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## Late Barremian–early Aptian ammonite bioevents from the Urgonian-type series of Provence, southeast France: Regional stratigraphic correlations and implications for dating the peri-Vocontian carbonate platforms

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# Late Barremian–early Aptian ammonite bioevents from the Urgonian-type series of Provence, southeast France

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1 **Late Barremian–early Aptian ammonite bioevents from the Urgonian-type series of Provence, southeast**  
2 **France: regional stratigraphic correlations and implications for dating the peri-Vocontian carbonate**  
3 **platforms**

4  
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18

19 **Abstract**

20

21 This work provides a new ammonite age-calibration of the rudistid limestones of the Urgonian-type Provence  
22 carbonate platform (Southeast France) based on sampling along three ~200 km-long platform-to-basin transects  
23 and re-examination of historical collections. Ammonite key findings indicate that the first rudistid platform stage  
24 (including the *Agriopleura* and requieniid–monopleurid beds) develops and spreads northward through the  
25 *Toxancyloceras vandenheckii*–*Gerhardtia sartousiana* zones interval (lower upper Barremian). This stage is  
26 interrupted by the tectonically-induced deepening of the southern Provence domain during the *Imerites giraudi*  
27 Zone while the northern regions records the massive deposition of *Palorbitolina*–*Heteraster* beds. Recovery of  
28 the rudistid carbonate system is illustrated by the development of caprinid-bearing rudistid limestones in the  
29 North Provence domain through the *Martelites sarasini* Subzone (lower *Martelites sarasini* Zone, uppermost  
30 Barremian), which shows a bidirectional progradation toward the South Provence and Vocontian basins. The

31 caprinid-bearing limestones terminate at a short-term exposure and are overlain by cherty–oobioclastic deposits  
32 spanning the *Pseudocrioceras waagenoides* Subzone (upper *M. sarasini* Zone) to the lower *Deshayesites forbesi*  
33 Zone. A regional-wide flooding of the study area is illustrated by the abrupt change to a marl-dominated regime  
34 occurring in the upper *D. forbesi* Zone. Compared to the previous datings, the Barremian/Aptian boundary  
35 should be relocated in the lower part of the post-caprinid, cherty–oobioclastic deposits although its precise level  
36 cannot be fixed due to the lack of a continuous ammonite record. Ammonite age-calibration of the surrounding  
37 Urgonian rudistid platform series is discussed and gives evidence of a comparable twofold demise of the peri-  
38 Vocontian rudistid biota during the uppermost Barremian. Accordingly, the link between the final demise of the  
39 peri-Vocontian rudistid biota and the onset and/or culmination of the mid-early Aptian Oceanic Anoxic Event  
40 (OAE) 1a should be reconsidered.

41

## 42 **Keywords**

43

44 Urgonian; Carbonate Platform; Ammonite; OAE 1a; Cretaceous; Southeast France.

45

## 46 **1. Introduction**

47

48 Urgonian carbonate platforms of Barremian–Aptian age are extensively recorded in southeast France  
49 which hosts the unit-stratotype at Orgon (Alpilles Massif, Bouches-du-Rhône) as introduced by d'Orbigny (1850,  
50 1852). At this time, the Urgonian platforms of Provence, Bas-Vivarais, Subalpine Chains and Swiss–French Jura  
51 record their maximum spatial extent and enclose the Vocontian Basin; i.e. forming a horseshoe-shaped marginal  
52 sea opened eastward to the Alpine Tethys Ocean (Arnaud, 2005a and references therein). In the existing models,  
53 the extensive growth of peri-Vocontian Urgonian carbonate platforms is first interrupted by a major shift from  
54 rudist–coral carbonate accumulation to mixed orbitolinid-dominated siliciclastic–carbonate deposition at, or  
55 close, to the putative Barremian/Aptian (B/A) boundary. This refers to the *Palorbitolina–Heteraster* guide level  
56 of the North Provence (Masse, 1976), the V4 episode of the Bas-Vivarais (Lafarge, 1978), the Lower *Orbitolina*  
57 Beds of the Subalpine regions (Arnaud et al., 1998) and the Poet Beds of Swiss–French Jura (Pictet et al., 2016).  
58 The recovery of the rudistid biota, dominated by caprinid rudists, supposedly unfolds in the lowermost Aptian  
59 but it subsequently collapses with large-scale exposure that ends the rudistid regime throughout the peri-  
60 Vocontian platforms (e.g. Masse, 1976, 1995, 2003; Masse et al., 1999; Masse & Fenerci-Masse, 2011, 2013a-b;

61 Arnaud-Vanneau & Arnaud, 1990; Arnaud-Vanneau et al., 2005; Arnaud & Arnaud-Vanneau, 1991; Arnaud et  
62 al., 1998, 2017; Chartreuse, 1998; Clavel et al., 2002, 2007; 2013, 2014; Embry, 2005; Linder et al., 2006;  
63 Léonide et al., 2008, 2012, 2014; Bastide, 2014; Pictet et al., 2015, 2016; Huck et al., 2011, 2013; Huck &  
64 Heimhofer, 2015; Godet et al., 2016a) and eastern Switzerland as well (Wissler et al., 2002, 2003; Föllmi, 2008,  
65 2012; Föllmi & Gainon, 2008; Föllmi et al., 1994; 2006, 2007; Stein et al., 2012a). Integrated approaches  
66 developed in the latter contributions, coupling sedimentology, palaeoenvironmental proxies and shallow-water  
67 biostratigraphy (viz. rudists, orbitolinid, dasycladaceans and charophytes), addressed the timing and causal  
68 relationships of the final demise of the Urgonian rudistid regime with the onset and/or culmination of the mid-  
69 early Aptian Oceanic Anoxic Event (OAE) 1a. Unfortunately, the lack of coeval biological markers across the  
70 B/A boundary limits the correlation of the Urgonian series with the Barremian- and Aptian-type basinal sections  
71 of the nearby Vocontian Basin. Here, various bio- (Dauphin, 2002; Herrle & Mutterlose, 2003), litho- (Bréhéret,  
72 1997; Cotillon et al., 2000; Cotillon, 2010) and geochemical (Westermann et al., 2013) expressions of the OAE  
73 1a have been constrained to the Mediterranean ammonite zonations; successively developed by the IUGS Lower  
74 Cretaceous Ammonite Working Group (Reboulet et al., 2011, 2014). This lack of robust biostratigraphic  
75 constrain caused a number of disputes in the literature about the calibration of shallow-water biological markers  
76 or correlation of major unconformities into the basin and their correspondence with major sea-level changes,  
77 which ultimately introduced significant confusion on the timing and predominant controlling factors of the  
78 stepwise demise of the Urgonian carbonate production.

79 Over the past decades, external calibration by means of chemostratigraphy (i.e.  $\delta^{13}\text{C}$ ,  $\delta^{18}\text{O}$ , Sr) has  
80 emerged and imposed itself as a powerful tool of stratigraphic significance for correlating and dating carbonate  
81 units (Scholle & Arthur, 1980). The carbon signature of the Urgonian platform series of SE France and  
82 Switzerland has been, therefore, intensively investigated in order to refine platform-to-basin correlations and  
83 palaeoenvironmental interpretations (e.g. Masse et al., 1999; Raddadi, 2005; Godet et al., 2006; Föllmi et al.,  
84 2006; Huck et al., 2011, 2013; Stein et al., 2012b; Léonide et al., 2014; Huck & Heimhofer, 2015); enough to  
85 enable the authors to come to the conclusion that chemostratigraphy has the potential to provide an independent  
86 control on the controversial dating based on biological markers (Huck et al., 2013). The uppermost Barremian is  
87 characterised by a global, sharp negative excursion in  $\delta^{13}\text{C}$  values in basinal sections (Kuhnt et al., 2000; Godet  
88 et al., 2006; Stein et al., 2011, 2012a-b). From this observation, several authors have characterised this time  
89 interval in the Urgonian platform successions by assuming a contemporaneous negative excursion in C-isotope  
90 signal observed at, or just below, the orbitolinid-rich episodes of the peri-Vocontian platforms (Raddadi, 2005;

91 Arnaud-Vanneau et al., 2005; Huck et al., 2011, 2013; Léonide et al., 2014). However, such trends may result  
92 from documented subaerial exposure surfaces (Masse & Fenerci-Masse, 2011; Huck et al., 2014) and their  
93 subsequent diagenetic alteration (Allan & Matthews, 1977; Joachimski, 1994; Fouke et al., 1995; Léonide et al.,  
94 2014) which strongly affect the isotope signature of Urganian carbonates (Godet et al., 2016b).

95 A limited number of works focused on the Sr-Isotope Stratigraphy (SIS), of the Urganian platform  
96 series of SE France (Huck et al., 2011, Huck & Heimhofer, 2015) and Switzerland (Godet et al., 2011). SIS was  
97 expected to improve the existing ammonite-based age models for the Barremian–Aptian time interval (Masse &  
98 Steuber, 2007). Unfortunately, Frau et al. (accepted) highlight that SIS provide limited utility for intervals with  
99 little or no variations through time, such as the Barremian–Aptian transition. Its low resolution has led to the  
100 inconsistent stratigraphic dating of the Urganian limestones of Provence (cf. Huck & Heimhofer, 2015). The  
101 foregoing considerations show that bio- and chemostratigraphic markers are frequently in conflict when dating  
102 the Urganian platform series of SE France and Switzerland and do not allow to accurately pinpoint the  
103 uppermost Barremian (*Imerites giraudi*–*Martelites sarasini* zones interval) to earliest Aptian (*Deshayesites*  
104 *oglanlensis*–*Deshayesites forbesi* zones interval) time interval.

105 To address this issue, new *in situ* ammonite findings along three ~200km-long platform-to-basin  
106 transects of the Provence platform are reported in this paper, together with a re-examination of the collection of  
107 one of us (J.-P. Masse). This allows a critical review of the ammonite age-calibration of the Urganian-type series  
108 with respect to the standard Mediterranean ammonite zonation (Fig. 1). Our data pinpoint a late Barremian  
109 stepwise demise of the Urganian rudistid regime throughout the peri-Vocontian carbonate platforms.

110

## 111 **2. Current ammonite age-calibration of the Provence platform**

112

113 According to the stratigraphical model developed in the past decades by Masse (1993, 1995, 2003),  
114 Masse & Fenerci-Masse (2011, 2013a-c) and Léonide et al. (2012), the Provence rudistid platform records its  
115 maximum northward progradation at the lower/upper Barremian transition and extends up into the mid-lower  
116 Aptian (*D. forbesi* Zone), from the southern (Calanques and Nerthe massifs) to the northern (Monts de Vaucluse  
117 and Rissas–Bluye Mountains) Provence where it plunges into the Vocontian Basin. Contrary to the Orgon unit-  
118 stratotype, the Monts de Vaucluse in northern Provence house complete Urganian-type series (Masse & Fenerci-  
119 Masse, 2013a), which was historically divided into three informal lithostratigraphic units; U<sup>1</sup> (bioclastic), U<sup>2</sup>  
120 (rudistid) and U<sup>3</sup> (bioclastic) *sensu* Leenhardt (1883). Three distinct rudistid episodes are recognised in the North

121 Provence rudist-bearing limestones (= U<sup>2</sup> *lato sensu*); these are from oldest to youngest; the (i) *Agriopleura*  
122 (Martigues fauna); (ii) requieniid–monopleurid (Orgon fauna) and (iii) caprinid (Rustrel fauna) rudistid faunas  
123 (see Tendil et al., accepted). The caprinid-bearing limestones (= U<sup>2</sup> *stricto sensu*) can be easily distinguished in  
124 the field since they usually overly the *Palorbitolina–Heteraster* guide level, traceable in the Monts de Vaucluse  
125 (Masse & Fenerci-Masse, 2011; Léonide et al., 2012) and adjacent settings of the Bas-Vivarais platform  
126 (Lafarge, 1978; Masse, 1995, Masse & Fenerci-Masse, 2011).

127         For the time being, only a handful of ammonite occurrences have contributed to the dating of the  
128 Urgonian-type limestones. Isolated occurrence of upper Barremian hemihopliteid and heteroceratid taxa have  
129 been documented in drowning discontinuities of the U<sup>1</sup> formation (Fahy, 1965; Masse, 1976; Léonide et al.,  
130 2008, 2012) or the basinward equivalent of the *Palorbitolina–Heteraster* guide level in pre-Vocontian settings  
131 (e.g. Masse, 1976; Monier, 1986; Conte, 1989; Delanoy, 1997a; Masse & Fenerci-Masse, 2011). These  
132 ammonite occurrences supported the location of the B/A boundary within the rudist-bearing U<sup>2</sup> *l.s.* formation but  
133 its precise location has been repeatedly questioned over the last two centuries (Leenhardt, 1883; Kilian, 1896;  
134 Pellat, 1903; Paquier, 1905; Pellat & Cossmann, 1907; Douvillé, 1918; Goguel, 1932; Rivier, 1960; Faure, 1965;  
135 Fahy, 1965; Maillard, 1965; Masse, 1976; Masse et al., 1999; Masse & Fenerci-Masse, 2011, 2013a-c; Léonide  
136 et al., 2012, 2014) (Fig. 2), and still remains a challenging issue in the understanding of the demise of the  
137 rudistid biota in peri-Vocontian Urgonian platforms (Frau et al., 2017). Unfortunately, a comprehensive review  
138 of the ammonite occurrences of the Provence platform had not previously been undertaken and no ammonite had  
139 been described from the overlying U<sup>3</sup> formation of North Provence, which might have provided a direct  
140 calibration.

141

### 142 **3. Geological setting**

143

#### 144 *3.1. Geographical context*

145

146         In this study, we examine classical and new localities of the Provence platform covering parts of the  
147 Bouches-du-Rhône (Calanques, Nerthe, Fare and Alpilles massifs), Vaucluse (western Monts de Vaucluse) and  
148 Alpes-de-Haute-Provence (eastern Monts de Vaucluse, Albion Plateau and Monges Massif) regions (Fig. 3). The  
149 study area is bounded by the Rhône River valley to the west and by the Durance River valley to the east, the  
150 Mediterranean coast to the south and the Ventoux–Lure mountains to the north.

151

152 3.2. Palaeogeography

153

154 In southern Provence, the Urgonian platform regime developed between the lower Valanginian and the  
155 upper Barremian at a palaeo-latitude of ~27–28° N (Masse, 1976, 1993; Masse et al. 2000; Masse & Fenerci-  
156 Masse, 2011, 2013b), and records successive phases of northward progradation and southward backstepping  
157 towards the Vocontian Basin (Masse, 1993) (Fig. 4). The maximum northward progradation of the Provence  
158 rudistid platform occurred during the lower upper Barremian (Fig. 4A and B), with the spreading of the  
159 *Agriopleura* and requieniid–monopleurid episodes south to the N100-trending Mont Ventoux–Lure axis (Masse,  
160 1976), which marks the palaeogeographic transition with the neighbouring Vocontian basinal setting (Kandel,  
161 1992). A progressive deepening, whose spatial extent remains unknown (Fig. 4C), is recorded in the Saint-  
162 Chamas area (Masse & Fenerci-Masse, 2013b) and precedes the regional collapse of the southern part of the  
163 Provence platform during the upper Barremian *Imerites giraudi* Zone (Masse & Fenerci-Masse, 2011; Frau et  
164 al., 2016). This event leads to the installation of the ammonite-rich, intra-shelf South Provençal Basin from the  
165 latest Barremian onward (*M. sarasini* Zone – Fig. 4C) up into the upper Aptian (Moullade et al., 2000a; Frau et  
166 al., submitted). The corresponding drowning sequence and lowermost basinal series are known to record short-  
167 lived, dys- to anoxic episodes (Machhour et al., 1998; Masse & Machhour, 2000), which are supposed to be  
168 coeval with the massive outbreak of *Palorbitolina*–*Heteraster* communities in northern Provence and adjacent  
169 settings of the Bas-Vivarais (Masse & Fenerci-Masse, 2011).

170 In northern Provence, recovery of the rudistid regime occurs and corresponds to the spreading of the  
171 caprinid biota (Fig. 4E), whose corresponding platform stage exhibits a bidirectional progradation toward the  
172 South Provence and Vocontian basins (Masse, 1976, 1993, 1995, 2003; Embry, 2005; Masse & Fenerci-Masse,  
173 2011; Léonide et al., 2008, 2012). The progradation of the North Provence platform *sensu* Masse (1993) is  
174 abruptly interrupted at a short-termed emersion surface herein dated to the uppermost Barremian (*M. sarasini*–*P.*  
175 *waagenoides* subzonal boundary) which ends the Urgonian rudistid regime through the study area. This  
176 discontinuity is overlain by a thick succession (~20 to 100 m) of calcarenites and cherty limestones (U<sup>3</sup>  
177 formation) in the North Provence (Fig. 4F), with a *Palorbitolina*–coral episode at its base (Masse & Fenerci-  
178 Masse, 2011; Léonide et al., 2012). As shown by Frau et al. (2017), the U<sup>3</sup> formation is partly coeval with the  
179 limestone-dominated basinal series (Fig. 4F), referred to the Calcareous Mb. (*sensu* Moullade et al., 2000b) in

180 the South Provence Basin and the Barremian–Bedoulian Limestones Fm. (*sensu* Delanoy, 1995a-b) in the  
181 Vocontian Basin.

182 A regional deepening event terminates the deposition of the U<sup>3</sup> platform calcarenites (Fig. 4G) and leads  
183 to the deposition of a thick (~ 80 m), marl-dominated succession of mid-early (Frau et al., 2017) to late Aptian  
184 age in the North Provence (Dutour, 2005; Moullade et al., 2012). This succession was itself divided into three  
185 units (A<sup>1</sup> to A<sup>3</sup>) by Leenhardt (1883) and forms the Aptian-type series of the Apt–Gargas area (Moullade, 1965).  
186 A minor discontinuity evidenced by a glauconitic horizon is documented between the yellowish A<sup>1</sup> and the blue–  
187 grey A<sup>2</sup> marls, which includes the OAE 1a time interval (i.e. culmination of the black shale deposits) dated to the  
188 uppermost *D. forbesi*–lower *D. deshayesi* zones interval (Frau et al., 2017 and references therein). This regional  
189 deepening is coeval with a change toward a marl-dominated regime in the South Provence (Marly-limestone  
190 Mb.) and Vocontian (Blue Marls Fm.) basins which continues up into the Albian (Bréhéret, 1995; Dauphin,  
191 2002).

192

#### 193 **4. Material and methods**

194

195 This paper deals with a coupled sedimentological–palaeontological study based on field observations  
196 and ammonite sampling obtained from 20 reference profiles of Provence described in the joint contribution of  
197 Tendil et al. (accepted). The ammonites were collected by the three first authors (C.F., A.J.-B.T., C.L.), but we  
198 also re-examined additional specimens collected by J.-P. Masse during his seminal study (Masse, 1976). A  
199 systematic description of the studied ammonite taxa is provided below. We recognised eight ammonite bioevents  
200 of regional significance which span the upper Barremian–lower Aptian and provide an improved age-calibration  
201 for the North Provence platform settings. The ammonite bioevents are here interpreted as Opportunity Faunal  
202 Uniformity Horizons (O-FUH) *sensu* Bulot (1993), and mainly correspond to mixed shelf–basin ammonite  
203 assemblages following major flooding events.

204 The direct recognition of the ammonite bioevents, or their derived stratigraphic correlations, enable us  
205 to reconstruct three platform-to-basin transects of the Provence platform (Fig. 5, 6, 7). Occurrence of ammonite  
206 faunas in platform settings are tentatively tied to the relative sea-level variations documented at that time in the  
207 Vocontian Basin and its margins (Arnaud, 2005b, fig. 88) (see also Fig. 2), and compared to the ammonite  
208 abundance changes of the Barremian-type series of Angles (Delanoy, 1995a-b, 1997a-b; Bréhéret, 1997;  
209 Vermeulen, 2005; Bert et al., 2008), and the Nice topographic high (Delanoy, 1992, Arnaud, 2005b, fig. 89).



210

211 **5. Systematic palaeontology**

212

213 This palaeontological appendix discusses and illustrates the ammonite taxa that are of biostratigraphic  
214 relevance for dating the studied sections of the Provence platform. The following palaeontological notes are by  
215 no means to be considered as definitive and many taxa are left in open nomenclature pending the collection of  
216 better preserved and/or more abundant material. Unless otherwise mentioned, all specimens and/or duplicates are  
217 deposited in the Frau collection at the Musée de Paléontologie de Provence (MPP – Aix-Marseille Université,  
218 France). The other acronyms of repositories indicate: FSL – Faculté des Sciences, Université Claude Bernard–  
219 Lyon-I, Lyon and UJF-ID – Institut Dolomieu, Université Joseph Fournier, Grenoble. Suprageneric classification  
220 is limited to the family level.

221

222 Family Ancyloceratidae Gill, 1871

223 Genus *Moutoniceras* Sarkar, 1955

224 *Moutoniceras* sp.

225 Fig. 8A–B

226

227 Material. One specimen, FSL.85850 from Roque Pourquière (Fontaine-de-Vaucluse).

228

229 Description. Shaft fragment of a *Moutoniceras* relatives marked by a compressed sub-oval whorl section bearing  
230 uniform ribs that are thickened and nodular on the upper flanks and venter.

231

232 Genus *Toxancyloceras* Delanoy, 2003

233 *Toxancyloceras vandenheckii* (Astier, 1851)

234 Fig. 8C

235

236 Material. Two specimens, MPP-V-MV.7 and V-MV.8 from the Mont Ventoux (Monts de Vaucluse).

237

238 Description. Specimen MPP-V-MV.7 is represented by a large-sized, sub-complete ancyloceratid ammonite  
239 lacking its spire. Growth rate is moderately low and marked by a long and massive, straight shaft terminated by a

240 moderately long, U-shaped hook. Its ornamentation is composed of the alternation of straight to slightly  
241 prorsiradiate, trituberculate primary ribs and variable number of atuberculate secondaries through most part of  
242 the shaft. As growth increase, primary ribs are enlarged and bears stronger tubercles. In the adult, the  
243 ornamentation changes into strong, spaced, sharp ribs with smooth interspaces.

244

245 *Toxancyloceras* sp.

246 Fig. 8D–E

247

248 Material. One specimen, MPP-A.45 (Masse *in* Frau coll.) from Roque Pourquière (Fontaine-de-Vaucluse).

249

250 Description. Poorly-preserved fragment tentatively assigned to the late part of a *Toxancyloceras* spire. It is  
251 marked by a compressed sub-oval whorl section bearing differentiated ribs; tri-tuberculate main ribs alternated  
252 with one to three fine, atuberculate intercalatories.

253

254 Genus *Kutatissites* Kakabadze, 1970

255 *Kutatissites* gr. *chreithiensis* Kakabadze, 1981

256 Fig. 9A–B

257

258 Material. Two specimens, n°28720 (private collection of G. Delanoy) and UJF-ID. 10590. We re-examined the  
259 specimen illustrated by Delanoy & Ebbo (1997) from Redortiers, ~4km north to Banon. It originates from the  
260 lateral equivalent of the basinal succession overlying the northward termination of the caprinid-bearing  
261 limestones represented by fine-grained calcisiltites at Banon. The specimen UJF-ID. 10590 (Gidon coll.)  
262 previously referred to *Ancyloceras* gr. *matheronianum* by Arnaud et al. (1998, pl. 7, fig. 7) is here referred to *K.*  
263 gr. *chreithiensis*.

264

265 Description. The specimen n°28720 has been precisely described by Delanoy & Ebbo (1997, p. 5-6) to which the  
266 reader is referred. The specimen UJF-ID. 10590 closely resembles the Delanoy's specimen by its morphological  
267 and ornamental features. It differs slightly by its robust tripartite coiling.

268

269 *Kutatissites* gr. *pouponi* Delanoy, Ropolo, Gonnet & Ebbo, 2000

270 Fig. 9C–D

271

272 Material. One specimen, MPP-V-SC.C.1 from Saint Christol (Plateau d'Albion). It originates from the lateral  
273 equivalent of the second lithological unit of the Sault section (see supplementary data).

274

275 Description. Specimen MPP-V-SC.C.1 is represented by a medium-sized, inflated shaft of a tripartite  
276 *Kutatissites* characterised by irregular alternation of trituberculate primary ribs, sometimes bifurcated, and  
277 variable number of simple secondaries. As growth increases, secondary ribs disappear while primary ribs  
278 strengthen and develop peri-ventral clavis. Whorl section is rounded to sub-hexagonal with a flattened venter on  
279 the shaft.

280

281 Genus *Pseudocrioceras* Spath, 1924

282 *Pseudocrioceras* sp.

283 Fig. 9E–G

284

285 Material. One specimen, MPP-A.113 (Masse *in* Frau coll.) from the Conque Verte Valley, Gorges de La Nesque  
286 (Monts de Vaucluse).

287

288 Description. MPP-A.113 corresponds to a large-sized, body chamber of an ancyloceratid ammonite. Whorl  
289 height increases rapidly with a compressed, higher than wide, sub-oval whorl section which become sub-rounded  
290 in the adult. The ornamentation of the shaft and lower part of the hook is marked by spaced, thick, slightly  
291 prorsiradiate, trituberculate ribs with smooth interspaces. The internal and external lateral tubercles are strong  
292 with a rounded base while the latero-ventral ones are elongated and form elevated clavi delimiting a ventral  
293 furrow. Near the aperture, the ornamentation changes into thick, spaced rounded atuberculate ribs. Suture line is  
294 of ancyloceratid type. By its morphology (ancyloceratid coiling) and ornamentation (trituberculate primary ribs  
295 ended by elongated clavi), the specimen belongs to *Pseudocrioceras*, but the lack of the spire prevents its  
296 specific identification.

297

298 Family Hemihoplitidae Spath, 1924

299 Subfamily Hemihoplitinae Spath, 1924

300 Genus *Camereiceras* Delanoy, 1990

301 *Camereiceras limentinum* (Thieuloy, 1979)

302 Fig. 10A, B–C, H–I

303

304 Material. Seven specimens, MPP-A.102 (*Masse in Frau coll.*) from La Redde, Gorges de La Nesque (Monts de  
305 Vaucluse); MPP-V-MV.5, 6, 9, 10, 11 from the Mont Ventoux section (Monts de Vaucluse); MPP-APH-  
306 BAU.R0.1 *ex situ* from Baudinard (Monges Massif). We also re-examined the specimen illustrated by Léonide et  
307 al. (2012, fig. 6G) from the Cire section Gorges de La Nesque (Monts de Vaucluse).

308

309 Description. Small- to large-sized, evolute, dimorphic hemihoplites. Ontogeny encompasses the three stages  
310 defined by Bert et al. (2006, p. 181) to which the reader is referred.

311

312 Genus *Janusites* Bert & Delanoy, 2000

313 *Janusites janus* (Thieuloy, 1979)

314 Fig. 10D–E

315

316 Material. One specimen, MPP-V-MV.4 from the Mont Ventoux (Monts de Vaucluse).

317

318 Description. Small-sized, evolute hemihoplite bearing the three ornamental stages described by Bert & Delanoy  
319 (2000, p. 71) to which the reader is referred.

320

321 Genus *Hemihoplites* Spath, 1924

322 *Hemihoplites* sp. gr. *feraudianus* (d'Orbigny, 1841)

323 Fig. 11A–B, C

324

325 Material. Six specimens, MPP-SC-S.1, 2, 3, 4, 5 and MPP-A.14335 (*Masse in Frau coll.*) from Saint-Chamas  
326 (Fare Massif)

327

328 Description. The collected specimens are represented by large-size body chambers whose inner whorls are  
329 generally crushed or lacking. This prevents a direct comparison with the plastrolectotype MNHN-R723

330 designated by Busnardo *in* Gauthier et al. (2006) based on a small-sized, macroconch morphotype from the  
331 basinal series of the Vocontian Basin. Nevertheless, the species is also known by a certain number of large-sized  
332 macroconch forms illustrated by Delanoy (1990) which perfectly match the specimens at our disposal.

333

334 Genus *Imerites* Rouchadzé, 1933

335 *Imerites giraudi* (Kilian, 1888)

336 Fig. 11D, E–F

337

338 Material. Two specimens, MPP-AHP-BAU.R28m+1.1 from Baudinard (Monges Massif); FSL.85837 (80)  
339 (Masse *in* Busnardo coll.) from Piedmoure, Sault (Plateau d'Albion).

340

341 Description. Small-sized, imericone, dimorphic hemihoplitids whose ontogenetic stages matches well the  
342 microconch variability illustrated by Delanoy (1997a).

343

344 Family Heteroceratidae Spath, 1922

345 Genus *Heteroceras* d'Orbigny, 1849

346 *Heteroceras emericianum* (d'Orbigny, 1842)

347 Fig. 11G

348

349 Material. One specimen, FSL.85842 (86) (Masse *in* Busnardo coll.) from Sault (Plateau d'Albion).

350

351 Description. A poorly-preserved fragment of retroversum which perfectly matches the morphological and  
352 ornamental features of the species known by numerous, complete specimens from the Lure Mountains (Delanoy,  
353 1997a) to which the reader is referred.

354

355 Genus *Martelites* Conte, 1989

356 *Martelites* gr. *sarasini* (Rouchadzé, 1933) – *marteli* Conte, 1989

357 Fig. 12A, B–C, D, 13A–B, C, 14A–B, C–D, E, F

358

359 Material. Thirteen specimens, MPP-BAN.1, 2, 3, 4, 6, MPP-BAN-BRX.1 and MPP-A.36-15 from Banon; MPP-  
360 V-MS.1 from Montsalier; MPP-SC-AA.1 from Saint-Christol (Plateau d'Albion); MPP-V-SV.1 from Savoillan  
361 and MPP-V-BR.1 from Brantes (Rissas–Bluye Massif); MPP-APH-BAU.R33.1 and BAU.R33.2 from Baudinard  
362 (Monges Massif).

363

364 Description. The material at our disposal is composed of small- to large-sized complete martelicone ammonite  
365 which either typologically belong to *M. sarasini* or *M. marteli* depending their turricone and size, as well as their  
366 density and strength of the ribs in the adult. It seems unnecessary to kept separate the two species in the present  
367 contribution since they both co-occur during two peak abundance episodes in the Provence platform

368

369 *Martelites* sp. gr. *sarasini* (Rouchadzé, 1933) – *marteli* Conte, 1989

370 Fig. 14G-H

371

372 Material. One specimen, MPP-A.88 (Masse in Frau coll.) from Les Estèves, Simiane-La-Rotonde (Plateau  
373 d'Albion).

374

375 Description. Incomplete body chamber of a middle-sized *Martelites*. The coiling seems to be moderately  
376 involute, with a compressed, higher than wide, sub-oval whorl section with bulged venter, convex flanks and  
377 low, rounded umbilical wall. The ornamentation is composed of slightly rursiradiate, single or bifurcate ribs that  
378 branch on the umbilical margin. Irregular intercalatory ribs are observed. Ribs cross the venter in thickening.  
379 Suture lines are hardly distinguishable.

380

381 Family Pulchelliidae Douvillé, 1890

382 Genus *Gerhardtia* Hyatt, 1903

383 *Gerhardtia galeatoides* (Karsten, 1858)

384 Fig. 10F, G

385

386 Material. Five specimens, MPP-V-MV.12, 13, 14, 15, 16 from the Mont Ventoux (Monts de Vaucluse)

387

388 Description. Small-sized pulchellid ammonites with an evolute, quasi-scaphitid coiling in the adult and  
389 compressed, higher than wide, whorl section. Ornamentation composed of slightly flexuous, broad and flattened  
390 simple, and rare intercalatory, ribs. They sometimes branch on peri-umbilical bullae with a marked  
391 retrocurvature. Ribs terminates as elongated ridge-like clavi on the peri-ventral margin and define a narrow  
392 ventral furrow.

393

394 Family Deshayesitidae Stoyanow, 1949

395 Genus *Deshayesites* Kazansky, 1914

396 *Deshayesites* aff. *euglyphus* Casey, 1964 in Delanoy, 1995b

397 Fig. 15A, B, ?C

398

399 Material. Three specimens, MPP-B-VC. 20 and 24 from bed 107 and MPP-B-EM.250 from bed 123 of the  
400 Bedoulian-type series.

401

402 Description. Small-sized, moderately evolute, deshayesitids characterised by regular alternation of slightly  
403 flexuous, simple, or rarely bifurcate, primary and generally one secondary ribs. All termination of the ribs show  
404 a smooth thickening on the peri-ventral margin and venter.

405

406 *Deshayesites* gr. *luppovi* Bogdanova, 1983

407 Fig. 15D, E, ?F

408

409 Material. MPP-B-VC.15 and 25 from bed 107 of the Bedoulian-type series and *in-situ* specimens observed at  
410 Savoillan and Brantes.

411

412 Description. Small-sized, moderately evolute, deshayesitids characterised by alternation of flexuous, simple and  
413 bifurcate primary ribs with irregular single secondary one. Point of furcation commonly falls at mid-flank. All  
414 ribs are dense and gracile but can be spaced and slightly flattened on the upper flank near the aperture.

415

416 *Deshayesites* sp.

417 Fig. 15G-H



418

419 Material. One specimen, MPP-V-FDV.1 from Fontaine-de-Vaucluse (Monts de Vaucluse).

420

421 Description. Small-sized fragment of a deshayesitid whorl composed of flexuous ribs which form distinct  
422 bulging in crossing the venter. Despite its poor state of preservation, it may belong to *Deshayesites* aff.  
423 *euglyphus*.

424

425 Family Desmoceratidae Zittel, 1895

426 Genus *Pseudohaploceras* Hyatt, 1900

427 *Pseudohaploceras matheroni* (d'Orbigny, 1841)

428 Fig. 15I–J

429

430 Material. One specimen, MPP-V-PF.2 from Petit Fribouquet (Monts de Vaucluse)

431

432 Description. Medium-sized desmoceratid ammonite with a moderately involute and compressed coiling, convex  
433 flanks and rounded venter. Ornamentation is composed of distinct, straight to slightly sinuous, constrictions  
434 collated in fine, branching ribs which cross the venter.

435

436 Family Macroscaphitidae Hyatt, 1900

437 Genus *Macroscaphites* Meek, 1876

438 *Macroscaphites yvani* (Puzos, 1832)

439 Fig. 15K–L

440

441 Material. Two specimens, MPP-V-PF.3 and V-PF.4 from the Petit Fribouquet (Monts de Vaucluse).

442

443 Description. Medium-sized, markedly evolute ammonites with dense, radial, rarely bifurcated, ribs interrupted  
444 by sporadic constrictions. The two specimens belong to macroconch morphotype by their size and  
445 ammonitonic coiling.

446

447 Family Douvilleiceratidae Parona & Bonarelli, 1897

448 Genus *Procheloniceras* Spath, 1923

449 *Procheloniceras sporadicum* (Rouchadzé, 1933)

450 Fig. 16A-B

451

452 Material. Two specimens, MPP-A17 (Masse *in* Frau coll.) from Sault (Plateau d'Albion); MPP.APH-BAN.5 *ex*  
453 *situ* from Banon (Plateau d'Albion).

454

455 Description. Fragment of a medium-sized douvilleiceratid ammonite showing a moderately evolute coiling and a  
456 depressed, sub-rounded whorl section. Ornamentation is composed of spaced, straight, simple ribs, strengthened  
457 on the venter.

458

459 *Procheloniceras* sp. gr. *dechauxi* (Kilian & Reboul, 1915)

460 Fig. 16C

461

462 Material. MPP-V-PF.1 from the Petit Fribouquet (Monts de Vaucluse).

463

464 Description. Medium-sized, poorly-preserved douvilleiceratid ammonite with a depressed, cadicone whorl  
465 section. Cast of its inner whorls shows a deep umbilicus whose ornamentation is composed of strong, radial,  
466 single or bifurcate, primary ribs, enlarged on the peri-umbilical margin, and smoothed interspaces.  
467 Ornamentation of its body chamber is composed of broad and spaced ribs, sharp on the venter, which branch on  
468 thick, peri-umbilical bullae.

469

## 470 **6. Key ammonite bioevents of the Provence Platform**

471

### 472 *6.1. The Toxancyloceras vandenheckii* bioevent

473

474 The Ancyloceratidae *T. vandenheckii* (Fig. 8C) was collected in the first marlstone episode cropping out  
475 in the south facing side of the Mont Ventoux together with numerous Barremitidae. In the current state of  
476 knowledge, *T. vandenheckii* defines the base of the upper Barremian in the Vocontian basinal settings which  
477 marks a deep renewal in ammonite assemblage with the increase of the Ancyloceratidae, followed by the

478 inception of the Hemihoplitidae (Bert et al., 2008). Unfortunately, the *T. vandenheckii* bioevent was not detected  
479 in the other pre-Vocontian settings surveyed (Brantes, Savoillan, Banon) due to limited outcrop exposure at this  
480 time interval.

481 An equivalent of the *T. vandenheckii* bioevent crops out in the outer platform deposits underlying the U<sup>1</sup>  
482 calcarenites of the Fontaine-de-Vaucluse–Sénanque area. Here, the ammonites *Moutoniceras* sp. (Fig. 8A–B),  
483 *Pseudovaldedorsella* sp., and *Toxancyloceras* sp. (Fig. 8D–E), dating the *Moutoniceras moutonianum*–*T.*  
484 *vandenheckii* zones interval, occur between the Unit 1e and 1h of the Roque Pourquière series *sensu* Masse  
485 (1976, fig. 14). These ammonites were misidentified by Busnardo *in* Masse (1976, p. 39) who alleged a late to  
486 latest Barremian age for the U<sup>1</sup> calcarenites (see also Léonide et al., 2012). The lack of the two age-diagnostic  
487 dasycladaceans *Piriferella paucicalcareia* and *Salpingoporella genevensis* in the corresponding interval supports  
488 our ammonite age-calibration (see Masse, 1976, fig. 14) since their extinction occurs in the middle part of the  
489 lower Barremian (Masse & Fenerci-Masse, 2013c; Clavel et al., 2014; see discussion in §6.1).

490 This dating differs southward since the LO of the two abovementioned dasycladaceans is documented  
491 in the calcarenites underlying the onset of the rudistid (*Agriopleura*-dominated) beds in the Alpilles (~150m) and  
492 Fare (~40m) massifs (Masse & Fenerci-Masse, 2013c; Clavel et al., 2014). The occurrence of the age-diagnostic  
493 caprinid rudist *Offneria simplex* just below the first rudistid limestones in the Fare Massif pinpoints the *M.*  
494 *moutonianum* Zone by comparison with the Bas-Vivarais record (Masse & Fenerci-Masse, 2013c; Tendil et al.,  
495 accepted; see discussion in §6.1). This suggests that the installation of rudistid regime in these areas is slightly  
496 older than the northern Provence settings and merely occurs at, or close to, the base of the upper Barremian.

497 The putative location of this boundary in the Calanques–Nerthe series was previously fixed in the lower  
498 part of the Port-Miou–Cassis Unit *sensu* Masse (1976) where it overlies the outbreak of the *Agriopleura*-bearing  
499 beds. Unfortunately, this assumption has not been yet confirmed by the lack of ammonite evidence and the  
500 recent thesis of Bastide (2014) failed to provide a comprehensive litho- and biostratigraphy of the southern  
501 Provence series with respect to the lithostratigraphic nomenclature introduced by Masse (1976).

502

## 503 6.2. The *Camereiceras limentinum* bioevent

504

505 The Hemihoplitidae *C. limentinum* (Fig. 10A, B–C) and *Janusites janus* (Fig. 10D–E) were found in the  
506 second marlstone episode on the south-facing side of the Mont Ventoux and its eastward equivalent (Banon)  
507 together with the Pulchellidae *Gerhardtia galeatoides* (10F, G) and numerous Barremitidae. The species has a

508 widespread record in pre-Vocontian setting (Thieuloy, 1979; Arnaud et al., 1998), and forms a regional-wide  
509 correlative bioevent in deeper settings of the Vocontian Basin dating the lower *G. sartousiana* Zone (Bert et al.,  
510 2008). The *C. limentinum* acme is accompanied by a minor faunal turnover in the pulchelliid stock, together with  
511 a peak abundance of numerous hemihoplitid, desmoceratid, lytoceratid and macroscaphitid ammonites in the  
512 Barremian-type series (Vermeulen, 2005).

513 The *C. limentinum* bioevent has been previously detected in the northern part of the Monts de Vaucluse  
514 as illustrated by the collection of the corresponding species in the Gorges de La Nesque (Léonide et al., 2012,  
515 fig. 6G, plus our own record on Fig. 10H–I). Its occurrence falls 150m below the northernmost progradation of  
516 the *Agriopleura*-bearing beds (Masse, 1976). Unfortunately, this bioevent was not detected southward and  
517 prevents the direct calibration of the *T. vandenheckii*–*G. sartousiana* zonal boundary in the South Provence.

518

### 519 6.3. *The Hemihoplites feraudianus* bioevent

520

521 In the Fare Massif (Saint-Chamas), the *Agriopleura*-bearing limestones are overlain by a cherty  
522 marlstone interval which exposes an ammonite-rich bed (1.5 m-thick) at its base. The presence of glauconite and  
523 abraded bivalve–rhynchonellid shells prove that it is a condensed bed, itself bracketed by two distinct  
524 hardground surfaces (Masse & Fenerci-Masse, 2011). This bed yields the Hemihoplitidae *Hemihoplites* sp. gr.  
525 *feraudianus* (Fig. 11A–B, C) and the nautiloid *Cymatoceras* sp.

526 According to Bert et al. (2008), the acme of *H. feraudianus* marks the lower part of the *H. feraudianus*  
527 Subzone (upper *G. sartousiana* Zone) in the nearby Vocontian basinal settings which includes the sequence  
528 boundary of the B4 depositional sequence *sensu* Arnaud (2005b). The lack of the requieniid–monopleurid  
529 rudistid beds in this area, replaced by a condensed, ammonite-bearing bed seemingly relates to the fault-induced  
530 formation of the Saint-Chamas corridor as assumed by Masse & Fenerci-Masse (2013a, fig. 3–6). Supposed  
531 temporal equivalence between the *H. feraudianus* Subzone dated deposits of the Fare Massif and the requieniid–  
532 monopleurid rudistid beds of the Provence platform conforms to the dating of the regional termination of the  
533 rudist genus *Agriopleura* in the upper *G. sartousiana* Zone (Masse & Fenerci-Masse, 2013a, 2015). Note that the  
534 Last Appearance Datum (LAD) of *Agriopleura* is associated to a short-term emersion surface through the inner  
535 Provence platform settings that merely relates to the SbB4 of the Vocontian basinal settings. Interestingly, a deep  
536 ammonite faunal turnover occurs at that time with the worldwide LO of the Pulchelliidae, subsequently balanced  
537 by the appearance of the Heteroceratidae during the *H. feraudianus* Subzone (Bert et al., 2008).

538

539 6.4. The *Heteroceras* bioevent

540

541 In the Vocontian basinal settings, the deposition of a basin-wide, marl-dominated wedge relates to the  
542 maximum sea-level rise of the B4 depositional sequence *sensu* Arnaud (2005b). This marlstone episode is  
543 commonly referred as the *Heteroceras* Marls *sensu* Paquier (1900) since it records the diversification and  
544 predominance of the Heteroceratidae, together with the acme of the late Hemihoplitidae *Imerites giraudi* (Fig.  
545 11D) marking the base of the *I. giraudi* Zone. This marlstone episode has an extensive record in pre-Vocontian  
546 settings (Brantes, Savoillan, Mont Ventoux and Banon) and yields a rich heteroceratid fauna in the Lure  
547 Mountains (Kilian, 1888; Delanoy, 1997). It can be traced up to the northern Provence platform settings where it  
548 changes into skeletal–peloidal limestones with abundant cherts (Sault) and further to mixed calcarenite–  
549 oobioclastic limestones with coral bodies overlying the requieniid–monopleurid beds (Gorges de la Nesque). The  
550 occurrence of ammonites dating the *I. giraudi* Zone has long been recognised at Sault (Conte, 1989, p. 40–41;  
551 Delanoy, 1997a), as illustrated by poorly-preserved specimens of the index species (Fig. 11E–F) and  
552 *Heteroceras emericianum* (Fig. 11G).

553 In the South Provence, this time interval corresponds to the fault-induced, drowning of the requieniid–  
554 monopleurid beds which initiates the opening of the intra shelf South Provence Basin (Masse & Fenerci-Masse,  
555 2011, 2013b; Frau et al., 2016). The drowning sequence records deep changes in the environmental conditions  
556 indicated by a positive  $\delta^{13}\text{C}$  shift and massive kaolinite input (Stein et al., 2012b). According to the previous  
557 authors, both signals convincingly reflect a shift toward a warm and humid climate. This enhanced burial of  
558 isotopically light organic carbon triggering episodes of dys- to anoxic conditions at that time illustrated by  
559 extensive organic-rich black shale horizons (Machhour et al., 1998; Masse & Machhour, 2000; Stein et al.,  
560 2012a). These litho- and geochemical signals are also documented in the Vocontian Basin (Godet et al., 2006,  
561 2008) during the *I. giraudi* Zone but only discrete organic-rich horizons are observed in this basin (De Renéville  
562 & Raynaud, 1981). These environmental perturbations are seemingly responsible for the drop in ammonite  
563 abundance and diversity observed in the upper *I. giraudi* Zone in both the South Provence (Frau et al., 2016) and  
564 Vocontian basins (Delanoy, 1995a, 1997a-b; Vermeulen, 2005; Bert et al., 2008). These perturbations are  
565 convincingly responsible for the massive outbreak of *Palorbitolina–Heteraster* communities above the  
566 requieniid–monopleurid unit through the North Provence (Masse & Fenerci-Masse, 2011).

567

568 6.5. The first *Martelites* bioevent

569

570 Above the *Heteroceras* Marls, the B4 depositional sequence progressively returns towards a limestone-  
571 dominated succession in the Vocontian basinal settings (Arnaud, 2005b), which records the peak abundance of  
572 the recoiled Heteroceratidae *Martelites sarasini* (Fig. 12B–C). The species characterises the last zone of the  
573 Barremian in both the South Provençal (Delanoy et al., 1997; Ropolo et al., 1999, 2000a-b; Frau et al., 2016) and  
574 Vocontian basins (Delanoy, 1995a; 1997a-b). This event is also well-developed in pre-Vocontian settings as  
575 demonstrated by the common record of *Martelites* of the *sarasini–marteli* group (Fig. 12D and 13A–B), together  
576 with *Heteroceras baylei* and *Macroscaphites yvani*, as well as rare *Kutatissites* spp. (Delanoy & Ebbo, 1997, fig.  
577 1; plus our own record Fig. 9C–D) and *Procheloniceras* of the *sporadicum* group (Fig. 16A–B) at the Brantes,  
578 Savoillan, Mont Ventoux, Sault and Banon sections.

579 Representatives of *Martelites* gr. *sarasini–marteli* have also been previously reported from around of  
580 distal platform settings of the Monts de Vaucluse (Sault, Saint-Christol, Rissas) but they have long been  
581 confused with lower Aptian Deshayesitidae (Masse, 1976; Monier, 1986). Only the *Martelites* specimens from  
582 Sault have been subsequently illustrated by Conte (1989) and Delanoy (1997a, pl. 52 to pl. 62). According to  
583 Delanoy (1997a, p. 252), an additional specimen of *M. marteli* was misidentified as *Prodeshayesites* sp. by  
584 Monier (1986, pl. 2, fig. f) from the Rissas Massif. In all localities listed above, the *Martelites*-bearing levels  
585 underlie coral build-up deposits considered to represent the basinward prograding termination of the caprinid-  
586 bearing limestones (Masse, 1976, 1995; Masse & Fenerci-Masse, 2011). This lateral variation can be tracked *in*  
587 *situ* along the south facing side of the Toulourenc syncline in the Rissas Massif (Arnaud-Vanneau et al., 1972;  
588 Masse, 1976; Monier, 1986; Masse & Fenerci-Masse, 2011), and prove that the *Martelites*-bearing levels  
589 represent a time equivalent of the topmost part of the *Palorbitolina–Heteraster* guide level.

590 For the time being, no ammonite has been collected in the *Palorbitolina–Heteraster* guide level  
591 cropping out in the southwestern Monts de Vaucluse. Nevertheless, we collected poorly-preserved fragments of  
592 *Martelites* gr. *sarasini–marteli* (Fig. 13C) and the nautiloids *Cymatoceras neocomiense* and *Eucymatoceras*  
593 *plicatum* in the orbitolinid-rich beds at Azé Aven, ~1.2km southwest to Saint-Christol interpreted as the distal  
594 equivalent of the guide level (Blanc et al., 1973). This consequently implies that the *Palorbitolina–Heteraster*  
595 guide level strictly encompasses the *I. giraudi* Zone and lowermost *M. sarasini* Zone.

596

597 6.6. The second *Martelites* bioevent

598

599 For the first time, age-diagnostic ammonites, here assigned to *Pseudocrioceras* sp. (Fig. 9E–G) and  
600 *Martelites* sp. (Fig. 14G–H), have been collected from the bottom part of the U<sup>3</sup> formation from the northwestern  
601 (Gorges de La Nesque) and southeastern (Simiane-la-Rotonde) Monts de Vaucluse, above the last caprinid-  
602 bearing beds. The co-occurrence of *Martelites* and *Pseudocrioceras* relatives are documented at the base of the  
603 *P. waagenoides* Subzone in the South Provençal Basin (Delanoy et al., 1997; Ropolo et al., 1999, 2000a-b)  
604 which marks the upper *M. sarasini* Zone. At Simiane-la-Rotonde, *Martelites* sp. originate from a level overlying  
605 a thin (~ 10cm) orbitolinid-rich horizon and a rudstone bed that represent the northward prograding termination  
606 of the post-caprinid, *Palorbitolina*-rich limestones of the southeastern Monts de Vaucluse (Masse & Fenerci-  
607 Masse, 2011; Léonide et al., 2012). This indicates that the demise of the North Provence rudistid biota, and its  
608 *Palorbitolina*-rich cover, is markedly older than previously assumed (see discussion §6.3), and falls in the  
609 uppermost Barremian.

610 In pre-Vocontian settings (Mont Ventoux, Savoillan and Banon sections), the second *Martelites*  
611 bioevent (Fig. 15A–B, C–D, E, F) was identified in a set of alternating marl-limestone beds unconformably  
612 overlying a coarse to fine-grained bioclastic unit. This unit may represent the basinward expression of the  
613 exposure topping the caprinid-bearing U<sup>2</sup> s.s. limestones (see discussion in Tendil et al., accepted).

614 In deeper Vocontian settings, the B/A boundary interval suffers from low-resolution dating since this  
615 time interval records a significant drop in ammonite abundance above the lower part of the *M. sarasini* Subzone  
616 (Delanoy, 1995a, 1997a-b; Vermeulen, 2005; Bert et al., 2008). This low abundance spans most of the B5  
617 depositional sequence as defined by Arnaud (2005b) and prevents the direct recognition of the *P. waagenoides*  
618 Subzone in the Vocontian Basin (Vermeulen, 2005). Note that a potential hiatus including part of the upper *M.*  
619 *sarasini* Zone merely occurs in Vocontian basinal settings (see Frau et al., 2018; and discussion in §5.3).

620

#### 621 6.7. The first *Deshayesites* event

622

623 From southern (Fontaine-de-Vaucluse–Sénanque) to northern (Pié Gros–Petit Fribouquet) platform  
624 settings of the Monts de Vaucluse, a drowning discontinuity is detected in the upper part of the U<sup>3</sup> formation. It  
625 can be either sealed by cherty calcisiltites or biocalcarenites (Masse & Fenerci-Masse, 2011; Frau et al., 2017).  
626 In the southern Monts de Vaucluse, this discontinuity corresponds to a serpulid-rich, firmground surface which  
627 yields poorly-preserved fragments of *Deshayesites* sp. (Fig. 15G–H) and *Macroscaphites* sp. at Fontaine-de-



628 Vacluse. Its northwestern counterpart (Petit Fribouquet) also contains *Pseudohaploceras matheroni* (Fig. 15I–  
629 J), *Macroscaphites yvani* (Fig. 16K–L) and *Procheloniceras* sp. gr. *dechauxi* (Fig. 16C).

630 In pre-Vocontian settings (Brantes, Savoillan, Mont Ventoux), this discontinuity is represented by a  
631 metre-thick marly episode cropping out in the lower part of the chert-rich limestones of the Calcaires de Vaison  
632 Fm. *sensu* Leenhardt (1883). This layer contains the taxa listed above as well as *Deshayesites* aff. *euglyphus* and  
633 *Deshayesites* gr. *luppovi* (Fig. 15F) that were previously assigned to *D. deshayesi* by Monier (1986) at Brantes.

634 In the Vocontian Basin, both *Deshayesites* aff. *euglyphus* and *D.* gr. *luppovi* occur in an ammonite peak  
635 abundance observed in the upper part of the Barremian–Bedoulian Limestones Fm. (Delanoy, 1995b, fig. 3)  
636 which is associated to the MFS of the A1 depositional sequence *sensu* Arnaud (2005b). Its southern counterpart  
637 in the South Provence Basin refers to the marlstone episode known as the Niveau Toucas *sensu* Moullade et al.  
638 (2000b) cropping out in the upper part of the Calcareous Mb. *D.* aff. *euglyphus* has also been collected there and  
639 throughout the rest of the Calcareous Mb. (Fig. 16A, B). In the Niveau Toucas, it also co-occurs with the *D.* gr.  
640 *luppovi* (Fig. 16D, E) which marks the uppermost *D. oglanlensis* Zone (Reboulet et al., 2011, 2014). Transitional  
641 form seemingly links both forms (Fig. 16C). As a result, the MFS of the A1 sequence occurs close to the *D.*  
642 *oglanlensis*–*D. forbesi* zonal boundary as currently defined by Frau et al. (2015) in the Bedoulian-type series and  
643 forms a regional-wide correlative bioevent in Provence.

644

#### 645 6.8. The second *Deshayesites* event

646

647 The U<sup>3</sup> platform carbonates of the North Provence platform are topped by a distinct hardground surface  
648 and capped by the ammonite-bearing A<sup>1</sup> marls in southwestern and southeastern Monts de Vacluse which yield  
649 common *Deshayesites forbesi* (see Frau et al., 2017, fig. 8–10). According to these authors, this species dates the  
650 upper (but non-uppermost) part of the *D. forbesi* Zone and characterises the lower part of the Marly-limestone  
651 Mb. in the South Provençal Basin (Moullade et al., 2000b). This time interval refers to depositional sequence  
652 BA2 *sensu* Arnaud (2005b), including the spreading of the OAE 1a-related oceanic anoxia (Frau et al., 2017).  
653 The top of the A<sup>1</sup> marls is interrupted by a burrowed, glauconitic firmground including the OAE 1a time interval,  
654 and overlain by the blue-grey A<sup>1</sup> marls whose base is dated to the upper *D. deshayesi* Zone by means of  
655 ammonites (Dutour, 2005; Frau et al., 2017).

656 In the Vocontian Basin and its margins, this time interval is generally lacking due to non-deposition gap  
657 and/or resedimentation at the transition between the limestone- (Barremian–Bedoulian Limestones) and marl-

658 dominated (Blue Marls) formations (Cotillon, 2010; Cotillon et al., 2000). Usually, only the upper *D. deshayesi*  
659 and/or *D. furcata* zones directly lies above eroded or slumped Barremian–Bedoulian limestones Fm.; except in  
660 few localities (Bréhéret, 1995).

661

## 662 **6. Biostratigraphic significance and regional implications**

663

664 Our revised calibration substantially modifies the datings of the North Provence platform developed in  
665 the five last decades. A comparative scheme is given in Fig. 17. Major results are discussed below.

666

### 667 *6.1. Installation of the North Provence rudistid biota*

668

669 Although its timing remains poorly constrained in the Calanques–Nerthe massifs, the outbreak of  
670 rudistid beds in the South Provence series, dominated by *Agriopleura* spp., is likely associated to its northward  
671 progradation during the *T. vandenheckii* in the Fare and Alpilles massifs, and delayed up into the *G. sartousiana*  
672 zones interval throughout Monts de Vaucluse. An orbitolinid-rich horizon underlies the deposition of the first  
673 *Agriopleura*-bearing beds at Fontaine-de-Vaucluse and can be seemingly tracked up to the Gorges de La Nesque  
674 area (Léonide et al., 2012; Tendil et al., accepted). This horizon and its overlying *Agriopleura*-bearing beds are  
675 enclosed between the *C. limentinum* and *H. feraudianus* ammonite bioevents which constrain the installation of  
676 the rudistid biota in northern Provence to the middle part of the *G. sartousiana* Zone. According to Arnaud  
677 (2005b), this time interval includes the maximum flooding surface of the Vocontian B3 depositional sequence,  
678 evidenced by the record of an ammonite peak abundance dominated by pulchelliid and hemihoplitiid taxa in the  
679 *G. provincialis* Subzone (Vermeulen, 2005). The wide extent (~20 km) and stratigraphic location of the  
680 orbitolinid-rich horizon make it as a potential candidate for the local expression of the corresponding MFS. This  
681 supports the concomitant northernmost progradation of the *Agriopleura*-bearing biota during the *G. provincialis*  
682 Subzone.

683

### 684 *6.2. Dating of the Palorbitolina–Heteraster guide level*

685

686 In previous contributions, the B/A boundary was located within, or at the top, of the *Palorbitolina*–  
687 *Heteraster* guide level, assigning *de facto* an early Aptian age to the overlying caprinid-bearing limestones of the

688 North Provence platform. This assumption involved the record of three alleged age-diagnostic bio- and  
689 chemostratigraphic markers in the guide level; these are:

690 (i) The co-occurrence of the orbitolinids *Palorbitolina lenticularis* and *Orbitolinopsis* spp. considered to  
691 be indicative of the lowermost Aptian (Arnaud et al., 1998; Arnaud-Vanneau et al., 2005);

692 (ii) The unfigured report of lowermost Aptian ammonites [*D. bedouliensis* and *Deshayesites* aff.  
693 *consobrinus*] in the cherty marlstones underlying the caprinid-bearing limestones in the Fare Massif (Masse,  
694 1995; Masse & Fenerci-Masse, 2011; Clavel et al., 2013);

695 (iii) The record of a negative carbon shift at the base of the guide level attributed to the latest Barremian  
696 negative carbon excursion (Léonide et al., 2014).

697

698 As discussed below, none of these arguments is reliable for the recognition of the B/A boundary within  
699 the *Palorbitolina–Heteraster* guide level:

700 (i) The orbitolinid zonation of the Urgonian-type series follows those developed in the nearby Subalpine  
701 platform series by Arnaud et al. (1998) and Arnaud-Vanneau et al. (2005). According to their foraminiferal  
702 distribution chart, the association of *P. lenticularis* and *Orbitolinopsis* spp. in the Lower *Orbitolina* Beds would  
703 be indicative of the lowermost Aptian. In line with previous contributions of Clavel et al. (2007, 2013, 2014),  
704 Granier et al. (2013) recently brought new light on the vertical range of Barremian–Aptian Orbitolinidae in  
705 southeast France by the study of reworked assemblages in the base-of-slope, ammonite-constrained Vocontian  
706 section (l'Estellon, Drôme). These authors suggested that the first co-occurrence of *P. lenticularis* and  
707 *Orbitolinopsis* spp. dates back to the lower Barremian (*N. pulchella* Zone) and these taxa are, therefore, of little  
708 help for defining the B/A boundary.

709 The early Aptian age assigned to the association of *P. lenticularis* and *Orbitolinopsis* spp. was also  
710 supported by the supposed co-occurrence of lower Aptian ammonites referred to *Ancyloceras* gr.  
711 *matheronianum*, *Deshayesites* gr. *weissi* and *Toxoceratoides* sp. in the Lower *Orbitolina* Beds of the Chartreuse  
712 and Vercors massifs (Gidon, 1952; Moret & Deleau, 1960; Arnaud et al., 1998). Re-investigation of the  
713 palaeontological collections of the Grenoble University failed to retrieve the specimens of *Deshayesites* sp. and  
714 *Toxoceratoides* sp. Their systematic assignments, therefore, remain doubtful in the absence of illustration. The  
715 ancyloceratid ammonite originally referred to *A. gr. matheronianum* and illustrated by Arnaud et al. (1998, pl. 7,  
716 fig. 7) is still kept in the Gidon collection under the catalogue number UJF-ID.10590. Our re-examination  
717 highlights that it lacks the typical adult ornamentation (i.e. regular alternation of trituberculate primaries and

718 inerme, secondaries ribs) and elongated coiling which typifies the genus *Ancyloceras*. The robust quadrate to  
719 depressed subhexagonal whorl section and irregular ribbing rather suggest that this specimen closely matches the  
720 body chamber of *Kutatissites* gr. *chreithiensis* (Fig. 9A–B). This taxon reaches its acme in the lowermost *M.*  
721 *sarasini* Zone in the North Provence platform and gives evidence of the potential coevality between the Lower  
722 *Orbitolina* Beds of the Subalpine Chains and the North Provence *Palorbitolina–Heteraster* guide level which  
723 both record *Kutatissites* peak abundance.

724 (ii) According to Masse (1976) and Masse & Fenerci-Masse (2011), the occurrence of lowermost  
725 Aptian Deshayesitidae in the cherty marlstones of the Saint-Chamas section supports the location of the B/A  
726 boundary below the caprinid-bearing limestones. However, Masse & Fenerci-Masse (2013a) revised the  
727 taxonomy of these ammonites subsequently referred to upper Barremian Hemihoplitidae. The authors also  
728 indicated that they originate from the condensed bed at the base of the cherty marlstones, herein dated to the *H.*  
729 *feraudianus* Subzone (see discussion in §6.3). Extensive fieldwork in the Fare Massif confirms the lack of any  
730 Aptian ammonites in the cherty marlstones of the Fare Massif.

731 (iii) According to Stein et al. (2012b), the negative  $\delta^{13}\text{C}$  shift documented in the Lower *Orbitolina* Beds  
732 of the Subalpine Chains (Raddadi, 2005; Arnaud-Vanneau et al., 2005, fig. 50) and the *Palorbitolina–Heteraster*  
733 guide level of the North Provence (Léonide et al., 2014) are coeval and correlate to the sharp negative carbon  
734 excursion of latest Barremian age observed across the Tethyan basins (Stein et al., 2012a). However, Frau et al.  
735 (2018) highlighted that the correlation of this negative carbon excursion was so far based on inaccurate  
736 ammonite age-calibration in basinal settings, thus questioning its correlation in shallow-water carbonates.  
737 Indeed, Masse & Fenerci-Masse (2011, p. 671) pointed out that the  $\delta^{13}\text{C}$  shift of the Lower *Orbitolina* Beds  
738 merely relates to the existence of an emersion surface whose carbon signal is diagenetically overprinted.  
739 Moreover, one of us (A.J.-B.T.) detected a significant lag between the vertical distribution of the carbon values  
740 and the litho-log of Fontaine-de-Vaucluse where the negative  $\delta^{13}\text{C}$  shift was documented by Léonide et al.  
741 (2014). His correction suggests that the 2‰ negative carbon shift falls within a requieniid–monopleurid bed,  
742 approximately 8m below the basal surface of the *Palorbitolina–Heteraster* guide level. It seemingly relates to  
743 the expression of a parasequence-related emersion surface typical for this part of the Urgonian-type series  
744 (Masse et al., 2001). As a result, the record of the latest Barremian negative peak in the Urgonian-type Provence  
745 platform is not substantiated by C-isotope data.

746

747 In the present contribution, the North Provence *Palorbitolina–Heteraster* guide level is correlated to the  
748 *I. giraudi* Zone and lowermost *M. sarasini* Subzone (Fig. 17), in agreement with ammonite findings and  
749 geological mapping. The overlying caprinid-bearing limestones, and its *Palorbitolina*-rich cover are strict time  
750 equivalent of the *M. sarasini* Subzone since they are overlain by the U<sup>3</sup> formation bearing ammonites of the *P.*  
751 *waagenoides* Subzone at its base. The latter is unanimously considered to be the last ammonite subzone of the  
752 Barremian (Delanoy et al., 1997; Ropolo et al., 1999; 2000a-b; Bert et al., 2008; Reboulet et al., 2014). As a  
753 result, the B/A boundary should be re-located in the lowermost part of post-caprinid U<sup>3</sup> formation, although its  
754 precise level cannot be fixed due to the lack of a continuous ammonite record. Relocation of this boundary above  
755 the North Provence rudistid limestones represents a return to the conceptions first developed by Faure (1965),  
756 Fahy (1965) and Maillard (1965) (see also Fig. 2).

757

### 758 6.3. Demise of the North Provence caprinid biota (Fig. 18)

759

760 According to our calibration, the North Provence caprinid-bearing U<sup>2</sup> s.s. limestones develop above the  
761 *Palorbitolina–Heteraster* guide level and record a bidirectional progradation toward the South Provence and the  
762 Vocontian basins during the *M. sarasini* Subzone *pro parte*. This unit is covered by a short-term epikarstic  
763 surface, indicated by minor dissolution of both low-Mg calcitic and aragonitic rudist shell layers (Masse, 1976;  
764 Masse & Fenerci-Masse, 2011; Léonide et al., 2012), that interrupted the overall progradation of caprinid-  
765 bearing deposition. This emersion is also confirmed by the record of a strong negative spike in the C-isotope  
766 signal indicating an influence of meteoric diagenesis (Léonide et al., 2014). In North Provence, this discontinuity  
767 is overlain by bioclastic–cherty limestones (U<sup>3</sup> formation). Its expression is less conspicuous in the southwestern  
768 Monts de Vaucluse since the last caprinid-rich levels give way, transitionally, to *Palorbitolina*-rich limestones  
769 including decametre-width coral mounds, and then to cherty, *Palorbitolina*-bearing limestones (Tendil et al.,  
770 accepted). These *Palorbitolina*-rich limestones thin northward and disappear along a NW–SE bulge, i.e. the so-  
771 called Flassan–Rustrel ridge *sensu* Masse & Fenerci-Masse (2011, fig. 11). As indicated by the record of the  
772 second *Martelites* bioevent, the demise of the caprinid episode, and subsequent deposition of its *Palorbitolina*-  
773 rich cover, occur in the uppermost *M. sarasini* Subzone.

774 In the South Provence, the *M. sarasini* Subzone marks the onset of the basinal sedimentary conditions  
775 above the drowning sequence (Frau et al., 2016). This time interval is characterised by the alternation of  
776 laminated organic-rich black shales and highly burrowed, shelly limestones, reflecting successive anoxic to

777 dysoxic/oxic depositional conditions at that time (Stein et al., 2012a). The high rate of accumulation and  
778 preservation of the organic matter is consistent with the proposed model of a restricted intra-shelf basin bordered  
779 by a shallow-water carbonate platform acting as an additional feeding sources of organic matter (Machhour et  
780 al., 1998). The *M. sarasini* Subzone records the peak abundance of micromorphic heteroceratid ammonite fauna  
781 showing a favourable adaptation to oxygen-depleted, sea-water conditions (Frau et al., 2016).

782         The transition between the *M. sarasini* and *P. waagenoides* subzones in the Bedoulian-type series (beds  
783 44–45 *sensu* Moullade et al., 2000b) consists of a serpulid-rich, wavy discontinuity which is approximately  
784 coeval with the faunal replacement of the Heteroceratidae by the Ancyloceratidae *Pseudocrioceras* (see Ropolo  
785 et al., 1999; 2000a). This bed interval is marked by a strong negative oxygen and carbon isotope shift (~1.5‰),  
786 seen in paired organic matter and carbonate carbon (Kuhnt et al., 2000; Masse & Fenerci-Masse, 2011; Stein et  
787 al., 2012a). Isotopic excursions give evidence of a short-termed, syn-depositional hiatus. In the absence of  
788 platform-derived material in the corresponding discontinuity, the negative carbon excursion may result from  
789 seawater enrichment by isotopically-light, dissolved inorganic carbon derived from intense weathering of the  
790 hinterland during the emersion of the platform. This interval is also characterised by a productivity increase  
791 (Bergen, 2000), maximum TOC values (~18%), and phosphorus enrichment (Stein et al., 2012a).

792         By contrast, the uppermost Barremian (*P. waagenoides* Subzone) and lowermost Aptian (*D. oglanlensis*  
793 Zone) of the South Provence Basin records the progressive recovery toward oxic palaeoenvironmental conditions  
794 illustrated by the deposition of regular, blue–grey basinal limestones lacking any redox sensitive trace elements  
795 anomaly (Stein et al., 2012a). This recovery is coeval with the abrupt termination of the *Pseudocrioceras* stock  
796 replaced by the peak abundance of the *Deshayesites* which marks the base of the Aptian Stage by means of  
797 ammonites (Delanoy et al., 1997; Cecca et al., 1999, 2000; Ropolo et al., 1999, 2000a-b, 2006; Reboulet et al.,  
798 2011, 2014).

799         In the Vocontian Basin, the B/A boundary is located in the Barremian–Bedoulian Limestones Fm. but  
800 its precise level remains unclear since the corresponding time interval records a marked drop in abundance and  
801 diversity of ammonite taxa above the lowermost part of the *M. sarasini* Subzone (Delanoy, 1995a, 1997a-b;  
802 Vermeulen, 2005; Bert et al., 2008). The putative boundary was fixed at the minimum value of a distinct  
803 negative  $\delta^{13}\text{C}$  excursion (Godet et al., 2006; Huck et al., 2011), considered to be the local expression of the latest  
804 Barremian negative excursion of the Bedoulian-type series by the latter authors. This negative  $\delta^{13}\text{C}$  excursion  
805 falls at the base of a bundle of thick limestone beds traceable throughout the basin (i.e. Thick Bundle *sensu*  
806 Delanoy, 1995b; beds 201–206 *sensu* Vermeulen, 2005), which yields few specimens of lower (but non-

807 lowermost) Aptian deshayesitids (Delanoy, 1995b). Following Frau et al. (2018), the record of the latest  
808 Barremian negative carbon excursion just below *Deshayesites*-bearing beds outlines the existence of a minor  
809 temporal hiatus, including, at least, the *P. waagenoides* Subzone, and (?) the lowermost part of the *D.*  
810 *oglanlensis* Zone. If this should prove correct, one may wonder if the lack of ammonite evidences of the *P.*  
811 *waagenoides* Subzone can really be explained by the deep water depth of the Vocontian settings (Bert et al.,  
812 2008) or is linked to the presence of a hiatus temporally linked to the demise of the North Provence platform.

813

## 814 7. Comparison with peri-Vocontian Urganian platforms

815

### 816 7.1. Bas-Vivarais (Fig. 19)

817

818 Along the western margin of the Vocontian Basin (Cévenole margin), the innermost known settings of  
819 the Urganian Bas-Vivarais platform deposits (Col de la Serre–Serre de Tourre sections) expose three main  
820 rudist-rich units pinching out toward the Vocontian Basin:

821 (i) Above ammonite-bearing shelf deposits, the installation of Urganian platform carbonates consists of  
822 calcarenite enriched in rudists upward, i.e. *Agriopleura*–requieniid beds (Lafarge, 1978; Masse and Fenerci-  
823 Masse, 2013b). The rudistid beds terminate at a distinct emersion surface overlain by mixed, rudist-poor, marls–  
824 carbonates (V3 *sensu* Elmi et al., 1996), including the Caribbean caprinid rudist *Offneria simplex* (see  
825 Chartrousse & Masse, 1998; Masse & Fenerci-Masse, 2013b). According to Clavel et al. (2007, 2013, 2014) and  
826 Masse & Fenerci-Masse (2013c), the first platform stage develops through the *K. nicklesi*–*N. pulchella* zones  
827 interval since it overlies ammonite-bearing marly-limestones of latest Hauterivian to earliest Barremian age and  
828 underlies the V3 episode which yields rare ammonites assigned to the upper *N. pulchella*–*M. moutonianum*  
829 zones interval.

830 We fully support the dating of the underlying shelf deposits but alternative dating of the V3 episode  
831 arises from ongoing studies by A. Pictet and P.-O. Mojon (unpublished data), who found new ammonites and re-  
832 examined specimens illustrated by Clavel and his collaborators. From the Serre de Tourre to outermost platform  
833 settings of the Bas-Vivarais, the V3 episode contains several ammonite-bearing horizons dating the *K.*  
834 *compressissima*, *M. moutonianum* and *T. vandenheckii* zones. The apparent lack of ammonite evidence from the  
835 *N. pulchella* Zone is consistent with the record of Vocontian marginal settings in which this zone is highly  
836 condensed (Delanoy et al., 2012; Vermeulen et al., 2013; Arnaud, 2005b) or lacking (Delanoy, 1992; Arnaud,



837 2005b). Given these considerations, the *Agriopleura*–requieniid beds of the Middle Urgonian Mb. should rather  
838 be assigned to the upper *K. nicklesi* Zone. The *N. pulchella* Zone merely lacks as a result of a short-term  
839 emersion hiatus.

840 (ii) Above the V3 episode, massive recovery of the Urgonian rudistid biota occurs as illustrated by the  
841 development of *Agriopleura*-, and requieniid–monopleurid beds (thickness comprised between ~25 and 50 m).  
842 This series conforms to the northward progradation of the Provence platform during the *T. vandenheckii*–*G.*  
843 *sartousiana* zones interval. As further evidence, the *Agriopleura*-bearing beds terminates at an epikarstic  
844 discontinuity (Masse & Fenerci-Masse, 2011); herein dated to the *G. provincialis*–*H. feraudianus* subzonal  
845 boundary.

846 (iii) The Bas-Vivarais requieniid–monopleurid beds are overlain by *Palorbitolina*-rich beds (V4 *sensu*  
847 Elmi et al., 1996) which represent the local equivalent of the North Provence *Palorbitolina*–*Heteraster* guide  
848 level (Lafarge, 1978; Masse & Fenerci-Masse, 2011; Frau et al. 2017). This is furthermore confirmed by the  
849 occurrence of poorly-preserved heteroceratid ammonites dating the *I. giraudi*–*M. sarasini* zones interval *pro*  
850 *parte* in the Vallon Pont d'Arc region (Pascal collection deposited at the University of Claude Bernard – Lyon I).

851 (iv) Above the guide level, the last platform stage consists of caprinid-bearing limestones (Lafarge,  
852 1978; Masse, 1995), which displays the maximum eastward progradation of the Bas-Vivarais platform toward  
853 the Vocontian Basin (Masse & Fenerci-Masse, 2011; Frau et al., 2017, fig. 11). According to Masse & Fenerci-  
854 Masse (2013b), the caprinid-bearing limestones were connected to their North Provence counterpart although the  
855 two domains are now disconnected by the N40 sinistral, strike-slip Nîmes fault (Masse & Fenerci-Masse,  
856 2013b).

857 Exception made for the lower Barremian, the spatial evolution of the Bas-Vivarais Urgonian limestones  
858 formation strictly conforms to the northward progradation of the Provence platform during the *G. sartousiana*–  
859 lower *M. sarasini* zones interval. Nevertheless, a westward pinching out of the North Provence U<sup>3</sup> formation is  
860 documented into the discontinuity topping the caprinid-bearing limestones in eastern Bas-Vivarais (Frau et al.,  
861 2017). As a result, the more proximal Bas-Vivarais settings experienced a longer exposure including the  
862 uppermost Barremian (upper *M. sarasini* Zone) up into the lowermost Aptian (lower *D. forbesi* Zone). This long-  
863 term exposure is reflected by the three generations of infills in epikarstic cavities documented by Pictet et al.  
864 (2015).

865 The emersion surface is regionally drowned by three successive, or conjugated, ammonite-bearing  
866 deepening-up phases (Chabert and Frayol formations *sensu* Pictet et al., 2015) spanning the upper *D. forbesi*

867 Zone to the *D. furcata* Zone (Pictet & Delanoy, 2016). This dating is consistent with those of the post-Urgonian  
868 marly cover (A<sup>1</sup>–A<sup>2</sup> units) of the North Provence (Frau et al., 2017), although it differs by its continuous  
869 succession across the OAE 1a-related time interval in the Bas-Vivarais settings. This new calibration challenges  
870 the recent studies which limited the duration of the final Urgonian emersion to the lower *D. forbesi* Zone (e.g.  
871 Masse, 1995; Masse & Fenerci-Masse, 2011; Bastide, 2014; Clavel et al., 2013, 2014; Pictet et al., 2015; Pictet  
872 & Delanoy, 2016).

873

## 874 7.2. Subalpine Chains (Fig. 20)

875

876 The Urgonian platform series extending from the Swiss–French Jura to the Subalpine Chains have been  
877 intensively studied over the past decades but its dating is part of a long-lived debate for which two main  
878 biostratigraphic models (Grenoble vs. Genève university conceptions) based on distinct orbitolinid scales have  
879 been developed and still await validation.

880 In the pioneering Grenoble model of Arnaud-Vanneau & Arnaud (1990) and Arnaud & Arnaud-  
881 Vanneau (1991) updated by Arnaud et al. (1998, 2017) and Godet et al. (2016a), the Urgonian series outcropping  
882 of the Subalpine platform includes two successive stratigraphic formations, i.e. the bioclastic-dominated  
883 Glandasse Fm. of early to early late Barremian age and the rudist-bearing Urgonian limestones Fm. of latest  
884 Barremian to early Aptian age. The latter consists of two rudist accumulation units (i.e. Lower and Upper  
885 Urgonian members) separated by the Lower *Orbitolina* Beds, which form a regional-wide correlative event  
886 (Arnaud et al., 1998). According to this model, "*the Glandasse Fm. is restricted to the southern part of the*  
887 *Vercors and pinches out northward, whereas the Urgonian Formation spreads over the entire subalpine domain*  
888 *including the French-Swiss Jura where it overlies directly Hauterivian platform limestones"* (Richet, 2011). The  
889 datings of the Urgonian limestones Fm. would be supported by correlation with ammonite-bearing, drowning  
890 discontinuities followed into basinward settings of the southern Vercors and Diois regions (Arnaud et al., 1998,  
891 fig. 36-38). For example, the recognition of the *G. sartousiana* Zone dated deposits below the Urgonian  
892 limestones Fm. in the southern Vercors was used as evidence for the latest Barremian inception of the rudistid  
893 limestones throughout the Subalpine Chains.

894 In the Genève University model developed over the past decades (Clavel et al., 1995, 2002, 2007, 2010,  
895 2013, 2014; Charollais et al., 2008; Granier et al., 2013), "*the Arnaud's Glandasse Fm. grades northwards to*  
896 *rudist bearing limestones, which implies that the Glandasse and the lower part of the Urgonian formation are*

897 *stratigraphically equivalent, and essentially early Barremian in age*" (Richet, 2011). This assumption relies on  
898 the record of upper Hauterivian to lowermost Barremian ammonites below the Arnaud's Glandasse Fm., which  
899 furthermore contains lower Barremian age-diagnostic dasycladaceans and orbitolinids (Clavel et al., 2007, 2010,  
900 2013, 2014). A similar shallow-water assemblage is also documented in the Lower Urgonian Mb. and gives  
901 evidence of its coevality with part of the Arnaud's Glandasse Fm. cropping out in the southern Vercors (Clavel et  
902 al., 2014 and references therein). Most recent sedimentological studies tend to corroborate the Genève University  
903 model but the lack of continuous high-resolution mapping of outcrop cliffs in the northeastern Vercors prevent to  
904 draw a general conclusion (Richet, 2011).

905 Preliminary review of the published data is summarised below and give new insight into the growth and  
906 demise of the Subalpine rudistid biota:

907 (i) In proximal settings of the Swiss–French Jura (Rocher des Hirondelles type section), the  
908 installation of the rudistid regime seemingly occurs in the upper Hauterivian and continues southward through  
909 the lowermost Barremian. Although no direct ammonite occurrence is presently known, this scenario is  
910 supported by the integration of shallow-water biological markers (Masse et al., 1998; Clavel et al., 2007, 2013,  
911 2014). This conforms to the southward inception of the Urgonian facies in the Subalpine Chains, which are  
912 seemingly delayed up into the (?)lower *K. nicklesi* Zone in the northern Vercors as indicated by the record of the  
913 ammonites *Emericiceras* sp. gr. *koechlini* and *Torcapella* sp. in an underlying marly episode at the Grands  
914 Goulets section (Clavel et al., 2014, pl. 1, fig. 5). Note that none evidence of sedimentary hiatus occurs between  
915 this marly episode and the first rudistid limestones (Clavel et al., 2014, see discussion on p. 37-38), as assumed  
916 in the Grenoble model (SbB3 *sensu* Arnaud et al., 1998).

917 (ii) In the southern part of the Swiss–French Jura, the rudistid regime is ended by a prominent karstic  
918 discontinuity, forming incised valleys infilled by *Palorbitolina–Heteraster* limestones locally referred as the  
919 Poet Beds in the Valserine Valley (Pictet et al., 2016). The Poet Beds previously yielded an ammonite specimen  
920 referred to *Deshayesites* gr. *saxbyi* by Martín-Closas et al. (2009), and recently figured in Pictet et al. (2016, Fig.  
921 7 f3; FSL.105033). Re-examination of this specimen highlights that it can be confidently assigned to *Martelites*  
922 sp. juv. This ammonite gives evidence of the likely coevality between the Poet Beds and the Lower *Orbitolina*  
923 Beds of the Subalpine Chains and the *Palorbitolina–Heteraster* guide level of the North Provence–Bas-Vivarais  
924 regions which all delivered ammonites dating the lowermost *M. sarasini* Subzone at their top. In the current state  
925 of knowledge, the early Barremian age *pro parte* of the underlying rudistid limestones indicates the presence of a  
926 major hiatus including part of the upper lower and lower upper Barremian at their top, i.e. (?) up to the *I. giraudi*

927 Zone according to Martín-Closas et al. (2009) and Clavel et al. (2007, 2013, 2014). However, ongoing studies of  
928 A. Pictet and P.-O. Mojon (unpublished data) suggest that the rudistid limestones of the Swiss-French Jura may  
929 locally have reached the uppermost Barremian, although this dating would contradict with dasycladale and rudist  
930 occurrences of older significance.

931 (iii) The Lower Urgonian Mb. of the Chartreuse and northern Vercors includes three main exposure  
932 surfaces –SbB4, SbB5 and SbA1 – whose ammonite age-calibration strongly varies between the two existing  
933 models. The Lower Urgonian Mb. encompasses the mid-upper Barremian to lowermost Aptian in the Grenoble  
934 model while it strictly spans the lower Barremian *pro parte* (*T. hugii* to *K. compressissima* zones interval) in the  
935 Genève one. Considering that the extinction of the age-diagnostic dasycladales *S. genevensis* and *P.*  
936 *paucicalcareia* occurs several tens of meters below the SbA1 while the rudist genus *Agriopleura* reaches the top  
937 of the member (Arnaud-Vanneau, 1980), the dating of the Lower Urgonian Mb. better conforms to the age-  
938 assignment of the Genève model. However, it has been documented in the seminal thesis of Richet (2011) that  
939 rudistid limestones develop below *G. sartousiana* zone dated deposits in the southern Vercors. If the early  
940 Barremian age of the Lower Urgonian Mb. proves correct, geometry of the platform across the lower/upper  
941 Barremian boundary is more complex than actually assumed. Note that the SbA1 topping the Lower Urgonian  
942 Mb. is of lesser importance compared to its northward counterpart although it is similarly overlain by Lower  
943 *Orbitolina* Beds herein assigned to the *I. giraudi* and lowermost *M. sarasini* zones (see discussion §6.2i).

944 (v) As for the North Provence–Bas Vivarais record, the recovery of the rudistid regime above the  
945 Lower *Orbitolina* Beds (i.e. Upper Urgonian Mb.) is expressed by the development of caprinid-bearing  
946 limestones, which also marks the maximum progradation of the Subalpine platform (Arnaud-Vanneau, 1980).  
947 Both Grenoble and Genève models so far assigned an early Aptian age *pro parte* to the Upper Urgonian Mb. by  
948 comparison with the North Provence record (e.g. Arnaud et al., 1998; Clavel et al., 2013, 2014). According to  
949 our recalibration, this member should be re-assigned to the *M. sarasini* Subzone.

950 In accordance with the proximal Bas-Vivarais platform settings, the Upper Urgonian Mb. is topped by  
951 a major exposure event ending the Urgonian rudistid regime. It is characterised by intense karstification  
952 processes which can form deeply, incised palaeovalleys infilled by a new episode of *Palorbitolina*-rich  
953 marlstones (locally referred as the Upper *Orbitolina* Beds) and capped by calcarenites (the Lumachelle). These  
954 levels yield ammonites of late early Aptian age (i.e. upper *Deshayesites deshayesi* and *D. furcata* zones) in the  
955 Upper *Orbitolina* Beds, and at the base of the Lumachelle (Thieuloy & Girod, 1964; Delamette et al., 1997;  
956 Pictet, unpublished data). As herein understood, the minimum duration of the hiatus related to the end of the

957 Urgonian rudistid regime (SbA2 in the Grenoble model) straddles the upper *M. sarasini* to the (?)lower *D.*  
958 *deshayesi* zones. This new calibration challenges both the Grenoble and Genève models which limited the  
959 duration of the SbA2 emersion to part of the lower *D. forbesi* Zone (Arnaud et al., 1998; Clavel et al., 2007,  
960 2013, 2014 amongst others).

961 (vii) The Upper Urgonian Mb. disappears northward since it has no equivalent in the Swiss–French  
962 Jura. In these areas, the Poet Beds are also topped by an emersive discontinuity and overlain by stacked units of  
963 variegated, detrital, marls and sandstones (i.e. Perte-du-Rhône Fm. *sensu* Pictet et al., 2016) dated to the upper  
964 *D. forbesi* to *D. furcata* zones interval by its ammonite content (Pictet et al., 2016). As a result, the associated  
965 hiatus topping the Poet Beds conforms well to the duration of the SbBA2-related hiatus in the Subalpine Chains.  
966 Above this discontinuity, this region acts as a topographic high whose sedimentary succession only records  
967 flooding events of third order significance, interrupted by an ammonite-bearing, condensed phosphoritic  
968 horizons spanning the upper Aptian to the lower Cenomanian (Pictet et al., 2016).

969

970 In summary, the installation of the rudistid biota in the Swiss–French Jura and its southward  
971 progradation in the Subalpine Chains during the Hauterivian–Barremian transition conforms to other record of  
972 the peri-Vocontian platforms. However, intra-Urgonian correlations with the Provence–Bas-Vivarais  
973 depositional sequences are made difficult due to an imprecise ammonite age-calibration and a complex  
974 accommodation history of the Subalpine regions. We hope that these preliminary results will stimulate new  
975 detailed investigations on the platform-to-basin correlations of the Subalpine platform.

976

## 977 **8. Conclusion**

978

979 Revised ammonite age-calibration of the Urgonian-type, Provence platform series leads to two main  
980 regional implications:

981 (i) The northward progradation of rudistid limestones in North Provence is, strictly, of late Barremian  
982 age and spans the *T. vandenheckii* to the lower *M. sarasini* zones;

983 (ii) The Urgonian rudistid limestones record a twofold demise. The first event corresponds to the  
984 tectonically-induced collapse of the South Provence domain during the *I. giraudi* Zone coeval with the North  
985 Provence *Palorbitolina* mass accumulation (*Palorbitolina–Heteraster* guide level). The second one terminates  
986 the Urgonian regime at the *M. sarasini–P. waagenoides* subzonal boundary.

987

988 Comparison with the peri-Vocontian Urgonian platforms pinpoints coeval demise of the rudistid biota in the  
989 uppermost Barremian:

990 (i) The first demise refers to the likely coeval, massive outbreak of a *Palorbitolina*-rich limestones of  
991 the Bas-Vivarais (V4 episode) and Subalpine platforms (Lower *Orbitolina* Beds) with the North Provence  
992 *Palorbitolina–Heteraster* guide level. This contrasts with the diachronous nature (~1 to 1.2 Myr offset)  
993 assumption developed by Huck et al. (2011, 2013, 2014) and gives evidence of large-scale environmental  
994 perturbations in both platform and basin settings during this time interval.

995 (ii) The second demise refers to the termination of the Urgonian caprinid episode at a regional exposure  
996 event. The associated hiatus occurs at the *M. sarasini–P. waagenoides* subzonal boundary (North Provence) but  
997 it can include a longer duration in reaching the middle part of the lower Aptian (as minimum constrained age) in  
998 most proximal settings (Western Bas-Vivarais, Subalpine Chains).

999

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1012

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1014

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1492

1493 **Figure list**

1494

1495 Fig. 1. The standard Mediterranean ammonite zonation of the upper Hauterivian *pro parte* to lower Aptian  
1496 (Reboulet et al., 2014) and the Vocontian depositional sequences (Arnaud, 2005b).

1497

1498 Fig. 2. Contrasting stratigraphic interpretations of the Urgonian-type lithostratigraphy – U<sup>1</sup>, U<sup>2</sup> *sensu lato* and U<sup>3</sup>  
1499 units *sensu* Leenhardt (1883) – with respect to the Barremian and Aptian stages.

1500

1501 Fig. 3. Regional extension of the Barremian–Aptian deposits in SE France and location of the surveyed outcrops  
1502 and transects (see Fig. 5, 6 and 7). A detailed description of each sections can be found in the joint contribution  
1503 of Tendil et al. (accepted).

1504

1505 Fig. 4. Temporal schematic evolution of the Provence platform during the Barremian–Aptian transition. A. lower  
1506 Barremian, B. *T. vandenheckii*–*G. sartousiana pars* zones interval, C. upper *G. sartousiana* Zone, D. *I. giraudi*  
1507 Zone, E. lower *M. sarasini* Zone, F. upper *M. sarasini*–*D. forbesi pars* zones interval, G. from the upper *D.*  
1508 *forbesi* Zone.

1509

1510 Fig. 5. Platform-to-basin correlations of the eight ammonite bioevents of the Provence domain between Cassis–  
1511 Roquefort-la-Bédoule and Brantes. The late Barremian regional drowning event, associated to the *Heteroceras*  
1512 bioevent, is used as datum (flattening surface) for this cross section. Facies types are according to the joint  
1513 contribution of Tendil et al. (accepted).

1514

1515 Fig. 6. Platform-to-basin correlations of the eight ammonite bioevents of the Provence domain between Cassis–  
1516 Roquefort-la-Bédoule and Savoillan. The late Barremian regional drowning event, associated to the *Heteroceras*  
1517 ammonite bioevent, is used as datum (flattening surface) for this cross section. Facies types are according to the  
1518 joint contribution of Tendil et al. (accepted).

1519



1520 Fig. 7. Platform-to-basin correlations of the eight ammonite bioevents of the Provence domain between Cassis–  
1521 Roquefort-la-Bédoule and Baudinard. The late Barremian regional drowning event, associated to the  
1522 *Heteroceras* bioevent, is used as datum (flattening surface) for this cross section. Facies types are according to  
1523 the joint contribution of Tendil et al. (accepted).

1524

1525 Fig. 8. Selected ammonites from the *Toxancyloceras vandenheckii* bioevent: *Moutoniceras* sp. – A–B.  
1526 FSL.85850; *T. vandenheckii* – C. MPP-M-MV.8 from Mont Ventoux; *Toxancyloceras* sp. – D–E. MPP-A.45  
1527 (Masse *in* Frau coll.) from Roque Pourquière (Fontaine-de-Vaucluse). All specimens x1 except A x0.7.

1528

1529 Fig. 9. Selected ammonites from the first (A–D) and second (E–G) *Martelites* bioevent: *Kutatissites* sp. gr.  
1530 *chreithiensis* (= *Ancyloceras* gr. *matheronianum* in Arnaud et al., 1998) – A–B. UJF-ID.10590 from the Lower  
1531 *Orbitolina* Beds of the Subalpine platform (Roche Blanche, Chartreuse). *Kutatissites* sp. gr. *chreithiensis* – C–D.  
1532 MPP-V-SC.c1 from Saint-Christol; *Pseudocrioceras* sp. – E–G. MPP-A.113 from Conque Verte (Gorges de La  
1533 Nesque). All specimens x0.7.

1534

1535 Fig. 10. Selected ammonites from the *Camereiceras limentinum* bioevent: *Camereiceras limentinum* – A. MPP-  
1536 M-MV.6 (plaster cast), B–C. MPP-M-MV.9 and H–I. MPP-A.102; *Janusites janus* – D–E. MPP-M-MV.2;  
1537 *Gerhardtia galeatoides* – F. MPP-M-MV.16 (plaster cast) and G. MPP-M-MV.14. All specimens from Mont  
1538 Ventoux except H–I from La Redde (Gorges de La Nesque). All specimens x1.

1539

1540 Fig. 11. Selected ammonites from the *Hemihoplites feraudianus* (A–C) and *Heteroceras* (D–G) bioevents:  
1541 *Hemihoplites* sp. gr. *feraudianus* – A–B. MPP-A.14335 and C. MPP-SC.1 from Saint-Chamas; *Imerites giraudi*  
1542 – D. MPP-APH.BAU.R28.1.1 from Baudinard and E–F. FSL.85837(80) from Sault; *Heteroceras emericianum* –  
1543 D. FSL.85842(86) from Sault. All specimens x1.

1544

1545 Fig. 12. Selected ammonites from the first *Martelites* bioevent: *Martelites* gr. *sarasini-marteli* – A. FSL.105070  
1546 from Cassis–Roquefort-la-Bédoule, B–C. MPP-APH-BAU.R33.2 from Baudinard; D. MPP-V-BR.1 from  
1547 Brantes. All specimens x1.

1548



1549 Fig. 13. Selected ammonites from the first *Martelites* bioevent: *Martelites* gr. *sarasini-marteli* – A–B. MPP-  
1550 BAN.3 from Banon and C. MPP-V-SC.AA.1 from Azé Aven (Saint-Christol). All specimens x1.

1551

1552 Fig. 14. Selected ammonites from the second *Martelites* bioevent: *Martelites* gr. *sarasini-marteli* – A–B. MPP-  
1553 V-BAN.BRX.1 from Banon, C–D. MPP-FSL.64209 from Mont Ventoux; E. MPP-V-MS.1 (plaster cast) from  
1554 Montsalier and F. MPP-V-SV.1 (plaster cast) from Savoillan; *Martelites* sp. – E–F. MPP-A.88 from Simiane-la-  
1555 Rotonde. All specimens x1.

1556

1557 Fig. 15. Selected ammonites from the first *Deshayesites* bioevent: *Deshayesites* sp. aff. *euglyphus* – A. MPP-B-  
1558 VC.20 (bed 107), B. MPP-B-EM.250 and ?C. MPP-B-VC.24 (bed 107) from Cassis–Roquefort-la-Bédoule;  
1559 *Deshayesites* gr. *luppovi* – D. MPP-B-VC.15 (bed 107), E. MPP-B-VC.25 (bed 107) from Cassis–Roquefort-la-  
1560 Bédoule and ?F. *in situ* from Savoillan; *Deshayesites* sp. – G–H. MPP-V-FDV.1 from Fontaine-de-Vaucluse;  
1561 *Pseudohaploceras matheroni* – I–J. MPP-V-PF.2 and *Macroscaphites yvani* – K–L. MPP-V-PF.3 from Petit  
1562 Fribouquet. All specimens x1 except G–H x2.

1563

1564 Fig. 16. Selected ammonites from the first *Martelites* (A–B) and first *Deshayesites* (C) bioevents:  
1565 *Procheloniceras* sp. gr. *sporadicum* – A–B. MPP.A.17 from Sault; *Procheloniceras* sp. gr. *dechauxi* – C. MPP-  
1566 V-PF.1 from Petit Fribouquet. All specimens x0.75.

1567

1568 Fig. 17. Ammonite age-calibration of the North Provence Urgonian- and Aptian-type series developed in the  
1569 present contribution and the previous interpretation (Masse, 1993, 1995; Masse & Fenerci-Masse, 2011, 2013a-  
1570 c; Léonide et al., 2012, 2014).

1571

1572 Fig. 18. Revised litho-, bio- and chemostratigraphic correlations between type basinal sections of the South  
1573 Provence (Cassis–Roquefort-la-Bédoule) and Vocontian basins (Angles–Combe Lambert–Glaise) and the  
1574 southern Monts de Vaucluse platform series. Note that the demise of the Urgonian rudistid regime and its  
1575 *Palorbitolina*-rich cover occurs long before the spreading (C2 *pro parte* – C3 isotopic carbon segments) and  
1576 culmination (C3 *pro parte* – C6 isotopic carbon segments) of the OAE 1a. Scale bar is 5 m.

1577

1578 Fig. 19. Revised ammonite age-calibration of the Urgonian Bas-Vivarais platform and comparison with previous  
1579 datings (Clavel et al., 2007, 2013, 2014; Pictet et al., 2015).

1580

1581 Fig. 20. Revised ammonite age-calibration of the Urgonian Subalpine platform and comparison with previous  
1582 datings (Clavel et al., 2007, 2013, 2014; Pictet et al., 2015).

<b>LOWER APTIAN</b>	<b>D. FURCATA</b>	<i>D. dufrenoyi</i>	—		
		<i>D. furcata</i>			
	<b>D. DESHAYESI</b>	<i>D. grandis</i>		—	
<b>D. FORBESI</b>	<i>R. hambrovi</i>	<u>SbA2</u>			
<b>D. OGLANLENSIS</b>	<i>D. luppovi</i>	<u>SbA1</u>			
<b>UPPER BARREMIAN</b>	<b>M. SARASINI</b>	<i>P. waagenoides</i>	—		
		<i>M. sarasini</i>		<u>SbB5</u>	
	<b>I. GIRAUDI</b>	<i>H. emerici</i>		—	
		<i>I. giraudi</i>			
	<b>G. SARTOUSIANA</b>	<i>H. feraudianus</i>			<u>SbB4</u>
		<i>G. provincialis</i>			
<i>G. sartousiana</i>					
<b>T. VANDENHECKII</b>	<i>B. barremense</i>	<u>SbB3</u>			
	<i>T. vandenheckii</i>				
<b>LOWER BARREMIAN</b>	<b>M. MOUTONIANUM</b>		<u>SbB2</u>		
	<b>K. COMPRESSISSIMA</b>				
	<b>N. PULCHELLA</b>		<u>SbB1'</u>		
	<b>K. NICKLESI</b>				
	<b>T. HUGII AUCTORUM</b>	<i>P. colombiana</i>	<u>SbB1</u>		
<i>T. hugii auctorum</i>					
<b>U. HAUT.</b>	<b>"P. OHMI"</b>	<i>P. picteti</i>	—		
		<i>P. catulloi</i>			
		<i>"P. ohmi"</i>			

Arnaud (2005b) →

<b>LOWER APTIAN</b>	<b>D. FURCATA</b>	<i>D. dufrenoyi</i>	—		
		<i>D. furcata</i>			
	<b>D. DESHAYESI</b>	<i>D. grandis</i>		—	
<b>D. FORBESI</b>	<i>R. hambrovi</i>	<u>SbA2</u>			
<b>D. OGLANLENSIS</b>	<i>D. luppovi</i>	<u>SbA1</u>			
<b>UPPER BARREMIAN</b>	<b>M. SARASINI</b>	<i>P. waagenoides</i>	—		
		<i>M. sarasini</i>		<u>SbB5</u>	
	<b>I. GIRAUDI</b>	<i>H. emerici</i>		—	
		<i>I. giraudi</i>			
	<b>G. SARTOUSIANA</b>	<i>H. feraudianus</i>			<u>SbB4</u>
		<i>G. provincialis</i>			
<i>G. sartousiana</i>					
<b>T. VANDENHECKII</b>	<i>B. barremense</i>	<u>SbB3</u>			
	<i>T. vandenheckii</i>				
<b>LOWER BARREMIAN</b>	<b>M. MOUTONIANUM</b>		<u>SbB2</u>		
	<b>K. COMPRESSISSIMA</b>				
	<b>N. PULCHELLA</b>		<u>SbB1'</u>		
	<b>K. NICKLESI</b>				
	<b>T. HUGII AUCTORUM</b>	<i>P. colombiana</i>	<u>SbB1</u>		
<i>T. hugii auctorum</i>					
<b>U. HAUT.</b>	<b>"P. OHMI"</b>	<i>P. picteti</i>	—		
		<i>P. catulloi</i>			
		<i>"P. ohmi"</i>			

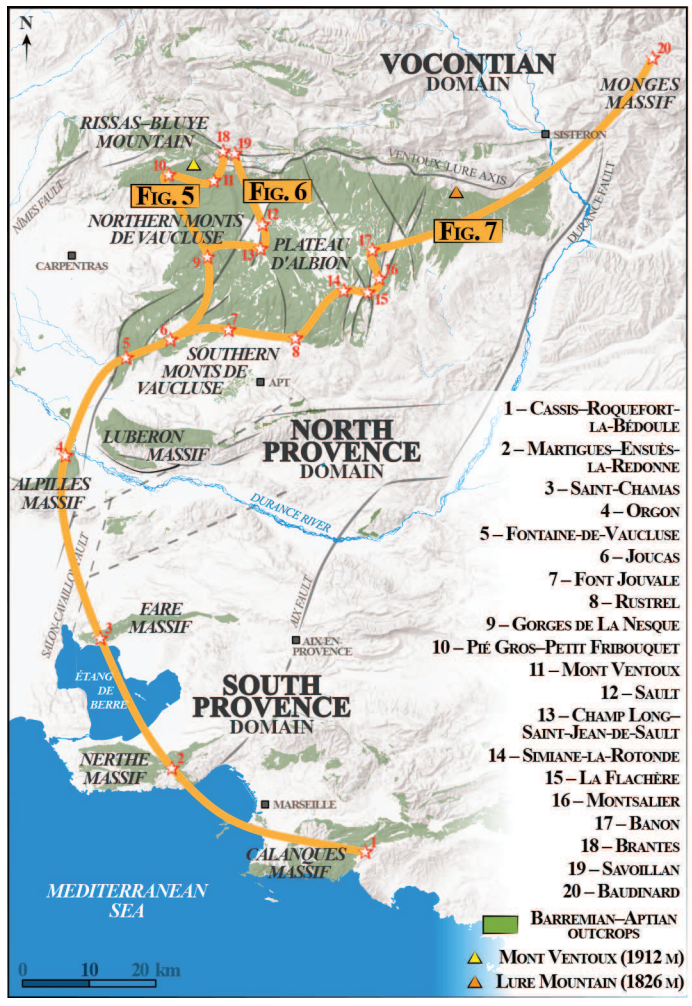
Arnaud (2005b) →

URGONIAN-TYPE LITHOSTRATIGRAPHY

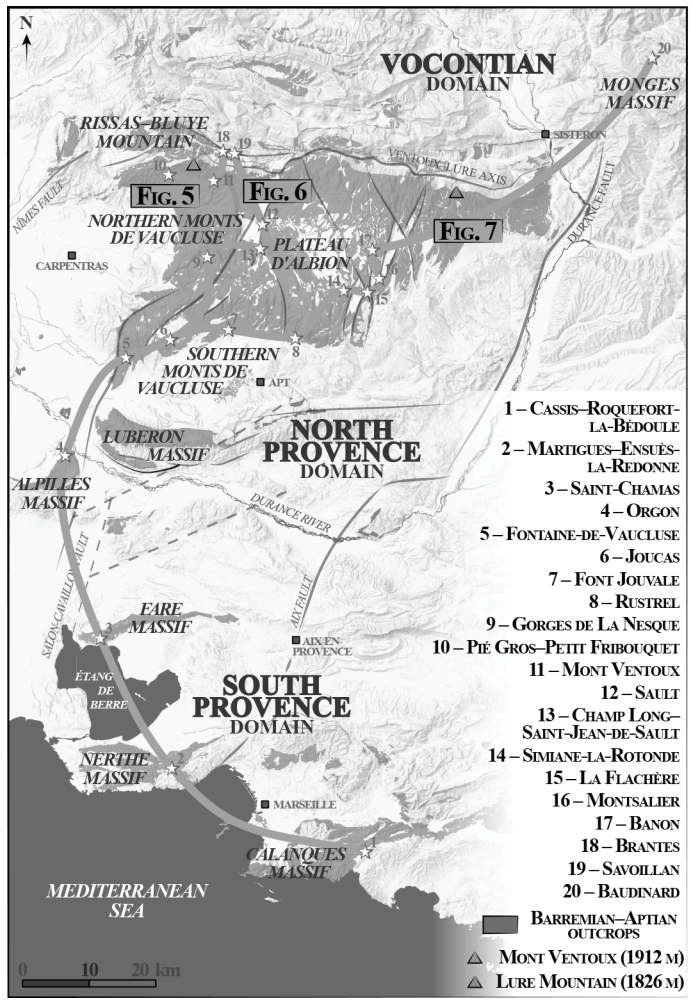
LEENHARDT (1883)	U <sup>1</sup>	U <sup>2</sup> <sub>S.L.</sub>	U <sup>3</sup>
	LOWER APTIAN (= BEDOULIAN)		
KILIAN (1896)	U. BARREMIAN	LOWER APTIAN	
PELLAT (1903)	U. BARR.	LOWER APTIAN	
PAQUIER (1905)	U. BARREMIAN	LOWER APTIAN	
PELLAT & COSSMANN (1907)	M. BARR.	U. BARR.	L. APTIAN
DOUVILLÉ (1918)	M. BARR.	U. BARR.	L. APTIAN
GOGUEL (1932)	U. BARR.	LOWER APTIAN	
RIVIER (1960)	LOWER APTIAN		
FAURE (1965) MAILLARD (1965) FAHY (1965)	UPPER BARREMIAN	L. APTIAN	
MASSE (1976)	U. BARR.	LOWER APTIAN	
MASSE ET AL. (1999)	U. BARREMIAN	LOWER APTIAN	
MASSE & FENERCI-MASSE (2011, 2013a-c)	U. BARREMIAN	LOWER APTIAN	
LÉONIDE ET AL. (2012, 2014)	U. BARREMIAN	LOWER APTIAN	
THIS WORK →	UPPER BARREMIAN	L. APTIAN	

**URGONIAN-TYPE LITHOSTRATIGRAPHY**

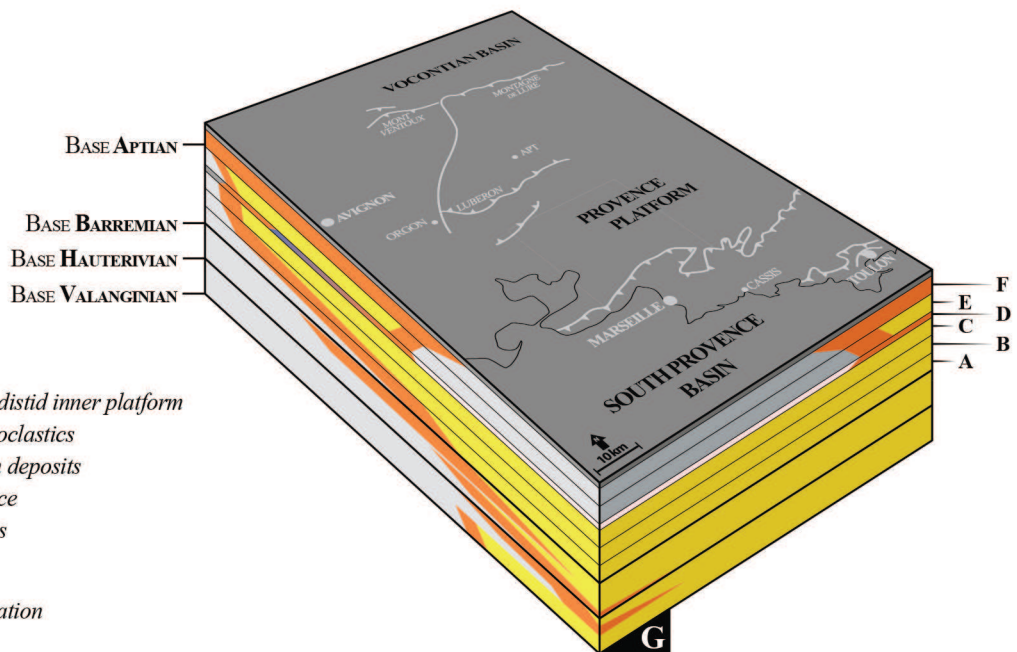
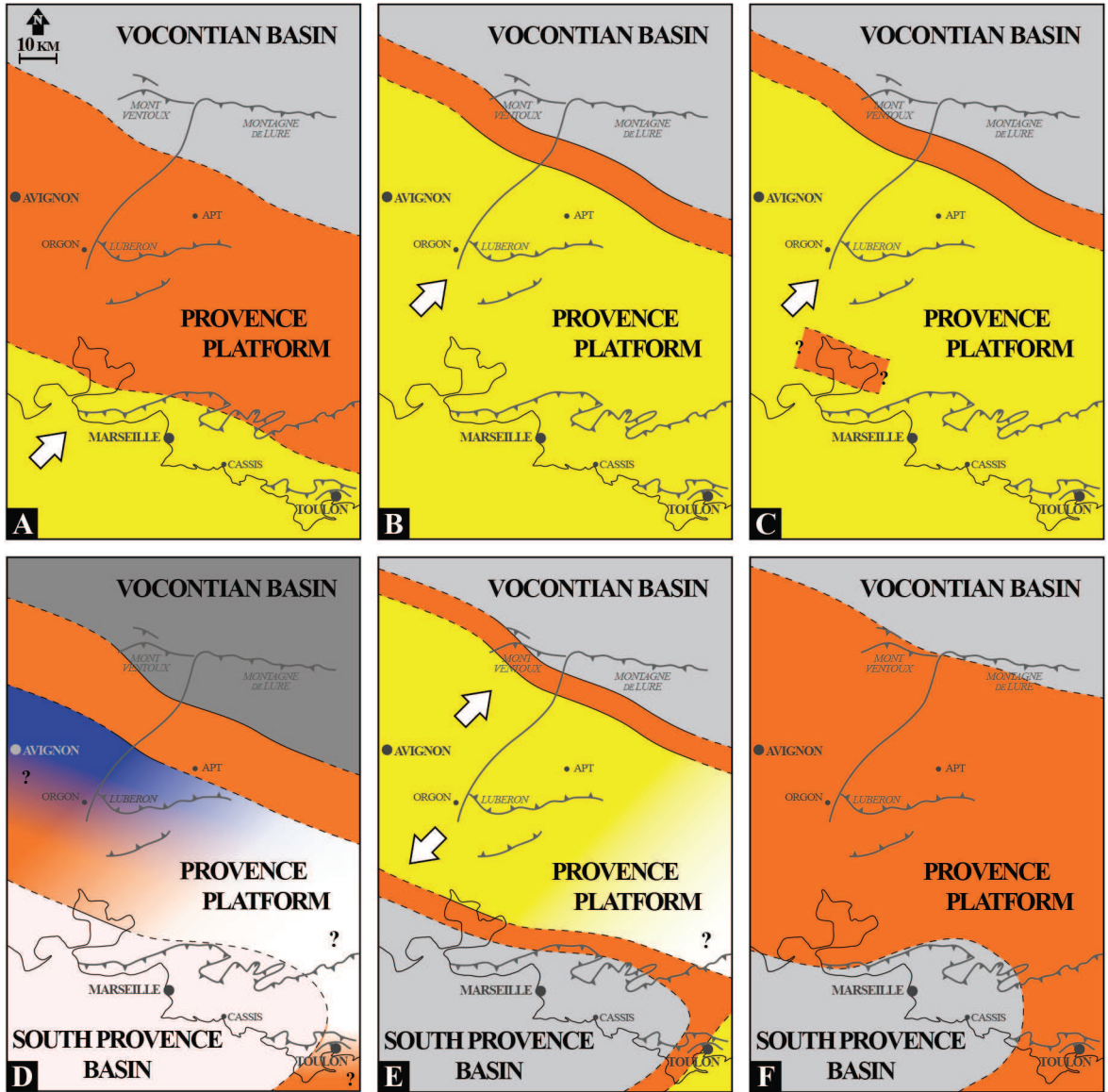
<b>LEENHARDT (1883)</b>	<table border="1"> <tr> <td align="center"><b>U<sup>1</sup></b></td> <td align="center"><b>U<sup>2</sup><sub>S.L.</sub></b></td> <td align="center"><b>U<sup>3</sup></b></td> </tr> <tr> <td align="center" colspan="3">LOWER APTIAN (= BEDOULIAN)</td> </tr> </table>	<b>U<sup>1</sup></b>	<b>U<sup>2</sup><sub>S.L.</sub></b>	<b>U<sup>3</sup></b>	LOWER APTIAN (= BEDOULIAN)		
<b>U<sup>1</sup></b>	<b>U<sup>2</sup><sub>S.L.</sub></b>	<b>U<sup>3</sup></b>					
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<b>KILIAN (1896)</b>	<table border="1"> <tr> <td align="center">U. BARREMIAN</td> <td align="center">LOWER APTIAN</td> </tr> </table>	U. BARREMIAN	LOWER APTIAN				
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<b>PAQUIER (1905)</b>	<table border="1"> <tr> <td align="center">U. BARREMIAN</td> <td align="center">LOWER APTIAN</td> </tr> </table>	U. BARREMIAN	LOWER APTIAN				
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<b>PELLAT &amp; COSSMANN (1907)</b>	<table border="1"> <tr> <td align="center">M. BARR.</td> <td align="center">U. BARR.</td> <td align="center">L. APTIAN</td> </tr> </table>	M. BARR.	U. BARR.	L. APTIAN			
M. BARR.	U. BARR.	L. APTIAN					
<b>DOUVILLÉ (1918)</b>	<table border="1"> <tr> <td align="center">M. BARR.</td> <td align="center">U. BARR.</td> <td align="center">L. APTIAN</td> </tr> </table>	M. BARR.	U. BARR.	L. APTIAN			
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<b>MASSE (1976)</b>	<table border="1"> <tr> <td align="center">U. BARR.</td> <td align="center">LOWER APTIAN</td> </tr> </table>	U. BARR.	LOWER APTIAN				
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<b>MASSE &amp; FENERCI-MASSE (2011, 2013a-c)</b>	<table border="1"> <tr> <td align="center">U. BARREMIAN</td> <td align="center">LOWER APTIAN</td> </tr> </table>	U. BARREMIAN	LOWER APTIAN				
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<b>LÉONIDE ET AL. (2012, 2014)</b>	<table border="1"> <tr> <td align="center">U. BARREMIAN</td> <td align="center">LOWER APTIAN</td> </tr> </table>	U. BARREMIAN	LOWER APTIAN				
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<b>THIS WORK</b> →	<table border="1"> <tr> <td align="center">UPPER BARREMIAN</td> <td align="center">L. APTIAN</td> </tr> </table>	UPPER BARREMIAN	L. APTIAN				
UPPER BARREMIAN	L. APTIAN						



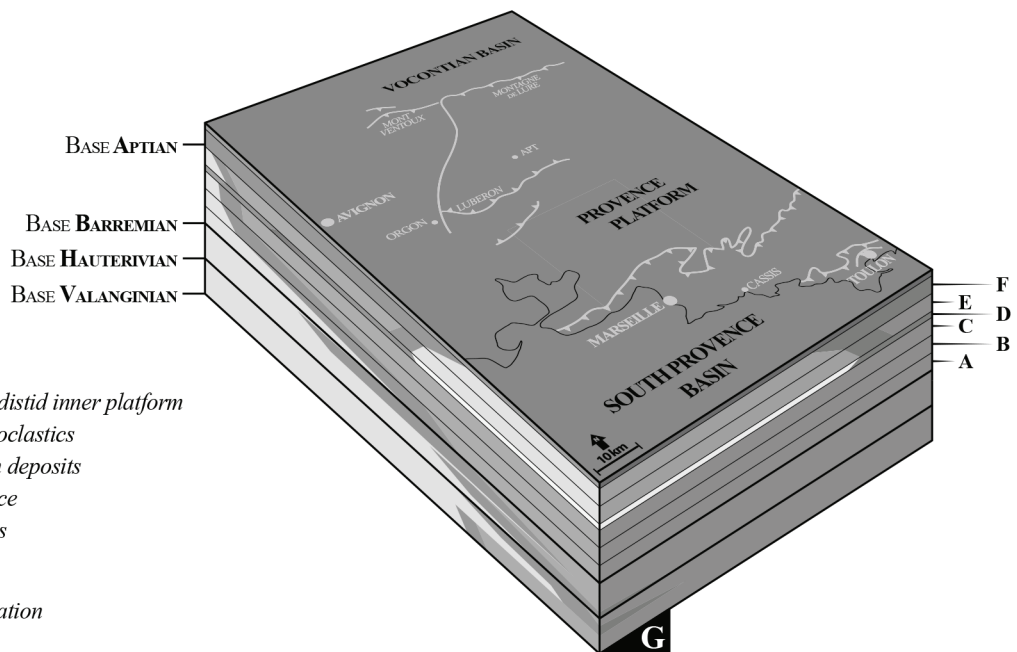
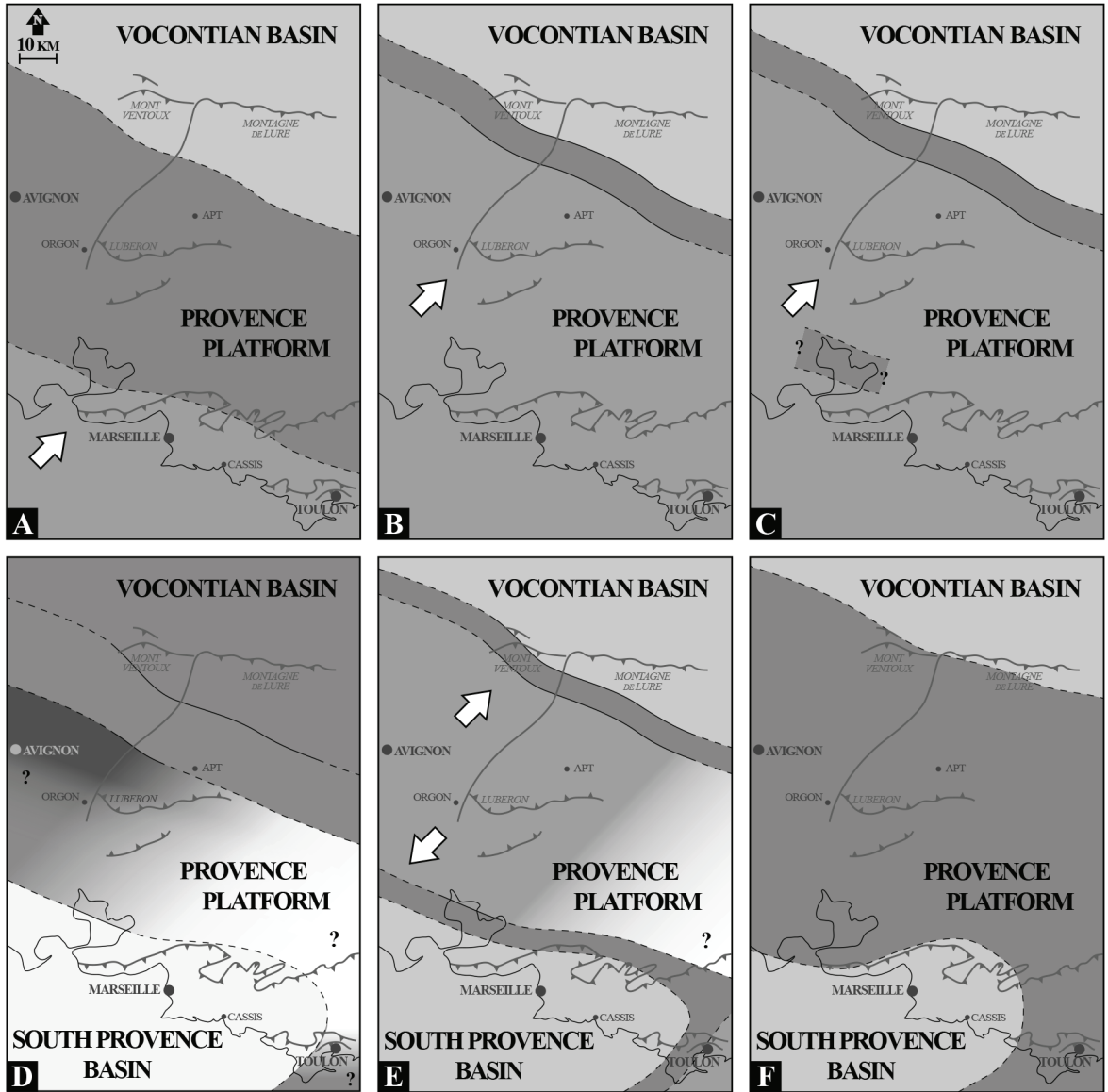




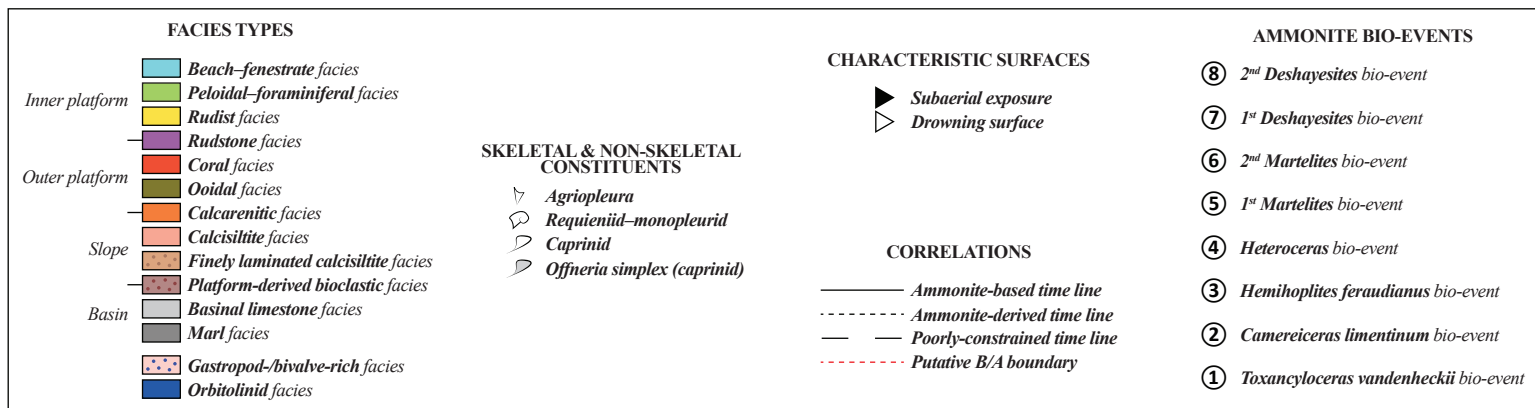
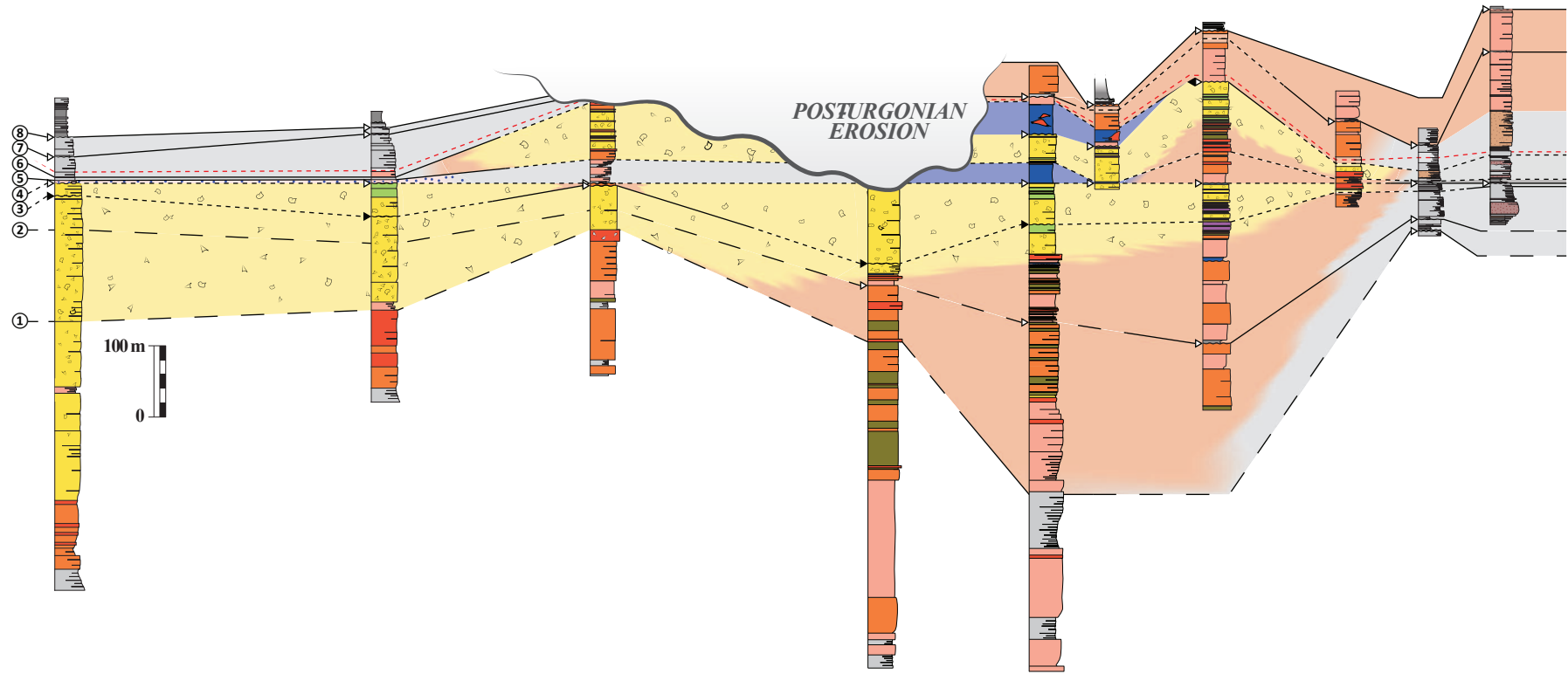
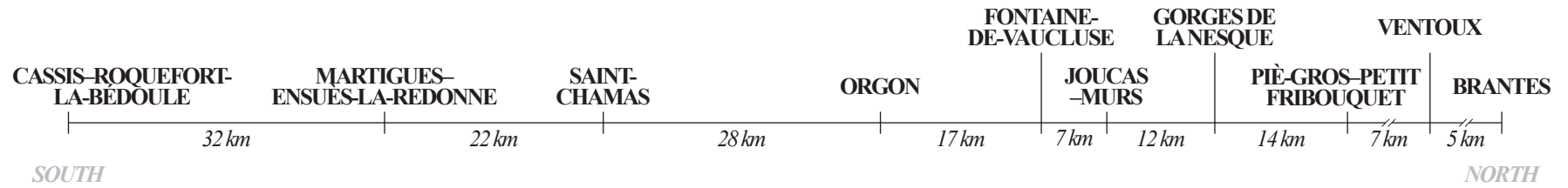




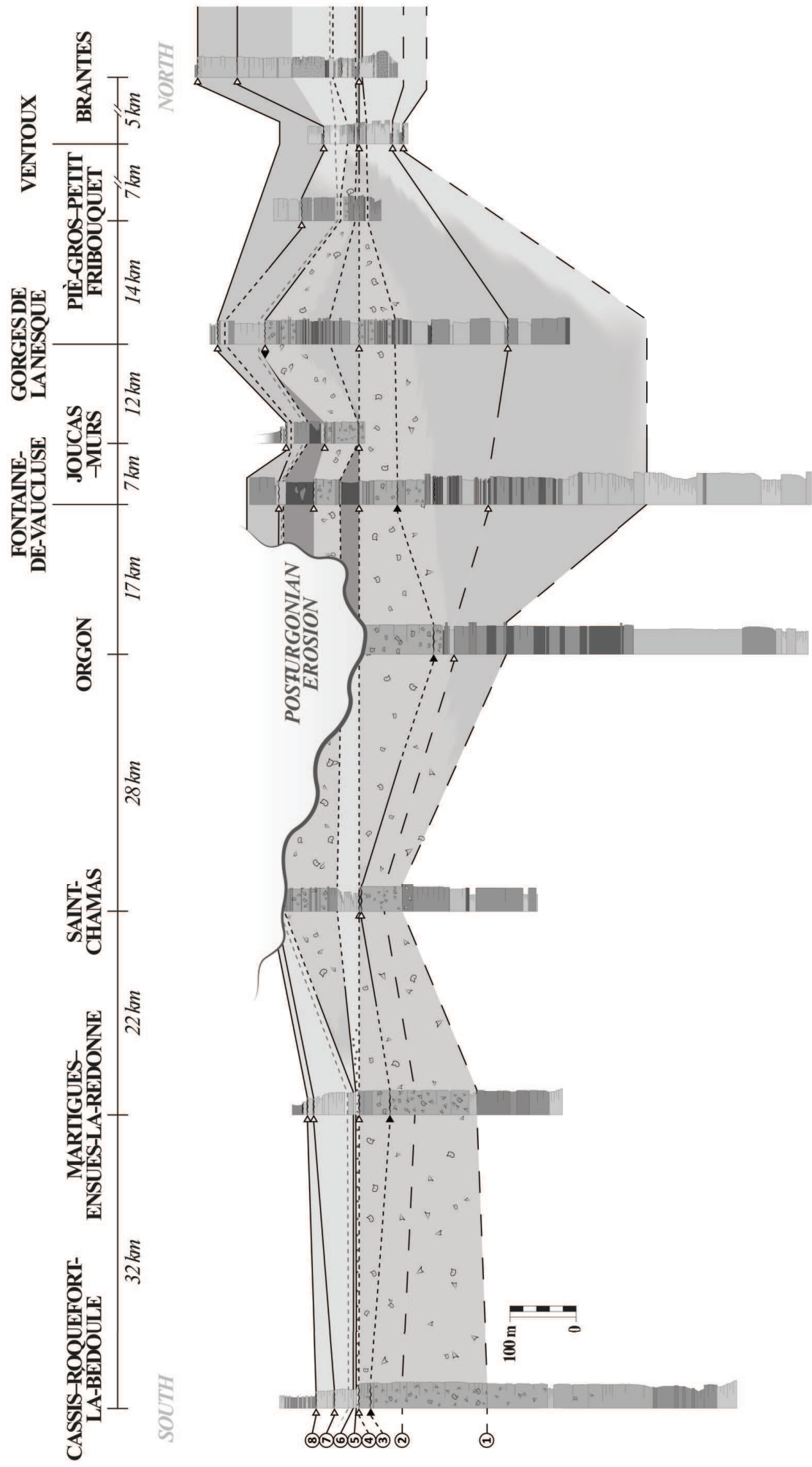
- Shallow-water, rudistid inner platform
- Outer platform bioclastics
- Palorbitolina-rich deposits
- Drowning sequence
- Basinal limestones
- Basinal marls
- Platform progradation



- Shallow-water, rudistid inner platform
- Outer platform bioclastics
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- Drowning sequence
- Basinal limestones
- Basinal marls
- Platform progradation







**FACIES TYPES**

- Beach-fenestrate facies
- Peloidal-foraminiferal facies
- Rudist facies
- Rudstone facies
- Corral facies
- Ooid facies
- Calcaremitic facies
- Calcsiltite facies
- Finely laminated calcsiltite facies
- Platform-derived bioclastic facies
- Basinal limestone facies
- Marl facies
- Gastropod-bivalve-rich facies
- Orbitolinitid facies

**SKELETAL & NON-SKELETAL CONSTITUENTS**

- Agriopleura
- Requienii-monopleurid
- Caprinid
- Offneria simplex (caprinid)

**CHARACTERISTIC SURFACES**

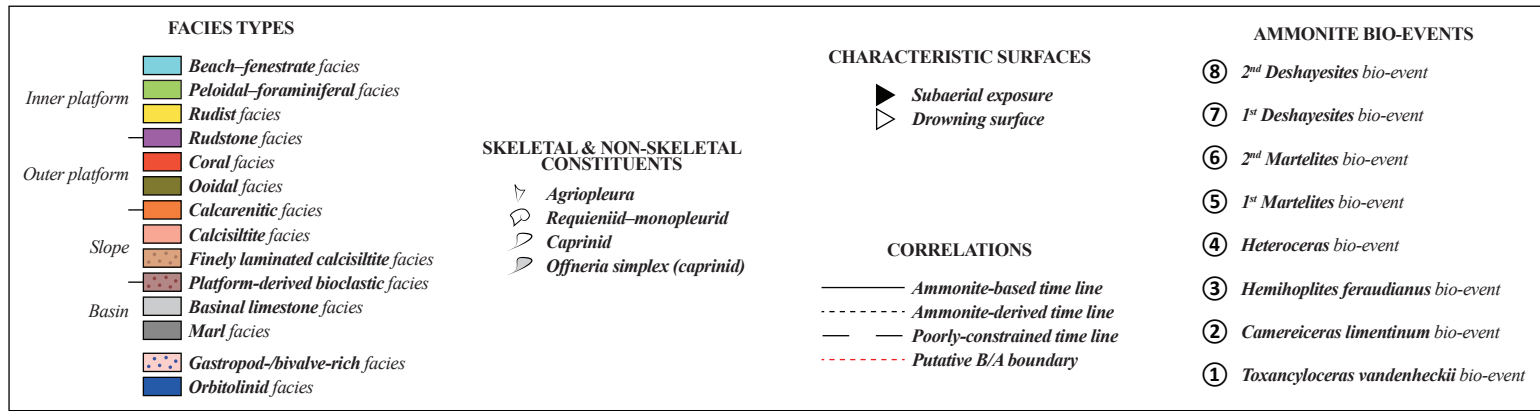
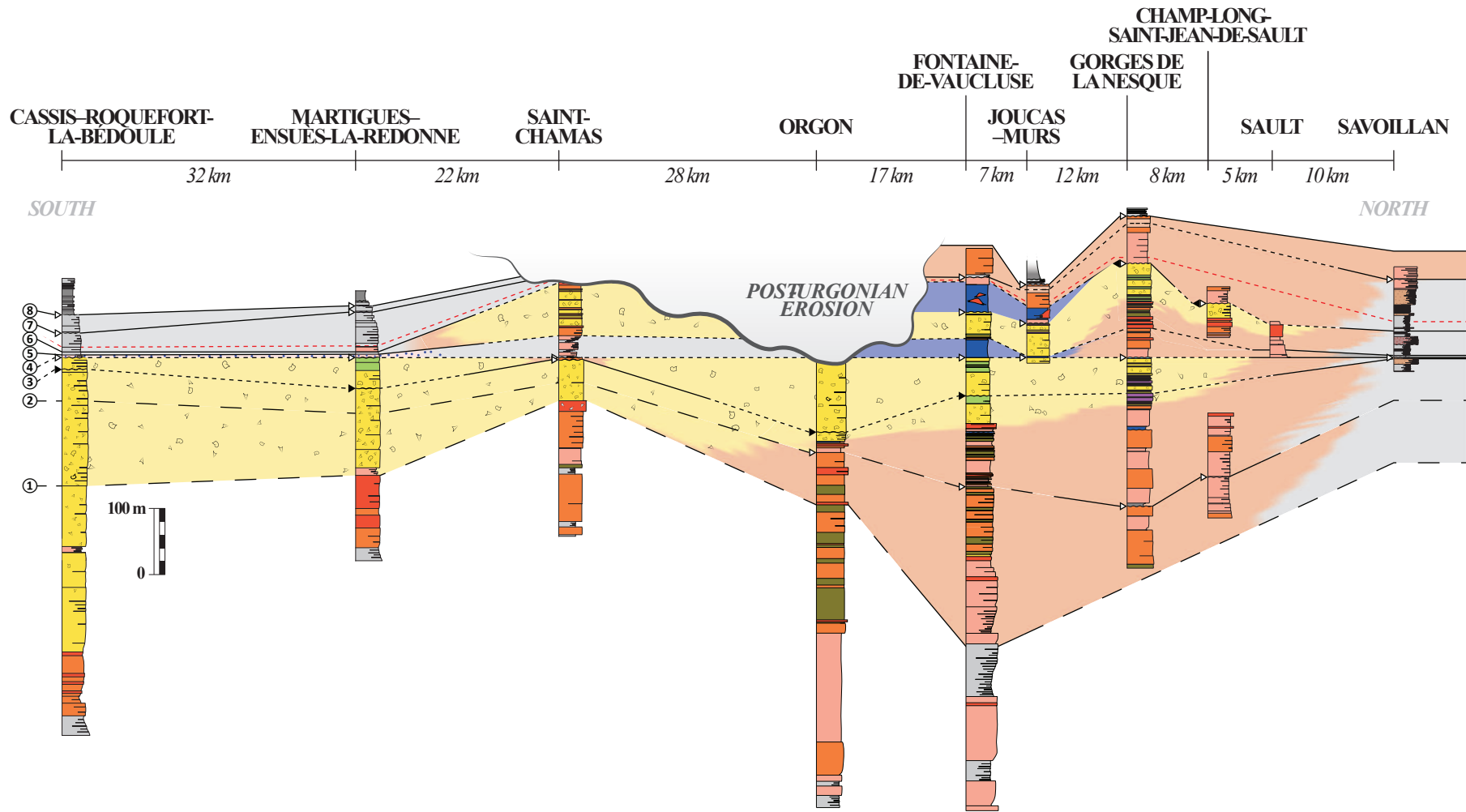
- ▲ Subaerial exposure
- △ Drowning surface

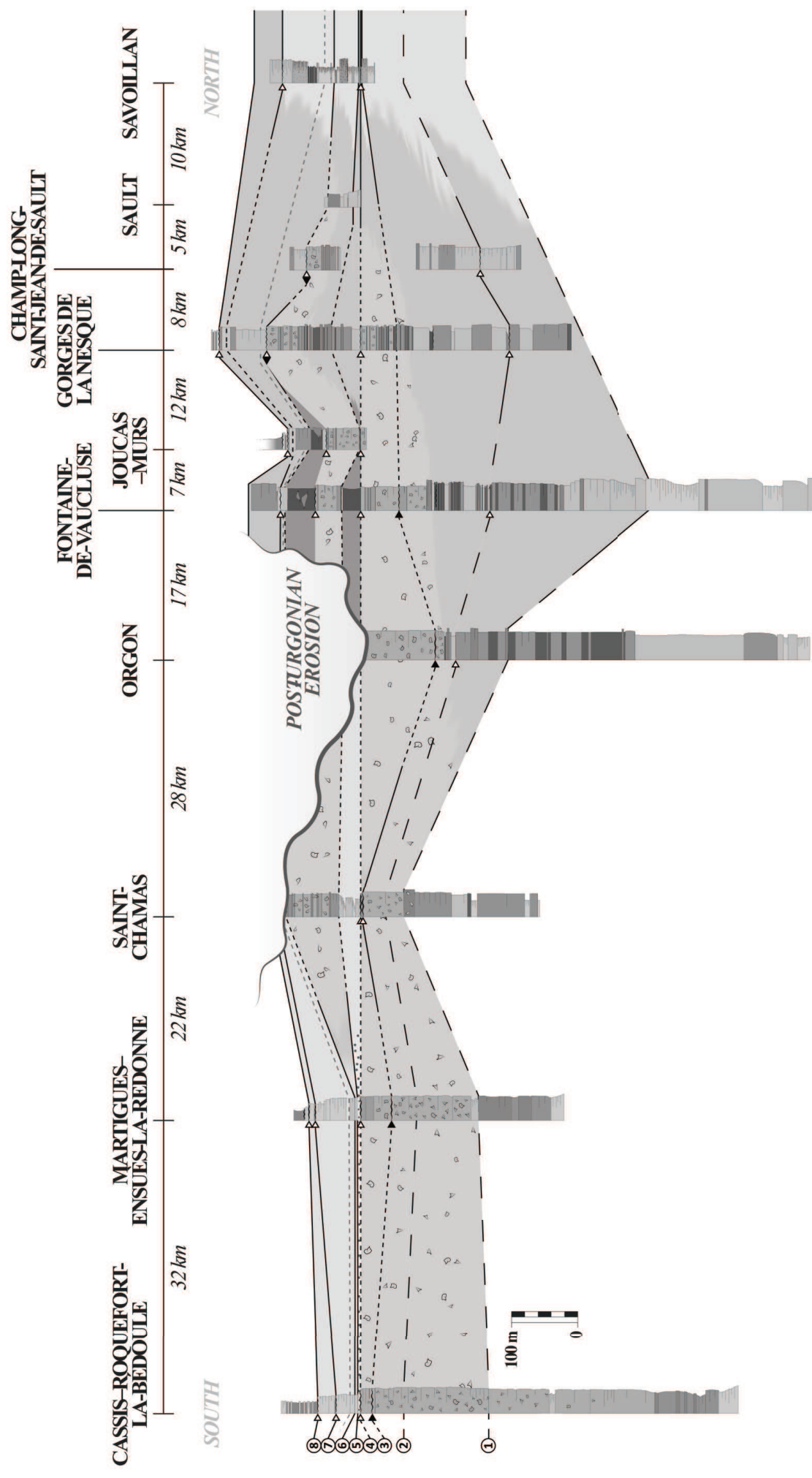
**CORRELATIONS**

- Ammonite-based time line
- - - Ammonite-derived time line
- · - Poorly-constrained time line
- · · Putative B/A boundary

**AMMONITE BIO-EVENTS**

- ⑧ 2<sup>nd</sup> Deshayesites bio-event
- ⑦ 1<sup>st</sup> Deshayesites bio-event
- ⑥ 2<sup>nd</sup> Martelites bio-event
- ⑤ 1<sup>st</sup> Martelites bio-event
- ④ Heteroceras bio-event
- ③ Hemihoplites feraudianus bio-event
- ② Cameroceras limentinum bio-event
- ① Toxancyloceras vandanteckii bio-event





**FACIES TYPES**

- Inner platform
  - Bench-fenestrate facies
  - Peloidal-foraminiferal facies
  - Rudist facies
  - Rudstone facies
  - Coral facies
  - Ooidal facies
  - Calcarenitic facies
  - Calcisiltite facies
- Slope
  - Finely laminated calcisiltite facies
  - Platform-derived bioclastic facies
- Basin
  - Basinal limestone facies
  - Marl facies
  - Gastropod-bivalve-rich facies
  - Orbitolinitid facies

**SKELETAL & NON-SKELETAL CONSTITUENTS**

- Agriopleura
- Requieniid-monopleurid
- Caprinid
- Offneria simplex (caprinid)

**CHARACTERISTIC SURFACES**

- Subaerial exposure
- Drowning surface

**CORRELATIONS**

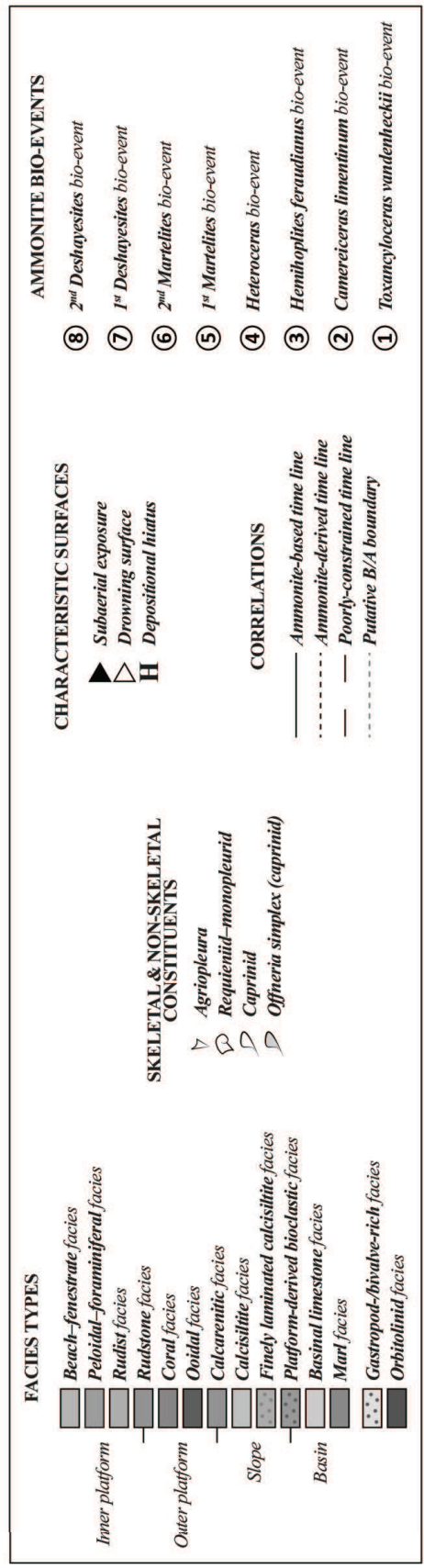
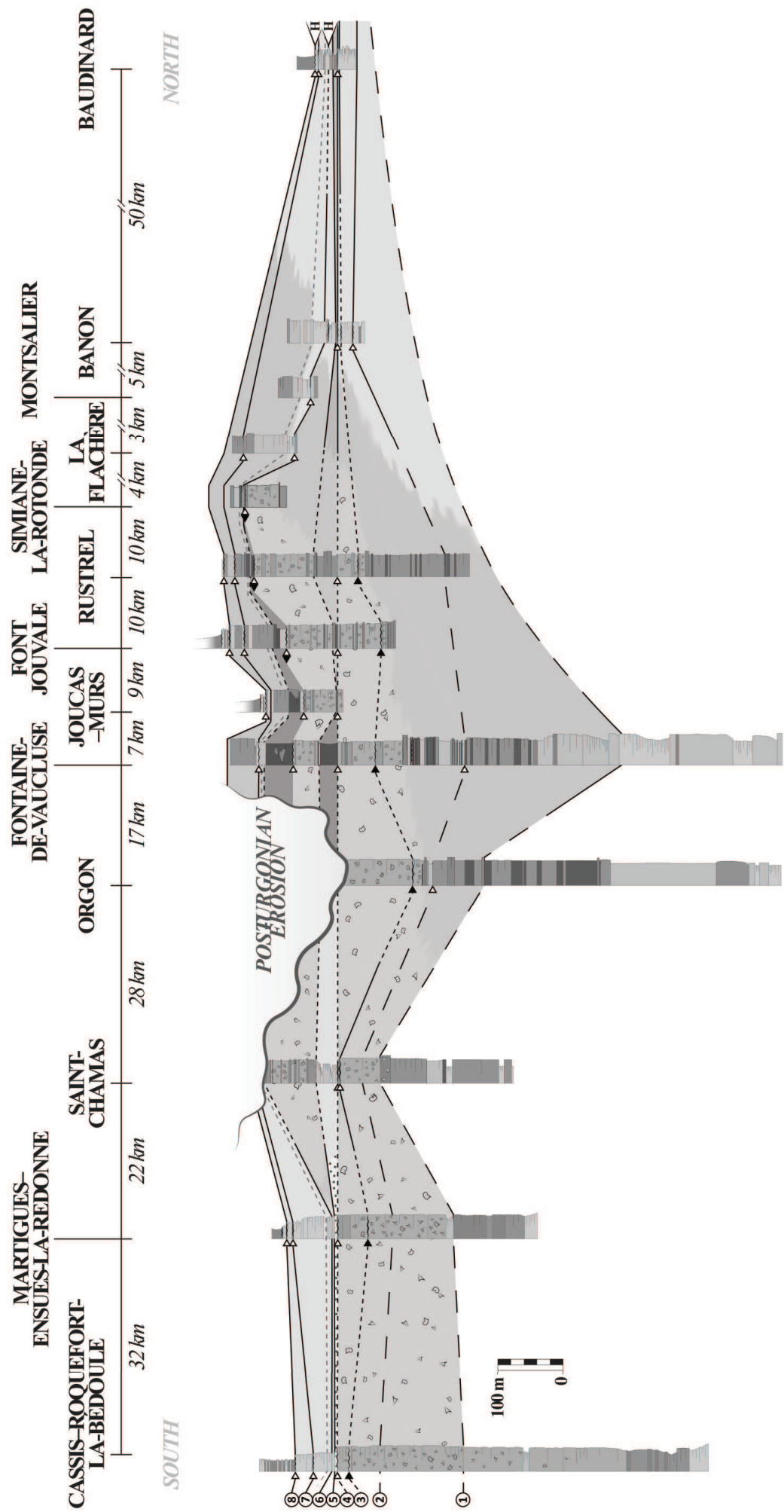
- Ammonite-based time line
- Ammonite-derived time line
- Poorly-constrained time line
- Putative B/A boundary

**AMMONITE BIO-EVENTS**

- 8 2<sup>nd</sup> Deshayesites bio-event
- 7 1<sup>st</sup> Deshayesites bio-event
- 6 2<sup>nd</sup> Martelites bio-event
- 5 1<sup>st</sup> Martelites bio-event
- 4 Heteroceras bio-event
- 3 Hemihoplites ferudianus bio-event
- 2 Cameroceras limnetinum bio-event
- 1 Toxancyloceras vandendheckii bio-event



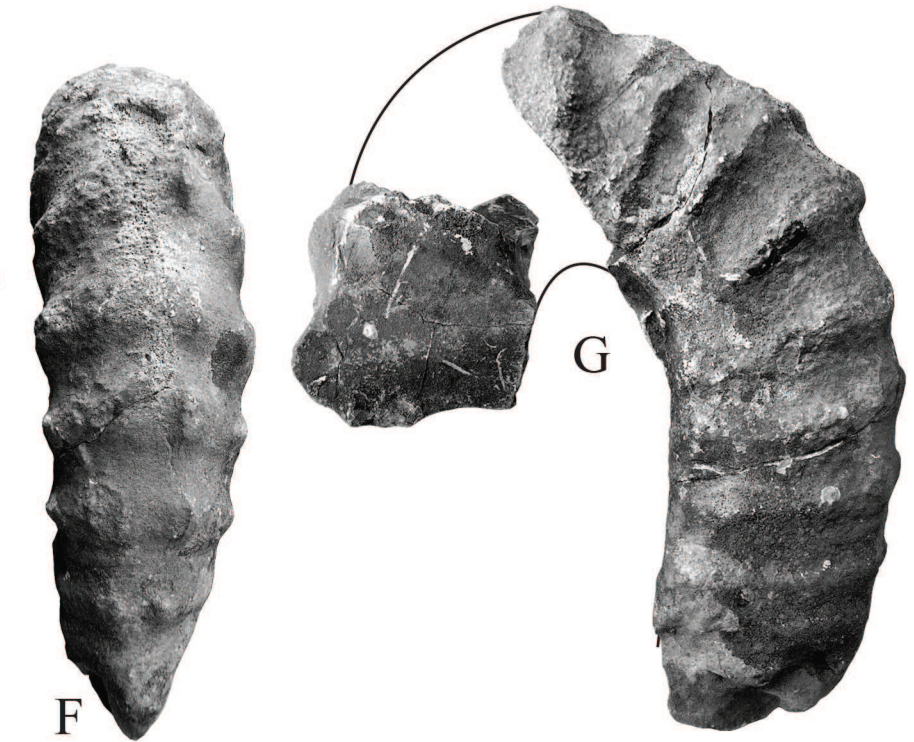
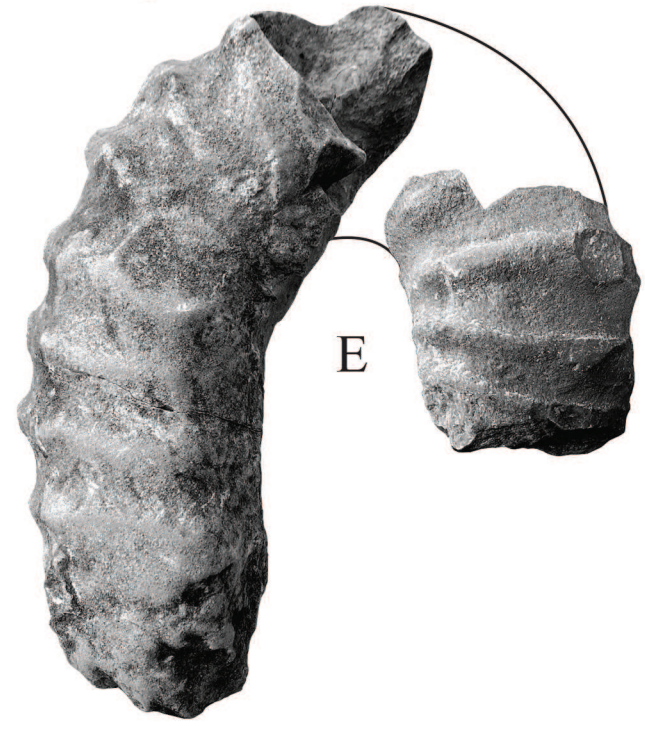
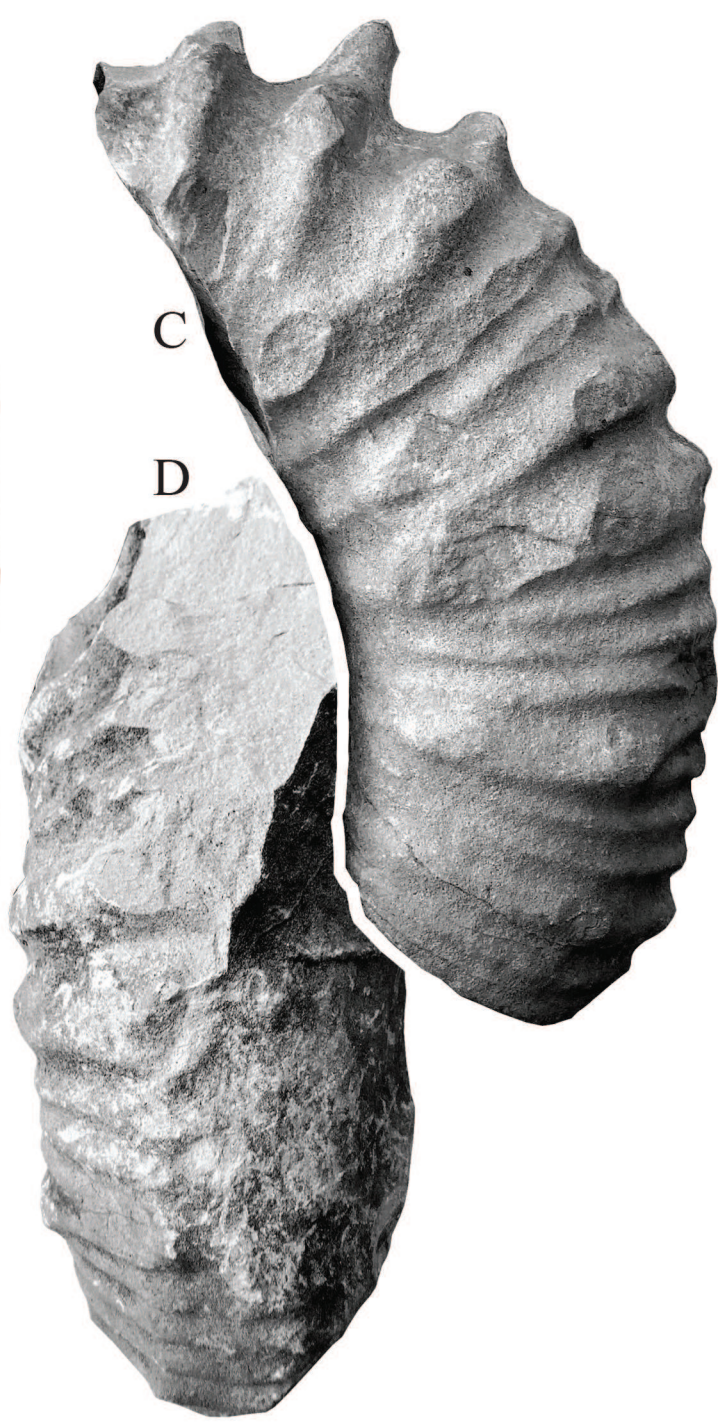
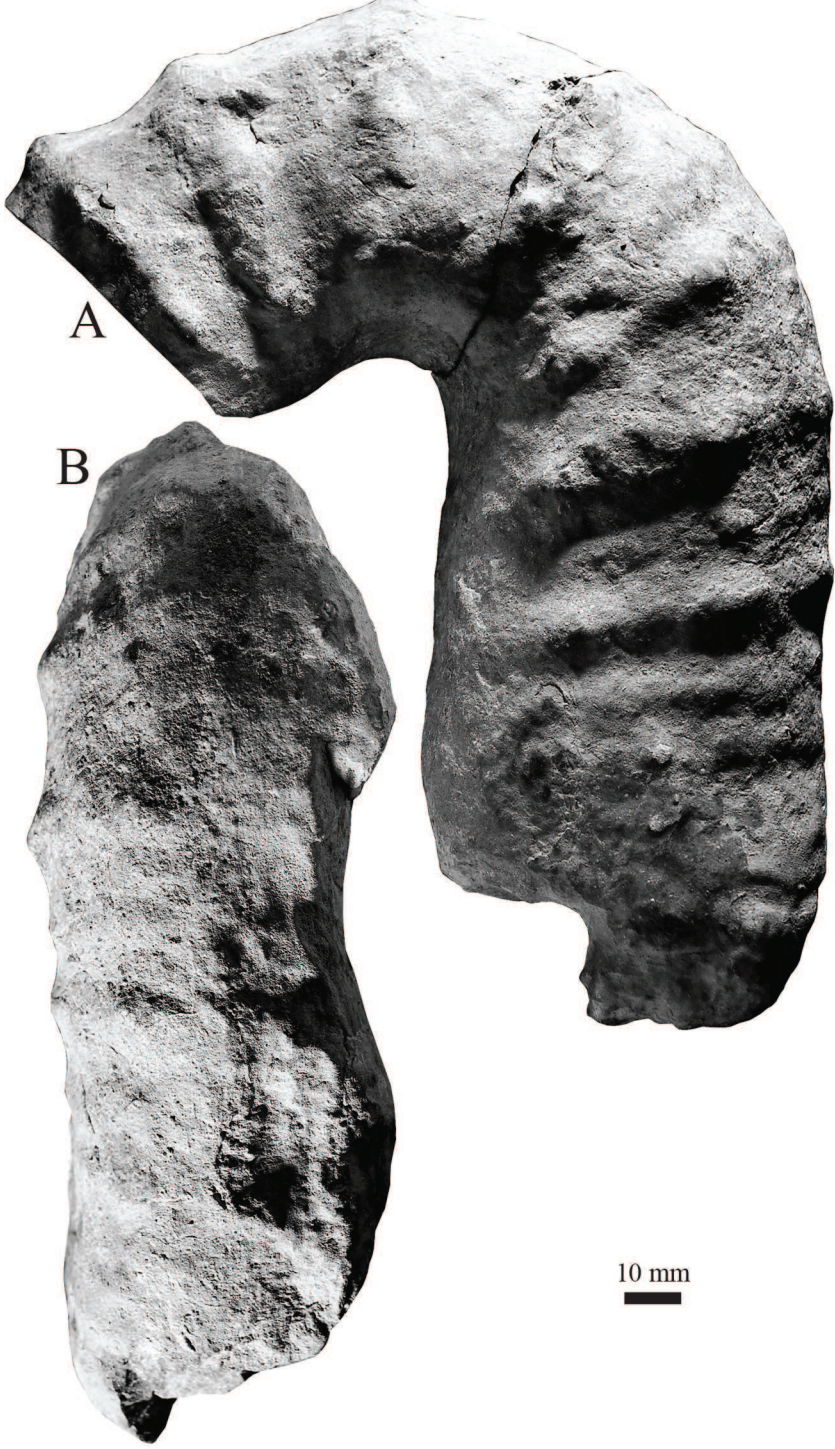




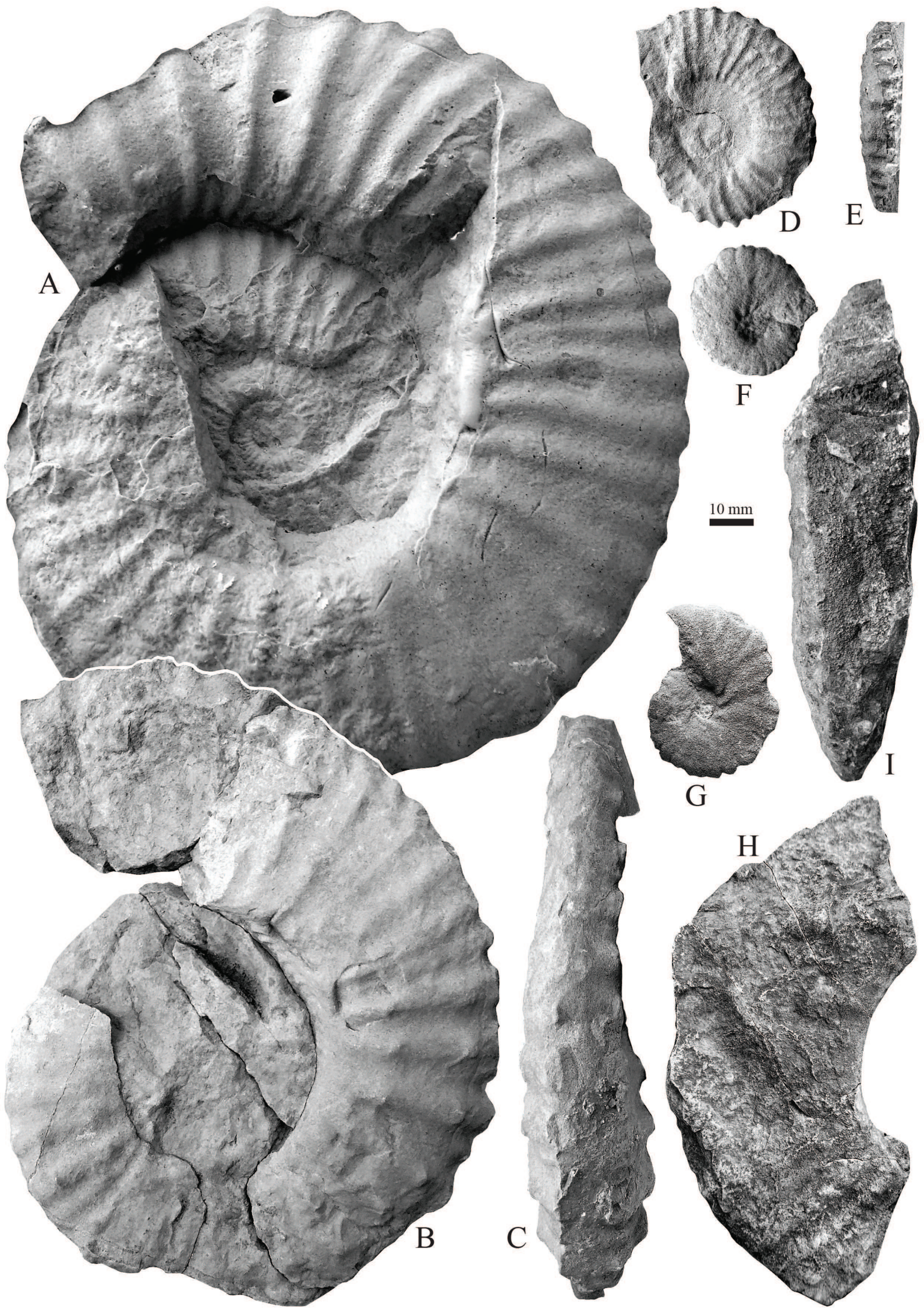




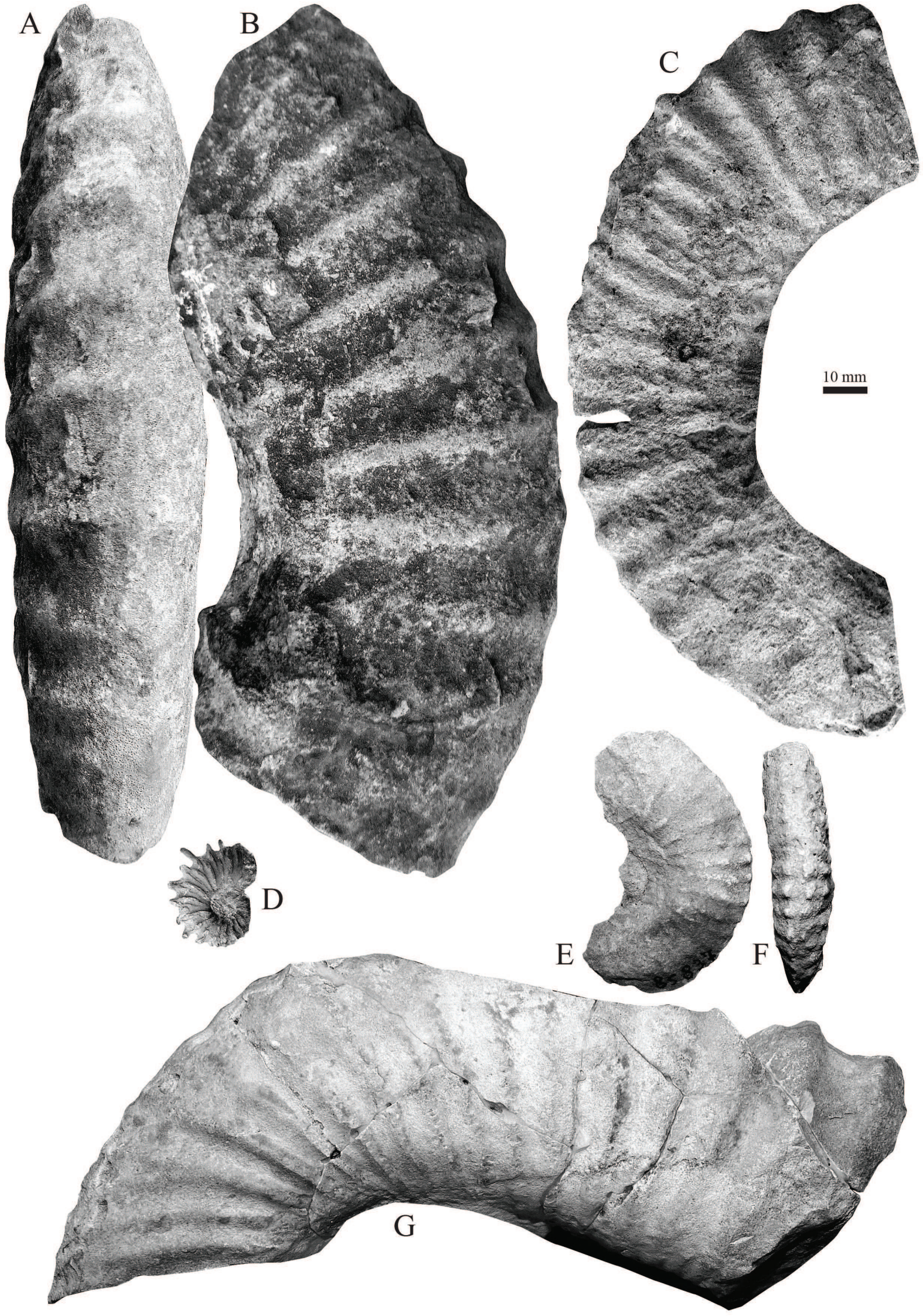




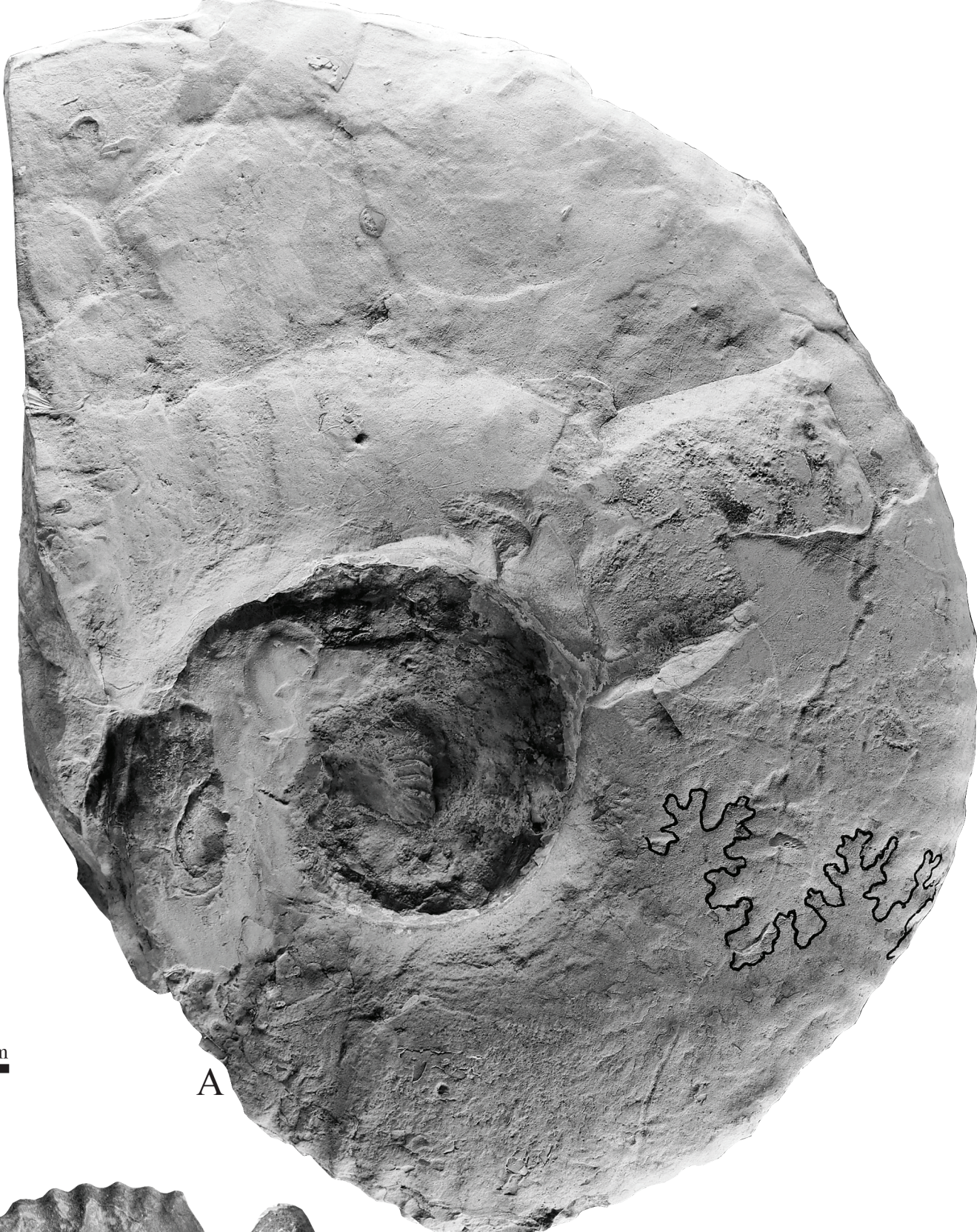












10 mm

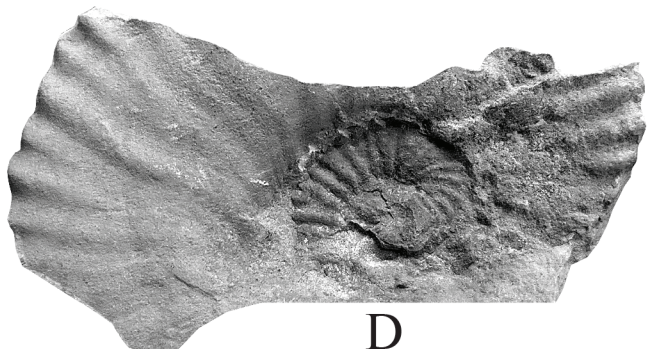
A



B

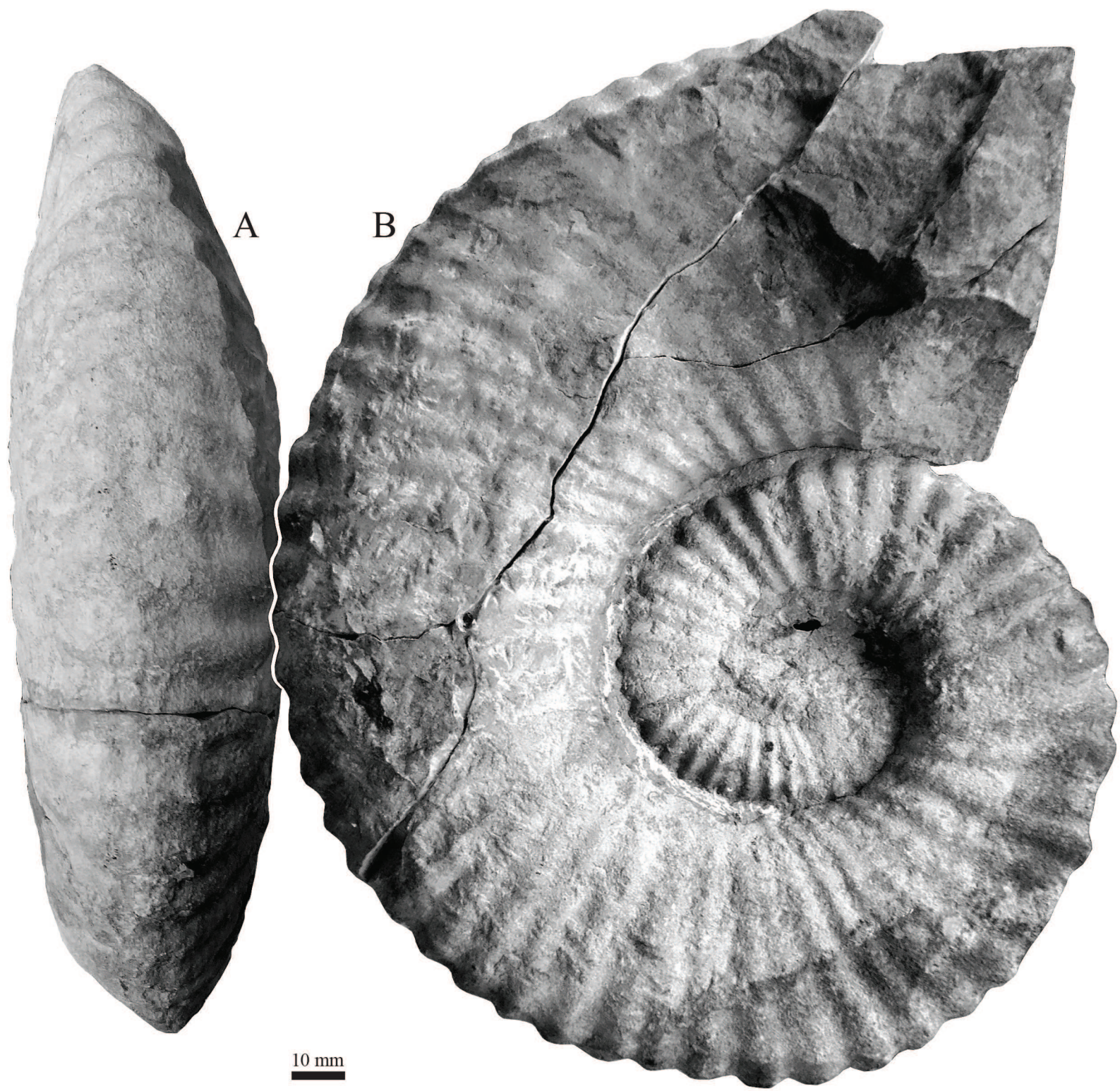


C

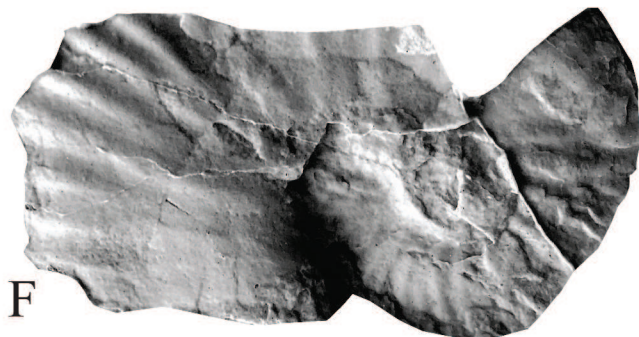


D

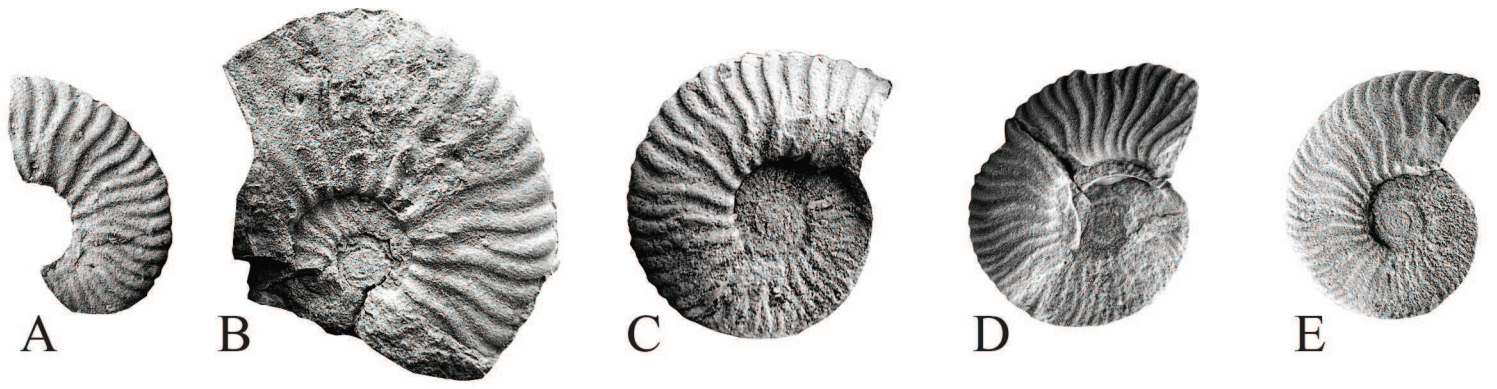












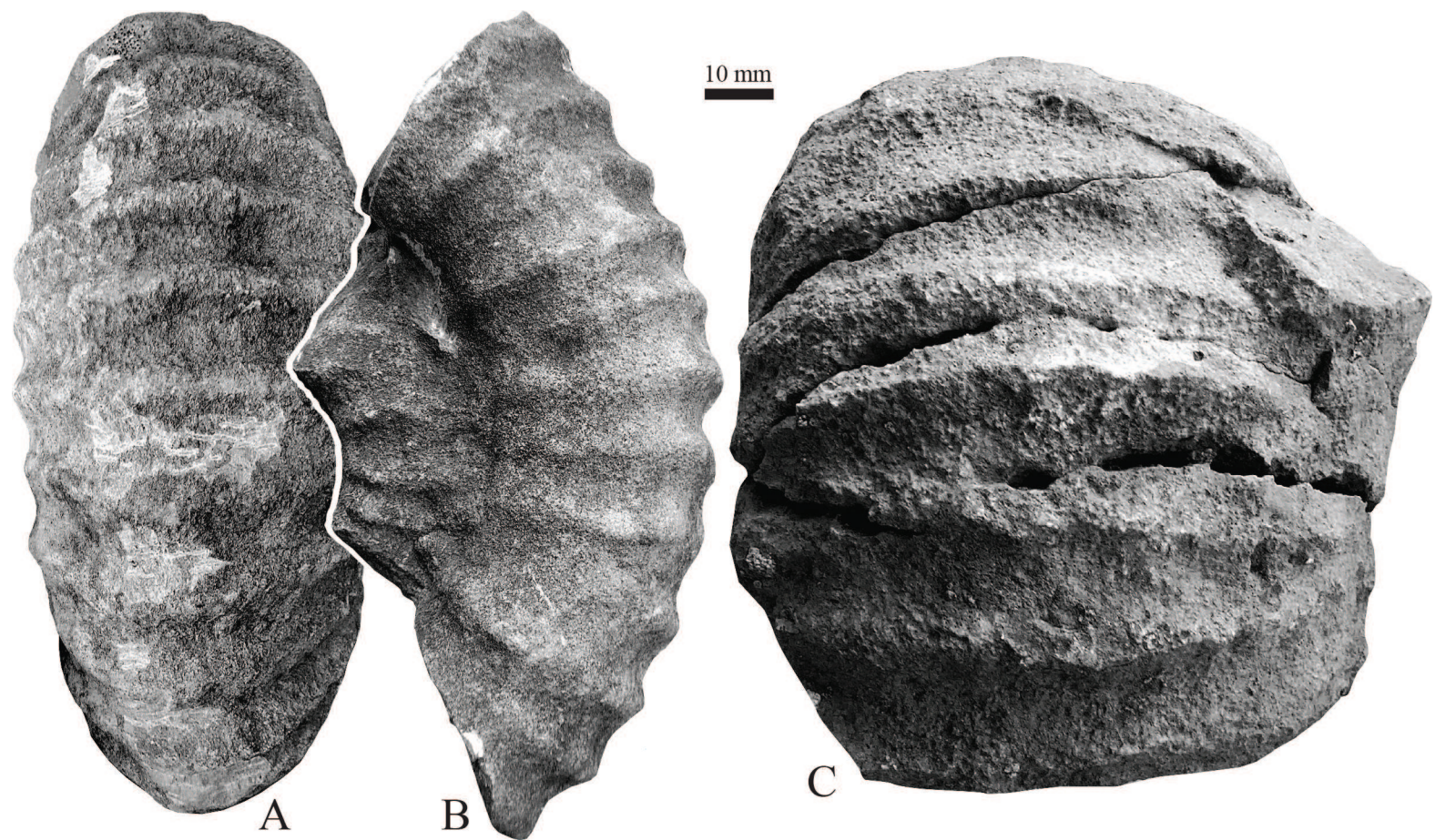
10 mm

I

J

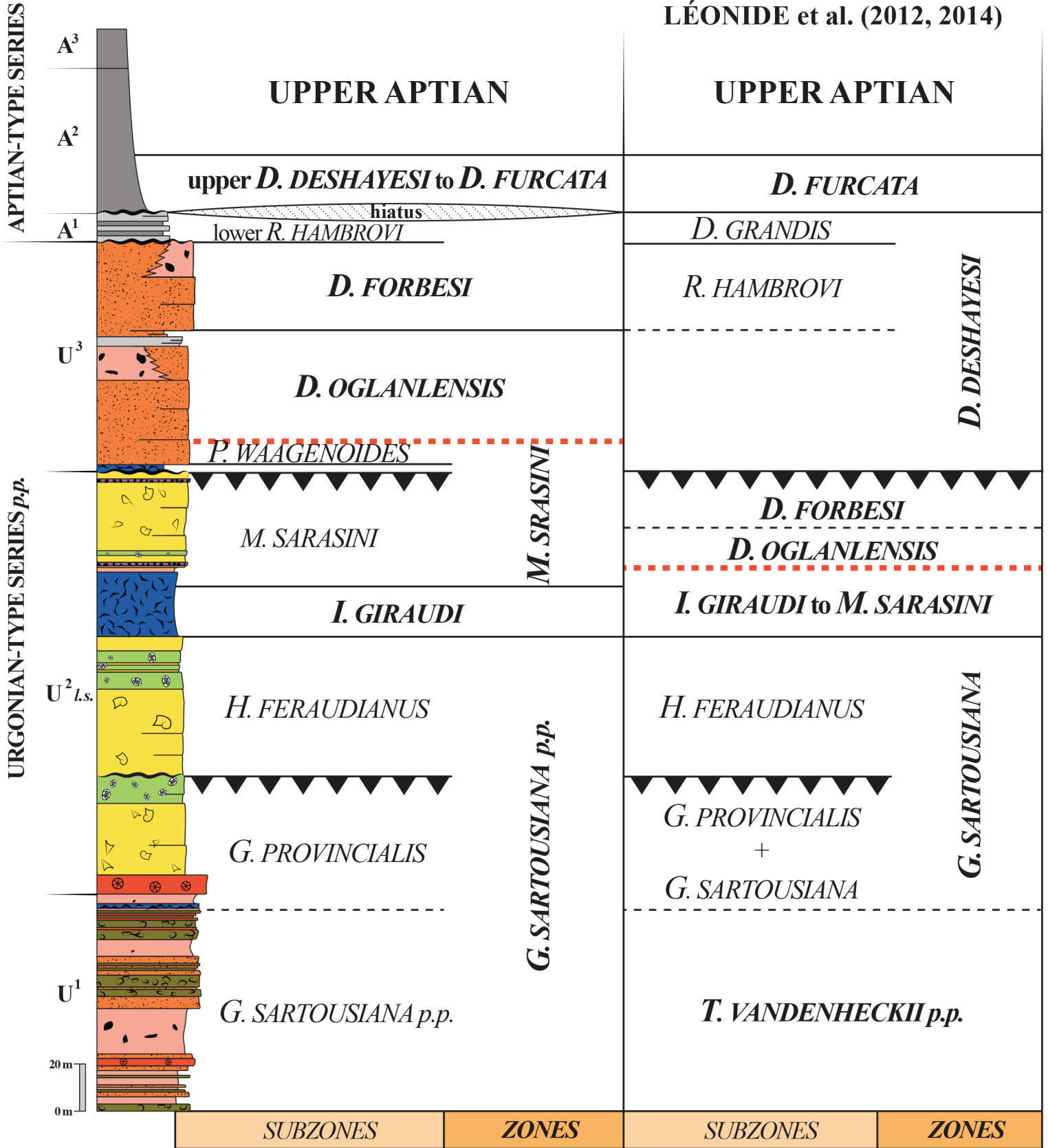






THIS WORK

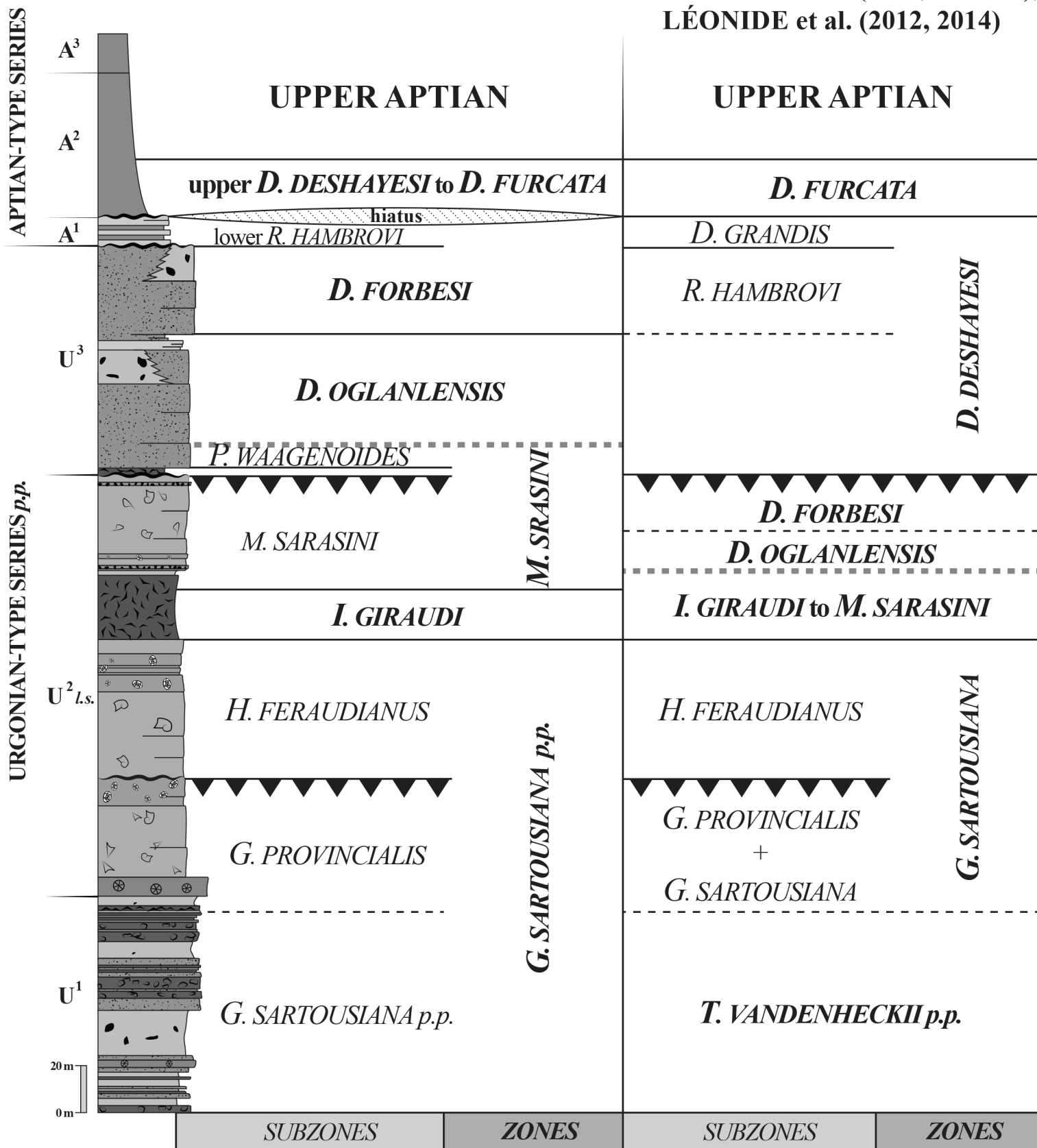
MASSE (1993, 1995), MASSE & FENERCI-MASSE (2011, 2013a-c), LÉONIDE et al. (2012, 2014)



- Putative B/A boundary
- Ammonite-derived time line
- Ammonite-based time line
- ▼ Emersion surface

THIS WORK

MASSE (1993, 1995), MASSE & FENERCI-MASSE (2011, 2013a-c), LÉONIDE et al. (2012, 2014)



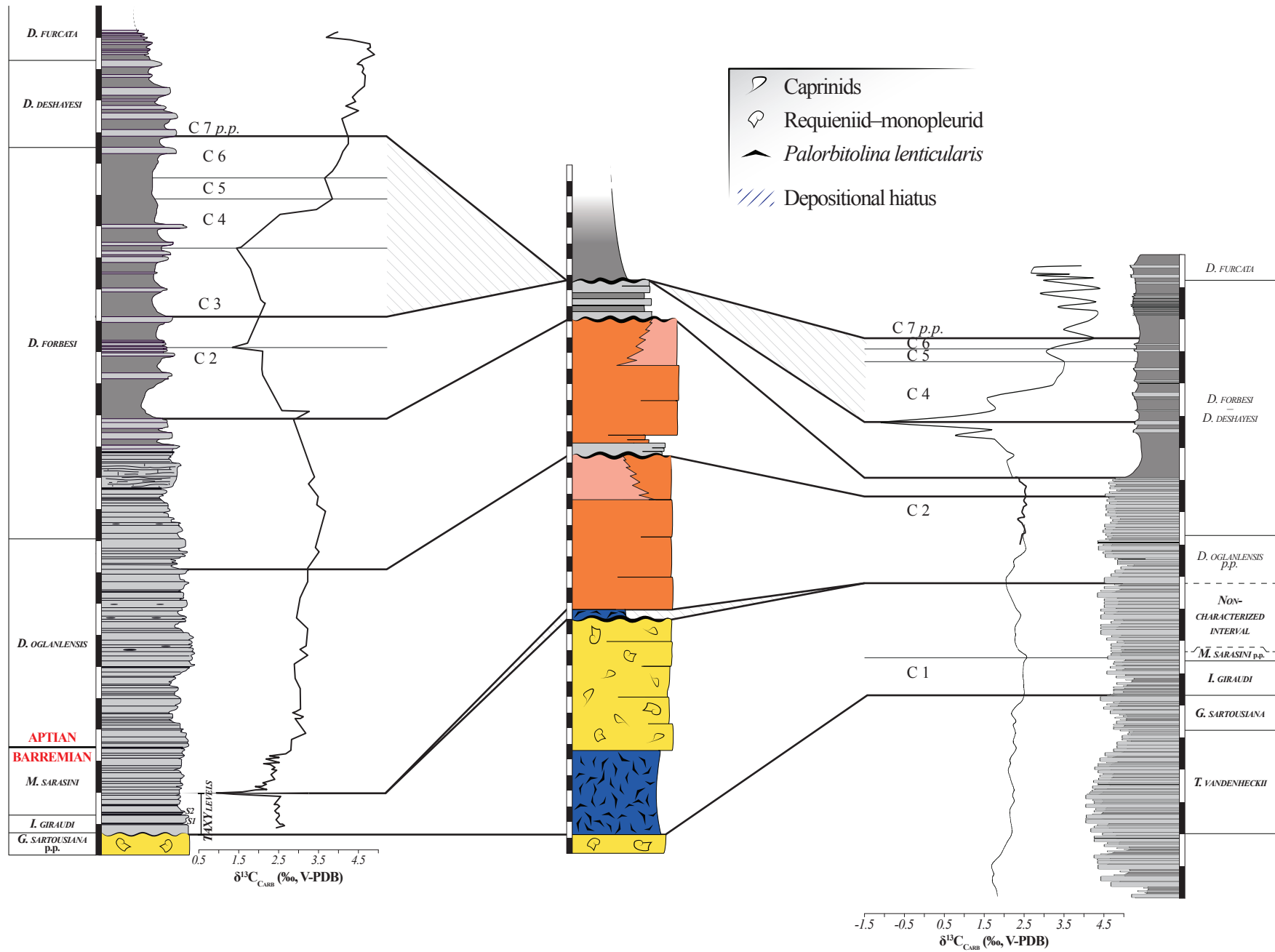
--- Putative B/A boundary      --- Ammonite-derived time line

— Ammonite-based time line      ▼ Emersion surface

**SOUTH PROVENCE  
TYPE SECTION**

**SOUTHERN MONTS DE VAUCLUSE  
TYPE SECTION**

**VOCONTIAN  
TYPE SECTION**

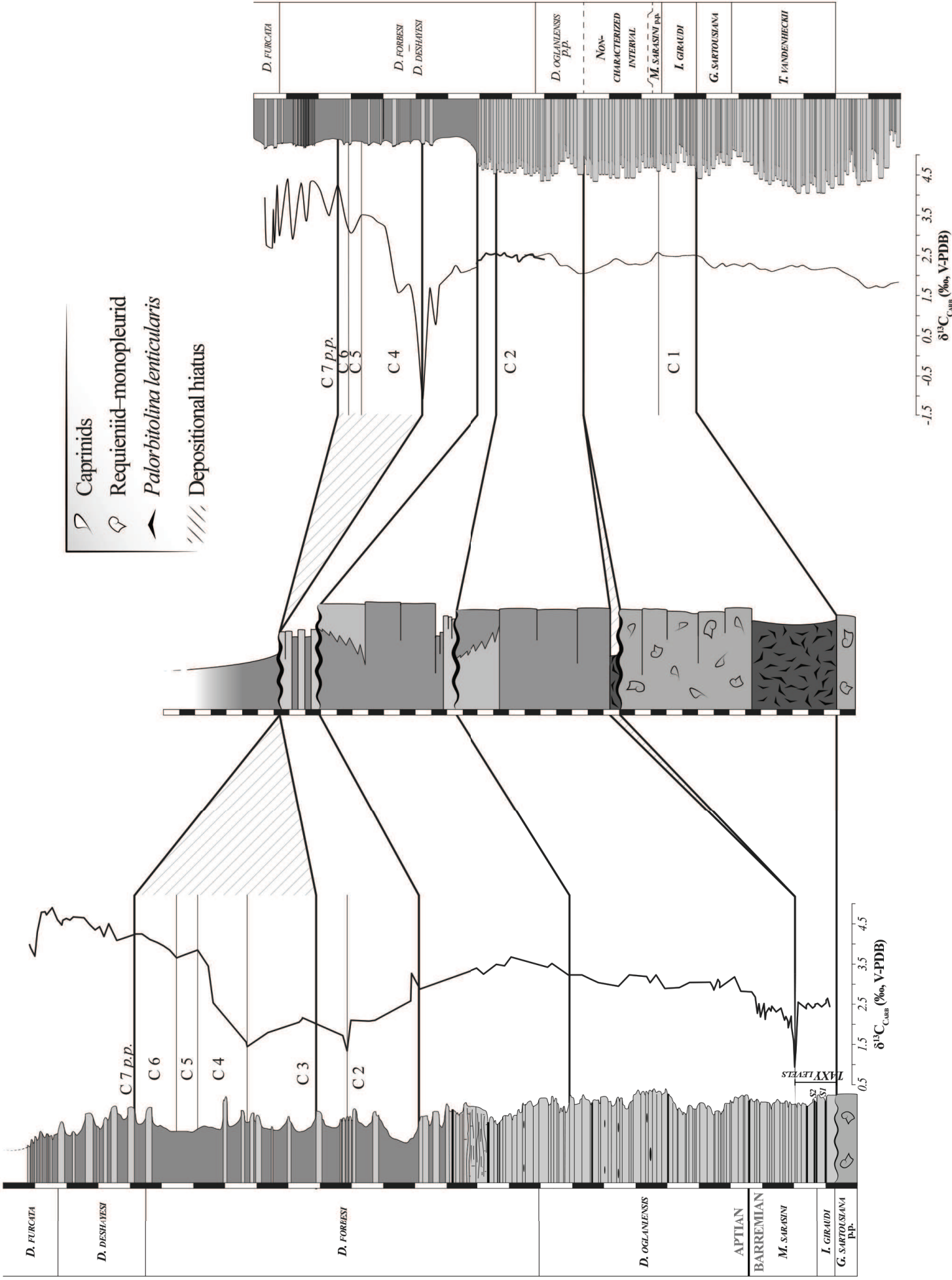




**SOUTH PROVENCE  
TYPE SECTION**

**SOUTHERN MOUNTS DE VAUCLUSE  
TYPE SECTION**

**VOCONTIAN  
TYPE SECTION**



- Caprinids
- Requienuid-monopleurid
- Palorbitolina lenticularis*
- Depositional hiatus

$\delta^{13}C_{carb}$  (‰ V-PDB)

$\delta^{13}C_{carb}$  (‰ V-PDB)



