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1 **Ammonoid and foraminiferal biostratigraphy from uppermost Valanginian to**  
2 **lowermost Barremian of the Jebel Boulahouajeb section (northern Tunisia)**

3

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15

16 **Abstract**

17 A stratigraphic study was carried out on the Jebel Boulahouajeb section (Lansarine Chain;  
18 Tebourba area, northern Tunisia) in order to establish a relatively detailed biostratigraphic  
19 framework of the Hauterivian pelagic deposits of the Tunisian trough. The limestone–marl  
20 alternations are represented by five limestone-dominated intervals, named calcareous bundles  
21 H1 to H5, separated by thick marly-dominated intervals. The well exposed Jebel  
22 Boulahouajeb section (873 m in thickness) is relatively continuous, rich in ammonoid  
23 macrofauna, and provides an ideal succession for this approach. Concerning the Hauterivian  
24 ammonoid zonal scheme, the following (sub-)zones have been identified: *Acanthodiscus*  
25 *radiatus*, *Crioceratites loryi*, *Lyticoceras nodosoplicatum*, *Balearites balearis* (with *B.*

26 *balearis*, *Balearites binelli*, *Balearites krenkeli* and *Balearites angulicostatus* Subzones) and  
27 *Pseudothurmannia ohmi* (with *P. ohmi*, *Pseudothurmannia mortilleti* and *Pseudothurmannia*  
28 *picteti* Subzones) Zones. Thus, except the *Subsainella sayni* and *Plesiospidiscus ligatus*  
29 Zones, the standard zonation of the Mediterranean Province has been recognized in this area  
30 of the Tunisian trough. The boundaries of the Hauterivian stage have been characterized by  
31 identifying the last zone of Valanginian (*Criosarasinella furcillata* Zone) and the first zone of  
32 Barremian (*Taveraidiscus hugii* Zone). The benthic and planktic foraminiferal assemblages  
33 have been used to characterize some stratigraphic levels of the studied section; however the  
34 lack of certain data did not allow to well recognize and establish a complete zonal scheme.  
35 Mainly on the base of ammonoid biostratigraphy, the Jebel Boulahouajeb section is correlated  
36 with the Jebel Oust section (north–west of Zaghouan) that is the Lower Cretaceous reference  
37 section of the Tunisia trough.

38  
39 Keywords: Ammonoids; Foraminifera; Hauterivian; Jebel Boulahouajeb; Jebel Oust; Tunisia

## 41 1. Introduction

42 In his monography on Mesozoic cephalopods of Tunisia, Pervinquière (1907) provided a  
43 subdivision of the Early Cretaceous series. This important work was completed by Solignac  
44 (1927) who focused his geological survey on the northern Tunisia. Since the middle part of  
45 the 20<sup>th</sup> century, a succession of papers allowed to constraint the bio-lithostratigraphy of this  
46 interval using mainly ammonoids and foraminifera, and sometimes calpionellids (Castany,  
47 1951; Bolze et al., 1952; Jauzein, 1967; Memmi, 1965, 1969, 1973, 1979, 1981, 1989;  
48 Busnardo and Memmi, 1972; Memmi and Maamouri, 1974; Stranik et al., 1974; Donze et al.,  
49 1975; Memmi and Salaj, 1975; Maamouri and Salaj, 1978; Salaj, 1980, 1984; Ben Haj Ali et  
50 al., 1993; Maamouri et al., 1994; Ben Haj Ali, 2005, 2006, 2008). Recently Ben Haj Ali and

51 Memmi (2013) compiled a synthesis presenting a correlation between the ammonoid and  
52 foraminifera zonal schemes for the Lower Cretaceous of northern Tunisia. Since Castany  
53 (1951), the Jebel Oust locality (north–west of Zaghouan, 40 km South-East of Tebourba,  
54 Tunisia trough) has been considered as a reference for the Lower Cretaceous marine  
55 succession, and consequently numerous authors quoted previously focused on this section.  
56 Due to its relative continuity and richness in micro and macrofauna, Salaj proposed, during  
57 the meeting of the working Group on Pelagic Facies in Urbino in 1989, the Jebel Oust section  
58 as a standard for marine Lower Cretaceous successions of the Tethyan realm (see Maamouri  
59 et al., 1994). In his work on the Lansarine Chain (Tebourba area, northern Tunisia), Zargouni  
60 (1975) described and figured two sections for the Lower Cretaceous series: the Jebel  
61 Boulahouajeb and Tazega sections. The Jebel Boulahouajeb section appeared interesting for  
62 the Valanginian–Aptian interval due to its important thickness and richness in ammonoids  
63 that was also sampled by Solignac (1927). Zargouni (1975) underlined the presence in this  
64 section of several foraminifera, calpionellid and nannofossil taxa. Considering the literature  
65 on the stratigraphy of north Tunisia, it is important to note that, even in the works published  
66 during the last decades, the stratigraphic columns of the most sections were generally not  
67 detailed as they concerned the Lower Cretaceous period, and the sampling of macrofauna was  
68 very sparse. The data was often presented as a species list, and the ammonoids collected were  
69 generally not documented (rarely illustrated; as noted by Lehmann et al., 2009).

70 The aim of this work is to (1) establish a detailed biostratigraphic framework with both  
71 ammonoids and foraminifera of the Jebel Boulahouajeb section, mainly for the Hauterivian  
72 stage including the characterization of its boundaries, (2) illustrate some ammonoid and  
73 foraminifera species of the studied section, and (3) establish correlations with the Jebel Oust  
74 reference section using mainly the ammonoid data. The Jebel Boulahouajeb section provides  
75 an ideal succession for this approach owing to the expanded, continuous well exposed

76 outcrops and relatively abundant fossil records, in particular ammonoids which are relatively  
77 abundant and well preserved (see Melliti, 2012; Melliti et al., 2013).

78

## 79 **2. Geological setting**

80 The Jebel Boulahouajeb section is located in northern Tunisia near Tebourba city, about 40  
81 km west of Tunis (Fig.1). The studied section belongs to the Lansarine Chain, delimited by  
82 the vast plain of the Medjerda valley to the south and east, and by the plain of the Oued Ettine  
83 to the north and north–west. The Mesozoic stratigraphy, palaeogeography, structures and  
84 tectonics of northern Tunisia were described by numerous authors as Burollet (1956, 1991),  
85 Bonnefous (1972), Zargouni (1975), Memmi et al. (1989), Bobier et al. (1991), Rais et al.  
86 (1991), Souquet et al., (1997), Chikhaoui et al. (1998), Soussi et al. (2000), Kamoun et al.  
87 (2001), Bensalem (2002), Piqué et al. (2002), Soussi (2003), Boughdiri et al. (2006), Ben  
88 Abdesselam-Mahdaoui et al. (2010, 2011), Masrouhi et al. (2013), Naji et al. (2018a,b). The  
89 Jebel Boulahouajeb section belongs the Tunisian trough (“sillon tunisien”, Castany, 1951), a  
90 strongly subsiding basin from the Jurassic to Cretaceous time span. It corresponds to a deep  
91 marine palaeoenvironment characterized by pelagic-deep deposits. The Lower Cretaceous  
92 succession of this area is represented by very thick marly-limestone series with intercalation  
93 of some sandstone beds. Large and numerous diapiric intrusions of mainly evaporitic triassic  
94 material are also present (Perthuisot, 1981; Burollet, 1991). Zargouni (1975) described the  
95 Hauterivian–Aptian interval of the Jebel Boulahouajeb section, suggesting that this pelagic  
96 succession could start with the Valanginian; he noted the presence of a Triassic intrusion at its  
97 base. In northeastern Tunisia, the Valanginian–Aptian succession is named the M’Chergua  
98 Formation (Ben Ferjani et al., 1990; Burollet, 1991). Recently, it was raised to the rank of  
99 Group and subdivided into four formations which are from the bottom up (Ben Haj Ali,  
100 2008): El Mergueb (Valanginian to lower Hauterivian), Kef En Nemour (upper Hauterivian to

101 upper Barremian), Sidi Amor (uppermost Barremian to basal Aptian) and Oued Ellouz  
102 (Aptian) formations.

103

### 104 **3. Material and methods**

#### 105 **3.1. Ammonoids**

106 A preliminary study of macrofauna of the Jebel Boulahouajeb section was started by Melliti  
107 (2012) in the El Manar University of Tunis. This palaeontological material has been  
108 completed by further samplings made by Melliti, from 2013 to 2016. Sampling of  
109 macrofaunal specimens was carried out at fifty four beds. Due to the thickness of the section  
110 (873 m, see part 4.1), a bed by bed sampling was not possible for this preliminary study. The  
111 marly intervals were not sampled as the outcrop conditions were not favourable. The selected  
112 intervals were sampled for their content of pelagic (589 ammonoids representing 95% of  
113 macrofauna; 8 aptychi; 15 belemnites) and benthic macrofauna (1 bivalve and 6 echinoids);  
114 nautiloids (shells and rhyncholites) were not found.

115 Dissolution of the ammonoid shells is the norm and specimens are preserved as internal  
116 calcareous moulds. The ammonoid fauna is relatively well preserved, but the fragmentation of  
117 specimens can be frequent in some beds. The compaction of specimens is relatively  
118 important, particularly for the phragmocone. Consequently, some characteristics, such the  
119 whorl section, the strength of ribs and tubercules, and how they change between the inner and  
120 outer whorls, cannot be observed and compared for some specimens. The palaeontological  
121 material was reviewed and taxonomically identified at the University of Lyon (Reboulet and  
122 Melliti). The identification of ammonoids at specific level is sometimes difficult or  
123 impossible. Some data are here presented at the generic level and some specimens identified  
124 with doubt are indicated by a question mark. The material is stored in the palaeontological

125 collections of the Observatory of Lyon at the Claude Bernard University of Lyon (France,  
126 Melliti's collection).

127

### 128 **3.2. Foraminifera**

129 One hundred and fifty four samples were collected in the Jebel Boulahouajeb section; most of  
130 them (75%) come from the marly beds. Spacing is variable and ranges from less than 5 m to  
131 10 m as the section is very thick. In the laboratory, 300 gr of each sample were analyzed at the  
132 University of Tunis by Ben Haj Ali and Melliti. Marly sediments were soaked in tap water  
133 and H<sub>2</sub>O<sub>2</sub>. After twenty four hours, the samples were washed through a set of sieves (63 µm–  
134 500 µm). The sieve with mesh opening of 63 µm is recommended. Processed samples, once  
135 dried, were stored in closed small plastic bags. The microfaunal assemblage is represented by  
136 benthic and planktic foraminifera, ostracods (rare) and echinoid spines (frequent). It is  
137 necessary to note that planktic foraminifera were carried out only in the fine fraction. They  
138 have a well preserved calcitic test, unlike for the forms described in other sections of the  
139 northeastern Tunisia, which are represented by a pyritised test. Due to their very small size,  
140 their identification is often difficult. Even if planktic foraminifera are rare, they have been  
141 studied for their biostratigraphic interest. The benthic foraminifera are common to frequent in  
142 residus and were found in the coarse and fine fraction. Despite of their abundance, just a  
143 preliminary study of this group is presented here. The samples were examined under a  
144 binocular microscope with optics power twenty times; this magnification is not very adequate  
145 to recover easily very small planktic foraminifera. Specimens were mounted in one hundred  
146 and sixty cell-slides. Representative specimens illustrated were photographed using Scanning  
147 Electron Microscope. The selection of illustrated specimens is based on the stratigraphic  
148 importance of the index-species of planktic foraminifera and the importance of associated  
149 benthic foraminifera taxa.



150

151 **4. Results**152 **4.1. Description of the Jebel Boulahouajeb section**

153 The Jebel Boulahouajeb section (JBH; 873 m in thickness) is composed by two  
154 complementary sections (sections JBH-A and JBH-B) from the M'Chergua Group (*sensu* Ben  
155 Haj Ali, 2008), with abnormal contact of Triassic deposits at the base. On the well-exposed  
156 intervals, all beds have been identified and drawn on the field notebook (Melliti, Ben Haj Ali  
157 and Sabri Arfaoui); however, due to the important thickness of the section JBH-B, the drawn  
158 scheme was simplified. Outcrop conditions are sometime less favorable to make a precise  
159 observation as some marly-dominated intervals are more or less affected by scree-cover.

160 The section JBH-A (Fig. 2; 50 m. thick) starts with a metric bed of red sandstone, followed by  
161 an alternation of yellowish limestones and gray marls, attributed to the upper Valanginian.

162 The section JBH-B (Fig. 3ab; 823 m thick) starts after a lateral displacement of 10 m to  
163 north-west from the top of section JBH-A. About 20 m of limestone-marl alternations of the  
164 upper Valanginian are exposed at the base of the succession. The Hauterivian is represented  
165 by 783 m of thickness, including a 65 m gap of observation. The deposits are made of  
166 nodulous limestones, yellow in patina and grey colour when broken, and alternating grey  
167 marls. The succession is characterized by calcareous bundles that are limestone-dominated  
168 intervals (thick calcareous beds and reduction of marl-bed thickness); they are separated by  
169 thick marl-dominated intervals. Starting by a sandstone bed (JBH-B3; 3 m, ochre's color), the  
170 lower part of the section JBH-B is composed by two calcareous bundles named H1 (JBH-B5  
171 to B20; 34 m) and H2 (JBH-B22 to B32; 27 m), separated by a marly interval. In the middle  
172 part of the section JBH-B, the marly interval is characterized by two calcareous bundles,  
173 named H3 (JBH-B86 to B97; 24 m) and H4 (JBH-B163 to B170; 28 m), and several more or  
174 less continuous sandstones or siltstones beds (above JBH-B32, JBH-B48-59-65-72-75, above

175 JBH-B115, and JBH-B181). In the upper part of the section JBH-B, a succession of thick beds  
176 allows to recognize a fifth calcareous interval named H5 (JBH-B202 to B219; 26 m), known  
177 as the “cornice of Jebel Boulahouajeb” of Zargouni (1975). The uppermost part of the section  
178 JBH-B is represented by marls and grey limestones attributed to lowermost Barremian (20 m).

179

## 180 **4.2. Ammonoids**

### 181 **4.2.1. Systematics**

182 The ammonoid fauna of the studied section consists of thirty one genera grouped into fourteen  
183 families and nine super-families (Appendix 1), mainly using the classification proposed by  
184 Klein (2005), Vermeulen and Klein (2006), Klein et al. (2007, 2009), and Klein and Vašíček  
185 (2011). As the purpose is not to make a systematic revision, only palaeontological comments  
186 are made for some taxa and quantitative data are also given. Further information is available  
187 in the papers of Company (1987), Reboulet et al. (1992), Bulot et al. (1993), Bulot (1995),  
188 Hoedemaeker (1995, 2013), Reboulet (1996), Cecca et al. (1998), Reboulet and Atrops  
189 (1999), Busnardo et al. (2003), Company et al. (2003, 2005), Vermeulen (2003), Ettachfani  
190 (2004), Vermeulen et al. (2012, 2013).

191

192 Neocomitids are rare to common and they occur in the lower part of the Jebel Boulahouajeb  
193 section (section JBH-A, Fig. 2; section JBH-B, Fig. 3a). They are represented by *Teschenites*  
194 (12 specimens), *Eleniceras* (3 specimens), *Lyticoceras* (4 specimens; Figs. 4A and 4B),  
195 *Jeanthieuloyites* (6 specimens) and *Spitidiscus* (31 specimens). Due to the relatively bad  
196 preservation of the material in these beds, the identification of species is difficult for the first  
197 three genera; only few *Teschenites subflucticulus* (Fig. 4C) have been recognized in beds  
198 JBH-A5 and A7. In this interval also occur *Jeanthieuloyites keyserlingiformis* (Fig. 4D),  
199 *Jeanthieuloyites quinquestriatus* (Fig. 4E) and *Jeanthieuloyites solignaci* (Figs. 4F and 4G).

200 The first *Spitidiscus* (identified with doubt) occurs in JBH-B7; the lowest occurrences (LO) of  
201 *Spitidiscus lorioli* (Figs. 4H and 4I) and *Spitidiscus meneghini* (Figs. 4J, 4K, 4L) are recorded  
202 in beds JBH-B9 and B10, respectively; only one *Spitidiscus rawsoni* (Fig. 4M) have been  
203 found in bed JBH-B30. Even though *Himantoceras* is characterized by a cryptoconic shell, this  
204 genus should be assigned to the Neocomitinae (the phyletic relation has been shown by  
205 Reboulet, 1996, 2007, 2008) and not to the Ancyloceratids as kept by Klein et al. (2007). One  
206 specimen of *Himantoceras* cf. *trinodosum* (Fig. 4N) has been found in bed JBH-B4.  
207 Olcostephanids are common to frequent in some beds. Among *Olcostephanus* (62 specimens),  
208 *Olcostephanus densicostatus* (Figs. 5A and 5B) has been identified in the section JBH-A (Fig.  
209 2). *Jeannoticeras jeannoti* (2 specimens; Fig. 5C) has been recorded in beds JBH-B20 and  
210 B21 (Fig. 3a).  
211 Oosterellids are rare and this family is represented by three species of *Oosterella* (8  
212 specimens; Figs 2 and 3a): *Oosterella undulata* (Fig. 5D), *Oosterella cultrata* (Fig. 5E) and  
213 *Oosterella cultrataeformis*.  
214 Holcodiscids are very rare and only three specimens of *Avramidiscus intermedius* (Fig. 6A)  
215 have been found at the uppermost part of the section JBH-B (beds JBH-B232 and B234; Fig.  
216 3b).  
217 Barremitids are mainly represented by *Plesiospitidiscus* (50 specimens): *Plesiospitidiscus*  
218 *fasciger* (Figs. 6B and 6C) have been sampled in beds JBH-B18 and B20 (Fig. 3a); the middle  
219 part of the section JBH-B is characterized by *Plesiospitidiscus subdifficilis* (Figs. 6D and 6E;  
220 Fig. 3b). In this interval, one *Abrytusites neumayri* (Fig. 6F) has been recorded. Other genera  
221 of this family occur in the upper part of the section JBH-B with one *Barremites* gr. *cassida*  
222 (Fig. 6G), two *Montanesiceras* cf. *dimboviciorensis* and two *Valdedorsella?* *uhligi* (Fig. 6H).  
223 Pulchelliids are very rare in the section JBH-B and only five specimens of *Discoideilia* have  
224 been recorded (Fig. 3b): *Discoideilia* cf. *couratieri* (Figs. 6I and 6J) and *Discoideilia favrei*.

225 Haploceratids, with *Neolissoceras grasianum* (Fig. 7A), mainly occurs in the section JBH-A  
226 and in the lowermost part of the section JBH-B (13 specimens; Figs. 2 and 3a); only one  
227 specimen has been sampled in the middle part of the section JBH-B (bed JBH-B163; Fig. 3b).  
228 Phylloceratoids are represented by *Phylloceras* (*Hypophylloceras*) with 16 specimens  
229 (*Phylloceras* (*Hypophylloceras*) *tethys*, Fig. 7B; *Phylloceras* (*Hypophylloceras*) *ponticuli*)  
230 and *Phyllopachyceras* with 31 specimens (*Phyllopachyceras winkleri*, Fig. 7C;  
231 *Phyllopachyceras infundibulum*, Figs. 7D and 7E) which are more frequent in the lower part  
232 rather in the upper part of the section JBH-B (Figs. 2 and 3ab). This last species has not been  
233 found in the section JBH-A (Fig. 2); it seems that the first specimen (identified with doubt)  
234 occurs in bed JBH-B9 (Fig. 3a).  
235 Lytoceratids (61 specimens) are represented by *Lytoceras subfimbriatum* (Figs. 7F and 7G);  
236 the genus *Lytoceras* is relatively common (Figs. 2 and 3ab).  
237 Crioceratitids are represented by *Balearites* (69 specimens) and *Pseudothurmannia* (161  
238 specimens) which are relatively abundant, particularly in beds JBH-B163 and B202,  
239 respectively (Fig. 3b). In this work, the opinion of Company et al. (2003) is followed:  
240 *Balearites balearis*, *Balearites binelli*, *Balearites krenkeli* and *Balearites angulicostatus* could  
241 constitute a phylogenetic lineage. These species were included in the genus *Crioceratites* by  
242 these authors. More recently, the first three species were considered as belonging to  
243 *Balearites* by Vermeulen et al. (2012). However, these both teams have a different conception  
244 of the genus *Balearites*; for Vermeulen et al. (2012), some species of *Pseudothurmannia*  
245 should be included in *Balearites*, and these authors do not consider *angulicostatus* as a  
246 *Balearites*. Taking into account their new data and observations, Matamales and Company  
247 (personal communication, 2017) suggest that the group/lineage *balearis-binelli-krenkeli-*  
248 *angulicostatus* should belong to the genus *Balearites*. According to Company et al. (2003),  
249 the evolutionary trend of this group is towards “a stronger ornamentation and a clear

250 differentiation between main and intermediate ribs in the middle ontogenetic stages". The  
251 ornamentation of *B. balearis* is characterized in the middle stages by uniform and dense ribs  
252 lacking distinct umbilical tubercles. In bed JBH-B92 (Fig. 3b), three specimens have been  
253 identified as *B. cf. balearis* (Fig. 8A). The second member of the lineage is *B. binelli* (Figs.  
254 8B to 8E); it differs in the appearance of ribs bundles rising from well-defined umbilical  
255 bullae. *B. binelli* seems relatively frequent as fifteen specimens have been sampled in bed  
256 JBH-B163 and numerous *Balearites* sp. ind. found in this bed probably belong to this species.  
257 The next species of the group is *B. krenkeli*; a clear differentiation between main and  
258 intermediate ribs from quite early ontogenetic stage can be observed. One specimen belonging  
259 to bed JBH-B195 is identified with doubt to this species (Fig. 8F). *Balearites angulicostatus*  
260 is the last species of this lineage and the ancestor of *Pseudothurmannia* forms (Hoedemaeker,  
261 1995; Company et al., 2003). In the studied section, two specimens are identified as  
262 *Balearites cf. angulicostatus* (Figs. 8G and 8H) in bed JBH-B195. In their work, Company et  
263 al. (2003) recognized four species of *Pseudothurmannia*. These authors observed the  
264 consecutive appearance of *Pseudothurmannia ohmi*, *Pseudothurmannia mortilleti* and  
265 *Pseudothurmannia picteti*; this evolutionary trend is towards a more involute coiling. They  
266 noted that *P. ohmi* "differs from its ancestor *angulicostatus* in having the whorls always in  
267 touch and having definitively lost the initial trituberculate stage". In the Jebel Boulahouajeb  
268 section, *P. mortilleti* (Figs. 9A to 9E) is well represented and co-occurs with  
269 *Pseudothurmannia pseudomalbosi* (Figs. 9F, 9G and 10A). Just above this stratigraphic  
270 interval, one specimen of *P. picteti* (Fig. 10B) has been recorded (bed JBH-B219, Fig. 3b). *P.*  
271 *ohmi* has not been recognized. Taking into account the stratigraphic distribution of the last  
272 *Balearites* and first *P. mortilleti* found in beds JBH-B195 and JBH-B202, respectively, *P.*  
273 *ohmi* should take place in this interval (from top JBH-B195 to base JBH-B202) in which first  
274 specimens of *Pseudothurmannia* sp. ind. have been sampled (bed JBH-B200); indeed,

275 according to the distribution of species given by Company et al. (2003), *Balearites* (*balearis-*  
276 *binelli-krenkeli-angulicostatus* group) and *Pseudothurmannia* (*ohmi-mortilleti-picteti* group)  
277 do not coexist (no overlapping of their ranges). The identification at the specific level was not  
278 possible for the three specimens of *Sornayites* found in this part of the section JBH-B  
279 characterized by numerous *Pseudothurmannia*.  
280 Emericiceratids (2 specimens: *Honnoratia* cf. *thiollieri*; *Paraspiticerias* sp. ind., Fig. 10C),  
281 Leptoceratoidids (4 specimens: *Hamulinites* sp. ind.; *Sabaudiella simplex*, Fig. 10D) and  
282 Hamulinids (2 specimens: *Anahamulina lorioli*; *Amorina*?) are very rare and restricted in the  
283 upper part of the section JBH-B (Fig. 3b). Bochianitids (5 specimens: *Bochianites*  
284 *neocomiensis*) have been found in the section JBH-A and in the lowermost part of the section  
285 JBH-B (Figs. 2 and 3a).

286

#### 287 **4.2.2. Biostratigraphic implications**

288 According to the stratigraphic distributions of ammonoid taxa of the studied section (Figs. 2  
289 and 3ab), the whole Hauterivian stage is represented in the Jebel Boulahouajeb section. Most  
290 of the Hauterivian zones of the Standard zonation (Hoedemaeker et al., 2003; Reboulet et al.,  
291 2018) have been recognized. All of these are interval zones and their lower boundary is  
292 identified by the LO of the index-species (their upper boundary is identified by the base of the  
293 next zone). The main references concerning the stratigraphic distribution of taxa allowing to  
294 characterize the zones are indicated.

295 The section JBH-A belongs to the *Criosarasinella furcillata* Zone (Fig. 2), of Valanginian  
296 age, taking into account the occurrence of *Teschenites* sp. ind., *T. subflucticulus* (Reboulet,  
297 1996; Reboulet and Atrops, 1999) and *J. keyserlingiformis* (Avram, 1995). This interval is  
298 also marked by the occurrence of *Eleniceras* sp. ind., *O. densicostatus*, *O. ondulata*, *J.*  
299 *quinqwestriatus* and *J. solignaci*; these taxa are present in the uppermost part of the

300 Valanginian, but they are also known in the lowermost part of the Hauterivian (Reboulet,  
301 1996). The Hauterivian is not characterized here due to the absence of *Spitidiscus* and *P.*  
302 *infundibulum*.

303 The Valanginian–Hauterivian boundary can be drawn in the lowermost part of the section  
304 JBH-B (Fig. 3a), and is placed at the base of bed JBH-B7 in which a specimen of *Spitidiscus*  
305 sp. ind. has been found. When *Acanthodiscus* or *Breistrofferella* are absent (*Acanthodiscus*  
306 *radiatus* is the index-species of the first zone of the Hauterivian stage), the LO of *Spitidiscus*  
307 can be used to characterize the base of the Hauterivian (Reboulet, 1996; Busnardo et al.,  
308 2003). Just below bed JBH-B7, a specimen of *H. cf. trinodosum* has been recorded in bed  
309 JBH-B4. According to Reboulet (1996; see also Reboulet and Atrops, 1999), *H. trinodosum* is  
310 restricted to the upper Valanginian. Bulot et al. (1993) found in the lowermost part of the *A.*  
311 *radiatus* Zone (La Charce section, France) a (or few?) specimen(s) of *Himantoceras* identified  
312 as *H. cf. trinodosum*. This/these specimen(s) could correspond to *Himantoceras* n. sp. 2, taxa  
313 described by Reboulet (1996) and located in the basal part of the *A. radiatus* Zone (only three  
314 specimens found in the Les Sias section, France). Consequently, *H. trinodosum* should be  
315 restricted to the upper Valanginian. The *A. radiatus* Zone is characterized by the occurrences  
316 of *S. lorioli*, *S. meneghini* and *P. infundibulum* (Bulot, 1995; Reboulet, 1996); all or a part of  
317 these taxa are recorded in beds JBH-B9 and B10. The assemblage of the interval JBH-B8 to  
318 B10 is also characterized by *Teschenites* sp. ind., *O. cultrata* and *O. cultrataeformis*. The bed  
319 JBH-B9 could correspond to the middle part of the *A. radiatus* Zone as the range of these  
320 Oosterrelid species ends in the lower part of this zone in SE France and the range of *P.*  
321 *infundibulum* starts in its upper part (Reboulet, 1996).

322 The *Crioceratites loryi* Zone is not directly characterized as the index-species has not been  
323 found. In the Jebel Boulahouajeb section, the highest occurrence (HO) of *S. meneghini* and *S.*  
324 *lorioli* (in bed JBH-B11) is used to put the lower boundary of this zone at the base of bed



325 JBH-B12 (Fig. 3a). Even if Reboulet (1996) noted the occurrence of *S. meneghini* in the  
326 lowermost part of the *C. loryi* Zone, it seems that these both species of *Spitidiscus* are mainly  
327 restricted in the *A. radiatus* Zone (see Bulot, 1995).

328 The *Lyticoceras nodosoplicatum* Zone has been recognized with the LO of *Lyticoceras* sp.  
329 ind. in bed JBH-B20 (Fig. 3a). The fact that this taxa co-occurs with *P. fasciger*, in bed JBH-  
330 B20, and *J. jeannoti*, in beds JBH-B20 and 21, allows to characterize the lowermost part of  
331 the zone (the *Olcostephanus variegatus* Horizon; Bulot, 1995). *Lyticoceras* sp. ind. and *S.*  
332 *rawsoni* have been found in beds JBH-B24 and B30, respectively; according to Bulot (1995)  
333 and Reboulet (1996) these both taxa are restricted to the *L. nodosoplicatum* Zone.

334 The *Subsaynella sayni* and *Plesiospitidiscus ligatus* Zones have not been identified as the  
335 interval from the top of JBH-B30 to the base of JBH-B86 has not been sampled for  
336 macrofauna (Fig. 3a). Consequently, the upper boundary of the *L. nodosoplicatum* Zone is  
337 provisionnaly placed at the top of bed JBH-B30.

338 The *Balearites balearis* Zone is well identified in the studied section. Its base is placed at the  
339 base of bed JBH-B92 in which several specimens of *Balearites* sp. ind. and *B. cf. balearis*  
340 have been recorded (Fig. 3b). Two specimens identified with doubt to the genus *Balearites*  
341 have been found in beds JBH-B86 and B89. This interval is also characterized by the  
342 occurrence of *P. subdifficilis* and *D. cf. couratieri*; according to Company et al. (2003), the  
343 LO of these two latter species are at the base of the *B. balearis* Zone. These observations  
344 could be in favour to place the base of this zone at bed JBH-B86. However, even if the acme  
345 of *D. couratieri* occurs in the *B. balearis* Zone (Vermeulen, 1995), the LO of *D. couratieri* is  
346 in the lower part of the *P. ligatus* Zone (Vermeulen, 2003). Due to the difficulty in identifying  
347 the different species of *Plesiospitidiscus* and considering that their stratigraphic distribution is  
348 not well known around the interval of the *P. ligatus* Zone, it is preferable not to put the base  
349 of the *B. balearis* Zone at the LO of *P. subdifficilis*. The lower boundary of *Balearites binelli*



350 Subzone is placed at the base of bed JBH-B163 where its index-species occurs. It is difficult  
351 to identify the upper boundary of this subzone. The lower boundary of *Balearites*  
352 *angulicostatus* Subzone is drawn at the LO of *B. cf. angulicostatus* sampled in bed JBH-  
353 B195. In this bed, there is also *B. krenkeli*?; the specimen probably represents the end of the  
354 range of the species. Indeed, according to Company et al. (2003), *B. angulicostatus* and *B.*  
355 *krenkeli* co-exist in a short stratigraphic interval of the lowermost part of the *B. angulicostatus*  
356 Subzone. Thus, the *B. krenkeli* Subzone can be provisionally assigned to the interval from the  
357 top of bed JBH-B170 (just above the range of *B. binelli*) to the base of bed JBH-B195 (just  
358 below the LO of *B. cf. angulicostatus*).

359 The *Pseudothurmannia ohmi* Zone is well characterized. Its lower boundary is placed at the  
360 base of bed JBH-B200 where one specimen of *Pseudothurmannia* sp. ind. has been recorded  
361 (Fig. 3b). As observed by Company et al. (2003) for the SE Spain, the HO of *L.*  
362 *subfimbriatum* and *P. subdifficilis* are recorded in the lower part of the zone of the Jebel  
363 Boulahouajeb section; a comparison with their work can also be done for *V.?* cf. *uhligi*, *M. cf.*  
364 *dimboviciorensis* and *D. favrei* that are sampled in the *P. ohmi* Zone of the studied section.

365 The base of the *Pseudothurmannia mortilleti* Subzone is placed at the base of bed JBH-B202  
366 where its index-species first occurs. Its range is similar to that of *P. pseudomalbosi*; this is in  
367 accordance with the data of Company et al. (2003). The lower boundary of *P. picteti* Subzone  
368 is put at the base of bed JBH-B219. This subzone is difficult to characterize as there is a large  
369 stratigraphic interval (65 m in thickness) without observation.

370 The Hauterivian–Barremian boundary is provisionally placed at the base of bed JBH-B232  
371 where the LO of *A. intermedius* is recorded (Fig. 3b), even if this species first occurs in the  
372 uppermost part of the *P. picteti* Subzone as observed by Company et al. (2003). The base of  
373 the Barremian stage is also characterized by the presence of *B. gr. cassida* found in bed JBH-  
374 B234.

375

376 **4.3. Foraminifera**377 **4.3.1. Systematics**

378 The micropaleontological study of planktic foraminifera is based essentially on the work of  
379 Moullade (1974), Caron (1985), Premoli-Silva and Sliter (2002), Ben Haj Ali (2005; 2006),  
380 Ben Haj Ali and Memmi (2013; Appendix 2). Their determination is often difficult due to the  
381 very small size of the studied specimens; the problem of the identification of the lowermost  
382 Cretaceous planktic foraminifera was also noted by Cecca et al. (1994) and Coccioni and  
383 Premoli-Silva (1994). As also underlined by these authors for this interval in Italy and Spain  
384 respectively, the planktic foraminiferal assemblages of the Boulahouajeb section is poorly  
385 diversified; this was also observed in north–west Tunisia by Ben Haj Ali (2005) and Ben Haj  
386 Ali and Memmi (2013). In the studied section (Fig. 11), Favusellids are represented by  
387 *Favusella hoterivica* (Figs. 12A and 12B). Praehedbergellids are composed by two genera:  
388 *Gorbachikella*, represented by *Gorbachikella kugleri* (Figs. 12C and 12D), *Gorbachikella*  
389 *anteroapertura* (Fig. 12E) and *Gorbachikella grandiapertura*, and *Praehedbergella*  
390 represented by *Praehedbergella sigali* (Figs. 12F to 12H). Planktic foraminifera occur only in  
391 the upper part of the section (Fig 11). They are rare to very rare but *P. sigali* is more abundant  
392 in the upper part of its range. The low abundance of the small planktic forms in the  
393 Valanginian and Hauterivian stages is also noted by Coccioni and Premoli-Silva (1994).  
394 Benthic foraminifera are represented by thirty six taxa, which constitute the main part of the  
395 assemblages (Fig. 11). Their palaeontological study is based on Moullade (1974), Neagu  
396 (1975), and Holbourn and Kaminski (1995). In the studied section, calcareous taxa are  
397 represented by nine genera (*Lenticulina*, *Dentalina*, *Frondicularia*, *Marginulinopsis*,  
398 *Catharina*, *Ramulina*, *Marginulina*, *Spirillina* and *Gavelinella*) including twenty two  
399 species/taxa. The agglutinated foraminifera, that are generally less frequent, are composed by

400 five genera (*Dorothia*, *Marsonella*, *Ammodiscidus*, *Bathysiphon* and *Rhizimina*) including  
401 fourteen species/taxa. A poor assemblage of benthic foraminifera is recorded in the upper  
402 Valanginian interval (6 samples; from JBH-B1 to B6) that is characterized by the occurrence  
403 of rare *Lenticulina roemeri* (Fig. 12I). A moderate diversification is observed in the lower  
404 Hauterivian of the Jebel Boulahouajeb section. A stronger increase of number of taxa is  
405 recorded from the lowermost part of the upper Hauterivian (from level JBH-B76 to the top of  
406 the section). The foraminiferal succession for the studied Hauterivian section is subdivided  
407 into nine assemblages based on changes in the composition of dominant taxa and on  
408 occurrences of species with biochronological interest: *Lenticulina eichenbergi* (Fig. 12J),  
409 *Dorothia lilliformis* (Fig. 12K), *Lenticulina multicella* (Fig. 12L), *Dorothia praehauteriviana*  
410 (Fig. 12M), *Lenticulina ouachensis ouachensis* (Fig. 12N), *Dorothia kummi* (Fig. 12O),  
411 *Dorothia zedlerae* (Fig. 12P), *Lenticulina rotulata* (Fig. 12Q) and *Gavellinella barremiana*  
412 (Fig. 12R). These index-species are accompanied by other abundant benthic species (Fig. 11).

413

#### 414 **4.3.2. Biostratigraphic implications**

415 The planktic foraminifera zonation adopted in this work (Fig. 11) corresponds to the local  
416 zonal scheme established by Ben Haj Ali (2005) and Ben Haj Ali and Memmi (2013).

417 Contrary to Maamouri et al. (1994), benthic foraminifera are not used here to define  
418 foraminiferal subzones because the occurrence and distribution of the group is highly  
419 controlled by local ecological conditions (see Moullade, 1974).

420 No planktic forms have been observed in the uppermost Valanginian–lower Hauterivian of  
421 the Jebel Boulahouajeb section. This could be partly explained by the difficulty to identify  
422 specimens due to their small size. Salaj (1984) and Ben Haj Ali (2005; see also Ben Haj Ali  
423 and Memmi, 2013) have noted that the LO of planktic foraminifera are respectively at the  
424 base of the lower Hauterivian and the base of the upper Hauterivian. The low diversification

425 of the lowermost Cretaceous foraminiferal planktic assemblages and their scarceness  
426 (Coccioni and Premoli-Silva, 1994; Cecca et al 1994; Robaszynski and Caron, 1995) could  
427 also explain why these microfossils have not been found in this interval of the studied section.  
428 In the Jebel Boulahouajeb section, only five planktic foraminifera species have been recorded  
429 in the upper Hauterivian–lowermost Barremian interval. The first bioevent (JBH-B37 at the  
430 lowermost part of the upper Hauterivian) is characterized by the LO of *Favusella hoterivica*.  
431 The *F. hoterivica* Interval Range Zone is identified by the LO of the index-species (Van  
432 Hinte, 1972). In the Cretaceous Mediterranean zonal scheme based on planktic foraminifera,  
433 Sigal (1977) indicated that “*Caucasella* gr. *hauterivica-kugleri*” first occurs at the base of the  
434 upper Hauterivian (see also Caron, 1985). In Tunisia (Jebel Oust area), *F. hoterivica* first  
435 occurs at the base of the Hauterivian (Salaj, 1984). For Maamouri et al. (1994), the  
436 “*Globuligerina hoterivica* Zone” characterizes the Hauterivian stage. According to Coccioni  
437 and Premoli-Silva (1994), the “mean range” of “*C. hoterivica*” starts at the base of the  
438 Hauterivian (synthetic data); however these authors indicated that the LO of this species in SE  
439 Spain is at the base of “*Thurmanniceras*” *pertransiens* Zone (base of the Valanginian).  
440 According to Ascoli (1988 in Robaszynski and Caron, 1995), the LO of *F. hoterivica* could be  
441 lower, in the middle–late Berriasian in the NW Atlantic margin of North America. In the Jebel  
442 Boulahouajeb section, only a short part of the stratigraphic range of *F. hoterivica* is recorded  
443 corresponding to the lower part of the upper Hauterivian. Consequently, it is not really  
444 possible to identify this zone in the studied section.

445 The second set of bioevents concerns the LO of three species belonging to *Gorbachikella*: *G.*  
446 *kugleri*, *G. anteroapertura* and *G. grandiapertura* in levels JBH-B73, B91, B109,  
447 respectively. As previously evoked, the range of “*Caucasella* gr. *hauterivica-kugleri*” would  
448 start at the base of the upper Hauterivian (Sigal, 1977). In north Tunisia, BouDagher-Fadel et  
449 al. (1995) indicated that *G. kugleri* occurs in the Hauterivian and its range goes up to the

450 lower Aptian. Ben Haj Ali (2005) recorded the LO of *G. kugleri* at the base of the upper  
451 Hauterivian and she defined the *G. kugleri* Interval Zone that characterized this substage (see  
452 also Ben Haj Ali and Memmi, 2013). When BouDagher-Fadel et al. (1995) described the new  
453 species *G. grandiapertura* and *G. anteroapertura* they did not provide their stratigraphic  
454 distribution; the authors indicated that *G. grandiapertura* ranges in Tunisia from Hauterivian  
455 to Barremian, and *G. anteroapertura* ranges from the upper Hauterivian to lower Aptian. For  
456 Ben Haj Ali (2005), these two species allow to characterize the *G. kugleri* Zone. Referring to  
457 the zonal scheme of this author, the LO of *G. kugleri* in the Jebel Boulahouajeb section is  
458 used to indicate the base of the *G. kugleri* Zone that is also characterized by *G.*  
459 *grandiapertura* and *G. anteroapertura* (Fig. 11).

460 The third bioevent in the planktic distribution of the Jebel Boulahouajeb section is the LO of  
461 *Praehedbergella sigali* in level JBH-B221. For Sigal (1977), "*Hedbergella sigali*" first occurs  
462 at the base of the Barremian (see also Caron, 1985). It is the index-species of the first planktic  
463 foraminifera zone of this stage; this interval zone was defined by Moullade (1966). For  
464 Maamouri et al. (1994), *H. sigali* should be put in synonymy with *Hedbergella tuschpsensis*;  
465 its LO is recorded at the base of the Barremian and this defined the base of the *H.*  
466 *tuschpsensis* Interval Zone. According to Coccioni and Premoli-Silva (1994), the "mean  
467 range" of "*H. sigali*" starts at the base of the Barremian (synthetic data); however, these  
468 authors indicated that this species first occurs at the base of "*T.*" *pertransiens* Zone in SE  
469 Spain. Robaszynski and Caron (1995) underlined that *H. sigali* is rare in the Valanginian and  
470 becomes more frequent during the Hauterivian and Barremian. More recently, Premoli-Silva  
471 et al. (2017) confirmed that *H. sigali* is already present in the upper Hauterivian of SE Spain.  
472 Ben Haj Ali (2005) was the first to recognize the *P. sigali* Zone as the first zone of the  
473 Barremian in Tunisia (see also Ben Haj Ali and Memmi, 2013). In the Jebel Boulahouajeb

474 section, a similar observation is done; the base of the *P. sigali* Zone is placed in the uppermost  
475 part of the Hauterivian where the LO of its index-species is recorded.

476

## 477 5. Discussion

### 478 5.1. Integrated biostratigraphy: ammonoid and foraminifera zonations

479 The calibration of the ammonoid and planktic foraminifera zonations proposed here is  
480 restricted to the upper Hauterivian–lowermost Barremian of the Jebel Boulahouajeb section  
481 (Figs. 3 and 11). The LO of *G. kugleri* and *G. anteroapertura* are in the upper part of the *S.*  
482 *sayni*–*P. ligatus* Zones. *G. grandiapertura* first occurs in the lowermost part of the *B. balearis*  
483 (Sub-)Zone. These three foraminifera species also occur in the *P. ohmi* Zone. So, they  
484 characterize the upper Hauterivian as observed in other Tunisian sections by BouDagher-  
485 Fadel et al. (1995), Ben Haj Ali (2005), and Ben Haj Ali and Memmi (2013). Taking into  
486 account the ammonoid distributions of the Jebel Boulahouajeb section, the base of the  
487 Barremian is placed at bed JBH-B232 (LO of *A. intermedius*), and so the LO of *P. sigali*  
488 (JBH-B221) is recorded in the upper part of the *P. ohmi* Zone (*P. picteti* Subzone). However,  
489 the Hauterivian–Barremian boundary could be lowered at level JBH-B221 where the LO of *P.*  
490 *sigali* is recorded. Indeed, as the ammonoid *Taveraidiscus hugii* (index-species of the first  
491 Barremian zone) has not been found, this boundary can be placed between the HO of  
492 *Pseudothurmannia* (in bed JBH-B219; this genus is restricted in the uppermost part of the  
493 Hauterivian; Busnardo et al., 2003; Company et al., 2003; Hoedemaeker, 2013) and the LO of  
494 *A. intermedius* (bed JBH-B232). In this interval, ammonoid species with a biostratigraphic  
495 interest as *D. favrei* and *B. cf. dimboviciorensis* are rare and they can occur in the *P. ohmi* and  
496 *T. hugii* Zones. The proposal to put the base of the Barremian stage at level JBH-B221 could  
497 be supported considering that *P. sigali* is the index-species of the first Barremian zone in  
498 Tunisia. However, as previously evoked, the LO of *P. sigali* is placed lower in other areas of

499 the Tethyan realm (base of the Valanginian in Spain). Consequently, the Hauterivian–  
500 Barremian boundary is kept at the base of bed JBH-B232.

501

## 502 **5.2. Correlations: Jebel Boulahouajeb and Jebel Oust sections**

503 The Jebel Boulahouajeb section is correlated with the Jebel Oust section (Fig. 13) that is  
504 considered as the reference section for the northern Tunisian lower Cretaceous series (see  
505 Introduction chapter). This correlation is made using the biostratigraphic data (ammonoids  
506 and foraminifera), and the lithologic changes.

507 The ammonoid zonation of the Jebel Oust section was made by Memmi (1981, 1989); it is not  
508 complete for some intervals as some zones were not recognized by the author and the  
509 boundaries between some zones are not defined. Memmi (1989, p. 64) underlined that her  
510 zonal scheme is based on the zonation established for SE France and SE Spain; however she  
511 quoted authors who have worked on the Tithonian to lowermost Hauterivian. For the  
512 Hauterivian, it seems that Memmi (1989) mainly used the zonal scheme established by  
513 Moullade and Thieuloy (1967) and Thieuloy (1977) for SE France; the correlation between  
514 this former zonal scheme and a more recent version is established by Bulot et al. (1993; their  
515 Table 1). Memmi (1989) replaced the *A. radiatus* Zone by the *Breistrofferella castellanensis*  
516 Zone used by Company (1987). Her zonal scheme included the *J. jeannoti* Zone, now  
517 considered as the second subzone of the *C. loryi* Zone in the standard zonation (Reboulet et  
518 al., 2018). Memmi (1989) considered that the *S. sayni* and *P. ligatus* Zones should be  
519 separated but the author grouped them as she was not able to distinguish them in the Jebel  
520 Oust section, and also in other northern Tunisian sections (see Memmi, 1981, 1989). For the  
521 uppermost Hauterivian, Memmi (1981, 1989) considered the “*Balearites balearis*–  
522 *Pseudothurmannia angulicostata* Zone”. For this interval, she recognized in some sections (as  
523 Jebel Bou Kornine) ammonoid assemblages with both index-species and also “*Crioceratites*



524 *krenkeli* and *Pseudothurmannia mortilleti*". The *B. balearis* Zone was introduced by  
525 Busnardo (1984). In Ben Haj Ali and Memmi (2013), the Hauterivian zonal scheme of  
526 Memmi (1989) was slightly modified with the introduction of the *B. balearis* Zone; however,  
527 the *B. castellanensis* Zone and the *S. sayni*–*P. ligatus* Zone are kept. For the lower Barremian,  
528 Memmi (1989) did not use the zonal scheme established by Busnardo (1965; see also Sornay,  
529 1977; Roger, 1980) for the stratotype of Angles section (France) and she replaced the  
530 "Nicklesia pulchella Zone" by her "Holcodiscus caillaudi Zone". For the upper Barremian,  
531 Memmi (1989) used the "Silesites seranonis–Barremites strettostoma Zone" that corresponds  
532 to the "Silesites seranonis Zone" of Busnardo (1965). This latter author subdivided this zone in  
533 three subzones recognized by Memmi (1989) in the Jebel Oust section. For the northern  
534 Tunisia, Ben Haj Ali and Memmi (2013) used the Barremian zonal scheme of Memmi (1989).  
535 Ammonoid taxa with a biostratigraphic interest for the Jebel Oust locality have been reported  
536 on the redrawn section (Fig. 13). Unfortunately, it was impossible to check the identifications  
537 of this material; the ammonoids studied by Memmi (1989) are not illustrated, except for few  
538 taxa occurring around the lower–upper Valanginian and Valanginian–Hauterivian boundaries  
539 (Memmi, 1965, 1970, 1973) and, for the moment, the Memmi's collection is not accessible.  
540  
541 The interval around the Valanginian–Hauterivian boundary in the Jebel Oust section is  
542 relatively well characterized by assemblages allowing to Memmi (1989) to define the  
543 uppermost zone of the Valanginian, the "Teschenites callidiscus Zone" (= *T. callidiscus*  
544 Subzone of the *C. furcillata* Zone in the standard zonation), and the first zone of the  
545 Hauterivian, the "*B. castellanensis* Zone" (= *A. radiatus* Zone in the standard zonation). Even  
546 if this latter index-species has not been found, Memmi (1989) put the base of the Hauterivian  
547 stage at the first bed of Formation 5 (but no ammonoid sampled in this bed; Fig. 13). The  
548 genus *Oosterella* is well represented around the boundary and Busnardo and Memmi (1972)



549 defined a “*Oosterella* interval” corresponding to Formations 4e, 5 to 7 (see also Memmi and  
550 Maamouri, 1974; Memmi, 1981, 1989; Maamouri et al., 1994). In SE France, oosterellids are  
551 more represented in the upper Valanginian but they also occur in the lowermost Hauterivian  
552 (mainly in the *A. radiatus* Zone; Reboulet, 1996, and references therein). The LO of *P.*  
553 *infundibulum* is recorded at the top of Formation 5 of the Jebel Oust section; Memmi (1989,  
554 p. 71) suggested that the LO of this species could be in her “*B. castellanensis* Zone”. In SE  
555 France, the same observation is made and the LO of *P. infundibulum* is recorded in the upper  
556 part of the *A. radiatus* Zone (Reboulet, 1996). The correlative datum (key horizon) for the  
557 Jebel Boulahouajeb and Jebel Oust sections is placed at the base of bed JBH-B7 (near the  
558 base of the calcareous bundle H1) and the first bed of Formation 5, respectively.

559  
560 The *C. loryi* Zone was not recognized in the Jebel Oust section (Memmi, 1989). The author  
561 underlined (p. 46 and 72) that a fault occurs between the formations 7 (“*B. castellanensis*  
562 *Zone*”) and 8 (“*Olcostephanus (Jeannoticeras) jeannoti* Zone”). In the current standard  
563 zonation, *J. jeannoti* is the index-species of the second subzone of the *C. loryi* Zone. In SE  
564 France, the LO of *J. jeannoti* is in the upper part of the *C. loryi* Zone and its HO is in the  
565 lowermost part of the *L. nodosoplicatum* Zone (Bulot et al., 1993; Reboulet, 1996; Reboulet  
566 and Atrops, 1999). Consequently, the lower part of Formation 8 of the Jebel Oust section in  
567 which *J. jeannoti* occurs is correlated with the upper part of the *C. loryi* Zone and the  
568 lowermost part of the *L. nodosoplicatum* Zone of the Jebel Boulahouajeb section where *J.*  
569 *jeannoti* has been also found (beds JBH-B20 and B21); thus, the upper part of Formation 8  
570 should belong to the *L. nodosoplicatum* Zone (see below).

571  
572 The *L. nodosoplicatum* Zone was not clearly identified in the Jebel Oust section; this zone was  
573 not separated from the *S. sayni* and *P. ligatus* Zones. Memmi (1989) probably used these

574 zones *sensu* Moullade and Thieuloy (1967) or *sensu* Thieuloy (1977). Bulot et al. (1993, p.  
575 46) recognized two successive populations of *Subsaynella*: *S. sayni* and *Subsaynella mimica*  
576 (see also Thieuloy and Bulot, 1993). In the first interval, they identified an assemblage made  
577 of “true” *S. sayni*, *Cruasicerias cruasense* and *Abrytusites juliani*. Consequently, the base of  
578 the *S. sayni* Zone *sensu* Bulot et al. (1993) was lowered and *C. cruasense* became the index-  
579 species of the first horizon of this zone; these authors underlined (p. 50) that *S. mimica*,  
580 classically identified to *S. sayni*, was considered in literature as the index-species to place the  
581 base of the *S. sayni auctorum* Zone (see Moullade and Thieuloy, 1967; Busnardo, 1984;  
582 Hoedemaecker et al, 1990). In the second interval, Bulot et al. (1993) identified an  
583 assemblage characterized by *S. mimica* (= *S. sayni auctorum*), *P. ligatus sensu stricto* (= *sensu*  
584 d’Orbigny; not *sensu* Moullade and Thieuloy, 1967) and *S. rotula*. Thus, the base of the *P.*  
585 *ligatus* Zone *sensu* Bulot et al. (1993) was lowered and its top was defined by the LO of *B.*  
586 *balearis*; *P. ligatus sensu lato* (= *sensu* Moullade and Thieuloy, 1967) occurs higher in the *P.*  
587 *ligatus* Zone *sensu* Bulot et al., 1993).

588 Among ammonoids found by Memmi (1989) in the lowermost part of Formation 9, there are  
589 “*Neocomites* gr. *nodosoplicatus*”, *S. sayni*, *Abrytusites juliani*, *P. ligatus* and *Spitidiscus*  
590 *rotula*. This author probably used the occurrence of “*Neocomites* gr. *nodosoplicatus*” to  
591 characterize the lower part of Formation 9 to the *L. nodosoplicatum* Zone. However, it is  
592 difficult to use this assemblage of five taxa for correlations with the Jebel Boulahouajeb  
593 section. Indeed, according to the stratigraphic distribution of ammonoids given by Bulot et al.  
594 (1993) for the interval around the lower–upper Hauterivian boundary in SE France, all these  
595 five species cannot co-occur together. *A. juliani* can be found with “true” *S. sayni* in the  
596 lowermost part of the *S. sayni* Zone *sensu* Bulot et al. (1993), and *S. rotula* co-occurs with  
597 “true” *P. ligatus* in the lower part of the *P. ligatus* Zone *sensu* Bulot et al. (1993). Therefore,  
598 the identification of some species made by Memmi (1989) must be interpreted differently. As

599 *L. nodosoplicatum* is only present in the lower part of the *L. nodosoplicatum* Zone *sensu*  
600 Bulot et al. (1993), it can be considered here that the specimen(s) identified by Memmi as “*N.*  
601 *gr. nodosoplicatus*” could correspond to *Lyticoceras claveli* or *Lyticoceras kiliani*, that occur  
602 in the upper part of this zone in SE France (Bulot et al., 1993; Bulot, 1995; Reboulet, 1996;  
603 Reboulet and Atrops, 1999), or to *C. cruasense*, that occurs in the lower part of the *S. sayni*  
604 Zone in SE France (Bulot et al., 1993; Bulot, 1995). In this case, *P. ligatus* and *S. rotula* were  
605 probably also misidentified at the specific level (the identification of these taxa is difficult,  
606 more particularly to distinguish the different species of *Plesiospitidiscus*). Consequently,  
607 according to this new interpretation, the lower part of Formation 9 in the Jebel Oust section  
608 could belong to the *S. sayni* Zone. However, the lowermost part of Formation 9 could belong  
609 to the *L. nodosoplicatum* Zone as the assemblage described by Memmi (1989) is located  
610 around 35 meters above the base of this formation. For this reason, the stratigraphic interval  
611 corresponding to the upper part of Formation 8 and lower part of Formation 9 is correlated  
612 with the calcareous bundle H2 of the Jebel Boulahouajeb section in which the boundary  
613 between the *L. nodosoplicatum* and *S. sayni* Zones is placed (at the top of JBH-B30). This  
614 correlation is also supported by the lithologic change observed above; from the base to the top  
615 of Formation 9 of the Jebel Oust section, the sedimentation becomes more marly as observed  
616 in the Jebel Boulahouajeb section (between beds JBH-B32 and B86). It is interesting to note  
617 that in SE France (Vocontian basin), the limestone–marl alternations are mainly characterized  
618 by thick calcareous beds and thinner marly interbeds in the lower Hauterivian, and it is the  
619 opposite in the lower part of the upper Hauterivian for which marly interbeds are generally  
620 thicker, with relatively thin calcareous beds in the *S. sayni* Zone (see Ferry and Rubino, 1987;  
621 Bulot, 1995; Reboulet, 1996).

622

623 In all sections studied by Memmi (1989), the *S. sayni* and *P. ligatus* Zones have not been  
624 separated. The author (p. 72) underlined that both index-species have been found in same  
625 beds, as recorded in the uppermost part of Formation 9 at Jebel Oust (Fig. 13) and she  
626 suggested that a condensation cannot be excluded. This hypothesis appears unlikely for most  
627 of northeastern Tunisian sections, often characterized by dilated series. A misidentification of  
628 some taxa could be an alternative; thus, new interpretations of identification can be proposed  
629 here for the specimens located in the uppermost part of Formation 9 and three biostratigraphic  
630 implications can be evoked as follows (a to c). a) If the identification of *S. sayni* made by  
631 Memmi (1989) is correct, that of *P. ligatus* is wrong (see above); in this case, this interval  
632 could correspond to the *S. sayni* Zone (its upper part). b) If her identification of *P. ligatus* is  
633 correct, the specimen(s) identified as *S. sayni* by Memmi (1989) could be interpreted here as  
634 *S. mimica* (see above), for which the LO is in the upper part of the *S. sayni* Zone *sensu* Bulot  
635 et al. (1993) and its HO is in the lower part of the *P. ligatus* Zone *sensu* Bulot et al. (1993) in  
636 SE France (Bulot et al., 1993; Bulot, 1995). Consequently, the uppermost part of Formation 9  
637 (represented by two thick calcareous beds) could belong to the lower part of the *P. ligatus*  
638 Zone and the base of this calcareous interval could be correlated with the base of bed JBH-  
639 B86 in the Jebel Boulahouajeb section where the sedimentation becomes more calcareous  
640 (bundle H3). c) The specimens of *S. sayni* located in the uppermost part of Formation 9 could  
641 belong to *Discoideilia*. Indeed, Vermeulen (1998) evoked the great morphological affinities  
642 between some species of *Discoideilia* and *Subsaynella*, and their phyletic relation. Taking into  
643 account the stratigraphic distribution of *Discoideilia* (Vermeulen, 1995, 1999), this genus can  
644 occur in the *B. balearis* Zone with *Plesiospitidiscus*. The specimen(s) of *P. ligatus* occurring in  
645 the uppermost part of Formation 9 can be correspond to the *P. ligatus sensu lato*, for which  
646 the distribution ends in the lowermost part of the *B. balearis* Zone according to Bulot et al.  
647 (1993). These ammonites could be also misidentified and could correspond to *P. subdifficilis*

648 that occur in the *B. balearis* Zone (Figs. 3b and 13). Consequently, the couple of calcareous  
649 beds located in the uppermost part of Formation 9 could belong to the lower part of the *B.*  
650 *balearis* Zone and could be correlated with the couple of calcareous beds JBH-B163 and  
651 B170 (bundle H4). In this case, the lithologic changes seem more similar in both sections than  
652 those observed in the previous attempt of correlations.

653  
654 Memmi (1981, 1989) has not used the *B. balearis* Zone in her zonal scheme of the  
655 northeastern Tunisian area; she considered the “*B. balearis*–*P. angulicostata* Zone” (see  
656 above). In the zonation of the Jebel Oust section, Memmi (1989) indicated the “*P.*  
657 *angulicostata* Zone” (= *P. ohmi* Zone in the standard zonation) for Formation 11 in which she  
658 found the index-species and *P. mortilleti*. This allows to correlate the couple of calcareous  
659 beds of this formation with the couple of calcareous beds JBH-B202 and B219 of the Jebel  
660 Boulahouajeb section as this bundle H5 mainly belongs to the *P. mortilleti* Subzone.  
661 Consequently, Formation 10 (no ammonoid sampling) is correlated with the interval  
662 belonging to the *B. balearis* Zone in the Jebel Boulahouajeb section.

663 Above the calcareous bundle of the *P. ohmi* Zone, the sedimentation becomes more  
664 argillaceous and a thick marly interval occurs in both sections. In the Jebel Boulahouajeb  
665 section, the Hautervian–Barremian boundary is placed in the uppermost part of this interval  
666 (bed JBH-B232 corresponding to the base of *T. hugii* Zone), while Memmi (1989) placed this  
667 boundary at the base of Formation 12. The author indicated the “*H. caillaudi* Zone” for this  
668 formation despite the lack of the index-species. Memmi (1989) underlined that the  
669 assemblage of this zone is very poor; among few identified taxa, she recognized the genus  
670 *Valdedorsella*. In the Jebel Boulahouajeb section, the LO of *Valdedorsella? uhligi* is at the top  
671 of *P. mortilleti* Subzone (top of the calcareous bundle H5). So, the Barremian age of  
672 Formation 12 of the Jebel Oust section is probably given by the planktic foraminiferal

673 *Hedbergella sigali* Zone reported by Memmi and Maamouri (1974), and Memmi (1989).  
674 Classically, this zone is considered as the first zone of the Barremian in Tunisia (see above  
675 and Ben Haj Ali, 2005), but some authors as Coccioni and Premoli-Silva (1994) and Premoli-  
676 Silva et al. (2017) have recorded this index-species in the Valanginian and Hauterivian of SE  
677 Spain. Consequently, Formation 12 could belong to the uppermost Hauterivian (*P. picteti*  
678 Subzone) considering that the base of Barremian is put at the base of bed JBH-B232 with the  
679 LO of *A. intermedius*. It can be added that the upper part of Formation 12 could correspond to  
680 the lowermost Barremian in the case of the Hauterivian–Barremian boundary at the Jebel  
681 Boulahouajeb section could be lowered at the level JBH-B221 where the LO of *P. sigali* is  
682 observed (see part 5.1).  
683  
684 In the Jebel Oust section, Formation 13 (around 100 m in thickness, mainly represented by  
685 thick calcareous beds) corresponds to the Barremian bundle of the literature (“Barre  
686 barrémienne”, Memmi, 1981, 1989). According to this author, it is placed in the  
687 “*Hemihoplites feraudi* Subzone” of the “*Silesites seranonis*–*Barremites strettostoma* Zone”  
688 (upper Barremian), even if these index-species have not been found in this part of the section.  
689 The author found only two species of ammonoids: “*Silesites vulpes*” and “*Ancyloceras*  
690 *trispinosum*” (see Fig. 12 in Memmi, 1989). In the Jebel Boulahouajeb section, there is also a  
691 thick calcareous bundle (around 200 m of limestone–marl alternations; only the first beds are  
692 represented here) that could be correlated with Formation 13. The zonal scheme is not  
693 established for this calcareous bundle of the Jebel Boulahouajeb section; only the basal part of  
694 this interval belongs to the lower Barremian (bed JBH-B232 and above).  
695  
696 In comparison with the Jebel Oust section, the study of the Jebel Boulahouajeb section  
697 provided a more detailed lithological succession of the uppermost Valanginian–lowermost

698 Barremian interval of the northern Tunisia, a more complete sampling of macrofauna, a  
699 greater set of data on the ammonoid distributions and assemblages, and a greater illustration  
700 of this fauna. Contrary to the Jebel Oust section where the boundaries between several  
701 ammonoid zones were not identified, the work on the Jebel Boulahouajeb section allowed to  
702 update the zonal scheme for the north Tunisia with the recognition of most of the zones of the  
703 standard zonation (Mediterranean Province; see Reboulet et al., 2018). Consequently, it  
704 appears that the Jebel Boulahouajeb section could be considered as a good reference section  
705 for the Tunisian trough, at least for the Hauterivian interval.

706

## 707 6. Conclusion

708 The study of ammonoids and foraminifera from the uppermost Valanginian to lowermost  
709 Barremian of the Jebel Boulahouajeb section of the northern Tunisia has led to three majors  
710 results.

711 1- Most of the ammonoid zones of the standard zonation (Mediterranean Province) have been  
712 identified and well characterized by their diversified assemblages: for the uppermost  
713 Valanginian, *C. furcilla* Zone; for the lower Hauterivian, *A. radiatus*, *C. loryi* and *L.*  
714 *nodosoplicatum* Zones; for the upper Hauterivian, *B. balearis* and *P. ohmi* Zones (with their  
715 subdivisions in four and three subzones, respectively); for the lowermost Barremian, *T. hugii*  
716 Zone. The *S. sayni* and *P. ligatus* Zones have not been recognized as the lower part of the  
717 upper Hauterivian has not been sampled for macrofauna.

718 2- The planktic foraminiferal fauna, observed only in the upper Hauterivian and lowermost  
719 Barremian, is poorly diversified. Distributions of some species are similar to those recorded in  
720 some previous studies done in Tunisia, but not in accordance with data from other Tethyan  
721 areas.



722 3- Correlations between the Jebel Boulahouajeb and Jebel Oust sections are proposed using  
723 mainly the ammonoid zonal schemes. The Jebel Boulahouajeb section has to be considered  
724 more complete in the lithologic succession, and in the distributions and assemblages of  
725 ammonoids. Therefore, it could be a new reference section of the Tunisia trough for the  
726 studied interval (mainly Hauterivian).

727

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738

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### 1133 **Appendix 1 - Systematic of ammonoids**

1134 This appendix presents the list of ammonoid taxa found in the Jebel Boulahouajeb section; the  
1135 index-species used for the zonation and other taxa evoked in the text have been added. The  
1136 classification is mainly based on Klein (2005), Vermeulen and Klein (2006), Klein et al.  
1137 (2007, 2009), and Klein and Vašíček (2011); some short comments are made for some taxa.

1138

#### 1139 **Perisphinctoidea STEINMANN**

1140 Neocomitidae SALFELD

1141 Neocomitinae SALFELD

1142 « *Thurmanniceras* » COSSMANN

1143 « *Thurmanniceras* » *pertransiens* (SAYN)

1144 *Criosarasinella* THIEULOUY

1145 *Criosarasinella furcillata* THIEULOUY



- 1146 *Himantoceras* THIEULOUY; see Reboulet, 1996, 2007, 2008; included in Ancyloceratoidea by Klein et al. (2007, p. 31)
- 1147 *Himantoceras trinodosum* THIEULOUY
- 1148 *Himantoceras* n. sp. 2; see Reboulet, 1996
- 1149 *Teschenites* THIEULOUY
- 1150 *Teschenites callidiscus* (THIEULOUY); included in *Neocomites* (*Teschenites*) by Klein (2005, p. 315)
- 1151 *Teschenites subflucticulus* REBOULET; included in *Neocomites* (*Teschenites*) by Klein (2005, p. 320)
- 1152 *Eleniceras* BRESKOVSKI; included in Endemoceratinae by Klein (2005, p. 351)
- 1153 ? Endemoceratinae SCHINDEWOLF
- 1154 *Acanthodiscus* UHLIG
- 1155 *Acanthodiscus radiatus* (BRUGUIERE)
- 1156 *Breistrofferella* THIEULOUY
- 1157 *Breistrofferella castellanensis* (D'ORBIGNY)
- 1158 *Lyticoceras* HYATT
- 1159 *Lyticoceras claveli* BUSNARDO & THIEULOUY
- 1160 *Lyticoceras kiliani* REBOULET & ATROPS
- 1161 *Lyticoceras nodosopicatum* (KILIAN & REBOUL)
- 1162 *Cruasiseras* BUSNARDO
- 1163 *Cruasiseras cruasense* TORCAPEL
- 1164 Spitidiscinae VERMEULEN & THIEULOUY
- 1165 *Jeanthieuloyites* COOPER
- 1166 *Jeanthieuloyites keyserlingiformis* AVRAM & GRADINARU
- 1167 *Jeanthieuloyites quinquestriatus* BESAIRIE
- 1168 *Jeanthieuloyites solignaci* (MEMMI)
- 1169 *Spitidiscus* KILIAN; this genus is included in Desmoceratidae by Busnardo et al., 2003 (p. 49)
- 1170 *Spitidiscus lorioli* (KILIAN)
- 1171 *Spitidiscus meneghini* (RODIGHERO)
- 1172 *Spitidiscus rawsoni* BULOT
- 1173 *Spitidiscus rotula* (SOWERBY)
- 1174 Olcostephanidae HAUG
- 1175 Olcostephaninae HAUG
- 1176 *Olcostephanus* NEUMAYR
- 1177 *Olcostephanus densicostatus* (WEGNER)
- 1178 *Olcostephanus variegatus* PAQUIER
- 1179 *Jeannoticeras* THIEULOUY
- 1180 *Jeannoticeras jeannoti* (D'ORBIGNY)
- 1181 Oosterellidae BREISTROFFER
- 1182 *Oosterella* KILIAN
- 1183 *Oosterella cultrata* (D'ORBIGNY)

- 1184 *Oosterella cultrataeformis* (UHLIG)
- 1185 *Oosterella undulata* REBOULET
- 1186 Holcodiscidae SPATH
- 1187 *Taveraidiscus* VERMEULEN & THIEULOY
- 1188 *Taveraidiscus hugii* (OOSTER)
- 1189 *Avramidiscus* VERMEULEN
- 1190 *Avramidiscus intermedius* (D'ORBIGNY); included in *Taveraidiscus* by Company et al., 2003
- 1191 *Holcodiscus* UHLIG
- 1192 *Holcodiscus caillaudianus* (D'ORBIGNY)
- 1193 **Desmoceratoidea VON ZITTEL**
- 1194 Barremitidae BRESKOVSKI
- 1195 *Abrytusites* NIKOLOV & BRESKOVSKI
- 1196 *Abrytusites juliani* (HONNORAT-BASTIDE)
- 1197 *Abrytusites neumeyri* (HAUG)
- 1198 *Plesiospitidiscus* BREISTROFFER
- 1199 *Plesiospitidiscus fasciger* (THIEULOY)
- 1200 *Plesiospitidiscus ligatus* (D'ORBIGNY)
- 1201 *Plesiospitidiscus subdifficilis* (KARAKASCH)
- 1202 *Barremites* KILIAN
- 1203 *Barremites cassida* (RASPAIL)
- 1204 *Montanesiceras* BRESKOVSKI
- 1205 *Montanesiceras dimboviciorense* (BRESKOVSKI); Company et al. (2005) included this species in *Barremites*
- 1206 *Valdedorsella* BREISTROFFER
- 1207 *Valdedorsella ? uhligi* (HAUG); Company et al. (2003) included this species in "*Barremites*"
- 1208 *Barremiites* AVRAM
- 1209 *Barremiites strettostoma* (UHLIG)
- 1210 Silesitidae HYATT
- 1211 *Silesites* UHLIG
- 1212 *Silesites seranonis* (D'ORBIGNY)
- 1213 *Silesites vulpes* (MATHERON)
- 1214 **Pulchelliioidea DOUVILLE** (for an alternative classification, see note 96, p. 188 in Vermeulen and Klein, 2006)
- 1215 Pulchelliidae DOUVILLE
- 1216 Buergliceratinae VERMEULEN
- 1217 *Subsaynella* SPATH
- 1218 *Subsaynella mimica* THIEULOY & BULOT
- 1219 *Subsaynella sayni* (PAQUIER)
- 1220 *Discoidellia* VERMEULEN
- 1221 *Discoidellia couratieri* VERMEULEN

- 1222 *Discoidellia favrei* (OOSTER)
- 1223 *Pulchelliinae* DOUVILLÉ
- 1224 *Nicklesia* HYATT
- 1225 *Nicklesia pulchella* (D'ORBIGNY)
- 1226 **Haploceratoidea** VON ZITTEL
- 1227 Haploceratidae VON ZITTEL
- 1228 *Neolissoceras* SPATH
- 1229 *Neolissoceras grasianum* (D'ORBIGNY)
- 1230 **Phylloceratoidea** VON ZITTEL
- 1231 Phylloceratidae VON ZITTEL
- 1232 Phylloceratinae VON ZITTEL
- 1233 *Phylloceras* (*Hypophylloceras*)
- 1234 *Phylloceras* (*Hypophylloceras*) *tethys* (D'ORBIGNY)
- 1235 *Phylloceras* (*Hypophylloceras*) *poniculi* (ROUSSEAU)
- 1236 Phyllopachyceratinae COLLIGNON
- 1237 *Phyllopachyceras* SPATH
- 1238 *Phyllopachyceras infundibulum* (D'ORBIGNY)
- 1239 *Phyllopachyceras winkleri* (UHLIG)
- 1240 **Lytoceratoidea** NEUMAYR
- 1241 Lytoceratidae NEUMAYR
- 1242 Lytoceratinae NEUMAYR
- 1243 *Lytoceras* SUESS
- 1244 *Lytoceras subfimbriatum* (D'ORBIGNY)
- 1245 **Ancyloceratoidea** GILL
- 1246 Crioceratitidae GILL
- 1247 *Crioceratites* (LEVEILLE)
- 1248 *Crioceratites loryi* (SARKAR)
- 1249 *Balearites* SARKAR; the opinion of Company et al. (2003) is here followed: *B. balearis*, *B. binelli*, *B. krenkeli* and *B.*
- 1250 *angulicostatus* could constitute a phylogenetic lineage. These 4 species are included in
- 1251 *Balearites* following the opinion of Matamales and Company (personal communication, 2017)
- 1252 *Balearites balearis* (NOLAN)
- 1253 *Balearites binelli* (ASTIER); included in *Binelliceras* by Klein et al., 2007 (p. 50)
- 1254 *Balearites krenkeli* (SARKAR); included in *Crioceratites* by Klein et al., 2007 (p. 42)
- 1255 *Balearites angulicostatus* (D'ORBIGNY); included in *Crioceratites* by Klein et al., 2007 (p. 36)
- 1256 *Pseudothurmannia* SPATH; the opinion of Company et al. (2003) and the classification of Klein et al. (2007, p. 54) are here
- 1257 followed: the type species designated by Company et al. (2003) is *Ammonites angulicostatus*
- 1258 D'ORBIGNY in PICTET, Pl. 1bis, Fig. 1ab (= *Pseudothurmannia picteti* SARKAR, holotype by
- 1259 original designation Pictet, Pl. 1bis, Fig. 1ab)

- 1260 *Pseudothurmannia mortilleti* (PICTET & DE LORIO); in view of Company et al. (2003), *P. mortilleti* is here considered as a  
 1261 senior synonym of *P. catulloi* (Parona)
- 1262 *Pseudothurmannia ohmi* (WINKLER)
- 1263 *Pseudothurmannia picteti* SARKAR
- 1264 *Pseudothurmannia pseudomalbosi* (SARASIN & SCHÖNDELMAYER)
- 1265 *Sornayites* WIEDMANN
- 1266 Emericiceratidae VERMEULEN
- 1267 *Honnoratia* BUSNARDO
- 1268 *Honnoratia thiollieri* (ASTIER)
- 1269 *Paraspiticeras* KILIAN
- 1270 Leptoceratoididae THIEULOY
- 1271 *Hamulinites* PAQUIER
- 1272 *Sabaudiella* VASICEK & HOEDEMAEKER
- 1273 *Sabaudiella simplex* BUSNARDO
- 1274 Hemihoplitidae SPATH
- 1275 Hemihoplitinae SPATH
- 1276 *Hemihoplites* SPATH
- 1277 *Hemihoplites feraudianus* (D'ORBIGNY)
- 1278 *Hemihoplites? trispinosus* (VON KOENEN)
- 1279 **Ptychoceratoidea** GILL
- 1280 Hamulinidae GILL
- 1281 *Anahamulina* HYATT
- 1282 *Anahamulina lorioli* (UHLIG)
- 1283 *Amorina* VERMEULEN
- 1284 **Bochianitoidea** SPATH
- 1285 Bochianitidae SPATH
- 1286 *Bochianites* LORY
- 1287 *Bochianites neocomiensis* (D'ORBIGNY)
- 1288
- 1289 **Appendix 2 - Systematic of foraminifera**
- 1290 **Alphabetic planktic foraminifera list**
- 1291 *Favusella hoterivica* (SUBBOTINA)
- 1292 *Gorbachikella anteroapertura* BOUDAGHER-FADEL ET AL.
- 1293 *Gorbachikella grandiaptura* BOUDAGHER-FADEL ET AL.
- 1294 *Gorbachikella kugleri* (BOLLI)
- 1295 *Praehedbergella sigali* (MOULLADE)

1296 **Alphabetic benthic foraminifera list**

- 1297 *Ammodiscus cretaceus* (REUSS)
- 1298 *Bathysiphon brotzei* TAPPAN
- 1299 *Catharina* sp.
- 1300 *Dentalina deflexa* GRZYBOWSKI
- 1301 *Dentalina ejuncida* LOEBLICH & TAPPAN
- 1302 *Dentalina gracilis* D'ORBIGNY
- 1303 *Dentalina oligostegia* (REUSS)
- 1304 *Dorothia gradata* (BERTHELIN)
- 1305 *Dorothia hauteriviana* (MOULLADE)
- 1306 *Dorothia kummi* (ZEDLER)
- 1307 *Dorothia lilliformis* (BERTHELIN)
- 1308 *Dorothia ouachensis* (SIGAL)
- 1309 *Dorothia oxycona* (REUSS)
- 1310 *Dorothia hechti* DIENI & MASSARI
- 1311 *Dorothia praeauteriviana* DIENI & MASSARI
- 1312 *Dorothia zedlerae* MOULLADE
- 1313 *Fronicularia hastata* ROEMER
- 1314 *Gavelinella barremiana* BETTENSTAEDT
- 1315 *Lenticulina eichenbergi* BARTENSTEIN & BRAND
- 1316 *Lenticulina heiermanni* BETTENSTAEDT
- 1317 *Lenticulina multicella* BARTENSTEIN, BETTENSTAEDT & BOLLI
- 1318 *Lenticulina nodosa* (REUSS)
- 1319 *Lenticulina ouachensis* (SIGAL)
- 1320 *Lenticulina roemeri* (REUSS)
- 1321 *Lenticulina rotulata* LAMARCK
- 1322 *Marginulina planiscula* (REUSS)
- 1323 *Marginulina striatocostata* REUSS
- 1324 *Marginulinopsis*.sp.
- 1325 *Marsonella kummi* ZEDLER
- 1326 *Nodosaridea* sp.
- 1327 *Nodosaria detruncata* SCHWAGER
- 1328 *Planularia complanata* (REUSS)
- 1329 *Ramulina* sp.
- 1330 *Rhizammina* sp.
- 1331 *Spirillina minima* SCHACKO
- 1332 *Spirillina neocomiana* MOULLADE

1333

1334 **Figure captions**

1335 Fig. 1. Geographic map of north Tunisia with location of the Jebel Boulahouajeb and Jebel  
1336 Oust sections.

1337

1338 Fig. 2. Jebel Boulahouajeb section (section JBH-A), Tunisia, lithology and ammonoid  
1339 distribution; upper Valanginian stage (*Criosarasinella furcillata* Zone *p.p.*).

1340

1341 Fig. 3. Jebel Boulahouajeb section (section JBH-B), Tunisia, lithology and ammonoid  
1342 distribution; Fig. 3a: Hauterivian stage (from *Acanthodiscus radiatus* Zone to  
1343 *Plesiospitidiscus ligatus* Zone *p.p.*) and its lower boundary (Valanginian *Criosarasinella*  
1344 *furcillata* Zone *p.p.* recognized); Fig. 3b: Hauterivian stage (from *P. ligatus* Zone *p.p.* to  
1345 *Pseudothurmannia ohmi* Zone) and its upper boundary (Barremian *Taveraidiscus hugii* Zone  
1346 *p.p.* recognized). Abbreviations: up. Val.: upper Valanginian; Bar.: Barremian; H1 to H5:  
1347 calcareous bundles (limestone-dominated intervals separated by thick marly-dominated  
1348 intervals).

1349

1350 Fig. 4. Ammonoids from the Jebel Boulahouajeb section (sections JBH-A and JBH-B),  
1351 Tunisia. Scale bar: 1 cm; black arrow: end of phragmocone; SC: Silicone cast. **A**, *Lyticoceras*  
1352 sp. ind., JBH-B20, *Lyticoceras nodosoplicatum* Zone. **B**, *Lyticoceras* sp. ind., JBH-B24, *L.*  
1353 *nodosoplicatum* Zone. **C**, *Teschenites subflucticulus*, JBH-A5, *Criosarasinella furcillata*  
1354 Zone. **D**, *Jeanthieuloyites keyserlingiformis*, JBH-A2, *C. furcillata* Zone. **E**, *Jeanthieuloyites*  
1355 *quinquestriatus*, JBH-A7, *C. furcillata* Zone. **F**, **G**, *Jeanthieuloyites solignaci*, JBH-A7, *C.*  
1356 *furcillata* Zone. **H**, **I**, *Spitidiscus lorioli*, JBH-B9, *Acanthodiscus radiatus* Zone. **J** (SC), **K**  
1357 (SC), *Spitidiscus meneghini*, JBH-B10, *A. radiatus* Zone. **L** (SC), *Spitidiscus meneghini*,

1358 JBH-B11, *A. radiatus* Zone. **M**, *Spitidiscus rawsoni*, JBH-B30, *L. nodosoplicatum* Zone. **N**  
 1359 (SC), *Himantoceras cf. trinodosum*, JBH-B4, *C. furcillata* Zone.

1360  
 1361 Fig. 5. Ammonoids from the Jebel Boulahouajeb section (sections JBH-A and JBH-B),  
 1362 Tunisia. Scale bar: 1 cm; black arrow: end of phragmocone; SC: Silicone cast. **A**,  
 1363 *Olcostephanus densicostatus*, JBH-A5, *Criosarasinella furcillata* Zone. **B**, *Olcostephanus*  
 1364 *densicostatus*, JBH-A6, *C. furcillata* Zone. **C**, *Jeannoticeras jeannoti*, JBH-B20, *Lyticoceras*  
 1365 *nodosoplicatum* Zone. **D** (SC), *Oosterella ondulata*, JBH-B6, *C. furcillata* Zone. **E**,  
 1366 *Oosterella cultrata*, JBH-B10, *Acanthodiscus radiatus* Zone.

1367  
 1368 Fig. 6. Ammonoids from the Jebel Boulahouajeb section (section JBH-B), Tunisia. Scale bar:  
 1369 1 cm; black arrow: end of phragmocone; SC: Silicone cast. **A** (SC), *Avramidiscus*  
 1370 *intermedius*, JBH-B232, *Taveraidiscus hugii* Zone. **B** (SC), *Plesiospitidiscus fasciger*, JBH-  
 1371 B18, *Crioceratites loryi* Zone. **C**, *Plesiospitidiscus fasciger*, JBH-B20, *Lyticoceras*  
 1372 *nodosoplicatum* Zone. **D**, *Plesiospitidiscus subdifficilis*, JBH-B86, *Subsaynella sayni*-  
 1373 *Plesiospitidiscus ligatus* Zones. **E**, *Plesiospitidiscus subdifficilis*, JBH-B163, *Balearites*  
 1374 *balearis* Zone, *Balearites binelli* Subzone. **F**, *Abrytusites neumaryi*, JBH-B163, *B. balearis*  
 1375 Zone, *B. binelli* Subzone. **G**, *Barremites gr. cassida*, JBH-B234, *T. hugii* Zone. **H**,  
 1376 *Valdedorsella? uhligi*, JBH-B215, *Pseudothurmannia ohmi* Zone, *Pseudothurmannia*  
 1377 *mortilleti* Subzone. **I**, *Discoideilia cf. couratieri*, JBH-B86, *S. sayni*-*P. ligatus* Zones. **J**,  
 1378 *Discoideilia cf. couratieri*, JBH-B89, *S. sayni*-*P. ligatus* Zones.

1379  
 1380 Fig. 7. Ammonoids from the Jebel Boulahouajeb section (section JBH-B), Tunisia. Scale bar:  
 1381 1 cm; black arrow: end of phragmocone. **A**, *Neolissoceras grasianum*, JBH-B10,  
 1382 *Acanthodiscus radiatus* Zone. **B**, *Phylloceras (Hypophylloceras) tethys*, JBH-B10, *A. radiatus*

- 1383 Zone. **C**, *Phyllopachyceras winkleri*, JBH-B30, *Lyticoceras nodosoplicatum* Zone. **D**,
- 1384 *Phyllopachyceras infundibulum*, JBH-B9, *A. radiatus* Zone. **E**, *Phyllopachyceras*
- 1385 *infundibulum*, JBH-B86, *Subsaynella sayni*–*Plesiospitidiscus ligatus* Zones. **F**, *Lytoceras*
- 1386 *subfimbriatum*, JBH-B6, *Criosarasinella furcillata* Zone. **G**, *Lytoceras subfimbriatum*, JBH-
- 1387 B163, *Balearites balearis* Zone, *Balearites binelli* Subzone.
- 1388
- 1389 Fig. 8. Ammonoids from the Jebel Boulahouajeb section (section JBH-B), Tunisia. Scale bar:
- 1390 1 cm; black arrow: end of phragmocone; SC: Silicone cast. **A**, *Balearites* cf. *balearis*, JBH-
- 1391 B92, *Balearites balearis* Zone and Subzone. **B**, **C**, **D**, **E**, *Balearites binelli*, JBH-B163, *B.*
- 1392 *balearis* Zone, *B. binelli* Subzone. **F** (SC), *Balearites krenkeli*?, JBH-B195, *B. balearis* Zone,
- 1393 *Balearites angulicostatus* Subzone. **G**, **H**, *Balearites* cf. *angulicostatus*, JBH-B195, *B.*
- 1394 *balearis* Zone, *B. angulicostatus* Subzone.
- 1395
- 1396 Fig. 9. Ammonoids from the Jebel Boulahouajeb section (section JBH-B), Tunisia. Scale bar:
- 1397 1 cm; black arrow: end of phragmocone; SC: Silicone cast. **A**, **B**, **C**, **D**, **E**, *Pseudothurmannia*
- 1398 *mortilleti*, JBH-B202, *Pseudothurmannia ohmi* Zone, *P. mortilleti* Subzone. **F** (SC), **G** (SC),
- 1399 *Pseudothurmannia pseudomalbosi*, JBH-B202, *P. ohmi* Zone, *P. mortilleti* Subzone.
- 1400
- 1401 Fig. 10. Ammonoids from the Jebel Boulahouajeb section (section JBH-B), Tunisia. Scale
- 1402 bar: 1 cm; black arrow: end of phragmocone. **A**, *Pseudothurmannia pseudomalbosi*, JBH-
- 1403 B202, *Pseudothurmannia ohmi* Zone, *Pseudothurmannia mortilleti* Subzone. **B**,
- 1404 *Pseudothurmannia picteti*, JBH-B219, *P. ohmi* Zone, *P. picteti* Subzone. **C**, *Paraspitoceras*
- 1405 sp. ind., JBH-B161, *Balearites balearis* Zone and Subzone. **D**, *Sabaudiella simplex*, JBH-
- 1406 B215, *P. ohmi* Zone, *P. mortilleti* Subzone.
- 1407



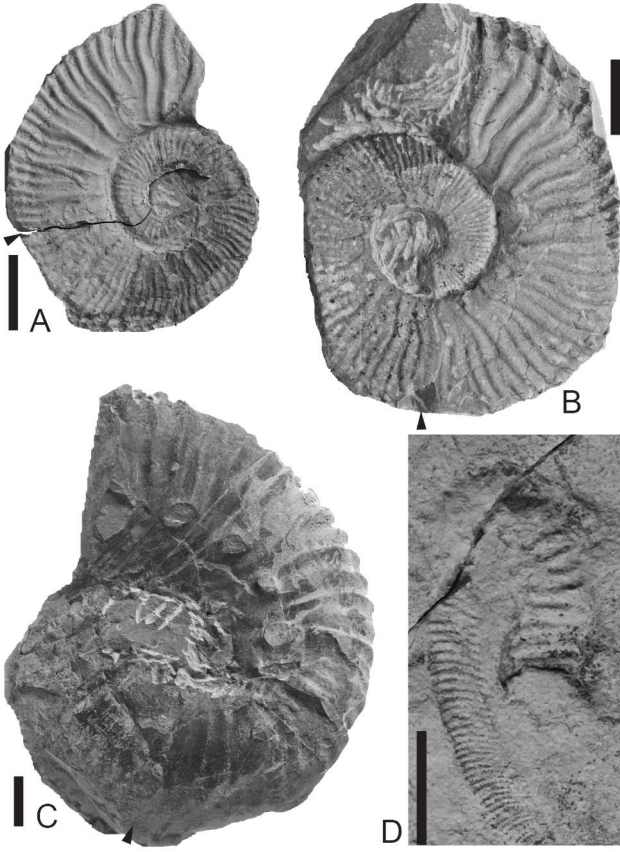
1408 Fig. 11. Jebel Boulahouajeb section (section JBH-B), Tunisia, lithology and Hauterivian  
1409 foraminifera distribution.

1410

1411 Fig. 12. Scanning Electronic Microscope (SEM) micrographs of selected foraminifera from  
1412 the Jebel Boulahouajeb section (section JBH-B), Tunisia; the scale bar is indicated in  
1413 brackets. **A**, *Favusella hoterivica* (50  $\mu\text{m}$ ), JBH-B76. **B**, *F. hoterivica* (50  $\mu\text{m}$ ), JBH-B109. **C**,  
1414 *Gorbachikella kugleri* (50  $\mu\text{m}$ ), JBH-B91. **D**, *G. kugleri* (10  $\mu\text{m}$ ), JBH-B231. **E**,  
1415 *Gorbachikella anteroapertura* (10  $\mu\text{m}$ ), JBH-B172. **F**, *Praehedbergella sigali* (50  $\mu\text{m}$ ), JBH-  
1416 B221. **G**, *P. sigali* (50  $\mu\text{m}$ ), JBH-B 225. **H**, *P. sigali* (10  $\mu\text{m}$ ), JBH-B236. **I**, *Lenticulina*  
1417 *roemeri* (100  $\mu\text{m}$ ), JBH-B2. **J**, *Lenticulina eichenbergi* (100  $\mu\text{m}$ ), JBH-B44. **K**, *Dorothia*  
1418 *lilliformis* (100  $\mu\text{m}$ ), JBH-B31. **L**, *Lenticulina multicella* (100  $\mu\text{m}$ ), JBH-B94. **M**, *Dorothia*  
1419 *praeauteriviana* (100  $\mu\text{m}$ ), JBH-B59. **N**, *Lenticulina ouachensis ouachensis* (100  $\mu\text{m}$ ), JBH-  
1420 B120. **O**, *Dorothia kummi* (100  $\mu\text{m}$ ), JBH-B111. **P**, *Dorothia zedlerae* (100  $\mu\text{m}$ ), JBH-B156.  
1421 **Q**, *Lenticulina rotulata* (100  $\mu\text{m}$ ), JBH- B205. **R**, *Gavelinella barremiana* (50  $\mu\text{m}$ ), JBH-  
1422 B224.

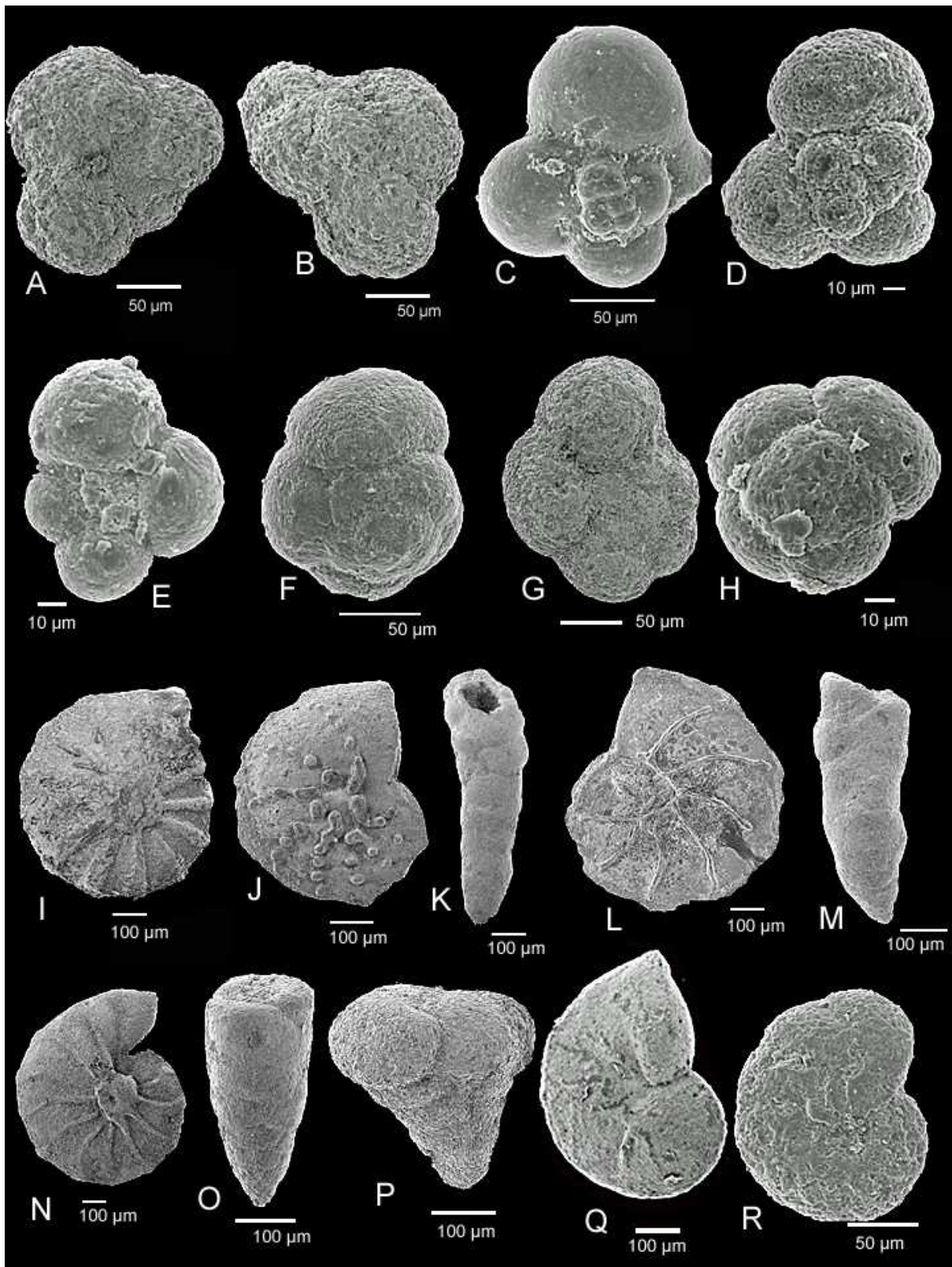
1423

1424 Fig. 13. Correlations between the Jebel Bouahouajeb (JBH) and Jebel Oust (JO) sections for  
1425 the uppermost Valanginian–lowermost Barremian interval. The Jebel Oust section (lithology,  
1426 formations 4d to 13, ammonoid taxa and zonation) is after Memmi (1989). For abbreviations  
1427 see Figure caption 3.








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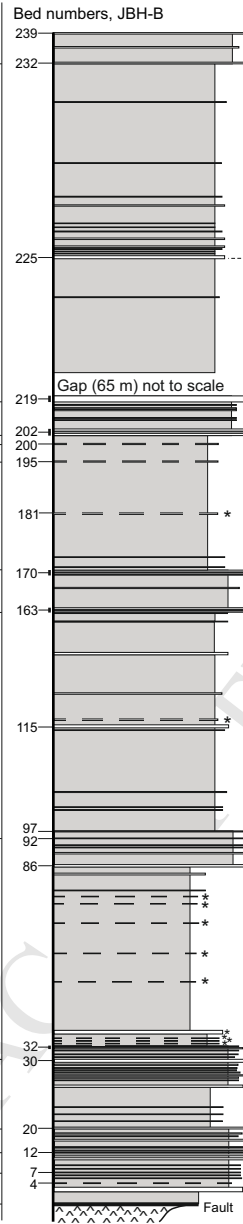
Jebel Boulahouajeb

-  Limestone
-  Marl
-  \* Sandstone/siltstone
-  Gypsum
-  Discontinuous bed

Stages - Zonation  
Bar. *T. hugii*

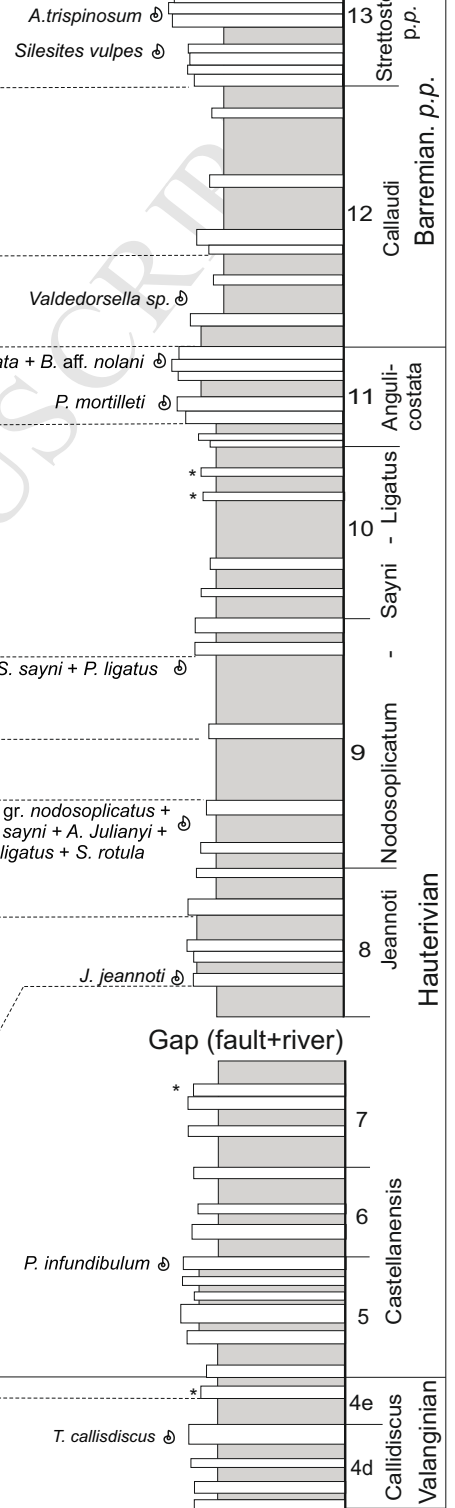
upper Hauterivian  
Balearites balearis  
*B. balearis*  
*B. binelli*  
*B. krenkeli*  
*B. angulicostatus*  
*P. mortilleti*  
*P. picteti*  
*Pseudothurmannia ohmi*

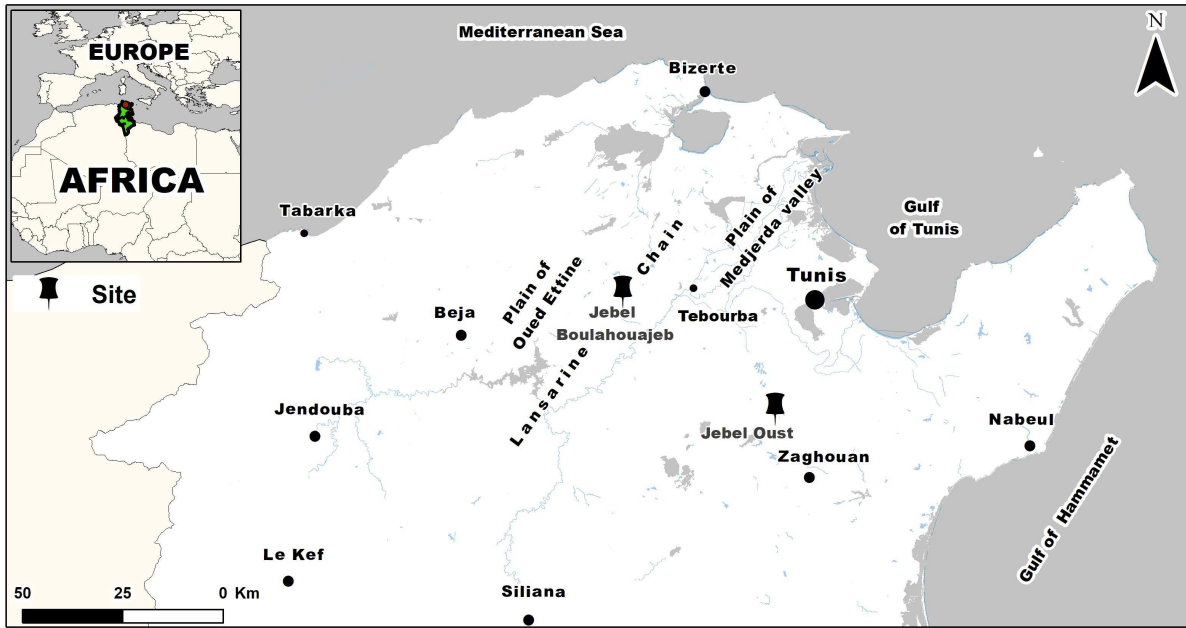
lower Hauterivian  
*L. nodosoplicatum*  
*A. radiatus*  
*L. loryi*  
up. Val. *C. furcillata* p.p.  
Trias p.p.



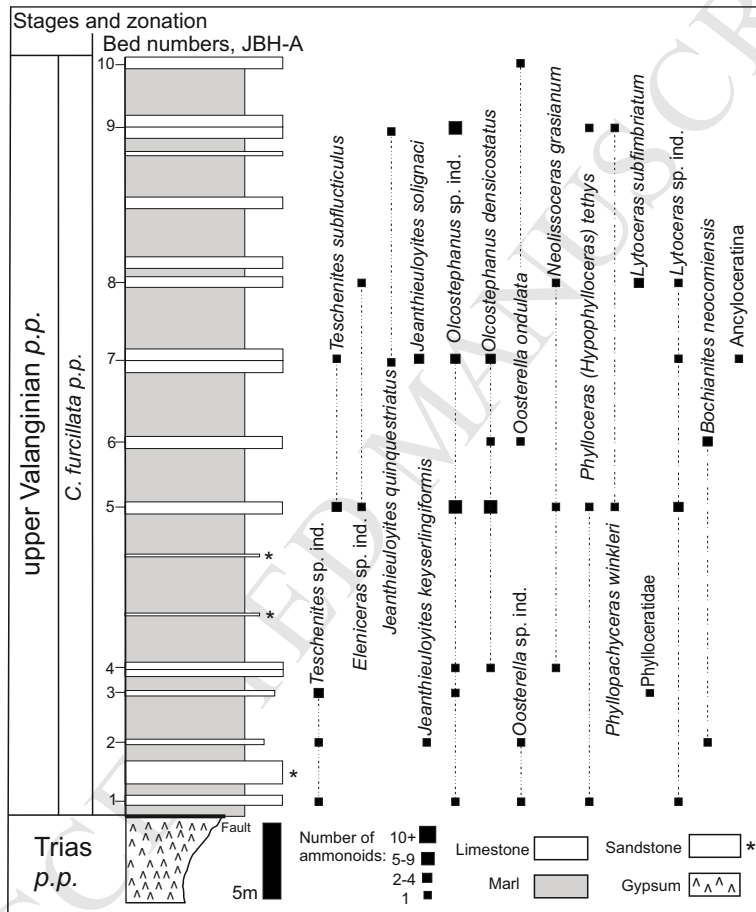
Jebel Oust

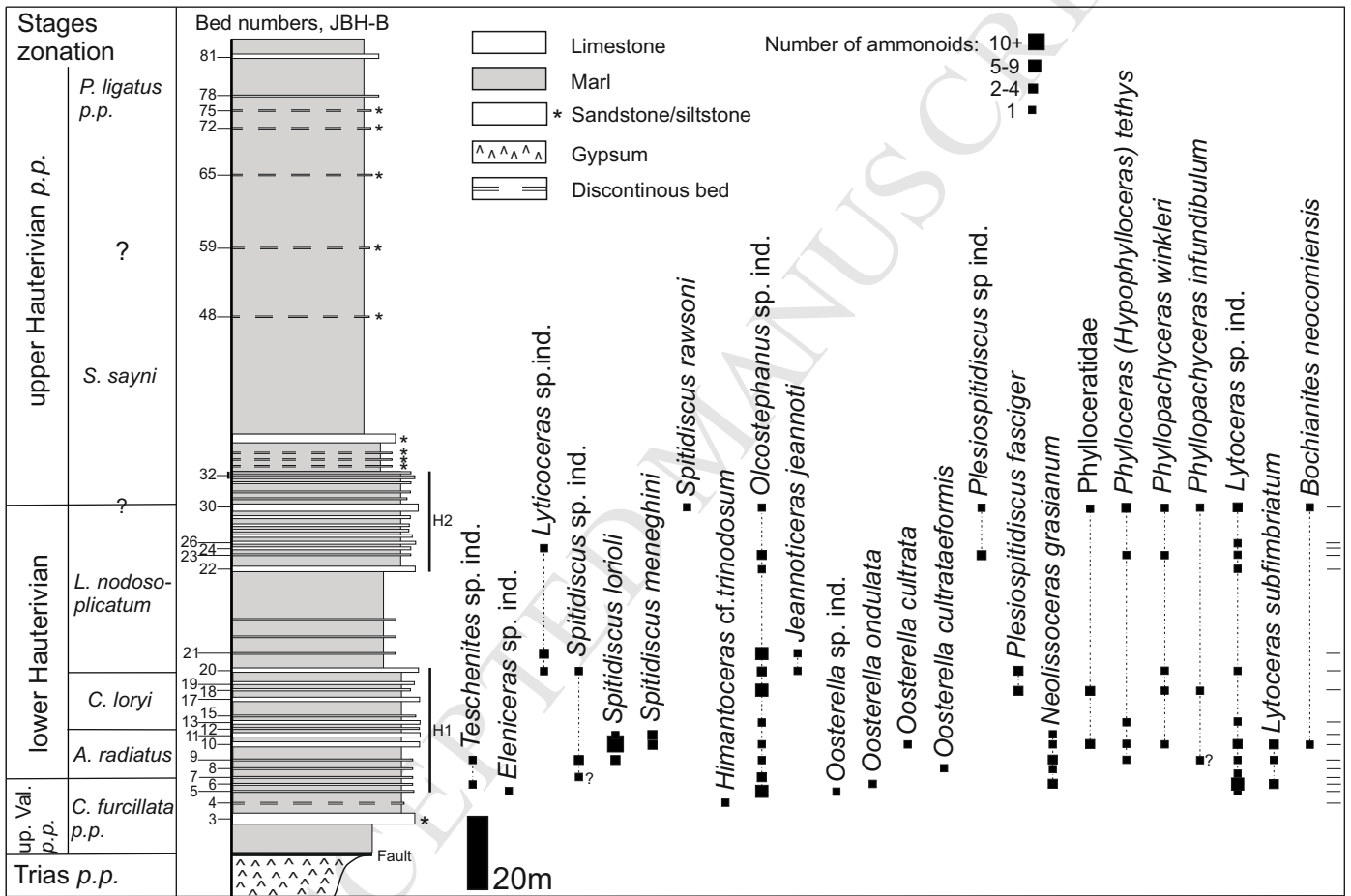
Formations - Zonation - Stages



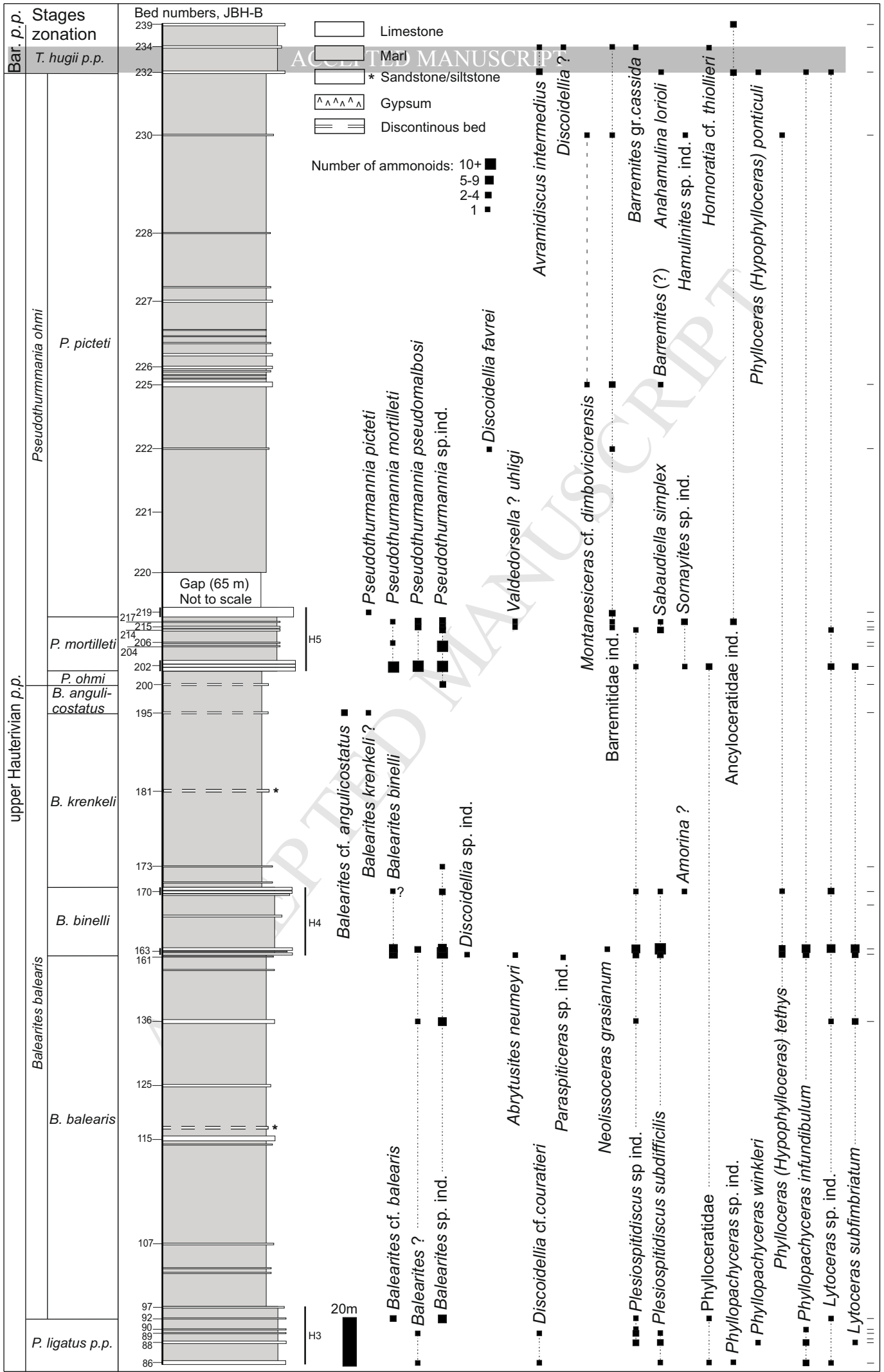


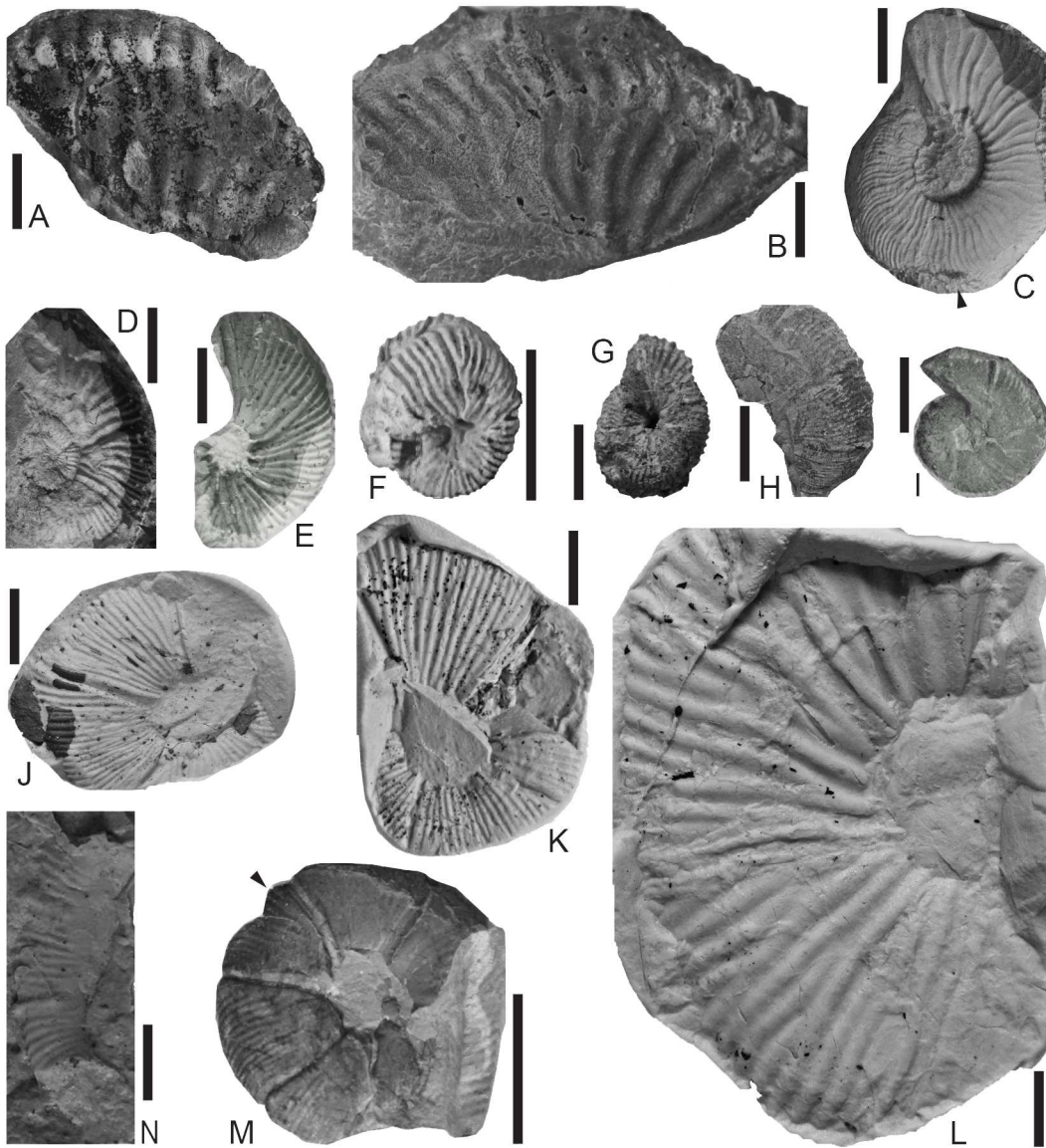




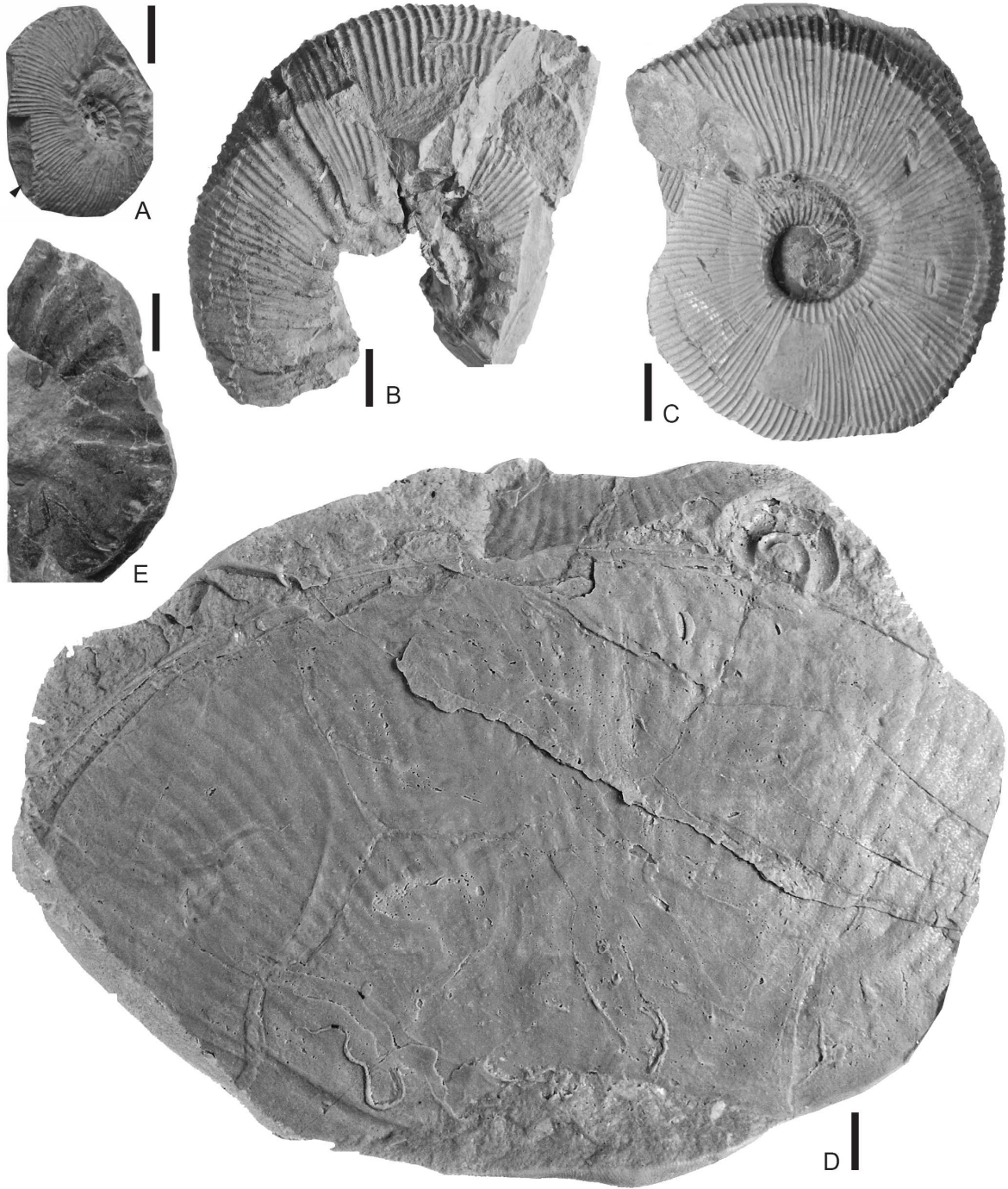






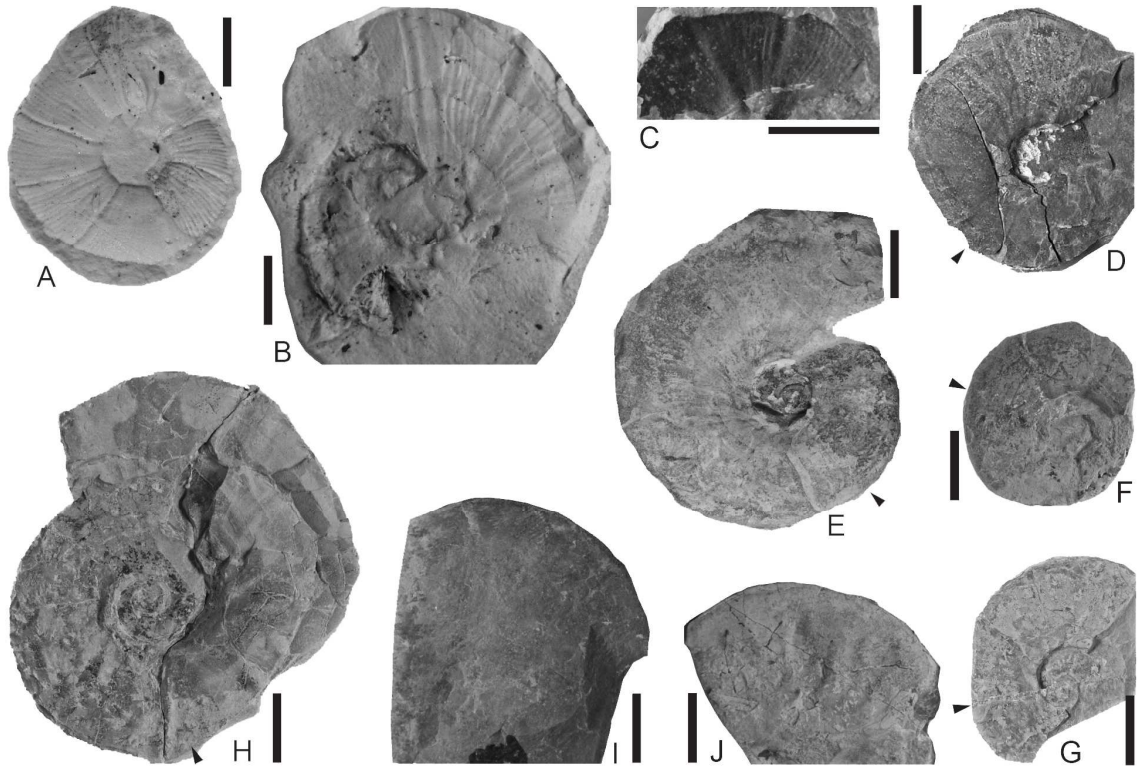


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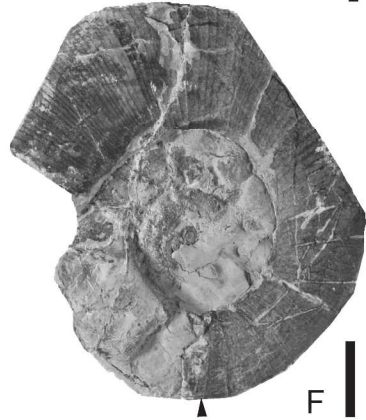
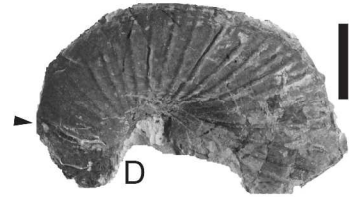
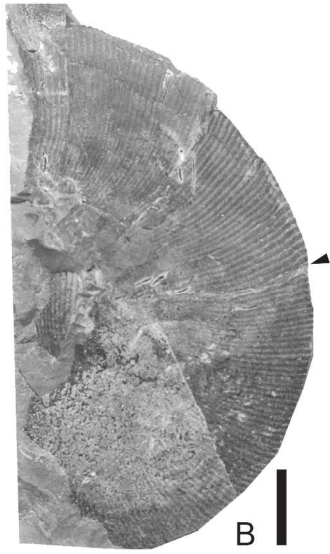


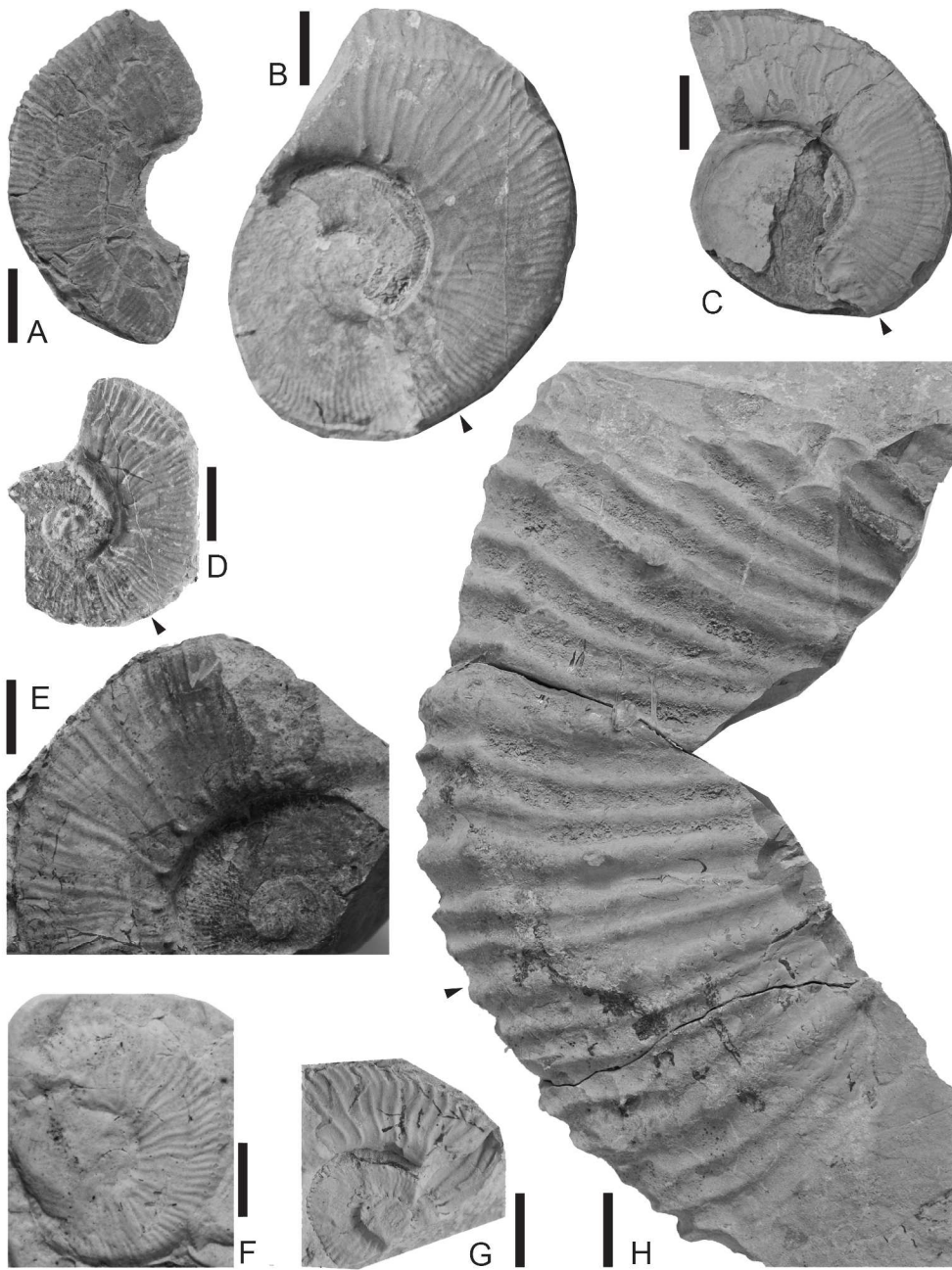
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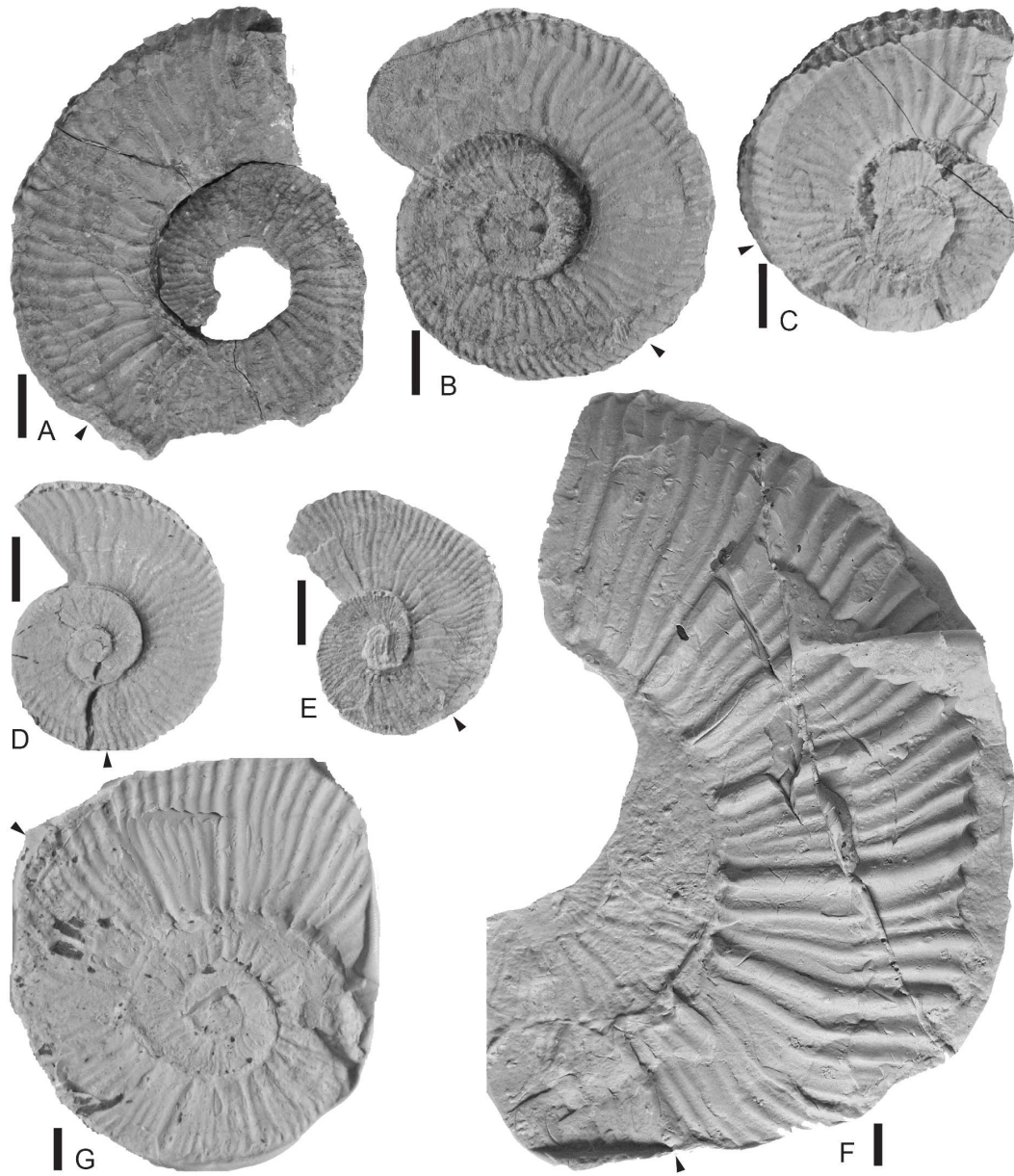


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ACC

**Highlights**

Detailed biostratigraphic study of the Jebel Boulahouajeb's section (Tunisia)

Identification of the ammonoid zones of the Hauterivian and its boundaries

Identification of the upper Hauterivian planktic foraminiferal zones

Biostratigraphic correlations of the Jebel Boulahouajeb and Jebel Oust sections

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