POLSKIE TOWARZYSTWO MINERALOGICZNE – PRACE SPECJALNE
MINERALOGICAL SOCIETY OF POLAND – SPECIAL PAPERS
Zeszyt 26, 2005; Volume 26, 2005

Sławomir ILNICKI[1], Jacek SZCZEPAŃSKI[2]

PETROLOGICAL FEATURES OF METABASITES FROM THE SOUTHERN PART OF THE BYSTRZYCKIE MTS., WEST SUDETES

Abstract: Metabasites from the western part of the Orlica-Śnieżnik Massif reveal petrological features documenting two main metamorphic events related to different deformation episodes. The older M_1 metamorphic stage under greenschist facies conditions (450°C, 1.8 kbar) is related to the D_1 deformation resulting from ductile thrusting resposible for juxtaposition of the Nové Město and the Orlica-Śnieżnik units. The younger, peak metamorphism episode M_2, was probably coeval with the D_2 and D_3 events resposible for later modification of the original overthrust contact. This episode is characterised by a westward increase of metamorphic grade from epidote amphibolite facies conditions (540°C, 3.5 kbar) to amphibolite facies conditions (650°C, 7.2 kbar), which is typical of the Barrowian-type metamorphism.

Keywords: metabasites, mineral assemblage, deformation, geothermobarometry, Barrowian, Bystrzyckie Mts., Orlica-Śnieżnik unit, Sudetes

INTRODUCTION

The Bystrzyckie Mts., forming the western part of the Orlica-Śnieżnik Massif (OSM), comprise a large orthogneiss body (the Bystrzyckie orthogneiss) mantled by rocks of the Stronie formation. The protolith age of the Bystrzyckie orthogneiss was dated by the single zircon evaporation and SHRIMP method, at 495-515 Ma (Kröner *et al.* 2001). The Stronie formation, originally forming metasedimentary cover of the orthogneiss protolith, represents a relatively thick sequence (4000-5000 m) composed of mica schists, paragneisses, marbles as well as mafic and felsic metavolcanics believed to be of the Late Proterozoic or Early Paleozoic age (Gunia, Wierzchołowski 1979). According to Szczepański (2003) rocks of the southern part of the Bystrzyckie Mts. recorded a Barrowian type sequence of metamorphism resulting in the westward trend of the increase in temperature. Mafic metavolcanics in the Stronie series usually occur as small lenses with their longer axes parallel to the main foliation preserved in the surrounding metasediments.
Three separate deformation events were documented in the rocks of the study area. The D_1 event produced the S_1 foliation defined by thin, folded amphibole lamina, mainly preserved in microlithons in between younger foliations, as well as inclusion trails in plagioclase porfiroblasts. During the D_2 phase the S_1 foliation was folded into the F_2 isoclinal folds. Parallel to axial planes of these folds axial cleavage S_2 was developed. In places, S_2 planes are developed as a crenulation cleavage. Its growth documents flattening as a major component of the D_2 strain. The following the D_3 deformation phase was associated with reactivation of the older S_2 foliation. On the complex $S_{2=3}$ planes the N-S trending L_3

[1]*Warsaw Uniwersity, Institute of Geochemistry, Mineralogy and Petrology, al. Żwirki i Wigury 93, 02-089 Warszawa, Poland, e-mail: slawomir.ilnicki@uw.edu.pl*
[2]*Institute of Geological Sciences, University of Wrocław, pl. M. Borna 9, 50-204 Wrocław, Poland, js@ing.uni.wroc.pl*

mineral lineation was developed. Sparse kinematic indicators show dextral asymmetry. They document noncaoxial shear being the main component of the D_3 event. On the other hand, presence of the asymmetrical boudinage and V-pull-apart structures point to the constrictional component of the D_3 strain.

RESULTS AND DISCUSSION

The total of 39 samples of metabasites were collected within the Gniewoszów-Kamieńczyk tectonic unit and 36 thin sections were prepared and studied microscopically. Seven samples were then selected for detailed electron microprobe study on Cameca SX100 apparatus in Inter-Institutional Analytical Laboratory for Minerals and Synthetic Substances (Faculty of Geology, Warsaw Uniwersity).

The studied rocks are fine grained sometimes porphyroblastic with moderately to well-developed directional texture as indicated by foliation planes. Metabasites were subjected to metamorphic recrystallisation, however, a few samples were less susceptible to deformation and they reveal vestigial pre-metamorphic, probably magmatic features vaguely resembling subophitic or ophitic structures. All of the studied samples are composed mainly of amphibole and plagioclase, subordinate chlorite, epidote and ilmenite, and accesory quartz, biotite, apatite, titanite, rutile, zircon and potassium feldspar.

Green amphibole blast form elongated prism, rarely needles, parallel to the dominant penetrative foliation plane $S_{2=3}$. Quite often blasts of this mineral are also oriented obliquely or perpendicularly to the main foliation thus documenting an earlier foliation S_1.

Plagioclase occurs as small blasts dispersed among amphibole prisms or forms porphyroblasts or rounded recrystallised aggregates of crystals. Porphyroblasts frequently are elongated parallel to foliation and preserve small inclusions of amphibole and epidote, while outside them strain shadows filled with plagioclase, chlorite and amphibole are visible. Some porphiroblasts of plagioclase are pulled apart and the space between crystals comprises the same assemblage as strain shadows.

Epidote and chlorite appear in rock matrix sometimes forming anhedral to subhedral blasts or aggregates of blasts. Both minerals, together with K-feldspar, occur also in thin veins cutting the rocks. Chlorite rarely occurs as a secondary mineral replacing amphibole.

Main minerals of the metabasites show zoning of chemical composition, although homogeneous blasts, most often parallel to the dominant foliation, also occur. Amphibole usually show increase of tschermakitic and pargasitic component from core to rim of the blasts, although the scheme of zonation in not exactly the same in each sample. As a rule, the core is composed of actinolite or fairly Si-rich Mg-hornblende (Si^{4+}: 6.95-7.80 apfu, X_{Mg}: 0.75-0.96; Leake *et al.* 2004), whereas the rim is usually tschermakite and pargasite, sometimes Mg-hastingsite (Si^{4+}: 6.07-6.48 apfu, X_{Mg}: 0.61-0.77), though in one sample (PNT 3) the rims yielded less Al-rich composition (Si^{4+}: 6.44-7.13 apfu, X_{Mg}: 0.66-0.76). In the westernmost located sample (PNT 1.3) inversed amphibole zonation was observed: core composed mainly of Fe-tschermakite (Si^{4+}: 5.90-6.40 apfu, X_{Mg}: 0.36-0.58 with rare isolated relics of Fe-hornblende) and rim is Mg-hornblende (Si^{4+}: 7.00-7.43, X_{Mg}: 0.61-0.75). Plagioclase, both porphyroblasts and single grains in aggregates and matrix, quite often preserve albitic composition of the core (X_{An}: 0.00-0.09). Towards rim anorthite content increases yielding oligoclase-to-andesine (X_{An}: 0.18-0.31) and andesine (X_{An}: 0.33-0.39) composition. In two samples (PNT 1.3, GNW 1) plagioclase crystals were more Ca-rich than in the remaining samples and yielded in core even labradorite composition (X_{An}: 0.47-0.63). Chlorite in the analysed samples also shows considerable variation of chemical composition. All of the studied blasts straddle the boundary between ripidolite and

pycnochlorite fields (Si^{4+}: 5.3-5.7) on the Hey's diagram (1954) and on the basis of X_{Fe} three groups can be distinguished: the lowest value (X_{Fe}: 0.23-0.28) is typical for cores of zoned blasts and small crystals in the rock matrix, a higher X_{Fe} value (0.32-0.40) charactrizes rims of zoned blasts and crystals appearing in strain shadows, while the highest X_{Fe} (0.45-0.55) yield late retrogressive blasts and post-amphibole crystals or in veins.

On textural and compositional evidence, two mineral assemblages defining metamorphic events have been ascertained: an earlier one (M_1) defining the S_1 foliation plane comprises actinolite + albite ± chlorite ± epidote and a later one (M_2) defining the complex $S_{2=3}$ anisotropy plane composed of tschermakite/pargasite + oligoclase/andesine (bytownite) ± chlorite ± epidote + ilmenite; in sample PNT 3 the younger assemblage comprises Mg-hornblende instead of tschermakite. Sample PNT 1.3 developed different assemblages: an older (M_1) related to the D_1 event containing Fe-hornblende + oligoclase/andesine and a younger one (M_2) related to the D_2 event comprising Fe-tschermakite + andesine/bytownite. Almost in every sample a final retrogressive assemblage (M_3?) of albite + chlorite + epidote/allanite + K-feldspar ± calcite ± sericite is observed.

Therefore, the studied rocks document transition from greenschist facies conditions to amphibolite-epidote or even lower amphibolite facies conditions with retrograde metamorphism under greenschist facies conditions. Judging by the composition of amphibole (Laird, Albee 1981) the peak metamorphic conditions correspond to biotite zone (*e.g.* sample PNT 3), garnet zone (samples from vicinity of Gniewoszów) and staurolite-kyanite zone (*e.g.* sample PNT 1.3). Estimation of PT conditions of metamorphism further confirm these relationships. Applying different calibrations of amphibole-plagioclase geothermometer and geobarometer (Spear 1980, Plyusnina 1982, Gerya *et al.* 1997) temperature and pressure of metamorphic events were calculated. The mean values for M_1 yielded 450°C and 4.2 kbar (in sample PNT 3: 500°C, 1.8 kbar). Moreover, similar P-T conditions for the M_1 were reported by Mazur *et al.* (2005) for mica schist from the Orlica-Śnieżnik unit. Conditions of peak metamorphism (M_2) differ between samples and show distinct spatial zonation: 540°C, 3.5 kbar for northeastern-most sample PNT 3, 565°C, 6.4 kbar for samples from vicinity of Gniewoszów and 650°C, 7.2 kbar for sample PNT 1.3 located furthest to the west. These results are in good agreement not only with the observed changes in mineral assemblages, but also with data obtained by Szczepański (2003) for coexisting metapelites. Unfortunately, absence of garnet in the studied metabasites disables application of wider variety of geothermobarometers, which is particularly troublesome as far as pressure estimation is concerned.

FINAL REMARKS

The P-T estimates for the metabasites from the southern part of the Bystrzyckie Mts. provide evidence for two distinct metamorphic events related to different deformation episodes. The earliest metamorphism M_1 is related to the D_1 deformation. This event is interpreted by Mazur *et al.* (2005) as a result of ductile thrusting responsible for early juxtaposition of the Nové Město and the Orlica-Śnieżnik units. The peak metamorphic conditions (M_2) in the southern part of the Bystrzyckie Mts. were attained during the D_2 and the D_3 events. Both deformations are interpreted to be responsible for later modification of the original overthust contact by deformation dominated by flattening in the first stage (D_2) and finally dextral-shearing during the D_3 event (Szczepański 2003, Mazur *et al.* 2005). Simultaneous the M_2 metamorphic episode is characterized by

westward increase of temperatures towards the contact zone between the Nové Město and the Orlica-Śnieżnik units typical of the Barrovian-type metamorphism.

Acknowledgements: The study was financed by the Polish Research Committee (KBN) research grant No 2P04D 22 27.

REFERENCES

GERYA T.V., PERCHUK L.L., TRIBOULET C., AUDREN C., SER'KO A.I. 1997: Petrology of Tumanshet Zonal Metamorphic Complex, Eastern Sayan. *Petrology*, 5, 563-595.

GUNIA T., WIERZCHOŁOWSKI B. 1979: Microfossils from the quartzitic schists in vicinity of Goszów, Śnieżnik Kłodzki Massif, Central Sudetes. *Geol. Sudet.*, 14: 8-25.

HEY M. H. 1954: A new review of chlorites. *Mineral. Mag.,* 30, 277-292.

KRÖNER A., JAECKEL P., HEGNER E., OPLETAL M. 2001: Single zircon ages and whole-rock Nd isotopic systematics of early Palaeozoic granitoid gneisses from the Czech and Polish Sudetes (Jizerské hory, Krkonose Mountains and Orlice-Sneżnik Complex). *Int. J. Earth Sci.,* 90: 304-324.

LAIRD J., ALBEE A. L. 1981: Pressure, temperature, and time indicators in mafic schist: their application to reconstructing the polymetamorphic history of Vermont. *Am. J. Sci.*, 281, 127-175.

LEAKE B.E., WOOLLEY A.R., BIRCH W.D., BURKE E.A.J., FERRARIS G., GRICE J.D., HAWTHORNE F.C., KISCH H.J., KRIVOVICHEV V.G., SCHUMACHER J.C., STEPHENSON N.C.N., WHITTAKER E.J.W. 2004: Nomenclature of amphiboles: additions and revisions to the International Mineralogical Association's amphibole nomenclature. *Eur. J. Miner.*, 16, 191-196.

MAZUR S., ALEKSANDROWSKI P., SZCZEPAŃSKI J., 2005: The presumed Tepla-Barrandian/Moldanubian terrane boundary in the Orlica Mountains (Sudetes, Bohemian Massif): structural and petrological characteristics. *Lithos,* 82, 85-112.

PLYUSNINA L. P. 1982: Geothermometry and geobarometry of plagioclase-hornblende bearing assemblages. *Contrib. Mineral. Petrol.,* 80, 140-146.

SPEAR F. S. 1980: NaSi-CaAl exchange equilibrium between plagioclase and amphibole. *Contrib. Mineral. Petrol.,* 72, 33-41.

SZCZEPAŃSKI J., 2003: Metamorphic records in the metasediments from the Bystrzyckie Mts, West Sudetes. *Pol. Tow. Miner. Prace Spec*., 23: 163-165.