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EVOLUTION AND PALAEOENVIRONMENTAL CONDITIONS OF AN INTERFAN AREA IN EASTERN SPAIN (NAVARRÉS, VALENCIA)

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RIASSUNTO - Gli studi effettuati nella valle del Canal de Navarrés e lo studio di una carota di 25 m proveniente dalla valle del Canal de Navarrés hanno consentito di comprendere l'evoluzione recente di questa depressione tettonica. La valle è stata oggetto di episodi sia eso - che endoreici durante i quali conoidi alluviali ed importanti formazioni di travertino hanno sbarrato il fondovalle. Lo studio sedimentologico conferma l'esistenza di facies fluviali ad alta energia alternate ad episodi di dilavamento diffuso seguiti da decantazione di sedimenti fini. I livelli superiori corrispondono ad un ambiente lacustre con depositi torbose. I resti di ostracodi, molluschi, gasteropodi e carofite trovati a 4,30 m dalla superficie sarebbero legati a sedimentazione di alta energia; da 2,20 m dal piano di campagna invece condizioni di bassa energia caratterizzerebero la sequenza fino alla sua sommità. Le datazioni radiometriche indicano che la sequenza abbraccia un periodo compreso fra circa 178.000 B.P. fino a meno di 3.000 B.P.. Le analisi polliniche dei livelli superiori di due carote evidenziano *Pinus* come albero dominante, all'incirca fra 15.000 B.P. e 5.000 B.P.. Il pino poi è parzialmente sostituito da *Quercus*, accompagnato da specie arbustive mediterranee e da caducifoglie. L'installazione di un villaggio eneolitico, verso 5.000 B.P., sembra coincidere con una importante fase erosiva e con una frequenza elevata di idrofita, con conseguente eutrofizzazione del bacino.

ABSTRACT - The paper reports the results of a study carried out in the Canal de Navarrés tectonic valley to establish its evolution. The study was based on field surveys and the analysis of a 25 m long core. Both exorheic and endorheic episodes occurred in the valley, giving rise to alluvial fans and thick travertine deposits which dammed the valley bottom. Sedimentological analyses confirmed the presence of high energy fluvial episodes alternating with diffuse rainwash and decantation of fine deposits. The upper levels in the studied core correspond to a lacustrine environment with peat layers. At the depth of 4.30 m, remains of ostracods, molluscs, gastropods and charophytes are present suggesting high energy conditions; from 2.20 m lower energy conditions prevail up to the end of the sequence. Absolute datings indicate that the sequence spans over a period from about 178 ka BP to less than 3 ka BP. Pollen analyses of the most superficial portions of the studied core show *Pinus* as the predominant tree from 15 to 5 ka BP, when it is partially replaced by *Quercus* with Mediterranean shrubs and deciduous trees. The presence of an Eneolithic settlement at ca. 5 ka BP seems to coincide with a period of greater erosion with eutrofication of the basin and diffusion of hydrophytes.

Parole chiave: Spagna, Pleistocene, Olocene, valle tettonico, endorreismo, geomorfologia, paleoambiente, sedimentologia, micropaleontologia, palinologia.
Key words: Spain, Pleistocene, Holocene, tectonic valley, endorheism, geomorphology, palaeoenvironment, sedimentology, micropaleontology, palynology.

1. INTRODUCTION

In the semi-arid east-southeast of the Iberian Peninsula where away from the coast wetlands become scarce, endorheic areas provide important records for palaeogeographical and palaeoenvironmental reconstruction.

Palaeoenvironmental reconstruction in a semiendorheic environment presents two main problems. The first is due to the exposure of the remains of organisms that live in the interior or surroundings of this type of setting to taphonomic processes. The second is due to the influence that geotectonic and geomorphic evolution exercises upon the reliefs in which the endorheic basin is placed and evolves.

To deal with the first of these problems we have considered a series of fossil groups that appear in the sequence of a core realized in Canal de Navarrés, principally through the study of pollen and charophytes for palaeobotanical information, as well as ostracods and gastropods for palaeozoological information. The former can shed some light on the evolution of the vegetation both in the exterior of the ancient quaternary lake, through pollen analysis, and on the inside, through the charophytes. The number of species and the abundance of individuals in the fossil fauna can give some idea as to the stable or unstable conditions of the lake, and to its evolution through the sequence.

In attempting to solve the second problem, the study of the geological setting before the installation of the basin is undertaken, and the geomorphic evolution deriving from the processes of erosion and sedimentation which have taken place during the Pleistocene and Holocene. Finally, radiometric dating can help to locate in time those processes which are inferred by sedimentological and palaeontological characteristics.

2. STUDY AREA, LOCATION, CLIMATE, VEGETATION AND ARCHAEOLOGICAL RECORD

Location and geographic setting

The Canal de Navarrés is a flat-bottom valley (39º 06 N, 0º 41 W), 1 to 2km in width, situated at 255m above sea level and running NW-SE (Fig. 1). The valley is flanked to the West by the Caroig massif, and to the East

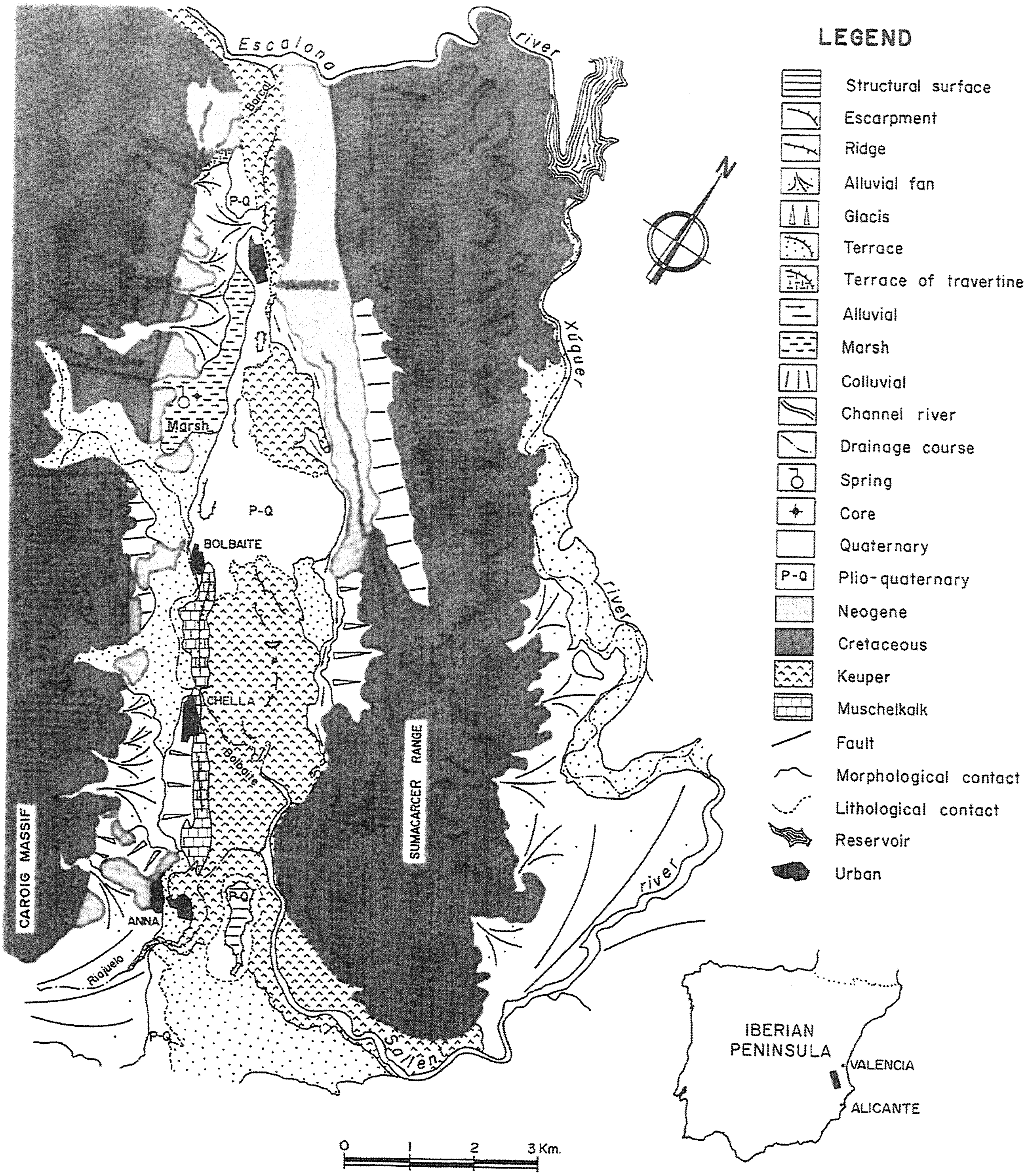

Fig. 1. The site of Navarrés. Geomorphological map and coring locations.
Il sito di Navarrés. Carta geomorfologica e localizzazione delle carote.

by the Sumacarcer range, both with planation surface remnants. To the East, the channel of the River Xúquer, with a height variation of 150m, provokes active and regressive erosion in the ravines and in other tributary courses. Among these the Escalona to the North and the Riajuelo-Sallent to the South delimit the Canal valley.

The valley has a semiendorheic character related to the dinamics of alluvial fans. Large quantities of water springing up from the calcareous Caroig gave rise to significant formations of travertine and peat.

Climate

The Canal de Navarrés belongs to the lower mesomediterranean vegetation belt, with dry to subhumid rainfall regime (Rivas-Martínez, 1987). The mean annual temperatures are around 15-16º C with the possibility of harsh winter frosts. Average precipitation oscillates around the 550 mm mark, with maxima in November/December and minima from June to August. It is spread across about 50 days of the year, and often takes the form of heavy downpours. This zone can be considered as transitional between coastal and inland sectors. For predominantly topographic reasons a significant diminution in precipitation can be observed, as can greater seasonal thermal gradients than at the coast. The sea breezes practically do not reach here.

Vegetation

The potential natural vegetation of the more abrupt slopes are *Rhamno-Juniperetum phoeniciae* shrubs, followed by a bushy *Rhamno-Quercetum cocciferae lentiscetosum* formation. Toward the bottom of the valley, where the ground permits, holly oak formations can be found (*Bupleuro-Quercetum rotundifoliae lentiscetosum*). Closer to the water there is poplar, including black poplar grow with ash (*Populion albae*) next to humid surfaces there are reed and *Typho-Scirpetum tabernaemontani* growths (Rivas-Martínez, 1987; Costa, 1986).

Today these formations have practically disappeared, being substituted in the lower areas by the cultivation of vegetables, fruits, lucernes, flowers etc. The slopes show degraded bushy growths (mastic tree, alaternum shrubs, kermes oak, gorse, palm heart) with the presence of Aleppo pine, and, bearing witness to now abandoned terrace cultivation, carob, almond and olive trees.

Archaeological record

Even where there is some certainty as to previous human inhabitation of this area, what may have had an earlier and more decisive influence upon the landscape seems to have been the Eneolithic village of Ereta del Pedregal. This settlement, sited very close to the drilling points (some 200m), is set on a small hummock on peaty levels. Archaeological excavations point to a cultural period which would have spanned from the Neolithic, or the end thereof (first half of the third millennium B.C.) to the so-called Valencian Bronze Age, with a bell-shaped transition level around 2000 B.C. (Fletcher *et al.*, 1965; Pla *et al.*, 1983).

METHODS

It has been possible to carry out stratigraphic, sedimentological and paleontological studies from the Navarrés 1 (N1) core of 25m depth, made with a hydraulic drill rig. At *ca.* 5 m from the first point, the upper two meters of peat were also extracted for pollen analysis, Navarrés 2 (N2)).

The geomorphical study is based on the interpretation of aerial photographs of the area (1:33,000). The presence of faults was checked in the field, and different sections were analyzed. Along with spatial considerations, this allowed the sequential reconstruction of the alluvial fans.

The sediment samples were selected with the characteristics of the material in mind, paying special attention to composition of texture, calcimetry, organic matter content, and finding statistical indexes from the frequency graphics to distinguish the main mobilization and deposition processes of the sediments (Visher, 1969; Reineck and Singh,1975).

The pollen samples have been extracted every 10cm from the N1 core, until sterile levels were reached at about 1.90m of depth. Given the slow rate of sedimentation (Fig. 2), N2 was sampled every 5cm so as to achieve better definition in the pollen zoning (Carrión and Dupré, 1996). Sediments for pollen analysis have

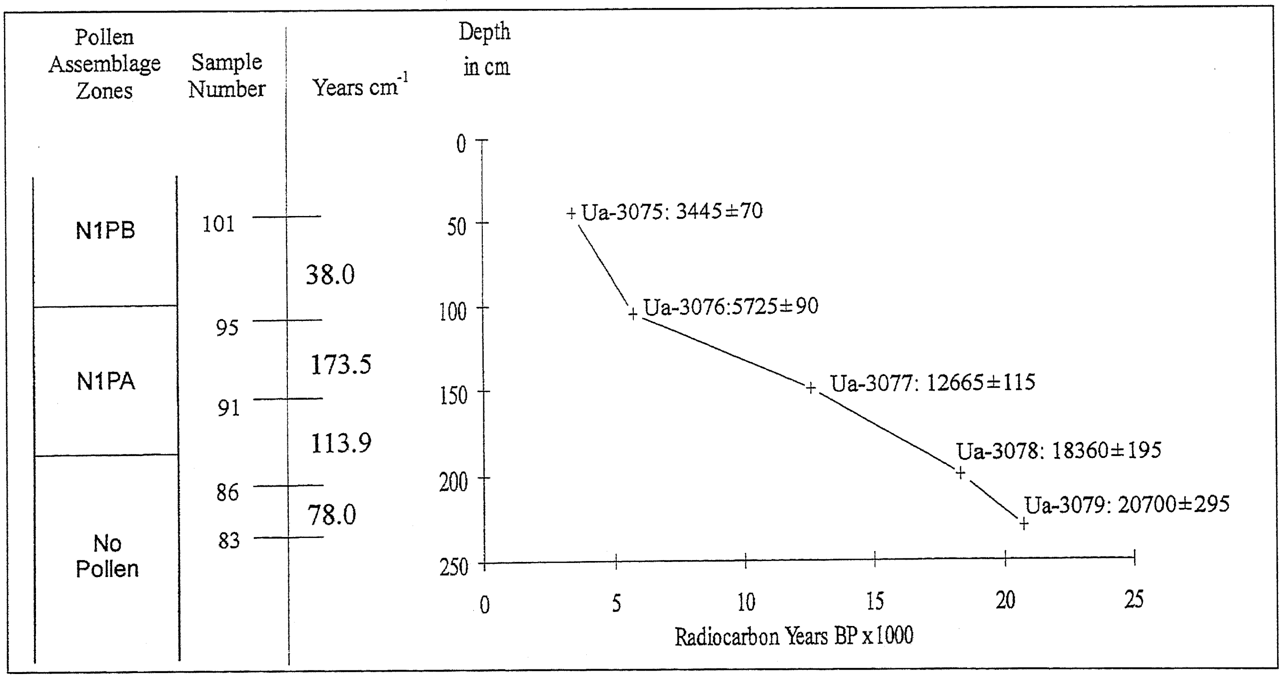

Fig. 2. The time depth curve for Navarrés 1. / *Curva della velocitá di sedimentazione per Navarrés 1.*

been treated following the modified classic method (HCl, HF, KOH or NaOH), and concentrated by means of the Thoulet heavy liquid (Girard, Renault-Miskovsky, 1969; Dupré, 1992). Tablets of *Lycopodium clavatum* (12,100 spores/tablet) were added to each sample to calculate the pollen concentration. Pollen identification and counting followed standard procedures. For the pollen diagrams, the percentages of Cyperaceae, monads of *Typha, Apium*, and spores of non-vascular cryptogams, were calculated apart from the total sum of pollen and spores. Pollen percentage zone boundaries were determined from the results of constrained incremental sum-of-squares cluster analysis (CONISS, Grimm, 1987), using a square root transformation and chord-distance dissimilarity measure for the pollen taxa that occur at greater than 2% abundance (Figs. 5 and 6)

The sedimentary material from which the remaining microorganisms were extracted was prepared only with water in order not to introduce a new taphonomic process derived from the use of more aggressive disagregating substances which might destroy non-mineralized skeletal elements.

Chronology

Previous studies of peat levels close to the cores under study gave the following radiocarbon dates 3930 +/- 250 B.P. (M753) and 6130 +/- 300 B.P. (M754) (Menéndez Amor and Florschütz, 1961) and these could be correlated with more recent dates.

The radiocarbon datings given by the University of Uppsala (Norway), seems to testify one of the most complete sequences in Valencia for the Upper Pleistocene and Holocene. The lower levels were dated by thermoluminescence, at Warsaw University (Poland), (Fig. 3)

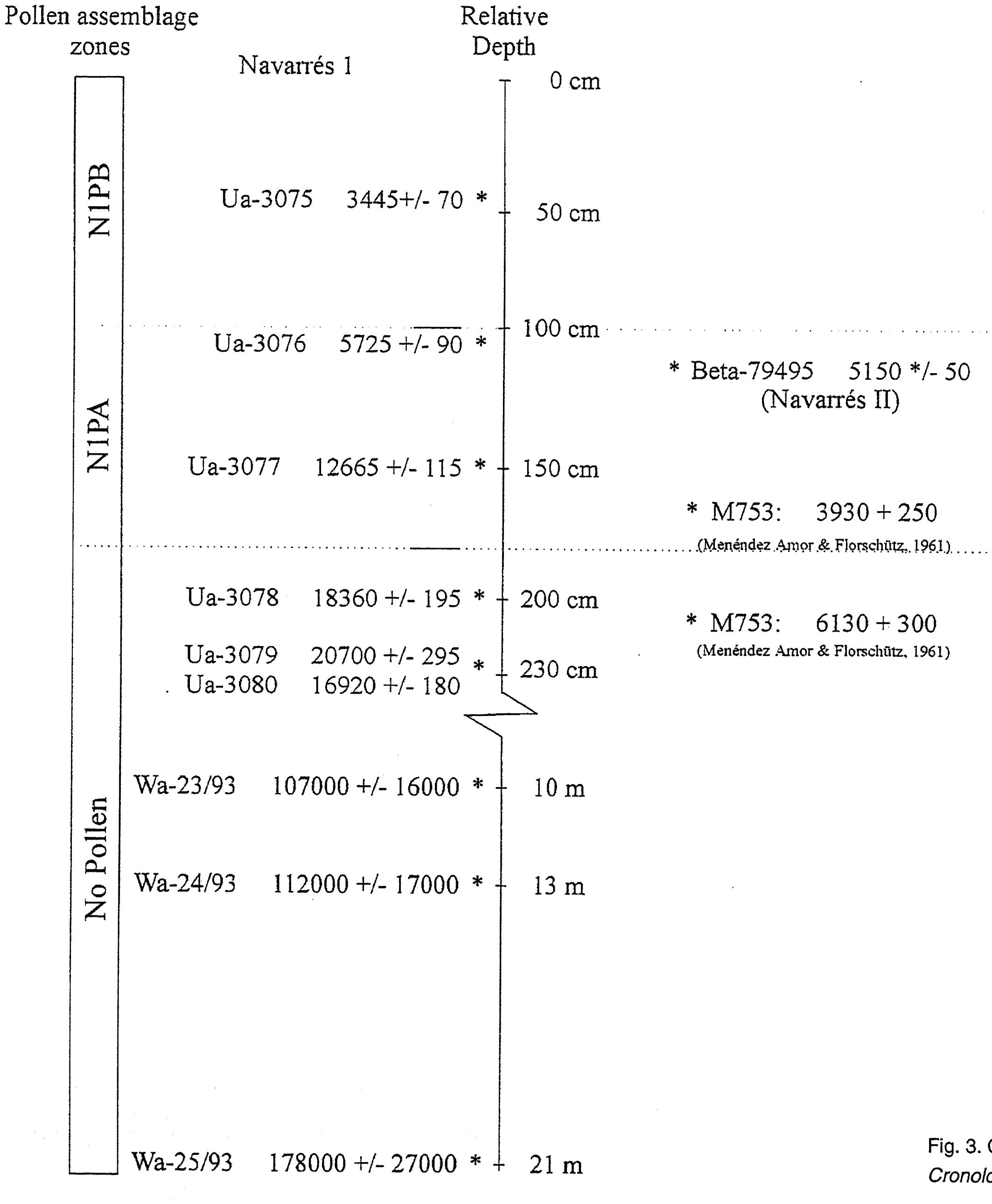

Fig. 3. Chronology.
Cronologia.

3. GEOLOGICAL ASPECTS. STRUCTURES AND LITHOLOGY

The "Canal de Navarrés" is an Iberian tectonic rift valley, situated in the SW limit of the Iberian cordillera. It belongs to a crank-shaped group of troughs and is injected with plastic triassic material whose rise was controlled by distensive faulting presumably linked to shield accidents (Ríos *et al.*, 1980), which affect the whole secondary of the Senonense.

This stuctural setting was obtained in the Miocene. The oldest deposits sedimented in the graben, discordant to the cretacic calcareous rocks date from the Helvetian (Ríos *et al.*, 1980) and continue till the Upper Miocene. Discordant to them and also to the plastic materials from the Keuper period are the plioquaternary travertine sediments that appear fractured by the thrust of the Keuper clays.

The outcropping pre-Neogenic lithology in the area is basically the cretaceous limestone which forms the relief structure of the "Canal". In the interior of the trough there remains some residue of these calcareous rocks. The principal materials, however, are the aforementioned Keupers, constituted mainly of gypsum and clay. The Helvetian is composed by detritic materials, basically conglomerates, calcirudits and sandstones. At the Upper Miocene the sea reached the area as supported by the grey marls and marine calcareous rocks and at the end of this period the sea regressed and the materials underwent continental: lacustrine calcareous and sandstones, conglomerates and red marls. The Pliocene are represented by patches of travertine sediments at the top of some elevations (Ríos *et al.*, 1980). From among the quaternary sediments, the following are noteworthy: a) All along the Canal there are excellent travertine formations and crusts. There stands out the travertine cascade at the northern side of the Canal, the travertines in the Rambla (braided ephemeral stream) Bolbaite channel between Bolbaite and Chella and that in the Riajuelo River channel at the end of the Riajuelo fan till Anna. b) At the lateral margins of the "Canal" alluvial fans were developed at least since the Middle Pleistocene; they sporadically work at present. These deposits locally merge with the Upper Pleistocene alluvial deposits from Rambla Bolbaite. Alluvial fans have created a playa-lake type topography that leaved depressions, which favoured the later set up of little humid zones and marshes, mainly feeded by freatic waters coming from the Caroig calcareous aquifer. c) The Holocene deposits are basically very anthroposized alluvial silts dedicated to agriculture, and the just mentioned local lacustrine and marshy sediments.

4. HYDROGEOMORPHOLOGICAL CHARACTERISTICS. THE DRAINAGE NETWORK

The geomorphological study has been limited to those aspects which are directly related to the humid areas, and attention has been centered upon the drainage network (Fig. 1).

The form of this network is conditioned by tectonic structure and the nature of lithologic material. The gullies and ramblas flowing into the "Canal" follow grabens perpendicular to it.

The North sector of the Canal is partially drained by a collector of little substance, the Barcal gully, which flows into the Escalona river after a large fall. The principal streams which intermittently reach the northern half of the "Canal" are the Olivares and Pelotero gullies, which construct the present-day alluvial fans. They have shaped a local, anthroposized, course, only slightly incised in the northern part (Dupré *et al.*, 1985). These flows, in part of karstic origin, coming from the Caroig aquifer fall into the Barcal with a drop of over 50m. They construct a significant travertinic edifice, which occupies the whole of the front of the Canal. Presently, at wet times, the waterfall can be seen functioning, and travertine being formed. ESR datations from samples taken at one of the deepest and most internally parts of the travertine fall pointed to 52.1 and 53.4 ka. Other more external samples were holocene. From the plioquaternary tops (Ríos *et al.*, 1980) of the triassic hills down to the present-day waterfall there is a clear sequence of staggered travertine levels. The creation of lithochemical deposits continues today also in the Bolbaite, largely due to the contrastive climate and to the chemical composition of the calcareous waters, of normal temperature, that drain the Caroig.

The southern section is presently drained by the Bolbaite-Sallent river, but there are clear signs that it was not always so. The ancient alluvial fan of the Rambla del Riajuelo formed the southwestern closure of the Canal in the past (Carmona *et al.*, 1989). Later, the network became incised and affected by headward erosion (Fig. 1).

The palaeonetwork: Fieldwork and TL datings realized on deposits in the area allow some temporal limits to be established (La Roca *et al.*, 1989). The incision in the upper course of the Bolbaite began at the end of the Upper Pleistocene. The filling of the Rambla Bolbaite upstream of Chella is Upper Pleistocene. This fluvial conglomerate, which forms the southern enclosure of the Navarrés marsh, erosions the top of a red paleosoil TL datated as 98 $^{+}/_{-}$ 15 ka (Proszinska-Bordas, H., 1986).

The at present incised Riajuelo fan worked during the Upper Pleistocene (Carmona *et al.*, 1989) and the incision began at the end of this period. Therefore in the western part of the Canal the incision took place during the Holocene. At the central course of the Rambla Bolbaite general topography, stratigraphy and the sequence of terraces point to an earlier incision, favoured on the soft Keuper rocks. The middle pleistocene terrace deposits contain a high quantity of travertine fragments.

The Navarrés marsh.

The ancient Navarrés lake was to be found between the fans of the Rambla de Olivares to the North and the deposits of the Rambla Bolbaite, which although cut through, still act to close off the South. To the East, a tertiary hillock delimits the space. In other times it might have been connected to the group of playa-lakes at the farther reaches of the small fans but the progradation of the northern fan came to cut this connection.

The detailed analysis of the aerial photograph reveals the coincidence of the peat bog with a depressed area. Multiple water sources fed the drilled area:

1) Palaeochannels on the Upper Pleistocene fan of the Olivares indicate flows originating from the North. 2) Flows have originated occasionally to the South from a

palaeo-Bolbaite. This fact is also underlined by the existence of palaeochannels. 3) A small drainage basin empties directly into the depressed zone, and despite its dimensions, its slope is sufficient to justify the arrival in the depression of energetic flows. 4) Finally the type and thickness of the lacustrine sediments of the Canal de Navarrés (Unit I, Fig. 4) and the parallel with the nearby Albufera de Anna lake (Rosselló, 1995), both point toward a subterranean feed into the wetland called "Fuentes secas" (dry springs).

The 20th of June of 1792 the valencian naturalist Joseph Antonio de Cavanilles noted in his unpublished diary: "Water abundance [in la Canal de Navarrés] results in abundant crops. Water springs from southern located marshes and at the top of the basin in four major areas with springs called "Loca", "Negra", "Mansa", and "Del Pescado", which end up in a common channel or river to, later on, aplit into four drainage ditches. Except for the marshes, all the soil is red, clayish, and compact, ... Befor man settled in this district, when farming was not a practice, water flowed freely downslope, stagnating and rottening in many areas, feeding the bulrush and other plants where frogs took shelter. But ... man started to manage water and so marshes dried up, and the precious land was exploited. Indeed, practically all marshes are cultivated today ... Navarrés waters flow northbound: they always run downwards together with the fields, amidst which a waste stream is formed after irrigation which later joins the Escalona River." (Cavanilles, 1792, f. 66 r).

5. STRATIGRAPHY AND SEDIMENTOLOGY

The core Navarrés 1 (N1) offers a sequence of 25m depth, from which 40 samples were obtained for sedimentological analysis. Its general lithological characteristics allow the division of the record into ten sedimentological units, which are described from the base to the top (Fig. 4)

Unit X (Sedimentological samples 1 and 2). 4m thick. Massive silty sediment, with diffuse spots of grey clays, probably due to bioturbation. Small dispersed carbonated nodules can be distinguished. It corresponds to diffuse rainwash, frequent in flood plain areas.

Unit IX (Sample 3). Thickness 1m. In clean contact there is a massive consolidated homometric sandstone, yellowish-white in colour. On top a centimetric calcrete is found. Transport is by concentrated flow. The depositional processes probably corresponds to a sandy channel fill.

Unit VIII (Samples 4 to 8). 2.50m thick. A series of levels of similar characteristics: predominantely clay and silt. Sedimented by slow settling, always in an alluvial environment. Intercalated streaks of white loam appear to fill in a pattern of disseccation cracks previously formed in the sediment.

Unit VII (Samples 9 to 15). Total thickness 4m. Marked contact with the previous unit. It begins with white cemented sandstones with laminar structures upon which a conglomerate of rounded heterometric pebbles is deposited. At the top (sample 12), well sorted grey sands, including small size gravels. This sedimentary episode of fluvial facies and high energy is interrupted in sample 13, which corresponds to a reddish muddy-clayey material with decantation facies deposited in erosive contact. At the top, there are again, well sorted sands and gravel layers which correspond to an increase in water transportation energy. The whole unit shows a fluvial facies.

Unit VI (Samples 16 to 18). Thickness 2.5m. Clayey, muddy sediments transported in a low energy environment with phases of decantation inside an alluvial setting. In sample 18, disseccation cracks are detectable, later filled in by clearer material. At this level (18) a dating by Tl is obtained of 112,000 +/- 17,000 yr B.P. (Wa 24-93)

Unit V (Sample 19 to 22). Thickness 2.50m. Deposits of pebbles of fluvial origin and a sandy matrix, of fine size at the beginning and then progressively larger toward the top. These materials, transported in energetic, concentrated flows, show intercalations of oxides. Their compactness is at a maximum in sample 21. At level 22, (clay deposits) there is a transition toward the following phase. In sample 22 a dating was obtained by Tl of 107,000 +/- 16,000 yr B.P. (Wa 23-93)

Unit IV (Sample 23 to 26). Thickness 1.5m. Very homogenous deposit. Made up of limestone elements of between 5 and 6cm in size, of subangular morphology, which include some gravels. This is all held together in an open, sandy/muddy matrix. It corresponds to a gravitational transport mechanism of debris flow type. This kind of sediment is only present in this unit.

Unit III (Sample 27 and 28). Thickness 2m. Grey loam (50% clay), with laminar structures and decantation processes. Lacustrine facies. Clean contact with respect to the previous unit.

Unit II (Sample 29 to 35). Thickness 3,50m. In erosive contact with the top of the preceding unit, this layer persistently presents fluvial facies of differing subenvironments. At the base (samples 29-32) there is a conglomerate formed by pebbles, with abundant remains of terrestrial gastropods. Sample 32, which is sandy/muddy with similarly fluvial traces, tops this phase. Above it, sample 33 implies a brief interruption of the described characteristics, giving way to phases of decantation probably corresponding to a lacustrine environment. At the top (samples 34 and 35) there is a new sandy contribution which at the beginning presents abundant oxide laminations and which terminates with the inclusion of organic remains, as well as numerous molluscan fauna typical of shallow lacustrine environments. Gradual contact

Unit I (Sample 36 to 40). 2.50m thick. Overall top of the deposit. It is a sandy/muddy zone which corresponds to decantation in a lacustrine environment. It begins (sample 36) with a level of peat whose contents of organic matter decreases clearly in sample 37, composed of greyish organic muds.

Comments

The sedimentological study (Fig. 4) highlights the following features: a) The sedimentary units frequently present high energy fluvial facies (bottom of the channel). Units IX, VII, V and II belong to this group. This feature points to the existence of an exorheic palaeovalley, drained by free flows of high energy. b) This behaviour alternates with episodes of possible morphogenetic stability in which the energy ostensibly decreases

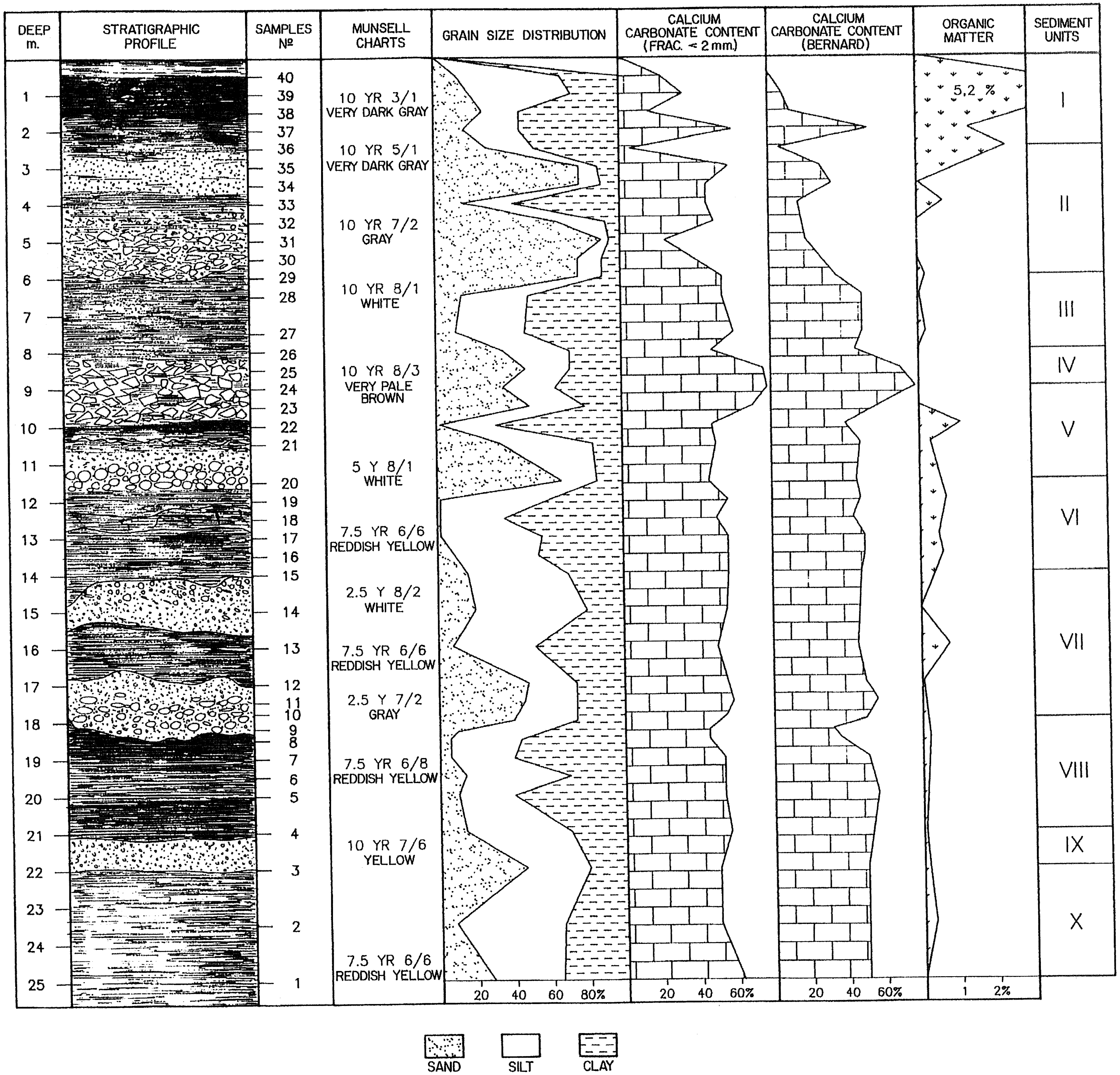

Fig. 4. Stratigraphy and sedimentological curves.

Stratigrafia e curve sedimentologiche di alcuni taxa.

and gives way to diffuse rainwash and frequent phases of decantation of fine sediments (this is the case in units X, VIII, VI). c) Only in one unit (IV) do we find evidence of lateral contributions from the slopes of colluvial-alluvial origin. d) Only the first unit corresponds with certainty to a sedimentary lacustrine environment of shallow water. Unit III may have a similar origin, but with the obvious difference of the absence of peat. e) Only in the case of Unit I can the existence of conditions favourable to the formation of peat inside a reducing and not oxidizing environment be detected. f) The absolute chronology clearly informs us that the endorheic conditions of the Canal are possibly sporadic, and develop thanks to the filling in of the valley which proceeds from the sediments of the surrounding mountains. This is by way of alluvial fans generated by active meteorization especially during isotopic stage 6 or in the middle or end of the Pleistocene.

6. MICROPALEONTOLOGY

The group of fossil organisms which are represented in the Navarrés series includes ostracods, molluscs (gastropods, bivalves) and charophytes. Pollen and unidentified plant remains appear above all in the peaty levels.

The first fossil remains are located a 4.30m of depth, in which fragments of ostracods and gastropods (*Melanopsis* sp.) are mixed with pyritised materials. This appears to correspond with times of flooding in the evolution of the basin. After some levels with thick abundant detritic material, at 2.20m of depth there is a clearly established grouping of macro and microorganisms which remains until the end of the series.

We find principally the following three species of ostracod: *Candona* sp., *Loxoconcha* sp. e *Ilyocypris gibba* (Ramdohr). These are very abundant and are accompanied by fragments of unidentified gastropods. The fossil gastropods subsequently come to dominate the series. The more frequent species among these are: *Melanopsis dufouri* (Fer.), *Theodoxus fluviatilis* (Linné) and *Bithynia* sp.

Melanopsis dufouri is a thermophilous species that lives in the annual isothermal regions between 14 and 15ºC, and shows preference for well oxygenated waters. It generally appears in water of high carbonate and calcium content, with a pH of between 7.1 and 8.4. *Theodoxus fluviatilis* is less temperature dependent, but is less tolerant of high salt content (Martínez-López et al., 1987; Usera et al., 1990). *Ilyocypris gibba* lives in permanent fresh water and in silty, muddy bottoms.

There are times, however, when fossil remains do not appear, as at the level of 1.80m of depth. In other cases ostracods are not to be found (from 2 to 1.40m). At -1.40m *Ilyocypris gibba* reappears as the only species of the group and continues to be frequent up to 1.15m, where the number of valves is particularly high. Ostracod remains do not reappear until the ceiling of the series, and they are only a very few fragments which do not allow identification of the species.

The fossil molluscs are very abundant in these last metres of the Navarrés series. At -2m, -1.25m, - 0.95m (with numerous *Melanopsis*) and -0.75m their abundance is noteworthy mostly in the peaty levels.

The charophytes appear at -1.40m, -1.15m and later from -0.85m until the top of the series.

Interpretation of micropaleontological information.

The lower levels of the Navarrés series, which present a predominance of thick detritic material, correspond to a high energy level in which it is unlikely that organisms found in the upper levels could live. If they could, however, their preservation would be difficult in this kind of environment. Only at -4.30m do we find fragments of ostracods and gastropods, bearing witness to a moment of lower energy with stagnation of the water.

It is from 2.2m onwards that conditions are established such that the almost continuous development of fauna and flora in a calmer environment is allowed. Here, there is significant carbonate content and low salinity, in which ostracods are abundant. They are represented by three species, along with gastropods. These characteristics of the basin seem to be generally maintained until the top of the series, with ostracods being dominant in some cases and gastropods in other, above all in those levels with greater peat content.

7. PALYNOLOGY

The principal arboreal pollen are *Pinus* and *Quercus*. They are accompanied, although somewhat scarcely, by thermo and mesomediterranean taxa. Poaceae are the most abundant herbaceous types, followed by Cyperaceae, *Plantago*, *Artemisia*, Chenopodiaceae, Asteraceae, etc.

The results have been presented in two synthetic pollen diagrams of selected taxa (Figs. 5 and 6). Mesophilous trees include: *Alnus, Ulmus, Salix* and *Fraxinus*. Mediterranean shrubs: *Olea, Phillyrea, Pistacia, Myrtus, Cistus, Ephedra* t. *fragilis* and *Genista* type.

Two major pollen zones can be easily recognized (Figs 5 and 6). The lower spectra (N1PA and N2PA) show a clear predominance of pine above other tree taxa, and the upper spectra (N1PB and N2PB), reflects the strong development of the mainly evergreen *Quercus*. The upper spectra are also notable for the greater representation of Mediterranean shrubs and mesophilous trees, as well as the development of *Plantago*. *Artemisia* is, by contrast, better represented in earlier times. The significant development of Cyperaceae, Zygnemataceae and *Typha*, as well as greater diversity must be pointed out (N1PB and N2PB).

In a previous work (Carrión and Dupré, 1996), a lack of correspondence between the variation in percentages and concentrations was demonstrated for the two cores. This is not surprising if the concentrations are considered to depend mainly on the rate of sediment accumulation. This implies that the taphonomic processes are very important in Navarrés, where a relatively shallow deposit corresponds to a very long time lapse (Fig. 2). The relative changes in the tree cover are reflected in the AP/NAP percentage better than in concentration curves, above all when considering that the AP and NAP show concordant fluctuations. In consequence, the environmental interpretations have been based principally upon the percentage curves.

Navarres Core I

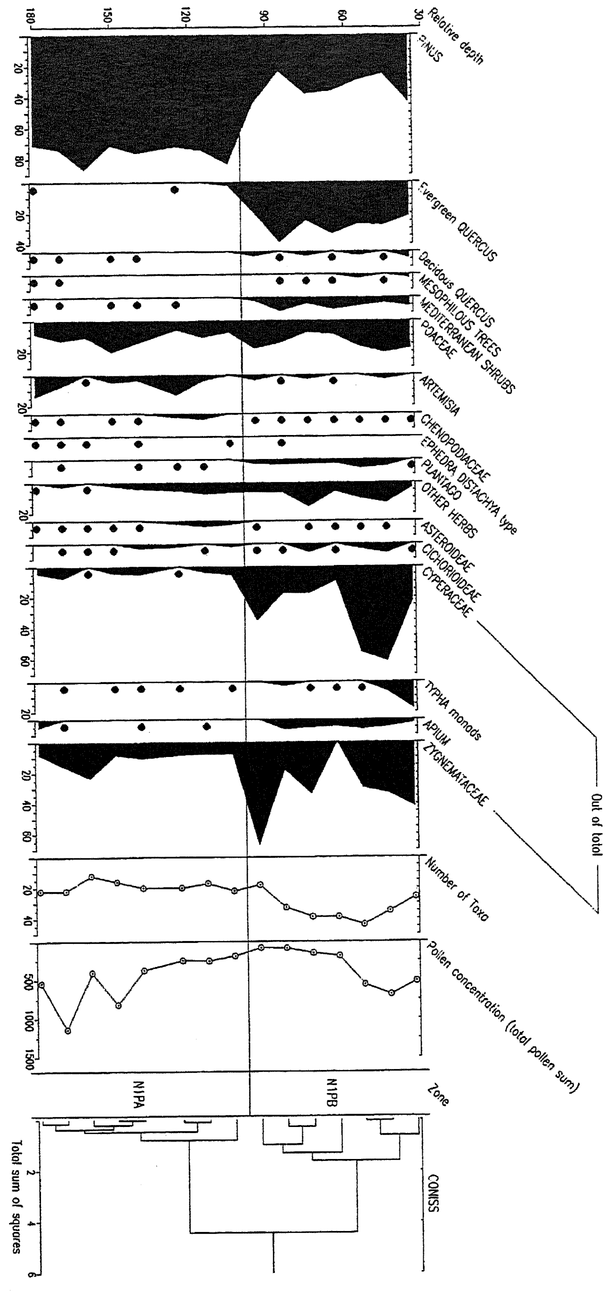

Fig. 5. Pollen diagram of selected taxa of Navarrés 1 core.
Diagramma pollinico di alcuni taxa della carota Navarrés 1.

Navarres Core II

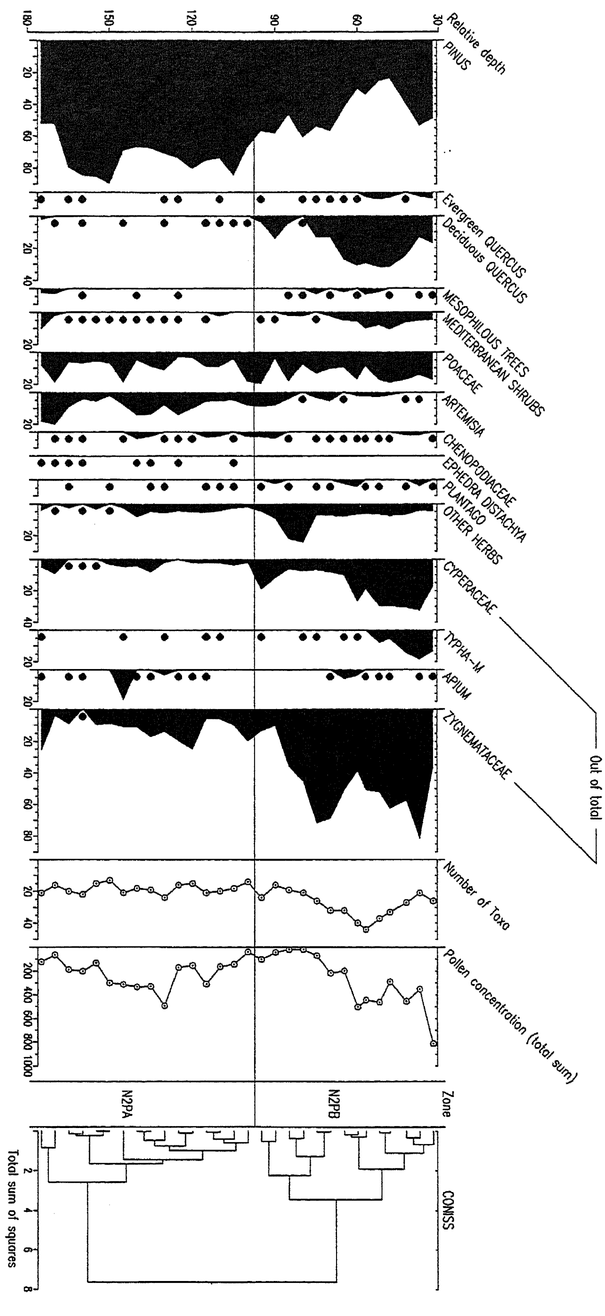

Fig. 6. Pollen diagram of selected taxa of Navarrés 2 core.
Diagramma pollinico di alcuni taxa della carota Navarrés 2.

Interpretation of the diagrams Throughout a period of climatic fluctuations of small magnitude, and despite slight changes which might be related to the schemes of occidental Europe, the fact that changes in the model of *in situ* vegetation from the start of the sequence are not recorded is particularly striking.

Pinus predominates from the first moments of the sequence, some 15,000 to about 5500 years B.P., when we witness a significant development of evergreen oak and hygrophytes, a decrease in the steppic taxa and a greater taxonomic diversity. The substitution of *Pinus* for *Quercus* is usually recorded beforehand - for example toward 12,500 BP in Padul (Pons and Reille, 1988).

The environmental conditions of the Atlantic have favoured the competition of *Quercus* against *Pinus*, especially if it would have been Austrian pine (*Pinus nigra*). Today we can find Austrian pines, coexisting with thermophilous taxa, some 175 km north of Navarrés, and the same height, but only 15 km from the sea. Anthracology shows that *Pinus nigra* was represented at the beginning of the Holocene (Badal, 1995). In part, its substitution by *Pinus halepensis* with the first deforestation and anthropic pressure can be explained by the fact that it cannot compete after fires, with *Pinus halepensis* (Trabaud and Campant, 1991).

The distinct pine areas gave way to mixed oak zones with Mediterranean undergrowth, including kermes oak. In Navarrés, the development of *Quercus* begins some 800 years before the settlement of man, and it seems reasonnable to expect that towards the end of the Atlantic period there were formations of holly oak (*Quercus rotundifolia*) accompanied by thermo and mesophilous species, including kermes oak (*Quercus coccifera*) and groups of gall-oak (*Quercus faginea*) in the cooler areas. One of the greatest shortcomings for both palynology and anthracology in these semiarid areas is the impossibility of distinguishing between *Quercus rotundifolia* and *Quercus coccifera*. When the human impact was first felt, with the establishment of the Ereta del Pedregal, the *Quercus rotundifolia* areas receded, being partly substituted by bushy growths, groups of kermes oak (*Quercus coccifera*), pines (*Pinus halepensis*) and agricultural fields. The general oak areas reached their maximum at times of heavy anthropization. The initial tree growths of *Quercus rotundifolia* gave way to shrub vegetation of predominantly the same genus (*Quercus coccifera*). Indicators of shrubby formations include *Pistacia, Olea, Buxus, Myrtus, Cistus, Helianthemum*, Ericaceae and Lamiaceae. Indicators of arboreal formations include *Fraxinus, Alnus, Betula, Corylus* and deciduous *Quercus* (presumably *Quercus faginea*) among others. In any case it is likely that *Quercus* were mainly shrubby, because their development coincides with peaks of both Mediterranean shrubs and heliophytic herbs.

8. CONCLUSION

1) In the geomorphology of the Canal de Navarrés, the difficult drainage stands out, due to the small degree of longitudinal gradient in the valley and to fluvial, alluvial, colluvial, lacustrine/marshy and lithochemical material which has filled it, coming from the relief framework. This badly organised network has been above the base level (Xúquer with Escalona and Bolbaite) at least since the Upper Pleistocene.

The filling is derived from streams, alluvial fans, glacis, and peat bogs deposition, and also has a temporal projection which is manifest in the stratigraphic column of the cores N1 and N2.

2) Sedimentological analyses reflects, along general lines, a filling in of this area of the valley by alluvial and colluvial material transported by high energy flows of an intermittent or ephemeral nature, with a tendency to flooding in the upper part of the record, which chronologically corresponds to the Upper Pleistocene and Holocene.

3) The Navarrés lake occupies a small depression, between alluvial deposits. This is in accord with the continued filling in which is reflected in the sedimentological column and the change to lacustrine environments (units III and I), whilst beside this the debris construct fans or glacis.

4)The lacustrine environments recognised in the drilling show different characteristics:

The first level (unit III), from the Upper Pleistocene, corresponds to a playa-lake type environment: there is no peat, but there is precipitation of calcium carbonate and abundant mud deposits.

The second (toward the half way mark of unit II), still inside the Upper Pleistocene shows similar characteristics. After a detritic phase, the area floods again and is colonised by *Melanopsis* sp amongst others. All this appears to indicate a dynamic change in an environment of playa-lakes and fans.

c) The lake (unit I) had subterranean supply. The presence at the base of *Melanopsis dufouri*, a thermophilous species which inhabited this lake in one of the coldest periods of the Upper Pleistocene (18,360 +/- 195), supports the idea of the presence of spring waters.

5) Between approximately 11,000 and 8000 B.P. - extrapolation calculated by the speed of sedimentation (Fig. 2) - the waters are clear and fresh. Significant communities of ostracods and charophytes are present. The pollen sequence shows few changes in the types of vegetation from the beginning of the Holocene. From about 15,000 B.P. *Pinus* is predominant, yet its presence cannot be attributed to anthropic action, but rather to a climax until approximately 5500 B.P.

6) Towards 5000 BP, (from -1.05m) the ostracods disappear definitively. Anthropic pressure now begins, with greater erosion and increment in the speed of mud sedimentation. At -0.95m *Melanopsis dufouri* becomes very abundant once again, now in peaty levels - a marshy environment - which become filled-in gradually with fine sediment in the presence of man.

The change from *Pinus* to *Quercus* is recorded some 800 years before the establishment of the Ereta del Pedregal village, and somewhat later than in other Mediterranean areas. *Quercus* could have corresponded to holly oak, kermes oak or both, the first favoured by the climatic conditions of the Atlantic period and the other by anthropic pressure which supported the change from open tree cover to thermo and mesophilous thicket vegetation.

7) Around 4000 B.P. (-0.85m), the charophytes become abundant once more, perhaps in a moment of decreased erosion when the overriding tendency was that of filling in the lake. The Zygnemataceae curves, which experience an augmentation even in previous times (about 5500 B.P.), point to a greater eutrophication of the water. The hygrophytes which then developed in the valley, the augmentation of the rate of sedimentation and the presence of *Glomus* also seem to indicate times of greater erosion related to anthropization.

In general terms, at the end of the Upper Pleistocene and during the Holocene, the competition of trees was between *Pinus* and *Quercus*, which were always accompanied -albeit in much smaller quantities - by other thermo and mesophilous taxa. The importance of local factors must be pointed out (climatic changes, soils, blight, fires, anthropogenic disturbance, competition, etc.), which are largely responsible for the vegetal mosaic characteristic of the Mediterranean basin. The substitution of one for another cannot be explained here solely by the climate, as this part of the Iberian Peninsula seems not to have experienced drastic changes during this period; nor can it be explained solely by anthropic action. Such changes in vegetation will require further research. Finally, and since we found evidence of the climax of *Pinus* from about 15,000 B.P. to 5500 B.P., another implication of our results is the need to reexamine certain phytosociological concepts such as the generalisation of the Quercus climax during the larger part of the Holocene.

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REFERENCES

E. Badal (1995) - *La vegetación carbonizada. Resultados antracológicos del País Valenciano.* In El Cuaternario del País Valenciano, p. 217-226. Universitat de Valéncia.

P. Carmona, M.P. Fumanal and N. La Roca (1986) - *Paleosuelos pleistocenos en el País Valenciano.* In Estudios sobre Geomorfología del S. de España, p.43-46. Murcia.

P. Carmona, M.P. Fumanal, R. Julia, H. Proszynska-Bordas, A. Solé and M.J. Viñals (1989). - *Los paleosuelos cronoestratigráficos.* Actas 2 Reunión de Cuaternario Ibérico, Madrid, 25-29 sep.

J.S. Carrión, and M. Dupré (1996) - *Late quaternary vegetational history at Navarrés. Eastern Spain. A two core approach.* The New phytologist.**13**, p.177-191.

A.J. Cavanilles - *Diario de las excursions del viaje a Valencia,* 20-III-1972/17-VIII-1792 (leg: XIII, 7, 1) microfilm de los manuscritos depositados en el Archivio del Real Jardin Botanico de Madrid (A.R.J.B.).

M. Costa, (1986) - *La vegetación en el País Valenciano.* **5**, 246 p., Universitat de Valéncia, Valencia.

M. Dupré (1992) - *Palinología.* Cuadernos Técnicos de la S.E.G., 30 p., Logroño.

M. Dupré, M.P. Fumanal y N. La Roca (1985) - *Modifications de l'environnement endoreique: la tourbière de la Canal de Navarrés (Valencia, Espagne).* Cahiers Ligures de Préhistoire et de Protohistoire, N.S. n. **2**, p.297-311.

D. Fletcher, E. Plá and E. Llobregat (1965) - *La Ereta del Pedregal (Navarrés, Valencia).* Excavaciones arqueológicas en España, **42**, p. 3-21.

M. Girard, and J. Renault-Miskovsky (1969) - *Nouvelles techniques de préparation en Palynologie appliquées à trois sédiments du Quaternaire final de l'Abri Cornille, (Istres - Bouches-du-Rhône).* Bulletin de l'AFEQ., **4**, p. 275-284.

E. C. Grimm (1987) - *CONISS: A FORTRAN 77 program for stratigraphically constrained cluster analysis by the method of incremental sum of squares.* Computers and geosciences, **13**, p. 13-35.

N. La Roca, M.P. Fumanal and M. Dupré (1989) - *La Canal de Navarrés (Valencia): evolución de un medio endorréico.* Actas XI Congr. Nac. de Geografía, vol. II, A.G.E, Madrid, 25-29 sep., p. 401-410.

F. Martínez López, A. Pujante and J.F. Amela (1987) - *Tipificación ecológica de Melanopsis dufouri Fer 1823 (Mollusca, Prosobranchia, Thiaridae) en el Levante Ibérico.* Actas VIII, Bienal de la Real Sociedad Española de Historia Natural, T. **I**, p. 59-67.

J. Menéndez-Amor and F. Florschütz (1961) - *Resultados del análisis polínico de una serie de turba recogidas en la Ereta del Pedregal (Navarrés, Valencia).* Archivo de Prehistoria Levantina, **IX**, p. 97-99. Valencia.

E. Plá, B. Martí and J. Bernabeu (1983) - *La Ereta del Pedregal (Navarrés, Valencia) y los inicios de la Edad del Bronce.* XVI Congreso Nacional de Arqueología, (Murcia-Cartagena, 1982), p. 239-245, Zaragoza.

A. Pons and M. Reille (1988) - *The Holocene and Upper Pleistocene pollen record from Padul (Granada, Spain): A new study.* Palaeogeography, Palaeoclimatology, Palaeoecology, **66**, p 243-263.

H. Proszynska-Bordas (1986) - *Thermoluminiscence Dating of Sediments from fossil red soils in the region of Valencia (Spain).* In Estudios sobre Geomorfología del S. de España, p.113-115, Murcia.

H. E. Reineck and I. Singh (1975) - *Depositional sedimentary environments.* Springer-Verlag. Berlin.

L.M. Ríos, F.J. Beltrán, M.A. Zapatero, J.L. Goy & C. Zazo (1980) - *Mapa Geológico de España 1:50.000. 2ª serie. Hoja Navarrés, nº 769,* IGME, Madrid, 28 p.

S. Rivas-Martinez (1987) - *Memoria del mapa de series de vegetación de España.* Serie Técnica I.C.O.N.A,268 p., Madrid.

V. M. Rosselló (1995) - *Geografía del País Valenciá.* 640 p., Ed. Alfons el Magnànim, València.

L. Trabaud and C.Campant (1991) - *Difficulté de recolonisation naturelle du pin de Salzmann, Pinus nigra Arn. ssp. salzmannii (Dunal) Franco après incendie.* Biological Conservation, **58**, p. 329-343.

J. Usera, F. Robles, F. Martínez-López and Y. Arco (1990) - *Fauna actual de gasterópodos y foraminíferos de la Marjal de Torreblanca (Castellón).* Iberus, **9** (1-2), p. 515-526. 81969.

G.S.Visher, (1969) - *Grain size distributions and depositional processes.* Journal of Sed. Petrol., **39** 3, p. 1074-1106.

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