Stratigraphy of Iberian and Mediterranean Basins

North Tunisian Lower Cretaceous, stratigraphical approach by ammonites and microfaunas: a model for the Tethys Southern margin

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During Early Cretaceous times, an open marine basin, the "Sillon tunisien" (=Tunisian Trough), occupied the North of Tunisia. Situated on the meridional edge of the Tethys Ocean, it was marked by an active tectonic subsidence. The great thickness and the lithology of the sediments were influenced by the Tethys transgressions issued from the NW which deposited deep marine (circalittoral and bathyal) shaly units with limestones and by Saharian detritic sediments prograding from the South-West. Lower Cretaceous rocks are represented by thick sequences of shales with thin beds of limestones and sandstones in the western side of the basin. Neverthless in the eastern side the series are thinner due to positive movements of the basement along the "Zaress-Zaghouan axis". They contain nektonic faunas (ammonites) and planktonic fauna (calpionellids and foraminifera) which allow us to establish biostratigraphical scales. Recognized biozonations are integrated into the general scheme developed for the Mediterranean Province (ammonites) and the Mesogean areas (planktonic foraminifers and a correlation between the two zonations is presented.

Keywords: Lower Cretaceous, Biozonations, Correlation, Northern Tunisia.

Clay minerals in the Toarcian marly limestone deposits of the Eastern sectors of the Lusitanian Basin (Portugal). Stratigraphic and palaeoenvironment significance

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The Toarcian in the Lusitanian Basin (central-western Portugal) is mainly composed by marly limestone hemipelagic deposits, belonging to the Prado, S. Gião and Póvoa da Lomba (partially) formations, well controlled by ammonite biostratigraphy. The stratigraphic succession is organized in several third-order sequences, limited by regional sequence boundaries, deposited in a carbonate ramp dipping towards north and west. In this sedimentary context, we performed a high resolution clay minerals study developed in the eastern part of the basin, across proximal (Tomar; around 70 m thick) and distal (Coimbra; around 280m thick) areas. In order to understand the role of the clay minerals in the sedimentation across proximal and distal settings of the Lusitanian Basin, a total of 169 samples, only just considered clay fraction <2μm, from four reference sections (Tomar, Alvaiázere, Rabaçal and Coimbra), were analyzed by X-Ray Diffraction (XRD). Considering the important palaeoenvironmental changes observed in the basin across the early Toarcian (Toarcian anoxic event), other main goal was to see the influence of these events in the clay minerals record.

In the whole succession the clay fraction is clearly dominated by illite + mixed-layer illite/smectite (between 69% and 100%), associated with kaolinite, chlorite, smectite and vermiculite. The kaolinite presents significant values (between 3% and 25%) and the other minerals are less abundant. Among the vertical and lateral variations of the clay minerals associations observed across the studied area, we highlight two main evidences: the great diversity of clay minerals observed in the lower-middle (Bifrons Zone) Toarcian of distal (Rabaçal-Coimbra) sectors, related to the different sedimentary changes recognized in this interval in the Lusitanian Basin (several units, sea level changes and tectonics), including chemical weathering and diagenesis; the second main evidence is the progressive decreasing of kaolinite across the upper Toarcian, with local disappearance . This particularity seems

to be related with an increase of arid conditions, comparing to the most humid palaeoenvironment admitted to the early Toarcian.

Keywords: Clay minerals, Marly limestones, Palaeoenvironment, Toarcian, Lusitanian Basin, Portugal.

Clays and vegetation: comparing palaeoclimatic signatures in the Portuguese Lower Cretaceous

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A set of 120 clay assemblages were collected with a detailed stratigraphic location in the Lower Cretaceous coastal outcrops of the Ericeira area (western Portugal). The kaolinite *vs*. illite dominance can be considered as revealing wet or dry climates, respectively, prevailing in the watershed. Swelling clays are associated with seasonally dry climates. However, since the hydrodynamics and some rejuvenation events also controls clay associations, the relative role of climate *vs*. depositional setting remains to be fully deciphered. Since the onshore Lower Cretaceous of western Portugal is a key area for studying Early Cretaceous initial diversification of angiosperms, several well studied floras are summarized and their environmental interpretations presented.

Keywords: Clay minerals, climate, depositional systems, fossil floras, Lower Cretaceous, Portugal.

The stratigraphy and rifting evolution of the Oxfordian-Upper Barremian (Upper Jurassic-Lower Cretaceous) in the Serranía de Cuenca (Southwestern Iberian Ranges, Spain)

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The geological history of the Serranía de Cuenca Basin is very different from other domains of the Iberian Basin between the Oxfordian and the Upper Barremian. A thermal uplift stage of the area, related to rifting, provoked the emersion of the Jurassic marine platforms in the Oxfordian. For almost 30 m.y. the Jurassic carbonates were covered by thick tropical soils and preserved from true erosion. The onset of the extension in this area started karst processes and progressively generated small and complex half graben like basin that were filled by a continental subtropical system of wetlands (La Huérguina Fm). This unit shows a complex internal architecture that has been separated into six different stratigraphic units, some of them defined for the first time.

Keywords: Upper Jurassic- Lower Cretaceous, Rifting, Iberian Basin, Serranía de Cuenca.

Correlation of the Middle Jurassic (Callovian) Formations across the Dead Sea rift

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We have correlated the highest of the Middle Jurassic units exposed on both sides of the Dead Sea Rift (DSR) in Jordan, Israel and adjacent Egypt. Since the scarcity of cosmopolitan ammonites renders correlation of these units within the standard bio-stratigraphic time-scale difficult, we compared the brachiopod and molluscan faunas in order to constrain the ages of Jurassic formations in the Levant. The Callovian Mughanniyya Formation in the Zarqa - Arda area of northwest Jordan, East of the DSR, is compared with the Zohar and Matmor formations of the Negev (Israel) and Gebel Minshera (Sinai, Egypt), West of the DSR, as well as with the Arroussiah Formation of Gebel El-Maghara (northern Sinai, Egypt). The Mughanniyya Formation is correlative with the lowermost part of the Zohar Formation in the Negev that is coeval with the lowermost part of the Arroussiah Formation in Sinai (Egypt).

Keywords: Callovian, Biostratigraphy, Correlation, Dead Sea Rift, Molluscs, Brachiopods.

Palaeogeographical evolution of the Lusitanian Basin (Portugal) during the Jurassic. Part I: the tectonical constraints and the sedimentary response

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In this paper we present the general tectonic framework that conditioned the evolution of the Lusitanian Basin during the Jurassic, when most of the filling of the basin was accumulated. The rifting episodes and the evolution of the basin's geometry are presented and their close relation with the main basin-wide unconformities is discussed. The unconformity bounded sequences are briefly presented, in order to understand the evolution of the sedimentary environments. This constitutes the basic geological information to make the palaeogeographical maps presented in Part II of this paper (*in* this volume).

Keywords: Lusitanian Basin, Jurassic, tectono-stratigraphical evolution, unconformities, palaeoenvironments.

Palaeogeographical evolution of the Lusitanian Basin (Portugal) during the Jurassic. Part II: the slow-to-fast transformations of the sedimentary infilling

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In this paper we will present the first palaeogeographical maps of the Lusitanian Basin during the Jurassic. We will present the methodology to produce those maps and discuss the close relation of facies distribution along time and space with the sequence of tectonic events in the basin (already discussed in Part I of this presentation, *in* this volume). One of the inedited conclusions is that the main bordering N-S faults conditioned the facies architecture only during paroxismal events, with short intervals of "instantaneous" modifications on the facies distribution. A second conclusion is that in the time between those events the distribution of facies was controlled by the large ENE-WSW oriented transfer faults and sedimentary environments gradually rotated from N-S to ENE-WSW after each event.

Keywords: Lusitanian Basin, Jurassic, palaeogeographical maps, palaeoenvironments, gradual facies rotation.

Paleoenvironmental changes and C-isotope stratigraphy in the Alarcón Formation stratotype (Upper Cenomanian-Lower Coniacian, Iberian Ranges, Spain)

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This study analyzes sedimentary facies, paleosols development, and the $\delta^{13}C$ stratigraphy of the Alarcón Formation in its stratotype in the Iberian Ranges (Spain). The aim is to characterize the paleoenvironmental changes that occurred in the carbonate shallow marine environments of central Iberia during the late Cenomanian to early Coniancian time-interval. These changes, recorded in seven transgressive-regressive cycles, are interpreted in the framework of regional sea-level variations, local subsidence, and climate. The possible influence of supra-regional changes such as those related to the Oceanic Anoxic Event 2 (OAE2) on the Alarcón Fm. sedimentary succession is also analyzed and discussed.

Keywords: Shallow marine carbonates, paleosol, stable isotopes, Upper Cretaceous, Iberian Ranges, Cenomanian-Turonian.

Stratigraphical features of the Yeşilyurt-Konak area (Malatya, Turkey)

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The stratigraphic sequence in the study area starts with Carboniferous-Triassic Malatya Metamorphics, which are composed of marble and schist, covered unconformably by the Maastrichtian Gündüzbey Group. The Group includes Kızılgüney formation with conglomerate and sandstones, and Kapullu Formation containing.limestone-marl alternations, with turbiditic sandstone intercalations. The sequence continues with the Lutetian Yeşilyurt Group includes Zorbon, Yukarıbanazı and Gedik Formations, overlying unconformably the Kapullu Formation. The Zorbon Formation is composed of conglomerate interbedded with sandstone and mudstone while the Yukarıbanazı Formation consists of of sandstone and shale alternation with intercalations of conglomerates and olistolithes. The Gedik Formation is composed of reefal limestone, claystone and marl, and underlies the Pliocene-Quaternary.Beylerderesi Formation including conglomerate interbedded with sandstone. The Holocene alluvium unconformably overlies all the units in the region.

Keywords: Malatya, Yeşilyurt, Kapullu, Yukarıbanazı, Zorbon, Gedik, Alpine-Himalayan.

A description of Terrestrial Neogene Deposits in Beyköyü-Gökçeyazi area (Ereğli, Konya, Central Turkey)

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The stratigraphic sequence in the area starts with Paleocene – Lower Eocene Güneydağı Formation, including limestone interbedded with calcirudite, calcarenite and marl; overlaid with an angular unconformity by Beyköyü Formation with two members; Kabaktepe gypsum and Kayalıdagtepe stromatolitic limestone. A Miocene lacustrine environment is suggested by existence of blue-green algae of *Schizothrix* sp., *Scytonema* sp. and *Phormidium* sp. as well as green algae of *Chara* sp., lacustrine Gastropoda of *Planorbarius* sp. and lacustrine ostracode for the deposition of the Beyköyü Formation. The sequence continues with Upper Pliocene-Holocene Kuskuncuk Formation, containing alternation of conglomerate, sandstone and mudstone, with caliche bands in some levels; deposited in alluvial fan and braided stream environments. Quaternary alluvium is the youngest formation in the sequence.

Keywords: stromatolite, gypsum, fluvial, Beyköyü, Ereğli, Turkey.

Correlating Mediterranean shallow water deposits with global Oligocene-Miocene stratigraphy and oceanic events

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The Oligo-Miocene Decontra section in the Maiella Platform of the Abruzzi Mountains has been studied in respect to facies and lithostratigraphy, biostratigraphy, chemostratigraphy and sequence stratigraphy,

supplemented by geophysical data. Based on few biostratigraphic tie points the widely complete section allows correlation with the global carbon stable isotope curve and with the 3rd order sea level curve.

Keywords: Oligocene, Miocene, carbonate rocks, biostratigraphy, chemostratigraphy, sequence stratigraphy.

Palaeoenvironmental and palaeoecological significance of sponge-microbialite buildups from the Toarcian of Northern Lusitanian Basin (Portugal)

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The Toarcian (Lower Jurassic) succession in the western palaeomargin of Iberia (Lusitanian Basin, Portugal), is a monotonous marl-limestone alternance deposited in an external homoclinal ramp setting, dipping northwestwards. Between Middle and Upper Toarcian, meter-scale buildups grew here and occur in the middle-upper part of the S. Gião and Póvoa da Lomba formations. This work is focused on the typology of these buildups of the S. Gião Formation and in the characterization of their controlling factors.

Buildups appear as sedimentary anomalies disturbing the regular and monotonous order of the marl-limestone alternation. They are more or less massive plano-convex bodies with a low relief and lenticular shape, usually only a few decimeters thick. The buildups are always related laterally with carbonate beds and they are commonly composed by several more or less lenticular smaller bodies separated by distinct planar or slightly convex upwards surfaces. The main components of the buildups are siliceous sponges, microbialite and parautochthonous micritic matrix (bioclastic wackestone or packstone). The sponges correspond to Hexactinellida (73% Hexactinosida and 18% Lychniskosida) and secondarily to Lithistida (9%). The microbialite is a main component in the studied buildups growing on siliceous sponges and other macroinvertebrates. Moreover, encrusting organisms are serpulids, bryozoans and foraminifera.

Two main stages in the development of the buildup can be differentiated: 1.- Colonization of the muddy bottom by siliceous sponges, favoured by a previous skeleton of sponge, ostreids, *Plagiostoma* or a thin shelled bivalve biostrome. In this part the microbialite is not abundant and benthic macroinvertebrates, mainly siliceous sponges dominate. 2.- Growth of a buildup of siliceous dish-shaped sponges with thick microbial encrustations (thrombolites and less leiolites) and abundant micritic matrix. The alternance of sponges-dominated and microbialite-dominated phases in buildups is related to cycles of interruption of growth and resumption. This sequence is repeated in each body constituting the buildup.

Clearly, some controlling factors played an important role in the development of the Toarcian buildups of the Lusitanian Basin. The buildups consist of several microfacies types (wackestones, packstones, floatstones and boundstones). All of them are micrite-dominated and represent low energy environments suggested by the absence of sedimentary structures in the surrounding marly muddy bottom. Low sedimentation rate enabled the sponges to colonise the seabed and favoured the dominance of large dish-shaped forms, and the occurrence of microencrusters and microbialites. This is in agreement with the initial basin-wide growth of the buildups related to the intra Bifrons Zone regional flooding surface. The high sedimentation rate and the muddy bottom prevented the colonization of the seabed by epibenthic, sessile organisms due the high input of fine-grained detritic particles that caused turbidity at the seabed and the low consolidation degree (softness of the bottom). Thus, sponge colonization was limited to reduced areas of lower sedimentation and turbidity at the seabed. Here, small benthic islands or hillocks formed, suitable for colonization by sessile epibenthos and for the development of benthic microbial communities. The preferential record of the buildups at the top of the fourth order sequences is related to sediment-starved intervals.

Keywords: Microbes, siliceous sponges, palaeoecology, Toarcian, Lower Jurassic.

Elemental geochemical analysis at the Lower Toarcian of the Rabaçal section (Northern Lusitanian Basin, Portugal): approaching the environmental disturbance produced by the T-OAE

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The Coimbra-Rabaçal area is located in the northern part of the Lusitanian Basin (Portugal). The Lower Toarcian sequence in this sector corresponds to the base of the S. Gião Formation, dominated by hemipelagic marls and limestones enriched in benthic and nektonic macrofauna. Despite these general sedimentary characteristics, the base of Levisoni Zone marks in the basin a great facies variation evidenced by thin nodular limestones (centimetre-scale), sometimes silty to sandy, alternating with marly-clay inter-beds.

The geochemical analyses of the Lower Toarcian in the Rabaçal section allowed the characterization of environmental changes around the Polymorphum-Levisoni zone boundary (Tenuicostatum-Serpentinum zone boundary in NW European ammonite zonation). Coinciding with this boundary, palaeoproductivity proxies such as Ba/Al and P/Ti reach a maximum indicating a high productivity event. This level records the highest TOC values of the section (0.44 wt.%) but still low compared with Lower Toarcian deposits from central and north Europe. Analyses of C and O isotopes on these sampling layers describe the same trend that previous works. From the Polymorphum-Levisoni zone boundary $\delta^{13}C$ (2 – -0.2‰) decreases and $\delta^{18}O$ and Mg/Ca increase. The Levisoni Zone is typically characterized by a negative isotopic excursion and well correlated with the decreasing values here recorded. In the lower part of Levisoni Zone an increase of Ti/Al ratio is recorded together with a diminution of Rb/Al and Th/Al ratios. These detrital proxies indicate increasing aridity as Si/(Si+K) is always >0.5 indicating dominance of eolian supply. The inferred maximum aridity is coincident with the highest values of $\delta^{18}O$ and Mg/Ca.

Regarding the redox proxies, U/Al, U/Th, Mo/Al and Ni/Al ratios show a peak coincident with the minimum values of $\delta^{13}C$, and high values of $\delta^{18}O$ and Mg/Ca. These redox proxies indicate suboxic conditions in spite of the low values of TOC compared with central and north European sections. The most extreme conditions are located just above the base of Levisoni Zone. In the marls and marly limestones of the upper part of Levisoni Zone and the base of Bifrons Zone the values of geochemical proxies and isotopes are similar to those from marls and marly limestones of the Polymorphum Zone.

As concluding remarks from this research, the use of geochemical proxies for palaeoproductivity, detrital supply and redox conditions, compared with isotopic data allowed the identification of environmental changes in the Coimbra-Rabaçal area such as suboxic conditions and increasing aridity during the lower part of Levisoni Zone, probably correlated with the Toarcian Oceanic Anoxic Event.

Keywords: geochemistry, redox conditions, detrital input, palaeoproductivity, Lower Jurassic.

The Lower and Middle Jurassic of the Western Mediterranean Tethys (Morocco - Algeria and Tunisia)

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This work summarizes the lithostratigraphic and palaeogeodynamic data of the Lower and Middle Jurassic margin of the Tethys Maghreb (Morocco, Algeria, Tunisia). Comparative analysis of these successions done so far can now establish correlations and propose a geodynamic evolution of this margin during the Lower and Middle Jurassic, which can be summarized as follows: a) Edification and development of Liassic carbonate platform (Lower and Middle Lias) ; b) Individualization and compartmentalization of basins (Pliensbachian-Early Toarcian) ; c) Filling of basins (Upper Lias supérieur-Bajocian) ; d) Senescence of basins (Bathonian-Callovian).

Keywords: Lower and Middle Jurassic, Western Mediterranean Tethys, Atlas domain, Morocco – Algeria – Tunisia, Lithostratigraphy, Palaeogeodynamic evolution.

3rd order sequence stratigraphic scheme for the Pliensbachian in the Lusitanian Basin (Portugal)

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Sequence stratigraphy has been extensively used by academia and industry as a valuable tool in Basin Analysis and modelling of the several parameters that govern sedimentation and resource's availability, ultimately resulting in de-risking of a given area of prospect. One of the main characteristics of the Mesozoic record of the Lusitanian Basin is the occurrence of several organic-rich intervals, which are especially expressive in the marly limestones with organic-rich facies member of the Vale das Fontes Formation (Lower-Upper Pliensbachian). Based on the study of four classical and "rediscovered" sections at Tomar, Rabaçal, Peniche and S. Pedro de Moel areas, some of them well controlled by ammonite biostratigraphy, the aim of this work is to establish a 3rd-order sequence stratigraphic scheme for the main Pliensbachian organic-rich interval. This exercise is supported by a high-resolution basinwide stratigraphic correlation of the main Pliensbachian organic-rich interval and individual black shales.

As a result of the Meso-Cenozoic tectonic evolution of the Lusitanian Basin there is an absence of proximal marine, transitional and continental environments records for the Pliensbachian interval which coupled with the fact that only outcrop data are available (hence no large scale stratal terminations or geometric features can be inferred) makes it difficult to confidently assign the observed sedimentological features to changes of base-level or shoreline trajectory (offshore depositional trends may uncouple from shoreline environments) and, therefore, to a particular shoreline-related system tracts. In the marly limestones with organic-rich facies member three unconventional sequences for the Early-Late Pliensbachian time interval are defined, based in the arrangement of main discernible architectural element of the studied series: the thickness of limestone and marl beds. These unconventional systems tracts are named Decreasing Limestone Bed Thickness (DLBT) and Increasing Limestone Bed Thickness (ILBT) systems tracts and the bounding sequence stratigraphic surfaces are defined as Trend Inflection Surfaces (TIS) type 1 (at the base of ILBT) or type 2 (at the base of DLBT). The three sequences correspond to the 3rd-order sequence Lower Pliensbachian Ω [LoPΩ, base not defined but including the Ibex Chronozone, Luridum Subchronozone, Crassum (top of Rotundum?) horizon–extreme base of the Davoei Chronozone], 3rd-order sequence Lower–Upper Pliensbachian (Lo-UP, extreme base of the Davoei Chronozone–Margaritatus Chronozone, Stokesi Subchronozone, Celebratum horizon) and the 3rd-order sequence Upper Pliensbachian A (UPA, Margaritatus Chronozone, Stokesi Subchronozone, Celebratum horizon–top not defined).

These newly defined 3rd-order sequences in the Lusitanian Basin for the Pliensbachian seem to be linked to, or at least reflected in, time-equivalent successions of several neighbouring basins (e.g. Basque-Cantabrian, Asturias,

Aquitaine and Cleveland basins), suggesting that the Pliensbachian European epeiric seas share a more similar story than previously admitted.

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