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# Vegetation history and human activity during the last 6000 years on the central Catalan coast (northeastern Iberian Peninsula)

**S. Riera-Mora and A. Esteban-Amat**

Servei C-T de Gestió i Evolució del Paisatge, Divisió I, University of Barcelona, C/Baldiri Reixach, s/n., E-08028 Barcelona, Spain

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**Abstract.** In this paper, we present the results of four pollen diagrams obtained from the northeastern coast of the Iberian Peninsula. These data, together with a set of 11 radiocarbon dates, allow us to make some suggestions about human activity in this area mainly during the last 6000 years. We have established four main stages of this activity. Phase I (7000-3000 B.P.) shows some sporadic human clearance without qualitative and/or quantitative changes inside the natural woodland, except for slight oscillations in AP values. These clearances are synchronous with Neolithic and Bronze Age settlements. Phase II (3000-1500/1300 B.P.) demonstrates a different human action on the landscape along the Catalan coast. Sampling sites located in rich agricultural plains and close to urban centres show continuous woodland clearance during the Iberian period and especially during Roman times. In contrast, at boring sites far from these towns, the irregular and sporadic woodland disturbances continue, although these become more common. Phase III (1500/1300-850 B.P.) shows further woodland clearance fires along the coast. Pollen, archaeological and historical evidence allow us to relate this to the introduction of grazing in the coastal area, connected with seasonal transhumance between the littoral and mountain regions. Phase IV (850-300/150 B.P.) is characterised by the final clearance of woodland and the development of olive farming. During this phase the agrarian Mediterranean landscape was definitively formed.

**Key words**: Human disturbances – Fires – Seasonal transhumance – Olive – northeast Iberian Peninsula

## Introduction

In this paper, we present pollen results from four sampling sites located along the central area of the Catalan coast (Fig. 1), which allow us to demonstrate landscape evolution and associated human influence over the last 6000 years.

*Correspondence to*: S. Riera-Mora

Several boring sites are located in small coastal plains, closed towards the southeast by the Mediterranean Sea, and towards the northeast by the range of hills called the Catalanid System, not exceeding 500 m a.s.l., which runs parallel to the coast (Fig. 1) (Llopis-Llado 1947, Riba et al. 1976).

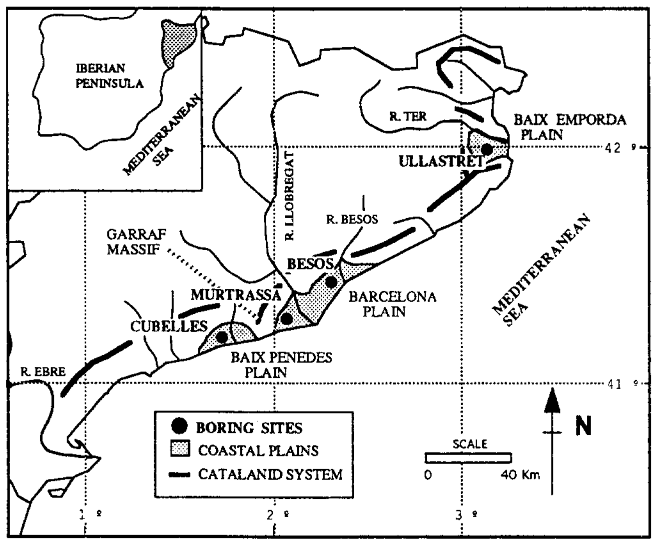


**Fig. 1.** Map of the northeastern Iberian Peninsula with the main topographical features. The Garraf Massif has been included because of its relevance as a present-day biogeographical boundary between the Boreo- and Austro-Mediterranean regions. Pollen records also prove that this boundary has existed at least for the last 6000 years

### *Natural Environment*

The study area has a Mediterranean climate, with a summer dry period during June, July and August. The mean annual precipitation ranges from 476 mm in Tarragona to 600 mm in Barcelona (Fig. 2). Rainfall is irregular, with a main maximum during autumn and a secondary one during spring. Mean annual temperature ranges from 16-17 C (Martin-Vide 1987, UNESCO-FAO 1963).

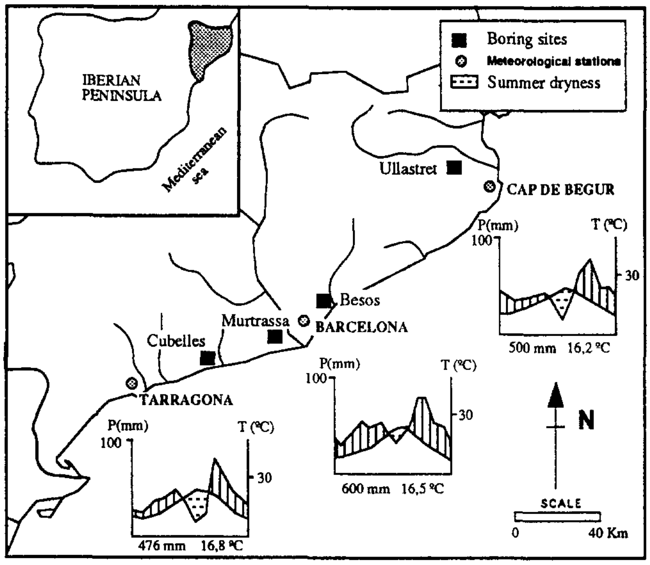


**Fig. 2**. The main climatic features of the study area. Data have been obtained from metereological stations nearest to different boring sites (Riba et al. 1976). A Mediterranean climate regime can be observed from the graphs of precipitation (P) and temperature (T) from January to December and the averages for the year underneath. They indicate a summer dry period of over three months

The vegetation has been described by Bolos-Capdevila (1956, 1957, 1985). The coastal area can be subdivided into two main regions (Fig. 3). The Boreo-Mediterranean province extends northwards from the Garraf Massif, with the main plant communities *Quercetum ilicis galloprovinciale* along the coast, and *Quercetum mediterraneo-montanum* in the lower Mediterranean mountain zone between 400 and 700 m a.s.l. The main tree in these two communities is the evergreen oak (*Quercus ilex*).

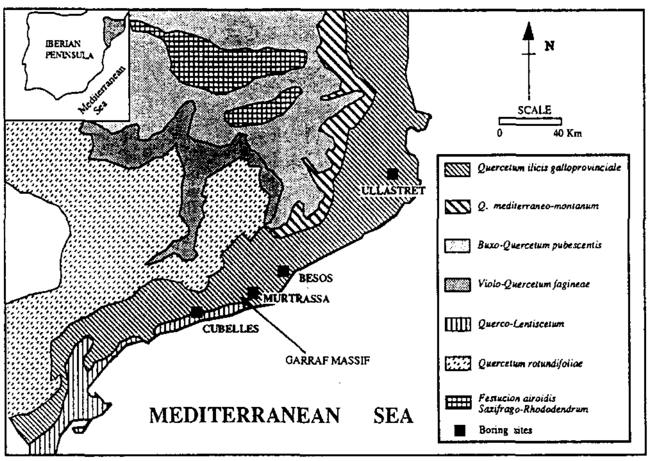


**Fig. 3**. Main vegetational communities from the area studied, according to Bolos-Capdevila (1956, 1957, 1985)

The Austro-Mediterranean province extends southward from the Garraf Massif. The most widespread community is *Querco-Lentiscetum*, characterised by the dominance of meridional (thermomediterranean) species, such as *Olea europea* var. *sylvestris, Pistacia lentiscus, Chamaerops humilis, Quercus coccifera, Rhamnus lycioides*, etc.

In somewhat wetter inland areas, close to the northern coast, there is a submediterranean vegetation, dominated by xeromesophilous deciduous woodland. In northern areas, *Buxo-Quercetum pubescentis* is the prevailing community, while in the less rainy parts, the *Violo-Quercetum fagineae* community is well developed.

Drier southern inland areas are characterised by a Boreo-mediterranean sclerophyllous (semi-evergreen) woodland, with *Quercetum rotundifoliae* as the main plant community.

Along the Pyrenees, there is an alpine and subalpine belt, with *Festucion airoides* and *Saxifrago-Rhododendrum*, respectively.

## Prehistoric and Historic Events

Some early Neolithic sites are known along the coast (Table 1). Small settlements have been noted in the north (Barcelona and Baix Empordà plains) on low hills bordering the coastal plains. A large settlement from this period is known in the Plain of Barcelona (St. Pau del Camp) close to a coastal lagoon (Granados et al. 1993).

**Table 1**. Summary table with the main prehistoric and historic periods and their main features along the central part of the Catalan coast

| B.P. | | |
|---|---|---|
| 1000 | CHRISTIAN | End of christian conquest. |
| | ARABIAN | Arabian invasion. |
| | GOTHIC STATE | Establishment of Gothic State. |
| 2000 | ROMAN TIMES | Roman colonisation. Foundation of Tarraco and Emporion, and later, Baetulo and Barcino. |
| | IRON AGE IBERIAN CULTURE | Villages close to the coast (Ullastret). Greek colonies (Emporion) |
| 3000 | LATE BRONZE AGE | Small settlements on high ground near the coast. |
| | EARLY & MIDDLE BRONZE AGE | Cave dwellings and settlements in the open. Megalithic burials in the northern part of the area. |
| 4000 | LATE NEOLITHIC | Cave dwellings. Megalithic burials in the north. |
| 5000 | MIDDLE NEOLITHIC | "Sepulcres de Fossa" culture. Cementiries in the plains. |
| 6000 | EARLY NEOLITHIC | Cave dwellings and settlements in the open, near the coast. |
| 7000 | | |

In this plain and in the Baix Penedès plain, caves were also occupied, for example Can Sadurní cave (Barcelona plain) from which the archaeological strata from this period have been radiocarbon dated to 5800±160 and 5700±110 B.P. (Edo et al. 1986).

The middle Neolithic period in the whole coastal area is characterised by cemeteries in the plains, consisting of several typical graves. This culture has been named *sepulcres de fossa* (Muñoz 1965). During this cultural phase, a large complex for quarrying turquoise came into being in the Plain of Barcelona (Can Tintorer) (Villalba et al. 1986).

There was more scattered cave occupation during the late Neolithic and the early and middle Bronze Age. During this phase, megalithic burials were particularly numerous in the northern area (Empordà plain) (Pons 1982), although unknown in the southern coastal area.

Although some small settlements are known from the early and middle Bronze Age, this pattern became denser in the late Bronze Age with settlements on the hills close to the coast, a typical feature of the settlement pattern during the Iberian Culture period (Iron Age).

During the pre-Roman Iron Age, communities of the Iberian Culture developed between ca. 2600 and 2200 B.P. in the coastal study area (Tarradell 1963) (Table 1). The Greeks and the Phoenicians exerted a considerable influence on this culture. Emporion, a Greek colony located in the northern part of the study area, was founded in the 6th century B.C. (Ruiz de Arbulo 1991) (Fig. 4). The peak of the Iberian Culture is characterised by stable settlements in villages on hills near the coastal plains, one of the best known of which is Ullastret, close to the boring site with the same name (Martin 1986) (Fig. 4).

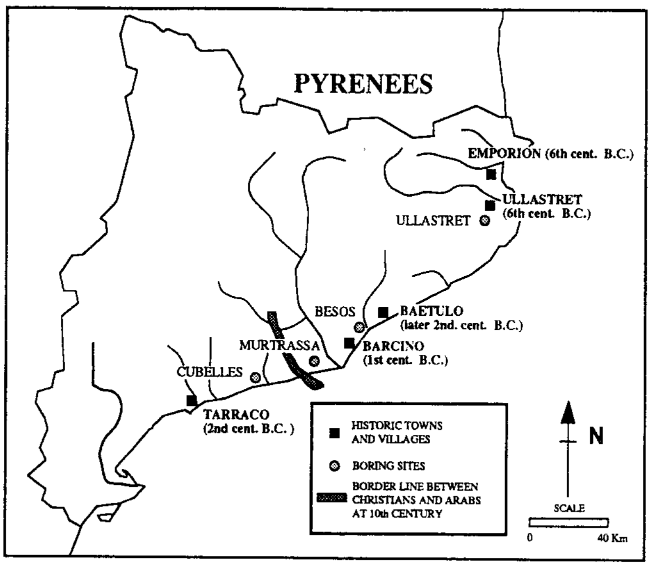


**Fig. 4.** Location of main towns and villages during Iberian Culture and Roman times. Foundation dates are given in brackets

Roman colonisation started at the beginning of the 2nd century B.C., with two important towns, Emporion and Tarraco (Fig. 4) (Ruiz de Arbulo 1991). After approximately the middle part of the 2nd century, the Roman colonisation of rural areas started by means of the introduction of the *Villae* farming system and the foundation of numerous small agrarian towns, such as *Baetulo* (Prevosti et al. 1986). At the same time, most of the Iberian settlements were gradually abandoned.

During Imperial Roman times, a territorial reorganisation was carried out in the whole of the Iberian Peninsula by Caesar Augustus. In our area, these changes brought a new network of *Villae* with a specialised economy based on viticulture. At the same time some new administrative towns were also founded, such as *Barcino* (Barcelona) (Fig. 4).

After the 2nd/3th century A.D., the political, administrative and economic structures that the Romans had established began to dissolve. This process is documented archaeologically by the abandonment of numerous *Villae*.

During the 5th century A.D., the Goths established themselves in the Iberian Peninsula until the Arabian invasion in 711 A.D. This conquest caused the rise of Christian Counties in the Pyrenean mountains, protected by the Frankish state. The town of *Barcino* was conquered back from the Arabs in 801 A.D. The border line between Arabs and Christians was established at the Penedès Plain during the 10th century (Fig. 4). Christian conquest of the northeast Iberian Peninsula was finally completed in the 12th century.

## Sampling sites

The northernmost site analysed is the Ullastret boring (42°00' N lat., 3°05' E long.), Fig. 1. Boring was carried out in the Baix Empordà littoral plain, in an ancient lake drained during the 18th and 19th centuries, at 15 m a.s.l. The core was 10 m deep (Esteban-Amat 1988). The lithology of the profile is described in Fig. 5.

Boring has been carried out in the deltaic plain of the river Besós, on the Barcelona littoral plain (41°24' N lat., 2°15' E long.) at 7 m a.s.l. (Riera-Mora 1993) (Fig. 1). This river rises in the pre-littoral plains and mountains. The boring was 35 m deep, and the lithology of its profile is given in Fig. 6.

The Murtrassa site was in an ancient marsh, located in the river Llobregat delta, on the Barcelona littoral plain at 4 m a.s.l. (41°17' N lat., 2°00' E long.) (Fig. 1). This marsh was drained between the 16th and 17th centuries. The boring was 4 m in depth. The main sedimentological units are also described in Fig. 7.

The boring at the southernmost boring site, Cubelles, was carried out in an ancient marsh drained during the 18th and 19th centuries and called „Mar Morta" (Dead Sea). This littoral lagoon is located in the small littoral plain of „Baix Penedès" at 1 m a.s.l. (41°12' N lat, 1°40' E long). It was 5 m in depth and sedimentological features are shown in Fig. 8 (Esteban-Amat and Riera-Mora in press).

## Methods

The four cores studied were retrieved with a mechanical rotary borer and a continuous core was taken.

Samples for pollen analyses were extracted at regularly-spaced intervals. Pollen analyses were carried out using the standard method in palynology (Fægri and Iversen

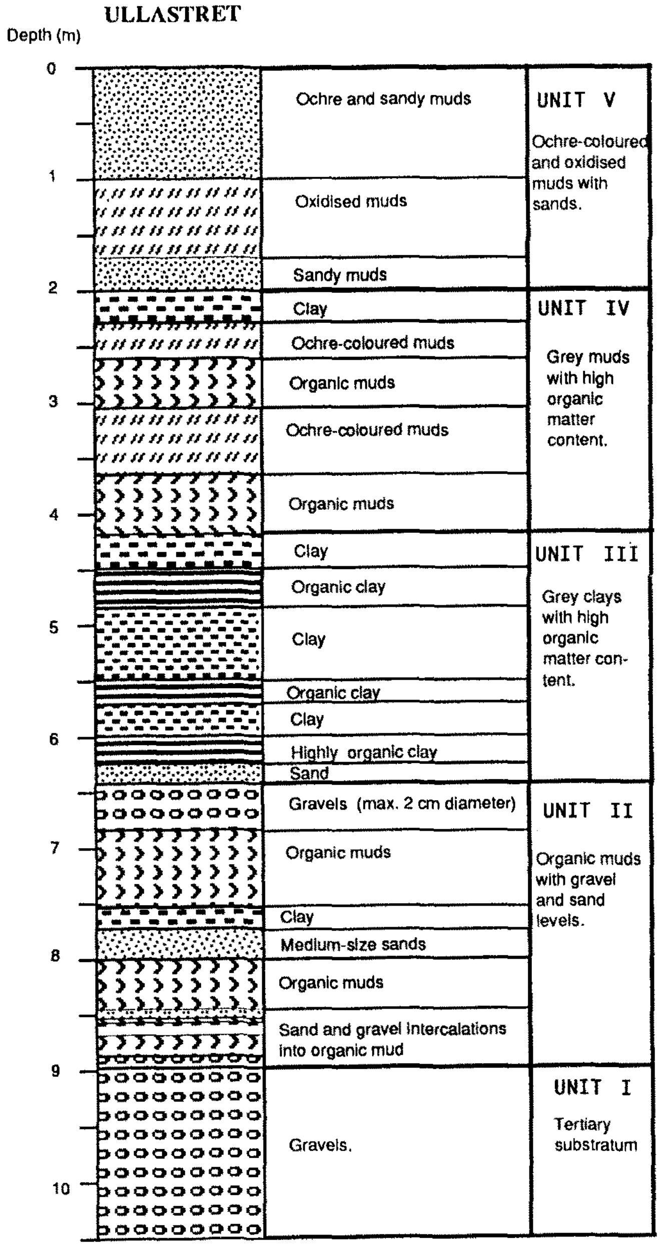


**Fig. 5.** Lithology of the Ullastret core (ULL)

1975). In some detritic and poor samples it was necessary to use a concentration method (Guillet and Planchais 1962). The volumetric method was also used with the aim of obtaining concentration pollen values (Cour 1974). A set of 11 radiocarbon dates is available for all the cores (Table 2).

Six pollen diagrams are presented (Figs 9-14). Percentage diagrams are presented for the four sites (Figs. 9,10,12,14), calculated on the basis of the total palynomorphs counted per sample. A notable feature of these percentage spectra is the great influence of the local and extra-local pollen deposition (sensu Janssen 1981), that corresponds to the vegetation of the shore area. This type of vegetation consists of certain herbs (i.e. Chenopodiaceae in saline soils; Cyperaceae, Poaceae and *Sparganium* sp. in and close to the littoral lagoons), and shrubs (i.e. Cupressaceae and *Pistacia* sp. on sandy soils) and also certain trees (i.e. *Pinus* sp. also on sandy soils). Examples of this great influence of littoral vegetation on pollen spectra are the high values of *Sparganium* (70%) or Cyperaceae (60%) in some levels of the Murtrassa pollen diagram, or the values of *Pinus* (85%) in Cubelles.

In order to evaluate accurately regional changes of vegetation and the human impact in these coastal areas, it has been necessary to calculate concentration pollen values.

In the Besós and Ullastret sites, due to heterogeneous lithology, pollen concentration values depend almost entirely on the type of sediment, and so these data do not furnish us valid information for this study. On the other hand, at the Cubelles and Murtrassa sites, pollen concentration values bring us significant information on the percentage oscillations of certain taxa (Figs. 11,13). There are no sudden changes in the lithology, although there is some evidence of variation.

**Table 2.** Summary of the radiocarbon dates from the four diagrams studied

| DRILLING | DEPTH (cm) | AGE (B.P.) | REFERENCE Nº |
|---|---|---|---|
| ULLASTRET | 540-550<br>810-820 | 1510±80<br>4300±330 | UBAR-58<br>GIF-6921 |
| BESOS | 1275-1290<br>1600-1625<br>2140-2145<br>2680-2690 | 1310±110<br>1300±40<br>3250±50<br>6870±100 | UBAR-232<br>UBAR-211<br>UBAR-231<br>UBAR-212 |
| MURTRASSA | 190-200 | 1248±24 | DEM/262-215 |
| CUBELLES | 130-140<br>204-213<br>320-322<br>424-438 | 950±50<br>2390±130<br>3680±80<br>5040±70 | Gd-5918<br>Gd-6597<br>Gd-7041<br>Gd-5919 |

Concentration values from the Cubelles core have been obtained as pollen grains per $cm^{-3}$ of sediment, while in Murtrassa these values were obtained as pollen grains per $gr^{-1}$ of sediment.

The criteria used for the zonation of the diagrams are the changes in pollen percentages, including those of local and extra-local origin. Zonation of the four diagrams have been based on percentage values, in order to obtain homogeneous information. Therefore, in those sites where both percentage and concentration diagrams are presented, it is important to note that certain changes in concentration values occur earlier than in percentages, such as between zones CUB-C and CUB-D (Figs. 13,14).

Every diagram has been divided in local zones, and correlation between the different local zones has been established in four phases, on the basis of the criteria of chronology and human activity.

Charcoal debris has also been quantified, in two different categories. Firstly, debris smaller than 0.15 mm in diameter has been calculated by the point count estimate method (Clark 1982). In the second category of debris bigger than 0.5 mm diameter, every individual particle was counted. These two different classes were established in order to differentiate between local and regional fires (Patterson et al. 1987).

## Results

### *Ullastret Pollen Diagram*

*Subzone ULL-A1*. Defined by a pollen assemblage dominated by deciduous *Quercus*, with *Pinus* and *Corylus*. Some sclerophyllous taxa, such as *Quercus ilex*-type are also present (Fig. 9).

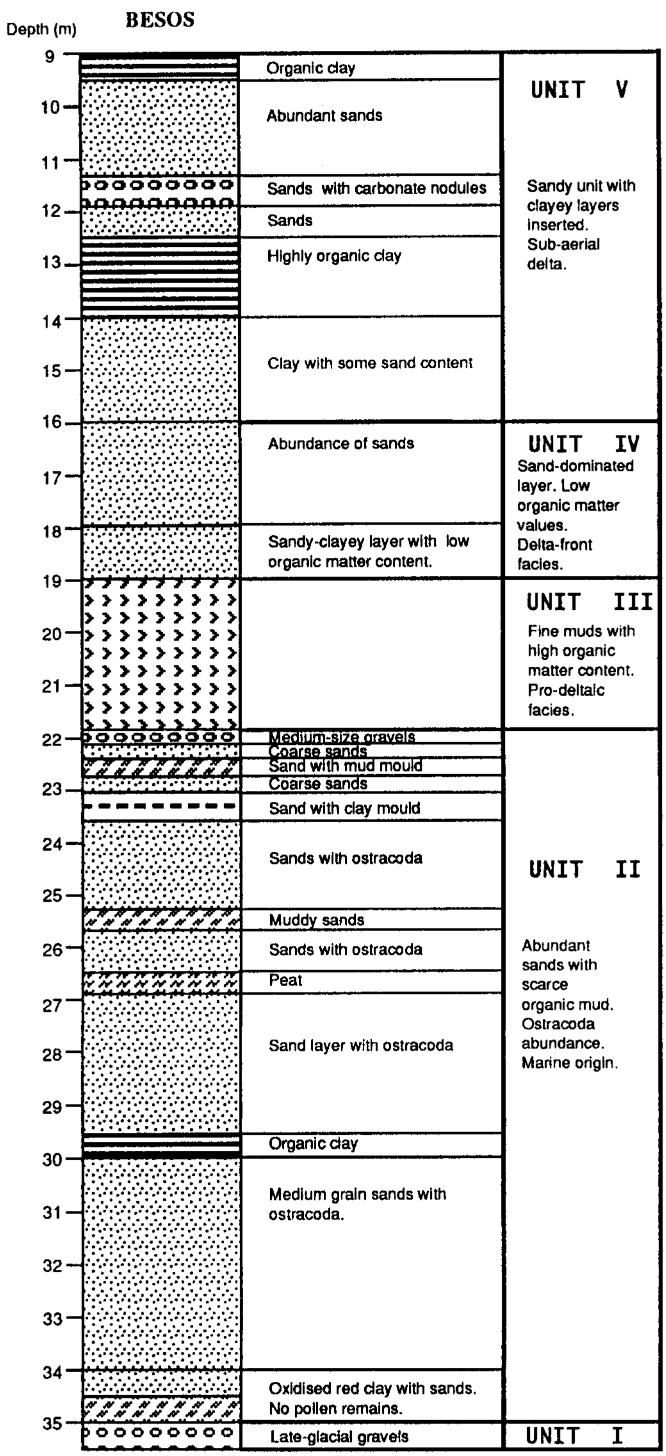


**Fig. 6**. Lithology of the Besós core (BES)

*Subzone ULL-A2*. AP decreases, mainly deciduous *Quercus*, also *Pinus*, *Corylus* and *Quercus ilex*-type. Increase in shrubby taxa (Σ Ericaceae and Cupressaceae) and in anthropogenic indicators such as *Plantago lanceolata*-type and Cannabaceae. *Olea* pollen first appears, as well as *Juglans*. *Vitis* is scarce, as in the preceding subzone. These pollen changes occur after the horizon radiocarbon dated 4300±330 B.P.

*Subzone ULL-A3*. Similar AP percentages to Subzone ULL-A1, but increased deciduous *Quercus* and *Pinus*. *Olea* disappears, and Cerealia-type increases significantly at this point.

*Zone ULL-B*

Sudden decrease in AP, mainly deciduous *Quercus*, also *Quercus ilex*-type, *Pinus* and *Corylus*. Increase of some shrubby taxa such as Ericaceae and Cupressaceae and of possible anthropogenic indicators (Behre 1981) such as *Plantago lanceolata*-type and Cruciferae. Peak of Cannabaceae, reappearance of *Olea*. Soon after 1500±80 B.P.

*Zone ULL-C*

Low deciduous *Quercus* and *Pinus*. Slight increase in evergreen *Quercus* and certain shrubby taxa (Σ Ericaceae and Cupressaceae). High percentages of *Olea* (8%) are

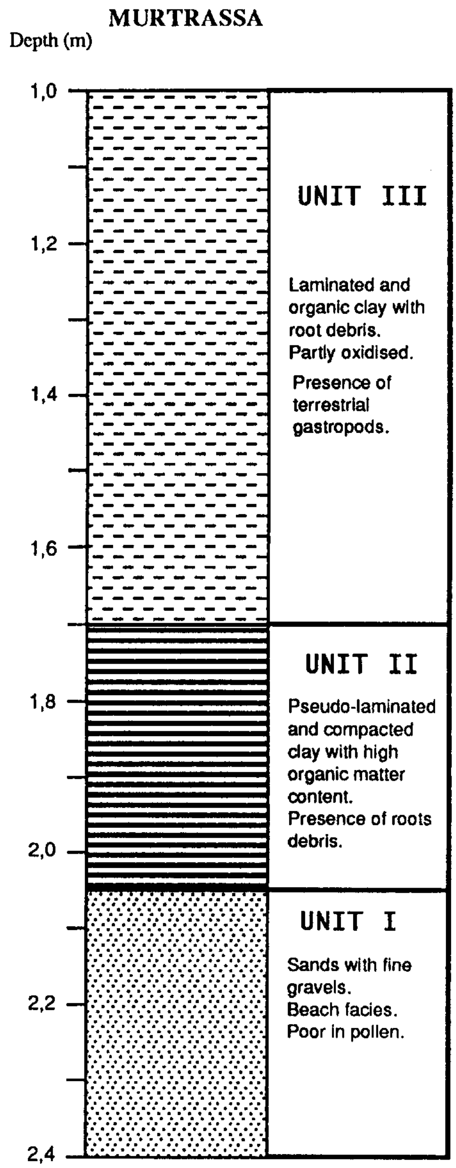


**Fig. 7**. Lithology of the Murtrassa core (MTR)

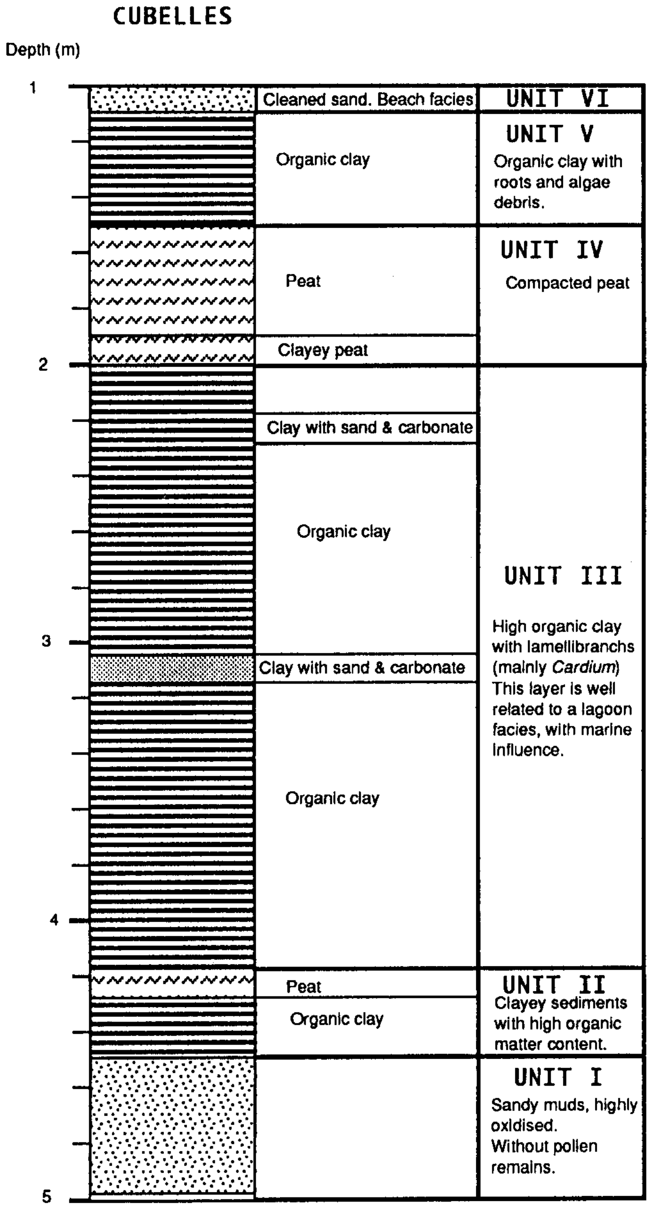


**Fig. 8**. Lithology of the Cubelles core (CUB)

probably the main feature of the zone, *Vitis* and *Juglans* become continuous. Asteraceae liguliflorae and Cruciferae increase substantially.

*Zone ULL-L*

Characterised by the decrease in AP, such as *Quercus ilex*-type, deciduous *Quercus* and *Olea*. Increase in *Pinus*, and in some NAP taxa, such as Asteraceae liguliflorae, Cruciferae, Chenopodiaceae and Liliaceae.

**Besós Pollen Diagram**

*Zone BES-A*

This part of the Besós pollen diagram (Fig. 10) is dominated by deciduous *Quercus* and *Pinus*, while *Corylus* and *Quercus ilex*-type are important. The AP values fluctuate. Values of shrubby taxa are also significant. An increase of *Cistus*, Lamiaceae and Ericaceae pollen percentages occurs at 25 m, synchronous with two high peaks of charcoal debris larger than 0.5 mm. There are also high percentages of certain herbaceous taxa such as Asteraceae tubuliflorae, *Artemisia*, Σ *Plantago* etc. The base the the diagram is dated to 6870±100 B.P.

*Zone BES-B*

The highest AP and *Quercus* values of the entire sequence occur here. The main increases takes place in the values of *Quercus ilex*-type, although *Pinus* percentages are still high. The pollen values of deciduous *Quercus* are slightly reduced, the curves showing marked oscillations and as in the preceding zone, the decreases correspond to increases in shrubby taxa, mainly Σ Ericaceae and Cupressaceae, although charcoal values remain low. There is a reduction in the values of most herbaceous taxa. The beginning of this zone is dated to 3250±50 B.P.

*Zone BES-C*

Arboreal pollen decreases sharply, such as deciduous *Quercus* and *Pinus*. Shrub and herb percentages increase. Two radiocarbon dates are available in this zone: 1300±40 B.P. and 1310±110 B.P. (Table 2). Three subzones have been distinguished.

*Subzone BES-C1*. There is a sudden fall of AP values, dated to slightly before 1300±40 B.P. First, the percentages of deciduous *Quercus* and *Pinus* decrease and later a drop also occurs in *Quercus ilex*-type. This coincides with increases in shrubby taxa values - first Σ Ericaceae and later *Cistus*. Values of herbaceous pollen taxa also increase: Poaceae, *Plantago lanceolata*-type, *P. coronopus*-type, Asteraceae tubuliflorae, *Artemisia*, Cruciferae, Lamiaceae and Cannabaceae, as do the charcoal values of both categories.

*Subzone BES-C2*. Tree pollen values recover, although oscillations continue and small decreases correspond to increases in shrubby taxa percentages. At the end of this subzone, there is a peak of Poaceae values just below a significant increase of smaller charcoal debris. Cerealia-type percentages are the highest of the entire sequence. *Olea* increases, although it is present throughout the sequence. *Juglans* appears more frequently than in Zone BES-A. There is a date of 1310±110 B.P. near the end of the subzone.

*Subzone BES-C3*. Deciduous *Quercus* and *Pinus* decrease further. *Quercus ilex*-type and shrubby taxa (Cupressaceae, Σ Ericaceae and *Cistus*) increase, as do herbs such as Asteraceae tubuliflorae, *Plantago lanceolata*-type, *P. coronopus*-type, Cruciferae and Lamiaceae.

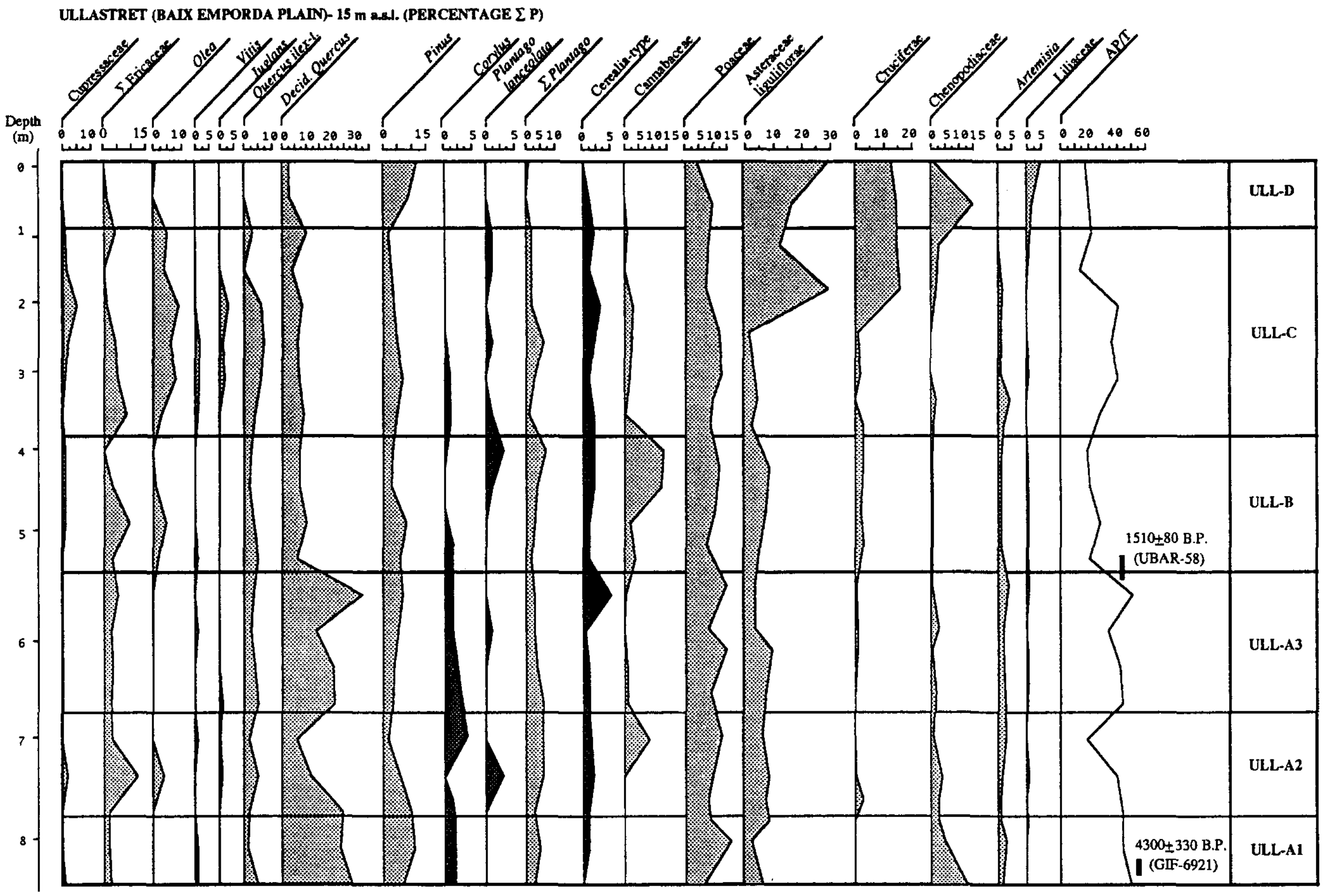


**Fig. 9**. Selected taxa from the Ullastret pollen diagram, based on % total pollen. The horizontal scales vary, as indicated

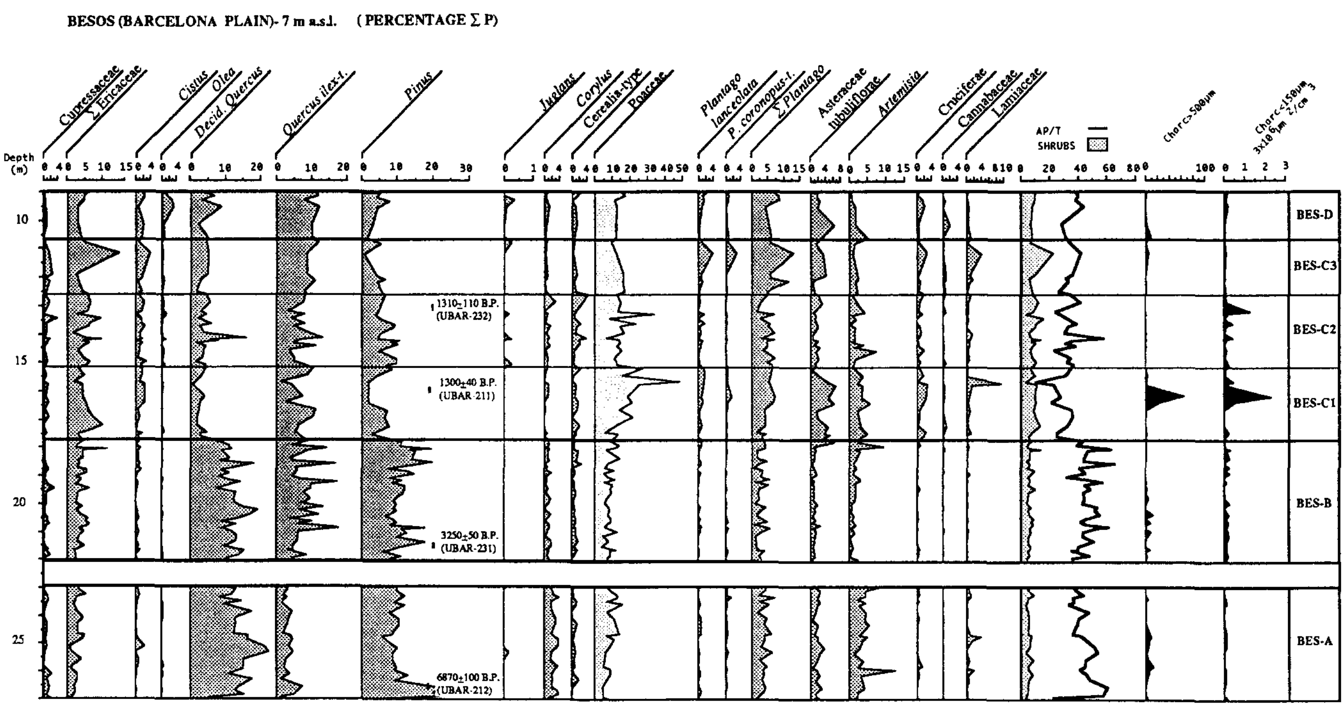


**Fig. 10**. Selected taxa from the Besós pollen diagram, based on % total pollen. The horizontal scales vary, as indicated

*Zone BES-D*

Tree pollen recovers, and shrubby taxa percentages decrease. *Olea* increases significantly to 4% and there are further records of *Juglans*. Percentages of Asteraceae tubuliflorae, *Artemisia* and Cannabaceae also rise.

## Murtrassa Pollen Diagram

Description of this pollen sequence is mainly based on the concentration diagram (Fig. 11), although pollen percentage values are also used to corroborate certain oscillations of the concentration pollen curves (Fig. 12).

*Subzone MTR-A1*. *Pinus* pollen is dominant, with shrubby taxa already rather high, mainly Ericaceae, *Erica* cf. *arborea*, Cupressaceae and *Cistus*. Small amounts of other arboreal taxa (Figs. 11,12). There is an isolated peak of some herbaceous taxa, Poaceae, Cerealia-type, *Plantago lanceolata*-type, *Lotus*, Apiaceae, Asteraceae tubuliflorae, etc. Charcoal >0.5 mm shows the highest values in the whole diagram. There is a date of 1248±24 B.P. here.

*Subzone MTR-A2*. Shrub pollen is abundant as in MTR-A1, with continuous records of Σ Ericaceae and Cupressaceae, and an increase in *Cistus* (Fig. 11), although percentage values show a rise in all of these taxa (Fig. 12). *Olea* increases substantially over its values in MTR-A1, as do *Quercus ilex*-type and *Pinus* values. There is less pollen from most herbaceous taxa, except from Asteraceae liguliflorae and tubuliflorae, and *Plantago coronopus*-type. Small particles of charcoal are now dominant (Fig. 11).

*Zone MTR-B*

Concentration values of certain herbaceous, shrubby and arboreal taxa decrease, with the exception of two important littoral taxa: *Pinus* and Cupressaceae. The curves of these taxa differ substantially in the concentration and percentage diagrams. The sudden decrease of their percentage values is a consequence of the great increase in Cyperaceae values (60%) in the middle part of the zone. Values of small particle charcoal are still high (Fig. 11).

*Subzone MTR-C1*. Evergreen and deciduous *Quercus* concentration values rise, as well as *Pinus*, some shrubby taxa (Ericaceae, *Cistus*) and *Olea*, although in the percentage diagram these increases are concealed by the rise in some herbaceous taxa (Fig. 12). The most noticeable evidence in this subzone is the high value of herbaceous human indicator taxa, such as *Plantago lanceolata*-type, *P. coronopus*-type, Cerealia-type, *Lotus*-type, Asteraceae tubuliflorae and *Polygonum persicaria*-type (Figs. 11,12) (Behre, 1981).

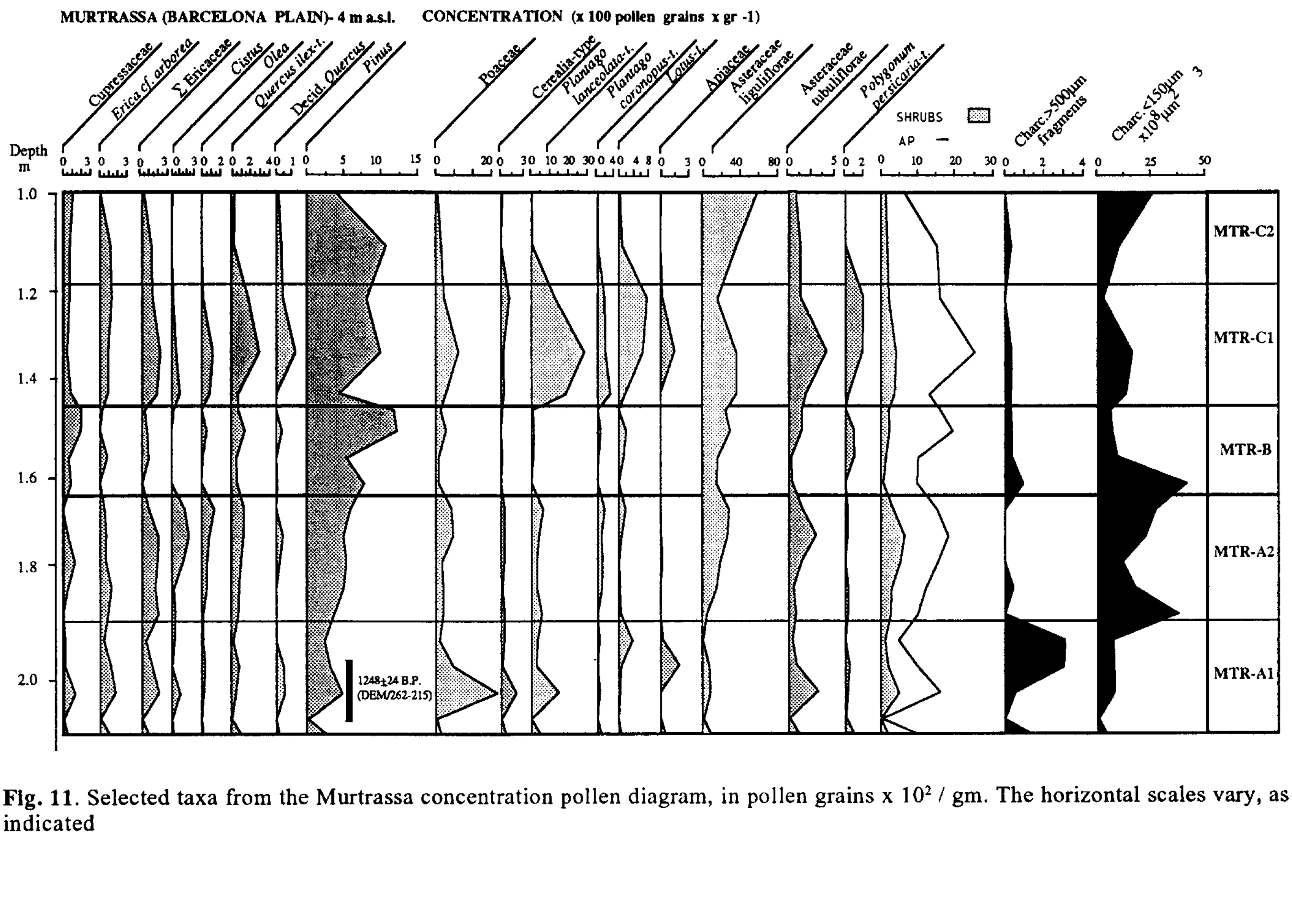


**Fig. 11**. Selected taxa from the Murtrassa concentration pollen diagram, in pollen grains x $10^2$ / gm. The horizontal scales vary, as indicated

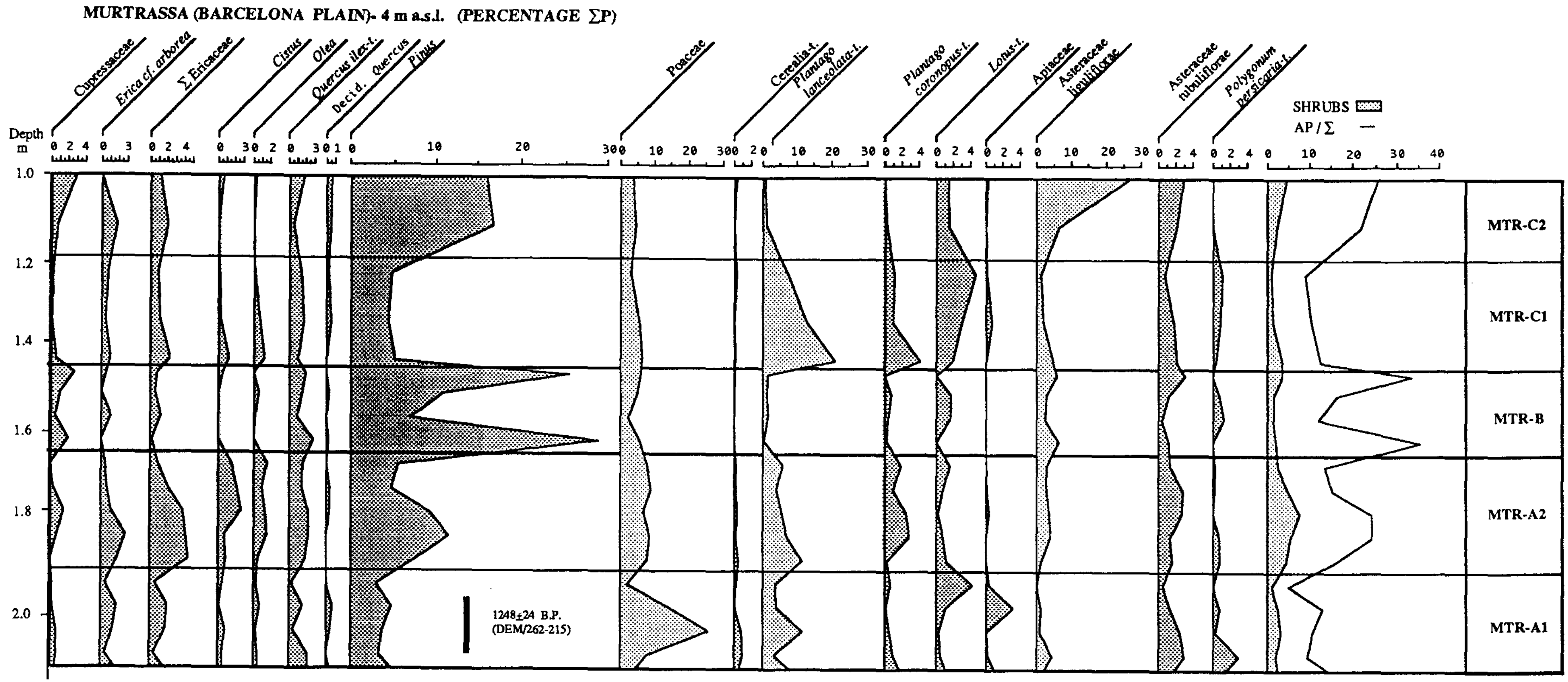


**Fig. 12**. Selected taxa from the Murtrassa percentage pollen diagram. The horizontal scales vary, as indicated

*Subzone MTR-C2*. The concentration values of all taxa decrease, with the exception of *Pinus* and Asteraceae liguliflorae.

## Cubelles Pollen Diagram

*Subzone CUB-A1*. The Cubelles concentration and percentage diagrams (Figs. 13,14) show moderate values, mainly of *Pinus*, *Quercus ilex*-type, deciduous *Quercus* and *Pistacia*. There is a date of 5040±70 B.P. in this subzone.

*Subzone CUB-A2*. There is a marked increase in AP concentration and percentage values, mainly of *Pinus*, *Quercus ilex*-type, deciduous *Quercus* and *Pistacia*. Other shrubby taxa increase such as Σ Ericaceae and *Corylus*. In the middle part of this subzone, a decrease in concentration and percentage values of certain AP taxa occur, such as *Quercus ilex*-type, deciduous *Quercus* and *Pinus*, with a corresponding increase in values of *Pistacia*. Increases in possible anthropogenic indicators cannot be observed.

*Subzone CUB-A3*. *Pinus* values are generally high, but concentration and percentage values differ. There is a significant rise of Σ Ericaceae. Anthropogenic indicators such as Cerealia-type and *Plantago lanceolata*-type also increase. *Pistacia*, *Corylus*, evergreen and deciduous *Quercus* values fluctuate. There is a date 3680±80 B.P. from near the base of this subzone.

*Zone CUB-B*

Cupressaceae values increase, while other arboreal taxa such as *Quercus ilex*-type, deciduous *Quercus* and *Pistacia* decrease somewhat. AP concentration values fall abruptly (*Pinus*, *Quercus ilex*-type, deciduous *Quercus*) with the first significant peak of charcoal values. *Olea* increases noticeably for the first time, and *Artemisia*, Asteraceae tubuliflorae and Cannabaceae values also increase. The middle part of CUB-B is dated to 2390±130 B.P.

*Zone CUB-C*

AP concentration values are higher but evergreen and deciduous oaks are dominant here, while values of *Pinus* are low. Concentration and percentage values of Cupressaceae, Ericaceae and *Pistacia* increase, as do Poaceae, *Plantago lanceolata*-type, Asteraceae liguliflorae, etc. The fall in AP values corresponds with a great increase in charcoal values (5,000 $mm^2/cm^3$). In the concentration diagram this occurs before 950±50 B.P. (Fig. 13).

*Zone CUB-D*

Arboreal pollen decreases further, except *Pinus*. *Olea* increases, and also some herbaceous taxa (Σ *Plantago*, Asteraceae liguliflorae). In the uppermost samples, there are sudden increases in the percentages of certain taxa: *Pinus*, Poaceae and Asteraceae liguliflorae (Fig. 14). This is because of great changes in pollen representation, mainly the disappearance of Cyperaceae because of the draining of the marsh. The transition between CUB-C and CUB-D has been dated to 950±50 B.P.

## Discussion and conclusions

The four pollen diagrams allow a synthesis of vegetation history and the effects of human activity in the coastal area studied. Our main aim is to study accurately the last three millenia because more information is available for this period. There are four phases of human activity:

Phase I 7000-3000 B.P.

Phase II 3000-1500/1300 B.P.

Phase III 1500/1300-ca. 850 B.P.

Phase IV ca. 850-ca. 300/250 B.P.

### Phase I

During this period, human activity takes place in different biogeographical contexts, north and south of the Garraf Massif (Fig. 3). This is of considerable importance, since the effect of human activity may depend on the natural plant communities in which it takes place. Thus, to the north of the mountain there grew a sub-Mediterranean deciduous oak wood as is clear in the Ullastret and Besós diagrams, and also in other pollen diagrams such as Drassanes 1 on the Barcelona Plain (Riera-Mora 1990) and Sobrestany, located further north on the Emporda plain (Parra 1988). To the south of the massif there was a sclerophyllous woodland with evergreen oak and other deciduous trees (mainly deciduous oak) and with some Mediterranean taxa such as *Pistacia* fairly abundant, as shown by the Cubelles diagram. For this phase, evaluating human activity and its effect on the landscape is not easy.

The first evidence that we observe is that Cerealia-type pollen curves are present at the beginning of all diagrams - before 6700 B.P. at BES-A. This is unlikely to be a sure argument in favour of human activity, because in coastal areas some wild grasses can also produce Cerealia-type pollen (Andersen 1978). Secondary anthropogenic indicators (Behre 1990) are scarce during most of Phase I.

At Besós, in Zone BES-A, we can observe an increase in the values of *Cistus* and Lamiaceae, which can be interpreted as possible pyrophytic taxa (indicators of burning) in Mediterranean areas (Bottema and Woldring, 1990). At the same time, slight increases in the values of larger charcoal particles can be interpreted as reduced burning close to the basin (Fig. 10).

During the first drop of AP values in CUB-A2, only the values of *Plantago lanceolata*-type rise slightly, later than 5040 B.P. (Fig. 13). At the same site, in Subzone CUB-A3, there is an increase in Cerealia-type

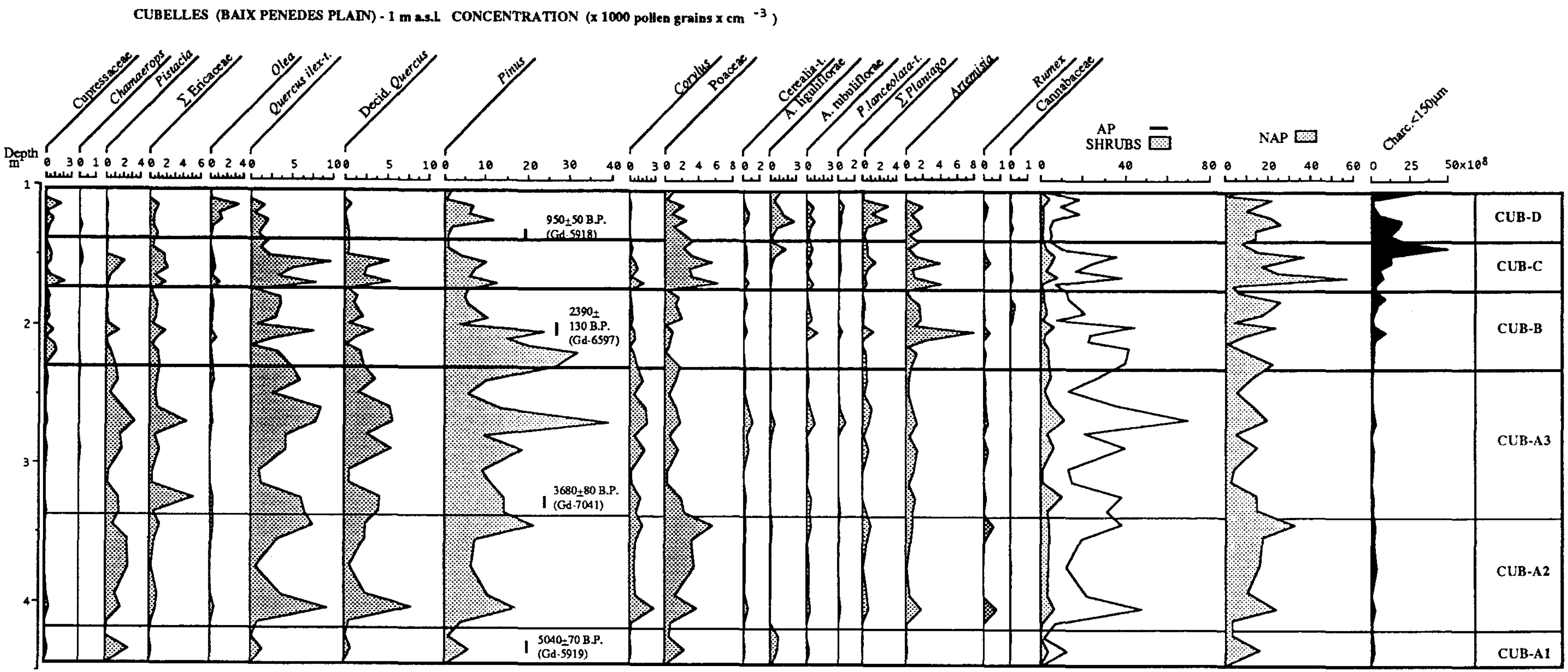


**Fig. 13**. Selected taxa from the Cubelles concentration pollen diagram, in pollen grains x $10^3$ / $cm^3$. The horizontal scales vary, as indicated

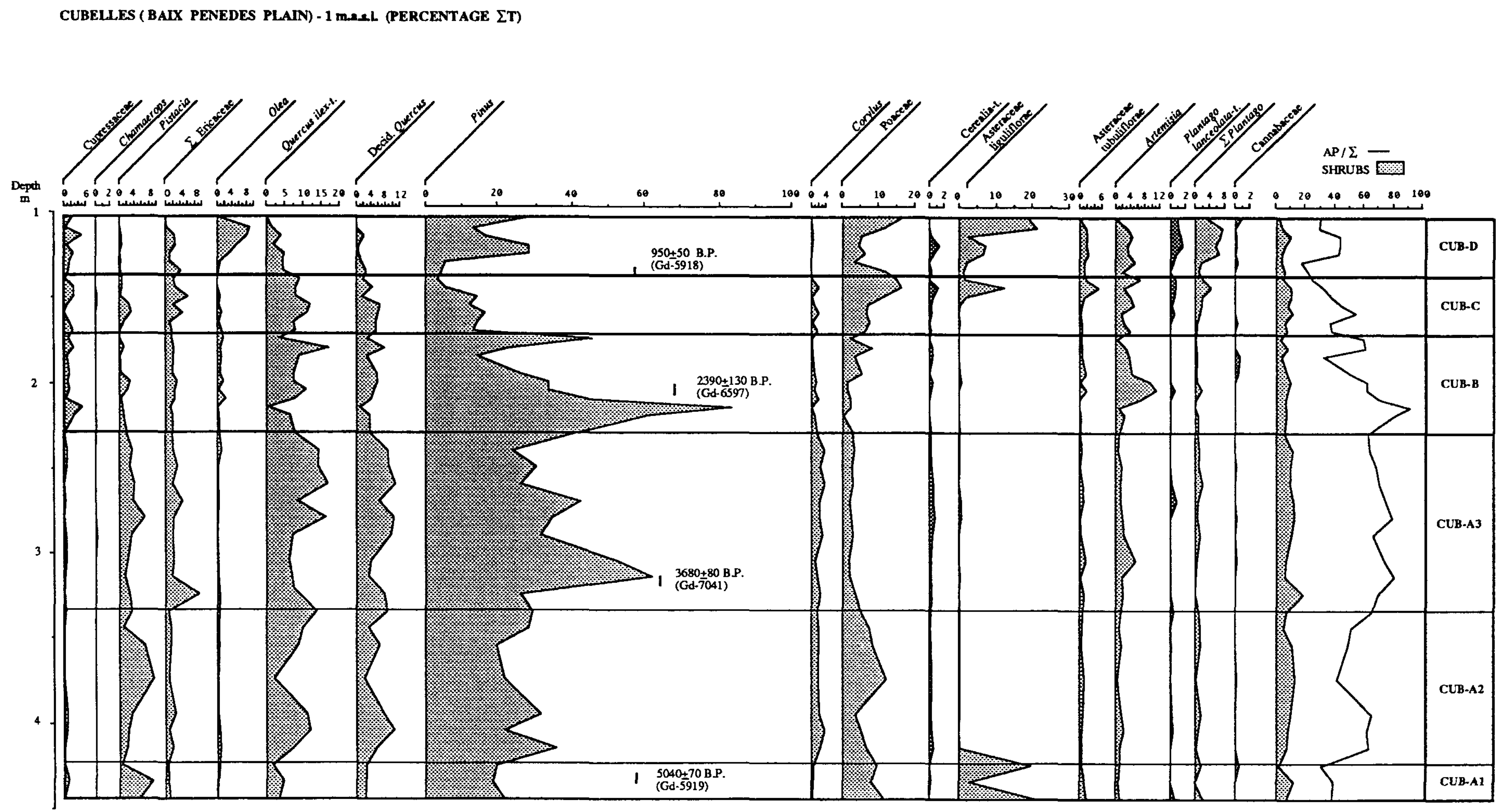


Fig. 14. Selected taxa from the Cubelles percentage pollen diagram in % total pollen. The horizontal scales vary, as indicated

and in other anthropogenic indicators (*Plantago lanceolata*-type, Asteraceae tubuliflorae, etc.). This episode is not radiocarbon dated, but it is later than 3680 B.P. (Fig. 13). During the two episodes of the Cubelles diagram belonging to Phase I, only very slight increases in microscopic charcoal values have been recorded.

The AP/NAP ratio can also be valuable for evaluating human influence (Bottema and Woldring, 1990). As has been mentioned above, the oscillations of the AP curve during Phase I are represented in the percentage diagram from Besós and in the concentration and percentage diagrams from Cubelles.

The evidence presented above allows us to suggest that human activity could have existed during this phase. However, the small changes recorded in the pollen sequences show that it was relatively isolated and did not greatly affect natural vegetation qualitatively (absence of woodland floristic changes) or quantitatively (making woodland regrowth possible), with the exception of these isolated AP oscillations. There are secondary anthropogenic indicators and several slight increases in charcoal values.

Pollen analyses of a small littoral basin have provided evidence of the burning of woodland and the cultivation of cereal crops in the Plain of Barcelona (Drassanes-1 pollen sequence). This boring site was located a few metres from a large early Neolithic settlement, St. Pau del Camp (Granados et al. 1993). This suggests that anthropogenic woodland clearance probably started in small areas close to the settlements, and, in this case, along the coast. Absolute dates obtained for the Drassanes-1 pollen diagram show that these disturbances start at 7000 B.P. in the Barcelona plain (Riera-Mora 1990).

Early and middle Neolithic burning phases have also been found in other parts of the western Mediterranean near the Catalan coast. Thus, charcoal was found at

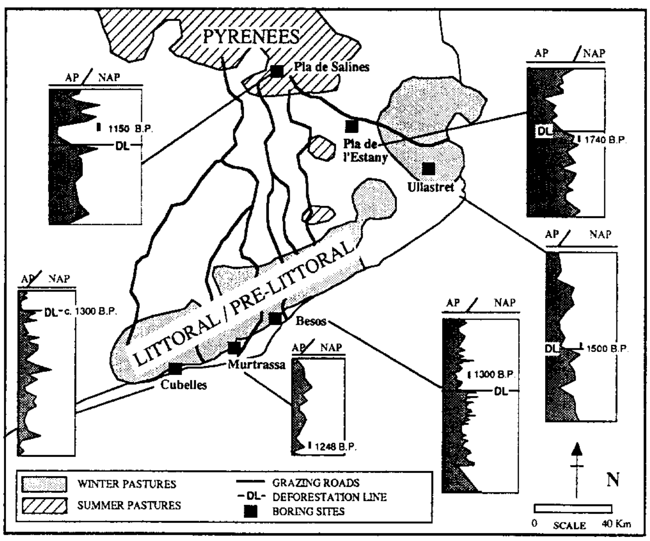


**Fig. 15.** Map of the northeast Iberian area showing summer pasture in the Pyrenees and winter pasture along the coast (littoral). The main routes used for seasonal transhumance are shown by thick lines. From Vila Valenti (1950). The pollen diagrams show the main episodes of woodland clearance

7350±170 B.P. with a few anthropogenic indicators in the Courthézon pollen diagram (Provence, southern France) (Triat-Laval 1978), and confirmed by analyses of soil charcoal (Pons and Thinon, 1987). Ancient human clearances have also been noted at Palavas (Provence, southern France) at 6780±70 B.P. (Planchais, 1987) and at St. Cyprien (Roussillon, southern France) at 6900 B.P. (Planchais 1985).

Other data indicate woodland clearance episodes along the coast in early and middle Neolithic times. These disturbances were probably local, of limited extent and involving little burning as shown by the low charcoal values. The woodland recovered again afterwards, floristically unchanged.

This kind of anthropogenic action has some common features with Landnam episodes first described in northern Europe (Iversen 1941, 1949). In the Mediterranean region these scattered woodland clearance episodes have some distinctive characteristics, such as the low values of charcoal debris in the diagrams, the development of pyrophytic taxa (responding to fire) or the plant succession of woodland recovery as the result of the particular ecological features of Mediterranean plant communities (Esteban-Amat and Riera-Mora, in press).

According to the evidence described above, we suggest that human activity was isolated in time and space, and conclude that itinerant farming took place in short and long cycles (Roberts 1989). These features also suggest a low density of human occupation during Phase I.

These relatively early farming activities correlate with archaeological data (Table 1). Early Neolithic cave dwellings and settlements on the Barcelona plain are well known, such as St. Pau del Camp or Can Sadurní cave (with radiocarbon dates of 5800 and 5700 B.P.) (Edo et al. 1986). Middle Neolithic times are particularly important on the Barcelona plain, as shown by a large mine system. On the Penedès plain, there are some archaeological burial remains from middle Neolithic times (5800-4800 B.P.) (Muñoz 1965). During the late Neolithic and Bronze Age, some caves and small settlements near the coast continued to be inhabited.

## Phase II

During this phase, great differences appear between pollen diagrams from the north and the south of the Garraf Massif. To the north, the Ullastret and Besós pollen diagrams continue to show oscillations of AP values (decrease and recovery) that imply continuous scattered human activity.

Subzone ULL-A2 shows one of these episodes, in which AP values decrease and values of Cerealia-type, *Olea* and Cannabaceae increase (Fig. 9). *Juglans* makes its first appearance in ULL-A2, while it was also present in Zone BES-A. If the *Juglans* grain at 25.5 m at Besós was not redeposited by the sea, and there is no hiatus in the lower part of the Ullastret profile, this occurrence would indicate the presence of *Juglans* prior to Greek and Roman colonisation. Carrion and Sanchez-Gomez (1992) assumed that *Juglans* was already native to the

Iberian peninsular. Although radiocarbon ages are not available for this level, it could be contemporary with two important Iberian settlements near the boring site, Ullastret and Illa d'en Reixach, which started between 2700 and 2400 B.P. (Martin 1986). A considerable number of seeds have been analysed from these sites, mainly cereals (*Avena* sp., *Hordeum vulgare, Triticum dicoccum, T. durum/aestivum, T. aestivum/compactum*), but also *Olea* and *Vitis* (Buxo, 1992).

As in the diagram just mentioned, in Zone BES-B (Fig. 10), there are oscillations in AP values as in the Ullastret diagram, but they are more frequent than in the previous zone. Despite these, AP percentages are still high, similar to those in the preceding zone. The most noticeable evidence is the change in woodland composition: values of deciduous *Quercus* and other sub-Mediterranean taxa decrease progressively, parallel to the increase of sclerophyllous taxa. This process starts approximately at 3250 B.P. (Fig. 10). These vegetational changes also occur in other areas with a sub-Mediterranean vegetation in the mid-Holocene (Riera-Mora 1993), as for example in the Rome area of Italy (Follieri et al. 1988), Provence (Triat-Laval 1978) or Languedoc in southern France (Planchais 1987).

On the other hand, vegetation history to the south of the Garraf Massif is quite different. Thus, at Cubelles (Fig. 13), from the top of Subzone CUB-A3, a progressive woodland clearance occurs, with only brief episodes of regrowth. More or less during Roman times, fires became important in this woodland destruction.

As has been explained, to the north of the Garraf Massif, isolated anthropogenic disturbances do not restrict woodland recovery, but it becomes slower, in accordance with the model for vegetation cover-biomass and successive fires in Mediterranean ecosystems (Thornes 1987). The main consequence of this process would be the progressive change to Mediterranean vegetation.

It is not easy to explain the causes of the vegetational change from deciduous to sclerophyllous communities. We suggest that the beginning of this process may be related to climatic changes towards drier conditions, but human influence induces a „feed-back" process. Thus, the progressive climate-induced change to Mediterranean vegetation favours fires and impoverishes soil and so a different and slower recovery occurs afterwards.

In southern areas such as Cubelles, more continuous woodland loss was caused by persistent human activity together with the presence of natural sclerophyllous woodland that was slower to recover. Here a more intensive farming system was established, probably due to urban influence, particularly during Roman times with the foundation of the city of Tarraco in the 2nd century B.C. (Fig. 16, Table 1). Sclerophyllous woodland recovered again (end of CUB-B, beginning of CUB-C) (Fig. 13), probably during late Roman times, when numerous rural settlements were abandoned.

In conclusion, human activity is not evenly represented along the Catalan coast during Phase II between 3000 and 1500/1300 B.P., which includes the zenith of Iron Age cultures (Fig. 16). This dissimilarity could be the result of the different economies of the different areas, and the direct influence of some urban centres such as Tarraco (Fig. 4). Lastly, we should note that Roman influence is not a common factor, and that some areas were more heavily farmed.

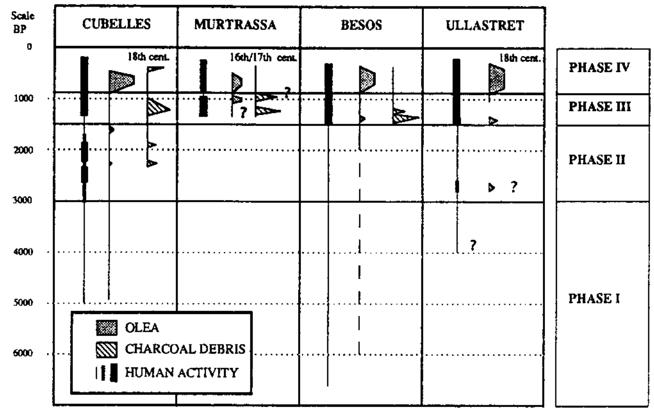


**Fig. 16**. Synthetic table with main characteristics of several human activity phases in the diagrams. Phase I (7000-3000 B.P.); Phase II (3000-1500/1300 B.P.); Phase III (1500/1300-850 B.P.) and Phase IV (850-300/150 B.P.). Thick black lines represent the intensity of human activity

## Phase III

Between 1500 and 1300 B.P. (5th-7th centuries A.D.) a general decrease in AP values is evident at Ullastret (Zone ULL-B), Besós (Subzone BES-C1), Cubelles (end of Zone CUB-C), while the sedimentation record begins during this time at Murtrassa. At the same moment, great rises in charcoal curves representing local and regional fires are noticeable (Fig. 16). The values of shrubby and pyrophytic taxa also increase.

The direct consequence of this general woodland reduction phase is the increase in erosion. Thus the pollen diagrams from Besós and Murtrassa, obtained in deltaic areas, show a great increase of sedimentation rate and a first expansion of deltaic plains (Palet and Riera-Mora 1992; Palet and Riera-Mora, in press).

Changes in sedimentation records and rates can also be observed in closed basins, such as Cubelles (from Unit IV to Unit V) (Fig. 8).

The radiocarbon dates from the different diagrams allow us to establish an approximate chronology for this process (Table 2). At Ullastret, woodland reduction takes place at 1500±80 B.P., at Besós, not much before 1300±40 B.P., at Murtrassa, sedimentation starts at 1248±24 B.P., representing the beginning of the first expansion of deltaic plains; and lastly, at Cubelles woodland reduction occurs before 950±50 B.P., with an approximate date estimated around 1300 B.P.

During this period of change, other palynological aspects should be also noted. At Besós and Ullastret there is a small peak in *Olea* pollen, interpreted as a small expansion of olive cultivation, which may be compared with nearby Mauguio (Roussillon, southern France) at 1200 B.P. (Planchais 1982). At Ullastret the great increase of Cannabaceae pollen is also noticeable, with similar but slighter rise of this taxon in the Besós and

Cubelles diagrams, and synchronous with those in other European diagrams (Godwin 1967). Despite this, Cannabaceae appears earlier in our diagrams: at ULL-A2, BES-A and CUB-A1, with a first significant rise at CUB-B.

Large woodland clearances and regular fires demonstrated by the increases in charcoal, shrubs and pyrophytic taxa values do not coincide with increases in certain cultivated taxa, such as *Cerealia*-type pollen, while the assemblage of pollen indicators of grazing such as *Plantago lanceolata*-type, *P. coronopus*-type, *Lotus*-type, Poaceae, Asteraceae liguliflorae, A. tubuliflorae and Lamiaceae is important (Behre 1981, 1990).

This evidence allows us to propose that grazing activities were widespread in our coastal area during this period and thus a new homogeneity in land use took place in this region (Fig. 16).

It has been mentioned that woodland clearances would be the cause of an intensive erosional process. The growth of deltaic plains of both the rivers Llobregat and Besós would therefore imply that these woodland clearances also occurred in inland regions.

Some pollen diagrams from the Pyrenees also show loss of woodland at the same time. In the eastern Pyrenees, the Pla de Salines diagram (2200 m a.s.l.) shows woodland clearance just before 1150 B.P. (Jalut 1977, Bolos-Masclans 1982), while in the Central Pyrenees, the Tramacastilla diagram (1682 m a.s.l.) shows that woodland clearance and an episode of much erosion occurred at 1240±60 B.P. (Montserrat 1992). In the eastern Pyrenean foothills area, there was woodland clearance not much later than 1740±50 B.P. as shown the sequence of Pla de l'Estany (Olot area) (Burjachs 1990) (Fig. 15). All this evidence suggests that much land was used for grazing, and also in the inland areas.

Ethnographic studies have shown the great importance of seasonal transhumance all over the country. This movement takes place between winter pastures along littoral and pre-littoral areas and summer pastures in the Pyrenees (Fig. 15) (Vila Valenti 1950). We must also take into account that coastal areas were much used as a winter pasture during historical times; written sources show the existence of hygrophyllous (damp) pastures in the deltaic plain of the river Llobregat (Fernandez 1989) as well as dry pastures in the mountain ranges enclosing these plains.

Written sources indicate that there was transhumance from the Penedès plain to the Pyrenees at least during the 11th and 12th centuries A.D., and that it survived until the middle part of the present century (Bertran 1986). However, the origin of this transhumance is difficult to establish. Although archaeological and written evidence is scarce, some new studies on landscape morphology in the Plain of Barcelona have shown that grazing roads came into use after Roman times and before the appearance of the first medieval documents in the 10th century (Palet in press).

On the other hand, a legislative corpus from Visigothic times is known for the whole Iberian Peninsula, and it strictly regulates the movement of flocks, the use of communal pastures, location of grazing roads, etc. (Garcia Moreno 1989).

Pollen and other data suggest that the seasonal transhumance mentioned in medieval documents has its origin during Visigothic times, with an approximate chronology from the 5th to 8th centuries A.D. based on absolute dates obtained in the available pollen diagrams.

Pollen analyses from parts of north Africa show similar trends. A. Brun (1983) points out a woodland clearance phase caused by grazing activities between 1400 and 1500 B.P. at Gabes Golf. A similar period of woodland loss and erosion at 1500 B.P. has been also observed in the Middle Atlas in Morocco (Lamb et al. 1991).

**Phase IV**

This phase begins approximately at 950 B.P. and ends with the draining of the coastal marshes. During this period, woodland greatly decreases and *Pinus* becomes the main tree, while shrubby and herbaceous vegetation develops.

The increase in *Olea* is the most noticeable feature (Fig. 16). In the Ullastret diagram it reaches values of 4% (Zone ULL-C); at Besós, 4% (Zone BES-D); 4% also at Cubelles (Zone CUB-D) and 2% at Murtrassa (Subzones MTR-A2 and MTR-C1). Recently, new data from a pollen diagram from the Plain of Barcelona makes possible to establish the date of 790 B.P. for the increase of *Olea* pollen values (Cano et al. in press).

Historical documents inform us that olive cultivation was well developed along the Catalan coast during the 12th century A.D. (Bonnassie 1979). The uppermost samples from the four diagrams show an *Olea* decrease shortly before the 17th and 18th centuries, when the accumulation of sediment stops.

Some other pollen records from the French Mediterranean coast also prove how olive cultivation spread out extensively in the whole area after the 11th century (Leveau et al. 1991).

Although medieval documents often refer to vineyards, which have been interpreted as the main factor of the agrarian expansion of the 11th century A.D. in Catalonia (Bonnassie 1979), significant values of *Vitis* are only to be found in the Ullastret diagram.

Lastly, pollen data from Cubelles and Murtrassa show the development of damp pastures close to the littoral areas, as can be seen from the high values of *Plantago lanceolata*-type, *P. coronopus, Lotus*-type, *Polygonum persicaria*-type etc. (Figs. 9,10). These pastures are also well documented in the Llobregat deltaic plain after the 12th and 13th centuries (Fernandez 1989).

In conclusion, during this last pollen phase, the agrarian Mediterranean landscape took shape on the northeast Iberian coast.

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