ORDOVICIAN CONODONT BIOSTRATIGRAPHY
OF THE POLISH PART OF THE BALTIC SYNECLISE

WIESŁAW S. BEDNARCZYK


Ordovician lithostratigraphic units distinguished in the subsurface of the Polish part of the Baltic syneclise were dated by means of conodonts. The oldest Ordovician deposits, ranging from the (?upper part of the Cordylodus proavus(? ) Zone to the C. angulatus Zone (the top part of the Piaśnica Formation) were penetrated in offshore boreholes. On land, the Ordovician starts with the Drepanoistodus deltifer–Paroistodus proteus zones (the Gardno Formation) (with stratigraphic gap) or with the Oepikodus evae or Baltoniodus navis zones (the Klewno Formation). Because of their lithologic and faunistic similarities, the overlying formations (Stuchowo, Pieszkowo, Sasino) can be correlated with the lithostratigraphic and biostratigraphic units of the southern part of Sweden (Scania and Västergötland) thus indicating a common history of both parts of the sedimentary basin. The Ordovician ends with the Macronaspis macronatus trilobite zone. Possible equivalents of the Glyptagnostus persculptus Zone have been identified only in one borehole so far. Local stratigraphic gaps within the Kaszuby Formation are a result of the Taconian synorogenesis. They correspond to the Upper Ashgill (Hirnantian), and separate the sandy limestone (the Kokoszki Member) and the claystone (western part) from the nodular limestone (eastern part) of Llandovery age.

Key words: Conodonta, lithostratigraphy, biostratigraphy, Ordovician.

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INTRODUCTION

In the Polish part of the Baltic synclise one can distinguish three platform facies belts (Fig. 1). The central platform facies consists of red and grey carbonates and extends across the Baltic Synclise to Gdansk Bay in the west and to the central part of the Podlasie Depression in the east. This facies corresponds to the Central Baltoscandian facies belt (JAANUSSON 1976). The eastern platform facies consists of grey carbonates and is recognized in the easternmost part of Poland including the Suwalki Lake district and the eastern part of the Podlasie Depression. This facies corresponds to the Lithuanian facies belt. In the Łeba area, in the most western part of the Baltic Synclise (BEDNARCZYK 1979; PODHALANSKA 1980) and in the Warsaw basin, one can distinguish the western platform facies of black bituminous clays. It corresponds to the Scanian facies. Along the south-western margin of the East-European Craton, the platform facies interfinger laterally with the deep basin facies of the graptolite-bearing claystone belt (BEDNARCZYK 1974).

Materials. — The conodonts found by the present author in the sections of the Baltic Synclise represent successive conodont zones which are known from Sweden (LINDSTRÖM 1971; LÖFGREN 1978, 1993; BERGSTROM 1971). The analyzed material includes the cores from 15 boreholes drilled by the Polish Oil Company, as well as the lowermost Ordovician samples from the Gdansk IG 1 borehole. The analysis is based on 10 selected cores only. A detailed biostratigraphic description including taxonomic treatment of the entire material will be presented elsewhere.

Laboratory treatment of the samples. — The samples from several sections were treated with a buffered acetic or formic acid and washed through a 75 μm sieve. The residue was separated mainly by magnetic separation. Especially rich conodont material was found in the red or greenish-grey limestones of the Pieszkowo Formation.

Thermal alteration. — The conodonts are practically unaltered thermally (CAI 1 to 2; see EPSTEIN et al. 1977) in the central part of the Baltic syncline but more altered (CAI 3 to 5) in the western part (Łeba area).

Repository. — The conodonts illustrated are deposited in the BEDNARCZYK’S collection (WB100–WB139), Institute of Geological Sciences, Polish Academy of Sciences, Warszawa, Twarda 51/55, Poland.

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LITHOSTRATIGRAPHY

In marine offshore sections of the Baltic Synclise the Ordovician begins with a black claystone unit (up to 8.5 m thick) containing numerous graptolites and conodonts (MODLIŃSKI et al. 1994). The units represents the uppermost part of the Piaśnica Formation (Fig. 3; HEINSALU and BEDNARCZYK 1997). In the onshore area of the Baltic Synclise (the Łeba area), the Middle and Upper Ordovician deposits were first subdivided into three formations (PODHALANSKA 1980). Later on, in the more offshore part of the synclise, the Ordovician deposits were subdivided into six formations; including six members (Fig. 3; BEDNARCZYK 1995, 1996).

The sequence starts with an up to 2 m thick claystone with glauconitic limestone intercalations in the Łeba area, partly, Gdansk area (Gardno Formation) or, elsewhere in the Baltic synclise, an up to 2.5 m thick glauconitic sandstone (Klewno Formation); Fig. 2. The succeeding grey-green marly claystone of the Sluchowo Formation is 15.0 m thick. It is present in the Łeba area (BEDNARCZYK 1979) and extends to the Gdansk Depression, where it is thinnest (0.8 m).

The overlying limestone of the Pieszkowo Formation consists of the following four members (Fig. 3): (i) the Kopalino Member which consists of grey or beige marly micritic limestones (calciutite), locally with nodular structure ranging in thickness from 4.2 in the Gdansk area to about 20 m in the Łeba area; (ii) the Łankiejmy Member which consists of cherry-brown nodular biomicritic limestones (calcilutite or calcarenite) from 9.7 m to 29.4 m thick; (iii) The Kielno Member which consists of the greenish-grey marly limestones (calcilutite) from 8 m up to 26 m thick; and (iv) Aniołowo Member which occurs locally, consists of light-grey or greenish-grey limestones with numerous brown iron ooliths and bentonite intercalations (from 3.6 m to about 16 m thick) and commonly begins with a thin layer of conglomerate
Fig. 1

consisting of grey-green limestone (calcirudite) cemented by a dark-grey marl with numerous iron ooliths. The overlying graptolitic claystone of the Sasino Formation (Figs 2, 3) contains intercalations of crystalline limestone and bentonite. The thickness of the Sasino Formation is from about 43 m in the western part of the Baltic Synclise to 3.4 m in its central part. The lower part of the formation consists of grey marls or marly claystones (the Krokowo Member). The overlying Kaszuby Formation consists of grey or light-grey marls and marly limestones (calciulitite). The upper part of the formation contains mudstone or sandy limestone layers (Kokoszki Member); Fig. 3. The thickness of the formation is about 2 m in the eastern part of the Baltic Synclise but in some places it reaches about 40 m. The total thickness of the Ordovician succession reaches in places 100 m.
The oldest Ordovician deposits were encountered in boreholes of the marine sections of the Baltic Basin (Fig. 1; Modliński et al. 1994). These are Tremadoc black claystones of the uppermost part of the Pińska Formation (Heinsalu and Bednarczyk 1997), most of which belongs to the Upper Cambrian succession (Bednarczyk 1979, 1994b). The Tremadoc strata contain an assemblage of the conodonts (Cordylodus; see Lendzion 1983), graptolites (Rhabdinopora flabelliforme s.l.), and brachiopods (Obo- lus cf. apollinis, see Modliński 1991).

In the continental area of the Baltic Synclise (the Łeba and partly the Gdańsk area), the Ordovician starts with the Gardno Formation. On the basis of an abundant conodont fauna (Table 1, Pl. 1: 1, 2, 21) from the Białogóra 1 and Gdańsk IG 1 drill cores, these beds are assigned to the upper Tremadoc (the Paltodus deltifer and lower part of Paroistodus proteus zones, Fig. 3). In other drillholes of this area (i.e. Dębki 2, Pińska 2, see Bednarczyk 1979), the Ordovician begins with the Stuchowo Formation, which on the basis of graptolites was correlated with the Tetraraptus phylograptoidei to Phyllograptus angustifolius elongatus zones. In carbonate intercalations of this formation, conodonts of the Paroistodus proteus to Paroistodus originalis zones were found (Table 1, Pl. 1: 3–8, 16, 18, 20, 23–25; see also Bednarczyk 1979).

In the other part of the Baltic Synclise, the Ordovician begins with the Klewno or, in places, with the Pieszkowo (Lankiejmy Mb) Formations (Fig. 3). The assemblage of conodonts (Table 1), found within Klewno Formation permits the recognition of the Prioniodus elegans–Oepikodus evae or Baltoniodus navis zones (Bednarczyk 1989). Within the Łeba area, the Kopalino Member of the Pieszkowo Formation overlies the Stuchowo Formation (Fig. 3).
On the basis of conodonts, it is possible to distinguish equivalents of the *Baltioniodus navis* and *Pygodus serra* zones (Table 1, Fig. 3, see also BEDNARCYZK 1979, PODHALANSKA 1980). In other parts of the Baltic Synclise (the Lankiejmy Member of the Pieszkowo Formation), the present author (Table 1 and Pl. 1: 9–15, 19, 22, Pl. 2: 1–7, 9–12, 14–16) established the presence of the *Oepikodus evae* or the *Baltioniodus navis* (Billingenian to Volkovian) zones at the base of the member. The top of the member ends with the *Microzarkodina ozarkodella* Subzone of the *Amorphognathus variabilis* Zone or, in places, with the *Pygodus anserinus* or *Eoplacognathus linststroemi* Subzone of the *Pygodus serra* Zone (Fig. 3). It is worth noting that between the *Eoplacognathus robustus* Subzone and *E. suecicus* Zone a gap has been previously recognized (see BIERNAT and BEDNARCYZK 1990). Similarly, in the western part of the Synclise, the presence of a gap in the Llanvirn sequence was suggested by PODHALANSKA (1980). The succeeding Kielno Member contains conodont fauna (e.g. Table 1 and Pl. 2: 8) of the *Amorphognathus variabilis* to the *A. tvarenesis* zones (Fig. 3). The Aniolowo Member is the uppermost unit within the Pieszkowo Formation. On the basis of conodonts (Table 1) this unit is assigned to the *Pygodus anserinus* and the *Amorphognathus tvaerensis* zones (Fig. 3).

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**Fig. 3**

Table 1
Conodont occurrence in the Ordovician formations in the Polish part of the Baltic Syncline.

<table>
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<th>Lithostratigraphy, boreholes, depths</th>
<th>Gardno Fm</th>
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The succeeding Sasino Formation ranges from the Caradoc to the Ashgill (Fig. 3). In the eastern part of the Baltic Synclise, within limestone intercalations, the present author has found an assemblage characteristic of the *Pygodus serratus* to the *Amorphognathus superbus* zones (Table 1).

The overlying Kaszuby Formation corresponds to the Ashgill Series and, in some cases, to the Llandeilo and/or Caradoc Series (Fig. 3). Its fauna consists mainly of trilobites and graptolites (Bednarczyk 1968; Podhalańska 1980; Młodinowski 1982). An assemblage of conodonts from the upper part of the formation, (e.g. from the Rodnowo 1 section, depth 1931.0–1921.0 m, Fig. 1) includes *Aphelognathus cf. nudus* Orchard, *A. furcatus* (Hinde), *Besselodus cf. arcticus* Aldridge, *Dapsilodus mutatus* (Branson et Mehl), *Icriodella cf. prominens* Orchard, *Protopanderodus liripipes* Kennedy, *Plectodina cf. tenuis* (Branson et Mehl), *Scabardella altipes* (Henningmoen) and, thus, suggests the *Amorphognathus ordovicianus* Zone (Fig. 3).
FINAL REMARKS

In the Ordovician, the northern and central Poland made up the southern part of the Baltic Basin (Fig. 1; BEDNARCZYK 1968b). To the north-west, this marine epicontinental basin bordered the Caledonian deformation zone of Scandinavia. Its western boundary is unclear because Ordovician deposits are not preserved at the Jutland peninsula in Denmark (JAANUSSON 1976). In the south-west, the Trans-European Fault separates the East-European Craton from the Baltic Basin and the Rügen–Koszalin–Chojnice Zone (the Marginal Thrust Belt, BERTHELESEN 1993; the Pomerania Terrane, POZARZYSKI et al. 1992; FRANKE 1994), which are tectonically and depositionaly different (BEDNARCZYK 1974). In the southeast (Fig. 1), the Baltic Basin extended to the southern part of the Holy Cross Mountains (the Małopolska Massif?) Proximal Terrane, DADLEZ et al. 1994).

The Ordovician deposits of the Balto-Scandian type occur also farther southeast in Volhynia, Podolia and Moldova (ZINOVENKO 1986). To the east, the Baltic Basin reached the MOSCOW Basin (MÅNNIL 1966).

Within the Balto-Scandian part of this basin, JAANUSSON (1976) distinguished several facies zones e.g. the Scanian, Central Balto-Scandian facies belts, etc. The majority of Poland was occupied by the coexisting red and grey carbonate facies comparable to the Swedish-Latvian facies zone (BEDNARCZYK 1968b) and the Central Balto-Scandian facies belt (BEDNARCZYK 1979).

The Conodont elements discussed here permit to recognize several Conodont communities through time. In the north-eastern part of Poland (e.g. the Klewno 1 section, Fig. 2), the facies equivalent of the Łankiejmy Member is characterized by frequent elements of Baltoniodus and Drepanoistodus genera. In the central part of the area (e.g. the Łaniewo 1 section, Fig. 1), more frequent are elements of Drepanoistodus and Protoperiopods.

Almost everywhere in the Polish part of the Baltic Basin, except of the Leba area, cherry-brown nodular limestones of the Łankiejmy Member of the Pieszkowo Formation overlie, grey-greenish biomicritic limestones with dispersed grains of glauconite and grains of quartz and chamosite ooliths of the sandy Klesnno Formation which, in turn, transgressively cover various members of the Middle and Uppermost Cambrian sandstones containing valves of Ungula ingrica EICHWALD and Ungula convexa PANDER (BEDNARCZYK 1989, 1994a). The deposits of the Klesnno Formation are characterized by frequent elements of Protopanderodus and Paroistodus in the eastern part of the basin, and by frequent elements of Drepanoistodus and Paroistodus in its central part (Figs 1, 2).

The Łankiejmy Member may be related to the Latorp and Lanna Limestone of Sweden (JAANUSSON 1982). It grades upward and laterally into the marly limestone of the Kielno Member and in places into the oolitic limestone of the Aniołowo Member. Similarly, to the Łankiejmy Member, the Kielno Member is characterized by frequent elements of Baltoniodus. The elements of Dapsilodus are also numerous (Fig. 2). In contrast, the Aniołowo Member is characterized by frequent elements of Scabbardella.

In the southern part of the Scanian – Leba facies belt, the Upper Cambrian black ferrarugineous claystones of the Piaśnica Formation grade upwards into the Lower Tremadoc marly claystones (MODŁIŃSKI et al. 1994). However, in the Leba area, the Ordovician begins with the Upper Tremadoc marly, strongly bituminous claystone of the Gardno Formation with intercalations of glauconite and glauconitic limestone (BEDNARCZYK 1979; HEINSAU and BEDNARCZYK 1997). The boundary between these two formations is a glauconite lamina (see the Białogóra 1 column in BEDNARCZYK 1979). However, a little farther eastward in the Gdańsk Depression (the Gdańsk IG 1 section), the Gardno Formation is separated from the Upper Cambrian (Peltura scarabaeoides Zone) by a thin conglomerate consisting of sandstone pebbles.

Lithofacially and stratigraphically, the Gardno Formation corresponds to the Ceratopyge (Björkasholmen) Limestone of South Öland (compare ERDTMANN 1995). The deposits of this formation are characterized by frequent elements of Drepanodus and Paroistodus (Fig. 2). The limestone of the Gardno Formation gradually grades upwards into the Sluchowo Formation, which consists of grey-green marly claystones with glauconite laminae and grey-brownish claystones with scattered glauconite grains and with carbonate intercalations in which conodonts Drepanodus, Paroistodus and Drepanoistodus (Fig. 2) are common.

The Sluchowo Formation can be regarded a southern extension of the Tøyten Shale of Scandinavia (BERGSTRÖM 1982; MALETZ et al. 1996). Grey-beige to dark-grey or grey-green marly limestones with scattered glauconite grains, intercalated with black claystone and veins or nests of calcite of the Kopalino
Member of the Pieszkowo Formation, overlie the deposits of the Sluchowo Formation. The elements of *Drepanoistodus* and *Protopanderodus* are very common in this succession (Fig. 2).

The Kopalino Member may be considered a western tongue of the Pieszkowo Formation between the Sluchowo Formation and the Sasino Formation. A similar model of sedimentation was presented by JANUSSON (1982) for the Swedish part of the Baltic Basin where the Komstad Formation occurs between the Tøyen Formation and the Upper *Didymograptus* Shale (BERGSTRÖM 1982).

The Kopalino Member and its equivalents in the Pieszkowo Formation are succeeded by the Sasino Formation in the whole area under discussion. In places, these claystones contain thin interbeds of grey limestone. Numerous bentonite and tuffitic intercalations also occur within this succession (PRZYBYŁOWICZ 1980). The elements of *Scabbardella* and *Amorphognathus* and *Hamarodus* are very common (Fig. 2).

The facies equivalent of the Sasino Formation may be the clayey complex of the Upper *Didymograptus* and *Dicellograptus* shales in Scania (BERGSTRÖM 1982). In the other part of the area under discussion the Sasino Formation is represented by grey or dark-grey claystone with organodetritic laminations. In the Łeba area, the Sasino Formation is succeeded by marls and marly limestones of the Kaszuby Formation. The deposits contain an admixture of terrigenous material consisting of grains of quartz and feldspar. Locally, the topmost part of the formation is the sandy limestone of the Kokoszki Member. In the other part of the Baltic Basin, the Kaszuby Formation begins with rust-colored, brown or red-brown limestones or claystones. In Västergötland such red deposits represent the mudstones of the Jonstorp Formation (JANUSSON 1982). These red deposits are replaced by grey micritic, in places seminodular, limestones with dispersed quartz grains and nests and concentrations of pyrite. The facies is characterized by frequent *Hamarodus* and *Scabbardella* elements (Fig. 2). Locally, stratigraphic gaps end the sedimentation of the Ordovician in the Polish part of the Baltic Basin (BEDNARCYZK 1968b).

**REFERENCES**


CONODONT STRATIGRAPHY OF THE ORDOVICIAN FORMATIONS

PLATE 1

Paltodus deltifer (LINDSTRÖM, 1955)
1. Drepanodontiform element, WB100, Białogóra 1, 2701.4–2702.0 m, × 150.
21. Oistodontiform element, WB101, Gdański IG 1, 3135.4–3137.3 m, × 150. Samples from the Gardno Fm.

Paraistodus numarcuatus (LINDSTRÖM, 1955)
2. Drepanodontiform element (WB102) from the Gardno Fm, Białogóra 1, 2701.4–2702.0 m, × 160.

Microzarkodella flabellum (LINDSTRÖM, 1955)
3. Oistodontiform element, WB103, 2423.5–2425.0 m, × 80.
8. Cordylodontiform element, 2423.5–2425.0 m, × 70.
16. Ozarkodiniform element, WB104, 2423.5–2425.0 m, × 80. All samples from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 1.

Periodon flabellum (LINDSTRÖM, 1955)
4. Cordylodontiform element (WB105) from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 1, 2424.5–2425.0 m, × 85.
7. Trichonodelliform element (WB106) from the Klewno Fm, Łaniewo 1, 1979.2 m, × 100.

Paraistodus originalis (SERGEEVA, 1963)
6. Oistodontiform element, WB107, 1979.2 m, × 110.
18. Drepanodontiform element, WB108, 1979.2 m, × 75. Samples from the Klewno Fm, Łaniewo 1.

Paraistodus parallelus (PANDER, 1956)
5. Oistodontiform element, WB109, 1979.2 m, × 70.
24. Drepanodontiform element, WB110, 1979.2 m, × 100. Samples from the Klewno Fm, Łaniewo 1.

Baltoniodus prevariabilis (FÄHRJÉUS)
9. Paracordylodontiform element, WB111, 2419.2 m, × 120.
10. Ambalodontiform element, WB112, 2419.2 m, × 80.
12. Amorphognatiform element, WB113, 2423.5–2424.8 m, × 80.
13. Oistodontiform element, WB114, 2424.8–2425.0 m, × 130. Samples from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 1.

Sagittodontina cf. furcata (KNÜPPER, 1967)
11. Ambalodontiform element (WB115) from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 1, 2418.5, × 80.

Walliserodus cf. ethingtoni (FÄHRJÉUS, 1966)
14. Trichonodelliform element (WB116) from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 1, 2424.3 m, × 100.

Baltoniodus cf. variabilis (BERGSTRÖM, 1963)
15. Paracordylodontiform element, WB117, 2419.7 m, × 100.
19. Trichonodelliform element, WB118, 2421.5–2422.5 m, × 130.
22. Tetrarioniodontiform element, WB119, 2419.3 m, × 130. Samples from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 1.

Oistodus lanceolatus PANDER, 1956
20. Oistodontiform element (WB120) from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 1, 2421.5–2422.5 m, × 100.
23. Oistodontiform element (WB121) from the Klewno Fm, Łaniewo 1, 1979.8 m, × 110.
25. Trichonodelliform element, WB122, 1979.8–1980.0 m, × 150. Samples from the Klewno Fm, Łaniewo 1.

Microzarkodella ozarkodella LINDSTRÖM, 1971
17. Oistodontiform element (WB123) from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 1, 2418.0–2420.2 m.

1, 2 and 21 represent elements from the Gardno Formation; 5–7, 11, 14, 18, 23–25 elements from the Klewno Formation; 3, 4, 8–10, 12, 13, 15, 17, 19, 20 elements from the Łankiejmy Member of the Pieszkowo Formation. Element in 16 from the Łaniewo 1 and element in 22 from the Henrykowo 1 boreholes.
Eoplacognathus lindstroemi (Hamar, 1964)
3. Amorphognathiform element, WB124, 2413.8 m.
5. Ambalodiform element, WB125, 2412.6 m, × 110.
6. Ambalodiform element, WB126, 412.7 m, × 110.
7. Amorphognatiform element, WB127, 2413.8 m, × 90.
10. Amorphognatiform element, WB128, 2413.8 m, × 120. Samples from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 1.

Eoplacognathus reclinatus (Fähræus, 1966)
11. Amorphognatiform element (WB129) from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 1, 2413.8 m, × 90.

Eoplacognathus suecicus Bergström, 1971
9. Ambalodiform element (WB130) from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 1, 2419.0 m, × 110.

Eoplacognathus zgierzensis (Dzik, 1976)
2. Ambalodiform element, WB131, 2413.5 m, × 180 from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 1.

Eoplacognathus cf. robustus Bergström, 1971
1. Amorphognathiform element, WB1132, 2410.6–2411.0 m, × 180.

Eoplacognathus cf. lindstroemi (Hamar, 1964)
12. Amorphognatiform element (WB133) from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 1, 2413.5 m, × 180.

Pygodus anserinus Lamont et Lindström, 1957
4. Haddingodiform element, WB134, 2413.2 m, × 120.
16. Pygodiform element, WB135, 2413.5 m, × 120. Samples from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 1.

Amorphognathus superbus (Rhodes, 1953)
8. Amorphognatiform element (WB136) from the Kielno Mb of the Pieszkowo Fm, Henrykowo 1, 2384.0 m, × 110.

Erraticodon balticus Dzik, 1978
13. Hindeodelliform element (WB137) from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 1, 2411.2 m, × 100.

Polonodus sp.
15. Specimen (WB138) from the Łankiejmy Mb of the Pieszkowo Fm, Henrykowo 2, 2423 m, × 100.

Sagittoninia sp.
14. Specimen (WB139) from the Łankiejmy Mb of the Pieszkowo Fm, 2424.8 m, × 130.

All samples from the Henrykowo 1. 1–7, 9–16 elements from the Łankiejmy Member of the Pieszkowo Formation; 8 element from the Kielno Member of the Pieszkowo Formation.