Carnets Geol. 21 (4)

E-ISSN 1634-0744
DOI 10.2110/carnets.2021.2104

Mediterranean Neocomian belemnites, part 5: Valanginian temporal distribution and zonation (and some lithological remarks)

Nico M.M. Janssen [1]

Abstract: A zonation based on the temporal distribution of belemnites is presented for the Valanginian and its boundaries. It is calibrated on ammonite controlled and bed-by-bed correlated sections from the pre-Vocontian Basin (southeast France). Three new sections are introduced herein that have previously not been investigated. All together, seven zones and six subzones are introduced. In addition, both within the Vocontian area, as well as outside (Bulgaria, Crimea, Czech Republic, France, Hungary, Morocco, Romania, Slovakia, Spain, Switzerland), differences regarding the spatial distribution of belemnites are investigated. Also, in two addenda, some remarks are given regarding lithological oddities.

Key-words:

- Belemnites;
- Neocomian;
- Valanginian;
- Hauterivian;
- zonation

Citation: Janssen N.M.M. (2021).- Mediterranean Neocomian belemnites, part 5: Valanginian temporal distribution and zonation (and some lithological remarks).- *Carnets Geol.*, Madrid, vol. 21, no. 4, p. 67-125.

Résumé : ***Les bélemnites néocomiennes méditerranéennes, partie 5 : Distribution temporelle et zonation du Valanginien (avec quelques remarques sur la lithologie).-*** Une zonation établie sur la distribution temporelle des bélemnites est présentée pour le Valanginien et ses limites. Elle est calibrée sur des coupes du bassin pré-vocontien (sud-est de la France) datées par ammonites et corrélées banc par banc. Trois coupes inédites sont présentées ici. Ce sont au total sept zones et six sous-zones qui sont proposées ici. De plus, les différences concernant la répartition spatiale des bélemnites sont analysées au sein du domaine vocontien ainsi que dans d'autres régions (Bulgarie, Crimée, Espagne, France, Hongrie, Maroc, Roumanie, Slovaquie, Suisse, Tchèquie). Enfin, deux addenda présentent des remarques concernant certaines particularités lithologiques.

Mots-clefs :

- Bélemnites ;
- Néocomien ;
- Valanginien ;
- Hauterivien ;
- zonation

[1] *hibolithes@hotmail.com*

Published online in final form (pdf) on February 28, 2021
[Editor: Bruno R.C. Granier; language editor: Simon F. Mitchell]

1. Introduction

This paper is devoted to the temporal distribution of belemnites in the Valanginian, including across its upper and lower boundaries, and refines, extends, and provides further evidence regarding the temporal and spatial distribution of Valanginian belemnites in the pre-Vocontian Basin (ARNAUD, 2005), previously published in JANSSEN and CLÉMENT (2002) and JANSSEN (2009). The distribution pattern is compared to more proximal parts of that basin, *i.e.*, sections in proximity to Les Allaves (THIEULOY *et al.*, 1991) and Preynes (Fig. 1). However, most of the material originates from the more distal parts. The zonation herein proposed, based on belemnites, is helpful when ammonites are rare and gives additional tie points around stage/substage boundaries and helps with proximal-distal correlation within the basin.

The recent fine-tuning of ammonite zones in the lower Valanginian resulted in a fundamentally different ammonite zonation/subzonation for the interval due to revision of the taxonomy and stratigraphy as discussed by COMPANY and TAVERA (2015). These changes are implemented to the stratigraphical data previously published (Table 1). However, as the investigated sections in the pre-Vocontian Basin for the most part (Hirsutus Subzone to Furcillata Zone) can be correlated bed-by-bed, ammonite divisions (Subzone, Sz, and Zone, Z) are herein used as Chronozones (cf. SALVADOR, 1994, p. 83-84). In the French literature the term "Horizon" is often used; it can mean both zonule as well as subzone.

Table 1: Stratigraphical data for the Vergol section (**VGL**), modified after REBOULET (1996), KENJO (2014), COMPANY and TAVERA (2015) (= C&T, 2015), and field observations (range of *Baronnites hirsutus* in VGL). Both *Saynoceras contestanum* and *Valanginites* are extremely rare in the distal parts of the pre-Vocontian Basin, therefore there *Neocomites (Eristavites) platycostatus* and *Busnardoites subcampylotoxus* are more appropriate as subchronozonal index ammonites (see text for explanation). Abbreviations used: neocom. = neocomiensis. For affiliation of ammonite genera see references cited.

rock	Ammonite Zonation (Vergol): modified after: Reboulet, 1996; Kenjo, 2014 – Zones	Subzones	taxonomy : C.&T., 2015 – Zones	Subzones	zonation after: C.&T., 2015 – Zones	Subzones	Chronozonation used herein – Zones	Subzones	time
upper Valanginian	*C. furcillata*	*T. callidiscus*					Furcillata	Callidiscus	late Valanginian
	V. peregrinus	*O. nicklesi*					Peregrinus	Nicklesi	
		V. peregrinus						Peregrinus	
	S. verrucosum	*K. pronecostatum*					Verrucosum	Pronecostatum	
		"*N. neocom.*"						"Neocom."	
		S. verrucosum						Verrucosum	
lower Valanginian	*B. campylotoxus*	*N. (E.) platycostatus*	"*B. campylotoxus*"	"*N. platycostatus*"	*K. inostranzewi*	*S. contestanum*	Inostranzewi	Platycostatus	early Valanginian
		K. biassalense		*K. inostranzewi*		*K. inostranzewi*		Inostranzewi	
		S. fuhri		*S.* nov. sp. 1	*N. neocomiensiformis*	*V. dolioliformis*	Neocomiensiformis	Subcampylotoxus	
		K. quadristrangulatum		*B. subcampylotoxus*					
	N. neocomiensiformis	*L. superba*	*N. neocomiensiformis*			*B. hirsutus*		Hirsutus	
	T. pertransiens	*N. salinarium*	*T. pertransiens*		*T. pertransiens*	*V. salinarium*	Pertransiens	Pertransiens	
		N. premolicus				*T. pertransiens*			

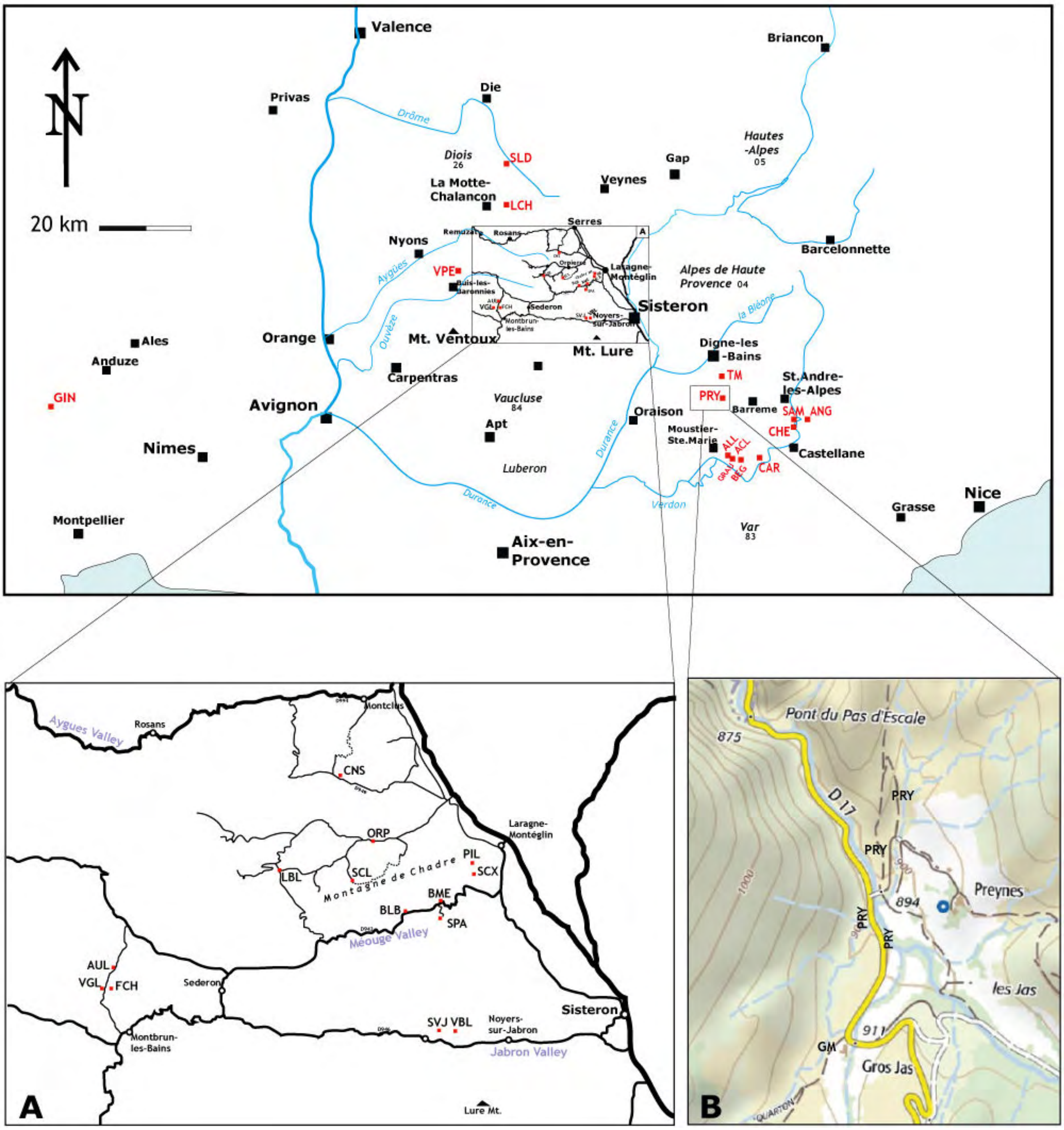


Figure 1: Geographical distribution of areas and sections studied. **Fig. 1.A**. Details of outlined area in the Baronnies. **Fig. 1.B**. Details of position of sections in Preynes area. Abbreviations used: **ACL** (Ravin du Coteau d'Acle), **ALL** (Les Allaves), **ANG** (Angles), **AUL** (Aulan), **BEG** (La Bégude), **BLB** (Barret-le-Bas), **BME** (Barret-sur-Méouge), **CAR** (Carajuan), **CHE** (Cheiron), **CLZ** (Col de Lazarier), **FCH** (Farme de Chilet), **GIN** (Ginestous), **GM** (Gros Mas; see Fig. 1.B), **GRAU** (Grau de Lèbres), **LBL** (Laborel), **LCH** (La Charce), **PIL** (Piloubeau), **PRY** (Preynes), **SCL** (Saint Colombe), **SCX** (Serre de la Croix), **SLD** (Saut de la Drôme), **SPA** (St. Pierre-Avez), **SVJ** (St. Vincent-sur-Jabron), **TM** (Terre Masse), **VBL** (Vaubelle), **VGL** (Vergol), and **VPE** (Vallon des Péchières).

Previously, only informal belemnite zonal schemes have been proposed for the pre-Vocontian Valanginian. Largely, the zones herein established will be based on the first occurrence (hereafter FO) and associations of belemnites that characterize certain stratigraphic intervals. Herein, the outcrops at Vergol/Aulan/Fm.Chilet, Angles/Cheiron/Source de l'Asse de Moriez, and Vaubelle/St.Vincent-sur-Jabron serve as reference sections as most of the material originates from them. The latter two sections are new and described here. In addition several sections (see Fig. 1) have not been investigated as intensively, but provided interesting or additional material important for parts of this work.

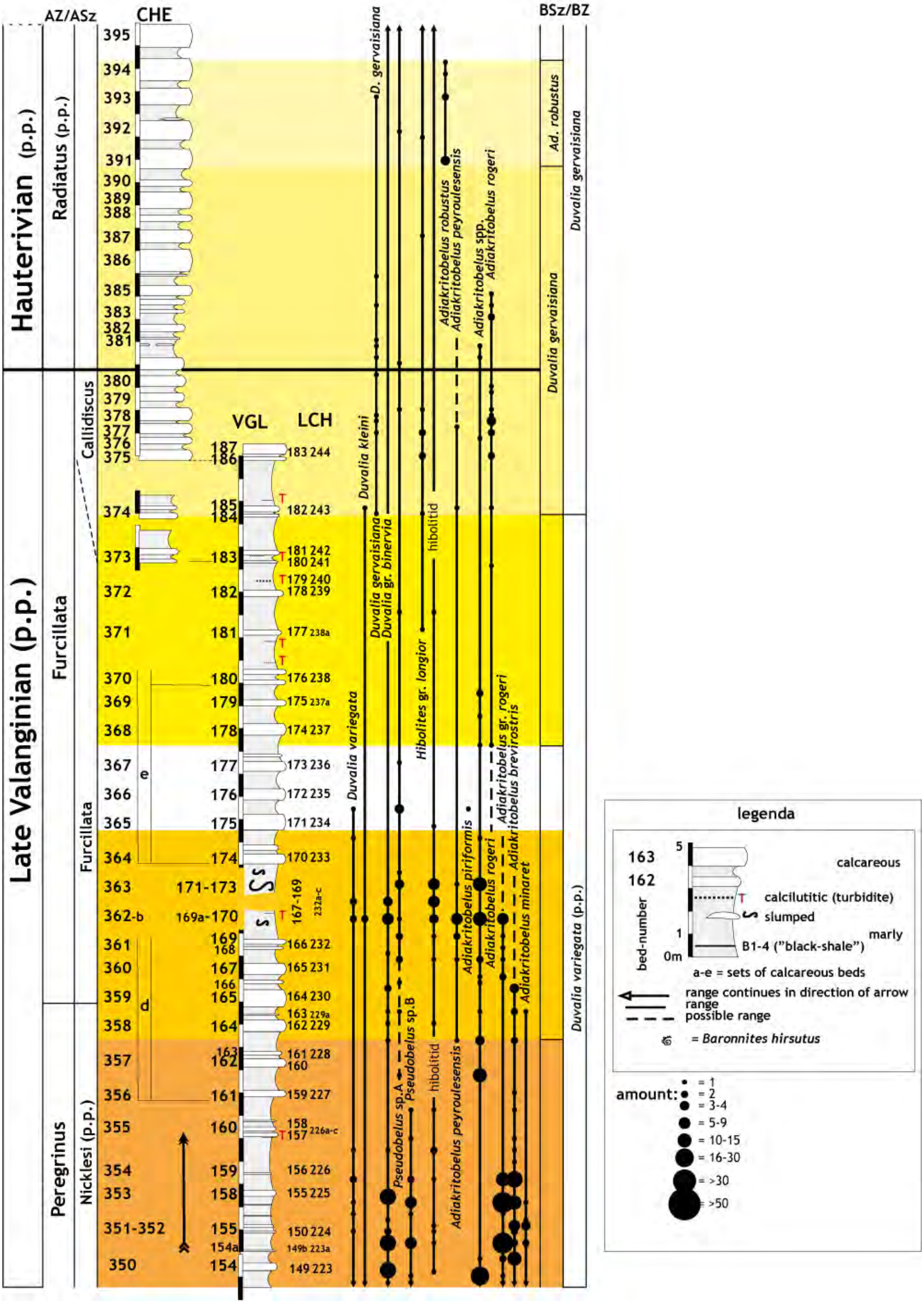
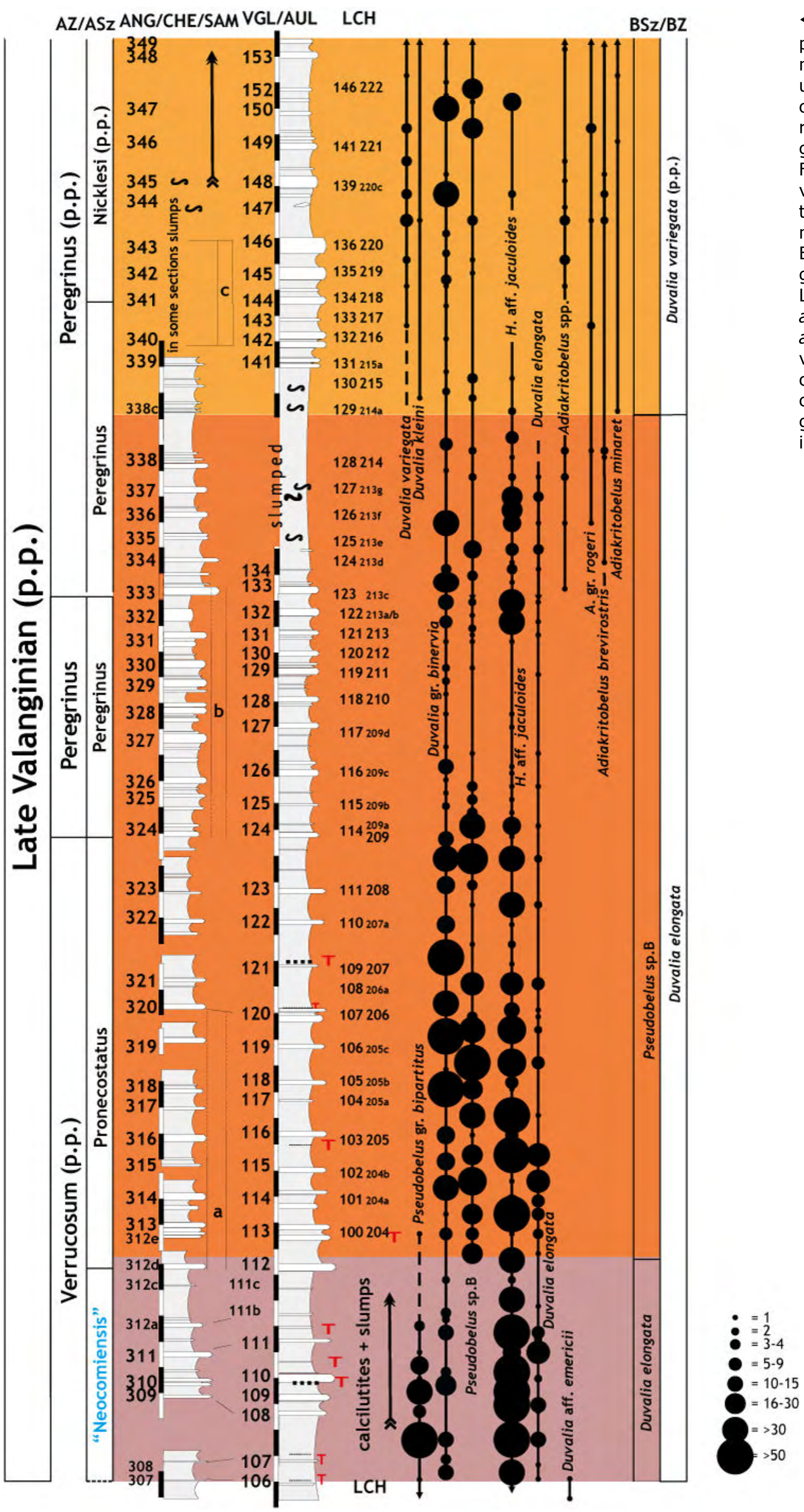


Figure 2: Stratigraphic distribution of belemnites in the upper Valanginian (p.p.) and lowermost Hauterivian (Peregrinus to Radiatus Zones pro parte). The legend is applicable for Figs. 2-8. For explanation of abbreviations of sections mentioned see Fig. 1. Bed-numbers of Angles follows BUSNARDO (1979), of Vergol (REBOULET, 1996), and La Charce (REBOULET *et al.*, 1992, and BULOT *et al.*, 1993a). Each bar in scale = 1 m.



◀ **Figure 3:** Stratigraphic distribution of belemnites in the lowermost upper Valanginian ("Neocomiensis Subzone" (Verrucosum Zone) to Peregrinus Zone pro parte). For explanation of abbreviations of sections mentioned see Fig. 1. Bed-numbers of Angles follows BUSNARDO (1979), of Vergol (REBOULET, 1996), and La Charce (REBOULET *et al.*, 1992, and BULOT *et al.*, 1993a). Ammonite division into subzones indicated in blue is not officially recognized. For legend see Fig. 2. Each bar in scale = 1 m.

2. Regional geological setting

In the investigated sections ammonites provide the foundation of the temporal framework, to which the distribution of the belemnites will be compared. These sections combined, cover the whole of the Valanginian. Bed-by-bed correlation is possible in the investigated distal sections for parts of the lowest Valanginian (Pertransiens Zone). The distal sections typically show the alternation of limestone and calcareous-clay (marl; marlstone) beds (COTILLON *et al.*, 1980; GIRAUD *et al.*, 1995; REBOULET & ATROPS, 1997), sometimes with slumped beds or sets of beds, characteristic of the more distal parts of the basin. Some intervals show intercalated with thin to very-thin (a few mm thick, but ocassionally up to 50 cm thick) brown-weathering layers (see Appendix A), the so-called "plaquettes calcaréo-gréseuses rousses" (calcarenitic brownish beds).

A distal to proximal, bed-by-bed correlation is not possible for some parts of the basin, except for certain sets of beds, based on their fauna (mainly ammonites) and overall lithology (limestone vs. marlstone dominated sets of beds; FERRY & MONIER, 1987; THIEULOY *et al.*, 1991; REBOULET, 1996). The more proximal (hemipelagic: COTILLON *et al.*, 1980) sections, are typically composed of sets of limestone beds intercalated with marlstone dominated sets of beds (COTILLON, 1971; THIEULOY *et al.*, 1991). These beds and/or sets of beds often yield large amounts of almost monospecific associations of various fossil groups, among which small brachiopods (*Pugitella*) or echinoids (*Toxaster*) are most typical. In the area surrounding Preynes (PRY), sedimentary rocks were deposited on an outer ramp (ROBERT, 1994, p. 10; BLANC, 1996, Fig. 59), between the distal sediments of the basin and the more proximal sediments of the more southern areas (hemipelagic area and "Provence platform area", cf. MASSE *et al.*, 2009).

3. Description of sections studied

The distal settings

Most of the investigated sections are from the deeper parts of the pre-Vocontian basin (Figs. 2-6). As not all of the sections have been extensively investigated in regard to ammonites, bed-by-bed correlation of these sections provides a satisfying alternative, at least from the Hirsutus Sz up into younger levels. In general, ammonites are common, generally as haematitic casts in the marls and as calcareous casts in the limestone beds. In addition, aptychi (VAŠÍČEK *et al.*, 2016a, 2016b, 2016c), rhyncholites, belemnites, porifera (HÉRENGER, 1944; Pl. 1, figs. 3-11, 14-16), and gastropods ("pelican-feet"), occur in varying abundance. Other macrofossil groups, such as, bivalves, brachiopods, corals, echinoids, and vertebrates, are less common.

Angles (ANG-V) and surrounding. These sections are situated roughly to the north-east of Castellane and are exposed in a wide area around lake Castillon. The uppermost lower and upper Valanginian at ANG-V yield abundant ammonites (THIEULOY, 1979; LE HÉGARAT & FERRY, 1990; BULOT *et al.*, 1993a; BULOT, 1995; REBOULET, 1996). It was chosen as a complementary section for the Valanginian (hypostratotype; BUSNARDO *et al.*, 1979). The Berriasian-Valanginian boundary is placed - based on calpionellids - at a slumped interval (beds ANG-V201-207; LE HÉGARAT & FERRY, 1990, p. 371). Some belemnites have been mentioned by COMBÉMOREL (1979) and JANSSEN (2009). Bed numbers for ANG-V follow BUSNARDO (1979). The exposures known as Source de l'Asse de Moriez (SAM) and especially Cheiron (CHE) cover the whole Valanginian and belong to the classical areas in which at the beginning of the 19th century many macrofossils were collected. Nowadays, the amount of exposure varies due to the level of water in the artificial lake Castillon, but belemnites and ammonites occur quite commonly in the surrounding hills. Here, especially, the interval from the upper Valanginian to lowermost Hauterivian is well-exposed (Fig. 2), and compares well lithologically with ANG-V. In the late Valanginian (Niclesi Sz and Furcillata Z) at CHE there are intervals with small-scale slumping.

Vergol (VGL) and surroundings. The hamlet of Vergol (05°25'01"E - 43°12'27"N) is situated to the north of Montbrun-les-Bains. Valanginian sedimentary rocks are well exposed in the area. Details of bed numbers can be found in REBOULET (1996, 2015, 2017a, 2017b), MCARTHUR *et al.* (2007), JANSSEN (2009), KENJO *et al.* (2014), and herein. The Verrucosum Zone is exposed in an area running approximately south of Vergol, to the farm of Chilet (section FCH; Fig. 1). As macrofossils (chiefly ammonites; BLANC *et al.*, 1994; REBOULET, 1996; KENJO, 2014) are abundant and the area is easily accessible and continuous over large areas, the Vergol succession has a well-developed, ammonite-based, stratigraphical framework, especially in the upper Valanginian (REBOULET, 1996, 2015). The lower Valanginian is slightly more problematic as in parts of the lithological column ammonites appear rather scarce, especially in the lower Pertransiens Zone. BLANC *et al.* (1994) and BLANC (1996, p. 85-88) investigated the Vergol section as a potential reference section for the Berriasian-Valanginian boundary.

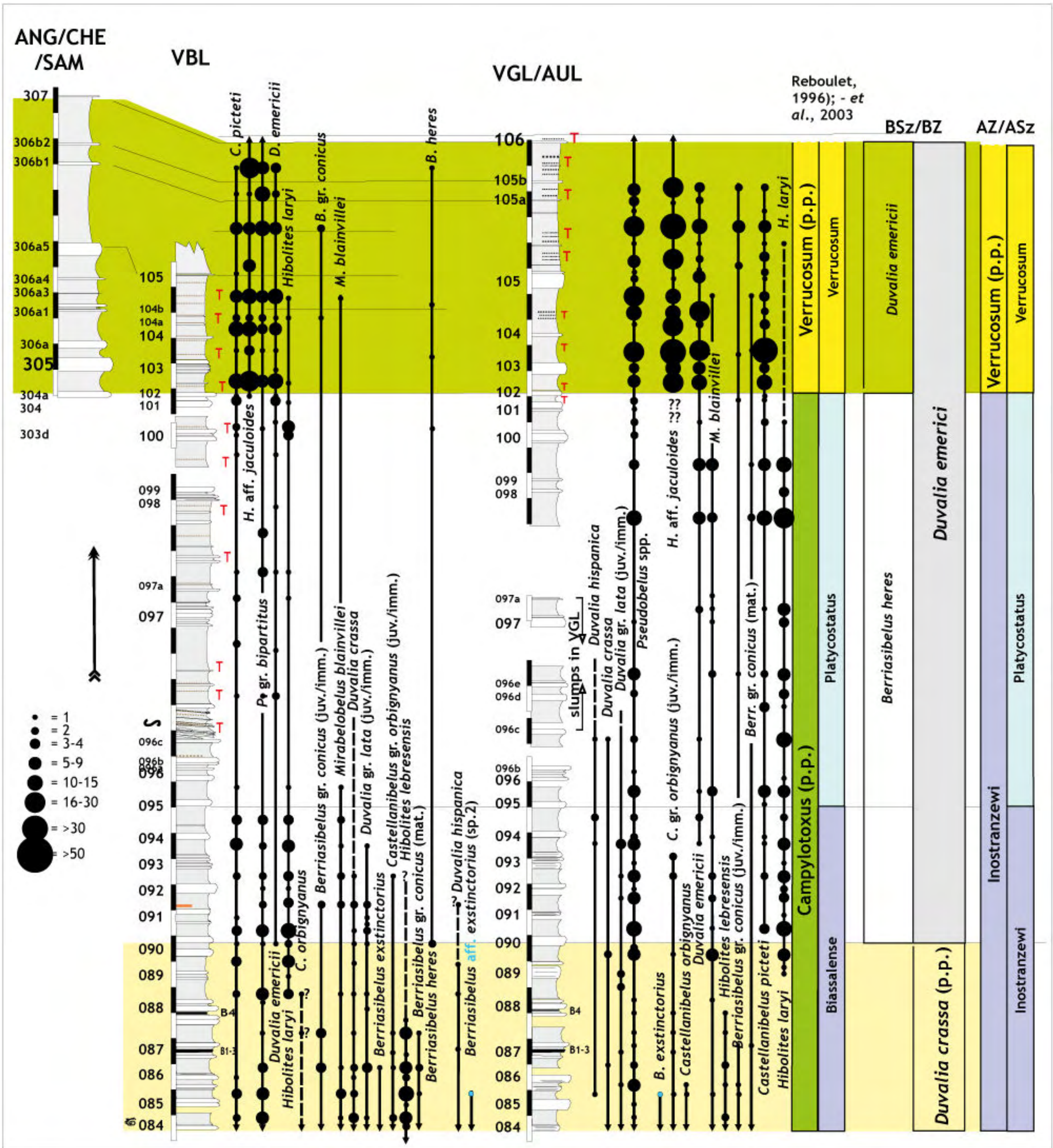


Figure 4: Stratigraphic distribution of belemnites in the upper lower Valanginian to lowermost upper Valanginian (Inostranzewi Zone to Verrucosum Horizon). For explanation of abbreviations mentioned see Fig. 1. Bed-numbers of Angles follows BUSNARDO (1979), of Vergol (REBOULET, 1996; MCARTHUR *et al*, 2007; KENJO, 2014), and La Charce (REBOULET *et al.*, 1992, and BULOT *et al.*, 1993a). For legend see Fig. 2. Each bar in scale = 1 m.

The succession around the boundary between the lower and upper Valanginian yields abundant taxa. The base of the Verrucosum Zone is placed at the inter-bed VGL102-103 (REBOULET, 1996; REBOULET & ATROPS, 1997) (Fig. 4). The index-species (*Saynoceras verrucosum*) is ubiquitous and abundant in a few beds that can be traced across the pre-Vocontian Basin and into its more proximal parts (THIEULOY, 1973; COTILLON *et al.*, 1980; BULOT *et al.*, 1993a; BULOT & THIEULOY, 1995). It is succeeded by a marlstone-dominated interval that is poorly characterized by ammonites. So far, it has yielded only long ranging species. The index-species for the underlying and overlying subzones are absent. This is the Neocomiensis Horizon of ATROPS and REBOULET (1993). It is in this interval, characterized by many rust-coloured intercalations, that the typical lower Valanginian and lowermost upper Valanginian (Verrucosum Horizon) belemnites disappear. In the Inostranzewi Zone the BARRANDE levels are clearly visible (Pl. 4, fig. 8), and pre-date the Valanginian positive carbon excursion.

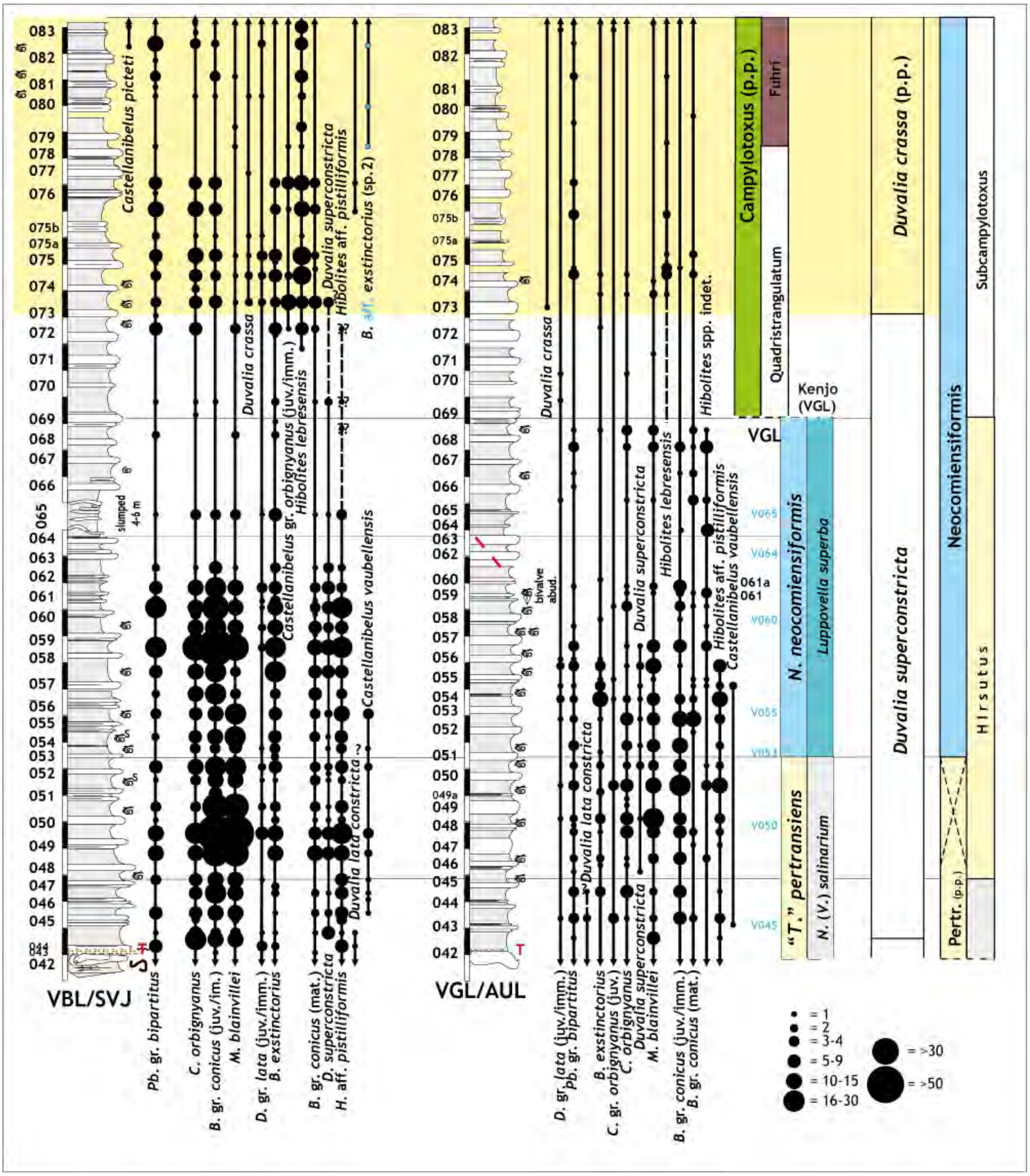


Figure 5: Stratigraphic distribution of belemnites in the lower Valanginian (Pertransiens Zone pro parte to Neocomiensiformis Zone). For explanation of abbreviations mentioned see Fig. 1. Bed-numbers of Angles follows BUSNARDO (1979), of Vergol (REBOULET, 1996; MCARTHUR *et al*, 2007; KENJO, 2014), and La Charce (REBOULET *et al.*, 1992, and BULOT *et al.*, 1993a). For legend see Fig. 2. Each bar in scale = 1 m.

The section herein called Col d'Aulan (AUL) is comparable to the Morénas section of REBOULET (1996). It is generally similar to VGL, but in the latest early Valanginian (part of the Platycostatus Sz) the intervals that are partially slumped in VGL are undisturbed (Fig. 4).

Vaubelle (VBL) - St.Vincent-sur-Jabron (SVJ). These sections are located to the WSW of Sisteron. Valanginian sedimentary rocks are exposed over a wide area around the farm of Vaubelle. Sections to the west and north-west of the farm (at the southern, western and eastern foot of the Serre Michel) were measured (Pl. 2, figs. 1-2). SVJ is located to the west of VBL. Exposures are numerous, but sometimes complicated by faults and changes in lithology caused by mass-flow deposits. Belemnites are generally common. The lower part of the Hirsutus Sz yields a level with abundant large haematitic specimens of the ammonite *Olcostephanus stephanophorus* (VBL 048-049). In the Hirsutus Sz the characteristic belemnite *Duvalia superconstricta* occurs. Typically, the *Berriasibelus conicus*-group is most common together with *Mirabelobelus blainvillei*, whereas some levels yield large numbers of *Castellanibelus*. The Verrucosum Horizon is characterized by abundant *Duvalia emericii*, succeeded by sediments of the "Neocomiensis Sz" dominated by *Hibolites* aff. *jaculoides*, aptychi and many small brown-weathered beds. Younger levels were not investigated.

The so-called BARRANDE levels (B1-4) are present (Pl. 2, figs. 4-5; see beds VBL087 and 088 in Fig. 4), and in the inter-bed between VBL091-092 an ochre-coloured level occurs and may correspond to O4 of FRESNEAU *et al.* (2009). Several slumped intervals are common to many of the investigated sections: *i.e.*, at the base of the Valanginian, below the Hirsutus Sz (Pl. 3, figs. 1, 3), in the Neocomiensiformis Zone (Pl. 3, figs. 6-7), and at the top of the Inostranzewi Zone (Platycostatus Sz) (Pl. 3, fig. 5). A thin calcarenitic bed occurs in the lower Pertransiens Zone and yields many fragmented aptychi and some belemnites (mainly *M. blainvillei*).

In contrast to the other investigated sections, there are occurrences of redepositional deposits consisting of micro-conglomerates, redeposited macrofossils (mainly early-middle Berriasian ammonites), and variously sized calcareous clasts, nodules and boulders (Fig. 6; Pl. 3, fig. 4; see Appendix B). These sediments are often overlain by brownish-weathering calcarenites with thickness of 2-50 cm (VBL042, Pl. 4, fig. 5), which sometimes containing ichnofossils (*Chondrites* isp.) at top.

To date, the following sections have been less completely investigated with respect to the bed-by-bed distribution of belemnites. However, they confirm the general stratigraphi distributions seen in other sections or provide valuable additional information. They include:

La Charce (LCH). Here, the upper Valanginian and especially the Hauterivian have been extensively investigated with regards to ammonites (THIEULOY, 1977b; FERRY & RUBINO, 1988; REBOULET *et al.*, 1992; BULOT *et al.*, 1993a; BULOT, 1995; BULOT & THIEULOY, 1995; REBOULET, 1996). The lower Valanginian is also well developed, but has only been partially investigated to date (FERRY & RUBINO, 1988; REBOULET, 1996), even though both belemnites and ammonites are quite common.

The lower/upper Valanginian boundary appears to be disturbed. Here, these sediments are characterised by many small, generally only few mm thick, but sometimes up to 20 cm thick brownish-weathering calcilutitic to (calc)arenitic beds ("la Zone Jaune" or "yellow zone" of LE DOEUFF, 1977). These beds yield trace-fossils (*e.g.*, *Palaeodictyon*, *Zoophycos*), scour marks, ripple marks, and parallel and convolute laminations. These marlstone-dominated sedimentary successions succeed a calcareous bed dated as belonging to the lowermost Inostranzewi Zone (bed LCH098; this bed correlates to bed VGL085) and the succeeding sediments appear in part to be missing (a.o. the BARRANDE levels are missing). The upper part of this marly sedimentary unit consists of relative thinly-bedded, brownish-weathering layers and few calcareous beds that are slumped and is followed by a succession of undisturbed, well-bedded typical alternations of limestone and marlstone. Below the thin-bedded slump deposit is a rather large slump (MKIII) that consists of a thick calcareous bed that yielded the belemnite *Duvalia elongata* (Pl. 9, figs. 31-32). This species first occurs in the upper parts of the "Neocomiensis Horizon", indicating these slumps are of post "Verrucosum Horizon" time. The index species of the latter horizon appears to be absent here, although FERRY *et al.* (1989, p. 777) indicate *Saynoceras* in the lower part of the slumped beds above LCH098. Most probably this record refers to "*S. fuhri*" (*sensu* REBOULET). Just above the first calcareous bed (LCH100 *sensu* REBOULET) *Pseudobelus* sp. B occurs. This calcareous series of bedsets also yields many specimens of *H.* aff. *jaculoides*, *Duvalia binervia*, and *D. elongata*.

Several levels with slumped beds occur in the lower Valanginian. In the Pertransiens Zone, calcareous ammonites are quite common, but belemnites and haematitic ammonites are relatively scarce. Some limestones beds show burrows filled with phosphatised faecal pellets (LCH065 and LCH066), whereas a thick limestone bed (LCH 055) shows fluid-escape structures. It is interesting to note the presence of the so-called "Teschener fauna" (UHLIG, 1902). Herein, ammonites like *Fuhriella* and *Sarasinella* occur abundantly (det. J. KLEIN) in the upper part of the Pertransiens Zone, below the Hirsutus Sz. This part is not divided into subzones, but is, in the pre-Vocontian Basin, characterized by the (near) absence of the nominal species of the Pertransiens Zone. The Otopeta Sz, very rich in ammonites, also yielded the nautilus *Xenocheilus*.

Vallon des Péchières (VPE). This outcrop is exposed in a valley to the north of Buis-les-Baronnies and shows the upper lower Valanginian and lowermost upper Valanginian. In the "Neocomiensis Sz", up to 10 mm thick, non-continuous beds occur that are completely made up of fragments of aptychi. Thin brownish-weathering levels occur frequently; they are typically up to several mm thick. Also, the BARRANDE levels B1-4 occur.

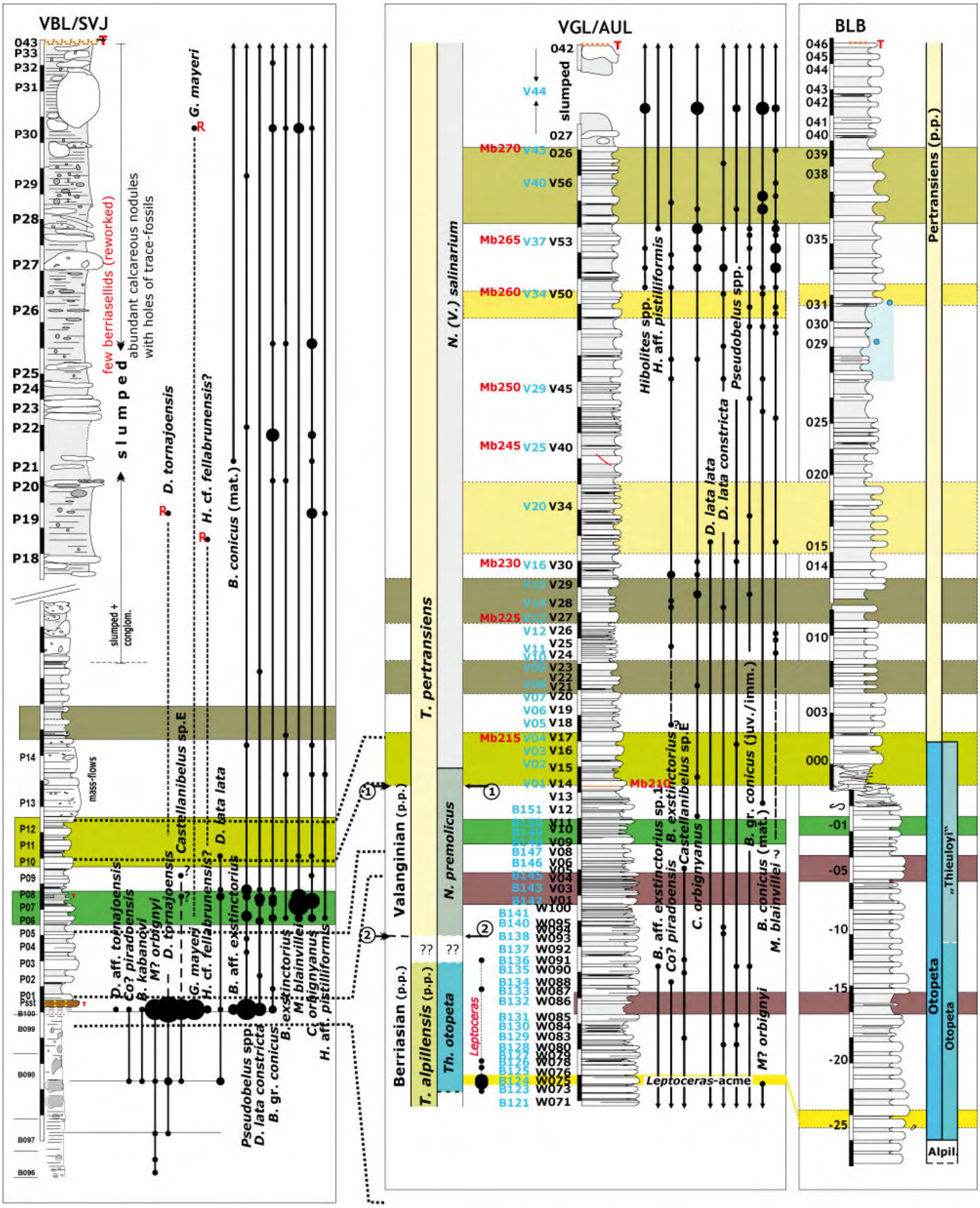


Figure 6: Stratigraphic distribution of belemnites in the uppermost Berriasian to lowermost Valanginian (Alpillensis Zone (p.p.) - Pertransiens Zone). Bed-by-bed correlation appears to be difficult, coloured bands indicate possible correlative (sets of) beds. Also the abundant occurrence of the ammonite *Leptoceras* (indicated by yellow band) is a possible correlative level. The belemnites *B. exstinctorius*, *C. orbignyanus*, and *M. blainvillei* are the first typical members of Valanginian belemnite associations. For explanation of abbreviations used see Fig. 1. Bed-numbers of Vaubelle (and St. Vincent-sur-Jabron) herein new presented, of Vergol follows (BLANC *et al.*, 1994; REBOULET, 1996; MCARTHUR *et al*, 2007; KENJO, 2014), and Barret-le-Bas follows BUSNARDO (1979). For legend see Fig. 2. Each bar in scale = 1 m.

The Baronnies. The sections described below, roughly occur in an area to the north of the Lure Mountain and west of Sisteron (Fig. 1.A). They crop out in five E-W orientated valleys. From north to south they include:

(1) the valley W of Montclus of the Blème (a tributary of the Buëch),

(2) the valley of the Blaisance (a tributary of the Buëch),

(3) the valley of the Céans (a tributary of the Buëch), north of the Chadre Mountain, in the valley of the river Céans sections (Laborel, LBL; St. Colombe, SCL), yields late early Valanginian to late Valanginian belemnites (cf. CLÉMENT, 1999). Here, no apparent brownish-weathering levels were observed in the lowermost upper Valanginian. The lowest beds exposed at SCO are from the Hirsutus Sz and above these beds, slumping is observed in the interval below the Subcampylotoxus Sz and in the Platycostatus Sz, and

(4) the valley of the Méouge (a tributary of the Buëch); this valley yields the section known as Barret-le-Bas (BLB), east of the village of Barret-sur-Méouge. Valanginian outcrops are widespread in this area to the south of the Chadre Mountain (Barret-le-Bas, BLB; Barret-sur-Méouge, BME (LE HÉGARAT, 1973, p.423-425); St.-Pierre-Avez, SPA) where ammonites, calpionellids (LE HÉGARAT, 1973; REMANE & THIEULOY, 1973; BUSNARDO *et al.*, 1979; BULOT, 1995), and belemnites (COMBÉMOREL, 1979; CLÉMENT, 1999) have been investigated. The BLB section was selected as a Valanginian hypostratotype (BUSNARDO *et al.*, 1979). The interval around the lower/upper Valanginian boundary commonly yields *Berriasibelus heres* and *Duvalia emericii*. Thin brownish-weathering beds occur in the "Neocomiensis Sz" and yield many broken aptychi (see Appendix A).

North of this valley, west of Laragne-Montéglin (Fig. 1), the classical outcrops of Serre de la Croix (SCX) and Piloubeau (PIL) can be found. Here, in the eastern part of the Chadre Mountain the earliest Valanginian is exposed yielding at SCX abundant belemnites in the Hirsutus Sz. In addition, many haematitic fossils occur in these beds, among these are ammonites, corals, porifera (Pl. 1, figs. 3-11), and small bivalves. At PIL the Pertransiens Zone and older leves occur, in part slumped, but are currently largely obscured by vegetation. However, a few belemnites (*e.g.*, *Berriasibelus incertus*, however not *in situ*) could be collected, among which *Pseudobelus* and *Castellanibelus* are the most common. The slumped beds are succeeded by a thick limestone bed (corresponding to BLB 000), that in turm is overlain by a series of undisturbed beds that are exposed in some small gullies in an otherwise forested area. At PIL, the Pertransiens Zone yields ammonites, such as, *Platylenticeras*, especially well-known from higher-latitudes (THIEULOY, 1977a, p. 402-404) and rare species like *Cantianiceras*? *diense* (det. J. KLEIN).

(5) the valley of the Jabron, which is located further to the south. In this valley sections around Vaubelle were investigated (see above).

All the above mentioned sections are from the more distal parts of the Vocontian Basin. More proximal areas, so-called hemipelagic settings, are characterized by alternating sets of limestone and marlstone dominated beds, hiatuses, condensed deposits, different fossil abundances, and the absence of slumps. Here, cephalopods (ammonites, belemnites, nautiloids) may be abundant, but aptychi and rhyncholiti are extremely rare. Benthic macrofossils are common to very abundant and include bivalves, brachiopods, and echinoids, whereas corals, crustacean, and vertebrate remains are rare. Intermediate settings show characteristics of both the distal and proximal areas. Deposition was often fault-related and during compressional tectonic episodes, movements along several of these faults led to the development of sub-basins (*i.e.*, the Preynes-Majastres unit).

The sections investigated - intermediate settings

Preynes (PRY).

Localities within intermediate palaeogeographical affinity between the distal and proximal settings are uncommon in the investigated area. One example is found in a valley east of the Pas d'Escale, around the farm of Preynes (PRY) and "Gros Mas" (= GM; Fig. 1.B). Sections here were previously studied (ammonites and calpionellids) and logged by ARNAUD *et al.* (1993), ROBERT (1994), and BLANC (1996). However, belemnites were not mentioned in these studies, despite their relative abundance. Nautiloids are extremely rare and only one strongly weathered *Xenocheilus* was obtained from the Pertransiens Zone. The middle Berriasian (indicated by the abundance of *Dalmasiceras dalmasi* and other species) to upper Berriasian is mainly calcareous, with subordinate thin to very thin marl intercalations. Conglomeratic (mud flows) and/or gully-like calcareous levels occur. The uppermost Berriasian contains variable proportions of glauconite, phosphate, and iron-rich concretions, especially in the Alpillensis Z. Herein, erosional surfaces occur, expressed as partially eroded ammonites. This set of beds is covered by an iron crust and shows a rather irregulair surface. A conspicuous bed yielding abundant rhynchonellids occurs in the lower part of the Alpillensis Sz (BULOT, 1995, p. 278; BLANC, 1996, p. 89). These calcareous dominated sediments (upper Berriasian - lowermost Valanginian) precede lower Valanginian marl dominated sediments, yielding abundant belemnites (mainly *B.* gr. *conicus*, *C. orbignyanus*, and *M. blainvillei*) separated by slumped beds (Fig. 7). Apparently, beds with common *T. pertransiens* are absent or the latter species is extremely rare.

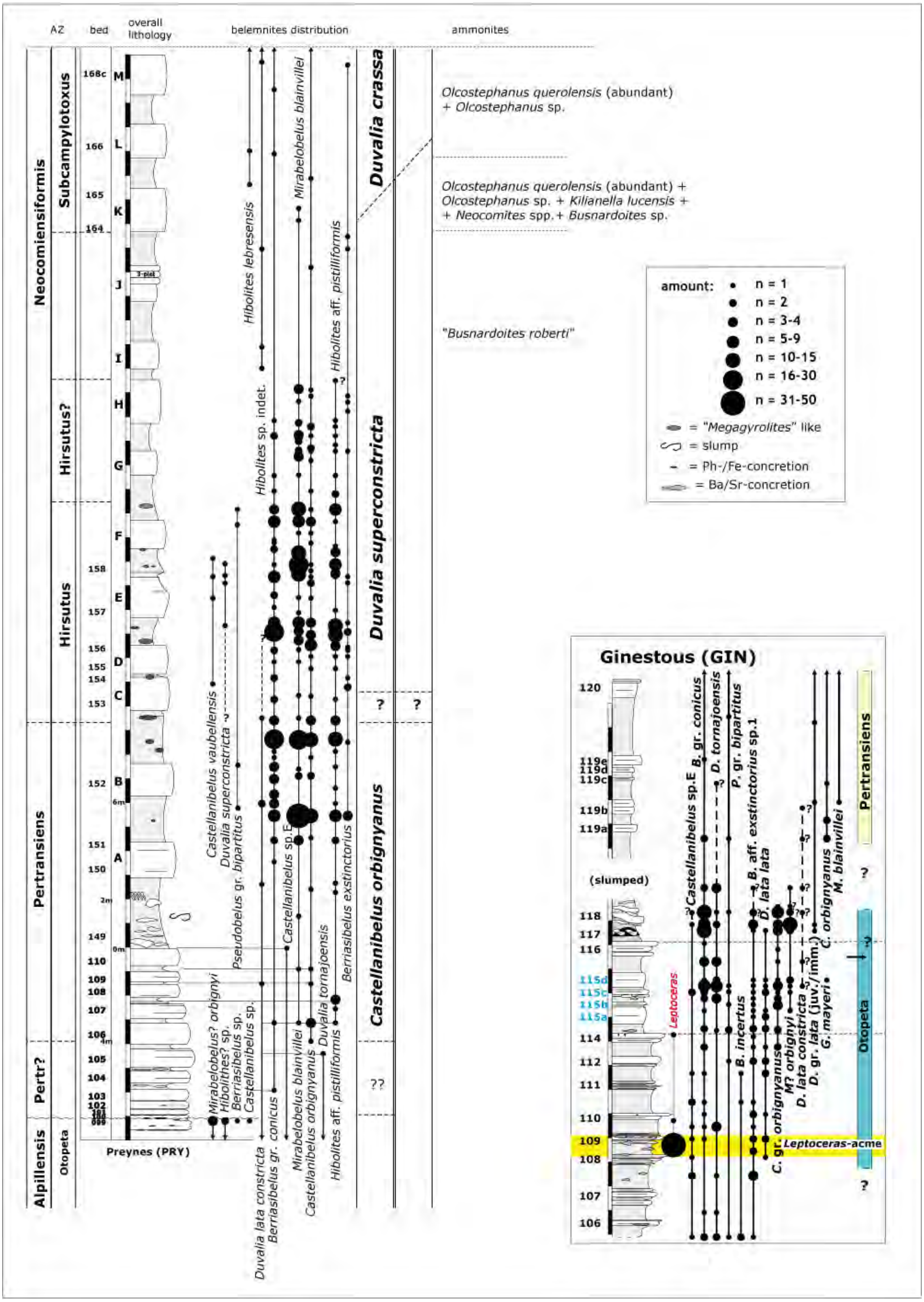


Figure 7: Stratigraphic distribution of belemnites in PRY (see Fig. 1.B). Indicated are lithology, bed-numbers, calcareous complexes (A-M), and ammonite (sub-)zonation (field observations and see text for references). For legend see Fig. 2. Bed-numbers for Ginestous (GIN) modified from Gayte (1984). Each bar in scale = 1 m.

In the Valanginian, the initially marl-dominated sediments actually consist of alternating sets of marlstone- or limestone-dominated beds (Pl. 6, figs. 3, 5) with a "sandy" appearance. In the depicted section, for this part, individual beds are not figured, but for sets of beds (calcareous complex, indicated by A to M). Bed-numbers of Arnaud *et al.* (1993) are, where possible, indicated (*e.g.*, PRY148). In the lower marly intervals especially, *Megagyrolites*-like burrows (Gaillard, 1980) or concretions occur with sizes ranging from a few centimetres to several decimetres. In addition, some porifera (Pl. 1, figs. 15-16) and decapods (Pl. 1, fig. 17) occur. Slightly higher in the section, the marly levels yield a few haematitic ammonites (*Platylenticeras*, *Sarasinella*, and more abundantly *Lytoceras* and *Phylloceras*) and driftwood. Here, belemnites are quite frequent, indicating the Hirsutus Sz (*D. superconstricta*, *Castellanibelus vaubellensis*). Higher up in the sequence, limestone sets of beds are more pronounced and calcareous ammonites (det. J. Klein) become progressively more abundant. Initially, these sets of beds are dominated by *Olcostephanus* gr. *drumensis*, and above by *Olcostephanus guebhardi*, accompanied by "*Busnardoites roberti*" and *Neocomites neocomiensiformis*. Thereafter, *Bochianites*, *Olcostephanus*, *Vergoliceras*, and *Busnardoites* become the dominant ammonites with subordinate *Valanginites*. The latter beds weather out as thin bedded limestones (Pl. 6, figs. 1, 5; just below the light blue line). They are succeeded by several tens of metres of marly sediments yielding turbiditic limestone beds with an abundant ichnofauna (Pl. 6, fig. 4). Above these beds, two succeeding, thick limestone sets of beds occur with *Duvalia crassa* and few *Castellanibelus*. These beds yield, besides *O. guebhardi*, many macroconchs of neocomitidae, indicating the Subcampylotoxus and Inostranzewi Zones. However, these sediments were only briefly investigated for this paper.

Ginestous (GIN).

The Ginestous section is situated in the so-called "depression of Nimes" ("la Gouttière némausienne"; Gayte, 1984), a western extension of the pre-Vocontian Basin, and is the westernmost section investigated (Fig. 1). It is situated approximately at the boundary between the basin and the outer ramp. Here especially, the uppermost Berriasian yields many belemnites (Fig. 7). The section has previously been investigated for belemnites (Gayte, 1984, p. 35-36). Ammonites have been studied (Le Hégarat, 1973, p. 251-259, 344-348; Le Hégarat & Remane, 1968, 1973, p. 79-85) in complementary sections, known as Ginestous-La Garenne, Les Oliviers, and Lacisterne. In the uppermost Berriasian conspicuous barite nodules occur and there is also a level (marly bed GIN108-109; Fig. 7) that has the potential to be correlated across this area that yields abundant *Leptoceras*. This level can be found throughout the investigated area and was mentioned by Thieuloy (1966) from the Grande-Chartreuse.

The uppermost Berriasian yields *B.* aff. *exstinctorius* sp. 1, *B. incertus*, and *M.*? *orbignyi*. *Castellanibelus* is very frequent, but the other genera are rather rare. These sediments are succeeded by a number of slumped limestone beds, among which one bed yields the ammonite *Pseudohimalayites* gr. *nieri* in abundance, in a marly matrix containing large angular quartz grains. The sedimentary succession shows characteristics from both distal (slumps) as well as from more proximal (marl dominance) sets of beds. Given this section's palaeogeographical position, it was probably formed in an "intermediate" setting.

The sections investigated - proximal settings

Valanginian sedimentary successions, on the southern margin of the pre-Vocontian Basin yield abundant cephalopods (Thomel, 1964; Cotillon, 1971; Thieuloy *et al.*, 1991; Autran, 1993; Bulot, 1995; Reboulet, 1996; and refs. therein). Among these, ammonites and nautilids are most abundant, while belemnites sometimes occur in large quantities (*e.g.*, in condensed glauconite rich beds; cf. Janssen, 2009), but in general are rare as compared to other cephalopods. The sediments were deposited between the open marine (distal) parts of the basin and a carbonate platform situated to the south. The upper Valanginian is characterized by relatively thin limestone beds intercalated with rather thick marlstone successions. Large differences can be observed between the amount of condensation, extension of the hemipelagic sediments and cephalopod richness in certain sections. Several sections (Fig. 8) have been investigated, including: Les Allaves (ALL), Ravin du Couteau d'Acle (ACL), La Bégude (BEG), Grau de Lèbres (GRAU), and Carajuan (CAR), all located in the Moustiers-La Palud area. This area is well known for the "canyon du Verdon". In general, sections are easily accessible, but especially the softer, calcareous-clayey sediments (marlstones) can be covered by lush vegetation. Also, weathering can be quite strong and as some beds appear to be rather patchy, eventually parts of these sections might turn out to be unaccessible from time to time. All sections show more-or-less condensed upper Valanginian sediments and apparently less condensed lower Valanginian sediments. In all investigated areas the Verrucosum Sz is well developed. In general, cephalopod abundances fluctuate heavily within these sediments. Notably, the lower Valanginian (but for the uppermost) is nearly barren of belemnites and nautiloids. Other macrofossil groups, especially brachiopods and echinoids show fluctuating, but often high abundances, especially in the marl dominated intervals. In several of these sections the Platycostatus Sz and the Verrucosum Sz show tubular concretions, such as, *Tisoa siphonalis* Serres, 1840 (comparable to Friren, 1876, Pl. II, figs. 6-9), that are more-or-less perpendicular to bedding. These structures probably represent fluid-escape structures (venting conduits), remobilized along existing burrows (often several meters long). They are often associated with cold-seep deposits (KNAUST, 2019). Also, irregular beds with abundant small oysters and patches of bivalves occur and are apparently associated with these concretions.

Nautilids are common, especially *Cymatoceras*, but also some other genera occur sporadically, such as *Angulithes* and *Xenocheilus*. The latter genus occurs in the Platycostatus Sz of TM, while *Angulithes* occurs in ALL and in BEG (in both sections as single specimens), in the "Neocomiensis Sz". Among the belemnite "*Belemnites pistilliformis*" is relatively common in the proximal areas. These include juvenile to sub-adult hibolitid belemnites of the genera *Hibolites* and *Adiakritobelus*.

Initially BUSNARDO and COTILLON (1964), but more extensively and covering a wider area COTILLON (1971, p. 25-34), based on lithostratigraphy, defined various formations within these proximal deposits. Fossil abundances and lithological differences were obvious, and several sets of beds were defined, such as the "Grand Lumachelle" (GL) and the "Petite Lumachelle" (PL), or as marly successions with abundant small brachiopods (*Pugitella*; SANDY, 1987) or echinids (*Toxaster*; DAVID, 1979, 1980; FRANÇOIS & DAVID, 2006).

Terre Masse (TM). This exposure, previously known as Chabrières (THOMEL, 1964), located to the north of PRY, yields few belemnites (Fig. 8), except for a condensed level at the base of bed TM108. Herein belemnites are abundant (a.o. *Adiakritobelus peyroulesensis*). Also, the uppermost lower Valanginian yields few belemnites. This section was reinvestigated by THIEULOY *et al.* (1991) and BULOT (1995). The lowermost Hauterivian is typically developed in a glauconitic facies with an abundance of cephalopods.

Tubular concretions occur around the lower/upper Valanginian boundary. Bed TM102 yields the nautiloid *Xenocheilus malbosi* (PICTET, 1867) (Pl. 1, fig. 12).

Les Allaves (ALL). This section was investigated and illustrated by THIEULOY *et al.* (1991). The GL is well exposed, but most of the beds above it, and below the glauconitic uppermost Valanginian - lowermost Hauterivian on top, are not always easily accessible or exposed. At the base of the GL, bed ALL106 is especially rich in large nautiloids. Contrary to the ACL section, ammonites and belemnites appear to be rare in the GL. This is in part due to the poor accessibility of these sections. However, the lower beds yield abundant belemnites (*Hibolites*), visible as cross-sections in the outcrop. The sediments below the GL are generally well exposed and visible in several outcrops along a small gully. The latter overlies the PL, and is overlain, though the contact is not exposed, by marly calcareous sediments of the Verrucosum Horizon. These highly bioturbated sediments are approximately 1 m thick, and yield irregular marly calcareous nodules, with many small bivalves, echinoids (a.o. *Salinaria*; *Toxaster*), and ammonites. Among the latter, *S. verrucosum* and *Valanginites* are especially common. Tubular concretions also occur. The glauconitic lowermost Hauterivian is very rich in belemnites (JANSSEN, 2009).

La Bégude (BEG). In this section (Fig. 8), located to the east of Les Allaves, the general development of the GL is comparable to ALL and ACL, but individual beds vary in thickness. The section is illustrated in THIEULOY *et al.* (1991, Fig. 7, p. 62). The sediments between the GL and the succeeding marls are not well exposed anymore, while small faults and lush vegetation disturbs the continuity of the younger succession. On top of the GL, condensed sediments occur, yielding abundant ammonites, belemnites, and brachiopods (a.o. *Peregrinella*). The glauconitic lowermost Hauterivian yields: *Adiakritobelus*, *Hibolites* and abundant "*Belemnites pistilliformis*", together with a few *Duvalia* and *Pseudobelus*, and in the upper Valanginian *Duvalia* gr. *binervia* occurs.

Grau de Lèbres (GRAU). This section (Fig. 8) is situated slightly to the east of ACL (see below). The GL is not well exposed (covered by vegetation). The top of the PL forms the crest of a small hill and the preceding *Karakaschiceras*-beds are well exposed. The section is illustrated in BULOT (1995, Figs. 11 and 34). The PL is especially rich in *O. guebhardi* and few boreal ammonites also occur. However, belemnites appear to be very rare. Only, in the marly inter-bed GRAU112-113 of the Subcampylotoxus Sz, a single belemnite (*Hibolites lebresensis*) was found.

Ravin du Coteau d'Acle (ACL). This section, previously not described, is exposed to the west of BEG and indicated on the topographic map as Ravin du Côte d'Acle. Belemnites are rather common, but in the lowermost upper Valanginian only (Fig. 8). Here, post Verrucosum Horizon sediments are well exposed, especially the GL. The latter consists of hard-wearing calcareous sediments with often a characteristic appearance of ball-like structures (called "boules" in French). These beds yield nautilids (*Cymatoceras*), ammonites (especially *Karakaschiceras*), and commonly the belemnite *H.* aff. *jaculoides*. On top of the GL two thin calcareous beds (ACL097 and ACL098) are developed that contain a few belemnites (*Hibolites*), some boreal ammonites (*Dichotomites* and *Prodichotomites*) occur and the ammonite *Neohoploceras* is present in abundance. Bed ACL098a consists of two more or less nodular levels. The upper bed shows traces of glauconite, abundant bivalves and reworked and *in situ* cephalopods. Among the cephalopods the most common are: *Cymatoceras*, *Varlheideites peregrinus*, *Neocomites neocomiensis* (with fine ribbing), *Duvalia* gr. *binervia* and *Pseudobelus*. The marly sediments above bed ACL098a are poorly exposed, but some small marly-limestones could be recognized that yielded few ammonites (a.o. *Teschenites robustus*). This sequence is overlain by lowermost Hauterivian glauconitic limestones that yield belemnites (*A. robustus*, *Pseudobelus* sp. A).

At the base of the gully, a single *D.* cf. *emericii* was found, in a patch of oyster and bivalve rich sediment. However, the contact with the underlying PL, which forms a ridge in the forested area, is not exposed. The marl-dominated sediments at the base of the exposure yield patches of nodular limestones very rich in small oysters and sometimes other molluscs (various double-valved bivalves), while the marls themselves yield abundant small *Toxaster*. Tubular concretions also occur commonly.

Carajuan (CAR). Carajuan is seen as the reference section for the outer platform facies (see Thieuloy *et al.*, 1991, p. 57 and references therein; Arnaud *et al.*, 1993; Bulot, 1995; Bulot *et al.*, 1995; Reboulet, 1996). In recent years an increasingly detailed framework based on the distribution of ammonites was presented by these authors. Cephalopods, occur but are not common, except in a few beds. A few belemnites were found mainly in the upper Valanginian (Fig. 8). The sediments above the GL are partially covered by vegetation, but generally well exposed. On top of bed CAR084 a glauconitic phosphatic bed of 2 cm thickness, with an accumulation of rolled and fragmented belemnites could be observed; it mainly yielding "*B. pistilliformis*" and *Hibolites*. In addition a few *D.* gr. *binervia* and *Pseudobelus* occur. It was not possible to see if this was only represented by pockets filled with reworked clasts, or if there was any lateral continuation.

Apparently, CAR077 yielded the ammonite *Karakaschiceras* (cf.) *pronecostatum* (see Hennig Fischer, 2003, Fig. 4.17; Bulot, 1995, p. 253). However, this seems to contradict with the belemnites that occur, and most probably it represents a conch of the *K. inostranzewi-biassalense*-group; unfortunately it has not been figured nor described. The marly bed below CAR078 yielded *D. emericii*. The latter species belongs to the belemnite association that characterizes the pre-Verrucosum-event association *sensu* Janssen and Clément (2002). However, the base of bed CAR 078 yields already *D. elongata* indicating a post-Verrucosum-event belemnite association.

4. Ammonite stratigraphy

General remarks

Much of the belemnite material originated from sections that have been investigated for ammonites (Le Hégarat, 1973; Le Hégarat & Remane, 1973; Thieuloy, 1973; Busnardo *et al.*, 1979; Thieuloy *et al.*, 1991; Atrops & Reboulet, 1993, 1995; Bulot *et al.*, 1993a, 1993b; Bulot & Thieuloy, 1995; Reboulet, 1996). In some cases data were used from unpublished works (Robert, 1994; Bulot, 1995; Blanc, 1996; Kenjo, 2014). For the lower Valanginian, as a result, many discrepancies occur and various groups of researchers have used different ammonites in their zonal schemes (compare Bulot, 1995; Reboulet, 1996; Kenjo, 2014). Recently, Company and Tavera (2015) published a modified zonation to the standard that was in use (Reboulet *et al.*, 2011) to accommodate for some of the discrepancies and taxonomical problems that existed between the "standard zonation" and their findings in the SE of Spain (Betic Cordillera). In their text, they gave supporting evidence that this new zonation can also be applied outside the Betic Cordillera. At the moment, differences appear to be largely the result of variations in the abundance of certain ammonites (hence the different subzones) and in part due to taxonomical discrepancies, as explained by Company and Tavera (2015). Therefore, the work of Company and Tavera (2015) is extremely useful to shed new light on the temporal and spatial distribution and the taxonomical interpretation of ammonites for this sub-stage. However, Company and Tavera (2015) used several subzonal index species that do not occur in abundance in the more distal parts of the pre-Vocontian Basin, but do in the more proximal parts. For that reason, some different taxa are herein used to characterize some of the subzonal ammonite associations (see Table 1). The newly introduced zonal (not subzonal) scheme was proposed in advance (Reboulet *et al.*, 2014) to be valid as a "standard zonation" for the Valanginian of the Mediterranean Tethys. However, at the moment, papers that confirm the zonation proposed for the lower Valanginian are lacking for the pre-Vocontian Basin except for the unpublished work of Kenjo (2014). In Table 1 the different zonations (Reboulet *et al.*, 2011, 2014; Company & Tavera, 2015) are shown and the correlation for the lower Valanginian as proposed by the latter authors, is partially followed.

At present, the modified ammonite zonation as proposed by Company and Tavera (2015) appears to deviate, at the boundary of the Pertransiens Zone to Neocomiensiformis Zone, when applied to the pre-Vocontian Basin. The nominal species for the Hirsutus Sz (*Baronnites hirsutus*; Pl. 1, fig. 14) is quite frequent in Vergol (but not mentioned by Reboulet, 1996, or Kenjo, 2014) (see Fig. 5; indicated by ammonite symbol). It occurs first in the inter-bed VGL045-046 (= V47-48), *i.e.*, several beds below the FO of the index species of the Neocomiensiformis Zone of Company and Tavera (2015). The latter is mentioned by Kenjo (2014) and Reboulet (2017b) from bed V53 (= VGL051), but specimens comparable to Kenjo (2014, Pl. 1, fig. 5) occur also one bed lower (det. J. Klein).

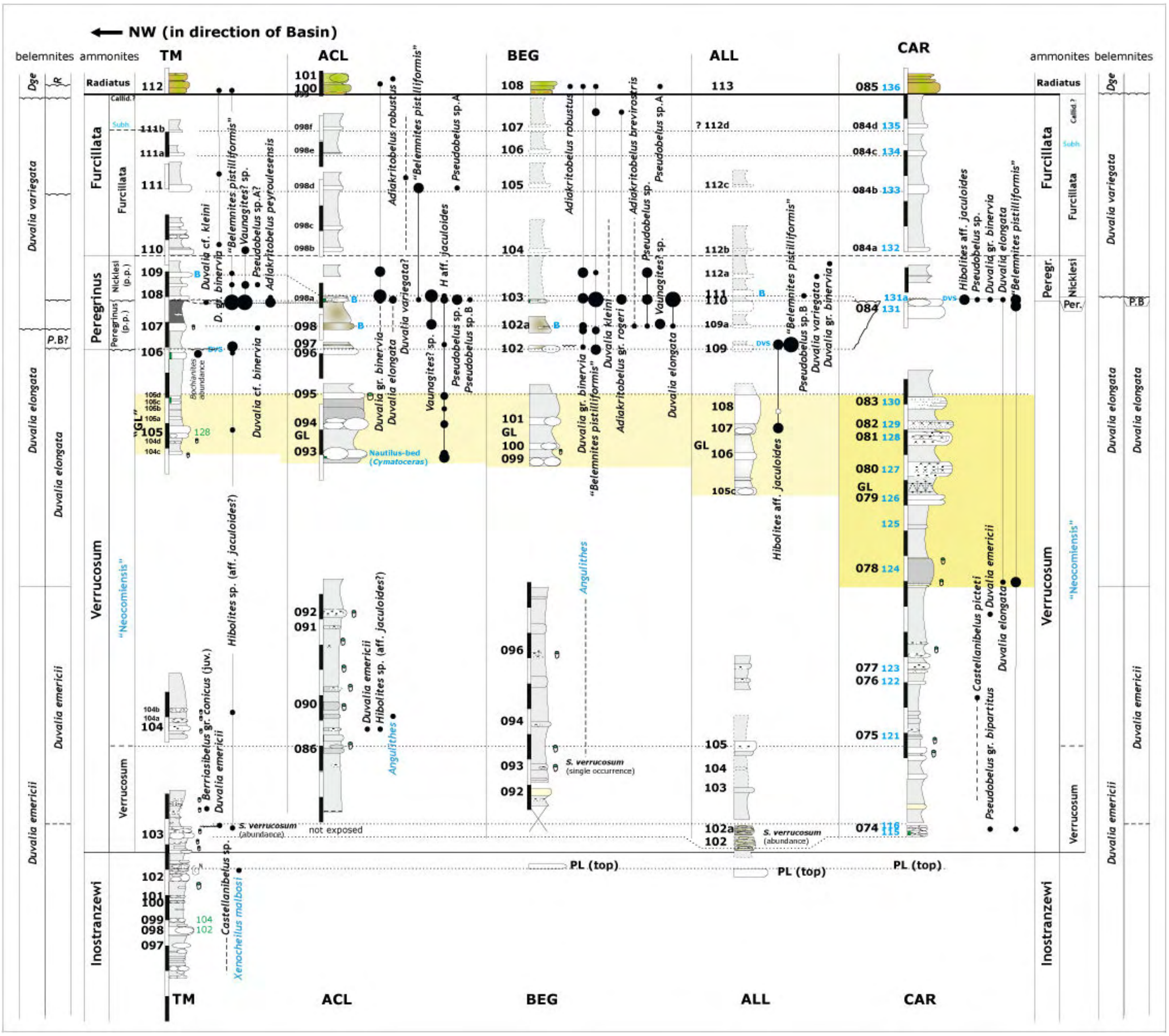


Figure 8: Stratigraphic distribution of belemnites and a few nautiloids in the proximal settings. Indicated are bed-numbers, ammonite (sub-)zonation (see text for references), belemnite (sub-)zonation, lithology and geography. Bed-numbers of Terre Masse, La Bégude, Les Allaves, and Carajuan after THIEULOY *et al.*, 1991, while alternative bed-numbers TM (in green) after THOMEL (1964) and in blue (CAR) after REBOULET (1996). Ravin du Côte d'Acle is herein first presented. Abbreviations used: GL = Grande Lumachelle, "GL" = correlative part with GL (but not defined there), PL = Petite Lumachelle, Callid. = Callidiscus, Sub. = Subheterocostata. **B** = *Dichotomites* occurrence, *Abr* = *Adiakritobelus brevirostris*, *Dge* = *Duvalia gervaisiana*, *P.*B? = possibly *Pseudobelus* sp. B, *R* = *Adiakritobelus robustus.* For the legend see Fig. 2. Each bar in scale = 1 m.

Other striking differences that exist between the two palaeogeographical domains are in the relative abundance of several ammonite taxa. These differences are most apparent in the rarity of *Valanginites* in the proximal parts of the pre-Vocontian Basin in the lower Valanginian, and the near absence of species like *Saynoceras contestanum*. However, these differences might be artificial, and be based on the more thorough investigations in the Betic Cordillera and, in part, this might be explained by the high abundance of (juvenile) haematitic internal casts in the pre-Vocontian Basin.

In the pre-Vocontian Basin the upper Valanginian (Figs. 2-3) is more thoroughly investigated regarding ammonites as compared to the lower Valanginian, resulting in a much more uniform distribution pattern. However, some additions are made to the proposed scheme, because of their significance in the temporal distribution of the belemnites. These include the use of the "Neocomiensis Sz" (Fig. 3) introduced by ATROPS and REBOULET (1993) for the upper part of the Verrucosum Sz without the index specimen, either of the name-giving Subzone or with the index specimen of the following Subzone. This interval is of special interest for belemnites in the pre-Vocontian Basin, as it includes the transition from typical early to late Valanginian faunas, the "Verrucosum-event" of JANSSEN and CLÉMENT (2002).

The Berriasian-Valanginian boundary

The boundary between the Berriasian and Valanginian, *i.e.*, the base of the Valanginian is placed at the FO of *Calpionellites darderi*, apparently almost co-occurring with the FO of the ammonite *T. pertransiens* (BLANC *et al.*, 1994; BULOT *et al.*, 1995, 1996; AGUADO *et al.*, 2000; COMPANY & TAVERA, 2015). BLANC *et al.* (1994) placed this boundary in Vergol at the bed Mb210 (= VGL014; = V01; Fig. 6). However, the FO of *T. pertransiens* appears to be earlier (det. J. KLEIN), bed W93 (= base B138; Fig. 6), and thus occurring throughout the larger part of the latest Berriasian Otopeta Sz *sensu* BLANC *et al.* (1994). KENJO (2014) placed this boundary at a different, even slightly early, level (B136; Fig. 6; see also REBOULET, 2017a) based on the FO of the ammonite *Neocomites premolicus* and doubtful *T. pertransiens* (see KENJO, 2014, p. 30). Thus, the recent work of KENJO (2014) and the findings presented here indicate that the FO of *C. darderi* and *T. pertransiens* are even further apart than previously assumed.

In the lowest Valanginian bed-by-bed correlation appears to be more difficult (but see coloured bands in Fig. 4). In addition there is a lack of ammonite data in several sections mentioned. Still some biostratigraphical tie points are potentially present. In several sections an abundance of *Leptoceras* occurs, apparently being a correlative level in the upper Berriasian Otopeta Sz (Fig. 6). This level can be found throughout the investigated area and was mentioned by THIEULOY (1966) from the Grande-Chartreuse. So for the moment, within the Pertransiens Zone and latest Berriasian some correlation points seem to exist, *i.e.*, the abundance of *Leptoceras* in the Otopeta Sz and some beds in the Pertransiens Zone (Fig. 6), resulting in the relative position of belemnites (FO of) that occur around the base of the Valanginian (as based on belemnites). However, this level does not coincide with the FO of any species hitherto used to fix the lower boundary of the Valanginian in the pre-Vocontian Basin (the calpionellid *C. darderi* or the ammonite *T. pertransiens*).

The Valanginian-Hauterivian boundary

The base of the Hauterivian is defined by the FO of the ammonite genus *Acanthodiscus*, which marks the base of the Radiatus Zone (MUTTERLOSE *et al.*, 2020). The GSSP for the base of the Hauterivian Stage is defined in the La Charce section (LCH) at the base of bed 189 (REBOULET *et al.*, 1992). This bed corresponds to bed 380a in ANG and CHE (Fig. 2).

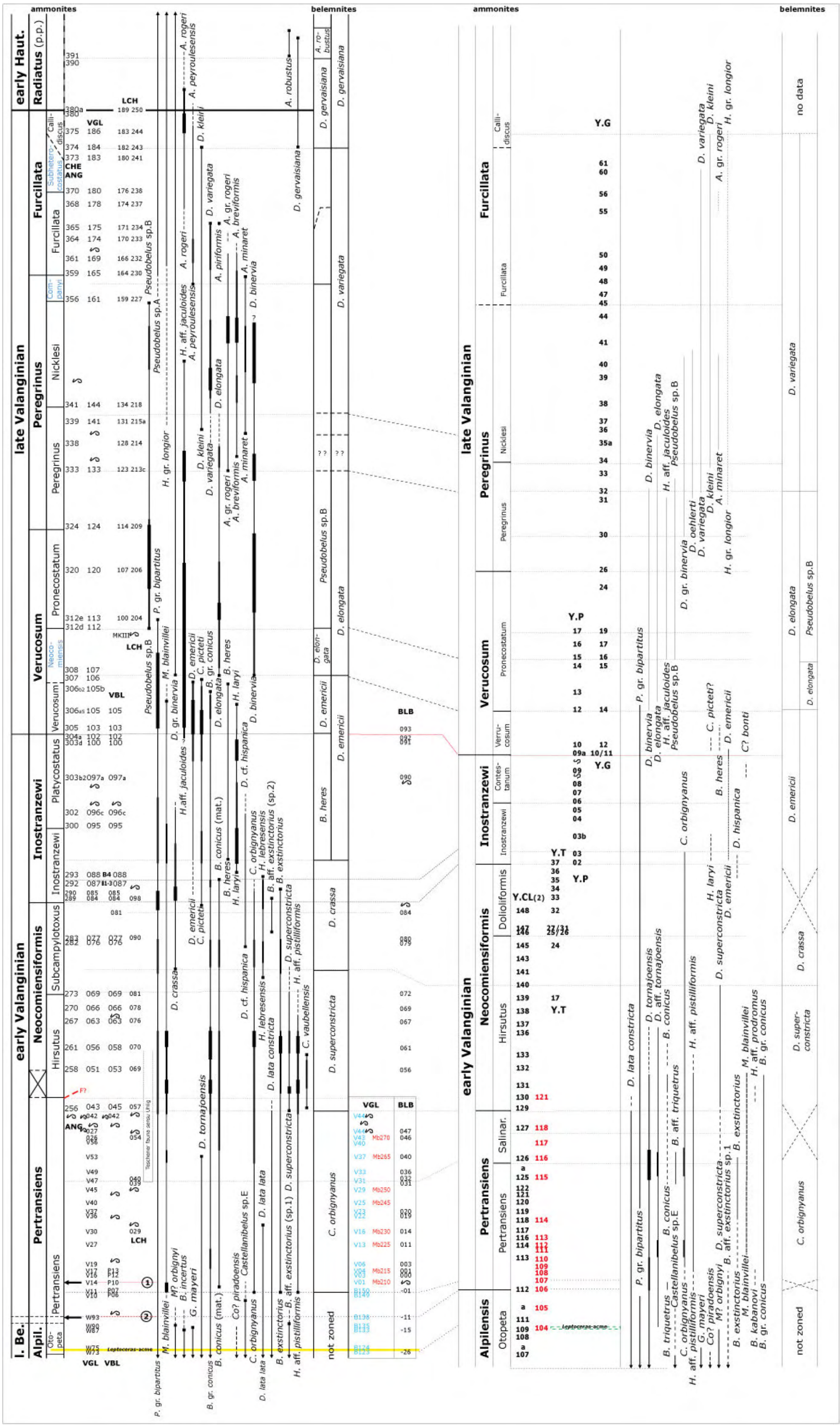
5. Temporal distribution of the belemnites

In Figures 2-6 the occurrences of the belemnites are shown for the most extensively investigated sections. Based on the temporal distribution in these sections combined, a zonal scheme is proposed (see below). In Figure 9 the temporal distribution of belemnites is shown for the latest Berriasian to earliest Hauterivian. As mentioned previously, correlations between sections become complicated below the Hirsutus Sz. This is due to lithological differences caused by slumping and debris-flows, and also because the sedimentary succession appears more variable, resulting from differences in weathering patterns and primary limestone-dominated intervals.

It turns out that characteristic Valanginian belemnite species, such as, *B. exstinctorius*, *C. orbignyanus*, *M. blainvillei*, and *H.* aff. *pistilliformis*, do have their FOs above the FO of the ammonite *T. pertransiens*.

In addition, some belemnites that show their FOs in the uppermost Berriasian disappear shortly after the FO of *T. pertransiens*. One of these species is *D. tornajoensis*. However, in the southeast of Spain it ranges into the Hirsutus Sz (Fig. 9), while *Castellanibelus* sp. E and *D. lata lata* range into the lowermost Valanginian. *Duvalia lata constricta* and *Pseudobelus* gr. *bipartitus* are taxa typical of the uppermost Berriasian ranging in the Valanginian.

▶ **Figure 9:** Stratigraphic distribution of belemnites in the Valanginian of ANG/CHE, VBL, VGL, LCH, and BLB (all SE of France), and to sections Y.Cl(2), Y.G, Y.T, and Tornajo (all SE of Spain). Bed numbers of French sections after personal field observations and after BUSNARDO (1979), REBOULET *et al.* (1992), BULOT *et al.* (1993a), BLANC *et al.* (1994), BULOT (1995), MCARTHUR *et al.* (2007), KENJO (2014), and REBOULET (1996). Bed numbers of Spanish sections after personal field observations, COMPANY and TAVERA (2015) and AGUADO *et al.* (2018). The positions of the published "possible Berriasian/Valanginian boundaries", based on data from VGL, are indicated by black arrows and are indicated by circled "1" and "2". For the legend see Fig. 2. Other abbreviations used: Alpil. = Alpillensis, u.Be. = upper Berriasian. Each bar in scale = 1 m.


ammonites
belemnites
early Haut.
Radiatus (p.p.)
late Valanginian
Furcillata
Peregrinus
Verucosum
Inostranzewi
early Valanginian
Neocomiensiformis
Pertransiens
I. Be.
Alpil.
Otopeta
Pertransiens
Hirsutus
Subcampylotoxus
Platycostatus
Pronecostatum
Nicklesi
Callidiscus
not zoned
Alpilensis
Salinar.
Dolloliformis
Contestanum
Verrucosum
no data
VGL
VBL
LCH
BLB

The earliest Valanginian belemnites (Pertransiens Z) in the pre-Vocontian Basin are largely dominated by taxa including *B.* gr. *conicus*, *C. orbignyanus*, *H.* aff. *pistilliformis*, and *M. blainvillei*, while *D. lata constricta* is common and a few typical Berriasian species occur rarely (*Castellanibelus* sp. E, *D. lata lata*, and *D. tornajoensis*). In the Hirsutus Sz a few characteristic belemnites have their FOs, including *C. vaubellensis* and *D. superconstricta*, while *B.* (gr.) *conicus*, *B. exstinctorius*, *C. orbignyanus*, *H.* aff. *pistilliformis*, and *M. blainvillei* occur abundantly. Above, in the Subcampylotoxus Sz, new taxa appear, such as, *D. crassa*, *D. hispanica*, and *H. lebresensis*, while *B. exstinctorius* becomes common but disappears shortly after.

Approaching the upper Valanginian, several earliest Valanginian species are replaced and characteristic species like *D. emericii* and *B. heres* occur. Eventually, though some species are already rare, the uppermost lower to lowermost upper Valanginian is characterized by the last occurrence (hereafter LO) of almost all taxa so far present (Figs. 3-4). Characteristic taxa that do not occur in stratigraphically younger sediments include: *Berriasibelus*, *Castellanibelus*, *Mirabelobelus*, *D. emericii*, *D.* gr. *lata*, and some species of *Hibolites* (see JANSSEN & CLÉMENT, 2002; data herein presented, Fig. 9). Only taxa that relate to *P. bipartitus* range up to the base of the Pronecostatum Sz succeeded by a new species herein called *Pseudobelus* sp. B.

This assemblage change is accompanied by the abundant occurrence of belemnites that are either homeomorphic, or identical to *H. jaculoides*. The latter species is well-known from the Boreal-Atlantic and Boreal-Arctic Provinces (eastern England, northern Germany, noth-east Greenland, Svalbard; SWINNERTON, 1937; MUTTERLOSE, 1978, 1990; DOYLE & KELLY, 1988; ALSEN & MUTTERLOSE, 2009).

In France, at least from the top of the Verrucosum Sz up to the Peregrinus Sz a specimen very similar to *H. jaculoides* (herein named *H.* aff. *jaculoides*) occurs regularly and commonly in abundance in the investigated sections in the distal areas. In addition, a few occurrences are recorded at the top of the Peregrinus Sz and the base of the Nicklesi Sz. Moreover, it constitutes a near mono-specific association in the sediments of the younger parts of the Verrucosum Zone in the more proximal parts of the Vocontian Basin (Fig. 8), and apparently disappears in the Nicklesi Sz.#

The post-Verrucosum-event succession is further characterized by *D. binervia* and *D. elongata*. In younger levels the genus *Adiakritobelus* occurs, while *H.* aff. *jaculoides* becomes rare and disappears. Now, *Adiakritobelus* become an important constituent of the belemnite associations and also the species that relate to *D. binervia* diversify further, with *D. gervaisiana*, *D. kleini*, *D. oehlerti* (however, so far not known from the southeast of France), and *D. variegata*. Several of the groups of species that characterize the upper Valanginian can be found up to and including the sediments that are attributed to the lowermost Hauterivian Radiatus Zone (Fig. 2), being replaced in the younger part of the latter zone by a different association of belemnites (cf. JANSSEN, 2009) characterized by *Duvalia* gr. *dilatata* and *Hibolites* gr. *subfusiformis*.

The distal - proximal trends in the distribution of the belemnites

In general, belemnites are more abundant and more diverse in distal sections, except for some condensed levels in the proximal areas. However, in distal sections, abundances and diversities fluctuate (Figs. 2-8). In the pre-Vocontian Basin belemnites appear most common in the Hirsutus Sz (Fig. 5), around the boundary between the lower and upper Valanginian (Figs. 3-4), and in the lowermost upper Valanginian (Fig. 3). This is partly explained by lithology, as this interval consists of more marly sediments; however similar marl dominated intervals in the upper Valanginian and uppermost lower Valanginian do not yield abundant belemnites. Therefore these differences in abundance are likely due to palaeoenvironmental causes, such as higher sea-levels, accommodation space, food-supply, and also selective processes due to mass-flows.

In the proximal areas, belemnites become significant from the uppermost lower Valanginian onwards (Fig. 8). They occur only very sporadically in older sediments. However, in PRY and GIN (Fig. 7; intermediate sections), the uppermost Berriasian and the lowermost Valanginian yield belemnites in abundance.

Some genera and/or species do occur solely in the distal parts of the basin, or are very rare in the more proximal parts, these include: *Berriasibelus*, *Castellanibelus*, and *Mirabelobelus*. While *Duvalia*, *Adiakritobelus*, and hibolitids are sometimes very common in the proximal parts, but also occur in the distal parts in abundance. Size differences are noted among some belemnites (see REBOULET, 2001, regarding ammonites) related to combinations of intrinsic and external factors, like species longevity, maturity time, temperature, environmental range, and food-supply. This is especially noticeable in *H.* aff. *jaculoides*. Rather robust specimens (Pl. 11, fig. 7) can be found in the more proximal sections (ALL, ACL) as compared to the distal area.

Belemnite zonation for the Valanginian

In the 19th century French researchers discriminated roughly between "Valanginian" (zone à *Belemnites bicanaliculatus*; zone à *Duvalia lata*/*conica*, zone à *Duvalia emericii*) and "Hauterivian" sediments (zone à *Belemnites dilatatus*). It was only recently (Table 2) that in the southeast of France, a preliminary proposal for a zonation based on belemnites was introduced in a congress abstract and a manuscript (GAYTE, 1982, 1984). This was based on duvaliids for parts of the Valanginian-Hauterivian, but without further explanation. This was partially copied and published by CHRISTENSEN and COMBÉMOREL (1998, chart 5), but has never been elaborated on or formalized (*e.g.*, no type section or bed-numbers were indicated).

More or less simultaneously with the latter paper, JANSSEN (1997) and CLÉMENT (1999) defined zonations based on belemnites from the Betic Cordillera (Spain) and the Barret-sur-Méouge area, respectively (Table 2). However, the first (JANSSEN, 1997) is no longer applicable as some of the material that was used for that zonation was misidentified (see JANSSEN, 2003, and subsequent papers), and the latter (CLÉMENT, 1999) was published as a master's thesis and never formalized. Eventually, JANSSEN and CLÉMENT (2002) divided part of the Valanginian sedimentary record into three assemblage zones based on the temporal distribution of belemnites based on a few sections in the southeast of France (Table 2).

Table 2: Different zonal schemes compared, as proposed by the various authors in the pre-Vocontian Basin. (A)Z = (ammonite) zone, (A)Sz = (ammonite) subzone, SBZ = superbiozone, BZ = biozone, Hor. = Horizon. BA = belemnite association. J&C = JANSSEN & CLÉMENT. For generic affiliation see text. Ammonite subzones in blue are (at the moment) not included in the recommended zonation, but are sometimes used in the papers indicated in the text.

		Gayte, 1984	Janssen,1997		Combémorel,1988		Clément, 1999		J.&C., 2002	herein	
AZ	ASz		SBZ	BZ	Z	Sz	Z	Hor.		Z	Sz
Radiatus		D. gervaisiana				D. gervaisiana				D. gervaisiana	A. robustus
	Callidiscus	D. clapiti						D. clapiti			D. gervaisiana
Furcillata	Furcillata	D. valnagensis		P. brevis			D. binervia	P. brevis		D. variegata	
	Nicklesi							D. maioriana	BA3		
Peregrinus	Peregrinus	D. emericii			D. emericii			D. hybrida			
	Pronecostatum		D. dilatata			P. bipartitus				D. elongata	Pseudobelus sp. B
Verrucosum	Neocomiensis						D. emericii	C. heres			D. elongata
	Verrucosum			D. emericii				D. emericii	BA2	D. emericii	D. emericii
Inostranzewi	Platycostatus										B. heres
	Inostranzewi							C. nov. sp. A		D. crassa	
Neocomiensiformis	Subcampylotoxus									D. superconstricta	
	Hirsutus	D. lata			D. lata		D. lata s.l.			C. orbignyanus	
Pertransiens								D. lata constricta	BA1		
Alpillensis	Otopeta									not zoned	
	Alpillensis										
Boissieri	Picteti		D. lata	P. bip.							

The framework for the zonation herein proposed is based on bed-by-bed correlation in the pre-Vocontian Basin, resulting in 6 zones (Fig. 10). All the Valanginian zones and subzones are defined by the FO (except for one) of the index species and are furthermore characterized by distinctive associations of belemnites. However, to date no species or assemblages of belemnites appear to clearly mark the position of the Berriasian-Valanginian boundary hitherto proposed in the pre-Vocontian Basin. Typical Valanginian belemnites (*C. orbignyanus*, *B. conicus*, *B. exstinctorius*, *M. blainvillei*, and *H.* aff. *pistilliformis*) occur already within the Pertransiens Zone, while a few typical Berriasian species have there LOs approximately there (Fig. 9).

Herein, the uppermost Berriasian has yielded several belemnites that appear to be restricted to this substage. However, to date, their exact distribution is as-of-yet unknown and it is out of the scope of this paper (but will be treated in a subsequent paper). Among others, these belemnites include: *B.* aff. *exstinctorius* sp. 1, *B. incertus*, *D. miravetesensis*, *D. papretravinensis*, *G. mayeri*, and *M.*? *orbignyi*.

The Berriasian-Valanginian boundary is defined by the FO of *C. darderi* (Fig. 6 indicated by (1.)) in VGL and is about 6 m higher as compared to this boundary based on ammonites (Fig. 6 indicated by (2.)).

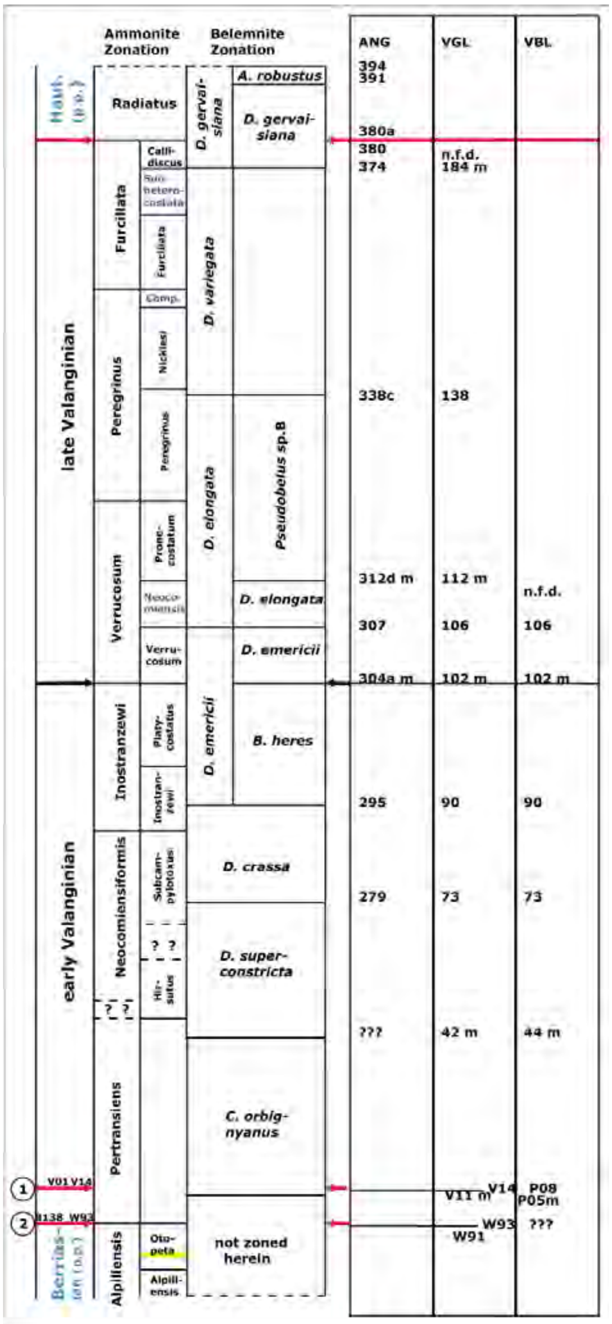


Figure 10: Stratigraphic (sub-)zonation for the Valanginian of the pre-Vocontian Basin. Circled "1" and "2" indicate possible position of Berriasian-Valanginian boundary. Yellow band indicates relative position of *Leptoceras* abundance. For generic affiliation of belemnites see text. Bed numbers in type sections (Cheiron-Angles, CHE-ANG; Vergol, VGL, and VBL, Vaubelle) are indicated, *e.g.*, bed "367 m" indicates marl on top of calcareous bed 367. In VGL the marl bed above V11 corresponds to B150 *sensu* Kenjo (Fig. 4). For further details and sections see Figs. 2-4. Abbreviations used: Comp. = Companyi, and Haut. = Hauterivian.

The following zonation based on belemnites is proposed for the pre-Vocontian Basin (Fig. 10). This zonation is based mainly on the succession of different species of *Duvalia* (Fig. 11) because they are generally common, sometimes abundant, have relatively short stratigraphic ranges, and probably the most easily recognizable among the various belemnite taxa. Herein "(Range) (Sub)Zones", "Taxon-range (Sub)Zones", and "Abundance (Sub)Zones" are defined based on the first appearance datum(s) (which are biohorizons; hereafter FAD). They are actually the FOs (lowermost documented occurrences of the taxon in the specific sections) combined.

(1) ***Castellanibelus orbignyanus* Zone**

Lower boundary definition: FAD of the index species (Pl. 7, figs. 7-10).

Secondary markers: FOs of *B. exstinctorius*, *B. conicus*, *H.* aff. *pistilliformis*, and *M. blainvillei*.

Correlation to Ammonite Zones: restricted to the Pertransiens zone.

Type section: VGL (interbed V11-12 to bed 042).

Auxiliary reference section: VBL (interbed P06-07 to bed 044).

Remarks: This is the first typical Valanginian belemnite association. The LOs of Berriasian taxa, such as *D. lata lata*, *D. lata constricta* and *D. tornajoensis* occur within this zone.

(2) ***Duvalia superconstricta* Taxon-range Zone**

Lower boundary definition: FAD of the index species (Pl. 7, figs. 27-28).

Definition: total range of the index species.

Secondary markers: total range of *C. vaubellensis*.

Correlation towards Ammonite Zone: From to the uppermost part of the Pertransiens zone to the middle part of the Neocomiensiformis Zone.

Type section: VGL (interbeds 042-043 to 072-073).

Auxiliary reference section: VBL (interbeds 044-045 to 072-073).

Remarks: several taxa are very abundant, especially *B.* gr. *conicus*, *C. orbignyanus*, and *M. blainvillei*. The FO of *H. lebresensis* is in the uppermost part.

(3) ***Duvalia crassa* Zone**

Lower boundary definition: FAD of the index species (Pl. 8, figs. 1-6).

Secondary markers: LOs of *B. exstinctorius*, *B. conicus*, *C. orbignyanus*, and *H.* aff. *pistilliformis*. In addition, the FO of *D. hispanica*, while *B.* aff. *exstinctorius* sp. 2 is restricted to this zone.

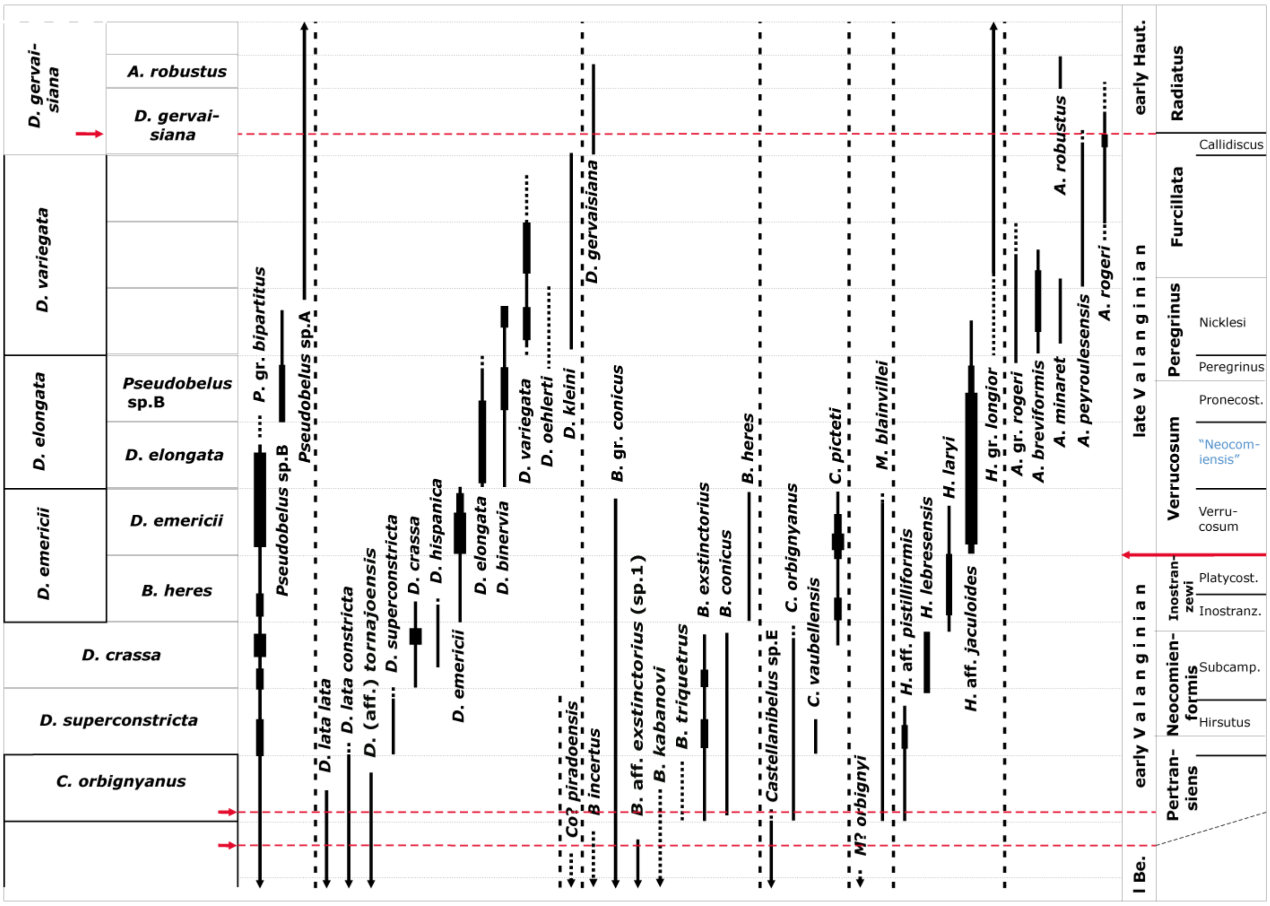


Figure 11: Distribution and relative abundances of the belemnites in the pre-Vocontian Basin. Here, "duration" of each belemnite-subzone (left column) is arbitrarily equalized. Ammonite subzones are indicated to the right. Stage and sub-stage boundaries are indicated by hatched red lines and red arrows. Abbreviations used: Haut. = Hauterivian, u.Be. = upper Berriasian.

Correlation to Ammonite Zones: Upper part of the Neocomiensiformis Zone to lower part of the Inostranzewi Zone.

Type section: VGL (bed 073 to interbed 089-090).

Auxiliary reference section: VBL (bed 073 to interbed 089-090).

Remarks: Most taxa common in the previous zone prevail here too. Gradually *Hibolites* become more abundant and *Pseudobelus* becomes more and more omnipresent and abundant. The FOs *C. picteti* and *H. laryi* is in the uppermost part.

(4) *Duvalia emericii* Zone

Lower boundary definition: FAD of index species (Pl. 8, figs. 9-10, 19-22).

Secondary marker: the FO of *B. heres*.

Type section: VGL (bed 090 to interbed 105b-106).

Correlation to Ammonite Zones: Inostranzewi to lower part of the Verrucosum Zone (Verrucosum Subzone).

Auxiliary reference section: ANG (bed 295 to interbed 306b2-307).

Remarks: *Pseudobelus* is very common and often abundant. This Zone includes two Subzones which mark the boundary between the lower and upper Valanginian.

(4a) *Berriasibelus heres* Subzone

Lower boundary definition: FAD of *D. emerici*.

Secondary marker: FO of *B. heres* (Pl. 8, figs. 23-27).

Correlation to Ammonite Zones: Restricted to the Inostranzewi Zone.

Type section: VGL (bed 090 to interbed 102-103).

Auxiliary reference section: ANG (bed 295 to interbed 304a-305).

Remarks: *Pseudobelus*, *C. picteti* and *H. laryi* are common.

(4b) *Duvalia emericii* Abundance Subzone

Definition: the abundant occurrence of the index-species.

Additional characteristics: the abundance occurrence of *H.* aff. *jaculoides*.

Correlation to Ammonite Zones: Restricted to the Verrucosum Subzone.

Type section: VGL (interbeds 102-103 to 105b-106).

Auxiliary reference section: ANG (interbeds 304a-305 to 306b2-307).

Remarks: Both diversity and abundances are generally high. The transition to the next Zone is marked by the so-called "Verrucosum-event" of

JANSSEN and CLÉMENT (2002). Herein, most of the typical early Valanginian taxa vanish.

(5) ***Duvalia elongata* Zone**

Definition: the total range of the index species (Pl. 9, figs. 21-22, 31-32).

Secondary marker: the FO of *D. binervia*.

Correlation to Ammonite Zones: Verrucosum Zone (from the "Neocomiensis" Subzone) to the Peregrinus Zone (chiefly Peregrinus Subzone).

Type section: VGL (interbeds 105b-106 to 137-138).

Auxiliary reference section: ANG (interbeds 306b2-307 to 338b-c).

Remarks: Characteristicly, the belemnite association is of low diversity and high abundance; in addition it is characterized by the size decrease of the *Pseudobelus* taxa and the general abundance of *H.* aff. *jaculoides*. This Zone includes two Subzones.

(5a) ***Duvalia elongata* Subzone**

Lower boundary definition: the FAD of the index species.

Secondary marker: the FAD of *D. binervia*.

Correlation to Ammonite Zones: Restricted to the "Neocomiensis" Subzone.

Type section: VGL (interbeds 105b-106 to 122-123).

Auxiliary reference section: ANG (interbeds 306b2-307 to 312d-e).

Remarks: *H.* aff. *jaculoides*, *Pb.* gr. *bipartitus* and the index species are (very) abundant, while the overall diversity is low.

(5b) ***Pseudobelus* sp. B Subzone**

Lower boundary definition: FAD of the index species (Pl. 10, figs. 1-4).

Correlation to Ammonite Zones: Pronecostatum Subzone to Peregrinus Subzone but for the uppermost part.

Type section: VGL (interbeds 122-123 to 137-138).

Auxiliary reference section: ANG (interbeds 312d-e to 338c).

Remarks: *Adiakritobelus* occurs first (*A.* gr. *rogeri* and *A. brevirostris*) in the uppermost part.

(6) ***Duvalia variegata* Zone**

Lower boundary definition: FAD of the index species (Pl. 10, figs. 13-18).

Secondary markers: FOs of *D. kleini* and *A. minaret*.

Correlation to Ammonite Zones: Uppermost part of the Peregrinus Subzone to Furcillata Zone (but for the Callidiscus Subzone).

Type section: VGL (interbeds 137-138 to 184-185).

Auxiliary reference section: ANG (beds 338c to 374).

Remarks: This zone is characterized by the radiation and dominance of *Adiakritobelus* taxa. Duvaliids become less abundant, and *H.* aff. *jaculoides* disappears from the assemblage. Tentatively this zone can be divided into intervals based on the succession of *Adiakritobelus* (abundance of *A. brevirostris* and *A. minaret*; FO of *A. peyroulensis*; FO of *A. rogeri*), but more material is needed to confirm the succession of assemblages. In addition, very elongated hibolitid belemnites (*H.* gr. *longior* and/or *Vaunagites*?) and *Pseudobelus* sp. A occur for the first time. With the exception of *Adiakritobelus*, the latter species typically characterize the sediments around the Valanginian-Hauterivian boundary.

(7) ***Duvalia gervaisiana* Zone**

Lower boundary definition: FAD of the index species (Pl. 10, figs. 25-28).

Upper boundary definition: FAD of *D. dilatata* (cf. JANSSEN, 2009, Fig. 11).

Correlation to Ammonite Zones: Callidiscus Subzone (topmost part of the Furcillata Zone) to the boundary between the Radiatus and Loryi Zone (not exactly known yet).

Type section: CHE (beds 374 to interbed 401-402).

Auxiliary reference section: ANG (beds 374 to interbed 401-402).

Remarks: Typical late Valanginian taxa, such as, *Duvalia* gr. *binervia* and *Adiakritobelus* disappear within this zone. Hibolitid taxa are relatively common. Apparently, *A. robustus* has a short range in the upperpart of this zone. This zone includes the Valanginian-Hauterivian boundary. It includes two Subzones and an undefined upper part.

(7a) ***Duvalia gervaisiana* Subzone**

Lower boundary definition: FAD of the index species.

Correlation to Ammonite Zones: Callidiscus Subzone to lower part of the Radiatus Zone.

Type section: CHE (bed 374 to interbed 390-391).

Auxiliary reference section: ANG (bed 374 to interbed 390-391).

Remarks: includes the LO *A. peyroulesensis*, while *A. rogeri* is relatively common. It includes the Valanginian-Hauterivian boundary.

(7b) ***Adiakritobelus robustus* Taxon-range Subzone**

Definition: total range of the index species (Pl. 12, figs. 7-9).

Correlation to Ammonite Zones: Part of the upper part of the Radiatus Zone.

Type section: CHE (beds 391-394).

Auxiliary reference section: ANG (beds 391-394).

Remarks: includes the LO of *D. gervaisiana*.

(7c) the upperpart of this zone is not subzoned.

The zonation above, as applied in the pre-Vocontian Basin, is chiefly defined on the FOs of belemnite taxa and correlated to ammonite datums available from various sources (see text above for references). Outside the investigated areas, ammonite datums might be available, but details about the temporal distribution of belemnites are generally lacking except for some sections in the southeast of Spain (Fig. 9). These sections have been investigated for ammonites by Company and Tavera (2015). Despite the relatively low abundances of belemnites, it is obvious that some differences occur between the ammonite and belemnite datums, which is especially apparent in the latest early Valanginian (the FO of *D. emericii*) and in the earliest late Valanginian (the FO of *H.* aff. *jaculoides*). Otherwise, the general succession of species seems to be comparable except for individual abundances.

Table 3: Ammonite (sub-) zonation versus Belemnite (sub-) zonation for the pre-Vocontian Basin. Ammonite subzones in blue are not (yet) formalized at the moment.

Sub-stage	Ammonite Zonation	Ammonite Subzonation	Belemnite Zonation	Belemnite Subzonation
	Radiatus		***D. gervaisiana***	***A. robustus***
upper Valanginian	**Furcillata**	**Callidiscus**		***D. gervaisiana***
		Furcillata	***D. variegata***	
	Peregrinus	**Nicklesi**		
		Peregrinus	***D. elongata***	***Pseudobelus* sp. B**
	Verrucosum	**Pronecostatum**		
		Neocomiensis		***D. elongata***
		Verrucosum	***D. emericii***	***D. emericii***
lower Valanginian	**Inostranzewi**	**Platycostatus**		***B. heres***
		Inostranzewi	***D. crassa***	
	Neocomiensiformis	**Subcampylotoxus**		
		Hirsutus	***D. superconstricta***	
	Pertransiens		***C. orbignyanus***	
		Pertransiens	**? ?**	
	Alpillensis	Otopeta Alpillensis	**not zoned herein**	

6. General and stratigraphic remarks about the belemnite taxa

Family Duvaliidae Pavlow, 1914

Genus *Duvalia* Bayle, 1878

Type: *Belemnites dilatatus* Blainville, 1827

Typically, members of this genus are more or less strongly compressed (laterally-compressed), characterized by a dorsally placed alveolar groove and an asymmetrical profile. Among the Valanginian *Duvalia* two morphological (stratigraphical) groups can be distinguished (Janssen, 2018), principally based on common taxa: the *lata*-group (Berriasian - early Valanginian) and the *binervia*-group (late Valanginian - earliest Hauterivian).

The *binervia*-group is characterized by strongly-compressed (laterally-compressed), small to medium sized rostra, with a short alveolar groove. The outline (lateral view) is leaf-like to elongated, while the profile (dorsal or ventral view) is hastate to elongate sub-conical. Principally, these taxa occur in the late Valanginian to earliest Hauterivian, except for their predecessor *D. emericii*, which first occurs in the latest early Valanginian. The *binervia*-group including its predecessor is derived through species that relate to the *lata*-group. The latter is especially abundant and diverse in the uppermost Berriasian (Alpillensis-Otopeta Sz) and lowermost Valanginian (Pertransiens Zone), but is much more uncommon throughout the rest of the lower Valanginian.

The *lata*-group includes: *D. lata constricta*, *D. lata lata* (Pl. 7, figs. 11-12), *D. miravetesensis* (Pl. 7, figs. 13-14), *D. tornajoensis* (Pl. 5, figs. 3-6), *D.* aff. *tornajoensis* (Pl. 5, figs. 7-8), *D. superconstricta* (Pl. 7, figs. 27-28), *D. crassa* (Pl. 8, figs. 1-6), and *D. hispanica* (Pl. 8, figs. 7-8, 11-14; Pl. 9, figs. 33-34). In between the *lata*- and the succeeding *binervia*-group, *Duvalia emericii* (Pl. 8, figs. 9-10, 19-22) is common in the uppermost lower Valanginian and lowermost upper Valanginian. In the upper Valanginian the *binervia*-group dominates (Fig. 2). The latter group is common both in the distal as well as the proximal parts of the basin. The *binervia*-group includes: *D. binerva* (Pl. 9, figs. 3-20, 23-30), *D. elongata* (Pl. 9, figs. 31-32; Pl. 10, figs. 11-12), *D. kleini* (Pl. 9, figs. 1-2), *D. variegata* (Pl. 10, figs. 13-18), *D. oehlerti* (Pl. 10, figs. 19-20), and *D. gervaisiana* (Pl. 10, figs. 25-28).

Genus *Berriasibelus* Delattre, 1952b

Type: *Belemnites exstinctorius* Raspail, 1829 (OD)

The genus occurs abundantly in the distal parts of the pre-Vocontian basin, is common in the intermediate sections, but appears to be very rare in the proximal settings investigated. Most of the specimens can be attributed to *B.* (gr.) *conicus* (Pl. 7, figs. 15-24) which is especially abundant in the Hirsutus Sz. In the investigated distal sections *B. exstinctorius* (Pl. 2, figs. 22-23) occurs regularly, being characterized by a sudden and strong lateral flattening (compression) of the apex, the broad alveolar groove, the deep alveolus and the short conical shape of the rostrum; it appears first in the lower part of the Pertransiens Zone and disappears in the uppermost lower Valanginian (Inostranzewi Zone). It is preceded by *Berriasibelus* aff. *exstinctorius* sp. 1 (Pl. 5, figs. 20-21, 24-25) which is characterized by a tapering-down-the-apex aspect of the rostrum and a well-rounded cross-section in the apical region, that lacks the lateral flattened apex. The youngest morphologically comparable specimens show a very robust outline (*B.* aff. *exstinctorius* sp. 2; Pl. 8, figs. 15-18). These rostra are succeeded by *Berriasibelus heres* (Pl. 8, figs. 23-27), disappearing in the lowermost upper Valanginian (Verrucosum Sz).

Typically, but being rare, *B. incertus* occurs in the uppermost Berriasian (Pl. 5, figs. 26-27) to lowermost Valanginian. The conglomerate in VBL yields a.o. *B. kabanovi* (Pl. 5, figs. 9-10) and *B. triquetrus.* The temporal distributions of the latter species are not yet known, but the few bed-by-bed records from Spain suggest occurrences in the uppermost Berriasian and possibly lowermost Valanginian (Fig. 4). Actually, the latter species does not occur together with *B. exstinctorius*, a characteristic early Valanginian taxon. Among the Duvaliidae, *Berriasibelus* appears to be the most abundant taxon in the lower Valanginian, followed by *Castellanibelus*.

Genus *Castellanibelus* Combémorel, 1972

Type: *Belemnites Orbignyanus* Duval-Jouve, 1841 (SD)

The genus occurs very abundantly in the distal parts of the basin, is common in intermediate sections, but appears to be very rare in the most proximal settings investigated. The genus occurs at least from the uppermost Berriasian onwards, ranging into the lowermost upper Valanginian (Verrucosum Sz). The latest Berriasian species is characterized by a rather elongated cylindrical rostrum (*Castellanibelus* sp. E; Pl. 5, figs. 1-2; Pl. 7, figs. 3-4). Most common is *C. orbignyanus* (Pl. 7, figs. 7-10). It first occurs in the lowermost Pertransiens Z, co-occurring with a robust morph (*C. vaubellensis*; Pl. 7, figs. 1-2) in the Hirsutus Sz and eventually being replaced by another near cylindrical morph in the uppermost lower Valanginian (*C. picteti*; Pl. 7, figs. 5-6).

Genus *Gillieronibelus* Janssen, 2003

Type: *Belemnites Mayeri* Gilliéron, 1873 (SD)

This genus occurs in the uppermost Berriasian, but reworked specimens can be found in the Pertransiens Z (lowermost Valanginian) at VBL (Fig. 4). The exact temporal distribution is not known, but it has been mentioned previously from the Paramimouna to Alpillensis Z from the southeast of Spain (Janssen, 2003). It is very rare in GIN (Pl. 5, figs. 28-30), but occurs quite in abundance in the conglomerate at VBL (Pl. 5, figs. 11-15).

Genus *Pseudobelus* Blainville, 1827

Type: *Pseudobelus bipartitus* Blainville, 1827 (SMT)

Pseudobelus occurs in fluctuating abundances from the distal to the more proximal areas. It is characterized by the 8-shaped cross-section of the *rostrum solidum*. Typically, the temporal distribution shows size decrease from the Berriasian into the upper Hauterivian (Rouville, 1872). *Pseudobelus* gr. *bipartitus* (Pl. 10, figs. 5-8) occurs at least from the upper Berriasian onwards, ranging into the lowermost upper Valanginian Pronecostatum Sz. Herein, it is replaced by a new species *Pseudobelus* sp. B; Pl. 10, figs. 1-4). In the uppermost Valanginian, from the topmost part of the Peregrinus Zone, another new species *Pseudobelus* sp. A (*sensu* Janssen, 2009) occurs.

Family Hibolitidae Nerodenko, 1983

Among this family, *Hibolites* dominates in the Valanginian, but abundances can fluctuate heavily. In addition, *Mirabelobelus* occurs quite abundant and regularly in the lower Valanginian but it is only in the upper Valanginian that various other genera appear, like *Adiakritobelus* and *Vaunagites*. However, so far, the latter, extremely elongated taxon is unequivocally known only from proximal areas (Combémorel & Gayte, 1981), and possibly Morocco (Mutterlose & Wiedenroth, 2008). Juvenile or sub-adult specimens might occur in more distal areas, but could not be recognized as such so far. Especially at the transition from the early to the late Valanginian, *Hibolites* become extremely abundant. They diminish in the late Valanginian in favour of *Adiakritobelus*. While in the Hauterivian and earliest Barremian, *Hibolites* become dominant again, while other genera like *Adiakritobelus* and *Vaunagites* disappear in the earliest Hauterivian. In the late Valanginian, at least from the Peregrinus Sz on, in the proximal facies, very elongated hibolitid belemnites occur (*Vaunagites* or *Hibolites* gr. *longior*), however, with a relatively short but clear alveolar groove.

Genus *Hibolites auctorum* (non *Hibolithes* DENYS de MONTFORT, 1808)

The monotypical genus *Hibolithes* DENYS de MONTFORT, 1808, is clearly an Early Cretaceous duvaliid. Given the taxonomic conundrum this implies, for which the solution is outside of the scope of this paper, the most commonly used 'alternative' is for the moment preferred.

Within the Valanginian taxa several hibolitid species can be distinguished. The lowermost Valanginian yields a slender very elongated hibolitid often without a clear alveolar groove (*H.* aff. *pistilliformis*; Pl. 11, figs. 10-13; note the figured specimens show a faint alveolar groove). This species is especially abundant in the Hirsutus Sz. It is succeeded by a less elongate, slightly depressed taxon with a clear alveolar groove, reaching well beyond the protoconch (*H. lebresensis*, Pl. 11, figs. 14-23) and eventually the less elongate, slightly stout, *H. laryi* (Pl. 11, figs. 8-9). The latter species is generally pitted by *Acrothoracia* and first occurs in the late early Valanginian and disappears in the earliest late Valanginian. Hereafter, the Valanginian hibolitids are dominated by the (sudden) appearance of *H.* aff. *jaculoides* (Pl. 11, figs. 1-7). It occurs from the Verrucosum Horizon onwards, being especially abundant in the younger parts of the Verrucosum Zone and is also very common in the proximal part of the basin. Apparently size differences exist between specimens from the proximal parts of the basin and those from the distal part of the basin. The specimens from the proximal areas appear to be more robust, or of larger size. This is a common phenomenon among cephalopods and probably relates a.o. to the availability of more food (REBOULET, 2001). Among the Tethysian hibolitids morphological variation, possibly expressed as dimorphism, has been suggested (GAYTE, 1984). After the Verrucosum-event *H.* aff. *jaculoides* is extremely common and abundant. However, it disappears in the Peregrinus Zone, in the base of the Nicklesi Sz, both in the proximal as well as in the distal areas. Apparently, both *Adiakritobelus* and *H.* gr. *longior* are the succeeding taxa. However, long elongated hibolitid taxa (*H.* gr. *longior*) occur already from the Peregrinus Sz on, at least in the proximal setting. They eventually gave rise to the extremely elongated *Vaunagites*.

Genus *Adiakritobelus* JANSSEN & FŐZY, 2004

Type: *Hibolites rogeri* DELATTRE, 1952a (OD)

A genus characterized by a hibolitid morphology, often more robust as compared to typical elongated and subhastate *Hibolites*. The genus occurs from the late Valanginian onwards, and disappears in the earliest Hauterivian. In the pre-Vocontian Basin, the genus is quite common. Both distal as well as proximal areas yield *Adiakritobelus* commonly. Among the first are *A. brevirostris* and *A. minaret* (Pl. 12, figs. 12-17). These are followed by the more elongate *A.* gr. *rogeri* and extremely elongate *A. peyroulesensis* (Pl. 12, figs. 1-6). The youngest species is very robust (*A. robustus*; Pl. 12, figs. 7-9). Outside the area of investigation the genus is so far rarely described or recognized. It occurs in Hungary (JANSSEN & FŐZY, 2004, Pl. II, figs. 11-12; and possibly BUJTOR *et al.*, 2013, Fig. 6.Q1-2), the southeast of Spain (Pl. 12, figs. 10-11, 16-17; JANSSEN, 2009, Pl. 5, figs. 11-13), the Czech Republic (VANKOVÁ & KOSTÁK, 2019), Rumania (CONSTANTIN, 2001), and Morocco (pers. obs.; specimens in the collection of WIEDENROTH, University of Bochum, Germany). However, they were neither mentioned nor figured by MUTTERLOSE and WIEDENROTH (2008).

Genus *Mirabelobelus* JANSSEN & CLÉMENT, 2002

Type: *Belemnites bicanaliculatus* BLAINVILLE, 1827 (OD)

This small sized genus is very common in the lower Valanginian in the pre-Vocontian Basin. Apparently, The FO of *Mirabelobelus blainvillei* is in the Pertransiens Z. Lateral lines can be well-developed giving the taxon a superficial pseudobeloid appearance. The Valanginian species shows some morphological plasticity (Pl. 12, figs. 24-39). Exceptionally, specimens show a short alveolar groove on the rostrum solidum. Lateral lines can be rather insignificant, like thin scratches, but often like in *Pseudobelus*, produce a symmetric 8-shaped cross-section of the rostrum. Size differences are apparent without clear indication of ontogenetical differences, some species appear more slender and elongate, while others appear stouter. However, in all specimens, the alveolar area is missing, apparently being very fragile or non-calcitic. It is only known from a few examples and a few specimens outside this geographical area (JANSSEN, 2003, Tornajo, Spain; coll. A. IPPOLITOV, Crimea).

Table 4: Distribution of belemnite taxa through various palaeogeographical areas. Taxa in blue are used as (sub-) zonal index taxa. Abbreviations used: Bg = Bulgaria, Ch = Switzerland, Cr = Crimea, CzS = Czech Republic + Slovakia, E = Spain, F = France, Hu = Hungary, Mor = Morocco, Ro = Romania, (d) = distal, (i) = intermediate, (p) = proximal, ? = unsure, x = present, xx = common, xxx = very common, and (#) = principally upper Berriasian taxon.

		F (d)	F (i)	F (p)	E (d)	E (i)	Ch	Hu	Cr	Ro	CzS	Bg	Mor
Adiakritobelus	spp.	xx		xxx	x	x	?	x	?	x	x		x
	brevirostris	xx		x									
	minaret	x		x		x							
	peyroulesensis	x		xx									x
	robustus	x		x				x					x
	rogeri	x		xx									
	rogeri gr.	x		xx	x								
Berriasibelus	*conicus*	xxx	xx	x	x	x	x	x	x	x	x	x	
	exstinctorius	xx	x		x		x		x		x	x	
	exstinctorius aff. sp. 1	x	x		x		?		x		x		
	exstinctorius aff. sp. 2	x											
	heres	x			x				x		?		x
	incertus	x	x		x	x		x	x		?		
	kabanovi	x			x			x	x				
	triquetrus	x			x				x		?		
Castellanibelus	*orbignyanus*	xxx	xx	x	xx	x	x	x	x	?	x	?	?
	picteti	xx		x		?	x						?
	sp. E (#)	x	x	x	x				x		?		
	vaubellensis	x	x										
Castellanibelus?	*bonti*					x							
Conobelus	spp. (#)	x				x	x		x		x		
Conobelus?	*piradoensis* (#)	x				x		x	x				?
Duvalia	*binervia*	x		x	x	x	x	x		x	x	x	x
	crassa	x	x		?	?							
	elongata	x		x	x	x							
	emericii	x		x	x	x		x		x	x	x	x
	gervaisiana	x		x						x			
	hispanica	x			x	x		x					
	hungarica (#)				x			x					
	kleini	x		x	x	x				x	?		
	lata constricta	x	x		x	x	x	x	x	x	x	x	x
	lata lata	x			x					x		x	
	miravetesensis (#)	x			x	x		x		x			
	oehlerti				x	x		?					
	papretravinensis (#)				x			x	x	?			
	superconstricta	x	x		x		x	?	x				?
	tornajoensis	x	x		x	x		x	x	x			
	tornajoensis aff.	x			x	x		x	x	x			
	variegata	x		x	x					x			
Gillieronibelus	*mayeri* (#)	x			x	x	x						
Hibolites	aff. *jaculoides*	x		x	x	x	x	x	?	x		x	
	laryi	x			?		x						
	lebresensis	x	x	x									
	longior gr.	x		x		x		x					x
	pistilliformis aff.	x	x		x	x	x						
	prodromus aff.					x		x	x				
Mirabelobelus	*blainvillei*	xxx	xx			x	x		x				
Mirabelobelus?	*orbignyi* (#)	x	xx		x								
Pseudobelus	*bipartitus* gr.	xxx	x	x	x	x	x	x	x	x	x	x	x
	sp. A	x		x	x	x		x					
	sp. B	x		x	x	x		x	x				
Vaunagites	spp.	?		x								?	?

Janssen and Clément (2002) originally include two species within this genus. The second is an enigmatic species depicted by Orbigny (1840), that originates from Andruze (= Anduze), north-east of GIN (Fig. 1). It is figured by Janssen (2003, Pl. 1, figs. 8-9; erroneously indicated as figs. 5-6 in plate explanation) from Mirabel and here refigured (Pl. 12, figs. 40-41). However, attribution to the genus is highly uncertain and most likely the figured specimen represents a duvaliid.

Mirabelobelus? *orbigny* is a late Berriasian species. It occurs in the Picteti and Alpillensis Z of PRY, the Alpillensis Z of GIN, and few species are known from the upper Berriasian (Picteti Z) of BME. Contrary to the type species, it shows a clear alveolar groove and the alveolar area is well-preserved. It is without the alveolar constriction seen in *M. blainvillei*. The pseudobeloid appearance, *i.e.*, the 8-shaped cross-section, is most apparent in the apical area. In this aspect there seems to be some relation to, or it is homeomorphic with, the Late Jurassic - early Berriasian "*Pseudobelus*" around *Belemnites zeuschneri* Oppel, 1865, or more like "*Pseudobelus*" gr. *pilleti* (Pictet, 1868; Pl. 12, figs. 42-46). Otherwise the apical area is characterized by some lateral compression, while the alveolar area shows a much more angular, rounded cross-section.

7. Conclusions

1.) Based on the temporal distribution of belemnites in the Valanginian of the Vergol, Vaubelle, and Angles-Cheiron sections, a zonal scheme for the pre-Vocontian Basin is presented (Table 4). The zonation is based on bed-by-bed distribution and correlation. The latter is, at least in the distal settings, possible from the Hirsutus Sz up to the Furcillata Sz. Lowermost Valanginian sediments are apparently not well correlatable resulting in a more tentative temporal distribution of the belemnite taxa.

2.) The stratigraphic distribution pattern of the belemnites, based on a combination of distinguished assemblages and subzonal indexes, seems to provide a comparable resolution as compared to the zonal scheme established for the ammonites (Fig. 11). However, both the lower as well as the upper boundary of the Valanginian do not exactly coincide with any species of belemnite, or any assemblage changes. Yet, the lower stage boundary, especially, appears to be recognizable by a suite of FOs of belemnites, see (3).

3.) The first typical Valanginian belemnites are *B. exstinctorius*, *B. conicus*, *C. orbignyanus*, *H.* aff. *pistilliformis*, and *M. blainvillei* (Figs. 6, 9). They show their FOs separated by a few beds only.

4.) Except for some long-ranging taxa (*D. lata constricta*, *P. bipartitus*), few typical Berriasian species extend their ranges into the earliest Valanginian (*Castellanibelus* sp.E, *D. lata lata*, *D. tornajoensis*).

5.) Differences exist between belemnite taxa and abundances in the proximal, intermediate, and distal parts of the basin that involves both genera and species. High abundances in the more proximal facies are often the result of condensation, but not always as can be seen from the large numbers of *H.* aff. *jaculoides* in both distal and proximal facies. *Berriasibelus*, *Castellanibelus*, and *Mirabelobelus* are (nearly) absent from proximal facies, while species of *Duvalia* are ubiquitous. *Adiakritobelus*, although having a more patchy distribution, appears to be quite common overall. Also *Pseudobelus* shows a patchy distribution in proximal facies, but seems to be most common in more distal facies (Figs. 2-9).

6.) The species *H.* aff. *jaculoides* occurs suddenly and in abunadnce, first in basinal, and later in more proximal facies. It originated most probably from the Boreal-Atlantic and would indicate that exchange was possible in that period. The population yields juvenile and adult specimens, indicating successful conditions. However, only a few occurrences are recorded in the top of the Peregrinus Sz and the base of the Nicklesi Sz, in which it disappears. In Spain, the taxon first occurs at the base of the Pronecostatum Sz. Either, the Neocomiensis Sz in France correlates with the base of the Pronecostatum Sz in Spain (Fig. 9), and/or there is a sampling bias, as differences in conditions between both areas, and/or (causing) a time delay in the spread of *H.* aff. *jaculoides*, seem to be unlikely.

7.) Regarding the newly established ammonite zonation of Company and Tavera (2015), it can be applied more easily to the proximal part of the basin, but appears to be more difficult in the more distal sections, either due to lacking ammonite data, or differences in the spatial distribution of some ammonite taxa.

8.) Validation of the proposed belemnite zonation outside the pre-Vocontian Basin is not yet possible because of the lack of sufficient bed-by-bed investigation of sections with respect to belemnites. Only a few sections have been investigated in the southeast of Spain and show several common species, but their ranges appear not always comparable, either due to the amount of available belemnites, uncertainty of some correlations, or the possible absence of some species (Fig. 9). The same holds true for the moment for other areas, such as, Hungary (Hu), the Crimea (Cr), the Czech Republic and Slovakia (CzS), Bulgaria (Bg), Romania (Ro), Switzerland (Ch), and Morocco (Mor) (Tab. 4).

Acknowledgements

Kind and warm gratitude goes to Willem Bont (Amsterdam, NL) for making the photos; Myette Guiomar and Didier Bert (Réserve géologique, Digne, F) for permission of sampling some protected sections; Arnaud Clément (Gap, F), Gero Moosleitner (Vienna, AT), and Paul Floor (Zwolle, NL) for sharing and donating materials; Martin Schobben and Bas van de Schootbrugge (Utrecht University, NL) for joining in some fieldwork and without the continuous contribution and inspiration of Jaap Klein (Vinkeveen, NL; Oraison, F) this work would not have been possible at all. Also, I would like to acknowledge the influence and inspiration of Wolfgang Riegraf on my work over the years, who unfortunately was lost to the coleoid community earlier this year.

Finally, I thank the reviewers Alexei Ippolitov, Oksana Dzyuba, and Simon F. Mitchell for their valuable suggestions and linguistic corrections that significantly improved this paper.

Bibliographic references

Aguado R., Company M. & Tavera J.M. (2000).- The Berriasian-Valanginian boundary in the Mediterranean region. New data from the Caravaca and Cehegín sections (SE Spain).- *Cretaceous Research*, vol. 21, no. 1, p. 1-21.

Aguado R., Company M., Castro J.M., Gea G.A. de, Molina J.M., Nieto L.M. & Ruiz-Ortiz P.A. (2018).- A new record of the Weissert episode from the Valanginian succession of Cehegín (Subbetic, SE Spain): Bio- and carbon isotope stratigraphy.- *Cretaceous Research*, vol. 92, p. 122-137.

ALSEN P. & MUTTERLOSE J. (2009).- The Early Cretaceous of North-East Greenland: A crossroads of belemnite migration.- *Palæaeogeography, Palæoclimatology, Palæoecology*, vol. 280, p. 168-182.

ARNAUD H., BULOT L.G. & THIEULOY J.-P. (1993).- Provence Platform (Berriasian to Barremian) Early Cretaceous backstepping, faunal renewals and sequence stratigraphy. *In*: ARNAUD H. & LEMOINE M. (eds.), Alpine Mesozoic basin in the South East of France.- *Field Course of the American Association of Petroleum Geologists*, Nice, vol. C5 (1992), p. 111-120.

ARNAUD H. (2005).- The South-East France Basin (SFB) and its Mesozoic evolution. *In*: The Hauterivian-Lower Aptian sequence stratigraphy from Jura Platform to Vocontian Basin: A multidisciplinary approach.- *Géologie Alpine*, Grenoble, série spéciale "Colloques et excursions", no. 7, p. 5-28.

ATROPS F. & REBOULET S. (1993).- Nouvelles données sur la zonation des ammonites du Valanginien supérieur de l'hypostratotype d'Angles (Alpes de Haute-Provence) et sur ses corrélations.- *Comptes Rendus de l'Académie des Sciences* (série IIa), Paris, t. 317, p. 499-506.

ATROPS F. & REBOULET S. (1995).- Le Valanginien-Hauterivien basal du bassin vocontien et de la bordure provençale : Zonations et corrélations.- *Comptes Rendus de l'Académie des Sciences* (série IIa), Sciences de la Terre et des Planètes, Paris, t. 320, p. 985-992.

AUTRAN G. (1993).- L'évolution de la marge nord-est provençale (Arc de Castellane) du Valanginien moyen à l'Hauterivien à travers l'analyse biostratigraphique des séries de la région de Peyroules : Séries condensées, discontinuités et indices d'une tectogenèse distensive. Paléobiologie.- *Annales du Muséum d'Histoire naturelle*, Nice, t. X, 240 p.

BAYLE E. (1878).- Fossiles principaux des terrains. Atlas.- *Explication de la Carte Géologique de France* (série 4), Paris, vol. 1 (158 Pls.).

BLAINVILLE H.M.D. de (1827).- Mémoire sur les bélemnites, considérées zoologiquement et géologiquement.- F.G. Levrault, Paris, Strasbourg, 136 p.

BLANC É. (1996).- Transect plate-forme - basin dans les séries carbonatées du Berriasien supérieur et du Valanginien inférieur (domaines jurassien et nord-vocontien). Chronostratigraphie et transferts des sédiments.- *Géologie Alpine*, Grenoble, Mémoire H.S. no. 25, 312 p.

BLANC É., BULOT L.G. & PAICHELER J.-C. (1994).- La coupe de réference de Montbrun-les-Bains (Drôme, SE France) : Un stratotype potentiel pour la limite Berriasien-Valanginien.- *Comptes Rendus de l'Académie des Sciences* (série IIa), Sciences de la Terre et des Planètes, Paris, t. 318, p. 101-108.

BUJTOR L., JANSSEN N.M.M. & VERREUSSEL R.M.C.H. (2013).- Early Cretaceous (Valanginian and Hauterivian) belemnites and organic-walled dinoflagellate cysts from a deep-marine hydrothermal vent site and adjacent facies of the Mecsek Mts., Hungary.- *Neues Jahrbuch für Geologie und Paläontologie*, Stuttgart, *Abhandlungen* 269, p. 135-148.

BULOT L.G. (1995, unpublished).- Les formations à ammonites du Crétacé inférieur dans le Sud-Est de la France (Berriasien à Hauterivien) : Biostratigraphie, paléontologie et cycles sédimentaires.- Doctoral thesis, Muséum national d'Histoire Naturelle, Paris, 399 p.

BULOT L.G. (compiler), BLANC É., COMPANY M., GARDIN S., HENNIG S., HOEDEMAKER Ph.J., LEEREVELD H., MAGNIEZ-JANNIN F., MUTTERLOSE J., POP G. & RAWSON P.F. (1996).- The Valanginian Stage. *In*: Proceedings "Second International Symposium on Cretaceous Stage Boundaries. Brussels 8-16 September 1995". - *Bulletin de l'Institut Royal des Sciences naturelles de Belgique*, *Sciences de la Terre*, Bruxelles, vol. 66-Supplement, p. 11-18.

BULOT L.G., BLANC É., THIEULOY J.-P. & REMANE J. (1993b).- La limite Berriasien-Valanginien dans le Sud-Est de la France : Données biostratigraphiques nouvelles.- *Comptes Rendus de l'Académie des Sciences* (série II), Paris, t. 316, p. 1771-1778.

BULOT L.G. & THIEULOY J.-P. (1995).- Les biohorizons du Valanginien du Sud-Est de la France : Un outil fondamental pour les corrélations au sein de la Téthys occidentale.- *Géologie Alpine*, Grenoble, Mémoire H.S., no. 20 (1994), p. 15-41.

BULOT L.G., THIEULOY J.-P., ARNAUD H. & DELANOY G. (1995).- The Lower Cretaceous of the South Vocontian basin and margins. The Lower Cretaceous Cephalopod Team. First Field Meeting (Digne, 1990).- *Géologie Alpine*, Grenoble, Mémoire H.S. no. 20 (1994), p. 383-399.

BULOT L.G., THIEULOY J.-P., BLANC É. & KLEIN J. (1993a).- La cadre stratigraphique du Valanginien supérieur et de l'Hauterivien du Sud-Est de la France : Définition des biochronozones et caractérisation de nouveaux biohorizons.- *Géologie Alpine*, Grenoble, t. 68 (1992), p. 13-56.

BUSNARDO R. (1979).- Aspect lithologique de la série étudiée.- *Les Stratotypes français*, Paris, vol. 6, p. 23-29.

BUSNARDO R. & COTILLON P. (1964).- Stratigraphie du Crétacé inférieur dans la région des gorges du Verdon (Basses-alpes et Var).- *Compte Rendu sommaire des Séances de la Société Géologique de France*, Paris, 1964, fasc. 8, p. 321-322.

BUSNARDO R., THIEULOY J.-P. & MOULLADE M. (1979).- Hypostratotype mesogéen de l'étage Valanginien (sud-est de la France).- *Les Stratotypes français*, Paris, vol. 6, 143 p.

CHRISTENSEN W.K. & COMBÉMOREL R. (1998).- Tethyan Belemnites. Cretaceous biochronostratigraphy. *In*: GRACIANSKY P.C. de, HARDENBOL J., JACQUIN Th. & VAIL P.R. (eds.) Mesozoic and

Cenozoic sequence chronostratigraphic framework of European basins.- *SEPM Special Publication*, no. 60, Chart 5.
CLÉMENT A. (1999, unpublished).- Étude paléontologique et biostratigraphique des Duvaliidae (Belemnitida) du Valanginien de la région des Baronnies (bassin vocontien, Sud-Est de la France).- Mémoire de Maîtrise des Sciences de la Terre, Paléontologie et Sédimentologie, Université Claude Bernard, Lyon, 25 p.
COMBÉMOREL R. (1972).- Position systématique de *Castellanibelus* nov. gen. et de trois espèces de Bélemnites du Crétacé inférieur français.- *Géobios*, Villeurbanne, no. 5, fasc. 1, p. 67-81.
COMBÉMOREL R. (1979).- Les bélemnites. *In*: BUSNARDO R., THIEULOY J.-P. & MOULLADE M. (eds.), Hypostratotype mésogéen de l'étage Valanginien (sud-est de la France).- *Les Stratotypes français*, Paris, vol. 6, p. 69-76.
COMBÉMOREL R. & GAYTE D. (1981).- *Vaunagites pistilliformis* (BLAINVILLE) n. gen. et *V. nemausina* n. sp., deux bélemnites remarquables du Crétacé inférieur du sud-est de la France.- *Géobios*, Villeurbanne, no. 14, fasc. 1, p. 105-113.
COMPANY M. & TAVERA J.M. (2015).- Lower Valanginian ammonite biostratigraphy in the Subbetic Domain (Betic Cordillera, southeastern Spain).- *Carnets Geol.*, Madrid, vol. 15, no. 8, p. 71-88.
CONSTANTIN M. (2001, unpublished).- Fauna de coleoidee de vârstă Cretic inferior din Bazinul Dâmbovicioara.- Facultatea de Geologie şi Geofizică, Universitatea din Bucureşti, p. 1-34 (9 Pls.).
COTILLON P. (1971).- Le Crétacé inférieur de l'arc subalpin de Castellane entre l'Asse et le Var, stratigraphie et sédimentologie.- *Mémoires du Bureau des Recherches Géologique et Minières*, Paris, no. 68, 313 p.
COTILLON P. (1988).- La sédimentation pélagique dans le bassin vovontien au Crétacé. *In*: FERRY S. & RUBINO J.-L. (eds.), Eustatisme et séquences de dépôt dans le Crétacé du Sud-Est de la France (livret-guide de l'excursion du Groupe Français du Crétacé en fosse vocontienne, 25-27 mai 1988).- *GéoTrope*, Villeurbanne, vol. 1, p. 8-12.
COTILLON P., FERRY S., GAILLARD C., JAUTÉE E., LATREILLE G. & RIO M. (1980).- Fluctuation des paramètres du milieu marin dans le domaine vocontien (France Sud-Est) au Crétacé inférieur : Mise en évidence par l'étude des formations marno-calcaires alternantes.- *Bulletin de la Société Géologique de France* (série 7), Paris, t. XXII, no. 5, p. 735-744.
DAVID B. (1979, unpublished).- Les *Toxaster* (échinides, Spatangoïdes) de l'éocrétacé subalpin de Castellane.- Thèse de la faculté des sciences et des techniques de l'Université de Franche-Comté, Besançon, no. 328, 183 p.
DAVID B. (1980).- Un paléo-environnement de vasière circalittorale dans le Crétacé inférieur (Valanginien) de l'Arc de Castellane (Alpes de Haute-Provence).- *Bulletin de la Société Géologique de France* (série 7), Paris, t. XXII, no. 3, p. 463-468.
DELATTRE M. (1952a).- Deux nouvelles *Hibolites* du Crétacé inférieur. – *Bulletin de la Société Géologique de France* (série 6), Paris, t. 2, p. 41-45 (Pl. IIa).
DELATTRE M. (1952b).- Caractères et position systématique de *Berriasibelus extinctorius* (RASPAIL) nov. gen. (Bélemnites).- *Bulletin du Muséum National d'Histoire naturelle* (série 2), Paris, t. 24, no. 3, p. 321-327.
DENYS de MONTFORT P. (1808).- Conchyliologie systématique, et classification méthodique des coquilles ; offrant leurs figures, leur arrangement générique, leurs descriptions caractéristiques, leurs noms ; ainsi que leur synonymie en plusieurs langues. Tome 1.- F. Schoell, Paris, 409 p. (100 Pls.).
DOYLE P. & KELLY S.R.A. (1988).- The Jurassic and Cretaceous belemnites of Kong Karls Land, Svalbard.- *Skrifter Norsk Polarinstitutt*, Oslo, no. 189, 77 p.
DUMAS E. (1876).- Statistique géologique, minéralogique, métallurgique et paléontologique du département du Gard, 2ième partie.- Bertrand, Paris; Peyrot-Tinel, Nîmes; Brugueirolle, Allas, 735 p.
DUVAL-JOUVE J. (1841).- Bélemnites des terrains crétacés inférieurs des environs de Castellane (Basses-Alpes), considérées géologiquement et zoologiquement, avec la description de ces terrains.- *Académie des Sciences Naturelles de Paris*, 80 p.
FERRY S. (2017).- Summary on Mesozoic carbonate deposits of the Vocontian Trough (Subalpine Chains, SE France). *In*: GRANIER B. (ed.), Some key Lower Cretaceous sites in Drôme (SE France). Excursion du Groupe Français du Crétacé.- *Carnets de Géologie*, Madrid, ISBN13: 978-2-916733-13-5, CG2017_B01, p. 9-42. DOI: 10.4267/2042/62543
FERRY S., GROSHENY D., BACKERT N. & ATROPS F. (2015).- The base-of-slope carbonate breccia system of Céüse (Tithonian, S-E France): Occurrence of progradational stratification in the head plug of coarse granular flow deposits.- *Sedimentary Geology*, vol. 317, p. 71-86.
FERRY S. & MONIER P. (1987).- Note brève. Correspondances entre alternances marno-calcaires de bassin et de plate-forme (Crétacé du SE de la France).- *Bulletin de la Société Géologique de France* (série 8), Paris, t. III, p. 961-964.
FERRY S., POCACHARD J., RUBINO J.-L. & GAUTIER F. (1989).- Inversions magnétiques et cycles sédimentaires : Un premier résultat dans le Crétacé de la fosse vocontienne (S-E de la France).- *Comptes Rendus de l'Académie des Sciences* (série II), Sciences de la Terre, Paris, t. 308, p. 773-780.

FERRY S. & RUBINO J.-L. (1988).- Séquences climato-eustatiques A, C, M ou modulation eustatique du signal orbital en fosse vocontienne. *In*: FERRY S. & RUBINO J.-L. (eds.), Eustatisme et séquences de dépôt dans le Crétacé du Sud-Est de la France (livret-guide de l'excursion du Groupe Français du Crétacé en fosse vocontienne, 25-27 mai 1988).- *GéoTrope*, Villeurbanne, vol. 1, p. 18-31.

FRANÇOIS É. & DAVID B. (2006).- Variations morphologiques des *Toxaster* (Echinoida : Spatangoida) en regard des fluctuations spatiales (Arc de Castellane, SE France) et temporelles (Valanginien-Hauterivien) du milieu sédimentaire : Expression d'un potentiel adaptatif restreint.- *Géobios*, Villeurbanne, no. 39, p. 355-371.

FRESNEAU C., DECONINCK J.-F., PELLENARD P. & REBOULET S. (2009).- Evidence of aerial volcanic activity during the Valanginian along the northern Tethys margin.- *Cretaceous Research*, vol. 30, no. 6, p. 533-539.

FRIREN A. (1876).- Mélanges paléontologiques. 1. *Orthoidea*, *Straparolus*, *Ammonites*, *Aulacoceras* & *Tisoa siphonalis* du Lias moyen.- *Bulletin de la Société d'histoire naturelle* (série 2), Metz, Cahier 4, p. 1-22 (2 Pls.).

GAILLARD Ch. (1980).- *Megagyrolithes ardescensis* n. gen., n. sp., trace fossile nouvelle du Valanginien d'Ardèche (France).- *Géobios*, Villeurbanne, no. 13, fasc. 3, p. 465-471.

GAYTE D. (1982).- Biostratigraphie du Valanginien et de l'Hauterivien fondée sur les *Duvalia* (Belemnitida).- *9e Réunion Annuelle des Sciences de la Terre*, Paris, 1982, p. 272.

GAYTE D. (1984, unpublished).- Le Valanginien et l'Hauterivien de la bordure cévénole méridionale. Biostratigraphie, paléontologie, sédimentologie.- Thèse de Docteur de 3ème Cycle, Université Claude Bernard, Lyon, 147 p.

GILLIÉRON V. (1873).- Aperçu géologique sur les Alpes de Fribourg en général et description spéciale du Monsalvens en particulier.- *Matériaux pour la Carte Géologique de la Suisse*, Berne, Livret 12, 268 p.

GIRAUD F., BEAUFORT L. & COTILLON P. (1995).- Periodicities of carbonate cycles in the Valanginian of the Vocontian Trough: A strong obliquity control. *In*: HOUSE M.M. & GALE A.S. (eds.), Orbital forcing timescales and cyclostratigraphy.- *Geological Society of London*, *Special Publication*, vol. 85, p. 143-164.

HENNIG FISCHER S. (2003, unpublished).- Geochemical and sedimentological evidence for environmental changes in the Valanginian (Early Cretaceous) of the Tethys Region.- Dissertation ETH Zurich, Nr. 15106, x + 189 + 45 p.

HÉRENGER L. (1944).- Spongiaires siliceux du Crétacé du sud-est de la France.- *Travaux du Laboratoire de Géologie*, Grenoble, t. XXIV (1943-1944), p. 1-32.

HERMITE H. (1879).- Études géologiques sur les Iles Baléares. Ière partie : Majorque et Minorque.- F. Pichon & F. Savy, Paris, 329 p.

JANSSEN N.M.M (1997).- Mediterranean Neocomian belemnites, part 1: Río Argos sequence (province of Murcia, Spain): the Berriasian-Valanginian and the Hauterivian-Barremian boundaries.- *Scripta Geologica*, Leiden, no. 114, p. 1-55.

JANSSEN N.M.M. (2003).- Mediterranean Neocomian belemnites, part 2: The Berriasian-Valanginian boundary in southeast Spain (Río Argos, Cañada Lengua and Tornajo).- *Scripta Geologica*, Leiden, no. 126, p. 121-183.

JANSSEN N.M.M. (2007).- Records of new species of Duvaliidae PAVLOW, 1914.- *Scripta Geologica*, Leiden, no. 135, p. 275-282.

JANSSEN N.M.M. (2009).- Mediterranean Neocomian belemnites, part 3: Valanginian-Hauterivian belemnites.- *Carnets Geol.*, Madrid, vol. 9, no. M01 (CG2009_M01), 44 p.

JANSSEN N.M.M. (2018).- Valanginian belemnites: New taxonomical and stratigraphical observations.- *Carnets Geol.*, Madrid, vol. 18, no. 7, p. 167-181.

JANSSEN N.M.M. & CLÉMENT A. (2002).- Extinction and renewal patterns among Tethyan belemnites in the Verrucosum Subzone (Valanginian) of southeast France.- *Cretaceous Research*, vol. 23, no. 6, p. 509-522.

JANSSEN N.M.M. & FŐZY I. (2004).- Neocomian belemnites from the Bersek-hegy (Gerecse Mountains, Hungary), part I: Late Valanginian to earliest Barremian.- *Fragmenta Palaeontologica Hungarica*, Budapest, vol. 22, p. 27-49.

KENJO S. (2014, unpublished).- Biostratigraphie intégrée à nannofossiles calcaires et ammonoïdes : Développement et implications pour la définition et la valorisation des stratotypes d'unité et de limite. L'exemple des étages Berriasien et Valanginien et de leur limite (~140 Millions d'années).- Thèse de l'Université de Lyon, Université Claude Bernard, no. 156, 273 p.

KENJO S., MATTIOLI E., REBOULET S., BERT D. & MA'LOULLEH K. (2014).- Integrated biostratigraphy of calcareous nannofossils and ammonoids. Implications for the definition of the stratotype of the Berriasian-Valanginian boundary (139.4 Ma).- *Strati*, Bern, 2013, p. 261-265.

KNAUST D. (2019).- The enigmatic trace fossil *Tisoa* de SERRES, 1840.- *Earth-Science Reviews*, vol. 188, p. 123-147.

LE DOEUFF D. (1977, unpublished).- Rythmes et contournements synsédimentaires en série carbonatée alternante : Reconstruction paléomorphologique au Crétacé inférieur dans les chaînes subalpines méridionales.- Thèse de l'Université Paris Sud, Paris XI, 239 p.

LE HÉGARAT G. (1973).- Le Berriasien du Sud-Est de la France.- *Documents des Laboratoires de Géologie de la Faculté des Sciences de Lyon*, Villeurbanne, no. 43, fasc. 1-2, 576 p.

LE HÉGARAT G. & FERRY S. (1990).- Le Berriasien d'Angles (Alpes-de-Haute-Provence, France).-

Géobios, Villeurbanne, no. 23, fasc. 3, p. 369-373.

LE HÉGARAT G. & REMANE J. (1968).- Tithonique supérieur et Berriasien de l'Ardèche et de l'Hérault. Corrélation des ammonites et des calpionelles.- *Géobios*, Villeurbanne, no. 1, p. 7-70 (10 Pls.).

LE HÉGARAT G. & REMANE J. (1973).- Excursion A. 2ème Journée : Alès - Nyons (231 km). *In*: Colloque sur la limite Jurassique-Crétacé (Lyon-Neuchâtel, 7-16 septembre 1973). Livret-Guide des excursions. Bordure cévenole, chaînes subalpines, Jura.- *Documents des Laboratoires de Géologie de la Faculté des Sciences de Lyon*, Villeurbanne, H.S. 1, p. 77-87.

MASSE J.-P., VILLENEUVE M., LEONFORTE E. & NIZOU J. (2009).- Block tilting of the North Provence Early Cretaceous carbonate margin: Stratigraphic, sedimentologic and tectonic data.- *Bulletin de la Société Géologique de France*, Paris, t. 180, no. 2, p. 105-115.

MAYER Ch. (1866).- Diagnoses de Bélemnites nouvelles.- *Journal de Conchyliologie* (série 3), Paris, t. 6, vol. 14, p. 358-369.

MCARTHUR J.M., JANSSEN N.M.M., REBOULET S., LENG M.J., THIRLWALL M.F. & SCHOOTBRUGGE B. van de (2007).- Palaeotemperatures, polar ice-volume, and isotope stratigraphy (Mg/Ca, $\delta^{18}O$, $\delta^{13}C$, $^{87}Sr/^{86}Sr$): The Early Cretaceous (Berriasian, Valanginian, Hauterivian).- *Palæogeography, Palæoclimatology, Palæoecology*, vol. 248, p. 391-430.

MUTTERLOSE J. (1978).- Ontogenie und Phylogenie der Belemnitenart *Hibolites jaculoides* SWINNERTON, 1937 aus dem Hauterivium (Unterkreide) von NW-Deutschland (Sarstedt) und NE-England (Speeton).- *Mitteilungen aus dem Geologischen Institut der Technischen Universität*, Hannover, Heft 16, p. 37-117.

MUTTERLOSE J. (1990).- A belemnite scale for the Lower Cretaceous.- *Cretaceous Research*, vol. 11, no. 1, p. 1-15.

MUTTERLOSE J., RAWSON P.F., REBOULET S., with contributions by BAUDIN F., BULOT L., EMMANUEL L., GARDIN S., MARTINEZ M. & RENARD M. (2020).- The Global Boundary Stratotype Section and Point (GSSP) for the base of the Hauterivian Stage (Lower Cretaceous), La Charce, southeast France.- *Episodes* (in press).

MUTTERLOSE J. & WIEDENROTH K. (2008).- Early Cretaceous (Valanginian – Hauterivian) belemnites from western Morocco: Stratigraphy and paleoecology.- *Cretaceous Research*, vol. 29, p. 814-829.

NERODENKO V.M. (1983).- Стратигафіне розровсюдження нижньокрейдових белемнітів [Stratigraphical research on Lower Cretaceous belemnites].- *Вісник Київського університету*, геологія, Kiev, 1983, V. 2, p. 41-50.

OPPEL A. (1865).- Die tithonische Etage.- *Zeitschrift der deutschen geologischen Gesellschaft*, Berlin, vol. 17, p. 535-558.

ORBIGNY A.D. d' (1840-1842 [1840]).- Paléontologie française. Description zoologique et géologique de tous les animaux mollusques et rayonnés fossiles de France, Tome 1 (1840-1842), Terrains Crétacés.- Chez l'auteur, Paris, part 1, 120 p. (36 Pls.).

PAQUIER V. (1900).- Recherches géologiques dans le Diois et les Baronnies orientales.- Allier frères, Grenoble, 402 + viii p. (8 Pls.) [also: *Annales de l'Université de Grenoble*, Paris, Grenoble, t. 12, p. 373-516, 551-806, i-viii (appendice paléontologique) (8 Pls.)].

PAVLOW A.P. (1914).- Les Céphalopodes du Jura et du Crétacé inférieur de la Sibérie septentrionale.- *Mémoires de l'Académie Impériale des Sciences* (série 8), Classe Physico-Mathématique, St.-Pétersbourg, vol. XXI (1913), no. 4, 68 p.

PICTET F.-J. (1867).- Études paléontologiques sur la faune à *Terebratula diphyoides* de Berrias (Ardèche).- *Mélanges paléontologiques*, Genève, livr. 1, p. 43-130 (8 Pls.).

PICTET F.-J. (1868).- Études provisoires des fossiles de la Porte-de-France, d'Aizy et de Lémenc.- *Mélanges paléontologiques*, Genève, livr. 4, p. 207-220 (1 Pl.).

RASPAIL F.V. (1829).- Histoire naturelle des bélemnites, accompagnée de la description et de la classification des espèces, que M. ÉMERIC de Castellane a recueillies dans les Basses-Alpes de Provence.- *Annales des Sciences d'Observation*, Paris, t. 1, p. 271-331.

REBOULET S. (1996).- L'évolution des ammonites du Valanginien-Hauterivien inférieur du bassin vocontien et de la plate-forme provençale (sud-est de la France) : Relations avec la stratigraphie séquentielle et implications biostratigraphiques.- *Documents des Laboratoires de Géologie de la Faculté des Sciences*, Villeurbanne, no. 137 (1995), 371 p.

REBOULET S. (2001).- Limiting factors on shell growth, mode of life and segregation of Valanginian ammonoid populations : Évidence from adult-size variations.- *Géobios*, Villeurbanne, no. 24, fasc. 4, p. 423-435.

REBOULET S. (2015, unpublished).- Le Valanginien du Bassin Vocontien : La coupe de Vergol (Montbrun-les-Bains, Drôme). *In*: Le Valanginien-Hauterivien inférieur du SE de la France : Les coupes de Vergol, La Charce et Cougourdas. 30 septembre - 2 octobre 2015. Livret-Guide des Excursions du Groupe Français du Crétacé.- HAL Archives, Villeurbanne, p. 7-32 [hal-01238133].

REBOULET S. (2017a).- Montbrun-les-Bains (Drôme, France, Vocontian Basin): A lower-upper Valanginian boundary. *In*: GRANIER B. (ed.), Some key Lower Cretaceous sites in Drôme (SE France). Excursion du Groupe Français du Crétacé.- *Carnets de Géologie*, Madrid, ISBN13: 978-2-916733-13-5, CG2017_B01, p. 6-7. DOI: 10.4267/2042/62543

REBOULET S. (2017b).- Montbrun-les-Bains (Drôme, France, Vocontian Basin): A Berriasian-Valanginian boundary. *In*: GRANIER B. (ed.), Some key Lower Cretaceous sites in Drôme (SE France). Excursion du Groupe Français du Crétacé.- *Carnets de Géologie*, Madrid, ISBN13: 978-2-916733-13-5, CG2017_B01, p. 8. DOI: 10.4267/2042/62543

REBOULET S. & ATROPS F. (1997).- Quantitative variations in the Valanginian ammonite fauna of the Vocontian Basin (southeastern France) within limestone-marl cycles and parasequence sets.- *Palæogeography, Palæoclimatology, Palæoecology*, vol. 135, p. 145-155.

REBOULET S., ATROPS F., FERRY S. & SCHAAF A. (1992).- Renouvellement des ammonites en fosse vocontienne à la limite Valanginien–Hauterivien.- *Géobios*, Villeurbanne, no. 25, fasc. 4, p. 469-476.

REBOULET S., RAWSON P.F., MORENO-BEDMAR J.A. (reporters), AGUIRRE-URRETA M.B., BARRAGÁN R., BOGOMOLOV Y., COMPANY M., GONZÁLEZ-ARREOLA C., IDAKIEVA-STOYANOVA V., LUKENEDER A., MARRION B., MITTA V., RANDRIANALY H., VAŠÍČEK Z., BARABOSHKIN E.J., BERT D., BERSAC S., BOGDANOVA T.N., BULOT L.C., LATIL J.-L., MIKHAILOVA I.A., ROPOLO P. & SZIVES O. (2011).- Report on the 4th International Meeting of the IUGS Lower Cretaceous Ammonite Working Group, the "KILIAN Group" (Dijon, France, 30th August, 2010).- *Cretaceous Research*, vol. 32, no. 6, p. 786-793.

REBOULET S., SZIVES O., AGUIRRE-URRETA M.B., BARRAGÁN R., COMPANY M., IDAKIEVA V., IVANOV M., KAKABADZE M, MORENO-BEDMAR J.A., SANDOVAL J., BARABOSHKIN E.J., ÇAĞLAR M.K., FŐZY I., GONZÁLEZ-ARREOLA C., KENJO S., LUKENEDER A., RAISSOSSADAT S.N., RAWSON P.F. & TAVERA J.M. (2014).- Report on the 5th International Meeting of the IUGS Lower Cretaceous Working Group, the "KILIAN Group" (Ankara, Turkey, 31st August 2013).- *Cretaceous Research*, vol. 50, p. 126-137.

REMANE J. (1960).- Les formations bréchiques dans le tithonique du sud-est de la France.- *Travaux du Laboratoire de Géologie de la Faculté des Sciences*, Grenoble, t. 36, p. 75-114 (4 Pls.).

REMANE J. (1973).- Introduction générale. *In*: Colloque sur la limite Jurassique-Crétacé (Lyon-Neuchâtel, 7-16 septembre 1973). Livret-Guide des excursions. Bordure cévenole, chaînes subalpines, Jura.- *Documents des Laboratoires de Géologie de la Faculté des Sciences de Lyon*, Villeurbanne, H.S. 1, p. 3-12.

REMANE J. & THIEULOY J.-P. (1973).- Coupe A. III-2 : Barret-les-Bas, Les Sausses. Excursion A. 3ème Journée : Nyons - Gap (158 km). *In*: Colloque sur la limite Jurassique-Crétacé (Lyon-Neuchâtel, 7-16 septembre 1973). Livret-Guide des excursions. Bordure cévenole, chaînes subalpines, Jura.- *Documents des Laboratoires de Géologie de la Faculté des Sciences de Lyon*, Villeurbanne, H.S. 1, p. 90-95.

ROBERT E. (1994, unpublished).- Caracterisation des séquences de dépôt du Valanginien et de l'Hauterivien par l'analyse d'une coupe de talus externe (Preynes, Commune de Beynes, Alpes de Haute-Provence).- Université Joseph Fourier, Grenoble, Mémoire Maîtrise de Géologie 1993-1994, 36 p.

ROUVILLE P.G. de (1872).- Sur le Néocomien du département de l'Hérault.- *Bulletin de la Société Géologique de la France* (série 2), Paris, t. 29, p. 723-731.

SALVADOR A. (1994).- International Stratigraphic Guide (2nd edition): A guide to stratigraphic classification, terminology, and procedure.- Boulder, IUGS & GSA, xix+214 p.

SANDY M.R. (1987).- Lower Cretaceous brachiopods from Provence, France, and their biostratigraphical distribution.- *Bulletin of the British Museum of natural History, Geology*, vol. 40, part 4, p. 177-196.

SERRES M. de (1840).- Description de quelques mollusques nouveaux des terrains infra-jurassique et de la craie compacte inférieure du Midi de la France.- *Annales des Sciences Naturelles* (série 2), Zoologie, Paris, t. XIV, p. 5-25 (2 Pls.).

SWINNERTON H.H. (1937).- A monograph of British Lower Cretaceous belemnites. Part 2.- *Monograph of the Palaeontological Society*, London, 1936, p. xvii-xxxii + 17-30 (Pl. VI-IX).

TANGRI A.K. (1980, unpublished).- Paléopentes, glissements synsédimentaires et reconstitution de bassin dans le domaine vocontien (Valanginien-Hauterivien de la zone subalpine méridionale des Alpes occidentales françaises).- Thèse de l'Université scientifique et medicale de Grenoble, 197 p.

THIEULOY J.-P. (1966).- Leptocères berriasiens du massif de la Grande-Chartreuse.- *Travaux Laboratoire Géologique*, Grenoble, t. 42, p. 281-295.

THIEULOY J.-P. (1973).- Le genre *Saynoceras* (Ammonoidea) et la zonéographie valanginienne dans l'Arc subalpine de Castellane (Alpes-de-Haute-Provence).- *Compte Rendu de l'Académie des Sciences* (série D), Paris, t. 276, p. 925-927.

THIEULOY J.-P. (1977a).- Les ammonites boréales des formations néocomiennes du Sud-Est français (province subméditerranéenne).- *Géobios*, Villeurbanne, fasc. 10, no. 3, p. 295-461.

THIEULOY J.-P. (1977b).- La zone à Callidiscus du Valanginien supérieur vocontien (Sud-Est de la France). Lithostratigraphie, ammonitofaune, limite Valanginien-Hauterivien, corrélations.- *Géologie Alpine*, Grenoble, t. 53, p. 83-143.

THIEULOY J.-P. (1979).- Les ammonites. Description des espèces indices et de quelques autres formes fondamentales.- *Les Stratotypes français*, Paris, vol. 6, p. 37-57.

THIEULOY J.-P., FUHR M. & BULOT L.G. (1991).- Biostratigraphie du Crétacé inférieur de l'Arc de Castellane (S.E. de la France). 1 : Faunes d'ammonites du Valanginien supérieur et âge de l'horizon dit de "La Grand Lumachelle".- *Géologie Méditerranéenne*, Marseille, t. XVII, no. 1 (1990), p. 55-99.

THOMEL G. (1964).- Le Crétacé des environs de Chabrières (Basses-Alpes).- *Bulletin de la Société Géologique de France* (série 7), Paris, t. V (1963), p. 333-344.

UHLIG V. (1902).- Ueber die Cephalopodenfauna der Teschener und Grodischter Schichten.- *Denkschriften der kaiserlichen Akademie der Wissenschaften*, *mathematisch-naturwissenschaftliche Classe*, Wien, Band 72 (1901), p. 1-87 (9 Pls.).

VANKOVÁ L. & KOŠTÁK M. (2019).- Upper Jurassic–Lower Cretaceous belemnites reveal the geological history of the Outer Western Carpathians (Czech Republic): Exemplified by the Štramberk cliff. *In*: FETEKE K., MICHALÍK J. & REHÁKOVÁ D. (eds.), Field trip guide and abstracts book.- XIV[th] Jurassica Conference, Workshop of the ICS Berriasian Group, Bratislava, p. 175-176.

VAŠÍČEK Z., JANSSEN N.M.M. & KLEIN J. (2016a).- The chronostratigraphical record of *Didayilamellaptychus* (Lamellaptychi, Ammonitina).- *Neues Jahrbuch für Geologie und Paläontologie*, Stuttgart, *Abhandlungen* 280/1, p. 37-48.

VAŠÍČEK Z., JANSSEN N.M.M. & KLEIN J. (2016b).- The distribution of *Thorolamellaptychus* and some rare *Mortilletilamellaptychus* (Cephalopoda) in the Valanginian of south-east France and Spain.- *Neues Jahrbuch für Geologie und Paläontologie*, Stuttgart, *Abhandlungen* 281/2, p. 111-121.

VAŠÍČEK Z., KLEIN J. & JANSSEN N.M.M. (2016c).- Ontogeny and variability in ribbing of Late Valanginian lamellaptychi (Ammonitina).- *Annales Societatis Geologorum Poloniae*, t. 86, p. 7-28.

VETTERS H. (1905).- Die Fauna der Juraklippen zwischen Donau und Thaya.- *Beiträge zur Paläontologie Österreich-Ungarns*, Wien, Band XVII (no. 4 for 1904), p. 223-259 (2 Pls.).

WEISS A.F. (1991).- Revision of the belemnite genus *Conobelus* STOLLEY, 1919.- *Paleontological Journal*, Moscow, 1991, no. 2, p. 18-33. [in Russian; translation in *Palaeontological Journal*, Virginia, vol. 25 (1992), p. 21-40].

WIPPICH M.G.E. (2001, unpublished).- Die tiefe Unterkreide (Berrias bis Unter-Hauterive) im Südwestmarokkanischen Becken: Ammonitenfauna, Bio- und Sequenzstratigraphie.- Dissertation Ruhr-Universität Bochum, 142 p.

Plates

Plate 1: fig. 1. Orientated group of belemnites (CLZ 104, Col Lazarier, Verrucosum Sz).;
fig. 2. *Pseudobelus* sp. B and aptychi on top of wavy calcilutite (on top of VGL121, Vergol, Pronecostatum Sz);
fig. 3. Porifera (*Pseudocavispongia stellata* HÉRENGER, 1944) VGL058-059, Vergol, Hirsutus Sz;
fig. 4. Porifera (*Verrucocoelia alpina*? HÉRENGER, 1944) VGL056-057, Vergol, Hirsutus Sz;
fig. 5. Porifera (*Verrucocoelia alpina* HÉRENGER, 1944) SCX, Hirsutus Sz (ex coll. THIEULOY);
figs. 6-7. Porifera (*Sporadopyle* sp.) VBL094-095, Vaubelle, Platycostatus Sz;
figs. 8-9. Porifera (*Sporadopyle obliqua* GOLDFUSS *sensu* HÉRENGER, 1944) SAM, Verrucosum Sz (ex coll. THIEULOY);
fig. 10. Porifera (*Craticularia* sp.) SAM, Source de l'Asse de Moriez, Verrucosum Sz (ex coll. THIEULOY);
fig. 11. Porifera (*Craticularia*? sp.) VGL049-050, Vergol, Hirsutus Sz;
fig. 12. *Xenocheilus malbosi* (PICTET, 1867) TM102, Terre Masse, Platycostatus Sz;
fig. 13. *Baronnites hirsutus* FALLOT & TERMIER, Vaubelle, VBL059-060, Hirsutus Sz;
fig. 14. Porifera (*Craticularia*? sp.) VGL049-050, Vergol, Hirsutus Sz;
fig. 15. Porifera (*Verrucocoelia alpina* HÉRENGER, 1944) just below PRY cplxA, Pertransiens Z;
fig. 16. Porifera (*Verrucocoelia alpina* HÉRENGER, 1944) just below PRY cplxA, Pertransiens Z;
fig. 17. Carapax of a crab from PRY cplxA-B, Pertransiens Z.


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17

Plate 2: Vaubelle:
fig. 1. Geographical situation. Indicated are the SVJ and VBL areas. White circle indicates the farm of Vaubelle. VBL sections are scattered over the hill called Serre Michel (725m). Box indicates position of fig. 2;
fig. 2. View to the west with beds of the Hirsutus to Platycostatus Sz. The latter beds are partially slumped, while below the Hirsutus Sz, the main slope of the south dipping strata is made by a calcarenitic bed VBL Psst. The strata north of the tree in the front yield *Busnardoites campylotoxus* (see fig. 3) and are from the Subcampylotoxus Sz becoming eventually "Neocomiensis Sz". Inbetween the so-called Barrande levels are visible (see figs. 4-5);
fig. 3. *Busnardoites campylotoxus* (M) with lappet from VBL085 (diameter approx. 15cm);
fig. 4. Barrande level B4, inbetween VBL088a-b. Hammer approx. 25 cm;
fig. 5. Barrande levels B1-3, inbetween VBL087a-b.

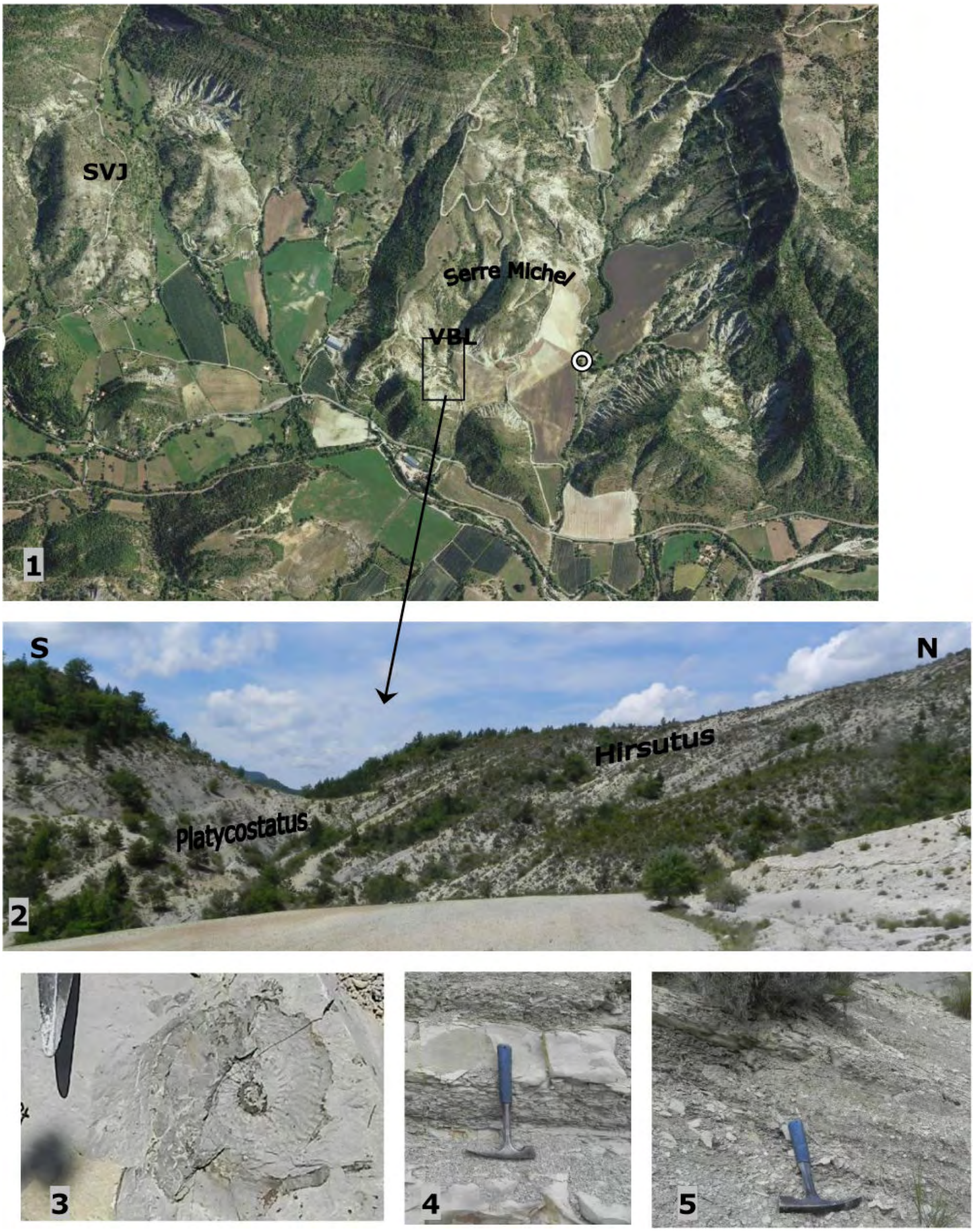

SVJ
Serre Michel
VBL
1
S
N
Hirsutus
Platycostatus
2
3
4
5

Plate 3: Vaubelle:
fig. 1. Slump, mass-flow, in "Big Canyon" (below Hirsutus Zone);
fig. 2. VBL P-beds (Pertransiens Zone) above conglomerate and calcarenite;
fig. 3. View on conglomerate and slump (below Hirsutus Sz) in "Big Canyon";
fig. 4. Conglomerate in middle mass-flow (VBL P20; Pertransiens Z);
fig. 5. Slumped beds in Platycostatus Sz;
fig. 6. View in "Small Canyon" with fault and slumps. VBL065 (top of Hirsutus Sz) to the left and VBL043 (below Hirsutus Sz) to the right. Note thin level with slumps below bed VBL043 (approx. 2m) as compared to figs. 1 and 3;
fig. 7. Detail of slump (VBL065) in "Small Canyon".

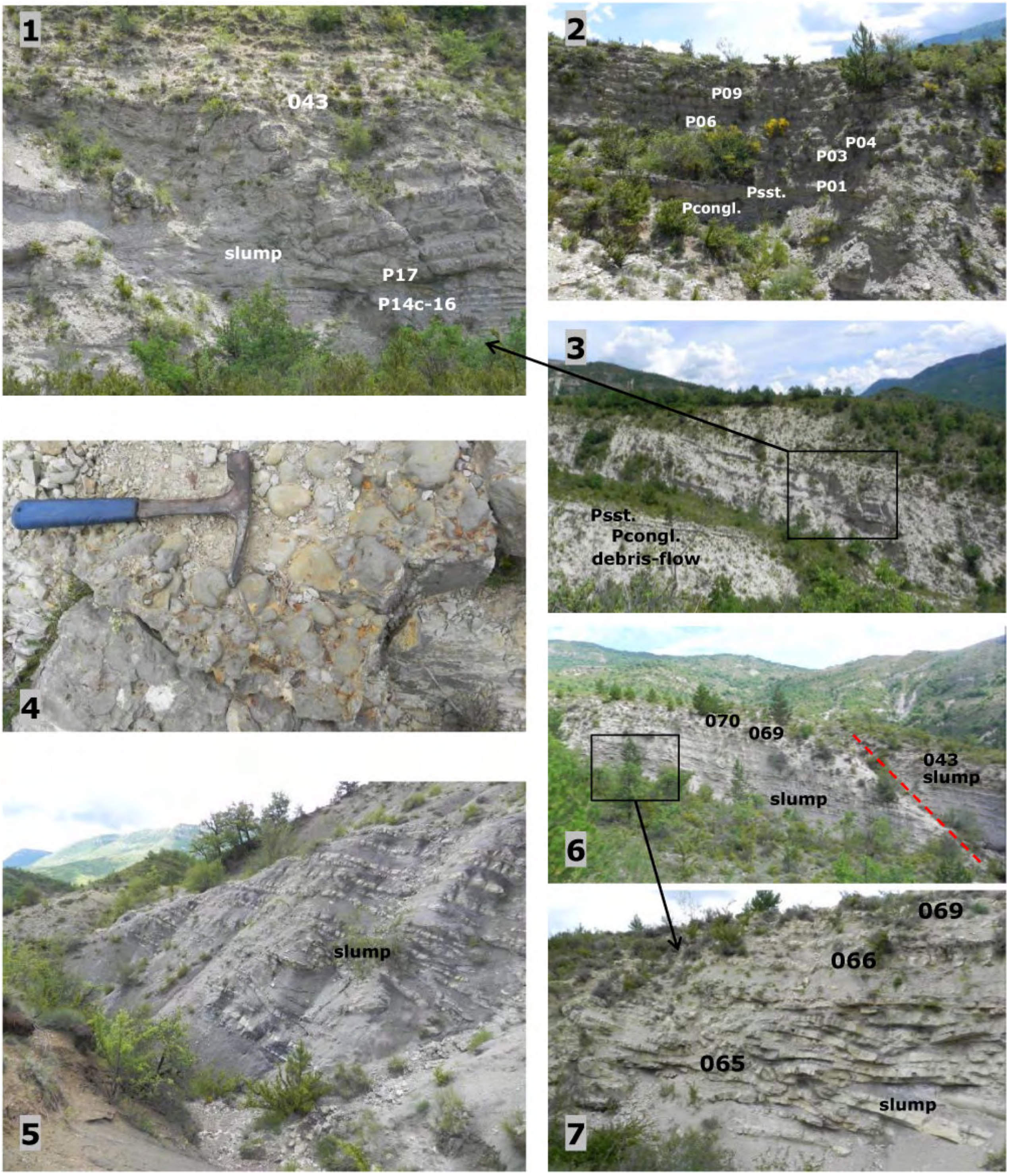

1
043
slump
P17
P14c-16
2
P09
P06
P04
P03
Psst.
P01
Pcongl.
3
Psst.
Pcongl.
debris-flow
4
5
slump
6
070
069
043
slump
slump
7
069
066
065
slump

Plate 4: Vaubelle and Vergol:
fig. 1. Conglomerate/debris flow, VBL B100; Alpillensis/Otopeta Sz;
fig. 2. Detail of fig. 1 (hammer 25 cm for scale);
fig. 3. Micro-conglomerate, VBL B100 (hammer 28 cm for scale);
fig. 4. *Kilianella chamalocensis* from bed VBL P02 (diameter approx. 7 cm);
fig. 5. Calcarenitic turbidite VBL042 (thickness 15 cm);
fig. 6. Beds VBL087b to VBL094 (Inostranzewi Z), south side of "small canyon";
fig. 7. Detail of fig. 9 showing aptyche-lumachelle (VBL P08; Pertransiens Z);
fig. 8. BARRANDE levels (B1-3, 4) at Vergol. Hammer (25 cm) for scale;
fig. 9. Beds VBL P06 to VBL P08, west side of "big canyon", with position of aptyche-lumachelle (see fig. 7).

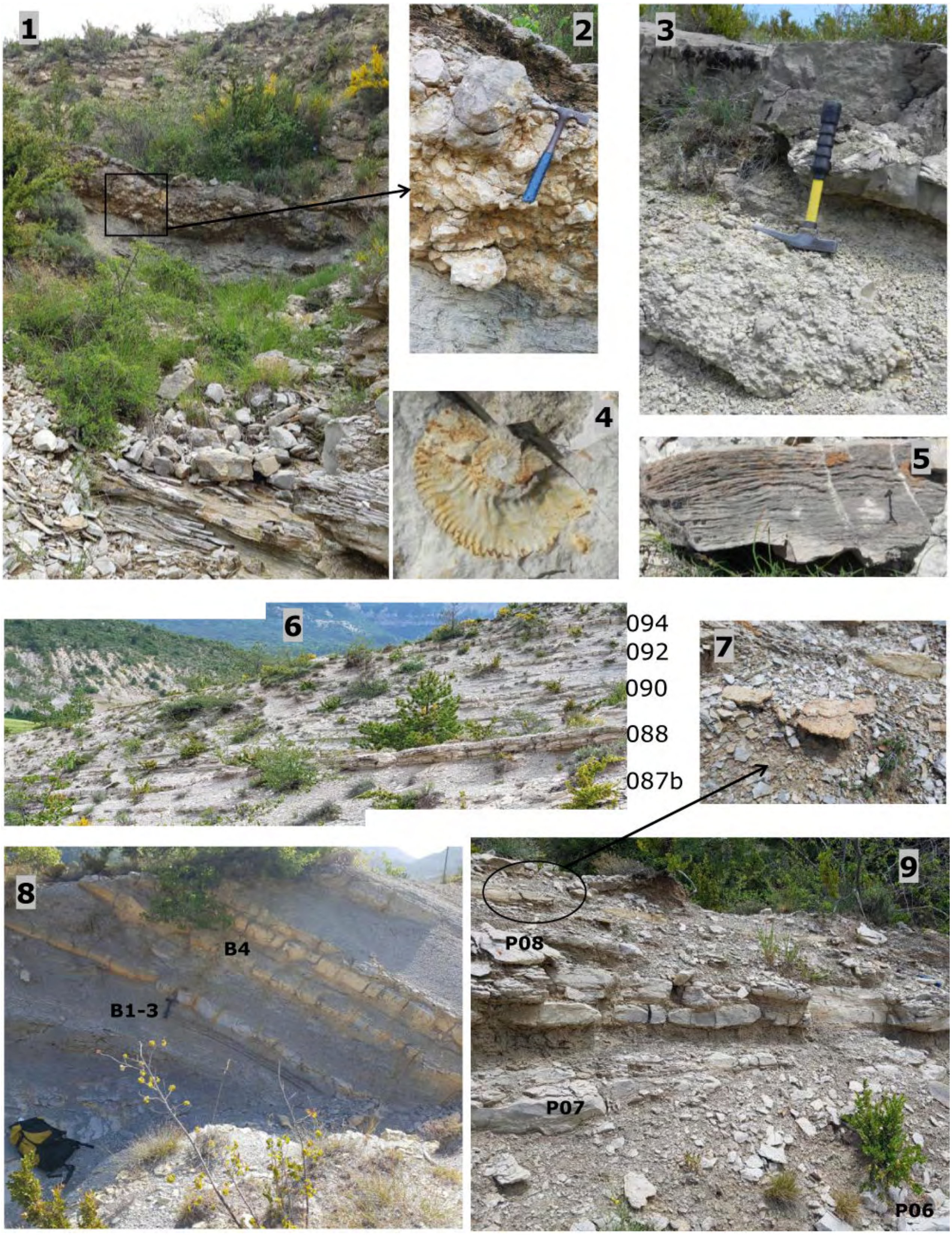

1
2
3
4
5
6
094
092
090
088
087b
7
8
B4
B1-3
9
P08
P07
P06

Plate 5: Preyes (PRY):
fig. 1. Preynes section, the farm of Preynes is just to the right of the picture. View approximately northeast. Note Valanginian-Hauterivian boundary is at the boundary with the plant growths in the upper part of the photo. Circled areas refer to the investigated lowermost Valanginian part;
fig. 2. Aerial picture with investigated sections. Farm of Preynes to the right of the circle. North is to the left side of the picture;
fig. 3. Details of calcareous complex E and F (Hirsutus Sz).;
fig. 4. Ichnofossils in upper part of investigated section. Coin (1 euro) for scale;
fig. 5. Section in upper part, blue line indicates boundary between calcareous dominated part and marly part with abundant ichnofossil-rich turbidites (see fig. 4). Complex K indicated, approximately boundary between Hirsutus and Subcampylotoxus Sz.

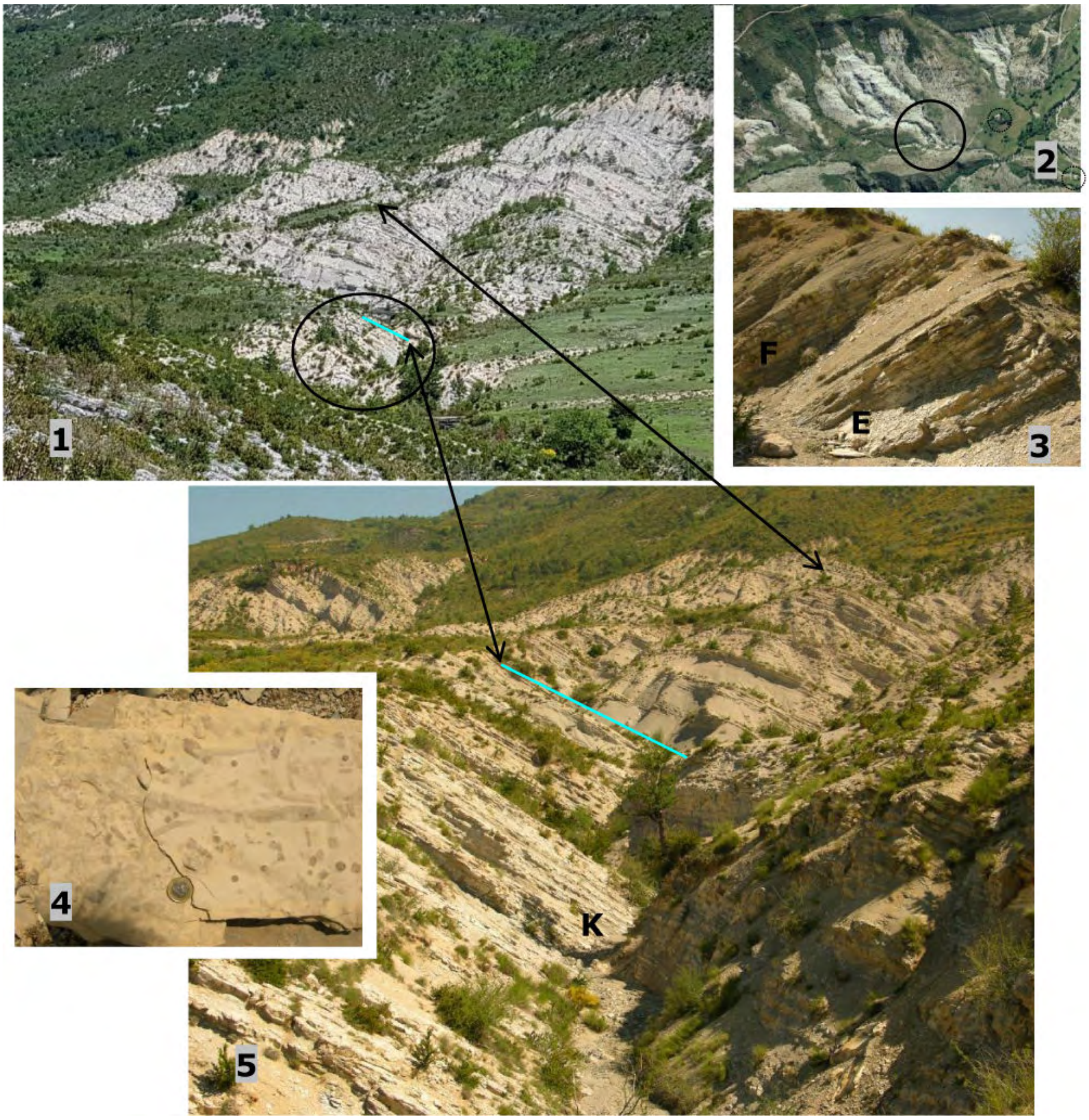

1
2
3
F
E
4
K
5

Plate 6: Berriasian belemnites:
figs. 1-2. *Castellanibelus* sp. E (juvenile), RGM613654, VBL B098, ?Alpillensis Z;
figs. 3-4. *Duvalia tornajoensis* Janssen, 2003, RGM613693, VBL B100 congl., Alpillensis Z;
figs. 5-6. *Duvalia tornajoensis* Janssen, 2003, RGM613536; VBL B098, ?Alpillensis Z;
figs. 7-8. *Duvalia* aff. *tornajoensis* Janssen, 2003, RGM613455, VBL B100 congl., Alpillensis Z;
figs. 9-10. *Berriasibelus kabanovi* Weiss, 1991, RGM612507, VBL B100 congl., Alpillensis Z;
figs. 11-13. *Gillieronibelus mayeri* (Gilliéron, 1873), RGM613696, VBL B100 congl., Alpillensis Z;
figs. 14-15. *Gillieronibelus mayeri* (Gilliéron, 1873), immature, RGM613464, VBL B100 congl., Alpillensis Z;
figs. 16-17. *Gillieronibelus mayeri* (Gilliéron, 1873), juvenile, RGM612162, GIN115d, Otopeta Sz;
figs. 18-19. *Conobelus* sp., RGM613646, VBL B100 congl., Alpillensis Z (reworked from ?Jacobi Z);
figs. 20-21. *B.* aff. *exstinctorius* sp. 1 (Raspail, 1829), RGM613703, VBL B100 congl., Alpillensis Z;
figs. 22-23. *Berriasibelus exstinctorius* (Raspail, 1829), RGM613678, VBL061-062, Hirsutus Sz;
figs. 24-25. *B.* aff. *exstinctorius* sp. 1 (Raspail, 1829), RGM612122, GIN114, Otopeta Sz;
figs. 26-27. *Berriasibelus incertus* (Weiss, 1991), RGM612083, GIN105-106, Otopeta Sz;
figs. 28-29. "*Pseudobelus*" gr. *pilleti* (Pictet, 1868), RGM613655, VBL B096, ?Alpillensis Z (probably reworked from the Jacobi Z or the Tithonian);
figs. 30-31. "*Pseudobelus*" gr. *pilleti* (Pictet, 1868), Saut de la Drôme, SLD15 (Jacobi Z, Grandis Sz; see Le Hégarat, 1973, p. 383);
figs. 32-33. "*Pseudobelus*" gr. *pilleti* (Pictet, 1868), Saut de la Drôme, SLD10-19 (Jacobi Z, Grandis Sz);

VBL and GIN; Dorsal view to the left unless otherwise indicated (d).

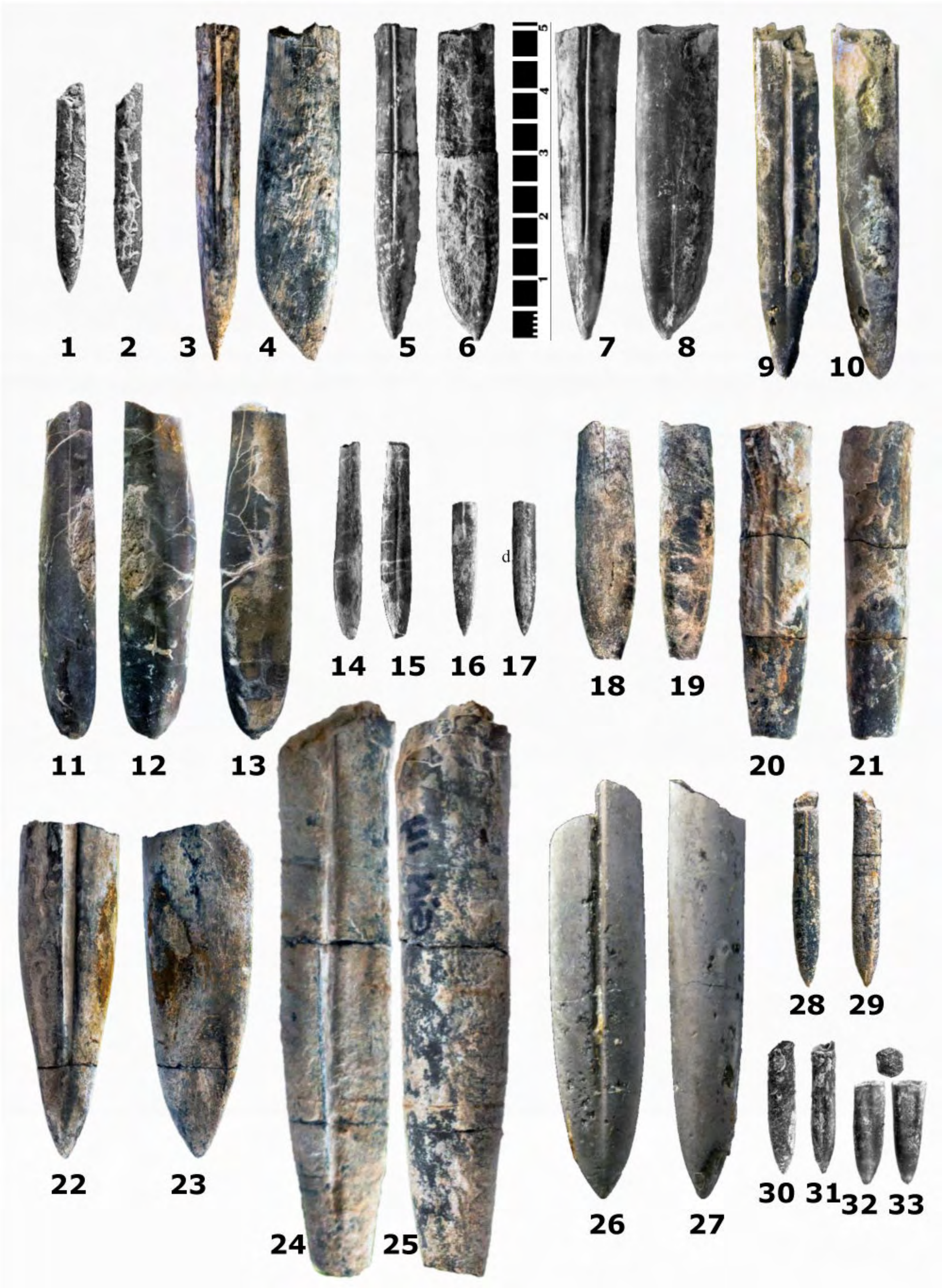

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33

Plate 7: figs. 1-2. *Castellanibelus vaubellensis* Janssen, 2018, RGM543617; PRY E-mid, Hirsutus Sz;
figs. 3-4. *Castellanibelus* sp.E; RGM612502; VBL B100 congl., Alpillensis/Otopeta Sz;
figs. 5-6. *Castellanibelus picteti* (Mayer, 1866), RGM613644, VBL094-095, Platycostatus Sz;
figs. 7-8. *Castellanibelus orbignyanus* (Duval-Jouve, 1841), RGM613479; VBL P09-10, Pertransiens Z;
figs. 9-10. *Castellanibelus orbignyanus* (Duval-Jouve, 1841), RGM613528, VBL P09-10, Pertransiens Z;
figs. 11-12. *Duvalia lata lata* (Blainville, 1827), RGM613527, VBL P08, Pertransiens Z;
figs. 13-14. *Duvalia miravetesensis* Janssen, 2003, RGM612512, VBL B100 congl., Alpillensis/Otopeta Sz;
figs. 15-16. *Berriasibelus conicus* (Blainville, 1827), RGM613052, VBL076-077, Subcampylotoxus Sz;
figs. 17-18. *Berriasibelus conicus* (Blainville, 1827), RGM613507, VBL062-063, Neocomiensiformis Z;
figs. 19-20. *Berriasibelus conicus* (Blainville, 1827), RGM612881, VBL076-077, Subcampylotoxus Sz;
figs. 21-22. *Berriasibelus conicus* (Blainville, 1827), RGM288400, CHE266-267, Hirsutus Sz, topotype.
figs. 23-24. *Berriasibelus conicus* (Blainville, 1827), RGM612941, VBL046-047, Hirsutus Sz;
figs. 25-26. *Conobelus*(?) *piradoensis* Janssen, 2003, RGM613529, VBL B100 congl., Alpillensis/Otopeta Sz;
figs. 27-28. *Duvalia superconstricta* Janssen, 2018, RGM612857, VBL052-053, Hirsutus Sz.

Dorsal view to the left unless otherwise indicated (d).

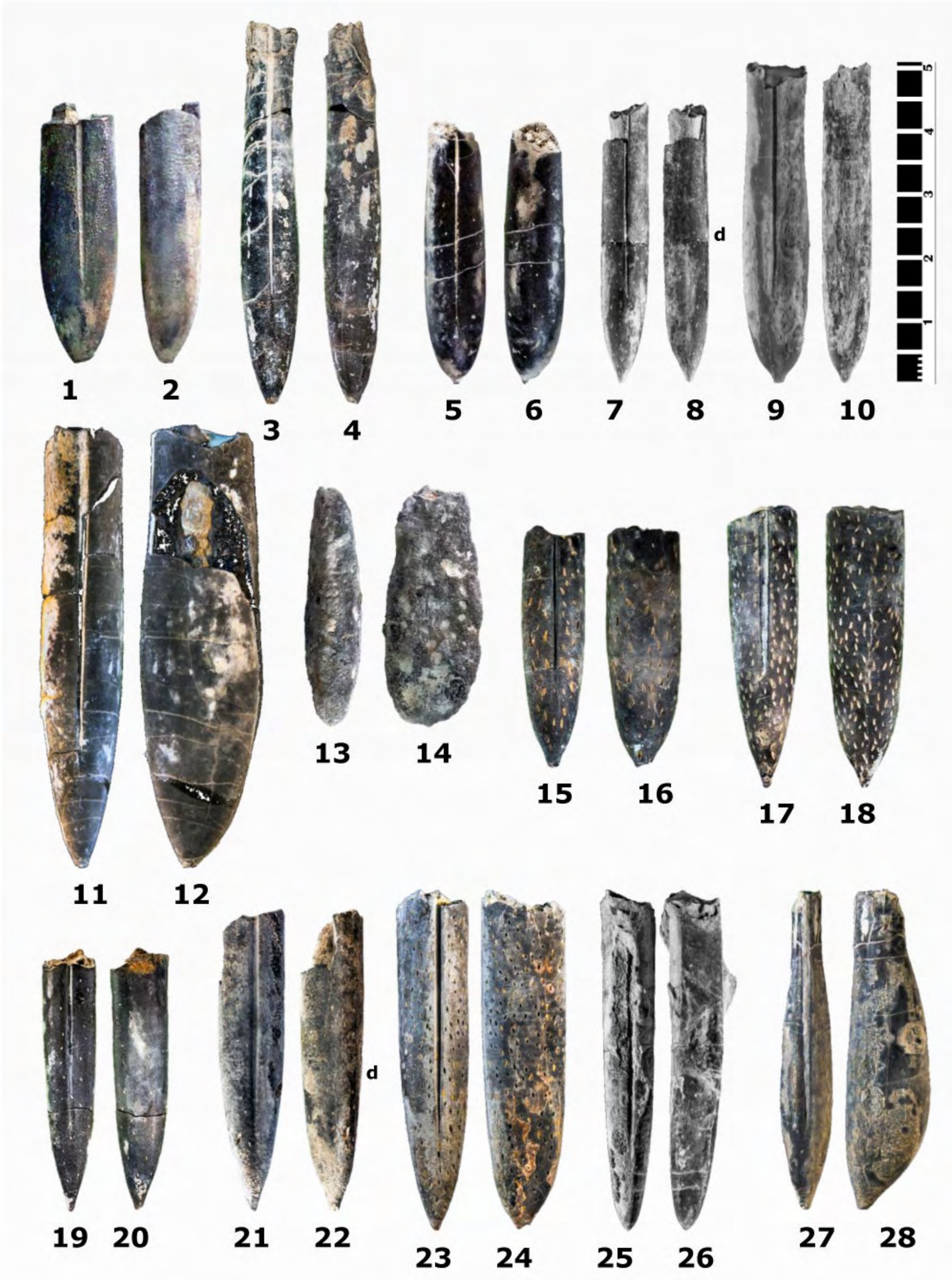

1
2
3
4
5
6
7
8
d
9
10
11
12
13
14
15
16
17
18
19
20
21
22
d
23
24
25
26
27
28

Plate 8: figs. 1-3. *Duvalia crassa* JANSSEN, 2018, RGM613215; VBL077, Subcampylotoxus Sz;
figs. 4-6. *Duvalia crassa* JANSSEN, 2018, RGM612897; VBL075b-076, Subcampylotoxus Sz;
figs. 7-8. *Duvalia hispanica* JANSSEN, 2007, immature, RGM613042; VBL075b-076, Subcampylotoxus Sz;
figs. 9-10. *Duvalia emericii* (RASPAIL, 1829) immature, RGM613030; VBL090 top, Inostranzewi Sz;
figs. 11-12. *Duvalia hispanica* JANSSEN, 2007 [refigured: text-fig. 4b-c], Spain, Tornajo, B75, Subcampylotoxus Sz;
figs. 13-14. *Duvalia hispanica* JANSSEN, 2007, juvenile, RGM613184; VBL084, Subcampylotoxus Sz;
figs. 15-16. *Berriasibelus* aff. *exstinctorius* (RASPAIL, 1829) sp. 2, RGM613011; VBL085-085a, Inostranzewi Sz;
figs. 17-18. *Berriasibelus* aff. *exstinctorius* (RASPAIL, 1829) sp. 2, RGM612847; VBL078-079, Subcampylotoxus Sz;
figs. 19-20. *Duvalia emericii* (RASPAIL, 1829) immature, RGM582396; VGL(099)-100, Platycostatus Sz;
figs. 21-22. *Duvalia emericii* (RASPAIL, 1829), RGM543175; CAR123-124, Neocomiensis Sz;
figs. 23-25. *Berriasibelus heres* WEISS, 1991, RGM288399 (coll. CLÉMENT); BLB104-105, Verrucosum Sz;
figs. 26-27. *Berriasibelus heres* WEISS, 1991 (= *Duvalia conica* (BLAINVILLE) *sensu* MUTTERLOSE & WIEDENROTH, 2008, p. 817), RGM288398 (coll. WIEDENROTH); Morocco, section A1, bed 100 (see WIPPICH, 2001, Anhang 4), Verrucosum Sz.

Dorsal view to the left unless otherwise indicated (d).


1
2
3
4
5
6
7
8
d
11
12
d
15
16
17
18
9
10
13
14
d
24
19
20
d
21
22
d
23
25
d
26
27

Plate 9: figs. 1-2. *Duvalia kleini* Janssen, 2018 (gr. *binervia*), RGM560708; SAM343b-c, Nicklesi Sz;
figs. 3-4. *Duvalia binervia* (Raspail, 1829), RGM560777; VPE328-329, Peregrinus Sz;
figs. 5-6. *Duvalia binervia* (Raspail, 1829), juv., RGM612897; VPE313-a, Pronecostatum Sz;
figs. 7-8. *Duvalia binervia* (Raspail, 1829), RGM560810a; VPE318-319, Pronecostatum Sz;
figs. 9-10. *Duvalia binervia* (Raspail, 1829), RGM560651; ANG-V325-326, Peregrinus Sz;
figs. 11-12. *Duvalia binervia* (Raspail, 1829), RGM561232; VGL122e-123, Pronecostatum Sz;
figs. 13-14. *Duvalia binervia* (Raspail, 1829), RGM561221; VGL123c-124, Peregrinus Sz;
figs. 15-16. *Duvalia binervia* (Raspail, 1829), RGM561482a; VGL107-a, Neocomiensis Sz;
figs. 17-18. *Duvalia binervia* (Raspail, 1829), RGM561482c; VGL107-a, Neocomiensis Sz;
figs. 19-20. *Duvalia binervia* (Raspail, 1829), teratologic, RGM561291; VGL118-119, Pronecostatum Sz;
figs. 21-22. *Duvalia elongata* Janssen, 2018, RGM543067; ACL098a, Peregrinus Sz;
figs. 23-24. *Duvalia binervia* (Raspail, 1829), RGM543078; ACL098a-b, Peregrinus Sz;
figs. 25-26. *Duvalia binervia* (Raspail, 1829), RGM583901; Y.G23-24, Spain, Pronecostatum Sz;
figs. 27-28. *Duvalia binervia* (Raspail, 1829) m. *hybrida* (Duval-Jouve, 1841), RGM583896; Y.G22-a, Spain, Pronecostatum Sz;
figs. 29-30. *Duvalia binervia* (Raspail, 1829), teratologic, RGM345481; LCH100-101, Pronecostatum Sz;
figs. 31-32. *Duvalia elongata* Janssen, 2018, RGM345470; LCH MKIII (slump), Neocomiensis Sz;
figs. 33-34. *Duvalia hispanica* Janssen, 2007, VBL089-90, Inostranzewi Sz.

Dorsal view to the left unless otherwise indicated (d).

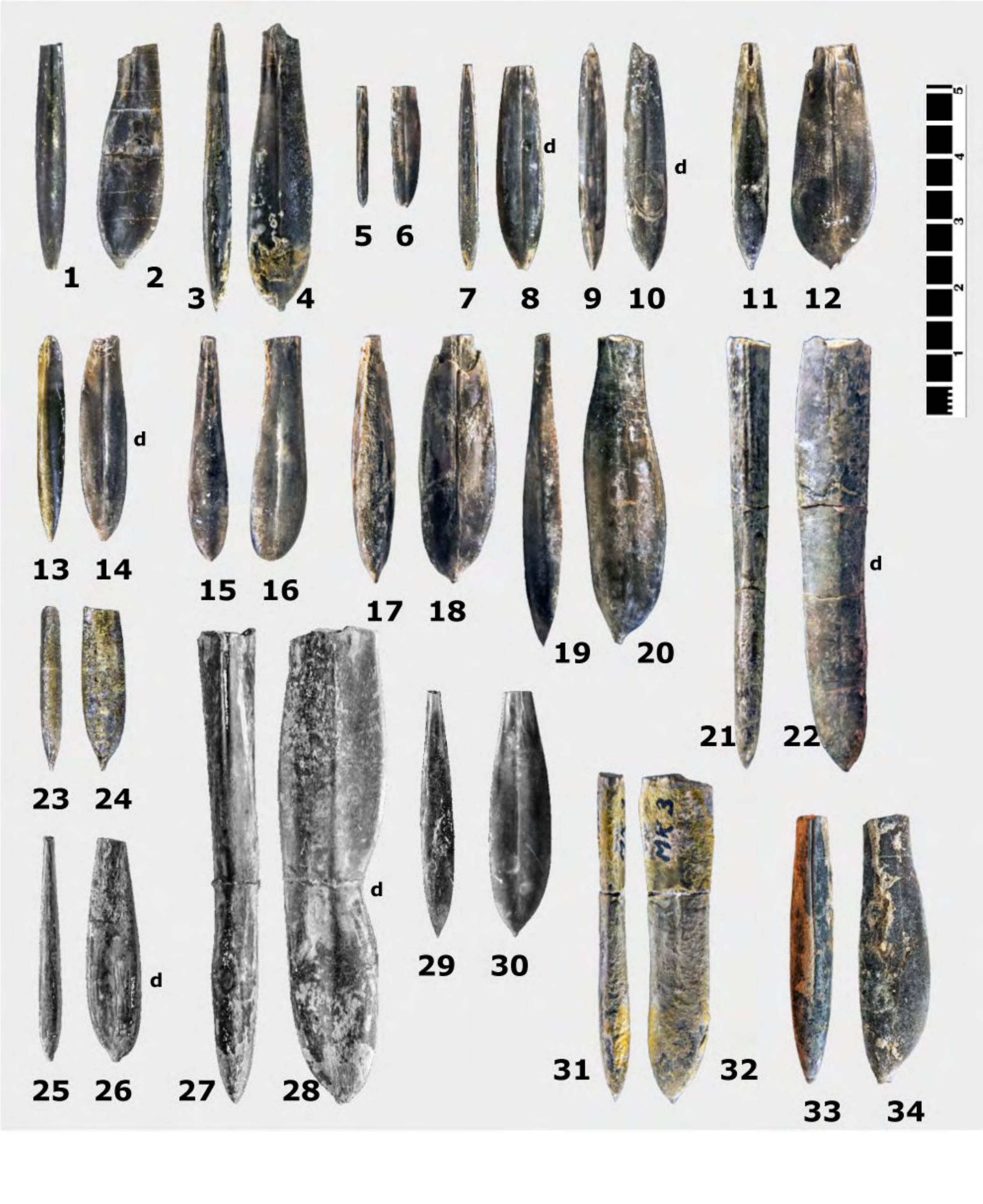

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
d
1
2
3
4
5
MK3

Plate 10: figs. 1-2. *Pseudobelus* sp. B, RGM560733; SAM320-321, Pronecoststum Sz;
figs. 3-4. *Pseudobelus* sp. B, RGM611814; LCH140-141, Nicklesi Sz;
figs. 5-6. *Pseudobelus* gr. *bipartitus* Blainville, 1827, RGM613712; VBL061-062, Hirsutus Sz;
figs. 7-8. *Pseudobelus* gr. *bipartitus* Blainville, 1827, RGM612146; GIN115b, Otopeta Sz;
figs. 9-10. *Pseudobelus* gr. *bipartitus* Blainville, 1827, RGM613458; VBL B100 congl., Alpillensis/Otopeta Sz;
figs. 11-12. *Duvalia elongata* Janssen, 2018, RGM560927; ANG-V307-308, Neocomiensis Sz;
figs. 13-14. *Duvalia variegata* (Raspail, 1829), RGM560706; SAM345-346, Nicklesi Sz;
figs. 15-16. *Duvalia variegata* (Raspail, 1829), RGM560621; ANG-V352b-c, Nicklesi Sz;
figs. 17-18. *Duvalia variegata* (Raspail, 1829), RGM583942; Spain, Y.G(47-53), Furcillata Sz;
figs. 19-20. *Duvalia oehlerti* (Hermite, 1879), RGM583912; Spain, Y.G31, Nicklesi Sz;
figs. 21-22. *Duvalia* gr. *binervia* (Raspail, 1829) (=? *variegata*), RGM543083; ACL098d-(099), Furcillata Sz;
figs. 23-24. *Duvalia* gr. *binervia* (Raspail, 1829) (=? *variegata*), RGM543082; ACL098c-(099), Furcillata Sz;
figs. 25-26. *Duvalia gervaisiana* (Dumas, 1876), juv., RGM543084; ACL104-105, Radiatus Z;
figs. 27-28. *Duvalia gervaisiana* (Dumas, 1876), RGM560590, CHE378, Radiatus Z. (= Pl. 7, figs. 23-24 in Janssen, 2009).

Dorsal view to the left unless otherwise indicated (d).

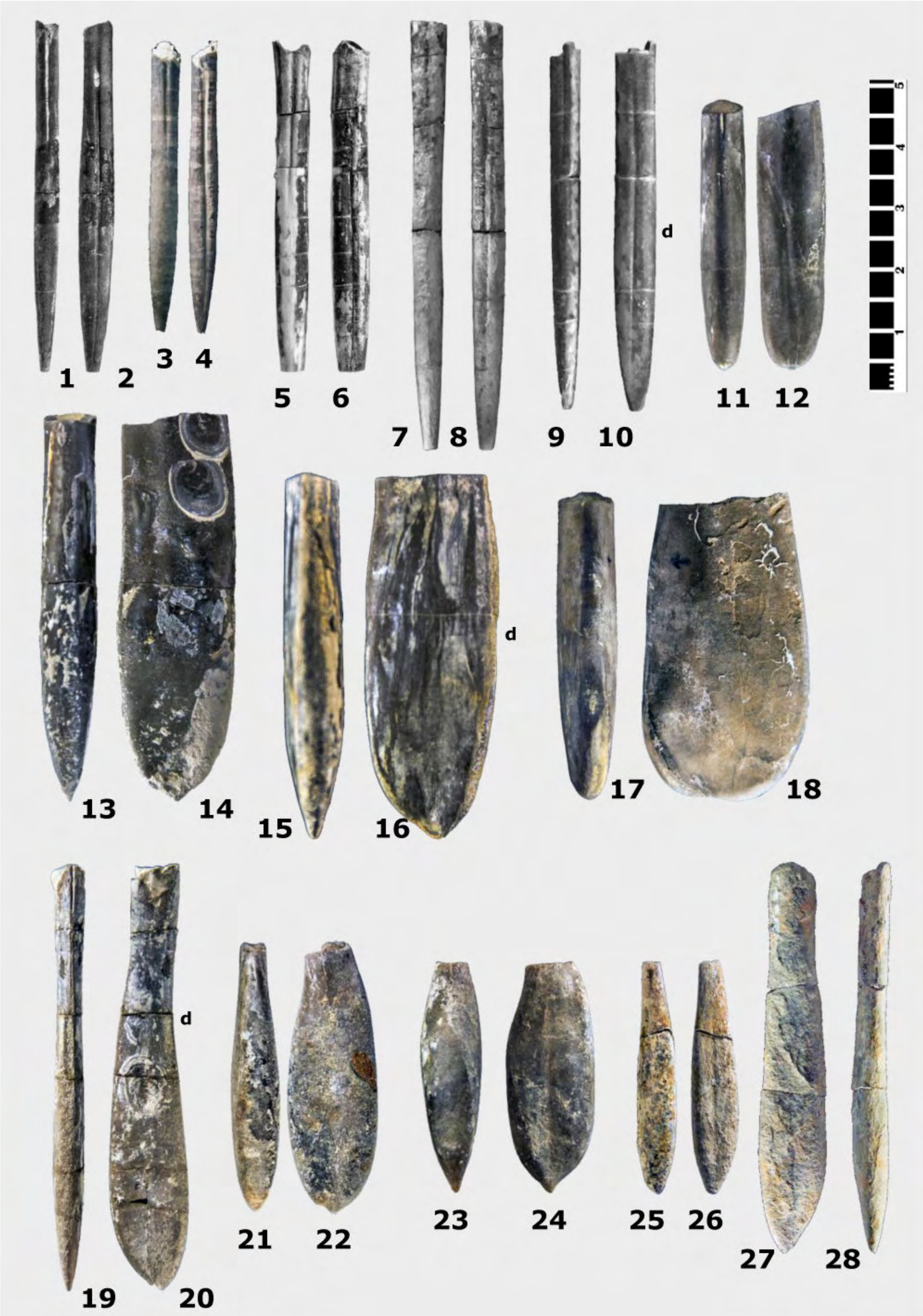

1
2
3
4
5
6
7
8
9
10
d
11
12
5
4
3
2
1
13
14
15
16
d
17
18
19
20
d
21
22
23
24
25
26
27
28

Plate 11: figs. 1-2. *Hibolites* aff. *jaculoides* SWINNERTON, 1937, RGM583889, Y.G16, Pronecostatum Sz;
figs. 3-4. *Hibolites* aff. *jaculoides* SWINNERTON, 1937, RGM561217, VGL128-129, Peregrinus Sz;
figs. 5-6. *Hibolites* aff. *jaculoides* SWINNERTON, 1937, VGL122a-e, Pronecostatum Sz;
fig. 7. *Hibolites* aff. *jaculoides* SWINNERTON, 1937, RGM543091, ACL094-095, Neocomiensis/Pronecostatum Sz;
figs. 8-9. *Hibolites laryi* (MAYER, 1866), RGM561000, ANG301-a, Platycostatus Sz;
figs. 10-11. *Hibolites* aff. *pistilliformis* (BLAINVILLE, 1827), RGM543603; PRY cplxB-C low, Pertransiens Z [apex reconstructed];
figs. 12-13. *Hibolites* aff. *pistilliformis* (BLAINVILLE, 1827), RGM612929, VBL046-047, Hirsutus Sz [apex reconstructed];
figs. 14-15. *Hibolites lebresensis* JANSSEN, 2018 imm., RGM613025; VBL087-088, Subcampylotoxus Sz;
figs. 16-17. *Hibolites lebresensis* JANSSEN, 2018, RGM613623; VBL075-a, Subcampylotoxus Sz. ("Fuhri" Sz);
figs. 18-19. *Hibolites lebresensis* JANSSEN, 2018, RGM613591, VBL071-072, Subcampylotoxus Sz;
figs. 20-21. *Hibolites lebresensis* JANSSEN, 2018, RGM613198, VBL086, Inostranzewi Sz;
figs. 22-23. *Hibolites lebresensis* JANSSEN, 2018, RGM613182; VBL082-083, Subcampylotoxus Sz.

Ventral view to the right unless otherwise indicated (v).

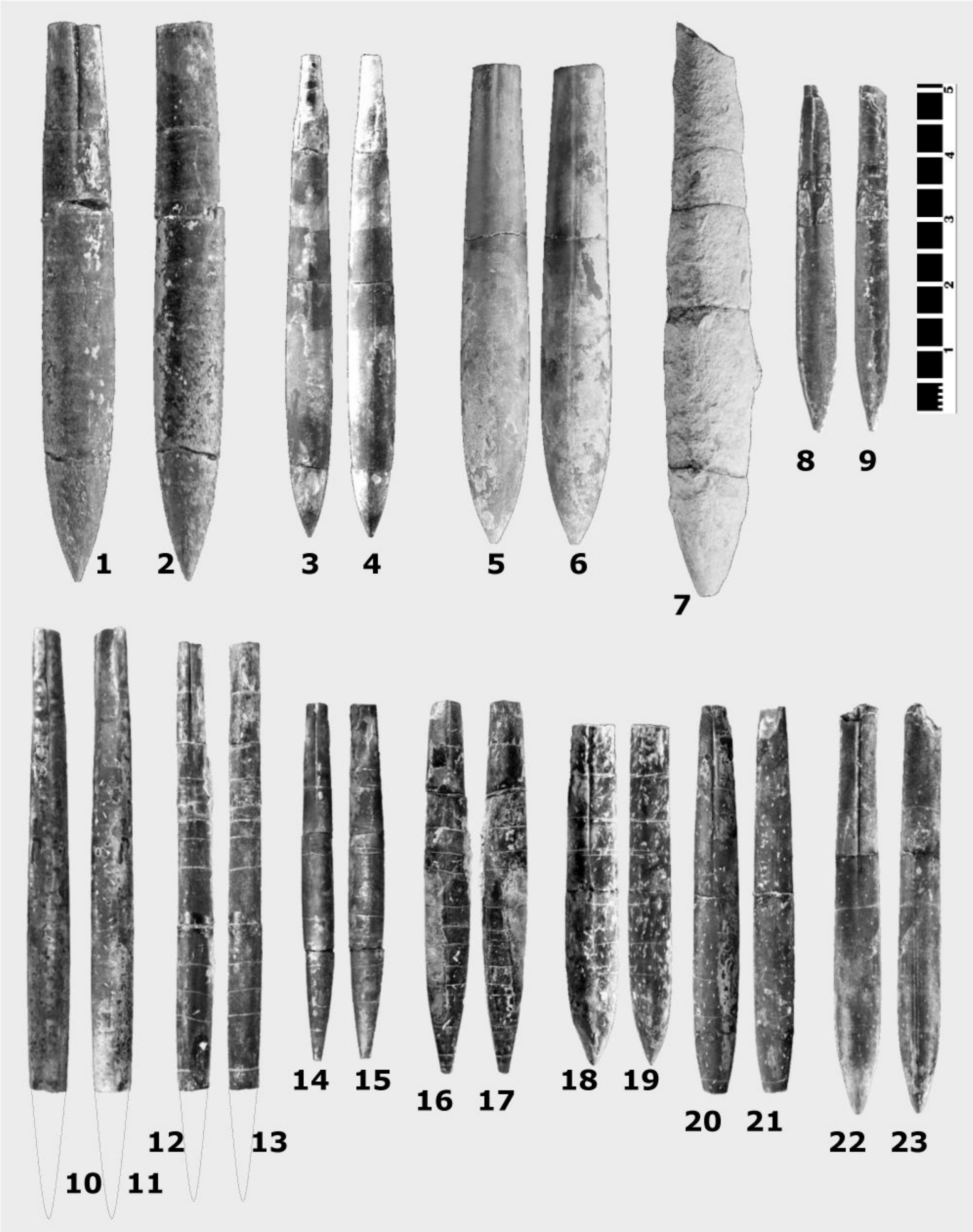
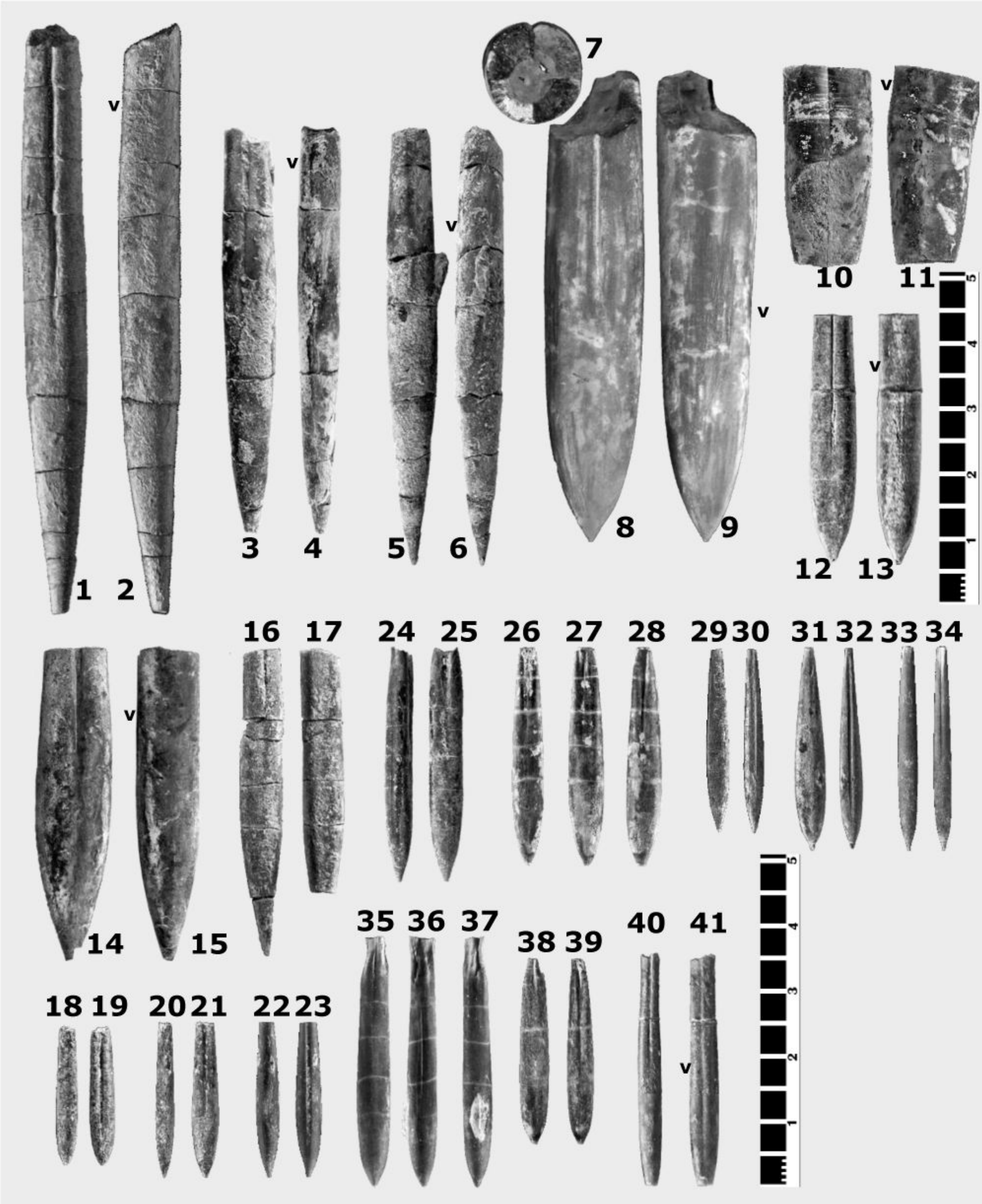

1 2 3 4 5 6 7 8 9
1
2
3
4
5
10 11 12 13 14 15 16 17 18 19 20 21 22 23

Plate 12: figs. 1-2. *Adiakritobelus peyroulesensis* Janssen, 2009, RGM543245, TM108b Nicklesi-Furcillata Sz;
figs. 3-4. *Adiakritobelus peyroulesensis* Janssen, 2009, RGM543289, TM108b Nicklesi-Furcillata Sz;
figs. 5-6. *Adiakritobelus peyroulesensis* Janssen, 2009, RGM543290, TM108b Nicklesi-Furcillata Sz;
figs. 7-9. *Adiakritobelus robustus* (Duval-Jouve, 1841), RGM543120, ANG390-393. Radiatus Z;
figs. 10-11. *Adiakritobelus* gr. *rogeri* (Delattre, 1952), RGM583943, Spain, Y.G(55-56) loose specimen, ?Furcillata Z;
figs. 12-13. *Adiakritobelus minaret* (Raspail, 1829), RGM288398, CHE353-354, Nicklesi Sz;
figs. 14-15. *Adiakritobelus minaret* (Raspail, 1829), RGM288396, SPA, Nicklesi Sz; (ex coll. Thieuloy);
figs. 16-17. *Adiakritobelus peyroulesensis* Janssen, 2009, RGM361508, Spain, Tornajo, B111, Nicklesi Sz;
figs. 18-19. *Mirabelobelus blainvillei* Janssen & Clément, 2002, RGM582320, VGL097a, Platycostatus Sz;
figs. 20-21. *Mirabelobelus blainvillei* Janssen & Clément, 2002, RGM612757, VBL049-050, Hirsutus Sz;
figs. 22-23. *Mirabelobelus blainvillei* Janssen & Clément, 2002, RGM543339, PRY cplxE-F base, Hirsutus Sz;
figs. 24-25. *Mirabelobelus blainvillei* Janssen & Clément, 2002, RGM613635, VBL075-a, "Fuhri" Sz;
figs. 26-28. *Mirabelobelus blainvillei* Janssen & Clément, 2002, RGM613320, VBL050-051, Hirsutus Sz;
figs. 29-30. *Mirabelobelus blainvillei* Janssen & Clément, 2002, RGM543315, PRY cplxF-G base, Hirsutus Sz;
figs. 31-32. *Mirabelobelus blainvillei* Janssen & Clément, 2002, RGM611864, SCX050-051, Hirsutus Sz;
figs. 33-34. *Mirabelobelus blainvillei* Janssen & Clément, 2002, RGM543395, PRY cplxB-C, Pertransiens Z;
figs. 35-37. *Mirabelobelus blainvillei* Janssen & Clément, 2002, RGM613492, VBL P07-08, Pertransiens Z;
figs. 38-39. *Mirabelobelus blainvillei* Janssen & Clément, 2002, RGM612757, VBL049-050, Hirsutus Sz;
figs. 40-41. *Mirabelobelus*? *orbignyi* Janssen & Clément, 2002, RGM361510, MIR34b-c, Otopeta Sz (refigured from Janssen, 2003, Pl. 1, figs. 8-9, in plate explanation erroneously indicated figs. 5-6; and not from the Pertransiens Zone as was erroneously indicated).

Ventral view to the right unless otherwise indicated (v).


1 2
3 4
5 6
7
8 9
10 11
12 13
14 15
16 17
18 19 20 21 22 23
24 25 26 27 28 29 30 31 32 33 34
35 36 37 38 39 40 41

Appendix A (calcilutites, -siltites, or –arenites)

Thin brownish-coloured layers, so-called "plaquettes calcaréo-gréseuses rousses" (calcarenitic rust-coloured layers), are often quite common in the uppermost lower Valanginian (Platycostatus Sz) to lowermost upper Valanginian (Verrucosum and "Neocomiensis" Sz). Only occasionally they occur in older or younger parts of the Valanginian. Generally, they are several mm thick but in exceptional cases up to 50 cm.

The thicker layers are generally associated with slumped beds and often occur on top of the disturbed sets of beds. They generally lack abundant macrofossils except for ichnofossils, which are clearly visible on the upper surface. The thinner beds contain a few echinoid spines, but more often, variable amounts of cephalopod remains (aptychi, rhyncholiti, and belemnites). Frequently these beds are characterized by abundances of (debris of) aptychi, the so-called "Lumachelle à Aptychus", as mentioned by PAQUIER (1900, p. 109-110) from the lowermost upper Valanginian. It occurs in the following sections: BLH, LBL, VBL, VGL, and VPE, and Montclus (Fig. 1). PAQUIER (1900) also mentions Raton, to the NW of Rosans.

In VBL a thin aptychi rich calcarenite, additionally yielding belemnites (mainly *M. blainvillei*), occurs in the Pertransiens Zone, with a restricted lateral extension. In other sections rust-coloured calcarenitic layers of this age were not found.

In LCH these brownish weathered beds (generally only few mm thick, but sometimes up to 20 cm thick) and calcareous slumps occur in abundance between the Subcampylotoxus Sz (p.p.) and the Pronecostatum Sz ("la Zone Jaune" or "yellow zone" of LE DOEUFF, 1977). They are difficult to assess, but it appears as if the base of this unit truncates the upper part of the Subcampylotoxus Sz (and probably also the Platycostatus Sz and Verrucosum Horizon). These beds show laminated parallel bedding, sometimes convolute bedding at the base, wavy structures on top, scour marks, and abundant ichnofossils (a.o. *Paleodictyon*, *Zoophycos*). However, the presence of large-scale hummocky cross-bedding is not evident, giving direct evidence for tempestites.

TANGRI (1980, p. 30-31) mentioned the occurrence of thin beds (generally several cm's thick, occasionally up to 10-20 cm) separated by marly sediments of several cm's to metres in thickness, situated above the Verrucosum Horizon. The area investigated by this author is situated to the north of our area (around the town of Die, northern edge of the pre-Vocontian). Apparently, calcarenitic beds appear to be much more abundant there (15-20% of the total lithology). Several sedimentary structures can be noted within, and on top of these calcarenites (TANGRI, 1980, p. 82-85). TANGRI (1980, p. 83) mentions the occurrence of a flute cast probably as a result of a transported belemnite. However, fossils were not mentioned from these calcarenitic beds.

Occasionally belemnites occur within, or on top of these beds, either as orientated groups of rostra (Pl. 1, fig. 1), as randomly orientated, but size-sorted, or as single specimens (Pl. 1, fig. 2). The following sections yielded belemnites associated with these layers: CLZ, VBL, VGL, Gouravour and Chanousse.

These beds are either interpreted as turbidites or tempestites, indicating the occurrence of transported material into the proximal areas of the basin. Apparently, cephalopod remains were incorporated and eventually sorted during transport. They are most abundant in the uppermost lower to lowermost upper Valanginian. They occur also outside this time-frame, but are rare and often confined to the bottom or top of slumped sedimentary units most probably indicating a turbiditic origin. The peak of their occurrence appears to be around the major excursion of the Valanginian positive C-isotope excursion. As this event might well be connected to climatic change (a wetter climate), these beds are here probably best explained as originating through tempestites in the more proximal areas, becoming turbiditic in the more distal parts of the pre-Vocontian Basin.

Appendix B
(debris flows/slumps VBL)

In contrast to all other investigated sections are the occurrences of redepositional deposits (debris-flows) consisting of micro-conglomerates, redeposited macrofossils (mainly early-middle Berriasian ammonites; both in nodules as well as loose steinkerns), and variously sized calcareous clasts, nodules and boulders (Pl. 3, fig. 4; Pl. 4, figs. 1-3) in the Vaubelle area (VBL and SVJ). Sometimes these sediments are covered by brownish-weathered calcarenites of 2-50cm (Pl. 4, fig. 5; see Appendix A), yielding traces of ichnofossils (*Chondrites*) on top.

These redeposited sediments (debris flows) were also mentioned from nearby sections by LE HÉGARAT (1973), and are especially common in the latest Jurassic and earliest Berriasian (REMANE, 1960, 1973, Fig. 2; FERRY *et al.*, 2015). However here, these sediments occur below the Hirsutus Sz, in the Pertransiens Zone (slumps and debris flows; Pl. 3, fig. 1), and at the base of the Valanginian.

The deposits at the base of the Valanginian yield in its top part, a poorly sorted conglomerate (VBL B100; Pl. 3, fig. 2; Pl. 4, figs. 1-3), deposited in gully-like structures, often ranging to a micro-conglomerate and being covered by a brownish weathered calcarenitic bed (VBL Psst; Pl. 4, figs. 1-3) (cf. FERRY, 2017, Fig. 20D). This conglomerate yields fossils including brachiopods, aptychi, belemnites and ammonites. The ammonites (det. J. KLEIN) indicate redeposition from the uppermost Tithonian (*Moravisphinctes* cf. *Moravica*), but mainly from the lower Berriasian (*Berriasella jacobi*, *B.* cf. *subatasi*?, *B.* cf. *moesica*, *Delphinella subchaperi*, *Malbosiceras* cf. *chaperi*, *Pseudosubplanites* cf. *grandis*, *Ps.* cf. *combesi*, *Picteticeras elmii*, *P. enayi*, *P. oxycostata*, *Pseudargentiniceras* sp. (Jacobi Z), and *Delphinella* sp. (Jacobi-Privasensis Z). In addition, a few late Berriasian ammonites occur, *e.g.*, *Berriasella* (*Hegaratella*) *kaffae* (Paramimouna-Picteti Z), besides long-ranging taxa like *Ptychophylloceras*, *Haploceras*, Lytoceratinae and many indeterminable, badly and/or partially preserved, berriasellids. They occur both in calcareous clasts as well as loose fossils. So, the majority of the ammonites point to redeposition from lower Berriasian sediments, while most typical upper Berriasian ammonites appear to be absent. On the other hand, the belemnites herein, point mainly to the latest Berriasian (Picteti-Alpillensis Z), including species like: *Castellanibelus* sp. E, *D.* (aff.) *tornajoensis*, *Gillieronibelus mayeri*, and *Mirabelobelus*? *orbignyi*. In addition, the bed yields taxa of the *Duvalia lata*-group and several *Berriasibelus* species. The latter include a.o. *Berriasibelus kabanovi*, *B.* cf. *triquetrus*, and *B.* aff. *exstinctorius* sp. 1. Possible early Berriasian belemnite taxa are rare and include: *Conobelus* sp. (Pl. 6, figs. 18-19), incomplete fragments of a long grooved hibolitid, probably like *H.* cf. *fellabrunensis* (VETTERS, 1905), and "*Pseudobelus*" gr. *pilleti* (PICTET, 1868; Pl. 6, figs. 28-29). The latter taxon is comparable to specimens from the Jacobi Z of SLD (Pl. 6, figs. 30-34).

Below these deposits the sediments consist of, several tens of metres, the base is not exposed, marlstone dominated, mud-flows with various sized calcareous clasts and fine dispersed silica, yielding a few ammonites, such as, *Berriasella privasensis*, *Jabronella* cf. *jabronensis*, and *J.* cf. *cisternensis*, indicating the Privasensis-Paramimouna Z (det. J. KLEIN) besides indeterminable ammonite specimens and only a few belemnites (Fig. 6). Above these sediments, in bed VBL P02, slightly above the sandstone bed (Fig. 6) the ammonite *Kilianella chamalocensis* (Pl. 4, fig. 4) occurs. Here, in addition, *T.* gr. *pertransiens* and *Erdenella paquieri* occur, indicating the latest Berriasian to earliest Valanginian.

Thus in VBL mass transport deposits, such as debris flows and slumps, are quite common, indicating transport/reworking - mainly based on ammonites - from uppermost Tithonian(?) to upper Berriasian. These sediments, either expressed as conglomeratic levels (in the uppermost Berriasian or lowermost Valanginian) or as debris flows (in the upper Berriasian and in the upper Pertransiens Zone), might be of local origin, resulting from paleofault activity. The general picture indicates reworking of younger to older strata and their fossils in progressively younger sediments. It should be noted that most belemnites indicate the latest Berriasian while most ammonites have older ages (Jacobi-Privasensis Zones, early-middle Berriasian).