Early Cretaceous ammonites and dinoflagellates from the Western Tatra Mountains, Poland

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The first Early Cretaceous (Valanginian–Hauterivian) ammonite fauna from the lower part of the Kościeliska Marl Formation (Wściekły Żleb Member) of the Lower Sub-Tatric (Krížna) Nappe, in the Lejowa Valley of the Tatra Mountains are described. The fauna is precisely placed in the succession and consists of five species: *Olcostephanus densicostatus*, *Spitidiscus* cf. *cankovi*, *Criosarasinella* cf. *subheterocostata*, *Crioceratites primitivus*, and *Crioceratites coniferus* and additionally an aptychus *Didayilamellaptychus seranonis*. Remarkable are the valves of anomiid bivalves attached to body chamber of large size heteromorph ammonite *C. primitivus*. Moreover, a variety of stratigraphically important organic-walled dinoflagellate cysts are recovered from this locality. Dinoflagellates: *Cymososphaeridium validum*, *Circulodinium vermiculatum*, and representatives of *Bourkidinium* define the Upper Valanginian–Lower Hauterivian *Sentusidinium* sp. A Dinocyst Subzone of the *Cymososphaeridium validum* Zone. The character of deposits, the palynofacies, and associations of dinoflagellate cysts indicate a calm marine outer neritic environment.

Key words: Ammonoidea, Anomiidae, Dinoflagellata, Valanginian, Hauterivian, Western Carpathians.

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Introduction

The Kościeliska Marl Formation (Lefeld et al. 1985) is a characteristic element of the Lower Sub-Tatric (Krížna) Nappe in the Tatra Mountains, and a typical component of the Neocomian facies, widely distributed in the Western Carpathians (Kędzierski and Uchman 1997; Vašíček and Michalík 1999; Uchman 2003, 2004; Gedl et al. 2004; Michalík 2007; Jach et al. 2014). It comprises mostly light- to dark-grey marlstone and calcilutite, subordinately calcarenite and sandstone.

The ammonites from the Kościeliska Marl Formation have been collected and reported by Wigilew (1914) and afterwards by Edward Passendorfer in the first half of the 20th century—but not illustrated nor studied in detail. A description and illustration of these older collections were given by Lefeld (1974), including additional specimens collected by himself.

A new collection of ammonites from the Kościeliska Marl Formation was obtained during fieldwork in 2018–2019 by BB and AG and Tomasz Zwijacz-Kozica (Tatra National Park, Zakopane, Poland). It includes external moulds and imprints of 25 ammonites (sometimes with limonitised remnants of preceding whorls) belonging to 5 species of the 4 families. Ammonites are often preserved fragmentarily and

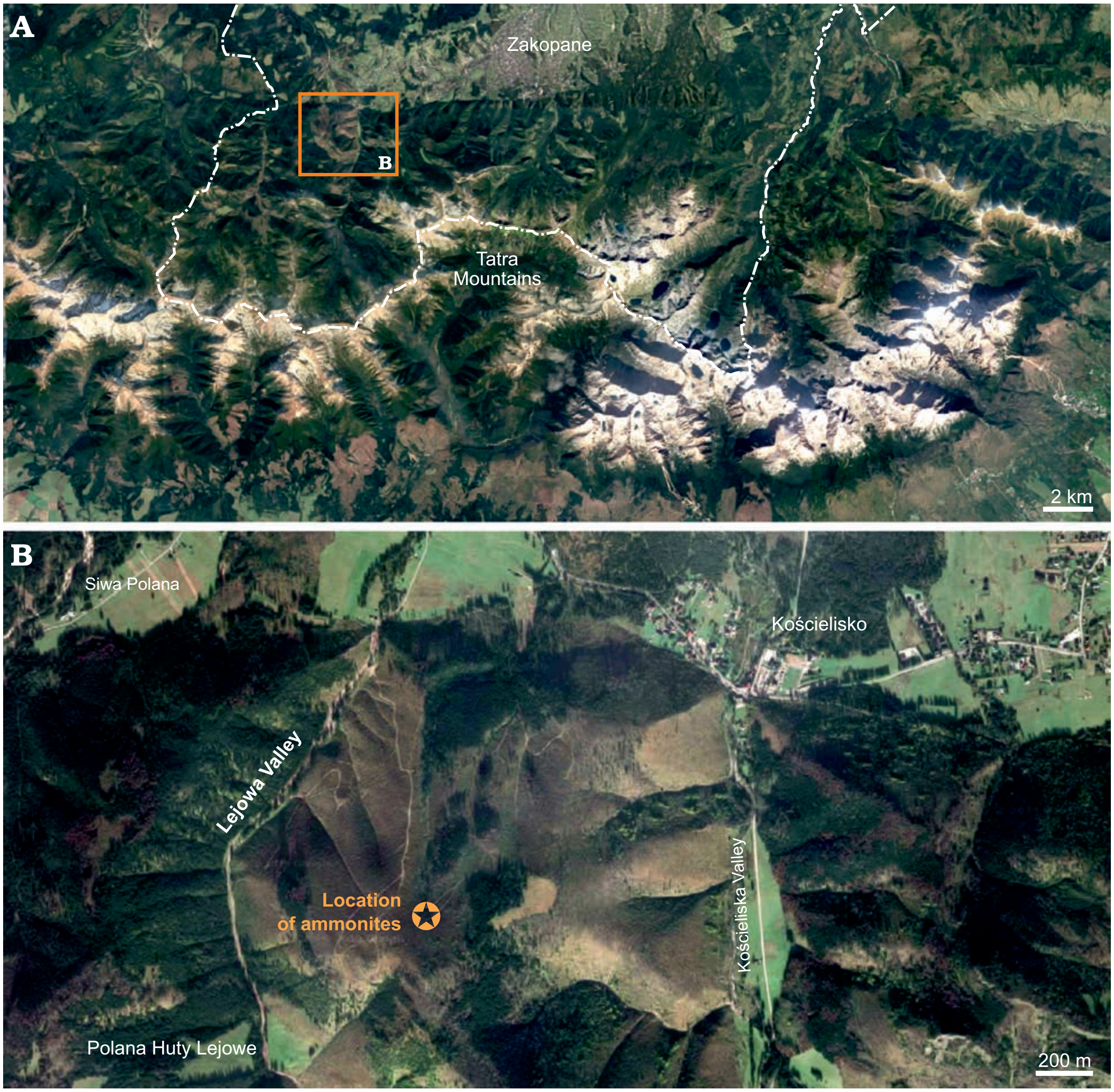

Fig. 1. Location of ammonite collection area (asterisk shows fossil sampling locality, 49°16.109' N, 19°51.194' E). Satellite views from the Google Maps.

strongly deformed, nevertheless the association represents the best collection from the area so far. The detailed study of the microfossils from the rock matrix taken from ammonites revealed a well to moderately preserved assemblage of organic-walled dinoflagellate cysts. The ammonites and dinoflagellate cysts give the basis for a detailed chronostratigraphic interpretation of the studied strata, and their correlation with the previously existing datings.

Institutional abbreviations.—GEO, Museum and Education Centre of the Tatra National Park, Zakopane, Poland; VSB, Vysoká škola báňská, Technical University of Ostrava, Czech Republic; ZPAL, Institute of Paleobiology, Polish Academy of Sciences, Warsaw, Poland.

Other abbreviations.—B, whorl breadth; D, diameter; H, whorl height; U, umbilicus width.

Geological setting

The fauna of Early Cretaceous ammonites discussed herein was found in the lower part of the Kościeliska Marl Formation (Lower Subtatric = Krížna Nappe), see Lefeld et al. (1985) and Pszczółkowski (2003). This part of the formation, corresponding to the Podfurkaska Member, the Kryta Member, and the Wściekły Żleb Member (see Pszczółkowski 2003 and papers cited therein) consists predominantly of marl with intercalations of limestone, the origin of which resulted from the overwhelming inflow of the finest detrital material laid down onto the Pieniny Limestone Formation (Tithonian + Berriasian) of Biancone type (Lefeld 1974). The deposition rate of the detrital material was faster than that of the pure calcareous deposition of

Fig. 2. Outcrop of the Lower Cretaceous sequence of the Kościeliska Marl Formation, the Western Polish Tatra Mountains (arrow indicates approximate location of collected samples). Photo taken by Andrzej Gaździcki, 3 August 2018.

typical Biancone. The original thickness of the Kościeliska Marl Formation is difficult to evaluate due to numerous tectonic reductions and/or repetitions. It may be estimated as about 200 meters in the western part of the Polish part of the Tatra Mountains. Calcareous nannofossils from the Kościeliska Marl Formation have been determined by Kędzierski and Uchman (1997), whereas calpionellids and planktonic foraminifers by Pszczółkowski (2003).

The limestone lens that furnished the ammonites is exposed in the upper reaches of the Lejowa Valley in the Polish part of the Western Tatra Mountains (Fig. 1, at GPS coordinates 49°16.109’ N, 19°51.194’ E). It is a part of the Kościeliska Marl Formation corresponding to the Wściekły Żleb Member (see Pszczółkowski 2003: fig. 2). These lens of pelitic limestone are embedded in the surrounding marl. The limestone body is 7 m long and 4 m thick, nevertheless its complete geometry is unknown (Fig. 2). The limestone within the Kościeliska Marl Formation are possibly infillings of narrow furrows cut into the marl or/and (seldom) are broader limestone sheets. Another (less probable) hypothesis is that the limestone has been laid down at a time when the marly deposition ceased for some time. Usually the limestone members well known from the higher (younger) parts of the Formation (Pszczółkowski 2003) represent faster deposition than that of the marls. These deposits belonging already to the Muráň Limestone Member sensu Pszczółkowski (2003) were placed in the Lower Hauterivian (after Pszczółkowski 2003) or even in the Upper Hauterivian (after Gedl et al. 2007).

The studied fossils (ammonites and organic-walled dinoflagellate cysts) presented herein from the Wściekły Żleb Member are indicative of the uppermost Valanginian–lowermost Hauterivian. This is the first finding of such a precisely located fossiliferous limestone unit with ammonites within the whole Kościeliska Marl Formation in the Polish part of the Tatra Mountains.

Material and methods

The ammonite specimens are mainly incomplete or fragmentary, however, mostly determinable. At first, the marly limestone beds, where the ammonites occur, were affected by strong compaction flattening the shells at the bedding planes. In addition, they were consequently subjected to lateral pressure. The original aragonite shells of ammonites, preserved in the form of outer moulds, were buried and then dissolved during diagenesis.

The six samples obtained from the rocks with ammonites were studied for dinoflagellate cysts content. After washing and drying, a standard processing method involved chemical treatment of 15–20 g of the sample with HCl to remove the calcareous fraction and with HF to remove silicates. Sieving was performed using a 15 μm nylon mesh, and the samples were centrifuged to concentrate the residues. Oxidation was not used. Three slides of each sample were prepared. Whole slides of residues were investigated under a binocular transmitting light microscope to identify and count the palynomorphs.

The permanent palynological mounts are stored at the Department of Geological Engineering at the VSB-Technical University of Ostrava, Czech Republic.

The collected ammonites are housed at the Institute of Paleobiology, Polish Academy of Science in Warszawa (ZPAL Am. 25), two specimens (G/1728/MT, G/1729/MT) at the Tatra Museum in Zakopane and one (GEO 1.2018) at the Museum and Education Centre of the Tatra National Park in Zakopane.

The determined ammonites have been classified to suborders according to Beznosov and Michailova (1983) and Kvantaliani et al. (1999), into superfamilies and lower taxonomic units according to Klein (2005) and Klein et al. (2007). The dimensional parameters of species, if determinable, i.e., the shell diameter (D), the whorl height (H) and the umbilicus width (U) were measured. Because of the state of ammonite preservation, the whorl breadth (B) could not be measured. As the specimens were affected by overburden pressure and by lateral pressure, the measured values and calculated parameters H/D, U/D are only approximate.

The mentioned stratigraphic information, i.e., that presented in the occurrence paragraph in the descriptions of species up to the ammonite level zones, are based on the data published after the Meeting of the Kilian Working Group in Vienna 2017 (Reboulet et al. 2018).

Systematic palaeontology

Class Cephalopoda Cuvier, 1797

Subclass Ammonoida Zittel, 1884

Order Ammonitida Agassiz, 1847

Suborder Olcostephanina Kvantaliani, Topchishvili, Lominadze, and Sharikadze, 1999

Superfamily Olcostephanoidea Pavlow, 1892

Family Olcostephanidae Pavlow, 1892

Subfamily Olcostephaninae Pavlow, 1892

Genus *Olcostephanus* Neumayr, 1875

Type species: *Ammonites astierianus* d'Orbigny, 1840; Castellane, France, Lower Hauterivian, by original designation.

Olcostephanus densicostatus (Wegner, 1909)

Fig. 3G.

1909 *Astieria atherstoni* var. *densicostata* n. v.; Wegner 1909: 82, pl. 16: 3.

1974 *Olcostephanus astierianus* (d'Orb.); Lefeld 1974: 350, pl. 10: 3, ?4.

2005 *Olcostephanus densicostatus* (Wegner); Klein 2005: 84 (cum syn.).

2010 *Olcostephanus densicostatus* (Wegner); Vašíček 2010: 398, pl. 2: 1.

Material.—A single, strongly flattened, relatively imperfect outer mould (ZPAL Am. 25/4b), preserved partially as an imprint, primarily positive, from Cretaceous, Tatra Mountains, Poland.

Description.—Involute specimen with high whorls. Dmax about 75 mm (affected by deformation). The sculpture is formed by thin and dense ribs slightly inclined to the aperture. Venter ribs run across without interruption, very strongly arched toward the aperture over a short section. With a few exceptions, the ribs do not bifurcate. Only on the imprint, deep, probably short and longitudinally elongated depressions after strong umbilical tubercles, which correspond to primary ribs, appear near the umbilicus. About 4–5 ribs run out of the tubercles; other ribs, approximately in the same number, are connected to the area between the primary ribs.

Remarks.—Imperfectly preserved outer mould bears dense, thin ribs which are not bifurcated on flanks of the whorl. A similar finding designated as *Olcostephanus astierianus* is mentioned by Lefeld (1974: pl. 10: 3) and Grabowska-Hakenberg (1958) from Lower Cretaceous marl in the Kościeliska Valley in the Polish part of the Tatra Mountains).

Stratigraphic and geographic range.—According to Reboulet (1996), *Olcostephanus densicostatus* occurs from the upper part of Upper Valanginian (the uppermost part of *Neocomites peregrinus* Zone) to the base of *Crioceratites loryi* Ammonite Zone (Lower Hauterivian). The species has a very broad geographical distribution. Among others, according to Vašíček (2010) it occurs also in the uppermost Valanginian of the Mráznica Formation in the Butkov Quarry (Slovakia).

Suborder Perisphinctina Beznosov and Michailova, 1983

Superfamily Perisphinctoidea Steinmann and Döderlein, 1890

Family Holcodiscidae Spath, 1923

Subfamily Spitidiscinae Vermeulen and Thieuloy, 1999

Genus *Spitidiscus* Kilian, 1910

Type species: *Ammonites rotula* Sowerby, 1827; Speeton, UK, Hauterivian, by original designation.

Spitidiscus cf. *cankovi* Vašíček and Michalík, 1986

Fig. 3F.

Material.—A small fragment of whorl of outer mould (ZPAL Am. 25/9), from Cretaceous, Tatra Mountains, Poland.

Description.—Only three slight constrictions at approximately ¼ of whorl are preserved with ribs of unequal length appearing in between them. In a single complete interval between two constrictions, 8 ribs are developed on the specimen perimeter. The ribs prolong through venter without interruption. In the interval stated, a complete simple rib occurs on front side of the first constriction. Behind

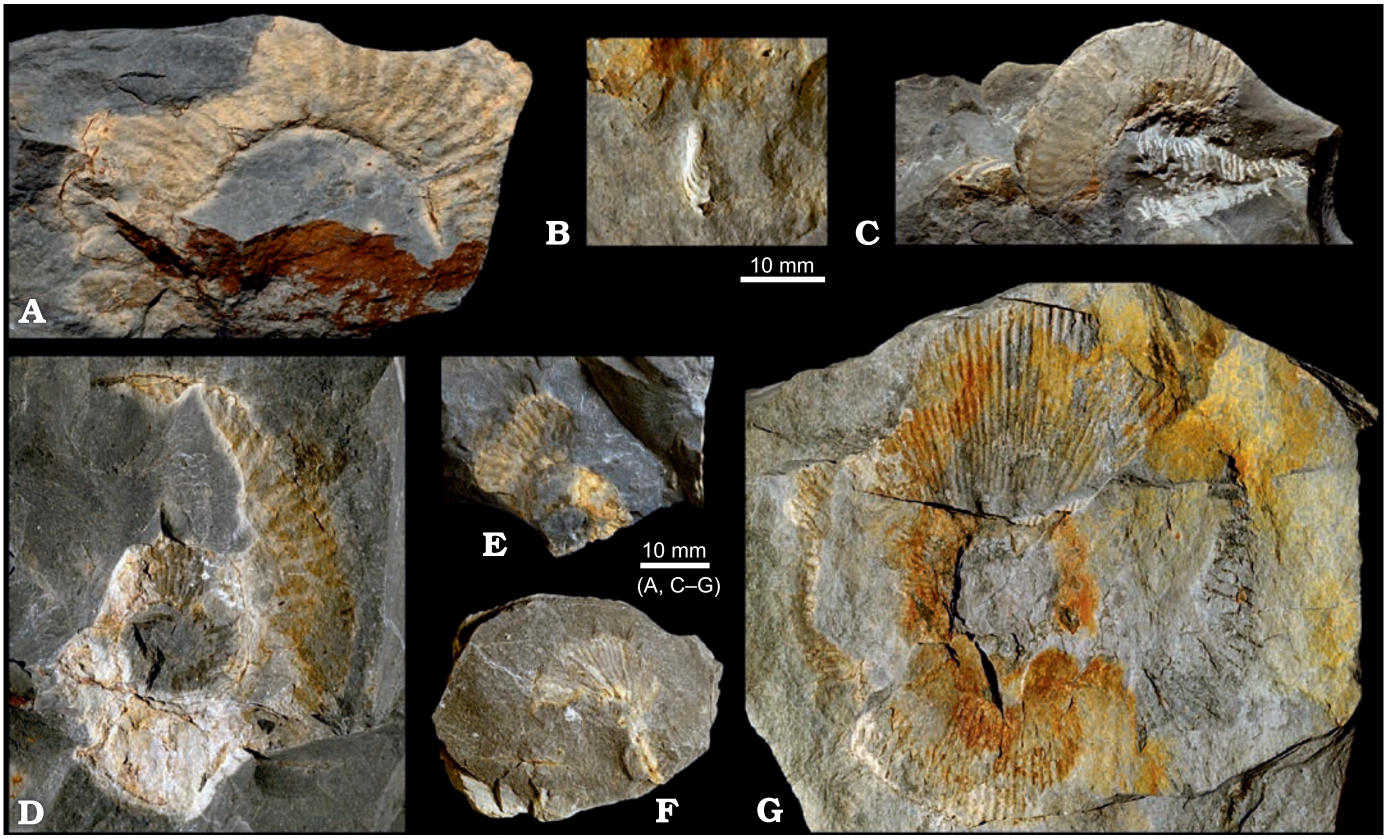

Fig. 3. The Lower Cretaceous ammonites from the Kościeliska Marl Formation in the Lejowa Valley, Tatra Mountains, Poland. **A**, **C**–**E**. *Criosarasinella* cf. *subheterocostata* Reboulet, 1996. **A**. ZPAL Am. 25/19. **C**. ZPAL Am. 25/7. **D**. ZPAL Am. 25/17. **E**. ZPAL Am. 25/14. **B**. Calcite valve of aptychus *Didayilamellaptychus seranonis* (Coquand, 1841), ZPAL Am. 25/12. **F**. *Spitidiscus* cf. *cankovi* Vašíček and Michalík, 1986, ZPAL Am. 25/9. **G**. *Olcostephanus densicostatus* (Wegner, 1909), ZPAL Am. 25/4. All in lateral view.

the constriction, a short inserted rib appears on its outside and in front of it, another shorter one ending approximately at half-whorl can be found. A set of three ribs follows: the posterior rib is complete, starting in markedly elevated, not particularly large umbilical tubercle. Another rib runs in this tubercle and starts bifurcating. A pair of bifurcated ribs lies closer to another one than the interval between the individual and the bifurcated rib. Afterwards, there is a complete simple rib which might be connected to the above-mentioned umbilical tubercle or perhaps is independent. It is followed by a shorter inserted rib reaching approximately the mid-high whorl and by the last complete simple rib. On the rear side, the rib is limited by constriction. Four ribs reach as far as the umbilicus. The height of whorl is approximately 18 mm.

Remarks.—The incomplete specimen does not allow for an unambiguous identification. Remarkable is a large number of constrictions per whorl. Bulgarian specimens which Vašíček and Michalík (1986) included in the synonymy of *Spitidiscus cankovi* occur in the Lower Hauterivian. Vašíček and Michalík (1986) refer it to a similar age in the Mráznica Formation, the Butkov Quarry. Avram (1995) mentions it from the Valanginian–Hauterivian boundary in Romania.

Family Neocomitidae Salfeld, 1921

Subfamily Neocomitinae Salfeld, 1921

Genus *Criosarasinella* Thieuloy, 1977

Type species: *Criosarasinella furcillata* Thieuloy, 1977; La Charce, France, uppermost Valanginian, by original designation.

Remarks.—Vašíček (2005) according to the style of ribbing and tendency towards a criocone coiling suggested that *Criosarasinella* could be reclassified to the family Ancyloceratidae.

Criosarasinella cf. *subheterocostata* Reboulet, 1996

Fig. 3A, C–E.

Material.—Four incomplete outer moulds (ZPAL 25/7, 14, 17, 19) with a preserved part of the ultimate whorl and preserved part of the penultimate whorl, with one exception (ZPAL 25/14). All from Cretaceous, Tatra Mountains, Poland.

Description.—The involute specimen with moderately low, slightly vaulted whorls. The ultimate whorl bears relatively strong, slightly arched ribs with inter-rib spaces broader than the ribs. Ribs running from the umbilicus in pairs can be sporadically found between simple ribs which do not start at tubercles near the line of coiling. The ribs are convexly bent near the umbilicus over a short section towards the aperture and then become slightly concavely curved on the flanks. Some ribs bifurcate close to the venter. Only on one specimen, a print can be found over a very short section of the penultimate whorl which bears distinct thin and dense subradial ribs. Simple ribs prevail over sporadically appearing shorter inserted ribs.

Measurements.—The most complete specimen ZPAL Am. 25/17 reaches a maximum diameter of 62 mm. In the penultimate whorl, at D = 39 mm, H is approximately 14.0 mm (H/D = 0.36), U approximately 15.0 mm (U/D = 0.38).

Remarks.—Preservation of the specimen from the Tatra Mountains is definitely unfavourable to an unambiguous identification. *Criosarasinella furcillata* Thieuloy, 1977 and *Criosarasinella mandovi* Thieuloy, 1977 seem to be relatives, not varying much from the studied material. The last species was mentioned by Lefeld (1974: 351, pl. 10: 1) from the Kościeliska Marl Formation of the Tatra Mountains identified as *Crioceratites* aff. *sornayi* (Sarkar, 1955), see Thieuloy (1977: 110). According to Reboulet (1996) *Criosarasinella subheterocostata* occurs in the uppermost Valanginian (together with the zonal species *C. furcillata*). Typical *C. subheterocostata* is known from France as well as from the Ladce Formation (*Criosarasinella furcillata* Zone), the Butkov Quarry (Western Slovakia; see Vašíček 2005).

Suborder Ancyloceratina Wiedmann, 1966
Superfamily Ancyloceratoidea Gill, 1871
Family Crioceratitidae Gill, 1871
Subfamily Crioceratitinae Gill, 1871
Genus *Crioceratites* Léveillé, 1837

Type species: *Crioceratites Duvalii* Léveillé, 1837; Cheiron, France, Hauterivian, neotype designated by Busnardo in Busnardo et al. (2003).

Crioceratites primitivus Reboulet, 1996

Fig. 4A–C.

1996 *Crioceratites primitivus* n. sp.; Reboulet 1996: 175, pl. 24: 1–5, non pl. 23: 3 (= *Crioceratites heterocostatus* Mandov, 1976).
2007 *Crioceratites primitivus* Reboulet; Klein et al. 2007: 44.

Material.—Three large specimens (ZPAL Am. 25/15, 25/2, and positive G/1728/MT, rock slab with imprint), preserved mainly in form of weathered imprints of the ultimate whorl and as limonitised outer moulds of the flattened part of the penultimate whorl. Flattening results from lateral deformation. The imprint of the ultimate whorl of the ZPAL Am. 25/15 shows attached three calcite valves of small bivalves (Fig. 4C–G). All from Cretaceous, Tatra Mountains, Poland.

Description.—Distinctly free coiled specimens. Thin and dense ribs occur on a better preserved limonitised positive. Occasionally, some of the ribs seem to be stronger than others. A partially preserved ventrolateral spine with an incomplete length of 8 mm (at the height of the deformed whorl of approximately 20 mm) can be found at the end of the penultimate whorl of the second specimen. Trituberculated main ribs are visible on imprints of the ultimate whorl. Two significant ventrolateral spines reaching the length of approximately 20 mm are preserved on the ZPAL Am. 25/15. The first main rib occurs on the ZPAL Am. 25/2 at the diameter D of about 75 mm. Seven thin ribs are inserted between the pair of main ribs.

Measurement.—In the axis of elongation the ZPAL Am. 25/15 reaches maximum diameter of 150 mm. At D = 73.5 mm, H = 19.0 mm (H/D = 0.26) and U = 43.5 mm (U/D = 0.59). The maximum diameter of the ZPAL Am. 25/2 in the axis of elongation is about 200 mm.

Remarks.—Large, imperfectly preserved specimens provide information about the maximum size of shells of *Crioceratites primitivus*. Strong trituberculated ribs bear significant ventrolateral spines.

Stratigraphic and geographic range.—The Reboulet's (1996) type material comes from the uppermost Valanginian sediments of the Vocontian Basin in France. The findings from the Western Carpathians (the Butkov Quarry, Slovakia) come from the sediments around the Valanginian–Hauterivian boundary (Michalík et al. 2013).

Crioceratites coniferus Busnardo in Busnardo et al., 2003

Fig. 5A–C.

1996 *Crioceratites* n. sp. 1; Reboulet 1996: 177, pl. 23: 1, 2, 4, pl. 24: 7.
2003 *Crioceratites coniferus* n. sp.; Busnardo et al. 2003: 61, pl. 4: 3, 6.
2005 *Crioceratites coniferus* Busnardo, Charollais, Weidmann, and Clavel, 2003; Vašíček 2005: 251, figs. 4.1, 4.2.
2007 *Crioceratites coniferus* Busnardo; Klein et al. 2007: 38 (cum syn.).
2013 *Crioceratites coniferus* Busnardo et al.; Michalík et al. 2013: 94, fig. 65/4, 5.

Material.—Two large deformed specimens (GEO.1.2018, Fig. 5A; G/1729/MT, Fig. 5C), imperfectly preserved mainly in form of imprints. A silicone cast has been made from the GEO.1.2018 (ZPAL Am. 25/1, Fig. 5B) favourably showing morphology of the inner whorl, in particular.. All from Cretaceous, Tatra Mountains, Poland.

Description.—Free coiled involute specimens. From the earliest preserved diameter D of about 47 mm (in the axis of elongation), main and accessory ribs are distinct. The main ribs are strong and trituberculated. At first, 2–3 simple ribs are inserted between the pairs of the main ribs. The number of inserted ribs increases up to 4–5. In the ultimate whorl, the silicone cast bears strong umbilical, lateral and ventrolateral tubercles, often connected with spines. In one case, a strong ventrolateral spine with a length of approximately 21 mm is preserved.

Measurements.—In the axis of elongation GEO.1.2018 reaches a diameter of about 123 mm, while G/1729/MT of 150 mm.

Stratigraphic and geographic range.—The holotype originates from the base of Hauterivian in the External Alps of Switzerland. Reboulet (1996) states that the find-

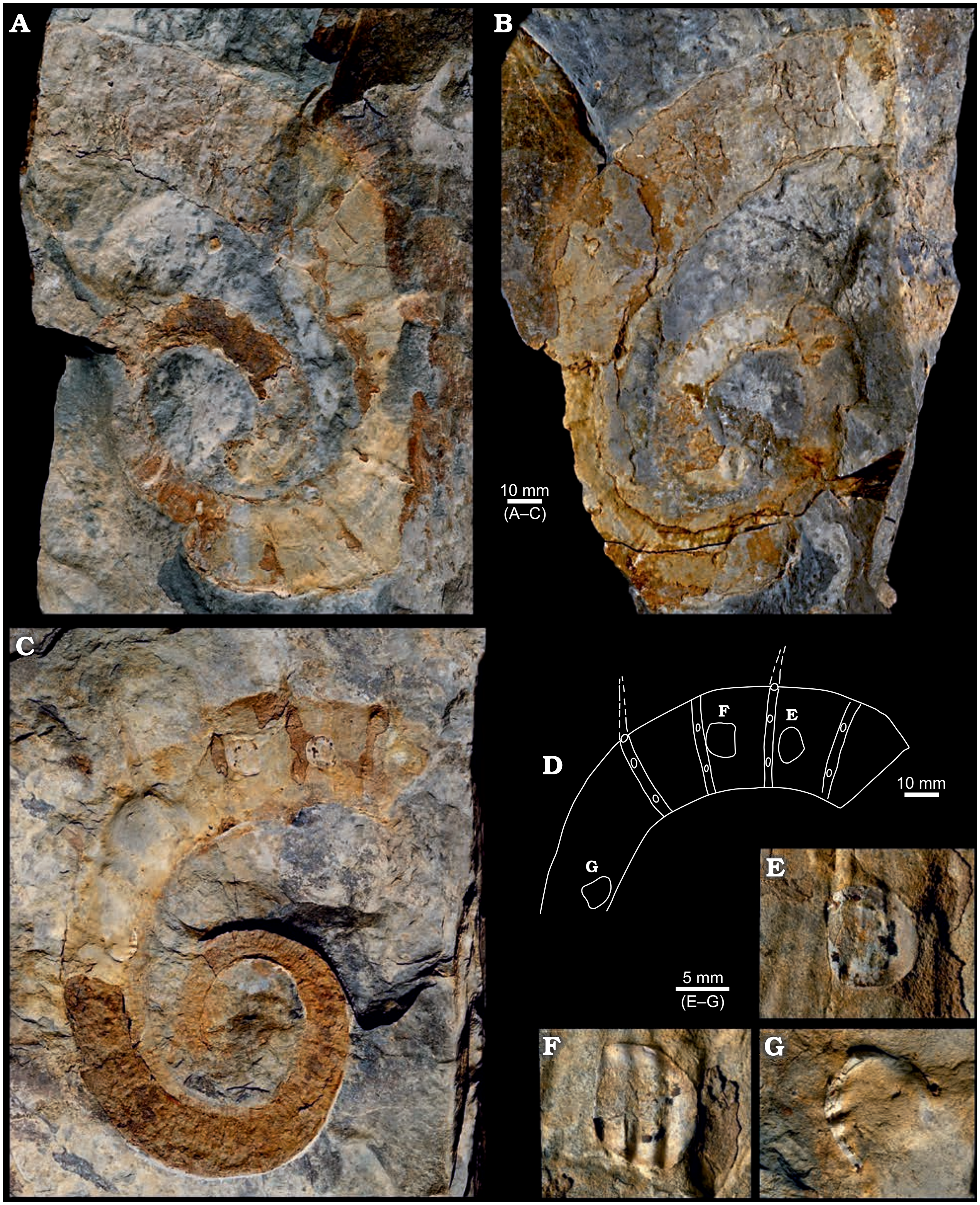

Fig. 4. **A**–**C**. The Lower Cretaceous heteromorph ammonite *Crioceratites primitivus* Reboulet, 1996 from the Kościeliska Marl Formation in the Lejowa Valley, Tatra Mountains, Poland. **A**. G/1728/MT. **B**. ZPAL Am. 25/2. **C**. ZPAL Am. 25/15. **D**. Distribution of anomiid individuals on a specimen of *C. primitivus* (ZPAL Am. 25/15). **E**–**G**. Close up views of bivalves attached to the body chambers of the ammonite *C. primitivus* (ZPAL Am. 25/15). All in lateral view.

ings from the Vocontian Basin originate from sediments around the Valanginian–Hauterivian boundary. At Butkov, *Crioceratites coniferus* occurs in the Upper Valanginian (*Criosarasinella furcillata* Zone), as well as in sediments around the Valanginian–Hauterivian boundary (Vašíček 2005).

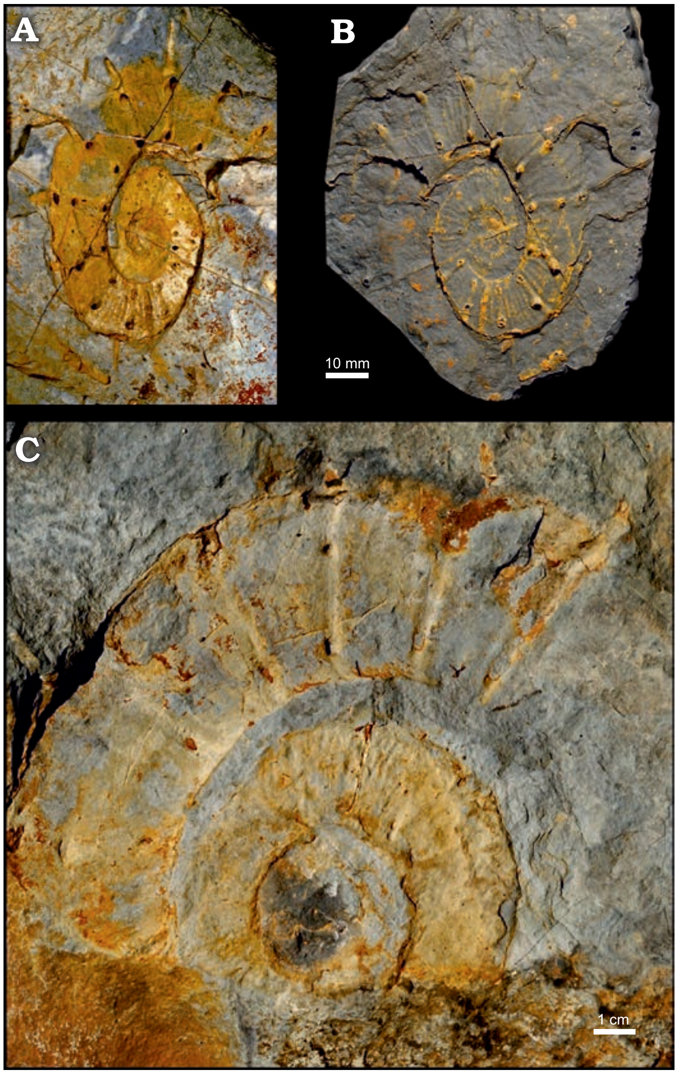

Fig. 5. The Lower Cretaceous heteromorph ammonite *Crioceratites coniferus* Busnardo, Charollais, Weidmann, and Clavel, 2003 from the Kościeliska Marl Formation in the Lejowa Valley, Tatra Mountains, Poland. **A**. GEO.1.2018. **B**. ZPAL Am. 25/1 (silicone cast). **C**. G/1729/MT. All in lateral view.

Aptychi

Family Lamellaptychidae Měchová, Vašíček, and Houša, 2010

Genus *Didayilamellaptychus* Turculet, 1994

Type species: *Aptychus didayi* Coquand, 1841; ?Lioux (Basses Alpes), France, Lower Hauterivian, by original designation.

Didayilamellaptychus seranonis (Coquand, 1841)

Fig. 3B.

1841 *Aptychus Seranonis* (nobis); Coquand 1841: 390, pl. 9: 13.
2010 *Didayilamellaptychus seranonis* (Coquand, 1841); Měchová et al. 2010: 258, fig. 11B (cum syn.).

Material.—An imprint of a thick-walled, incomplete valve with a slight rest of the original calcite material in the terminal area (ZPAL Am. 25/12), from Cretaceous, Tatra Mountains, Poland.

Description.—On the flank of the incomplete valve, ribs with inflection are distinct. The ribs are gradually increasing in thickness and running arched towards the symphysal margin. They are connected with this margin as reversely bent toward the non-preserved existing apex of the valve. The incomplete symphysal margin is 19.5 mm long.

Stratigraphic and geographic range.—According to Měchová et al. (2010) *D. seranonis* occurs in the Western and Central Europe (including the Western Carpathians) in Upper Valanginian to the Lower Hauterivian.

Organic-walled dinoflagellate cysts

Out of six samples prepared for palynomorphs, three proved to be fossiliferous. In general, the samples give rich, good to moderately preserved, low diverse palynological assemblages. Marine elements predominate in all of them, being represented mainly by dinoflagellate cysts, some acritarchs, and foraminiferal linings.

Most common dinoflagellate cysts (Fig. 6) in the investigated samples are *Bourkidinium elegans*, *Circulodinium distinctum*, *Cymososphaeridium validum*, *Endoscrinium campanula*, *Kiokansium polypes*, *Phoberocysta neocomica*, *Sentusidinium* sp., *Spiniferites ramosus*, *Stanfordella*? *cretacea*, *Systematophora* sp. For detailed composition see Table 1.

Discussion

Ammonites.—The ammonites derived from a 0.3 m thick layer of limestone within the Kościeliska Marl Formation (the Wściekły Żleb Member) of the Polish Tatra Mountains (so-called Sub-Tatric succession) belong, in a broader sense, to the Neocomian assemblage of the Krížna Nappe of the Western Carpathian System. In European localities (France, Switzerland, Spain, Bulgaria, Romania, Slovakia) the recognised species occur largely in the uppermost Valanginian and lowermost Hauterivian. Nevertheless, none of the determined species are, according to the used international ammonite zonation (Reboulet et al. 2018), indicative of a zone of either the uppermost Valanginian or basal Hauterivian.

The studied ammonite association is similar to that of the upper part of the Ladce Formation that is exposed in the Butkov Quarry near the municipality of Ladce in the Manín Unit of the Slovak part of the Central Western Carpathians (Vašíček 2005). The ammonite associations from Poland and Slovakian localities are close to those from the Vocontian Basin in France (see Reboulet 1996). Historical findings of Early Cretaceous ammonites of older collections from the Sub-Tatric succession were discussed by Lefeld (1974). According to him, the ammonites came from several stratigraphic levels.

The stratigraphically oldest ammonites were identified by Lefeld (1974) as *Olcostephanus astierianus* (d'Orbigny, 1840) and *Crioceratites* aff. *sornayi* (Sarkar, 1955). According to Thieuloy (1977: 110), the last-mentioned spe-

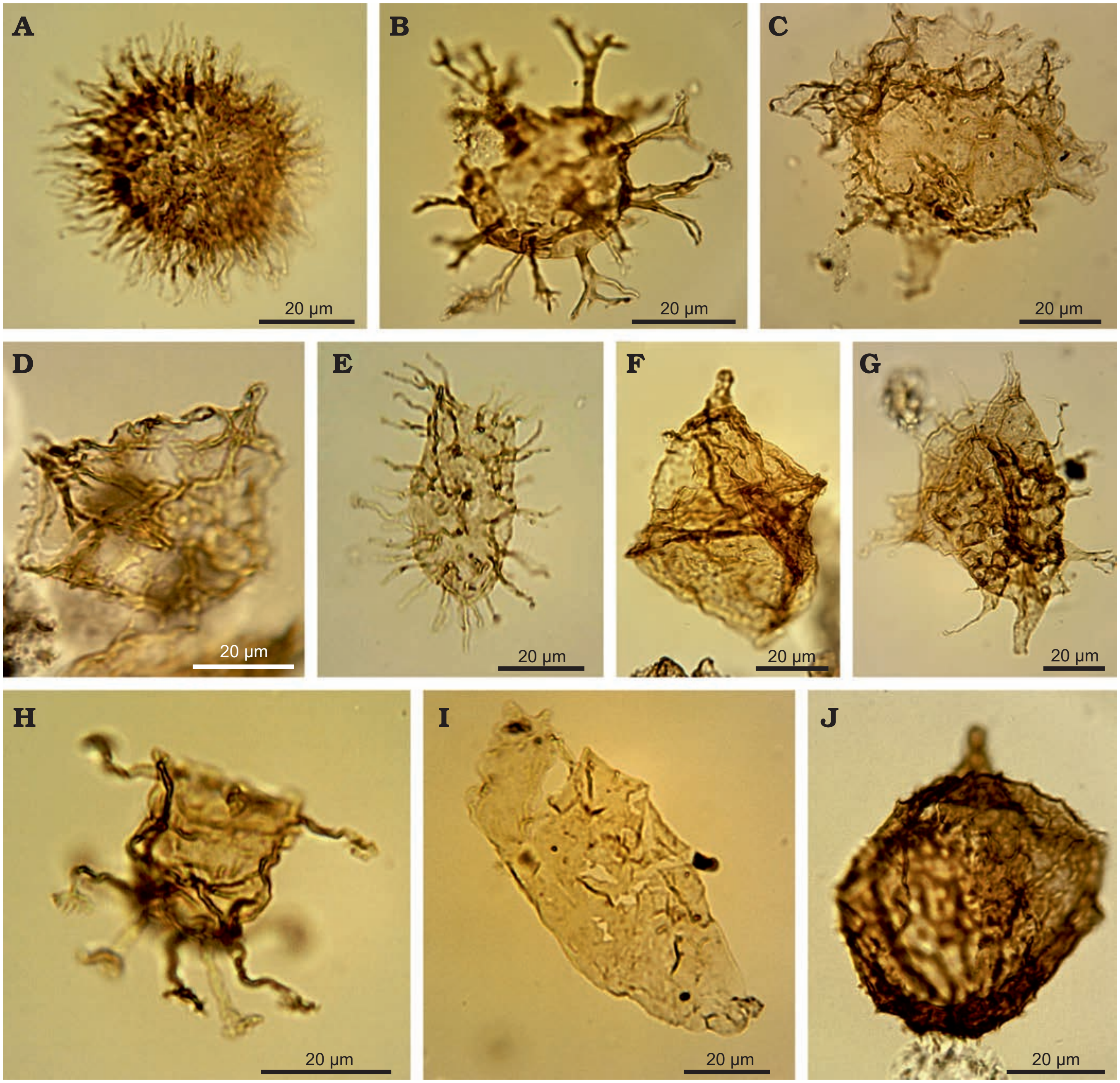

Fig. 6. The Lower Cretaceous organic-walled dinoflagellate cysts from the Kościeliska Marl Formation in the Lejowa Valley, Tatra Mountains, Poland. **A**. *Cometodinium habibii* Monteil, 1991. **B**. *Cymososphaeridium validum* Davey, 1982. **C**. *Phoberocysta neocomica* (Gocht, 1957) Millioud, 1969. **D**. *Stanfordella*? *cretacea* (Neale and Sarjeant, 1962) Helenes and Lucas-Clark, 1997. **E**. *Prolixosphaeridium* sp.. **F**. *Endoscrinium campanula* (Gocht, 1959) Vozzhennikova, 1967. **G**. *Phoberocysta neocomica* (Gocht, 1957) Millioud, 1969. **H**. *Bourkidinium elegans* Torricelli, 1997. **I**. *Wallodinium krutzschii* (Alberti, 1961) Habib, 1972. **J**. *Cribroperidinium orthoceras* (Eisenack, 1958). A–I sampled from ZPAL Am. 25/2; J sampled from ZPAL Am. 25/7.

cies belongs to *Criosarasinella mandovi* Thieuloy, 1977. The described species are stratigraphically placed around the Valanginian–Hauterivian boundary, and close to those presented herein.

The specimen classified by Lefeld (1974: 12) as *Crioceratites emerici* Léveillé, the typical representatives of which occur in the Barremian, appears rather dubious. Despite the unfavourable state of preservation, it cannot be excluded that this specimen belongs to *Crioceratites coniferus*, which also occurs in the studied locality.

Findings identified by Lefeld (1974: pl. 10: 2 and pl. 11: 1) as *Hamulina* sp. and *Balearites* sp. are, however, stratigraphically younger. Both ammonites are also poorly preserved. The first one is possibly a representative of the genus *Euptychoceras* Breistroffer, 1952 when taking into account its size and the barely touching shafts. The second one represents rather a relative to the genus *Binelliceras* Sarkar, 1977. In both cases, the findings belong, according to the recent knowledge, to the forms known from the Upper Hauterivian. These observations suggest that a younger ammonite assem-

Table. 1. Occurrence of organic-walled dinoflagellate cysts.

Species	Sample from ZPAL Am.		
	25/2a	25/7	25/11
Bourkidinium elegans	2	1	1
Cassiculosphaeridia magna	1		
Circulodinium distinctum	3		
Circulodinium vermiculatum	1		
Cometodinium whitei	1	1	1
Cometodinium habibii	1		
Cribroperidinium orthoceras		2	1
Cymososphaeridium validum	30	17	4
Dapsilidinium multispinosum	1	1	
Endoscrinium campanula	3	2	1
Hystrichodinium pulchrum			1
Gonyaulacysta sp.	3		
Kiokansium polypes	5	1	
Oligosphaeridium complex			1
Phoberocysta neocomica	5		
Prolixosphaeridium sp.	1		
Sentusidinium sp.	3	3	1
Spiniferites ramosus	19	3	2
Stanfordella? *cretacea*	2		
Systematophora sp.		5	1
Tehamadinium sp.	4		
Wallodinium krutzschii	1		

blage occurs in deposits overlying those of the Wściekły Żleb Member studied herein. It is possible that the ammonites in question could have been collected from younger deposits of this member or even from the marly intercalations in younger deposits of the Kościeliska Marl Formation.

The occurrence of *Spitidiscus* cf. *cankovi* in the studied ammonite association of Butkov Quarry suggests that the studied strata belongs to the basal part of Hauterivian. It suggests the first occurrences of *Spitidiscus* in the lowermost base Hauterivian by the Busnardo et al. (2003).

Dinoflagellate cysts.—The stratigraphically most important species of organic-walled dinoflagellate cysts are: *Cymososphaeridium validum*, *Circulodinium vermiculatum*, and representatives of *Bourkidinium*. This association meets definition of the Upper Valanginian–Lower Hauterivian *Cymososphaeridium validum* Zone set by Leereveld (1997a, b) for the interval from the top of the ammonite *Saynoceras verrucosum* Zone (beginning of Upper Valanginian) to the *Acanthodiscus radiatus* Zone (earliest Hauterivian).

The lowest occurrences of *Circulodinium vermiculatum* and *Cymososphaeridium validum* may be considered as important. They correspond to the middle part of the ammonite *Saynoceras verrucosum* Zone. Notable are the lowest occurrences of *Bourkidinium elegans* (*Bourkidinium* sp. 2 in Leereveld 1997b) and *Sentusidinium* sp. (probably *Sentusidinium* sp. A in Leereveld 1997b), which were in southern Spain used to characterize the *Sentusidinium* sp. A Dinocyst Subzone from the top of the ammonite *Himantoceras trinodosum* Subzone to a substantial part of the *Acanthodiscus radiatus* Zone (Leereveld 1997a, b). Similar occurrence-ranges of both species were observed in the Mráznica Formation of the Manín Unit of Slovakia (Skupien et al. 2003; Michalík et al. 2013).

Boorová et al. (2015) describe lowest occurrence of *Cymososphaeridium validum* and *Bourkidinium* sp. from ammonite Peregrinus Zone of the Eastern Calcareous Alps. *Cassiculosphaeridia magna* has lowest occurrence from the Upper Valanginian ammonite *Saynoceras verrucosum* Zone in the Southeastern France (Monteil 1992).

Cymososphaeridium validum and *Phoberocysta neocomica* are most abundant in the Upper Valanginian deposits of the Western Carpathians (Skupien and Smaržova 2011; Svobodova et al. 2011).

Other species, such as *Cometodinium whitei*, *C. habibii*, *Kiokansium polypes*, and *Stanfordella*? *cretacea*, commonly occur in deposits of the same age (Below 1982; Habib and Drugg 1983; Leereveld 1997b), however, their ranges are not limited to the Valanginian, but are typical of the Early Cretaceous as a whole.

Dinoflagellate cysts that could characterize higher part of the Lower Hauterivian or younger were not identified in the samples. For example, as the study by Gedl et al. (2007) identified organic-walled dinoflagellate cysts association dated at the early Upper Hauterivian *Aprobolocysta eilema* Taxon Range Zone, *Canningia pistica* Interval Subzone of Leereveld (1997a).

It should be remembered that such a stratigraphic interpretation is in accordance with that given by Pszczółkowski (2003) who correlated the deposits of the Wściekły Żleb Member with the Valanginian and lowermost Hauterivian on the basis of calpionellids and planktonic foraminifers.

Palaeoenvironment.—The body chambers of the heteromorph ammonite *Crioceratites primitivus* are frequently encrusted by evenly spaced and concentrated sessile anomiid bivalves (Fig. 4C). Although the phragmocones are well-preserved, anomiids are not observed on their surfaces. Thus, the encrustation by anomiids might have occurred on live conchs and not on ammonite shells lying on the sea bottom (post-mortem floating or sunken carcasses), suggesting that the anomiids lived in a close commensal (host-specific) relationship with heteromorph ammonites. Quite recently, commensal anomiid bivalves encrusting Cretaceous heteromorph ammonites have been reported by Misaki et al. (2014).

In addition to organic-walled cysts of Dinoflagellata typical for neritic sea (such as species of *Spiniferites*), the inshore and brackish water types (species of *Circulodinium*, *Systematophora*, and *Phoberocysta*) occur also in the samples. The species of *Spiniferites* have their highest abundance in outer neritic environments (Leereveld 1995), but highest abundance is also observed in shallow neritic sediments (Svobodová et al. 2004). It is possible to assume that such an organic material originated mainly from a marginal, near-shore sea. Of microfossils, acritarchs, inner linings of foraminifers, pollen grains and spores appear in very minute quantities (up to 3%) in our samples. All these features suggest a calm marine sedimentation with an insignificant contribution of terrestrial material and relatively high proportion of near-shore components.

Conclusions

The whole assemblage of ammonites studied consists of five species belonging to four families: Olcostephanidae: *Olcostephanus densicostatus* (Wegner, 1909); Holcodiscidae: *Spitidiscus* cf. *cankovi* (Vašíček and Michalík, 1986); Neocomitidae: *Criosarasinella* cf. *subheterocostata* Reboulet, 1996; Crioceratitidae: *Crioceratites primitivus* Reboulet, 1996 and *Crioceratites coniferus* Busnardo in Busnardo et al., 2003, as well an aptychus *Didayilamellaptychus seranonis* (Coquand, 1841). Recognised species occur largely in the uppermost Valanginian and lowermost Hauterivian. Remarkable are the valves of anomiid bivalves encrusting one *C. primitivus* body chamber.

The analysis of organic-walled dinoflagellate cysts assemblage (*Cymososphaeridium validum*, *Circulodinium vermiculatum*, and representatives of *Bourkidinium*) reveals similar stratigraphic result leading to the conclusion that the locality under our study yields the Valanginian–Hauterivian boundary beds.

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