GEOLOGIA SUDETICA Vol. XI, nr 1, 1977

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TECTONIC AND METAMORPHIC EVENTS IN THE POLISH PART OF THE ORLICKIE MTS.

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Abstract

Brief petrographical characteristic of rocks belonging to the Stronie formation and the Nové Město formation as well as gneisses of the Śnieżnik type is given. Three major stages and within them six deformational phases (F_1-F_6) were recorded in these rocks. The two oldest phases (F_1 and F_2) stimulated and were followed by metamorphic events (M_1 and M_2) taking place at the time of kinematic calm. F_1 and F_2 folds are tight and roughly co-axial. They have NW – SE or NE – SW trending (because of subsequent rotations), generally northwesterly or westerly dipping axial planes and plunge at different angles to NW or at very

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small angles to NE. Folds of these both sets were accomplished at first by flexure mechanism and later on by superimposed shearing. The shear gliding in $F_2 + M_2$ phase was parallel to the planes of axial foliation referred to as S_2 and perpendicular to F_2 axial directions. This shearing exerted considerable influence on the mode of transformations of rock fabric involved as well as arrangement of rock-forming minerals. $F_1 + M_1$ and $F_2 + M_2$ phase gave rise to independent mineral indexes and sets of fabric characteristic of each of the phases. Features of these two sets of fabric were recognized well and studied in the hinge regions of F_2 folds occuring in every lithological variety. Original sedimentary rocks (perhaps of Proterozoic age) were regionally metamorphosed and metamorphically differentiated under conditions of greenschist facies (M_1 phase) and next under those of amphibolite facies (M_2 phase). The main folds of the investigated region were developed during $F_2 + M_2$ phase, probably at the Caledonian-Variscan turn. They display tight or isoclinal geometry. The fourth deformational movements referred to as F_4 resulted in diagonal (transversal refolding of the earlier structures on the southwesterly dipping axial planes (S_4) and about westerly plunging axes. F_4 folds were accomplished by flexure mechanism and are characterized by persistently northern asymmetry. Brittle structures started to develop in the F_4 phase. F_4 and F_6 folds are responsible for the reorientations of structural elements of the main folds (F_2).

INTRODUCTION

Polish part of the Orlickie Mts. is considered as small northwestern fragment of a large geological structure known as the Kłodzko—Orlica dome (Pauk 1953), or determined as the Kłodzko dome or the Śnieżnik dome (H. Teisseyre 1973). Geographically this structure includes the mountain massifs bordering the Kłodzko Valley. There are the Orlickie Mts. and the Bystrzyckie Mts. on the western side of the Valley and the Śnieżnik Mountain Group, the Bialskie Mts., the Złote Mts. and the Krowiarki Range on the eastern side (fig. 1).

To the principal rock formation of the Kłodzko—Orlica dome belong: the Stronie formation, the Śnieżnik—Gierałtów formation (H. Teisseyre 1973), the Nové Město formation as well as the so-called Staré Město schist belt and the Zabřeh series (fig. 1).

Brief review of the history of geological investigations in the region will be given below.

The Stronie formation is built of meta-sedimentary rocks and partly of metamorphosed volcanic rocks. The most common rock varieties of the discussed formation are as follows: mica schists, two-mica paragneisses, quartzites, marbles and erlans, amphibolites and amphibole schists (Smulikowski 1973).

The Gierałtów gneisses are fine even-grained rocks, usually laminated. They consist of quartz, plagioclases occuring in two generations (older—oligoclase, younger—albite), microcline, two micas, and garnets. These rocks often display features of migmatic gneisses and granites (Smulikowski 1973).

The Śnieżnik gneisses do not differ from the Gierałtów ones in their mineral composition. They are characterizded by coarse-grained structure and very uneven grain dimensions. Microcline augen and lensoid structure are typical for the Śnieżnik gneisses. Both types of the gneisses are intricately joined with each other, and are together determined as the Śnieżnik—Gierałtów formation (H. Teisseyre 1973).

Both of the above mentioned formations make the core of the Kłodzko—Orlica dome. This core is mantled by: the Staré Město schist belt, the Zabřeh series, and the Nové Město formation (fig. 1).

The so-called schist belt of Staré Město occurs between the core rocks and the Branné series. The following rocks can be distinguished in this belt: gneisses and paragneisses, garnet schists, so-called motley series (metamorphosed basic rocks, metamorphosed cherts, limestones, quartz phyllites, graphitic phyllites), amphibolites, and tonalite intrusions (Svoboda, Chaloupský 1961). Those rocks pass continuously southwards and westwards into rocks of the Zabřeh series which is composed of mica schists, paragneisses, and amphibolites.

The Zabreh series passes continuously into the Nové Město formation (Svoboda, Chaloupský 1961). This formation is built of sericite phyllites, greenschists, and quartzites. The rocks in question are cut by igneous rocks of the Variscan cycle — mainly tonalites.

The Kłodzko—Orlica dome is bordered in the east by the Branné series, in the south and west by Cretaceous rocks of the North Bohemian basin, and in the north by the Upper Cretaceous rocks of the Stołowe Mts. and the Kłodzko metamorphic unit (fig. 1). The discussed dome was formed probably during Laramide

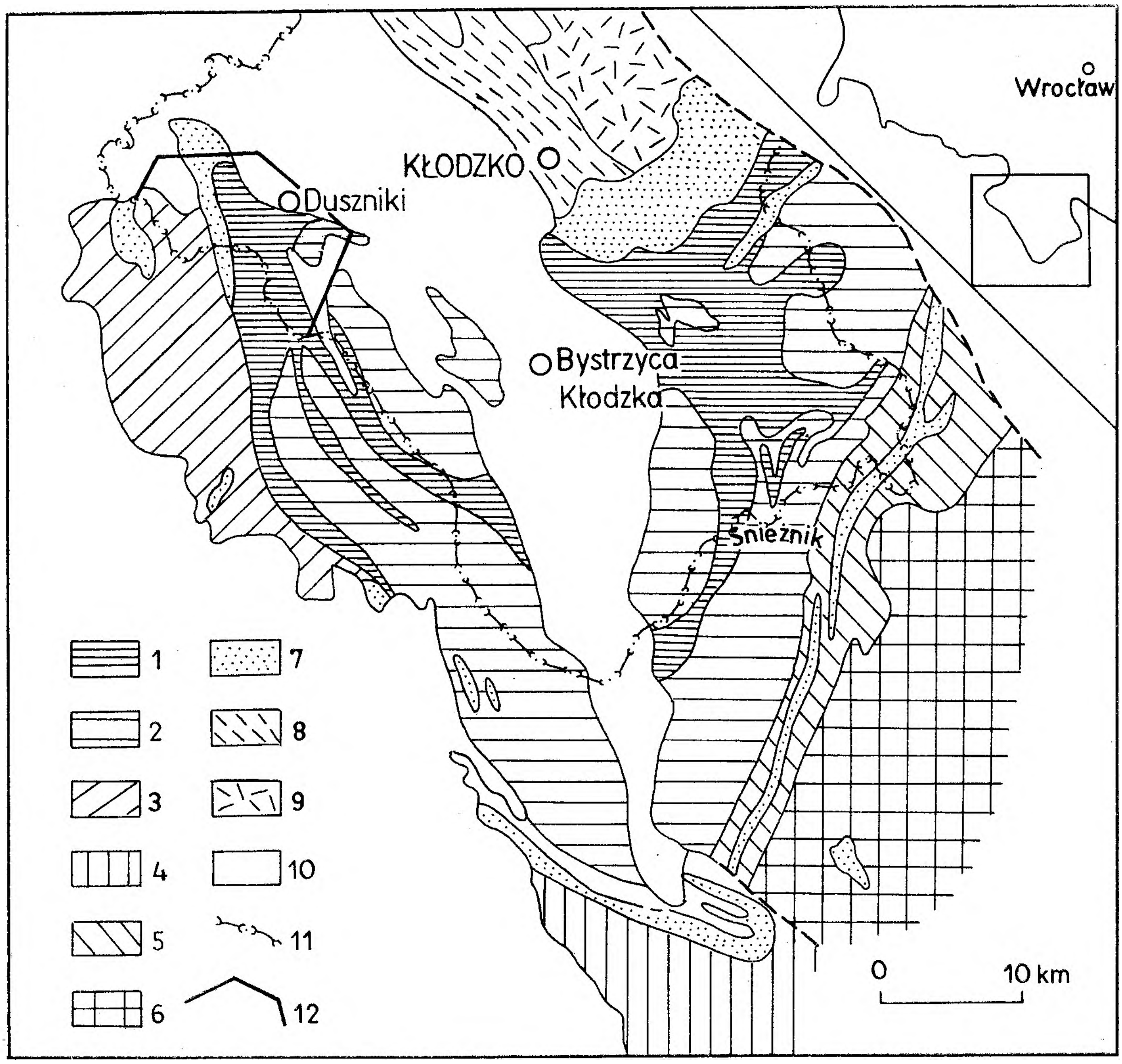

Fig. 1
Tectonic sketch-map of the Kłodzko-Orlica dome (according to F. Pauk 1953, Geological Map of ČSSR an scale 1 : 500 000, and Geological Map of ČSSR on scale 1 : 200 000 — sheet Nachod)

1 — Stronie formation; *2* — Śnieżnik — Gierałtów formation; *3* — Nové Město formation; *4* — Zabřeh series (formation); *5* — Staré Město schists belt; *6* — Branné series and Velké Vbrno series: *7* — plutonic rocks of the Variscan cycle; *8* — Kłodzko metamorphic unit; *9* — Bardo structure; *10* — Permo-Mesozoic rocks; *11* — state frontier; *12* — boundaries of the investigated area

Szkic tektoniczny kopuły kłodzko — orlickiej (wg Pauka 1953 — mapy geologicznej ČSSR w skali 1 : 500 000 oraz geologicznej mapy ČSSR w skali 1 : 200 000 — arkusz Nachod)

1 — formacja strońska; *2* — formacja śnieżnicko-gierałtowska; *3* — formacja Nového Města; *4* — seria (formacja) zabrzeska; *5* — pasmo łupkowe Starého Města; *6* — seria Branné i seria Velkého Vrbna; *7* — skały plutoniczne cyklu waryscyjskiego; *8* — metamorfik kłodzki; *9* — struktura bardzka; *10* — skały piętra permo-mezozoicznego; *11* — granica państwa; *12* — granice badanego obszaru

movements (during Caledonian orogeny according to Pauk 1953).

The geologists cannot agree as to the age of rock formations making the Kłodzko — Orlica dome as well as to their mutual tectonic positions.

Vagnerow (1943) ascribed the Stronie series (formation) partly to the Algonkian and partly to the Cambrain.

According to German geologists (e.g. Finckh 1931) the Gierałtów gneisses were older than the Stronie series (formation) which was deposited over the former. During Caledonian epoch granitic magma was intruded between the "Stronie schists" and their gneissic basement. The magma was later transformed into the Śnieżnik gneisses.

Fischer (1936) distinguished two series within the complex of the "Stronie schists". The older series (Archean) called the Młynowiec series was transformed into the Gierałtów gneisses owing to the intrusion of granitic magma. Both the Młynowiec series and the Gierałtów gneisses were subsequently covered with the younger series called later on the Stronie series.

Smulikowski (1957, 1958, 1960) and H. Teisseyre (1957) found no reasons to distinguish separately the Młynowiec series and the Stronie series. Moreover, both these investigators arrived at the conclusion that the Stronie formation and the Śnieżnik—Gierałtów formation are closely joined. Those formations were derived from the same parent assemblage transformed in different manner and degree by metamorphism and metasomatic felspathization. Thus, both types of the gneisses were regarded by them to be of the same age.

Don (1964) stated that the Gierałtów gneisses are the youngest element of the Śnieżnik metamorphic unit. The supracrustal Stronie formation was invaded by the young-Precambrian granitic magma which in turn was transformed subsequently into the Śnieżnik gneisses. During Caledonian movements "the Gierałtów gneisses were attached to them from beneath causing the transformations of the overlying rocks". Front of migmatization moved from beneath, from younger to older rocks which according to Don's interpretation occured at the top of the vertical sequence. This concept was later supported by certain structural observations (Don 1972a).

Ansilewski (1966) investigated metamorphic rocks of the Bialskie Mts. He ascertained that during the progressive metamorphism mainly owing to an increase of temperature, acid plagioclases were growing prior to more basic ones. This statement collides with Smulikowski's observations which were carried out in other parts of the Lądek—Śnieżnik metamorphic unit. Ansilewski claimed that "the development of the metamorphic rocks of the Bialskie Mts. took place without any significant influence of deep, alkali-bearing emanations". Various types of the gneisses occuring in this region resulted from "the diversified parent sediments and the metamorphic differentiation processes". Ansilewski assumed that the Gierałtów and Śnieżnik gneisses were derived from arkoses and two-felspar graywackes. Plagioclase paragneisses were transformed from plagioclase graywackes.

It is noteworthy that Juroszek (1974) found three generations of plagioclases in crystalline rocks of the Bystrzyca Mts. The oldest generation is represented in mica schists by albite developed during the regional metamorphism of parent sedimentary rocks. Two remaining generations are distinctly connected with the metasomatic processes. Microcline blastesis is widespread only in gneisses. Microcline is practically absent from mica schists. Two generations of biotite were distinguished by Juroszek. Flakes of the older generation are characterized by dark-green pleochroism, they are arranged parallel to foliation planes, and were developed during the regional metamorphism contemporaneously with the oldest albite. The second generation of biotite characterized by brown pleochroism is considered as the post-deformational one and connected with metasomatic processes.

The Zabřeh series was assigned by Kretschmer (1903) to the Devonian. However, Petrascheck (1910) claimed its correspondence to the Nové Město formation included by him to the Cambrian.

Kettner (1922) stated that the Zabřeh series belongs to the Algonkian alike the Stronie series (formation).

Kodym, Svoboda (1948) supposed that the Nové Město phyllitic formation is a stratigraphic counterpart of the Karkonosze phyllitic formation. According to them the Nové Město phyllites correspond also to phyllites of the Kłodzko metamorphic unit.

Phyllites and greenschists occuring in the last region were recognized by Bederke (1923) to have formed its younger, northern part. The older, southern zone was built, according to him, mainly of amphibolites. Wojciechowska (1966), however, distinguished in the Kłodzko metamorphic region three members of different age, namely: 1) the oldest one composed of gneisses, 2) the middle one built of phyllites and 3) the youngest member represented by the Ścinawka metamorphic granitoids as well as by granitized rocks of the two lower members.

Recently, however, there have been no sufficient reasons to parallelize the phyllites of the Kłodzko metamorphic unit with the phyllites of the Nové Město formation.

Rock formation making the Kłodzko—Orlica dome are divided into two areas by the Nysa graben filled up with Upper Cretaceous deposits. Thus, two limbs of the dome can be distinctly seen. These limbs converge gradually southwards to join each other to the south of Kraliký in Czechoslovakia.

It was Pauk (1953) who assumed that the rock series occuring on the both sides of the Nysa graben are of the same age and tectonic structure. This enabled him to distinguish the Kłodzko—Orlica dome. Striking similarities between rocks of the Orlickie Mts. and Bystrzyckie Mts. on the one hand and the rocks of the Lądek—Śnieżnik metamorphic unit on the other hand have been pointed many times (H. Teisseyre 1973). Czech geologists for a long time extended the usage of names attributed to metamorphic rocks of the eastern limb of the discussed dome to the respective series in the western limb. Therefore, in both these areas the terms: the Stronie formation (series), the Gierałtów gneisses or the Śnieżnik gneisses are commonly employed.

Sawicki (1958) stated that the metamorphic rocks of the Bystrzyckie Mts. and those of the Lądek—Śnieżnik region are joined by the Boboszów—Potoczek tectonic unit considered as the common one for these two regions.

Similar opinion was expressed by Oberc (1960, 1972) who found that metamorphic rocks occuring on the both sides of the graben represent the same "old-crystalline (Precambrian) series of the Sudetes".

All the data given in this paper concern those rock formations of the Kłodzko—Orlica dome, which are outcropped in the Polish part of the Orlickie Mts. It seems to me that they may be a certain contribution to the controversial opinions quoted above.

The detailed tectonic investigations, based on mesostructural studies, have been carried out for more than ten years in the Polish part of the Kłodzko—Orlica dome. The investigations, initiated in the Lądek—Śnieżnik metamorphic unit by H. Teisseyre, provided a number of interesting results. They allowed, among others, to establish a seqence of fold deformations recognized in this region.

H. Teisseyre (1973) distinguished five generations of mesostructures in metamorphic rocks of the Śnieżnik Mountain Group. Isoclinal folds (F_1) displaying eastern asymmetry form the oldest set preserved, however, only in relics. Axial planes to these folds are parallel to the main foliation referred to as S_1. Usually open folds displaying also eastern asymmetry constitute the second set (F_2). Axial planes (S_2) to F_2 folds are parallel either to strain-slip cleavage or to fracture cleavage. The S_2 planes are only exceptionally distinct. F_1 and F_2 folds are coaxial, trending N—S, NNW—SSE, or NNE—SSW. Therefore, it is difficult to distinguish L_1 lineations from L_2 ones. The L_2 lineation is virtually marked as rodding. The third set (F_3) includes small folds trending NE—SW and displaying SE asymmetry. Their axial planes are parallel to weakly developed both strain-slip and fracture cleavages. The fourth set (F_4) is generally well developed in rocks of the Stronie formation. It is represented mostly by kink folds displaying NE asymmetry and trending NW—SE. S_4 axial cleavage is weakly developed. F_3 and F_4 fold sets are accompanied by lineation (L_3 and L_4) marked as: crenulation of the main foliaton surfaces, quartz rods as well as S_1(S_3 and S_1) S_4 intersection lineation. The fifth set (F_5) is represented by kink bands, angular folds or joint drags trending E—W, or in approximate directions. According to H. Teisseyre (1973) the F_1 folds were due to shearing. Granitization of the supracrustal series (the Stronie formation) started after their development. F_1 folds were involved in F_2 ones. The latter are usually open with vertical or steeply dipping axial planes. Folds of megascopic dimensions observed in the discussed region were formed during F_2 deformation. H. Teisseyre (1973) claimed that the five fold sets are Caledono-Variscan in age.

Four successive deformational phases were distinguished in rocks of the Stronie formation occuring in the Ołdrzychowice region (Wojciechowska 1972). The oldest folds (F_1) were developed in the result of shearing. F_1 axes plunge steeply to SE. Distinct metamorphic crystallization took place along their axial planes referred to as S_2. The F_1 folds were coaxially deformed by F_2 folds which were also developed due to shearing under conditions of considerable plasticization of the rock series involved. F_2 folds plunge also to SE. F_1 and F_2 folds were also involved in F_3 concentric

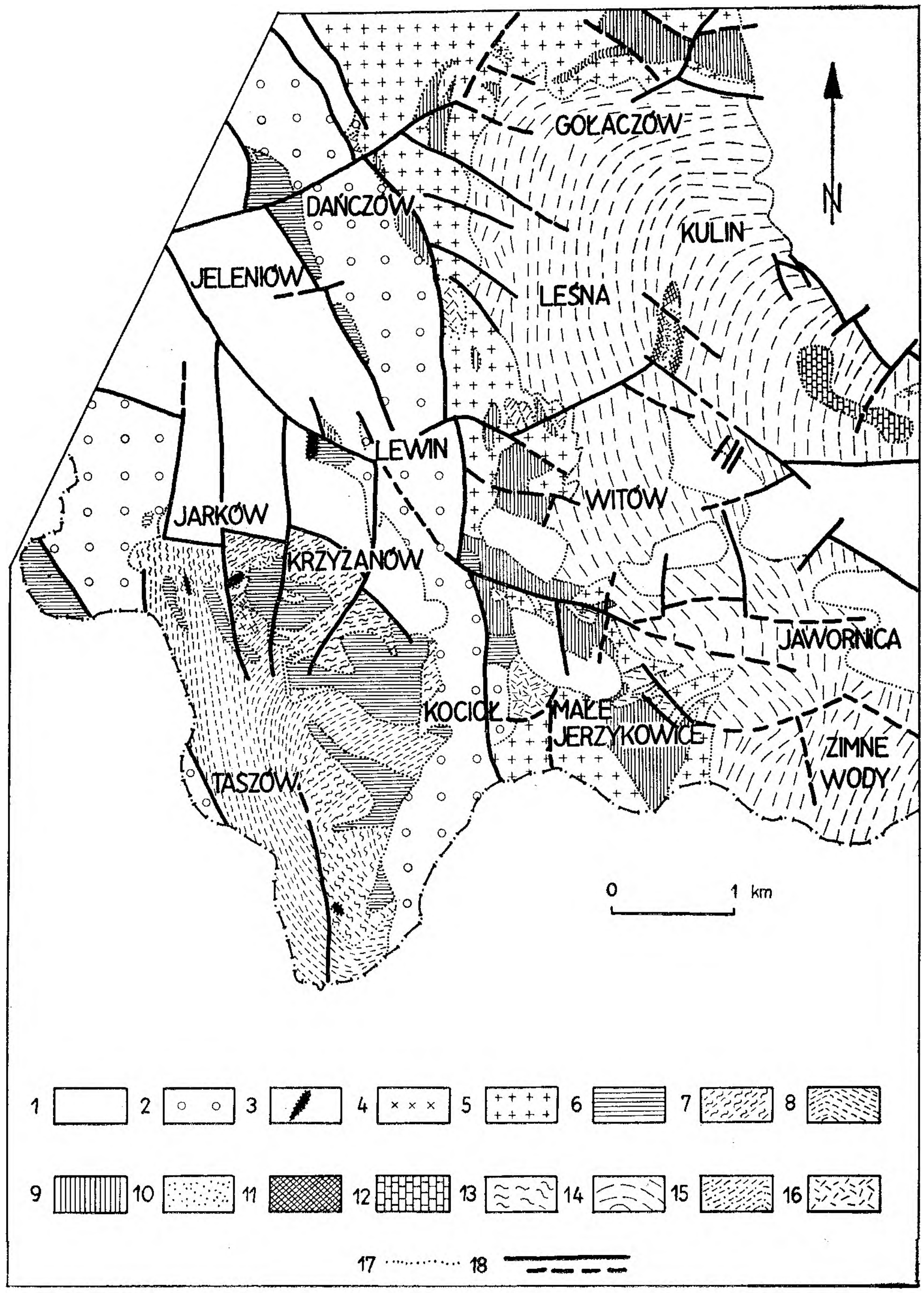

Fig. 2

Geological sketch-map of the Lewin – Gołaczów region (western part of the investigated region)

1 – Createaceous; *2* – Rotliegends; *3* – gabbro; *4* – microgranite; *5* – granitoids of the Kudowa – Olešnice massif; *6* – amphibole phyllites; 7 – twomica phyllites with graphitic admixture; *8* – sericite (-quartz) phyllites; *9* – amphibolites, amphibole schists; *10* – porphyroids; *11* – quartz-phengite schists; *12* – crystalline limestones; *13* – mica schists with graphite; *14* – mica schists; 15 – microcline gneisses; 16 – tectonic breccias, mylonites; 17 – lithological boundaries; *18* – faults: solid lines – recognized, dashed lines – inferred

Szkic geologiczny strefy Lewin – Gołaczów (zachodnia część polskiego fragmentu Gór Orlickich)

1 – kreda; *2* – czerwony spągowiec; *3* – gabro; *4* – mikrogranit; *5* – granitoidy masywu Kudowy – Olešnic; *6* – fyllity anfibolowe; *7* – fyllity dwułyszczykowe z przymieszką grafitu; *8* – fyllity kwarcowo-serycytowe; *9* – amfibolity, łupki amfibolowe; *10* – porfiroidy; *11* – łupki fengitowe, łupki kwarcowo-fengitowe; *12* – wapienie krystaliczne; *13* – łupki łyszczykowe z przymieszką grafitu; *14* – łupki łyszczkowe; *15* – gnejsy mikroklinowe; *16* – brekcje tektoniczne; *17* – granice wydzieleń litologicznych; *18* – uskoki: linie ciągłe – pewne; linie przerywane – przypuszczalne

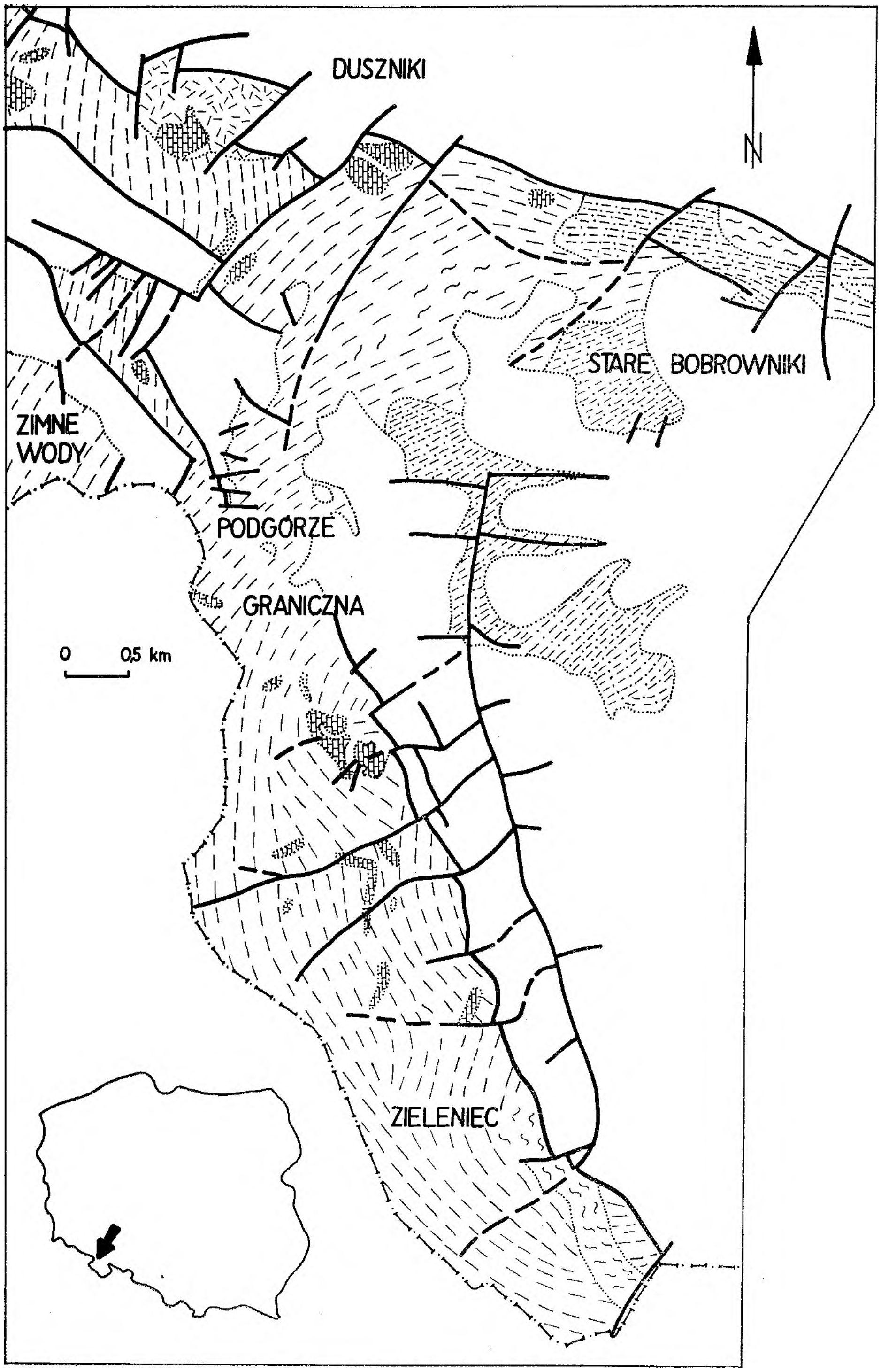

Fig. 3
Geological sketch-map of the Duszniki – Zieleniec region (eastern part of the investigated area). Legend as in figure 2

Szkic geologiczny strefy Duszniki – Zieleniec (wschodnia część badanego obszaru). Objaśnienia jak na figurze 2 folds while the deformed material got slightly more rigid. F_3 axes plunge 60/20. The fact resulted from changes of the stress field orientation. F_4 folds are represented by kink band structures. After their development the discussed rock series were subject only to the boudinage processes.

An interesting fold structure was described in the Różane Mts. by Don (1972b). F_1 isoclinal megafold was coaxially refolded by similar F_2 fold. Thus, axial planes to both these folds were brought into parallelism and the planes are in agreement with the main foliation of the region. F_2 fold axis is paralleled by L_2 lineation expressed as rodding. Moreover, a number of F_2 drag folds has been recognized. The F_2 axes plunge steeply to N or NE. The F_1 and F_2 axes are considered to be steepened during transversal refolding referred to as F_3. The F_3 axes are horizontal or plunge at the angles of 0—20 degrees either to NW or to SE. According to Don (1972b) the deformed rock material in the Krowiarki Range attained high plasticity during F_3 folding. He supposed that the very phase was accompanied by development of migmatic gneisses of the Gierałtów type. The view is supported by the presence of relics of country rocks within the Gierałtów gneisses.

So far few data have been published on mesostructural studies in the western limb of the Kłodzko—Orlica dome. Two sets of linear structures were observed by Dumicz (1964). The elder is striking approximately meridionally with plunges either to the south or to the north. It is represented by linear arrangement or elongation of mineral grains, drag folds, and small flexures. The second set recognized by Dumicz as the younger one, is scarce in evidence. It has been determined as the "northwestern set". Structures of the second set are recorded only in schists rocks occuring in the northern part of the Bystrzyckie Mts. The structures are developed as goufrage and more rarely as elongation of mineral grains. Linear structures of the second set plunge to NW at the angles of 5—20 degrees. Beside these two Dumicz recognized also the third set. It is rather rare and appears only as "small flexures trending W—E". The flexures are consistently characterized by southern asymmetry. According to Dumicz the meridional set (the oldest one) agrees generally with a trend of the higher order geological units of othe Bystrzyckie Mts. The main fold structures occuring in the discussed region are believed to have been Precambrian in age.

Granitegneisses of the Bystrzyckie Mts. have been parallelized by Dumicz (1964) with the Śnieżnik gneisses. According to him, the granitegneisses always display gradual transitions to the mica schists. However, Juroszek (1974) observed frequently tectonic nature of such contacts.

Evolutional development of the metamorphic rocks of the Bystrzyckie Mts. can be divided into ten stages, starting from the Precams brian and ending after the Upper Cretaceou- (Dumicz 1964). It is noteworthy that according to Pauk (1953) the Kłodzko—Orlica domd is built of two Caledonian nappe units movee eastwards. These are: the Kłapacz nappe structure recognized as the lower one and the Orlica nappe structure considered as the higher. Unfortunately this interesting concept has not been satisfactorily proved.

My investigations have been limited only to the Polish part of the Orlickie Mts., dealing with very small fragment of the Kłodzko—Orlica dome (fig. 1). The fragment is bordered in the south by the state frontier and on other sides by Upper Cretaceous rocks forming the Kudowa depression and the Stołowe Mts. (figs. 2; 3). There are Bobrowniki, Duszniki, Zieleniec, Taszów, Lewin, Gołaczów, and Dańczów in the investigated area. So far only few papers were devoted to metamorphic rocks of this region. Most of the investigators were concerned with rocks of the sedimentary cover overlying the metamorphic rocks. The cover consists of Rotliegendes rocks and most of all of Upper Cretaceous rocks which covered the older formations with numerous fragments strongly diversified as to their dimensions.

The Polish part of the Orlickie Mts. still lacks geological map on the scale greater than 1 : 200 000. Presently, there is only the sheet of Jeleniów done by Gierwieleniec (1958) on the scale 1 : 25 000. However, this sheet has covered only a small fragment of the metamorphic rocks area.

The first remarks on metamorphic rocks occuring in the discussed region can be found in Petrascheck (1910, 1944). They were rather general. The papers by Gierwielaniec (1957, 1965) have provided more information, though an extensive study of metamorphic rocks was not the aim of the author who investigated mostly granitoids of the Kudowa—Olešnice massif[1] and rocks of the Upper Cretaceous formation. The granitoid rocks were examined in details by Borkowska (1959, 1969).

Other papers published after War II dealt only very generally with the problems of the metamorphic rocks occuring in the Polish part of the Orlickie Mts., no matter whether they were petrographic works (Smulikowski 1952), tectonic works (Pauk 1953), or regional synthesis (H. Teisseyre *et al.* 1957; Oberc 1957).

In this situation my study may be regarded as the first attempt to discuss — at least approximately — the majority of problems connected with the metamorphic rocks of the Polish part of the Orlickie Mts.

The study which follows is, for the most part, a detailed description of the lithological units in micro- and mesoscopic dimensions in respect to the fold structures as well as to metamorphic transformations of the rock fabric. At first various lithological varieties will be discussed. Six deformational episodes have been revealed in the course of structural studies. In this paper, however, an influence of only first four phases will be featured. Small structural elements and evolution of metamorphic rock fabric dependent upon lithology, geometrical properties of folds of every sets as well as their mutual relations will be also characterized. The main point of this paper is to discuss the features of the tectonic structures and metamorphic fabric developed in the successive phases of the evolution of the region in question.

The field data on which this paper was based were collected in the years 1970—1972 under the scientific guidance of Prof. Dr Henryk Teisseyre. The studies were financially supported by the Geological Institute of the Polish Academy of Sciences. I would like to express my deep gratitude to Professor Teisseyre for his tutelage as well as for introducing me to the problems and research methods of the metamorphic regions of the Sudetes. I also wish to thank Doc. Dr Jerzy Don, Mgr Tadeusz Morawski, Doc. Dr Jan Burchart and Dr Michał Mierzejewski for reading the typescript and critical discussion allowing me to improve the text.

LITHOLOGY

The rock assemblages forming the metamorphic complex of the Polish part of the Orlickie Mts. are lithologically not too much diversified (figs. 2; 3). The most common rock domain is represented by mica schists occuring east of the Lewin graben filled up with Rotliegendes deposits. The schists are accompanied by lenses of crystalline limestones especially abundant in the Zieleniec—Duszniki region as well as by small bodies of porphyroids.

Amphibolites and amphibole schists occur in a narrow zone starting nearby the villages of Dańczów and Gołaczów and extending to the Czech side where most of these rocks are outcropped.

All the above mentioned rocks belong to the Stronie formation. The Kudowa—Olešnice granitoid massif separates this formation from the Nové Město formation. The last formation in Polish territory, is represented by sericite and amphibole phyllites accompanied south of Lewin by small gabbroic bodies.

Microcline gneisses of the Śnieżnik type occur only in the area situated immediately to the east and south of Duszniki, namely in the Strążyska Valley and the Bobrowniki region. They are considered as subordinate lithological element of the Polish part of the Orlickie Mts.

The principal petrographic features of the above listed rock varieties will be presented below.

THE STRONIE FORMATION

MICA SCHISTS

Mica schists of the Stronie formation, in the Orlickie Mts., are composed of minerals of a wide paragenesis including quartz, acid plagioclase, phengite, biotite, calcite, epidote, chlorite, tourmaline, apatite and garnet. Nevertheless, these rocks are lithologically fairly monotonous and there are only several not too distinct varieties. Most likely the varie-

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[1] The name used by Czech geologists. In the Polish literature the term "the Kudowa massif" has been employed.

ties resulted from lithological differences existing in the parent sediment. This can be expresed as variable content of the main minerals. Hence, there are layers richer either in quartz or chlorite and biotite, or in plagioclase. Sometimes, fairly thin layers are met, which consist only of for instance: albite + biotite, or albite + biotite + phengite, or albite + biotite + epidote, or albite + two micas + quartz + epidote, etc.

Because of strong fold defromations accomplished during the activity of metamorphic factors one can define the essential features of rock fabrics which were attained and subsequently alternated in the course of successive phases of development of rocks of the discussed region. It is also possible to establish a sense and degree of mineral transformations during the consecutive phases of the regional metamorphism. Thus, certain typical interrelations between main minerals can be ascertained, characteristic of each of the phases.

Plagioclase appears to be an especially characteristic and interesting mineral of the schists. Some plagioclase blasts include dark internal trails, hard to be recognized mineralogically under the microscope. These are most probably graphitic dust, opaque oxides and tiny mica flakes. The inclusions resulted partly from internal impurities of the primary felspar grains not involved into a crystal lattice of the albite blasts and developed at the expense of the former during the first phase of metamorphism. Undoubtedly, however, such inclusions originated mostly in other fashions. The second kind of inclusions encountered within the discussed plagioclases is formed by tiny quartz grains. Generally they are of a drop-like appearance, often rounded, and only occasionally irregular. Sometimes the quartz inclusions are wedge-shaped, and in such a case the direction of their alingment is parallel with the orientation of the dusty trails. Moreover, the internal trails follow the same direction which is expressed by the phengite of the surrounding schists and by relics of sedimentary banding. So, it can be inferred that the albite grains in the mica schists were growing under the static conditions.

Albite coming from the quartz-poor varieties never contains quartz inclusions or they are very rare. It is noteworthy that the discussed plagioclases irrespectively of their surroundings contain no mica inclusions. I was successful with findings of such inclusions only in 3 from over 1200 investigated blasts.

External edges of those albite grains are always very sharp and therefore they strongly contrast with a rock groundmass.

The above described plagioclases, so distinctly different from other felspars have been recognized to form an independent group within the felspars of mica schists. In order to avoid the term generation, bearing certain temporal implications I have determined the albites as the plagioclases of the first kind (group).

The features displayed by the second group of plagiocalses are fairly different from those of the first group. These plagioclases overgrew other, most likely older minerals. Internal inclusions within the plagioclases are represented mainly by phengite scales arranged parallel to foliation planes. In numerous instances blasts of the second group plagioclases include also fragments of directional fabric of the mica schists. Then streaks consisted of phengite and quartz are overgrown by plagioclases, and the streaks are usually parallel to foliation. Such inclusions can be abundant being, as a rule, concentrated at marginal parts of plagioclase blasts. Therefore, outlines of the blasts become obliterated and often hard to be precisely detected. The discussed plagioclase grains give an impression that they possess a great deal of intergrowths with the surrounding minerals. It is interesting that a content of the An particle is variable within the plagioclases of the discussed group. Some part of these plagioclases possess only several per cent of An. Remaining part of the plagioclase blasts are characterized by the An content ranging about 20 %. Plagioclases corresponding with their composition to acid oligoclase are, as a rule, lacking. The fact may suggest the presence of the so-called peristheritic plagioclases characteristic of the low metamorphic mineral assemblages (Barth 1969). It is interesting that blasts of the second group of plagioclases are usually smaller than those of the first group (albite). The above described plagioclases are considered as the second kind of plagioclases occuring in the mica schists of the Stronie formation in the Orlickie Mts.

There are only blasts of the third kind plagioclases that contain as internal inclusions scales of biotite arranged parallel to foliation planes. Fragments of microfolded fabric have been overgrown by these blasts. Hence, an orientation of the inclusions, excepting biotite ones, are rarely in agreement with foliation. The blasts are irregularly and undistinctly outlined. Plagioclases of the discussed group are characterized by the An content lower than 10% (albite). The third kind of plagioclases has been distinguished on the basis of the presence of biotite inclusions as well as on the basis of their characteristic structural position—they occur commonly in the hinge zones of microfolds referred to as F_2.

It is noteworthy that the An content increases usually in those plagioclases of the first kind, which are coming from calcareous phyllites or mica schists neighbouring to crystalline limestones. The same is true about epidote-rich varieties of the mica schists. It seems to be obvious that primary content of Ca in the parent sediment had to control the composition of plagioclases during the metamorphic convertions.

Epidote appears to be the progressive mineral of the first metamorphic phase. Its presence in the schists depended only on the concentration in the sediment of Ca, Mn, Fe and Al ions. Epidote minerals are associated only with the rocks containing biotite, chlorite or carbonate. They are lacking in the quartz-phengite varieties.

Also tourmaline appears to be the progressive metamorphic mineral. Boron concentration in the marine clay deposits is sufficient for its inception (Polański 1969). Hence, it is quite understandable that the greatest amount of tourmaline is encountered within the micaceous laminae. This is very common and stable accessoric mineral.

It should be stressed that both epidote and tourmaline can be met occasionally as internal inclusions within the albite grains of the first kind. Therefore, it is suggested that they slightly preceded the growth of the plagioclase itself and they did not originate from any secondary processes.

White mica has always very small optic axis angle, and according to Winchell's classification (Winchell, Winchell 1951) it can be defined as ferromuscovite. In this paper it is called more briefly – phengite. Flakes of the mineral are arranged along two directions representing two independent foliation surfaces. This suggests two generations of phengite.

Sometimes scarce phengite scales occur in the neighbourhood of the third kind plagioclases. They are intergrown with these plagioclases, but no relation to the directional fabric has been detected. May be such a phengite is of secondary origin developed as a byproduct of the plagioclase convertions. In the mica schists in the immediate vicinity of granitoids of the Kudowa—Olešnice massif occasional scales of similar phengite also occur, but no connection with any kind of plagioclases has been found there.

Chlorite, mainly clinochlorite, crystallized most frequently together with white mica. This is suggested by parallel arrangement of chlorite and phengite flakes. Some part of chlorite flakes may be, however, developed contemporaneously with biotite because these two minerals also form parallel intergrowths. Scarce pennine was probably associated with growth of the third kind plagioclase, and only exceptionally appears as the vein mineral displaying a spherulitic habit and filling up minute fissures in mica schists.

Preliminary investigations of the schists in question suggest that they do not display any easy detectable sign of metasomatic afflux of alkali ions. Plagioclases occuring in the mica schists may reach in some bands even 45 per cent of rock volume.

Finally, it seems to be noteworthy that mica schists occuring south of Duszniki, in the vicinity of Zieleniec, display in their mineralogical composition the greatest amount of the first kind albite whereas the schists abundant in the second and the third kinds of plagioclases outcrop in the region of Lewin, Kulin, and Gołaczów. Therefore, it is suggessted that the former area was subject to somewhat weaker metamorphic conditions during the main metamorphic phase than the latter. Such a view seems to be supported, among others by the occurence of the chlorite-bearing varieties of mica schists solely near Duszniki and Zieleniec.

AMPHIBOLITE, AMPHIBOLE SCHISTS

Amphibole-bearing rocks make an interesting but not extensively investigated group of metamorphic rocks of the Orlickie Mts. They are remarkably diversifield as to their attitude and to some extent as to their mineral composition. They outcrop, in Poland, only in the environment of Lewin and Gołaczów. The most common variety of the amphibole-bearing rocks is composed of actinolite, quartz, acid plagioclase, epidote, and common hornblende, but the mutual quantitive relations between these minerals can be significantly variable. Hence, the amphibole-bearing rocks occur in several varieties.

Weakly foliated massive amphibolite, met only in few sites (e. g. rocks from the summit of the Pański Kopiec Hill), display slightly different mineral composition, probably owing to its different origin. This rock consists of pretty randomly oriented actionolite, common hornblende, andesine, acid plagioclase, antigorite, zoisite, common epidote, sphene, garnet, and badly preserved pyroxene relics. The relics have been defined as augite and presumably occasional hypersetne. These primary pyroxene underwent strong uralitization accompanied with production of antigorite. Andesine of the parent rock was altered to acid plagioclase with intensive production of epidote minerals. Such retrogressive alternations were accomplished under the *p/t* conditions, most likely determining the main metamorphic phase, because the antigorite fibres have been arranged along planes parallel to the main foliation. Hence, it is suggested that the primary minerals of the parent rock were in disequilibrium under the conditions of regional metamorphism (Żelaźniewicz 1973b). Severe transformation of the parent rock fabric does not facilitate the determination of the origin of those amphibolites. Insignificant field dimensions and their scarcity seem to suggest rather sills and dikes—probably doleritic ones— than typical volcanic flows of the basic magma.

Igneous origin could be also assigned to the amphibolites occuring on the rocky slope above the road from Lewin to Jawornica, some 500 meters from Lasek Miejski. Rock fabric is completely orderless. Chief constituents are: fine-grained hornblende with deep green pleochroism and oligoclase which are accompanied by a great deal of garnets and limpid, tiny crystals of sphene. The latter are scattered and associated with leucoxene. Microscopical observations have revealed that certain amount of hornblende blasts was recrystallized yielding coarse-crystallic, poikiloblastic amphibole ($z/\gamma = 15-16°$) overprinted on the pre-existing fabric. Therefore, the new amphibole blasts attained their characteristic appearance owing to numerous inclusions of plagioclase and quartz. Oligoclase often yielded to alternations providing albite which occurs always in larger and more lucid grains than initial ologoclase. Such an albite inception was accompanied by epidote production. Garnets of this rock are strongly resorbed and plagioclase blasts are rimmed with opaque minerals.

There are no direct and undoubtful data to determine the age of those possible intrusions, if the above described rocks were really derived from the igneous ones. Metamorphic and to some extent structural phenomena recorded by fabric of the discussed rocks allow only to state that inception of those rocks possibly preceded the main metamorphic phase. The rocks cannot be clearly related to the porphyroid rocks.

Petrascheck (1910) and Gierwielaniec (1965) assigned the igneous origin only to certain part of amphibolites of the Orlickie Mts. Borkowska (1959) assumed, however, that all the amphibolites were derived from magmatic rocks but her view contradicts the opinions of other geologists.

All the above mentioned authors' claim one of the variety of the amphibolites, namely the coarse-grained amphibolite rocks occuring near Witów and Jawornica to have been of an igneous origin. Petrascheck called them "meta-gabbro", but this statement was supported only by his single discovery of a relic of the ophitic structure within similar rocks but outcropping on the Czechoslovakian side. Such rocks, however, are scarce there, accordingly to the opinions by Czech geologists.

There is no doubt about the differences existing between amphibolites from the Witów and Jawornica region and the amphibolites discribed above. The coarse-grained amphibolites contain much more quartz, their preferred orientation is far better developed, and display constant tendency to metamorphic segregation. This relies upon gathering of amphiboles in their own laminae and the same is true about plagioclase accompanied by epidote. Relatively extensive petrographical description of the rocks in question can be found in Borkowska (1959).

Variations in the quantitative relations of the main minerals make it possible to observe all transitions from the actinolite-quartz phyllites through the schists with an increasing content of acid plagioclase and epidote to the amphibolites composed of common hornblende, oligoclase, epidote, and quartz. In the last named amphibolites epidote, often subautomorphic is considered, at least in part, as the progessive metamorphic mineral beacuse of lack of any distinct proofs of secondary alternations. It is of equal rank with plagioclase in metamorphic processes and therefore very rarely appears in the form of internal inclusions within oligoclase occuring in those amphibolites.

There are two striking features of the amphibole-bearing rocks. Consistently large content of quartz is the first feature. The second one relies upon considerable tendency of plagioclase to be concentrated in the hinge zones or axial plane zones of folds referred to as F_2. Within the amphibolites numerous relics of folds of F_1 and F_2 sets occur as well as those of fabric developed during the $F_1 + M_2$ and $F_2 + M_2$ consecutive phases. The discussed rocks possess an excellent directional fabric and they often contain laminae made of light minerals. The laminae are involved in F_1 and F_2 folds. Thus, they must have undoubtedly belonged to the pre-diastrophic cycle and probably represented basic tuff derivatives.

Interesting amphibolitic rocks can be encountered some 500 metres from the eastern end of Lewin on the left stream-side. This rock is very abundant in plagioclase grains (up to 1,5 mm) excellently visible with a naked eye. The rock, seen both with a naked eye and under the microscope, immediately reminds albite-rich mica schists occuring near Duszniki (possibly metamorphosed felspathic wacke). It consists of common hornblende, oligoclase, epidote, and scarce quartz. All the minerals are only roughly directionally oriented. Plagiocalse grains display slightly rounded outlines, and are intergrown at their margins with amphibole-epidote matrix. Moreover, these oligoclases contain inclusions of drop-shaped quartz, epidote, and idiomorphic fibrous amphibole.

Certain peculiarity of the mineral composition of the amphibole-bearing rocks is due to an increased content of An particles in their plagioclases in regard to those occuring in the surrounding mica schists. Alternations of parent rocks (presumably dolerite or related tuffs) which must have been rich in calcium may be one of the reasons of that. Partly, however, it could be due to a convertion of marl sediment rich in calcium. Anyway, it seems to be undoubtful that the presence of Ca ions could control an amount of the An particles in the metamorphic felspars. There is no evidence that this phenomenon can be related to and connected with granitoid rocks of the Kudowa-Olešnice massif, though amphibolites occur always in the neighbourhood of the plutonic rocks.

CRYSTALLINE LIMESTONES

Carbonate rocks of the Stronie formation appear, in the Orlickie Mts. in two varieties. One of them is encountered as lenticular bodies of coarse-layered limestones, the second as calcareous phyllites. The first variety is composed mainly of calcite or dolomite rocks, pinkish due to hematite admixture. These rocks display fairly orderless internal structure. The microfloristic discoveries of Gunia (1974) were done in these very rocks, in the quarry situated in Duszniki. According to him, they would be limestones of the reef origin, developed in the Upper Proterozoic.

The aforesaid limestones are commonly associated with calcite-bearing schists or simply with calcareous phyllites in which calcite laminae alternate with those made of mica schist material (mica + quartz + felspar). In the extreme cases an incremental content of calcite which steadily pushes aside mica, quartz and plagioclases, finally yields thinly laminated limestones light in colour, and only occasionally of greyish hue. The fine lamination of the discussed rocks is due to the presence of either quartz-phengite or quartz-phengite-calcite laminae consisting of much coarser grains than those of the surrounding carbonate background. There is no trace of mobilization of calcium carbonate within the phyllites. Thus, it is inferred that the paragenesis embracing calcite, quartz, felspar, and mica was stable under the conditions of regional metamorphism affecting rocks of the Stronie formation. Signs of slight corrosion of plagioclase by calcite met sometimes along its margins are very insignificant. Occasional calcite filling up of tiny fissures transecting plagioclase grains seems to have developed during rather brittle deformation which affected subsequently metamorphic rocks of the Orlickie Mts.

Calcareous phyllites have never occurred independently but have been gradually turning into the above mentioned coarse-layered limestones what suggests their common origin probably in the same facies and stage of development of the parent deposit. It is also quite possible that we have to do here with a washing-out effect of the reefs having been primarily built up by the algae discovered by Gunia (1974).

QUARTZ-PHENGITE SCHISTS, PORPHYROIDS

Small lenses of quartz-phengite schists occur amidst the mica schists of the Stronie formation. Besides quartz and phengite insignificant amounts of plagioclases occur in their mineral composition. The plagioclases contain phengite inclusions and frequently overgrow the hinge zones of microfolds. They seem to be comparable with plagioclases of the second and third kinds distinguished in the mica schists. Rocks from each individual outcrop differ from one another solely in a coarseness of their mineral grains. Central parts of these outcrops are usually occupied by porphyroid bodies. Mineral compositions of both rocks are similar. Microcline phenocrysts reaching 2—4 mm are common in the porphyroids. Quartz phenocrysts are scarce. Those large crystals emerge from the fine-grained quartzo-felspathic background strewn with tiny scales of not too frequent phengite. The scales are arranged parallel to the distinct foliation of the porphyroid rocks. Both phenocrysts and minerals of the groundmass are slightly flattened in the plane parallel to the main foliation. Outlines of the phenocrysts are variably ragged. Sometimes large grains of potash felspar have thin outgrowths of secondary microcline. It seems that microcline in the rock groundmass is overdominated by acid plagioclase.

GNEISSES OF THE ŚNIEŻNIK TYPE

Microcline gneisses characterized by textural properties proper to those of the Śnieżnik gneisses occur in the Strążyska Valley south of Duszniki, and in the valley of the village of Stare Bobrowniki. Foliation of the gneisses is expressed by parallel arrangement of flaky minerals. Other minerals are grouped to various degree into directionally elongated aggregates and blasts. The main minerals of the discussed gneisses are as follows: microcline, quartz, acid plagioclase, and phengite. Microcline occurs in two generations. Biotite, chlorite, common garnet, and apatite appear far less frequently. Variable arrangement and distribution of these minerals throughout the gneisses allow to discern among them several varieties poorly differing, however, from each other. The predominant variety contains microcline as the main mineral which forms large blasts or even augen. Xenoblastic grains of potash-felspar are usually more or less sericitized, slightly flattened in the foliation planse and elongated parallel to the main lineation. The large blasts of microcline are poor in inclusions which do not display any distinct signs of reactions with their host. Those blasts are enveloped with streaks of phengite. So it may be thought that the mica was developed slightly later than the discussed microcline. The mentioned above characters of the microcline allow to distinguish it from the second kind (generation) of potash-felspar, looking completely differently.

The microcline described above has been determined as the first generation microcline.

Blasts of medium plagioclase (max. An_{36}) are also flattened in the foliation plane and wrapped with phengite scales. Microcline of the first generation may contains sometimes such plagioclases as the internal inclusions. Hence, it can be inferred that andesine or oligoclase slightly preceded the growth of the large microcline blasts. It seems, however, that the recrystallization of both felspars was roughly contemporaneous.

Acid plagioclase (albite—min. An_4) is much more frequently met component of the gneisses. Its grains are often more automorphic than those of the medium plagioclase. Their outlines and fashion of arrangement point to their inception under conditions closer to the hydrostatic pressure. Albite is fairly rich in quartz and mica inclusions. Not seldom it encloses both microcline of the first generation and more basic plagioclases. Therefore, it may be assumed that the discussed gneisses have presently character of the monometamorphic diaftorite (in the sense of Hsu 1955) resulting from the decrease of temperature during the regional metamorphism. Lowering of temperature and decrease of intensity of stresses were probably contemporaneuos with an afflux of alkali solutions bringing Na and K-ions. Presumably, the very metasomatic process greatly influenced the development of the above discussed albite.

It seems that the albitization was in a close connection with the secondary microclinization which renderred quite limpid, interstitial, microcline refered to as microcline of the second generation. Sometimes it formed rims around grains of the older felspars or reacted with them. However, it enclosed, as a rule, grains or fragment of the pre-existing fabric. These two generations of microcline differ from each other in a degree of sericitization. Microcline of the first generation yielded considerably to this process, but microcline of the second generation did only to a very limited extent. Such striking differences in a degree of the sericitization might result either from different resistance of both potash-felspars to weathering depending on slight variations in their chemical composition, or from an influence of metasomatic solutions bringing alkali ions on microcline of the first generation.

The processes of albitization and microclinization were accompanied by the growth of new phengite at the expense of both the first generation microcline and the medium plagioclase. Moreover, the mobilization of K and Na-ions was most likely contemporaneous with a significant mobilization of silica. Silica-bearing solutions penetrated the rock, providing, as the result of crystallization and recrystallization of the gneiss-forming minerals, the aggregate which consists of microcline of the second generation, albite, quartz, and phengite. Irregular streaks of this aggregate appear among fragments of the pre-existing fabric of the discussed gneisses. Considerable activity of SiO_2 resulted in a strong corrosion of the first microcline and medium plagioclase by quartz.

Light veins, reaching 5—10 centimetres in thickness, occur sometimes among the gneisses. They are always parallel to the main foliation of the surroundings. The veins are composed solely of albite and intergranular microcline displaying a microperthitic appearance. Gneisses adjacent immediately to walls of these thin sills were permeated by the vein material. Thus, in such places, the albite-microcline aggregate was projected into both the gneiss fabric and individual mineral grains forming the gneisses. The presence of such veins provides not only one more proof of the activity of hydrothermal solutions but also seems to indicate the manner of migration of these solutions as well as the fashion of ions wandering (mostly parallel to foliation planes).

Biotitization and chloritization of scarce garnets as well as chloritization of biotite are also expected to have taken place during the period of activity of hydrothermal solutions.

It is difficult to define precisely the nature of a source providing the alkali-rich solutions. In my opinion the mobilization of local material in only slightly deeper levels seems to be far more probable than assuming the true metasomatism caused by any undefined emanations coming from beneath. Of course, this assumption needs more extensive studies.

The microcline gneisses occuring in the vicinity of Duszniki are fairly poor in white mica. It could be due to involving of potash-ions into microcline. In such a case, however, small amount of quartz and mica may be expected to occur where potash felspar is abundant, but such a relation has not been observed.

The discussed gneisses are rather rich in quartz. Not seldom laminae composed only of quartz and phengite can be encountered. Moreover, the gneisses are accompanied with schists consisting of quartz, phengite and microcline, in which quartz appears to be the prevailing mineral, mica is abundant and microcline very scarce.

Microcline gneisses of the Orlickie Mts. are passing pretty rapidly into mica schists of the Stronie formation. Bounding horizon is usually made of quartzitic schists rather poor in phengite and almost completely short of acid plagioclase and microcline (only the first generation, if any). Thickness of this horizon is variable but never exceeds 80 metres. Obviously, directional fabric of the discussed schists is much better developed than that of the gneisses. Scarce flakes of phengite most frequently lie parallel to the main foliation planes. Quartz grains, despite their quite random distribution within the gneisses, are here directionally oriented, and considerably flattened in the planes of poorly developed foliation which is marked mostly by parallel arrangement of phengite scales. This foliation is oriented at the angle of about 30 degrees to the surfaces of the most distinct foliation.

It is noteworthy that microcline of the first generation (microcline of the second generation is lacking here) disappears very quickly from the mineral composition of the quartzitic schists with an increasing distance from the gneisses. Those transitional schists do not display any sign of a secondary mobilization of potash-felspar, or of an afflux of K-ions. They were touched only with postkinematic albitization (in respect to the main phase of deformation referred to as F_2). New albite invaded, enclosed, and partly replaced both microcline of the first generation and pre-existing plagioclase. That is why, myrmekite may be sporadically found. New albite formed sometiems a fine-grained aggregate, associated usually with quartz.

No recognizable traces of a secondary microclinization have been discovered in mica schists of the Stronie formation occuring in the Orlickie Mts. Sedimentary rocks from which the mica schists were derived, were presumably poor in detrital grains of potash-felspar. Postkinematic albitization of rocks of the Stronie formation was much weaker than that suffered by the discussed gneisses. The fact seems to confirm the above expressed hypothesis suggesting only local mobilization of alkali, restricted, in the Orlickie Mts., solely to the gneisses of the Śnieżnik type. Obviously, extensive investigations are needed on this subject, but it seems that presently the following work hypothesis may be stated: alkali-bearing silics solutions were due to metamorphic differentiation processes which took place in only slightly deeper levels of the same rock domain —i.d. within the mass of gneisses of Śnieżnik type. The horizon of the quartzitic schists could act, to some extent, as a sort of screen which practically stopped the wandering of alkali ions from the microcline gneisses to the overlying mica schists of the Stronie formation (in the investigated region).

The discussed microcline gneisses are exposed over a very small area, and they are lacking of meticulous petrological studies. That is why, there are not sufficient data to draw any well established conclusions on their origin and tectonic position. Therefore the following idea should be also treated hypothetically. Some facts seem to suggest that the microcline gneisses resulted from the regional metamorphism of arkosic sediment, and the process was considerably accompanied by metamorphic differentiation. Of course, other views on their origin can be by no means excluded. Nevertheless it is noteworthy that mineral composition of the gneisses points to similar metamorphic conditions like those influencing the development of rocks of the Stronie formation.

THE NOVÉ MĚSTO FORMATION

The Nové Město phyllites are the second principal rock formation occuring in the Polish part of the Orlickie Mts. (Stronie formation is the first one). It belongs to the mantle of the Kłodzko—Orlica dome. The formation crops out on the Polish side over rather small area.

The Nové Město formation is built up of two principal rock domains, namely the sericite phyllites and the amphibole phyllites. The phyllites differ but very little mineralogically and petrographically from their presumable counterparts in the Stronie formation — mica schists and amphibolites which were only stronger metamorphosed. Practically the only distinctive feature which allows to distinguish between the rocks of the Nové Město formation and rocks of the Stronie formation appears to be the dimensions of mineral grains. The Nové Město rocks are always much fine-grained than those of the Stronie formation. The Nové Město rocks can be determined as phyllites, according to the nomenclature proposed by Williams *et al.* (1958).

Since the Petrascheck time Czech geologists have considered all the phyllitic rocks as the epizonal age counterparts of the rocks belonging to the Stronie formation, and believed them to be the Algonkian sediment (Svoboda, Chaloupský 1961). Presently K. Domečka and M. Opletal (personal communication) cautiously suggest, in their inferred stratigraphical sequence, the higher position of rocks of the Nové Město formation than that assigned to rocks of the Stronie formation. According to them, amphibole rocks of the Nové Město formation were derived from both basic lavas and related tuff deposits. Moreover, K. Domečka and M. Opletal distinguished two lithological varieties within the group of the sericite phyllites. One of them was developed from greywacke and the other from pelitic sediment. The phyllites coming from greywacke are relatively coarse-grained and characterized by mineral assemblage comprising quartz, sericite, biotite, albite, and additionally tourmaline, oligoclase, garnet, apatite, opaque iron oxide as well as graphite. The pelitic rocks were metamorphosed to strongly micaceous (biotite and/or sericite) phyllites enriched commonly in opaque minerals.

On the Polish part of the Orlickie Mts. the meta-greywacke variety derived from psammitic deposits is quantitatively overwhelming. Biotite, if encountered in the microfolded portions, appears always to be an axial mineral (of F_2 folds). Sporadically observed growth of oligoclase followed the biotite blastesis.

Frequently some bands within the sericite phyllites are enormously abundant in albite grains (so-called Gneissphyllit of Petrascheck). This is obviously the lithological character inherited from the primary sediment and reflecting its features. It must be emphasized that structural features of the albite-bearing phyllites are identical with those presented by the mica schists cropping out in the Zieleniec area.

The second rock domain of the Nové Město formation can be generally defined as amphibole-bearing rocks. Amphibole phyllites (greenschists) and so-called amphibolites of the Nové Město formation should be mentioned here. Massive amphibolites of the Nové Město formation occur only on the Czech territory. Actinolite or chlorite-bearing phyllites are the main varieties which outcrop on the Polish territory. They are characterized by two principal mineral assemblages: 1) actinolite-epidote-quartz-chlorite-albite and 2) actinolite-epidote-guartz-albite. Other possible, but rarely occuring mineral associations are as follows: calcite-chlorite-quartz-sericite-acid plagioclase or chlorite-calcite-quartz-acid plagioclase.

Actinolite phyllites can be layered and particular bands appear to be composed of: 1) actinolite and epidote; 2) chlorite, epidote, actinolite, quartz, and acid plagioclase; 3) actinolite, plagioclase (albite) and insignificant amount of quartz. When such rocks are examined with a naked eye they are seen as darker and lighter laminae.

So far, excepting Petrascheck, nobody succeeded in finding any relics of igneous rock fabric within the amphibole-bearing rocks. Therefore, the long ago established view about lava and tuff origin of the rocks in question has been based only upon the traditional opinion supported by some lithological observations, and on the analysis of their field relationships in regard to the outcrop pattern visible in the geological map.

Calcite-bearing varieties of the phyllites could be possibly derived from the calcareous intercalations accompanying tuff deposits. Such rocks, however, are constantly arranged only along the definite zones of remarkably strong shearing, mainly along the fault thrust separating the Stronie formation from the Nové Město formation. It is well known that in strongly sheared zones fibrous amphibole is less prominent or may disappear entirely converting into chlorite (Moorhouse 1959). The same is true of epidote and clinozoisite. An inception of calcite might have been facilitated due to providing of CO_2 through the sheared zone. The latter mechanism was presumably responsible for the development of the phyllites rich in calcite and chlorite. Besides there is no valid reason to assume that under the same conditions of regional metamorphism parent calcareous deposits could be converted to rocks composed of chlorite, calcite, and plagiocalse in one place and to calcareous chlorite-free phylites in the other (Zieleniec region).

It is noteworthy that amphibole-bearing rocks of both the Stronie and Nové Město formations display all gradations from massive to well foliated varieties. The common origin of all those rocks seems to be probable. It may be assumed presently that the rocks in question are derived from basic lavas and their related tuffs, but extensive studies are needed to solve the problem satisfactorily. Igneous rocks were presumably in minority—otherwise any texture relics of the primary magmatic rocks should have been observed. Such findings ought to be expected if the low grade regional metamorphism is taken into account, even considering the action of severe shearing stresses. But so far the only discovery of relic of an ophitic texture was reported by Petrascheck. Massive, less altered rocks could suggest the presence of basic dikes preceding at least the main phase of deformation and metamorphism.

It is obvious that only petrographical or even chemical investigations cannot reveal the primary nature of amphibole-bearing rocks occuring in the Orlickie Mts. Other methods must be employed in this case. So far the rocks lack any serious, extensive and adequate studies, though such studies were initiated in the Lądek—Śnieżnik metamorphic unit by Smulikowski (1964). I managed to collect some new facts in the course of my structural research which can throw a litlle more light on the problem. These observations will be discussed below.

The Stronie and Nové Město formations, on the Polish territory, are separated from each other by the Kudowa—Olešnice massif and the Lewin Graben filled up with Rotliegendes deposits. Therefore it is a very hard task to study the very contact of these two formations. There are only two quite small exposures where the possibility of such studies is accessible. Careful examinations of thin section coming from the exposures have revealed that the possible transition, if any, must be very quick and rapid as well as accomplished in a distance of several to some tenths metres. This can be explained by rapid enlargement of the grain dimensions due to recrystallization of tiny actinolite needles to bigger crystals of common hornblende. Simultaneously with the recrystallization epidote disappears from a rock composition and more calcic plagioclase comes to grow. Actinolite phyllites have been involved in F_2 microfolds. The fact allows to notice that new growing crystals of common hornblende have been randomly distributed and overprinted on the pre-existing directional fabric of the phyllite. The enlargement of hornblende crystals was going on together with increasingly changing pleochroism. The discussed phenomena can be accounted for by assuming that recrystallization took place under lowered stress conditions approximating those of confining pressure (so after main intensity of kinematic events of main deformational phase referred to as F_2 and during the highest activity of metamorphic agents of M_2 phase).

K. Domečka and M. Opletal investigated the problem of the contact in question on the Czech side. They ascertained (personal communication) that the Stronie and Nové Město formations are constantly separated by a fairly narrow zone of thrust fault accompanied frequently by mylonitic rocks. Obviously, this zone prolonges to the Polish territory and runs in parallel to the strike of the main foliation planes referred to as S_2. It is this zone that is occuppied by the Kudowa—Olešnice granitoids. There are some facts (leaving apart their discussion now) which indicate that these granitoids were emplaced just after development of S_2 foliation, and they took advantage of the existence of those penetrative surfaces to be intruded into higher portions of the earth's crust (Żelaźniewicz 1973b). Shearing movements occuring along planes of the main foliation played a great role in this process. Hence, it can be stated that the inception of the discussed thrust fault dates back to the main deformational phase (F_2) and because the development of this discontinuity took place under still metamorphic conditions no cataclasis, brecciation, or mylonitization of rocks were attained. Nevertheless, the shearing movements along this zone were active considerably long, at least to the Upper Cretaceous period. Hence, metamorphic rocks which became much more brittle were also affected by these movements, in further stages of their so prolonged activity. This provided the mylonites mentioned by K. Domečka and M. Opletal. Microscopical examination of those mylonites have shown that at least last mylonitization operated in rocks after completely ended metamorphism. Thus, it is suggested that the observed mylonites are younger than the main metamorphic and deformational phase. Nowadays, as the result of the prolonged displacements, the zone of this thrust fault separates two different intersection levels of metamorphic rocks—the Stronie formation and the Nové Město formation. Therefore, no simple continuous transition betwen the discussed formations can be presently observed.

The above described phenomena of recrystallization of the actinolite phyllites recorded in the rocks adjacent to the border between these two formations (the rocks belong to the Stronie formation) most likely preceded or were contemporaneous, with the earliest stages of the development of the bordering thrust fault when the absolute vertical displacement was still low, or yet not actual.

It is probable that the fine-grained structure of the phyllites resulted from less intense (and, may be, shorter) activity of metamorphic factors (M_2) in the rocks of the Nové Město formation.

PLUTONIC ROCKS OF THE VARISCAN CYCLE

GRANITOIDS OF THE KUDOWA—OLEŠNICE MASSIF

The subject of this paper is limited only to the metamorphic rocks. Therefore, it does not cover the problem of granitoid rocks. Thus the rocks will be treated very briefly.

The granitoid rocks occur in a form of meridionally elongated body having about 17 kilometres in length, and its width ranging from 500 metres to 5 kilometres in the northern part of the massif, which outcrops in the vicinities of Kudowa, Czermna, Darnków, Gołaczów, and Dańczów. The body extends to the village of Olešnice on the Czech territory. There is a great deal of mica schists and amphibolite lenses which occur amidst the granitoid rocks, especially in the south, and are arranged chiefly parallel to the borders of the massif. The elongation of the massif is in an agreement with foliation of those xenolithic lenses.

Granitoids of the Kudowa-Olešnice massif were described in details by Borkowska (1959, 1969), and also by Gierwielaniec (1957, 1965). Borkowska stated that rocks of the massif comprise monzonite, granodiorite, tonalite and occasionally alkali granite. Moreover, Gierwielaniec additionally mentioned granogabbro and syenogabbro.

Borkowska (1959) ascertaining the prominent role of metasomatic processes in the development of the discussed granitoids states, however, that "it is little probable that the whole massif of the Kudowa granitoids could be developed due to simple' in situ' metasomatism of the older crystalline schists under the conditions of relatively low temperatures". Therefore, she assumes the hypothesis about profound granitization of earlier metamorphosed supracrustal rocks (of the Stronie formation) which owing to undefined tectonic movements were to be partly pushed to the deeper levels of the Earth's crust. The process of metasomatism caused those rocks to be granitized, plasticized and increased in their volume. Reomorphic intrusion took place as the result of this process. The granitoid masses intruding into mica schists contained a little of the fluid phase enriched in sodium and potash. According to Borkowska (1959) they were "the reason of contact felspathization and granitization observed in the mica schists occuring at marginal parts of the Kudowa granitoid massif".

Gierwielaniec (1965) supposes that the granitoids were due to "reomorphic and anatectic processes, and next during tectonic movements they were intruded into strongly folded series of mica schists". According to this author the discussed granitoids are of late-orogenic nature. This has been proved by internal directional textures as well as by concordant emplacement into the cover rocks. Gierwielaniec claimed that the granitoids in question are early Variscan or even may be Caledonian in their age.

Radiometric dating (K/Ar and Rb/Sr methods) of the discussed granitoid rocks resulted in ages 317—293 m.y. (cf. Burchart 1971).

GABBRO

Gabbroic rocks in the Orlickie Mts. are known to me only from few, very small exposures situated nearby Lewin, Jarków and Taszów. They are always outcropped amidst the phyllites of the Nové Město formation. The discussed gabbro appears to be a coarse-grained rock characterized by orderless fabric. There are big, green hornblende pseudomorphs after pyroxene. They interlock with large tabular plagioclase (An_{45}). Fibrous amphibole, streaks of fine-granulated quartz, and spots of epidote occur as interwoven matrix. Large crystals of acid plagioclase are occasionally encountered.

All the accessible samples are not fresh, still distinct signs of strong uralitization and sassauritization processes are recognizable. Much more detailed descriptions of the discussed rock are included in the papers by Petrascheck (1910) and Gierwielaniec (1965).

It must be stressed that the gabbro I have studied does not display any signs of influence of regional metamorphism.

Similar gabbroic rocks outcropping at the Špičak Hill near the village of Deštna (ČSSR) are crosscut by granitoid veins.

CHARACTERISTIC OF THE TECTONIC AND METAMORPHIC EVENTS

The evolutional development of metamorphic rocks of the Orlickie Mts. can be divided into three principal stages. During the first stage rock series were affected by isoclinal folding and, in turn, tight coaxial refolding. These deformations were accompanied by pro-

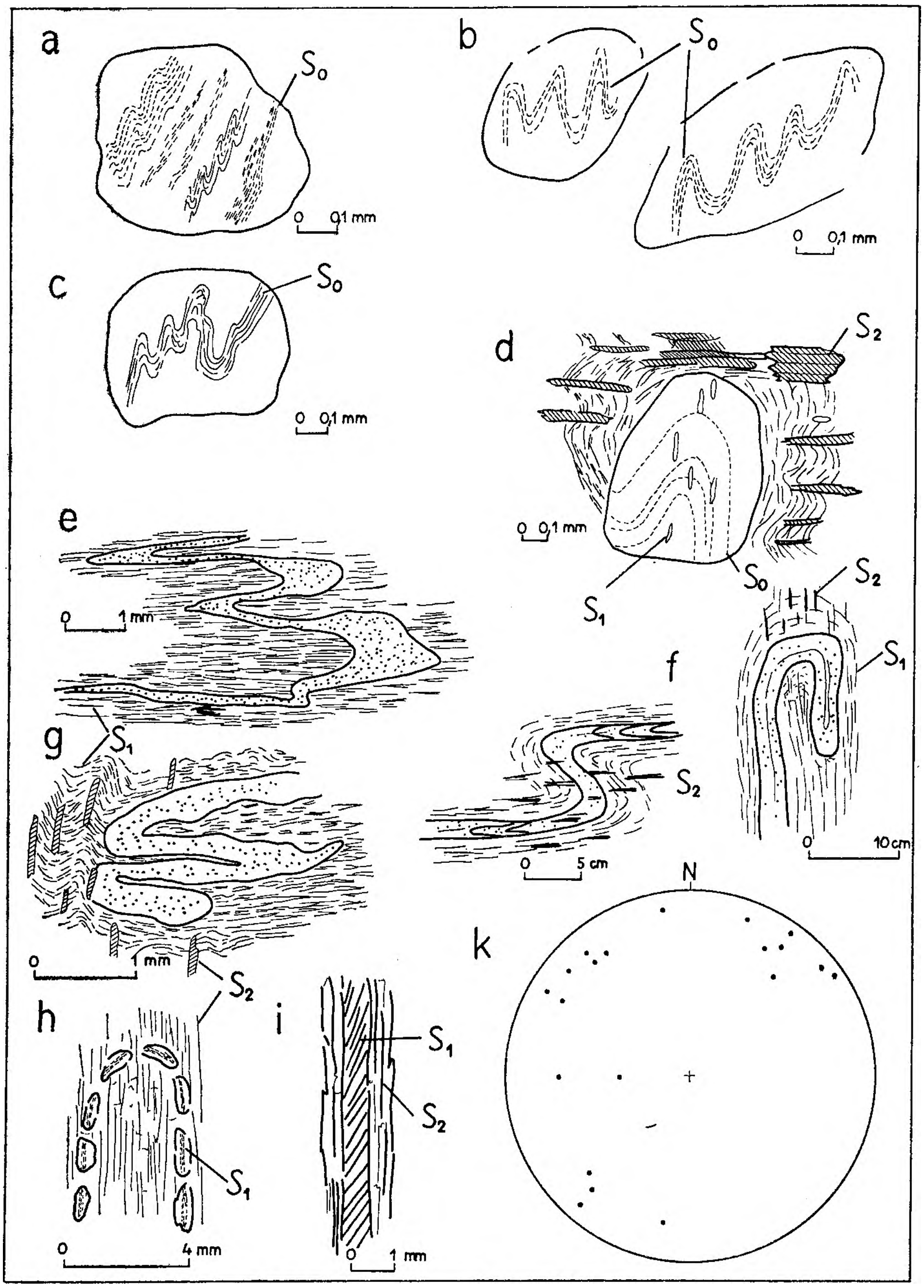

Fig. 4

Structural elements of $F_1 + M_1$ phase

S_0 – relic surfaces of sedimentary banding (bedding); S_1 – axial foliation of F_1 folds, developed during $F_1 + M_1$ phase and expressed by parallel arrangement of phengite scales in mica schists and actinolite needles in amphibole schists (phyllites); S_2 – axial foliation to F_2 folds, developed during the main phase of deformation and metamorphism referred to as $F_2 + M_2$, marked remarkably well by parallel arrangement of biotite flakes (obliquely lined)

a,b,c – dark dusty trails considered as relics of sedimentary banding involved in F_1 microfolds which are enclosed in the grains of $F_1 + M_1$ albite; *d* – relic of F_1 fold with tiny scales of axial phengite, enclosed in grain of $F_1 + M_1$ albite. Phengite flakes outside the grain are involved in F_2 microfolds whose axial planes are marked by large flakes of biotite (obliquely lined). Inclusions in albite are not affected by

Elementy strukturalne fazy $F_1 + M_1$

S_0 – relikty powierzchni sedymentacyjnego warstwowania; S_1 – foliacja fazy $F_1 + M_1$, równoległa do powierzchni osiowych fałdów F_1, wyrażona równoległym ułożeniem blaszek fengitu w łupkach łyszczykowych i aktynolitu w łupkach amfibolowych; S_2 – foliacja fazy $F_2 + M_2$ (główna), równoległa do powierzchni osiowych fałdów F_2, wyrażona równoległym ułożeniem blaszek biotytu (skośnie kreskowane) *a, b, c* – smugi ciemnych wyrostków ujęte w mikrofałdki F_1, które zamknięte zostały w blastach albitu $F_1 + M_1$. Smugi te stanowią relikty powierzchni sedymentacyjnego warstwowania; *d* – relikt fałdu F_1 obrośnięty przez ziarno albitu $F_1 + M_1$. Powierzchnię osiową fałdu podkreślają drobniutkie blaszki fengitu. Blaszki fengitu pozostające na zewnątrz tego ziarna ujęte zostały w mikrofałdki zespołu F_2. Równolegle do powierzchni osiowych tych mikrofałdków wzrasta biotyt (skośnie kreskowane). Wrostki w ziarnie albitu nie zostały dotknięte przez deformację F_2. Albit powstał zatem przed fazą $F_2 + M_2$; *e* – warstewka zbudowana z kwarcu i kwaśnego plagioklazu (kropkowane) ujęta gressive metamorphism which ceased at the end of the first stage. The second stage was recognized as the period of diagonal refolding of earlier developed structures, accomplished under much more brittle conditions. No distinct metamorphic transformations took place in the second stage. The third stage is marked by development of kink folds, joint drags and various discontinuous structures — cleavages, joints, and faults.

The above mentioned stages were distinguished on the basis of the followings items: 1) the character and style of deformation, 2) the similarities in orientation of the principal stresses and 3) the relations of deformations to metamorphic processes. Closely interrelated phases of deformation (F) and metamorphism (M), subordinate to the stages, have been distinguished if tectono-metamorphic phenomena of a given stage display certain diversity. Two phases are well established in the first stage. They are referred to as $F_1 + M_1$ and $F_2 + M_2$. $F_3(+M_3)$ phase is conditionally included into the first stage because F_3 structures were recognized only locally, and there is lack of any data on its regional meaning. The second stage comprise only one phase referred to as F_4. The third stage embraces three phases referred to as F_5, F_6 and F_7.

All the mentioned phases have been distinguished most of all on the basis of meticulous studies of relations occurring between folds recognized in the field. It has been assumed that the folds of every older phase deform the folds belonging to any earlier one. F_1 and F_2 deformational phases were accompanied by respective phases of progressive. metamorphism. The phases are referred to as M_1 and M_2.

The Kudowa — Olešnice granitoids occupy a peculiar position. They were intruded both at the end of the first stage and after the second stage, though presently it is hard to say when the main part of the granitoid masses was emplaced.

The metamorphic and tectonic phenomena discussed below differ but little in their intensity and nature in each lithological variety. Therefore the succession of the description of the rocks affected by them will be slightly different from that employed in previous chapter. The rocks in which all the questioned events have been recorded and recognized best will be featured at first.

THE FIRST STAGE

THE $F_1 + M_1$ PHASE

Structural elements

There are only scarce relics of the structures developed during the oldest deformation. Within albite grains encountered in mica schists south of Zieleniec relics of microfold hinges were preserved (fig. 4 *a — c*; pl. III) Careful microscopical examinations have revealed that inferred axial planes to those folds were involved in other folds accompanied by extremely characteristic axial biotite foliation. The latter were recognized as belonging to the main set in the region and referred to as F_2. Obviously those microfolds must have been developed earlier and can be referred to as F_1. Hence, microfolded dusty trails included in the albite grains and reflecting the geometry of the earliest folds must have been regarded as the relics of sedimentary banding (S_0). The style of the

F_2 folding, thus this albite preceded the $F_2 + M_2$ phase; *e* — band composed of quartz and acid plagioclase (stippled) involved in F_1 folds whose axial planes are expressed by perfect parallel arrangement of actinolite neddles (of $F_1 + M_1$ phase); *f* — F_1 intrafolial folds seen in plagioclase-rich layres (stippled) which are involved in F_2 folds whose axial planes are marked by parallel arrangement of biotite scales; *g* — quartz-acid plagioclase band (stippled) involved in F_1 fold whose axial foliation is expressed by parallel growth of phengite. This phengitic foliation is folded about F_2 axes. F_2 folds have axial biotite foliation (obliquely lined). Note that phengite matrix remains unfolded in the immediate vicinite of the quartz-plagioclase band which resisted F_2 compression in the very place (difference in competence of the mineral material involved); *h* — grains of $F_1 + M_1$ albite including dusty trails considered as the relics of sedimentary banding. Both grains and relics are involved in F_2 fold; *i* — scales of $F_1 + M_1$ phengite preserved as incompletely reoriented relics which are arranged obliquely within the streak of micas of $F_2 + M_2$ fabric; *k* — diagram showing an orientation of linear structures of $F_1 + M_1$ phase

w fałdki F_1, których powierzchnie osiowe podkreśla foliacja wyrażona równoległym ułożeniem igiełek aktynolitu (powstałego w fazie $F_1 + M_1$); *f* — śródfoliacyjne fałdki zespołu F_1 przefałdowane wokół osi F_2. Blaszki biotytu równoległe do powierzchni foliacji głównej S_2; *g* — warstewka zbudowana z kwarcu i kwaśnego plagioklazu (kropkowane) została ujęta w fałdek F_1, którego powierzchnię osiową podkreśla równoległe ułożenie blaszek fengitu. Powierzchnie S_1 zostały ujęte w fałdy F_2. Równoległe do powierzchni osiowych otwartych fałdków F_2 rośnie biotyt (skośne kreskowanie). Blaszki fengitu leżące w sąsiedztwie tej warstewki nie zostały zdeformowane. Sama warstewka również nie uległa deformacji w fazie F_2, co wynikło z jej większej, w stosunku do otoczenia, kompetencji; *h* — ziarna albitu $F_1 + M_1$ z ciemnymi smugami wrostków stanowiącymi relikty powierzchni sedymentacyjnego warstwowania. Ziarna te (oraz zawarte w nich wrostki) ujęte zostały w fałdek F_2; *i* — blaszki fengitu $F_1 + M_1$ ułożone skośnie w obrębie pasemek łyszczyków fazy $F_2 + M_2$, jako wynik niedokończonej reorientacji; *k* — diagram ilustrujący orientację drobnych form linijnych fazy $F_1 + M_1$

discussed microfolds is variable. Isoclinal though asymmetric ones are predominating. Thickness of the individual dusty layers when measured along a line parallel to the axial planes of the microfolds has been analyzed according to the method proposed by Ramsay (1962). The carried out analysis has revealed that the F_1 structures were due to flexure mechanism and later modified in various extent by differential shearing along S_1 axial planes.

Other examples of F_1 folds have been collected in the railway cutting nearby Gołaczów. One of them is shown in fig. 4*d*. Oval (unflattened) albite grain overgrew here the closure of F_1 fold which has been marked by arrangement of dusty trails. In this case it took place after the development of S_1 axial phengite foliation because its fine relics were also embodied inside the grain. The inner traces of S_1 surfaces are roughly parallel with the preferred orientation of white mica flakes of the surroundings. These phengite scales were involved in F_2 folds recognizable due to the presence of S_2 penetrative biotite foliation. However, straight lines of the internal S_1 mica inclusions do contrast with folded S_1 phengite matrix outside the plagioclase grain. This leads to the conclusion that the growth of $F_1 + M_1$ albite (plagioclase of the first kind) was ended before the begining of F_2 movements. Thus, this albite[2] was developed during the oldest phase of deformation (F_1) and metemorphism (M_1) referred to as $F_1 + M_1$. Such a conclusion is supported by the fact that the directional $F_1 + M_1$ fabric[3] of mica schists formed jointly with other minerals by the described albite, and marked most of all by a parallel arrangement of phengite scales, was involved in F_2 folds, the ones developed during the main deformational phase.

F_1 microfold structures were found also in amphibole schists occuring in the vicinities of Lewin and Gołaczów (fig. 4*e*, *g*). In figure 4*e* thin quartz band contains a subordinate inner streak composed of acid oligoclase and rare amphibole needles. This band is isoclinally folded and the fold closures are intergrown with fibrous amphibole oriented parallel to the axial planes. Thus, the axial plane foliation arises, expressed excellently by parallel arrangement of actinolite needles. Also the blasts of the light minerals such as quartz and plagioclase are strongly flattened in the very plane. This actinolite foliation is referred to as S_1, because of extremely good parallelism of the amphibole needles and its discordant orientation to the axial planes of the main F_2 folds occuring in the surroundings being folded during the main stage of deformation. Thus, S_1 foliation in the amphibole schists is marked by a perfect parallel arrangement of actinolite needles. The analysis of the geometry of the fold presented in figure 4*e* indicates that it was undoubtedly modified by superimposed shearing.

Similar structure is shown in figure 4*g*. Quartz-albite bands were isoclinally folded. S_1 axial plane foliation was also marked by the parallel growth of actinolite needles and this foliation was involved later in F_2 folds.

All the above quoted examples have distinctly indicated that the careful observations, first of all, of F_2 fold closures can—at least in part—allow to reconstruct the features of the $F_1 + M_1$ fabric. It has been revealed in this very way that the albite grains with dusty inclusions, strongly flattened in S_1 planes should be considered as the relics of $F_1 + M_1$ fabric, not yielded to subsequent recrystallization (fig. 4*h*). Frequently observed diagonal orientation of phengite flakes or amphibole needles within the bands made up by those minerals generally arranged in parallel to S_2 planes (main foliation) appears to be also the structural relic of the $F_1 + M_1$ fabric. Rough microscopical observation of such a pattern of disposition of flaky minerals suggests the idea of their orderless orientation due to recrystallization in $F_2 + M_2$ phase, implying immediately conditions of the process. Careful examination, however, seems to indicate that this apparently random orientation is just the result of the unfinished process of rotation and recrystallization of the $F_1 + M_1$ flaky and needle minerals to the position characteristic of the minerals forming $F_2 + M_2$ fabric—i.d. the position of parallelism with S_2 foliation (e.g. fig. 4*i*).

F_1 fold structures can be also discovered where the undoubted F_2 folds refolding the older but still visible isoclines are met (fig. 4*f*), and two sets of independent directional

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[2] For the sake of simplification of the further description it will be referred to as $F_1 + M_1$ albite.

[3] $F_1 + M_1$ fabric means structures, textures and relations between the rock-forming minerals attained during $F_1 + M_1$ phase, $F_2 + M_2$ fabric — during $F_2 + M_2$ phase, and so forth.

fabric may be distinguished, mostly under the microscope, in the F_2 fold closures.

The F_1 folds are rather scarce and their actual forms are generally very small. Therefore only a few measurements of their axial directions could be collected. However, an interpretative value of these measurements seems to be insignificant owing to intense rotations accomplished in the course of superimposed deformations. Nevertheless, it can be stated that F_1 fold axes are either coaxial or nearly coaxial with F_2 ones, thus their spatial orientation does not differ from the position of the main structures (fig. 4*k*).

Mineral lineations developed during $F_1 + M_1$ phase were almost completely recrystallized and/or obliterated. Hence, they could be recognized only very rarely. In a few cases L_1 lineation happened to be discovered and traced around the closures of F_2 folds. It has revealed that the angle between these two linear structures is usually low, ranging from 0 up to 20 degrees. The highest values of this angle, within the mentioned limit, are met in the Zieleniec area. L_1 lineation is usually due to parallel arrangement of $F_1 + M_1$ albite blasts (plagioclase of the first kind) and due to fine warpings of micas which wrap up the felspar grains. The density of the lineation seen in the rock profile (in mica schists) depends on the content and unequal distribution of the albite blasts throughout the rock. Thus L_1 structures do not occur in every folia.

Metamorphic phenomena

Metamorphic events accompanying the oldest deformation can be reconstructed only in those places where there is no doubt about the existence of $F_1 + M_1$ fabric. Fold closures (both F_1 and F_2) are usually most suitable places. Therefore one cannot investigate a sequence of metamorphic phenomena until the structural setting and manner of development of tectonic forms are understood and featured as fully as possible.

Progressive metamorphism (M_1) followed an advancing deformation of the primary sedimentary pile. Most likely the metamorphism was later but little in reference to purely kinematic phase (F_1) because the $F_1 + M_1$ albite overgrew fragments of both hinges and limbs of the oldest folds. It has been considered that the minerals of the earliest fabric crystallized roughly simultaneously, still the growth of epidote and tourmaline probably could slightly precede the blastesis of albite which sometimes contained the two minerals as internal inclusions. It has already been mentioned that only few from over 1200 investigated albite grains did contain white mica flakes in the form of inclusions. Usually drop-shaped quartz inclusions are practically the only significant inclusions within the grains of $F_1 + M_1$ albite (pl II). This quartz is considered to have come either from the primary intergrowths in the pre-existing detrital felspars or simply from the relic quartz grains belonging to the parent sedimentary rocks. It has already been mentioned that, in the mica schist varieties poor in quartz, the $F_1 + M_1$ albite grains are free from inner quartz inclusions. In the common mica schists—usually rich in quartz—the dark dusty trails occuring inside the $F_1 + M_1$ plagioclase often parallel the tiny guartz accumulations inherited from the lamination existing in sedimentary rock. The lamination seems to be reflected, among others, by variable amount of quartz in particular layers. This can be seen well in F_2 fold hinges (cf. pl. I). Sometimes such accumulations are prologned into albite grains which get then rich in quartz inclusions arranged parallel to orientation of dusty trails. These fine opaque inclusions behave in much same way. They also find their outer extension in a parallelism with the $F_1 + M_1$ phengite fabric. All the above observations lead to the conclusion that during its development the $F_1 + M_1$ albite did overgrow and include tiny fragments of the sedimentary rock fabric and kept them preserving as the internal relics (pls. II; III). The above information supported by the already mentioned attitude of the plagioclase grains (sharp outlines), character of their internal inclusions (especially the complete lack of mica ones, though quartz inclusions are abundant), and abundance of plagioclase (up to 45 per cent) within the quartz-free varieties of mica schists seem to indicate that the $F_1 + M_1$ albite was developed due to generally isochemical recrystallization of both detrital grains and quartzo-felspathic aggregates existing in the primary sedimentary rocks —i.d. in the graywackes (pls. I; II; III). It may be expected that strong shearing stresses—those typical for epizone (Huang 1962)—considerably facilitated the detrital plagioclase grains to be solved and these stresses influenced the growth of $F_1 + M_1$ albite blasts tending to be stable in the conditions of the $F_1 + M_1$ phase. Blastesis of those albites as well as their arrangement in the metamorphic rock were undoubtedly controlled by distribution of grains of detrital felspar throughout the graywackes. These grains could act as the seeds of crystallization. It seems, however, that usually strongly limited, local metamorphic differentiation was employed which made the solutions migrate over certain, very short distances to any places at least slightly more convenient for crystallization. Frequently the F_1 microfold hinges were such places. In agreement with a tendency displayed by albite crystals for developing large porphyroblasts, the $F_1 + M_1$ albite tended to build big blasts. Insignificant dimensions of $F_1 + M_1$ phengite flakes seem to be indication, though by no means infallible, of rather short time of activity of metamorphic agent of M_1 phase.

It must be emphasized that I have found no symptom of true metasomatic processes taking part in the development of felspars occuring in mica schists. Obviously, an extensive petrological investigations should be done on this subject. The hypothesis about the detrital ancestors of $F_1 + M_1$ albite could be also supported by some other facts. Calcite laminae within the calcareous schists often include more plagioclase grains than laminae composed of mica, quartz and felspar (cf. pl. III *2*, *3*). In other case some nearly exclusively quartz-micaceous bands are met within mica schists. The only difference from their schists surroundings characterized by common mineral composition is due to the very shortage in plagioclase. These phenomena may be easily explained as the effect of primary distribution of felspar grains within sedimentary rock, without assuming the selective felspathization whose existence is hard to prove because of lack of sufficiently convincing data.

Many of the $F_1 + M_1$ albite porphyroblasts are rimmed with fine opaque film. Most likely it is these grains that were developed by enlargement of seed crystals present in the parent rock. All primary impurities (especially opaque) did not contribute to the growth of porphyroblasts and therefore became crowded aside as the growth proceeded.

It is rather hard to reconstruct precisely all peculiarities of the fabric developed during the oldest phase referred to as $F_1 + M_1$ (F_1 – kinematic, M_1 – static) because of remarkably strong recrystallization taking place in the subsequent phases. Nearly complete lack of inclusions of white mica inside the $F_1 + M_1$ albite grains seems to bear evidence on the plagioclase blastesis prior to the growth of phengite. In the places where $F_1 + M_1$ fabric was occasionally well preserved one can notice, within such relics, that the phengite flakes parallel to S_1 planes thoroughly envelope the sharply outlined blasts of albite.

The blastesis of $F_1 + M_1$ phengite was associated with the inception of $F_1 + M_1$ chlorite because these two minerals are commonly encountered in mutual intergrowths. Certain part of chlorite flakes belonging to these intergrowths happened sometimes to be arranged diagonally to the phengite flakes marking the S_1 foliation. This is probably due to very low position of chlorite in the crystalloblasts series, even below quartz. It should be stressed that such chlorite-phengite intergrowths are characteristic of very weakly metamorphosed rocks.

Sometimes in the samples of amphibole schists the relics of $F_1 + M_1$ fabric and F_1 folds are still preserved. They allow to ascertain that, at least in the case of sampled rocks, the oldest metamorphic events gave rise to principal mineral assemblage consisting of actinolite, quartz, albite as well as subordinate epidote which may be often lacking. Lack of epidote when plagioclase is present may provide a certain genetical indication. Low content of Ca could be a feature of the parent rock. Thus, the possibility of derivation of the discussed metamorphic rock from basic igneous rock or from marls seems to be excluded. Presumably, the initial rock might be some sort of tuffs. It is hard to say, because of shortage of discernible relics of $F_1 + M_1$ fabric, whether all the varieties of amphibole-bearing rocks were characterized during the $F_1 + M_1$ phase by mineral assemblage like the one cited above. It seems that the assemblage was typical for a large part of those rocks.

The reconstruction of the characters of $F_1 + M_1$ fabric in other lithological varieties of the Orlickie Mts. is practically impossible – at least so far.

All the above cited data permit to draw some conclusions. They are as follows below.

1. Huge mass of deposits, presumably of geosynclinal type, intercalated with small bodies of acid and basic igneous rocks was subject to the oldest deformation. It is very hard to establish the scale of this folding. Supposedly it was rather large. All preserved relics of F_1 folds suggest tight or isoclinal geometry. Primary axial directions of those folds are impossible to be reconstructed because of later refoldings. The F_1 fold structures were greatly obliterated by recrystallization of the main metamorphic phase referred to as M_2. Outcrop pattern also brings no answer to the question because no undoubed F_1 folds can be distinguished in the course of analysis of the geological map.

The oldest folds were accomplished by flexure mechanism and subsequently modified by superimposed shearing along planes of S_1 axial foliation marked by parallel arrangement of phengite flakes in mica schists and amphibole needles in amphibole schists.

Careful examination of the angle relations between surfaces of S_1 and S_2 foliations led me to the conclusion that in the Zieleniec region the discussed F_1 folds were upright whereas in the Lewin—Gołaczów region they attained recumbent position.

2. The oldest deformation (F_1) preceded the begining of metamorphic events (M_1) which started after the F_1 folds had been formed, that is after a rotation of the fold limbs had been ended. This first metamorphism affecting the sedimentary series was of low grade, epizonal type characterized by very strong stresses and high content of H_2O. The mineral paragenesis embracing quartz, phengite, albite, chlorite, tourmaline, epidote, calcite, and garnet was developed in mica schists. Amphibole schists were built by minerals of the paragenesis including actinolite, quartz, acid plagioclase and epidote.

3. The oldest plagioclase occuring in mica schists was developed during M_1 phase. This plagioclase referred to as $F_1 + M_1$ albite was derived from both detrital plagioclase grains and quartzo-felspathic aggregates existing in the parent sedimentary rocks. Their inception was controlled by the process of metamorphic differentiation most likely effected by the solutions principle and the principle of enrichment of the stables constituents, envisaged by P. Eskola (cf. Moorhouse 1959). Large amount of felspar in the mineral composition of mica schists was inherited from the graywackes from which the mica schists were derived. The above statement should be treated hypothetically as long as extensive petrological researches will be done in order to test it in details.

THE $F_2 + M_2$ PHASE

The most effective tectonic events and the strongest metamorphic recrystallization affected rocks of the Orlickie Mts. in this very phase.

Development of F_2 mega-folds was accompanied by contemporaneous inception of related F_2 folds of meso and microscopic dimensions, which acquired various geometry, amplitude and wave-length. This variability resulted from their different position in regard to the larger fold structures and depended also on lithology and competence of rocks to be folded. In order to differentiate between the small F_2 folds and folds of other sets several distinguishing features of the F_2 folds and $F_2 + M_2$ fabric have been established. They are following. 1) Minerals of $F_1 + M_1$ fabric are folded around F_2 fold axes. This is expressed by a) phengite flakes or actinolite needles paralleling S_1 foliation and b) $F_1 + M_1$ albite grains possessing internal dusty trails arranged most frequently in parallel to S_1 foliation. 2) Common growth of brown or green biotite flakes parallel to S_2 axial planes—the fact recognized as the most characteristic and very persistent feature of folds of F_2 set. 3) Remarkably significant recrystallization of older minerals taking place under stress control, which tended to reorientate them and bring into parallelism with planes of S_2 foliation. 4) Distinct symptoms of the migration of rock and/or mineral material to the hinge areas of the discussed folds. The process was connected and followed by equally significant though spatially limited and much more random recrystallization of the migrating material. Therefore, the recrystallization has been recognized to have taken place under vanishing stress conditions. 5) Additionally, the noncritical but classifying data are: the amount of flattening of folds, the amount of shearing, and the axial directions. The latter have been considered with paying constant attention to all possible reorientations resulting from later refoldings.

The F_2 folds are commonly accompanied by L_2 linear structures which always parallel their axes. The linear structures are developed as: intersection lineation (S_1/S_2), arrangement in arrays of mineral grains — mostly plagioclases, fine warpings of mica flakes due to enveloping felspar blasts by the mica, elongation of grains of rock-forming minerals, and exceptionally boudins. The above mentioned linear structures are the most distinct in the mica schists. They are much weaker developed in other lithological varieties, or may be completely lacking.

In present paper a great attention will be paid to fold structures because they are incomparably important tectonic structures than lineation. Folds provide much more observational and interpretational data because not only axial directions but also axial surfaces can be subject of the direct investigations. Because directions of L_2 lineation are always concordant with F_2 axes thus all informations concerning the spatial attitude of F_2 folds are also valid for L_2 lineation. Therefore, there is no reason to discuss separately the L_2 linear structures.

Interdependence of structural and metamorphic phenomena in fabric transformations in different lithological varieties

Mica schists. S_1 foliation planes were folded about F_2 fold axes. Thus, the arrays of $F_1 + M_1$ albite grains were also curved about those axes. One of the not infrequently preserved structures of that type has been pictured in fig. 4*h*. It is known from the previous chapter that dusty trails included in the $F_1 + M_1$ albite blasts are usually concordant with the orientation of the directional $F_1 + M_1$ fabric. This significant fact allows to reveal the existence of F_2 folds even after very strong directional recrystallization of $F_1 + M_1$ fabric, if the $F_1 + M_1$ albite blasts survived the recrystallization. Therefore, a careful analysis of spatial arrangements of the dusty trails included in $F_1 + M_1$ plagioclase porphyroblasts, carried out throughout a rock profile, can reveal the existence and even the geometry of F_2 folds (fig. 10*a,b,g*), though all other minerals of the rock were yielded to almost complete recrystallization which made them arrange parallel with S_2 foliation (pl. II). Obviously, such a recrystallization must have exerted some influence on the discussed felspar blasts. This was marked by slight changes of outlines of the blasts, and occasional rough readjustment of their longest dimensions to the agreement with orientation of S_2 planes (pls. IV; V). Character of such changes seems to indicate that $F_1 + M_1$ albite grains were only slightly dissolved along their outer parts. Subsequently the solved mineral material crystallized most frequently close to the parent blasts according to Riecke's principle (pl. II*1*, *2*, *6*).

It is noteworthy that nearly untransformed $F_1 + M_1$ albite blasts are especially frequent in the mica schists occuring in the vicinity of Zieleniec. They are surrounded by directionally oriented minerals to form the $F_2 + M_2$ fabric, and thus they can be considered as the specific relics of $F_1 + M_1$ fabric preserved within $F_2 + M_2$ fabric. Moreover, the paragenesis including albite, epidote and chlorite was maintained within many horizons of the mica schists of the Zieleniec region. The facts suggest less efective M_2 metamorphism to have operated in this region rather than elsewhere. This conclusion is valid for rocks of the Stronie formation.

Careful microscopical examinations of the felspar blasts of mica schists occuring in the Lewin—Gołaczów region have allowed to recognize the successive stages of plagioclase recrystallization during the main phase of regional metamorphism (M_2). These transformations were progressive with respect to the prior ones when $F_1 + M_1$ albite and $F_1 + M_1$ phengite were developed. Hence, it is obvious that $F_1 + M_1$ albite was subject to metamorphic agents characteristics of M_2 phase. The discussed plagioclase could remain essentially untransformed maintaining its previous chemical composition or could be converted into oligoclase owing to an increase of content of the An particle (up to about 20 per cent). It seems that in mica schists of the Lewin—Gołaczów region plagioclase started to recrystallize before other minerals, perhaps excluding quartz. The beginning of transformations of plagioclase of $F_1 + M_1$ fabric during M_2 phase was not simultaneous all over the investigated area. In some instances the beginning of recrystallization of these plagioclase had taken place still before the rotation of F_2 fold limbs was completely ended. The observed blasts of the pre-existing $F_1 + M_1$ albite tended to enlarge at first their dimensions but without any change in their An content. This was going on under the movement control. Therefore dark s_i trails came to be slightly distorted[4], though the causative F_2 deformation could be seen much better as folded s_e surfaces in the surroundings of the transformed albite grains (e.g. fig. *5b*; pl. V*6*). In the extreme cases porphyroblasts subject to recrystallization could acquire guite random pattern of dusty inclusions. The phenomenon is seen where the inclusions did not yield to a complete dispersion and pushing out aside the grains (fig. *5c*). Perhaps the process just featured was much more common than it could be concluded on the basis of scarce evidence.

It has been ascertained that most of plagioclase blasts belonging to $F_1 + M_1$ fabric was subject to metamorphic recrystallization during M_2 phase after the flexure movements (rotation of F_2 fold limbs) had ceased, but stresses were still operating. The process of their recrystallization happened to be controlled by the nature of mineral surrounding of the plagioclase grains to be transformed. If the felspar was encountered in monomineral matrix of micaceous or more rarely quartz laminae, then it hardly yielded to the discussed process, kept preserving its hitherto prevailing features (fig. *5d*; pl. VI*4*). However, plagioclase grains were easily transformed when occuring in layers characterized by normal mica schists composition. The mode of transformation of plagioclase as well as other indications—e.g.emergence of biotite—allow to assume that the described recrystallization took place under conditions of the increased p/t ratio with respect to that of M_1 phase. Thus, the recrystallizing plagioclases tended to attain higher An content up to that characteristic of oligoclase. In some instances the growing oligoclase seemed to develop from the centre of the pre-existing felspar grains, and then the undigested opaque impurities were pushed aside retaining at first in albite rims, later—after the recrystallization ended—in thin films around newly formed blasts. According to the remark expressed previously, the $F_1 + M_1$ albite could be yielded to definite recrystallization, though there was no accompanying change in its An content (no significant change in chemical composition). Nevertheless, the $F_2 + M_2$ plagioclase blasts (those recrystallized during $F_2 + M_2$ phase—plagioclase of the second kind) owing to the process of recrystallization lost sharp outlines which were replaced by ragged ones (pls. II*2*; IV; V*6*). The blasts are intergrown at their margins with the earlier developed minerals, or they overgrew numerous fragments of the pre-existing fabric. That is why, the discussed blasts of recrystallizing plagioclase acquired very irregular and ragged outlines. Common spatial agreement observed between the direction of those internal intergrowths and orientation of minerals of $F_2 + M_2$ fabric can be accounted for by general parallelism of S_1 and S_2 foliation planes due to repeated isoclinal folding about similarly trending axes.

It is well known that a metamorphic mineral blast yielding to recrystallization does not have to necessarily increase its initial size expected on the theoretical grounds (Turner, Verhoogen 1960). According to Joplin (1935) the presence of fine, chemically inert substances, notably graphite, which collect upon the surfaces of growing crystals, may so impede chemical reactions and growth of crystals during metamorphism as to impose a conspicuously fine grain upon the fabric of the resultant rock. It seems that it is this case of the plagioclase blasts coming from mica schists of the Orlickie Mts. The presence of typical and common impurities inside the blasts of $F_1 + M_1$ albite might be one of the reasons of diminution of the plagioclase blasts developed during the main metamorphic phase as the result of recrystallization of prior albite. Sometimes this may be also true about quartz that often form numerous inclusions in blasts of $F_1 + M_1$ albite. Probably some part of the quartz could also be chemically passive, behaving as opaque substances. Obviously, the above featured process is not the only reason which caused that plagioclase blasts developed during $F_1 + M_1$ phase were smaller than blasts of $F_1 + M_1$ albite. For example, certain part of relatively fine-grained plagioclase aggregates resulted from a mechanical granulation of older blasts subject to subsequently operated stresses (fig. *5e,f*). Owing to those reasons plagioclase of the second kind occuring in mica schists appears commonly as fine-grained aggregate with interwoven phengite flakes, and usually associated with quartz.

It must be emphasized that the blasts and aggregates of $F_2 + M_2$ plagioclase are usually slightly flattened in planes parallel to S_2 folia-

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[4] s_i — Intergefuege, s_e — Externgefuege of B. Sander.

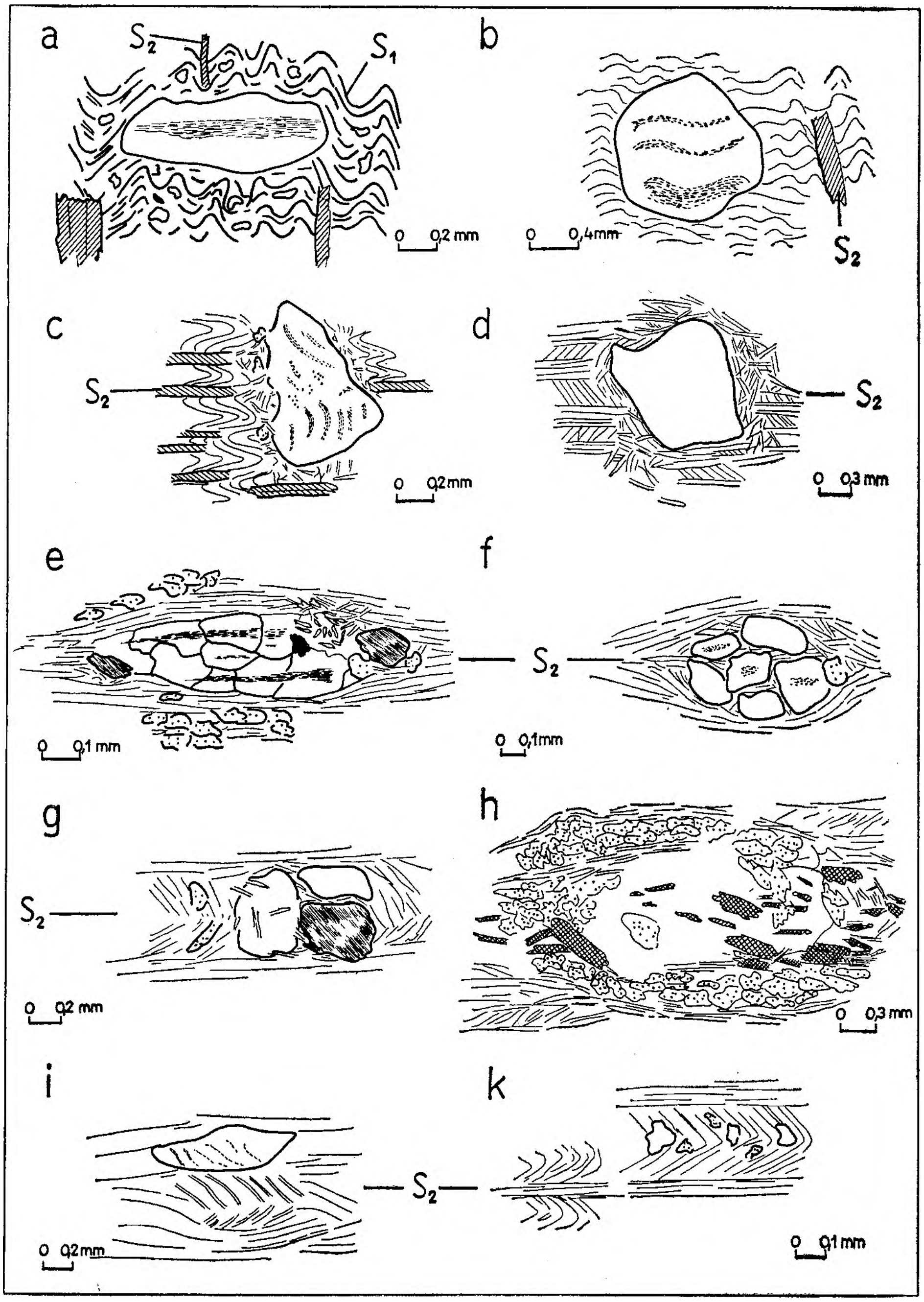

Fig. 5

Plagioclases in mica schists (of the Stronie formation) subject to recrystallization during F_2+M_2 phase

a – grain of F_1+M_1 albite not affected by recrystallization. Note straight lines of its internal dusty trails in contrary to the deformed surroundings involved in F_2 folds whose axial planes are marked by parallel growth of biotite flakes (obliquely lined). Development of this albite grain preceded F_2 folding; *b* – grain of F_2+M_2 albite slightly affected by deformation and recrystallization of F_2+M_2 phase. Internal trails are involved in open F_2 fold. See also explanation in the text; *c* – recrystallization of plagioclase during F_2+M_2 phase caused the dispersion of internal dusty trails. See the text for further explanations; *d* – grain of F_1+M_1 albite preserved within F_2+M_2 fabric of mica schists. Note that the grain is wrapped up with F_1+M_1 white mica flakes; *e* – diminution of F_1+M_1 albite during recrystallization of M_2 phase. The grain is fractured into smaller pieces. Some of these pieces are converted into more basic plagioclase and then in-

Plagioklazy w łupkach łyszczykowych poddanych rekrystalizacji w fazie F_2+M_2

a – nie dotknięte przez rekrystalizację ziarno albitu F_1+M_1. Prosty przebieg wrostków w albicie. Minerały otaczające to ziarno ujęte zostały w fałdki F_2, których powierzchnie osiowe podkreślają równolegle ułożone blaszki biotytu (skośnie kreskowane). Ziarno powstało przed deformacją F_2; *b* – ziarno albitu F_1+M_1 poddane niewielkiej deformacji i rekrystalizacji w fazie F_2+M_2. Smugi wrostków ujęte zostały w otwarte fałdki zespołu F_2 (patrz również objaśnienia w tekście); *c* – rekrystalizacja plagioklazu w fazie F_2+M_2 spowodowała dyspersję ciemnych wrostków (porównaj objaśnienia w tekście); *d* – ziarno albitu F_1+M_1 zachowane w obrębie struktury F_2+M_2 (fabric) łupka łyszczykowego. Ziarno to otulone jest blaszkami fengitu F_1+M_1; *e* – rekrystalizacja albitu F_1+M_1 w fazie M_2 prowadzi do pomniejszenia rozmiarów ziaren plagioklazu. Wyjściowe ziarno rozpada się na mniejsze fragmenty, z których część przeobraża się w bardziej zasadowy tion surfaces. This has brought the evidence of constant tectonic control which influenced the process of the described recrystallization. One has to realize that actual attitude of plagioclase of the second kind as well as the whole $F_2 + M_2$ fabric were additionally modelled by strong shearing which acted along surfaces of S_2 foliation.

Succesive stages of convertion of $F_1 + M_1$ albite porphyroblasts into fine-grained felspar aggregate are shown in figure 5*e*, *f*. Certain part of newly growing fine grains reached the content of An particles as high as that typical for oligoclase. It seems that the process was associated with occasional development of new phengite resulting from transformations of plagioclases. However, both examples have been taken from the mica schists adjacent to granitoid rocks. Therefore, subsequent influence of the acid plutonic rocks on blastesis of this phengite can be, by no means, excluded.

Almost complete lack of biotite inclusions within plagioclases of the second kind are considered as their symptomatic feature. Biotite, however, is the extremely characteristic mineral of the $F_2 + M_2$ fabric, its flakes are always parallel to axial planes of F_2 folds, referred to as S_2. Therefore, it may be assumed that the plagioclase of the second kind was developed prior to the growth of biotite. Mica schists occuring in the Lewin—Gołaczów region are rather poor in blasts of $F_1 + M_1$ albite. In spite of that, the per cent content of felspar in these mica schists are comparable to that displayed by mica schists of the Duszniki—Zieleniec region. Hence it is seen that mica schists in the both regions differ in the amount of plagioclases of the individual kinds. This suggests that the development of plagioclase of the second kind was esentially due to recrystallization of the older felspars—the $F_1 + M_1$ albite—under the conditions characterized by higher *p*/*t* rate of the regional metamorphism, and under the influence of the process of metamorphic differentiation.

It is known from the petrographical description that mica schists contain three kinds of plagioclases. The third kind differs from the second, among others, in lower content of the An particle (below 10 per cent) and the presence of biotite inclusions. Hence the development of plagioclases of the second and third kind was interrupted by the period of biotite growth and cessation of lateral stresses in favour of shearing movements which acted parallel to S_2 planes. It is well known that shearing stress can control nucleation of these new crystals whose nuclei are located on still active glide planes. Moreover, according to Johnson (1963) "in metamorphic rocks directed pressure will be only slowly released and may be present even after movement has ceased". Since the newly growing crystals tend always to develop in the places which enable them to be stable, thus they willingly grow in the fold hinge areas—the areas characterized by lowered pressure and distinct active gliding. Simultaneously the fold hinge zones are also the places of concentration of dissolved mineral material which has been migrated from fold limbs. G. Voll (cf. Johnson 1963) points out that numerous structural defects in crystals store strain energy of deformation, and according to Rast (1962) the storing of strain energy in crystals is an important factor conditioning the growth of metamorphic minerals. This roughly featured mechanism may account for the reasons of the growth of plagioclase blasts in the zones of F_2 fold closures. Obviously this growth took place after the rotation of fold limbs had finished when still active stresses conditioned the pos-

tergrown with phengite of the surroundings (upper right hand side of the grain). New large flakes of phengite also crystallize (shaded). Note that the most intense changes of the initial blasts are seen at its parts discordant with S_2 foliation. Note also that internal trails are continuous despite the fracturing. Stippled is quartz; *f* — the same process in figure 5*e*. Initial blasts of $F_1 + M_1$ albite was divided into several slightly displaced parts still maintaining the albite composition. Internal trails within these parts remain parallel. This is distinctly seen only within central parts of the resultant grains. Stippled is quartz; *g*, *h*, *i*, *k* — development of plagioclase blasts within $F_2 + M_2$ fabric, mainly in the hinge areas of F_2 folds. Their growth was influenced by recrystallization and metamorphic diffrentiation of mineral material throughout the rock fabric as well as by shearing along S_2 planes. Cross-lined is biotite, shaded is new flakes of phengite. Note slight rotation of inclusions paralleling S_1 micas involved in F_2 folds. This rotation is due to movement along S_2 planes

plagioklaz przerastany blaszkami fengitu z otoczenia (prawa, górna część ziarna). Jednoczesna krystalizacja nowych blaszek fengitu (jednolicie ciemne). Ziarno ulega najintensywniejszym zmianom tam, gdzie jego brzegi są niezgodne z foliacją S_2. Ciemne smugi wrostków w przeobrażanym ziarnie zachowują ciągłość, mimo jego rozdrobnienia. Minerały kropkowane oznaczają kwarc; *f*—ten sam proces co na figurze 5*e*. Blast albitu $F_1 + M_1$ rozpadł się na kilka, lekko wobec siebie przesuniętych części, zachowujących nadal skład albitu. Wrostki pozostały względem siebie równoległe, co widać wyraźnie w centralnych partiach tych nowych, drobnych ziarenek. Ziarna kropkowane oznaczają kwarc; *g*, *h*, *i*, *k*—rozwój blastów plagioklazu w strukturze $F_2 + M_2$, głównie w przegubach fałdów F_2, dzięki procesom rekrystalizacji, metamorficznej dyferencjacji oraz działaniu ścinania równolegle do powierzchni foliacji S_2. Widoczna lekka rotacja wrostków w ziarnie skalenia na figurze 5*i*. Rotacja ta jest wynikiem ruchu zachodzącego wzdłuż powierzchni S_2

sibility of movement of mineral material to hinge regions and the occurence of remarkable gliding along planes of S_2 foliation (fig. 5*g*, *k*, *i*; pl. V*5*). In the case of the discussed felspar it means that blasts of the third kind plagioclase contain as the internal inclusions all the earlier developed minerals and the blasts display very ragged outlines due to strong intergrowths with the elements of the pre-existing fabric. This also explains their being the only plagioclase blasts which could internally enclose flakes of biotite lying constantly parallel to S_2 foliation planes. In fact, the presence of biotite inclusions appears to be the most distinctive feature of plagioclase blasts which are referred to as the third kind of plagioclase occuring in mica schists of the Stronie formation of the Orlickie Mts. (fig. 5*h*; pl. V*4*, *5*).

Blasts of plagioclase of the third kind very often enclose the closures of F_2 microfolds. Therefore, it is suggested that the discussed plagioclase can be regarded as the youngest of the three kinds of plagioclases distinguished in mica schists. It seems that the development of the youngest albite (post-deformational one with respect to F_2 phase) was due to processes of metamorphic differentiation, and due to crystallization of the whole locally mobilized alkali solutions in places of more suitable pressure—so, in the hinge regions of F_2 folds.

Sometimes, in the hinge areas, those strongly mobilized light minerals display a distinct tendency to metamorphic differentiation by means of forming their own bands and retaining the rest of the rock constituents in others. In light bands large plagioclase and quartz crystals were frequently developed. The latter acquired marked deformation lamellae paralleling always the planes of gliding. These big crystals have occurred against the background of fine-grained aggregates composed of quartz and plagioclase. Co-existence of such aggregates and large blasts of the same minerals could be considerably influenced by the speed of local recrystallization, action of shearing, or rapid arrest of the recrystallization process. Not infrequent displacements of those aggregates, parallel to planes of the main foliation, suggest that the discussed phenomena, controlled by the aforesaid factors, took place more or less simultaneously with the period of highest intensity of gliding along S_2 planes.

There is no potash felspar in the mica schists of the Stronie formation occurring in the Orlickie Mts. The only exception to the rule, however, has been met in mica schists rocks adjacent to the granitoid body. Mica schists can contain small amount of microcline there. As Borkowska (1959) noted it was proceded by the development of pre-microcline myrmekite. The microcline was commonly developed within intergranular spaces, and very rarely as antiperthitic intergrowths, but almost no other symptom was met of reaction with earlier plagioclase to be surrounded by the microcline. Quite new flakes of phengite can be, however, encountered in the neighbourhood of the microcline. Obviously both microcline and phengite crystals could originate only due to an afflux of K-ions. This afflux did not result directly from regional metamorphic conditions but was closely connected only with the granitoid intrusion. Thus it exerted no regional influence, and did not affect rocks of the whole region. Microcline halo around the granitoid rocks appears to be very narrow and spatially limited.

It is quite understood that flakes of $F_1 + M_1$ phengite had to be subject to rotation in the course of rotation of the limbs of F_2 folds. Arrest of the rotation made the phengite flakes acquire a mechanically stable position. It is hard to define precisely when $F_1 + M_1$ phengite started to recrystallize during $F_2 + M_2$ phase—probably the process took place essentially contemporaneously with the plagioclase convertion. This view is supported by the interrelations of these two minerals. Obviously the recrystallization of phengite was accomplished more readily where S_1 foliation planes were brought into parallelism with S_2 ones—that is everywhere except for the hinge areas of F_2 folds. It was ascertained that $F_2 + M_2$ phengite flakes in the hinge areas are infrequently larger than $F_1 + M_1$ ones. So during the recrystallization phengite flakes could enlarge their crystals but without any discernible change in their chemical composition influencing their optic properties. Therefore, it is often a hard task to distinguish between $F_1 + M_1$ and $F_2 + M_2$ phengite flakes. The flakes of phengite developing undoubtedly during $F_2 + M_2$ phase are arranged commonly in their own independent strips oriented in parallel to planes of S_2 foliation (fig. 5*i*, *k*).

Biotite has been recognized to be a new mineral of $F_2 + M_2$ fabric. It is known that, the lower limit of the emergence of biotite is usually marked by a temperature of 400° (Turner) – 450° (Zwart), (cf. Johnson 1963). Therefore, a distinct increase of p/t rate should be expected during $F_2 + M_2$ phase. An increment of temperature facilitated the reaction between previously low metamorphic ferro-muscovite and chlorite yielding brown or green biotite whose flakes were constantly oriented in parallel to S_2 foliation and closely associated with $F_2 + M_2$ phengite ones in micaceous bands. The presence of biotite appears to be one of the most characteristic features of the S_2 foliation. According to Turner (1960), by-products of the mentioned reaction include the nearly ideal muscovite, chlorite of variable composition, and notably anhydrous phase made of hematite and magnetite. This statement allows to understand why the bands of $F_2 + M_2$ micas are so frequently accompanied by opaque minerals whose most abundant accumulations are encountered along zones of the most intense shearing movements (pls. V*7*; VI*1,2*; VIII*6*).

Casual inspection of a thin section may sometimes suggest quite random distribution of phengite and even biotite flakes. Owing to general parallelism of S_1 and S_2 planes the phenomenon hardly occurs in the limbs of F_2 folds. Thus, an orderless fabric can be expected in the fold hinges. It can be easily checked whether one deals with limb or closure by comparing the handspecimen and the thin section which has been cut from the former. Careful examination of the thin section in which such a random fabric has been found, reveals easily that the disorder is most frequently apparent. It seems to result from a simple fact that flakes of white and dark micas are arranged along two directions. Scales of $F_1 + M_1$ phengite trace a curvature of F_2 fold and moreover S_1 mica foliation has been crenulated parallel to S_2 planes. Obviously, the scales of $F_2 + M_2$ phengite are concordant with S_2 foliation. This introduces two directions of arrangement of phengite flakes and the apparent disorder. The same is true about biotite. According to the properties of $F_2 + M_2$ fabric its flakes lie in S_2 planes and thus intergrow the fold closures. Nevertheless, some part of flakes of the dark mica appears to be arranged along S_1 planes. It is impossible to find under the microscope any difference between the biotite flakes paralleling planes of these two sets. So the simplest explanation of the described phenomena assumes the partial, mimetic growth of $F_2 + M_2$ biotite along S_1 planes. It seems to be quite probable that under certain conditions the mimetic growth and adjustment to the well develeoped structural framework of $F_1 + M_1$ fabric were more attractive for certain part of the growing biotite crystals, mainly due to locally lowered and less determined directional pressure in the fold hinge areas, than directional blastesis parallel to planes of the main foliation.

There are three reasons of reorientation of $F_1 + M_1$ phengite flakes to the position parallel with S_2 planes. These are: isoclinal geometry of F_2 folds of microscopic dimensions, crenulation of closure areas of those folds, and recrystallization parallel to the main foliation.

F_1 and F_2 microfolds may be impossible to be differentiate from each other where owing to repeated isoclinal folding S_0, S_1 and S_2 planes have been brought in mutual parallelism which caused, under conditions of regional metamorphism, the biotite flakes to grow concordantly along these three parallel surfaces (Żelaźniewicz 1972). Of course, flakes of $F_1 + M_1$ and $F_2 + M_2$ phengite are parallel. In such instances the evidence of the existence of F_1 and F_2 folds can be based only upon the presence of superimposition of these folds, or upon the observation of s_i dusty trails included in $F_1 + M_1$ albite blasts. Where such observations are impossible the S_1 and S_2 foliations cannot be distinguished (pls. IX; X; XI).

Garnets are not abundant in mica schists of the Stronie formation outcropping on the Polish territory. Thus, it is hard to place the mineral in a scheme of fabric evolution of the mica schists. In the Duszniki – Zieleniec region the crystals of common garnet are nearly automorphic, and lacking any inner inclusions. No trace of secondary alternations is observed. However, the garnet crystals coming from the mica schists occuring in the Lewin – Gołaczów region appear to be remarkably chloritized and intergrown with quartz.

During the $F_2 + M_2$ phase mica schists of the Stronie formation were characterized by the mineral paragenesis which compared with that of the $F_1 + M_1$ phase appeared to be enriched in biotite and plagioclase corresponding mainly to oligoclase. Other minerals to form the discussed mica schists were common for these two phases.

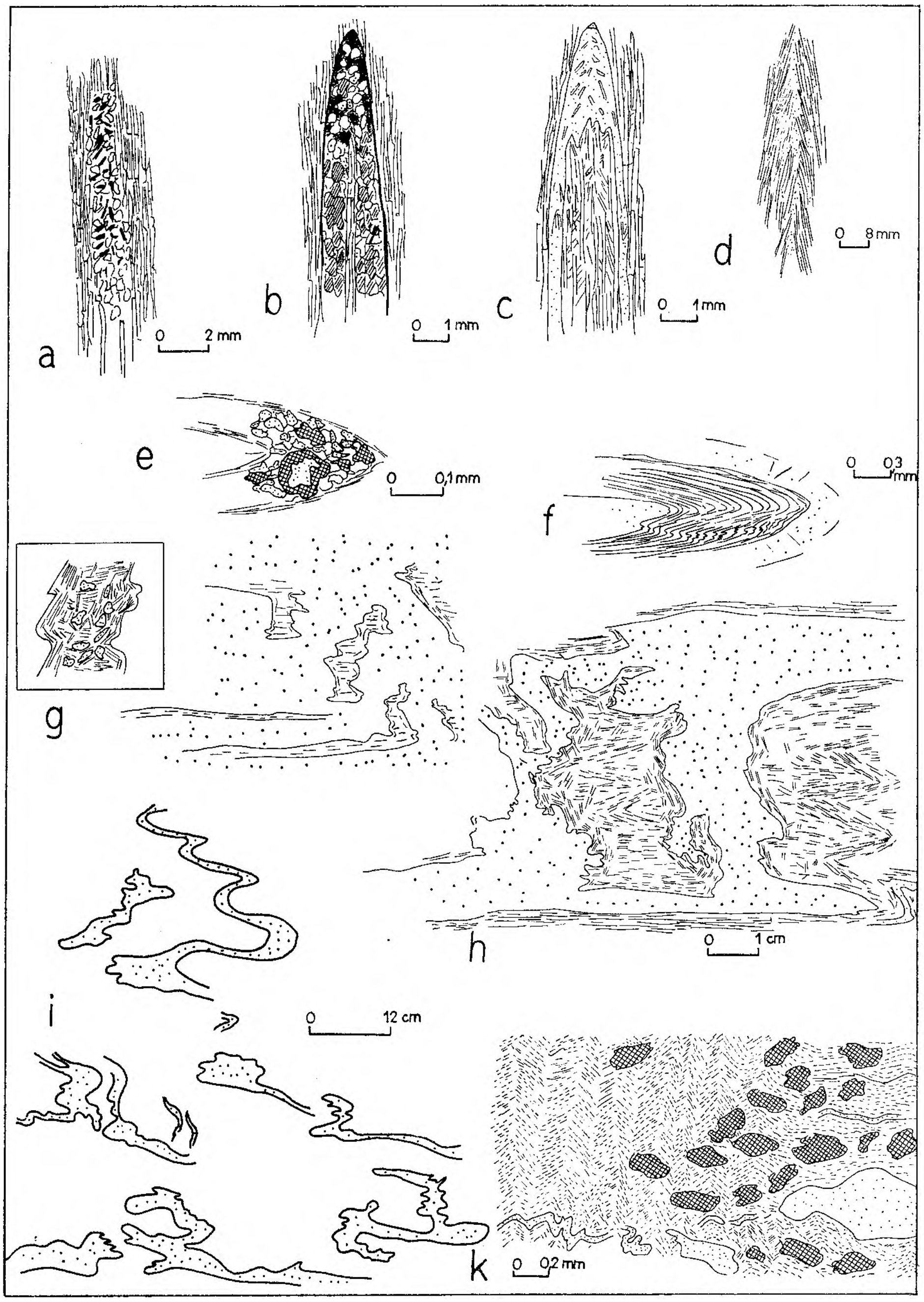

Fig. 6

Structural elements and mineral transformations within fabric of amphibolites and amphibole schists during F_2+M_2 phase

a, b, c, d – various attitudes of F_2 folds of microscopic dimensions in amphibole schists. Actinolite needles (relics of F_1+M_1 fabric) are folded about F_2 axes. This is seen well if the actinolite needles occur within thin layers composed mainly of plagioclase, quartz and epidote; *e* – transformations of plagioclases in the hinge region of F_2 fold. Oligoclase (stippled) is rimmed and replaced by albite (cross-lined). Quite new albite grains come also to grow; *f* – drag fold in the limb of thight F_2 fold; *g, h* – mineral transformations taking place in the structure of drag fold of F_2 set. Note orientation of amphibole needles. Stippled are epidote-acid plagioclase matrix strongly recrystallized and mobilized during the recrystallization of F_2+M_2 phase. See the text for further explanations; *i* – appearance of plagioclase-epidote-quartz concentrations (bands) in the Jawornica amphibolite. Note relics of folds belonging to F_2 set, which are dismembered into pieces by shearing movement along S_2 planes. The pieces attain "patched" appearance after strong recrystallization; *k* – hornblende crystals (cross lined) imprinted during M_2 phase on the pre-existing fabric of actinolite-quartz phyllite. Stippled are plagioclase-epidote-quartz bands. See the text for further explanations

Elementy strukturalne i przeobrażenia mineralne w strukturze amfibolitów i łupków amfibolowych dokonane w fazie F_2+M_2

a, b, c, d – mikrofałdki F_2 w łupkach amfibolowych. Igiełki aktynolitu obwijają się wokół osi F_2, co jest dobrze widoczne w przypadkach, gdy amfibol znajduje się w warstewkach plagioklazowo-kwarcowo-epidotowych; *e* – przeobrażenia plagioklazów w strefie przegubowej fałdu F_2. Oligoklaz (kropkowane) jest zastępowany lub otaczany przez albit (kratkowane). Albit tworzy też nowe samodzielne blasty; *f* – fałdek ciągniony w skrzydle wąskopromiennego fałdu F_2; *g, h* – przeobrażenia mineralne zachodzące w obrębie struktury fałdu ciągnionego zespołu F_2. Widoczna orientacja igiełek amfibolu. Zakropkowano tło zbudowane z epidotu i kwaśnego plagioklazu, poddanych silnej rekrystalizacji i mobilizacji w czasie fazy F_2+M_2. Dalsze objaśnienia w tekście; *i* – koncentracje plagioklazowo-epidotowo-kwarcowe w amfibolitach z okolic Jawornicy. Widoczne relikty fałdów zespołu F_2. Fałdy te są rozczłonkowane wskutek ruchów ścinających zachodzących równolegle do powierzchni S_2. Zjawisko to prowadziło do „łaciatego" wyglądu tych skał; *k* – blasty hornblendy (kratkowane) narastające w fazie M_2 na wcześniejszą strukturę (fabric) łupka aktynolitowego. Partie zakropkowane oznaczają warstewki plagioklazowo-epidotowo-kwarcowe. Dalsze objaśnienia w tekście

Amphibole-bearing rocks. Reconstruction of succesive stages of development of $F_2 + M_2$ fabric in amphibole-bearing rocks appears to be much more difficult. This is due to smaller number of the preserved relics of F_2 folds. The task is getting more complicated because the problem of origin of the questioned rocks has not been proved convicingly enough. It is clear that the initial nature of these rocks must have remarkably conditioned the way of their metamorphic transformations.

A scheme of rebuilding of $F_1 + M_1$ fabric to $F_2 + M_2$ one, recognized in the well foliated amphibole schists seems to be similar to such a scheme established for mica schists. Besides two exceptions all the folds of the second deformational phase (F_2) recognized in the amphibole-bearing rocks have displayed an isoclinal geometry. Thus, after the F_2 refolding $F_1 + M_1$ actinolite needles came to parallel planes of S_2 foliation. The fact facilitated considerably the recrystallization of the fibrous amphibole during M_2 phase. However, only some crystals of this mineral were affected by the process which produced coarser grains of common hornblende ($z/\gamma = 15-17°$). The fine-grained and well foliated amphibolites or amphibole schists have been frequently laminated due to fairly regular alternations of the amphibole laminae with those composed of plagioclase, quartz and epidote occuring in various quantitative proportions. Folds of mesoscopic dimensions are visible owing to the presence of this lamination (pl. XI). The folds are less distinct in more homogenous amphibolites. Nevertheless, existence of F_2 microfolds can be revealed under the microscope by means of examination of distribution pattern of $F_1 + M_1$ actinolite needles.

The fibrous amphibole crystals are folded about F_2 axes, or they remain mutually oriented at the angle of some 10–16 degrees (fig. 6*a*,*b*,*c*). Such a zonal lack of parallelism in the arrangement of $F_1 + M_1$ actinolite needles indicates the existence of F_2 microfolds characterized by interlimb angles of the above mentioned values. These interlimb angle values were however influenced by later gliding parallel to S_2 foliation (fig. 6*d*).

Felspar of the light laminae (bands) has been characterized by the diversified composition. Obviously, this is always acid plagioclase, but the microscopical determinations point alternatively to albite and oligoclase. Therefore, it is very hard to differentiate the plagioclase crystals developed in $F_1 + M_1$ phase from those nucleated during $F_2 + M_2$ phase. Blasts of these plagioclases are often at least slightly flattened which suggests their growth under stress control. Nevertheless, there are many proofs of a strong plagioclase recrystallization still after the cessation of lateral stresses.

Due to perfectly parallel arrangement of needles fibrous amphibole the actinolite foliation displayed some sort of remarkable conductivity and shear gliding readily acted along its planes. Thus, the dissolved light mineral material easily moved from limbs to the closure areas of tight or isoclinal folds. In such places nucleation of new metamorphic crystals was remarkably effected owing to lowered pressure and relaxation of strain energy of deformation (cf. p. 129). Albite blasts were mostly developed there. These new, clear blasts of acid plagioclase either overgrew the older felspar grains which usually were more sericitized or appeared as the independent crystals (fig. 6*b*, *c*). The plagioclase was always more acid than the older one. So the described process commonly associated with a strong production of epidote has been recognized as the sassauritization. Clinozoisite crystals happened to be overgrown by the acid plagioclase, and therefore they could be converted to internal inclusions within the felspar blasts. It seems that the degree of mobilization of the light minerals sometimes could be even very significant (fig. 6*g*, *h*; pl. XI*1*, *2*, *3*). This undoubtedly depended on a bulk mineral composition of individual bands. The bands (laminae) composed of actinolite and quartz were affected only by fold deformation. However, the bands (laminae) strongly enriched in plagioclase or those consisting only of amphibole were subject additionally to remarkably intense recrystallization. In the hinge zones of F_2 folds the layers rich in plagioclase yielded to utterly random recrystallization.

The fact of existence of thick, independent layers composed exclusively of epidote minerals denies the secondary nature of the minerals. Hence, epidote can be considered, at least partly, as the primary metamorphic constituent of the discussed rock. Actual value of p/t rate was too low to involve the whole of Ca-ions in the crystal lattices of plagioclase and amphibole. Nevertheless, there is no doubt that the secondary development of epidote minerals—especially in fold hinge areas—is the result of decomposition of more basic plagioclase. Besides epidote, the process of sassauritization provided also small amount of calcite.

Systematic analysis of arrangement of actinolite needles occuring as inclusions in plagioclase blasts of amphibolitic rocks described in p. 113 has revealed that the needles display their own independent, and fairly constant spatial orientation. So it is suggested that the growing plagioclase enclosed some older directional fabric oriented diagonally to $F_2 + M_2$ fabric. Thus it had to have been the relic of $F_1 + M_1$ fabric—the only one structurally possible here. Therefore, the significant plagioclase recrystallization connected with $F_2 + M_2$ phase can be ascertained. The discussed rock has been surrounded by mica schists which are believed to be the metamorphosed graywacke. Characters of the rock fabric, type of mineral interrelations as well as composition of the plagioclase do not bring any evidence on the activity of metasomatic solutions but allow to assume that the amphibolite in question is only a lithological variety of the diversified assemblage inherited from the metamorphosed parent deposits.

Apart from the closures of F_2 folds the process of significant recrystallization and decalcification of plagioclase has been recognized to have occured in short limbs of the drag folds produced during the second deformational phase (pl. XI *1*, *2*, *3*). Asymmetrical drag folds occuring in the limb of larger isoclinal fold have been shown in fig. 6*f*, *h*; pl. XI*3*. Penetrative gliding acted along planes parallel to axial planes of tight or isoclinal folds of F_2 set. Obviously the gliding must have affected not only axial foliation planes but also other planes of similar orientation (that is fold limbs). Isoclinal geometry of the parent folds caused short limbs of the drag folds of second order to be sheared in much the same way and degree as hinge areas of the first order folds. It is known that during the folding under metamorphic conditions the flexure strength of a given lamina (layer) can be overcome, and thus the fold to be developed must yield to shearing. This shearing may be exerted in three ways: the shearing resulting from mutual movement of the two neighbouring layers to be folded by a mechanism of flexure, the shearing which results from spreading out of glide movements along planes of axial foliation and their superimposition on the whole folded portion of a rock, the local shearing along axial planes to individual drag folds, which is limited only to structure of the very folds. It is obvious that owing to the advanced development of a parent fold far beyond the treshold of flattening the axial planes to subsidiary drag folds are made be parallel with the axial planes of a parent fold.

Occurence of shear gliding acting in the hinge zones of the first order folds as well as in short limbs of subsidiary drag folds may be expected to exert a significant influence on mineral recrystallization employed in the mentioned places (cf. p. 129). This assumption allows to account for the pattern of mineral arrangement in amphibole-bearing rocks subject to strong shearing and recrystallization. Almost all needles of the fibrous minerals became arranged parallel to the axial foliation planes of F_2 folds (pl. VII). Sometimes, only in the zone immediately adjacent to the boundary between pre-existing (that is existing before recrystallization) dark and light layers of amphibolite, some amphibole foliae maintained discordant orientation with respect to S_2 planes and by means of that imitating the parent fold geometry attained prior to shearing and recrystallization (fig. 6*f*, *h*). These discordant foliae can be considered as the structural relic of a stage of flexing — the one earlier in the process of fold development. Where such relics have not been preserved all amphibole needles were reorientated to be parallel to S_2 planes. Then the boundary between dark and light layers was formed by a significant concentration of fine-grained epidote aggregates.

$F_1 + M_1$ fibrous amphibole subjected to recrystallization during M_2 phase were often converted to common hornblende of $F_2 + M_2$ phase. It formed usually bigger blasts than those of the $F_1 + M_1$ actinolite. On the basis of microscopical studies it has been established that the hornblende crystals at first grew parallel to the main foliation planes, but later came to recrystallize in a quite random manner (as plagioclase) — first of all in the fold hinge zones. Equal dimensions of some blasts of common hornblende, plagioclase, and epidote as well as their partly orderless distribution have suggested that blastesis of these minerals was ended after stress cessation, under conditions close to confining pressure.

The above described phenomena seem to indicate that the process of metamorphic differentiation was employed to shape the fabric of amphibole-bearing rocks. Due to this process light and dark constituents of these rocks tended to be segregated from each other to form their own independent accumulations. According to the above remarks the concentration of light minerals, mostly plagioclase, can be expected to have been most readily derived from the mineral material which was moved into hinge zones of F_2 folds that subsequently were strongly sheared out. Probably due to the very process the coarse-grained and plagioclase-rich amphibolites occurring in the vicinities of Witów and Jawornica acquired their characteristic patched appearance (Żelaźniewicz 1973b). The appearance resulted presumably from the unfinished metamorphic differentiation of the questioned rocks. One of the examples of such a gradational development of fabric of these amphibolites has been shown in fig. 6*i* (note the relics of closures of F_2 folds).

The patched amphibolites occur, on the Polish territory, only in the vicinity of the villages of Zimne Wody, Witów and Jawornica. Those very irregulary shaped patches (concentrations of light minerals) have been constantly flattened in the plane parallel to main foliation. The elongated patches can be considered as the initial stages of development of the secondary metamorphic layering.

Presently it is rather hard to say whether all the coarse-grained amphibolites displaying structural segregation of light and dark minerals have been due to mechanism like that just featured above. The convergence phenomena could completely obscure any possible indications of the different ways of development of the resultant amphibolite rocks acquiring the patched appearance. Transformation of primarily layered rocks by means of the above featured process as well as metamorphic differentiation of the constituents of igneous rocks characterized by random texture seem to be equally possible. Therefore, the above expressed suggestions are valid only for those amphibolites in which the relics of F_2 folds no matter how sheared out they can be, are still recognizable. The relics, however, are not met ubiquitously.

Amphibolites may be sometimes intercalated with thin (several centimetres thick) bands whose appearence and composition point to typical gneisses. The bands are usually oriented concordantly with planes of the main foliation (S_2) though tiny off-sets are also encountered. The rock forming these intercalatians is composed of quartz, medium plagioclase, phengite, and scarce biotite. Boundaries between the intercalations and the host amphibolites appear always to be very sharp. Origin and significance of such intercalations so far are not convicingly accounted for.

There are several characteristic features displayed by the patched, weakly banded amphibolites. They are summarized below: 1) Constant tendency of light and dark minerals to be segregated. 2) Common flattening of individual, roughly monomineral accumulations in planes parallel to S_2 foliation of the surroundings (despite their very irregular shapes). The accumulations usually tend to combine laterally producing larger bands or lenses. 3) Rough agreement of the longest dimensions of tabular plagioclase crystals with S_2 foliation of the surrounding rocks. 4) Similar tendency, though less marked and variable from place to place, has been recognized for hornblende crystals. 5) Amphibole is characterized by angle $z/\gamma = 15-18°$. 6) Common occurence of medium plagioclase (An_{22-30}) accompanied by frequently occuring oligoclase and albite. Albite is always less sericitized, and happens to be gathered in larger accumulations. 7) Large amont of epidote minerals which are dispersed against rock groundmass, or make monomineral aggregates associated with light irregular lenses. 8) Co-existence of plagioclase, epidote and calcite. 9) Amphibole and epidote inclusions within plagioclase blasts. 11) Scarce garnet and sphene. 11) Sporadical occurrence of almost completely altered diopside.

The data included in points 6–11 suggest the way of transformations similar to that featured above in pp. 133–135. Hence it may be assumed that the well foliated and laminated epidote amphibolites which had been derived from tuff deposits during $F_1 + M_1$ phase, in the course of the strongest metamorphism (M_2), became converted into the amphibolites abundant in medium plagioclase but poor in epidote (points 5, 6). Next the rocks were subject to retrogressive alternations under conditions of vanishing stress and lowered p/t rate. This interpretation seems to be supported by sassauritization of plagioclase (points 6–9) and orderless texture (points 3–4). Nevertheless, the reasons of remarkable differences in a degree of metamorphic transformations displayed by different though often neighbouring varieties of amphibole-bearing rocks are not fully understood. Therefore, no ultimite conclusion concerning the origin of the discussed rocks can be drawn at present. Certain indications as to the manner of progressive metamorphic transformations of $F_1 + M_1$ fabric of amphibolite to $F_2 + M_2$ one have been found in the crag situated at the turn of the road from Lewin to Witów. There is a relic band of excellently foliated actinolite-quartz phyllites which are concordantly included in the coarse-grained, patched, poorly layered amphibolite. Foliation planes occuring in these both rock types are parallel. Microscopical examination has revealed that large crystals of common hornblende were randomly overprinted on the directional $F_1 + M_1$ fabric of the actinolite phyllites (fig. 6*k*). Moreover, occasional albite-epidote layers were locally enlarged as the result of the growth of big oligoclase blasts which were presumably developed at the expense of the former minerals. Most likely metamorphic differentiation was also employed here. It seems that this actinolite-quartz phyllite survived the M_2 metamorphism owing to its mineral composition (only amphibole and quartz) and owing to the primary diversity of sedimentary (tuff) complex in which among series rich in felspar sometimes thin layers occurred almost completely devoided of plagioclase. Probably the actinolite-quartz assemblage was not suspectible to easy metamorphic transformations. Much more advanced transformations appeared where plagioclase had been included in the composition of the initial (pre-metamorphic) rock. Therefore, it is suggested that the discussed actinolite-quartz band should be considered as the reflection of lithological variations to be inherited from the unmetamorphosed rocks—presumably of tuff nature. The rocks were usually rich in plagioclase but occasionally intercalated with felspar-free layers.

It is easily to note that the above described phenomenon displays considerable similarity to that recognized in the actinolite schists of the Stronie formation, which have been immediately adjacent to the thrust fault separating the Stronie from the Nové Město formation. In both cases crystals of common hornblende were overprinted on directional fabric of the initial actinolite phyllites. The fabric was involved in F_2 microfolds. Hence, the recrystallization of amphibole took place after the main kinematic activity—that is during M_2 metamorphic phase. It may be assumed that a transition from well foliated fine-grained amphibolites or amphibole phyllites (schists) to amphibolites characterized by coarser grains and more random texture was, at least partly, due to progressive regional metamorphism.

Phyllites of the Nové Město formation. It is very hard to reconstruct the features of $F_1 + M_1$ fabric in phyllites of the Nové Město formation. Recognition of tectonic and metamorphic events of $F_2 + M_2$ phase, recorded in these rocks appears to be much more possible.

The set of F_2 folds can be recognized owing to some of their characteristic features. Surfaces of the earlier developed foliation were curved about the axes of the questioned folds. In sericite phyllites axial planes to F_2 folds are usually underlined, as in mica schists, by parallel arrangement of biotite flakes. So, this is a striking similarity to mica schists of the Stronie formation. Those axial planes are in a spatial agreement with the most distinct foliation occuring in the unfolded surroundings. Thus, due to general isoclinal geometry of the folds in question their structural elements parallel the main foliation. And finally, the most distinctive feature—some older isoclinal folds, preserved in relics, have been coaxially refolded by the discussed folds referred to as F_2. The earlier ones must be regarded as F_1 fold structures.

It seems that the presence of those scarce but still recognizable relics of F_1 folds as well as the analogy to mica schists of the Stronie formation allow to consider the actinolite or white mica foliation which has been involved in F_2 folds as the S_1 foliation. This foliation has been recognized to parallel the axial planes to F_1 folds.

The F_2 folds in amphibole phyllites resulted from folding of S_1 actinolite foliation planes. Their nearly isoclinal geometry caused the rock-forming minerals to be arranged parallely. So the preferred orientation of $F_2 + M_2$ minerals appears to be the same as that of $F_1 + M_1$ ones. It has been recognized that the growth of plagioclase crystals took place after the development of F_2 folds. That is why, the

$F_2 + M_2$ plagioclase blasts were strongly intergrown with actinolite needles. These internally included needles are either discordant to planes of S_2 foliation, where the microfold hinges have been surrounded by growing plagioclase or parallel to this foliation where the plagioclase was developed in limbs of isoclinal folds. Sometimes, the amount of such intergrowths is so large that, in the absence of quartz in a given place of rock, the outlines of the individual crystals are no longer discernible (fig. 10*e,f*; pl. V*1,3*). Chemical composition of those plagioclase crystals varies sometimes from place to place even in one handspecimen, but albite always dominates over oligoclase. The content of the An particle within plagioclases of the discussed rocks seems evidently to be governed by an amount of epidote and calcite occurring in the individual layers of those rocks. Albite can be commonly encountered inside the bands enriched in these two above mentioned minerals. Oligoclase usually appears in the bands short of epidote and calcite. Some Ca-ions are included in the oligoclase. It can be established, on the basis of mineral interrelations seen under the microscope that both calcite and epidote were the primary minerals produced during progressive metamorphism and not resulting from any secondary alternations. The exact reason of such variations concerning the composition of plagioclase blasts has not so far been revealed. It seems that this phenomenon is somehow connected with the development of metamorphic layering paralleling S_2 axial planes of F_2 microfolds. The layering results from persistent repetition of fold limbs and axial plane zones throughout the profile of isoclinally folded rock (e.g. pl. VIII*5*). Slightly different conditions of recrystallization, which usually dominate in the hinge regions (axial plane zones), produce, in a rock, certain lithological diversity resulting in the inception of new mineral banding. One must realize, however, that such a layering is of secondary, dyanamo-metamorphic nature conditioned by an unequal distribution of metamorphic agents throughout the rocks to be transformed. These agents remain, to some extent, under the tectonic control. It causes the strongest and most remarkable transformations to occur in the axial plane zones. This tectonic control depended on the isoclinal geometry of F_2 folds and strong action of shearing along S_2 axial surfaces. The shearing has been recognized as the final expression of kinematic activity during $F_2 + M_2$ phase. Crenulation of planes of S_1 foliation, attenuation of fold limbs to produce intrafolial folds, considerable accumulations of opaque minerals along the planes of intense gliding, and the facility of usually retrogressive alternations taking place along these planes are considered as the typical effects of shear action.

Sometimes, axial gliding could produce certain discontinuities in the fold structures. Such discontinuities in actinolite phyllites happen occasionally to be filled up with veins made of even coarse-crystalline quartz associated with calcite and chlorite. These veins may give an impression of quite independent layers to build the rocks. Crystals occuring in the discussed veins lack any preferred orientation. This implies the non-stress conditions when the veins were developed. It is suggested that shearing parallel to S_2 planes caused the mobilization of local solutions derived most likely from the same rock and made them move on for very short distances. The solutions contained the most mobile components which were crystallizing just as the above mentioned vein minerals.

As it has already been mentioned the development of mineral assemblage of the phyllites composed of chlorite, calcite, quartz, plagioclase, sericite and relic actinolite was greatly controlled by strong shearing movements (p. 117). Such phyllites are outcropped in two places—near the village of Krzyżanów and in the railway-cutting above Lewin. These two outcrops occur in the zone of the thrust fault which separates the Stronie formation from the Nové Město formation. Intensity of shear movements which affected the rocks in question was so severe that all F_2 folds became completely sheared out and damaged.

Especially interesting is the fact that plagioclase coming from the discussed phyllites appears mainly to be acid oligoclase. Higher content of calcium displayed by these plagioclase might be due to two reasons. Increased susceptibility of the felspar to recrystallization resulting partly from a storage of strain energy of deformation within blasts of this mineral could be the first reason. The second reason is the high intensity of shearing, which released some Ca-ions. Hence, it can be concluded that the mode of plagioclase recrystallization might be considerably influenced by a tectonic factor under some conditions. Thus, the felspar could be provided with abnormally higher content of the An particle owing to locally stronger stress whose value overcame the general value of "p" parameter of the regional metamorphism. Experiments by Turner (1960) indicated the possibility of considerable transformation within a crystall lattice of a mineral and even serious changes in its composition merely due to shear stress action.

In sericite phyllites of the Nové Město formation, where they adjoin to the above mentioned zone of thrust fault, the F_2 flexure folds were also remarkably modified by shearing (fig. 10*e*, *f*). This allowed to state that occasional porphyroblasts of well-twinned oligoclase grew after the shearing had acted. The plagioclase porphyroblasts are considerably overprinted on the sheared out $F_2 + M_2$ fabric of phyllite, and they acquire numerous mica inclusions oriented in parallel to S_2 foliation. Quite similar phenomena can be observed in the actinolite phyllites adjacent immediately to the thrust zone.

Albite appears to be the most common and typical plagioclase of sericite phyllites. Some of its grains display the same features as the $F_1 + M_1$ albite occuring in mica schists of the Stronie formation. Thus it could be assumed, by an analogy, that the very albite coming from the discussed phyllites also enclosed fragments of $F_1 + M_1$ fabric as early as in the M_1 phase. The fragments have been preserved as relics presently visible owing to the presence of fine dark trails included in the albite blasts. The presence of these trails enabled to reconstruct spatial positions of planes of S_1 axial foliation. Sometimes the planes were underlined by quartz veins. S_1 foliation became involved in tight F_2 folds whose axial planes are paralleled by flakes of brown biotite. The dark mica often co-exists with chlorite, occurring in mutual intergrowths of these two minerals. Having studied the $F_2 + M_2$ fabric of phyllites one can state that the recrystallization of the rock-forming minerals during $F_2 + M_2$ phase took place after rotation of limbs of F_2 folds had been ended, but under prolonged control of still active directional pressure—that is in quite the same way as it was in mica schists of the Stronie formation. Therefore, the mineral crystals growing during $F_2 + M_2$ phase tended to parallel planes of S_2 foliation.

However, on the basis of external features and relations to the mineral surroundings, only some albite grains may be considered as the plagioclase which were developed during $F_1 + M_1$ phase. It seems that most of albite crystals occuring in the phyllites grew and recrystallized later. Nevertheless it is very hard to relate those albite crystals to any of the three kinds of plagioclases recognized in the mica schists of the Stronie formation. The presence of internal biotite inclusions appears to be the most striking feature of the majority of plagioclase blasts coming from the phyllitic rocks. Accordingly, crystallization of biotite preceded most likely the growth of plagioclase. The phyllites of the Nové Město formation do not display any reliable symptoms pointing to retrograde transformations. It is a difficult task to interpret the above described phenomena, and many doubts arise. Did the biotite in mica schists and biotite in phyllites grow at the same time and under the same regional conditions? Perfectly constant structural position of the dark mica whose flakes almost always parallel the planes of S_2 foliation brings certain answer to the question, though by no means satisfactory. Next, can one assume that the albite blasts with inner biotite inclusions crystallized during M_2 phase, or not? This could be suggested by the common appearance of those albite blasts. Unfortunately, there is no evidence would support fully the answers to the above questions. However, if the answers were positive, one could assume that the metamorphic transformations of M_2 phase affecting the phyllites were not only weaker but also slightly later in respect to M_2 metamorphic convertions which affected the rocks of the Stronie formation.

When the thin sections cut from phyllites are examined under the microscope a fairly interesting phenomenon can be observed. Almost always albite grains are pretty strongly flattened when occuring in the limbs of microfolds which were developed in thinly laminated rocks. Also flattening affected those felspar blasts which have occured in the hinge zones of F_2 folds, but only in the places where the plagioclase has been surrounded by thick mica bands folded about F_2 axes. Still, if albite crystals are encountered in the sites richer in quartz, then the crystals acquired much more spherical shape not only in the fold limbs but also in the fold hinge zones. It could be concluded that the mode of plagioclase blastesis depended, to some extent, on both the character of mineral neighbourhood of the growing crystals and the tectonic structures of the rock preceding the blastesis.

Quartz-phengite schists, porphyroids. There are only four small outcrops of these rocks in the investigated region (figs. 2; 3). It could be supposed that the quartz phengite were due to metamorphism of quartz siltstones or sandstones layers. However, the common occurence of porphyroid bodies inside the outcrops of the discussed schists, pointing rather to close connection of these two rock varieties, seems to contradict the above supposition. This co-existence suggests rather genetical realtions between the quartz-phengite schists and presumably acid igneous rocks. Hence the quartz-phengite schists may be considered either as the metamorphosed counterpart of acid tuffs interbedding sedimentary complex or as fine-grained marginal zones of porphyroid intrusions, strongly altered owing to metamorphic processes. The data so far collected seem to support rather the last hypothesis. Fabric of the quartz-phengite schists recorded structural and metamorphic phenomena indicative of $F_1 + M_1$ and $F_2 + M_2$ phases. Relics of S_1 foliation surfaces and distinct S_2 foliation should be mentioned here. Thus it can be concluded that parent rocks to these schists were developed prior to the beginning of metamorphic events.

Mineral compositions of the schists and porphyroids are similar. Dynamometamorphic processes of both $F_1 + M_1$ and $F_2 + M_2$ phases caused the considerable flattening of both microcline and quartz phenocrysts as well as minerals of the rock groundmass. Parallel arrangement of white mica flakes lying concordantly with S_2 foliation as well as damage of outer parts of the phenocrysts are also assigned to the mentioned processes. Shearing movements along planes of the main foliation were sometimes so intense that phenocrysts happened to be completely sheared out.

The schists which surround porphyroids are considerably richer in phengite. This seems to result mostly from the removal of K-ions from felspars. Complete disappearing of microcline is assigned to the phenomenon. Acid plagioclase are better preserved. The above observations suggest that the quartz-phengite schists and porphyroids were initially the same rock but variously subject to dynamometamorphic processes. So, it may be presently assumed that the fine-grained outer parts of the porphyroid intrusions were transformed to quartz-phengite schists, yielding to strong shearing and removal of alkali-ions. Central parts of such intrusions preserved their still recognizable features of igneous rocks.

An outcrop pattern of quartz-phengite schists and porphyroids associations is either parallel or discordant with orientation of the main foliation. The significance of the observed discordance, recognized in only one outcrop, has not been satisfactorily explained. It may be due to a dike character of the parent porphyroid intrusions cutting the consolidated sediment, or it may result from the occurrence of the questioned outcrop in the closure of F_2 fold of megascopic dimensions. The porphyroid bodies are much more frequent on the Czech side of the Orlickie Mts., and they are always parallel to the main foliation there (M. Opletal, personal communication). Thus it may be assumed that the above discussed rocks were due to metamorphism of small acid intrusions intruding the sedimentary complex during its deposition or after its diagenesis and consolidation.

Gneisses of the Śnieżnik type. Reconstruction of metamorphic events which affected the microcline gneisses seems to be the hardest task. The difficulties arise partly from the lack of any discernible fold relics as well as from transience of the area over which the gneisses are outcropped. Nevertheless some remarks can be given on the basis of microscopical observations presented in pp. 114—116. They are summarized below: 1) Assuming that gneisses and mica schists were subject to the same successively operating agents of regional metamorphism it must be stressed that it is impossible to reconstruct the $F_1 + M_1$ fabric of the gneisses because of the lack of places where independent fabric sets could be established. Thus the $F_2 + M_2$ fabric cannot be recognized either. Therefore, the whole rock structure must be treated as the entirety with no possibility of distinguishing the features appearing during successive phases of deformation and metamorphism. 2) The absence of any higher metamorphic minerals made me assume that the development of microcline

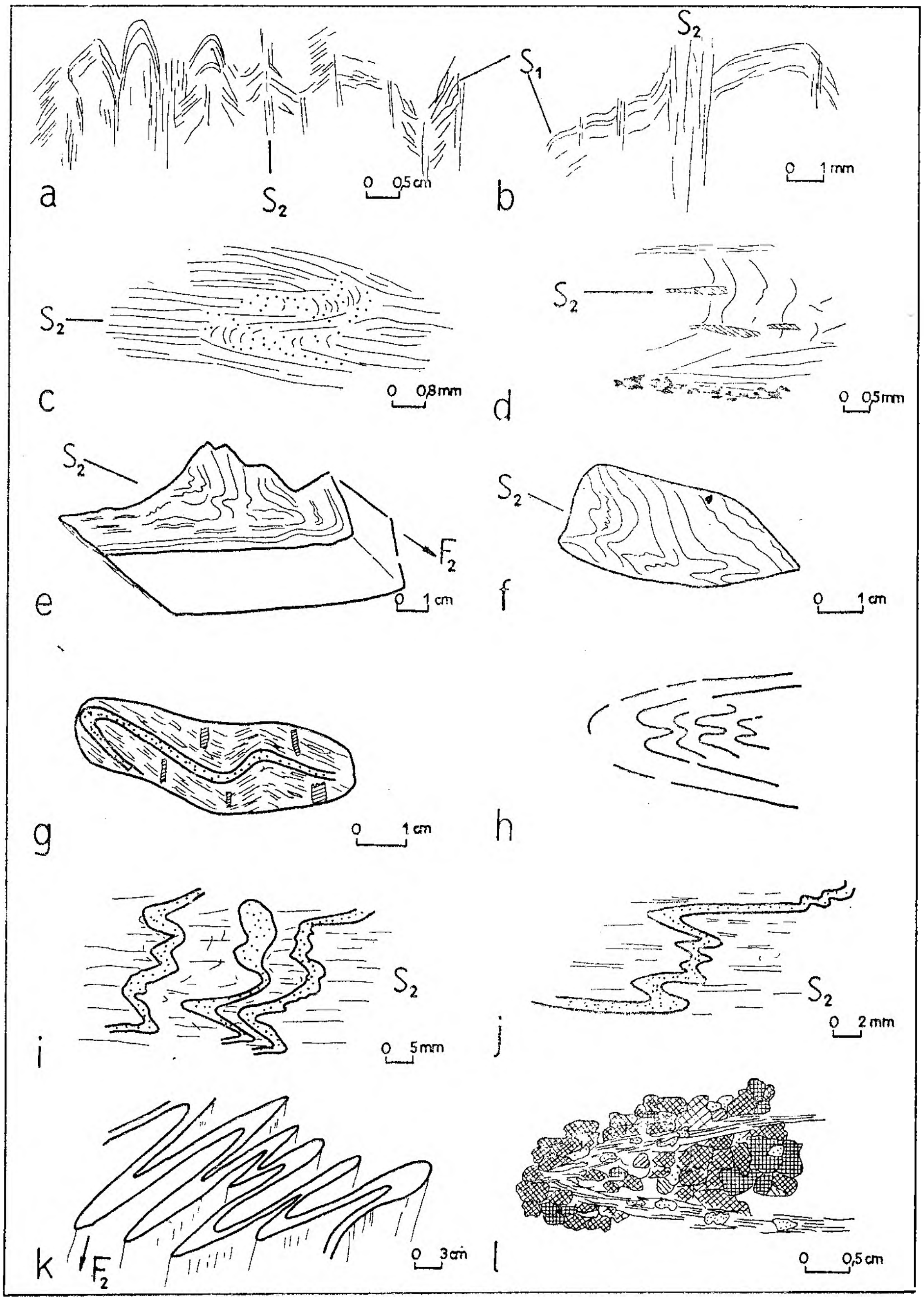

Fig. 7

Fold structures developed during F_2+M_2 phase

a, b – various spacing of the most intensely sheared zones within F_2+M_2 fabric of mica schists; *c* – strong mineral accumulations and recrystallization in the hinge regions of F_2 folds; *d* – sheared out limbs of F_2 fold. Note concentrations of opaque minerals in the zones of intense movements; *e* – *k* – various attitudes of F_2 folds. Note superimposition of F_2 folds on F_1 ones in figure 7*g* – plagioclase-quartz layer is involved in tight F_1 fold subsequently refolded by F_2 open fold whose axial plane is parallel to biotite foliation (obliquely lined is biotite); *l* – relic of F_2 microfold within calcareous phyl'ite subject to recrystallization during F_2+M_2 phase. The fold is due to deformation of mica-quartz-plagioclase lamina surrounded by calcite matrix (cross – lined)

Drobne struktury fałdowe powstałe w fazie F_2+M_2

a, b – strefy silniejszego ścinania w obrębie struktury F_2+M_2 łupków łyszczykowych; *c* – rekrystalizacja jasnych minerałów nagromadzonych w strefach przegubowych fałdów F_2; *d* – prawie zupełnie zredukowane wskutek ścinania skrzydła fałdu F_2. Koncentracje minerałów nieprzezroczystych w strefach silnych ruchów ścinających; *e* – *k* – zmienność kształtów fałdów F_2. Na figurze 7*g* nakładanie się fałdów F_2 na fałdy zespołu F_1. Warstewka plagioklazowo-kwarcowa ujęta została w ściśnięty fałd F_1, zdeformowany otwartym fałdem F_2. Równolegle do powierzchni osiowej tego ostatniego rosną blaszki biotytu (skośnie kreskowane); *l* – relikt mikrofałdku F_2 w fyllicie wapiennym poddanym rekrystalizacji w fazie F_2+M_2. Warstewka mikowo-kwarcowa, mimo znacznej wewnętrznej rekrystalizacji, oddaje ułożenie zdeformowanej w fazie F_2 laminy łupkowej, otoczonej kalcytowym tłem (skośnie kreskowane) porphyroblasts of the first generation, probably co-crystallizing with medium plagioclase was the result of the strongest metamorphism to have affected the discussed rocks. 3) Inception of the felspar porphyroblasts as well as the development of microcline augen, or polymineral ones had taken place under stress conditions and went on after stress relaxation. 4) The above mentioned blasts and augen together with quartzo-felspathic aggregates have been directionally elongated to form rods paralleling L_2 lineation and F_2 fold axes

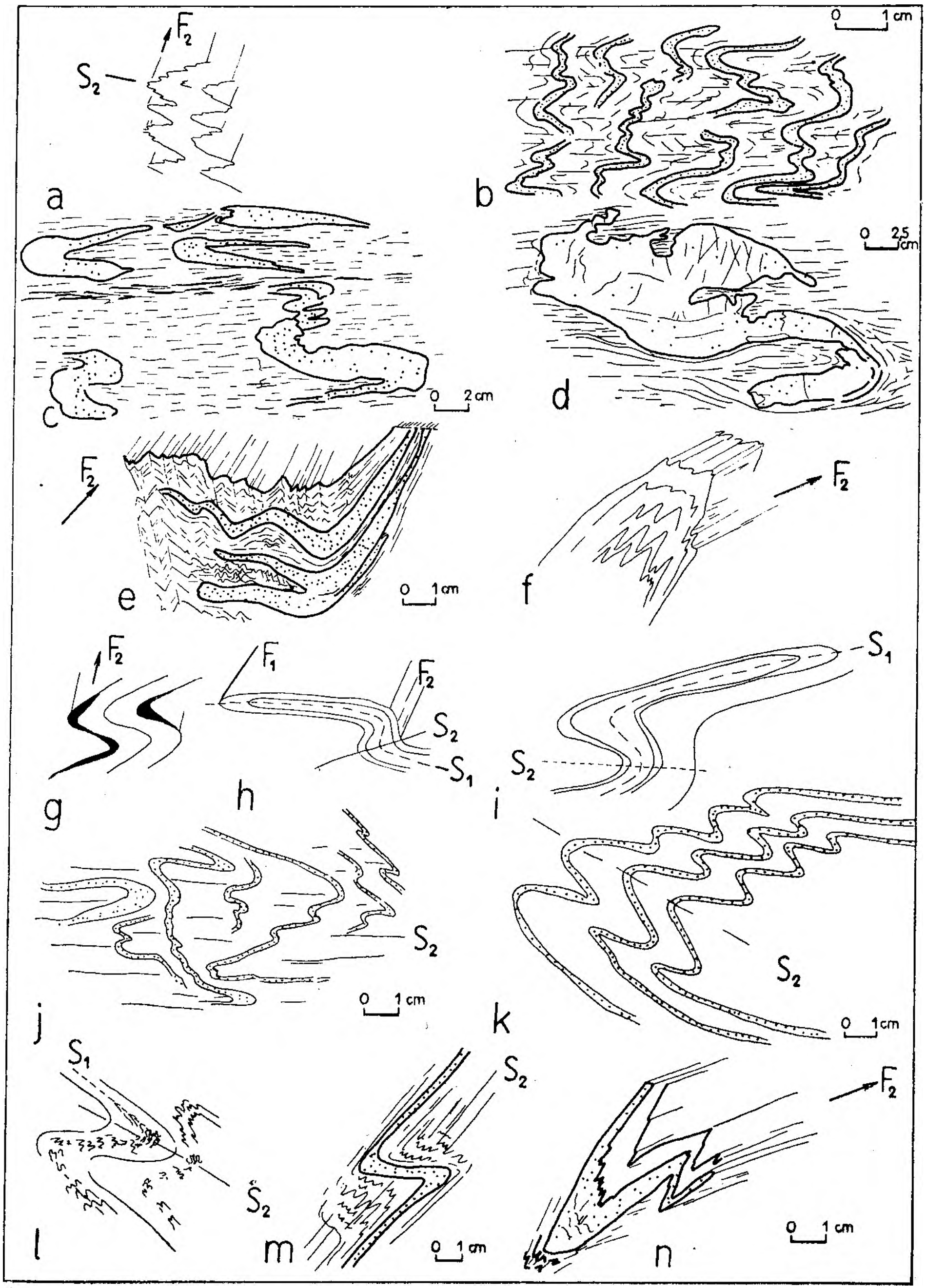

Fig. 8

Various fold structures developed during $F_2 + M_2$ phase

a, b, c, d – S_1 quartz veins involved in F_2 folds in mica schists; *j* – disharmonic F_2 folds of quartz-plagioclase layers in mica schists. The phenomenon was amplified by subsequent shearing parallel to S_2 planes; *e, m* – note dependence of a fold geometry on different competence and thickness of the layers involved. Mica schists

Rodzaje struktur fałdowych zespołu F_2

a, b, c, d – żyły kwarcu ujęte w fałdki F_2 w łupkach łyszczykowych; *j* – sfałdowane dysharmonijnie warstewki plagioklazowo-kwarcowe w łupku łyszczykowym. Zjawisko to zostało wzmocnione późniejszym ścinaniem zachodzącym równolegle do powierzchni S_2; *e* – *m* – zwróć uwagę na zależność geometrii fałdu od różnic w kompetencji i miąższości deformowanych warstewek. Łupek łyszczykowy recognized in the adjacent mica schists of the Stronie formation. 5) On the basis of the data included in the last two points one can assume that the main deformation and main metamorphism of the discussed gneisses took place, as elsewhere, during $F_2 + M_2$ phase. 6) Low order of the gneiss fabric, differentiation between the effects of secondary albitization and microclinization, and quite random fabric of albite-microcline veins of pegmatitic appearance seem to indicate the prolonged activity of metamorphic factors operating stresses of $F_2 + M_2$ phase

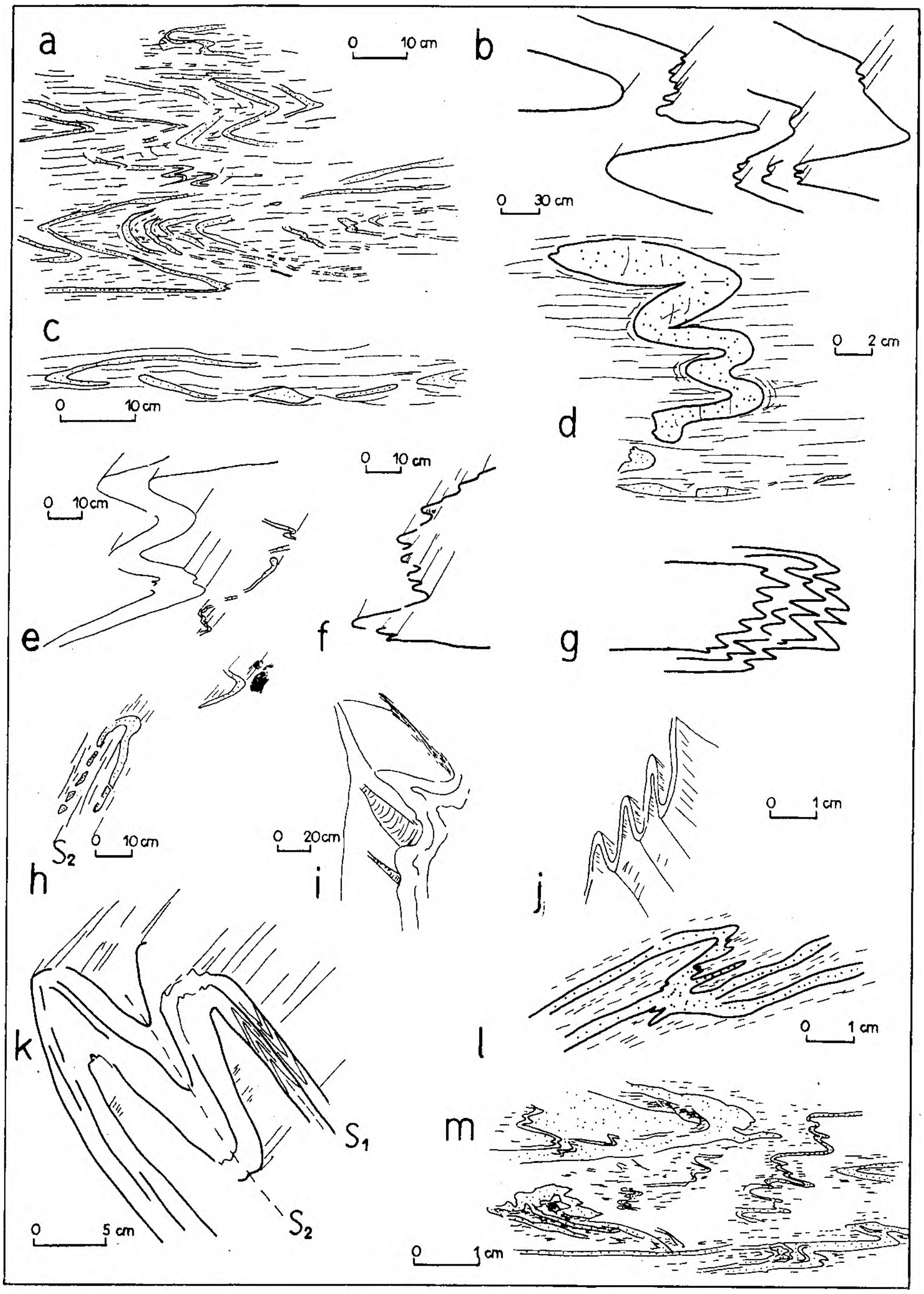

Fig. 9

Various fold structures developed during $F_2 + M_2$ phase

a, c, d – stippled are quartz layers in mica schists; *b, f, g* – subsidary folds in F_2 hinge zones; *e, h, i* – stippled is quartzo-felspathic layer in mica schists; *j, k* – folded banded amphibolite; *l, m* – initial geometry of F_2 folds in banded amphibolite is partly obliterated due to slightly later mobilization and recrystallization of light minerals (plagioclase, epidote, quartz)

Struktury fałdowe powstałe w fazie $F_2 + M_2$

a, c, d – łupki łyszczykowe (zakropkowano warstewki kwarcowe); *b, f, g* – podrzędne zafałdowania w strefie przygubów fałdów F_2; *e, h, i* – łupki łyszczykowe (zakropkowano warstewki kwarcowo-skaleniowe); *j, k* – amfibolity; *l, m* – równoczesna lub nieco późniejsza od powstania fałdów mobilizacja, rekrystalizacja i migracja jasnych minerałów, zacierająca pierwotną formę fałdów F_2

were relaxed. 7) Perhaps the secondary albitization might refer to the growth of plagioclase of the third kind recognized in the mica schists.

Structural elements and their variation

Geometry of F_2 folds, their amplitude and wavelength are fairly varied. F_2 folds of megascopic dimensions are usually isoclinal, but F_2 fold of mesoscopic, and especially microscopic dimensions are reasonably diversified. This diversity is a function of numerous, generally known factors.

The variation in geometry of F_2 folds has been shown in figs. 5—7 and pls. IV—XI.

The behaviour of rock-forming minerals in the hinges of F_2 folds has already been discussed many times in the preceding pages. Only some new facts will now be featured.

$F_1 + M_1$ fabric can be observed best at the places where the dihedral angle between S_1 and S_2 planes attains the highest value—that is in the hinge zones of F_2 folds, under condition that $F_1 + M_1$ minerals were not subject to a complete recrystallization and reorientation (cf. pl. II). The process of mineral transformation and reorientations did not at all have to be brought to the and to produce the entirely new fabric, but could be broken at any moment. Therefore, in the extreme instances only the layers to be mechanically flexed are the only effect of F_2 deformational phase. In such places of the deformed rocks still present and well preserved mineral framework of $F_1 + M_1$ fabric could control to some extent both the growth of $F_2 + M_2$ biotite and the recrystallization of plagioclase during $F_2 + M_2$ phase. Thus the minerals of $F_2 + M_2$ fabric could sometimes adjust their longer dimensions to be oriented in parallel to S_1 surfaces. Probably too low amount of active fluid phase was partly responsible for this phenomenon. Therefore in the discussed places even quartz veins concordant with S_1 foliation do not display any signs of recrystallization. They constantly keep sharp boundaries and nearly the same orthogonal thickness throughout the fold (of F_2 set). $F_2 + M_2$ phase effected only in the breaking down the crystal lattice of quartz which resulted in distinct deformation lamellae parallel to S_2 foliation (pls. VI*5,6*; VIII*3*). The lamellae were most likely due to shearing associated with this very phase (cf. Gangopodhay, Johnson 1962).

Generally, however, all medial stages of transformations can be observed in the hinge zones of F_2 folds: crenulation of S_1 phengite foliation, recrystallization of plagioclase and quartz crystals of $F_1 + M_1$ fabric to $F_2 + M_2$ blasts of these minerals more or less flattened in S_2 planes, and so forth (pl. VI). Sometimes all minerals to form the rocks were subject to definite recrystallization, and being more or less flattened in planes of S_2 foliation they assumed orientation parallel to those planes. In such cases the existence of F_2 folds may be revealed owing to the presence of fine, dark trails included in blasts of $F_1 + M_1$ plagioclase. When traced from one blast to the other throughout the rock profile the trails may indicate the existence of F_2 fold (fig. 10*a*, *b*: pl. II). The F_2 folds may also be recognized in the case where despite the total directional recrystallization the unobliterated primary lamination can be distinguished—for instance where micaceous and quartz bands alternate diagonally to S_2 foliation planes (pl. I; VII*1, 2*; VIII*2,4,6*).

Considerable concentrations of quartz which moved in from the surroundings appear to be relatively rare feature of F_2 fold closures in mica schists (pls. VI*6*; VIII*1,3*). In these very places S_1 quartz veins happened to be enlarged in this way. One of such veins involved in a framework of remarkably tight fold has been shown in figure 10*g*. The veins acquired the shape of thick crescent whose occurence was strictly limited to the zone of maximum fold curvature. Structure of this fold was continued to both directions outside the crescent with no disturbance. Therefore, the quartz crescent must have been developed after the end of rotation of the fold limbs. Silica, which had been mobilized during folding, migrated to the places of lowered pressure owing to still strong lateral stress (flattened-flexure fold). Undulose exctinction is a characteristic feature of the mosaic quartz forming the discussed crescent. The silica solution crystallized most likely after the cessation of external stress. Accordingly, the crystallization was controlled by local compression resulting from the transfer of mineral material to the hinge zone and from inert resistance of framework of the existing fold, considered as the reaction to the transfer. Strongly chloritized scales of biotite appear amidst grains of the quartz mosaic. It is known that biotite was commonly developed in the ready (flexed) fold, growing para-

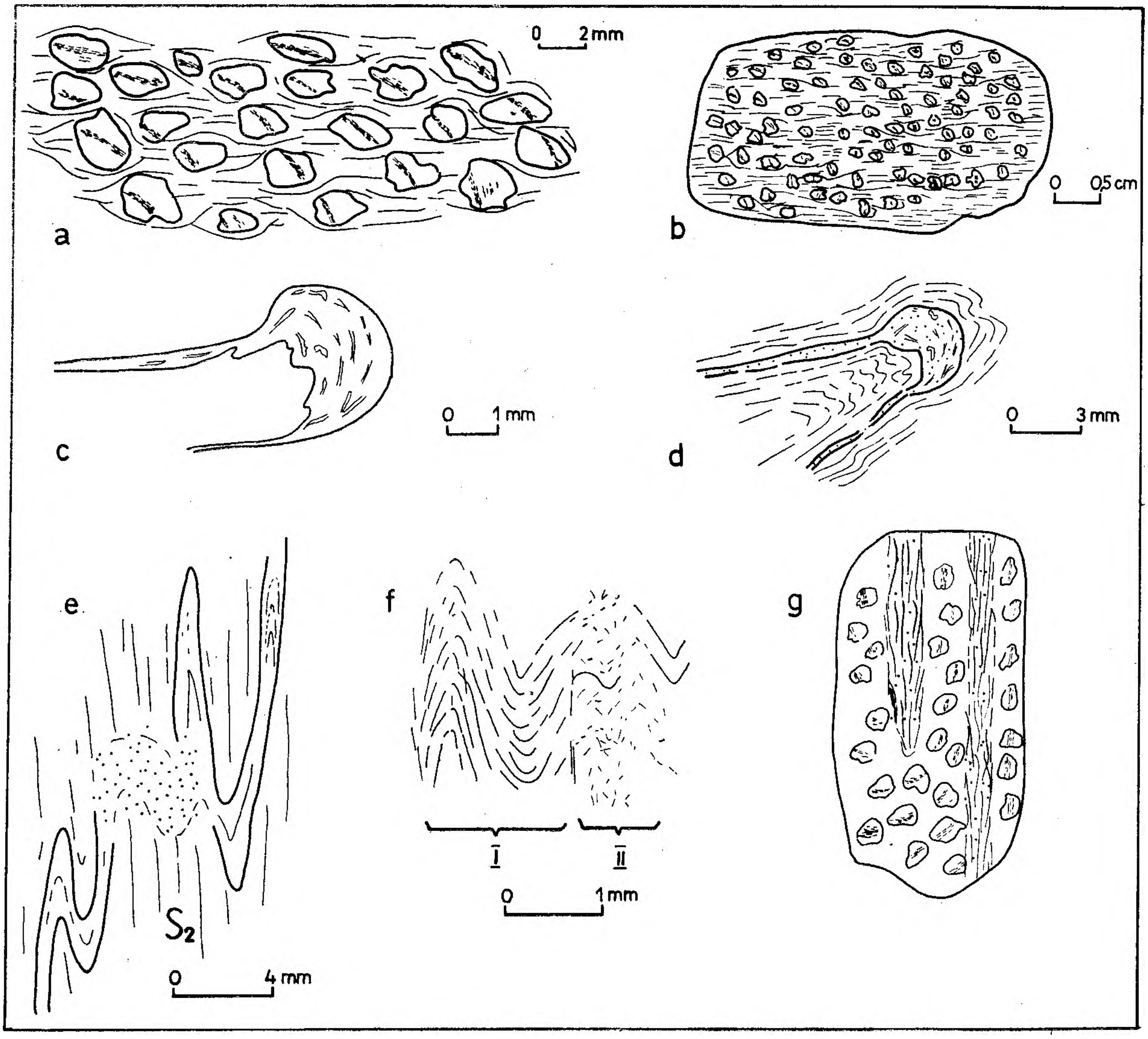

Fig. 10

Various phenomena in the hinge regions of F_2 folds

a, b – mode of arrangement of dust opaque trails in F_1+M_1 albite grains included into F_2+M_2 fabric of mica schist. These trails are curved around F_2 axes and they are the only indication of F_2 folding. Albites are not affected by recrystallization of F_2+M_2 phase because their dusty inclusions are entirely undisturbed and very regularly spaced (thickening in the hinges and thinning in the limbs of F_2 folds are even preserved). The plagioclase grains occur in biotite matrix definitely directionally recrystallized. All flakes of biotite are parallel to S_2 axial foliation. Content of plagioclases in these rocks, forming several meters thick layers among mica schists, reaches nearly 50 per cent of a rock volume; *c, d* – quartz veins considerably thickened in the fold closure. See the text for further explanations; *e, f* – mode of recrystallization of light minerals (plagioclase, quartz) within the structure of F_2 folds occuring in amphibole phyllites; *f, g* – inception of new metamorphic layering parallel to S_2 planes, in amphibole phyllite (f) and mica schists (*g*). See also the text for further explanations

Zjawiska w przegubach fałdów zespołu F_2

a, b – sposób ułożenia w blastach albitu F_1+M_1 ciemnych koncentracji nieprzezroczystych minerałów, stanowiących relikty powierzchni sedymentacyjnego warstwowania. Skała jest ujęta w fałdy F_2, o czym świadczy jedynie ułożenie wrostków w tych plagioklazach. Ziarna albitu nie uległy rekrystalizacji w czasie fazy F_2+M_2, gdyż układ wrostków nie został zaburzony nawet w najmniejszym stopniu (zachowało się nawet zgrubienie w przegubach fałdów F_2). Ziarna plagioklazu tkwią w całkowicie przekrystalizowanym kierunkowo tle biotytowym. Blaszki biotytu leżą równolegle do powierzchni foliacji S_2 .Przykłady te pochodzą ze skał stanowiących kilkumetrowej grubości przeławicenia w łupkach łyszczykowych. Zawartość plagioklazów w skałach tych przeławiceń dochodzi do 50 %; *c, d* – żyłki kwarcu znacznie pogrubione w przegubie fałdu. Dokładne objaśnienie w tekście; *e, f* – sposób rekrystalizacji jasnych minerałów (plagioklaz, kwarc) w obrębie struktury fałdów F_2, występujących w fyllitach amfibolowych; *f, g* – powstawanie warstwowania metamorficznego równoległego do powierzchni S_2 w fyllicie amfibolowym (*f*) i łupku łyszczykowym (*g*). Dokładniejsze objaśnienia w tekście llel to S_2 foliation. Here, most of the chloritized biotite scales is concordant with the folded surface, and only some of the scales follow axial plane of the fold. Still, it seems undoubtful that the flaky mineral was altered from the same $F_2 + M_2$ biotite occuring in the surroundings of the discussed structure. Probably during the transfer of silica throughout the fold structure, the biotite scales were reoriented roughly perpendicular to the direction of the movement. It may be assumed that the process of significant concentrations of quartz in the hinge zone of F_2 fold took place after the main metamorphic activity of M_2 phase.

Other example of remarkable enlargement of the hinge zone of F_2 fold due to strong accumulation of quartz and plagioclase has been shown in figure 10*e*. It seems, however, that the reasons of the phenomenon were slightly different from those of the above quoted example. Lateral stress gave rise to light mineral concentrations in both instances. But in the presently discussed case, the strong influence of shearing along S_2 planes and lack of reliable framework of $F_1 + M_1$ micas were of considerable importance.

Significant concentration and recrystallization of quartz and plagioclase were especially typical for the axial plane zones of F_2 folds developed in amphibole schists (pls. VI*5*; VII *1*, *2*). According to the previous remarks the process took place under nearly confining pressure conditions. Therefore, actinolite needles failed in the fold hinges their preferred orientation which was replaced by their random distribution against the background of simultaneously recrystallizing light minerals (quartz and plagioclase). New crystals of plagioclase and quartz became much more equidimensional. Secondary metamorphic layering came to exist where the fibrous amphibole acquired quite random arrangement and the light minerals were concentrated so strongly as to contrast distinctly with a rest of isoclinally folded rock (fig. 10*f*, pl. VIII*5*).

Also in the mica schists a new metamorphic layering was fairly commonly developed during $F_2 + M_2$ phase. One of the examples has been shown in fig. 10*g*. The closure of F_2 fold is illustrated in the figure. This fold was due to nearly isoclinal bending of S_2 lamination. The lamination resulted from the presence of layers rich in $F_1 + M_1$ plagioclase, alternating with phengite ones. Perfect spatial agreement of the phengite flakes with S_2 foliation planes caused no difference between $F_1 + M_1$ and $F_2 + M_2$ fabric. The existence of F_2 fold can be revealed only through studies on orientation of the dark trails included in the blasts of $F_1 + M_1$ albite, and thus the presence of metamorphic layering may be recognized. So, the tapering micaceous lamina in figure 10*g* appears to be of secondary and not primary nature. Accordingly, the lamination developed in parallel to S_2 surfaces appears to have been of secondary metamorphic nature—or, strictly speaking, of mechanical-metamorphic one. The discussed lamination, as the result of general isoclinal geometry of F_2 folds, repeated the pre-existing banding across the vertical sequence of the rock unit folded in the same way. This earlier banding was in common spatial agreement with the sedimentary bedding.

It seems that a flexure mechanism is the only mechanism to form a fold. Obviously the fold may result not only from the externally applied compression.

All the layered (laminated) rocks display the competence differences to exist between individual layers (laminae). During the folding of a rock complex diversified with respect to the competence, tiny displacements occur in the fold limbs due to migration of rock mass from the places most strongly affected by compression (fold limbs) to the regions of fold hinges. Obviously the movement must show opposite sense in the opposite fold limbs. This phenomenon is roughly maintained throughout the whole structure of a fold. The rock mass movement appears to be the most distinct in the layers characterized by lower competence (Williams 1961). One must be aware of the change in the movement direction to take place along a fold limb at the half distance between two neighbouring fold closures (antiformal and synformal), (fig. 11). This is a site in which the strongest tension has been employed in the structure of fold. Therefore, open fissures or fractures occur most readily in the very area (if some additional conditions are fulfilled). These fractures cut the layers boundaries at high angle, or perfectly perpendicularly. Direction of flowage (expansion) of a rock mass appears to be roughly parallel to the axial plane of a given fold (Williams 1961). An amount of such displacement is considered to be function of both flexing and flattening of fold. Accordingly, under metamorphic conditions non-isometric minerals tend to be orientated parallely to the direction of the flowage (cf. pl. VII*2*, *3*). This way a strong anisotropy comes to exists. If the discussed movement is prolonged in time, the anisotropy will yield to convertion to common metamorphic foliation. Inception of the foliation causes the shearing movement to be transferred and continued along the foliation planes. Hence, the following conclusion arises. If folding of rocks takes place under the conditions which enable the rock-forming minerals to be reoriented and arranged parallel to the axial plane, then the mechanism of flexure must be replaced by shearing movements which can act only along the planes parallel to the axial foliation. In my opinion the same mechanism brought about the folding of metamorphic rocks of the Orlickie Mts.

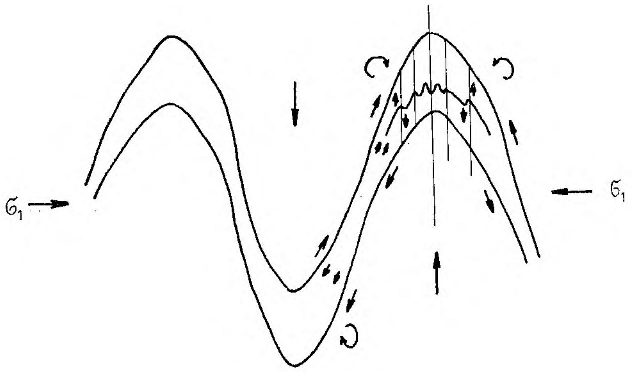

Fig. 11
Mode of deformation of less competent layer during folding and direction of mass flowage throughout a fold (of this layer)

Sposób deformacji i kierunek ruchu materiału skalnego w obrębie mniej kompetentnej warstwy w czasie fałdowania

The most important facts exposing the essential role of a flexure mechanism during development of F_2 folds are the following. 1) There are several places where L_1 lineation (arrays of $F_1 + M_1$ albite) slightly oblique to F_2 axes was preserved. In all the cases the lineation has been folded about F_2 axes. The angle between L_1 direction and F_2 one keeps constant value. L_1 lineation and F_2 fold axes have been plotted against the stereographical projection. This easily reveals that L_1 measurements form small circle around F_2 axes (fig. 12). Insignificant variations in the value of L_1/F_2 angle seen in figure 12 have been most likely due to later remodelling of the structure of flexure fold by superimposed shearing. 2) An analysis of layer thickness measured parallel to the axial planes of F_2 folds provides well established feature – the lowest values are always found at the fold hinges (cf. Ramsay 1962). 3) Development of small drag folds in the limbs of parent fold of isoclinal or tight geometry.

Careful observations of orthogonal thickness of a folded layer reveals that almost always the thickness is at least slightly greater in the fold hinge than in the fold limbs (pls. VII*3*–*6*; X*1*,*6*). This seems to be quite clear in the light of the aforesaid remarks (pp. 145, 146). Obviously every fold developed during plastic deformation must yield more or less to a flattening. An amount of the flattening to affect the fold is measureable. The amount of flattening calculated for F_2 folds according to the method given by Ramsay (1962) ranges from 2 up to 62 per cent. Ramsay's method is applicable, however, only to a plastic folding, when rock beds overcome a specifing limiting angle

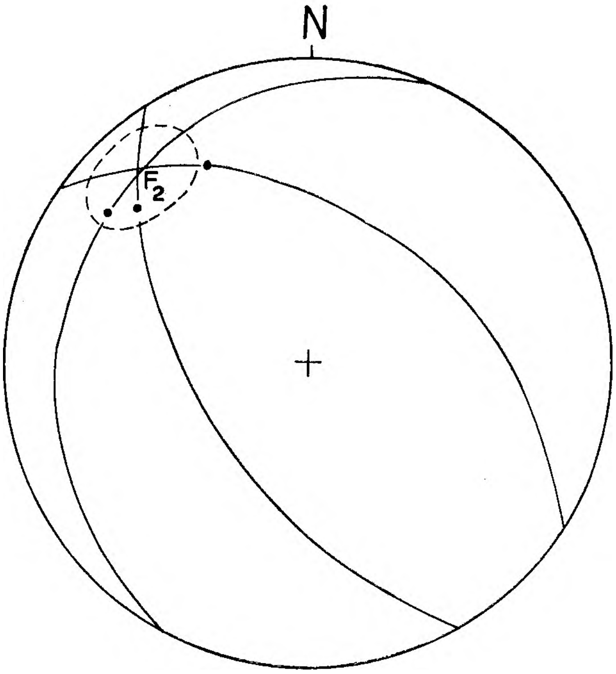

Fig. 12
Diagram showing orientations of S_1 surfaces (solid great circle) and L_1 lineation (dots) involved in F_2 fold. L_1 plots are arranged along the small circle of the projection. Accordingly F_2 fold was developed by flexure mechanism. Lower hemisphere of Schmidt net

Diagram orientacji powierzchni S_1 (łuki ciągłe) oraz struktur linijnych L_1 (kropki) ujętych w fałd F_2. Lineacja L_1 leży na małym kole, którego centrum stanowi oś F_2. Fałd F_2 postał zatem wskutek zginania. Półkula dolna siatki Schmidta

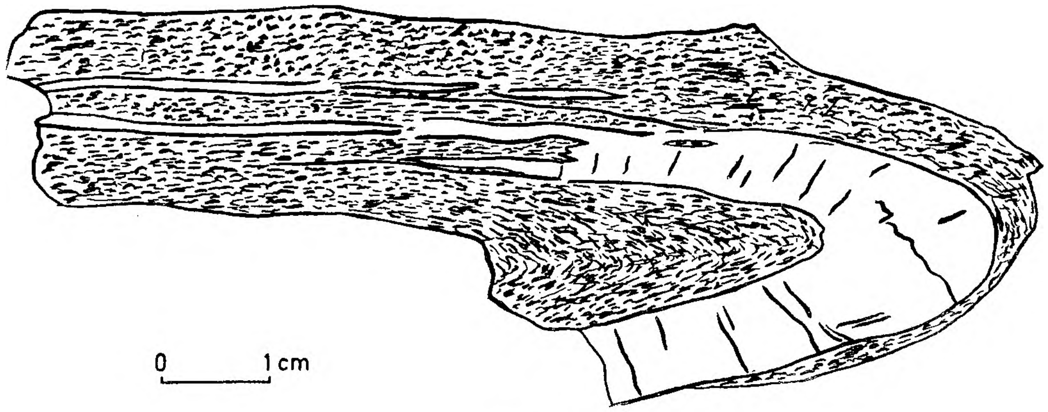

Fig. 13

Flattened fold of F_2 set developed in mica schist. Deformed quartz band (white) was developed before F_2+M_2 phase

Spłaszczony fałdek fazy F_2 w łupkach łyszczykowych. Zdeformowana warstewka kwarcu (bez szrafury) powstała przed fazą F_2+M_2

of the dip of fold limbs and later they resist further deformation by the flattening mechanism. In other cases the further development of a fold may be arrested, or boudinage may come to exist. One of the F_2 folds produced by flexure and modified by uniform flattening (48 %) is shown in figure 13.

Still, the amount of flattening calculated for a number of F_2 folds sometimes appeared to exceed 100 per cent (pls. VI*1*; VIII*2*,*4*; IX*2*; XI*2*,*5*,*6*). Thus the development of those folds by the flexure and flattening mechanisms must have been complicated due to some additional factors. The complications may be caused by several reasons.

One of the possible complications arises when the competent layer does not reach a state of sufficient plasticity during the folding.

Where rupture limit of a given rock bed is overcome, the further expansion of a rock mass to the fold closures regions must be exerted by extension. The extension evokes either boudinage or at least development of fractures. These fractures are approximately perpendicular to the layers boudaries. The fractures when displaced and converted into open cracks may be, or may be not, filled up with some secondary material. Quartz layer (concordant with S_1) involved in the fold shown in figure 13 recorded fractures probably of this very kind.

Shearing parallel to the axial plane appears to be another reason which causes further complication of a fold development (cf. pp. 146). The effects of the shear action are seen best in the cases of these "overflattened" folds (over 100 per cent). The shearing mechanism controls also a pattern of graphically recorded measurements of bed thickness taken across the bedding parallely to the axial planes of folds. An example of the F_2 fold considerably modified by superimposed axial shearing is shown in figure 10*e* and plate X*2*.

F_2 folding in the Orlickie Mts. has been considered a fairly complex process. Incipient folds developing by flexure were greatly modified due to flattening mechanism which commonly started to act still before the complete ending of rotation of the fold limbs. Further deformation went on under the prominent control of shearing, in the presence of still active lateral stresses.

Shear movements generally took place along the surfaces concordant or nearly parallel to the axial planes of F_2 folds. Owing to their tight or isoclinal geometry remarkable gliding occurred also in the fold limbs. This can be well recognized when special attention is paid to the studies of successive stages of development of drag folds occuring in the limbs of parent isoclinal fold. Flexure mechanism which gave rise to these small secondary folds must have been replaced, according to the general rule, by shearing mechanism. This shearing, in the case of the drag folds, was expressed mainly by gliding along longer limbs of these folds (fig. 14*a*). The shear movement was transferred and imposed on the whole structure of individual drag fold, and therefore its short limb yielded to crenulation along planes parallel

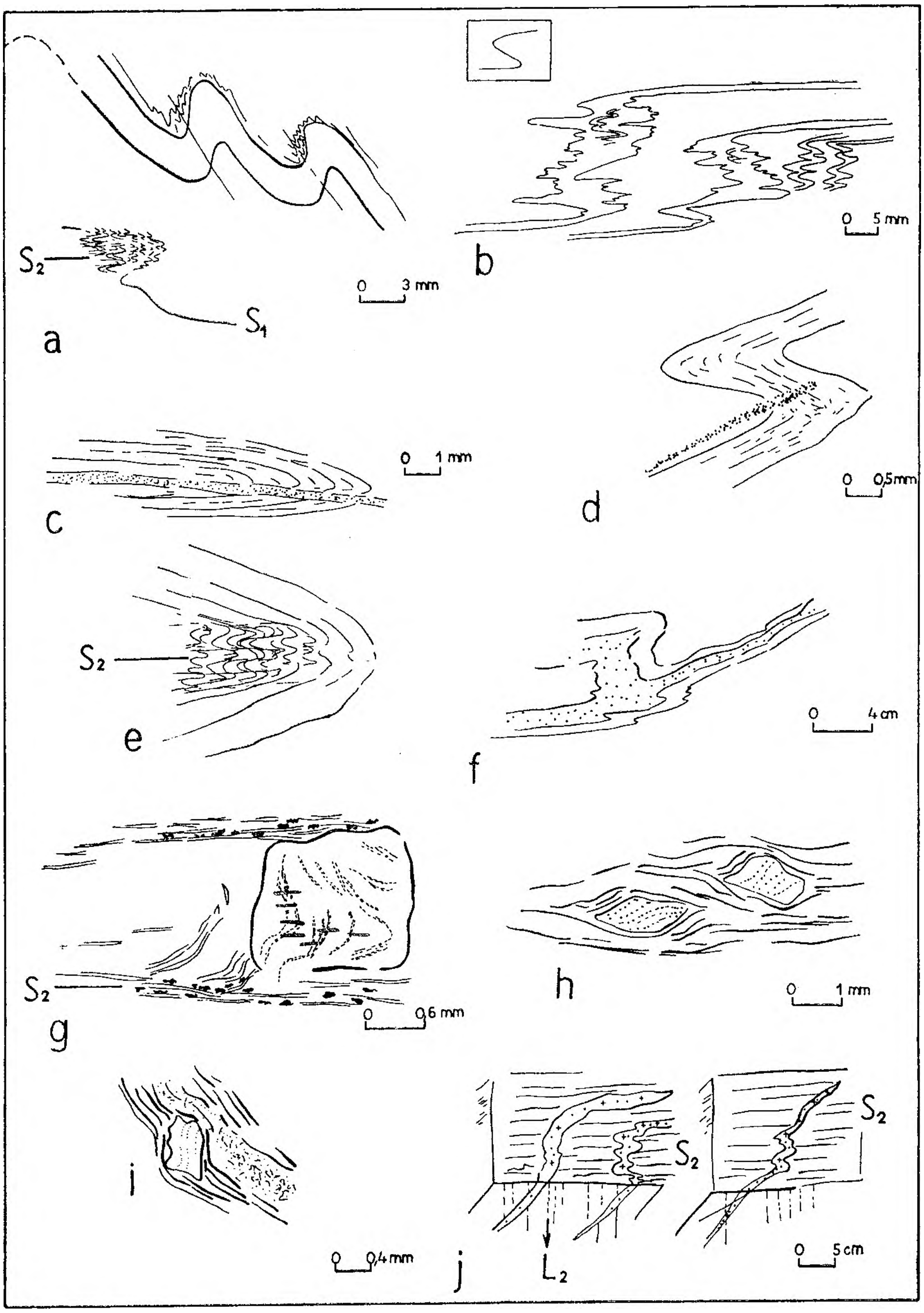

Fig. 14

Influence of shearing on attitude of F_2 folds and on arrangement of minerals to form F_2+M_2 fabric

a, b – drag folds of F_2 set are modified by slightly later shearing and crenulation. In consequences the folds attain a similar geometry. See also the text for further explanations; *c, d* – zones of more intense glide movements are often healed with plagioclase in amphibole schist (*c*), or quartz in mica schists (*d*); *e* – intensely crenulated core of F_2 fold; *f* – F_2 fold in mica schists subject to shearing parallel to S_2 planes. Initial geometry of the fold is slightly obliterated during strong concentration of light minerals (stippled) in the zone of movement; *g* – intrafolial fold of F_2 set. The closure of F_2 fold preserved in the grain of plagioclase of the third kind (biotite flakes parallel to S_2 axial planes); *h, i* – pre-existing mineral grains slightly rotated in the result of shearing movements along planes of S_2 foliation; *j* – quartz-felspar veins oblique to S_2 foliation and considered to be younger than this foliation are deformed and involved in shear folds due to shearing movements occuring along planes of S_2 foliation

Wpływ mechanizmu ścinania na strukturę i geometrię fałdów F_2 oraz na sposób ułożenia minerałów rekrystalizujących lub powstających w fazie F_2+M_2

a, b – modyfikacja fałdków ciągnionych zespołu F_2 wskutek ścinania i krenulacji aż do uzyskania przez te fałdy geometrii typu „similar". Patrz także objaśnienia w tekście; *c, d* – zabliźnianie stref silniejszych ślizgów plagioklazem w łupku amfibolowym (*c*) lub kwarcem w łupku łyszczykowym (*d*); *e* – jądro fałdu F_2 poddane silnej krenulacji; *f* – fałd zespołu F_2 w łupku łyszczykowym ulegającym ścinaniu równoległemu do powierzchni S_2. Pierwotna geometria fałdu została nieco zatarta przez znaczne koncentracje jasnych minerałów (kropkowane) w strefie ruchu; *g* – fałd śródfoliacyjny zespołu F_2. Przegub fałdku F_2 zachował się w blaście plagioklazu trzeciego rodzaju (blaszki biotytu równoległe do powierzchni osiowej S_2); *h, i* – rotacja wcześniej powstałych ziarn plagioklazu pod wpływem ruchów ścinających, zachodzących równolegle do powierzchni foliacji S_2; *j* – żyłki kwarcowo-skaleniowe skośne do foliacji S_2 i młodsze od niej zostały ujęte w fałdki ze ścinania zachodzącego równolegle do powierzchni tej foliacji to the planes of dominating displacements. This way the zones of short limbs acquaired a number of very small, subsidiary folds generally symmetrical in respect to one another (cf. pl. X*2*). The axial planes to these drag folds were either parallel to the surfaces of S_2 foliation (developed slightly later than the inception of drag folds) or slightly oblique to them. This depended on the amount of rotation of the limbs of parent fold. Where all the above mentioned planes of gliding were brought into parallelism the final attitudes of primary drag folds, owing to a total effect of the employed shearing, could be converted to those which acquired a perfect similar geometry characteristic of typical shear folds (fig. 14*b*; pls. X*2*; XI*3*).

The shear mechanism could considerably influence the local mobilization of the most mobile light minerals (pls. VI*5*; VII*1,2*; VIII *1,3*; XI*1*–*3*). Probably that is why in the fold shown in figure 14*d* the path of gliding (more distinct in the long limb) was healed with fine-grained quartz. This mineral formed thin vein oriented at low angle to S_2 planes but parallel to glide planes which occured in the long limb of the discussed drag fold. The veins cut across both the hinge and short limb of this fold where the continuity of arrangement of $F_1 + M_1$ phengite was broken down.

Significant influence of the shear mechanism on the fabric of amphibole-bearing rocks has already been featured in pp. 133–135 (cf. pls. VII; XI). One more example of the phenomenon is show in figure 14*c*. Loosenings existing within the structure of rock were filled up with plagioclase whose recrystallization was controlled by the shearing.

Careful observations of geometry and position of the tiny subsidiary folds developed in the zones of short limbs of secondary drag folds indicate three reasons of their inception. These are: 1) dragging of n-order due to flexure mechanism, 2) fine squeezing due to resultant action of the unavoidable local compression, 3) the most important one – crenulation and shearing along surfaces parallel to the long limbs of folds of $n - 1$ order.

Development of small folds within the axial plane zones of F_2 folds has been considered as distinct evidence on the appearance of shear action (fig. 14*e*). This, however, may be slightly ambiguous because the phenomenon can be easily misidentified as a symptom of simple squeezing which is able to effect a very similar structures. Nevertheless, one must be aware of common co-operation of these two mechanisms in the advanced stages of fold development.

Obviously, crenulation of S_1 foliation planes at the hinge areas of F_2 folds was also due to the shear action. This mechanism considerably facilitated the development of the main metamorphic foliation referred to as S_2 (e.g. figs. 7*a*; 10*f*; pls. VI; VII; VIII; IX and others).

While examining the structures like those pictured in figure 7*a*, *b*, *h* one can easily state that the intensity of shearing was irregularly spaced throughout the rock. Hence the displacements of elements of a rock fabric by the glide mechanism were unequal and only certain surfaces appeared to be the planes of the most intense gliding.

Remodelling of the geometry of F_2 folds due to superimposed shearing might be sometimes very significant (figs.6g,*h*;7*f*,*i*; pls. VI–VIII). Where the mobilization of light minerals was empolyed contemporaneously, even a complete obliteration of the prior shape of fold could be attained as the result of remarkable recrystallization in the zone of the strongest shear movement (fig. 14*f*; pl. VII*1,2*).

Gradual attenuating of limbs of F_2 folds toward an inception of relic intrafolial folds appears to be another common result of the shearing. One of the microstructures of this type is shown in figure 14*g*. Albite crystal (third kind of plagioclases occuring in mica schists) slightly preceded the most intense shearing, and contained internal inclusions made of relics of $F_1 + M_1$ directional fabric curved about F_2 axis of the fold developed prior to the albite. The inner inclusions were at first oriented concordantly with external $F_1 + M_1$ micas. The relic of this situation has been preserved in the surroundings close to one of the albite blast corners. Beside the very place all the flaky minerals were recrystallized and reoriented to spatial agreement with S_2 axial planes just due to shearing which operated along those planes, generally after the discussed albite inception. Significant concentrations of opaque minerals commonly occured where gliding along S_2 planes was more intense. This can be seen also in figure 14*g* in the form of elongated arrays or accumulations of those minerals. Such accumulations indicate the zones of strong shearing, and therefore they may be easily discerned under the microscope (pls. V*5*; VIII*6*).

Sometimes significant displacements along surfaces of the main foliation caused the rotation of some mineral grains (fig. 14*h*,*i*). Infrequently the shear action could control considerably the growth of plagioclase (the third kind of plagioclases) in mica schists rocks (fig. 7*c*; pl. V; VII).

In mica schists adjacent immediately to the Kudowa—Olešnice granitoids one may sometimes notice that microcline blasts (cf. p. 130) which came to crystallize owing to the presence of those igneous rocks were arranged along zones of the most intense shearing parallel to S_2 planes.

Thin veins cutting S_2 foliation can be occasionally met in the mica schists neighbouring the granitoid rocks. The veins are composed of quartz, plagioclase and microcline. They have filled up some fissures which have not been so far identified in respect of their nature and time of development. The fissures and veins were undoubtedly younger than S_2 foliation. It is especially interesting that the discussed veins were involved in folds (fig. 14*j*). Axial directions of these folds were controlled by the orientation of intersection between two surfaces—planes of S_2 foliation and these unidentified ones. These directions differ from those of true F_2 folds. Despite these differences, the axial planes to the questioned folds are parallel to S_2 foliation. An analysis of variations in the vein thickness measured parallel to the axial planes of the discussed folds revealed that the folds could not have been formed by a mechanism of flexure. Thus the observations presented above indicate that the veins were deformed due to shear folding. The planes of S_2 foliation are recognized to be the planes of the causative gliding. Obviously the gliding took place after the development of the veins in question. It is very hard to state whether the described phenomenon took place during $F_2 + M_2$ phase or shortly afterwards. So, the problem remains open—it is not certain whether the shearing belonged to the last stage of F_2 fold development, or whether it marked another period of glide movements along S_2 planes, most likely not too distant in time from the former. Mineral grains composing the veins in question appear to be equidimensional. Accordingly they may be expected to develop with no compressive lateral stress influence, but only under prevailing control of shear stresses. The statement has been confirmed by the presence of distinct deformation lamellae within quartz grains parallel to S_2 foliation planes. Hence it can be suggested that remarkable shearing which operated in the rocks of the Orlickie Mts. along planes of S_2 foliation and the shear action was fairly prolonged in time, at least beyond the kinematic period of the $F_2 + M_2$ phase.

Probably the shear action leading to deformation of the above described veins by a shear mechanism caused the development of tiny free spaces close to the closures of the questioned shear folds in their surroundings in mica schists. As it has been mentioned the discussed example has been taken from the mica schists adjacent to granitoids. Country rocks of the immediate neighbourhood of the granitoids were subject to insignificant and rather restricted microclinization (cf. p. 130). Crystallization of microcline often took place in the above mentioned tiny free spaces resulting in the rock from gliding along S_2 planes.

Despite the extensive evidence on the appearance of shearing which acted along S_2 surfaces, there are no sufficient data to define precisely the direction of the glide movements. It has been recognized that the displacements due to shearing occurred along both the S_2 surfaces and the planes oriented at very low angles to the latter (limbs of tight F_2 folds). It has already been mentioned that every potential glide plane did not appear to be an actual glide plane, and the zones of more intense shear movements were irregularly spaced throughout the rock domains. The manner of further modification of the flexed-flattened folds by shear mechanism suggests that "a" direction of main movement was oriented at high angle or perpendicularly to F_2 axes. The assumption has been supported to some extent by structural observations. An interesting case is presented in figure 15 (crag in a wood above Gołaczów, some 1000 meters west of the railway station in Kulin, eastern slope of 718,4 m hill). Lineation represented by elongated arrays of plagioclase grains runs generally in parallel to the axis of a fold belonging to F_2 set. In certain point this lineation turns and passes across the limb from syn- to antiform hinge where it again acquires and still maintains its

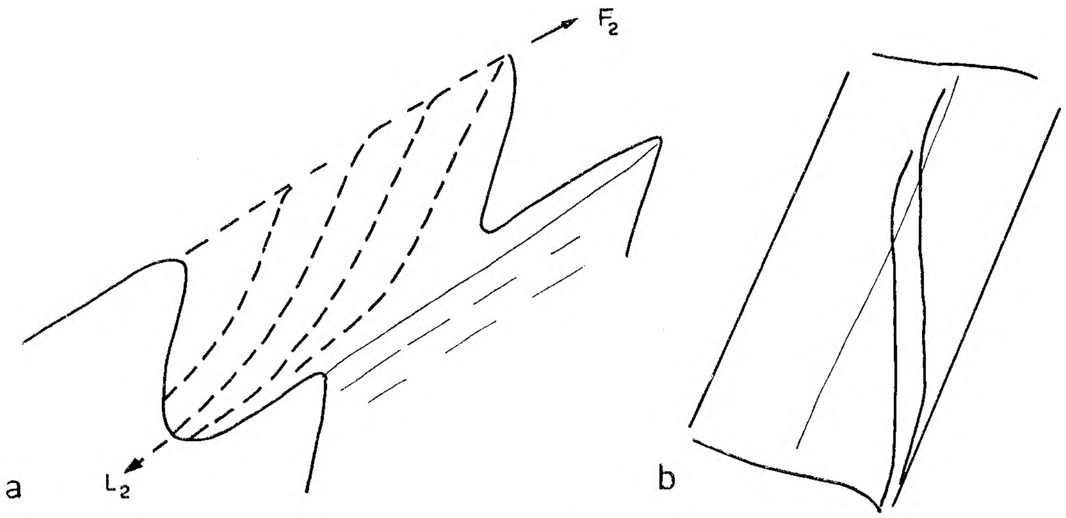

Fig. 15
Linear structures of L_2 set are reoriented duc to shear gliding in F_2+M_2 phase
a – geometry of F_2 fold; *b* – the fold and lineation rotated back to the plane

Reorientacja struktur linijnych L_2 wskutek działania ścinania w fazie F_2+M_2
a – pokrój fałdku F_2; *b* – fałd i lineacja po rozprostowaniu

directional agreement with the fold axis. The angle between the lineation and the fold axis is variable. This suggests the development of the discussed structure under control of shearing. The geometry of rotation of the lineation (fig. 15*b*) indicates the movement operating in the plane which contains this lineation. It moves along a great-circle path of the projection. Accordingly the surface of movement must be planar and the discussed lineation must be rectilinear before its deformation (cf. Weiss 1959; Ramsay 1960). Not only the charasteristic feature of this lineation but also its general parallelism to F_2 axes allow to determine it as the L_2 lineation developed contemporaneously with the main structures referred to as F_2. Thus the above described deformation of L_2 linear structures must have taken place later on. This deformation was due to shearing (gliding) which acted along the steep limb of the fold – the one lying closer to S_2 axial plane of this fold (fig. 15*a*). The plane of movement contained the "a" direction of the movement. The observed modification of the arrangement of L_2 lineation was due to variable speed of a movement of rock particles along the planes of movement. However the geometry of the rotation of L_2 lineation does not allow to define precisely the "a" direction. Such phenomena are rare and therefore two geometrical possibilities of equal rank may be envisaged: 1) "a" direction is roughly parallel to F_2 axes, or 2) "a" direction is roughly perpendicular to F_2 axes. Studies on modification of the hinge zones of F_2 folds by superimposed shearing seem to support the second possibility. It may be assumed the direction of shear gliding along S_2 surfaces was generally perpendicular to F_2 fold axes, and the shearing itself was a common factor appearing during the development of the main fold structures referred to as F_2 (cf. pp. 145, 146).

All the aforesaid remarks lead to the conclusion that the shearing along S_2 surfaces was a prolonged phenomenon, though of irregular intensity both in time and place. The shear action appeared to operate since the end of uniform flattening of F_2 folds until far beyond the period of pure kinematic activity of the main deformational phase (perhaps even till F_3 phase), influencing final moments in the process of blastesis of $F_2 + M_2$ minerals.

It has been recognized that the emplacement of the Kudowa – Olešnice granitoids took place at least in two stages (M. Opletal personal communication; Żelaźniewicz 1973b). The oldest portions of the granitoids intruded concordantly to S_2 planes. Numerous field and microscopical evidence not discussed in this paper for the brevity's sake indicate close relation between the emplacement of granitoids and the presence of strong shearing along planes parallel to S_2 foliation. Zone of thrusting separating the Nové Město formation from the Stronie formation was the reason of considerable discontinuity in internal coherence of the rock domains in this very place. Therefore the granitoids intruded just along this zone recognized as the zone of strong shearing. Thus the age of the main deformational stage may be roughly determined. Determinations of the radiometric age of biotite coming from the granitoids have yielded the ages of 293, 301 and 312 m.y. by the Rb/Sr method, and the ages of 307, 317, 328 m.y. by K/Ar method (cf. Burchart 1971). Hence the F_2 deformation must have preceded these ages. Unfortunately no differentiation has so far been made as to the spreading out of various parts of the granitoid massif, which differ from one another in their time of emplacement. Therefore it is uncertain to which part of the granitoid rocks the above quoted deteminations may refer. Moreover, it has been recognized that sills of the granitoids (concordant with S_2 planes) have been involved in F_4 folds. The granitoid body, however, also cut the F_4 structures. Therefore it can be ascertained that the emplacement of the granitoids took place before and after F_4 phase. So the formation of the massif was prolonged in time—it started at the end or after $F_2 + M_2$ phase, and was ended after F_4 phase. The radiometric age determinations enable to define the age of these foldings in a fairly broad limit. If the determinations are accurate, it may be expected that the main fold deformation referred to as F_2 took place in the Devonian.

It is noteworthy that all determinations of the radiometric age of the Karkonosze granite have yielded quite the same ages—292 to 322 m.y. (cf. Burchart 1971). According to the opinion expressed by Mierzejewski (1973) the Karkonosze granite was subject to an open folding while consolidating. Axes of these folds are parallel to b_2 fold lineation recognized in the Kaczawskie Mts. by H. Teisseyre (1967). Mierzejewski suggests that the foldings recorded in these two neighbouring (though so different) geological units were effected in the same field of regional stresses.

H. Teisseyre (1964, 1967, 1968) claimed the main tectogenic and epimetamorphic events in the Kaczawskie Mts. took place during the "Caledono-Variscan" mountain-building epoch. They were younger than the zone of Monograptus hercynicus but older than the upper part of Middle Devonian (Reusische Phase).

J. Teisseyre (1971) assumed that the main deformation in the metamorphic belt of the Eastern Karkonosze took place either in the old Variscan or in the young Caledonian time—and then distinct Variscan rebuilding was employed.

On the basis of quite convincing stratigraphic evidence Wojciechowska (1973) concluded that the essential folding in the Kłodzko metamorphic unit took place between the Silurian and the Upper Devonian.

According to H. Teisseyre (1973) most of the mega-folds discernible in the Lądek-Śnieżnik region are regarded as the "Caledono-variscic". Biotite from the Gierałtów gneisses yielded the age of 382 m.y., and phengite coming from eclogites yielded the age of 384 m.y. (the determinations were made by N. Bakun-Czubarow, cf. Burchart 1971). Both determinations indicate the Devonian.

Considering the lithological and structural similarities in the above mentioned Sudetes regions, reported by various authors one can presume that they are not merely casual coincidences. It seems probable that the Middle and Western Sudetes are fragments of one large, Young Caledonian or Old Variscan orogen, though both deformation and metamorphism could change in space and time throughout the orogen. One should realize that large geological units may be subject to metamorphism whose agents are irregularly distributed throughout the region to be metamorphosed as to the grade, intensity and time. Generally deformation is prior to metamorphism. Hence the structural and lithologic differences in the above mentioned regions of the Sudetes seem to be not too great.

Similar suggestions as to the uniformity of the tectonic and metamorphic events in this part of the Sudetes have already been presented (H. Teisseyre 1972).

It should be mentioned that axial directions of F_2 folds are variable due to subsequent rotations. They plunge commonly to NW or NNW in the Duszniki—Zieleniec region, and in the Lewin—Gołaczów region they plunge to S or run horizontally in NE—SW direction.

THE F_3 + (M_3) PHASE

Fold and planar structures assigned to this phase happened to be found only in few outcrops. Hence, no conclusion may be drawn as to its regional meaning and significance for the development of the discussed region. F_3 folds are characterized by an open geometry, eastern asymmetry, and plunges to NW. They are accompanied by weakly expressed axial foliation or axial fractures referred to as S_3 and dipping at moderate angles usually to W or WWN.

Distinct F_3 folds can be observed in the crag of mica schists situated in Podgórze. There are preserved good examples of the superposition of F_2 and F_3 folds. Recumbent F_2 folds plunge to NW. They are deformed by open F_3 folds plunging also to NW and displaying an eastern asymmetry. S_3 planes are expressed by axial cleavege or fractures, and dip steeply to WWN. In several places numerous S_3 frac-

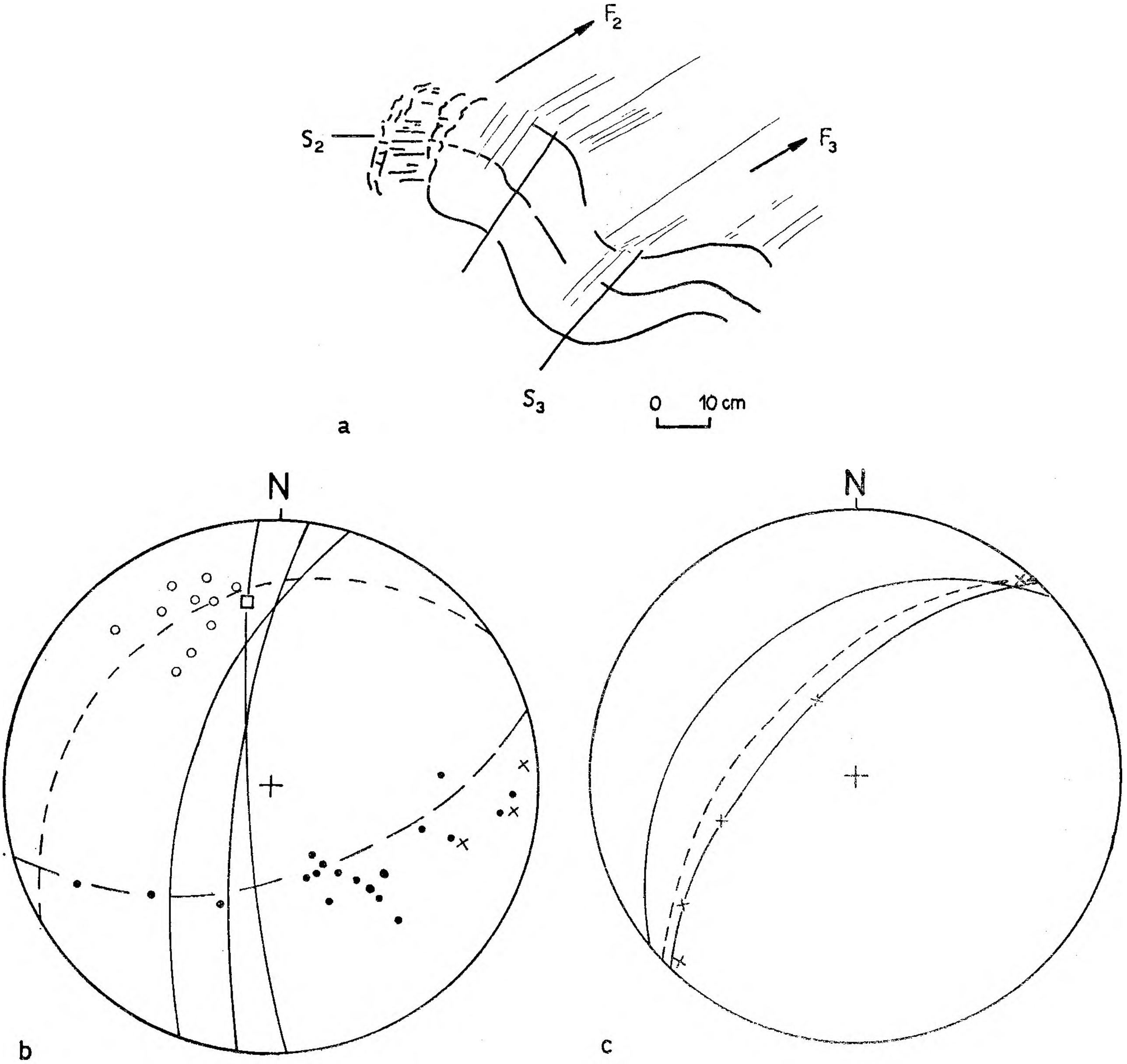

Fig. 16

Folds of F_3 set

a – interference of folds of F_2 and F_3 set found in the crag in Podgórze; b – diagram showing orientation of linear and planar structures developed during $F_2 + M_2$ and F_3 (+ M_3) phase in the crag in Podgórze. Open circles – F_2 fold axes, squere – F_3 fold axis, black solid circles – normals to S_2 planes involved in F_3 fold, solid great circles – S_3 planes; c – diagram showing orientation of the structural elements illustrated in figure 15a. Solid great circles – S_1 surfaces in F_2 fold limbs. Dashed great circle – inferred axial plane to the fold. Crosses – L_2 lineation

Fałdy zespołu F_3

a – interferencja fałdków F_2 i F_3 w skałce w Podgórzu; b – diagram ilustrujący orientację struktur linijnych i powierzchniowych faz $F_2 + M_2$ i F_3(+M_3) w skałce w Podgórzu; kółka – fałdki F_2; kwadracik – fałd F_3; kropki – bieguny powierzchni S_2 ujętych w fałdy F_3; łuk ciągły – powierzchnie S_3; c – diagram ilustrujący ułożenie elementów strukturalnych przedstawionych na figurze 15a; łuk ciągły – powierzchnia S_1; łuk przerywany – powierzchnia osiowa fałdku F_2; krzyżyki – lineacja L_2

tures became displaced and open fissures were developed. They were filled up with thin veins of quartz.

An example of F_2 and F_3 folds to interfere is seen in figure 16*a*. Spatial orientation of F_2 and F_3 folds as well as S_2 and S_3 planar structures visible in Podgórze can be read from the diagram in figure 16*b*.

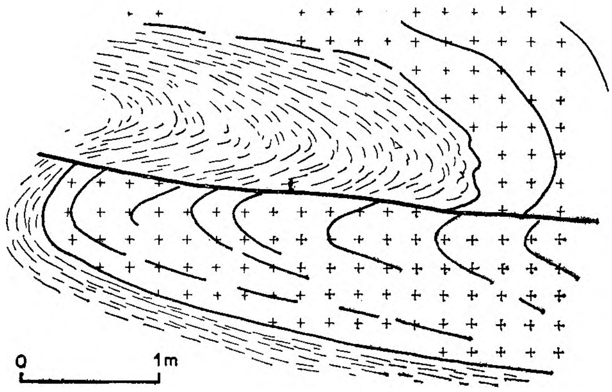

Fig. 17
Sketch of F_4 fold in which sheet of the Kudowa—Olešnice granitoid rocks was involved. The fold is faulted along its axial plane. Granitoid injection was prior to F_4 folding and paralleled S_2 foliation

Szkic fałdu F_4 deformującego żyłę granitoidu intrudującego wzdłuż powierzchni foliacji S_2 po fazie F_2, ale przed fazą F_4. Skrzydła fałdu są przemieszczone wzdłuż powierzchni osiowej

The described crag is situated nearby outcrops of the microcline gneisses. There are planar structures in gneisses oriented in much the same way as S_3 planes discerned in the crag in Podgórze. Within the gneiss fabric the planes are marked as weak foliation due to poor recrystallization of phengite flakes. The planes intersect the main foliation surfaces of gneisses, and the line of intersection is parallel to the elongation of minerals forming the gneisses and assumed as L_2. Because F_2 and F_3 folds are co-axial, it may be supposed that the weak foliation is a pronouncement of S_3 planar structures in the microcline gneisses. The S_2/S_3 intersection lineation amplifies the pencil structures (most likely L_2) in the gneisses.

In the quartzitic schists—those transitional from gneisses to mica schists—presumable S_3 planes are especially well visible due to the directional recrystallization of quartz and very poor recrystallization of phengite flakes. Therefore, the transitional schists display very characteristic fabric. Nearly all phengite scales lie in parallel to S_2 foliation whereas larger dimensions of quartz grains are frequently arranged along the envisaged S_3 planes.

If the discussed planar structures within the gneiss fabric are really the S_3 planes, it means that during $F_3 + (M_3)$ phase a very weak metamorphism affected the microcline gneisses. Still, mica schists, even those adhering to the gneisses, do not display any signs of mineral transformations due to $F_3 + (M_3)$ phase.

Unsignificant fold dimensions, distinct tendency for development of fractures only and not foliation paralleling S_3 axial planes, subsequent rotations, and scarcity of these structures—all these factors make it impossible to describe closer these structures.

No form of $F_3 + (M_3)$ phase was found in the mica schists outcropping nearby Zimne Wody, Lewin and Gołaczów. So this phase and the intrusion of the Kudowa—Olešnice granitoids cannot be related.

Having assumed that the presence of L_3 and S_3 structures in the microcline gneisses was established in a correct way, a certain hypothesis can be made. It should be remembered that the microcline gneisses were affected by metamorphic factors during M_1, M_2 and M_3 phases, but mica schists of the Stronie formation only in M_1 and M_2 phases. Thus the gneisses—in absolute terms—were being metamorphosed longer than the mica schists, and the mica schists perhaps even longer than phyllites (cf. p. 118).

Considering the co-axial development of F_2 and F_3 folds ($F_2 \parallel F_3 \parallel F_1$) one can say that F_3

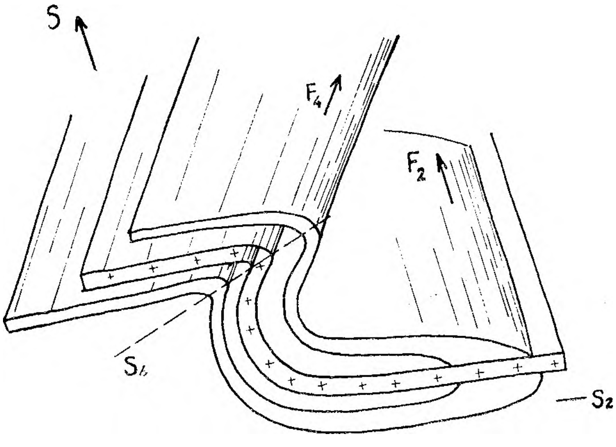

Fig. 18
Schematic block-diagram showing structural setting of the fold illustrated in figure 17

Schematyczny blok-diagram przedstawiający pozycję strukturalną fałdu z figury 17 structures were generated in the same field of principal stresses which also gave rise to the earlier fold structures (F_1 and F_2). It may be assumed, in the light of theory of permanent stresses, that the three successive deformations were effected in the same stress field. Intensity of the stresses steadily increased till F_2 phase and next decreased in F_3 phase. Deformations which resulted from the stresses were taking place under the metamorphic conditions. Development of isoclinal F_1 folds could establish for certain time a state of dynamic balance. In the very moment, under static conditions, the parent rock pile was subject to metamorphism of low greenschists facies. Further increase in the intensity of the stresses gave rise to the generally isoclinal F_2 folds. Their development considerably relaxed the stresses and remarkably amplified the action of regional metamorphism agents which caused the strong

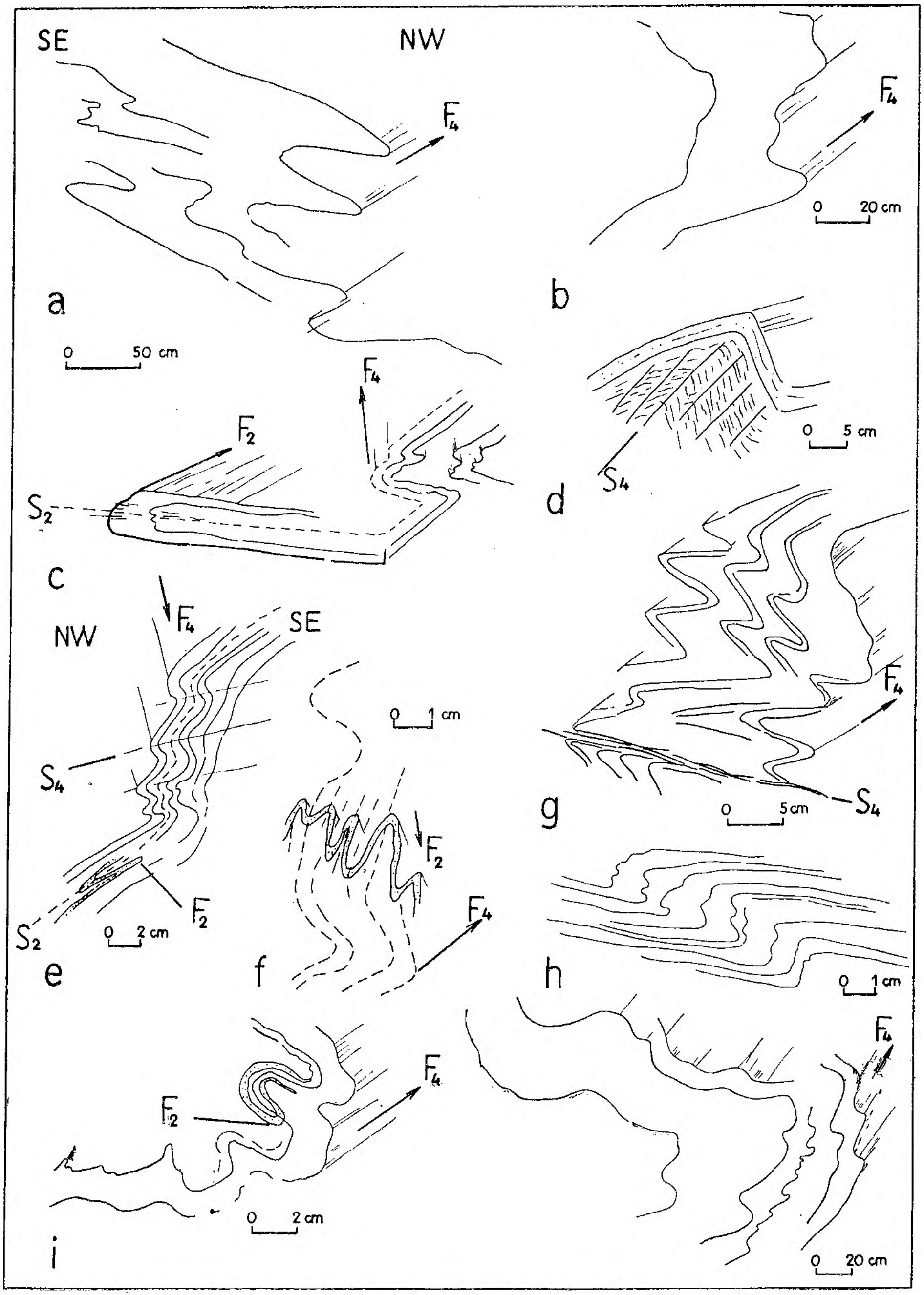

Fig. 19
Various attitudes of F_4 folds

Drobne struktury fałdowe fazy F_4. Patrz objaśnienia w tekście directional recrystallization as well as the development of the mineral assemblages characteristic of low amphibolite facies. Next, an orogenic period of the tectogen formation probably started. This could be the reason of only local occurrence of $F_3 + (M_3)$ phase which was marked merely in the core of a great just developing structure. The core would be represented by the microcline gneisses if the stratigraphical scheme established for the discussed region by Gierwielaniec (1965) is reliable. This scheme implies the core position of those gneisses. If so, it is clear that the regional metamorphism should be essentially ended in M_2 phase.

It may be expected, on the basis of the featured facts, that $F_1 + M_1$, $F_2 + M_2$ and $F_3 + (M_3)$ phases should be linked with one another and recognized as the subsidiary elements of one large continuous stage of the tectonometamorphic development of the region under discussion. The $F_3 + (M_3)$ phase could be considered as the final, decay episode of this stage (Żelaźniewicz 1972).

The above remarks also suggest that in the Polish part of the Orlickie Mts. the causative focus of the regional metamorphism should have been placed to the east, and the intensity of the metamorphism decreased westwards. This suggestion should so far be treated very hypothetically.

THE SECOND STAGE – THE F_4 PHASE

It is hard to say if vertical movements of the orogen took place at the end of the first stage or afterwards. Still, intrusion of the oldest masses of the Kudowa-Olešnice granitoids was most likely connected with these movements.

It has already been mentioned that all hitherto prevailing observations suggest the several-stage development of the Kudowa–Olešnice massif. One of the stages took undoubtedly place before the fourth deformational phase (F_4). The most important evidence is based on the observation that some granitoid veins intruding parallel to the planes of S_2 foliation are involved in F_4 folds whose axial directions are diagonal to F_2 ones (figs. 17; 18). Owing to the determinations of the radiometric age of the granitoids even the absolute age of this phase can be roughly ascertained – it is about 300 m.y. ago (cf. p. 152). It seems that the second and fourth phases of kinematic activity were not too distant in time.

The planes of S_2 foliation underlined by parallel arrangement of biotite flakes were involved in F_4 folds. The folds display variable geometry, being both tight and open (fig. 19; pl. XII). F_4 folds are characterized by constant, generally northern asymmetry of the fold limbs, and usually low dihedral angle between S_4 axial planes and planes of S_2 foliation (those in longer limbs of F_4 folds). The S_4 axial planes dip generally to SW at low or moderate angles (e.g. 230/20 near Zieleniec, 240/20 near Dańczów, or 215/20 near Małe Jerzykowice). F_4 axial directions are controlled by lines of the intersection between S_2 and S_4 planes. F_4 axes usually plunge to W with small departures to SW or NW. Thus the angle between F_2 and F_4 axial directions appears to be variable throughout the discussed region. However, the most common instance is characterized by transversal (oblique) orientations of F_4 folds in respect

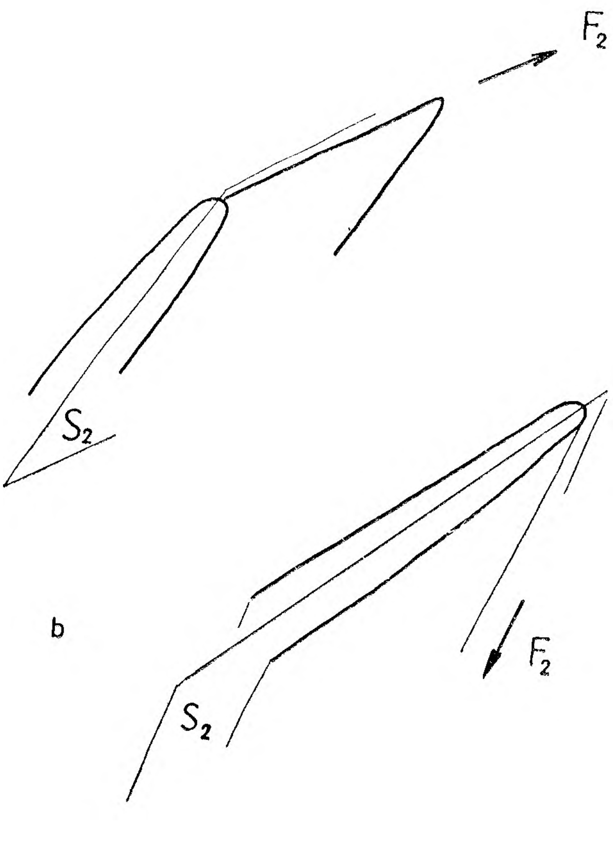

Fig. 20
Extremal positions of F_2 fold axes and S_2 surfaces, resulting from rotations during F_4 folding

Skrajne pozycje przestrzennej orientacji powierzchni osiowych S_2 oraz osi fałdów F_2, wynikające z rotacji tych elementów w czasie fałdowania F_4

to F_2 ones (fig. 25). Different attitudes of F_4 folds are shown in figure 19 and plate XII.

Generally no metamorphic events have been recognized to accompany the F_4 kinematic phase. Therefore F_4 folding was not followed by any mineral transformations, and F_4 folds possess no axial foliation or schistosity, which depended on reorientation of the pre-existing minerals during metamorphic recrystallization. Thus the axial planes to F_4 folds can be either inferred only or recognized as axial fracture cleavage. Nevertheless, the state of the rock material still considerably maintained plastic properties. This allowed the folds to acquire tight geometry, especially in the eastern area of the investigated region. Fold wavelength decreases with decreasing dimensions of F_4 folds—the smaller the fold is the tighter is its geometry. Significant compresion, felt in the cores of F_4 folds, caused that shearing occurred along the axial planes and parallel to the fold limbs where these folds of meso- and microscopic dimensions attained remarkably tight geometry. This shearing was displayed by a flowage of rock material to the outside of the closures, but parallel to the axial planes. In such instances biotite flakes tended to be mechanically reoriented in the F_4 fold hinge zones and brought into parallelism with S_4 planes. This gives an impression that a new schistosity was developed due to parallel growth and arrangement of flaky minerals. But lack of any traces of simultaneous recrystallization of quartz or even calcite in the calcareous phyllites clearly contradicts the assumption.

Certain weak transformations and reorientation of the minerals constituting the $F_2 + M_2$ rock fabric were displayed only in the mica schists adjacent immediately to some off-sets of the granitoid body. Most likely this phenomenon was caused by the influence of these intrusive rocks. This influence allowed the occurence of such convertions, though in strongly restricted halo around the granitoid veins. It is known that the youngest part of the intrusion was emplaced after F_4 deformational phase because the granitoid body truncates obliquely F_4 fold structures.

Reconstruction of position and significance of F_4 megafolds in regional structural setting is severaly impeded by poor outcrop pattern (figs. 2; 3). However, the existence of F_4 folds of megascopic dimensions seems to be undoubtful. It has been recognized owing to systematic studies on the spatial orientations of the structural elements of F_2 small folds, namely plunges of their axes and dips of their axial planes. The elements can acquire in the discussed region the extreme orientations like those pictured in figure 20. Thus the F_2 fold axes may be concordant either with strike (fig. 20*a*) or with dip lines of the main foliation planes (fig. 20*b*). The nature of such deviations is hard to be explained unless one assumes the rotation of F_2 fold structures during the diagonal refolding of metamorphic rock of the Orlickie Mts. Spatial dispersion of S_2 foliation planes, seen both in the maps (figs. 2, 3, 24) and in the stereograms (fig. 23), must result from subsequent refoldings—particularly during just F_4 phase, and also during F_6 phase. Obviously, the effects of these both phases must be carefully differntiated.

Where the outcrop pattern can be well established owing to distinct differences in lithology, the existence of F_2 folds subject to diagonal refolding referred to as F_4 is also confirmed. Numerous artificial trenches allowed to determine exactly the outcrop pattern of crystalline limestones and mica schists occurring south of the village of Podgórze.

Figure 21 is an enlarged fragment of the geological map (cf. fig. 3). In figure 22 several geological cross-sections drawn along subparallel lines are shown. They illustrate the structural situation of metamorphic rocks, determined in the very place of the Orlickie Mts. Isoclinal folds of the main deformational stage (F_2) have been involved in diagonal F_4 folds displaying distinct northern asymmetry and curving the planes of S_2 foliation.

During the field studies of forms of F_4 phase one more interesting observation has been made. It appears that the set of F_4 folds is not structurally uniform. Beside the "pure" flexure folds (developed only by flexure mechanism, fig. 19*c,f,k*) kink-bands have been also included in this set (fig. 19*e,g*). However in these two instances the deformation was due to folding of S_2 foliation on the same axial planes. The axial planes to kink-bands are marked as cleavage—usually fracture cleavage, sometimes poor slaty cleavage. That is why both these types of folds could laterally pass into each other giving rise to a visual effect of disharmonic folding (fig. 19*a,b*). Still they cannot be treated as true disharmonic folds because the folding has not resulted from diversified competence

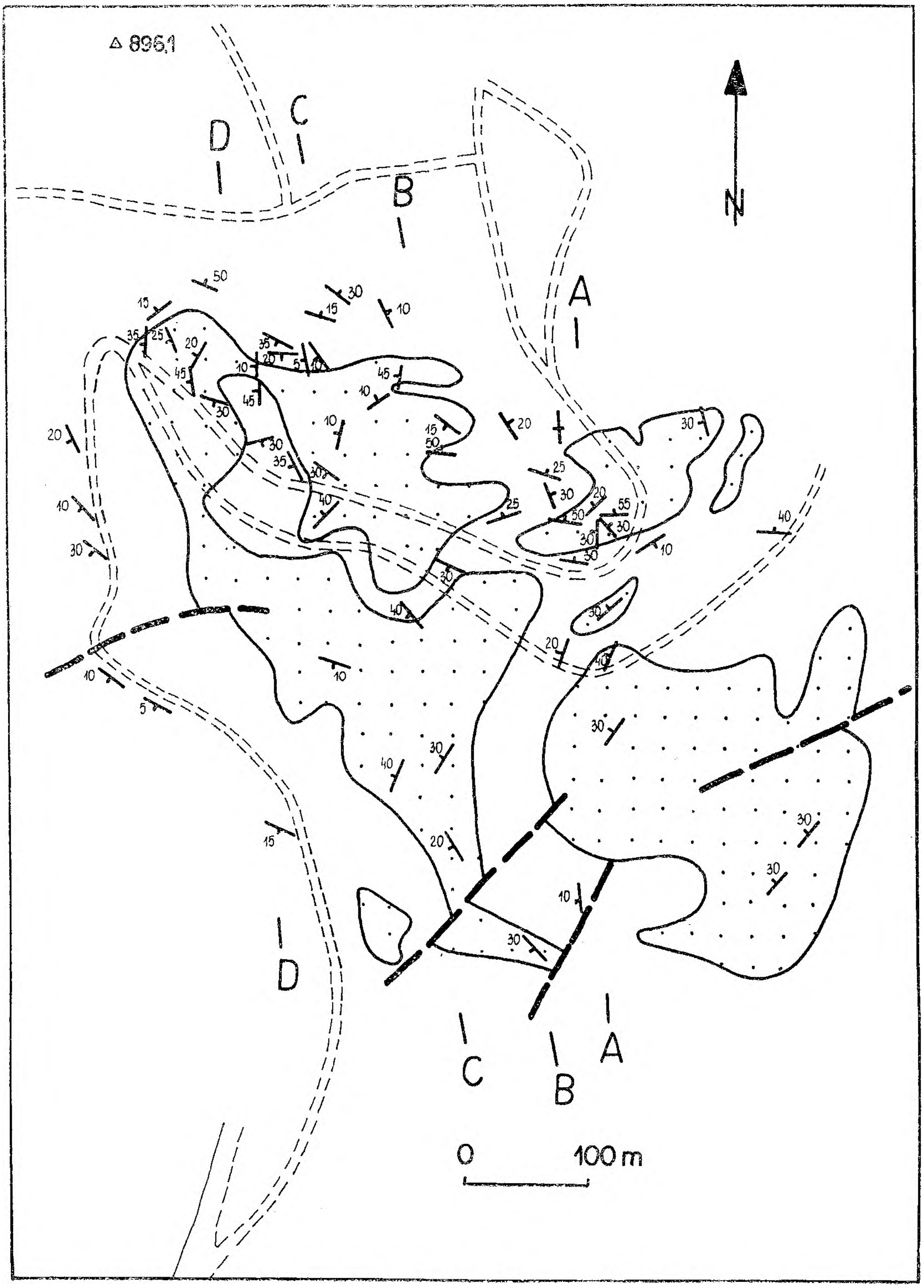

Fig. 21
Sketch map of the outcrop of crystalline limestones (dotted) occuring among mica schists (white) some 1 kilometres south of the village of Graniczna

Szkic wystąpienia wapieni krystalicznych (kropki), pojawiających się między łupkami łyszczykowymi (bez szrafury) około 1 km na S od Granicznej of the layers involved in the folds. The phenomenon resulted only from a change in style, or strictly speaking from a change in the mechanism responsible for folding. The change took place at the final episodes of development of F_4 deformational stage. These ending episodes have been recognized as fairly brittle ones. F_4 kink-band structures are considered as the result of the same prolonged deformation which at first generated more plastic, pure flexure folds. Kink folds maintained dextral asymmetry (as one looks at a fold down the plunge of its hinge line) — northern in geographical terms — and very characteristic of F_4 folds. It may be expected that no considerable change in the orientation of causative principal stresses took place during the whole F_4 deformation. The development of kink-bands was conditioned by a simple shear mechanism which operated along the planes of anisotropy produced in the very phase, that is, the axial planes to F_4 folds. Obviously, the control exerted by main foliation planes on axial directions of F_4 folds was increased and the axial planes themselves came to be converted into penetrative cleavage. Thus it can be recognized that the above described phenomena were of regional character instead of local one limited to individual folds, due to the structural conditions of deformations which appeared then. The very conditions allowed also the development of brittle discontinuous structures in metamorphic rocks of the Orlickie Mts.

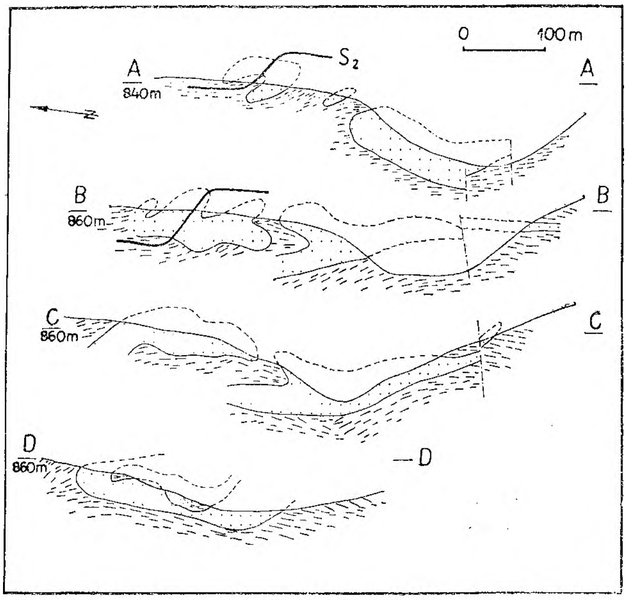

Fig. 22
A series of geological cross-sections to the map presented in figure 21

Thick solid lines in sections A and B represent S_2 surfaces involved in F_4 fold plunging to WWN and characterized by northern (dextral) asymmetry. F_4 folds can be observed directly in the abandoned quarry of limestones

Seria przekrojów geologicznych do mapy przedstawionej na figurze 21

Gruba, ciągła linia na przekrojach A i B oznacza schematycznie powierzchnie S_2 ujęte w asymetryczne fałdy F_4 nachylające się ku WWN. Fałdy te można także obserwować w nieczynnym kamieniołomie wapieni

THE THIRD STAGE

To supplement the history of the deformation of the metamorphic rocks of the Orlickie Mts. one must, at least briefly, characterize the latest fold deformations referred to as F_5, and F_6. These three last deformationa phases make together the third stage of the structural development of the region under discussion. Cleavages, fractures, joints as well as kink-bands and joint-drags were developed during this stage. It is noteworthy that the inception of development of kink folds started already in F_4 phase (second stage). Faulting of the metamorphic rocks belonged also to the third stage. Only some open upright folds of megascopic dimensions were generated then. Nearly all folds belonging to the third stage are only of mesoscopic and microscopic dimensions. These are kink-bands and joint-drags unseparably connected with the production of cleavages, fractures and joints. Small folds of this type did not exert any considerable influence on the pattern of megastructures in the Orlickie Mts. Obviously no metamorphic factors operated at that time. It should be stated that the conditions and mechanisms of the deformations as well as then developed tectonic structures differ greatly from those produced in the prior stages of the structural development of the region under discussion. Accordingly all the structural phenomena of the third stage are discussed in a separate paper (Żelaźniewicz in press).

The kink-band structures of the Orlickie Mts. were featured previously (Żelaźniewicz 1973a). Some words should be mentioned about linear structures paralleling kink fold axes before the structural analysis will be discussed. Beside microscopical crenulation they are always marked as the intersection lineation resulting from the intersections between the planes of S_2 foliation and the surfaces of cleavages, fractures and joints. Obviously spatial attitudes of L_5-L_6 lineations are very varied and depend on mutual position of these surfaces that cut one another. Therefore those lineations cannot be important for purposes of structural analysis. F_5 folds plunge most frequently to SW, whereas F_6 folds plunge to NW. The latter are usually accompanied by longitudinal axial fractures or even sometimes joints. F_6 folds are visible in the map (figs. 2; 3). One of them was called the Kulin anticline by Gierwielaniec (1965). It is open, antiformal folds of megascopic dimensions curving surfaces of S_2 foliation in amphibolites and mica schists in the vicinity of Dańczów, Gołaczów and Żyznów.

ELEMENTS OF THE STRUCTURAL ANALYSIS

To analyse geometrically the tectonic structures recorded in the metamorphic rocks of the Orlickie Mts. the whole investigated region has been divided into eleven roughly homogenus areas, in respect to orientations of S_2 foliation planes and F_2 axial directions. For each of them the synoptic diagram has been made (fig. 23) to illustrate the orientation of S_2 foliation (1485 measurements) and F_2 and F_4 axial directions (875 measurements) in the investigated area. It has been revealed in the course of structural analysis that region no. VI embracing outcrops of microcline gneisses appearing from beneath Cretaceous cover south of Duszniki was not subject to fold deformations later than the F_2 one, at least in the considerable degree reflecting in the diagram. This result may be misleading because of lack of any exposures in the vicinity of Bobrowniki. Thus the statistical data are irregularly collected. The remaining ten regions display signs of younger fold deformation. This is shown by spatial relations between structural elements plotted against the sterograms.

It can be seen distinctly in the diagrams nos. I–V, VII, VIII that poles to S_2 surfaces are arranged along great circles representing the planes whose Π poles fall into the area occupied by F_4 fold axes. Similarly, the planes corresponding to the extreme values of the S_2 foliation contours cross-cut themselves in the area of F_4 axes. Plots of F_2 folds are arranged on partial small circles of the projection around F_4 plots. Thus F_4 fold deformation should be regarded as being due to the flexure mechanism resulting in open asymmetrical folds.

The diagrams for regions nos V and VII allow to state the presence of open mega-antiform referred to as F_6, and plunging to NW (the Kulin anticline of Gierwielaniec 1965). Therefore distinct dispersion of F_4 plots can be seen in diagram no. VII. So far, significant steepeness of planes of S_2 foliation in region no. VII has not been understood satisfactorily in the terms of structural analysis.

The diagrams for regions nos. III, IV have been constructed on the basis of only few measurements because of scarcity of exposures in the very regions. Moreover, small F_4 folds have been observed only in one outcrop. However the great circles representing the extreme orientations of planes of S_2 foliation intersect each other in both these diagrams at the point of 245/20. This point may be interpreted as the plot of F_4 axial direction. If so, the intersection of the two great circles fixes the position of F_4 axis. Now, looking at the diagrams nos. I–VII one can recognize a slight arch affecting the trends of F_4 axial directions. This is believed to be due to sinistral displacements along fault surfaces running NE–SW, and being remarkably abundant in the very zone covering regions nos. III and IV.

Diagrams nos. IX–XI refer to the observations made in the phyllitic rocks of the Nové Město formation. Considering the particular lithological properties of the phyllites the kink-bands, joint-drags and related structures were developed extremely well, as it could be expected. This led to almost entire obliteration of the traces of the older deformations. Mainly the deformations are responsible for the arrangements of plots of S_2 surfaces along great circles of the projection. Π poles to the planes representing the circles are plunged to SW (kink folds of F_5 phase). Moreover, the departures from the structural patterns shown in other synoptic diagrams are due to the presence of F_6 open folds plunging to NW, and due to rotations connected with the displacem ments of rock masses along planes of faults developed parallel to S_6 planes in later episodes of the structural development of the investigated region.

FINAL STATEMENTS

Metamorphic rocks of the Orlickie Mts. were derived from the regionally metamorphosed sedimentary pile. So far, the age of the sediment is hard to be definitely established. It is suggested that a significant role in the sediment was played by subfelspathic wackes which were converted into mica schists (speaking more correctly—rocks displaying a schist habit). The transformations were due to regional metamorphism of low amphibolite grade, without any significant and discernible metasomatic afflux of alkali ions.

It seems to be most probable that both deformation and metamorphism, which led the pre-Carboniferous rocks of the Orlickie Mts. to acquire their recent attitude, spreading and spatial position, can be considered as the one great, extensive, and essentially unbroken process. Changes in the intensity of metamorphic factors as well as changes in the amount and direction of action of the principal stresses allow to distinguish in the process three specificly autonomous stages, and within them, in turn, six subsidiary phases. Each of the phases was characterized by relatively constant orientation and value of the principal stresses. Moreover, during these phases which were closely associated with active metamorphism the internal rock fabric was subject to multiple rebuilding due to metamorphic recrystallization. Owing to this phenomenon the rocks to be transformed acquired in the successive phases not only the characteristic and distinctive fabric, but also certain typical mineral index. Therefore the structural forms of the individual phases attained certain characteristic features indicative of each of the phases.

The first stage appeared to be the period of the strongest kinematic and metamorphic activity. The first stage comprised three phases, namely: $F_1 + M_1$, $F_2 + M_2$ and $F_3 + (M_3)$. The maximum intensity of the tectonometamorphic processes has been recognized to have taken place in $F_2 + M_2$ phase. Owing to the correlation of the recognized structural phenomena with radiometrically dated intrusion of the Kudowa—Olešnice granitoids the age of the main tectonometamorphic events can be inferred, though only in a fairly broad limit. K/Ar and Rb/Sr methods have resulted in the ages 293 —312 m.y. But the granitoids were intruded at least in two stages. It is unknown to which part of the massif these age determinations may refer. Thus the age of the main deformation and metamorphism affecting the rocks in the Polish part of the Orlickie Mts. may be established only in rough approximation. It has been assumed that both main deformation and metamorphism took place in the beginning of the Variscan mountain-building epoch or in its turning-point to the Caledonian one.

Accordingly the oldest fold movements referred to as F_1 must have taken place at least slightly earlier. Then such folds were developed whose preserved and still recognizable relics commonly display tight or isoclinal geometry. On the whole the axial directions of these folds were running either NW—SE or NE—SW. However, due to superimposed refoldings it cannot be established which of these two directions actually existed in the region. The development of F_1 folds was accompanied by the development of S_1 foliation paralleling the axial planes to the discussed folds. This foliation was marked by parallel arrangement of phengite flakes in mica schists and fibrous amphibole in actinolite schists (phyllites). Metamorphic phenomena started a bit later in respect to the period of kinematic activity. Metamorphism (M_1) caused the primary sedimentary rocks to be transformed under greenschist facies conditions. In the rocks displaying a schist habit (mica schists) plagioclases of the first kind recognized as albite were developed. Blasts of this felspar preserved internally relics of limbs and closures of the oldest microfolds belonging also to F_1 set.

Persistent activity of the responsible stresses as well as constant directions of their action caused still existing fold structures to be refolded about similarly oriented axes (F_2). F_2 folds characterized by varied geometry usually plunge to NW or NE, roughly co-axial with the folds produced during the prior deformational phase. Thus the same difficulties arise in establishing which of these directions was really existing in the region.

F_2 deformation took place under advanced conditions of the regional metamorphism. So the p/t ratio was increased and this caused the transformations of rocks under conditions of low-amphibolite facies. The mineral index of the rocks to be transformed was changed.

New minera's were crystallizing: biotite, more basic plagioclase, common hornblende. Other minerals to form the $F_2 + M_2$ fabric were subject to remarkably strong or even entire recrystallization.

F_2 deformation was accompanied by extremely good development of S_2 foliation which paralleled the axial planes to F_2 folds. This foliation is considered as the main metamorphic foliation of the rocks occuring in the Orlickie Mts. It was underlined by parallel growth of the axial biotite in mica schists of the Stronie formation prevailing in the discussed region.

It seems that intensity of the main deformation was constant throughout the investigated region. But the eastern part of this region was most probably subject to weaker metamorphic factors during M_2 phase. This is the vicinity of Zieleniec where the rocks preserved best the $F_1 + M_1$ fabric. Supposedly the phenomenon was due to less severe than elsewhere mineral transformations connected with $F_2 + M_2$ phase.

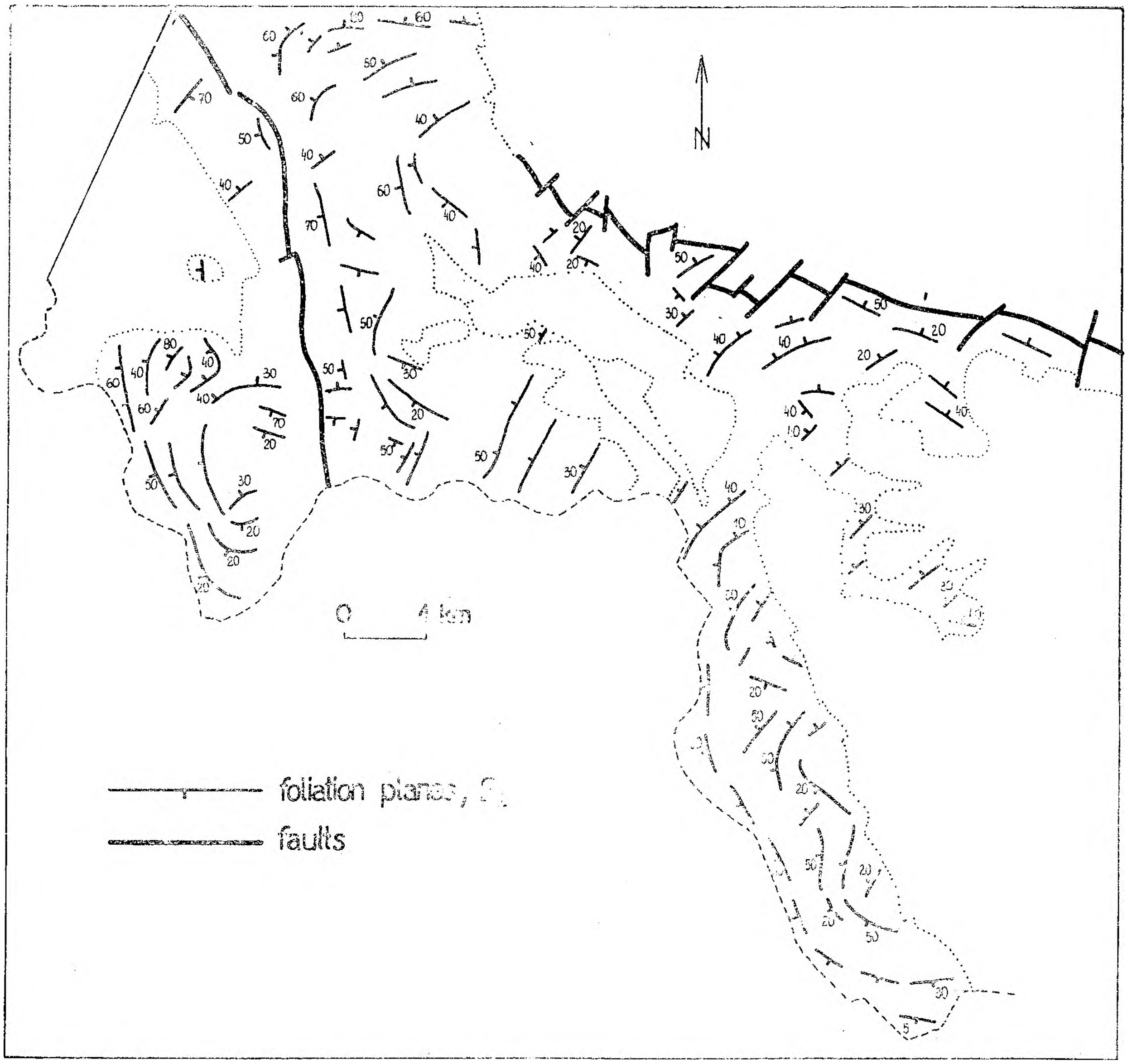

Fig. 24
Structural sketch showing strike and dip of surfaces of S_2 foliation in metamorphic rocks of the Polish part of the Orlickie Mts.

Szkic strukturalny ilustrujący bieg i zapad powierzchni foliacji S_2 w skałach metamorficznych polskiej części Gór Orlickich

It has been inferred that F_1 folds had a fan-like arrangement throughout the investigated region. These folds in its eastern part kept upright attitudes and were accompanied by steep axial foliation (S_1). In the western part, however, the F_1 folds steadily assumed a character of inclined and in turn recumbent structures which made the S_1 surfaces relatively flat-lying. Still active further deformation (F_2) going on in the same field of principal stresses caused co-axial refolding of this complex fold structure. Obviously the manner of spatial arrangement of F_1 folds must have conditioned the orientation of structural elements of F_2 folds. Thus F_2 folds in the western area acquired now the upright position, being associated with steeply dipping S_2 axial foliation. But in the eastern area the F_1 folds, primarily upright, must have been involved in F_2 folds with gently inclined S_2 axial planes paralleling the regional foliation referred to as S_2. Of course, the above suggestion should be tested more carefully, still it has allowed to explain the actual differences between the eastern and western areas

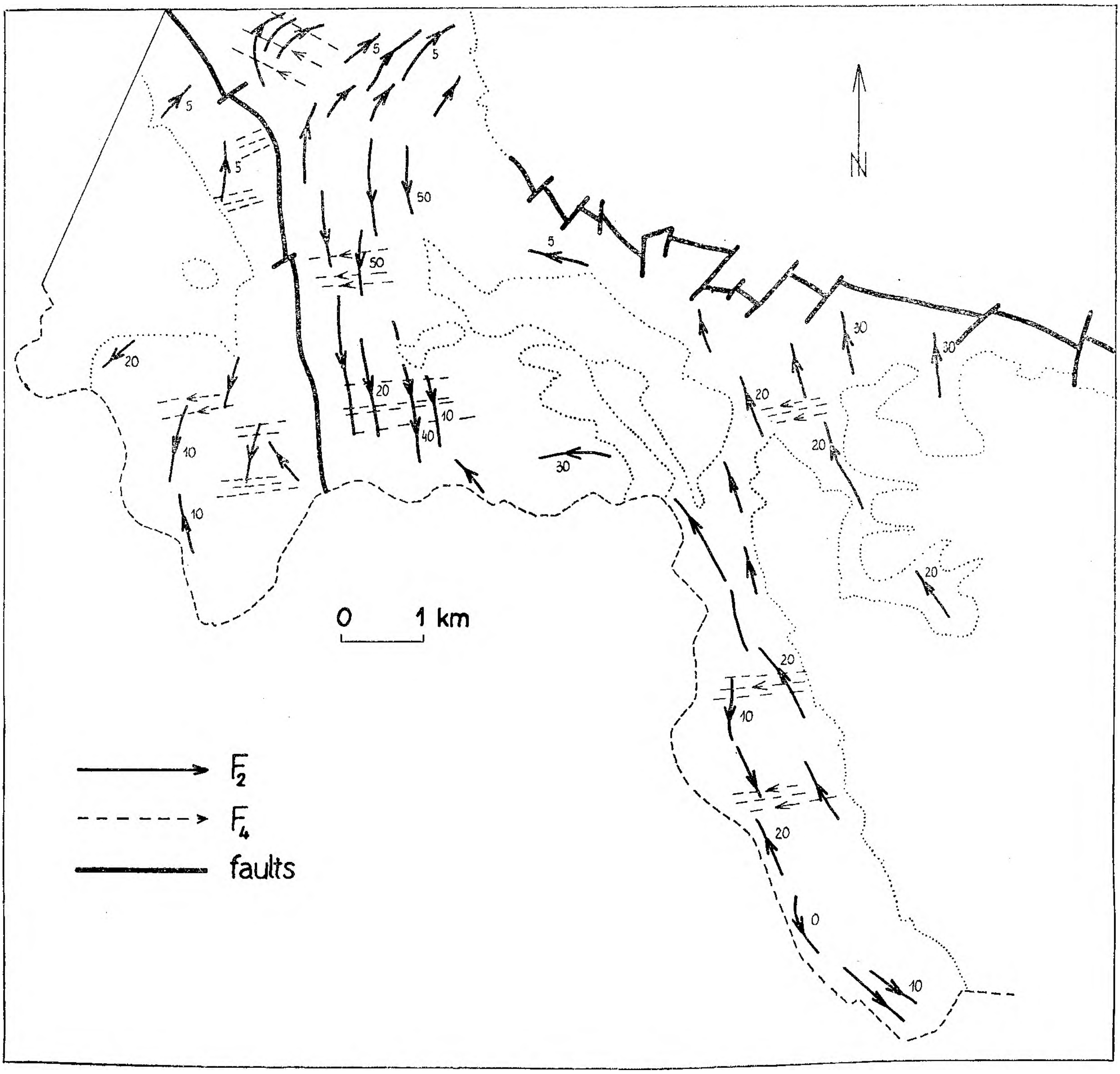

Fig. 25
Structural sketch showing trend and plunge of linear structures produced during F_2+M_2 and F_4 phase in metamorphic rocks of the Polish part of the Orlickie Mts.

Szkic strukturalny ilustrujący bieg i nachylenie struktur linijnych faz F_2+M_2 i F_4 w skałach metamorficznych polskiej części Gór Orlickich of the discussed region. Steep arrangement of the surfaces of S_2 foliation in the Lewin—Gołaczów area might remarkably facilitate the heat to be conducted from beneath, and accordingly the rock series of this area were metamorphosed stronger than those occuring in the Duszniki—Zieleniec area. More gentle attitude of penetrative S_2 foliation in the last mentioned area decreased the influence of temperature, and hence the effects of metamorphism decreased as well.

Moreover, in the western part of the investigated region the steeply dipping surfaces of S_2 foliation facilitated greatly the shearing to operate along S_2 planes. This shearing has been considered as being closely connected with orogenic (in Wegmann's sense) period of the building of the Orlickie Mts., which started at the end of the main deformation (F_2). Thus the emplacement of the Kudowa—Olešnice granitoids just in the western area was by no means accidental. Obviously the steep, penetrative S_2 foliation must have been the easiest way of their migration from beneath. It seems to be quite probable that the emplacing granitoid masses were the source of raised temperature which augumented the metamorphism (400—450°; cf. Borkowska 1969). There is an evidence on the prolonged, several-stages emplacement of these granitoids. So, the presence of a metamorphic focus in the western area was long-lived. Presumably, because of borning and emplacing granitoids, the rocks of the Lewin—Gołaczów region (adjacent to the granitoid body)—especially amphibolites—suffered so strong transformations of their mineral fabric. The transformations were accomplished in static conditions though catalysed by shearing which followed the main period of kinematic activity (F_2).

M_2 phase has been recognized to be a period of the strongest metamorphism. Afterwards the metamorphism ceased very quickly. Hence, folds produced during F_3 phase, though co-axial with the older ones, were accompanied by quite insignificant, local recrystallization. $F_2 + M_2$ fabric was affected by this recrystallization (M_3) to very limited extent.

Therefore, the first stage of the structural development of the investigated region may be treated as one continuous process of deformation that was spatially and temporally connected with an increase and cessation of metamorphic events while the principal stresses were constantly oriented. The folds generated during this stage were developed by a flexure mechanism and subsequently strongly modified due to superimposed shearing.

The temporal difference between the first and the second stage seems to have been insignificant. During the second stage orientation of the principal stresses must have changed, and no metamorphism took place. These allowed to distinguish the independent deformational phase referred to as F_4. Axial directions of the folds produced during this phase were oblique or transversal to the pre-existing fold structures. F_4 folds consistently plunge to W with small departures to WWN or WWS. F_4 folds, in spite of their varied geometry, display always the same asymmetry—generally northern. These folds have been found all over the investigated region.

Structural elements of folds developed during the preceding deformational phases were rotated due to F_4 folding. Therefore F_2 axial directions and dips of S_2 planes are changing in the investigated region. Unfortunately F_4 folds of megascopic dimensions are unmappable due to poorly exposed ground and lack of any sufficiently distinct marker horizons.

Kink-bands and related cleavages started to develop in the second stage. However, the most extensive development of kink-bands, joint drags, cleavages, fractures, joints, and faults was characteristic of the third stage of structural development of the discussed region. The third stage has not been discussed in this paper.

The Stronie formation and the Nové Město formation are separated by the zone of shear discontinuity in the Orlickie Mts. Both formations are considered as different levels of one great unit of metamorphic rocks. Phyllites of the Nové Město formation represent the higher one. It is therefore suggested that the development of this thrust zone took place at the end of the kinematic activity of $F_2 + M_2$ phase but before the emplacement of granitoids of the Kudowa—Olešnice massif. Moreover, significant movements in the very zone operated simultaneously with a raising of the granitoid masses from beneath. Complex displacements in the discussed zone went on at least to Cretaceous period.

The remarks included in the introduction to this paper have reflected the different opinions expressed by geologists on the origin fo rocks forming the Kłodzko—Orlica dome as well as on the mode and sequence of deformations affecting those rocks.

Presently, three different versions about the development of the Śnieżnik—Gierałtów formation are known among Polish geologists, not taking into account historical German conceptions. The first version is represented by opinions of Smulikowski (1957, 1958, 1960, 1973), H. Teisseyre (1957, 1968, 1973), Juroszek (1972), and others. According to these authors the Śnieżnik—Gierałtów formation is of the same age as the Stronie formation and was developed due to strong though diversified metasomatic felspathization of the Stronie rocks. The second conception was proposed by Don (1964). He assumed that the Śnieżnik gneisses were due to transformations of the magma which had been syntectonically intruded into earlier metamorphosed and felspathized rocks of the Stronie formation. Next, the Gierałtów migmatic gneisses were attached from beneath to the above complex consisting of the Stronie and Śnieżnik rocks. Veins of the Gierałtów gneisses cut obliquely the overlying rock series. The third version was given by Ansilewski (1966). He stated that the different varieties of those gneisses (in the Bialskie Mts.) resulted from the diversities occuring in the parent sedimentary complex (arkoses, two-felspar graywackes, plagioclase graywackes) subject to uniform processes of the regional metamorphism and metamorphic differentiation.

Gneisses of the Śnieżnik type in the Polish part of the Orlickie Mts. are outcropped over rather small area. Lack of sufficient observational data does not permit to draw any reliable conclusions. I suppose, however, that the discussed gneisses are due to transformation of arkosic rocks under the influence of both regional metamorphism and metamorphic differentiation.

Gneisses of the Śnieżnik type occuring in the Polish part of the Orlickie Mts. pass continuously into mica schists of the Stronie formation. Metasomatic felspathization of these schists is hard to be proved in the Orlickie Mts. The schists do not contain microcline which can be encountered in mica schists of the Stronie formation outcropping in other parts of the Kłodzko—Orlica dome. According to the majority of investigators the metasomatic agents operated most distinctly just in the mica schists of the Stronie formation. Other rocks making this formation were considerably less affected by the agents (cf. Smulikowski 1964; Butkiewicz 1972).

All geologists agree that the oldest folds (F_1 and F_2 sets) recorded in metamorphic rocks of the Kłodzko—Orlica dome are generally co-axial, trending approximately meridionally with departures to NE or NW. According to H. Teisseyre (1973), however, F_1 folds were due to shearing but F_2 folds resulted from a flexure mechanism. Wojciechowska (1972) stated that both F_1 and F_2 folds were developed only due to shearing. H. Teisseyre claimed that F_1 phase was followed by the strongest metamorphism which caused granitization of the supracrustal series. The metamorphic transformations following F_2 phase must have been considerably weaker because the axial planes to F_2 folds are parallel only to poorly developed fracture cleavage. However, the data published by Wojciechowska (1972) point unambiguously to very strong recrystallization of minerals of the Stronie rocks, accompanying the second deformational phase referred to as F_2. The F_2 folds described by her possess distinct axial foliation. Considerable displacements occuring along planes of this foliation gave rise to intrafolial folds. According to H. Teisseyre, however, the intrafolial folds are characteristic only of F_1 folds. Don's investigations on the Różane Mts. fold indicate that the axial foliations of F_1 and F_2 isoclinal folds are parallel and are in a spatial agreement with the main foliation of the region. The folds described by Don (1972) could not be developed by shear mechanism because they are associated with drag folds. It is known that drag folds may be produced only during the deformation of rock beds, evoked by a flexure mechanism.

During the third deformational phase (F_3) small folds trending NE—SW were developed in the rocks of the Lądek—Śnieżnik metamorphic unit (H. Teisseyre 1973). Their axial planes are parallel to very weakly marked surfaces of both flow and fracture cleavage. Wojciechowska's observations provided proofs on remarkable distinct recrystallization of mica along the axial planes to F_3 folds. Don stated that in the Krowiarki Range during the third deformational phase respective to F_3 phase of H. Teisseyre, the rock series were very strongly plasticized, earlier structures were diagonally refolded and this refolding was accompanied by the development of the migmatic gneisses of Gierałtów type. According to Don (1972) F_3 folds plunge either to NW or SE — so they are perpendicular to F_3 folds distinguished by H. Teisseyre and perpendicular to F_3 folds described by Wojciechowska.

It has been established on the basis of my studies in the Polish part of The Orlickie Mts. that the folds produced during F_1 and F_2 phases were generally co-axial, and were developed by a flexure mechanism and later strongly modified due to shearing. The axial planes to F_2 folds are concordant with the main foliation occuring in metamorphic rocks of the investigated region. The strongest deformation took place during F_2 phase being followed by the most effective metamorphism of the rock series of the Orlickie Mts.

Plunging to W diagonal folds (F_4) recognized by me in the Orlickie Mts. could be referred to B_3 lineation striking W—E, distinguished by Dumicz (1964) in the Bystrzyckie Mts. Small, brittle folds of the B_3 set are always characterized, however, by southern asymmetry while F_4 folds distinguished by me display persistently northern asymmetry. It is hard to say whether these structures may be referred to F_3 folds recognized in metamorphic rocks occuring on the other side of the Nysa graben. Diagonal refolding of the Lądek—Śnieżnik metamorphic unit was assigned by H. Teisseyre (1973) to F_5 phase whose folds trend E—W.

This brief review shows clearly that both observations and results of the investigations carried out by various geologists in various parts of the Kłodzko—Orlica dome are still divergent and often far from the satisfactory agreement. It seems that such a splitting of opinions and observations recquires the employment of more exact and more complex research methods because difficult problems of the geology of this region are still distant from an adequate solution.

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ZJAWISKA TEKTONICZNE I METAMORFICZNE W POLSKIEJ CZĘŚCI GÓR ORLICKICH

Streszczenie

WSTĘP

Polska część Gór Orlickich stanowi niewielki północno-zachodni fragment dużej struktury geologicznej, znanej pod nazwą kopuły kłodzko-orlickiej (Pauk 1953), względnie też określanej nazwą kopuły Kłodzka lub kopuły Śnieżnika (H. Teisseyre 1973).

Podstawowe formacje skalne budujące kopułę kłodzko-orlicką to: formacja strońska, formacja śnieżnicko-gierałtowska, formacja Nového Města oraz tzw. pasmo łupkowe Starého Města i seria zabrzeska (fig. 1).

Formację strońską budują głównie zmetamorfizowane skały osadowe, w mniejszym stopniu — częściowo przeobrażone wulkanity. Do formacji tej należą: łupki łyszczykowe, dwułyszczykowe paragnejsy, kwarcyty, marmury i erlany, amfibolity i łupki amfibolowe (Smulikowski 1973).

Gnejsy gierałtowskie zbudowane z kwarcu, dwóch generacji plagioklazów, mikroklinu, dwóch łyszczyków i granatu to drobno- i równoziarniste skały, przeważnie laminowane (Smulikowski 1973).

Skład mineralny gnejsów śnieżnickich jest taki sam jak gnejsów gierałtowskich. Cechuje je: gruboziarnista oczkowa struktura i bardzo nierówne wymiary ziaren.

Oba typy gnejsów przechodzą w siebie wzajemnie w skomplikowany sposób, tworząc wspólnie formację śnieżnicko-gierałtowską (H. Teisseyre 1973). Obie wymienione formacje stanowią jądro kopuły kłodzko-orlickiej. Płaszcz tej kopuły tworzą wzajemnie w siebie przechodzące skały pasma Starého Města, tzw. serii zabrzeskiej oraz formacji Nového Města (fig. 1; Svoboda, Chaloupský 1961).

Formację Nového Města budują fyllity kwarcowo-serycytowe, łupki zieleńcowe oraz kwarcyty. Przecinają je skały plutoniczne cyklu waryscyjskiego — głównie tonality (Svoboda, Chaloupský 1961).

Wiek i sposób powstania skał wymienionych formacji były różnie ujmowane przez badaczy niemieckich i czeskich (Kretschmer 1903; Petrascheck 1910; Kettner 1922; Finckh 1931; Fischer 1936; Kodym, Svoboda 1948; Pauk 1953).

Wśród geologów polskich panują zresztą również mocno rozbieżne opinie. Szeroko znane są poglądy Smulikowskiego (1952, 1957, 1958, 1960, 1964, 1973) i H. Teisseyre'a (1957, 1964, 1968, 1973), wedle których formacja śnieżnicko-gierałtowska jest równowiekowa z formacją strońską i powstała wskutek silnej, lecz zróżnicowanej metasomatycznej feldszpatyzacji skał tej ostatniej formacji. Drugą koncepcję zaproponował Don (1964), przyjmując, że gnejsy śnieżnickie powstały z przeobrażenia magmy, która intrudowała syntektonicznie w już zmetamorfizowane i sfeldszpatyzowane skały formacji strońskiej. Później zaś do kompleksu zbudowanego ze skał strońskich i śnieżnickich dobudowane zostały od dołu migmatyczne gnejsy gierałtowskie. Żyły tych gnejsów przecinają niezgodnie serie skalne leżące wyżej. Trzecią wersję podał Ansilewski (1966), który uważa, że istnienie w Górach Bialskich różnych odmian gnejsów wynika ze zróżnicowania pierwotnego kompleksu osadowego (arkozy, szarogłazy dwuskaleniowe, szarogłazy plagioklazowe), poddanego jednolitym procesom regionalnej metamorfozy i metamorficznej dyferencjacji.

Styl i sekwencja deformacji fałdowych zanotowanych w skałach jądra kopuły różnią się nieco w poszczególnych jej częściach. Dokumentują to prace Dumicza (1964), Dona (1972a, b), Wojciechowskiej (1972) i H. Teisseyer'a (1964, 1973). Panuje zgodna opinia, że najstarsze fałdy są izoklinalne lub ściśnięte i biegną w przybliżeniu południkowo z odchyleniami ku NW—SE i NE—SW. Taki też kierunek mają główne fałdy regionu. Wiek głównego fałdowania skał kopuły kłodzko-orlickiej wiązany jest albo z prekambrem (Dumicz 1964; Oberc 1957, 1972), albo z ruchami kaledono-waryscyjskimi (H. Teisseyre 1973).

Polska część Gór Orlickich to niewielki fragment kopuły kłodzko-orlickiej (fig. 1). Fragment ten z trzech stron ograniczony został skałami górnej kredy, tworzącymi obniżenie Kudowy i Góry Stołowe (fig. 2, 3). Skały metamorficzne opisywanego obszaru były przed-

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miotem badań Petraschecka (1910, 1944), Gierwielańca (1957, 1965) oraz Borkowskiej (1959). Stanowiły one jednak raczej margines zainteresowań tych geologów.

W tej sytuacji poniższe opracowanie jest pierwszą próbą usiłującą objąć, przynajmniej w przybliżeniu, całość zagadnień związanych z rozwojem skał metamorficznych polskiej części Gór Orlickich.

LITOLOGIA

Zespół skał tworzącach metamorficzny kompleks polskich Gór Orlickich obejmuje formację strońską formację Nového Města oraz gnejsy typu śnieżnickiego

FORMACJA STROŃSKA

Łupki łyszczykowe

Łupki łyszczykowe formacji strońskiej zbudowane są z kwarcu, kwaśnego plagioklazu, fengitu, biotytu, kalcytu, epidotu, chlorytu, turmalinu, apatytu i granatu.

Plagioklazy są reprezentowane przez albit i oligoklaz. Ziarna albitu zawierają charakterystyczne wrostki, tworzone przez smugi pyłu grafitowego, nieprzezroczystych tlenków, i nadzwyczaj małe blaszeczki łyszczyków. Drobne ziarenka kwarcu stanowią drugi, rzadszy nieco, rodzaj inkluzji w albitach, które zostały określone jako skalenie pierwszego rodzaju.

Plagioklazy drugiego rodzaju zawierają blaszki fengitu, wrostki kwarcu lub zamykają całe fragmenty wcześniej ukierunkowanej struktury skały (fabric). Powoduje to nieraz bardzo nieregularne kształty ziaren gospodarzy. Część plagioklazów drugiego rodzaju zawiera kilka procent cząsteczki An, pozostała część, około 20% – plagioklazy perysterytowe.

Plagioklazy trzeciego rodzaju różni od poprzednich obecność wrostków biotytu oraz fakt obrastania przez nie zafałdowanych fragmentów struktury skały. Mają one zawsze poniżej 10% An.

Jasną mikę cechuje bardzo mały kąt osi optycznych. Blaszki jej układają się w skale na ogół równolegle do dwóch kierunków. Brązowy, czasem tylko zielony, biotyt leży zgodnie z główną foliacją skały.

Poza epidotem i turmalinem pojawia się także chloryt, tworzący równoległe przerosty z fengitem lub biotytem.

Amfibolity, łupki amfibolowe

Można wyróżnić kilka odmian tych skał. Najpowszechniejsza odmiana zbudowana jest z aktynolitu, kwarcu, kwaśnego plagioklazu, epidotu i zwyczajnej hornblendy, przy czym stosunki ilościowe tych minerałów są bardzo zmienne. Dlatego też obserwuje się przejścia od aktynolitowo-kwarcowych fyllitów przez łupki amfibolowe z rosnącą zawartością kwaśnego plagioklazu i epidotu do dość masywnych amfibolitów, złożonych ze zwyczajnej hornblendy, oligoklazu, epidotu i kwarcu. Łupki amfibolowe bywają laminowane i wtedy widać, że jasne laminy (skaleń + kwarc) są nierzadko zafałdowane.

Różne od opisanych powyżej są masywne, źle lub wcale niefoliowane amfibolity, pojawiające się w kilku zaledwie wystąpieniach (Pański Kopiec). Złożone są one z aktynolitu, zwyczajnej hornblendy, andezynu, kwaśnego plagioklazu, antygorytu, zoizytu, zwyczajnego epidotu, tytanitu, granatu i źle zachowanych reliktów znacznie zuralityzowanych piroksenów. Orientacja tych minerałów jest bezładna. Skałki ponad drogą z Lewina do Jawornicy buduje amfibolit o zupełnie bezładnej strukturze. Składa się on z drobnoziarnistego amfibolu o głębokim zielonym pleochroizmie, gruboziarnistej poikiloblastycznej hornblendy, oligoklazu oraz granatu i tytanitu, którym podrzędnie towarzyszą wtórny albit i epidot.

W okolicach Witowa i Jawornicy występują dość charakterystyczne gruboziarniste amfibolity, uznane przez Petraschecka (1910), Gierwielańca (1965) i Borkowską (1959) za zmetamorfizowane skały magmowe. Od opisanych powyżej masywnych, źle foliowanych amfibolitów różnią się one znacznie większą zawartością kwarcu, o wiele grubszym ziarnem, daleko lepiej wykształconą teksturą kierunkową i stałą tendencją do metamorficznej segregacji budujących je minerałów. Ta ostatnia cecha polega na tworzeniu się odrębnych warstewek, z których jedne zbudowane są głównie z plagioklazu i epidotu, a drugie – prawie wyłącznie z amfibolu.

Interesującą cechę składu mineralnego wielu odmian skał bogatych w amfibol stanowi podwyższona zazwyczaj zawartość cząsteczki An w ich plagioklazach, w porównaniu z plagioklazami łupków łyszczykowych otaczających amfibolity.

Wapienie krystaliczne

Skały węglanowe formacji strońskiej pojawiają się w Górach Orlickich w dwóch odmianach. Jedną stanowią gruboławicowe wapienie o dość bezładnej teksturze, występujące w soczewkowatych nagromadzeniach, drugą – fyllity wapienne, w których warstewki kalcytowe przekładają się z warstewkami zbudowanymi z materiału łupkowego (mika, kwarc, skaleń). Fyllity wapienne nigdy nie występują samodzielnie, przechodząc stopniowo w wapienie gruboławicowe. W gruboławicowych wapieniach koło Dusznik, Gunia (1974) odkrył kilkanaście gatunków mikroflory wskazującej na górnoproterozoiczny wiek tych wapieni.

Łupki kwarcowo-fengitowe, porfiroidy

W obrębie łupków łyszczykowych formacji strońkiej pojawiają się czasami niewielkich rozmiarów, soczewki łupków kwarcowo-fengitowych. W ich składzie mineralnym poza dominującym kwarcem i fengitem występuje nieznaczna ilość plagioklazów, które zawierają w sobie wrostki fengitu. W centralnych partiach wystąpień takich łupków spotyka się zazwyczaj ciała porfiroidów, gdzie w drobnokrystalicznym tle skaleniowo-kwarcowym tkwią duże fenokryształy mikroklinu (2–4 mm) i kwarcu oraz drobne blaszki fengitu, ułożone zgodnie z wyraźną foliacją tej skały.

Gnejsy typu śnieżnickiego

Mikroklinowe gnejsy występujące w okolicach Dusznik mają cechy teksturalne gnejsów śnieżnickich. Główne minerały gnejsów to: mikroklin, kwarc, kwaśny plagioklaz i fengit. Mikroklin występuje w dwóch generacjach. Zupełnie podrzędnie pojawiają się: biotyt, chloryt, zwyczajny granat i apatyt.

Mikroklin pierwszej generacji tworzy duże ksenoblastyczne ziarna lub nawet oczka, lekko spłaszczone zgodnie z foliacją i wydłużone równolegle do głównej lineacji. Ziarna te, ubogie we wrostki, z reguły są mniej lub bardziej zserycytyzowane. Druga generacja mikroklinu pojawia się jako wypełnienia międzyziarnowe lub obwódki wokół blastów starszych skaleni. Mikroklin ten, zawsze przezroczysty z wyraźną kratką bliźniaczą, otacza także ziarna lub całe fragmenty wcześniej istniejącej struktury skały.

Dość powszechnym składnikiem gnejsów jest albit, otaczający nierzadko zarówno blasty mikroklinu pierwszej generacji jak i sporadyczne ziarna bardziej zasadowego plagioklazu. Albit ten bogaty jest we wrostki kwarcu i jasnego łyszczyka.

Wydaje się, że procesy albityzacji i wtórnej mikroklinizacji gnejsów były dość ściśle ze sobą związane.

Niekiedy spotyka się wśród gnejsów żyłki o grubości 5—10 cm, zawsze zgodne z foliacją gnejsów. Buduje je jedynie albit i międzyziarnowy mikroklin o wyglądzie mikropertytu.

Gnejsy mikroklinowe z okolic Dusznik są dość ubogie w jasną mikę, natomiast stosunkowo bogate w kwarc.

Kwarcytowy łupek, niezbyt bogaty w fengit i bardzo ubogi w plagioklaz oraz mikroklin (tylko pierwszej generacji), stanowi strefę przejściową między gnejsami i łupkami łyszczykowymi. W łupku tym brak dowodów na wtórną mikroklinizację.

Można hipotetycznie przyjąć, iż niosące alkalia krzemionkowe roztwory powstawały w wyniku procesu metamorficznej dyferencjacji, który dokonywał się jedynie w głębszej intersekcyjnie strefie tej samej domeny skalnej, tzn. gnejsów śnieżnickich. Horyzont łupków kwarcytowych mógł działać jako rodzaj ekranu, praktycznie zatrzymującego wędrówkę jonów alkaliów od mikroklinowych gnejsów do wyżej leżących łupków łyszczykowych formacji strońskiej (w badanym regionie).

FORMACJA NOVÉHO MĚSTA

Budują ją dwie podstawowe domeny skalne: fyllity serycytowe oraz fyllity amfibolowe. Geolodzy czescy uważają skały fyllitowe za epizonalne odpowiedniki skał formacji strońskiej (np. Svoboda, Chaloupský 1961). K. Domečka i M. Opletal (inf. ustna) wyróżnili w obrębie grupy fyllitów serycytowych dwie odmiany litologiczne, z których jedna pochodzi z przeobrażenia szarogłazowego osadu, a druga — pelitowego sedymentu. Z szarogłazów rozwinęły się stosunkowo gruboziarniste fyllity złożone głównie z kwarcu, serycytu, biotytu i albitu. Paragenezę tę uzupełniają: turmalin, oligoklaz, granat, apatyt, nieprzezroczyste tlenki i pył grafitowy. Skały pelitowe uległy metamorfozie, przechodząc w drobnoziarniste, bardzo obfite w łyszczyk fyllity (biotyt i serycyt), wzbogacone ponadto w nieprzezroczyste tlenki i grafit.

Metaszarogłazowa odmiana fyllitów pojawia się w polskiej części Gór Orlickich w przytłaczającej większości.

Druga domena skalna opisywanej formacji to skały bogate w amfibol—fyllity amfibolowe oraz odmiany masywniejsze, tzw. amfibolity Nového Města. Na obszarze Polski występują jedynie aktynolitowe (względnie chlorytowe) fyllity. Budują je głównie: aktynolit, epidot, kwarc, chloryt i albit. Znacznie rzadsza jest asocjacja kalcyt—chloryt—kwarc—serycyt—kwaśny plagioklaz, spotykana w strefach silnego ścinania, m. in. w strefie nasunięcia dzielącego formację strońską od formacji Nového Města.

Poza wspomnianym nasunięciem obie formacje na obszarze Polski dzieli także granitoidowy masyw Kudowy—Olešnic oraz permski rów Lewina. Tę rozgraniczającą dyslokację można śledzić także po stronie czeskiej, gdzie dość często towarzyszą jej mylonity. Liczne obserwacje wskazują, że wzdłuż tej dyslokacji zachodziły długotrwałe i wielokrotnie odnawiane przemieszczenia. Skutkiem tego ścinająca nieciągłość dzieli dzisiaj dwa różne poziomy intersekcyjne metamorfiku — formację strońską i formację Nového Města.

SKAŁY PLUTONICZNE CYKLU WARYSCYJSKIEGO

Granitoidy masywu Kudowy—Olešnic

Problematyka skał granitoidowych leży poza tematem tego opracowania, toteż potraktowana została skrótowo. Granitoidy masywu zostały opisane szczegółowo przez Borkowską (1959, 1969) oraz Gierwielańca (1957, 1965). Borkowska stwierdziła, że wśród skał granitoidowych można wyróżnić: granit monzonitowy, granodioryt, tonalit i sporadyczny granit alkaliczny. Gierwielanic wspomina dodatkowo o granogabrze i sjenogabrze.

Gabro

Pojawia się ono jedynie w kilku, bardzo małych odsłonięciach. Jest to gruboziarnista o bezładnej teksturze skała, którą budują pseudomorfozy zielonej hornblendy po piroksenie, tabliczkowe plagioklazy (An_{45}) oraz włóknisty amfibol, epidot, kwarc i kwaśny plagioklaz.

CHARAKTERYSTYKA ZJAWISK METAMORFICZNYCH I TEKTONICZNYCH

W ewolucyjnym rozwoju skał metamorficznych polskiej części Gór Orlickich można wyodrębnić trzy zasadnicze etapy. Wyróżnione one zostały na podstawie charakteru i stylu deformacji, podobieństwa w orientacji zasadniczych stressów oraz stosunku deformacji do procesów metamorficznych. Gdy w obrębie poszczególnych etapów zjawiska tektono-metamorficzne wykazały pewne zróżnicowanie czasowe, wydzielono dodatkowo — podrzędne do etapów — fazy deformacji (*F*) i metamorfozy (*M*).

ETAP PIERWSZY

Faza $F_1 + M_1$

Elementy strukturalne

W plagioklazach pierwszego typu, wchodzących w skład łupków łyszczykowych w rejonie Zieleńca, zakonserwowane zostały przeguby mikrofałdków deformujących relikty powierzchni sedymentacyjnego warstwowania (S_0) (fig. 4*a*, *b*, *c*). Figura 4*d* przedstawia ziarno albitu, którego wzrost nastąpił nieco później niż powstanie foliacji S_1 wyrażonej równoległym wzrostem blaszek fengitu. Foliacja ta przedłuża się poza blast, gdzie jest ujęta w fałdki F_2. Wynika z tego, że kierunkowa struktura oznaczona jako S_1, a także opisany albit, powstały przed deformacją F_2.

Mikrofałdki F_1 znaleziono także w łupkach amfibolowych w okolicach Gołaczowa (fig. 4*e*, *g*). Powstały one wskutek sfałdowania kwarcowo-plagioklazowych warstewek. Powierzchnie osiowe (S_1) tych fałdków tworzy foliacja wyrażona równoległym ułożeniem igiełek aktynolitu.

Analiza rozkładu miąższości warstw tworzących te fałdki, dokonana według metody zaproponowanej przez Ramsaya (1962), wykazała, że fałdy F_1 powstały dzięki zginaniu, a następnie zostały zmodyfikowane nieco później nałożonym ścinaniem, działającym równolegle do powierzchni osiowych S_1.

Albity z ciemnymi smugami wrostków, partie o niezgodnej orientacji fengitowych blaszek do ułożenia powierzchni późniejszej foliacji głównej (fig. 4*h*, *i*, *f*), izoklinalne fałdy deformowane przez niewątpliwe fałdy zespołu F_2 stanowią rozpoznawalne relikty fazy $F_1 + M_1$.

Możliwość obserwacji kierunków osi F_1 i lineacji L_1 jest wprawdzie ograniczona, można jednak stwierdzić, że położenie przestrzenne fałdów F_1 nie odbiega zbytnio od pozycji głównych struktur fałdowych (F_2). Kierunki te są jednak bardzo zmienne skutkiem późniejszych rotacji form fałdowych F_1 i F_2 (fig. 4*k*).

Zjawiska metamorficzne

W ślad za postępującą deformacją pierwotnego kompleksu osadowego posuwała się jego progresywna metamorfoza (M_1). Była ona nieco spóźniona w stosunku do kinematycznej fazy F_1, skoro albit obrastał istniejące już przeguby fałdków tej fazy.

Ziarna albitu $F_1 + M_1$ są dość bogate we wrostki kwarcu, a przede wszystkim we wrostki nieprzezroczystych minerałów (pl. II). Brak im natomiast wrostków innych minerałów. Te ciemne pyłowe inkluzje oraz linijne koncentracje wrostków kwarcu przedłużają się poza blasty albitu. Są one wtedy zgodne z ułożeniem blaszek fengitu $F_1 + M_1$ (pl. II; III). Typowe dla strefy epi warunki ciśnieniowe (por. Huang 1962) — silne stressy ścinające — ułatwiły znacznie rozpuszczenie ziarn detrytycznego plagioklazu i wzrost albitów, stabilnych w istniejących warunkach fazy $F_1 + M_1$. Na blastezę tych albitów, a także na sposób ich rozmieszczenia w skale miał niewątpliwie wpływ rozkład detrytycznych ziarn w wyjściowym szarogłazie. Ziarna te mogły bowiem stanowić ośrodki zaczynającej się krystalizacji. Wydaje się jednak, że zwykle dochodziła do głosu, co prawda w sposób ograniczony, lokalna dyferencjacja metamorficzna, dzięki której „roztwory” przenosiły się na bardzo krótkie odległości, do miejsc najbardziej sprzyjających krystalizacji. Nierzadko takimi miejscami były strefy przegubowe mikrofałdków F_1.

W łupkach łyszczykowych polskiej części Gór Orlickich nie znaleziono żadnych dowodów przemawiających jednoznacznie za działaniem prawdziwej metasomatozy.

Prawie zupełny brak wrostków fengitu w albicie $F_1 + M_1$ dość przekonywająco świadczy o wcześniejszej blastezie plagioklazu, niż jasnej miki.

Blasteza fengitu $F_1 + M_1$ musiała postępować wspólnie z blastezą chlorytu, bowiem oba te minerały pojawiają się często we wzajemnych przerostach.

Relikty fałdków F_1 i struktury $F_1 + M_1$, zachowane w niektórych próbkach łupków amfibolowych pozwalają stwierdzić, że najstarsza metamorfoza (M_1) — w wypadku tych skał oczywiście — doprowadziła do powstania paragenezy obejmującej aktynolit, kwarc i albit. Prawie zupełny brak epidotu, przy obecności plagioklazu, zdaje się stanowić pewną wskazówkę co do pochodzenia skały, którą pierwotnie był prawdopodobnie bliżej nieokreślony rodzaj tufu.

Metamorfoza M_1 rozpoczęła się po zakończeniu rotacji skrzydeł fałdków F_1. Odbyła się ona w warunkach odpowiadających bardzo płytkim poziomom strefy epi. Generalnie w łupkach łyszczykowych rozwinęła się wtedy parageneza: kwarc + fengit + chloryt + turmalin + epidot + kalcyt + granat, zaś w łupkach amfibolowych — parageneza: aktynolit + kwarc + kwaśny plagioklaz + epidot.

Dokładne zbadanie relacji kątowych między powierzchniami S_1 i S_2 pozwoliło stwierdzić, że w rejonie Duszniki — Zieleniec fałdy F_1 były najprawdopodobniej stojące, zaś w strefie Lewin — Gołaczów — obalone.

Faza $F_2 + M_2$

Z fazą tą związane są zarówno najsilniejsza deformacja, jak i największa metamorfoza skał Gór Orlickich.

Rozwojowi megafałdów towarzyszyło powstawanie zespołów drobnych fałdków F_2, o bardzo zmiennej geometrii, amplitudzie i rozpiętości skrzydeł (fig. 5—7; pl. IV—XI).

Najważniejszymi cechami fałdków F_2, różniącymi ją od fałdków innych generacji są: 1) obwijanie się kierunkowo ułożonych minerałów struktury $F_1 + M_1$ wokół osi F_2 oraz 2) powszechny wzrost blaszek biotytu równolegle do powierzchni osiowych S_2 — jest to stała i charakterystyczna cecha fałdów zespołu F_2.

Fałdom F_2 towarzyszą zwykle struktury linijne L_2, przy czym kierunki lineacji L_2 są zawsze zgodne z osiami fałdków F_2. Lineacja ta wykształcona jest jako: lineacja intersekcyjna S_1/S_2, szeregowe ułożenie ziarn mineralnych skały i ich wydłużenie, delikatne zmarszczenia blaszek łyszczyków i wyjątkowo budiny.

W niniejszym opracowaniu scharakteryzowano przede wszystkim fałdy, które są bez porównania ważniejszymi strukturami tektonicznymi niż lineacja. Dostarczają one bowiem o wiele więcej materiału obserwacyjnego i interpretacyjnego, jako że bezpośrednim badaniom dostępne są nie tylko kierunki osi fałdów, ale także ich skrzydła i powierzchnie osiowe.

Współzależność zjawisk strukturalnych i metamorficznych w przekształceniach struktury skał (fabric) w różnych odmianach litologicznych

Łupki łyszczykowe

Fałdy F_2 powstały wskutek sfałdowania powierzchni wcześniejszej foliacji S_1. Razem z tą foliacją uległy pofałdowaniu szeregi ziarn albitu $F_1 + M_1$ (fig. 4*h*). Analiza przestrzennego uporządkowania smug ciemnych wrostków w tych albitach, dokonana w przekroju skały, pozwala stwierdzić nie tylko istnienie fałdów F_2, ale nawet odczytać ich geometrię, mimo iż pozostałe minerały łupka łyszczykowego zostały prawie zupełnie przekrystalizowane kierunkowo do pozycji właściwej strukturze $F_2 + M_2$ (fig. 10*a*, *b*, *g*; pl. II).

Pod wpływem progresywnych czynników metamorfizujących fazy $F_2 + M_2$ wcześniej istniejące skalenie albo pozostały w zasadzie niezmienione, utrzymując w przybliżeniu swój dotychczasowy skład chemiczny, albo uległy przeobrażeniom w oligoklaz, wskutek podwyższenia zawartości cząsteczki An (do ok. 20%). W pierwszym wypadku albity $F_1 + M_1$ doznały pewnego spłaszczenia oraz postrzępienia zarysów ziarn, dostosowując swe dłuższe wymiary do zgodności z powierzchniami foliacji S_2 — zgodnie z regułą Riecke'go (pl. II*1*, *2*, *6*). W drugim przypadku doszło do rekrystalizacji plagioklazu, w zasadzie po zakończeniu procesu rotacji skrzydeł, ale jeszcze przed całkowitym zanikiem stressu (pl. II*2*; IV; V). Prowadziło to do zaburzenia pierwotnie uporządkowanego układu smug ciemnych wrostków (fig. 5*b*, *c*; pl. V*6*). Rekrystalizujące blasty plagioklazu obrastały lub przerastały się, szczególnie przy brzegach, z całymi nieraz fragmentami wcześniej istniejącej struktury mineralnej skały (fabric). Orientacja tych przerostów, widoczna wyraźnie dzięki blaszkom fengitu, odpowiada najczęściej orientacji powierzchni foliacji S_2. Wypływa to z faktu powszechnej równoległości elementów strukturalnych fałdów F_1 i F_2, która wynikła z dwukrotnego izoklinalnego przefałdowania serii skalnych wokół tak samo lub bardzo podobnie zorientowanych osi (Żelaźniewicz 1972).

Plagioklaz drugiego typu w łupkach łyszczykowych, który tworzył się jeszcze przed wzrostem biotytu, stanowi często drobnoziarnisty agregat współwystępujący przeważnie z kwarcem i poprzerastany blaszkami jasnej miki. Małe rozmiary ziarn częściowo wynikły z hamującej ich wzrost obecności nieprzezroczystych minerałów (por. Joplin 1935), częściowo zaś z mechanicznej granulacji pod wpływem stressów (fig. 5*e*, *f*).

Powstanie plagioklazów drugiego i trzeciego rodzaju zostało rozdzielone okresem blastezy biotytu oraz zaniku bocznego ciśnienia kierunkowego na rzecz pojawienia się ruchów ścinających równolegle do powierzchni głównej foliacji S_2. Stress ścinający jak i zjawisko magazynowania energii deformacji w kryształach (por. Johnson 1963; Rast 1962) miały znaczny wpływ na blastezę trzeciego rodzaju plagioklazów, których blasty często zamykają w sobie przeguby mikrofałdków F_2 (fig. 5*g*, *k*, *i*, *h*; pl. V*4*, *5*).

Plagioklaz $F_2 + M_2$ (II i III rodzaju) krystalizował w znacznej mierze pod wpływem procesu metamorficznej dyferencjacji. Proces ten prowadził także do powstawania metamorficznej laminacji, polegającej na tworzeniu się naprzemianległych lamin, z których jedne złożone były z jasnych minerałów (kwarc, skaleń), a drugie z pozostałych mineralnych składników skały.

Blaszki fengitu $F_1 + M_1$ w czasie głównego fałdowania (F_2) poddane były mechanicznej rotacji. Następnie ulegały rekrystalizacji, na ogół równocześnie z plagioklazami, najłatwiej oczywiście tam, gdzie skutkiem izoklinalności fałdów powierzchnie S_1 i S_2 były równoległe. Proces rekrystalizacji polegał, jak się zdaje, na powiększeniu wymiarów blaszek fengitu, bez dostrzegalnej optycznie zmiany składu chemicznego. Blaszki fengitu $F_2 + M_2$ tworzą zwykle własne niezależne pasemka, ułożone zgodnie z powierzchniami głównej foliacji (fig. 5*i*, *k*).

Zupełnie nowym minerałem struktury $F_2 + M_2$ jest biotyt, o którym wiadomo, że pojawia się w temperaturze 400–450°C (por. Johnson 1963). W czasie fazy $F_2 + M_2$ musiał nastąpić wyraźny wzrost parametru p/t. Wzrost temperatury umożliwił reakcję między niskometamorficznym ferromuskowitem a chlorytem, co doprowadziło do powstania biotytu. Wśród produktów ubocznych tej reakcji pojawia się bezwodna faza w postaci hematytu i magnetytu (por. Turner, Verhoogen 1960). Pozwala to zrozumieć, dlaczego pasemkom łyszczyków $F_2 + M_2$ tak często towarzyszą nieprzezroczyste minerały, koncentrujące się przede wszystkim wzdłuż powierzchni i stref najsilniejszych ślizgów ścinających (pl. V*7*; VI*1*, *2*; VIII*6*).

Niekiedy pozornie bezładne ułożenie blaszek obu łyszczyków wynika z układania się ich wzdłuż dwóch kierunków foliacji istniejących w skale, a to: S_1 i S_2 co łatwo dostrzec przy uważnej obserwacji płytek cienkich. W wypadku biotytu jest to wzrost mimetyczny.

W badanej części Gór Orlickich łupki łyszczykowe formacji strońskiej są — jak stwierdzono — ubogie w granaty. W strefie Duszniki–Zieleniec granaty są zwykle prawie automorficzne, bez wrostków i bez śladów wtórnych przeobrażeń. W strefie Lewin–Gołaczów ziarna granatów bywają niejednokrotnie schlorytyzowane oraz poprzerastane kwarcem.

W czasie fazy $F_2 + M_2$ w łupkach łyszczykowych utrzymywała się parageneza, która w stosunku do paragenezy typowej dla fazy $F_1 + M_2$ została wzbogacona w biotyt oraz plagioklaz o składzie oligoklazu. Pozostałe minerały budujące łupki łyszczykowe były wspólne dla paragenz obu tych faz.

Amfibolity, łupki amfibolowe

Odtworzenie etapów budowy struktury $F_2 + M_2$ w skałach bogatych w amfibol jest trudniejsze, niż w łupkach łyszczykowych. Powodem tego jest mniejsza ilość rozpoznawalnych fałdków F_2. Zadanie to komplikuje również fakt niewyjaśnienia genezy tych skał. Nie ulega wątpliwości, że ich wyjściowa natura musiała mieć zasadniczy wpływ na sposób przeobrażeń metamorficznych.

Po fałdowaniu F_2, w cienko foliowanych łupkach amfibolowych, igiełki aktynolitu $F_1 + M_1$ znalazły się w pozycji generalnie równoległej do powierzchni foliacji S_2, co bardzo ułatwiło rekrystalizację tego minerału (pl. VII). Nie dotknęła ona jednak całego amfibolu *en masse*, a tylko część jego igiełek, przeobrażając je w zwyczajną hornblendę o większych rozmiarach ziarn ($z/\gamma = 15-17°$). Dzięki laminowaniu tych skał często dostrzec można drobne fałdki zespołu F_2 (pl. XI). W jednorodnych amfibolitach fałdki F_2 można stwierdzić wtedy, gdy igiełki aktynolitu układają się wokół osi fałdów lub zbliżają się do siebie pod kątem 10–16° (fig. 6*a*, *b*, *c*, *d*).

Cechą plagioklazu znajdującego się w jasnych laminach (warstewkach) jest jego zmienny skład. Jest to zawsze kwaśny plagioklaz – bądź albit, bądź oligoklaz.

Plagioklaz skał bogatych w amfibol uległ silnej rekrystalizacji w czasie fazy $F_2 + M_2$, przy czym znaczny wpływ miała tu metamorficzna dyferencjacja. Jest rzeczą interesującą, iż dostrzegalne dziś w skale ślady przeobrażeń mają w dużej mierze charakter sassaurytyzacji. Przejawiło się to we wzroście nowego, czystego plagioklazu, który albo obrastał starsze, zawsze silniej zserycytyzowane ziarna skaleni, albo rozwijał się w formie niezależnych blastów (fig. 6*b*, *c*). Wzrostowi tego plagioklazu – zawsze kwaśniejszego od starszych – towarzyszyło powstawanie epidotu. Ziarna klinozoizytu obrastane przez skaleń zamieniły się we wrostki w tym minerale. Stopień mobilizacji jasnych minerałów mógł być nawet bardzo znaczny (fig. 6*g*, *h*; pl. XI*1*, *2*, *3*). Zależało to niewątpliwie od ogólnego składu mineralnego konkretnych warstewek skały.

Epidot amfibolitów czy łupków amfibolowych ma częściowo charakter wtórny, częściowo zaś jest pierwotnym składnikiem tych skał metamorficznych.

Zjawisko silnej rekrystalizacji i zubożenia plagioklazów w wapń pojawia się głównie w przegubach fałdków F_2 (pl. VII) oraz w strefach krótszych skrzydeł asymetrycznych fałdków F_2, mających charakter ciągnionych (pl. XI*1*–*3*). Na proces ten znaczny wpływ miało pojawienie się ślizgów ścinających w przegubach większych fałdów i w krótszych skrzydłach form drugorzędnych. Od nasilenia tych procesów zależał rozkład i ułożenie minerałów w skałach bogatych w amfibol (fig. 6*f*, *h*; pl. XI*3*).

Gruboziarniste amfibolity z okolic Witowa i Jawornicy były, jak się zdaje, w znacznej mierze kształtowane przez procesy metamorficznej dyferencjacji. Nieregularne skupienia jasnych minerałów stanowią zaczątki wtórnego metamorficznego warstwowania i przynajmniej w części pochodzą z przekształcenia wcześniej sfałdowanych lamin (fig. 6*i*).

Relikty łupka aktynolitowo-kwarcowego pojawiające się w gruboziarnistych amfibolitach, zorientowane zgodnie z ich foliacją wskazują na sposób progresywnych przeobrażeń skał bogatych w amfibol. Pod mikroskopem widać, że duże słupki zwyczajnej hornblendy narastały bezładnie na kierunkową strukturę opisywanego łupka (fig. 6*k*). Ponadto, sporadyczne tu warstewki albitowo-epidotowe zostały rozepchane przez narastające duże blasty oligoklazu, który zapewne tworzył się na koszt tych dwóch minerałów. Nie ulega wątpliwości, że ten łupkowy relikt przeżycie progresywnej metamorfozy zawdzięcza jedynie pierwotnemu zróżnicowaniu osadowego (tufowego) kompleksu, gdzie w serii powszechnie bogatej w skaleń pojawiły się cienkie wkładki, pozbawione prawie zupełnie tego minerału.

Jest rzeczą prawdopodobną, że istniejące dzisiaj różnice między odmianami skał bogatych w amfibol stanowią odbicie pierwotnych litologicznych różnic kompleksu osadowego (tufowego) poddanego jednolitym warunkom regionalnej metamorfozy.

Fyllity formacji Nového Města

Odtworzenie cech struktury $F_1 + M_1$ w fyllitach Nového Města jest bardzo trudnym zadaniem. Znacznie łatwiej można określić charakter i stopień przeobrażeń tych skał dokonanych w głównej fazie deformacji (F_2) i metamorfozy (M_2).

W fyllitach amfibolowych w fałdy F_2 zostały ujęte powierzchnie foliacji S_1 wyrażonej równoległym ułożeniem igiełek aktynolitu. Plagioklaz tych skał ulegał rekrystalizacji w czasie fazy $F_2 + M_2$. Nowe blasty tego minerału zostały obficie przerośnięte igiełkami amfibolu. Ułożenie tych igiełek może być albo zgodne, albo niezgodne w stosunku do foliacji S_2. Niekiedy ilość amfibolowych przerostów w plagioklazie jest tak duża, że dokładne granice blastów skaleni stają się zupełnie nieuchwytne (fig. 10*e*, *f*; pl. V*1*, *3*). Skład plagioklazu waha się między albitem a oligoklazem. Wydaje się, że zawartość cząsteczki An w plagioklazach opisywanych skał jest wyraźnie związana z ilością epidotu i kalcytu w poszczególnych warstewkach (laminach) fyllitów.

W fyllitach aktynolitowych nierzadko obserwuje się przejawy wtórnej metamorficznej laminacji (np. pl. VIII*5*).

Fyllity, podobnie jak inne skały Gór Orlickich, dostarczają licznych dowodów na aktywną działalność ścinania i jego wpływu na proces rekrystalizacji skały. Ścinanie to było końcowym przejawem aktywności kinematycznej w fazie $F_2 + M_2$.

Albit jest typowym skaleniem struktury (fabric) fyllitów serycytowych. Pewna część jego ziarn ma te same cechy co albity $F_1 + M_1$ wchodzące w skład łupków łyszczykowych. Pozostała część ziarn albitu zawartego w fyllitach powstała później lub pochodziła z późniejszej rekrystalizacji – trudno jednak paralelizować te ziarna z którymkolwiek z trzech rodzajów skaleni występujących w łupkach łyszczykowych formacji strońskiej. Znamienną cechą tej drugiej części albitów są wrostki biotytu. Musiały więc one powstać później niż ciemna mika. Blaszki biotytu – podobnie jak w łupkach łyszczykowych – leżą zawsze równolegle do powierzchni osiowych fałdów F_2. Biotyt w fyllitach współwystępuje zazwyczaj z chlorytem.

Łupki kwarcowo-fengitowe, porfiroidy

W strukturze łupków kwarcowo-fengitowych zostały zarejestrowane zjawiska metamorficzne i strukturalne faz $F_1 + M_1$ i $F_2 + M_2$. Stanowią je m. in. relikty powierzchni foliacji S_1 oraz bardzo wyraźna foliacja S_2. Można przypuszczać, że powstanie skały wyjściowej dla tych łupków musiało mieć miejsce jeszcze przed rozpoczęciem metamorfozy. W środkowych partiach wystąpień tych łupków pojawiają się ciała porfiroidów, co wespół z cechami „fabric" tych ostatnich sugeruje genetyczną zależność obu omawianych typów skał. Łupki kwarcowo-fengitowe wywodzą się przypuszczalnie z drobnoziarnistych, brzeżnych stref porfiroidowych intruzji, wnikających syn- lub posedymentacyjnie w osad, silnie zmienionych wskutek procesów dynamometamorficznych.

Gnejsy

Najtrudniejszym chyba zadaniem jest odtworzenie przebiegu procesu metamorfozy w gnejsach. Po części trudności te wynikają z braku jakichkolwiek dostrzegalnych reliktów form fałdowych. Niesposób zrekonstruować w gnejsach strukturę $F_1 + M_2$. Oczka i agregaty skaleniowo-kwarcowe są wydłużone kierunkowo i tworzą pręty mineralne zgodne z lineacją L_2 oraz osiami fałdków F_2 występującymi w przyległych łupkach łyszczykowych. Wydaje się, iż można przyjąć, choć brak na to bezpośrednich dowodów, że główna deformacja i metamorfoza gnejsów odbyła się w fazie $F_2 + M_2$.

Elementy strukturalne i ich zmienność

Zmienność geometrii fałdów F_2, jak i różne ich formy, przedstawiono na figurach 6–8 i pl. IV–XI.

Fałdowanie i metamorfoza w fazie $F_2 + M_2$ spowodowały reorientację i transformację minerałów. Procesy te zostały w różnym stopniu zaawansowane. W skrajnych przypadkach, poza mechanicznym wygięciem warstewek, nie widać prawie żadnych innych efektów działania fazy $F_2 + M_2$. Na ogół dostrzegalne są pośrednie stadia przeobrażeń – najlepiej w przegubach fałdów. Przejawem ich jest krenulacja powierzchni S_1 oraz rekrystalizacja blastów plagioklazu, kwarcu i innych minerałów (pl. II, VI). Niekiedy wszystkie minerały skały są idealnie zrekrystalizowane i zreorientowane do pozycji równoległej z powierzchniami foliacji S_2 oraz silnie spłaszczone równolegle do tych powierzchni (por. fig. 10*a*, *b*; pl. II; VI*5*; VII*1*, *2*). Mimo to można i wtedy rozpoznać fałdy F_2 pod warunkiem, że zachowały się ślady pierwotnego warstwowania, np. tam gdzie mikowe czy kwarcowe warstewki są skośne do foliacji S_2 lub tam gdzie można prześledzić orientację ciemnych wrostków w ziarnach albitu $F_1 + M_1$ (fig. 10*a*, *b*; pl. I; II; VII*1*, *2*; VIII*2*, *4*, *6*).

Warstewki bogate w minerały jasne (plagioklaz, kwarc) ulegały z reguły łatwiej kierunkowej rekrystalizacji niż warstewki zbudowane głównie z minerałów ciemnych – przeważnie igiełkowych lub blaszkowych (pl. VI*5*, *6*; VII; VIII*3*).

Dość rzadką cechą przegubów fałdów F_2 w łupkach łyszczykowych są znaczne koncentracje kwarcu przyniesionego tam z otoczenia, przy czym na ogół rozbudowywane są w ten sposób żyłki kwarcowe, zgodne z powierzchniami S_1 (pl. VI*6*; VIII*1*, *3*). Zjawisko to jest znacznie częstsze w łupkach amfibolowych. W tym przypadku nad kwarcem przeważa jednak plagioklaz (pl. VI*5*; VII*1*, *2*). Nierzadko prowadziło to do powstawania nowego metamorficznego warstwowania, tak w łupkach amfibolowych jak i w łupkach łyszczykowych (fig. 10*f*, *g*; pl. VIII*5*).

Ogromna większość fałdów powstaje wskutek zginania. Mechanizm ten wyzwala jednolite spłaszczanie (uniform flattening), które po przekroczeniu pewnej granicznej wartości prowadzi do pojawienia się ruchów ścinających, działających z grubsza równolegle do powierzchni osiowych fałdów (por. Williams 1961; fig. 11; pl. VII*2*, *3*).

O tym, że fałdy F_2 były kształtowane przez zginanie, świadczą: 1) układanie się lineacji L_1 wokół małego koła projekcji stereograficznej (fig. 12), 2) występowanie w przegubach fałdów najmniejszych wartości miąższości warstw mierzonych równolegle do powierzchni osiowych fałdów (por. Ramsay 1962), 3) obecność fałdków ciągnionych.

Wielkość spłaszczenia fałdów F_2 jest zmienna (fig. 13; pl. VII*6*; X*1*,*6*). Niekiedy przekracza 100%. Jest to widomym dowodem wpływu ścinania na kształtowanie się tych fałdów (fig. 10*e*; pl. VI*1*; VIII*2*,*4*; IX*2*; X*2*; XI*2*,*5*,*6*). Czasami mogły powstać fałdy nawet o geometrii typu „similar”. Pochodzą one z przemodelowania pierwotnych fałdków ciągnionych (fig. 14*a*, *b*; pl. X*2*; XI*3*).

Stressy ścinające ułatwiały lokalną mobilizację i rekrystalizację minerałów. Prowadziło to do zacierania pierwotnej formy fałdów (fig. 6*g*, *h*, *f*, *i*; 7*a*; 14*f*; pl. VI*5*; VII*1*, *2*; VIII*1*, *3*; XI*1*, *2*, *3*).

O istnieniu ścinania świadczą także drobne fałdki rozwinięte w strefach powierzchni osiowych (fig. 14*e*) oraz krenulacja powierzchni S_1 w przegubach fałdów F_2 (np. fig. 7*a*; 9*f*) lub rozwój fałdów śródfoliacyjnych (fig. 14). Ruchy ścinające powodowały rotacje istniejących ziarn minerałów (fig. 14*h*, *i*) oraz koncentrację minerałów nieprzezroczystych w strefach największych przemieszczeń (fig. 14*g*; pl. V*5*; VIII*6*). Ścinanie bardzo ułatwiło rozwój foliacji S_2 i wpłynęło na geometrię fałdów zespołu F_2 (fig. 6*g*, *h*; 7*a*, *f*, *i*; 10*f*; pl. VI; VII; VIII; IX).

Nasilenie ślizgów ścinających nie było równomierne w całej skale. Tylko niektóre powierzchnie były widownią ich zwiększonej aktywności (fig.7*a*,*b*,*h*).

Obecność struktur takich jak przedstawiono na figurze 14*j* zdaje się wskazywać, że istnienie ślizgów działających równolegle do powierzchni foliacji S_2 było zjawiskiem długotrwałym. Działanie ścinania przedłużyło się nawet poza fazę $F_2 + M_2$, tzn. przynajmniej poza jej stadium kinematyczne, wywołane bezpośrednio działaniem naprężeń kompresyjnych.

Precyzyjne określenie kierunku opisywanych ślizgów ścinających jest dość trudne, gdyż nawet geometryczna interpretacja relacji istniejących między elementami linijnymi zespołu F_2 jest dwuznaczna (fig. 15). Tym niemniej wydaje się, że można przyjąć, iż kierunek ślizgów ścinających zachodzących równolegle do powierzchni S_2 przy końcu faz $F_2 + M_2$ był generalnie prostopadły do osi fałdów.

Zostało stwierdzone, że tworzenie się masywu granitoidowego Kudowy–Olešnic odbyło się przynajmniej w dwóch etapach (M. Opletal – inf. ust.; Żelaźniewicz 1973b). Skały tworzące najstarsze partie tego masywu intrudowały równolegle do powierzchni foliacji S_2, wykorzystując przede wszystkim dużą strefę nieciągłości rozdzielającą formację fyllitów Nového Města od skał formacji strońskiej. Oznaczenia wieku radiometrycznego dały wyniki w granicach 293–328 mln lat (Burchart 1971). Deformacje fazy $F_2 + M_2$ odbyły się zatem wcześniej. Obecnie nie jest wiadome, jak przedstawia się rozprzestrzenienie, w obrębie masywu, skał z poszczególnych etapów intruzji. Dlatego też nie wiadomo, któremu etapowi intruzji odpowiadają powyższe datowania radiometryczne. Część granitoidów, i to jak się zdaje znaczna, intrudowała po fazie F_4. Trudno więc wyznaczyć dokładnie wiek głównej deformacji. Można przypuścić, że główne fałdowanie (F_2) skał metamorficznych w polskiej części Gór Orlickich odbyło się na przełomie ruchów kaledońskich i waryscyjskich, choć młodszy jego wiek nie może być wykluczony. Podobny wiek przyjmuje H. Teisseyre (1973) dla metamorfiku Lądka—Śnieżnika i Gór Kaczawskich (H. Teisseyre 1964, 1967, 1968), J. Teisseyre (1971) dla Wschodnich Karkonoszy i Wojciechowska (1973) dla metamorfiku kłodzkiego.

Faza $F_3(+M_3)$

Struktury fałdowe i planarne tej fazy rozpoznano zaledwie w kilku odsłonięciach koło Dusznik. Trudno więc powiedzieć, czy faza ta miała jakieś znaczenie regionalne i jaki był jej wpływ na rozwój strukturalny badanego regionu. Fałdki F_3 są zawsze otwarte, cechuje je wschodnia asymetria i nachylenie ku NW. Powierzchnie osiowe (S_3) tych fałdów zapadają pod umiarkowanymi kątami ku W lub WWN. W łupkach łyszczykowych w Podgórzu reprezentuje je kliważ spękaniowy (fig. 16*a*, *b*). Taką samą orientację wykazuje niewyraźna foliacja w pobliskich gnejsach mikroklinowych typu śnieżnickiego oraz w przejściowych łupkach kwarcytowych. Wyraża ją głównie równoległe ułożenie blaszek fengitu. Formy linijne fazy F_3, tam gdzie je rozpoznano, są zawsze zgodnoosiowe z formami linijnymi fazy $F_2 + M_2$.

Wydaje się, iż można przyjąć, że fazy $F_1 + M_1$, $F_2 + M_2$ i F_3 $(+M_3)$ stanowią podrzędne elementy czasowe jednego dużego i w zasadzie ciągłego procesu, uznanego za pierwszy etap rozwoju tektono-metamorficznego badanego obszaru. W ciągu całego etapu utrzymywała się mniej więcej taka sama orientacja zasadniczych stressów. Stopniowo gromadzące się naprężenia były wyładowywane przez deformacje poszczególnych faz. Wyładowania te każdorazowo stymulowały działalność czynników regionalnej metamorfozy. Metamorfoza serii skalnych została zakończona w zasadzie po fazie $F_2 + M_2$. Po niej doszło, jak się zdaje, do orogenicznego stadium budowy tektogenu. Być może dlatego faza F_3 $(+M_3)$ zaznaczyła się tylko lokalnie — w jądrowych partiach budowanej (wypiętrzanej) struktury, reprezentowanych przez gnejsy.

ETAP DRUGI

Faza F_4

Fałdy F_4 powstały wskutek wyginania powierzchni głównej foliacji (S_2). Geometria ich jest zmienna — od ściśniętych do otwartych (fig. 19; pl. XII). Charakterystyczną ich cechą jest stała, generalnie północna, asymetria skrzydeł. Geometryczne płaszczyzny osiowe (S_4) tych fałdów zapadają łagodnie lub umiarkowanie ku SW. Osie F_4 nachylają się zwykle ku W, względnie ku NW lub SW, wskutek czego są poprzeczne (skośne) do struktur głównych (F_2).

Fałdowaniu F_4 nie towarzyszyły w zasadzie żadne przeobrażenia mineralne. Dlatego też fałdy F_4 nie wykształciły swojej foliacji osiowej. Powierzchnie S_4 mają charakter czysto geometryczny lub też wyrażone są jako gęste spękania.

Nazbyt ubogi obraz intersekcyjny warstw na mapie geologicznej nie pozwala na precyzyjne odtworzenie pozycji i znaczenia megafałdów zespołu F_4. Wszelako wydaje się, że obserwowana w odkrywkach zmienność orientacji elementów strukturalnych fałdów F_2, przy skrajnych ustawieniach takich jak na figurze 20, wynikła z ich rotacji w czasie fałdowania F_4.

Tam gdzie udało się dokładnie prześledzić intersekcję warstw skalnych, uzyskany obraz potwierdza istnienie poprzecznie przefałdowanych (w fazie F_4) fałdów zespołu F_2 (fig. 21; 22).

Zespół fałdów F_4 nie jest zespołem strukturalnie jednorodnym. Oprócz fałdów powstałych wyłącznie wskutek zginania (fig. 19*c*, *f*, *k*) pojawiają się bowiem także i fałdki załomowe (fig. 19*e*, *g*). W obu jednak wypadkach deformacja fałdowa dokonała się wokół tych samych powierzchni osiowych (S_4), które dla fałdów załomowych wyrażone zostały osiowym kliważem. Dzięki temu oba typy fałdów mogą wzajemnie bocznie w siebie przechodzić, dając wizualny efekt dysharmonijnego fałdowania (fig. 19*a*, *b*). Nie jest to dysharmonia *sensu stricto*, albowiem wynika ona tylko ze zmiany stylu, czy ściślej, mechanizmu fałdowania w końcowym etapie rozwoju deformacji. Opisane zjawisko ma charakter regionalny dzięki powodującym je, a panującym wtedy warunkom strukturalnym deformacji, które umożliwiły rozwój sztywnych struktur nieciągłych w skałach metamorficznych Gór Orlickich.

Należy wspomnieć, że jeden z etapów intruzji granitoidów miał miejsce przed fazą F_4, albowiem żyły granitoidów zgodnie wnikające w zluźnienia foliacji S_2 były ujmowane w fałdy fazy F_4, poprzeczne do głównych struktur (fig. 17; 18).

ETAP TRZECI

W etapie trzecim wyróżniono dwie fazy deformacji — F_5 i F_6, w których powstawały fałdki załomowe, kliważe, spękania i uskoki. Formom fałdowym towarzyszy z reguły lineacja intersekcyjna. Jej przestrzenna orientacja (lineacja L_5, L_6) jest bardzo zmienna, zależna od wzajemnego ułożenia przecinających się powierzchni (foliacji S_2 i odpowiednich kliważy).

Załomowe fałdki F_5 mają zmienną asymetrię i nachylają się zwykle ku SW, zaś fałdki F_6 — ku NW. Te ostatnie podkreślane są zwykle podłużnymi spękaniami. Fałdy fazy F_6 zaznaczają się także w intersekcji mapy, jako stojące otwarte fałdy (antyklina Kulina, Gierwielaniec 1965).

Struktury nieciągłe i fałdowe tego etapu będą przedmiotem osobnego opracowania (Żelaźniewicz, w druku).

ELEMENTY ANALIZY STRUKTURALNEJ

Cały badany obszar podzielono na 11 homogenicznych regionów (fig. 23). Dla każdego z nich wykonano zbiorczy diagram obrazujący orientację powierzchni foliacji S_2 oraz osi fałdów F_2 i F_4. Z analizy tych diagramów wynika, że fałdy F_4 powstały wskutek zginania. Megaantyforma F_6 nachylająca się ku NW (diagram V; VII) powoduje dyspersję osi fałdków F_3. Łagodnie esowaty przebieg fałdów F_4 wynika z ruchów wzdłuż powierzchni uskokowych w rejonie III i IV. Diagramy IX—XI rejestrują zaburzenia wynikające z obecności fałdów F_5 i F_6 oraz rotacji w płaszczyznach późniejszych powierzchni uskokowych.

Orientację powierzchni foliacji S_2 i osi fałdów F_2 i F_4 przedstawiono także na fig. 24 i 25.

UWAGI KOŃCOWE

Skały metamorficzne Gór Orlickich powstały z przeobrażenia osadowego kompleksu o niezbyt jeszcze sprecyzowanym wieku (prawdopodobnie górny proterozoik).

Subskaleniowe waki tego kompleksu przeszły w bogate w plagioklaz łupki łyszczykowe, bez znaczniejszego udziału metasomatycznego dopływu jonów pierwiastków alkalicznych.

Deformacja oraz metamorfoza stanowiły jeden, właściwie ciągły proces. Zmienność natężenia metamorfozy oraz zmiany w wielkości i orientacji stressów pozwoliły na wydzielenie w tym procesie trzech swoiście autonomicznych etapów, a w ich obrębie sześciu faz. W czasie tych faz, którym towarzyszyła metamorfoza przeobrażane skały zyskiwały w kolejnych fazach nie tylko charakterystyczny układ minerałów (fabric), ale także i pewien typowy indeks mineralny. W ten sposób formy strukturalne poszczególnych faz uzyskały pewne charakterystyczne i wyodrębniające je cechy.

Fałdy F_1 mają charakter izoklin lub fałdów ściśniętych, biegnących NW–SE lub NE–SW. Metamorfoza M_1 przeobraziła wyjściowe skały osadowe w warunkach płytkiej facji zieleńcowej.

Fałdy F_2 zgodnoosiowo przefałdowały fałdy wcześniejsze, tworząc główne struktury regionu. Metamorfoza M_2 odbyła się w warunkach niskiej facji amfibolitowej.

Układ struktur fałdowych F_1 miał, jak się zdaje, charakter wachlarzowy.

Foliacja S_2 była ustawiona stromo w strefie Lewin – Gołaczów. Tam właśnie z końcem fazy $F_2 + M_2$ rozpoczęła się intruzja granitoidów Kudowy – Olešnic.

Końcowe akty intruzji nastąpiły po fazie (F_4) poprzecznego fałdowania wcześniej powstałych struktur.

Wśród geologów panują różne opinie nie tylko co do genezy skał poszczególnych formacji tworzących kopułę kłodzko – orlicką, ale także co do sposobu i sekwencji deformacji skalnych. Wydaje się, że taka rozbieżność poglądów i obserwacji wymaga zastosowania bardziej precyzyjnych i bardziej kompleksowych metod badawczych, gdyż trudne zagadnienia geologii tego regionu ciągle odległe są od dostatecznego rozwiązania.

PLATE I

PLANSZA I

1. Mica schist. Relics of sedimentary banding (bedding). Layers rich in quartz (left hand side of the photo) alternate with layers composed mostly of mica and plagioclase. S_2 foliation perpendicular to this banding (parallel to top and bottom sides of the photo). Crag below the "Orlica" hostel in Zieleniec. Mag. 30 ×. Nicols crossed

Łupek łyszczykowy. Relikty sedymentacyjnego warstwowania. Warstewki bogate w kwarc (lewa część zdjęcia) przekładają się z warstewkami złożonymi głównie z łyszczyków i plagioklazów. Powierzchnie foliacji S_2 są poprzeczne do tego warstwowania (foliacja równoległa do poziomych brzegów zdjęcia). Skałki na zboczu poniżej schroniska „Orlica" w Zieleńcu. Pow. 30 ×. Nikole skrzyżowane

2, 3. Mica schist. Relics of sedimentary banding in the closures of F_2 folds. Minerals forming both quartz and mica-plagioclase layers directionally recrystallized along S_2 surfaces (F_2+M_2 fabric). Slope below the "Orlica" hostel in Zieleniec. Mag. 30 ×. Nicols crossed

Łupek łyszczykowy. Relikty powierzchni sedymentacyjnego warstwowania w przegubach fałdów F_2. Minerały budujące oba rodzaje warstewek przekrystalizowano kierunkowo, równolegle do powierzchni S_2 (struktura F_2+M_2). Zbocze poniżej schroniska „Orlica" w Zieleńcu. Pow. 30 ×. Nikole skrzyżowane

4. Mica schist. Relic of sedimentary banding surfaces in the limbs of F_2 fold. Layers rich in quartz alternate with those rich in metadetritic felspar. (Probably, quartzose layers were interbedded in the sediment with those built of felspathic wacke). Note directional recrystallization of the rock fabric parallel to S_2 planes (parallel to vertical sides of the photo). Crag in Podgórze. Mag. 30 ×. Nicols crossed

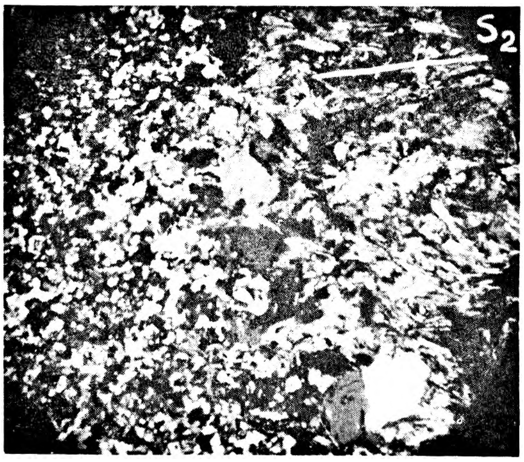
Łupek łyszczykowy. Relikty powierzchni sedymentacyjnego warstwowania w skrzydle fałdu F_2. Warstewki bogate w kwarc przekładają się z warstewkami bogatymi w metadetrytyczny skaleń. Pierwotnie były to prawdopodobnie warstewki piaskowca alternujące z warstewkami o składzie skaleniowej waki. Kierunkowa rekrystalizacja skały równoległa do powierzchni foliacji S_2 (równoległa do pionowych brzegów zdjęcia). Skałki w Podgórzu. Pow. 30 ×. Nikole skrzyżowane

5. Mica schist. Relics of sedimentary banding seen in the closure of F_2 microfold. Layer rich in quartz is distinctly curved around the fold axis. S_2 foliation marked by parallel arrangement of F_2+M_2 biotite flakes (S_2 planes parallel to top and bottom sides of the photo). Internal inclusions in the grains of F_1+M_1 albite are perpendicular to S_2 foliation. Crag in Podgórze. Mag. 110 ×. Nicols crossed

Łupek łyszczykowy. Reliktowo zachowane powierzchnie sedymentacyjnego warstwowania widoczne w przegubie mikrofałdku F_2 zaznaczonego przez wygięcie warstewki bogatej w kwarc. Foliacja S_2 jest równoległa do poziomych brzegów zdjęcia, podkreślona przez zgodne ułożenie blaszek biotytu F_2+M_2. Szeregi wrostków w albicie F_1+M_1 zorientowane poprzecznie do powierzchni foliacji S_2. Skałki w Podgórzu. Pow. 110 ×. Nikole skrzyżowane

6. Mica schist. Relic of sedimentary banding in the closure of F_2 fold. Layers rich in quartz alternate with layers rich in metadetritic felspar. Note directional recrystallization parallel to planes of S_2 foliation (parallel to vertical sides of the photo). Crag in Podgórze. Mag. 30 ×. Nicols crossed

Łupek łyszczykowy. Relikt sedymentacyjnego warstwowania w przegubie fałdku F_2. Warstewki bogate w kwarc przekładają się z warstewkami bogatymi w metadetrytyczny skaleń. Foliacja S_2 równoległa do pionowych brzegów zdjęcia. Kierunkowa rekrystalizacja minerałów wzdłuż powierzchni foliacji. Pow. 30 ×. Nikole skrzyżowane. Skałki w Podgórzu



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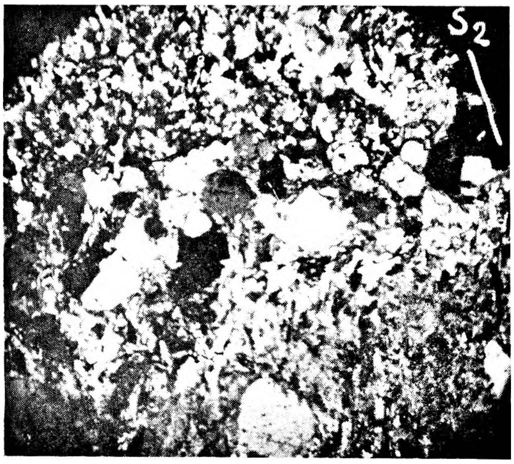

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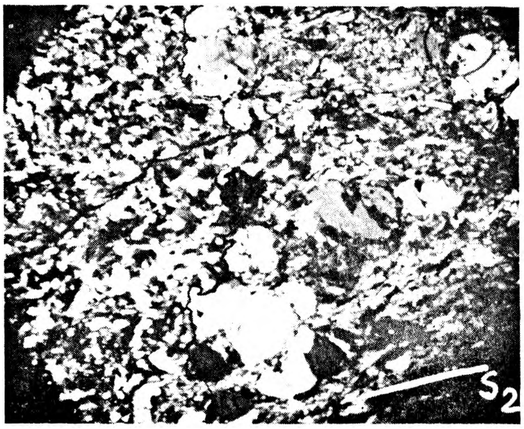

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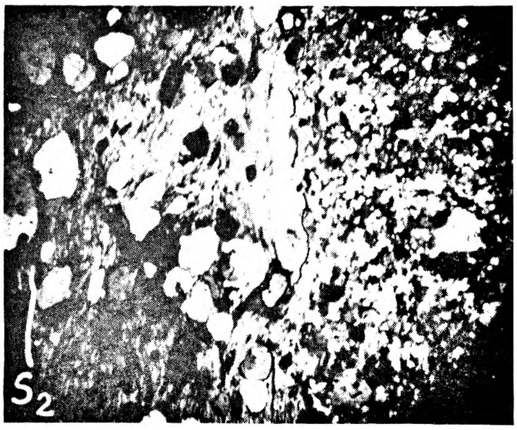

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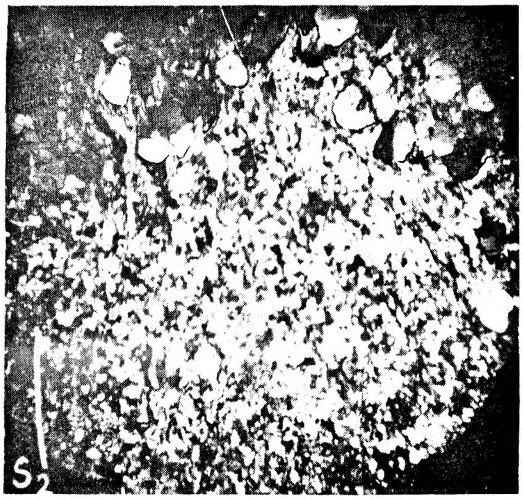


6

Andrzej ŻELAŹNIEWICZ — Tectonic and metamorphic events in the Polish part of the Orlickie Mts.
Zjawiska tektoniczne i metamorficzne w polskiej części Gór Orlickich

PLATE II

PLANSZA II

1. Mica schist. F_1+M_1 albite grain against F_2+M_2 fabric of the schistose rock rich in biotite and almost completely absent from quartz. Inclusions of opaque minerals and minute scales of dark flaky mineral (chlorite?) are discordant with very distinct S_2 foliation marked by parallel arrangement of biotite flakes. Note slight recrystallization of the grain in F_2+M_2 phase, appearing as tiny parallel projections of this grain into foliated surroundings. Crag at the state frontier, south of Zieleniec. Mag. 240 ×. Nicols crossed

   Łupek łyszczykowy. Ziarno albitu F_1+M_1 tkwiące w strukturze F_2+M_2 skały o pokroju łupkowym, bardzo bogatej w biotyt i prawie całkowicie pozbawionej kwarcu. Wrostki nieprzezroczystych minerałów oraz drobniutkich blaszek ciemnego łuseczkowego minerału (chloryt?) zorientowane niezgodnie do powierzchni bardzo wyraźnej foliacji S_2, podkreślonej równoległym ułożeniem blaszek biotytu. Nieznaczna rekrystalizacja ziarna w fazie M_2 polegająca na dobudowywaniu się „wypustek" zgodnych z foliacją S_2. Skałki przy granicy państwowej, na S od Zieleńca. Pow. 240 ×. Nikole skrzyżowane

2. Mica schist. Grains of F_1+M_1 albite against F_2+M_2 fabric. Internal inclusions discordant with S_2 foliation underlined by parallel arrangement of biotite and chlorite flakes. The inclusions are considered as the relics of S_1 surfaces. Crag south of Zieleniec. Mag. 240 ×. Nicols crossed

   Łupek łyszczykowy. Blasty albitu F_1+M_1 tkwiące w strukturze F_2+M_2. Wrostki w tych blastach leżą niezgodnie w stosunku do foliacji S_2, którą podkreśla równoległe ułożenie blaszek biotytu i chlorytu. Wrostki te stanowią relikty powierzchni S_1. Skałki na S od Zieleńca. Pow. 240 ×. Nikole skrzyżowane

3. Mica schist. F_1+M_1 albite occuring in the directional fabric developed during F_2+M_2 phase. The rock is composed almost exclusively of this plagioclase and biotite whose flakes are always parallel to the planes of S_2 foliation. Inclusions in the albite grains are discordant to S_2 foliation. This enables the recognition of the presence of fold of F_2 set. Crag in Podgórze. Mag. 110 ×. Nicols crossed

   Łupek łyszczykowy. Ziarna albitu F_1+M_1 tkwiące w wybitnie kierunkowej strukturze F_2+M_2. Skała jest zbudowana prawie wyłącznie z tego plagioklazu oraz z biotytu, którego blaszki leżą zawsze równolegle do powierzchni foliacji S_2. Poprzeczna do niej orientacja wrostków w albitach pozwala na stwierdzenie obecności fałdku F_2. Skałki w Podgórzu. Pow. 110 ×. Nikole skrzyżowane

4. Mica schist. Grains of F_1+M_1 albite. Inclusions are made only of elongated quartz grains. The inclusions are oriented diagonally to planes of S_2 foliation. Exposure below the summit of the Orlica Mt. Mag. 110 ×. Nicols crossed

   Łupek łyszczykowy. Wrostki w ziarnach albitu F_1+M_1 stanowią wyłącznie ziarna kwarcu, wydłużone zgodnie z S_1. Wrostki te są zorientowane poprzecznie w stosunku do powierzchni foliacji S_2. Skałki poniżej szczytu Orlicy. Pow. 110 ×. Nikole skrzyżowane

5. Mica schist. F_1+M_1 albite grain possesses only quartz inclusions. Note sharp outlines of the blast. Crags south-east of the summit of the Orlica Mt. Mag. 110 ×. Nicols crossed

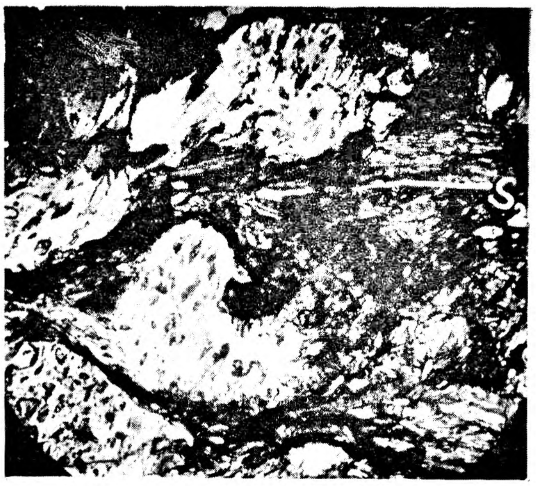
   Łupek łyszczykowy. Ziarno albitu F_1+M_1 o ostrych granicach posiada tylko wrostki kwarcu. Skałki na SE od od szczytu Orlicy. Pow. 110 ×. Nikole skrzyżowane

6. Mica schist. F_1+M_1 albite grain with spindle-shaped quartz inclusions. The blast is wrapped up by micas belonging to F_2+M_2 fabric, and marking S_2 foliation. S_2 foliation and these inclusions are discordantly oriented. Note that the blast margins parallel to foliation are sharply outlined whereas the margins perpendicular to the foliation are ragged due to slight recrystallization of this albite during F_2+M_2 phase. Crags south-east of the summit of the Orlica Mt. Mag. 110 ×. Nicols crossed

   Łupek łyszczykowy. Blast albitu F_1+M_1 z wrzecionowatymi wrostkami kwarcu, tkwiący w strukturze F_2+M_2. Opływają go łyszczyki wyrażające foliację S_2 zorientowaną niezgodnie do ułożenia wrostków w albicie. Wrostki te są najprawdopodobniej równoległe do powierzchni foliacji S_1. Granice blastu zgodne z foliacją są bardzo ostre, natomiast granice poprzeczne do przebiegu foliacji są nieregularne. Jest to wynik nieznacznej rekrystalizacji tego albitu w czasie fazy F_2+M_2. Skałki na SE od szczytu Orlicy. Pow. 110 ×. Nikole skrzyżowane

PLATE II
PLANSZA II

1



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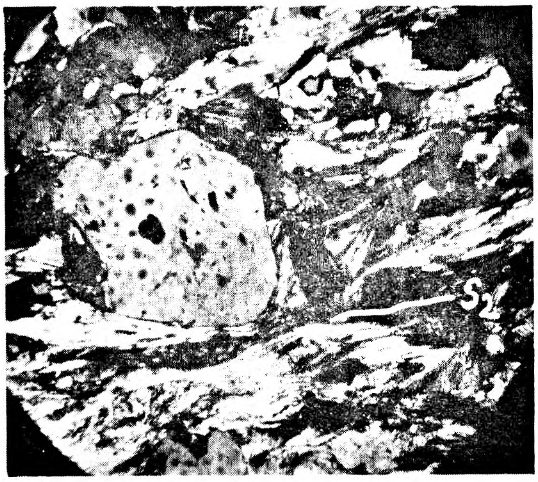

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6

Andrzej ŻELAŹNIEWICZ – Tectonic and metamorphic events in the Polish part of the Orlickie Mts.
Zjawiska tektoniczne i metamorficzne w polskiej części Gór Orlickich

PLATE III

PLANSZA III

1. Mica schist. Fabric of the rock. Numerous grains of $F_1 + M_1$ albite aginst $F_2 + M_2$ fabric. Besides the plagioclase biotite and chlorite are the main constituents of this rock. Those flaky minerals occur in parallel intergrowths concordant with S_2 foliation (parallel to top and bottom sides of the photo). Careful microscopical observation revealed the presence of three closures of F_2 microfolds seen in the field of view of the photo. Note usually sharp outlines of the albite blasts. Crags above Zieleniec, north of the summit of the Szerlich Mt. Mag. 30 ×. Nicols crossed
Łupek łyszczykowy. Struktura skały. W strukturze $F_2 + M_2$ tkwi wielka ilość blastów albitu $F_1 + M_1$. Poza plagioklazem głównymi składnikami są biotyt i chloryt, występujące w równoległych przerostach, zgodnych z foliacją S_2 (równoległa do poziomych brzegów zdjęcia). Dokładna mikroskopowa obserwacja ułożenia wrostków w ziarnach albitu pozwoliła na stwierdzenie, że we fragmencie objętym zdjęciem znajdują się trzy przeguby mikrofałdków F_2. Granice blastów plagioklazu są zazwyczaj ostre. Skałki ponad Zieleńcem, przy granicy państwowej, na N od szczytu Szerlich. Pow. 30 ×. Nikole skrzyżowane

2, 3. Calcareous phyllite. Grains of $F_1 + M_1$ albite occuring in the calcite layers. Note sharp outlines of the plagioclase blasts. Crags south of the forester's lodge in Graniczna. Mag. 110 ×. Nicols crossed
Fyllit wapienny. Ziarna albitu $F_1 + M_1$ o ostrych granicach tkwiące w tle lamin kalcytowych. Skałki na S od leśniczówki w Granicznej. Pow. 110 ×. Nikole skrzyżowane

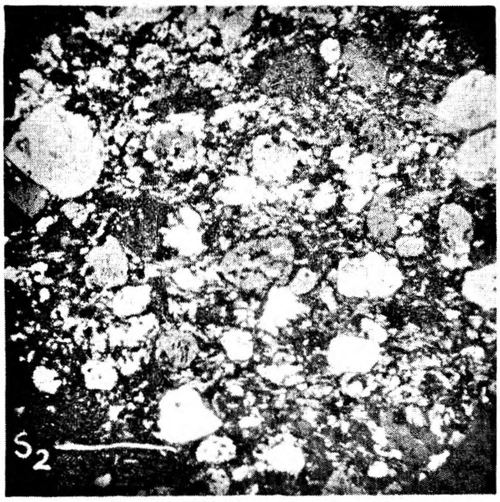
4. Mica schist with graphite. Grains of $F_1 + M_1$ albite with distinct and very abundant inclusions of opaque minerals (mostly graphite). Crags on the eastern slope of the Szerlich Mt. Mag. 110 ×. Nicols crossed
Łupek łyszczykowy z grafitem. Ziarno albitu $F_1 + M_1$ z bardzo obfitymi i wyraźnymi wrostkami nieprzezroczystych minerałów (głównie grafitu). Skałki na wschodnich zboczach Szerlicha. Pow. 110 ×. Nikole skrzyżowane

5. Fabric of mica schist rich in $F_1 + M_1$ plagioclase. This rock is composed mostly of plagioclase and biotite. Quartz is rather scarce. Outcrop in the creek valley east of the "Orlica" hostel in Zieleniec. Mag. 110 ×. Nicols crossed
Struktura łupka łyszczykowego bardzo bogatego w skaleń $F_1 + M_1$. Skała zbudowana jest głównie z plagioklazu i biotytu oraz niewielkiej ilości kwarcu. Odkrywka w dnie potoku na E od schroniska ,,Orlica" w Zieleńcu. Pow. 110 ×. Nikole skrzyżowane

6. Mica schist with graphite. $F_1 + M_1$ albite grains with characteristic dark, internal trails oriented discordantly to S_2 foliation. Outcrop below the forester's lodge in Zieleniec. Mag. 240 ×. Nicols parallel
Łupek łyszczykowy z grafitem. Ziarno albitu $F_1 + M_1$ z charakterystycznymi smugami ciemnych wrostków, niezgodnych z foliacją S_2. Skałki poniżej leśniczówki w Zieleńcu. Pow. 240 ×. Nikole skrzyżowane

7. Mica schist with chlorite. Fragments of $F_1 + M_1$ fabric preserved among elements of $F_2 + M_2$ directional fabric as the result of weak recrystallization of the $F_1 + M_1$ minerals during $F_2 + M_2$ phase. Note that orientation of rectilinear inclusions agrees with the orientation of $F_1 + M_1$ flaky minerals of the surroundings involved in F_2 folds. F_2 folding did not affect the arrangement of these inclusions. Hence the grain of albite did not yield to recrystallization during $F_2 + M_2$ phase. $F_1 + M_1$ flaky minerals are represented by phengite and chlorite. Larger flakes of chlorite grow roughly parallel to biotite marking S_2 foliation (roughly parallel to vertical sides of the photo). Crags above Zieleniec, north of the summit of the Szerlich Mt. Mag. 110 ×. Nicols crossed
Łupek łyszczykowy z chlorytem. Między elementami kierunkowej struktury $F_2 + M_2$ wyraźnie zachowane fragmenty struktury $F_1 + M_1$ — skutek niewielkiej rekrystalizacji minerałów w fazie $F_2 + M_2$. Orientacja wrostków ułożonych prostolinijnie w ziarnie albitu jest zgodna z przebiegiem minerałów blaszkowych $F_1 + M_1$, ujętych na zewnątrz tego ziarna w fałdki F_2. Deformacja F_2 nie zaburzyła układu wrostków tkwiących w ziarnie, co świadczy, iż nie zostało ono zrekrystalizowane w fazie $F_2 + M_2$. Drobniutkie blaszkowe minerały fazy $F_1 + M_1$, to fengit i chloryt. Większe blaszki chlorytu rosną w przybliżeniu zgodnie z biotytem podkreślającym powierzchnie foliacji S_2 (w przybliżeniu zgodna z pionowymi brzegami zdjęcia). Skałki ponad Zieleńcem, na N od szczytu Szerlicha, przy granicy państwowej. Pow. 110 ×. Nikole skrzyżowane

8. Mica schist with graphite. Grains of $F_1 + M_1$ albite are so abundant in the internal dark trails of graphite that their outlines are hardly recognizable. These trails are parallel to well preserved $F_1 + M_1$ fabric of the surroundings involved in tight F_2 folds. Their axial planes are underlined by parallel arrangement of large biotite flakes. Despite the folded background of $F_1 + M_1$ minerals the inclusions occuring in albite blasts are always rectilinear. Development of this albite preceded the F_2 folding. Slope above the church in Duszniki Zdrój. Mag. 110 ×. Nicols not fully crossed
Łupek łyszczykowy z grafitem. Ziarna albitu $F_1 + M_1$ są tak bogate we wrostki grafitowego pyłu, że trudno zauważalne stają się ich granice. Wrostki te znajdują swe przedłużenie poza ziarnami, w dość dobrze zachowanej strukturze $F_1 + M_1$, która ujęta jest w wąskopromienne fałdki F_2. Powierzchnie osiowe tych fałdków podkreślane są równoległym ułożeniem dużych blaszek biotytu. W przeciwieństwie do zafałdowanego tła minerałów fazy $F_1 + M_1$ wrostki w blastach albitu mają prawie zawsze przebieg prostolinijny. Skałki na zboczu ponad kościołem w Dusznikach Zdroju. Pow. 110 ×. Nikole niezupełnie skrzyżowane



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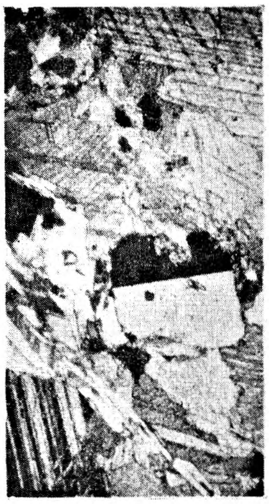

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Andrzej ŻELAŹNIEWICZ — Tectonic and metamorphic events in the Polish part of the Orlickie Mts.
Zjawiska tektoniczne i metamorficzne w polskiej części Gór Orlickich

PLATE IV

PLANSZA IV

1. Mica schist. F_1+M_1 plagioclases subject to recrystallization of F_2+M_2 phase. Their blasts become undistinctly outlined. Note dark dusty trails involved in F_1 fold enclosed in F_1+M_1 albite. Slope above the forester's lodge in Zieleniec. Mag. 110 ×. Nicols crossed
   Łupek łyszczykowy. Plagioklazy F_1+M_1 poddane rekrystalizacji w fazie F_2+M_2. Granice blastów tracą swą pierwotną ostrość i stają się niewyraźne. W fałdek F_1 ujęte są ciemne smugi wrostków zamkniętych w albicie F_1+M_1. Skałki powyżej leśniczówki w Zieleńcu. Pow. 110 ×. Nikole skrzyżowane

2. Mica schist. Grains of plagioclase of the second type (F_2+M_2 fabric) are due to recrystallization of F_1+M_1 albite. Note very irregular outlines of these grains in comparison with usually sharp outlines of F_1+M_1 plagioclases. Slope nearby Lewin above the road Kudowa – Duszniki. Mag. 30 ×. Nicols crossed
   Łupek łyszczykowy. Ziarna plagioklazów (F_2+M_2) drugiego rodzaju pochodzące z rekrystalizacji albitu F_1+M_1. Brzegi tych ziarn są bardzo nieregularne w przeciwieństwie do zazwyczaj ostrych zarysów plagioklazów fazy F_1+M_1. Skałki nad szosą Kudowa – Duszniki w pobliżu Lewina. Pow. 30 ×. Nikole skrzyżowane

3. Mica schist. F_2+M_2 plagioclases developed due to recrystallization of F_1+M_1 albite. Railway-cutting above Gołaczów. Mag. 110 ×. Nicols crossed
   Łupek łyszczykowy. Plagioklazy F_2+M_2 pochodzące z rekrystalizacji albitu F_1+M_1. Przekop kolejowy ponad Gołaczowem. Pow. 110 ×. Nikole skrzyżowane

4. Mica schist. Blast of F_2+M_2 plagioclase derived from the recrystallizing F_1+M_1 albite. Outer parts of the blast are strongly intergrown with minerals of F_2+M_2 fabric. Primary sharp outlines are lost owing to this phenomenon. Note that the process does not affect equally the whole blast. Crags on the slope above the road Kudowa – Duszniki, some 1 000 metres east of Lewin. Mag. 110 ×. Nicols crossed
   Łupek łyszczykowy. Plagioklaz fazy F_2+M_2. Pochodzi on z rekrystalizacji albitu F_1+M_1. W brzeżnych partiach blast ten jest silnie poprzerastany minerałami struktury F_2+M_2, w wyniku czego stracił on w znacznym stopniu pierwotną ostrość swych zarysów. Proces ten nie dotyka równomiernie całego blastu. Skałki ponad szosą Kudowa – Duszniki, około 1 km na E od Lewina. Pow. 110 ×. Nikole skrzyżowane

5. Mica schist. Plagioclase recrystallizing during F_2+M_2 phase. Note that the blast is intergrown with minerals of F_2+M_2 fabric involved in tight F_2 folds. Railway-cutting above Gołaczów. Mag. 110 ×. Nicols crossed
   Łupek łyszczykowy. Plagioklaz przekrystalizowany w fazie F_2+M_2. Liczne przerosty blastu z minerałami struktury F_2+M_2 ujętej w wąskopromienne fałdki F_2. Przekop kolejowy ponad Gołaczowem. Pow. 110 ×. Nikole skrzyżowane

6. Mica schist. F_2+M_2 plagioclase of the second type with numerous intergrowths of other minerals forming F_2+M_2 fabric of the rock. Railway-cutting above Gołaczów. Mag. 110 ×. Nicols parallel
   Łupek łyszczykowy. Plagioklaz drugiego rodzaju (F_2+M_2) z licznymi przerostami innych minerałów tworzącymi strukturę F_2+M_2 skały. Przekop kolejowy ponad Gołaczowem. Pow. 110 ×. Nikole równoległe

7. The same blast. Nicols crossed
   Ten sam blast co na poprzednim zdjęciu, sfotografowany przy nikolach skrzyżowanych

PLATE IV
PLANSZA IV

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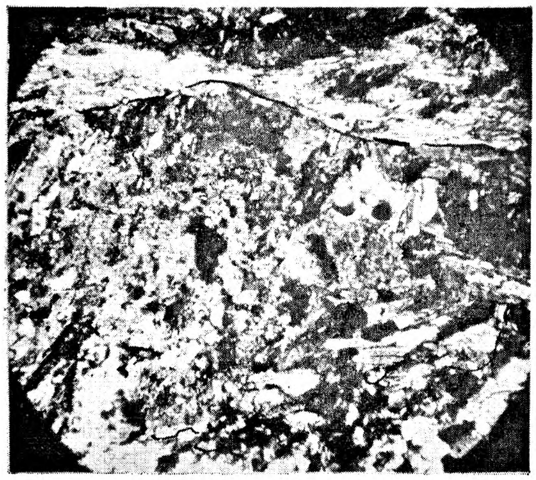

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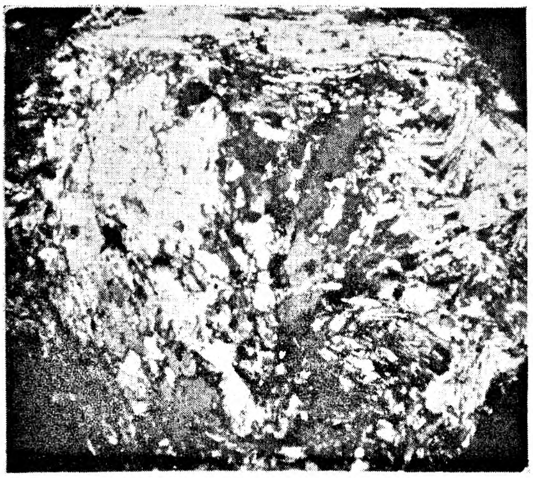

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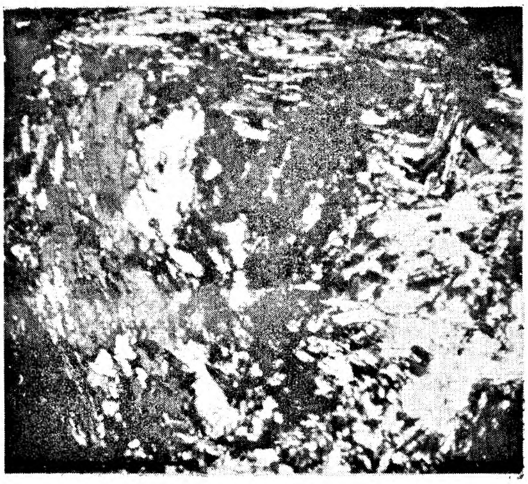

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Andrzej ŻELAŹNIEWICZ — Tectonic and metamorphic events in the Polish part of the Orlickie Mts.
Zjawiska tektoniczne i metamorficzne w polskiej części Gór Orlickich

PLATE V

PLANSZA V

1. Amphibole phyllite. Strongly recrystallized grain of acid plagioclase occuring in the hinge region of microfold (probably of F_2 set). Outlines of the blast were completely obliterated owing to plenty of intergrowths, mainly of actinolite needles. Crags on the eastern slopes of the Taszowskie Hills. Mag. 240 ×. Nicols crossed

   Fyllit amfibolowy. Silnie zrekrystalizowane ziarno kwaśnego plagioklazu znajdujące się w strefie przegubowej mikrofałdku (prawdopodobnie zespołu F_2). Kontury ziarna zostały zupełnie zatarte wskutek olbrzymiej ilości przerostów — głównie igiełkami aktynolitu. Skałki na NE zboczach Wzgórz Taszowskich. Pow. 240 ×. Nikole skrzyżowane

2. Plagioclase in sericite phyllite. It overgrows the closures of microfolds considered as belonging to F_2 set because their axial planes, as in mica schists, are paralleled by biotite flakes. Northern slope of the Taszowskie Hills. Mag. 110 ×. Nicols parallel

   Plagioklaz w fyllicie serycytowym. Obrasta on przeguby mikrofałdków uznanych za F_2, gdyż ich powierzchnie osiowe podkreślają blaszki biotytu. Skałki na N zboczu Wzgórz Taszowskich. Pow. 110 ×. Nikole równoległe

3. Chlorite-actinolite phyllites. Blast of acid plagioclase strongly intergrown with other rock-forming minerals. Its outlines were completely obliterated owing to this phenomenon. Northeastern slope of the Taszowskie Hills. Mag. 110 ×. Nicols not fully crossed

   Fyllit chlorytowo-aktynolitowy. Blast kwaśnego plagioklazu silnie przerośnięty z innymi minerałami skały, co doprowadziło do całkowitego zatarcia jego konturów. Skałki na NE zboczu Wzgórz Taszowskich. Pow. 110 ×. Nikole niezupełnie skrzyżowane

4. Mica schist. Plagioclase of the third kind growing in the closure of F_2 fold during $F_2 + M_2$ phase. Railway-cutting above Gołaczów. Mag. 30 ×. Nicols crossed

   Łupek łyszczykowy. Plagioklaz trzeciego rodzaju ($F_2 + M_2$) rosnący w przegubie fałdku F_2. Przekop kolejowy ponad Gołaczowem. Pow. 30 ×. Nikole skrzyżowane

5. Mica schist. Plagioclase of the third kind containing biotite inclusions parallel to the planes of S_2 foliation. Crags on the slope above the railway station in Kulin. Mag. 110 ×. Nicols crossed

   Łupek łyszczykowy. Plagioklaz trzeciego rodzaju zawierający w sobie wrostki biotytu zorientowane zgodnie z powierzchniami foliacji S_2. Skałki w okolicy stacji kolejowej w Kulinie. Pow. 110 ×. Nikole skrzyżowane

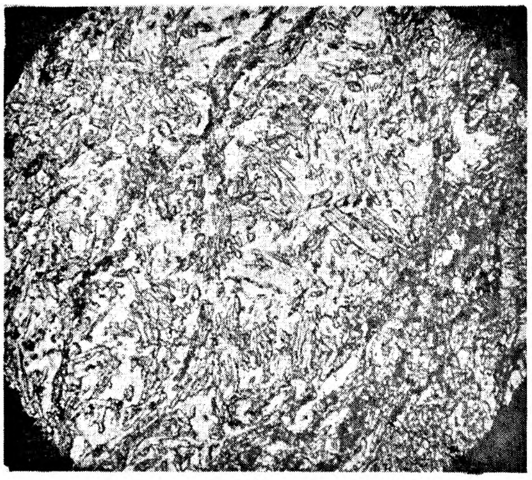
6. Mica schist. Fragment of F_2 microfold. Blast of the plagioclase of the second kind (left-hand side of the photo) and blast of the plagioclase of the third kind containing biotite inclusions parallel to S_2 axial planes (right bottom corner of the photo). Railway-cutting above Gołaczów. Mag. 30 ×. Nicols crossed

   Łupek łyszczykowy. Fragment mikrofałdku F_2. Ziarno plagioklazu drugiego rodzaju (lewa strona zdjęcia) oraz ziarno plagioklazu trzeciego rodzaju (prawy dolny róg) z wrostkami biotytu zgodnymi z powierzchnią osiową S_2. Przekop kolejowy ponad Gołaczowem. Pow. 30 ×. Nikole skrzyżowane

7. Mica schist. $F_2 + M_2$ fabric. Note crenulation of S_1 surfaces resulting in the development of S_2 foliation underlined by parallel arrangement of biotite flakes. Note also small displacements along S_2 planes. Paths of the glide movements are marked by linear concentrations of opaque minerals. Stream-side in Duszniki Zdrój, back of the "Barbara" pension. Mag. 110 ×. Nicols crossed

   Łupek łyszczykowy. Struktura $F_2 + M_2$. Krenulacja powierzchni S_1 wzdłuż powierzchni foliacji S_2 wyrażonej równoległym ułożeniem blaszek biotytu oraz przesunięcia wzdłuż powierzchni tej foliacji. Strefy ślizgów podkreślone są linijnymi koncentracjami nieprzezroczystych minerałów. Skałki w Dusznikach Zdroju za D. W. „Barbara". Pow. 110 ×. Nikole skrzyżowane

PLATE V
PLANSZA V



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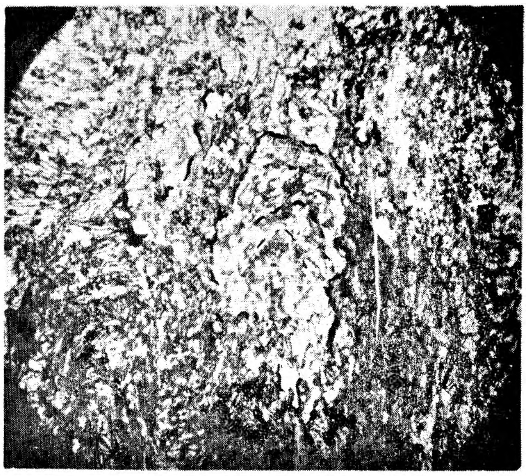

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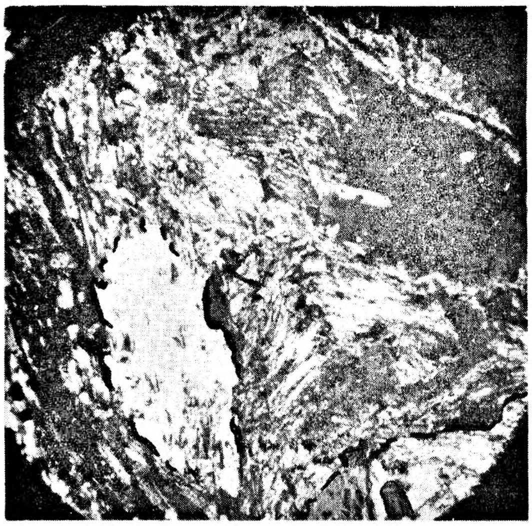

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Andrzej ŻELAŹNIEWICZ – Tectonic and metamorphic events in the Polish part of the Orlickie Mts.
Zjawiska tektoniczne i metamorficzne w polskiej części Gór Orlickich

PLATE VI

PLANSZA VI

1. Mica schist. F_2 microfold modified by shearing occuring along planes of S_2 foliation. Crags on the southern slope above the road in Gołaczów. Mag. 30 ×. Nicols not quite parallel
Łupek łyszczykowy. Mikrofałdek F_2 zmodyfikowany przez mechanizm ścinania zachodzącego równolegle do powierzchni foliacji S_2. Skałki na S zboczu ponad szosą w Gołaczowie. Pow. 30 ×. Nikole niezupełnie równoległo

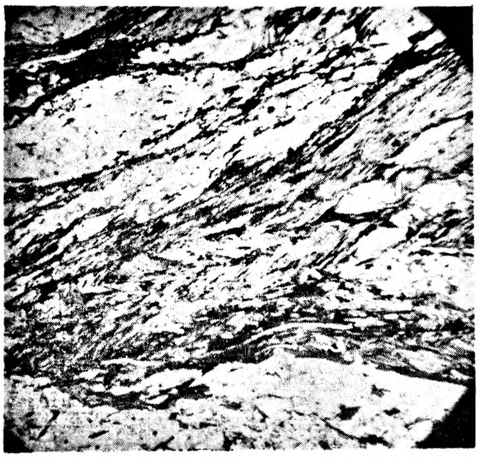
2. Amphibolite. Directional $F_2 + M_2$ fabric. Note elongation of the rock-forming minerals and darker, finer-grained zones of more intense shear movements. Crags on the southern slope, northeast of Lewin. Mag. 30 ×. Nicols crossed
Amfibolit. Kierunkowa struktura $F_2 + M_2$. Wydłużenie minerałów skały oraz ciemniejsze drobnoziarniste strefy silniejszych ruchów ścinających. Skałki na S zboczu, na NE od Lewina. Pow. 30 ×. Nikole skrzyżowane

3. Mica schist. Directional recrystallization of minerals of $F_2 + M_2$ fabric within the structure of F_2 folds. Crags on the northern slope some 1 500 meters east of Lasek Miejski. Mag. 30 ×. Nicols crossed
Łupek łyszczykowy. Kierunkowa rekrystalizacja mienerałów struktury $F_2 + M_2$ w obrębie fałdków F_2. Skałki na N zboczu, okolo 1 500 m na E od Lasku Miejskiego. Pow. 30 ×. Nikole skrzyżowane

4. Mica schist. F_2 microfold. Flakes of $F_1 + M_1$ phengite were isoclinaily curved around F_2 axis and subsequently were subject to directional recrystallization parallel to the planes of S_2 foliation. Road-cutting on the slope of the Deštna Mt. Mag. 110 ×. Nicols crossed
Łupek łyszczykowy. Mikrofaldek F_2. Blaszki fengitu $F_1 + M_1$ uległy izoklinalnemu zafałdowaniu wokól osi F_2, a następnie, w fazie $F_2 + M_2$, kierunkowej rekrystalizacji równolegle do powierzchni foliacji S_2. Skałki we wrzynce szosy na zboczach Destny. Pow. 110 ×. Nikole skrzyżowane

5. Amphibole schist. Veinlet (lamina) of quartz concordant with S_1 surfaces was involved in F_2 fold. Remarkably strong quartz concentration in the closure of this fold resulted from the transfer of mineral material to the region of lowered pressure. Deformation lamellae in quartz grains are parallel to S_2 foliation, evidencing considerable control of shearing on the process. Slope above the water-supply filter-station in Dańczów. Mag. 110 ×. Nicols crossed
Łupek amfibolowy. Żyłka (lamina) kwarcowa zgodna z powierzchniami S_1, ujęta w fałdek F_2. Bardzo silna koncentracja kwarcu w przegubie fałdku wynikła z przemieszczenia materiału mineralnego do strefy mniejszego ciśnienia. Lamelki deformacyjne w ziarnach kwarcu równoległe do powierzchni foliacji S_2 świadczą, iż proces ten dokonywał się pod wpływem ścinania. Skałki ponad stacją uzdatniania wody w Dańczowie. Pow. 110 ×. Nikole skrzyżowane

6. Mica schist. F_2 microfolds. Deformation lamellae in quartz grains are parallel to S_2 axial planes. Crags on the northern slope some 1500 meters east of Lasek Miejski. Mag. 30 ×. Nicols crossed
Łupek łyszczykowy. Mikrofałdki zespołu F_2. Lamelki deformacyjne w ziarnach kwarcu równoległe do powierzchni osiowych S_2. Skałki na N zboczu, okolo 1 500 m od Lasku Miejskiego w kierunku E. Pow. 30 ×. Nikole skrzyżowane



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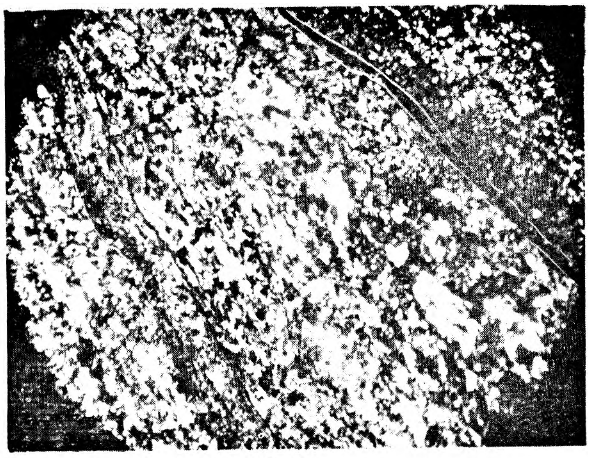

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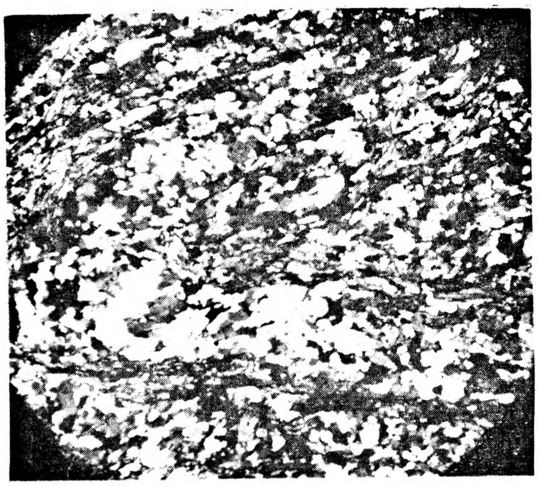

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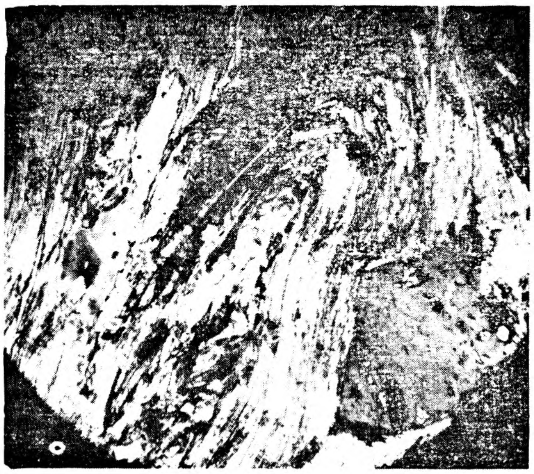

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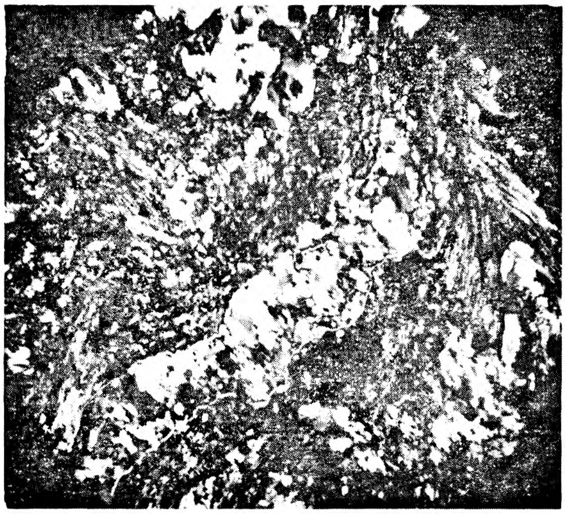

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Andrzej ŻELAŹNIEWICZ — Tectonic and metamorphic events in the Polish part of the Orlickie Mts.
Zjawiska tektoniczne i metamorficzne w polskiej części Gór Orlickich

PLATE VII

PLANSZA VII

1. Amphibolite. Concentration of plagioclase in the hinge region of F_2 fold and recrystallization of the mineral under control of shearing occuring parallel to the axial planes. Development of light minerals concentrations — patches. Crags in Jawornica. Mag. 30 ×. Nicols crossed
Amfibolit. Koncentracja plagioklazu w strefie przegubowej fałdku F_2 oraz rekrystalizacja tego minerału pod wpływem ścinania równoległego do powierzchni osiowej. Rozwój skupień jasnych minerałów — „łat". Skałki w Jawornicy. Pow. 30 ×. Nikole skrzyżowane

2. Amphibolite. Influence of shearing on geometry of F_2 folds, $F_2 + M_2$ fabric and on recrystallization of plagioclase in the closures of F_2 folds. Slope above water-supply-filter-station in Dańczów. Mag. 30 ×. Nicols parallel
Amfibolit. Wpływ ścinania na geometrię fałdków F_2, strukturę $F_2 + M_2$, rekrystalizację plagiokazu w przegubach fałdów zespołu F_2. Skałki ponad stacją uzdatniania wody w Dańczowie. Pow. 30 ×. Nikole równoległe

3. Amphibolite. Directional recrystallization of amphibole crystals (parallel to S_2 axial foliation) in layers rich in plagioclase. Amphibole crystals occuring in amphibole layers do not yield to such a recrystallization. Slopes below Małe Jerzykowice. Mag. 30 ×. Nicols parallel
Amfibolit. Kierunkowa rekrystalizacja amfibolu, zgodnie z powierzchniami foliacji osiowej S_2, w warstewkach bogatych w plagioklaz. Amfibol w warstewkach amfibolowych nie ulega takiej rekrystalizacji. Skałki na zboczu poniżej Małych Jerzykowic. Pow. 30 ×. Nikole równoległe

4. Amphibolite. Manner of recrystallization of minerals forming F_2 microfold. Note dark minerals growing parallel to S_2 axial plane. Slope above water-supply-filter-station in Dańczów. Mag. 30 ×. Nicols parallel
Amfibolit. Sposób rekrystalizacji minerałów w obrębie struktury fałdku F_2. Wzrost ciemnych minerałów równolegle do powierzchni osiowych S_2. Skałki ponad stacją uzdatniania wody w Dańczowie. Pow. 30 ×. Nikole równoległe

5. Amphibolite. $F_2 + M_2$ fabric in the closure of F_2 fold. Directional recrystallization of both dark and light minerals in parallel to S_2 axial planes. Slope above water-supply-filter-station in Dańczów. Mag. 30 ×. Nicols parallel
Amfibolit. Struktura $F_2 + M_2$ w przegubie fałdku F_2. Zgodna kierunkowa rekrystalizacja minerałów jasnych i ciemnych. Skałki ponad stacją uzdatniania wody w Dańczowie. Pow. 30 ×. Nikole równoległe

6. Amphibolite. Orientation of minerals in diversely composed laminae occuring in the closure of F_2 fold. Slope above water-supply-filter-station in Dańczów. Mag. 42 ×. Nicols parallel
Amfibolit. Orientacja minerałów w przegubie fałdku F_2, w laminach o różnym składzie mineralnym. Skałki ponad stacją uzdatniania wody w Dańczowie. Pow. 42 ×. Nikole równoległe

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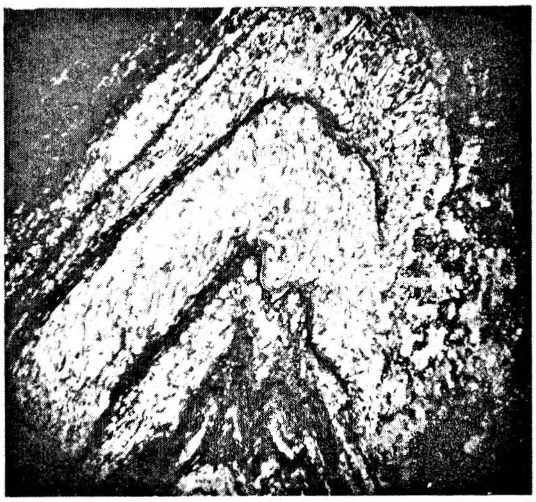

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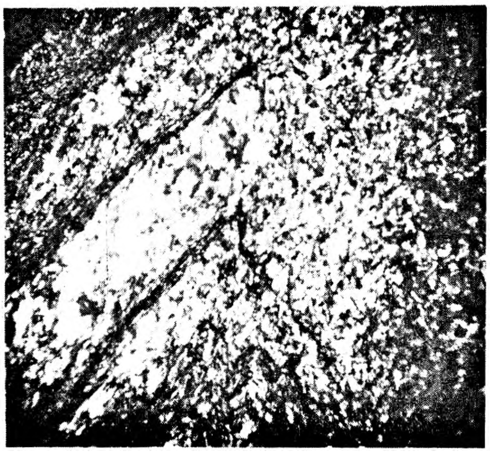

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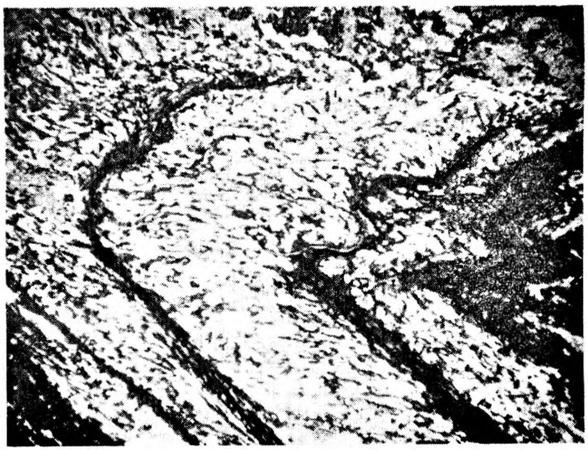


6

Andrzej ŻELAŹNIEWICZ – Tectonic and metamorphic events in the Polish part of the Orlickie Mts.
Zjawiska tektoniczne i metamorficzne w polskiej części Gór Orlickich

PLATE VIII

PLANSZA VIII

1. Mica schist. Closure of F_2 fold was modified by superimposed shearing. Manner of arrangement of the recrystallizing minerals within the structure of this fold. Crags above Zimne Wody. Mag. 30 ×. Nicols crossed

   Łupek łyszczykowy. Przegub fałdku F_2 zmodyfikowanego ścinaniem. Sposób ułożenia rekrystalizujących minerałów w obrębie tego fałdku. Skałki w Zimnych Wodach. Pow. 30 ×. Nikole skrzyżowane

2. Mica schist. Influence of shearing on the manner of arrangement of minerals in the hinge region of F_2 fold. Eastern slope of the Orlica Mt. Mag. 30 ×. Nicols parallel

   Łupek łyszczykowy. Wpływ ścinania na sposób ułożenia minerałów w przegubie fałdku F_2. Skałki na E zboczu Orlicy. Pow. 30 ×. Nikole równoległe

3. Mica schist. S_1 quartz veinlet thickened in the hinge of F_2 fold owing to migration of silica from the fold limbs. Note deformation lamellae in quartz grains parallel to the axial plane of fold. Crags nearby electrical-power substation in Gołaczów. Mag. 30 ×. Nicols crossed

   Łupek łyszczykowy. Żyłka kwarcowa zgodna z powierzchniami S_1 pogrubiona w przegubie fałdku F_2 wskutek migracji krzemionki ze skrzydeł. Lamelki deformacyjne równoległe do powierzchni osiowej fałdku. Skałki koło podstacji elektrycznej w Gołaczowie. Pow. 30 ×. Nikole skrzyżowane

4. Mica schist. F_2 folds shaped by shearing parallel to their axial planes. Crags in the wood some 500 meters west of the electrical-power substation in Gołaczów. Mag. 30 ×. Nicols crossed

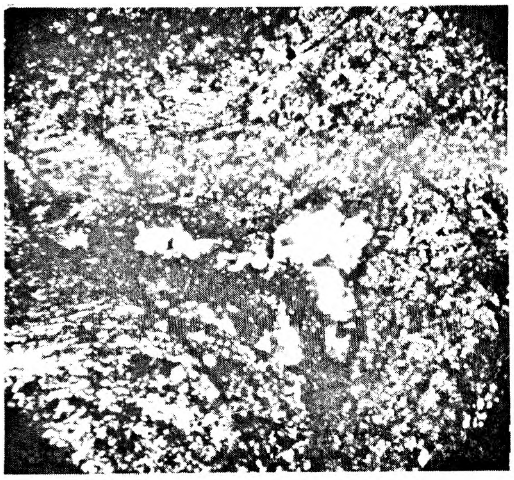
   Łupek łyszczykowy. Fałdki F_2 rozbudowane pod wpływem ścinania równoległego do powierzchni osiowych. Skałki w lesie około 500 m na W od podstacji elektrycznej w Gołaczowie. Pow. 30 ×. Nikole skrzyżowane

5. Amphibolite. Plagioclase-epidote-quartz layer involved in isoclinal F_2 fold. Note the inception of secondary metamorphic layering in this rock. Crags above water-supply-filter station in Dańczów. Mag. 30 ×. Nicols crossed

   Amfibolit. Warstewka plagioklazowo-epidotowo-kwarcowa ujęta w izoklinalny fałdek F_2. Zaczątki wtórnego metamorficznego warstwowania skały. Skałki ponad stacją uzdatniania wody w Dańczowie. Pow. 30 ×. Nikole równoległe

6. Mica schist. Recrystallizing plagioclase in sheared fabric of $F_2 + M_2$ phase. Note zone of more intense shear movement. Crags on southern slope above the road in Gołaczów. Mag. 110 ×. Nicols crossed

   Łupek łyszczykowy. Rekrystalizujący plagioklaz w poddanej ścinaniu strukturze $F_2 + M_2$. Strefy silniejszych ruchów ścinających. Skałki na S zboczu ponad szosą w Gołaczowie. Pow. 110 ×. Nikole skrzyżowane



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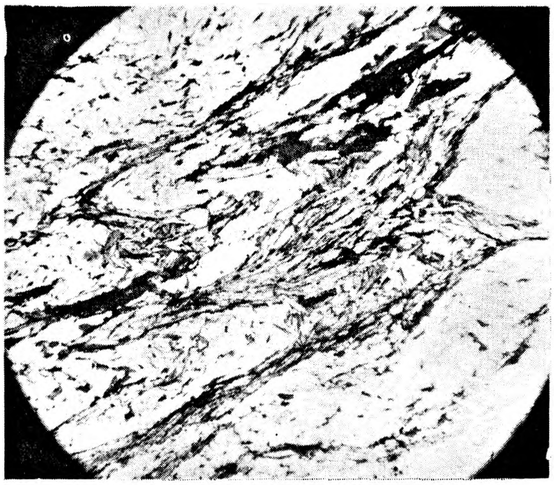

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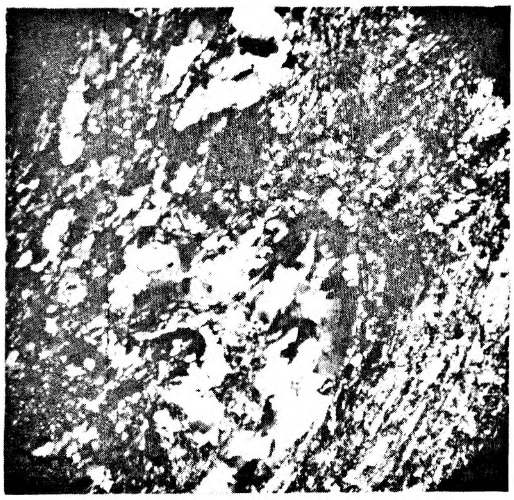

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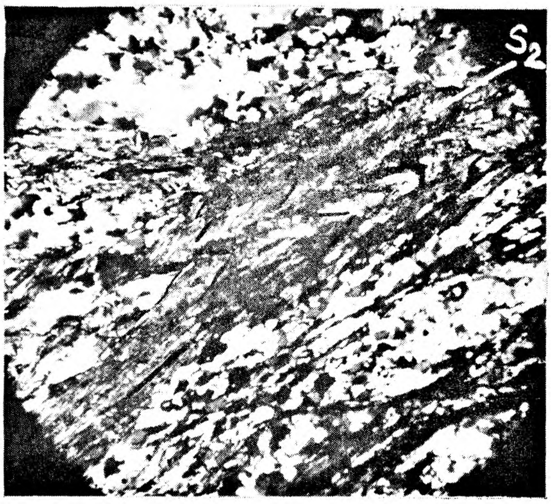

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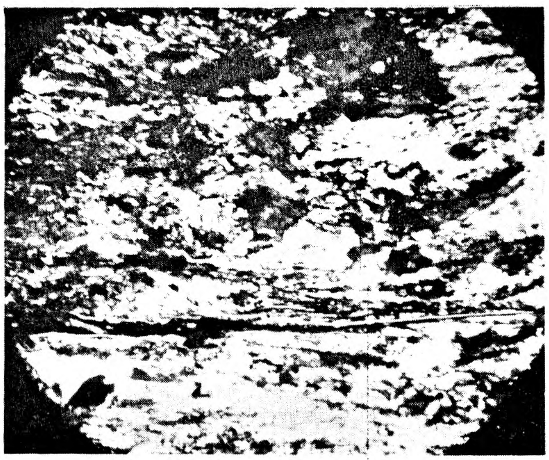

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Andrzej ŻELAŹNIEWICZ — Tectonic and metamorphic events in the Polish part of the Orlickie Mts.
Zjawiska tektoniczne i metamorficzne w polskiej części Gór Orlickich

PLATE IX

PLANSZA IX

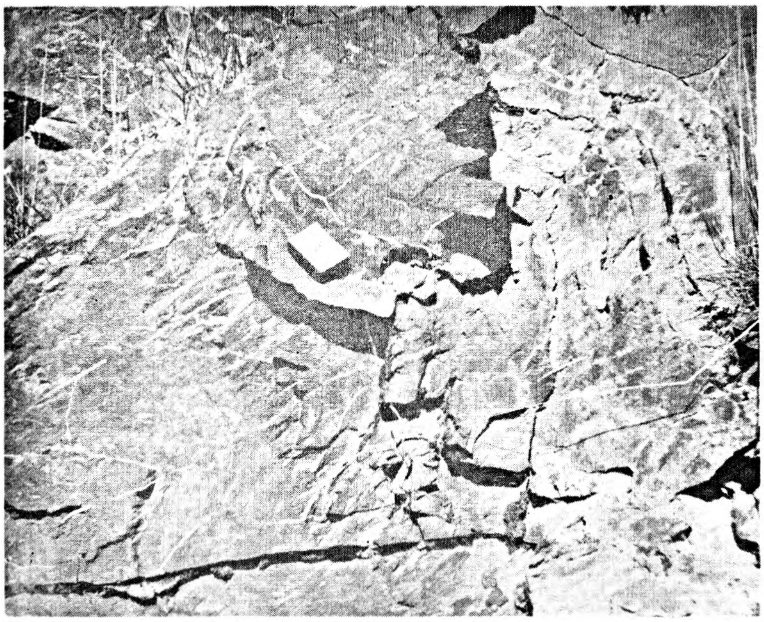
1. F_2 fold in massive mica schist. Note the parting along S_1 surfaces involved in this fold as well as along surfaces of S_2 axial foliation which is locally underlined by thin quartz veins. Abandoned quarry in Zieleniec some 500 meters east of the PKS-bus station
   Fałd zespołu F_2 w masywnych łupkach łyszczykowych. Widoczna oddzielność wzdłuż zafałdowanych powierzchni S_1 oraz wzdłuż powierzchni foliacji S_2 równoległych do powierzchni osiowej fałdu. Foliację S_2 podkreślają miejscami cieniutkie żyłki kwarcu. Stary kamieniołom w Zieleńcu, na S zboczu wzgórza o wysokości 886,0 m npm., 500 m na E od przystanku PKS w Zieleńcu

2. Isoclinal folds of calcite laminae in calcareous phyllite. Small abandoned quarry of limestones at the green tourist route, some 600 meters northeast of the "Orlica" hostel in Zieleniec
   Izoklinalne fałdki lamin kalcytowych w fyllicie wapiennym. Malutki kamieniołom wapieni przy zielonym szlaku prowadzącym do schroniska ,,Orlica" w Zieleńcu

3. F_2 folds in mica schist recognizable due to the presence of layers rich in quartz. Crags on the northern slope some 1 500 meters east of Lasek Miejski
   Fałdki F_2 w łupku łyszczykowym widoczne dzięki obecności warstewek bogatych w kwarc. Skałki nad brzegiem potoku około 1 500 m na E od Lasku Miejskiego

4. F_2 folds occuring in the closure of larger F_2 fold in mica schist. Note the parting along distinctly seen S_2 surfaces. Surfaces of S_2 foliation examined under the microscope are markedly underlined by parallel arrangement of biotite flakes. Enveloping surface to these small F_2 folds (so folded S_1 surfaces) are generally vertical whereas planes of S_2 foliation lie nearly horizontally. Road-cutting on slope of the Deštna Mt. some 1 500 meters from the "Masarykova chata" hostel
   Drobne fałdki zespołu F_2 w przegubie większego fałdu F_2 w łupkach łyszczykowych. Widoczna oddzielność wzdłuż wyraźnych tutaj powierzchni S_1. Powierzchnie foliacji S_2, widziane pod mikroskopem, podkreślone są równoległym ułożeniem blaszek biotytu. Zafałdowane powierzchnie S_1 ustawione są generalnie pionowo, powierzchnie foliacji S_2 leżą prawie horyzontalnie. Odkrywka w skarpie nad nową szosą na zboczach Destny około 1500 m od schroniska ,,Masarykova chata" na Szerlichu

5. Mica schist rich in grains of plagioclase of the second kind resulting from the recrystallization of F_1+M_2 albite. Small crag above the road Kulin-Gołaczów some 300 meters from the electrical-power substation in Gołaczów
   Łupek łyszczykowy bogaty w plagioklazy drugiego rodzaju pochodzące z rekrystalizacji albitu F_1+M_1. Skałki nad szosą Kulin – Gołaczów, około 300 m od podstacji elektrycznej w Gołaczowie



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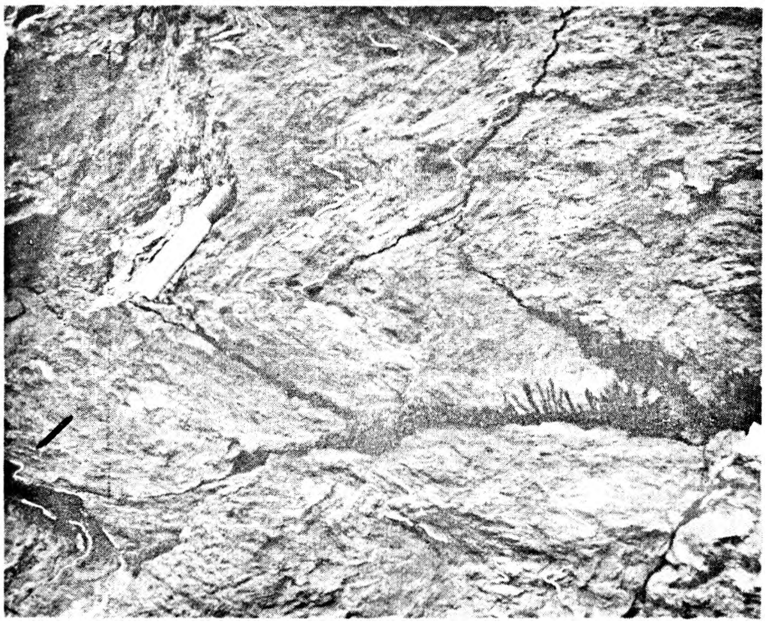

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Andrzej ŻELAŹNIEWICZ – Tectonic and metamorphic events in the Polish part of the Orlickie Mts.
Zjawiska tektoniczne i metamorficzne w polskiej części Gór Orlickich

PLATE X

PLANSZA X

1. F_2 folds in mica schist. Thin quartz veins involved in the folds are concordant with S_1 surfaces. Crags nearby a big turn of the so-called upper road in Zieleniec, some 1 500 meters northeast of the "Orlica" hostel in Zieleniec
   Fałdki F_2 w łupku łyszczykowym. Zafałdowane żyłki kwarcowe zgodne z powierzchniami S_1. Skałki ponad zakrętem górnej szosy w Zieleńcu, około 1500 m na NE od schroniska „Orlica" w Zieleńcu

2. Drag fold of F_2 set occuring in the limb of larger isoclinal fold. Quartz-phengite schist. This drag fold was sreongly modified by shearing acting parallel to the axial plane of the parent fold and parallel to the limbs both of the parent fold and the very drag fold. The drag fold, in the result of this process, acquired features of a fold of perfectly similar geometry. Abandoned quarry of limestones nearby Ludowe, some 500 meters north of the Homole castle
   Fałdek ciągniony zespołu F_2 występujący w skrzydle większego fałdu izoklinalnego. Łupek kwarcowo-fengitowy. Fałdek ten został bardzo silnie zmodyfikowany ścinaniem równoległym do powierzchni osiowej S_2 oraz skrzydeł fałdu dużego i fałdu ciągnionego. Wskutek tego zjawiska fałdek ciągniony wtórnie zyskał cechy typowego fałdu ze ścinania. Stary kamieniołom wapieni koło Ludowego, 500 m na N od zamku Homole

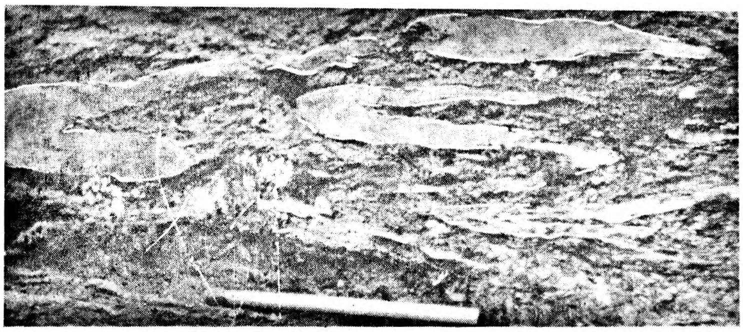
3. F_2 folds occuring in mica schist, and distinctly seen owing to the presence of laminae rich in quartz. Crags in the wood nearby Nowa Jawornica, some 1 100 meters west of Kozia Hala
   Fałdki F_2 w łupku łyszczykowym widoczne dzięki obecności lamin bogatych w kwarc. Skałki w lesie koło Nowej Jawornicy, około 1000 m na W od Koziej Hali

4. F_2 folds in mica schist. Quartz veins parallel to S_2 foliation. Crags on the estern slope above the road from Lewin to Zimne Wody, some 400 meters southwards from the wayside shrine situated at the cross-roads from Lewin to Jawornica and Zimne Wody
   Fałdki F_2 w łupku łyszczykowym. Żyłka kwarcu zgodna z foliacją S_2. Skałki na E zboczu ponad szosą z Lewina do Zimnych Wód, około 400 m na S od kapliczki przy skrzyżowaniu dróg z Lewina do Jawornicy i Zimnych Wód

5. Felspar-quartz layers involved in F_2 fold in mica schist. Crags on the southern slope some 350 meters west of the PKS bus-station in Gołaczów
   Warstewki skaleniowo-kwarcowe łupka łyszczykowego ujęte w fałdki F_2. Skałki na S zboczu około 350 m na E od przystanku PKS w Gołaczowie

6. F_2 fold in schistose rock rich in plagioclase and quartz. Road-cutting some 200 meters south of the electrical-power substation in Gołaczów
   Fałdek F_2 w skale o przekroju łupkowym, bogatej w kwarc i skalenie. Wrzynka szosy około 200 m na S od podstacji elektrycznej w Gołaczowie

7. Quartz-plagioclase layers in mica schist involved in F_2 folds. Crags on the northern slope some 1 500 meters east of Lasek Miejski
   Warstewki skaleniowo-kwarcowe ujęte w fałdki F_2 w łupku łyszczykowym. Skałki na N zboczu około 1 500 m na E od Lasku Miejskiego



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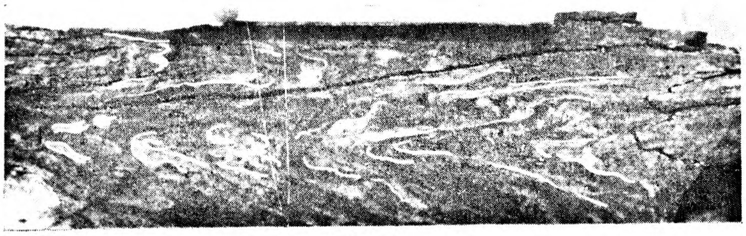

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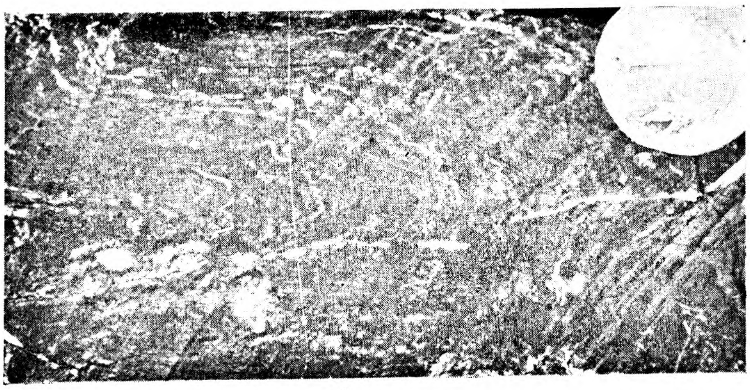

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Andrzej ŻELAŹNIEWICZ – Tectonic and metamorphic events in the Polish part of the Orlickie Mts.
Zjawiska tektoniczne i metamorficzne w polskiej części Gór Orlickich

PLATE XI

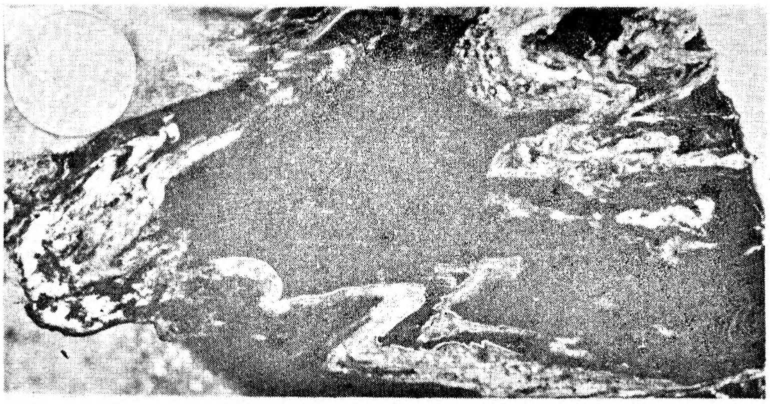
PLANSZA XI

1, 2. F_2 folds in amphibolites. Plagioclase-epidote-quartz layers were involved in these folds. Geometry of F_2 folds was considerably changed due to recrystallization of minerals to form the layers. Process of recrystallization was controlled by shearing. Note concentrations of light minerals in the hinge regions of F_2 folds. Crags on the slope above the water-supply-filter station in Dańczów
Fałdy F_2 w amfibolitach. W fałdki te zostały ujęte warstewki plagioklazowo-epidotowo-kwarcowe. Rekrystalizacja minerałów w tych warstewkach spowodowała znaczne zmiany w geometrii fałdów F_2. Proces rekrystalizacji odbywał się pod znacznym wpływem ścinania. Widoczne koncentracje jasnych minerałów w przegubach fałdów. Skałki ponad stacją uzdatniania wody w Dańczowie

3. Drag fold of F_2 set occurring in amphibolite. The fold was strongly modified at the final stages of its development, as the result of shearing acting parallel to its limbs and to axial plane of the parent fold. Note significant concentrations of light minerals (epidote, acid plagioclase) occurring in the portions subject to the most intense shearing. Crags on the northern slope some 300 meters west of the wayside shrine situated at the cross-roads from Lewin to Jawornica and to Zimne Wody
Amfibolit. Fałdek ciągniony zespołu F_2 w końcowym stadium swego rozwoju został silnie zmodyfikowany ścinaniem równoległym do jego skrzydeł oraz do powierzchni osiowej dużego fałdu. Widoczne pokaźne koncentracje jasnych minerałów (epidot, kwaśny plagioklaz) w partiach najbardziej ulegających ścinaniu. Skałki w lesie poniżej Małych Jerzykowic

4. Closure of F_2 fold in striped amphibolite. Note significant concentration of light minerals (epidote, acid plagioclase, quartz). Crags on the northern slope above the water-supply-filter station in Dańczów
Przegub fałdku F_2 w warstwowanym amfibolicie. Widoczne pokaźne koncentracje jasnych minerałów (epidot, kwaśny plagioklaz, kwarc). Skałki ponad stacją uzdatniania wody w Dańczowie

5, 6. Plagioclase-epidote layers involved in F_2 fold in amphibolite. Crags on the northern slope above the water-supply-filter station in Dańczów
Warstewki plagioklazowo-epidotowe ujęte w fałdki F_2 w amfibolicie. Skałki na N zboczu ponad stacją uzdatniania wody w Dańczowie



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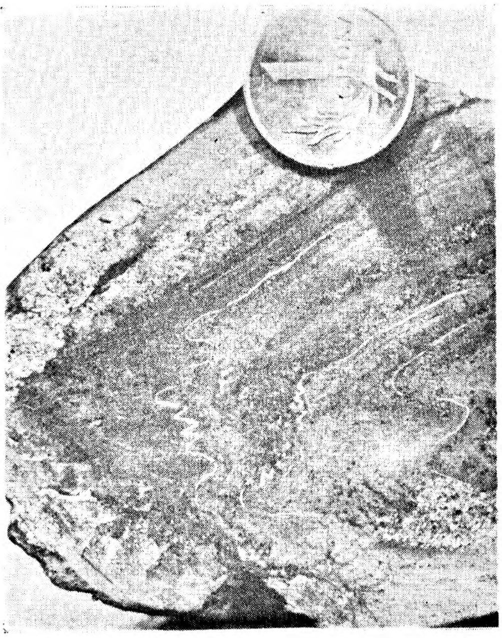

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Andrzej ŻELAŹNIEWICZ — Tectonic and metamorphic events in the Polish part of the Orlickie Mts.
Zjawiska tektoniczne i metamorficzne w polskiej części Gór Orlickich

PLATE XII

PLANSZA XII

1. F_4 fold in crystalline limestones. Fold axis is plunging gently from a viewer. Note small overthurst parallel to S_4 axial plane of the fold. Abandoned quarry nearby the "Golden stailen", slopes of the Orlica Mt.
Fałdek zespołu F_4 w wapieniach krystalicznych. Oś fałdku pochyla się od patrzącego. Widoczne małe nasunięcie wzdłuż powierzchni równoległej do powierzchni osiowej S_4. Stary kamieniołom przy „Złotej Sztolni" na zboczach Orlicy

2. F_4 fold in mica schist. Railway cutting above Gołaczów, near a fly-over
Fałdek F_4 w łupku łyszczykowym. Przekop kolejowy ponad Gołaczowem, koło wiaduktu nad torami

3. F_4 fold in mica schist interbedded with calcite layers. Crags on the northern slope of the 806 m hill above the road Duszniki – Zieleniec
Fałdek F_4 w łupku łyszczykowym z warstewkami kalcytowymi. Skałki na N zboczu wzgórza 806,0 m npm., ponad szosą Duszniki – Zieleniec

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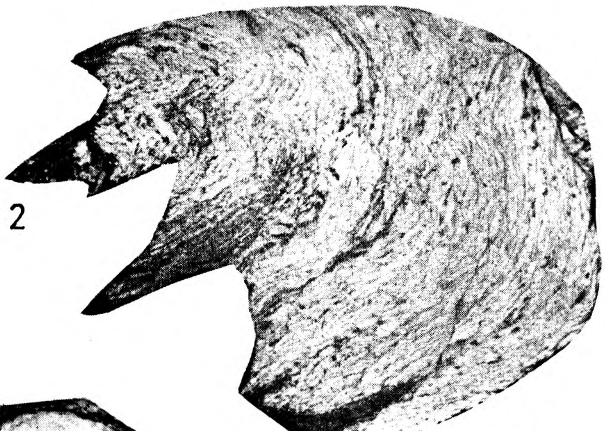

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Andrzej ŻELAŹNIEWICZ – Tectonic and metamorphic events in the Polish part of the Orlickie Mts.
Zjawiska tektoniczne i metamorficzne w polskiej części Gór Orlickich

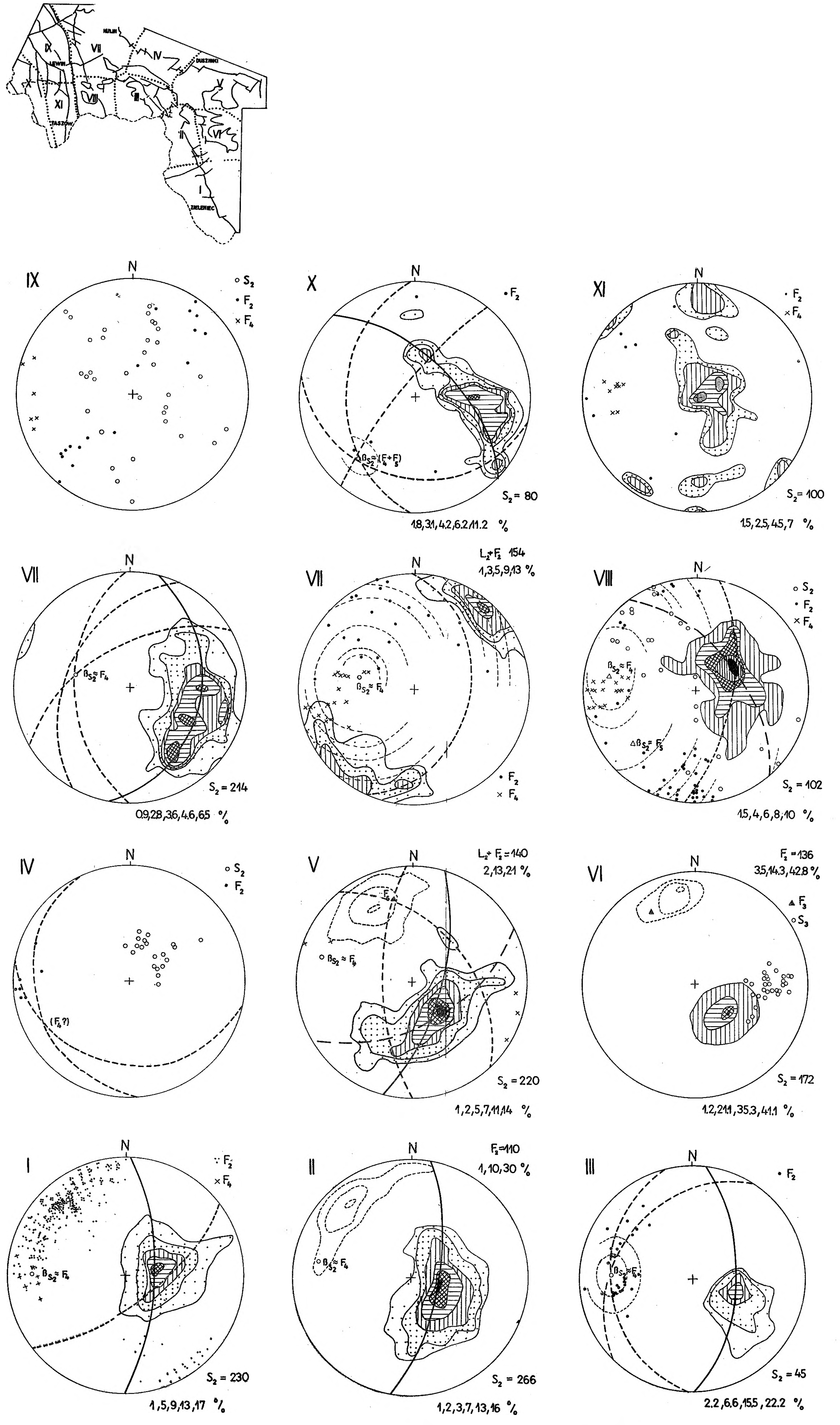

Fig. 23

Elements of structural analysis. Diagrams show the orientations of S_2 main foliation, L_2 lineation as well as F_2 and F_4 axial directions

Solid contours or open circles — surfaces of S_2 foliation, dashed contours or solid dots — L_2 lineation and F_2 folds, crosses — F_4 folds. Numbers at diagrams denote: 1° quantity of measurements, when follow marks S_2 (main foliation) and F_2 (main folds); 2° value of contouring isolines, then given respectively below marks S_2 or F_2 for foliation at the bottom right of a diagram and for F_2 axial directions at the top right of a diagram. Lower hemisphere of Schmidt net. Solid or coarse dashed great circles — scatter of foliation readings. Fine dashed great circles — extremal readings of orientation of S_2 foliation. Dashed small circles express an arrangement of F_2 plots about F_4 axes. Inset shows division of the investigated area into 11 rougly homogenous regions in respect to orientation of F_2 fold and mains foliation. One diagram refers to one region

Elementy analizy strukturalnej. Diagramy ilustrują ułożenie foliacji S_2, struktur linijnych L_2 oraz osi fałdówF_2 i F_4

Kontury ciągłe lub kółka otwarte — powierzchnie foliacji S_2; kontury przerywane lub kropki pełne — lineacja L_2 i fałdki F_2; krzyżyki — fałdki F_4. Diagramy wykonano przy użyciu półkuli dolnej siatki Schmidta. Cyfry przy diagramach oznaczają: za symbolem foliacji S_2 — ilość wykonanych pomiarów; ze znaczkiem % — wartości poszczególnych konturów, które dla foliacji S_2 podane są u dołu z prawej strony każdego z diagramów, zaś dla fałdków F_2 i lineacji L_2 u góry z prawej strony. Łuki kół wielkich na diagramach oznaczają albo pasy rozrzutu pomiarów ułożenia foliacji S_2, albo skrajne wartości pomiarów orientacji powierzchni tej foliacji. Łuki przerywane małych kół ilustrują rozkład struktur linijnych fazy F_2 wokół osi F_4. Rozkład ten świadczy o znacznym udziale mechanizmu zginania w modelowaniu form deformacji poprzecznej. Mapka przedstawia podział badanego regionu na 11 homogenicznych obszarów. Każdemu z tych obszarów przyporządkowany jest jeden diagram