PLATFORM TO BASIN CORRELATIONS IN CRETACEOUS TIMES
- *ABSTRACTS* -

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Foreword

The "5th Thematic Meeting" of the "French Working Group on the Cretaceous" (GFC), organized by Danièle Grosheny and Bruno Granier, was held in Paris from November 30 to December 1st, 2009, on the broad topic "platform to basin correlations". It was attended by 34 people from France, Switzerland, Belgium and Morocco. Twelve communications were presented on subtopics ranging from biostratigraphy to sequence stratigraphy. Invited speaker Philippe Razin from the University of Bordeaux 3 made an outstanding synthesis on the stratigraphic architecture of Lower Cretaceous carbonate platforms of the Sultanate of Oman.

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Abstracts

Stratigraphic, sedimentological and palaeoenvironmental constraints on the rise of the Urgonian platform in the western Swiss Jura, correlation with the Helvetic zone of the Alps and the northern Subalpine chains (Chartreuse, Vercors)

Thierry ADATTE, Alexis GODET, Karl B. FÖLLMI, Stéphane BODIN,
Eric De KAENEL, Annie ARNAUD-VANNEAU & Hubert ARNAUD

Urgonian-type carbonates are a characteristic feature of many late Early Cretaceous shallow-marine, tropical and subtropical environments. The presence of typical photozoan carbonate-producing communities including corals and rudists indicates the prevalence of warm, transparent and presumably oligotrophic conditions in a period otherwise characterised by the high density of globally occurring anoxic episodes. Of particular interest, therefore, is the exploration of relationships between Urgonian platform growth and palaeoceanographic change. In the French and Swiss Jura Mountains, the onset and evolution of the Urgonian platform have been controversially dated, and a correlation with other, better dated successions is correspondingly difficult. It is for this reason that a series of recently exposed sections were sampled (Éclépens, Vaumarcus, Neuchâtel), in addition to the Gorges de l'Areuse section. The stratigraphy and sedimentology of these sections were analysed. Calcareous nannofossil biostratigraphy, the evolution of phosphorus contents of bulk rock, a sequence-stratigraphic interpretation, and a correlation of drowning unconformities with better dated sections in the Helvetic Alps were used to constrain the age of the Urgonian platform. The sum of the data and field observations suggests the following evolution. During the Hauterivian, important outward and upward growth of a bioclastic and oolitic carbonate platform is documented in two sequences, separated by a phase of platform drowning during the late Early Hauterivian. Following these two phases of platform growth, a second drowning phase occurred during the latest Hauterivian and Early Barremian, which was accompanied by important platform erosion and sediment reworking. The Late Barremian witnessed the renewed installation of a carbonate platform, which initiated with a phase of oolite production, which progressively evolved into an Urgonian-type carbonate production under the inclusion of corals and rudists. This phase terminated at the latest in the middle Early Aptian, due to a further drowning event. The evolution of this particular platform segment is compatible with that of more distal and well-dated segments of the same northern Tethyan platform preserved in the Helvetic zone of the Alps and in the northern subalpine chains (Chartreuse, Vercors).

Key words: Barremian, Early Cretaceous, nannofossil biostratigraphy, phosphorus, sequence stratigraphy, Urgonian, Western Swiss Jura.

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Urgonian carbonate platform to Vocontian Basin correlation (France SE) by means of biostratigraphy

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The Vercors is the only one of the northern subalpine massifs of which the outcrop is good enough to have permitted the establishment over a period of more than thirty years of excellent correlations between the Urgonian platform and the Vocontian basin. The hemipelagic facies of the northern border of the Vocontian basin has been dated by ammonites, particularly near surfaces of maximum flooding (mfs). Some of these levels are intercalated in the carbonate facies at the edge of the Urgonian platform. This very favorable juxtaposition permits the unambiguous recognition of the stratigraphic location of certain organisms, in particular that of the benthic foraminfers that inhabited the shallow waters of this platform during the Barremian and Early Aptian.

South of the Vercors a major transgression of which the marls of Font Froide (mfs) are located in the Gerhardtia sartousiana zone in the middle portion of the Upper Barremian allows the carbonates of the subalpine carbonates of the Urgonian platform to be divided into two lithologic entities: below the Calcaires de Glandasse Formation (Glandasse Limestones) and above the Formation des Calcaires urgoniens (Urgonian Limestones Formation) where sedimentation under oligotrophic conditions provided fewer nutrients than those obtaining during the Early Barremian. So the lower unit is essentially of Early Barremian age, while the upper one has been dated or attributed to Late Barremian-Early Aptian.

Farther north, detailed analysis of the sections and the Urgonian cliff that can be followed almost continuously for more than a hundred kilometers has permitted, although ammonites are not present, dating the Urgonian Limestones Formation as Late Barremian - earliest Aptian in the northern Vercors and in the subalpine massifs even farther north. Until recently, this dating could have been questioned because it is based in part on interpretation of sequences and in part on the distribution of orbitolinids that had been established in the southern Vercors and Diois in series dated by ammonites. Recently its validity has been confirmed by the study of the Urgonian limestones of the Gard region.

In the Gard the Urgonian Limestones Formation begins abruptly. It rests on marls (Seynes marls) of which the uppermost levels have been dated by ammonites as being at the top of the Early Barremian (*Coronites darsi* Zone of Vermeulen). Above them, the succession of orbitolinids in the Urgonian limestones of the Gard has been found to be identical to that known for a long time in the northern subalpine massifs.

In addition to the clarification of sequence, from another point of view the correlations established make possible in certain instances the recognition of parasequences allowing a better understanding of the geometric relationships of the deposits that in turn allow a better approach to the paleogeography and evolution of the platform. Furthermore, the platform-basin correlations proposed for the Barremian-Lower Aptian interval, and current geochemical studies will improve our knowledge of climate changes at that time.

Key words: Urgonian platform, Vercors, Gard, Barremian, Early Aptian.

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Expression of the oceanic anoxic event 2 in carbonate platform and in hemipelagic basin, example from Mexico and Tibet

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The majority of the published sections that span the Cenomanian-Turonian oceanic anoxic event when production of black shale was at a maximum concern the Atlantic, western Tethys and Western Interior (Kerr, 1998). The deposition of these black-shales is the result of an interruption of normal pelagic sedimentation by several discrete episodes of widespread oceanic anoxia (Schlanger & Jenkyns 1976, Jenkyns 1980, Arthur et al. 1990) that coincide with a positive excursion of the $\delta^{13}C$ isotope. Several studies show that the onset of this anoxia called the OAE2 event was triggered by a short-lived but significant increase in the burial of phosphorus (Mort et al. 2007). This increase caused bottom waters to become anoxic as the sea floor became a source of P rather than a recipient for it, with its continuity maintained by a positive feedback loop. On a larger scale, away from the main depocenters of black shale, the behaviour of Total Phosphorus (Ptot) and trace metals in different paleogeographies and paleodepths is still poorly known. Here we discuss the expression of this OAE2 event in the outer shelf/slope environment of northern Tibet and in the shallow carbonate platform of central Mexico.

The Gongzha section (Tibet, China) is at the north margin of the Indian plate (SE Tethys). It consists of a succession of monotonous hemipelagic marly limestones. $\delta^{13}C$ data exhibit the classical C-T positive shift. Significant peaks in Ptot occur at the onset of the shift, followed by a depletion at the end of *R. cushmani* zone that persists up to the end of the *W. archaeocretacea* zone. A similar P maximum and decrease is observed in the western Tethys and central Atlantic sections, so it appears to be global, coinciding in part with increased detrital inputs. At Gongzha, trace-metals contents are less than the background level of sections in which anoxic conditions are strong. Redox sensitive elements such as Va, Ni, Co, U, generally indicative of anoxic conditions, do not increase during the $\delta^{13}C$ shift, suggesting that dysoxic rather than anoxic conditions prevailed in the Tibet area during OAE2.
The Axaxacualco and Barranca El Cañon sections are on the Guerrero-Morelos carbonate platform in southern Mexico. Their $\delta^{13}C$ curves can be correlated. In the distal part of the carbonate platform at Axaxacualco, the maximum $\delta^{13}C$ positive excursion coincides with oligotrophic carbonate platform environments, characterized by an abundant and diversified benthic microfauna and rudists, and low concentrations of Ptot. The impact of OAE appears to be more significant in the proximal part of the carbonate platform at Barranca, where it is associated with the deposition of thick laminated microbialites indicative of mesotrophic conditions. Oligotrophic to mesotrophic conditions persisted on the Morelos Carbonate platform and throughout the entire OAE2 in Central Mexico despite the proximity of the Carribean plateau. Definitive drowning, marked by the deposition of black shale and turbidite, occurs only in the lower Turonian (*P. flexuosum* zone), well above the end of the $\delta^{13}C$ shift.

Key words: Carbonate platform, hemipelagic basin, OAE 2, geochemistry, Cenomanian-Turonian, Mexico, Tibet.

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Impact of meteoric diagenesis on microporous carbonates of the Middle-East. Example from the Mishrif Fm. (Cenomanian - Lower Turonian) of Qatar

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The marine carbonates of the Mishrif Formation (Middle Cenomanian - Lower Turonian) were deposited in shallow, low energy ramp environments, before the fall of the eustatic level during the Middle Turonian. Depositional environments change laterally from an internal ramp facies to the more open facies of a median ramp. These facies are associated locally with very shallow, higher energy rudistid biostromes. In the predominating micritic facies (mudstones and floatstones) the vertical and lateral heterogeneity of petrophysical properties (porosity, permeability, the distribution of pore sizes) seem to be linked closely to variations in the microtexture of the micritic matrix. Microporosity is relatively uniform, high (up to 35% porosity) and may may represent up to 98% of the total porosity measured in plugs. Permeability is low (less than 1 mD) to moderate (up to 100 mD).

Use of cathodoluminecence (CL) and a scanning electron microscope (SEM) on 240 samples, as well as spaced isotopic analyses permitted identification of the sedimentologic and diagenetic factors that controlled variations in the microtexture of micritic matrices as well as the associated reservoir properties associated with them.

Our results show two poles of micronitic organization (each with its own crystalometry, luminescence and petrological properties) that can be discriminated:

(A) The micritic facies with the best permeabilities (up to 100 mD) as well as the largest mean-size pore throats (more than 0.5 µm) are generally coarse micrites (crystal size more than 2 mm) tha are poorly sorted and but slightly luminescent under CL. These micrites are associated both spatially and chronologically with a early diagenesis indicating the development of a zone of high energy (up to 30 m thick in the axial region of the field) sited below the mid-Turonian discontinuity. These diagenetic phases are (1) endokrastic cavities, (2) low magnesian calcites (LMC), weakly luminescent and with minor of $\delta^{18}O$ and $\delta^{13}C$, (3) intervals of corrosion between the different phases of calcite. In the Vadose zone the development of coarse micrites with low luminescence is explained by the early dissolution of fine aragonite and magnesian calcite (HMC) with the concomitant development of overgrowths on the LMC particles (phenomena of Ostwald ripening).

(B) Under the zone of high energy most of the micritic faces have low permeabilities and very small pore throats (respectively less than 10 mD and 0.5 µm). The particles of micrite are fine (less than 2 µm) fairly well sorted and luminescent under CL. This micritic group is spatially and chronologically associated with a later development of luminescent calcite crystals (probably precipitated under a moderate depth of cover and locally with a high concentration of pyrite, pseudomorphs of sulfates and positive $\delta^{13}C$ values. The micrite particles are generally polyhedral and only rarely show important traces of dissolution. This grouping of micrites may then be explained by a slower mineralogic stablization with the neomorphism of metastable particles (aragonite and HMC). This phenomenon may have taken place in waters low in oxygen content, probably after the deposition of the Laffan shales (uppermost Turonian - Lower Coniacian) which seals the Mishrif reservoir.

The initial dstribution of certain sediments influenced the dichotomous distribution of these two micritic groups. The sediments initially the finest and most argillaceous (deposited in the calmest environments) hindered the renewal of meteoric waters and caused a confinement capable of delaying the minerologic stabilization of fine particles in HMC and in aragonite. Consequently, these micrites were more affected by pression-dissolution during burial, thus altering their reservoir properties. On the other hand the coarsest bioclastic sediments favored the drainage of meteoric waters and so favored the genesis of permeable micrites toward the coarser pole.

Key words: diagenesis, microporosity, micrite, Upper Cretaceous, Middle-East.

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The fluvial-marine transition in genetic sequences of the uppermost Albian ("Vraconnian") of the Moroccan Atlantic margin (Agadir area)

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Four sections correlated in detail and together covering about 100 km extend inland from the present-day coast at Taghazoute north of the Agadir City to the lower slopes of the High Atlas Mountains (Tamaloukt/Afansou north of the Taroudant Town). They examine the so-called "Vraconnian bar" (uppermost Albian) of authors in order to clarify the relationships between marine and fluvial facies in the 6 to 8 short-term depositional sequences (genetic sequences) that comprise the sedimentary wedge at the Albian - Cenomanian (A - C) transition. In all these sequences fluvial aggradation is concurrent with the seaward shift of the beach facies in a regime of stepped forced regression. The fluvial facies is thus the upper regressive half-cycle of the transgresssive-regressive (T/R) sequence. Work in progress shows that this relationship holds for the overlying Cenomanian sequences, and in the same area for the upper Hauterivian Talmest Fm. (see Ferry et al., this volume). One major findings of this study is that despite the absence of biostratigraphic markers, it offers the possibility of making very precise stratigraphic correlations between beach facies in the distal area, and red fluvial facies upslope.

The "Vraconno" - Cenomanian successions discussed herein include several intercalations of gypsum between the regressive beach facies and the red continental shales. These lagoonal evaporites do not occur in the Hautervian successions seen along the same transect so it is possible that the climate became more humid as the Cretacous period approached its end.

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Key words: Morocco, Cretaceous, Albian, sequence stratigraphy, fluvial-marine transition.

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Sequential organization of a fluvial to marine sedimentary wedge (Upper Hauterivian of the Moroccan Atlantic margin)

Serge FERRY, Moussa MASROUR & Olivier PARIZE

An Upper Hauterivian sedimentary wedge, the Talmest Formation, has been mapped by eighteen correlated sections from its marine expression in the west on the coast up to its fully continental facies in the central High Atlas in the east, a distance of about 200 km. The section of the Insouane-Amizmiz transect reveals in detail how fluvial aggradation in the Tamest Fm. follows the forced strong regression of beach deposits at the upper limit of the Loryi Zone. The red beds then retreat in four major steps during the upper Hauterivian before Barremian - Aptian flooding. Each step comprises a set of aggrading genetic T/R sequences. In all of them fluvial aggradation as a meandering fluvial cycle occurs during the regressive phase and results in the progradation of distal red clays on the sands and calcareous deposits of the beach facies. This sequence demonstrates that the "Exxon" model of sequence sratigraphy is completely valid at the parasequence level (fluvial aggradation is caused by the seaward displacement of the "bayline"). This concept is not new for it was formulated by Élie de Beaumont during the mid-19th century. Consequently, we must disagree with the "transgressive" concept of fluvial aggradation used in some applications of genetic stratigraphy (Cross, Homewood, Guillocheau).

Key words: Morocco, Cretaceous, sequence stratigraphy, fluvial-marine transition.

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Facies partitioning in the prograding genetic sequences of the Subalpine Urgonian carbonate platform. Their relationship to the significance given the Urgonian Rudist facies

Serge FERRY, Didier QUESNE & Mahmoud KHASKA

The succession of facies and the geometric relationships of the genetic units that constitute the limestone cliffs of the Archiane area (southern Vercors) again brings into question the validity of the classical concept of an 'Urgonian sequence' in which calcarenitic, coral-reef and rudistid facies are taken to be contemporaneous (Quesne & Ferry 1995, Quesne 1998, Quesne et al. 2006). On the contrary, the calcarenites are formed during a lowstand when the width of transgression is minimal and are overlain by a platform facies during the subsequent highstand when coral and rudistid facies occupy a broader area, either the entire platform or a large part of it. This coral-rudistid facies is interpreted as having been deposited at moderate depths (?20-30 m), by an open advancing sea and not as an inner platform facies protected by outer calcarenitic shoals, as the current interpretation would have it.

In our view, the “outer” calcarenites represent a seaward border of swell-dominated deposits which precede the true Urgonian facies that we take to be open-marine deposits. Because of the lowstand, the rudistid limestones are exposed, so a true boundary thus exists in any genetic sequence. This boundary is at the base of the calcarenites at the edge of the platform, and at the upper limit of the exposed rudistid facies on the platform. The fact that the open-marine flooding facies is terminated by a surface demonstrating emergence is explained by the extremely low gradient of the platform profile which does not accomodate a prograding “highstand wedge” that is commonly emplaced during the first stages of a lowering of sea level. The classical “Urgonian sequence” is thus based on a mistaken application of Walther's law because all the facies involved do not coexist at any one period of time.

The high frequency sequences in the Archiane area are also found in the low-angled progradational clinoforms studied along the eastern cliff-face of the Vercors plateau between Grenoble and Archiane (Khaska 2008). The “outer” “peri-Urgonian” calcarenites of some authors do not represent shoals that protected an inner platform rudistid facies. They are lowstand wedges laid down at the time when the open-marine rudistid platform was exposed.

Key words: SE France, Cretaceous, Barremian, Urgonian, sequence stratigraphy.

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Stratigraphic ranges of some Tithonian-Berriasian benthic foraminifers and Dasycladales. Re-evaluation of their use in identifying this stage boundary in carbonate platform settings

Bruno GRANIER & Ioan I. BUCUR

Introduction

This review is dedicated to our late colleagues É. Fourcade (specialist of large benthic foraminifers) and M. Jaffrezo (expert on dasycladalean algae), who in 1973 (*in* Benest et al. 1973) published a first attempt to make use of these forms for boundary resolution at this level. It deals only with species of which the FAD (First Appearance Datum) or LAD (Last Appearance Datum) are near the Tithonian-Berriasian boundary or has been reported as being so.

Benthic foraminifers

Anchispirocyclina lusitanica (Egger) was formerly considered the best marker of the Tithonian for its range was thought to be restricted to this Jurassic stage. However its find by Galbrun et al. (1990) in the M18 and M18n of the Bias do Norte section (Portugal) documented its occurrence in strata of earliest Berriasian age.

Stratigraphic ranges of the foraminifers cited below either span the boundary {*Mohlerina basiliensis* (Mohler) [formerly *Conicospirillina basiliensis* Mohler], *Pseudocyclammina lituus* (Yokohama), *Feurtillia frequens* Maync} or their LAD is well below the upper limit of the Tithonian {*Kurnubia palastiniensis* Henson, *Everticyclammina virguliana* (Koechlin)}, or their FAD is far above the lower limit of the Berriasian {*Pseudotextulariella courtionensis* Brönnimann, *Pfenderina neocomiensis* (Pfender)}. Although not considered by Fourcade (*in* Benest et al. 1973) *Protepeneroplis striata* Weynschenk is a long-ranging species (it appears in the Aalenian) that in the current state of knowledge terminates in the Late Tithonian and hence should not be overlooked. A second representative of *Protepeneroplis, P. trochangulata* Septfontaine [Remark: according to one of us (I.I.B.), this species is a junior synonym of *Hoeglundina (?) ultragranulata* Gorbatchik] is another long-ranging species (extinct in the Barremian according to Bucur 1993) that should merit our attention. Its first appearance seems to be Early Berriasian although Heinz & Isenschmid (1988) tentatively correlated the strata containing this microfossil with basinal Tithonian strata. On the basis of this indirect dating, some authors presume *P. trochangulata* has appeared in the Late Tithonian. However, we retain the Berriasian FAD as a working hypothesis. If it is correct the find of an assemblage with both *P. trochangulata* and *Anchispirocyclina lusitanica* in Crimea, Ukraine (Granier et al. 2009), would necessitate the assignement of an Early Berriasian age to these strata. The poorly known *Dobrogelina ovidi* Neagu that spans the Berriasian and Valanginian stages (Krajewski & Olszewska, 2007) is another species with some biostratigraphical potential for it too is in the Crimean assemblage. There are some limitations on the use of the benthic foraminifers, among which is endemism (for instance *Pavlovecina* [formely *Keramosphaera*] *allobrogensis* (Steinhauser et al.)) and paleoenvironmental constraints (*Protepeneroplis trochangulata* is found in high-energy, commonly transgressive, environments).

As Benest et al. (1973) did earlier we conclude that: ... “il ne paraît pas possible de fixer la limite entre ces deux étages en utilisant ce groupe d'organismes” [*translation*: it does not appear possible to set the boundary between these two stages using this group of organisms].

Dasycladales

Jaffrezo (*in* Benest et al. 1973) deals only with 6 key species:

(1) *Campbelliella* [formely *Vaginella*] *striata* (Carozzi) spans both the Kimmeridgian and the Tithonian; it becomes extinct before the Tithonian ends.

(2) The well known *Clypeina sulcata* (Alth), formerly called *C. jurassica* Favre (a “misleading” name), appears in the Kimmeridgian and dies out in the Berriasian well before the stage ends.

(3) *Salpingoporella annulata* Carozzi is a long ranging species known from both the Tithonian and below and from the Berriasian and above.

(4) *Selliporella* [formely *Triploporella*?] *neocomiensis* (Radoičić), a rare species, was thought to be restricted to the Berriasian until its find in Tithonian strata in association with *Campbelliella striata*.

(5) Similarly *Zergabriella* [formely *Macroporella*] *embergeri* (Bouroullec & Deloffre), a species characteristic of innermost plaform settings, was thought to be restricted to Berriasian and Lower Valanginian strata until its find in Tithonian strata in association with *Anchispirocyclina lusitanica*.

(6) The Rajkaella group with the species “*Goniolina minima* Jaffrezo” and “*Kopetdagaria iailaensis* Maslov” was considered Middle-Late Berriasian and Early Valanginian in age. The find of *Rajkaella iailaensis* in its type area in association with the foraminifers: *Dobrogelina ovidi, Protopeneroplis trochangulata* and *Anchispirocyclina lusitanica*, documents its occurrence in lowermost Berriasian strata (Granier et al. 2009).

With respect to the three later forms, Benest et al. (1973) conclude that: ... “il semble nécessaire d'indiquer que ces Algues sont pour la plupart de description récente et que leur répartition, tant stratigraphique que géographique, est peut-être encore mal connue” [*translation*: it appears necessary to indicate that most of these Algae were described recently and that both their stratigraphic and geographic distributions are perhaps still poorly known]. If this is so, we can extend this conclusion to species not considered by Jaffrezo (*in* Benest et al. 1973). For instance: *Salpingorella (Hensonella) dinarica* Radoičić was known

only from the Hauterivian-Aptian interval until its find in Lower Berriasian strata (Granier 2002, 2008). *Otternstella* [formely *Heteroporella*] *lemmensis* (Bernier) was first thought to be restricted to Kimmeridgian and Tithonian strata, but there are several records of it in Berriasian strata. In addition, the understanding of the structure of most of them has been significantly revised: the revised genus *Heteroporella* Praturlon -to which *H. lemmensis* Bernier was originally ascribed- now has only one representative, its type-species *H. lepina* (Praturlon).

The list of species erected by Jaffrezo (*in* Benest et al. 1973) should be supplemented. A new list would include *Macroporella ? praturloni* Dragastan, a form characteristic of high energy environments and apparently restricted to Berriasian and Lower Valanginian strata.

Conclusion

The definition of biozones using benthic foraminifers and dasycladales together demands further investigation. There are few paleontological "tools" available to define the Tithonian-Berriasian boundary in carbonate platform/ramp settings. Very few species end at, or appear first near the boundary, and many species span it. This conclusion does not dispute our understanding of this stage boundary but questions the current view ot the criteria used to define the Jurassic-Cretaceous systems boundary in non-basinal settings.

Erratum

Some time after the Thematic Meeting of the GFC took place the first author (B.G.) received a reprint of a newly published paper by Gawlick & Schlagintweit (2009) in which the authors report the co-occurrence of "*Protopeneroplis ultragranulata* (Gorbatchik, 1971)" and a calpionellid assemblage which characterizes zone A: *Calpionella alpina* Lorenz and *Crassicollaria intermedia* (Durand-Delga). Consequently the transition from the ancestral *Protepeneroplis striata* Weynschenk to its descendant *P. trochangulata* Septfontaine [? = *Protopeneroplis ultragranulata* (Gorbatchik)] seems to have occurred in latest Tithonian times, not in the earliest Berriasian as postulated previously.

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New data on the Hawar, Shu'Aiba, Bab, and Sabsab regional stages of the Lower Cretaceous in the United Arab Emirates and in Oman

Bruno GRANIER, Robert BUSNARDO & Bernard PITTET

Introduction

The boundaries of most regional stages of the Kahmah and Wasia regional series have been recently revised (Granier 2000, 2008, Granier et al. 2003). However some authors (most of them employees of the oil industry or service companies) persist in duplicating either wrong or obsolete information and unsupported interpretations derived therefrom.

Hawar*

To comply with nomenclatural rules regarding stages, Hawar should be supplemented by an 'ian' ending, i.e. Hawarian. But since the designation Hawar was agreed on more than two decades ago, this rule has been ignored by the petroleum industry operating in the Middle East. This non-compliance applies to most oil-industry-named stages there. Here an asterisk following the name of each stage indicates the omission of an 'ian' termination.

In the ADMA offshore field 'A', the base of the Hawar, the oldest of the four units discussed here, is a karstified surface: vugs found in the uppermost level of the underlying Kharaib are due to the subaerial dissolution of formerly aragonitic rudist shells and are partially filled with sediment (Granier 2000, 2008, Granier et al. 2003, P. Skelton, pers. comm. 2009). In the ADMA reference well (see Granier 2008: fig. 9), the Hawar sequence is 7.6 m thick: most of it is the TST while the uppermost 0.8 m, a shaly interval, represents the HST. Keystone vugs (see Granier 2008: pl. 3: E) at the base of the TST are indicative of a beach deposit; the remainder of the systems tract consists predominantly of offshore carbonate-sand deposits with abundant *Palorbitolina* (including *P.* cf. *ultima*, see Schroeder et al. 2007). *Choffatella decipiens*, a foraminifer that after Early Barremian times became a marker of deeper-water environments, is found in the upper half of the systems tract. Consequently both facies and fossil assemblages record a deepening of the succession. The maximum flooding surface is thought to be just above a glauconitic packstone bed (see Granier 2008: pl. 3: F). As stated by Granier (2008): "The upper limit of the Hawar Formation is coincident with an abrupt change in sedimentation from the uppermost shale (characteristic of open-marine environments and deposited below storm-wave base) to very shallow-water carbonates (with a rich photophylic algal association characteristic of shallow protected environments). As does the lower boundary, the upper one records a forced regression: the fall in sea level can be estimated to have been 40 meters or more". To date most authors (Azer & Toland 1993, Boichard et al. 1994, Sharland et al. 2001, van Buchem et al. 2002) have not recognized the existence of this major sequence boundary. In Oman, at Wadi Bani Kharus (van Buchem et al. 2002, Pittet et al. 2002), the Hawar interval is 25 m thick (i.e., it is more than triple that of the equivalent section in the ADMA well). With respect to paleogeographical settings this Omani locality was considered be have been sited in a sea shallower than that over the Emirati oil field (which is in the earlier "Kharaib 2" and the later "Bab" basins). While revising a set of thin sections from Wadi Bani Kharus, one of us (B.G.) found *Choffatella decipiens* in the lowermost 5 m of the unit. Consequently this level records the deeper-water facies of an interval spanning not only the Hawar but also the next term in the succession, the Shu'aiba. This find confutes the sequential interpretations of authors who consider the Hawar comprising the entire TST or being the lower part of the TST of a higher scale sequence that extends into the Shu'aiba (Sharland et al. 2001, van Buchem et al. 2002, Strohmenger et al. 2004, 2006; see Granier et al. 2003: fig. 2, Granier 2008: fig. 10). We suggest that in the Omani outcrop the maximum flooding surface of the Hawar sequence is at about the 5 m level in a marly layer with the highest shaliness (Fig. 1).

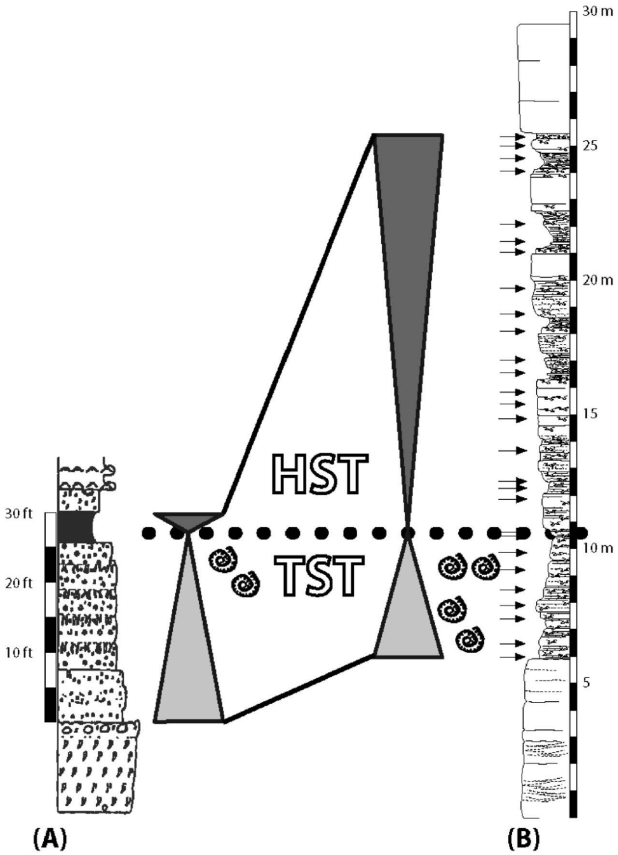

Figure 1: Correlation of the Hawar sequence from the Abu Dhabi offshore (field "A", left column), with that of the Oman Mountains (Wadi Bani Kharus, right column). Paleogeographically, the section of field "A" was sited in an area deeper bathymetrically than that of the Wadi Bani Kharus succession.

Shu'Aiba* (Shuaibaian)

In field 'A', offshore Abu Dhabi, the Shua'iba succession begins with a facies characteristic of protected shallow-water (Granier et al. 2003) with aragonitic 'calcareous algae', such as *Clypeina ummshaifensis* (Granier 2002: pl. I: 2, 2008: pl. 3: B), *Gyroporella lukicae* and *Cylindroporella lyrata* among others and foraminifers, such as *Voloshinoides murgensi*. It is succeeded by a set of facies that contain *Choffatella decipiens, Epistominids* (Granier 2008: pl. 4: B) and planktonic foraminifers, all confirming the overall deepening-upward trend of the remainder of the section, a 18.3 m thick interval representing the TST of the Shu'aiba sequence. Two ammonite-rich subnodular beds that represent the highly condensed HST (less than 0.9 m thick) end the sequence. Ammonites (Busnardo & Granier work in progress) of the genera *Cheloniceras*, *Gargasiceras* and *Pseudohaploceras* indicate a Gargasian (middle Aptian) age for this HST. In Oman, in wells Dhulaima-5 and Yibal-201, the record by Witt & Gökgag (1994: pl. 10.1: 8 and 10) of *Orbitolina (Mesorbitolina) parva* from correlative shallow-water facies provide additional evidence for disregarding the assignment of a Bedoulian (Early Aptian) age to these strata.

Bab* (Babian)

Still in field 'A' the Bab interval begins and ends with dark-colored organic-rich chalks (respectively ~7.6 m and ~6.1 m thick). The lower interval rests on the condensed section of the Shu'aiba, the upper interval predates the transgressive shaly facies of the Sabsab / Nahr Umr. Both episodes of anoxic sedimentation were probably caused by eustatic isolation of the "Bab" intrashelf basin. Depending on their location, surrounding contemporaneous carbonate plaforms record either one or two falls in relative sea-level (Granier 2000: fig. 3, 2008: fig. 18, Granier et al. 2003: fig. 21). Between these LST episodes a rise in sea-level (TST + HST) led to a temporary interruption of anoxia and to the sedimentation of beige chalk facies (the main constituent of theses chalks is nannoconids). The lower LST facies yields *Colombiceras* although the remainder of the Bab includes representatives of the genera *Cheloniceras*, *Epicheloniceras* and *Pseudohaploceras* (Busnardo & Granier, work in progress).

Sabsab* (Sabsabian)

The Sabsab records a main transgressive event at the base of the Nahr Umr shales. This unit caps both the Shu'aiba and the Bab carbonate platforms and is a major seal for lower "mid-Cretaceous" oil reservoirs in the area. The record of *Orbitolina (Mesorbitolina) texana* (Roemer) by Witt & Gökgag (1994: pl. 10.1: 7, 9) from shallow-water facies in wells Lekhwair-87 and 69, should be taken cum grano salis for they were found not more than 2 m below the top of their so-called Shu'aiba. This interval could have been deposited above the subaerial surface of the exposed Shu'aiba and represent sedimentation that took place after a significant hiatus and including a period of time equivalent to the Sabsab.

Conclusions

With respect to stratonomy, both the Hawar and the Shu'aiba sequences in field 'A' are highly asymetrical: thick TST and thin HST; at Wadi Bani Kharus, the Hawar is asymetrical but the pattern is the reverse: a thin TST and a thick HST.

With respect to the calibration of these regional stages in the international stratigraphic chart, the model of correlation presented here provides the best available to date: the Hawar is Bedoulian in age, the Bab is Gargasian in age. The transition from Bedoulian to Gargasian probably takes place during the TST of the Shu'aiba sequence. The beginning of the Nahr Umr transgression (its first TST corresponding to the Sabsab) is Gargasian (middle Aptian sensu gallico = early Late Aptian sensu anglico) in age, not Clansayesian (late Aptian sensu gallico = late Late Aptian sensu anglico), nor is it Albian.

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Key words: Bab, Hawar, Shu'aiba, Sabsab, Nahr Umr, Gargasian, Bedoulian, ammonites.

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The Cenomanian-Turonian transition on a W-E transect of the Moroccan Atlantic margin (Agadir). Isotope geochemistry and sequence stratigraphy

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The Cenomanian-Turonian transition associated with the glocal oceanic anoxic event OAE2 is coincident with a triple anomaly: (1) a lithologic anomaly consisting of organic-rich deposits (black shales) wherever conditions favored the preservation of such deposits, (2) a geochemical anomaly (a positive $\delta^{13}C$ found in both carbonates and in oganic material), and (3) a biological crisis, particularly among planktonic foraminifers.

For explaining the causes of the anoxic event, most authors propose the major transgression associated with the passage from Cenomanian to Turonian. This explanation is often based on interpretations of the sedimentary successions in deep basins where changes in water depth are difficult to demonstrate. The only valid approach to the elucidation of changes in sea level is through the study of platform-basin transitions. In the Agadir basin deposits of Cenomanian age are generally very thick (500 to 800 m) made up of a large number of repeated small sequences. The series exposed on the western and eastern flanks of the Haut Atlas too are repetitive, made up mainly of lagoonal successions deposited by a transgressive phase following an emergence. In the intervening area between the Atlas and the existing Atlanic coast the sections are coastal progradations in which the deepest facies are marls and nodular, bioturbated limestones that are more or less bioclastic and with a variable content of oysters. The shallowest facies are calcarenitic and/or fine grained sandstones beach deposits that represent a low sea level coincident with emergence in the Atlas sequences.

As regards the interval in which to place the Cenomanian-Turonian boundary, several sections have been measured ranging from the current shore (the most distal portion of the Taghazoute-Plage section) to the foothills of the Atlas (the most proximal portions of the Tamaloukt and Afansou sections) with the Askoutti section between them. The lithology, paleontology and geochemistry of these sections have been studied in detail. Proximal-distal correlations have been proposed and validated by data from stable isotopes and foraminifers.

The results obtained show that the Cenomanian-Turonian transition occurred in a shallow sedimentary succession, characterized by oyster shell mounds and interbeded marl and limestone, not in the black shale facies where it has been sited classically in the literature. The base of the deposits of black shale is coincident with that of the total range of *Helvetoglobotruncan helvetica*. So these beds are of Turonian age, both later in time and in a transgressive facies. In addition the $\delta^{13}C$ anomaly which develops in the partial range of *Whiteinella archaeocretacea* occurs before black shale deposition begins. It is marked by the three peaks as commonly seen in other basins. On either side of the anomaly are two remarkable surfaces. The first is a karstified surface, the second is a conglomerate. If the first is interpreted as an indication of emergence (karst of which the cavities are filled by debris from the transgressive oyster shell beds); the second would then represent a transgression after emergence (wave erosion). The East-West correlations of the Agadir transect, validated by isotopic and micropaleontologic data, integrate the two surfaces that indicate emergence. The results show that the Cenomanian-Turonian transition occurred during a sucession of forced regressions. The transgression proposed as the only explanation of the anoxic event should be put in question. The regressive nature of the Cenomanian-Turonian transition on the Atlantic coast of Morocco demonstrates that the establishment of an anoxic regime cannot be explained as being caused by a single event (a transgression). Local events influence strongly the development of anoxic conditions (local tectonics, subsidence). Considering the displacement between the sites of occurrence of black shales and those of the geochemical anomaly and the biologic crisis, it is possible to ask which of the three is truly related to the global anoxic event. The geochemical anomaly (disturbance of the Carbon cycle) in the deep basins indicates precisely the beginning and end of anoxic conditions. Therefore the global synchronous existence of the $\delta^{13}C$ anomaly may be a criterion better than the black shales. Their deposition is dependent on local and biologic conditions, extinctions being caused by the anoxic environment.

Key words: Morocco, Upper Cretaceous, Cenomanian-Turonian boundary, isotope geochemistry, sequence stratigraphy.

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The RGF Program (Geologic reference map of France): a geodynamic geologic map

Eric LASSEUR, Laurent BECCALETTO, Yannick CALLEC, Renaud COUËFFÉ, Fabien PAQUET, Jean-Pierre PLATEL, Olivier SERRANO & Isabelle THINON.

The BRGM (Bureau des Recherches Géologiques et Minières = French Geological Survey) is now undertaking scientific programs which in the near future will replace the Geologic Map program. As a continuation of previous work, the main purpose of these programs is to improve understanding of the subsurface and to gain an increasingly precise representation of it that in the end will provide a three-dimensional homogeneous and continuous coverage of the geology of the whole of metropolitan territory. This will permit the completion of diverse academic and industrial projects (specialized geologic maps, three-dimensional models, 4D representations of the evolution of the French substratum).

The construction of these maps on a nationwide scale requires that the evolution over time of geologic entities of the metropolitan territory (sedimentary basins and orogenic areas s.l.) be adjusted to a common scale. This adjustment can be accomplished only by a thorough comprehension of the dynamic and sequential aspects of the geologic phenomena that formed the substratum of France, and so requires a deep comprehension of its geodynamic evolution. This can be gained by understanding the influence of events taking place at plate boundaries (rifting, orogenesis, subduction) as they affect sedimentary sequences in several basins, and the precise determination of the phases of basinal evolution that have molded the geology of France.

Based on the available bibliography, the method used consists of the construction of a chart that plots the Mesozoic-Cenozoic evolution of each of the sedimentary basins (Paris Basin, Aquitaine Basin, Southeastern Basin, Eocene-Oligocene sunken troughs, continental plateau). These charts include a second order sequential breakdown of the basins development along with any potential indicators of deformation (discordances, changes in the paleogeography, changes in the distribution of thickness, major influxes of terrigenous detritus, tectonic deformations). In the case that during a given period, areas in any one basin are found to be in discrete geodynamic provinces (for example the Aquitaine and Southeastern basins) a chart is constructed for each of these discrete subdomains.

Comparison of these charts will permit categorization of the deformations recorded according to their geographic extent (from local deformations up to deformations that included all the basins of France) and according to their duration in time. In addition, they will allow the evaluation of their synchronicity (or diachronicity) and the ways in which the sediments respond to the major phases of deformation of the substratum. The several events so recorded are then correlated with the the known developments at the edge of the plate.

Here we present the results of the first work carried out on the Mesozoic, comparing the effects on sedimentation in the several basins of the major phases of deformation identified over large areas ranging in age from the Triassic to the end of the Cretaceous (Cimmerian, Austrian, Subhercynian, Laramide).

One of the main aims of this project is to bring to light elements for understanding the response of the European plate to the different constraints affecting its boundaries. The Cretaceous Period is of particular interest because the transition between the end of the opening of the great oceanic domains and the beginning of the compression caused by the convergence of Europe and Africa.

To constrain more precisely the timing of the beginning of that compression and its effects on the deformation of the European plate we must consider a synthesis of Upper Cretaceous geometry and paleogeography, as well as data provided by metamorphism in the mountain chains and information concerning alteration and thermochronology from areas now without sediments. This is the kind of work under way, and we hope to invite the participation of all of the community working on the Cretaceous.

Key words: Basin analysis, deformations, geodynamic, French sedimentary basins.

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OAE1a: late Early or early Late Bedoulian event?

Michel MOULLADE, Wolfgang KUHNT, Guy TRONCHETTI, Pierre ROPOLO & Bruno GRANIER

Oceanic anoxic events are usually thought to be global and thus isochronous. Through several examples (see Fig. 1) selected in both basin and platform or transitional facies, an attempt is made to clarify the temporal correlation of the "Selli" - "Goguel" (i.e. OAE1a) Early Aptian event.

These examples show that either Lower Aptian micropaleontological and ammonite datums are insufficiently calibrated, or the isotopic signatures are not always properly elucidated. By using orbitochronologic methods it is now possible to obtain relatively accurate estimations of the duration of the various steps of OAE1a, but the position of this worldwide event in the Early Aptian (Bedoulian) substage is still uncertain.

The Lower Aptian series in the Cassis-La Bédoule historical stratotype is expanded and rich in ammonites, benthic and planktonic foraminifers and calcareous nannofossils, which allow good biostratigraphic control. Preliminary investigations based on a too loosely spaced sampling in the now poorly cropping out upper Bedoulian provided a somewhat atypical $\delta^{13}C$ record. Thus the lower Gargasian to lower Bedoulian interval has recently been drilled and cored in La Bédoule, with a complete recovery. Detailed investigations based on various methods of the integrated stratigraphy, which will lead to a more precise calibration and better positioning of the OAE1a, are being currently processed in the framework of the Aptian

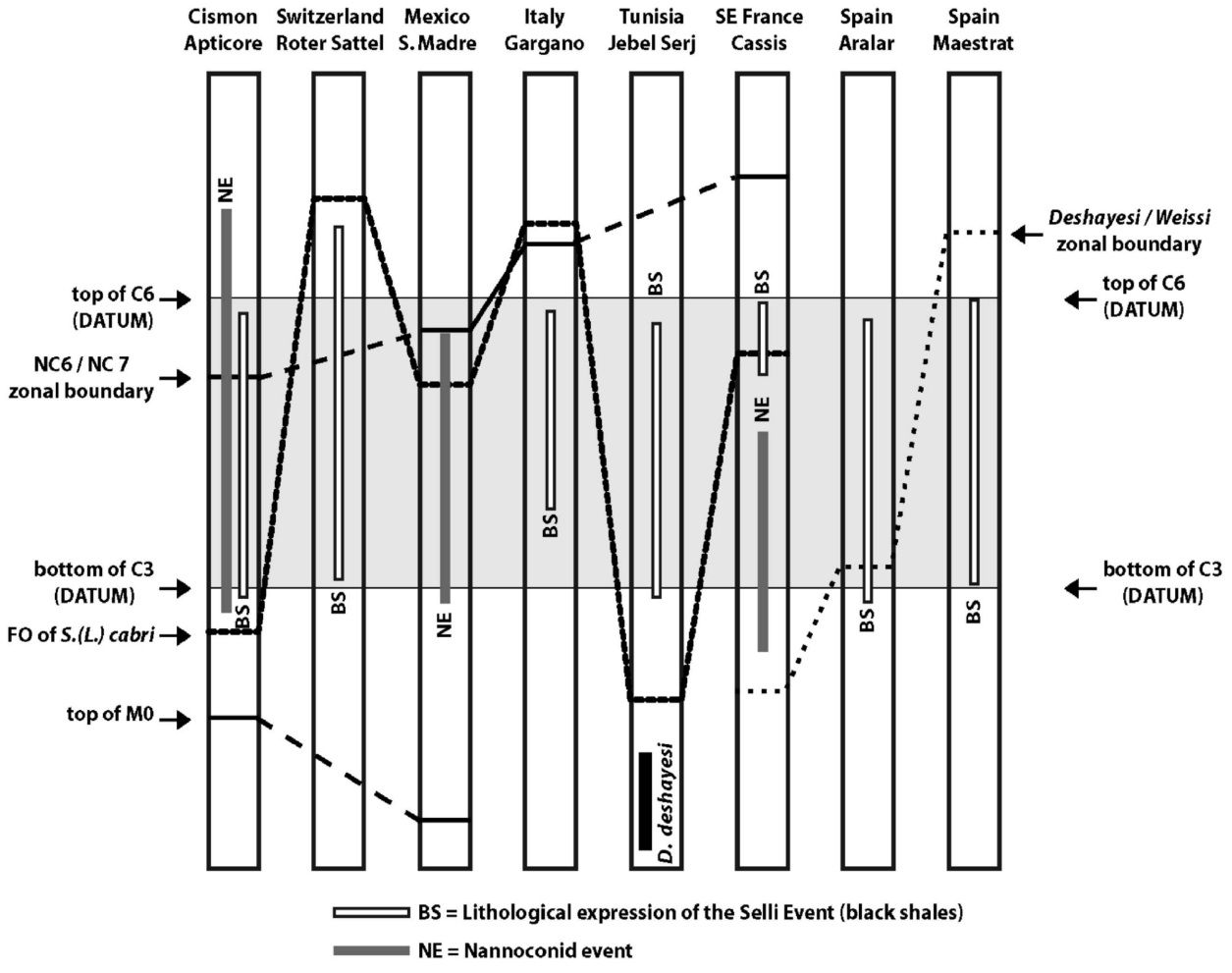

Figure 1: Correlation of sections from Italy (Cismon Apticore, Gargano Promontory), Switzerland (Roter Sattel), SE France (Cassis-La Bédoule), Spain (Maestrat, Aralar Mts.), Tunisia (Jebel Serj) and Mexico (Sierra Madre). C3 at the bottom and C6 at the top are datums assumed to be isochronous and used here for flattening.

Working Group.

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Key words: OAE1a, Bedoulian, Aptian, Early Cretaceous.

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The Cretaceous carbonate series of the Oman Mountains

Philippe RAZIN & Carine GRÉLAUD

A succession of carbonates of Cretaceous age more than 1300 m thick crops out in the autochthonous units of the Oman Mountains and extends southward in the subsurface where it includes several petroliferous sequences that are being produced (Fig. 1). This series accumulated on the Arabian platform under passive margin conditions. The base of this succession is a local discordant relationship between Tithonian-Berriasian strata on an eroded Jurassic, but is made more apparent because of the subsidence and an important drowning of this edge of the Arabian platform shown by hemipelagic deposits of the basal Cretaceous. The uppermost unit of the succession is dated lower Turonian. It was subjected to synsedimentary deformation and the development of the flexured Muti basin because of the initiation of the processes of obduction.

The Tithonian-Turonian stratigraphic succession is divided into two groups: the Khama Group and the Wasia Group. They are separated by a major unconformity that includes the absence almost everywhere of upper Aptian and lower Albian strata linked to an uplift and emergence of the platform. Both groups include some ten formations of which the limits are either time-planes (sequence limits, maximum flooding surfaces) or facies limits, or both. The formations are conformed of facies associations including the several domains of the carbonate systems: open pelagic basins (Raydah Fm.), the foot of clinoforms with gravitational and hemipelagic sedimentation (Salih Fm.), intra-shelf basins (Bab Fm., Natih Fm. p.p.), oolitic or bioclastic platform edge ("Habshan" Fm., Al Hassanat Fm., Shu'aiba Fm. p.p., Natih Fm. p.p.), inner platform carbonates (Lekhwair Fm., Kharaib Fm., Shu'aiba Fm. p.p., Natih Fm. p.p.), mixed inner domain (Nahr Umr Fm.).

This series is made up of a succession of third order sequences, their length ranging between 2 and 5 Ma. These sequences record aperiodic cycles resulting from changing relationships between accommodation and production of carbonates, and are bounded by more or less pronounced emergent surfaces. These carbonate systems formed as a succession of prisms of prograding and/or aggrading deposits which fill more than 300 km^2 of the Rayda basin caused by a marked subsidence of the eastern edge of the platform during the Jurassic-Cretaceous transition. At the outer edge of the platform progradational clinoforms are 200 to 300 m thick. In the platform interior, intra-shelf basins 50 to 80 m deep developed through differential aggradation that also caused the formation of clinoforms.

Generally speaking, the type and geometry of the deposits expresses the way the different kinds of sedimentaray systems behave under relatively stable tectonic conditions. Thus, this series offers the opportunity of analysing in detail the architecture and dynamics of carbonate systems on the margin of a platform (Berriasian-Albian) and in the interior (Hauterivian-Turonian) and to attempt to understand the respective roles of the factors that control them. An integrated approach is under way for this study, based on the analysis of studies on the field over a large area (Mountains of Oman and Iran) and subsurface information (Interior of Oman). This approach will lead to the quantification of certain parameters such as the angle and geometry of clinoforms, the rapidity of progradation, the orientation and geometry of the platform incisions, and the changes in rates of sedimentation among others. It will also allow the characterization of platform-basin relationships whether on the outer border of the system on the oceanic side, or in the intra-shelf basins.

Key words: Arabian platform, carbonate depositional sequences, prograding systems, platform to basin correlations.

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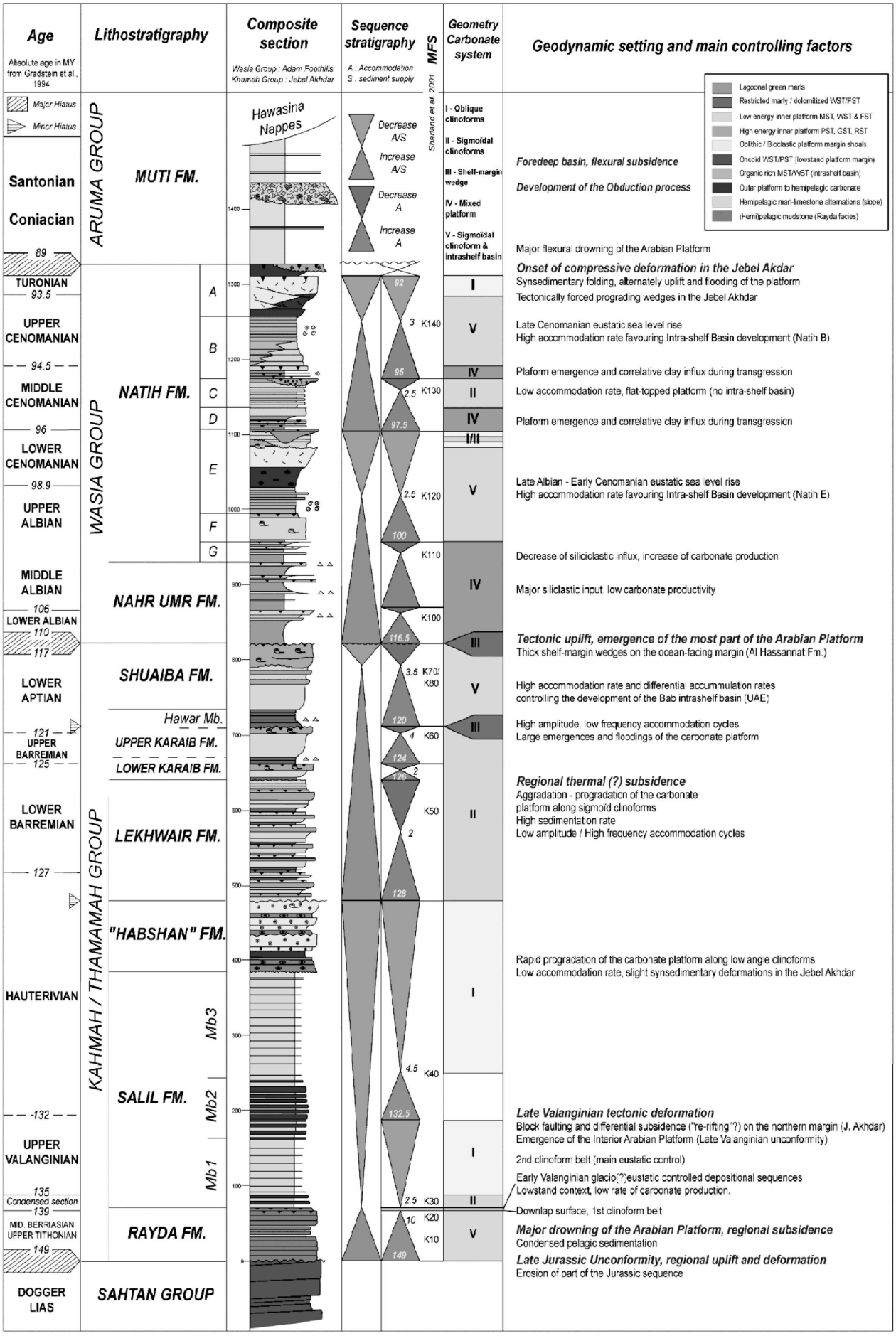
Figure 1. Stratigraphy, sedimentary systems and geodynamic context of the Cretaceous series of the Oman mountains.


Age
Absolute age in MY from Gradstein et al., 1994
Lithostratigraphy
Composite section
Wasia Group : Adam Foothills
Khamah Group : Jebel Akhdar
Sequence stratigraphy
A : Accommodation
S : sediment supply
MFS
Sharland et al. 2001
Geometry Carbonate system
Geodynamic setting and main controlling factors
Major Hiatus
Minor Hiatus
Santonian
Coniacian
89
TURONIAN
93.5
UPPER CENOMANIAN
94.5
MIDDLE CENOMANIAN
96
LOWER CENOMANIAN
98.9
UPPER ALBIAN
MIDDLE ALBIAN
106
LOWER ALBIAN
110
117
LOWER APTIAN
121
UPPER BARREMIAN
125
LOWER BARREMIAN
127
HAUTERIVIAN
132
UPPER VALANGINIAN
135
Condensed section
139
MID. BERRIASIAN UPPER TITHONIAN
149
DOGGER
LIAS
ARUMA GROUP
MUTI FM.
WASIA GROUP
NATIH FM.
A
B
C
D
E
F
G
NAHR UMR FM.
SHUAIBA FM.
Hawar Mb.
UPPER KARAIB FM.
LOWER KARAIB FM.
KAHMAH / THAMAMAH GROUP
LEKHWAIR FM.
"HABSHAN" FM.
Mb3
SALIL FM.
Mb2
Mb1
RAYDA FM.
SAHTAN GROUP
Hawasina Nappes
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
Decrease A/S
Increase A/S
Decrease A
Increase A
92
3
K140
95
2.5
K130
97.5
2.5
K120
100
K110
K100
116.5
3.5
K70
K80
120
4
K60
124
2
120
2
K50
2
128
4.5
K40
132.5
2.5
K30
10
K20
K10
149
I - Oblique clinoforms
II - Sigmoidal clinoforms
III - Shelf-margin wedge
IV - Mixed platform
V - Sigmoidal clinoform & intrashelf basin
I
V
IV
II
IV
I/II
V
IV
III
V
III
II
I
I
II
V
Lagoonal green marls
Restricted marly / dolomitized WST/FST
Low energy inner platform MST, WST & FST
High energy inner platform PST, CST, RST
Oolithic / Bioclastic platform margin shoals
Oncoid WST/PST (lowstand platform margin)
Organic rich MST/WST (intrashelf basin)
Outer platform to hemipelagic carbonate
Hemipelagic marl-limestone alternations (slope)
(Hemi)pelagic mudstone (Rayda facies)
Foredeep basin, flexural subsidence
Development of the Obduction process
Major flexural drowning of the Arabian Platform
Onset of compressive deformation in the Jebel Akdar
Synsedimentary folding, alternately uplift and flooding of the platform
Tectonically forced prograding wedges in the Jebel Akhdar
Late Cenomanian eustatic sea level rise
High accommodation rate favouring Intra-shelf Basin development (Natih B)
Plaform emergence and correlative clay influx during transgression
Low accommodation rate, flat-topped platform (no intra-shelf basin)
Plaform emergence and correlative clay influx during transgression
Late Albian - Early Cenomanian eustatic sea level rise
High accommodation rate favouring Intra-shelf Basin development (Natih E)
Decrease of siliciclastic influx, increase of carbonate production
Major siliclastic input, low carbonate productivity
Tectonic uplift, emergence of the most part of the Arabian Platform
Thick shelf-margin wedges on the ocean-facing margin (Al Hassannat Fm.)
High accommodation rate and differential accumulation rates
controlling the development of the Bab intrashelf basin (UAE)
High amplitude, low frequency accommodation cycles
Large emergences and floodings of the carbonate platform
Regional thermal (?) subsidence
Aggradation - progradation of the carbonate
platform along sigmoid clinoforms
High sedimentation rate
Low amplitude / High frequency accommodation cycles
Rapid progradation of the carbonate platform along low angle clinoforms
Low accommodation rate, slight synsedimentary deformations in the Jebel Akhdar
Late Valanginian tectonic deformation
Block faulting and differential subsidence ("re-rifting"?) on the northern margin (J. Akhdar)
Emergence of the interior Arabian Platform (Late Valanginian unconformity)
2nd clinoform belt (main eustatic control)
Early Valanginian glacio(?)eustatic controlled depositional sequences
Lowstand context, low rate of carbonate production.
Downlap surface, 1st clinoform belt
Major drowning of the Arabian Platform, regional subsidence
Condensed pelagic sedimentation
Late Jurassic Unconformity, regional uplift and deformation
Erosion of part of the Jurassic sequence