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FLYSCH FACIES IN THE EPIMETAMORPHIC OF THE NORTHERN PART OF THE KACZAWA MOUNTAINS (SW POLAND)

(Pl. I—VIII and 7 Figs.)

Facja fliszowa w epimetamorfiku północnej części Gór Kaczawskich

(Tabl. I—VIII i 7 fig.)

Abstract. In the metasedimentary rocks under study the occurrence of relict sedimentary structures has been ascertained. The formation consists of alternate layers of quartzites, metasiltstones, slates and siliceous slates. Quartzites (metagreywackes) represent metamorphosed lithic, feldspathic and quartz wackes. A considerable thickness of the sediments as well as the preserved sedimentary structures and their sequence in the beds imply that the formation in question represents metamorphosed flysch rocks. Within this facies, the normal and shaly flysch subfacies have been distinguished.

INTRODUCTION

The present paper is an attempt at reconstructing the original character of the metasedimentary formation that is one of the principal elements of the geological structure of the Kaczawa Mts. In the metamorphic formations of the Sudetes sedimentological investigations have not been so far conducted. An identification of the primary sedimentary features or, if possible, of the primary sedimentary facies should permit a correct correlation of the individual geological units.

GEOLOGICAL SETTING

The Kaczawa Mts. (Western Sudetes, SW Poland) may be divided into the southern and northern part. These parts are separated by the Świerzawa graben, which extends into the North Sudetic Basin (Fig. 1). In the Kaczawa Mts. two structural stages are to be distinguished (H. Teisseyre, 1957): 1. the lower stage that comprises strongly folded and metamorphosed formations from the Eocambrian to Upper

Silurian; 2. the upper stage, slightly tectonized, made up of unmetamorphosed rocks ranging in age from the Late Carboniferous to Miocene.

The investigated area covers a part of the lower structural stage in the northern part of the Kaczawa Mts. (see Fig. 1). In this part the occurrence of the following formations has been noted: 1. volcanic greenschist formation[1], regarded to be of Late Cambrian age; 2. metasedimentary formation consisting of Ordovicain, Silurian rocks[2].

Assuming after F. Dahlgrün (1934) that the greenschist formation is Late Cambrian in age, some authors (E. Zimmermann, B. Kühn, 1936; M. Schwarzbach, 1939; J. Jerzmański, 1965) consider it to be the basement of the metasedimentary unit. According to the others (H. W. Quitzow, 1939; J. Oberc, 1972), greenschists are thrusted over the metasedimentary rocks. In the present author's opinion it is not inconceivable that the activity of submarine volcanism lasted up to the Silurian and that greenschists interfinger with the Ordovician-Silurian metasedimentary formation.

The age of the metasedimentary formation has been established on the basis of poorly preserved conodont (Z. Baranowski, Z. Urbanek, 1972) and graptolite fauna (F. Roemer, 1862; G. Gürich, 1882; R. Hundt, 1920).

A more precise characterization of the metamorphic complex is furnished by B. Kühn and E. Zimmermann (1918); E. Zimmermann and B. Kühn (1936). According to this author, the principal lithological units, apart from greenshists and diabases, are: a) light, sandy, mica-rich slates with quartzite intercalations; b) greywackes; c) black siliceous and graphite slates; d) blue-greyish mica-free clay slates. He regarded the whole metamorphic complex to be of Early Palaeozoic age.

The lithological units shown on the map (Fig. 2) will be discussed in the following sections. It should be emphasized however that, notwithstanding the ocurrence of some fauna sites in the area under study, the lack of key beds (cf. E. Zimmermann, B. Kühn 1936), intensive tectonics and the monotonous character of the metasedimentary sequence do not permit in the present state of investigations to distinguish stratigraphic units s.s. For that reason, the lithological units presented on the map (Fig. 2) cannot be treated as stratigraphic subdivisions.

The total thickness of the Cambrian-Silurian rocks in the Kaczawa Mts. is estimated to be about 3000 m (M. Schwarzbach, 1939; H. Teisseyre, 1967). Thickness of the metasediments without eruptive rocks (greenschists) is less than 2000 m (M. Schwarzbach, 1940),

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[1] In this paper "formation" refers to informal lithostratigraphic unit traditionally used in investigated area. A "complex" is the unit next in rank above a formation.

[2] Recent investigation have shown that the metasedimentary formation under study contain also Lower and Middle Devonian rocks.

while that of the Ordovician and Silurian about 1000 m (E. Zimmermann, B. Kühn 1936; M. Schwarzbach, 1940).

As mentioned earlier in this paper, the lower stage of the Kaczawa Mts. was strongly folded and metamorphosed in the epizone. Main folding and metamorphism occurred presumably in the Early or Middle Devonian (H. Teisseyre, 1968). According to H. Teisseyre, repeated tectonic deformations took place during the Variscian Revolution. The subsequent violent movements on the Cretaceous/Tertiary boundary disintegrated the area of the Kaczawa Mts. into a number of horsts and grabens. In the Neogene the whole area was uplifted along the Sudetic marginal fault.

Both in the southern (H. Teisseyre, 1956) and northern (J. Jerzmański, 1965) part of the Kaczawa Mts. geological units, probably of nappe-like type, are distinguished. According to J. Jerzmański (1965), in the northern part the lowermost position is occupied by the parautochthonous unit Złotoryja-Luboradz, on which is overthrusted the Chełmiec unit. The unit Rzeszówek-Jakuszowa is, in turn, thrusted over the latter (Fig. 1). The southern vergency of folds and southern direction of overthrusts in the S part of the Kaczawa Mts. are unquestionable. The presumable northern vergency of folds as well as northern direction of overthrusts and the tectonic position of units in the N part of the mountains are still a problem open to discussion (Z. Baranowski, A. Haydukiewicz, 1970; J. Oberc, 1972).

Field observations have demonstrated that both the metasedimentary rocks and greenschists are in normal position. Folds and cleavage in the rocks under study were formed in several stages (cf. Z. Baranowski, A. Haydukiewicz, 1970), though their sequence has not been established yet.

The characteristic features of the metasedimentary formation are discussed in the following sections of this paper.

PETROGRAPHY

Rocks making up the formation under study are phyllites, phtanites, quartzites and metagreywackes. Among the phyllites sericite, chlorite, graphite, etc. slates are to be distinguished.

In the rocks a characteristic mineral assemblage quartz — albite — muscovite (— epidote) — chlorite has been noted. This assemblage is typical for the greenschist facies of regional metamorphism, and more precisely for the quartz-albite-muscovite-chlorite subfacies (F. J. Turner and J. Verhoogen, 1960).

According to H. G. F. Winkler's classification (1970), the rock complex under study represents the lower range of low-stage metamorphism, which is comprised between the "zoisite/clinozoisite in" and "stilpnomelane out/biotite in" isograds. Thus the lower limit of the interval may be delineated basing on the presence of the mineral assemblage with mutual contacts, i.e. chlorite + quartz + zoisite/clinozoisite, in the investigated rocks. The upper limit, on the other hand, is determined by the absence of metamorphic biotite in the rocks. The interval corresponds approximately to the metamorphism in the range of 350—470°C and 3—8 kilobars.

In the present paper metasediments have been treated as sedimentary rocks. Metasediments consist of terrigenous material (except siliceous slates) with clay, silt and sand fractions.

Slates

These rocks are most appreciably altered when compared with the primary sediment. The most frequent rock-forming minerals that can be identified under the microscope are sericite, quartz and chlorite. In some thin sections, very fine-grained mass, weakly reacting to polarized light is observed, in which streaks of sericite and single fine quartz crystals may be distinguished. This mass very likely represents weakly altered clayey minerals. This has been confirmed by X-ray analyses, which show the presence of illite, montmorillonite and kaolinite.

The dominant constituent of slates is sericite, which gives the rock a visibly planar texture. Varieties of slates with less distinct orientation are rare.

Chlorite either appears as flakes with orientation conformable to sericite, or forms single larger flakes. It has been recorded in all the varieties of slates, but is common only in some of them.

Quartz is found in various forms. It often forms small laminae together with sericite and chlorite flakes. Single quartz crystals or fine-grained aggregates are disseminated in the shaly mass, distinct grains being unusual. Quartz is often elongated concordantly to the direction of recrystallization of sericite. There are cases when, in consequence of selective migration of quartz disseminated in the rock, small lenticular aggregations or laminae displaying mosaic texture are formed.

In some portions of slates graphite appears in great quantities. Graphite slates are thinly foliated; apart from graphite, sericite quartz and pyrite often enters into their composition.

In green chlorite slates an admixture of tuffite may be seen. Under the microscope altered volcanic rock fragments and large aggregates of leucoxene are visible. Epidote and actinolite are present beside chlorite and sericite.

Accessory minerals are represented by leucoxene, carbonates, pyrite and iron oxides. Among carbonates siderite is most common, dolomite and calcite being subordinate minerals. Siderite and pyrite often form idiomorphic crystals. Carbonate occurrences are very irregular; in

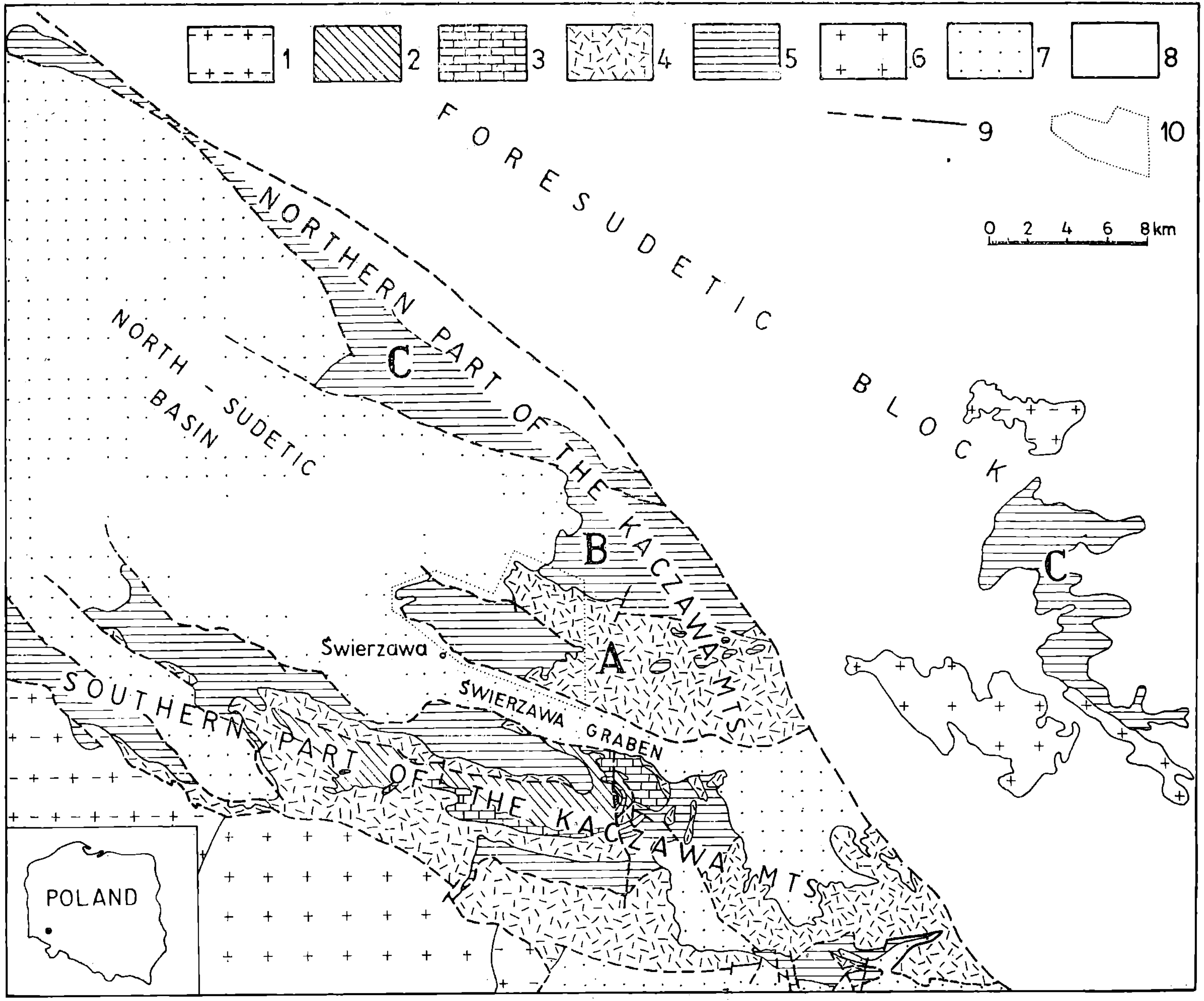

Fig. 1. Tectonic sketch map of the Kaczawa Mts (based on geological map of Lower Silesia — without Quaternary deposits; L. Sawicki, 1966). 1 — gneisses of the Karkonosze granite cover and gneisses of Wądroże Wielkie (Proterozoic and Early Paleozoic); 2 — slates (Eocambrian); 3 — marbles (Lower and Middle Cambrian); 4 — greenschists (Middle and Upper Cambrian); 5 — metasediments and diabases (Ordovician and Silurian); 6 — Variscian granitoids; 7 — sedimentary rocks (Carboniferous, Permian, Triassic, Upper Cretaceous; in SE part of the map — Upper Devonian); 8 — sedimentary rocks (Tertiary); 9 — faults; 10 — area of investigation; Tectonic units of the northen part of the Kaczawa Mts (after J. Jerzmański 1965): A — Rzeszówek — Jakuszowa unit; B — Chełmiec unit; C — Złotoryja — Luboradz unit

Fig. 1. Szkic tektoniczny Gór Kaczawskich (na podstawie mapy geologicznej regionu dolnośląskiego — bez utworów czwartorzędowych; L. Sawicki 1966). 1 — gnejsy osłony granitu Karkonoszy i gnejsy Wądroża Wielkiego (proterozoik — starszy paleozoik); 2 — metałupki (eokambr); 3 — wapienie krystaliczne (kambr dolny i środkowy); 4 — zieleńce (kambr środkowy i górny); 5 — metaosadowce i diabazy (ordowik i sylur); 6 — granitoidy waryscyjskie; 7 — skały osadowe (karbon, perm, trias, g. kreda; w części SE górny dewon); 8 — skały osadowe (trzeciorzęd); 9 — dyslokacje; 10 — rejon badań; Jednostki tektoniczne północnej części Gór Kaczawskich (wg J. Jerzmańskiego 1965): A — jednostka Rzeszówek — Jakuszowa; B — jednostka Chełmca; C — jednostka Złotoryja — Luboradz

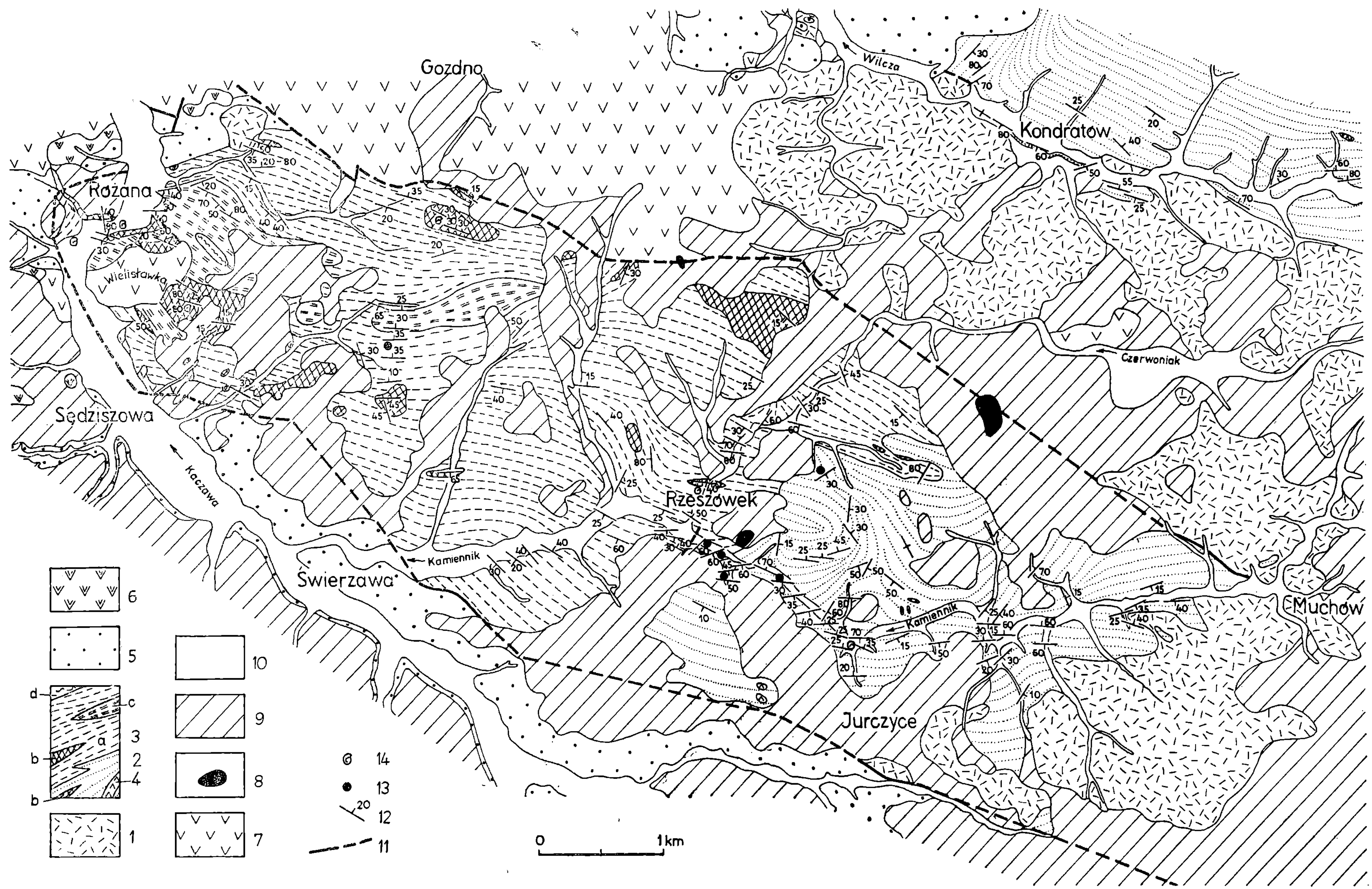

Fig. 2. Geological sketch map of the western part of the Rzeszówek—Jakuszowa unit. 1 — greenschists (Upper Cambrian-Silurian?); 2 — normal flysch (Ordovician-Silurian); 3 — shaly flysch (Ordovician-Silurian); 3a — dark-grey and grey-bluish sericite slates; 3b — black graphite slates and black siliceous slates (phtanites); 3c — grey-greenish sericite-chlorite slates with intercalations of light siliceous slates; 3d — green chlorite slates; 4 — keratophyre and metaporphyry (Ordovician-Silurian?); 5 — conglomerates, sandstones and shales (Upper Carboniferous — Lower Permian); 6 — melaphyre (Lower Permian); 7 — porphyre (Lower Permian); 8 — basalts (Tertiary); 9 — fluvioglacial deposits (Pleistocene); 10 — alluvial deposits (Holocene); 11 — faults; 12 — dip and strike; 13 — location of slumps and sediment flows; 14 — localities of fauna

Fig. 2. Szkic geologiczny zachodniej części jednostki Rzeszówek—Jakuszowa. 1 — zieleńce (g. kambr—sylur?); 2 — flisz normalny (ordowik—sylur); 3 — flisz łupkowy (ordowik—sylur); 3a — ciemnoszare i szaroniebieskie łupki serycytowe; 3b — czarne łupki grafitowe i krzemionkowe (lidyty); 3c — szarozielonkawe łupki serycytowo-chlorytowe z wkładkami jasnych łupków krzemionkowych; 3d — zielone łupki chlorytowe; 4 — keratofir i porfiroid (ordowik—sylur?); 5 — zlepieńce, piaskowce i łupki (najwyższy karbon—dolny perm); 6 — melafiry (d. perm); 7 — porfiry (d. perm); 8 — bazalty (trzeciorzęd); 9 — utwory wodno-lodowcowe (plejstocen); 10 — utwory aluwialne (holocen); 11 — uskoki; 12 — bieg i upad warstw; 13 — miejsce występowania struktur osuwiskowych i spływów osadu; 14 — stanowiska fauny

some thin sections their aggregations or single crystals are quite common while in others they are missing altogether.

The colour of slates is variable. The overwhelming majority of sericite and sericite-chlorite slates are black-grey and grey. Grey-greenish sericite-chlorite slates are exceptional. In isolated cases silver-grey sericite slates, green-violet sericite-chlorite slates and dark-green chlorite slates have been encountered.

Siliceous slates

Siliceous slates form strata from some to several cm thick, interbedded with graphite slates. If the intercalations are thin, the rock is called phtanite; if, on the other hand, they are thick and numerous, the rock is defined as siliceous slate.

Practically no other mineral but quartz may be observed under the microscope. It appears as recrystallized, interfingering mosaic of the size of silt fraction, in which graphitic pigment is disseminated (Pl. I, Figs. 1, 2). Sometimes quartz grains are separated by sericite flakes. In some thin sections, coarse recrystallized Radiolaria remains are encountered. Accessory minerals are represented by siderite, pyrite and apatite.

In the area under study, also light or cream-grey quartzite slates occur among sericite slates (cf. Fig. 2). These layers, up to some cm thick, are very resistant and massive. Under the microscope they reveal a structure similar to that of phtanite, but they are free of graphite. They contain, however, the remains of Radiolaria (Pl. I, Fig. 3). Considering these similarities, they have been classified as siliceous slates.

Phtanites and siliceous slates are considered to be the equivalents of radiolarian cherts (cf. e.g. Z. Sujkowski, 1937; A. V. Carozzi, 1960). Submarine basic lavas (ophiolites) that are, as a rule, associated with radiolarian cherts are regarded as the source of silica.

Metasiltstones

Inequigranular structure of these rocks becomes manifest under the microscope. The matrix is made up of sericite-quartz-chlorite mass in which coarser quartz, rarely feldspar, grains are distributed.

The boundaries of quartz grains are usually vague, interfingering with the recrystallized matrix. In some thin sections single grains of zircon, sometimes of tourmaline, have been observed. These grains show indications of rounding. Feldspar grains are not of metamorphic origin.

Sericite, very fine-grained recrystallized quartz and variable amounts of chlorite predominate in the matrix. In places, the components of the matrix are unrecognizable under the microscope. Muscovite, which partly is presumably of detrital origin, is present in small quantity. Accessory are siderite, pyrite, authigenic epidote, leucoxene and iron oxides.

Most of metasiltstones reveal preferred orientation of sericite, though sometimes it is not very distinct. The siltstones often show graded bedding. They also have sharply defined bottom surface. The top surface, on the other hand, is vague and the siltstone gradually passes into shale (cf. Pl. VII, Figs. 4, 5).

Metasandstones

Individual sandstone beds differ in thickness, colour and grain size. Sandstones are characterized by different hues of grey and sometimes by black colour. The majority of layers are composed of grains of sand fraction, the fine pebble fraction of 2—8 mm (s.c. quartzites from Tarczyn — Kuttenbergquarzit E. Zimmermann and B. Kühn, 1936) appearing only in isolated cases.

The mineral composition of sandstones was determined in thin sections. In each section 300 grains were analysed, and the contents of quartz, rock fragments (stable and unstable), feldspar, micas and matrix were determined in volume percentage.

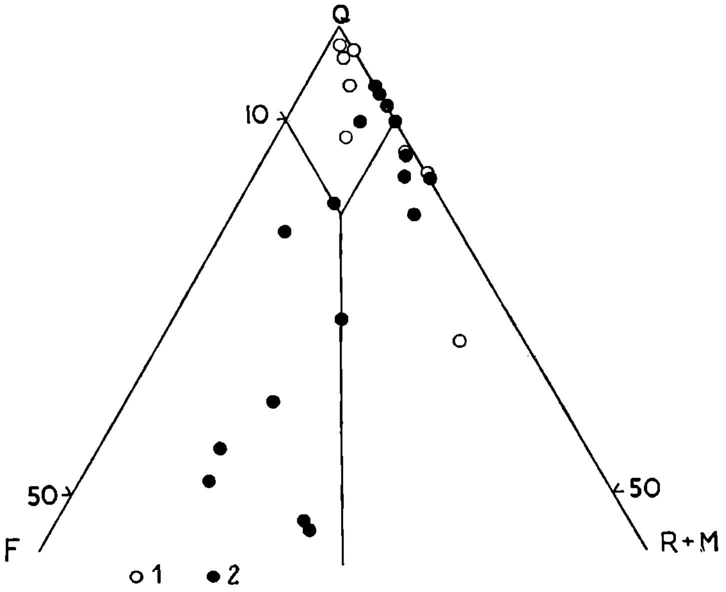

Fig. 3. Detrital framework of metagreywackes. 1 — shaly flysch; 2 — normal flysch; Q — quartz; R + M — unstable rock fragments and mica; F — feldspar

Fig. 3. Skład szkieletu ziarnowego metaszarogłazów. 1 — z fliszu łupkowego; 2 — z fliszu normalnego; Q — kwarc; R + M — niestabilne okruchy skał i łyszczki; F — skalenie

The size 0.03 mm was taken as the limit size between the grains of the detrital framework and the matrix (cf. H. Williams et al., 1954; R. H. Dott, 1964). Assuming a smaller size (0.02), also recommended by these authors, would be unpractical considering the recrystallization of the matrix (cf. Pl. II, Figs. 3, 4).

Granulometric composition was established by measuring 100 grains in thin sections and then applying a correction according to G. M. Friedman (1958) in order to obtain data comparable with sieve-size distribution. Sorting coefficient of individual samples was calculated using Trask's formula

$$S_o = \sqrt{Q_3/Q_1}$$

Mineral composition

In the detrital framework quartz plays the most important part (cf. Fig. 3). Most numerous are monocrystalline grains, but grains of polycrystalline (vein) quartz are also frequently observed (Pl. III, Fig. 3). The few coarser grains show wavy extinction. There are also grains containing unidentifiable inclusions.

Among rock fragments most frequent are those of low-grade slates (Pl. III, Figs. 1, 2, 4). Less numerous are fragments of quartzites or siliceous slates consisting of polygonized quartz (Pl. IV, Fig. 3). Still more rare are fragments of volcanic rocks. Small size of fragments makes their precise classification difficult, but in the majority of cases they are most likely fragments of acid volcanic rocks.

Feldspars are represented solely by plagioclase with An content not exceeding 10%. They are usually albite twinned, but sometimes checkered albite intergrown with quartz has been recorded. Fairly common are albite grains sericitized in a greater or lesser degree. Some very fine albite crystals embedded in the recrystallized matrix are very likely of secondary origin. The amount of feldspar in the individual samples is variable.

Micas almost entirely belong to muscovite, which occurs in variable quantities. Muscovite flakes are usually oriented parallel to the bedding. In general, muscovite is detrital though it is not inconceivable that it partly recrystallized during the metamorphism. Chloritized, detrital biotite has been observed in some thin sections.

There is no cement in the sandstones under study. The space between the grains larger than 0.03 mm is filled with recrystallized matrix that often interfingers with individual grains of the framework. Individual grains, particularly in fine-grained sandstones, not uncommonly happen to contact (e.g. Pl. IV, Fig. 1). It is, however, more usual for the grains to „float" in the matrix (e.g. Pl. III, Figs. 1—4; Pl. IV, Figs. 2, 3, 4).

The matrix consists fundamentally of sericite and quartz, but a small amount of opaque minerals (pyrite, iron oxides) is always present. Chlorite, if any, appears in insignificant quantity. The occurrences of carbonates (mainly siderite) are irregular. There are cases when they do not appear at all, but there are others when they constitute some, exceptionally several, per cent of the matrix. In black sandstones graphite has been noted in the matrix.

To characterize the investigated sandstones, C. M. Gilbert's classification (H. Williams, F. J. Turner, C. M. Gilbert, 1954) as modified by R. H. Dott (1964) was adopted. All the sandstones under study contain more than 10% (24—73%) of the matrix, to they should be regarded as wackes. In Dott's classification triangle (Fig. 3) the projection points concentrate in the field of quartz wackes, in the upper part of the field of lithic wackes, and in the field of feldspathic wackes[3]. The rocks are then characterized by textural immaturity (high matrix content) and simultaneous mature mineral composition (quartz wackes). Quartz wackes in the region under study are characteristic of shaly flysch.

The individual varieties of wackes are presented on photographs (Pl. III and IV). For simplicity's sake, in the following sections these rocks will be referred to as greywackes (metagreywackes).

Granulometric composition

Size measurements of grains of the detrital framework were made for 22 out of 24 samples specified in the classification triangle (Fig. 3).

Median diameter (Md) ranges from 0.056 to 1.319 mm, and the value of sorting coefficient (So) from 1.43 to 2.50. In one specimen So amounts to 4.15. Sorting coefficients from 1.43 to 2.5 testify to a high degree of sorting.

Considering the interfingering of the detrital framework grains with the matrix, the degree of grain roundness has not been determined. It can be noticed, however, that roundness of grains generally tends to increase with an increase in grain diameter. Fine-grained sand fraction consists, as a rule, of angular and subangular grains (Pl. IV, Figs. 1, 2). Coarse and very coarse sand grains are very often rounded (Pl. III, Figs. 3, 4; Pl. IV, Fig. 3) and so are some slate fragments, whereas feldspars are usually angular or subangular (cf. Pl. IV, Fig. 4).

Source rocks of terrigenous material

Heavy minerals of the metagreywackes in question are represented predominantly by zircon that is usually more or less rounded. Other heavy minerals are rutile, tourmaline (rounded), leucoxene, titanite and amphibole.

Compared with the heavy mineral associations characteristic of the principal kinds of source rocks that have been distinguished by G. Feo-Codecido (1956) and F. J. Pettijohn et al. (1972), the minerals occurring in the rocks under study belong to two associations:

1. Leucoxene, rutile, tourmaline (rounded grains), zircon (rounded grains) belong to the association characteristic of reworked sedimentary rocks.

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[3] F. J. Pettijohn, P. E. Potter, R. Siever (1972) present a modification of Dott's classification. According to these authors, quartz wackes containing less than 95% of quartz should be included among lithic wackes, whereas feldspathic wackes should be called arkosic wackes (cf. Fig. 3).

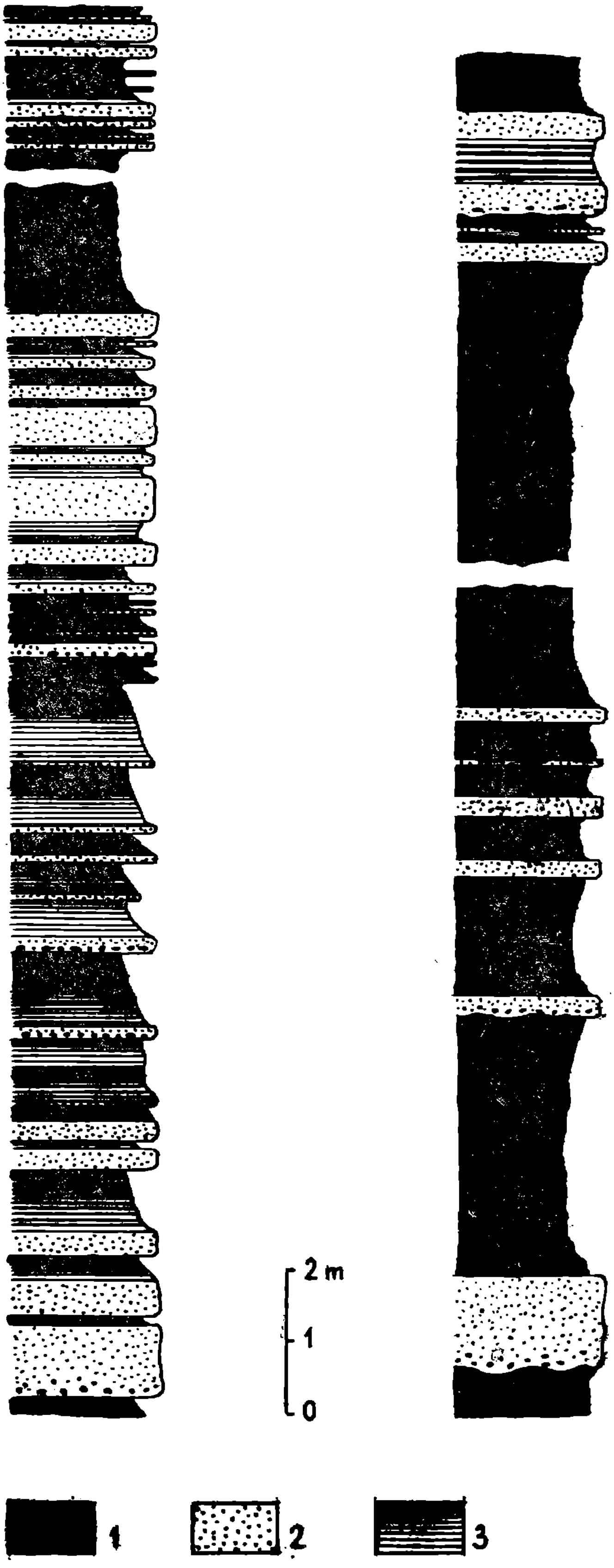

Fig. 4. Profiles of the normal flysch exposed in the valley of the Kamiennik stream. 1 — layers of slate; 2 — layers of metagreywackes; 3 — laminated layers

Fig. 4. Profile fliszu normalnego odsłonięte w dolinie potoku Kamiennik. 1 — ławice łupkowe; 2 — ławice metaszarogłazowe; 3 — ławice laminowane

2. Biotite, muscovite, rutile, titanite and zircon make up the association characteristic of acid igneous rocks.

From the mineral composition of rock fragments, metagreywackes and the heavy mineral association it may be inferred that the material of the rocks under study is derived from the source area made up of reworked sedimentary rocks that very likely underwent low-grade metamorphism and of acid igneous rocks, those of volcanic origin being included.

SEDIMENTARY STRUCTURES

The characteristic feature of the metasedimentary series in the area under study is the occurrence of alternate layers of metagreywackes and slates (Fig. 4; Pl. VI, Figs. 1—3). Greywacke layers have, as a rule, sharply defined bottom surface. Towards the top they pass through laminated portions into slate layers. Metagreywacke layers often show graded bedding.

The effect of tectonics and metamorphism on the sedimentary structures

Compared with unmetamorphosed flysch area of Alpine tectonics, as e.g. the Carpathian flysch, the metasedimentary Kaczawa complex shows a different tectonics. The essential features of this area are an intensive development of metamorphic cleavage and an abundance of other planar and linear mesoscopic structures formed during the successive stages of tectonic deformations. Tightly compressed folds are due to folding under metamorphic conditions. These processes have also changed the internal structure of the rocks.

All these factors make the identification of the primary sedimentary structures extremely difficult or simply impossible. Sedimentary structures are in the majority of cases obliterated by foliation and cleavage. This becomes manifest particularly in slates, in which the bedding can be ascertained only on polished sections. Foliation is often oblique to the bedding.

In coarse-grained greywackes the changes are confined to recrystallization of the matrix. The recrystallization may be directional (Pl. II, Figs. 1, 2, 3). In fine-grained beds re-orientation of sericite and, in some cases, of quartz takes place (Pl. II, Fig. 1; Pl. V, Figs. 1, 2). Fundamental changes resulting from metamorphism become manifest in slates. Sometimes even selective migration of quartz is visible, which initiates the process leading to the development of new, metamorphic lamination (Figs. 5, 6). The intensity of recrystallization and quartz migration is variable and remains most likely in intimate association with the position in the fold. In the investigated cases the beginning of the material selection takes place in planes parallel to the axial planes of folds, and this seems to be a general tendency (cf. P. F. Williams, 1972).

Generally speaking; relatively well preserved are internal (sensu S. Dżułyński and E. K. Walton, 1965) sedimentary structures. External structures (sole markings) are extremely rare; moreover, their state of preservation is very bad.

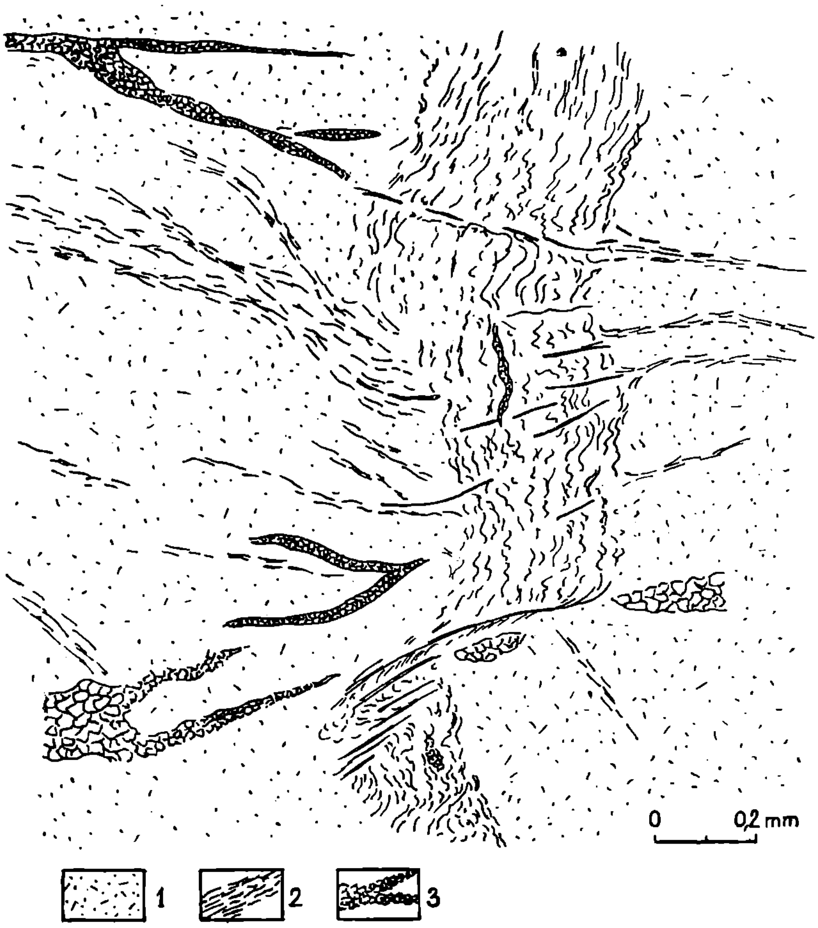

Fig. 5. Sericite-quartz slate seen under the microscope. Primary lamination is in vertical position secondary (metamorphic) lamination — horizontal. 1 — sericite-quartz groundmass; 2 — recrystallized sericite; 3 — recrystallized quartz

Fig. 5. Łupek serycytowo-kwarcowy (rysunek na podstawie obrazu mikroskopowego). W kierunku pionowym przebiega laminacja pierwotna, laminacja wtórna (metamorficzna) zaznacza się w kierunku poziomym. 1 — masa serycytowo-kwarcowa; 2 — ukierunkowany, zrekrystalizowany serycyt; 3 — zrekrystalizowany kwarc

In recent years, several papers dealing with sedimentary structures in metamorphic rocks have been published (e.g. C. A. Hopson, 1964; S. Gavelin, R. V. Russel, 1967; A. Siedlecka, 1967; G. W. Fischer, 1970; R. G. Walker, F. J. Pettijohn, 1971; G. J. Dunbar, G. J. H. McCall, 1971). Metamorphic rocks in which sedimentary structures have been preserved belong to epi- and mesozone. It seems that in low-grade regional metamorphism the state of preservation of

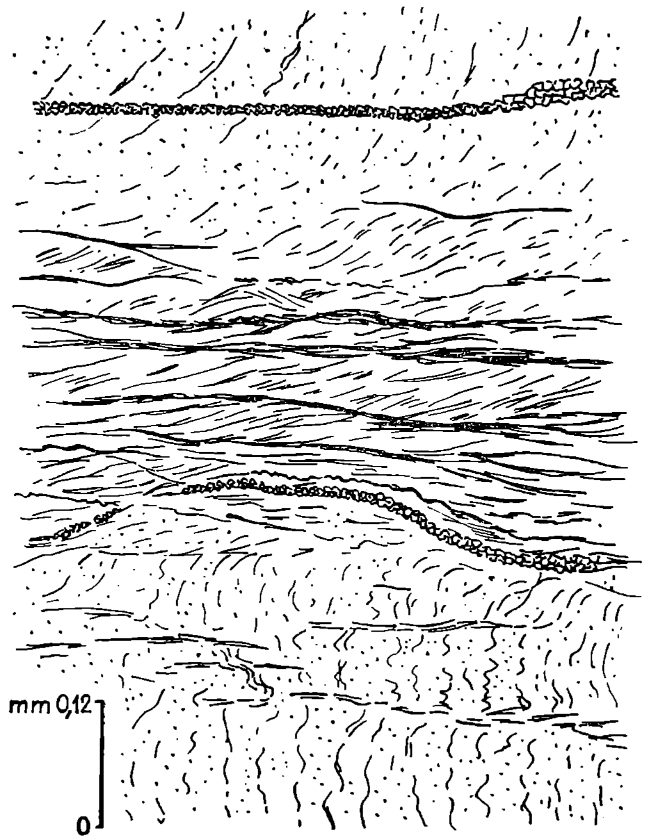

Fig. 6. Hinge zone of a fold in quartz-sericite slate seen under the microscope. Recrystallization of sericite and selective migration of quartz is parallel to axial plane of fold laying horizontally. For explanations see fig. 5

Fig. 6. Przegubowa partia fałdu w łupku kwarcowo-serycytowym (rysunek na podstawie obrazu mikroskopowego). W kierunku poziomym, równoległym do powierzchni osiowej fałdu przebiega rekrystalizacja serycytu oraz selektywna migracja kwarcu. Objaśnienia jak przy fig. 5

sedimentary structures depends on the intensity of tectonic movements rather than on metamorphic processes.

Bedding

In the area under study graded bedding, parallel and cross lamination have been ascertained.

Thickness of the individual metagreywacke beds varies from 1 cm to over 1 m (cf. Pl. VI, Figs. 1, 2, 3). Most numerous are strata 10—20 cm thick (cf. Fig. 7). Metagreywacke layers often reveal graded bedding (cf. Pl. VII, Figs. 1, 6), which shows best in those more than 20 cm thick.

In fine-grained layers grading is sometimes visible due to the presence of slate fragments (Pl. VII, Figs. 2, 3). It should be noted that redeposited slate fragments may be also randomly distributed throughout the profile of the bed.

Graded bedding, though hard to detect, also appears in thin, some centimetres thick, strata made up of fine silty material. Grading becomes conspicuous only on polished surfaces.

Massive beds without grading are often encountered. In general, these are fine-grained, thin-layered and well sorted metagreywackes.

Some thin, very fine-grained beds have both the bottom and top surfaces sharply defined. Their internal structure is completely obliterated by recrystallization, so that only homogeneous quartz mosaic is visible under the microscope (cf. Pl. I, Fig. 3). These beds are very likely a recrystallized siliceous sediment.

Parallel lamination is common all over the investigated area. The sandy and silty laminae are light, the shaly ones dark. Thickness of the laminated beds ranges from some to several cm (cf. Pl. VI, Fig. 2).

Many cases of grain gradation have been noted. This finds expression in the decreased thickness of the light laminae and increased intervals between them towards the top (Pl. VIII, Fig. 5).

Sporadically, lateral passing of the parallel into cross lamination may be observed (cf. Pl. VIII, Fig. 3) as well as lateral changes in the thickness of the laminae.

In outcrops cross lamination is hard to detect because it is masked by cleavage, yet the occurrence of low-angle cross stratification, developed on a small scale, is unquestionable (cf. Pl. VIII, Figs. 1—2). Occasionally lenticular forms appear, within which ripple-load convolutions have been observed (cf. S. Dżułyński and A. Ślączka, 1965).

The above-mentioned sedimentary structures occur in a definite, recurring sequence that was described by A. H. Bouma (1962) in the Maritime Alps flysch. Yet complete sequences of sedimentary structures are hardly ever encountered. In the normal flysch most frequent are top truncated sequences Ta-b as well as those with cut out base Td-e (cf. A. H. Bouma, 1962), the latter predominating in the shaly flysch.

Slump structures

In some outcrops there appear sedimentary structures that imply deformations penecontemporaneous with sedimentation. They have been discussed in an earlier paper by the present author (Z. Baranowski, 1971).

Worthy of note is the presence of a fragment of acid tuffite coated with a rim of black slate that is probably a consequence of the fragment having rolled along the clayey bottom. In all likelihood, this fragment is of exotic origin since rocks of this kind have not been so far recorded in the Kaczawa Mountains.

Sole markings

The bottom surfaces of metagreywacke layers are often uneven. Yet, only exceptionally sole markings (Pl. VI, Fig. 4) can be determined more precisely as flute casts (see e.g. S. Dżułyński, J. E. Sanders, 1962; S. Dżułyński and E. K. Walton, 1965).

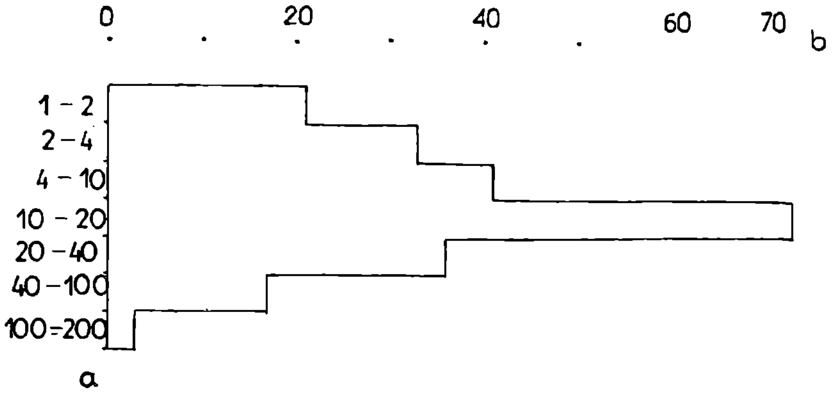

Fig. 7. Histogram presenting thickness of metagreywacke beds outcropping in the valley of the Kamiennik stream. a — thickness of beds in cm; b — number of beds

Fig. 7. Histogram miąższości warstw metaszarogłazów z odsłonięć w dolinie potoku Kamiennik. a — miąższość warstw w cm; b — ilość warstw

On the top surfaces of metagreywacke layers no sedimentary structures have been found.

Direction of sedimentary structures

A dozen or so measurements of cross lamination made in the eastern part of the area under study give a scatter from SE to NW. Although the number of observations is insufficient, these directions correspond to the distribution of the lithofacies (cf. Fig. 2).

It can be then assumed that, in relation to the present position of directional structures, the transport of material during sedimentation proceeded from the east or north-east to the west or south-west.

SEDIMENTARY ENVIRONMENT

Palaeontologic material affords most of the data on the sedimentary environment of the series under study. Unfortunately it is rather scant and its state of preservation is very bad, making sometimes any determinations impossible.

In dark-grey and blue-grey sericite slates, recrystallized Foraminifera remains have been found. One of the best preserved specimens is shown on Pl. I, Fig. 4. The remains have not been so far studied in detail nevertheless they proove the marine origine of slates.

The presence of conodonts implies also the marine sedimentary environment. Conodonts appear both in shallow and deep-water sediments. Their most numerous occurrences have been recorded in the areas of submarine rises with an insignificant supply of terrigenous sediments and in fine-grained black shales accumulating in deeper basins (cf. M. Lindström, 1964). According to K. J. Müller (1956), the zone occupied by corals, crinoids and brachiopods seems to be an environment unfavourable for the growth of conodonts.

In some sites graptolite fauna has been found in black and black-grey graphite slates. The graptolites belong to the order Graptoloidea. Their majority is known from black, fine-grained deep-water sediments. There is no palaeontologic evidence, on the other hand, of the pelagic character of slates free of graphitic pigment. It should be assumed that, as in other flysch areas, a part of slates without sedimentary structures represents pelagic sediments.

Graptolite slates occur together with black siliceous slates and phtanites, forming thin intercalations in them.

In fact, in phtanites, which are considered to be the metamorphosed radiolarian cherts, recrystallized Radiolaria remains have been found (Pl. 1, Figs. 1, 2; see also J. Jerzmański, 1965; E. Zimmermann, B. Kühn, 1936). Similar remains have been encountered in light siliceous slates (Pl. 1, Fig. 3). Radiolarian cherts are commonly regarded as deep sea pelagic sediment (see e.g. Z. Sujkowski, 1933, 1937; R. C. Moor, 1954; H. R. Grunau, 1965).

The presence of graptolite slates and radiolarian cherts implies the deep-water character of the sediment, and so does the lack of sedimentary structures characteristic of shallow-water deposits. Nowhere has been tabular, large-scale cross bedding ascertained, nor have the ripple marks on the top surfaces of metagreywacke layers, etc.

Dark, as a rule, colour of the sediment (blue-grey, grey-greenish, grey, black) as well as the abundance of pyrite and siderite indicate that reduction conditions prevailed in the sedimentary basin. Authigenic pyrite is common both in slates and metagreywackes; moreover, pyrite laminae some millimetres thick and small concretions are encountered. Siderite is still more common; it appears in the form of single crystals and irregular granular aggregations. Sometimes it forms concretions and flat intercalations within the slates.

Basing on the data obtained it may be stated that the discussed series was deposited in a deep, geosynclinal basin, on the bottom of which reduction or nearing euxinic conditions prevailed.

CONCLUDING REMARKS

Flysch structures have been described by several authors (cf. e.g. S. Dżułyński, M. Książkiewicz, Ph. H. Kuenen, 1959; A. H. Bouma, 1962; S. Dżułyński and A. J. Smith, 1964). The features discussed in the foregoing sections demonstrate that there is a substantial similarity between the metasedimentary formation under study and the flysch sequences (cf. S. Dżułyński and A. J. Smith, 1964). On that basis the author presumes that this formation represents metamorphosed flysch rocks.

Compared with the set of diagnostic features suggested for flysch (cf. S. Dżułyński and A. J. Smith, 1964), the investigated metasedimentary formation differs in that a considerable submarine volcanism (greenschist formation) is present. As mentioned earlier in this paper, there is a possibility for greenschists to interfinger with the metasedimentary formation. Cases are known however that basic volcanism lasted over a longer period of the geosyncline development, and that volcanism was synchronous with flysch (cf. Z. Jovanović, 1965; J. Don, 1970, 1971).

Considering the proportions of metagreywackes to slates the whole formation should be assigned to the subfacies of the shaly flysch lithofacies. However, to emphasize the conspicuous difference in the amount of sandy material in the two parts of the area, its division seems to be pertinent. Therefore the eastern part, where the content of sandy material is 50—15%, was arbitrarily assigned to the subfacies of normal flysch and the western part to that of shaly flysch.

Zone of interfingering of normal with shaly flysch may also reflect vertical changes in the character of sedimentation. This is supported by stratigraphic data since shaly flysch (together with phtanites, siliceous and graphite slates) at least partly belongs to the Silurian, whereas the fauna of the only site in the normal flysch is of the Ordovician age. The solution of this problem requires further investigations both in the area discussed and in the neighbouring regions.

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STRESZCZENIE

Jednostka tektoniczna Rzeszówek-Jakuszowa w północnej części Gór Kaczawskich zbudowana jest ze skał osadowych i wulkanicznych, silnie sfałdowanych i zmetamorfizowanych w facji zieleńcowej. Formacja metaosadowa (łupki, metalidyty, kwarcyty, metaszarogłazy) jest wieku ordowicko-sylurskiego, natomiast wiek formacji wulkanicznej (zieleńców), zaliczanej do górnego kambru, jak również pozycja tektoniczna tej formacji nie są jasne.

Badana formacja metaosadowa zbudowana jest głównie z łupków. Są to na ogół ciemne, szaroczarne, szare i szarozielone łupki serycytowe i serycytowo-chlorytowe, często laminowane materiałem mułowcowym i piaszczystym, oraz łupki grafitowe. Łupkom grafitowym towarzyszą zwykle lidyty, uważane za przeobrażone radiolaryty. Obok czarnych lidytów w badanym obszarze występują jasne, kilkucentymetrowej miąższości warstwy kwarcytów, których struktura jest analogiczna do lidytów. Lidyty i jasne kwarcyty zaliczono do łupków krzemionkowych. Metapiaskowce (metaszarogłazy, kwarcyty — w tym tzw. kwarcyty z Tarczyna, „Kuttenbergquarzit”) wykazują strukturę i teksturę charakterystyczną dla wak. Według klasyfikacji Dotta (1964) są to waki lityczne, skaleniowe i kwarcowe. Skład mineralny szkieletu ziarnowego, rodzaj okruchów skalnych i zespół minerałów ciężkich pozwala wnioskować, że materiał metapiaskowców pochodzi z obszaru źródłowego zbudowanego z przerobionych skał osadowych, być może w niskim stopniu zmetamorfizowanych, oraz z kwaśnych skał magmowych, w tym również wulkanicznych.

Procesy tektoniczne i metamorficzne spowodowały, że zarówno struktura skał, jak i struktury sedymentacyjne uległy w znacznym stopniu zatarciu lub zniszczeniu. Jednak zachowały się pewne cechy, pozwalające na próbę odtworzenia pierwotnego charakteru badanej formacji metaosadowej.

Zasadniczą cechą badanej formacji jest naprzemianległość ławic metaszarogłazowych i łupkowych. Warstwy piaszczyste na ogół mają ostro zarysowane powierzchnie spągowe, natomiast powierzchnie stropowe stanowią przejście do łupków. Warstwy piaszczyste, a także mułowcowe często są warstwowane frakcjonalnie. Frakcjonalność zaznacza się również w laminowanych partiach łupków. Warstwowanie i laminacja równoległa należą do najczęściej występujących struktur, natomiast znacznie rzadziej obserwuje się warstwowanie przekątne. W obserwowanych przypadkach zawsze jest to warstwowanie przekątne rozwinięte na małą skalę. Powierzchnie spągowe ławic metaszarogłazowych bardzo często są nierówne, lecz tylko w wyjątkowych przypadkach można stwierdzić, że są to niewątpliwie hieroglify. W kilku odsłonięciach występują struktury wskazujące na podmorskie osuwisko oraz spływy osadu. Wymienione cechy są charakterystyczne dla osadów, powstałych w wyniku depozycji prądów zawiesinowych. Kierunek transportu materiału przebiegał przypuszczalnie z E lub NE na W lub SW.

Charakter zachowanej fauny, charakter zespołu skalnego, barwa osadu, rodzaj minarałów akcesorycznych pozwalają wnioskować, że sedymentacja omawianej formacji odbywała się w głębokim basenie, na którego dnie panowały warunki redukcyjne lub zbliżone do euksynicznych.

Badana formacja wykazuje wiele cech charakterystycznych dla facji fliszowej. W porównaniu z zespołem cech diagnostycznych dla fliszu różni się ona jedynie obecnością kontaktujących z nią zasadowych law (zieleńców). Jednak znane są przypadki istnienia zasadowego wulkanizmu synchronicznego z fliszem. Biorąc więc pod uwagę morski, eugeosynklinalny, głębokowodny charakter osadów, ich pokaźną miąższość oraz zachowany zespół struktur sedymentacyjnych można stwierdzić, że omawiana epimetamorficzna formacja należała pierwotnie do facji fliszowej.

W obrębie omawianego obszaru wyraźnie zaznaczają się różnice litologiczne. W części wschodniej metaszarogłazy stanowią od 15 do 50%, na pozostałą ilość składają się łupki i w bardzo niewielkiej części metalidyty. W części zachodniej warstwy metaszarogłazów pojawiają się sporadycznie, a wzrasta ilość warstw mułowcowych, warstwy piaszczyste i mułowcowe stanowią mniej niż 15% ogólnej ilości skał. Znaczną część wśród nich stanowią metalidyty i metałupki krzemionkowe. Na podstawie tych różnic obszar wschodni, o wyższej zawartości materiału piaszczystego zaliczono umownie do subfacji fliszu normalnego, obszar zachodni zaś do subfacji fliszu łupkowego. Litologiczne zróżnicowanie w badanym obszarze może również odzwierciedlać zmiany charakteru sedymentacji w kierunku pionowym. Co najmniej część fliszu łupkowego należy do syluru, zaś fauna konodontowa jedynego, jak dotąd, stanowiska we fliszu normalnym jest wieku ordowickiego.

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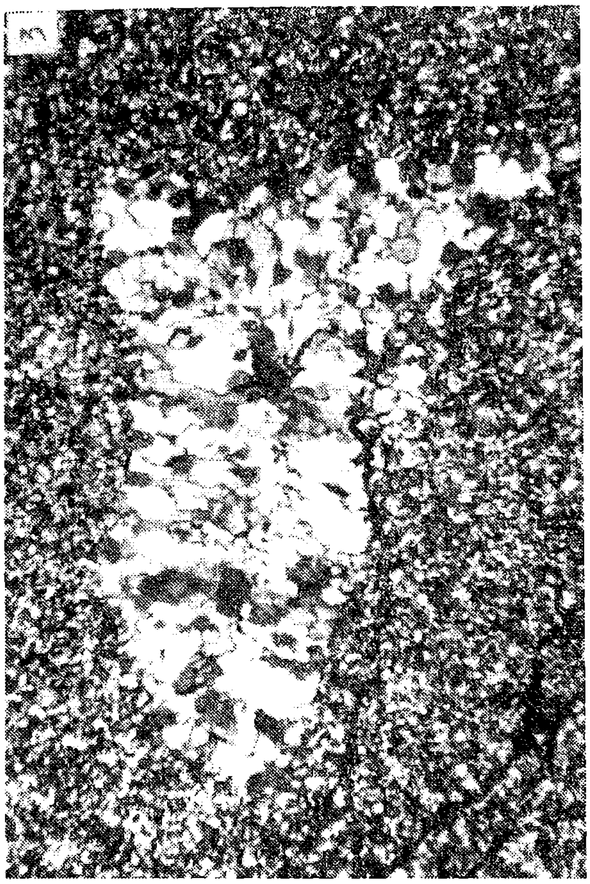

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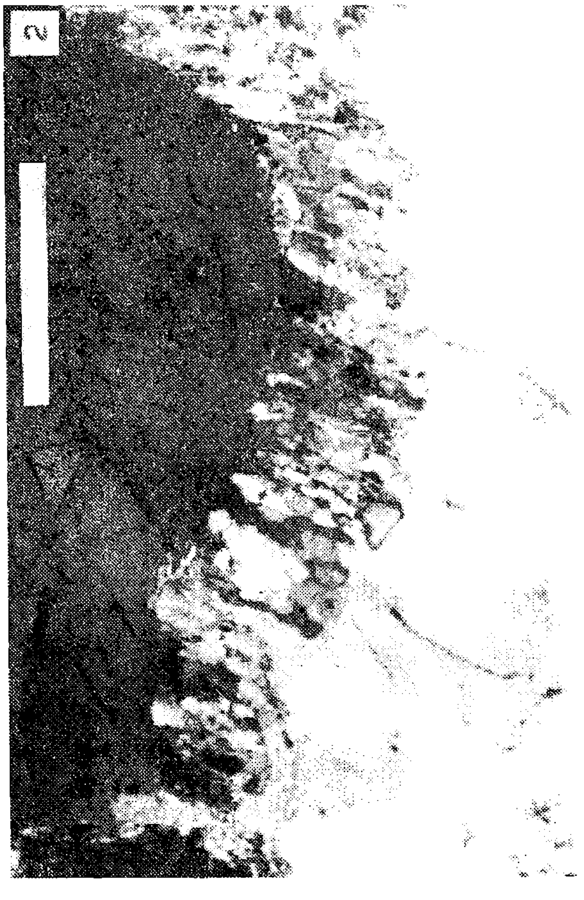
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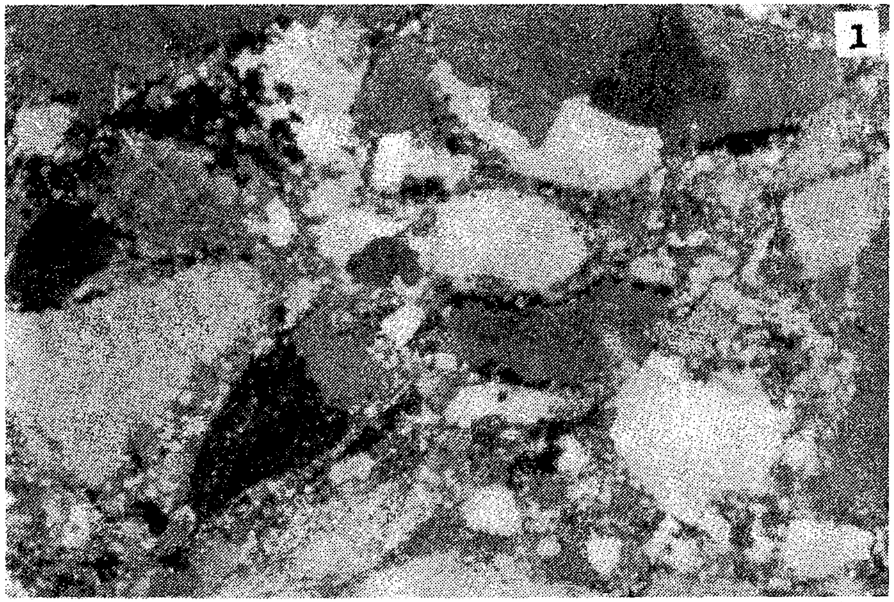
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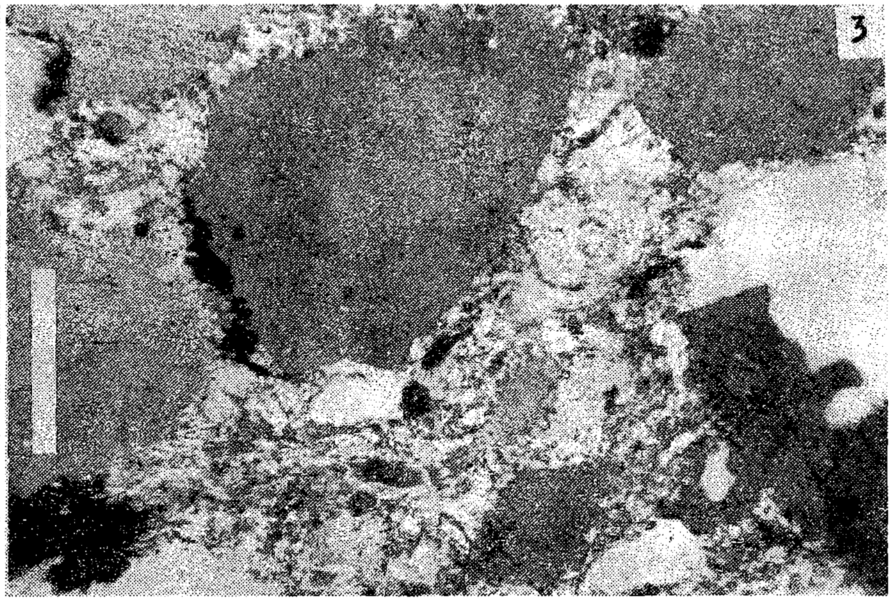
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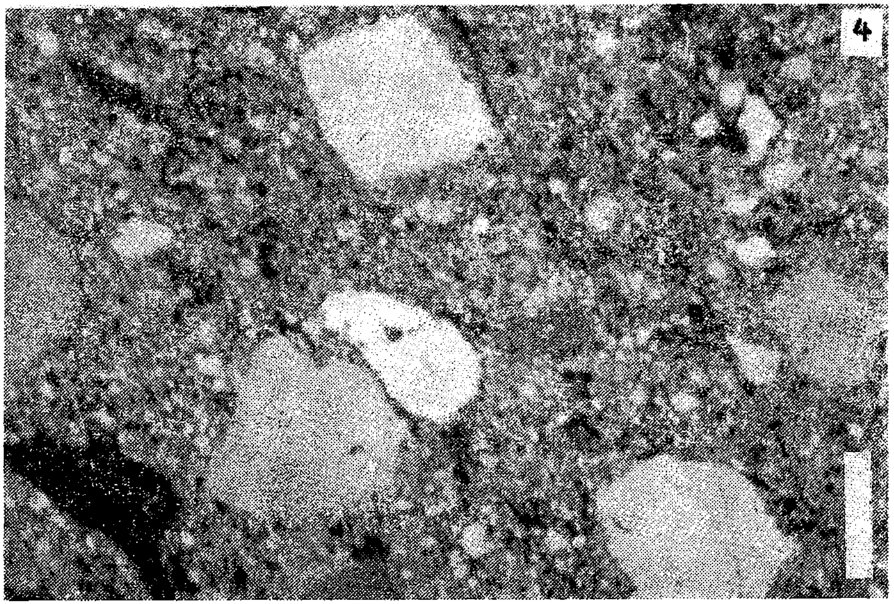
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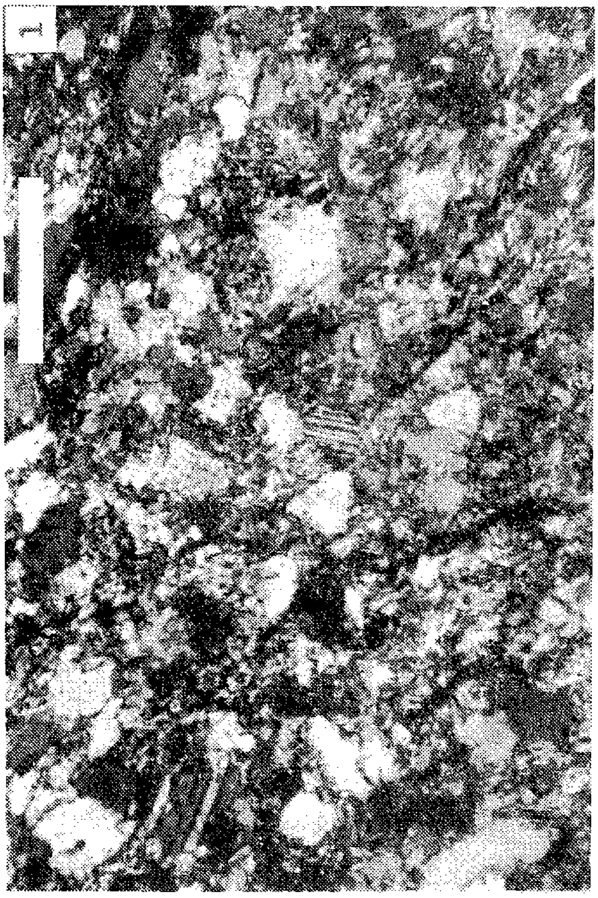
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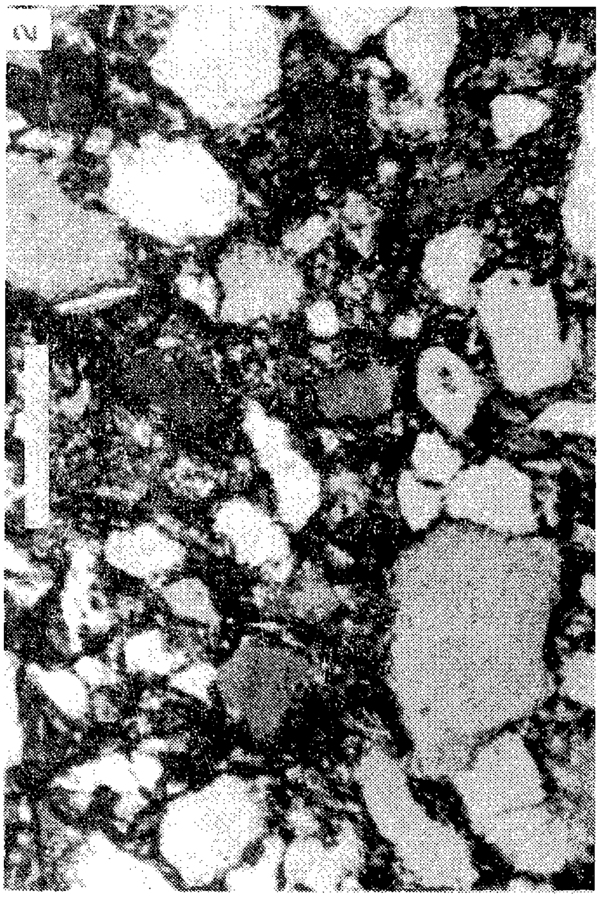
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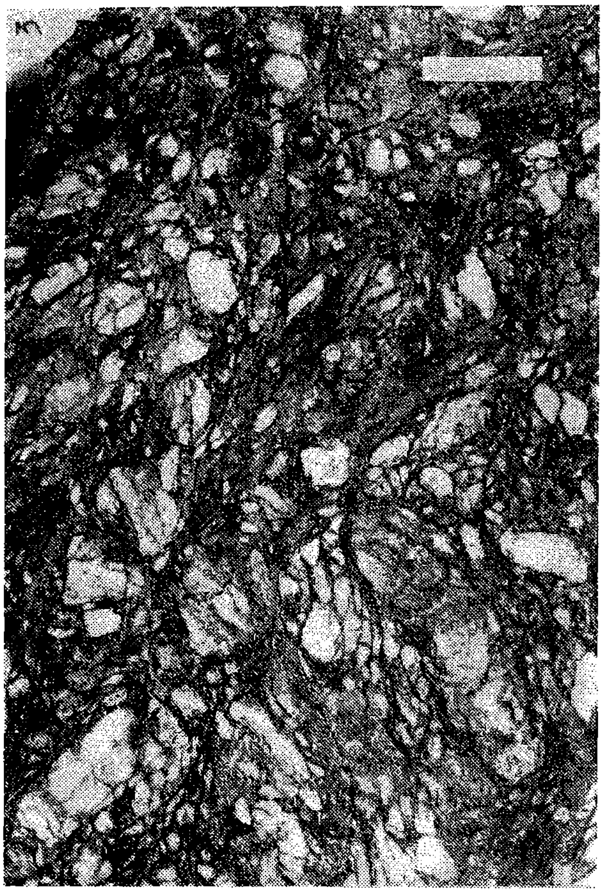
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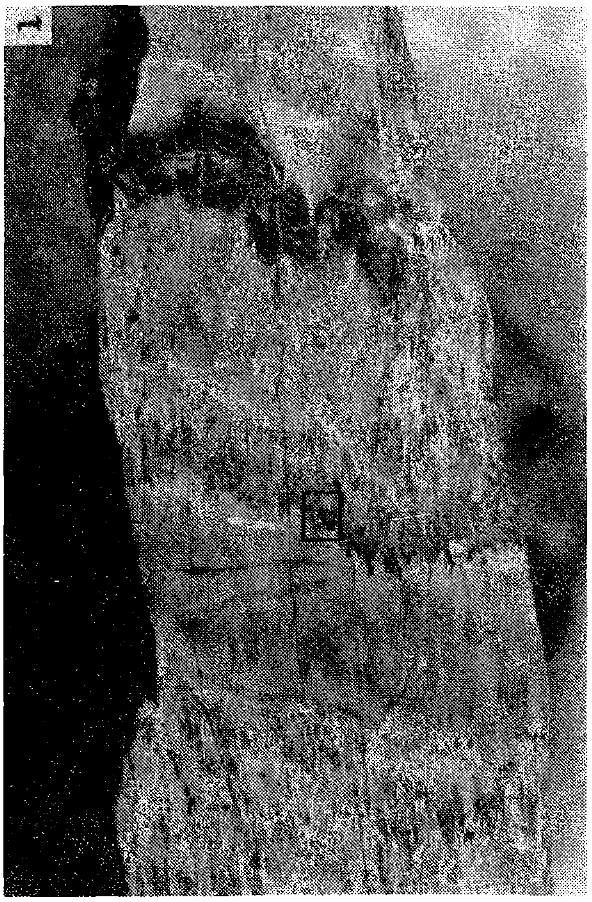
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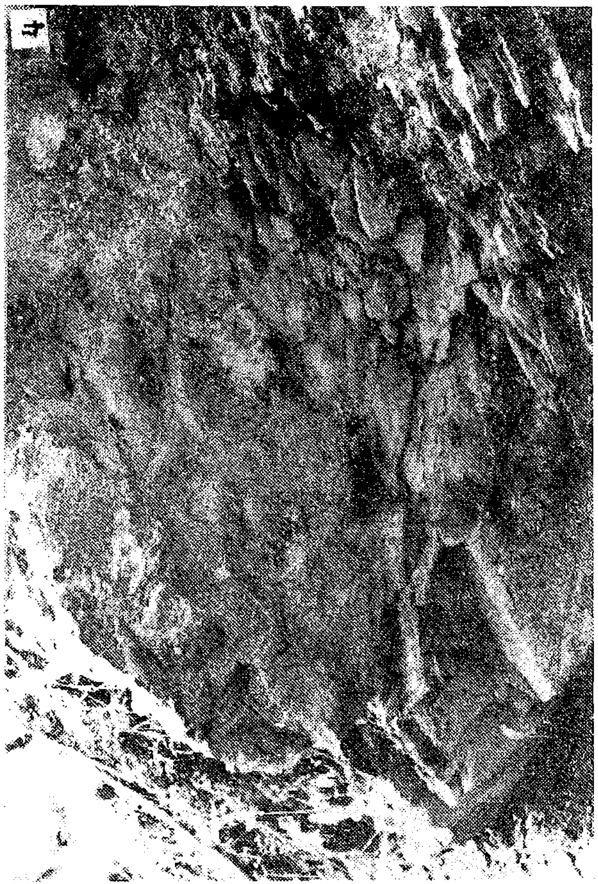

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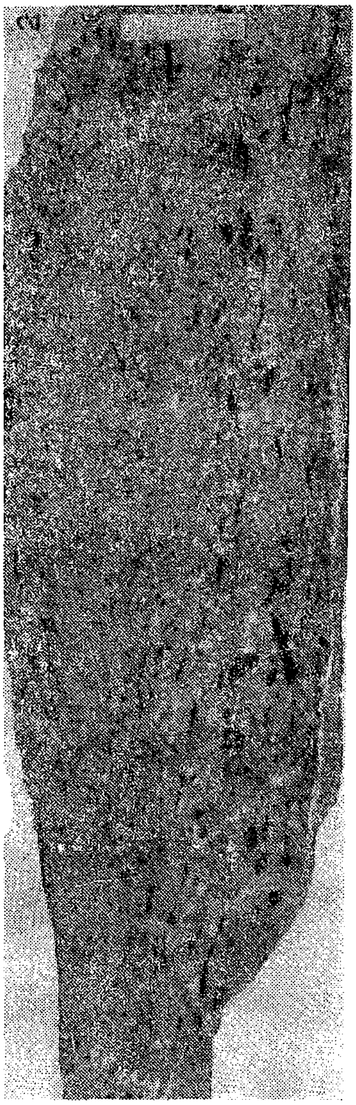
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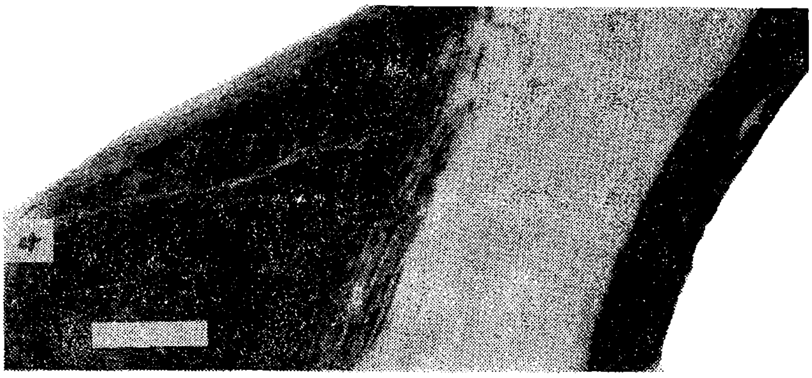
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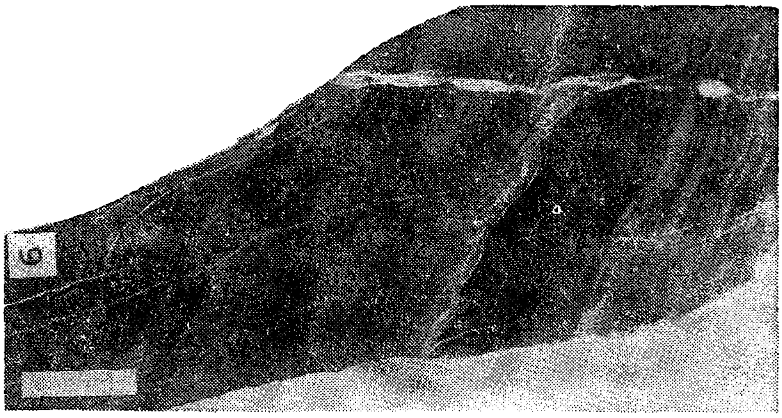
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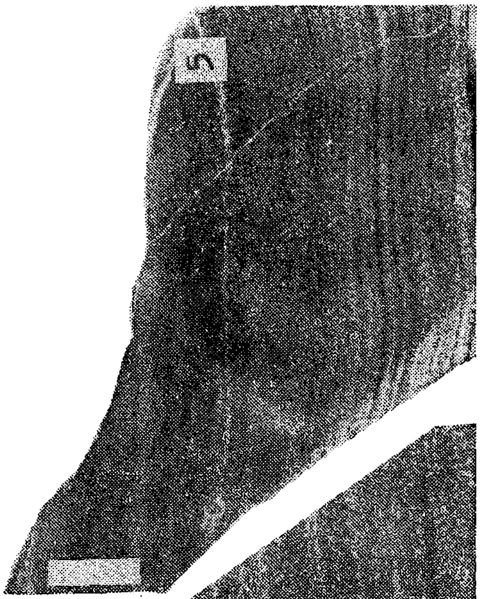
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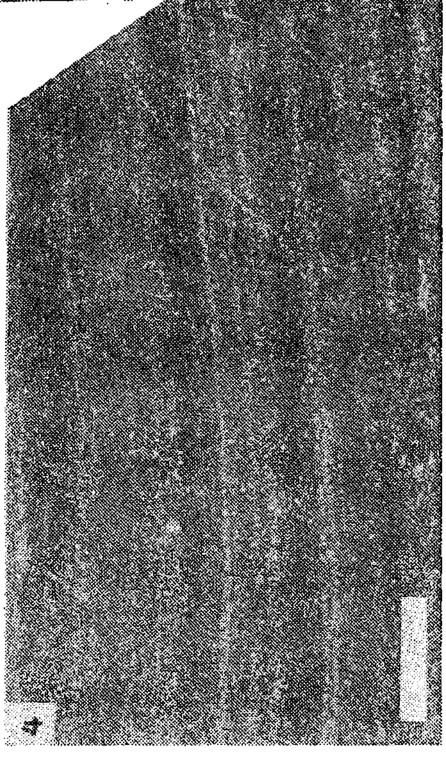
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EXPLANATION OF PLATES

OBJAŚNIENIA TABLIC

Plate — Tablica I

Fig. 1. Recrystallized Radiolaria remains in phtanite, crossed nicols
Fig. 1. Zrekrystalizowane szczątki radiolarii w ftanicie, nikole skrzyżowane
Fig. 2. The same. Visible dark graphitic pigment, parallel nicols
Fig. 2. Ten sam obraz. Widoczny ciemny pigment grafitowy, nikole równoległe
Fig. 3. Recrystallized Radiolaria specimen in light siliceous slate. Crossed nicols
Fig. 3. Zrekrystalizowany okaz radiolarii w jasnym łupku krzemionkowym. Nikole skrzyżowane
Fig. 4. Section of a recrystallized foraminifera. Partly crossed nicols
Fig. 4. Przekrój zrekrystalizowanej otwornicy. Nikole częściowo skrzyżowane
All scales correspond to 0,2 mm.
Wielkość podziałki na wszystkich zdjęciach wynosi 0,2 mm.

Plate — Tablica II

Fig. 1. Directional recrystallization of matrix between two quartz grains. Grain boundaries interfinger with recrystallized quartz of the matrix. Crossed nicols
Fig. 1. Kierunkowa rekrystalizacja kwarcu tworząca laminację metamorficzną. W lewym dolnym rogu żyłka kwarcowa. Nikole skrzyżowane
Fig. 2. Intergrowth of two quartz grains. Crossed nicols
Fig. 2. Rekrystalizacyjny zrost dwu ziarn kwarcu. Nikole skrzyżowane
Fig. 3. Directional recrystallization of quartz-sericite matrix between quartz grains. In the right-hand lower corner distinct interfingering of quartz grains with the matrix is visible. Crossed nicols
Fig. 3. Kierunkowa rekrystalizacja serycytowo-kwarcowego tła między ziarnami kwarcu. W prawym dolnym rogu dobrze widoczne zazębianie się ziarn kwarcu z tłem. Nikole skrzyżowane
Fig. 4. Recrystallization of matrix blurring the boundaries between the detrital framework and the matrix. Crossed nicols
Fig. 4. Rekrystalizacja tła zacierająca granice między szkieletem ziarnowym a tłem skalnym. Nikole skrzyżowane
All scales correspond to 0,2 mm.
Wielkość podziałki na wszystkich zdjęciach wynosi 0,2 mm.

Plate — Tablica III

Fig. 1. Lithic wacke. In the lower part visible slate fragments (graphite slate — dark, sericite slate — light). Crossed nicols. Scale corresponds to 0,5 mm
Fig. 1. Waka lityczna. W dolnej części widoczne fragmenty łupków (ciemny, grafitowy i jasny, serycytowy). Nikole skrzyżowane. Wielkość podziałki 0,5 mm
Fig. 2. Lithic wacke, light quartz grains, twinned plagioclase and slate fragments. Crossed nicols. Scale corresponds to 0,2 mm
Fig. 2. Waka lityczna, jasne ziarna kwarcu, zbliźniaczone plagioklazy i fragmenty łupków. Nikole skrzyżowane. Wielkość podziałki 0,2 mm
Fig. 3. Quartz wacke, rounded quartz grains in recrystallized matrix with carbonates (light gray flakes). Crossed nicols. Scale corresponds to 0,2 mm
Fig. 3. Waka kwarcowa (tzw. kwarcyt z Tarczyna). Obtoczone ziarna kwarcu

w zrekrystalizowanym spoiwie z węglanami (skupienia jasnoszare). Nikole skrzyżowane. Wielkość podziałki 0,2 mm

Fig. 4. Lithic wacke. Quartz grains and slate fragments "floating" in silty matrix. Crossed nicols. Scales corresponds to 0,5 mm

Fig. 4. Waka lityczna. Ziarna kwarcu i okruchy łupków „pływające" w mułowcowym tle. Nikole skrzyżowane. Wielkość podziałki 0.5 mm

Plate — Tablica IV

Fig. 1. Fine-grained feldspathic wacke. Crossed nicols

Fig. 1. Drobnoziarnista waka skaleniowa. Nikole skrzyżowane

Fig. 2. Quartz wacke with graphite matrix. Crossed nicols

Fig. 2. Waka kwarcowa z grafitowym tłem skalnym. Nikole skrzyżowane

Fig. 3. Coarse-grained quartz wacke. In the central part a mosaic quartz grain. Crossed nicols

Fig. 3. Waka kwarcowa gruboziarnista. W części środkowej ziarno kwarcu mozaikowe. Nikole skrzyżowane

Fig. 4. Feldspathic wacke, feldspars partly sericitized. In the central part visible chloritized biotite. Crossed nicols

Fig. 4. Waka skaleniowa, skalenie częściowo zserycytyzowane. W części środkowej widoczny schlorytyzowany biotyt. Nikole skrzyżowane

All scales correspond to 0,2 mm.

Wielkość podziałki na wszystkich zdjęciach wynosi 0,2 mm.

Plate — Tablica V

Fig. 1. Cleavage oblique to the bedding. Scale correspond to 1 cm

Fig. 1. Złupkowanie skośne do warstwowania. Wielkość podziałki wynosi 1 cm

Fig. 2. Microscopic image of the fragment shown on Fig. 1. The boundary of the bed runs obliquely, from the top to the bottom. Sericite and quartz display horizontal orientation, concordant with the cleavage. Crossed nicols. Scale corresponds to 0,2 mm

Fig. 2. Obraz mikroskopowy fragmentu zamieszczonego na fig. 1. Skośnie, od góry do dołu przebiega granica warstw, serycyt i kwarc zorientowane są poziomo, zgodnie ze złupkowaniem. Nikole skrzyżowane. Wielkość podziałki 0,2 mm

Fig. 3. Slump breccia consisting of sandy fragments disseminated in the shaly mass. Scale corresponds to 1 cm

Fig. 3. Brekcja osuwiskowa złożona z fragmentów piaszczystych rozrzuconych w masie łupkowej. Wielkość podziałki 1 cm

Fig. 4. Slump breccia consisting of sandy fragments (grey) and single quartz grains (white) embedded in the shally mass. Scale corresponds to 0,5 cm
0,5 cm

Fig. 4. Brekcja osuwiskowa złożona z fragmentów piaszczystych (szare) i pojedynczych ziarn kwarcu (białe) tkwiących w masie łupkowej. Wielkość podziałki 0,5 cm

Plate — Tablica VI

Fig. 1. Alternate beds of metagreywackes and slates. Normal flysch

Fig. 1. Naprzemianległe warstwy metaszarogłazów i łupków. Flisz normalny

Fig. 2. Alternate beds of metagreywackes and slates. In the upper part visible lamination. Normal flysch

Fig. 2. Naprzemianległe warstwy metaszarogłazów i łupków, w górnej części widoczna laminacja. Flisz normalny

Fig. 3. Sharply defined bottom surface of the metagreywacke layer about 1 m thick

Fig. 3. Ostro zarysowana powierzchnia spągowa ławicy metaszarogłazu o miąższości ok. 1 m

Fig. 4. Bottom surface of the layer from fig. 3 with visible load structures

Fig. 4. Powierzchnia spągowa ławicy z fig. 3, z widocznymi pogrązami

Plate — Tablica VII

Fig. 1. Metagreywacke layer showing graded bedding

Fig. 1. Warstwa metaszarogłazu warstwowana frakcjonalnie

Fig. 2. Bottom part of a metagreywacke layer. Graded bedding marked by fragments of black shale

Fig. 2. Spągowa część ławicy metaszarogłazowej. Warstwowanie frakcjonalne zaznaczone przez fragmenty czarnego łupku

Fig. 3. Metagreywacke layer. Graded bedding marked by shale fragments

Fig. 3. Warstwa metaszarogłazowa. Warstwowanie frakcjonalne zaznaczone fragmentami łupków

Fig. 4. Metasiltstone layer (light) with sharply defined bottom and vague top surface

Fig. 4. Warstwa mułowcowa (jasna) z ostro zarysowanym spągiem i nieostrą granicą stropową

Fig. 5. Fine grained silty bed (light) showing graded bedding with sharply defined bottom and vague top surface

Fig. 5. Warstwa drobnoziarnistego mułowca warstwowana frakcjonalnie z ostrą granicą spągową i nieostrą granicą stropową

Fig. 6. Fragment ławicy metaszarogłazu warstwowanego frakcjonalnie, ostro graniczącej z leżącym niżej łupkiem

Fig. 6. Detail of metagreywacke layer showing graded bedding. Note sharp boundary with underlying shale

Plate — Tablica VIII

Fig. 1. Cross lamination

Fig. 1. Laminacja przekątna

Fig. 2. Cross lamination in a metagreywacke layer

Fig. 2. Warstwowanie przekątne w warstwie metaszarogłazu

Fig. 3. Parallel lamination. On the right-hand side visible lateral passing of the parallel into cross lamination and a change in the thickness of laminae

Fig. 3. Laminacja równoległa. Z prawej strony widoczne poziome przejście laminacji równoległej w laminację przekątną oraz zmiana grubości lamin

Fig. 4. Parallel lamination. Towards the top the thickness of laminae grows smaller

Fig. 4. Laminacja równoległa. W kierunku stropu laminy stają się coraz cieńsze

Fig. 5. Graded bedding of the laminated bed

Fig. 5. Frakcjonalność warstwy laminowanej

Fig. 6. Lamination and graded bedding in fine grained siltstone

Fig. 6. Laminacja i frakcjonalność w materiale drobnomułowcowym

All scales correspond to 1 cm.

Wielkość podziałki na wszystkich zdjęciach wynosi 1 cm.