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UNCHANGING ENVIRONMENTAL CONDITIONS DURING THE "VILLAFRANCHIAN" TIME-SPAN IN LITTORAL BASINS (EASTERN BETICS, SE SPAIN)*

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RIASSUNTO - *Condizioni ambientali costanti durante il "Villafranchiano" in bacini costieri (Betici orientali, Spagna sud-orientale)* - Il Quaternario *Italian Journal of Quaternary Sciences,* **8**(2), 1995, 383-390 - Dato caratteristico della catena dei Betici orientali durante il Plio-Pleistocene è la presenza di bacini litoranei sul lato che si affacciava verso il Mediterraneo. Il formarsi di tali bacini è legato alla progressiva emersione dei precedenti bacini tortoniano-messiniani marini comunemente accompagnata dall'instaurarsi di ambienti di transizione. In particolare, lo studio delle varie "facies plioceniche" del SE della Spagna nella zona di Murcia-Alicante (gli attuali bacini della bassa valle Segura e Campo Cartagena-Mar Menor) mostra che la loro distribuzione corrisponde all'instaurarsi di diversi ambienti sedimentari di transizione coincidenti con l'attuale posizione di questi due bacini. Le condizioni iniziali furono caratterizzate dallo sviluppo di un sistema laguna-cordone costiero per l'intero bacino. Nella zona di Campo Cartagena-Mar Menor (verso sud) la formazione di corsi d'acqua extra-bacino produsse un cambiamento da tali condizioni iniziali a quelle di un sistema di estuario-piana costiera paludosa, mentre nella bassa valle Segura le condizioni ambientali rimanevano immutate. Entrambe le zone mostrano una tendenza regressiva continua nel corso del loro sviluppo, senza – però – che siano registrati vistosi cambiamenti dal punto di vista faunistico e/o sedimentario. Fauna e dati paleomagnetici indicherebbero che lo sviluppo degli ambienti di transizione in questi bacini copre l'intervallo dal Pliocene inferiore al Pleistocene medio, cioé comprende il "Villafranchiano". Per quanto concerne i dati riportati in questo lavoro, le condizioni ambientali sembrano essersi mantenute costanti durante l'intero periodo investigato e non si sono riscontrate variazioni climatiche di spicco in questa zona della Catena Betica. Rilevanti cambiamenti paleogeografici e ambientali sarebbero avvenuti dopo l'attività tettonica della fine del Pleistocene.

ABSTRACT - *Unchanging environmental conditions during the "Villafranchian" time-span in littoral basins (eastern Betics, SE Spain)* - Il Quaternario *Italian Journal of Quaternary Sciences,* **8**(2), 1995, 383-390 - The occurrence of littoral basins along the Mediterranean waterfront of the Eastern Betics Cordilleras (SE Spain) was a characteristic feature during the Plio-Pleistocene. Their development responds to the progressive emersion of the former marine Tortonian-Messinian basins, being common the establishment of transitional environments. In particular, the study of the different "Pliocene facies" of SE Spain in the Murcia-Alicante zone (present Lower Segura and Campo Cartagena-Mar Menor basins) reveals that their distribution is matched by the occurrence of different transitional sedimentary environments coinciding with the present location of these two basins. Initial conditions were characterized by the development of a lagoon-barrier island system along the entire basin. In the Campo Cartagena-Mar Menor zone (South) the installation of feeding extrabasinal rivers brought abaut a change from this environment to an estuarine-paludal coastal plain system whilst, in the Lower Segura zone, the environment remained unchanged. Both zones show a continuous regressive trend during their development, but no dramatic sedimentary and/or faunal changes are recorded. Faunal contents and paleomagnetic data indicate that the development of transitional environments in the basin covers the interval from the early Pliocene up to the middle Pleistocene, *i.e.* including the "Villafranchian" time-span. As far as the data reported in this work are concerned, environmental conditions remained relatively constant during the studied time interval, and there is no record of relevant climatic changes in this zone of the Betics Cordilleras. Major environmental and paleogeographical changes would have been accompanied further late Pleistocene tectonic activity.

Keywords: Littoral basins; environmental conditions; Villafranchian time-span, eastern Betics, Spain
Parole chiave: Bacini costieri, condizioni ambientali, Villafranchiano, Batici orientali, Spagna

1. INTRODUCTION

The Plio-Pleistocene evolution of littoral basins in the Murcia-Alicante zone of the Eastern Betics (south-eastern Spain) is an example of unchanging environments along this time interval, where no dramatic sedimentary and/or faunal changes are recorded. Previous papers (Montenat, 1973; Goy *et al.*, 1990) indicate that the late Neogene scenery of this zone comprised a wide and irregular basin, characterized by the development of an extensive and unique lagoon-beach barrier system, which extended along the present location of the Lower Segura and Campo de Cartagena-Mar Menor basins (Fig. 1). Actually these two basins are separated by the Betic massif of Carrascoy and, further to the North, by E-W trending anticline reliefs (Fig.1) where the sediments of the former Plio-Pleistocene basin are greatly

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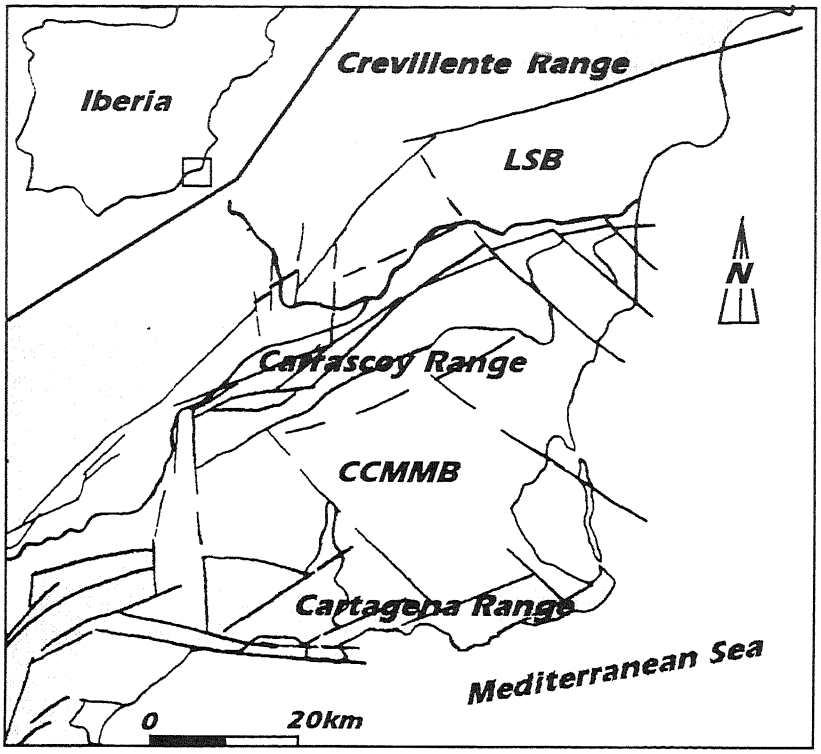


Fig. 1 - Location of the studied zone. Shaded areas are the pre-quaternary formations; white areas show Quaternary basins. LSB: Lower Segura Basin; CCMMB: Campo de Cartagena-Mar Menor Basin.

Ubicazione dell'area studiata. Le aree in grigio rappresentano il pre-Quaternario; le aree in bianco sono i bacini quaternari. LSB: Bacino del basso Segura ; CCMMB: Bacino di Campo de Cartagena-Mar Menor.

deformed. The final isolation of the Lower Segura Basin from the Campo de Cartagena-Mar Menor Basin was reached only in the middle Pleistocene, when an important tectonic event took place, promoting a strong redistribution of relief and sedimentary environment changes (Goy *et al.*, 1990; Silva *et al.*, 1993).

The sedimentary sequence of this Plio-Pleistocene basin has largely been used to state the classic Pliocene lithostratigraphy of the Eastern Betics. This was firstly established by Montenat (1973), who proposed a type sequence mainly based on lithofacies and faunal contents and consisting of two slightly unconformable main units. The lower unit (P.I) formed of marine grey-blue marls and dated to early-middle Pliocene on the basis of the microfaunal assemblage of *G. margaritae , G. puncticulata* and *G. crassaformis* (N20 of Blow, 1969). The upper unit (P.II), traditionally considered as of late Pliocene age on the basis of its malacofaunal content (*Strombus coronatus, Flabellipecten allesii,* etc.), is mostly composed of yellow calcarenites, which commonly pass laterally and upwards to variegated silts or to lacustrine limestones-marls.

This paper deals with environmental significance, paleogeographical occurrence, evolutionary trends and relationships among the different lithofacies of P.II unit of Montenat (1973) within the above mentioned littoral basin. Recent studies based on paleomagnetic and sedimentological analyses (Bardají *et al.*, 1994; 1995) show that the P.II unit lithofacies assemblage developed from the late Pliocene up to the early Pleistocene, coinciding in time with the "Villafranchian" time-span. The reconstruction of the paleogeographical and environmental evolution during this interval was possible after a detailed mapping and sedimentologic and paleomagnetic analyses. The proposed evolution model has relevant interest because important climatic and environmental changes are reported to have occurred in the Mediterranean domain during the "Villafranchian" time span, contrasting with the results exposed here, which do not evidence important changes except for those promoted by further Pleistocene tectonic activity.

2. ENVIRONMENTAL CONDITIONS: DATA FROM THE SEDIMENTARY RECORD

The large Plio-Pleistocene littoral basin studied in this work presents a continuous sedimentary record covering the interval from early Pliocene to late Pleistocene (Fig. 2), which has allowed us to recognize the occurrence of different although similar sedimentary environments and to reconstruct the basin's evolution during the "Villafranchian".

In particular, detailed mapping, stratigraphical and sedimentological analyses of the different lithofacies have shown that their spatial distribution is not casual and that only the calcarenitic bodies outcrop all along the entire basin whilst variegated silts and lacustrine limestones have a very specific geographical distribution. Variegated silts are characteristic of the northern portion of the basin (present Lower Segura Basin) outcropping along the NW side of the Carrascoy Range and within the present E-W trending anticline reliefs, whereas lacustrine limestones outcrop only along the SE side of the Carrascoy Range (present Campo Cartagena-Mar Menor Basin).

Present dichotomy in the geographical distribution of the outcrops of these two Pliocene "lithofacies" talks about the occurrence of two similar transitional environments with different depositional dynamics in the large Plio-Pleistocene basin. In the present Lower Segura Basin, systems of lagoon-barrier island developed with

no external influence of feeding streams. On the contrary, in the area of the present Campo Cartagena-Mar Menor Basin, the environment was that of an estuarine-paludal coastal plain fed by important rivers and closed towards the sea by barrier island systems. In spite of the presence of different depositional dynamics within the Plio-Pleistocene basin, its sedimentary sequence records similar climatic and/or tectonic trends with no important changes. In both northern and southern parts of the former Basin, sedimentary sequences show a clear regressive trend (Fig. 2) that could have been triggered by a continuous tectonic uplift and/or by a progressive sea-level lowering. Major differences steam from the extrabasinal sediment supply (feeding rivers) developed in the Campo Cartagena-Mar Menor Basin.

2.1 Northern zone (present Lower Segura Basin)

The characteristic transitional environment developed in this zone is mainly that of a lagoon-barrier island system. In the sedimentary model (Fig. 3A) the "pliocenic" facies match with the different sub-environments of this system as follows: i) variegated silts represent a lagoon sub-environment; ii) yellow calcarenites correspond to the barrier island or beach-barrier bodies; and finally, iii) grey-blue marls represent the open marine environment. Anyway, these latter lithofacies are to be referred to the early Pliocene only, and in most cases they are overlaid by "facies" properly belonging to the lagoon-barrier island system.

Mutual relations among different facies and their spatial distribution show that this environmental system was shifting towards the sea, which caused a repetition of lithologic and sedimentary facies in space and time (Fig. 4). This fact brought about also pronounced heterochronism of "facies," which cannot thus be considered as chronostratigraphic but just as lithostratigraphic units. This dynamics has had as a consequence the development of a continuous sedimentary record with no important internal unconformities in this part of the basin. Two gently unconformable transitional units have been distinguished in this zone (Bardají *et al.*, 1994; 1995) (Fig. 2): (from bottom to top) a) Lower Segura Transitional Unit, made up of properly lagoon-barrier island facies; and b) El Moncayo-El Molar Transitional Unit, with similar facies assemblage, but with a marked extrabasin influence recorded by the calcarenitic facies detrital contamination and the progradation of distal alluvial fan deposits (red silts) over the lagoonal sediments at the top of the unit.

2.2 Southern zone (present Campo de Cartagena-Mar Menor Basin)

The transitional environment developed in this zone is that of an estuarine coastal plain closed by beach-barrier systems, triggering the development of paludal lakes within the estuarine zone and between it and the beach-barrier system (Fig. 3B). Anyway at the bottom of the sedimentary sequence of this zone, lagoon-barrier island sediments, similar to those developed in the northern zone, are recorded (Silva, 1994). These systems also show calcarenitic bodies and variegated silts as characteristic facies (Fig. 2). In this sense, initial environmental conditions were similar along the entire basin, leading to the development of similar lagoon-barrier island systems in both the northern and southern parts of the basin .

The main difference between the two lagoon-barrier island systems developed in the basin, steam from the record of an anomalous input of extrabasin detrital (metamorphic and mesozoic limestone grains) and reworked microfauna (cretaceous microforaminifera) at the top of the variegated silt "facies" in the Campo Cartagena-Mar Menor Basin (Silva, 1994). This fact indicates the presence of a former extrabasin drainage coming from the Subbetic mesozoic limestones and pouring into this zone of the basin (Fig. 4A). Nowadays, the Subbetic outcrops closer to the Campo Cartagena zone are at up to 50 km to the west; thus the only drainage able to transport Subbetic materials and microfauna would be the Guadalentín River (Silva, 1994), a E-W transverse stream which has its headwaters in the Subbetic zone of the Betic Cordilleras (see Fig. 1).

A further progressive progradation of the Guadalentín River towards the sea (to the East), led to the development of the estuarine-paludal coastal plain environment mentioned above, where the "lacustrine" limestone facies (white limestones and marls) matches with paludal lakes and/or lagoonal sub-environments (Fig. 4B). In particular, the development of rich-in-carbonate sub-environments in this part of the basin was a direct consequence of the heavy supply of calcareous materials conveyed from the Subbetic limestone source area by the Guadalentín River. Metamorphic and Subbetic sands are "facies" very characteristic in this zone of the basin which match with riverbed and sand plain sub-environments (Fig. 3B). Yellow calcarenites, representing the beach-barrier sub-environments, are also common and very often overlie the marl and limestone facies. Characteristic feature of this superposition is a pseudo-gley red soil intercalated between the calcarenite and marl and/or limestone facies (Fig. 3B).

This coastal plain environment also records a regressive trend in its development similar to that recognized for the lagoon-barrier island system in the northern zone (Lower Segura Basin), although the tectonically induced activity of the feeding fluvial system in this area caused sudden changes not recorded in the other part of the basin. In this zone, a sudden sedimentary progradation of the feeding fluvial system is recorded as apparent rapid regressive episodes (extensive development of red soils) followed by false rapid transgressive episodes (red soils buried by calcarenitic bodies) when the system comes back to its "normal" progressive-regressive trend (Fig. 3B). Such as in the northern zone, the regressive

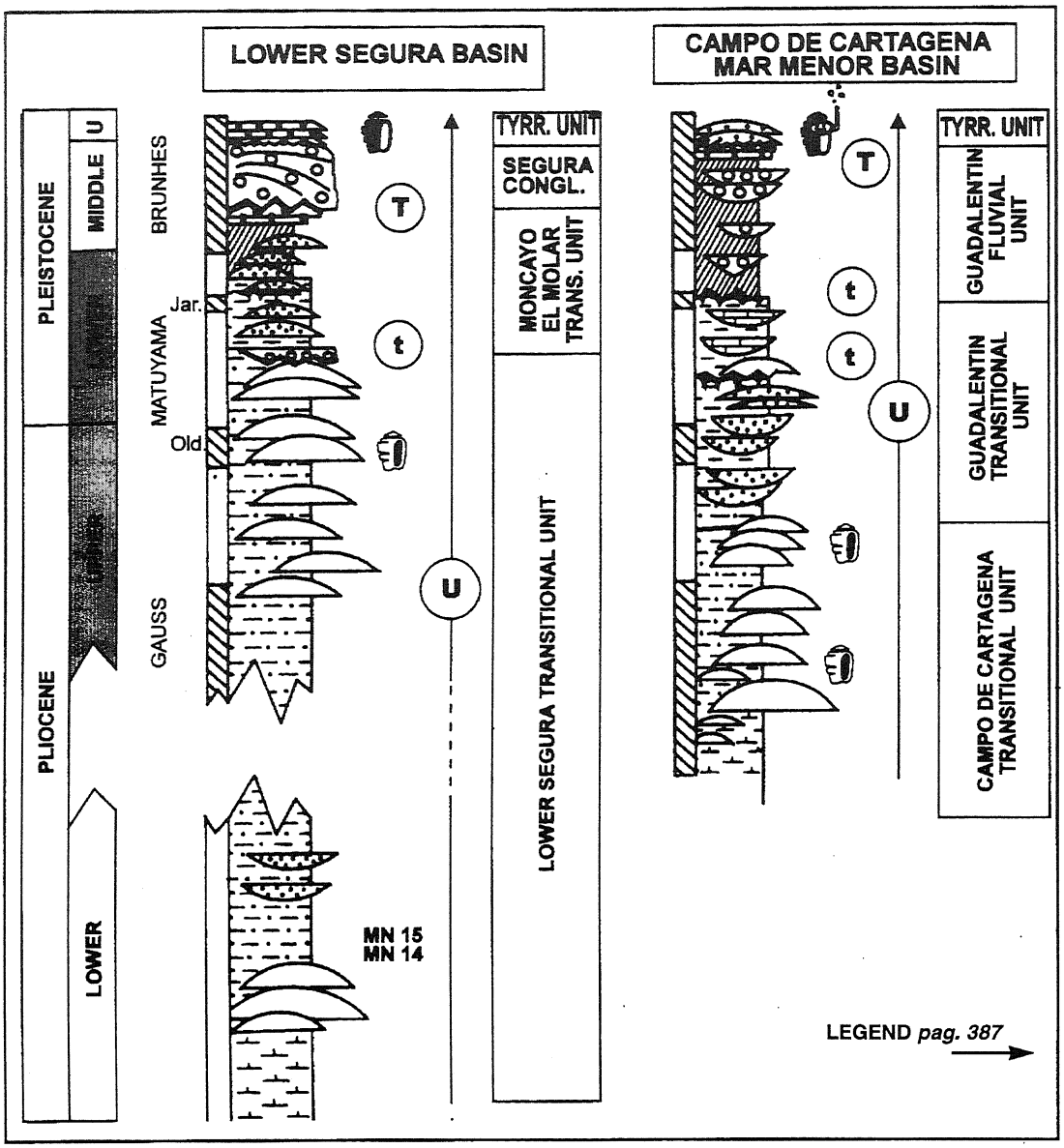


Fig. 2 - Schematic representation of the Plio-Pleistocene sedimentary records of the Lower Segura and Campo de Cartagena-Mar Menor Basins. Shaded area = studied time interval. See Legend on page 387.

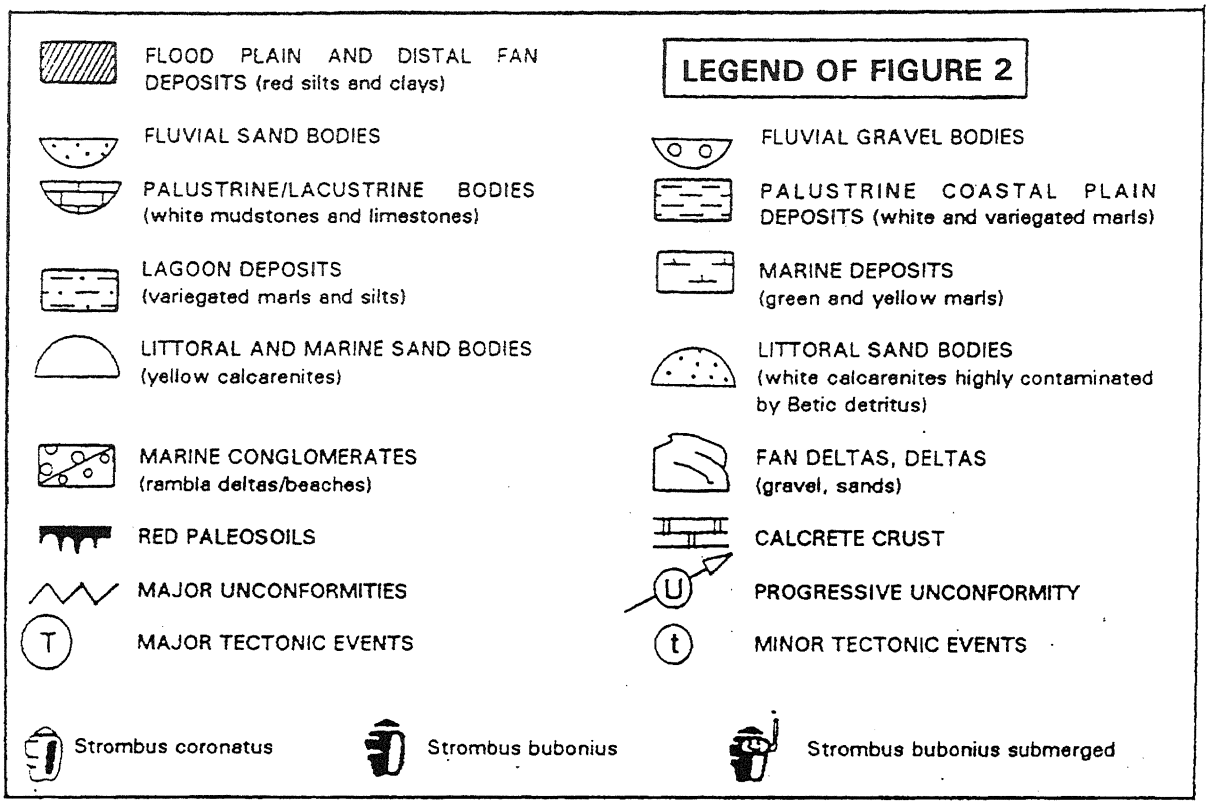
Rappresentazione schematica della stratigrafia del Bacino della bassa valle Segura e del Bacino di Campo de Cartagena-Mar Menor. L'area retinata rappresenta l'intervallo di tempo studiato. Per la Legenda vedi pag. 387.

trend gave rise to a marked heterochronism of facies. In the southern zone of the basin two characteristic transitional units attributed to the "Villafranchian" interval have been distinguished (Silva, 1994), *i.e.* (from bottom to top) (Fig.2): i) the Campo de Cartagena Transitional Unit, made up of the lower lagoon-barrier island facies; and ii) the Guadalentín Transitional Unit, made up of the estuarine-paludal coastal plain facies. The mutual disposal of the units proves the existence of a relevant progressive unconformity, heavily controlled by tectonics in the regressive trend of the sedimentary sequence.

3. CHRONOLOGICAL BASIS: FAUNAL AND PALEOMAGNETIC RECORD

The chronology of the sedimentary sequence in the Lower Segura Basin zone has been stated on the basis of the faunal contents as given in the literature for the different units (Montenat, 1973; Montenat & Crussafont Pairó, 1970; Montenat & De Bruijn, 1976) and on paleomagnetic data (Bardají *et al.*, 1993; 1994; 1995).

The following foraminifera have been identified in outcropping grey-blue marls: *Globorotalia margaritae, G.*



puncticulata and *G. crassaformis,* which allowed us to define the respective biozones indicating an early-middle Pliocene age (Montenat, 1973; Montenat *et al.*, 1990).

Montenat & Crussafont Pairó (1970) report the appearance of *Hipparium* cf. *crassum* [MN14 of Mein (1975)] at the base of the variegated silts unit. Likewise the rodent association *(Ruscinomys* cf. *europeus, Stephanomys* cf. *minor, Cricetus* cf. *barrieri* [MN14- MN15 of Mein (1975)] found at La Juliana (Montenat & De Bruijn, 1976) in the same unit indicates a Ruscinian (early Pliocene) age. On the other hand, the occurrence of *Chlamys glabra* at the top of this unit points to a quite younger age. In the Mediterranean area, this species appear in Plio-Plesitocene deposits and in Spain it usually indicates an early Pleistocene age. These paleontological observations confirm the diachronic character of the facies and support the conclusion that the whole sedimentary sequence formed in the interval from early Pliocene to middle Pleistocene.

These ages are in good agreement with paleomagnetic data (Bardají *et al.*, 1993; 1994; 1995), which show that the Olduvai-Upper Matuyama transition occurs in the upper part of the Lower Segura Transitional Unit, within the yellow calcarenites unit, and the Matuyama-Brunhes inversion takes place within the Moncayo-El Molar Transitional Unit. It is worth noting that similar paleomagnetic results have been obtained from other basins of the eastern Betics (Bardají *et al.*, 1994; 1995) where the Olduvai-Upper Matuyama transition also occurs at the top of the yellow calcarenites unit.

The lack of characteristic fauna in the Campo Cartagena-Mar Menor zone, and of a paleomagnetic study of the whole sequence, have not allowed us to date properly its sedimentary record. In this zone, chronology has then been obtained by correlating data to those of the Guadalentín Depression (Silva, 1994) and to fragmentary paleomagnetic records carried out in its sedimentary sequence (Somoza *et al.*, 1989). The only reliable data are from a paleomagnetic record of the topmost part of the sedimentary sequence carried out in the easternmost part of this zone by Somoza *et al.* (1989). The results obtained by these authors show that the Matuyama-Brunhes inversion takes place within the alluvial and fluvial sediments overlying the paludal facies in this zone of the basin. In the studied section the paludal facies show a continuous reverse polarity without recording the Olduvai-Upper Matuyama inversion. This suggests that the estuarine-paludal coastal plain environment practically lasted up to the middle Pleistocene.

On the other hand, at the base of the sequence, the variegated silts unconformably rest over a thick (up to 100 m) "messinian" sedimentary sequence composed of grey-blue marls and calcarenitic bodies (Silva, 1994). The foraminiferal contents of this deposits show the presence of characteristic messinian microfauna: *G. mediterranea, G. humerosa* and *G. accostaensis* (Montenat, 1973;

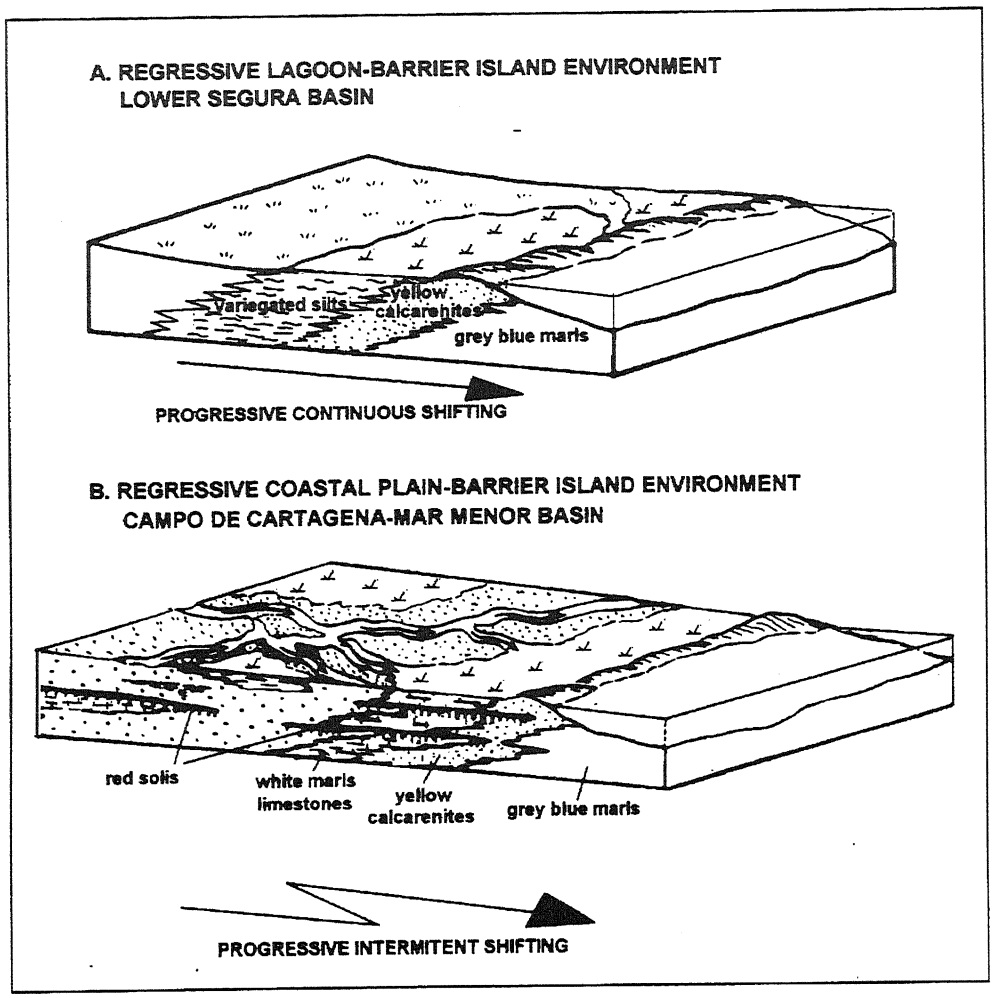


Fig. 3 - Lower Segura and Campo de Cartagena-Mar Menor Basins: environmental models during the interval late Pliocene-early Pleistocene.

Bacini della bassa valle Segura e di Campo de Cartagena-Mar Menor: modelli ambientali nell'intervallo di tempo Pliocene superiore-Pleistocene inferiore.

Larouzziere, 1985); moreover, the presence of the messinian ostracod *Peteraurila* cf. *musculus* Aruta & Ruggieri at the top of this deposits is again a characteristic datum (Silva, 1994).

All these data allow us to assume that the development of the transitional environments in this zone of the basin, and also in the northern one, covers the entire Pliocene and most of the lower Pleistocene. The time interval covered by each transitional unit in the Campo de Cartagena-Mar Menor zone is still uncertain; however, if the development of coastal plain proximal facies in the Guadalenín Depression is used for comparison, the transition between the two environmental scenarios can be placed within the upper Pliocene (Silva, 1994; Bardají *et al.*, 1994; 1995).

4. DISCUSSION

The sedimentary record of the Lower Segura Basin (Fig. 2) suggests a marked continuity in environmental conditions and depositional style in the zone. The only difference between the two transitional units of this basin is in the lithologic variations caused by the distal progradation of alluvial fans over the lagoon-beach barrier system during the lower Pleistocene, while the sedimentary environment remained essentially the same. Major disturbance of this scenery is given by the strong unconformity recorded between the El Moncayo-El Molar Transitional Unit and the overlying Segura Conglomerates, which are the uppermost middle Pleistocene Unit. These have a very special environmental and geodynamic significance, since they represent a major and sudden paleogeographic change triggered by the last important tectonic event occurred in the Eastern Betics (Goy *et al.*, 1990; Silva *et al.*, 1993). This tectonic event caused the definitive division of the former Plio-Pleistocene basin into the two present basins and the development of a fan-delta system in the Lower Segura Basin (Segura Conglomerates), which, later, during a new regressive stage, would have evolved to a fluvial plain closed by beach-dune systems during late Pleistocene-Holocene times (Goy *et al.*, 1990; Dabrio *et al.*, 1990).

On the other hand the sedimentary record of the Campo de Cartagena-Mar Menor zone (Fig. 2) shows a similar continuity. However, in this zone, the presence of a feeding fluvial system caused the initial lagoonal conditions to evolve into an estuarine-paludal coastal plain, although if the environmental conditions still had a transitional character (Fig. 4). Transition between the two sedimentary environments was progressive and no relevant climatic and/or tectonic causes can be invoked. In this case the coastal plain sedimentary record is more readily affected by environmental changes (mainly tec-

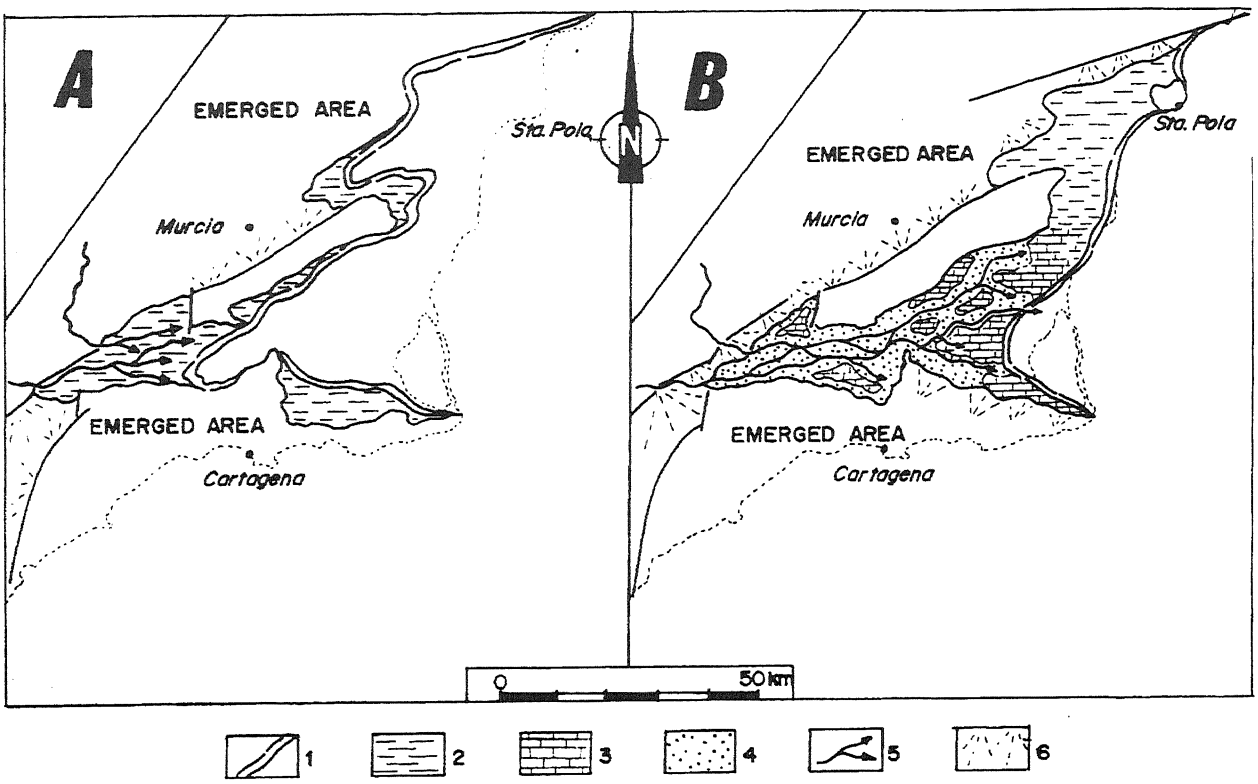


Fig. 4 - A: Paleogeographical reconstruction of the environmental conditions during the Pliocene; B: Same during the interval from late Pliocene to middle Pleistocene. The dashed line shows the present coast-line. Legend: 1 = Beach-barriers; 2 = Lagoon; 3 = Paludal lakes; 4 = Sandy coastal plain; 5 = Main feeding rivers; 6 = Alluvial fans.

A: Ricostruzione paleogeografica delle condizioni ambientali durante il Pliocene. B: La stessa nell'intervallo Pliocene superiore-Pleistocene. La linea tratteggiata indica la linea di costa attuale. Legenda: 1 = cordoni costieri; 2 = laguna; 3 = laghetti palustri; 4 = piana costiera sabbiosa; 5 = principali corsi d'acqua; 6 = conoidi alluvionali.

tonics) occurring in the surrounding reliefs. A proximal tectonically induced progradation and withdrawal of the feeding fluvial system are overprinted in the general regressive trend shown by the sedimentary sequence. This is shown as rapid regressive-transgressive episodes, which are not recorded in the neighbouring northern zone (Lower Segura) and therefore can not be explained by climatically-induced fluctuations of the sea level.

The evolution of the coastal plain during the Pleistocene is characterized by a distinct progradation of the fluvial system over the entire basin and by the changing of transitional conditions to properly terrestrial ones with the formation of the Guadalentín Fluvial Unit (Fig. 2B). Tectonic activity caused the uprising of internal reliefs in the westernmost part of the basin — which was already isolated from the Lower Segura zone — destroying the feeding fluvial system and allowing the re-establishment of the initial lagoon environment conditions, represented by the present Mar Menor lagoon (Silva, 1994).

In summary, the main conclusion can be drawn from the sedimentary, faunal and paleomagnetic records of this Plio-Pleistocene littoral basin: during the time interval corresponding to the "Villafranchian" no dramatic changes took place. The sedimentary record indicates that in both the northern and southern parts of the basin no environmental changes linked either to a climatic deterioration or amelioration occurred. Moreover, the continuity of sedimentary transitional environments from the early Pliocene up to the middle Pleistocene indicates a relative paleogeographical stability along this period of time (Fig. 4). As said above, major paleogeographical changes were triggered by middle-late Pleistocene tectonic activity generating internal reliefs within the basin and bringing about the inversion of the Plio-Pleistocene environmental conditions between the two parts of the basin as they are at present.

Similar conclusions can be reached from paleontological data. The cold fauna which is reported to occur in the Mediterranean Basin at the beginning of the Pleistocene has never be found in Spain and in the studied zone, in particular. Thus, we can say that there is no record of such climatic deterioration in the studied zone. Major climatic changes and/or fluctuations are recorded in SE Spain only during the uppermost middle Pleistocene and in late Pleistocene as a climatic amelioration reflected by the development of Tyrrhenian episodes characterized by the presence of *Strombus bubonius*.

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