Geological Quarterly, 2001, **45** (2): 155–163

New data on Caledonian, Alpine-style folding in the Holy Cross Mts., Poland

Jerzy ZNOSKO

Znosko J. (2001) — New data on Caledonian, Alpine-style folding in the Holy Cross Mts., Poland. Geol. Quart., **45** (2): 155–163. Warszawa.

There has been a century-long debate on the nature of the major orogeny in the Holy Cross Mts. Some research workers consider that they were folded during the Variscan orogeny, and that Caledonian movements were responsible only for the formation of mesostructures. Others provide evidence for great folding movements and detachments, suggesting that strong Caledonian compression formed or "squeezed out" Ordovician-Silurian synclines; they consider Variscan deformation to be of platform-type. Laramide and Late Alpine platform-type faults also deformed the Holy Cross Mts. Ordovician haematites show 3 generations of folds in the Brzeziny Syncline, showing it to be over 250 m in amplitude. This structure is thus not a mesostructure but a large-scale structure formed as a result of orogenic compression. The Devonian-Carboniferous cover shows a platform tectonic style. Differences in style between the folded Cambro-Silurian basement and the unconformably overlying Devonian-Carboniferous sedimentary cover are great and cannot be explained in terms of different rock competence. These tectonic relationships are supported by borehole and geophysical evidence. The Caledonian faulting style is identical in the southern part of the Holy Cross Mts. and the northern Łysogóry area. Laramide and Late Alpine stresses are likely related to Atlantic ocean-floor spreading; stresses acting on the crystalline margin of the East European Craton rejuvenated tectonic lineaments in the Holy Cross Mts. and deformed the Devonian-Cenozoic cover throughout the Polish Lowlands.

Jerzy Znosko, Polish Geological Institute, Rakowiecka 4, PL-00-975 Warszawa, Poland *(received: November 11, 1999; accepted: March 10, 2001).*

Key words: Caledonian folding, Cambrian, Ordovician, Brzeziny Syncline, Devonian-Cenozoic platform cover.

INTRODUCTION

The Holy Cross Mts. are the cradle of Polish geology. This area is a tectonically delineated and uplifted fragment of a larger orogenic system, degraded and hidden under a sedimentary cover. The Holy Cross Mts. are relatively small in area and lack good exposures. Nevertheless, they show a range of Vendian-Cambrian to Tertiary and Quaternary rocks. The Holy Cross Mts. are composed largely of sedimentary rocks with small occurrences of Palaeozoic effusive rocks — lamprophyres and diabases.

The sum of tectonic deformation caused the WNW–ESE-trending Holy Cross Mts. massif to be divided into 3 structural units: the Łysogóry area (in the north); the Central Synclinorium; and the Dyminy-Klimontów Range (in the south) (Fig. 1).

The nature of orogeny in the Holy Cross Mts. has been discussed in many papers for over a hundred years.

Poor exposure of tectonic structures in early Palaeozoic rocks, with better and more abundant exposures of faulted late Palaeozoic deposits resulted in two different views on the tectogenesis of the Holy Cross Mts. Some research workers considered that the Caledonian orogeny *sensu stricto* was the last one to affect the Holy Cross Mts. Others suggested that it was the Variscan orogeny *sensu stricto*. The controversy has remained. Advocates of Variscan orogenesis neglect the absence of foredeep or intramontane molasse in, or around, the Holy Cross Mts. They suggest that Caledonian deformation is limited only to small mesostructures — drag folds (Mizerski, 1995). Supporters of Caledonian primacy have suggested that Variscan tectonism was marked in the Holy Cross Mts. by platform-type faulting, later enhanced by Laramide and Late Alpine tectonism, and that major Caledonian tectonic deformation was of orogenic type, as repeated strong folding, detachments and thrusts which were Alpine in style[1] (Znosko,

[1]= alpinotype *sensu* Stille (1924).

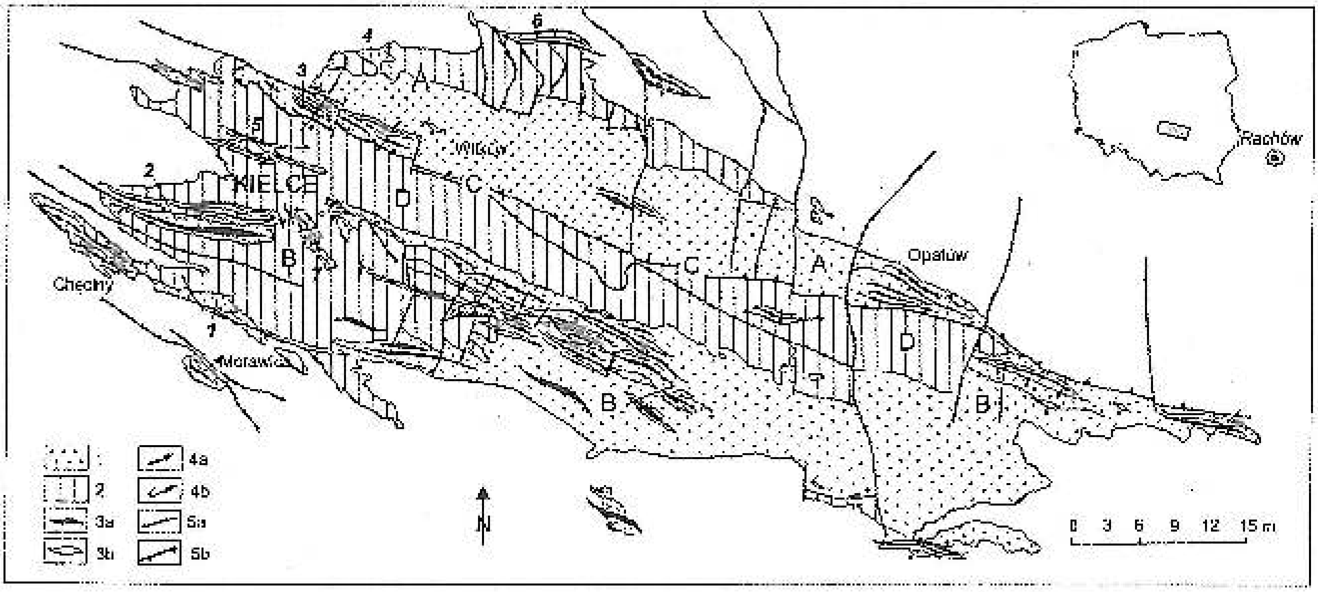

Fig. 1. Tectonic sketch of the Holy Cross Mts. with location of outcrops and boreholes described in the text

1 — Cambrian through Silurian, 2 — Devonian and Carboniferous, 3 — anticlines (a) and synclines (b), 4 — inclined (a) and overturned (b) folds, 5 — faults (a) and overthrust (b); A — Łysogóry — Main Range, B — Dyminy-Klimontów Anticlinorium, C — Holy Cross overthrust, D — Kielce-Łagów (central) Synclinorium; ***1*** — Brzeziny Syncline, ***2*** — Dyminy Anticline, ***3*** — Wiśniówka and Krzemianka, ***4*** — Kajetanów, ***5*** — Niewachlów-Szydłówek Anticline, ***6*** — Bronkowice Anticline, ***7*** — Mójcza Anticline

1996*a*; Kowalczewski and Dadlez, 1996; Kowalczewski, 2000). The early Palaeozoic sedimentary cycle was concluded with flysch deposits of considerable thicknesses, and molasse sedimentation that accompanied Caledonian uplift (Malec, 1990, 1991, 1993; Kowalczewski *et al*., 1998).

This paper provides new data relevant to this argument.

In 1958–1959 the Geological Institute conducted geological investigations of the Ordovician Brzeziny structure (Fig. 1). A number of boreholes, auger holes and shafts were sunk to explore for haematite (Fig. 2). Encouraging preliminary results in November 1959 (Cieśla and Tomczyk in: Mieczysławski, 1962) led the Kielce Geological Enterprise — Częstochowa Branch, to investigate further and Serwan, Cieśla and Tomczyk (in: Mieczysławski, 1962) prepared an appendix.

Regarding the Brzeziny slice near Morawica, Cieśla and Tomczyk said as follows: "...the work done so far on the iron ore...confirmed the synclinal pattern of Ordovician beds and distinct asymmetry of the geological structure. Lower Ordovician deposits abut rocks, of probable Early Cambrian age.... The present mining works, conducted mainly in the southern flank of the structure, show that the Cambrian rocks are thrust over Ordovician deposits.... The iron ore occurs in the lowermost Ordovician beds (Lower Skiddaw, Upper Tremadoc),...which unconformably overlie Cambrian deposits both in the southern and northern flanks".

The work on the Ordovician syncline and surrounding Cambrian deposits that followed in 1960–1961, in accord with the geological exploration project prepared by the Kielce Geological Enterprise — Częstochowa Branch, comprised: 6 shafts with horizontal galleries, 7 exploration trenches, about 500 auger holes, resistivity surveys and 53 boreholes, 20–301 m deep, including 8 directional ones. The boreholes and shafts were arranged along 9 lines (L1–L9) perpendicular to the axis of the Ordovician syncline. The most valuable results were received from lines L1, L2 and L3 (Fig. 2).

The results were collected by Mieczysławski (1962). Tomczyk and Turnau-Morawska (1964) subsequently described the stratigraphy and petrography of Ordovician deposits from the Brzeziny area, on the basis of the three most stratigraphically complete borehole sections. Arenig, Llanvirn, Llandeilo and Caradoc age rocks were recorded. Arenig deposits are represented by glauconitic sandstones and siltstones with admixture of pyrogenic minerals quartz, biotite and feldspars. Llanvirn, Llandeilo and Caradoc rocks are mudstones, variably sandy, with thin interbeds of siderite and dolomitic limestone (Tomczyk and Turnau-Morawska, 1964). In that paper Tomczyk noted abundant slickensides, compressional structures and fractures, local tectonic breccias and variable, mostly steep, stratal dips. He noted, but did not describe, sedimentary structures. Turnau-Morawska described angular quartz grains (!), allochthonous, but very well preserved, angular glauconite grains, glauconite pseudomorphs after micas as well as feldspar grains.

Those observations support later opinions (Chlebowski, 1971) of a volcanogenic origin of these rocks.

This ore deposit description was classified as category "B" — i.e. an accurate exploration of an ore deposit of simple geological structure (category "A" refers to complex ore deposits that require exploration by shafts and mine roads). However, the ore deposit was small and "non-economic". The report was archived. 40 years later, it came into to my hands.

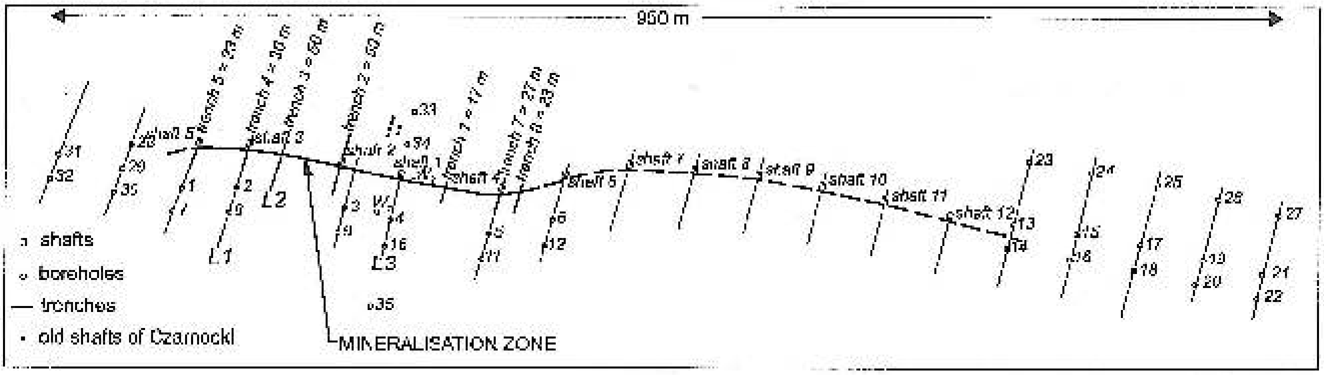

Fig. 2. Situation sketch of trenches, shafts and boreholes in Brzeziny (Figs. 2–9 after Mieczysławski, 1962)

NEW OBSERVATIONS

The Ordovician Brzeziny Syncline, not a slice as previously thought, is over 1320 m long. Its length within the ore deposit is 600 m (Fig. 2). Their flanks are steep in individual cross-sections and dip at 75–85° close to the contact with Quaternary deposits. Northward vergence is seen in shafts 1, 2, 3, 6 and 6a (Figs. 3–6). A flexural bend of the southern flank of the syncline, and its partial tectonic erosion, was observed in shafts 1, 2 and 3. All the cross-sections, constrained by the shafts (1, 2 and 3), show a detachment and thrust zones (Fig. 7) and later faults with throws not exceeding 20 m.

Mining also revealed complicated small folds in both flanks of the Ordovician syncline. These may represent either 2nd- and 3rd-order folding or synsedimentary deformation (Fig. 8). These structures can therefore reflect ductility of the rocks or the severity of compression. Such tectonism tended to compress the syncline in its upper parts, causing the strongly folded Cambrian rocks, adjoining the syncline to the north and south, to be brought closer. Comparable styles have been recorded in the early Palaeozoic rocks of the whole Holy Cross Mts. (Znosko, 1996*a*, figs. 5, 7, 8, 11–13).

Depths of the syncline, measured in individual cross-sections along the axial surface, are: 120, 60, 200, 100, 258, 80 and 85 m. The syncline thus undulates along its longitudinal axis. The Ordovician Brzeziny Syncline extends eastwards beyond the Kielce–Morawica road (Figs. 1, 10), as documented by boreholes and resistivity surveys. It is not known how far the syncline extends westwards beyond the "slice" marked on the map by Czarnocki (1938). However, it cannot be precluded that it extends farther westwards as a plunging fold. The syncline is thus a distinct element within the Cambrian Brzeziny Anticline.

Widths of the syncline (=distance between flanks) measured perpendicular to strike just beneath the Holocene cover in the cross-sections, are as follows: 30, 45, 70 and 90 m. A small, but distinct, widening of the syncline is observed at hinge zones. The narrowness of the syncline in its upper part indicates strong compression. Moreover, its width is dependent on the depth of erosional surface.

TECTONIC IMPLICATIONS

Similar longitudinal undulation was observed in the Dyminy Anticline (Czarnocki, 1938). I have suggested two possible interpretations (sucked-in or pushed-up syncline, Znosko, 1996*a*, fig. 5). Such interpretations are supported by mining in the Ordovician Brzeziny Syncline, and presumably represent a structural pattern typical of the Holy Cross Mts.

The upturned Cambrian and Ordovician strata in the Kajetanów exposure (Czarnocki, 1939, p. 19–20) and interpretation of the Wiśniówka and Krzemianka sections (Znosko, 1996*a*, figs. 12 and 13; Kowalczewski and Dadlez, 1996, fig. 8) also match the pattern discussed above. A cross-section through the Dyminy Anticline and the structural pattern of Devonian strata on the 1:100 000 scale geological map (*op. cit*), indicate that this Alpine-style tectonism, occurred after the Silurian and before the Devonian. It is perfectly well visible in the map by Czarnocki (1938).

Horst cores of early Palaeozoic deposits contrast with adjacent, extensive weakly folded Devonian rocks (Fig. 11). They largely comprise strongly folded Cambrian strata forming complex anticlines. Locally, between these anticlines lie synclines of Ordovician-Silurian deposits which are strongly folded, as seen in the Ordovician Brzeziny Syncline (Fig. 8).

These early Palaeozoic rocks were uplifted after folding and deeply eroded. Anticlinal cores were eroded down to Cambrian rocks, whereas synclinal areas were eroded as deeply as their hinges composed of imbricated Ordovician and Silurian rocks (e.g. the Dyminy Anticline). The folded and deeply eroded early Palaeozoic deposits are unconformably overlain by Emsian sandstones and siltstones (Czarnocki, 1938).

During field reconnaissance in September 1963 I found both the patches of Devonian deposits mapped by Czarnocki (1938) on either side of the Kielce–Morawica road (Fig. 1). Around the eastern erosional outlier of Devonian rocks, Cambrian strata generally dip at 65–75°, also showing 2nd- and 3rd-order folds. The Emsian compact quartzitic sandstones overlie the Cambrian rocks with a marked angular unconformity. They dip southwards at an angle of up to 10°, most frequently 5–7°.

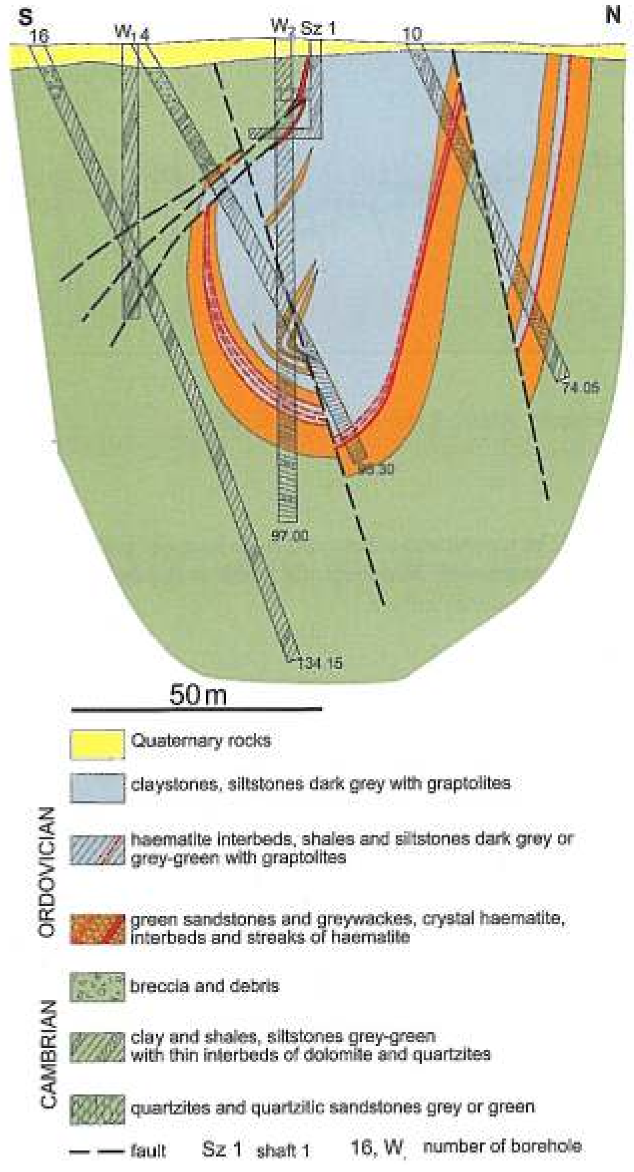

Fig. 3. Geological cross-section of Ordovician syncline along the boreholes 16, W_1, 4, W_2, 10 and shaft 1

Such a structural pattern of the Dyminy and Brzeziny Anticlines clearly indicates post-Silurian folding which, in the southern part of the Holy Cross Mts., were accompanied by uplift. This resulted in deep erosion that removed almost all the Ordovician and Silurian deposits, preserving them only in synclinal cores. Drop-like shape of such synclines (Figs. 3–6) suggests strong compression which may have led to complete squeezing of the more ductile Ordovician-Silurian rocks up or down and to come the two neighbouring anticlines built of more brittle Cambrian rocks into direct contact. Longitudinal fault zones within the Cambrian anticlines may represent contact planes.

Transition from Late Silurian deposits into Gedinnian rocks, which show a decreasing marine character upwards, becoming brackish and limnic in the Siegenian, is observed on the northern flank of the Niewachlów-Szydłówek structure. This reflects a sedimentary continuity in a relict basin which rapidly became a fresh-water one as communication with the open see was lost. Such tectonic evolution thus stimulated the formation of intramontane depressions with continuous sedimentation in relict basins: hence the term "Central Synclinorium" of past literature.

The depressions are bounded to the north by the early Palaeozoic Łysogóry Range, which shows southward diagonal and shear back-thrust over Devonian and Lower Carboniferous deposits. Early Palaeozoic rocks of the Łysogóry area show identical structure to those in the southern region. This can be seen in the cross-section through the Wiśniówka and Krzemianka exposures, Wilków section, the upturned Late Cambrian and late Ashgill sequence at Kajetanów, very strongly folded Cambrian deposits near Opatów (Znosko, 1996*a* and in: Dadlez *et al.*, 1994), and very strongly folded and imbricated Ordovician and Silurian rocks penetrated by a number of boreholes drilled between Kajetanów in the west and Pobroszyn near Opatów in the east (Tomczykowa, 1968; tectonic interpretation by Znosko, 1996*a*, 1999).

Continuous Silurian-Gedinnian sedimentation is documented by Czarnocki (1938) both north of the Łysogóry Range and in the Central Synclinorium. Hence, there are a few questions: what are the Cambrian or Cambro-Silurian deposits of the Łysogóry area thrust over? How far to the north does the area of Silurian-Gedinnian continuous sedimentation extend? Where does the Cambro-Silurian uplift zone, as a fold belt, be-

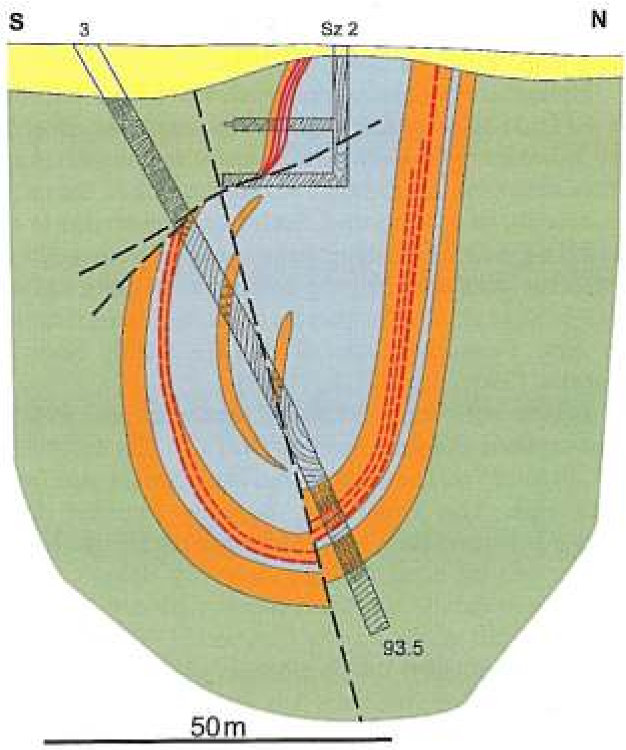

Fig. 4. Geological cross-section of Ordovician syncline along the borehole 3 and shaft 2

For explanations see Fig. 3

gin? The Cambrian in the Rachów borehole (Znosko, 1996*a*, fig. 1) and the folded and imbricated Upper Silurian rocks in the Bronkowice Anticline are unconformably overlain by the Emsian deposits (Fig. 1) (Dadlez *et al*., 1994, fig. 3b). This interpretation was supported also by Stupnicka and Przybyłowicz (1998) who discussed a hypothetical massif extending north of the Holy Cross Mts., and its relation to the Silurian deposits from the Bronkowice Anticline in terms of sediment transport direction.

TECTONIC STYLE AND DIFFERENCES BETWEEN EARLY AND LATE PALAEOZOIC ROCKS OF THE HOLY CROSS MTS.

The last question is: what are the tectonic differences between the Cambro-Silurian and Devonian rocks in the Holy Cross Mts.? The tectonic style of early Palaeozoic deposits is undoubtedly Alpine in style, characteristic of orogenic belts.

The Palaeozoic core of the Holy Cross Mts. and its Mesozoic fringe is well shown on 1:300 000 (Czarnocki, 1950) and 1:500 000 (Rühle ed., 1972) maps, showing that the Mesozoic cover exhibits large-scale open folds.

Devonian deposits, occurring in the cross-section between the Brzeziny Anticline and Łysogóry region, do not show any signs of Alpine-type tectonism on the map by Czarnocki (1938) (Fig. 11). Flanks of the broad syncline located between the Brzeziny and Dyminy anticlines are symmetric and composed of steeply dipping Devonian rocks. Its core is flat-bottomed and several kilometres wide, consisting of Frasnian, Famennian and Carboniferous deposits, exposed beneath a Permian and, locally, Bunter cover.

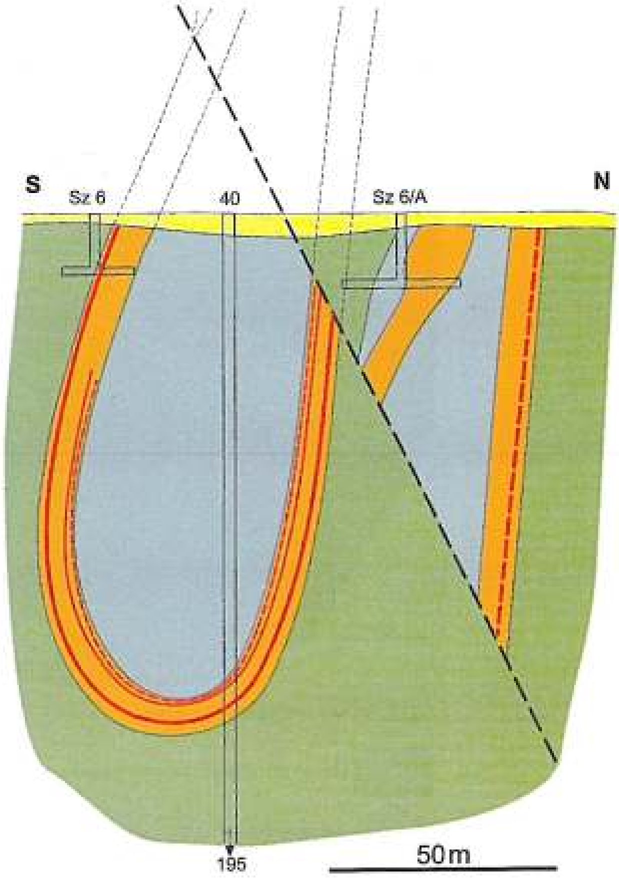

Fig. 6. Geological cross-section of Ordovician syncline along the shafts 6 and 6/A and the projected borehole 40

For explanations see Fig. 3

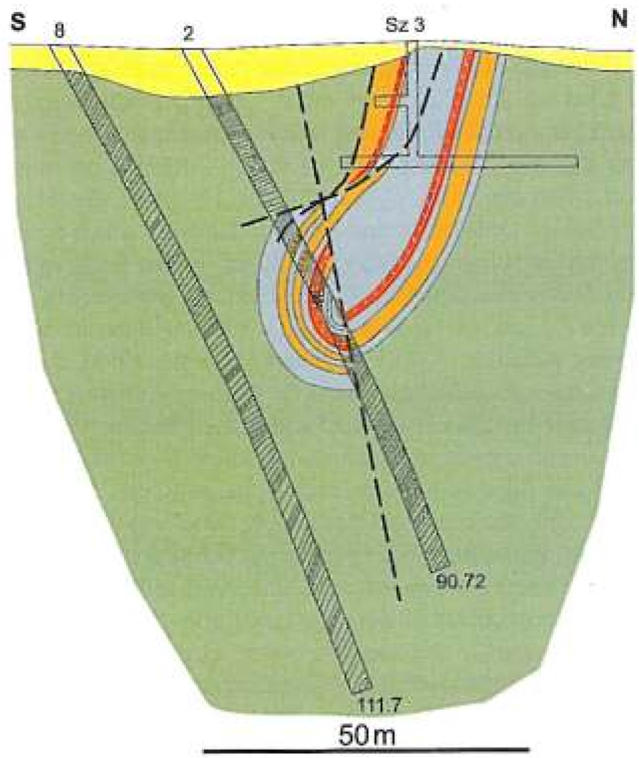

Fig. 5. Geological cross-section of Ordovician syncline along the borehole 8, 2, and shaft 3

For explanations see Fig. 3

A similar relationship can be observed between the Dyminy Anticline and Łysogóry region. An extensive area of Devonian and Carboniferous deposits forms a broad syncline, symmetrically surrounding a fold core of Frasnian, Famennian and Carboniferous strata that has a brachyanticlinal character with subordinate, 2nd-order, small-amplitude folds. This represents the original structural pattern shown by late Palaeozoic rocks in the Holy Cross Mts., and has nothing in common with typical Variscan orogenic tectonics.

Major faults delineated by Czarnocki (1938) are younger. Thrusts of Palaeozoic deposits over Triassic and even Jurassic rocks (Znosko, 1996*a*, fig. 7) indicate faulting after the Jurassic and, as shown by Stupnicka (1972), continuing into the Miocene.

This was probably related to Atlantic ocean-floor spreading, in particular at the Cretaceous/Tertiary transition and in Tertiary and Pleistocene/Holocene time.

Thus structural reconstruction of the late Palaeozoic and Mesozoic cover occurred in several phases, which, however, do not show orogenic character. This tectonic activity caused, consolidated Lower Palaeozoic structures to break through the

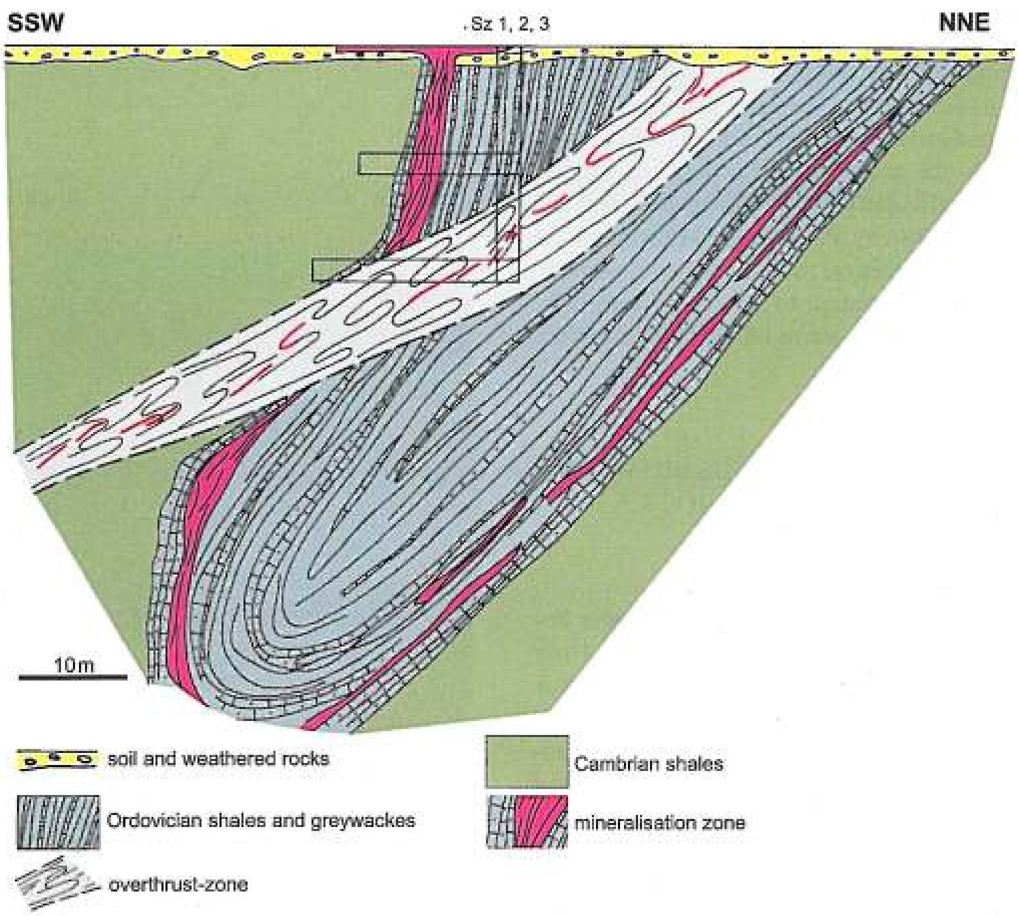

Fig. 7. Hypothetical cross-section through the Ordovician Brzeziny Syncline

Devonian-Carboniferous (and most likely Mesozoic) cover as grabens and horsts, as shown by Czarnocki (1938).

In ductile zones of repeated movement, largely fault zones with repeatedly translocated early Palaeozoic cores, local fold-thrust structures were formed within Devonian and Carboniferous deposits. However, these are small-scale structures formed by ramp tectonics. Such structures include the Śluchowice folds near Kielce, and folded, imbricated and overthrust Devonian beds at Jaźwica, north of Chęciny. Racki and Zapaśnik (1979) consider that younger movements, associated with "...for example Laramide activity of deep fault zones bounding original facies zones and, later, structural units...", contributed to the formation of those structures.

TECTONIC INTERPRETATIONS — DISCUSSION

The conclusions of Orłowski and Mizerski (1998) — repeated after earlier papers of these authors — should be modified in the light of the observations documented here.

Czarnocki (1919) suggested that "...the inner structure of the Chęciny Anticline (and other Cambrian anticlines, my remark) is a result of repeated tectonic movements, and Cambrian deposits — composing its core — form a number of smaller fold structures...", is up-to-date. However, the tectonically hidden Ordovician and Silurian deposits, which accompany the Cambrian anticlines, also form smaller folds, as seen in the Ordovician deposits of the Brzeziny Syncline (Fig. 8).

The "...lack of Ordovician and Silurian deposits in the Chęciny Anticline..." (Orłowski and Mizerski, 1998) is seeming because geological images of the Dyminy Anticline and the Ordovician syncline discovered within the Brzeziny Cambrian Anticline do not suggest such a conclusion. Most of the Ordovician and Silurian deposits within the anticlines have been eroded. Only their remnants, adjoining anticlines composed of Cambrian rocks, have been preserved. Orłowski and Mizerski (1998) seemed unaware of erosional remnants (or slices) of Early Silurian (Zbrza Shales) and Late Ordovician (Morawica Shales) deposits in the northern part of Brzeziny village, discovered by Filonowicz (1963) and cited by Tomczyk and Turnau-Morawska (1964, p. 505–506). It is not true that "...Ordovician and Silurian deposits are absent in the Chęciny Anticline..." (Orłowski and Mizerski, 1998) since both the Brzeziny and Chęciny anticlines form a tectonic whole (see Czarnocki, 1938). So, there is no foundation for the assumption that "...this problem is insoluble..." (*op. cit.*). Neither does the Dyminy Anticline as mapped by Czarnocki (1938) suggest such a regional conclusion.

The Brzeziny and Dyminy anticlines (Fig. 1) are about 4–5 km apart. This distance is small enough to consider the structure of these anticlines jointly. Thus, Ordovician and Silu-

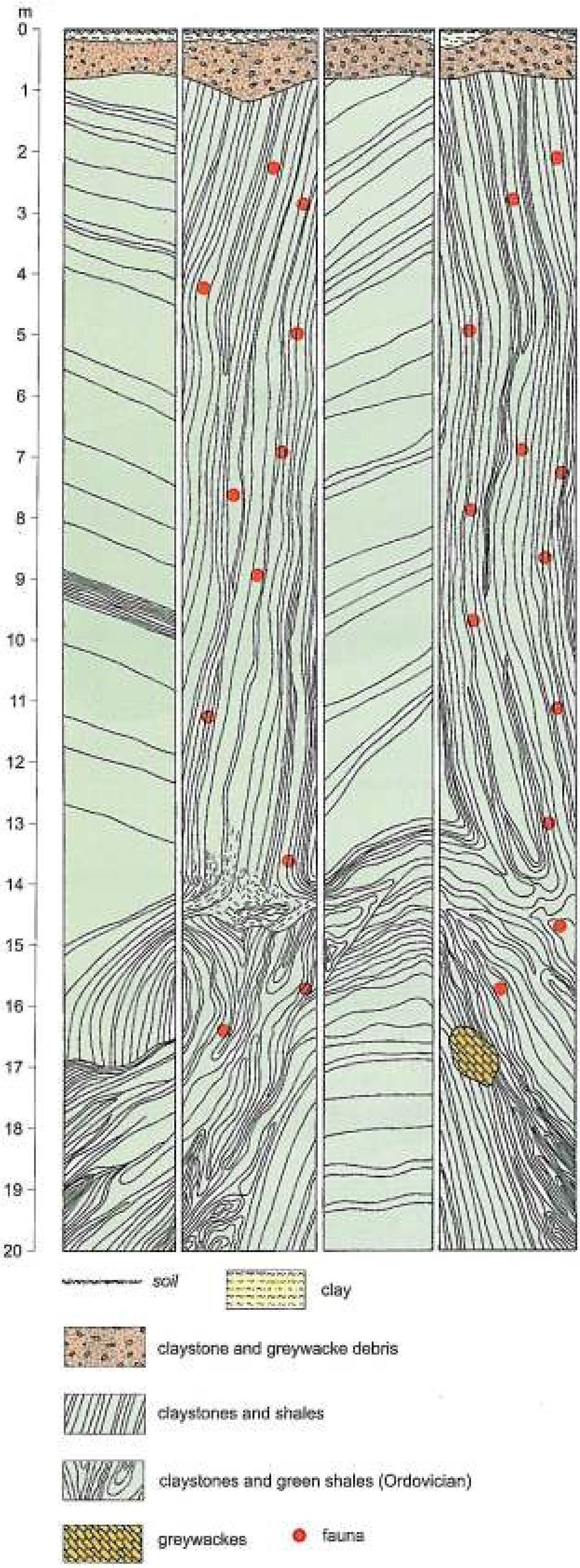

Fig. 8. Geological profile of shaft 2

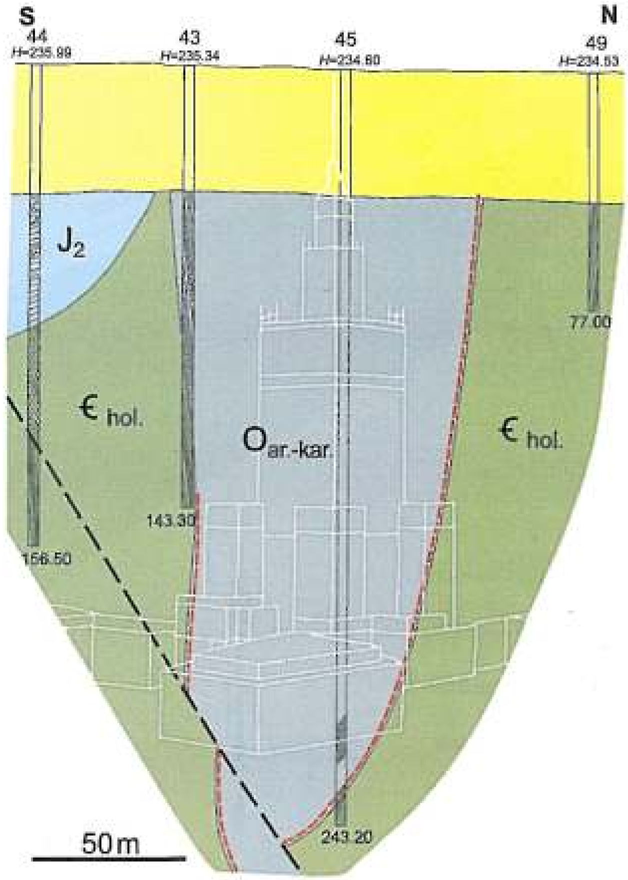

Fig. 9. Geological cross-section of Ordovician syncline along the boreholes 44, 43, 45 and 49; the depth of the syncline is shown by enclosed contour of the Palace of Culture and Science in Warsaw

hol. — Lower Cambrian, Holmia Cambrian, $O_{ar.-kar.}$ — Ordovician, Arenig-Caradoc, J_2 — Middle Jurassic

rian deposits occur in both these anticlines and there is angular unconformity between the Cambro-Silurian and Devonian deposits. The difference between them results from the depth of erosion which removed all the Devonian deposits from the Brzeziny Anticline.

In my opinion, the role of Caledonian tectonic movements was a dominant one everywhere in the Holy Cross Mts., and the importance of Variscan tectonic movements has been overstated since Nowak (1928).

Variscan tectonic activity did not result in the formation of narrow Cambrian anticlines, as postulated by Orłowski and Mizerski (1998). The map of Cambrian, Ordovician and Silurian rocks in the Dyminy and Brzeziny anticlines, and the position of the overlying Devonian cover clearly indicate the occurrence of pre-Devonian (pre-Emsian) folding. Early Palaeozoic narrow (!) folds formed before the Emsian, not during the Variscan, although Variscan tectonism occurred. The map of the Devonian cover indicates the sequence of events discussed above (Fig. 11).

Changes in stress direction from WNW–ESE to NW–SE were the effect of Laramide tectonic movements which also affected the Sudetic orogen, as expressed in both the structural pattern of the Fore-Sudetic Block and the orientations of the

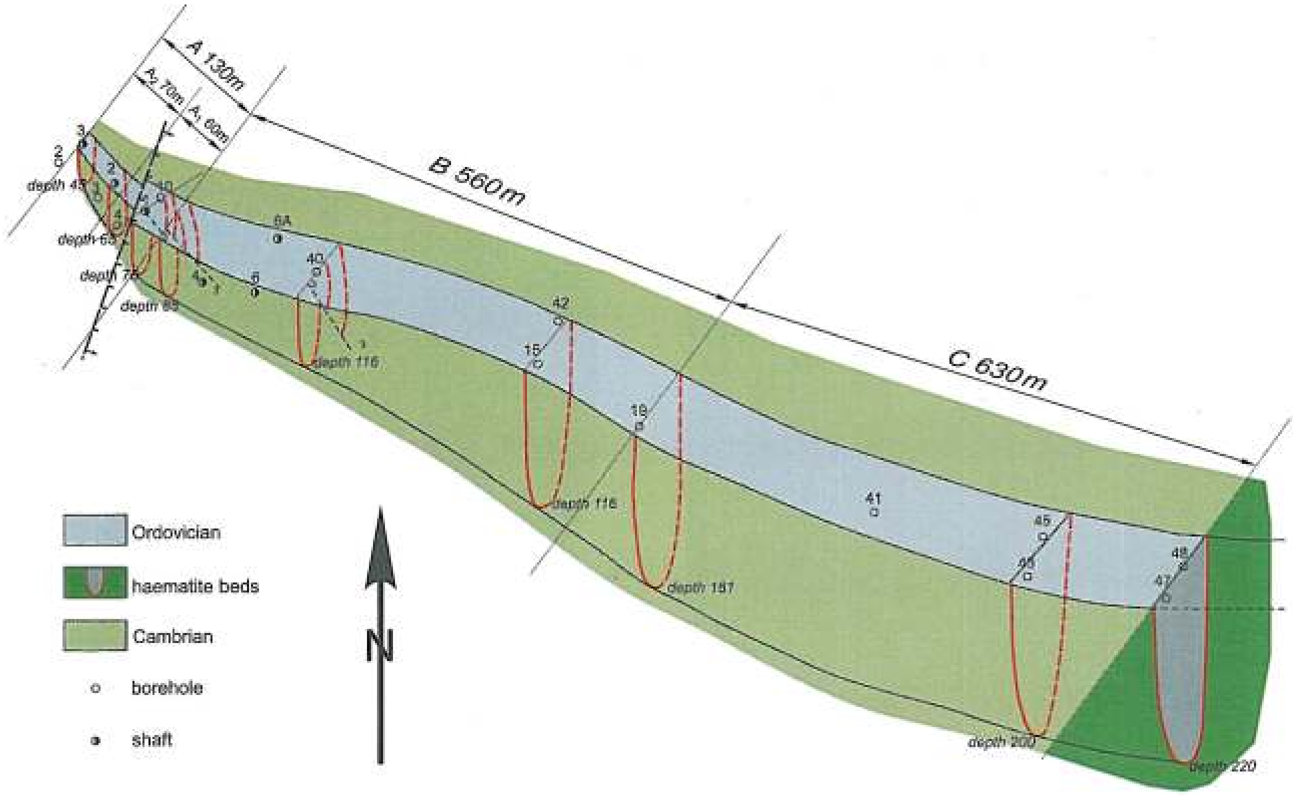

Fig. 10. Perspective scheme of the haematite beds at the Ordovician syncline in Brzeziny

For explanations see Fig. 3

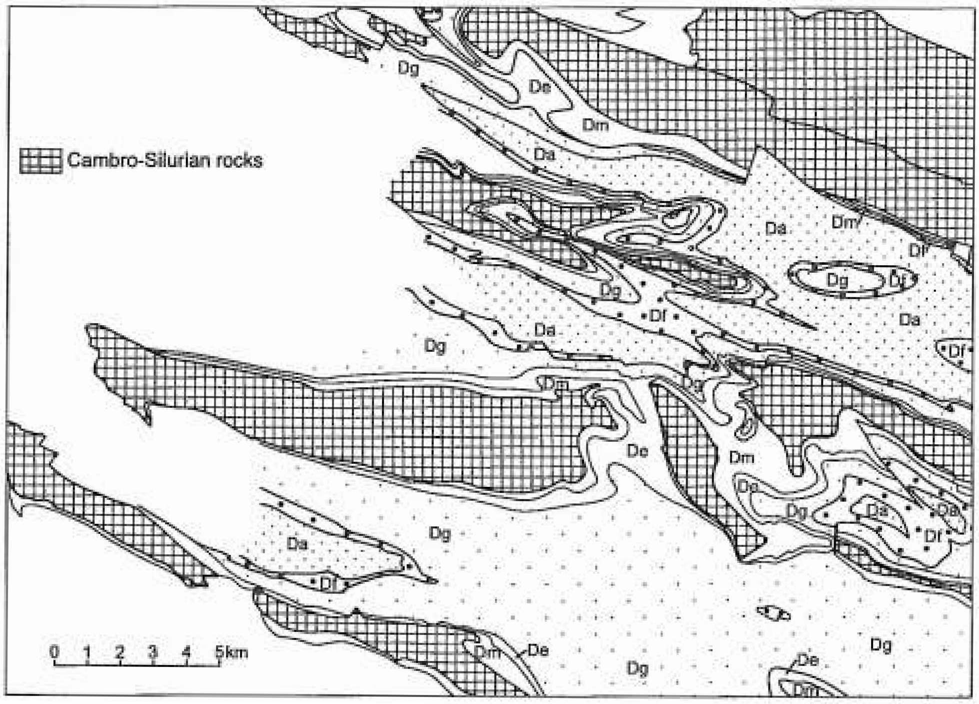

Fig. 11. Generalised division of stratigraphic stages of Devonian rocks; based on the map Czarnocki, sheet Kielce 1:100 000; exposed version, without faults

Dm — Emsian, De — Eifelian, Dg — Givetian, Df — Frasnian, Da — Famennian long axes of geophysical anomalies largely reflecting buried geological structures (Karaczun *et al.*, 1978; Królikowski and Petecki, 1995).

The youngest deformations, conventionally understood as of Laramide age, caused a considerable reconstruction of not only the Palaeozoic core of the Holy Cross Mts. but also of the whole Mesozoic cover throughout Poland. “Laramide” trends could not manifest themselves strongly enough everywhere within the consolidated Lower Palaeozoic cores. Hence, there are differences between Palaeozoic and Laramide trends in the Holy Cross Mts. The latter are most strongly manifested in the Mójcza Anticline (Fig. 1). The Laramide trend, parallel to the edge of the crystalline basement of the old platform, and the trend of the Mid-Polish Swell with adjoining troughs, clearly indicate the stress field generated by Atlantic ocean-floor spreading.

REFERENCES

CHLEBOWSKI R. (1971) — Petrography of the Ordovician deposits of the Bardo syncline in the southern part of the Świętokrzyskie Mts (in Polish with English summary). Arch. Miner., **29** (1/2): 193–304.

CZARNOCKI J. (1919) — Stratygrafia i tektonika Gór Świętokrzyskich. Pr. Tow. Nauk. Warsz., **28**: 1–172.

CZARNOCKI J. (1938) — Ogólna mapa geologiczna Polski 1:100 000. Sheet 4 — Kielce.

CZARNOCKI J. (1939) — Sprawozdanie z badań terenowych wykonanych w Górach Świętokrzyskich w 1938 r. Biul. Państw. Inst. Geol., **15**: 1–44.

CZARNOCKI J. (1950) — Przeglądowa Mapa Geologiczna Polski 1:300 000, sheet Kielce, ed. B.

DADLEZ R., KOWALCZEWSKI Z. and ZNOSKO J. (1994) — Some key problems of the pre-Permian tectonics of Poland. Geol. Quart., **38** (2): 169–190.

KARACZUN K., KARACZUN M., BILIŃSKA M. and UHRYNOWSKI A. (1978) — Mapa Magnetyczna Polski 1:500 000. Inst. Geol. Warszawa.

KOWALCZEWSKI Z. (2000) — Litostratygrafia, paleogeografia, facje i tektonika kambru świętokrzysko-nidziańskiego (zagadnienia podstawowe i stan ich znajomości). Pr. Inst. Geogr. WSP w Kielcach, **4**: 7–66.

KOWALCZEWSKI Z. and DADLEZ R. (1996) — Tectonics of the Cambrian in the Wiśniówka area (Holy Cross Mts., Central Poland). Geol. Quart., **40** (1): 23–46.

KOWALCZEWSKI Z., JAWOROWSKI K. and KULETA M. (1998) — Klonów Beds (uppermost Silurian-?lowermost Devonian) and the problem of Caledonian deformations in the Holy Cross Mts. Geol. Quart., **42** (4): 341–378.

KRÓLIKOWSKI C. and PETECKI Z. (1995) — Atlas Grawimetryczny Polski 1:500 000. Państw. Inst. Geol. Warszawa.

MALEC J. (1990) — Profil górnego syluru i dolnego dewonu z północnej części Kielc w aspekcie regionalnym. Kwart. Geol., **34** (4): 778–779.

MALEC J. (1991) — Szarogłazy niewachlowskie w profilu górnego syluru regionu południowego Gór Świętokrzyskich. Kwart. Geol., **35** (2): 284–285.

MALEC J. (1993) — Upper Silurian and Lower Devonian in the western Holy Cross Mts. Geol. Quart., **37** (4): 501–536.

MIECZYSŁAWSKI A. (1962) — Opracowanie geologiczne wyników badań wystąpień hematytu w rejonie Brzezin k/Kielc. Przeds. Geol. w Kielcach, Zakł. Złóż Rud Żelaza Częstochowa. Centr. Arch. Geol. Państw. Inst. Geol.: 1–64.

MIZERSKI W. (1995) — Geotectonic evolution on the Holy Cross Mts. in Central Poland. Biul. Państw. Inst. Geol., **372**: 5–47.

NOWAK J. (1928) — La nature et rôle des plissements hercyniens en Pologne. In: XIV Congr. Geol. Intern. Madrid 1926. C.r. Fsc. 3 Madrid 1928: 1077–1083, m. 1, tabl. 4.

ORŁOWSKI S. and MIZERSKI W. (1998) — New data on the Cambrian of the Chęciny Anticline (Holy Cross Mts, Central Poland) (in Polish with English summary). Prz. Geol., **46** (3): 278–282.

RACKI G. and ZAPAŚNIK T. (1979) — Some remarks on the tectonics of Devonian rocks in the Gałęzice syncline (in Polish with English summary). Prz. Geol., **27** (3): 154–158.

RÜHLE E. ed. (1972) — Mapa Geologiczna Polski bez Utworów Kenozoicznych 1:500 000. Inst. Geol. Warszawa.

STILLE (1924) — Grundfragen der vergleichenden Tektonik. Verl. Bornträger.

STUPNICKA E. (1972) — Tectonic of the SW margins of the Holy Cross Mts (in Polish with English summary). Biul. Geol. Wydz. Geol. UW, **14**: 21–109.

STUPNICKA E. and PRZYBYŁOWICZ T. (1998) — Hipothetical massif north of the Holy Cross Mts and the Upper Silurian of the Bronkowice Anticline (in Polish with English summary). Prz. Geol., **46** (9/1): 836–844.

TOMCZYK H. and TURNAU-MORAWSKA M. (1964) — Stratigraphy and petrography of the Ordovician in Brzeziny near Morawica (in Polish with English summary). Acta Geol. Pol., **14** (4): 501–546.

TOMCZYKOWA E. (1968) – Stratratigraphy of the uppermost Cambrian deposits in the Świętokrzyskie Mountains (in Polish with English summary). Pr. Inst. Geol., **54**.

ZNOSKO J. (1996*a*) — Tectonic style of the Early Palaeozoic sequences in the Holy Cross Mountains. Geol. Quart., **40** (1): 1–22.

ZNOSKO J. (1996*b*) — Styl strukturalny skał kambro-syluru Gór Świętokrzyskich. Pol. Tow. Geol. Oddz. Poznań, **5**: 65–70.

ZNOSKO J. (1999) — Etapy ewolucji tektonicznej Gór Świętokrzyskich. Posiedz. Nauk. Państw. Inst. Geol., **55** (7): 5–8.