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Ordovician between Pilzno and Busko in the Carpathian Foreland (Southern Poland)

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The Ordovician carbonates encountered in the Pilzno 40 borehole at depth of 3593–3733 m have yielded index conodonts and ostracods which enabled to determine the age of the rocks as Llandeilo and Caradoc. Comparison with columns of other 6 boreholes in the area has shown a significant facies differentiation: Lower Ordovician sandstones of the western part pass eastwards into shales. Middle Ordovician shales in the northern sector are replaced by carbonates to the south. Ordovician is preserved in narrow synclines formed during the Caledonian and Early Variscan stages. Earlier, it covered greater areas and was removed by post-Variscan erosion. Ordovician transgression has proceeded from north to south.

INTRODUCTION

The Ordovician rocks are known in the Carpathian Foreland from several boreholes. In the central part of this area these sediments were first found in the Mędrzechów 1 borehole (H. Tomczyk, 1959–1960, 1963; P. Karnkowski, E. Głowacki, 1961; Z. Obuchowicz, 1963) — Fig. 1. Several years later they were pierced in the Zalesie 1 borehole near Szczucin (S. Kwiatkowski *et al.*, 1966), in the Niwki 3 (W. Moryc, 1974) and in the Lubasz 2. Recently they were found in the Pilzno 40 borehole and most probably in the Zgórsko 2 one. The Pilzno 40 column has served as a starting point to correlate the Ordovician sequences in the whole region.

THE PILZNO 40 PROFILE

The Pilzno 40 borehole pierced by the Polish Oil and Gas Company is located in the so-called Miocene "bay" of Pilzno within the border zone of the overthrust Flysch Carpathians (the Skole nappe) with the parautochthonous sediments of the Miocene "bay".

The following sediments were pierced there (Fig. 2):

Under the Quaternary there is a parautochthonous sandy-clayey Miocene series (Upper Badenian) resting on flysch of the Skole Unit. The flysch deposits are shale and sandstone with fucoid marly interbeds which represent the Inoceramus Beds of the Upper Cretaceous. The dips are up to 50°. The flysch deposits are thrust over the sandy-clayey Miocene series (Upper Badenian) of the Zgłobice Unit. The latter rests according to borehole geophysics on similar sediments of probable autochthonous Miocene (there is no core material). The Miocene basement consists of epicontinental Upper Cretaceous marls resting on Upper Jurassic marls and limestones. Below the Jurassic there are clastic sandy-clayey reddish and greenish beds of the Buntsandstein (middle part) which in turn rest on Silurian graptolitic shales and Ordovician limestones, the latter not pierced down to depth of 3733 m.

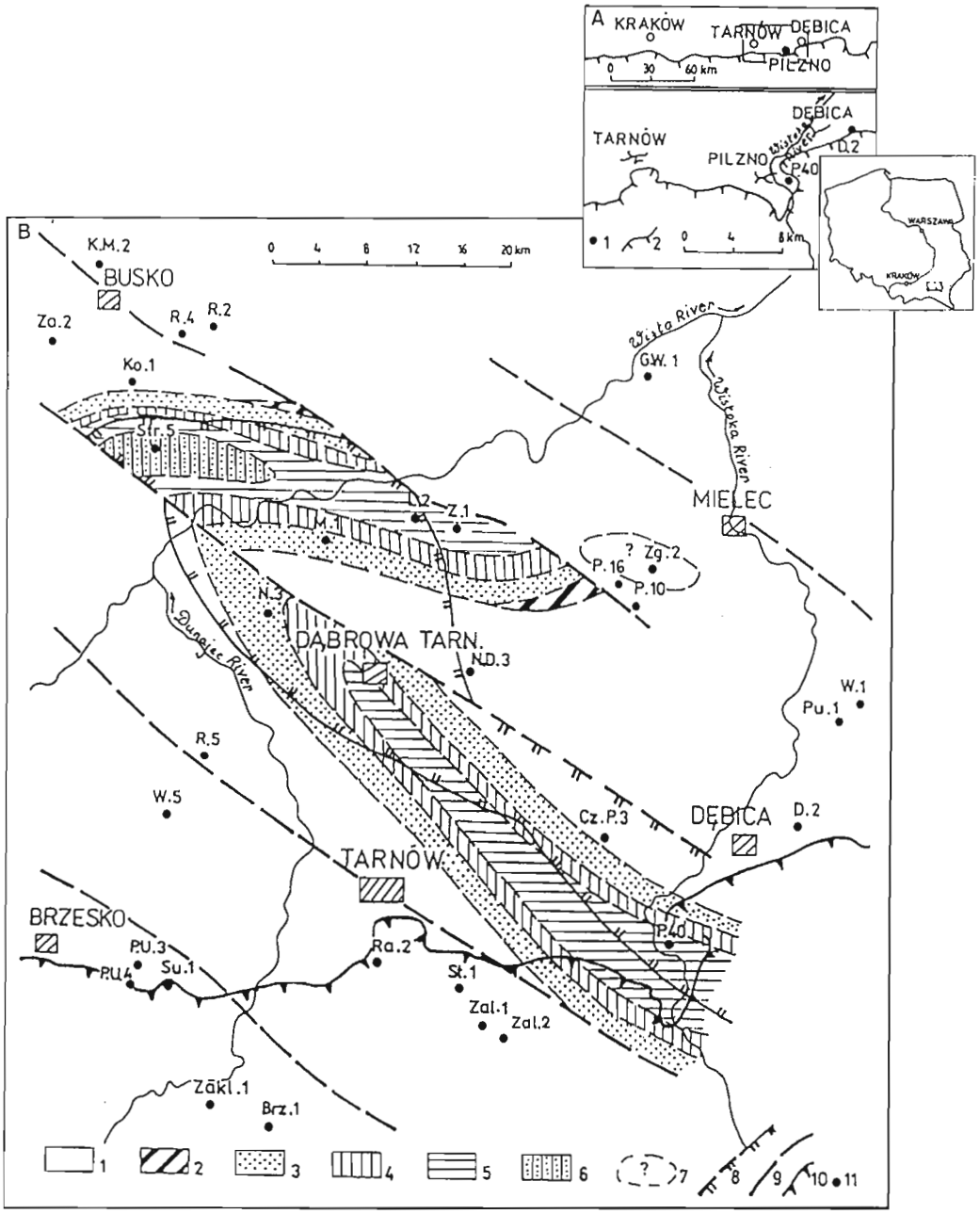

Fig. 1. **A**. Situation sketch-map of the Pilzno 40 borehole

1 — boreholes, 2 — Carpathian overthrust

B. Geological sketch-map of the Ordovician deposits found in the Pilzno–Busko–Mielec area

1 — older rocks (Precambrian), 2 — Tremadoc(?)-Lower Arenig, 3 — Arenig, 4 — Llanvirn-Llandeilo, 5 — Caradoc, 6 — Ashgill, 7 — presumed Ordovician, 8 — Silurian extent, 9 — faults, 10 — Carpathian overthrust, 11 — boreholes in which the Ordovician or older deposits were pierced: Brz. 1 — Brzozowa 1, Cz. P. 3 — Czarna Pilzno 3, D. 2 — Dębica 2, G. W. 1 — Gliny Wielkie 1, Ko. 1 — Kobylniki 1, K. M. 2 — Kostki Małe 2, L. 2 — Lubasz 2, M. 1 — Mędrzechów 1, N. D. 3 — Nieczajna Dolna 3, N. 3 — Niwki 3, P. 40 — Pilzno 40, P. 10 — Podborze 10, P. 16 — Podborze 16, P. U. 3 — Porąbka Uszewska 3, P. U. 4 — Porąbka Uszewska 4, Pu. 1 — Pustków 1, Ra. 2 — Radlna 2, R. 5 — Radłów 5, R. 2 — Radzanów 2, R. 4 — Radzanów 4, St. 1 — Stawiska 1, Str. 5 — Strożyska 5, Su. 1 — Sufczyn 1, W 5 — Waryś 5, W. 1 — Wola Ociecka 1, Za. 2 — Zagość 2, Zakl. 1 — Zakliczyn 1, Zal. 1 — Zalasowa 1, Zal. 2 — Zalasowa 2, Z. 1 — Zalesie 1, Zg. 2 — Zgórsko 2

A. Szkic sytuacyjny otworu wiertniczego Pilzno 40

1 — otwory wiertnicze, 2 — linia nasunięcia Karpat fliszowych

B. Szkic geologiczny utworów ordowiku z obszaru Pilzna–Buska–Mielca

1 — skały starsze (prekambr), 2 — tremadok(?)-dolny arenig, 3 — arenig, 4 — lanwirn-landeil, 5 — karadok, 6 — aszgil, 7 — przypuszczalny ordowik, 8 — zasięg syluru, 9 — uskoki, 10 — linia nasunięcia Karpat fliszowych, 11 — otwory wiertnicze, w których stwierdzono utwory ordowiku lub starsze; objaśnienia symboli otworów — patrz tekst angielski

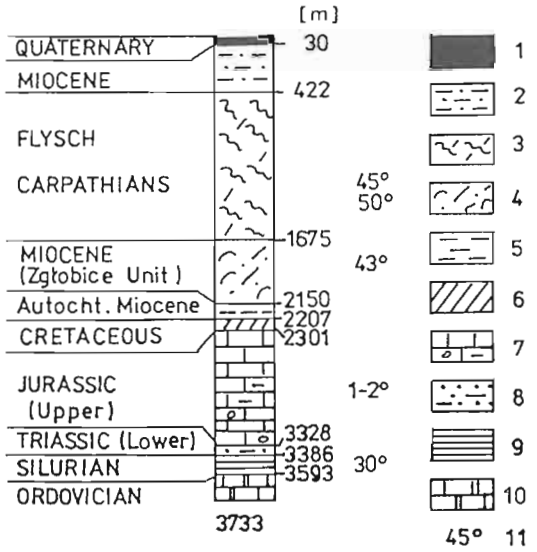

Fig. 2. Stratigraphic column of the Pilzno 40 borehole

1 — weathering loam (Quaternary), 2 — clay with sandstone inliers (Upper Badenian), 3 — shales with sandstones and marly inliers (Inoceramus Beds — Upper Cretaceous), 4 — shales with sandstone interbeds (Badenian) — allochthonous deposits, 5 — claystones, 6 — marls, 7 — organogenic, partly marly nodular limestones, 8 — sandstones with inliers of variegated clays, 9 — claystones and graptolitic shales, 10 — claystones and dolomites, 11 — dips of beds

Profil stratygraficzny otworu Pilzno 40

1 — glina zwietrzelinowa (czwartorzęd), 2 — iłołupki z wkładkami piaskowca (baden górny), 3 — łupki i piaskowce z wkładkami margli (warstwy inoceramowe — kreda górna), 4 — iłołupki z wkładkami piaskowców (baden) — osady allochtoniczne, 5 — iłowce, 6 — margle, 7 — wapienie organogeniczne, miejscami margliste, gruzłowe, 8 — piaskowce z wkładkami iłów pstrych, 9 — iłowce i łupki graptolitowe, 10 — wapienie i dolomity, 11 — upady warstw

ORDOVICIAN LITHOLOGY IN THE PILZNO 40 BOREHOLE

The Ordovician sediments have been found at depth of 3593–3733 m (Fig. 3). These are mostly carbonates in which the following rock complexes can be distinguished on the basis of cores and geophysical logs. The upper part consists of carbonate deposits (3593–3642 m) of similar geophysical characteristics. In a core from the uppermost part of this interval (3598–3607 m) there are vari-coloured, reddish, greenish dolomites showing character of altered rocks (metasomatosis). They are cavernous and interbedded with red-greenish shale in places. They contain veins of white calcite. Next rock interval down (3642–3692 m) these are pinkish-gray, crystalline, mainly nodular limestones. Matrix is composed of dark clay of euxinic character. The rocks are tectonised and small veins of white or pink calcite are common. These rocks have been recognized in two cores (3645–3654 and 3673–3676 m).

Below (3692–3718 m) there is a limestone bed characterized by positive gamma anomaly (Fig. 3). One core has been obtained there (3695–3703 m). These are compact, detrital limestones greenish-gray with pinkish spots. They contain fine white calcite concentrations. Wavy texture is present in some parts of the column. Moulds and destroyed Orthid shells are to be found. Some parts of the limestone are clayey and sandy. In one of such samples (3697 m) the petrographic study revealed a strongly arenaceous marl with abundant quartz and glauconite grains. The quartz grains up to 0.08 mm in diameter (seldom 0.16–0.18 mm) are subangular as a rule. Flakes of biotite, muscovite and feldspar grains are to be found sporadically. Numerous brownish spots point to enrichment of the rock in phosphatic compounds which is supported by positive gamma anomaly. Similar record is known from the phosphorite occurrence chemically documented in the Lower Ordovician sediments of the Lubasz 2 borehole (Fig. 4).

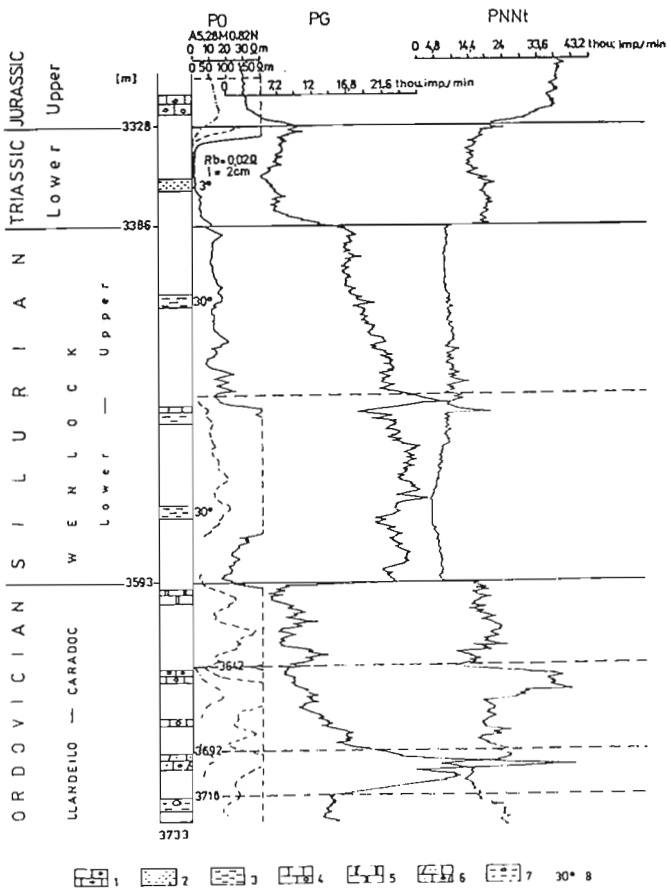

Fig. 3. Lower Palaeozoic deposits in the Pilzno 40 borehole

1 — nodular limestones, 2 — sandstones, 3 — clayey shales and claystones, 4 — crystalline limestones, party nodular, 5 — dolomites, 6 — limestones and marls, partly sandy, traces of phosphorite, 7 — claystones with inliers of nodular silicified limestones, 8 — dips of beds

Utwory dolnopaleozoiczne w otworze wiertniczym Pilzno 40

1 — wapienie gruzłowate, 2 — piaskowce, 3 — łupki ilaste i iłowce, 4 — wapienie krystaliczne, miejscami gruzłowate, 5 — dolomity, 6 — wapienie i margle, miejscami piaszczyste, ślady fosforytów, 7 — iłowce z gruzłowatymi wtrąceniami wapieni zsylifikowanych, 8 — upady warstw

Clayey-carbonate sediments have been stated in the lowermost part of the column (3718–3733 m). Only one core has been obtained from this interval (3720–3728 m). These are greenish-gray somewhat brownish claystones with cherry red spots and numerous nest-like or nodular, less frequently bedded inliers of brownish-gray limestone. The claystones are limeless or only slightly carbonate, dolomitic in places or arenaceous of siltstone character. Petrographic analysis reveals in silty inlier (depth of ca. 3726 m) a clayey or clayey-carbonate matrix with fine needles of mica minerals (mainly muscovite), detrital quartz, fine semisharp-edged glauconite grains and ore minerals. There are circular and oval postorganic pseudomorphoses infilled with chalcedony or with chalcedony rims. The rock is in places almost completely silicified (sponge spiculae).

Carbonate inliers are irregular of various size usually several centimetres in diameter. They make about 30% of the rock volume. These are grayish-brown compact, crystalline silicified limestones or dolomitic limestones and dolostones frequently making nodular-like nests. These limestones are interwoven by calcite and sporadically pyrite veins 1–3 mm in width. Poorly preserved remnants of Orthid brachiopods were found in the lowermost part of the column. Seldom are inliers of gray quartzitic sandstone, 5–10 cm thick, of slightly dolomitic matrix. Petrographic analysis (3721 m) shows that the rock is silicified limestone (micrite infiltrated by silica mainly chalcedony). Round forms of organic origin are to be seen in thin sections (sponge spiculae).

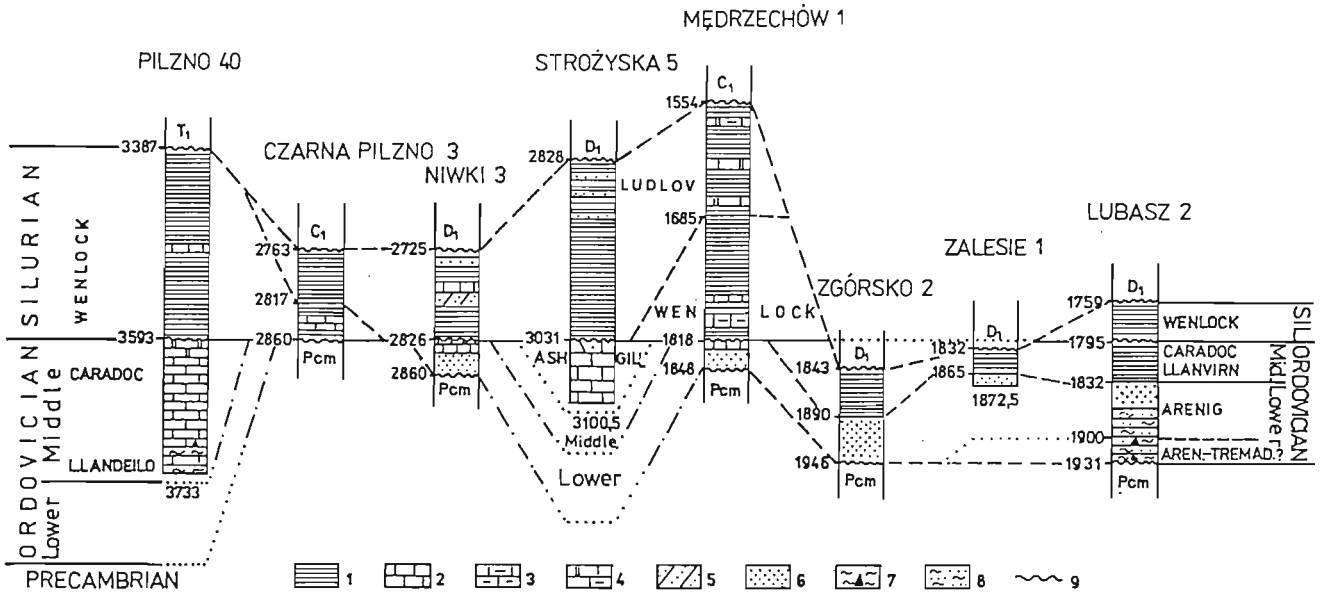

Fig. 4. Correlation of Lower Palaeozoic deposits in the Pilzno–Busko area

1 — shales, 2 — limestones, 3 — clayey limestones, 4 — limestones and dolomites, 5 — quartzitic sandstones, 6 — sandstones, 7 — siltstones with phosphorite inliers, 8 — sandstones and siltstones, 9 — unconformity surfaces, T_1 — Lower Triassic, C_1 — Lower Carboniferous, D_1 — Lower Devonian, Pcm — Precambrian

Korelacja utworów dolnopaleozoicznych z obszaru Pilzna–Buska

1 — łupki, 2 — wapienie, 3 — wapienie ilaste, 4 — wapienie i dolomity, 5 — piaskowce kwarcytowe, 6 — piaskowce, 7 — mułowce z wkładkami fosforytów, 8 — piaskowce i mułowce, 9 — powierzchnie niezgodności, T_1 — trias dolny, C_1 — karbon dolny, D_1 — dewon dolny, Pcm — prekambr

MICROPALAEONTOLOGICAL ANALYSIS

The conodont studies have been done on 18 samples taken from 5 cores of the Pilzno 40 borehole (3598–3728 m). Positive results were obtained from 13 samples (down to depth of 3699.5 m).

Dissolution of the rock samples in order to separate conodonts have been done using ($CH_3ClCOOH$).

The palaeontological material includes 660 specimens the majority of which was good for identification. Natural taxonomy was used in identification of the conodonts. The specific names of specimens determined according to the rules of parataxonomy are marked with abbreviation *s.f.* (*sensu formae*). Aside of conodonts also presence of inarticulate brachiopods, bryozoans, ostracods and gastropods was stated.

The conodonts are well preserved as a rule. The assemblage consists predominantly of forms of single cone and the branching ones. The platform conodonts occur but sporadically and are preserved in fragments.

The carbonate sediments found in the Pilzno 40 borehole at depth of 3598.0–3699.5 m should be determined as Middle Ordovician on the basis of conodonts (Tab. 1). The correlation can be done due to identification of such species as *Baltoniodus variabilis* (Bergström), *Amorphognathus tvaerensis*

Table 1

Conodonts in the Ordovician of the Pilzno 40 borehole

Core interval [m]	Number of box	Interval in box [cm]	Depth calculated [m]	Number of specimens in sample	Identified conodonts
3598–3607	I	50–55	3598.5	28	*Baltoniodus variabilis* (Bergström), *Dapsilodus mutatus* (Branson et Mehl), *Strachanognathus parvus* Rhodes, *Drepanoistodus venustus* (Stauffer), *Cornuodus longibasis* (Lindström), *Amorphognathus* sp., *Panderodus gracilis* (Branson et Mehl)
	II	45–48	3599.45	0	–
	III	15–20	3600.2	0	–
3645–3654	I	40–45	3645.4	12	*Amorphognathus* sp., *Baltoniodus variabilis* (Bergström), *Cornuodus longibasis* (Lindström), *Panderodus gracilis* (Branson et Mehl)
	II	30–35	3646.3	15	*Amorphognathus* sp., *Baltoniodus variabilis* (Bergström), *Cornuodus longibasis* (Lindström), *Drepanoistodus venustus* (Stauffer)
	III	–	3647.5	7	*Baltoniodus variabilis* (Bergström), *Panderodus gracilis* (Branson et Mehl), *Roundya* sp.
	IV	40–45	3648.4	24	*Amorphognathus tvaerensis* Bergström, *Panderodus gracilis* (Branson et Mehl), *Cornuodus longibasis* (Lindström)
	V	75–80	3649.8	182	*Eoplacognathus ?elongatus* (Bergström), *Baltoniodus variabilis* (Bergström), *Amorphognathus tvaerensis* Bergström, *Drepanoistodus venustus* (Stauffer), *Cornuodus longibasis* (Lindström), *Eoplacognathus* sp.
3673–3676	I	60–65	3673.6	65	*Baltoniodus variabilis* (Bergström), *Scabbardella antipes* (Henningsmoen), *Panderodus gracilis* (Branson et Mehl), *Cornuodus longibasis* (Lindström)
	II	60–65	3674.6	55	*Baltoniodus variabilis* (Bergström), *Amorphognathus* sp., *Drepanoistodus venustus* (Stauffer), *Panderodus gracilis* (Branson et Mehl)
3695–3703	I	30–35	3695.3	57	*Baltoniodus variabilis* (Bergström), *Drepanoistodus venustus* (Stauffer), *Panderodus gracilis* (Branson et Mehl)
	II	–	3696.5	25	*Baltoniodus variabilis* (Bergström), *Oistodus parvidentatus* Sergeeva *s.f.*, *Acodus* sp.
	III	55–60	3697.6	160	*Baltoniodus variabilis* (Bergström), *Drepanoistodus venustus* (Stauffer), *Panderodus gracilis* (Branson et Mehl), *Drepanodus homocurvatus* Lindström *s.f.*
	IV	–	3698.5	10	*Drepanoistodus venustus* (Stauffer), *Panderodus gracilis* (Branson et Mehl), *Acodus* sp.
	V	45–50	3699.5	20	*Oistodus parvidentatus* Sergeeva *s.f.*, *Drepanoistodus venustus* (Stauffer), *Cornuodus longibasis* (Lindström)
3720–3728	I	–	3721.0	0	–
	II	–	3723.0	0	–
	III	–	3725.0	0	–

Bergström, *Eoplacognathus ?elongatus* (Bergström) and *Panderodus gracilis* (Branson et Mehl) (Pl. I).

The last mentioned species belongs to the most common conodonts in the Old Palaeozoic sediments. Nevertheless, as it appears for the first time above the lower boundary of the Middle Ordovician its presence excludes Lower Ordovician age of the deposits in question.

Majority of the conodonts in this assemblage belong to the conodont elements (= formal species) included to the multi-element species *Baltoniodus variabilis* (Bergström). These

Table 2

Stratigraphic position of conodonts found in the Ordovician deposits of the Pilzno 40 borehole

British division	Conodont zones and subzones (S. M. Bergström *et al.*, 1985)		Pilzno 40
Ashgill	*ordovicicus*		
	superbus		
Caradoc	*tvaerensis*	*alobatus*	
		gerdae	3598.0 m
		variabilis	
Llandeilo	*anserinus*	*inaequalis*	3699.5 m
		kielcensis	
Llanvirn?	*serra*	*lindstroemi*	
		robustus	
		reclinatus	
		foliaceus	
	suecicus	*sulcatus*	
		gracilis	
Arenig	*variabilis*	*ozarkodella*	
		flabellum	
	flabellum-parva		
	originalis		
	navis-triangularis		
	evae		
	elegans		
	proteus		

are: *Prioniodus variabilis* Bergström *s.f.*, *P. alatus* Hadding *s.f.*, *Oistodus robustus* Bergström *s.f.*, *Paracordylodus lindstroemi* Bergström *s.f.* and *Tetraprioniodus asymmetricus* Bergström *s.f.*

Baltoniodus variabilis (Bergström) is a characteristic species in the Llandeilo and Lower Caradoc (S. M. Bergström, 1971; S. M. Bergström *et al.*, 1985). Using the conodont zonation established for the Middle and Upper Ordovician (S. M. Bergström, 1971) the occurrence of *Baltoniodus variabilis* (Bergström) is associated with the upper part of the *anserinus* Zone (*inaequalis* Subzone) and the lower part of the *tvaerensis* Zone (*variabilis* Subzone — Table 2). This species is particularly common in the Lundibundus Limestone (lowermost Caradoc) of Sweden (Tvaren area) (S. M. Bergström, 1962). It has been described also from the Llandeilo and Lower Caradoc sediments of the British Isles, from the Baltic-Scandinavian region, from Poland and from North America.

In samples from the cores at 3598–3607 and 3645.4–3647.5 m depths (Tab. 1) there were found usually damaged specimens of conodonts of *Amorphognathus* Branson et Mehl. This genus is known from the Upper Llanvirn up to Ashgill. Several short-living species have been distinguished within it which are cosmopolitic. They are very useful in precise stratigraphy.

The fragmentarily preserved specimens of *Amorphognathus* found in samples from depth of 3648.4–3649.8 m belong most probably to the multielement species *Amorphognathus tvaerensis* Bergström. This species is characteristic of conodont assemblages in the Lower Caradoc and is an index taxon for the conodont Zone *tvaerensis* (Tab. 2). It is known from the Caradoc sediments in the Baltic-Scandinavian region, in Poland, in Scotland and in the North America.

Concurrence in the column of the Pilzno 40 borehole at depth of 3645.0–3649.8 m of the species *Baltoniodus variabilis* (Bergström) and *Amorphognathus tvaerensis* Bergström shows that the sediments containing them should be correlated with the uppermost Llandeilo and Lower Caradoc (S. M. Bergström *et al.*, 1985). At depth of 3649.8 m (Tab. 1) there was found damaged specimens of a platform conodonts. There are most probably *Eoplacognathus ?elongatus* (Bergström), the occurrence of which is associated with the Caradoc. In the conodont zonation the stratigraphic range of this taxon (Tab. 2) is confined to the upper part of the *inaequalis* Subzone as well as Subzones *variabilis* and in part *gerdae* (S. M. Bergström *et al.*, 1985). This determination, however, due to bad preservation state is problematic.

Aside of the above mentioned species of conodonts occurring in the carbonate sediments in the Pilzno 40 borehole in the core taken from depth of 3598.0–3699.5 m *Cornuodus longibasis* (Lindström), *Drepanoistodus venustus* (Stauffer), *Dapsilodus mutatus* (Branson et Mehl), *Scabbardella antipes* (Henningsmoen), *Strachanognathus parvus* Rhodes and *Oistodus parvidentatus* Sergeeva *s.f.* (Tab. 1) were found. The last mentioned species is known in the Baltic-Scandinavian region from the Upper Arenig (Upper Volkhov) up to the Lower Caradoc (Idavere Stage). The species *Cornuodus longibasis* (Lindström), *Drepanoistodus venustus* (Stauffer) and *Strachanognathus parvus* Rhodes are known from the Arenig up to Ashgill, whereas the occurrence of *Dapsilodus mutatus* (Branson et Mehl) is associated with Middle and Upper Ordovician.

Ostracods were also found in the column studied. Aside of abundant but indeterminable smoothshelled forms there are representatives of genera *Sigmobolbina* Henningsmoen, *Ctenonotella* Opik and *Klimphores* Schallreuter. The occurrence of *Sigmobolbina* is associated with deposition of the Middle and Upper Ordovician. Specimens of those ostracods were found at depth of 3696.5 m. They are strongly damaged, nevertheless, similar to *Sigmobolbina camarota* Jaanusson, described from the Caradoc Chasmops Limestone of Norway. In Lithuania they occur in sediments of Upper Caradoc and Ashgill (Rakvere-Vormsi Stages). Also in Latvia their presence is associated with the Upper Caradoc and Ashgill. They appear there slightly earlier in sediments correlated with the Estonian Keila Stage.

The *Ctenonotella* Opik genus is known so far from the Middle Ordovician only. It was found here in the core from depth of 3695–3703 m. The specimen is slightly damaged but it is possible to classify it to the *Ctenonotella superba* Sarv a species common in the Upper Caradoc in Estonia and Lithuania. The Middle Ordovician age of sediments seems to be supported by a find of ostracods of the species *Klimphores holdrensis* Gailite (3645–3654 m). This species has been described from the uppermost Caradoc and Lower Ashgill (Wormsi-lower part of Pirgu Stages) of Lithuania (N. Sida-

raviczene, 1992), Ashgill of Belarus and Upper Caradoc (Oandu-Rakvere Stages) of northeastern Poland. The so far known stratigraphic range of the genus *Klimphores* Schallreuter is restricted to the Middle and Upper Ordovician.

Summing up it should be said that the deposits pierced in the Pilzno 40 borehole (3598–3703 m) maybe classified on the basis of conodont and ostracod fauna to the Middle Ordovician: Lower Caradoc and Llandeilo. Exact boundaries of this interval determined on the basis of logs of geophysical measurements correspond to depth of 3593–3718 m (Fig. 3). The underlying clayey-carbonate sediments (3718–3733 m) do not contain fossils hence its age cannot be determined. Similar lithology and presence of substance of organic origin suggest their Ordovician age. On that basis these sediments have been classified to Llandeilo as well, although it is not out of question that they may represent Llanvirn, or they may be older.

COMPARISON OF THE ORDOVICIAN DEPOSITS FROM BOREHOLES IN THE CENTRAL PART OF THE CARPATHIAN FORELAND

In the central part of the Carpathian Foreland the Ordovician strata have been encountered so far in 7 boreholes (Figs. 1B and 4).

The oldest deposits of this system are known from the Lubasz 2 borehole. In the lower part (1900–1931 m) (Fig. 4) there are sandstones with glauconite, greenish-gray and conglomerates containg pebbles of quartzite, sandstone and claystone with phosphorite concretions. Remnants of fossils determined as *Lingulella* sp., *Acrotreta* sp. and "*Obolus*" sp. were found there. On the basis of lithology and the above mentioned fossil remains one may suppose that these sediments belong to Early Ordovician. In the opinion of H. Tomczyk (oral communication) they may represent the Upper Tremadoc *Thysanotos siluricus* Zone. Even in the case they would be younger than Tremadoc, in the light of geophysical logs they should be older than the Upper Arenig sandstone found in the Mędrzechów 1 and Niwki 3 boreholes (Fig. 4)

In the Mędrzechów 1 borehole the Ordovician sediments have been long recognized (P. Karnkowski, E. Głowacki, 1961; H. Tomczyk, 1963). These are mainly sandstones, with glauconite, in the upper part also limestones. H. Tomczyk (*op. cit.*) has determined their age as Upper Arenig. Analogous rocks pierced in the Niwki 3 borehole (W. Moryc, 1974) are most probably of similar age. Thus it seems reasonable to correlate the Ordovician deposits from the Mędrzechów 1 and Niwki 3 boreholes with the sandstone of the Lubasz 2 borehole marked on geophysical logs, the upper boundary of which i.e. the top of the Arenig lies at depth of 1832 m.

This boundary according to geophysical logs should correspond to sandstone (Fig. 4) the top of which has been pierced in the Zalesie 1 borehole at depth of 1865 m. Above that boundary in both boreholes there occur clayey-arenaceous sediments at bottom and higher up — argillaceous ones. Graptolites were found in the upper part of this complex pointing to Lower Caradoc and in the lower part — of the Arenig-Llanvirn boundary (most probable Llanvirn) (S. Kwiatkowski *et al.*, 1966).

A strong positive anomaly in the gamma logs is to be observed in both boreholes Zalesie 1 and Lubasz 2 in the lower part of the clayey complex. It may point to rocks rich in phosphatic compounds similar to those ones described above from older members of Middle Ordovician in the Pilzno 40 borehole (Fig. 3). These facts suggest that also in the boreholes Lubasz 2 and Zalesie 1 the clayey complex maybe of Middle Ordovician age as well (Lower Caradoc-Llandeilo or possibly Llanvirn).

Similar profile of probable Ordovician age is recognized in the Zgórsko 2 borehole (Fig. 4). No core was obtained there (traces of shale in the upper part) but similarity of geophysical logs to the Zalesie 1 and Lubasz 2 boreholes allows to put a boundary at depth about 1890 m between sandstone of probable Lower Ordovician age and the clayey complex of presumable Middle Ordovician age.

Clayey sediments of probable Lower Caradoc age are younger members in the area in question. Those are, however, not the youngest ones of the Ordovician as in the Strożyska 5 borehole (Figs. 1B and 4) where under the Ludlow graptolite shales, crystalline and marly limestones were stated the age of which is probably Upper Ashgill (W. Bednarczyk *et al.*, 1968). These sediments were not pierced to the bottom thus their relation to the older Upper Ordovician members is unknown. Carbonate sediments of Upper and Middle Caradoc age are known from the Pilzno 40 borehole. Clayey facies of that age is known from the Lubasz 2 and Zalesie 1 boreholes and from the drillings located further east in the area of Sędziszów–Rzeszów (W. Moryc, 1992, 1996).

In the light of the so far known data a distinct facies differentiation is to be observed in this area.

In the Lower Ordovician in the Lubasz–Mędrzechów–Niwki zone an arenaceous facies prevails which further east in the Nosówka area — according to geophysical logs — passes to more clayey facies. This is proved by the results of the Dobromil Strzelbice 33 borehole in the Ukraine (D. M. Drygant, L. T. Boychevskaya, 1984) in which clayey facies of the Arenig documented by graptolites and conodonts occurs.

Greater facies differentiation is marked in the Middle Ordovician. In the northern part of the area within the zone Lubasz–Zalesie and Będziemyśl 3–Podgórze 1–Nosówka–Kielanówka the Middle Ordovician (Caradoc-Llandeilo-Llanvirn) is developed in clayey facies with graptolites (very rare marly limestone inliers). In the south almost entirely carbonates occur as it is shown by Pilzno 40 borehole. The limestones of Upper Ashgill in the Strożyska 5 borehole can be possibly a continuation of that facies as it is the case farther north-west in the area of the Małopolska Massif near Zawiercie, Mrzygłód and Myszków. The carbonate Ordovician sequence there embraces also deposits of Early Ordovician (K.

Piekarski, A. Siewniak-Witruk, 1978; A. Piekarski *et al.*, 1982; M. Nehring-Lefeld *et al.*, 1992).

The results obtained so far allow to present a preliminary geological sketch and presumable distribution of the Ordovician deposits in the Carpathian Foreland. The Ordovician strata are preserved in two zones (Fig. 1B) — in the northern part in a zone Strożyska 5, Zalesie 1 and probably Zgórsko 2 boreholes and in the central part from Niwki 3 up to Pilzno 40. Farther east they continue south of Dębica, Sędziszów and Rzeszów (W. Moryc, 1992, 1996). Those are relic occurrences that escaped pre-Silurian and later erosion. Primarily they made presumably more or less continuous cover — though not thick — in the whole area of the Małopolska Massif and the adjacent areas in the Miechów Basin as well as the neighbouring in the north and east areas of the Polish Lowlands.

The present-day distribution of the Ordovician deposits is limited to synclinal zones that were formed most probably during the Taconian phase and then established by later Late Caledonian and Bretonian phases. Lack of Ordovician deposits in the Czarna–Pilzno 3 borehole is remarkable. In the light of their presence at Pilzno 40 and Niwki 3 it should not be a result of primary absence but maybe caused by pre-Silurian erosion. The erosion of that time is well marked in the whole area as various Ordovician levels are present under the Silurian deposits. This is well illustrated by such boreholes as Mędrzechów 1 and Niwki 3 in which under the Silurian the Upper Arenig sediments occur and at Lubasz 2, Zalesie 1, Pilzno 40 and probably Zgórsko 2 in which Caradoc sediments are to be found under the Silurian. At Strożyska 5 Upper Ashgill occurs under the Silurian.

The Ordovician fields shown on Figure 1B are limited by boreholes that have reached Precambrian rocks. Cambrian sediments do not occur in the area.

The synclinal fields of the Ordovician are limited by the Lower Ordovician arenaceous sediments (Tremadoc?-Arenig). The axial parts are infilled with Caradoc sediments and at Strożyska 5 — of the Upper Ashgill.

The results obtained so far enable to draw conclusions about the transgression directions of the Ordovician sea in the area.

The oldest Ordovician sediments are conglomeratic-arenaceous ones with phosphorites known from the northern part of the area only (Lubasz 2, possibly also Zalesie 1 and Zgórsko 2 boreholes). Regardless of whether these deposits represent Upper Tremadoc or Lower Arenig it seems undoubtful that those are members older than the Upper Arenig ones known from the Mędrzechów 1 and Niwki 3 boreholes. This fact univocally shows that the transgression has proceeded from north to south. The regional premises also support this thesis. The oldest Ordovician sediments (Tremadoc) crop out on the northern slope of the Łysogóry part of the Holy Cross Mts. and at Lubaczów (H. Tomczyk, 1962,1963,1974; E. Tomczykowa, H. Tomczyk, 1968). Farther south on the southern slope of Łysogóry and in the Kielce region younger Ordovician transgressive sediments crop out. Those are arenaceous rocks from Międzygórze (W. Bednarczyk, 1964, 1967, 1981). They represent higher members of the Tremadoc (or the lowest Arenig). These deposits can be correlated with the phosphate-bearing ones of the lowermost part of the Ordovician in the Lubasz 2 borehole.

Similar overlapping character of the Ordovician deposits is marked near Lubaczów (H. Tomczyk, *op. cit.*) as well as in the Miechów Basin as it comes from analysis of the Jaronowice IG 1 and Książ Wielki IG 1 boreholes (H. Jurkiewicz, 1975). These facts point to greater uplift of the southern part of the Małopolska Massif prior to the Ordovician which retarded the Ordovician transgression.

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REFERENCES

BEDNARCZYK W. (1964) — The stratigraphy and fauna of the Tremadocian and Arenigian (Olandian) in the Kielce region of the Holy Cross Mountains (Middle Poland) (in Polish with English summary). Biul. Geol. Wydz. Geol. UW, **4**.

BEDNARCZYK W. (1967) — Lithology of the Lower Ordovician (Oelandian) in the Kielce region of the Holy Cross Mts. (in Polish with English summary). Biul. Geol. Wydz. Geol. UW, **8**.

BEDNARCZYK W. (1981) — Stratygrafia ordowiku Gór Świętokrzyskich. Przew. 53 Zjazdu Pol. Tow. Geol., p. 35–41. Kielce 6–8.09.1981.

BEDNARCZYK W., KOREJWO K., ŁOBANOWSKI H., TELLER L. (1968) — Stratigraphy of the Paleozoic sediments from borehole Strożyska 5 (Miechów Trough, S Poland) (in Polish with English summary). Acta Geol. Pol., **18**, p. 677–689, no. 4.

BERGSTRÖM S. M. (1962) — Conodonts from the Lundibundus Limestone (Middle Ordovician) of the Tvaren area (SE Sweden). Arkiv Miner. Geol., **3.1**.

BERGSTRÖM S. M. (1971) — Conodont biostratigraphy of the Middle and Upper Ordovician in Europe and Eastern North America. In: Symp. on Conodont Biostratigraphy (eds. W. C. Sweet, S. M. Bergström). Mem. Geol. Soc. Amer., **127**, p. 83–161.

BERGSTRÖM S. M. *et al.* (1985) — Conodonts of the Cambrian and Ordovician systems from the British Isles. In: A stratigraphical index of conodonts (eds. A. C. Higgins, R. L. Austin), p. 32–67.

DRYGANT D. M., BOYCHEVSKAYA L. T. (1984) — Pervaya nakhodka nižneordovikskich graptolitov i konodontov v Ukrainskikh Karpatakh. Dokl. Nauk USSR, Ser. B, p. 8–11, no. 6.

JURKIEWICZ H. (1975) — The geological structure of the basement of the Mesozoic in the central part of the Miechów Trough (in Polish with English summary). Biul. Inst. Geol., **283**, p. 5–83.

KARNKOWSKI P., GŁOWACKI E. (1961) — Geological structure of sub-Miocene sediments of the Middle Carpathian Foreland (in Polish with English summary). Kwart. Geol., **5**, p. 372–419, no. 2.

KWIATKOWSKI S., MORYC W., TOMCZYK H. (1966) — Palaeozoic deposits pierced by the borehole Zalesie 1 near Szczucin (in Polish with English summary). Kwart. Geol., **10**, p. 283–295, no. 2.

MORYC W. (1974) — Stratigraphy of the geological formations in the deep borehole Niwki 3 near Dąbrowa Tarnowska (in Polish with English summary). Zesz. Nauk. AGH, **412**, Geol., no. 19, p. 87–106.

MORYC W. (1992) — Budowa geologiczna utworów podłoża miocenu w rejonie Sędziszów Młp.–Rzeszów i ich perspektywiczność. Nafta-Gaz, **48**, p. 205–223, no. 9, 10.

MORYC W. (1996) — Budowa geologiczna podłoża miocenu w rejonie Pilzno–Dębica–Sędziszów Młp. Nafta-Gaz, **52**, p. 521–550, no. 12.

NEHRING-LEFELD M., MODLIŃSKI Z., SIEWNIAK-MADEJ A. (1992) — Biostratigraphy of the Old Paleozoic carbonates in the Zawiercie area (NE margin of the Upper Silesian Coal Basin). Geol. Quart., **36**, p. 171–178, no. 2.

OBUCHOWICZ Z. (1963) — Geological structure of the Middle Carpathian Foreland (in Polish with English summary). Pr. Inst. Geol., **30**, part. 4, p. 321–354.

PIEKARSKI K., SIEWNIAK-WITRUK A. (1978) — On the occurrence of Ordovician in the vicinities of Mrzygłód (in Polish only). Prz. Geol., **26**, p. 647–648, no. 11.

PIEKARSKI K., MARKIEWICZ J., TRUSZEL M. (1982) — Lithological-petrographic characteristics of Ordovician strata in the Myszków–Mrzygłód area (in Polish with English summary). Prz. Geol., **30**, p. 340–347, no. 7.

SIDARAVICZENE N. (1992) — Ostrakody ordovika Litwy. Lit. Naucz. Issled. Geol. Inst., p. 7–252.

TOMCZYK H. (1959–1960) — Atlas geologiczny Polski. Zagadnienia stratygraficzno-facjalne. Zesz. 3 — ordowik, zesz. 4 — sylur. Inst. Geol. Warszawa.

TOMCZYK H. (1962) — Stratigraphy of old Palaeozoic sediments from bore-holes at Uszkowce near Lubaczów (in Polish with English summary). In: Księga pamiątkowa ku czci J. Samsonowicza. PAN, Kom. Geol., p. 123–148. Inst. Geol. Warszawa.

TOMCZYK H. (1963) — Ordovician and Silesian in the basement of the Fore-Carpathian Depression (in Polish with English summary). Rocz. Pol. Tow. Geol., **33**, p. 289–320, no. 3.

TOMCZYK H. (1974) — Struktury epok tektonicznych bajkalskiej, kaledońskiej i waryscyjskiej. Góry Świętokrzyskie. In: Budowa geologiczna Polski, **4** — Tektonika, cz. 1 — Niż Polski, p. 128–197. Inst. Geol. Warszawa.

TOMCZYKOWA E., TOMCZYK H. (1968) — Ordowik. Sylur. In: Budowa geologiczna Polski, **1** — Stratygrafia, cz. 1 — Prekambr i paleozoik, p. 181–304. Inst. Geol. Warszawa.

ORDOWIK MIĘDZY PILZNEM A BUSKIEM NA PRZEDGÓRZU KARPAT

Streszczenie

Opisano rozwój litologiczny utworów środkowego ordowiku z otworu Pilzno 40 i określono ich wiek na podstawie konodontów. Osady te skorelowano z utworami ordowiku z innych otworów ze środkowo-południowej części przedgórza Karpat, a także omówiono stosunek tych utworów do ograniczających je osadów sylurskich i prekambryjskich. Otwór Pilzno 40, odwiercony przez Polskie Górnictwo Naftowe i Gazownictwo — Poszukiwania Nafty i Gazu, Kraków, jest usytuowany w strefie granicznej nasuniętych Karpat fliszowych (płaszczowina skolska) z paraautochtonicznymi utworami miocenu występującymi w tzw. „zatoce" mioceńskiej.

Osady ordowiku stwierdzono w tym otworze na głęb. 3593–3733 m. W interwale tym występują utwory węglanowe, wśród których wyróżniono następujące kompleksy skalne (od góry):

3593–3642 m — osady węglanowe o zbliżonej charakterystyce geofizycznej; w najwyższej części tego kompleksu (3598–3607 m) stwierdzono dolomity pstre, krystaliczne, zbite;

3642–3692 m — wapienie zbite, szaroróżowe i szare, głównie gruzłowe;

3692–3718 m — wapienie zwięzłe, szorstkie, detrytyczne, szarozielone, miejscami zailone i piaszczyste, charakteryzujące się dodatnią anomalią profilowania gamma (fig. 3);

3718–3733 m — utwory iłowcowo-węglanowe.

Osady węglanowe napotkane w otworze Pilzno 40 na głęb. 3598.0–3699.5 m na podstawie analizy biostratygraficznej konodontów zostały zaliczone do środkowego ordowiku (tab. 1). Do przeprowadzenia korelacji upoważniło zidentyfikowanie gatunków: *Baltoniodus variabilis* (Bergström), *Amorphognathus tvaerensis* Bergström, *Eoplacognathus ?elongatus* (Bergström) i *Panderodus gracilis* (Branson et Mehl). Współwystępowanie w profilu tego otworu na głęb. 3645–3654 m *Baltoniodus variabilis* (Bergström) i *Amorphognathus tvaerensis* Bergström wskazuje, iż zawierające je osady winny być skorelowane z najwyższym Llandeilem-dolnym karadokiem.

W środkowej części przedgórza Karpat, między Pilznem a Buskiem utwory ordowickie stwierdzono dotychczas w 7 otworach wiertniczych (fig. 1, 4). W rejonie tym w ordowiku zarysowuje się dość wyraźne zróżnicowanie facjalne. W dolnym ordowiku w strefie Lubasza–Mędrzechowa–Niwek dominują piaskowce, które ku wschodowi w rejonie Nosówki najprawdopodobniej przechodzą w osady bardziej ilaste. Zróżnicowanie facjalne w większym stopniu zaznacza się w środkowym ordowiku. W północnej części obszaru, w strefie Lubasza–Zalesia oraz Będziemyśla 3–Podgórza 1–Nosówki–Kielanówki, środkowy ordowik jest wykształcony w facji ilastej z graptolitami, natomiast w południowej (na co wskazuje jak dotychczas tylko otwór Pilzno 40) występują w tym czasie prawie wyłącznie utwory węglanowe. Być może kontynuacją ich byłyby wapienie górnego aszgilu z otworu Strożyska 5, podobnie jak na masywie małopolskim w rejonie Zawiercia, Mrzygłodu i Myszkowa.

Dotychczasowe wyniki badań umożliwiają przedstawienie wstępnego szkicu geologicznego i przypuszczalnego rozprzestrzenienia utworów ordowickich w środkowej części przedgórza Karpat. Ordowik zachował się w dwóch strefach (fig. 1B): w części północnej, w pasie Strożysk 5, Zalesia 1 i prawdopodobnie Zgórska 2, oraz w części środkowej, od rejonu Niwek 3 po okolice Pilzna 40. Dalej ku wschodowi kontynuują się te utwory na południe od Dębicy, Sędziszowa i Rzeszowa. Są to dziś reliktowe wystąpienia tych utworów, które nie uległy przedsylurskiej i późniejszej erozji, a pierwotnie stanowiły przypuszczalnie dość cienką pokrywę osadową obejmującą cały omawiany obszar masywu małopolskiego i sąsiadującą z nim nieckę miechowską oraz graniczący od północy i wschodu Niż Polski.

Dzisiejsze występowanie utworów ordowiku ogranicza się do stref synklinalnych uformowanych zapewne wstępnie tektoniką takońską, ale ugruntowanych również późniejszą tektoniką i erozją młodokaledońską i bretońską. Płaty synklinalne ordowiku ograniczone są dolnoordowickimi osadami piaszczystymi (?tremadok–arenig), osiowe partie wypełnione są utworami karadoku, a w Strożyskach 5 — aszgilu górnego.

Dotychczasowe wyniki umożliwiają również wyrażenie wstępnych sugestii dotyczących kierunku transgresji morza ordowickiego w tym rejonie. Jak się wydaje, transgresja ta postępowała z północy ku południowi.

EXPLANATIONS OF PLATES

PLATE I

Fig. 1. *Baltoniodus variabilis* (Bergström)

a, b — ambalodontform elements, depth 3696.5—3697.6; c — amorphognathiform element, depth 3646.3 m; d — amorphognathiform element, depth 3649.8 m; e — paracordylodontiform element, depth 3696.5 m; f — tetraprioniodontiform element, depth 3697.6 m; g — oistodontiform element, depth 3697.6 m

Fig. 2. *Scabbardella antipes* (Henningsmoen)

Depth 3673.6 m

Fig. 3. *Panderodus gracilis* (Branson et Mehl)

Depth 3598.5 m

Fig. 4. *Cornuodus longibasis* (Lindström)

Depth 3699.5 m

Fig. 5. *Dapsilodus mutatus* (Branson et Mehl)

Depth 3598.5 m

Figs. 6, 7. *Amorphognathus tvaerensis* Bergström

Amorphognathiform element, damaged specimen; Fig. 6 — depth 3648.4 m, Fig. 7. — depth 3649.8 m

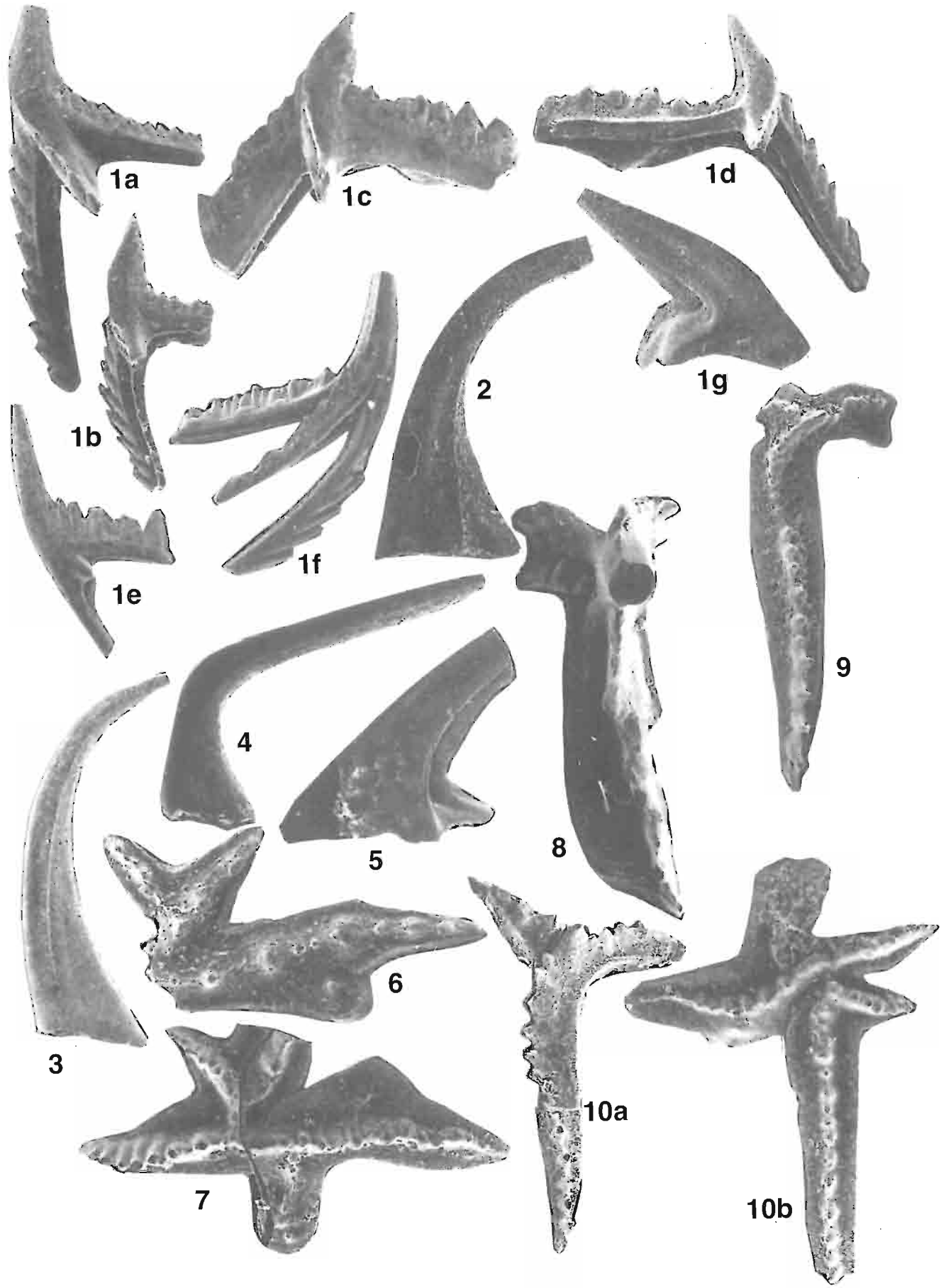
Fig. 8. *Eoplacognathus* sp.

The specimen damaged, depth 3649.8 m

Figs. 9, 10. *Eoplacognathus ?elongatus* (Bergström)

Fig. 9 — depth 3649.8 m; Fig. 10: a — ambalodontiform element, b — amorphognathiform element, depth 3649.0 m

All the conodonts are of Middle Ordovician age and were found in the Pilzno 40 borehole; x 180



Władysław MORYC, Maria NEHRING-LEFELD — Ordovician between Pilzno and Busko in the Carpathian Foreland (Southern Poland)