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Major palaeoenvironmental changes in the Campanian to Palaeocene sequence of Caravaca (Subbetic zone, Spain)

Cambios paleoambientales mayores en la sucesión Campaniense a Paleoceno de Caravaca (Zona Subbética, España)

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Abstract

An integrated sedimentological and biostratigraphical study of the Campanian to Palaeocene succession of Caravaca de la Cruz (SE Spain) has allowed to recognize the palaeoenvironmental evolution of this area, located within the pelagic/hemipelagic domains of the ancient southern continental margin of Iberia. This succession has been divided in four stratigraphic intervals on the basis of their sedimentological and palaeoecological features. The first interval (middle to upper Campanian, *Globotruncana ventricosa, Globotruncanita calcarata*, and *Globotruncana falsostuarti* biozones) consists in rhythmically bedded limestones formed by a slow and relatively steady fallout of biogenic debris in an upper bathyal setting. The second interval (latest Campanian to lower Maastrichtian, lower to middle part of the *Gansserina gansseri* biozone) is defined by the presence of fine-grained calcarenites deposited under the influence of bottom currents. The onset of that influence was probably related with the beginning of the convergence between Iberia and Africa that led to a narrowing of the passage between them, and thus to an intensification and a deepening of the oceanic currents in the area. The third interval (upper Maastrichtian, upper part of the *G. gansseri* biozone and the *Abathomphalus mayaroensis* biozone) is formed by marls deposited in a mixed hemipelagic environment, deeper than that of the previous unit, and with high fine terrigenous input. Towards the end of this interval, this environment began to receive sporadic turbiditic deposits. During the fourth interval (Palaeocene, *Parasubbotina pseudobulloides*, *Praemurica trinidadensis*, *Praemurica uncinata*, *Morozovella angulata*, *Igorina pusilla*, and *Globanomalina pseudomenardii* biozones) the same type of sedimentation, including turbidite input, prevailed.

The four intervals are bounded by episodes of rapid environmental change, reflected in the stratigraphic succession by abrupt transitions in facies. These episodes, latest Campanian, "middle" Maastrichtian and latest Maastrichtian to earliest Palaeocene in age, can be correlated with regional stratigraphic unconformities in the more proximal and shallower sections of the Prebetic domain, and be interpreted as regional events. The origin of these events, according to their regional features, is mainly tectonic, probably related to the onset of the alpine convergence in that continental margin.

*Keywords:*Hemipelagic, Betics, Planktic foraminifera, Palaeoenvironmental changes, latest Cretaceous, Palaeocene.

Resumen

En este trabajo se presenta un estudio sedimentológico y bioestratigráfico integrado de la sucesión de edad Campaniense a Paleoceno de Caravaca de la Cruz (SE de España), el cual permite reconstruir la evolución ambiental para ese periodo en este sector de los dominios pelágicos a hemipelágicos de la antigua margen continental sur de Iberia. Atendiendo a sus características sedimentológicas y paleoecológicas, estos depósitos se han dividido en cuatro unidades estratigráficas. La primera unidad (Campaniense medio a superior, biozonas de *Globotruncana ventricosa, Globotruncanita calcarata* y *Globotruncana falsostuarti*) está constituida por calizas de aspecto rítmico, formadas a partir de la decantación de fino material biogénico en un ambiente marino abierto a profundidades batiales superiores. La segunda unidad (Campaniense terminal a Maastrichtiense inferior, parte inferior a media de la biozona de *Gansserina gansseri*) se caracteriza por la presencia de depósitos calcareníticos de grano fino producidos por la acción de corrientes de fondo. El inicio de la actividad de estas corrientes sobre el fondo marino estuvo probablemente relacionado con el comienzo de la convergencia entre Iberia y África, que pudo originar un estrechamiento en la zona de paso entre ambas zonas emergidas y, por consiguiente, una intensificación y profundización de las corrientes oceánicas. La tercera unidad (Maastrichtiense superior, parte superior de la biozona de *Gansserina gansseri* y biozona de *Abathomphalus mayaroensis*) está formada por margas depositadas en un ambiente hemipelágico mixto, probablemente algo más profundo que el desarrollado durante la etapa anterior y que recibía mayores aportes de terrígenos de grano fino. Hacia el final de este intervalo, este medio comenzó a recibir esporádicos aportes turbidíticos. Durante el cuarto intervalo diferenciado (Paleoceno, biozonas de *Parasubbotina pseudobulloides*, *Praemurica trinidadensis*, *Praemurica uncinata*, *Morozovella angulata*, *Igorina pusilla* y *Globanomalina pseudomenardii*) la sedimentación continuó en un medio similar al descrito para la etapa anterior.

Estas cuatro unidades están limitadas por episodios de rápido cambio en las condiciones de depósito, reflejadas en la sucesión estratigráfica por cambios abruptos en las facies. Estos episodios, de edad Campaniense terminal, Maastrichtiense “medio” y Maastrichtiense terminal a Paleoceno basal, pueden correlacionarse con discontinuidades estratigráficas de carácter regional descritas en series más someras y proximales del dominio Prebético, y ser considerados por ello, como eventos de carácter regional. El origen de los mismos, de acuerdo a sus características regionales, debe ser tectónico y estar relacionado con el inicio de la convergencia alpina en esa margen continental.

Palabras clave: Hemipelágico, Béticas, foraminíferos planctónicos, cambios paleoambientales, Cretácico terminal, Paleoceno.

1. Introduction

This paper focuses on the deep marine carbonates and marls of Campanian to Palaeocene age that crop out in the Subbetic Zone near Caravaca de la Cruz (SE of Spain). Because its completeness, this sedimentary sequence has become a world-wide referent for the study of global bioevents, specially for the Cretaceous-Palaeogene (K-P) and the Palaeocene-Eocene (P-E) boundaries (Canudo *et al.* 1991, 1995; Molina *et al.*, 1994, 1998; Kaiho and Lamolda, 1999; Arz *et al.* 2000). Despite its global importance, the Caravaca section has received little attention as a whole, and, at this moment, there is a big gap between those, very specific, papers on the bioevents and the broad, regional stratigraphic papers carried out several decades ago (e.g.: Van Veen, 1969; Paquet, 1969; Baena, 1973; Vera *et al.*, 1982).

With this paper, we try to fill that gap with an integrated sedimentological and biostratigraphical analysis of the Campanian to Palaeocene sequence in Caravaca. The main objectives therefore are: 1) to characterize the palaeoenvironmental evolution, 2) to precise the age of the main environmental changes occurring in the sequence, and 3) to discuss its possible regional or supraregional significance.

2. Regional setting

The studied rocks crop out 3 km south of the town of Caravaca (Murcia province, SE Spain), in the Loma de la Solana and Barranco del Gredero zones (Fig. 1). From a tectonic point of view, these outcrops form part of the Subbetic Zone, a major allochthonous unit of the Betic orogen, which was mainly structured during the Miocene (Vera, 1988). From a more palaeogeographical perspective, the considered stratigraphic succession probably corresponds to the proximal zones of the deep marine environments of the ancient southern margin of Iberia (García-Hernández *et al.*, 1980, 1988) (Fig. 2). That continental margin was developed during Jurassic and early Cretaceous times under a complex extensional – transtensional regime controlled by the relative motions between Africa and Eurasia (e.g., Savostin *et al.*, 1986; Vera, 1988; Martín-Chivelet *et al.*, 2002). During the considered time interval (Campanian – Palaeocene) the tectonic regime of the basin started to change, due to the onset of the convergence between those two main plates. As result of this, the broad passive margin began its transition into a convergent one (Martín-Chivelet, 1996, Martín-Chivelet *et al.*, 1997; Reicherter and Pletsch, 2000; Chacón and Martín-Chivelet, 2001a). This process culminated later in the Tertiary with the complete destruction of the margin and the formation of the thrust-and-fold belt.

3. Methods

The Cretaceous and Palaeogene succession in the Caravaca area forms a thick and rather homogeneous series of hemipelagic to pelagic carbonates and marls which extensively crop out in the Barranco del Gredero, Barranco

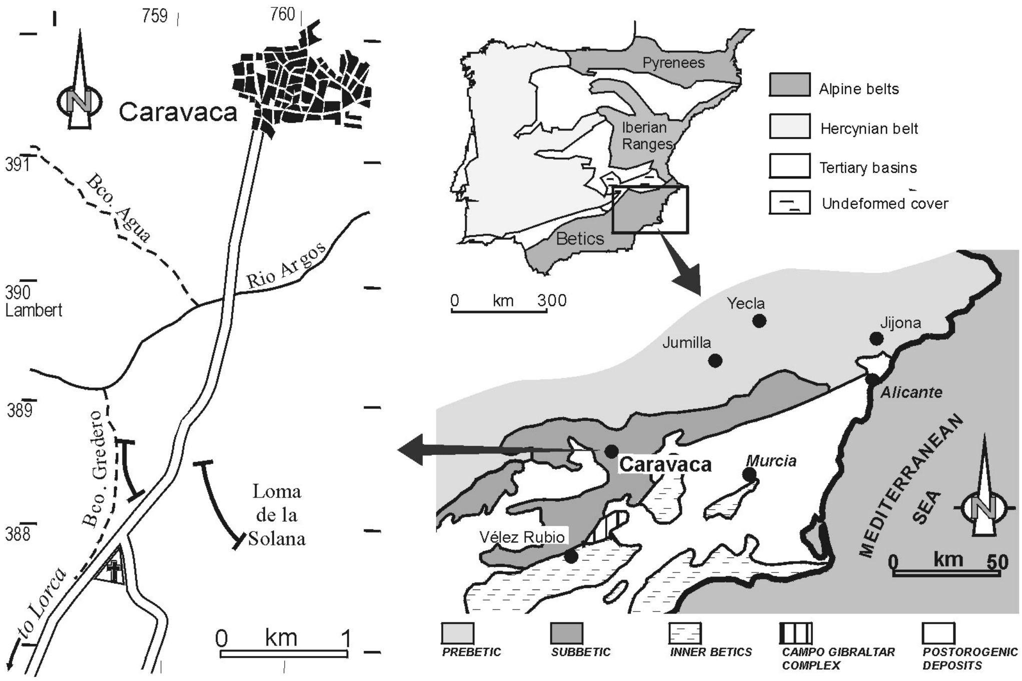


Fig. 1.- Location map of the studied area and analysed outcrops.
Fig. 1.- Localización del área de estudio y de los afloramientos analizados.

del Agua, and in the Rio Argos. This paper concentrates in the Campanian to Palaeocene interval, which includes three lithostratigraphic units: Aspe fm., Raspay Fm. and Agost fm. The Aspe and Agost fms. were informally defined by Chacón (2002), while the Raspay Fm. was formally defined for the Prebetic of the Jumilla – Yecla region by Martín-Chivelet (1994).

The biostratigraphic analysis of the Caravaca succession relies on the study of planktic foraminifera, in washed residues and in thin sections. Deep-water benthic foraminifera allowed getting a first approximation to the age and, mainly, they allowed to obtain a palaeo-water-depth range for these deposits.

For the study of Upper Cretaceous planktic foraminifera, the works of Robaszynski *et al.* (1984), Caron (1985), Robaszynski and Caron (1995), Premoli Silva and Sliter (1995), the biochronostratigraphic chart from Hardenbol *et al.* (1998) and the work of Robaszynski *et al.* (2000), have been followed. For the Palaeocene planktic foraminifera, we have followed the works of Berggren and Miller (1988), Tourmakine and Luterbacher (1985), Berggren and Norris (1997), and Pujalte *et al.* (1994).

4. Stratigraphy, environments and biostratigraphy

The Campanian to Palaeocene succession in Caravaca is 280 m thick and has been divided into four stratigraphic units (Figs. 3 and 4), each of them characterized by distinctive sedimentological and palaeoecological features. The limits between these units are marked by rapid transitional zones, which define changes in lithofacies and, in some cases, in fossil assemblages. It should be noted however that, for the definition of these units we have taken into account not only those vertical changes observed in the Caravaca area, but also the regional stratigraphic background (i.e., Chacón, 2002). The units described here have a regional character, although in the shallower hemipelagic areas of the basin (i.e, the Prebetic of Alicante) they are bounded by stratigraphic unconformities instead of rapid transitional changes (see below).

The ages of these units, on the basis of the planktic foraminifera assemblages, are from base to top: middle to late Campanian, latest Campanian to early Maastrichtian, late Maastrichtian, and Palaeocene.

4.1. Middle to late Campanian unit

The lower considered unit, middle to late Campanian in age, is 87 m thick and consists of a very homogeneous succession of white to pinkish hemipelagic/pelagic limestones and marly limestones. They show a marked rhythmic character, defined by gradual, minor changes in the argillaceous content at dm-scale. Despite of the variable siliciclastic content (0 to 10%), the dominant facies consists of moderately burrowed, fine grained, wackestones with abundant planktic foraminifera, calcisphaerulids, ostracods, some small benthic foraminifera, and rests of inoceramids and echinoids.

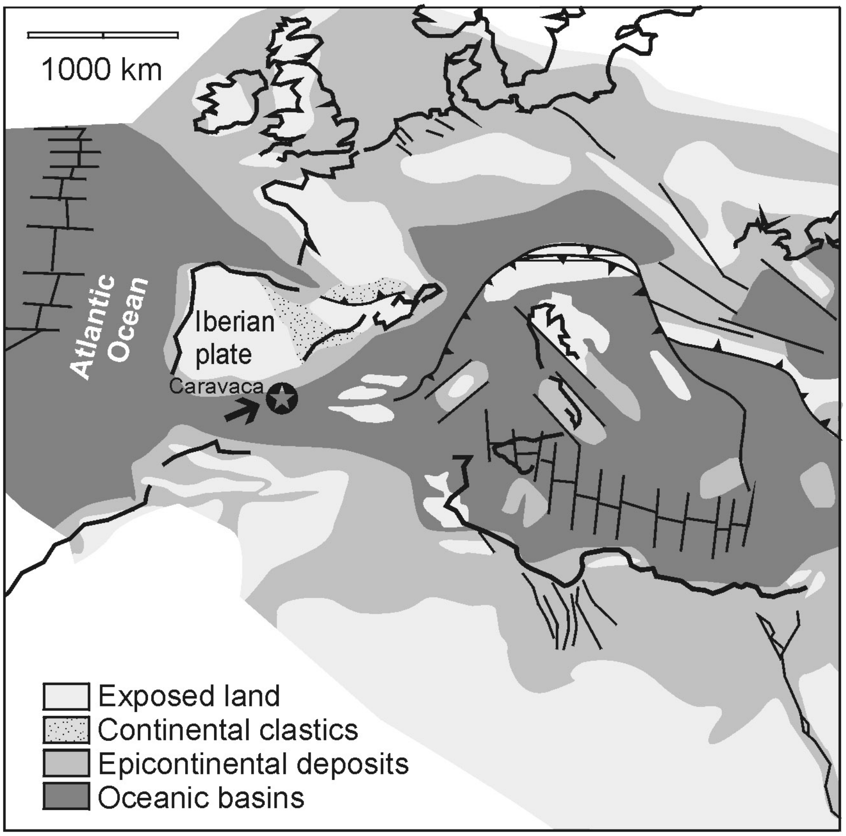


Fig. 2.- Palaeogeographic reconstruction of the western Tethys for the Maastrichtian (based on Philip and Floquet, 2000) showing the approximate location of the Caravaca area in the Betic continental margin.

Fig. 2.- Reconstrucción paleogeográfica del Tethys occidental para el Maastrichtiense (basado en Philip y Floquet, 2000) en la que se muestra la situación aproximada del área de Caravaca, en el margen continental bético.

Palaeoenvironmental interpretation: This unit was deposited in a deep marine carbonate, hemipelagic to pelagic, environment, with slow and relatively steady fallout of biogenic particles. This environment received a variable but always low input of fine terrigenous material. The assemblage of benthic foraminifera, which includes *Gavelinella becariiformis* (White, 1928), *Gaudryina pyramidata* Cushman, 1926, *Lenticulina* sp., *Oridorsalis* sp., *Pullenia* sp., *Quadrimorphina* sp., *Reussella szajnochae* (Grzybowski, 1896), and *Stensioina pommerana* Brotzen, 1940 (Fig. 5), suggests an upper bathyal palaeo-waterdepth (according to the depth ranges for benthic foraminifera given by van Morkhoven *et al.*, 1986, and Schnack, 2000).

Biostratigraphy and age: From base to top, we have identified the following planktic foraminifera zones: *Globotruncana ventricosa*, *Globotruncanita calcarata*, and *Globotruncana falsostuarti*. According to Caron (1985) and Premoli Silva and Sliter (1995), the time interval represented by the *Globotruncana falsostuarti* zone could be subdivided in other two biozones: *Globotruncanella havanensis* zone (between the L.A. of *G. calcarata* and the F.A. of *Globotruncana aegyptiaca*), and *Globotruncana aegyptiaca* zone (between the F.A. of *G. aegyptiaca* and the F.A. of *Gansserina gansseri*). However, in the studied section the F.A. of *G. aegyptiaca* is previous to the L.A. of *G. calcarata*, so we cannot adopt that subdivision in this case and the *G. falsostuarti* zone, proposed by Robaszynski *et al.* (1984), has been thus adopted. The age of this first interval is middle to late Campanian.

4.2. Latest Campanian to early Maastrichtian unit

The second unit, latest Campanian to early Maastrichtian in age, consists of 43 m of white limestones and marly limestones that are quite similar to those of the previous interval. However, this unit differentiates from the former in the presence of abundant intercalations of tabular calcarenite beds (Fig. 4). These, 0.1 to 1.6 m thick, are bounded by sharp contacts. The base of each bed is often erosive, showing flute and scour casts, whereas the top is never erosive and usually defined by a flat surface. Within each bed, abundant traction structures, internal erosive surfaces and inverse and normal grading at various scales can be recognized. These calcarenite beds are characterized by a distinctive vertical distribution sequence of sedimentary structures. Most of these beds can be roughly divided into two different intervals: (1) A lower interval, characterized by the dominance of cross lamination, produced by the migration of ripples under the influence of a tractive current. Reactivation and slightly erosive surfaces are also frequent in this interval. (2) An upper interval, which is dominated by very thin and parallel lamination, grain size being generally finer than in the underlying interval. Texturally, they are very fine to medium grained grainstone to packstone calcarenites, which include abundant fragments of the same organisms that appear in the hemipelagites (planktic foraminifera, few deep water benthic foraminifera and calcisphaerulids, as well as calcite prisms coming from the break up of inoceramid tests). These deposits have been studied in detail by Martín-Chivelet *et al.* (2003).

Palaeoenvironmental interpretation: The sedimentation of the unit took place in an hemipelagic environment that was periodically affected by currents which actively modified the bottom. The recognized sequence of structures in the calcarenite beds allowed us to conclude that each of these beds was deposited by contourite currents. Such strata represent the deposit of a multiepisodic, long-standing, bottom tractive current, which decreases in strength and average velocity over time and in space. Although in this unit benthic foraminifera are scarce and bad preserved, the assemblage is very similar to that of the former unit, so, the interpreted palaeo-waterdepth is also upper bathyal.

Biostratigraphy and age: This unit corresponds with the lower/middle part of the *Gansserina gansseri* biozone, defined by the presence of the index species together with *Contusotruncana walfischensis*, but without *Contusotruncana contusa* or *Racemiguembelina fructicosa*. According to Hardenbol *et al.* (1998), the age of this unit is latest Campanian to early Maastrichtian in age.

4.3. Late Maastrichtian unit

The third unit, late Maastrichtian in age, is, at least, 45 m thick. It mainly consists of grey to green marls and marly limestones, which are more abundant towards the top of the unit. Also, some few intercalations of turbidites have been recognized (Fig. 4). The marls contain abundant planktic foraminifera, small sized benthic foraminifera, ostracods, and rests of echinoids and inoceramids.

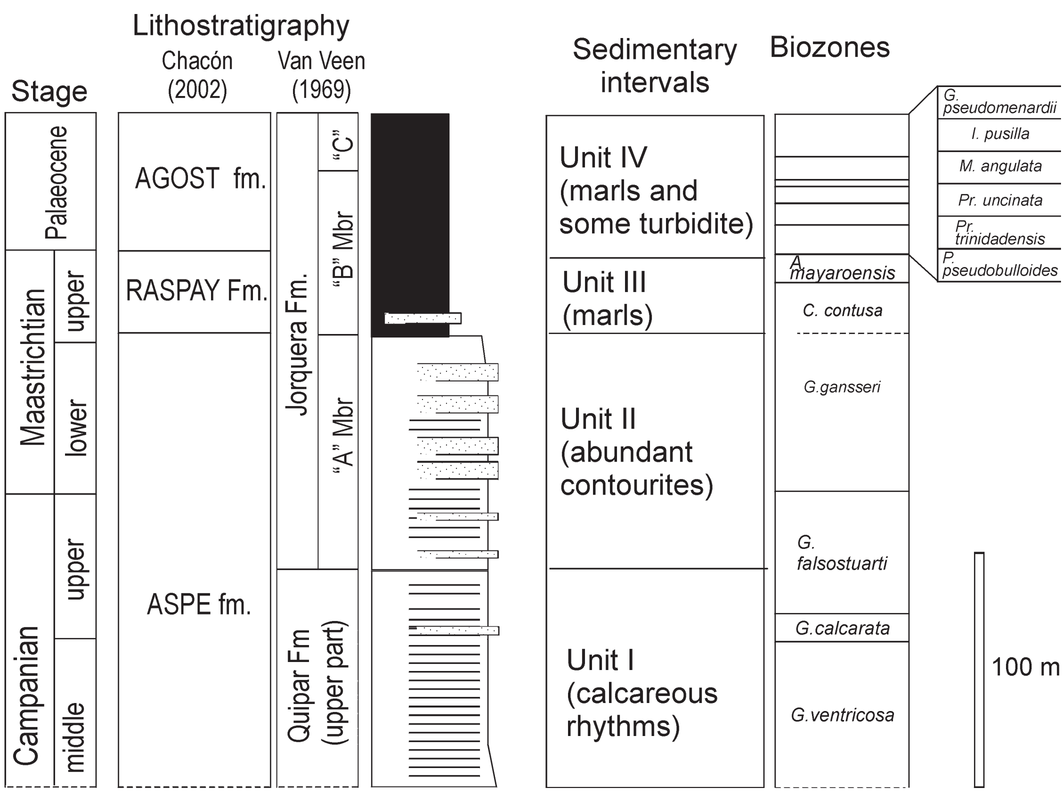
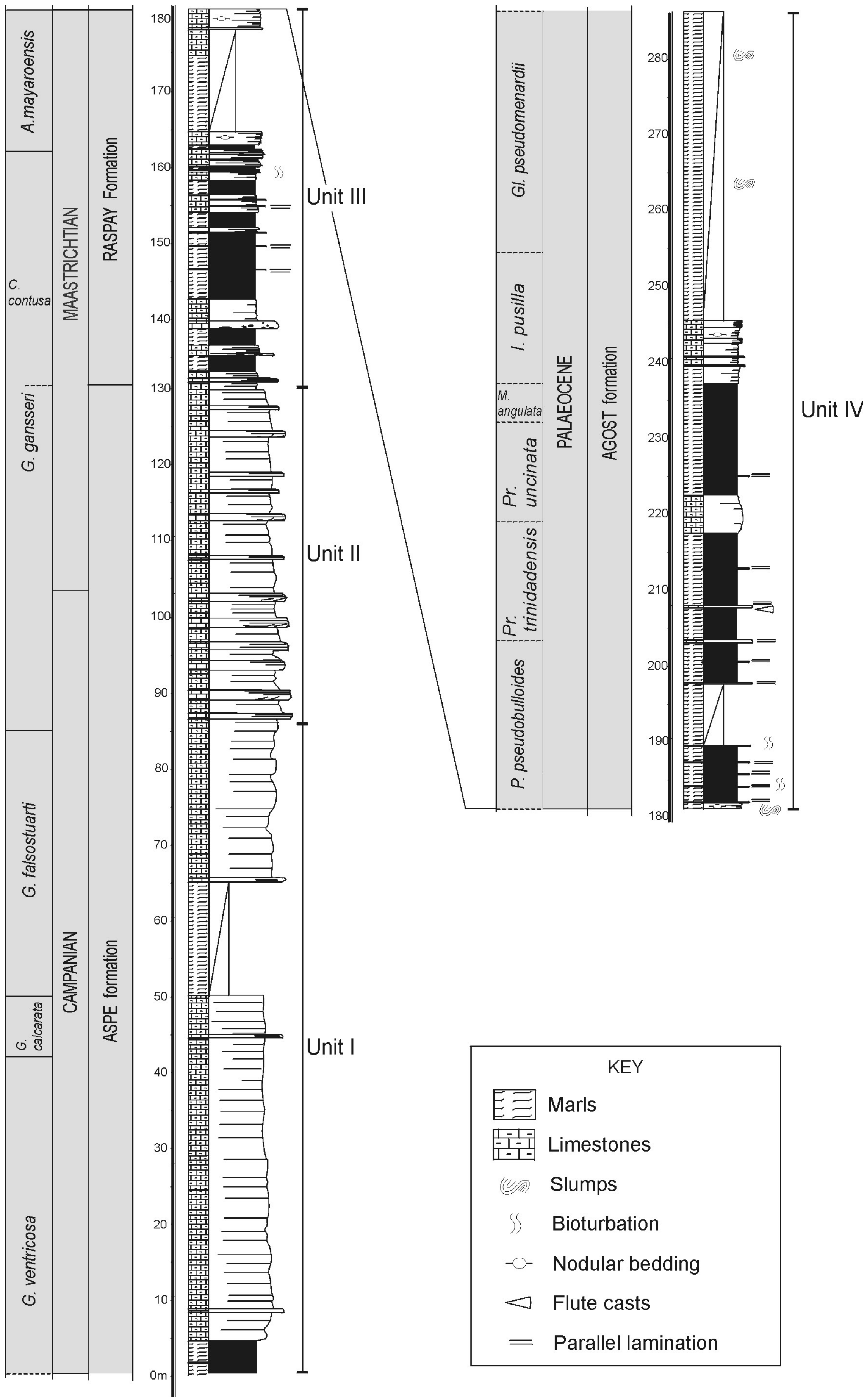


Fig. 3.- Stratigraphic summary chart of the Campanian to Palaeocene sequence in Caravaca. The lithostratigraphic subdivision by van Veen, 1969 has been included for comparison.

Fig. 3.- Cuadro resumen de la estratigrafía de la sucesión Campaniense – Paleoceno en Caravaca. Junto con las unidades utilizadas en este trabajo, se ha incluido la subdivisión litoestratigráfica propuesta por van Veen (1969).


A.mayaroensis
C. contusa
G. gansseri
G. falsostuarti
G. calcarata
G. ventricosa
MAASTRICHTIAN
CAMPANIAN
RASPAY Formation
ASPE formation
Unit III
Unit II
Unit I
Gl. pseudomenardii
I. pusilla
M. angulata
Pr. uncinata
Pr. trinidadensis
P. pseudobulloides
PALAEOCENE
AGOST formation
Unit IV
0m
180
280
KEY
Marls
Limestones
Slumps
Bioturbation
Nodular bedding
Flute casts
Parallel lamination

The turbidite intercalations are scarce, but they are distinctively different of the contourite beds that characterize the underlying unit. They consist of dm-scale beds formed by normal-graded, medium to coarse-grained calcarenites, which often show sharp bases and tops. They contain abundant lithoclasts and reworked bioclasts of very shallow water faunas (bivalve fragments, orbitoidids, echinoids). A noticeable fact is that, near the base of the unit, a 1 m thick calcareous conglomerate bed, interpreted as a debris flow, can be recognized. This level could be related with the event that controlled the rapid environmental change from the previous unit (Fig. 4).

Palaeoenvironmental interpretation: This third unit was deposited in a mixed hemipelagic environment. The rich association of benthic foraminifera allowed to obtain palaeo-waterdepth estimates for these deposits. The assemblage yielded by the lower to middle part of the unit, which includes *Bolivinoides draco draco* (Marsson, 1878), *Cibicidoides dayi* (White, 1928), *Cibicidoides hyphalus* (Fisher, 1969), *Cibicidoides velascoensis* (Cushman, 1925), *Eouvigerina subsculptura* McNeil y Caldwell, 1981, *Gaudryina pyramidata* Cushman, 1926, *Gyroidinoides globosus* (Hagenow, 1842), *Lenticulina* sp., *Marssonella oxycona* (Reuss, 1860), *Nuttallides truempyi* (Nuttall, 1930), *Nuttallinella florealis* (White, 1928), *Oridorsalis* sp., *Reussella szajnochae* (Grzybowski, 1896), and *Stensioina pommerana* Brotzen, 1940, suggests an upper to middle bathyal depth for these rock interval (following the work of van Morkhoven *et al.*, 1986). The association included in the upper part of the unit is formed by *Bolivinoides delicatulus* (Cushman, 1927), *Bolivinoides draco draco* (Marsson, 1878), *Cibicidoides hyphalus* (Fisher, 1969), *Cibicidoides velascoensis* (Cushman, 1925), *Coryphostoma incrassata* (Reuss, 1851), *Coryphostoma midwayensis* (Cushman, 1936), *Gaudryina pyramidata* Cushman, 1926, *Lenticulina* sp., *Marssonella oxycona* (Reuss, 1860), *Oridorsalis plummerae* (Cushman), and *Stensioina pommerana* Brotzen, 1940 (Fig. 5), which might point to an slightly shallower depth (according to van Morkhoven *et al.*, 1986).

This environment sporadically received the input of sediment gravity flows.

Biostratigraphy and age: In the uppermost deposits of the Cretaceous, corresponding to the third considered unit, the upper part of the *Gansserina gansseri* biozone (which includes the species *C. contusa* and/or *R. fructicosa*) and the *Abathomphalus mayaroensis* biozone have been recognized. Following Hardenbol *et al.* (1998), the represented biozones give an late Maastrichtian age to this unit.

4.4. Palaeocene unit

The fourth and last considered unit is Palaeocene in age. It is constituted by greyish to reddish marls and marlstones, with some turbidite intercalations. The dominant facies include a fossil assemblage formed by planktic and deep-water benthic foraminifera, some ostracods and abundant rests of echinoids. The turbidite beds consist of fine-grained bioclastic packstones, with echinoids and bryozoan's fragments, and abundant planktic and small deep-water benthic foraminifera.

Palaeoenvironmental interpretation: The sedimentation of these deposits took place in a mixed hemipelagic environment, similar to that of the Raspay Fm., but with a more important input of turbiditic material. As we can obtain from its assemblage of benthic foraminifera, with *Anomalinoides* cf. *rubiginosus* (Cushman, 1926), *Aragonia velascoensis* (Cushman, 1925), *Bulimina trinitatensis* Cushman and Jarvis 1928, *Cibicidoides dayi* (White, 1928), *Cibicidoides velascoensis* (Cushman, 1925), *Gavelinella becariiformis* (White, 1928), *Gyroidinoides globosus* (Hagenow, 1842), *Neoflabellina jarvisi* (Cushman, 1935), and *Nuttallides truempyi* (Nuttall, 1930), the palaeo-waterdepth was slightly deeper than at the end of the previous interval, probably in the upper to middle bathyal depth range.

Biostratigraphy and age: Finally, in the last unit, the following zones of planktic foraminifera have been recognized: *Parasubbotina pseudobulloides* (corresponding to the P1b zone of Berggren and Norris, 1997), *Praemurica trinidadensis* (P1c), *Praemurica uncinata* (P2), *Morozovella angulata* (lower part of P3a), *Igorina pusilla* (upper part of P3a and P3b), and *Globanomalina pseudomenardii* (P4a and b). According with these biozones, the age of this interval is early to late Palaeocene.

Furthermore, the first biozone of the Palaeocene, a thin level (few millimetres thick) over the KP boundary defined by the presence of *Guembelitria cretacea* and *Parvularugoglobigerina longiapertura*, had been previously described in the Caravaca outcrops by other authors (i.e. Arenillas and Molina, 1997; Arz *et al.* 2000).

Fig. 4.- (opposite page) Stratigraphic log for the Campanian to Palaeocene sequence in Caravaca, showing the four differentiated intervals and the planktic foraminifera biozones. Horizontal scale reflects the topographical expression of the materials in the outcrop.

Fig. 4.- (página opuesta) Columna estratigráfica de Caravaca en la que se muestran los cuatro intervalos diferenciados y las biozonas de foraminíferos planctónicos. La escala horizontal refleja el resalte topográfico de los niveles en el afloramiento.

5. Regional correlation and discussion

The Campanian to Palaeocene environmental evolution deduced from the Caravaca section is punctuated by three episodes of rapid environmental change, which are not clearly outlined by unconformities, but by transitional zones. For a better understanding of factors controlling these episodes, the Caravaca section has been compared with other sectors of the Betic Ranges, with special attention to those from shallower settings of the ancient continental margin (i.e. the Prebetic). These consist of mixed carbonate-siliciclastic sequences, deposited in environments ranging from coastal lakes and shabkhas to open marine, hemipelagic settings (e.g.: Martín-Chivelet, 1995, 1996; Chacón and Martín-Chivelet, 2001a, 2001b, 2003; Chacón, 2002). These environments, very sensitive to most forcing factors, should reflect both regional and global changes better than those of the, less sensitive, deeper ones of Caravaca.

At the end of Santonian and the beginning of the Campanian times, an abrupt regional tectonic event took place in the continental margin, causing important block movements in the Prebetic area and a decrease of regional subsidence in both, the Prebetic (Martín-Chivelet *et al.*, 1995) and the Subbetic domain (Reicherter and Pletsch, 2000). Within the new basin configuration, defined by a complex mosaic of elevated blocks and depressed areas, carbonate sedimentation with variable terrigenous influx took place, in settings which ranged from tidal flats (Rambla de los Gavilanes Fm., Martín-Chivelet, 1994) to open shelf (Carche Fm., Martín-Chivelet, 1994) and to bathyal environments (Aspe Fm., Chacón, 2002; and Capas Rojas Fm., Vera *et al.*, 1982). In some of the elevated blocks of the Prebetic, however, no sedimentation took place. Instead, major hiatuses, representing all or part of the Campanian period, developed.

During the latest Campanian to early Maastrichtian, the carbonate sedimentation that had prevailed during Campanian times continued in most areas without significant changes. However, a notable increase in the siliciclastic input has been recognized for this interval in the shallower areas of the Prebetic, which could correspond with a regional reactivation of source areas in the continent (Martín-Chivelet, 1992). Furthermore, sedimentation started on most of the topographic highs that had prevailed without it during the Campanian (Martín-Chivelet, 1992; Chacón, 2002). In Caravaca, the onset of contourite deposition could reflect the changes that are occurring in the basin. Probably, these changes allowed the oceanic currents to deep enough to modify and control sedimentation at the sea floor. Similar deposits (but much less abundant) have been described in outer shelf to hemipelagic sequences of the same age in the Prebetic (Chacón, 2002).

During the "middle" Maastrichtian, a major tectonic event changed drastically the sedimentary patterns and the palaeogeography of the continental margin. In the shallower areas of the basin, this event implied some erosion, which led to the development of a regional unconformity. Basinwards, a correlative unconformity have been recognized. This can be marked by an iron-rich surface, or, as in the Aspe area, by synsedimentary inverse faulting and development of olistholiths and massive slumps. These features, described by Chacón and Martín-Chivelet (2001a) strongly suggest the compressional character of the tectonic event. In the Caravaca area, this tectonic event marked the end of the influence of bottom currents on the sea floor and the high input of fine-grained siliciclastics.

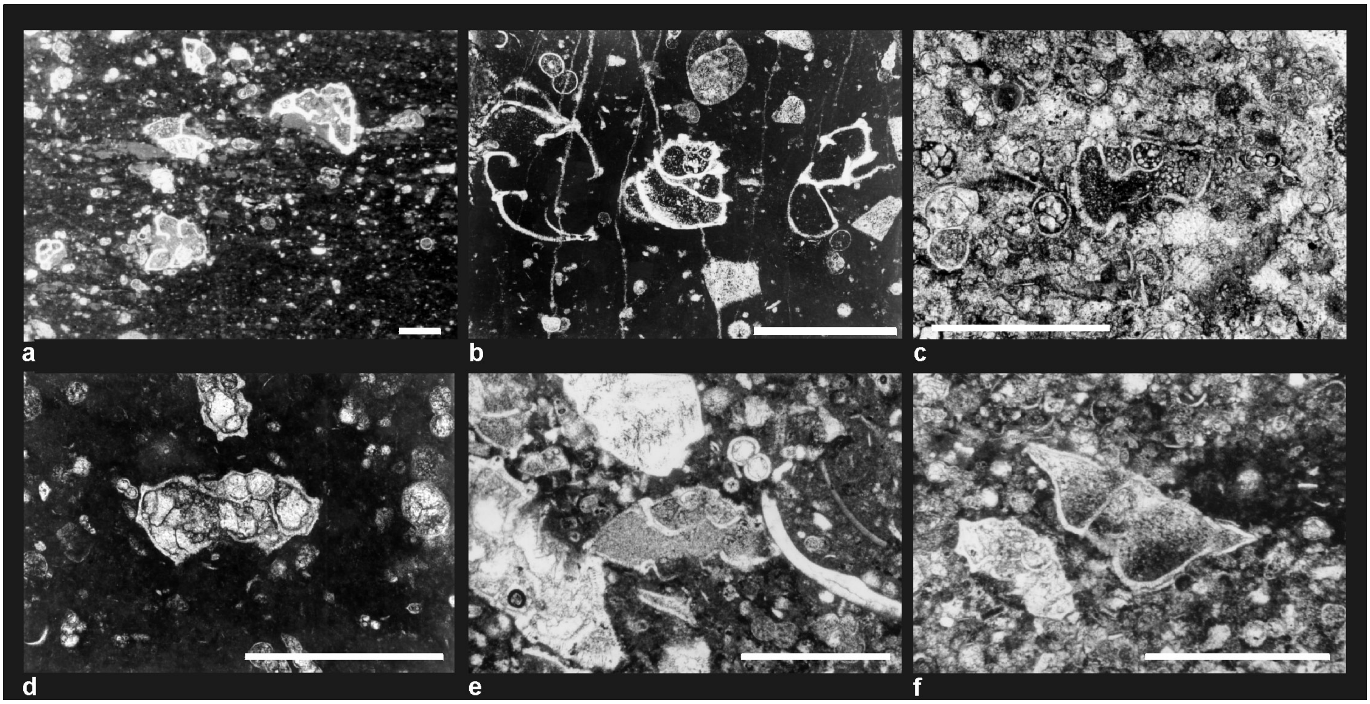
After the "middle" Maastrichtian event, a widespread, mixed carbonate-siliciclastic sedimentation took place in the continental margin. In the shallowest areas, two narrow facies belts developed, these respectively corresponding to coastal lakes (Cerrillares Fm., Martín-Chivelet, 1994) and a shallow platform (Molar Fm., Martín-Chivelet, 1994). Basinwards, the outer shelf to bathyal deposits are represented by the Raspay Fm. (Martín-Chivelet, 1994), a pervasive unit of grey to green

Fig. 5.- Upper part: Planktic foraminifera in thin section. a) *Contusotruncana contusa*. b) *Contusotruncana walfischensis*. c) *Gansserina gansseri*. d) *Globotruncana aegyptiaca*. e) *Globotruncana falsostuarti*. f) *Globotruncanita calcarata*. Scale bar: 0.5 mm.

Lower part: benthic foraminifera SEM images. 1) *Aragonia velascoensis*, front view. 2) *Eouvigerina subsculptura*, side view. 3) *Cibicidoides dayi*, spiral view. 4) *Gavelinella becariiformis*, umbilical view. 5) *Gyroidinoides globosus*. 5a- peripheral view, 5b- spiral view. 6) *Neoflabellina jarvisi*, side view. 7) *Nuttallinella florealis* 7a- spiral view, 7b- umbilical view. 8) *Oridorsalis plummerae*, spiral view. 9) *Pullenia* sp., side view. 10) *Quadrimorphina* sp., umbilical view. Scale bar: 100 µm. All the studied samples are stored in the collection of the Department of Stratigraphy, Complutense University.

Fig. 5.- Parte superior: foraminíferos planctónicos en lamina delgada. a) *Contusotruncana contusa*. b) *Contusotruncana walfischensis*. c) *Gansserina gansseri*. d) *Globotruncana aegyptiaca*. e) *Globotruncana falsostuarti*. f) *Globotruncanita calcarata*. Escala gráfica: 0.5 mm.

Parte inferior: foraminíferos bentónicos al microscopio electrónico de barrido (SEM). 1) *Aragonia velascoensis,* vista frontal. 2) *Eouvigerina subsculptura,* vista lateral. 3) *Cibicidoides dayi,* vista espiral. 4) *Gavelinella becariiformis,* vista umbilical. 5) *Gyroidinoides globosus*. 5a- vista periférica, 5b- vista espiral. 6) *Neoflabellina jarvisi*, vista lateral. 7) *Nuttallinella florealis* 7a- vista espiral, 7b- vista umbilical. 8) *Oridorsalis plummerae,* vista espiral. 9) *Pullenia* sp., vista lateral. 10) *Quadrimorphina* sp., vista umbilical. Escala gráfica: 100 µm. Las muestras estudiadas se encuentran incluidas en las colecciones del Departamento de Estratigrafía, Universidad Complutense.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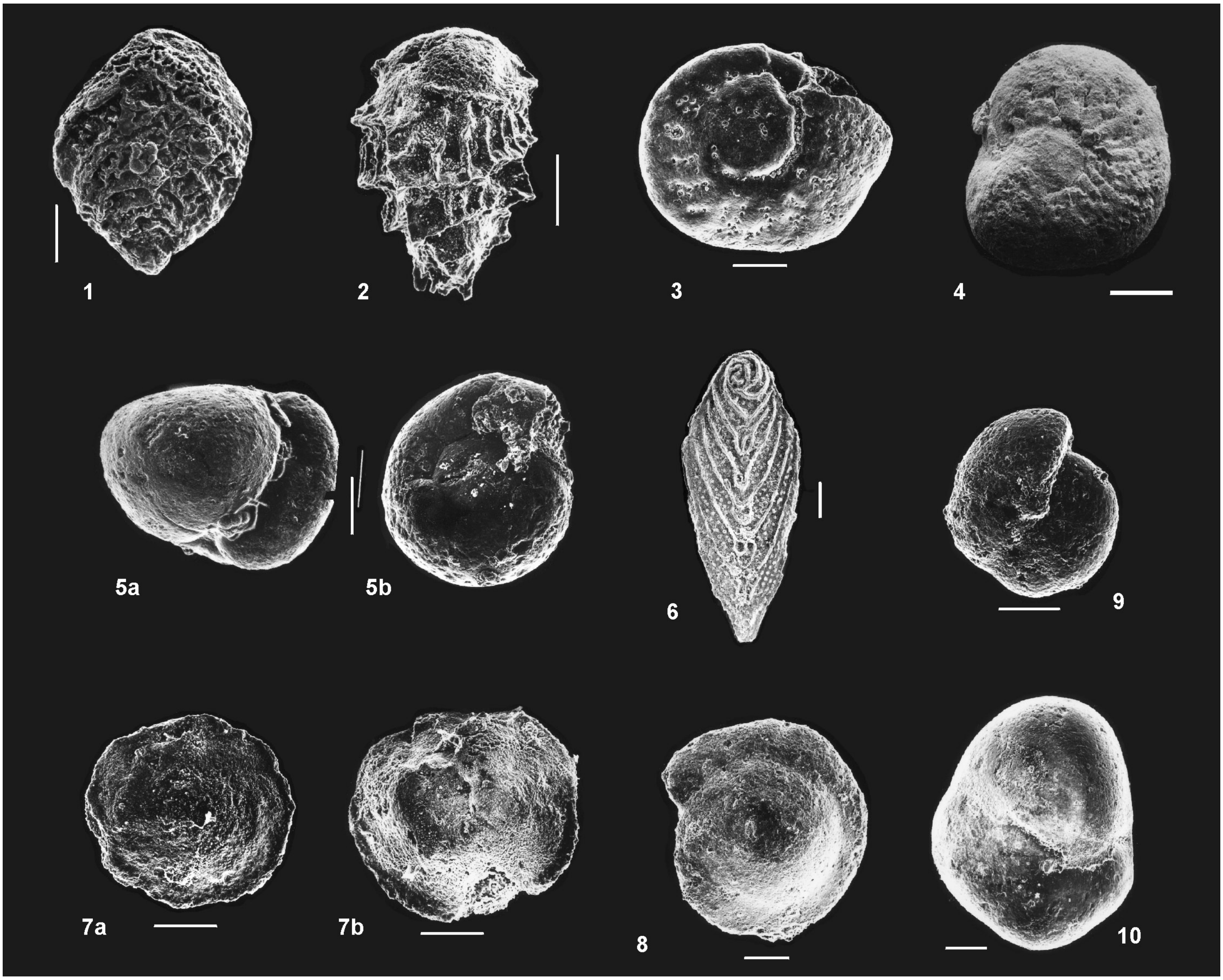
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7b
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marls with some intercalations of marly limestones. This unit shows, in most outcrops, abundant evidences of turbidite deposition, as well as synsedimentary slumps and debris-flow beds. In Caravaca, as indicated above, this unit is also present, and shows very similar characteristics to those observed in some areas of the Prebetic.

As in Caravaca, the Cretaceous-Palaeogene (K/P) bioevent has also a very complete record in some areas of the Prebetic (e.g.: Agost), where a gradual transition between the Maastrichtian and the Danian has been found (e.g., Canudo *et al.* 1991; Arz and Arenillas, 1996). However, in most areas of the Prebetic the Maastrichtian deposits are separated from the Palaeocene or younger rocks by an unconformity of variable hiatus, which could be the result of a new regional tectonic event that took place around Cretaceous-Palaeogene transition. In the hemipelagic settings of the Prebetic, the unconformity may be marked by intensely burrowed and bored, mineralised hardgrounds, that sometimes show a crust of pelagic stromatolite laminae (Vera and Martín-Algarra, 1994; Chacón, 2002).

After the K-P event, the sedimentation continued in the deeper areas of the Prebetic, where those hardgrounds became covered by hemipelagic marly deposits (Agost fm., Chacón, 2002). In the areas closer to the continent, these early Palaeocene facies evidence shallower environments, even outer platform and even reefal and para-reefal complexes, these corresponding to the La Aberquilla fm. (Chacón, 2002). This rapid shallowing trend cannot be correlated with that observed in Caravaca, which shows, as explained above a slightly deepening trend at the beginning of the Palaeocene. This aspect suggests differential vertical block movements in the basin at the onset of the Tertiary.

In the shallower areas of the Prebetic, where the late Maastrichtian was represented by shallow marine and lacustrine facies (Molar and Cerrillares Fms.), the K/P transition is not preserved, and these deposits are cut by erosional surfaces, and overlain by Eocene or younger deposits. In some points of these areas, however, fluvio-lacustrine deposits of possible early Palaeocene age overlie late Maastrichtian rocks (e.g., Fourcade, 1970; Champetier, 1972; Martín-Chivelet, 1992). Further work on these deposits is necessary before trying any tentative correlation with the marine facies.

The three pulses of rapid environmental change recognized in Caravaca in the Campanian to Palaeocene interval can be thus correlated with regional unconformities described in the proximal domains of the continental margin. According to previous works (Martín-Chivelet, 1996; Chacón, 2002), these unconformities represent changes in the geometry of the basin, sedimentary environments, terrigenous influx, subsidence patterns and tectonic behaviour, and can be interpreted as the result of tectonic pulses, probably induced by changes in intraplate stresses related to the onset of the Africa-Europe convergence.

6. Conclusions

An integrated sedimentological and biostratigraphical study of the Campanian to Palaeocene deposits of the Caravaca area allowed to characterize the palaeoenvironmental evolution of this sector of the Subbetic during that time interval and to compare it with the evolution of the shallower areas of the ancient southern continental margin of Iberia. The main conclusions of this work are the following:

1.- The Campanian to Palaeocene interval can be divided into four main sedimentary episodes, each of them characterized by distinctive palaeoenvironmental conditions. During the first interval (middle to late Campanian) a relatively homogeneous, rhythmic, hemipelagic, carbonate deposition took place, probably at upper bathyal depths. In the second interval (early Maastrichtian) these hemipelagic conditions persisted, although the sedimentation was strongly influenced by deep semi-permanent bottom currents which generated contourite facies. The third interval (late Maastrichtian) started with an increase in the water depth and a net cessation of the influence of currents on the sea floor. This was accompanied by a rapid increase in the terrigenous influx, and by the deposition of few turbidite beds with material coming from the shallow platform. During the fourth interval (Palaeocene), the sedimentation continued in a mixed hemipelagic environment, but in which the arrival of fine-grained turbidite deposits became usual.

2.- These four sedimentary episodes are bounded by short intervals during which rapid environmental changes occurred. These took place at latest Campanian, “middle” Maastrichtian, and in the K-P boundary. The events, which involve waterdepth, terrigenous influx, influence of deep currents, turbidite deposition and biotic assemblages, are not represented in the Caravaca area by stratigraphic unconformities but by rapid facies transitional zones.

3.- The age of all these sedimentary intervals and events has been established mainly by planktic foraminifera biostratigraphy. From base to top of the studied succession, eleven biozones have been identified. For the first unit we recognized the *Globotruncana ventricosa*, the *Globotruncanita calcarata*, and the *Globotruncana falsostuarti* zones. The lower to middle part of the Gansserina gansseri biozone characterizes the second unit. In the third unit we identified the upper part of the *G. gansseri* biozone (with the presence of *Contusotruncana contusa* and/or *Racemiguembelina fructicosa*), and the *Abathomphalus mayaroensis* biozone. And, in the last unit the *Parasubbotina pseudobulloides*, *Praemurica trinidadensis*, *Praemurica uncinata*, *Morozovella angulata*, *Igorina pusilla*, and *Globanomalina pseudomenardii* biozones have been recognized.

4.- Comparison of the studied section with other areas located more to the N-NW, corresponding to proximal zones of the basin (Prebetic domain), allows to correlate the episodes of rapid environmental change of Caravaca with abrupt changes in facies patterns, subsidence, palaeogeography and fossil assemblages in the Prebetic. This suggests a strong tectonic control for these episodes. In the Prebetic, however, those events are, in most cases, represented by stratigraphic unconformities with hiatuses of variable duration.

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