

Vegetational Evidence for Late Quaternary Climatic Changes in Southwest Europe in Relation to the Influence of the North Atlantic Ocean

C. Turner and G. E. Hannon

Phil. Trans. R. Soc. Lond. B 1988 **318**, 451-485
doi: 10.1098/rstb.1988.0019

References

Article cited in:

<http://rstb.royalsocietypublishing.org/content/318/1191/451#related-urls>

Email alerting service

Receive free email alerts when new articles cite this article - sign up in the box at the top right-hand corner of the article or click [here](#)

To subscribe to *Phil. Trans. R. Soc. Lond. B* go to: <http://rstb.royalsocietypublishing.org/subscriptions>

Vegetational evidence for late Quaternary climatic changes in southwest Europe in relation to the influence of the North Atlantic Ocean

BY C. TURNER¹ AND G. E. HANNON²

¹ *Department of Earth Sciences, The Open University, Walton Hall, Milton Keynes, Bucks MK7 6AA, U.K.; Subdepartment of Quaternary Research, Botany School, University of Cambridge, Downing Street, Cambridge CB2 3EA, U.K.*

² *School of Botany, Trinity College, University of Dublin, Dublin 2, Eire*

During the period 20–8 ka BP, movements of the polar front in the North Atlantic Ocean between the latitudes of Iceland and the Iberian peninsula greatly affected the climate of western Europe. During the Lateglacial, sea-surface temperature changes were particularly marked in the Bay of Biscay. Such migrations of the polar front, which have been shown to be time-transgressive, have been used to explain Lateglacial climatic events in northwestern Europe.

A comparative study of Lateglacial and early Holocene records from lacustrine sites in northern and northwestern Spain and the Pyrenees confirms that the Lateglacial climatic amelioration was time-transgressive along the seaboard of western Europe, beginning 500–1000 years earlier in northwestern Spain than in the British Isles. This time-lag is further exaggerated in the vegetational response by migrational lags and edaphic factors. There are marked differences in the nature and chronology of Lateglacial plant successions, not only between southwest and northwest Europe, but particularly between sites in northwestern Spain, the coastal lowlands of the Pays Basque and the Pyrenees.

Sites in northwestern Spain, including that of Sanabria Marsh, here published in detail for the first time, show the moderating climatic influence of the Atlantic Ocean throughout the Lateglacial. There, the climatic amelioration began early, perhaps before 14 ka BP. Deciduous oak forest had already begun to develop during Lateglacial times; this observation suggests that the periglacial refugia for these trees lay close to the maritime Atlantic coasts of Spain and Portugal, and not in the Pyrenees as some authors have proposed.

After the onset of the Lateglacial climatic amelioration, pine and birch forest became widespread in the Pyrenees but oaks were very sparse or absent. Oak forest only developed there after 10 ka BP in the early Holocene. The Younger Dryas episode of cooling can be detected, but only by a small expansion of herbaceous plant communities in some areas and with almost no lowering of the treeline.

In contrast, Lateglacial conditions in the Pays Basque appear to have been cold and bleak. Even birch and pine forest was poorly developed and may have disappeared with the onset of the Younger Dryas cooling. Acid heathland with *Empetrum* and ericaceous plants then developed, to be replaced by oak–hazel forest in the early Holocene. Here, clearly, the influence of cold polar water conditions in the Bay of Biscay was very strong.

Pollen diagrams from marine cores in the Bay of Biscay are also reviewed, but low sedimentation rates, bioturbation and differential transport and preservation of pollen make comparison with continental pollen diagrams difficult and correlation only possible in broad terms. Accurate vegetational interpretations are impossible.

Palynologists working on archaeological cave and rock shelter sequences in

[41]

southwest France and northern Spain have claimed to recognize, between 32 and 14 ka BP, a series of interstadial intervals with expansions of temperate trees. Careful consideration of pollen diagrams covering the purported Laugerie and Lascaux interstadials, said to occur between 16 and 20 ka BP (conventionally the maximum period of glacial advance of the last glacial stage), suggests that temperate pollen has percolated down through overlying deposits and been preserved in certain sedimentologically favourable beds. Although widely accepted by archaeologists, these interstadials appear to have no reality and must be rejected. There is no trace of them in the long lacustrine records of Les Echets (Beaulieu & Reille 1984) and Grande Pile (Woillard 1975, 1978). There is thus no good palynological record for 30–16 ka BP from south-west Europe, other than the long pollen sequence from Padul in southern Spain (Pons & Reille 1986).

1. INTRODUCTION

This paper examines the evidence for vegetational changes in the northern and northwestern parts of the Iberian peninsula and in southwest France and their relation to conditions in the North Atlantic Ocean between approximately 30 and 7 ka BP, from the period just before the glacial maximum to the completion of the major warming of the early Holocene. In a series of papers that changed the whole background of European Lateglacial palaeoclimatic studies, Ruddiman & McIntyre described the migrations of the polar front in the North Atlantic Ocean during the late Quaternary and, in particular, its advances and retreats over the past 20 ka in the eastern sector, adjacent to the coastline of western Europe (Ruddiman & McIntyre 1973, 1981; Ruddiman *et al.* 1977). They showed that the maximum southward extension of polar water in the North Atlantic during the last interglacial–glacial cycle occurred between 20 and 16 ka BP at the period when the Laurentide and Scandinavian ice sheets reached their greatest size. At that time polar water, defined as water sedimenting low-carbonate sediment with only a single species of polar foraminiferan *Globigerina pachyderma* (s.), extended down to about 40° N, approximately the latitude of Lisbon. A later sharp readvance, to the latitude of northwest Spain, brought a return to almost full-glacial conditions in the Bay of Biscay between 11 and 10 ka BP (Duplessy *et al.* 1981). This readvance clearly corresponds to the Younger Dryas cooling in the continental Quaternary record of northwest Europe.

Numerous papers have discussed the climatic, vegetational and faunal history of northwest Europe during the Lateglacial period and its relation to changes in the North Atlantic (see particularly Lowe *et al.* 1980; Atkinson *et al.* 1987). The southwestern seaboard of Europe is also in a very critical geographical position with regard to these oceanic events, but the implications of studies there have received much less attention.

In this paper the term Lateglacial is used informally to cover the period between approximately 14 and 10 ka BP. There is an unresolved problem of nomenclature when discussing Quaternary stratigraphy with respect to southwestern Europe. As yet, no local stage-names have been defined for any glacial or interglacial stages. Archaeologists, particularly in France, have long used the scheme, developed by Bordes (1954), which subdivides the last glacial period into four substages, Würm I–IV, separated by three interstadials, Würm I–II, II–III and III–IV. This scheme has overtones that we very much wish to avoid. In any case, the stage name Würmian has now been formally defined, with a proper stratotype and in its original sense, as a local stage-name for the Alpine region (Chaline & Jerz 1983) and is really not relevant to the area under discussion. When unavoidable, we reluctantly use the more general term Weichselian to refer to the last glacial stage.

This area of southwestern Europe is also critical to Quaternary biogeographical studies, because it has long been assumed that the Iberian peninsula has been one of the major refuge areas in which plants and animals characteristic of interglacial stages in northern Europe survived the severe conditions of the glacial stages. Palynological evidence to support this is less well developed than, for example, for the Balkan area of southeast Europe (Huntley & Birks 1983).

2. THE PRE-WEICHSELIAN VEGETATIONAL RECORD

Ideally, we would have reviewed in this paper vegetational development within this region throughout the Quaternary; however, unlike the situation in northwestern Europe, the number of sites in Spain and Portugal that have yielded palaeobotanical data for any part of the Quaternary before the last glacial stage is very small indeed. Briefly, there are a handful of Early and Middle Pleistocene sites in Catalonia (Elhai 1966; Deckker *et al.* 1979; Suc 1980) and three sites in central Spain, all associated with Palaeolithic industries of Acheulean type: terrace deposits of the river Manzanares at Villaverde (Madrid) and lacustrine deposits at Torralba and Ambrona (Soria) (Menendez Amor & Florschütz 1959; C. Turner, unpublished results). In the north, fragmentary coastal interglacial sites have just been described in Galicia (Nonn 1966; Mary *et al.* 1975), and just across the border in the French Pays Basque, Oldfield (1968) has described a series of Early and Middle Pleistocene interglacial deposits at Bidart and Marbella, the latter of particular floristic interest, because of the indications of an oceanic vegetation with such taxa as *Arbutus*, *Daboecia* and *Rhododendron*.

Potentially the most important of all Spanish Quaternary sites is Padul (Granada), where a 50 m core indicated a succession of several cold and temperate stages (Menendez Amor & Florschütz 1964; Florschütz *et al.* 1971). Unfortunately, the sampling interval for this core, 50 cm, was far too large to give an adequate palynological record, as compared to the other long continental Quaternary pollen sequences from Grande Pile (Woillard 1978) and Les Echets (Beaulieu & Reille 1984) in France. The deposits at Padul are currently being reinvestigated and should yield a continuous pollen sequence which is directly comparable with the deep-ocean oxygen-isotope record, but so far only the results back to 30 ka BP have been released (Pons & Reille 1986).

At present, it must be concluded, these older Quaternary sites are simply too few in number, too scattered and too poorly dated to give a detailed and consistent picture of vegetational development, over this wide geographical area, that could be related accurately to the Atlantic record of climatic change. We considered it far better, therefore, to concentrate on the vegetational record since 30 ka BP, for which many more sites are available, and which is directly comparable with the best-studied part of the oceanic record. Of great importance too is the fact that this timespan lies within the range of radiocarbon dating, so that comparisons of vegetational development at different sites can be made with reference to an absolute timescale, a procedure still impossible for older Quaternary vegetational records.

3. SOURCES OF EVIDENCE

Pollen analysis provides the only method for reconstructing detailed sequential changes in local and regional vegetation. The concomitant study of plant macrofossils can, however, be of the greatest help in the interpretation of pollen diagrams. The calculation of pollen

concentrations or, where sequences have adequate radiocarbon dating control, of pollen influx rates, can also shed insights on vegetational dynamics, undetectable in relative percentage pollen diagrams. Unfortunately neither plant macrofossil records nor absolute pollen counts are available for most of the sites discussed.

For this study, palynological information is available from three very different sedimentary environments. Firstly there are pollen analytical studies carried out in freshwater aquatic environments on lacustrine and bog deposits. In the area under consideration, the available studies have largely been undertaken in the mountains of northern Spain, Portugal and the Pyrenees. The sites are mostly lake basins of glacial origin, some now overgrown by bog vegetation. They contain only sediments laid down since the melting of ice formed during the last glacial maximum. Consequently these records generally cover only the period since 16 ka BP. Exceptionally, lowland bogs have been studied, but these too go back no earlier into the last glacial period. We describe in detail the results of a new investigation into a particularly important site in northwestern Spain, Sanabria Marsh; this study provides a pollen and vegetational record as a cornerstone for the discussion and comparison of similar records from other sites. A second source of palynological evidence comes from two deep-sea boreholes from the Bay of Biscay, where cores have also been subjected to pollen analysis.

A third and more controversial source of palynological information is the quite extensive series of pollen-analytical studies that have been carried out on the sediments of caves and rock-shelters in association with archaeological excavations. Geographically these studies relate to the Dordogne in southwest France, the Pyrenees, and the coastal region of northern Spain. In time, they extend back from the Holocene through the Lateglacial to cover much of the last glacial period. The nature of cave sedimentation, however, means that individual records are fragmented rather than being continuous in time. Nevertheless, they are deemed to cover an important period of time, 30–15 ka BP, which is not (or barely) represented by lacustrine sites in the area under consideration. To compare these records with equivalents from lacustrine sites it is necessary to extend our view to the French sites, Grande Pile in the Vosges (Woillard 1978) and Les Echets near Lyon (Beaulieu & Reille 1984) and to Padul in southern Spain (Pons & Reille 1986).

It must be stressed that palynological results from these three sedimentary environments are not directly comparable. There are important differences in the taphonomy of pollen assemblages and in their mode of incorporation into the sediments. Numerous studies have been made on the relations between pollen assemblages deposited in lake basins and the surrounding regional and local source vegetation, and also on the effects of such complications as redeposition and mixing of pollen assemblages because of sediment focusing on lake floors and the incorporation of pollen from eroded and inwashed soils. The taphonomy of marine pollen assemblages is not so well understood, but there tend to be recognizable patterns of differential transportation, degradation and deposition, such as the overrepresentation of conifer pollen, fern spores and certain types of Compositae pollen (Heusser & Florer 1973; Turon 1980). Another problem with marine sediments stems from their slow sedimentation rates and rather intense bioturbation and mixing. This generally precludes fine resolution, not only in pollen analysis but also in radiocarbon dating. By contrast, sedimentation in lakes may be an order of magnitude faster and bioturbation appears to be of lesser significance.

The taphonomy of pollen assemblages in cave and rock-shelter deposits is very much more

complex. General comments have been made by Leroi-Gourhan & Renault-Miskovsky (1977), but a much more critical approach to the origin and interpretation of pollen from cave deposits has been taken by Couteaux (1977) and Turner (1985). Such problems will be discussed more fully later.

4. PRESENT-DAY CLIMATIC AND VEGETATIONAL FACTORS IN SOUTHWESTERN EUROPE

The Iberian peninsula is the largest of the three Mediterranean peninsulas of southern Europe. It is also one of the most mountainous areas of Europe, with a mean altitude of more than 500 m above sea level. Indeed, more than 34 % of Spain lies between 800 and 2400 m in altitude. The central plateau of Spain forms a major climatic divide between the Atlantic coastal areas of the west and north of the peninsula and the Mediterranean coastlands. The former are characterized by mild, almost frost-free winters and cool summers, with rainfall fairly evenly spread through the cooler months of the year and particularly heavy precipitation in the mountains. The Mediterranean coasts also have mild winters but warm, dry summers with most rainfall in the spring and autumn. Because of its altitude, the plateau itself has very cold winters but hot, dry summers. The Pyrenees form a substantial physical barrier between the Iberian peninsula and France, and indeed a few small glaciers survive at altitudes above 3000 m (Hollermann 1968). However, from west to east the range itself forms a transitional area between the Atlantic climatic zone and that of the Mediterranean. A similar zone of transition occurs across the lower-lying areas of southwest France, from the Atlantic coasts of Gascony and Guyenne to the Mediterranean of Languedoc.

These climatic divisions are reflected in the modern vegetation patterns and particularly in the distribution of many individual taxa. The Cantabrian mountains in northern Spain form an important phytogeographical boundary. The natural forest vegetation of the coastal regions of northern and northwestern Spain contains many tree taxa common to the woodlands of northwestern Europe, particularly western France, such as *Quercus robur*, *Q. petraea*, *Q. pyrenaica*, *Ulmus glabra*, *Corylus avellana* and *Salix caprea*. Several of these taxa reach their southwestern limit of distribution in this area. *Carpinus betulus*, however, does not occur in Spain; its distribution in this part of Europe is apparently limited by the Pyrenees. *Fagus sylvatica* is an important tree in the Cantabrian forests but does not occur further south in the Iberian peninsula, although it is widespread in other parts of southern Europe. Many typical Mediterranean tree species fail to occur in the Cantabrian region, although they are found in southern and eastern Spain and in some cases in the Pyrenees and even on the central plateau. These include *Quercus coccifera*, *Pinus pinea*, *P. halepensis*, *Ephedra major* and *Celtis australis*. Mediterranean species that do occur in northern Spain and also along the Atlantic coasts of south-west France include *Quercus ilex*, *Q. suber* and *Pinus pinaster*. The distribution of *Q. ilex* has been of particular interest to Quaternary biogeographers. Widespread in the central and eastern Mediterranean, its range extends northwards along the Atlantic coast of France into southern Brittany. On the basis of pollen evidence, Van Campo & Elhai (1956) have suggested that it temporarily expanded into Normandy during the Middle Holocene. In Spain, although here as elsewhere it is much planted, it occurs as a native species largely along the eastern, Mediterranean coast and the northern, Atlantic coast. It has been suggested that the species

has spread westwards into Spain from the central Mediterranean area during the Holocene (Huntley & Birks 1983). Over much of the Iberian peninsula *Q. ilex* is apparently replaced by the closely related *Q. rotundifolia*, a widely distributed species endemic to Spain and Portugal.

5. THE NORTH ATLANTIC CLIMATIC RECORD 20–9 ka BP

As mentioned earlier, Ruddiman & McIntyre (1981) placed the position of the polar front in the North Atlantic at about 40° N between 20 and 16 ka BP. They suggest that, north of the polar front, ocean-surface conditions with only moderate meltwater influx and winter sea-ice cover favoured enough winter moisture to provide sufficient precipitation, falling as snow, to fuel the final southward advance of the major ice sheets. From 16 to 13 ka BP they conclude that decay of continental ice sheets led to the entire surface of the North Atlantic, down to at least 60° N, being flooded in summer by meltwater and icebergs, and consequently covered by sea ice in winter, thus starving the continents of moisture and creating rather arid conditions there. Van Campo (1984) has examined the vegetational evidence for southern Europe during this interval and strongly supports this conclusion. By 13 ka BP the polar front had withdrawn northwards and westwards, as far as Iceland, allowing warmer waters and much more temperate climatic conditions to reach the whole Atlantic coastline of western Europe. Between 13 and 11 ka BP Duplessy *et al.* (1981) estimate that summer sea-surface temperatures in the Bay of Biscay were even warmer than at present, particularly in the earlier part of this interval. A sharp readvance of the polar front in the eastern Atlantic to the latitude of northwest Spain brought a return to almost full-glacial cold conditions in the Bay of Biscay between 11 and 10 ka BP. The cause of this readvance is somewhat speculative, but Ruddiman & McIntyre (1981) consider that it may relate to the break-up of large ice-shelves in the Arctic Ocean, as suggested by Mercer (1969). From 10 to 9 ka BP there was a very rapid northwesterly retreat of the polar front and a warming to nearly full postglacial temperatures throughout most of the North Atlantic Ocean. The dating of these events is imprecise, partly because of the problems of bioturbation and slow sedimentation rates, but also because, as stressed by Ruddiman & McIntyre (1981), they were by their very nature time-transgressive.

6. THE NORTHWEST EUROPEAN CONTINENTAL RECORD 14–9 ka BP

This framework for events in the eastern North Atlantic not only integrates reasonably well with Van Campo's account of the climate and vegetation of much of Europe before 13 ka BP (Van Campo 1984), but is also in broad agreement with climatic interpretations of the much more complicated Lateglacial stratigraphic sequences of northwest Europe. These are based on many well-dated sites to which the study of palynology and also of fossil Coleoptera have made the most important contributions (Lowe *et al.* 1980). Indeed, analysis of fossil coleopteran data has recently provided an even more detailed and refined picture of Lateglacial climatic change for the British Isles (Atkinson *et al.* 1987). In the oceanic record, however, it has not been possible to identify minor, short-lived climatic oscillations, such as the Older Dryas, which have been detected on land.

The northwest European Lateglacial continental record has virtually been used as a model by some authors, and particularly by archaeologists and their collaborators, in the interpretation of Lateglacial sequences not only in northern Europe but also in our study area

VEGETATIONAL HISTORY OF SOUTHWEST EUROPE 457

in the southwest. For this reason we list Iversen's now classic sequence of Lateglacial pollen zones (Iversen 1954), together with the chronozones proposed by Mangerud *et al.* (1974) to formalize this sequence (table 1).

The use of this sequence and its nomenclature as a model for the interpretation of Lateglacial sequences at southwest European sites raises a number of questions. The first of these is the

TABLE 1. LATEGLACIAL POLLEN ZONES AND CHRONOZONES

(From Iversen (1954) and Mangerud *et al.* (1974).)

pollen zones (Denmark)		chronozone (Scandinavia)	
		chronozone	age/ka BP
zone III	Younger Dryas period	Preboreal	10–9
zone II	Allerød period	Younger Dryas	11–10
zone Ic	Older Dryas period	Allerød	11.8–11
zone Ib	Bølling period	Older Dryas	12–11.8
zone Ia	Daniglacial tundra period (‘Oldest Dryas’)	Bølling	13–12

often implicit assumption that the major episodes of climatic change during the Lateglacial were synchronous along the Atlantic seaboard. Ruddiman & McIntyre (1981) have shown that the movements of the polar front across the North Atlantic were clearly time-transgressive. The second point is that the criteria used to infer climatic change in most pollen diagrams have been the appearance and expansion of tree pollen taxa. Coope (1977) has pointed out repeatedly that Lateglacial beetle faunas demonstrate that climatic amelioration begins well before the expansion of tree birches in the British Isles. The spread of trees appears to be controlled by distance from refugia and by soil nutrient conditions (Van Geel *et al.* 1984). It must be assumed that refugia for temperate tree species lay much closer to sites in southwest Europe than to those in the north.

The third matter relates to the resolution of climatic events during the Lateglacial. Watts (1980) has reviewed the evidence for the recognition of Bølling and Younger Dryas climatic events in different areas of northern and central Europe and concluded that both of these are most marked in their expression in the British Isles. Evidence for a definable Bølling interval becomes more difficult to recognize with certainty eastwards beyond the Netherlands and certain sites in Germany. The Younger Dryas becomes less distinct in southern Germany and the Alps. Pine and birch remain present there during Younger Dryas time, but indications of climatic change may be limited to a decrease in birch, small rises in juniper and *Artemisia* pollen curves or inwash of inorganic sediment. Clearly the intensity, and consequently the expression, of Lateglacial climatic oscillations may vary geographically even over relatively short distances.

7. POLLEN-ANALYTICAL INVESTIGATIONS OF LACUSTRINE SEDIMENTS IN NORTHERN AND NORTHWESTERN SPAIN AND PORTUGAL

A relatively small number of sites has been investigated in the mountains of this region of the Iberian peninsula. Here we discuss only those which relate to the Lateglacial period and to which radiocarbon dating has been applied. The location of these sites is given in figure 1. The

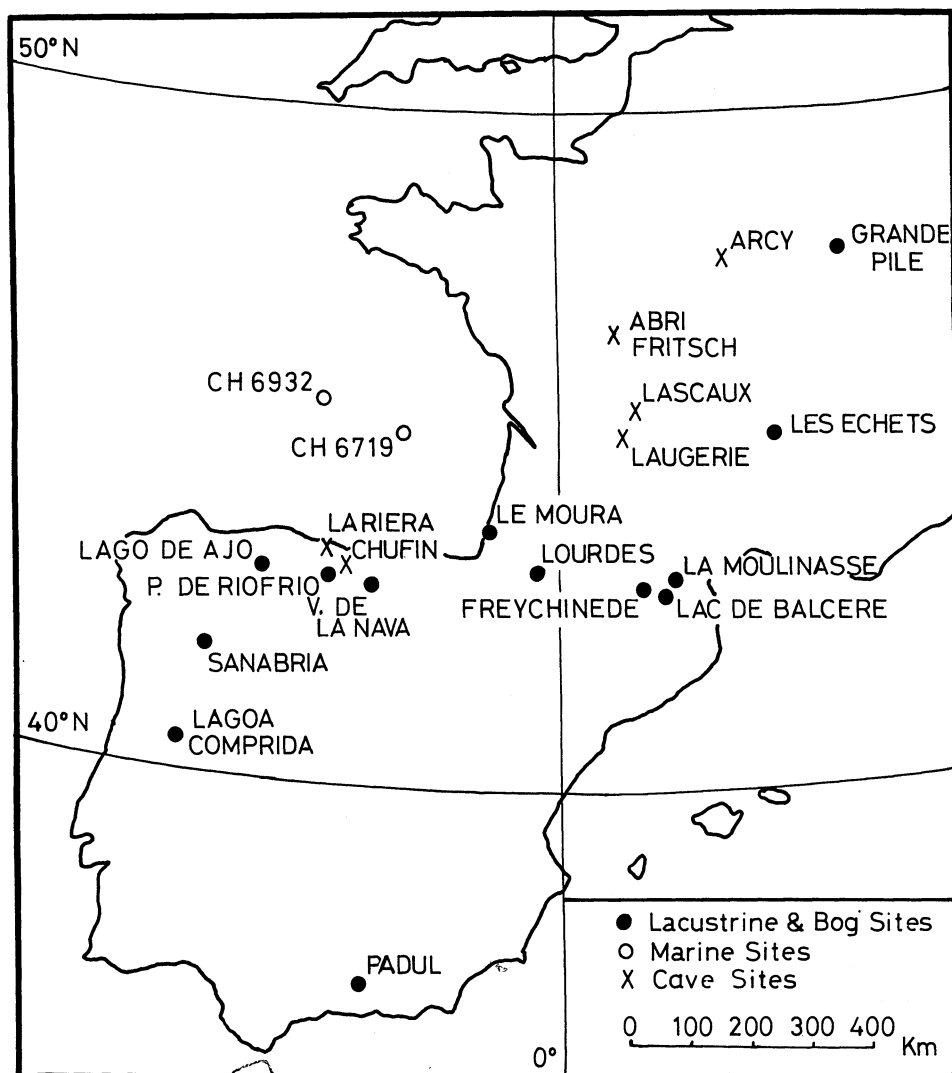


FIGURE 1. Sites of late Quaternary palynological investigations in southwest Europe and adjacent areas.

most important are Sanabria Marsh (Hannon 1984; Watts 1986), which is virtually the same locality as Laguna de las Sanguijuelas (Menendez Amor & Florschütz 1961), and Lago de Ajo, another recently investigated site (McKeever 1984; Watts 1986). Two sites further east near Santander, Puertos de Riofrio (Florschütz & Menendez Amor 1962) and Valle de la Nava (Menendez Amor 1968), and also Lagoa Comprida in the Serra da Estrela of northern Portugal (Janssen & Woldringh 1981; Van den Brink & Janssen 1985) are also discussed briefly.

(a) *Sanabria Marsh*

It was decided to reinvestigate the site of the Laguna de las Sanguijuelas examined by Menendez Amor & Florschütz (1961). This lies at an altitude of *ca.* 1050 m above sea level in a mountainous area of northwestern Spain about 20 km north of the frontier with Portugal ($42^{\circ} 06' N$, $06^{\circ} 44' W$). The new investigations, hitherto largely unpublished and therefore described here in some detail, were carried out by G. E. Hannon at a site here referred to as

Sanabria Marsh. This lies about 700 m from the original site of Menendez Amor & Florschütz (1961) and is an overgrown small lake (100 m × 200 m) occupying what is probably an ice-block hollow in a moraine near a large natural lake, Lago de Sanabria.

There is geomorphological evidence for a recent glaciation in the area, and Schmidt-Thomé (1983) describes a young lowland glaciation, probably Weichselian, in the neighbouring part of Portugal (Minho district) very close to the study area. The mountains are of Cambrian and Silurian rocks with much granite. Much of the upland area around the site is above 1500 m, rising to over 2000 m in the Sierra de la Cabrera range to the north. The modern vegetation in the valley is woodland dominated by Pyrenean oak, *Quercus pyrenaica*, with virtually no other tree species present. The surrounding hillslopes are covered by multi-stemmed *Q. pyrenaica*-Leguminosae scrub, much of which has been burnt in the past. The mountain tops are dominated by ericaceous plant communities, with much *Calluna*. The area where coring took place is now covered with poor fen vegetation.

A Livingstone corer was used to recover sediment cores to a depth of 10.55 m. The sediments consisted of fibrous peat, fen peat, gyttja (lake mud) and clay (figure 2) and were polleniferous to a depth of 9.86 m. They also contained a rich macrofossil flora (figure 3). Three radiocarbon dates were obtained at important biostratigraphical horizons. The investigation of the upper part of the sequence relating to the later Holocene is not described here.

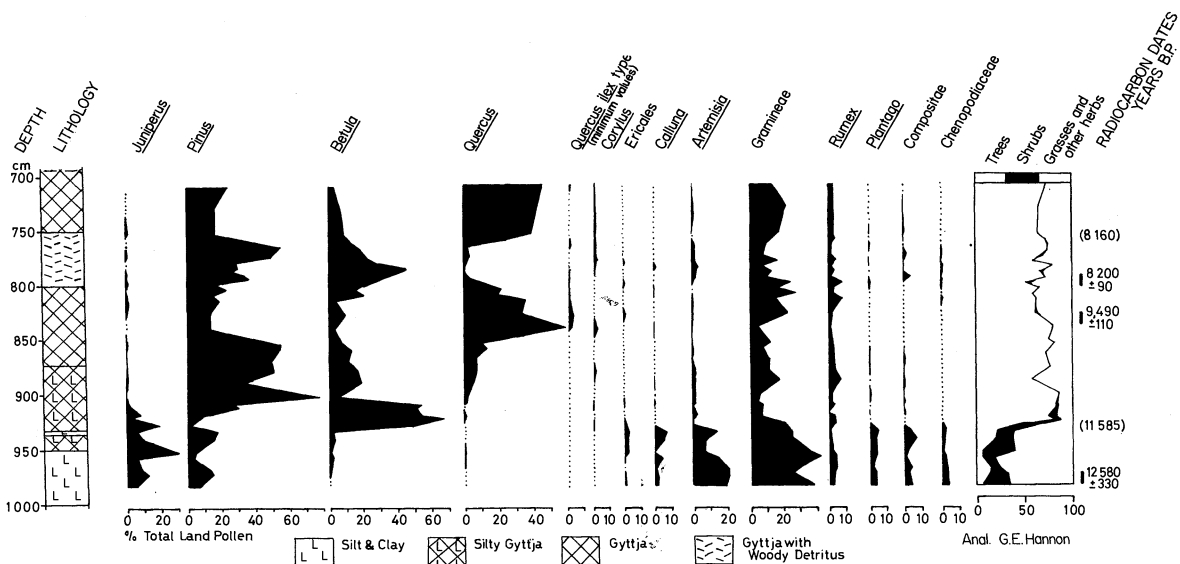


FIGURE 2. Pollen diagram (selected taxa only) from Sanabria Marsh, northwestern Spain. In the summary diagram *Corylus* is included with the tree pollen, and *Ericaceae* pollen with that of shrubs. Radiocarbon dates in brackets relate to the closely similar pollen diagram from Laguna de las Sanguijuelas.

Although the sediment depth was greater than that recorded by Menendez Amor & Florschütz (1961), the new pollen sequence (figure 2) does not extend quite so far back in time. Nevertheless, there is a very close similarity between the major pollen curves in both studies although a large number of taxa, and in particular *Juniperus*, which were not recognized in earlier work, have now been recorded. Because the pollen diagrams are so similar, it is also possible to apply the radiocarbon dates obtained for the earlier study to the interpretation of the present diagram. The granitic soils in the neighbourhood of the site make it very suitable for radiocarbon dating because the problem of 'old carbon' and hard-water error does not

need to be considered. Pollen concentrations were also measured. The pollen-concentration and influx diagrams are not reproduced here, as they resemble the relative pollen diagram (figure 2) in all major features, but they confirm that the vegetational changes described are real rather than statistical artefacts.

Menendez Amor & Florschütz (1961) recorded an early zone with high percentages of herbs, grasses, *Artemisia* and *Pinus*. The early Lateglacial age of this zone is confirmed by radiocarbon dates of $13\,700 \pm 300$ years BP (Gro 705) and $12\,830 \pm 280$ years BP (Gro 702) and we suggest that it ended just before $11\,585 \pm 220$ years BP (Gro 688). Minor fluctuations in the *Betula* and *Pinus* curves suggest a small expansion of trees at about 13 700 years BP, followed by a return to open vegetational conditions. The vegetational record for the new studies (figure 2) commences shortly before $12\,580 \pm 330$ years BP (Beta-9162), so that unfortunately it does not cover the period of this early presence of tree pollen, for which confirmation is very desirable.

The earliest pollen assemblages from Sanabria Marsh closely resemble those from the Laguna de las Sanguijuelas in showing high percentages of grasses, *Artemisia* and herbs such as Chenopodiaceae, Compositae, *Plantago* and *Rumex*, but they also contain significant amounts of *Juniperus*. The Ericaceae pollen, rising to a peak at this horizon in both pollen diagrams, is here identified as referable largely to *Calluna*. These early grass and *Artemisia*-rich pollen assemblages from both diagrams are interpreted as indicating a treeless pioneer vegetation, which had colonized a barren, relatively recently deglaciated landscape. The grains of *Pinus* pollen recorded are poorly preserved, and this, together with the absence of macrofossil needles, suggests they were probably derived from an extra-local source, perhaps further south in Spain or at a lower elevation, rather than locally. The same may be true of *Ephedra*, a xeromorphic shrub.

Many full-glacial floras in southern parts of Europe from Spain to Greece are characterized by *Artemisia*, grasses and Chenopodiaceae and have been referred to as indicating steppe vegetation. Van Campo (1984) has made a powerful case for linking this vegetation to a period of markedly arid climate affecting most of southern Europe between 16 and 13 ka BP, but at Sanabria the presence of ling (*Calluna*) and other Ericaceae suggest a heathlike aspect and must indicate a reasonably humid climate. Locally, stony open ground is indicated by macrofossils of arctic-alpine plants, such as seeds of *Minuartia* sp., *Cerastium cerastioides* (Caryophyllaceae) and *Draba* cf. *aizoides* (Cruciferae) (figure 3).

The rising abundance of *Juniperus* and *Calluna* pollen provides a new insight into the nature of these pioneer vegetation communities. *Juniperus* pollen was unrecognized or overlooked in most earlier pollen studies from Spain. At Sanabria Marsh, values of 30% are observed, accompanied by frequent macrofossil needles. European fossil pollen maps (Huntley & Birks 1983) show that juniper was widespread throughout much of western Europe between 13 and 10 ka BP, although not in the southwest. These new data extend the range to northwestern Spain. *Calluna vulgaris* has not previously been recorded from Spain during this time period, and the pollen is accompanied by abundant macrofossil remains which include leaves, flower-heads and seeds; these remains confirm its local presence and provide the earliest unambiguous evidence for extensive heath communities in the deglaciating landscape of northwestern Spain. The area probably provided a refugium for this species during the last glacial period.

A white silt band, devoid of both pollen and macrofossils, occurs between 935 and 937 cm, after which many of the pioneer taxa except *Juniperus* and Gramineae disappear. This band records a brief event, probably a flash flood.

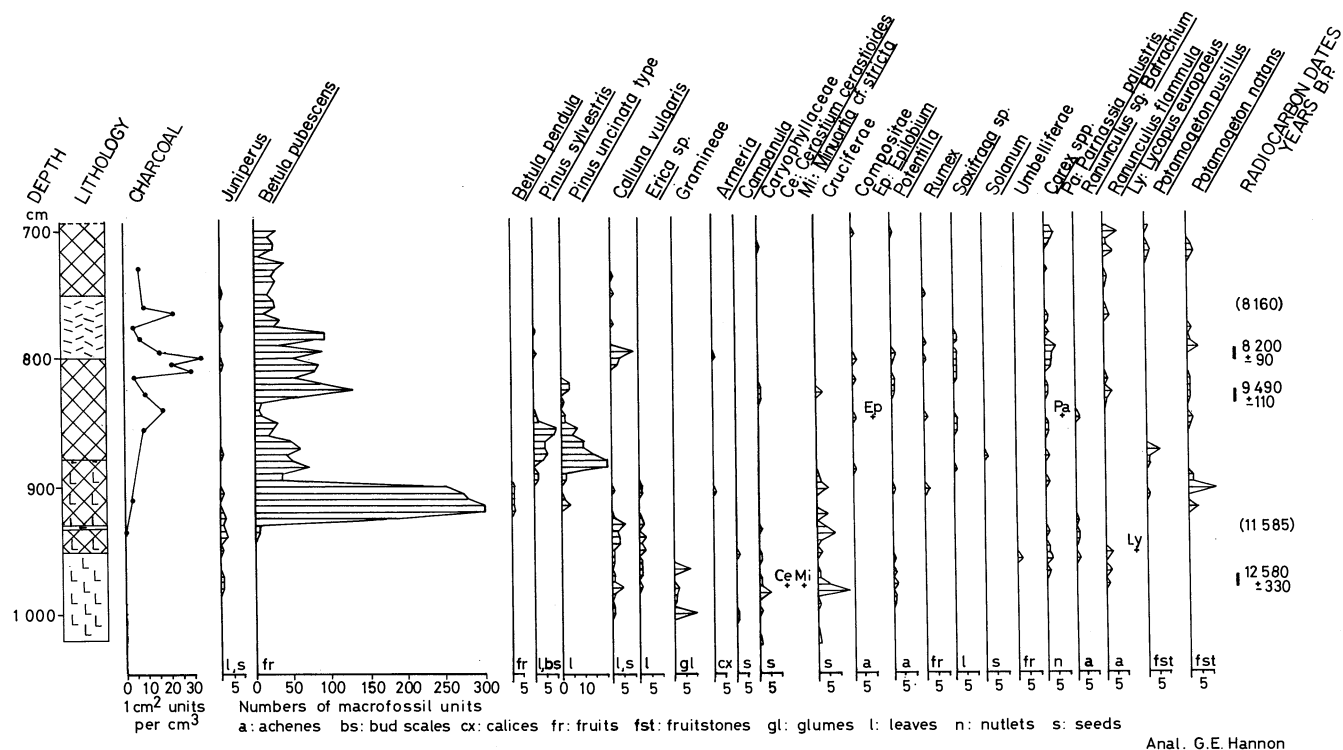


FIGURE 3. Plant macrofossil diagram (selected taxa only) from Sanabria Marsh, northwestern Spain. (Lithological symbols as for figure 2.)

Sedimentation of gyttja is resumed, whereupon a rapid rise in the *Betula* curve provides the first definite evidence of climatic change. This event has been dated to $11\,585 \pm 220$ years BP (Gro 688) by Menendez Amor & Florschütz (1961). At the same time, herbaceous pollen types, mainly Gramineae with some *Rumex* and *Plantago*, fall to about 20%.

The pollen assemblages suggest a period when scrubby open woodland, with juniper and downy birch (*Betula pubescens*) colonized the slopes near the lake. Subsequently this developed into closed-canopy birch woodland; very large numbers of birch fruits (about 200 per 50 ml sample) and high pollen values (65%) are recorded. The macrofossils show that *Betula pubescens* was the predominant species, with some silver birch (*B. pendula*) also present.

Pinus pollen values rise gradually and replace *Betula* as the most abundant tree type above 910 cm. A low curve for *Corylus* begins at 915 cm but values for this tree are usually below 5% throughout the diagram. The *Quercus* pollen curve also starts to rise gradually. Macrofossil needles show that pine is first represented by a dwarf mountain pine, either *Pinus mugo* or *P. uncinata*, and at a higher level by Scots pine, *P. sylvestris* (figure 3). *Pinus uncinata* forms the natural treeline in the Pyrenees today, ascending to well over 2000 m (Gausson 1948). *Pinus mugo* is common in the mountains of central Europe. The fossil needles of these two species are indistinguishable when studied in small fragments, but it seems more likely that the needles belonged to *P. uncinata*, given its modern distribution.

At 840 cm the *Pinus* pollen curve falls, after the gradual expansion of *Quercus*. A radiocarbon date of 9490 ± 110 years BP (Beta-9161) was obtained between 827 and 837 cm; this result suggests that *Pinus sylvestris* woodland was being largely replaced by oak woodland at a time roughly corresponding to the onset of Holocene warming in northwestern Europe.

Both deciduous and evergreen oaks were present. Where possible, these were distinguished on the basis of pollen morphology. However, the separation is not entirely reliable, as there is some degree of overlap. Pollen of evergreen oak is presented as a minimum curve of definite grains. It is labelled as *Quercus ilex* type because (as discussed earlier) in addition to *Q. ilex*, two other species of evergreen oak, *Q. rotundifolia* and *Q. coccifera*, grow in Spain today.

Having reached a maximum of 55% at 830 cm, the *Quercus* curves show a strongly marked decline between 825 and 800 cm. The *Betula* curve rises to a renewed peak, followed by a further *Pinus* maximum. A radiocarbon date for 792–802 cm places this second expansion of birch at 8200 ± 90 years BP (Beta-9160). In the macrofossil record *Betula pubescens* is once again represented by large numbers of fruits (120 per 50 ml sample) (figure 3). *Pinus* is only represented by occasional bud scales. There is no overall rise in Gramineae pollen at this time but certain relatively minor herb pollen curves do show slight increases, including *Artemisia*, Chenopodiaceae, Caryophyllaceae, *Helianthemum*, *Armeria* and Cruciferae.

At 750 cm the *Quercus* pollen curve shows a recovery, even sharper than its earlier decline, and returns to dominance. This second rise in the *Quercus* was equally marked in Menendez Amor & Florschütz's (1961) diagram and dated there to 8160 ± 190 years BP (Gro 703).

To summarise the sequence of vegetational changes on the slopes around Sanabria Marsh between 12580 and 9490 years BP, herbaceous vegetation with steppe, arctic–alpine and heathland elements was in turn replaced quite rapidly by a sequence of first *Betula*, then *Pinus* and finally *Quercus* woodland. All the evidence suggests that this represents a straightforward ecological succession in response to ameliorating climatic and edaphic conditions. In particular, there is no record of any apparent climatic fluctuations within this timespan. After 8 ka BP there was a short interval when the oak population collapsed and *Betula pubescens* woodland developed very close to the site. The subsequent *Pinus* peak is not substantially supported by any macrofossil record, so the tree, although abundant, was probably not growing close to the site.

Menendez Amor & Florschütz (1961) in their study of the area referred the initial *Quercus* peak to the end of the Allerød and the second *Quercus* peak, which they had dated, to the onset of the postglacial *Quercus* rise. They therefore regarded the period of the second *Betula* maximum as the equivalent of the Younger Dryas. This correlation has been quoted in most subsequent papers on the Lateglacial period in southwestern Europe. However, their interpretation is in conflict with the new data from Sanabria, in particular with the radiocarbon dates for both the first *Quercus* rise (827–837 cm), 9490 ± 110 years BP, and the onset of the second *Betula* rise (792–802 cm), 8200 ± 90 years BP. It must be emphasized again that the two pollen diagrams show a remarkable degree of agreement, and clearly identify the same sequence of vegetational events. Likewise the two sets of radiocarbon dates combine to form a consistent and mutually supporting sequence.

The conclusions that can be drawn from this new study of the area are:

- (i) There is no evidence for any marked cooling of climate at this site between 11 and 10 ka BP, equivalent to the Younger Dryas oscillation recorded elsewhere.
- (ii) The *Quercus* decline identified by Menendez Amor & Florschütz (1961) as evidence for Younger Dryas cooling is clearly an early Holocene event, dated at about 8200 years BP.
- (iii) Although the first *Quercus* maximum is dated to 9490 years BP, after the beginning of the Holocene, both *Quercus* and *Corylus* (hazel) appeared earlier and were present in low quantity in the area during the Lateglacial.

It will be shown that evidence for similar conclusions can be found in other sites in northwestern Spain and Portugal.

It is still necessary to explain the temporary fall in *Quercus* pollen at 8200 years BP and the subsequent reversion to a *Betula* phase. Although the dates bounding the event come from two separate diagrams, it seems to have occupied a relatively short period of time. It can be considered in two different contexts.

The first is that this represents a local forest catastrophe resulting in the destruction of the oak forest by fire or disease and the initiation of a seral woodland succession once again. In support of this hypothesis, the macrofossils and their residues are largely composed of charcoal between 820 and 800 cm, and the gyttja overlying this level from 800 to 760 cm shows an increase in its minerogenic component. Because this is an area of granitic bedrock, loss of nutrients as a result of a forest fire could have seriously affected the rate and species composition of forest regeneration. Macrofossils demonstrate that *Calluna* again invaded the site at this time.

There is, however, a certain amount of evidence to suggest that a more widespread episode of vegetational change may have taken place at this time, in which case a climatic explanation might be necessary. A fall in *Quercus* pollen accompanied by a rise in *Betula* is recorded at 8310 ± 160 years BP (GrN 9916) in the pollen diagrams from Lagoa Comprida in the Serra da Estrela (Janssen & Woldringh 1981; Van den Brink & Janssen 1985). In the new diagram from Padul there is a temporary fall in the curves for both deciduous and evergreen oak over a short interval between 9300 ± 90 years BP (Gif 6382) and 8200 ± 80 years BP (Gif 6383) (Pons & Reille 1986). Neither pine nor birch plays any significant role in the vegetation at Padul at that period. The decline in *Quercus* is associated with a rise in the Gramineae pollen curve and then with a great increase in monolet fern spores (included in the pollen sum in that diagram). Without pollen concentration measurements it is difficult to gauge whether or not there is a genuine decline of oak populations at Padul or alternatively whether the fall in *Quercus* pollen is largely a statistical artefact of the relative percentage diagram because of a highly localized input of fern spores. However, these observations indicate no common climatic trend, and only further observations will confirm or negate such an alternative explanation of the event at Sanabria Marsh.

(b) *Lago de Ajo*

Lago de Ajo is a lake occupying a large cirque in the north-west part of the Cantabrian mountains (43° N, 6° W). It lies about 135 km north-northeast of Sanabria Marsh but at a higher altitude (1570 m). The local bedrock, exposed in the steep walls of the cirque, consists of dolomitic limestone. The lake lies above the tree-limit and is surrounded by herbaceous alpine vegetation with juniper bushes. At a slightly lower level, beech (*Fagus sylvatica*) forest occurs, with some birch and hazel present. Pines and oaks are absent from the surrounding area, although deciduous oaks occur at lower altitudes.

A recently studied sediment core from this lake yielded a pollen diagram covering most of the Holocene and Lateglacial (McKeever 1984; Watts 1986). The principal features of the vegetational development at this site were as follows.

(i) The earliest part of this diagram suggests a vegetation dominated by *Artemisia*, grasses and other herbs. In terms of pollen percentages *Pinus* is quite abundant (30–35%), but the low pollen concentrations suggest that vegetation was very sparse and treeless, much of the pollen, particularly that of *Pinus* and *Ephedra*, being carried in from lower altitudes elsewhere.

(ii) A sharp rise in the *Pinus* and *Betula* curves probably signals the return of trees to the area, although there are no supporting macrofossils at the peak of this event. This horizon has been dated to 14270 ± 180 years BP (Beta-6740), but this determination may be somewhat too old; in this area of calcareous bedrock, early Lateglacial dates from predominantly inorganic sediments are likely to have been affected by hard-water error. There followed a brief resurgence of *Artemisia*, perhaps indicating a cooler oscillation, then, at 12610 ± 90 years BP (Beta-9157), *Betula* again became abundant with macrofossils of *B. pubescens* indicating that trees were growing close to the site, which is now above the treeline.

(iii) This spread of birch was followed within a short time by a major expansion of oak. Nearly a metre of sediment in which *Quercus* pollen dominates was deposited below the level at which *Corylus* expanded, dated to 9780 ± 80 years BP (Beta-6739). During this period of oak dominance, pine was present in the immediate vicinity of the lake, as indicated by finds of macrofossil needles.

To summarize, the lake basin was already deglaciated before 14 ka BP. The possibility of a minor episode of climatic warming, early in the Lateglacial, is suggested by a rise in *Betula* and *Pinus* pollen at the site, before the main expansion of *Betula* and other trees about 12610 years BP. If the radiocarbon date for this horizon, 14270 years BP, is too old then this oscillation may well represent the same event as the early *Betula* maximum in Menendez Amor & Florschütz's (1961) diagram from Laguna de Sanguijuelas, dated to 13700 years BP. As at Sanabria Marsh, expansion of oak takes place within the Lateglacial. Finally, the vegetational record at this site again shows no evidence of an identifiable Younger Dryas event.

(c) *Lagoa Comprida*

Investigations of this site at an altitude of 1600 m in the Serra da Estrela in northern Portugal relate exclusively to the Holocene (Janssen & Woldringh 1981; Van den Brink & Janssen 1985). Neither of the boreholes penetrated Lateglacial sediments, but it is significant that oak, as well as pine and birch, formed a major component of the forest at the base of the diagrams some time before 9200 BC. The fall in *Quercus* pollen at this site during the early Holocene, dated at 8310 ± 160 years BP, has already been noted.

(d) *Valle de la Nava and Puertos de Riofrio*

Menendez Amor (1968) made three pollen diagrams from an area of peat bog in the Valle de la Nava near the boundary between the provinces of Burgos and Santander, well to the east of the sites previously discussed (figure 1). The altitude of the site is not stated, but it is less than 1000 m. A second site lies high up at an altitude of 1700 m in the Picos de Europa, called Puertos de Riofrio (Florschütz & Menendez Amor 1962). At both sites the diagrams for the early Holocene are generally similar and show a predominance of *Pinus* and *Quercus* with lesser amounts of *Betula*. The onset of the rise of *Quercus* is dated to 10210 ± 115 years BP at Riofrio and to 10000 ± 200 years BP at Valle de la Nava. Before this the vegetation at Riofrio, the higher site, appears to have been largely open with non-tree pollen curves, Gramineae, *Artemisia* and Chenopodiaceae dominating the lowest assemblages, together with 20–30% *Pinus* pollen. At Valle de la Nava, about 1000 m lower, pine forest clearly dominated the end of Lateglacial times; *Pinus* pollen values are high (70–80%) with 20–30% Cyperaceae and Gramineae pollen and only traces of other trees.

8. LACUSTRINE AND BOG SITES IN THE PYRENEES AND PAYS BASQUE

Here the most important palynological studies come from three altitudinally distinct regions (figure 1). There is a cluster of high-level lake and bog sites in the eastern Pyrenees at altitudes between 1300 and 1800 m above sea level; a second cluster of sites in the neighbourhood of Lourdes in the central Pyrenees, lying at about 400–420 m above sea level; and a valley bog, Le Moura, in the Pays Basque near Biarritz, at only 40 m above sea level.

The three principal high-level sites, Lac de Balcère (Van Campo & Jalut 1969), La Moulinasse (Jalut 1973) and Freychinède (Jalut *et al.* 1982), have all yielded pollen records covering the Lateglacial, and their basins of deposition relate geomorphologically to the melting of the last major glaciers of the area. Lac de Balcère lies at an altitude of 1764 m and is surrounded by *Pinus uncinata* forest. La Moulinasse and Freychinède, lying at altitudes of 1330 m and 1350 m respectively, are now both peat bogs occupying basins where morainic barriers blocked drainage. Forests close to La Moulinasse consist primarily of *Pinus uncinata* and *Abies alba*, but the area around Freychinède has been extensively deforested. La Moulinasse lies in an area of schists and granites, but at Freychinède calcareous rocks outcrop, which may be important when considering radiocarbon dates.

Altitudinally and topographically these sites have much in common with those of the mountains of northwest Spain. The pollen records, initially similar, develop differently.

The oldest pollen assemblages suggest once again a treeless vegetation with low pollen productivity, dominated by grasses, *Artemisia* and other herbs, with *Pinus* pollen carried in by long-distance transport. A series of radiocarbon dates for this pollen zone at Freychinède range from $14\,600 \pm 770$ years BP (Gif 5017) to $21\,300 \pm 760$ years BP (Gif 4957) and older than 22000 years BP (Gif 5015), but older dates are interstratified with younger ones.

The first signs of climatic amelioration are provided by the spread of *Juniperus*, dated at Freychinède at $14\,700 \pm 800$ years BP (Gif 5018) and at La Moulinasse to before 13600 years BP (Gif 1775). As at Lago de Ajo, and in contrast to Sanabria Marsh, Ericaceae played no significant role.

This early phase of open Lateglacial vegetation was brought to an end by the invasion of *Pinus uncinata* and *Betula*. Subalpine dwarf pine forest, characteristic of the modern tree limit, must have spread to virtually its present altitudinal limit at that time. At this altitude *Betula* played a much less important role, except at Freychinède, where it appears to have arrived before *Pinus* at *ca.* $13\,150 \pm 300$ years BP (Gif 4958), and *Pinus* peaks at Freychinède and Lac de Balcere with dates of $11\,200 \pm 250$ years BP (Gif 4959) and 11240 years BP (Gif 792) respectively. *Pinus uncinata* continues to dominate the pollen diagrams at all three sites throughout the rest of the Lateglacial, until the expansion of *Quercus* and *Corylus* curves in the early Holocene. Curves for *Quercus* and *Corylus*, of course, represent the expansion of these trees at lower altitudes. They have played no role in the vegetation of these higher mountain areas at any time in the Holocene.

Evidence for a Younger Dryas oscillation is only weakly expressed. At the highest site, Lac de Balcère, there is a small rise in the Gramineae and *Artemisia* curves and a corresponding temporary fall in the *Pinus* curve from 60 to 50%. At La Moulinasse low sedimentation rates give a very condensed record. A single sample shows a Gramineae peak and a relatively low *Pinus* value, followed by a single-sample *Artemisia* peak corresponding with the recovery of *Pinus*. At Freychinède there is no appreciable vegetational change detectable.

It must be concluded that at high altitudes in the eastern Pyrenees there was no significant movement of the treeline corresponding to a Younger Dryas cooling; at most a slight opening up of the tree cover took place, allowing a small increase in herbaceous pollen.

With respect to the dating of these pollen diagrams, it must be concluded that the early dates for the Gramineae–*Artemisia* zone at Freychinède should be disregarded. It seems probable that many of the dates from this site are affected by hard-water error and are too old. Jalut and his co-authors reject such a possibility but still fail to explain the inconsistent sequence of dates. They comment that, because the lowest sediments are less calcareous than those above, much of the carbonate must have been in solution. These are precisely the conditions under which ‘old carbon’ is taken up by aquatic plants. The comparatively early date for the expansion of the *Quercus* pollen curve at Freychinède, 10850 ± 120 years BP (Gif 5524), serves to support the suggestion that some dates at this site are too old, because the *Quercus* expansion at La Moulinasse nearby is dated to shortly before 9150 years BP (Gif 1776) and at Lac de Balcère to shortly before 9250 years BP (Gif 791).

Although the sites in the neighbourhood of Lourdes are at a much lower altitude, they too relate to lakes formed behind morainic barriers after the melting of a glacier at the end of the last major glacial event in the Pyrenees. The investigations of Kolstrup (1980) of a core taken close to the still extant Lac de Lourdes cover only the older part of the Lateglacial sequence. A fuller record has been published by Mardones & Jalut (1983) for Biscaye, an adjacent lake basin, now totally infilled and overgrown by woodland swamp and bog vegetation. The latter basin also seems to include the site investigated by Florschütz and Menendez Amor under the name Poueyferré, for which only an outline pollen diagram has been published (De Vries *et al.* 1960; Alimen *et al.* 1964).

The oldest deposits occur at Biscaye, where organic peats and lake clays overlie at least 5 m of inorganic laminated clays. The basal 3.5 m contain many scattered cobbles and thin beds of gravel with striated clasts. These must represent the deposits of a proglacial lake into which ice was actually carrying rock debris. Mardones & Jalut (1983) nevertheless applied pollen analysis to these sediments and obtained low concentrations of pollen, particularly *Pinus* (70–90%) together with small amounts of pollen of grasses, other herbs and even thermophilous trees. These assemblages must be interpreted as consisting overwhelmingly of reworked pollen from older peats and soils destroyed by glacial and periglacial processes. Such an interpretation is supported by radiocarbon analysis of small amounts of organic material incorporated in these otherwise inorganic sediments. The dates obtained are much older than any others for the region: 29500 ± 1200 years BP (Gif 5683), 31900 ± 2000 years BP (Gif 5684) and $38400 \pm \frac{2000}{1800}$ years BP (Gif 5685). Extraordinarily, Mardones & Jalut (1983) accept these as true dates for the age of the deposits and even propose an interstadial at that time on the basis of the high *Pinus* pollen percentages. Such an interpretation is quite inconsistent with either the actual lithology of the sediments or the generally accepted glacial history both of the Pyrenees in this region and of western Europe in general.

The earliest reliable pollen assemblages from all three pollen records again show the now familiar pattern of early Lateglacial vegetational development, namely a treeless open vegetation dominated by grasses and *Artemisia*, followed by the spread of juniper and then of trees, particularly tree birches and shortly afterwards pine. The *Betula–Pinus* maximum at these sites is accompanied by a low but consistent pollen curve for *Quercus* with values of 1–2%. This suggests the possibility that oaks may have been present somewhere in the region in small

quantity but not in the immediate neighbourhood of the basins of deposition. The major expansion of oak, closely followed by that of hazel, was clearly a Holocene event in this region.

Radiocarbon dates at Biscaye suggest that the *Juniperus* expansion took place after 14820 ± 240 years BP (Gif 5682) and that the expansion of *Betula* there began at 13250 ± 120 years BP (Gif 5693). These dates are in good agreement with that from the Poueyferré diagram of 13600 ± 110 years BP (Gro 1679) for the upper part of the Gramineae–*Artemisia* zone (*Juniperus* was not counted in this diagram). At Lac de Lourdes the expansion of *Betula* is dated to 13480 ± 140 years BP (GrN-8675). Older dates for the Gramineae–*Artemisia* zone from Lac de Lourdes, 18950 ± 400 years BP (GrN-8512) and 19300 ± 600 years BP (GrN-8682), and from Poueyferré, 18790 ± 225 years BP (Gro 1890), interstratified between dates of 13600 ± 110 years BP (Gro 1679) and 15800 ± 120 years BP (Gro 1671), should be viewed with caution. At Biscaye the older lake sediments are characterized by the presence of the carbonate-secreting alga *Chara*, a good indicator of bicarbonate-rich waters. These rather old dates are likely to have been affected by hard-water error or possibly a small admixture of reworked organic matter. At Poueyferré, the *Pinus*–*Betula* maximum is dated to 12310 ± 130 years BP (Gro 1681), compared with a date of 12760 ± 200 years BP (Gif 5735) at Biscaye, and the major expansion of *Quercus* to just before 9260 ± 100 years BP (Gro 1889).

At both Poueyferré and Biscaye there is evidence for vegetational reversion indicating some climatic deterioration at the time of the Younger Dryas event in the millenium before the onset of the Holocene. At Poueyferré the outline diagram shows a decline in the *Betula* and, to a lesser extent, the *Pinus* curves, but more significantly a temporary rise in the non-tree-pollen values from 25% to 60% of the pollen sum. At Biscaye at *ca.* 10860 years BP birch declined, and a very brief and small resurgence of *Juniperus* and *Artemisia* took place, correlated with a short-term fall in pollen concentration. Unfortunately this is followed by a sharp break in the pollen diagram at a critical horizon or lithological change, so there may be a hiatus here concealing the full nature of the event.

The site of Le Moura (Oldfield 1964) is at a much lower altitude (40 m above sea level) than previous sites discussed and remote from the direct effects of glaciation. It lies within 20 km of the Bay of Biscay and is a valley bog, surrounded by a region of heathland on poor sandy soils. The pollen diagrams from Le Moura, unlike others, were calculated on the basis of a pollen sum comprising only tree pollen. After recalculation, the pollen record at this site appears very different from the impression given by the published diagrams. Unfortunately the only relevant radiocarbon date for this site lies close to the onset of the Holocene: 9960 ± 160 years BP (Q 616+617) but at a horizon in the pollen diagram where the *Quercus* and *Corylus* curves have attained moderately high values. The Lateglacial vegetational record itself is therefore undated, but comes from such a critical location close to the shores of the Bay of Biscay that it must be discussed.

In the principal borehole, five metres of peats and organic muds are underlain by one metre of inorganic silty clay. This basal deposit is represented by Oldfield's pollen zones F and L1 ('full-glacial' and 'Late-glacial 1'). Pollen assemblages for both zones are dominated overwhelmingly by Gramineae pollen with that of Compositae, *Polygonum* cf. *viviparum* and Caryophyllaceae frequent. Values for *Pinus* pollen are less than 1% in zone F and only 5–10% in zone L1. Towards the top of zone L1, *Juniperus* and *Artemisia* appear in small quantity. In

zone L2, with the onset of organic sedimentation, the *Betula* and *Pinus* curves rise, but only to peaks of 6% and 20%; there is a slight increase in *Juniperus*.

In zone L3, tree pollen values fall again to less than 10%. First the diagram shows high values for Gramineae and Cyperaceae pollen, then there is a massive increase in Ericaceae pollen, particularly *Calluna*, and in *Empetrum*. Towards the end of zone L3 the pollen curves for *Betula* and *Pinus* begin to rise again erratically, reaching peaks of over 30%. Ericaceae and *Empetrum* pollen curves remain high.

Zone P1 is marked by the expansion of first *Quercus* and then *Corylus*. The radiocarbon date was obtained from a separate borehole.

Zones F and L1 indicate a very open treeless environment with grassland and other herb communities that included a few arctic-alpine species such as the fern *Cryptogramma crispa* and possibly *Polygonum viviparum*. The so-called steppe elements such as *Artemisia* play almost no role in this vegetation. The virtual absence of even long-distance transport of *Pinus* pollen suggests that the prevailing wind direction was from the northwest, over the Bay of Biscay, perhaps as a result of anticyclonic conditions over an ocean covered with sea ice.

In zone L1, conditions ameliorated slowly; there was some long-distance transport of *Pinus* pollen, principally *P. uncinata*, and a small spread of *Juniperus*. In zone L2, the spread of *Betula* and *Pinus*, with *P. sylvestris* more frequent than *P. uncinata*, is restricted. It seems unlikely that there was woodland growing very close to the site, which was then an open-water habitat, but a notable increase in abundance of aquatic plants also suggests a climatic amelioration. In zone L3 the initial fall in tree pollen to very low values suggests a return, regionally, to open grassland conditions and the elimination of tree cover, but this is followed by the rapid spread of acid heathland, reminiscent of the Lateglacial heathlands of western Ireland, with crowberry (*Empetrum*), ling (*Calluna*) and other ericaceous plants. Since the actual site was undergoing a transition from reedswamp to bog, this development is particularly marked in the pollen record. The fluctuating record of birch and pine may be the result of individual trees that had actually colonised the bog surface at that time. The strong climatic amelioration in zone P1 is marked not only by the expansion of oak and hazel forest but the appearance of such thermophilous taxa as holly (*Ilex aquifolium*) and saw sedge (*Cladium mariscus*).

Oldfield broadly correlated his zones L1–L3 with Iversen's three Lateglacial pollen zones and P1 with the onset of the Holocene. The true age of the zones cannot be established without further investigation and radiocarbon dating. What does seem inescapable is that, for most of the Lateglacial, the area around Le Moura carried open grassland and then heathland vegetation with very little development of woodland. If zone L2 does represent the Lateglacial interstadial then at that time the spread of trees was particularly restrained, compared with other sites discussed, but in Ireland very oceanic conditions in the Lateglacial interstadial also seem not to have favoured the growth of birch. Zone L3 would represent a period of very dramatic vegetational change with grassland expanding and then being partially replaced by heathland with finally a local reinvasion by birch and pine. An alternative interpretation, that the main phase of Lateglacial climatic amelioration is represented by fluctuations of the tree pollen curve within zone L3 and that L2 represents a brief earlier climatic oscillation, cannot be excluded in the light of the comparatively early expansion of oak at this site, if the radiocarbon date is correct. In either case the vegetational development at Le Moura is very different indeed from that described from any other sites in southwest Europe. Such differences cannot be ascribed to altitude alone, but must also relate to the proximity of the Bay of Biscay with its rather extreme climatic conditions during the Lateglacial.

9. THE MARINE PALYNOLOGICAL RECORD FROM THE BAY OF BISCAY

Pollen analysis has been applied by Turon to two deep-sea cores from the Bay of Biscay, where the marine planktonic fauna, particularly Foraminifera, has also been studied. Core CH 6932, taken from a site *ca.* 300 km from land (45° 24' N, 05° 9' W) covers approximately the past 20 ka (Pujol & Turon 1974; Turon 1974). Core CH 6719, taken 200 km from land (45° 45' N, 3° 57' W), a deeper sequence with a higher sedimentation rate, relates only to the Lateglacial and Holocene (Duplessy *et al.* 1981).

The diagrams bear a broad similarity to those from terrestrial sites, but are difficult to interpret in detail. The dominance of *Pinus* at every level, often 80–95% of the total pollen, and the very low values for Gramineae, make it clear that the assemblages have undergone much differential sorting and degradation. Because of the high tree-pollen values, the diagram for core CH 6932 is calculated on the basis of a pollen sum based only on tree pollen, and core CH 6719 on a pollen sum excluding *Pinus*, by far the major constituent of the assemblages. This also makes comparison with other diagrams difficult. Neither of these cores has been subjected to radiocarbon dating; ages are inferred from faunal correlations with other dated cores. However, Ruddiman & McIntyre (1981) regarded Turon's dating of CH 6932 as 1500–2000 years too old.

The two issues raised by these diagrams are (i) whether they permit any interpretation of vegetation patterns and vegetational changes on the adjacent continent, and (ii) to what extent it is possible to correlate these pollen records with continental pollen diagrams. Because there is so much distortion of the pollen assemblages by processes of transport, sorting and degradation, the answer to the first question must be negative. With so many non-tree-pollen taxa under-represented or lost, cold-stage plant communities cannot be adequately recognized. For the Holocene, although both diagrams yield pollen curves for a variety of deciduous tree taxa, the abundance of pine gives the impression that western France and northern Spain were dominated by coniferous forest vegetation with a small admixture of deciduous trees. Continental diagrams show conclusively that this was not the case; nor, alternatively, can the marine assemblages be explained as representing simply a mixture of pollen from montane and lowland forest sources.

The possibilities for making detailed correlations between these marine and continental pollen diagrams are affected not only by problems of assemblage distortion but also by the effects of bioturbation and slow sedimentation rates, both of which obscure pollen-zone boundaries. In lacustrine pollen diagrams such boundaries, particularly for the Lateglacial, represent rapid vegetational changes of important climatic significance. However, broad correlations between the marine and continental pollen records are clear. The Holocene part of these marine diagrams is characterized, once the massive pine contribution is set aside, by relatively prominent *Quercus* and *Corylus* curves and by minor curves for other temperate trees such as *Ulmus* and *Tilia*, which are absent in the Lateglacial and earlier sections of the diagrams. Similarly the Lateglacial is marked by a prominent *Artemisia* curve, although grass values are only 5–10%. It is very difficult to subdivide the Lateglacial part of the diagrams with any confidence. The different phases of the Lateglacial, as recognized by Turon, are based on only one or two samples. At these levels interpretation often depends on the behaviour of individual taxa. Information from other taxa may be contradictory. Thus in core CH 6719, the Younger Dryas cooling, although not well marked, is apparently recognized by a small

decrease in *Quercus* and *Corylus* pollen which coincides with a fall in the *Artemisia* curve, whereas a rise in *Artemisia* might be expected on the evidence from continental pollen diagrams.

The lower part of the diagram from core CH 6932 shows assemblages where the highest values for non-tree pollen, including maxima for *Artemisia* and Gramineae, coincide with minor peaks for *Corylus*, *Betula* and *Quercus*. Turon suggests that this horizon represents the Würm III–IV interstadial, but elsewhere there is no evidence of such temperate conditions at this time, *ca.* 20 ka BP, either in the continental record or in other marine records. The peaks of temperate elements are over-emphasized because of the arboreal pollen sum, but the mixture of temperate and cold-climate elements in the pollen assemblages suggests some local reworking. It may be significant that the results from CH 6932 are not discussed at all by Duplessy *et al.* (1981) when presenting the pollen diagram from CH 6719.

The conclusion must be that these marine pollen diagrams can only be used to make very broad correlations with continental sequences. They are certainly not reliable indicators of short-lived events of less than 1000–2000 years' duration, such as the climatic changes of the Lateglacial. They may detect some features of these changes but the detailed record is erratic because of the unpredictable effects of bioturbation.

10. POLLEN RECORDS FROM CAVES AND ROCK SHELTERS

For more than twenty years archaeological excavations of Palaeolithic caves and rock shelters in France, and recently in northern Spain, have included palynological investigations of the sedimentary infills. Because of the very low pollen concentrations, the sediment samples analysed generally have to be larger than those from lacustrine sites (25–50 g, as opposed to 1–2 g) and special techniques of preparation are used to extract the palynomorphs (Girard & Renault-Miskovsky 1969).

On the basis of these palynological studies, an increasingly detailed scheme, subdividing the latter part of the last glacial stage in France and adjacent areas into alternating stadial and interstadial intervals, has been proposed and developed by Leroi-Gourhan (1965; Leroi-Gourhan & Renault-Miskovsky 1977; Renault-Miskovsky & Leroi-Gourhan 1981). The scheme (figure 4) is closely linked to Upper and Middle Palaeolithic cultural sequences with a chronology based on radiocarbon dates from excavated bone and charcoal samples. A different stratigraphic classification of sedimentary sequences from caves and rock shelters in the Périgord (Dordogne) area of southwest France has been developed by Laville (Laville *et al.* 1980), largely on the basis of sedimentology but with strong climatic overtones, also with the support of palynological studies (Paquereau 1974–75, 1978). Laville's classification is essentially a detailed refinement of Würm I, II, III, IV subdivision proposed earlier by Bordes (1954).

After a period of competition these classifications now coexist with only relatively minor disagreements over the dating and possible overlap of some interstadial intervals (Laville *et al.* 1985). What is important is that both advocate a radically different interpretation of the sequence of climatic changes and vegetation patterns that took place in western, particularly southwestern, Europe between 35 and 10 ka BP from those suggested by non-archaeological palynologists. This alternative interpretation is widely accepted and taught in universities in Europe and North America and thus requires comment here.

As shown in figure 4, as well as the Allerød and Bølling interstadials, no less than six further

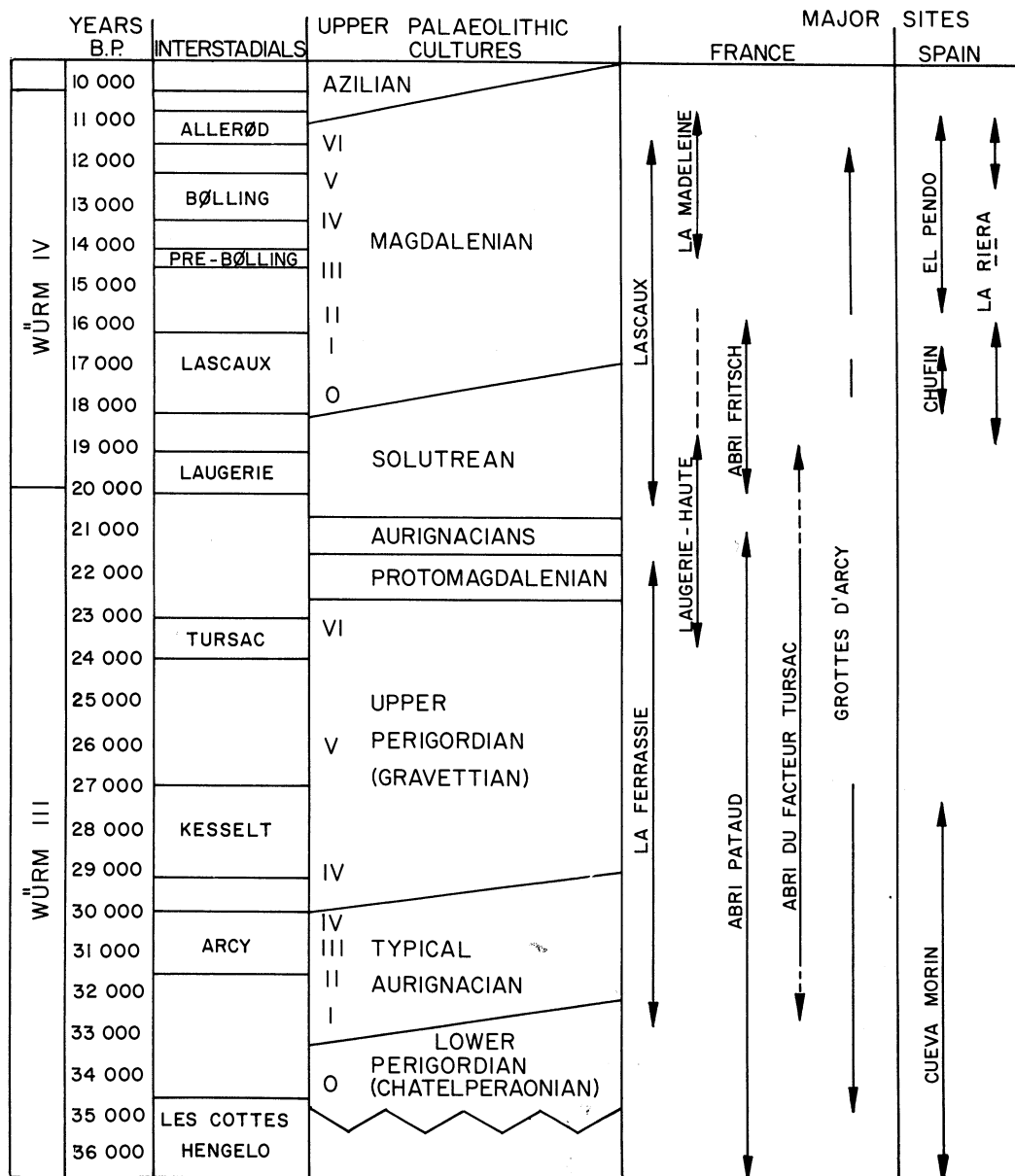


FIGURE 4. Climatic phases between 36 and 10 ka BP and their relation to major Palaeolithic sites in France and Spain, principally according to Renault-Miskovsky (1986).

interstadial intervals have been proposed between 32 and 10 ka BP. These interstadials are based on the occurrence of varying amounts of pine and relatively small percentages of temperate tree pollen at specific dated horizons in the cave sequences. As indicated in figure 4, these interstadials have been recognized at a range of sites in France and Spain.

The Laugerie and Lascaux interstadials are of particular importance because the radiocarbon-dated sequences suggest that these occurred between 19.5 and 18.5 ka BP and 18 and ca. 16.5 ka BP, respectively; these intervals are contemporary with those suggested by deep-ocean isotope and faunal records to have been very cold indeed just off the coasts of southwest France (Duplessy *et al.* 1981).

The type locality for the Laugerie interstadial is the rock shelter of Laugerie-Haute near Les Eyzies (Dordogne). Excavations by Bordes (1959) revealed a sequence of stratified deposits containing Perigordian VI, Solutrean and Magdalenian industries. A pollen diagram prepared by Paquereau (1978) demonstrated, at several horizons within the sequence, beds containing pollen assemblages with 30–40% tree pollen. Although separated by beds in which non-tree pollen predominates (95%), particularly Compositae pollen and especially Liguliflorae and *Artemisia*, the assemblages in the different beds containing tree pollen are rather uniform with *Pinus* values of 5%, *Salix* 4–6%, *Corylus* 10–15%, *Alnus* 5–10% and *Quercus* 1–3%. The uppermost levels, 60 cm thick, covered by Paquereau's diagram (Laugerie-Haute Ouest) are associated with a Solutrean industry with a radiocarbon date of 17790 years BP. In addition to the trees listed above, small amounts of *Tilia*, *Ulmus*, *Carpinus*, *Fagus*, *Juglans* and other trees were recorded. At several other sites in the Dordogne area of southwest France, similar pollen assemblages with small amounts of temperate trees have been recovered in association with Solutrean industries, in some instances with radiocarbon dates of ca. 19200 years BP. These too have been ascribed to the Laugerie interstadial and occur at the Abri Fritsch (Leroi-Gourhan 1967), the Abri du Facteur at Tursac (Leroi-Gourhan 1968) and the cave of Lascaux (Leroi-Gourhan & Girard 1979) (figures 1 and 4).

Naturally the type locality for the Lascaux interstadial is the famous cave of Lascaux, also in the Dordogne, with its Magdalenian wall paintings. A pollen diagram through the sediment sequence in the cave (Leroi-Gourhan & Girard 1979) is dominated by Compositae pollen (especially Liguliflorae), Gramineae and *Pinus*, but shows a small series of samples containing temperate tree taxa in low quantity at the same level as the Magdalenian occupation, associated with a radiocarbon date of 17190 years BP. Pollen sums are conspicuously low (56, 85, 90, 155 grains total pollen) for most of these levels. In fact, the peak of the *Quercus* curve at 7% represents only six grains of oak pollen and that of *Alnus* at 6% only three. The occurrence of lime (*Tilia*), elm (*Ulmus*), hornbeam (*Carpinus*), beech (*Fagus*), and walnut (*Juglans*) is based only on the presence of one or two grains of each taxon. *Pinus* values, however, reach 20–30%. At the level, with a pollen sum of 56 grains, 16 grains of *Corylus*, 11 grains of *Pinus* and 3 grains of mixed oak forest species, contribute towards a total of 60% tree pollen, a point to note shortly. At the same time these levels also show changes in the composition of the non-tree-pollen assemblages with pollen of Compositae (Liguliflorae) much lower than in the pollen assemblages from other parts of the diagram. Again the actual number of pollen grains involved is minuscule.

The Lascaux interstadial has been recognized at other sites (Leroi-Gourhan 1980a), particularly at the Abri Fritsch, where it stratigraphically overlies levels assigned to the Laugerie interstadial (Leroi-Gourhan 1967, 1980b), and at the caves of Chufin (Boyer-Klein 1980) and La Riera (Straus *et al.* 1981, 1983; Straus & Clark 1986) in northern Spain. Leroi-Gourhan's (1980b) outline pollen diagram for the site of Abri Fritsch (figure 5) shows features which she regards as important for the recognition and differentiation of the Lascaux and Laugerie interstadials: the fluctuations of the *Pinus* curves, including that for the southern European species *Pinus pinaster*, with a distribution just reaching south-west France today; the balance between tree and non-tree pollen; and the behaviour of the Gramineae and Compositae curves. The latter differ for the two interstadials, leading Leroi-Gourhan (1980a) to postulate that conditions during the Lascaux interstadial were more oceanic than during that of Laugerie.

ABRI FRITSCH (ALT : 130 mètres)

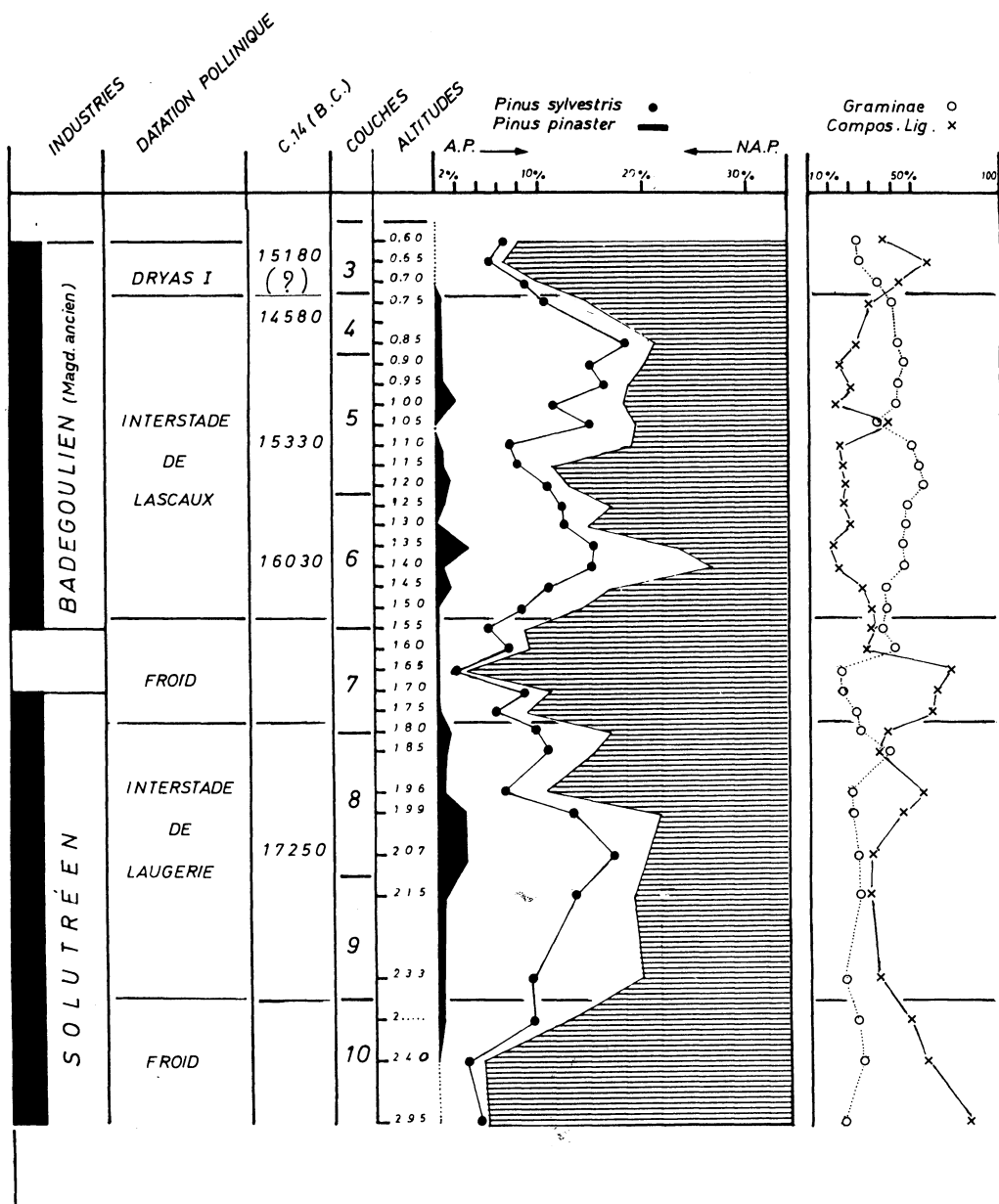


FIGURE 5. Pollen diagram from rock-shelter sediments of the Abri Fritsch (Indre), western France (Leroi-Gourhan 1980b).

The authors of these pollen diagrams have interpreted the temperate element in the assemblages in terms of the spread of either park woodland or of riverine forest in sheltered valleys. Implicit in both assumptions is the concept that these temperate trees had refugia close at hand within southwest France and northern Spain, for example on sheltered cliffs and gorges, where they survived the rigours of the colder intervals of the glacial period. The extremes of this interpretation are represented in a recently published volume (Renault-Miskovsky 1986). In translation: 'During this Lascaux interstadial, the principal features of

the vegetation are characterized by: a significant forest cover (60% tree pollen), pines, but rather poorly represented, much hazel which declines with the advent of mixed oak forest at the maximum of the amelioration, and the presence of thermophilous elements, the occurrence of walnut being particularly interesting at the height of the Würm glacial period'. Clearly this description is based on the very sparse pollen assemblages from Lascaux described above. The high non-tree-pollen assemblages are interpreted as steppe, rich in Compositae in the earlier stadials, but with much *Artemisia* in the 'ancien Dryas' stadial after the Lascaux event.

Couteaux (1977) made a trenchant critique of the application of palynology to cave sediments. Amongst the various aspects which he and Turner (1985) insisted needed careful investigation were: (i) the origin and taphonomy of the pollen comprising the assemblages, and thus whether the assemblages actually reflect local or regional vegetation at particular points in time and provide a basis from which accurate palaeoclimatic and palaeoenvironmental deductions can be made; (ii) whether the pollen assemblages are actually contemporary with the sediments in which they are contained; and (iii) whether the deductions made from the pollen evidence are in agreement with evidence from other, independent lines of investigation, such as the fauna and sedimentary structures.

The taphonomy of pollen transport into caves is very poorly understood; little experimental work has been carried out on actual pollen deposition, nor its spatial variation within caves. However, there are many possible vectors. Pollen may be carried in by wind or by water seeping through fissures, on the fur of animals or internally as dung, or by insects such as mason bees. In human habitation sites pollen may be introduced deliberately or accidentally with food or bedding. Clearly there is unlikely to be much uniformity in pollen assemblages between sites, given this range of possible sources.

There remains the question of what happens to pollen grains once they are deposited on a sediment surface within a cave or rock shelter, and how they are incorporated into the sediment and preserved. Cave-sediment sequences can be compared to a series of immature soils, although they differ from soils in microbiological activity, because organic matter is much sparser, and in the rather abrupt changes in grain size (and consequently geochemistry) that characterize different beds in the sequences. Pollen studies of soils (Dimbleby 1961; Havinga 1968, 1971) have shown that pollen grains move in a complex way downwards through soil profiles, where they are also exposed to differential destruction and corrosion, depending on the physical and chemical conditions of the soil and the relative resistance of pollen grains of different taxa to destructive processes. As a result, pollen assemblages in soils, although they may vary at different horizons, consist of a mixture of pollen grains of different ages. Furthermore, some pollen types are likely to increase in relative frequency with time because they are resistant to destruction, whereas others become progressively diminished.

The pollen diagram from the Abri Fritsch (figure 5) has been redrawn in a more conventional way (figure 6), together with additional pollen curves published elsewhere (Leroi-Gourhan 1967, 1980a), so that it can be compared with diagrams from lacustrine sites. A full pollen diagram for this site has apparently never been published, so the data is necessarily incomplete. Pollen sums are also not published, but are generally above 250 grains. It is instructive to consider this diagram in the light of the discussion above. The first point to note is that, in this case, Holocene deposits actually overlie the older sequence. There is a discontinuous scatter of temperate pollen types, not only trees but also ivy (*Hedera*), throughout the diagram down to 185 cm, with only two levels lacking at least some representation.

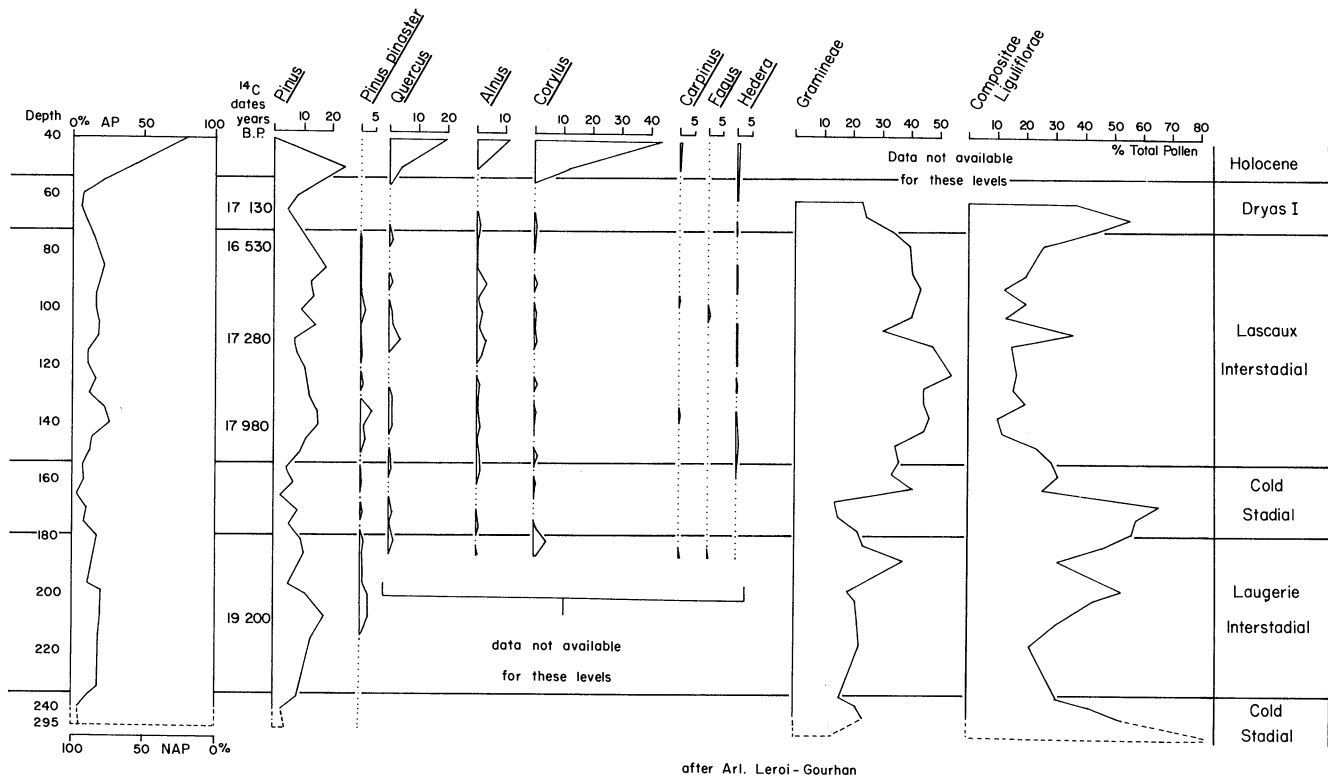


FIGURE 6. Pollen diagram from the Abri Fritsch (Indre), western France, redrawn with information from Leroi-Gourhan (1967, 1980a, b).

The interstadials and particularly their upper and lower boundaries are actually defined solely on the percentage curves of *Pinus* pollen; this is also largely true for the pollen diagram from Lascaux itself. When the diagram is drawn up in a conventional way, it becomes more obvious that the *Pinus* pollen curve shows comparatively low values. The fluctuations between samples can be seen to be grossly exaggerated by the graphic representation in figure 4. Equivalent values for *Pinus* pollen in diagrams from lacustrine sites are normally assumed to be referable to long-distance transport and show just as much variation.

There is also a critical ecological observation to be made. A well-established characteristic of pollen diagrams covering the climatic amelioration at the beginning of the Holocene and of interglacial stages is that they demonstrate how pioneer tree species immigrate and expand before the expansion of temperate taxa (Turner & West 1968). Interstadial vegetational successions show a similar but less developed succession. In virtually all pollen diagrams from caves and rock shelters, and specifically those from Laugerie-Haute, Lascaux and the Abri Fritsch, there is no evidence at all for vegetational succession. The temperate taxa simply appear 'unannounced'. In short, the pollen diagrams for the Lascaux and Laugerie, and likewise for other claimed interstadials, make no ecological sense.

Some of the less common thermophilous taxa can provide further evidence of the origin of the temperate pollen grains in these assemblages. Attention has been drawn to the occurrence of *Juglans* and likewise *Platanus* (plane) pollen in cave sites. Renault-Miskovsky *et al.* (1984) suggest that this provides evidence for their native status in western Europe. Pollen of these taxa

is so rare in any Quaternary pollen diagrams from Europe that this is unlikely, but the idea cannot be positively refuted. However, several diagrams from archaeological sites in southwest France also contain pollen of *Carpinus*, which is claimed as evidence for its survival in refugia in the Périgord region along with other temperate tree species. However the spread of this tree during the Holocene has been mapped in detail by Huntley & Birks (1983). These maps make it quite clear that *Carpinus* spread very gradually westwards from southeastern Europe during the early and middle Holocene and only reached southwest France after 2 ka BP. *Fagus*, for which there are similar pollen records, has almost the same history. There seems to be no likelihood at all that these particular taxa were present in the Périgord in the latter part of the last glacial period. The source of *Carpinus* pollen in these diagrams must be either downwash from relatively recent Holocene deposits, reworked pollen from older interglacial sources or contamination within the laboratory during sample preparation. The low pollen concentrations make contamination from any of these sources much more significant than in samples from lacustrine and bog sediments. At Abri Fritsch the likelihood is that much of the pollen, including that of *Pinus pinaster*, which is moderately resistant to degradation, has undergone downwash from the surface in late Holocene times, when both hornbeam and this pine had arrived in the region.

Carpinus pollen was also found in the assemblages assigned to the Lascaux interstadial at the site of Chufin in northern Spain (Boyer-Klein 1980). The deposits concerned are dated to 17470 years BP and contain a Solutrean industry. Firstly, *Carpinus* is completely absent in Spain as a native plant in the Holocene, having failed to migrate across the Pyrenees. Secondly, the existence of a temperate period at that time in northern Spain (based on 50% absolute pollen (AP) values, but very low pollen sums in the Chufin diagram) seems very unlikely in view of climatic conditions inferred for the Cantabrian mountains and the Bay of Biscay at that time. Here, again the source of the pollen must be regarded as extraneous.

Finally, these cave pollen records must be compared with the evidence from other kinds of investigations. The archaeology is not particularly instructive in terms of palaeoclimatic reconstruction, but studies have generally been made on the sedimentology and vertebrate faunas from the same cave deposits. One of the reasons why the interpretation of pollen data from caves, as indicating relatively temperate conditions, has been so widely accepted is that it very often supports the climatic interpretations of the sedimentological studies (Laville 1980). Laville tends to make the assumption that deposition of fine-grained sediments takes place under mild, relatively humid conditions, whereas coarser rubbly deposits and breccias, which may or may not show evidence of solifluction and cryoturbation, are associated with colder climates. Other sedimentologists do not agree that this is always the case (Guillien & Lautridou 1974; Farrand 1985). However, fine-grained sediments certainly provide a more favourable matrix for the accumulation and protection of palynomorphs carried downwards over long periods of time, so that the relation between sediment type and pollen content may not, in fact, be independent. At Laugerie-Haute there seems to be a repeated correlation between beds of finer-grained sediment and the occurrence of less robust pollen types such as those of most temperate trees and also sedges, whereas assemblages from coarser grained beds, or those affected by weathering, tend to contain assemblages dominated by thick-walled or resistant pollen types such as Compositae, *Artemisia* and *Pinus*.

Turning to the vertebrate evidence, Delpech (1983) reports that the fauna from the interstadial horizon at Laugerie-Haute consists very largely of reindeer (*Rangifer tarandus*) with

horse (*Equus caballus*) also frequent. This fauna shows, according to her, no trace of a climatic amelioration, not even an increase in humidity. With the exception of one site, excavated in the last century, the same conclusions are drawn from other sites of the same age in the Dordogne. Saiga antelope (*Saiga tatarica*) appears quite prominently in the faunal record shortly after this time, giving a strong impression of a cold, dry steppe environment. Likewise at Lascaux, despite the variety of animals painted on the cave walls, the actual faunal remains are predominantly those of reindeer. Remains of animals, such as roe deer (*Capreolus capreolus*) and wild boar (*Sus scrofa*), which today prefer wooded habitats, are rare.

The conclusions from this survey must be that these so-called interstadials based on pollen analyses of cave and rock shelter sediments do not, in fact, represent genuine climatic events or clearly demonstrable vegetational changes. This does not mean that all pollen in cave sediments is derived from younger deposits. At La Riera (Straus & Clark 1986) *Juniperus* pollen occurs in sediments dated to the early Lateglacial and *Artemisia* at lower horizons, but they form components of pollen assemblages which have at least in part moved downwards within the sediment column and also undergone differential destruction, hence the dominance of robust pollen grains, such as those of Compositae, identifiable even when partially degraded.

At Grande Pile and Les Echets in France (Woillard 1975, 1978; Beaulieu & Reille 1984) and at Padul in Spain (Pons & Reille 1986) there are now pollen diagrams from deep lacustrine sequences that cover the entire period of the last glacial stage. It is appropriate to complete this discussion by quoting the comments of Beaulieu & Reille (1984) on their sequence at Les Echets.

The well established and dated sequence of Les Echets does not give evidence of the least climatic amelioration of any length between 25000 BP and the Lateglacial: none of the numerous interstadials that have been described and recognized in caves by non-botanist researchers and that encumber both the end of the Würm and the literature concerned can objectively be found; neither are they found in the diagrams from la Grande Pile published by Woillard (1975).

At first it seemed logical that in southwest Europe these purported interstadial intervals represented small oscillations in the position of the polar front, which brought about minor vegetational changes in coastal areas of Spain and France. These need not have had a widespread impact. Unfortunately it is clear that the palynological evidence itself must be rejected, on the grounds that the pollen assemblages that contain small quantities of tree pollen appear on balance of the evidence to be intrusive and not contemporary with the sediments in which they were contained.

11. VEGETATIONAL AND CLIMATIC HISTORY OF SOUTHWEST EUROPE 30–10 ka BP: CONCLUSIONS 30–22 ka BP

The only evidence for vegetational conditions before the glacial maximum comes from cave and rock-shelter sites. Proposed interstadial intervals, such as the Arcy, Kesselt and Tursac interstadials, are rejected as artefacts based on the presence of intrusive temperature pollen, although they have been claimed to be represented at a number of sites not only in the Pyrenees and Spain, as well as in other parts of France (Leroi-Gourhan 1959, 1971; Leroi-Gourhan & Leroi-Gourhan 1964; Bui-Thi-Mai & Girard 1984). Other levels in these sites indicate open vegetational conditions, although again the pollen may likewise not be contemporary with

the enclosing sediments. These pollen assemblages, usually dominated by Compositae (Liguliflorae), are too distorted by differential destruction to permit a vegetational interpretation, but it does seem likely that at this period before the glacial maximum *Artemisia* was a very minor component of the vegetation, compared with its abundance after 16 ka BP.

22–16 ka BP

The Pyrenees and other mountain ranges in northern Spain and Portugal were quite extensively glaciated during the last glacial stage. It is concluded that, as elsewhere in western Europe, the glacial maximum occurred at approximately 18–20 ka BP, but it is virtually impossible to secure reliable absolute dates for such events. Dates suggesting that this episode of glaciation occurred much earlier (Mardones & Jalut 1983) or that the ice had melted substantially before 18 ka BP (Kolstrup 1980; Jalut *et al.* 1982) are rejected. Likewise rejected are the purported Laugerie and Lascaux interstadials of Paquereau (1978) and Leroi-Gourhan (1980*a, b*); Leroi-Gourhan & Girard (1979), not simply because they are in utter discord with other palaeoclimatic reconstructions for this interval, but primarily because, as discussed earlier, the palynological evidence on which they were based appears to be unsound from several lines of evidence.

16–ca. 14.5 ka BP

It can probably be assumed that by 16 ka BP melting of these mountain glaciers was well under way or complete and sediment was already accumulating in most of the lacustrine basins thereby created. In these mountain areas deglaciation was followed by the appearance of very open grass- and herb-dominated pioneer plant communities. In a short time there developed a vegetation dominated by grasses and *Artemisia*. Van Campo (1984), noting that vegetation of this kind became widespread over much of southern Europe at this time, has made a convincing case that this was essentially a steppe vegetation associated with an arid climate, where lack of rainfall restricted tree growth at least as effectively as low temperatures. This agrees with predictions by Ruddiman & McIntyre (1981) that sea ice cover between 16 and 13 ka BP would have led to a greatly reduced precipitation over the continent of Europe. Certainly pollen assemblages of this age are very uniform at Lago de Ajo, at the Pyrenean sites and even in Italy and Greece. However, at two sites in the area considered here, there is evidence for different conditions. In the undated basal levels at Le Moura, *Artemisia* is very sparse, but conditions seem to have been particularly chill and bleak there at low altitude on the very edge of the Bay of Biscay. By contrast at Sanabria, in the Laguna de las Sanguijuelas diagram, as later in time in the Sanabria Marsh diagram, evidence for extensive ericaceous plant communities from the earliest levels suggest a moderating oceanic influence on temperature and a much less arid climate. From no lacustrine site is there any indication of a major or even a minor climatic oscillation with any development of tree growth between deglaciation and the main Lateglacial spread of birch and pine.

ca. 14–10 ka BP

Clearly there is no uniform pattern of Lateglacial vegetational development in southwest Europe. Part of the variation between the sites discussed can be attributed to factors such as altitude, soil type and local hydroseral conditions. However, even given the uncertainties of dating suggested for some sites, there remain significant differences in the pattern and timing

of immigration and expansion of particular taxa and in the impact and intensity of climatic changes as interpreted from the vegetational record.

In the Pyrenees, as in northern Europe, the earliest vegetational evidence for climatic amelioration during the Lateglacial seems to be an increase in *Juniperus* pollen productivity. At Biscaye, this took place shortly after 14820 years BP and at Freychinède, at 14700 ± 800 years BP, although neither of these dates is secure. At La Moulinasse, where hard-water dating error is unlikely, the *Juniperus* rise took place before 13600 years BP.

In the mountains of northwestern Spain at Sanabria, the climate was already mild enough for ericaceous plants to flourish, but information about the behaviour of juniper in this early period of the Lateglacial is sparse. Juniper was never abundant at Lago de Ajo, the record for Sanabria Marsh begins a thousand years later, and in the Laguna de las Sanguijuelas diagram *Juniperus* pollen was not counted. Nevertheless, it seems that at that site tree birches were already present by 13700 years BP. Thus, to the west, closer to the Atlantic seaboard, the expansion of trees, particularly birches, took place probably several hundred years earlier than in the Pyrenees and, of course, more than a thousand years before the expansion of birch in the British Isles; indeed, five hundred years before the earliest sign of climatic warming there postulated on the evidence of coleopteran faunas (Atkinson *et al.* 1987).

It is only from the two sites in northwestern Spain, Laguna de las Sanguijuelas and Lago de Ajo, that there is any evidence for two periods of expansion of birch and pine, separated in time by a minor re-expansion of open ground vegetation. Further investigations are needed to confirm that a minor climatic oscillation local to northwestern Spain took place and to date it more precisely. Note that evidence for climatic change is clearly time-transgressive along the seaboard of western Europe; this minor episode of warming and cooling is very unlikely, if confirmed, to correlate in time with the Bølling of northwestern Europe.

The concept of separate Bølling and Allerød interstadials has led other authors (e.g. Mardones & Jalut 1983) to try and identify, on very flimsy grounds, an interval of cooling in their pollen diagrams before the main Lateglacial expansion of birch and pine. There seems to be no good evidence for any such climatic oscillation from pollen diagrams in the Pyrenees. Indeed, it is doubtful whether those authors would have been tempted to identify such an event if they had not been influenced by the all too general use of the northwestern European evidence as a model.

Undoubtedly the most significant feature of the Lateglacial vegetational record for northwestern Spain is the relatively early appearance of oak, at least deciduous species, and the continuous record of their presence there into Holocene time. The Lateglacial occurrence of oak in the Pyrenees is rather tenuous; if established there, its occurrence must have been very sparse and local. It was certainly not present around Le Moura at that time.

As already noted, there is no evidence for any Younger Dryas cooling at either Sanabria Marsh or Lago de Ajo, nor, of course, from the Laguna de las Sanguijuelas pollen diagram in the light of new radiocarbon evidence. The mildness of conditions suggests that between 11 and 10 ka BP this part of Spain was still under the influence of weather patterns originating to the south of the polar front. Likewise there is very little evidence for climatic deterioration at high altitudes in the eastern Pyrenees, but to the west, closer to the Bay of Biscay, and with decreasing altitude some opening of the forest appears to have taken place at around 10860 years BP but again no real change in its composition. At Le Moura, where throughout the Lateglacial the vegetation had a rather bleak, open aspect, whether for edaphic or climatic

reasons, there do seem to have been very substantial vegetational changes in the period immediately before 10 ka BP. These, if reinvestigated and properly dated, could well show the influence of the very cold conditions in the Bay of Biscay during Younger Dryas times postulated by Duplessy *et al.* (1981).

In the course of their reinvestigation of Padul, Pons & Reille (1986) have reported a marked vegetational event, which they relate to the Younger Dryas oscillation. Their pollen diagram shows a substantial rise in the *Artemisia*, Chenopodiaceae and *Pinus* pollen curves, accompanying a fall in those of Gramineae and *Quercus*, particularly evergreen oak type. These vegetational changes appear to represent a short period of aridity. The dating of this event is somewhat ambiguous, because it has a basal date of 9830 ± 110 years BP (Gif 6006), but an older date of 10000 ± 110 years BP (Gif 6212) marks the expansion of oak above. It seems unlikely that these vegetational changes are directly linked with the migration of the polar front in the North Atlantic. They may be more closely related to Lateglacial changes in aridity in North Africa.

The amelioration of climate at approximately 10 ka BP is well-marked in sites throughout the region. In northwestern Spain, where oak was already established, a substantial expansion of oak forest took place. Oak spread rapidly into other areas of northern Spain and to the lowlands around the Bay of Biscay. In the Pyrenees the amelioration is marked by an increase in birch and pine before the invasion of the lower and middle slopes of the mountains by oak. Everywhere open vegetational communities contracted with the spread of forest. Similarly the appearance and rapid expansion of hazel characterised this period, though the dating of the rise of the *Corylus* curve is not yet good enough to yield information on the migration routes and possible refugia for this species.

Finally, comparisons between these Lateglacial vegetational records do throw some new light on the probable refugia of a few important plant taxa. The claims by archaeological palynologists that their evidence shows that such refuges existed in the Dordogne and other areas have already been dismissed. If we turn to more reliable pollen diagrams, little can be said about tree birches and pines. These pioneer trees invaded many different areas soon after the amelioration of climate. Refugia were probably widespread and soil conditions, particularly enrichment in nutrients by blue-green algae, as well as climatic factors (Van Geel *et al.* 1984), may have acted as a control on the successful establishment of tree growth. It is clear that *Pinus uncinata* played an important role as a pioneer tree well beyond its present altitudinal and geographical limits.

More important is the new evidence that deciduous oak species were present during Lateglacial times in northwestern Spain and were abundant there, whereas they were sparse or absent in the Pyrenees. Jalut (1973) claimed in early publications that very small quantities of pollen of temperate trees, not only *Quercus* but also *Corylus*, *Alnus*, *Abies* and *Fagus*, detected in Lateglacial pollen sequences, indicated the local presence of refuges for these trees in the northern part of the Pyrenees. This pollen, if not related to contamination from use of Hiller corers, has almost certainly been reworked from older Quaternary peat and soil deposits. The new evidence from Sanabria and from Lago de Ajo suggests strongly that the refuges for these oaks lay in maritime areas of western Spain and Portugal. At *ca.* 18 ka BP, these were the only areas of the western European seaboard lying between the 12 °C and 18 °C August sea-surface temperature isotherms (McIntyre *et al.* 1976). Such isotherms bracket the northern and southern limits of deciduous and mixed coniferous-deciduous forests along both the eastern and

western seaboard of the North Atlantic Ocean today (Van Campo 1984). As additional support, even in the early Holocene, there is evidence for increasingly later dates for the arrival and expansion of deciduous oaks eastwards from Cantabria along the Pyrenees.

The history of evergreen oak species is less clear, partly because of difficulties in recognizing and assessing the frequencies of their pollen. At Sanabria the record for evergreen oaks begins at *ca.* 9500 years BP and at Le Moura they were present at *ca.* 9960 years BP. In the south of Spain, at Padul, evergreen oaks were already abundant in the vegetation well before 12000 years BP. Because this pollen type is virtually absent from Lateglacial levels of pollen diagrams from northern and northwestern Spain, the refugia do not seem to have been nearby and were probably in the south or the maritime southwest of the Iberian peninsula, at least for species such as *Quercus rotundifolia* and *Q. coccifera*, although possibly not for *Q. ilex*.

There is good reason to suggest that *Calluna* and other ericaceous taxa, which today have an oceanic western European distribution, probably also survived the last glacial period in refuges in western Spain and Portugal.

12. LATEGLACIAL VEGETATIONAL CHANGES AND THE CLIMATIC INFLUENCE OF THE NORTH ATLANTIC OCEAN

A number of further conclusions may be drawn concerning the relation of Lateglacial climatic and oceanographic changes in the North Atlantic and vegetational changes in western Europe.

(i) Ruddiman & McIntyre (1981) have shown that movements of the polar front in the eastern North Atlantic during the period under consideration were time-transgressive. Clearly the vegetational response was also time-transgressive. In northwestern Spain climatic amelioration took place between 500 and 1000 years earlier than in northwestern Europe.

(ii) Vegetation patterns over most of western Europe were probably never in equilibrium with the rapidly changing climate, so that migrational factors increase still more the time differential between vegetational changes in different areas along the western seaboard of Europe.

(iii) The climate of the Atlantic Ocean not only influences the timing of vegetational changes but also affects some areas more intensely than others, either because they are ecotonal or because local factors magnify the climatic impact. Within southwest Europe the contrasts between Lateglacial vegetational development at Sanabria in the oceanic west, Le Moura, close to the Bay of Biscay and the Pyrenean sites are very considerable even if allowances are made for altitudinal and edaphic differences. Northwestern Spain remained under the influence of a moderating oceanic climate throughout the Lateglacial, so that even oak could survive when elsewhere conditions deteriorated during the Younger Dryas cooling. The shores of the Bay of Biscay, by contrast, seem to have been affected strongly by this cooling. Although Duplessy *et al.* (1981) thought that the interstadial conditions were, by contrast, very warm, there is no evidence from the Le Moura pollen record to confirm that idea. Lateglacial vegetational development in the Pyrenees, perhaps because of the altitude of the sites investigated, responded much less strongly to changing conditions in the North Atlantic than at sites farther west. During the Lateglacial interstadial there was little, if any, development of thermophilous trees in the area; the subsequent climatic deterioration of Younger Dryas times was likewise poorly marked.

(iv) Given the differences of timing and the intensity of vegetational change between sites, the traditional subdivision of the Lateglacial widely used in northern Europe (table 1), but already shown to have its areal limitations by Watts (1980), is clearly quite inapplicable farther south. Indeed, attempts to use this scheme in areas where neither the chronology nor the detailed climatic history apply have caused misinterpretations.

(v) The pattern of Lateglacial vegetational and climatic development along the western seaboard of Europe, although regionally diverse, clearly has a direct link to changes in atmospheric and oceanic circulation patterns in the eastern North Atlantic. It appears to be a complex, time-transgressive local event, and attempts to make long-distance correlations between Lateglacial sequences in distant extra-European areas with the classical tripartite sequence of the northwestern European Lateglacial should be regarded with scepticism.

We thank Professor W. A. Watts and Dr R. H. W. Bradshaw for helpful discussion and criticism; Professor R. G. West, F.R.S., for advice and support; and Mrs Sylvia Peglar for help in drafting the diagrams. Investigations at Sanabria Marsh were supported by the E.E.C. Climatology Programme.

REFERENCES

- Alimen, H., Florschütz, F. & Menendez Amor, J. 1964 Étude géologique et palynologique sur le Quaternaire des environs de Lourdes. *Actes 4e Congrès int. Études pyrénéennes*, pp. 7–26.
- Atkinson, T. C., Briffa, K. R. & Coope, G. R. 1987 Seasonal temperatures in Britain during the past 22,000 years, reconstructed using beetle remains. *Nature, Lond.* **325**, 587–592.
- de Beaulieu, J.-L., Pons, A. & Reille, M. 1985 Recherches pollenanalytiques sur l'histoire tardiglaciaire et holocène de la végétation des Monts d'Aubrac (Massif Central, France). *Rev. Palaeobot. Palynol.* **44**, 37–80.
- de Beaulieu, J.-L. & Reille, M. 1984 A long Upper Pleistocene pollen record from Les Echets, near Lyon, France. *Boreas* **13**, 111–132.
- Bordes, F. H. 1954 *Les limons Quaternaires du bassin de la Seine*. Paris: Archive de l'Institut de Paléontologie Humaine, Memoire 26.
- Bordes, F. 1959 Laugerie Haute. *Gallia Préhist.* **2**, 156–167.
- Boyer-Klein, A. 1980 Nouveaux résultats palynologiques de sites solutréens et magdaléniens cantabriques. *Bull. Soc. préhist. Fr.* **17**, 103–107.
- Bui-Thi-Mai & Girard, M. 1984 L'analyse pollinique de la grotte de Saint-Jean-de-Verges (Ariège). *Bull. Soc. préhist. Ariège* **39**, 27–41.
- Chaline, J. & Jerz, H. 1983 Proposition de création d'un étage würmien par la sous-commission de stratigraphie du Quaternaire européen de l'INQUA. *Bull. Ass. fr. Étude Quat.* (N.S.) **16**, 149–152.
- Couteaux, M. 1977 A propos de l'interprétation des analyses polliniques de sédiments minéraux, principalement archéologiques. In *Approche écologique de l'homme fossile* (ed. H. Laville & J. Renault-Miskovsky), pp. 259–276. *Bull. Ass. Fr. Étude Quatern.*, **47** (suppl.).
- Deckker, P. de, Geurts, M. A. & Julia, R. 1979 Seasonal rhythmites from a lower Pleistocene lake in northeastern Spain. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **26**, 43–71.
- Delpach, F. 1983 *Les faunes du Paléolithique supérieure dans de Sud-Ouest de la France*. Cahiers du Quaternaire, no. 6. Paris: C.N.R.S.
- De Vries, H., Florschütz, F. & Menendez Amor, J. 1960 Un diagramme pollinique simplifié d'une couche de 'gyttja', située a Poueyferré près de Lourdes (Pyrénées françaises centrales), daté par la méthode du radio-carbone. *Proc. ned. Akad. wet.* **B 63**, 498–500.
- Dimbleby, G. W. 1961 Soil pollen analysis. *J. Soil Sci.* **12**, 1–11.
- Duplessy, J. C., Delibrias, G., Turon, J. L. & Duprat, J. C. 1981 Deglacial warming of the northeastern Atlantic Ocean: correlation with the palaeoclimatic evolution of the European continent. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **35**, 121–144.
- Elhai, H. 1966 Deux gisements du quaternaire moyen: Bruges (SW de la France), Bañolas (Catalogne). *Bull. Ass. fr. Étude Quat.* **6**, 69–78.
- Farrand, W. R. 1985 Rockshelter and cave sediments. In *Archaeological sediments in context* (ed. J. K. Stein & W. R. Farrand), pp. 21–39. (*Peopling of the Americas: Edited volume series 1.*) Orono: University of Maine.
- Florschütz, F. & Menendez Amor, J. 1962 Beitrag zur Kenntnis der quartären Vegetationsgeschichte Nordspaniens. In *Festschrift Franz Firbas. Veröff. geobot. Inst., Zürich* **37**, 68–73.

- Florschütz, F., Menendez Amor, J. & Wijnstra, T. A. 1971 Palynology of a thick Quaternary succession in southern Spain. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **10**, 233–264.
- Gaussen, H. 1948 *Carte de la végétation de la France*. Perpignan: C.N.R.S.
- Girard, M. & Renault-Miskovsky, J. 1969 Nouvelles techniques de préparation en palynologie appliquées à trois sédiments du Quaternaire final de l'Abri Cornille (Istres-Bouches-du-Rhône). *Bull. Ass. fr. Étude Quat.* **21**, 275–284.
- Guillien, Y. & Lautridou, J. P. 1974 Conclusions des recherches de géolifraction expérimentale sur les calcaires des Charentes. *Bull. Cent. Géomorphol.* **19**, 25–34.
- Hannon, G. E. 1984 Late Quaternary vegetation of Sanabria Marsh, northwest Spain. M.Sc. thesis, Trinity College, University of Dublin.
- Havinga, A. J. 1968 Some remarks on the interpretation of a pollen diagram of a podsol profile. *Acta bot. neerl.* **17**, 1–4.
- Havinga, A. J. 1971 An experimental investigation into the decay of pollen and spores in various soil types. In *Sporopollenin* (ed. J. Brooks, P. R. Grant, M. D. Muir, P. van Gijzel & G. Shaw), pp. 446–479. London: Academic Press.
- Heusser, C. J. & Florer, L. E. 1973 Correlation of marine and continental Quaternary pollen records from the Northeast Pacific and Western Washington. *Quat. Res.* **3**, 661–670.
- Höllermann, P. 1968 Die rezenten Gletscher der Pyrenäen. *Geographica helv.* **23**, 157–168.
- Huntley, B. & Birks, H. J. B. 1983 *An atlas of past and present pollen maps for Europe: 0–13,000 years ago*. Cambridge University Press.
- Iversen, J. 1954 The lateglacial flora of Denmark and its relation to climate and soil. *Danm. geol. Unders. ser. 2*, **80**, 87–119.
- Jalut, G. 1973 Analyse pollinique de la Tourbière de la Moulinasse: nord oriental des Pyrénées. *Pollen Spores* **15**, 472–509.
- Jalut, G., Delibrias, G., Dagnac, J., Mardones, M. & Bouhours, M. 1982 A palaeoecological approach to the last 21,000 years in the Pyrenees: the peat bog of Freychinède (alt. 1350 m, Ariège, South France). *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **40**, 321–359.
- Janssen, C. R. & Woldringh, R. E. 1981 A preliminary radiocarbon dated pollen sequence from the Serra da Estrela, Portugal. *Finisterra* **16**, 299–307.
- Kolstrup, E. 1980 Climate and stratigraphy in northwestern Europe between 30,000 B.P. and 13,000 B.P. with special reference to the Netherlands. *Meded. Rijks geol. Dienst* **32**(15), 181–253.
- Laville, H., Delpech, F. & Rigaud, J.-P. 1985 Sur la zonation du Pleistocène récent: les précisions du domaine Aquitain. In *Palynologie archéologique* (ed. J. Renault-Miskovsky, Bui-Thi-Mai & M. Girard), pp. 245–249. (Centre de Recherches Archéologiques; notes et monographies techniques no. 17.) Paris: C.N.R.S.
- Laville, H., Rigaud, J.-P. & Sackett, J. 1980 *Rock shelters of the Perigord: geological stratigraphy and archaeological succession*. New York: Academic Press.
- Leroi-Gourhan, A. 1959 Résultats de l'analyse pollinique de la grotte d'Isturitz. *Bull. Soc. préhist. Fr.* **56**, 619–624.
- Leroi-Gourhan, A. 1965 Les analyses polliniques sur les sédiments des grottes. *Bull. Ass. fr. Étude Quat.* **7**, 145–152.
- Leroi-Gourhan, A. 1967 Analyse pollinique des niveaux paléolithiques de l'abri Fritsch. *Rev. Palaeobot. Palynol.* **4**, 81–86.
- Leroi-Gourhan, A. 1968 L'Abri du Facteur à Tursac (Dordogne): III Analyse pollinique. *Gallia Préhist.* **11**, 123–132.
- Leroi-Gourhan, A. 1971 Analisis polinico de Cueva morin. In *Cueva Morin: Excavaciones 1966–1968* (ed. J. G. Echegaray & L. G. Freeman), pp. 359–365. Santander: Patronato de las Cuevas Prehistoricas.
- Leroi-Gourhan, A. 1980a Interstades Würmiens: Laugerie et Lascaux. *Bull. Ass. fr. Étude Quat.* (n.s.) **3**, 95–100.
- Leroi-Gourhan, A. 1980b Les interstades du Würm supérieur. In *Problemes de stratigraphie Quaternaire en France et dans les pays limitrophes* (ed. J. Chaline), pp. 192–194. (*Suppl. Bull. Ass. fr. Étude Quat.* (n.s.) **1**.)
- Leroi-Gourhan, A. & Leroi-Gourhan, A. 1964 Chronologie des grottes d'Arcy-sur-Curé. *Gallia Préhist.* **7**, 1–64.
- Leroi-Gourhan, A. & Girard, M. 1979 Analyses polliniques de la grotte de Lascaux. In *Lascaux inconnu* (*Gallia Préhist. Suppl.* **12**). pp. 75–80.
- Leroi-Gourhan, A. & Renault-Miskovsky, J. 1977 La palynologie appliquée à l'archéologie: méthodes, limites, résultats. In *Approche écologique de l'homme fossile* (ed. H. Laville & J. Renault-Miskovsky), pp. 35–49. (*Bull. Ass. fr. Étude Quat.*, suppl. no. 47.)
- Lowe, J. J., Gray, J. M. & Robinson, J. E. 1980 *Studies in the Lateglacial of North-west Europe*. Oxford: Pergamon Press.
- McIntyre, A., Kipp, N., Be, A. W. H., Crowley, T., Gardner, J. V., Prell, W. L. & Ruddiman, W. F. 1976 Glacial North Atlantic 18,000 years ago: a CLIMAP reconstruction. In *Investigations of late Quaternary paleoceanography and paleoclimatology* (ed. R. M. Cline & J. D. Hays), pp. 43–76. *Mem. geol. Soc. Am.* **145**.

- McKeever, M. 1984 *Comparative palynological studies of two lake sites in western Ireland and northwestern Spain*. M.Sc. thesis, Trinity College, University of Dublin.
- Mangerud, J., Andersen, S. T., Berglund, B. E. & Donner, J. J. 1974 Quaternary stratigraphy of Norden, a proposal for terminology and classification. *Boreas* **3**, 109–127.
- Mardones, M. & Jalut, G. 1983 La Tourbière de Biscaye (Alt. 409 m, Hautes Pyrénées) : approche paléocologique des 45,000 dernières années. *Pollen Spores* **25**, 163–212.
- Mary, G., Médus, J. & Delibrias, G. 1975 Le quaternaire de la côte asturienne (Espagne). *Bull. Ass. fr. Étude Quat.* **42**, 13–24.
- Menendez Amor, J. 1968 Estudio esporo-polinico de una turbera en el Valle de la Nava (prov. de Burgos). *Boln R. Soc. esp. Hist. nat. (Geol.)* **66**, 35–39.
- Menendez Amor, J. & Florschütz, F. 1959 Algunas noticias sobre el ambiente en que vivió el hombre durante el gran interglaciar en dos zonas de ambas Castillas. *Estudios geol. Inst. invest. Geol. Lucas Mallada* **15**, 277–282.
- Menendez Amor, J. & Florschütz, F. 1961 Contribucion al concimiento de la historia de la vegetacion en Espana durante el Cuaternario. *Estudios geol. Inst. invest. Geol. Lucas Mallada* **17**, 83–99.
- Menendez Amor, J. & Florschütz, F. 1964 Results of the preliminary palynological investigation of samples from a 50 m boring in southern Spain. *Boln R. Soc. esp. Hist. nat. (Geol.)* **62**, 251–255.
- Mercer, J. H. 1969 The Allerød oscillation: a European climatic anomaly? *Arct. alp. Res.* **1**, 227–234.
- Nonn, H. 1966 *Les régions cotières de la Galice (Espagne)*. Etude géomorphologique T. III. Faculté des Lettres de l'Université de Strasbourg, Fondation Baulig.
- Oldfield, F. 1964 Late-Quaternary deposits at Le Moura, Biarritz, south-west France. *New Phytol.* **63**, 374–409.
- Oldfield, F. 1968 The Quaternary vegetational history of the French Pays Basque: I Stratigraphy and pollen analysis. *New Phytol.* **67**, 677–731.
- Paquereau, M. M. 1974–75 Le Wurm ancien en Périgord. Etude palynologique. Première partie: Les diagrammes palynologiques – la zonation climatique. *Quaternaria* **18**, 67–116. Deuxième partie: L'évolution des climats et des flores. *Quaternaria* **18**, 117–160.
- Paquereau, M. M. 1978 Flores et climats du Wurm III dans le Sud-Ouest de la France. *Quaternaria* **20**, 123–164.
- Pons, A. & Reille, M. 1986 Nouvelles recherches pollenanalytiques à Padul (Granada) : La fin du dernier glaciaire et l'Holocène. In *Quaternary Climate in Western Mediterranean (Proceedings of the Symposium on Climatic Fluctuations during the Quaternary in the Western Mediterranean Regions, Madrid, June 16–21, 1986)* (ed. F. Lopez-Vera), pp. 405–420. Universidad Autonoma de Madrid.
- Pujol, C. & Turon, J.-L. 1974 Paléoclimatologie et stratigraphie du Quaternaire terminal du Golfe de Gascogne déduites de l'analyse des Foraminifères planctoniques et des ensembles sporopolleniques des sédiments marins. *Boreas* **3**, 99–104.
- Renault-Miskovsky, J. 1986 *L'Environnement au temps de la préhistoire: méthodes et modèles*. Paris: Masson.
- Renault-Miskovsky, J., Bui-Thi-Mai, M. & Girard, M. 1984 A propos de l'indignat ou de l'introduction de *Juglans* et *Platanus* dans l'ouest de l'Europe au Quaternaire. *Revue Paléobiol.*, volume spécial, 155–178.
- Renault-Miskovsky, J. & Leroi-Gourhan, A. 1981 Palynologie et archéologie: nouveaux résultats du Paléolithique supérieur au Mésolithique. *Bull. Ass. fr. Étude Quat. (n.s.)* **7–8**, 121–128.
- Ruddiman, W. F. & McIntyre, A. 1973 Time-transgressive deglacial retreat of Polar water from the North Atlantic. *Quat. Res.* **3**, 117–130.
- Ruddiman, W. F. & McIntyre, A. 1981 The North Atlantic Ocean during the last deglaciation. *Palaeogeogr. Palaeoclimatol. Palaeoecol.* **35**, 145–214.
- Ruddiman, W. M., Sancetta, C. D. & McIntyre, A. 1977 Glacial/Interglacial response rate of subpolar North Atlantic waters to climatic change: the record in oceanic sediments. *Phil. Trans. R. Soc. Lond. B* **280**, 119–142.
- Schmidt-Thomé, P. 1983 Besonders niedrig gelegene Zeugen einer wurmzeitlichen Vereisung in Nordwestspanien und Nord-Portugal. In *Late and post-glacial oscillations of glaciers: glacial and periglacial forms* (ed. A. A. Balkema), pp. 213–230. Rotterdam: Balkema.
- Straus, L. G., Altuna, J., Clark, G. A., Gonzales Morales, M., Laville, H., Leroi-Gorhan, A., Menendez de la Hoz, M. & Ortea, J. A. 1981 Paleocology at La Riera (Asturias, Spain). *Curr. Anthropol.* **22**, 655–682.
- Straus, L. G. & Clark, G. A. 1986 *La Riera cave: stone age hunter-gatherer adaptations in northern Spain*. Arizona State University anthropological research paper no. 36.
- Straus, L. G., Clark, G. A., Altuna, J. & Ortea, J. A. 1980 Ice-Age subsistence in Northern Spain. *Scient. Am.* **242**, 42–152.
- Suc, J.-P. 1980 *Contribution à la connaissance du Pliocène et du Pleistocène inférieur des régions méditerranéennes d'Europe occidentale par l'analyse palynologique des dépôts du Languedoc-Roussillon (Sud de la France) et de la Catalogne (Nord-Est de l'Espagne)*. Thèse, Université de Montpellier.
- Turner, C. 1985 Problems and pitfalls in the application of palynology to Pleistocene archaeological sites in Western Europe. In *Palynologie archéologique* (ed. J. Renault-Miskovsky, Bui-Thi-Mai & M. Girard), pp. 347–373. (Centre de Recherches Archéologiques; notes et monographies techniques, no. 17.) Paris: C.N.R.S.

VEGETATIONAL HISTORY OF SOUTHWEST EUROPE 485

- Turner, C. & West, R. G. 1968 The subdivision and zonation of interglacial periods. *Eiszeitalter Gegenw.* **19**, 93–101.
- Turon, J.-L. 1974 Étude palynologique d'une carotte prélevée dans le Golfe de Gascogne. Intérêt paléoclimatique et stratigraphique. *Pollen Spores* **16**, 475–487.
- Turon, J.-L. 1980 La sédimentation pollinique actuelle le long de la ride Reykjanes et dans la fracture de Gibbs. Intérêt dans la détermination des apports sédimentaires. *C. r. Acad. Sci. Paris D* **291**, 453–456.
- Van Campo, M. 1984 Relations entre la végétation de l'Europe et les températures de surface océaniques après le dernier maximum glaciaire. *Pollen Spores* **26**, 497–518.
- Van Campo, M. & Elhai, H. 1956 Étude comparative des pollens de quelques chênes: application a une toubière normande. *Bull. Soc. bot. Fr.* **103**, 254–260.
- Van Campo, M. & Jalut, G. 1969 Analyse pollinique de sédiments des Pyrénées orientales: Lac de Balcère (1,764 m). *Pollen Spores* **11**, 117–126.
- Van den Brink, L. M. & Janssen, C. R. 1985 The effect of human activities during cultural phases on the development of montane vegetation in the Sierra da Estrela, Portugal. *Rev. Palaeobot. Palynol.* **44**, 193–215.
- Van Geel, B., De Lange, L. & Wieggers, J. 1984 Reconstruction and interpretation of the local vegetational succession of a Lateglacial deposit from Usselo (The Netherlands), based on the analysis of micro- and macrofossils. *Acta bot. neerl.* **33**, 535–546.
- Watts, W. A. 1980 Regional variation in the response of vegetation to Lateglacial climatic events in Europe. In *Studies in the Lateglacial of northwest Europe* (ed. J. J. Lowe, J. M. Gray & J. E. Robinson), pp. 1–21. Oxford: Pergamon Press.
- Watts, W. A. 1986 Stages of climatic change from Full Glacial to Holocene in northwest Spain, southern France and Italy: a comparison of the Atlantic coast and the Mediterranean basin. In *Current Issues in Climate Research (Proceedings EEC Climatology Programme, Sophia Antipolis, France, October 1984)* (ed. A. Ghazi & R. Fantechi), pp. 101–112. Dordrecht: D. Reidel.
- Woillard, G. 1975 Recherches palynologiques sur le Pleistocène dans l'est de la Belgique et dans les Vosges Lorraines. *Acta geogr. lovaniensia* **14**, 114 pp.
- Woillard, G. 1978 Grande Pile peat bog: a continuous pollen record for the last 140,000 years. *Quat. Res.* **9**, 1–21.