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Revision of "Falaise de BLANCHE" (Lower Cretaceous) in Lebanon, with the definition of a Jezzinian Regional Stage

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Abstract: The "Falaise de BLANCHE" is a prominent cliff, consisting mostly of Lower Cretaceous limestones that extends as linear outcrops over most of the Lebanese territory and provides geologists a remarkable reference for stratigraphic studies. However, until now, this unit was lacking a clear definition. We introduce herein the Jezzinian Regional Stage, the type-locality of which is at Jezzine. It equates as an unconformity-bounded unit and, per definition, it is framed by two discontinuities. Because we identified an additional, median sequence-boundary, poorly-expressed in the type-section but better at Aazour, only 4.5 km westward of Jezzine, the new regional stage implicitly spans two sequences. The lithostratigraphic framework being properly redefined, we were able to investigate time-constrained micropaleontological assemblages, consisting mostly of benthic foraminifers and calcareous algae. Typically Southern Tethysian, these assemblages contribute to high-resolution, holostratigraphic correlations with the Persian Gulf area, on the eastern part of the Arabian Plate. The Jezzinian interval correlates with the upper part of the Kharaibian Regional Stage (also known as "Thamama II" reservoir unit in the oil industry). In turn, the Jezzinian is indirectly correlated with the Northern Tethysian Urgonian stratigraphic units where it corresponds to a rather short interval encompassing the standard Barremian - Bedoulian stage boundary. Locally the upper discontinuity is associated to a significant intra-Bedoulian hiatus. The macrofossil assemblages found in the Jezzinian (echinids) and above it (ammonites) support, or at least do not contradict, our micropaleontological dating.

Key Words: Lebanon; Lower Cretaceous; Barremian; Bedoulian; Aptian auct.; Falaise de BLANCHE; Jezzinian Regional Stage; rudists; echinids; ammonites; foraminifers; Dasyycladales.

Résumé : Révision de l'"Falaise de BLANCHE" (Crétacé inférieur) au Liban et définition de l'Étage Régional Jezzinien. Les calcaires du Crétacé inférieur de la "Falaise de BLANCHE" affleurent sur une grande partie du territoire libanais. Ils apparaissent dans le paysage sous forme d'escarpements linéaires saillants constituant autant de points d'ancrage remarquables pour tout recalage stratigraphique. Toutefois, jusqu'à très récemment, cette unité était piètrement caractérisée : il lui manquait notamment une définition rigoureuse. Nous introduisons ici l'Étage Régional Jezzinien, dont la localité-type est sise à Jezzine. Il s'agit d'une unité stratigraphique particulière, aussi appelée U.B.U. (pour "unconformity-bounded unit"), une unité qui, par définition, est encadrée par deux discontinuités. Parce que nous avons identifié une limite de séquence supplémentaire, en position médiane, peu exprimée dans la section-type, mais beaucoup mieux à Aazour, à 4,5 km à peine à l'ouest de Jezzine, le nouvel étage régional devrait implicitement couvrir deux séquences. Le canevas lithostratigraphique étant clairement redéfini, nous avons pu étudier les associations micropaléontologiques, constituées essentiellement de foraminifères benthiques et d'algues calcaires, associations dorénavant relativement bien contraintes au point de vue de leur âge. Typiquement sud-téthysiennes, elles facilitent les corrélations holostratigraphiques à haute résolution avec la région du Golfe persique, sur le côté oriental de la Plaque arabe. L'intervalle Jezzinien correspond ainsi à la partie supérieure de l'Étage Régional...
Kharaibien (aussi connu comme unité réservoir "Thamama II" dans l’industrie pétrolière). À son tour, le Jezzinien est indirectement corrélé avec les unités stratigraphiques urgoniennes nord-téthysiennes où il correspond à un intervalle relativement court comprenant la limite des étages standards (internationaux) Barrémien et Bédoulien. Localement la discontinuité sommitale est associée à un hiatus intra-Bédoulien significatif. Les associations macropaléontologiques reconnues dans le Jezzinien (échinides) et au-dessus de cette unité (ammonites) viennent à l’appui de notre datation micropaléontologique ou tout au moins ne la contredisent pas.

**Mots-clefs :** Liban ; Crétacé inférieur ; Barrémien ; Bédoulien ; Aptien auct. ; Falaise de BLANCHE ; Étage Régional Jezzinien ; rudistes ; échinides ; ammonites ; foraminifères ; Dasycladales.

### 1. Introduction

The "Falaise de BLANCHE" is a sheer-sided limestone cliff of alleged Aptian sensu lato (Bedoulian - “Gargasian”) age that trends throughout the chains of Mount Lebanon, Anti-Lebanon (Lebanon: Fig. 1), Southern Alawite Mountains (Syria) and northern Galilee. This distinctive geomorphological unit forms the natural bridge of Fakra-Kfardebiane (Fig. 2) and the background of the waterfalls at Jezzine (Fig. 3), where it is some 70 meters in height. Actually Dubertret (1955: p. 20) was the first to attempt - unsuccessfully - to re-label it as "Falaise de Djezzine" after the name of this last locality. This stratigraphical unit required a full re-evaluation as, for instance, Heybroek (1942) and later Dubertret (1947) stated that it consists of a "calcaire récifal blanc" [a white reefal limestone], an assumption that is not consistent with our field observations and the scarcity of corals. Furthermore, it was lacking a type-locality and clear definitions of its lower and upper boundaries. Finally, there are also many interpretations regarding its dating: Dubertret (1963) claimed a late Aptian (= "Gargasian") age for his unit "c2b" (op. cit.: p. 43: "depuis la muraille de BLANCHE jusqu’à la base des bancs à Cardium") while the fossiliferous strata below it, i.e., his unit c2a, should be early Aptian (= Bedoulian) in age; on the other hand, Saint-Marc (1970), without excluding a late Aptian age for the uppermost layers, assumed its mainly early Aptian age. However due partly to the recent updates in the definitions and our understanding of the Barremian [1], Bedoulian and Aptian [2] stages and substages in their historical stratotypic areas these old datings should be fully reconsidered.

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[1] In 1998, the Barremian-Bedoulian boundary was moved upward from bed 45 to bed 60 in the historical stratotypic section of the Bedoulian (Moullade et al., 1998).

[2] Moullade et al. (2011) recommended a new status for the Aptian substages, raising them to the rank of genuine stages. Accordingly the lower Aptian sensu anglico et gallico would equate with the historical Bedoulian; the Gargasian (middle Aptian sensu gallico) should be treated as a junior synonym of the historical Aptian auct. [there are no Bedoulian strata in Apt, nor in Gargas]. At La Bédoule, in the historical stratotypic section of the Bedoulian, the boundary between the Bedoulian and the Aptian auct. is located on top of bed 170 (Moullade et al., 2011).
After summing up the notes of earlier authors (BLANCHE, 1847; FRAAS, 1878; DIENER, 1886; DOUVILLE, 1910, 1913; ZUMOFFEN, 1926; DUBERTRET, 1934, 1947, 1955, 1963; DUBERTRET & VAUTRIN, 1937; SAINT-MARC, 1970, 1972), we propose herein a new holostratigraphic definition for this unit, i.e., a definition based on our faciological, lithostratigraphical, sequential, and paleontological analyses. The microfossil assemblages are compared with those of the Persian Gulf, because both areas belong to the same tectonic plate, i.e., the Arabian Plate.

2. Review of past lithostratigraphic information and new definition

The discrete geological/morphological unit corresponding to "Falaise de BLANCHE" was named by DOUVILLE (1910) after Charles-Isidore BLANCHE (1823-1887). According to BLANCHE (1847, p. 14-15), it consists of "8º Un calcaire jaunâtre, terreux, à texture parfaitement oolithique" [8th] A yellowish limestone, earthy, with a purely oolitic texture], below, and "7º (...) un calcaire blanc, très dur, très compacte, à grain extrêmement fin et presque cristallin" [7th] a very hard and compact, white micritic limestone], above (Table 1) [Note that BLANCHE described the section from top to bottom]. This unit represents the "Gastropodenzone von Abeih" of FRAAS (1878), sandwiched between his "Sandsteinzone des Libanon" below and his "Braune Kreide (Cardiumbänke)" above. In 1963, for the edition of the "Lexique Stratigraphique International", DUBERTRET re-labelled the Gastropodenzone as "Falaise de Mdairej" and the Sandsteinzone as "Grès de Base". Unfortunately, for the neighborhoods of Beirut, he introduced an unnamed transitional zone (op. cit.: p. 56) consisting of "170 m de terrains argilo-sableux et calcaires fossilifères" [170 m of shaley to sandy and fossiliferous calcareous strata] between "Falaise de Mdairej" and "Grès de Base". WALLEY's "revision" (1983) merely introduced new names for the old units (from base to top "Chouf Sandstone Formation", "Mdairej Formation", and "Hammana Formation"). However, he failed to give clear definitions for most of these newly re-labelled lithostratigraphic units and he even added more confusion as, for instance, he ascribed a formal name to DUBERTRET's transitional unit (i.e., "Abeih Formation") without providing any data supporting its distinctiveness among the Lebanese Cretaceous formations (Table 1).
Figure 3: The cliff at Jezzine and Wadi Jezzine. A: The eastern side with the road section (see Log); B: The waterfall and the lower boundary at 0 m; C: The western side and the upper boundary at 61.5 m. Number labels refer to the metrics from the road section.
Figure 4: Lithostratigraphic scheme of the Jezzinián Regional Stage showing the two bounding sequence boundaries (SB) - transgressive surfaces (TS). For a simplification purpose, each hiatus does not take erosion in consideration, but only non-deposition. Similarly, the median boundary and the associated hiatus are not illustrated.

The lithostratigraphic approach of Dubertret (as that of Walleys) is essentially facies-driven:

1) grain-dominated, shoal facies (oolitic and bioclastic wackestones and grainstones) are referred to the Abeih Formation;

2) mud-dominated, lagoonal facies (mudstones and bioclastic wackestones, with some gastropod floatstones) to the "Falaise de Blanche" or Mdairej Formation (Table 1). Dubertret (1947) described it as "calcaire blanc récifal" [white reef limestone] (Dubertret, 1963: p. 44), but there is no evidence of a reef environment. Dubertret (1963) named it "Falaise de Mdairej" after he established its type-section in this locality. Nowadays, the section is no longer available because of recent urbanization.

The micritic facies ("Mdairej") are commonly found in the upper part of most sections, above the calcarenitic facies ("Abeih"). They may locally be missing or interfinger with the later, suggesting that these areas represent transition zones between a shoal barrier and a protected lagoon behind it. This geometrical relationship is merely the signature of regular lateral changes in facies within a single time-unit. In addition, the orbitolinid and algal assemblages are very similar in both of these units. Rather than using the obsolete and meaningless facies-driven units, we have adopted the concepts of "Unconformity Bounded Unit", i.e., UBU or Alloformation (Murphy & Salvador, 1999; see Granier, 2000, for application in the Middle East), or "Regional Stage" (see Granier et al., 2011).

The term "Falaise de Blanche" is obviously ambiguous; first because some authors confused this unit with the "Cardium Beds" and others ignored the grainy facies that should be included, second because the term describes a geomorphological feature rather than a stratigraphic unit. Hence, we selected Jezzine (Jezzine District, South Governorate, Lebanon) as the most representative locality to define the Jezzine UBU, Jezzine Alloformation and Jezzinián Regional Stage, all of these terms being synonymous in our understanding (Fig. 4), as the interval having:

1) the lower boundary corresponding to the sequence boundary at the top of the siliciclastic coastal and estuarine deposits of the "Grès de Base". This paleoenvironmental interpretation is suggested by the occurrence of marine bivalves in bioturbated sands and shales, in association with lignite. At the Jezzine waterfall, the boundary, which is amalgamated with a transgressive surface at the top of the underlying siliciclastic unit, occurs directly above a lignite-rich horizon (Figs. 3.A-B : 0, and 5). "Floated" amber clasts found in such lignite-rich levels yield numerous biological inclusions, mostly Early Cretaceous arthropod remains (Azar, 1997; Azar et al., 2010), previously thought to be Beudoulian-Aptian in age (Azar et al., 2003). Not far from Jezzine, outcrops have charophyte remains (Grambast & Lorch, 1968; Tixier, 1972; note: the material was originally collected by Tixier, 1965), which in places are associated with the Triporoporellacean alga Salpingoporella dinarica (Radoicic, 1959) and the foraminifer Choffatella gr. decipiens Schlumberger, 1905 (Granier et al., work in progress);
Table 1: Summary of the attributed terminology to the Jezzinian and its surrounding units over the period 1847 to date.

| Blanche (1847) |
|----------------|
| 6th) yellowish limestone, earthy or crystalline (le calcaire jaunâtre, terreux ou cristallin) with ammonites |
| 7th) very hard and compact, white limestone (le calcaire blanc, très dur, très compact) |
| 8th) yellowish limestone, earthy, with a purely oolitic texture (le calcaire jaunâtre, terreux, à texture parfaitement oolithique) |
| 9th) Sands and clays with lignite (les sables et argiles à lignite) |

| Fraas (1875) |
|--------------|
| 5. Zone des Ammonites sycrus |
| 4. Cardiumbanke, braune Kreide |
| 3. Gastropodenzone von Abelth |
| 2. Sandsteinformation des Libanon |

| Zumoffen (1926) |
|------------------|
| "Vraconien" |
| "Albien" |
| "Aptien supérieur" |
| "Aptien inférieur" |
| "Néocomien" |

| Dubertret & Vautrin (1934) |
|-----------------------------|
| Banc à Cardium |
| "Albien" |
| "Aptien supérieur" |
| "Néocomien" |

| Heybroek (1942) |
|----------------|
| Couches à knemiceras |
| Banc de Zumoffen |
| Couches à Orbitolines |
| Muralle de Blanche |
| Couches à Gastérocoodes |
| Banc de Mrjâtt |
| Calcaries à pisolites |
| Grès lignifières |

2) the upper boundary corresponding to another sequence boundary at the top of the muddy facies. In Jezzine, it is also amalgamated with a transgressive surface; the next sequence starts with a bioclastic orbitolinid-rich limestone (Fig. 3.C: 61.5). In other localities, these bioclastic limestones may be missing and a marly facies with orbitolinids and eventually scattered ammonites is found lying directly above the micritic limestones. In some places coral colonies are concentrated in strata lying below this upper boundary and locally emersion evidences (fenestrae, casts or molds of former aragonitic bioclasts filled with sediment) are found there too. The surface itself may be encrusted by oysters and bored by worms and pholadids (Fig. 6.A-B, D & G-F), indicative of an early lithification of the muddy sediment.

At Jezzine, we measured the type-section on the side of the main road at the entrance to the town (Fig. 3.A). There it is more than 48 m thick (Log) because it reaches some 61.5 m (estimated) in the nearby cliff section at Wadi Jezzine (Fig. 3.B-C). The detail of the section will be the main topic of a forthcoming publication. It is worth mentioning that in Jezzine area muddy facies dominates over grainy facies. On the opposite, in other localities (for instance, in Aazour, only 4.5 km WNW of Jezzine, or at Aarbet Qozhaya: Fig. 1), grainy facies dominates over muddy facies. In these localities the occurrence of a muddy "tongue" in the grainy facies led us to identify a median unconformity on top of the muddy "tongue": at Aarbet Qozhaya, it consists of a burrowed and bored surface (Figs. 6.C&E and 7), and therefore to discriminate two Jezzinian subunits/sequences.
Having identified the key facies and defined the lithostratigraphical and sequential framework, we can review the fossil contents and biostratigraphic interpretations.

3. Biostratigraphic review

On the basis of macrofossil finds, FRAS (1878) proposed the first chronostratigraphic framework for the "Late Cretaceous" Lebanese units. According to DIENER (1886), FRAS' succession consisting from base to top of the Sandsteinzone, the Gastropodenzone and the Cardiumbanke is respectively Cenomanian in age for the first unit and Turonian for the last two.

According to DOUVILLÉ (1910) and DUBERTRET (1934), the mud-dominated facies of "Falaise de BLANCHE" should be referred to the Albian. However actually, some age-diagnostic fossils were collected by a third person from a discrete cliff located above the "Falaise de BLANCHE", i.e., "Falaise de ZUMOFFEN" [see discussion below]. In his later publications, DUBERTRET (DUBERTRET & VAUTRIN, 1937; DUBERTRET, 1955, 1963) ascribed this facies to the "Aptien supérieur" (i.e., Aptian auct.). He mentioned some macrofossils (echinids, rudists and pelecypods) and few microfossils (orbitolinids). SAINT-MARC (1970) was the first to base his dating mainly on micropaleontological data. He identified several benthic foraminifers and calcareous algae that led him to ascribe the "Falaise de BLANCHE" an Aptian age: both "inférieur" (early, i.e., Bedoulian), most of it actually, and "supérieur" (late, i.e., Aptian auct.), as he did not exclude this dating at least for the uppermost strata. The overlying "couches à Orbitolines" (Orbitolina Beds), an informal unit he introduced (SAINT-MARC, 1970), can be treated either as part of the Cardium Beds of previous authors or as a junior synonym.

4. Review of paleontological data

Since 1910 many paleontological data have been reported in the Lebanese literature.

4.1 Macrofossils

4.1.a) Rudists

DOUVILLÉ (1910, 1913) identified some rudists from Lebanon but he did not collect the material himself. For instance, he identified Polyconites verneuili BAYLE, 1860 (1913: Pl. IX, figs. 1-3) and Eoradiolites plicatus CONRAD, 1852 (DOUVILLÉ, 1910: Figs. 71-75; DOUVILLÉ, 1913: Pl. IX, fig. 5) among the specimens collected by ZUMOFFEN (DOUVILLÉ, 1913: p. 409; ZUMOFFEN, 1926) from a small cliff consisting of a compact limestone and misinterpreted as "Falaise de BLANCHE" (DUBERTRET, 1963). In fact, this cliff is located above "Falaise de BLANCHE". Both species, Polyconites verneuili and Eoradiolites plicatus, are known from the Aptian auct. - Albian interval (MASSE, 1995; SKELTON & MASSE, 2000).

DOUVILLÉ (1913) also identified Agria marticensis ORBIGNY, 1847 (op. cit.: Pl. IX, fig. 4), in material collected by ZUMOFFEN (op. cit.: p. 409) probably from the base of the "Falaise de BLANCHE" and ascribed to the Aptian. Actually, it is not a genuine Agriopleura marticensis as it was re-labelled Agriopleura libanica by STRE (1930; MASSE & FENERCI-MASSE, 2014).

HEYBROEK (1942, p. 44) reported the find of "Toucasia sp." at the "sommet de Muraille de BLANCHE" in Kfer Matta [= Kfarmatta], near Abeih. This record was forgotten by subsequent authors.

The identification and the age of these rudists require revision. In addition new rudistid finds are under evaluation (J.-P. MASSE et al., in preparation).
4.1.b) Echinids

Fraas (1878: p. 331) reported Heteraster oblongus (Brongniart, 1821) in his Cardium-bänke, which was then erroneously ascribed to the Cenomanian. These specimens were described as "Enallaster syriacus" by P. de Loriol (1887: Pl. VII, figs. 2-3; Pl. XVI, figs. 2-3). Later Keller and Vaufrin (1937) illustrated this echinoid under the name of "Heteraster oblongus Brongniart race syriaca" (op. cit.: Pl. VI, figs. 5-12; Pl. VII, figs. 1-19) from the "Aptien inférieur". Heybroek (1942), Dubertret (1947, 1955, 1963), and Saint-Marc (1970) also reported it without illustrating it contrary to the "visual guide" of the "fossils of Lebanon" (Arslan et al., 1995: Pl. XX, figs. 87-88; 1997) where it appears as "Heteraster sp.".

Keller and Vaufrin (1937) illustrated from the "Aptien supérieur" Trochodiadema libanoticum Loriol, 1887 (op. cit.: p. 140, Pl. V, figs. 2-3), Salenia scutigera Gray, 1835 (op. cit.: p. 144, Pl. V, figs. 4-5), Holecystopus portentosus Coquand, 1879 (op. cit.: p. 147, Pl. V, fig. 6), Clitopygus (Echinobrissus) goybeti Cotteau, 1885 (op. cit.: p. 152, Pl. V, fig. 13), and Toxaster dieneri Loriol, 1887 (op. cit.: p. 154, Pl. V, figs. 17-20).

Dubertret (1955) reported from the "Falaise de Blanche" Clitopygus (Echinobrissus) goybeti Cotteau [now considered as a junior synonym of Nucleopygus roberti (A. Gras, 1848)], and Diplopodia hermonensis Loriol without illustrating them.

The nomenclature and the age of these echinoids require revision too because either identifications are inaccurate or the location of the studied outcrops are uncertain.

In a preliminary evaluation of our own finds (legit D.A., R.G., B.G., S.M.), B. Cleavel accurately identified four species:

i) First, the irregular urchin, Heteraster oblongus, is commonly found in most Jezzinian outcrops: Kanat Bakich (Pl. 3, figs. C & E; MHNUL 22797/0001-0007), Kfardebiane (Pl. 3, figs. D & I; MHNUL 25439/0001-0003), Ehden (MHNUL 33211/0001). In southeastern Europe, this species is characteristic of the Urgonian sequences Ba5 to Bd2 of Cleavel et al. (2007), i.e., the uppermost Barremian (top Giraudia ammonite Zone) and the lower Bedoulian (basal Forbesi ammonite Zone).

ii) Another irregular urchin, Heteraster delgadoi (Loriol, 1888), is found above the cliff in the Cardium Beds at Kanat Bakich (Pl. 3, fig. F, MHNUL 22797/0001). It is a very long-ranging species, commonly found in Albain and Cenomanian strata.

Figure 6: Perforations from different localities. A: Ghineh, Oysters (arrows); B: Sannine; C & E: Aarbet Qozhaya, thin-section AAR18.3 (graphic scale = 1 mm); D: Ghineh, borings (arrows); F-G: Zaarour (hammer for scale).
iii) The third irregular urchin, *Nucleopygus roberti* (A. Gras, 1848), is from the uppermost strata of "Grès de Base" (Pl. 3, fig. G-H; Qanater Zoubeyde, MNHUL 37321/0001-0002) and the lower part of the Jezzinian (Jeita, MNHUL 25261/0001). It is a long-ranging form, known in the whole Barremian - Bedoulian interval.

iv) A regular urchin, *Tetragramma malbatis* (Agassiz & Desor, 1846), was actually found in the *Cardium* Beds (Pl. 3, figs. A-B, Zaarour, MNHUL 22733/0001). It first appears in upper Bedoulian strata.

4.1.c) Ammonites

*Dubertret* (1955) reported a specimen of *Douvilleiceras* from the basal part of the Jezzinian section in a quarry at Mkalles, E Beyrouth. So far, it is the only ammonite record from this stratigraphic unit; unfortunately the specimen, was never illustrated and is lost.

In a preliminary evaluation of our own finds in the basal *Cardium* Beds, above the Jezzinian interval (legit R.G., B.G., S.M.), one of us (J.A.M-B.) identified a few questionable Deshayesitidae from "Mechmech" Jbeil (MNHUL 26218/0001-0002), a *Dufrenovia?* sp. from Kfar Nabrakh (MNHUL 23655/0007), and *Cheloniceras cornuelianum* (Orbigny, 1841) from Kfar Nabrakh (MNHUL 23655/0001 and 0011: Pl. 2, fig. E) and from Kanat Bakich (MNHUL 22797/0001: Pl. 2, figs. C-D). Also a number of *Cheloniceras* sp. are from Kanat Bakich (MNHUL 22797/0001 to 0006: Pl. 1, figs. A-B; Pl. 2, figs. A-B), including a questionable one from Kfar Nabrakh (MNHUL 23655/0005). *Cheloniceras cornuelianum* spans both the Deshayesii and Furcata ammonite zones, suggesting that the Jezzinian is not younger than the Bedoulian. In addition to the ammonites, some large nautiloids, *Cymatoceras?* sp., were collected at Kfar Nabrakh (MNHUL 23655/0002 to 0003).

4.2) Microfossils

4.2.a) Calcareous algae

*Saint-Marc* (1970) illustrated and identified *Hensonella cylindrica* Elliott, 1960 (op. cit.: Pl. 2, figs. 1-2), from the "Falaise de B Lancie", and *Basson* and *Edgell* (1971) reported *Pianella dinarica* (Radoičić, 1959) from the Jezzine limestone (op. cit.: p. 418, Pl. 3, figs. 5-8). However both names are synonymized with *Salpingoporella dinarica* (Radoičić, 1959) according to Bassoon et al. (1978).

In addition, Basson and Edgell (1971) reported a number of forms from the "Jezzine limestone" on Mount Lebanon. However several incorrect identifications, taxonomic changes and problems of synonymy are listed below.

i) Incorrect identifications:

*Montiella elitzae* (Bakalova, 1971) was erroneously identified as *Cylindroporella sugdeni* Elliott, 1957 (op. cit.: p. 417, Pl. 2, figs. 1-3). Note that the figured specimen in their Pl. 2, fig. 4 (op. cit.) does correspond to a genuine *Cylindroporella sugdeni*.

ii) Taxonomic changes:

Three specimens of *Macroporella pygmaea* (Gumel, 1982) are correctly identified (op. cit.: p. 417-418, Pl. 5, figs. 1-3), but the species was transferred to the genus *Salpingoporella* (Bassoulet et al., 1971). Actually, we should refer them to *Salpingoporella* gr. *pygmaea-*johnsoni.

iii) Problem of synonymy:

*Salpingoporella carpathica* Dragastan, 1969 (op. cit.: p. 420, Pl. 4, fig. 1), is a junior synonym *S. muehlbergii* Lorenz, 1902, according to Bassoulet et al. (1978).
BASSON and EDGELL (1971) also gave two discrete names for a single (?) algal specimen: *Carpathoporella occidentalis* DRAGASTAN, 1995, non 1969 (op. cit.: p. 420, Pl. 4, figs. 7-8), and "*Coprocampa* *ydon lineolatus* ELLIOTT, 1963" (op. cit.: p. 420, 422, Pl. 4, fig. 9-11). The type of the second species is a coprolite (see GRANIER & DELOFFRE, 1993).

4.2.b) Orbitolinids

According to DOUVILLÉ (1913: p. 411), "un échantillon d’*Orbitolina conoidea* GRAS, 1852, adhère à la valve supérieure" [a specimen of *Orbitolina conoidea* is adhering on the upper valve surface] of the *Agria martenensis* he was studying. This foraminifer is also reported by DUBERTRET (1955) as *Orbitolina conoidea-discoidea*. HENSON (1948) described *Orbitolina discoidea var. libanica* var. nov. (op. cit.: p. 55-56, Pl. II, figs. 10, 12) from Mdairej, above "Muraile de Blanche" but, according to SCHROEDER and NEUMANN (1985), it is a synonym of *Mesorbitolina texana* (ROEMER, 1852).

Both DOUVILLÉ (1910) and DUBERTRET (1955) reported the occurrence of *Orbitolina lenticularis* (BLUMENBACH, 1805). HENSON (1948: p. 56-59) assumed that both *Orbitolina cf. lenticularis* and *Orbitolina discoidea var. libanica* have "previously been included under the names of *O. lenticularis* Blum. and *O. conoidea-discoidea*" by DUBERTRET and VAUTRIN (1937).

SIMMONS et al. (2000) revised the HENSON’s material (1948). It was an uneasy task due to the loss of specimens and petrographic thin-sections for any further review; and also due to the scarcity or lack of sections cut through the embryonic apparatus in the thin-section material. They prepared new petrographic thin-sections from the material that was used to describe *Orbitolina discoidea var. libanica* (SIMMONS et al., 2000: p. 416) and *Orbitolina cf. lenticularis* (BLUMENBACH) (op. cit.: p. 416) from topotype material. They demonstrated that *Orbitolina discoidea var. libanica* is a junior synonym of *Mesorbitolina texana*.

In his 1970 publication, SAINT-MARC cited and illustrated several orbitolinids. However since this work was published there have been several taxonomic changes and problems of synonymy or incorrect identifications have been evidenced.

i) Incorrect identifications:

According to SCHROEDER et al. (2010), a specimen of *Paleodictyoconus arabicus* (HENSON) figured by SAINT-MARC (1970: Pl. 1, fig. 14) is actually a *Palorbitolina* sp.; another specimen (op. cit.: Pl. 1, fig. 13) is probably a *Rectodictyoconus giganteus* SCHROEDER, 1964.

ii) Taxonomic changes:

Only two specimens of *Paleodictyoconus arabicus* (HENSON, 1948) are correctly identified (SAINT-MARC, 1970: Pl. 1, figs. 12, 15) according to SCHROEDER et al. (2010), but the species was transferred to the genus *Montseciella* by CHERCHI and SCHROEDER (1999); *Mesorbitolina texana* (ROEMER, 1849) parva DOUGLASS, 1960, is figured in his paper (SAINT-MARC, 1970: Pl. 1, fig. 6) and again in MOULLADE and SAINT-MARC (1975: Pl. XII, fig. 10) as *Orbitolina* (*Mesorbitolina*) parva DOUGLASS, 1960, but the variety is now given a species status.

iii) Problems of synonymy:

*Mesorbitolina libanica* (HENSON) is also figured by SAINT-MARC (1970: Pl. 3, figs. 1-3). It was described by HENSON (1948) as *Orbitolina discoidea var. libanica* and later again by MOULLADE and SAINT-MARC (1975) as *Orbitolina* (*Mesorbitolina*) *libanica*, but it is a junior synonym of *Mesorbitolina texana* (ROEMER, 1849) according to SCHROEDER and NEUMANN (1985: p. 79) as well as to SIMMONS et al. (2000).

Finally, the specimens of *Mesorbitolina lotzei* SCHROEDER, 1964, figured by SAINT-MARC (1970: Pl. 1, figs. 7-9), were ascribed to *Praeorbitolina cormyi* SCHROEDER, 1964, by MOULLADE and SAINT-MARC (1975: Pl. XII, fig. 5) and later to *Praeorbitolina wienandsi* SCHROEDER, 1964, by SCHROEDER (1979).

5. New microfossil data

During a first field work campaign in summer 2012, we sampled and logged several sections in discrete localities of Lebanon (Fig. 1). Thin section analyses of the material collected prove to bear rather rich micropaleontological assemblages consisting of calcareous algae (mostly Dasycladales) and benthic foraminifers (with representatives of the Charentiidae, Cyclamminidae, Orbitolinidae, Nezzazatidae, and Miliolidae families). These benthic microfossils are not usually given enough attention, though some proved to be efficient biostratigraphic tools to date rocks where, until recently, the classical markers (ammonites, planktonic foraminifers) were not found.

5.1) Dasycladalean algae

Some long-ranging species cannot give a precise dating.

- According to GRANIER (1994), *Actinoporella gr. podolica* (ALTH, 1878) (Pl. 4, figs. L & P) spans at least the Tithonian - Barremian interval. Two poor random sections ascribed to *Actinoporella podolica* by BASSON and EDGELL (1971: Pl. 3, figs. 1-2) from the Upper Jurassic of Mount Lebanon cannot be ascribed to this taxon.
- *Montiella elitzei* (BAKALOVA, 1971) (Pl. 4, figs. C-D) spans the Barremian-
tian auct. interval according to GRANIER and DELOFFRE (1993).

- *Salpingoporella dinarica* (RADOIĆIĆ, 1959) (Pl. 4, figs. R & V) probably starts in the Tithonian Stage because it was found by GRANIER (2002) in association with *Anchispirocyclina lusitanica* (EGGER) and ranges up to the Albian (SOKAČ, 1996).

- *S. muehbergii* (LORENZ, 1902) (Pl. 4, figs. G, K & O) ranges from the Upper Hauterivian to the Bedoulian according to GRANIER and DELOFFRE (1993).

- *S. hasi* (CONRAD et al., 1977) (Pl. 4, figs. A-B) spans the Alban-Cenomanian interval according to GRANIER and DELOFFRE (1993) but its first occurrence might well be Bedoulian in age (CARRAS et al., 2006) or even Barremian.

- *Suppliliumaella polyremark* ELLIOTT, 1968 (Pl. 4, fig. I), spans the Barremian-Aptian auct. interval according to GRANIER and DELOFFRE (1993).

Other, poorly-known species cannot give an accurate dating.

- *Harlanjohnsonella annulata* ELLIOTT, 1968 (Pl. 4, fig. J), was, until now, known only from its type-region, including its type locality, Zlatibor, Serbia (ELLIOIT, 1968; RADOIĆIĆ, 1995; RADOIĆIĆ & SCHLAGINTWEIT, 2010), where it is Cenomanian in age. The form illustrated and labelled "Harlanjohnsonella cf. annulata" in JAFFREZZO et al. (1980: Pl. II, fig. 9) from the Aptian of Bey Dağlıları in SW Turkey cannot specifically be referred to the species (MAKSOU et al., 2014).

- According to GRANIER and DELOFFRE (1993), *Genotella pfenderae* (KONISHI & EPIŚ, 1962) (Pl. 4, fig. E) spans the Alban - Turonian interval. The *Neomeris pfenderae* reported by BASSON and EGDELL (1971, Pl. 5, fig. 6) from the Cenomanian of Mount Lebanon is not referable to this taxon.

Finally we also identified some new species that, per definition, lack of stratigraphic relevance as, for instance, a new Triploporellacean species (Pl. 4, fig. H).

**5.2) Benthic foraminifers**

The most abundant foraminifera in our material are *Choffatella* and *Palorbitolina*. *Choffatella* preferred calm environments, either in back-shoal settings with Dasycladales or in fore-shoal settings in deeper, slightly clayey environments, in contrast to *Palorbitolina*, which preferred high energy, oxygenated and shallower areas (CUGNY, 1975; see discussion in GRANIER & BUSNARDO, 2013). Therefore they are rarely found together, the abundance of one explains the scarcity or even the absence of the other. They may eventually co-occur in transgressive facies, due to reworking (see discussion in GRANIER & BUSNARDO, 2013). In the Ain Dara section, for instance, *Choffatella* is abundant in the lowermost strata before its almost complete disappearance and its replacement by orbitolinids higher in the section.

More generally, when dealing with the benthic foraminifers, we faced the same difficulties as for the algae. The stratigraphic ranges of several species found in the interval ("Early Cretaceous"): *Buccicrenata hedbergi* (MAINC, 1953) (Pl. 4, fig. Q), *Pseudotextulariella scarSELLAI* (DE CASTRO, 1964) (Pl. 4, fig. W), *Prechrysalidina infracreata* LUPERTO SINNI, 1979 (Pl. 4, fig. F), and *Lituala cf. infilata* LOZO, 1944 (Pl. 4, fig. N), are too poorly constrained. Among them, *Involutina hungarica* (SIDO, 1952) (Pl. 4, figs. S-T), appears many times in the literature as "Hensolina", or "Trocholina", "lenticularis" or even "lenticularis var. minima HENSON, 1947" (SCHLAGINTWEIT & PILLER, 1990; CONSORTI et al., 2014; RIGAUD et al., 2014); originally described from the Lower Cenomanian of Dukhan (Qatar) and quite common in Alban strata, this form was also referred from Lower Barremian strata (GRANIER et al., 2003), which qualifies it as long-ranging species. However, according to one of us (B.G.), there might be multiple species belonging to the same phylogenetic branch.

Furthermore many species have rather long ranges, encompassing two or more stages. For instance, *Choffatella gr. decipiens* (Pl. 4, figs. M & U), a morphospecies already reported from Lebanon by SAINTE-MARC (1970: Pl. 1, figs. 4-S), ranges up to the Aptian auct. (*Martini ammonite Zone*) according to GRANIER and BUSNARDO (2013). It probably starts in the Valanginian because it may derive from *Choffatella pyrenaeica* PEYBENÈS, 1976.

Fortunately, some species may have rather short ranges and help ascribing ages:

1) *Palorbitolina lenticularis* (BLUMENBACH, 1805) (Fig. 8.C-F) is as a zonal marker of the Upper Barremian - lower Bedoulian for SCHROEDER et al. (2010), although it first occurs in the Lower --not lowermost-- Barremian strata (Nicklesi ammonite Zone) and last occurs in lowermost Aptian auct. strata (Furcata ammonite Zone) according to CLAVEL et al. (2013; GRANIER et al., 2013, 2014). It has been previously identified in Lebanon by SAINTE-MARC (1970), which led him later to distinguish an "Aptien inférieur" in "Falaise de BLANCHE" (SAINTE-MARC, 1972);
Figure 8: A-B: Slightly oblique and axial sections of *Praeorbitolina cormyi* SCHROEDER, 1964, from the "Orbitolina Beds", directly above the Jezzinian section at Jezezine, thin-section JEZh; C-D: Axial and slightly oblique sections of *Palorbitolina lenticularis* (BLUMENBACH, 1805) from Jezzinian strata, East Ain Dara, thin-section EAD38; E-F: Tangential and axial sections of *Palorbitolina lenticularis* (BLUMENBACH, 1805) from Jezzinian strata, East Ain Dara, thin-section EAD 68; scale bar = 250 µm (or 500 µm for "x2").
ii) Montseciella arabica (Henson, 1948) is as a subzonal marker of the Late Barremian ranging from the Sartousiana to the base of the Oglanlensis ammonite zones (Clavel et al., 2013) and in the Palorbitolina lenticularis Zone (Schroeder et al., 2010). In Lebanon it is apparently restricted to the lowermost part of "Falaise de Blanche" as indicated by Saint-Marc (1970: Pl. 1, figs. 12-13, 15). In July 2014, we collected new material from the same area (Pl. 5);

iii) Rectodictyoconus giganteus Schroeder, 1964, is an early Bedoulian marker (Deshayesites oglanlensis Zone, see Schroeder et al., 2010). Saint-Marc (1970: Pl. 1, fig. 13) found it in Lebanon but he erroneously ascribed this microspheric form to "Paleodictyoconus arabicus" (Henson). So far, we have not identified new specimens in our material;

iv) Praeorbitolina cormyi Schroeder, 1964, is a zonal marker of the uppermost Bedoulian-lowermost Aptian auct. (i.e., Deshayesi-Furcata ammonite zones) (Schroeder et al., 2010). In Iran, it was found in Bedoulian strata too (Schlagintweit et al., 2013). In Lebanon it was first reported by Moulade and Saint-Marc (1975: Pl. XI, figs. 1-7, 10). Actually, we did find it (Fig. 8.A-B) in outcrops at the top of the cliff in Jezzine, not in the Jezzinian interval but in the Sartousiana and early Bedoulian in age (Montseciella arabica, P. arabica, which characterizes the Late Barremian and extends into the earliest Bedoulian, and Rectodictyoconus giganteus, which is mostly early Bedoulian in age (Deshayesites oglanlensis Zone, see Schroeder et al., 2010 (3)). In conclusion, based on the microfossil contents, the Jezzinian Alloformation/Regional Stage spans a rather short time interval corresponding to the transition of the Barremian to the Bedoulian.

vi) Praeorbitolina cormyi is found in the first layers above the Jezzinian section at Jezzine. According to Cherchi and Schroeder (2013), this species is not reported from strata younger than the Deshayesi ammonite Zone, i.e., not younger than the late Bedoulian, a datum which again is consistent with our interpretation.

The micropaleontological associations in Lebanon can be compared with those of the Persian Gulf, on the eastern side of the Arabian plate. According to the synthetic stratigraphic schema for Abu Dhabi (Granier, 2000, 2008; Granier et al., 2003, 2011; Busnardo & Granier, 2011; Granier & Busnardo, 2013), which is also valid for Oman and Qatar, biostratigraphically significant species range throughout lithostratigraphic units:

i) Montseciella arabica occurs in the Kharaib Formation from Kharaib 1 to Kharaib 3 intervals;

ii) Rectodictyoconus giganteus is restricted to the Kharaib 3 interval;

iii) Choffatella decipiens spans the interval from the Lekhwair to the Bab formations (encompassing the Kharaib Formation);

iv) Palorbitolina lenticularis spans the whole Kharaib - Shu’aina formations interval;

v) Salpingoporella dinarica was found in the uppermost part of the Lekhwair Formation and most of the Kharaib (except for Kharaib 2), the Hawar and the Shu’aina formations. It is also known much lower in the series, i.e., from the Bu Haseer Formation (Tithonian-Berriasian transition according to Granier, 2002);

vi) Involutina hungarica is reported as "Hensonina lenticularis" in the uppermost part of the Lekhwair Formation and most of the Kharaib (except for Kharaib 2) (Granier et al., 2003);

vii) and, in Oman, Praeorbitolina cormyi first occurs in the Shu’aina (Witt & Gökdag, 1994: Pl. 10.1, fig. 5; Pl. 10.1, fig. 6 under "Orbitolina (Mesorbitolina) lotzei").

(3) Schroeder et al. (2010: fig. 18, "Bab Basin" column) present selected data from a well offshore Abu Dhabi (Granier, 2000, 2008; Granier et al., 2003): the ranges of two species only, Eopalorbitolina transiens and Montseciella arabica, remain whereas those of three more species, Palorbitolina lenticularis, P. cf. ultima and Rectodictyoconus giganteus, were omitted. In the same figure, the Kharaib is ascribed a Barremian age, excluding a Bedoulian age for its upper part, in blatant contradiction of the ranges of the fossil contents reported in the referenced papers.
6.2) Correlation of the Jezzinian Regional Stage with the Urgonian of SE France (Northern Tethyan association)

The Kharaibian Regional Stage was correlated with a North-Tethyan scale in SW Europe (Granier, 2000; Granier et al., 2003). The time range corresponding to this South-Tethyan unit is equivalent to sequences Ba3 to Bd1 of Clavel et al. (2007) as in Granier et al. (2003), not Ba1-Ba4 as in Granier (2000), i.e., Late Barremian-early Bedoulian interval. Accordingly, it can be indirectly correlated with the Moutonian-Ogalianis ammonite zones.

If we take into consideration the occurrence of Rectodictyoconus giganteus in the Jezzinian itself, we can narrow the correlation to the sequences Kharaib 3 and Kharaib 4, or its North-Tethyan equivalent Ba5 and Bd1 of Clavel et al. (2007).

On another side, our macrofossil finds, more specifically that of the irregular echinoid Heteraster oblongus, a marker of the latest Barremian - early Bedoulian in southeastern Europe, below and inside the cliff (i.e., in the Jezzinian), and that of the ammonite Cheloniceras cornuelianum, above the cliff (in the basal Cardium Beds), confirm our age ascription for the newly defined Jezzinian Regional Stage.

6.3) Estimation of the duration of the hiatus at the top of the Jezzinian Regional Stage

In Lebanon, the occurrence of Praeorbitolina comyi in the first strata above the Jezzinian, i.e., at the base of the Cardium Beds, and those of Montseciella arabica and Rectodictyoconus giganteus in the Jezzinian itself suggest that the
upper discontinuity of the regional stage might correspond to a hiatus (Fig. 9) equivalent at least to the duration of the Hawarian (and possibly that of the "ghost" sequence Kharab 5). With respect to CLAVERET et al. (2007), the hiatus would then encompass at least the sequence Bd3 (and possibly that of the "ghost" sequence equivalent, Bd2), i.e., parts of the Weissi and Deshayesian ammonite zones (and possibly the whole Weissi Zone with parts of both the Oglanlensis and the Deshayesi zones).

7. Conclusion

An holostratigraphic re-evaluation of the "Falaise de BLANCHE" led us to redefine it, not as in DUBERTRET's times as a facies-driven "formation" but, as a 'time-constrained' stratigraphic unit, i.e., an unit bounded by two discontinuities: the Jezzinian Regional Stage, UBU or Alloformation (in our understanding these three terms represent slightly similar concepts). On the basis of biostratigraphic information (mostly derived from micropaleontological data, but only supplemented by some macropaleontological data) and through a holostratigraphic approach, the newly defined Jezzinian should fall in a time interval corresponding to the latest Barremian - early Bedoulian. The upper boundary may locally correspond to a significant intra-Bedoulian hiatus (i.e., spanning at least parts of the Weissi and Deshayesian ammonite zones). As currently understood, the lower boundary is probably intra-latest Barremian. Consequently the underlying strata, which yield charophyte remains (GRAMBAST & LORCH, 1968) overlying (e.g., "ZUMOFFEN Cliff") units will probably help to confirm and refine these preliminary results.

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A part of the studied material (ammonites and echinoids) is registered with MHNUL numbers in the collections of the Muséum d'Histoire naturelle, Université Libanaise, Fanar - El-Matn (Lebanon); another part, consisting of the thin sections, is deposited with LPB numbers in the collections the Département des Sciences de la Terre et de l'Université de Bretagne Occidentale, Brest (France).

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Plates

**Plate 1:** Lateral view (A) and ventral view (B) of *Cheloniceras* sp. (MHNUL 22797/0006), lowermost *Cardium* Beds, Kanat Bakich. Scale bar = 1 cm.

**Plate 2:** A-B: Lateral view (A) and ventral view (B) of *Cheloniceras* sp. (MHNUL 22797/0002), lowermost *Cardium* Beds, Kanat Bakich; C-D: Lateral view (C) and ventral view (B) of *Cheloniceras cornelianum* (ORBIGNY, 1841) (MHNUL 22797/0001), lowermost *Cardium* Beds, Kanat Bakich; E: Lateral view of a *Cheloniceras cornelianum* (ORBIGNY, 1841) (MHNUL 23655/0001), lowermost *Cardium* Beds, Kfar Nabrakh. Scale bar = 1 cm.
Plate 3: A-B: Apical view (A) and oral view (B) of *Tetragramma malbosi* (AGASSIZ & DESOR, 1846), *Cardium* Beds, Zaarour (MHNUL 22733/0001), Leg. 12/09/2013; C-E: Apical views and I: Left side view of *Heteraster oblongus* (BRONGNIART, 1821), lower Jezzinian; C and E: Kanat Bakich; C (MHNUL 22797/0002) and E (MHNUL 22797/0003); D and I: Kfardebiane (MHNUL 25439/0001); F: Apical view of *Heteraster delgadoi* (LORIOL, 1888), *Cardium* Beds, Kanat Bakich (MHNUL 22797/0001). G-H: Apical views of *Nucleopygus roberti* (A. GRAS, 1848), uppermost strata of "Grès de Base", Daychounieh; G (MHNUL 37321/0001) and H (MHNUL 37321/0002). Material identification by B. CLAVEL. All scale bars = 1 cm.
Plate 4: Microfossils, calcareous algae and benthic foraminifers, from the Jezzinian interval. A: Axial section of *Salpingoporella hasi* CONRAD et al., 1977, Maarab, thin-section MEB44; B: Transverse section of *Salpingoporella hasi* CONRAD et al., 1977, Maarab, thin-section MEB44; C: Transverse section of *Montiella elitzae* (BAKALOVA, 1971), East Ain Dara, thin-section EAD18; D: Subaxial section of *Montiella elitzae* (BAKALOVA, 1971), East Ain Dara, thin-section EAD19; E: Oblique sections of *Genotella pfenderae* (KONISHI & EPIS, 1962), Ain-El-Bnaya, thin section VO4; F: Subaxial section of *Praechrysalidina infracretacea* LUPERTO SINNI, 1979, Maarab, thin-section MEB74; G: Longitudinal section of *Salpingoporella muehlbergii* (LORENZ, 1902), Maarab, thin-section MEB73; H: Oblique section of a new species of Triploporellaceae, East Ain Dara, thin-section EAD18; I: Longitudinal section of *Suppliersiumaella polycreme* ELLIOTT, 1968, Aarbet Kozhaya, thin section AAR 16.4; J: Oblique section of *Harlanjohnsonella annulata* ELLIOTT, 1968, El Sheayeb, thin-section VO15; K: Transverse section of *Salpingoporella muehlbergii* (LORENZ, 1902), Maarab, thin-section MEB73; L: Oblique section of a verticil of *Actinoporella* gr. *podolica* (ALTH, 1878), East Ain Dara, thin-section EAD19; M: Equatorial section of *Choffatella decipiens* SCHUMBERGER, 1905, Maarab, thin-section MEB44; N: Longitudinal-subaxial section of *Lituola cf. inflata* LOZO, 1944, Ain-El-Bnaya, thin-section VO36; O: Tangential sections of *Salpingoporella muehlbergii* (LORENZ, 1902), Maarab, thin-section MEB73; P: Tangential section of a verticil of *Actinoporella* gr. *podolica* (ALTH, 1878), East Ain Dara, thin-section EAD20; Q: Longitudinal-subaxial section of *Buccicrenata hedbergi* (MAYNC, 1953), East Ain Dara, thin-section EAD20; R: Oblique section of *Salpingoporella dinarica* (RADOIČIĆ, 1959), East Ain Dara, thin-section EAD19; S: Oblique section of *Involutina hungarica* (SIDŐ, 1952), East Ain Dara, thin-section EAD38; T: Axial section of *Involutina hungarica* (SIDŐ, 1952), East Ain Dara, thin-section EAD38; U: Subaxial section of *Choffatella decipiens* SCHUMBERGER, 1905, East Ain Dara, thin-section EAD18; V: Transverse section of *Salpingoporella dinarica* (RADOIČIĆ, 1959), Maarab, thin-section MEB73; W: *Pseudotextulariella scarsella* (DE CASTRO, 1964), Ain-El-Bnaya, VO74. Scale bar = 500 µm.
Plate 5: Montseciella arabica. Deir Kreim, Ghosta. A: Axial section, thin section Krim-4a; B: Axial section, thin section Krim-6a; C: Axial section, thin section Krim-2b; D: Oblique section, thin section Krim-3b; E: Subaxial section, thin section Krim-3a; F: Subaxial section, thin section Krim-2a; G: Subtransverse section, thin section Krim-4c; H: Subtransverse section, thin section Krim-1b; I: Oblique section, thin section Krim-2c; J: Subaxial section, thin section Krim-6b. Thin sections prepared by B. CLAVEL. Scale bar = 500 µm.
