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First report of the Mid Barremian Event from the Transdanubian Range (Hungary) and associated Leptoceratoididae (Ammonoidea) fauna

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A Középső Barremi Esemény felismerése a Dunántúli-középhegységben és az azzal egykorú Leptoceratoididae ammoniteszek revíziója

Összefoglalás

Jelen munkánkban a Leptoceratoididae-család kora és késő barremiben élt képviselőinek magyarországi elterjedését vizsgáltuk, valamint azokat a környezeti tényezőket igyekeztünk megkeresni, amelyek hatást gyakorolhattak a csoport gyakoriságára, diverzitására és paleoökológiájára. Ezen ammoniteszcsalád példányai két hazai lelőhelyről kerültek elő: a Bersek-hegy (Gerecse hegység) két szelvényéből és a Sümeg Süt-17 fúrásból (Déli-Bakony).

Legfontosabb rétegtani eredményünk a Bersek-hegy barremi rétegeiről készült korábbi rétegoszlopok adatainak integrálása és a Leptoceratoididae család képviselőinek eltérő rétegtani elterjedésének a demonstrálása. Az általunk létrehozott rétegoszlop korábbi szerzők rétegszámait korrelálja egymással, valamint saját geokémiai és nannofosszília mintáinkkal. Ez a kompozit rétegsor nagy pontossággal használható a *Toxancyloceras vandenheckii* Zónában, valamint megbízható a *Moutoniceras moutonianum* Zónában, viszont a *Kotetishvilia compressissima* Zóna alsó részében pontossága fenntartásokkal kezelendő. Taxonómiai vizsgálatunk eredményeképp megállapítottuk, hogy a *Karsteniceras*- és a *Leptoceratoides* nemzetségek nem egymás szinonimái. A Bersek-hegy szelvényeiben a Leptoceratoididae családot három faj képviseli részben eltérő rétegtani elterjedéssel: a *Leptoceratoides balernaensis* a *M. moutonianum* Zónában, a *Leptoceratoides pumilus* főként a *T. vandenheckii* Zónában fordul elő. Rétegtani elterjedésük a *M. moutonianum* Zóna felső részén fed csak át. A *Karsteniceras ibericum* a leggyakrabban előforduló faj, a *K. compressissima* Zóna alsó részétől a *T. vandenheckii* Zóna aljáig terjedő rétegtani elterjedéssel. A Sümeg Süt-17 fúrásban a *L. pumilus* kizárólagos tömeges előfordulása mutatható ki. Azonban ez utóbbi rétegsorban a *M. moutonianum* Zóna rétegtani helyzete csak indirekt módon állapítható meg.

A vizsgált két lelőhely faunájának eltérését részben a rétegsorok eltérő ősföldrajzi helyzetével és ebből következően eltérő paleoceanográfiai paramétereivel magyarázzuk, vagyis a különböző ősföldrajzi helyzetű egykori medencék ammoniteszei eltérő módon reagálhattak a környezetváltozásra, illetve eltérő környezeti igényeik lehettek. Feltételezhetően ezek az apró ammoniteszek is különböző ökológiai igényekkel rendelkeztek, vagyis nem alkottak homogén csoportot. Taxonómiai eredményeinket őskörnyezeti keretbe helyezve arra a következtetésre jutottunk, hogy a Bersek-hegyi előfordulás kapcsán a különböző belemniteszcsoportokon korábban mért stabil szénizotóp görbe hirtelen +1‰ kilengése a *M. moutonianum* Zónában a Középső Barremi Eseményt (KBE) jelzi. A gyors környezetváltozással összefüggő melegedésre utal a stabil oxigén izotóp -1,5‰ feletti változása is. Ekkor a szárazulatok felől a gerecsei üledékgyűjtőbe jutó megnövekedett szerves anyag mennyisége, és az ezt valószínűleg követő primer produktivitás növekedése dyzoxikus környezetet idézhetett elő a medence aljzatán. A megnövekedett szerves anyag mennyiségét a Leptoceratoididae család képviselői, valamint más epipelágikus zónában élő ammoniteszek jól tolerálhatták, míg bizonyos csoportok hiányoznak ebből a rétegösszletből.

Tárgyszavak: Leptoceratoididae; Középső Barremi Esemény, Dunántúli-középhegység, Magyarország

Abstract

Here the distribution of criocone members of the family Leptoceratoididae that proliferated during the early and late Barremian are investigated. We attempted to identify environmental factors that may have influenced the abundance, diversity and palaeoecology of the group. Specimens of this ammonite family were found at two Hungarian localities: the Bersek Hill (Gerecse Mountains) and the Sümeg Süt-17 drill core (Southern Bakony).

Our most important stratigraphic result is the integration of stratigraphic frameworks of different autors from the

Bersek Hill section which enabled us to precisely evaluate the stratigraphic distribution of this ammonite family. This integrated stratigraphy can be used with high accuracy for the *Toxancyloceras vandenheckii* Zone and is reliable for the *Moutoniceras moutonianum* Zone, but its accuracy for the lower part of the *Kotetishvilia compressissima* Zone is less stable. Our taxonomic analysis confirmed that *Karsteniceras* and *Leptoceratoides* should be kept as separate genera. In the Bersek Hill sections, family Leptoceratoididae is represented by *Karsteniceras ibericum* as the most common species found in basal *K. compressissima* to basal *T. vandenheckii* Zones. *Leptoceratoides balernaensis* occurs in the *M. moutonianum* and *Leptoceratoides pumilus* occurs mainly in the *T. vandenheckii* Zone. Their stratigraphic occurrence displays that only a few beds overlap at the top *M. moutonianum* Zone. In the Süt-17 borehole, the family is monospecific with *L. pumilus* occurrences. Unfortunately, the stratigraphic position of the *Moutoniceras moutonianum* Zone in Süt-17 borehole could only be inferred indirectly. Local response of Leptoceratoididae to the Mid Barremian Event shows spatial distribution patterns and resulted in different assemblage composition between the two localities. Discussion on lifestyle and paleoecology of criocone Leptoceratoididae ammonites is presented. Comparing our paleontologic findings to previously measured stable isotope data on belemnite rostra from Bersek Hill, we suggest that within the *Moutoniceras moutonianum* Zone, a sudden +1‰ shift in the stable carbon isotope excursion indicates the Mid Barremian Event (MBE). The -1.5‰ shift in the stable oxygen isotope excursion also indicates warming associated with rapid environmental change. During this time interval, increased organic matter might have entered into the Gerecse basin that could have induced increased primary productivity, hence dysoxic environment on the ocean floor. The increasing organic matter content was probably well tolerated by members of the family Leptoceratoididae and by other ammonite taxons that might have lived in the epipelagic zone, while certain groups of ammonites are missing from these strata.

Keywords: Leptoceratoididae; Mid Barremian Event, Transdanubian Range, Hungary

Introduction

In the past few decades, several new achievements were accomplished on the investigation of Lower Cretaceous deposits and their fauna of the Transdanubian Range including the Bersek Hill quarry (FŐZY & FOGARASI 2002; FŐZY et al. 2002; JANSSEN & FŐZY 2003, 2004, 2005; FŐZY & JANSSEN 2009; FŐZY 2017, 2024; BAJNAI et al. 2017; LODOWSKI et al. 2022). These authors provided new additions to the classical geological compilations (FÜLÖP 1958, HAAS et al. 1985). Related to the Bersek Hill quarry, detailed faunal lists of the sequence were given, which defined its Valanginian–Barremian age. Paleontologic, geochemical and stratigraphic data were combined into multiproxy analysis, and the Valanginian Weissert Event was reported (Bajnai et al. 2017). Moreover, a detailed integrated bio- and chemostratigraphy was carried out on the Barremian strata, where stable ^{18}O and ^{13}C isotopes were measured from different belemnite taxa together with Mg/Ca ratios (PRICE et al. 2011).

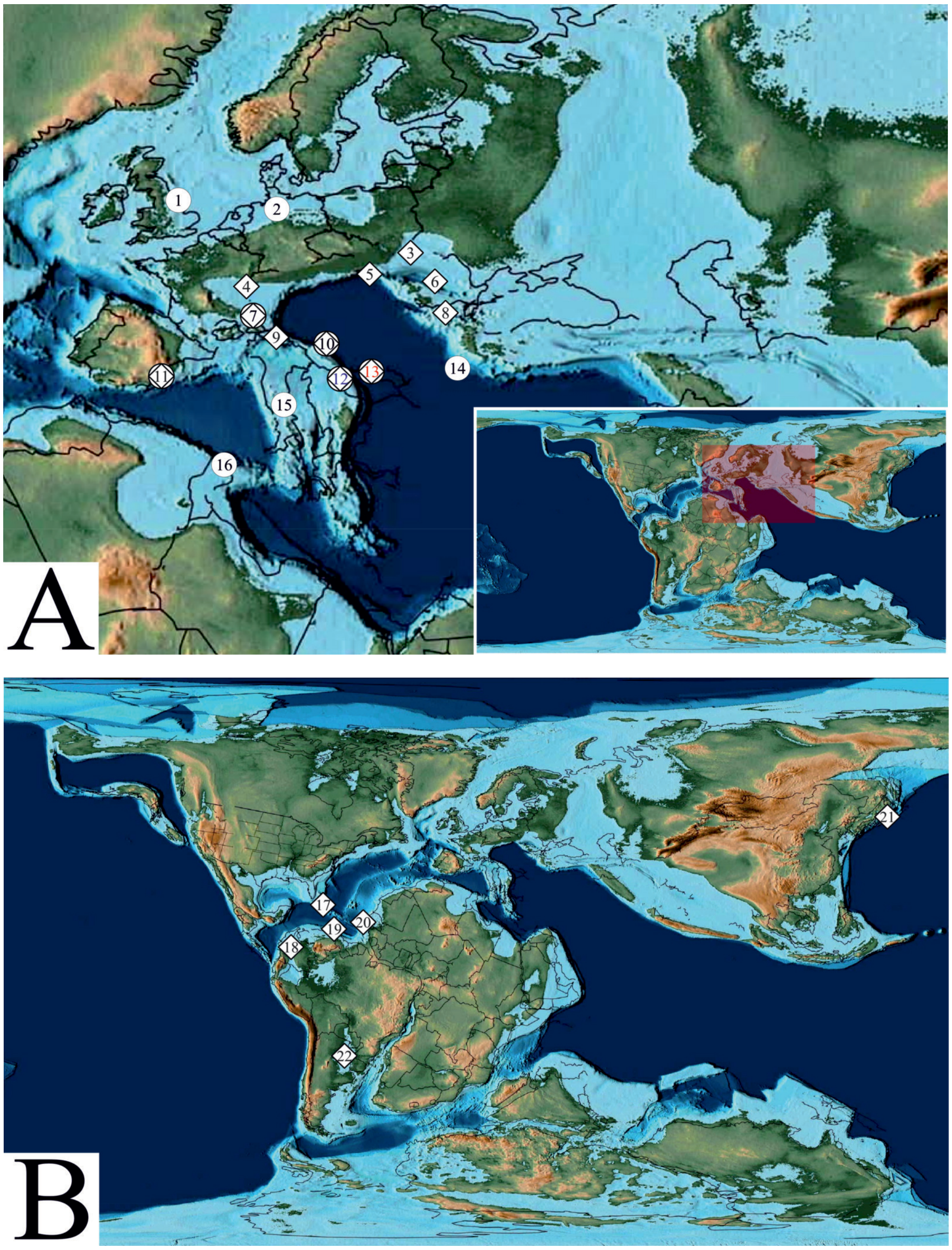
Although the macrofauna of this locality is well documented (see references above), there are still faunal elements – including tiny heteromorph Leptoceratoididae – which are less investigated. During our previous work on Cretaceous deposits of Hungary (SZIVES et al. 2007) one of us encountered two sequences in the Transdanubian Range where enrichments of tiny heteromorphs of Barremian age were detected. Appearance of this group is linked to certain paleoenvironmental perturbations (LUKENEDER & TANABE 2002); however, their ecology and periodic mass occurrences in the paleontologic record is still obscure.

Scientific interest on global scale is focussed on the environmental and climatic changes of the Earth, and some of them can be traced in the deep past as well with the tools of geochemistry and paleontology. One of the less known environmental changes is called „Mid Barremian Event (MBE)" by COCCIONI et al. (2003), who documented a thin black shale level from the Umbria–Marche Basin (UMB, Italy) and associated a 0.5 per mil positive shift in the carbon isotope values in addition to certain biotic turnovers. This observed event occured in the *Moutoniceras moutonianum* standard Mediterranean ammonite Zone (SZIVES et al. 2023). Within this ammonite zone, a significant enrichment of tiny heteromorph ammonites (*Karsteniceras ternbergense* LUKENEDER & TANABE 2002) from family Leptoceratoididae of Barremian age was also observed first by LUKENEDER & TANABE (2002); however, reports on this family are very sporadic worldwide (*Fig. 1*). These enrichment levels are

→ **Figure 1.** Occurrences of family Leptoceratoididae (rectangle) and records of the MBE (circle) from the Tethyan and Boreal regions (A), and other paleogeographic realms (B) (Barremian paleomaps are modified after SCOTESE, 2014).

Numbers refer the following localities: (A) 1, England (Speeton) (MUTTERLOSE et al. 2009); 2, North Germany (Letter, Gott, A39, Roklum) (MUTTERLOSE et al. 2009; MALKOC & MUTTERLOSE 2010); 3, Silesia (Czech Republik) (UHLIG 1883; VAŠÍČEK 1972, 1979, 1999; VAŠÍČEK & WIEDMANN 1994; VAŠÍČEK & KLAJMON 1998); 4, Veveyse (Switzerland) (OOSTER 1860; SARASIN & SCHÖNDELMAYER 1902; VAŠÍČEK & WIEDMANN 1994; BUSNARDO et al. 2003; VAŠÍČEK & HOEDEMAEKER 2003a); 5, Inner Carpathians (Slovakia) (VAŠÍČEK & WIEDMANN 1994); 6, Southern- and Eastern Carpathians (Romania) (AVRAM & KUSKO 1984; VAŠÍČEK & WIEDMANN 1994; AVRAM 1999); 7, SE France (Angles, Cluses) (VAŠÍČEK & WIEDMANN 1994; KAKABADZE & HOEDEMAEKER 1997; VERMEULEN 1998; WISSLER et al. 2002; BUSNARDO et al. 2003; GODET et al. 2006; BODIN et al. 2009; HUCK et al. 2013; MARTINEZ et al. 2023); 8, Kraptshene (Prebalkan Mts., Bulgaria) (MANOLOV 1962; DIMITROVA 1967; VAŠÍČEK & WIEDMANN 1994); 9, Swiss Alps and Southern Alps (RIEBER 1977; LUKENEDER & GRUNERT 2013); 10, Austria (WIEDMANN 1978; VAŠÍČEK & WIEDMANN 1994; LUKENEDER & TANABE 2002; LUKENEDER 2003, 2005, 2007); 11, SE Spain (FALLOT & TERMIER 1923; VAŠÍČEK & WIEDMANN 1994; VAŠÍČEK & HOEDEMAEKER 2003a; COMPANY et al. 2005; AGUADO et al. 2014, 2022; MATAMALES-ANDREU et al. 2019; MARTINEZ et al. 2020, 2023); 12, Sümeg Süt-17 drill core (Hungary) (HAAS et al. 1985); 13, Bersek Hill (Hungary) (FÜLÖP 1958; NAGY 1967; JANSSEN & FŐZY 2005; FŐZY & JANSSEN 2009); 14, Vezirhan (Turkey) (YILMAZ et al. 2012); 15, Italy (COCCIONI et al. 2003; SPROVIERI et al. 2006; HUCK et al. 2013); 16, NE Tunisia (TALBI et al. 2021); (B) 17, Cuba (MYCZYNSKI & TRIFF 1986; MYCZYNSKI 1977; VAŠÍČEK & WIEDMANN 1994); 18, Colombia (ROYO Y GOMEZ 1945; ETAYO-SERNA 1968; VAŠÍČEK & WIEDMANN 1994; KAKABADZE & HOEDEMAEKER 1997; VAŠÍČEK & HOEDEMAEKER 2003b); 19, Trinidad (IMLAY 1954; VAŠÍČEK & WIEDMANN 1994); 20, Cape Verde (Maio) (STAHLECKER 1935; VAŠÍČEK & WIEDMANN 1994; CASSON et al. 2020); 21, Japan (YABE et al. 1927; MATSUKAWA 1987, 1988, 2019, 2022; VAŠÍČEK & WIEDMANN 1994; OBATA & MATSUKAWA 2007); 22, Argentina (Neuquén Basin) (AGUIRRE-URRETA & RAWSON 2012).

→ ***1. ábra.*** *Leptoceratoididae-család elterjedése (rombusszal jelölve) és a Középső Barremi Esemény (körrel jelölve) megjelenése a tethysi és a*



boreális területeken (A), valamint a Leptoceratoididae család Európán kívüli elterjedése (B) (barremi paleotérkép Scotese 2014 után modosítva).

A számok a következő földrajzi elterjedéseket jelölik: (A) 1, Anglia (Speeton) (Mutterlose et al. 2009); 2, Észak Németország (Letter, Gott, A39, Roklum) (Mutterlose et al. 2009; Malkoc & Mutterlose 2010); 3, Szilézia (Csehország) (Uhlig 1883; Vašíček 1972, 1979, 1999; Vašíček & Wiedmann 1994; Vašíček & Klajmon 1998); 4, Veveyse (Svájc) (Ooster 1860; Sarasin & Schöndelmayer 1902; Vašíček & Wiedmann 1994; Busnardo et al. 2003; Vašíček & Hoedemaeker 2003a); 5, Belső-Kárpátok (Szlovákia) (Vašíček & Wiedmann 1994); 6, Déli- és Keleti-Kárpátok (Románia) (Avram & Kusko 1984; Vašíček & Wiedmann 1994; Avram 1999); 7, Délkelet-Franciaország (Angles, Cluses) (Vašíček & Wiedmann 1994; Kakabadze & Hoedemaeker 1997; Vermeulen 1998; Wissler et al. 2002; Busnardo et al. 2003; Godet et al. 2006; Bodin et al. 2009; Huck et al. 2013; Martinez et al. 2023); 8, Kraptshene (Balkán-hegység előtere, Bulgária) (Manolov 1962; Dimitrova 1967; Vašíček & Wiedmann 1994); 9, Svájci-Alpok és Déli-Alpok (Rieber 1977; Lukeneder & Grunert 2013); 10, Ausztria (Wiedmann 1978; Vašíček & Wiedmann 1994; Lukeneder & Tanabe 2002; Lukeneder 2003, 2005, 2007); 11, Délkelet-Spanyolország (Fallot & Termier 1923; Vašíček & Wiedmann 1994; Vašíček & Hoedemaeker 2003a; Company et al. 2005; Aguado et al. 2014, 2022; Matamales-Andreu et al. 2019; Martinez et al. 2020, 2023); 12, Sümeg Süt-17 fúrás (Magyarország) (Haas et al. 1985); 13, Bersek-hegy (Magyarország) (Fülöp 1958; Nagy 1967; Janssen & Főzy 2005; Főzy & Janssen 2009); 14, Vezirhan (Törökország) (Yilmaz et al. 2012); 15, Olaszország (Coccioni et al. 2003; Sprovieri et al. 2006; Huck et al. 2013); 16, Északkelet-Tunézia (Talbi et al. 2021); (B) 17, Kuba (Myczynski & Triff 1986; Myczynski 1977; Vašíček & Wiedmann 1994); 18, Kolumbia (Royo y Gomez 1945; Etayo-Serna 1968; Vašíček & Wiedmann 1994; Kakabadze & Hoedemaeker 1997; Vašíček & Hoedemaeker 2003b); 19, Trinidad (Imlay 1954; Vašíček & Wiedmann 1994); 20, Zöld-foki Köztársaság (Maio) (Stahlecker 1935; Vašíček & Wiedmann 1994; Casson et al. 2020); 21, Japán (Yabe et al. 1927; Matsukawa 1987, 1988, 2019, 2022; Vašíček & Wiedmann 1994; Obata & Matsukawa 2007); 22, Argentína (Neuquén-medence) (Aguirre-Urreta & Rawson 2012).

named as "*Karsteniceras* Level" by Lukeneder (2003, 2005) and are possibly linked to an environmental perturbation, which resulted in dysaerobic conditions. This is inferred from their age, which may fit the stratigraphic extent of the MBE (Lukeneder & Tanabe 2002; Lukeneder 2007) within the *M. moutonianum* Zone. Organic-rich levels did not always form during the MBE, but they were recently interpreted as episodes of regional expansion of the oxygen minimum zone (Martínez et al. 2020, Föllmi 2012).

The ecologic affinities of the family Leptoceratoididae of mainly Barremian age are not straightforward and their possible connection with the Mid Barremian Event is still unlcear; however, their mass occurrence was observed to be in the middle Barremian (Lukeneder 2003, 2005, 2007). Rieber (1977) considered Leptoceratoididae to be a nekton, Vašíček & Wiedmann (1994) considered them to be a group living and grazing within the algal mats, while Westermann (1996), due to the shape of the fragile small shell, suggested a pseudoplanktonic or planktonic lifestyle in contrast to feeding on the shallow neritic waters.

Based on these previous observations, we present the first complete account of Hungarian representatives of the family with a precise stratigraphy, together with giving a taxonomic revision of the fauna. Furthermore, we attempt to link Leptoceratoididae occurrences to the MBE on the basis of the stable isotope curve measured from belemnites of the Bersek Hill (Price et al. 2011). Moreover, we also outline and discuss the spatial and temporal abundance and diversity changes of this family with regards to paleoecologic and paleoenvironmental factors.

Geological background

Levels with members of family Leptoceratoididae were found within Barremian sediments of the Bersek Hill and the Sümeg Süt-17 drill core, situated in the Transdanubian Range, Gerecse and Bakony mountains, respectively (*Fig. 2A*). Related to their previous paleogeographic position (*Fig. 2B*), both sections are within the ALCAPA (acronym from **Al**ps, **Ca**rpathians and **Pa**nnonian Basin) terrain (Csontos & Vörös 2004); however, these sections belonged to different segments of a foreland basin system (Fodor et al. 2013; Fodor & Főzy 2013, 2022; Főzy 2024).

Sümeg Süt-17 (Süt-17) drill core

To better understand the Southern Bakony basin, the Hungarian Geological Survey drilled several boreholes in the area including the Sümeg Süt-17 core in 1983, which is situated within the town of Sümeg (*Fig. 2A, B*).

The extensively investigated core (Haas et al. 1985) starts with a Jurassic pelagic limestone which grades into a Lower Cretaceous siliciclastic deposit called Sümeg Marl Formation (SMF). The depositional environment was interpreted (Haas et al. 1985) as a calm deep neritic zone below the wave base. Upward increasing amount of terrigenious material may be related to the southwestward movement of the forebulge towards the Southern Bakony basin of the Sümeg area (Fodor et al. 2013; Fodor & Főzy 2013, 2022; Főzy 2024). The SMF is rich in macro– and microfauna, which also point to an open neritic environment (Haas et al. 1985, Bence et al. 1990, Knauer 1996). According to the most recent summary (Császár & Haas 2023), this sedimentary unit was deposited in a shallow bathyal depth. Planispiral ammonites do not appear within the same interval together with Leptoceratoididae, but otherwise are relatively abundant in the Süt-17 core. Nevertheless, these are beyond the scope of this work.

Bersek Hill quarry

Another sedimentary unit where Barremian tiny heteromorphs were found is situated in the Gerecse Mountains, south from the small town of Lábatlan (*Fig. 2A, B*).

During the late Berriasian, in the Gerecse Basin a turbidite system connected to a foredeep basin was established, which caused the termination of carbonate sedimentation much earlier than in the Bakony Mountains. This resulted in the onset of a mixed siliciclastic–carbonate sedimentation in the late Berriasian (Sasvári 2009, Császár et al. 2012, Fodor et al. 2013, Fodor & Főzy 2013, Sztanó et al. 2018, Főzy 2024). The Lower Cretaceous "flysch" succession (Kázmér 1987, Fogarasi 1995a, b) crops out in the northern wall of a huge open pit quarry at Bersek Hill (*Fig. 3*).

The so-called Bersek Marl Formation (BMF, Fülöp 1958), which represents the lower part of the clastic succession (*Fig. 3*), crops outin the lowest level of the quarry. Its age is early Valanginian to late Hauterivian based on its abundant ammonite findings (Főzy 2017, 2024 and references within) and rich in aptychi. During the Barremian, input of coarse clastic material increased, and the marlstone deposition was replaced by the deposition of the Lábatlan Sandstone Formation (LSF, Fülöp 1958). Ammonites are less frequently found within this grey sandstone; however, its age was first established on the basis of ammonites (Főzy 2017) as late Hauterivian/early Barremian to earliest Aptian (Lb-36 drill core, Főzy et al. 2002).

The boundary between the Bersek and Lábatlan Formations (*Fig. 3*) is a greenish grey slump–fold unit (Fogarasi 1995a), which is a very important marker level observed continuously (Főzy 1995, Sztanó et al. 2018). This greenish unit contains chaotically folded sandstone and marl layers, deformed in the frontal part of an extensive slump (Fogarasi 1995a, Sztanó et al. 2018).

The Lábatlan Sandstone Formation in the Bersek Hill is comprised of rhytmic alternation of sandy beds and marly intercalations (*Fig. 3*) interpreted as the margin of a turbidite system (Fogarasai 1995b, Császár et al. 2012, Sztanó et al 2018). The upward coarsening and thickening sandstone series with thick, massive, amalgamated sandstones deposited on the progradational lobes and lobe complexes (Sztanó 1990, Fodor et al. 2013). The deposition of LSF was mostly controlled by gravity mass movements, mainly

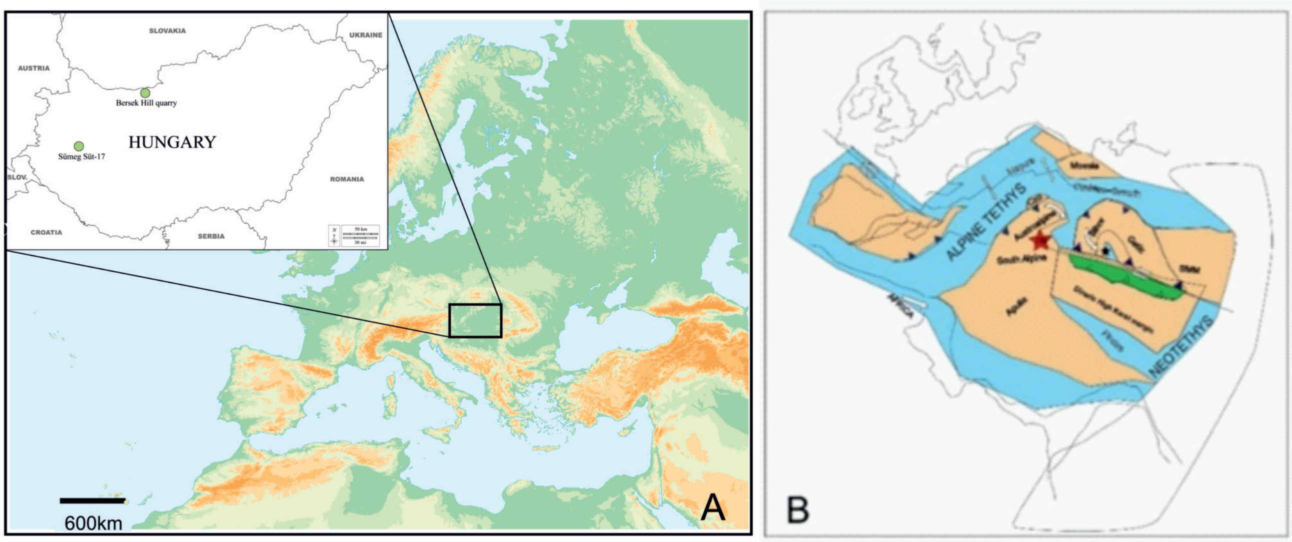


Figure 2. Geographic position of the investigated sections. (A): present day (green circles mark the localities), (B): during the early Aptian after CSONTOS & VÖRÖS (2004). Red star marks the Transdanubian Range, blue areas are deep oceanic basins, brown areas are shallower neritic water masses. Thrust fronts marked with triangles, thrust zones with arrows. Continental areas are not coloured

2. ábra. *A vizsgált területek földrajzi elhelyezkedése. (A): napjainkban (zöld körökkel jelölve), (B): valamint a kora apti során CSONTOS & VÖRÖS (2004) után. A vörös csillag a Dunántúli-középhegységet, a kék területek az óceáni medencéket, a barna területek a sekélytengeri övezeteket jelölik. A takarófrontok háromszögekkel, míg a takaró zónák nyíllal vannak jelölve. A kontinentális területek fehérek*

turbidity currents and rarely debris flows, where the two different paleocurrent directions were from east to west and northeast to southwest (in present direction) (FOGARASI 1995a, FODOR et al. 2013).

The depth of the basin is still debated, but on the basis of nannofossil studies and sedimentry features, FOGARASI (1995b) placed it between the aragonite (ACD) and calcite compensation (CCD) depths. Based on foraminifers, SZŰCS (2004) concluded that estimates of sea depth between ACD and CCD came from a probable misinterpretation and the lack of aragonite ammonite shells is not a depositional feature but is due to diagenetic processes. The Barremian paleoposition of the Gerecse in a foredeep setting is in contrast to that of the Bakony Mts, since the Bakony Mts was probably located in the backbulge of the foreland basin system (TARI 1994, FODOR & FŐZY 2022).

The upper part of the Lower Cretaceous sedimentary cycle is missing from the early Aptian and upwards due to the tectonism related to the Alpine orogeny (TARI 1994, SASVÁRI 2009, FODOR & FŐZY 2013, SZIVES et al. 2018)

Figure 3. The north wall of the Bersek Hill quarry with the sequence of the Lábatlan Sandstone Formation (LSF) and the underlying Bersek Marl Formation (BMF). The boundary between the two sedimentary units (greenish grey slump-fold unit [base of LSF] and BMF) is marked with yellow line

3. ábra. *A Bersek-hegy északi oldalában található szelvény feltárja a Lábatlani Homokkő Formációt (LSF), valamint a fekü Berseki Márga Formációt (BMF). A két képződmény határa (zöldesszürke, deformált homokkő réteg [LSF bázisa] és BMF között) sárga vonallal jelölve*

Material

Sümeg Süt-17 drill core

The Leptoceratoididae from Sümeg Süt-17 borehole have been already depicted in the literature (HAAS et al. 1985). All of the relatively abundant ammonites revealed in the Süt-17 core are shelled, among them 28 specimens were determined to belong to Leptoceratoididae, which were investigated and photographed for taxonomic purposes. Our investigated heteromorph material is from between 257.5–297.4 meters, but in one level (263.6 m; core sample is archived as K.12649), mass occurrence of specimens is observed. Specimens were labelled with the exact depth of occurrence and a repository number with "K." prefix. To our knowledge, futher collecting work is not possible as no surface outcrop is present that reveals the Barremian part of the SLF.

Specimens are archived in the Cretaceous Collection of the Geological Survey Collection Department belongs to the Supervisory Authority of Regulatory Affairs (SARA) governmental institution.

Bersek Hill quarry

A huge collection of more than 11,000 ammonite internal moulds were collected by the FÜLÖP team and is informally called the "Fülöp Collection", which contains heteromorph ammonites in great numbers (FŐZY 2017), from which more than two dozens belong to the family Leptoceratoididae. These ammonites were collected in the early 1960's from the A, B and E sections (*Fig. 4*). Accordingly, specimens from the Bersek Hill are labelled with a letter (A, B, E) and a number, where the letters refer to the exact section and the numbers mean bed numbers.

All specimens are internal moulds, no shelled specimens are found. The specimens are listed bed-by-bed in *Appendix 1*. During recent field work, five additional Leptoceratoididae remains (*M. moutonianum* Zone, *T. vandenheckii* Zone) and 78 rock samples were collected (A, B, E sections) in order to perform geochemical and microfossil investigations. Ammonites are housed in the Department of Paleontology and Geology of the Hungarian Natural History Museum and catalogued with "INV" prefix.

Methods

The investigated specimens underwent cleaning, preparation and photographing. Collected specimens were cleaned with soap water and prepared with Dremel vibrotool, all of them were measured with electronic scale, examinded with lupe of 3x magnification. Ammonites were covered with NH_4Cl vapor and photographed using NIKON camera and Xiaomi 12X cellphone with a Sony IMX766 camera.

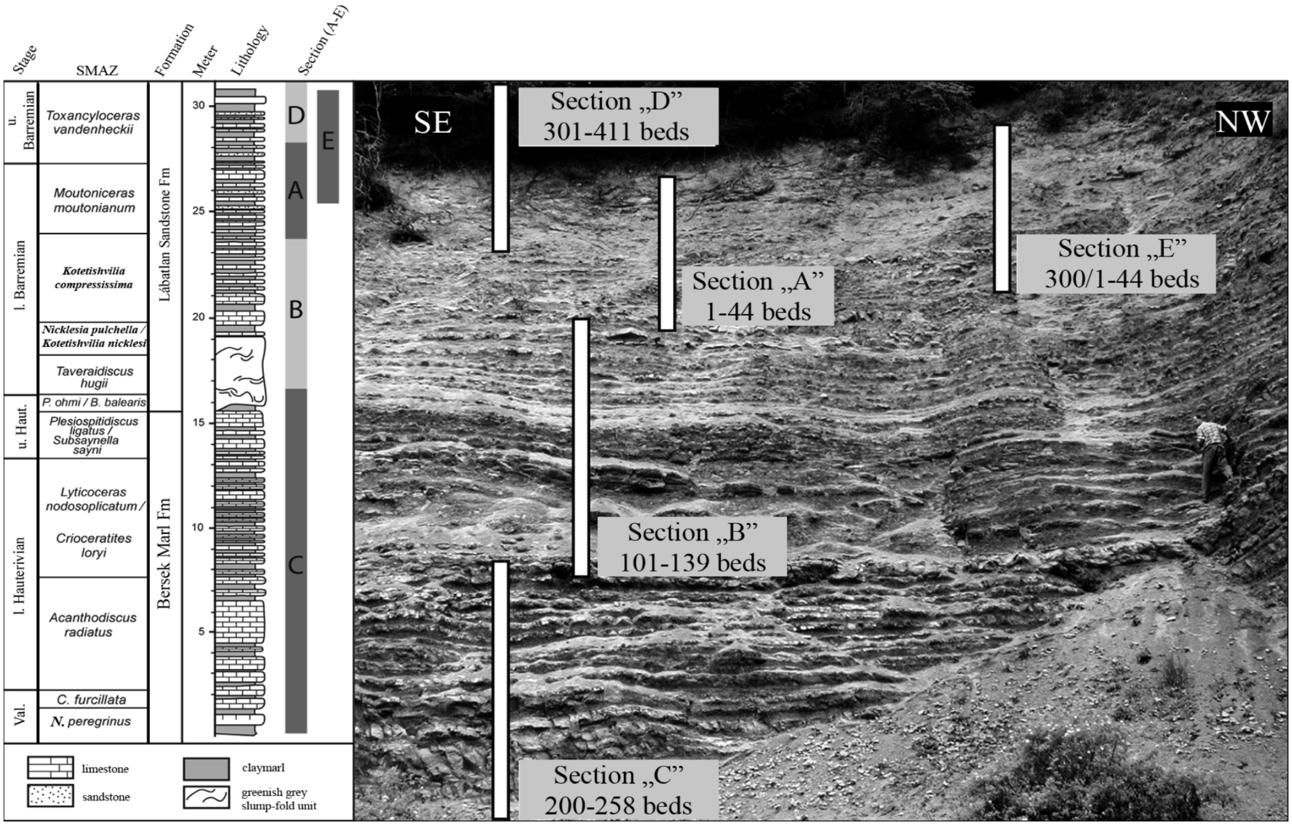


Figure 4. Positions of different collecting sections of FÜLÖP named by FŐZY (2017 and references therein) as Sections A, B, C, D, E and this work (modified after FŐZY 2017) on the Bersek Hill succession. Abbreviations: Val.: Valanginian, l.: lower, u.: upper, Haut.: Hauterivian, SMAZ: Standard Mediterranean Ammonite Zonation is after SZIVES et al. (2023)

4. ábra. *A FÜLÖP által létrehozott különböző szelvények elhelyezkedése a Bersek-hegyen. Ezeket FŐZY (2017) A, B, C, D, E szelvényeknek nevezte el (módosítva FŐZY 2017 után). Rövidítések: Val.: valangini, l.: alsó, u.: felső, Haut.: hauterivi, SMAZ: tethysi ammoniteszzónák SZIVES et al. (2023) után*

For purposes of stratigraphy, we used the latest Tethyan Standard Mediterranean Ammonite Zonation (SMAZ) recently updated by Szives et al. (2023). For measuring the small heteromorph specimens, we established metric parameters (*Fig. 5*).

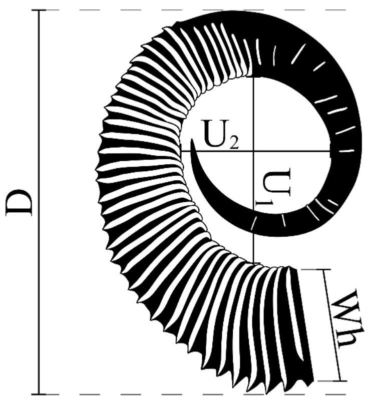


Figure 5. Measurements of a leptoceratoid conch: D: diameter; Wh: whorl height; U1: height of the umbilical opening; U2: width of the umbilical opening

***5. ábra.** A vizsgált vázparaméterek egy leptoceratoid-maradványon: D: átmérő; Wh: kanyarulat magasság; U1: köldök magasság; U2: köldök szélesség*

Ammonite taxonomy

Our most important paleontologic result is the taxonomic revision of the Barremian small heteromorph fauna collected from Hungarian sections. During this work we confirmed that genera *Karsteniceras* and *Leptoceratoides* are different and should not be used as synonyms.

Taxonomic interpretation of the fauna is documented below; higher taxonomic ranks follow recent updates by Hoffmann et al. (2022).

Phylum Mollusca Linnaeus, 1758
Class Cephalopoda Cuvier, 1797
Order Ammonitida Haeckel, 1866
Superfamily Ancyloceratoidea Gill, 1871
Family Leptoceratoididae Thieuloy, 1966

Within the Leptoceratoididae, 12 genera (*Eoheteroceras*, *Hamulinites*, *Josticeras*, *Karsteniceras, Leptoceratoides*, *Manoloviceras*, ?*Monsalveiceras*, *Orbignyceras*, *Sabaudiella*, *Vasicekites*, *Veveysiceras*, ?*Veveysiella*) are separated (Klein et al. 2007). Separation of genera and species is very difficult because they share a similar biostratigraphic occurrence mostly in the Barremian.

The earliest known stratigraphic distribution of the family reported by Matamales-Andreu et al. (2019) is in the upper Hauterivian *Balearites krenkeli* Subzone of the *Balearites balearis* Zone where the genus *Hamulinites* appears. The appearance of several other genera is linked to the Faraoni Event during the late Hauterivian (*Pseudothurmannia ohmi* and *Pseudothurmannia mortilleti* subzonal boundary), where *Karsteniceras* (*K.* cf. *beyrichoide*), *Sabaudiella* (*S. simplex* Busnardo, 2003) and *Leptoceratoides* (Thieuloy, 1966) are first observed. Moreover, first reports of *Hamulinites munieri* (Nicklès, 1894) and *Hamulinites nicklesi* (Avram, 1999) were documented (Company et al. 2005, Lukeneder 2012, Lukeneder & Grunert 2013, Matamales-Andreu et al. 2019). Furthermore, Vašíček & Wiedmann (1994) and Matamales-Andreu et al. (2019) reported the first representatives of the genus *Veveysiceras* from the upper Hauterivian/lower Barremian *Pseudothurmannia picteti* Subzone.

The dispersal of Leptoceratoididae was rather rapid as the first *Sabaudiella* are also reported (Aguirre-Urreta & Rawson 2012) from the uppermost Hauterivian *Sabaudiella riverorum* Zone (= upper part of the *Pseudothurmannia picteti* Subzone in the Mediterranean Province following Szives et al. 2023) of Neuquén Basin. In the lower Barremian deposits, various representatives of Leptoceratoididae are documented worldwide from the Central Atlantic (Stahlecker 1935, Royo y Gomez 1945, Imlay 1954, Etayo-Serna 1968, Myczynski 1977, Myczynski & Triff 1986, Vašíček & Wiedmann 1994, Kakabadze & Hoedemaeker 1997, Vašíček & Hoedemaeker 2003b, Casson et al. 2020) and Japan (Yabe et al. 1927; Matsukawa 1987, 1988, 2019, 2022; Vašíček & Wiedmann 1994; Obata & Matsukawa 2007).

Based on our material at disposal, we do not agree with Vašíček & Wiedmann (1994) who used *Leptoceratoides* and *Karsteniceras* as synonyms. In our opinion, they show strong morphological differences that do not fall within intraspecific variation detailed below.

Genus *Leptoceratoides* Thieuloy, 1966
Type species: *Crioceras* (*Leptoceras*) *pumilum* Uhlig, 1883

Genus *Leptoceratoides* is generally characterized by tiny, few centimetres in diameter criocone morphology (Vašíček & Wiedmann 1994, Wright et al. 1996), apart from ?*Leptoceratoides heeri* (Ooster, 1860), which is much bigger with different (criocone, ?baculicone, ?hamulicone) type of coiling. In our opinion, this species does not belong to *Leptoceratoides*, probably not even into the family Leptoceratoididae.

Ribbing pattern is simple; however, the direction of ribs may vary between species (Vašíček & Wiedmann 1994, Wright et al. 1996). Moreover, in certain species [*L. balernaensis* (Rieber, 1977)] rib direction, density and thickness may change during the ontogeny [*L. subtilis* (Uhlig, 1883), *L. pumilus* (Uhlig, 1883)] resulting in simple, but somewhat irregular ribbing pattern. The most important generic feature is that no ventrolateral tuberculation or spines are present, which clearly mark the difference from *Karsteniceras*. Likewise, the ribbing and suture are also simple with wide saddles and trifid lobes (Sarasin & Schöndelmayer 1902, Vašíček & Wiedmann 1994, Wright et al. 1996).

Leptoceratoides balernaensis (RIEBER, 1977)
Plate I, Figures 1–4

?1967 *Leptoceras subtile* – DIMITROVA, p. 39, pl. 12, fig. 7
*1977 *Karsteniceras balernaense* – RIEBER, p. 779, pl. 1, figs 1–7, text-fig. 3.
1994 *Karsteniceras balernaense* – VAŠÍČEK & WIEDMANN, p. 218, pl. 3, fig. 4.

Material – Three internal moulds in various state of preservation. The phragmocone of specimen from B/108 (INV.2023.12.) is a spire with several rounds. We collected a specimen from layer 300/40 of section E (INV.2023.32.) which has a similar character, while the remains from layer 16 of section A (INV.2023.21.) consist of a single phragmocone fragment.

Measurements

Bed numbers	Number	Wh (cm)	D (cm)	U_1 (cm)	U_2 (cm)
Bersek Hill, section B, bed 108	INV.2023.12.	0.415	1.98	1.08	–
Bersek Hill, section A, bed 16	INV.2023.21.	–	1.335	0.705	–
Bersek Hill, section E, bed 300/40	INV.2023.382.	0.455	1.365	0.685	–

Description – Criocone internal moulds with basically rectiradiate ribs (mainly on the body chamber), then towards the spire some ribs become rursiradiate. The ribs are simple, dense, high and there are no nodules on the ventrolateral side. No depression is visible on the ventral side. No lobeline is observed.

Discussion – The absence of nodules on the ventrolateral side rules out the possibility that the specimens belong to the genus *Karsteniceras*. Species of *L. brunneriformis* (AVRAM, 1999) or *L. svinitensis* (AVRAM, 1999) resemble the specimens, but the ribs are not as prominent as in these two species. The ribs of these two species are rectiradiate, whereas some reported transitional forms are characterised mainly by rectiradiate, and in some cases prorsiradiate ribs. The specimen depicted by DIMITROVA (1967) differs quite a bit from the holotype of the species as its ribbing is more rigid and the coiling is much more open.

Stratigraphic and geographic occurrence – The species occurs in the lower Barremian strata of the Bersek Hill section of the LSF Formation (B section 108, E section 300/40 and A section 16). The species is known from the Southern Alps (Breggia Gorge, Switzerland) and the Pre-Balkan (Krapchene, Bulgaria). The age of the remains is restricted to the Barremian (Switzerland), Bulgarian specimens are from lower Barremian strata. The specimens from Bersek Hill (Hungary) confirm the early Barremian age.

Leptoceratoides pumilus (UHLIG, 1883)
Plate II, Figures 1–5; Plate III, Figures 1–5; Plate IV, Figures 1–3; Plate V, Figures 1, 2; Plate XI, Figure 4

1860 *Ancyloceras Escheri* – OOSTER, pl. 37, figs 3, 4.
*1883 *Crioceras (Leptoceras) pumilum* – UHLIG, p. 270, pl. 29, figs 4, 5, 6a, 6b.
1927 *Leptoceras* cfr. *pumilum* – YABE et al., p. 73(41), pl. 15(4), fig. 30.
1938 *Leptoceras parvulum* – ROMAN, pl. 35, figs 335–336 (= UHLIG 1883, pl. 29, figs 4, 5).
?1958 *Leptoceras parvulum* – FÜLÖP, pl. 7, fig. 3.
1962 *Leptoceras pumilum* – MANOLOV, p. 532.
1966 *Leptoceratoides pumilus* – THIEULOY, p. 289.
1969 *Leptoceras pumilum* – WIEDMANN, pl. 2, fig. 3 (= UHLIG 1883, pl. 29, fig. 6a).
1972 *Leptoceratoides pumilus* – VAŠÍČEK, p. 54, pl. 4, fig. 5.
1984 *Leptoceras pumilum* – AVRAM & KUSKO, p. 14, pl. 2, fig. 8.
1985 *Leptoceras parvulum* – HAAS et al., p. 89, pl. 24, fig. 3.
1987 *Leptoceratoides pumilus* – MATSUKAWA, p. 349.
1994 *Karsteniceras pumilum* – VAŠÍČEK & WIEDMANN, p. 213, pl. 1, fig. 9 (= UHLIG, 1883, pl. 29, fig. 4). pl. 2, figs 3 (= UHLIG, 1883, pl. 29, fig. 6a), 4.
2023 *Leptoceratoides pumilus* – VAŠÍČEK, p. 113.

Material – Several specimens in variable state of preservation. Most of them are fragments that accumulated in a single piece of rock, so the identification number does not indicate the specimen itself, but the hosting piece of rock. Among the Bersek sections, there are two specimens from layer 300/8 of section E (INV.2023.2.), seven remains from layer 300/11 (INV.2023.3., INV.2023.4., INV.2023.383., INV.2023.384., INV.2023.385.), and one fragment of a spire is from layer 16 of section A (INV.2023.30.). The specimens from Bersek Hill are internal moulds, while shelly specimens appear in the drill core of Süt-17.

Measurements

Bed / Depth (m)	Jele	Wh (cm)	D (cm)	U_1 (cm)	U_2 (cm)
Bersek Hill, section E, bed 300/8	INV.2023.2.	–	0.75	0.37	–
		–	0.61	0.32	–
Bersek Hill, section E, bed 300/11	INV.2023.3.	–	–	–	–
		3.7	1.05	3.7	–
		0.59	1.275	–	–
Bersek Hill, section E, bed 300/11	INV.2023.4.	0.535	1.37	0.575	–
Bersek Hill, section A, bed 16	INV.2023.30.	0.355	0.975	0.385	–
Bersek Hill, section E, bed 300/11	INV.2023.383.	–	–	–	–
Bersek Hill, section E, bed 300/11	INV.2023.384.	–	1.01	–	–
Bersek Hill, section E, bed 300/11	INV.2023.385.	0.41	–	–	–
Bersek Hill, section E, bed 300/11	INV.2023.401.	0.49	1.38	0.575	–
		–	–	–	–
Süt–17, 257.5 m	K.12639	0.265	1.145	0.785	–
Süt–17, 262.7 m	K.12646	0.44	1.26	0.545	0.52
Süt–17, 264.0 m	K.12647	0.34	1.19	0.54	0.47
Süt–17, 263.6 m	K.12649	0.44	1.49	0.82	–
		0.475	1.56	0.83	0.655
		–	0.725	0.465	0.385
		0.245	0.92	0.54	0.365
		0.145	0.55	0.415	–
		0.29	0.99	0.57	0.47
		0.15	0.62	0.465	–
		0.165	0.795	0.525	–
		0.21	–	0.5	0.415
		0.365	1.22	0.69	–
		0.26	–	–	–
		0.235	0.86	0.48	0.395
		0.155	0.69	0.4	–
		0.26	0.85	0.52	0.475
		0.25	0.805	0.55	0.39
		0.23	0.62	0.39	0.35
		0.44	1.44	0.766	–
		0.28	1.065	0.61	–
		0.235	1.015	0.615	0.435
		0.145	0.67	0.425	–
		0.26	1.23	0.925	–
		0.24	0.96	0.595	–
Süt– 17, 270.1 m	K.12655	0.565	–	1.085	–
		0.415	–	–	–
		0,555	–	–	–

Description – Finely ornamented criocone internal moulds are assigned to this species. The ribs are sharp, some on the body chamber becoming biconcave (INV.2023.3., INV.2023.4.) and rarely bifurcated (INV.2023.4., K.12649). Later they become rectiradiate as the ribs progress towards the spire. In some specimens, rursiradiate ribs are also observed in the body chamber (INV.2023.4.), and ribs may also be thickened on the phragmocone (INV.2023.2.). No ventral furrow is observed, no lobeline is visible.

Discussion – No nodules are visible on the ventrolateral part of the criocone phragmocone, so the remains belong to genus *Leptoceratoides*. Based on the irregular rib pattern (thickened ribs), *L. pumilus* and *L. subtilis* (UHLIG, 1883) are the most likely species that are similar to our fragments. Among them, only *L. pumilus* has biconcave, bifurcated ribs. A further difference is that the fragments do not show a thickening of the ribs in the ventrolateral part, nor a weakening of the ornamentation in the ventral part, which is characteristic of *L. subtilis*. Most of the specimens from Süt-17 do not show the biconcave ribs typical of the lectotype, except for a few specimens from samples K.12646 and K.12649 (pl. 4, fig 1a, 1b, 1c, 1d). Furthermore, the specimens show similarities with specimens illustrated by UHLIG (1883, pl. 29, fig. 6a) and VAŠIČEK & WIEDMANN (1994, pl. 2, fig. 3), which also show rectiradiate ribs. Specimens with a similar appearance to the fauna of Sümeg (INV.2023.401., INV.2023.30.) are also known from Bersek Hill. The presence of morphological separation/variation within the species can be interpreted as intraspecific variation.

The difference between the genera *L. balernaensis* and *L. pumilus* is mainly reflected in the rib pattern. *L. balernaensis* has a smaller number of ribs, the distance between them does not vary, and the shape of the shell shows more variability compared to *L. pumilus*. This latter is more densely ornamented and the distance between the ribs and their thickness may vary. Furthermore, *L. pumilus* is characterized by lower ribs, which are often biconcave.

Stratigraphic and geographic occurrence – The species is present between 254.3 to 270.1 m of the Süt-17 borehole, as well as in the lower Barremian *M. moutonianum* Zone of the Bersek Hill quarry Lábatlan Sandstone (A section, bed 16) and in the upper Barremian *T. vandenheckii* Zone (E section, beds 300/11 and 300/8).

The species occurs at several localities in the Carpathians: Czechia (Tichá) and in the Silesian–Beskydy Mountains (Straconka and Górki Wielkie) in Poland, as well as in the Romanian Carpathians. The species has also been documented from the Swiss Alps (Veveyse). Its presence in Japan (Shinano Province) is questionable. The species is typical of the Barremian period; specimens from Silesia (Tichá) are early Barremian. The Hungarian specimens are both early and late Barremian in age.

?*Leptoceratoides* sp.
Plate V, Figure 3

Material – A single specimen in poor state of preservation from the Süt-17 drill core.

Measurements

Bed / Depth (m)	Jele	Wh (cm)	D (cm)	U_1 (cm)	U_2 (cm)
Süt-17, 297.4 m	K.12661	0.57	3.905	–	–

Description – Hamulicone phragmocone with prorsiradiate ribs on the body chamber, which towards the spire, become rectiradiate. The ventral part and the lobe line are not visible on the specimen.

Discussion – Due to the poor preservation of the specimen, the classification is questionable. The few morphological characters suggest the species may belong to ?*Leptoceratoides heeri.* We exclude this specimen from further interpretations, because this specimen is fundamentally different from leptoceratoid ammonites and probably belong to a different family.

Stratigraphic and geographic occurrence – The specimen is from Süt-17 297.4 m depth, its age is likely late Hauterivian–early Barremian inferred indirectly after HAAS et al. (1985).

Genus *Karsteniceras* ROYO Y GOMEZ, 1945
Type species: *Ancyloceras beyrichii* KARSTEN, 1858

Genus *Karsteniceras* is generally characterized by tiny, few centimetres in diameter criocone morphology (VAŠÍČEK & WIEDMANN 1994, WRIGHT et al. 1996), apart from *K. aequicostatum* VAŠÍČEK & HOEDEMAEKER 2003b and ?*K. filicostatum* (STAHLECKER, 1935) ,which are bigger. The ribbing pattern is similar to *Leptoceratoides*; the major difference is the presence of ventrolateral tuberculation, which is the generic feature of *Karsteniceras*. The suture is simple, very similar to *Leptoceratoides* (VAŠÍČEK & WIEDMANN 1994, WRIGHT et al. 1996).

Karsteniceras ibericum VAŠÍČEK & WIEDMANN, 1994
Plate VI, Figures 1–3; Plate VII, Figures 1–3; Plate VIII, Figures 1–3; Plate IX, Figures 1–4; Plate X, Figures 1–5; Plate XI, Figures 1–3

1945 *Karsteniceras beyrichii* – ROYO Y GOMEZ, p. 461, pl. 71, fig. 1a, 1b, 1c.
1968 *Karsteniceras beyrichii* – ETAYO-SERNA, p. 54, pl. 1, figs 1–3, text-fig. 4: 8–9.
1978 *Karsteniceras beyrichii* – WIEDMANN, pl. 4, fig. 2a, 2b.
*1994 *Karsteniceras ibericum* – VAŠÍČEK & WIEDMANN, p. 212, pl, 1, figs 4, 5.

Material – 19 fragments of specimens, which are mostly spire fragments, all are from the Bersek Hill.

Measurements

Bed	Rep. nr.	Wh (cm)	D (cm)	U_1 (cm)	U_2 (cm)
Bersek Hill, section A, bed 8	INV.2023.5.	0.66	–	–	–
Bersek Hill, section A, bed 8	INV.2023.6.	–	–	–	–
Bersek Hill, section A, bed 8	INV.2023.7.	0.51	1.82	0.93	0.655
Bersek Hill, section E, bed 300/35	INV.2023.8.	0.6	2.1	1.1	–
Bersek Hill, section A, bed 16	INV.2023.9.	–	–	–	–
Bersek Hill, section B, bed 108	INV.2023.11	–	1.97	0.97	–
Bersek Hill, section B, bed 114	INV.2023.13.	0.51	–	–	–
Bersek Hill, section B, bed 126	INV.2023.14.	–	1.72	0.635	–
Bersek Hill, section B, bed 116	INV.2023.15.	0.225	–	–	–
Bersek Hill, section A, bed 25	INV.2023.17.	0.29	–	–	–
Bersek Hill, section A , bed 25	INV.2023.18.	–	–	–	–
Bersek Hill, section A, bed 17	INV.2023.20.	0.35	1.4	0.72	–

Bersek Hill, section E, bed 300/40	INV.2023.22.	0.34	–	–	–
Bersek Hill, section A, bed 12	INV.2023.23.	–	–	–	–
Bersek Hill, section A, bed 7	INV.2023.24.	0.455	2.08	1.015	–
Bersek Hill, section E, bed 300/15	INV.2023.25.	0.26	–	0.615	–
Bersek Hill, section E, bed 300/15	INV.2023.28.	0.53	1.59	0.615	–
Bersek Hill, section B, bed 111	INV.2023.29.	–	1.2	0.44	–
Bersek Hill, section E, bed 300/11	INV.2023.381.	–	–	–	–
Bersek Hill, section E, bed 300/11	INV.2023.400.	–	–	–	–

Description – Criocone fragments of internal moulds, where dense rectiradiate ribs are present on the body chamber. In addition, few rursiradiate ribs also appear, which are not only present on the body chamber but also on the spire, and then, towards the spire, prorsiradiate ribs (INV.2023.6.) also appear. The spire itself is missing from the internal moulds. In the ventrolateral part, most of the ribs display small tuberculation, and a ventral furrow is visible. In some fragments, some ribs show thickening and a change in rib density (INV.2023.5.). In some specimens (INV.2023.20, INV.2023.25), the ribs pass the ventral part interrupting the course of the ventral depression. On two specimens (INV.2023.17, INV.2023.5), the ventral depression is not visible. In other specimens (INV.2023.25, INV.2023.381), the ventral depression is only visible on the ribs. No lobeline is visible on any specimens.

Discussion – Based on the generic features – criocone phragmocone and small tubercles on the ventrolateral part – the specimens are assigned to genus *Karsteniceras*. On the basis of its irregular rib pattern, the specimens resemble *K. beyrichii*, but there is no ventral depression displayed at any *Karsteniceras* species but *K. ibericum*. A further difference is that *K. beyrichii* has been described only from the Central Atlanticum, in contrast to *K. ibericum*, which has been detected from the Alpine Tethys and Neotethys basins.

Stratigraphic and geographic occurrence – The species has been described from the Western Tethyan region, mainly from the Iberian Peninsula (Sierra Mediana, Spain) and the Alps (Ranzenberg, Vorarlberg, Austria; WIEDMANN 1978). In the Central Atlantic it occurs in Colombia, where it was reported from Barremian strata, in Austria it was discovered around the lower/upper Barremian boundary, while in Spain it occurs only in the upper Barremian strata. The Hungarian findings confirm the early Barremian occurrence of the species.

Karsteniceras sp. 1
Plate XII, Figures 1–3

Material – Four badly preserved internal moulds from the Bersek Hill.

Measurements

Bed	Rep. nr.	Wh (cm)	D (cm)	U_1 (cm)	U_2 (cm)
Bersek Hill, section A, bed 16	INV.2023.10.	0.47	–	–	–
Bersek Hill, section A, bed 35	INV.2023.16.	–	–	–	–
Bersek Hill, section E, bed 300/15	INV.2023.27.	–	–	–	–
		–	–	–	–

Description – The specimens have simple rectiradiate ribs. The width of the ribs is greater than the distance between them and there is no abrupt change in the spacing (density) of the ribs. Nodules are visible in the ventrolateral part. In the ventral part, no depression and no lobeline are visible.

Discussion – Species level identification is not possible on the basis of the morphological features observed on the internal moulds, most likely due to the poor preservation.

Differences between *Karsteniceras* sp. 1 and *K. ibericum* are manifested in the ornamentation. In *Karsteniceras* sp. 1, rectiradiate ribs are observed, equally spaced apart, whereas in *K. ibericum* specimens, the ribbing pattern is rather irregular as rectiradiate and prorsiradiate ribs both appear, as well as rursiradiate ones. In addition, on *K. ibericum*, a thickening of the ribs and a change in the density of the ornamentation are also observed. Furthermore, no ventral depression is visible on the specimens, which is present on the majority of *K. ibericum* specimens.

Stratigraphic and geographic occurrence – The specimens occur in different strata of the LSF of the Bersek Hill. The lowest occurrence is in the *M. moutonianum* Zone (in beds 16 and 35 of section A), followed by the *T. vandenheckii* Zone (in bed 300/15 of section E).

Karsteniceras sp. 2
Plate XII, Figure 4

Material – A single internal mould of a specimen from the Bersek Hill.

Measurements

Bed	Rep. nr.	Wh (cm)	D (cm)	U_1 (cm)	U_2 (cm)
Bersek Hill, section E, bed 300/15	INV.2023.26.	0.26	1.12	0.615	–

Description – Criocone phragmocone with rectiradiate ribs on the body chamber. Towards the spire, rursiradiate ribs also appear on the remains. There is no visible thickening between the ribs and no abrupt change in rib spacing (density). Tuberculation is visible on the ventrolateral part. No ventral depression and lobe are visible.

Discussion – The morphological features of the phragmocone and the poor preservation do not allow species level specification. Both rectiradiate and rursiradiate ribs appear on *Karsteniceras* sp. 2, which shows similarity with *K. ibericum*, but no variation in the density of ornamentation and thickness of ribs is observed. Furthermore, the ventral depression, which is characteristic of *K. ibericum,* is not visible on the specimen.

Stratigraphic and geographic occurrence – The internal moulds are from the *T. vandenheckii* Zone of Bersek Hill (E section, bed 300/15).

Stratigraphy

Bersek Hill quarry

Compilation of an integrated section log is the main stratigraphic achievement of this work, which allows comparing different bed numberings of FÜLÖP, FŐZY and FOGARASI available in the literature (FÜLÖP 1958; FŐZY 1995, 2017; FOGARASI 1995a, b, 2001; FŐZY & FOGARASI 2002; FŐZY & JANSSEN 2009; PRICE et al. 2011).

Originally, all the specimens collected by the FÜLÖP team were assigned a letter (A, B, C, D, E) and a number. Some of them were published by FÜLÖP (1958). After FÜLÖP passed away, for many years it was not clear what these letters meant. This problem was solved in the late 1990's by István FŐZY with the help of the late Tibor STEINER, the last living member of the original collecting team by then, who showed the positions of collected sections, which likely corresponded to the letters (A, B, C, D, E). Their approximte position on the quarry wall was also shown by Tibor STEINER, depicted on *Fig. 4*. However, the lack of the original field notes was still a problem that inhibited the precise identification of ammonite bearing beds in the field (FŐZY 1995, 2017). FOGARASI (1995a, b, 2001), who worked on the nannofossils and sedimentary features of Bersek Hill, gave his own, new bed numberings and documented an extremely detailed sedimentologic log based on his field observations. His results were documented in his PhD (FOGARASI 2001) and later published (FŐZY & FOGARASI 2002). In 2015, FŐZY & SZENTE also prepared a new section log with new bed numbers based on *their* field observations. This log is not published but was used on the field during our sampling.

Our objective was to reconcile the various bed numbering systems. We examined the bed thicknesses in the field and the fauna given by the various authors. Based on these observations, we created a synthesis of bed numbers (*Appendix 2*) and made a composite section.

The integrated stratigraphic column (*Appendix 2*) includes the bed numbers of

(i) FÜLÖP's sections (A, B, C, D, E) and bed numbers displayed on the ammonites. FŐZY published his works with these numberings;

(ii) FOGARASI (2001) (115 beds) based on his very precisely measured lithology;

(iii) *this work*, where we collected 78 samples to nannofossil and geochemical analysis.

As a first step, on the basis of lithology observed in the field, we identified marker beds and used *i–iii* numberings. Two beds fit the requirement: the greenish grey slump bed at the base of LSF (*Fig. 3*) with an approximate 3-metres-thickness, which decreases with distance, and a massive sand bed of uniform, 20 cm thickness numbered as "Bed 20". After fixing these two marker levels as *i–iii* numberings, we correlated the pack of 113 beds of FOGARASI and the 43 beds with our numbers based on observations of bed thicknesses and lithology. Matching of these *i–iii* beds is completed. The greatest inconsistence was around the top 1–8 beds of ours because were measured these thicker than the top few beds of FOGARASI.

The next step was the most problematic: to fit the original bed and section (A, B, E) numbers of FÜLÖP displayed on the ammonites to the integrated stratigraphic column. In order to proceed with this, ammonite biozones given by FŐZY (2017) were fit to the integrated stratigraphy on the basis of lithology, number of collected specimens and even based on the non–ammonitiferous beds. We double-checked our correlations in the field by short collecting campaigns. These resulted in several new specimens with only five of them suitable for specific identification. Our correlation was the least precisc for section B where only the biozones and the base of the LSF were possible to be determined, and not the exact beds.

Sümeg Süt-17 drill core

The ammonite fauna of Süt-17 drill core was published by HAAS et al. (1985) focussing on biostratigraphical points. The tiny heteromorph mass occurrence was also displayed on a plate. However, the lack of modern biostratigraphic framework of microfossil groups, age indicative ammonites and chemostratigraphy makes it difficult to assign a precise stratigraphic position of Leptoceratoididae occurrences within the *M. moutonianum* Zone approximate; the comparisons to Bersek Hill section are somewhat hypotethical.

Occurrences of Leptoceratoididae

Bersek Hill quarry

Leptoceratoididae from the Bersek Hill are diverse (Plates I–IV, VI–XII) with co-occurrences of *Leptoceratoides* and *Karsteniceras* species. Specimens from this locality are internal moulds with variable but mostly medium to poor state of preservation. Their abundance is given bed-by-bed (*Fig 6*).

Sümeg Süt-17 drill core

Our findings related to Leptoceratoididae are the following:

(i) five accumulation levels (270.1 m; 264.0 m; 263.6 m; 262.7 m; 257.5 m) of Leptoceratoididae were observed;

(ii) from 297.4 m depth, a ?*Leptoceratoides* sp. was found, which is excluded from this investigation due to its uncertain taxonomic position discussed above;

(iii) all are shelled specimens;

(iv) 28 specimens were eligible for species level determination, among them 27 is *L. pumilus*;

(v) a mass occurrence level (263.6 m) is found with more than 20 specimens in a 10 cm of diameter drill core – and 100% of them is *L. pumilus;*

(vi) no planispiral ammonites or accompanying macrofauna is present between 264.0 m and 262.7 meters, also at 257.5 m;

(vii) Leptoceratoididae in Süt-17 (Plates II, IV, V) are less diverse compared to the Bersek Hill fauna.

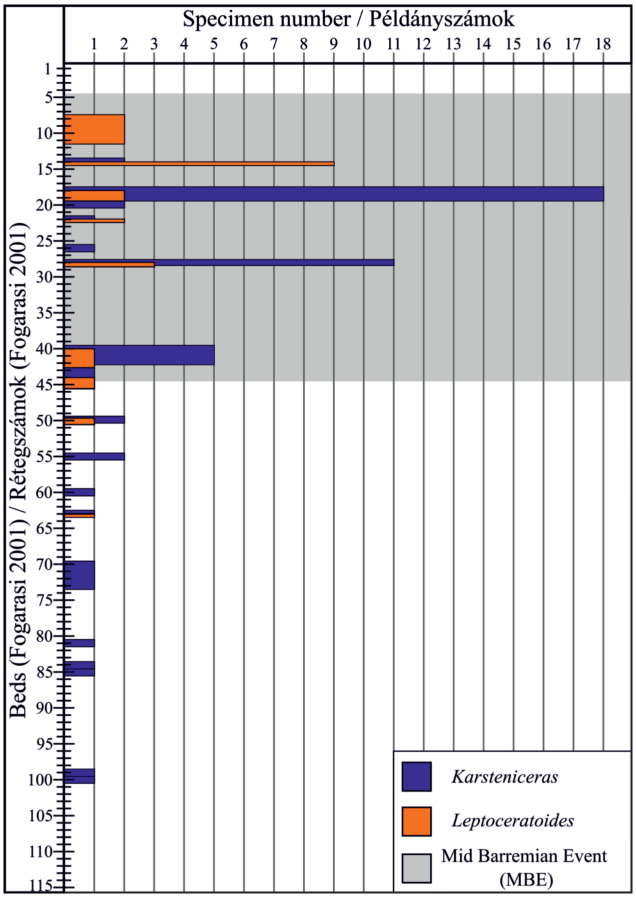


Figure 6. Specimen numbers of *Karsteniceras* spp. and *Leptoceratoides* spp. at the Bersek Hill. Grey band represents the inferred MBE interval (detailed below). Data is visualized from the *Appendix 1.* data matrix

6. ábra. Karsteniceras *spp. és* Leptoceratoides *spp. példányszámai a Bersek-hegyen. Szürke sáv jelöli a Középső Barremi Eseményt (részletesen lejjebb). Adatok megjelenítése az* 1. számú melléklet *mátrixából származik*

Discussion

Paleoenvironmental perturbations during the Mid Barremian Event

During the mid Barremian time interval, an environmental change took place and caused a positive 0.5‰ shift of the δ^{13}C that is documented by SPROVIERI et al. (2006) and named as Mid Barremian Event, along with the radiation of planctonic foraminifers and the sudden change of the radiolarian faunas (COCCIONI et al. 2003). MAHANIPOUR & EFTEKHARI (2017) observed an increasing trend in the number of warm water taxa in NC5D [nannozone] that they linked to a warming event that occured during the mid Barremian. Moreover, reported from southern Spain (AGUADO et al. 2014), an increasing trend in the number of eutrophic nannofossil taxa is also recorded from the middle part of NC5D nannozone which may indicate intermittent episodes of relative eutrophication of surface waters throughout the latest Hauterivian to earliest late Barremian interval. This also suggests warm and humid climatic conditions in the adjacent hinterlands with increased freshwater, nutrient rich runoff into the basin. Under these climatic conditions, the less saline surface waters facilitated the stratification of the water column including the development of dysoxic/anoxic bottom environments. In summary, both authors link bottom anoxia to increased pelagic primary production. Fertile pelagic watermasses might be unfavorable for most of the ammonites but provided an interval of opportunity for tiny Leptoceratoididae. The very recent summary of MARTÍNEZ et al. (2023) based on cyclostratigraphic observations, is that 1‰ PDB increase of bulk carbonate δ^{13}C values and a reduced pelagic sedimentation rate is observed during the MBE, which, in their interpretation could be a consequence of basin starvation at a time of fastest rise in sea level.

Characterization of the Mid Barremian Event in Hungary

Bersek Hill quarry

The precise stratigraphic position of the *M. moutonianum* Zone can be depicted on the basis of previously published data (FŐZY & JANSSEN 2009; PRICE et al. 2011). The separate 5-point running mean stable δ^{18}O and δ^{13}C isotope excursions measured from different belemnite taxa were previously published by PRICE et al. (2011) where mean values are plotted against the lithologic log and stratigraphic and percentile Leptoceratoididae occurrences (*Figure 7*).

The latter displays the characteristics of the Mid Barremian Event as a slight positive +0.5‰ shift in δ^{13}C values. Moreover, a slow but continuous increase the δ^{18}O values from the early Hauterivian towards the mid Barremian is observed which was interpreted by PRICE et al. (2011) as a gradual warming. They concluded that the Mg/Ca data run parallel the δ^{18}O data suggest that the overriding control on the oxygen isotope trends is indeed temperature and not evaporation or/and freshwater input. This fits to the concept of MBE by AGUADO et al. (2014) and MARTÍNEZ et al. (2023) who both assume a warm and humid pulse during the MBE.

Moreover, stratigraphic occurrences of the documented Leptoceratoididae specimens can be separated as *L. balernaensis* occurs in the *M. moutonianum,* while *L. pumilus* mainly in the *T. vandenheckii* Zone. Their stratigraphic occurrence displays only few beds that overlap at the top *M. moutonianum* Zone. *K. ibericum* is the most common species found from basal *K. compressissima* to basal *T. vandenheckii* Zones. Leptoceratoididae diversity peak observed in section A, bed 16 and a mass occurrence level at section E, bed 300/11 are both within the *M. moutonianum* Zone and, based on the above mentioned observations, might have been deposited during the MBE.

Sümeg Süt-17 drill core

Biodiversity loss of the macrofauna is observed between 264.0 and 262.7 meters (HAAS et al. 1985, table 4) where the otherwise abundant planispiral ammonites and associated macrofauna is absent, only monospecific Leptoceratoididae were found and named here as the "Leptoceratoididae interval". Compiling published data (HAAS et al. 1985) with our findings, we assume this 1.3-meter-thick "Leptoceratoididae interval" might have been deposited during the Mid Barremian Event, but the exact stratigraphic position of *M. moutonianum* Zone (including the MBE) needs further confirmation. Taking the lithology in consideration, between 270–273 metres a double terrigenious input peak was observed on the $CaCO_3$ curve by HAAS et al. (1985, fig. 27a–b). In our opinion this reflects two sudden increases in terrigenious material. These might be linked to two rapid pulses of a warmer and more humid climatic conditions and/or intensification of orogenic (uplift) movements. However, biostratigraphic uncertanties and the lack of chemostratigraphy make these assumptions and possible comparisons to the Bersek Hill section hypotethical to a degree.

Paleoecology and lifestyle of Leptoceratoididae

Paleoecology and lifestyle of heteromorph ammonites, including tiny Leptoceratoididae are still poorly understood (LUKENEDER 2003, 2005). However, all authors agree in the specialized nature of heteromorphs. Here we summarize the limited information available in the literature on this family.

RIEBER (1977) was the first who suspected a nectic mode of life for *Leptoceratoides balernaensis* (RIEBER, 1977) grazing above the anoxic seafloor. VAŠÍČEK & WIEDMANN (1994) connected the presence of small Leptoceratoididae with dark grey or black, organic matter rich pyritic muddy laminated sediments which are indicative of anoxia. They concluded that their habitat might be related to seafloor algal mats where they were grazing similar to those of Middle Jurassic heteromorphs (DIETL 1978). Due to the excellent state of preservation, all mentioned authors believe that these tiny forms did not suffer post-mortem transportation. Later, WESTERMANN (1996) interpreted a stable vertical position in the water column for criocones (= gyrocones see LUKENEDER 2015) based on the strong resistance of the forms against water currents thus indicating a pseudoplanktonic lifestyle within the epipelagic zone. LUKENEDER (2015) also shared this opinion.

Some authors (RIEBER 1977; VAŠÍČEK & WIEDMANN 1994; LUKENEDER & TANABE 2002; LUKENEDER 2003, 2005, 2007) have documented mass occurrence of Leptoceratoididae. The abundance of *Karsteniceras ternbergense* is above 90% in low oxygenated facies as LUKENEDER & TANABE (2002) and LUKENEDER (2003, 2005, 2007) reported. These authors interpreted its mass occurrence to indicate *r*–lifestyle (opportunistic) strategy. They assumed these forms were adapted to low oxygen levels that likely dominated the dysoxic sea bottom. They placed this environment to the epipelagic zone with approximate water depth of 70–80 m (LUKENEDER 2003), where the lack of bottom currents likely allowed the in-situ fossilization of finely detailed shells together with their aptichi (LUKENEDER & TANABE 2002). Nutricline depths were measured in the eastern Pacific where the number and diversity of planktonic organisms is concentrated in the 35–80 m depth zone (LONGHURST 1985). When comparing this observation with those of LUKENEDER & TANABE (2002), it becomes apparent that these tiny forms were possibly quasi-planktonic and preferred the most nutrient rich interval of the epipelagic zone which could have easily been dysoxic.

COMPANY et al. (2005) and LUKENEDER & GRUNERT (2013) believe that small Leptoceratoididae as *Karsteniceras*, *Sabaudiella* and *Hamulinites* might have lived planktonic "drifter" lifestyle. COMPANY et al. (2005) inferred that they might have lived in the epipelagic area and, therefore, anoxic events did not affect their population negatively. Nevertheless, nutrient increase during dysoxic/anoxic periods is directly linked to their increase in diversity according to these authors. Based on data reported by WESTERMANN (1996), LUKENEDER & TANABE (2002), COMPANY et al. (2005) and LUKENEDER & GRUNERT (2013), it can be assumed that the planktonic, plankton-feeding criocone shell Leptoceratoididae lived in the most nutrient-rich (nutricline) depth range of the epipelagic zone. Their fragile shell (with high interfacial resistance) might have made it difficult for Leptoceratoididae – which might have been passive drifters – to move out of this zone, thus their chances of survival would have significantly declined due to the reduced nutrient supply within this zone.

The main food source of Cretaceous heteromorphs was likely zooplankton, as confirmed by the morphology of the jaws and radula and the remains of prey animals (gastropoda, crustacea, crinoidea) (WIPPICH & LEHMANN 2004, KRUTA et al. 2011, HOFFMANN et al. 2021).

Tiny heteromorphs were more diverse in the proximal Gerecse basin, while *L. pumilus* was exclusively present in the distal Bakony basin (if we accept that the two Leptoceratoididae findings are the same age). This may give the idea that they might have lived in the epipelagic area but even tiny heteromorph ammonites could have had different ecological preferences and might have tolerated certain stress factors like lack of food, water clarity or dysoxia differently. We do not believe that with such a fragile shell these tiny forms were grazing among the sea grass and risk injuries. Combining our results with WESTERMANN (1996), it seems logical that these tiny criocone Leptoceratoididae were attracted to certain vertical levels (close to, or even within the nutricline) and movement out vertically from this level was at the mininum challenging – or almost impossible – due to the shape of the conch.

Local response of Leptoceratoididae to the Mid Barremian Event

Appearance of family Leptoceratoididae is linked to the upper Hauterivian (COMPANY et al. 2005, LUKENEDER 2012, LUKENEDER & GRUNERT 2013, MATAMALES-ANDREU et al. 2019) where their first representatives are observed in sedi-

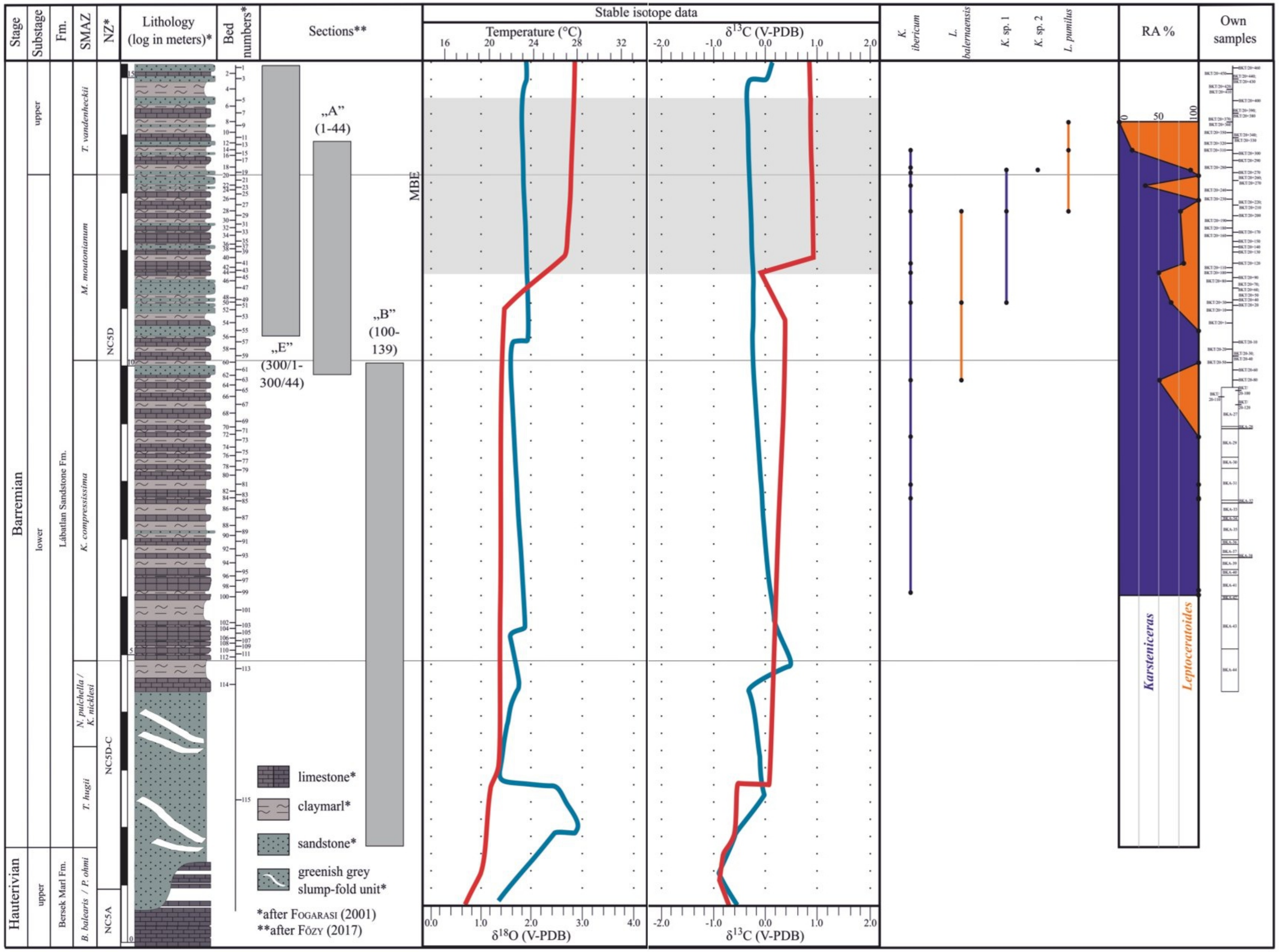


Figure 7. Biostratigraphy, lithology, sections, bed numbers and stratigraphic occurrences of identified *Karsteniceras (K.)* spp. and *Leptoceratoides (L.)* spp. of Bersek Hill quarry. Relative abundances (RA%) of these two genera (on the right) are plotted against the lithologic log. Inferred stratigraphic position of the Mid Barremian Event (MBE) is shaded grey. Chemostratigraphy data lines are simplified, measured from *Duvalia/Pseudobelus* is coloured blue, *Vaunagites pistilliformis/ "Belemnites" pistilliformis/Hibolithes* is coloured with red line (after PRICE et al. 2011)

Abbreviations: Fm.: Formation, NZ.: Calcareous nannofossil zonation

7. ábra. *A Bersek-hegy integrált biosztratigráfiája, litológiája, szelvények és rétegszámok elhelyezkedése, valamint a* Karsteniceras (K.) *spp. és* Leptoceratoides (L.) *spp. rétegtani elterjedése. Belemnitesz-taxonokból kinyert kemosztratigráfiai adatok felhasználásával készült trendvonalak mutatják a Középső Barremi Eseményt (szürke mezővel jelölve), ahol a kék vonal a* Duvalia/Pseudobelus *taxonokat, míg a vörös vonal jelöli a* Vaunagites pistilliformis/"Belemnites" pistilliformis/Hibolithes *taxonokat (PRICE et al. 2011)*

Rövidítések: Fm.: Formáció, NZ.: mészvázú nannofosszília zónák, RA: Relatív abundancia (%)

mentary sequences. Their dispersal was rather rapid towards the Central Atlantic and Japan during the early Barremian, but the members of this family were only present as suppressed elements in ammonite assemblages. In contrast, their mass occurrences are observed in middle Barremian deposits.

If we accept the hypothesis that the "Leptoceratoididae interval" of Süt-17 and the Leptoceratoididae from the Bersek Hill are coeval, the diversity of the family shows spatial and temporal changes. The greatest diversity of tiny heteromorphs is within *M. moutonianum* Zone of Bersek Hill (*Fig. 6*), with co-occurrence of *Karsteniceras ibericum, Leptoceratoides balernaensis* and *L. pumilus* (*Fig. 7*). In contrast, a monospecific mass occurrence of *L. pumilus* is visible (263.6 m) at Süt-17.

In our opinion, diversity differences may be related to the different paleogeographic positions and likely reflect different paleoceanographic features of the two basins: sediments of Süt-17 were deposited in a shallow bathyal depth of a back-bulge of the fordeep (Bakony Basin) (Tari 1994, Fodor & Főzy 2022) where increasing terrigenus input upward in the section reflects a regression according to Haas et al. (1985); while the Bersek Hill succession (Gerecse basin) was deposited in a forebulge side of a fordeep basin (Fodor et al. 2013). If we assume the Leptoceratoidiae occurrences of Bersek Hill and Süt-17 are coeval, there could be a starvation of detrital (but not carbonate) sediments in the distal Bakony basin because siliciclastic sediments are trapped on the platform at times of rapid rise in sea level. Meantime, there would be a greater influx of nutrients on the continental shelves (or in basins closer to them, like in the Gerecse basin), so primary productivity would be higher there compared to pelagic settings. This is in apparent contrast with Haas et al. (1985), which warrants further investigations.

This observed temporal and spatial shift in diversity is linked to phenomena which might be closely related to the environmental perturbations during the Mid Barremian Event, in particular, conincident with the orogenic movements of the Alpine system:

(i) Expanding dysoxia: the vertical expansion of the oxygen minimum zone forced the less tolerable forms to leave and provided and opportunity to various tiny heteromorphs to take over the more nutrient rich, proximal (however deeper) basin of the Gerecse (Bersek Hill). In the meantime, within the more distal Bakony basin (Süt-17) only one species, *L. pumilus* was able to handle the expanding dysoxic environment, which is supported by the complete lack of the accompanying fauna. Although many ammonites with different conch types could migrate vertically to higher, therefore, more oxygenated parts of the water column, criocone shell type allow only limited vertical migration (Westermann 1996, Lukeneder 2015). Vertical (and horizontal) migration necessarily occurs if the food sources leave the area or die due to expanding dysoxic conditions of the water column or the seafloor. Moreover, dwelling in the bottom might be important for hatching and was impossible for those groups that did not tolerate dysoxic conditions;

(ii) Different food supply: tiny heteromorphs moved to the proximal (but deeper) Gerecse basin, but not due to the expanding anoxia but in search of more easily available nutrients. The Gerecse basin was closer to the thrust front; therefore, higher detrital input and nutrients supported greater diversity of planctic and nektic groups than in the more distal Bakony basin;

(iii) Increased riverine input of fresh water can intensify during humid periods – like the Mid Barremian Event – or during periods of more intese uplift of the hinterland. Freshwater input may also play an important role as it facilitats both the stratification of the water column and changes in diversity of fitoplankton living on the sea surface. Runoff is more expressed in the proximal Gerecse basin; therefore, the greater diversity is directly related to the increased nutrient supply there. We do not agree with Price et al. (2011) who linked the lower oxygen isotope values from the Barremian part of the Bersek Hill section to episodes of increased freshwater input due to arid climatic conditions. In contrast, we believe their data are consistent with the scenario of Aguado et al. (2014) and Martínez et al. (2023) who interpreted the onset of more humid and warm climatic conditions that characterize the MBE.

Conclusions

1) A precise integration of independent stratigraphic columns of different authors is presented here on the Barremian strata of the Lábatlan Sandstone Formation of the Bersek Hill from the *K. compressissima*, *M. moutonianum* and *T. vandenheckii* Zones. Reliability of the integrated column is the lowest in the lower *K. compressissima* Zone.

2) Tiny heteromorph ammonites can be observed in certain levels in both the Bersek Hill quarry and Süt-17 drill core, also mass occurrence levels of them are reported. These are taxonomically revised to belong to family Leptoceratoididae apart from one specimen from Süt-17 (297.4 m).

3) Our taxonomic analysis confirmed that the genera *Karsteniceras* and *Leptoceratoides* should be kept as different genera and not be used as synonyms.

4) There is a stratigraphic shift between species that can be observed at the Bersek Hill: *L. balernaensis* occurs in the *M. moutonianum,* while *L. pumilus* mainly in the *T. vandenheckii* Zone. Their stratigraphic occurrence displays only a few beds that overlap at the top *M. moutonianum* Zone. *K. ibericum* is the most common species found from basal *K. compressissima* to basal *T. vandenheckii* Zones.

5) There are major differences in the assemblage composition of Leptoceratoididae between the two sections: assemblage of Süt-17 dominated by *L. pumilus,* while assemblage of Bersek Hill is comprised by *K. ibericum*, *L. balernaensis* and *L. pumilus*. The synchroneity of Leptoceratoididae occurrences from Süt-17 drill core and Bersek Hill is not fully established and thus remain hypothetic.

6) Discussion on the lifestyle and paleoecology of criocone Leptoceratoididae ammonites is presented.

7) Based on already published stable isotope and biostratigraphic data, we suggest the presence of the Mid Barremian Event within the *M. moutonianum* Zone of the Bersek Hill at sections E and A. Position of the MBE in Süt-17 core can only be inferred indirectly.

Acknowledgements

With this contribution we would like to tribute to the scientific works and outstanding personality of our beloved professors, András GALÁCZ and Attila VÖRÖS, on their 80th birthday. Both authors are lucky to know them, grateful for the supervision, the help, the kind guidance and the possibility of joint work with them. We wish them a lot more healthy and active years with our warmest regards and deepest honour.

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Plate I – I. tábla

Figure 1. *Leptoceratoides balernaensis* (Rieber, 1977) – INV.2023.12. BHQ; section B; bed 108; Compressissima Zone.
Figure 2. *Leptoceratoides balernaensis* (Rieber, 1977) – INV.2023.382. BHQ; section E; bed 300/40; Moutonianum Zone.
Figure 3. *Leptoceratoides balernaensis* (Rieber, 1977) Holotype (Rieber 1977, Pl. 1, Fig. 1)
Figure 4. *Leptoceratoides balernaensis* (Rieber, 1977) – INV.2023.21. BHQ; section A; bed 21; Moutonianum Zone.

1. ábra. Leptoceratoides balernaensis *(Rieber, 1977) – INV.2023.12. Bersek-hegy; B szelvény; 108. réteg; Compressissima zóna.*
2. ábra. Leptoceratoides balernaensis *(Rieber, 1977) – INV.2023.382. Bersek-hegy; E szelvény; 300/40. réteg; Moutonianum zóna.*
3. ábra. Leptoceratoides balernaensis *(Rieber, 1977) Holotípus (Rieber 1977, pl. 1, fig. 1)*
4. ábra. Leptoceratoides balernaensis *(Rieber, 1977) – INV.2023.21. Bersek-hegy; A szelvény; 21. réteg; Moutonianum zóna.*

Plate II – II. tábla

Figure 1. *Leptoceratoides pumilus* (Uhlig, 1883) – INV.2023.384. BHQ; section E; bed 300/11; Vandenheckii Zone.
Figure 2. *Leptoceratoides pumilus* (Uhlig, 1883) – INV.2023.385. BHQ; section E; bed 300/11; Vandenheckii Zone.
Figure 3. *Leptoceratoides pumilus* (Uhlig, 1883) Lectotype (Vašíček & Wiedmann 1994, pl. 1, fig. 9)
Figure 4. *Leptoceratoides pumilus* (Uhlig, 1883) – K.12647. Sümeg Süt-17; 264.0 m; Barremian?
Figure 5. *Leptoceratoides pumilus* (Uhlig, 1883) – K.12646. Sümeg Süt-17; 262.7 m; Barremian?

1. ábra. Leptoceratoides pumilus *(UHLIG, 1883) – INV.2023.384. Bersek-hegy; E szelvény; 300/11. réteg; Vandenheckii zóna.*
2. ábra. Leptoceratoides pumilus *(UHLIG, 1883) – INV.2023.385. Bersek-hegy; E szelvény; 300/11. réteg; Vandenheckii zóna.*
3. ábra. Leptoceratoides pumilus *(UHLIG, 1883) Lektotípus (VAŠÍČEK & WIEDMANN 1994, pl. 1, fig. 9)*
4. ábra. Leptoceratoides pumilus *(UHLIG, 1883) – K.12647. Sümeg Süt-17; 264,0 m; Barremi?*
5. ábra. Leptoceratoides pumilus *(UHLIG, 1883) – K.12646. Sümeg Süt-17; 262,7 m; Barremi?*

Plate III – III. tábla

Figure 1. *Leptoceratoides pumilus* (UHLIG, 1883) – INV.2023.2. BHQ; section E; bed 300/8; Vandenheckii Zone.
Figure 2. *Leptoceratoides pumilus* (UHLIG, 1883) – INV.2023.3. BHQ; section E; bed 300/11; Vandenheckii Zone.
Figure 3. *Leptoceratoides pumilus* (UHLIG, 1883) – INV.2023.4. BHQ; section E; bed 300/11; Vandenheckii Zone.
Figure 4. *Leptoceratoides pumilus* (UHLIG, 1883) – INV.2023.383. BHQ; section E; bed 300/11; Vandenheckii Zone.
Figure 5. *Leptoceratoides pumilus* (UHLIG, 1883) – INV.2023.30. BHQ; section A; bed 16; Moutonianum Zone.

1. ábra. Leptoceratoides pumilus *(UHLIG, 1883) – INV.2023.2. Bersek-hegy; E szelvény; 300/8. réteg; Vandenheckii zóna.*
2. ábra. Leptoceratoides pumilus *(UHLIG, 1883) – INV.2023.3. Bersek-hegy; E szelvény; 300/11. réteg; Vandenheckii zóna.*
3. ábra. Leptoceratoides pumilus *(UHLIG, 1883) – INV.2023.4. Bersek-hegy; E szelvény; 300/11. réteg; Vandenheckii zóna.*
4. ábra. Leptoceratoides pumilus *(UHLIG, 1883) – INV.2023.383. Bersek-hegy; E szelvény; 300/11. réteg; Vandenheckii zóna.*
5. ábra. Leptoceratoides pumilus *(UHLIG, 1883) – INV.2023.30. Bersek-hegy; A szelvény; 16. réteg; Moutonianum zóna.*

Plate IV – IV. tábla

Figure 1. Mass-occurrence of *Leptoceratoides pumilus* (UHLIG, 1883) from drilling core (Süt-17) – K.12649. 263.6 m; Barremian?
Figure 2. *Leptoceratoides pumilus* (UHLIG, 1883) – INV.2023.401. BHQ; section E; bed 300/11; Vandenheckii Zone.
Figure 3. *Leptoceratoides pumilus* (UHLIG, 1883) – K.12649. Sümeg Süt-17; 263.6 m; Barremian?

1. ábra. Leptoceratoides pumilus *(UHLIG, 1883) tömeges megjelenése a Süt-17 fúrásban – K.12649. 263,6 m; Barremi?*
2. ábra. Leptoceratoides pumilus *(UHLIG, 1883) – INV.2023.401. Bersek-hegy; E szelvény; 300/11. réteg; Vandenheckii zóna.*
3. ábra. Leptoceratoides pumilus *(UHLIG, 1883) – K.12649. Sümeg Süt-17; 263,6 m; Barremi?*

Plate V – V. tábla

Figure 1. *Leptoceratoides pumilus* (UHLIG, 1883) – K.12655. Sümeg Süt-17; 263.6 m; Barremian?
Figure 2. *Leptoceratoides pumilus* (UHLIG, 1883) – K.12639. Sümeg Süt-17; 257.5 m; Barremian?
Figure 3. *Leptoceratoides*? sp. – K.12661. Sümeg Süt-17; 297.4 m; Barremian?

1. ábra. Leptoceratoides pumilus *(UHLIG, 1883) – K.12655. Sümeg Süt-17; 263,6 m; Barremi?*
2. ábra. Leptoceratoides pumilus *(UHLIG, 1883) – K.12639. Sümeg Süt-17; 257,5 m; Barremi?*
3. ábra. Leptoceratoides*? sp. – K.12661. Sümeg Süt-17; 297,4 m; Barremi?*

Plate VI – VI. tábla

Figure 1. *Karsteniceras ibericum* VAŠÍČEK & WIEDMANN, 1994 – INV.2023.22. BHQ; section E; bed 300/40; Moutonianum Zone.
Figure 2. *Karsteniceras ibericum* VAŠÍČEK & WIEDMANN, 1994 (ETAYO-SERNA 1968, pl. 1, figs 1, 2, 3)
Figure 3. *Karsteniceras ibericum* VAŠÍČEK & WIEDMANN, 1994 – INV.2023.6. BHQ; section A; bed 8; Vandenheckii Zone.

1. ábra. Karsteniceras ibericum *VAŠÍČEK & WIEDMANN, 1994 – INV.2023.22. Bersek-hegy; E szelvény; 300/40. réteg; Moutonianum zóna.*
2. ábra. Karsteniceras ibericum *VAŠÍČEK & WIEDMANN, 1994 (ETAYO-SERNA 1968, pl. 1, figs 1, 2, 3)*
3. ábra. Karsteniceras ibericum *VAŠÍČEK & WIEDMANN, 1994 – INV.2023.6. Bersek-hegy; A szelvény; 8. réteg; Vandenheckii zóna.*

Plate VII – VII. tábla

Figure 1. *Karsteniceras ibericum* VAŠÍČEK & WIEDMANN, 1994 – INV.2023.7. BHQ; section A; bed 8; Vandenheckii Zone.
Figure 2. *Karsteniceras ibericum* VAŠÍČEK & WIEDMANN, 1994 – INV.2023.24. BHQ; section A; bed 7; Vandenheckii Zone.
Figure 3. *Karsteniceras ibericum* VAŠÍČEK & WIEDMANN, 1994 – INV.2023.28. BHQ; section E; bed 300/15; Vandenheckii Zone.

1. ábra. Karsteniceras ibericum *VAŠÍČEK & WIEDMANN, 1994 – INV.2023.7. Bersek-hegy; A szelvény; 8. réteg; Vandenheckii zóna.*
2. ábra. Karsteniceras ibericum *VAŠÍČEK & WIEDMANN, 1994 – INV.2023.24. Bersek-hegy; A szelvény; 7. réteg; Vandenheckii zóna.*
3. ábra. Karsteniceras ibericum *VAŠÍČEK & WIEDMANN, 1994 – INV.2023.28. Bersek-hegy; E szelvény; 300/15. réteg; Vandenheckii zóna.*

Plate VIII – VIII. tábla

Figure 1. *Karsteniceras ibericum* Vašíček & Wiedmann, 1994 – INV.2023.5. BHQ; section A; bed 8; Vandenheckii Zone.
Figure 2. *Karsteniceras ibericum* Vašíček & Wiedmann, 1994 – INV.2023.17. BHQ; section A; bed 25; Moutonianum Zone.
Figure 3. *Karsteniceras ibericum* Vašíček & Wiedmann, 1994 – INV.2023.25. BHQ; section E; bed 300/15; Vandenheckii Zone.

1. ábra. Karsteniceras ibericum *Vašíček & Wiedmann, 1994 – INV.2023.5. Bersek-hegy; A szelvény; 8. réteg; Vandenheckii zóna.*
2. ábra. Karsteniceras ibericum *Vašíček & Wiedmann, 1994 – INV.2023.17. Bersek-hegy; A szelvény; 25. réteg; Moutonianum zóna.*
3. ábra. Karsteniceras ibericum *Vašíček & Wiedmann, 1994 – INV.2023.25. Bersek-hegy; E szelvény; 300/15. réteg; Vandenheckii zóna.*

Plate IX – IX. tábla

Figure 1. *Karsteniceras ibericum* Vašíček & Wiedmann, 1994 – INV.2023.8. BHQ; section E; bed 300/35; Moutonianum Zone.
Figure 2. *Karsteniceras ibericum* Vašíček & Wiedmann, 1994 – INV.2023.9. BHQ; section A; bed 16; Moutonianum Zone.
Figure 3. *Karsteniceras ibericum* Vašíček & Wiedmann, 1994 – INV.2023.11. BHQ; section B; bed 108; Compressissima Zone.
Figure 4. *Karsteniceras ibericum* Vašíček & Wiedmann, 1994 – INV.2023.13. BHQ; section B; bed 114; Compressissima Zone.

1. ábra. Karsteniceras ibericum *Vašíček & Wiedmann, 1994 – INV.2023.8. Bersek-hegy; E szelvény; 300/35. réteg; Moutonianum zóna.*
2. ábra. Karsteniceras ibericum *Vašíček & Wiedmann, 1994 – INV.2023.9. Bersek-hegy; A szelvény; 16. réteg; Moutonianum zóna.*
3. ábra. Karsteniceras ibericum *Vašíček & Wiedmann, 1994 – INV.2023.11. Bersek-hegy; B szelvény; 108. réteg; Compressissima zóna.*
4. ábra. Karsteniceras ibericum *Vašíček & Wiedmann, 1994 – INV.2023.13. Bersek-hegy; B szelvény; 114. réteg; Compressissima zóna.*

Plate X – X. tábla

Figure 1. *Karsteniceras ibericum* Vašíček & Wiedmann, 1994 – INV.2023.14. BHQ; section B; bed 126; Compressissima Zone.
Figure 2. *Karsteniceras ibericum* Vašíček & Wiedmann, 1994 – INV.2023.15. BHQ; section B; bed 116; Vandenheckii Zone.
Figure 3. *Karsteniceras ibericum* Vašíček & Wiedmann, 1994 – INV.2023.20. BHQ; section A; bed 17; Moutonianum Zone.
Figure 4. *Karsteniceras ibericum* Vašíček & Wiedmann, 1994 – INV.2023.18. BHQ; section A; bed 25; Moutonianum Zone.
Figure 5. *Karsteniceras ibericum* Vašíček & Wiedmann, 1994 – INV.2023.400. BHQ; section A; bed 16; Moutonianum Zone.

1. ábra. Karsteniceras ibericum *Vašíček & Wiedmann, 1994 – INV.2023.14. Bersek-hegy; B szelvény; 126. réteg; Compressissima zóna.*
2. ábra. Karsteniceras ibericum *Vašíček & Wiedmann, 1994 – INV.2023.15. Bersek-hegy; B szelvény; 116. réteg; Vandenheckii zóna.*
3. ábra. Karsteniceras ibericum *Vašíček & Wiedmann, 1994 – INV.2023.20. Bersek-hegy; A szelvény; 17. réteg; Moutonianum zóna.*
4. ábra. Karsteniceras ibericum *Vašíček & Wiedmann, 1994 – INV.2023.18. Bersek-hegy; A szelvény; 25. réteg; Moutonianum zóna.*
5. ábra. Karsteniceras ibericum *Vašíček & Wiedmann, 1994 – INV.2023.400. Bersek-hegy; A szelvény; 16. réteg; Moutonianum zóna.*

Plate XI – XI. tábla

Figure 1. *Karsteniceras ibericum* Vašíček & Wiedmann, 1994 – INV.2023.29. BHQ; section B; bed 111; Compressissima Zone.
Figure 2. *Karsteniceras ibericum* Vašíček & Wiedmann, 1994 – INV.2023.381. BHQ; section E; bed 300/11; Vandenheckii Zone.
Figure 3. *Karsteniceras ibericum* Vašíček & Wiedmann, 1994 – INV.2023.23. BHQ; section A; bed 12; Moutonianum Zone.
Figure 4. *Leptoceratoides pumilus* (Uhlig, 1883) – INV.2023.401. BHQ; section E; bed 300/11; Vandenheckii Zone.

1. ábra. Karsteniceras ibericum *Vašíček & Wiedmann, 1994 – INV.2023.29. Bersek-hegy; B szelvény; 111. réteg; Compressissima zóna.*
2. ábra. Karsteniceras ibericum *Vašíček & Wiedmann, 1994 – INV.2023.381. Bersek-hegy; E szelvény; 300/11. réteg; Vandenheckii zóna.*
3. ábra. Karsteniceras ibericum *Vašíček & Wiedmann, 1994 – INV.2023.23. Bersek-hegy; A szelvény; 12. réteg; Moutonianum zóna.*
4. ábra. Leptoceratoides pumilus *(Uhlig, 1883) – INV.2023.401. Bersek-hegy; E szelvény; 300/11. réteg; Vandenheckii zóna.*

Plate XII – XII. tábla

Figure 1. *Karsteniceras* sp. 1 – INV.2023.10. BHQ; section A; bed 16; Moutonianum Zone.
Figure 2. *Karsteniceras* sp. 1 – INV.2023.16. BHQ; section A; bed 35; Moutonianum Zone.
Figure 3. *Karsteniceras* sp. 1 – INV.2023.27. BHQ; section E; bed 300/15; Vandenheckii Zone.
Figure 4. *Karsteniceras* sp. 2 – INV.2023.26. BHQ; section E; bed 300/15; Vandenheckii Zone.

1. ábra. Karsteniceras *sp. 1 – INV.2023.10. Bersek-hegy; A szelvény; 16. réteg; Moutonianum zóna.*
2. ábra. Karsteniceras *sp. 1 – INV.2023.16. Bersek-hegy; A szelvény; 35. réteg; Moutonianum zóna.*
3. ábra. Karsteniceras *sp. 1 – INV.2023.27. Bersek-hegy; E szelvény; 300/15. réteg; Vandenheckii zóna.*
4. ábra. Karsteniceras *sp. 2 – INV.2023.26. Bersek-hegy; E szelvény; 300/15. réteg; Vandenheckii zóna.*

Plate I – I. tábla

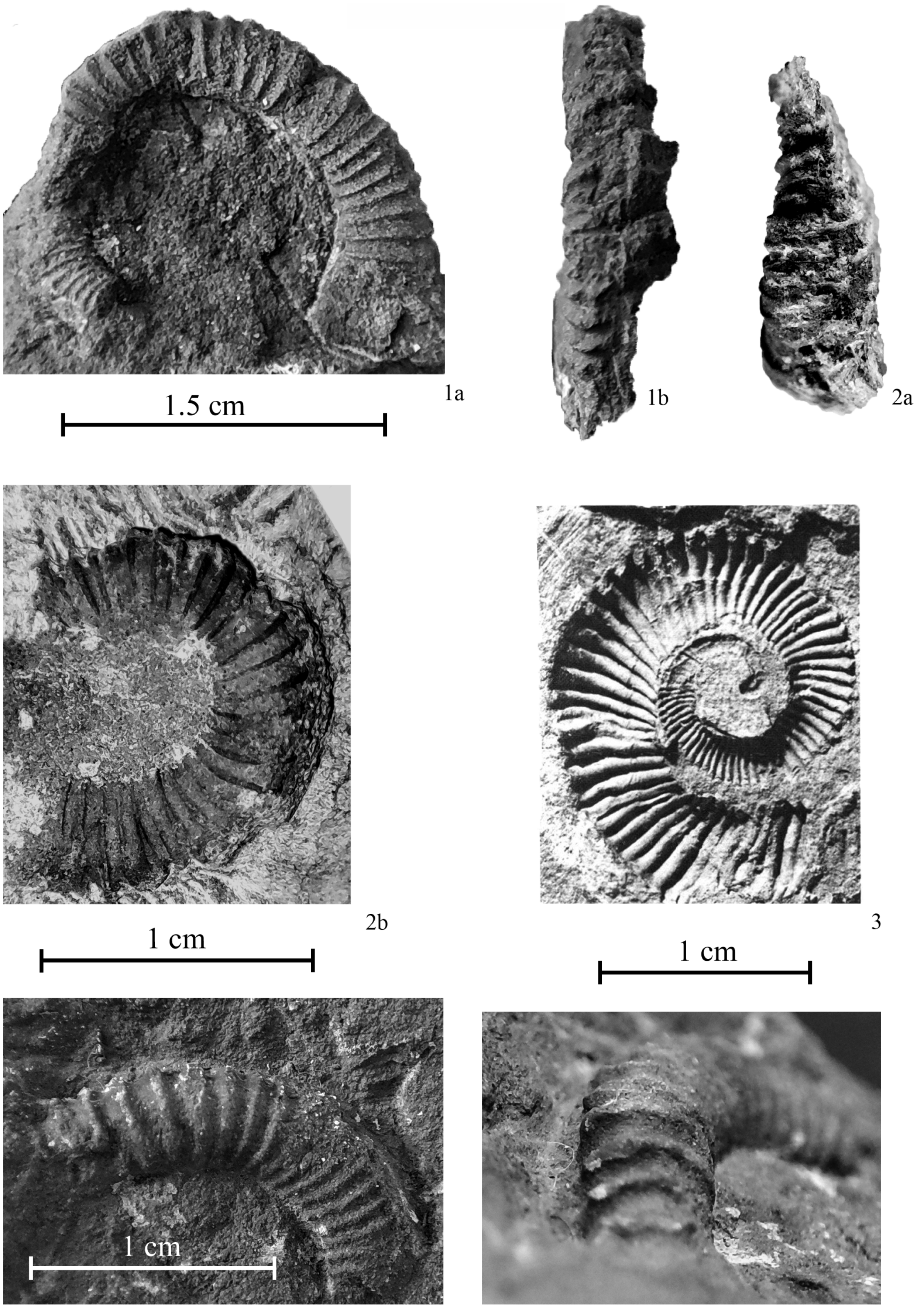

Plate II – II. tábla

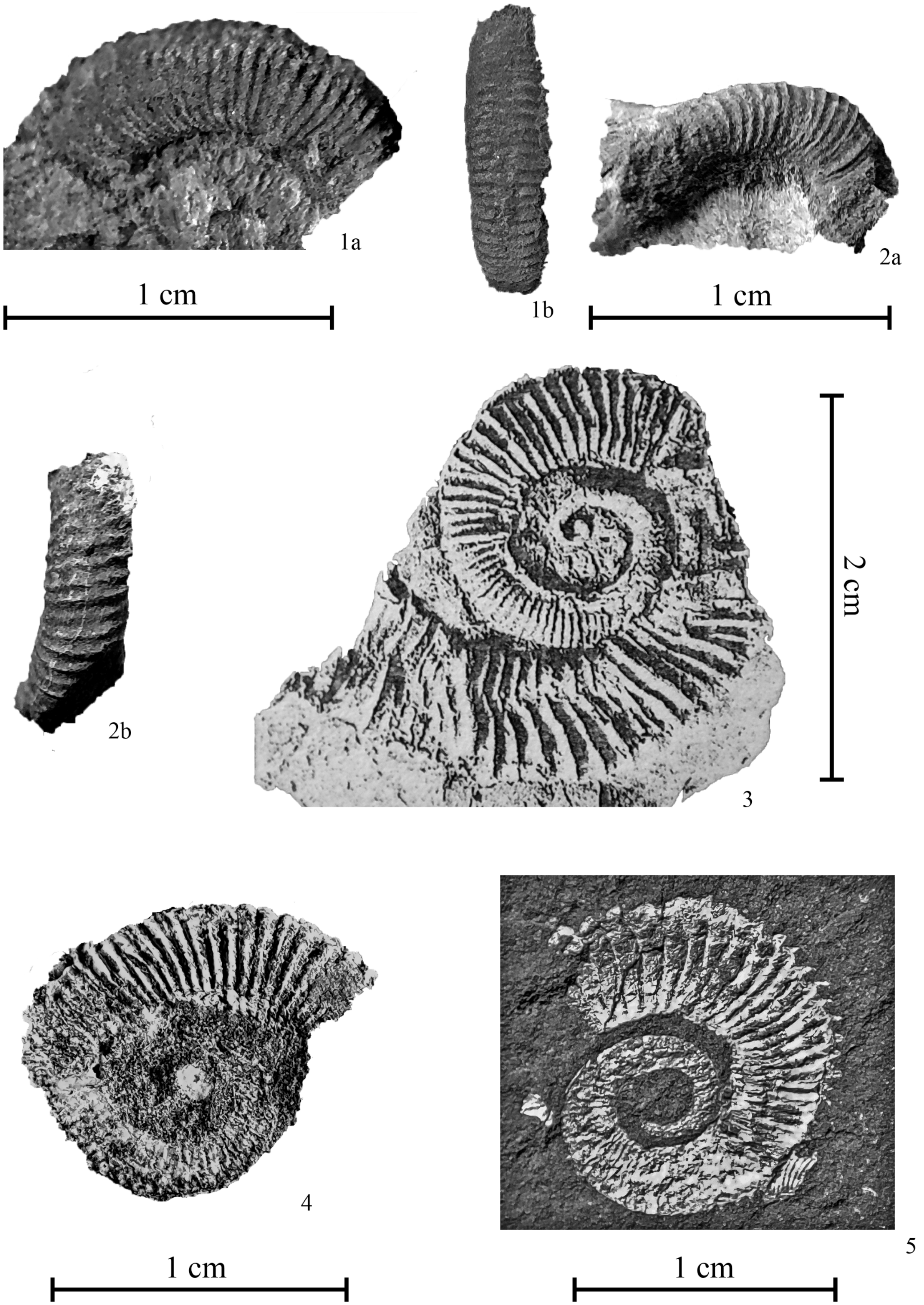

Plate III – III. tábla

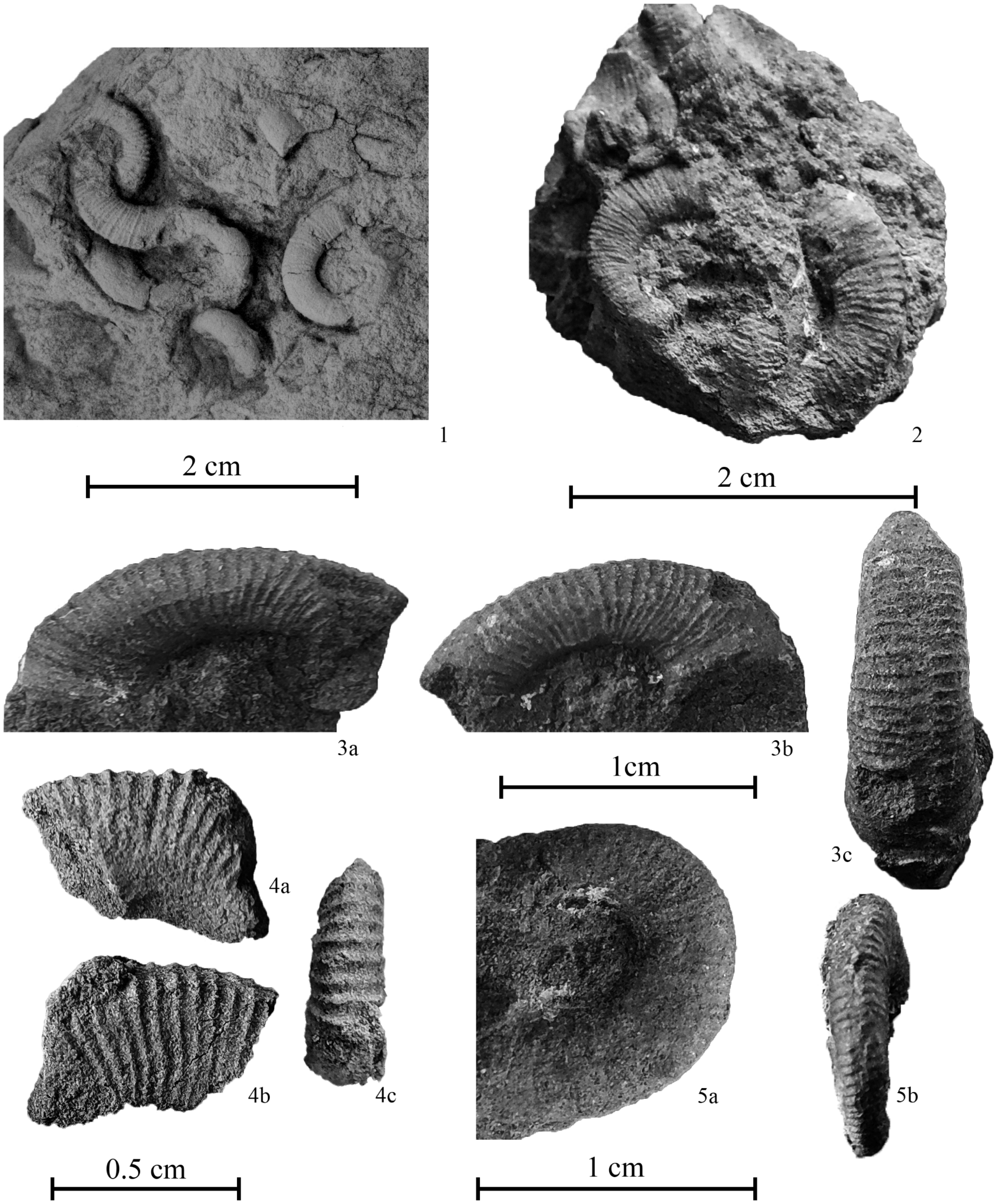

Plate IV – IV. tábla

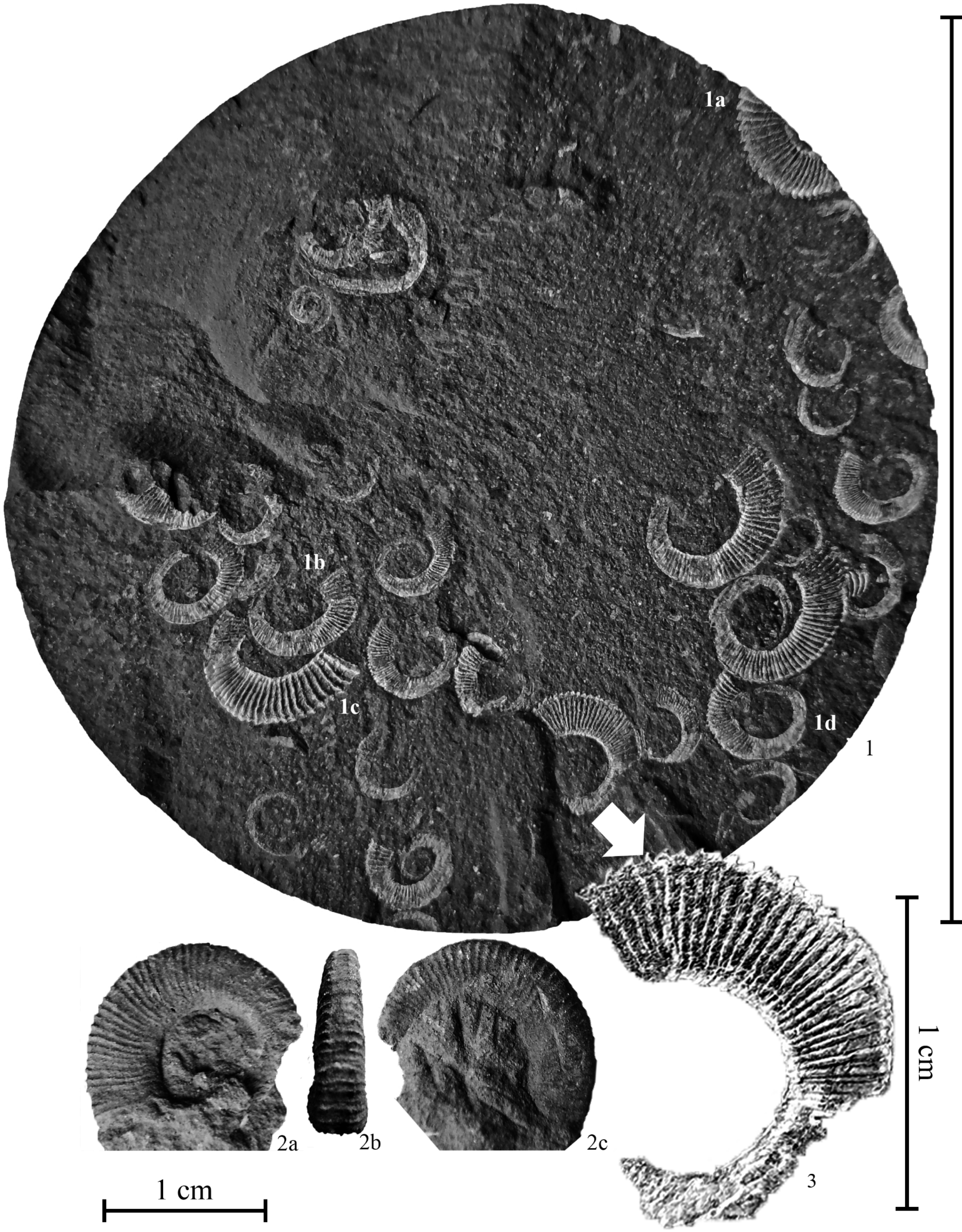

Plate V – V. tábla

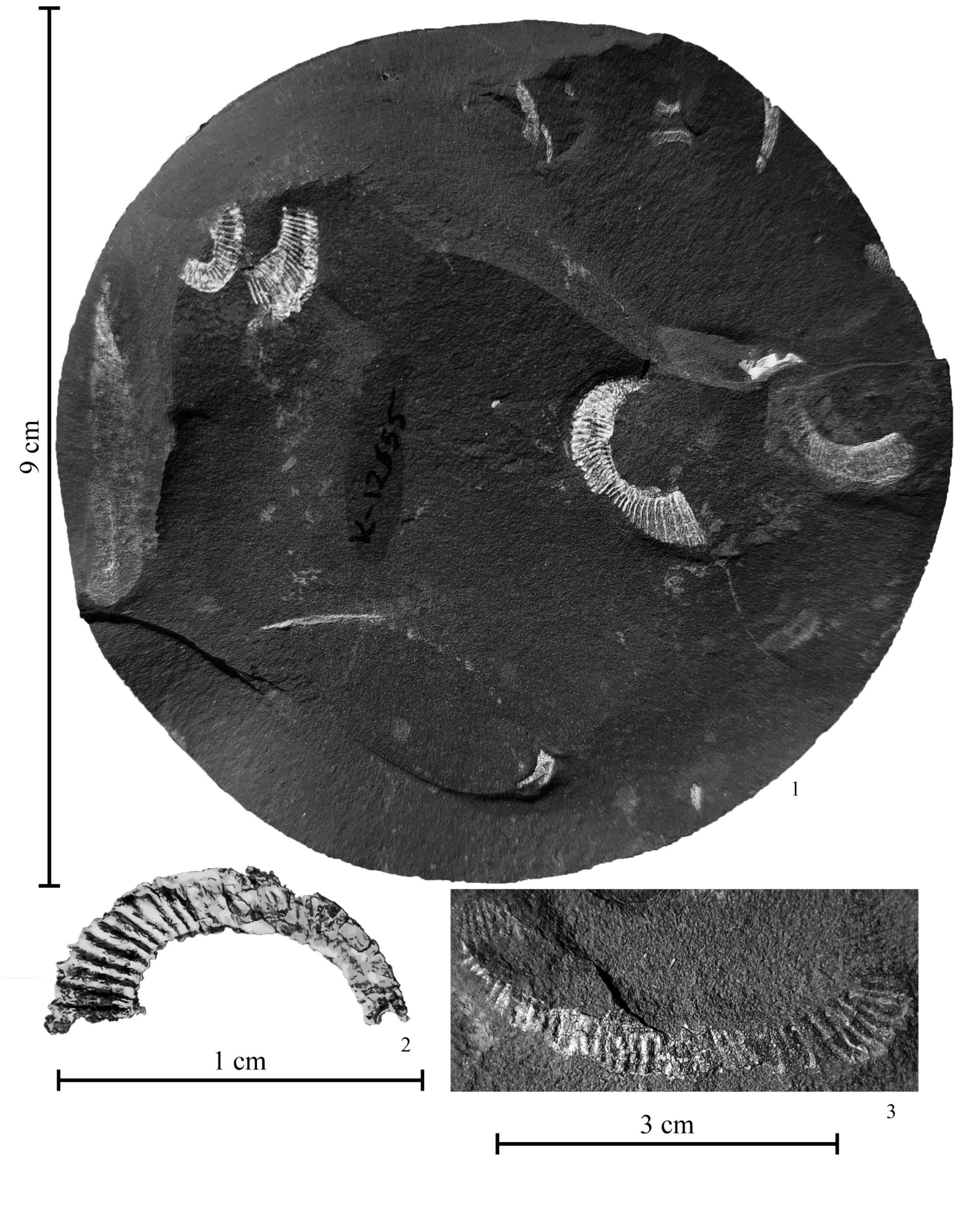

Plate VI – VI. tábla

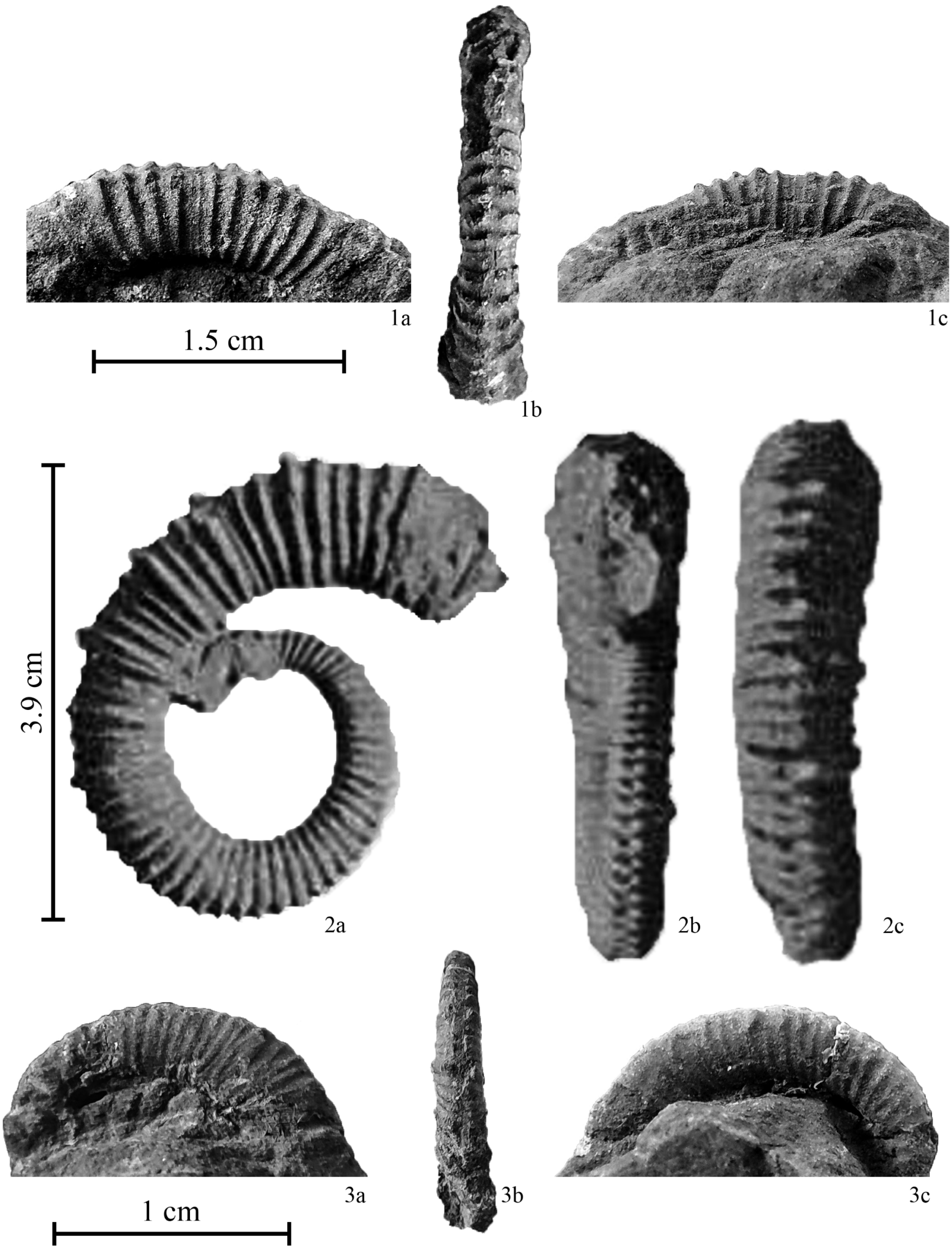

Plate VII – VII. tábla

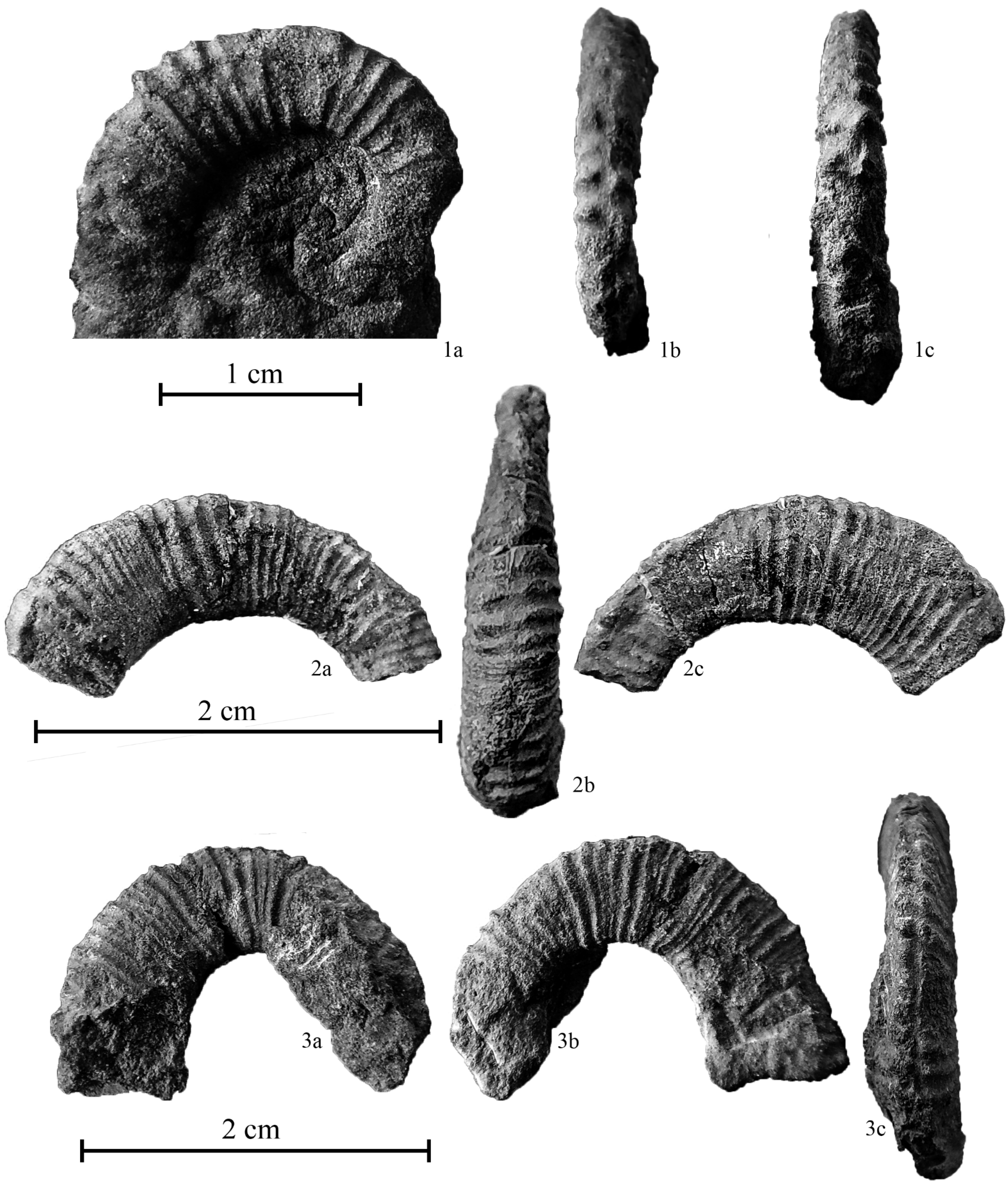

Plate VIII – VIII. tábla

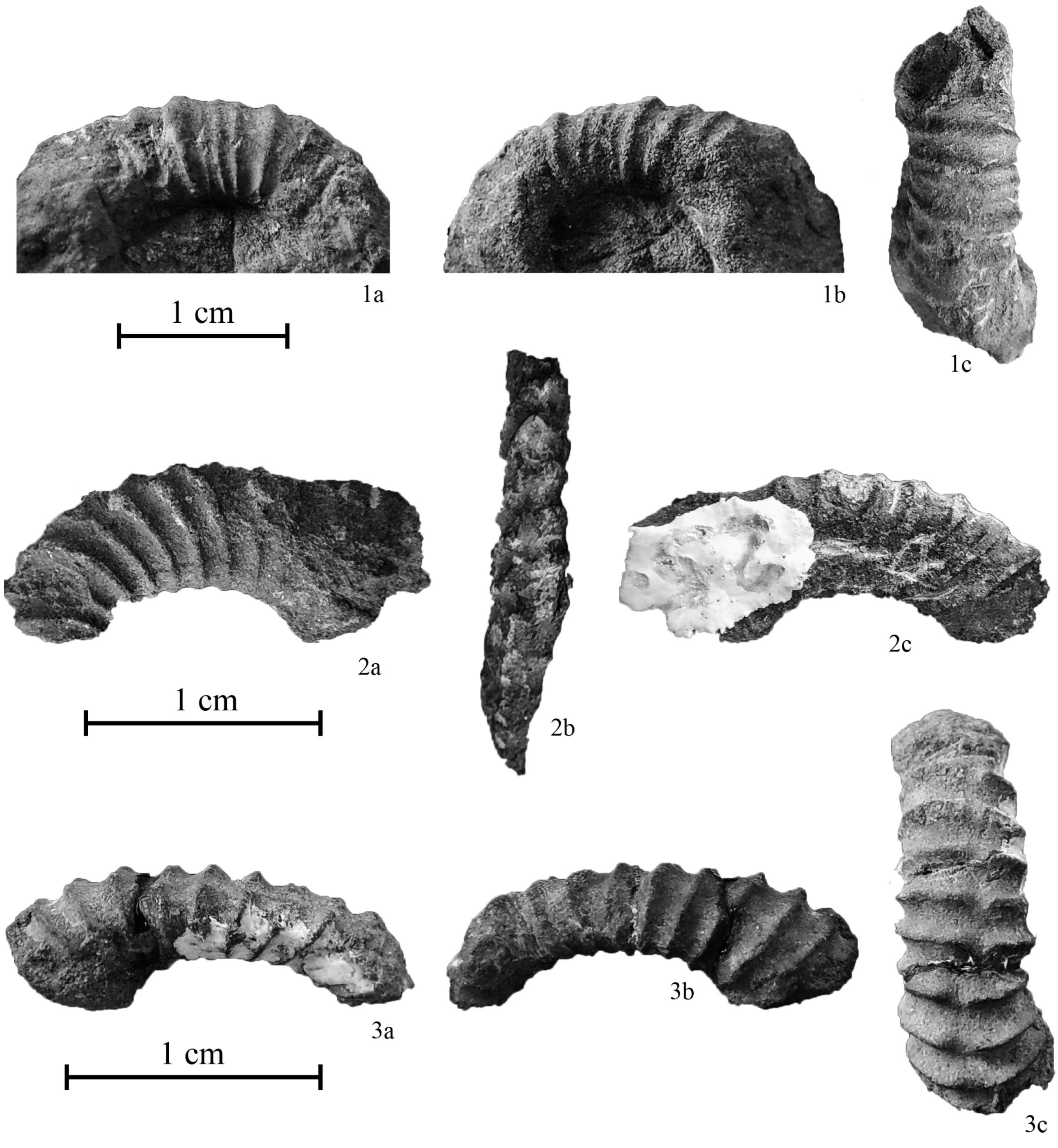

Plate IX – IX. tábla

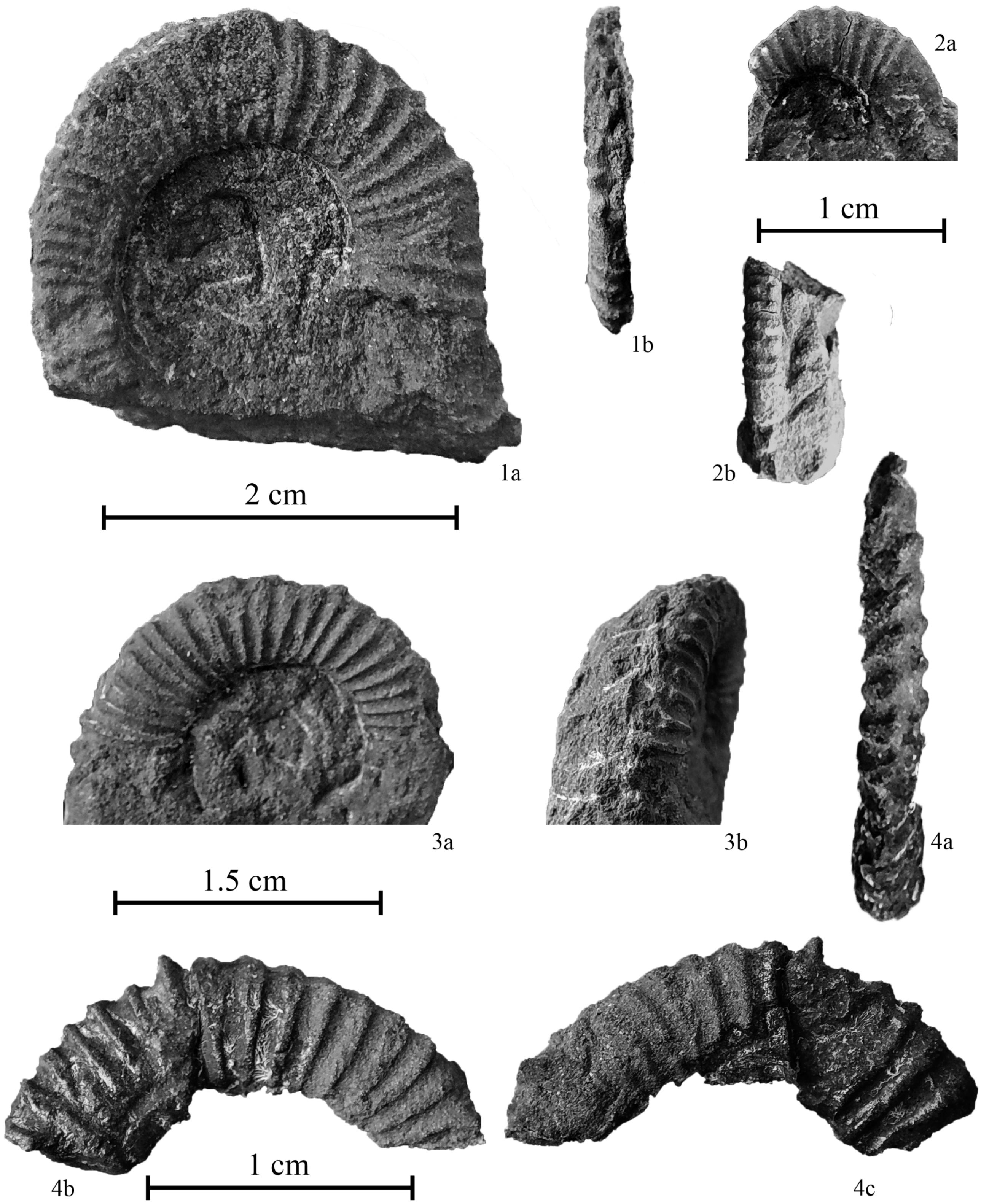

Plate X – X. tábla

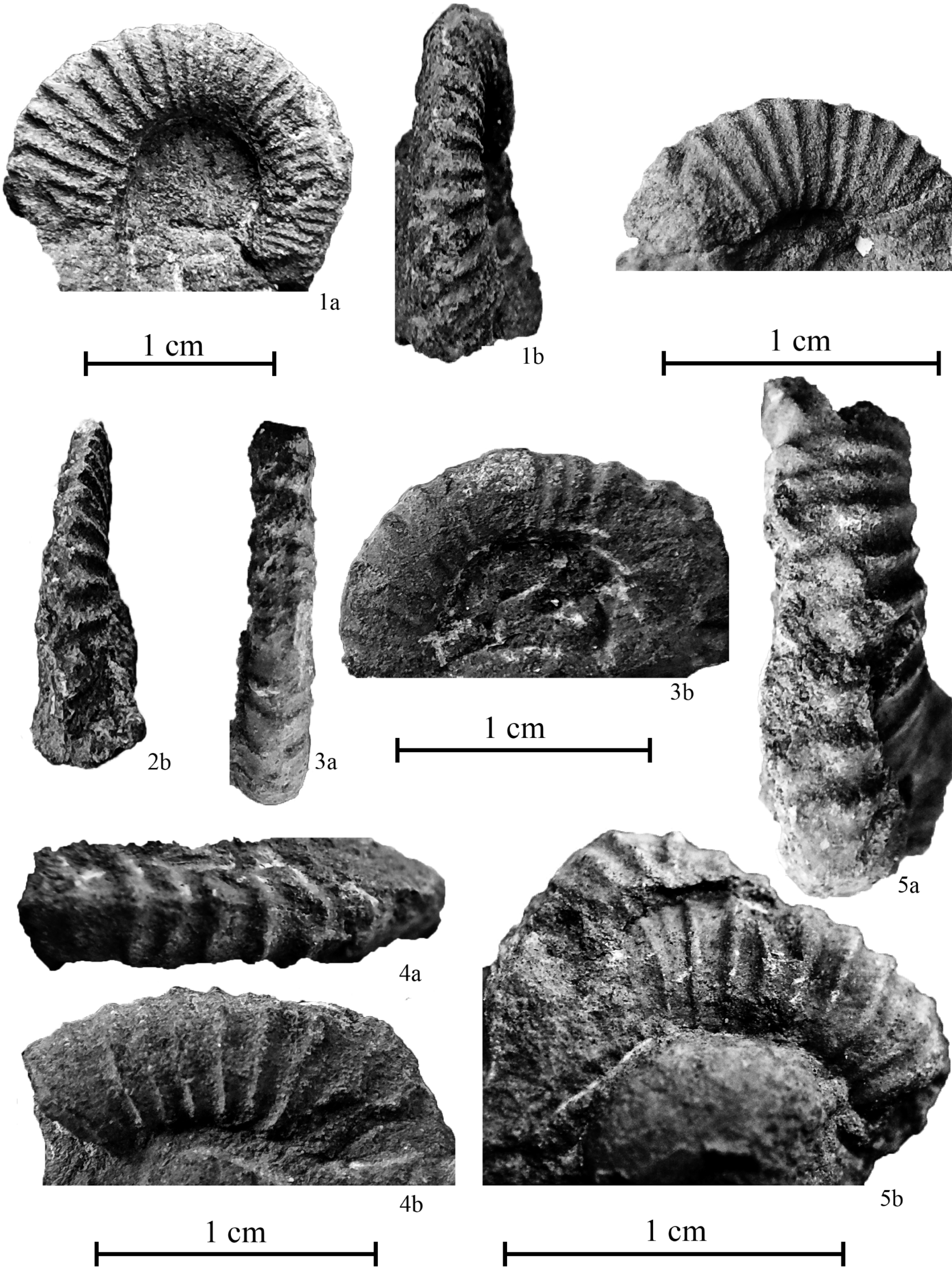

Plate XI – XI. tábla

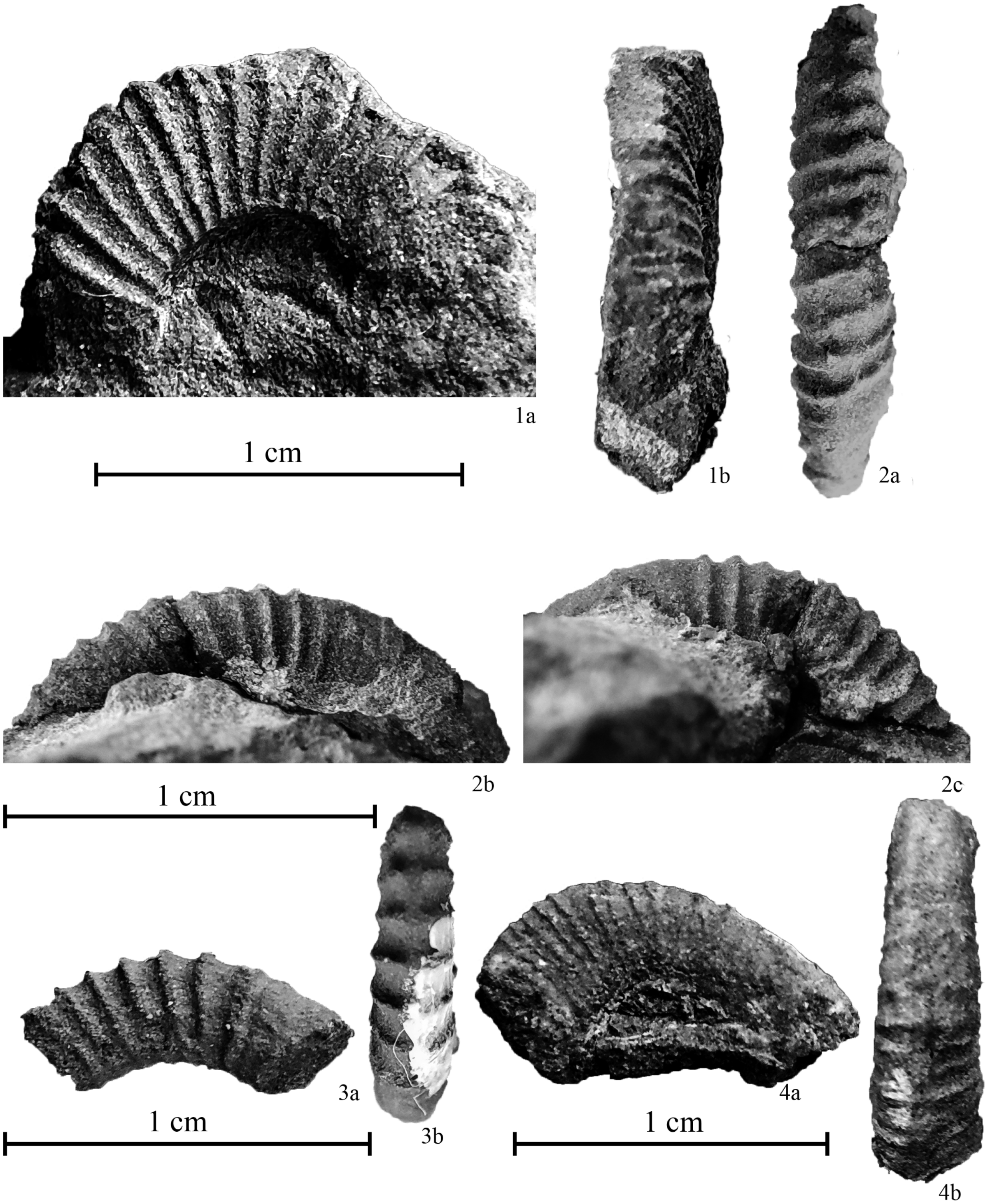

Plate XII – XII. tábla