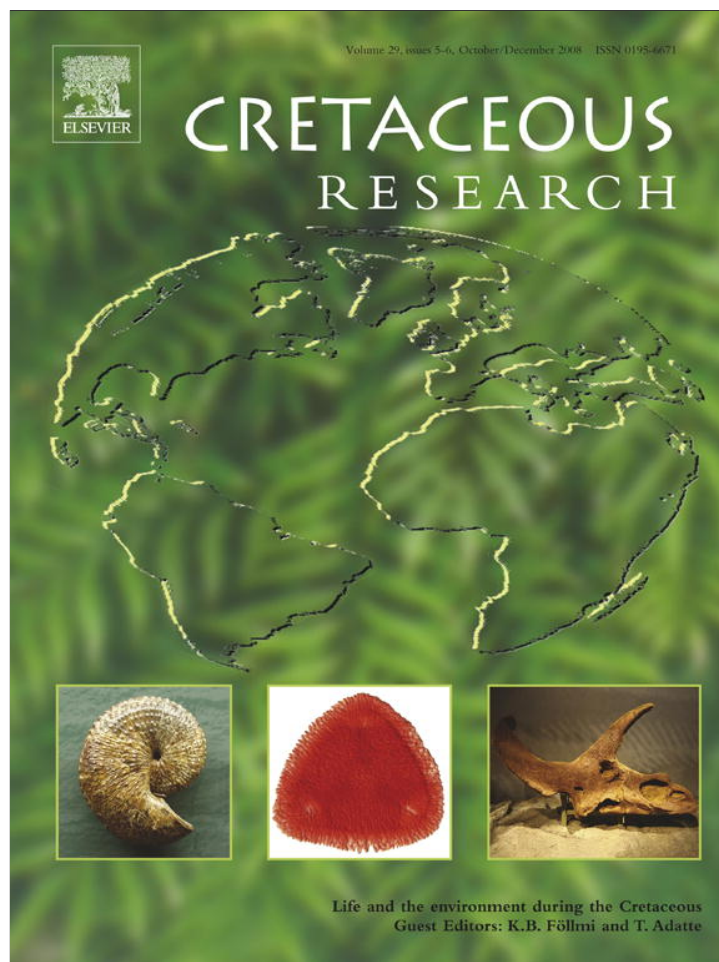


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Stratigraphy and allogenic controls of the western Portugal Cretaceous: an updated synthesis

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ABSTRACT

The stratigraphy of the western Portugal on-shore Cretaceous record (western Iberian margin, Lusitanian Basin) is described, including formal units and a selection of informal units prevailing in the geological literature. This paper is a synthesis based on a review of previous works, but with an innovative emphasis on the interpretation of eustatic and tectonic controls. The sedimentary record is dominated by siliciclastics and comprises fluvial and deltaic coastal marine siliciclastic systems, as well as extensive deposits of shallow marine carbonate platforms, both open and rimmed. Several regional unconformities and transgressive/regressive cycles are identified and the allogenic controls interpreted, namely the geodynamic events along the boundaries of the Iberian plate. Above the Berriasian deposits belonging to the Upper Jurassic cycle, the five main unconformity-bounded units are: (1) upper Berriasian–lower Barremian, (2) upper Barremian–lower Aptian, (3) upper Aptian–uppermost Cenomanian, (4) mid lower Turonian–lower Campanian and (5) middle Campanian–Maastrichtian. These units show transgressive peaks in the lower Hauterivian, lower Aptian, base of the upper Cenomanian and mid lower Turonian. The general trend of the Lower Cretaceous reflects the transition from late rifting to passive margin, with the last break-up unconformity dated as late Aptian. The Lusitanian Basin achieved full infill by the Cenomanian, when a large carbonate platform extended far inland. The later deposits were preserved only in the northern sector and the accompanying unconformities reflect transpressive intraplate stresses generated in boundaries of the plate with Africa and Eurasia. With very low accommodation being created throughout the Late Cretaceous, fluvial deposits were dominant, including a few marine levels related with eustatic rises in the early Turonian, the Coniacian, the early Campanian and the Maastrichtian.

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1. Introduction and setting

The break-up of Pangea developed a complex NNE-oriented system of graben structures in the western margin of Iberia, known as Lusitanian Basin and located between the Hercynian mainland and a set of basement horsts currently represented by the Berlengas Islands (Fig. 1). This structural basin reached its post-rifting stage during the Kimmeridgian and became infilled during Cenomanian times. The resulting passive margin had a simple geometry and the sedimentary systems linked directly the emerged continent with the deep margin.

During the Cretaceous the palaeogeographic position of the western Iberian margin was around 30° N (Stampfli and Borel, 2002), with the palaeontological assemblages reflecting a dominant Tethyan influence. This influence fades due to the closure of

the Tethys. The palaeontological record reveals increasing Boreal influence during the Late Cretaceous in response to the northward propagation of the Atlantic opening.

The goal of this work is to present an updated lithostratigraphy of the Cretaceous sedimentary record (Fig. 2), including 2nd order transgressive–regressive cycles separated by basin-wide unconformities, and to propose interpretations on the allogenic controls of the regional stratigraphic evolution.

Until the Aptian, the continental break-up and opening of the Atlantic progressed northward in discrete episodes along three sectors of the western Iberian margin (Pinheiro et al., 1996), named after the adjacent abyssal plains as Galicia, Iberia and Tagus (Fig. 3). Later, the break-up continued eastward of the Galicia triple-junction along the Bay of Biscay. The extensional progression resulted in counter-clockwise rotation of Iberia, allowing for transpressive interactions with Eurasia and Africa reflected in the western Iberian margin by intraplate transmission.

The Western Iberia–Newfoundland rifting model and timing is currently under debate (Russell and Whitmarsh, 2003; Shipboard

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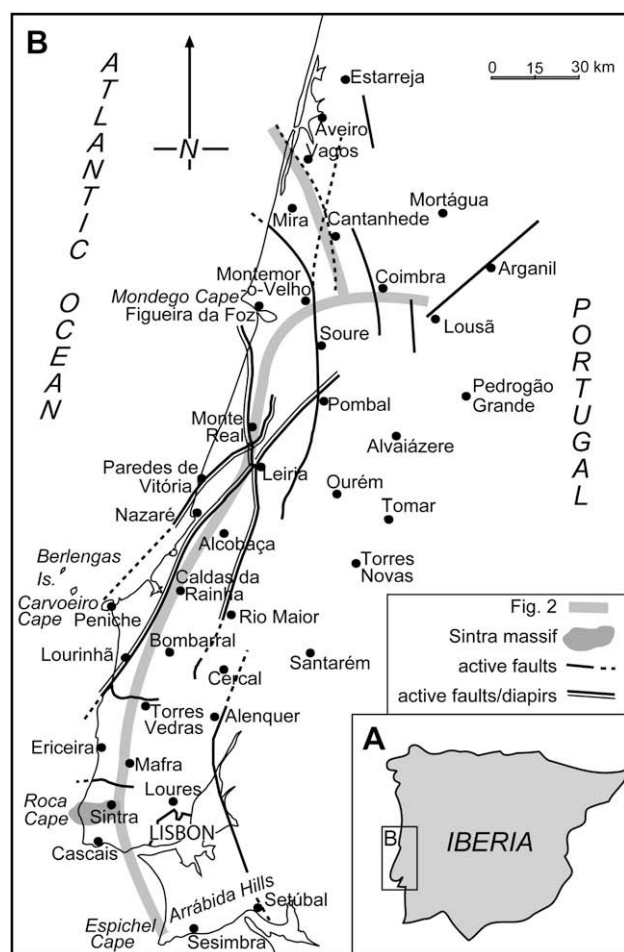


Fig. 1. Location of the studied area displaying the main localities and the most relevant tectonic structures interpreted as active during all or part of the Cretaceous (namely the faults with significant diapiric activity). In the approximate location of Fig. 2, note that the northern extreme includes a proximal-distal Lousã-Figueira da Foz branch and the axis of the Late Cretaceous Aveiro-Mira gulf.

Scientific Party, 2004). The discussion is focused on the nature of the transitional crust, and some authors (Srivastava et al., 2000; Sibuet et al., 2004) consider it as slowly accreted oceanic crust, implying an age of rifting and onset of seafloor spreading older than previously thought. However, the same authors admitted recently (Srivastava et al., 2005) that the transitional crust is in essence composed of tectonically exposed and later serpentinized mantle peridotites, following the Brun and Beslier (1996) model.

2. Methodological remarks and data sources

Fig. 2 presents the above mentioned synthesis for the on-shore record, including formal units and a selection of informal units prevailing in the geological literature. The synthesis presented below is mainly based on Rey (1992, 1993); Cunha and Pena dos Reis (1995); Pena dos Reis (2000); Pena dos Reis et al. (2000); Dinis et al. (2002); Rey et al. (2003, 2006); Rey and Dinis (2004); and Callapez (2004).

The major unconformities and cycles fit well with those recognized in several West-European basins (Jacquin et al., 1998), and we admit that they can be related to 2nd order eustatic cycles and/or discrete tectonic episodes within the geodynamic motion of Iberia. The 3rd order sequences identified in the Valanginian-lower Aptian and in the Albian strongly resemble in number and age those described from other European basins (Jacquin et al., 1998; Rey

et al., 2003), namely the Paris Basin (Rusciadelli, 1999), and therefore should be considered as eustatically driven.

In general, two major domains can be distinguished in the on-shore. South of the Caldas da Rainha parallel (Fig. 1) a domain with a relatively complete Berriasian-middle Cenomanian record (Fig. 2) had its depocentre located on the Lisbon peninsula, south of Ericeira. In the northern areas of the basin, over a Valanginian-Aptian p.p. hiatus, the Cretaceous stratigraphic record is mainly post Aptian, including extensive middle Cenomanian to lower Turonian platform carbonates, and Turonian to Maastrichtian marine and fluvial siliciclastics.

3. Lithostratigraphy, unconformities and allogenic controls

3.1. Berriasian

The lowermost Cretaceous deposits are included in the Upper Jurassic cycle, which is characterized by the progradation of alluvial systems over the basin axis and the reduction of the marine and brackish sedimentation area. The biostratigraphic age assignments are poorly constrained due to the nature of the deposits, but the use of detailed sequential analysis allowed the identification of Berriasian deposits (Pena dos Reis et al., 2000). In the depocentre region west of Lisbon, the Farta Pão Formation corresponds to a brackish carbonate platform with litooids, charophytes, and ostracodes (“purbeckian” facies of Ramalho, 1971, and Rey, 1972). This domain is surrounded to the N, W, and S by coastal plains where mixed carbonate-siliciclastic deposition built the Porto da Calada Formation and the top of the Freixial Formation (Leinfelder, 1986). In proximal areas to the north and the east, the coarse arkosic deposits of the Serreira Formation and the top of both the Lourinhã and Bombarral Formations record fluvial systems.

In the northern sector, presumed Berriasian fluvial to deltaic deposits, with rare carbonate intercalations, constitute the top of the “Upper sandstone with plants and dinosaurs” and the Boa Viagem sandstone (Bernardes, 1992; Pena dos Reis et al., 1996). Brackish lagoonal deposits (mainly marls and mudstones) occurring along a NNW-trending axis have been identified in the offshore around 10 km west of Figueira da Foz (Alves et al., 2002) and can be correlated with the top of the Alcobaça beds.

3.2. Late Berriasian unconformity

In most of the on-shore record, the Late Berriasian unconformity is marked by substantial clastic input and an extensive erosion surface, revealing a marginal uplift. The coeval increase of subsidence verified in the depocentre west of Lisbon can be explained by a regional tilting towards the extensional axis. It can be related to an extensional event with expression in the whole western Iberian margin (Fig. 3), previous to the creation of oceanic crust in the Tagus sector (Pinheiro et al., 1992), matching the initiation of mantle exhumation in the Iberia sector (Dean et al., 2000), as well as the rifting climax in the northern part of the Iberia sector (Wilson et al., 2001) and in the Galicia sector (Reston, 2005).

3.3. Valanginian – lower Barremian

Deposited under a stable tectonic regime, the Valanginian-lower Barremian T-R cycle is preserved only in the southern domain. After the initial fluvial expansion corresponding to the coarse and arkosic Vale de Lobos Formation, the subtidal Serradão Formation indicates the onset of a transgressive open carbonate platform in the southern depocentre. Due to a rapid rise in relative sea-level, the areas of Cascais, Sintra, and the Espichel Cape become an open shelf, with water depth reaching 40 to 50 m at the Valanginian-Hauterivian boundary. Accompanied by a sudden increase in

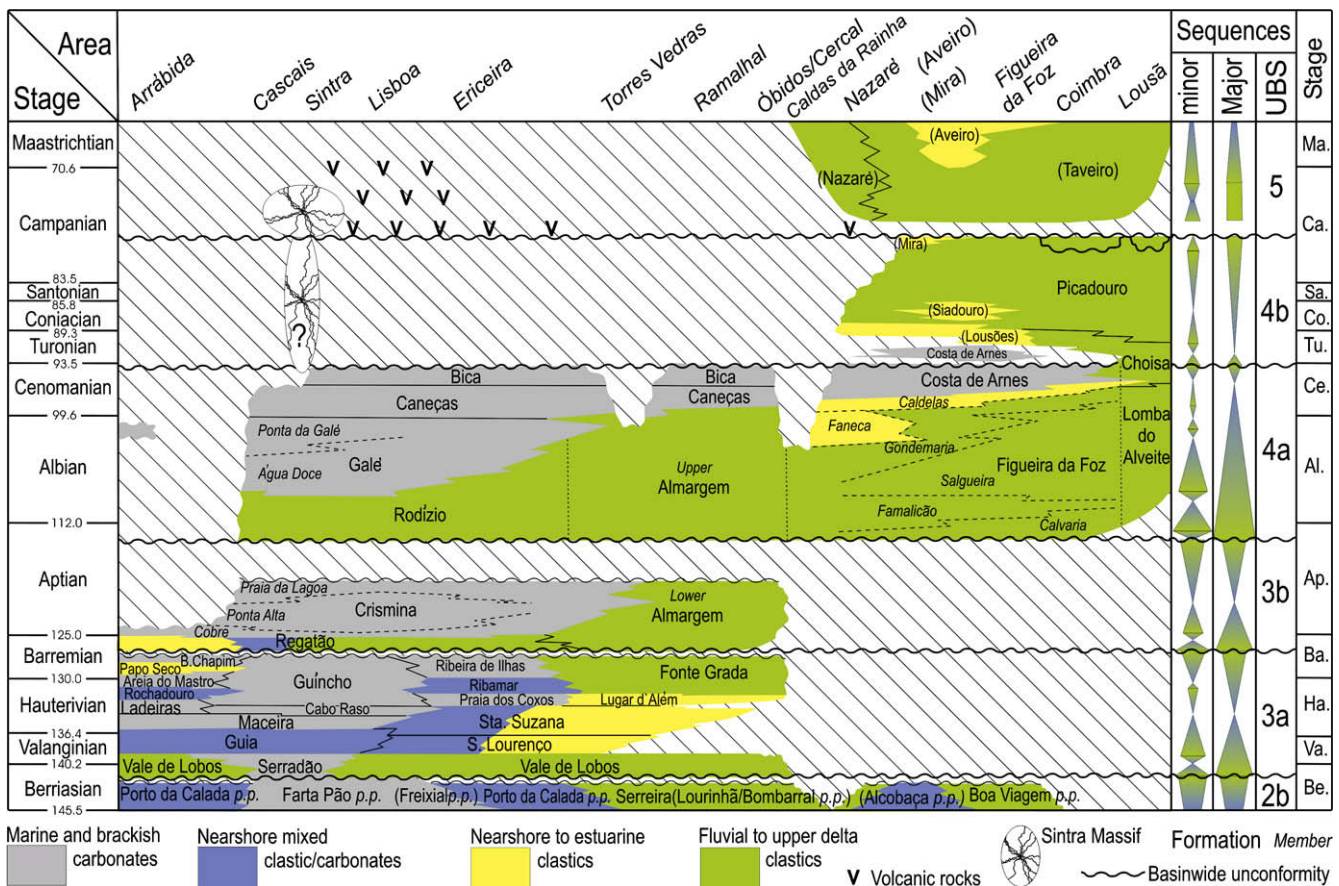


Fig. 2. Synthetic lithostratigraphic chart of the Cretaceous of the western Portuguese margin. Informal units within parenthesis. Triangles: blue - transgressive phase; green - regressive phase. UBS: unconformity bounded sequences after Cunha and Pena dos Reis (1995).

cephalopods abundance, the initially calcareous sedimentation was replaced by marls (Guia and Maceira Formations). The sea progressed widely towards the north and to the east, since the tidal flats of the São Lourenço and Santa Susana Formations reached the vicinities of Torres Vedras and Alenquer (Fig. 4).

A maximum sea-level rise at the Valanginian–Hauterivian boundary is expressed in the depocentre by condensed successions and the maximum flooding during the early Hauterivian by the widespread occurrence of reefs of the Cabo Raso Formation consisting of dolomitic limestone with scleractinian corals and

stromatoporoids. Then, the shoreline reaches the Torres Vedras vicinity (Fig. 4). Subsequently, the gradual infill of the basin resulted from the progradation of depositional systems. In the Cascais and Sintra areas, the build-ups are overlain by limestone with rudists and dasycladacean algae of the Guincho Formation, characterising the inner environment of a reef-rimmed platform.

Near Ericeira (Praia dos Coxos, Ribamar, and Ribeira de Ilhas Formations) and in the Arrábida hills (Ladeira, Rochadouro, Area do Mastro, Papo Seco, and Boca do Chapim Formations), subtidal inner marls and limestone with rudists and echinoids are

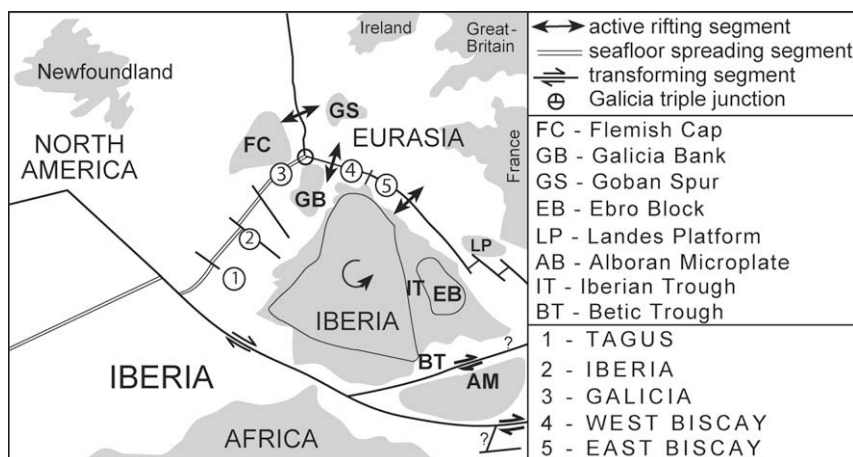


Fig. 3. Geodynamic setting of Iberia during the Cretaceous, showing the break-up situation in the latest Aptian. 1 to 5: western and northern Iberian margins rifting segments.

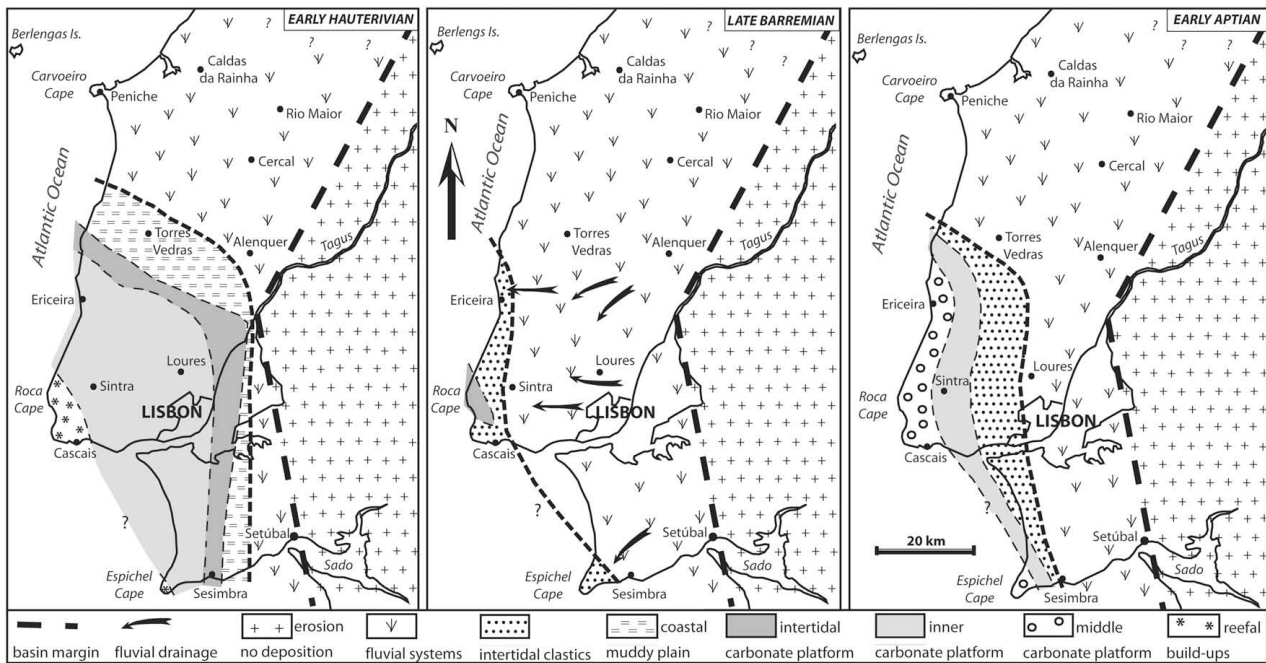


Fig. 4. Palaeogeographic maps of depositional environments for selected times of the Early Cretaceous (modified after Rey et al., 2006). There is no depositional record for those times in the northern domain of the Lusitanian Basin.

interbedded with lagoonal dolostone and sandstone. These units reflect minor sea-level changes, but an important transgressive peak is located near the Hauterivian-Barremian boundary. The maximum flooding is marked in Ericeira and in the north face of the Espichel Cape by more distal marine environments, present in all the system tracts (maximal marine conditions were mid platform), in contrast with the lagoonal to intertidal conditions dominating the deposition of the underlying sequences.

Eastwards and northwards, the paralic and littoral plains of the Lugar d'Além Formation were replaced by braided alluvial systems of the Fonte Grada Formation.

3.4. Barremian unconformity

An important (mid?) Barremian regression creates a basin-wide emersion surface, marked by coarse fluvial siliciclastics overlaying a karstified surface in the depocentre area west of Lisbon. The regression can be assigned to the regional uplift created by the onset of seafloor spreading in the Iberia sector (Whitmarsh and Wallace, 2001; Shillington et al., 2004), in which the oldest identified magnetic anomaly is M3 (earliest late Barremian; Whitmarsh et al., 1996). In the Galicia sector, it seems coeval with the beginning of mantle exhumation and with the last pulse of continental extension in the Galicia Interior Basin and in the southern limit of the sector, where is marked by an unconformity between the lower Barremian and the upper Barremian (Sibuet et al., 1978). In the Newfoundland conjugate Jeanne d'Arc Basin, a phase of intense extension and subsidence starts in the late Barremian (Driscoll et al., 1995). A major Barremian unconformity in the southern Iberia margin is interpreted as recording a compressional event (Maldonado et al., 1999), which is compatible with the increasing rate of Atlantic opening.

3.5. Upper Barremian-lower Aptian

Following the emersion, the upper Barremian in the depocentre of the basin is composed by fine clastics and dolostone of the Regatão Formation, deposited in inter to supratidal coastal plains and estuaries. However, large parts of this unit as well as of the deposits of the remaining southern sector (lower member of the Almargem Formation) were accumulated in fluvial systems draining the Hercynian mainland (Fig. 4). A sea-level rise allowed the onset of a rimmed carbonate platform environment in the region from the Arrábida hills to Ericeira: the Crismina Formation. In this unit, inner platform limestone and marls (Cobre Member) are followed by build-ups with corals and rudists associated with barrier grainstones (Ponta Alta Member; Fig. 4), culminating in the deposition of oyster-rich regressive marls representing a protected lagoonal setting (Praia da Lagoa Member, lower Aptian, Heimhofer et al., 2005), scarcely preserved in thickness and area due to erosion during the Late Aptian tectonic event.

Showing reduced subsidence, the upper Barremian-lower Aptian defines a distinct transgressive-regressive cycle. Its maximal transgression, with an extension smaller than the previous major sequence, occurred in the mid early Aptian (*Deshayesites deshayesi* Zone; Rey et al., 2003). This evolution was recorded in several other European basins (Jacquin et al., 1998) and was most probably contemporary with the global OAE1 (ocean anoxic event), identified in the Galicia offshore (Tremolada et al., 2006).

3.6. Late Aptian unconformity

Around the Aptian-Albian transition an important tectonic event created a basinward erosional surface, covered by coarse fluvial deposits which overlay tilted Mesozoic units and the Hercynian basement. The unconformity was probably caused by

the continental break-up and initiation of seafloor spreading in the Galicia sector (e.g. Schärer et al., 2000), an event showing up clearly in the magnetic anomalies around (at least south and E) the Galicia triple-junction (Sibuet et al., 2004). It separates the transitional from the alkaline magmatic cycles in Iberia, namely in Portugal and Catalonia, considered as postdating the main plate extension and rotation (Martins, 1991; Solé et al., 2003). This break-up unconformity was also identified in offshore boreholes in Galicia, both in the deep margin (Sibuet et al., 1978; Mauffret and Montadert, 1988; Reston, 2005) and the Interior Basin (Murillas et al., 1990), as well as in the conjugate Newfoundland margin (Foster and Robinson, 1993; Driscoll et al., 1995; Shipboard Scientific Party, 2004). In many Western Europe basins, in both Tethyan and Boreal realms, late (possibly latest) Aptian unconformities were recognized, including several linked with key geodynamic changes (Jacquin et al., 1998).

In the Galicia and Newfoundland offshore wells a late Aptian to early Albian age was assigned to the deposits that overlay the break-up unconformity (Graciansky et al., 1978; Foster and Robinson, 1993; Shipboard Scientific Party, 2004). In the on-shore of the western Iberia margin, no fossils with precise chronostratigraphical significance were identified in the lower part of the Rodízio and Figueira da Foz Formations, were the oldest accurate biostratigraphic (palynological) data points to the early Albian (Heimhofer et al., 2005, 2007). Such data do not exclude a late Aptian age for the deposits directly over the main unconformity.

3.7. Upper Aptian-upper Cenomanian

Following the late Aptian tectonic event, the Rodízio Formation and the Figueira da Foz Formation (equivalent to the upper member of the Almargem Formation) correspond to the fast progradation of braided fluvial systems covering the entire studied region (Fig. 5). In the northern sector, the Figueira da Foz Formation includes several members defined by the 3D distribution of clastic facies and some marine intercalations. Along the eastern border of the basin, the Lomba do Alveite Formation displays onlap geometry, overlaying Palaeozoic and Proterozoic meta-sediments. Due to the different resistance of the basement to weathering and erosion, narrow NW-SE-trending Palaeozoic synclines produced quartzitic ridges, whereas the large anticlines cores composed of slates and metagreywakes developed flat valleys. Because the Lomba do Alveite Formation overlies these quartzite inselbergs a long period of general chemical weathering followed by erosion, occurring in Early to Middle Jurassic and Early Cretaceous times, has been inferred (Cunha and Pena dos Reis, 1995). The Lomba do Alveite Formation comprises alluvial plain sediments with a composition indicating a source area dominated by granites and phylites; the quartzite inselbergs provided the larger extraclasts.

During the Albian, the long-term eustatic rise initiated the diachronic establishment of a carbonate platform in the southern domain. The uppermost lower and upper Albian carbonate record is known as the Galé Formation. This unit includes nerineid-rich sandy shoals and fringes of rudist build-ups (Ponta da Galé Member) as well as inner lagoonal marly deposits (Água Doce Member). These deposits are linked with siliciclastics in the northeast, representing large fluvial systems draining to SW.

Three major T-R cycles (2nd to 3rd order) can be defined in the upper Aptian-Albian interval: (1) upper Aptian/lower Albian, (2) middle Albian/upper Albian *p.p.*, and (3) uppermost Albian (Vraconian). The lower one reflects a latest Aptian (Grötsch et al., 1998) or lower Aptian (Jacquin et al., 1998) eustatic maximum, the middle one was probably triggered by the onset of oceanic crust in the northern margin of Galicia (Malod and Mauffret, 1990) and/or an eustatic drop (Haq et al., 1988; Ruffell, 1991; Grötsch et al., 1998), and the base of the upper cycle is possibly linked with the onset of

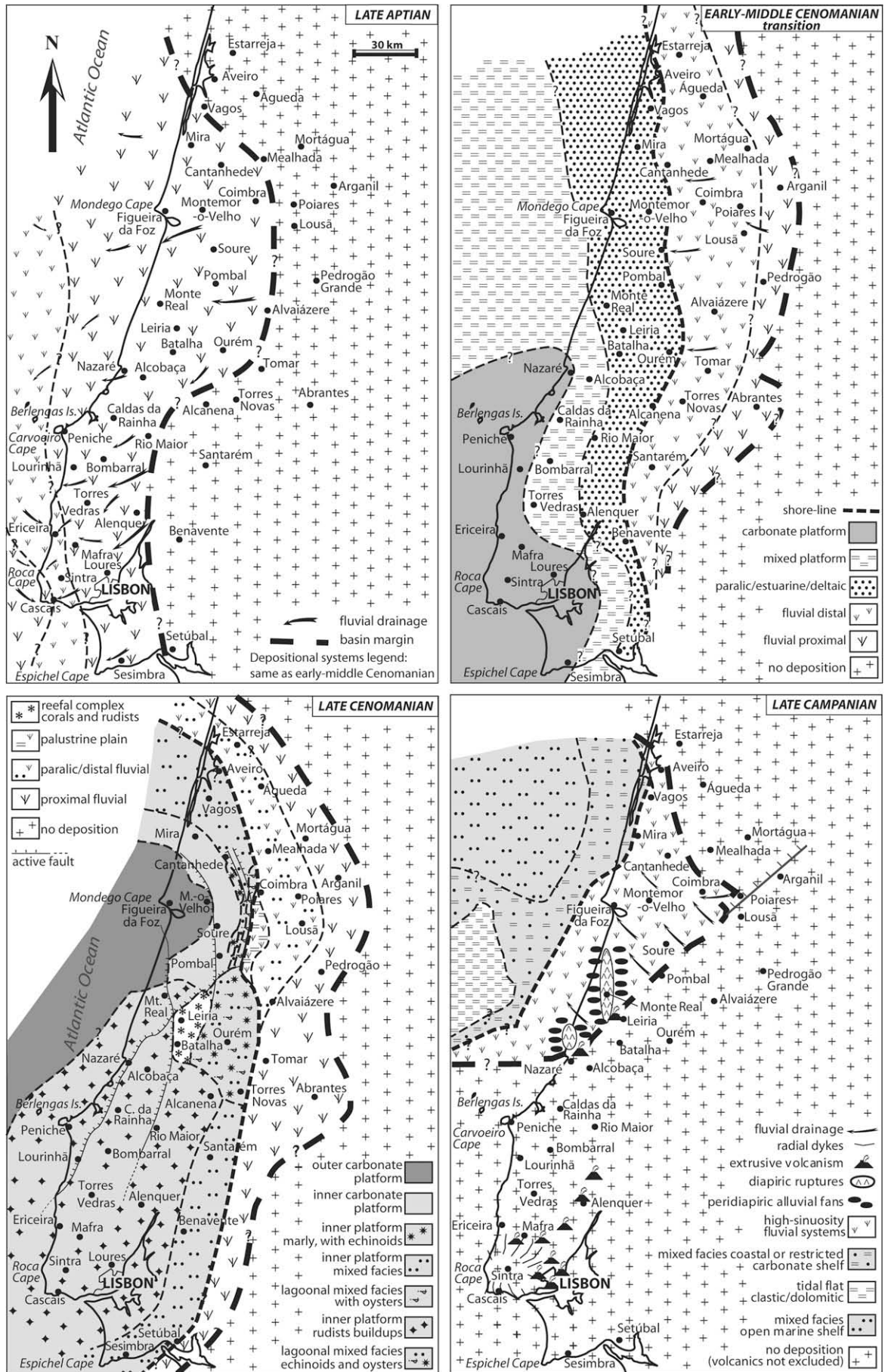


Fig. 5. Palaeogeographic maps of depositional environments for selected times of the late Early and Late Cretaceous (modified after Rey et al., 2006).

oceanic crust production in the eastern Bay of Biscay, inducing transpression in the Pyrenean domain.

The Albian/Cenomanian transition corresponds to a discontinuity which is connected to a regressive episode within the carbonate platform. It can be related with increase in compression with Africa (Martín-Chivelet, 1995) and transpression in the Pyrenees (Olivet, 1996; Canérot et al., 2005). It was an ample and widespread sea-level drop recognized in the Boreal and the Tethyan main cycles (R15 in Jacquin et al., 1998), possibly eustatic considering its recognition in the cratonic Moscow depression (Sahagian et al., 1996; Immenhauser, 2005). After Uchupi and Emery (1991) this regression is coeval with the onset of oceanic crust north of the Galicia triple-junction, recognized as the break-up unconformity in the Porcupine Basin (Sinclair, 1995) and the north of the Jeanne d'Arc Basin (Driscoll et al., 1995).

The lithostratigraphy and the geological maps with Albian-middle Cenomanian deposits of the southern sector are based in a set of units defined by Choffat (1885, 1886, 1900): (1) the “*Knemiceras uhligi* level”, (2) the “*Polyconites subverneuili* level”, (3) the “*Exogyra pseudaficana* level” [*Ilymatogyra*], (4) the “*Pterocera incerta* level” [*Harpagodes*], (5) the “*Neolobites vibrayanus* beds” and (6) the “rudists limestone” (systematic update sensu Callapez, 2003). The four lower ones were grouped as “Bellasio” by Choffat (1886). Recently, the two lower levels define, respectively, the Água Doce and Ponta da Galé Members of the Galé Formation (Rey, 1992). The units (3) and (4) compose the Caneças Formation and the upper two levels correspond to the Bica Formation (Rey et al., 2006).

The Cenomanian T-R cycle: within the long-term eustatic rise (Fig. 5) the maximal Cretaceous transgression in the basin was during the initial upper Cenomanian (*Calyoceras guerangeri* Zone; Berthou, 1984; Callapez, 2003). Afterward, individualization of open platform domains with ammonite facies took place in the northern sector (Baixo Mondego region; Choffat, 1900; Soares, 1980; Lauverjat, 1982; Fig. 5). Southwards, there was a rimmed platform with extensive calcarenitic shoals, a coral reef complex (Callapez, 2004) and fringes of rudist build-ups. Local uplift movements along the main diapiric axis also contributed to the diversification of the palaeogeography, particularly in the northern and central domains of the platform (Callapez, 2003).

3.8. Turonian-lower Campanian

Marked by a hiatus and a karstified surface in the carbonate succession, the Cenomanian-Turonian transition exhibits an unconformity (Soares, 1980; Berthou, 1984; Callapez, 2003) which is out of phase with the long-term eustatic trend, possibly due to increased compression in both, the Pyrenean and the Betic domains. After a brief resume of carbonate deposition, the Turonian-middle Campanian long-term regressive evolution is recorded exclusively in the northern domain, clearly shown by the Picadouro Formation succeeding the Choisa Formation. An initial fluvial progradation trend, mainly represented by the distal alluvial plain micaceous sandstones of the Choisa Formation and its coastal marine equivalent, the Lousões Formation, was most likely stopped by a geographically restricted shallow marine episode (Siadouro sandstone member, probably of Coniacian age; Gutierrez and Lauverjat, 1978). This short marine incursion was followed by significant aggradation, leading to the accumulation of about 130 m of alluvial siliciclastics (maximal thickness of the Picadouro Formation in the Lousã area). The subsequent fluvial incision reached around 100 m in depth and was followed by another limited shallow marine episode (the “Mira conglomerate,” uppermost lower Campanian). The top of the Picadouro Formation exhibits a thick silcrete, indicating long-term landscape stability and tropical weathering, probably caused by very low and decreasing subsidence during the early Campanian.

The reduction of the counterclockwise rotation of Iberia (Malod, 1989) from the Turonian onwards preceded the establishment of compression along the northern boundary of the plate, marked in its western margin by the top of the UBS4b (Fig. 2; Cunha and Pena dos Reis, 1995).

3.9. Middle Campanian-Maastrichtian tectonic framework

A kinematic change in the northern boundary of Iberia is thought to have deeply modified the overall tectonic framework. Ocean crust formation in the Bay of Biscay ended by anomaly A330 (Sibuet and Ryan, 1979; Malod, 1989; Srivastava et al., 2005) of early to middle Campanian age (ca. 80–83 Ma; Gradstein and Ogg, 2004). At the same time, Iberia accreted to Africa and the two plates began to move together (Galdeano et al., 1989; Srivastava et al., 1990; Sibuet and Collette, 1991; Maldonado et al., 1999).

The direction of convergence in the Pyrenees suffered a deep change, namely decreasing the sinister transpressive motion and increasing the N-S compression (Olivet, 1996; Sibuet et al., 2004), including active subduction (Sibuet and Le Pichon, 1971; Grimaud et al., 1982; Sibuet et al., 2004). As a consequence, a NNW-SSE-oriented maximum compression was established (N-S cf. Mougnot, 1981; Lepvrier and Mougnot, 1984; Gräfe and Wiedmann, 1993). The development of W-E directed intraplate tension is likely as a minor horizontal stress in the overall compression focused in the Bay of Biscay, as well as linked with the persistence of ocean spreading west of Iberia.

In the western margin of Iberia, the deposition of the UBS5 sequence was under this geodynamic configuration. Such a stress field may have stimulated the uplift of fault-related anticlines with evaporite cores, documented by erosion of the Cretaceous and sometimes Jurassic units in Nazaré, Vale Furado (Paredes de Vitória), and Leiria-Monte Real as well as the reactivation of some parallel structures, like the N-S Arunca-Montemor-o-Velho fault. During this period the intrusion of the Sines and Monchique alkaline plutons occurred, as well as the main phase of the Sintra massif emplacement (e.g. Ribeiro et al., 1979; Abranches and Canilho, 1981), probably by the reactivation of ENE directed faults (González-Clavijo and Valadares, 2003) along a deep-seated dextral major strike-slip fault (Terrinha, 1998; Gomes and Pereira, 2004). Some upper Campanian interstratified basic alkaline volcanism is also considered as associated with the tensional component.

3.10. Middle Campanian-Maastrichtian deposits

Important palaeogeographic changes resulted from the diapirism along N-S-trending faults and vertical displacement along NE-SW-trending faults such as the Lousã one, probably with a left-lateral transpressive component and uplift of the southern block (Fig. 5). This resulted in a direction of the fluvial drainage to NW, as recorded by the Taveiro Formation (Pena dos Reis, 1983).

The upper Cretaceous sediments of the UBS5 overlie the thick regional silcrete on the top of UBS4, but along the diapirs they cover a deeply erosional angular unconformity. With a maximum thickness around 200 m onshore, the sequence includes mostly yellowish quartz sandstone and reddish and brown lutites with nodular calcareous crusts (Taveiro Formation). Around the diapirs, the interfingering coarse clastics and lutitic facies can be interpreted as deposited in alluvial fans, including frequent mud flow beds, lakes, and highly sinuous rivers. The unit displays a general fining upward trend, although the architecture can be rather complex.

In areas distant from the narrow diapiric anticlines, the Taveiro Formation facies associations record a fluvial meandering system draining towards the NW, grading distally into lagoonal and restricted shallow marine deposits, with barrier-island facies in the

Aveiro region (the Aveiro Formation; Bernardes and Corrochano, 1987). Its offshore equivalents (Fig. 5) are the very shallow marine fine clastics and dolomites of the upper Campanian–Maastrichtian Dourada Formation (90 m thick). This unit consists of grey-brown, dolomite cemented quartzarenites grading to sandy crystalline dolostones with intercalations of grey to light brown marl and occasionally sandy limestone in the lower part (Witt, 1977).

4. Concluding remarks

The Cretaceous deposits of the Portuguese western margin reflect two main phases. The first phase (Berriasian – Cenomanian) corresponds to the total infill of the Lusitanian Basin during the late rifting stage, and is composed by three transgressive-regressive cycles (and the upper part of a cycle below) separated by unconformities related with the northward propagation of the Atlantic opening. The depocentre during this phase was located on the Lisbon peninsula, mainly composed of marine platform carbonates, fringed by transitional mixed deposits linked with continental siliciclastics; the northern sector includes a large hiatus due to uplift, probably cumulating those three basin-wide unconformities. The identified cycles were also controlled by eustasy, especially the minor ones. The establishment of a large Cenomanian carbonate platform was a turning interval towards a tectonic setting controlled by the counterclockwise rotation of the Iberian plate, reflecting the opening of the Bay of Biscay and the transpressive interactions with Africa and Eurasia. During the second phase, the depocentre was relocated to the northern sector whereas the southern one experienced uplift. The post-Cenomanian stratigraphic record is characterized by a low subsidence rate and is dominated by fluvial deposits with occasional marine intercalations. The upper Campanian and Maastrichtian deposits mirror the end of seafloor spreading in the Bay of Biscay and the start of incipient compression between Iberia and Eurasia, as well as with Africa, during the mid Campanian.

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