On the track of a major trans-Tethyan discontinuity

Bruno Granier

On the trail of a major trans-Tethyan discontinuity

[Sur la piste d'une discontinuité majeure trans-Téthys]

Bruno Granier[1]

Citation: Granier B. (2007).- On the trail of a major trans-Tethyan discontinuity. *In*: Bulot L.G., Ferry S. & Grosheny D. (eds.), Relations entre les marges septentrionale et méridionale de la Téthys au Crétacé [*Relations between the northern and southern margins of the Tethys ocean during the Cretaceous period*].- Carnets de Géologie / Notebooks on Geology, Brest, Memoir 2007/02, Abstract 07 (**CG2007_M02/07**)

Abstract: At the base of the Valanginian a major discontinuity associated with one of the major transgressions of the Cretaceous is nominated as a candidate for the boundary between the Cretaceous and Jurassic systems. This surface has been identified in both platform and basinal domains, at the eastern edge of the North American continent and in the Middle East, as well as through the western edge of Africa and Europe.

Key Words: Jurassic; Cretaceous; Tithonian; Berriasian; Valanginian; boundary; stages; systems; periods

Résumé : À la base du Valanginien, une discontinuité majeure associée à une des plus grandes transgressions du Crétacé est désignée comme candidate pour le titre de limite des systèmes Jurassique et Crétacé. Cette surface a été identifiée aussi bien en domaine de plate-forme qu'en domaine de bassin, de la bordure orientale du continent nord-américain au Moyen-Orient, en passant par la bordure occidentale du continent africain et l'Europe.

Mots-Clefs : Jurassique ; Crétacé ; Tithonien ; Berriasien ; Valanginien ; limite ; étages ; systèmes ; périodes

I - Introduction

While working in the field in southeastern Spain in connection with the preparation of my PhD thesis (Granier, 1987) I made my first contact with a particular surface that for years I was to continue to track in the literature, or encounter by chance during exploratory trips (Iraq, Oman, Ukraine) and while living abroad (United Arab Emirates). The surface involves a major discontinuity that in a chronostratigraphic sense is situated at the transition from the Berriasian to the Valanginian stages (more precisely in the basal levels of the Valanginian).

II - A trans-Tethyan Tour

II.1 - Spain (Fig. 1)

I first recognized this discontinuity in southeastern Spain within the platform series of the Prebetic of Alicante, at Puig Campana (Granier, 1987). One of the first problems was its stratigraphic position. In facies of this type the absence of the ammonites and calpionellids that are the classic markers of the Early Cretaceous led me to make use of larger foraminifera and calcareous algae that allowed me to attribute a Late Berriasian to Early Valanginian age to the beds that bound it.

Using lithostratigraphic correlation it was then possible to establish a correlation between the beds laid down immediately above this stratigraphic unconformity at Puig Campana, the "Calcarenites with *Pseudocyclammina*", and a sequence of strata rich in fine-grained siliciclastics accumulated in the Sierra de Fontcalent at the edge of the citrabetic basin, dated by ammonites as Early Valanginian (Rasplus & Fourcade (eds.) *et alii*, 1987). The stratigraphic position of the event that created this sedimentary discontinuity could then be refined from an initially relatively broad interval involving the Upper Berriasian-Lower Valanginian to the extreme base of the Lower Valanginian (in the *Thurmanniceras pertransiens* Zone). A return to the sites between the two localities, Cabezon de Oro (a platform margin domain) and the village of Busot (a talus/slope area), resulted in new collections of ammonites and calpionellids that complete and make more precise the age assignments of Azéma (1977) and of Estevez *et alii* (1984), and validated my earlier correlation.

In the platform domain (at Puig Campana) we saw no indication of emergence at the top of the underlying unit, the "Limestones with *Trocholina*" and at the edge of this platform (at Cabezon de Oro) the same stratigraphic unit contains indications (presence of calpionellids and of the foraminifer *Protopeneropolis ultragranulata*) of a slightly more open-marine environment.

In both areas the transition to the overlying beds, the "Calcarenites with *Pseudocyclammina*" is not the mark of an abrupt downward shift of facies that is there is no indication of a forced regression, but rather the reverse, the installation of a more open-marine environment (as documented by the presence of ammonites, calpionellids and characteristic foraminifera such as *Protopeneropolis ultra-*

[1] *Département des Sciences de la Terre, UFR Sciences et Techniques, Université de Bretagne Occidentale, 6 avenue Le Gorgeu - CS 93837, F-29238 Brest Cedex 3 (France)*
bruno.granier@univ-brest.fr
Manuscript online since May 15, 2007

granulata and *Montsalevia salevensis*) with an associated change in the hydrodynamics to a wave-dominated regime (as indicated by hummocky and swaley cross-bedding).

The "Calcarenites with *Pseudocyclammina*" (also known as the "upper member of the Sierra del Pozo Formation" in regional literature) have been identified over most of the Prebetic platform domain: for instance, this unit crops out in the Sierra Mariola, an historical locality (BUSNARDO & DURAND-DELGA, 1960: "13. grès calcareux" in text-fig. 2) some 40 km north of the localities studied; and farther northward it almost reaches the southern borders of both the Meseta (to the NW) and the Iberian domain (to the NE).

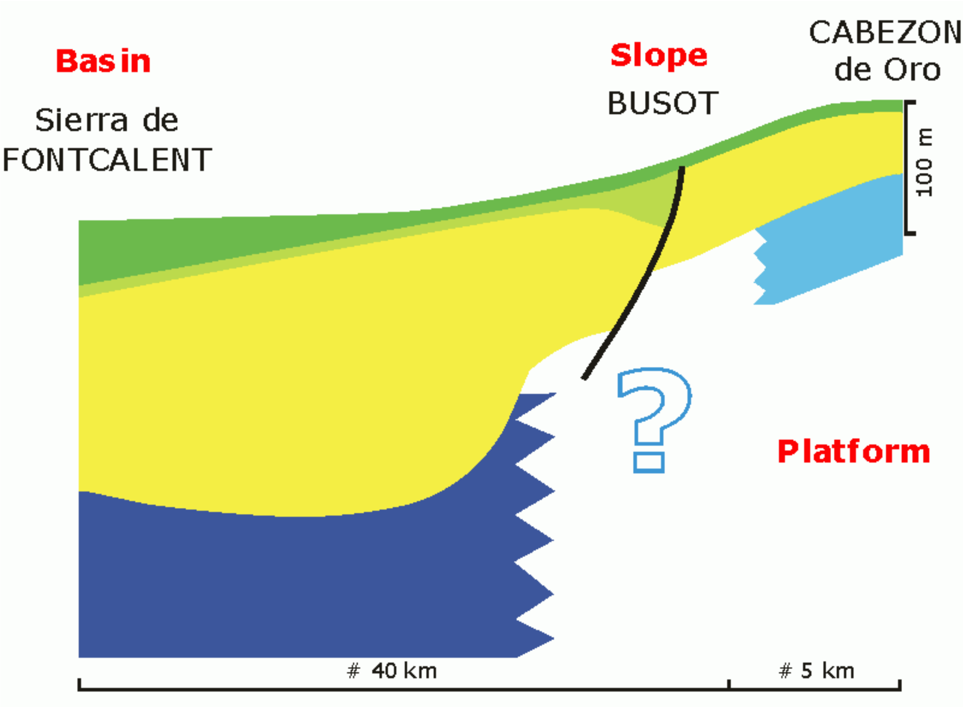

Figure 1: Correlations of lithostratigraphic successions on a platform (Cabezon de Oro) to basin (Sierra de Fontcalent) profile in SE Spain (modified from GRANIER *et alii*, 1995). Dark blue: Berriasian marls and calcareous limestones; light blue: Berriasian limestones; yellow: Valanginian silty limestones and calcarenites; light green: Valanginian-Hauterivian strata; dark green: Hauterivian-Barremian strata (including a ferruginous oolite).

This major discontinuity at the base of the Valanginian is marked above by the abrupt appearance of siliciclastics of which the clay fraction is either lacking or present in negligible quantities. What was the source of this well-sorted and abundant material (silts at Sierra de Fontcalent, sands and gravels at Cabezon de Oro and Puig Campana)? Among the gravels extraclasts (not endoclasts) predominate, *i.e.* lithoclasts derived from older calcarenites that consist of allochems and quartz or feldspar grains with a mosaic-calcite cement (Fig. 2); the larger lithoclasts reach the size of cobbles (up to 10 cm in their larger dimension). These older calcarenites were formed by an episode of cementation affecting mixed, calcareous and siliciclastic, sand layers in a meteoric-phreatic zone. Examination of the derived lithoclasts by cathodoluminescence (Fig. 2) indicates a strong resemblance to calcarenites at the base of the Berriasian that are known to me only from outcrops in the Sierra Mariola (see BUSNARDO & DURAND-DELGA, 1960: "5. grès calcareux" in text-fig. 2).

As a whole, the source of the siliciclastics appears to have been an important stock of detritus that accumulated over time in the innermost part of the platform or on the emergent Meseta at the edge of the Iberian microcontinent. Presumably it was a general transgression onto this carbonate platform inherited from Jurassic times that caused remobilization of this material. Surprisingly, deposition of carbonates did not cease, for small bulbous coral colonies occur and carbonate grains (ooids, aggregates, bioclasts) exist in association with the siliciclastic material; it suggests that the turbidity was low, an interpretation supported by the scarcity of very fine-grained siliciclastic particles (clay-size). One cannot call this type of transgression a drowning, although it involved a major change in hydrodynamics with the change to a wave- and storm- dominated regime as documented by hummocky and swaley cross-bedding. A large part of the detritus was carried over the edge of the platform to accumulate beyond it, both on the slope and below it in the basin, thus constituting an enormous transgressive, prograding prism (a special case in which the rate of sedimentation, a variable supposedly insignificant and treated as a constant in classic models of sequence stratigraphy, is by far more important than accomodation).

II.2 - Westward, oceanic sites DSDP 392A and 416A

Site DSDP 416A is in the open sea off the Atlantic coast of Morocco at the foot of the continental plateau. Its situation is analogous to that of Sierra of Foncalent with a thick accumulation of Lower Valanginian beds consisting mainly of deepwater turbite deposits. Farther West on the other side of the North Atlantic, site DSDP 392A is located well off the Florida coast at the edge of the continental plateau which is bounded by the Blake Nose submarine escarpment. The limestone series of the platform of which the uppermost layers are attributed to the Berriasian (FOURCADE & GRANIER, 1989) is capped by a pelagic series, Barremian or younger; strata representing the Valanginian and Hauterivian, as well as a part of the Barremian, are either condensed or absent. In this distal portion of the platform, one can truly speak of drowning; however carbonate sedimentation was not interrupted in its proximal portion.

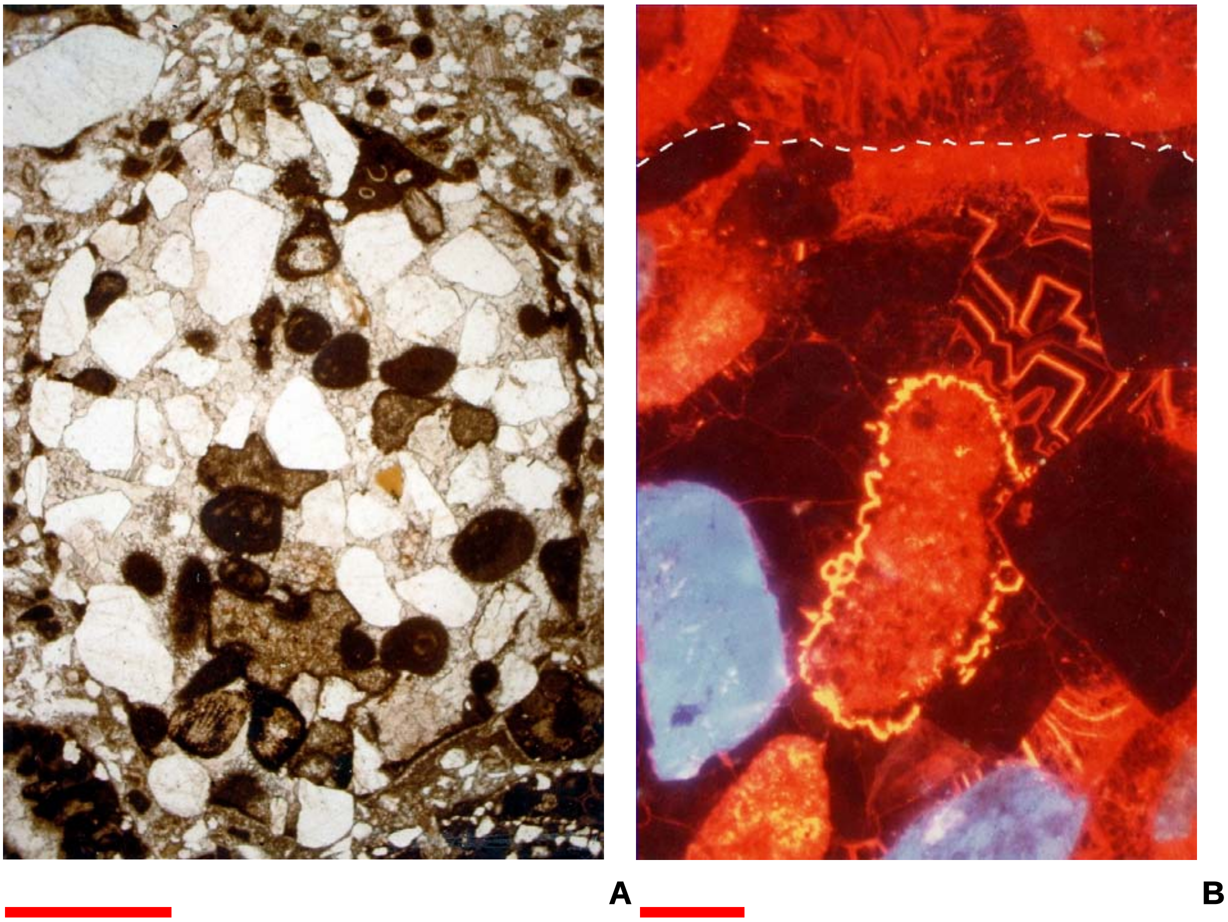

Figure 2: A.- Lithoclastic floatstone with a grainstone matrix, a mixture of carbonate allochems and terrigenous sand or silt. The large lithoclast has the same composition and the same texture as the matrix. Sample CLUSE 5, "Calcarenites with *Pseudocyclammina*", Lower Valanginian, Puig Campana. Scale bar = 1 mm; **B.-** Cathodoluminescence analyses indicate that these lithoclasts are not intraclasts, but genuine extraclasts reworked from older rocks and then transported to the edge of the platform. The colors of the calcite cements and their zonations differ in the lithoclast (bottom) and matrix (top). Sample CAM 8, "Calcarenites with *Pseudocyclammina*", Lower Valanginian, Puig Campana. Scale bar = 100 µm.

II.3 - Eastward, the United Arab Emirates and Oman

The author (GRANIER, 2000) recently presented a revision of the stratigraphy of the Kahmah Group (better known regionally as the Thamama Group, although the two entities are not strictly synonymous). Here, relationships between platform and basin domains are discussed in print for the first time.

In the platform domain a succession of distinctive lithostratigraphic units is encountered; as they are bounded by regional or supra-regional discontinuities they were treated as alloformations. From bottom to top (see a part of the sequence in Figure 3, Zakum 1) they are named: Habshan Fm (Tithonian), Bu Haseer Fm (Tithonian and Berriasian), Belbazem Fm (Berriasian), and Zakum Fm (Lower Valanginian).

In the basinal domain, above a tectonic discontinuity that includes a more or less important stratigraphic hiatus, the series begins with "porcellanites", sometimes preceded by a polygenic conglomerate; together they make up the Rayda Fm; from it Late Tithonian ammonites and Berriasian calpionellids have been collected. These dense white limestones are replaced abruptly by the marls and argillaceous limestones of the Salil Fm. The upper portion of this unit has a few more calcareous strata that contain *Pseudo-cyclammina lituus*; this more limy subunit has been called erroneously "Habshan" (see Fig. 3, Dhulaima 4).

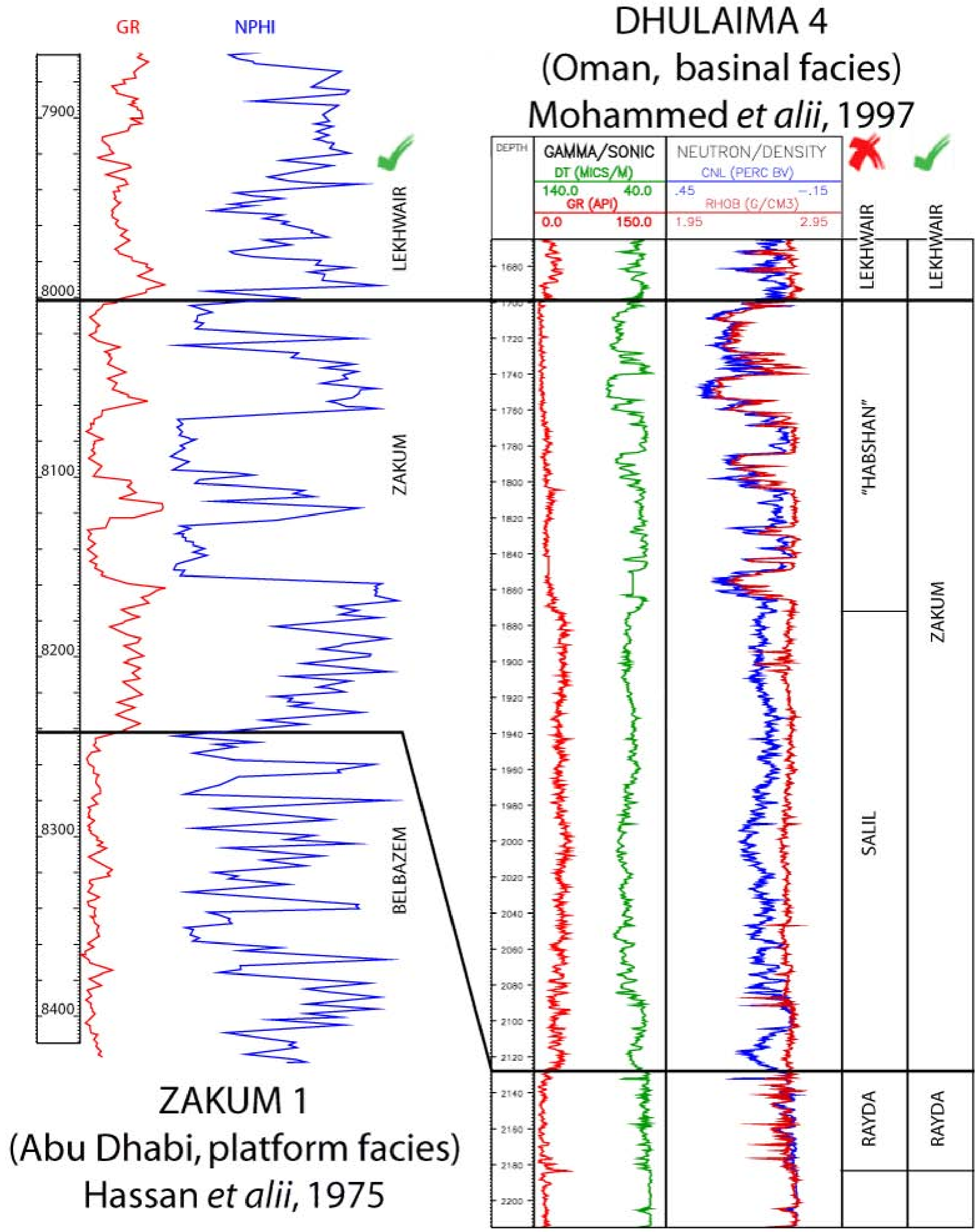

Figure 3: Correlation of platform sequence: a Zakum well in the Abu Dhabi offshore (modified after HASSAN *et alii*, 1975) and basinal facies: Dhulaima No. 4 in the Oman onshore (modified after MOHAMMED *et alii*, 1997).

Biostratigraphic arguments can be evinced to establish:

- the contemporaneity of the Bu Haseer (lower unit) and Belbazem (upper unit) formations of the platform domain with the Rayda Fm of the basin domain, and
- the equivalence in time of the Zakum Fm on the platform with the Salil Fm and the so-called "Habshan Fm" in the basin.

A major discontinuity separates the Belbazem and Zakum formations on the platform and the Rayda and Salil facies in the pelagic sequence. In these lithologic successions the distinction is reinforced by the abrupt appearance of an important argillaceous fraction in the upper unit.

As is the case in southern Spain lithostratigraphic arguments (here the argillaceous content) may be used to supplement biostratigraphic information.

II.4 - In France (Provence and the Jura)

In Provence a discontinuity spanning the same interval of time separates the "Marnes vertes" Formation from the "Calcaires blancs supérieurs" (VIRGONE, 1997). Here, there was no emergent land-mass to provide detrital siliciclastics. They are replaced by granular limestones called "high energy" that mark the locations occupied by the sandstones and calcarenites in Spain.

Work in progress concerns the Jura and will be the subject of new publications.

III - Discussion

The limits of the stages of the Jurassic and Cretaceous are defined by "good stratigraphic fossils" that classically are ammonites, but the fact that ammonites are "facies fossils" is all too often not considered. Consequently, in platform domains the rarity of these biostratigraphic markers often makes it impossible to identify the limits of stages as they were defined (and amended) in basinal domains.

The problem is even more grave when in addition the stratigrapher is not able to define/map the limit of systems. Consider the very special case of the boundary between the Jurassic and Cretaceous systems; this surface as currently defined must be found "somewhere":

- within the mass of the "Calcaires Blancs Inférieurs" in Provence (VIRGONE, 1997),
- in the body of Purbeckian limestones in the French-Swiss Jura,
- within the "barre tithonique" of southeastern France (JAN DU CHÊNE *et alii*, 1993),
- in the Bu Haseer Fm of the United Arab Emirates, *etc.*

Note that if the Boreal domain too is taken into consideration, confusion increases because the boundary between the Jurassic and Cretaceous in the Tethyan province is founded on the same criteria as those used to separate the Tithonian from the Berriasian (for a long time this boundary was located in the middle of an ammonite zone called the *Jacobi-Grandis* Zone), but according to the several authors, in the Boreal domain it is either intra-Volgian or at the limit between the Volgian and Ryazanian (intra-Berriasian).

In the platform domain, the transition from the Tithonian to the Berriasian is gradual, unmarked by lithologic or faunal distinctions. A break does occur higher in the succession in the vicinity of the limit between the Berriasian and the Valanginian. As we have seen in this rapid review this major discontinuity does not have a unique signature but it can be well identified in both the proximal and distal domains, on the platform and in the basin, for it is contingent on one of the largest Mesozoic transgressions. From a chronostratigraphic viewpoint it is very close to a stage limit defined by ammonites (it is even closer if one accepts that the *Thurmanniceras otopeta* (Sub-) Zone should be included in the Berriasian (see BULOT *et alii*, 1996).

IV- Conclusions

The criteria proposed in the several fields (sedimentological, petrographical, biological, geochemical, *etc.*) to define the Tithonian-Berriasian limit are too tenuous to be of value as a system limit (but have been so employed since KILIAN) or even for bounding a stage. therefore, I propose to return to a more practical definition of systems (and stages). Authors - as d'ORBIGNY did in his time - should focus on the identification of significant events (any record of a global "catastrophy") to set unit limits. Such a concept involves the integration of litho-, bio-, and sequence stratigraphies to delimit chronostratigraphic units defined by physical criteria that will be calibrated as closely as possible with biozone "proxies", and not defined strictly/solely by biozones as has been the practice to date. From sedimentological, petrographical, biological, *etc.* standpoints the trans-Tethyan discontinuity at the base of the Valanginian (which passes laterally into a continuity in the basinal domain) merits elevation to the rank of a system boundary (an option close to the viewpoints of TOUCAS and HAUG, see BARBIER & THIEULOY, 1965).

Acknowledgments

This proposal has benefited from discussions with a number of colleagues whom I thank for having taken the time to discuss counter-arguments or to offer me new keys to my thesis. I hope to be able to associate them in forthcoming publications.

References

AZÉMA J. (1977).- Étude géologique des zones externes des Cordillères bétiques aux confins des provinces d'Alicante et de Murcie (Espagne).- Thèse Doctorat d'État, Université Pierre et Marie CURIE, Paris, 393 p.

BARBIER R. & THIEULOY J.-P. (1965).- Étage Berriasien.- *In*: Colloque sur le Crétacé inférieur (Lyon, septembre 1963).- *Mémoires du Bureau de Recherches Géologiques et Minières*, Orléans, n° 34, p. 69-77.

BULOT L.G. *et alii* (1996).- The Valanginian stage.- *In*: RAWSON P.F. *et alii* (eds.), Second International Symposium on Cretaceous Stage Boundaries, Brussels (1995).- *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique*, Bruxelles, 66 (Supplement), p. 11-18.

BUSNARDO R. & DURAND-DELGA M. (1960).- Le Jurassique et le Crétacé inférieur dans l'Est des Cordillères bétiques.- *Bulletin de la Société Géologique de France*, Paris, (7ème série), t. II, p. 278-287.

ESTEVEZ A., GARCIA HERNANDEZ M., PINA J.A. & HAUERNHEIMER C. (1984).- Nuevas precisiones estratigraficas sobre el Cretacico inferior del Cabeço d'or (provincia de Alicante, zona prebetica).- 1° Congreso Español de Geología, Segovia, (23), t. III, p. 189-197.

FOURCADE É. & GRANIER B. (1989).- Âge des carbonates de plate-forme du site 392A DSDP (Leg 44), marge atlantique du continent nord américain.- *Marine Geology*, Amsterdam, vol. 90, n° 3, p. 197-204.

GRANIER B. (1987).- Le Crétacé inférieur de la Costa Blanca entre Busot et Altea, Alicante (Espagne) : Biostratigraphie, Sédimentologie, Évolution tectono-sédimentaire.- Thèse, Docteur de l'Université Paris VI (nouveau régime), 23 novembre 1987; *Mémoires des Sciences de la Terre, Université Pierre et Marie CURIE*, Paris, 87-49, vol. I (texte): 281 p.; vol. II (planches): 54 pls.

GRANIER B. (2000).- Lower Cretaceous stratigraphy of Abu Dhabi and the United Arab Emirates- A reappraisal.- The 9th Abu Dhabi International Petroleum Exhibition & Conference, October 15th-18th, *Conference Proceedings*, Abu Dhabi, ADIPEC 0918, p. 526-535.

GRANIER B., VIRGONE A., BUSNARDO R. & BULOT L.G. (1995).- Des calpionelles dans l'Hauterivien supérieur. Découverte exceptionnelle à Busot (Alicante, Espagne).- *Comptes-Rendus de l'Académie des Sciences*, Paris, (série II, fasc. a), t. 321, p. 1179-1186.

HASSAN T.H., MUDD G.C. & TWOMBLEY B.N. (1975).- The stratigraphy and sedimentation of the Thamama Group (Lower Cretaceous) of Abu Dhabi.- Ninth Arab Petroleum Congress, Dubai, 107(B-3), 11 p.

JAN DU CHÊNE R., BUSNARDO R., CHAROLLAIS J., CLAVEL B., DECONNINCK J.-F., EMMANUEL L., GARDIN S., GORIN G., MANIVIT H., MONTEIL E., RAYNAUD J.-F., RENARD M., STEFFEN D., STEINHAUSER N., STRASSER A., STROHMENGER C. & VAIL P.R. (1990).- Sequence-stratigraphic interpretation of Upper Tithonian-Berriasian reference sections in South-East France: a multidisciplinary approach.- *Bulletin des Centres de Recherches Exploration-Production elf-aquitaine*, Pau, vol. 17, n° 1, p. 151-181.

MOHAMMED A.R., HUSSEY J.A. & REINDL E. (1997).- Catalogue of Oman lithostratigraphy.- CD-ROM, Petroleum Development Oman, Muscat, 373 p.

RASPLUS L. & FOURCADE É. (eds.) *et alii* (1987).- Stratigraphie intégrée du sillon citrabétique (Sierra de Foncalent, Province d'Alicante, Espagne).- *Géobios*, Lyon, n° 20, fasc. 3, p. 337-387.

VIRGONE A. (1997).- Stratigraphie, sédimentologie et dynamique d'une plate-forme carbonatée : Le Berriasien supérieur - Valanginien basal de Basse Provence occidentale (S.E. France).- Thèse, Docteur de l'Université de Provence - Aix-Marseille I (nouveau régime), 6 juin 1997, 196 p.