Geological Quarterly, 1998, 42 (1): 29–40

Ordovician stratigraphy in the Żarki–Mysłów area (NE margin of the Upper Silesian Coal Basin)

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Nehring-Lefeld M., Szymański B. (1998) — Ordovician stratigraphy in the Żarki–Mysłów area (NE margin of the Upper Silesian Coal Basin). Geol. Quart., 42 (1): 29–40. Warszawa.

Preliminary results are presented of studies of the Ordovician sediments in the NE margin of the Upper Silesian Coal Basin in the area of Żarki (in ENE) and Mysłów (in WSW). Structural position, lithology, main petrographic features, and results of biostratigraphic investigations of the Ordovician complex are described. On the basis of conodonts it was found that the carbonate Ordovician sequence contains sediments of Arenig, Llanvirn, Llandeilo, Caradoc and Ashgill. Sedimentary continuity between the Ordovician and Silurian is estimated on the basis of conodont succession in the profiles of the carbonate sequence found in boreholes Ż-88 and Ż-89. Attention was given to anchimetamorphosis of the Ordovician rocks as well as intensive tectonisation in the particular profiles. Incompleteness of the Ordovician profiles has been caused by tectonisation and intensive erosion of pre-Devonian and pre-Triassic age.

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INTRODUCTION

In the years 1989–1996 the authors carried out complex studies of cores of Lower Palaeozoic rocks from the north-eastern margin of the Upper Silesian Coal Basin. Finding of carbonate Ordovician sequences in some of the boreholes was the most important fact, especially those ones in which fossils were encountered. Identification of this material allowed to broaden or verify up to date knowledge on distribution, structural position, lithology and stratigraphy of the Ordovician sequence. The main, lithostratigraphic part of the results of these investigations is the subject of this paper.

Borehole columns, thin sections and microfossils from the Ordovician carbonate rocks were the source material for the investigations, derived from profiles of eight selected wells. The boreholes were drilled in the two areas namely the Winowno–Będusz and Żarki in the years 1980–1989 in the frame of programme of geological prospection carried out by the Polish Geological Institute. The target of the prospection were the Triassic zinc-lead deposits including definition of degree and character of mineralization. It embraced also the recognition of degree and character of polymetallic mineralization of the rock complexes of older and younger Palaeozoic in the area. Five boreholes were drilled near Żarki (toward ENE) and the other three — near Mysłów in WSW part (the Winowno–Będusz area). The Lower Palaeozoic intervals of the cores in all the analysed boreholes were preserved in 100% within the Ordovician sequence. The Żarki–Mysłów area is located within the contact zone of the Małopolska (BM) and Upper Silesian Blocks of the European Palaeozoic Platform (Z. Buła, 1994). Compilation and location of the analysed boreholes is presented on Fig. 1.

The Ordovician columns from the particular boreholes differ in length from 0.6 m in the Ż-88 well up to 129.0 m in WB-31 (Fig. 2). They represent invariably partial sequences and are composed of fragments of the Ordovician (of various thickness and age). In some boreholes the Ordovician sequences were not drilled to the bottom hence their age and character of their substratum remain unknown (Fig. 2).

The total length of the Ordovician columns from all the investigated boreholes was about 340 m. Altogether 270 samples were taken. Out of these 147 samples were for palaeontological investigations and 123 samples — for petrographic studies. 110 standard thin sections and 20 polished surfaces were produced. A part of the thin sections was stained

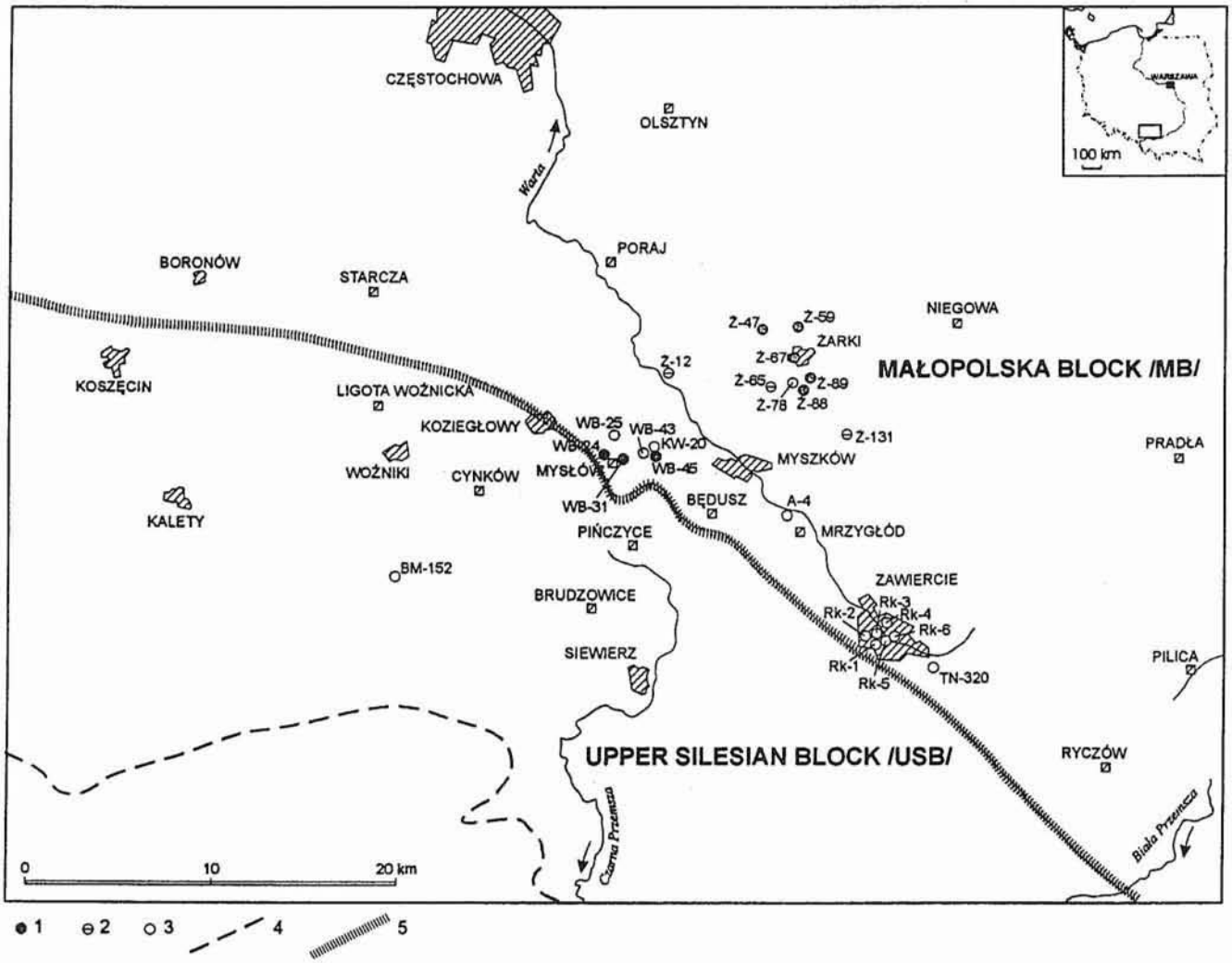

Fig. 1. Location map of boreholes in the Żarki–Mysłów area in the northeastern margin of the Upper Silesian Coal Basin
1 — boreholes with investigated Ordovician sediments, 2 — boreholes in which clasts of Ordovician limestones were found as secondary deposit, 3 — other boreholes mentioned in the text, 4 — boundary of the Upper Silesian Coal Basin (according to J. Jureczka *et al.*, 1995), 5 — presumed course of the zone of strike-slip fault

Mapa lokalizacji otworów wiertniczych w rejonie Żarek–Mysłowa (NE obrzeżenie GZW)
1 — otwory wiertnicze z opracowanymi osadami ordowiku, 2 — otwory wiertnicze, w których stwierdzono klasty wapieni ordowiku na złożu wtórnym, 3 — inne otwory wiertnicze wymienione w tekście, 4 — granica Górnośląskiego Zagłębia Węglowego (według J. Jureczki i in., 1995), 5 — przypuszczalny przebieg strefy uskoku przesuwczego

with alizarine-S and the Evamy's solution in order to identify carbonate minerals (see G. M. Friedman, 1959, 1971).

The investigations embraced description of lithology, sedimentological observations, tectonic studies (mesostructures), qualitative and quantitative petrographic analyses as well as study of microfacies in thin sections and microfaunistic determinations (conodonts, brachiopods, ostracods and others).

Due to intensive recrystallization and homogenization of the Ordovician carbonates their lithologic characterization has been broadened by results of microscopic analyses. Quantitative and semiquantitative data of such basic parameters as mineral composition in volume percentage, kind of bioclastic material, structures, textures, size of coarsest and most frequent quartz grain, rounding and sphericity of grains were taken into account. This has been done by point geometric analysis.

The basic types of carbonate rocks have been distinguished on the basis of textural features and content and character of allochemical components. A simplified subdivision was applied considering sparites, clayey sparites and sparse biosparites. R. L. Folk's (1962, 1968) classification has been used in limestone description.

As far as it was possible we tried to decipher the "primary rock type" during the petrographic studies i.e. the protolite of the sediment. It was possible in the case of some of the analysed samples as microscopic images showed some relics of primary structures or revealed analogies to those ones of unmetamorphosed or weakly metamorphosed rocks obtained from other boreholes. In exceptional cases we could compare

the microscopic images with those of correlative rocks from adjacent areas among others from the area of Mrzygłód (borehole A-4) and Zawiercie (boreholes Rk1–Rk-6).

The basic data concerning previous views about the geology of the Żarki–Mysłów area and occurrence, stratigraphy and lithology of the Ordovician sequences can be found in papers and archive materials by S. Siedlecki (1962), H. Tomczyk (1959), H. Tomczyk and E. Tomczykowa (1983), F. Ekiert (1971), K. Łydka (1973), S. Bukowy (1978, 1984), C. Harańczyk (1982, 1992), K. Piekarski *et al.* (1982, 1985), L. Wielgomas *et al.* (1986, 1988, 1989), M. Nehring-Lefeld *et al.* (1992), A. Siewniak-Madej (1993, 1994), Z. Buła (1994), Z. Buła *et al.* (1995), M. Jachowicz (1995) and B. Szymański and M. Nehring-Lefeld (1995).

Thin sections and polished surfaces were prepared in the Central Chemical and Technological Laboratory of the Polish Geological Institute, processing of micropalaeontological samples was done by J. Serafin and M. Mrowiec, illustrations — by M. Bejger and T. Grudzień. Lithological samples, thin sections and collections of microfossils are stored in the Department of Regional and Petroleum Geology of the Polish Geological Institute in Warsaw.

LITHOLOGY

The palaeontologically dated Ordovician sediments have been encountered in five borehole sections namely Ż-47, Ż-59, Ż-67, Ż-88 and Ż-89 (Fig. 2). The carbonate rocks devoid of organic remains pierced by boreholes WB-24 (depth 464.5–585.0 m), WB-31 (depth 327.0–456.0 m) and WB-45 (depth 267.0–300.0 m) have been ascribed to the Ordovician on the basis of lithology, position in the sections and spatial relations to the correlative sections dated palaeontologically.

The Ordovician rocks occur in the profiles of boreholes under the cover of Silurian rocks (boreholes Ż-59, Ż-67, Ż-88 and Ż-89) and Lower Triassic rocks (borehole Ż-47). There is either sedimentary continuity (boreholes Ż-88 and Ż-89) or tectonic contact with the overlying Silurian rocks (boreholes Ż-59 and Ż-67). A great sedimentary hiatus occurs toward the Röt (Lower Triassic) sediments (borehole Ż-47).

The Ordovician complex is underlaid by clastic series of Vendian–Lower(?)Cambrian age. The contact is a distinct tectonic unconformity (boreholes Ż-47, Ż-59, Ż-88 and Ż-89). In majority of cases both the bottom and top boundaries of the Ordovician complex show angular disconformities with angles varying from 10–27 up to 30–40°.

Generalized lithology, stratigraphy and correlation of the Ordovician profiles are presented on Fig. 2.

The Ordovician carbonate sediments have been also found in the columns in form of redeposited detrital material. Such concentrations were identified in coarse-clastic fraction, among others within the transgressive basal conglomerates of the Lower and Middle Triassic. They occur in three horizons of various age namely: the lower one Buntsandstein, middle one — Röt and upper — the Ore-Bearing Dolomite of Middle Triassic. The lithology of those Ordovician clasts is poorly diversified in the particular horizons. Those are mostly rock fragments and pebbles of recrystallized and marly limestone of sparite and microsparite type, vari-coloured or greyish-brown, frequently silicified and impregnated with hydroxides and iron oxides. The clast diameter varies from 0.5 up to 3 cm, maximum about 4 cm. Usually those are more or less rounded pebbles oval or isometric in shape. No organic remains were found in clasts separated from the Middle Triassic basal conglomerates (the Ore-Bearing Dolomite) of the Ż-12 borehole (depth 197.2–197.9 m), Ż-65 (depth 315.7–316.9 m) and Ż-131 (depth 352.0–353.5 m)[1].

The Ordovician sequence is composed predominantly of intensively recrystallized carbonate sediments of poorly diversified lithology. Those are mainly limestones and dolomitic limestones and subordinately marly and organodetrital limestones. Their petrographic character corresponds to three basic textural types i.e. medium- to coarse-crystalline sparites, clayey sparites and biosparites. The rocks are massive, compact and hard, in places more or less silicified and usually devoid of bedding.

The rocks are invariably grey, only locally in upper part epigenetically altered to greyish-brown (borehole Ż-47). In the most complete profiles the limestones in near-bottom parts show increased quantities of detrital quartz in silty and sandy fraction (borehole Ż-47).

The limestone sequences show frequent uneven unconformity surfaces with thin clayey films on them, and poorly preserved stylolites of various orientation and origin, minor fractures and voids as well as irregular carbonate and quartz veins with sulphide concentrations. Quite exceptional are — particularly in the lower and uppermost parts — irregular bands of clayey substance grey to greenish-grey in colour and small nest-like concentrations of brownish-grey phosphatic substance (borehole Ż-67). Neither macroscopic organic remains nor trace fossils have been found so far in any of the studied sections of the Ordovician carbonate complex. Sediments corresponding to five standard Ordovician stages were recognized on the basis of conodonts. These are: Arenig, Llanvirn, Llandeilo, Caradoc and Ashgill (Figs. 2 and 3).

The boundaries of the particular series were delineated only roughly due to fragmentary character of the profiles and considerable gaps in palaeontological record. Incomplete biostratigraphic data and some indirect premises like lithologic and sedimentary features were taken as criteria to such delineations.

As a lithostratotype of the Żarki–Mysłów Ordovician sequence in the NW part of the Upper Silesian Coal Basin one may regard the partial sections from the Ż-47 and Ż-89 boreholes. Those are so far the most complete stratigraphic sequences dated palaeontologically as Arenig–Llandeilo and Ashgill in the area. As a hypostratotype may serve a partial profile from the WB-45 borehole (depth 267.0–300.0 m) in

[1]The occurrences of detrital carbonates described as Ordovician in age and found as secondary deposit were cited by F. Ekiert (1971). They have been found in Upper Silurian conglomerates (Upper Ludlow) in the TN 320 borehole (Fig. 1). At least a part of those carbonate clasts should be regarded as Llandovery in age according to new biostratigraphic data.

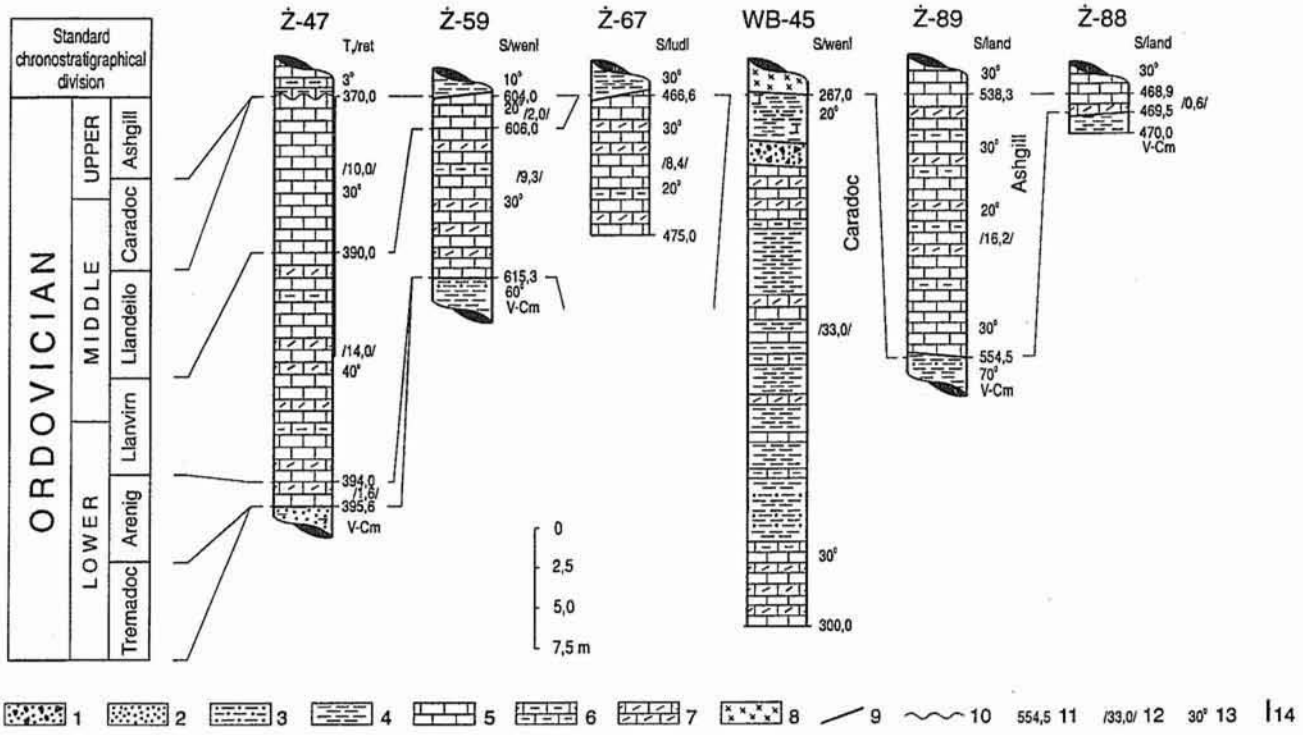

Fig. 2. Correlation table of the Ordovician profiles from Żarki–Mysłów area
1 — tectonic breccias, 2 — fine- and medium-grained sandstones, 3 — claystones and siltstones, 4 — claystones, 5 — limestones, dolomitic limestones, 6 — marly limestones, 7 — organodetrital limestones, 8 — igneous rocks (diabases, porphyries), 9 — faults, 10 — erosional unconformities, 11 — depth in metres, 12 — series thickness in metres, 13 — dip of beds, 14 — zone of secondary epigenetic alterations; V-Cm — youngest Precambrian (Vendian)–Lower(?)Cambrian; Silurian: Sld — Llandovery, Sw — Wenlock, Slu — Ludlow; Tpr — Lower Triassic (Röt)

Zestawienie korelacyjne profilów ordowiku z rejonu Żarek–Mysłowa
1 — brekcje tektoniczne, 2 — piaskowce drobno- i średnioziarniste, 3 — iłowce i mułowce, 4 — iłowce, 5 — wapienie, wapienie dolomityczne, 6 — wapienie margliste, 7 — wapienie organodetrytyczne, 8 — skały magmowe (diabazy, porfiry), 9 — uskoki, 10 — niezgodności erozyjne, 11 — głębokość w metrach, 12 — miąższość oddziałów w metrach, 13 — upad warstw, 14 — strefa wtórnych przeobrażeń epigenetycznych; V-Cm — najmłodszy prekambr (wend/kambr dolny?); sylur: Sld — landower, Sw — wenlok, Slu — ludlow; Tpr — trias dolny (ret)

which according to K. Piekarski *et al.* (1985) a fragment of Caradoc sequence of clastic-carbonate development was recognized (Fig. 2).

The true total thickness of the Ordovician carbonate sediments reconstructed on the basis of partial profiles is probably about 85.0–90.0 m. The dips of layers vary within 20–40° (Fig. 2).

ARENIG

Palaeontologically dated Arenig sediments were found in the Ż-47 borehole section (depth 394.0–395.6 m). It is a small portion of carbonate rocks resting unconformably on silty-arenaceous rocks of Vendian–Lower(?)Cambrian age. A continuity is noted of this series with the overlying Llanvirn carbonate sediments (Figs. 2 and 3).

The Arenig consists of recrystallized medium- to coarse-crystalline limestones and dolomitic limestones (about 70%). Marly limestones (10%) and sparse biosparites (20%) are subordinate. The latter make irregular indistinct interlayers 0.1–0.3 m thick.

With the exception of marly limestones the other lithotypes are macroscopically poorly contrasted. Transitions between these lithotypes are invariably gradual and the boundaries — indistinct. The bedding is poorly marked or does not exist at all. The structure of carbonate rocks is allotriomorphic (granular) and texture massive, nonoriented.

In limestones frequent are nodular-like surfaces of disconformities with thin clayey films, fragmentarily preserved stylolites of various origin and relatively large admixture of clayey material, which forms irregular bands of indistinct outlines. The rocks are strongly tectonised. Tectonic breccias are frequent. The same can be said about cracks, fissures and steep glide surfaces. Majority of the fissures and cracks is filled with quartz and calcite. Thin irregular veins of oblique orientation filled with quartz, carbonates and sulphides — mainly pyrite occur throughout the interval.

Quantitative and qualitative mineral composition of the carbonate rocks is poorly differentiated and does not exhibit statistically important changes in vertical succession. The main mineral background of the rocks is usually mosaic of xenomorphic calcite and/or dolomite crystals 0.3–3.1 mm in diameter. These components form crystalline network or are separated by concentrations of fine-grained carbonate mass

showing optical features of dolomite. Many calcite grains and crystals show polysynthetic twins and fine cracks. They bear in some parts marks of dynamometamorphosis which is shown by granuloblastesis of larger particles (depth 395.1 m).

The allochem components consist of biogenic material, clayey minerals (illite, chlorite) and detrital quartz that occur in variable quantitative proportions. Bioclastic grains are represented by small fragments of structures of biogenic origin and their relics recrystallized to various degree 0.1–0.5 mm in size, usually 0.2 mm. Their distribution is irregular and uneven. In some places in biosparites they form larger concentrations but in sparites in places they do not exist at all. The biogenic material is represented chiefly by fragments of brachiopods, crinoids, gastropods, ostracods and bryozoans(?). Other structures are indeterminable. Proportion of bioclasts is small. In sparites it ranges from 0 up to 6.0% and in biosparites it is up to 16% of the rock volume.

There have been found variable quantities of clay minerals (about 6.0–17.0% per volume) and detrital quartz in silt and arenaceous fraction (0.0–6.5% per volume). Quartz grains are usually well rounded but poorly sorted. Mean diameter of the most frequent quartz grain is 0.06 mm and maximum one — 0.26 mm. The composition of the limestones is sporadically supplemented by fine-scale aggregates of chlorite (0.0–2.3% per volume), small quantities of minerals from epidote group, pleochroic concentrations of biotite and impregnations and nest-like concentrations of iron oxides and hydroxides, siderite and sulphides — mainly of pyrite.

The Arenig carbonate complex in the Ż-47 section shows many similarities to the coeval carbonate sequence found earlier in the profiles of boreholes Rk-1 (depth 1217.6–1224.0 m) and Rk-5 (depth 1209.0–1216.7 m) from Zawiercie area (M. Nehring-Lefeld *et al.*, 1992). These similarities consist of mineral composition, facies, range and degree of secondary alterations and position in the profile.

The incomplete apparent thickness of the Arenig carbonate sediments in the Ż-47 borehole section is about 1.6 m (Fig. 2).

LLANVIRN

The Llanvirn sediments dated with conodonts have been found in three borehole sections namely Ż-47, Ż-59 and Ż-67 (Fig. 2). In the Ż-47 borehole the Llanvirn deposits rest conformably on the Arenig carbonates. In the Ż-59 one they lie unconformably on clastic rocks of Vendian–Lower(?)Cambrian age. In Ż-67 borehole the Llanvirn deposits were not pierced to the bottom. They are covered by Llandeilo sediments in Ż-47, probable Llandeilo in Ż-59 and by clastic rocks of the Silurian (Ludlow) in Ż-67 borehole.

The Llanvirn sediments are uniform in their lithology and do not show major qualitative nor quantitative differences in the sections of the particular boreholes. The main lithologic component is recrystallized medium- and coarse-crystalline limestone and dolomitic limestone (60%). Associated are marly limestones (10%) and granular limestones of sparse biosparite type (about 30%).

All the structural and textural features of the Llanvirn limestones, their petrographic character and recrystallization degree are analogous to those ones of the Arenig carbonates. Similar are also: content of clayey material, quantity and grain size of detrital quartz, content and composition of grained biogenic material and preservation state of sedimentary structures. They are characterized by larger frequency of biogenic material and its relatively weaker recrystallization degree.

The Llanvirn carbonate complex — as the Arenig one — contains numerous surfaces of sedimentary unconformities with thin clayey films, fragmentarily preserved stylolites of various origin as well as network of irregular veins of several generations consisting of quartz, carbonates and sulphides — mainly of pyrite. Tectonisation of the Llanvirn sediments is considerable and spatially diversified. It is more intensive in Ż-47 section and markedly weaker in Ż-59 one.

The incomplete apparent thickness of the Llanvirn carbonate sediments in the profiles of the particular borehole is variable and ranges from 9.3 m (borehole Ż-59) up to 14.0 m (Ż-47).

LLANDEILO

The upper part of the carbonate sequence drilled in Ż-59 and Ż-47 boreholes (Fig. 2) has been ascribed to the Llandeilo. In the first section the age determination was based on presence of conodonts. In the second case it is based entirely on indirect premises (lithology, position in the profile). At the bottom the Llandeilo series displays a sedimentary transition from the Llanvirn sediments but in the top there is a sedimentary unconformity with the overlying Lower Triassic (Röt) (borehole Ż-47). In the Ż-59 borehole it contacts unconformably with clastic rocks of Silurian (Wenlock).

The Llandeilo sequence consists of monotonous intensely recrystallized carbonate sediments, medium- to coarse-crystalline limestones and dolomitic limestones grey in colour, in some parts silicified to various degree, devoid of traces of bedding as a rule. There are some poorly preserved sedimentary discontinuities and fragments of stylolites. The structure of the limestones and dolomitic limestones is allotriomorphic (granular) and texture is massive, nonoriented.

Quantitative proportions of the limestones and dolomitic limestones vary. In the lower part of the profile limestones prevail whereas in the upper — dolomitic limestones. Mean proportion of the former is about 40% and of the latter ones — about 60% of entire thickness.

There is either lack or a very small proportion of allochemic components (up to 1.5% per volume) in the rocks. Small fragments of biogenic structures and/or their recrystallized relics are to be found but in few places in the grainy material. The particles are from 0.09 up to 0.2 mm in size. Those are fragments of conodonts, inarticulate brachiopods and indeterminable other organic remains. Content of clayey material is subordinate (up to 5.0% per volume) the same refers to detrital quartz (up to 2.5% per volume) as well as to silty fraction. The mean diameter of the most frequent quartz grain is 0.04 mm and maximum one — 0.08 mm.

The incomplete apparent thickness of the Llandeilo sediments ranges from 4.0 m in Ż-59 borehole up to 10.0 m in Ż-47 borehole (Fig. 2).

CARADOC

A sequence of sediments representing most probably the Caradoc has been found in the sections WB-24 (depth 464.5–585.0 m) and in WB-45 (depth 267.0–300.0 m)[2]. The Caradoc sediments are covered by clayey-carbonate ones of the Silurian (Wenlock?). There exists a tectonic unconformity between them. At the bottom of the first two sections the Caradoc sediments contact with tectonic discordance the clastic rocks of Vendian–Lower(?)Cambrian. In the third borehole they were not drilled to the bottom (Fig. 2)[3].

The series of the probable Caradoc consists of two groups of rocks of different origin. Those are: limestones, dolomitic limestones as well as organodetrital limestones and clayey and silty-clayey rocks; the latter containing variable admixture of micritic carbonates. Quantitative relations of these two groups of rocks are similar in the particular profiles. Mean proportion of the limestones is about 60% and that of clayey and silty-clayey ones — about 40% of the sequence thickness.

The lower part of the sequence is formed by dolomitic limestones, limestones (sparites) and organodetrital limestones (sparse biosparites), light grey and grey in colour, silicified in some parts. Large content of terrigenous components (up to 20% of the rock volume) is remarkable. The Caradoc sequence differs from the Llandeilo limestones in its larger content of clayey material and more distinct bedding. The structure of the limestones is allotriomorphic (grained), and texture massive, nonoriented.

As episodic interbeds in the limestones there appear irregular laminae of claystone and silty-clayey rocks dark grey to greenish grey in colour. Their thickness is small — 0.1–0.3 m.

The upper part of the sequence consists mainly of claystones and silty-clayey rocks with variable carbonate content. The rocks are dark grey, almost black in places. Large fragments of the sequence are silicified and devoid of bedding. There are irregular interbeds of light grey dolomitic limestone, marly limestone and organodetrital ones 0.1–1.2 m thick.

The limestone beds are intensely cracked and deformed diagenetically. In places they are interrupted and form lense-like or nodular concentrations.

The Caradoc sequence shows high degree of tectonisation expressed by numerous zones of breccias representing in the profile WB-24 up to 60% of thickness (see J. Żaba, 1994), presence of probable repetitions of some fragments of the sequence, and conspicuous intervals of intrusive bodies of porphyries and diabases (boreholes WB-24 and WB-31).

The above described Caradoc sequence of the Mysłów area has no counterparts in other sections of the Małopolska Massif, nor in the Zawiercie area (M. Nehring-Lefeld *et al.*, 1992). On the other hand, a fragment of clastic-carbonate sequence drilled under the Lower Devonian in the BM-152 borehole (depth 255.3–375.6 m) localized on the Upper Silesian Block between Kalety and Siewierz maybe regarded as its counterpart (A. Siewniak-Madej, M. Jeziorowska, 1978; J.Gładysz *et al.*, 1990; Z. Buła, 1994).

The incomplete apparent thickness of the probable Caradoc carbonate sediments is from 33.0 m in the profile WB-45 up to129.0 m in WB-31 (Fig. 2).

ASHGILL

The uppermost Ordovician is represented in the Ż-89 and Ż-88 borehole sections (Fig. 2). In the first of these sections the age of sediments was determined on the basis of conodonts and ostracods. In the second one the age is estimated entirely on indirect premises such as lithology and position in the profile. The Ashgill series passes continuously upward to the carbonate sediments of the Llandovery. In the bottom it contacts with tectonic unconformity with clastic series of Vendian–Lower(?)Cambrian age.

This is monotonous series of carbonate sediments: intensely recrystallized medium- to coarse-crystalline limestones and dolomitic limestones (sparites) and organodetrital limestones (sparse biosparites), light grey and grey in colour, in some parts silicified to various degree, devoid of traces of primary stratification and showing deformation of sedimentary structures. The structure of the limestones is allotriomorphic (granular) and texture — nonoriented, massive. Quantitative proportions of the lithotypes vary from one part of the profile to another. Dolomitic limestones and limestones (60 and 20%, respectively) prevail in the lower part of the sequence whereas limestones (40%) and organodetrital ones (30%) in the upper part.

Bedding is hardly marked in all these rock types or does not exist at all. Boundaries of beds are macroscopically poorly traceable, indistinct or gradual.

All the structural and textural characters of the distinguished varieties of the Ashgill limestones, their petrographic character and recrystallization degree are analogous to those described above for the rocks of the Arenig and Llanvirn. Similar are also the content of clayey material, quantity and granulometry of quartz, content and taxonomic composition of the biogenic material as well as the preservation state of sedimentary structures. They differ in larger frequency of biogenic components with weaker recrystallization and more diversified composition. The proportion of grained biogenic material in sparites reaches 6.0% and in biosparites — up to 18.0% of rock volume. The grainy bioclastic material is

[2]Similar deposits of probable Caradoc age has been encountered in other sections in the Mysłów area among others in WB-25, WB-43 and KW-20 boreholes. In the first two ones these rocks were regarded as the Devonian or Silurian in age, and in the third one — as Carboniferous or Silurian (see K. Piekarski *et al.*, 1985).

[3]Large thickness of the series of probable Caradoc age in the profiles of WB-24 (120.5 m) and WB-31 (129.0 m) is a result of two factors of post-depositional nature namely considerable proportion of intrusive rocks (porphyries, diabases) and intensive tectonisation which led to possible repetition of some fragments of the sequence.

poorly sorted. Size of bioclasts is usually from 0.05 up to 0.28 mm.

The content of terrigenous components is insignificant. These are clay material (illite up to 15%) and detrital quartz (1.5–10% per volume), of silty and sandy fraction. The mean size of the most frequent quartz grain is 0.08 mm, maximum — 0.21 mm. The quartz grains are usually particularly in the fraction over 0.1 mm, well-rounded, of isometric shape close to spherical.

The carbonate complex contains — similarly as that of the Arenig and Llanvirn — numerous nodular-like surfaces of sedimentary unconformities with thin clayey films, fragmentarily preserved stylolites of various origin and a network of several generations of irregular veins composed of quartz, carbonates and sulphides — mainly of pyrite. Tectonisation of the Ashgill sediments varies. It is more intensive near the contact with the underlying clastic series of Vendian–Lower(?)Cambrian age and relatively weak in the top part.

Subordinate are interbeds of clayey and clayey-marly material mainly in intervals of high frequency of sedimentary discontinuities. These interbeds are indistinct as a rule and their thickness ranges from 1.0 up to 3.0 cm. Quantity and thickness of these interbeds increase markedly upwards.

The incomplete apparent thickness of the carbonate sediments of the probable Ashgill age in the Ż-88 borehole section is about 0.6 m and in the Ż-89 borehole — 16.2 m (Fig. 2).

BIOSTRATIGRAPHY

The biostratigraphy has been based on micropalaeontological data except Caradoc the sediments of which are dated indirectly basing on earlier findings of macrofauna and microflora (acritarchs) and some indirect premises.

The palaeontological material which served for stratigraphic determinations comprised 584 specimens of fossils mainly conodonts, inarticulate brachiopods and ostracods. Some specimens are so well preserved that they allowed taxonomic identification. In conodont determinations natural taxonomy has been used. The names of natural species are given according to M. Lindström (1960), S. M. Bergström (1971) and W. A. Van Wamel (1974). The conodont determinations concordant with the rules of parataxonomy have been distinguished giving to the specific names an abbreviation *s.f.* (*sensu formae*).

Majority of the obtained microfossils are poorly preserved. Specimens of conodonts and brachiopods are more or less damaged and incomplete as a rule. Ostracods are preserved as moulds. The distribution of microfossils in rocks is uneven. In some intervals there are no fossils at all (e.g. borehole Ż-47, depth 370.0–390.0 m). The mean frequency of conodont occurrence is low (3–5), with 45 specimens at maximum in one sample (borehole Ż-47, sample 31, depth 393.5–394.0 m). The colouration of conodonts varies from almost white (borehole Ż-67), through grey (borehole Ż-89) to dark grey (boreholes Ż-47, Ż-59 and Ż-88).

Due to poor preservation, uneven distribution and low frequencies of the microfossils as well as gaps in biostratigraphic record the presented version of the stratigraphic subdivision is preliminary.

Compilation of the sampled parts of the Ordovician sequence in the particular profiles, intervals of the proved occurrence of conodonts and interpretation of their stratigraphic ranges are presented on Fig. 3.

ARENIG

The conodont assemblage found in the Ż-47 borehole section contains: *Oistodus complanatus* Lindström *s.f.*, *Baltoniodus* sp., and *Protopanderodus* sp.

Moulds of ostracods have been found, including *Laccochilina* ?(*Laccochilina*) *berdanae* Olempska, as well as some fragmentarily preserved bryozoans.

The basis for age determination of the described Arenig limestones was identification of the formal conodont species *Oistodus complanatus* Lindström. It is a component of multielement species *Microzarkodina flabellum* (Lindström) which appears at the base of Volkhov and ranges up to the middle Kunda Stage (A. Löfgren, 1978). The stratigraphic range of *Microzarkodina flabellum* (Lindström) comprises zones *navis–triangularis, originalis* and *flabellum–parva* of the Arenig and ranges up to the lowermost part of the *variabilis–ozarkodella* of the lowermost Llanvirn (A. Löfgren, 1978; S. M. Bergström *et al.*, 1985).

The assemblage of the determined conodonts and ostracods from the Arenig carbonate rocks of the Ż-47 borehole shows great similarities to the generic composition and position in the profile of the analogous associations described earlier from carbonate sequences of the Lower Ordovician of the Rk-1 (depth 1217.6–1222.0 m) and Rk-5 boreholes (depth 1209.0–1213.7 m) in the Zawiercie area (M. Nehring-Lefeld *et al.*, 1992).

LLANVIRN

In the samples of carbonate rocks from the Ż-47 borehole microfossils were found at interval 390.0–394.0 m (Fig. 3). Those are conodonts, numerous inarticulate brachiopods belonging to the order Acrotretida Kühn, poorly preserved ostracods and bryozoans. The following conodonts were identified from depth 393.25–394.0 m: *Acodus* sp. indet. Pander, *Distacodus* Hinde, *Drepanodus* Pander, *Eoplacognathus* Hamar, *Baltoniodus* Lindström, *Scapellodus cavus* Van Wamel, *Oistodus* sp. and *Drepanodus* sp.; and from depth 390.0–393.25 m: *Baltoniodus* sp., *Drepanoistodus venustus* (Stauffer), *Cornodus* ?*bergstroemi* Serpagli, *Amorphognathus* sp., *Prioniodus* sp., *Distacodus* sp. and *Drepanodus* sp.

From interval 390.0–394.0 m the following brachiopods were determined: *Ephippelasma spinosum* Biernat and *Scraphelasma subquadratum* Biernat. Also bryozoans — *Wollinella baltica* Dzik and fragmentarily preserved specimens of *Voigitia oeilensis* (Wiman) as well as numerous but poorly preserved ostracods of the genus *Healdianella* sp. Posner and *Pseudorayella* sp. Neckaja.

The conodonts identified at interval 393.25–394.0 m represent multielement species *Eoplacognathus suecicus* Berg-

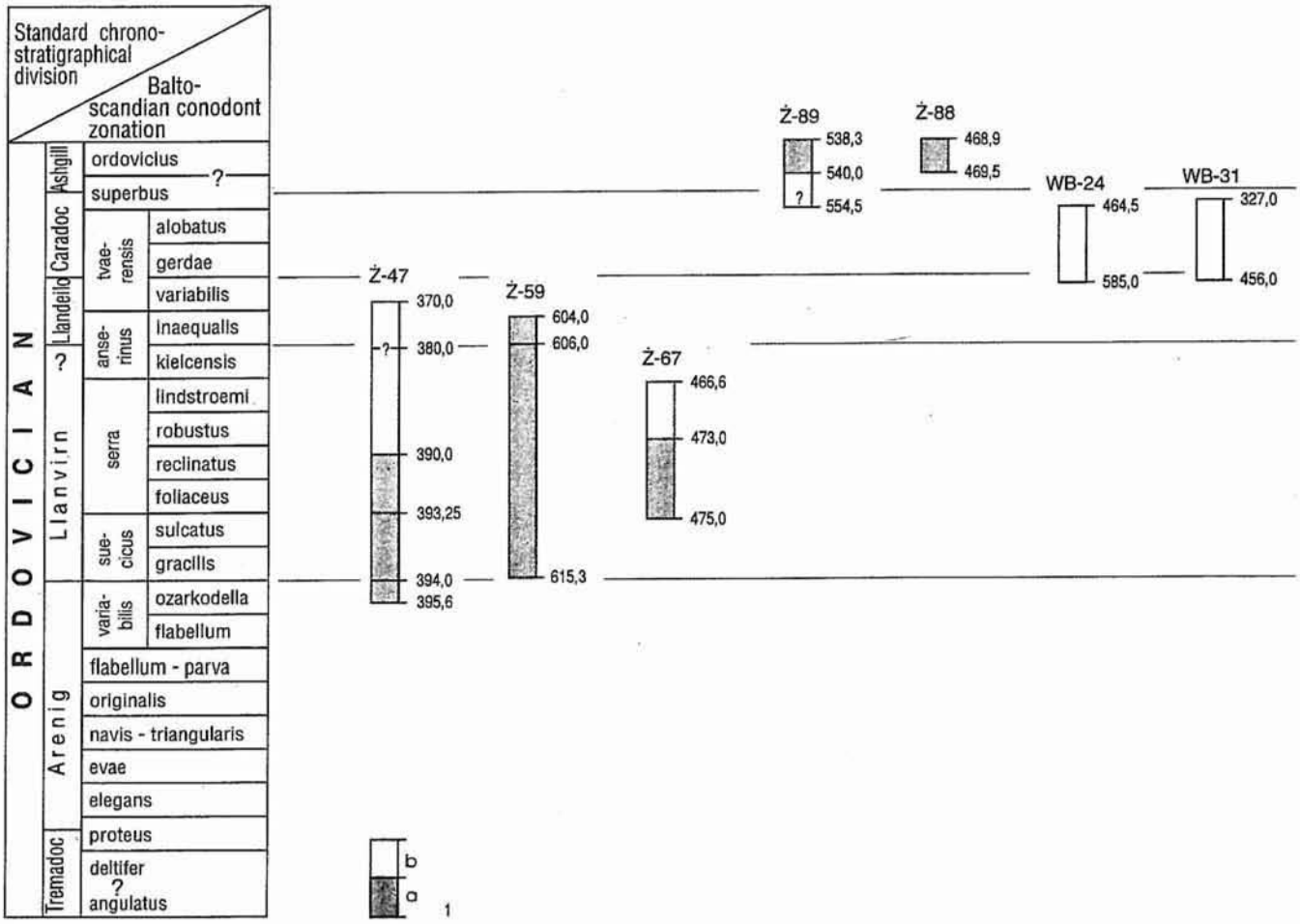

Fig. 3. Stratigraphic correlation of the investigated profiles of the Ordovician sediments
1 — intervals of proved occurrence of Ordovician sediments: a — intervals from which microfossils were obtained, b — intervals devoid of microfossils; depth in metres; conodont zonation of the Ordovician after A. Löfgren (1978) and S. M. Bergström *et al.* (1985)

Zestawienie stratygraficzne profilów osadów ordowiku
1 — interwały występowania osadów ordowiku: a — z których uzyskano mikroskamieniałości, b — pozbawione mikroszczątków organicznych; głębokość w metrach; zonacja konodontowa ordowiku według A. Löfgren (1978) i S. M. Bergströma i in. (1985)

ström. The range of this taxon embraces upper part of Kunda, Aseri up to the lower part of Lasnamagi which are correlated with Llanvirn. It is an index species for the conodont zone *Eoplacognathus suecicus* (S. M. Bergström, 1971) thus its presence makes a basis to ascribe the sediments of interval 393.25–390.0 m to Llanvirn. With respect to the graptolite zonation the *Eoplacognathus suecicus* Zone correlates with the upper part of the *Didymograptus murchisoni* Zone (S. M. Bergström, 1971), or according to newer interpretations — with the upper part of the *Didymograptus artus* Zone (= *bifidus*) and lower part of *Didymograptus murchisoni* of the British subdivision (R. A. Fortey *et al.*, 1995).

Eoplacognathus suecicus Bergström has been described so far from Sweden (M. Lindström, 1960; S. M. Bergström, 1971; A. Löfgren, 1978), from Estonia (V. Viira, 1974), Poland (J. Dzik, 1976; T. Podhalańska, 1978; M. Nehring-Lefeld, 1993), Western Australia (The Canning Basin) and Canada (A. Löfgren, 1978).

The specimens of *Eoplacognathus suecicus* Bergström are accompanied by the conodonts of the genus *Prioniodus* (*sensu* S. M. Bergström, 1971). The latter genus appears in the Upper Arenig and ranges to the Lower Caradoc. The found specimens belong most probably to the multielement species *Baltoniodus prevariabilis* (Fahraeus), the occurrence of which is associated with sediments of Llanvirn–lowermost Llandeilo.

Drepanoistodus venustus (Stauffer) identified at interval 390.00–393.25 m is a species common in sediments of the Middle Ordovician in Europe and North America. In Sweden (Jämtland) it was described from the middle part of Kunda Stage as well as from younger sediments (A. Löfgren, 1978). *Cornuodus ?bergstroemi* Serpagli described for the first time from Ashgill of Karnian Alps (E. Serpagli, 1967) appears in the Balto-Scandian area already in Volkhov and is known from Llanvirn as well.

The above mentioned species of inarticulate brachiopods have been described from many sections of other regions of

Poland. For example from Llanvirn–Llandeilo in boreholes Gołdap IG 1, Bartoszyce IG 1 and Kętrzyn IG 1 in the Peribaltic Depression (G. Biernat, 1973) and from Llanvirn of southwestern Lublin area (M. Nehring-Lefeld, 1993) northeastern margin of the Upper Silesian Coal Basin (M. Nehring-Lefeld *et al.*, 1992) and Holy Cross Mts. (J. Dzik, 1994). *Scraphelasma subquadrata* is known in Estonia also from the Upper Arenig (G. Biernat, 1973).

The bryozoans found are known also from the Mójcza section in the Holy Cross Mts. *Wollinella baltica* occurs there in the Llanvirn sediments in the lower part of the section and the second cited species is common in the upper part of the same section correlated with Caradoc and Ashgill (J. Dzik, 1994; E. Olempska, 1994).

In the Ż-59 borehole section microfossils were obtained from interval 606.0–615.3 m (Fig. 3). Those are poorly preserved conodonts and rare inarticulate brachiopods. The following conodonts were indentified: *Drepanodus conulatus* Lindström *s.f.*, *Scandodus pipa* Lindström *s.f.*, *Drepanoistodus venustus* (Stauffer), *Tetraprioniodus asymetricus* Bergström *s.f.* and *Prioniodus* sp.

Occurrence of microfossils was noted in Ż-67 section at interval 473.0–475.0 m (Fig. 3). The material contains rare conodonts of single cone type, numerous inarticulate brachiopods and ostracod moulds. The state of preservation of the conodonts excluded their closer taxonomic identification. The following brachiopods were identified: *Ephippelasma spinosum* Biernat and *Acraphelasma subquadratum* Biernat. The identified brachiopods are very common in sediments which on the basis of other biostratigraphic criteria (e.g. conodonts) were classified to Llanvirn.

The conodont assemblage from Llanvirn carbonate sediments of Żarki–Mysłów area shows close similarities in its generic composition and position in the sequence to analogous associations described earlier from carbonate sequences of the Lower Ordovician of boreholes Rk-2 (depth 1194.1–1195.1 m) and Rk-4 (depth 640.2–644.9 m) near Zawiercie (M. Nehring-Lefeld *et al.*, 1992).

LLANDEILO

The Llandeilo sediments were found in the Ż-47 and Ż-59 borehole sections (Fig. 2). Few poorly preserved fragments of conodonts were found only in the second profile at interval 604.0–606.0 m. Poor preservation state allows but a general assignment to genus *Eoplacognathus* Hamar.

Stratigraphic range of *Eoplacognathus* Hamar embraces the time span Llanvirn — lower part of Llandeilo hence precise age determination is impossible. Taking into account, however, their position in the profile Ż-59 it seems probable that these sediments may be correlated with the Lower Llandeilo.

CARADOC

A carbonate-clayey series recognized in the boreholes WB-24 (depth 464.5–585.0 m), WB-31 (depth 327.0–456.0 m) and WB-45 (depth 267.0–300.0 m) represents most probably this time interval.

Carbonate rocks of the first two sections did not furnish organic remains. Stratigraphic interpretation has been based on the data obtained from the WB-45 and WB-24 boreholes. In the first one Caradoc brachiopods were found (K. Piekarski *et al.*, 1985) and in the second one — an acritarch assemblage pointing generally to Llanvirn–Caradoc, according to M. Jachowicz (1995)[4].

ASHGILL

The Ashgill sediments have been distinguished on the basis of biostratigraphic criteria in the Ż-88 and Ż-89 sections. In the first section microfossils were found at interval 468.9–469.5 m and in the second one — at interval 538.3–540.0 m (Fig. 3).

In the borehole Ż-88 only poorly preserved conodonts of single cone type have been found. Only *Panderodus gracilis* (Branson et Mehl) was determined. Stratigraphic range of this taxon is Middle Ordovician–Middle Devonian which means that its presence proves the age of sediments being not older than Middle Ordovician.

The conodonts found in the Ż-89 section are rare and poorly preserved. These are: *Panderodus gracilis* (Branson et Mehl), *Ambalodus triangularis* Branson et Mehl *s.f.*, *Amorphognathus* sp. Branson et Mehl and *Distomodus ?extrorsus* (Rexroad).

The stratigraphic range of these forms is broad. The first species ranges from Middle Ordovician to Lower Devonian, the three other ones from upper part of Lower Ordovician up to lowermost Silurian.

Specific determination of *Amorphognathus* would give better age constraints but poor preservation state excludes such a possibility. Hence, it is highly probable that the sediments from interval 538.3–540.0 m in the Ż-89 borehole section belong to the Upper Ordovician, most probably to Ashgill. Nevertheless, a possibility of correlation with Lower Llandovery cannot be excluded (O. H. Walliser, 1964). The latter possibility seems to be supported by finding of *Distomodus ?extrorsus* (Rexroad) which is known in Wales from sediments correlated with Llandovery (Idvian–Telychian) (R. J. Aldridge, 1972). The first interpretation seems to be supported by two facts namely (1) there are no index forms for the lowermost Silurian (Llandovery) in the analysed interval and (2) the spatial relations of the carbonates of the probable Ashgill toward Llandovery series are well documented by conodonts in the Ż-88 and Ż-78 boreholes (Fig. 1).

[4]As the Caradoc rocks in both these profiles are strongly tectonised the stratigraphy based on acritarchs must be taken with caution. This pertains in particular to the acritarch assemblage found in the WB-24 section (depth 576.0–585.0 m) pointing to Llanvirn–Caradoc (M. Jachowicz, 1995). It is not out of question that these acritarchs derive from secondary deposit.

CONCLUSIONS

The investigations of borehole data of the Ordovician sediments from Żarki–Mysłów area in the northeastern margin of the Upper Silesian Coal Basin allow to draw the following general conclusions:

1. The Ordovician sediments rest unconformably on clastic complex of the youngest Precambrian (Vendian)–Lower(?)Cambrian age. This contact is of tectonic nature. The direct overburden are either transgressive Lower Triassic sediments (Röt) or rock complexes of various Silurian age underlain the Ordovician with continuous sedimentary transition (boreholes Ż-88 and Ż-89) or separated by tectonic discontinuities (boreholes Ż-59 and Ż-67).

2. The both tectonic boundaries are characterized by large angular discordance (10–40°).

3. Uniformly developed Ordovician sequences are represented by intensely recrystallized complex of carbonate and clayey-carbonate rocks (Caradoc) consisting of limestones, dolomitic limestones and subordinate marly and organodetrital limestones. Those are medium- to coarse-crystalline sparites, clayey sparites and biosparites.

4. The Ordovician carbonate rocks in all the sections of the analysed boreholes exhibit analogous petrographic character and similar mineral composition both qualitatively and quantitatively.

5. As a result of recrystallization the Ordovician rocks are devoid of depositional structures. Relics of biogenic forms and sedimentary structures preserved in few places allow but a general conclusion about their sedimentary environment. They have been deposited most probably in a shallow water environment of carbonate platform developing in a neritic zone.

6. Sediments of five series have been distinguished on the basis of conodonts namely: Arenig, Llanvirn, Llandeilo, Caradoc and Ashgill. Their total reconstructed thickness is probably around 85.0–90.0 m.

7. The succession of conodonts in the sections of the carbonate rocks of the Ordovician and Silurian in the Ż-88 and Ż-89 boreholes seems to suggest that there is probably depositional continuity at the boundary of the two systems in the investigated area.

8. Considerable degree of fragmentation of the studied stratigraphic sequences of the Ordovician and also of the Silurian results from two basic factors i.e. intensive epigenetic erosion in pre-Devonian time and then in the pre-Triassic time and highly advanced tectonisation in the Variscan epoch.

9. The Ordovician carbonate complexes are intensely tectonised which is reflected in breccia zones, numerous fractures, fissures and steep glide surfaces. Dips of layers are variable in particular profiles. Usually they are within 20–40° (Fig. 2) in all those cases in which their identification is fully reliable. The range and scale of tectonisation are spatially diversified: relatively weaker near Żarki (borehole Ż-88) and more intensive — near Mysłów (borehole WB-24) i.e. in the direct proximity of the course of probable strike-slip fault separating the Upper Silesian Block from the Małopolska Block (Fig. 1).

10. The lithostratigraphic analysis of the partial profiles of the Ordovician series in the Żarki–Mysłów area shows that three discontinuities related to lithological gradients and contrasts of petrophysical properties of rocks were marked within the Lower Palaeozoic sequence. Release of stress and tectonic transport had taken place along those surfaces. These are: contact of the Wenlock clayey series with the Llandovery–Ashgill carbonate complex, the interval within the Caradoc clayey-carbonate series and the contact of the Lower Ordovician carbonates with the clastic series of the youngest Precambrian (Vendian)–Lower(?)Cambrian.

11. In the studied Ordovician sequence no beds were found in which stratigraphic position, distribution of organic remains and spatial orientation of sedimentary structures would point univocally to reversed position.

12. The Ordovician–Lower Silurian (Llandovery) carbonate series may be regarded as index correlation horizon of isochronous character for the Lower Palaeozoic complex at least in the studied area. This is proved by reliable palaeontological documentation, constant position in the profiles and presence of distinct identification features.

13. The investigated Ordovician rock complex reveals initial stages of anchimetamorphic alteration (regional, dynamic and thermo-metasomatic) that run in greenstone facies, chlorite zone and shallow biotite zone. The record of those alterations is imprinted among others by partial change of textural parameters of the carbonate rocks and the occurrence of neomorphic association chlorite-epidote-biotite as typomorphic minerals. The microscopic data confirm earlier studies by K. Łydka (1973), W. Ryka (1973, 1978) and W. Heflik *et al.* (1975) who stressed regional character of metamorphism of the Lower Palaeozoic sediments in this area. Different opinion has been expressed by Z. Belka and A. Siewniak-Madej (1996).

14. The Ordovician carbonate complex of the described sections shows great similarity in pattern of facies development, mineral composition, range and degree of post-depositional alterations as well as position in the profile of the Early Palaeozoic complex, to the correlative carbonate series found earlier in other boreholes in the south-central part of Poland among others to the Upper Ordovician limestone complex from the A-4 borehole (depth 250.0–296.4 m) (?) near Myszków regarded by K. Piekarski *et al.* (1982) and W. Heflik and K. Piekarski (1978) as the Upper Ordovician (Ashgill) in age which was found also near Zawiercie in the Rk-1–Rk-6 boreholes (M. Nehring-Lefeld *et al.*, 1992).

Acknowledgements. The paper was reviewed by R. Dadlez and Z. Modliński to whom the authors express their thanks for critical remarks and discussion. Thanks are also due to the management and geologists of the Geological Enterprise in Cracow for lending the core material and geophysical data from the boreholes drilled in the Zawiercie area for investigation.

REFERENCES

ALDRIDGE R. J. (1972) — Llandovery conodonts from the Welsh Borderland. Bull. British Mus. (Nat. Hist.), Geology, **22**, p. 127–237, no. 2.

BELKA Z., SIEWNIAK-MADEJ A. (1996) — Thermal maturation of the Lower Paleozoic strata in the southwestern margin of the Małopolska Massif, southern Poland: no evidence for Caledonian regional metamorphism. Geol. Rundsch., **85**, p. 775–781.

BERGSTRÖM S. M. (1971) — Conodont biostratigraphy of the Middle and Upper Ordovician in Europe and Eastern North America. In: Symposium on conodonts biostratigraphy (eds. W. C. Sweet, S. M. Bergström). Geol. Soc. Am. Mem., **127**, p. 83–157.

BERGSTRÖM S. M., ORCHARD M. J. *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.

BIERNAT G. (1973) — Ordovician inarticulate brachiopods from Poland and Estonia. Palaeont. Pol., **28**.

BUKOWY S. (1978) — Stratigraphy and lithology of the Palaeozoic formations. In: Prospecting for zinc and lead ores in the Silesia–Cracow (in Polish with English summary). Pr. Inst. Geol., **83**, p. 43–52.

BUKOWY S. (1984) — Struktury waryscyjskie regionu śląsko-krakowskiego. Geologia UŚl, no. 691.

BUŁA Z. (1994) — Problemy stratygrafii i wykształcenia osadów starszego paleozoiku północno-wschodniego obrzeżenia Górnośląskiego Zagłębia Węglowego. In: Paleozoik północno-wschodniego obrzeżenia Górnośląskiego Zagłębia Węglowego. Przew. 65 Zjazdu Pol. Tow. Geol., Sosnowiec, Pr. Nauk. UŚl, no. 1431, p. 31–57, 137–140.

BUŁA Z., JACHOWICZ M., SIEWNIAK-MADEJ A., MARKIEWICZ J., TRUSZEL M. (1995) — Badania litostratygraficzne i petrograficzne starszego paleozoiku NE obrzeżenia GZW. Arch. Państw. Inst. Geol. Sosnowiec.DRYGANT D. M. (1974) — Prostye konodonty silura i nizov devona Volyno-Podolya. Pal. Sbor., **2**, p. 64–70, no. 10.

DZIK J. (1976) — Remarks of the evolution of Ordovician conodonts. Acta Palaeont. Pol., **21**, p. 395–455, no. 4.

DZIK J. (1994) — Conodonts of the Mójcza Limestone. Palaeont. Pol., **53**, p. 43–128.

EKIERT F. (1971) — Geological structure of the Sub-Permian basement of the north-eastern margin of the Upper Silesian Coal Basin. Pr. Inst. Geol., **66**.

FOLK R. L. (1962) — Spectral subdivision of limestone types. Am. Ass. Petrol. Geol. Mem., **1**.

FOLK R. L. (1968) — Petrology of sedimentary rocks. Hemphills. Austin. Texas.

FORTEY R. A., HARPER D. A. T., INGHAM J. K., OWEN A. W., RUSHTON A. W. A. (1995) — A revision of Ordovician series and stages from the historical type area. Geol. Mag., **132**, p. 15–30, no. 1.

FRIEDMAN G. M. (1959) — Identification of carbonate minerals by staining methods. J. Sed. Petrol., **29**, p. 87–97, no. 1.

FRIEDMAN G. M. (1971) — Staining. In: Procedures in sedimentary petrology, p. 511–530. Wiley — Interscience.

GŁADYSZ J., JACHOWICZ M., PIEKARSKI K. (1990) — Palaeozoic acritarcha from the Siewierz vicinity (northern margin of the Upper Silesian Coal Basin) (in Polish with English summary). Kwart. Geol., **34**, p. 623–630, no. 4.

HARAŃCZYK C. (1982) — Nowe dane do poznania kaledońskiego górotworu krakowidów. In: Przew. 54 Zjazdu Pol. Tow. Geol., Sosnowiec, p. 90–101.

HARAŃCZYK C. (1992) — Budowa geologiczna obszaru badań. In: Sprawozdanie z prac poszukiwawczych i badawczych mineralizacji miedziowo-molibdenowej w obrębie skał dewonu i syluru na obszarze miasta Zawiercia. Arch. PG. Kraków.

HEFLIK W., PIEKARSKI K. (1978) — Lidites from the basement in the Myszków area (Częstochowa voivodship) Prz. Geol., **26**, p. 501–503, no. 8.

HEFLIK W., PARACHONIAK W., PIEKARSKI K., RATAJCZAK T., RYSZKA J. (1975) — Petrografia utworów staropaleozoicznych z okolic Myszkowa (Górny Śląsk). Zesz. Nauk. AGH, Geologia, **1**, no. 4.

JACHOWICZ M. (1995) — Opracowanie stratygrafii starszego paleozoiku NE obrzeżenia GZW w oparciu o badania mikropaleontologiczne Acritarcha. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

JURECZKA J., AUST J., BUŁA Z., DOPITA M., ZDANOWSKI A. (1995) — Geological map of the Upper Silesian Coal Basin 1:200 000. Państw. Inst. Geol. Warszawa.

LINDSTRÖM M. (1960) — A Lower-Middle Ordovician succession of conodont faunas. 21. st. Internar. Geol. Congr. Rept., **7**, p. 88–96.

LÖFGREN A. (1978) — Arenigian and Llanvirnian conodonts from Jämtland, northern Sweden. Fossils and Strata, **13**.

ŁYDKA K. (1973) — Late-Precambrian and Silurian in the Myszków area (in Polish with English summary). Kwart. Geol., **17**, p. 700–712, no. 4.

NEHRING-LEFELD M. (1993) — Biostratygrafia ordowiku na podstawie mikrofauny. In: Budowa geologiczna starszego paleozoiku południowo-wschodniej Lubelszczyzny. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

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. 171–198, no. 2.

OLEMPSKA E. (1994) — Ostracods of the Mójcza Limestone. Palaeont. Pol., **53**, p. 129–209.

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.

PIEKARSKI K., SZYMAŃSKI B., WIELGOMAS L. (1985) — A new Ordovician stratigraphic references point in the vicinities of Myszków (in Polish with English summary). Prz. Geol., **33**, p. 501–503, no. 9.

PODHALAŃSKA T. (1978) — Middle Ordovician biozones in the Łeba Elevation NE Poland. Bull. Acad. Pol. Sc. Sér. Sc. Terre, **26**, p. 221–227, no. 3–4.

RYKA W. (1973) — Metamorphic rocks of the Caledonian basement in the vicinity of Zawiercie (in Polish wiht English summary). Kwart. Geol., **17**, p. 667–682, no. 4.

RYKA W. (1978) — Metamorphic rocks. In: Prospecting for zinc and lead ores in the Silesia–Cracow (in Polish with English summary). Pr. Inst. Geol., **83**, p. 69–71.

SERPAGLI E. (1967) — I conodonti dell Ordoviciano superiore (Ashgilliano) delle Alpi Carniche. Boll. Paleont. Italiana, **6**, p. 30–111.

SIEDLECKI S. (1962) — On the occurrence of Silurian in the eastern and north-eastern periphery of the Upper Silesian Coal Basin. Bull. Acad. Pol. Sc. Sér. Sc. Géol. Géogr., **10**, p. 41–46, no. 1.

SIEWNIAK-MADEJ A. (1993) — Wyniki badań konodontowych osadów węglanowych starszego paleozoiku w otworach Ż-78 i Ż-88. Arch. Państw. Inst. Geol. Sosnowiec.

SIEWNIAK-MADEJ A. (1994) — A review of the conodont studies of the Paleozoic deposits of the NE border of the Upper Silesian Coal Basin (SW Poland) (in Polish only). Prz. Geol., **42**, p. 649–652, no. 8.

SIEWNIAK-MADEJ A., JEZIOROWSKA M. (1978) — Badania mikropaleontologiczno-konodontowe wykonane na próbkach z otworu BM-152. Arch. Inst. Geol. Sur. Miner. AGH. Kraków.

SZYMAŃSKI B., NEHRING-LEFELD M. (1995) — Opracowanie osadów starszego paleozoiku w podłożu NE obrzeżenia GZW. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

TOMCZYK H. (1959) — Geological atlas of Poland. Stratigraphic and facial problems. Fasc. 3 — Ordovician. 1:3 000 000. Inst. Geol. Warszawa.

TOMCZYK H., TOMCZYKOWA E. (1983) — Sylur. In: Złoża rud metali na tle budowy geologicznej NE obrzeżenia GZW, p. 81–105. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

VAN WAMEL W. A. (1974) — Conodont biostratigraphy of the Upper Cambrian and Lower Ordovician of the north-western Öland, south-eastern Sweden. Utrecht Micropal. Bull., **10**.

VIIRA V. (1974) — Konodonty ordowika Pribaltiki. Walgus.

WALLISER O. H. (1964) — Conodonten des Silurs. Abh. Hess. Landesanst. Bodenforsch., **41**.

WIELGOMAS L. *et al.* (1986) — Dokumentacja geologiczna Żarki Zachód w północnej części obszaru śląsko-krakowskiego. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

WIELGOMAS L. *et al.* (1988) — Dokumentacja geologiczno-surowcowa wyników poszukiwań złóż rud cynku i ołowiu w rej. Winowno–Będusz. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

WIELGOMAS L. *et al.* (1989) — Badania geologiczno-poszukiwawcze w rej. Boronów–Niegowa. Centr. Arch. Geol. Państw. Inst. Geol. Warszawa.

ŻABA J. (1994) — Tektonika starszego paleozoiku. In: Paleozoik północno-wschodniego obrzeżenia Górnośląskiego Zagłębia Węglowego. Przew. 65 Zjazdu Pol. Tow. Geol., Sosnowiec, Pr. Nauk. UŚl, no. 1431, p. 140–172.

STRATYGRAFIA OSADÓW ORDOWIKU NA OBSZARZE ŻAREK–MYSŁOWA (NE OBRZEŻENIE GZW)

Streszczenie

Zaprezentowano wyniki badań litologicznych i stratygraficznych rdzeni skał ordowiku z 8 wybranych otworów wiertniczych z rejonu Żarek–Mysłowa północno-wschodniego obrzeżenia GZW (blok małopolski), które uzupełniono wstępnymi rezultatami analiz petrograficznych i mikrofacjalnych płytek cienkich oraz obserwacjami sedymentologicznymi i tektonicznymi. Z grupy opracowanych otworów 5 wykonano w rejonie Żarek, a 3 w rejonie Mysłowa (fig. 1).

W badanych rdzeniach datowane paleontologicznie osady ordowickie napotkano *in situ* w profilach 5 otworów wiertniczych (Ż-47, Ż-59, Ż-67, Ż-88 i Ż-89; fig. 2). Za osady ordowickie uznano ponadto umownie pozbawione mikroszczątków organicznych skały węglanowe stwierdzone w profilach otworów: WB-24 (głęb. 464,5–585,0 m), WB-31 (głęb. 327,0–456,0 m) i WB-45 (głęb. 267,0–300,0 m).

W analizowanych profilach osady ordowickie stwierdzono pod bezpośrednim przykryciem dwu serii skalnych, tj. syluru (otwory: Ż-89, Ż-88, Ż-67 i Ż-59) lub triasu dolnego (otwór Ż-47). Z nadkładem sylurskim graniczą one bądź zgodnie sedymentacyjnie (otwory: Ż-88 i Ż-89), bądź niezgodnie wzdłuż płaszczyzn nieciągłości tektonicznych (otwory: Ż-59 i Ż-67), podczas gdy z osadami triasu dolnego (ret) ich granica ma charakter niezgodności sedymentacyjnej manifestującej się znacznych rozmiarów hiatusem stratygraficznym (otwór Ż-47). Kompleks osadów węglanowych ordowiku podścielony jest serią klastyków najmłodszego prekambru (wend)–kambru dolnego?, z którymi kontaktują wzdłuż wyrazistej powierzchni niezgodności tektonicznej (otwory: Ż-59, Ż-88 i Ż-89). Granicę osadów ordowiku zarówno z seriami bezpośredniego nadkładu, jak i z podłożem, podkreśla zwykle zmiennych rozmiarów dyskordancja kątowa, która zmienia się od 10–27 do 30–40° (fig. 2).

Skały węglanowe ordowiku stwierdzono również w profilach wiertniczych w formie redeponowanego materiału okruchowego na złożu wtórnym. Ich nagromadzenia zidentyfikowano wśród składników frakcji grubookruchowej, m.in. transgresywnych zlepieńców podstawowych kompleksu triasu dolnego i środkowego, w których występują w trzech różnowiekowych poziomach: dolnym (niższy pstry piaskowiec), środkowym (ret) i górnym (dolomit kruszconośny). Jakościowy skład ordowickiego materiału litycznego w zlepieńcach poszczególnych poziomów jest mało urozmaicony i nie wykazuje istotniejszych zmian lateralnych. Z próbek klastów wapieni, wyseparowanych ze zlepieńców podstawowych triasu środkowego (dolomity kruszconośne, otwór Ż-12 (głęb. 197,5–197,9 m), nie uzyskano mikroszczątków organicznych. Znaczniejsze nagromadzenia redeponowanych klastów wapieni ordowiku stwierdzono m.in. w profilach otworów: Ż-12 (głęb. 197,2–197,9 m), Ż-65 (głęb. 315,7–316,9 m) i Ż-131 (głęb. 352,0–353,5 m).

Zapis litologiczny ordowiku tworzą głównie osady węglanowe, podrzędnie ilaste i ilasto-mułowcowe. Człon sekwencji węglanowej reprezentowany jest przez wapienie, wapienie dolomityczne oraz wapienie margliste i organodetrytyczne. Ich charakter petrograficzny odpowiada trzem podstawowym typom teksturalnym: średnio- i grubokrystalicznym sparytom, sparytom zailonym i biosparytom. Skały te są na ogół masywne, zwięzłe i twarde, miejscami mniej lub bardziej skrzemionkowane o nierównym przełamie, najczęściej pozbawione uławicenia. Ich barwa jest jednolita, zwykle jasnoszara i szara, lokalnie w odcinku przystropowym wtórnie zmieniona — szarobrunatna (otwór Ż-47). Struktura skał węglanowych jest allotriomorficzna (ziarnista), a tekstura bezładna, masywna.

W sekwencjach wapieni powszechnie notuje się charakterystyczne nierówne powierzchnie nieciągłości sedymentacyjnych z cienkimi powłokami ilastymi, słabo zachowane stylolity o różnej orientacji i genezie, drobne spękania i próżnie oraz nieregularne żyłki węglanowe i kwarcowe ze skupieniami siarczków. Zupełnie wyjątkowo pojawiają się w dolnym i przystropowym odcinku profilu nieregularne smugi i przemazy materiału ilastego barwy szarej i szaroseledynowej oraz drobne gniazdowe skupienia szarobrunatnej substancji fosforanowej (otwór Ż-67). W żadnym z badanych profilów w kompleksie węglanów ordowiku nie napotkano dotychczas makroszczątków organicznych i śladów działalności życiowej organizmów.

Zapis stratygraficzny ordowiku reprezentowany jest przez 5 standardowych serii systemu: arenig, lanwirn, landeil, karadok i aszgil. Identyfikację wiekową arenigu, lanwirnu, landeilu i aszgilu oparto na datowaniach mikropaleontologicznych, natomiast karadoku — na wcześniejszych znaleziskach makrofauny i mikroflory (akritarcha) oraz przesłankach pośrednich, w tym ich litologii i pozycji w profilu. Za sprawą złego stanu zachowania większości mikroskamieniałości, ich nierównomiernego rozmieszczenia i niskiej na ogół frekwencji, wreszcie luk w rozpoznaniu biostratygraficznym przyjęta wersja podziału stratygraficznego ma charakter przybliżony.

Zestawienie opróbowanych odcinków sekwencji ordowickiej w poszczególnych profilach, interwały występowania konodontów oraz interpretację ich zasięgów stratygraficznych przedstawia fig. 3.

Zespoły skalne węglanów ordowiku są intensywnie stektonizowane, często notuje się strefy brekcji lub druzgotu tektonicznego, liczne spękania, szczeliny i strome powierzchnie poślizgów. Upady warstw w poszczególnych profilach są zmienne i najczęściej mieszczą się — we wszystkich tych przypadkach, gdy ich identyfikacja jest w pełni wiarygodna — w granicach 20–40° (fig. 2). Zakres i skala tektonizacji są zróżnicowane przestrzennie — relatywnie słabsze w rejonie Żarek (otwór Ż-88), a wyraźnie intensywniejsze w rejonie Mysłowa (otwór WB-24), tj. w bezpośrednim sąsiedztwie przebiegu domniemanej strefy uskoku przesuwczego między blokiem górnośląskim a małopolskim (fig. 1).

Za tymczasowy litostratotyp ordowiku żarecko-mysłowskiego segmentu NE obrzeżenia GZW mogą być uznane cząstkowe profile z otworów Ż-47 i Ż-89, w których stwierdzono najpełniejszą dotychczas sukcesję stratygraficzną datowanych paleontologicznie osadów arenigu–landeilu i aszgilu. Jako hipolitostratotyp może służyć cząstkowy profil z otworu wiertniczego WB-45 (głęb. 267,0–300,0 m), gdzie według K. Piekarskiego i in. (1985) rozpoznano fragment sekwencji karadoku o wykształceniu węglanowo-klastycznym (fig. 2).

Inwentarz litologiczny i zespoły mikroskamieniałości osadów węglanowych ordowiku rejonu Żarek wykazują liczne analogie z równowiekowymi ich odpowiednikami w profilach obszarów sąsiednich, tj. rejonu Mrzygłodu (otwór A-4) i Zawiercia (M. Nehring-Lefeld i in., 1992).

Zrekonstruowana na podstawie opracowanych profili cząstkowych całkowita miąższość rzeczywista osadów ordowiku żarecko-mysłowskiego segmentu NE obrzeżenia GZW wynosi przypuszczalnie około 85,0–90,0 m.