Rivista Italiana di Paleontologia e Stratigrafia	volume 110	no. 1	pp. 151-162	April 2004

THE MIDDLE JURASSIC EASTERN MARGIN OF THE IBERIAN PLATFORM SYSTEM (EASTERN SPAIN). PALAEOGEOGRAPHY AND BIODISPERSAL ROUTES OF AMMONOIDS.

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Received September 19, 2002; accepted September 18, 2003

Keywords: facies, carbonate platform, condensed section, deepening/shallowing cycle, extensional basin, palaeobiogeography, dispersal route, Proto-Atlantic, Western Tethys.

Abstract. From a sedimentological and palaeogeographical point of view, in the eastern margin of the Iberian platform system, Middle Jurassic deposits are represented by a thick pile of carbonates with minor marls interbedded. Different facies, within the Tortosa, Aragonese and Castilian platforms, pertain to two categories: internal platform and external platform facies. A system of extensional faults was the major factor determining the differentiation of several shallow, carbonate, epicontinental platforms. The so-called Iberian Basin was a shallow intracratonic platform system, in which a relatively deep extensional basin (the Catalan Basin) started to be differentiated during the late Bajocian. In the eastern part of this faulted platform system, the occurrence of a listric fault, dipping towards the east, conditioned the development of a late Bajocian differentiated subsident area named the Tortosa Platform.

From a palaeobiogeographical point of view, the ammonite fossil assemblages of the Iberian platforms are composed of Sub-Mediterranean taxa. At the eastern margin of the Iberian platform system, the appearance and distribution of shells of ammonoids were taphonomically and ecologically controlled by regional changes of relative sea level. A Sub-Mediterranean zonation can be recognized, although most of the ammonites shells correspond to adult individuals arrived by necroplanktic drift from more open-marine or oceanic areas. The following criteria are relevant in recognizing the maximum deepening episodes in the Iberian platform system: colonization (including ontogenic development) of open-marine taxa, immigration of oceanic taxa and development of endemic species. In terms of Sequence Stratigraphy, the development of expanded, external platform sections in the Tortosa Platform during the Garantiana Biochron (late Bajocian) is noteworthy. During this episode, the Iberian platform system reached the maximum bathymetric values and acted as a biogeographical dispersal area for some taxonomic groups of ammonoids between the Western Tethys and the Proto-Atlantic.

Riassunto. Da un punto di vista sedimentologico e paleogeografico, sul margine esterno del sistema di piattaforme iberiche, i depositi medio-giurassici sono rappresentati da una spessa pila di carbonati con poche marne intercalate. Nelle piattaforme di Tortosa, aragonese e castigliana, le differenti facies appartengono a due categorie: facies di piattaforma interna ed esterna. Un sistema di faglie distensive è stato il fattore principale nel determinare la differenziazione di molte piattaforme carbonatiche epicontinentali di acqua bassa. Il cosiddetto Bacino Iberico era un sistema intracratonico di piattaforme d'acqua bassa, in cui durante il Bajociano superiore ha cominciato a differenziarsi un bacino estensionale relativamente profondo (il Bacino Catalano). Nella parte orientale di questo sistema di piattaforme fagliato, la comparsa di una faglia listrica, immergente verso Est, ha condizionato nel Bajociano superiore lo sviluppo di un'area subsidente differenziata detta Piattaforma di Tortosa.

Da un punto di vista paleobiogeografico, le associazioni fossili ad ammoniti delle piattaforme iberiche sono composte da taxa submediterranei. Al margine orientale del sistema di piattaforma iberico, la comparsa e la distribuzione delle conchiglie di ammonoidi è stata tafonomicamente ed ecologicamente controllata da cambiamenti regionali del livello marino relativo. Si può riconoscere una zonazione submediterranea, sebbene la maggior parte delle conchiglie di ammoniti corrisponda ad individui adulti arrivati per deriva necroplanctonica da aree di mare più aperto od oceaniche. I seguenti criteri sono rilevanti per riconoscere gli episodi di massimo approfondimento nel sistema di piattaforma iberico: colonizzazione (incluso sviluppo ontogenetico) dei taxa di mare aperto, immigrazione di taxa oceanici e sviluppo di specie endemiche. In termini di Stratigrafia Sequenziale, lo sviluppo di sezioni espanse di piattaforma esterna nella Piattaforma di Tortosa durante il Biocrono Garantiana (Bajociano superiore) è degno di nota. Durante questo episodio, il sistema di piattaforma iberico ha raggiunto i massimi valori batimetrici ed ha agito come un'area di dispersione biogeografica per alcuni gruppi tassonomici di ammonoidi tra la tetide Occidentale ed il Proto-Atlantico.

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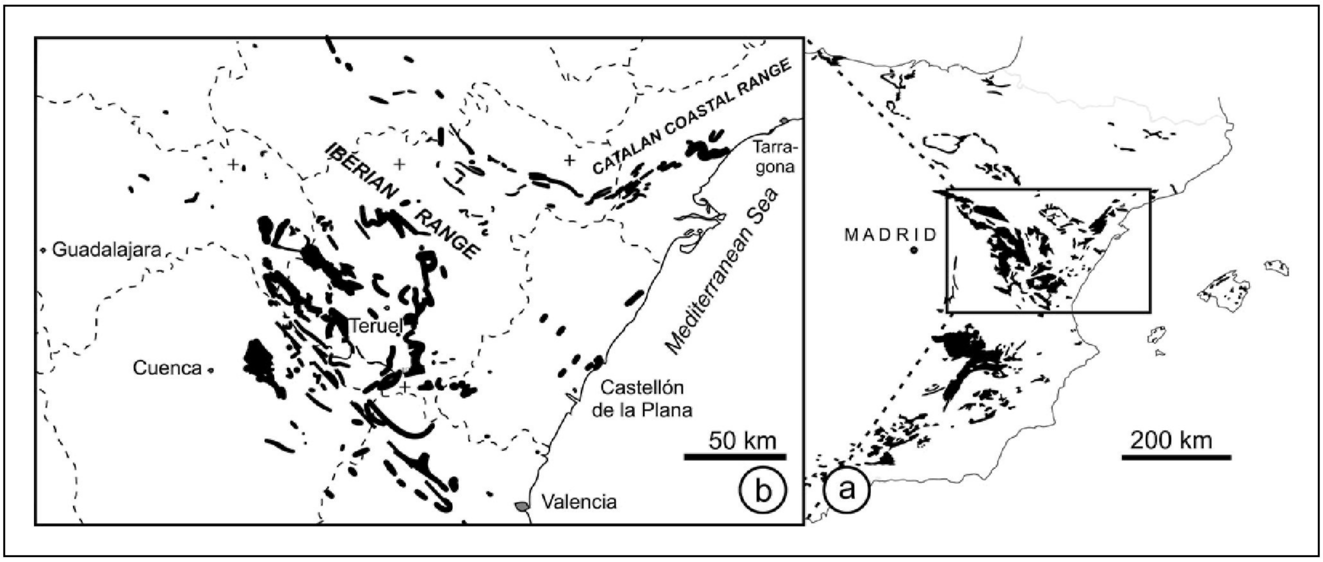

Fig. 1 - Maps showing the location of the studied area in Spain. a. Black areas represent the outcrops of Jurassic sediments. b. Middle Jurassic outcrops (black) in the Iberian Range and in the Catalan Coastal Range. Dashed lines represent the province boundaries.

Introduction

The Iberian and Catalan Coastal ranges, located in the eastern part of the Iberian Peninsula, are Alpine folded belts, oriented respectively NW and NE (Fig. 1). Many regional, stratigraphical, sedimentological and palaeontological works dedicated to the study of the Middle Jurassic deposits, at a local scale in both areas, have been carried out by numerous authors. In particular, referring to the lithostratigraphic studies, the following works have been published: Goy et al. 1976; Gómez & Goy 1979; Cadillac et al. 1981; Salas 1987,1989; and Fernández-López et al. 1996. The Iberian platform system, or the so-called Iberian and Catalan basins, was a set of shallow epicontinental platforms located in the eastern margins of the Iberian Plate. These platforms served as biogeographical routes between the Western Tethys and the Proto-Atlantic and the Central Atlantic Ocean during the Middle Jurassic.

The two main objectives of this work are to perform the palaeogeographical reconstruction of the eastern margin of the Iberian platform system, as well as to examine the distribution patterns of ammonoids to show the palaeoenvironmental changes and the appearance of active migrational routes throughout these shallow marine areas during the Middle Jurassic.

Facies distribution and palaeogeography

Palaeogeographical reconstruction of the Iberian platform system in eastern Spain for the Middle Jurassic has been carried out in two phases. In a first phase, criteria such as the presence and the absence of Middle Jurassic deposits due to non-sedimentation or erosion, as well as thickness variations, have been used. The result of mapping these criteria is summarized in Fig. 2. In a second phase of analysis, overlay of the chronostratigraphical correlation diagram (Fig. 3) with the thickness distribution map (Fig. 2) allowed palaeogeographical reconstruction of the Middle Jurassic eastern margin of the Iberian platform system shown in Fig. 4.

Middle Jurassic sediments are absent in the western, northern and northeastern areas of the studied zone, due to non-deposition or Cretaceous to Recent erosion (Fig. 2). From west to east, major depositional areas, having Middle Jurassic expanded sections thicker than 150 m, were the Pozuel, the Enguídanos, the Casinos, the El Maestrazgo and the Tortosa depocentres. In the eastern portion, the Tortosa and the El Maestrazgo depocentres are surrounded by deposits of low thickness, generally less than 50 m, like the sections located north and south of the El Maestrazgo Depocentre (Fig. 2).

Thickness and facies distribution (Fig. 2) in the eastern Iberian Peninsula were mainly controlled by a grid of synsedimentary faults trending northeast and northwest. Some of these structures has been pointed out by several authors (Canerot 1974; Anadón et al. 1982; Canerot et al. 1984; Cadillac et al. 1981, 1984; Salas & Casas 1993; Roca et al. 1994; Sàbat et al. 1997; Fernández-López et al. 1996, 1998,1999b). Detailed biostratigraphical studies and facies analysis of numerous stratigraphic sections, published in previous works (see below) as well as unpublished data of the authors, allow us reconstruction of a new chronostratigraphical correlation diagram shown in Fig. 3.

Diverse palaeogeographical elements, controlled by synsedimentary faults, were developed in the eastern margin of the Iberian platform system during Middle Jurassic (Fig. 4). From east to west, at least three different platforms can be distinguished: the Tortosa, Aragonese and

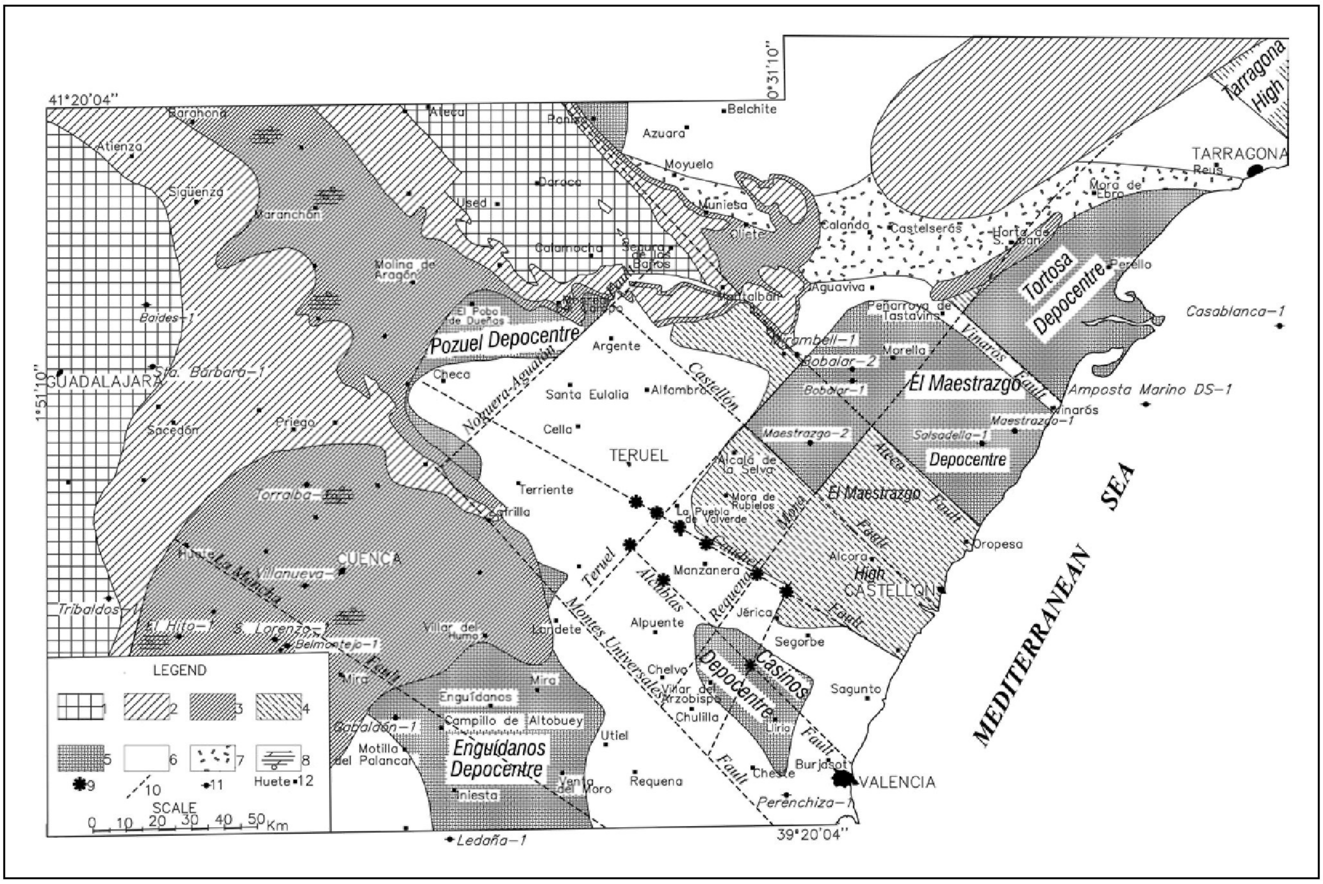

Fig 2 - Map of the eastern margin of the Iberian platform system showing the distribution of areas with the presence and the absence of Middle Jurassic deposits as well as the main highs and depocentres. 1. Jurassic deposits totally absent due to non-deposition or erosion. 2. Middle Jurassic deposits totally absent due to non-deposition or erosion. 3. Middle Jurassic deposits partially absent due to non-deposition or erosion. 4. Palaeogeographical highs showing Middle Jurassic condensed sections. 5. Palaeogeographical depocentres showing Middle Jurassic expanded sections. 6. Middle Jurassic sediments showing thickness values between 50 and 150 m. 7. Middle Jurassic reduced sections. 8. Facies of the internal Castilian Platform. 9. Volcaniclastic tuffs. 10. Synsedimentary faults. 11. Wells. 12. Villages.

Castilian platforms. The Requena-Mora Fault induced differentiation of the Tortosa Platform whilst the Ateca Fault controlled separation of the Aragonese and Castilian platforms.

The so-called Catalan Basin started to be differentiated during the Middle Jurassic, when two palaeogeographical elements appeared: the Tarragona High (Salas & Casas 1993) and the Tortosa Platform (Fernández-López et al. 1996,1998). The northeastern portion of the Catalan Basin constituted the Tarragona High, where dolomitic facies of very shallow platform environments have been observed. However, the best developed palaeogeographical element was the Tortosa Platform. Expanded sections of external platform facies, thicker than 350 m, including deepening-upwards sequences, were deposited in this area. The Tortosa Platform started differentiation during the Toarcian and open-marine environments, of normal salinity and inhabited by stenohaline organisms, were dominant during the Middle Jurassic (Fernández-López et al. 1998). Strong early Bajocian subsidence occurred on the northern portion of this platform. Maximum subsidence values, with the accumulation of 60 m of alternating marls and limestones, were reached during the late Bajocian due to a listric fault dipping to the east. Maximum subsidence and maximum palaeobathymetric values were recorded during latest Niortense and earliest Garantiana zone intervals. However, in the Tortosa Platform, a Bathonian facies belt composed of oolitic shoals and dolomites locally prograded over the external platform facies. Bathonian and Callovian deposits show unusually high values of thickness and biostratigraphical completeness, representing one of the best sections in the Iberian platform system for chronostratigraphical purposes. The Tortosa Platform is partially controlled by the Requena-Mora and Vinarós faults, and offshore drilling (Casablanca-1 and Amposta Marino DS-1 wells; Fig. 4) confirms the persistence of this external platform towards the east (Fernández-López et al. 1996, 1998).

The El Maestrazgo High represents a structurally complex system, reflected by the development of patchy shallow marine environments within the blocks between the Tortosa Platform and the Castilian Platform, which has been interpreted in many different ways (Canerot 1974; Burrollet & Winnock 1977, Cadillac et al. 1981;

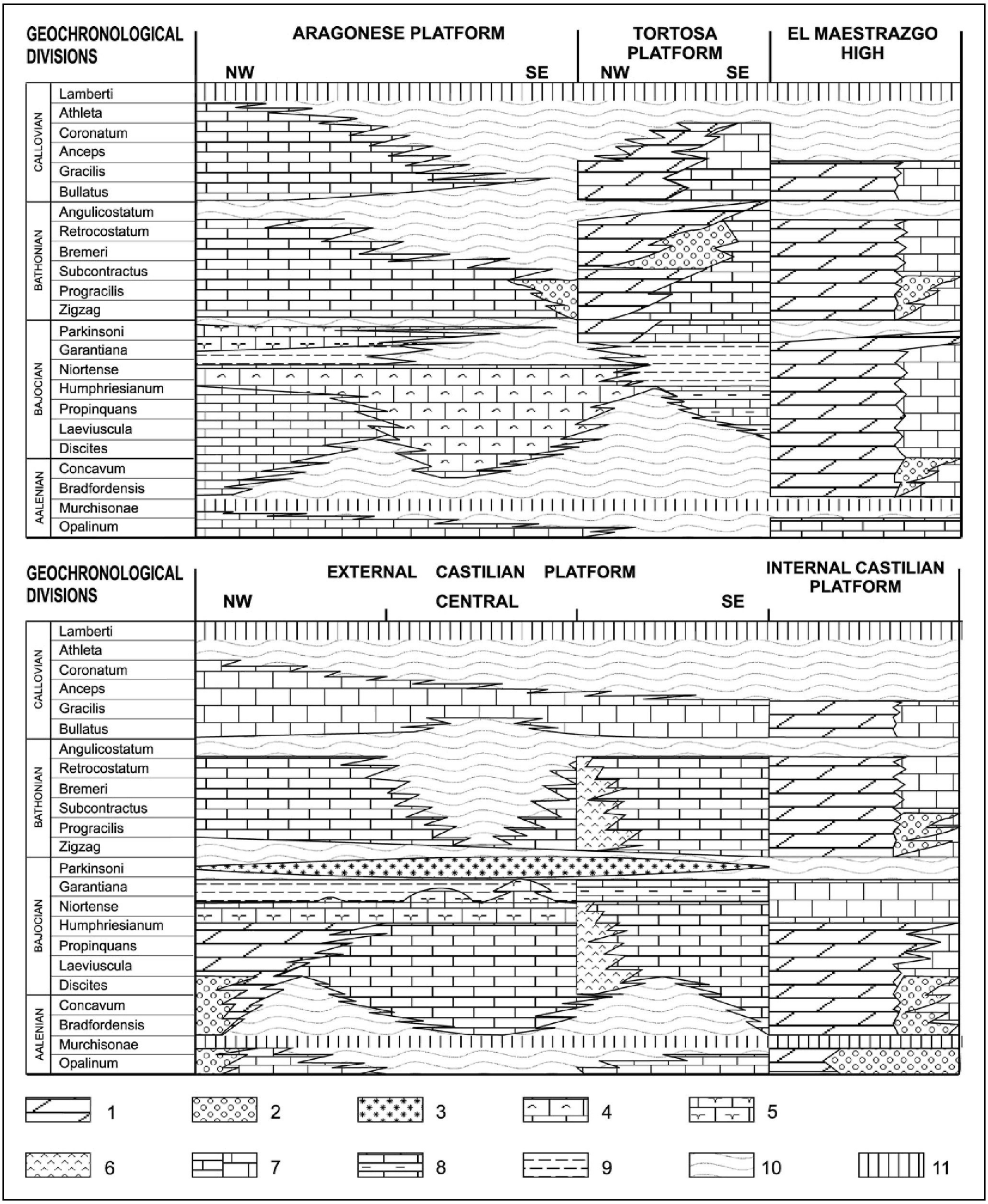

Fig. 3 - Chronostratigraphical correlation chart showing the distribution of facies in the eastern margin of the Iberian platform system during the Middle Jurassic. 1. Dolomitic facies. 2. Oolitic grainstone-packstone limestones. 3. Crinoidal packstone-grainstone. 4. Bioclastic wackestone. 5. Sponge-bearing carbonates, including build-ups. 6. Volcaniclastic tuffs. 7. Mudstone-wackestone facies. Thin-bedded (left), thick-bedded (right). 8. Marls and limestones. 9. Marls. 10. Condensed sections locally containing limestone with ferruginous ooliths. 11. Major regional stratigraphic gaps. Some chert nodules can be contained in facies 2, 3, 4, 5 and 7.

Canerot et al. 1984; Salas 1987, 1989). Two main facies, from the central to the peripheral areas of the El Maestrazgo, are characteristic of confined environments with no evidence of stenohaline organisms such as ammonoids

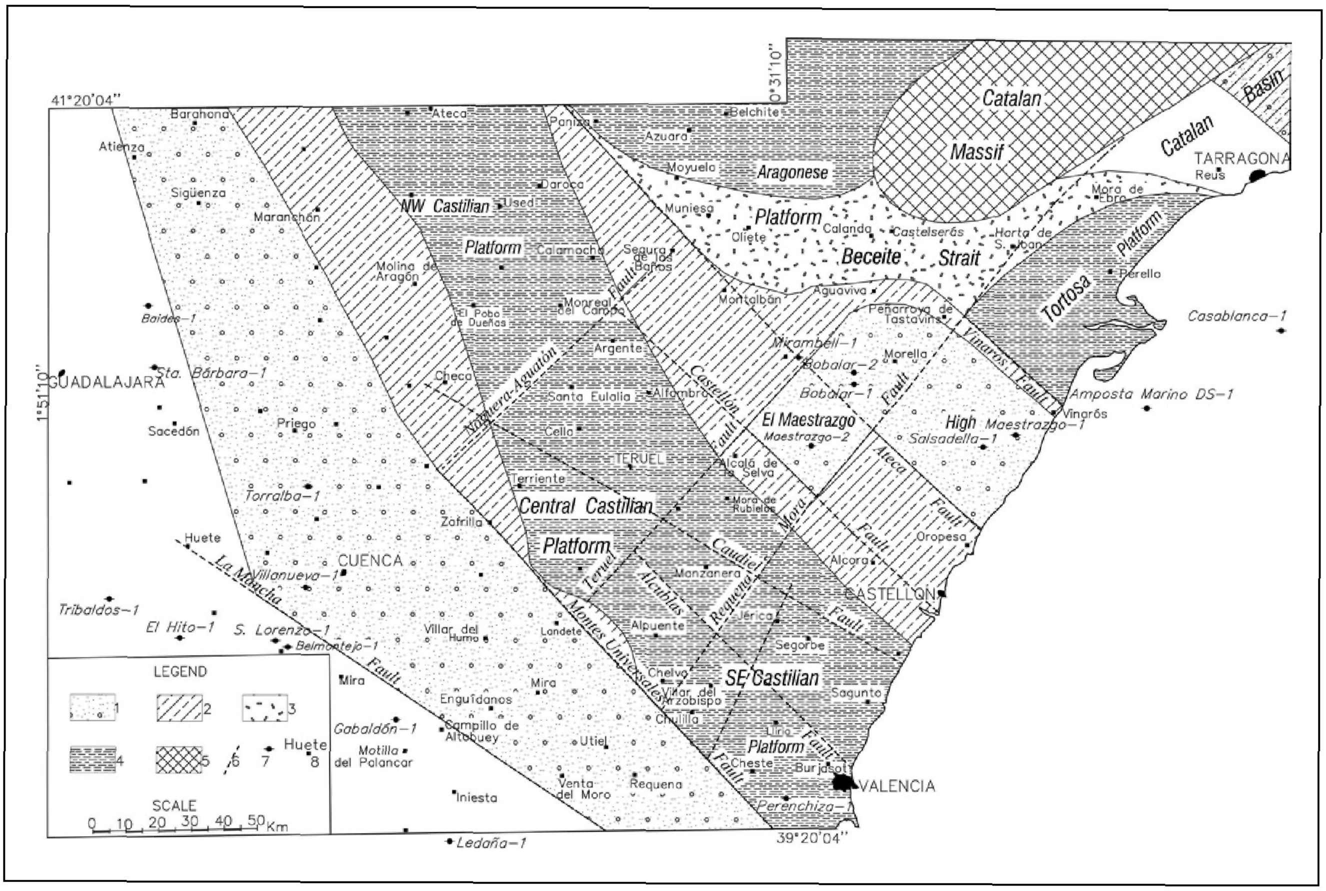

Fig. 4 - Palaeogeographical map of the Iberian platform system showing the distribution of facies and the extensional synsedimentary structures. 1. Internal platform facies of the Castilian Platform and El Maestrazgo. Expanded sections of very shallow environments composed of oolitic and bioclastic limestones, lime mudstones and dolomites with very scarce to absent ammonoids. 2. Intermediate platform facies of the Castilian Platform and El Maestrazgo High. Fine-grained to packstone-grainstone limestones and dolomites. Some ammonoid-bearing levels allow dating to the stage scale. 3. Condensed sections of external shallow platform facies of the Beceite Strait. 4. Facies of external marine platform of the Castilian, Aragonese and Tortosa platforms. Mudstone to wackestone limestones with interbedded sponge-bearing carbonates and marls. Common ammonoids allow dating to the zonal scale. 5. Catalan Massif as inferred from subsoil data. Middle Jurassic deposits are absent due to non-deposition or erosion. 6. Syndepositional faults controlling the Middle Jurassic facies distribution in the eastern margin of the Iberian platform system. 7. Wells. 8. Villages.

(Figs. 3, 4). The boundaries between these two facies at El Maestrazgo High were conditioned by several NW-trending faults such as the Vinarós, Ateca, and Castellón faults, as well as NE-trending synsedimentary structures such as the Teruel, and Requena-Mora faults. The central area is characterized by the presence of thick piles of expanded dolomitic sections, developed in very shallow environments and on strongly subsident blocks. The peripheral areas of the El Maestrazgo High contain relatively reduced sections (thickness generally lower than 50 m) with diverse sediments of a shallow marine platform, from low-energy microfilament mudstone and wackestone carbonates to higher energy oolitic and bioclastic packstone to grainstone lithologies with widespread dolomitic deposits. High-energy carbonates are dominant towards the north, in the transition between the El Maestrazgo High and the Aragonese Platform. In contrast, the low-energy muddy carbonates are common towards the southwest, in the transition to the Castilian Platform.

Open-marine environments, of normal salinity, inhabited by stenohaline organisms prevailed in the Aragonese Platform. Ammonoids are generally common through the sections and zonal subdivision of the stages has been established. Two main types of facies characterised this platform. In the northern portion, normal to expanded sections, commonly more than 100 m thick, composed of mudstone-wackestones with microfilaments and abundant sponge-bearing lithologies, including sponge mud mounds a few meters tall, are the dominant facies. Marly levels are commonly interbedded and stratigraphic successions are generally organized in shallowing-upwards sequences. In the southern portion, condensed sections generally thinner than 50 m and composed of bioclastic wackestone-packstone and calcareous oolitic grainstone facies are widely represented (Gautier & Mouterde 1964; Bulard 1972). The wackestone-packstone can contain ferruginous ooliths or be composed of sponge-bearing glauconitic limestones. The main constituents of these condensed sections are discontinuous tempestitic deposits separated by common sedimentary gaps. These ephemeral deposits represent expanded sediments of high accumulation rate developed in shallow open-marine environments, and should not be interpreted as condensed sediments generated in deep starved conditions. These areas showing stratigraphic condensation during the Middle Jurassic, in the Aragonese Platform, represent a facies belt of shallow open-marine environments, between deeper, thicker and more subsident blocks located in the northern areas and in the Tortosa Platform. The Beceite Strait communicated the Aragonese and the Tortosa platforms, being situated between the north of the El Maestrazgo High and the southern margin of the Catalan Massif. The Catalan Massif influence and the absence of Middle Jurassic sediments, by erosion or non-deposition, has been inferred on the basis of well-log information (Stoeckinger 1976; Canerot et al. 1984; Lanaja 1987).

The Castilian Platform is composed of diverse NW-trending facies belts which can be followed in outcrops for at least 250 km. From the western margin of El Maestrazgo High towards the Iberian Massif, a progressive facies change from open-marine to restricted environments can be observed (Figs. 3, 4). The best-developed facies belt corresponds to open-marine ammonite-bearing carbonates, showing fine-grained limestones and marls which locally include sponge-bearing deposits (Viallard 1973; Gómez 1979; Fernández-López 1985; Fernández-López et al. 1985; Fernández-López & Gómez 1990 a, b; Friebe 1995). Ammonoid zonal scales to subdivide Middle Jurassic stages have been established. The thickness of the sections commonly varies between 50 and 150 m, but up to 250 m can be reached in depocentres. Deposits are generally organized in shallowing-upwards sequences of mudstones and wackestones with microfilaments. Within the external Castilian Platform, three areas showing different stratigraphic sections can be recognized: the NW the Central and the SE Castilian platforms, conditioned by several northeast-trending extensional structures such as the Noguera-Aguaton, Teruel and Requena-Mora faults. The NW Castilian Platform is characterized by the development of thick lower Bajocian dolomitic deposits and lower Callovian thick limestone successions. In the Central Castilian Platform, the Bajocian sediments are the main component of Middle Jurassic sections, whilst Aalenian, Bathonian and Callovian deposits are very reduced or locally absent. In this central area, upper Bajocian carbonates with interbedded marls commonly contain sponge build-ups, reaching up to 20 m in thickness. In the SE Castilian Platform, the Middle Jurassic fine-grained limestone sections are dominated by thick Bathonian deposits. Some Aalenian, Bajocian and Bathonian carbonate deposits contain Volcaniclastic patches showing positive reliefs with thickness of up to 30 m (Gautier 1968; Gómez 1979; Fernández-López et al. 1985; Martínez-Gonzalez et al. 1997).

Internal Castilian Platform facies constitute a single belt of very shallow-marine environments, located west of the Iberian Massif, being more continuous and homogeneous than the external facies belt. Within this internal belt, however, from oolitic and bioclastic limestones representing high-energy environments to lime mudstones and dolomites corresponding to confined and low-energy environments are clearly differentiated (Gaibar-Puertas & Geyer 1969; Morillo-Velarde Gómez-Bravo & Meléndez Hevia 1981). Ammonoids are virtually absent but certain fossiliferous levels allow dating to the stage scale of stratigraphic sections. Where sections are complete, showing no evidence of post-Jurassic erosion, thickness surpasses 250 m and NW-trending faults, like the Montes Universales and La Mancha faults controlled the boundaries of the internal Castilian Platform. These synsedimentary faults conditioned the higher subsidence rates of this block and the piling of thicker sections during Middle Jurassic, while very shallow environments persisted.

Between the internal and external platform belts of the Castilian Platform, a third facies belt can be distinguished in the northern and central areas. This belt shows intermediate features with regard to the adjacent belts. Marine facies consist of fine-grained limestones, oolitic, bioclastic and oncolitic packstone-grainstone, and dolomitic deposits organized in shallowing-upwards sequences. Ammonoids are very scarce or absent, but some fossiliferous levels allow dating of stratigraphic sections at the stage level. This facies belt reaches up to 150 m thickness in the central area, although it is partially eroded out in the northern outcrops.

Facies distribution in the Castilian Platform from internal to external areas strengthens a transition model from restricted to open-marine environments. This model serves as the key to interpret the parallelism of facies developed in the internal Castilian Platform and the El Maestrazgo High. Both areas represent the margins of the external Castilian Platform, and comparisons between the sections recorded in the two areas have been a helpful tool to interpret the processes that occurred at the scale of the whole Iberian platform system.

Iron-oolite horizons are found in the Middle-Upper Jurassic transition both in the Castilian and Aragonese platforms. These stratigraphic intervals are heterochronous and diachronous at the stage scale and represent the top of the Middle Jurassic deepening-shallowing cycle (Geyer et al. 1974; Gómez 1979; Meléndez 1989; Aurell 1990; Ramajo & Aurell 1997; Fernández-López 1997). The major stratigraphic discontinuities in the Middle Jurassic correspond to the middle Aalenian (Murchisonae Biochron) and to the late Callovian (Lamberti Biochron, Fig. 3).

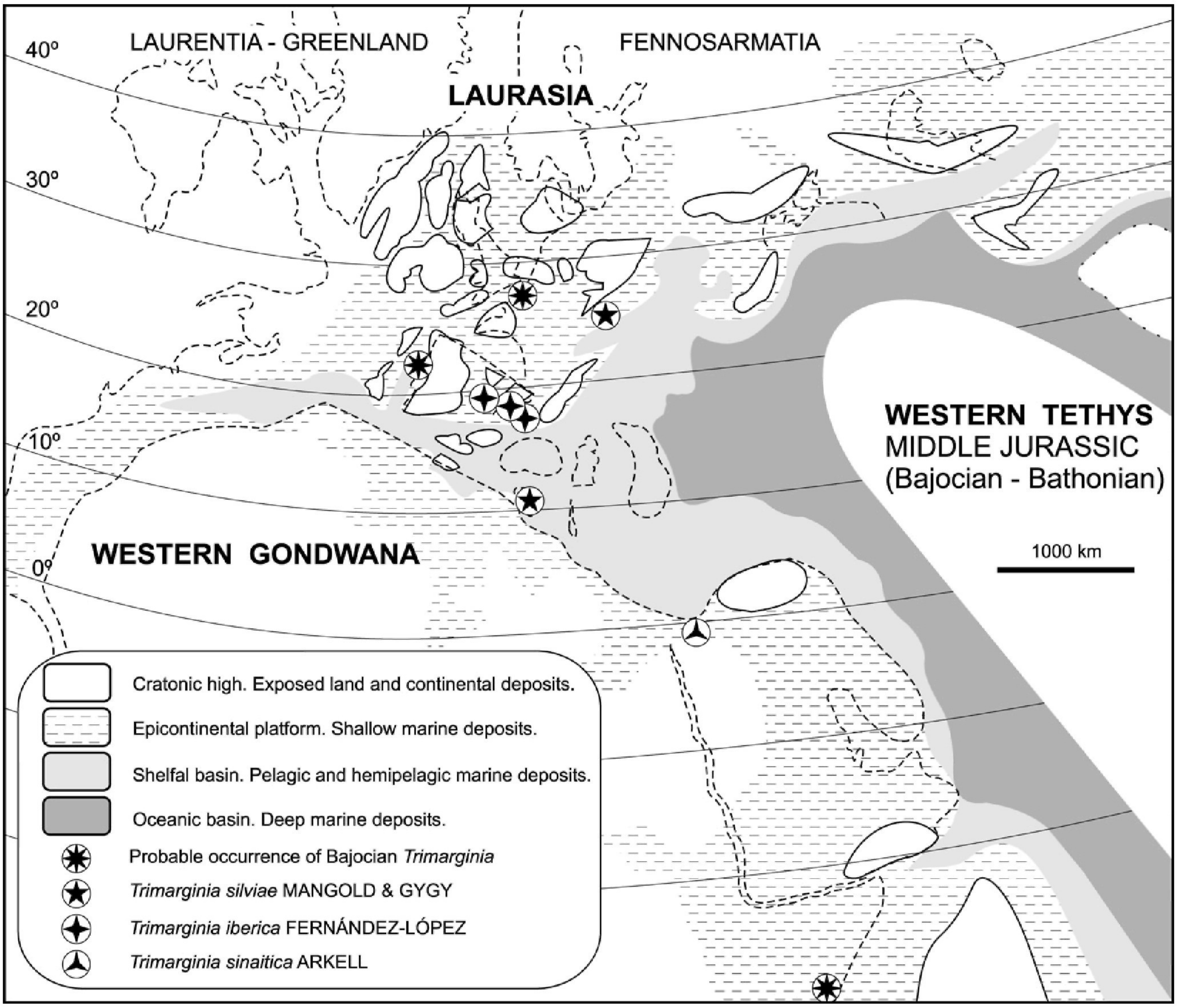

Fig 5 - Bajocian-Bathonian palaeogeographical reconstruction of Western Tethys, showing the distribution of cratonic highs, epicontinental platforms and shelfal and oceanic basins (based on Ziegler 1990; Dercourt et al., 1993; Ziegler et al., 2001). As can be seen, the Iberian Plate occupied an intermediate position between the Laurasian epicontinental seas in the north, and the epicontinental seas of Western Gondwana in the south. Preservation features of *Trimarginia iberica* specimens are indicative of eudemic populations. The relatively restricted distribution of this species mainly in the eastern margin of the Iberian platform system suggests an endemic character during late Bajocian.

Palaeobiogeography of ammonoids

The Iberian Peninsula lay at a latitude of approximately 20ºN during the Middle Jurassic, in the Western Tethyan belt of carbonate deposition (Fig. 5). Ammonoid habitats of two categories, in marine areas of the Iberian Peninsula during the Middle Jurassic, can be distinguished: habitats of epicontinental platforms and habitats of shelfal basins (Fernández-López et al. 1999a). Habitats of shelfal basins, situated on the continental shelf and showing open-marine or oceanic environments, were developed in the Betic and the Lusitanian basins The so-called Iberian Basin, or the Iberian platform system, was a set of shallow epicontinental platforms located between the Tethyan and Proto-Atlantic margins of the Iberian Plate. Habitats of these epicontinental platforms were cratonic areas, with neritic environments, flooded by very shallow marine waters. The Middle Jurassic deposits of the Iberian platform system are predominantly carbonates, showing an increase in the proportion of siliciclastic deposits to the north. Ammonoid assemblages of these habitats varied from those with predominance of Phylloceratina and Lytoceratina (e.g., in the Subbetic Basin) to those that were mainly Ammonitina (e.g., in the North Lusitanian Basin and the Iberian platform system).

From the Aalenian to Callovian ages, ammonoids of the Iberian platform system are commonly intermediate between Northwest European and Mediterranean faunas. Throughout this platform system, the diversity of ammonoid faunas decreases towards the northern areas, from the Mediterranean Province to the Northwest European Province. Ammonite fossil assemblages of the Iberian platform system are composed of Submediterranean taxa, with Middle Jurassic Phylloceratina and Lytoceratina representing less than 1% of the whole ammonoids (Fernández-López & Meléndez 1996). The Sub-Mediterranean Province essentially occupied the epicontinental seas bordering the northern margins of Western Tethys: in particular, the eastern areas of the Iberian Peninsula (SE Castilian, Tortosa and Aragonese platforms, at least), but also some regions open to oceanic influence such as the North Lusitanian Basin. In the Sub-Mediterranean Province, demic Phylloceratina were generally absent, ademic Phylloceratina were not important elements of the preserved associations, and diversity of Ammonitina were relatively high (Fernández-López & Meléndez 1996; Fernández-López et al. 1999a). The distribution of the Sub-Mediterranean Province in the Iberian Plate, from areas of open-marine to oceanic influence in the Lusitanian Basin to areas occupied by shallow epicontinental seas in the eastern margin of the Iberian platform system, has been argued to exclude a bathymetric control of this bioprovince (Fernández-López et al. 1999a). The ammonoid provincialism through the Middle Jurassic in these areas may have been latitudinally limited by environmental factors, including temperature rather than depth, since the diversity of ammonoid faunas decreases towards the northern areas in Tethyan and Proto-Atlantic margins of the Iberian Plate.

In the Iberian platform system, the appearance and distribution of shells of ammonoids were taphonomically and ecologically controlled by regional changes of relative sea level (Fernández-López 1985, 1997). Isolated, adult specimens of ammonoids recorded in open-marine carbonates of the external platform can be interpreted as resulting from arrival of shells by necroplanktic drift (i.e., taphonomic dispersal) or by passive biodispersal of certain individuals. In contrast, associations composed of a high proportion of juvenile individuals, showing macro- and microconch representatives, are indicative of true interbreeding, biological populations. The occurrence of taphonic populations of type 1 (Fernández-López 1997), showing no signs of sorting by post-mortal drift or transport, is indicative of autochthonous biogenic production of shells. In accordance with these criteria, most of the Middle Jurassic ammonite shells of the Iberian platform system represent ademic organisms and are interpreted as allochthonous elements having arrived at their present location by necroplanktic drift. Regional absence of ammonoids of the middle and late Murchisonae Biochron, as well as of the Lamberti Biochron, suggests extreme shallow marine conditions hindering arrival of drifted shells and carbonate deposition. Consequently, middle Aalenian and late Callovian correspond to two major regional stratigraphic gaps at the scale of the whole Iberian platform system (Fig. 3).

From a palaeobiological point of view, the following processes are relevant for recognition of the maximum deepening episodes in the eastern margin of the Iberian platform system: colonization (including ontogenic development) of open-marine taxa, immigration of oceanic taxa and development of endemic species. Middle Jurassic demic ammonoids of the following genera, colonizing the eastern margin of the Iberian platform system, have been identified: early Aalenian *Tmetoceras* [M+m] and *Leioceras [m]-Cypholioceras* [M]; late Bajocian *Bajocisphinctes [M]-Microbajocisphinctes* [m], *Spiroceras* [M+m], *Trimarginia* [M+m] and *Lissoceras* [M]- *Microlissoceras* [m]; and late Bathonian *Epistrenoceras* [M+m] and *Parapatoceras.*

The immigration of oceanic taxa, in the Iberian platform system, can be tested taking into account the distribution of phylloceratаceans. The occurrence of oceanic phylloceratаceans is remarkably constant within the upper Bajocian and at the lower/middle Callovian boundary (Fernández-López & Meléndez 1996). These two dispersal episodes of Phylloceratina into the eastern margin of Iberian platform system are regarded as reflecting changes in their palaeoecological and taphonomical behaviour, as a consequence of regional sea-level changes. A relative sea-level rise during the late Bajocian favoured the immigration of juvenile phylloceratаceans of the genera *Phylloceras* and *Adabofoloceras* (Fernández-López 1985). In contrast, phylloceratаceans recorded at the lower/middle Callovian boundary constitute polyspecific assemblages, dominated by adult individuals. These Callovian assemblages were formed by necroplanktic drift, related to a relative sea-level fall and general homogenization of the platform bottom, hence favouring the concentration of remains of stenohaline organisms from more open-marine and oceanic areas.

Northwest European immigrants were scarce at the eastern margin of the Iberian platform system. However, South Tethyan or Arabian ammonites among Sub-Mediterranean and NW European faunas occur in several Jurassic episodes (Cariou et al. 1985; Enay et al. 1987, 2001; Enay 1993). The presence of scarce late Bathonian Clydoniceratids (*Clydoniceras* [M] + *Delecticeras* [m]) in the Tortosa Platform has been recently reported (Fernández-López 2001). The occurrence of several Middle Jurassic specimens of *Trimarginia* in Sicily, Spain, Normandy and Portugal can be interpreted as resulting from arrival of shells by necroplanktic drifting or by passive biodispersal of certain individuals. Bathonian representatives of *Trimarginia* found in Sicily are immature individuals. An upper Bathonian specimen of *T. sylviae* Mangold & Gygi (M) has also been reported from Switzerland. Common specimens of *T. iberica* Fernández-López (M+m) in the eastern margin of the Iberian platform system compose taphonic populations of monospecific shells, showing unimodal and asymmetric distribution of size-frequencies, with positive skew. These populations

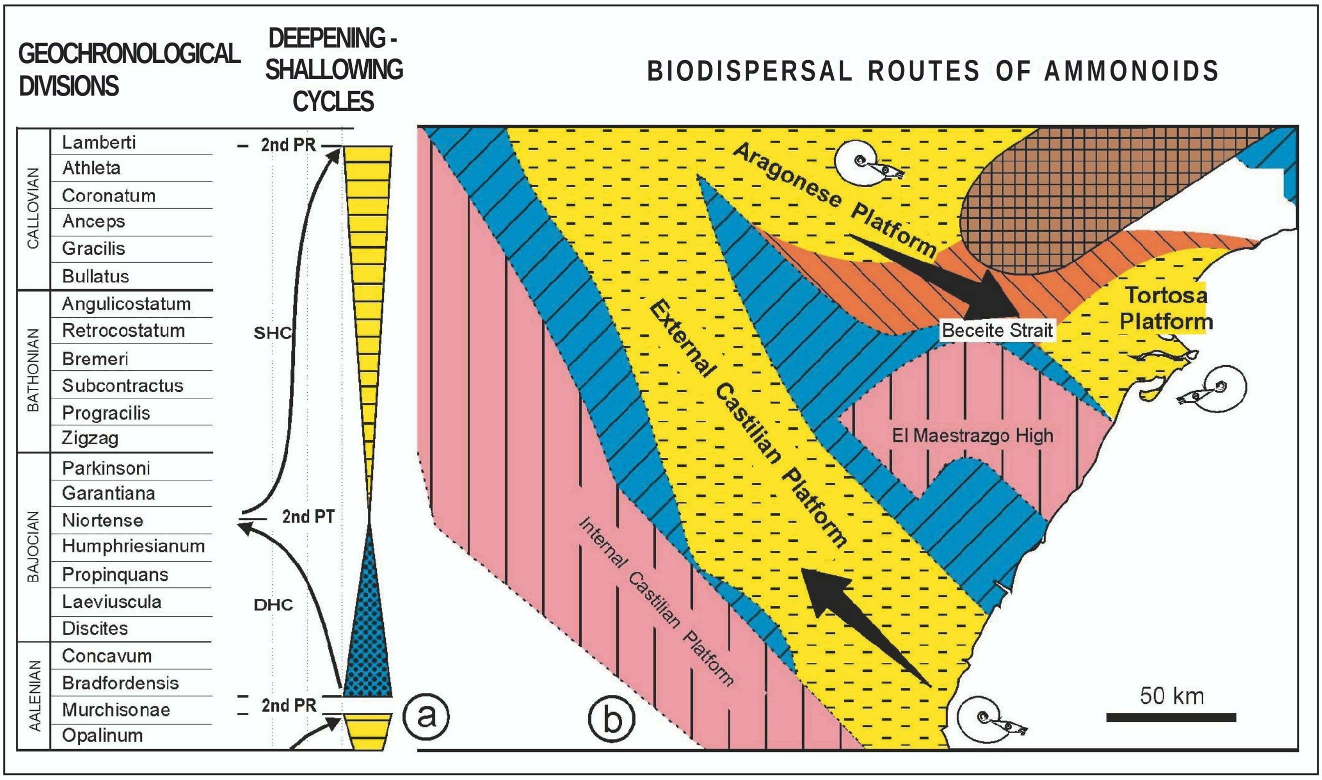

Fig. 6 -a. Middle Jurassic *2nd* -order deepening-shallowing cycles in the Iberian platform system. Deepening half-cycle (DHC) started at the base of the Bradfordensis Zone (Aalenian), peak transgression (PT) was reached during the Niortense Zone (upper Bajocian), and the peak regression (PR) at the top of the shallowing half-cycle (SHC) corresponds to the Lamberti Zone (Callovian). b. Palaeogeographical map showing the Middle Jurassic facies distribution and the biodispersal routes of ammonoids. SE Castilian, Aragonese and Tortosa platforms were episodically inhabited by ammonoids. The Beceite Strait was an active biodispersal route of ammonoids from the Aragonese Platform to the Tortosa Platform. However, evidence of biogeographical opening or taphonic input from areas located east of the Tortosa Platform, is lacking. Castilian Platform acted as a biodispersal route from the West Tethyan Subrealm towards the Proto-Atlantic Ocean at least during late Bajocian.

have a high proportion of microconchs and the shells of juvenile individuals are predominant, whereas shells of adult individuals are scarce. These preservational features, giving no signs of sorting by post-mortal drift or transport, are indicative of autochthonous biogenic production of shells by eudemic biological populations (i.e., true interbreeding biological populations, in the sense of Callomon 1985).

The relatively restricted distribution of the specimens, mainly in the eastern margin of the Iberian platform system, suggests that this species acquired an endemic character during the late Bajocian (Fig. 5, Fernández-López 2000).

The type of taphonic population, abundance and frequency of specimens, stratigraphic persistence and degree of packing of ammonites are some of the distinctive taphonomic criteria in interpreting the palaeoecology and palaeobiogeography in the Iberian platform system. Eastern areas of the Iberian Peninsula (in particular, the Tortosa, Aragonese and SE Castilian platforms) were episodically inhabited by ammonoids along the Middle Jurassic (Fig. 6b). However, NW and Central areas of the Castilian platform were not inhabited by ammonoids, although shells arrived by necroplanktic drift to these shallow, epicontinental, outer environments. The Central Castilian Platform outcrops have been traditionally known to provide one of the finest fossiliferous sections of Middle Jurassic in the Iberian Range, and recorded associations of this area are of greatest relevance in biochronostratigraphical correlation, but ammonoids of these areas do not represent eudemic organisms.

Middle Jurassic colonizer ammonoids and Mediterranean immigrants were relatively common in the SE Castilian, Aragonese and Tortosa platforms. The Beceite Strait was an active biodispersal route of ammonoids from the Aragonese Platform to the Tortosa Platform. Although certain palaeogeographic reconstructions have portrayed the Tortosa Platform as a trough closed towards the East (Burollet & Winnock 1977), many of the later reconstructions suggest on the contrary an eastern opening towards the Tethyan basins (Cadillac et al. 1981; Canerot et al. 1984; Roca et al. 1994; Fauré 2002). According to the most recent data about ammonoids, the Tortosa Platform seems to have persisted as an area scarcely influenced by Mediterranean faunas throughout the Middle Jurassic, well connected with the Aragonese Platform: evidence of biogeographical opening or taphonomic input from eastern areas is lacking.

Sub-Mediterranean faunal elements inhabiting the eastern margin of the Iberian platform system were particularly abundant at the beginning of the third-order shallowing half-cycles; mainly, during the Garantiana (late Bajocian) and the Retrocostatum (late Bathonian) biochrons (Fernández-López 1997, 2001). In terms of Sequence Stratigraphy, the development of expanded sections, of outer marine environments, during the latest Niortense Biochron and the early Garantiana Biochron (late Bajocian) in the Tortosa, northern Aragonese and Castilian platforms is noteworthy (Fig. 6a). During this Bajocian interval, the whole Iberian platform system reached maximum bathymetric values and the external Castilian Platform acted as a biodispersal route towards the Proto-Atlantic Ocean for some taxonomic groups of ammonoids characteristic of the West Tethyan Subrealm. The major stratigraphical discontinuities and the foremost shallowing episodes during the Middle Jurassic, representing a peak regression of second-order, correspond to middle Aalenian (Murchisonae Biochron) and late Callovian (Lamberti Biochron). Consequently, Middle Jurassic deposits comprising from the middle Aalenian until the upper Callovian, through the upper Bajocian peak transgression, represent a stratigraphic cycle of second-order in the whole Iberian platform system.

Conclusions

From east to west, in the Iberian platform system, at least three different platforms can be distinguished: the Tortosa, Aragonese and Castilian platforms. A system of faults was the major factor determining the differentiation of several shallow, carbonate-depositing, epicontinental platforms, which are of utmost importance in interpreting the biodispersal routes between the Western Tethys, the Proto-Atlantic and the Central Atlantic oceans. The so-called Iberian Basin was a shallow intracratonic platform system, in which a relatively deep extensional basin (the Catalan Basin) started to be differentiated during the late Bajocian. A listric fault, dipping towards the east, conditioned the development of a late Bajocian subsident area named the Tortosa Platform. The Requena-Mora Fault induced differentiation of the Tortosa Platform whereas the Ateca Fault controlled separation of the Aragonese and Castilian platforms.

Middle Jurassic deposits are represented by a thick pile of carbonates with minor interbedded marls. Different facies within the Tortosa, Aragonese and Castilian platforms pertain to two main categories: internal platform and external platform facies. The internal platform facies was developed in the western portion of the Castilian Platform and in the El Maestrazgo High. This facies was clearly differentiated from oolitic and bioclastic limestones, representing a high-energy belt, to lime mudstones and dolomitic limestones, corresponding to confined and low-energy environments. The external platform facies was developed in the Tortosa, Aragonese and Castilian platforms. It is composed of fine-grained, ammonite-bearing carbonates, which locally includes sponge-bearing deposits.

Ammonite fossil assemblages in the eastern margin of the Iberian platform system are composed of Sub-Mediterranean taxa. A Sub-Mediterranean zonation can be recognized, although most of the ammonite shells correspond to adult individuals that arrived by necroplanktic drift from more open-marine or oceanic areas. The following palaeobiological processes are relevant for recognition of the maximum deepening episodes in the eastern margin of the Iberian platform system: colonization (including ontogenic development) of open-marine taxa, immigration of oceanic taxa and development of endemic species. Colonizer ammonoids and Mediterranean immigrants were relatively common in the SE Castilian, Aragonese and Tortosa platforms. Among the colonizers the following have been identified: early Aalenian *Tmetoceras* [M+m] and *Leioceras [m]-Cypholioceras* [M]; late Bajocian *Bajocisphinctes [M]-Microbajocisphinctes* [m], *Spiroceras* [M+m], *Trimarginia* [M+m] and *Lissoceras* [M] - *Microlissoceras* [m]; and late Bathonian *Epistrenoceras* [M+m] and *Parapatoceras.* A relative sea-level rise during the late Bajocian favoured the immigration of juvenile oceanic phylloceratacean of genera *Phylloceras* and *Adabofoloceras.* The relatively restricted distribution of *Trimarginia iberica,* mainly in the eastern margin of the Iberian platform system, suggests that this species acquired an endemic character during the late Bajocian. The Beceite Strait was an active biodispersal route of ammonoids from the Aragonese Platform to the Tortosa Platform during the Middle Jurassic. In contrast, the external Castilian Platform acted as a biodispersal route from the West Tethyan Subrealm towards the Proto-Atlantic Ocean at least during late Bajocian.

The major stratigraphical discontinuities and the foremost shallowing episodes during the Middle Jurassic, representing a peak regression of second-order, correspond to middle Aalenian (Murchisonae Biochron) and late Callovian (Lamberti Biochron). In terms of Sequence Stratigraphy, it is noteworthy that the expanded, external platform sections in the Catalan Basin were developed during the Garantiana Biochron (late Bajocian). During this episode, the eastern margin of the Iberian platform system reached the maximum bathymetric values and acted as a biodispersal route for some ammonoids characteristic of the West Tethyan Subrealm. Consequently, from the middle Aalenian to the upper Callovian, through the upper Bajocian peak transgression, Middle Jurassic deposits represent a stratigraphic cycle of the second-order in the whole eastern margin of the Iberian platform system.

Acknowledgements. This work has been funded by the BTE2000-1148 (CICYT-CSIC) Project. We are grateful to the professors H.C. Jenkins (Oxford Univ.) and P. Ruiz Ortiz (Jaen Univ.) for critical reading and suggestions of the manuscript.

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