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Tectonics of the Łysogóry unit in the Holy Cross Mts

ABSTRACT: Results of tectonic investigations in the Łysogóry unit in the Holy Cross Mts, Central Poland, are presented. The Łysogóry unit is a monocline with subordinate disharmonic-type fold structures. Those fold structures occur exclusively in the Middle Cambrian and Silurian shale-and-sandstone-bearing complexes, while they are absent from the Upper Cambrian sandstones. This is due to differential tectonic competencies of the sandstones and shales. The present-day geological structures of the area formed under a preponderant influence of the Holy Cross dislocation; this steep and very deep dislocation makes up a boundary between two blocks of the Earth crust. The Upper Cambrian sedimentation developed under conditions of the substrate lability and activity of transverse dislocations causing a variation in subsidence rate. This resulted in variable thickness (850 to 1,800 m) of the Upper Cambrian deposits. The old dislocations were rejuvunated during the Variscan orogeny. The present-day transverse faults are mostly of normal, hinge, or pivotal type. The Łysogóry unit was formed during the Variscan orogeny, probably during the Sudetic phase.

INTRODUCTION

The present paper is aimed to consider tectonics of the southern part of the Łysogóry region, Holy Cross Mts, Central Poland, in relation to the adjacent areas. The investigated area called the *Łysogóry unit* (Mizerski 1978, Mizerski & Ozimkowski 1978) has for long been studied but nevertheless, its tectonics is contrastingly interpreted. Most authors claim that the Łysogóry unit shows a fold structure. The others, basing usually upon some portions of the area, regard it rather as a simpler

structure, close to a monocline. The present authors work all-over the Łysogóry unit made possible to base the inference upon a structural analysis and to recognize the structure and origin of the unit.

The Łysogóry unit (Fig. 1) is built up by the Cambrian, Ordovician, and Silurian deposits. It borders in the south, along the Holy Cross dislocation, upon the Kielce-Łagów synclinorium. The area is poorly exposed which causes commonly much equivocality in tectonic interpretations.

Acknowledgements. The author is grateful to Docent Ewa Stupnicka for discussion during the study, and to Professor Stanisław Orłowski for kindly introducing him into the problem of the Łysogóry Cambrian. Professor Andrzej Radwański and Professor Jerzy Znosko are gratefully acknowledged for their criticism making possible improvement of the present paper.

HISTORY OF THE INVESTIGATION

The first informations on geology, mostly stratigraphy, of the investigated area were those given by Staszic (1815), Bloede (1846), Roemer (1866), and Zejszner (1869). A significant progress was made by Michalski (1883, 1888) who was the first to recognize the Łysogóry fault basing upon purely morphological data. An important work was also made by Siemiradzki (1887, 1889, 1903), Gürich (1892, 1896, 1900), and Sobolew (1900, 1910).

Modern tectonic investigations started with the work by Czarnocki and Samsonowicz. They dealt with two main problems of the area, namely the tectonic style and the age of the orogeny. Czarnocki (1919) regarded the Cambrian deposits as considerably folded and the Łysogóry unit as an anticline. He presented subsequently an outline of the Holy Cross Mts tectonics (Czarnocki 1927), some tectonic observations made in vicinity of Słupia Nowa (Czarnocki 1928*b*), an interpretation of the Upper Cambrian structure of Mt. Wiśniówka as a fold structure (Czarnocki 1928*a*), and a geological map of the central Holy Cross Mts (Czarnocki 1938). The tectonics of the region of Mt. Wiśniówka was studied later on by Putzer (1941). In his monographs of the area, Czarnocki (1950, 1957) considered the Cambrian strata of the Łysogóry unit as forming an asymmetrical anticline with its shorter limb reduced almost entirely due to a southerly overthrust along the Holy Cross dislocation.

Tectonics of the eastern part of the investigated area was studied by Samsonowicz (1926, 1934*a*, 1934*b*) who considered also the role of the so-called Sandomierz orogeny of Cambrian/Ordovician age. Tomczyk (1964) postulated the so-called Holy Cross phase of Middle Cambrian/Upper Cambrian age and the so-called Łysogóry phase of Llanvirnian age; he demonstrated also that the so-called Sandomierz phase had followed the deposition of *Dictyonema* shales of Tremadocian age.

Kowalczewski & Rubinowski (1962) and Znosko (1962) discussed the nature of tectonic units of the Holy Cross Mts. Later on, Kowalczewski (1963*a*, 1963*b*) considered the orientation of the main transverse elevations and depressions within the Paleozoic core of the Holy Cross Mts. Orłowski (1968*a*) was of the opinion that the Cambrian deposits of the Łysogóry anticline had been at least twice folded, namely during the Sandomierz and Variscan orogenies. The same author discussed also the tectonic development of the Holy Cross Mts (Orłowski 1971).

Kowalczewski (1965, 1970, 1971, 1973, 1975) followed Czarnocki (1950, 1957) in assuming the occurrence of the Lower Cambrian in the Łysogóry region and discussed the role of the Caledonian orogeny in the investigated area.

Many authors considered tectonics of the Łysogóry unit within a framework of tectonic development of the whole Holy Cross Mts. Most commonly, they supported the opinion of Czarnocki (1919, 1950, 1957) on the anticlinal structure of the Łysogóry Cambrian strata. The geological age of this structure remains controversial; actually, the tectonic processes responsible for its formation were assigned to either Caledonian, Variscan, or Alpine orogeny (Znosko 1963, 1970, 1974; Kowalczewski & Rubinowski 1968; Pożaryski & Tomczyk 1968, 1969; Kowalczewski 1971; Kutek & Głazek 1972).

Geophysical studies did also give an insight into tectonics of the investigated area (Pawłowski 1947, Stein & Stopiński 1968, Kowalczewski & *al.* 1976). An important progress in recognition of the deep structure of the Holy Cross Mts was achieved due to the seismic profiling along the transsect *VIIa;* it was then demonstrated that the Earth crust is split into blocks in this area and the Holy Cross dislocation attains the Moho surface causing its vertical displacement of some 6 km (Guterch & *al.* 1976).

Disjunctive tectonics of the Łysogóry unit was studied on air photographs permitting recognition of several lineaments equivalent possibly to fault zones (Mizerski & Ozimkowski 1978).

LITHOLOGY AND STRATIGRAPHY

The stratigraphic pattern recognized for the Cambrian of the investigated area by Orłowski (1975), for the Ordovician by Kielan (1956) and Bednarczyk (1971), and for the Silurian by Teller (1969) was accepted for the field work.

The oldest deposits of the Łysogóry unit are assigned to the Góry Pieprzowe Shale Formation of late Middle Cambrian age (Orłowski 1975). These are shales interbedded in places with sandstones. The Formation crops out along and borders in the south upon the Holy Cross dislocation. According to Orłowski (1975), the accessible thickness of the Formation attains some 400 m.

The Góry Pieprzowe Shale Formation is overlain concordantly by the clearly bipartite Upper Cambrian (Orłowski 1975); the Wiśniówka Sandstone Formation represents Olenus Zone, while the Klonówka Shale Formation represents higher biostratigraphic zones and grades at the top into the Tremadocian (Dictyonema Zone).

The highest elevations of the Holy Cross Mts are built up by deposits of the Wiśniówka Sandstone Formation. The Formation comprises quartzitic sandstones and orthoquartzites highly variable in bed thickness (10 cm to 3 m) interbedded with siltstones and shales. The Formation thickness was estimated by Orłowski (1975) as approximating 400 m.

The Klonówka Shale Formation comprises mostly shales interbedded with siltstones and fine- to medium-grained sandstones; the sandstone proportion considerably increases in places. Chlebowski (1978) recorded also some volcanogenic deposits within the Formation. The Formation attains some 450 m in thickness (Orłowski 1975).

The total accessible thickness of the Cambrian was estimated by Orłowski (1975) as approximating 1,200 m in the Łysogóry region (with the Upper Cambrian thickness of some 850 m included). The present author's investigations demonstrated

(see below) that the Upper Cambrian thickness is much larger in places and ranges from 850 to 1,800 m.

The Klonówka Shale Formation is overlain by the Lower Ordovician with a sedimentary discontinuity inbetween. The new depositional cycle started with accumulation of limestones a few meters thick, probably of Late Llanvirnian age (Tomczyk & Turnau-Morawska 1967, Kowalczewski & *al.* 1976). The Llandeilan is represented by limestones dolomitic or sideritic in places and up to 10 m thick (Tomczykowa 1968). These deposits are overlain by the Caradocian black siliceous shales and grey mudstones calcareous in places and with abundant graptolite fauna; the Caradocian attains up to 130 m in thickness (Bednarczyk 1971). The overlying Ashgillian siltstones, mudstones, calcareous shales, and marls grade upwards into sandstones; the total thickness approximates 100 m (Bednarczyk 1971).

In the Łysogóry unit, the Silurian deposits attain a considerable thickness but they are lithologically monotonous which makes difficult any lithostratigraphic correlation (Teller 1969). The Llandovery, Wenlock, and Lower Ludlow are represented by graptolitic shales of 110 m in thickness. They are overlain by the Wydrzyszów Beds comprising the Upper Ludlovian shales with greywacke intercalations, highly variable in thickness (max. 1,500 m; see Teller 1969). The overlying Rzepin Beds comprising shales with greywacke and limestone intercalations attain some 630 m in thickness and are assigned to the Postludlovian stage.

The Rzepin Beds grade upwards continuously in the Łysogóry area into the Lower Devonian Bostów Beds comprising dark claystones and siltstones with sandstone intercalations; these strata are assigned to the Gedinnian (Łobanowski 1971). The Siegenian is represented by the sandstones and red shales of the Klonów Beds. Higher in the section, there are the Emsian sandstones interbedded in their lower portion with claystones. Some tuffite intercalations related to acid-lava eruptions occur at the base of those strata. The total thickness of the Lower Devonian attains some 800 m in the Łysogóry area (Łobanowski 1971).

The Permian and Lower Triassic deposits overlying in places the Lower Paleozoic rocks were also studied in the eastern and western parts of the investigated area. The Permian is represented by the Zechstein breccias, conglomerates, and limestones. The red and mottled sandstones of the Buntsandstone formation are attributed to the Lower Triassic.

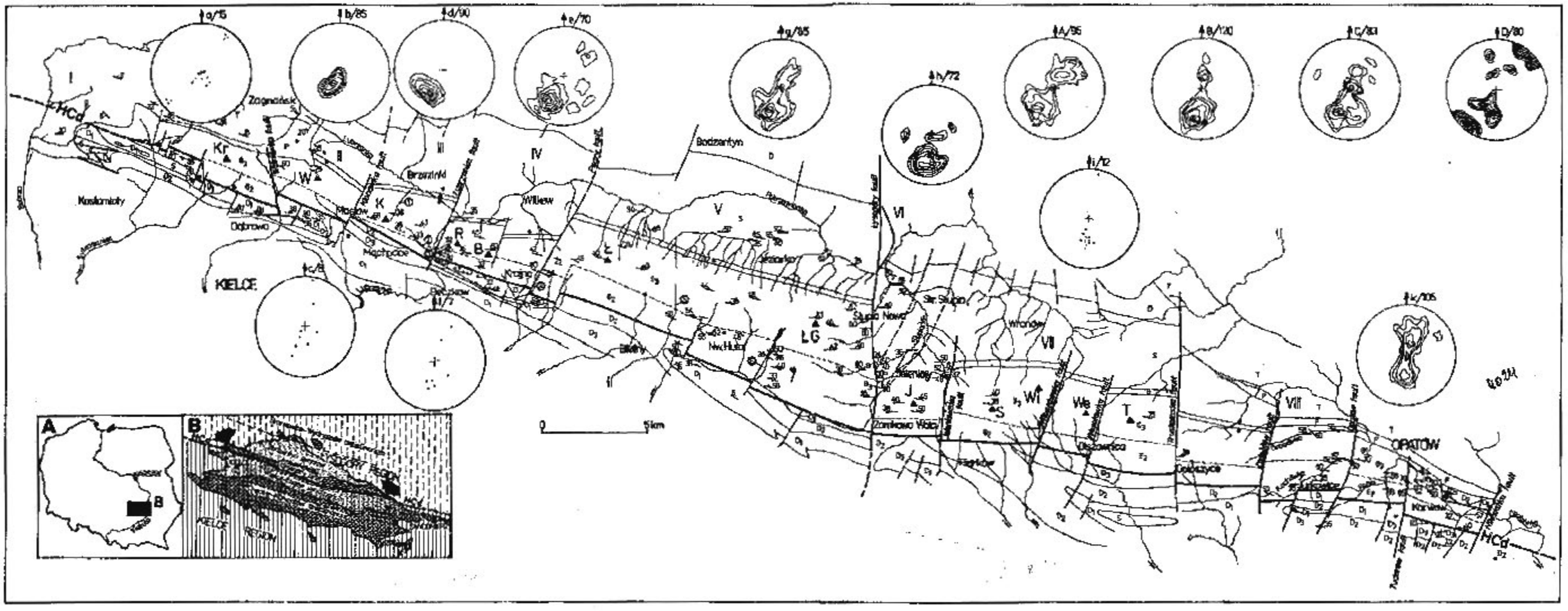
OUTLINE TECTONICS OF THE ŁYSOGÓRY UNIT

The Łysogóry unit runs along WNW-ESE direction in its western part and very closely to W-E direction in the east; the change in trend occurs at the Łysogóry fault (*cf.* Fig. 1).

The investigated area has been divided into 8 regions each one showing a fairly uniform tectonic style; these are (see Fig. 1):

I Bobrza river through Mt. Wiśniówka region;
II Mt. Wiśniówka region;
III Mt. Klonówka region;
IV Lubrzanka stream through Krajno region;
V Mt. Łysica through Mt. Łysa Góra (Holy Cross Mount) region;
VI Słupia Nowa region;
VII Jeleniów Range region;
VIII Opatów region.

Tectonic map of the Łysogóry unit in the Holy Cross Mts



Insets show position of the area in Poland (**A**), and general tectonic sketch of the Holy Cross Mts (**B**)
HCd — Holy Cross dislocation

Within the map indicated are: the main transverse faults (called by their names), particular regions of the investigation (numbered *I—VIII* as in the text), and boreholes (*black dots*); associated are diagrams of the attitude of layers (contours of 2, 4, 6, 8, 10 and 12%; numbers of measurements are circled) for particular regions (symbolled *a—k*) and for successive stratigraphic members (*A* Middle Cambrian, *B* Upper Cambrian, *C* Ordovician and Silurian, *D* Devonian of the northern part of the Kielce—Łagów synclinorium)

Black triangled are the summits of: **Kr** — Mt. Krzemianka, **W** — Mt. Wiśniówka, **K** — Mt. Klonówka, **R** — Mt. Radostowa, **B** — Mt. Bęczkowska, **Ł** — Mt. Łysica, **ŁG** — Mt. Łysa Góra (= Holy Cross Mount), **J** — Mt. Jeleniowska, **S** — Mt. Szczytniak, **Wi** — Mt. Witosławska, **We** — Mt. Wesołówka, **T** — Mt. Truskolaska

Numbers in circles: *1* Janosów Dół ravine, *2* Mąchocice ravine, *3* Podmąchocice ravine, *4* Krajno ravine, *5* Podlesie ravine, *6* Huta ravine

For each particular region, the geological structure is discussed below. The attitude of strata was analysed, and the contour diagrams were plotted wherever possible; where such diagrams would be statistically unreliable because of too few measurements available, point diagrams are shown (see diagrams *a-k* in Fig. 1). Strata are always plotted in the diagrams as traces of their dips on the upper projection hemisphere (*cf.* Dimitrijević & Petrović 1965). The fold structures and faults are described, and geological sections are constructed wherever sufficiently large numbers of field observations have been available.

I. BOBRZA RIVER THROUGH MT. WIŚNIÓWKA REGION

The Cambrian deposits occur in the central part of the region building up an indistinct belt of hills, the highest of which is Mt. Krzemianka (Fig. 1). Northwards, rather homogeneous topographically outcrops of the Permo-Mesozoic strata occur. There is a belt of hills built up by the Devonian rocks south to the Cambrian belt.

There are virtually no exposures of the Cambrian deposits in the region. The only exposure occurs in the eastern part of the region and shows strata of the Góry Pieprzowe Shale Formation; the strike of those strata approximates 70° and largely differs from the trend of Cambrian outcrops. There are fairly abundant exposures of the Zechstein and Lower Triassic strata north to the Cambrian belt. In the south, the Cambrian borders along the Holy Cross dislocation (Fig. 2) upon the Lower Devonian sandstones. The latter deposits are considerably disturbed tectonically which can be observed in several exposures.

ATTITUDE OF THE STRATA

Because of very few exposures, attitude of the Cambrian strata (diagram *a* in Fig. 1) has to be considered with a great caution. Acutally, the observed position may be untypical, as it is indicated by the largely different trend of Cambrian outcrops (Fig. 2).

The Permian and Triassic deposits overlying discordantly the Paleozoic sediments show an average attitude of the strata 100—110/15—20N. Northwestwards, outside the investigated area, some southerly dips have also been recorded.

The Lower Devonian sandstones south to the Holy Cross dislocation show variable, both southerly and northerly dips (Fig. 2). Their strike remains more or less constant and approximates 120° but their dips range from 80N to 78S. Both normal and reverse attitude of the strata has been observed which demonstrates that they are considerably folded; this is also supported by an indirect evidence from the width of Lower Devonian outcrops.

FOLD STRUCTURES AND FAULTS

No fold deformations have been recorded within the Łysogóry unit in the region.

In proximity of the Holy Cross dislocation, one can see folds within the Devonian strata of the northern Kielce—Łagów synclinorium. There is a normal fold with symmetrically steeply (80°) dipping limbs in the western part of the investigated region, close to the Holy Cross dislocation (section *1* in Fig. 2). In the east, there is an overturned fold with northerly vergency (section *2* in Fig. 2). The axes of both the structures are horizontal, parallel to the Holy Cross disloca-

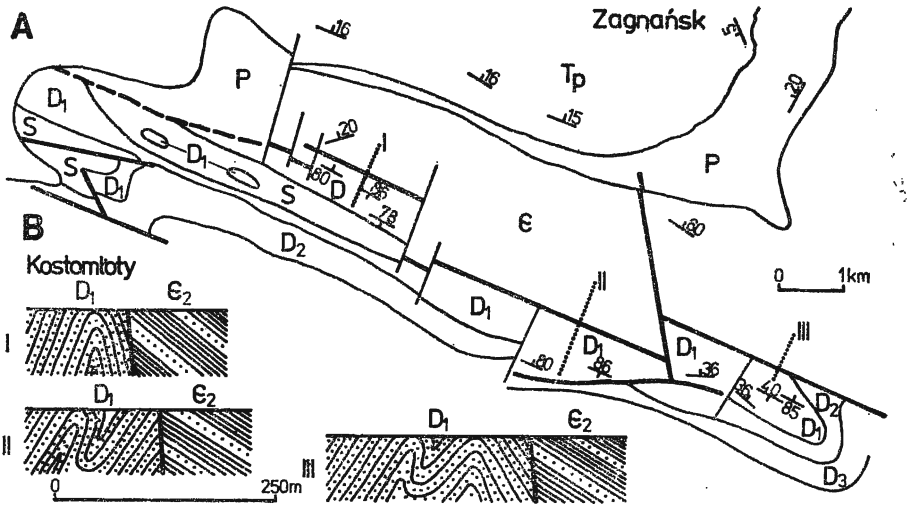


Fig. 2. Tectonic sketch of the western part of the Łysogóry unit (**A**), and geological sections (*I, II, III*) through the Holy Cross dislocation (**B**)

tion. These narrow folds appear as minor structures within the northern limb of the Bukowa anticline (Filonowicz 1973) extending along the Holy Cross dislocation (Fig. 2). There are no minor folds within the southern limb of the anticline which supports the hypothesis of a genetic relation of fold structures within the northern limb to the dislocation. Because of its undulations, the anticline axis plunges both westwards and eastwards running parallel to the Holy Cross dislocation.

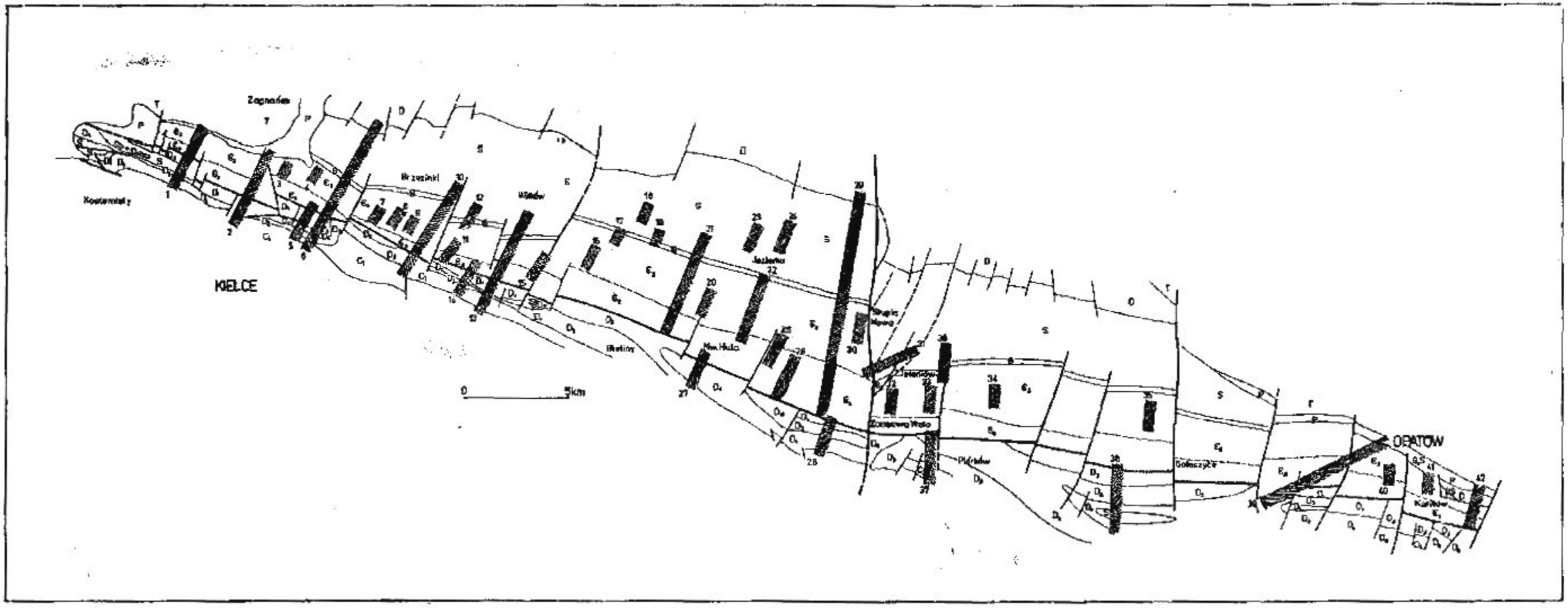
Faults can be recognized only after topographic criteria and cartographic image of the region. There is a normal fault along the Sufraganiec stream in the western part of the region; it crosses the Holy Cross dislocation without causing any lateral displacement of the latter structure and it disappears rapidly northwards in the Permo-Mesozoic deposits. Other faults result in lateral displacements of the Holy Cross dislocation (Fig. 2) and hence, they are to be interpreted as oblique-slip faults. The faults affect locally strikes and dips of the strata.

Tectonic style of the Łysogóry unit cannot be clearly recognized in the discussed region. Basing upon analogy with the adjacent region, it is here assumed that the unit is monoclinal in structure and borders in the south along a tectonic contact upon the Bukowa anticline; the latter structure shows a deformed northern limb (sections *1—2* in Fig. 3).

II. MT. WIŚNIÓWKA REGION

The highest topographic elevation is Mt. Wiśniówka (Fig. 1) in the center of the region. Two large quarries Wiśniówka Mała and Wiśniówka Wielka occur in the Upper Cambrian deposits of Mt. Wiśniówka. There are no other exposures of the Cambrian deposits in the region.

Geological sections through the Łysogóry unit (*cf.* Text-fig. 1); numbering of the sections (*1—42*) the same as in the text



Deposits of the Wiśniówka Sandstone Formation appear in the quarry Wiśniówka Mała. They comprise mostly quartzitic sandstones (up to 50 cm in bed thickness) interbedded with siltstones and shales. In addition to these deposits, the mottled shales of Klonówka Shale Formation overlying the Wiśniówka Sandstone Formation are exposed in the quarry Wiśniówka Wielka. The latter quarry appears as an outstanding locality for recognition of the Holy Cross Cambrian tectonics, stratigraphy (Orłowski 1968a,b, 1975), facies (Dżułyński & Żak 1960; Radwański & Roniewicz 1960), and trilobite-produced ichnofossils (Radwański & Roniewicz 1963, 1972; Orłowski & *al.* 1970, 1971). In both the quarries, the Cambrian deposits are commonly cut by variscite-bearing quartz veins and barite veins.

The Ordovician and Silurian deposits crop out north to the Cambrian belt. Nevertheless, there is but a single locality with the Lower Silurian graptolitic shales. The Cambrian to Silurian strata are overlain discordantly by the Zechstein conglomerates and breccias (Czarnocki 1929); the contact is also exposed in the road cutting to the quarry Wiśniówka Wielka (Pl. 1, Fig. 1).

The Middle Cambrian deposits border in the south along a tectonic contact upon the Lower Devonian (Fig. 2).

ATTITUDE OF THE STRATA

Attitude of the Cambrian strata can be determined after the long sections exposed in walls of both the quarries. All but a few strata dip northerly at 60—70° in the quarry Wiśniówka Mała. This appears clearly in the southern wall of the quarry (Fig. 4). As demonstrated by observations made on both base and top surfaces of the beds, the position of strata is normal.

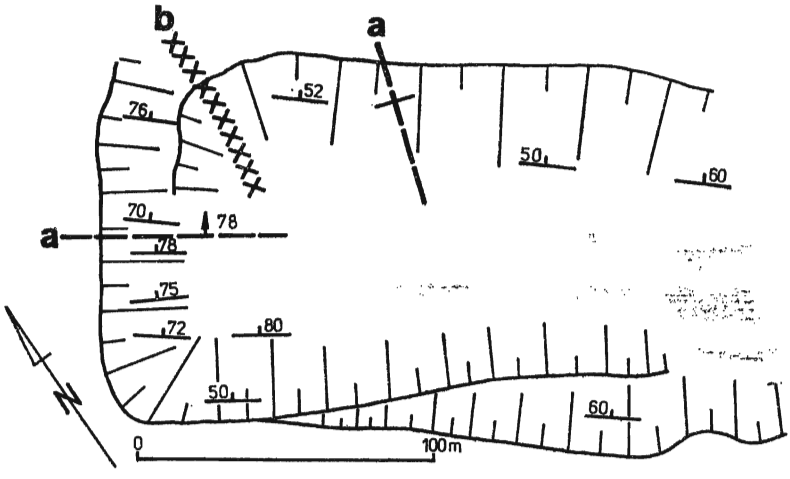


Fig. 4. Sketch of the southern part of the Wiśniówka Mała quarry; *a* faults, *b* zone of dense joints

There are no large-scale fold deformations in the quarry Wiśniówka Wielka eventhough the strata dip steeply northerly (Pl. 1, Fig. 2 and Pl. 2, Fig. 1). Even the thick shaly series exposed in the road cuts towards the quarry do not show any variability in dip. Fold deformations and strata reversals in the high walls of the road cuts resulted from surface landsliding. A similar interpretation appears adequate to changes in attitude of the strata recorded by Czarnocki (1928*a*) in shallow pits within the quarry and interpreted as fold-type tectonic deformations. The present-day sections of the quarry walls (*cf.* Pls 1—2) do not support the latter interpretation or the opinion of Putzer (1941) on fold structure of Mt. Wiśniówka.

The average attitude of the Cambrian strata is 120/70N (diagram *b* in Fig. 1); the Upper Cambrian rocks form a monocline in Mt. Wiśniówka region (Fig. 5).

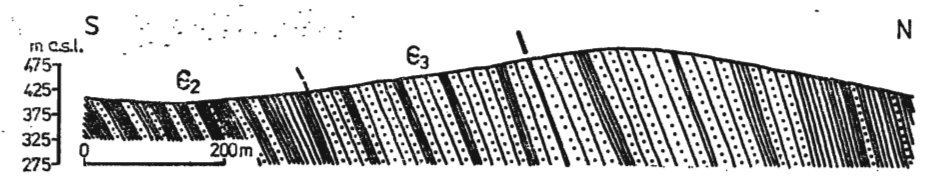


Fig. 5. Section through the Upper Cambrian deposits of Mt. Wiśniówka

The Silurian strata exposed in the north dip more gently, while their strike remains the same as in the Cambrian. The Lower Devonian sandstones north to the Łysogóry unit show still more gentle dips and their position is 120/20N. This demonstrates a gradual decrease in dip towards the axis of Bodzentyn syncline.

The Permian breccias overlying the Lower Paleozoic strata dip northerly at some 5° (Pl. 1, Fig. 1). Thus, the angular unconformity between the Upper Cambrian and Permian strata attains 70°.

There is a high variability in attitude of the strata south to the Holy Cross dislocation. The Lower Devonian strata range from 110° to 130° in strike and from 35N to 40S in dip (diagram *c* in Fig. 1) which indicates the occurrence of fold structures.

FOLD STRUCTURES AND FAULTS

There are no large-scale fold deformations in the Cambrian; actually, the Cambrian strata show monoclinal setting (Pl. 1, Fig. 2 and Pl. 2, Fig. 1). Some fault-related small-scale fold deformations have been recorded in the quarry Wiśniówka Wielka. All these folds are broad, with their axes perpendicular to the

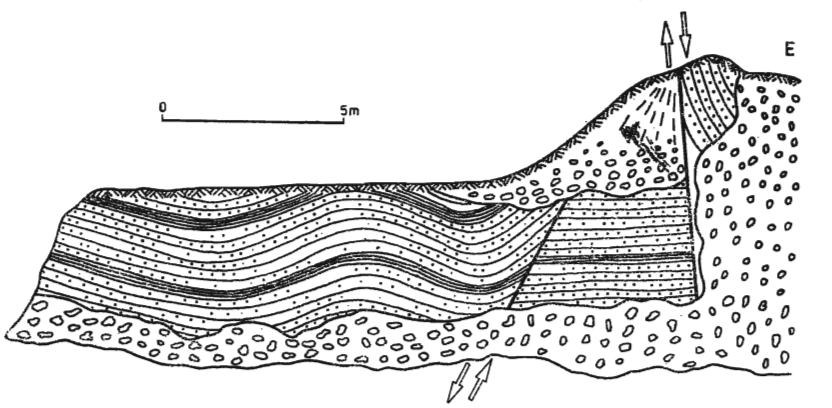
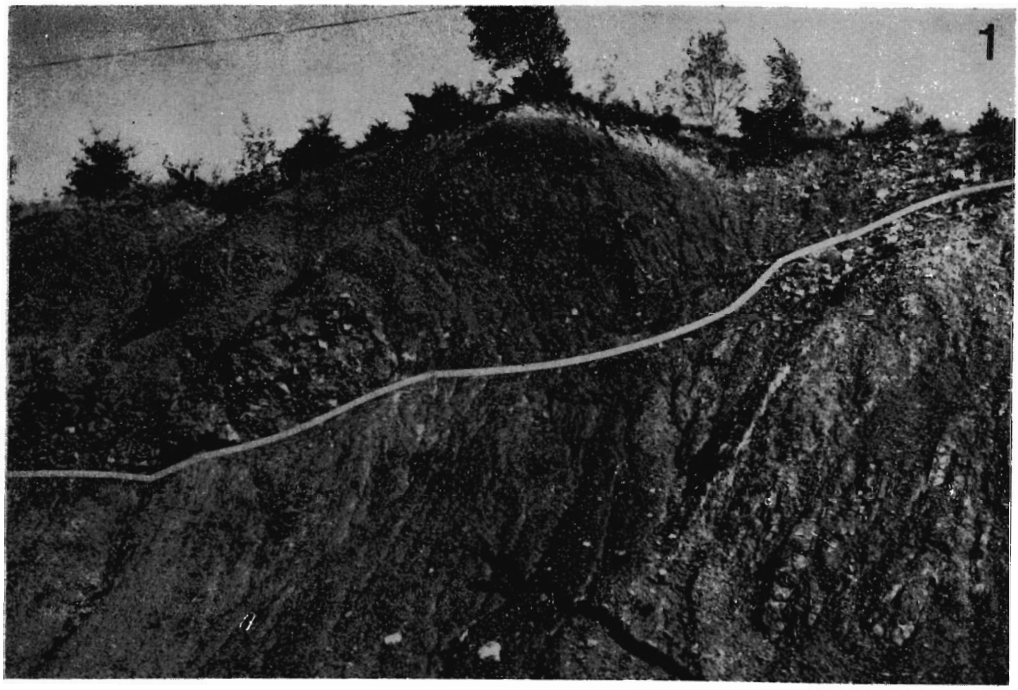
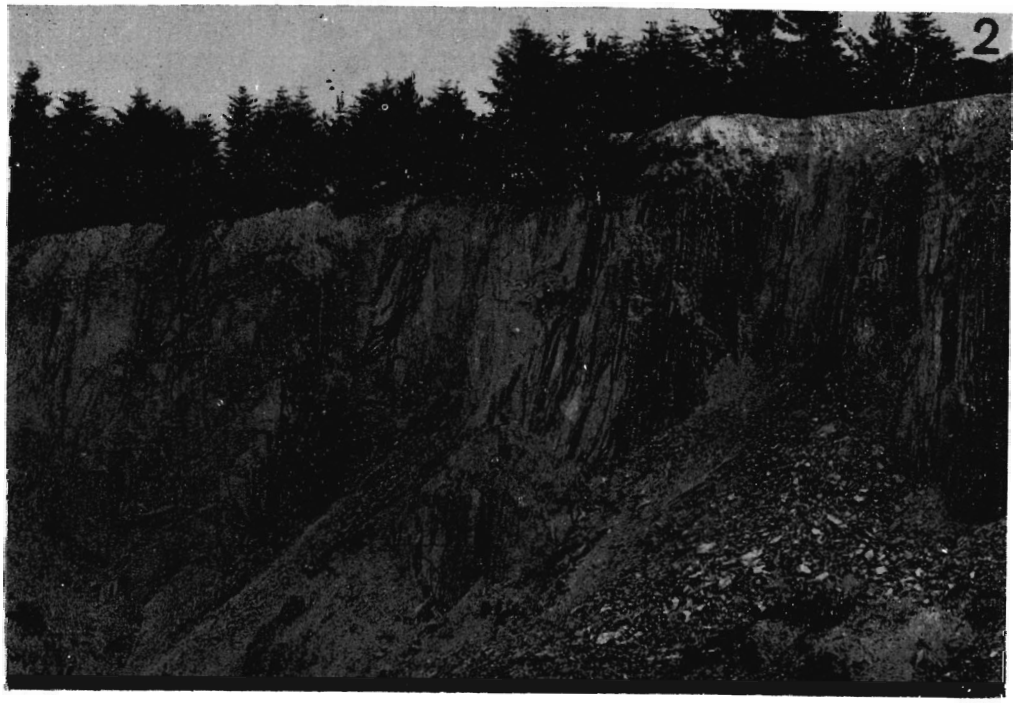


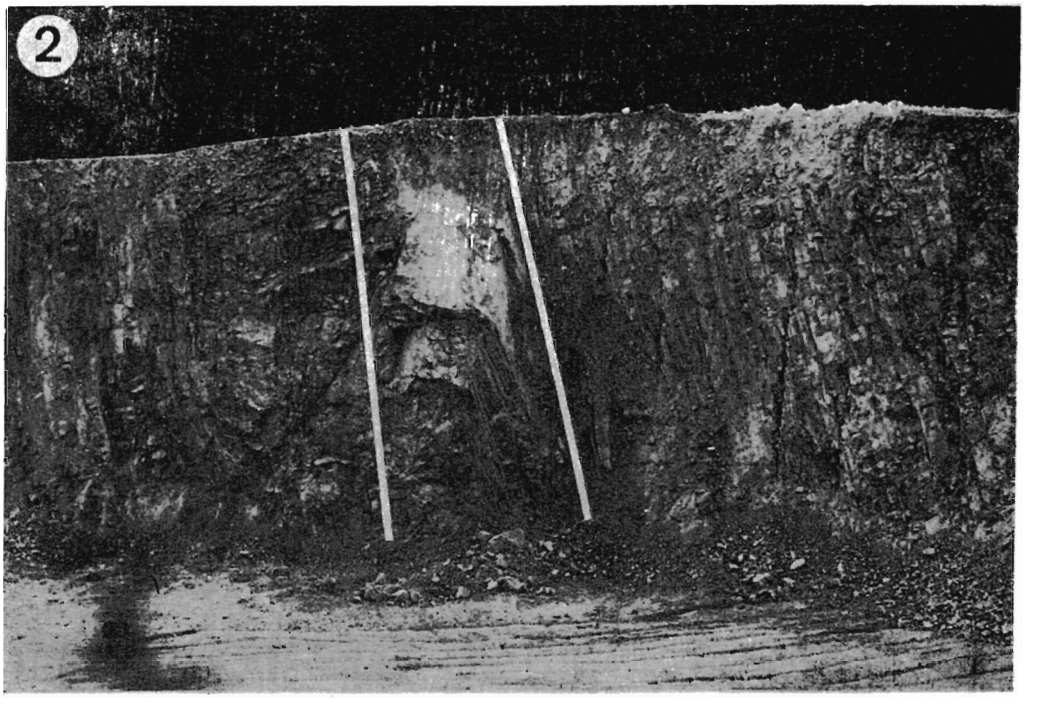
Fig. 6. Small foldings contacting the faults; Wiśniówka Wielka quarry (surveyed in 1975), wall azimuth 115°





1 — Angular unconformity between the Upper Cambrian shales (belonging to the Klonówka Shale Fm.) and overlying Permian (Zechstein) conglomerates; Wiśniówka Wielka quarry

2 — Isoclinal sequence of the Upper Cambrian Wiśniówka Sandstone Fm., exposed at the Wiśniówka Wielka quarry (southern wall)



1 — Another part of the isoclinal sequence of the Upper Cambrian Wiśniówka Sandstone Fm., exposed at the Wiśniówka Wielka quarry (southern-eastern wall)
2 — Drag fold in the deposits of the Upper Cambrian Wiśniówka Sandstone Fm., exposed at the Wiśniówka Wielka quarry (western wall); outlined are discontinuity surfaces parallel to the bedding

strata strike (Fig. 6), and related to normal faults. A single drag fold delimited by fault surfaces parallel to the bedding planes (Pl. 2, Fig. 2) had also been observed but it disappeared due to the further quarrying; the fold axis displayed 110° in azimuth, that is it was parallel to the strata strike, and it was inclined easterly at some 70°. All the fold deformations recorded in the quarry are limited in their lateral extension and of but a local significance. Outside the quarry Wiśniówka Wielka, there are no fold structures north to the Holy dislocation in Mt. Wiśniówka region.

Fold structures occur, however, south to the Holy Cross dislocation. There is a large anticline built up by the Devonian deposits; its axis parallels the Holy Cross dislocation and plunges eastwards. The Lower Devonian sandstones in the anticline core are considerably folded, whereas the Middle through Upper Devonian strata in the limbs are underformed (Fig. 2) which indicates disharmonic nature for those minor folds. They are symmetrical normal or inclined northerly (section *3* in Fig. 2). Their axes parallel the Holy Cross dislocation.

Faults occur rather commonly in the Cambrian strata (Figs 4 and 6—7). They include some slight wrench faults causing displacements of merely 10 to 20 cm (Fig. 7). Most wrench faults show 10—20° in azimuth. They may result in slight

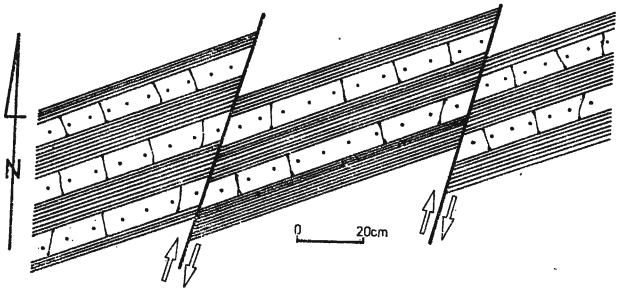


Fig. 7. Small wrench faults in the Upper Cambrian deposits; sketchmap, Wiśniówka Mała quarry

changes in the strata strike. Only a few faults run parallel to the bedding planes. Normal faults of 10—30° in azimuth and 20 to 150 cm in vertical displacement appear to be of much more importance in the region. Those normal faults parallel to the Holy Cross dislocation show their northern sides thrown down, as indicated by the associated slikolites.

With the normal attitude and northerly dip of the Upper Cambrian strata in the quarries Wiśniówka Mała and Wiśniówka Wielka taken into account, one has to regard them as building up a monocline (sections *3—4* in Fig. 3). In contrast, those strata occurring south to the Holy Cross dislocation underwent a considerable tectonic deformation (section *5* in Fig. 3). Then, one may conclude that the Łysogóry unit and the northern part of Kielce—Łagów synclinorium differ in their tectonic style.

III. MT. KLONÓWKA REGION

There are several exposures in the Mt. Klonówka region making possible detailed observations on lithology and tectonics of the Łysogóry

unit. At the top of the hills, some more resistant Upper Cambrian quartzitic layers appear in the waste. The same sandstones interbedded with shales are also exposed in the Mąchocice ravine; they are assigned to the Wiśniówka Sandstone Formation. Higher lithostratigraphic units are exposed in the Janosów Dół ravine at the northern slope of Mt. Klonówka (Fig. 1), at the eastern slope of the hill, and along the Lubrzanka stream. The Góry Pieprzowe Shale Formation is nowhere exposed in the region but its occurrence is documented with some boreholes and the nature of waste deposits. There are only a few exposures of the Ordovician and Silurian strata.

There are no exposures in the southern part of the region, in proximity of the Holy Cross dislocation. Considerably deformed Devonian and Carboniferous strata can, however, be observed along the Lubrzanka stream.

ATTITUDE OF THE STRATA

Attitude of the Upper Cambrian strata can be rather reliably determined owing to the large number of exposures. Both the strike and dip of the strata are more or less constant all-over the region and approximate 110—120/30—40N (diagram *d* in Fig. 1). The northerly dips may sporadically vary in angle (Fig. 8). Judging from the observations made on both the base and top surfaces of the strata, their attitude is always normal. Largely

Fig. 8. Section through the Upper Cambrian deposits exposed along the Janosów Dół ravine

different attitudes of the strata occur exclusively along the Lubrzanka stream which indicates the tectonic nature of that picturesque gap of the Lubrzanka stream (Czarnocki 1950, 1957; Orłowski 1968*a*). The northerly dips of the Upper Cambrian strata, their normal attitude and merely a slight variability in dip angle demonstrate clearly the monoclinal structure of the Łysogóry unit in Mt. Klonówka region (*cf.* Saternus 1976).

Attitude of the Ordovician to Silurian strata can be but indirectly determined because of the lack of their exposures. The carthographic image shows their monoclinal structure which appears also supported by the air photographs.

In the northern part of Kielce—Łagów synclinorium, the strata approximate 110—120/40S in their attitude.

FOLD STRUCTURES AND FAULTS

There are no fold structures within the monocline north to the Holy Cross dislocation. South to the dislocation, there is a large Miedziana Góra syncline (Czarnocki 1919, 1938) with the Lower Carboniferous deposits in its core. The syncline is asymmetrical with a distinct northerly vergency in the region. Its axis parallels the Holy Cross dislocation. The northern limb neighbors upon the dislocation and shows a simple tectonic structure; the southern limb, outside the investigated area, is considerably secondarily disturbed (Filonowicz 1962).

As shown by the air photographs (Mizerski & Ozimkowski 1978), most small-scale faults are normal to the trend of Łysogóry unit; some longitudinal faults

perpendicular to the larger Lubrzanka fault occur, however, at the eastern slope of Mt. Klonówka.

One may conclude that the Łysogóry unit shows a monoclinal structure in the discussed region (sections *7—9* in Fig. 3), bordering southwards along a tectonic contact upon a large syncline (section *10* in Fig. 3).

IV. LUBRZANKA STREAM THROUGH KRAJNO REGION

Mt. Radostowa, Mt. Bęczkowska, and Kraińskie Hills feature morphology of the region. There are a large number of exposures (Fig. 1) allowing to draw some conclusions on tectonic structure of the Łysogóry unit as well as on the very nature of the Holy Cross dislocation.

Strata making part of the Góry Pieprzowe Shale Formation are exposed in the Krajno ravine in the eastern part of the region, and in the Podmąchocice ravine in the west (Fig. 1). Deposits of the Wiśniówka Sandstone Formation can be observed at the top of the hills, and the lower part of the Klonówka Shale Formation is exposed in the Bęczków ravine running northwards (Fig. 1).

The Ordovician strata are covered with waste deposits and alluvia of the Lubrzanka stream and its tributaries; they have, however, been recorded in some boreholes. A few exposures of the Silurian deposits occur along some tributaries of the Lubrzanka stream.

There are some exposures of the Devonian strata south to the Cambrian belt. Some isolated exposures occur also south to the Podmąchocice ravine.

ATTITUDE OF THE STRATA

The strata largely vary in their attitude in the region (diagram *e* in Fig. 1). Within the Góry Pieprzowe Shale Formation the strike is most commonly 100—120°, whereas the dips range from northerly at 50° to southerly at 60°. The northerly dips prevail in the north, while the southerly ones occur in proximity of the Holy Cross dislocation (Fig. 1). The Upper Cambrian strata dip northerly at some 40° with their strikes parallel to the Holy Cross dislocation (90—120°) as a rule. Close to the Lubrzanka fault, the strike may change and approximate 60° in places. The Upper Cambrian strata appear always in normal attitude.

A few measurements taken in the normally lying Silurian strata show an average of 120/35N. The dips may decrease down to 25° in the northern part of the Silurian outcrops. Similar attitudes of the strata have also been recorded in the overlying Lower Devonian deposits.

South to the Holy Cross dislocation, the Devonian and Carboniferous strata range from 100° to 120° in strike and from 90 to 35N in dip (diagram *f* in Fig. 1), showing usually a reverse attitude close to the dislocation.

FOLD STRUCTURES AND FAULTS

Fold structures occur in the region both in the Middle Cambrian strata of the Łysogóry unit and in the Devonian to Carboniferous strata south to the Holy Cross dislocation.

Fold deformations and associated small-scale faults have been recorded within the Góry Pieprzowe Shale Formation exposed in the Podmąchocice ravine (Fig. 9). A large anticline with its northern limb disturbed additionally with some minor folds can be recognized clearly in the ravine. The anticline axis parallels the Holy Cross dislocation and it plunges westwards, that is towards the Lubrzanka fault, at some 10°. The axes of minor folds are horizontal, parallel to the major anticline axis. The minor folds vary in vergency. They are commonly cut down with small-scale longitudinal faults with their northern walls thrown down. All these faults

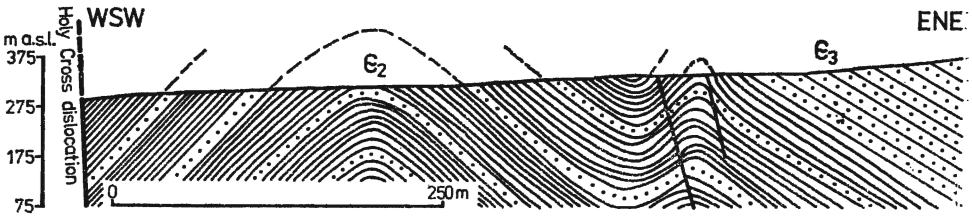


Fig. 9. Section through deposits of the Góry Pieprzowe Shale Fm., exposed along the Podmąchocice ravine

are of normal type with their downthrows ranging from merely a few to a dozen or so centimeters.

Easterly prolongation of the anticline seems doubtful. The shales and thin-bedded sandstones of the Góry Pieprzowe Shale Formation dip northwards at some 50° in the Krajno ravine in the eastern part of the outcrop belt of the Formation. There are some drag folds (Fig. 10) within those deposits, originated

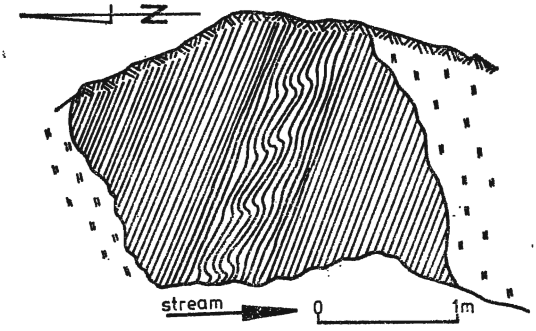


Fig. 10
Small drag folds in shales of the Góry Pieprzowe Shale Fm., exposed in the Krajno ravine

probably due to sliding at a contact of competent and incompetent rocks; in fact, the exposure occurs closely to the base of the Wiśniówka Sandstone Formation. Deposits of the Góry Pieprzowe Shale Formation dip southwards at some 35° in an exposure at the southern slope of Mt. Bęczkowska. Nevertheless, the pattern of drag folds observed in the Krajno ravine suggests that this divergence in dip does probably not reflect any single anticlinal structure.

There is a large asymmetrical syncline south to the Holy Cross dislocation; this is a prolongation of the Miedziana Góra syncline. The syncline appears overturned and its axial surface plunges northwards at some 60°. The syncline axis runs here somewhat obliquely to the Holy Cross dislocation.

One may conclude that the tectonic style is largely uniform in the discussed region. Within the Łysogóry unit, there are fold deformations in the Góry Pieprzowe Shale Formation, whereas the Upper Cambrian shows a monoclinal structure. This difference results merely from a difference in tectonic competence between the shales and sandstones. The Łysogóry unit borders in the south along the Holy Cross dislocation upon the Miedziana Góra syncline overturned southwards in the region (sections *11—15* in Fig. 3).

V. MT. ŁYSICA THROUGH MT. ŁYSA GÓRA REGION

The highest and the most distinct topographic unit of the Holy Cross Mts, that is the Łysogóry range, occurs in the region.

Deposits of the Góry Pieprzowe Shale Formation are exposed at the southern slopes of the Łysogóry range in the center and east of the region. The best exposures are situated along the Słupianka stream and in ravines descending from the Łysogóry range southwards.

The Upper Cambrian formations are much better exposed, and most exposures occur at the top of the Łysogóry range and in their northern slopes. Along these exposures the block screes of large extent developed under periglacial conditions of the Pleistocene epoch; this is the classical locality of periglacial phenomena in Europe, recognized here for the first time by Łoziński (1909, 1912).

The Ordovician is nowhere exposed in the region but it has been recorded in some boreholes. In contrast, there are many exposures of the Silurian, most of them along the Pokrzywianka stream and its tributaries (Fig. 1).

The Devonian deposits build up a range of hills called the Wał Małacentowski south to the Holy Cross dislocation. There are several pits showing the Lower Devonian sandstones disturbed tectonically to a variable extent.

ATTITUDE OF THE STRATA

The attitude of strata of the Góry Pieprzowe Shale Formation is variable. The strike ranges usually from 110° to 120°. The dips are rather gentle as a rule (35—50°); however, there are both northerly and southerly ones which indicates the presence of fold structures. In all the investigated exposures, the strata are in normal attitude.

The Upper Cambrian formations show a monoclinal structure, the average attitude of the strata approximating 120/40—50N (Fig. 1). As indicated by observations made on the base and top surfaces of the strata, they are always in normal attitude.

The Silurian strata vary in their attitude. The strike ranges usually from 90° to 120°. There are both northerly and southerly dips at 35° to 75°. This suggests the presence of some fold structures. Close to the Lower Devonian outcrops of the Bodzentyn syncline, the position of the Silurian strata approximates 120/30N which is also typical of the Lower Devonian.

One may thus conclude that attitude of the strata involved in the Łysogóry unit appears largely variable in the region (diagram *g* in Fig. 1) accordingly to the geological age and lithology of the formations.

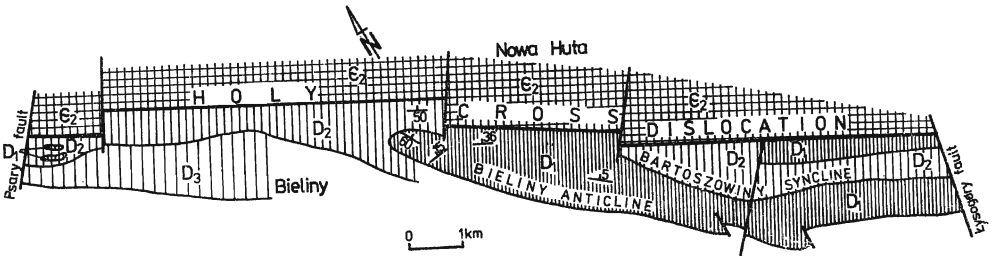


Fig. 11. Tectonic sketch of the southern part of the Mt. Łysica — Mt. Łysa Góra region, to show the details of the Holy Cross dislocation (*cf.* Text-fig. 1)

South to the Holy Cross dislocation, the Devonian strata vary in attitude (Fig. 11). They dip northwards at 5° to 60°, while their strikes are highly variable; most commonly, however, the strikes parallel the Holy Cross dislocation.

FOLD STRUCTURES AND FAULTS

In Mt. Łysica through Mt. Łysa Góra region, tectonic deformations of the Cambrian strata of the Łysogóry unit are to be observed within the Góry Pieprzowe Shale Formation.

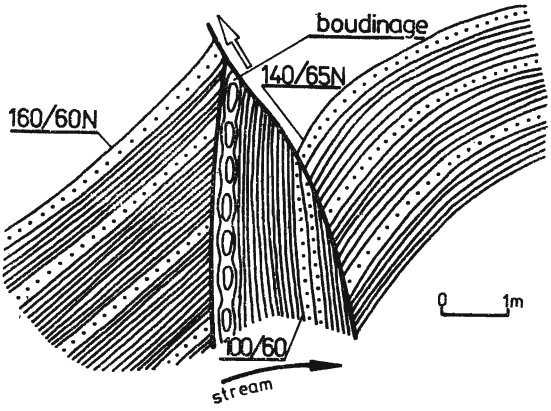


Fig. 12
Tectonic disturbances in shales of the Góry Pieprzowe Shale Fm., exposed in the Podlesie ravine

The shales and sandstones exposed along the Podlesie ravine approximate usually 100—110/50—60N in attitude, resembling thus closely the Upper Cambrian strata. There are some small-scale longitudinal faults with their surfaces inclined southerly in those exposures. These are reverse faults with their northern sides thrown down; they do never exceed 1 m in downthrow. A boudinaged sandstone bed has been recorded in a single exposure; it parallels a fault surface (Fig. 12) associated with a larger fault zone. The boudinage suggests the conditions of tangential stress (*cf.* Wilson 1951).

Fold deformations occur in strata exposed in the Podłysica and Huta ravines (Fig. 1). They appear particularly distinct in the geological section of the Huta ravine; one can see there symmetrical and slightly oblique (axial surfaces inclined northwards at 85°) folds (Fig. 13). The fold axes are almost parallel to the Holy Cross dislocation and the trend of Łysogóry unit in the region.

A large fold with its synclinal part reaching the Holy Cross dislocation has been recorded some 700 m east to the Huta ravine (Fig. 14). It is asymmetrical

with northerly vergency (the axial surfaces are inclined southwards at 70—80°). Both the syncline and anticline axes are horizontal, parallel to the Holy Cross dislocation.

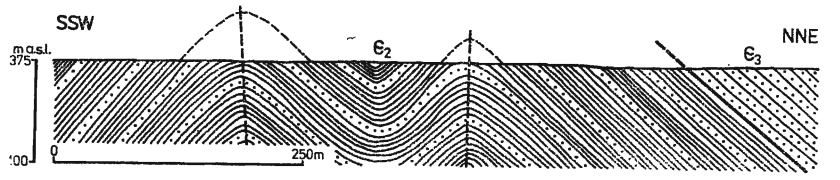


Fig. 13. Folding in the deposits of the Góry Pieprzowe Shale Fm., exposed in the Huta ravine

No fold structures have been found in any other exposures of the Góry Pieprzowe Shale Formation; actually, apart from the above mentioned localities, the dips are always northerly.

There are some fold deformations in the Silurian strata. Most commonly, these are narrow folds with their axes oblique to the trend of Łysogóry unit. They are

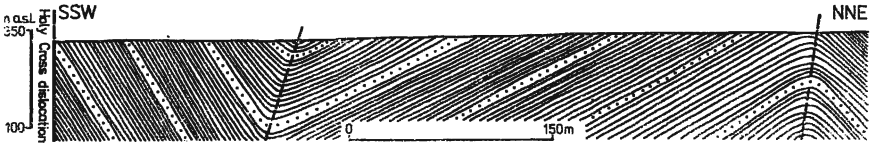


Fig. 14. Fold in the deposits of the Góry Pieprzowe Shale Fm., exposed SE of the Huta ravine

normal or show southerly vergencies with the axial surfaces being inclined at 50—60° (Fig. 15). These folds are of but a local significance and do not considerably disturb the monoclinal structure of the Silurian (*cf.* Filonowicz 1962).

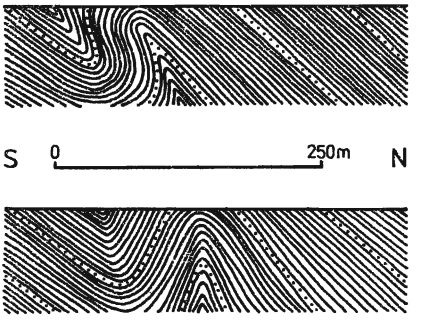


Fig. 15
Folds in the Silurian deposits exposed along the stream, north of village Jeziorko

Aside of true folds, there are also some Silurian strata in apparently reverse position in the region (Fig. 16). These phenomena can hardly be interpreted with certainty because of the poor exposures. One might argue that the reverse positions reflect some local bendings of the strata as well as fold deformations.

The Devonian strata cropping out south to the Holy Cross dislocation show fold structures of variable trend and characteristics. Narrow folds with their

axes parallel to the Holy Cross dislocation occur in the western part of the region (Fig. 11). They are usually delimited by transverse faults. A broad anticline occurs in the central part of the region. Its axis runs somewhat obliquely to the Holy Cross dislocation and plunges westwards which results in that the dislocation cuts down the northern limb in the west. In the eastern part of the region, there is a fold with distinctly southerly vergency (the axial surfaces are inclined northwards at some 70°); its synclinal portion contacts directly with the Holy Cross dislocation. The latter fold is broken with some pivotal faults changing its general trend. This pattern of the fold structures south to the Holy Cross dislocation indicates that all those structures make up a single large fold (*cf.*

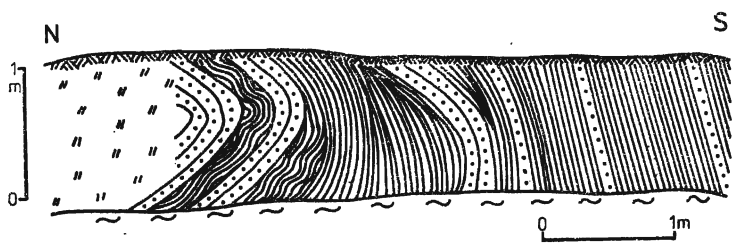


Fig. 16. Tectonic disturbances in the Silurian deposits exposed along the stream, west of village Jeziorko

Fig. 11) composed of the Bartoszowiny syncline (Czarnocki 1924) and the Bieliny anticline (Czarnocki 1924). The fold axes run obliquely to the Holy Cross dislocation and hence, the synclinal part of the fold is gradually cut down westwards by the dislocation.

Faults have been recorded mostly in the southern part of the region. These are mostly normal and oblique-slip faults transverse to the strike of the strata. Most faults cross not only the Middle Cambrian deposits (Fig. 1) but also the Holy Cross dislocation; they do usually continue southwards in the Kielce—Łagów synclinorium, but most of them die rapidly northwards off the Middle Cambrian belt. A few longitudinal faults have been recognized both in the field and in the air photographs (*cf.* Mizerski & Ozimkowski 1978).

One may thus conclude that in Mt. Łysica through Mt. Łysa Góra region the Łysogóry unit shows a monoclinal structure with some minor fold deformations of the strata assigned to the Góry Pieprzowe Shale Formation and the Silurian. The Upper Cambrian is clearly monoclinal in structure without any overfoldings or tectonic repetitions of the sequence. The attitude of strata approximating 110—120/40—50N appears as an average typical of most formations cropping out in the region. Subordinate maxima of the strata position (diagram *g* in Fig. 1) indicate the occurrence of minor fold deformations. The rapidly dying off folds present exclusively within incompetent shaly deposits may indicate disharmonic nature of the fold deformations in the Łysogóry unit (sections *16—26* in Fig. 3). The Łysogóry unit borders in the south along the Holy Cross dislocation upon a fold making part of the northern Kielce—Łagów synclinorium (sections *27—28* in Fig. 3).

VI. SŁUPIA NOWA REGION

This area has been recognized for a distinct tectonic region because the Łysogóry fault, that is the largest transverse dislocation of the entire Holy Cross Mts, runs through it (see below). Exposures of the Cambrian to Silurian strata are clustered at the eastern slopes of Mt. Łysa Góra, western slopes of Mt. Jeleniowska, and along the Słupianka stream and its tributaries (Fig. 1).

ATTITUDE OF THE STRATA

Most Cambrian strata show the attitude of 90—100/40—60N. They are always in normal position. The strike and dip are the same in both the sides of the Łysogóry fault. In a single exposure situated very close to the fault, the strike of the Upper Cambrian strata appears meridional.

The Ordovician and Silurian strata vary in their attitude; in most cases, however, they resemble the attitude of the Cambrian strata. Strikes and dips different from their normal range in the region indicate the occurrence of some fold deformations. Most commonly, dip is the only variable, while strike remains more or less constant and parallels the trend of Łysogóry unit; this is shown by the subordinate maxima of the strata attitude (diagram *h* in Fig. 1). The Silurian strata are in normal position in all the investigated exposures.

The Devonian strata of the northern Kielce—Łagów synclinorium display highly variable attitudes which indicates the occurrence of fold structures.

FOLD STRUCTURES AND FAULTS

In the Słupia Nowa region, fold deformations within the Łysogóry unit can be observed exclusively in the Silurian deposits exposed along the Słupianka stream. Their origination appears related to the activity of hinge faults associated with the Łysogóry fault (Fig. 1). There are both normal and reverse faults with the fault surfaces inclined both northwards and suothwards. They range in azimuth

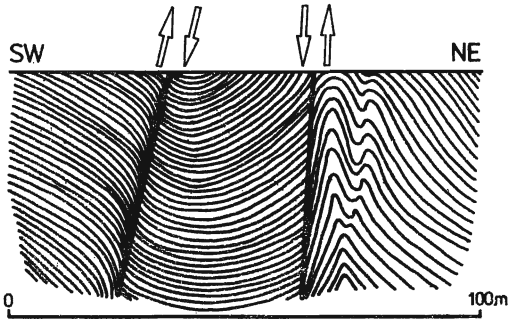


Fig. 17
Folding resulting from fault disturbances in the Silurian deposits exposed along the Słupianka stream, SW of Słupia Nowa

from 20° to 30°. The observed folds are usually normal or with a slight northerly vergency (Fig. 17) and they rapidly die off. The associated faults parallel to the fold axes; downthrow of their northern sides averages some 10 to 15 cm.

The Łysogóry fault runs meridionally through the region; it will be considered in some detail in a succeeding chapter. There are some hinge faults with small but increasing northwards downthrows in the eastern side of the Łysogóry fault. Those associated faults have formed two tectonic wedges comprising the Upper

Cambrian and Ordovician deposits (*cf.* Fig. 1). There are no large-scale longitudinal faults in the region. Nevertheless, the small-scale longitudinal faults perpendicular to the Łysogóry fault have been recognized in both its sides (Mizerski & Ozimkowski 1978).

South to the Łysogóry unit there are fold structures set apart by the Łysogóry fault; in the west (*cf.* Fig. 11), these are the Bartoszowiny syncline (Czarnocki 1924) and the Bieliny anticline (Czarnocki 1950), the axes of which parallel the Holly Cross dislocation. In the east, one deals with a syncline with the Lower Carboniferous deposits in its core (Fig. 1); its axis runs obliquely (at some 30°) to the Holy Cross dislocation and emerges westwards.

The region is thus monoclinal in structure, disturbed here and there by the faults associated with the Łysogóry fault (sections *29—32* in Fig. *3*).

VII. JELENIÓW RANGE REGION

The Jeleniów Range comprises the following elevations: Mt. Jeleniowska, Mt. Szczytniak, Mt. Witosławska, Mt. Wesołówka, and Mt. Truskolaska, all of them built up of the Cambrian strata (Fig. 1).

There are but a few exposures of the Cambrian strata; they show exclusively the Wiśniówka Sandstone Formation. The Ordovician and Silurian strata are exposed along the Słupianka stream and its tributaries. They have also been recorded in boreholes.

There are no exposures south to the Łysogóry unit. The occurrence of the Devonian and Carboniferous deposits is, however, demonstrated by some boreholes and the nature of waste deposits.

ATTITUDE OF THE STRATA

Attitude of the strata of the Góry Pieprzowe Shale Formation can be merely inferred after Czarnocki (1957) who claimed that those strata dip always northwards and parallel the Holy Cross dislocation in their strike.

The Upper Cambrian strata are always in normal attitude and resemble in their dip and strike those of the other regions of the Łysogóry unit. Actually, they approximate the position of 90—110/40N. The northerly dip increases up to 70° only in the eastern part of the region.

The Ordovician and Silurian strata vary in their attitude. The northerly and southerly dips associated with strikes parallel to the Holy Cross dislocation alternate north to Mt. Jeleniowska (Fig. 1), which indicates the occurrence of fold structures. In the central and northern parts of the Silurian outcrop belt, the strata are in normal attitude and dip northwards at some 50°.

One may thus conclude that the attitude of strata involved in the Łysogóry unit is variable (diagram *i* in Fig. 1) accordingly to the geological age and lithology of the formations.

The strata of the northern Kielce—Łagów synclinorium do also vary in their attitude suggesting the occurrence of fold structures.

FOLD STRUCTURES AND FAULTS

Fold deformations have been recorded in exposures situated along a tributary stream running down from Mt. Jeleniowska to the Słupianka stream. There are

asymmetrical folds with distinct southerly vergencies within the Ordovician and Silurian strata. The folds asymmetry and their size relative to the whole Łysogóry unit permit their interpretation as large drag folds (Fig. 18). Their origination could be related to sliding at the Cambrian/Ordovician contact, which is indeed supported by the tectonic mirrors reported from the Cambrian/Ordovician boundary from the boreholes located at Jeleniów (Tomczykowa 1968).

Several major transverse faults running across the Łysogóry unit occur in the region; they will be considered in some detail in a succeeding chapter. Some

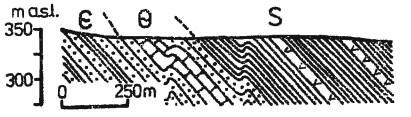


Fig. 18
Large drag folds in the Ordovician and Silurian deposits exposed along the stream running down from Mt. Jeleniowska, east of Jeleniów

smaller-scale faults perpendicular in most cases to the trend of Łysogóry unit have also been recognized in the region (Mizerski & Ozimkowski 1978).

South to the Holy Cross dislocation, there is a fold structure with the axes oblique to the dislocation. Consequently, the fold is gradually cut down eastwards by the dislocation; its axial surfaces vary in orientation.

The Łysogóry unit shows a simple monoclinal structure in the discussed region, with some disharmonic deformations of incompetent strata (sections *33*—*36* in Fig. 3). In the south, it borders along the Holy Cross dislocation upon a fold structure displaying variable vergencies (sections *37*—*38* in Fig. 3).

VIII. OPATÓW REGION

The topographically elevated part of the Łysogóry unit disappears east to the hill Truskolaska. There are no exposures of the Cambrian deposits at a distance of some 5 km. Strata assigned to the Wiśniówka Sandstone Formation have only been recorded at Gołoszyce (Fig. 1); the Cambrian, Ordovician, and Silurian strata have also been reported from boreholes in the northeast of the region. Good exposures of the Góry Pieprzowe Shale Formation appear only in the sections along the Grabówka and Kochówka streams and the Kania stream; the Wiśniówka Sandstone Formation is also exposed in the latter section. Several exposures of the Wiśniówka Sandstone Formation occur in the section along the Opatówka river; the exposed deposits supplied the Upper Cambrian fauna studied by Samsonowicz (1934*b*) and Orłowski (1968*b*). There are also tectonically reduced Ordovician to Silurian strata and the Devonian deposits in the eastern part of the region. They are overlain by the Permian lying directly over the Cambrian in the west. There are some isolated exposures of the Devonian south to the Holy Cross dislocation.

The Opatów region shows the most complex tectonic structure among all the regions of the Łysogóry unit. In spite of the occurrence of the

same stratigraphic units as in the other regions (*cf.* Fig. 1), there is no topographic elevation which may indicate a difference in lithology.

ATTITUDE OF THE STRATA

The strata vary in their attitude in the region (diagram *k* in Fig. 1); there are, however, some differences among particular stratigraphic units.

The strata of the Góry Pieprzowe Shale Formation do most commony parallel the trend of Łysogóry unit in their strike (90—110° as a rule), while their dips range from 60N to 40S. The strata are always in normal attitude. This variability indicates the occurrence of fold structures.

The Upper Cambrian formations do also show variable attitudes. The strata dip northwards in the central part of the region; their positions are normal and hence, the structure appears as a monocline (section *39* in Fig. 3). In contrast, there are both northerly and southerly dips ranging in angular value up to 70° in the eastern part of the region; those strata range usually from 80° to 110° in their strike. It was shown by Samsonowicz (1934*a*) and confirmed by the present author's field investigations that the strata dipping southwards are in reverse attitude. This indicates that the southerly dips reflect bending of the strata related probably to the adjacent faults (*cf.* Fig. 1) rather than any overfolding. In fact, a continuous gradation from normal to reverse attitudes of the strata has been recorded in the section of the Kania stream which confirms the above interpretation (sections *40—41* in Fig. 3).

South to the Holy Cross dislocation, the strata are most commonly parallel to the dislocation in strike. They dip northwards at 50° in average but both the normal and reverse attitudes have been observed.

FOLD STRUCTURES AND FAULTS

Within the Łysogóry unit, fold deformations occur in deposits assigned to the Góry Pieprzowe Shale Formation. They appear the most distinctly in the section of the Kochówka stream. There are some synclines and anticlines with consi-

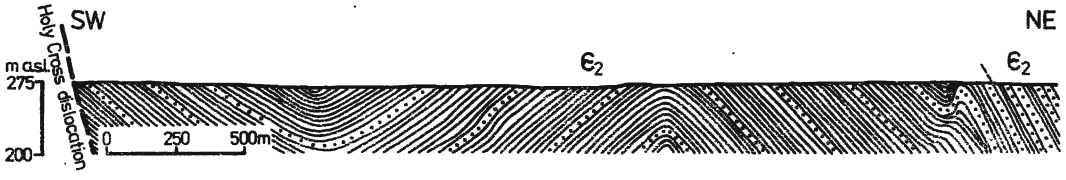


Fig. 19. Section through deposits of the Góry Pieprzowe Shale Fm., exposed along the Kochówka stream

derable southerly vergencies. The most disturbed is the top part of the formation. There is a clearly asymmetrical fold with its axial surfaces inclined northwards at some 60°; it does not continue into the overlying strata of the Wiśniówka Sandstone Formation. The fold structures are more gentle in the southern part of the outcrop belt of the Góry Pieprzowe Shale Formation (Fig. 19) where a syncline contacts directly with the Holy Cross dislocation; nevertheless, the folds do also show southerly vergencies (axial surfaces inclined northwards at some 85°). There are also some small-scale longitudinal reverse faults in the south. Their southern sides are thrown down with downthrows averaging 20 cm. Both the fold vergency and the fault nature indicate a horizontal tectonic transport southwards in the region. Some small-scale longitudinal faults have also been recorded in the strata of the Góry Pieprzowe Shale Formation exposed along the Kania stream.

The Upper Cambrian strata are unfolded. There are merely some small-scale longitudinal faults associated locally with reverse positions of the strata (Fig. 20).

The Devonian strata are considerably folded and broken with transverse faults south to the Holy Cross dislocation (Kowalczewski & *al.* 1976). The fold axes parallel the dislocation; the folds are usually delimited by transverse faults of most commonly normal type.

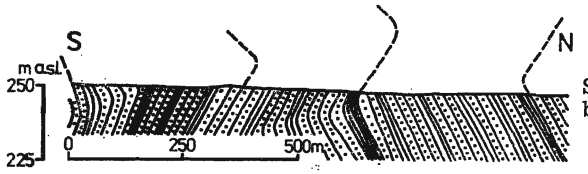


Fig. 20
Section through the Upper Cambrian deposits exposed near Wąworków

One may thus conclude that the Łysogóry unit shows a complex tectonic structure in the region. There are fold structures in the south, whereas the northern part of the region displays a monoclinal structure with some locally reverse positions of the strata (sections *39—42* in Fig. 3). The tectonic style of the region resembles the style typical of the entire Łysogóry unit.

RELATION OF STRATA ATTITUDE TO LITHOLOGY AND STRATIGRAPHY

The Middle Cambrian strata (Góry Pieprzowe Shale Formation) are largely variable in both the strike and dip (diagram *A* in Fig. 1). Actually, there are both southerly and northerly dips. Those strata dipping northwards average 120° in strike. The strata dipping southwards are clustered about the maximum of 140° in strike. The main maximum of the diagram approximates the position of 110-130/40-55N which is equivalent to the average for the entire Łysogóry unit. This variability in strata attitude reflects the occurrence of subordinate fold deformations. The dominant northerly dips associated with the normal attitude of the strata contradict the opinion that outcrop belt of the Góry Pieprzowe Shale Formation represents the axial zone of the Łysogóry anticline of Czarnocki (1950, 1957).

The most common attitude of the Upper Cambrian strata (diagram *B* in Fig. 1) approximates 120/40-60N resembling closely the main maximum for the Middle Cambrian (diagram *A* in Fig. 1). An indistinct subordinate maximum of the strata attitude (95-120/70-75S) reflects the reverse positions of the Upper Cambrian strata in the eastern part of the Łysogóry unit (Opatów region).

The close resemblance of the main maxima for the Middle and Upper Cambrian strata (diagrams *A*, *B* in Fig. 1) suggests the same geological age for the origination of fold deformations in the Góry Pieprzowe Shale Formation as for the dipping of the Upper Cambrian strata. This is also consistent with the opinion of Orłowski (1968*a*, 1975) that the Upper Cambrian overlies concordantly the Middle Cambrian.

The largest variability in attitude show the Ordovician to Silurian strata cropping out north to the Cambrian belt (diagram *C* in Fig. 1). The main maximum approximates 110-120/50N and appears almost identical to the maximum for

the Upper Cambrian strata (*cf.* diagram *A* in Fig. 1). The dominance of a single maximum co-occurring with some other, clearly subordinate maxima indicates the local nature of fold deformations of the Ordovician to Silurian strata. The apparent variability in strike reflects the occurrence of mostly meridional faults and probably also some lithological variation. The patterns of the position of the Middle Cambrian and Ordovician to Silurian strata resemble each other with many respects.

One may thus conclude that local fold structures occur exclusively in incompetent shale-and-sandstone-bearing complexes. There are no fold deformations in the competent strata of the Wiśniówka Sandstone Formation. Apart possibly of a single tectonic region (Lubrzanka stream through Krajno region), there is no axial zone of any large anticline in the southern part of the Łysogóry unit. Hence, the fold deformations recorded in the Góry Pieprzowe Shale Formation do not appear related to any large fold structure. The comparison of fold deformations in the Middle Cambrian strata to those recorded in the Ordovician to Silurian strata suggests that these are merely local disharmonic deformations.

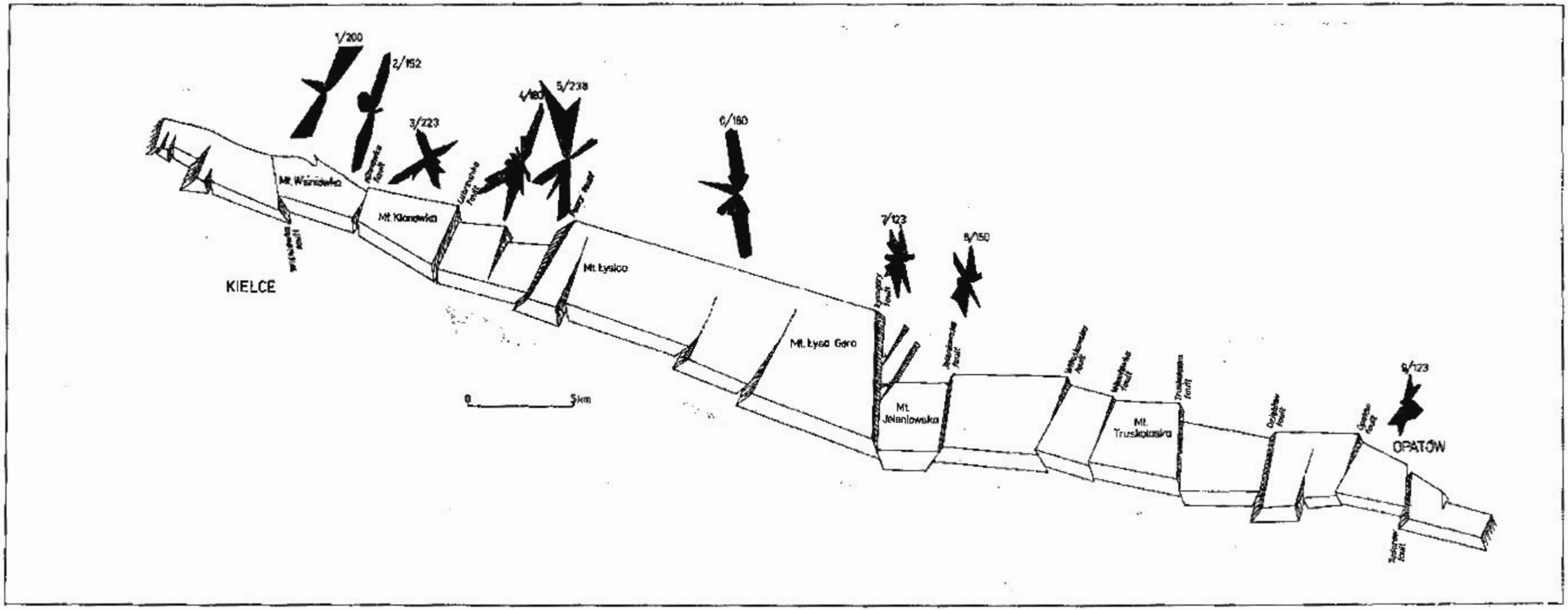
Most considerable fold deformations in the Middle Cambrian and Ordovician through Silurian strata occur close to the base or the top of the Upper Cambrian formations, respectively. One may then claim that they resulted from a discharge of tectonic stresses in a contact zone of strata of different competence.

The apparent consistence of the main maxima for the attitude of strata assigned to different stratigraphic units involved in the Łysogóry unit indicates the common geological age for their deformations.

The Łysogóry unit contrasts in strata attitude the northern part of the Kielce—Łagów syclinorium where mostly the Devonian strata are exposed (diagram *D* in Fig. 1). The co-occurrence of some distinct maxima in the latter area reflects the presence of various fold structures. The dips are most commonly very steep. The variability in both trend and nature of the fold structures is caused mostly by the influences of the Holy Cross dislocation and several transverse faults variable in their orientation. The alternation of synclinal and anticlinal structures in the neighborhood of the Holy Cross dislocation (Fig. 3) rejects any interpretation of that area as the axial zone of an anticline, scale, or slice. The identical strikes of the strata of the Łysogóry unit to those of the northern Kielce—Łagów synclinorium suggest the common geological age for their tectonic deformations.

As clearly demonstrated by the successive sections constructed in particular tectonic regions (sections *1—42* in Fig. 3), the Łysogóry unit is complex in structure. It shows neither distinctly anticlinal, nor purely monoclinal structure. Small-scale and large fold deformations occur exclusively in the incompetent Middle Cambrian and Ordovician to Silurian deposits. The folds within the Góry Pieprzowe Shale Formation do not appear related to the Holy Cross dislocation. This is indicated by the width of the deformation zone *e.g.* in the section of the Kochówka stream (section *39* in Fig. 3) or in the Mt. Łysica through Mt. Łysa Góra region (sections *25, 26* in Fig. 3); whereas the strata of the Góry Pieprzowe Shale Formation reach monoclinally the Holy Cross dislocation elsewhere (*e.g.* in the Jeleniów Range region). This demonstrates the variability and limited extent of the fold deformations of the Middle Cambrian strata. It appears noteworthy that a similar tectonic style is also shown by some blocks delimited by major transverse faults. One may thus suppose that some large transverse faults running across the Łysogóry unit are of the same geological age as the fold deformations.

Blockdiagram to show the extent of the Middle and Upper Cambrian deposits within the Łysogóry unit (*cf.* Text-figs 1 and 3); associated are the diagrams of joints



JOINT

Three distinct joint [1] systems can be recognized in the Łysogóry unit, changing their orientation accordingly to the position of the involved strata. There are two systems oblique to the extent of Łysogóry unit and the strata strike; the third system is almost parallel to the strike (Fig. 21). The systems are represented each by fairly broad and indistinct maxima in the diagrams. It is so especially in those tectonic regions with highly variable positions of the strata. With the nature of joint and its relationship to the general tectonic structure of the Łysogóry unit taken into account, both the joint sets oblique to the strike are attributed to the diagonal system, while the set parallel to the strike represents orthogonal system.

The diagonal system is very well developed all-over the Łysogóry unit (Fig. 21) but the orientations of particular sets are variable and range in intervals of some 30°. The fractures run straight; in some cases, they are smooth or bear a mineralization. In some regions, both the sets are well developed; only a single set appears clearly elsewhere. In some exposures, the diagonal joint system cannot be recognized at all. In the western part of the Łysogóry unit, the fractures of this system show a considerable mineralization (Fig. 22). One can see there quartz

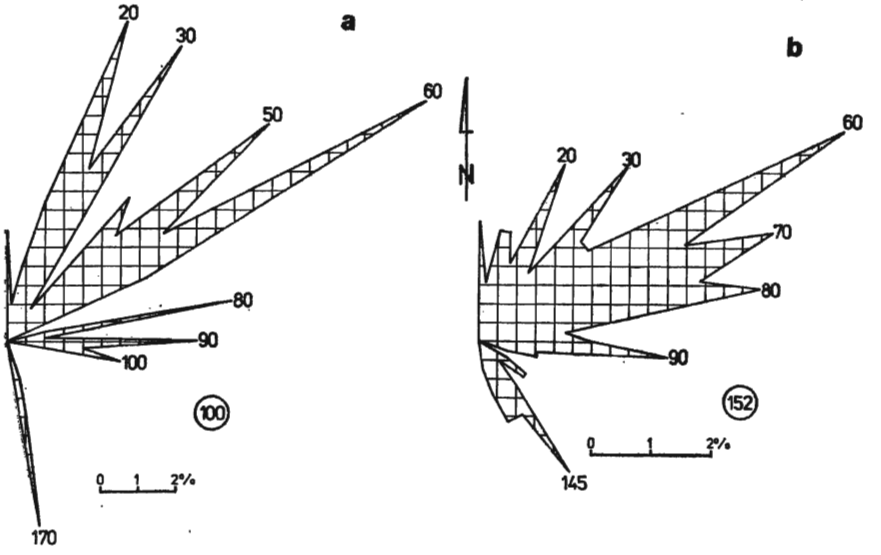


Fig. 22. Diagrams of the mineralized joints in the Upper Cambrian deposits of Mt. Wiśniówka (**a**) and Mt. Bęczkowska (**b**); circled is the number of measurements

or barite veins running most commonly straight but furcating sometimes to form sets or bundles of little veins (Fig. 23). Some striae occur in the Mt. Wiśniówka region in both mineralized and non-mineralized fractures of the diagonal system. Tectonic mirrors occur very commonly in the Opatów region. All these characteristics of the diagonal joint system document its shear natur (*cf.* Price 1959, 1966).

[1] The joint is presented in orientation diagrams produced after the commonly used surface diagrams (*cf.* Dimitrijević & Petrović 1965).

The fractures of the orthogonal joint system run straight and lack any tectonic mirrors or slikolites; sporadically, feather structures occur. The characteristics of the fracture surfaces indicate (*cf.* Jaroszewski 1972) that they are of extension type.

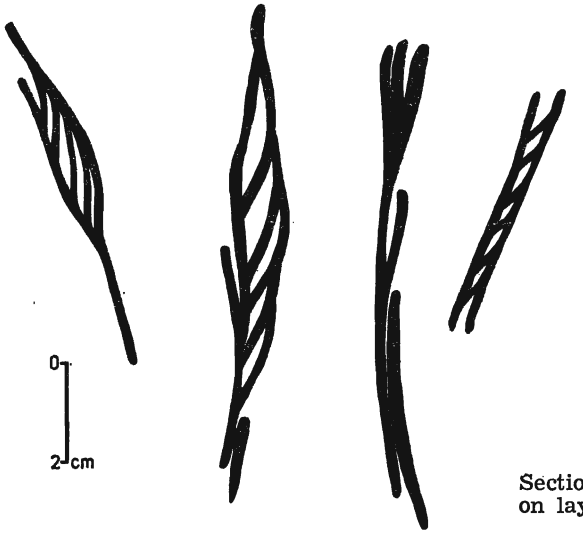


Fig. 23
Sections of the mineralized joints on layer surfaces; Wiśniówka Wielka quarry

The age and origin of the joint systems of the Łysogóry unit can hardly be unequivocally determined for the moment. The diagonal joint bears much more considerable mineralizations than the orthogonal joint (Fig. 22) which may indicate that it is older. The joint orientation differs from the orientation of the faults (Mizerski & Ozimkowski 1978) suggesting a difference in geological age of their origination. At the moment, one may only suppose that the diagonal joint system developed in response to the Variscan orogeny. The problem requires, however, further investigations all-over the Łysogóry region of the Holy Cross Mts (*cf.* Fig. 1*B*).

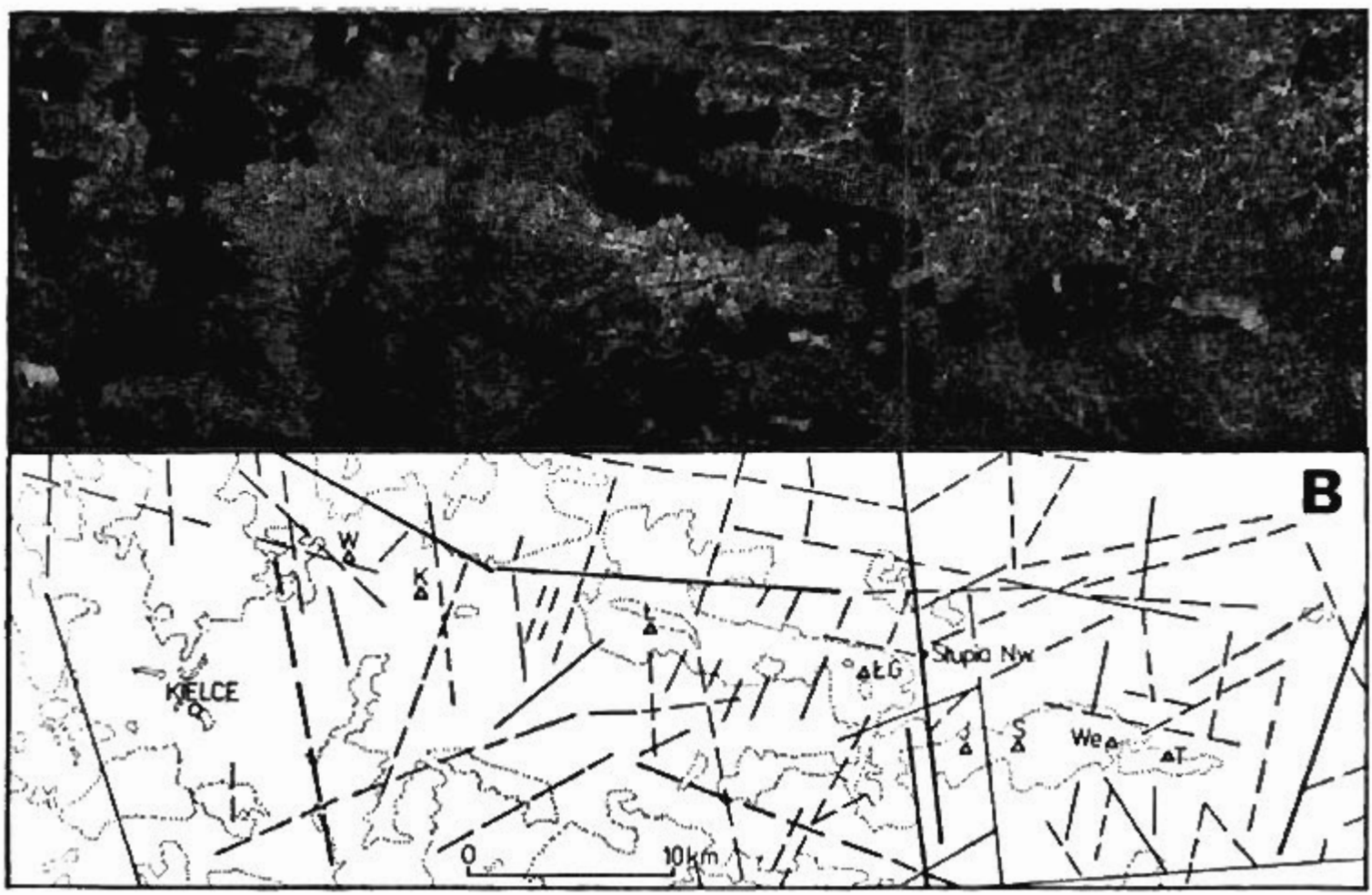
TRANSVERSE FAULTS

The transverse faults running across the Łysogóry unit vary in their nature and size. Some faults cross the entire Łysogóry unit, the Holy Cross dislocation, and the northern Kielce—Łagów synclinorium. The others cut only a portion of the Łysogóry unit and rapidly die off. The major transverse faults will be briefly discussed below.

ŁYSOGÓRY FAULT

The Łysogóry fault running across the Łysogóry unit in the Słupia Nowa region (Fig. 1) appears as the most important and the largest transverse dislocation in the Holy Cross Mts. It runs almost along a meridional and continues far outside the Łysogóry unit itself (Czarnocki 1957, Pawłowski 1965).

Space aerogram of the central part of the Holy Cross Mts (**A**) and sketch map of the faults recognized by the photointerpretation methods (**B**)



The carthographic image of the fault can hardly be unequivocally interpreted. Czarnocki (1950, 1957) and other authors working in this area or treating the dislocation in purely theoretical terms (*e.g.* Jaroszewski 1973) considered the Łysogóry fault as a wrench fault or at least an oblique-slip fault with a considerable lateral component.

The most clear cartographically segment of the fault zone is situated in the Cambrian outcrop belt of the Łysogóry unit. The fault splits the Łysogóry unit into the western and eastern parts which is made even more distinct due to a change in general orientation of the Łysogóry unit and the Holy Cross dislocation (Fig. 24). The lateral displacement along the fault can be most easily determined at the Middle/Upper Cambrian, Upper Cambrian/Ordovician, and Silurian/Devonian boundaries. The stratigraphic boundaries are considerably displaced southwards in the eastern wall of the fault; the Holy Cross dislocation remains however continuous (Fig. 1). North to the Holy Cross dislocation, the lateral displacement is more or less constant and approximates 3 km. The outcrop belt of the Góry Pieprzowe Shale Formation is wide in the western side of the Łysogóry fault, while it is narrow in the eastern side; such a carthographic image suggested to some authors the wrench nature of the Łysogóry fault north to the Holy Cross dislocation.

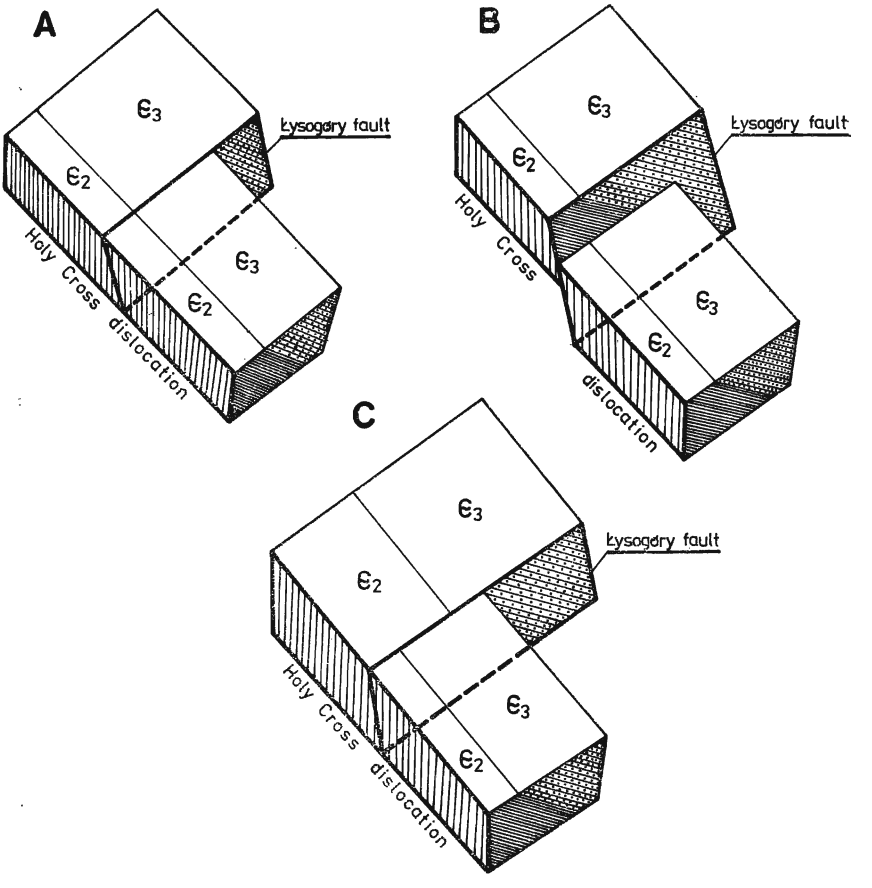


Fig. 25. Development of the Łysogóry fault (**A**, **B**), and the present-day situation (**C**) south of Słupia Nowa

This interpretation appears, however, undermined by that segment of the Łysogóry fault running across the Holy Cross dislocation and the Kielce—Łagów synclinorium. In fact, there is no lateral displacement of the eastern part of the Holy Cross dislocation relative to the western part (Fig. 1). Very well developed slikolites indicative of vertical displacements have been recorded in deposits of the Wiśniówka Sandstone Formation close to the Łysogóry fault. One may then claim the normal nature for the Łysogóry fault.

Provided that the Holy Cross dislocation *(see below)* is vertical, one can fairly easily interpret the carthographic image of the Łysogóry fault and reconstruct the tectonic history of the area. The eastern side of the fault is thrown down at some 1000 m. This is reflected by the lateral displacements along the fault north to the Holy Cross dislocation. The dislocation itself is vertical and hence, it has not become disrupted (Fig. 25).

The Łysogóry fault is reached en-echelon by smaller-scale faults recognized already by Czarnocki (1950, 1957). They occur exclusively in the eastern side of the fault. These are normal or hinge faults disturbing sometimes the Silurian strata. They form also the tectonic wedges comprising the Upper Cambrian and Ordovician deposits (Fig. 1). As noticed by Jaroszewski (1973), these faults may be related to the dying of the main dislocation off.

It is commonly accepted that the Łysogóry fault is younger than the Holy Cross dislocation and originated during the Variscan orogeny. There are, however, some reasons *(see below)* to claim that the fault is much older than this, eventhough still younger than the Holy Cross dislocation, rejuvenated merely during the Variscan orogeny.

PSARY FAULT

This is a large dislocation clearly recognizeable in an air photograph (Fig. 24). It runs generally along the NNE-SSW direction. This is a pivotal fault (Fig. 21). In the north, it is marked by a diabase dike cutting the Lower Paleozoic and Devonian strata, which may be used to estimate the size and geological age of the fault.

The Psary fault continues northwards up to Triassic outcrops, whereas it dies rapidly off in the northern Kielce—Łagów synclinorium. The downthrow it highly variable. The eastern side is thrown down at some 100 m in the north (within the Devonian outcrop belt). In contrast, the western side is trown down at some 400—500 m in the central segment of the fault. The vertical displacement decreases down to some 50 m at the Holy Cross dislocation.

LUBRZANKA, KLONÓWKA, AND WIŚNIÓWKA FAULTS

The Lubrzanka fault runs along the NNE-SSW direction (Fig. 24). Its most distinct segment is just between Mt. Radostowa and Mt. Klonówka, and the fault dies rapidly off both southwards and northwards. This is a normal fault with the downthrow increasing northwards up to 300 m (Fig. 21). Small-scale perpendicular dislocations occur in both the walls of the Lubrzanka fault (Mizerski & Ozimkowski 1978).

The Klonówka fault (NNE-SSW direction) appears almost limited to the Cambrian belt (Fig. 24); this is a pivotal fault (Fig. 21) with the maximum downthrow approximating 150 m.

In contrast to the insofar discussed faults, the Wiśniówka fault runs along the NNW-SSE direction (Fig. 24). It cuts across both the Cambrian belt and the Holy Cross dislocation, resulting in their discontinuity. This is a wrench fault, as indicated clearly by small-scale displacements recorded at planes parallel to the fault in the Wiśniówka Mała quarry.

FAULTS EAST OFF THE ŁYSOGÓRY FAULT

There are some more or less meridional, fairly large dislocations east to the Łysogóry fault (Fig. 1). These are mostly pivotal or hinge faults, and the Truskolaska fault is the only one of a wrench nature (*cf.* Fig. 21).

The geological age of these faults remains unclear. It is commonly accepted that they are related to the Variscan orogeny. Some faults cut also across the Mesozoic strata which suggests that they were rejuvenated during the Laramide phase.

GENERAL REMARKS

The most interesting are the faults delimiting in the east and west the Cambrian of the Łysogóry unit. These faults related genetically to the Variscan orogeny must have also been active during the Laramide phase when their outer walls have become thrown down. This could be related to the uplift of the central part of the Holy Cross Mts at that time (Kutek & Głazek 1972).

In addition to the above discussed transverse faults, there are also some other, smaller-scale faults in the Łysogóry unit, mostly west to the Łysogóry fault. They are usually restricted to the southern part of the Łysogóry unit and result

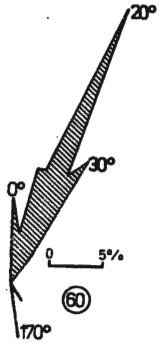


Fig. 26
Diagram of faults in the Łysogóry unit; circled is the number of measurements

in a clear discontinuity of the Holy Cross dislocation (Fig. 1). These are mostly oblique-slip faults running along the NNE-SSW direction.

Most investigated faults range from 10° to 30° in azimuth (Fig. 26). They are mostly of normal or oblique-slip type and split the Łysogóry unit into a number of relatively uplifted or thrown down blocks (Fig. 21); the most uplifted is the block of Mt. Łysica through Mt. Łysa Góra.

HOLY CROSS DISLOCATION

The problem of the geological nature and age of the Holy Cross dislocation appears as one of the most important points in explanation for tectonics of the whole Holy Cross Mts. The dislocation has not been

recorded in any boreholes; it is accessible to direct observations in but a few exposures; even the geophysical investigations undertaken by the *Geological Survey of Poland* did not ultimately recognize the geometry of the dislocation. Therefore, any conclusions must follow from indirect arguments.

Most commonly, the opinion of Czarnocki (1919) is accepted that the Holy Cross dislocation is actually an overthrust. In most geological sections (*e.g.* Tomczyk 1974, Znosko 1974), the Cambrian deposits are shown as thrust over the Kielce—Łagów synclinorium. Most authors follow Czarnocki (1950, 1957) in assigning the dislocation origin to the Variscan orogeny.

The present author found out some reasons to claim that the Holy Cross dislocation runs vertically or almost vertically. The modern geological literature allows also to draw the conclusion on much earlier origin of this structure.

The Holy Cross dislocation, fold structures and faults associated with it display the following geometrical features: *(i)* the actual trace of the Holy Cross dislocation in the field is independent of the topography; *(ii)* the anticline and syncline axial surfaces are usually vertical or inclined very steeply (at 70° to 85°) northwards or southwards off the Holy Cross dislocation; *(iii)* the fold axes in the northern Kielce—Łagów synclinorium run commonly somewhat obliquely to the Holy Cross dislocation; *(iv)* in proximity of the dislocation, longitudinal fault surfaces are usually inclined very steeply (at 70° to 85°) southwards or northwards irrespective to their normal or reverse nature; and *(v)* transverse normal faults do not displace the dislocation laterally. All the above characteristics indicate clearly the vertical or almost vertical nature of the Holy Cross dislocation.

As demonstrated by the recent seismic surveys (Guterch & *al.* 1976), the Earth crust varies in thickness in the Holy Cross area. Actually, the *Moho* surface lies some 6 km deeper in the northern Holy Cross Mts (Earth crust approximates 44 km in thickness) than in the southern part of the area (Earth crust approximates 38 km in thickness). The discontinuity in *Moho* surface coincides with the present-day boundary between the Łysogóry and Kielce regions (*cf.* Fig. 1*B*) and hence, with the Holy Cross dislocation. One may thus conclude that the Holy Cross dislocation runs vertically or very steeply and reaches the *Moho* surface, reflecting a boundary between two Earth-crust blocks of different thicknesses. In fact, dislocations of this type recorded in Poland (Pożaryski 1975) as well as elsewhere (Khain 1971, 1977) are commonly interpreted as very steep ones.

The Łysogóry and Kielce regions differ in facies and thickness of the Paleozoic formations (Czarnocki 1919, 1950, 1957; Bednarczyk 1971; Kutek & Głazek 1972; Szulczewski 1977). It seems sound to claim that the

above differences resulted from some tectonic pre-conditions and factors. The boundary between the regions runs along the Holy Cross dislocation and hence, one may suppose that the dislocation is much older than it was proposed by Czarnocki (1950, 1957). Actually, it could be founded in the Cambrian Period (*cf.* Kutek & Głazek 1972) or even earlier. Larger Paleozoic thicknesses in the Łysogóry region than in the Kielce region suggest that the dislocation must have been active during the Paleozoic sedimentation, eventhough it must not have been distinctly marked in the basin topography; it could just cause higher subsidence and accumulation rates on its northern side.

There are some reasons to claim that the boundary between the facies typical of the Kielce and Łysogóry regions was not constant throughout the entire Paleozoic but instead shifted here and there (Szulczewski 1977). Actually, a number of faults could be associated with the Holy Cross dislocation, displaying highly variable displacement rates; then, an associated dislocation could appear much more active and important than the Holy Cross dislocation itself in some epochs (as *e.g.* during the Late Devonian, *cf.* Szulczewski 1977).

To summarize, the Holy Cross dislocation can be regarded as a vertical or very steep, deep-seated fault reaching the *Moho* surface, originated with the beginning of the Paleozoic Erathem or even earlier, and affecting the Paleozoic sedimentation and facies pattern.

UPPER CAMBRIAN THICKNESS VARIATION

As demonstrated above, the Upper Cambrian of the Łysogóry unit is monoclinal in structure without any overfoldings or tectonic repeats of the sequence. Then, the variation in width of the Upper Cambrian outcrop belt (Fig. 1) is to be reconsidered. This variation cannot reflect merely a variability in the strata dip as the range of the latter (45—75°) appears insufficient to account by itself for the observed variation in outcrop width. Provided the monoclinal structure, the variation in outcrop width must reflect a variability in the actual thickness of the Upper Cambrian deposits.

The Upper Cambrian thickness was estimated after the geological sections constructed for particular tectonic regions of the Łysogóry unit. The Upper Cambrian formations are here jointly considered because their mutual boundary can hardly be everywhere recognized with certainty. One may conclude that the total Upper Cambrian thickness ranges from 850 m in Mt. Wiśniówka region up to some 1,800 m in Mt. Łysica through Mt. Łysa Góra region.

As shown by the geological map (Fig. 1), the Upper Cambrian outcrops remain more or less constant in width in areas delimited by major transverse faults. Then, the major transverse faults make up the bound-

aries of the areas displaying differential actual thicknesses of the Upper Cambrian. It seems therefore sound to claim that the variation in Upper Cambrian thickness resulted from the paleotectonic situation.

The major transverse faults appear thus to have been founded earlier than during the Variscan orogeny, as they affected already the Upper Cambrian sedimentation of the Łysogóry region. Active dislocation zones must have existed at the bottom of the sedimentary basin at that time. They were not marked in the basin topography but nevertheless, they caused a variability in subsidence rate among particular segments of the basin (Fig. 27). The major transverse faults were merely rejuvenated during the Variscan orogeny and to a lesser extent the Laramide phase.

This hypothesis is also supported by some sedimentological arguments. The Upper Cambrian is fairly monotonous in lithology. Nevertheless, the sandstones of the Wiśniówka Sandstone Formation show much thicker beds in those regions with large total Upper Cambrian thickness, as *e.g.* Mt. Łysica through Mt. Łysa Góra region (70% of the beds range from

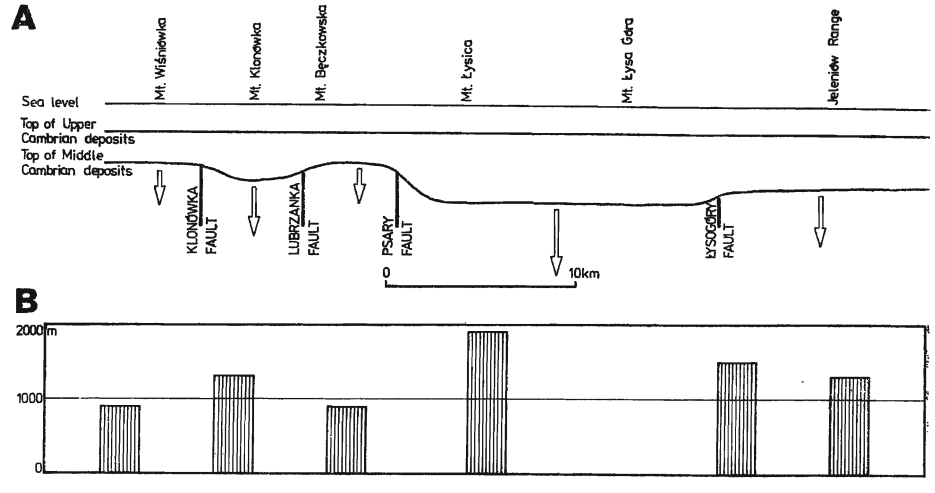


Fig. 27. Diagram to show the bearing of transverse faults upon the Upper Cambrian sedimentation: **A** — situation after completion of the Upper Cambrian sedimentation, **B** — the resulting thickness of the Upper Cambrian deposits in particular regions

1 to 2.5 m in thickness; 3 m thick beds do also sporadically occur), than in the others (80% of the beds range from 25 to 50 cm in thickness in Mt. Wiśniówka region). The shale intercalations occur much more commonly in those regions with smaller total Upper Cambrian thickness. A similar pattern is also observed in the Klonówka Shale Formation. In fact, the Formation appears more sandy in those regions with larger total Upper Cambrian thickness.

Because of too few exposures of the Ordovician and Silurian deposits, one cannot determine ultimately whether the transverse dislocations did

also affect the post-Cambrian sedimentation patterns. The variation in thickness of the Silurian (Teller 1969) may actually reflect the activity of the dislocations at that time but further investigations are required to solve the problem.

DEVELOPMENT OF THE ŁYSOGÓRY UNIT

Basing upon the above presented structural analysis, one may put forward a hypothesis on tectonic development of the Łysogóry unit within a framework of the entire Holy Cross Mts.

As indicated by the tectonic style of deformations recorded in the Góry Pieprzowe Shale Formation and in the northern Kielce—Łagów synclinorium, the Łysogóry unit is neither anticline, scale, nor slice. The Cambrian strata are monoclinal in structure, with merely minor additional deformations (except of the Opatów region). In contrast, there are considerable fold deformations south to the Holy Cross dislocation.

The analysis of tectonic deformations within the strata assigned to the Góry Pieprzowe Shale Formation permits recognition of areas of similar tectonic structure. These areas are delimited by major transverse faults just as the regions of constant Upper Cambrian thickness are. Close to the Holy Cross dislocation, the strata of the Góry Pieprzowe Shale Formation build up gentle anticlines and synclines in some places, while they are monoclinal in structure elsewhere. This rejects any interpretation of the Holy Cross dislocation at the axial zone of an anticline, scale, or slice. It is noteworthy that there are folds rapidly dying off also in the Silurian. The absence of fold deformations from the Upper Cambrian sandstones and the Lower Devonian sandstones of the southern limb of Bodzentyn syncline (*cf.* Fig. 1*B*), and the occurrence of local fold structures in the Middle Cambrian and Silurian shales are to be explained by the apparent difference in competence between the sandstones and shales.

In order to explain tectonic development of the Łysogóry unit, the following phenomena are to be taken into account: *(i)* tectonic deformations are clearly related to lithology and never very intense north to the Holy Cross dislocation; *(ii)* fold deformations recorded in shales are of but a local significance; *(iii)* there are no fold deformations within the Upper Cambrian formations; *(iv)* major transverse faults split the area into regions of different tectonic structure; *(v)* diverse fold structures, with considerable minor deformations, built up by the Paleozoic strata of highly variable lithology occur south to the Holy Cross dislocation; *(vi)* fold axes in the northern Kielce—Łagów synclinorium run obliquely to the Holy Cross dislocation in places; *(vii)* the Holy Cross dislocation dips vertically or almost vertically; and *(viii)* the Permo-Mesozoic strata

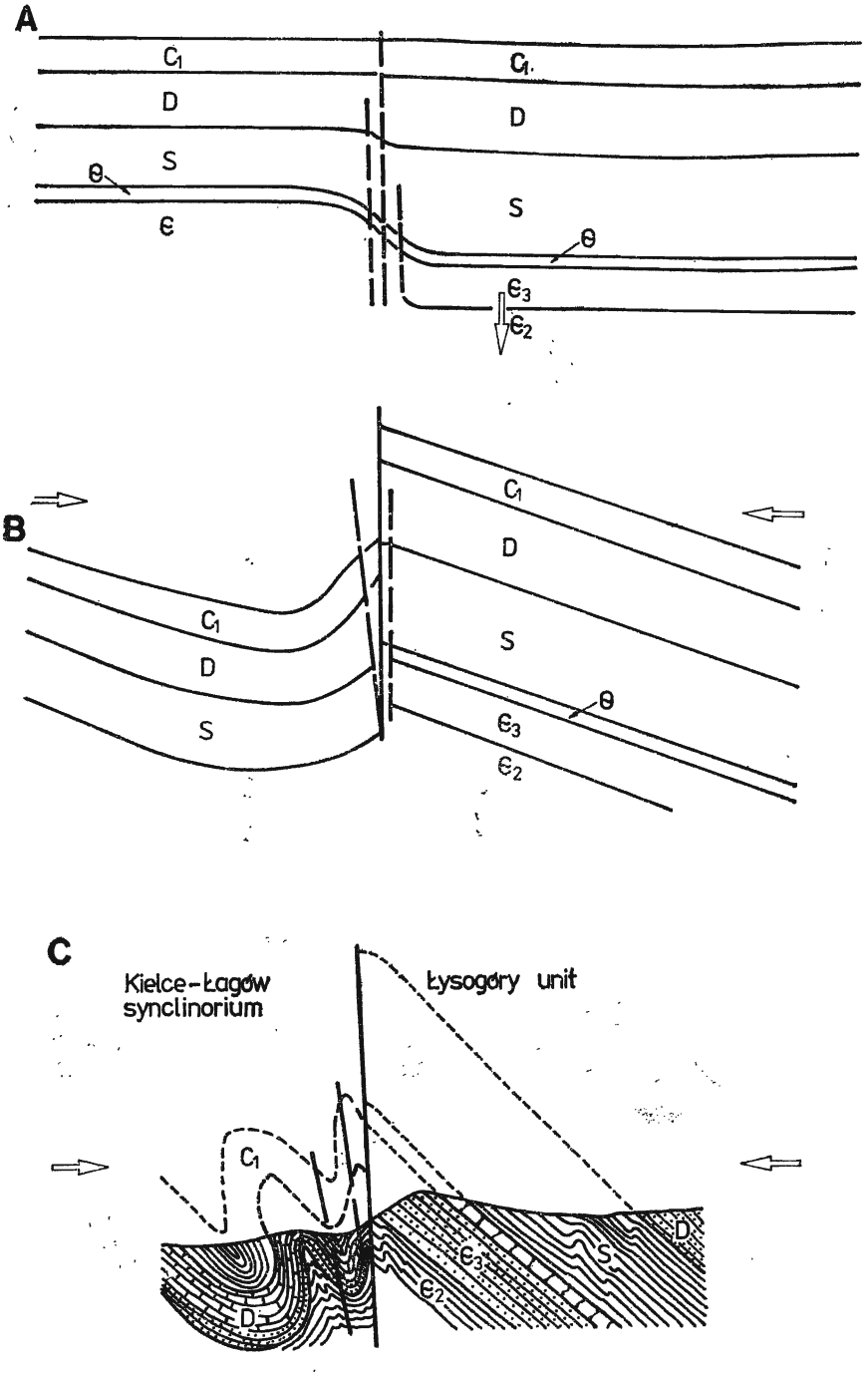


Fig. 28. Successive stages of the formation of the Łysogóry unit during the Variscan folding (**A**, **B**, **C**), and present-day situation of that tectonic structure and its foreland (Kielce—Łagów synclinorium) after erosion (*also* **C**)

overlie discordantly, with a different structural pattern, the sequence of the Cambrian through Devonian strata.

With all the preceding analysis taken into account, one may conclude that the main role in tectogenesis of the Łysogóry unit was played by the Holy Cross dislocation; this dislocation appears as a steep and deep-seated fault reaching the *Moho* surface and separating two Earth-crust block of different thickness (*cf.* Guterch & *al.* 1976). At first, the northern side of the dislocation subsided more or less continuously for a very long time, which resulted in accumulation of deposits more thick here than in the other side (Fig. 28*a*). The situation changed during the Variscan orogeny when the northern side started to uplift. This caused disruption of the strata continuity and considerable deformations in proximity of the Holy Cross dislocation (Fig. 28*b*). The early stages of tectonic development of the Łysogóry unit permit thus a comparison to the Rattlesnake Mountain, Wyoming, United States (Stearns 1971, Berg 1976). The deformation model proposed for the latter structure by Stearns (1971) appears to resemble also most closely the tectonic processes active during the formation of the Łysogóry unit. Some tangential stresses coeval with the uplift resulted in fold deformations of the shales, whereas the resistant sandstones became merely steeply inclined (Fig. 28*c*). The tectonic style of the Łysogóry unit indicates that this is neither anticline, scale, nor slice, but a block structure. The local fold structures are related to differences in lithology and hence, are to be conceived as disharmonic deformations. During the uplift of the Łysogóry unit, the old transverse dislocations were rejuvenated.

The apparent difference in Earth-crust thickness and in tectonic-deformation intensity between the Łysogóry and Kielce regions allows to regard these two areas as making part of two distinct crustal blocks. The Łysogóry block exerted a considerable stress southwards resulting in deformation of the sedimentary strata of the Kielce block. Actually, the most intense deformations are exhibited by the Kielce—Łagów synclinorium in the foreland of the Łysogóry block. The larger thickness of the Earth crust and the relative uplift of the Łysogóry block explain why the rocks of the Kielce block show much more intense deformations than those of the Łysogóry block (*cf.* Szulczewski 1973).

The Łysogóry unit was formed as a distinct tectonic unit during the Variscan orogeny, most probably during the Sudetic phase. Later on, the Laramide phase resulted in rejuvenescence of some faults but not in structural reconstruction of the area.

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TEKTONIKA JEDNOSTKI ŁYSOGÓRSKIEJ

(Streszczenie)

Przedmiotem pracy jest analiza struktur tektonicznych występujących na obszarze jednostki łysogórskiej (antykliny łysogórskiej *sensu* Czarnocki 1950, 1957). Stwierdzono, że jednostka ta (fig. 1) posiada budowę monoklinalną z podrzędnymi zaburzeniami fałdowymi typu dysharmonijnego. Większe struktury fałdowe występują wyłącznie w miękkich utworach łupkowo-piaskowcowych kambru środkowego oraz ordowiku i syluru, a nie występują natomiast w obrębie górnokambryjskiej formacji piaskowcowej (fig. 2—23 oraz pl. 1—2), co wynika z różnej odporności piaskowców i łupków na deformacje tektoniczne. Główną rolę w formowaniu się obecnych stosunków tektonicznych odegrała stroma i bardzo głęboka dyslokacja świętokrzyska, stanowiąca granicę między dwoma blokami skorupy ziemskiej. Stwierdzono, że sedymentacja górnokambryjska rozwijała się na mobilnym dnie basenu pociętym poprzecznymi strefami dyslokacyjnymi, które wpływały na rozmaite tempo subsydencji, co doprowadziło do powstania osadów górnokambryjskich o zróżnicowanej miąższości wahającej się od 850 do 1800 m (fig. 27). Starsze strefy dyslokacyjne zostały odmłodzone w czasie ruchów waryscyjskich, czego rezultatem są uskoki poprzeczne mające w większości charakter zrzutowy, zawiasowy lub nożycowy (fig. 21 oraz 24—26). Jednostka łysogórska powstała w czasie ruchów waryscyjskich, prawdopodobnie w fazie sudeckiej, jako struktura blokowa (fig. 28), zaś ruchy laramijskie odzwierciedliły się w odmłodzeniu niektórych uskoków poprzecznych.