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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

40

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 20th 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 H₂O₂. 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), Ettachfini
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 *unfundibulum*.

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 *unfundibulum* 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 *Subsarynella 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 "Teschentites 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 comparaison 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
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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* THIEULOY

1145 *Criosarasinella furcillata* THIEULOY

- 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 nodosoplicatum* (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 Desmocerotidae by Busnardo et al., 2003 (p. 49)
- 1170 *Spitidiscus lorioli* (KILIAN)
- 1171 *Spitidiscus meneghinii* (RODIGHIERO)
- 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 & THIEULOUY
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* (THIEULOUY)
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 *Barremites* AVRAM
1209 *Barremites 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* THIEULOUY & BULOT
1219 *Subsaynella sayni* (PAQUIER)
1220 *Discoidellia* VERMEULEN
1221 *Discoidellia couratieri* VERMEULEN

- 1222 *Discoideilia 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*) *ponticuli* (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	<i>Ammodiscus cretaceus</i> (REUSS)
1298	<i>Bathysiphon brotzei</i> TAPPAN
1299	<i>Catharina</i> sp.
1300	<i>Dentalina deflexa</i> GRZYBOWSKI
1301	<i>Dentalina ejuncida</i> LOEBLICH & TAPPAN
1302	<i>Dentalina gracilis</i> D'ORBIGNY
1303	<i>Dentalina oligostegia</i> (REUSS)
1304	<i>Dorothia gradata</i> (BERTHELIN)
1305	<i>Dorothia hauteriviana</i> (MOULLADE)
1306	<i>Dorothia kummi</i> (ZEDLER)
1307	<i>Dorothia lilliformis</i> (BERTHELIN)
1308	<i>Dorothia ouachensis</i> (SIGAL)
1309	<i>Dorothia oxycona</i> (REUSS)
1310	<i>Dorothia hechti</i> DIENI & MASSARI
1311	<i>Dorothia praeauteriviana</i> DIENI & MASSARI
1312	<i>Dorothia zedlerae</i> MOULLADE
1313	<i>Fronicularia hastata</i> ROEMER
1314	<i>Gavelinella barremiana</i> BETTENSTAEDT
1315	<i>Lenticulina eichenbergi</i> BARTENSTEIN & BRAND
1316	<i>Lenticulina heiermanni</i> BETTENSTAEDT
1317	<i>Lenticulina multicella</i> BARTENSTEIN, BETTENSTAEDT & BOLLI
1318	<i>Lenticulina nodosa</i> (REUSS)
1319	<i>Lenticulina ouachensis</i> (SIGAL)
1320	<i>Lenticulina roemeri</i> (REUSS)
1321	<i>Lenticulina rotulata</i> LAMARCK
1322	<i>Marginulina planiscula</i> (REUSS)
1323	<i>Marginulina striatocostata</i> REUSS
1324	<i>Marginulinopsis</i> .sp.
1325	<i>Marsonella kummi</i> ZEDLER
1326	<i>Nodosaridea</i> sp.
1327	<i>Nodosaria detruncata</i> SCHWAGER
1328	<i>Planularia complanata</i> (REUSS)
1329	<i>Ramulina</i> sp.
1330	<i>Rhizammina</i> sp.
1331	<i>Spirillina minima</i> SCHACKO
1332	<i>Spirillina neocomiana</i> 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 µm), JBH-B76. **B**, *F. hoterivica* (50 µm), JBH-B109. **C**,

1414 *Gorbachikella kugleri* (50 µm), JBH-B91. **D**, *G. kugleri* (10 µm), JBH-B231. **E**,

1415 *Gorbachikella anteroapertura* (10 µm), JBH-B172. **F**, *Praehedbergella sigali* (50 µm), JBH-

1416 B221. **G**, *P. sigali* (50 µm), JBH-B 225. **H**, *P. sigali* (10 µm), JBH-B236. **I**, *Lenticulina*

1417 *roemeri* (100 µm), JBH-B2. **J**, *Lenticulina eichenbergi* (100 µm), JBH-B44. **K**, *Dorothia*

1418 *lilliformis* (100 µm), JBH-B31. **L**, *Lenticulina multicella* (100 µm), JBH-B94. **M**, *Dorothia*

1419 *praeauteriviana* (100 µm), JBH-B59. **N**, *Lenticulina ouachensis ouachensis* (100 µm), JBH-

1420 B120. **O**, *Dorothia kummi* (100 µm), JBH-B111. **P**, *Dorothia zedlerae* (100 µm), JBH-B156.

1421 **Q**, *Lenticulina rotulata* (100 µm), JBH- B205. **R**, *Gavelinella barremiana* (50 µm), 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.



Mediterranean Sea

Bizerte

Tabarka

Gulf of Tunis

Tunis

 **Site**

Beja

Plain of Oued Ettine

Jebel Boulahouajeb

Chain

Tebourba

Plain of Medjerda valley

Jendouba

Lansarine

Jebel Oust

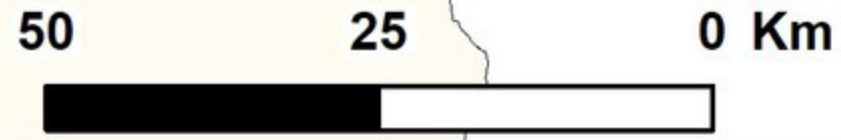
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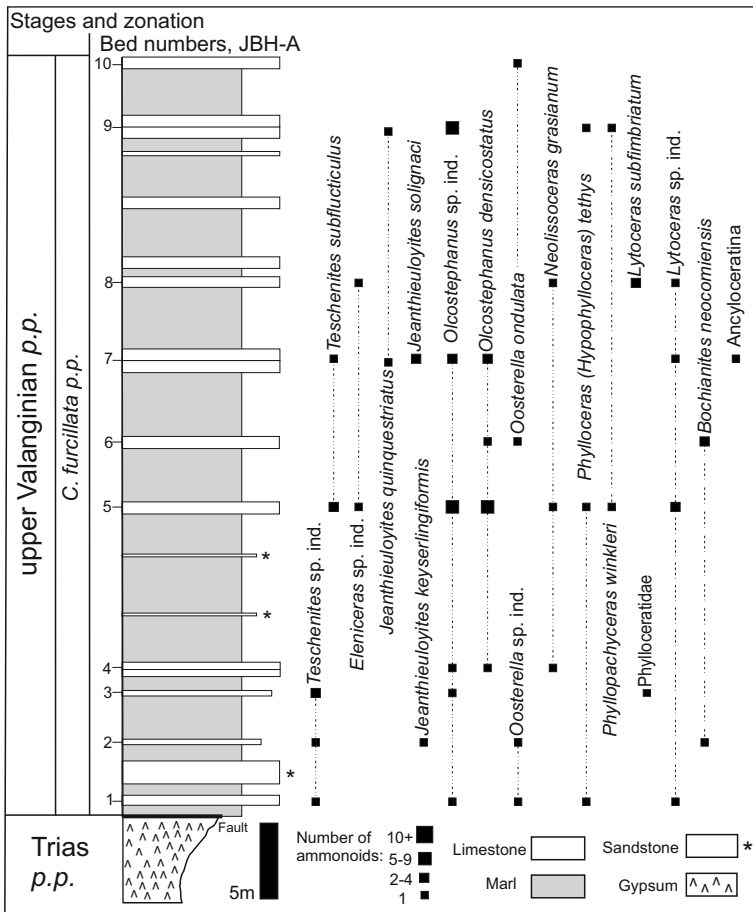
Nabeul

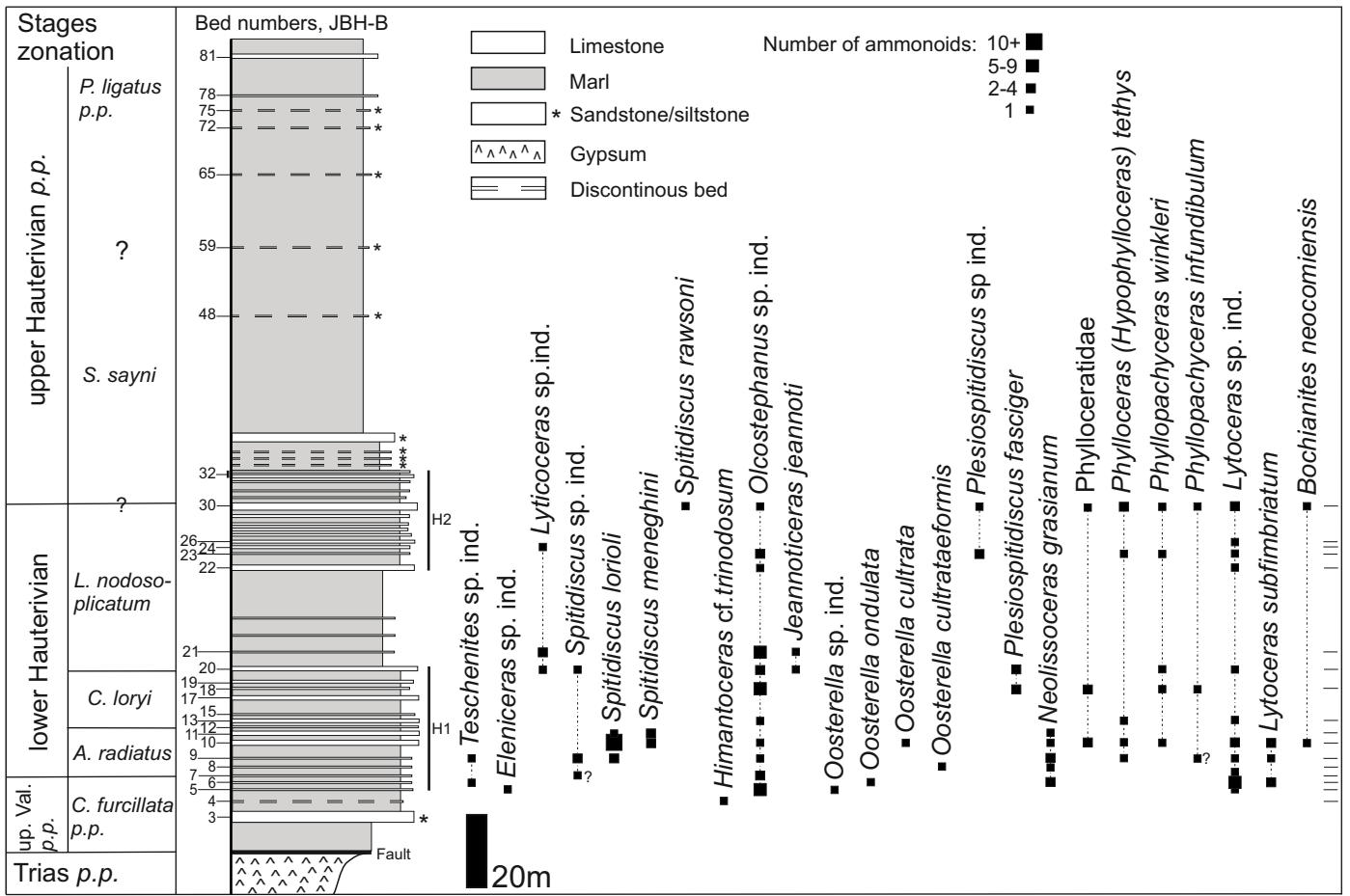
Gulf of Hammamet

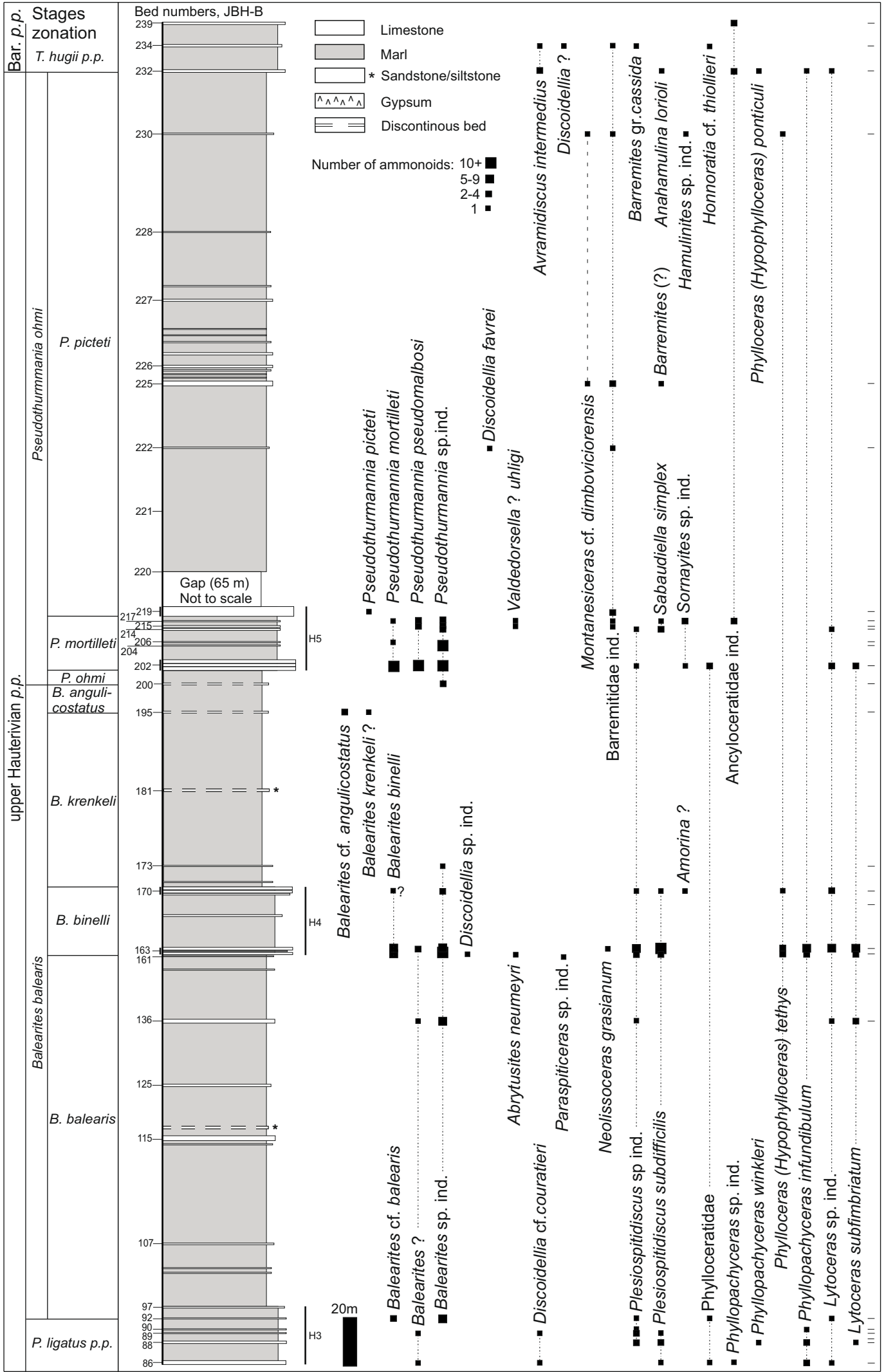
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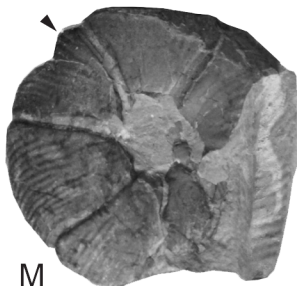
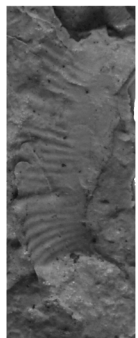
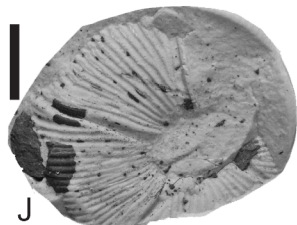
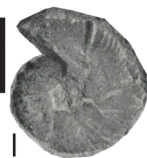
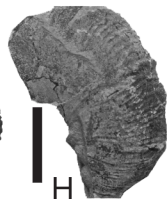
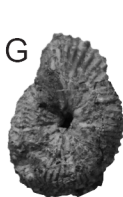
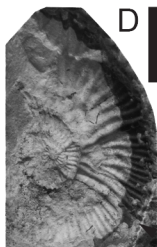
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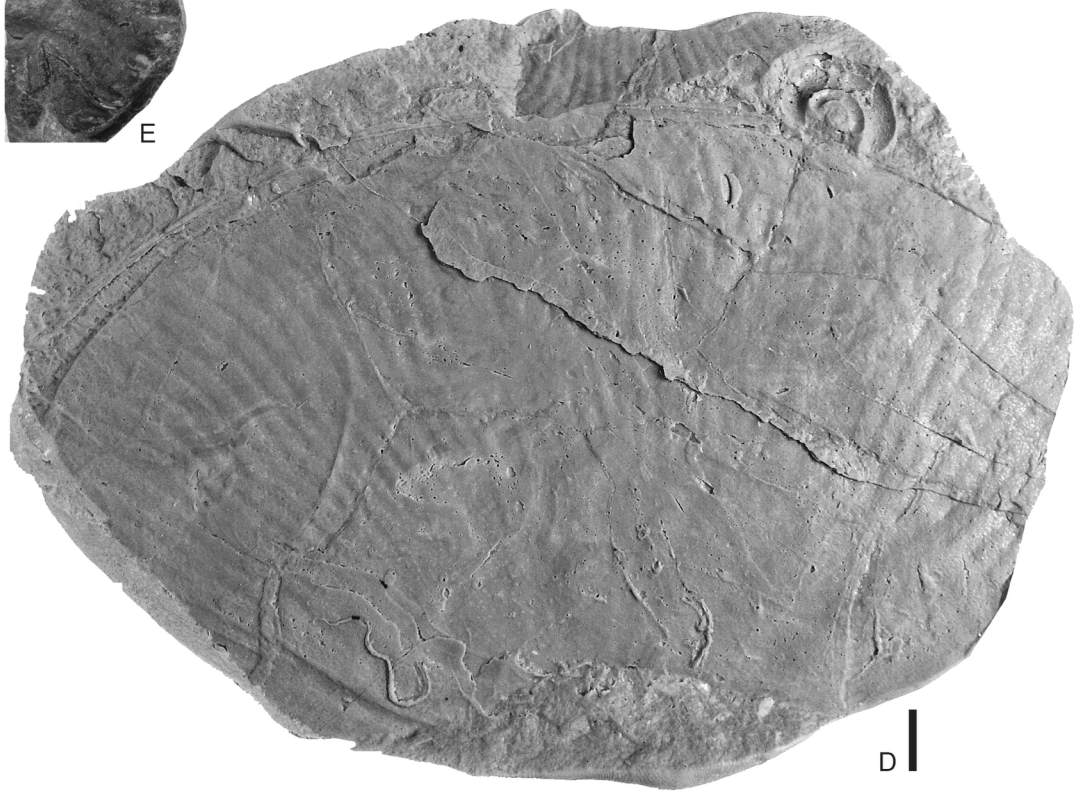
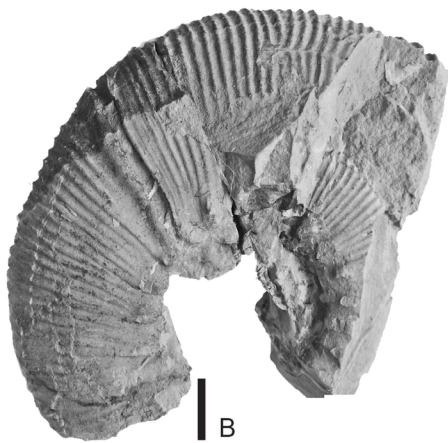






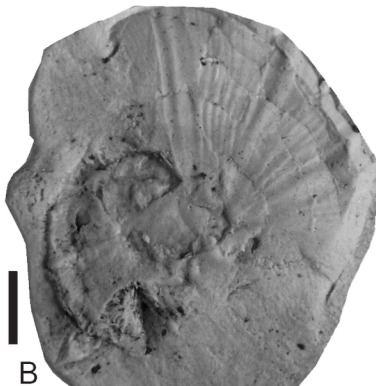




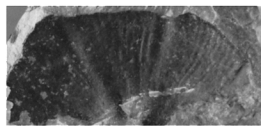




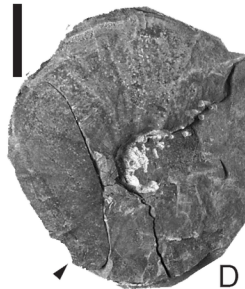
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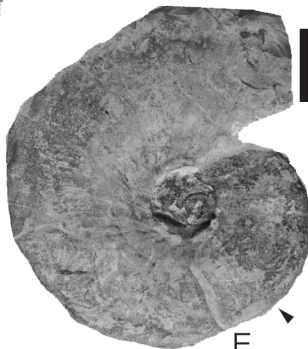
B



C



D



E



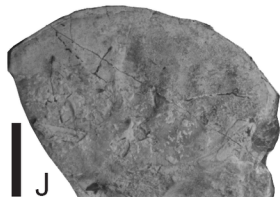
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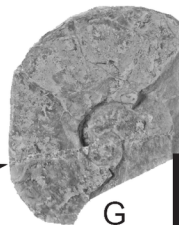
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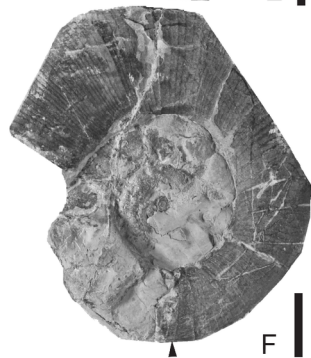
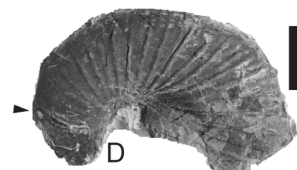
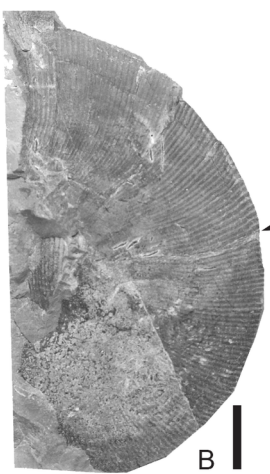
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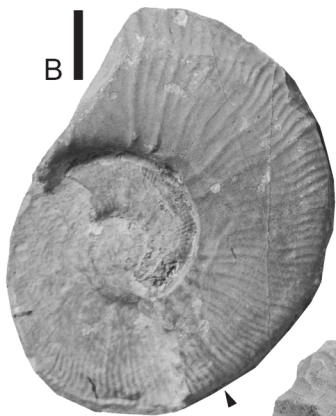


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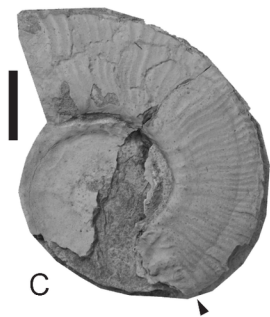




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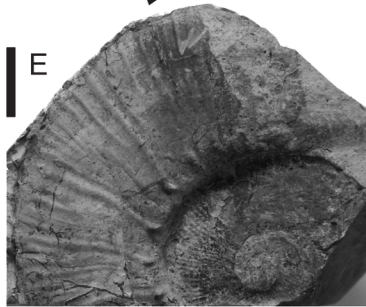
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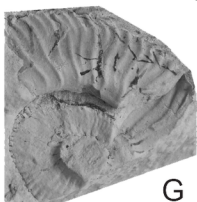
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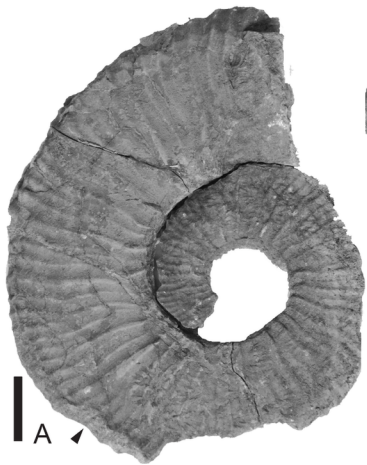
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G



H



A



B



C



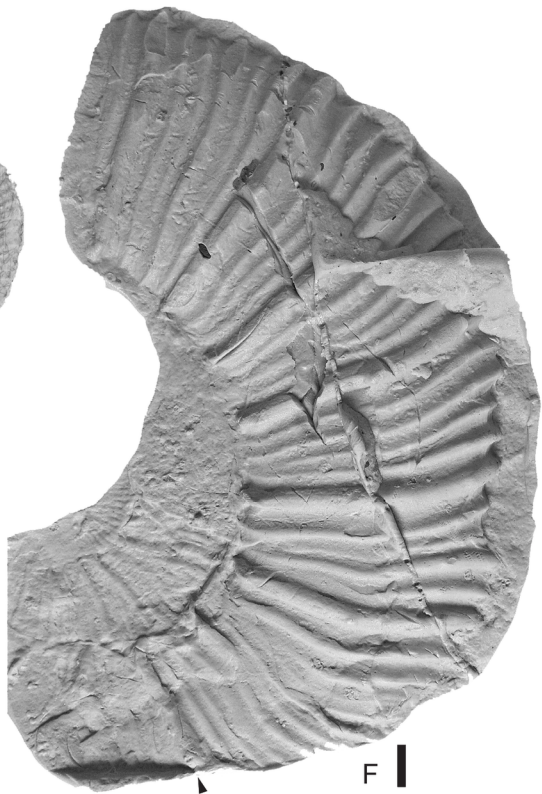
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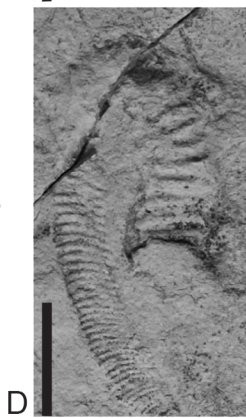
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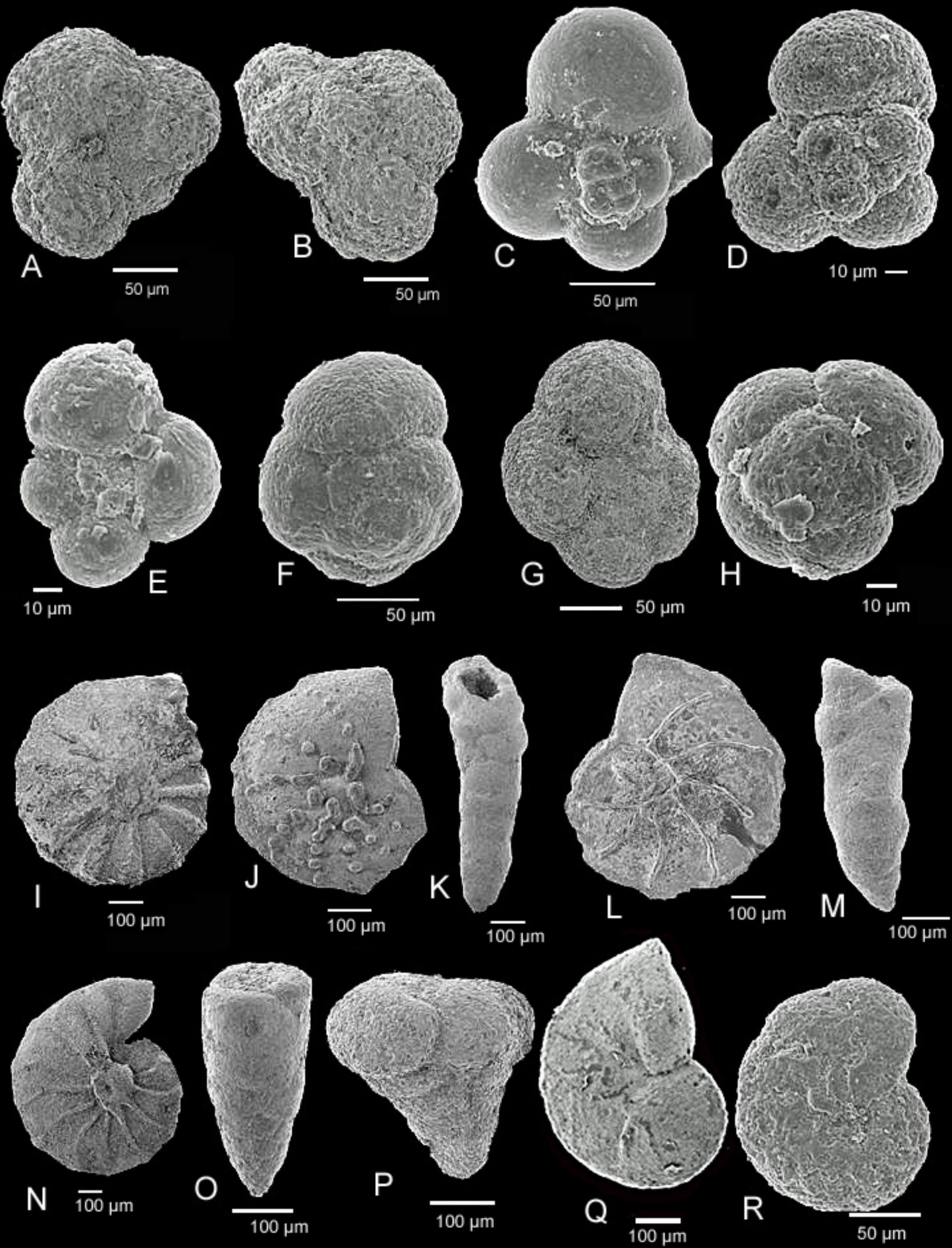


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






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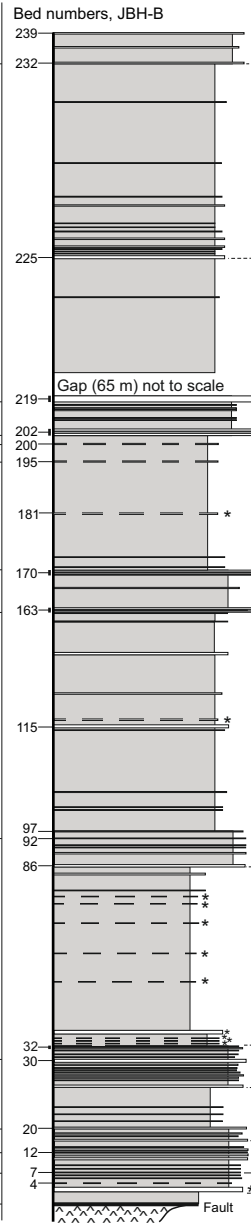




Jebel Boulahouajeb

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

Stages - Zonation	
Bar. <i>T. hugii</i>	
upper Hauterivian	<i>Pseudothurmannia ohmi</i>
	<i>P. picteti</i>
	Gap (65 m) not to scale
	<i>P. mortilleti</i>
	<i>P. ohmi</i>
	<i>B. angulicostatus</i>
	<i>B. krenkeli</i>
	<i>B. binelli</i>
	<i>B. balearis</i>
	<i>P. ligatus</i>
lower Hauterivian	<i>L. nodosoplicatum</i>
	<i>L. loryi</i>
	<i>A. radiatus</i>
	up. Val. <i>C. furcillata p.p.</i>
Trias p.p.	



Jebel Oust

Formations - Zonation - Stages

