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New data on geology of the Middle Cambrian rocks in the Klimontów Anticlinorium (Holy Cross Mts.)

The Middle Cambrian rocks in the Klimontów Anticlinorium consist of various sandstones with fossils and trace fossils, accumulated in the littoral zone of a marine basin. The sandstones belong to the Ociesęki Formation and the Usarzów Sandstone Formation but mainly to the Słowiec Formation. From the point of view of biostratigraphy they represent the Insularis, Pinus and Polonicus Zones. The sandstones are now situated in the Bardo and Wygiełzów Synclines and in local tectonic grabens. Faults and cleavage phenomena are clearly visible in these rocks. The geometric and genetic features of these tectonic elements suggest their origin as the result of the stress pair situated in the vertical plane under the thick rock cover. This was realised during the Variscan orogeny.

INTRODUCTION

The Klimontów Anticlinorium is built mainly of Lower Cambrian rocks well exposed on the surface. The lithology, sedimentological environment and fossils of this epoch were recognized and lithostratigraphic and biostratigraphic subdivisions were made. The knowledge of the Middle Cambrian is poorer, because the rocks were as a rule eroded and only small fragments of the sandy cover were protected in local synclinal structures. The biggest of these are the Bardo and Wygiełzów Synclines. The authors investigated the Middle Cambrian in the last few years and gathered many new data about the fossils, stratigraphy and tectonics. A new geological map of the Cambrian of the anticlinorium was made too.

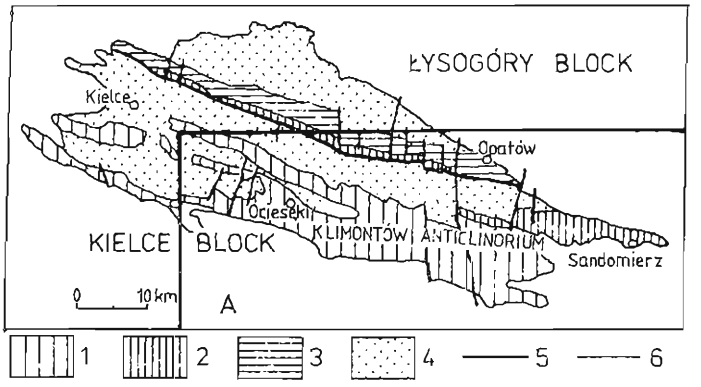


Fig. 1. Geological map of the Holy Cross Mts., with area of the detailed research designed A
1 — Lower Cambrian, 2 — Middle Cambrian, 3 — Upper Cambrian, 4 — Ordovician through Carboniferous rocks, 5 — Holy Cross Dislocation, 6 — transversal faults
Schematyczna mapa geologiczna Gór Świętokrzyskich z zaznaczonym obszarem badań (A)
1 — kambr dolny, 2 — kambr środkowy, 3 — kambr górny, 4 — utwory paleozoiczne młodsze od kambru, 5 — dyslokacja świętokrzyska, 6 — uskoki poprzeczne

LITHOLOGY AND STRATIGRAPHY

The Klimontów Anticlinorium is mainly built of Lower Cambrian and at places, Middle Cambrian rocks (Figs. 1 and 2). Lithology and rock sequence of the Lower Cambrian have been lithostratigraphically subdivided and published many times (S. Orłowski, 1975, 1985*a*, *b*, 1992*a*, *b*, *c*). Fossils, mainly trilobites, were described and the biostratigraphic zones were named (W. R. Kowalski, 1983; K. Lendzion *et al.*, 1982; M. Masiak, A. Żylińska, 1994; S. Orłowski, 1975, 1985*a*, *b*, 1992*c*; S. Orłowski, B. Waksmundzki, 1986). Trace fossils were recognized and described too (W. R. Kowalski, 1978, 1983, 1987; S. Orłowski, 1989, 1992*c*; J. Pacześna, 1985) and according to them the palaeobathymetry of the basin was partly reconstructed.

On the surface of the anticlinorium the upper part of thick Early Cambrian strata is mainly exposed (Figs. 2 and 3). The Ociesęki Sandstone Formation is visible in the western part of the Klimontów Anticlinorium whereas the Kamieniec Shale Formation is exposed in the eastern part of this area. Additionally in the latter area the Ociesęki Sandstone Formation exists as a narrow belt on the southern margin disappearing to the east. The boundary between two main lithostratigraphic units — the Ociesęki and Kamieniec Formations — is situated along the Łagowica river and Łagowica Fault (W. Mizerski, S. Orłowski, 1993).

Above the Lower Cambrian rocks, well documented by fossils, various sandstones occur in local synclines and tectonic grabens. These are fragments of a previously continuous cover in the whole area. The stratigraphic position of these sandstones was suggested to be Middle Cambrian by J. Samsonowicz (1962) based on their lithology. Fossils from these sandstones were subsequently described in the western part of the Klimontów Anticlinorium

in the Słowiec Hill (S. Orłowski, 1965, 1985*b*) and in Brzechów (W. Bednarczyk, 1970) and later in the eastern part, from Konary Hill (S. Orłowski, 1971).

These sandstones are easy to correlate on the basis of lithology and fossils with sandstones of Słowiec Hill (= Słowiec Sandstone Formation) and with sandstones of the Jugoszów – Usarzów section (= Usarzów Sandstone Formation). The Jugoszów – Usarzów section, which is the stratotype section for the lower part of the Middle Cambrian, is situated on the NE limb of the Klimontów Anticlinorium, i.e., that part of the structural unit (Figs. 1 and 2), which is covered to the west by Devonian rocks of the Kielce – Łagów Synclinorium (W. Mizerski, S. Orłowski, 1993; S. Orłowski, 1964, 1975, 1992*b*, *c*; J. Samsonowicz, 1962).

More detailed data concerning lithology, fossils, trace fossils and thickness of the separate sandstone sections are the basis for stratigraphic correlations. Lithology and fossils of 8 localities are described below. Their distribution is given in Figure 1 and their lithostratigraphic and biostratigraphic position in Figure 3.

BRZECHÓW

North of the village the surface is covered by numerous fragments of sandstone. They are thin- and thick-bedded, hard, and greenish; the thickness of beds is as much as 20 cm. They are fine- and coarse-grained. Numerous pebbles of greenish shales up to 5 cm in diameter are common in the sandstones. The thickness of the section is hard to determine because of soil cover, but it is no more than 30 m.

The most common fossils are trilobites important for stratigraphy: *Paradoxides oelandicus* Sjögren, *Protolenus bodzanti* Czarnocki, *Ellipsocephalus sanctacruciensis* (Samsonowicz), *Jakutus kielcensis* Bednarczyk (W. Bednarczyk, 1970). Others are *Velumbrella czarnockii* Stasińska (M. Masiak, A. Żylińska, 1994), brachiopods and fossils of unknown origin.

SŁOWIEC HILL

The outcrop is the top part of the hill and is the stratotype for the Słowiec Sandstone Formation. Exposed are medium-grained, bedded sandstones and poorly sorted, often coarse-grained sandstones, light grey, light yellow and reddish, with bed thicknesses up to 60 cm. There are horizons with numerous pebbles of greenish shales as much as 3 cm in diameter. The thickness of the section is difficult to establish, but it is about 100 m.

Fossils are common and consist of trilobites and brachiopods. Trace fossils were not found here. The most important are: *Paradoxides polonicus* Orłowski, *P. slowiecensis* Orłowski, *P. socius* Orłowski, *Solenopleurina linnarsoni* Brögger, *Solenopleura trapezoides* Orłowski, *Kootenia enigmatica* Orłowski (for a complete list see S. Orłowski, 1985*b*).

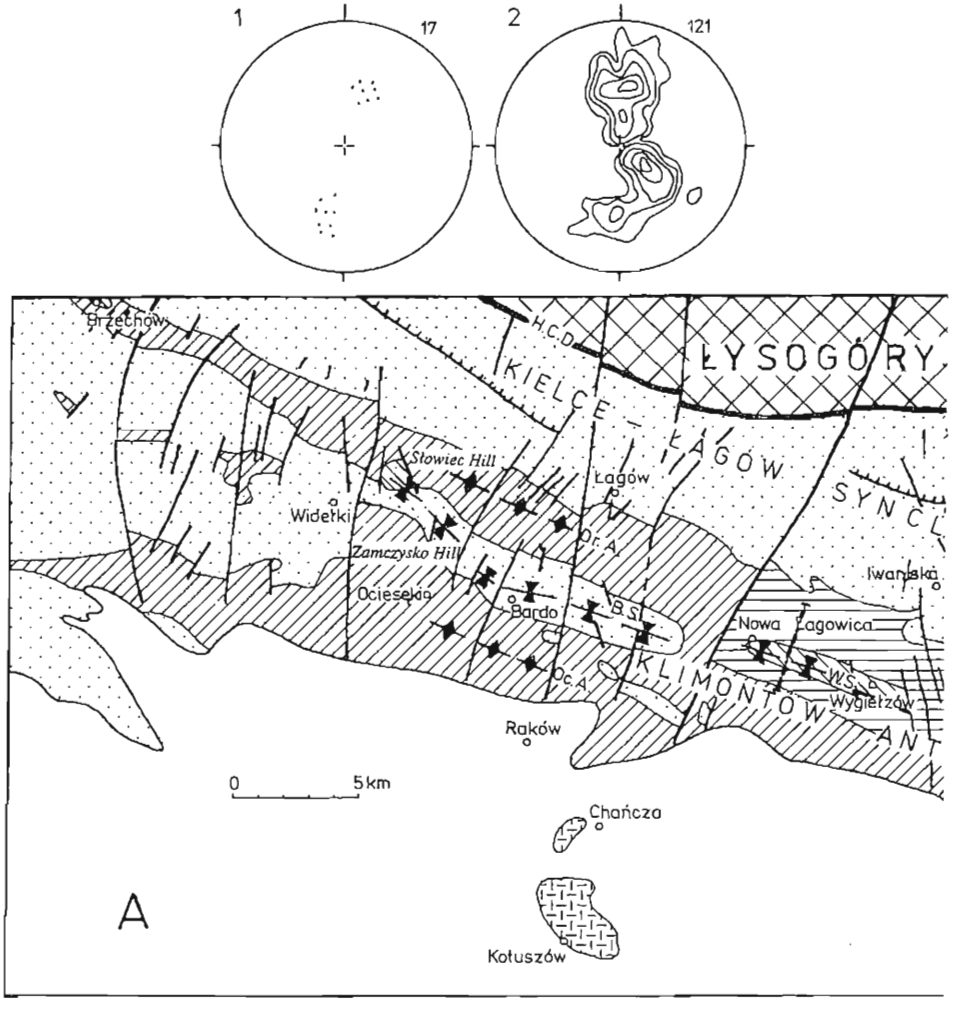
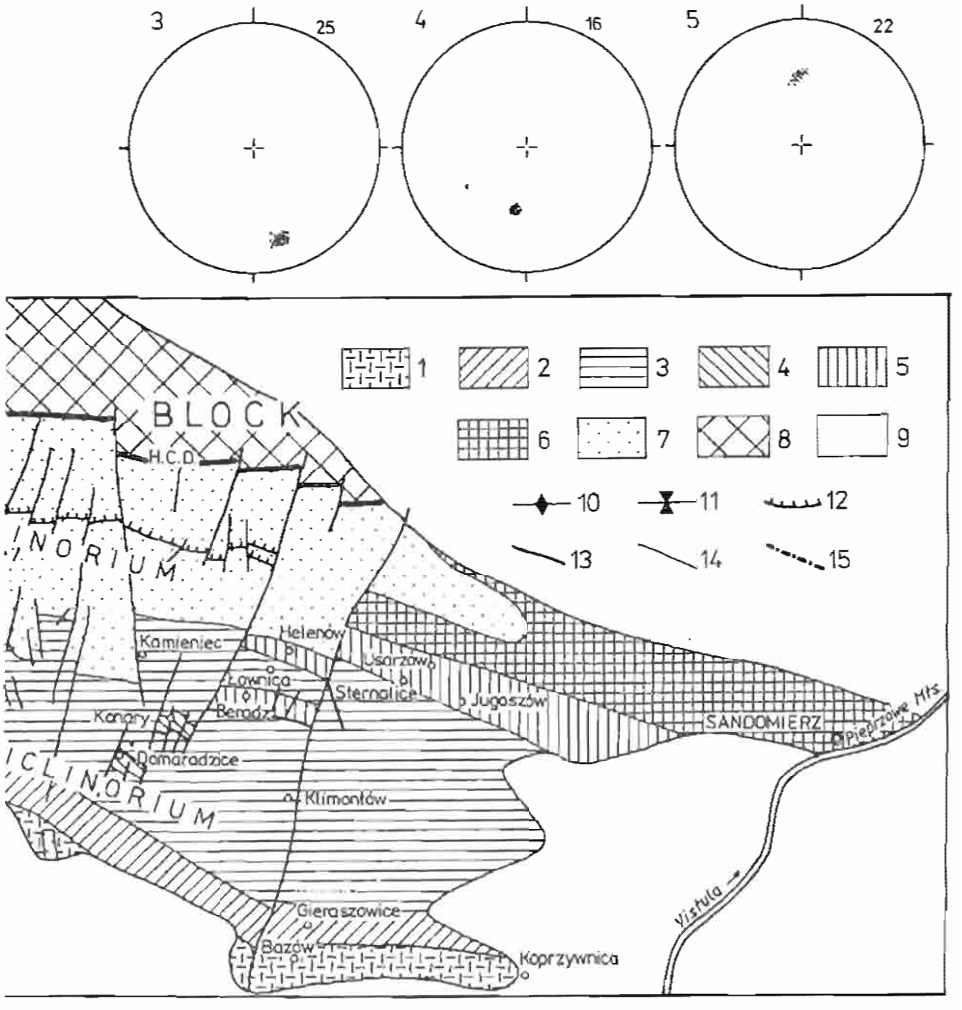


Fig. 2. Tectonic sketch of the Klimontów Anticlinorium

1 — Czarna Shale Formation, 2 — Ciesęki Sandstone Formation, 3 — Kamieniec Shale Formation, 4 — Słowiec Sandstone Formation, 5 — Usarzów Sandstone Formation, 6 — Pieprzowe Góry Shale Formation, 7 — Ordovician through Carboniferous rock, 8 — Palaeozoic rocks of the Łysogóry Block, 9 — Permian, Mesozoic and Tertiary rocks, 10 — axes of anticlines, 11 — axes of synclines, 12 — overthrusts, 13 — main faults, 14 — geological boundaries, 15 — cross-section line (see Fig. 4); Oc. A. — Ciesęki Anticline, Or. A. — Orłowiny Anticline, B. S. — Bardo Syncline, W. S. — Wygiełzów Syncline, H. C. D. — Holy Cross Dislocation; above the tectonic sketch there are diagrams of the attitude of the strata in the Cambrian rocks (numbered 1–5 as in the text); number of measurements is given in upper right corner of the diagrams; projection of normals at the upper hemisphere; percent isarhythms: 2, 4, 6, 8, 10



Szkic tektoniczny antyklinorium klimontowskiego

1 — formacja łupków z Czarnej, 2 — formacja piaskowców z Ociesęk, 3 — formacja łupków z Kamieńca, 4 — formacja piaskowców ze Słowca, 5 — formacja piaskowców z Usarzowa, 6 — formacja łupków z Gór Pieprzowych, 7 — utwory ordowiku-dolnego karbonu, 8 — utwory paleozoiczne bloku łysogórskiego, 9 — obrzeżenie permomezozoiczne i trzeciorzędowe, 10 — osie antyklin, 11 — osie synklin, 12 — nasunięcia, 13 — główne uskoki, 14 — granice geologiczne, 15 — linia przekroju (patrz fig. 4); Oc. A. — antyklina Ociesęk, Or. A. — antyklina Orłowin, B. S. — synklina Barda, W. S. — synklina Wygiełzowa, H. C. D. — dyslokacja świętokrzyska; powyżej szkicu tektonicznego — diagramy położenia utworów kambryjskich (numery diagramów 1–5 w tekście); po prawej stronie u góry diagramu — liczba pomiarów; projekcja normalnych na górną półkulę; izarytmy procentowe: 2, 4, 6, 8, 10

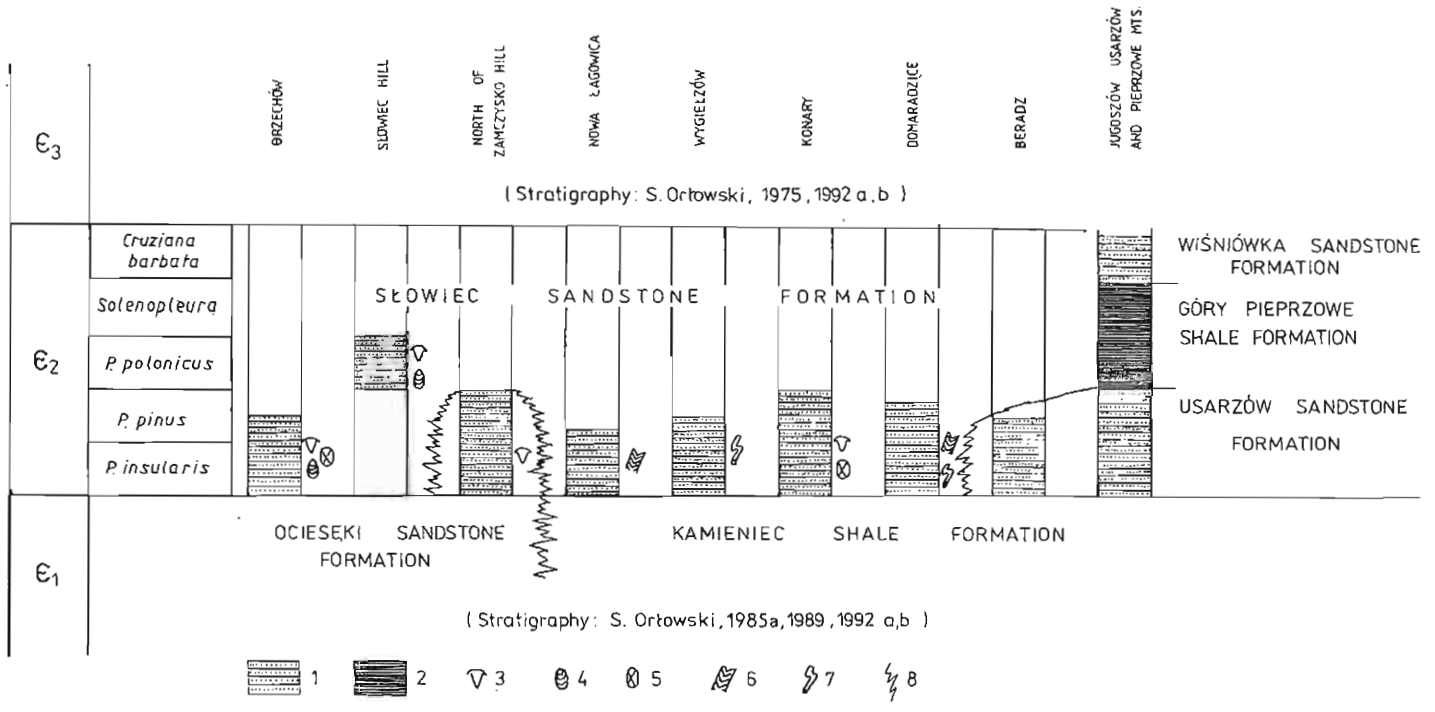


Fig. 3. Stratigraphic correlation of Middle Cambrian Sandstones in the Klimontów Anticlinorium; localities of the profiles — see Fig. 2
1 — sandstones, 2 — shales, 3 — trilobites, 4 — brachiopods, 5 — other fossils, 6 — trilobite trace fossils, 7 — other trace, 8 — boundary of the facies
Korelacja stratygraficzna piaskowców kambru środkowego antyklinorium klimontowskiego; lokalizacja profili na fig. 2
1 — piaskowce, 2 — łupki ilaste, 3 — trylobity, 4 — ramienionogi, 5 — inne skamieniałości, 6 — ślady organiczne trylobitów, 7 — inne ślady organiczne, 8 — granice facji

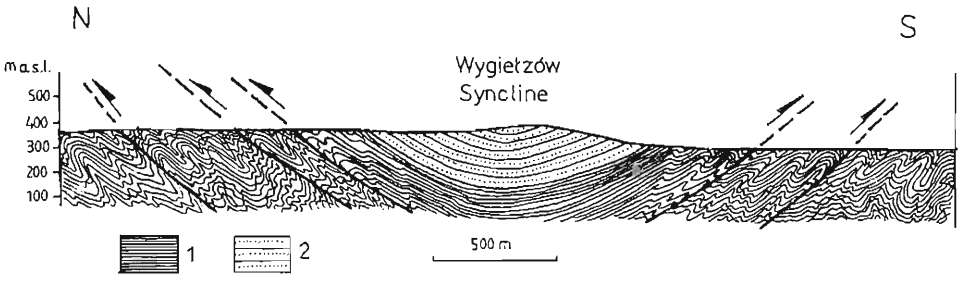


Fig. 4. Geological cross-section through the Wygiełzów Syncline; localities of the cross-section — see Fig. 2
1 — Kamieniec Shale Formation, 2 — Słowiec Sandstone Formation
Przekrój geologiczny przez synklinę wygiełzowską; lokalizacja przekroju na fig. 2
1 — formacja łupków z Kamieńca, 2 — formacja piaskowców ze Słowca

ZAMCZYSKO HILL

This elongated, well exposed hill is built of the Ociesęki Sandstone Formation. North of the hill the mentioned rocks pass into fine-grained, regularly bedded, dark grey sandstones. The bed thicknesses are up to 20 cm. The thickness of the section is about 100 m.

Trilobites are common and well preserved, trace fossils do not exist. The most important for stratigraphy are: *Paradoxides* sp., *Ellipsocephalus puschi* Orłowski, *E. guerichi* Orłowski, *Comluella opatowi* Orłowski, *C. usarzowi* Orłowski (S. Orłowski, 1964, 1985*b*).

NOWA ŁAGOWICA

In the old, small quarries near this village, medium- to coarse-grained, light grey sandstones are exposed. The bed thicknesses vary from 5 to 15 cm. There are horizons with pebbles of shales up to 3 cm in diameter. Ripple marks are common. The thickness of the section is estimated as 130 m.

Only trace fossils were found in these sandstones. Very common is *Planolites beverleyensis* (Billings) but more important is *Cruziana regularis* Orłowski because this ichnospecies is indicative of the Oelandicus Stage of the Middle Cambrian (S. Orłowski, 1992*c*).

WYGIEŁZÓW HILL

An interesting section is visible from the bottom to the top of the hill in the village. Above the Kamieniec Shale Formation (Lower Cambrian) are situated fine-grained, grey sandstones with irregular intercalations of mudstones. The horizons with pebbles of shales up to 4 cm in diameter are common inside sandstones or on the bed surfaces. The thickness of individual beds is about 25 cm in the lower part of section and about 5 cm in the upper part. The thickness of the section is about 100 m.

Only trace fossils were found in the sandstones: *Planolites beverleyensis* (Billings) and *Monocraterion* sp. are common.

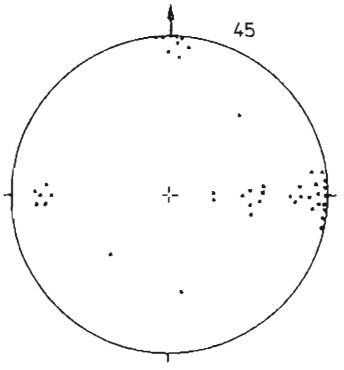


Fig. 5. Diagram of the small faults in the Middle Cambrian rocks
Number of measurements is given in upper right corner of the diagram; projection of normals at the upper hemisphere
Diagram drobnych uskoków w utworach kambru środkowego
Po prawej stronie u góry — liczba pomiarów; projekcja normalnych na górną półkulę

KONARY HILL

The sandstones are exposed in the rural quarries situated close to the tops of two hills, north of the village. Here, under thick loess cover, coarse-grained and compact, very hard light grey sandstones, are exposed. The sandstones are often intercalated with coarse-grained layers, consisting of quartz grains, 1–2 mm and occasionally up to 5 mm in diameter. Horizons of pebbles of greenish or yellowish shales up to 5 cm in diameter, are numerous. The sandstones are medium- to thick-bedded, 20 cm to 1 m in thickness. The thickness of the section is about 100 m.

Some trilobite fragments were found in the larger quarry. They were described as: *Comluella hupei* Orłowski, *Kingaspis (Kingaspis) henningsmoeni* Orłowski, *?Ellipsocephalus longus* Orłowski, *Paradoxides* sp. and *Hyolithes* sp. (S. Orłowski, 1971).

DOMARADZICE

A large outcrop within an old quarry of fine-grained, grey sandstones is situated on the steep escarpment on the riverbank near the village (Figs. 1 and 2). The bed thicknesses vary significantly from 5–10 to 30 and to 50 cm. The thickness of the section is about 100 m.

Only trace fossils were found in the rocks: *Planolites beverleyensis* (Billings) and *Monocraterion* sp. are frequent but *Cruziana* cf. *regularis* Orłowski, *Diplichnites* cf. *obliquus* Seilacher, *Phycodes palmatum* (Hall) are rare.

BERADZ

A large outcrop of sandstones is situated on the eastern bank of the river. These are well exposed fine-grained light grey, regularly bedded sandstones with intercalations of mudstones, about 20–25 cm thick. Fossils were not found. The thickness of the section is about 50 m.

TECTONICS

The Middle Cambrian rocks are preserved in local synclines and tectonic grabens. The biggest of these are the Bardo and Wygiełzów Synclines (Figs. 1 and 2).

In the Bardo Syncline, sandstones belong to Słowiec Sandstone Formation and Ociesęki Sandstone Formation and are exposed in the western part of this tectonic unit. The Słowiec Sandstone Formation fills the whole Wygiełzów Syncline. In other places the same sandstones are preserved in the fragments of

Fig. 6. Example of normal fault in the Middle Cambrian rocks at Domaradzice
Przykład drobnego uskoku normalnego w utworach kambru środkowego w Domaradzicach

synclines the south or north limbs of which were cut by longitudinal faults (Figs. 1 and 2) — these structures are half-grabens. On the area of the Klimontów Anticlinorium were recognized the Konary and Domaradzice half-grabens filled by sandstones of Słowiec Sandstone Formation. The Brzechów structure may have the same tectonic structure, but it is poorly exposed. The Beradz half-graben is filled by sandstones of the Usarzów Sandstone Formation (Fig. 3).

ATTITUDE OF THE STRATA

The Middle Cambrian sandstones of the Słowiec and Zamczysko Hills are situated in the limbs of a gentle syncline with NW–SE strike (Fig. 2, diagram 1). Sandstone beds are not overturned. The axis of the Bardo Syncline is elevated both to the east and west as a result of folding of the axis. These folds are partly connected with transverse faults.

Sandstones of the Słowiec Formation build a regular, gentle syncline between Nowa Łagowica and Wygiełzów (Fig. 2, diagram 2). The rocks are not overturned (Fig. 4), the dips are rather small (20–30°), and the axis of the syncline is oriented WNW–ESE.

Near the village of Wygiełzów only the northern part of the syncline is preserved. The southern part was cut by a longitudinal fault and was probably uplifted and completely eroded.

The Domaradzice half-graben is preserved only in the southern part of the syncline. Sandstone beds are not overturned strike is 70–80° azimuth, dip 55–65°N (Fig. 2, diagram 3).

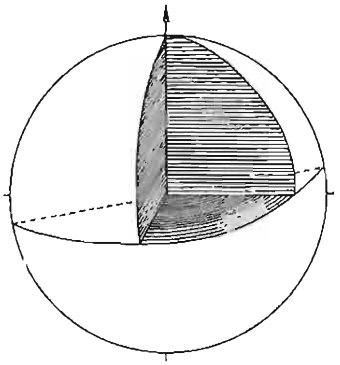


Fig. 7. Connection between the cleavage surface and the bedding surface in stereographic projection (bedding surface is demonstrated as a half of the great circle)

Stosunek położenia powierzchni kliważu do powierzchni uławicenia w projekcji stereograficznej (powierzchnia uławicenia przedstawiona w formie połowy koła wielkiego)

The Konary half-graben is present only in the northern part of the syncline. Sandstones are not overturned with dips about 40°S. The axis has direction about 100° azimuth (Fig. 2, diagram 4).

The Beradz half-graben presents the southern limb of the syncline. Sandstones are not overturned with strike about 90° azimuth and dip about 40–50°N (Fig. 2, diagram 5).

The strikes in the Middle Cambrian sandstones in synclines and half-grabens are very close to that of the Lower Cambrian rocks of this area (W. Mizerski *et al.*, 1986, 1991; W. Mizerski, S. Orłowski, 1993).

The analysis of attitude of the strata of the Middle Cambrian sandstones suggests a gentle style of folding and that the tectonic activity of these sandstones was the same or very similar to the Lower Cambrian sandstones (Ociesęki Sandstone Formation) of this area (W. Mizerski *et al.*, 1986). In contrast, the Lower Cambrian Kamieniec Shale Formation is often strongly folded in the form of chevron folds (W. Mizerski *et al.*, 1991; W. Mizerski, S. Orłowski, 1993).

These facts agree with the earlier suggestions of both authors that the tectonic deformations of the Cambrian rocks of the Klimontów Anticlinorium are mainly disharmonic deformations (W. Mizerski *et al.*, 1986).

FAULTS

The Middle Cambrian sandstones of the Klimontów Anticlinorium are cut by many faults rather small in scale. They exist in sandstones with both small and big dips. The diagram of faults (Fig. 5) suggests that the most important are transverse faults. Faults with other orientations are rare.

Within the set of faults there prevails a group of normal faults with strikes 90–100° and dipping steeply to the north. As a rule they are small-scale faults.

Sporadically as in Domaradzice half-graben, the faults were on a greater scale so that mylonitization processes took place along them; in this case the fault zone is up to 20 cm broad and is infilled with crushed sandstones (Fig. 6). They are recognized as brittle faults. The analysis of these faults suggests the existence of a strain plane with the main axis of stress directed vertically. Their formation is connected to orogenic processes rather than with the stress of thick depositional cover. It seems that they are associated with bigger longitudinal faults, cutting down one of the synclinal limbs.

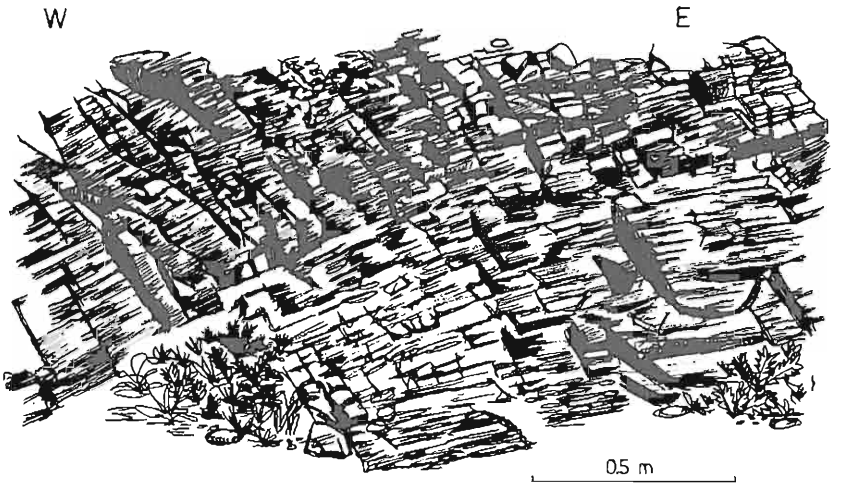


Fig. 8. Shear cleavage in the Middle Cambrian sandstones at Beradz
Kliważ ścięciowy w środkowokambryjskich piaskowcach w Beradzu

The small faults of the biggest group are oriented perpendicularly to the strike of beds. Their dips are different and directed both to the west and to the east (Fig. 7). They are result of tectonic activity in the shearing zone which took place under thick depositional cover (L. Mastella, 1988). It is almost certain that the age of this activity is younger than the Sandomierz tectonic phase and is very probably associated with the early Variscan orogeny (W. Mizerski, 1988, 1991, 1994).

Fault striae were observed on some fault surfaces, situated along the strike of transverse faults. They are interpreted as a result of tectonic transport along these surfaces which was initiated by movements directed north-south.

The directions of tectonics transport of the limbs of small faults are not clear so the results of the discussed tectonic analysis must be treated with some caution.

CLEAVAGE

The differences in lithology between Early and Middle Cambrian rocks cause cleavage phenomena in the Middle Cambrian sandstones to be much more common than in the Early Cambrian shales. The majority of cleavage fractures demonstrate an almost longitudinal strike — almost transverse to the strike of the beds (Fig. 7). The biggest part belongs to shear cleavage, cutting some sandstone beds. The geometrical characteristics of the cleavage plane is similar to that of small faults (Figs. 7 and 8). This is Riedel type cleavage, which is a result of shearing under the stress of thick sediment cover. It may have originated during the Variscan orogeny (W. Mizerski, 1994).

Axial cleavage was documented only sporadically. It is observed in thin-bedded sandstones and sandy-silty intercalations of beds. This cleavage is situated along the strike of beds and rarely vertically.

FINAL REMARKS

Middle Cambrian sedimentation took place in the same basin as the Early Cambrian — as a rule there is sedimentological and stratigraphical continuity with the Lower Cambrian but only various sandstones were deposited.

These sandstones were deposited in a shallower basin than the Early Cambrian. Such features as ripple marks, coarse-grained sandstones, horizons of pebbles of shales up to 4–5 cm in diameter, rare trace and body fossils, and crushed trilobite carapaces confirm this interpretation.

The stratigraphic position of sandstones was recognized as Middle Cambrian on the basis of trilobites in Brzechów, Słowiec Hill, Zamczysko Hill, Konary Hill, on the basis of trace fossils (*Cruziana regularis* Orłowski) in Nowa Łagowica and Domaradzice, and on the basis of lithostratigraphic correlation with the Słowiec Sandstone, Usarzów Sandstone and Ociesęki Sandstone Formations (Fig. 3).

Middle Cambrian sedimentation lasted at least to the Polonicus Zone (Słowiec Hill). Its deposits covered the whole area of the Klimontów Anticlinorium. Only fragments of this sandy cover are now preserved in local synclines and grabens.

The analysis of small scale tectonic deformations in the Middle Cambrian sandstones suggested three structural stages in the geological history of Klimontów Anticlinorium and even in the Kielce Block as a whole.

The first stage is connected with the local tectonic Sandomierz phase (early orogeny) situated on the Cambrian-Ordovician boundary. In that time the main structural units — for example, the Wygiełzów Syncline — came into being. The direction of tectonic stress was north-south.

The Late Caledonian tectonic phases are hard to determine in Cambrian rocks though they are visible in the entire mentioned area.

The second tectonic stage took place during the Early Variscan orogeny. The results of activity are many transverse faults and cleavage.

The third tectonic stage is connected with the main phase of the Variscan orogeny. The results of this activity are the main tectonic units in Palaeozoic rocks of the Holy Cross Mts.

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NOWE DANE O GEOLOGII SKAŁ KAMBRU ŚRODKOWEGO ANTYKLINORIUM KLIMONTOWSKIEGO (GÓRY ŚWIĘTOKRZYSKIE)

Streszczenie

Skały kambru środkowego antyklinorium klimontowskiego występują w oddzielnych płatach w synklinach: Barda i Wygiełzowa oraz w rowach tektonicznych: Brzechowa, Domaradzic, Konar i Beradza. Jedynie na północno-wschodnich stokach antyklinorium leży zwarta pokrywa skał środkowokambryjskich, najlepiej widoczna w profilu Jugoszów – Usarzów; jest to profil stratotypowy dla dolnej części kambru środkowego Gór Świętokrzyskich (fig. 1–3).

Nad zróżnicowanymi litologicznie skałami kambru dolnego osadziły się utwory kambru środkowego w tym samym, ale płytszym zbiorniku morskim. Między tymi oddziałami istnieje ciągłość sedymentacyjna i stratygraficzna. W środkowym kambrze powstały różnorodne piaskowce, często gruboziarniste, ze śladami falowania, poziomami otoczaków ilastych, z rzadkimi skamieniałościami i śladami organicznymi. Cechy te wskazują na zbiornik sedymentacyjny płytszy niż w dolnym kambrze; sedymentacja następowała w strefie litoralnej.

Sedymentacja piaskowców trwała co najmniej do poziomu Polonicus włącznie (fig. 3), a prawdopodobnie i dłużej. Późniejsza erozja usunęła większość pokrywy piaskowców i obecnie zachowały się jedynie strzępy tej pokrywy w lokalnych synklinach i rowach tektonicznych.

W rejonie gór Słowiec i Zamczysko oraz Wygiełzowa zachowały się szerokopromienne synkliny (fig. 4), natomiast w okolicach Brzechowa, Konar, Domaradzic i Beradza — wyłącznie skrzydła dawnych synklin w postaci półrowów tektonicznych, powstałych w czasie ruchów sandomierskich. Ten stan jest wynikiem obcięcia jednego ze skrzydeł dawnych synklin uskokami podłużnymi (fig. 1, 2). Słaby stopień zaangażowania tektonicznego piaskowców środkowokambryjskich kontrastuje z intensywnym miejscami sfałdowaniem łupków i piaskowców kambru dolnego.

W skałach kambru środkowego powszechne są drobne uskoki oraz spękania kliważowe. Parametry orientacji przestrzennej i stosunek do uławicenia większości tych uskoków (fig. 5–8) sugerują ich powstanie w wyniku działania pary sił w płaszczyźnie poziomej skierowanych wzdłuż linii W–E. Stanowi to potwierdzenie wcześniejszych wniosków autorów o działalności naprężeń subrównoleżnikowych we wczesnych fazach ruchów waryscyjskich. Orientacja spękań ścięciowych i drobnych uskoków pozwala na stwierdzenie, że w ich powstaniu miało udział również obciążenie nadkładem, który w przypadku skał kambryjskich musiał liczyć kilka kilometrów.