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Tectonics of the Cambrian in the Wiśniówka area (Holy Cross Mts., Central Poland)

The tectonics of the Wiśniówka area (Łysogóry Unit) is discussed in connection with the opinions of W. Mizerski who believes in the monoclinal arrangement of the Cambrian strata and the Variscan age of deformations. Results of exploratory pits and of geophysical survey are presented. Fundamental facts are given speaking for the folded structure of the Cambrian and the evidence is considered of its Late Caledonian folding.

INTRODUCTION

This paper has been inspired by a short note published recently by S. Orłowski and W. Mizerski (1995*a*). We were accused there of misleading the participants of the international EUROPROBE meeting in Kielce, September 1994, by presentation of the false information about the stratigraphy and tectonics of the Wiśniówka area. Since that note did not contain any new arguments and referred to the earlier papers of its authors, a broader discussion of these earlier achievements became necessary. Stratigraphic scheme of the Cambrian by S. Orłowski was considered by Z. Kowalczewski (1995). The aim of the following text is to discuss the tectonic problems of the Wiśniówka area in the Łysogóry Unit, in connection with interpretations by W. Mizerski. We shall concentrate upon the facts because our opponent complains that we do not take them into account.

We think that his interpretations are best expressed by the appropriate quotations from his several papers:

—"*... Łysogóry Unit is neither anticline, scale nor slice ...*". It is "*... a monocline with subordinate, disharmonic type fold structures ...* " caused by "*... differential tectonic competencies of the sandstones and shales ...*" (W. Mizerski, 1979, p. 1 and 31).

— "*... Units of the Łysogóry region originated in several phases during the Variscan movements ...*" (W. Mizerski, 1988*a*, p. 52).

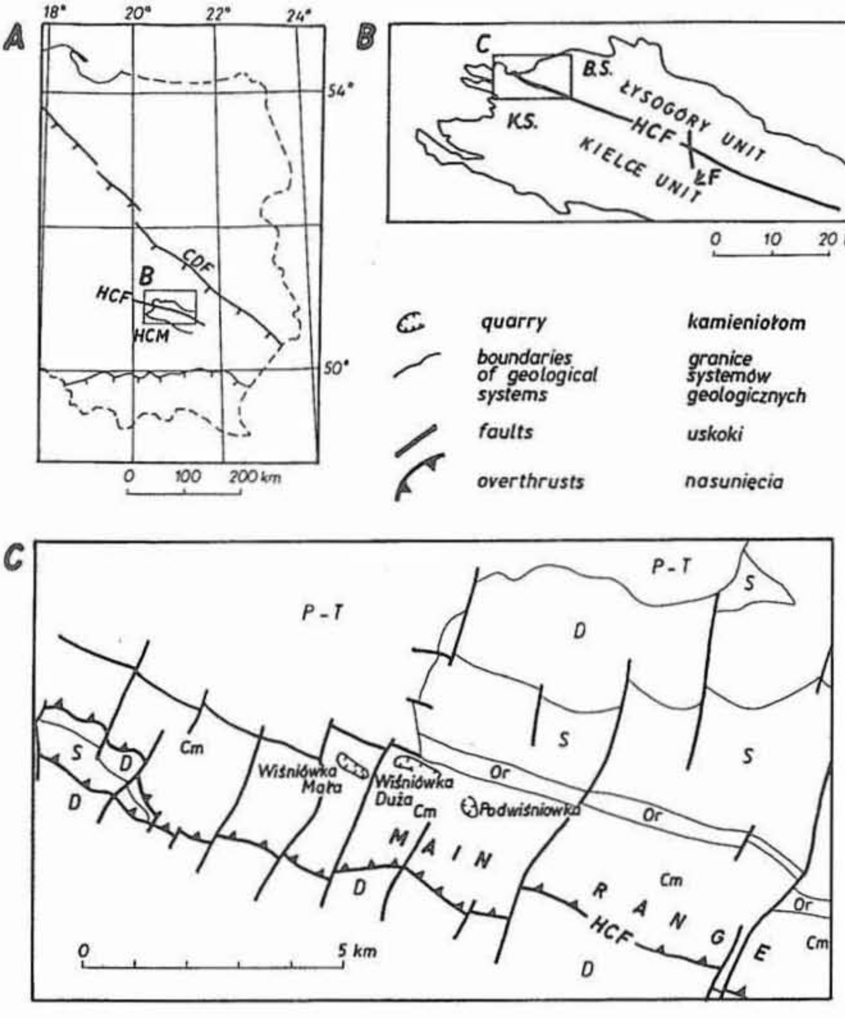


Fig. 1. Wiśniówka area and its regional setting

CDF — Caledonian deformation front, HCF — Holy Cross Fault, HCM — Holy Cross Mountains, B.S. — Bodzentyn Syncline, K.S. — Kielce Syncline, ŁF — Łysogóry Fault; Cm — Cambrian, Or — Ordovician, S — Silurian, D — Devonian, P–T — Permian and Triassic

Obszar Wiśniówki i jego regionalne położenie

CDF — front deformacji kaledońskich, HCF — uskok świętokrzyski, HCM — Góry Świętokrzyskie, B.S. — synklina bodzentyńska, K.S. — synklina kielecka, ŁF — uskok łysogórski; Cm — kambr, Or — ordowik, S — sylur, D — dewon, P–T — perm i trias

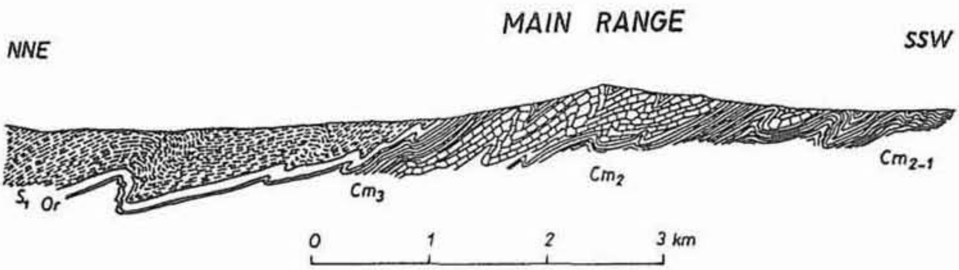


Fig. 2. Section across the Main Range (after J. Czarnocki, 1947, fragment)
Cm_{2-1} — Lower and Middle Cambrian, Cm_2 — Middle Cambrian, Cm_3 — Upper Cambrian, Or — Ordovician, S_1 — Lower Silurian
Przekrój przez Pasmo Główne (według J. Czarnockiego, 1947, fragment)
Cm_{2-1} — kambr dolny i środkowy, Cm_2 — kambr środkowy, Cm_3 — kambr górny, Or — ordowik, S_1 — sylur dolny

— "*... All the Palaeozoic beds ... were folded ... after the Devonian, during the Variscan orogeny...*" (W. Mizerski, 1991, p. 133).

— "*... Shales and shale/sandstone sequences of the Middle Cambrian are featured by comparatively numerous folds of small sizes, while sandstones (often thick-bedded) of the Upper Cambrian are steeply inclined, sometimes even reversed, but the plicative deformations within them are practically lacking (except for peri-fault zones in more shaly portions)...*" (W. Mizerski, 1992, p. 143).

— "*... In the Variscan Stage ...all the tectonic structures within the Łysogóry Cambrian originated ... It did not occur in one phase but in two or more phases of the Variscan orogeny ...*". In the Łysogóry Unit "*... the Variscan movements were the first folding movements ...*" (W. Mizerski, 1994, p. 725).

— "*... Early Palaeozoic and Devonian formations ...*" (in the Łysogóry Block — our remark) "*... form one Variscan structural stage ... Within this stage there are three structural complexes separated by stratigraphic hiatuses ... lying one upon another without angular unconformity: early Caledonian, late Caledonian and Variscan ...*" (W. Mizerski, 1995, p. 9).

— "*...The Łysogóry Unit is not a fold structure ...*". It is "*... a monocline with subordinate disharmonic-type fold structures ...*" (W. Mizerski, 1995, p. 13).

On the basis of these quotations, the opinions of W. Mizerski may be summarized as follows:

Cambrian rocks in the Łysogóry Unit were deformed only once — in the Variscan diastrophic epoch. The deformations are not a result of compressional folding and horizontal shortening but rather of vertical block movements. The deformations are characterized by a monoclinal arrangement of beds. Minor folds are subordinate features being an effect of disharmonic folding due to differences between the competent sandstones and incompetent shales.

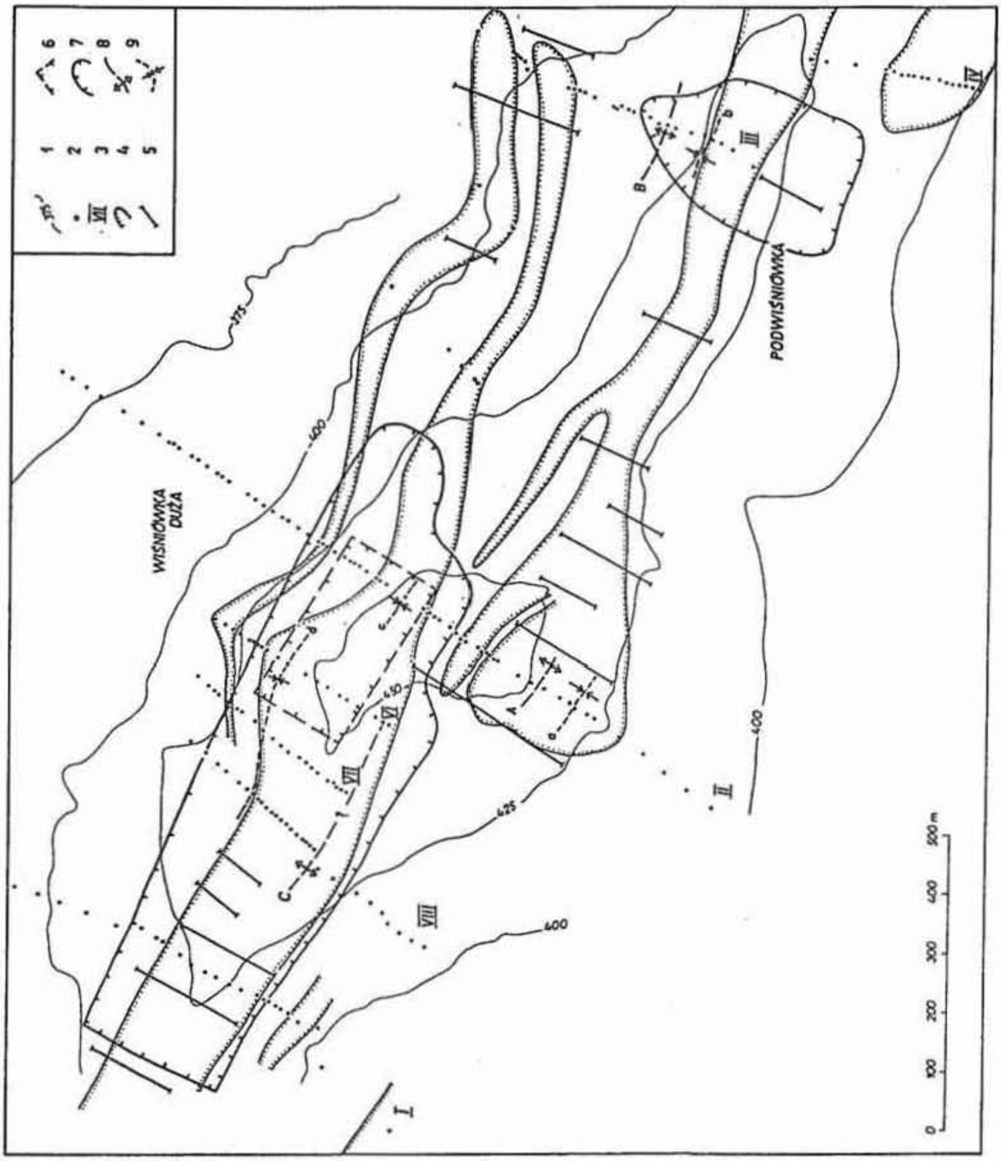


Fig. 3. Geological sketch of the Wiśniówka area (after J. Czarnocki, 1958*a*, supplemented)

1 — contour lines in metres a.s.l., 2 — pre-war pits, 3 — symbols of pit lines, 4 — quartzites (1–4 after J. Czarnocki), 5 — lines of post-war pits and trenches, 6 — boundaries of the quarry in 1939, 7 — present boundaries of the quarries, 8 — axes of major anticlines, 9 — axes of major synclines; for details see text

Szkic geologiczny obszaru Wiśniówki (według J. Czarnockiego, 1958*a*, uzupełniony)

1 — poziomice w m n.p.m., 2 — szybiki przedwojenne, 3 — numery linii szybikowych, 4 — kwarcyty (1–4 według J. Czarnockiego), 5 — linie szybików i rowów powojennych, 6 — granice kamieniołomu w 1939 r., 7 — obecne granice kamieniołomów, 8 — osie głównych antyklin, 9 — osie głównych synklin; szczegóły w tekście

MONOCLINE OR FOLDS?

The Wiśniówka area, situated at the western end of the Łysogóry Unit (so called Cambrian Main Range — Fig. 1C) is a crucial area for understanding the tectonics of this unit because three quarries aimed at the exploitation of the Cambrian quartzites are located there. The whole area has been an object of intense reconaissance works for the past sixty years.

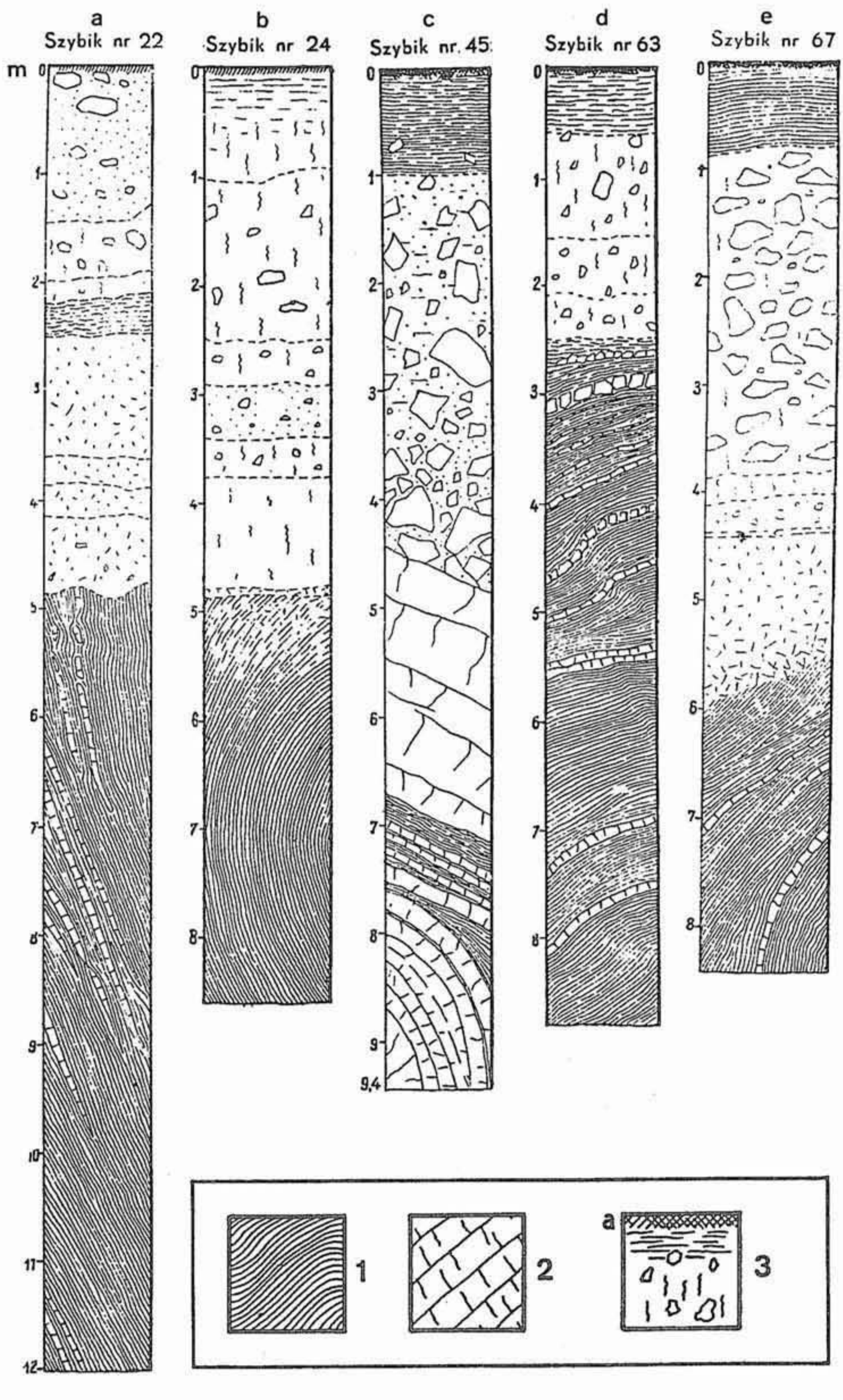
W. Mizerski based his tectonic views mainly on the observations in quarries. He stated that (S. Orłowski, W. Mizerski, 1995*a*, p. 13): "... *The idea of the folded structure of the Cambrian of Wiśniówka Hill came from J. Czarnocki who obtained his information ... from the shallow pits. After the* ... (quartzite — our remark) ... *deposit had been accessible* ... (in the quarry — our remark) ... *it became obvious that J. Czarnocki's interpretations have nothing in common with the facts* ...". And a few phrases below (S. Orłowski, W. Mizerski, 1995*a*, p. 14): "... *At that time* ... (of J. Czarnocki's research — our remark) ... *the quarries did not exist yet. However, they exist now and everybody can find that the view of J. Czarnocki about the folded structure of the Wiśniówka Cambrian cannot be maintained by no means because it is inconsistent with the scientific objectivity* ...".

The last phrase is simply not true because the first quarry (Wiśniówka Duża) was opened in the late thirties. J. Czarnocki knew it quite well and in spite of this he did not change his opinion as to the folded structure of the area. The best proof is his later paper where he wrote explicitly: "... *Both series* ... (Cambrian and Silurian — our remark) ... *and, particularly, the Cambrian are strongly folded and monoclinally inclined to the north* ..." (J. Czarnocki, 1947, p. 8). Perhaps the word "monoclinally" used in this quotation has inclined W. Mizerski to become so closely attached to this term. However, a short glance at the cross-section in the cited paper (reproduced here as Fig. 2) shows without any doubt that J. Czarnocki meant a monoclinal northward inclination of beds in the frames of folded structure with overall southern vergence (see also J. Znosko, 1995)

It is clear from the above that the results of the exploratory pits are decisive in this debate. First pits were made in the years 1928–1935. They were supervised and described by J. Czarnocki (1958*a*). They covered the entire area of the Wiśniówka Hill. Their results were frequently cited (e.g. J. Znosko, 1988, 1989, 1995) but their detailed analysis was never presented.

Altogether about 240 pits were made at that time (Fig. 3). More than 180 pits reached the Cambrian rocks and were deepened in the fresh rock so as to enable the measurements of the strikes and dips of strata. The bulk of the pits was arranged in eight lines, the distance between them being from 100 to 500 m, and the average distance between the neighbouring pits in a line being less than 20 m. The pits were on the average 3–4 m deep (maximum 18 m), some of them with horizontal galleries at the bottom. The arrangement of strata in pit walls were thoroughly portrayed (examples of these drawings are given in Fig. 4) and the preliminary near-surface interpretation of three pit lines was made by J. Czarnocki himself (1958*a*, pl. XIII).

The longest line was 1400 m long while the present width of the quarry (which was later excavated in the northern part of the hill) is about 300 m. The area covered by the exploration pits was about 100 ha while the area of the quarry is about 25 ha. It seems obvious from the comparison of the above numbers that the rejection of the data acquired from the pits is not


a
Szybik nr 22
b
Szybik nr 24
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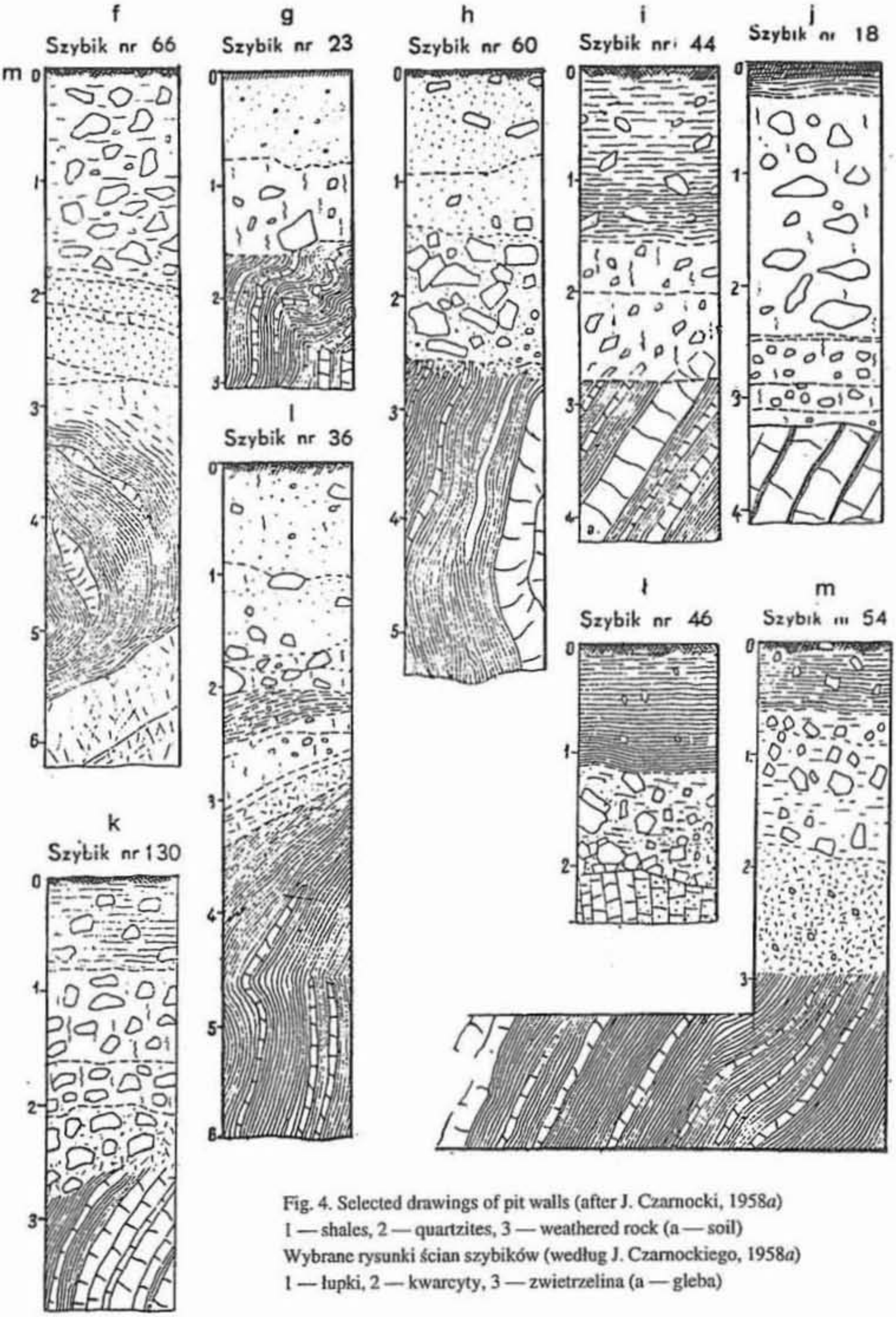

Fig. 4. Selected drawings of pit walls (after J. Czarnocki, 1958*a*)
1 — shales, 2 — quartzites, 3 — weathered rock (a — soil)
Wybrane rysunki ścian szybików (według J. Czarnockiego, 1958*a*)
1 — łupki, 2 — kwarcyty, 3 — zwietrzelina (a — gleba)

justified. These data are collected from more dispersed points than in the quarry but they do cover a greater area and the usefulness of both sources for tectonic interpretation is at least of the same value.

A general remark is necessary at the start of discussion. It is true that the Cambrian rocks in the quarry are inclined predominantly (though not exclusively) to the north. However, the area of observation in the quarry is relatively limited. Monoclinal arrangement of beds in a small outcrop (hundreds of metres wide) may be a fragment of a larger fold (a few kilometres wide). It is sufficient to look at the monoclinal arrangement of strata in the spectacular northern wall of the Giewont Peak (Tatra Mts.), 600 m high, or in any of a number of quarries in the Flysch Carpathians. In spite of monoclinal arrangement of beds in these outcrops there is no doubt that they represent small fragments of the Carpathian nappes what can be identified on any regional map.

The same is true of the Wiśniówka quarry when compared with the greater Wiśniówka area. What are the results of the analysis of the exploratory pits?

1. 91% of strikes are of the NW–WNW orientation. The remaining 9% lie between the northern and eastern direction. Diagram of strikes is shown in Figure 5A. More precisely, the dominating strike of beds is WNW (100–130°). Consequently, the dips are either NNE or SSW. From there on, for the sake of simplicity, we shall use the form "northern" and "southern" dips respectively.

2. Although the northern dips prevail, it is not the overwhelming prevalence. 29% of dips (from among 167 measurements with NW and NNW strikes) are directed towards south.[1] This is illustrated in Figure 5B.

3. The dips along some segments of the pit lines decrease or increase regularly in one direction suggesting the gradual bending of strata (e.g. in syncline (d) on the cross-sections VII and VIII — Fig. 3).

4. The southern dips are, on the average, smaller than the northern ones pointing to an asymmetric structure.

5. In such a situation the most probable interpretation of structural data must be in terms of an assemblage of folds. Folded structure was presented by J. Czarnocki in his first interpretative versions, especially of the longest cross-section II (J. Czarnocki, 1958*a*, pl. XIII). Three versions of more recent interpretation along this cross-section are shown in Figures 6–8. The near-surface picture in Figures 6 and 7 is identical with that given by J. Czarnocki. In Figure 8 it is slightly changed at places because of corrections of dips in several pits, among others with regard to the difference between the trends of pit lines and the direction of dip. The authors of all three figures are responsible for broader interpretation (dashed and dotted lines). These three versions differ in details but they have one feature in common: all of them present folds and overthrusts instead of a monocline because it seems to be the simplest way of interpretation of the structural data.

[1] W. Mizerski (1979; S. Orłowski, W. Mizerski, 1995*b*) called in question the results of dip measurements by J. Czarnocki, particularly the southern dips on the northern slope of the hill. He believes that they are a result of landslides. We do not agree with him for several reasons: (1) the pits were sufficiently deep to separate the weathered rock from the fresh rock; (2) landslides are acceptable in shales but are highly improbable in quartzites; (3) why are the northern dips on the southern slope not classified as caused by landslides? (4) there are also southern dips on the southern slope; would they be a result of "up-slope slides"?

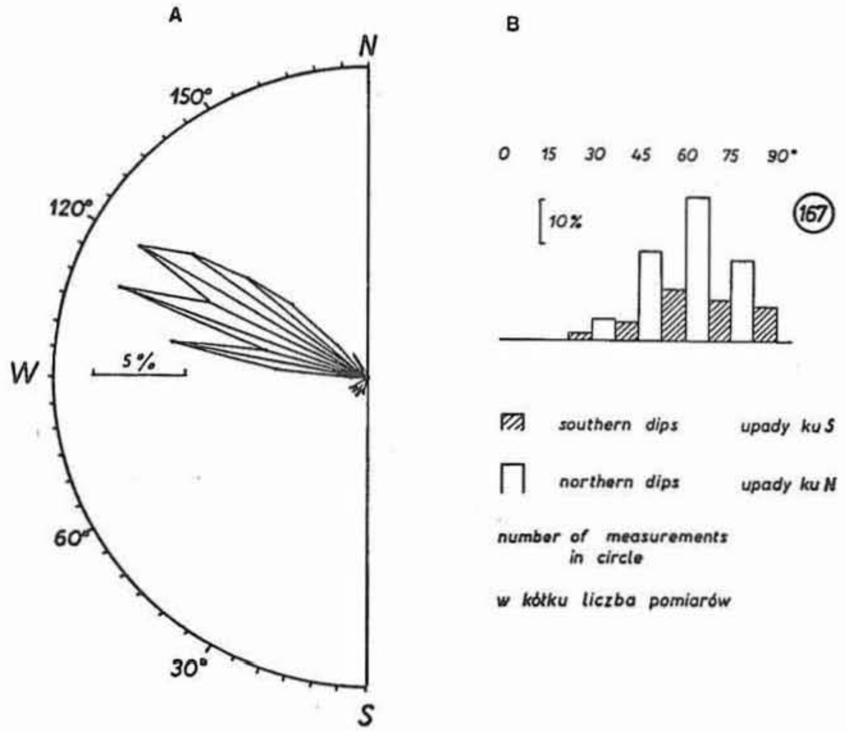

Fig. 5. Strikes (A) and dips (B) measured in the pre-war pits (after the data collected by J. Czarnocki, 1958*a*)
Biegi (A) i upady (B) zmierzone w szybikach przedwojennych (według danych zebranych przez J. Czarnockiego, 1958*a*)

If we accept such an interpretation, what further implications can be drawn from this phase of exploration?

1. Folds of variable sizes and shapes have been ascertained. There are large folds, more than 100 m wide in quartzites and minor folds, tens of metres wide, in shales. The axes of the former are shown in Figure 3.

2. Some large folds are upright folds (e.g. syncline **d** in cross-section VIII or syncline **a** in cross-section II with dips in both limbs, respectively, of about 65° and 52–54°) while some are inclined folds. For example the syncline **d** on cross-sections VII and VI is characterized by average dips of, respectively, 57 and 52° to the north in its southern limb, and 78 and 68° to the south in its northern limb. In case of the anticline **A** on cross-section II, the average northern dips in its northern limb are 69° while the southern dips in its southern limb are 43°. These data point both to the southern and northern vergence of folds (see also Figs. 6–8). Both directions are accentuated by overthrusts and imbrication of folds.

3. Shaly portions of the sequence are folded stronger than the quartzitic ones. It confirms the idea of disharmonic folding.

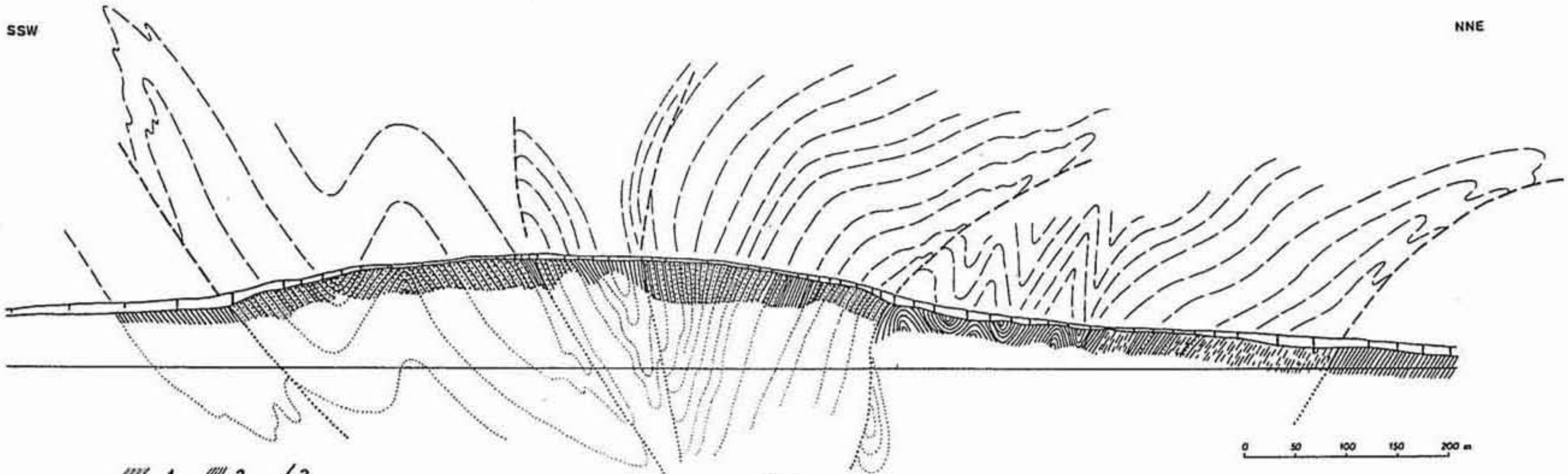

Fig. 6

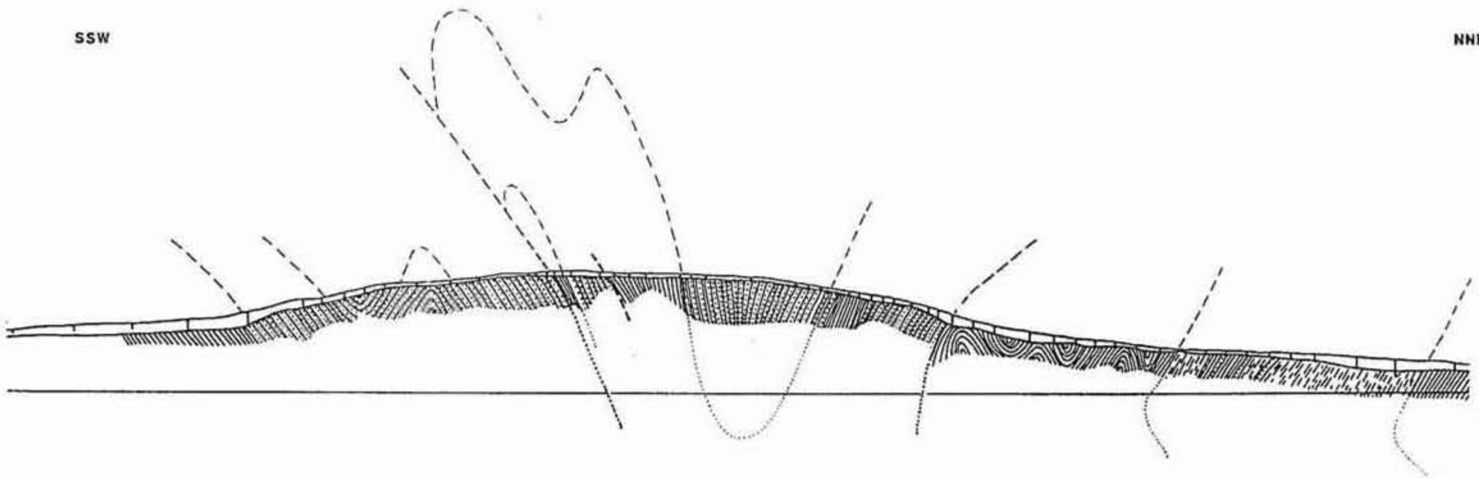

Fig. 7

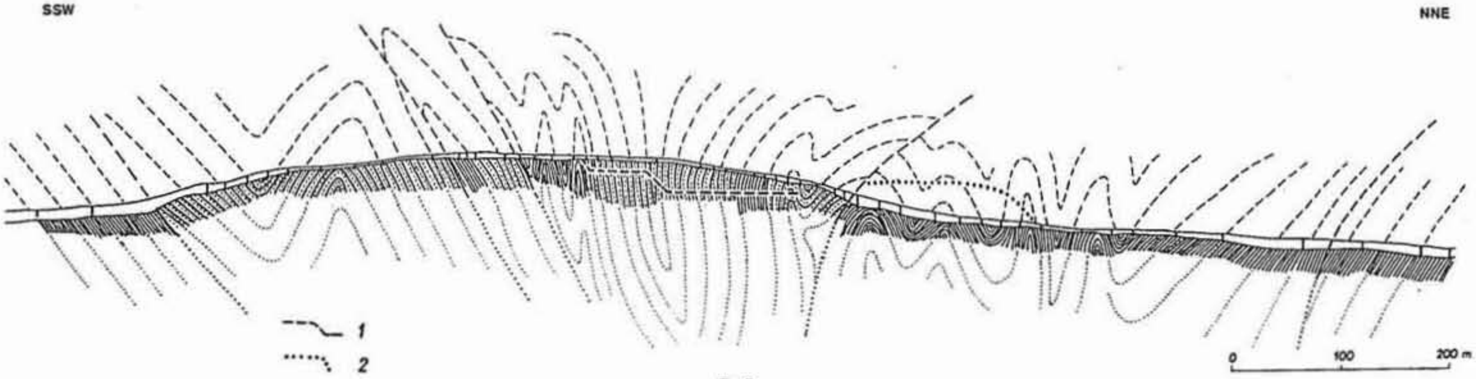

Fig. 8

Fig. 6. Cross-section along the line II (after J. Znosko, 1996, fig. 12, slightly simplified, reversed in relation to the north)
1 — quartzites, 2 — shales, 3 — faults
Przekrój wzdłuż linii II (według J. Znoski, 1996, fig. 12, nieco uproszczony, odwrócony względem północy)
1 — kwarcyty, 2 — łupki, 3 — uskoki
Fig. 7. Cross-section along the line II interpreted by Z. Kowalczewski
For explanations see Fig. 6
Przekrój wzdłuż linii II według interpretacji Z. Kowalczewskiego
Objaśnienia przy fig. 6
Fig. 8. Cross-section along the line II interpreted by R. Dadlez
1 — quarry, 2 — heap; for other explanations see Fig. 6
Przekrój wzdłuż linii II według interpretacji R. Dadleza
1 — kamieniołom, 2 — hałda; inne objaśnienia przy fig. 6

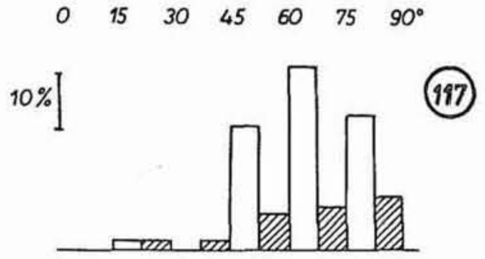

Fig. 9. Dips measured in the post-war pits
For explanations see Fig. 5
Upady pomierzone w szybikach powojennych
Objaśnienia przy fig. 5

4. The drawings of pit walls show clearly — on a smaller scale — that not only shales and shale/quartzite sequences (Figs. 4b and e) but also quartzites (Figs. 4c, k and h) are deformed in a plastic manner. In another case (Fig. 4f) possible drag folds in shales are visible. Moreover, in a few drawings (Figs. 4a, d, f and l) a distinct boudinage of quartzites is worth mentioning. All these features point to strong compression and penetrative character of fold deformations.

* * *

In the process of further research aimed at the extension of exploitation of quartzites much work has been done in post-war period. These works were extended into a greater area of Wiśniówka between villages Wiśniówka Mała and Masłów. They included the geophysical survey with electric resistivity method (Z. Kowalczewski *et al.*, 1986) and nearly 120 exploratory pits and trenches.

The results of these post-war works can be summarized as follows.

Histogram of recorded dips (Fig. 9) shows striking similarity to that from Figure 5. The majority of dips is to the north but 24% — to the south. Southern dips are concentrated in the northern and western part of the area. The values of dips in both directions are also comparable. It is the evidence that the structural style presented above is characteristic not only of the quarries but of the entire segment of the Main Range.

Electric resistivity profiles were made at an average distance of 50 m. They revealed (Fig. 10) two major belts of quartzites which pass southwards gradually into shaly-sandy and shaly beds whereas from the north they are bordered by sharp boundaries. It suggests again the asymmetry of structure and possible fault contacts along the northern boundaries of both belts. Moreover — according to this geophysical survey — the dominant northern dips at the surface change frequently into southern dips at a depth of several tens of metres pointing to the bending of strata and their reverse position close to the surface.

Two ridges in the relief of the area are built of two series of sandstones, mainly quartzitic which run more or less parallel to each other in the WNW–ESE direction (Z. Kowalczewski *et al.*, 1986, see also Fig. 10). The Wiśniówka Duża quarry is located in the middle of the northern series while a new Podwiśniówka quarry and an abandoned quarry in Wiśniówka Mała are situated in the southern series.

The inner structure of each series which are split by transversal faults is complicated and changes along the strike (Fig. 10). Generally, two packages of quartzitic sandstones

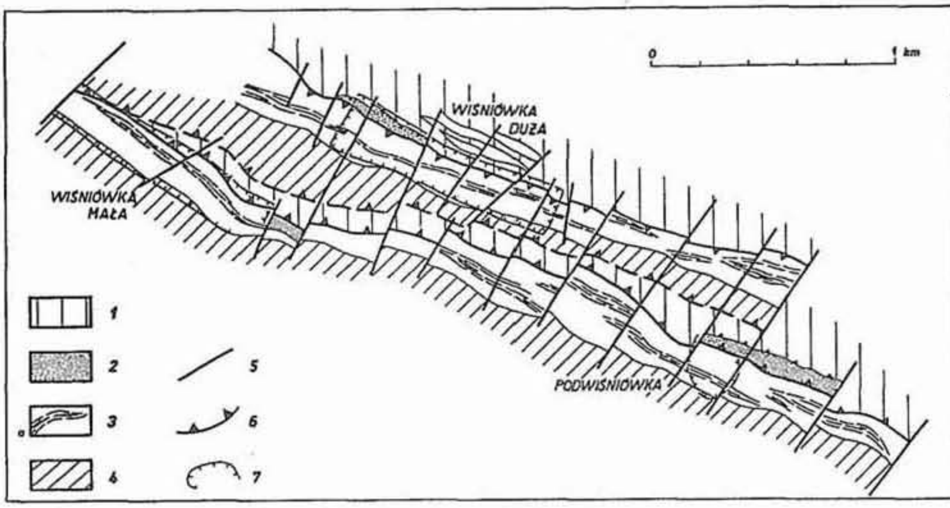

Fig. 10. Geological sketch of the Main Range between Wiśniówka and Masłów

1 — Upper Cambrian/Tremadoc — Łysogóry Beds (Shales), 2 — Upper Cambrian — Wąworków Sandstones, 3 — Middle/Upper Cambrian — Łysogóry Quartzites with shaly complex (a), 4 — Middle Cambrian — (?)Góry Pieprzowe Shales, 5 — faults, 6 — overthrusts, 7 — quarries

Szkic geologiczny Pasma Głównego między Wiśniówką a Masłowem

1 — kambr górny/tremadok — warstwy łysogórskie (łupki), 2 — kambr górny — piaskowce wąworkowskie, 3 — kambr środkowy/górny — kwarcyty łysogórskie z dzielącym kompleksem łupkowym (a), 4 — kambr środkowy — (?)łupki z Gór Pieprzowych, 5 — uskoki, 6 — nasunięcia, 7 — kamieniołomy

predominate in every series. They are separated by a complex of dark grey, subordinately red, siltstones and shales. In these two packages the sandstones are quartzitized more strongly — these fragments are mined in the quarries. Blocks where these packages become less distinct contain also the sets of other rocks: quartz sandstones and siltstones, greywacke sandstones, sandy siltstones, pyroclastic rocks and varicoloured claystones and shales. Sandstones are more weakly quartzitized in these blocks. Pyroclastic rocks appear in both zones in similar position i.e. at the northern side of quartzitic series.

In the blocks dominated by two series of quartzitic sandstones only steep dips of 60–80° have been recorded, almost exclusively to the north. In the blocks of more complex lithological composition the variable dips, both northern and southern, have been observed. The beds in these blocks are more or less strongly folded.

Geophysical survey (electric resistivity profiles every 2–3 km) and geological reconaissance works were also made farther to the east as far as the Opatów area. Two ridges in relief and two series of quartzites have been recognized at several places along the entire Main Range, some 40 km long. On the southern slope of the range subordinate folds have been ascertained.

The most important problem is, how to explain the mutual relationship between both quartzitic series in the Wiśniówka area. Are they of the same age or were they formed one after another at different times? In the remaining segments of the Main Range there are also

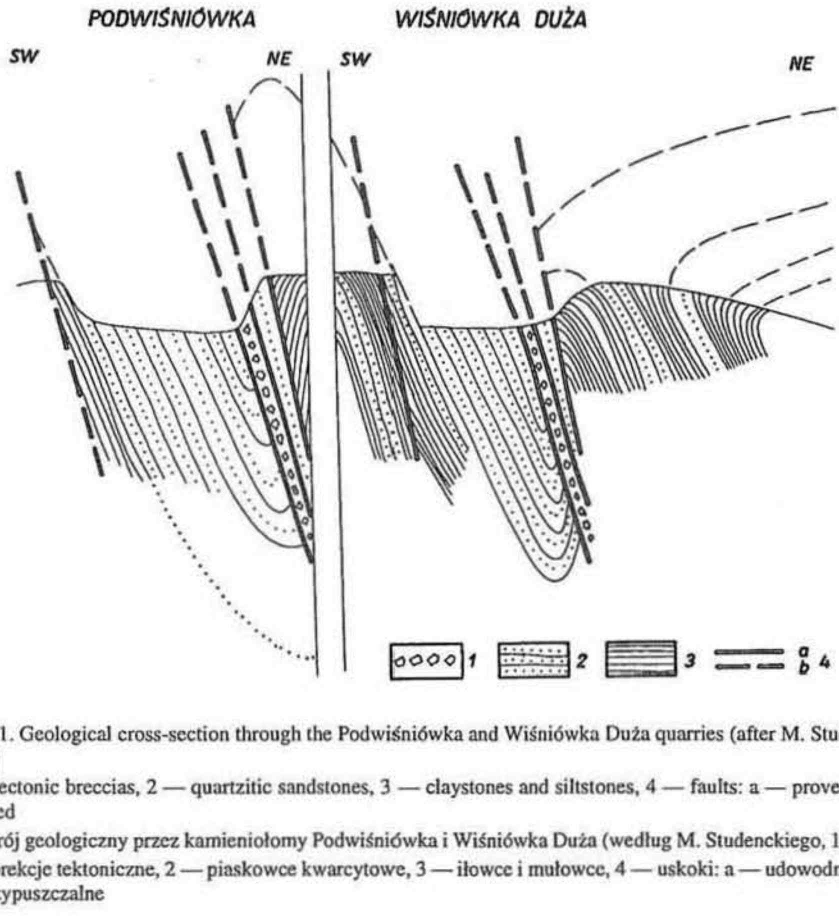

Fig. 11. Geological cross-section through the Podwiśniówka and Wiśniówka Duża quarries (after M. Studencki, 1994)

1 — tectonic breccias, 2 — quartzitic sandstones, 3 — claystones and siltstones, 4 — faults: a — proved, b — inferred

Przekrój geologiczny przez kamieniołomy Podwiśniówka i Wiśniówka Duża (według M. Studenckiego, 1994)

1 — brekcje tektoniczne, 2 — piaskowce kwarcytowe, 3 — iłowce i mułowce, 4 — uskoki: a — udowodnione, b — przypuszczalne

the areas with three or four quartzitic series. If all these series were not coeval and their number change from one block to another, the cumulative thickness of the Wiśniówka Sandstones *sensu* S. Orłowski would change in similar way attaining from 400 to even 1400 m. This is the opinion expressed by S. Orłowski and W. Mizerski (1995*a*). However, the striking similarity of both quartzitic series, of their general pattern and even of individual beds, as well as the position of pyroclastic rocks suggest the alternative interpretation (see below). It is substantiated also by a general concept of sedimentation of the Cambrian rocks on the shallow siliciclastic shelf. Synsedimentary transversal faults of almost 1000 m throw (as visualised by S. Orłowski and W. Mizerski) active during the relatively short time of sedimentation of the Łysogóry Sandstones (quartzites) and causing a significant differentiation of subsidence are at variance with the model of shallow shelf sedimentation. There is no evidence in the sedimentary record to support such a hypothesis. All the faults are post-sedimentary and breccias are tectonic.

Our alternative interpretation is that the two main quartzitic series (or, in some cases three or four series) are precisely coeval. They constitute simply the same series which is repeated twice (or even three or four times) due to folding.[2] They are exposed in cores or limbs of several tight folds. True thickness of the Łysogóry Quartzites does not exceed 180 –200 m and frequently decreases to 100 m.

Cambrian rocks in the Wiśniówka area are very strongly disturbed by longitudinal and transversal faults. The former cause the tectonic reduction of more ductile (incompetent) rocks and brecciation or crushing of more competent, brittle quartzitic sandstones in the compressed and squeezed out sequences. These longitudinal faults are either dip-slip faults (normal or reverse) or overthrusts. The transversal faults are strike-slip or oblique-slip (both normal and reverse) faults.

The most important among the longitudinal faults are the major fault zones with complicated inner structure developed at the northern side of the quartzitic series in both belts. The geological structure of these belts limited by the longitudinal faults is identical. In both cases a bed of tectonic breccia occurs in the centre of the fault zone (M. Studencki, 1994, fig. 22). They originated in the same place of the stratigraphic sequence at the boundary between the Łysogóry Quartzites and Łysogóry Shales. In the Wiśniówka Duża quarry at the northern side of this zone a reversed position of the Tremadoc strata is clearly visible.

The tectonic position and the nature of these fault zones is complicated. They were formed probably during several phases after the folding of the beds in Wiśniówka. Primarily, the longitudinal faults started to form as normal faults (with northern downthrown side), in places predisposed by lithology, i.e. at the contact between the series of different competency (sandstones and shales). During the subsequent phase the fault (at least in the Wiśniówka Duża quarry) transformed into overthrust, along which the Łysogóry Beds (Shales) — pressed against the quartzites which in turn were pushed upwards — were deformed into fold, imbricated and overthrusted towards south in its frontal part and overturned towards north in its rear part.

DRAG FOLDS AND DISHARMONIC FOLDING

It is commonly accepted that there are at least two categories of drag folds. The first one includes folds of wide range of sizes which are connected with faults and are caused by the movement along the fault planes: they are a result of drag of beds during the motion of either of the fault sides. The second category includes predominantly microfolds (width of a few metres or less) resulting from a secondary effect of folding of interlayered sets of beds, e.g. more competent sandstones or limestones and less competent shales. During folding processes the less competent (more ductile) rocks are folded more intensely due to slip parallel to layers of more competent rocks.

A fine example of an assemblage of folds belonging to the second category is illustrated by W. Mizerski (1991, fig. 10) while the fold shown in figure 16A in the same paper may

[2] The idea of this repetition is shown in the simplest way on a cross-section by M. Studencki (1994) reproduced here as Fig. 11. This section and the map in Fig. 10 do not agree in every detail with cross-sections in Figs 6–8, mainly because of stratigraphic uncertainties.

represent the first category. However, in some other cases (W. Mizerski, 1991, figs. 9C, 11C, 12, 15) doubts arise whether the portrayed folds are drag folds at all. They could be simply secondary folds accompanying the larger folds, both caused by compression. Small folds, developed particularly in shales are not only local: peri-fault or drag folds. They are a result of disharmonic, penetrative folding of the entire series composed of alternating sandstones (quartzites) and shales (see Figs. 6–8).

The disinclination of W. Mizerski to accept the widespread folded structure of the Łysogóry Cambrian is sometimes incomprehensible. The folds — including the recumbent ones — in other places of the Main Range (Krzemianka, Opatów) where the quartzitic series is also folded are illustrated by him (1979, fig. 20; 1991, fig. 14A) without any comment. He only stressed elsewhere (S. Orłowski, W. Mizerski, 1995*b*) that both localities: "*... are the extreme regions of the Łysogóry Unit and their tectonics is slightly different than that of the middle segment ...*". However, he did not give any arguments in favour of this statement. Looking at his sections across the Krzemianka and Opatów areas (W. Mizerski, 1991, figs. 14A and B) we cannot understand the accompanying comment (p. 48): "*... Folded structures are lacking in the Upper Cambrian strata ... We have here to do only ...* (!!! — our exclamation marks) *... with the gradual change of dips from the normal through vertical to reverse position ...* ". The first impression is that our opponent looks at the folds and does not see the folds. What is more convincing of the folded structure than the gradual change along the section from normal to reverse position of beds (compare also the Krzemianka cross-section in J. Znosko, 1996, fig. 13)? W. Mizerski wrote earlier (1979, p. 21): "*The tectonic style of the ...* (Opatów — our remark) *... region resembles the style typical of the entire Łysogóry unit ...*" and we think this earlier statement to be justified. The style is the same in either the Cambrian quartzites or the Ordovician/Silurian shales (comp. J. Znosko, 1996, fig. 11) along the entire length of the unit.

W. Mizerski believes so deeply in his monoclinal concept that he even changes someone else's cross-section: his fig. 11 in W. Mizerski (1995) comes allegedly from the earlier paper by Z. Kowalczewski but is "corrected" in its northern part according to this concept.

AGE OF DEFORMATIONS

This is the most difficult problem. There are no outcrops in the Łysogóry Unit with exposed contact between the Cambrian (or Ordovician/Silurian) and Devonian. Angular discordance between the both was noted in an exploratory trench located on the southern limb of the Bronkowice Anticline (some 20 km from the Wiśniówka area — E. Mariańczyk, 1973) and in the Rachów borehole (about 85 km from it, beyond the limits of the Łysogóry Unit *sensu stricto* — A. Tokarski, 1958).

In such circumstances we must look for indirect evidence.

It is clear that the decisive arguments should be acquired from the comparison of tectonic involvement of the Devonian against that of the Cambro-Silurian. Because direct contacts are scarce we must replace such observations by the comparison of dips in neighbouring outcrops. There are hundreds of strike and dip measurements in the Holy Cross Mountains (HCM). Their statistical value is variable because it may be distorted by two factors. First, the distribution of measurements may be irregular, concentrated in one areas and sparse in

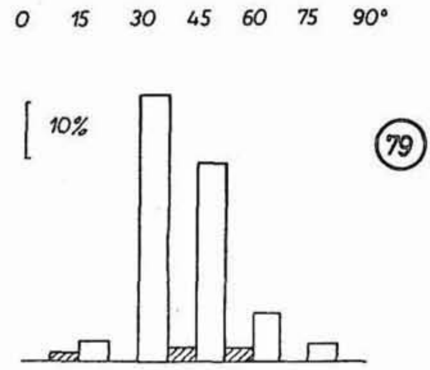

Fig. 12. Dips measured in the Main Range Cambrian
For explanations see Fig. 5
Upady pomierzone w kambrze Pasma Głównego
Objaśnienia przy fig. 5

the others. Second, the zones with steeper dips are more predisposed to form outcrops than the areas with flat-lying beds. Therefore the statistical average in such cases may be displaced towards steeper dips.

In spite of these reservations we tried to analyse those measurements in the western part of the HCM, basing on the detailed geological maps by P. Filonowicz (1962, 1963, 1965, 1971).

First example is a histogram of dips in the Cambrian of the Main Range between its western end and the transversal Łysogóry Fault (Fig. 12 — for location of the area see Fig. 1B). The measurements are here evenly distributed and the results — in comparison with that from the Wiśniówka area (Figs. 5B and 9) — show a general decreasing of dips, with culmination between 30 and 60° and a minor percentage (5%) of southern dips.

Figure 13 is an example of irregular distribution of data in the Bodzentyn Syncline filled in with the Devonian (Łysogóry Unit — for location see Fig. 1B). About a half of measurement sites is located on both limbs of the syncline built of the Emsian sandstones. Here, the majority of dips (61%) is located between 30 and 45° (Fig. 13A). The rest is concentrated along the valleys of the Psarka River and of its tributaries. These valleys in turn might be founded on the longitudinal and transversal faults and therefore the dips are steeper there (45–60° — Fig. 13B).

In the Kielce Syncline (Kielce Unit) the distribution of measurement sites is also relatively uniform (Fig. 14). However, we can see that there are narrow zones with steeper dips (maximum between 60 and 75° — Fig. 14B), covering a few percentage of the area only. They are connected with the rims of syncline adjoining the horst-like Early Palaeozoic anticlines and — in the centre — they are presumably related to longitudinal faults. Elsewhere (Fig. 14A) the dips are moderate or small (more than a half between 0 and 30°) and these represent the regional situation of remarkable discordance between the Devonian and underlying rocks.

It is not ruled out that the situation in the Bodzentyn Syncline would be similar if the measurements were distributed uniformly there. This presumption is supported by the observations of the Devonian barely 4 km from Wiśniówka (Barcza Hill — Fig. 13) where exploratory works in pre-war period (J. Czarnocki, 1958*b*) were also made. A trench and a dozen of pits were made along lines crossing the hill. A cross-section, more than 500 m long (J. Czarnocki, 1958*b*, pl. XV), shows the southern limb of a syncline filled in with the

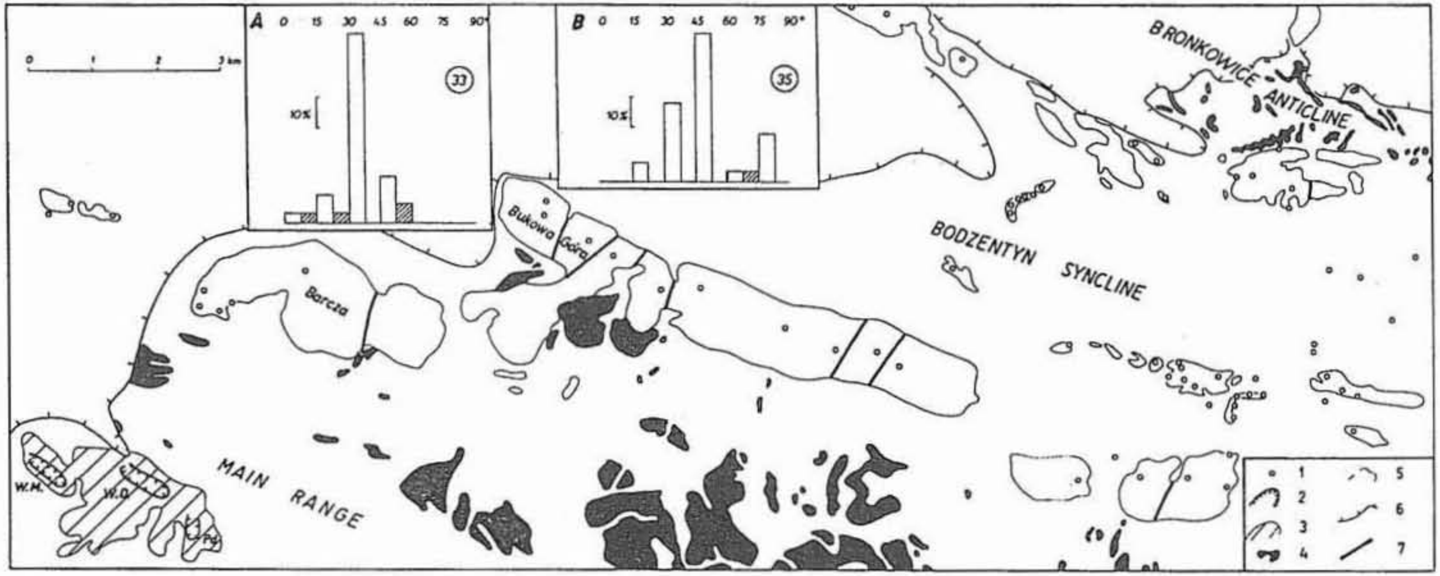

Fig. 13. Geological sketch of the Bodzentyn Syncline with histograms of dips in the Devonian of both limbs (A) and of the central part B

1 — sites of measurements, 2 — quarries, 3 — Cambrian and Ordovician, 4 — Silurian, 5 — Devonian, 6 — extent of the Permian and Mesozoic, 7 — faults; Pd — Podwiśniówka, W.D. — Wiśniówka Duża, W.M. — Wiśniówka Mała; for other explanations see Fig. 5

Szkic geologiczny synkliny bodzentyńskiej z histogramami upadów w dewonie obu skrzydeł (A) i części centralnej (B)

1 — miejsca pomiarów, 2 — kamieniołomy, 3 — kambr i ordowik, 4 — sylur, 5 — dewon, 6 — zasięg permu i mezozoiku, 7 — uskoki; inne objaśnienia przy fig. 5

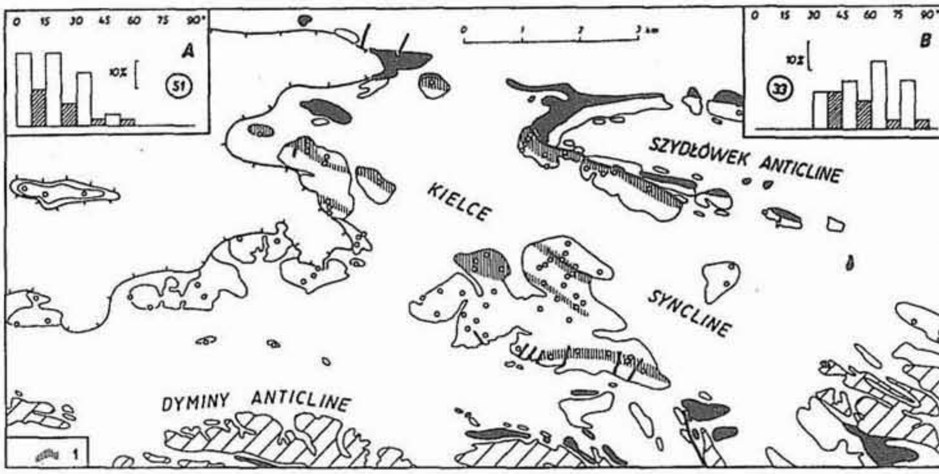

Fig. 14. Geological sketch of the Kielce Syncline with histograms of dips in the Devonian of the syncline bottom (A) and of peri-fault zones (B)

1 — peri-fault zones; for other explanations see Figs. 5 and 13

Szkic geologiczny synkliny kieleckiej z histogramami upadów w dewonie dna synkliny (A) i stref przyuskokowych (B)

1 — strefy przyuskokowe; inne objaśniena na fig. 5 i 13

Eifelian strata. The dips in the axial zone are less than 10°. They increase updip, in a flexural bend, to 40° and — farther southwards — they decrease again to 10–15°. Detailed mapping in this area (Z. Kowalczewski *et al.*, 1989) recorded the dips 3–15° (central and western part of the Barcza Syncline) and 33–45° (southern limb of the Bodzentyn Syncline).

Similar structural style of the Devonian is visible in a new Bukowa Góra quarry situated also in the Łysogóry Unit, 9 km ENE from the Wiśniówka area (Fig. 13). Small dips (10–15°) are observed in southern wall of the quarry while much steeper dips (up to 40–50° — flexural bend?) are recorded in the oposite wall.

The next argument refers to the ductile style of deformation of the Cambrian quartzites. The pebbles of quartzites are known from the conglomerates in the Devonian. So, the transformation of rocks from sandstones to quartzites must have occurred before the Devonian. If the folding took place after the Devonian the brittle behaviour of quartzites in response to tectonic stresses would be expected. Then, it may be presumed that they were folded in ductile style still as sandstones, before the quartzitization and before the Devonian.

In conclusion, we believe that the main folding event occurred in both units of the HCM before the Devonian and that the angular discordance between the Devonian and Silurian (or, perhaps, within the lowest Devonian) exists also in the Łysogóry Unit, particularly in its southern zone, although it is probably smaller and not so widespread as in the Kielce Unit.

W. Mizerski frequently illustrates his works with stereographic diagrams of different structural features: bedding planes, fold axes, surfaces of faults, cleavage planes and orientation of joints. We do not intend to discuss here in detail these mesostructural arguments. It seems sufficient to recall a discussion between W. Mizerski and one of the most prominent Polish expert in structural geology, the late W. Jaroszewski, which was published a few years ago. In the first paper of this series (W. Mizerski, 1988*a*) the author put forward seven mesostructural arguments in favour of the exclusively Variscan deformation of the Łysogóry Unit. All these arguments, one after the other, were called in question by W. Jaroszewski, both from the point of view of methodology and the conclusions drawn (W. Jaroszewski, 1988). He opposed, among others, the selection of 8% maxima of orientation of bedding planes and rejection of smaller percentages. He wrote also: "*... In orogens where the folds of different ages are coaxial (it is a frequent feature in the areas activized several times , among others ... in the Holy Cross Mts.) the differences in dips which decide about angular unconformities do not appear in the summary picture ...*" (W. Jaroszewski, 1988, p. 601). He stressed that if the structures are coaxial it does not determine their age relations. Finally, regarding W. Mizerski's conclusions he wrote: "*... If anything would arise from the diagrams the conclusion would be contradictory to the author's statement about the one-stage deformations. Silurian fold axes are distinctly aggregated in directions near parallel and horizontal ... while the majority of fold axes in the Devonian are placed in the middle belt of the II quadrant and plunge at middle angles towards NW ... A second ... assemblage of the Silurian axes does not have any significant equivalent in the Devonian ...*" (W. Jaroszewski, 1988, p. 602).[3]

It is clearly stated in the reply of W. Jaroszewski (1989) that W. Mizerski (1988*b*) did not substantially respond to any of these reservations.

What concerns the regional setting, we must add that the opinions of W. Mizerski are inconsistent in his latest papers (1994, 1995). He presents the end-Silurian event in the HCM (W. Mizerski, 1994, fig. 4; 1995, fig. 26) as a sort of oblique collision between the Kielce and Łysogóry crustal blocks. He accepts the location of the Variscan orogenic front to the west of the HCM and, consequently, the location of the latter in the Variscan forefield (W. Mizerski, 1994, fig. 1; 1995, fig. 1) This general opinion — which we share with him — is explicitly expressed in the following phrase: "*... after the Late Caledonian movements both Holy Cross Palaeozoic blocks occupied their present position. It may have occurred due to transpression ... after the main phase of folding ...*" (W. Mizerski, 1994, p. 725).

However, in the same papers he does not give more attention to this event and maintains the view about the main role of Variscan deformations in the Łysogóry Unit. He writes that both blocks were "*... finally consolidated during ... Variscan movements ...*" (W. Mizerski, 1995, p. 41). The term "consolidation", albeit somewhat out-dated, always meant and means the end of orogenic deformations at the active plate margins. In the sense used by W. Mizerski the consolidation would never be attained in any area because the tectonic processes everywhere are still active to-day.

It is obvious that the Variscan epoch of tectonic activization influenced significantly the structure of the area in question. It was expressed, first of all, by the rejuvenation of earlier faults and formation of new ones. The best example is the rejuvenation of the Holy Cross Fault. This process was accompanied by folding which was locally remarkable.

[3] This quotation also implies that the structural patterns of the Devonian from one side and the Early Palaeozoic from the other are significantly different.

Present fan-like pattern of the Cambrian folds in the Main Range may have originated during the strong vertical uplift of the terrains of the Łysogóry Unit and their southward thrusting over the Kielce Unit. Moreover, the next rejuvenation in the Late Cretaceous/Early Tertiary must not be neglected. It must have been significant what is testified by a huge amount of the Permian-Mesozoic deposits removed from the HCM area and by strong activization of faults recorded along its southwestern rim where Palaeozoic strata are thrusted over the Mesozoic.

CONCLUSIONS

We are convinced that the main compressional phase of deformations and crustal shortening occurred in the HCM as a whole before the Devonian or in the earliest Devonian. It resulted in a complicated pattern of tight, frequently asymmetric or even recumbent folds as well as numerous overthrusts. Folding is of penetrative and disharmonic character with stronger involvement of shaly portions than of quartzitic ones. In the Variscan epoch the area was significantly activized due to the proximity of the Variscan orogenic front. The activization was expressed by the rejuvenation of faults which accounted for local folding.

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REFERENCES

CZARNOCKI J. (1947) — Przewodnik XX Zjazdu Polskiego Towarzystwa Geologicznego w Górach Świętokrzyskich w r. 1947. Rocz. Pol. Tow. Geol., **17**.

CZARNOCKI J. (1958*a*) — W sprawie rozbudowy kamieniołomów państwowych w Zagnańsku. Surowce mineralne w Górach Świętokrzyskich. Pr. Inst. Geol., **21**, p. 122–159, vol.V, no. 3 (after a report published in 1928 and later manuscripts).

CZARNOCKI J. (1958*b*) — O zastosowaniu piaskowca dewońskiego do wyrobu kostki brukarskiej w Barczy wschodniej pod Zagnańskiem. Surowce mineralne w Górach Świętokrzyskich. Pr. Inst. Geol., **21**, p. 160–162, vol.V, no. 3 (reprinted report published in 1936).

FILONOWICZ P. (1962) — Szczegółowa mapa geologiczna Polski 1:50 000, ark. Bodzentyn. Inst. Geol. Warszawa.

FILONOWICZ P. (1963) — Szczegółowa mapa geologiczna Polski 1:50 000, ark. Słupia Nowa. Inst. Geol. Warszawa.
FILONOWICZ P. (1965) — Szczegółowa mapa geologiczna Polski 1: 50 000, ark. Morawica. Inst. Geol. Warszawa.
FILONOWICZ P. (1971) — Szczegółowa mapa geologiczna Polski 1:50 000, ark. Kielce. Inst. Geol. Warszawa.
JAROSZEWSKI W. (1988) — Structural analysis in a distorting mirror (in Polish with English summary). Prz. Geol., **36**, p. 601–602, no. 10.
JAROSZEWSKI W. (1989) — Analiza strukturalna w krzywym zwierciadle (replika). Kwart. Geol., **33**, p. 329–332, no. 2.
KOWALCZEWSKI Z. (1995) — Fundamental stratigraphic problems of the Cambrian in the Holy Cross Mts. Geol. Quart., **39**, p. 449–470, no. 4.
KOWALCZEWSKI Z., KULETA M., LISIK R., MOCZYDŁOWSKA M. (1986) — New data on Cambrian and Lower Ordovician rocks in the vicinities of Wiśniówka in the Góry Świętokrzyskie Mts. Kwart. Geol., **30**, p. 201–228, no. 2.
KOWALCZEWSKI Z., KOWALSKI B., JANIEC J. (1989) — The influence of geological structure on the sculpture of the Pasmo Klonowskie in the Góry Świętokrzyskie (in Polish with English summary). Biul. Państw. Inst. Geol., **362**, p. 65–95.
MARIAŃCZYK E. (1973) — New data on the geology of the Bronkowice region (in Polish with English summary). Prz. Geol., **21**, p. 158–160, no. 3.
MIZERSKI W. (1979) — Tectonics of the Łysogóry Unit in the Holy Cross Mountains. Acta Geol. Pol., **29**, p. 1–38, no. 1.
MIZERSKI W. (1988*a*) — Tectonic evolution of the Łysogóry region, Holy Cross Mts. (in Polish with English summary). Prz. Geol., **36**, p. 46–52, no. 1.
MIZERSKI W. (1988*b*) — On the tectonics of the Łysogóry region in the Holy Cross Mts., distorting mirror and scientific critique (in Polish with English summary). Prz. Geol., **36**, p. 670–672, no. 11.
MIZERSKI W. (1991) — Tectonic evolution of the Łysogóry region in Świętokrzyskie (Holy Cross) Mountains (in Polish with English summary). Rozpr. UW, **362**.
MIZERSKI W. (1992) — Tectonics of the Cambrian sequence in the Holy Cross Mts. (in Polish with English summary). Prz. Geol., **40**, p. 142–146, no. 3.
MIZERSKI W. (1994) — Palaeotectonic evolution of the Cambrian of the Holy Cross Mts. (in Polish with English summary). Prz. Geol., **42**, p. 721–727, no. 9.
MIZERSKI W. (1995) — Geotectonic evolution of the Holy Cross Mts in central Europe. Biul. Państ. Inst. Geol., **372**.
ORŁOWSKI S., MIZERSKI W. (1995*a*) — Once more about geology of the Góra Wiśniówka outcrops (Holy Cross Mts., Central Poland) (in Polish with English summary). Prz. Geol., **43**, p. 11–14, no. 1.
ORŁOWSKI S., MIZERSKI W. (1995*b*) — Jeszcze raz o budowie geologicznej Góry Wiśniówki (Góry Świętokrzyskie) — odpowiedź. Prz. Geol., **43**, p. 1051–1052, no. 12.
STUDENCKI M. (1994) — EUROPROBE workshop, Kielce. Excursion guidebook, the Holy Cross Mts., stop 4: Wiśniówka Duża quarry.
TOKARSKI A. (1958) — Notes on structure types in the meta-Carpathian arch (in Polish with English summary). Kwart. Geol., **2**, p. 807–824, no. 4.
ZNOSKO J. (1988) — On some tectonic interpretations of the Holy Cross Mts (in Polish only). Prz. Geol., **36**, p. 597–601, no. 10.
ZNOSKO J. (1989) — O niektórych interpretacjach tektonicznych Gór Świętokrzyskich (Replika). Kwart. Geol., **33**, p. 333–340, no. 2.
ZNOSKO J. (1995) — Jeszcze raz o budowie geologicznej Góry Wiśniówki (Góry Świętokrzyskie) — dyskusja. Prz. Geol., **43**, p. 1049–1051, no. 12.
ZNOSKO J. (1996) — Tectonic style of the Early Palaeozoic sequences in the Holy Cross Mountains. Geol. Quart., **40** (this volume), p. 1–22, no. 1.

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TEKTONIKA KAMBRU W OBSZARZE WIŚNIÓWKI (GÓRY ŚWIĘTOKRZYSKIE)

Streszczenie

Przedstawiono tektonikę obszaru Wiśniówki (jednostka łysogórska Gór Świętokrzyskich) w formie dyskusji z poglądami W. Mizerskiego, głoszącymi, że układ warstw kambru jest monoklinalny, a wiek deformacji — waryscyjski. Szczegółowo przeanalizowano wyniki międzywojennych i powojennych szybików i rowów badawczych oraz badań geofizycznych metodą elektrooporową. Stwierdzono obecność zarówno upadów ku północy, jak i ku południowi. Najprostszą interpretacją danych strukturalnych jest zespół fałdów o wergencji po części północnej, po części południowej. W szerszym planie strukturalnym, wzdłuż całego Pasma Głównego, występują na ogół dwa pasma kwarcytów, w których odsłaniają się serie kwarcytowe tego samego wieku, powtórzone tektonicznie. Deformacje są rezultatem penetratywnego fałdowania dysharmonijnego, z dużym udziałem nasunięć. Uskoki powstały równocześnie z fałdowaniem i później.

Na podstawie porównania stopnia zaangażowania tektonicznego kambru i dewonu oraz wychodząc z założenia, że plastyczne deformacje kwarcytów były możliwe przed ich kwarcytyzacją, wysnuto wniosek, iż fałdowanie nastąpiło po sylurze lub w najniższym dewonie