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# The Jurassic/Cretaceous system boundary is an impasse. Why do not go back to Oppel's 1865 original an historic definition of the Tithonian?

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1     **The Jurassic/Cretaceous System Boundary is at an impasse.**  
2             **Why not go back to Oppel's 1865 original and historic**  
3             **definition of the Tithonian?**

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9     **Abstract**

10    The lack of an absolute and persistent opinion regarding definition of the base of the  
11    Berriasian Stage, i.e., its instability over the past 50 years, casts grave doubts on its  
12    suitability to be the Jurassic/Cretaceous System boundary. The question "when does the  
13    Jurassic ends?" is addressed in a discussion on the highest Jurassic stage, the Tithonian of  
14    Oppel. The Berriasian of Coquand that came later was, amongst other options, considered  
15    either as Cretaceous and to be its lower stage, or as Jurassic and to be the upper substage of  
16    the Tithonian. The first option, the Kilian view, was so far the most popular but it is most  
17    debatable because the base Berriasian is not accurately correlated over long distances and  
18    across domains (Austral, Tethyan, Boreal, basin, ramp or platform, land). In contrast, the  
19    second option, which is known in the literature as the Oppel view, although it should be called  
20    the Toucas view, has recently been resurrected from oblivion. As a matter of fact, the base  
21    Valanginian, which corresponds to biotic crises affecting the ammonites and other groups, is  
22    far the better alternative to be selected as the Jurassic/Cretaceous System boundary.

23    **Keywords**

24    Jurassic/Cretaceous boundary; Tithonian; Berriasian; Valanginian; Kilian view; Oppel view;  
25    Toucas view

26    **Introduction**

27 The question of the highest Jurassic stage was first discussed during two Jurassic  
28 Colloquia, Luxembourg 1 (1962) and Luxembourg 2 (1967), again in the Cretaceous  
29 Colloquium in Lyon (1963) and in the Lyon-Neuchâtel (1973) Colloquium that was devoted  
30 to the Jurassic/Cretaceous boundary.

31 Now, according to the new guidelines of the ICS (International Commission on Stratigraphy),  
32 the aim is to fix a boundary at a point in a section providing a well-defined standard. Such  
33 GSSPs (Global Stratotype Sections and Points) are most commonly defined at a  
34 biostratigraphical marker point (Remane et al., 1996).

35 Thus, the International Subcommittee on Jurassic Stratigraphy (ISJS) is responsible for  
36 identifying the highest Jurassic stage and to propose a GSSP, in which its basal boundary is  
37 defined. Likewise, the International Subcommittee on Cretaceous Stratigraphy (ISCS) is  
38 tasked to define the lowest Cretaceous stage and to propose a discrete GSSP, in which its  
39 basal boundary is defined. The latter is likely to serve as the Jurassic/Cretaceous system  
40 boundary. As yet no GSSP has been defined either for the higher stage of the Jurassic or for  
41 the lower stage of the Cretaceous. This situation was no longer tenable and in 2007 the ISCS  
42 Berriasian Working Group has resumed a new phase of activity.

#### 43 **1. What name for the highest stage of the Jurassic System?**

44 **Here fig. 1.**

45 At the end of the 19th and the beginning of the 20th century, in addition to Orbigny's stages,  
46 numerous other names were proposed and used with quite different meanings (Arkell, 1946).  
47 Thus, without considering the Havrian of Brongniart (1829), between 1833 and 1943, no  
48 fewer than 35 stage names or stage-sounding names were proposed for the Upper Jurassic  
49 alone. Figure 1 lists only the stage names referring directly to uppermost Jurassic  
50 nomenclature and the Jurassic/Cretaceous boundary.

51 The great variability of the facies explains why most stage names been created in the Jura  
52 Mountains or adjacent regions. The Havrian, the Crussolian (Rollier, 1917), the Suebian  
53 (Hennig, 1943), the Bolonian (Blake, 1881), the Bononian and the Aquilonian (Pavlow, 1892,  
54 1896), the Ardescian (Toucas, 1890) and the Dorsetian (Barthel et al., 1964) stages are  
55 directly concerned. Most of these names were quickly abandoned, but some were more  
56 successful and were used outside the typical region as, for instance, the Ardescian (Énay,

57 1964; Wiedmann, 1967, 1968, 1971, 1975), the Crussolian (Zeiss, 1964, 1975; Wiedmann,  
58 1968, 1971), the Danubian (Zeiss, 1964, 1975; Wiedmann, 1967, 1968, 1971, 1975), and the  
59 Bolonian (Blake, 1881; Cope, 1993, 1995, 1996). The Havrian, the Suebian and the Dorsetian  
60 did not have any success.

61 The Bolonian stage was introduced by Blake (1881) for beds in uppermost Kimmeridgian and  
62 lowermost Portlandian. The ambiguous understanding of Orbigny's Kimmeridgian and  
63 Portlandian resulted in two opposing concepts, a short Portlandian *sensu anglico* (Arkell,  
64 1946; Cope 1995) and a longer Portlandian *sensu gallico* (Haug, 1898; Pavlow, 1896; Cope,  
65 1995).

66 As soon as the Tithonian stage (Oppel, 1865) was introduced, the new stage name was  
67 rejected by Hébert (1869). His position was taken up by Buckman (1922, p. 31) and  
68 developed especially by Spath (1923, 1925, p. 159). For a long time Spath (1950) assumed  
69 the post-Portlandian age of the Tithonian. Arkell (1946) discouraged using the Tithonian  
70 because the name was not based on a locality name and lacked a stratotype. However, he used  
71 Tithonian again in his synthetic work on the Jurassic Geology of the World (Arkell, 1956),  
72 because he confessed being obliged to use it for the regional stratigraphic descriptions of the  
73 vast Tethyan domain. Much discussed at the two 1962 and 1967 Jurassic Conferences (Barthel  
74 et al., 1964; Énay, 1963, 1964), the Tithonian stage was quickly adopted for the Tethyan  
75 domain and considered the equivalent of the Portlandian *sensu gallico*.

76 **Here Fig. 2.**

77 Owing to the occurrence of separate and distinct ammonite faunas in the Tethyan regions, NW  
78 Europe (northern France, Britain and Greenland) and Russia and Poland, Cope (1985, 1996)  
79 proposed to distinguish two types of stages (Fig. 2),

80 • Primary Standard Stages: ultimately the aim must be to use only the primary standard,  
81 but the acceptance of the Secondary Standard Stages would provide an immediate  
82 answer in many cases and would undoubtedly speed up the proposals and acceptances  
83 of the primary GSSPs;

84 Secondary Standard Stages: they should be accepted as necessary expedients in cases where  
85 correlation with the primary standard is at present difficult (or even impossible). This is the  
86 reason that for a long time the use of distinct terms, Tithonian, Volgian and Portlandian,

87 Berriasian and Ryazanian, was necessary. Presently the Volgian and Ryazanian stages are used  
88 in the Boreal Realm (east and north Greenland, Spitsbergen, Arctic Canada, Alaska, Barents  
89 sea, North sea, Norwegian sea, Kara sea shelves).

90 • faunal provinces side by side with Tithonian and Berriasian stages elsewhere in the  
91 world.

## 92 **2. The Jurassic/Cretaceous boundary is not yet "at the end of the tunnel"**

93 The Tithonian Stage defined by Opiel (1865) was accepted as the highest stage of the  
94 Standard Jurassic Time Scale in the International Congress of the International  
95 Subcommittee on Jurassic Stratigraphy in Poitiers (1991) and confirmed by the International  
96 Commission on Stratigraphy.

97 Although no GSSPs has been selected as yet to define the base of the Tithonian, the lower  
98 boundary was accepted to be at the base of the Lithographicum-Hybonotum Zone of the  
99 Tethyan Zonal standard (Geysant, 1997) and equivalents in other provincial zonal standards  
100 [e.g., Elegans Zone in NW Europe (Geysant, 1997); Klimovi Zone in E. Europe  
101 (Hantzpergue et al., 1998; Gallois, 2011, 2012; Rogov, 2010)]. The upper boundary will be at  
102 the base of the overlying unit. But what precisely is this unit and what is its position according  
103 to the Jurassic/Cretaceous boundary?

104 On the other hand the Jurassic/Cretaceous problem has been pending and is still awaiting a  
105 proposal that will gain a large acceptance (Remane, 1991; Wimbledon, 2008). And this issue  
106 persists in spite of new global data from multiple disciplines other than ammonite  
107 biostratigraphy. Discussions during the earlier symposia or working groups were dominated  
108 by ammonite biostratigraphy. In 2007 that has been put aside by the Berriasian Working  
109 Group.

110 **Here fig. 3.**

111 The reason for this situation is the deep provincialism of the ammonite faunas and other  
112 groups at the transition from the Jurassic to the Cretaceous (Arkell, 1956, text-fig. 101; Casey,  
113 1971, text-fig. 2; herein Fig. 3). This was also a time of a large expansion of non-marine  
114 environments that developed in N. Europe beginning in the late Oxfordian-Kimmeridgian  
115 onwards (e.g., Purbeck and Wealden facies).

116 During the concerned period three realms (or super-realms according to Westermann, 2000)  
117 are distinguished (Énay & Cariou, 1997): Boreal, Tethyan and Austral or Subaustral (not on  
118 Fig. 3). Because the biota of these realms are not homogeneous they are divided into  
119 provinces, the extent and boundaries of which were changing during time. Each of them  
120 hosted separate ammonite faunas and biozonations. Portlandian, Volgian and Ryazanian  
121 (Zakharov, 2003; Rogov & Zakharov, 2009; Callomon & Birkelund, 1982) are of restricted  
122 extent (e.g., northwestern Europe and Greenland, Russian platform, **east and north Greenland,**  
123 **Spitsbergen, Arctic Canada, Alaska, Barents sea, North sea, Norwegian sea, Kara sea shelves**)  
124 compared to the Tethyan (Mediterranean in the Central European Tethys, Indo-Pacific in the  
125 Eastern Tethys).

126 The regressive portion of the second Jurassic sequence stratigraphic cycle ends in the  
127 uppermost Berriasian; Valanginian marks the beginning of an overall transgressive phase and  
128 from the base of the Valanginian to the lower Hauterivian carbonate platforms were  
129 progressively drowned (Hoedemaeker, 1987; Hardenbol et al., 1998; Haq, 2014).

### 130 **3. The Kilian view: the Tithonian/Berriasian boundary is the Jurassic/Cretaceous** 131 **System Boundary.**

132 From many decades definition of the Jurassic/Cretaceous boundary has been a correlation  
133 enigma (Wimbledon, 2008) dating back to when stages were first defined.

134 Only a few years separate the definitions of the Tithonian (Oppel, 1865) and Berriasian  
135 (Coquand, 1871) stages. In contrast of the other stages around the Jurassic/Cretaceous  
136 boundary (e.g., Portlandian, Volgian, Ryazanian; Purbeck and Wealden), the Tithonian was  
137 not defined at a type-locality or based on a stratotype. Instead Oppel listed numerous localities  
138 in Central and Southern Europe, S Germany and SE France. Oppel's ammonite and other  
139 fossil data were published after his death by his pupil, Zittel (1868, 1870).

140 Coquand's Berriasian (1871) was not defined any better. As early as 1846 (Malbos & Dumas,  
141 1846) rock sequences in SE France were well-studied. The name Berriasian was derived from  
142 the locality of Berrias, and it is based on the "Calcaires de Berrias" Formation, which then  
143 was assumed to be part of the Neocomian Stage (Malbos & Dumas, 1846). However this  
144 position was inconsistent with the opinion of Orbigny (1842-1851). Later, their fauna was

145 described by Pictet (1867) and was named the “Berriasian Fauna” by Coquand (1870). Thus  
146 the question of the position of the Berriasian was posed early.

147 The prevailing usage became the "Kilian view" (Kilian (1890a, b, c, 1891, 1896, 1907, 1910)  
148 in spite of different views of Toucas (1888, 1889, 1890), Lapparent (1892a, b) and Haug  
149 (1898). This “Kilian view”, based on the ammonite fauna of SE France localities only, was  
150 adopted in Mazenot’s monograph (1939) on the Tithonian and Berriasian ammonites, and  
151 Remane’s studies (1963, 1968) on calpionellids. Later this view was adopted by Le Hégarat  
152 (1973) in his exhaustive thesis on the Berriasian of SE France, as well as by Barbier and  
153 Thieuloy (1963), Busnardo et al. (1965), Donze and Le Hégarat (1965 a, b, 1966 a, b, 1972),  
154 and Le Hégarat and Remane (1968).

155 Mazenot’s monograph (1939) was the first general view on the Tithonian/Berriasian and  
156 Jurassic/Cretaceous boundary in SE France but it was based mainly on ammonite specimens  
157 held in collections. Actually very few specimens were collected on the field by the author  
158 himself (Fig. 4). Le Hégarat (1973) modified Mazenot’s definition by revising the Berrias  
159 stratotype of.

160 **Here Fig. 4. ) If possible, on two facing pages**

161 **Here Fig. 5. )**

162 From new and numerous field data (Fig. 5) Le Hégarat (1973) concluded that:

- 163 • Mazenot’s upper Tithonian horizons (Aizy and Noyarey) are not superimposed one  
164 another, as they were introduced in Mazenot’s monograph, but are of the same age;
- 165 • the Berriasian is limited to the two lowest Mazenot’s horizons [i.e., "Horizon inférieur  
166 à *Berriasella paramacilenta* n. sp. et *B. grandis* n. sp." and "Horizon principal à  
167 *Berriasella boissieri* (Pictet)"]; the highest horizon [i.e., "Horizon supérieur à  
168 *Kilianella* aff. *pexiptycha* (Uhlig) et *Thurmannites* aff. *pertransiens* Sayn"] is included  
169 in the Valanginian;
- 170 • the first Berriasian ammonite zonal view with three zones and six subzones, except the  
171 basal Grandis Zone that was not subdivided. According to Mazenot, the Grandis Zone  
172 should be separated from the underlying Jacobi Zone;

- 173 • the Jurassic/Cretaceous boundary is situated between the underlying Jacobi Zone and  
174 the overlying Grandis Zone above, but this part of the succession was somewhat  
175 unreliable and lacked field data;
- 176 • ammonite zones and subzones can be correlated with the Calpionellid zones and  
177 subzones (Le Hégarat & Remane, 1968);
- 178 • the Jurassic/Cretaceous boundary based on calpionellids falls into the middle of the  
179 Calpionella (B) Zone, although a well-defined boundary could not be clearly traced.

180 However, quite a different interpretation of the Jurassic/Cretaceous boundary and the  
181 Berriasian stage is possible if the original definition of the Tithonian by Oppel (1865) is  
182 considered.

#### 183 **4. Original definition of the Tithonian: a different view of the Jurassic/Cretaceous** 184 **System Boundary**

185 Oppel defined the Tithonian (1865, p. 535) as “...*a particular formation group located*  
186 *between the stage of Kimmeridge and the deepest Neocomian layers, which I call this*  
187 *Tithonian Stage, in order to indicate the relationship of this group of layers to the Cretaceous*  
188 *formations that begin immediately above”.*

189 This definition of the lower boundary of the Tithonian could be considered ambiguous  
190 according to the later interpretations of the Kimmeridgian Stage (*sensu anglico* Arkell, 1946  
191 vs *sensu gallico* Haug, 1898; Pavlow, 1896). However, the quoted faunas by Oppel (1865) are  
192 undoubtedly those of the (*Aulacostephanus*) Eudoxus Zone, later changed to an  
193 (*Aulacostephanus*) Autissiodorensis Zone in the Subboreal Province (equivalent of the  
194 Beckeri Zone of the Mediterranean Province in the Tethyan Realm and the highest zone of the  
195 Kimmeridgian Stage (Hantzpergue et al., 1997).

196 As stated above, the Tithonian Stage was confirmed as the highest stage of the Standard  
197 Jurassic Time Scale (Sarjeant & Wimbledon, 2000; Cope, 2013) and its lower boundary was  
198 accepted to be at the base of the Lithographicum/ Hybonotum Zone. It must be unequivocally  
199 stated that Oppel defined the upper boundary of the Tithonian at “**the deeper Neocom layers**”



200 (Oppel, 1865, p. 535) and “the lowest Neocom zone” (Oppel, 1865, p. 536) that are the  
201 overlying marls with pyritic fossils of Valanginian age in SE France.

202 Consequently, besides those who followed the Kilian view and accepted the Berriasian as the  
203 first Cretaceous stage (or substage within the Valanginian Stage) (Malbos & Dumas, 1846;  
204 Coquand, 1870, 1871; particularly Kilian, 1890a, b, c, 1891, 1907, 1910), others considered  
205 the Berriasian to be part of the Jurassic (particularly Toucas, 1889, 1890, 1908, but also Haug,  
206 1898; Lapparent, 1892a, b).

207 **Here Fig. 6.**

208 **Here Fig. 7.**

209 At first Toucas (1888) accepted the Berriasian as the lowest Cretaceous stage (or substage  
210 within the Valanginian Stage). Then in 1889 he considered the Berriasian Limestones  
211 (Calcaires de Berrias) to be the upper part of the Tithonian (Fig. 6). In 1890 he documented in  
212 detail the ammonite biostratigraphy and divided the Tithonian into three subunits (Fig. 7),  
213 lower (or Diphyakalk), middle (Ardescian) and upper (Berriasian).

214 The new Ardescian Substage (or Stage) (from *Ardesca* = Ardèche) was defined from the  
215 “Calcaires blancs” (White Limestones) Formation. The Calcaires blancs Formation extends  
216 on the left side of the Rhône valley (“Calcaires blancs vocontiens” in Le Hégarat, 1973),  
217 Vaucluse, Basses-Alpes, Hautes-Alpes, Savoie and Dauphiné (Toucas, 1890, tab. p. 625; here  
218 Fig. 7). Toucas placed the the Jurassic/Cretaceous boundary at the base of the overlying  
219 “Marnes à ammonites pyriteuses” of the Valanginian (Toucas, 1890, p. 566), which was  
220 consistent with Oppel’s original definition of the Tithonian Stage.

221 Toucas view, i.e., the Berriasian as the upper unit of the Tithonian Stage in Europe, was  
222 accepted by Haug in his masterful review on “Portlandien, Tithonique et Volgien” (1898) and  
223 was extended beyond southeastern France (e.g., Bassin du Rhône) to England and northern  
224 France, southern Germany (e.g., Swabia and Franconia), the Russian Platform and eastern  
225 Mediterranean area (with the type-localities of Oppel’s Tithonian faunas, described by Zittel)  
226 (Fig. 8).

227 **Here Fig. 8**

228 So the Jurassic/Cretaceous boundary was situated at the base of the Valanginian and the  
229 Berriasian was accepted as the upper part of the Tithonian Stage and the highest unit of the  
230 Jurassic directly below the Jurassic/Cretaceous boundary.

231 Although the Toucas view was also accepted by Lapparent (1892a, b), Haug (1898), and  
232 Pavlow (1896), it was not promoted as widely as the Kilian view (see “Polemic between  
233 Toucas and Kilian” in Hoedemaeker, 1994, p. 6). Kilian was professor at Grenoble University  
234 and an authority on the stratigraphy and palaeontology at the time. Toucas was not an  
235 academic geologist, but after a military career he devoted the last years of his life to geology.  
236 Moreover, Toucas is mainly known worldwide by his remarkable studies on Late Cretaceous  
237 *Hippurites* and *Radiolites*, but not for his studies on Upper Jurassic stratigraphy.

## 238 **5. Brief return of the Toucas view and the Lyon-Neuchâtel colloquium (1973)**

239 In 1967 Wiedmann (1967) was the first who reintroduced the original Opper’s understanding  
240 of the Tithonian Stage and later he stood by this opinion in several papers on the same topic  
241 (1968, 1971, 1974, 1975, 1980). At the Jurassic colloquium in Luxembourg (1967), Barthel  
242 (1974) assumed that the Berriasian faunas show still clear Tithonian affinities and suggested  
243 to place the Jurassic/Cretaceous boundary at top of the Boissieri Zone. This proposal received  
244 further support (Wiedmann, 1975; Druschichts, 1975; Badaluta, 1975) at the Lyon-Neuchâtel  
245 Colloquium (1973).

246 **Here Fig. 9.**

247 **Here Fig. 10.**

248 At the same time the Ardescian Stage was rediscovered (Druschichts, 1969; Patruilius et al.,  
249 1976; Wiedmann, 1980; Geyer, 1983), although Wiedmann and Druschichts did not agree  
250 exactly on its original meaning. However Toucas had not defined accurately his stage except  
251 that it was based on the “Calcaires blancs” Formation. A modern revision of the Ardescian  
252 stratotype section was presented much later (Énay, 1980; Cecca, 1986; Cecca et al., 1988,  
253 1989a, b; Jan du Chêne et al., 1993).

254 The Ardescian Stage was considered only as part of the Tithonian *s.l.* and the Berriasian was  
255 included as well. The Jurassic/Cretaceous boundary according to Wiedmann (1967, 1975,  
256 1980) and Druschichts (1974, 1975) was situated at the base of the *Th. thurmanni* Zone, the

257 lowest zone of the Valanginian in accordance with Oppel's Tithonian definition and Toucas  
258 view (Figs. 9 and 10).

259 Lyon-Neuchâtel Colloquium (1973) and results of the survey on the Jurassic/Cretaceous  
260 boundary.

261 Long discussion at the end of the Lyon-Neuchâtel Colloquium resulted in 12 resolutions that  
262 could not be discussed in the allotted time. Among these were two on the Toucas view even  
263 though it had little impact. Thus a survey was organized to be conducted following the  
264 meeting to poll opinions on the resolutions and on the Jurassic/Cretaceous boundary.

265 • Resolution III, by J. Flandrin, R. Énay, J.-P. Thieuloy, G. Le Hégarat and V.  
266 Druschichts with three proposals,

267 1. The Tithonian/Berriasian boundary at the base of the Jacobi-Grandis Zone and the  
268 calpionellids Calpionella (B) Zone;

269 2. Berriasian/Valanginian boundary at the base of the Pertransiens Zone;

270 3. The Jurassic/Cretaceous boundary at the base of the Valanginian.

271 • Resolution XII, by A. Zeiss,

272 1. Tithonian is the upper stage of the Jurassic system and

273 2. Tithonian is divided into four substages,

274 ○ *Danubian* (Hybonotum-Palatinum zones),

275 ○ *Neuburgian* (Bavaricum Zone *l.s.* = Semiforme-Ponti zones),

276 ○ *Ardescian* (Microcanthum-Durangites zones\*- Transitorius Zone *s.l.*; Calpionellid A  
277 Zone); [\*today Andreaei Zone]

278 ○ *Berriasian* (Jacobi-Boissieri zones; B-D Calpionellids zones).

279 Of the 120 questionnaires sent to the participants, only 70 concerned the resolutions but  
280 questions on the Jurassic/Cretaceous boundary gathered 84 votes. The detailed results of the  
281 survey are not presented again here, only the votes concerning Resolution III are listed.

- 282 • Resolution III itself, 22/70 favorable votes;
- 283 • Proposal 1 (Tithonian/Berriasian boundary), 52/84 favorable votes;
- 284 • Proposal 2 (Berriasian/Valanginian boundary), 73/84 favorable votes;
- 285 • Proposal 3 (Jurassic/Cretaceous boundary), 18/84 favorable votes (facing 33 favorable
- 286 votes to the boundary at the base of the Jacobi-Grandis Zone, see below).

287 There was a large consensus for:

288 (I) as far as possible no change to the classical view (e.g., Resolution IV);

289 (II) to shift the basal Berriasian boundary at the base of the Jacobi-Grandis Zone (52/84

290 votes);

291 (III) Berriasian/Valanginian boundary at the base of the Pertransiens Zone (73/84 votes);

292 (IV) Berriasian as a Cretaceous stage (48/84 votes);

293 (V) Opinions on the Jurassic/Cretaceous boundary were more divided, the relative majority

294 favored to be at the base of the Jacobi-Grandis Zone (33/84 votes), hence the absolute

295 majority (51/84) was opposed to this view. This status quo remained pending until new

296 arguments that could potentially be introduced at a later date.

297 **6. Fixing the Jurassic/Cretaceous boundary at the base of the Berriasian: Would it be**

298 **the right solution?**

299 One purpose of the Berriasian Working Group of the ISCS is to place the Jurassic/Cretaceous

300 boundary at the base of the present Berriasian stage (Wimbledon et al., 2011; Wimbledon,

301 2014, 2016). A definable GSSP needed to be, but has not yet, been accepted, and that « *datum*

302 *must be readily correlable, traceable as much as possible around the world* » (Wimbledon,

303 2008). It was agreed to follow the conclusion or recommendations of the earlier colloquia in

304 Lyon (1963), Lyon-Neuchâtel (1973) and Brussels (1995), i.e., it is very important to maintain

305 the base of the Cretaceous at the base of the Berriasian and to continue to use the vague

306 Jacobi-Grandis Zone (or equivalent) in defining a stage base (Wimbledon, 2008).

307 Earlier symposia and working groups were dominated by ammonite discussions. These have

308 been put aside by the Berriasian Working Group in 2007 and, since 2009, works were

309 refocused on integrated high-resolution studies, still including ammonites, but with effective  
310 use of several microfossil groups (e.g., Calpionellids, calcareous nannofossils, calcareous  
311 dinoflagellates), and calibrated with magnetostratigraphy (Wimbledon, 2008, 2014, 2017a, b;  
312 Wimbledon et al., 2011).

313 At the same time the Kilian Group (IUGS Lower Cretaceous Ammonite Working Group) re-  
314 affirmed the primacy of ammonites, “*While Wimbledon et al. (2011) regarded ammonites as*  
315 *secondary boundary markers for the J/K event, our meeting concluded that they could provide*  
316 *the primary marker*” (Reboulet et al., 2014).

#### 317 6.1. What locality and section as a potential GSSP of the Tithonian/Berriasian boundary?

318 The historical stratotype of Berrias being unsuitable because fossiliferous units do not extend  
319 low enough to reach the supposed base of the Berriasian and Cretaceous (Le Hégarat, 1965,  
320 1973), another locality should be selected 1) with the base of the acme of the small orbicular  
321 *Calpionella alpina* as the primary marker voted by the Berriasian Working Group,  
322 supplemented by 2) ammonite and 3) nannofossil datums, as well as a reliable 4)  
323 magnetostratigraphic record (Wimbledon, 2014, 2016). In addition, other parameters should  
324 be considered, including a rather thick interval spanning the Alpina Subzone and a full  
325 coverage of the M19r, M19n and 18r magnetochrons.

326 SE France is the original area for the Berriasian. Several relatively thick sections span the  
327 Tithonian–Berriasian interval and are rather close to each other in the Département of Drôme.  
328 One of these is the Le Chouet section, south-east of Luc-en-Diois (Drôme). This locality  
329 received significant attention by Le Hégarat (1973), Remane (1970), Boughdiri (1994), Cecca  
330 and Énay (1991), and Énay et al. (1998). The Le Chouet limestones have been considered to  
331 be equivalent of the «Calcaires blancs» Formation (Calcaires blancs vocontiens in Le Hégarat,  
332 1973) as the type-unit of the Ardescian (Toucas, 1890).

333 **Here Fig. 11.**

334 Frau et al. (2015) revised the ammonite succession of Wimbledon et al. (2013) and integrated  
335 the calpionellid ranges and magnetostratigraphy. The result was that no FAD or LAD datums  
336 of different fossils were synchronous (Fig. 11):

- 337 • the lower boundary of the Jacobi ammonite Zone, which was formerly one of the  
338 possible Jurassic/Cretaceous boundary marker candidates (cf. Lyon-Neuchâtel  
339 Colloquium, 1973), falls within the calpionellid Crassicollaria Zone, Colomi (A3)  
340 Subzone;
- 341 • the selected (Wimbledon et al., 2011) calpionellid zonal boundary between  
342 Crassicollaria (A) Zone and Calpionella (B) Zone, now considered by the Berriasian  
343 Working Group to be the Tithonian/Berriasian and Jurassic/Cretaceous boundary, is  
344 located within the lower part of the Jacobi Zone;
- 345 • concerning the magnetostratigraphy, the top of the uppermost Tithonian Andreaei  
346 ammonite Zone should here coincide within the M19r/m19n boundary, whereas the  
347 base of the Calpionella Zone (Alpina Subzone) is within the magnetochron M19n  
348 (Wimbledon et al., 2013). The latter is consistent with its position relative to  
349 magnetostratigraphy (Wimbledon et al., 2017b) at Puerto Escaño (Spain) and Lókút  
350 (Hungary), but not at Brodno (Poland).;
- 351 • moreover, the exact position of the boundary at Le Chouet defined by means of  
352 ammonites, i.e., between the Andreaei Zone and the Jacobi Zone, and therefore that of  
353 the Tithonian/Berriasian boundary are uncertain. This uncertainty is due to the absence  
354 of fauna in debris flow deposits (slump and breccias), notably those of the beds 86-88,  
355 which indicates a clear gap in the ammonite succession. This gap probably affected the  
356 magnetochrons too. It cannot be detected with the calpionellids because it occurs  
357 within a single subzone, i.e., in the calpionellid Crassicollaria Zone, Colomi (A3)  
358 Subzone.

359 These "*very important gaps due to synsedimentary slump deposits*" have clearly been  
360 highlighted by Le Hégarat and Ferry (1990) and Ferry and Granier (2019). Among the  
361 sections in the Département of Drôme, these breccia intercalations may be absent in the  
362 nearby section at La Haute-Beaume and in the more remote section at Tré Maroua. However,  
363 the distance from Le Chouet does not preclude the absence of gaps.

364 The Berriasian Working Group reviewed and discussed (Wimbledon, 2016) the positive or  
365 negative aspects of many other sections in southern Spain, Italy, Poland, Hungary, and Czech  
366 Republic. But none fully meets the criteria of choice required by ICS.

367 6.2. Recent advances in placement of the base of the Berriasian Stage and the  
368 Jurassic/Cretaceous boundary

369 These advances are directly related to calibrating magnetostratigraphy with fossil range data,  
370 especially the formerly suggested primary marker levels as the base of the Jacobi ammonite  
371 Subzone [published (1975) Lyon-Neuchâtel colloquium (1973) decision], the calpionellid  
372 Alpina Subzone (Wimbledon, 2014), and the Grandis ammonite Subzone. The use of Grandis  
373 Subzone was abandoned long time ago (Hoedemaeker & Bulot, 1990, p. 124, point 2.) due to  
374 its uncertain stratigraphic position and ammonite assemblage. Frau et al. (2016a, b) and  
375 Reboulet et al. (2018) suggested abandoning the Jacobi Zone due to the problematic  
376 systematic position of the index so their use is inappropriate for stratigraphic purposes.  
377 Hence, it was removed from the most recent standard Mediterranean ammonite zonation  
378 (Reboulet et al. 2018).

379 During the twelve past years, several Jurassic/Cretaceous boundary successions from regions  
380 outside the classic Western Tethys (references in Wimbledon, 2017b), such as North and  
381 South America, the Russian Platform and Northern Siberia (Nordvik), have been documented.  
382 Due to faunal and floral provincialism or endemism, a long-range correlation is difficult  
383 between the Mediterranean Western Tethys and the Boreal region and its extensive, non-  
384 marine basins (North Sea, Dorset).

385 Wimbledon et al. (2011) gave a list of no fewer than 14 possibilities or proposed markers for  
386 the Tithonian/Berriasian and Jurassic/Cretaceous boundary, also supplemented by Gradstein et  
387 al. (2012), which are (Fig. 12):

388 **Here fig. 12.**

389 Magnetostratigraphy:

390 1. Base of chron M18r (choice of Gradstein and Hinnov in Gradstein et al., 2012);

391 2. Base of chron M19n1n;

392 3. Base of chron M19n1r;

393 Ammonites:

394 4. Base of the Grandis Zone [Published (1965) Lyon colloquium (1963) decision]. Note that,  
395 as stated above, the Grandis Subzone was abandoned long ago (see Hoedemaeker & Bulot,  
396 1990, p. 124, point 2);

397 5. Base of the Jacobi Zone [Published (1975) Lyon-Neuchâtel (1973) colloquium decision];

398 6. Base of the Lamplughi Zone;

399 Calpionellids:

400 7. Base of the Calpionella (B) Zone (boundary of Crassicollaria (A)/Calpionella (B) zones),  
401 i.e., base of the acme of *Calpionella alpina*;

402 8. « Explosion » of small, globular *C. alpina*;

403 Calcareous nannofossils:

404 9. FAD of *Nannoconus wintereri* and *Cruciellipsis cuvillieri*;

405 10. FAD of *Nannoconus steimannii* var. *minor* and *N. kamptneri* var. *minor*;

406 Palynomorphs:

407 11. LAD of *Dichodogonyaulax pannea* and *Egmontodinium polyplacophorum*;

408 12. FAD of *Warrenia californica*, *Dichodogonyaulax bensonii*, and *Ampiculatisporis*  
409 *verbitskayae*;

410 13. FAD of *Matonisporites elegans* and *Aequitriradites spinulosus*;

411 14. *Classopolis* collapse.

412 At the Warsaw meeting (2013) of the Berriasian WG, a consensus was “*that the base of the*  
413 *Calpionella alpina (Alpina) Subzone provides the most widespread and consistent candidate*  
414 *for a primary boundary marker*” (Wimbledon, 2014). And at the end of the Vienna Cretaceous  
415 Symposium (2017), Wimbledon (2017b) published a complete review of “*Developments with*  
416 *fixing a Tithonian/Berriasian (J/K) boundary*”. At the present state of knowledge the situation  
417 is as follow (« Conclusions » in Wimbledon’s 2017b paper):



418 **Here fig. 13.**

- 419 • no species are globally distributed in the Tithonian-Berriasian interval. The most  
420 widespread is *Calpionella alpina*;
- 421 • «*Berriasella*» *jacobi* is missing in the lower part of the nominal Jacobi Subzone and is  
422 to be ruled out as GSSP marker, as well as the index-species of the Grandis Subzone  
423 (see above note concerning the Grandis ammonite Zone);
- 424 • calpionellids associated with magnetostratigraphy calibration allow the most effective  
425 primary marker for the J/K boundary, the *Crassicollaria* to *Calpionella* turnover, i.e.,  
426 the Colomi/Alpina subzone boundary as shown in figure 12 (dotted line). Note that it  
427 is not a FAD (but the base of an acme);
- 428 • the *Crassicollaria* to *Calpionella* turnover and base of the Alpina Subzone  
429 (*Calpionella* Zone) has been selected as the primary marker for the base of the  
430 Berriasian Stage by the Berriasian Working Group (2013);
- 431 • as shown on Fig. 13 this level falls within a number of nannofossil FADs.

432 New correlation advances and finds from **western** Siberia and South America (Argentina)  
433 (references in Wimbledon, 2017b) concerning calcareous nannofossils and calcareous  
434 dinoflagellates are hopeful but there are discrepancies of magnetostratigraphical results in  
435 South America.

### 436 6.3. Changing opinions and proposals on the Berriasian Stage and the Jurassic/Cretaceous 437 boundary

438 In spite of these positive advances, we do not see the end **of the Jurassic/Cretaceous boundary**  
439 **problem**. Indeed, we cannot hide the instability attached to the current Tithonian/Berriasian  
440 limit which, concerning ammonites and calpionellids (often seen as the most useful fossil  
441 group that could provide a Jurassic-/Cretaceous boundary), has changed four or five times in  
442 the last fifty years (Granier, 2019a):

- 443 • base of the ammonite Grandis Zone and within calpionellid zone *Calpionella* (B) Zone  
444 (Lyon Symposium, 1963) ;
- 445 • base of the ammonite Jacobi Zone, an event considered as equivalent to the boundary  
446 between the calpionellid *Crassicollaria* (A) Zone and *Calpionella* (B) Zone (Lyon-  
447 Neuchâtel Symposium, 1973) (boundary A in Hoedemaeker, 1991), since recognized

448 as being within the calpionellid Crassicollaria (A) Zone (Grabowski et al., 2011; Bulot  
449 et al., 2014);

- 450 • base of calpionellid Calpionella alpina (B1) Subzone, Calpionella (B) Zone, selected  
451 by the Berriasian Working Group (2013) and confirmed (2017) as the primary  
452 Tithonian/Berriasian boundary marker (Wimbledon, 2014, 2017);
- 453 • base of the ammonite Occitanica Zone, Subalpina Subzone very close to the base of  
454 the calpionellid Calpionella (B) Zone, Elliptica (B2) Subzone (boundary B in  
455 Hoedemaeker, 1991), but according to Wimbledon (2017) “*the Elliptica Subzone base*  
456 *is below that of the Occitanica Zone*”.

457 Magnetostratigraphy has been of great help for calibrating fossil range data and  
458 correlation between marine and non-marine deposits, but it cannot be used alone for fixing a  
459 GSSP, wherever the place where the boundary would be situated (it should be  
460 biostratigraphically calibrated, hence called "biomagnetostratigraphy"). However, regarding  
461 magnetostratigraphy, the results are just as uncertain,

- 462 • the Tithonian/Berriasian boundary (=Jurassic/Cretaceous boundary) was first placed at  
463 the base of Chron M18r (Wimbledon, 2008; Gradstein et al., 2012), because it is close  
464 to the base of the Jacobi Zone and even closer to the base of the calpionellid  
465 Calpionella (B) Zone. It was again proposed by Arkadiev et al. (2017), but it is  
466 considered an "approximation", not supported by any documentation of biotic events.  
467 Finally Wimbledon (2017b) stated that although it is widely identified it cannot be  
468 calibrated by any widespread fossil marker.
- 469 • in a report of the Berriasian working Group **meeting in Warsaw (2013 in Wimbledon,**  
470 **2014)**, the boundary is clearly set near the base of M19n.1r. The graphical display  
471 favors this proposal (Fig. 12). However, in the most recent contributions (Wimbledon,  
472 2014, 2017), the base of the calpionellid Calpionella (B) Zone is strongly shifted  
473 downward into the M19n.2n (Fig. 13).

474 This instability of opinions and proposals on the Berriasian Stage and the Jurassic/Cretaceous  
475 boundary contrasts with the greater stability of the Berriasian/Valanginian boundary. Instead,  
476 it encourages us to return to this alternative view, the best alternative as already suggested  
477 during Lyon-Neuchâtel (1973) colloquium and in the recent JK2018 meeting (Granier, **2019a,**  
478 **b**).

479 **7. Why the Jurassic/Cretaceous System Boundary should not be at the base of the**  
480 **Valanginian Stage?**

481 Two aspects will be examined, first the evolution of the place of the Berriasian/Valanginian  
482 boundary since Mazenot (1939), then the faunal changes at the level of this boundary  
483 compared to those at the Tithonian/Berriasian boundary.

484 7.1. Place of the Berriasian/Valanginian boundary by means of ammonites

485 Mazenot (1939) placed the Berriasien/Valanginian boundary between the beds with  
486 *Neocomites neocomiensis* at the base of the Valanginian and its upper horizon with *Kilianella*  
487 *aff. pexiptycha* (Uhlig) and *Thurmannites aff. pertransiens* Sayn at the top of the Berriasian.  
488 The latter was already considered as Valanginian by Le Hégarat (1973), as Pertansiens  
489 Subzone of the Roubaudi Zone.

490 With the definition of new zones, different authors have placed the Berriasian/Valanginian  
491 boundary, either at the base of the Pertransiens Subzone (Le Hégarat, 1973), which was the  
492 Orbigny view and the opinion of most authors, or at the base of the Otopeta Zone *sensu*  
493 Busnardo and Thieuloy (1979), or at the base of the Alpillensis Subzone *sensu* Hoedemaeker  
494 (1982).

495 **Here Fig. 14**

496 After discussing these proposals, a first synthesis attempt was proposed by Bulot et al. (1993)  
497 who placed the Berriasian/Valanginian boundary at the base of the Otopeta Subzone, then the  
498 lower subzone of the Pertransiens Zone. Later, the Kilian Group (Hoedemaeker et al., 2003;  
499 Reboulet et al., 2014) agreed to return the lower boundary of the Valanginian at the base of  
500 the Pertransiens Zone, and reascribe the Otopeta Subzone to the Boissieri Zone, which made  
501 the Otopeta Subzone the uppermost subzone of the Berriasian (Fig. 14).

502 This return to the original scheme defended by Le Hégarat (1973) underlines the stability of  
503 the Berriasian/Valanginian boundary.

504 7.2. Faunal changes at the Berriasian/Valanginian boundary compared to those at the  
505 Tithonian - Berriasian boundary.

506 Faunal changes at the Tithonian/Berriasian boundary and Berriasian/Valanginian boundary are  
507 not of a similar significance. These changes do not provide the same possibilities for wide  
508 geographic correlations.

509 1) Tithonian/Berriasian boundary.

- 510 • Tithonian/Berriasian boundary situated between the Jacobi and Grandis zones and  
511 within the Calpionella (B) Zone (Le Hégarat, 1973; Lyon Colloquium, 1963): As  
512 stated first by Le Hégarat (1973, p. 297), concerning both the ammonite and  
513 calpionellid faunas “(...) Tithonian-Berriasian transition is badly characterized  
514 paleontologically because no essential change occurs at this level”.
- 515 • Tithonian/Berriasian boundary situated between the Durangites (= Andreaei) and  
516 Jacobi zones and at the boundary of the Crassicollaria (A) and Calpionella (B) zones  
517 (Remane 1963, 1964, 1971; Cecca, 1986; Cecca et al., 1988, 1989a, b) or within the  
518 colomi (A3) Subzone, Crassicollaria Zone (Bulot et al. 2014; Frau et al., 2016a, c).  
519 According to Wimbledon et al. (2013), Bulot et al. (2014), Frau et al. (2015, 2016a, b,  
520 c) the change between the highest Tithonian Andreaei Zone and the lowest Berriasian  
521 Zone is of usual level for succeeding zones, i e., without any significant abrupt biotic  
522 discontinuity.

523 In contrast, in Southern Spain Tavera et al. (1986, 1994) described a quite different situation,  
524 the change from the Jacobi Zone with respect to the Andreaei Zone being named the « Second  
525 ammonite renovation ». It is likely that this contrast is due to the biogeography and the  
526 environments of the Mediterranean province where the faunas are richer and more diversified.  
527 The Himalayitidae occupy a dominant position there, which they do not have in the  
528 Submediterranean province.

529 **Here Fig. 14**

530 2) The Berriasian/Valanginian boundary (Fig. 15).

531 Unlike the Tithonian/Berriasian boundary, the boundary between the Berriasian (Boissieri  
532 Zone, Callisto Subzone) and the Valanginian (the former Roubaudi Zone, Pertransiens  
533 Subzone) is marked by “a nearly complete renewal of ammonite genera” (Le Hégarat, 1973,  
534 p. 295) and again (p. 299), “...in the present state of our knowledge the division line of the  
535 Berriasian and Valanginian faunas provides the best prospective boundary”. **But**, Le Hégarat

536 and Remane (1968) and Hoedemaeker (1981, 1982) observed that, **locally in SE France and**  
537 **Spain, the boundary could** be affected by a hiatus and some reworking.

538 As well-noticed by Patruilus et al. (1976, p. 118), results on ammonites, calpionellids and  
539 nannoplankton from the Berriasian/Valanginian boundary beds in southern Spain by Allemann  
540 et al. (1975) would “*discredit the assumption that the lower boundary of the Valanginian is*  
541 *better defined by changes in fauna than the base of the Berriasian*”. However, with respect to  
542 the ammonites listed, occurrences in the Jacobi Zone of species such as *Protacanthodiscus*  
543 *andreaei* and *Micracanthoceras microcanthum* cast some doubt on the accuracy of the  
544 determinations or document a possible reworking related to the tectono-sedimentary context  
545 of the area studied.

546 The Berriasian/Valanginian boundary was long ago fixed at the base of the Pertransiens Zone  
547 (Bulot et al., 1993). Recently, Reboulet et al. (2018) introduced *Neocomites premolicus*  
548 Subzone as the lower subzone of the Pertransiens Zone on the basis of work by Ettachfini  
549 (2004), Company and Tavera (2013a, b, 2015) and Kenjo (2014), but is still not fixed by a  
550 GSSP. Two faunal renewals occur within the Berriasian-Valanginian transition, one at the top  
551 of the Picteti Subzone and another at the base of the Pertransiens Zone. Both fit well with the  
552 calpionellids D2/D3 and D3/E boundary (Bulot et al., 1993). Besides, FADs of  
553 “*Thurmanniceras*” *pertransiens* and *Calpionellites darderi* (Zone E) are almost synchronous  
554 (Blanc et al., 1994), the ammonite turnover occurs slightly later than the calpionellid turnover.

## 555 **Conclusions.**

556 This paper lays out the detailed case to use the Berriasian/Valanginian boundary as the  
557 Jurassic/Cretaceous boundary

558 (i) would end decades of as yet unsuccessful discussions,

559 (ii) would provide easier and larger possibilities for world-wide correlation,

560 (iii) would be in agreement with the original definition of Oppel’s Tithonian Stage, whereas  
561 the concept of a Berriasian Stage as a full stage could be preserved as the highest stage of the  
562 Jurassic System.

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## 988 FIGURES CAPTIONS

989 Fig. 1. Some of the stage names proposed for the Upper Jurassic and lowermost Cretaceous  
990 and the various understandings according to various authors. Data concerning England from  
991 Cope (2008), South-East France, Southern Germany and Russian Platform from Hantzpergue  
992 et al. (1998), Rogov (2014), and Rogov et al. (2015). Gorodishchian and Kashpurian stages,  
993 which were proposed by Sasonov and Sasonova in 1979 and 1983 respectively as equivalents  
994 to the lower-middle and upper Volgian, are missing.

995 Fig. 2. Comparison of stage nomenclature across the Jurassic/Cretaceous boundary in the  
996 Tethyan regions of Southern Europe (providing the Primary Standard) with that of southern  
997 and eastern England and the Russian Platform (redrawn from Cope, 2008, text-fig. 3). (Recent  
998 advances on ammonite stratigraphy of the Volgian Stage of the Russian Platform have  
999 revealed that this succession is lacking any biostratigraphically traceable gaps. The only  
1000 possible gap in this succession lies at the base of the Ryazanian.

1001 Fig. 3. Present-day distribution of Tithonian (T), Volgian (V), and Portlandian (P) faunas  
1002 (modified and completed from Casey, 1971, text-fig. 2). The Volgian stage can be easily  
1003 traced throughout the Panboreal Realm (or Super-realm), including NW Europe (see for  
1004 example Zakharov, 2003; Rogov, Zakharov 2009; Callomon & Birkelund, 1982).

1005 Fig. 4. Tithonian and Berriasian Biostratigraphical review from Mazenot (redrawn from 1939,  
1006 tab. 29, p. 25).

1007 Fig. 5. First Standard Zones of the Berriasian in the Berrias type-section and equivalence with  
1008 the Calpionellid zones (Le Hégarat & Remane, 1968) (redrawn from Le Hégarat, 1973, tab.  
1009 30, p. 294).

1010 Fig. 6. Geological section of the Berrias region (excerpt from Toucas, 1889). Toucas original  
1011 figure caption (translated from the French language):

1012 • upper Kimmeridgian:

1013 17. tight limestones (Bois de Païolive), 50 m in thickness

1014 • Portlandian or Tithonic:

1015 18. Slightly marly limestone with breccia-like beds: *P. contiguus*, *P. ptychoicum*, *T. janitor*  
1016 (between Païolive and Berrias), 5 m in thickness

1017 19. Berrias limestone with *P. transitorius*, *P. senex*, *Ph. ptychoicum*, *H. privasensis*, *H.*  
1018 *microcanthus*, *H. occitanicus*, *H. callisto*, *H. dalmasi*, *H. chaperi*, *H. groteanus*, *T. euthymi*, *T.*  
1019 *janitor* (a strip extending from La Lauze to N Berrias), 15 m in thickness;

1020 • lower Neocomian or Valanginian:

1021 20. Laminated marly limestone, slightly ferruginous, with *B. latus*, *R. contracta* and few  
1022 Ammonites of the underlying levels, 10 m in thickness

1023 21. Marls with *B. latus* and small ferruginous Ammonites: *A. roubaudi*, *A. semisulcatus*;  
1024 Fig. 7. The Tithonian in the Ardèche region compared to the other regions (here limited to the  
1025 SE of France, excluding other countries: Andalusia, Friborg Alps, Verona and South Tyrol,  
1026 Carpathians and Southern Jura) and extent of the “Calcaires blancs vocontiens” of the  
1027 Ardesian in SE of France (redrawn from Toucas, 1890, p. 625).

1028 Fig. 8. The Tithonian according to Opper proposal in Europe (redrawn from Haug, 1898, p.  
1029 217).

1030 Fig. 9. Competing interpretations of the Jurassic/Cretaceous boundary. (According to: I  
1031 “Priority”, II Diastrophism and III Faunal changes) (redrawn from Wiedmann, 1971, text-fig.  
1032 1).

1033 Fig. 10. The Jurassic/Cretaceous boundary in facies areas in Europe (redrawn from  
1034 Wiedmann, 1968).

1035 Fig. 11. Integrated stratigraphy and distribution of the ammonites around the Tithonian-  
1036 Berriasian boundary at Le Chouet (modified after Wimbledon et al., 2013; Bulot et al., 2014,  
1037 text-fig. 2). Uncertainty on the Andraeai/Jacobi boundary falls at the level of an  
1038 intraformational conglomerate (beds 86-88), between 2 dotted lines red (below) and green  
1039 (above). The blue solid line marks the base of Calpionella (B) Zone, i.e., the  
1040 Tithonian/Berriasian boundary according to Rehakova (in Wimbledon et al., 2013) and the  
1041 Berriasian Working Group whereas the blue dashed line marks the base of Calpionella (B)  
1042 Zone according to Remane (1970) *vide* Ferry and Granier (2019). Note that the microconchs  
1043 studied and illustrated by Boughdiri (1994) and Énay et al. (1998), have been erroneously  
1044 assigned to the Mexican genus *Durangites*, but were clearly identified as the microconch  
1045 dimorph of *Protacanthodiscus*, recently named *Boughdiriella* (Frau et al., 2015).

1046 Fig. 12. Relative placements of selected markers under consideration for Jurassic/Cretaceous  
1047 boundary or useful for correlations and inter-regional comparison of zonations (1 to 14, see  
1048 text) (redrawn from Ogg & Hinnov in Gradstein et al., 2012, text-fig. 27/2).

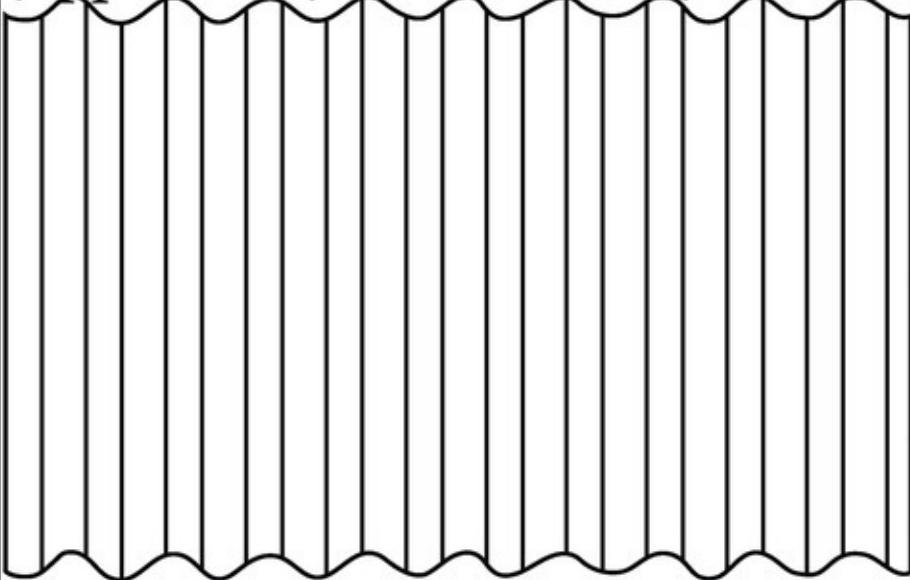
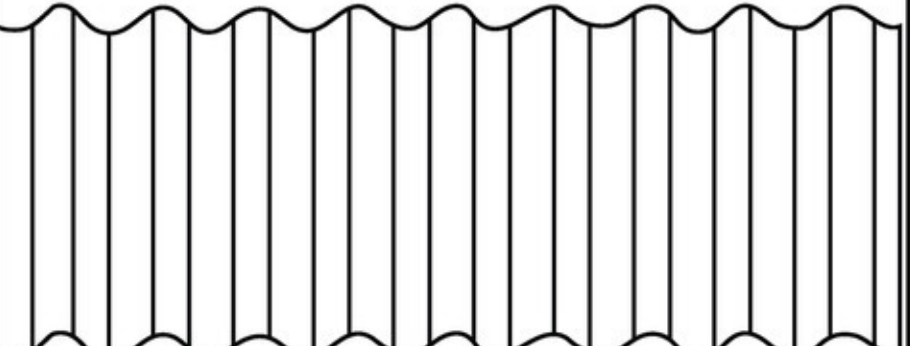
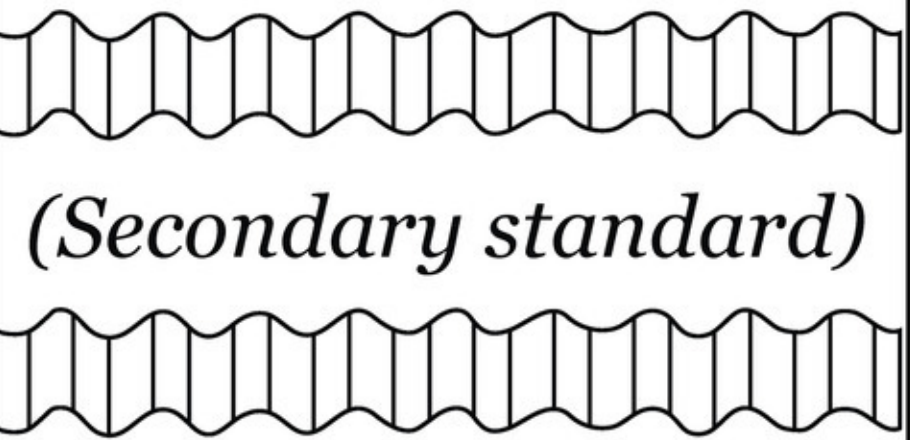
1049 Fig. 13. Correlations of Tethys with austral and boreal regions with FADs of calcareous  
1050 nannofossil species as helpful indicators, placements of previously selected markers [ $\alpha$ :  
1051 Published (1965) Lyon colloquium (1963) decision on J/K boundary;  $\beta$ : Published (1975)  
1052 Lyon-Neuchâtel (1973) colloquium decision on J/K boundary] and marker selected by the  
1053 Berriasian WG (red line) (redrawn from Wimbledon, 2017b, text-fig. 1). Note that in the  
1054 previous figure the base of the Calpionella (B) Zone was near the base of M19n.1r.

1055 Fig. 14. Different position of the Berriasian/Valanginian boundary (double line), various  
1056 ammonite zonations and calpionellid zonation around the Berriasian/Valanginian boundary  
1057 (Grand: Grandis; Neocom.: Neocomiensiformis; Pertran.: Pertransiens).

1058 Fig. 15. The development of the Ammonoidea families or subfamilies at the Jurassic–  
1059 Cretaceous transition from Wright et al., 1996., and Énay and Howarth, 2019. Shortened  
1060 family names : ASP. = Aspidoceratidae; PER. = Perisphinctidae; HIM. = Himalayitidae;  
1061 OLCOSTEPH. = Olcostephanidae; NEOCOM. = Neocomitidae.



ENGLAND			Names proposed for stages of the Upper Jurassic and lowermost Cretaceous and their uses according to different authors					Standard Zones																													
Southern England	Eastern England	Standard Zones						Southern Germany and SE France	Russian Platform																												
							VALANGINIAN																														
							Pertransiens																														
Wealden Beds	Purbeck Limest. Group	Sandrigham Sands	Upper Spilsby Sandst.	Albidum	Portlandian Orbigny, 1849	Portlandian Haug, 1898	Portlandian Blake, 1881	Portlandian Arkell, 1946	Aquilonian Pavlow, 1892	Tithonian Oppel, 1865 - Neumayr, 1873 - Haug, 1898	Tithonian Kilian, 1890	Berriasian Toucas, 1890	Berriasian Coquand, 1871	Ryazanian Sasonov, 1951	Boissieri	Albidum																					
			Durlston Formation	Stenomphalus											Icenii	Kochi	Runctoni	Lamplughi	Preplicomphalus	Primitivus	Anguiformis	Kerberos	Okusensis	Glaucolithus	Albani	Fittoni	Rotunda	Pallasioides	Pectinatus	Hudlestoni	Wheatleyensis	Scitulus	Elegans	Autissiodorensis	Eudoxus	Mutabilis	Uralensis
Lulworth Formation	Lower Spilsby Sandst.																								Jacobi/Euxinus	Singularis											
Portland Stone																								Andreaei	«Durangites»	Subditus											
Portland Sands																										Fulgens											
Kimmeridge Clay	Upper Kimmeridge Clay	Upper Kimmeridge Clay																								Microcanthum	Nikitini										
																										Ponti	Virgatus										
																											Palmatus	Panderi									
																											Ciliata	Pseudoschytica									
																											Penicillatum										
																	Palatinus																				
																		Vimineus																			
																		Mucronatum	Sokolovi																		
																		Hybonotum	Klimovi																		
																		Beckeri	Autissiodorensis																		
															Eudoxus	Eudoxus																					
															Acanthicum	Mutabilis																					
															Divisum	Uralensis																					
															Hypselocyclum	Baylei																					
															Platynota																						
Ringstead Coral Beds			Pseudocordata												Planula	Rosenkrantzi																					

	<b>SOUTHERN EUROPE</b>	<b>SOUTHERN ENGLAND</b>	<b>EASTERN ENGLAND</b>	<b>RUSSIAN PLATFORM</b>
<b>CRETACEOUS</b>	Valanginian <i>(Primary standard)</i>	Valanginian <i>(Primary standard)</i>	Valanginian <i>(Primary standard)</i>	Valanginian <i>(Primary standard)</i>
	Berriasian <i>(Primary standard)</i>	Berriasian <i>(Primary standard)</i>	Ryazanian <i>(Secondary standard)</i>	Ryazanian <i>(Secondary standard)</i>
			upper Volgian <i>(Secondary standard)</i>	upper Volgian <i>(Secondary standard)</i>
<b>JURASSIC</b>	Tithonian <i>(Primary standard)</i>	Portlandian <i>(Secondary standard)</i>	(uppermost) Portlandian <i>(Sec. st.)</i> 	 middle Volgian <i>(Secondary standard)</i>
			Bolonian <i>(Secondary standard)</i>	Bolonian <i>(Secondary standard)</i> 
	Kimmeridgian <i>(Primary standard)</i>	Kimmeridgian <i>(Primary standard)</i>	Kimmeridgian <i>(Primary standard)</i>	lower Volgian <i>(Secondary standard)</i>
				Kimmeridgian <i>(Primary standard)</i>



Étages	Zones (fossiles caractéristiques)	Horizons ou sous-zones	Principaux gisements du S.-E. de la France	
Valanginien sens. stric. (zone inférieure)	<i>Neocomites neocomiensis</i> (Orb.)	(pour mémoire)		
Berriasien = Infra-Valanginien	<i>Berriasella Boissieri</i> (Pict.) -- <i>pontica</i> (Ret.) -- <i>paramacilenta</i> n.sp. <i>Dalmasiceras Dalmasi</i> Sayn. (Pict.) <i>Dalmasiceras punctatum</i> (Dj.) <i>Neocomites occitanicus</i> (Pict.) <i>Neocomites subalpinus</i> n.sp. <i>Neocosmoceras Rerollei</i> (Paqu.) <i>Negreliceras Negreli</i> (Math.) <i>Spiticeras ducale</i> (Math.) -- <i>obiquenodosum</i> (Retow.) (Pas de PERISPHINCTIDÆ)	3. Horizon supérieur à <i>Kilianella</i> aff. <i>pexiptycha</i> (Uhl.) et <i>Thurmannites</i> aff. <i>pertransiens</i> Sayn.	Beaucels, Chamaloc, Lacadière (station) Eyguières et Eygalières p. p.	
		2. Horizon principal à <i>B. Boissieri</i> (Pict.), <i>D. Dalmasi</i> (Pict.), <i>N. occitanicus</i> (Pict.), etc.	Berrias, Lacadière (village), Ginestous, la Faurie, Eyguières et Eygalières p. p., Apremont, Pas-de-la-Fosse, etc.	
		1. Horizon inférieur à <i>Berriasella paramacilenta</i> n. sp. et <i>B. grandis</i> n. sp.	Noyarey, le Chevallon, Faucigny, Mont-Ruan.	
Limite jurassico-crétacée	-----	-----	-----	
Tithonique	Supérieur	3. Horizon supérieur à <i>B. Chaperi</i> (Pict.), <i>B. aizyensis</i> n. sp., <i>D. Djanelidzei</i> n. sp., <i>Neocomites suprajurensis</i> n. sp.	Aizy, le Chevallon, Faucigny, la Giettaz, Arpenaz.	
		2. Horizon moyen à <i>Berriasella Jacobi</i> n. sp., <i>Berriasella delphinensis</i> (Kil.), <i>Dalmasiceras nanum</i> (Jac.), <i>Neocomites Beneckei</i> (Jac.), <i>Proniceras pronum</i> (Opp.)	Chomérac (la Boissière et Sabotas), Billon, Fontasse.	
	Lacune de nos connaissances : à prévoir un horizon à PALAEOHOPLITIDÆ intermédiaires entre ceux de Chomérac et ceux de Neuburg (Bavière) ou de Saint-Concors et à nombreux PERISPHINCTIDÆ.			
	Inférieur	« <i>Perisphinctes</i> » <i>contiguus</i> (Cat.) et « <i>Per.</i> » <i>geron</i> (Zitt.) (d'après Kilian, Haug, etc ; non Spath, 1936) ; rares <i>Berriasella</i> des groupes de <i>B. Richteri</i> (Opp.), <i>B. privasensis</i> (Pict.) et <i>B. ciliata</i>	2. Horizon supérieur à <i>B. ciliata</i> Schn., <i>B. pergrata</i> Schn., <i>B. præcox</i> Schn. et à très nombreux PERISPHINCTIDÆ.	Saint-Concors.
		1. Horizon inférieur à rarissimes <i>Berriasella</i> ( <i>B. Richteri</i> ) et à très nombreux PERISPHINCTIDÆ.	le Pouzin.	
	<i>Streblites lithographicus</i> (Opp.)	(pour mémoire)		

ÉTAGES	ZONATIONS DES AMMONITES		ZONATIONS DES CALPIONELLES		
<b>Valanginien</b> <i>pro parte</i>	zone à Roubaudi <i>p.p.</i>	sous-zone à Pertransiens	zone à Calpionellopsis (zone D)	sous-zone D3	
<b>B E R R I A S I E N</b>	zone à Boissieri	sous-zone à Callisto		zone à Tintinnopsella (zone C)	sous-zone D2
		sous-zone à Picteti			sous-zone D1
		sous-zone à Paramimounum			
	zone à Occitanica	sous-zone à Dalmasi	zone à Calpionella (zone B)	moitié supérieure de la zone B	
		sous-zone à Privasensis			
		sous-zone à Subalpina			
	zone à Grandis			moitié inférieure de la zone B	
	zone à Jacobi				
	<b>T I T H O N I Q U E</b> supérieur	?	« calcaires blancs vocontiens » <i>pro parte</i> (niveau du Chouët)	zone à Crassicollaria (zone A)	sous-zone A3
		zone à Transitorius			sous-zone A2
zone à Ciliata		sous-zone A1			
<b>inférieur</b> <i>pro parte</i>	zone à Contiguus	(niveau de St Concors)	Pas de calpionelles	Chitinoïdella	
	zone à Ciliata	(niveau du Pouzin)			

**NW**

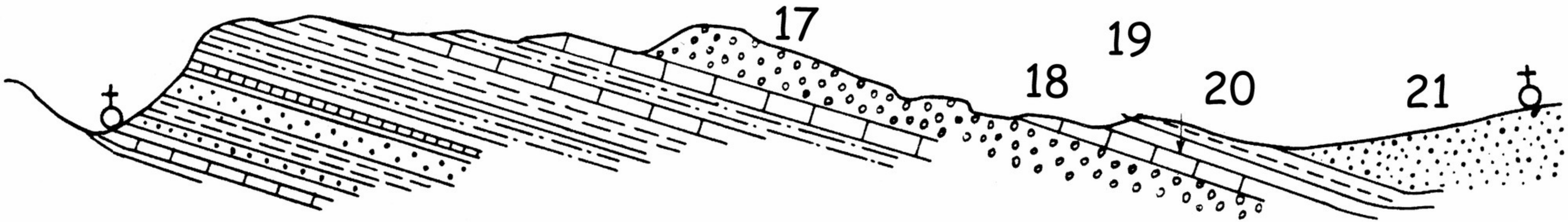
**SE**

Les Vans

Bois de Paiolive

Berrias








Beaulieu



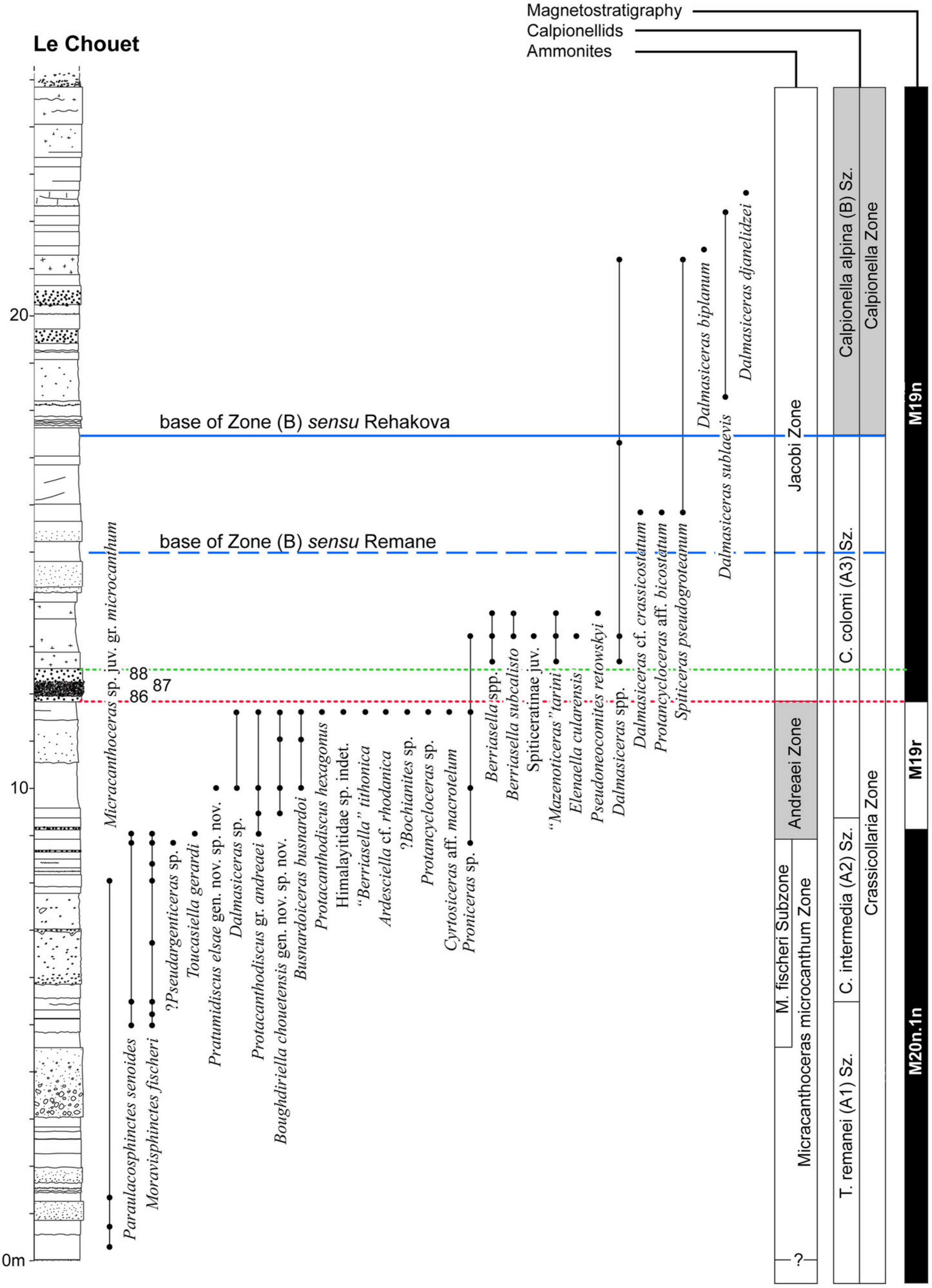
ÉTAGES	SOUS-ÉTAGES	Ardèche :	Vaucluse :	Basses-Alpes :		Hautes-Alpes :	Savoie et Dauphiné :
		Le Pouzin, Chomérac Vogué et Berrias.	Mont Ventoux (Mr Léenhardt).	Montagne de Lure. (Mr Kilian).	Cluse de Chabrières. (Mr Vélain).	St-Julien en Beauchêne. (Mr Vélain).	Lémenc et Aizy.
Néocomien	Valanginien	1° Marnes à petites ammonites pyriteuses 2° Marnes et calcaires feuilletés avec <i>Bel. latus</i> , <i>Rhynch. contracta</i> et grands <i>Hoplites neocomiensis</i> .	Marnes à <i>Belemnites latus</i> et petites ammonites pyriteuses. (N <sup>2</sup> )	Marnes à <i>Belem. latus</i> et petites ammonites pyriteuses.	Marnes à petites ammonites pyriteuses.	Marnes à <i>Bel. latus</i> et petites ammonites pyriteuses.	Marnes à <i>Belemnites latus</i> .
Tithonique ou Portlandien	Tithonique supérieur ou Berriasien = Purbeckien	Bancs calcaires et lits de marnes avec intercalations de bancs bréchoïdes ou rognoneux, contenant les deux faunes mélangées de Stramberg et de Berrias (maximum de développement des deux faunes dans les bancs bréchoïdes).	Bancs calcaires et lits de marnes avec : <i>Hoplites Boissieri</i> , <i>H. occitanicus</i> , <i>H. Calisto</i> , <i>H. Privasensis</i> , <i>Lytoceras Honnorati</i> , <i>Holcostephanus Grotei</i> , <i>Phylloceras silesiacum</i> , <i>Aptychus punctatus</i> . (N <sup>1</sup> , de 6 à 11)	Bancs calcaires et lits de marnes, avec intercalations de bancs bréchoïdes ou rognoneux à <i>Hoplites Boissieri</i> , <i>H. occitanicus</i> , <i>H. Privasensis</i> , <i>H. abscissus</i> , <i>Lytoceras Honnorati</i> , <i>Phylloceras silesiacum</i> , <i>Ph. ptychoicum</i> .	Calcaires marneux avec intercalations de bancs bréchoïdes à : <i>Hoplites occitanicus</i> , <i>H. Calisto</i> , <i>H. Boissieri</i> , <i>Lytoceras Honnorati</i> , <i>Phylloceras ptychoicum</i> .	Calc. marneux avec : <i>Bel. latus</i> , <i>Hoplites Boissieri</i> , <i>H. occitanicus</i> , <i>Phylloceras ptychoicum</i> , <i>Aspidoceras Rogoznicensis</i> , <i>Metaporhinus convexus</i> , <i>Pygope janitor</i> .	Calc. et marnes avec : <i>Hoplites Calisto</i> , <i>H. Privasensis</i> , <i>H. Boissieri</i> , <i>H. occitanicus</i> , <i>Lytoceras Liebigi</i> , <i>Phylloceras silesiacum</i> , <i>Phylloceras ptychoicum</i> , <i>Collyrites carinata</i> .
	Tithonique moyen ou Ardésien	Calcaires blancs, sublithographiques avec <i>Hoplites Calisto</i> , <i>Hoplites Privasensis</i> , <i>Perisphinctes eudichotomus</i> , <i>Belemnites ensifer</i> , <i>Metaporhinus convexus</i> (commencement de la faune de Stramberg, sans mélange avec la faune de Berrias)	Calc. blancs, sublithographiques, avec <i>Hoplites Calisto</i> , <i>Hoplites Privasensis</i> , <i>Holcostephanus pronus</i> , <i>Belemnites ensifer</i> , <i>Metaporhinus convexus</i> . (N <sup>1</sup> , de 1 à 5, et J <sup>2</sup> c supérieur)	Bancs calcaires et lits de marnes, avec intercalations de bancs bréchoïdes ou rognoneux à <i>Hoplites Boissieri</i> , <i>H. occitanicus</i> , <i>H. Privasensis</i> , <i>H. abscissus</i> , <i>Lytoceras Honnorati</i> , <i>Phylloceras silesiacum</i> , <i>Ph. ptychoicum</i> .	Calcaires blancs, lithographiques, avec <i>Phylloceras ptychoicum</i> , <i>Hoplites Calisto</i> , <i>Pygope janitor</i> , <i>Metaporhinus convexus</i> .	Calc. bréchoïdes ou rognoneux avec <i>Bel. ensifer</i> , <i>Phylloceras ptychoicum</i> , <i>Pygope janitor</i> .	Calc. bréchoïdes ou rognoneux avec <i>Perisphinctes geron</i> , <i>Perisphinctes eudichotomus</i> , <i>Phylloceras ptychoicum</i> , et lits marneux avec <i>Aptychus punctatus</i> , <i>Aptychus Beyrichi</i> , <i>Bel. Conradi</i> , <i>Bel. Pilleti</i> .
	Tithonique inférieur ou Diphyakalk	Calc. plus ou moins marneux, avec bancs, bréchoïdes ou rognoneux, renfermant la faune de Rogoznik et du Diphyakalk du Tyrol méridional. <i>Oppelia Fallauxi</i> , <i>Haploceras elimatum</i> , <i>H. verruciferum</i> , <i>Perisphinctes contiguus</i> , <i>P. geron</i> , <i>P. eudichotomus</i> , <i>P. colubrinus</i> , <i>P. Basilicæ</i> et nombreux <i>Aptychus Beyrichi</i> , <i>Apt. punctatus</i> dans les lits marneux	Calc. gris, violacés, avec <i>Bel. semisulcatus</i> , <i>Phylloceas ptychoicum</i> , <i>Perisphinctes Basilicæ</i> , <i>Aptychus punctatus</i> , <i>Pygope janitor</i> . (J <sup>2</sup> c inférieur)	Calc. bréchoïdes avec <i>Perisph. geron</i> , <i>Perisph. colubrinus</i> , <i>Aptychus punctatus</i> .	Calcaires et bancs bréchoïdes avec <i>Phylloceras ptychoicum</i> , <i>Perisph. geron</i> , <i>Pygope janitor</i> , nombreux <i>Aptychus</i> .	Calc. bréchoïdes ou rognoneux avec <i>Bel. ensifer</i> , <i>Phylloceras ptychoicum</i> , <i>Pygope janitor</i> .	Calc. bréchoïdes ou rognoneux avec <i>Perisphinctes geron</i> , <i>Perisphinctes eudichotomus</i> , <i>Phylloceras ptychoicum</i> , et lits marneux avec <i>Aptychus punctatus</i> , <i>Aptychus Beyrichi</i> , <i>Bel. Conradi</i> , <i>Bel. Pilleti</i> .

SUBDIVISIONS GÉNÉRALES	CENTRE ET SUD-EST DE LA RUSSIE	BASSIN ANGLO-PARISIEN	FRANCONIE ET SOUABE	BASSIN DU RHÔNE	
Néocomien s. str.	Hauterivien	Manque.	Z. à <i>Hoplites radiatus</i> (calcaire à Spatangues)	Manque.	Z. à <i>Crioceras Duvali</i> . Z. à <i>Hoplites radiatus</i> .
	Valanginien	Z. à <i>Polyptychites polyptychus</i> et <i>Pol. keyserlingi</i> . Z. à <i>Polyptychites stenomphalus</i> et <i>Oxynoticeras Marcousianum</i> .	Sables valanginiens sans fossiles (Hte-Marne).	Manque.	Z. à <i>Hoplites amblygonius</i> et <i>Hoplites Arnoldi</i> .  Z. à <i>Hoplites neocomiensis</i> .
Portlandien =Tithonique Opper	Supérieur	Volgien inférieur { Horizon de Riasan Z. à <i>Craspedites nodiger</i> . Z. à <i>Cr. Subditus</i> . Z. à <i>Cr. Okensis</i> .	Purbeckien.	Manque.	Z. à <i>Hoplites Boissieri</i> (Berriasien). Z. à <i>Hoplites Calisto</i> (Tithonique supér., Kilian).
	Inférieur	Volgien supér. { Z. à <i>Perisphinctes Nikitini</i> . Z. à <i>Virgatites virgatus</i> . Z. à <i>Perisphinctes Bleicheri</i> . ?	Z. à <i>Holcostephanus Blakei</i> . Z. à <i>Virgatites scythicus</i> . Z. à <i>Perisphinctes Bleicheri</i> . Z. à <i>Stephanoceras portlandicum</i> .	Manque.  Z. à <i>Oppelia tenuilobata</i> , (Calcaires de Solenhofen).	Z. à <i>Perisphinctes contiguus</i> (Tithonique inf., Kilian).  Z. à <i>Oppelia lithographica</i> (Calcaires du Château, assises supérieures).
Kimméridgien s. str.	Supérieur (Virgulien)	Z. à <i>Reineckeia Eudoxus</i> et <i>R. pseudomutabilis</i> de la Volga.	Sous-zone à <i>Aspidoceras longispinum</i> et <i>Reineckeia Eudoxus</i> . Sous-zone à <i>Asp. Caletanum</i> . Sous-zone à <i>Asp. Orthocera</i> .	Z. à <i>Reineckeia Eudoxus</i> (Weisser Jura δ).	Z. à <i>Reineckeia Eudoxus</i> (Calcaires du Château, assises moyennes).
	Inférieur (Ptérocérien)	Couches à <i>Cardioceras alternans</i> (partie supérieure).	Zone à <i>Pictonia Cymodoce</i> .	Z. à <i>Oppelia tenuilobata</i> , partie supérieure.	Z. à <i>Oppelia tenuilobata</i> , partie supérieure (Calcaires du Château, assises inférieures).



I.		II.		III.			
<i>F.-J. PICTET 1867</i> <i>H. COQUAND 1871</i> <i>W. KILIAN 1910</i>		<i>G. MAZENOT 1939</i> <i>COLL. CRET. INF. 1963</i> <i>BUSNARDO et al. 1965</i>		<i>R. CASEY 1963, 1967</i> <i>BREISTROFFER 1964</i> <i>P. ALLEN 1965</i>		<i>F.-J. PICTET 1867</i> <i>A. TOUCAS 1890</i> <i>E. HAUG 1898</i>	
<b>VALANGINIEN</b> <i>(DESOR 1854)</i>	<b>VALANGINIEN</b> <i>s. str.</i>	<b>VALANGINIEN</b> <i>s. str.</i>		<b>VALANGINIEN</b>  3 			
	<b>BERRIASIEN</b> <i>(COQUAND 1871)</i>	<b>BERRIASIEN</b> <i>s. str.</i> 		<b>TITHON</b>	<b>TITHON PORTLANDIEN</b> <i>s. l.</i> <b>VOLGIEN</b> <i>(NIKITIN 1881)</i>		
<b>PORTLANDIEN</b> <i>(ORBIGNY 1850)</i>   <b>TITHON</b> <i>(OPPEL 1865)</i>		<b>VOLGIEN</b> <i>s. str.</i>	<b>ARDESCIEN</b> <i>(TOUCAS 1890)</i>  2				
		<b>PORTL.</b> <i>s. str.</i>	<b>DANUBIEN</b> <i>(ROLLIER 1909)</i>  1				
<b>PORTLANDIEN</b> <i>(ORBIGNY 1850)</i>   <b>TITHON</b> <i>(OPPEL 1865)</i>		<b>OBERES KIMMERIDGIEN</b> <i>s. anglico</i>					

S-EUROPA		NW-RUSSLAND	NW-DEUTSCHL.	E-ENGLAND	S-ENGLAND	
H A U T E R I V I E N						
O.-VALANGINIEN		VALANGINIEN	O.-VALANGINIEN	CLAXBY BEDS	HASTING BEDS	
M.-VALANGINIEN			M.-VALANGINIEN			
U.-VALANGINIEN <sub>oo</sub>			U.-VALANGINIEN <sub>oo</sub>			
O-TITHON	ARDESCIEN	RJAZANIEN <sub>oo</sub>	WEALDEN	SPILSBY SDST. <sub>oo</sub>	PURBECK	DURLSTON
		O.-VOLGIEN <sub>oo</sub>	SERPULIT <sub>oo</sub>			LULWORTH BEDS
		?	MÜNDER MERGEL		oo	PORTLAND BEDS
U-TITHON	DANUBIEN	M.-VOLGIEN	EIMBECKHÄUSER SCHICHTEN)	"DORSETIEN-BOLONIEN" (O.-KIMMERIDGIEN <i>s. anglico</i> )		
		U.-VOLGIEN	GIGAS-SCH.			
K I M M E R I D G I E N <i>s. gallico</i>						
(= U.-KIMMERIDGIEN <i>s. anglico</i> )						

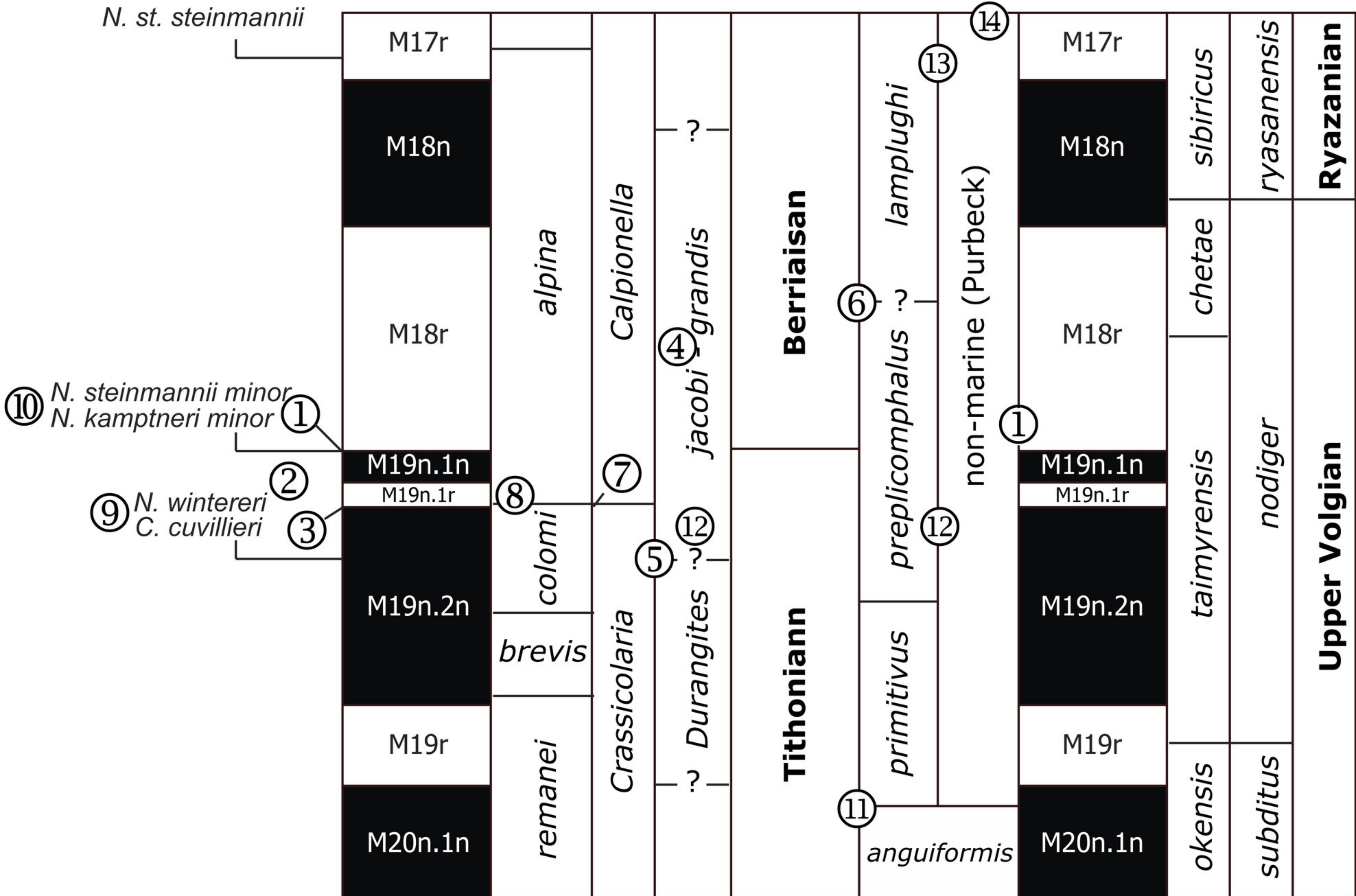


# Tethysian

# Boreal

West

Russian  
East Platform





Mazenot (1939)	Le Hégarat (1973)	Busnardo & Thieuloy (1979)	Hoedemaecker (1982, 1984, 1987)	Bulot et al. (1994)	Reboulet et al. (2014)	Calpionellids (Grün & Blau, 1997)						
<i>Neocomites neocomiensis</i>	Roubaudi		Pertransiens	Retrocostatum	Pertransiens	Pertransiens	Neocom.	Calpionellites	E	major		
Upper horizon with <i>K. aff. pexiptycha</i> and <i>Th. aff. pertransiens</i>		Pertransiens					Pertrans.			darderi		
Main horizon with	Boissieri	Callisto	Otopeta	Retrocostatum	Alpillensis	Alpillensis	Boissieri	Calpionellopsis	D3	dadayi		
<i>B. boissieri</i>		Picteti	Boissieri							Alpillensis	Alpillensis	Alpillensis
<i>D. dalmasi</i>		Paramimouna		Boissieri	Picteti	Picteti				Picteti	D2	oblonga
		Paramimouna		Boissieri	Picteti	Picteti				Paramimouna	D1	simplex
<i>N. occitanica</i>	Occitanica	Dalmasi		Occitanica	Dalmasi		Occitanica	Calpionella	C	cadischiana		
		Privasensis								Privasensis	Privasensis	elliptica
		Subalpina								Subalpina	Subalpina	B
Lower horizon with <i>B. grandis</i>	Grand.		Jacobi	Jacobi								

