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New data on the stratigraphy of the Ordovician at Pobroszyn, Holy Cross Mts., Central Poland

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ABSTRACT:

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New biostratigraphic and lithostratigraphic data are presented for the tectonically reduced Ordovician succession at Pobroszyn in the Łysogóry region of the Holy Cross Mountains, central Poland. Only some of the chronostratigraphic units known from the Łysogóry region can be recognized in this section. However, based on lingulate brachiopods, conodonts, acritarchs and chitinozoa, the units present may be referred to the Late Tremadoc, Late Arenig, Early Lanvirn, Late Lanvirn, Early Caradoc and to the Middle Caradoc and Ashgill. New lithostratigraphic units are established in the lower part of the Ordovician of the Pobroszyn section: the Opatówka Mudstone/Sandstone Formation (?Late Tremadoc) and the Pobroszyn Sandstone Formation (Late Arenig). Three species of lingulate brachiopods are described, of which two are new: *Myotreta anitae* and *Eoconulus lilianae*. The conodonts and acritarchs are illustrated and briefly discussed.

Key words: Ordovician; Brachiopods; Conodonts; Acritarchs; Pobroszyn section; Holy Cross Mountains; Poland.

INTRODUCTION

The Ordovician succession in the Łysogóry Region of the Holy Cross Mountains is known mainly from boreholes and exposures are extremely rare. The pits exposing the complete Ordovician succession of the region, near the village of Pobroszyn (Text-fig. 1), excavated by Trela *et al.* in 1998 (see Trela et al. 2001), are thus of extreme importance. The general geological log, lithostratigraphy and sedimentary environment of the Pobroszyn succession were already presented by Trela *et al.* (1999, 2001) and Trela (2006). This paper presents new data on biostratigraphy, based on conodonts, brachiopods and acritarchs, in addition to comments on the lithostratigraphy and general succession. This study is based on our own field observations in the Pobroszyn section, and on five rock samples (ca 4 kg) provided by W. Trela.

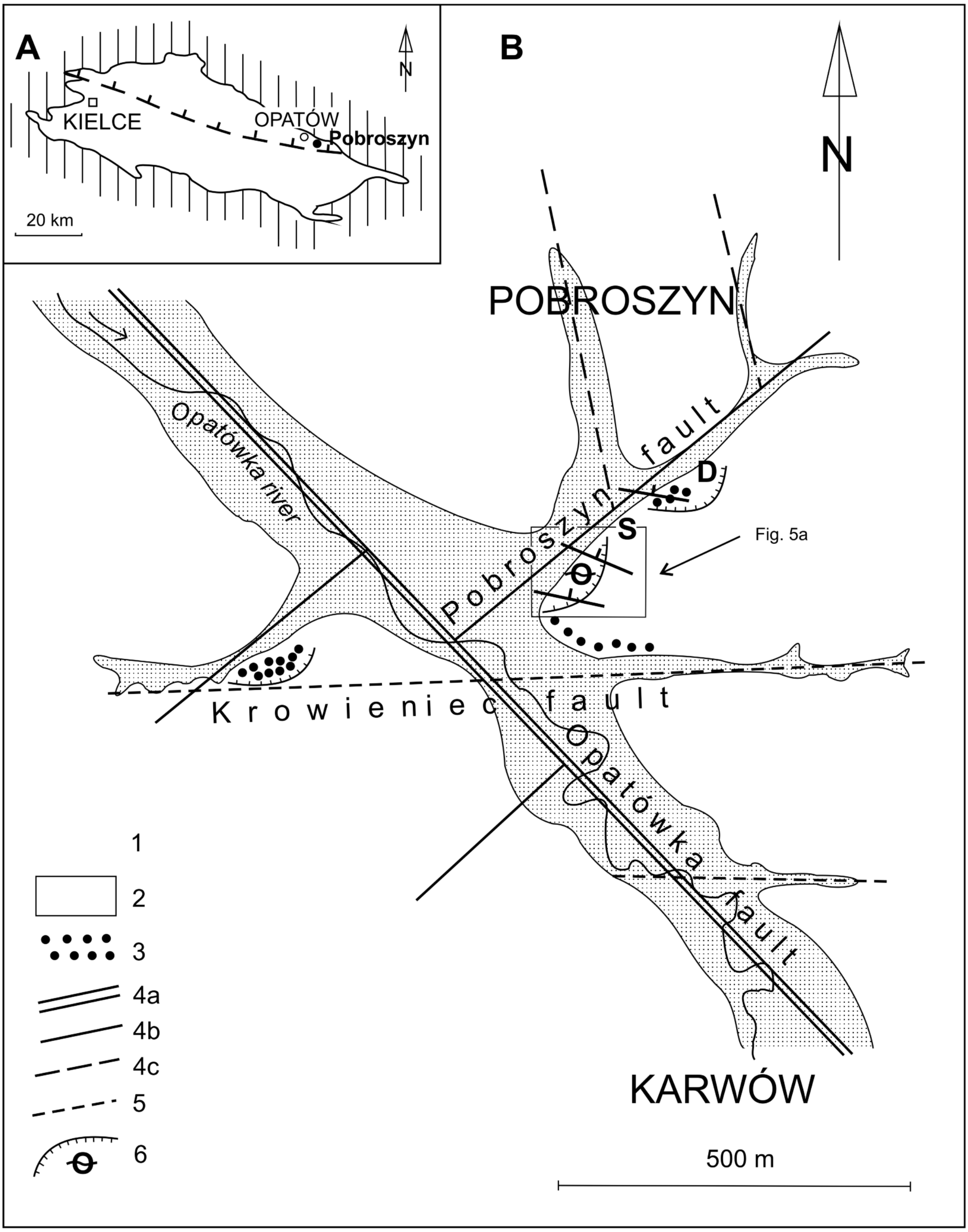
The village of Pobroszyn is located ca. 4 km southeast of the town of Opatów, in the north-eastern part of the Holy Cross Mountains (Text-fig. 1A, B). The Ordovician strata form a fault-bounded tectonic depression and are surrounded by Cambrian, Silurian and Devonian strata (Text-fig. 1C). Geological cross-sections through the Ordovician successions are presented in Text-fig. 3b (compare fig. 2 in Trela *et al*. 2001).

PREVIOUS WORK

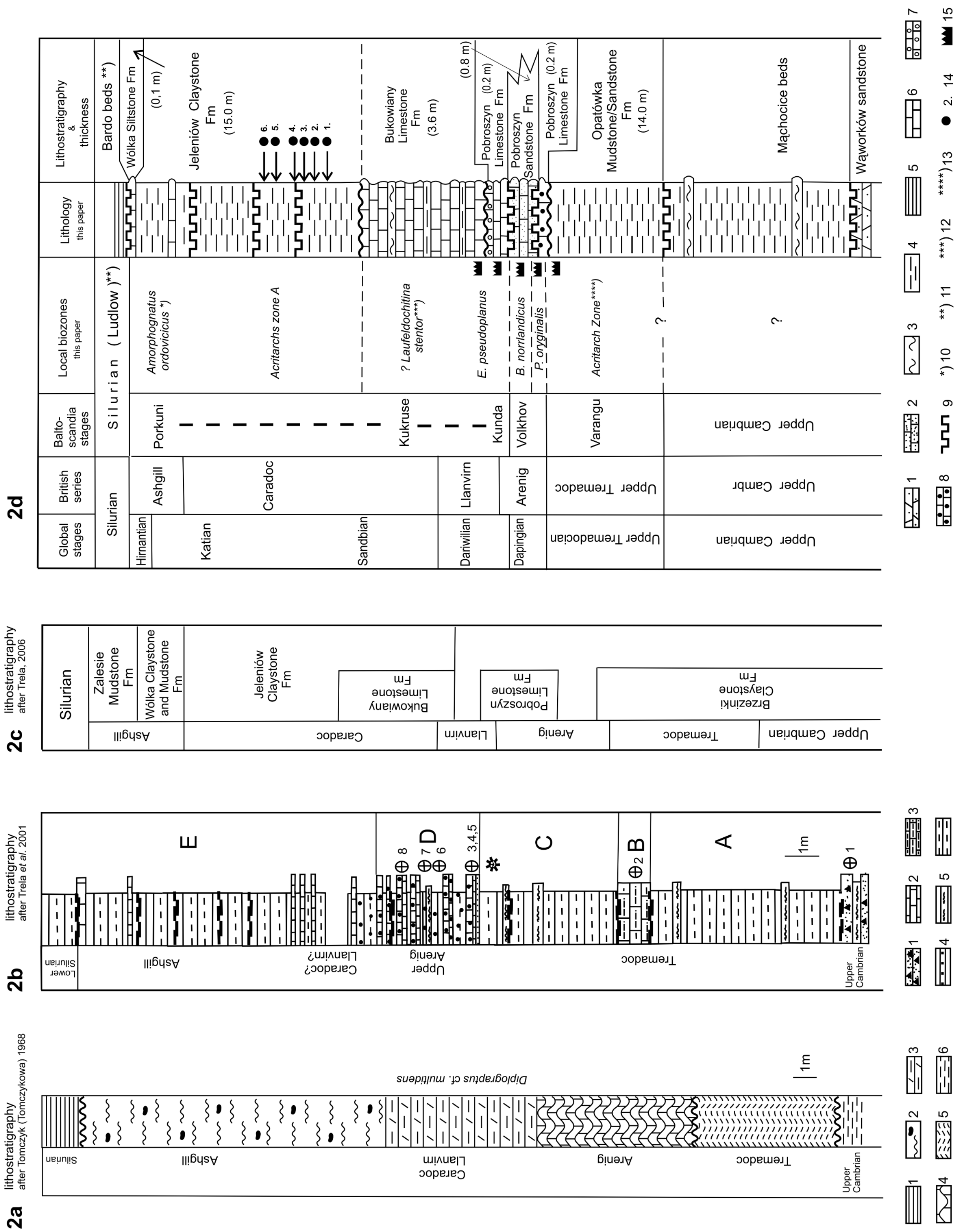
The Ordovician succession near Pobroszyn was first described by Samsonowicz (1934). He reported calcareous sandstone with abundant shells of *Lin-*

gulella at the base, followed by brick-red limestone, overlain by variegated shale with graptolite-, brachiopod- and ostracod-bearing phosphatic concretions. Samsonowicz (1934) correlated the basal sandstone with the *Thysanotos siluricus*-bearing sandstone from Międzygórz near Opatów; the variegated shale and the red limestone he correlated with bed 16 and with the middle part of the Zalesie Nowe section respectively. The total thickness of the Ordovician succession he estimated to be about 20 m.

In 1953, several shallow shafts near Pobroszyn were sunk by H. Tomczyk. According to him, the Ordovician started with limestone with phosphatic concretions, followed by shale and siltstone with graptolites of Llandeilo and Caradoc age (vide Tomczykowa 1968, see Text-fig. 2a in the present paper). He did not



Text-fig. 1. Geological sketch-map of the Pobroszyn area. A - Location of Holy Cross Mountains area in the map of Poland; B – Pobroszyn village in the Holy Cross area and outcrops with sections of the Ordovician succession. C – Pobroszyn area. 1 – alluvial deposits, 2 – Quaternary deposits, 3 – gravels, 4 – faults of various orders: 4a-set I, 4b-set II,4c-set III, 5 – Cenozoic faults, 6 – Ordovician (0), Silurian (S), Devonian (D)



Text-fig. 2. Comparison of the Ordovician section at Pobroszyn. 2a after Tomczykowa 1968: 1 – claystones and graptolitic shales, 2 – mudstones and claystones with calcareous concretions, 3 – weathered claystones, 4 – marly limestones, 5 – compressed slickensided claystones; 2b – after Trela *et al.* 2001: 1 – quartzitic sandstone, 2 – limestone, 3 – calcareous sandstone, 4 – limestone with pebbles, 5 – siltstone, 6 – claystone, 7 – tectonic contacts, 8 – phosphorite concretion, 9 – location of acritarchs 10 – lithological samples; A to E – lithofacies packages; 2c after Trela 2006; 2d after present authors:1 – quartzitic sandstone, 2 – sandstone, 3 – siltstone, 4 – claystone, 5 – shale, 6 – limestone, 7 – limestone with phosphorite concretions, 8 – limestone with pebbles, 9 – tectonic contacts 10 – after Dzik 1999, 11 – after Tomczykowa 1968, 12 – after Wrona 2002, 13 – after Szczepanik 2000, 14 – location of palynological samples; 15 – location of conodont samples find the basal sandstone with *Lingulella*, reported earlier by Samsonowicz (1934). Consequently, he considered that the Lower Ordovician was absent in the Łysogóry area, which he attributed to the activity of the Łysogóry tectonic phase (Tomczyk 1964).

The presence of the Ordovician succession as recognized originally by Samsonowicz (1934) was confirmed later by Bednarczyk (1971). The local lack of Lower Ordovician strata he explained by secondary tectonic processes (Bednarczyk 1971, tab. 3).

In their recent study, Trela *et al.* (1999 and 2001, fig. 3, see also Text-fig. 2b) recognized in the Pobroszyn Ordovician succession five lithological packages, grouped into three successive lithofacies (see Text-fig. 2b): (1) Clayey-silty lithofacies (packages A, B and C); (2) Carbonate-phosphorite lithofacies (package D); and (3) Grey claystone lithofacies (package E). The thickness of the whole succession was estimated as about 30 m and interpreted to span an interval from the Tremadoc to the Ashgill (Trela *et al*. 2001, fig. 3; see also Text-fig. 2b).

MATERIAL AND METHODS

The micro- and macrofaunal samples are from lithological packages A, B, C and D (see Text-fig. 2b). The samples from packages B and D yielded microbrachiopod valves and conodont elements. The richest conodont elements come from the calcareous sandstone. The red laminated limestone yielded numerous brachiopod valves (described herein by Bednarczyk), gastropods and ostracods. Both the brachiopods and conodont elements are poorly preserved.

The palynological samples come from the lower part of package E (Text-figs 2d, 3a; samples P.1–P.6). The samples were disintegrated using the standard method of Wood *et al*. (1996). Cover glasses were glued with a "jelly" prepared from glycerine and gelatine of *Elvacit* glue. The total number of slides, 24 x 24 mm in size, is 18 (three from each sample). Four of the studied samples proved palynologically positive. The palynological material is poorly preserved; the acritarchs are commonly devoid of ornamentation.

REPOSITORIES

The micropaleontological material and palynological samples are stored in the Institute of Geological Sciences, Polish Academy of Sciences (INGPAN) in Warsaw (macrobrachiopod material: Archiv. Inst. Geol. Sci PAN, nos. WB1-03, WB2-03, palynological samples from Pobroszyn: ING PAN nos. P.1–P.6.).

REMARKS ON LITHOSTRATIGRAPHY

The oldest Ordovician unit is composed of grey mudstone with claystone and sandstone interbeds (A, B and C lithofacies; Trela *et al. 2*001, see Text-fig. 2b). This lithofacies was formally referred to as the Brzezinki Claystone Formation by Trela (2006). In the present paper it is proposed to distinguish package A as the Mąchocice beds *sensu* Tomczykowa 1968, on the basis of the regional lithological analogy; package B as the Pobroszyn Sandstone Formation (new unit), which is referred to the Late Arenig on the basis of its conodont and brachiopod fauna. Package B is wedged between packages A (Upper Cambrian Mąchocice beds) and C (Upper Tremadoc Opatówka Mudstone/Sandstone Formation (new unit) (see Appendix).

The occurrence of the Lower Tremadoc Łysogóry beds with *Dictyonema* sp. of Tomczykowa (1968) has not been corroborated in this section.

BIOSTRATIGRAPHY

The palynological material was used to date the Opatówka Mudstone/Sandstone Formation (Szczepanik in Trela *et al.* 2001), the Jeleniów Claystone Formation (Stempień-Sałek, herein) and the Bukowiany Limestone (Wrona 2002). The lingulate microbrachiopods and conodonts were used to date the Pobroszyn Sandstone, Pobroszyn Limestone and Bukowiany Limestone formations (see Text-fig. 2d).

Conodonts and brachiopods

Three successive conodont assemblages indicative of the *Paroistodus originalis*, *Baltoniodus norrlandicus*, and *Eoplacognathus pseudoplanu*s zones are recognised. These document the Arenig and lower Llanvirn age of the Pobroszyn Limestone, Pobroszyn Sandstone and basal Bukowiany Limestone formations (see Text-fig. 2d). The zonal boundaries are tentative.

Paroistodus originalis Zone: The following conodonts were yielded by the sample from the basal part of the Pobroszyn Limestone: *Baltoniodus* cf. *crassulus* (Lindström) (Pl. 6, Fig. 6), *B.* cf. *navis* (Lindström), *Cornuodus longibasis* (Lindström), *Drepanodus arcuatus* Pander, *Drepanoistodus basiovalis* (Sergeeva) (Pl. 5, Figs 1–3), *Oistodus lanceolatus* Pander (Pl. 5, Fig. 7), *Drepanoistodus forceps*

(Lindström), *Gothodus* sp., ?*Oepikodus evae* (Lindström) (Pl. 5, Fig. 6), and *Protopanderodus rectus* (Lindström).

The zone is defined by ?*Oepikodus evae* and *Oistodus lanceolatus,* which are known from the *Oepikodus evae* and *Paroistodus originalis* zones (Latorpian–Volkhovian) of Sweden (Lindström 1971; Löfgren 1978). *Drepanoistodus basiovalis* is first recorded from the *Baltoniodus navis* and *Paroistodus originalis* zones (Volkhovian) while *D. forceps, Protopanderodus rectus* and *Gothodus* are known from the *O. evae* Zone (Latorpian) (Lindström 1971; Löfgren 1978).

The microbrachiopods recognized in this sample, *Acrotreta* sp., *Myotreta* cf. *crassa*, and *Eoconulus* sp., are characteristic of the Volkhovian and Kundan stages (Gorjansky 1969; Biernat 1973).

Baltoniodus norrlandicus Zone: The sample from the Pobroszyn Sandstone Formation yielded *Baltoniodus* cf. *norrlandicus* Löfgren and *Protopanderodus rectus*, which indicate the eponymous zone for this level. The former suggests correlation with the late Arenig (Volkhovian, Löfgren 1978), which is additionally supported by the occurrence of numerous *Palaeoglossa* ? *attenuata* (Sowerby) (Pl. 2, Figs 1-4), known from the Llanvirn of central and southern Wales (Lockley and Williams 1981).

Microbrachiopods are represented by poorly preserved ventral valves of *Myotreta*, *Acrotreta* and *Eoconulus*, species of which are known from the Arenig of the Kielce region (Bednarczyk and Biernat 1978) and from the Kundan to Aserian, in the Balto-Scandian zonation (Biernat 1973; Gorjansky 1969).

Eoplacognathus pseudoplanus Zone: The sample from the topmost part of the Pobroszyn Limestone Formation yielded: *Baltoniodus* sp., ?*Decoriconus peselephantis* (Lindström), *Drepanodus arcuatus, Drepanoistodus basiovalis, Drepanoistodus* cf. *forceps, Lenodus* sp. (cf . *Lenodus* n.sp. A Stoug and Bagnoli 1990) (Pl. 6, Fig. 4), *Microzarkodina ozarkodella* (Pl. 5, Figs 4, 5), *M. parva, Oistodus lanceolatus, Oslodus* cf. *semisymmetricus* (Hamar), *Protopanderodus rectus* and *Scalpellodus gracilis* (Sergeeva) (Pl. 6, Fig. 5). The species *M. ozarkodella* and *S. gracilis* are zonally indicative. Both were found in the Kundan to Aserian *E. pseudoplanus* Zone of Sweden (Lofgren 1978, 2000; Viira *et al.* 2001).

The top of the zone is poorly constrained; the sample from the basal part of the overlying Bukowiany Limestone Formation yielded poorly preserved *Baltoniodus* sp. and *Sagittodontina* sp. (Pl. 6, Figs 1–3).

Microbrachiopods are represented by *Acrotreta* cf. *korynievskii* Holmer and Popov (Pl. 4, Fig. 5)*, Myotreta anitae* sp. nov. (Pl. 3, Figs 1, 2; Text-fig. 3), *Biernatia rossica* (Goryansky) (Pl. 3, Figs 3, 5), *Scaphelasma bukovkense* (Bednarczyk and Biernat) (Pl. 4, Figs 2, 4), *Sc.* cf. *subquadratum* Biernat (Pl. 4, 3)*, Eoconulus* cf. *semicircularis* Biernat (Pl. 3, Fig. 6) and *E. lilianae* sp. nov. (Pl. 3, Figs 4, 7).

Numerous chitinozoa: *Cyathochitina sebyensis* Grahn, *C. clavaherculi* Eisenack and *Laufeldochitina stentor* (Eisenack) (see Wrona 2002) indicate the lowermost Caradoc (*L. stentor* Zone; Wrona 2002; Nölvak and Grahn 1993).

Acritarchs

Acritarchs were found in the topmost part of the Opatówka Mudstone/Sandstone Formation and in the lower part of the Jeleniów Claystone Formation (see Text-fig. 2d). However, the poor preservation and/or lack of stratigraphically important taxa in the material precludes recognition of the standard zones. The two intervals with acritarchs are local assemblage zones, with poorly constrained boundaries.

'Acritarch' Zone: This zone is distinguished based on the assemblage reported by Szczepanik (in Trela *et al*. 2001, p. 146) from the upper part of the Opatówka Mudstone/Sandstone Formation. The assemblage resembles that known from the Cambrian and Tremadoc of the Holy Cross Mountains (Górka 1969; Moczydłowska in Kowalczewski *et al*. 1986; Bednarczyk 1998), from the Tremadoc–early Arenig of Ireland (Connery and Higgs 1990), Rügen, Germany (Servais 1994), northwestern Russia (Raevskaya *et al.* 2004; Tolmaczeva *et al.* 2001), Scandinavia (Bagnoli *et al*. 1988, Ribecai *et al*. 1991; Tongiorgi and Di Milia 1999), Saharan Algeria and southern Tunisia (Vecoli *et al.* 1999).

Acritarch Assemblage A: The assemblage is documented in six samples from the lower part of the Jeleniów Claystone Formation (samples P.1–P. 6). The palynological matter found in these samples is mostly amorphous. Taxonomically determinable forms are poorly preserved and are a minor admixture. Species-level identifiable taxa were found in samples P. 1, P. 2 and P. 5. These are: *Actinotodiscus* cf. *crassus* Loeblich and Tappan (Pl. 1, Fig. 2), single *Baltisphaeridium* cf. *calcispinae* Górka, 1969, *B.* cf. *microspinosum* (Eisenack), *Multisphaeridium* cf. *raspa* (Cramer) Eisenack *et al.* (Pl. 1, Fig. 1), *Polonosphaeridium* cf. *francinae*

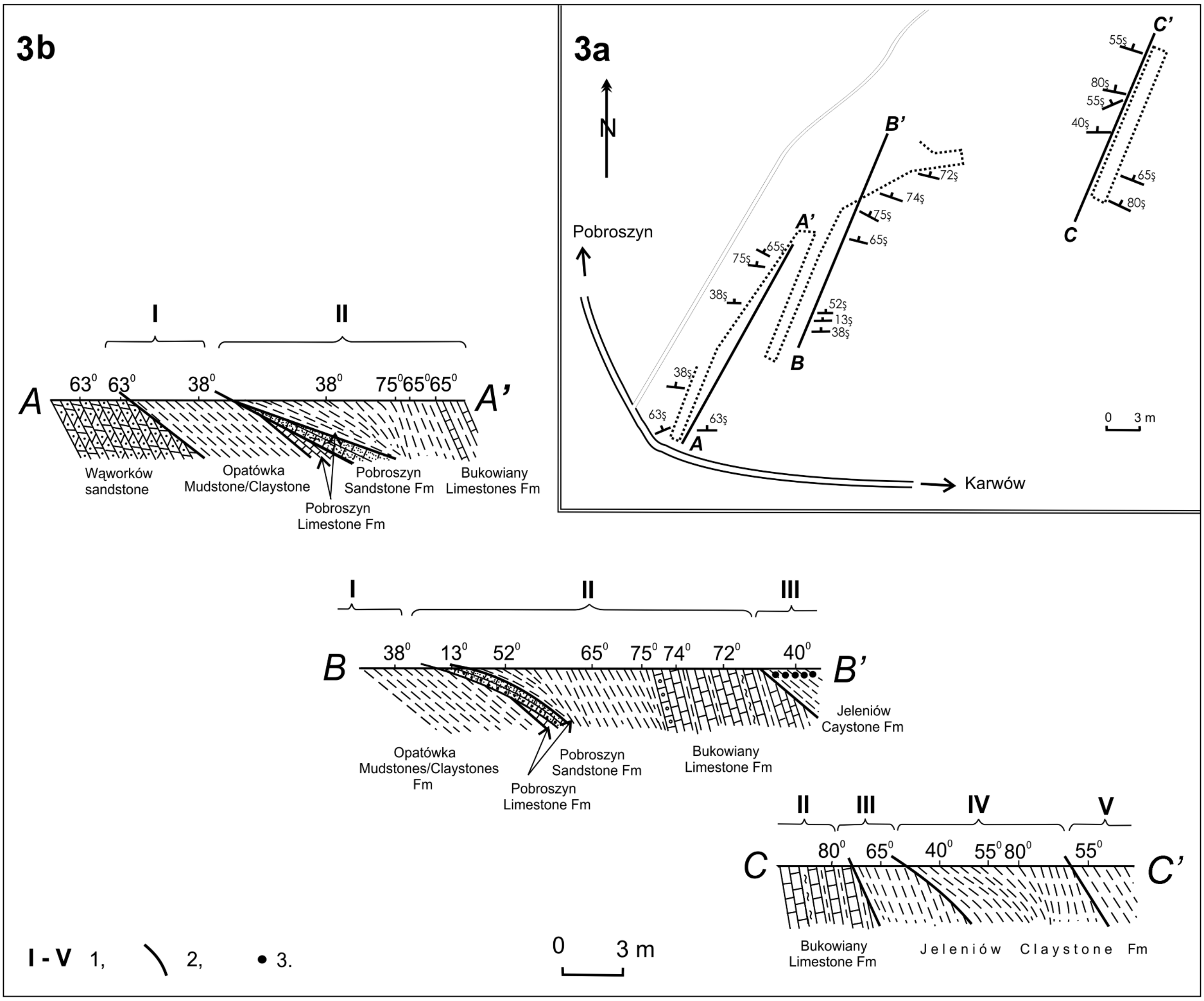
(Górka) Górka (Pl. 1, Fig. 8), *Polygonium* cf. *gracile* Vavrdova (Pl. 1, Fig. 13), *Vulcanisphaera* cf. *imparilis* Rasul (Pl. 1, Fig. 3), and some others, referred only to the genus level: *Acanthodiacrodium* sp. (Pl. 1, Figs 7, 9), *Baltisphaeridium* sp., *Cymatiogalea* sp. (Pl. 1, Figs 5, 6) *Goniosphaeridium* sp. (Pl. 1, Figs 11, 12), *Gorgoniosphaeridium* sp. (Pl. 1, Figs 4, 10), *Micrhystridium* sp. *Multisphaeridium* sp., *Veryhachium* sp., and ?*Ordovicidium* sp.

Sample 6 include badly preserved small, long-ranging taxa of simple morphology, such as *Goniosphaeridium* sp., *Gorgonisphaeridium* sp., *Micrhystridium* sp. *Veryhachium* sp. and some other unidentifiable acritarchs. Samples 3 and 4 were negative.

The palynomorphs are brown and dark brown; the thermal maturity of organic matter is high. The acritarch frequency is generally rather low, ranging from 10 (samples P.1 and P.6) to 40 (in samples P.2 and P.5) acritarchs per slide.

The acritarchs range in size between 25 and 35 µm, occasionally reaching 60 µm ("large" *Baltisphaeridium* with large appendages, broad at base).

The taxonomic composition of this assemblage shows some similarities to assemblages known from the Upper Ordovician (Caradoc) of Western Pomerania, Poland (Szczepanik 2000; Wrona *et al*. 2001; Stempień-Sałek 2007), Estonia (Uutela and Tyni 1999), Sweden (Kjellstroem 1971) and England (Turner 1984). It differs, however, in the lack of such forms as *Orthosphaeridium* and *Peteinosphaeridium* and in the presence of diacromorph acritarchs. From among the latter forms, *Actinotodiscus* cf. *crassus* is known from the late Caradoc of Indiana, USA (Loeblich and Tappan 1978), Upper Ordovician of Saudi Arabia (Miller and Al-Ruwaili 2007) and from the



Text-fig. 3. Geological cross-sections of the Ordovician strata and their location at Pobroszyn based on the authors' and Stupnicka (2004) observations; and on data from Trela *et al* (2001) and Salwa (2002). 3a – scheme of geological fieldwork done by Trela *et al.* (2001); 3b – cross-section 1: I to V units; 2 – faults and erosional surfaces; 3 – palynological samples (for explanations see Text-fig. 2)

Upper Ordovician of Algeria and Libya (Vecoli 2008).

The lack of evolutionary precursors of the Silurian forms, such as *Diexallophasis, Tylotopalla* or *Domasia*, typical of the uppermost Ashgill, suggest at the latest an early Ashgill age of assemblage A.

SYSTEMATIC PALAEONTOLOGY OF THE BRACHIOPODS [W.S.Bednarczyk]

The material is composed of calcareous-phosphatic valves of microscopic dimensions, and comes from the Pobroszyn Limestone and Pobroszyn Sandstone formations (late Arenig, Volkhovian–early Kundan) and the Bukowiany Limestone Formation (Late Llanvirn–earliest Caradoc).

Class Lingulata Goryansky and Popov, 1985
Family Obolidae King, 1846
Subfamily *Obolinae* King, 1846

Genus *Palaeoglossa* Cockerell, 1911 *emended* Williams, (1974)

TYPE SPECIES: *Lingula attenuata* Sowerby, 1839, designated by Cockerell, 1911, p. 96, Shropshire.

Palaeoglossa ?attenuata (Sowerby, 1839)
(Pl. 2, Figs 1–4)

MATERIAL: Single specimen.

DESCRIPTION: The shell is biconvex, ovally elongated. The ventral valve is convex, ovally elongated, with a sharp umbo forming an angle between 58° and 62° (Pl. 2, Fig. 1). The ornamentation consists of concentric growth lines and concentric ridges (filla) up to 12 lines per 1 mm and radially arranged costellae (Pl. 2, Figs 3, 4). The pseudointerarea of the ventral valve occupies about 70% of the total valve width and about 8–10% of the length. The proparea is cut by a narrow, rather shallow pedical furrow with almost parallel margins, ornamented with distinct flexure-like lines (Pl. 2, Fig. 2). The dorsal valve is ovally elongated, with a gently rounded umbo (Pl. 2, Fig. 1). The sculpture is similar to that of the ventral valve. The internal structure of the valves is difficult to identify.

DISCUSSION: The specimen is most similar to *Palaeoglossa attenuata* from southern Wales (Lockley and Williams 1981, pp. 12–13, figs 15–21) in size, shell outline, sculpture and shape of pseudointerarea, sculpture of proparea and shape of the pedical furrow.

The genus *Palaeoglossa* is represented so far by only one species described by Williams (1974, see Lockley and Williams 1981) from the Llanvirn of Wales, three species from the Lower Ordovician of Bohemia, Czech Republic (Havliček 1982) and one species from the southern Ural Mountains, Russia (Lower Ordovician) (Popov and Holmer 1994).

P. debilis, described from the Sarka Formation (uppermost Arenig–Llanvirn of the Prague Basin) by Havlicek, differs from our specimen in dimensions that are half the size, and in possessing a sharper umbo in the ventral valve. *P. ?razumovskii* (Lermontova 1933) is similar in shape and in the dimensions of shell and pseudointerarea of the ventral valve. It differs in details of ornamentation (broader radial striae) (vide Popov and Holmer 1994, fig. 51F).

OCCURRENCE: *Baltoniodus norrlandicus* conodont Zone, Pobroszyn Sandstone Formation, Pobroszyn, Poland.

Family Acrotretidae Schuchert, 1893
Subfamily Ephippelasmatinae Rowell, 1965

Genus *Myotreta* Goryansky, 1969

TYPE SPECIES: *Myotreta crassa* Goryansky (1969, pp. 67–68, pl. 11, fig. 20); Kunda; the borehole near Panikovichi, Pechora, north-west Russia.

Myotreta anitae sp. nov.
(Pl. 3, Figs 1, 2)

HOLOTYPE: WB1-03 (Pl. 3, Figs 1, 2).

TYPE HORIZON AND LOCALITY: *Eoplacognathus pseudoplanus* conodont Zone, Pobroszyn Limestone Formation, Pobroszyn, Poland.

DERIVATION OF NAME: From Anita, daughter of the first author.

MATERIAL: Numerous ventral and dorsal valves.

DIAGNOSIS: *Myotreta* with umbo strongly inclined posteriorly and with numerous sharp-pointed concentric growth lines.

DESCRIPTION: The ventral valve is low conical with an oval outline. The umbo is strongly inclined posteriorly. The pedicular foramen is oval on the top of a short pedicular tube. The pseudointerarea is gently concave in its central part and weakly delimited from the lateral surfaces of the valve (Pl. 3, Fig. 1). The anterior surface of the valve is weakly convex. The protegulum has a distinct vesicular structure (Pl. 3, Fig. 1). The outer shell surface is ornamented with numerous sharp-pointed concentric growth lines. The interior of the valve is unknown.

The dorsal valve is oval in outline. The pseudointerarea is in the shape of a low triangle with a broad, gently concave triangular furrow that occupies 1/19 of the length of the valve. The base of the pseudointerarea is curved at its top (Pl. 3, Fig. 2). The growth lines are distinct. The central part of the interior of the valve has a shallow oval depression. The remaining part of the valve interior is slightly elevated. The median septum is relatively high, triangular and occupies the central part of the valve. The cardinal muscle scars are oval-elongated and indistinct (Pl. 3, Fig. 2).

DISCUSSION: Some species of *Myotreta* have been described from the Early Ordovician of northeast Russia and Estonia (Goryansky 1969), the northern part of Poland (Bednarczyk 1985; Biernat 1973) the southern part of the Holy Cross Mountains (Bednarczyk and Biernat 1978) and from the Middle Ordovician of Sweden (Holmer 1989). The valve described here resembles in shape, and in the posteriorly strongly curved ventral valve umbo, *Myotreta crassa* Goryansky (Biernat 1973, fig. 29) but it differs in having fine internal furrow of the pseudointerarea and in sharp-pointed growth lines. From *Myotreta goryansky* Bednarczyk 1985 it differs in the posteriorly strongly inclined umbo and simple sharp-pointed growth lines.

From *Myotreta estoniana* Biernat 1973 it differs in smaller size, oval-shaped shell, and umbonally strongly arched ventral valve. Significantly younger species of *Myotreta* which have been described by Holmer (1989) from the Middle Ordovician of Sweden differ from our species in lacking an intertrough of the pseudointerarea of the ventral valve (*Myotreta dalecarlica*), or in lacking a well defined ventral pseudointerarea and intertrough (*Myotreta orensis*).

Family Eoconulidae Cooper, 1956
Genus *Eoconulus* Cooper, 1956

TYPE SPECIES: *Eoconulus rectangulatus* Cooper, 1956; Ordovician Pratt Ferry beds (Llandeilo); Alabama, USA.

Eoconulus lilianae sp. nov.
(Pl. 3, Figs 4, 7)

HOLOTYPE: WB2-03 (Pl. 3, fig. 7).

TYPE HORIZON AND LOCALITY: *Eoplacognathus pseudoplanus* Zone, red laminated limestone of the Pobroszyn Limestone Formation, Pobroszyn.

DERVATION OF NAME: From Liliana, the name of the first author's wife.

MATERIAL: Two dorsal valves.

DIAGNOSIS: Microscopic in size, transversally oval in outline, with concave pseudointerarea and eccentrically placed umbo.

DESCRIPTION: The dorsal valve is minute, low conical and almost square in outline. Width 0.8 mm and length 0.7 mm. The posterior margin is almost straight, the anterior and lateral margins are gently arched; the corners are rounded. The umbonal part is slightly flat on top, eccentric and placed near the posterior margin. The distinct vesicular structure of this part occupies 1/5 of the length of the valve. Pseudointerarea slightly concave toward lateral and anterior surfaces of the valve which are weakly convex (Pl. 3, Fig. 7). The surface ornamentation of the valve consists of concentric growth lines continuing on the pseudointerarea (Pl. 3, Fig. 4). The valve interior shows no traces of the cardinal muscle scars.

DISCUSSION: The valve described resembles in shape the dorsal valve of *Eoconulus transversus* Wright (1963, pp. 248–249, pl. 3, figs 4, 8, 12, 13) from the Portrane Limestone (Upper Ordovician) in the southeastern part of Ireland, but differs in being almost half the size, in lacking the depression (*sulcus*) on the anterior surface of the valve, and in possessing a more distinct pseudointerarea. From *E. rectangularis* Cooper (1956, p. 283, pl. 10B, figs 11–13) from the Pratt Ferry Formation (Chazyan in Alabama, USA) our specimen differs in smaller dimensions of the valve and in a distinct concave pseudointerarea. However it resembles this species in the almost straight posterior margin of the valve and eccentrically placed apex. From *E. dyminensis* Bednarczyk and Biernat (1978, pp. 309–310, pl. 20, figs 10–12; pl. 22, figs 3–5) from the Bukówka Limestone, vicinity of Kielce (Holy Cross Mountains, Poland) it differs in lacking the irregular radial folds which are a diagnostic feature of this species. From *E. cryptomyus* Goryansky (1969, pp. 108–109, pl. 20, figs 5–8) from the Lower and Middle Ordovician of Estonia and Russia it differs in smaller dimensions of the valve, and in having anterior and posterior margins that are almost the same length and an eccentrically placed apex. From *E. robustus* Holmer (1989, pp. 155–157, figs 108B–F 109B–E 111) from the Lower and Middle Ordovician of Sweden, it differs in having thicker valve walls.

OCCURRENCE: *Eoplacognathus pseudoplanus* conodont Zone, red laminated limestone of the Pobroszyn Limestone Formation, Pobroszyn, Poland

CONCLUSIONS

The new palaeontological and stratigraphical studies on the Ordovician succession in the Pobroszyn section allow the following inferences to be made:

1. The Ordovician at Pobroszyn starts with the Opatówka Mudstone/Sandstone Formation (new unit). Based on acritarchs, this unit is assigned to the Upper Tremadoc.
2. Based on conodonts, the Pobroszyn Limestone Formation and Pobroszyn Sandstone Formation (new unit) are assigned to the Upper Arenig. The presence of *Microozarkodina ozarkodella* and *Scalpelodus gracilis* in the upper part of the Pobroszyn Limestone Formation indicates the Lower Llanvirn. The Pobroszyn Sandstone Formation is wedged between the upper Cambrian Mąchocice beds and Upper Tremadoc Opatówka Formation.
3. The Bukowiany Limestone Formation is assigned, based on conodonts and chitinozoans, to the Llanvirn and lowermost Caradoc.
4. The Jeleniów Claystone Formation is assigned, based on conodonts, brachiopods and acritarchs, to the Middle Caradoc and Lower Ashgill.
5. The Ordovician starts at the base of the Opatówka Formation, which is in tectonic contact with the underlying Upper Cambrian Mąchocice beds. The occurrence of the uppermost Cambrian Łysogóry beds cannot be confirmed in the Pobroszyn section, suggesting a stratigraphic gap. The Ordovician/Silurian boundary lies at the base of the Bardo beds.

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APPENDIX

Lithostratigraphic units of the topmost Cambrian and Ordovician of the region

Opatówka Mudstone/Sandstone Formation (New name)

NAME: After Opatówka River ravine joining the Pobroszyn ravine (= Package C of Trela *et al*. 2001; see Text-fig. 1C in the present paper).

DEFINITION: Dark grey claystone with thin quartz mudstone intercalations and fine-grained sandstone of the same colour; rusty-yellowish at the contact with the calcareous phosphatic lithofacies.

THICKNESS: 7 metres (after Trela *et al.* 2001).

LOWER BOUNDARY: Tectonic contact with the Mąchocice beds *sensu* Tomczykowa 1968 (package A of Trela *et al.* 2001) referred to the Upper Cambrian.

UPPER BOUNDARY: Erosional with the sideritic limestone with pebbles of the Pobroszyn Limestone Formation.

STRATOTYPE: The Pobroszyn section, Poland (Text-figs 1 and 2b).

DISTRIBUTION: The ravine near Pobroszyn.

AGE AND CORRELATION: Late Cambrian–Tremadoc according to Szczepanik (Trela *et al.* 1999) on the basis of acritarchs occurring in the upper part of this formation.

REMARKS: Recently Szczepanik (Trela *et al. 2*001), on re-analysing the enriched acritarch assemblage from the upper part of this formation, has compared it with that described by Górka (1969) from the Upper Tremadoc Zbilutka Siltstone and Chalcedonite Member (Bednarczyk 1981, 1998). The latter member occurs commonly in the Bardo Syncline (middle part of the Kielce Region). However, it is not unlikely that the lower part of the Mąchocice beds (packet A, 7 m thick, Trela 2001) belongs to the upper Cambrian (Kowalczewski *et al*. 2006). The rocks of the Opatówka Mudstones/Sandstones Formation differ in lithology considerably from the dark grey, almost black claystone "with lenses or concretions of grey limestone" of the Łysogóry beds, which occur in borehole cores (Brzezinki 1, depth 73.0–91.7 m, and Jeleniów 2, 183.2–190.0 m) on the northern slope of the Łysogóry range (Tomczykowa,1968).

REFERENCES: Tomczykowa 1968; Orłowski 1975 ; Trela 2006; Trela *et al*. 1999, 2001; Kowalczewski, Żylińska and Szczepanik 2006. Buła *et al* 2008.

Pobroszyn Sandstone Formation (New name)

NAME. After the village of Pobroszyn (= package B of Trela *et.al*. 2001).

DEFINITION: Yellowish-grey, partly calcareous, fine-grained sandstone with crushed calcareous-phosphatic lingulate brachiopod valves preserved on the top surface and with Upper Arenig conodonts and microbrachiopods in the more calcareous part of the sandstone.

STRATOTYPE: The Pobroszyn section, Poland (Text-figs 1B, 2b, 4).

THICKNESS: 0.8 m (*fide* Trela *et al.* 2001).

BOUNDARIES: Tectonic in the study region (see Text-figs 2d, 5); it is wedged between packages A and C.

AGE. Late Arenig (Volkhovian, Jaanusson 1982) on the basis of brachiopods and conodonts taken from the calcareous part of the formation (see biostratigraphic part).

REMARKS: Dzik (1999) included the sandstone in the Klonówka Shale Formation. In his opinion, the brachiopods occurring on the top surface may represent species of the genus *Lingulella* described by Biernat (Biernat and Tomczykowa 1968). Closer analysis shows that these brachiopods belong to *Palaeoglossa*. This genus is known from the Arenig to Llanvirn strata of the Czech Republic and Ural Mountains, Russia. See also the palaeontological systematic section in this paper). The dating is additionally supported by the occurrence of conodonts that suggest the correlation of this unit with the Volkhovian Baltoscandian stage (Jaanusson 1982).

PLATES 1–6

PLATE 1

Acritarchs from the Jeleniów Claystone Formation.

1 – *Multiplicisphaeridium* cf. *raspa* (Cramer) Eisenack *et al.*, 1973, sample P.1;
2 – *Actinodissus* cf. *crassus* Loeblich and Tappan, 1978, sample P.2;
3 – *Vulcanisphaer*a cf. *imparilis* Rasu, 1976, sample P. 2;
4, 10 – *Gorgonisphaeridium* sp., sample P. 2;
5, 6 – *Cymatiogalea* sp., sample p. 2;
7, 9 – *Acanthodiacrodium* sp., sample P. 5, P. 2;
8 – *Polonosphaeridium* cf. *francinae* (Górka) Górka, 1987, sample. P. 2;
11, 12 – *Goniosphaeridium* sp., sample P. 2;
13 – *Polygonium* cf. *gracilis* Vavrdova, 1966, sample P. 5a;

All specimens ×750

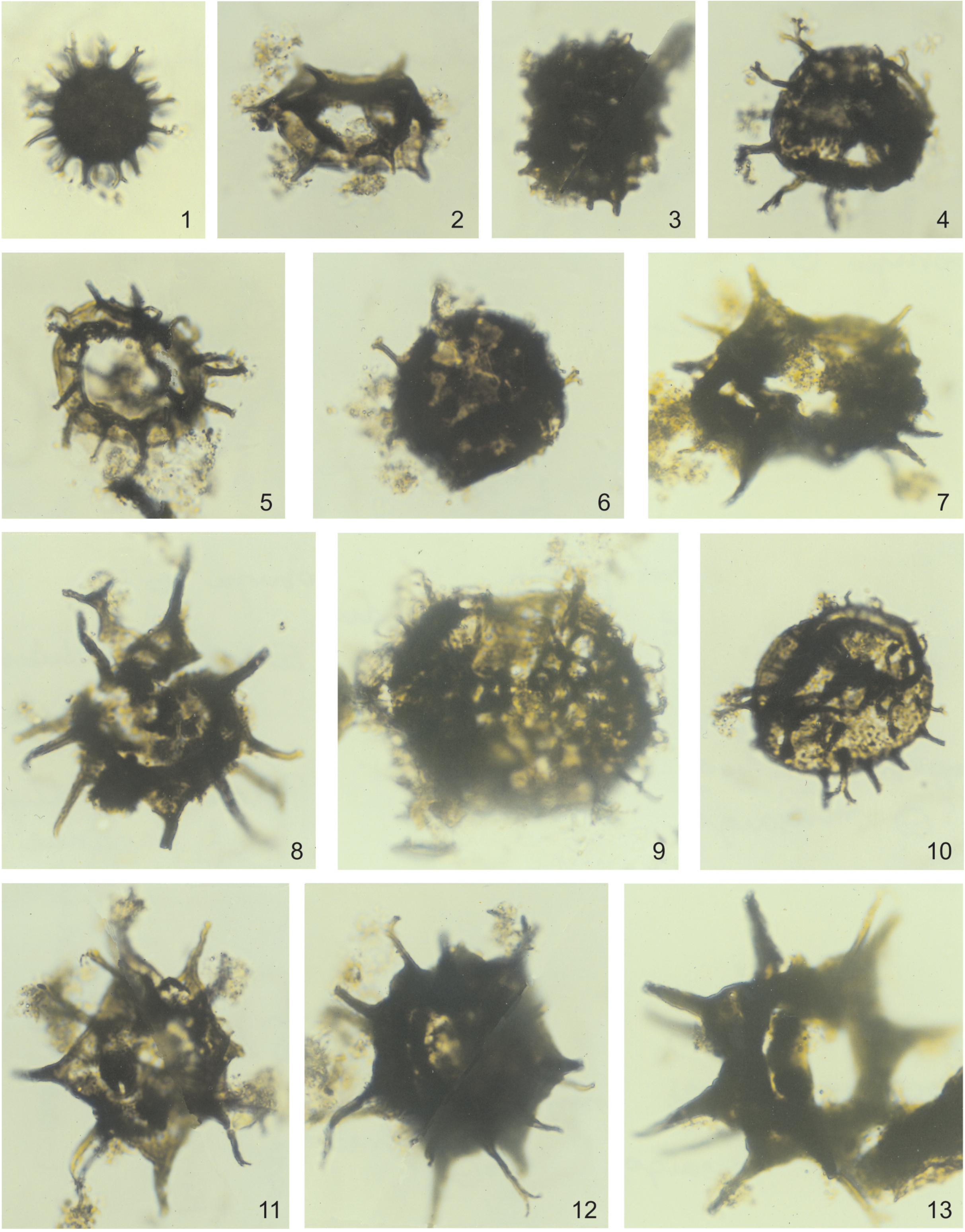
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PLATE 2

Brachiopods from the Pobroszyn Sandstone Formation *Palaeoglossa* ?*attenuata* (Sowerby, 1839).

1 – mould of shell, seen from dorsal valve with fragments of shell;
2 – mould of ventral valve, seen from ventral valve, pseudointerarea with pedicle furrow is visible;
3 – mould of ventral valve with fragments of shell and ornamentation preserved;
4 – fragment of ventral valve with outer ornamentation.

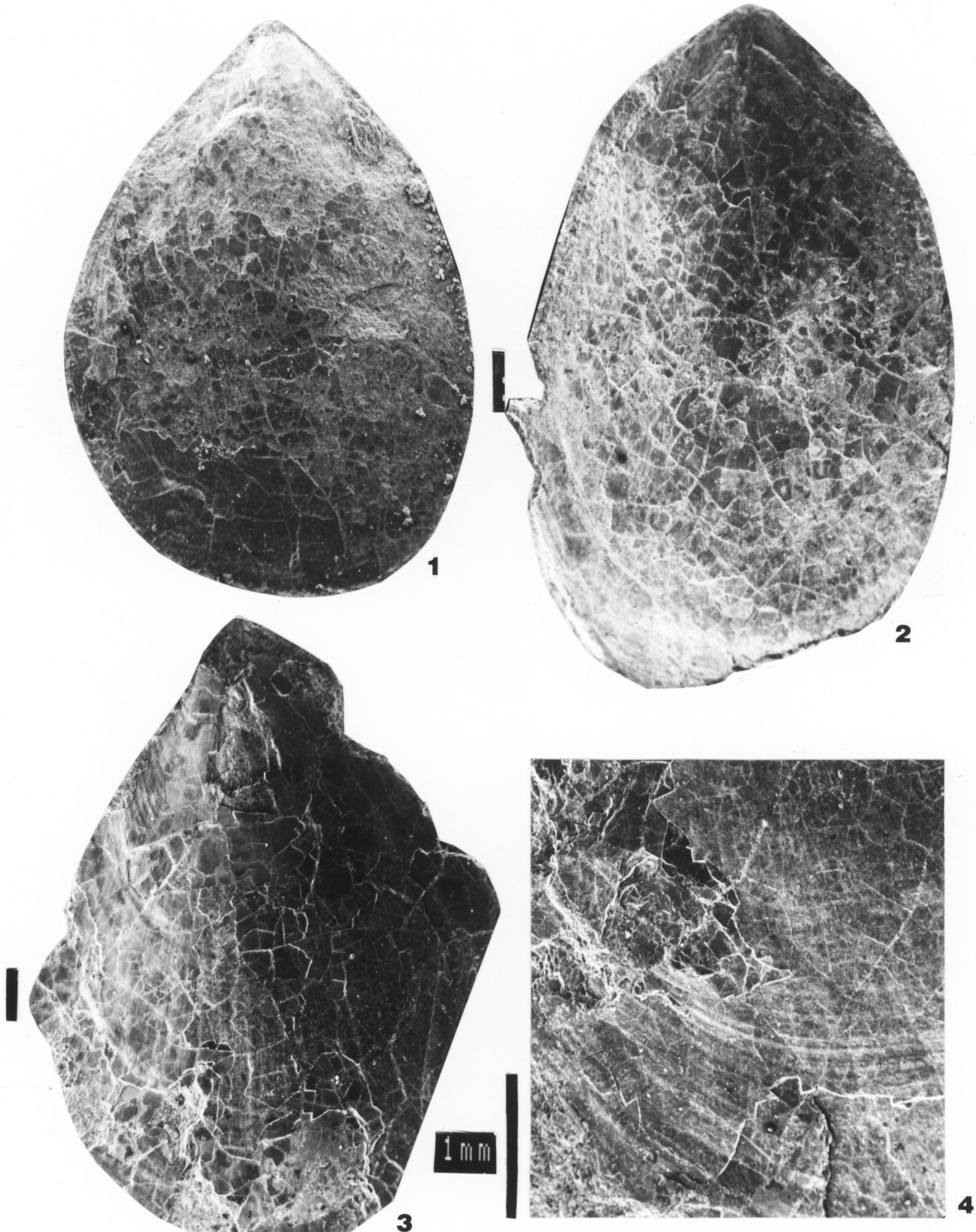
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PLATE 3

Brachiopods from the Pobroszyn Limestone Formation.

1-2 – *Myotreta anitae* sp. nov., holotype; 1 – ventral valve, posterior view, × 100; 2 – interior view of dorsal valve ×150;
3, 5 – *Biernatia rossica* (Goryansky, 1969); 3 – ventral valve, lateral view, × 220; 5 – ventral posterior view, × 150;
4, 7 – *Eoconulus lilianae* sp. nov., 4 – fragment of ventral valve, with ornamentation, × 100; 7 – *Eoconulus lilianae* sp. nov., holotype, dorsal valve, umbonal part with vesicular structure and concave area, × 100
6 – *Eoconulus* cf. *semiregularis* Biernat, valve with fragment of outer ornamentation preserved, × 100;

All specimens from the red laminated limestone

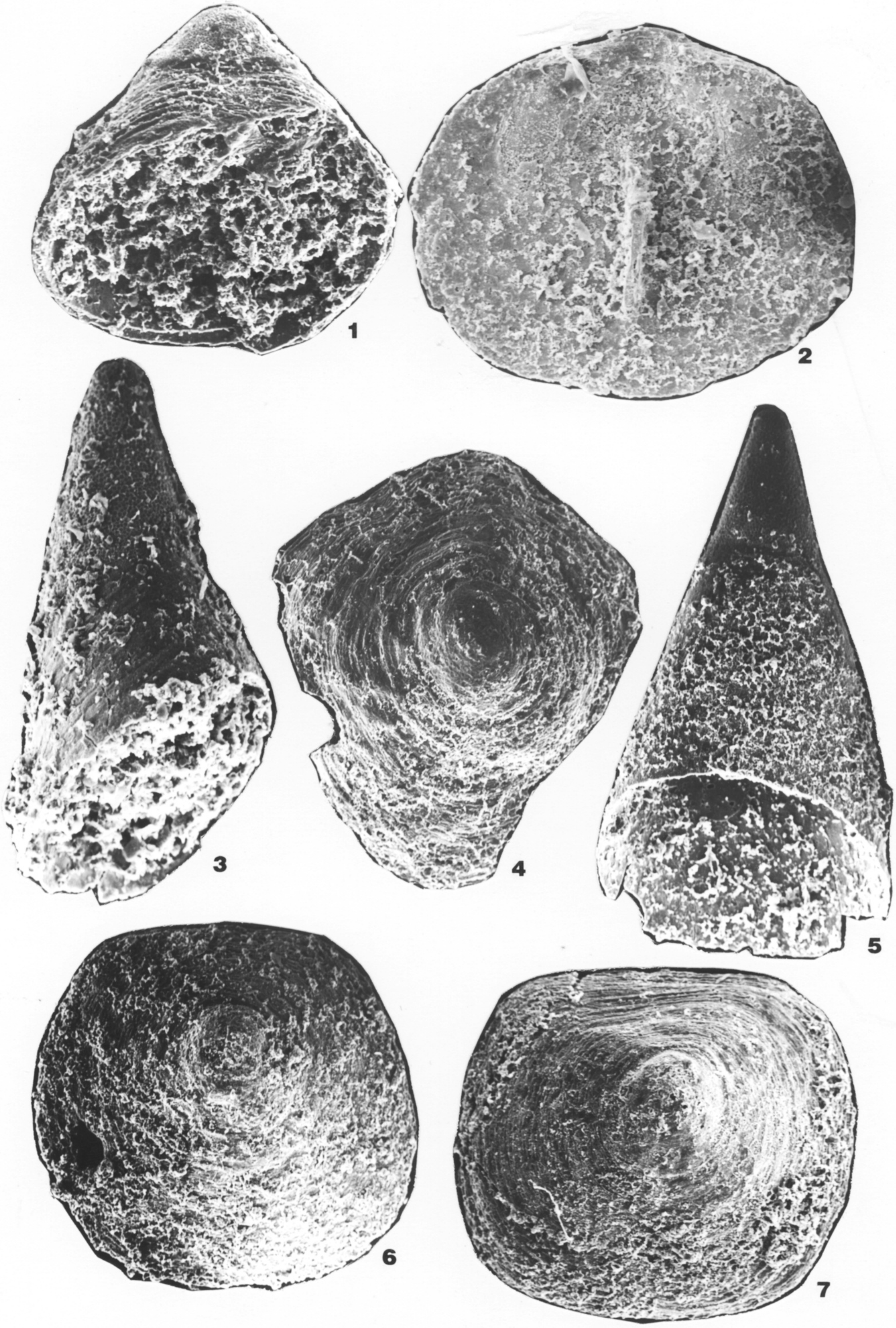
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PLATE 4

Brachiopods from the Pobroszyn Limestone Formation

1 – *Biernatia rossica* (Gorjansky), dorsal view of valve, × 100;
2, 4 – *Scaphelasma bukovkense* Bednarczyk and Biernat, 1978; 2 – fragment of dorsal valve, × 100; 4 – ventral valve, × 100;
3 – *Scaphelasma subquadratum* Biernat, 1973, ventral valve, ×180;
5 – *Acrotreta* cf. *koryniewskii* Holmer and Popov, 1994 - interior view of dorsal valve × 50;
6 – *Acrotreta* sp., interior view of dorsal valve × 45.

All specimens but one (Fig. 6,) are from the red laminated limestone

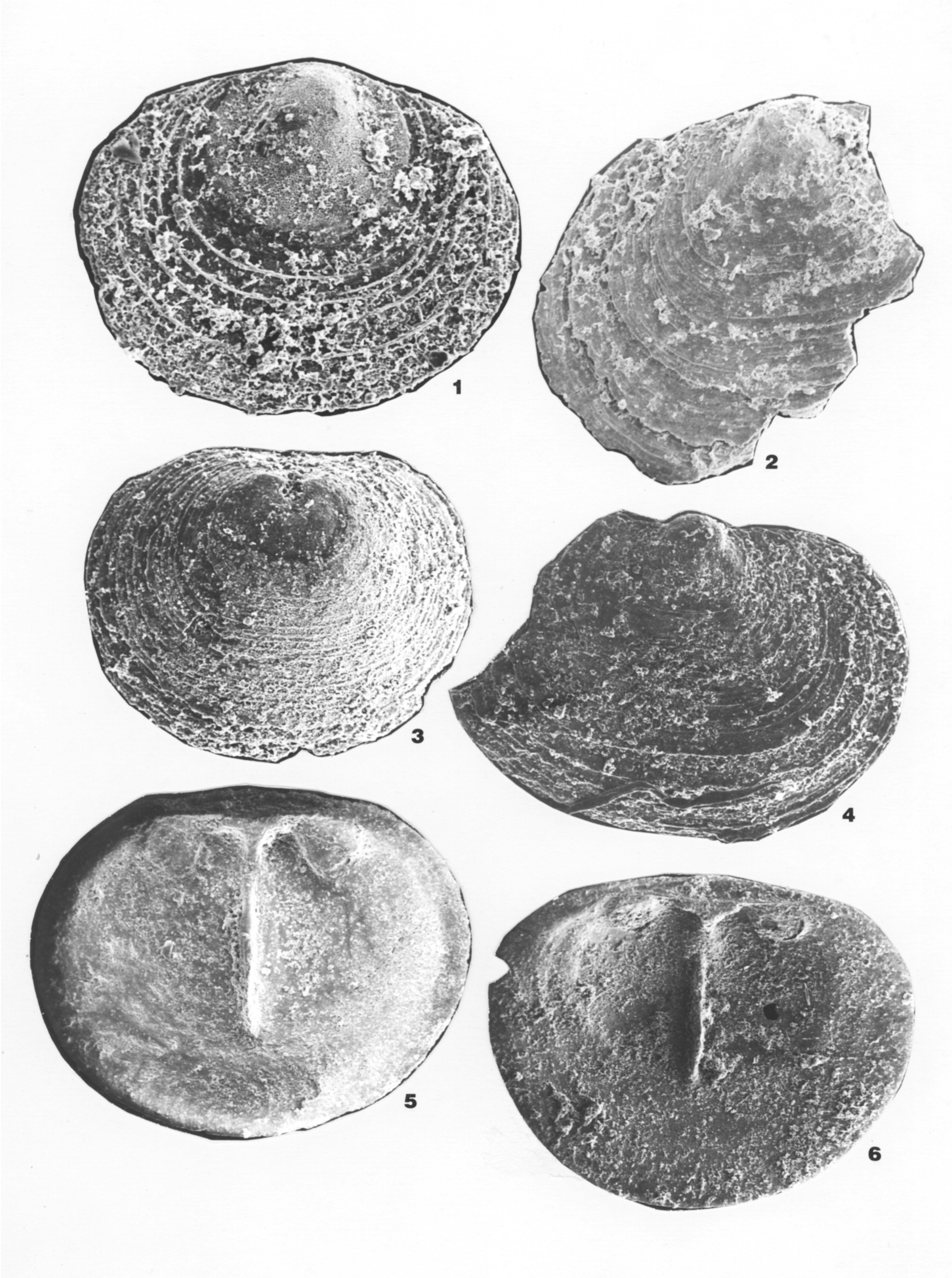
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PLATE 5
Conodonts from the Pobroszyn Limestone Formation

1-3 – *Drepanoistodus basiovalis* (Sergeeva, 1963); 1 – planiform element, × 100; 2 – oistodontiform element, × 180; 3 – suberectiform element, ×130;
4, 5 – *Microzarkodina ozarkodella* (Lindström, 1971); 4 – P element, ×250; 5 – M element, × 180;
6 – ?*Oepikodus evae* (Lindström, 1955), M element, × 120;
7 – *Oistodus lanceolatus* Pander, 1856, Sb element × 100.

D. basiovalis, O. *lanceolatus* and *M. ozarkodella* are from the red laminated limestone; the *Oepikodus evae* is from the grey limestone with pebbles


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PLATE 6

Conodonts from the Pobroszyn Limestone Formation and the Bukowiany Limestone Formation.

1 – *Sagittodontina* sp., Pb element, × 150;
2 – *Sagittodontina* sp., Sb element, × 220;
3 – *Sagittodontina* sp., Sb element, × 120;
4 – *Lenodus* sp., Pa element, × 150;
5 – *Scalpellodus gracilis* (Sergeeva), M. element, × 250;
6 – *Baltoniodus* cf. *crassulus* (Lindström, 1955), element, × 150.

B. cf. *crassulus* from the grey-green limestone, the *Scalpellodus gracilis* from the red laminated limestone of the Pobroszyn Limestone Formation; and the *Sagittodontina* sp. and *Lenodus* sp. from green-grey of the Bukowiany Limestone


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