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Mesostructural and kinematic characteristics of core gneisses in western part of the Orlica-Śnieżnik Dome, West Sudetes

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Abstract The Orlica-Śnieżnik Dome in the West Sudetes consists of an orthogneissic core and a schist-phyllite mantle. It is subdivided into two parts tectonically separated by the Upper Cretaceous Nysa Graben. In this paper structures developed during polyphase deformation of the c. 500 Ma core gneisses in the western part (Orlické hory, Góry Orlickie, Góry Bystrzyckie) are compared with those of the eastern part (Śnieżnik massif). The effects of deformations D_1 to D_4 structures are, in general, mutually comparable in the gneissic series of the Góry Orlickie (Mountains) and the Śnieżnik complex. D_5 structures, manifested in the Góry Orlickie as S-C structures which show a top-to-the-south or top-to-the-southwest sense of displacement, are, however, not known in this shape from the eastern part. Structures of such geometry in the gneisses of the latter region were ascribed to deformation D_3. The C element of the S-C structures is represented in the Góry Orlickie by a rough S_5 domainal cleavage, spatially related to the NW–SE fault zone of Olešnice–Uhřínov, which separated the gneissic core from the Nové Město series and the Zábřeh series of the mantle. This relationship suggests that both the S_5 cleavage and the fault zone are associated with the same deformation event D_5 and originated under similar rheological and kinematic conditions. In both cases cataclastic deformation was accompanied by only local and limited recrystallization of white micas. Kinematic analysis of the D_5 tectonic structures shows that these structures were formed in a sinistral transtension regime. In the Góry Bystrzyckie the tabular crystals of microcline, usually preserving their original shapes, are, in general, arranged along the S_3 gneissosity planes in which they show a considerable scatter. They are more or less lenticularly deformed, in concordance with the SSW-trending L_3 mineral recrystallization lineation, and point to a top-to-the-north sense of shearing during D_3 event.

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INTRODUCTION

This paper is based on the field mesostructural study conducted in 1996 in the western part of the Orlica-Śnieżnik Dome in the vicinities of Klášterec nad Orlicí and between the peak of mount Jagodna and the village of Poręba (Fig. 1). The subjects of the investigations were gneissic complexes, described in the Góry Orlickie (Mountains) as rocks of orthogneiss and migmatite characteristics (Opletal, 1980), and in the Góry Bystrzyckie (Mountains) as the Bystrzyckie gneiss, which were regarded as genetically equivalent to the Śnieżnik gneiss of the Śnieznik metamorphic complex (Smulikowski, 1957; Teisseyre, 1957; Dumicz, 1964; Oberc, 1972).

The thin section petrographical description of these rocks, carried out by Cz. Juroszek (pers. comm.), showed that structures estimated on a mesoscopic scale as the results of a single event, on a microscopic scale showed relicts of older and younger deformations, often accompanied by recrystallization. Considerable bearing of this observation upon structural accounts proposed for the Orlica-Śnieżnik Dome is discussed in this paper.

1 Professor Dr. Marian Dumicz passed away on the 26th of January 1998 before this manuscript could be finished.

DESCRIPTION OF STRUCTURES

KLÁŠTEREC NAD ORLICÍ AREA

The gneisses were examined mostly in crags on the right-hand side of the Divoká Orlice valley, between the Czech–Polish border to the NE and the Olešnice-Uhřínov fault to the SW, near Klášterec nad Orlicí (Fig. 1).

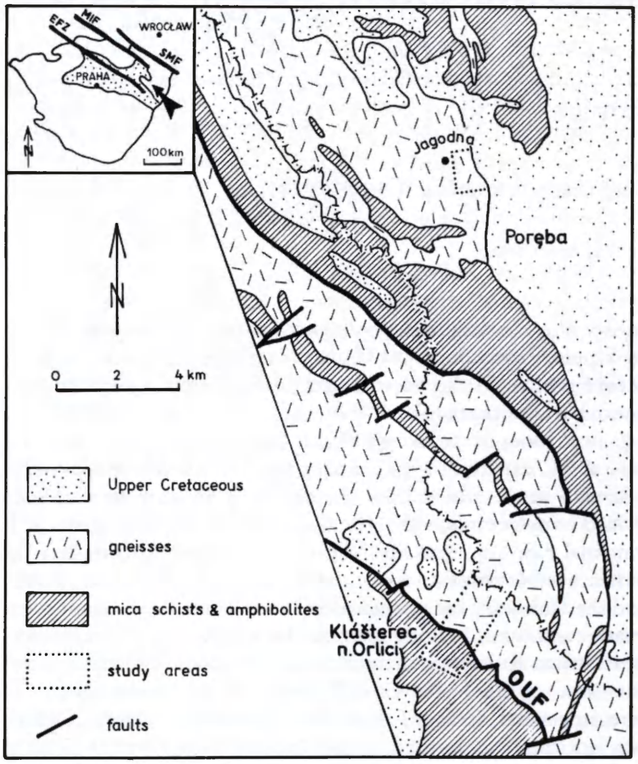


Fig. 1. Geological sketch map of the Góry Bystrzyckie–Orlické hory crystalline complex showing location of the study areas. Dashed-dotted lines marks the Czech–Polish border. Inset shows location (thick arrow) in the Bohemian Massif. Abbreviations: EFZ – Elbe Fault Zone; MIF – Main Intra-Sudetic Fault; OUF – Olešnice–Uhřínov Fault; SMF – Sudetic Marginal Fault

The oldest tectonic structure, D_1, recorded in the migmatitic variety of the gneissic series in the investigated part of the Góry Orlickie, is an S_1 metamorphic banding, defined by alternating pink-coloured quartzo-feldspathic laminae and dark-coloured thin biotite streaks.

During the next tectonometamorphic event D_2, this S_1 lamination was deformed, generally in two ways: either into single, rare, or perhaps rather sparsely preserved, F_2 intrafolial folds of decimetric size and similar geometry (Fig. 2), locally showing an S_2 axial-planar cleavage, or into penetrative F_2 folds of centimetric size and tight to gentle geometry (Fig. 3). This gave the rock its migmatitic gneiss appearance, similar to the migmatitic variety of the Gierałtów gneiss of the Śnieżnik metamorphic complex. However, no gneisses similar to the homogeneous variety of the Gierałtów gneiss have ever been found in the area under investigation. This conclusion is significant in the light of the recent results obtained by Borkowska (1996), who showed, on the basis of a study of feldspars, that the source of migmatization for the migmatitic variety of the Gieraltów gneiss was the Śnieżnik granite magma, the protolith of the Śnieżnik gneiss. On the other hand, the homogeneous Gieraltów gneiss was formed, in her opinion, under conditions different to the Śnieżnik gneiss and showed a longer evolutionary history. The D_2 deformation event also produced, as deduced by analogy to phenomena described from the Śnieżnik metamorphic complex (Żelaźniewicz, 1991; Dumicz 1995), the rarely encountered stretching lineation L_x in the augen gneisses, resulting from the elongation of microcline blasts and porphyroclasts in a non-rotational (coaxial) strain regime. An S_3 gneissosity is the most prominent among the structures related to the next deformation event D_3. This gneissosity,

Fig. 2. F_2 similar folds in S_1 metamorphic banding, preserved as relict in a finely banded mylonitic gneiss presumably developing during D_3 deformation event. Compass for scale. Klášterec nad Orlicí, Divoká Orlice valley (SW domain)

Fig. 3. Migmatitic variety of the Orlica gneisses exposed in a group of crags "Skalna brána", megascopically similar to migmatitic variety of Gierałtów-type gneiss from the Śnieżnik metamorphic complex. Divoká Orlice valley (NE domain). Scale given by a colourful circle 2 cm in diameter

on a mesoscopic scale, does not show the distinct dynamometamorphic features so typical of Śnieżnik-type gneisses. They become apparent only under the microscope. According to Cz. Juroszek (pers. comm.), all the principal components of the rock (feldspar, mica, quartz) underwent cataclasis, variable as to its intensity, and a weak blastesis, resulting in the formation of a small amount of quartz, spherulitic hydrothermal biotite and Fe-compounds. Linear structures related to the D_3 deformation event are, as a rule, poorly recognizable, which could result, at least partly, from their being relicts. Another D_3 structure is represented by an L_p rodding lineation, resulting from an S_1/S_3 intersection. Moreover, it has been noticed that cleavage zones which are related to the S_3 gneissosity, and which overprint the earlier stretching lineation L_x (associated with), define a sort of an anastomosing pattern and result in transversal and rather symmetrical lens-shaped boudinage of the elongated feldspars. This process is accompanied by the development of a fine L_m mineral lineation represented by linearly arranged dark and light micas. They are oriented transversally with respect to the L_x stretching lineation, i.e. approximately parallel to the axes of the lens-shaped boudinage. Linear aggregates of quartz and feldspar, sometimes accompanied by micas are also present and connected to the D_3 event forming an L_k mineral crystallization lineation.

Relatively rare, single, open F_4 folds, with rounded or nearly angular hinges, as well as a sporadic L_g crenulation lineation were described to the next event, D_4.

The tectonic structures resulting from the youngest deformation event include a rough zonal S_5 cleavage, whose planes are cyclically repated at distances of centimetres, and small forms showing the geometrical features of S-C structures, related to the cleavage (Fig. 4).

The S element is the S_1 metamorphic lamination with conformably superimposed S_{1+3} gneissosity, and the C element is the S_5 cleavage defined by thin (with thickness of tenth of a millimetre) mylonitic laminae, with surfaces showing the features of slickensides (Fig. 5). As shown by the petrographic investigations of Cz. Juroszek (pers. comm.), the laminae are composed of a microcrystalline biotite aggregate, containing fine quartz grains, feldspars and Fe-compounds. Single crushed or strongly fractured zircon grains were also found. The microflakes of biotite are arranged parallel to the slip planes, whereas the light components (quartz and feldspar) do not show any detectable preferred orientation. Post-mylonitic blastesis of this aggregate is only weakly noticeable.

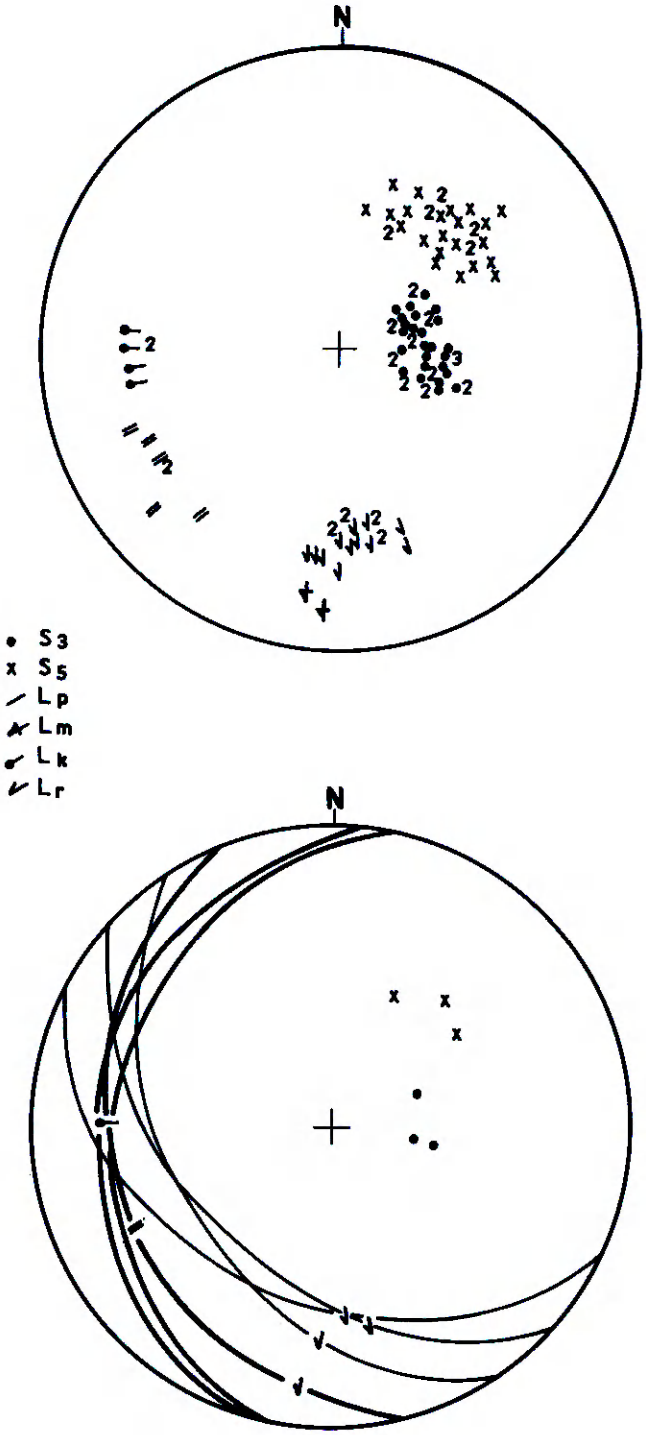
In the above description of the characteristics of the investigated mesostructures, the focus was on their temporal succession and deformational style. The spatial relationships between them are, in turn, presented on the enclosed stereograms (Fig. 6), which show spatial attitude of the five distinguished generations of planar and linear structures and folds. Their highly variable spatial orientation visible on the stereograms suggests that they related to several different rock domains. Based on the spatial relationships between the S_4 cleavage and the S_1 metamorphic lineation, F_2 folds and gneissosity S_3 (S_{1+3}), in the study area of Klášterec one can distinguish three rock domains: the central domain, the northeastern domain and southwestern domain.

In the central rock domain two groups of planar structures predominate. The older, polygenetic one is represented by S_{1+3} gneissosity and the younger one – by S_5 cleavage zones (Figs 4 and 6). The intersection of these structures resulted, as was already mentioned, in a structural arrangement typical of S-C geometry [S(S_3)-C(S_5)], showing characteristic, sigmoidal deflections of the S (S_3) element and L_r extension lineation (tectonic striae) on the surfaces of the C (S_5) element. The presented spatial relationship of these S-C structures points to the southward direction and sense of the tectonic transport of the rock masses (concordant with the plunge of the tectonic striae L_r) during the fifth deformation event D_5. This phenomenon is sometimes also related to the development of meso- and microscopic σ-type structures, which also indicate a southward sense of motion.

The northeastern rock domain, not yet completely studied because of its complexity, is characterized by a common occurrence of the S_1 metamorphic lamination, which is intensely deformed into fine, centimetric-scale F_2 folds. The folds are gentle to tight, mostly symmetric, often dysharmonic (Fig. 3) and give a migmatitic appearance to the gneisses. The orientation of these mesostructures is highly variable (Fig. 7) and the S_5 cleavage, present in this domain, defines two conjugate S-C-type sets, a steep one (C) and a shallow-dipping one (S). They are zonally and concordantly superimposed on the limbs of F_2 folds,

Fig. 4. Rough cleavage S_5 defined by dark bands steeply dipping southward, intersecting shallow dipping lamination and gneissosity S_{1+3} represented by light-coloured, often sigmoidal laminae. The relevant kinematics is discussed in the text. Arrows show sense of the D_5 shearing. Divoká Orlice valley (middle domain)

Fig. 5. Tectonic striae L_r on the S_5 cleavage surface. Divoká Orlice valley



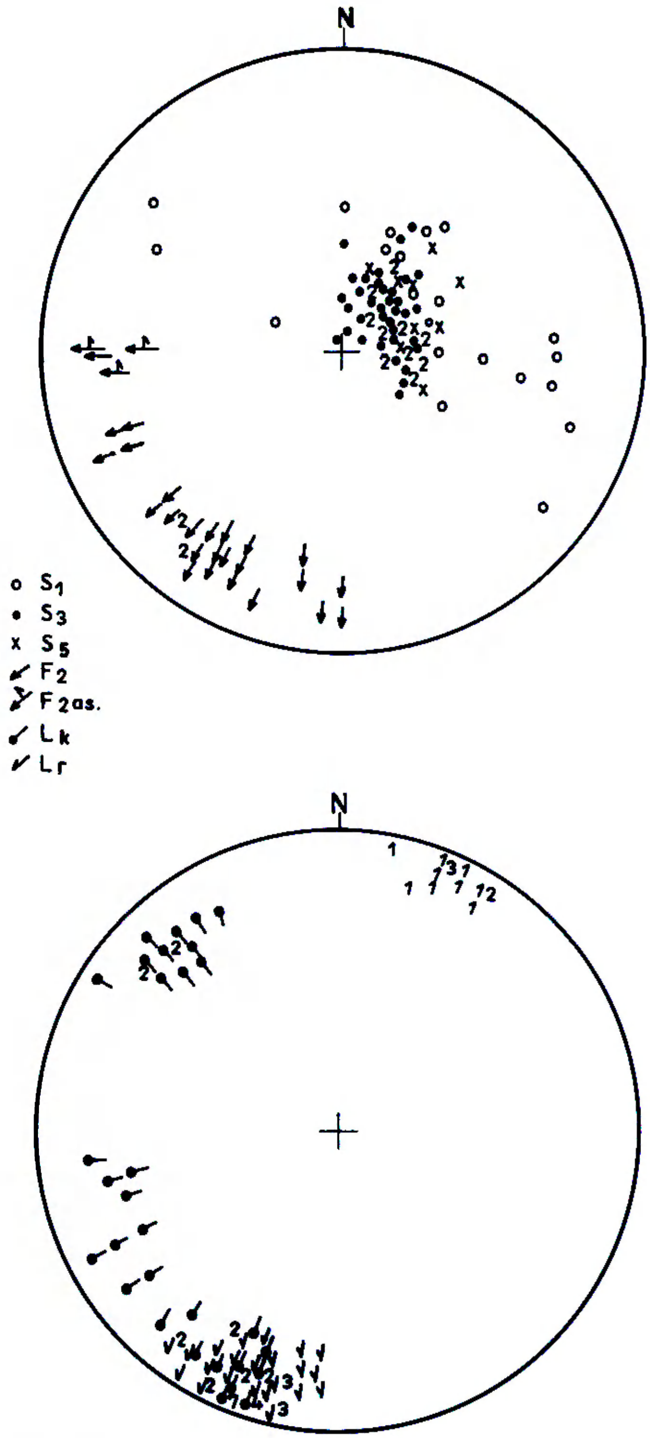


Fig. 6. Stereograms of planar and linear structures in the gneisses Klášterec nad Orlicí. Lower hemisphere, Schmidt net.
S_3 – gneissosity S_3, usually parallel to the metamorphic lamination S_1 (being often element S of S-C structures); S_5 – cleavage zones S_5 (usually being element C of S-C structures); L_p – rodding lineation; L_m – mineral lineation; L_k – mineral crystallization lineation; L_r – striation-type lineation on the S_5 cleavage surfaces; Roman numerals – number of readings of the same values; great circles – S_3 (solid) and S_5 surfaces

Fig. 7. Stereograms of planar and linear structures in the gneisses of the Klášterec nad Orlicí area. Lower hemisphere, Schmidt net.
S_1 – metamorphic lamination; S_3 – gneissosity S_3, usually parallel to the metamorphic lamination S_1 (being often element S of S-C structures); S_5 – cleavage zones S_5 (usually being element C of S-C structures); F_2 – F_2 fold axis; F_{2as} – axis of F_2 asymmetric fold; L_k – mineral crystallization lineation; L_r – striation-type lineation on the S_5 cleavage surfaces; Roman numerals – number of readings of the same values

in particular on those whose axes trend approximately east-west (Fig. 8). These sets cut the S_1 lamination transversally in the hinge zones of F_2 folds. This phenomenon is caused mostly by the steeply dipping set (C), which is characterized by high propagation and a slickensided appearance, including tectonic striations. The sigmoidal de-

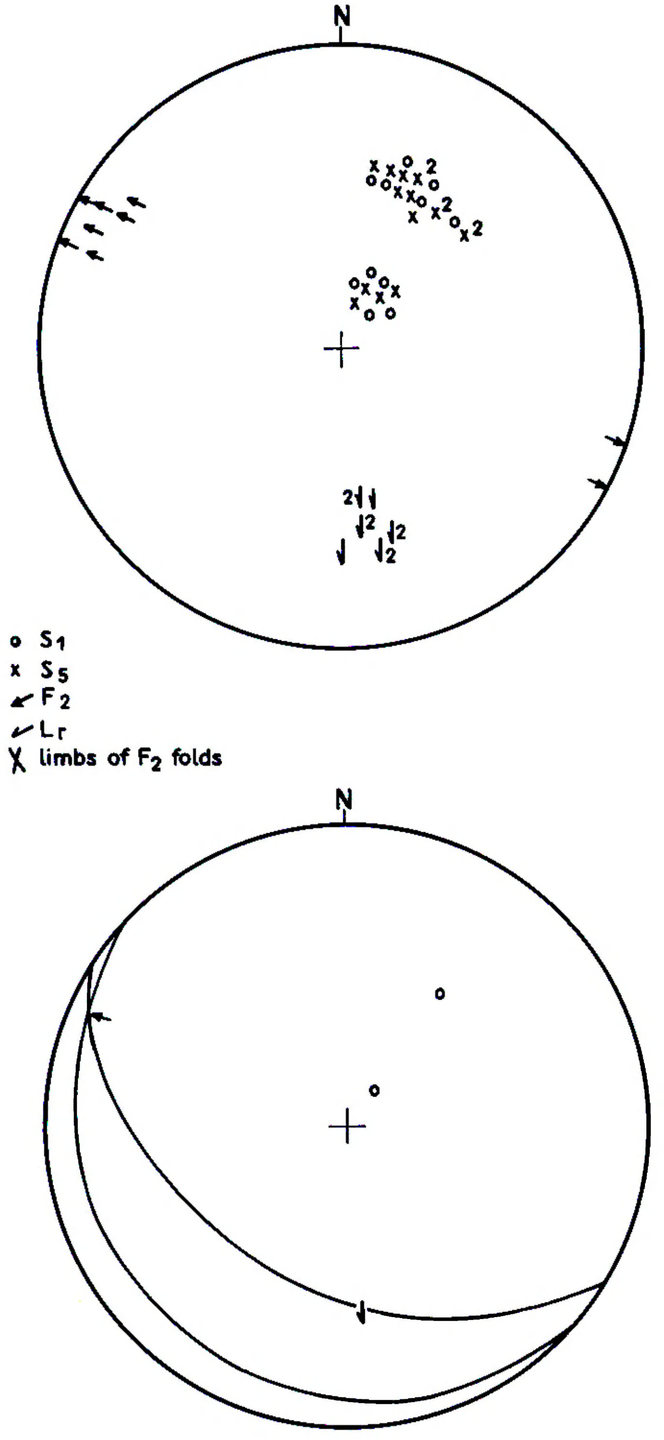


Fig. 8. Stereograms of planar and linear structures in the gneisses of the Klášterec nad Orlicí area. Lower hemisphere, Schmidt net. S_1 – metamorphic lamination; S_5 – cleavage zones S_5 (usually being element C of S-C structures); F_2 – F_2 fold axis; L_r – striation-type lineation on the S_5 cleavage surfaces; Roman numerals – number of readings of the same values; great circles – averaged attitude of the F_2 fold limbs with concordantly superimposed conjugate cleavage system S_5, resulting in S-C structures (details in the text)

flections of the S element, together with the tectonic striations Lr on the surfaces of the C element, clearly define the southerly sense of the tectonic transport in this domain during the fifth deformation stage D_5.

The southwestern rock domain is composed of laminated, fine- and medium-grained gneisses which show the S_3 zonal gneissosity, parallel to the S_1 lamination. The S_5 was laid down on those polygenetic (S_{1+3}) structures. It shows features typical of slickensides. These slickensides most often concordantly overprint the S_{1+3} gneissosity, or define a low-angle set of feather fractures with slickenside morphology together with it pointing to the southward and southwestward sense of tectonic transport during the D_5 stage.

The discussed rough S_5 cleavage is present in all of the rock domains distinguished here and in each of them assumes a different attitude with respect to the older structures S_1, F_2 and S_{1+3}, resulting in mesostructures which were interpreted here as kinematic indicators. The latter confirm the common southward and southwestward sense of displacement during the D_5 event. An analysis of the overview geological map (Opletal *et al.*, 1980) reveals that a similar sense of motion should also be ascribed to the major fault zone of Olešnice-Uhřínov of general NW–SE strike, which separates the investigated core gneissic series from the mantle of the Nove Město and Žabřeh series, which are located to the south-west (Fig. 1). This suggests ascribing the rough cleavage and the above mentioned fault with the same D_5 deformation event. Such an interpretation is favoured by the similar rheological and kinematic conditions under which these structures, otherwise fairly different in size, developed (since in both cases there is cataclasis accompanied by an only local, insignificant recrystallization component). The presented observations suggest that the Olešnice-Uhřínov fault was formed due to sinistral, transpressional displacement. As far as the effects of deformations D_1 to D_4 are concerned, they are comparable in both the gneissic series of the Góry Orlickie and of the Śnieżnik metamorphic complex (although as mentioned, there are some reservations as regards the comparability of the D_3 deformation event). However, the effects of the D_5 deformation, which manifest themselves mostly as S-C structures and which so univocally determine the southward or southwestward sense of late tectonic movement in the Góry Orlickie rocks, have not been found in the Śnieżnik metamorphic complex, at least not in the form they were recorded by rocks in the Divoká Orlice valley. Although various kinematic indicators (including S-C structures; Cymerman, 1991a, 1991b; Żelaźniewicz, 1991) are known from the Śnieżnik metamorphic complex, their formation was related to an overall, synkinematic preferentially oriented recrystallization, ascribed by Dumicz (1995) to the D_3 deformation event.

JAGODNA AREA

In the Góry Bystrzyckie investigations were conducted in a relatively small area located between the peak of mount Jagodna and the village of Poręba (Fig.1). Two phenomena were particularly interesting: (1) the presence of mesoscopically isotropic, granite-like crystalline rocks and (2) the spatial relationship of prismatic forms of K-feldspar to the S3 gneissosity and the L3 lineation in the Bystrzyca gneisses.

According to Cz. Juroszek (pers. comm.), the main components of the coarse-grained rock variety (1) are large blasts of microcline, showing clear signs of albitization, and fragments of the primary rock composed of quartz or quartz and feldspar and infrequent aggregates of biotite and muscovite. In Cz. Juroszek's interpretation, this rock must have formed due to a very strong cataclasis of granite and under a microscope it is possible to distinguish in it the following sequence of tectonometamorphic events. The cataclasis in the granite-like rocks was post-dated by intense microcline blastesis. This was followed by weak deformation leading to the fracturing of the new microcline blasts, sporadically associated with faint cataclasis. At the same time, or slightly later, an albitization leading to the formation of symplectitic structures (myrmekite, perthite) took place, which also resulted in the healing of the fractures within the K-feldspar. The blastesis of mica was earlier than the albitization.

The K-feldspar (2), mesoscopically discernible in the Góry Bystrzyckie gneisses, showing prismatic aspect, were recorded in the intensely weathered variety of these rocks, exposed in the road cut of the so called 'Sudetic motorway' (on the east slopes of the Jagodna Mount). Owing to the deep weathering it was possible to penetrate deep into the rock during the field work and to make observations on the details of the spatial relationships between the K-feldspar, the gneissosity and the lineation. The generally preserved microcline prisms are arranged, as a rule, in the plane of the gneissosity and show a considerable directional scatter (Fig. 9). They are weakly deformed and turned into lens-shaped porphyroclasts, conformably to the SSW–NNE mineral crystallization lineation. They sometimes show a distinct asymmetry, indicating a northward sense of motion related to the extension lineation with rotational (non-coaxial) characters. This lineation is closely related to the gneissosity, which, according to the regional data, must have been formed during the third deformation event D3. The microcline blastesis took place earlier under conditions of rather static pressure as microcline prisms are widely scattered within a single plane, mimetically overprinted by the gneissosity S3.

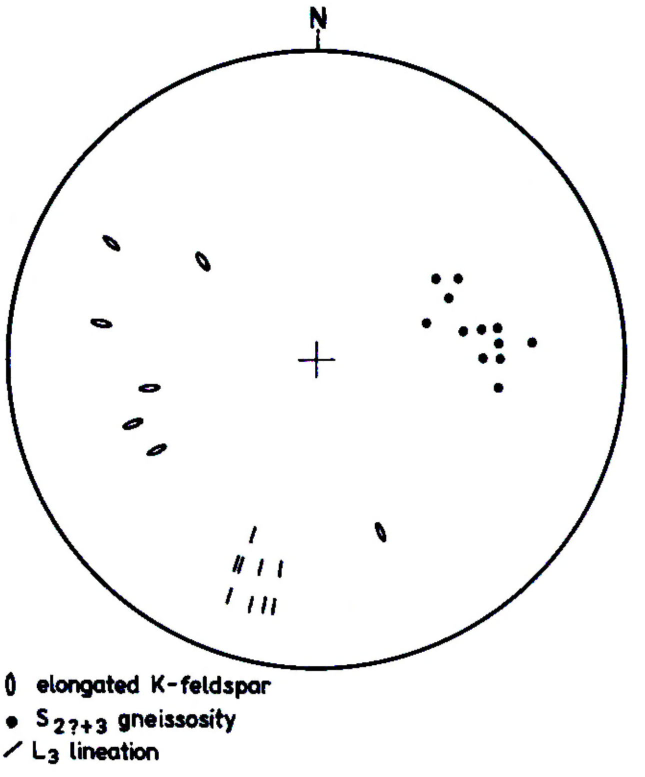


Fig. 9. Stereogram to show orientation of planar and linear structures in the gneisses on eastern slopes of mount Jagodna. Lower hemisphere, Schmidt net

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