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 D₁ to D₄ structures are, in general, mutually comparable in the gneissic series of the Góry Orlickie (Mountains) and the Śnieżnik complex. D₅ 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 D₃. The C element of the S-C structures is represented in the Góry Orlickie by a rough S₅ domainal cleavage, spatially related to the NW-SE fault zone of Oleśnica–Uhrmov, which separated the gneissic core from the Nové Město series and the Zabřeh series of the mantle. This relationship suggests that both the S₅ cleavage and the fault zone are associated with the same deformation event D₅ 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 D₅ 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 S₃ gneissosity planes in which they show a considerable scatter. They are more or less lenticularly deformed, in concordance with the SSW-trending L₃ mineral recrystallization lineation, and point to a top-to-the-north sense of shearing during D₃ event.

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 Śnieżnik metamorphic complex (Smulikowski, 1957; Teisseyre, 1957; Dumicz, 1964; Oberc, 1972).

The thin section petrographic description of these rocks, carried out by Čz. Juroszek (pers. comm.), showed that structures estimated on a mesoscopic scale as the results of a single event, on a microscopic scale showed relics 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–Uhrínov 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–Uhrínov Fault; SMF – Sudetic Marginal Fault

The oldest tectonic structure, D1, recorded in the migmatitic variety of the gneissic series in the investigated part of the Góry Orlickie, is an S1 metamorphic banding, defined by alternating pink-coloured quartzo-feldspathic laminae and dark-coloured thin biotite streaks.

During the next tectonometamorphic event D2, this S1 lamination was deformed, generally in two ways: either into single, rare, or perhaps rather sparsely preserved, F2 intrafolial folds of decimetric size and similar geometry (Fig. 2), locally showing an S2 axial-planar cleavage, or into penetrative F2 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 Gieraltów gneiss of the Śnieżnik metamorphic complex. However, no gneisses similar to the homogeneous variety of the Gieraltów 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 D2 deformation event also produced, as deduced by analogy to phenomena described from the Śnieżnik metamorphic complex (Zelaźniewicz, 1991; Dumicz 1995), the rarely encountered stretching lineation Lx in the augen gneisses, resulting from the elongation of microcline blasts and porphyroclasts in a non-rotational (coaxial) strain regime. An S3 gneissosity is the most prominent among the structures related to the next deformation event D3. This gneissosity,

Fig. 2. F2 similar folds in S1 metamorphic banding, preserved as relict in a finely banded mylonitic gneiss presumably developing during D3 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 Gieraltów-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 dynamo-metamorphic 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, sphalerite hydrothermal biotite and Fe-compounds. Linear structures related to the D3 deformation event are, as a rule, poorly recognizable, which could result, at least partly, from their being relics. Another D3 structure is represented by an Lp rodding lineation, resulting from an S1/S3 intersection. Moreover, it has been noticed that cleavage zones which are related to the S3 gneissosity, and which overprint the earlier stretching lineation Ls (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 Lm mineral lineation represented by linearly arranged dark and light micas. They are oriented transversally with respect to the Ls 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 D3 event forming an Lk mineral crystallization lineation.

Relatively rare, single, open F4 folds, with rounded or nearly angular hinges, as well as a sporadic Lg crenulation lineation were described to the next event, D4.

The tectonic structures resulting from the youngest deformation event include a rough zonal Ss cleavage, whose planes are cyclically repeated 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 S1 metamorphic lamination with conformably superimposed S1+3 gneissosity, and the C element is the S5 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 S4 cleavage and the S1 metamorphic lineation, F2 folds and gneissosity S3 (S1+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 S1+3 gneissosity and the younger one – by S5 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(S3)–C(S5)], showing characteristic, sigmoidal deflections of the S (S3) element and L5 extension lineation (tectonic striae) on the surfaces of the C (S5) 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 L5) during the fifth deformation event D5. 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 S1 metamorphic lamination, which is intensely deformed into fine, centimetric-scale F2 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 S5 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 F2 folds,

**Fig. 4.** Rough cleavage Ss defined by dark bands steeply dipping southward, intersecting shallow dipping lamination and gneissosity S1+3 represented by light-coloured, often sigmoidal laminae. The relevant kinematics is discussed in the text. Arrows show sense of the Ds shearing. Divoká Orlice valley (middle domain)

**Fig. 5.** Tectonic striae L5 on the S5 cleavage surface. Divoká Orlice valley
in particular on those whose axes trend approximately east-west (Fig. 8). These sets cut the $S_1$ lamination transversely 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-
during the fifth deformation stage D5.

The southwestern rock domain is composed of laminated, fine- and medium-grained gneisses which show the S3 zonal gneissosity, parallel to the S1 lamination. The S5 was laid down on those polygenetic (S1+3) structures. It shows features typical of slickensides. These slickensides most often concordantly overprint the S1+3 gneissosity, or define a low-angle set of feather fractures with slickenside morphology together with point to the southward and southwestward sense of tectonic transport during the D5 stage.

The discussed rough S5 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 S1, F2 and S1+3, resulting in mesostructures which were interpreted here as kinematic indicators. The latter confirm the common southward and southwestward sense of displacement during the D5 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 Oleśnice–Uhřínov of general NW–SE strike, which separates the investigated core gneissic series from the mantle of the Nove Mesto and Zábřeh series, which are located to the south-west (Fig. 1). This suggests ascribing the rough cleavage and the above mentioned fault with the same D5 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 Oleśnice–Uhřínov fault was formed due to sinistral, transtensional displacement. As far as the effects of deformations D1 to D4 are concerned, they are comparable in both the gneissic series of the Gory Orlickie and of the Śnieżnik metamorphic complex (although as mentioned, there are some reservations as regards the comparability of the D3 deformation event). However, the effects of the D5 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 Gory 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; Zelaźniewicz, 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 D3 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
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 albition, 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 albization leading to the formation of symplectic 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 albization.

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.

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