, or areas where old hydromorphic processes can be detected from sedimentological features. Secondly, it is of vital importance to use all the available information (pollen percentages, concentration, diversity and preservation) to establish a robust taphonomical model. This might facilitate the isolation of abnormal inputs, i.e. over-representation of some taxa, allowing a more reliable ecological interpretation of the data.

Preservation in coprolites has still to be understood; there may be factors such as digestive enzymes in addition to others mentioned so far. Why Crocuta and Hyaena coprolites have given pollen, while Pachycrocuta and Chasmaporthetes failed, remains puzzling (Table 7). Dietary variations seem unlikely since there is no crucial difference in hunting-scavenging behaviour between the four genera. *Hyaena brunnea* can certainly be more omnivorous than Crocuta, but most species are rather versatile in diet (Scott 1987). It is worth considering whether the Hyaena and Crocuta coprolites are polliniferous simply because the analysed sites are younger, and fossilisation processes in older samples of dung work against pollen preservation (Scott *et al*. 2003).

In sum, oxidation might be the main factor causing palynological sterility in the cases reported (Fig. 3). Hypothetically, oxidation occurs at different stages between the plant pollen-

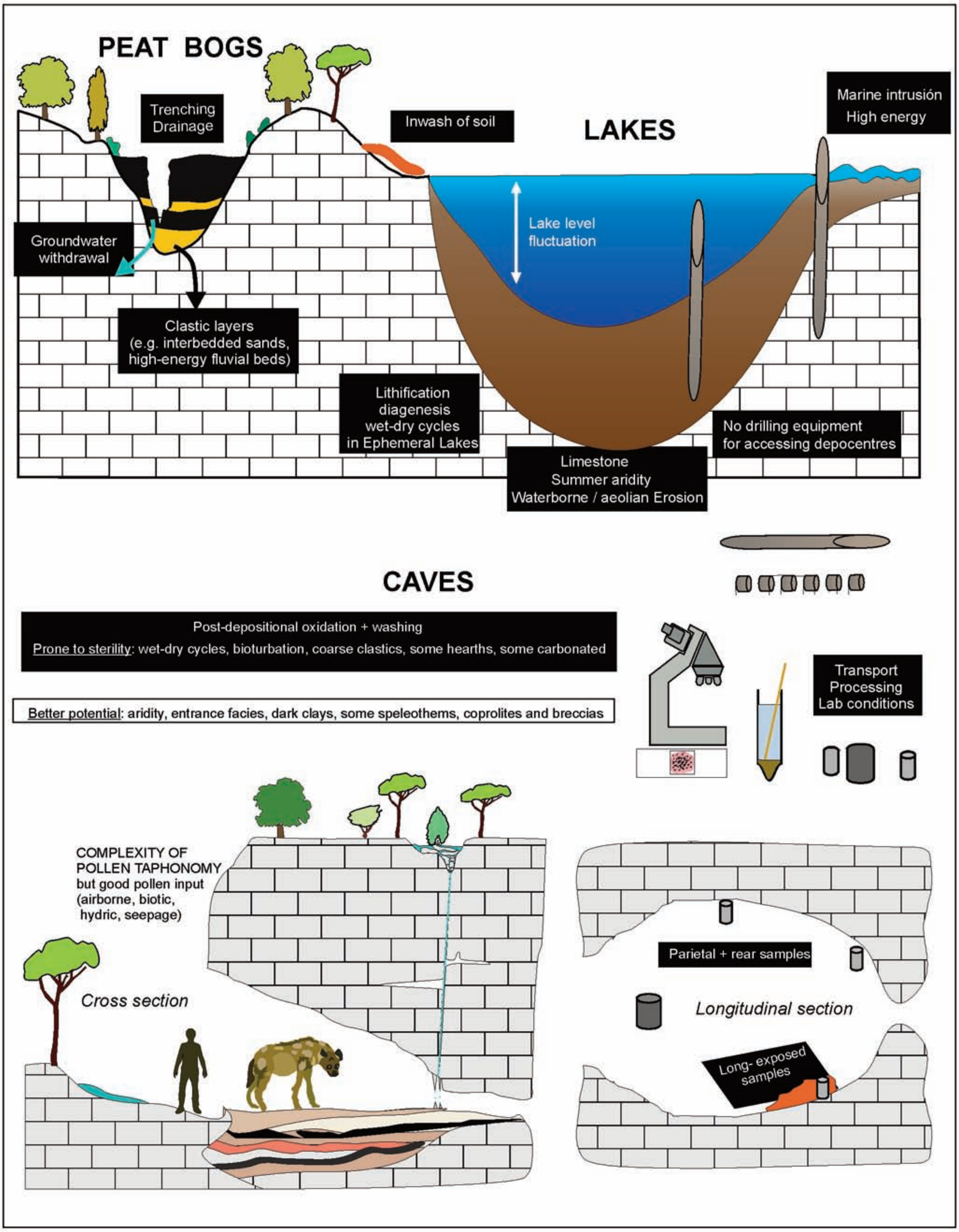


Figure 3. Scheme of the main causes of sterility in the Iberian Peninsula as applied to peat bogs, lakes and cave systems.

producing organ and the microscope: (i) pre-depositional, e.g. soil inwash in lakes and peat bogs; (ii) syn-depositional, e.g. high-energy sediment; (iii) post-depositional, e.g. fluctuation of lake levels; and (iv) post-excavational, e.g. during field sampling, sample preparation, and on the microscope slide. Arguably, the number of wet-dry cycles (or oxidation-reduction cycles), the duration of the exposure to air, as well as the role of decomposing bacteria and fungi, are critical factors.

5. Final Remarks

Failed pollen analyses in the Iberian Peninsula are so numerous as to suggest that there may be something intrinsic to this region that is inimical to the preservation of palynomorphs. Is the huge mass of calcium carbonate represented by the Iberian Peninsula somehow related to palynological sterility? Is the prevailing aridity/summer drought a limiting factor? Peat bogs are not abundant, but lakes are widespread, although many are saline and not a few experience periodic desiccation and strong oscillations of the water table. These are, doubtless, factors linked with oxidation processes. Equipment to drill permanent lakes is expensive, limiting access to depositional centres of continuous sedimentation. Only during the last decade have funding and co-operation allowed both Spain and Portugal to carry out deep lake drilling within national and international research programmes. For example, during three months in 2004, the Pyrenean Institute of Ecology (IPE)-CSIC carried out, for the first time in Spain, a large drilling expedition (LIMNO-CLIBER) throughout the Iberian Peninsula in collaboration with the Limnological Research Centre (LRC) of the University of Minneapolis (USA), with a final result of more than 200m of lacustrine sediments from eight Spanish lakes. Yet a number of possibly useful lakes and marshlands have not even been drilled. An example is the Laguna de La Janda in Cádiz, one of the more extensive tectonic depressions of Iberia (Dueñas and Recio 2000), where, to our knowledge, no palynologist has yet ventured. Further cases come from the mountains, like Sierra Nevada, the Cantabrian Mountains and the Pyrenees, where high-elevation lakes appear suitable for palaeoenvironmental studies. Problems of accessibility persist for some basins, but the potential is still there. The high number of endorheic lakes in La Mancha provinces of Albacete, Ciudad Real, and Cuenca, even Jaén in Andalucía, should not be neglected in spite of the discouraging results of Pétrola, Ontalafia, and El Acequión in Albacete. Many are low-salinity and nearly permanent, and peat deposits are sometimes preserved at their margins (Cirujano 1990; Casado and Montes 1995). The region contains archaeological and coprolite sites in abundance but the former often fail to contain pollen, and the latter have been insufficiently tested.

It is also worth wondering whether failures with pollen analysis have been equally common in other territories, but have simply not been reported. Collecting the data presented here has been time-consuming, and no doubt some would regard such an exercise as producing little career reward for the effort. Apart from the severe difficulties in getting active collaboration, there have been cases among the contributors where the laboratories have been demolished, or where the researcher has been moved and the original processing sheets have been impossible to rescue. So, with fragmentary information, we are aware that this work is incomplete in many aspects and needs further detail before we can achieve more far-reaching conclusions. This is a first step only. The next step is to stimulate future controlled investigation of negative results, a more multidisciplinary approach, more frequent collaborative research between palaeoecologists, and, necessarily, a more realistic assessment among Quaternary specialists of what information palynology can give and what it is unable to deliver.

Figure 4. Altamira. Palaeolithic wall paintings of Altamira, Cantabria, northern Spain. Photographs: J.S. Carrión.

Figure 6. Atapuerca Galería. Excavation in Atapuerca Galería. Photograph: M. García-Antón.

Figure 5. Atapuerca Sima de los Huesos. Exterior view of excavation in Atapuerca Sima de los Huesos. Photograph: M. García-Antón.

Figure 7. Atapuerca Gran Dolina. General view of Sections TD-1, TD-2, TD-3 in Atapuerca Gran Dolina. Photograph: M. García-Antón.

Figure 8. Barranco Hondo. A slope deposit palynologically unproductive in Barranco Hondo, Teruel. Photograph: P. González-Sampériz.

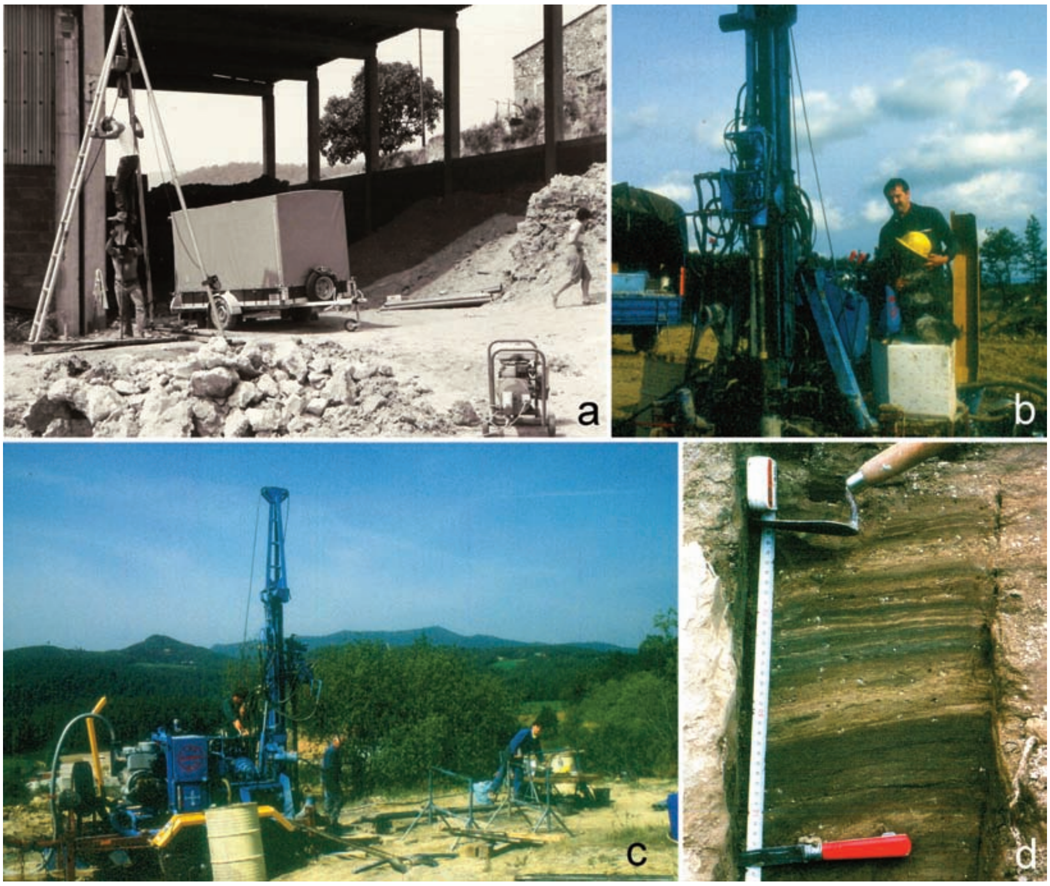


Figure 9. Bòbila Ordis. a) Coring in the brickyard of Bòbila Ordis (core II) in 1983. b-c) Coring of Bóbila Ordis (core IV) in 1988. d) Sediment in outcrop of Bòbila Ordis (Lake 2) showing the injection of older sediment along the fault plane. Photographs: S. Leroy.

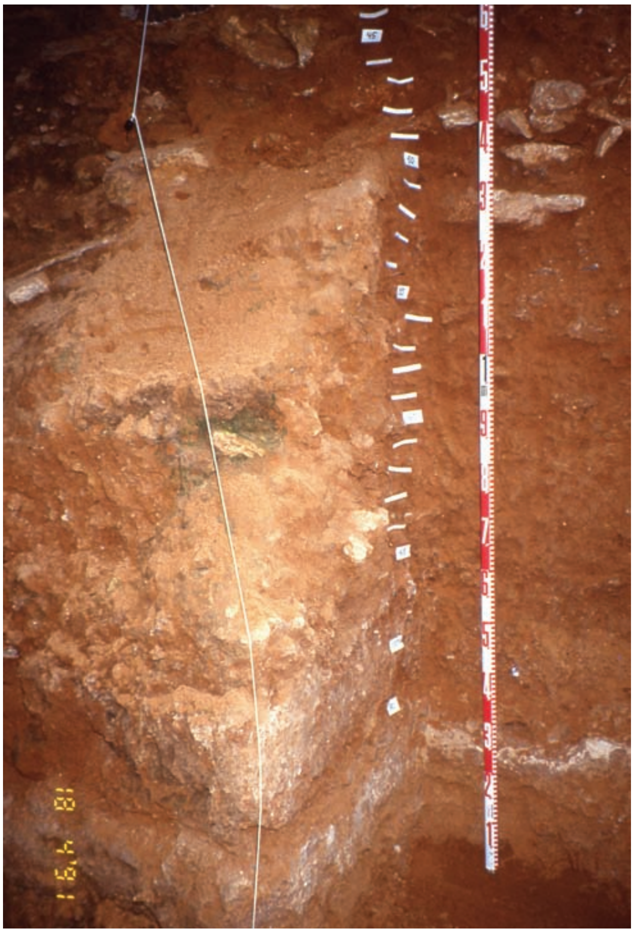


Figure 10. Bolomor. Main stratigraphical section of Cova Bolomor, a renowned Pleistocene cave site of eastern Spain. Photograph: M. Dupré.

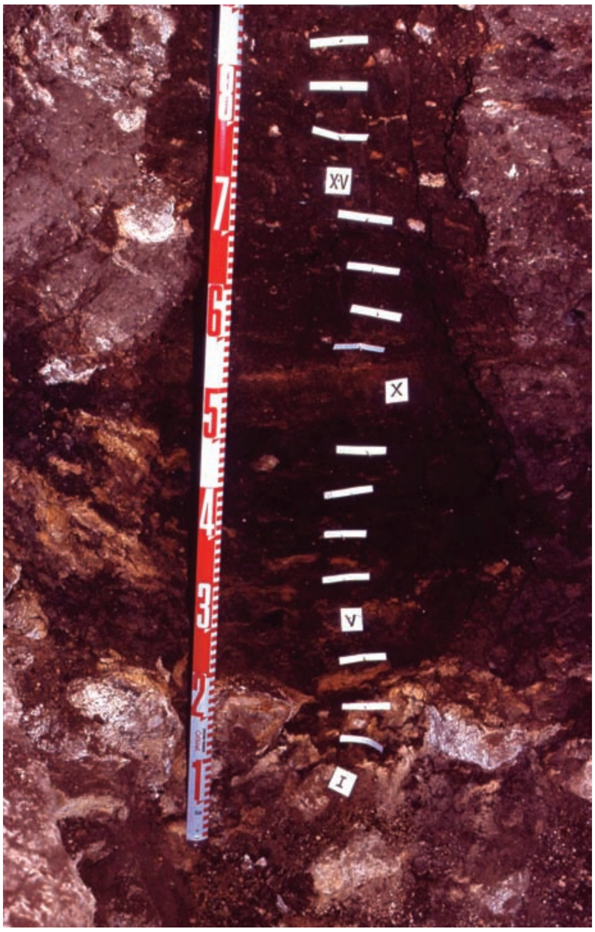


Figure 11. Carihuela. Carihuela Cave Chamber III Section 2 (Corte de Ico) showing the location of pollen samples in 1988. Most dark layers, despite their high organic content, were sterile. Photograph: J.S. Carrión.

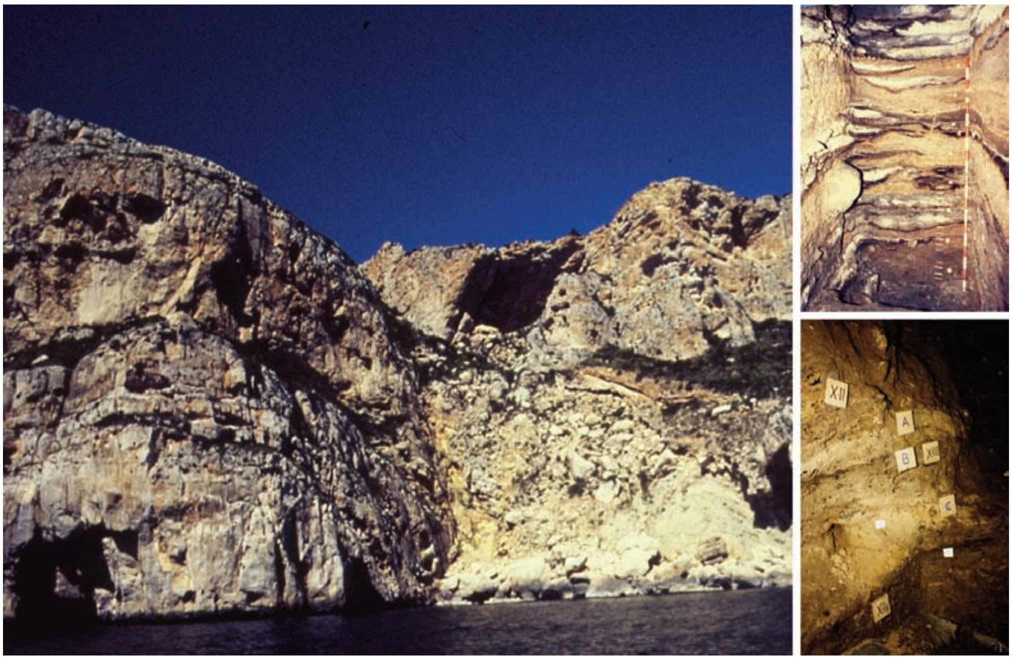


Figure 12. Cendres. Panoramic view and sections studied for pollen in Les Cendres cave (Alicante, Mediterranean littoral). Photographs: M. Dupré.

Figure 13. Conejos. The Barranco de los Conejos gully in the Orce region, Granada. Scale given by person in the lower left. Photograph: S. Leroy.

Figure 14. Cova Beneito. Entrance area and upper Palaeolithic section of Beneito cave, Alicante. Photographs: J.S. Carrión.

Figure 15. Cova Negra. The Mousterian cave of Cova Negra, Játiva. Photograph: M. Dupré.

Figure 17. El Acequión. Drilling with hydraulic piston corer the Holocene sediments of Laguna del Acequión salt lake in Albacete. All the pollen samples were sterile. Photographs: M. Dupré.

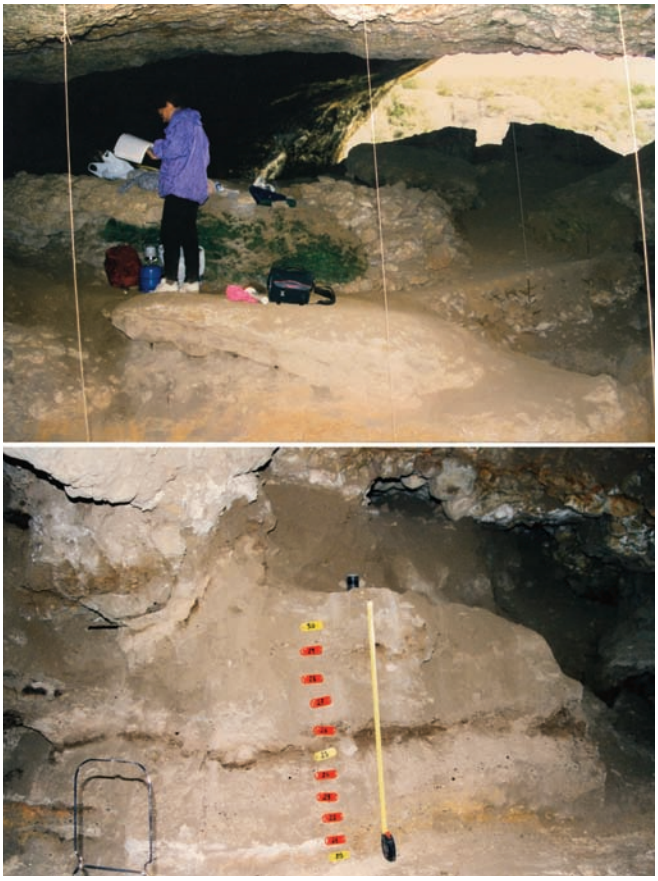


Figure 16. Chaves. General view and stratigraphical section from Chaves cave, Huesca. Photographs: P. González-Sampériz.

Figure 18. El Cañizar, Villarquemado. Deep coring in the Laguna del Cañizar, Villarquemado, Teruel. Photograph: P. González-Sampériz.

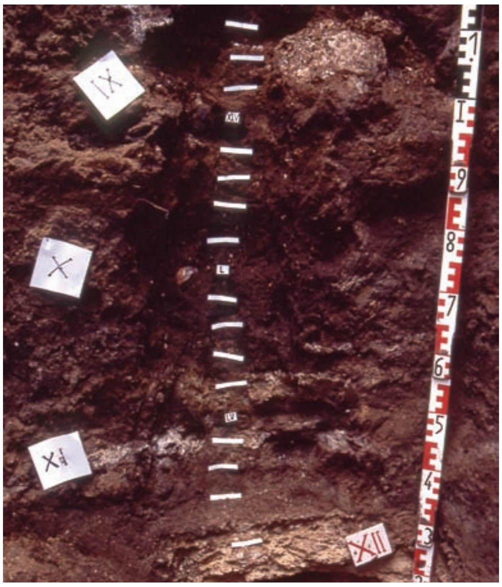


Figure 19. El Salt. Stratigraphical section of the Mousterian cave site of El Salt, Alicante. Both the stalagmitic crusts (below) and the darker, more organic levels were palynologically sterile. Photograph: M. Dupré.

Figure 20. Fonelas. The Upper Pliocene palaeontological site of Fonelas, Guadix Basin, very rich in mammal bones (d-e). Sediment samples (a-c), mostly of coarse fraction, and coprolites of the hyaenid Chasmaporthetes were palynologically sterile. Photographs: J. S. Carrión & S. Fernández.

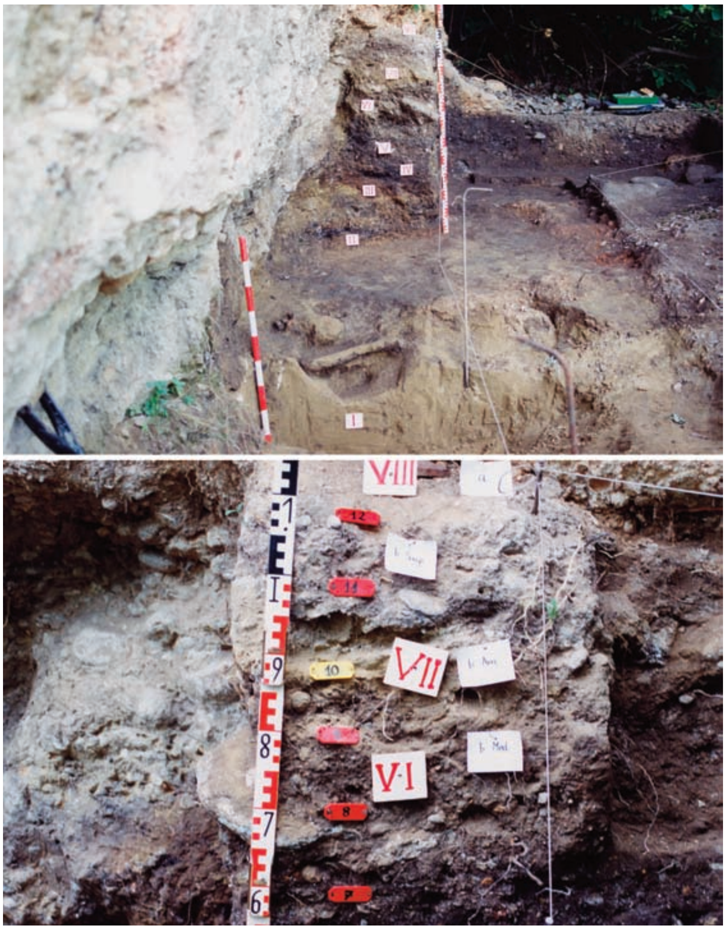


Figure 21. Forcas. Stratigraphical section considered for pollen in the Forcas rockshelter, Huesca. Photographs: P. González-Sampériz.

Figure 22. Gorham's Cave. The Palaeolithic levels of Gorham's Cave, Gibraltar Peninsula, have provided a number of coprolites (below right), presumably from hyaenids and canids. Some of these have been polliniferous while, inexplicably, others were totally barren of pollen. Photographs: C. Finlayson & J.S. Carrión.

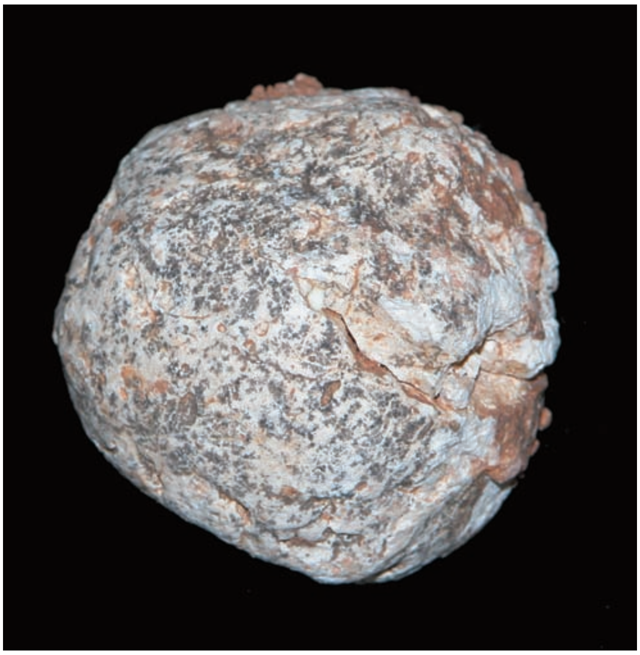


Figure 23. Grajo. Crocuta coprolite from Cueva del Grajo, Córdoba. Photograph: S. Fernández.

Figure 24. La Blanca. Longitudinal section of one of the several palynologically sterile calcium carbonate cave speleothems from La Blanca. Photograph: J. Carrión.

Figure 25. La Playa. Playa lake of La Playa, north-eastern Spain. Photograph: P. González-Sampériz.

Figure 26. Laguna de Orcera, Segura Mountains of southern Spain. A sediment core from this lake was palynologically sterile. Photograph: J. Carrión.

Figure 27. Legunova. The partially sterile Legunova rockshelter, an Azilian to Neolithic site of northern Spain. Photograph: P. González-Sampériz.

Figure 28. Mencal. The recently discovered large mammal fossil site of Mencal, Guadix Basin, semi-arid south-eastern Spain. Fossiliferous micrites and lutites (below) originated in Upper Pliocene lacustrine environments and were palynologically sterile. Photographs: S. Fernández and A. Arribas.

Figure 29. Molino del Vadico. The Neolithic rockshelter of Molino del Vadico, Albacete. Pollen grains were absent from all deposits. The section studied (below) showed abundant insect and root bioturbations. Photographs: J.S. Carrión.

Figure 30. Navarrés. The Navarrés peatbog produced a long pollen sequence from OIS3 to late Holocene. However, the OIS2, pleniglacial levels, dominated by aeolian sands (red lines), were palynologically sterile. Photographs: J.S. Carrión.

Figure 31. Ontalafia. Inundated and dry Ontalafia salt-lake in La Mancha Plain, central Spain. All sediment cores were palynologically sterile. Photographs: M. Dupré.

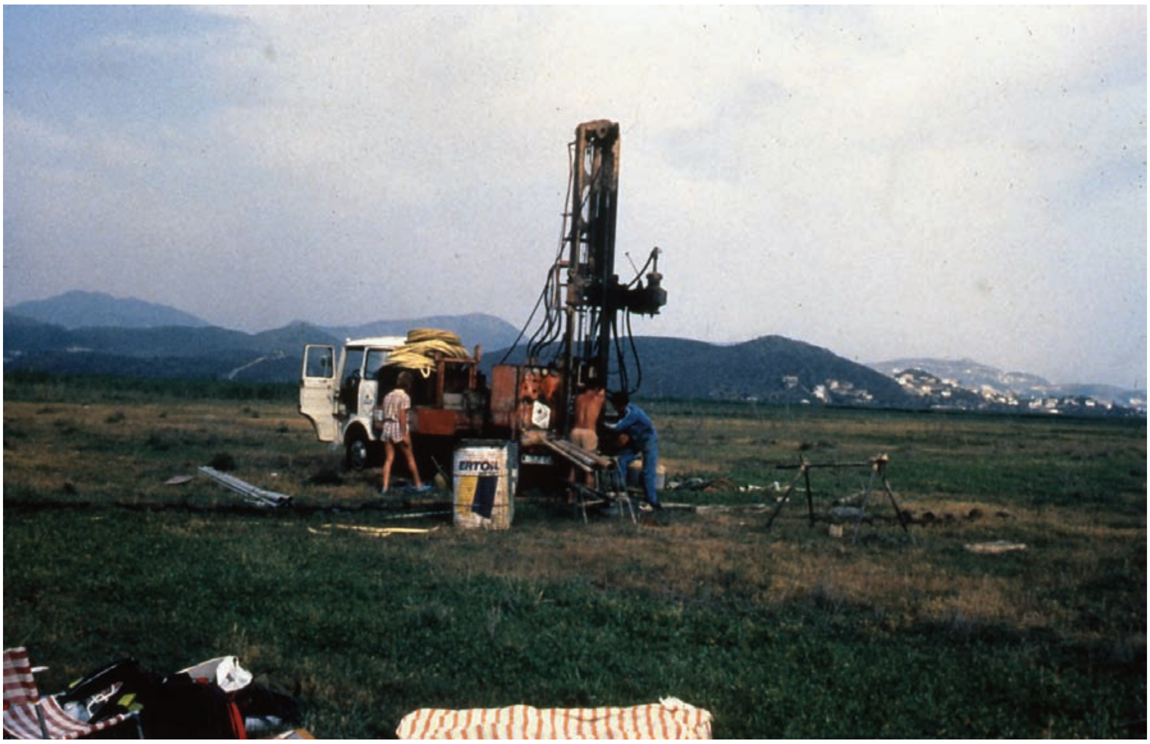


Figure 32. Pego. Pollen analyses of two coreholes in the Pego-Oliva littoral marsh were scarcely rewarding. Pollen was poorly preserved, and episodically absent from quite an organic-rich, yet salty, sediment. Photograph: M. Dupré.

Figure 33. Peña del Diablo rockshelter in Zaragoza province. Photographs: P. González-Sampériz.

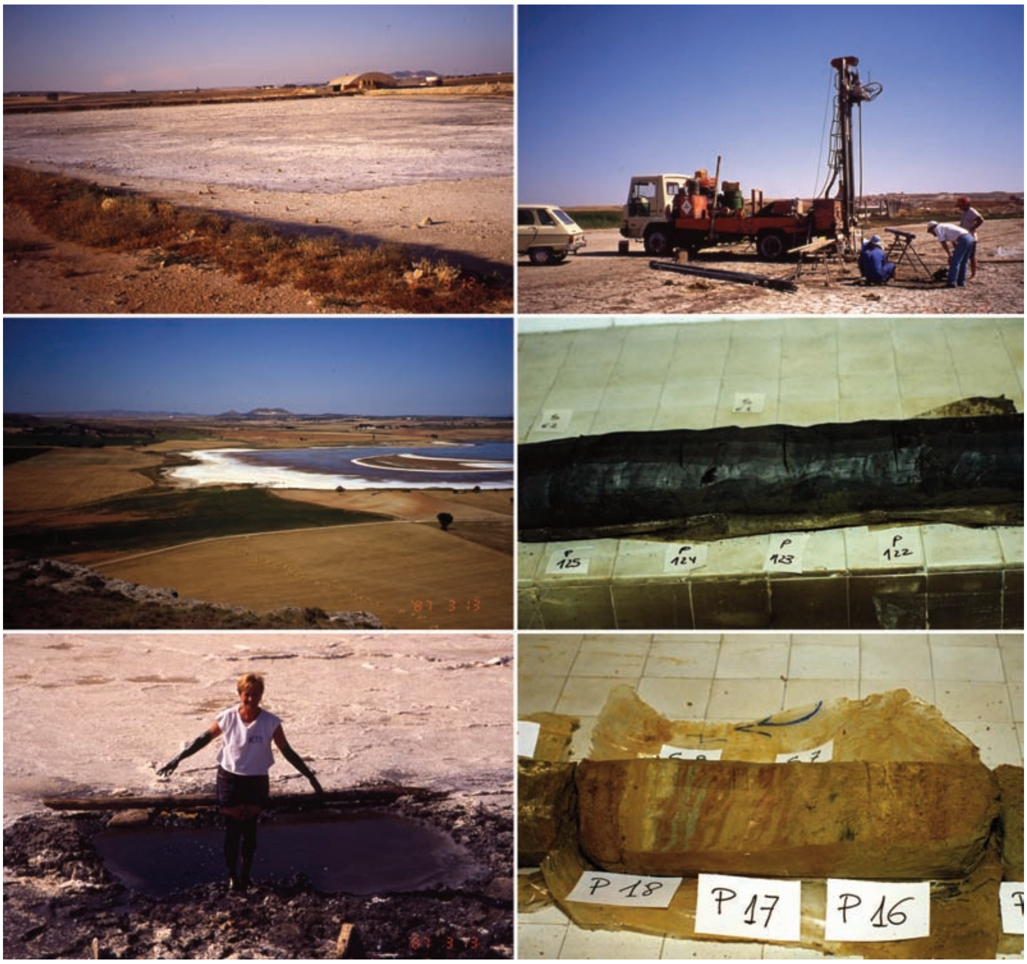


Figure 34. Pétrola. The sediments from the saline lake Pétrola were rich in carbonates and, especially, signs of oxidation were observed throughout the core, and chlorides and sulfates (anhydrite and gypsum) very common. All samples for pollen were sterile. Photographs: M. Dupré.

Figure 35. Ratlla del Bubo. The Upper Palaeolithic rockshelter Ratlla del Bubo, Alicante, fully sterile. Photographs: M. Dupré.

Figure 36. San Benito. San Benito seasonal lake. A sediment core gave palynologically rich levels alternating with sterile ones. Photograph: M. Dupré.

Figure 37. Torreblanca. A littoral peat bog, Torreblanca. Palynologically sterile levels occur under the influence of fluvial and marine depositional environments. Strictly paludal levels are polliniferous. Photograph: M. Dupré.

Figure 38. Torrejones. The Pleistocene infill of the Torrejones Cave (above), Central System, provided a number of hyaena (Crocuta crocuta) coprolites (below), with strong differences in their potential for palynology. Photographs: J.S. Carrión.

Figure 39. Tramacastilla. The moraine deposit of Tramacastilla, Huescan Pyrenees, completely sterile. Photograph: P. González-Sampériz.

Figure 40. Tres Pins. Coring of TPI core at Tres Pins, a Upper Pliocene-Lower Pleistocene site near Banyoles, in 1983. Photograph: S. Leroy.

Figure 41. Villacastín. Coprolites of Crocuta crocuta subsp, intermedia from the karstic site of Villacastín, Central System. Photograph: J.S. Carrión.

Figure 42. Yeseras. Yeseras, a Lower Pleistocene palaeontological site at the Guadix Basin, Granada. All samples for pollen were sterile. Photograph: S. Leroy.

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