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A Sinemurian-Pliensbachian belemnite assemblage from the Glasenbach Gorge (Northern Calcareous Alps, Austria)

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(With 4 figures)

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Abstract

A belemnite assemblage is described for the first time from the Lower Jurassic Adnet Fm. of the Austrian Alpine Tethys. Six taxa of the family Passaloteuthididae have been recognized (*Coeloteuthis oravica*, *C.* aff. *calcar*, *Nannobelus acutus*, *Passaloteuthis elongata*, *P.* cf. *laevigata*, *Pseudohastites carinatus*). The relatively high number of specimens attributed to *Coeloteuthis* and the apparent absence of *Subhastites* are the most remarkable features of this assemblage. The taxonomic analysis shows a close similarity of the Glasenbach Gorge fauna with coeval assemblages of the Slovakian Klippenbelt. It provides further evidence that Early Jurassic belemnite faunas were rather uniform in generic composition in at least northwestern and Tethyan Europe during the late Sinemurian and early Pliensbachian.

Keywords: Belemnitida, Passaloteuthididae, Lower Jurassic, Adnet Formation, Tethys.

Zusammenfassung

Zum ersten Mal wird eine Belemnitenvergesellschaftung aus der unterjurassischen Adnet Formation der Austro-Alpinen Tethys beschrieben. Sechs Arten der Familie Passaloteuthididae sind vertreten (*Coeloteuthis oravica*, *C.* aff. *calcar*, *Nannobelus acutus*, *Passaloteuthis elongata*, *P.* cf. *laevigata*, *Pseudohastites carinatus*). Bemerkenswerte Muster dieser Vergesellschaftung sind das relativ zahlreiche Auftreten der Gattung *Coeloteuthis*, sowie das scheinbare Fehlen von *Subhastites*. Die taxonomische Analyse zeigt eine große Ähnlichkeit der Belemnitenfauna mit gleichaltrigen Vergesellschaftungen aus der Slowakischen Klippenzone. Die hier beschriebenen Belemniten liefern zudem einen weiteren Hinweis auf die größtenteils einheitliche Zusammensetzung – zumindest auf Gattungsebene – der Faunen in Nordwest- und Tethyal-Europa während dem späten Sinemurium und dem frühen Pliensbachium.

Schlüsselwörter: Belemnitida, Passaloteuthididae, Lower Jurassic, Adnet Formation, Tethys.

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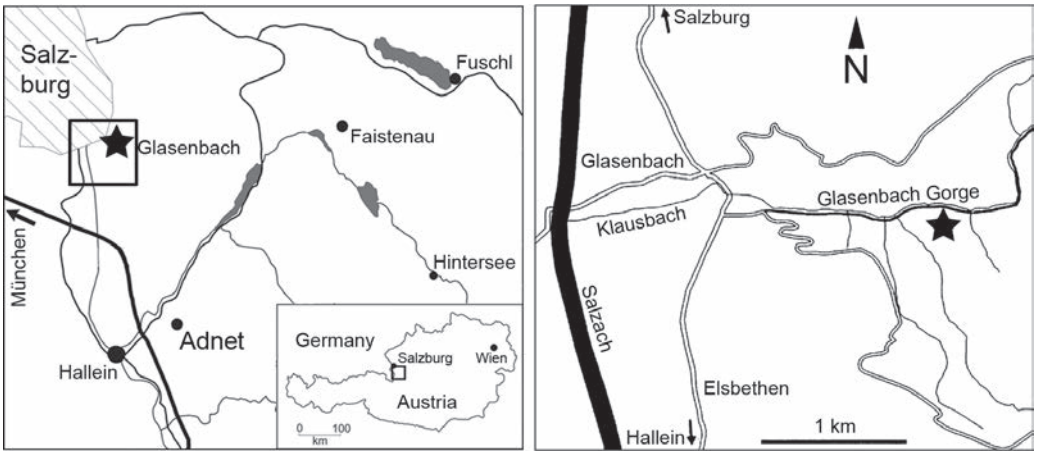

Fig. 1. Geographic location of the Glasenbach Gorge (left) and sampling position within the gorge (right).

Introduction

The belemnites (Belemnitida) represent an extinct order of coleoid cephalopods, whose origin is is currently re-evaluated (Weis & Delsate 2006; Iba *et al*. 2012, 2014). Their hard-parts (rostrum and phragmocone) are common fossils in Jurassic and Cretaceous rocks, and have been used as proxies for palaeoecologic and palaeogeographic reconstructions and in several cases also found an application in biostratigraphy. However, the distribution and diversification of Early Jurassic belemnites, and especially pre-Toarcian faunas, are still not fully understood, although having been in the focus of several generations of researchers (Schwegler 1962a, b; Schumann 1974; Riegraf 1980; Doyle & Mariotti 1991; Doyle 1991, 1994, 2003, 2010; Schlegelmilch 1996; Weis & Delsate 2006; Iba *et al*. 2012; Pinard *et al*. 2014). The here described belemnite assemblage from the Austrian Tethyan margin may contribute to elucidate the distribution patterns of belemnites in the late Sinemurian and early Pliensbachian, a period that marked a first peak of diversification (Doyle 1994).

Locality and geological setting

The belemnite remains were retrieved from a poorly consolidated marly breccia exposed along the banks of the Klausbach stream in the Glasenbach Gorge near Elsbethen, south of Salzburg, Austria, in the northern Calcareous Alps (Fig. 1). The marly breccia, formerly known as "Hauptknollenbrekzie" (*e.g.*, Vortisch 1970; Böhm 2003), is an amalgam of resedimented red to grey marls and nodular limestones, occurring in millimetre- to decimetre-sized clasts. The breccia is interpreted as a giant slumping mass, resulting from submarine erosion and downslope transport of unconsolidated to semi-consolidated sediments (Böhm *et al*. 1995) assignable to the Kehlbach and Scheck Members of the Adnet Formation (Böhm 2003). Ammonites recovered from

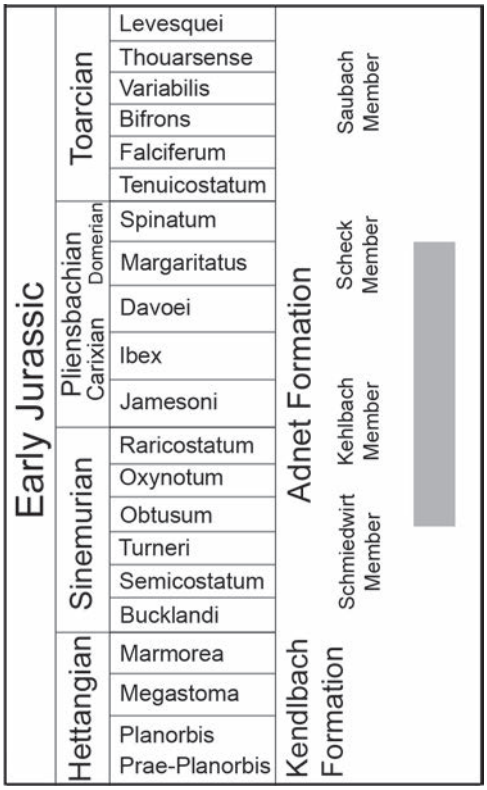

Fig. 2. Early Jurassic ammonite stratigraphy of the Northern Calcareous Alps (modified after Böhm *et al*. 1995) and regional lithostratigraphic units; the stratigraphic position of the belemnite-bearing "Hauptknollenbrekzie" is indicated by grey colour.

the breccia indicate an age ranging from the upper Sinemurian *Echioceras raricostatum* zone to the upper Pliensbachian *Amaltheus margaritatus* zone (Bernoulli & Jenkyns 1970; Thuy *et al*. 2014) (Fig. 2) for the components of the slumping mass including the belemnites.

Palaeo-environment reconstructions based on subsidence models and sedimentological comparisons with modern equivalents (Bernoulli & Jenkyns 2009), as well as ostracod and microendolithic evidence (Thuy *et al*. 2014) suggest original deposition of the sediments at bathyal depths on the slope of a submarine high in the northwestern Tethys Ocean.

Material and methods

Circa 100 specimens, most of which are in a fragmentary state, were recovered from the Glasenbach section, and only 40 of them could be determined at species level. Preservation of the rostra is moderate to good; phragmocones are preserved only occasionally.

The studied material is deposited in the collections of the Department of Geology and Palaeontology at the Natural History Museum Vienna, Austria (NHMW). Higher

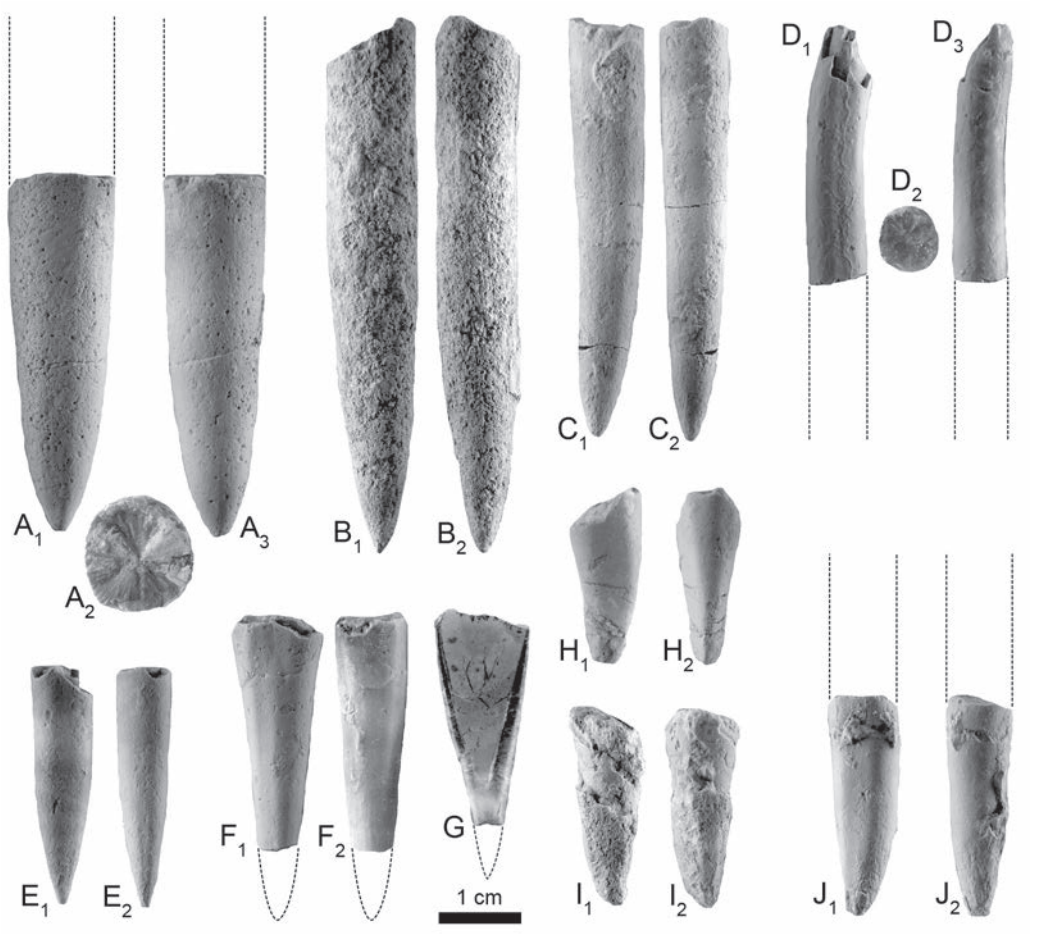

Fig. 3. Sinemurian-Pliensbachian belemnites from the Glasenbach Gorge, Austria. The dotted lines indicate missing parts of the rostrum. **A**: *Passaloteuthis* cf. *laevigata*; $\mathbf{A_1}$: lateral view; $\mathbf{A_2}$: section of the stem region; $\mathbf{A_3}$: ventral view. **B**: *Passaloteuthis elongata*; $\mathbf{B_1}$: lateral view; $\mathbf{B_2}$: ventral view. **C**: *Passaloteuthis elongata*, subadult specimen; $\mathbf{C_1}$: lateral view; $\mathbf{C_2}$: ventral view. **D**: *Pseudohastites carinatus*, alveolar region and stem (partially preserved); $\mathbf{D_1}$: lateral view; $\mathbf{D_2}$: section of the stem region; $\mathbf{D_3}$: ventral view. **E**: *Nannobelus acutus*; $\mathbf{E_1}$: lateral view; $\mathbf{E_2}$: ventral view. **F**: *Coeloteuthis oravica*; $\mathbf{F_1}$: lateral view; $\mathbf{F_2}$: dorsal view. **G**: *Coeloteuthis oravica*, section. **H**: *Coeloteuthis* aff. *calcar*; $\mathbf{H_1}$: lateral view; $\mathbf{H_2}$: dorsal view. **I**: *Coeloteuthis* aff. *calcar*, phragmocone partially preserved; $\mathbf{I_1}$: lateral view; $\mathbf{I_2}$: dorsal view. **J**: *Pseudohastites carinatus*, apical fragment; $\mathbf{J_1}$: lateral view; $\mathbf{J_2}$: ventral view.

classification is adopted from Doyle *et al*. (1994) and Riegraf *et al*. (1998). Synonymy lists and symbols are given according to the recommendations of Matthews (1973). Terminology follows Doyle & Kelly (1988). Size indications are as follows: small (<60 mm), medium (60–80 mm), large (>80 mm).

Systematic palaeontology

Subclass Coleoidea Bather, 1888

Order Belemnitida Zittel, 1895

Suborder Belemnitina Zittel, 1895

Family Passaloteuthididae Naef, 1922

Genus *Coeloteuthis* Lissajous, 1906

Type species: *Belemnites excavatus* Phillips, 1866; by original designation.

Remarks: As stressed by Schwegler (1962a: p. 17), the distinction of different species amongst the rather homogeneous material attributed to *Coeloteuthis* is difficult. Most taxa are characterized by a rather similar morphology, all sharing a short and thin rostrum, with broad lateral lines and a subtriangular, compressed section and an exceptionally deep penetration of the phragmocone. There is no data available on intraspecific variability, as only rare specimens are reported in literature. It can therefore not be excluded that several taxa are, in fact, subjective synonyms, and a review, based on a more extensive material, would be welcome. The present classification therefore reflects only tentative assignments of the studied specimens to known taxon which best fits the description.

Coeloteuthis oravica (Činčurová, 1994) nov. comb.

(Figs 3F–G)

*. 1994 *Nannobelus oravica* Činčurová: 3, text-fig. 1, pl. 1, figs 1a–b.

Material: Nine complete and sub-complete adult specimens and two juveniles (earliest ontogenetic stages) (NHMW 2014/0122/0002 to …/0004).

Description: Small sized, elongate-conical, *Nannobelus*-like rostrum. The profile is conical, the outline cylindroconical to conical. The apex shows weak epirostral growth. Lateral lines are developed as a single shallow depression on the total length of the rostrum. Transverse sections are compressed and subtriangular at the alveolar end, and rounded triangular at the apical part. The alveolus penetrates deeply, circa two thirds of the rostrum.

Remarks: Early ontogenetic stages of *C. oravica* have already the same elongate and slender shape as the adults. This species is close to *Coeloteuthis* aff. *calcar* (see below), which differs by a shorter rostrum at comparable diameter and its moderate compression. The species shows an intermediate morphology between the related genera *Nannobelus* and *Coeloteuthis*. However, based on its extreme deep alveolus and the presence of broad lateral depressions, it is in our opinion better assigned to *Coeloteuthis*, and not *Nannobelus*.

Occurrence: Sinemurian/Pliensbachian of the Glasenbach Gorge, Austria and upper Sinemurian of northwestern Slovakia (Činčurová 1994).

Coeloteuthis aff. *calcar* (Phillips, 1866)
(Figs 3H–I)

aff. 1866 *Belemnites calcar* Phillips: 38, pl. 2, fig. 5. [non fig. 5*l'''*= holotype of *Coeloteuthis cuneolus* (Mayer-Eymar, 1884)]
. 1962a *Belemnites* aff. *calcar* Phill. – Schwegler: 18, text-fig. 13.
? 1964 *Coeloteuthis calcar* (Phillips) – Činčurová: 17, pl. 1, fig. 4.

Material: Eight complete and sub-complete rostra (NHMW 2014/0122/0005 to …/0007).

Description: Small sized, very short and conical rostrum. Both outline and profile are strictly conical, and some individuals show a slight inflation of the venter. Broad dorsolateral lines extend on the whole length of the rostrum. The flanks are flattened in some individuals. The transverse sections are sub-trapezoid at the alveolar end, and weakly sub-triangular at the apical end. The alveolus penetrates deeply and almost reaches the apex.

Remarks: Only few specimens have been mentioned by Schwegler (1962a). It differs from typical *C. calcar*by its more sub-triangular section and stronger conical profile. These features put it close to *C. oravica*, which, however, differs by its more elongated and *Nannobelus*-like rostrum.

Occurrence: Sinemurian/Pliensbachian of the Glasenbach Gorge, Austria; in addition lower Pliensbachian of southern Germany (Schwegler 1962a) and possibly upper Sinemurian/lower Pliensbachian of Slovakia (Činčurová 1964).

Genus *Nannobelus* Pavlow, 1914

Type species: *Belemnites acutus* Miller, 1826; by subsequent designation (Stolley 1919).

Nannobelus acutus (Miller, 1826)
(Fig. 3E)

* 1826 *Belemnites acutus* Miller: 60, pl. 8, fig. 9.
. 1912 *Bel. acutus* Miller – Werner: 108, pl. 10, fig. 1.
1991 *Nannobelus acutus* (Miller, 1826) – Doyle & Mariotti: 357, pl. 2, figs 13-15, pl. 3 figs 1–2.
. 1996 *Nannobelus acutus* (Miller, 1826) – Schlegelmilch: 9, pl. 2, figs 1–7.
. 1998 *Nannobelus acutus* (Miller, 1826) – Schlegelmilch: 48, pl. 1, figs 8–10.
. 2010 *Nannobelus acutus* (Miller) – Doyle: 264, pl. 45, figs 5–6.

Material: One complete specimen (NHMW 2014/0122/0001).

Description: Small sized, cylindroconical rostrum. The profile is cylindroconical and slightly asymmetrical, the outline is moderately conical. The relatively short apex is sharp. The transverse section is elliptical compressed. The phragmocone penetrates less than half of the rostrum.

Remarks: The acute apex is apparently devoid of grooves. Careful examination of the magnesium oxide-coated apex under lateral light reveals however very weak impressions indicating short dorsolateral and apical grooves. These traces of three apical grooves and the short cylindroconical rostrum reveal the close relationships of *Nannobelus* with Hettangian *Schwegleria*, especially *S. praecox* (Schwegler, 1939), a species characterized by a strictly conical profile and three apical grooves (Schlegelmilch 1996, 1998).

Occurrence: Sinemurian/Pliensbachian of the Glasenbach Gorge, Austria; the species is widespread in the lower Sinemurian to lowermost Pliensbachian of Europe and adjacent areas. It has been chiefly described amongst others from England (Miller 1826; Doyle 2010), Germany (Werner 1912; Schlegelmilch 1996, 1998), France (Rulleau *et al*. 2007), Slovakia (Činčurová 1964), Bulgaria (Stoyanova-Vergilova 1979), and Turkey (Doyle & Mariotti 1991).

Genus *Passaloteuthis* Lissajous, 1915

Type species: *Belemnites bruguierianus* d'Orbigny, 1843; by original designation.

Passaloteuthis elongata (Miller, 1826)

(Figs 3B–C)

* 1826 *Belemnites elongatus* Miller: 60, pl. 7, figs 6–8.
. 1928 *Passaloteuthis elongata* (J.S. Miller) – Lang: 201, pl. 13, fig. 8; text-fig. 3(1).
1928 *Passaloteuthis argillarum* Lang: 200, pl. 13, fig. 7. [*fide* Doyle 2010: 268]
. 1974 *Belemnites paxillosus elongatus* Miller 1826 – Schumann: 23, pl. 2, fig. 14, pl. 3, figs 3–5.
? 1991 *Passaloteuthis armatus* (Dumortier, 1869) – Činčurová: 3, pl. 1, fig. 1.
? 1991 *Passaloteuthis meszarosi* Činčurová: 6, pl. 1, fig. 3.
. 2010 *Passaloteuthis elongata* (Miller) – Doyle: 268, pl. 45, figs 13–17.

Material: Two complete specimens and 6 fragments of the apical and stem regions (NHMW 2014/0122/0008 to …/0010).

Description: Medium to large sized, slender and cylindroconical rostrum. The profile is more cylindroconical as compared to the outline, which is rather cylindrical. The apical region is elongate and acute, and bears weak dorsolateral grooves. The transverse sections are rounded to elliptical compressed.

Remarks: The specimens reported by Činčurová (1991) as *Passaloteuthis armatus* (Dumortier, 1869) and *Passaloteuthis meszarosi* Činčurová, 1991 probably represent sub-adult and juvenile stages of the same taxon.

Occurrence: Lower Pliensbachian of UK (Lang 1928; Doyle 2010), Germany (Schumann 1974), Pliensbachian of France (Dumortier 1869; Rulleau *et al.* 2007).

Passaloteuthis cf. *laevigata* (Zieten, 1831)
(Fig. 3A)

* 1831 *Belemnites laevigatus* Zieten: 28, pl. 21, fig. 12.
1912 *Bel. paxillosus* Schlotheim [var. C] – Werner: 122.
1990 *Passaloteuthis bisulcata* (Blainville, 1827) [var. C] – Doyle: 19, pl. 3, figs 1–3.
. 1991 *Passaloteuthis* cf. *laevigatus* (Zieten) – Činčurová: 4, pl. 1, fig. 2.
1998 *Passaloteuthis laevigata* (Zieten, 1831) – Schlegelmilch: 51, pl. 2, fig. 8.

Material: Two apical fragments (NHMW 2014/0122/0011 to …/0012).

Description: Presumably large sized, cylindroconical rostrum. The apex is only weakly acute and bears two short dorsolateral grooves. The transverse section is rounded to subquadrate and slightly compressed.

Remarks: The studied specimens are not sufficiently well preserved to make a definite attribution, but allow a comparison with *P. laevigata*, a widely distributed species, which has been considered as synonym of *P. bruguieriana* (d'Orbigny, 1843) by some authors (Doyle 1990).

Occurrence: Widespread in Pliensbachian and lowermost Toarcian sediments of mainland Europe and UK (Doyle 1990); also northern Africa (Sanders *et al*. 2013).

Genus *Pseudohastites* Naef, 1922

Type species: *Belemnites scabrosus* Simpson, 1866; by original designation.

Pseudohastites carinatus (Hehl in Zieten, 1831)
(Figs 3D, J)

* 1831 *Belemnites carinatus* Hehl – Zieten: 27, pl. 21, fig. 6.
1863 *Belemnites virgatus* Mayer: 11.
. 1912 *Bel. virgatus* Mayer – Werner: 120, pl. 11, fig. 4.
. 1974 *Gastrobelus virgatus* (Mayer, 1863) – Schumann: 40, pl. 5, figs 5–13.
. 1998 *Passaloteuthis carinata* (He. in Z., 1831.) – Schlegelmilch: 52, pl. 3, figs 1–3.

Material: Eight fragments of the apical, stem and alveolar regions (NHMW 2014/0122/0013 to …/0015).

Description: Medium sized, slender cylindrical rostrum. The profile is cylindrical, the outline cylindrical to sub-hastate. The short apex is moderately acute. Distinct double lateral lines extend as broad depressions from the alveolar part, fading out towards the apex. The upper pair of lateral lines continues on the apical part as shallow dorsolateral grooves. The transverse sections are strongly compressed and sub-pyriform, with flattened flanks on the *rostrum solidum*.

Occurrence: Lower Pliensbachian of Germany (Schumann 1974; Schlegelmilch 1998), Pliensbachian of France (Lissajous 1915, 1927), Slovakia (Činčurová 1974).

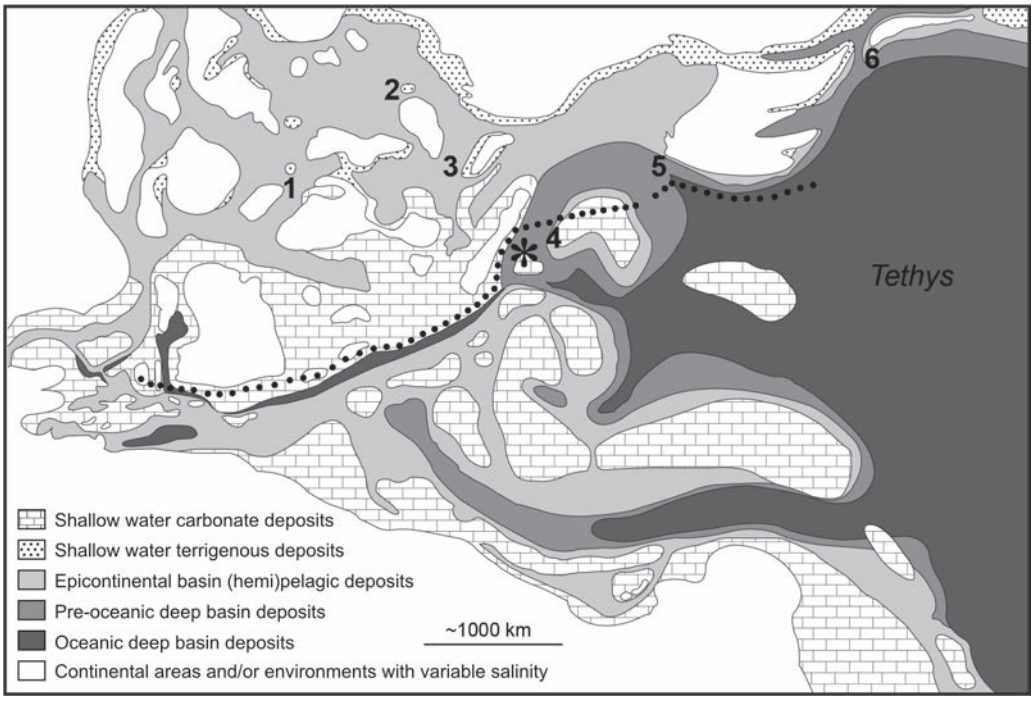

Fig. 4. Palaeogeographic map of the Sinemurian-Pliensbachian (modified after Venturi *et al*. 2007 and Thierry *et al*. 2000) showing the studied locality and relevant localities with coeval belemnite faunas. Location key: (*) Glasenbach Gorge, (1) Dorset (Lang 1928, Doyle 2010), (2) N Germany (Schumann 1974), (3) SW Germany (Riegraf 1980, Schlegelmilch 1998), (4) Slovakia (Činčurová 1964–1994), (5) Balkan Mts, Bulgaria (Stoyanova-Vergilova 1993), (6) NW Anatolia (Doyle & Mariotti 1991). The dotted line represents the limit between NW European and Tethyan ammonite faunas (after Dommergues *et al*. 2005).

The Glasenbach assemblage in relation to European belemnite diversity and biogeography

All the belemnite genera present in the Glasenbach assemblage are widely distributed in Europe and adjoining areas, with many similar, and in some cases probably synonymous, species. This taxonomic uniformity, at least at generic level, is consistent with the conclusions of Doyle (1994) and Sanders *et al.* (2013), who concluded that the European (*sensu lato*) Early Jurassic belemnite faunas had a similar composition until the basal Toarcian *Dactylioceras tenuicostatum* zone; subsequently, during Toarcian and Aalenian stages, significant changes took place, with a high diversification and a trend towards endemic Tethyan (Mediterranean) belemnite faunas (Doyle 1994; Mariotti *et al.* 2010, 2012; Weis *et al*. 2014).

The belemnite records from the Glasenbach Gorge strenghten and complete also the data presented from coeval Peri-Tethyan sediments of Slovakia by Činčurová (1964,

1974, 1975, 1987, 1989, 1991 and 1994). The species of *Passaloteuthis*, *Pseudohastites*, *Coeloteuthis* and *Nannobelus* reported from Slovakia show great similarities with the Austrian taxa discussed herein. Furthermore, it is interesting to note that the few Slovakian specimens originally attributed to *Subhastites* Gustomesov, 1977 ("*Rhopaloteuthis clavatus* Schlotheim" in Činčurová 1971: p. 52, pl. 3, fig. 6; "*Hastites microstylus* Phillips" in Činčurová 1975: p. 47, pl. 1, fig. 3) are rather passaloteuthids, as can be deduced from the cylindrical-subhastate shape and the relatively deep penetration of the alveolus. It thus appears that the genus *Subhastites* is absent from the Slovakian Klippenbelt fauna, a pattern that is observable also in the Austrian fauna reported herein. A comparable fauna from the lower Pliensbachian of northwestern Anatolia (Turkey; Doyle & Mariotti 1991) comprising *Passaloteuthis*, *Pseudohastites*, "*Pseudohastites sensu* Lang" (=*Bairstowius* Jeletzky in Doyle *et al*., 1994), *Angeloteuthis* (Lang, 1928), *Coeloteuthis*, *Nannobelus* and associated aulacoceratids (*Atractites* sp.) lacks the genus *Subhastites* as well. Hastitid belemnites are instead very common components of Pliensbachian faunas in southern England (Lang 1928; Doyle 2003, 2010), France (Dumortier 1869) and Germany (Schwegler 1962b; Schumann 1974; Schlegelmilch 1998). On the other hand, the genus *Coeloteuthis* is present only in rare specimens in the aforementioned regions, but it is one of the dominant genera (by numbers of specimens) in the Glasenbach Gorge assemblage.

At the current state of investigations, it is not possible to identify faunal endemism in the generic composition of belemnite associations for the Sinemurian-Pliensbachian as it is the case for ammonites, *e.g.*, in the early Pliensbachian (Dommergues *et al*. 2005; Venturi *et al*. 2007). However, as there is a strong bias between the number of well investigated areas in the NW European Province and the Mediterranean Tethys (Fig. 4), these palaeobiogeographic considerations have to be considered as preliminary.

Conclusions

The herein reported belemnites from the "Hauptknollenbrekzie (Kehlbach and Scheck Members of the Adnet Formation) have a stratigraphic distribution (upper Sinemurian to upper Pliensbachian) that corroborates the age previously established by means of ammonites. Furthermore, all taxa have a wide distribution in the European shelf seas and along the Peri-Tethyan continental margins. Our data supports the view that Sinemurian-Pliensbachian belemnite faunas were rather homogeneous, at least in generic composition. From a palaeobiogeographic point of view, the apparent absence of hastitid belemnites such as *Subhastites* in the Klippenbelt zone (Austria, Slovakia) is a remarkable feature, but needs further confirmation.

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