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PRECAMBRIAN IN SOUTH-WESTERN POLAND

CONTENTS

INTRODUCTION

The paper summarizes our knowledge about the regional development, petrology, stratigraphy and tectonics of the complexes of the Polish part of the Sudetes which are proved or believed to be older than Paleozoic. They are highcrystalline in character, except for some sequences now regarded as Infra- or Eocambrian. The successive development of theories and views cannot be presented in detail; only most important results will be discussed.

The Precambrian basement in Poland is almost entirely concealed by a cover of younger deposits, ranging from a few hundreds meters up to some 10.000 m in thickness. The Precambrian rocks occur on the surface only in south-western Poland where they have build up some major units in the Sudetes Mts. and their foreland. Unfortunately, the mountains mentioned have no bold and bare slopes except for isolated cliffs and they do not provide large continuous exposures. In general, the relief is covered by rock debris, residual loams and glacial drift leaving accessible only isolated patches of bedrocks. This is the main cause of serious difficulties in stratigraphical correlations. Many difficulties are encountered also when interpreting the origin and

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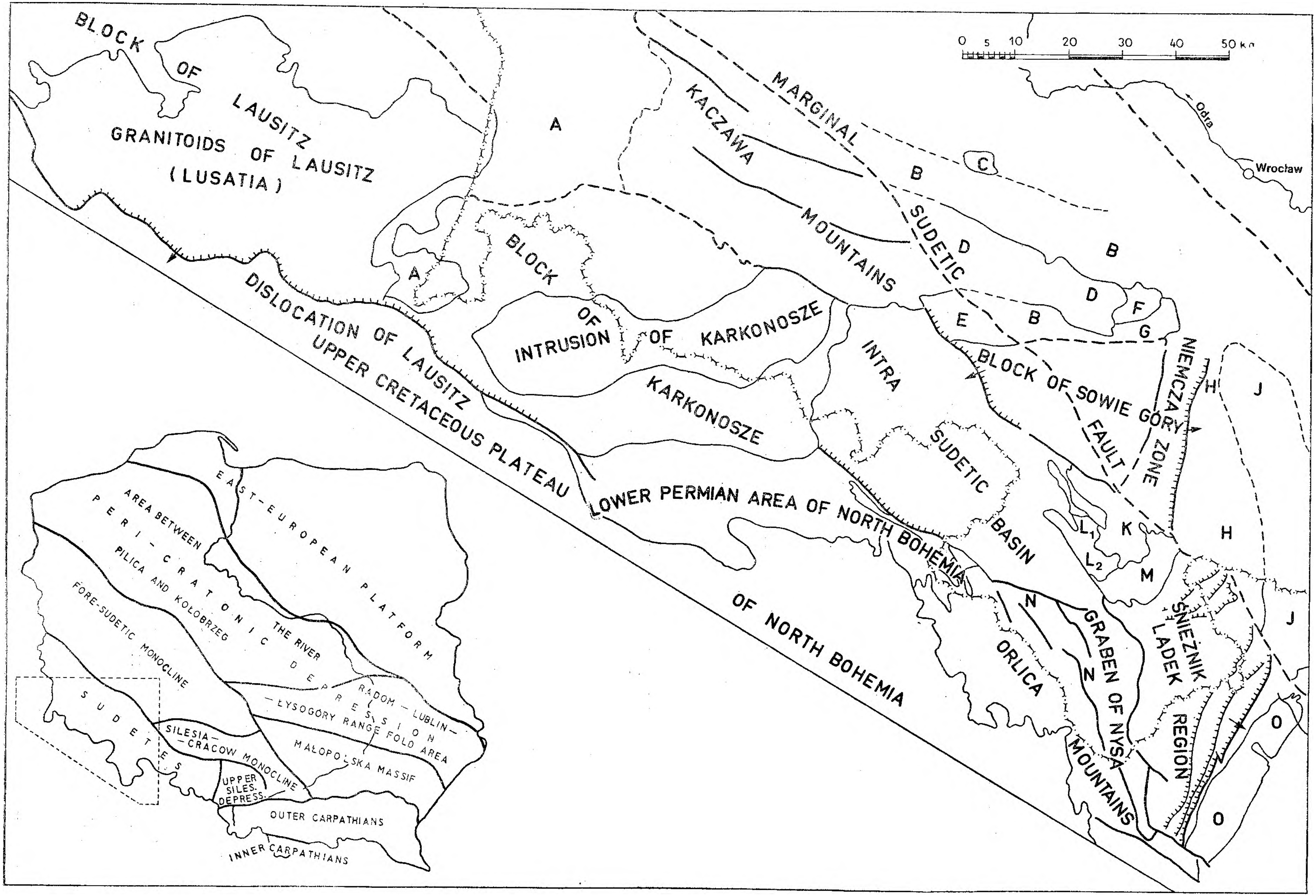
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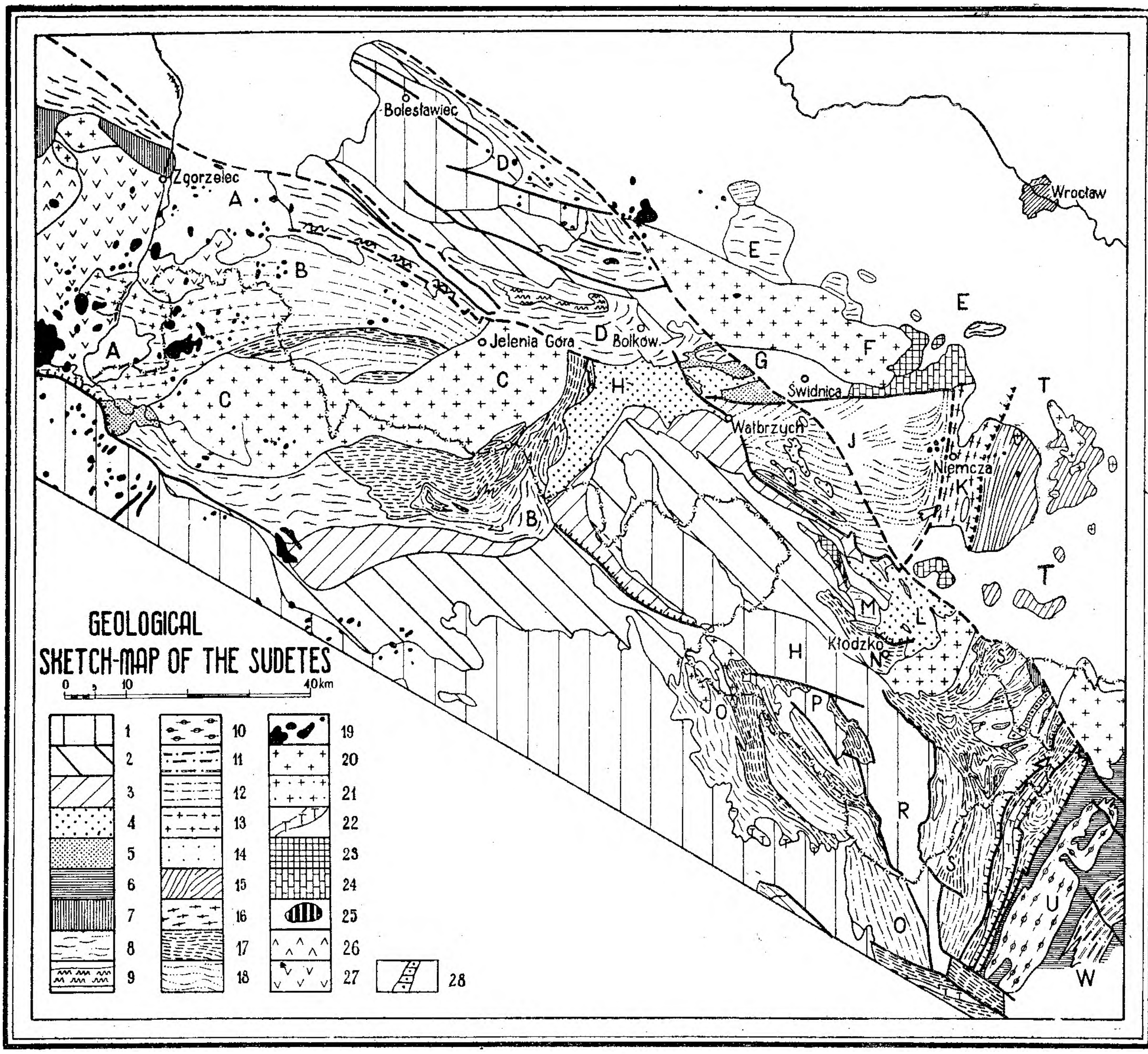

Fig. 2
Geological sketch-map of the Sudetes

1 — Upper Cretaceous; *2* — Permian; *3* — Upper Carboniferous; *4* — Lower Carboniferous; *5* — Upper Devonian; *6* — Lower and Middle Devonian of the Eastern Sudetes; *7* — greywacke formation of Lausitz (Lusatia); *8* — Cambro-Silurian; *9* — slates of Radzimowice; *10* — gneisses of Kepernik; *11* — gneisses of Desna; *12* — granite-gneisses in general; *13* — granite of Rumburk and transitions to the Izera gneisses; *14* — Gierałtów gneisses; *15* — schists and gneisses mantling the Strzelin-Zulova massif; *16* — schists and mylonites of the Niemcza zone; *17* — mica-schists with intercalations of paragneisses, amphibolites, quartzites, crystalline limestones and erlans; *18* — gneisses of the Sowie Góry Block; *19* — basalts (Tertiary); *20* — Young Variscan granites; *21* — granitoids of Kłodzko-Złoty Stok; *22* — tonalites; *23* — gabbro; *24* — serpentinites; *25* — diabases of Nowa Ruda; *26* — granodiorites of Lausitz (Lusatia); *27* — granodiorite of Zawidów; *A—A* — subsided zone of Żytawa-Węgliniec; *B—B* — Block of Karkonosze; *C—C* — granite massif of Karkonosze; *D—D* — Kaczawa Mountains; *E—E* — prolongation of the Kaczawa Mts. on the foreland; *G* — Depression of Świebodzice; *H—H* — Intra-Sudetic Basin (Central Sudetic Trough); *J* — Block of Sowie Góry; *K* — zone of Niemcza; *L* — Bardo Mountains; *M* — northern part of the metamorphic region of Kłodzko; *N* — southern part of the metamorphic region of Kłodzko; *O—O* — Orlickie Góry Mts.; *P* — Bystrzyca Mountains; *R* — Graben of Nysa; *S—S* — Region of Śnieżnik-Lądek; *T—T* — granite massif of Strzelin-Żulova and its country-rocks; *U* — Dome of Kepernik; *W* — Dome of Desna (Pradziad)

Fig. 1
Main structural units of the Sudetes and their foreland

A—A — lowered zone of Żytawa-Węgliniec; *B—B* — prolongation of the Kaczawa Mountains on the Sudetic foreland; *C* — gneisses of Wądroże Wielkie; *D—D* — granite massif of Strzegom-Sobótka; *E* — depression of Świebodzice; *F* — gabbro massif of Sobótka; *G* — serpentinites in the environs of Sobótka; *H—H* — schists and gneisses mantling the Strzelin-Żulova massif; *J—J* — granite massif of Strzelin-Żulova; *K* — Bardo Mountains; L_1 — northern part of the metamorphic region of Kłodzko; L_2 — southern part of the metamorphic region of Kłodzko; *N—N* — Bystrzyca Mountains; *O—O* — gneissic dome of Kepernik the structural features of the Precambrian rocks in the Sudetes.

A correct and well-founded stratigraphic record is missing for the Sudetic Precambrian till now. Even the very limit between the Precambrian and the Early Paleozoic, respectively the Lower Devonian strata is controversial in most areas. The same as in other parts of the Bohemian Massif, no reliable radiometric determinations have been obtained in the old crystalline rocks of the Sudetes. This is a consequence of a strong Variscan reworking and reheating caused by many late-Variscan granitoid mobilizations and intrusions.

The Sudetic area falls in Poland into two major physiographic and structural units. These are: the block of the Sudetes Mts. in the south-west and the block of the Sudetic Foreland (Subsudetic Block) in the north-east. They are separated from each other by an important fault-zone which has originated in the Variscan epoch of folding and subsequently rejuvenated in young-Tertiary times with a reverse sense of movement (Cloos 1922). In Tertiary times the block of the Sudetes was uplifted with respect to the foreland block.

One of the most striking features of both blocks is their mosaic-like composition (figs. 1, 2). Owing to many differentiated vertical movements and to erosion we can see side by side, on the earth surface, fragments of different structures and rock-sequences belonging to different tectonic styles and cycles. The following rocks sequences may be differentiated in the Polish part of the Sudetes:

1. The Moldanubian complex, believed to be Early Proterozoic or even Archean in age is represented by the Sowie Góry gneisses and the associated crystalline rocks. It is generally accepted that the sequence had been folded during the Moldanubian movements.

2. The Proterozoic supracrustal complex of the Lądek-Śnieżnik region, the Bystrzyca and Orlica Mts., the Kłodzko region and the Karkonosze block. The main folding is here most probably Variscan in age, though some geologists take it rather for Cadomian.

3. The Cambro-Silurian complex containing also the Eocambrian and the Devonian in some regions. It is present in the Kaczawa Mts. and their prolongation in the Foreland Block, as well as in the Karkonosze Block and the Kłodzko region. The main deformation took place during the early — Variscan movements.

4. The Young Paleozoic complex containing Upper Devonian, Carboniferous and Permian strata, originated and was essentially deformed in the Variscan epoch of folding.

5. The Upper Cretaceous-Tertiary complex which came into being and was deformed when the Alpine movements were in operation.

The Precambrian complexes are composed of metamorphic rocks exclusively and have been deformed and readjusted for several times.

THE MOLDANUBIAN COMPLEX OF THE SOWIE GÓRY BLOCK AND THE ASSOCIATED ROCKS (PL. I, II)

The unit is situated in the central part of the Sudetic area. It measures about 600 km^2 and is triangular in shape. It is composed mainly of paragneisses and migmatites penetrated by pegmatites and locally by small granite bodies. Amphibolite intercalations of different type and origin are very common. Far less frequent are the granulites, serpentinites, and crystalline limestones which are particularly rare.

The younger granite-gneisses appear in many places as concordant bodies amidst the (prevalent) paragneisses. The main occurrence of the granite-gneisses is represented by a longitudinal zone, striking parallel to the south-west margin of the Sowie Góry Block and constituting the main ridge of the Sowie Góry Mts.

The rock assemblage of the Sowie Góry Block has been studied by many geologists and petrologists. The last studies have been published by Polański (1955), Grocholski (1967), and Morawski (1973), who give also most important references. Let us follow the essential results obtained and published by these authors and other outstanding investigators.

P a r a g n e i s s e s a n d m i g m a t i t e s. The paragneisses are a supracrustal sequence, transformed highly by regional metamorphism, the recrystallization being essentially postkinematic. The parental rocks were for the most part argillaceous and sandy (greywackeous) sediments, accumulated to a great but unappraisable thickness in a geosyncline. The detritic sedimentary sequence contains scarce intercalations of dolomitic marls, very rare lenticular bodies of limestone and far more frequent but small intrusive or extrusive bodies of basic and ultrabasic igneous rocks.

The paragneisses of the Sowie Góry are grey or dark-grey in colour and occur in several varieties differing somewhat in composition, texture and structure. All transitions from fine-grained, poorly foliated, leptite-like gneisses to coarser-grained rocks and varieties more or less rich in dark mica may be observed. Some varieties with abundant biotite are distinctly foliated.

The rocks generally bear an aspect of migmatized series. Most common are the arterites composed of dark laminae rich in biotite or two micas, alternating with light and somewhat thicker laminae, built up essentially of quartz and feldspar. The strata are often folded and locally display an intricate ptygmatic folding.

The lamination, in some varieties gradually disappears being sometimes preserved in relicts only. In consequence of this, the migmatitic gneisses grade into migmatitic tonalites.

K. Smulikowski (1951) points out that the arterites of the Sowie Góry may have been formed in different ways. According to Finckh (1924) the banding of the arterites reflects the original alternation of greywacke and argillaceous laminae of the parental sedimentary series. Other authors accept a leucocratic "lit par lit" injection. Scheumann (1933) took these arterites as an example of metatexis, i.e., of ultrametamorphic process in mobilization of the "granitic" component of the paragneisses and in secretion of light coloured laminae. K. Smulikowski adds (1951) that the paragneisses may have been also formed by metasomatic granitization.

The paragneisses and arterites are characterized by the same mineral composition. The main constituents are quartz, oligoclase (20% An) and biotite. K-feldspar and muscovite are absent or occur in small quantities. Garnet and sillimanite, especially fibrolite, are very common.

According to some characteristic constituents different varieties of paragneisses and migmatites may be distinguished.

Microcline gneisses have been referred to as "augen-gneisses" ("granite-gneisses"). According to Grocholski (1967), they are strongly differentiated in structure and may occur as "augen", laminated or lepidoblastic varieties. The microcline gneisses form conformable intercalations or occur in longitudinal zones in the Sowie Góry migmatites and paragneisses. The main occurence is connected with the principal range of the mountains and accompanies its south-western slope.

The rock is rich in microcline; plagioclase (about 12% An), is less abundant (Polański 1955). They contain, as a rule, both white and dark micas; muscovite is present only in places. Fibrolite forms a common accessory mineral.

The microcline gneisses of the Sowie Góry were considered to be magmatic rocks in origin. Morawski (1973) showed, however, that they result from K-metasomatism of paragneisses. Microcline forms the youngest generation of feldspars which developed at the expense of earlier plagioclases, quartz and mica.

Granulites. Small bodies or intercalations of granulite are present in the Sowie Góry Block, most frequently in its north-western corner where the deepest part of the block is exposed. The granulites are light coloured, more or less laminated rocks. They contain elongated (flattened) grains of quartz, plagioclase, minute grains of K-feldspar, varying amounts of biotite, garnet and disthene. In places green hornblende and minute carbonate aggregates have been observed (Grocholski 1967). Dark intercalations with some pyroxenes and eclogite lenses have been reported from the environs of Bystrzyca. There are no sharp boundaries between the granulites and the enclosing gneisses.

Small bodies of serpentinite are also known from the Sowie Góry Block. The parental rocks (peridotites and picrites) were transformed during regional metamorphism.

Granites and granodiorites cut in concordant or discordant veins the Sowie Góry gneisses, being abundant especially where fibrolite gneisses occur. They have been formed in later phases of synkinematic migmatization and are evidently younger than the microcline gneisses. The granites are fine to coarse-grained, of granoblastic texture, with xenomorphic quartz and feldspars. They differ from the enclosing gneisses in a high content of K-feldspar and in the occurrence of muscovite. The mineral constituents do not exhibit a distinct orientation. In more leucocratic varieties the biotite is lacking and only more or less abundant muscovite occurs. The light, fine-grained aplitic and coarse-grained tourmaline-bearing pegmatite veins and nests may be observed. There are all transitions between the pegmatites rich in quartz and milky quartz veins.

Amphibolites occur as thin but frequent intercalations in the paragneiss complex. Both, para- and ortho-amphibolites are present.

Dolomitic and ferruginous marls are believed to be the parental rocks of the para-amphibolites. The type described by Polański (1955) contains (in decreasing order): hornblende, plagioclase, biotite, quartz and garnet. The ortho-amphibolites, often marked by a high content of titanium, represent rocks derived from diabases or diabasic tuffs (often with relicts of ophitic texture) or from coarse-grained gabbroic rocks with relicts of pyroxene and saussuritized plagioclase.

Crystalline limestones and lime-silicate rocks (erlans) may be encountered sporadically as small lenses in the Sowie Góry paragneisses. The crystalline limestone contains, besides calcite; diopside, grossular and other calcium silicate minerals. The lenticular intercalations of erlans contain quartz, pyroxene, amphibole and grossular, occasionally also graphite and zoisite.

Hyperites are the youngest rock of the Sowie Góry assemblage. They occur as small intrusive bodies among the older gneisses in the north-eastern part of the named unit, near the gabbro massif of Sobótka. They are probably Early Paleozoic or even Devonian in age.

STRATIGRAPHY

When studying the geology of the Central Sudetes in detail, a great antiquity of the formation described above becomes obvious. Bederke (1929) first drew attention to the fact that the crystalline rocks of the Sowie Góry block occur as pebbles and cobbles as early as in the Upper Devonian conglomerates which are most ancient psephites in the Central Sudetes. He also pointed out that the trends of the Caledonian and Variscan folds are strongly influenced by this block. The folds are arranged parallel to the three sides of the Sowie Góry triangle (fig. 3) forming thus a characteristic pattern, named by

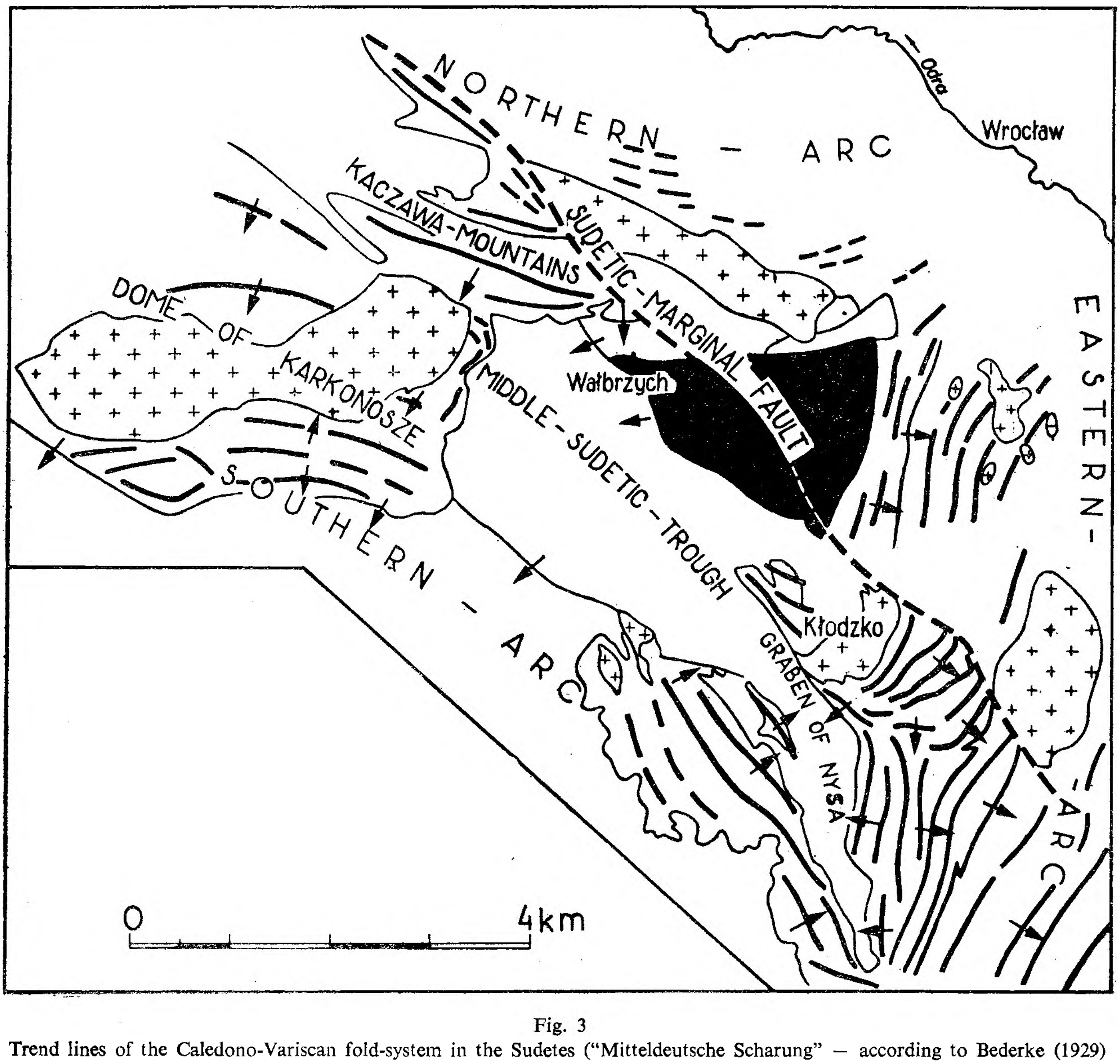

Fig. 3
Trend lines of the Caledono-Variscan fold-system in the Sudetes ("Mitteldeutsche Scharung" — according to Bederke (1929)
Solid black — Block of Sowie Góry; heavy black lines — general trends of folding; arrows — main directions of thrusting

Bederke (1929) „die mittelsudetische Scharung". In accordance with the author and some other geologists, the crystalline rocks of the block under discussion may be looked upon as Precambrian in age. Even an Early Precambrian age may be attributed to the supracrustal complex which has been transformed subsequently into paragneisses and migmatites (Polański 1955).

DEVELOPMENT HISTORY

In the geosynclinal basin, a thick sequence of sandy and argillaceous sediments originated. They were stratified in general, and in places thinly laminated. The psammitic sediments might have been arkoses and greywackes. Intercalations of dolomitic and ferruginous marls occurred occasionally; the lenses of pure limestones were scarce.

During the subsidence of the geosyncline the sedimentation was accompanied by a rather feeble basic volcanism giving rise to sporadic basaltic lavas and tuffs, sills and other subvolcanic intrusions. Intrusions of ultrabasic magmas also occurred. Finally, during the orogenic process, the supracrustal complex has been intensely folded and piled up, thus forming a huge body of sialic rocks. The lower tectonic units had been pressed down into deeper parts of the earth's crust and underwent progressive metamorphism which according to Polański (1955) reached the granulite facies (relicts of kyanite in paragneisses and occurrences of granulites amidst these rocks).

Subsequently, new crustal movements ensued, which lifted up and redeformed the rock complex under discussion. The sillimanite-almandine subfacies was installed (sillimanite and relicts ofalmandine) and finally equilibrated in the amphibolite facies. During this stage of retrograde metamorphism an anatectic process took place. According to Polański (1955) the sialic components of the paragneisses were mobilized giving arterites and other migmatitic rocks. As the composition of the most paragneisses and migmatites is very similar being very poor in potash feldspar in both cases, the light coloured layers and veinlets of artretites are presumably due to a partial solution in situ. Subsequently, in the course of some other phase of orogenic processes (supposedly in Late Precambrian) potash-rich granites originated. They are concordant and synkinematic.

The evolution of the rock-complex of the Sowie Góry Block has been terminated by diaphtoretic readjustments, bound with post-Precambrian movements. According to Polański (1955) these readjustments are evidenced by the formation of muscovite in the paragneisses and by the occurrence of secondary hornblende, chlorite, talk and serpentine in the ultramafic rocks. In highly redeformed parts, cataclastic crushing and even mylonitization took place.

TECTONICS

The oldest tectonic features of the Precambrian basement have been obliterated in the Sowie Góry region long ago by different processes — the successive metamorphic transformations and recrystallizations, the subsequent redeformation and a deep erosion reaching the root-portion of the highly-folded sequence.

The strike of the paragneiss and migmatite series is discordant with respect to the surrounding Variscan structures except for the eastern and a part of the south-western marginal zones. This discordant attitude is a proof of a great antiquity of the Sowie Góry Block.

Bederke (1929) has shown that all three sides of the Sowie Góry triangle are represented by major fault-zones. He has also pointed out that along the eastern and partially along the south-western margin of this triangle the gneisses were readjusted conformably to the adjacent younger structures. Here the Precambrian rocks were bent and sheared, or crushed and faulted conformably with younger formations. However, the interior of the Sowie Góry Block has been left relatively intact except for faults accompanied by mylonites.

Different types of mylonites have been reported by Scheumann (1937a) from the zone of Niemcza (figs. 1, 2) which borders upon the Sowie Góry block in the east. The origin of these rocks is due to the shifting of this block in the eastern direction which occurred, according to Bederke (1934), during the Bretonic phases.

The tectonic conditions along the north-western border of the Sowie Góry Block have been described newly by Grocholski (1958, 1961) who stated that the structural conditions of this border should be taken for the result of several superimposed deformations differing notably in age. During the Variscan epoch of folding, the triangle of Sowie Góry came into being as a rigid intramontane stable block, representing an uplifted fragment of the older basement. At this very time all three fault-zones bordering the triangle originated. The gneisses had been crushed during the Variscan movements along the south-western border of the Sowie Góry Block and have been transformed into cataclasites and mylonites. Nowadays, the cataclasites are well displayed only in the eastern-most part of the border under discussion.

The occupy here a zone which is about fifteen km long and more than one km wide.

The borders of the Sowie Góry block underwent a great modification during the Variscan epoch of folding. The south-western border has been dismembered by both longitudinal and transversal faults. In the western part, the rigid block of Sowie Góry has been pushed towards the SW onto the Carboniferous strata cutting them obliquely. When passing along the border of this block from the NW towards SE, first the Upper Culm deposits occur on the downthrown side of the thrust. Younger and younger Upper Carboniferous strata may be observed in this direction. Some of the older dislocations were rejuvenated in Early Tertiary time during the Late-Saxonian tectonic movements.

The faults bordering the Sowie Góry triangle are connected with great and deep-reaching disjunctive zones. These represent the most essential structural discontinuities of the earth's crust in the Sudetes and their foreland (the Subsudetic block), and were accompanied by volcanism or intrusions during the Variscan movements. We can see on the map (fig. 2) that a gabbro and serpentinite massif borders upon the Sowie Góry triangle in the north. The rocks may be Early Paleozoic or Devonian in age. Small bodies of serpentinite and gabbro as well as Late-Variscan granitoids occur along the eastern border of the Sowie Góry Block in the fault zone of Niemcza. Parallel to the SW margin of the block runs a volcanic range, with huge masses of extrusive rocks (porphyries and melaphyries) of Lower Permian age, locally more than two thousand meters thick. The Cambro-Silurian initial volcanism of the Kaczawa Mts. is also to be mentioned here. It attains its strongest development near the NW angle of the Sowie Góry triangle, and is represented by a greenschist formation up to two thousand meters in thickness.

The Sowie Góry block is cut by numerous faults of different directions and different mostly unknown ages which dismember the gneiss complex into many minor block units (Grocholski 1967).

Four sets of minor structures have been found in the Sowie Góry gneisses. The oldest poorly preserved structures (B_0) trend meridionally and may be linked with the Moldanubian or older folding. Most prominent is the second set of minor structures trending NW—SE and dipping in the NE direction. It is the strongest deformation of the Sowie Góry gneisses and is characterized by vast processes of migmatization. The folding had a SW vergency and was accompanied by granite intrusions and pegmatite dykes. It is rather of Moldanubian age. The third set of linear structures (B_2) and the corresponding foliation (S_2) of NE—SW direction is best developed in the NW part of the Sowie Góry block. These deformations are supposed to be Late Proterozoic. At that time ultrabasic intrusions occurred (Grocholski 1967, 1969). The fourth set of minor faults (lineation B_3 and foliation S_3) trends NNE—SSW and is well developed near the eastern margin of the region under discussion. It is apparently Variscan in age.

It must be emphasized that the mesostructural analysis in the Sowie Góry gneisses is not yet finished, and more detailed studies must be done to elucidate the problem of the sequence, the character and age of the deformations involved.

THE PRECAMBRIAN COMPLEX OF THE LĄDEK-ŚNIEŻNIK REGION (PL. III, IV)

STRATIGRAPHY

G e n e r a l r e m a r k s. The metamorphic rocks of this region have been looked upon as being partly Precambrian, even Archaean and partly Early Paleozoic in age. Now, however, the view prevails that they are all Precambrian (compare: K. Smulikowski 1951, Bederke 1956, and others). The complex in question has been divided by Fischer (1935) into two main units. The older unit, probably Archaean, was represented by paragneisses (the Młynów series, Mühlbach series of German geologists) and somewhat younger ortho- and migmatitic gneisses (Gierałtów gneisses, Gersdorfer Gneise of German geologists).

The supracrustal series of the younger unit (the Stronie-series, Seitendorfer Serie of German geologists) was estimated Upper Proterozoic and Cambrian in age and the accompanying gneisses (Śnieżnik gneisses — Schneeberg Gneise) were considered to be a granitic intrusion which took place in the Caledonian epoch of folding, between the formation of the Stronie series and the Gierałtów gneisses.

New detailed geological investigations (Oberc 1957) and especially the petrological studies of K. Smulikowski (1957) and his co-workers showed, that the Młynów-series may be correlated with the Stronie series and that evidence of only one supracrustal sequence is present in the region under discussion which is here comprehended under the name of Stronie Formation (sensu lato).

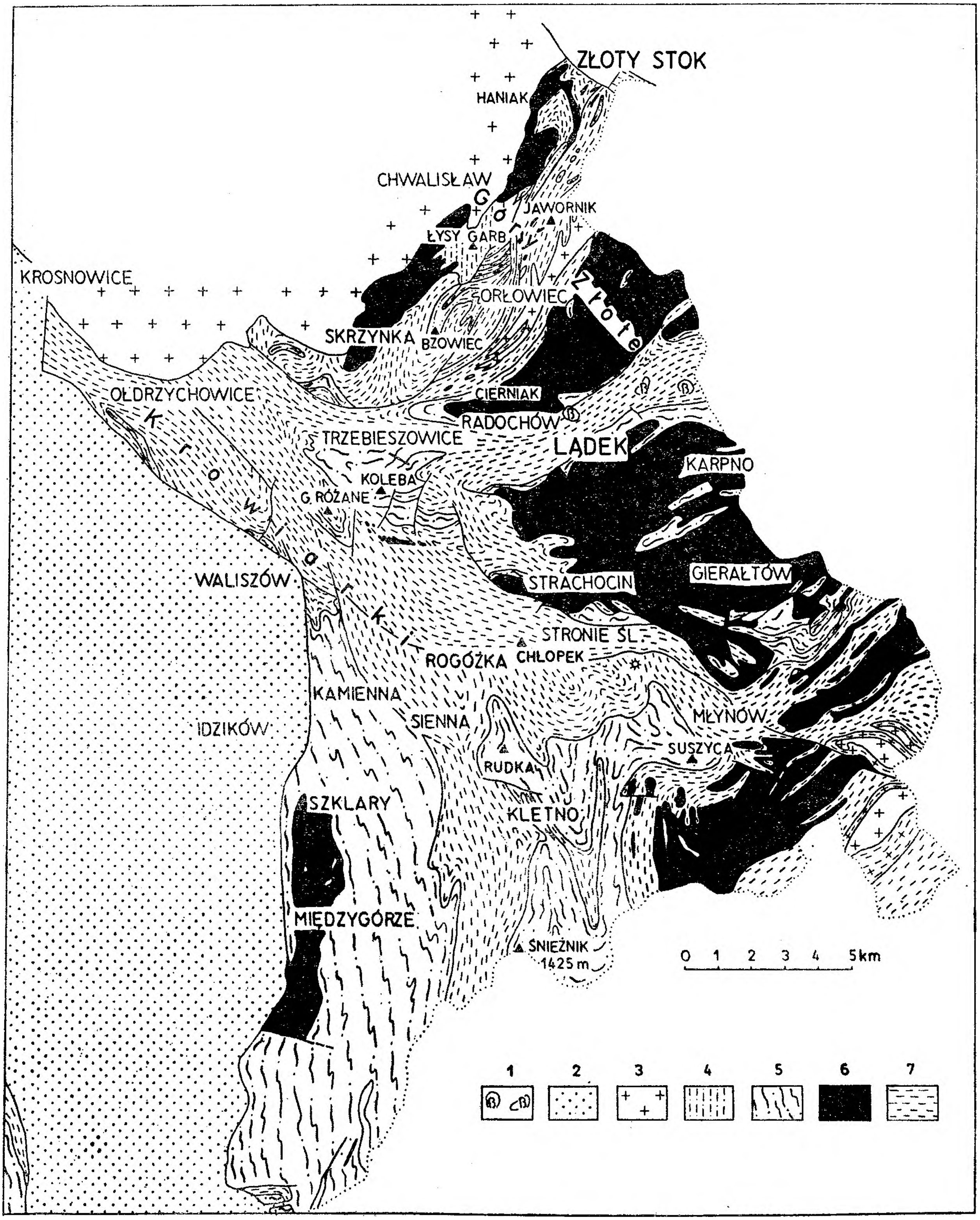

Fig. 4

Geological sketch map of the Lądek-Śnieżnik region (according to Don 1964)

1 — basalt (Tertiary); *2* — Upper Cretaceous deposits; *3* — Variscan granitoids; *4* — mylonites; *5* — Śnieżnik gneisses; *6* — Gierałtów gneisses; *7* — Stronie schists

Gradual transitions have been found between the Gierałtów gneisses and the Śnieżnik gneisses, the two rocks alternating in numerous layers. K. Smulikowski (1957, 1960) argued that both gneiss-types are of the same geological age and that they had been formed during the same tectogenic processes.

The supracrustal Stronie Formation (Finckh *et al.* 1942; Fischer 1935; K. Smulikowski 1957, 1960; T. Butkiewicz 1968) is composed essentially of mica -schists and paragneisses, quartzites and quartzite schists, amphibolites and amphibole schists, calcitic and dolomitic marbles and erlans.

Mica-schists and paragneisses of the Stronie series are linked together by gradual transitions and they often alternate many times with each other. They form the main rocks of the Stronie series. The mica--schists are usually well foliated rocks composed of thin laminae of quartz alternating with laminae containing muscovite and biotite in varying quantitative proportions. As a rule, muscovite predominates and occasionally it is the only representative of micas in the schists. In places larger quantities of chlorite occur and a small amount (0—10%) of plagioclase (oligoclase and albite) is often present. The albite blasts are generally more abundant. They have developed by successive replacing of micas. The main accessory minerals are garnet, staurolite and tourmaline; apatite and epidote are scarcer. Iron oxides and graphite are frequent. Black schists rich in graphite often form intercalations in the mica--schists and paragneisses.

When the amount of feldspar increases at the expense of quartz and mica, lamination and foliation become less distinct and the schists pass into more massive paragneisses. Several types of paragneisses have been distinguished by Butkiewicz (1968) in the Krowiarki range.

Quartzites are more or less schistose or layered rocks; they were looked upon as the lowermost part of the Stronie Formation (Vangerov, 1943). They are lacking in some sections and it seems that they appear at least locally in more than one horizon. They are white, yellow and greyish or dark grey and oven black and fine-grained, as a rule; coarse-grained varieties and especially fine-grained quartzose conglomerates are very rare. The light-coloured varieties pass vertically and often horizontally into mica-schists when the mica laminae grow in thickness and the quartz laminae diminish. The dark varieties contain graphite and may be intercalated by, or pass into black graphite-schists. The feldspars are occasionally abundant in the quartzites and in some regions transitions into quartzitic gneisses are present.

Amphibolites and amphibole schists are scattered as lenses and intercalations in different horizons of the Stronie Formation. According to K. Smulikowski (1960) they are either uniform greenish-black or laminated rocks. The light stripes are grey or yellow-green and are enriched in epidots, plagioclase, diopside, calcite as well as some other minerals. The amphibole rocks are both para- and ortho- in origin.

Butkiewicz (1968) has found in the Krowiarki range fine and medium grained amphibolites with green hornblende as the chief constituent. Plagioclase with 0—25% An, epidote concentrated mostly in albite blasts, zoisite and clinozoisite occur subordinately, while quartz, calcite, sphene and mica represent accessory minerals. Biotite may be often visible along the contact with gneisses, or in paraamphibolites which alternate with marbles. Lenses of calcitic or dolomitic marbles are common in some areas (Krowiarki). They are massive, uniform or striped and may contain intercalations of mica-schists and amphibolites. According to K. Smulikowski (1960) they contain admixtures of various accessory silicates as quartz, plagioclase, epidote, zoisite, phlogopite, termolite-actinolite, diopside, grossular and others, depending upon the primary sedimentary admixtures (sand, clay, dolomite) in the limestones.

The calc-silicate rocks (erlans), representing impure carbonate sediments occur far more rarely. They often alternate with calcite marbles and paraamphibolites. The main mineral components are diopside and epidote (J. H. Teisseyre 1961).

The Gierałtów and the Śnieżnik gneisses represent a special and very important problem. This rock assemblage may be estimated as being up to more than one thousand meters thick and occupies vast areas of the region. Both types of gneisses are now looked upon mostly as Late Proterozoic (Cadomian), though there are not adequate proofs supporting this view; the Caledonian age of the Gierałtów- and Śnieżnik gneisses can not be excluded.

The Gierałtów gneisses (Gersdorfer Gneise) have been described many times (Fischer 1935; Finckh *et. al.* 1942; K. Smulikowski 1952, 1957, 1960 etc.). The following petrographic description is based essentially on papers by K. Smulikowski (1957, 1960).

The Gierałtów gneisses are very variable. Usually they are fine grained; they may be massive, resembling a microgranite; or laminated, migmatitic in appearance. Massive layers contain separate, parallel oriented grains and flakes of mica. The varieties very poor in biotite and enriched in acide plagioclases have been distinguished as aplite gneisses.

In laminated gneisses the dark laminae, rich in mica, alternate with the light leucocratic ones. The light coloured laminae are composed essentially of quartz and feldspars; they are very thin up to several centimeters thick. The lamination is often irregular, swelling on and pinching out; lenslike and "augen" structures are thus formed. Lamination and foliation are often thrown into small folds; in the layers, the folds are rounded (open). Most deformations prove a high plasticity of the rocks involved. Even partial melting might have taken place in some portions, enabling the development of fluidal structures and small local intrusions (Don 1964). Different types of Gierałtów gneisses may alternate with each other, without distinct boundaries. They may also pass into each other laterally, within a few meters or even centimeters.

According to K. Smulikowski (1960) the main mineral components of the Gierałtów gneisses are; 1. Quartz, arranged usually in long, parallel stripes. 2. Plagioclases, exhibiting an automorphic tendency, An_{12}—An_{22} in composition, passing into albite in more leucocratic varieties and into basic oligoclase in darker rocks. The plagioclase is cloudy by sericite dust and often contains numerous intergrowths of other minerals. In places, especially in some leucocratic rocks, a younger plagioclase occurs, frequently replacing the older one. Old plagioclases often show dynamic deformations. 3. Microcline xenoblastic crystals replace plagioclases often producing "myrmekite". A penetration of plagioclase by the K-feldspar results in anti-perthite intergrowths. The microcline is never deformed, giving an impression of postkinematic blastesis. 4. Both white and dark mica occur in the Gierałtów gneisses. In some varieties, however, only biotite is present; muscovite is the only mica in leucocratic rock varieties.

Small grains of garnet are usually present in the Gierałtów gneisses, at least in traces. According to K. Smulikowski (1960) it is "distinctly retrogressive" and corroded.

Sporadic occurrence of metabasites is very characteristic of the sequence in question. They may appear in some more or less stable horizons as isolated and rather small lenticular bodies. Most metabasites are amphibolites; eclogites are rare.

The granite gneisses of Śnieżnik type differ distinctly in their typical development from the common representatives of the Gierałtów gneisses in texture and structure, though the chemical and mineralogical composition of both gneiss varieties is similar. The typical Śnieżnik gneiss is coarse-grained and exhibits "augen" structures. The "augen" vary considerably in size; they are formed of microcline which occurs in evengrained groundmass or as large individual crystals up to several centimetres and in places more than ten centimetres in size. The large and often pink-coloured microcline crystals are automorphic or nearly automorphic in places. Generally, however, they are stretched into elongated and parallel arranged spindles. According to K. Smulikowski (1957, 1960) these "augen" represent porphyroblasts grown at the expense of plagioclases, quartz and mica, which often occur as relicts enclosed in microcline. The same two generations of plagioclases which have been found in the Gierałtów sequence are also present in the Śnieżnik gneisses. The biotite and the muscovite form compact and coarse grained clusters. Separate mica flakes may occur in microcline porphyroblasts.

The granite-gneisses of Śnieżnik type form mostly large flattened bodies up to more than one thousand meters thick intercalated mostly between the Gierałtów gneisses and the Stronie schists. In places, small bodies of the Gierałtów rock-type occur in the gneisses of Śnieżnik forming sharply bounded enclosures. Also intrusive-like small bodies of the Gierałtów gneiss have been observed in the Śnieżnik gneiss. In places both rock types form alternating layers (fig. 5, W. Smulikowski 1959, 1959 a).

The petrogenetic relations. Fischer (1935), Finckh *et al.* (1942) considered the gneisses of Gierałtów as Early Precambrian in age and as migmatitic and partially even magmatic in origin. On the other hand, the gneisses of the Śnieżnik type were looked upon as ortho-rocks, formed and deformed during the Caledonian tectogenic processes. K. Smulikowski (1957, 1958 a, 1960), however, called attention to some facts strongly indicative of the rather metasomatic origin of the rocks in question and of close stratigraphic relations between the two main gneiss groups.

1. The Gierałtów and the Śnieżnik gneisses are linked by transitional zones, in which thick and thin layers of both rocks alternate many times, or they interpenetrate each other in a more intricate manner. As a rule, gradual transitions exist between the layers of the Gierałtów and Śnieżnik gneisses and even in one and the same layer. Sharp contacts are present in places too, but they are far less frequent.

2. The Gierałtów and the Śnieżnik gneisses are very similar in both the mineral composition and the sequence of mineral generations.

Hence, K. Smulikowski came to the conclusion that both rocks are of the same age and origin. He stated that they had been formed by granitization of the Stronie schists. At least two main generations of feldspars formed successively in a solid state, the younger generation replacing partially the older one. At first, plagioclase occurred and then microcline followed. Relicts of initial minerals, as formed in the crystalline schists, are everywhere present. In deeper horizons the replacement of quartz and biotite by feldspars attained more advanced stages and the microclinization of plagioclases was far stronger than in common paragneisses. In some layers of mica-schists granitization was only slightly accentuated; other more susceptible strata were transformed into paragneisses and the impure limestones gave the calc-silicate rocks (J. H. Teisseyre 1961).

The advanced granitization transformed, according to K. Smulikowski, the Stronie schists into the Gierałtów gneisses. In some parts of the supracrustal series the invading microcline was able to form large crystalloblasts. In these parts all traces of supracrustal origin have been obliterated and the initial rocks have been transformed "in situ" into the Śnieżnik "Augengneisses".

Relicts of layers o biotitized amphibolites and schists are arranged everywhere parallel to the foliation of the rocks and concordantly to the enclosing Stronie schists.

In some deep parts of the supracrustal complex subjected to metasomatic granitization, a high rheomorphic plasticity was attained. The leucocratic material was liquefied locally and the mobilized masses exhibiting a high degree of fluidity were squeezed up into overlying paragneisses and mica schists. Thus real small intrusions formed, but without typical contact or pneumatolytic minerals in the adjacent country-rocks. The temperature of the intruding masses was relatively low (500—600°C) and consequently most volatiles typical of granitic magmas were absent. The named author anticipates an intense synkinematic migration of Na and K from deeper, strongly heated parts of the forming tectogen.

On the contrary, Ansilewski (1966) claims that the migration was very restricted in space, taking place generally only in one and the same layer. The different types of gneisses thus reflect rather changes in mineral composition of the parental rocks.

Granulites and eclogites. All the occurrences of these rocks are associated with the Gierałtów gneisses. The granulites form a NE—SW trending zone up to about two kilometers broad and outcropping poorly in the northern part of the region mentioned, near a village called Stary Gierałtów. The granulite body is surrounded by typical Gierałtów gneisses which are supposed by some geologists to be a diaphtoritic derivative of the granulite. According to Kozłowski (1958), the granulite consists of quartz, acid plagioclase, microcline, minute garnet often arranged in parallel layers. Biotite is scarce forming gently curved streaks; it is sometimes dispersed within the fine-grained matrix. Rutile, kyanite and aggregates of hornblende have been found sporadically. The granulite contains dark, grey or greenish-grey layers up to several meters thick. The dark layers are frequently folded and may contain in turn thin laminae of light granulite, thus giving to the whole series a migmatitic appearance. According to the last-named author the dark laminae are true eclogites, while the somewhat lighter ones form gradations between eclogite and granulite, being intermediate in mineral composition.

The typical eclogites of Stary Gierałtów are representated according to Kozłowski by a dark-greenish rock, massive and rich in mafic minerals. The texture is heteroblastic. In a fine-grained granoblastic groundmass built up of oligoclase, microcline and quartz, larger grains of pyroxene and garnet occur, occasionally arranged in fine, parallel trending layers.

Garnet is the only euhedral mineral. The pyroxene is omphacite with about 25% of jadeite. The garnet abnormally rich in calcium is also typical of the eclogite facies. Kozłowski supposes that the above eclogites are isofacial with the accompanying granulites, or that the eclogites represent a certain subfacies of the granulite facies, depending upon primary chemical composition. Of gabbroic layers eclogite formed, while the more leucocratic intercalations changed into granulite in similar environmental conditions. Both rocks, however, are of supracrustal origin. It is supposed that, at first, they had been submitted to selective metasomatic granitization and then recrystallized under high p-t conditions.

Eclogites occur sporadically also outside the granulite zone of Stary Gierałtów, in the Gierałtów gneisses, as small concordant lenticular bodies. According to K. Smulikowski (1960, 1967), they are usually fine-grained, greenish or reddish rocks, composed of omphacite, garnet, amphibole and quartz. They often contain muscovite in considerable amounts and rutile kyanite, zoisite, iron ores, and pyrite as accessory minerals. The eclogites of the region are very varied rocks, each occurrence having its particular characteristics, depending upon the composition and the nature of the mother rock and upon environmental conditions. Eight types of eclogite differing in mineral composition, structure and texture may be distinguished in the Lądek-Śnieżnik region.

The eclogites represent transformed sediments as a rule. The mother rocks were most probably layers of iron-rich dolomitic marls, intercalated in a thick sequence of grey-wackeous and pelitic sediments. According to K. Smulikowski (1967), one single occurrence with a high Fe, Ti, P content and a low silica content might be developed from a basic igneous rock of lamprophyric character.

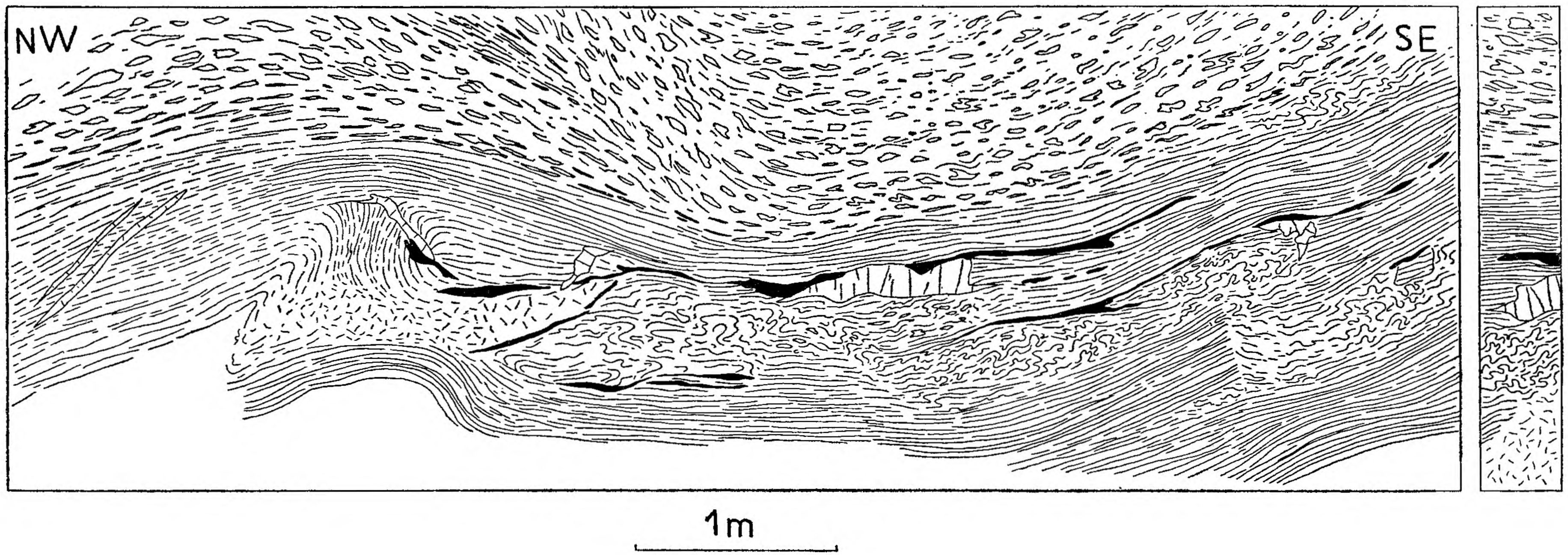

Fig. 5

Alternating Śnieżnik and Gierałtów gneisses in the transitional zone of Międzygórze. No sharp limit between the two rock types is to be noted

1 — coarse-grained Śnieżnik "augen" gneisses; *2* — gradual transition between the Śnieżnik and the Gierałtów "augen" gneisses; *3* — fine-grained and fine-laminated Gierałtów gneiss; *4* — fragments of biotitized amphibolite intercalations; *5* — quartz veins; *6* — Gierałtów gneiss with laminations deformed into small, fluidal folds, marking a high but local increase in plasticity of the rock; *7* — granitic rock with totally effaced directional (preferred) orientation of mica-flakes. The rock is coarse-grained

K. Smulikowski divided the metamorphic evolution of the region into four stages, as follows:

1. Pre-eclogitic stage: supracrustal chiefly sedimentary rock-complex with sills, dikes or pyroclastic intercalations of basic igneous rocks had been folded and metamorphosed.

2. Eclogitic stage: in deeper levels of the complex, intercalations of basic chemical composition have been subjected to eclogitization.

3. Amphibolitic stage: the omphacite was no more stable and it broke down to amphiboles and acid plagioclases. This may have occurred slowly under static conditions or suddenly in consequence of deformation.

4. Migmatitic stage: increasing mobilization of sodium and later mobilization of potassium caused selective granitization of the supracrustal complex. Amphibolites were more resistant to this process. The eclogites represent the metastable relicts of an early stage of metamorphism.

TECTONICS

The structural relations and the history of deformations are not adequately elucidated in the Lądek-Śnieżnik region as yet, the age of major tectonic events being disputable. Much difficulty in interpreting the structures arises from the uncertain stratigraphy, the scarcity of outcrops and from the intersection pattern of mesostructural elements, which is not clear in all details.

Most geologists suppose that the above described supracrustal complex might have been deformed initially during the Late Precambrian. Large portions of the complex were deeply downfolded. In this very time regional metamorphism occurred, a mica-schists sequence originated from the pelitic-greywackeous rocks. In the following Precambrian phase or during a younger tectonic phase the downfolding may have increased, and synkinematic granitization took place. According to K. Smulikowski (1957, 1958a, 1960) two successive alkaline fronts came into being, first plagioclase, later microcline-bearing. Thus, the mica-schists had been transformed into feldspathized schists or paragneisses, and in deeper or easier accessible parts strongly granitized Gierałtów and Śnieżnik gneisses originated (fig. 5).

The Gierałtów and the Śnieżnik gneisses are far more rigid than the encasing mica-schists and paragneisses. They acted as competent hardly flexible masses during the subsequent movements as it has been emphasized by Dumicz (1960, 1964). The age of the main folding is controversial in the Lądek-Śnieżnik region. It is estimated as Cadomian, Caledonian, Caledono-Variscan or Variscan. No convincing evidence has yet been found to solve unequivocally the problem. The mesostructural analysis of the region and of the adjacent areas, however, points to the Variscan folding as the most important one.

The style of folding has not yet been studied in details in the whole region. It seems, however, that shear-folding accompanied by thrusts is the ruling type of structures. Kodym and Svoboda (1948) postulated great Caledonian shear nappes in the Sudetes shifted towards the south or south-west (compare Watznauer 1953, 1955). Pauk (1953) drew attention to the fact that the crystalline series of the Orlické Hory Mts. and Bystrzyca Mts. on one side and the crystalline sequence of the Śnieżnik region on the other, are very alike and that they must belong to the same structural units. He also thought to have proved two great Variscan nappes within this area which had been shifted to the NE. The conception of Pauk has no adequate support in field evidence till now (Watznauer 1955), but small or greater thrusts are present in this region.

Thus, for example, it has been revealed by Kasza (1964) that the Śnieżnik gneisses in Kletno (north of the Śnieżnik massif) were shifted over a conglomerate, containing pebbles of unmetamorphosed rocks, supposed to be Carboniferous in age. The pebbles were imbedded in a black totally crushed matrix rich in coaly substance. The thrust plane dips gently to the east, as stated in an abandoned mine.

The Lądek-Śnieżnik area has been shifted "en block" towards the east during the Bretonian move-

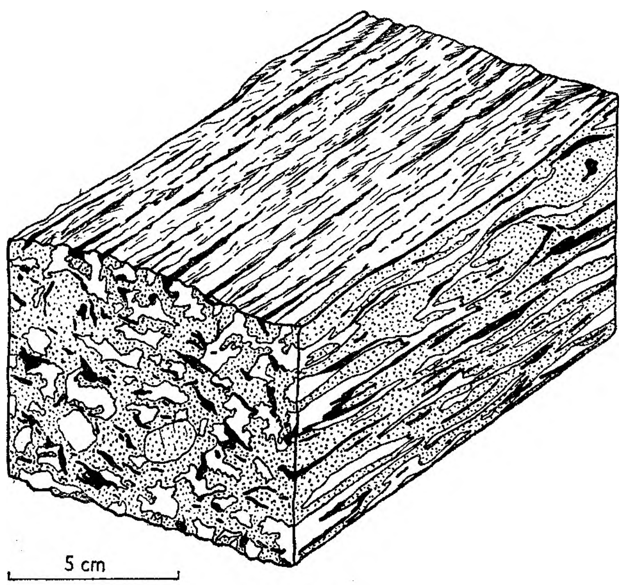

Fig. 6
"Augen" gneiss variety of the Śnieżnik type, with rolled-out microcline megablasts

white — microcline megablasts; dotted — groundmass composed mainly of quartz and plagioclase; solid black — mica, chiefly biotite. On the upper surface lineation (L_2 — rodding) well visible ments, as the Ramsova overthrust has been formed. The amplitude of this overthrust has been estimated by Oberc (1967) to at least 17 km.

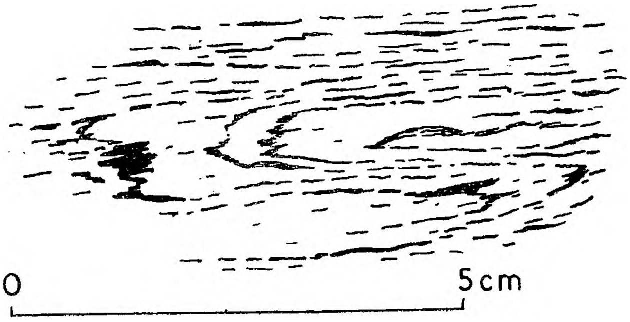

Fig. 7
Minor fold of the first generation (F_1) in the Gierałtów gneiss. According to a field sketch of the author

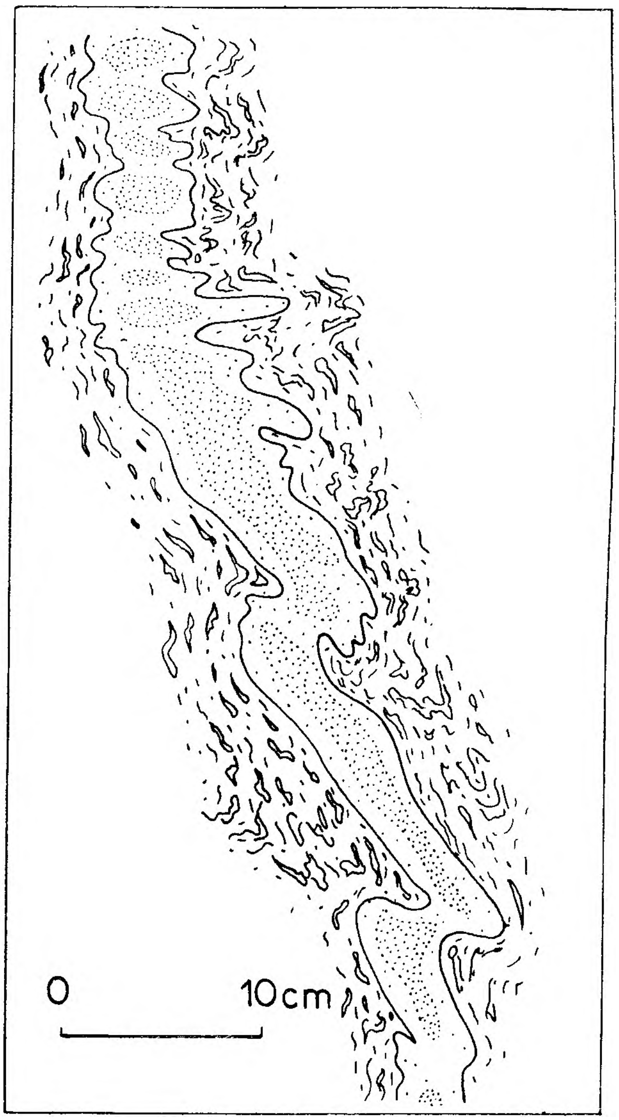

Fig. 8
Folding (F_2) and boudinage in aplitic layer, intercalated in the Gierałtów gneiss of migmatitic appearance. According to a field sketch by the author

Fig. 9
Irregular quartz rods in the mica-schists of the Stronie series. According to a field sketch by the author

According to Don (1964) the Lądek-Śnieżnik region contains four anticlinorial uplifts, with Gierałtów gneisses in the core and Śnieżnik gneisses on their limbs. The uplifts are arranged in a fanlike "virgation of Lądek", facing towards SE (fig. 4) and are separated by schists and paragneisses of the Stronie Formation (cf. Bederke 1929 — "die mittelsudetische Scharung"). The accompanying sketch (fig. 10) represents a schematic section across the SW (Śnieżnik) branch of the Lądek virgation.

A detailed study of minor structures has been in progress in the Lądek-Śnieżnik area for several years. At least four to five sets of linear structures have been revealed till now. The oldest set (F_1) preserved only in relicts is generally formed by isoclinal or very tight folds with axial planes parallel to foliation. In the Śnieżnik Massif the folds trend in a N—S direction. The F_2 set consists of minor folds with prevalent eastern vergency and different types of lineation as: rodding, pencil structures, wrinkling,

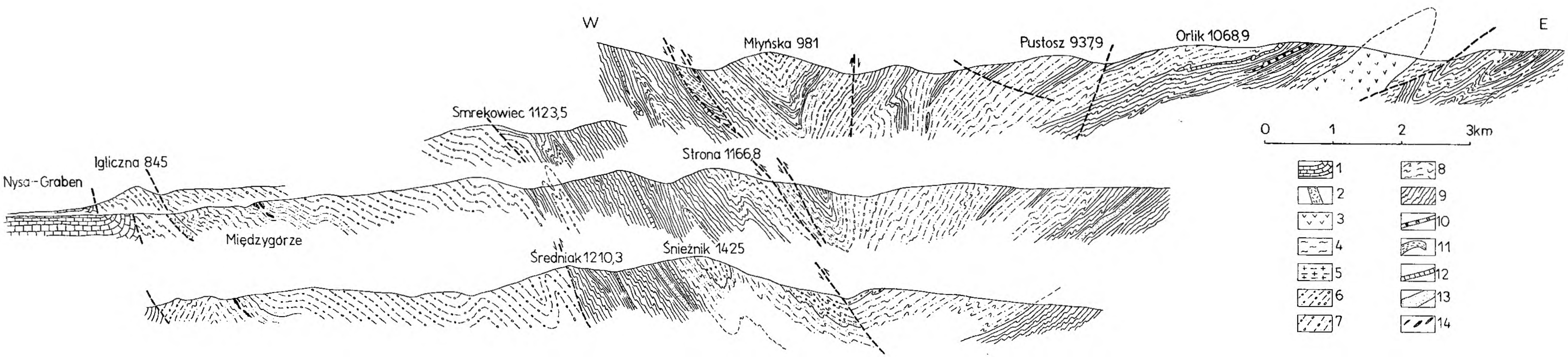

Fig. 10

Structural cross-section through the Śnieżnik and the Bialskie Mountains. The part east of Śnieżnik according to Kasza (1964), the part to the west of Śnieżnik according to H. Teisseyre (1957)

1 — Upper Cretaceous; *2* — mylonites; *3* — tonalites; *4* — injected amphibolites and migmatitic gneisses; *5* — amphibolites with injections of gneisses; *6* — gneisses of the Śnieżnik type; *7* — gneisses of the transitional zones; *8* — gneisses of Gierałtów; *9* — mica-schists and paragneisses; *10* — amphibolites; *11* — crystalline limestones and erlans; *12* — graphite-bearing quartzites and schists; *13* — quartzites; *14* — eclogites (*9—13* — different lithological components of the Stronie series) boudinage, mullion structures and spindles of microcline megablasts. A pronounced mineral parallelism may be observed. The set F_3 trends NE—SW as a rule. F_4 is composed of folds (often kink-bands) and wrinkles exhibiting the NW—SE direction. F_5 consists of flexures and kink-bands trending approximately E—W.

THE PRECAMBRIAN COMPLEX OF THE BYSTRZYCA AND ORLICKÉ HORY MTS (FIGS 1, 2, 11)

STRATIGRAPHY

The Lądek-Śnieżnik region forms the eastern limb of a vast dome-like elevation called the dome of Śnieżnik; the Bystrzyca and the Orlické Hory Mts. represent the western limb of this prominent structure. The middle (axial) part is occupied by a deep graben filled up with Upper Cretaceous deposits. The Bystrzyca and the Orlické Hory Mts. are represented in the morphology by three parallel, SSE—NNW trending ridges. According to Cloos (1922) they form as assemblage of three longitudinal -blocks, tilted in the SW direction. The eastern sides of these blocks moved up in relation to their western sides, which have been tilted towards W or SW.

In the mountain ridges and in the east-facing fault scarp metamorphic rocks are uncovered. On the tilted western sides, patches of Upper Cretaceous sediments occur, representing remnants of a previously uniform transgressive cover, worn back mostly by the erosion during Cenozoic times.

The stratigraphy of the Precambrian complex in the Bystrzyca and Orlické Hory Mts. resembles that of the Śnieżnik-Lądek region. Within a highly folded supracrustal sequence bodies of concordant granite-gneisses occur (the Bystrzyca gneisses of Dumicz). They are more resistant than the schistose supracrustal rocks, thus forming the crest parts of the mountain ridges. The supracrustal sequence is represented by mica-schists, paragneisses, quartzites, amphibolites and marbles, erlans and porphyroids being far scarcer. The description beneath is based on the papers by Dumicz (1960, 1964) and Gierwielaniec (1957, 1965).

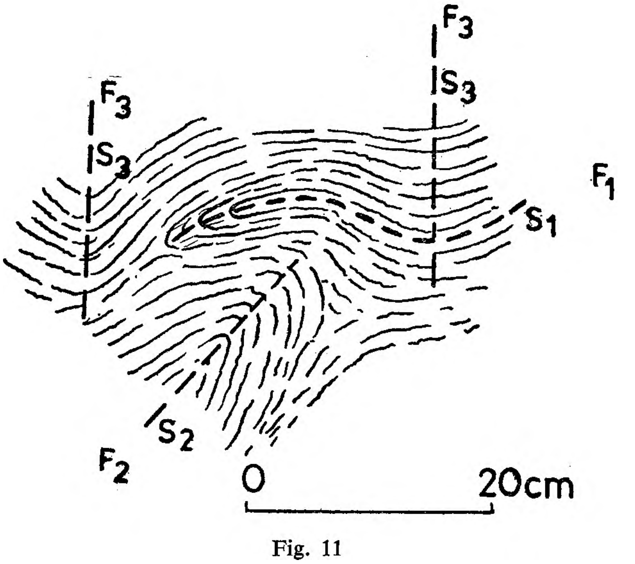

Fig. 11
Crumpled mica-schists in the Bystrzyca Mts. Visible are three generations of minor folds: F_1, F_2, F_3. S_2, S_2 and S_3 indicate the corresponding axial planes. According to a field sketch by the author

The mica-schists are well foliated rocks containing biotite and muscovite in very variable proportions, sometimes accompanied by chlorite and epidote. The mica-schists are more or less feldspathized and grade into more massive paragneisses.

The quartzites are light-coloured, mostly laminated and thin-layered rocks, containing parallel stripes of white mica, sometimes with admixture of biotite. In places numerous porphyroblasts of feldspar may be observed. The quartzites mostly occur along the boundary between the mica-schists and the Bystrzyca gneisses.

The amphibolites forming intercalations in the mica-schists consist of hornblende, plagioclase, epidote and calcite. Biotite occurs sporadically, above all at the contacts with the granite-gneisses. Titanite is a common accessory mineral.

The marbles are fine- or coarse grained, often streaky. Even thick and massive layers may contain parallel oriented muscovite and biotite flakes scattered scarcely in the rockmass. The mica may also form thin intercalations producing a marked bedding. The marbles are often linked with the mica-schists by transitions displaying thin layers or laminae of crystalline limestone, in alternation with slender laminae of well foliated schists.

The calcite marbles are accompanied in places by dolomitic lenses or by calc-silicate rocks, which are most common near the contact with the gneisses.

The granite-gneisses of the Bystrzyca and Orlické Hory Mts. are usually pink-coloured; they may be linked with the mica-schists by transitional zones. In such zones the rock is medium-grained, showing a distinct schistosity and often pencil structures. Intercalations and lenses of quartzites and graphite-bearing quartzitic schists may locally occur, the lenses of mica-schists being less abundant.

The granite-gneisses may be fine-grained and fine-laminated or massive aplite-like rocks. The most typical are the coarse-grained "augen-gneisses" with pink microcline porphyroblasts up to several centimetres in diameter. The "augen" are often stretched in parallel arranged spindles; the rock bears a striking resemblance to the Śnieżnik gneisses while the fine-grained varieties are similar to the Gierałtów gneisses.

The Bystrzyca gneisses are closely related in composition, age and origin to the gneisses of the Lądek-Śnieżnik region and occur in the same stratigraphical position.

TECTONICS

The tectonic development of the Bystrzyca nad Orlické Hory Mts. is similar to that of the Śnieżnik and Lądek region. The initial folding, seems to be Cadomian or Variscan.

The major structural units form an assemblage composed of three parallel zones of granite-gneisses, trending SSE—NNW and dipping monoclinally towards the south-west, generally at moderate angles.

Dumicz (*loc. cit.*) interprets the zones of granite-gneisses as anticlinal or thrust units moved towards the NE. The schist sequences, separating them, form the cores of synclinal structures.

The latest detailed structural investigations have shown that at least four or five generations of linear structures had been formed nearly everywhere in the region under discussion. They may be correlated easily with the linear structures of the Śnieżnik region.

The Lądek-Śnieżnik region as well as the Bystrzyca and Orlické Hory Mountains have been highly faulted during the alpine movements in Early Tertiary times. According to Dumicz (1960, 1964) first a nearly meridionally trending set of faults came into being which dismembered the whole area into longitudinal blocks, tilted towards W in the Bystrzyca and Orlické Hory Mts., with fault scarps facing the Nysa graben. A set of younger transversal faults disrupts the longitudinal dislocations. There is a common view that the Late-Saxonian fault pattern originated in the Sudetes by the rejuvenation of older, above all Hercynian faults. Dumicz (1960) revealed some evidence to confirm this assumption but in most cases the exact proofs are lacking. According to Don (1960) at least some of the post-Upper Cretaceous faults may represent independent structures resulting from new tectonic conditions.

THE METAMORPHIC REGION OF KŁODZKO (FIGS 1, 2, 12)

STRATIGRAPHY

In the town named Kłodzko and in its vicinity metamorphic rocks of the old basement crop out. The uplifted block is surrounded by a younger, unmetamorphosed sequence of Late Devonian, Early and Late Carboniferous and Early Permian age (fig. 2).

The uplifted block is elongated in the NNW—SSE direction and measures more than 15 km in length and up to 8 km in width. The strata strike nearly E—W or SE—NW and are strongly deformed.

The region under consideration may be divided into two parts. The northern part is built up of slightly metamorphosed Silurian rocks. In the southern part, higher metamorphic elements occur, which may be included into the Precambrian, though their stratigraphic position is rather uncertain.

The area was newly investigated by Wojciechowska (1966) and the southern part by Kozłowska-Koch (1960a).

In this part, following rock assemblages have been differentiated by the latter author: 1) ortho-amphibolites, 2) metavolcanites, 3) Ścinawka-gneisses, 4) phyllites and 5) metalydites. Among the amphibolites, many varieties differing in metamorphic grade have been distinguished. The original rocks — diabases and gabbros — have been highly deformed and subjected to a process of granitization. Relicts of hornblende gabbros may be observed in places, and in one case even a pyroxene of the original rock has been preserved. Usually, however, the pyroxene was replaced entirely by uralitic hornblende, and barroisite, and the feldspars were subjected to saussuritization. Afterwards the plagioclase recrystallized into albite, the sericite grew into muscovite flakes and common epidote originated at the expense of clinozoisite. During the next stage, light-coloured, mostly acidic infiltrations were introduced (quartz, feldspars), penetrating some parts of the amphibolitic rocks along their schistosity and thus giving a fine-striped rock variety. The infiltration was connected with a general feldspathization of the area. The rocks have been enriched in leucocratic components as plagioclase and quartz. The hornblende underwent biotitization and chloritization, while the epidote has been more or less resorbed. The subsequent period of strong deformations resulted in more or less advanced cataclastic textures.

The metavolcanites were described by German geologists under the collective name of keratophyres. They are, however, widely differentiated in composition, corresponding originally to rhyolites, andesites and basalts. The metavolcanites are generally light in colour and exhibit a distinct secondary cleavage or even schistosity. They have also been affected by regional granitization. At first albite blasts formed. Subsequently microcline developed, which was finally replaced by chess-board albite by a second Na-bearing front.

The Ścinawka gneisses form the third crystalline assemblage of the Kłodzko area, being now considered together with the adjacent amphibolites and metavolcanites as Precambrian in age. The Ścinawka gneisses have been described first as magmatic rocks transformed into gneisses during the Caledonian epoch of folding, but Kozłowska-Koch proved that they formed rather by metasomatic feldspathization of different supracrustal rocks. The primary minerals have been replaced by three successive generations of feldspar, the same as the adjacent rocks but this process was far more advanced in them. The gneisses of Ścinawka are very different in appearance, the differentiation being largely dependent upon the nature of the original rocks.

Three main types of rocks may be distinguished here: 1) ortho-amphibolites: medium-grained, dark coloured variety, derived from gabbros and diabases; 2) light-coloured, finegrained rocks of granitic and aplitic composition, derived from acid lavas; 3) porphyroblastic "augen" gneisses of granitic composition, which originated from sedimentary materials — tuffs and shales (Kozłowska-Koch *loc. cit.*).

Subsequent strong movements resulted in a more or less intensive mechanical transformation of the granitized sequence. All transitions from feebly crushed rocks to true mylonites and even ultramylonites may be observed (Wojciechowska 1966).

A postkinematic recrystallization furnished a new type of granitized rocks, which is clossed by M. Kozłowska-Koch as blastomylonitic gneisses. The more or less advanced recrystallization of crushed grains in a granoblastic ground-mass and the occurrence of great blasts of healed and recrystallized albite are the most characteristic features of this type.

TECTONICS

According to Wojciechowska (1966), three main structural units are present in the Kłodzko metamorphic region. In the central part an anticlinorial uplift pccurs with the Ścinawka gneisses in the core. On ooth sides two complicated synclinorial units are bresent. The northern synclinorium is built up of an intricately folded Silurian sequence of great thickness. It is pushed towards the south and thrust on the anticlinorial uplift. The folds trend nearly E—W or in the WWN—EES direction and plunge westwards conformably with the main set of linear structures (F_2). The main folding and the main lineation may be Late Caledonian or Early Variscan in age. A prominent meridional transversal fault system cuts the whole area.

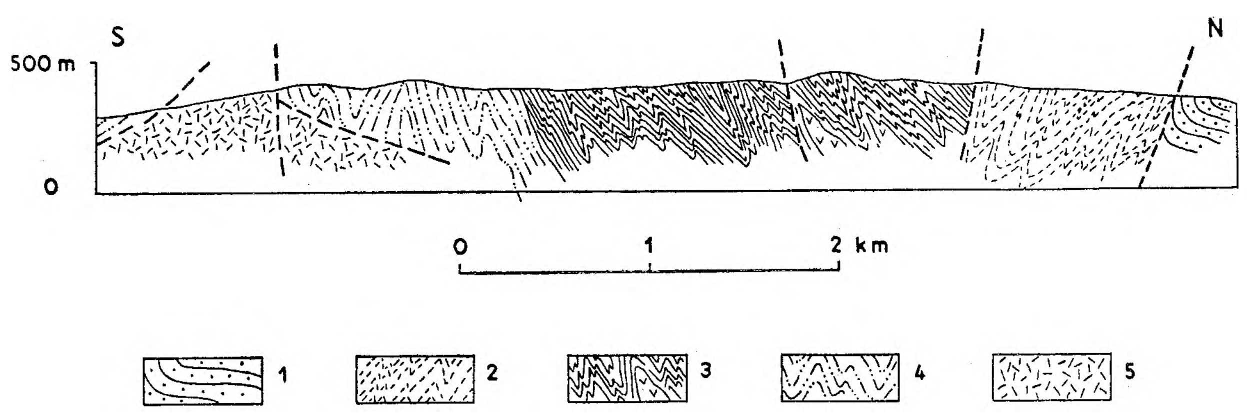

Fig. 12

Structural cross-section through the metamorphic series of Kłodzko. According to Irena Wojciechowska

1 — Lower Permian; *2* — argillaceous slates; *3* — chlorite schists with lenses of crystalline limestones; *4* — amphibole-epidote schists; *5* — cataclasites and mylonites ("gneisses of Ścinawka")

THE NIEMCZA FAULT ZONE, THE NIEMCZA-KAMIENIEC ZĄBKOWICKI METAMORPHIC AREA AND THE STRZELIN-ZIĘBICE METAMORPHIC ROCKS

Immediately east of the Sowie Góry Block the N—S fault zone of Niemcza occurs; according to Bederke (1929, 1929a) it represent a strongly folded graben-like downwarped area.

The most characteristic rocks of this area are blastomylonites initially taken for greywackes of the Lower Carboniferous age. Scheumann (1937a) showed, however, that these rocks originated by mylonitization of the crystalline rocks of the Sowie Góry block. They are accompanied on gliding planes by ultramylonitic intercalations (pseudotachylites), formerly taken for Silurian lydites. The blastomylonitic rocks are genetically associated with the thrust of the Sowie Góry Block to the east (Bederke 1929, 1929a, 1931, 1934; Scheumann 1937).

These movements are thought to be Bretonian (Bederke and other geologists) late Precambrian (Oberc 1966), or caused by more than one deformation phase (Dziedzic 1961). The main rocks of the crystalline complex of presumed Upper Proterozoic age of the area under discussion are lightcoloured quartzites, graphite quartzites with intercalations of graphite schists, and pencil gneisses. They are very alike some Precambrian rocks common in the Lądek-Śnieżnik region. A pecularity of the Niemcza zone are small intrusions of serpentinized peridotites, gabbros and granitoids. The serpentinites and gabbros are probably Devonian in age, though they are assigned to the Proterozoic by Oberc (1960a). The granitoides belong to the Late Variscan assemblage.

The foliation dips generally towards E in the western part of the Niemcza-zone and in the adjacent marginal sections of the Sowie Góry Block, towards W along its eastern margin, this giving an appearance of a fan-like structure.

The metamorphic area of Niemcza—Kamieniec Ząbkowicki has been recently re-examined by Dziedzic (1966). It borders upon the Niemcza zone in the east. The area is composed mainly of mica-schists and gneisses, looked upon by Fischer (1936) and Oberc (1960a, 1966) as Proterozoic. Bederke (1929a, 1929, 1931, 1934) traced namely in this zone the "Moldanubian overthrust". The western (Moldanubian) part of the Sudetes has been shifted eastwards onto the Silesian part along this overthrust plane (Suess, Bederke). Oberc (1966), however, expressed the view that the Moldanubian overthrust is situated further to the east, rather amidst the Strzelin—Ziębice crystalline complex.

The main rock type of the Niemcza—Kamieniec Ząbkowicki area are mica-schists. They are fine or coarse-grained, often with accessory garnet, staurolite, kyanite, andalusite and sillimanite, and occasionally contain intercalations of quartzitic schists. Locally black, graphite-bearing mica or quartizite-schists are present, amphibolites and crystalline limestones being very rare. The latter form interlayers or thin laminae in the mica-schists.

In some horizons, intercalations of fine-grained or even aphanitic quartz-feldspar schists occur, usually poor in mica. The feldspar is represented by plagioclase or microcline, the latter forming porphyroblasts in places. These rocks described previously as ortho-gneisses, aplite-schists or blastomylonites, are rather rhyolitic lavas or tuffs in origin (Dziedzic *loc. cit*).

In the Strzelin-Ziębice region, the Variscan granites and the metamorphic country rocks are present. Wójcik (1968) divides the respective metamorphic complex of the Strzelin-Ziębice region into two main groups: the groups of highly metamorphosed rocks and another one of lower degree of metamorphism. The first group may be looked upon as Proterozoic and the second one as Devonian. The group of higher metamorphism comprises the following lithological units: Strzelin granite gneisses, thin-flasered "augen" gneisses, mica-schists, amphibolites, crystalline limestones and calc-silicate rocks. The group of a low degree of metamorphism consists of quartzitic meta-conglomerates, quartzitic schists, polymict meta-conglomerates and intercalations of metagreywackes.

A somewhat different stratigraphic scheme has been given by Oberc (1966) for the environs of Strzelin The scheme is as follows:

Proterozoic: mica-schists and paragneisses, grey quartzites, graphite-bearing schists and quartzites, limestones and calcsilicate rocks, amphibolites, Strzelin-gneisses and metamorphic pegmatites.

Lower and Middle Devonian: Jegłowa beds, quartzites, conglomerate-like tectonites, Krzywina meta-conglomerates, meta-arkoses, sericite schists, phyllites, meta-tuffs of basic character.

Both stratigraphic assumptions however, are, uncertain. Especially the Strzelin-gneisses known formerly as older granite are erroneously classed with Proterozoic rocks by Oberc (1966). These rocks (gneissose granites) owe their origin to granitization of crystalline schists of sedimentary origin, as stated by Borkowska (1956). The granitization was accomplished by albitization and afterwards by microclinization of the primary material. These processes may have been caused by the same plutonic intrusion, which subsequently furnished the Late-Variscan Strzelin granite. The mother rock of the gneissose granite was probably Proterozoic in age, but the granitization and its products were rather Variscan.

The strike and the dip of the main foliation are variable in the Strzelin-Ziębice area; N—S or NE—SW strikes prevail. Both groups of metamorphic rocks are deformed into complicated thrust units trending N—S or NE—SW and shifted towards the SE (Wójcik 1968). The main deformation seems to be Bretonian throughout the whole region. There is no evidence for the Late Proterozoic folding postulated by Oberc (1966). Three distinct generations of linear structures have been revealed in the area under discussion by Oberc (1966) and Wójcik (1968). Oberc (1966) classed the three linear structures of the area of Strzelin according to the age he presumed. Wójcik (1968) has found some evidence pointing out that all three lineations are younger than the supposed Precambrian. He observed the B_1 set of linear structures in both the higher metamorphic rocks (Precambrian ?) and the series exhibiting a low degree of metamorphism (Lower- eventually also Middle Devonian) but he did not exclude that the B_1 set consists of two homoaxial generations, an older and a younger one.

The B_1 lineations trend NNE—SSW in general. In the northern part of the region it dips towards the NNE, in the southern part in opposite direction. The B_2 lineation plunges towards NW in the western part of the region and towards SE in the eastern part. The lineation B_3 is represented by flat open minor folds, plunging mainly towards WWS or EEN. The B_1 and B_2 lineations show that the rock assemblage of the Strzelin-Ziębice forms a dome-like elevation (Wójcik, *loc. cit*).

It is noteworthy that Dziedzic has found newly five sets of linear structures in the Niemcza-Kamieniec Ząbkowicki zone built up of mica-schists and gneisses (oral information). They may be correlated with the five generations of linear structures of the Lądek-Śnieżnik region. The set F_2 corresponds with the lineation B_1 as described by Wójcik. F_4 may be correlated with B_3 of the last author.

THE KACZAWA MOUNTAINS AND THEIR EASTERN PROLONGATION (FIGS 2, 13, 14; pl. V, 2)

The Kaczawa Mountains and their prolongation in the Sudetic Foreland represent one of the three orogenic areas, which border on the three sides the Sowie Góry triangle. It is the northern arc of the Sudetes, which has been highly folded in Early Variscan times. This arc is built up of two different rock complexes. The older, forming the basement is slightly metamorphosed in epizonal conditions. It consists of a Cambro-Silurian sequence, with Late Precambrian or rather Eocambrian beds in the basal portion. The overlying rocks are Permo-Mesozoic in age, being only preserved in Late Saxonian synclinal grabens.

There are some serious uncertainties in the stratigraphy of the basement sequence in the area under discussion. The diagnostic fossils have been found in the Devonian, Silurian, Ordovician and Lower Cambrian beds; the deeper sequences are entirely unfossiliferous. The stratigraphical column of the region is thus based partially on the relative position of major lithological units and on comparisons with adjacent regions, where the age has been proved by fossils.

The basal portions of the Cambro-Silurian in the Kaczawa-Mountains is represented by crystalline limestones, known under the name of Wojcieszów limestones (Kauffunger Kalke of German geologists). They represent the Lower Cambrian and perhaps also a part of the Middle Cambrian. The Wojcieszów limestone is well developed only in the south-eastern part of the Kaczawa Mountains, occurring on both flanks of a large and complex anticlinal uplift, called anticline of Bolków-Wojcieszów (figs. 13, 14); (Kauffunger Sattel of German geologists). The limestone is underlain by a sequence of schistose rocks, named the schists (beds) of Radzimowice (Altenberger Schiefer), and considered as Upper Proterozoic or Eocambrian. There is, however, no evidence of angular unconformity between this Eocambrian and the Wojcieszów limestone; on the contrary, both sequences grade into each other. This lithological transition has been proved by trenches and many pits dug down to the bedrock. The limestone beds are progressively thinner towards the base, while the intercalations of sericitic and chloritic schists grow gradually in thickness. In the highest Radzimowice schists only thin lenticular intercalations of limestone are encountered.

The Radzimowice schists are variable in texture, in mineralogical composition and in megascopic appearance. Block (1938) described three main facial varieties, supposing that they represent different stratigraphical horizons, but the lithological varieties are more numerous and they are often linked by gradual transitions. In the eastern part of the Bolków-Wojcieszów anticline the development of the Radzimowice beds is somewhat different than in its western portion. The main type of the eastern part is represented by dark-grey and black slates. These slates consist of laminae of light, fine-grained quartzite, alternating with thin laminae constituted largely of sericite. Secondary albite grains are more or less abundant. The dark colour is due to fine pigment of graphite. The laminae are up to several millimetres or more in thickness or they are thinner than one millimetre. The slates are generally crumpled; the quartz laminae are often rolled out into boudins and irregular fine rods. Where quartzite intercalations disappear, the slates become very finefoliated, and black in colour. Larger or smaller lenses of a black, finelly recrystallized lydite occasionally occur. When the quartzitic intercalations increase in thickness, and the small sericitic laminae thin out and vanish partially, the slates grade into quartzite schists and quartzites, very variable in megascopic appearance and colour. They are light coloured, nearly white or grey or even black, some of them being thinly striped.

On the other hand, the grey slates may pass into sericite schists, when the quartz grains decrease in amount and the quartz laminae are absent or very subordinate. Then the white varieties resemble the phengite schists of the Ordovician. The sericite schists, usually occur as local lenses or thin intercalations.

In the uppermost part of the Radzimowice beds, slates rich in sericite or in sericite and chlorite may be often encountered. They sometimes resemble the greenschists and occasionally contain thin lenticular intercalations of crystalline limestone. In the western part of the Bolków-Wojcieszów anticline the greywacke-like slates are the predominant facies.

The Eocambrian, Cambro-Silurian and the Devonian sequences of the Kaczawa Mts. have been

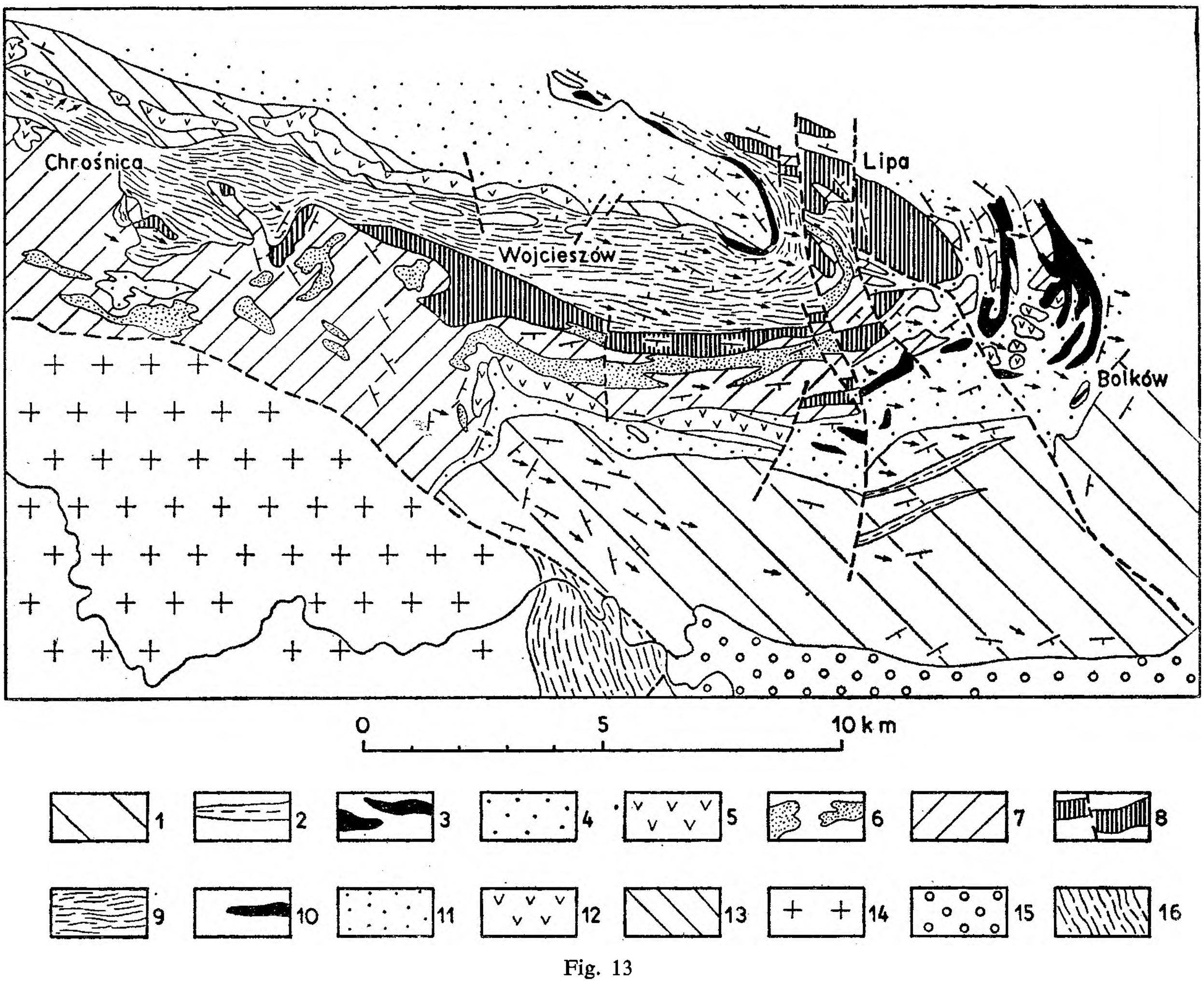

Fig. 13

Geological sketch-map of the anticline of Bolków-Wojcieszów (SE part of the Kaczawa Mountains). Based on the maps of Zimmermann and the author's detailed mapping

Dobromierz unit: *1* – greenschists; *2* – chlorite and sericite schists (*1* and *2* – Upper and Middle Cambrian); Bolków unit: *3* – Silurian, *4* – Ordovician, *5* – keratophyres, *6* – porphyroids, *7* – greenschists (*5–7* – Upper and Middle Cambrian), *8* – Wojcieszów limestone, *9* – Radzimowice slates – Eo-(Infra)-Cambrian; Świerzawa unit: *10* – Silurian, *11* – Ordovician, *12* – keratophyres, *13* – greenschists (Upper and Middle Cambrian); *14* – Karkonosze granite; *15* – conglomerates and breccias of the Intrasudetic Basin (Lower Carboniferous); *16* – metamorphic rocks of the Rudawy Janowickie Range (Early Paleozoic)

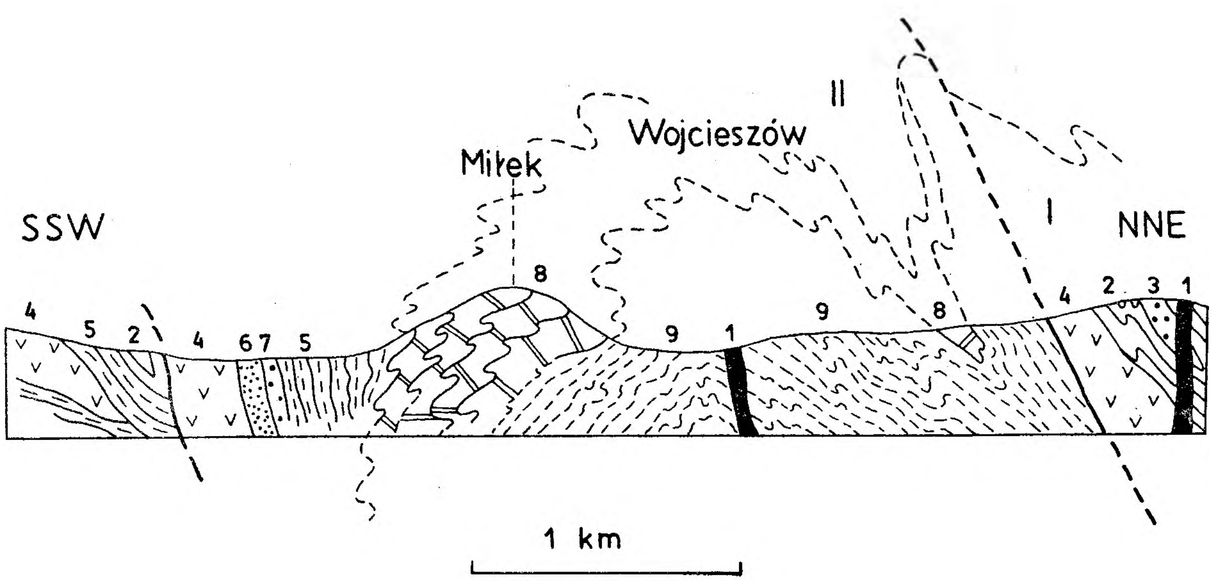

Fig. 14

Geological cross-section through the Bolków-Wojcieszów anticline along the Kaczawa River. According to the author's mapping

I — Świerzawa unit; *II* — Bolków unit: *1* — Young Paleozoic volcanites; *2* — Ordovician slates; *3* — Ordovician greenstones (diabases); *4* — keratophyres; *5* — Cambrian greenschists; *6* — Cambrian greenstones (mainly spilites); *7* — Cambrian porphyroids; *8* — Wojcieszów limestones (Lower Cambrian); *9* — Radzimowice beds (Eocambrian)

deformed several times. The Early Variscan intensive folding has been succeeded by Late Variscan refolding, faulting and uplift. Feeble Kimmerian readjustment had been followed by a strong Alpine compression linked with intensive faulting, upthrusting and finally by a notable but uneven elevation.

The resulting rock geometry is very complex and rather polygenous. Its most distinctive feature is the presence of great Variscan nappe-like thrust sheets, recognized first by Schwarzbach (1939), and then studied in detail by the present author (H. Teisseyre 1956, 1959, 1964, 1967; figs 13, 14). Six great tectonic units may be distinguished in the southern part of the Kaczawa Mts. They are thrust upon one another, at least five of them representing flat lying, nappe-like thrusts. The deepest unit may be an autochtonous fold. The Radzimowice beds occur only in the unit of Bolków, and perhaps also in the unit of Pilchowice (figs 15, 16, 17, 18).

The main set of linear structures (F_2, L_2) trends mostly parallel to the direction of major structures mentioned above. It is represented by minor folds, generally with a southern vergency, wrinkling, irregular fine rodding, linear arrangement of sericite, elongation of quartz grains, intersection of flow (S_1) and fracture (S_2) cleavage, pencil and mullion structures. This set has been designed formerly by the symbol B_1 (H. Teisseyre 1964, 1968). It trends W—E or NW—SE and plunges to the E or EES in the SE part of the southern branch of the Kaczawa Mts. and in the opposite direction in the NW part. Two other sets of linear structures previously differentiated as B_2 (now F_3 and L_3); (NE—SW) and B_3 (now F_4 and L_4); (NW—SE to N—S) are well visible in most areas. A relict of minor folds (F_1) older than F_2 and L_2 is present in the region under discussion (H. Teisseyre 1959). Analogous folds have been observed many times recently. The main foliation (flow cleavage — S_1) is parallel or subparallel to the axial

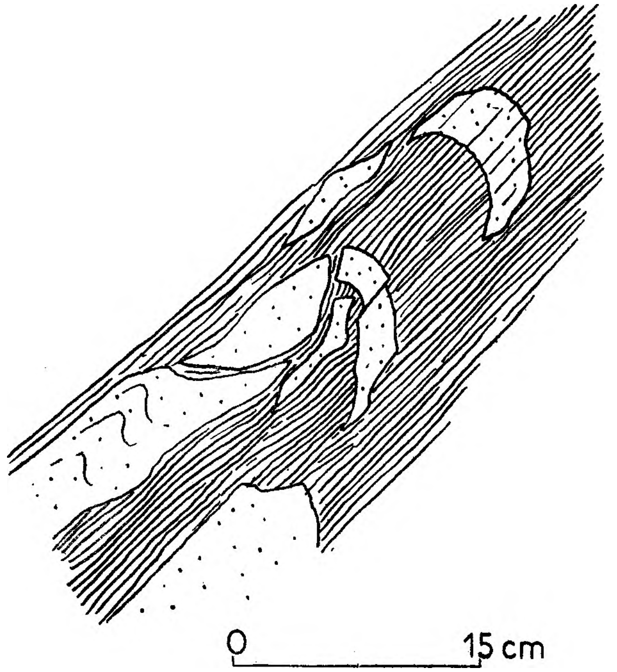

Fig. 15

Kaczawa Mountains, Ordovician

Relict minor fold (F_1) as shown by quartzite layers intercalated in grey slates. Schistosity (flow cleavage S_1) is parallel to the axial plane of the fold. The bedding is disrupted into mullion-like structures. According to a field sketch by the author planes of these relict folds. Generally four or even five sets of minor structures may be observed in the Kaczawa Mts. in the Eocambrian and in the Cambro-Devonian sequence.

The main folding is post-Upper Devonian, because newly conodonts of the Lower (?), Middle and Upper Devonian have been found in the epimetamorphic slates of the named mountains (Urbanek *et al.* 1975; Urbanek oral informations).

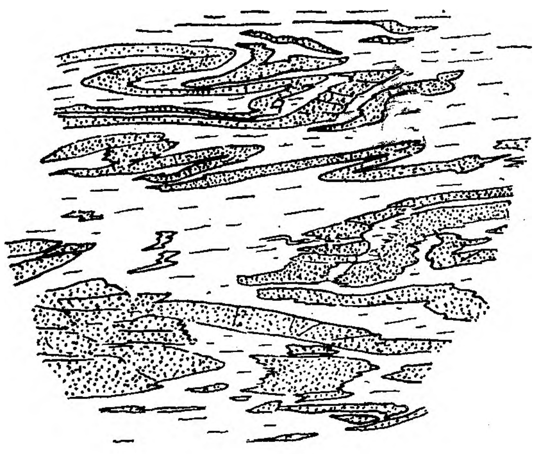

Fig. 16
Kaczawa Mountains. Radzimowice beds – Eocambrian. Quartzite bed with relicts of early minor folds (F_1). According to a field sketch by the author

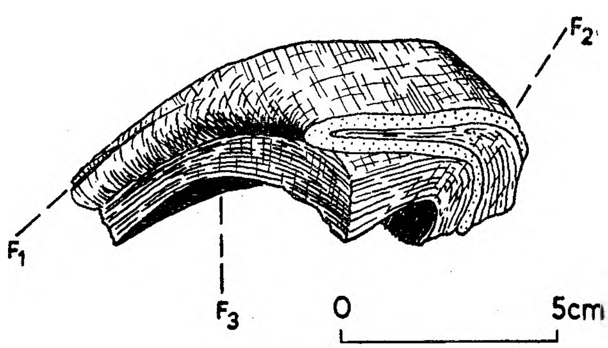

Fig. 17
Kaczawa Mountains, Ordovician slates. Three generations of minor folds in one specimen (F_1, F_2 and F_3). Dots – folded, early quartz vein

The Eocambrian may be easily recognized only in the south-eastern part of the Kaczawa M., where the Wojcieszów limestone is well developed. Where these rocks are lacking or where they occur only locally, the distinction of the Eocambrian from the Cambrian, Ordovician or Silurian slates is doubtful. Neither the age of the Wądroże Wielkie granite-gneisses (Grosswandrisser Gneiss) occurring in the foreland in the eastern prolongation of the Kaczawa Mts. is clear as yet. They form a flat, poorly exposed dome, which borders on the grey slates, generally considered (without any proofs) as Ordovician. The contact between the gneisses of Wądroże Wielkie and the encasing country rocks is concealed under Quaternary glacial deposits.

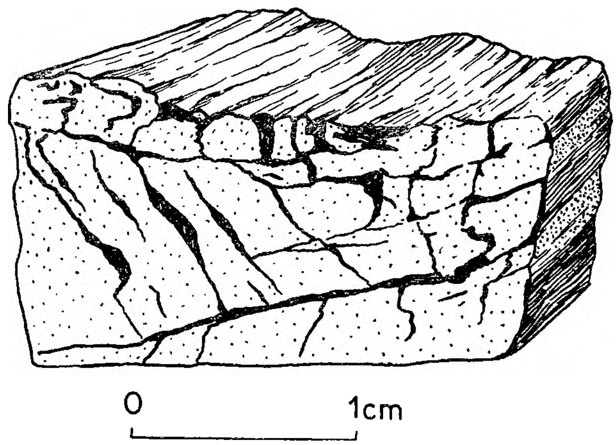

Fig. 18
Kaczawa Mountains. Radzimowice beds – Eocambrian
L_2 – lineation in quartzite bed. Solid black – sericite. The graphite-bearing sericite is partially squeezed out from the foliation planes and pressed into cracks

Different considerations of the origin and age of the granite-gneisses have been expressed. According to Kozłowska-Koch (1957) the gneisses of Wądroże Wielkie are light-coloured grey rocks, rather massive and porphyritic in appearance. The constituting minerals are: bluish quartz, plagioclase (albite), large grains of microcline, the elongated aggregates of mica-flakes being scarce as a rule.

These rocks originated by metasomatic transformation of mica-schists. The partially biotitized garnet enclosed in mica clusters may represent a relict of the original rock. In the first stage of metasomatic granitization in situ, the sequence was enriched in albite (8 % An). As the plagioclase grew at the expense of mica and garnet, the biotite was replaced by phengite and epidote. In the next stage a K-front occurred, and the microcline formed at the expense of plagioclase. A new albitization followed, transforming some microclines into younger infiltration perthite. Finally a pure albite originated. The quartz, quartz-fluorite and fluorite-albite veinlets are somewhat younger. Chlorite quartz and pyrite represent the last products of the hydrothermal crystallization.

The granitized sequence has been deformed and crushed during the subsequent period of intensive folding which may be correlated with Variscan movements. The gneisses have been locally mylonitized and transformed into phyllonite-like rocks along gliding surfaces.

THE BLOCK OF KARKONOSZE (FIGS 1, 2, 19, 20)

The Block of Karkonosze forms a dome-like elevation, which occurs in the Sudetes west of the Central Sudetic Trough, the deepest sedimentary basin of the Central Sudetes. The dome is up to 70 km in length and about 50 km in width. It is separated from the Kaczawa Mts. by a major fault zone, named the "Main Intrasudetic Fault" (Innersudetische Hauptverwerfung). To the E the dome plunges under a thick cover of Lower Carboniferous (Culm) conglomerates, greywackes and mudstones which rest on the older metamorphic complex discordantly. The southern margin of the Karkonosze dome is constituted by uppermost Carboniferous and Lower Permian strata, while the southwestern limit strikes along the Lužice (Lausitz) fault, being post-Upper Cretaceous in age. To the W, the crystalline rocks plunge under the cover of Tertiary sediments, accumulated in a flat limnic basin (the subsided zone of Żytawa-Węgliniec). This basin separates the dome of Karkonosze from the Block of Lausitz (Lusatia).

The Block of Karkonosze is built up essentially of metamorphic rocks, varied in their composition, intruded in the middle part by a Variscan granite (about 300 million years old; Przewłocki *et al.* 1962). The metamorphic rocks may be divided into three complexes of different age separated by major unconformities revealed on the Czechoslovak side by Chaloupsky (1965).

The lowermost complex is composed of mica-schists and gneisses. The age of the rocks is considered as Precambrian eventually Cadomian, but convincing stratigraphic indications are lacking till now.

The middle complex of lower (epizonal) metamorphism comprises Early Paleozoic (Ordovician and Silurian strata).

The Upper Devonian and the Lower Carboniferous strata which occur in the westernmost part of the Karkonosze Block on the Czechoslovakian territory, represent the third slightly metamorphosed complex.

It must be emphasized that there is no sharp limit between the higher metamorphosed first complex and the lower metamorphosed second one. Intermediate facial elements are known. The degree of metamorphism increases from west to east in the southern part of the Karkonosze Block and from south towards north in the eastern part. In the eastern part the Niedamirów phyllites (fig. 19) pass gradually northwards into the Czarnów mica-schists (Berg 1941; J. and M. Szałamacha 1967, 1968; J. H. Teisseyre 1971).

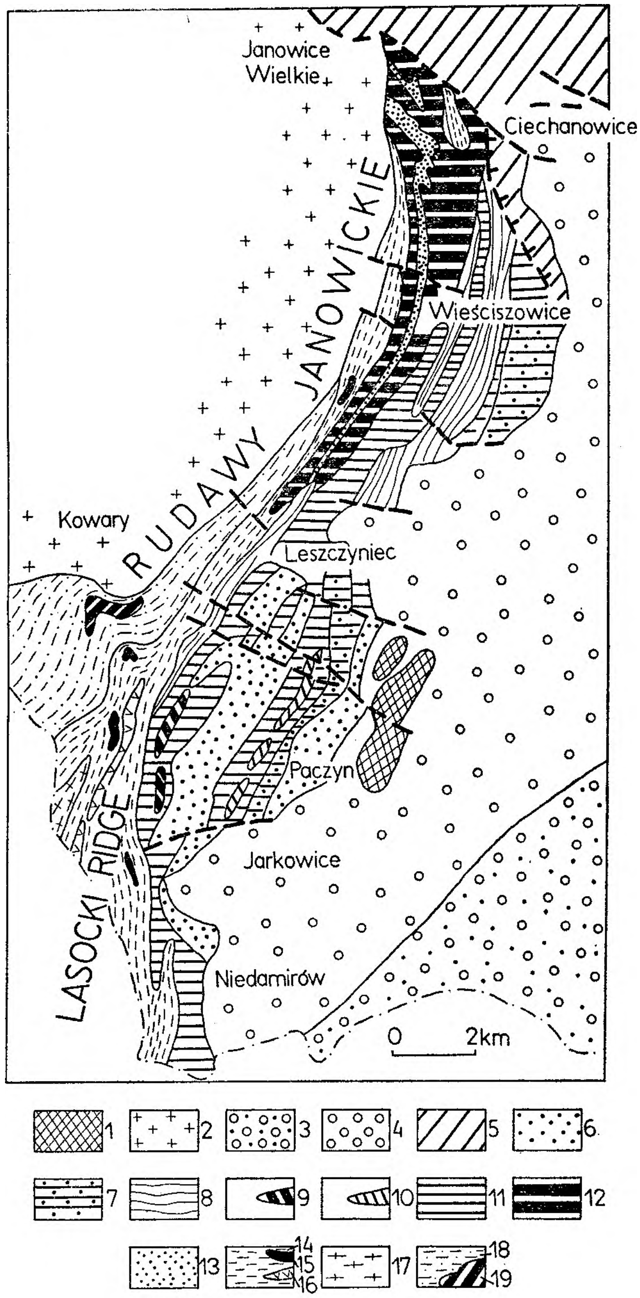

Fig. 19

Geological sketch-map of the Rudawy Janowickie and Lasocki Ridges. According to J. H. Teisseyre (1968)

1 — Young Paleozoic volcanites; *2* — Karkonosze granite (Upper Carboniferous); *3* — sediments of the Upper Carboniferous; *4* — sediments of the Lower Carboniferous; *5* — greenschist formation of the Kaczawa Mountains; *6* — albite-quartz gneisses of Paczyn; *7* — albite-quartz gneisses of Paczyn with metavolcanic intercalations; *8* — massive dark varieties of metavolcanites; *9* — zoisite amphibolites; *10* — porphyrites; *11* — schistose varieties of dark metavolcanites (greenschists, amphibole schists, prasinites); *12* — stripped amphibolites; *13* — leptynites; *14* — phyllites and mica-schists; *15* — calcite and dolomite marbles; *16* — chlorite and amphibole rocks within mica-schists; *17* — Malá Upa gneisses; 18 — Kowary gneisses and the accompanying schists; *19* — ore-bearing formation

The eastern and northern parts of the metamorphic mantle of the Karkonosze granites lies within the Polish territory and will be discussed below.

The metamorphic rocks of the Eastern Karkonosze appear in the Rudawy Janowickie, in the Lasocki Grzbiet and in the environs of Kowary. Of many papers dealing with this area, the following ones are to be mentioned: Berg (1912, 1938, 1941); Oberc (1960, 1961, 1966); Narębski and J. H. Teisseyre (1971); J. H. Teisseyre (1968, 1968a, 1971, 1973); J., M. Szałamacha (1958, 1967, 1968). Other publications are cited in the papers above.

According to J. H. Teisseyre two main metamorphic rock groups may be differentiated in the Lasocki Grzbiet and the Rudawy Janowickie ridges: the Kowary group and the Rudawy Janowickie group. Besides them, the Przybkowice greenschist formation occurs in the northern part of the area. The greenschist formation belongs to the elements of the Kaczawa Mountains and probably represents a relict of a greater thrust sheet moved towards the south during the Variscan foldings.

The Kowary Group (The Kowary series of J. and M. Szałamacha) is represented by mica-schists and the associated Kowary gneisses. According to J. and M. Szałamacha (1968) the mica-schists consist of quartz, muscovite, biotite, chlorite and small quantities of sodium feldspar. Iron oxides and zircon are common accessory minerals. In places garnet-rich mica-schists are present. Tourmaline and quartz often form laminae or small lenticular concordant bodies in the schists. Amphibolites, calc-silicate rocks and calcitic or dolomitic marbles occur in the schists sporadically. Along the contact with the Karkonosze granites the mica-schists have been converted into hornfelses.

In the locality called Kowary the mica-schists, amphibolites, calc-silicate rocks and crystalline limestones form the well known iron-bearing formation intercalated in the gneisses. According to Berg (1912) the Kowary gneisses are ortho-rocks in origin, but J. and M. Szałamacha (1968) claim that they represent (in most cases) granitized supracrustal rocks (mica-schists). The Kowary gneisses are variable in their structure and texture. They are often well laminated, even fine-laminated rocks, locally with fine "augen" structure formed by microcline. More massive, almost aphanitic varieties occur in places, resembling the leptite gneisses. The fine laminated types often form continuous transitions to "flaser" and coarse-grained "augen" gneisses grading in places into coarse-grained granite-gneisses, often with big microcline porphyroblasts and blue quartz. The main mineral components are: microcline, microcline-microperthite, normal and chess-board albite, quartz, muscovite, less frequent biotite, chlorite and often pinite. Garnet occurs as a relict. Accessory minerals are magnetite, apatite, tourmaline and rutile (J. and M. Szałamacha 1968).

The Rudawy Janowickie group may be divided into two formations: the Czarnów schist formation at the base and the Leszczyniec volcanic formation at the top. (J. H. Teisseyre 1971, 1973; W. Narębski, J. H. Teisseyre 1971).

The Czarnów schist formation corresponds nearly with the Niedamirów zone of J. and M. Szałamacha (1967, 1968). The main constituents are lower mica-schists and phyllites with lenses of crystalline limestones and calc-silicate rocks. Leptynites are intercalated in the northern part of the formation. This formation may be regarded as Ordovician and Lower and Middle Silurian in age, like the corresponding formations of the environs of Železný Brod and Rychorské Hory in Czechoslovakia (J. H. Teisseyre 1971). The Malá Upa light and fine-grained, muscovite bearing gneisses may be correlated with the leptynites of the Czarnów formation.

According to J. H. Teisseyre (1971), the Leszczyniec volcanic formation is built of two members. The lower member is represented by basic volcanites with intercalations of schists, tuffaceous in origin. The relict structures allow to classify them as metadiabases and metabasalts. The degree of metamorphism decreases towards the south; they pass consequently into greenstones in the environs of the Niedamirów. The thickness of the lower member is very variable and reaches up to 200 m, 500 m or even 800 m. The upper member of the Leszczyniec volcanic formation is composed of albite-hornblende-bearing Paczyn gneisses, containing irregular bodies of metadiabases and metagabbro. Veins of keratophyre, quartz-keratophyre and albite microgranite are subordinate.

The Leszczyniec volcanic formation probably represents the continuation of Upper Silurian volcanites of the Rychorské Mts. and of Železný Brod in Czechoslovakia. The cataclastic, quartz-albite-chlorite bearing gneisses of the environs of Leszczyniec may be compared with the cataclastic albite-granite known from Czechoslovakia and sometimes looked upon as Lower Devonian.

J. and M. Szałamacha (1967, 1968) assigned the Leszczyniec volcanic formation to the Precambrian, and also Oberc (1960, 1961, 1966) claims that this formation as well as the Czarnów schists are Proterozoic in age.

The tectonics of the Rudawy Janowickie ridge and of the Lasocki Grzbiet are not satisfactorily clarified as yet in all important details. The metamorphic rocks generally strike NNE—SSW, dipping monoclinally in the eastern direction, under a huge mass of Lower Carboniferous conglomerates, greywackes and mudstones. The angular unconformity between the two sequences is moderate. The eastern dips of the metamorphic complex and of the adjacent Culm strata are caused by a great flexural warp trending NNE—SSW. This flexure began to form in Lower Carboniferous time, due to the uplift of the Karkonosze Dome and to a simultaneous subsidence of the Intra-Sudetic Basin. The process developed progressively during the emplacement of the Karkonosze granite and perhaps has continued in the Alpine epoch of folding. The metamorphic sequence is bent towards the NW in the valley of the Bóbr river. On the northern slopes of this valley, along the boundary with the Kaczawa Mts., it is readjusted conformably to the adjacent greenschists. It plunges here steeply north and are cut by a major fault zone called the Main Intrasudetic Fault (fig. 19).

Many views, more or less different, have been advanced on the tectonics of the Eastern Karkonosze (comp. Cloos 1922; Berg 1938; Schwarzbach 1939; Kodym, Svoboda 1948; Oberc 1960, 1961, 1966; J., M. Szałamacha 1958, 1967, 1968; J. H. Teisseyre 1968, 1971). The main folding trends in this region WWN—EES to NW—SE and exhibits a southern or southwestern vergency. It is parallel to the main folding of the Southern Karkonosze and the Kaczawa Mts. Considerable differences exist in views of the age of the folding. Some geologists advanced the opinion that the main folding is Cadomian in the sequences which they claim to be Proterozoic, and Late Caledonian in Early Paleozoic strata (Oberc, J. and M. Szałamacha). Others support the view that the main deformation, as now distinctly visible, was Caledonian or rather Caledono-Variscan in both complexes (Bederke, Schwarzbach, Kodym and Svoboda, Máška, Chaloupský, H. Teisseyre, J. H. Teisseyre and others). Newly J. H. Teisseyre (1968, 1971) proved on ground of minor structures that the Eastern Karkonosze and the Kaczawa Mts. have all essential deformation phases in common.

The fold pattern of the Eastern Karkonosze is associated with numerous transversal and longitudinal faults. A main longitudinal fault, apparently inverse, separates the Czarnów schists formation from the overlying Leszczyniec volcanic formation. Two great shearing nappes thrust towards the S have been postulated in the Karkonosze Block by Kodym and Svoboda (1948). The concept has not been accepted by most geologists (Watznauer 1953, 1955). The studies of minor structures have recently been performed in the Eastern Karkonosze by Oberc (1960, 1961, 1966), J. and M. Szałamacha (1967, 1968) and J. H. Teisseyre (1968, 1973). The latter author has found four sets of minor structures in the area under discussion. The oldest set F_1 is preserved only in relicts as small isoclinal folds trending approximately N—S. The F_2 set is connected with the most prominent folding; it plunges steeply or at moderate angles towards EES or SE, often exhibits a southern vergency and is accompanied by different types of lineation. The F_3 minor folds accompanied by minute wrinklings trend NNE—SSW or NE—SW and show in general a western vergency. The last F_4 set is rather scarce and plays a subordinate role in minor structures. All four sets have precise analogues in the Kaczawa Mts. and belong, according to J. H. Teisseyre (1973), to Caledono-Variscan deformations.

THE IZERA REGION (THE IZERA BLOCK)

The Izera Block constitutes the north-western part of the Karkonosze Dome and is made up mainly of different gneisses, known under the comprehensive name of Izera gneisses. They are accompanied by some granitoid rocks and crystalline schists which appear in four longitudinal zones, as it is shown on the sketch-map in figure 20.

The southernmost part of the crystalline-schist zone has been converted into hornfelses in consequence of the Karkonosze granite intrusion. The hornfelses are massive or thinly laminated rocks, consisting of quartz, micas, cordierite, andalusite and small quantities of feldspars. Magnetite, zircon and in places tourmaline may be found among the accessory minerals (J., M. Szałamacha 1968). The sequences of crystalline schists situated more to the N are composed of different, well foliated rocks. The most prominent zone (Stara Kamienica zone) is situated in the central part of the Izera gneiss block. It is somewhat arcuate, trends nearly E—W, parallel with the main foliation (flow cleavage). This zone consists of muscovite-biotite-, muscovite-chlorite- and muscovite-biotite-chlorite-schists (K. Smulikowski 1958a). In addition, the rocks contain quartz, ordinary or checkered albite, in places also garnet, disthene, tourmaline and andalusite. Microcline and microcline-microperthite are less in evidence. Some varieties are rich in epidote or garnet. Amphibolites and calc-silicate rocks can be observed occasionally. The mica-schists with porphyroblastic biotite occur along the southern border of the Stara Kamienica zone, in contact with leucogranites. There is a sharp limit

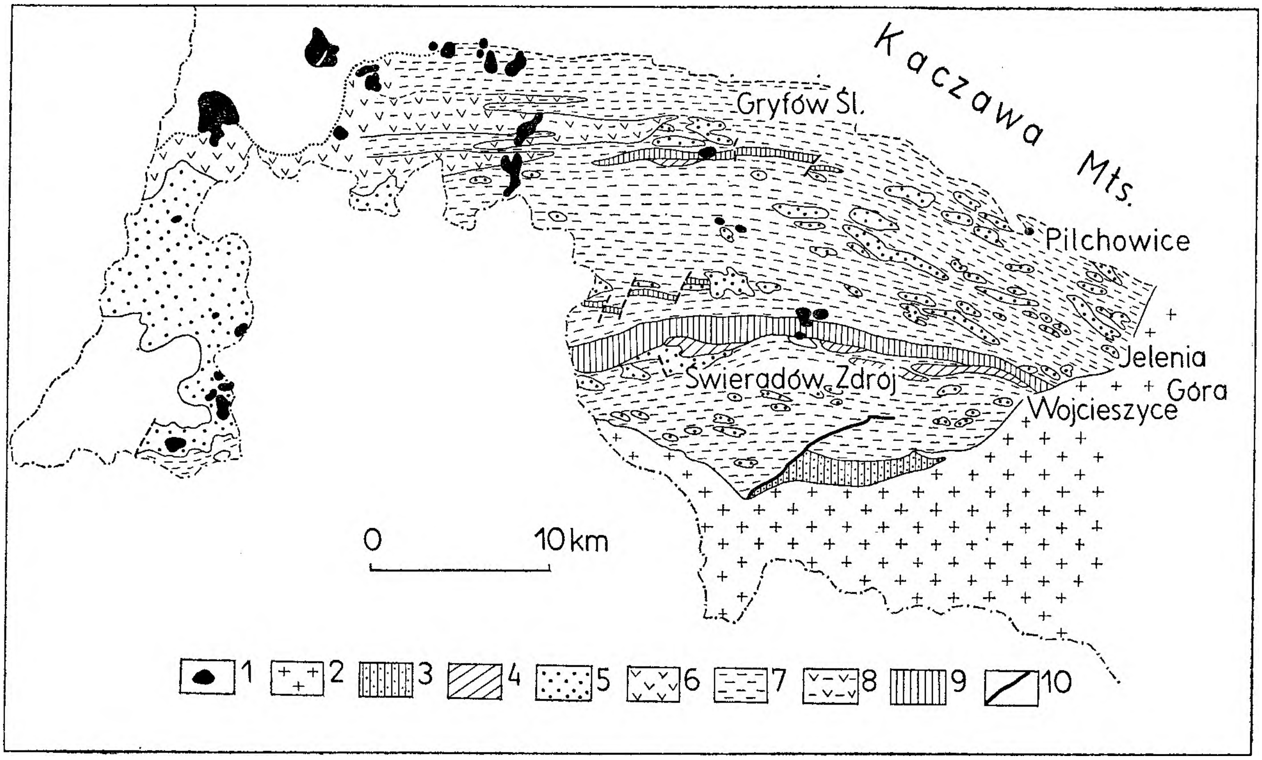

Fig. 20
Geological sketch-map of the Izera Block (according to J. and M. Szałamacha)

1 — basalts (Tertiary); *2* — granite of Karkonosze; *3* — hornfelses (altered mica-schists); *4* — leucogranites; *5* — Rumburk (Izera) granites; *6* — Zawidów granodiorite; *7* — Izera gneisses; *8* — granodiorite gneisses (dark gneisses of Leśna); *9* — mica-schists; *10* — quartz vein of Rozdroże Izerskie (quartzitized mylonite)

in the southern part of the Stara Kamienica schist zone, while in the north a gradual transition between the mica-schists and the thinly laminated Izera-gneisses may be observed (J. M. Szałamacha 1968).

The crystalline schists zone situated in the northern part of the Izera highlands may be called the Złotniki zone. It extends in the E—W direction and is largely made up of muscovite-biotite and muscovite-chlorite schists, passing locally into quartzitic schists (J., M. Szałamacha 1968; W. Smulikowski 1972). Large flakes of a secondary, porphyroblastic biotite are present in some schist layers. They do not exhibit any preferred orientation. The schists of the Złotniki zone contain varying amounts of normal or chessboard albite. They pass gradually towards the N into fine-laminated albite gneisses (called "transitional gneisses" by W. Smulikowski 1972) which often form the marginal part or the common Izera gneisses in contact with the schists also in other areas.

The Izera gneisses are very variable in their appearance and in structural and textural features. A coarse-grained "augen-gneiss" variety is the most characteristic. The rocks are often deformed, exhibiting more or less advanced cataclastic textures. Mylonitic zones appear locally. J. and M. Szałamacha (1968) have distinguished several types of the Izera gneisses varying in texture and structural properties:

1) thin laminated and partly "flaser-augen" gneisses, usually accompanied by schist relicts;

2) fine-grained gneisses with flake-shaped concentrations of biotite, and with feldspar porphyroblasts;

3) "flaser-augen" gneisses, in medium- and coarce-grained varieties grading into "augen" gneisses or granite.

The rock types alternate with each other and often with-out sharp boundaries. The mineral constituents are quartz, microcline, microcline-microperthite, oligoclase or albite and chessboard albite, biotite, muscovite and chlorite in very variable proportions.

The Izera gneisses are accompanied by some granitoids, the two rock types being often linked by gradual transitions. The following granitoid types have been distinguished: 1) Izera or Rumburk granites, 2) Zawidów granodiorites and 3) leucogranites.

The Rumburk (Izera) granite is known from the Lausitz crystalline complex and its outcrops are found over a vast area in the western part of the Karkonosze Dome (S from Zgorzelec). Towards E it is replaced largely by the Izera gneisses, but occurs within the latter as far as the eastern limits of the Izera Highlands, forming lenticular bodies, different in shape and size. The granite is variable in texture and appearance, a porphyritic variety being one of the most characteristic features. The rock is composed of bluish quartz, microcline-microperthite replacing the plagioclase, which is often zoned. Biotite and secondary muscovite are present, too, as well as pinite pseudomorphs after cordierite. Secondary albite and (younger) adularia are late constituents.

A granitoid rock of Chmieleń (W from Jelenia Góra) may be described as a good example of the Izera (Rumburk) granite. According to Kozłowska-Koch (1965), the rock is porphyritic or porphyroid granitic in appearance. About 60% of the volume is represented by a fine-grained groundmass. Plagioclase porphyroblasts are albite to basic oligoclase; they contain relicts of mica. This first generation of plagioclase has been replaced partially by a later microcline. The microcline poikiloblasts have been attacked in turn by the secondary checkered albite. The adularia is the youngest feldspar, cutting the checkered albite and thus producing younger perthitic intergrowths. Pinite pseudomorphs after cordierite replaced partially by quartz is another characteristic feature of the rock. The muscovitization of biotite is connected with the production of iron ores and of vermicular epidote. An aplitic variety is gneissoid in appearance when containing relicts of garnet-bearing schists.

Another granitoid rock of the region is the Zawidów granodiorite (Seitendorfer Granodiorit). It occurs in the eastern Lausitz and in the NW part of the Izera region, SE of Zgorzelec. The Zawidów granodiorite consists mainly of plagioclase, strongly clouded by fine sericite dust; quartz and microcline microperthite are scarcer. A secondary albite is usually present, and the only dark mineral is brown biotite, bearing sagenite needles.

In the environs of the village Stary Zawidów, the rock exhibits a more or less advanced cataclastic texture, resulting in places in a gneissose appearance (K. Smulikowski 1951).

The intrusive character of the Zawidów granodiorite is well visible in the environs of Zgorzelec, where a sharp contact between this rock and the Lausitz Greywacke Formation may be observed. The Lausitz Greywacke Formation is now dated as latest Precambrian and it has been converted into typical hornfelses along the contact with the Zawidów granodiorite.

The leucogranites may be observed amidst the Izera gneisses in some areas; according to J. and M. Szałamacha (1968), they occur along presumed fault zones. Berg (1922) described the leucogranites as pegmatite gneisses, K. Smulikowski (1958) showed that they derived from the ordinary Izera gneisses due to complex metasomatic processes. According to this author "the leucogranite is a coarse-grained and almost white or light-grey rock. The typical variety is entirely massive in megascopic appearance, but more or less gneissic parts and intercalations are also present. The main constituents are microcline, partially replaced by checkered albite and quartz. The mica is entirely absent. Tourmaline occurs everywhere in little rosettes; fluorite may be present, too".

The Izera gneisses have been submitted locally to the action of pneumatolytic and hydrothermal emanations, surging from beneath in some period after the main phase of movement. Biotite has been removed almost entirely. Microcline underwent more or less advanced albitization. The general recrystallization effaced the primary deformations and the gneissic texture, converting thus the highly deformed and often cataclastic rocks into a massive, coarse-grained, leucocratic granitoid.

The mica-schists, immediately adjacent to the leucogranite, have also been albitized and bleached, in consequence of leaching of the ferro-magnesian components. They form a sequence of up to several metres in thickness and have been described preliminarily as aplitic schists. The content of secondary albite is variable, as well as the amount of both micas and chlorite. Characteristic are poikiloblasts of a pale biotite (phlogopite). K. Smulikowski has recently proposed to classify the rock described as leptynite, the term being entirely descriptive and genetically neutral (cf. Kozłowski 1966).

The nearly white leptynites pass gradually into grey ones bearing large, megascopic porphyroblasts of dark biotite. The groundmass of the schistose rocks consists of quartz, plagioclases and microperthite, with a subordinate amount of micas and chlorite. The scaly minerals do not form continuous stripes. In the fine-grained groundmass poikiloblasts of biotite and chlorite are scattered. They grew after the main deformations and gave rise to a particular rock variety incorrectly interpreted by Berg (1922) as a contact facies formed by the thermal influence of the intrusion of the Izera gneisses.

Tourmaline-bearing quartzites form small lenticular bodies among the white leptynites in Czerniawa Zdrój (W of Świeradów).

The age of the Izera complex. The mica-schists represent the oldest lithologic element of the Izera complex. They are considered to be Proterozoic in age. The Izera gneisses and the associated granitoids have been interpreted as Late Caledonian rocks, but now they are connected rather with Cadomian tectogenic processes. However, there are no convincing proofs of such opinion and the problem remains open.

Of outstanding importance for the problem are the relationships of the Izera crystalline complex to the Kaczawa Eocambrian and Cambro-Silurian slate sequences. It was believed that the limit between the two regional units follows a great longitudinal dislocation called the Main Intrasudetic Fault. Recently it has been stated that this fault does not form any continuous surface separating clearly the Izera Block from the Kaczawa Mts. (H. Teisseyre *et al.* 1957; Gierwielaniec 1956; Schmuck 1957; Gorczyca-Skała 1966; W. Smulikowski 1966). It is a discontinuous fault zone, consisting of many longitudinal, oblique and transversal faults. The Izera Block and the Kaczawa Mts. are nowhere separated distinctly from one another. There are sections where the slaty sequences of the Kaczawa Mts. grade into mica-schists characteristic of the Izera complex, without any visible break or unconformity. These schists in turn are linked with the Izera transitional gneisses by a boundary which may be looked upon as metasomatic or intrusive (W. Smulikowski 1972). In consequence, J. Skałowa and W. Smulikowski have advanced the view that the supracrustal sequence of the Izera region and that of the Kaczawa Mts. represent one complex. According to the latter author, the problem is not clear enough and more than one explanation are possible. Further investigations in using new methods are needed.

The origin of the Izera gneisses. The Izera gneisses have been primarily looked upon as a magmatic intrusion, synorogenic with the Late Caledonian folding (Ahrens 1926; Berg 1922, and others). They are still considered to be of magmatic origin by some geologists (Bederke 1956).

K. Smulikowski (1951) has presumed that the Izera granite gneisses originated during the Caledonian epoch of folding in consequence of a high deformation of the Rumburk granite, which he estimated as an ortho-rock of Precambrian (Cadomian) age (Pietzsch 1956). Some years after, the same author expressed serious doubts as to the correctness of such an assumption, on the basis of the results obtained by himself and his school in different regions of the Sudetes. The doubts increased when Kozłowska-Koch (1957) showed that the Wądroże Wielkie gneisses, looked upon as the equivalents of the Izera-gneisses may not represent a magmatic intrusion, but rather "in situ" granitized sediments. Then K. Smulikowski (1958) described feldspathized schists and a gneiss variety strongly suggesting a sedimentary derivation. The author (1958a) mentioned stresses that he never met in the Sudetes "with such gneisses which are indubitably interpreted as derivatives from pure magmatic granitoids".

Essential contributions to the problem have been provided by Kozłowska-Koch (1960, 1961, 1965) who has investigated in detail the Izera gneisses in two sections on the eastern side of the region near the town Jelenia Góra (1960, 1965) and in the western part of the area in the neighbourhood of the village Leśna (1961, 1965).

The first section consists of granite-gneisses, intercalated by thinly laminated gneisses and amphibolites. The microscopic studies showed that these rocks had originated from a sedimentary sequence, which consisted of mudy sandstones and mudstones, with intercalations of dolomitic and ferruginous marls. The sequence had been converted into mica schists and amphibolites by regional metamorphism and then underwent metasomatic granitization in situ. Mica-schists had been submitted to a plagioclase feldspathization. The plagioclase developed at the expense of quartz and mica, the last mineral being in part preserved in the plagioclase blasts as relicts in its original preferred orientation. The following potash metasomatism caused a sericitization of oligoclase in its initial stage. Then the oligoclase grains were gradually purified from sericite and myrmekite: simultaneously, microperthite was produced. The potash supply resulted finally in a mass production of limpid microclines which removed previous structures. The rock has been leucocratized and locally the primitive lamination has been entirely obliterated.

After microclinization strong tectonic movements followed and cataclastic grinding of mineral constituents along gliding planes ensued. During subsequent albitization checkered albite has been formed, replacing partially the older microcline, and a general recrystalization cicatrized the highly deformed zones.

The gneissic texture, according to Kozłowska-Koch (1960), did not originate in consequence of the tectonization of a preexisting granite intrusion, as it was generally accepted till now. The parallel lamination of the Izera gneisses is a feature inherited from the primary schists. In extreme cases, the signs of initial schistosity have been obliterated almost totally. The amphibolites were less susceptible to these processes. Only thin intercalations of such rocks have converted into amphibole- and biotite-bearing gneisses. They contain abundant sphene, epidote, biotite or chlorite. All preserved thick amphibolite intercalations exhibit secondary albitization and a subsequent invasion of potash resulting in metasomatic perthites and antiperthites. They underwent biotitization and chloritization, mainly along their contact with the gneisses.

Kozłowska-Koch (1965) has found relicts of hornfelses in the sequence described above. The relicts contain sillimanite, corundum, andalusite and pinite pseudomorphs after cordierite. It is possible that such a mineral assemblage was produced by regional metamorphism, but the authoress suggests rather a contact activity of some older magmatic intrusion. She regards as probable that the granitization is due to this very intrusion, and that some part of the Izera gneisses might have originated from igneous rocks transformed by endoblastesis and subsequent metasomatism. These processes effaced any sharp limit between the schists and hornfelses on one hand and the intruding granitoid on the other.

In the environ of Leśna, Kozłowska-Koch (1961) distinguished two main types of Izera gneisses: the light-coloured one (rich in microcline nad quartz, poor in biotite) and the dark one (poor in quartz, rich in biotite). The first gneiss type does not differ in qualitative and quantitative composition from the Rumburk granite, while the second one is very like the Zawidów granodiorite in mineral composition. She proved that the Izera gneisses formed in the western part of the area due to mechanical transformations of the two older granitoids known in underformed state from the Lausitz Block. (Pietzsch 1956).

The origin of these two granitoids has been discussed. The Zawidów granodiorite is mostly believed to be of magmatic origin. J. and M. Szałamacha (1967, 1968) have advanced the view that the granitoid rock originated by granitization of the Lausitz greywacke formation, the adjacent hornfelses being a first stage of this process. W. Smulikowski (1972) has rejected this concept, pointing to the fact that the limit between the Zawidów granodiorites and the hornfelses is sharp and the very contact is rather an intrusive one.

The Rumburk granite has been classed initially also with magmatic rocks, but M. Borkowska (1957) admits the possibility that the Rumburk granite has derived from some sedimentary material (because it contains some relicts of hornfelses).

In a similar way came into being two-mica granites of the central Lausitz, which were proved by Ebert (1935), to be derived from greywackes, first converted into hornfelses by contact action of the granodiorite of Lausitz. The granitization of these hornfelses rose to various degrees.

J. and M. Szałamacha (1967, 1968) claim that all the old crystalline rocks of the Izera region represent granitized sediments, the Zawidów granodiorite and the Rumburk granite representing the most advanced stage of the process. A similar view has been published by Oberc (1960, 1961, 1966) but without adequate petrologic evidence.

When evaluating the final conclusions we should agree with Kozłowska-Koch (1960, 1965) that the Rumburk granite and the whole rock assemblage known under the collective name of Izera gneisses are heterogeneous in character, comprising both magmatic and sedimentary derivatives.

REMARKS ABOUT TECTONICS

The detailed tectonic investigations into the Izera gneiss complex are hindered by the scarcity of exposures available and also by the fact that the stratigraphic conditions are not adequately known. The brief description below is essentially bazed on the papers by Oberc (1960, 1961) and J. and M. Szałamacha (1967, 1968).

In the thick strongly folded complex of the Izera gneisses, four longitudinal zones of mica-schists are intercalated. They represent the remnants of higher parts of a supracrustal sequence and possibly mark the deepest synclinal zones, limited in the S by faults. The whole assemblage shows southern vergency of the movement and dips monoclinally N; opposite dips or vertical position of strata being scarce. At least two or three sets of linear structures have been found in the region.

The authors named above presumed the main folding of the Izera region to be Cadomian in age but no convincing proofs of such an assumption are available as yet. A comparison of the linear structures of the Izera region with those known from the Kaczawa Mts. supports rather the concept of a Variscan intensive folding. The subdivision of linear structures of the Izera region into Early and Late Assynthian/Cadomian and Caledonian, as proposed by Oberc (1961, 1966), is not supported by any evidence.

FINAL REMARKS

The description of the Precambrian complexes in the Polish part of the Sudetes as given in this paper, does not represent any uniform conception, worked out satisfactorily in all essential details. This is caused by many deficiencies of our knowledge and the shortage of the evidence available from some regions. New detailed investigations are not yet finished in the Sudetic area and many problems have not yet been clarified. The stratigraphical correlations of old crystalline sequences are more or less obscure in most cases, or controversial. Serious errors have been committed when calculating the radiometric age of some granitoids. Indubitably pre-Variscan rocks in spite of claer geological evidence give radiometric age of about 300—350 million of years, in consequence of readjusting and recrystallization processes, that occurred during the Variscan epoch of folding.

It is also not surprising that the tectonics of the sequences looked upon generally as Precambrian could not be clarified satisfactorilly. Different deformations have been repeated for several times. Each time some readjustment took place in order to conform rock geometries to new physical conditions. The main, discernible now deformation of the metamorphic sequences in the Sudetes may be Variscan or perhaps Caledono-Variscan in age, except for the Sowie Góry Block (H. Teisseyre 1968). This assumption is evidenced by the analysis of mesostructures; observations and measurements executed in the Śnieżnik-Lądek region, in the Bystrzyca and Orlica Mts., in the Kłodzko metamorphic massif, the Kaczawa Mts. and the Izera region exhibit the same or very similar succession of structural elements. Generally four or five generations of mesostructures have been evidenced. The first generation is preserved everywhere only in relicts and is represented by minor folds (F_1), in which the axial planes lie parallel to the surface of the first and main foliation (flow cleavage); (S_1). The second generation is generally the most prominent; it is marked by minor folds (F_2) in which the S_1 surfaces are bent and cut by axial planes, and occasionally by the second foliation (S_2). The second generation trends generally parallel or subparallel to the dominant macrostructures.

The gneissic block of the Sowie Mts. is the only region where the main deformation is rather older. It may be regarded here as Moldanubian. No convincing proofs of a Cadomian lineation are available till now in old crystalline rocks of the Sudetes (J. H. Teisseyre 1968a, 1971).

Further detailed investigations are in progress. They will indubitably improve the results obtained hitherto and they will enable to present a more satisfactory and complete picture of the Precambrian in the Sudetes in the future.

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PLATE I

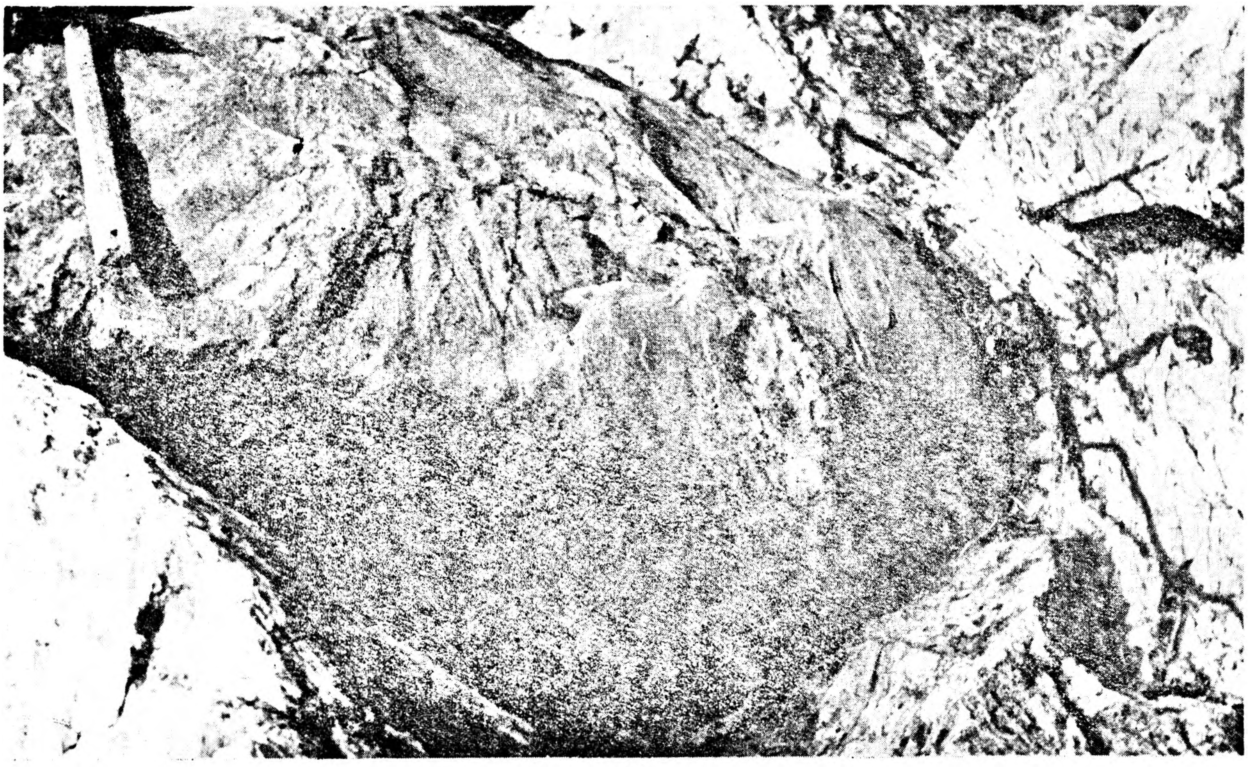
Boudins of amphibolite in a migmatitic sequence of the Sowie Góry Precambrian. Abandoned quarry in the area south of Dzierżoniów. Phot. W. Grocholski

1

Henryk TEISSEYRE — Precambrian in South-Western Poland

PLATE II

1. Amphibolite boudin in migmatitic gneisses of the Sowie Góry Precambrian. Photo. W. Grocholski
2. Migmatitic gneisses of Sowie Góry. Photo. W. Grocholski



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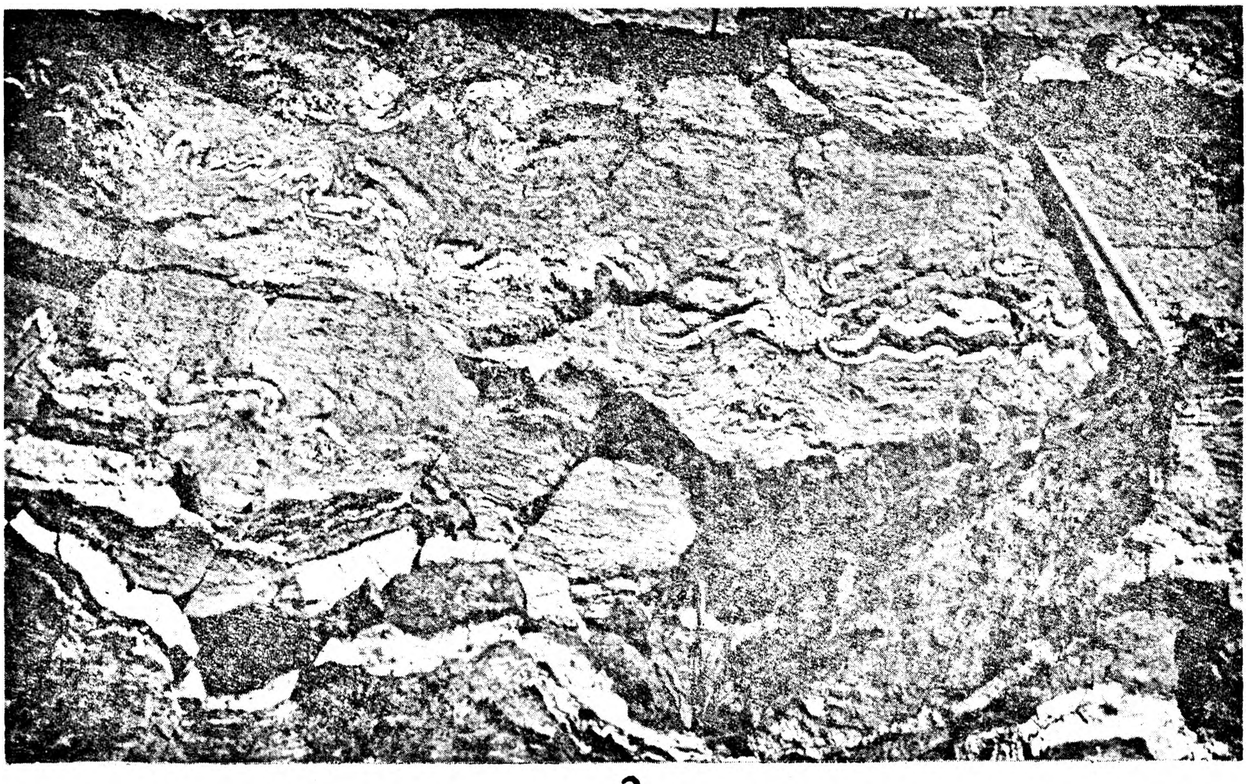

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PLATE III

1. Gierałtów gneiss from the Śnieżnik Mountain Group. In the right part migmatitic. In the left part the rock is thinly and regularly laminated. White lenses of leucocratic material are lacking

2. Fluidal folding in a partially mobilized layer of the Gierałtów gneiss in Międzygórze (Śnieżnik Mountain Group). The top and the bottom layers are unaffected by folding. Photo. T. Jerzykiewicz

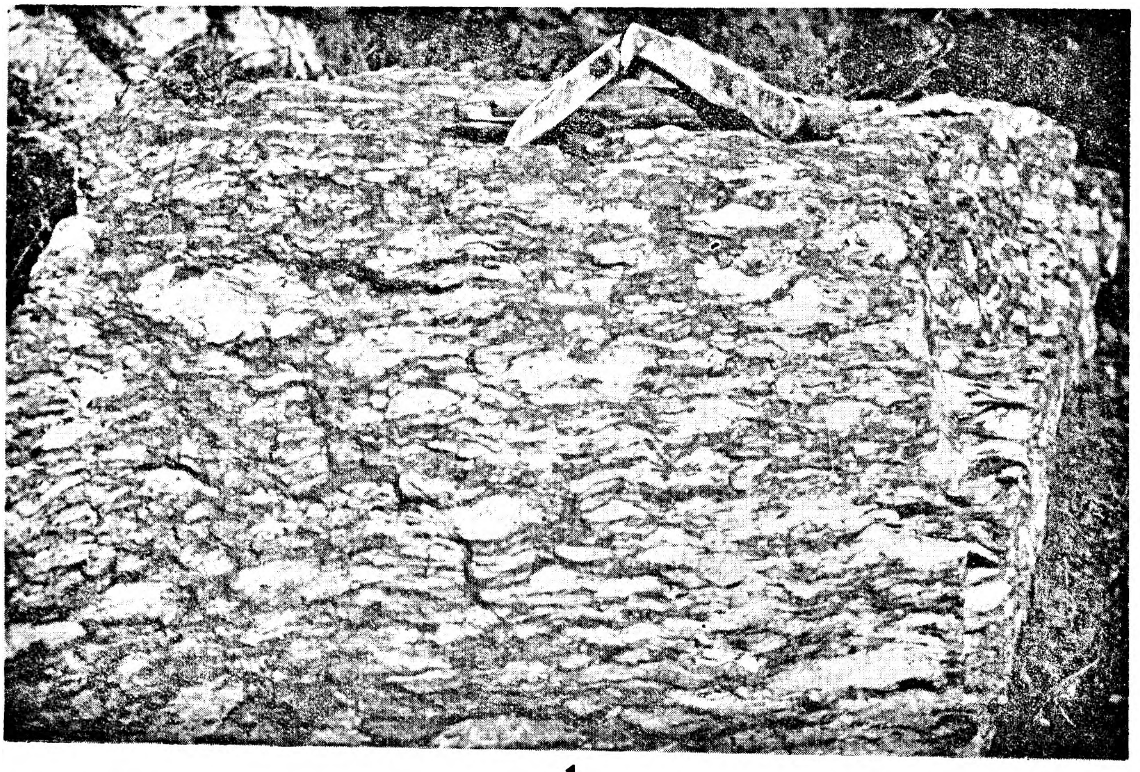
1

2

PLATE IV

1. Typical Śnieżnik "augen" gneiss. Light coloured are microcline metablasts in a fine-grained groundmass

2. Typical rodding in the Śnieżnik gneiss from Międzygórze (Śnieżnik Mountain Group). Photo. T. Jerzykiewicz



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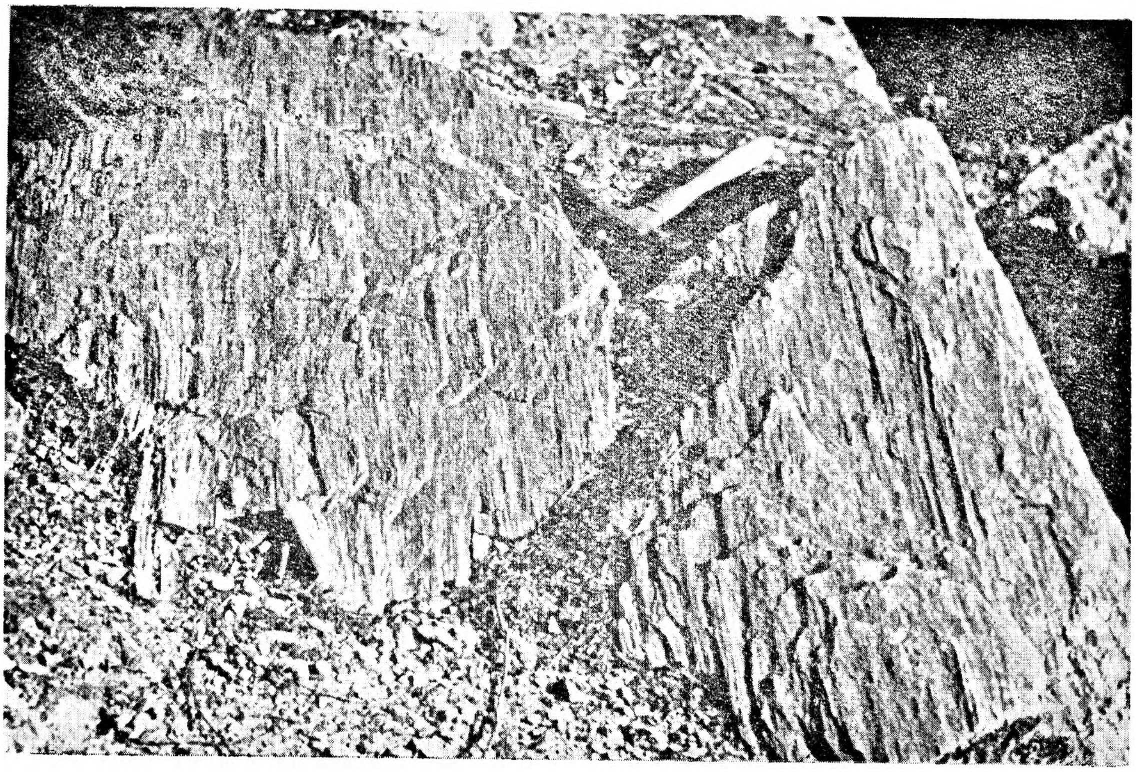

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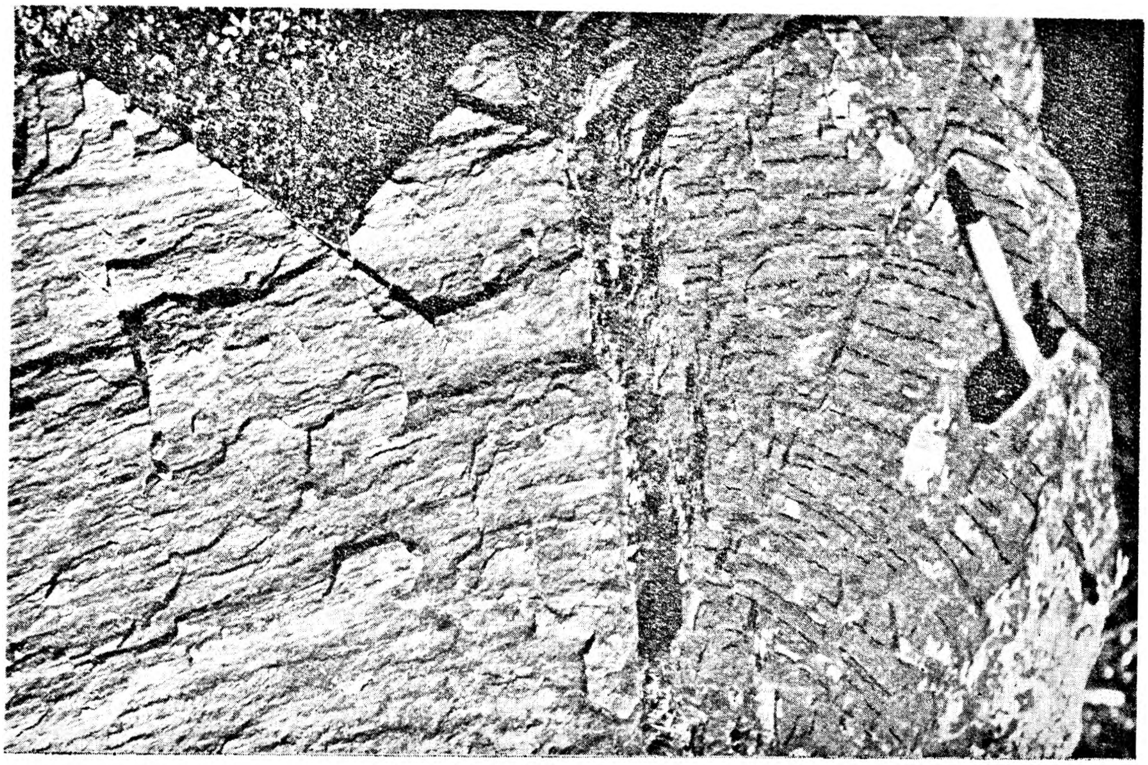
PLATE V

1. Curved rodding of the l_2 lineation in the Śnieżnik gneiss, seen on a foliation plane. Międzygórze. Śnieżnik Mountain Group. Photo. T. Jerzykiewicz

2. Highly folded slates of the Radzimowice beds (Eocambrian). Cores from exploratory drilling. Kaczawa Mts., Western Sudetes. Photo. W. Frąckiewicz

PLATE V
PLANSZA V



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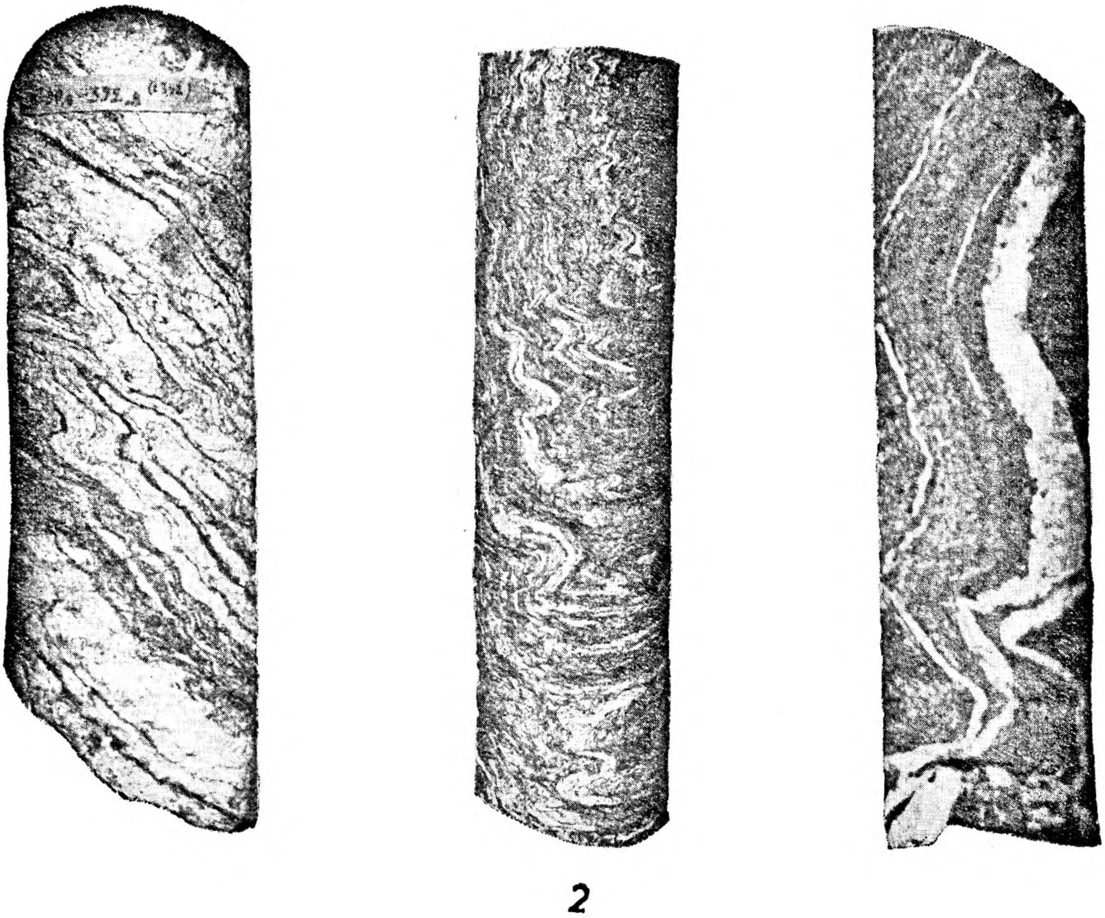

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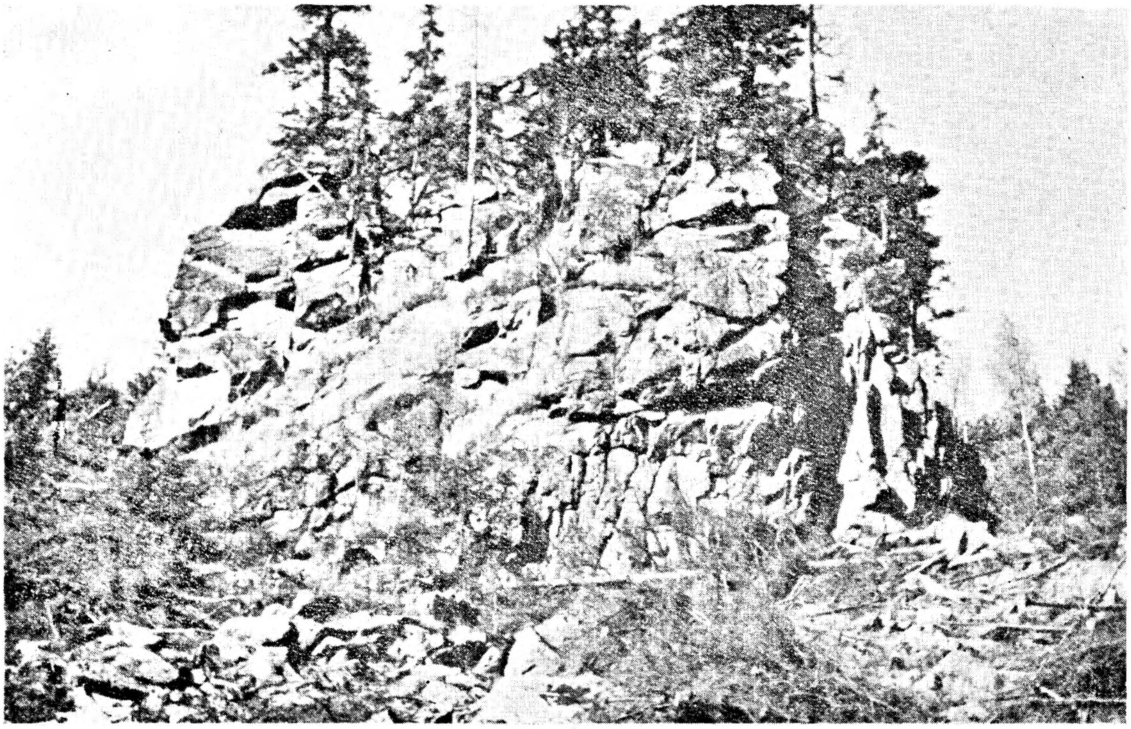
PLATE VI

1. Massive Śnieżnik "augen" gneisses are exposed in numerous scarps. Śnieżnik Mountain Group. Photo. T. Jerzykiewicz

2. Upper part of the Wilczka valley. A landscape in the Śnieżnik Mountain Group. Photo. T. Jerzykiewicz



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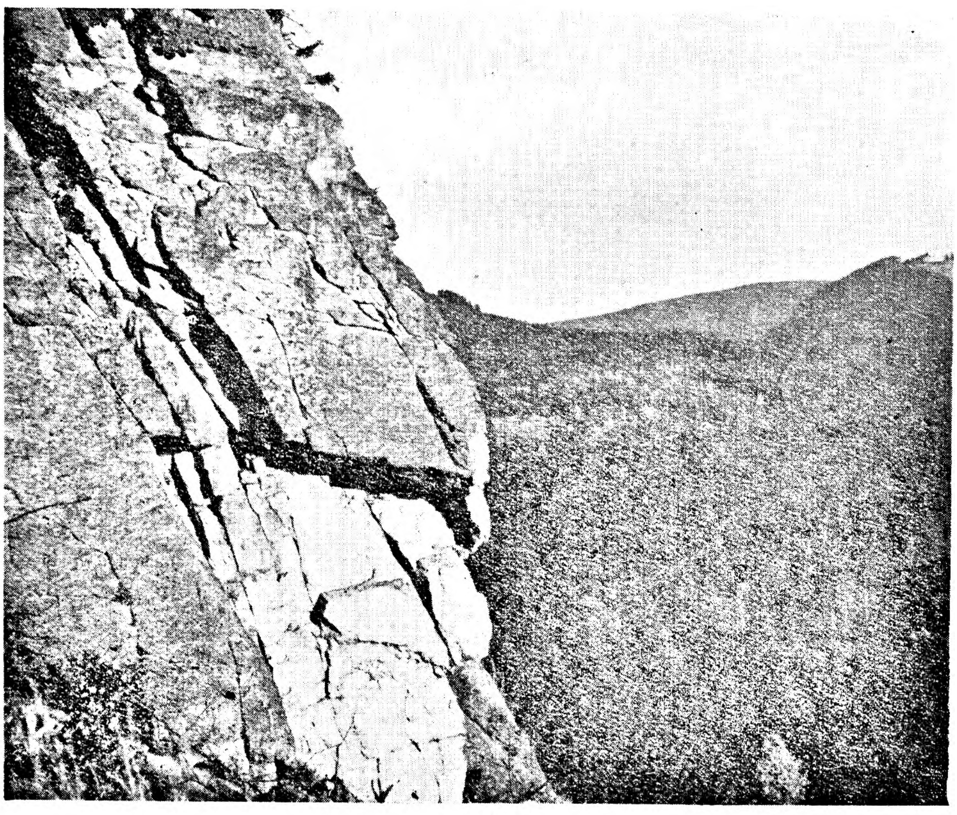

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