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STRATIGRAPHY AND NEW DATA ON TECTONICS OF THE ORDOVICIAN STRATA IN THE SECTION AT MIĘDZYGÓRZ QUARRY (EASTERN HOLY CROSS MOUNTAINS, POLAND)

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Abstract: The Ordovician strata cropping-out at Międzygórz represent the Międzygórz Sandstones Formation and the Mójcza Limestones Formation (*sensu* Bednarczyk 1981). The Międzygórz Sandstone Formation is correlated with the upper Tremadocian (the Kleczanów Sandstone Member), Upper Arenigian (the Chełm Conglomerate Member) and Lower Llanvirnian (the Dyminy Orthid Sandstone Member). The Mójcza Limestone Formation (the Mokradle Dolomite Member) corresponds to the lower Caradocian. Earlier observations about strong reduction of all Ordovician chronostratigraphic units are corroborated. In the quarry, the Kleczanów Sandstone Member and the Dyminy Orthid Sandstone Member make small tectonic unit consisting of 5 or more scales thrusted over each other in result of pressure of the Cambrian rocks from the north (the Łysogóry unit) onto the Ordovician–Silurian sequence making the core of the Międzygórz Syncline. The Mokradle Dolomite Member is a fragment of the northern limb of the Międzygórz Syncline. The rocks are thrown southward and partly squized out due to action of the Lower Ordovician tectonic scales thrown from the north. East of the Międzygórz quarry the Ordovician rocks were completely squeezed out. The recent research allows to presume that the Ordovician strata at Międzygórz form a separate tectonic unit which owes its origin to the same tectonic action which has formed the Holy Cross Dislocation.

Abstrakt: Utwory ordowiku odsłaniające się w kamieniołomie w Międzygórzu reprezentują dwie jednostki litostratygraficzne: formację piaskowców z Międzygórza i formację wapieni z Mójczy. Formacja piaskowców z Międzygórza jest korelowana z górnym tremadokiem (ogniwo piaskowca z Kleczanowa), górnym arenigiem (ogniwo zlepieńca z Chełma) i z dolnym lanwirnem (ogniwo piaskowca orthidowego z Dymin). Formacja wapieni z Mójczy jest tu reprezentowana przez ogniwo dolomitu z Mokradla i odpowiada dolnemu karadokowi. W wyniku badań potwierdzono wcześniejsze obserwacje o silnej redukcji tektonicznej poszczególnych jednostek chronostratygraficznych. W północno-wschodniej części kamieniołomu ogniwo piaskowca z Kleczanowa i ogniwo piaskowca orthidowego z Dymin tworzą małą jednostkę tektoniczną złożoną z conajmniej 5 łusek, nasuniętych jedna na drugą na skutek nacisku skał kambryjskich z północy na skały ordowiku. W południowo-zachodniej części kamieniołomu odsłaniają się skały ogniwa dolomitu z Mokradla stanowiące fragment północnego skrzydła synkliny międzygórskiej. Skały środkowego ordowiku są odwrócone na południe i częściowo wyciśnięte na skutek nasunięcia z północy dolnoordowickich łusek. Na wschód od kamieniołomu skały ordowiku zostały całkowicie wyciśnięte. Obecne badania pozwoliły wyciągnąć wniosek, że dolny ordowik w Międzygórzu reprezentuje oddzielną jednostkę tektoniczną utworzoną w wyniku tego samego waryscyjskiego procesu tektonicznego, który spowodował powstanie dyslokacji świętokrzyskiej.

Key words: Stratigraphy, tectonics, Ordovician, Holy Cross Mountains, Central Poland.

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INTRODUCTION

Between Opatów and Sandomierz at Międzygórz and Słaboszewice occurs a belt of Ordovician strata of WNW–ESE direction. The belt of streches (Fig. 1) several kilometers long and several dozen meters wide crop out under Quaternary cover in gullies of the left side tributaries of the Opatówka river: Chełm, Zapusty, Łączki and Glibiele (Fig.

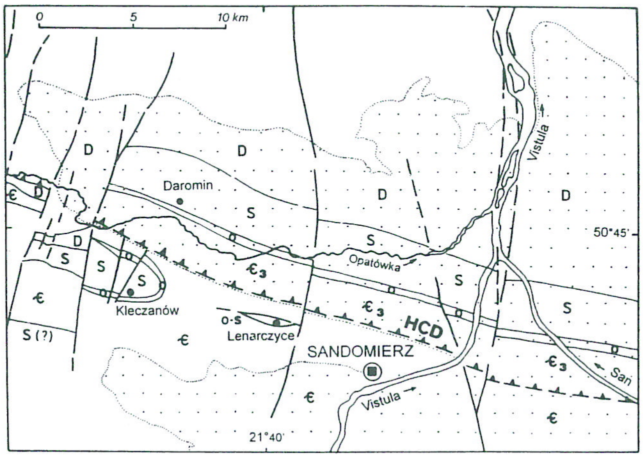


Fig. 1. Geological map of the eastern part of the Holy Cross Mountains (After Pożaryski and Tomczyk, 1993, generalized). HCD – Holy Cross Disclocation; € – Cambrian; €$_3$ – Upper Cambrian; O – Ordovician; S – Silurian; D – Devonian; uninterrupted and interrupted thick lines – faults; dotted lines and dotted area – extent of Tertiary of the Opatówka River; big black circle – borehole

2), being best exposed in the Międzygórz quarry (Figs 3 and 4). The Ordovician profile at Miedzygórz was for many years a type section for the Ordovician system in the eastern part of the Holy Cross Mountains. It was found, that the Międzygórz section contain in the stratigraphic order (Fig. 5): a conglomerate series, a series of glauconitic sandstones with obolids *Thysanotos siluricus* (Eichwald), a light-grey sandstones with brachiopod fauna represented *e. g.* by *Orthambonites calligrammus* (Dalman), *Antigonambonites planus* (Pander), *Lycophoria nucella* (Dalman) and at the top is a series of limestones and marls with ostracods and crinoids (Samsonowicz, 1928; Tomczyk, 1954). The presence of conglomerate is of primary importance. It was interpreted as a transgressive deposit starting the Ordovician sequence there (Bednarczyk, 1971; Dzik & Pisera, 1994; Samsonowicz, 1952; Tomczykowa & Tomczyk, 1970; Znosko & Chlebowski, 1976).

GEOLOGICAL SETTING

According to Samsonowicz (1934) and Tomczyk (1954) the Międzygórz Syncline composed of the Ordovician and Silurian strata is asymmetric in shape. Its southern limb dips gently whereas the northern one is steep and overturned southward. The Międzygórz exposure is located within the northern limb of the Syncline. North of the northern limb, a dislocation runs of WNW–ESE direction along which the Middle Cambrian rocks rest on the Lower Ordovician strata. On the map by Tomczyk (1954) the Ordovician strata in Międzygórz make a lens-like body about 120 meters long and 30 meters wide. Its longer axis of azimuth 120° is parallel to the axis of the Międzygórz Syncline. South of the Międzygórz quarry Tomczyk (1954) has described the Llandoverian shales.

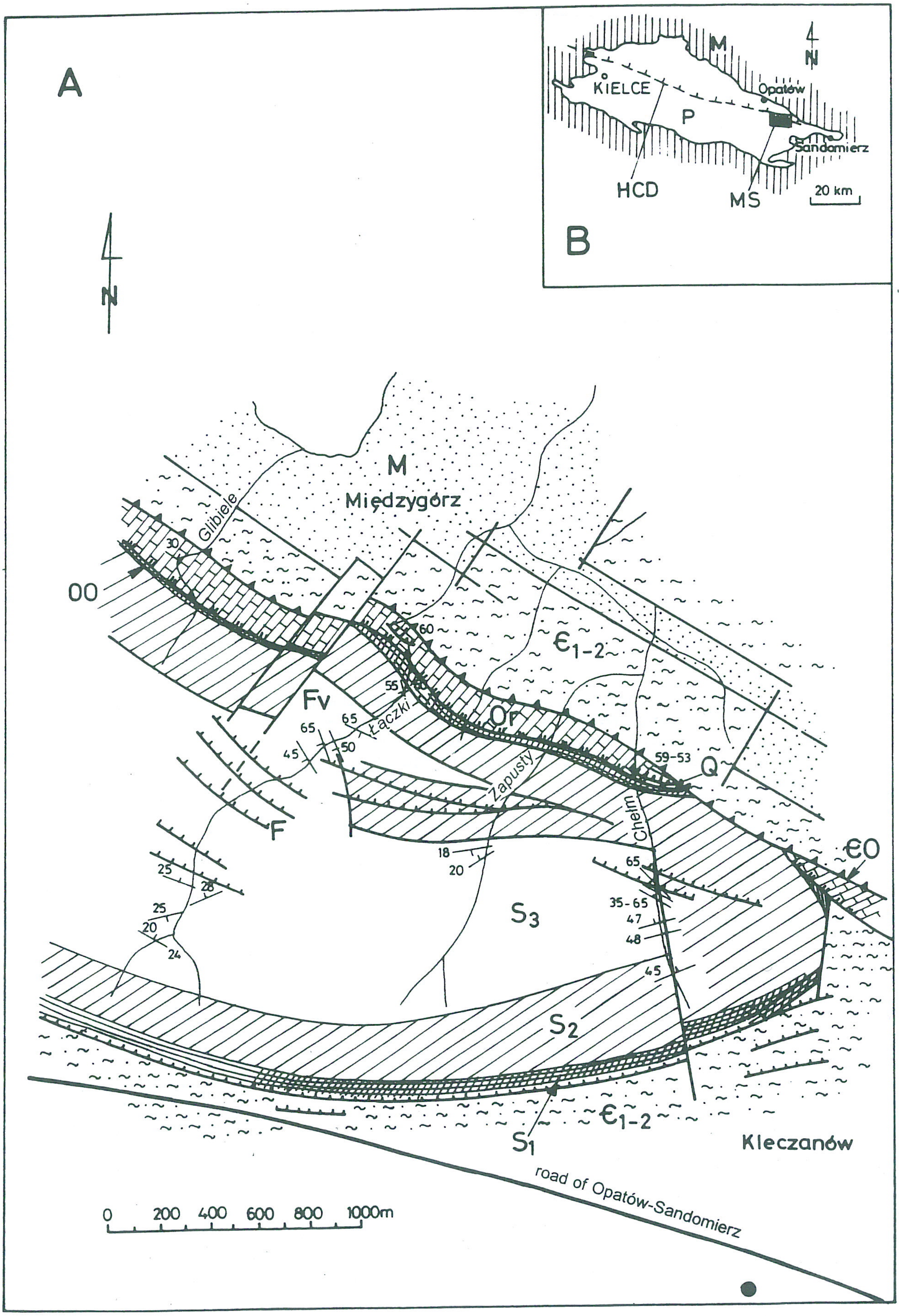
The main (eastern) wall of the Międzygórz quarry is shown on Fig. 3a, and the profile of the Ordovician strata measured from photographs – on Fig. 3b and Fig. 4. The Ordovician rocks are divided into seven tectonic units (scales) which are numbered with Roman numbers from I to VII (Fig. 3b). They differ both in lithology and age. Each scale shows different tectonic position of beds. The strikes range from 105° up to 145°, dips – from 45° up to 72° toward the north. The scales represent: the glauconitic sandstones with obolids – scales I to IV, the conglomerates – scale V, the Orthid Sandstones – scale VI and the limestones series makes the scale VII aside of the Wenlockian graptolite shale (Fig. 3).

ORDOVICIAN LITHOSTRATIGRAPHY AT THE MIĘDZYGÓRZ QUARRY

The oldest Ordovician strata at the Międzygórz quarry crop out as the scales I, II, III and IV (Fig. 3a). Those are the Kleczanów Sandstone Member of the Międzygórz Sandstones Formation (*sensu* Bednarczyk 1981). The scale I is composed of beds of medium- to coarse-grained sandstone with siliceous cement, grey in colour with greenish shade due to glauconite admixture. Those are regular beds up to 30 cm thick. They are interbedded with light-grey, somewhat silty shales up to 10 cm thick easily split into thin flakes. In the southern part of the scale thick shelled obolids *Thysanotos siluricus* (Eichwald) and *Rosobolus robertinus* Havliček occur (Bednarczyk, 1964, tab. I: 10; II: 1, 3; IX: 10, 12). In the northern part, there occur also abundant thin-shelled *Celdobolus mirandus* (Barrande) (Bednarczyk 1964, tab. VIII: 17, see also Fig. 9).

The scale I is about five meters thick. It is not a real stratigraphic thickness however, as in the south the Kleczanów Sandstone Member contacts with the Dyminy Orthid Sandstone Member (scale VI) along a fault and in the north with the Chełm Conglomerat Member (scale V; Fig. 3). The beds in the scale I show normal position which is proved by hieroglyphs seen on bedding planes. Strike and dip of beds is 114/65°N.

Fig. 2. **A.** Geological map of the Międzygórz Syncline (after Stein & Stupnicka, 1996); €$_{1-2}$ – Lower and Middle Cambrian sandstones and shales; Or – Ordovician sandstones and conglomerates; S$_1$ – Lower Silurian graptolitic Shales; S$_2$ – Upper Silurian greywackes; S$_3$ – Upper Silurian shales with intercalations of greywackes siltstones; M – Miocene sandstones interbedded with claystones and coal beds; €O – overlapping of the Cambrian rocks on the Ordovician scales; OO –overlapping of the Ordovician scales on the Międzygórz Syncline; F – normal faults; Fv – vertical faults; Q – quarry; black circle – the Kleczanów 1 borehole. **B.** Position of the Międzygórz Syncline within the Palaeozoic core of the Holy Cross Mountains. M – Mesozoic; P – Palaeozoic; HCD – Holy Cross dislocation; MS – the Międzygórz Syncline



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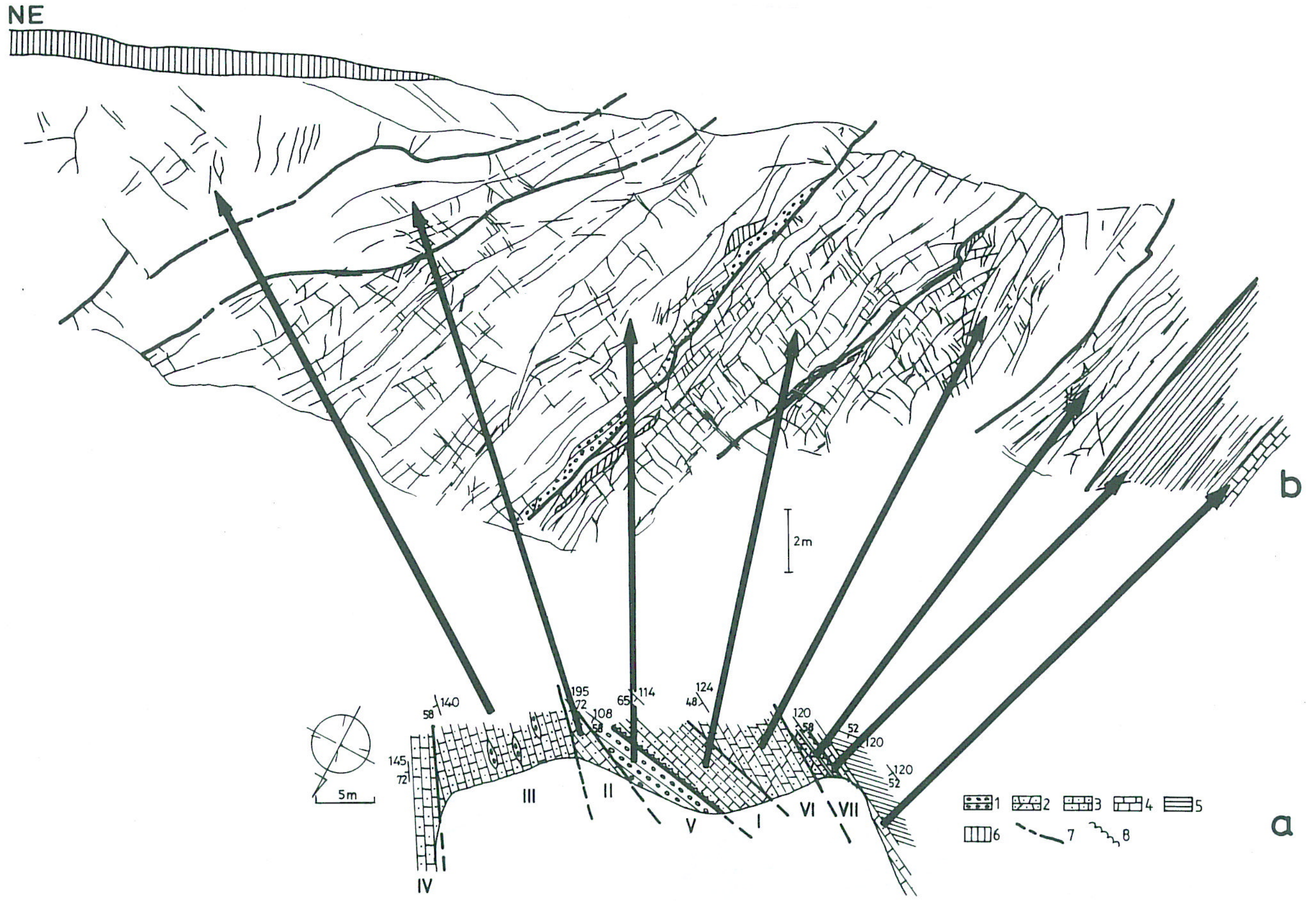

Fig. 3. General view of the main wall of the Międzygórz quarry based on photographic images (**b**) and the present author's sketch-plan (**a**). *1* – Chełm Conglomerate Member; *2* – Dyminy Orthids Sandstone Member; *3* – Kleczanów Sandstone Member; *4* – Mokradle Dolomite Member; *5* – Lower Silurian shales; *6* – loes; *7* – fault; *8* – overlapping zone; I–IV – scales of the Kleczanów Sandstone Member; V – scale of the Chełm Conglomerate Member; VI – scale of the Dyminy Orthid Sandstone Member; VII – scale of the Mójcza Limestones Formation

Scale II separated from the scale I by scale V consists of the Chełm Conglomerate Member. It contains sandstone beds not differing from those of scale I. Its thickness is small. Strike and dip of beds is 125/72°N and is slightly oblique toward to the beds of scale V situated below. The beds in scale II are older than the Chełm Conglomerate Member (scale V) hence they were thrust over the latter. A fragment of cast of *Celdobolus mirandus* has been found there. This scale wedges out quickly eastward.

Scale III about 10 m thick consists of sandstone beds

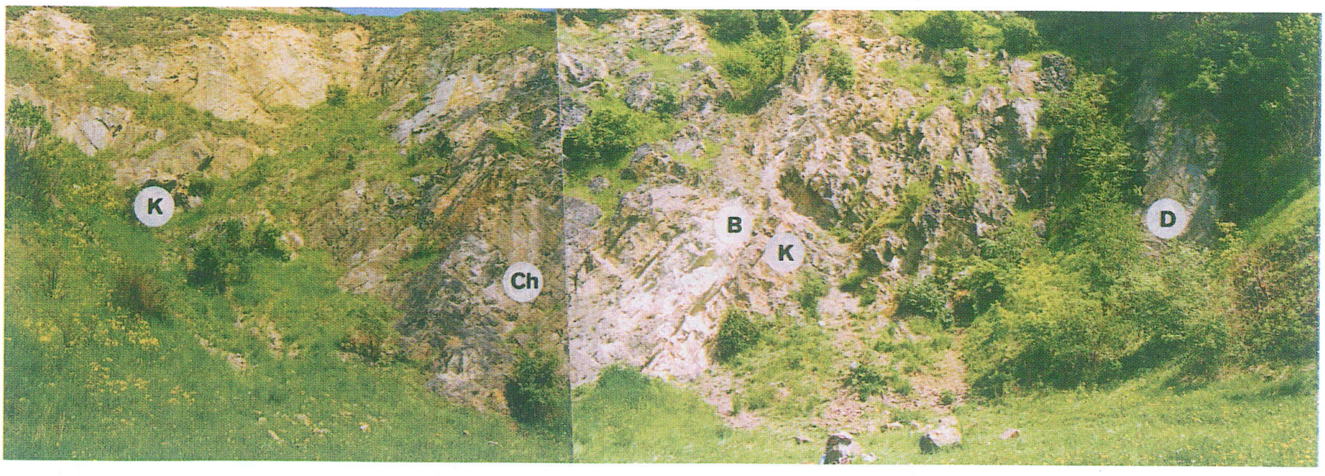

Fig. 4. General view of the Międzygórz quarry. K – the Kleczanów Sandstone Member; Ch – the Chełm Conglomerate Member; D – the Dyminy Orthid Sandstone Member; B – breccia horizon. Height of quarry wall about 13 m

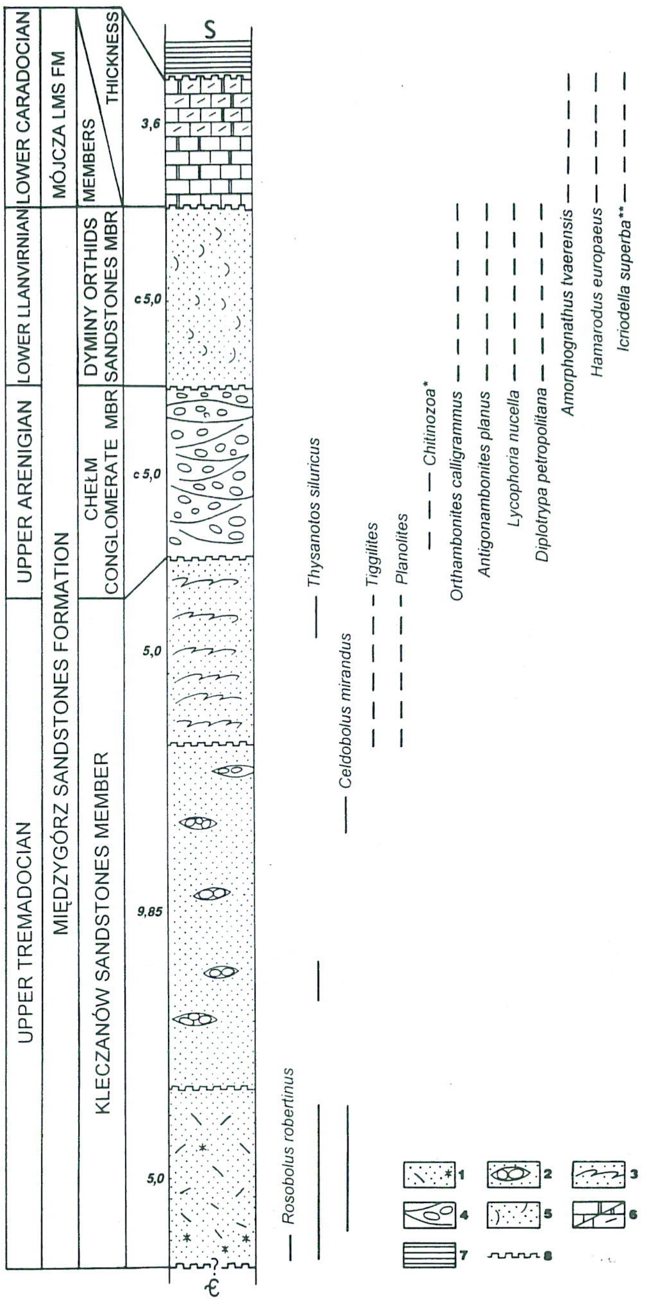

Fig. 5. Ordovician deposits in the Międzygórz section. *1* – sandstone with grains of glauconite; *2* – sandstone with conglomerate lenses; *3* – sandstone with ripplemarks; *4* – conglomerate; *5* – sandstone with casts and moulds of brachiopods; *6* – dolomitic or marly limestones; *7* – graptolitic shales; *8* – tectonic unconformities

separated by thin (up to 10 cm) conglomerate lenses as well as gravels composed of quartz pebbles. The longer axes of pebbles are concordant with bedding. The beds are in normal position. Strike and dip is 140/58°N.

The scale IV is situated in the northern part of the main quarry wall. It consists of sandstone beds the same as in scale I. It belongs to the Kleczanów Sandstone Member. Ripplemarks and channels of *Tiggilites* sp. as well as burrows determined as *Planolites* sp. (Fig. 6) and a fragmentar-

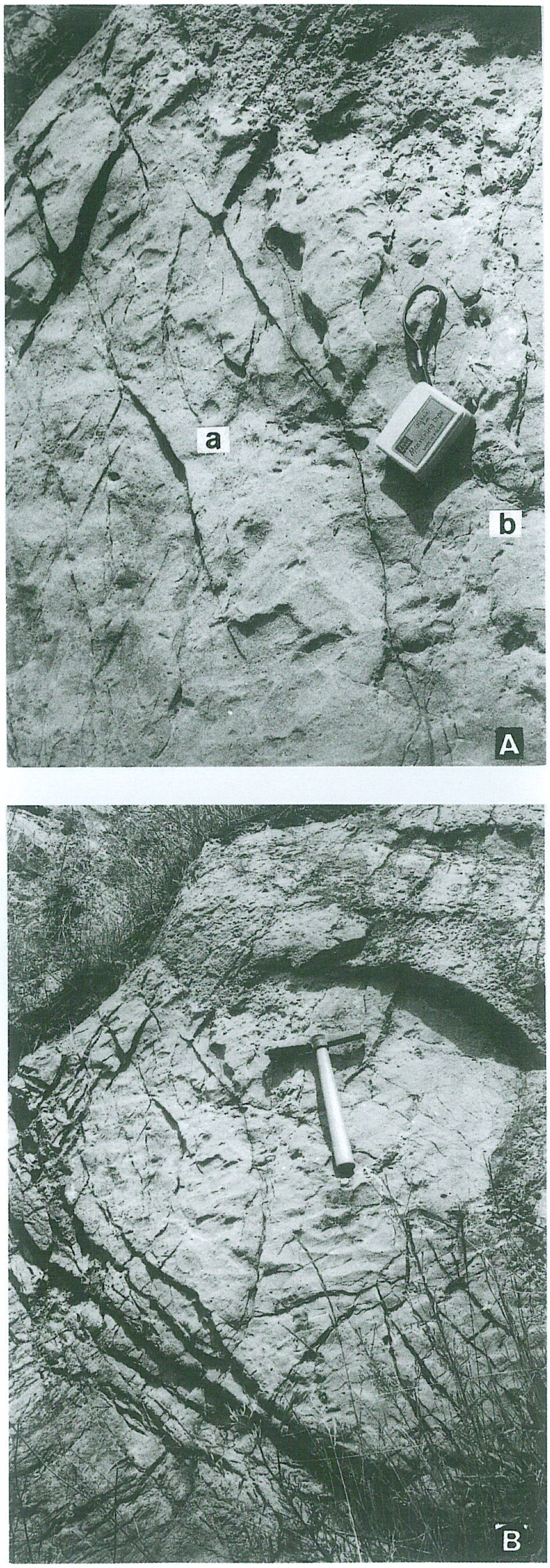

Fig. 6. **A.** Biohieroglyphs (a – *Tiggillites* sp.; b – *Planolites* sp.); **B** – interference ripplemarks on bedding planes of the Kleczanów Sandstone Member of the scale IV

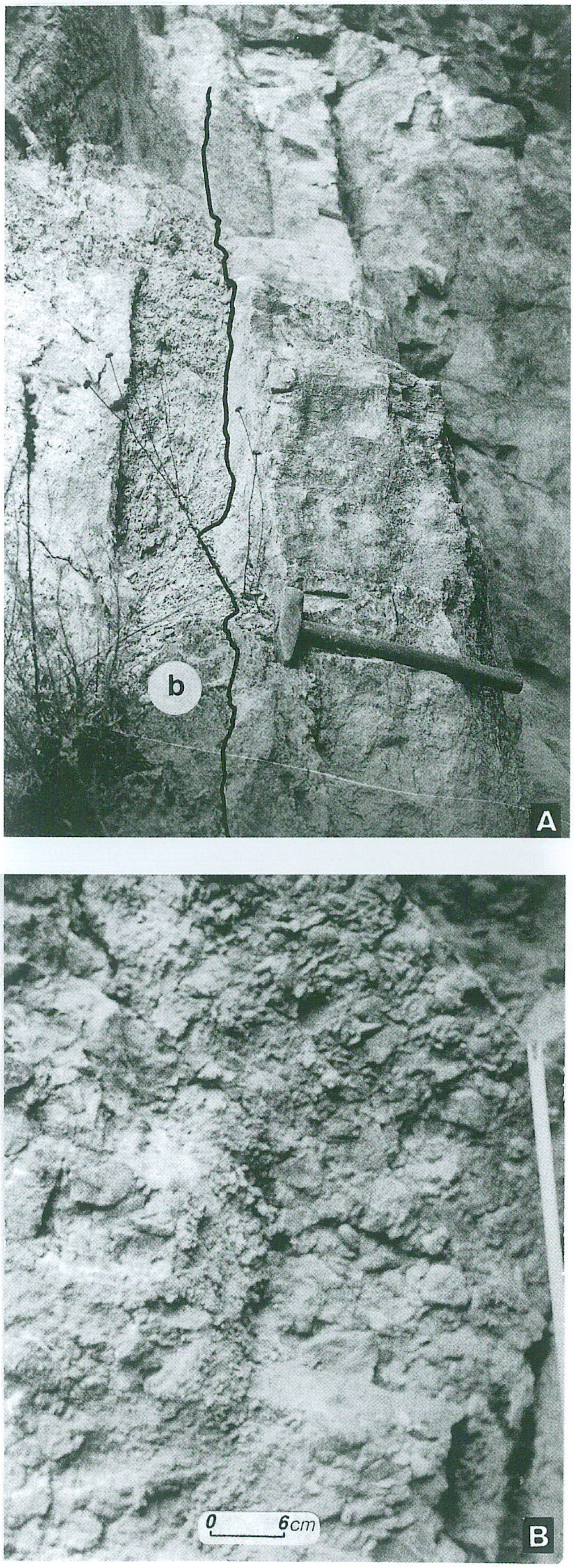

Fig. 7. **A.** A part of the tectonic breccia (b) consisting of crushed pebbles; **B.** Zone of the same tectonic breccia at the bottom of the Chełm Conglomerate Member – between scales I and V

Fig. 8. **A.** Typical conglomerate of the Chełm Conglomerate Member; **B.** Conglomerate from the breccia horizon (scale V)

ily preserved cast of shell of *Thysanotos siluricus* (Eichwald) have been found on sole of the sandstone beds. Strike and dip of beds is 145/72°N.

The scale V occurs between scales I and II (Fig. 3). It consists of conglomerate beds (the Chełm Conglomerate Member, Fig. 7). The conglomerate occurs in the form of flat lenses 0.20 to 2.5 m thick. This is grey to greenish-grey rock with siliceous cement. According to Turnau-Morawska (1960) it contains quartz, siltstone and vein-quartz pebbles. Spaces between them are infilled by quartz and phosphate particles as well as by glauconite, pyrite grains and iron oxides. The pebbles are usually coated by thin glauconitic film. The observable thickness of the conglomerate in the quarry does not exceed 5 m. Strike and dip of beds is 108/58°N. A tectonic breccia 0.2 to 0.6 m thick is to be found at bottom of the conglomerate (between scales I and V, Fig. 3).

It consists of crushed quartzitic pebbles (Fig. 8). Striae of glide were observed near the breccia on the sandstone plane surfaces. The Chełm Conglomerate Member is known in the Holy Cross region entirely from the Międzygórz quarry.

The scale VI is located south of the scale I (Fig. 3).

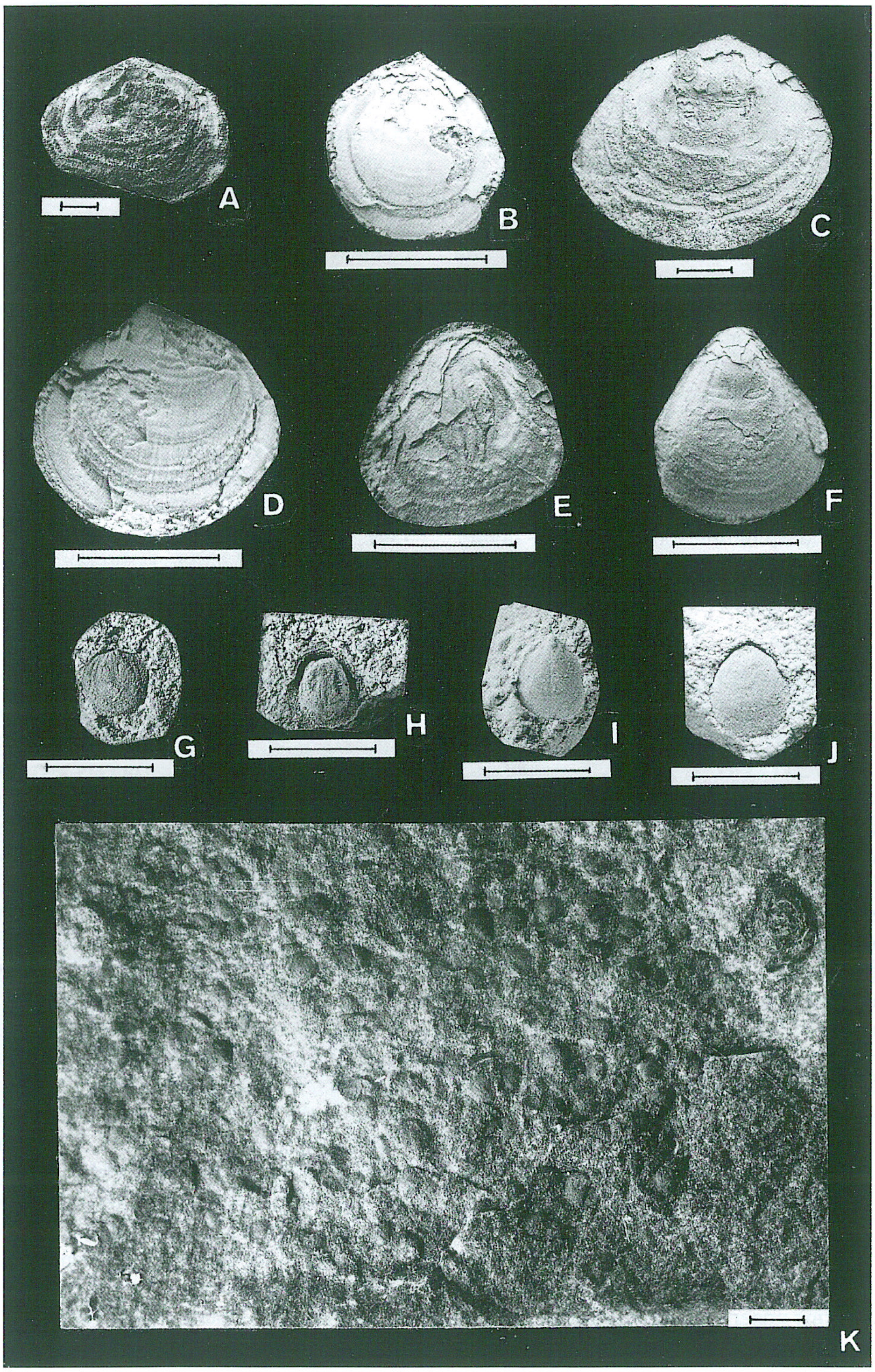

Fig. 9. Brachiopods from the Kleczanów Sandstone Member of the Międzygórz quarry and from the Zbilutka Siltstone and Chalcedonite and the Koziel *Conotreta* Siltstone members of the Bardo Syncline. *Thysanotos siluricus* (Eichwald, 1840): **A**, **C** – moulds of ventral valve, Międzygórz quarry. *Rosobolus robertinus* (Havlicek, 1982): **B**, **D** – partly peeled ventral valves, Międzygórz quarry. **E**, **F** – moulds of ventral valves, Szumsko. *Celdobolus mirandus* (Barrande, 1879): **G** – mould of ventral valve, Koziel; **H** – mould of dorsal valve, Koziel; **K** – moulds and casts of ventral and dorsal valves, Międzygórz. ? *Pidiobolus* cf. *minimus* Mergl, 1995: moulds of ventral valves, **I** – mould of ventral valve, Koziel; **J** – mould of ventral valve, Szumsko. Scale bars 5 mm

These are siltstones and fine grained sandstones medium to thick bedded. The greenish-grey rock is full of casts and moulds of Orthidae and bryozoans which in places form coquinas (Bednarczyk, 1964, tab. IX, 11). The cement is clayey-siliceous with dolomitic admixture. Strike and dip of beds is 124/48°N. The scale VI represents the Dyminy Orthid Sandstone Member.

The scale VII consists of various lithological rock types. A small lense of Silurian shale with Wenlockian graptolites occurs under the sandstones of the scale VI (Fig. 3). Still lower are limestones and dolomitic marls belonging to the Mokradle Dolomite Member (the Mójcza Limestones Formation). The member is about 3.6 m thick. Strike and dip of beds is 120/58°N. The beds are most probably overturned.

South of the scale VII, there occur shales with a thin interbed of siltstone containing Llandoverian graptolites (Tom-czyk, 1954). Strike of beds is about 120° and dip – 50°N. The Silurian strata continue in the Chełm ravine. They are covered by Upper Silurian graywackes in the central part of the Międzygórz Syncline (Fig. 2).

LITHOSTRATIGRAPHIC AND BIOSTRATIGRAPHIC CORRELATION OF THE MIĘDZYGÓRZ ORDOVICIAN

The Kleczanów Sandstone Member maybe correlated with the local *Thysanotos siluricus* Biozone as they contains this index form (Fig. 9A and C). Presence of this fossil as well as *Rosobolus robertinus* Havliček (Fig. 9B, D, E and F) allow to correlate this member with the upper part of the Třenice Formation and the Milina Formation (Tremadocian) of Bohemia (Havliček, 1982). The occurrence of *Celdobolus mirandus* (Barrande) and *Pidiobolus* cf. *minimus* Mergl (Fig. 9K) in the upper part of the member may suggest correlation with the lowermost part of the Klabava Formation (Arenigian) of central Bohemia (Havliček, 1982; Mergl, 1995).

Presence of the index form allows to correlate the Kleczanów Sandstone Member with the Klooga and partly Joa Members (partly Leetse Formation) of Estonia (Mens *et al.*, 1996). These members are correlated with the Hunnebergian Stage which in Scandinavia in its lower and middle part is correlated with the upper part o Tremadocian (Maletz *et al.*, 1996).

In the Bardo Syncline in the central part of the Kielce region *Thysanotos siluricus* (Eichwald) and *Rosobolus robertinus* (Havliček) and *Pidiobolus* cf. *minimus* Mergl (Fig. 9E–J) aside of *Leptembolon insons insons* (Barrande) occur in chalcedonites of the Zbilutka Siltstone and Chalcedonite Member is association with among others conodonts like *Paltodus deltifer pristinus* (Lindström) (Szaniawski, 1980; Bednarczyk & Biernat, 1978, tab. 2). This subspecies is characterstic for the Varanguan Stage in Estonia (upper Tremadocian) and in Sweden it lies within Biozone *Paltodus deltifer* (*Ceratopyge* Stage – upper Tremadocian) (Maletz *et al.*, 1996).

Szaniawski (Chlebowski & Szaniawski, 1974) described from shale fragments of the Chełm Conglomerate Member a chitinozoan assemblage among others: *Desmochitina minor* Eisenack, *Conochitina primitiva* (Szaniawski), *Rhabdochitina magna* Eisenack and *Lagenochitina* cf. *esthonica* Eisenack. These species are known from the Leetse Formation (the Klooga Member) (Mens *et al.*, 1996). This assemblage points to upper Tremadocian–Arenigian and "is analogous to Early Arenigian chitinozoan assemblage with *Conochitina symmetrica* Taugourdeau & Jeshkowsky, 1960 recorded in lowermost of Klabava Formation in the Prague Basin, Czech Republic" (Wrona, 1999). Hence the conglomerate is younger and was most probably laid down during the Late Arenigian. The conglomerate was treated earlier as a transgressive sediment (Bednarczyk, 1964; Chlebowski & Szaniawski, 1974; Samsonowicz, 1952; Tomczyk, 1954). This view was questioned by Turnau-Morawska (1960; see also Bednarczyk, 1966) who expressed the opinion that the conglomerate represents an intraformational conglomerate on the basis of large share of glauconite. The rock composed of Cambrian quartzites and Ordovician shales has originated most probably as cliff deposit.

The Dyminy Orthid Sandstone Member is younger than the Chełm Conglomerate and the Kleczanów Sandstone members. Numerous brachiopods found in the rock among which is the index species of Biozone *Lycophoria nucella* (Bednarczyk, 1964, tab. XVI: 1–5) known from the Ordovician of the Petersburg area (Männil, 1987) allow to correlate the member with the Baltoscandian Kunda Stage and Lower Llanvirnian in the British chronostratigraphy.

The Mójcza Limestones Formation (scale VII) did not furnish macrofossils except one poorly preserved nautiloid conch (Dzik & Pisera, 1994). The ostracods (Bednarczyk, 1964) suggested Caradocian age of this formation. The list

Fig. 10. Conodonts from the Mokradle Dolomite Member of the Mójcza Limestones Formation (Caradocian, Ordovician), the Międzygórz quarry, eastern part of the Holy Cross Mt. *Amorphognathus* (cf. *superbus* (Rhodes, 1953)) sp.: **A** – element oz ×100; **C** – fragment of element sp ×100. *Amorphognathus tvaerensis* Bergström, 1962: **B** – element sp ×100; **O** – element ne ×150; **V** – element ne ×160. *Amorphognathus* ? sp.: **DD** – fragment of element ? sp ×150. *Hamarodus europaeus* Serpagli, 1967: **P** – element hi ×140; **Q** – element hi ×150; **R** – element ne ×120. *Rodesognathus polonicus* (Dzik, 1976): **G** – element oz ×110; T – element pl ×140; **U** – element hi ×160; **Y** – element tri ×150. ? *Phragmodus* (cf. *undatus* Branson & Mehl, 1933, cf. Sweet *et al.* 1971, Pl. 2, Fig. 8) sp.: **S** – element sp ×150. *Sagittodontina* cf. *kielcensis* Dzik, 1976: **F** – element ne ×160; **J** – element ke ×110; **W** – element oz ×160. *Baltoniodus* cf. *variabilis* (Bergström, 1962): **E** – element oz ×130; **H** – element pl ×150; **I** – element tri ×100; **Z** – element pl ×110; **AA** – element ke ×120; BB – element ne ×130. *Baltoniodus* (cf. *prevariabilis* (Fahraeus) sp.: redeposited elements: **D** – element oz ×100; **K** – element ne ×150; **L** – element ne ×130; **M** – element ke ×110; **N** – element pl ×130; **X** – element oz 90. *Polonodus* ? (cf. *newfoundlandensis* Stouge 1984 cf. Fig. 15 Pl. 13) sp.: **CC** – oz element ×85


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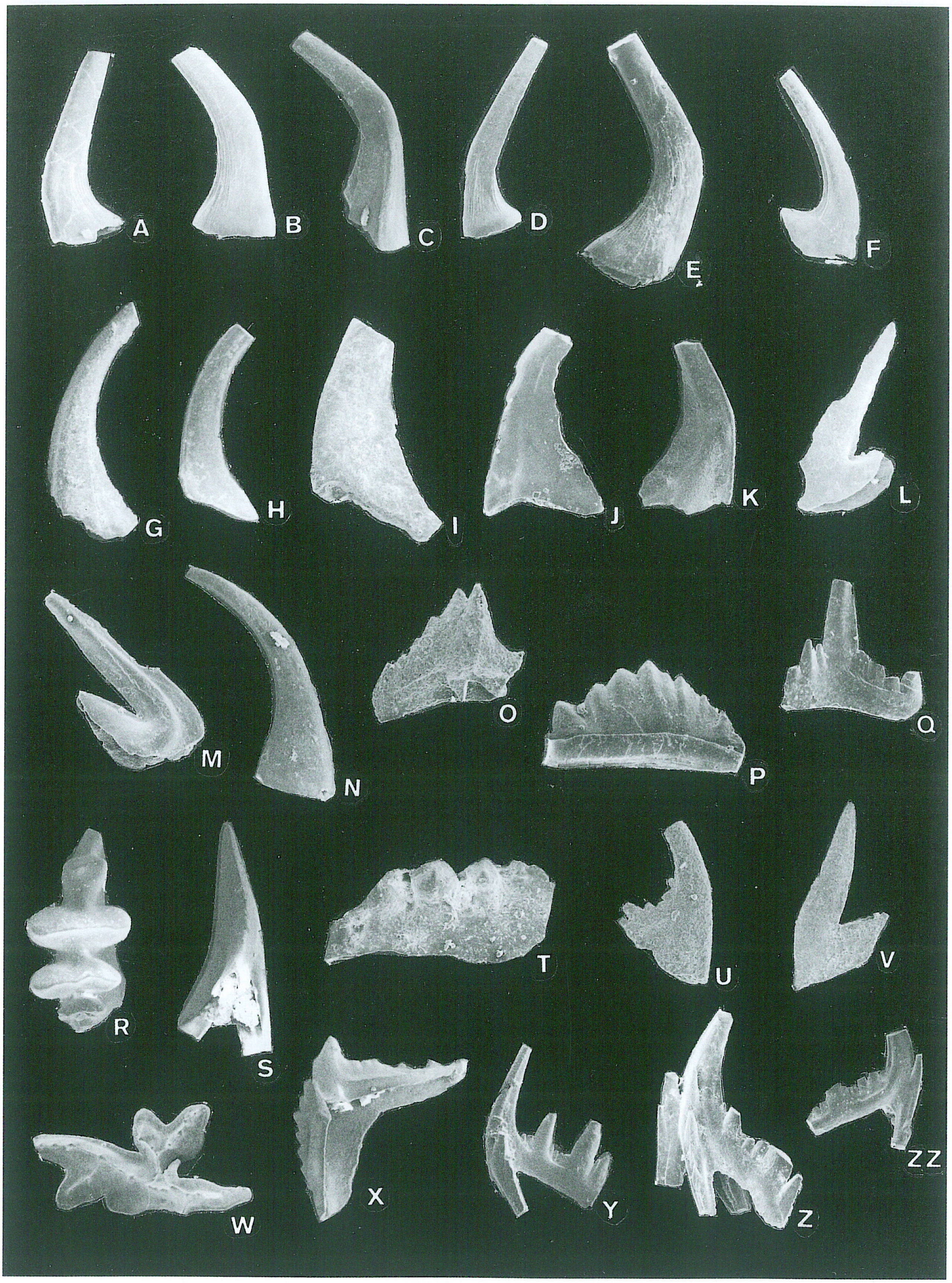
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of conodonts presented by Bednarczyk (1996) documents of two biozones of the Caradocian (*Amorphognathus twaerensis* and *A. superbus*, see also Figs 5 and 10–11). These biozones are known from the North Atlantic province embracing east coat of North America and Baltoscandia (Bergström, 1971). Dzik (1994) has mentioned the ne element of *Amorphognathus ordovicicus* (Branson & Mehl) from the Mójcza Limestones of the Międzygórz quarry; however, this species occurs also in older than the Ashgill strata in Europe and North America (Bergström, 1971).

TECTONIC ANALYSIS OF THE ORDOVICIAN SEQUENCE IN THE MIĘDZYGÓRZ QUARRY

The presented results shows that the tectonics of the Ordovician sequence in the Międzygórz quarry is much more complicated than it was supposed before (Tomczyk, 1954; Znosko & Chlebowski, 1976; Dzik & Pisera, 1994; Kremer, 1998, *vide* Dzik, 1999). There are several tectonic repetitions of older and younger strata from north to south (Figs 2 and 3). Tilted northward Ordovician strata were treated earlier as a northern limb of a syncline thrusted to the south (Tomczyk, 1954). According to this concept all the beds should be reversed. Nevertheless trace fossils and ripplemarks found on the bedding planes do not support such an interpretation. In scale I current hieroglyph were found on soles and in scale III – ripplemarks and biohieroglyphs (Fig. 6). In both cases the hieroglyphs prove to normal position of beds of the Kleczanów Sandstone Member occurring in the northern and central parts of the quarry. In the southern part of the quarry the Orthid Sandstone of Dyminy Member (Lower Llanvirnian (scale VI) rests on the Middle Ordovician dolomitic limestone of the Mójcza Limestones Formation with Caradocian fossils (scale VII). The latter underlies the Silurian shales the beds of which show reversed position (Fig. 3).

Measurements of strike and dip have been done in the quarry. The result is that within relatively restricted area of the quarry the strike of beds show considerable dispersion (Fig. 3). The strikes measured along the length of beds vary from 108 to 145°. Similar results were obtained in dip measurements. The values are 42° up to 72° to the north (Fig. 3). The particular strike values characterize different rock scales described before (I–VII).

Lines of the strikes of beds cross in northwest or southeast in a distance of a dozen or several tens of meters on a horizontal sketch-map of the southeastern wall of the quarry (Fig. 2). The Ordovician rock scales occur in form of large lenses that either wedge out or broaden parallel to the general direction of outcrops of the Ordovician strata. It comes from this statement that the Ordovician strata at Międzygórz make in fact many small tectonic scales contrary to Tomczyk's view (Tomczyk, 1954) according to which there exists one large lense wedging out toward NW and SE. Each scale shows its own strike and dip of beds being separated one from another by a tectonic surface. Revised interpretation is in accordance with the results of stratigraphic research which has proved existence of many stratigraphic gaps.

The tectonic surfaces separating the scales are hardly observable at presence. The only well visible tectonic surface is that one between scale I (the Kleczanów Sandstone Member) and scale V (the Chełm Conglomerate Member) (Fig. 3a). There exists a tectonic breccia (108°/58°N; Figs 7 and 8) in form a fault vein parallel to the conglomerate beds of scale V and slightly oblique to the sandstone beds of scale I the strike and dip of which is 114/65°N.

The breccia horizon stretches along the entire wall of the quarry from bottom to top (Fig. 3b). It consists of strongly joined sandstone pebbles the same as occur in the above conglomerates. Some pebbles were crushed and make now fine below 3 mm fragments. Larger fragments can also be found. Both the pebbles and sharpedged fragments are internally strongly joined (Fig. 8A).

The pebbles and sharpedged rock fragments contact each other densely. This cannot be seen in the conglomerates in which the pebbles are loosely spaced in the matrix (Fig. 8B). On polished surface of the breccia numerous impressions of pebbles into other ones is observable (Fig. 8A).

The breccia that occurs at the boundary of scales I and V proves considerable tectonic pressure that must have acted during thrusting of the scales. The conglomerates which primarily covered the Kleczanów Sandstone Member were shifted in relation to the latter rocks. The bottom part of the conglomerate was strongly crushed and pressed and the cement was dissoluted. It may be assumed that breccia is remnant of the part of conglomerate which primarily exhibited greater thickness. The breccia has originated due to NNE–SSW compression (azimuth 30°NE).

The surface between scales II and V is of tectonic nature. Older rocks (the Kleczanow Sandstone Member – scale II, upper Tremadocian) were thrust over the younger ones (the Chełm Conglomerate Member, scale V, Upper Arenigian) along this surface (Fig. 3). Also the surfaces be-

←

Fig. 11. Conodonts from the Mokradle Dolomite Member of the Mójcza Limestones Formation (Caradocian), Międzygórz Quarry. *Semiacontiodus* cf. *longicostatus* (Drygant, 1974): **A** – specimen ×110; **B** – specimen ×120; **D** – specimen ×120; **E** – specimen ×120. *Panderodus gracilis* (Branson & Mehl, 1933): **C** – specimen ×99. *Dapsilodus viruensis* (Fahraeus, 1966): **F** – element ne ×150; **J** – element sp (?) ×130. *Panderodus compressus* (Branson & Mehl, 1933): **G** – specimen ×90; **H** – specimen ×120; **I** – specimen ×130. ? *Walliserodus* sp.: **K** – element hi ×100. *Drepanoistodus suberectus* (Branson & Mehl, 1933): **M** – element ne ×150. *Drepanoistodus* cf. *basiovalis* (Sergeeva, 1963): **L** – redeposited element ne ×140. *Scabbardella altipes* (Henningsmoen, 1948): **N** – specimen ×95. ? *Histiodella* sp.: **P** – element sp ×150. ? *Ozarkodina* cf. *pseudofissilis* (Lindström, 1959) (cf. Orchard 1980, Pl. 6, Fig. 31): **Q** – element oz ×200. ? *Aphelognathus* sp.: **O** – element oz ×150. *Icriodella superba* Rhodes, 1953: **R** – element sp oral view ×180; **S** – element oz, lateral view ×110; **T** – element sp lateral view ×180. *Hamarodus europaeus* (Serpagli, 1967): **U** – element hi ×150; **V** – element ne ×110. *Amorphognathus tvaerensis* Bergström, 1962: **W** – element sp ×100; **X** – element oz ×110; **Y** – element tri 150; **Z** – element pl ×200; **ZZ** – element hi ×160

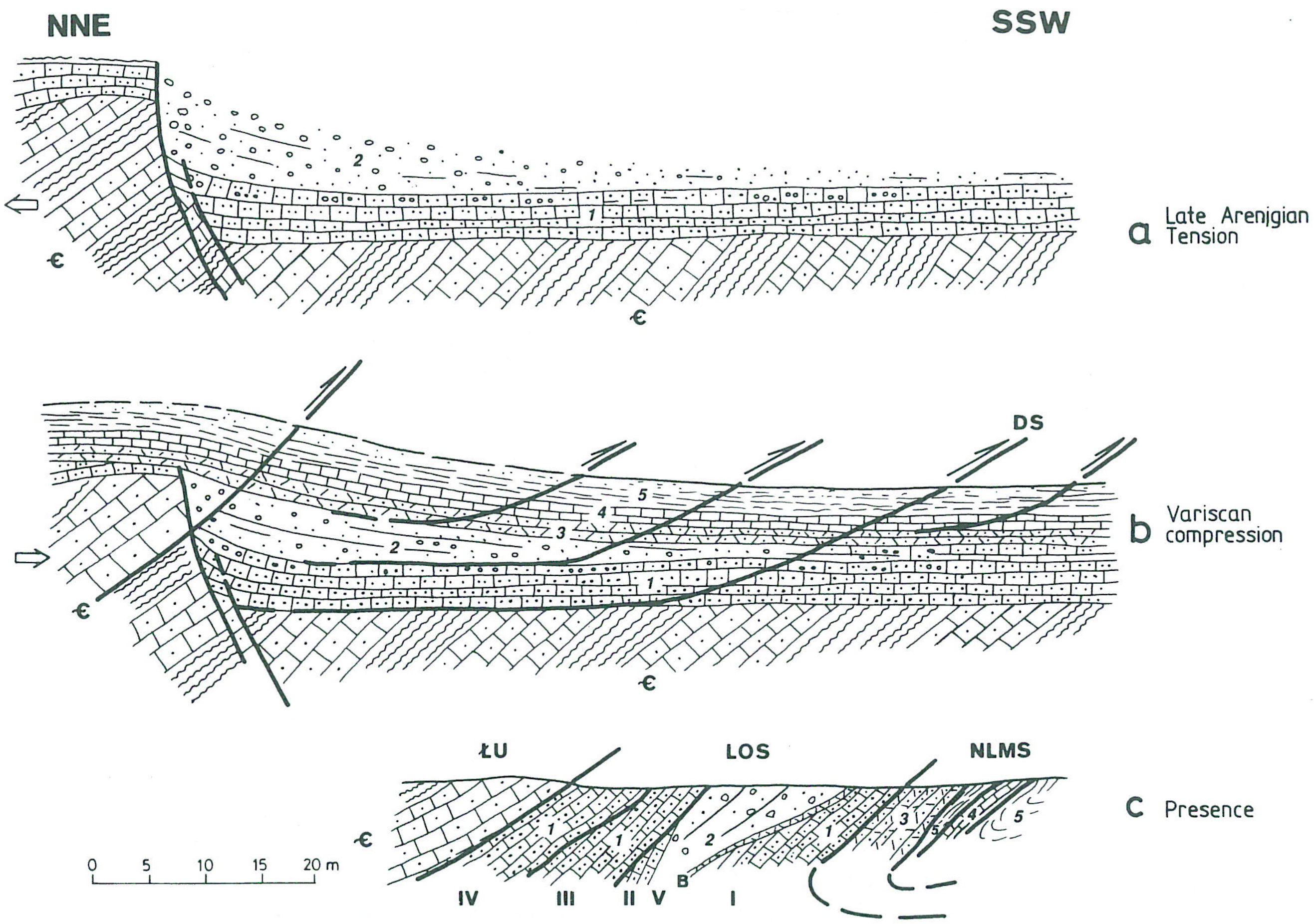

Fig. 12. Tectonic evolution of the Międzygórz area. **a.** Formation of the Chełm Conglomerate as results of the Lower Ordovician tectonic movements; **b.** Development of scales of the Lower Ordovician sequence as a results of Variscan compression; **c.** Tectonic position of the Lower Ordovician scales. € – Cambrian sandstones and shales; I to IV scales; 1 – The Kleczanów Sandstone; 2 – the Chełm Conglomerate; 3 – the Dyminy Orthid Sandstone; 4 – the Mójcza Limestones; 5 – Silurian shales; B – tektonic breccia; DS – Decollement surface; ŁU – Łysogóry Unit; LOS – Lower Ordovician Scales; NLMS – Northern Limb of the Międzygórz Syncline

tween the remaining scales occuring in the quarry are of tectonic origin. The scales I up to V are in fact tectonic scales arranged one over another northward (Fig. 3).

The scales VI and VII exhibit overturned position. It may be assumed that they make the strongly compressed and overturned southward, northern limb of the Międzygórz Syncline. Gaps in the Ordovician sequence and wedging of the Wenlockian shale inbetween the Ordovician rocks (Fig. 3a) is result of tectonic compression. The northern limb of the syncline was overturned southward in result of compression of the Międzygórz Sandstones Formation (scales I to V) thrust from the north. This is proved by investigations done south of the quarry.

Observations done in the Chełm and Łączki ravines (Fig. 2) point to assymetry of the Międzygórz Syncline. The northern limb is inclined southward about 50°, the southern one dips 20° up to 30° northward. The difference in tilt of both limbs of the syncline do not exceed 30° (Stein & Stupnicka, 1996). The northern limb of syncline which beds dip northerly is very narrow and is located very near the Lower Ordovician scales I to V showing normal position.

These scales containing hard, sandstone and siliceous conglomerate of the Międzygórz Sandstones Formation make a separate tectonic unit thrust from the north onto the northern limb of the syncline.

GENESIS OF THE ORDOVICIAN TECTONIC SCALES

The belt of the Ordovician strata stretches parallel to the axis of the Międzygórz Syncline. The Lower Ordovician strata are located between the northern limb of that syncline and the overthrust, which continues westward into the Holy Cross Dislocation (Fig. 1). According to Pożaryski & Tomczyk (1993) the Holy Cross Dislocation runs between Międzygórz and Daromin. At Daromin about 3700 m to the northwest of the Międzygórz quarry Cambrian rocks have been pierced at depth 340 m (Pożaryski & Tomczyk, 1993). These rocks are counterparts of the Cambrian belt making the main chain of the Holy Cross Mts (the Łysogóry unit). West of Międzygórz at Słaboszewice (Fig. 1) the Cambrian strata are thrust over the Lower and Middle Devonian rocks of the Łagów synclinorium.

The Ordovician strata of the Międzygórz Sandstones Formation make a separate tectonic unit composed of several scales and thrusted from the northeast (Fig. 12b–c). This unit is a result of a horizontal NNE–SSW compression perpendicular to the axis of the Ordovician belt. The fragile Lower Ordovician sandstones are detached from the Cambrian slate basement. Hence this unit shows the same direction and vergency as the Holy Cross Dislocation situated farther northwest. Most probably it has originated due to the same tectonic regime.

It results from the above, that the Ordovician scales at Międzygórz south of te Holy Cross Dislocation were formed probably due to the thrust of the Cambrian rocks of the Holy Cross unit from the north (Stupnicka, 1992). The Międzygórz scales, in turn, being thrust toward southwest compressed the rocks of the northern limb of the Międzygórz Syncline (fore-like position).

The Lower Ordovician rocks at Miedzygórz maybe treated as well as a kind of duplex detached from the Cambrian substratum and covered by the Łysogóry unit (Fig. 12c).

RELATION OF TECTONIC DISTURBANCE AT MIĘDZYGÓRZ TO SIMILAR PHENOMENA IN THE ADJACENT AREAS

Strong folding associated with recumbing of strata and scaling of rocks are known also from the western part of the Holy Cross Mountains near Miedziana Góra (Czarnocki, 1938). In both cases the disturbances occur south of the Holy Cross Dislocation in direct contact with the latter. Their origin and structure suggest close similarity to the phenomena observed in the frontal parts of nappes known from the Polish Carpathians where scales and folds were formed in front of the Magura and Silesian nappes (Książkiewicż, 1972). Such phenomena result from pressure of nappes onto the foreland (Lovell, 1990).

In Międzygórz the thrust amplitude of the Lower Ordovician unit is difficult to evaluate and can be estimated indirectly only. A comparison of the Ordovician section at Kleczanów located near the southern limb of the syncline (Fig. 1) with that of the Międzygórz one reveals considerable differences. At Kleczanów at depth 277.2 m sandsone of the Dyminy Orthid Sandstone Member overlie dark siltstone classified to the Cambrian (Bednarczyk, 1971). The entire Ordovician sequence there inclined at 40° is about 8 m thick. The Kleczanów sandstone and the Chełm conglomerate were not found in the borehole. Such a profile of the Ordovician is typical for the whole southern limb of the Międzygórz Syncline in which the rocks of that age (the Lower Ordovician sandstones in particular) are strongly reduced (Bednarczyk, 1971).

At Lenarczyce (Fig. 1) located several dozen km from Międzygórz the Kleczanów Sandstone Member show small thickness. In the borehole they are up to 2 m thick (Bednarczyk, 1971). Most probably the end of Arenigian times the Kleczanów area was elevated and denuded.

Differently is in the Międzygórz quarry where the Lower Ordovician strata are relatively thick. The particular units (scales) of the Kleczanów Sandstone Member reach 10 m in thickness. This fact and the presence of the Chełm Conglomerate Member suggest that the Lower Ordovician rocks at Międzygórz were deposited in a different zone than this one at Kleczanów and Lenarczyce. Presence of the Chełm Conglomerate Member which are of cliff origin suggests proximity to a fault that was active at the end of Arenigian (Fig. 12a). During Variscan compression when the Holy Cross overthrust was formed, tectonic scales were formed in result of NE–SW compression (Fig. 12b). These scales make now the scales I–V in front of that overthrust composed of hard sandstone and Lower Ordovician conglomerate (Fig. 12c). These rocks in result of approaching from the north Łysogóry nappe were detached from the substratum thus making scales that were then imbricated.

DEPOSITION OF THE CHEŁM CONGLOMERATE MEMBER

The formation of the Chełm Conglomerate Member dated as Late Arenigian was preceded by tectonic movements in the area of the southern part of the Holy Cross Moutains. Such movements were stated earlier (Bednarczyk, 1966, 1971; Chlebowski, 1971) as Late Arenigian in age in the area of Bardo Syncline. These movements have caused in the southern part of the Holy Cross Mountains thickness differentiation of the Lower Ordovician strata. In the vicinity of Międzygórz and Kleczanów they have caused denivelations and denudation in places. The Kleczanów area was elevated and denuded. On the contrary the area located north of the Międzygórz Syncline was depressed there conglomerate were laist down and the Kleczanów Sandstone Member remained non eroded (Fig. 12a). They were the rocks that were then shifted southward (Fig. 12b).

Restoring the primary situation it must be taken for granted that the conglomerates must have developed north of Międzygórz at distance of at least some kilometers. The minimal amplitude of the overthrust of the Lower Ordovician unit was probably toward southwest.

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Streszczenie

STRATYGRAFIA I NOWE DANE O TEKTONICE UTWORÓW ORDOWIKU W KAMIENIOŁOMIE W MIĘDZYGÓRZU (WSCHODNIA CZĘŚĆ GÓR ŚWIĘTOKRZYSKICH)

Wiesław S. Bednarczyk & Ewa Stupnicka

Utwory ordowiku odsłaniające się w kamieniołomie w Międzygórzu, we wschodniej części Gór Świętokrzyskich reprezentują dwie jednostki litostratygraficzne (*sensu* Bednarczyk, 1981, 1996): formację piaskowców z Międzygórza (fm) i formację wapieni z Mójczy (fm) (Fig. 5).

Formacja piaskowców z Międzygórza (fm) występuje tu w postaci (od dołu) ogniwa piaskowca z Kleczanowa (og), który z uwagi na obecność *Thysanotos siluricus*, brachiopoda wskaźnikowego dla górnego tremadoku nie tylko Gór Świętokrzyskich (Bednarczyk 1971, 1981), ale także dla górnego tremadoku Saksonii, Turyngii, Bawarii, Czech, Estonii i południowego Uralu (Bednarczyk 1999). Kolejnym ogniwem w profilu ordowiku Międzygórza jest zlepieniec z Chełma (og) w skład którego wchodzą okruchy łupka ilastego, z którego Szaniawski (Chlebowski & Szaniawski, 1974) opisał zespół chitinozoa, zapewne z wczesnego arenigu, a zatem sam zlepieniec powstał w terminie późniejszym, być może w późnym arenigu. Zarówno zlepieniec z Chełma (og) jak i piaskowiec z Kleczanowa (og) został omówiony wcześniej przez Znoskę i Chlebowskiego (1976, fig. 3) łącznie jako jedna jednostka litostratygraficzna – zlepieniec międzygórski, a następnie przez Dzika i Piserę (1994) jako formacja międzygórska (Międzygórz Formation). W obu przypadkach wiek zlepieńca z Chełma (og) został określony na wczesny arenig. Z badań obecnych autorów wynika jednak, że ogniwo to powstało po utworzeniu się piaskowca z Kleczanowa (og) w wyniku ruchów tektonicznych w dolnym ordowiku (Fig. 9a) i wtórnie zostało zaklinowane w obrębie piaskowca z Kleczanowa (og), którego wiek ustalono na górny tremadok.

Kolejnym odsłaniającym się tu ogniwem jest piaskowiec ortidowy z Dymin (og) z licznymi ośródkami i odciskami skorupek brachiopodów, między innymi z *Orthambonites calligrammus* (Dalman) i *Lycophoria nucella* (Dalman). Ten ostatni gatunek jest przewodni dla dolnego lanwirnu (piętro kunda) Estonii i północno-zachodniej Rosji (Männil, 1987), a zatem wiek tego ogniwa ustalony na dolny lanwirn (Bednarczyk, 1964) nie wymaga korekty.

Profil ordowiku w kamieniołomie międzygórskim kończą wapienie drobnokrystaliczne i wapienie margliste w obu przypadkach dolomityczne, reprezentujące formację wapieni z Mójczy (fm) (dolomit z Mokradla (og) *sensu* Bednarczyk, 1981). Ich pozycję stratygraficzną Bednarczyk (1964) ustalił na podstawie małżoraczków na karadok. Późniejsze badania tego autora (Bednarczyk, 1971, 1981) oparte głównie na materiale konodontowym, także z wierceń sąsiadujących (otwór Kleczanów 1) wniosek ten potwierdziły. Ostatnio Dzik (1994, 1999) wskazując na obecność w profilu elementów gatunku *Amorphognathus ordovicicus* sugeruje oprócz karadoku (zona *Amorphognathus tvaerensis*) występowanie także ekwiwalentów aszgilu. Natomiast zdaniem Bednarczyka (1996) w profilu Międzygórza można wyróżnić jedynie dwie zony konodontowe karadoku, a mianowicie zonę *Amorphognathus tvaerensis* i zonę *Amorphognathus superbus*.

Badania w kamieniołomie międzygórskim wykazały, że z punktu widzenia tektoniki skały ordowickie dzielą sie na dwie części. Część pierwsza w północnej części kamieniołomu, obejmuje piaskowce i zlepieńce dolnoordowickie. Są one nachylone pod kątem od 42° do 72° na północ i leżą w pozycji normalnej. Dzielą się one na pięć łusek (Fig. 3). Warstwy każdej z łusek mają inny bieg i upad (Fig. 3a). Pomiędzy łuskami I i V została znaleziona warstwa brekcji (Fig. 7B, 8B), a pozostałe łuski oddzielają powierzchnie nasunięcia wzdłuż których kolejne łuski zostały odkłute i nasunięte z NE na SW tworząc rodzaj dupleksu (Fig. 9b, c). Część druga (Fig. 3, łuski VI i VII) w południowej części kamieniołomu obejmuje piaskowce ortidowe dolnego lanwirnu, wapienie karadoku i łupki dolnosylurskie. Skały te są nachylone na północ od 48° do 58° i mają położenie odwrócone. Tworzą one złuskowane i częściowo wyciśnięte północne skrzydło synkliny międzygórskiej.

W czasie ruchów tektonicznych skały dolnoordowickie (łuski I do V) zostały nasunięte z północy na południe, na skały łusek VI i VII (Fig. 9b, c). Z badań wynika, że skały dolnoordowickie tworzą odrębną jednostkę tektoniczną, która powstała prawdopodobnie pod naciskiem płaszczowiny łysogórskiej w czasie orogenezy waryscyjskiej (Fig. 1).