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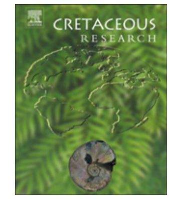

Occurrence of the Late Cretaceous belemnite *Belemnitella* in the Arabian Plate (Hakkari, SE Turkey) and its palaeogeographic significance

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ABSTRACT

Two incomplete rostra belonging to the Late Cretaceous belemnite genus *Belemnitella* have recently been recorded from the Arabian Plate (Tethyan Realm) and document the southernmost extent of migration in the Late Cretaceous belemnite family Belemnitellidae. The rostra were collected from argillaceous limestones belonging to the Lower Member of the Germav Formation (Late Campanian–Maastrichtian), the horizon in question being dated by benthic and planktic foraminifera as Late Campanian. This belemnitellid occurrence in the Arabian Plate in the Late Campanian suggests a previously unknown migration route connecting the Boreal Realm in the north with the Tethyan carbonate platform areas in the south. Both rostra are tentatively assigned to *Belemnitella* sp. cf. *B.* ex. gr. *mucronata*. The smaller and more complete rostrum probably represents an adolescent individual, suggesting the existence of a breeding population.

Q2 1. Introduction

Belemnites belonging to the Late Cretaceous family Belemnitellidae Pavlow, 1914 were typical inhabitants of the Northern Hemisphere shallower/platform seas. However, although these belemnites are a typical component of the Boreal faunal assemblages, their southward migrations have been recognized in several species (Christensen, 1997a). These migrations were probably connected with cooling and subsequent shallowing (Gale and Christensen, 1996; Christensen, 1997b). Within the North European Province of the Boreal Realm (sensu Christensen, 1976; Košťák et al., 2004), similar belemnitellid incursions in relation to cooling events have been recorded (Wiese et al., 2009; Košťák and Wiese, 2011). From the Cenomanian to the Maastrichtian, at least five genera (and three subgenera of the genus *Belemnella* Nowak) immigrated into the northernmost parts of the Tethys (Christensen, 1997a).

The belemnite genus *Belemnitella* d'Orbigny belongs to the most important taxon within the family Belemnitellidae in the Late Cretaceous (Santonian–Maastrichtian) seas of the Boreal Realm. The genus is recorded from Europe (Jeletzky, 1951; Naidin, 1952, 1964a, b, 1975, 1978; Birkelund, 1957; Kongiel, 1962; Ernst, 1963; Christensen, 1975, 1976, 1986, 1988, 1990, 1991, 1993, 1995, 1996, 1997a, b, 1998, 1999, 2000a, b; Christensen and Schmid, 1987; Christensen and Schulz, 1997; Christensen et al., 1992, 1993; Schulz, 1982; Schulz and Schmid, 1983; Keutgen and Van der Tuuk, 1990; Keutgen and Jagt, 1998; Keutgen et al., 2010 and many others), Western Siberia (Naidin, 1964a, b; Ali-Zade, 1972), Central Asia (i.e., Kazakhstan, Emba river; Naidin, 1964b; Naidin and Košťák, 1998), Turkmenistan (Tuarkyr; Naidin 1975; Schulz, 1979) and North America (Christensen 1997a; Jeletzky, 1955, 1962; Christensen 1997a and others). Many *Belemnitella* species show a high evolutionary potential, and the very large palaeobiogeographic distribution also proves their evolutionary success.

As shown and summarized by Christensen (1997b), *Belemnitella* species, especially *B.* ex gr. *mucronata* (Schlotheim) and five more species of the genus, also migrated to the Tethyan Realm in the Late Santonian–Late Maastrichtian interval. They are well known from southeast France (vicinity of Grenoble; Combémorel, 1996), Austria (Northern Calcareous Alps; Christensen, 1995), southern France (Aquitane Basin; Séronie-Vivien, 1972, French Pyreneés; Christensen, 1990), northern Italy, Serbia (Jeletzky, unpublished results), Bulgaria (Stoyanova-Vergilova and Jokilchev, 1993), the Carpathians of Romania (Negau and Georgescu, 1991), Crimea (Naidin, 1981), Kazakhstan (Mangyshlak; Naidin, 1975), Turkmenistan (Tuarkyr, Balkan Mountains; Naidin, 1964b; Jeletzky, unpublished results) and Azerbaijan (Transcaucasus, Caucasus; Ali-Zade, 1972). Christensen (1997a) has also mentioned, albeit

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without citing any references, doubtful records of *Belemnitella* from Turkey and Greece (also Jeletzky, unpublished results).

2. Geological and stratigraphic setting

The Late Cretaceous is one of the most significant periods in the geological history of the Arabian Plate, in view of the major structural and tectonic events that affected the region at this time (Alsharhan and Nairn, 1990; Sengör and Yılmaz, 1981). Southeast Turkey is situated in the northern part of the Arabian Plate and is bounded to the north and east by the Taurus Orogenic Belt (Fontaine et al., 1989). A thick sedimentary sequence ranging from Palaeozoic to Tertiary in age has been deposited in this basin.

The stratigraphy, facies and faunal content of the Upper Cretaceous autochthonous sequence of southeastern Turkey have been discussed in numerous publications, including those by Tromp (1941), Altınlı (1954), Kellog (1960), Ala and Moss (1979), Farinacci and Köylüoğlu (1982), Özkan and Altıner (1987), Köylüoğlu (1988), Perinçek (1990), Cater and Gillcrist (1994), Çoruh et al.(1997) and Yılmaz and Duran (1997). We present here the southernmost occurrence known of a Tethyan record of *Belemnitella* located close to the Turkey/Iraq boundary (Fig. 1). Of high palaeogeographic importance this record from a section of outcrop in the Cilo Dağ area (south of the town of Hakkari) is located on the northern part of the Arabian Plate (Figs. 1, 2, 4). One well-exposed stratigraphic section of Late Campanian–Maastrichtian strata was measured and sampled (Figs. 1, 3). This paper aims to clarify the stratigraphic setting of the Lower Member of the Germav Formation in the Hakkari region on the basis of the occurrence of the belemnite *Belemnitella* sp. cf. *B.* ex. gr. *mucronata* recovered and to discuss the palaeogeographic implications of this occurrence.

In the Cilo Dağ area, the stratigraphic sequence is composed of Middle Jurassic–Lower Tertiary units. The Middle Jurassic–Lower Cretaceous deposits are represented by the Latdağı Formation (limestones and dolomitic limestones). Above an unconformity, this is overlain by the Late Cretaceous–Early Paleocene Germav Formation (shales, marls, argillaceous limestones), followed by the shallow marine Kavalköy and Hoya formations (Perinçek, 1990; Fig. 3).

This paper concentrates on the Late Campanian–Maastrichtian part of the section, i.e., the Lower Member of the Germav Formation. The Germav Formation (Fig. 2) in southeastern Turkey was first described in 1936 by Maxson (see Tromp, 1941). It is about 700 m thick at the type locality (Germav Village, Batman) and is composed of grey shales, argillaceous limestones and marls. The formation has been suggested to be a possible source rock for most of the petroleum fields in southeast Turkey (Ala and Moss, 1979; Erkmen and Sadek 1981). It has been divided into Lower and Upper members. At the end of the Late Cretaceous a period of erosion led to a well-defined faunal break between late Cretaceous Lower and Paleocene Upper members (Erkmen and Sadek 1981; Perinçek, 1990) as recorded by the benthic and planktic foraminifera (Özkan and Altıner, 1987; Perinçek, 1990; Özcan, 1993), dinoflagellate cysts and calcareous nannoplankton (Erkmen and Sadek, 1981) and some rudists (Özer, 1993).

Different isochronous environments are easily recognized in the Campanian–Maastrichtian section on the basis of foraminifera that have good stratigraphic and facies value. The assemblages reflect deposition in continental slope and open sea environments, and on the outer and inner shelf (Farinacci and Köylüoğlu, 1982). It is worth mentioning that some reef limestones that are synchronous with the Germav Formation developed during the Late Cretaceous–early Tertiary (Erkmen and Sadek, 1981).

On the basis of records of some benthic and planktic foraminifera, namely *Orbitoides medius* (d'Archiac), *Globotruncana stuartiformis* Dalbiez, *G. calcarata* Cushman, *G. fornicata* (Plummer) and *Rugoglobigerina rotundata* (Brönnimann) from the Lower Member of the Germav Formation in the Hakkari area (Perinçek, 1990), a Late Campanian age is suggested for the lower part of this succession. This member can be correlated the Bozova and Üçkiraz formations of southeastern Turkey (Perinçek, 1990; Fig. 2).

Recently, the fill of the alveolus in specimen IGP/2011/A2 (see below) provided a positive nannofossil record (C.J. Wood and L.T. Gallagher, pers. comm. 2011) of *Broinsonia parca constricta* Stradner, which ranges from the Upper Campanian *Belemnitella* langei Zone to the Lower Maastrichtian *Belemnella sumensis Zone* in northern Germany (Niebuhr et al., 2011). Linnert et al. (2011) has shown that the stratigraphic range of the calcareous nannofossil *Broinsonia parca constricta* on the Goban Spur in the North Atlantic is from the Late Campanian UC14b to UC16 biozones. Another nannofossil recorded in the alveolus might be ?*Uniplanarius gothicus* Deflandre, a species that disappears either just below or just above the Campanian/Maastrichtian boundary (Niebuhr et al., 2011).

3. Cilo section, Lower Member of the Germav Formation

The argillaceous limestones and belemnite-bearing strata of the Lower Member of the Germav Formation at the Cilo locality have only recently been sampled. The section is located on the northern

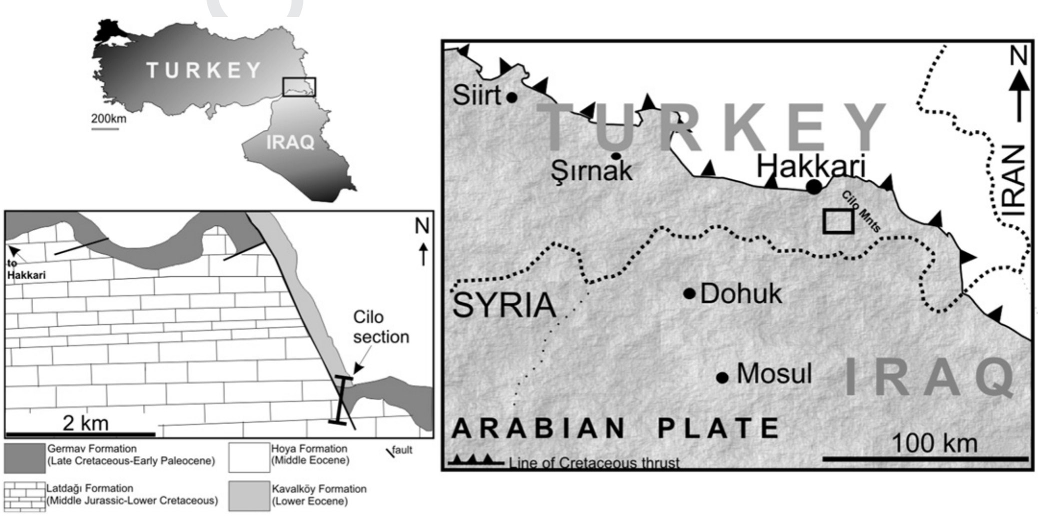

Fig. 1. Geographic position, generalized geological and location map of the Hakkari area, Cilo section (after Altınlı, 1954; Perinçek 1990).

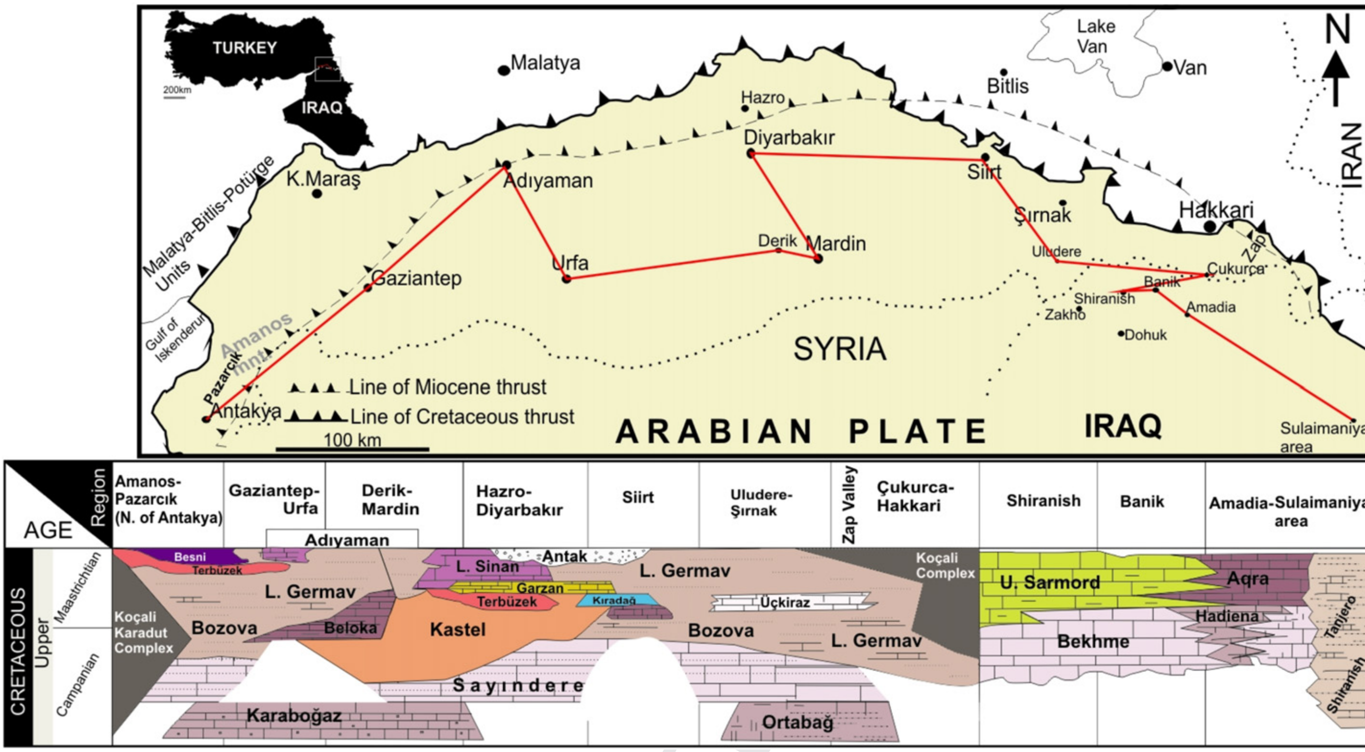

Fig. 2. General Upper Cretaceous lithostratigraphic columns for the northern margin of the Arabian plate, parts of southeast Turkey and northeast Iraq (after Perinçek, 1990; Çoruh et al., 1997).

bank of Cilo Mountain, which is about 15 km from the town of Hakkari in southeastern Turkey (Figs. 1, 2). The section is 5 m thick and consists mainly of argillaceous limestones interbedded with thin, grey shales and less silicified calciturbidites with pelagic limestones. The succession is divided into three separate lithological units. The lower part of the section is characterized by greenish laminated shales 1.5 m thick. Between 1.5 and 3 m above the base there is an alternation of brown and light grey to beige argillaceous limestones that contain belemnites with sparse yellowish-beige, thin-bedded shale intercalations. The overlying deposits, from 3 to 5 m above the base, are characterized by thin-bedded brownish to greenish-grey silty and argillaceous limestones.

The occurrence of the greenish laminated shales (suggesting a larger terrestrial input) in the lower part of the Lower Member interbedded with argillaceous limestones containing a belemnite fauna suggests a rapid bathymetric change in this sequence. This facies change may reflect the global cooling phase that took place during the Late Campanian–Early Maastrichtian (e.g., Barrera and Savin, 1999; Li and Keller, 1999; Li et al., 1999; Friedrich et al., 2005; Abramovich et al., 2003).

Karim and Surdashy (2006, p. 33) mentioned belemnites found together with rudists and gastropods in biogenic (organodetritic) limestones of the middle part, the so-called “Kato mixed siliciclastic-carbonate succession”, of the Campanian–Maastrichtian Tanjero Formation in northeast Iraq (Fig. 2). Larger foraminifera found in this mixed siliciclastic-carbonate succession are referred to the genera *Loftusia* (Brady), *Omphalocyclus* Bronn and *Discocyclina* Gümbel. Records of *Loftusia* in particular are predominantly from Maastrichtian deposits (see Goldbeck and Langer, 2009 for an exception in Oman). Because the belemnites mentioned by Karim and Surdashy are not described or figured, it is impossible to determine them. However, it is notable that belemnite (?belemnitellid) incursion(s) to distal southern Tethyan areas should also be recorded from other sites in the area and may be also recorded from different stratigraphic levels.

4. Systematic palaeontology

Class Cephalopoda Cuvier, 1795
Subclass Coleoidea Bather, 1881
Order Belemnitida Zittel, 1895
Family Belemnitellidae Pavlow, 1914
Genus *Belemnitella* d'Orbigny, 1840

Belemnitella sp. cf. *Belemnitella* ex gr. *mucronata* (Schlotheim)
Fig. 4A–J

?1955 *Belemnitella mucronata* (Schlotheim); Naidin, p. 111, figs. 1, 2.
?1964 *Belemnitella mucronata parva* Najdin, subsp. nov., p. 90.
?1972 *Belemnitella mucronata parva* Najdin; Ali-Zade, p. 192, pl. 28, figs. 1–7; pl. 29, figs. 1–8.

Material studied. The two rostra from the Germav Formation (Late Campanian–Maastrichtian), A2 and A3, are stored in the collection of Chlupáč's Museum of Earth History (Faculty of Science, Charles University in Prague, Czech Republic) as items IGP/2011/A2 and IGP/2011/A3. The material consists of the posterior part of a larger specimen (A3) and a smaller specimen preserving part of the alveolus (A2).

Description. Specimen IGP/2011/A2 consists of a nearly complete rostrum (34.9 mm long) of a small, probably juvenile/adolescent individual. The rostrum is subcylindrical in ventral view, conical in lateral view, and ventrally flattened. Vascular imprints are well developed on the ventral and both lateral sides. Dorsolateral double furrows and depressions are well developed. A mucro is indicated.

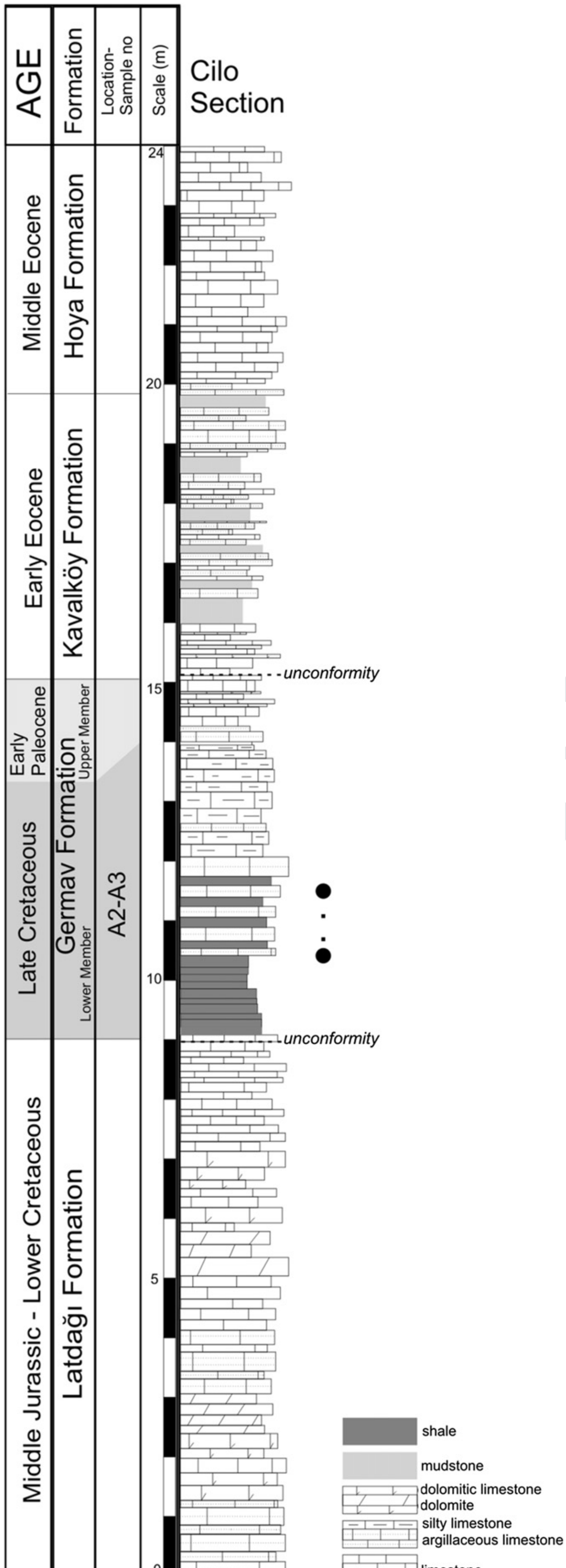

Fig. 3. Generalized columnar section of the Cilo section in the study area focused on the Late Cretaceous Lower Member of the Germav Formation. Dots indicate belemnite records from argillaceous limestones.

Specimen IGP/2011/A3 consists of the posterior part of a rostrum only (LAP = 34 mm; see Table 1). The general shape of the entire rostrum is unknown. Vascular imprints are well developed, especially on the ventral side (Fig. 4F). Dorsolateral double furrows and depressions are well developed. On the ventral side, several borings into the calcite of the rostrum belonging to the genus *Dendrina* (?*Dendrina belemniticola* Mägdefrau) are present (Fig. 4I). The mucro is clearly visible.

Christensen (1995) established a scheme of three ranges of *Belemnitella* rostrum sizes based on the length from the apex to the protoconch and also a classification of the relative length of the rostrum based on the Birkelund Index, i.e., the ratio between the length from the apex to the protoconch and the dorso-ventral diameter at the protoconch. According to his classification, both of our specimens can be categorized as small (i.e., length from apex to protoconch < 55 mm) and stout (Birkelund Index < 4 mm).

Internal characters of the rostrum. Specimen A2 was split along the dorsoventral plane in order to study the alveolar part. However, the part of the rostrum that includes the ventral fissure is not preserved; as a result, only the alveolar angle and a minimum value (9 mm) for the Schatzky distance can be given in Table 1. The most apical part of the alveolus, including the protoconch area, is recrystallized (Fig. 4E).

Geographic distribution. Northern part of the Arabian Plate, south-east Turkey, Hakkari, Cilo section.

Stratigraphic range. Late Campanian, Lower Member of the Germav Formation, in association with the foraminifera *Orbitoides medius*, *Globotruncana stuartiformis*, *G. calcarata*, *G. fornicata* and *Rugoglobigerina rotundata*.

5. Discussion

Christensen (1997a) recognized at least seven *Belemnitella* immigrations into the northern margin of Tethys: the latest Santonian incursion of *Belemnitella praecursor* Stolley, the Late Campanian *B.* ex. gr. *mucronata* and *B.* sp. (Combémorel), the late but not latest Campanian *B. hoeferi* (Schloenbach), the latest Campanian *B.* cf. *minor* II (Christensen), the Early Maastrichtian *B. pulchra* (Schulz) and the late but not latest Maastrichtian *B. junior* (Nowak). According to Christensen (1997a, c), immigration into the northern Tethys was connected to larger transgressive pulses and subsequent regression/shallowing (Gale and Christensen, 1996). This phenomenon (i.e., rapid sea-level changes in a greenhouse period) could be attributed to glacio-eustatic change (Wiese et al., 2009; Košťák and Wiese, 2011). The belemnitellid invasions into the northern Tethys could also have been a result of the extinction of the Tethyan belemnopseids (belemnite family Belemnopseidae) in the early Late Cretaceous. Christensen (1997a, b) considered immigration into the northern Tethys to be a result of a lack of competition from the Tethyan belemnites.

Zakharov et al. (2007) described and figured four specimens of *Belemnitella*? from oolitic limestone of the Gelendzhik Guyot in the Pacific (Magellan Rise, Marshall Islands). Their poor state of preservation does not allow more precise determination. It is highly likely that they are dimitobelid belemnites of the family Dimitobellidae, a group well known and widely distributed in the Southern Hemisphere, because belemnitellids are virtually unknown from the Pacific Region.

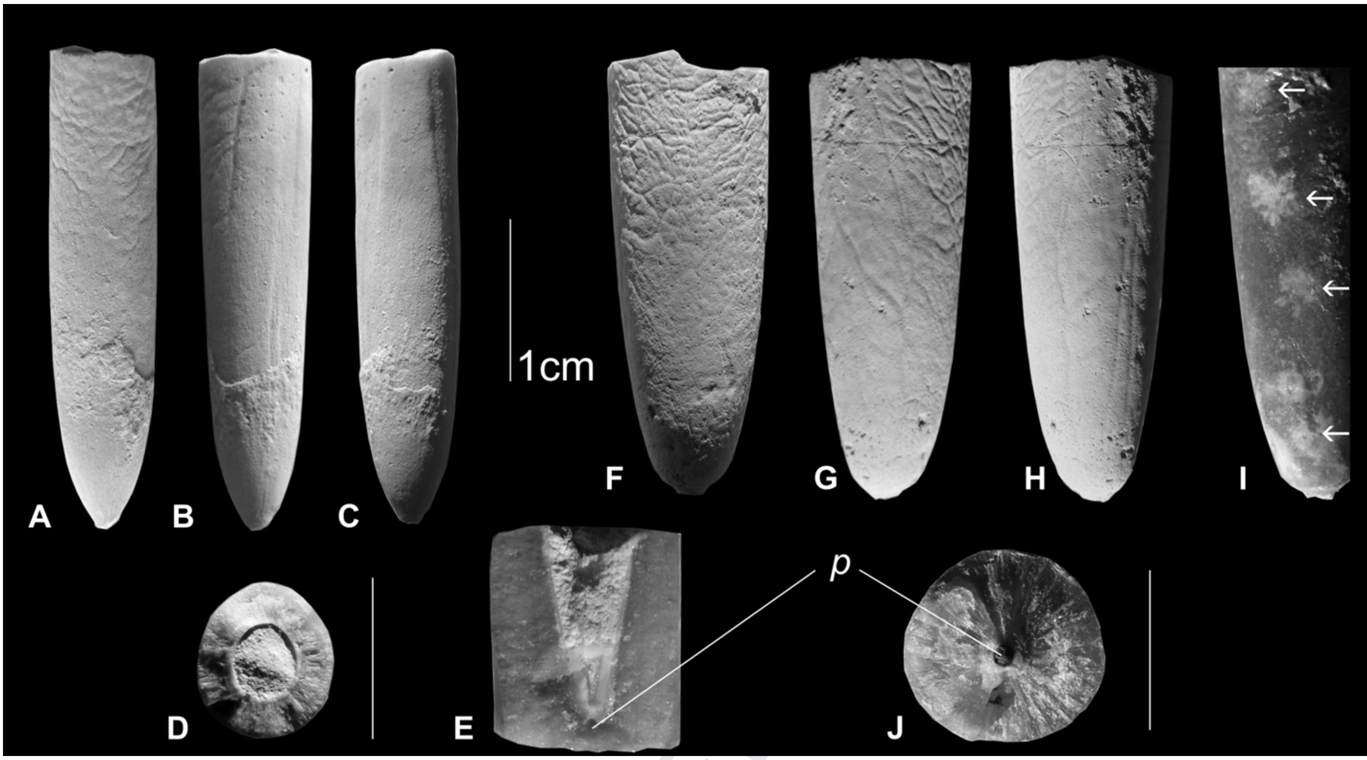

Fig. 4. *Belemnitella* sp. cf. *Belemnitella* ex gr. *mucronata* (Schlotheim) from the Cilo section. A–E, specimen IGP/2011/A2. A, ventral view. B, lateral view. C, dorsal view. D, cross-section of the alveolar part. E, alveolus. F–I, IGP/2011/A3. F, ventral view. G, ventro-lateral view. H, lateral view. I, Arrows, epibionts *Dendrina* sp. in the ventral side. J, cross-section at the protoconch area; *p*, protoconch. For A–C, F–H the specimens were coated with ammonium chloride before photographing them.

Based on morphometric analyses, Christensen (1995, 1999) divided the Campanian–Maastrichtian *Belemnitella* species into two major groups: *B. mucronata* and *B. langei* (Jeletzky). The *B. mucronata* group includes variable stout to slender belemnites with small to very large rostra. The Schatzky distance is medium-sized to large, the fissure angle is small to medium and the bottom of the ventral fissure is straight (Christensen, 1995). The *B. langei* group is characterized by small, slender rostra. The bottom of the ventral fissure is irregular, the Schatzky distance is small and the fissure angle is large (Christensen, 1995, 1999). Christensen (1997a, b) also established two *Belemnitella* lineages, i.e., the Santonian–Maastrichtian *B. schmidi* Christensen and Schulz–*B. junior* lineage and the latest Campanian–Early Maastrichtian *B. langei*–*B. pulchra* lineage, together comprising 20 species and subspecies.

As noted above, our specimens are both small (LAP < 55 mm) and stout (BI < 4), and are thus quite different from the typical European *Belemnitella* species. In fact, the BI of specimen A3 is only 2.7. The closest similarities are to the smaller subspecies of *B. mucronata* (i.e., similar LAP, SD and BI values). This species also probably included many other species of *Belemnitella* (e.g., *B. minor* Jeletzky, *B. minor* II, *B. junior*, *B. posterior* Kongiel), as has been clearly explained by Christensen (1995, 1998). Some of these taxa have

Table 1
Dimensions of rostra in (mm)

No.	LAP	DVDP	LDP	MLD	SD	FA	AA	BI
A2	26.4	8.1	7.9	8	> 9	-	23°	3.3
A3	34	12.4	12.5	-	-	-	-	2.7

LAP, length from apex to the protoconch; DVDP, dorso-ventral diameter at protoconch; LDP, lateral diameter at protoconch; MLD, maximum lateral diameter; SD, Schatzky distance (distance from the protoconch to the bottom of ventral fissure); FA, fissure angle; AA, alveolar angle; BI, Birkelund index (LAP/DVDP). Terminology and morphometry after Christensen (1975–2000).

significantly larger BI values (see Christensen, 1995, text-fig. 8). However, Christensen (1995, 2000b) concluded that *B. mucronata* persisted from the uppermost Lower Campanian through the lower Upper Campanian. Uppermost Campanian and Lower Maastrichtian records of *B. mucronata* in Europe are considered to be misconceptions (Christensen, 1998, 1999). Christensen (1995) considered that these records were based on *B. minor* II.

Christensen (1999) mentioned two specimens of *Belemnitella* sp. from the lower Spiennes Chalk formation of Belgium (Mons area) of Late Campanian age. These are small (LAP 45 and 55 mm), characterized by small BI values (2.9 and 3.2) and with an SD of about 9.0 mm. In these morphological features, they resemble the specimens described herein. However, they are poorly known and their geographic distribution is more western (also within the North European Province); hence, we suggest that the possible migration route was situated near the Caucasus region (see below).

Beyond the North European Province (sensu Christensen, 1975), taxonomic revision of species of *Belemnitella* in the context of their stratigraphic position is lacking. Naidin (1952, 1955, 1964a, b, 1975) reported many *Belemnitella* species and subspecies from the Russian Platform and adjacent areas. He described *B. mucronata* as an index taxon for the Upper Campanian. Naidin (1952) reported a lack of index ammonites in the Campanian and Maastrichtian of the Russian Platform, which may determine the age more precisely. However, he did not report any Maastrichtian records of *B. mucronata*.

Ali-Zade (1972) reported the *B. mucronata* group (i.e., several subspecies) from Azerbaijan (Caucasus). All of these records are from the Lower Upper Campanian, with an acme in the lower Upper Campanian. Of the subspecies recorded, namely *B. mucronata mucronata* (Schlotheim), *B. mucronata senior* Nowak, *B. mucronata profunda* Naidin, *B. mucronata agdadica* Ali-Zade, *B. mucronata postrema* Naidin and *B. mucronata parva* Naidin sensu Ali-Zade,

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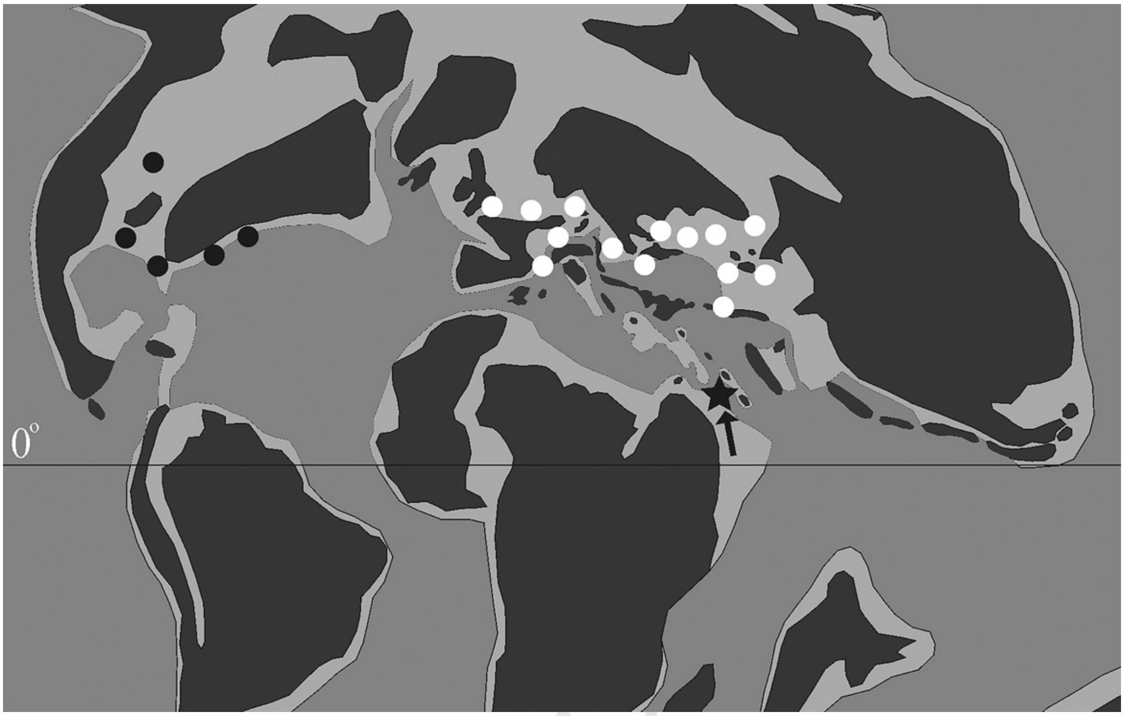

Fig. 5. The Late Campanian palaeogeographic map showing the distribution of *Belemnitella*. White dots, Eurasian occurrence (including the northernmost Tethyan records); red dots, North American occurrence; yellow dot with arrow, new record in the Arabian Plate. *Belemnitella* palaeogeographic distribution after Naidin (1964b), Ali-Zade (1972) and Christensen (1997a). Dark grey, land; light grey, shallow sea; blue, ocean.

1972, *B. mucronata parva* is most closely similar to our specimens. However, Ali-Zade (1972) reported that this Campanian subspecies had a limited geographic distribution within the Great Caucasus. The morphology of *B. mucronata parva* and its differences from other “mucronata” subspecies are so distinct that it is probable only this subspecies represents a truly independent species or subspecies. According to Naidin (1955, 1964b), the length of the rostrum varies between 40 and 60 mm and the SD exceeds 11–12 mm. In this respect, *B. mucronata parva* closely resembles our specimens of *Belemnitella* sp. However, *B. mucronata parva* probably originated during allopatric speciation in the Caucasus region and its occurrence seems to be highly endemic. It seems unlikely, therefore, that *B. mucronata parva* and our *Belemnitella* sp. are identical taxa.

Our belemnite records from the Arabian Plate (Fig. 5) probably represent a new *Belemnitella* species or subspecies. Unfortunately, based on the only two available specimens, it is impossible either to determine the species more exactly or to establish a new taxon. We therefore leave this palaeogeographically highly interesting and important record in open nomenclature for the time being. The exact taxonomic position of these belemnites within the genus *Belemnitella* will only be clarified when additional and more extensive material becomes available from the Cilo section.

6. Conclusions

The enigmatic occurrence of the Late Campanian *Belemnitella* in the Arabian Plate represents the southernmost belemnitelid immigration known in the Late Cretaceous. *Belemnitella* and *Belemnella* species incursions occurred at least six times in the Campanian–Maastrichtian interval (Christensen, 1997a). In all of these incursions, however, belemnites have been recorded only in the northernmost parts of the Tethys.

According to our new (but scarce) records from the Arabian Plate, it is obvious that belemnitellids penetrated more distal southern areas than previously realized. We present a new and still poorly known migration pattern for belemnites into tropical (almost equatorial) Tethyan areas during the Late Campanian–Maastrichtian. This immigration event is considered to be connected to global cooling during this period.

The closest relationship of *Belemnitella* sp. cf. *B.* ex gr. *mucronata* seems to be with *B. mucronata parva* Naidin, a highly endemic subspecies known from the Campanian of the Caucasus. However, its precise systematic position will only be clarified by further research.

Uncited references

Bather, 1888; Combémorel et al., 1981; Nowak, 1913.

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