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TWO AMMONITES FROM THE EARLY CRETACEOUS DEEP-SEA SEDIMENTS OF THE SILESIAN NAPPE, POLISH CARPATHIANS, AND STRATIGRAPHIC PROBLEMS RESULTED FROM MICROPALAEONTOLOGICAL DATING OF THEIR SITES

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Abstract: Two ammonites *Teschenites subflucticulus* Reboulet and *Criosarasinella mandovi* Thieuloy have been found for the first time in the Flysch Carpathians. They occur in the so far poorly dated Early Cretaceous flysch deposits of the Silesian Nappe at Poznachowice Dolne, in the Upper Cieszyn Shale and the Hradiště (Grodziszcze) beds lithotypes, respectively. *Teschenites subflucticulus* points to Late Valanginian (Furcillata Zone), but nannoplankton points to Late Hauterivian–Late Barremian and dinocysts to Late Hauterivian, all analyzed from the same sample. *Criosarasinella mandovi* points also to Late Valanginian (Furcillata Zone), what is not in contradiction with the nannoplankton assemblage (Early Valanginian–Early Barremian) analyzed from the same bed, but dinocysts suggest Late Hauterivian. Preservation of the ammonites and sedimentary features of their host beds exclude redeposition. The difference in age by almost 3 Ma years between the ammonites and microfossils cannot be satisfactorily explained according to the current knowledge on their biostratigraphic meaning; it is left as it is as a dilemma.

Key words: ammonites, nannoplankton, dinocysts, biostratigraphy, Lower Cretaceous, Flysch Carpathians.

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INTRODUCTION

Macrofossils are very rare in the deep-sea, mostly flysch deposits of the Carpathians. However, the Early Cretaceous dark sediments of the Silesian Nappe contain among others rare ammonites, which are known since the 19th century. Viennese geologist Ludwig Hohenegger mentioned association of ammonites from pelitic deposits designated by him as the Wernsdorfer Schichten (recent Veřovice beds). These ammonites were elaborated by Uhlig (1883) and dated to the Barremian–Early Aptian. Later, Uhlig (1902) studied another cephalopod collection of Hohenegger, which came only with some exceptions from the Oberen Teschener Schichten (recent Upper Cieszyn beds). They represent rare findings of the Valanginian age. Frequent Barremian–Early Aptian ammonites were analyzed by Kokoszyńska (1949), Szymakowska (1965, 1977, 1981) and Vašíček (1972, 1975, 2008).

Most of the so far described ammonites were found in the western part of the Silesian Nappe, where the Lower Cretaceous crops out in larger area and where its lithostratigraphy and biostratigraphy are better recognized. Lithostratigraphy and biostratigraphy of the Lower Cretaceous of the Silesian Nappe in the area south and south east of Kraków is much less recognized, mostly owing to generally poor exposure. However, in the region of Poznachowice Dolne (Fig. 1), the Lower Cretaceous is well exposed. Two ammonites were found *in situ* in two outcrops of that region. They belong to taxa, which so far were not found in the Flysch Carpathians. The ammonites enable dating of their sites. A calcareous nannoplankton and dinocyst analysis from these sites allow compare the biostratigraphic data obtained in different ways, and what is, beside description of the ammonites, the main aim of the paper.

GEOLOGICAL SETTING

The Lower Cretaceous of the Poznachowice Dolne region belongs to the Silesian Unit, which constitutes a large

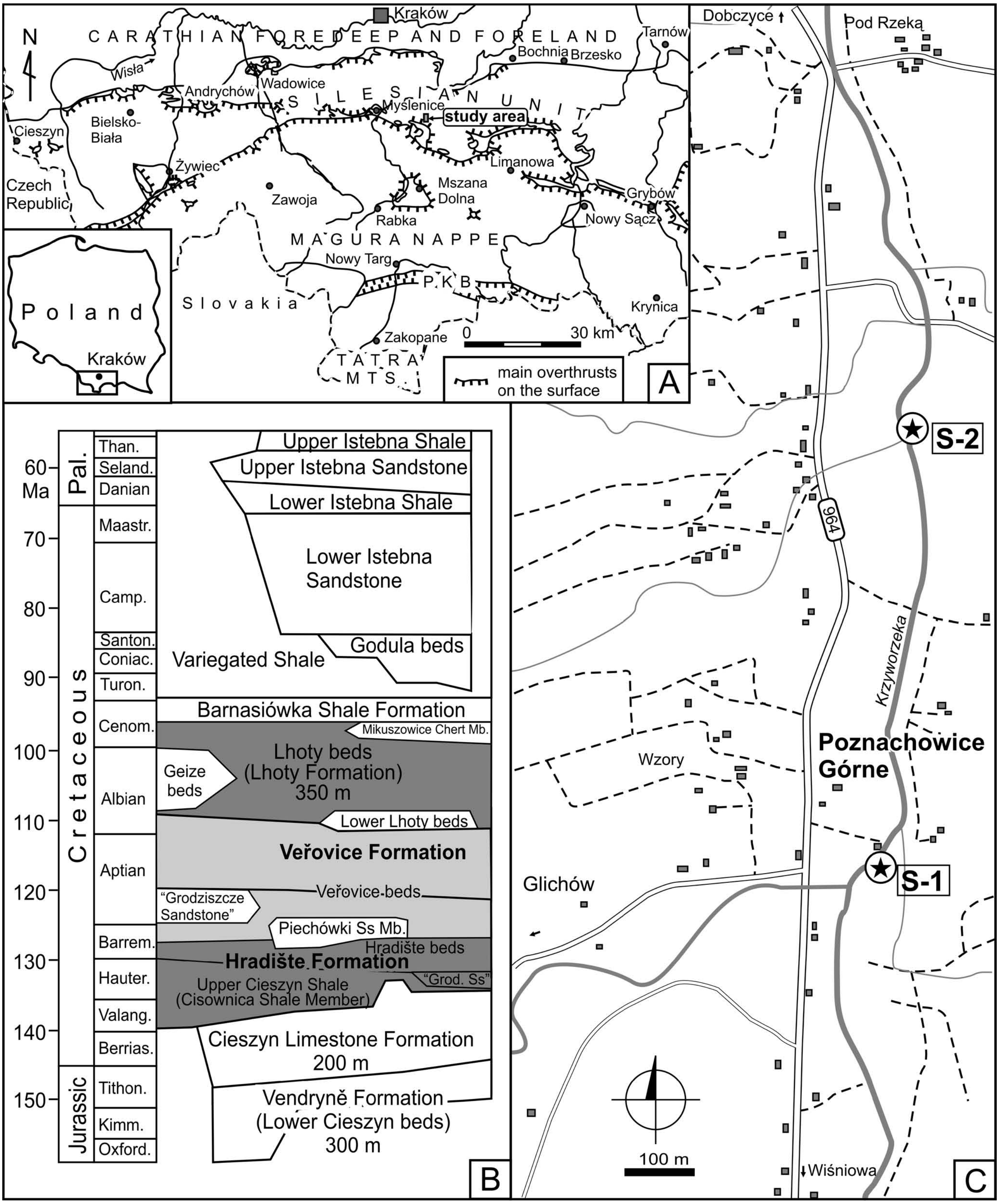

Fig. 1. Location maps and lithostratigraphic scheme of the Silesian Nappe. **A.** General maps; P.K.B. – Pieniny Klippen Belt. **B.** Lithostratigraphic scheme of the Silesian Nappe; the shaded units occur in the study area; the Veřovice beds of Polish geologists in lighter colour; compiled from Gąsiorowski (1960); Szymakowska (1977); Ślączka & Kaminski (1998), Bąk *et al.* (2001), Gedl (2001, 2003), Cieszkowski *et al.* (2003), Golonka *et al.* (2008), Olszewska *et al.* (2008), and references therein. **C.** Detailed location map; S-1 and S-2 refer to sites of *Teschenites subflucticulus* and *Criosarasinella mandovi*, respectively

complex nappe in the Ukrainian, Polish and Czech Flysch Carpathians. This nappe contains thick, diverse Kimmeridgian to the early Miocene deposits, mostly flysch, which accumulated in the deep-sea Silesian Basin, which is lately called also the Severin-Moldavidic Basin, or the Proto-Silesian Basin for the Early Cretaceous stage of development (*e.g.*, Ślączka *et al.*, 2006; Golonka *et al.*, 2008). This basin, a part of the Western Tethys, was at least a few tens of kilometres wide and a few hundreds of kilometres long. Deposits of the Silesian Basin were folded and thrust northward during the Miocene (*e.g.*, Ślączka *et al.*, 2006). Lithostratigraphy of the Lower Cretaceous of the Silesian Unit is a matter of discussion and runs to formalization and unification by Golonka *et al.* (2008).

The Cretaceous in the study area was mentioned by Kuźniar (1923, 1924). Tectonic framework and stratigraphic scheme of the area was provided by Burtan (1978, 1984). Application of the latest lithostratigraphic propositions for the Lower Cretaceous (Golonka *et al.*, 2008) in the study area is highly premature, but an approximate scheme can be given.

The oldest sediment of the study area are referred to the Upper Cieszyn beds (Valanginian–Hauterivian), which are proposed as the Cisownica Shale Member with the lowermost part of Hradiště Formation (Golonka *et al.*, 2008). However, according to Olszewska *et al.* (2008), sedimentation of the Cieszyn Limestone was continued at least until the end of Valanginian, what suggests that sedimentation of the Upper Cieszyn beds started not earlier than the Hauterivian. It is dominated by dark-grey marly mudstones alternating with regularly thin-bedded, calcareous sandstones. In the western part of the Silesian Unit, it is about 300 m thick.

The Upper Cieszyn beds are overlain or partly replaced by the Hradište (Grodziszcze) beds (Upper Hauterivian–Lower Aptian). In the Bielsko-Biała region, deposition of the Hradište beds ends in the middle Barremian (Gedl, 2003). They are represented by grey marly shales alternating with thin calcareous sandstone beds and marlstones. Locally, packages of thick-bedded calcareous sandstones occur. Traditionally, they are distinguished as the Grodziszcze Sandstone, which are now proposed as the Piechówki Sandstone Member within the Hradište Formation, which includes also the more shaly parts of the Hradište beds (Golonka *et al.*, 2008). In the study area, Burtan (1978) referred the Grodziszcze beds only the thick-bedded flysch occurring as lenses within the Upper Cieszyn beds. They contain conglomerates and exotic blocks, which can be interpreted as debris-flow deposits. Age of these deposits is older than the Barremian Piechówki Sandstone Member (Golonka *et al.*, 2008) and was assumed as the Hauterivian (Gąsiorowski, 1960). Most probably, these deposits as well as the Grodziszcze Sandstone (Lower Aptian) from Stępina in the eastern part of the Polish Carpathians (Szymakowska, 1977) represent three different lithosomes (Fig. 1B), which deserve a separation in lithostratigraphy (beyond scope of this paper). In the western part of the Silesian Unit, the Hradište beds are 95–140 m thick.

The Veřovice Shale (in Poland Barremian–Lower Albian) contain black shales, mudstones interbedded with rare cross-laminated thin sandstone beds and sideritic concretions. Their lowest part is calcareous and up the section, they are non-calcareous. In the western part of the Silesian Unit, they are confined to the Upper Aptian and distinguished as the non-calcareous Veřovice Formation, which is 200–500 m thick (Golonka *et al.*, 2008). However, different age and thicknesses of these deposits are known in the Po- lish Carpathians. According to Słomka *et al.* (2006), thickness of the Veřovice Shale is stable and ranges from 180 to 250 m. In the Moravian Carpathians, the Veřovice Shale is dated to the Late Aptian (Skupień, 2003; Golonka *et al.*, 2008). In the Polish Carpathians, the Veřovice Shale is dated to the Barremian–Aptian (*e.g.*, Szymakowska, 1981; Olszewska, 1997) and Barremian–earliest Albian (*e.g.*, Geroch & Nowak, 1963; Szydło, 1997). In the Andrychów region, sedimentation of the Veřovice Shale terminated in the Early Albian; in the Bielsko-Biała region it ranges from the Late Barremian–Late Aptian (Gedl, 2003).

Golonka *et al.* (2008) proposed a limitation of the Veřovice Formation to non-calcareous black shales confined to the upper Aptian. According to these authors, the older at least partly calcareous black shales in the Polish Carpathians considered so far as the Veřovice Shale should be ascribed to the Hradište Formation. In the Poznachowice Górne region, the Veřovice Shale is tectonically reduced.

The Lhoty (Lgota) beds (Albian–Middle Cenomanian) is composed mainly of thin bedded sandstone turbidites and non-calcareous grey-greenish spotty shales, which are about 300 m thick. It is proposed as the Lhoty Formation (Golonka *et al.*, 2008), which includes the Mikuszowice Chert Member in the uppermost part. The Lhoty beds are poorly exposed in the studied area.

In the study area, the Upper Cieszyn beds and the thin-bedded facies of the Hradište beds are difficult to separation in the field. Therefore, they are undivided on the geological maps by Burtan (1954, 1966a, b, 1974). They occur in several small imbricated thrust slices close to the northern margin of the Wiśniowa tectonic window, which belong to the Subsilesian Unit. In places, the beds are strongly tectonically disturbed. Burtan (1978) provided the only closer description of these deposits and ascribed them collectively to the Lower Cretaceous. Their palaeontology, biostratigraphy and internal lithostratigraphy are poorly recognized. Superposition of beds between the thrust slices is impossible at this stage of research. Therefore, we refer to lithotypes of the Upper Cieszyn beds or the Hradište beds rather than to these units *sensu stricto*.

Gąsiorowski (1960) described Early Cretaceous *Lamellaptychus* from the Grodziszcze Sandstone (thick-bedded sandstones in the Hradište beds) at Wiśniowa and Raciechowice-Wolica. Burtan (1978, p. 25) cited Gąsiorowski (1960) in description of the Upper Cieszyn Shale and indicated that the aptychae found by him point to the Hauterivian. Krajewski and Urbaniak (1964, p. 120) mentioned the occurrence of *Aptychus* in the Hradište beds at Poznachowice Dolne in a tributary stream of the Krzyworzeka River and undetermined Anthozoa and an ammonite of the genus *Crioceras* from the Hradište beds on an unnamed hill in feet of the Grodzisko Mount. Szymakowska (1981) showed a few sites with ammonites in the Poznachowice

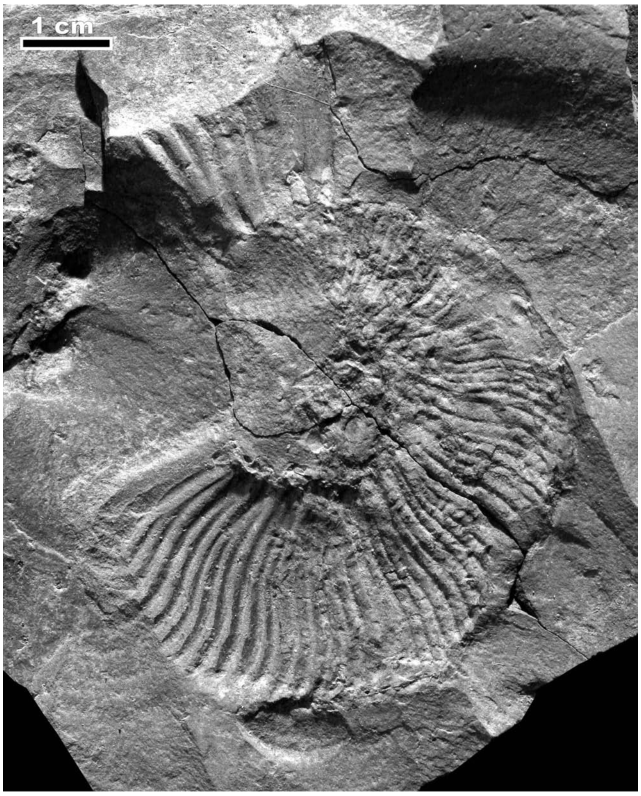

Fig. 2. *Teschenites subflucticulus* Reboulet, INGUJ 203P1. Lithotype of the Upper Cieszyn Shale, Poznachowice Górne

Dolne region on a general geological map of the Polish Carpathians but unfortunately without any closer data on the localities and determinations.

THE AMMONITES

The ammonites were found in two different outcrops along the Krzyworzeka River belonging to two different thrust slices. *Teschenites subflucticulus* Reboulet was found by Mariusz Hoffmann and Alfred Uchman in very thin-beded muddy turbidites with intercalations of very thin sandtone beds (GPS co-ordinates: N49°49’24.34”; E20°07’08.66”±5 m) ascribed provisionally to the Upper Cieszyn Shale according to Burtan’s (1978) description.

Criosarasinella mandovi Thieuloy was found by Elżbieta Włodarczyk in steeply dipping beds ascribed to the Hradište Beds (GPS co-ordinates: N49°49’49.05”; E20°07’ 12.05”±6 m). They are thin-bedded calcareous turbiditic sandstones intercalated with grey marly shales and rare medium-bedded sandstones. The turbiditic rhythms are here thicker (commonly more than 5 cm) than in the former locality (single centimetres).

By analogy to the lithostratigraphy in the western part of the Silesian unit, the beds bearing *Teschenites subflucticulus* should be older than the beds bearing *Criosarasinella mandovi*. However, there is no direct evidence of superposition of these beds.

The ammonites are preserved as incomplete impressions (*Teschenites subflucticulus*) or deformed internal moulds (*Criosarasinella mandovi*). With regard to the incompleteness of shells, only exceptionally some of dimensional parameters were measured, namely: D = shell diameter, H = last whorl height, U = umbilicus width. In the brackets after dimensions in mm, values of H/D and U/D ratios are stated. The whorl width cannot be measured in any case.

SYSTEMATIC DESCRIPTION

The classification at higher than genus level is based on the new edition of *Treatise of Invertebrate Paleontology*, part L (Wright *et al.*, 1996). The exception is the genus *Criosarasinella*, which is ascribed to the suborder Ancyloceratina (Vašíček, 2005).

Suborder AMMONITINA Hyatt, 1889
Superfamily PERISPHINCTOIDEA Steinmann, 1890
Family NEOCOMITIDAE Salfeld, 1921
Subfamily NEOCOMITINAE Salfeld, 1921
Genus *Teschenites* Thieuloy, 1971
Type species *Teschenites flucticulus* Thieuloy, 1977
(in Busnardo *et al.*, 2003)

Teschenites subflucticulus Reboulet, 1996
Fig. 2

1977. *Neocomites* (*Teschenites*) *flucticulus* n. sp.: Thieuloy, p. 98, pl. 3, fig. 9.
v 1994. *Neocomites* (*Teschenites*) *flucticulus* Thieuloy: Vašíček *et al.*, p. 58, pl. 17, fig. 8.
* 1996. *Neocomites subflucticulus* n. sp.: Reboulet, p. 106, pl. 8, figs. 1-9.
1996. *Neocomites flucticulus* (Thieuloy): Reboulet, pl. 9, fig. 9.
2005. *Neocomites (Teschenites) subflucticulus* (Reboulet): Klein, p. 320 (cum syn.)

Material: An incomplete imprint of the last whorl in grey mudstone. The imprint belongs to a rather large, flat deformed shell with the non-preserved ventral side. Poznachowice Górne, lithotype of the Upper Cieszyn beds. INGUJ 203P1.

Description: An imprint of semi-involute shell with high, slightly vaulted whorls and a rather wide umbilicus. The description of sculpture, probably in the vicinity of transition of the phragmocone into the body chamber, corresponds to the best preserved part of the imprint. There, the shell is densely ribbed with rather thin, proverse, S-shaped ribs. The ribs begin at the line of coiling in indistinct bulges and continue to umbilical tubercles. From these tubercles, two, locally even three ribs run. In the case of two ribs, one of them may bifurcate in the lower third of whorl. Occasionally it is clear that between the bundles of ribs running from the tubercles, one simple rib with the beginning closely above the umbilical tubercles can occur. All the ribs end in faint marginal tubercles on the ventral side.

Measurements: The maximal diameter of the shell is estimated at about 85–90 mm, it means that this is a macroconch. At the only measurable whole shell diameter D = 57 mm, H = 24.0 (0.42) and U = 17.5 (0.31).

Remarks: With regard to the density of ribbing, but especially to a rather wide umbilicus, the described impression corresponds best to the diagnosis of *T. subflucticulus*. The species is close to *T.*

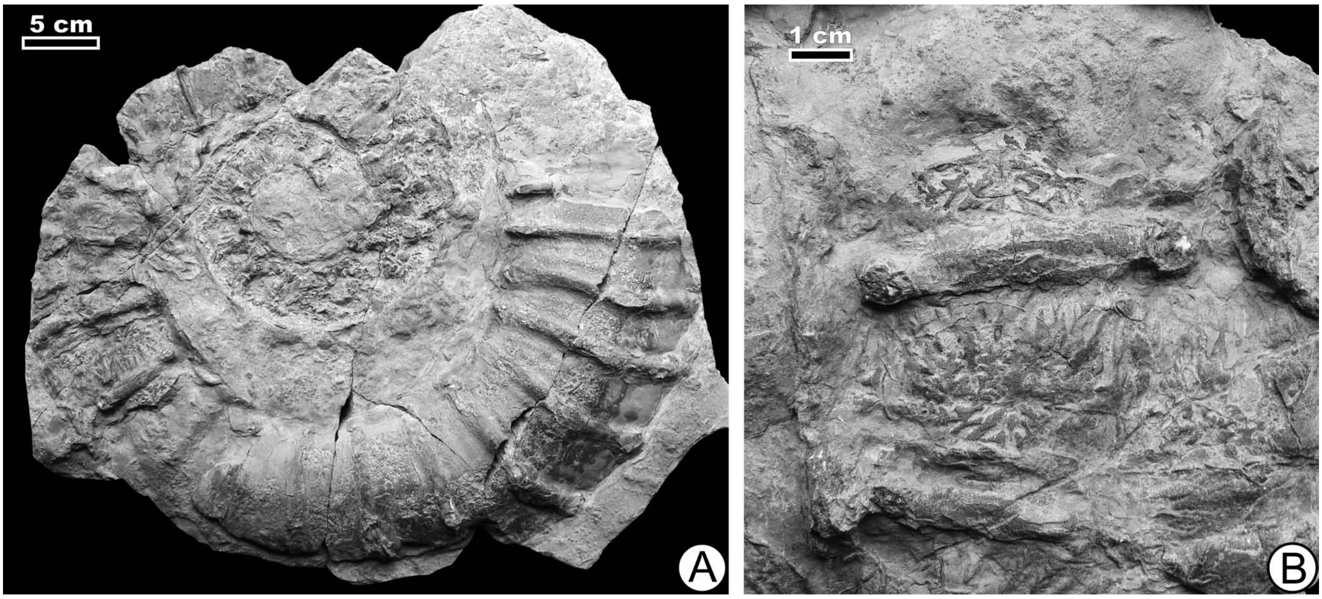

Fig. 3. *Criosarasinella mandovi* Thieuloy, INGUJ 203P2. Lithotype of the Hradište Beds, Poznachowice Górne. **A.** general view of the lower side. **B.** Detail of A

flucticulus, which differs by having the narrower umbilicus (after Reboulet, 1996, U/D ranges from 0.22 to 0.28). Busnardo in Busnardo *et al.* (2003, p. 44) expresses doubts about distinguishing *T. flucticulus* from *T. subflucticulus* as individual species when only their different stratigraphic positions are taken into account, although it is true that *T. flucticulus* developed from the previous species, and transient forms between them exist; however, the umbilicus width is a good diagnostic feature in this case. Forms with markedly wider umbilicus (*T. subflucticulus*) are stratigraphically older in the Western Carpathians.

Distribution: According to Reboulet (1996), *T. subflucticulus* occurs assuredly only in France, from the Late Valanginian to the basal Hauterivian (ammonite Furcillata Zone to the base of Radiatus Zone). On the basis of biostratigraphical researches done in the section of the Butkov quarry (Vašíček *et al.*, 1994; Vašíček, 2005), *T. subflucticulus* occurs in the Slovak Western Carpathians merely in the Late Valanginian (Furcillata Zone), whereas *T. flucticulus* occurs as late as the Early Hauterivian.

Suborder ANCYLOCERATINA Wiedmann, 1960
Superfamily ANCYLOCERATOIDEA Gill, 1871
Family ANCYLOCERATIDAE Gill, 1871
Subfamily CRIOCERATITINAE Gill, 1871
Genus *Criosarasinella* Thieuloy, 1977
Type species *Criosarasinella furcillata* Thieuloy, 1977

Criosarasinella mandovi Thieuloy, 1977
Fig. 3

* 1977. *Criosarasinella mandovi* n. sp.: Thieuloy, p. 110, pl. 5, figs. 6, 7.
1996. *Criosarasinella mandovi* Thieuloy: Reboulet, p. 78, pl. 16, fig. 4;, pl. 20, figs. 1, 7; pl. 21, figs. 1, 3-7.
v 2005. *Criosarasinella mandovi* Thieuloy: Vašíček, p. 249, figs. 3.2, 3.3.

Material: The only large, heavily deformed internal mould having poorly preserved inner whorls, and with a rather favourably preserved last half-whorl. The favourably preserved part of shell belongs, according to sutures, to the phragmocone, the prevailing remaining part belongs then to the body chamber. The specimen displays an unique, probably taphonomic feature: the last half-whorl is separated from the more juvenile evolute whorls so that the specimen appears to be a shell with free coiled last whorl (for taphonomic interpretation see Discussion). Lithotype of the Hradište beds, Poznachowice Górne, INGUJ 203P2.

Description: An originally evolute shell is demonstrated by internal whorls. The poorly preserved inner whorls are covered with ribs of uniform type. Poorly visible, delicate tubercles are visible throughout the umbilicus. The zone of transition of phragmocone into the body chamber and the body chamber display S-shaped main ribs. They are covered by three rows of tubercles: umbilical, ventrolateral and marginal ones. Between the main ribs, two or three markedly thinner ribs without tubercles are inserted. At the final half-whorl, 14–15 main ribs are located.

Measurements: In the poorly preserved shell, which is heavily flat deformed, the morphometric parameters of the last but one whorl can be measured along several rays: the diameter D = 155 mm, H = 53.- (0.34) and U = 70.- (0.45). At the diameter of the shell D = 120 mm, H = 38.- (0.32) and U = 54.- (0.45). If we theoretically attach the secondarily separated last whorl to the line of coil of the former whorl, we must add two relevant heights of the last whorl to the diameter. At the diameter of the shell of 155 mm, whorl at the end of phragmocone is about 80 mm high of and about 105 mm high in the vicinity of shell peristome. In the sum, the maximum diameter of the shell (influenced by deformation) attains about 340 mm. The boundary between the phragmocone and the body chamber is located at the diameter of 160–165 mm.

Remarks: The specimen falls to the category of the Late Valanginian macroconchs, which are rather rare. Their body chambers display considerably similar ornamentations in shape of trituberculate main ribs, between which inserted ribs without tubercles are gradually reduced or fade away. Their main representatives are *Neocomites* (*Varlheideites*) *peregrinus* Rawson et Kemper, *Rodighieroites cardulus* Company and *Criosarasinella mandovi* Thieuloy. For their accurate identification and generic classification, the sculpture and the coiling of inner whorls play a decisive role. In *V. peregrinus*, the inner whorls overlap each other partially, and thus the coiling can be taken as semi-evolute. According to Reboulet (1996, p. 95), the H/D ratio of most *V. peregrinus*

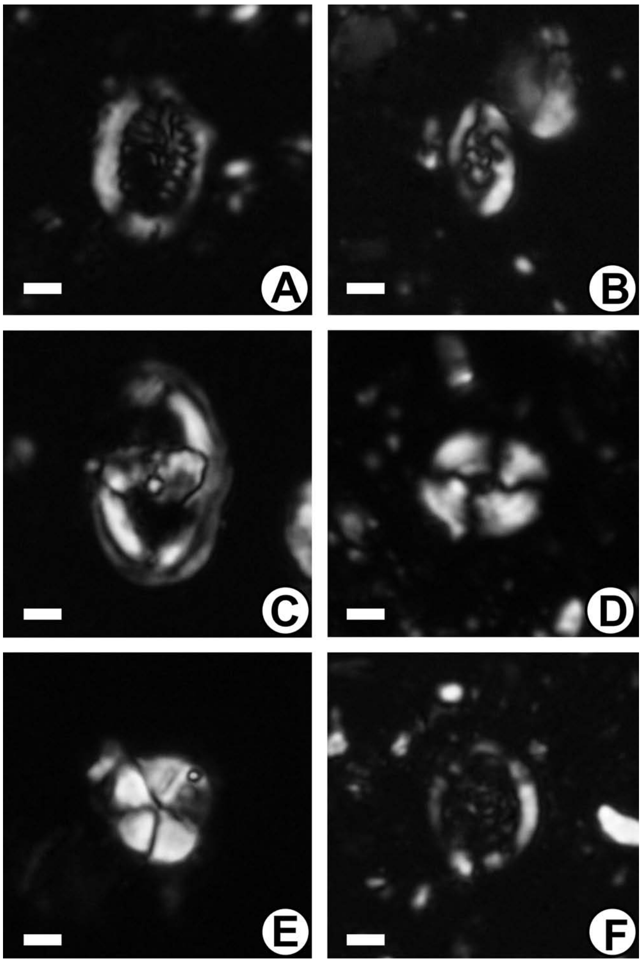

Fig. 4. Calcareous nannoplankton in cross-polarized light. **A.** *Cretarhabus conicus*, slide S-1; **B.** *Rhagodiscus* sp., slide S-2; **C.** *Zeugrhabdotus embergeri*, slide S-1; **D.** *Watznaueria fossacincta*, slide S-1; **E.** *Micrantholithus* sp., slide S-2; **F.** *Calcicalathina* sp., S-2. Length of scale bar is 1 μm

macro- conchs ranges broadly from 0.35 to 0.40 (mode 0.38) and the U/D ratio ranges from 0.35 to 0.40 (mode 0.36). Ribs on the inner whorls are thin and dense, of the so-called neocomitid type. *R. cardulus* displays all the whorls evolutely coiled, in which main and subsidiary ribs can be differentiated even on the inner whorls. The main ribs are trituberculate. The inner as well as adult whorls of *C. mandovi* are evolute to such an extent that the whorls are only in contact. In the largest specimen of Reboulet (1996, p. 78), the shell diameter attains 215 mm, with the ratios H/D = 0.31 and U/D = 0.49. Close parameters were measured in the studied specimen from Poznachowice Górne. Other small differences can be observed in the ornamentation of body chambers of macroconchs. Each of trituberculate ribs of *V. peregrinus* and *R. cardulus* are accompanied by a simple rib along their frontal sides. The ribs are separated from each other by a constriction. At the case of *C. mandovi*, paired ribs accompanied by a constriction are missing. According to the literature, the greatest macroconchs reach the diameter of 150–185 mm in of *V. peregrinus* and about 130 mm in *R. cardulus*. *C. mandovi* is up to 215 mm. The described features, especially the coiling of inner whorls, the specimen can be ascribed *C. mandovi*. The specimen attains more than 300 mm in diameter. However, it can be slightly overestimated because of deformation.

Distribution: *C. mandovi* occurs in the Late Valanginian in the ammonite Furcillata Zone. It is known foremost from the Vocontian Trough in France and from the Manín Unit of Slovak Western Carpathians. Furthermore, it is known from Bulgaria and a single finding comes from the Kościeliska Marl Formation of the Polish part of the Tatra Mountains (Lefeld, 1974).

STRATIGRAPHIC EVALUATION OF THE AMMONITES

Teschenites subflucticulus and *Criosarasinella mandovi* are known mainly from the Late Valanginian of the Vocontian Trough in France. According to Reboulet (1996), *Teschenites subflucticulus* occurs in the ammonite Furcillata Zone and reaches as far as the base of Hauterivian (Radiatus Zone). *Criosarasinella mandovi* occurs in the ammonite Furcillata Zone (ammonite zones according to Reboulet, 1996 and Reboulet *et al.*, 2006). Both the mentioned species have also been found in sections in the Butkov quarry in the Slovak Central Carpathians, in the same stratigraphic position (Vašíček, 2005). They are known merely from to the Mediterranean warm-water bioprovince. They are found for the first time in the Outer Carpathians.

CALCAREOUS NANNOPLANKTON

Two microscope slides were prepared from the calcareous mudstone of adhered to the ammonites using the routine simple smear-slide technique. They were investigated under the light microscope at magnification ×1000 in bright and cross-polarized light as well as phase-contrast. The slides contain moderately preserved nannofossil assemblages with an average abundance of 1 specimen of nannofossil per 1 to 10 fields of view, although assemblage coming from the *T. subflucticulus* bed (slide S-1) is a little more abundant and slightly better preserved than from the *C. mandovi* bed (slide S-2). State of preservation of the studied assemblages can be estimated as a slightly etched, e.g. E-1 for slide S-1 and E-2 for slide S-2 using Roth's (1983) scale.

The studied assemblages (Fig. 4) are poorly taxonomically diversified (Tab. 1). Only a few taxa have been recognized. The most popular species is *Watznaueria barnesiae*, which dominates in both slides. The next taxon commonly found is *W. fossacincta* and as well as genus *Retecapsa* spp. in slide S-1.

The most recent stratigraphic nannoplankton zonation for Lower Cretaceous is given by Bown *et al.* (1998), who concluded that the best nannofossils for biostratigraphy derive from NW Europe sections. They presented boreal nannoplankton zonation (BC zones) correlated against the boreal ammonite chronostratigraphy. The BC zones were also correlated with the Tethyan nannoplankton zonation (NC zones) previously established by Roth (1978, 1983), Bralower (1987) and Bralower *et al.* (1993).

In general, the studied nannofossils are typical of the Neocomian assemblages with dominance of *W. barnesiae*, *W. fossacincta* or *Rhagodiscus asper* and *Micrantholithus hoschultzii*. The most important species for this study is the index species *Calcicalthina oblongata*, which is present in slide S-2. It is a typical Tethyan species, which ranges from the lowermost Valanginian to the upper part of lower Barremian (Bown *et al.*, 1998). *Micrantholithus hoschultzii* (both slides) is known from the lowermost Berriasian up to the Aptian, with two acme zones in the upper Hauterivian and in the lower Barremian. Moreover, the studied slides do not contain *Haysites irregularis* or *Eprolithus floralis*, which have their FO in the Upper Barremian and in the Lower Aptian, respectively. Based on these calcareous nannoplankton zonal marker species, the age of the studied material could be determined as Lower Berriasian through Upper Barremian for S-1 (*T. subflucticulus*), and Lower Valanginian–Lower Barremian for S-2 (*C. mandovi*). However, slide S-2 (*T. subflucticulus*) contains also *Zeugrhabdotus scutula*, which hitherto reported FO is in the lower part of Upper Hauterivian (see also Bown *et al.*, 1998). In regard to that stratigraphic range, slide S-2 (*T. subflucticulus*) might represent Upper Hauterivian–Upper Barremian.

DINOCYSTS AND PALYNOFACIES

The same samples as for calcareous nannoplankton were used for study of dinocysts: sample Am-I is an equivalent of slide S-1 (ammonite *T. subflucticulus*) and sample Am-II is an equivalent of slide S-2 (ammonite *C. mandovi*). 15 g of mudstone from each sample were processed for palynological analysis: dissolving in 38% HCl and, then, in 40% HF, heavy liquid separation ($ZnCl_2$), sieving with a 15 µm sieve, and centrifuging to concentrate the residuum. Three gelatine-glycerine slides for each sample were prepared and studied under transfluent light microscope.

Palynofacies analysis were done on the basis of groups of components (*cf.* Tyson, 1995; Batten, 1996): black woody particles, brown woody particles, sporomorphs, dinocysts, foraminifera test linings, and amorphous organic matter. Three slides for each sample were searched to obtain stratigraphic data on the basis of dinocysts.

In sample Am-I (*Teschenites subflucticulus*), palynofacies are composed of black woody phytoclasts (20.2%), brown woody phytoclasts (12.6%), cuticules (0.2%), sporomorphs (33%), dinocysts (19.8%), amorphous organic matter (12.8%) and foraminifera linnings (1.4%). Dinocysts of various stage of preservation, from well (especially *Circulodinium* sp.) to very bad preserved cysts, are present (Fig. 5). They include *Achomosphaera neptunii*, *Avellodinium falsificum*, *Batioladinium jaegaerii*, *Batioladinium micropodum*, *Circulodinium distinctum*, *Cymososphaeridium validum*, *Hystrichodinium pulchrum*, *Hystrichosphaerina schindewolfii*, *Kiokansium polypes*, *Kleithriasphaeridium corrugatum*, *Lithodinia stoverii*, *Nelchinopsis kostromiensis*, *Oligosphaeridium complex*, *Phoberocysta neocomica*, *Pseudoceratium* cf. *solocispinum*, *Pseudoceratium pelliferum*, *Tanyosphaeridium regulare*, *Valensiella reticulate*, and *Wallodinium krutzschii*.

Achomosphaera neptunii has been reported from the north-west Europe and North Sea wells from the upper Ryazanian to upper Aptian (Heilmann-Clausen, 1987), but usually is noted from the Hauterivian to the Barremian (e.g., Prössl, 1995). The presence of *Lithodinia stoverii* (FO in Lower Hauterivian – Costa and Davey, 1992, or in upper Lower Hauterivian – Leereveld, 1995), *Nelchinopsis kostromiensis* (LO in Upper Hauterivian; Costa & Davey, 1992) and *Cymososphaeridium validum* (LO in Upper Hauterivian; Leereveld, 1995) indicate Hauterivian. Co-occurrence of these cysts with *Batioladinium jaegeri*, taxon known from rocks not older than Late Hauterivian (*e.g.*, Duxbury, 1977; Prössl, 1990) suggests the Late Hauterivian age.

The presence of common *Batioladinium jaegeri*, and, less common, *Avellodinium falsificum*, *B. micropodum*, *Discorsia nanna*, and *Hystrichosphaerina schindewolfii* suggests a connection with the Boreal Province; in the Tethys Province those cysts are usually recognised as boreal immigrants (cf., Leereveld, 1995).

Sample Am-II (*Criosarasinella mandovi*) contains palynofacies composed of black woody phytoclasts (41.5%), brown woody phytoclasts (15%), sporomorphs (18.5%), dinocysts (17%), amorphous organic matter (1%), foraminifera linnings (1.5%) and acritarchs (0.5%). Dinocysts (Fig. 5) are rather badly preserved, mechanically destroyed, with pyrite sphaeroids. They include: *Avellodinium falsificum*, *Cymososphaeridium validum*, *Dingodinium albertii*, *Discorsia nanna*, *Gonyaulacysta helicoidea*, *Kiokansium unituberculatum*, *Lithodinia pertusa*, *Muderongia staurota*, *Oligosphaeridium complex*, *Phoberocysta neocomica*, *Pseudoceratium pelliferum*, *Pseudoceratium* cf. *retusum*, *Rhombodella vesca*, *Spiniferites* sp., *Subtilisphaera terrula*, *Systematophora cretacea*, *Systematophora syliba*, *Tanyosphaeridium magneticum*, and *Valensiella magna.*

Table 1

Calcareous nannoplankton in slide S-1 (*T. subflucticulus*-bearing bed) and S-2 (*C. mandovi*-bearing bed);

	S-1	S-2
Biscutum constans (Górka)	x	
Calcicalathina oblongata (Worsley)		x
Cretarhabdus conicus (Bramlette & Martini)	x	
Cretarhabdus sp. Bramlette & Martini		x
Micrantholithus hoschulzii (Reinhardt)	x	x
Nannoconus sp. Kamptner		x
Percivalia fenestrata (Worsley)		x
Rhagodiscus asper (Stradner)		x
Retecapsa octofenestrata (Bralower)	x	
Retecapsa surirella (Deflandre & Fert)	x	
Retecapsa sp. Black	x	
Stradnelithus sp. Black		x
Tranolithus gabalus (Stover)	x	
Watznaueria barnesiae (Black)	x	x
Watznaueria fossacincta (Black)	x	
Zeugrhabdotus embergeri (Noël)	x	
Zeugrhabdotus scutula (Bergen)		x

x indicates the presence

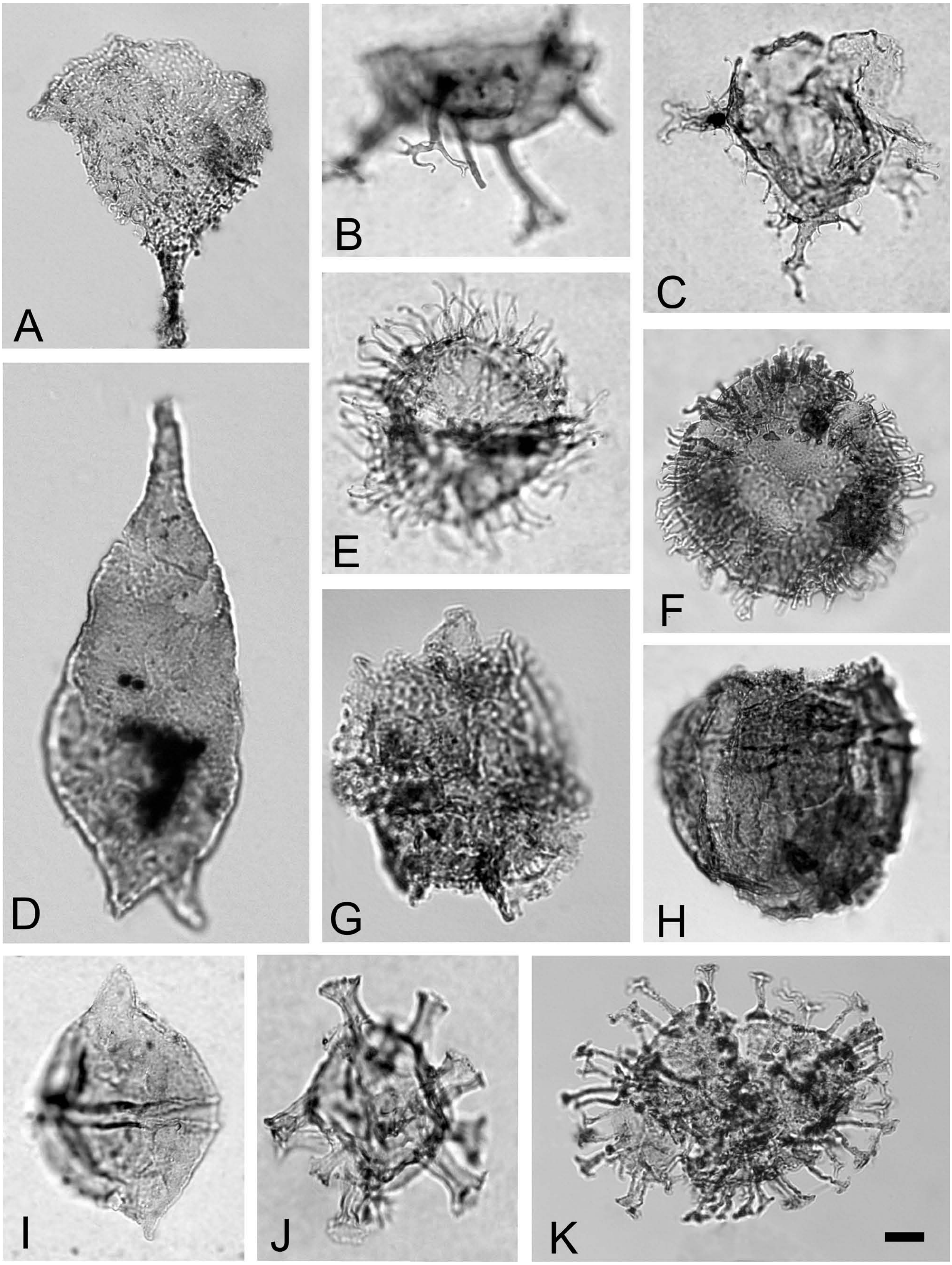

Fig. 5. Selected dinocysts. A, D, F–H and **K** from sample Am-I (*T. subflucticulus*); B, C, E, I and J from sample Am-II (*C. mandovii*). **A.** *Pseudoceratium pelliferum*; **B.** *Cymososphaeridium validum*; **C.** *Phoberocysta neocomica*; **D.** *Batioladinium jaegeri*; **E.** *Cometodinium habibi*; **F.** *Circulodinium distinctum*; **G.** *Nelchinopsis kostromiensis*; **H.** *Lithodinia stoveri*; **I.** *Subtilisphaera terrula*; **J.** *Discorsia nanna*; **K.** *Kiokansium* sp. Length of scale bar is 10 µm and it refers to all pictures

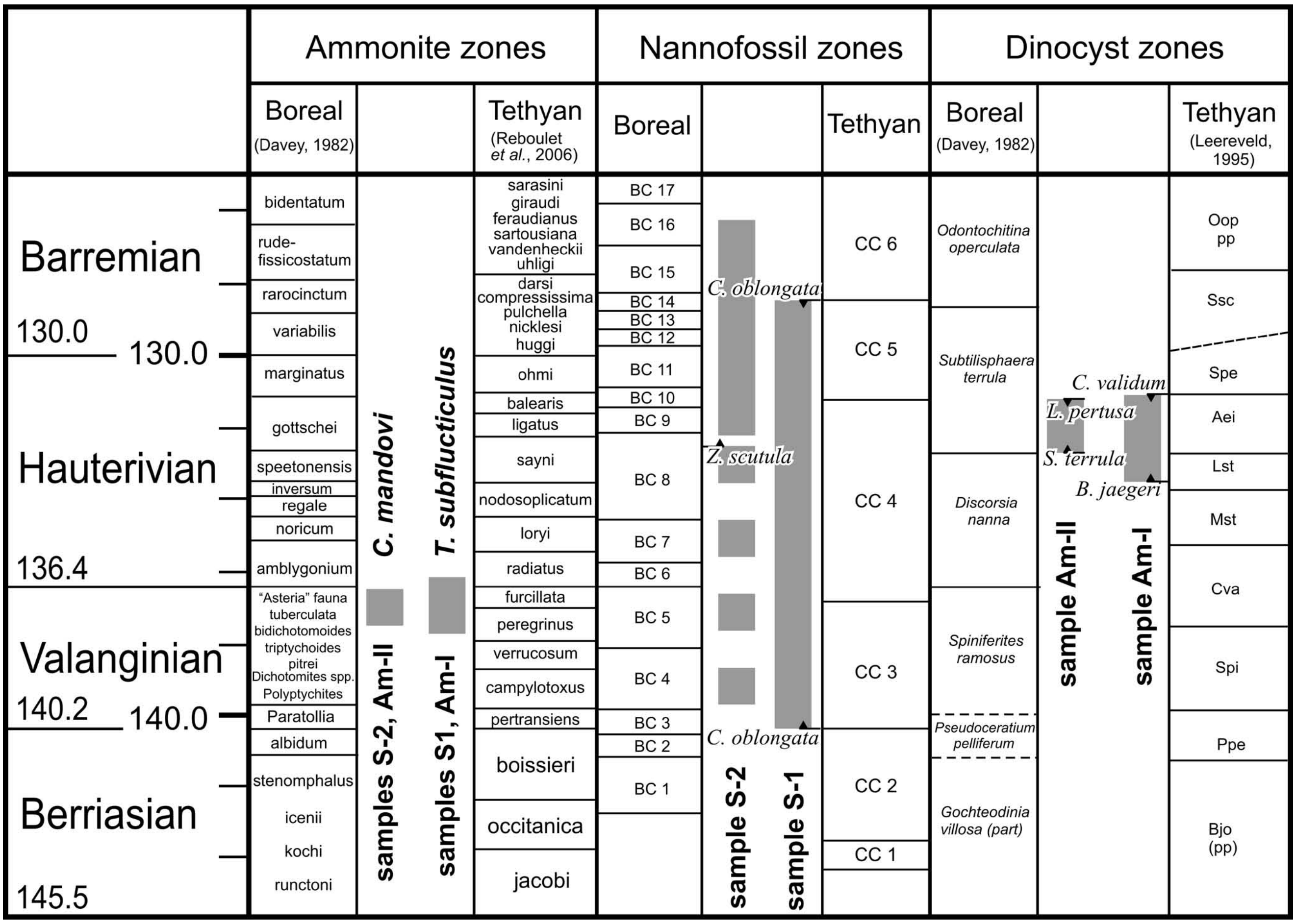

Fig. 6. Stratigraphic ranges of ammonites *Teschenites subflucticulus* and *Criosarasinella mandovi* and studied microfossils

The first occurrence data (FAD) of *Muderongia staurota* are known from both Tethyan and Boreal provinces at Early Hauterivian (A. radiatus and E. amblygonium ammonite zones, respectively; Leereveld, 1995). The first occurrence of *Subtilisphaera terrula* at Late Hauterivian is known both from Tethyan and Boreal provinces (*cf.* Davey, 1979, 1982; Leereveld, 1995). *Lithodinia pertusa* disappear at Late Hauterivian, according to Leereveld, 1995. These data suggest Late Hauterivian age of the sample Am-II (*Criosarasinella mandovi*). The presence of *Avellodinium falsificum*, *Discorsia nanna* and *Valensiella magna* implicates connection with the Boreal Province; in the Tethys Province those cysts are recognised as boreal immigrants (*cf.* Leereveld, 1995).

Both samples are rich in palynomorphs (50% in Am-I and 35% in Am-II). The presence of foraminifera linings and, occasionally, cuticles in sample Am-I indicates rather shallow marine provenance of the sediment, which was transported into deeper environment. Comparing palynofacies of these two samples, sample Am-II represents more distal environment than sample Am-I: cuticles are absent, sporomorphs less frequent and among dinocyst *Dingodinium* sp. occurs (outer neritic group; Leereveld, 1995). However, beds are thicker around sample Am-II than around sample Am-I.

DISCUSSION

Ammonites are considered as the most valuable stratigraphic indicators especially for the Jurassic and the Cretaceous. The ammonite specimens from this study show a narrow stratigraphic range restricted to the Late Valanginian (the ammonite Furcillata Zone in both cases) in contrast to the wide ranges obtained from dinocyst and markedly wider from the calcareous nannoplankton investigations (Fig. 6). Moreover, the ranges of the different groups of fossils are not synchronous.

In the case of *Teschenites subflucticulus*, nannoplankton assemblage comprises three nannoplankton zones from the base of Valanginian to the Lower Barremian and dinocyst assemblage represents only Upper Hauterivian against the Upper Valanginian based on the *T. subflucticulus*. In the case of *Criosarasinella mandovi*, nannoplankton assemblage indicates at least Upper Hauterivian based on the first occurrence of *Z. scutula*, which is consistent with the stratigraphic position based on the dinocyst assemblage, but still differs from the date based on the ammonite (Late Valanginian).

Thus, there is no conflict in age determination based on the calcareous nannoplankton and dinocysts, but the age based on them is different from the age based on the

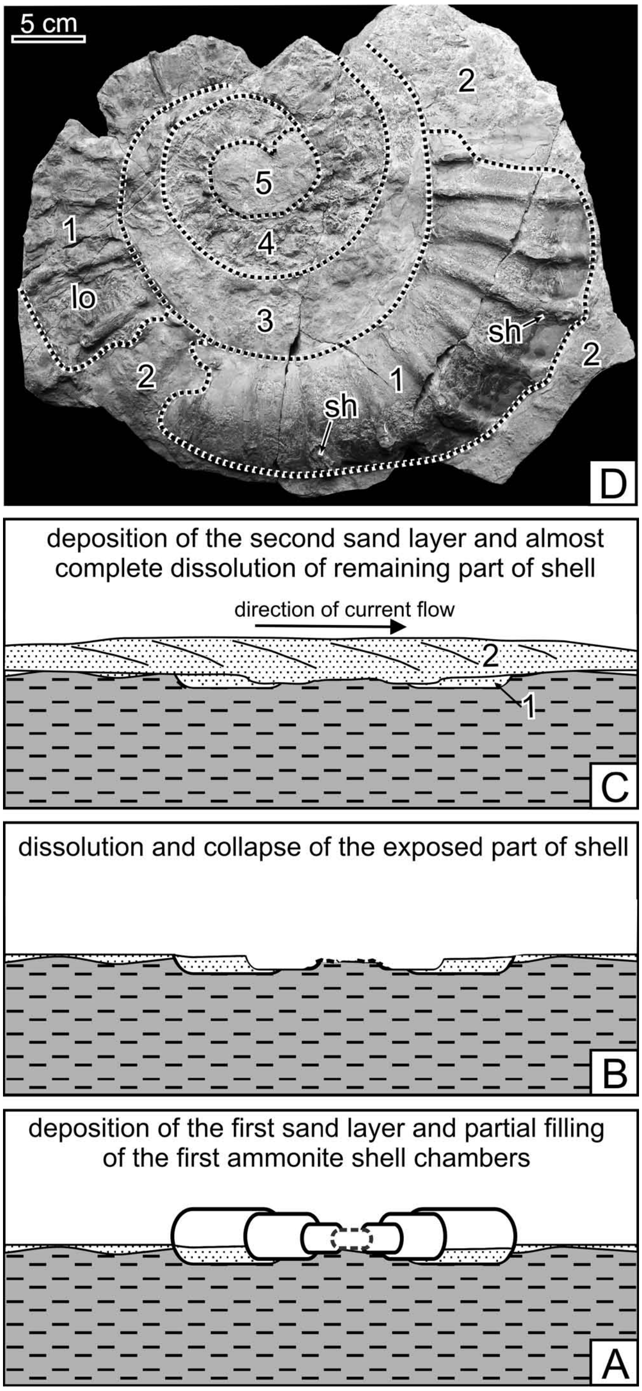

Fig. 7. Model of preservation of *Criosarasinella mandovi* Thieuloy. **A–C** – Taphonomic stages; 1 and 2 in **C** refer to the first and second sandstone layers, respectively. **D** – Lower part of the specimen; 1 – internal mould filled with the first sandstone layer; sh – shell fragments; lo – area of lobe line preservation; 2 – second sandstone layer with cross lamination, 3 – area of complete shell dissolution filled with the second sandstone layer, 4 – concave collapsed part of shell with casts of shell fragments, 5 – umbiculus part completely dissolved and filled the second sandstone layer

ammonites by about 3 Ma years. The situation is not easy to explain. As a reason, the redeposition of older ammonites and migration of biota can be considered.

The studied ammonites occur in very thin-bedded (*Teschenites*) or thin- to medium-bedded (*Criosarasinella*) package of beds. The packages display alternations of sandstones and shale sediments, in which the sandstone beds were deposits by weak turbidites or bottom currents (ripple mark phase). *Teschenites* was found in a thin marly shale layer, which was deposited by even weaker currents. *Criosarasinella* shell was laid flat in a marly shale and its first chambers were filled by sandstone (Fig. 7A). The firsts sandstone layer filling protected the shell. Its unprotected parts, including umbiculus and part of the inner whorls were dissolved and or collapsed (Fig. 7B, D). Than the next sandstone layer (second sandstone layer was deposited), which filled the depression after collapse and dissolution of the ammonite shell. It display distinct ripple cross lamination and slightly erosive base. The first and the second sandstone beds are welded and appear as one bed. The first sandstone layer shell filling form the internal mould of the lower part of the shell (Fig. 7D), which displays cast of ribs, fragments of shell and cast of lobe line. The preservation style is similar to the so-called half ammonites (Seilacher *et al.*, 1976; Maeda & Seilacher, 1996).

Such a preservation and the sedimentary features of the bearing strata point that the exhumation of the Late Valanginian ammonites and their redeposition after almost more than 3 Ma years during the Late Hauterivian is very little probable. After such a time (like from Pliocene to recent), the shells should be buried and filled with sediment. Redeposition of heavy (in case of large *Criosarasinella* several kilograms), sediment-filled shells by weak currents is not reliable. The closed shell cannot be filled with cross-laminated sediment. There is also no evidence of longer non-deposition. Thus, the ammonites should indicate an age of the beds in which they were found.

It should be stressed, that stratigraphic ranges of the nannoplankton taxa from this study were established by Bown *et al.* (1998) in reference to the boreal ammonite zonation, so some differences in chronostratigraphic position of stratigraphic ranges cannot be excluded for Tethyan realm. The study area represents a transitional domain with influence of boreal dinocysts but Tethyan ammonites, where such differences can be also expected.

Some nannoplankton taxa appear earlier in the Tethyan Province than in the Boreal one. For instance, Bown (1992) is of opinion that the oldest nannoplankton taxa from the Late Triassic evolved within the Tethys first and then spread into the new ecological niches outside, for instance into the Boreal Province. Such pattern seems to be repeated further for the other taxa, though the opposite preferences are also observed, *e.g.* origin of taxa in the subpolar (high-latitude) regions and migration through the time to the tropical bioprovince. The best known Cretaceous species with such preferences is *Nephrolithus frequens*, cool-water indicator which migrated through the almost all Maastrichtian to the warmer regions (Thierstein, 1981; Burnett, 1998). Therefore, biostratigraphic zonation of calcareous nannoplankton zones or the age of rock sample based on that group of fossils cannot be established without reference to palaeobiogeography. Accordingly, chronostratigraphic position of the first occurrence of *Z. scutula* given in Fig. 6

may be different in the Tethyan Province and, probably, lower than in Boreal Province. This can explain differences in age based on the ammonite *Criosarasinella mandovi* and on the nannoplankton zonation. Dinocyst ranges (FAD) of *M. staurota* and *S. terrula* in Early and Late Hauterivian respectively are well known and almost coeval both from the Tethyan and Boreal provinces (Davey, 1979, 1982; Leereveld, 1995). *Batioladinium jaegerii* (FAD in Late Hauterivian) is usually treated as boreal immigrant in the Tethyan province. In the Polish Carpathians, this species was noted before from Veřovice beds (Silesian Unit) near Bielsko-Biała (Gedl, 2003) from Upper Barremian. *Batioladinium jaegerii* was also noted in the Pieniny Limestone Formation, in Lower Barremian sample (Gedl, 2007).

None of the explanations of the differences in age determination on the basis of ammonites, calcareous nannoplankton and dinocysts is satisfactory. Therefore, we would like to left this problem as a dilemma. Probably, age determinations based on different taxonomic groups in other Carpathian flysch sections will bring similar problems, which solving should enhance biostratigraphic schemes.

Apart from the differences in dating the all groups of fossils point to more or less the same age of both sites, which were ascribed to two different lithotypes, which are typical of generally older Upper Cieszyn Shale and generally younger Hradište beds. However, these lithostratigraphic units interfinger and are partly coeval. The studied section confirms such a situation.

CONCLUSIONS

1. Tethyan ammonites *Teschenites subflucticulus* Reboulet and *Criosarasinella mandovi* Thieuloy have been indentified for the first time in the Flysch Carpathians, in the Lower Cretaceous of the Silesian Unit.
2. The ammonites point to Late Valanginian (Furcillata Zone), but nannoplankton and dinocysts from their sites point to Late Hauterivian.
3. Preservation of the ammonites and sedimentary features of the host beds exclude redeposition of the ammonites.
4. The 3 Ma years difference in age in dating by the ammonites and microfossils is unresolved dilemma; maybe migrations between bioprovinces influence stratigraphic ranges of these fossils.

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Appendix

Alphabetic list of dinocyst taxa from samples Am-I and Am-II (for taxonomic citation see Williams *et al.*, 1998).

Achomosphaera neptunii (Eisenack, 1958) Davey and Williams, 1966
Avellodinium falsificum Duxbury, 1977
Batioladinium jaegaerii (Alberti, 1961) Brideaux, 1975
Batioladinium micropodum (Eisenack & Cookson, 1960) Brideaux, 1975
Circulodinium distinctum (Deflandre & Cookson, 1955) Jansonius, 1986
Cymososphaeridium validum Davey, 1982b
Dingodinium? *albertii* Sarjeant, 1966
Discorsia nanna (Davey, 1974) Duxbury, 1977, emend. Khowaja-Ateequzzaman *et al.*, 1985
Gonyaulacysta helicoidea (Eisenack & Cookson, 1960) Sarjeant, 1966
Hystrichodinium pulchrum Deflandre, 1935
Hystrichosphaerina schindewolfii Alberti, 1961
Kiokansium polypes (Cookson and Eisenack, 1962) Below, 1982
Kiokansium unituberculatum (Tasch in Tasch et al., 1964) Stover & Evitt, 1978
Kleithriasphaeridium corrugatum Davey, 1974
Lithodinia pertusa Duxbury, 1977
Lithodinia stoverii (Millioud, 1969) Gocht, 1976
Muderongia staurota Sarjeant, 1966c, emend. Monteil, 1991b
Nelchinopsis kostromiensis (Vozzhennikova, 1967) Wiggins, 1972, emend. Harding, 1996
Oligosphaeridium complex (White, 1842) Davey & Williams, 1969
Phoberocysta neocomica (Gocht, 1957) Millioud, 1969, emend. Helby, 1987
Pseudoceratium cf. *retusum* Brideaux 1977
Pseudoceratium cf. *solocispinum* (Davey 1974) Harding 1990
Pseudoceratium pelliferum Gocht, 1957, emend. Dörhöfer & Davies, 1980
Rhombodella vesca Duxbury, 1980
Spiniferites sp.
Subtilisphaera terrula (Davey, 1974) Lentin & Williams, 1976; emend. Harding, 1986
Systematophora cretacea Davey, 1979
Systematophora syliba Davey, 1979
Tanyosphaeridium magneticum Davies, 1983
Tanyosphaeridium regulare Davey & Williams, 1966
Valensiella magna (Davey, 1974) Courtinat, 1989
Valensiella reticulata (Davey, 1969) Courtinat, 1989
Wallodinium krutzschii (Alberti, 1961) Habib, 1972 emend. Poulsen, 1996

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