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Biostratigraphy of the Old Paleozoic carbonates in the Zawiercie area (NE margin of the Upper Silesian Coal Basin)

Results are presented of biostratigraphic investigations of Old Paleozoic carbonate sediments from 6 boreholes of the Zawiercie area. Deposition of carbonate sediments had begun in this area probably in Arenig. An assemblage of microfauna traced in borehole samples consists mainly of conodonts and documents sediments of the Lower, Middle and Upper Ordovician and Lower Silurian.

INTRODUCTION

A series of boreholes drilled in the Zawiercie area have pierced under the Devonian and Permian cover a sedimentary sequence of clayey, silty, arenaceous rocks with a complex of carbonates. Basing on its lithology the sequence has been classified to the Old Paleozoic. No macrofossils have been found in it. Attention has been paid to carbonates with a hope of finding microfossils in them.

Micropalaeontological investigations in the area in question have been first executed near Mrzygłód where Ordovician sediments were documented (K. Piekarski, A. Siewniak-Witruk, 1978). Another attempt has been done in the years 1983–1985 to study carbonate rocks on the basis of conodonts in columns of boreholes RK 1 and RK 2 (A. Siewniak-Madej, 1985). The results obtained encouraged to further conodont studies in all the boreholes in the Zawiercie area (Figs 1, 2).

The authors are indepted to ings. L. Szostek and S. Rogoż for lending the drilling material for study and are thankful to Mrs J. Modrzejewska for the conodont photographs printed in the present paper.

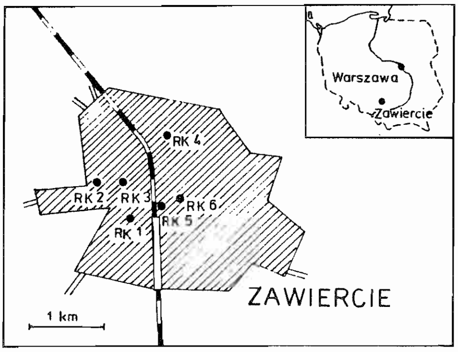


Fig. 1. Location of boreholes in the Zawiercie area
Szkic lokalizacji otworów wiertniczych w rejonie Zawiercia

GENERAL LITHOLOGY OF THE SEDIMENTS

Lithological columns have been set together entirely on the basis of macroscopic observations. The apparent monotony of the carbonate sequence results probably from the fact that most sedimentary structures have been obliterated due to metamorphic processes.

The Ordovician sediments of the Zawiercie area rest unconformably on various Cambrian and possibly also Pre-Cambrian members. The profile of the Ordovician starts with thin layer of basal conglomerate of transgressive character. This layer has been found in boreholes RK 1 and RK 4 (Fig. 2). The conglomerate is composed mainly of variously rounded fragments of dark-grey clayey rocks. Higher up there are marbles coarse- and medium-grained chiefly whitish-grey only at the bottom grey and greyish-brown silicified.

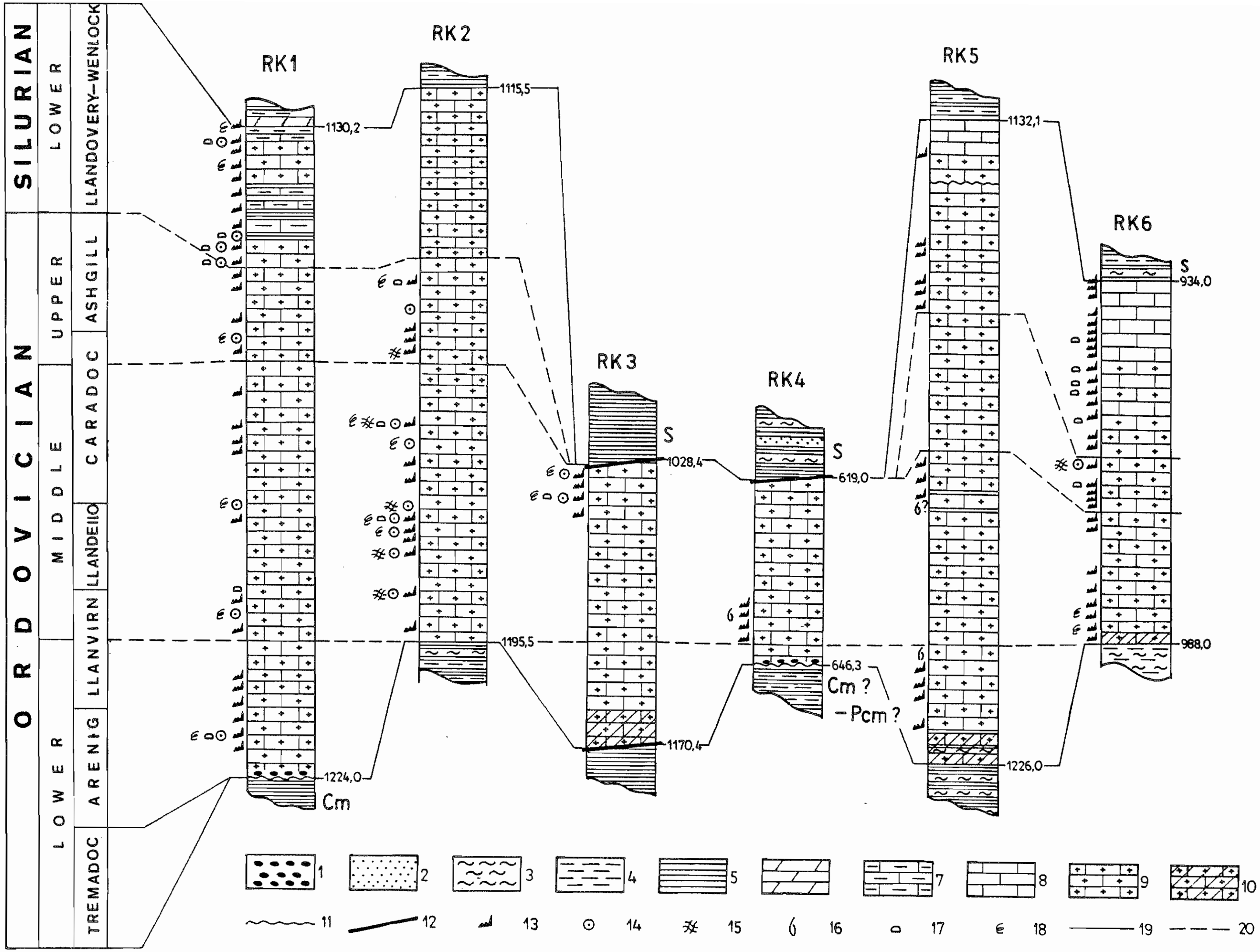
Thin interbeds of marls and clay appear in the limestones. They are grey to dark-grey in colour. They are more numerous in the lowermost part of the column (e.g. RK 5 borehole). Maximal thickness of the Lower Ordovician sediments is about 20 m (RK 1 borehole).

Middle Ordovician is represented by coarse- to medium-grained whitish to light grey marbles that have been pierced in all profiles studied (Fig. 2). In places there are interbeds of marl and clay. Middle Ordovician is from 20 up to 40 m thick.

Lithology of the Upper Ordovician is similar to that of the Middle Ordovician. Locally there are fine-crystalline marbles. Thickness is 10–20 m.

The topmost part of the carbonate series corresponds to the Lower Silurian. There is little difference in lithology. Some more distinct differences appear in the RK 6 borehole. The Silurian rocks are strongly recrystallized organodetrital limestones with numerous clayey interbeds. Indistinct sedimentary discontinuities have been noted in the RK 5 borehole. The carbonate Lower Silurian sediments are 20–25 m thick.

Total thickness of the Ordovician, Lower Silurian sequence in the Zawiercie area in about 100 m. Lower thickness values in boreholes RK 3 and RK 4 are caused by tectonic reduction (Fig. 2).


SILURIAN
LOWER
LLANDOVERY–WENLOCK
ORDOVICIAN
UPPER
ASHGILL
CARADOC
MIDDLE
LLANDEILO
LLANVIRN
LOWER
ARENIG
TREMADOC
RK1
1130,2
1224,0
Cm
RK2
1115,5
1195,5
RK3
S
1028,4
1170,4
RK4
S
619,0
646,3
Cm ?
– Pcm ?
RK5
1132,1
6?
1226,0
RK6
S
934,0
988,0
1 2 3 4 5 6 7 8 9 10
11 12 13 14 15 16 17 18 19 20

REMARKS ON DISTRIBUTION AND PRESERVATION OF MICROFOSSILS

Stratigraphic classification of the carbonate sequence to the Ordovician and Lower Silurian has been possible on the basis of find of a rich conodont assemblage. Documented are some conodont horizons established for the Ordovician (M. Lindström, 1971; S.M. Bergström, 1971; S.M. Bergström et al., 1985) and for the Silurian (O.H. Walliser, 1964, 1971) developed in the area of the North Atlantic conodont palaeozoogeographic province. These horizons are correlated with the standard subdivision of both systems.

Aside of conodonts the studied samples have furnished such fossils as ostracods, verms, fragments of brachiopods and echinoderms (mainly crinoids). Detailed observations allowed to find small fragments of inarticulate brachiopods and echinoderms. First of all the conodonts were in use for stratigraphy. Ostracods appeared useful as well. It should be pointed out that rather abundant conodont assemblages containing index fossils have been found in some rock parts only whereas thick portions in the profile are fossilless. Thus delimiting exactly the particular stages was impossible. The distribution of conodonts is very irregular in the carbonate sequence. They are most frequent in the sediments classified to the Upper Arenig and Lower Caradoc as well as Lower Wenlock. In the sediments classified to the upper part of the Middle and Upper Ordovician and the lowermost Silurian quantities of conodonts are but very small. Because of that the sediments of the Upper Ordovician are poorly documented palaeontologically.

The conodonts that occur in the studied sediments are white as a rule. Only specimens encountered in the RK 4 borehole are dark grey nontransparent. White colour was a factor that made the separation of the conodonts from white marbles difficult when dissolved in acetic acid.

Colour of conodonts is an important indicator of degree of metamorphism of sediments (A.G. Epstein et al., 1977). White nontransparent specimens are usually found in rocks of weak thermal metamorphism (anchimetamorphism). The mother rocks are primarily marbles and weakly metamorphosed shales. White conodonts have been found in the Upper Silurian marbles that crop out in the Austrian Alps near Salzburg.

Fig. 2. Correlation of Ordovician and Lower Silurian profiles in the Zawiercie area

1 — conglomerates; 2 — sandstones; 3 — siltstones; 4 — silty claystones; 5 — claystones; 6 — marls; 7 — marly limestones; 8 — fine- and micro-crystalline limestones; 9 — coarse- and medium-crystalline limestones; 10 — carbonate metasomatites; 11 — outwash surfaces; 12 — tectonic contact; 13 — conodonts; 14 — echinoderms; 15 — bryozoans; 16 — brachiopods; 17 — ostracods; 18 — vermes; 19 — boundaries of the carbonate complex; 20 — probable course of stratigraphic limits

Korelacja profilów ordowiku i dolnego syluru w rejonie Zawiercia

1 — zlepieńce; 2 — piaskowce; 3 — mułowce; 4 — iłowce mulaste; 5 — iłowce; 6 — margle; 7 — wapienie margliste; 8 — wapienie drobno- i mikrokrystaliczne; 9 — wapienie grubo- i średniokrystaliczne; 10 — metasomatyty węglanowe; 11 — powierzchnie rozmyć; 12 — kontakt tektoniczny; 13 — konodonty; 14 — szkarłupnie; 15 — mszywioły; 16 — ramienionogi; 17 — małżoraczki; 18 — robaki; 19 — granice kompleksu węglanowego; 20 — przypuszczalny przebieg granic stratygraficznych

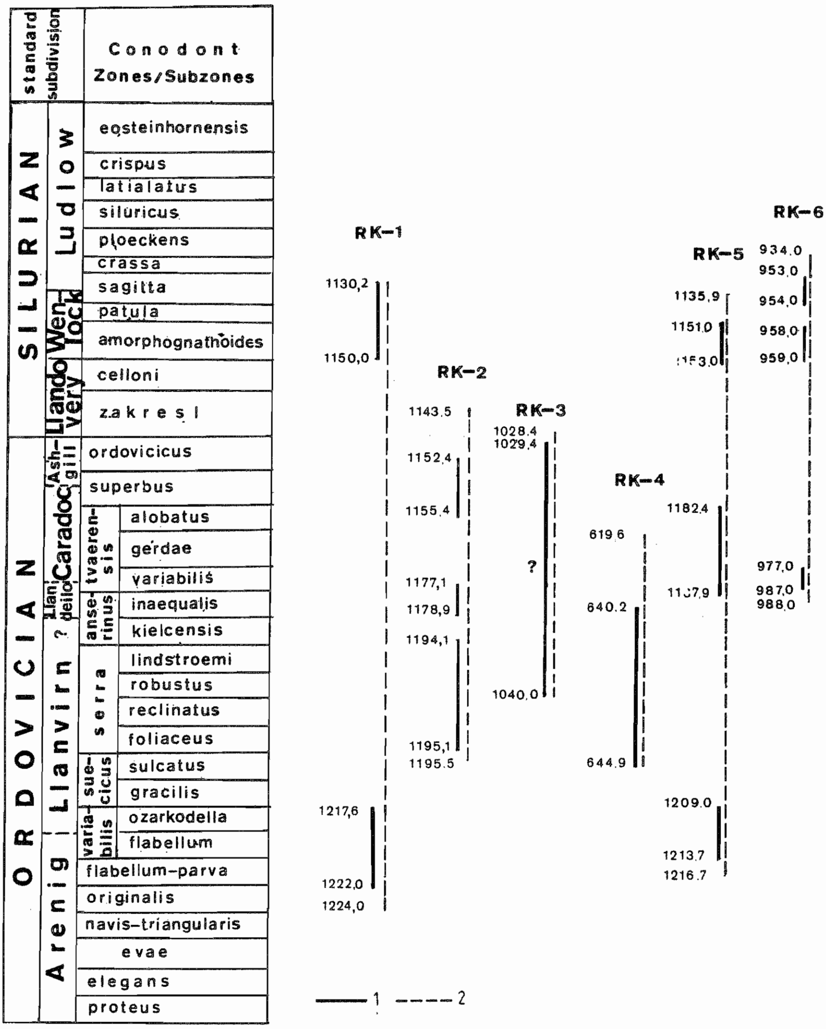


Fig. 3. Depth correlation of the studied Old Paleozoic profiles of the carbonate series in the Zawiercie area. Conodont Ordovician zones and subzones after M. Lindström (1971), S.M. Bergström et al. (1985), conodont Silurian zones after O.H. Walliser (1971)

1 — intervals correlated with the conodont zones; 2 — studied intervals

Zestawienie głębokości badanych profilów dolnopaleozoicznych serii węglanowej w rejonie Zawiercia. Poziomy i podpoziomy konodontowe ordowiku wg M. Lindströma (1971), S.M. Bergströma i in. (1985), poziomy konodontowe syluru wg O.H. Wallisera (1971)

1 — interwały skorelowane z poziomami konodontowymi; 2 — interwały przebadane

The conodont assemblage found in the Ordovician – Lower Silurian carbonate sequence of the Upper Silesian Coal Basin north eastern margin is typical for the North Atlantic conodont province which embraces the Balto-Scandinavia, England, Scotland and eastern part of the Appalachians (C.R. Barnes et al., 1973).

In determination of the conodonts chiefly the multielement taxonomy was in use. Names of "natural" species were applied as established by M. Lindström (1971), S.M. Bergström (1971) and W.A. van Wamel (1974). In some cases aside of those species names the names of formal species are given in parenteses. They are elements of natural species and their determination according to the rules of parataxonomy is marked by abbreviation s.f. = *sensu formae.*

BIOSTRATIGRAPHY

LOWER ORDOVICIAN

The age of the Lower Ordovician sediments is documented by conodonts from RK 1 (1215.7–1222.0 m) and RK 5 boreholes (1209.7–1216.6 m). The following taxons have been found here: *Eoplacognathus* sp., *Cornuodus longibasis* (Lindström), *Drepanodus arcuatus* Pander, *Drepanoistodus basiovalis* (Sergeeva), *Proniodus (Baltoniodus) prevariabilis* Fåhraeus, *P. (B.) prevariabilis ?medius* Dzik, *Protopanderosus rectus* Lindström.

The above taxons make a basis for a discussion about the age of the sediments in which they occur. Nevertheless, the age determination is based frequently on analysis of commonly occurring index forms.

Thus in RK 1 and RK 5 boreholes remarkable is first of all occurrence of conodonts known from the Lower Llanvirn (*Eoplacognathus*) together with species appearing in higher Arenig (*Protopanderodus rectus* Lindström, *Proniodus (Baltoniodus) prevariabilis* Fåhraeus). *Eoplacognathus* appears in the Lower Llanvirn and lasts till the Lower Caradoc. This genus is very common in Llanvirn deposits in the Balto-Scandinavia area and in the eastern part of the North America. It is a very characteristic element in the conodont assemblages in the above regions. Representatives of this genus derive rather rapidly from *Amorphognathus* making an assemblage of short-living but broadly distributed species (S.M. Bergström, 1971). State of preservation of the specimens of *Eoplacognathus* found in RK 1 (1216.7–1219.4 m) and RK 5 boreholes (1209.7–1213.7 m) does not allow to exact determination of their specific classification, nevertheless, the presence of this genus shows that the sediments cannot be older than Lower Llanvirn which corresponds to the Kundan Stage of the Baltic region.

This conclusion is supported by concurrence of *Eoplacognathus* sp. with the representatives of multielement species *Protopanderodus rectus* (Lindström) the range of which is closed between Arenig (Upper Latorpian — Billingenian Substage) — Lower Llanvirn (Kundan).

In the conodont scheme this range corresponds to zones e v a e – v a r i a b i l i s (A. Löfgren, 1978; S.M. Bergström et al., 1985). As *Eoplacognathus* forms are unknown below Kundan Stage and *Protopanderodus rectus* (Lindström) does not pass its top, it maybe assumed that the sediments found in the RK 1 (1217.6– 1222.0 m) and RK 5 (1209.0–1213.7 m) boreholes belong to Lower Llanvirn and possibly also the highest part of the Upper Arenig according to the British stratigraphic scheme.

Occurrence of conodonts belonging to the multielement species *Prioniodus (Baltoniodus) prevariabilis* Fåhraeus (*Prioniodus prevariabilis* Fåhraeus s.f., *Oistodus robustus* Bergström s.f., *Tetraprioniodus assymetricus* Bergström s.f., *Paracordylodus lindstroemi* Bergström s.f.) appeared to be useful in precise age determination. Unsatisfactory state of preservation and limited number of specimens make the decision to which of the three subspecies (A. Löfgren, 1978) they should be classified — impossible. Such classification would be of importance as the stratigraphic ranges of these taxons differ one from another. First conodonts representing *Prioniodus (Baltoniodus) prevariabilis* Fåhraeus appeared in Upper Arenig (Middle Volkhovian) and are known to occur till the Llandeilo (Uhakuan) inclusively. It seems probable that in the boreholes RK 1 and RK 5 the subspecies *Prioniodus (Baltoniodus) prevariabilis medius* Dzik occurs the stratigraphic range of which is limited to the lowermost Llanvirn corresponding to Kundan and Aserian stages.

The above conodonts are accompanied by: *Drepanodus arcuatus* Pander, *Cornuodus longibasis* (Lindström) and *Drepanoistodus basiovalis* (Sergeeva). The two first species are common in the conodont assemblages of the Lower Ordovician in the Baltic region and also are common in Scotland and eastern part of North America and in Argentina and Corea. *Cornuodus longibasis* (Lindström) appears in the Upper Latorpian (Billingenian) and the last representatives of this species were found in Ashgill. *Drepanodus arcuatus* Pander is known from the highest Tremadoc and is very frequent in the Arenig and was sometimes found in Llanvirn (A. Löfgren, 1978).

Drepanoistodus basiovalis (Sergeeva) is very common in the Balto-Scandinavia region. It appears in the Upper Arenig and lasts till the Llanvirn. In the conodont subdivision its range is confined within the zones navis — tri-angularis — lowermost serra (it does not reach the upper boundary of foliaceus Subzone) — S.M. Bergström et al. (1985) — which means that it is known also from the lowermost part of the Middle Ordovician.

In this way the sediments of the Lower Llanvirn have been documented in the studied columns. It maybe supposed, however, that the lower part of the carbonate sequence in which up to now no index microfossils were found — may correspond to the Arenig at least to its upper part.

MIDDLE ORDOVICIAN

The Middle Ordovician sediments have been distinguished in all the columns studied (Fig. 2). The presence of the lowermost Middle Ordovician has been documented in the boreholes RK 4 and RK 2.

In the borehole RK 4 determinable conodonts have been encountered only from depth 640.2–644.9 m. The presence of *Prioniodus (Baltoniodus) prevariabilis prevariabilis* Fåhraeus has been stated a species typical in the Llanvirn or more properly its higher part that corresponds to the Upper Aserian and Lasnamägian. The last representatives of this subspecies can be found in the lowermost Llandeilo. In the conodont subdivision its range is closed between the highest part of the sulcatus Zone and the lowermost part of the inaequalis Subzone (S.M. Bergström, et al., 1985). Beside that there are *Drepanoistodus basiovalis* (Sergeeva) and *D. forceps* (Lindström)

Table 1

Distribution of conodonts in the Ordovician and Lower Silurian carbonate series in the Zawiercie area

Form species	Boreholes and depth in metres					
	RK 1 1130.3–1148.6	RK 2 1143.5–1195.1	RK 3 1029.4–1037.2	RK 4 619.6–644.9	RK 5 1135.9–1216.7	RK 6 934.0–987.0
1	2	3	4	5	6	7
Acodus inornatus Ethington	1146.6–1148.6				1151.0–1152.0	936.0–959.0
Acodus mutatus (Branson et Mehl)			1035.5–1037.2			
Acodus similaris Rhodes					1172.1–1174.1	
Acontiodus rectus Lindström	1221.3–1222.0			643.1–644.9	1209.7–1210.7	
Ambalodus triangularis Branson et Mehl		1170.5–1182.7			1162.7–1191.7	964.0–968.0
Ambalodus triangularis Branson et Mehl subsp. *erraticus* Bergström					1184.0–1186.0	977.0–978.0
Ambalodus triangularis Branson et Mehl subsp. *suecicus* Bergström		1177.1–1178.9			1184.0–1185.7	977.0–984.0
Ambalodus triangularis ?frognoyensis Hamar						970.0–971.0
Amorphognatus ?gerdae Bergström					1186.5–1187.5	
Amorphognathus inaequalis Rhodes		1177.1–1178.9				
Amorphognathus ?kielcensis Dzik						986.0–987.0
Amorphognathus ?superbus Rhodes		1154.2–1155.4				
Amorphognathus tvaerensis Bergström					1182.0–1187.5	977.0–984.0
Coelocerodonthus trigonicus Ethington						947.0–948.0
Drepanodus aduncus Nicoll et Rexroad						941.0–959.0
Drepanodus ?amplissimus Serpagli					1166.4–1168.4	
Drepanodus cf. *Drepanodus arcuatus* Pander	1146.6–1148.6					
Drepanodus arcuatus Pander	1217.6–1222.0				1215.7–1216.0	
Drepanodus concavus (Branson et Mehl)	1146.6–1148.6					
Drepanodus homocurvatus Lindström	1215.7–1217.6			641.2–643.1		
Drepanodus longibasis Lindström				642.2–643.1		
Drepanodus planus Lindström	1217.6–1219.4			641.2–642.2		

Drepanodus sculponea Lindström	1217.6–1219.4				1215.7–1216.7	
Distacodus obliquicostatus Branson et Mehl			1035.2–1037.2		1139.5–1152.2	936.0–959.0
Distacodus procerus Ethington			1035.2–1037.2			
Eoplacognathus sp. indet.	1217.6–1219.4	1182.7–1184.0				969.0–986.0
Eoplacognathus ?lindstroemi Hamar		1177.1–1178.9				
Falodus parvidentatus Bergström	1217.6–1219.4					
Holodontus sp.						983.0–984.0
Ligonodina delicata (Branson et Mehl)						961.0–984.0
Ligonodina elongata Rhodes					1184.0–1187.5	983.0–984.0
Neoprioniodus bicurvatoides Walisser						953.0–954.0
Ozarkodina edithae Walliser						953.0–954.0
Ozarkodina ?typica Branson et Mehl						953.0–956.0
Oistodus basiovalis Sergeeva	1217.6–1219.4			642.2–644.9		
Oistodus forceps Lindström				641.2–643.1		
Oistodus robustus Bergström		1177.1–1178.9		640.2–644.9	1205.7–1216.7	977.0–984.0
Paltodus dyscritus Rexroad					1139.5–1141.4	947.0–948.0
Paltodus fragilis Branson et Mehl	1131.5–1148.6				1135.9–1136.9	941.0–956.0
Paltodus migratus Rexroad						958.0–959.0
Panderodus ?feulneri Glenister			1035.2–1036.7			
Panderodus flexus Drygant					1139.5–1136.9	
Panderodus gracilis (Branson et Mehl)	1129.5–1150.6		1031.4–1032.2		1135.9–1174.1	934.0–967.0
Panderodus panderi Stauffer	1131.5–1148.6		1035.2–1036.7			
Panderodus recurvatus Rhodes	1131.5–1148.6				1139.5–1141.4	935.0–936.0
Panderodus simplex (Branson et Mehl)	1131.5–1148.6				1139.5–1147.0	935.0–959.0
Panderodus unicostatus (Branson et Mehl)					1162.7–1164.6	934.0–962.0
Paracordylodus lindstroemi Bergström	1212.0–1213.8	1194.1–1195.1		640.2–643.1	1215.7–1216.7	
Paracordylodus speciosus Fåhraeus						981.0–982.0
Plectodina breviramea (Walliser)						961.0–970.0
Plectospathodus flexuosus Branson et Mehl						955.0–956.0
Prioniodina ?aflexa Hamar						967.0–968.0
Prioniodus alatus Hadding	1217.6–1219.4	1177.1–1195.1		640.2–644.9		
Prioniodus prevariabilis Fåhraeus	1213.8–1215.6	1194.1–1195.1		640.2–644.9		
Prioniodus variabilis Bergström		1177.1–1178.9				977.0–987.0
Roundya ?detorta Walliser					1151.0–1152.0	
Roundya cf. *gracilis* Rhodes					1190.5–1191.7	
Roundya gracilis Rhodes		1177.1–1178.9				977.0–978.0

Table 1 continued

1	2	3	4	5	6	7
Roundya inclinata Rhodes					1185.0–1187.5	986.0–987.0
Scandodus pipa Lindström	1216.7–1222.0				1202.0–1216.7	
Scolopodus varicostatus Sweet et Bergström				640.2–642.2		
Spathognathodus sagitta rhenanus Walliser						953.0–954.0
Synprioniodina silurica Walliser						953.0–954.0
Tetraprioniodus asymmetricus Bergström	1213.8–1219.4			640.2–644.9	1215.7–1216.7	981.0–984.0
Tetraprioniodus minax Sergeeva	1217.6–1219.4	1194.1–1195.1				
Tetraprioniodus parvus Ethington						981.0–982.0
Trichonodella incostans Walliser						953.0–954.0
Trichonodella symmetrica Branson et Mehl						953.0–954.0
Tvaerenognathus ordovicica Bergström					1184.0–1186.0	
Multielement species						
Amorphognathus inaequalis Rhodes		1177.1–1178.9				
Amorphognathus kielcensis Dzik						986.0–987.0
Amorphognathus tvaerensis Bergström					1184.0–1187.5	977.0–984.0
Complexodus pugionifer (Drygant)		1177.1–1178.9				
Cornuodus bergstroemi Serpagli		1182.7–1184.0		643.1–644.9		
Cornuodus longibasis (Lindström)		1177.1–1178.9		642.2–643.1	1182.0–1216.7	
Drepanodus arcuatus Pander	1217.6–1222.0				1215.7–1216.7	
Drepanoistodus basiovalis (Sergeeva)	1217.6–1219.4			642.2–644.9		
Drepanoistodus forceps (Lindström)				641.2–643.1		
Ozarkodina sagitta rhenana (Walliser)						953.0–954.0
Paraoistodus originalis (Sergeeva)				642.2–643.1		
Phragmodus polonicus Dzik				643.1–644.9		
Prioniodus ?gerdae Bergström					1186.5–1187.5	
Prioniodus (Baltoniodus) prevariabilis Fåhraeus					1215.7–1216.7	
Prioniodus (Baltoniodus) preveriabilis prevariabilis Fåhraeus		1194.1–1195.1				

Prioniodus (Baltoniodus) variabilis Bergström		1177.1–1178.9				977.0–987.0
Protopanderodus rectus (Lindström)				643.1–644.9	1209.7–1210.7	
Protopanderodus varicostatus (Sweet et Bergström)				640.2–642.2		
Pterospathodus pennatus procerus (Walliser)					1151.0–1152.0	958.0–959.0
Walliserodus costatus Dzik						986.0–987.0
Walliserodus ethingtoni (Fåhraeus)					1198.1–1199.1	

i.e. species which appear in the Upper Arenig but unknown above the top of Llanvirn. Hence the presence of equivalents of Llandeilo should be excluded from the columns under study. Occurrence of *P. (B.) prevariabilis prevariabilis* Fåhraeus shows that we deal here with the Upper Llanvirn which is confirmed by a find of spathognathus element at depths 643.1–644.9 m which is included to the multielement species *Phragmodus polonicus* Dzik of range Upper Llanvirn – Llandeilo (J. Dzik, 1978) and *Propanderodus varicostatus* (Sweet et Bergström) known from the Upper Llanvirn on.

In the RK 2 borehole coeval sediments have been encountered at depth 1194.1–1195.1 m. This supposition is based on the find of *Prioniodus (Baltoniodus) prevariabilis prevariabilis* Fåhraeus with lack of any other conodonts typical for the Llandeilo.

Also younger sediments of the Middle Ordovician have been documented in the same column. A rich and diversified conodont assemblage has been encountered at depth 1177.1–1178.9 m. It contains: *Amorphognathus inaequalis* Rhodes and *Complexodus pugionifer* Drygant. The first species occurs in the British Isles entirely in Llandeilo. In the conodont subdivision the position of it corresponds to i n a e q u a l i s Subzone and the lowermost part of v a r i a b i l i s one i.e. a sector correlated with Llandeilo (S.M. Bergström et al., 1985). The second species occupies similar stratigraphic position. It has been first described from the Llandeilo sediments in Podolia (D.M. Drygant, 1974). In Poland both species have been described from the Holy Cross Mts at Mójcza where they occur in beds correlated with Llandeilo (J. Dzik, 1978).

At depth 1177.1–1178.0 m together with the above mentioned species there occurs Prioniodus (Baltoniodus) variabilis (Bergström) which is an index fossil in the v a r- i a b i l i s Subzone (Upper Llandeilo – lowermost Caradoc). It appears already in the i n a e q u a l i s Subzone that is correlated with Llandeilo (S.M. Bergström et al., 1985). Hence the presence of this species does not invalidate the correctness of classification of these sediments to Llandeilo.

Ordovician sediments corresponding to Upper Llandeilo – Lower Caradoc have been pierced at depth 977.0–987.0 m in borehole RK 6. Concurrence of multielement species has been stated: *Amorphognathus tvaerensis* (Bergström) and *Prioniodus variabilis* Bergström. This makes sufficient basis for a correlation of these sediments with the conodont t v a e r e n s i s Zone that embraces the uppermost Llandeilo and Lower Caradoc (S.M. Bergström et al., 1985) and according to the Estonian subdivision the stages Kukruse, Idavere, Johvi and lower part of Keila. Three zones have been distinguished within the tvaerensis Zone. They are established on the basis of concurrence with the index species: *Prioniodus variabilis* Bergström, *P. gerdae* Bergström and *P. alobatus* Bergström. As the two last mentioned species were not found in the studied part of the RK 6 borehole it maybe assumed that these sediments correspond to the conodont variabilis Zone, i.e. the highest Llandeilo — lowermost Caradoc.

The sediments of the carbonate sequence found in the RK 5 borehole (1182.4–1187.5 m) should be also correlated with the tvaerensis Zone as many representatives of index species *Amorphognathus tvaerensis* Bergström were found in them. A find of damaged element of *Amorphognathus* at depth 1186.1–1187.1 m which seems to belong to *Prioniodus gerdae* Bergström is essential to more precise age determination of these sediments. The species is an index form in the gerdae Zone distinguished within the tvaerensis Zone correlated with Caradoc. Thus it maybe assumed that these sediments are Caradoc in age.

The tvaerensis Zone has been encountered in the whole Balto- Scandinavia region, in the southwestern Scotland and eastern part of North America. In Europe it was first found in Ordovician deposits in Sweden (Dalby Limestones) — S.M. Bergström (1971). In Poland it was stated in the Holy Cross Mts (Ch. Spasov, L. Teller, 1963; J. Dzik, 1978) and in the eastern part of the Podlasie Depression in boreholes Terespol 1 (W. Bednarczyk, 1971) and Mielnik IG 1 (M. Nehring-Lefeld, 1987).

UPPER ORDOVICIAN

Upper Ordovician age of sediments is relatively poorly documented in the Zawiercie area because of small number of conodonts. Specimens belonging to the following genera were found: *Panderodus, Ambalodus, Amorphognathus* as well as poorly preserved undeterminable conodonts of single cone type. A conodont assemblage from RK 2 borehole seems to be very interesting. Of high stratigraphic value is a fragment of an amorphognathus element found at depth 1154.2–1155.4 m. The specimen is damaged — a fragment of posterior process and the latero-posterior one are preserved. Shape and size as well as angle of it toward the posterior process it maybe assumed that it represents one of the distinguished species mainly on the basis of shape changes of this element — within the multielement genus *Amorphognathus* that appears but in the Caradoc. Such shape of the latero-posterior process suggests that the element in question may belong to *Amorphognathus tvaerensis* Bergström or to even younger one — *A. superbus* (Rhodes). The character of ambalodid elements found at the same depth, suggests classification of it to the last mentioned species. Hence, the sediments found in column of RK 2 borehole at depth 1154.4–1155.4 m should be correlated with Upper Caradoc. As no absolute certainty exists about the classification to either of the two species, the age of these sediments in the conodont scheme is embraced within the zones tvaerensis and superbus.

A specimen of *Ozarkodina pseudotypica* Lindström has been found at depth 1152.4–1154.2 m. So far it was known from the Crug Limestone of Wales classified to the Upper Caradoc (M. Lindström, 1959). This form is accompanied there by *Ozar-*

kodina pseudofissilis Lindström), that is very well localized in the Ordovician profile. Its presence is associated with the conodont zones s u p e r b u s and o r d o v i c i c u s (Upper Caradoc – Ashgill). Taking for granted that the studied sample is not younger than the s u p e r b u s Zone it seems reasinable to state that sediments located slightly higher in the column and containing *Ozarkodina pseudotypica* Lindström should be correlated with the s u p e r b u s Zone. Thus they correspond to the uppermost Caradoc or Lower Ashgill.

LOWER SILURIAN

The highest part of the carbonate sequence has been classified to the Silurian. Best palaeontological documentation of sediments of that age comes from boreholes RK 5 and RK 6. In the RK 5 (1151.0–1153.0 m) and RK 6 (958.0–959.0 m) boreholes a multielement species *Pterospathodus procerus* (Walliser) has been found. This makes a sufficient basis for including these sediments to the Silurian. This is one of the index forms which define the a m o r p h o g n a t h o i d e s Zone. In the Silurian conodont scheme (O.H. Walliser, 1964, 1971) this zone corresponds to the upper part of Apsidognathus Stage which in turn is correlated with Upper Llandovery and Lower Wenlock. In the classic Silurian profile in the Karnic Alps — Cellon profile (O.H. Walliser, 1971) lower limit of a m o r p h o g n a t h o i d e s Zone corresponds to the Llandovery – Wenlock boundary. This zone has been recognized in Tirol, Balkan Peninsula, in Norway and in Podolia. It has been documented in Wales and Welsh Borderland as well but in this area, however, the lower boundary of this zone has been placed within the uppermost Llandovery (Telychian). Upper boundary of the zone has not been recognized in Wales (R.J. Aldridge, 1972). In Poland the a m o r p h o g n a t h o i d e s Zone has been encountered in the Silurian sediments of the eastern part of the Podlasie Depression (M. Nehring-Lefeld, 1985). The conodonts characteristic for this zone occur there in quite different lithofacies than in the Upper Silesian Coal Basin border zone. Outside Europe equivalents of this zone are known from many profiles in North America and Thailand.

The representatives of *Pterospathodus pennatus procerus* (Walliser) in RK 5 and RK 6 boreholes are accompanied by numerous formal species: *Distacodus obliquicostatus* Branson et Mehl, *D. procerus* Ethington, *Drepanodus aduncus* Nicoll et Rexroad, *Panderodus gracilis* (Branson et Mehl), *P. simplex* (Branson et Mehl), *P. unicostatus* (Branson et Mehl) have much broader stratigraphic range.

Next conodont zone documented in the carbonate Silurian sequence is the s a g i t t a Zone. It corresponds to the highest Wenlock and the lowermost Lower Ludlow (O.H. Walliser, 1964, 1971). This zone has been recognized only in RK 6 borehole (953.0–954.0 m). *Ozarkodina sagitta rhenana* (Walliser) has been recognized here, an index species in the s a g i t t a Zone. In Europe this species has been first described from the Rheinische Schiefergebirge. It is also known from the Podolia (D.M. Drygant, 1969) correlated with Upper Wenlock. It is known from England and North America. In the latter region it was described from sediments of Kockelella amsdeni Zone documented in the Clarita Formation (Aubuckle Mts, Oklahoma). In the European conodont subdivision it corresponds to p a t u l a Zone (J.E. Barrick, G. Klapper, 1976). It comes from the above that in the American continent *Ozarkodina* *sagitta rhenana* (Walliser) has appeared earlier than in Europe but also in sediments correlated with Wenlock. The stratigraphic position of these sediments in the RK 6 borehole is also confirmed by presence of *Ozarkodina edithae* Walliser s.f. This species maybe treated as Pb element included in multielement species *Ozarkodina sagitta* (Walliser) similarly as accompanying species *Neoprioniodus bicurvatoides* Walliser s.f. which is N element of that species (J.E. Barrick, G. Klapper, 1976).

The sediments found in the RK 6 borehole are undoubtfully Silurian in age (depth 934.0–953.0 m). The microfaunal assemblage found here does not allow to make a correlation with any of definite Silurian conodont zones. Many formal species have been found here namely: *Acodus inornatus* Ethington, *Distacodus procerus* Ethington, *D. obliquicostatus* Branson et Mehl, *Drepanodus adunctus* Nicoll et Rexroad, *Paltodus fragilis* Branson et Mehl, *Panderodus gracilis* (Branson et Mehl), *P. simplex* (Branson et Mehl), *Paltodus dyscritus* Rexroad, *Coleocerodontus trigonicus* Ethington.

Almost identical conodont assemblage of single cone type has been found in the RK 5 borehole (1135.9–1151.0 m) hence, above sediments correlated with amorphognathoides Zone.

Outside Poland a very similar association dominated by conodonts of single cone type has been described from the Kitaygorod Stage of Volhynia and Podolia (D.M. Drygant, 1974). There, however *Distacodus obliquicostatus* Branson et Mehl is known only from the R Zone (highest Llandovery – Lower Wenlock).

The species mentioned above are characteristic in sediments of Upper Llandovery and Lower Wenlock of the British Isles. In the United States they have been described (C.B. Rexroad, W.W. Craig, 1971) from sediments representing higher members of the Silurian (Middle and Upper Ludlow). At the end of this analysis of the conodont assemblage of single cone type it should be pointed out that only *Drepanodus aduncus* Nicoll et Rexroad is typically Silurian species. All others are known already from the Middle Ordovician.

Also the uppermost part of the carbonate sequence in RK 1 borehole (1130.2–1150.0 m) belong probably to the Silurian. This supposition is based on find of *Drepanodus aduncus* Nicoll et Rexroad. The conodont assemblage with which the latter species is associated is dominated by representatives of the genus *Panderodus* the range of which is embraced within limits Middle Ordovician – Middle Devonian. The last mentioned forms are very common in sediments of Old Paleozoic in Europe and in North America but even their mass occurrence does not solve the problem of their age. In the cited part of RK 1 borehole mass occurrence of *Panderodus gracilis* (Branson et Mehl) has been stated together with *P. simplex* (Branson et Mehl), *P. recurvatus* Rhodes, *P. panderi* (Stauffer). All the conodonts encountered there that are of single cone type are present as well in the upper part of the carbonate sequence in boreholes RK 5 and RK 6.

Aside conodonts the Silurian carbonate sediments contain abundant fossils such as fragments of echinoderms, bryozoans, and ostracods. The latter appeared to be good index fossils in the stratigraphy.

In the boreholes RK 6 (947.0–956.0 m) and RK 5 (1139.5–1155.1 m) there occur: *Microcheilinella acutafilis* (Netskaya). *M. semibulbosa* (Netskaya), *M. variolaris* (Netskaya), *Silenis* aff. *subtriangulatus* Netskaya. These species are characteristic in Llandovery and Wenlock of Latvia (L. Gailite et al., 1967). Their presence indicates that the sediments belong still to the Wenlock. Found at the same depth in RK 6 borehole *Hemiaechminoides monospinus* Morris et Hill and *Spinobairdia kellettae* Morris et Hill are also typical Silurian species. They were first described from the Silurian shales (Newsom Shale) of Tennessee State (R.W. Morris, B.L. Hill, 1952). At depth 951.0–952.0 m in the same column there has been found *Silenis subtriangulatus longus* Abushik — a species common in sediments of Kitaygorod Stage in Podolia correlated with Wenlock (A.F. Abushik, 1971).

CONCLUSIONS

The Ordovician – Lower Silurian carbonate sequence of the Zawiercie area rests with angular disconformity on various members of the Cambrian and possibly also Pre-Cambrian. This is due to the tectonic movements of the Sandomirian orogenic phase (C. Harańczyk, 1982). These movements had taken place according to the newest opinions, at the Tremadoc – Arenig boundary and were common over the territory of Poland among others in the Holy Cross Mts in Central Poland, in the Carpathian Foreland and in the entire Pre-Vendian Platform (J. Znosko, R. Chlebowski, 1976; Z. Modliński, 1982).

The carbonate deposition in the Zawiercie area has probably begun in the Arenig. It embraced sediments of the Lower, Middle and Upper Ordovician and Lower Silurian. There is most probably no stratigraphic continuation in the columns between the Upper Ordovician and Lower Silurian. The gap embraces presumably higher Ashgill and Lower Llandovery.

The Ordovician profile in the Zawiercie area is condensed in stratigraphic sense and represents carbonate association of small thickness that has originated in result of very slow rate of deposition. This makes it similar to the Ordovician sequence in the central part of the Holy Cross Mts (J. Dzik, 1978) and eastern part of the Pre-Vendian Platform in the area of Poland (Z. Modliński, 1982). Quite different facies maybe observed in the Ordovician sequence near Myszków — Mrzygłód area located just northwest of Zawiercie where thick series of clastic sediments dominate (K. Piekarski, A. Siewniak-Witruk, 1978; K. Piekarski et al., 1982). Such a great diversity of facies at relatively small distance suggest juxtaposition resulting from tectonic transport (C.Harańczyk, 1982).

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BIOSTRATYGRAFIA WĘGLANOWYCH OSADÓW STARSZEGO PALEOZOIKU REJONU ZAWIERCIA (NE OBRZEŻENIE GZW)

Streszczenie

W opracowaniu przedstawiono wyniki badań biostratygraficznych osadów ordowiku i syluru z 6 otworów wiertniczych zlokalizowanych w rejonie Zawiercia (NE obrzeżenie Górnośląskiego Zagłębia Węglowego). Profil dolnego ordowiku rozpoczyna się tutaj cienką warstwą zlepieńca podstawowego, który stwierdzony został w otworach RK 1 i RK 4 (fig. 2). Wyżej występują wapienie zmarmuryzowane, grubo- i średnioziarniste, głównie białoszare, jedynie w dolnej części niekiedy szare i szarobrunatne, zsylifikowane. Maksymalna miąższość osadów ordowiku dolnego wynosi około 20 m. Osady ordowiku środkowego, wyróżnione we wszystkich przebadanych profilach, reprezentują wapienie zmarmuryzowane średnio- i grubokrystaliczne, białe i jasnoszare, miejscami z przerostami marglistymi; ich miąższość wynosi od ok. 20 do 40 m. Wykształcenie osadów górnego ordowiku jest podobne, jedynie lokalnie pojawiają się wapienie drobno- i mikrokrystaliczne z cienkimi przemazami ilastymi i marglistymi barwy szarej i ciemnoszarej. Miąższość ich wynosi ok. 10–20 m. Najwyższa część serii węglanowej odpowiada już dolnemu sylurowi. Makroskopowo osady te nie różnią się od utworów zaliczonych do ordowiku. Niewielkie różnice zaznaczają się nieco wyraźniej w profilu RK 6. Tutaj serię węglanową syluru stanowią silnie przekrystalizowane wapienie organodetrytyczne z licznymi przerostami ilastymi. W profilu RK 5 w obrębie wapieni syluru zaobserwowano niewyraźne powierzchnie nieciągłości sedymentacyjnych. Miąższość osadów zaliczanych do dolnego syluru wynosi 20–25 m. Ogólna miąższość ordowicko-sylurskiej serii węglanowej w rejonie Zawiercia wynosi ok. 100 m.

Zaliczenie serii węglanowej do ordowiku i dolnego syluru było możliwe dzięki bogatemu zespołowi konodontów. W profilach udokumentowano ekwiwalenty niektórych poziomów konodontowych ustalonych dla ordowiku i syluru i skorelowano je z podziałami standardowymi obydwu systemów. Z uwagi na nierównomierne rozprzestrzenienie konodontów w osadach serii węglanowej nie udało się dokładniej określić przebiegu granic pomiędzy poszczególnymi piętrami.

Dolnoordowicki wiek osadów dokumentuje fauna konodontowa (RK 1 — 1215,7–1222,0 m i RK 5 — 1209,7–1216,6 m), na podstawie współwystępowania *Eoplacognathus* sp. indet. z *Protopanderodus rectus* (Lindström), którego zasięg zamyka się w obrębie arenigu (górny latorp) - dolnego lanwirnu (kunda). Ponieważ *Eoplacognathus* jest nieznany poniżej spągu estońskiego piętra kunda, a *Protopanderodus* nie przekracza jego strop, należy przyjąć, że osady zawierające te konodonty należą do dolnego lanwirnu, a być może i najwyższej części górnego arenigu.

Osady środkowego ordowiku wyróżniono we wszystkich badanych profilach (fig. 2). W otworach RK 2 (1194,1–1195,1 m) i RK 4 (640,2–644,9 m) na podstawie występowania *Prioniodus (Baltoniodus) prevariabilis prevariabilis* Fåhraeus ustalono obecność odpowiedników pięter aseri i lasnamagi. W otworze RK 2 (głęb. 1177,1–1178,9 m) stwierdzono bardzo bogaty zespół konodontów zawierający m.in. *Amorphognathus inaequalis* Rhodes i *Complexodus pugionifer* Drygant, który dokumentuje osady landeila. Osady odpowiadające przedziałowi górny landeil — dolny karadok napotkano w otworze RK 6 (977,0–987,0 m). Stwierdzono tu współwystępowanie *Amorphognathus tvaerensis* (Bergström) i *Prioniodus variabilis* Bergström, co dało

podstawę do skorelowania osadów z konodontowym podpoziomem variabilis, odpowiadającym najwyższemu landeilowi i najniższemu karadokowi.

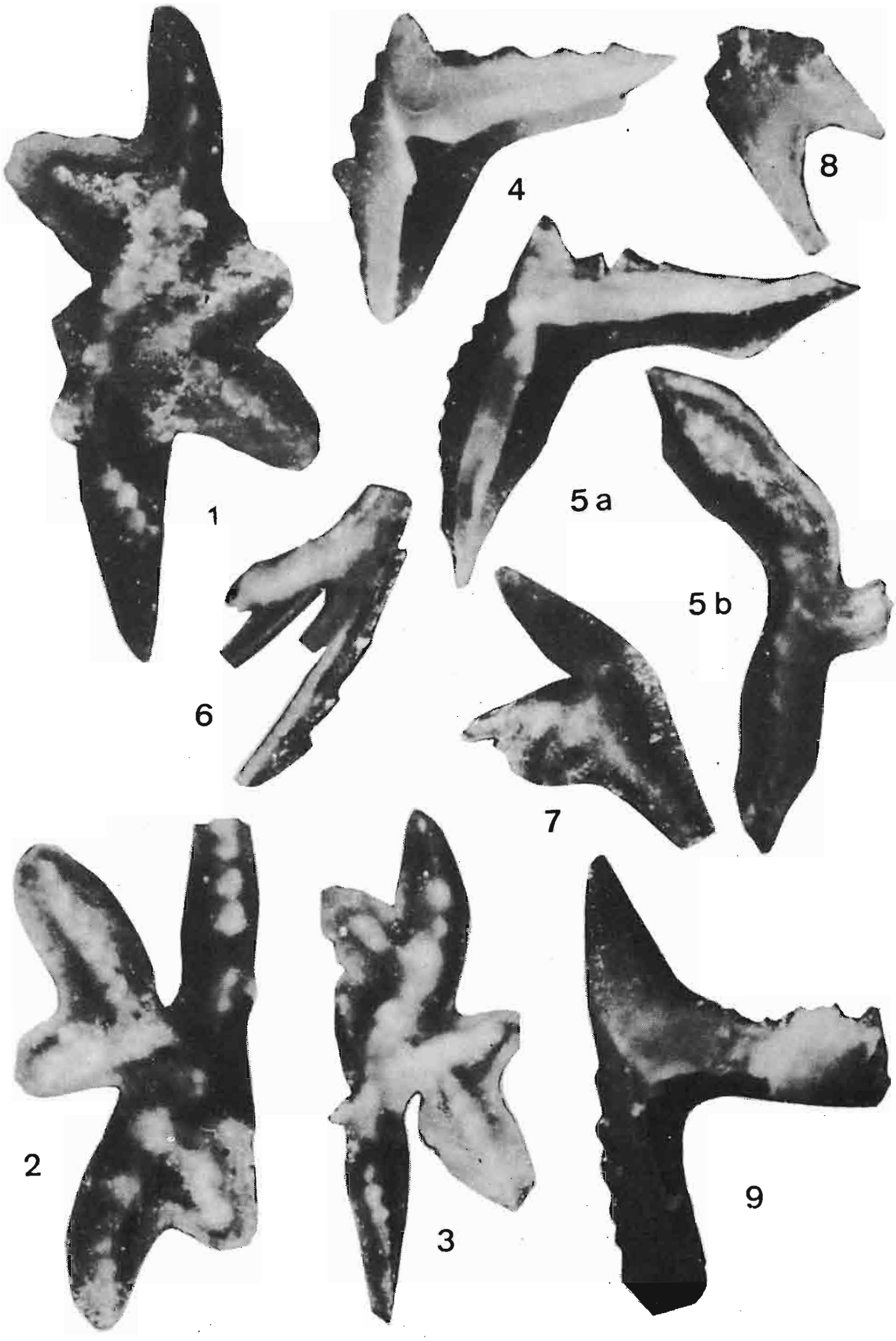
Górnoordowicki wiek osadów w rejonie Zawiercia jest słabo udokumentowany z uwagi na niewielką liczbę konodontów. Konodonty przewodnie napotkano jedynie w profilu RK 2. Na głęb. 1154,2–1155,4 m znaleziono fragmentarycznie zachowany okaz najprawdopodobniej reprezentujący *Amorphognathus ? superbus* (Rhodes), a na głęb. 1152,4–1154,0 m *Ozarkodina pseudotypica* Lindström. Osady te należą zapewne do najwyższego karadoku bądź dolnego aszgilu.

Najwyższa część serii węglanowej została zaliczona do syluru. W profilach RK 5 (1151,0–1153,0 m) i RK 6 (958,0–959,0 m) rozpoznano *Pterospathodus procerus* (Walliser), który jest jednym z gatunków wyznaczających konodontowy poziom amorphognathoides. Dolna granica tego poziomu odpowiada granicy landower – wenlok. Tylko w profilu RK 6 (953,0–954,0 m) rozpoznany został poziom sagitta odpowiadający najwyższemu wenlokowi i najniższej części dolnego ludlowu. Ustalenia te oparto na fakcie znalezienia w osadach *Ozarkodina rhenana* (Walliser). Charakterystyczną cechą zespołu konodontów występujących w osadach serii węglanowej syluru jest wyraźne zdominiowanie przez konodonty typu pojedynczego stożka, przy czym tylko *Drepanodus aduncus* Nicoll et Rexroad jest typowo sylurski, natomiast pozostałe znane są od środkowego ordowiku.

Ordowicko-sylurska seria węglanowa rejonu Zawiercia leży z niezgodnością kątową i stratygraficzną na różnych ogniwach kambru i ?prekambru osadowego. Jest to przejaw działalności ruchów tektonicznych fazy sandomierskiej z pogranicza tremadoku i arenigu. Sedymentacja tych węglanowych osadów rozpoczęła się prawdopodobnie w arenigu. Obejmowała osady ordowiku oraz dolnego syluru. W profilach brak jest prawdopodobnie ciągłości stratygraficznej między ordowikiem górnym a dolnym sylurem, przy czym luka obejmowała prawdopodobnie wyższy aszgil i niższy llandower. Profil ordowiku rejonu Zawiercia reprezentuje asocjację węglanową niewielkiej miąższości, powstałą przy powolnej akumulacji osadów, co upodabnia go do ordowiku centralnej części platformy prewendyjskiej na obszarze Polski.

TABLICA I

Fig. 1. *Amorphognathus inaequalis* Rhodes
RK 2 borehole, depth 1177.1–1178.9 m
Otwór RK 2, głęb. 1177,1–1178,0 m
Figs 2, 3. *Amorphognathus tvaerensis* Bergström
RK 2 borehole, 2 — depth 981.0–982.0 m, 3 — depth 983.0– 984.0 m
Otwór RK 6, 2 — głęb. 981,0–982,0 m, 3 — głęb. 983,0– 984,0 m
Fig. 4. *Ambalodus triangularis* Branson et Mehl subsp. *erraticus* Bergström
RK 6 borehole, depth 977.0–978.0 m
Otwór RK 6, głęb. 977,0–978,0 m
Fig. 5a,b. *Ambalodus triangularis* Branson et Mehl subsp. *suecicus* Bergström
5a — side view, 5b — oral view; RK 6 borehole, depth 977.0–978.0
5a — obraz widziany z boku, 5b — od strony powierzchni oralnej; otwór RK 6, głęb. 977,0–978,0 m
Fig. 6. *Tetraprioniodus asymmetricus* Bergström
RK 6 borehole, depth 981.0–982.0 m
Otwór RK 6, głęb. 981,0–982,0 m
Fig. 7. *Oistodus robustus* Bergström
RK 6 borehole, depth 983.0–984.0 m
Otwór RK 6, głęb. 983,0–984,0 m
Fig. 8. *Tvaerenognathus ordovicica* Bergström
RK 6 borehole, depth 983.0–984.0 m
Otwór RK 6, głęb. 983,0–984,0
Fig. 9. *Prioniodus variabilis* Bergström
RK 6 borehole, depth 983.0–984.0 m
Otwór RK 6, głęb. 983,0–984,0 m



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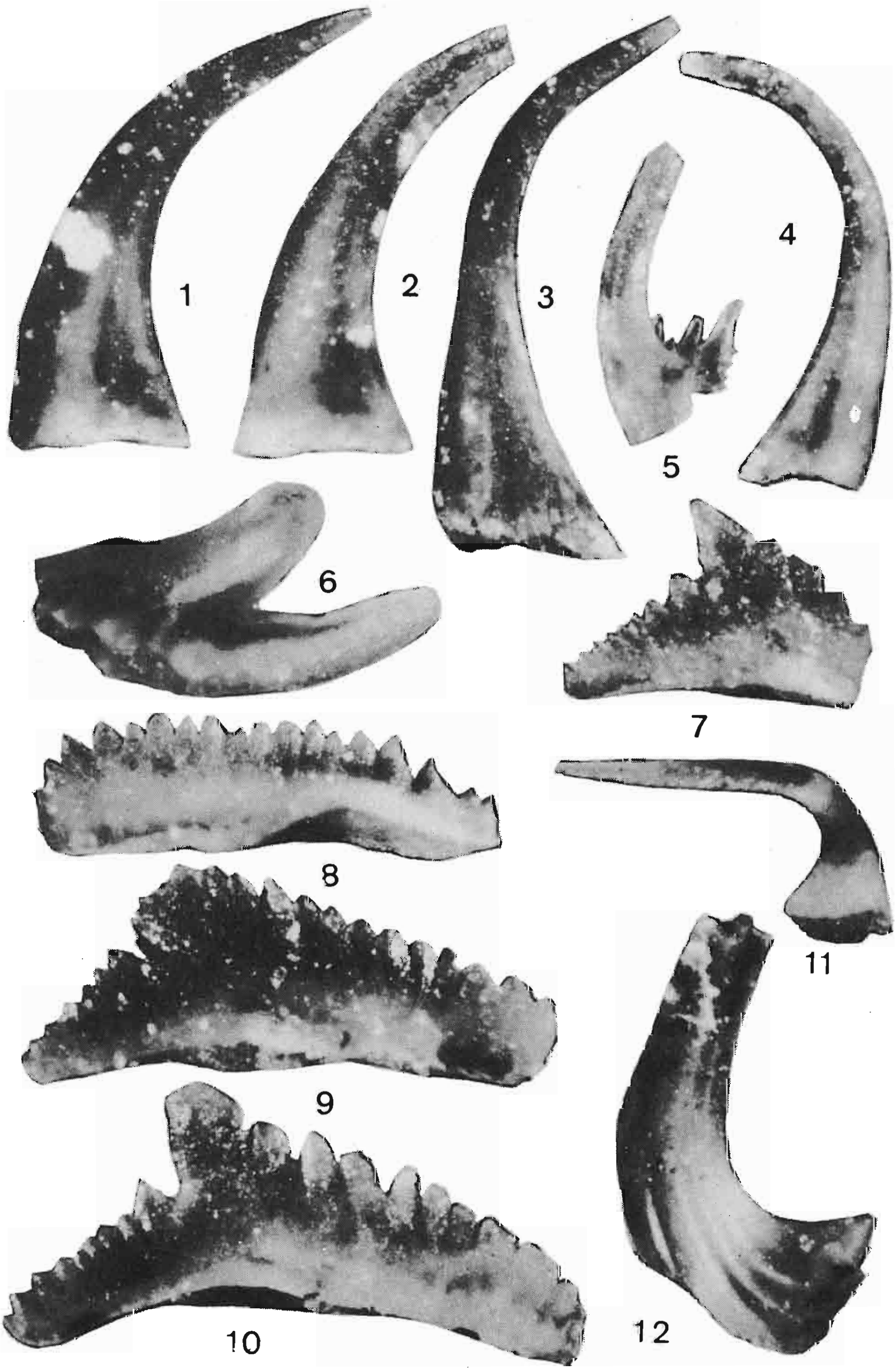
Figs 1, 2. *Panderodus simplex* (Branson et Mehl)
RK 5 borehole, depth 1139.5–1141.4 m
Otwór RK 5, głęb. 1139,5–1141,4 m
Fig. 3. *Panderodus gracilis* (Branson et Mehl)
RK 1 borehole, depth 1133.4–1136.0 m
Otwór RK 1, głęb. 1133,4–1136,0 m
Fig. 4. *Panderodus unicostatus* (Branson et Mehl)
RK 5 borehole, depth 1162.7–1164.5 m
Otwór RK 5, głęb. 1162,7–1164,5 m
Fig. 5. *Plectodina breviramea* (Walliser)
RK 6 borehole, depth 969.0–970.0 m
Otwór RK 6, gleb. 969,0–970,0 m
Fig. 6. *Amorphognathus* sp. indet.
RK 6 borehole, depth 986.0–987.0 m
Otwór RK 6, głęb. 986,0–987,0 m
Fig. 7. *Ozarkodina edithae* Walliser
RK 6 borehole, depth 953.0–954.0 m
Otwór RK 6, głęb. 953,0–954,0 m
Fig. 8. *Spathognathodus sagitta rhenanus* Walliser
RK 6 borehole, depth 953.0–954.0 m
Otwór RK 6, głęb. 953,0–954,0 m
Figs 9, 10. *Ozarkodina ?typica* Branson et Mehl
RK 6 borehole, depth 953.0–956.0 m
Otwór RK 6, głęb. 953,0–956,0 m
Fig. 11. *Drepanodus longibasis* Lindström
RK 4 borehole, depth 642.2–643.1 m
Otwór RK 4, głęb. 642,2–643,1 m
Fig. 12. *Walliserodus costatus* Dzik
RK 5 borehole, depth 1198.1–1199.1 m
Otwór RK 5, głęb. 1198,1–1199,1 m



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Figs 1, 2. *Pterospathodus pennatus procerus* (Walliser)
Oral view: 1 — RK 6 borehole, depth 958.0–959.0 m, 2 — RK 5 borehole, depth 1151,0–1152,0 m
Powierzchnia oralna: 1 — otwór RK 6, głęb. 958,0–959,0 m, 2 — otwór RK 5, głęb. 1151,0–1152,0 m
Fig. 3. *Protopanderodus rectus* Lindström
RK 4 borehole, depth 643.1–644.9 m
Otwór RK 4, głęb. 643,1–644,9 m
Fig. 4. *Lonchodina ?greilingi* Walliser
RK 6 borehole, depth 953.0–954.0 m
Otwór RK 6, głęb. 953,0–954,0 m
Fig. 5. *Ambalodus triangularis* Branson et Mehl
RK 6 borehole, depth 967.0–968.0 m
Otwór RK 6, głęb. 967,0–968,0 m
Fig. 6. *Distacodus procerus* Ethington
RK 3 borehole, depth 1035.2–1037.2 m
Otwór RK 3, głęb. 1035,0–1037,2 m
Figs 7, 8. *Acodus inornatus* Ethington
7 — RK 1 borehole, depth 1146.6–1148.6 m; 8 — RK 6 borehole, depth 936.0–937.0 m
7 — otwór RK 1, głęb. 1146,6–1148,6 m; 8 — otwór RK 6, głęb. 936,0–937,0 m
Fig. 9. *Paltodus fragilis* Branson et Mehl
RK 5 borehole, depth 1135.9–1136.9 m
Otwór RK 5, głęb. 1135,9–1136,9 m
Fig. 10. *Neoprioniodus bicurvatoides* Walliser
RK 6 borehole, depth 953.0–954.0 m
Otwór RK 6, głęb. 953,0–954,0 m
Figs 11, 12. *Distacodus obliquicostatus* (Branson et Mehl)
11 — RK 3 borehole, depth 1135.2–1137.2 m; 12 — RK 6 borehole, depth 936.0–937.0 m
11 — otwór RK 3, głęb. 1135,2–1137,2 m; 12 — otwór RK 6, głęb. 936,0–937,0 m
Fig. 13. *Ambalodus* sp. indet.
RK 6 borehole, depth 963.0–964.0 m
Otwór RK 6, głęb. 963,0–964,0 m
Fig. 14. *Tetraprioniodus asymmetricus* Bergström
RK 1 borehole, depth 1213.8–1219.4 m
Otwór RK 1, głęb. 1213,8–1219,4 m

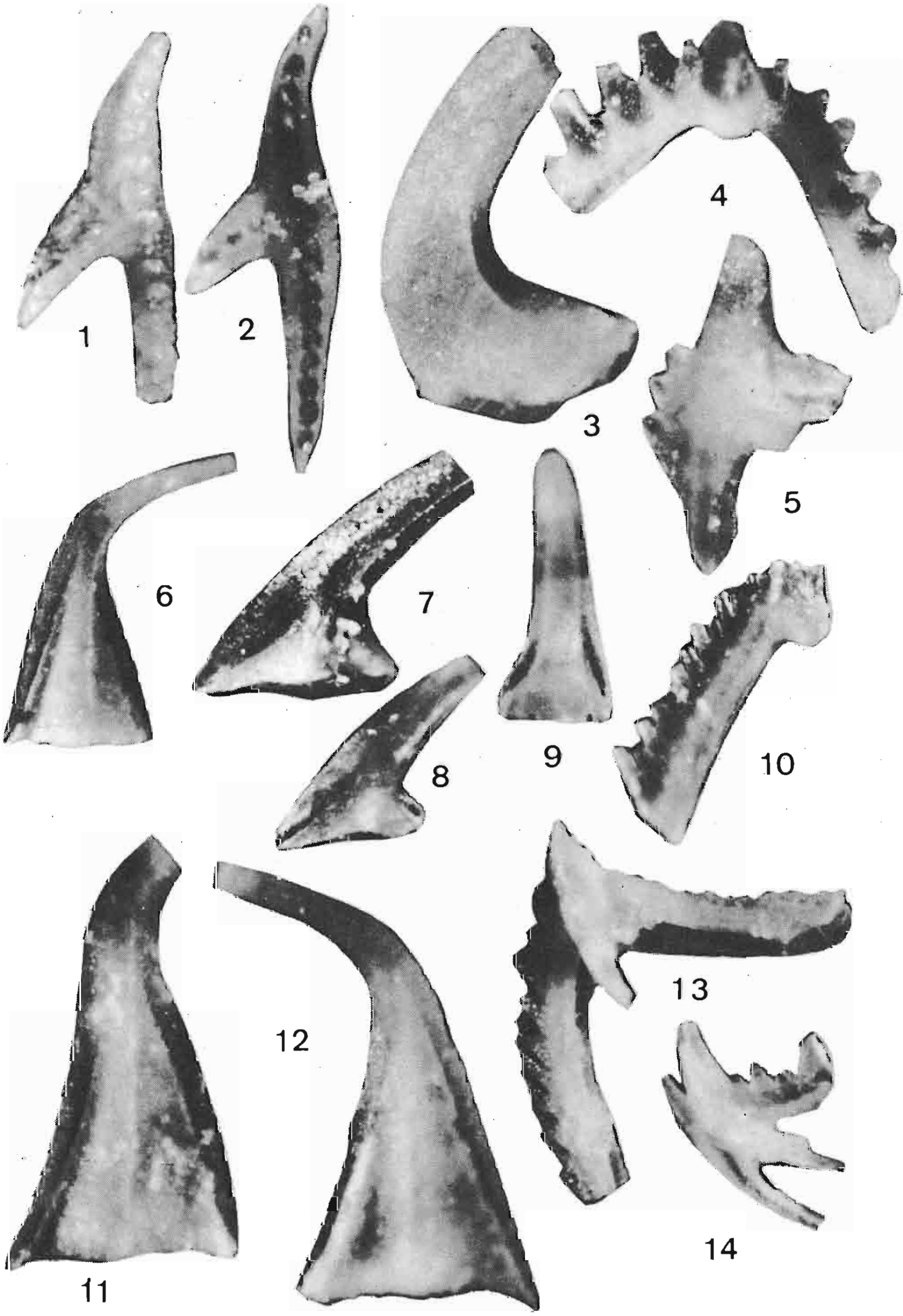

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Fig. 1a–f. *Amorphognathus tvaerensis* Bergström

1a — amorphognathiform element; 1b–e — ambalodontiform element, 1f — hibbardelliform element; RK 6 borehole, depth 977.0–984.0 m

1a — element amorfognatidowy; 1b–e — elementy ambalodidowe, 1f — element hibbardellidowy; otwór RK 6, głęb. 977,0–984,0 m

Fig. 2. *Amorphognathus inaequalis* Rhodes

Amorphognathiform element, RK 2 borehole, depth 1177.1–1178.9 m

Element amorfognatidowy, otwór RK 2, głęb. 1177,1–1178,9 m

Fig. 3a,b. *Amorphognathus ?kielcensis* Dzik

3a — amorphognathiform element, 3b — ambalodontiform element; RK 6 borehole, depth 986.0–987.0 m

3a — element amorfognatidowy, 3b — element ambalodidowy; otwór RK 6, głęb. 986,0–987,0 m

Fig. 4a–d. *Prioniodus (Baltoniodus) variabilis* Bergström

4a–c — prioniodontiform elements, 4d — oistodontiform element; RK 2 borehole, depth 1177.1–1178.9 m

4a–c — elementy prioniodidowe, 4d — element oistodidowy; otwór RK 2, głęb. 1177,1–1178,9 m

Fig. 5a, b. *Ambalodus triangularis* Branson et Mehl s.f.

RK 6 borehole, depth 964.0–968.0 m

Otwór RK 6, głęb. 964,0–968,0 m

Figs 6, 7. *Paltodus fragilis* Branson et Mehl

RK 6 borehole, depth 941.0–943.0 m

Otwór RK 6, głęb. 941,0–943,0 m

Figs 8–10. *Cornuodus longibasis* Lindström

RK 5 borehole, depth 1182.0–1184.0 m

Otwór RK 5, głęb. 1182,0–1184,0 m

Figs 11, 12. *Distacodus obliquicostatus* Branson et Mehl

RK 6 borehole, depth 949.0–950.0 m

Otwór RK 6, głęb. 949,0–950,0 m

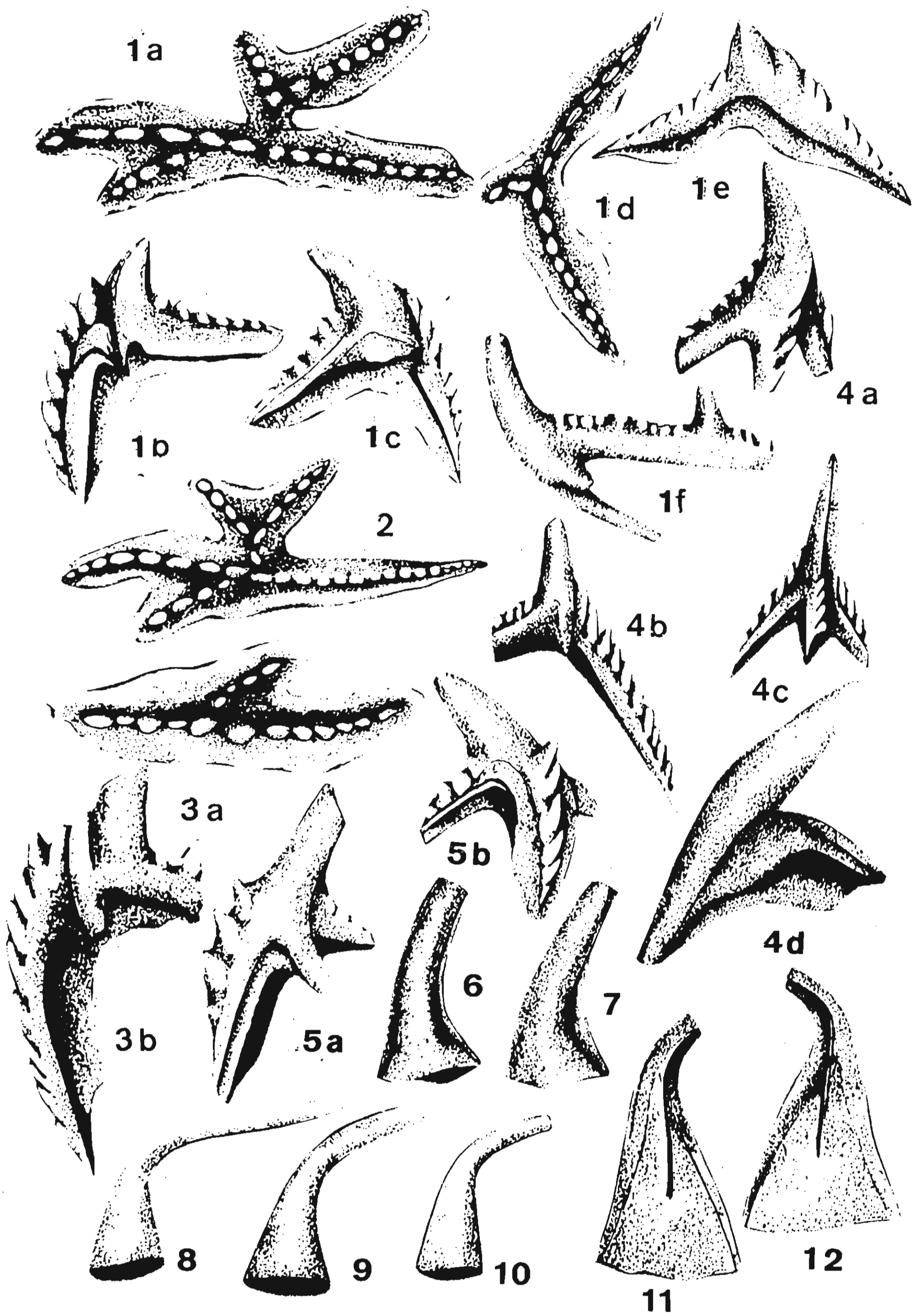

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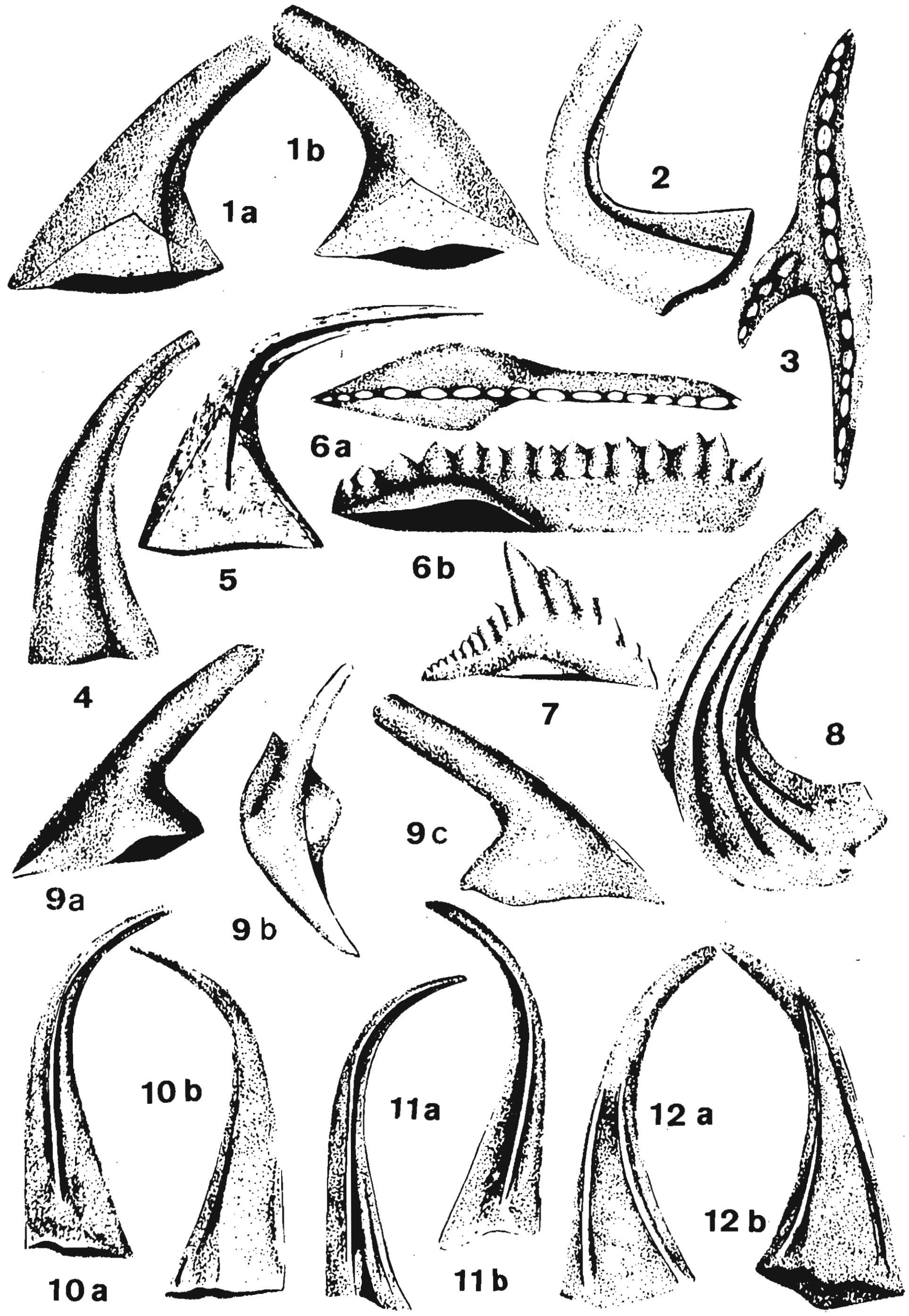
Fig. 1a, b. *Acodus inornatus* Ethington
RK 6 borehole, depth 944.0–945.0 m
Otwór RK 6, głęb. 944,0–945,0 m
Fig. 2. *Protopanderodus rectus* (Lindström)
RK 4 borehole, depth 643.1–644.9 m
Otwór RK 4, głęb. 643,1–644,9 m
Fig. 3. *Pterospathodus pennatus procerus* Walliser
RK 6 borehole, depth 958.0–959.0 m
Otwór RK 6, głęb. 958,0–959,0 m
Fig. 4. *Panderodus simplex* (Branson et Mehl)
RK 1 borehole, depth 1146.6–1148.6 m
Otwór RK 1, głęb. 1146,6–1148,6 m
Fig. 5. *Distacodus procerus* Ethington
RK 3 borehole, depth 1035.2–1037.2 m
Otwór RK 3, głęb. 1035,2–1037,2 m
Fig. 6a, b. *Spathognathodus sagitta rhenanus* Walliser
RK 6 borehole, depth 953.0–954.0 m
Otwór RK 6, głęb. 953,0–954,0 m
Fig. 7. *Ozarkodina edithae* Walliser
RK 6 borehole, depth 953.0–954.0 m
Otwór RK 6, głęb. 953,0–954,0 m
Fig. 8. *Protopanderodus varicostatus* (Sweet et Bergström)
RK 4 borehole, depth 640.2–642.2 m
Otwór RK 4, głęb. 640,2–642,2 m
Fig. 9a–c. *Drepanodus aduncus* Nicoll et Rexroad
RK 6 borehole, depth 941.0–942.0 m
Otwór RK 6, głęb. 941,0–942,0 m
Fig. 10a, b. *Panderodus unicostatus* Branson et Mehl
RK 5 borehole, depth 1162.7–1164.6 m
Otwór RK 5, głęb. 1162,7–1164,6 m
Fig. 11a, b. *Panderodus gracilis* (Branson et Mehl)
RK 3 borehole, depth 1031.4–1032.2 m
Otwór RK 3, głęb. 1031,4–1032,2 m
Fig. 12a, b. *Paltodus dyscritus* Rexroad
RK 5 borehole, depth 1139.5–1141.4 m
Otwór RK 5, głęb. 1139,5–1141,4 m



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