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TRANSGRESSIVE SEQUENCES ON FORELAND MARGINS: A CASE STUDY OF THE NEOGENE CENTRAL GUADALQUIVIR BASIN, SOUTHERN SPAIN.

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Abstract. The Guadalquivir foreland basin, located between the Iberian basement northward and the Betic orogen to the South, represents the western sector of the earlier foredeep basin of the Betic Cordillera. Along the northern foreland margin, the sedimentary fill of this basin includes a Tortonian Basal Transgressive Complex (BTC), composed of five internal sequences bounded by transgressive surfaces. Two main parts are distinguished within each sequence: the lower transgressive lag deposits, and the upper stillstand/prograding sediments. Three facies associations were distinguished within this stratigraphic succession along the central sector of this basin margin: unfossiliferous conglomerates and coarse-grained sands (A), fossiliferous conglomerates and coarse-grained sands (B), and yellow medium-coarse-grained fossiliferous sands (C). A fourth facies association (D: blue silty marlstones and shales) overlies the BTC. Deposits of alluvial sediments (facies association A) and shallow-marine/foreshore sediments (facies association C), were recurrently interrupted by transgressive pulses (facies associations B and C). Every pulse is recorded by an erosional, cemented sandy-conglomerate bar with bivalves (Ostreidae, *Isognomon*), balanids, gastropods and other marine bioclasts or their transgressive equivalents. The lateral facies changes in each individual sequence of the BTC are related to: (1) the influence on the northern foreland margin of the tectonic activity of the southern orogenic margin; (2) the palaeorelief formed by irregularities of the substrate which controls the sediment dispersal; and (3) the evolution stages of the sedimentary systems.

Riassunto. Il bacino di avanfossa del Guadalquivir, situato tra il cratone Iberico a nord e l'orogene Betico a sud, rappresenta la porzione occidentale di una avanfossa più antica della Cordigliera Betica. Lungo il margine settentrionale dell'avanfossa, il colmamento sedimentario comprende un Complesso Trasgressivo Basale (BTC) di età tortoniana, che è composto da cinque sequenze delimitate da superfici trasgressive. Entro ciascuna sequenza si possono distinguere due parti: i depositi del tratto trasgressivo inferiore ed i sedimenti del tratto superiore stazionario o trasgressivo. Sono state distinte tre associazioni di facies entro questa successione stratigrafica lungo il settore centrale del margine di bacino: conglomerati non fossiliferi e sabbie grossolane (A), conglomerati fossiliferi e sabbie grossolane (B), e sabbie fossilifere giallastre a grana media o grossolana (C). Una quarta associazione di facies (D: marne siltose bluastre e argilliti) ricopre il BTC. Depositi alluvionali (facies A) e sedimenti marini di acque basse e di spiaggia esterna (facies C), furono ripetutamente interrrotti da eventi trasgressivi (facies B e C). Ogni evento è documentato da una barra erosiva con conglomerati sabbiosi cementati con bivalvi (Ostreidae, *Isognomon*), balanidi, gasteropodi ed altri bioclasti marini o dai loro equivalenti trasgressivi. I cambiamenti laterali di facies in ogni singola sequenza della BTC sono connessi a: (1) la tettonica in atto sul margine dell'orogeno posto a sud; (2) il paleorilievo del substrato che controlla la dispersione dei sedimenti; (3) lo stadio evolutivo dei sistemi sedimentari.

Introduction

Along the northern foreland margin of the Guadalquivir Basin, S-SW Spain (Fig. 1), the Neogene record includes diverse facies overlying the foreland substrate. Because of the complex internal architecture of these facies, they have been arranged into the Basal Transgressive Complex (BTC). The facies are mainly clastic, deposited in continental (alluvial/fluvial), coastal (beach and fan deltas), and platform (shallow marine) environments. Data about the geometry, internal configuration, facies arrangements, and biostratigraphy of the BTC are scarce, being mainly focused in the western/central sectors of the basin (Civis et al. 1987 and 1994; Baceta & Pendón 1999; Pendón et al. 2001; Ruiz et al. 2001).

Study of the BTC is of interest for several reasons: (a) The BTC provides an approach to the Betic

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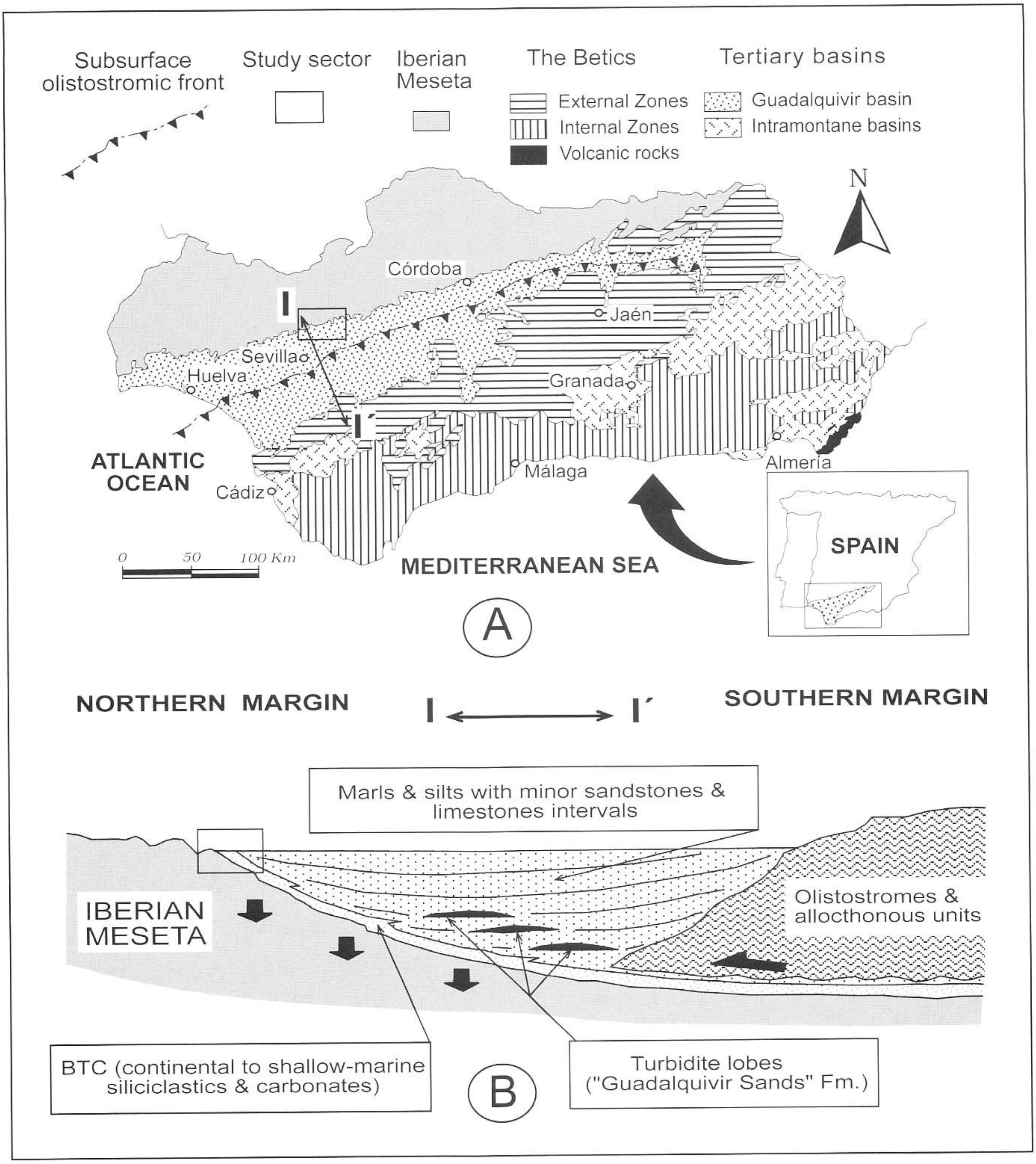

Fig. 1 - Location of the Guadalquivir basin within the context of the Betic Cordillera (A). Thrusting and olistostromes displacement, southern margin, and the resultant subsidence along the foreland basin – arrows- (B).

realm and Atlantic-Mediterranean relations during the Miocene. The region is a key for establishing biostratigraphic scales using planktonic foraminifers and calcareous nannoplankton (Perconig 1972; Sierro 1985a and b; Flores 1985). (b) Analysis delimits coastal interactions in the BTC involving distinct systems of sediment supply and sediment dispersion. (c) Petroleum exploration in 1950-1970 identified important gas shows within these facies (Perconig & Martínez-Díaz 1977).

In this paper, the stratigraphic, sedimentological, and palaeontological features of this unit are analysed to establish the origin and evolution of the BTC along the Cantillana-Lora del Río transect in the neighbourhood of Villanueva del Rio y Minas, in Sevilla Province (Fig. 2)

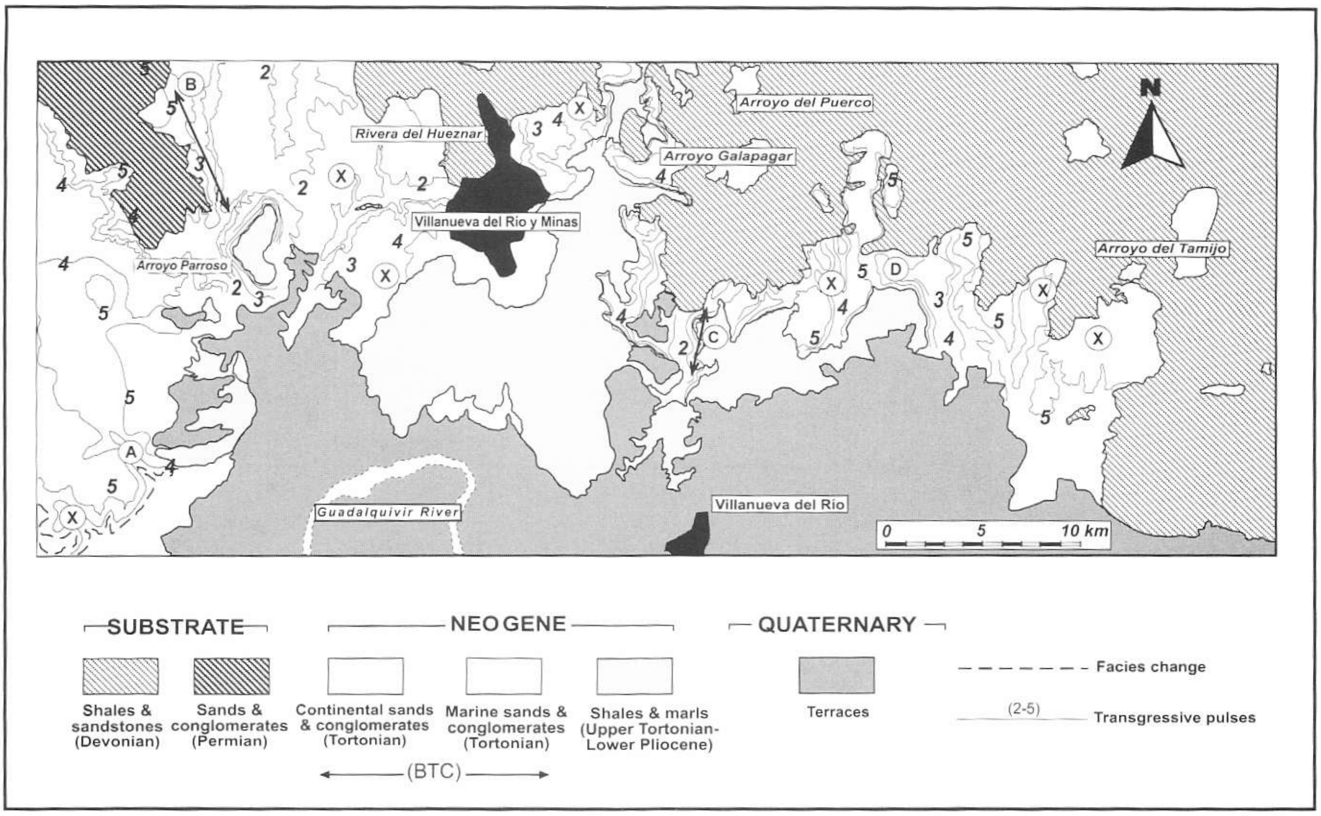

Fig. 2 - The study sector with location of the main stratigraphic sections (A, B, C, D) and another sections (X). Lateral correlation of transgressive pulses (2 to 5) within the Tortonian deposits is also indicated. Numbers refer to the respective pulse, being the first one the contact between the Palaeozoic substrate and the Tortonian rocks. See text for explanation.

on the central foreland margin of the Guadalquivir Basin. The purpose of this work is to contribute in drawing the whole picture of the BTC, which is the immediate consequence of the end of the tectonism in the Betic Cordillera. The reasons for the lateral facies variations in the BTC are also analysed. Finally, the implications of all of this are valid for the understanding of basins of the same style.

Regional Setting

The Neogene Guadalquivir Basin is an elongated depression located in southern Spain (Fig. 1A). Its geological history, closely related to the evolution of the major units of the Betic Cordillera, is controlled by its location between the Iberian basement to the north and the Betic orogen to the south and southeast (Fig. 1B). Subsidence events on the foreland margin caused by the thrusting of the Internal Zones have plaid a major role.

The Betic Cordillera, which is the western portion of the Mediterranean Alpine chains, has been subdivided into different realms. Two of them concern the history of this basin: the Internal Zones (Betic s.s.) or Alborán Block, mainly including Palaeozoic and Triassic rocks (Sanz de Galdeano 1990; Andrieux et al. 1971); and the External Zones, composed by Mesozoic-Cainozoic rocks (Fig. 1). After the continental collision of the Alborán block with the South Iberian margin during the Early Miocene, uplift occurred along the External zones, and the former Betic foredeep evolved into the Guadalquivir foreland basin. Initially, in the Tortonian, emplacement of the Internal Zones ceased. Fault-controlled intramontane basins were formed, together with the Guadalquivir Basin, on the Betic foreland (Sanz de Galdeano & Vera 1991; Vera 2000).

Concerning the western sectors of the basin, the overall succession has been subdivided into four lithostratigraphic units, the areal distribution of which can be assumed as to be relatively homogeneous. These units are: (a) Late Tortonian Niebla Fm. (Sierro 1985a; Civis et al. 1987, 1994; Baceta & Pendón 1999), composed of gravels and sands which rapidly evolve upward to calcarenites and bioclastic limestones with algal debris, bryozoa, molluscs, macroforaminifera and, finally, into a glauconite-rich silt level; (b) Late Tortonian – Early Pliocene Gibraleón Shales Fm. (Sierro 1985a; Flores 1985; Civis et al. 1987), formed by a monotonous succession of shales and marls, locally silts and sands, very rich in planktic and benthic microfauna; (c) Early Pliocene Huelva Sands Fm. (Civis et al. 1987; Civis et al. 1984; Sierro 1985a; González-Regalado 1987), consisting of silty sands and

Facies Association	Description	Texture/Fabric	Sedimentary Features	Grading	Bed Contact	Biota	Processes
A	Unfossiliferous conglomerates and coarse-grained sands	Clast-supported, Matrix-supported	Rubefied clasts Crude parallel laminataion Massive beds Avalanche-foresets	Normal Reverse	Lower: sharp scoured surface Upper: gradual	None	Debris flow Channel-fill Bar construction Planar bed flow
B	Fossiliferous conglomerates and coarse-grained sands	Cemented	Crude horizontal lamination, Scoured surface	Normal Reverse	Lower: Sharp scoured surface Upper: sharp	Ostreids, Echinoderms, Chlamys, Gastropods	Marine lag deposits
C	Fossiliferous medium-coarse-grained sands	Scattered pebbles	Parallel Lamination Foreshore lamination	In lag deposits	Sharp	Ophiomorpha, Ostreids, Pectinids	Shallow marine and/or beach deposition
D	Blue shales and silty marlstones		Structureless	-	Sharp	Planktonic/Benthic Foraminifers and Ostracods	Outer shelf deposition

Tab. 1 - Facies Associations of the BTC in the central foreland margin of the Guadalquivir Basin. See text for explanation.

sandy silts with a basal glauconite-rich layer 1 m thick and numerous accumulations of mollusc shells; (d) Early Pliocene (?) Bonares Sands Fm. (Mayoral & Pendón 1986-1987), consisting of sands with abundant littoral ichnofacies (mainly *Ophiomorpha*) which evolve upward in pebble conglomerates. These four units have an overall thickness over 400 m along the central-western sectors of the Guadalquivir Basin. Finally, the Pleistocene sandy-conglomerate, Upper Alluvial Level of Pendón & Rodriguez-Vidal (1986-1987), unconformably overlies the various Neogene units. This Neogene succession in the Huelva Province, western basin, has been considered as a transgressive-regressive cycle (González-Regalado & Ruiz-Muñoz, 1990; 1991), with its maximum depth in the basal portion of the Messinian Gibraleón Shales Fm.. This cycle was probably developed in a stepins way, because most of the unit bounding surfaces are sharp and paraconformable (Pendón & Borrego 1987), indicating fairly sudden shallowing or deepening.

The stratigraphic record has been subdivided into five depositional sequences (Sierro et al. 1995; 1997) arranged E-W as dipping clinoforms. Four main depositional environments were identified (Sierro et al. 1990): (1) basin facies, (2) toe of slope facies, (3) slope facies, and (4) platform facies. Sequences have been correlated with those derived from a seismic survey of the area (Martinez del Olmo et al. 1984). In this way the basal unit studied in this paper (BTC) correlates with the B Sequence of Sierro et al. (1995), as well as with the Betica Sequence of Martinez del Olmo et al. (1984) and Riaza & Martínez del Olmo (1995).

The age of the BTC´sequences is Tortonian s.l. (Sequences BTC-1 and BTC-2) and Late Tortonian (Sequences BTC-3, BTC-4, and BTC-5), according to the distribution of both planktic foraminifera and ostracodes (see below). This sedimentary unit correlates to the Niebla Fm. in western sectors of the basin margin, and ranks with the third order cycle TB 3.2 of Haq et al. (1988).

Deposition along the northern margin of the Guadalquivir Basin starts with different facies, according to the geographic location. Lithology varies from that occurring on central sectors. In the western sectors (Huelva and Sevilla provinces), the sedimentary record is thin, being composed by siliciclastic and calcarenite deposits (foramol facies) (Clauss & González-Regalado 1993; Baceta & Pendón 1999). The central sector is characterized by either siliciclastic or calcarenite deposits (Borrego & Pendón 1988; Sierro et al. 1997; Pendón et al. 2001), whereas the eastern areas (Córdoba and Jaén provinces) has mainly marly lithologies (Sierro et al. 1995). Those changes show all the different interaction among some factors controlling sedimentation (the sediment type, siliciclastic or calcareous; the tectonism; the eustatic changes; etc.).

Methods

This sedimentological study is based on detailed logs of eleven stratigraphic sections, using their lithologic characters and temporal correlation to determine the depositional architecture. Four stratigraphic sections were selected as summarising the vertical and lateral evolution of the BTC in the studied sector. Sequence analysis applied to these stratigraphic sections, and two- and three-dimensional study of the outcrops enabled interpretation of the internal architecture of the BTC.

Thirty samples were selected for the micropaleontological analysis. For each sample 350 gr. of dried sediment were washed through a 100 μm sieve. If possible, 300 tests of benthic foraminifers were picked. Planktic foraminifers were only studied in the lower, coarser sediments, because their distribution in the upper marls had previously been determined by Sierro (1984). In addition, the total ostracod population was picked from a tray sample, identified and counted.

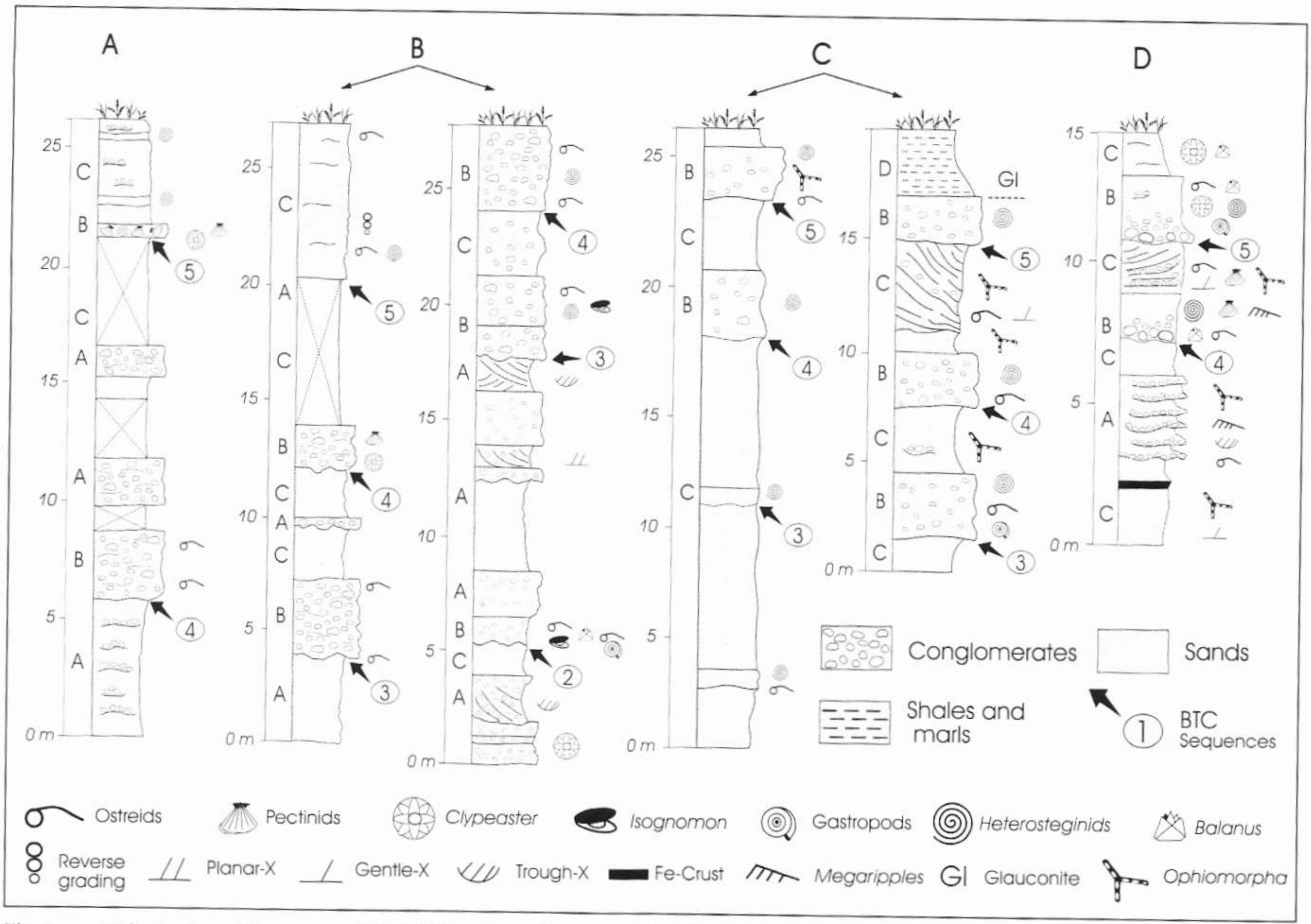

Fig. 3 - Main stratigraphic sections of the BTC in the study sector with indication of the Facies Associations arranged within them. Numbers refer to the sequence number as in Fig. 6. See Fig. 2 for location.

Stratigraphic Architecture

Substrate and Boundaries

In the central Guadalquivir basin, the Neogene sedimentary infill lies with angular unconformity over a Palaeozoic substrate, and dips southward or southeastward. The lower boundary is a transgressive surface marked by lag deposits with reworked clasts of Palaeozoic rocks. These clasts were sourced by two different zones of the Iberian Meseta (Julivert et al. 1972): the Ossa Morena Zone, including Permian conglomerates and sandstones with flora debris (Simon 1953); and the Sub-Portuguese Zone, a sedimentary succession of Upper Devonian shales and sandstones, in part metamorphosed to psammitic schists and micaschists.

The upper boundary of the BTC consists of the transition into a monotonous succession of silty marls and clays, the Late Tortonian-Early Pliocene Gibraleón Shales Fm. (Civis et al. 1987). This contact is marked by a regional discontinuity surface draped by fine-grained glauconitic sands. Marine flooding was relatively fast, as indicated by the faunal debris the overlying sediments, including abundant deep-marine microfauna (*Cytherella* spp., *Henryhowella asperrima, Krithe* spp., *Bulimina alazanenesis, Hansenica soldanii*), showing features of condensation (i.e. abundance of glauconite grains).

Facies Association and Interpretation

Four facies associations have been distinguished on the basis of grain size, sorting, fabric, palaeontological content, sedimentary structures, microfacies features, and associated lithologies: unfossiliferous conglomerates and coarse sands (A); fossiliferous conglomerates and coarse sands (B); yellow medium-coarse-grained fossiliferous sands (C); and blue silty marlstones and shales (D). The last facies association overlies the BTC. These facies have been identified in the stratigraphic sections in the studied sector (Fig. 3) and summarised in Table 1.

- Unfossiliferous conglomerates and coarse sands (A)

This facies association consists of clast-supported pebbly conglomerate, with a mean clast-size of 4-5 cm. The matrix of coarse yellow sands shows a crude horizontal lamination and gradational contacts. Locally conglomerates pass laterally into structureless sandy massive beds

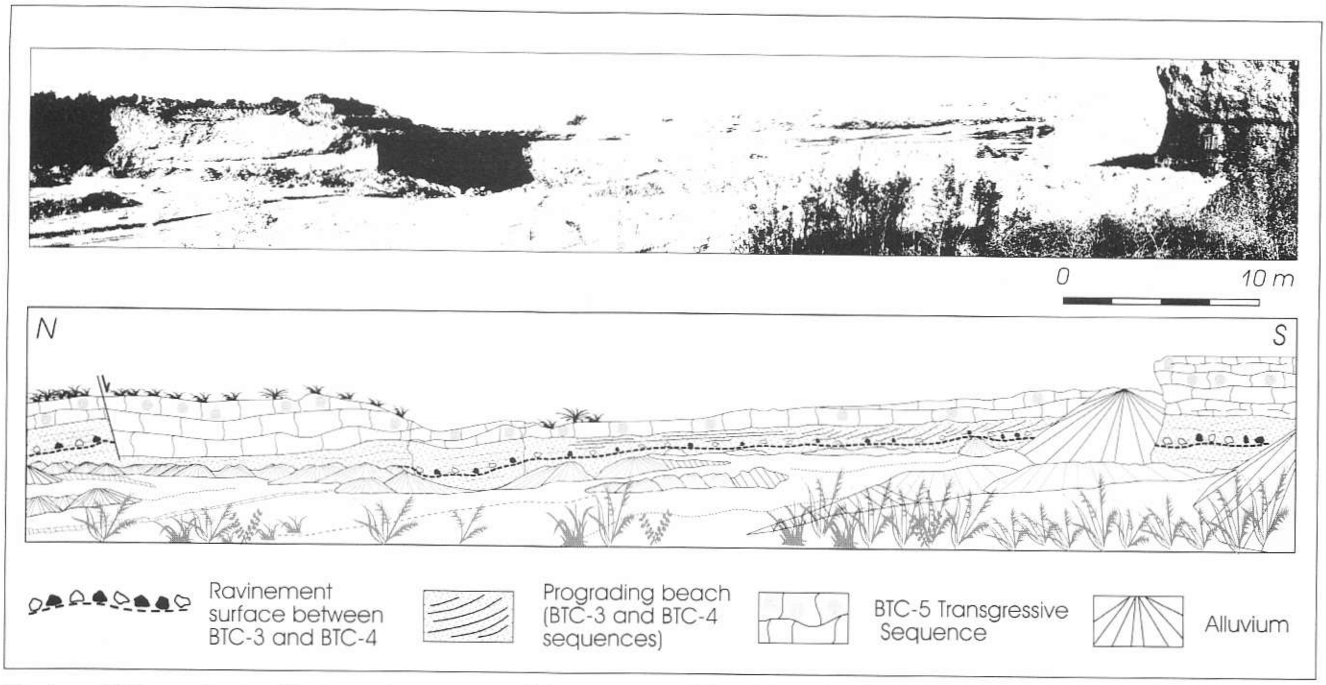

Fig. 4 - El Cuervo Section. The internal arrangement of the upper part of the BTC can be observed. See text for explanation.

or, in other cases, into cross-bedded sands. Thickness is from 0.6 m up to over 2 m. The presence of both coarsening-upward and fining-upwards units, and rubefied clasts are characteristic of this association. Fossil shells are lacking. Lithofacies **Gms**, **Gm**, **Gt**, and **Gp** (according to Miall 1978) can be recognised in conglomerates. Sedimentary structures include crudely bedded gravels (**Gm**), massive beds of either clast-supported and/or matrix-supported gravels (**Gms**), in both horizontal and/or cross-bedded horizons (**Gt** and **Gp**). The conglomerates usually form single flow bed units with erosive bases. Sandy facies (**Sh**) can be arranged into lenticular trough cross-beds with either gradational or erosional boundaries, interbedded with conglomerate units, and laterally forming avalanche foresets. Yellow medium-coarse-grained sands with scattered pebbles, in beds several meters thick also occur. Strata are disposed either in massive horizons, or with trough- or planar-cross-bedding (**Sh**, **St**, **Sl**, **Se**), delimited by erosional surfaces. When observed, sandy strata show erosional tops.

Interpretation: Sedimentary structures within these facies suggests alluvial processes such as debris flow, lag deposits, channel fill, or bar construction (Miall 1978; 1982). The sorting, the common lack of stratification, the polymodal grain size suggest that they were deposited suddenly from rapidly decelerating flows. The matrix-supported conglomerates are debris flow deposits located in proximal sectors of alluvial fan environments. The clast-supported channelised conglomerates instead represent more distal alluvial deposits from dense currents within distributary channels. Channelised flow in dune stage of lower flow regime, and plane bed stage of upper flow regime, generated other sandy facies (**Sh**, **St**, **Sl**, and **Se**).

- Fossiliferous conglomerates and coarse sands (B)

This facies association consists of alternating conglomerates and sands which show a crude horizontal lamination with normal or reverse grading. Common macrofossils are bivalves (*Crassostrea crassisima*, *Chlamys seniensis*, *Chlamys radians*, *Chlamys latissima*), cirripeds and fragments of echinoderms (*Clypeaster campanulatus*, *C. portentosus*). Moulds of another bivalves (Veneridae), gastropods (*Conus*, *Turritella*) and isolated heterosteginids (*Heterostegina gomezangulensis*) also occur.

Microfossils are poorly represented (< 20 individuals / 100 g; < 10 species per sample). Foraminifera are absent or very scarce, with *Ammonia beccarii*, *Neocorbina williamsoni*, *Elphidium macellum* and *Lobatula lobatula* as the main species. This assemblage was found together with sporadic ostracodes (*Urocythereis favosa*, *Aurila zbyszewskii*, *Cytheretta rhenana rhenana*) near the upper boundary of the BTC.

Interpretation: Both facies association and fossil record are characteristic of coastal, shallow (< 10 m depth) marine environments (Yassini 1979; Ruiz et al. 1997). Fossil record and sedimentary structures indicate that these lag deposits may be related to a marine transgression with rapidly increasing accomodation space.

- Yellow medium-coarse-grained fossiliferous sands (C)

This facies association consists of medium-coarse-grained sands with scattered pebbles in a massive layer,

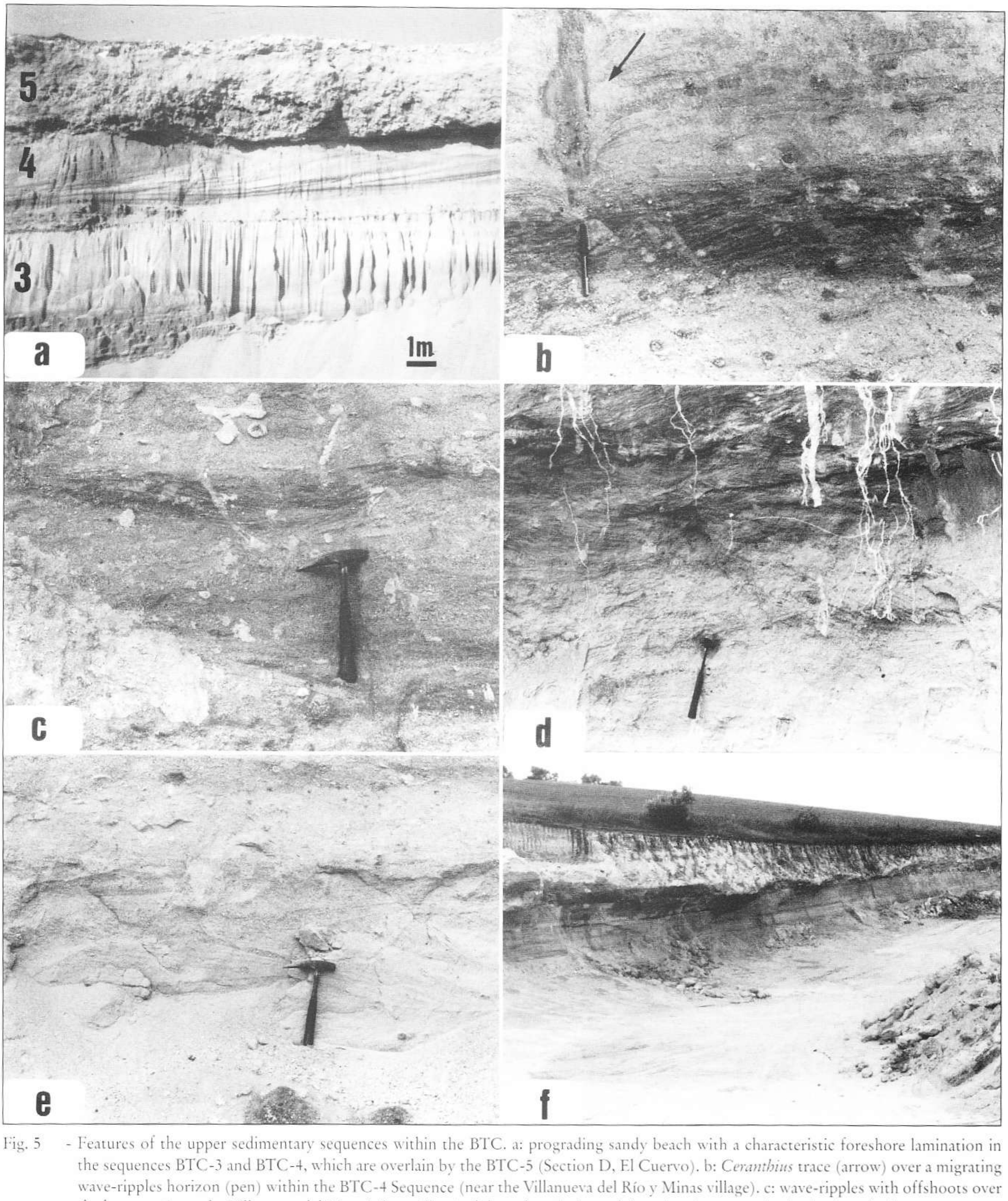

Fig. 5 - Features of the upper sedimentary sequences within the BTC. a: prograding sandy beach with a characteristic foreshore lamination in the sequences BTC-3 and BTC-4, which are overlain by the BTC-5 (Section D, El Cuervo). b: *Ceranthius* trace (arrow) over a migrating wave-ripples horizon (pen) within the BTC-4 Sequence (near the Villanueva del Río y Minas village). c: wave-ripples with offshoots over the hammer (near the Villanueva del Río y Minas village). d: lateral equivalent of the migrating wave-ripples horizon in the same outcrop of Fig. 5.b. e: the filling sequence of a runnel below the migrating wave-ripples horizon. f: panoramic view of the western edge of the outcrop of Figs. 5.b to 5.e, where the upper part of the BTC (sequences 4 and 5) is overlain by the shally formation (facies association D).

locally cemented, or with only a crude horizontal foreshore lamination partially destroyed by bioturbation (*Ophiomorpha*). Vertical and lateral sequences of bedforms show littoral organic traces (*Ophiomorpha, Ceriantbus*), and wave-ripples within a characteristic foreshore lamination (Figs. 4 and 5). Migrating ridge and runnel systems are also recorded, as well as some levels of wave-ripples. A hummocky cross-bedding horizon point to inner shelf environments.

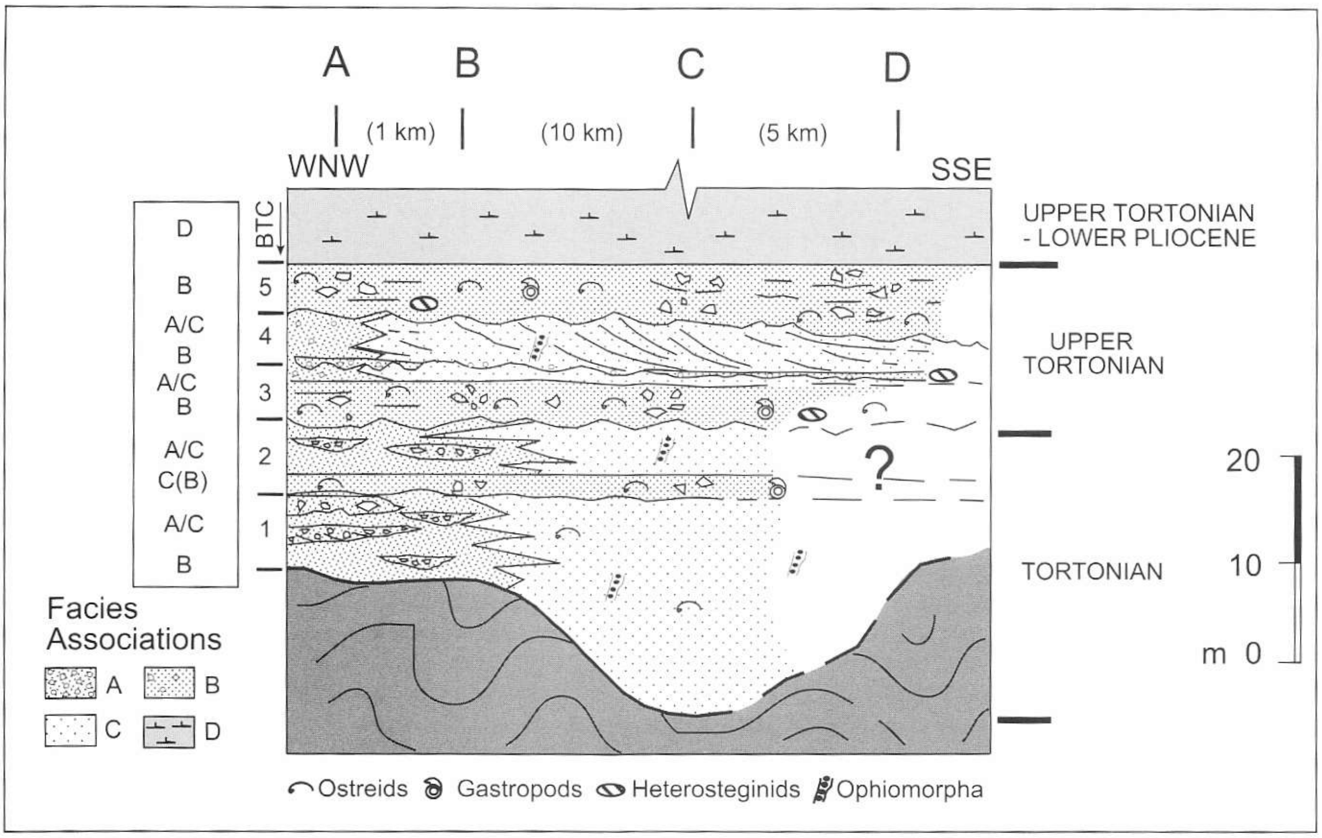

Fig. 6 - Depositional architecture of the BTC along the study sector. Letters (A, B, C, D): stratigraphic sections outlined in Figs. 2 and 3. BTC: Number (1 to 5) of every sequence within the BTC is also indicated. Key symbols as in Fig. 3. See text for explanation.

Cemented lumachelle accumulations (15-100 cm thickness) of the nummulitid *Heterostegina gomezangulensis* are commonly found with large echinoderms (*Clypeaster campanulatus, Clypeaster portentosus*) and Pectinidae (*Crassotrea crassisima, C. senoniensis, C. radians, C. latissima*), Veneridae (*Venus multilamella*) and Ostreidae pelecypods (*Ostrea edulis lamellosa, Anomia ephippium, Neopycnodonte cochlear*).

These facies have a richer microfaune than the facies association B. The foraminiferal assemblage is dominated by *Ammonia inflata, A. beccarii, Elphidium crispum, Heterolepa bellincionii* and *Nonion boueanum*; diversity increases towards the top. Ostracods are locally well represented (*Aurila zbyszewskii, Cytheretta rhenana rhenana*, and *Urocythereis favosa*). *Pterigocythereis jonesii, Celtia quadridentata* and *Costa batei* also occur near the upper boundary of the BTC.

Interpretation: This facies was deposited in shallow marine and beach environments. Both physical sedimentary structures and fossil content confirm this interpretation. The microfossil assemblage suggest inner platform conditions (< 30 m depth) (Murray 1991; Villanueva 1994; Barbieri & Ori 2000). All samples contain high percentages of adult ostracods (71-100% of total) and closed caparaces (43-65%), indicating energetic environments with moderate to high sedimentation rates (Oertly 1970; Whatley 1988). Near the top, these shallow assemblages are accompanied by both circalittoral foraminifera (*Hanzawaia boueana*) and ostracodes (*P. jonesii, C. batei*), indicating deep-water conditions (30-50 m).

- Blue silty marlstones and shales (D)

This facies association correlates to the Upper Tortonian – Lower Pliocene Gibraleón Shales Fm., and overlies the BTC. Sediments overlie a thin, sandy horizon with common glauconite interbedded within fine-grained sediments. These facies consist of a structureless and monotonous succession of alternating blue to greenish shales and marls most often weathered to an orange-yellow colour. The macrofauna is scarce (Pectinidae, Ostreidae). Nevertheless, these sediments are rich in planktonic foraminifera of Late Tortonian age (Sierro 1985a). Below the glauconite-rich horizons, the basal deposits contain an abundant and diversified assemblage of benthic foraminifera (*Bulimina costata, Cibicidoides pseudoungerianus, Heterolepa bellincionii, Uvigerina longistriata*) and ostracods (*Costa punctatissima, Ruggieria nuda, Krithe soustaensis, Cytherella consueta, Bairdoppilata rhomboidalis, Carinocythereis galilea*). These groups are rare within the glauconite horizon. In the upper clays and marls, both the ostracode density (< 15 individuals/100 g dry weigth) and diversity (< 10 species/sample) are low, with scattered valves of *Parakrithe dactylomorpha, Pterigocythereis jonesii, Henryhowella asperrima, C. consueta* and *Krithe* spp.

Interpretation: The basal deposits contain both foraminiferal and ostracode assemblages representative of a mid-shelf environment (< 75 m depth), whereas ostracode species (*Cytherella spp., H. asperrima, Krithe* spp.) in the upper marls are characteristic of a deep neritic or upper bathyal zone (Peypouquet 1970; Ruiz & González-Regalado 1996). The glauconite bed between these two horizons represents a condensed section produced by a rapid sea level rise (maximum flooding surface).

Internal Cyclicity

Five main sequences were recognized in the BTC (Fig. 6). The BTC-1 Sequence is located between the regional Palaeozoic-Neogene angular unconformity and a transgressive surface capped by a cemented marine bar. This sequence comprises thin alluvial sandy conglomerates in the WNW sector, whereas marine sands dominate elsewhere. Lag deposits with clasts of Palaeozoic rocks at the base represent the transgressive part of the sequence. The upper part is composed of alluvial sandy conglomerates and/or shallow marine sands, representing the stillstand/prograding deposits. Similar stratigraphic and lithologic features were found in the BTC-2 Sequence, delimited by two erosional transgressive surfaces.

The BTC-3 Sequence starts with a marine conglomerate with lag deposits over the erosive surface (transgressive basal part), passing upwards to shallow-marine sands overlain by another ravinement surface (Fig. 5). An extended prograding sandy beach, with numerous reworked clasts overlies this ravinement surface, forming the BTC-4 Sequence. The boundary with the next sequence, BTC-5, is another erosion surface. This last sequence is composed of a marine conglomerate bar overlain by a thin layer of silts (stillstand/prograding deposits). The upper boundary is the top of the BTC, a discontinuity surface with a condensed section (glauconitic horizon), representing the transition to the overlying Late Tortonian-Lower Pliocene strata, indicating rapid marine flooding.

The basal part of each internal sequence is a transgressive pulse. These transgressions can be summarised by their lithologic and biologic patterns, within every sequence, in the following manner:

- BTC-1 (first transgressive pulse): sandy conglomerates lag deposits within facies associations A and C.

- BTC-2 (second transgressive pulse): cemented yellow sands (facies association C) with *Isognomon* moulds, Bivalves (Veneridae and Ostreidae), Gastropods and shallow marine Ostracods (i.e. *Aurila*).

- BTC-3 (third transgressive pulse): a cemented conglomeratic bar (facies association B) with *Heterosteginids* lumachelle, Balanids, Ostreids and *Isognomon* moulds.

- BTC-4 (fourth transgressive pulse): a ravinement surface with sandy conglomerates lag deposits of the facies associations B and C, with Heterosteginids.

- BTC-5 (fifth transgressive pulse): erosional and burrowed conglomeratic bar (facies association B) with Heterosteginids lumachelle, bivalves and planktonic Foraminifera.

● FRANCE-PORTUGAL-SPAIN

□ WESTERN MEDITERRANEAN

SPECIES	PLIOCENE	MIOCENE: MESSINIAN	TORTONIAN	SERRAVALIAN	LANGHIAN	BURDIGALIAN	AQUITANIAN	ENVIRONMENT: COASTAL	INFRALITTORAL	CIRCALITTORAL	BAHYIAL	FACIES ASSOCIATION: B	C	BTC SEQUENCES: 1	2	3	4	5	UPPER CLAYS: D
Aurila punctata	●	●	●	●	●	●	●		●			●	●	●	●		●	●	●
Aurila zbyszewskii			●						●			●	●	●				●	
Bairdoppilata triangulata						●	●			●	?	●		●					
Buntonia dertonensis	□	●	●						●										●
Carinocythereis galilea		□	●					●	●										●
Cistacythereis pokornyi	●		□						●										●
Costa batei	●		●	●	●	●	●		●	●			●					●	
Costa tricostata			●	●	●	●	●			●	●								●
Cytherelloidea variopunctata			●	●		●	●		●										●
Cytheretta rhenana rhenana			●	●			●		●			●	●						
Cytheropteron lancei		●	□			□				●		●	●	●				●	
Falunia plicatula	●	●	●	●	●	●	●		●			●	●	●				●	
Henryhowella asperrima	●	●	●	●	●	●	●			●	●								●
Hiltermannicythere sphaerulolineata	●	●	●	●	●	●	●		●										●
Krithe papillosa	●	●	●	●	●	●	●			●	?								●
Krithe soustaensis		?	●	●	●	●	●			●	?								●
Loxoconcha punctatella	●	●	●	●	□	●	●		●										●
Mutilus labiatus			●	●					●			●	●	●			●	●	
Neocytherideis linearis			●	●		●	●		●				●					●	
Pontocythere lithodomoides	●		●	●	●	●	●	●	●				●					●	
Pterigocythereis jonesii	●	●	●	□						●								●	●
Ruggieria nuda	●	●	●	●	●	●	●			●									●
Sagmatocythere grateloupiana	●	●	●	●	●	●	●		●				●		●			●	
Urocythereis favosa	●		●	●					●			●	●	●	●		●	●	
Xestoleberis glabrescens	●		●	●		●	●	●	●			●	●					●	●

Fig. 7 - Ostracode biostratigraphy and palaeoecological data of species collected within the BTC sediments.

Physical tracing of these transgressive pulses is possible across the study sector (see Fig. 2). This allowed us to trace time-lines (1 to 5) across the basin margin. It may be useful as a tool for stratigraphic correlations along this basin margin, in particular for those levels with cemented rocks, which can be controlled in the outcrops.

Discussion

Biostratigraphy

Most of the Ostracode taxa (Fig. 7) observed (i.e. *Aurila punctata, Falunia sphaerulolineata, Ruggieria nuda, Xestoleberis glabrescens*) are inadequate guide fossils for the Lusitanian ostracode province, because they range from the Aquitanian to the Pliocene (Moyes 1965; Yassini 1969). A Tortonian age (s.l.) may be inferred by the co-existence of pre-Messinian (e.g. *Cytherelloidea variopunctata, Cytheretta rhenana rhenana, Neocytherideis linearis*) and post-Serravalian taxa (*Buntonia dertonensis, Cystacythereis pokornyi*). Two other species (*Aurila zbyszewskii, Carinocythereis galilea*) have been found only in Tortonian deposits of Portugal and Spain (Nascimento 1983; Ruiz et al. 1999). The former species were found in the BTC-1 Sequence, indicating a Tortonian age (s.l.) for the lower Sequence of the BTC.

Planktic foraminifera were found in three samples of both BTC-3 and BTC-5 sequences, being represented mainly *Globigerina bulloides, G. parabulloides, G. eamesi, Globigerinoides obliquus, G. trilobus* and *Orbulina universa*. The age of these sequences may be inferred by the presence of some occasional species, such as *Turborotalia (T.) acostaensis, Globorotalia merotumida, G. scitula, Globigerina decoraperta,* and *Globigerinoides ruber.* This assemblage is indicative of a Late Miocene (Late Tortonian) age (N.16 Zone of Blow 1979; *Turborotalia humerosa* Zone of Sierro 1985a; M13 Zone of Berggren et al. 1995).

According to these data, the age of the early transgressions (BTC-1 and –2) would be Tortonian sensu lato, and the late transgressions (BTC- 3 to BTC–5) would be late Tortonian.

Depositional Model

In the study sector, the facies associations distinguished along a WNW-SSE transect of the BTC (Fig. 6) can be grouped into three genetic assemblages: alluvial (A), coastal (B and C), and platform (B and D). Tortonian transgressive sediments were deposited on an angular unconformity, and begin (Sequence BTC-1) with coarse alluvial sedimentation (Facies Association A) in the WNW corner of the sector. Debris flow deposits (matrix-supported conglomerates), and density currents transport within secondary distributary channels (clast-supported conglomerates) produced the channel-fill, whereas shallow marine deposits occur toward the SSE (Facies Association C). A cemented marine bar (Facies Association B) overlies this sequence, meaning the start of deposition of the Sequence BTC-2. This second sequence was deposited as the result of a new transgression originated during a paracycle of sea level rise. Sedimentary facies are similar to those of the previous sequence (BTC-1).

Deposits of the third transgression consist of a cemented sandy conglomerate bar (facies association B), passing upwards to sands of facies association C, deposited in shallow-marine to foreshore environments. A ravinement surface, which occurs in the Galapagar section and in much of the El Cuervo section (Fig. 6), marks cap of the BTC-3 Sequence. On this transgressive surface with both conglomerate lag deposits and a lenticular conglomerate bar, the rest of the BTC-4 sequence deposition constituted a prograding sandy foreshore. The fifth transgressive pulse is recorded in a marine bar with pebbles and cobbles, marine shells and littoral organic traces (*Ophiomorpha*). It is a ravinement conglomerate, which laterally encloses boulders of Palaeozoic quartzite, indicating transgression on a rocky coast. The Upper limit of the BTC (Tortonian Transgressive System Tract) marks the transition to the marly Highstand System Tract (Late Tortonian –Early Pliocene) with deposition of the facies association D on top of a condensed section represented by the glauconite horizon.

The above model implies that a Tortonian sandy coast was present in the eastern edge of the sector throughout deposition of the BTC (Sequences 1 to 5). These coastal conditions expanded westward during the Late Tortonian (mainly BTC-3 and BTC-4 sequences). The coast was wave-dominated, as the Holocene coast of Huelva (Dabrio 1982; Pendón et al. 1998; Pendón 1999). We suppose that the dominant wave activity produced important littoral drift dynamics (Davis & Hayes 1984). Sediment supply to this coast was carried out from the emerged foreland, via alluvial fan and fan delta systems. Sediment dispersal of marine sediments was also performed by waves activity.

Each sequence within the BTC can be subdivided into two main parts: (1) the basal part (Transgressive lag deposits or their equivalents: facies associations B and C), and (2) the upper part (Stillstand or Prograding deposits: facies associations A and C). The depositional model is depicted in Fig. 8. The facies associations appearing within the five internal sequences of the BTC in every distinctive situation are indicated: the basal transgressive lags or equivalents, and the stillstand/prograding deposits. Sediment is supplied from both landward and seaward directions. The shoreline and shoreface migrate landward by ravinement. There is a significant reworking of underlying deposits, as a consequence of both shoreface bypassing and shoreface retreat.

Lateral facies changes within the BTC

Emplacement of the main olistostromes along the southern orogenic margin of the Gadalquivir Basin

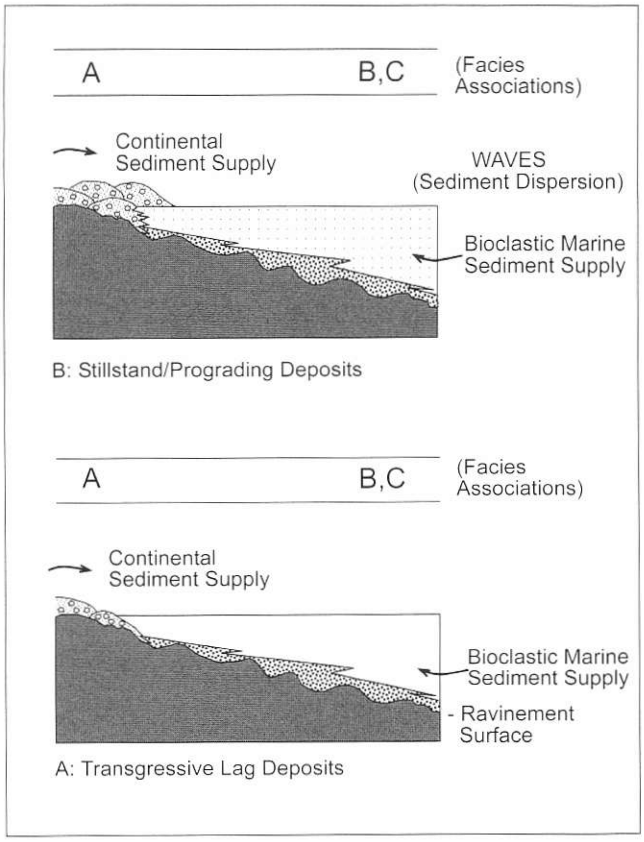

Fig. 8 - Depositional model for every sequence within the BTC. See text for explanation.

is synchronous with deposition of the BTC, as pointed out by Riaza & Martinez del Olmo (1995). Subsidence along the northern foreland margin of this basin, produced as a result of the tectonic events in the southern thrust front (thrusting, olistostromes, etc.), permitted deposition of the BTC sequences, which correspond to a Tortonian Transgressive System Tract. Tectonism is thus the main controlling factor of the sequences deposition of the BTC. In fact, the siliciclastic nature of their deposits, along the central sector of the foreland margin, is the response to the tectonic activity and the subsequent erosion of the foreland highs.

High energy alluvial systems developed in the foreland margin, with streams passing from the foreland highs through a rocky coast, deposit in the WNW sector and form part of the lower sequences, BTC-1 to BTC-4 (Figs. 6 and 8). The irregularity of the substrate paleorelief controls the sedimentary systems, and consequently facies changes. The co-existence of marine and continental sediment supplies produces the facies change occurring between continental (WNW sector) and marine (SSE sector) facies. Wave action causes sediment dispersal supplied by littoral currents. The marine environment extends throughout the sector during deposition of the upper sequence (BTC-5).

Finally, and at the scale of the whole basin, the sedimentary environments located in the foreland margin received two main types of sediment, calcareous or siliciclastic. In areas where the calcarenite deposits are predominant, outside of the study sector, a carbonate factory could be installed because the siliciclastic sediment supply was relatively low in such a way that it could not inhibit the calcareous deposition.

Conclusions

Three facies associations were distinguished within the BTC along the central foreland margin of the Guadalquivir Basin, grouped into two assemblages: alluvial (A) and coastal-platform deposition (B and C). These facies are arranged into five sequences (BTC-1 to BTC-5) by distinctive, internal bounding surfaces. Each sequence is subdivided into a basal part (transgressive lags and their equivalents), and an upper part (stillstand/prograding deposits).

The facies associations are recurrently interrupted by transgressive pulses, as a result of stepinse sea level rise (parasequences), and extended throughout the study sector. These pulses allow stratigraphic correlation along the basin margin and interpretation of the depositional architecture. This correlation can be physically traced along the outcrops for sequences with basal parts composed of cemented rocks.

Macro- and microfaunal assemblages give precise information on the environmental setting of the BTC. In the Tortonian littoral palaeoenvironments, both macro- and microfaunas were scarce, being represented by bivalves (Ostreidae), benthic foraminifera (*A. beccarii, E. crispum, N. boueanum*) and ostracodes (*U. favosa*, and *A. punctata*). The main feature of the infralittoral-circalittoral environments is the abundance of nummulitids (*H. gomez-angulensis*), bivalves, and ostracods (*C. pokornyi*). Macrofauna is scattered in the external platform and upper slope during the Late Tortonian (marls and clays which overlies the BTC), when the benthonic foraminifera (*B. lappa, H. boueana*) dominated the microfauna. In these palaeoenvironments, ostracodes were minor (*H. asperrima, Krithe* spp., *Cytherella consueta*).

A wave-dominated sandy coast was developed during the Late Tortonian in the central passive margin of the Guadalquivir foreland basin. Littoral drift was related to wave activity, which controlled the sediment dispersal systems.

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REFERENCES

Andrieux A., Fontboté J.M. & Mattauer M. (1971) - Sur un modèle explicatif de l´arc de Gibraltar. *Earth & Planet. Sci. Lett.*, 12: 191-198, Amsterdam.

Baceta J.I. & Pendón J.G. (1999) - Estratigrafía y arquitectura de facies de la Formación Niebla, Neógeno superior, sector occidental de la cuenca del Guadalquivir. *Rev. Soc. Geol. España*, 12: 419-438, Madrid.

Barbieri R. & Ori G.G. (2000) - Neogene palaeoenvironmental evolution in the Atlantic side of the Rifian Corridor (Morocco). *Palaeogeogr., Palaeoclim., Palaeoecol.*, 163: 1-31, Amsterdam.

Berggren W.A., Kent D.V., Swisher C.C. & Aubry M.P. (1995) - A revised Cenozoic geochronology and chronostratigraphy. In: Berggren W.A., Kent D.V., Aubry M.P. & Hardenbol J. (eds.)- Geochronology, time scales and global stratigraphic correlations *Soc. Econ. Palaeont. Miner. Spec. Publ.*, 54: 129-212, Tulsa.

Blow W. (1979) - Late Middle Eocene to Recent planktonic Bioestratigraphy. *Proc. Ist. Conf. Plank. Mic.* Geneva, 1967, 1: 199-241.

Borrego J. & Pendón J.G. (1988) - Progradación deltaica Tortoniense en el sector de Villanueva del Río y Minas (Provincia de Sevilla). *II Congr. Geol. Esp.*, Granada, Comunicac., 1: 47-50.

Civis J., Sierro F.J., González-Delgado J.A., Flores J.A., Andrés I., Porta J. &Valle M.F. (1987) - El Neógeno marino de la Provincia de Huelva: Antecedentes y definición de las unidades litoestratigráficas. In: *Paleontología del Neógeno de Huelva (W Cuenca del Guadalquivir)*, Edic. Univ. Salamanca, Dt. Estratigrafía, 9-20.

Civis J., González-Delgado J.A., Andrés I., Sierro F.J., Valle M.F. & Flores J.A., (1984) - Catálogo malacológico (Gastropoda y Bivalvia) del Plioceno de Huelva. *Stud. Geol. Salmant.* 19, Suppl. 1: 28 pp., Salamanca.

Civis J., Alonso G., González-Delgado J.A. & Braga J.C. (1994) - Sédimentation carbonatée transgressive sur la bordure occidentale du couloir Nord-bétique pendant le Tortonien supérieur (Fm. Calcarenita de Niebla, SW de l´Espagne. *Géol. Méditerranée*, 21: 9-18, Paris.

Clauss F.L. & Conzález-Regalado M.L. (1993) - Caracterización de las microfacies carbonatadas de la formación Calcarenita de Niebla (Provincia de Huelva, España). *Bol. R. Soc. Hist. Nat. (Sec. Geol.)*, 88: 5-16, Madrid.

Dabrio C.J. (1982) - Sedimentary structures generated on the foreshore by migrating ridge and runnel systems on microtidal and mesotidal coasts of South Spain. *Sedimentary Geology*, 32: 141-151, Amsterdam.

Davis R.A.& Hayes M.O. (1984) - What is a wave-dominated coast? *Marine Geol.*, 60: 313-329, Amsterdam.

Flores J.A. (1985) - Nannoplancton calcáreo en el Neógeno del borde noroccidental de la Cuenca del Guadalquivir (SO de españa). *Doctoral thesis Univ.* Salamanca, 714 pp. (Unpublished).

González-Regalado M.L. (1987) - Asociaciones de foraminíferos bentónicos en el Plioceno de Huelva. *Publicac. Univ. Sevilla, Ser. Ciencias* 27: 1-72.

González-Regalado M.L. & Ruiz F. (1990) - Los Ostrácodos del tramo inferior de la Formación "Arcillas de Gibraleón" (Gibraleón, Provincia de Huelva, S.W. España). *Rev. Soc. Geol. España*, 3: 23-31, Madrid.

González-Regalado M.L. & Ruiz F. (1991) - Signifcado paleoecológico y bioestratigráfico de los Ostrácodos del Neógeno Superior de la Sección de Huelva. *Rev. Esp. Paleont.*, 6: 107-116, Madrid.

Gupta S. (1999) - Controls on sedimentation in distal margin palaeovalleys in the Early Tertiary Alpine foreland basin, south-eastern France. *Sedimentology*, 46: 357-384, London.

Haq B.U., Hardenbol J. & Vail P.R. (1988) - Mesozoic and Cenozoic Chronostratigraphy and Eustatic Cycles. In: Wilgus C.K., Hasting B.S., Kendall C.G.S.C., Posamentier H., Rossy C.A & Van Wagoner J.V. (eds.)- Sea-level changes.- An integrated approach . *Soc. Ec. Palaeont. Mineral. Spec. Publ.*, 42, 71-108, Tulsa.

Julivert J., Fontboté J.M., Ribeiro A.& Nabais-Conde L.E. (1972) - Mapa Tectónico de la Península Ibérica y Baleares, E. 1:1.000.000. *Inst. Geol. Min. Esp.*, Mem., 113 pp., Madrid.

Martínez del Olmo W., García-Mallo J., Leret G., Serrano A. & Suarez J. (1984) - Modelo tectosedimentario del Bajo Guadalquivir. *I Congr. Esp. Geol.*, 1: 199-213, Segovia.

Massari F., Grandesso P., Stefani C. & Jobstraibizer P.G. (1986) - A small polyhistory foreland basin evolving in a context of oblique convergence:the Venetian basin (Chattian to Recent, southern Alps, Italy). In: Allen P.A. & Homewood P. (eds.) Foreland Basins, *Int. Ass. Sedim. Spec. Publ.*, 8: 141-168, London.

Mayoral E. & Pendón J.G. (1986-1987) - Icnofacies y Sedimentación en Zona Costera. Plioceno Superior, Litoral de Huelva. *Acta Geol. Hisp.*, 21-22: 507-513, Barcelona.

Miall A.D. (1978) - Lithofacies types and vertical profile models in braided rivers: a summary. In: Miall, A.D. (ed) - Fluvial Sedimentology, *Can. Soc. Petrol. Geol. Mem.* 5: 597-604, Victoria.

Miall A.D. (1982) - Analysis of Fluvial Depositional Systems. *Am. Ass. Petrol. Geol. Educat. Course Note Ser.*, 20: 75 pp., Tulsa.

Moyes J. (1965) - Les ostracodes du Miocène Aquitain: essai de paléoécologie stratigraphique et de paléogéographie. *Thése Université de Bordeaux*, 339 pp.

Murray J.W. (1991) - Ecology and paleoecology of benthic foraminifera. Longman Scientific & Technical, New York, 397 pp.

Nascimento A. (1983) - The ostracoda fauna of the Portuguese Neogene and its relationship to those from the Atlantic and Mediterranean Basins. In: Maddocks R. (ed.) - *Applications of Ostracoda*, 429-436. Ed. Univ. Houston.

Oertli H. J. (1970) - The aspect of ostracode faunas. A possible new tool in petroleum sedimentology. *Bull. Centre Recherche SNPA*, 5: 137-151, Pau.

Pendón J.G. (1999) - La costa de Huelva. *Serv. Publ. Univ.* Huelva, 198 pp.

Pendón J.G. & Borrego J. (1987) - El Neógeno del extremo occidental de la Cuenca del Guadalquivir. *Mediterránea, Ser. Geol.*, 6: 97-114, Alicante.

Pendón J.G., González-Regalado M.L., Ruiz F., Abad M. & Tosquella J. (2001) - Pulsos transgresivos neógenos en el sector central del margen pasivo de la Cuenca del Guadalquivir. *Geotemas,* 3 (2): 13-16, Madrid.

Pendón J.G., Morales J.A., Borrego J., Jiménez I. & López M. (1998) - Evolution of estuarine facies in a tidal channel environment, SW Spain: evidence for a change from tide- to wave-domination. *Marine Geol.,* 147: 43-62, Amsterdam.

Pendón J.G. & Rodriguez-Vidal J. (1986-1987) - Caracteres sedimentológicos y geomorfológicos del Alto Nivel Aluvial cuaternario en el litoral de Huelva. *Acta Geol. Hisp.,* 21-22: 107-111, Barcelona.

Perconig E. (1972) - *Heterostegina gomez-angulensis* nueva especie del Mioceno superior español y *Heterostegina complanata* Meneghini. *Rev. Esp. Micropaleont.,* núm. extr. XXX Aniv. E.N. Adaro, 7-137, Madrid.

Perconig E. & Martínez-Díaz C. (1977) - Perspectivas petrolíferas de Andalucia Occidental. *Bol. Geol. Min.,* 88: 417-433, Madrid.

Peypouquet, J. P. (1970) - Les ostracodes de la région de Capbreton. Intéret écologique et paléoécologique. *Thèse Université de Bordeaux* I. 266 pp.

Riaza, C. & Martinez del Olmo, W. (1995) - Depositional Model of the Guadalquivir – Gulf of Cádiz Tertiary basin. In: Friends, P. & Dabrio, C.J. (eds), *Tertiary Basins of Spain.* Cambridge University Press, 330-338, Cambridge.

Ruiz, F., & González-Regalado, M. L. (1996) - Les ostracodes du Golfe Mio-Pliocene du sud-ouest de l'Espagne. *Rev. Micropaleont.* 39: 137-151, Paris.

Ruiz, F., González-Regalado, M. L. & Muñoz, J. M. (1997) - Multivariate analysis applied to total and living fauna: seasonal ecology of recent benthic ostracoda off the North Cádiz Gulf coast (SW Spain). *Mar. Micropaleont.* 31: 183-203, Amsterdam.

Ruiz, F., Baceta, J. I., González-Regalado, M. L. & Tosquella, J. (1999) - Los ostrácodos de las arenas con *Heterostegina* de la Formación "Calcarenita de Niebla" (Depresión del Guadalquivir, S. O. de España). *Studia Geologica Salmanticensia,* 35: 9-19, Salamanca.

Ruiz, F., González-Regalado, M.L., Baceta, J.I., Pendón, J.G., Tosquella, J. (2001) - Datos preliminares sobre los ostrácodos de las arenas basales de la Formación "Niebla" (Depresión del Guadalquivir, S.O. de España). *Geogaceta* 29: 115-118, Madrid.

Sanz de Galdeano, C. (1990) - Geologic evolution of the Betic Cordilleras in the Western Mediterranean. Miocene to Present. *Tectonophysics,* 172: 107-119, Amsterdam.

Sanz de Galdeano, C. y Vera, J.A. (1991) - Una propuesta de clasificación de las cuencas neógenas béticas. *Acta Geol. Hisp.,* 26: 205-227, Barcelona.

Sierro F.J. (1985a) - Estudio de los microforaminíferos planctónicos, bioestratigrafía y cronoestratigrafía del Mio-Plioceno del borde occidental de la Cuenca del Guadalquivir (S.O. de España). *Studia Geologica Salmaticensia,* 21: 7-85, Salamanca.

Sierro F.J. (1985b) - The replacement of the "*Globorotalia menardii*" group by the *Globorotalia miotumida* group: an aid to recognizing the Tortonian-Messinian boundary in the Mediterranean and adjacent Atlantic. *Mar. Micropaleont.,* 9: 525-535, Amsterdam.

Sierro F.J., González-Delgado J.A., Dabrio C.J., Flores J.A. & Civis J. (1990) - The Neogene of the Guadalquivir basin (SW Spain). *Paleont. Evolucio. Mem. Spec.,* 2: 209-250, Sabadell.

Sierro F.J., González-Delgado J.A., Dabrio C.J., Flores J.A. & Civis J. (1995) - Late Neogene depositional sequences in the foreland basin of Guadalquivir (SW Spain). In: Friends, P.F. & Dabrio, C.J. (eds.)- Tertiary Basins of Spain. The Stratigraphic Record of Crustal Kinematics, *Cambridge Univ. Press,* 339-345, Cambridge.

Sierro F.J., González-Delgado J.A., Dabrio C.J., Flores J.A. & Civis J. (1997) - The Neogene of Huelva (Guadalquivir Basin, SW Spain). In: González-Delgado, J.A. Sierro, F.J. & Pais, J. (coords.), The Guadalquivir Basin and Algarve (Spain, Portugal) (Field-Trip Guide 2nd Excursión) *2nd Congress R.C.A.N.S.,* Salamanca, 11-34.

Simon W. (1953) - Lithogenesis Kambrischer Kalke der Sierra Morena (Spanien). *Senckenbergiana,* 21: 297-311, Wilelhmshaven.

Vera J.A. (2000) - El Terciario de la Cordillera Bética: Estado actual de conocimientos. *Rev. Soc. Geol. España,* 13: 345-373, Madrid.

Villanueva P. (1994)- Implicaciones oceanográficas de los foraminíferos bentónicos recientes en la bahía y plataforma gaditana. Taxonomía y asociaciones. *Tesis Doctoral. Univ.* de Cádiz, 363 pp. (Unpublished).

Whatley R. C. (1988) - Population structure of ostracods: some general principles for the recognition of palaeoenvironments. In: De Deccker P., Colin J. P. & Peypouquet J. P. (eds.) - Ostracoda in the Earth Sciences, Elsevier Publ. Co., 245-256, Amsterdam.

Yassini I. (1969) - Ecologie des associations d'Ostracodes du Bassin d'Arcachon et du littoral Atlantique. Application à l'interpretation de quelques populations du Tertiaire Aquitain. *Thèse Université de Bordeaux.* 288 pp.

Yassini I. (1979) - Répartition des ostracodes dans une série marine régressive d'âge pliocène dans la région d'Alger, Algérie. *Rev. Micropaléont.,* 22: 289-124, Paris.