Methods

Two samples of metapelites (S5, S16) were investigated by means of the electron microprobe CAMECA-CAMEBAX in the laboratory of the Warsaw University. Samples were collected in the vicinity of Wójtowice in the Bystrzyckie Mts. Calculations were performed using the program THERMOCALC of Powell and Holland (1994). Additionally, temperatures of metamorphism were estimated using the garnet-biotite (Ferry and Spear, 1978; Hodges and Spear, 1982, Ganguly and Saxena, 1984) and garnet-muscovite (Green and Helmann, 1982) geothermometers.

Petrography and mineral composition

Investigated rocks are mainly composed of quartz, plagioclase, micas (both muscovite and biotite) and garnet with apatite, zircon, turmaline, chlorite, rutile and opaque minerals as accessories. Muscovites contain significant and variegated amount of Si^{4+} (6.75–6.16 a. p.f.u.). Analysed plates are characterised by low Ti^{4+} content (0.05–0.01 a.p.f.u.) and wide variety of Na^{+} content (0.4–0.11 a.p.f.u.). Biotites display Si^{4+} content in the range of 5.61–5.27 a.p.f.u. The XFe[=Fe/(Fe+Mg)] ranges between 0.64 and 0.45 and Ti^{4+} concentration varies from 0.19 to 0.13 a.p.f.u. Garnet is almandine with normal growth zoning pattern implying its growth during progression of metamorphism. The cores and rims compositions are Alm57-63Py4-5Spe13-21Gr13--23 and Alm63-75Py5-7Spe17-13Gr6-23, respectively. Analysed plagioclase grains display albite composition (An0-2).

P-T conditions

Temperatures calculated using garnet-biotite and garnet-muscovite geothermometers differ by about 40 °C and yielded values of 424±46 °C and 463±63 °C, respectively. Further P-T estimations were performed using the Thermocalc program. The sample S5 recorded P=7.4±1.7 kbars and T=381±62 °C for the final equilibration conditions corresponding to the mineral assemblage: quartz + muscovite + biotite + garnet. A similar result was obtained for the sample S16. Peak metamorphic conditions recorded by the same paragenesis yielded P=8.0±1.9 kbars and T=438±70 °C. Presented results were obtained using the rim composition of minerals. Calculations based on the assemblage quartz+muscovite+biotite+plagioclase+garnet indicate the eclogite facies metamorphic conditions (P=14.4±6.1 kbars and T=643±100 °C). They imply the lack equilibrium between plagioclase and the rest of minerals within the analysed samples.

Summary and conclusions

The P-T metamorphic conditions recorded by the metapelites from the Bystrzyckie Mts are within the HP range of the greenschist facies, close to the field of the blueschist facies. Since, both the analysed samples were collected in the same outcrop, the obtained results cannot be taken as representative for the whole Bystrzyckie Mts. Nevertheless, the present data already suggest a significant difference between the P-T conditions recorded by the investigated metapelites and those from the eastern part of the Orlica-Śnieznik dome. This preliminary conclusion should be verified and possibly extended by further extensive petrological studies in other parts of the Bystrzyckie Mts.

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Oxygen Isotope Plagioclase-Based Palaeothermometry and Whole Rock Isotope Dating in the Ślęża Ophiolite Can Be Unreliable

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Introduction

Stable isotope analysis is one of the most valuable geochemical techniques available to constrain the conditions of formation and alteration of rocks. Likewise, it is a very useful tool to reconstruct the history of tectonic and metamorphic processes when mineral recrystallisation, fluid infiltration and volatilisation take place. Oxygen isotope data can help understand: fluid flow direction, origin of fluids, variation in fluid/rock ratios and thermal history of the rock (regardless pressure variation) etc. Recently developed microanalytical methods, especially in situ oxygen isotope ratio determination in silicates and oxides, allow to analyse single or accessory crystals, i.e. separation of minerals are not necessary.

In this study, oxygen isotope analyses in gabbroic rocks of Ślęża ophiolite (Sl) have been carried out. This ophiolite belongs to the group of mafic-ultramafic massifs surrounding the significantly older Precambrian Sowie Mts. gneissic block. The Ślęża ophiolite represents almost complete ophiolite sequence and the pillow lava and sedimentary members have not been found. The ophiolite is in overturned position. Comparison of mesostructural features of the ophiolite to such features of other Sudetic units of known age, suggests that the emplacement of these ophiolites took place during Variscan orogenesis (continental collision with NE-SW suture zone), (Jędrysek, 1985). Sm-Nd age determination of the mafic member confirmed that thesis. The Sm-Nd age of the mafic member of Sl is 353 ±21 Ma and that of NR is 351 ±16 Ma (Pin et al., 1988). Other authors evidenced that the Ślęża ophiolite is a fragment of Palaeozoic ocean crust consolidated 420 ±20 Ma ago (Oliver, 1993). The main aim of this work is to evaluate tectonic conditions of metamorphic processes, especially discriminate between the role of ocean floor metamorphism and metamorphic processes in continental conditions.

Results and discussion

In situ oxygen isotope analysis in gabbro yields rather narrow ranges of δ^{18}_{O} values: plagioclases (5.01 to 5.33 ‰), ilmenite (3.89 to 4.31 ‰) and magnetite (3.87 to 4.44 ‰). The initial step for the model output was calculation of crystallisation temperature for mineral pairs (plagioclase-magnetite and plagioclase-ilmenite) on the basis of calibrated equations of oxygen isotope fractionation (Friedman and O'Neil, 1977). Estimated temperatures of crystallisation show significantly higher values than those generally accepted (pl-ilm pairs: 1441–1548 °C and pl-mt pairs: 1387–1746 °C). This overestimation is meaningful and could be caused by two factors:

a) the accepted, to paleothermometric reconstruction, anortite content in plagioclase was not representative for the whole rock, or b) an isotope reequilibration, i.e. potential change in the primary isotope composition of at least one mineral examined, took place. In fact, the plagioclase in Ślęża gabbros show wide variation in the anortite content (from 7 to 70 %). This is due to the process of albitization and saussuritization that led to crystallisation of new mineral phases, what in turn may deplete the altered plagioclase in ^{18}O isotope. Consequently, calculated temperature of crystallisation could be about 150 °C higher than that actual one. It can be expected that more advanced albitization or saussuritization results proportionally higher isotope temperature calculated. Moreover, postmagmatic processes could result in plagioclase reequillibration – the δ^{18}_{O}pl value can decrease again. However, this effect is difficult to estimate. Anyway, the plagioclase analysed shows lower thus not primary δ18O values. Consequently, the δ^{18}_{O}pl-mt and δ^{18}_{O}pl-ilm values do not represent oxygen isotope equilibrium, and the calculated temperatures are not really representative. Nevertheless, the change in δ^{18}_{O} value was extensive enough to consider whether albitization and saussuritization occurred due to an ocean floor metamorphism or took place within the continental crust. The previous isotopic data on Ślęża ophiolite (Jędrysek and Weber-Weller, 1997; Jędrysek et al, 2001) shows that some parts of gabbroic rocks were alternated by reaction with seawater. The difference of isotope composition between plagioclases and seawater is 5 ‰. This may indicate that oxygen isotope reequilibration in the seawater-plagioclase system took place at 250–260 °C (Friedman and O'Neil 1977) – providing full isotope equilibrium. However, to accept in this model constant δ^{18}_{O} value of seawater is required. These rocks studied represent deeper parts of ocean crust and their contact with seawater was probably limited to cracks-faults and pervasive fluid flows. Thus, it can be expected that the water/rock ratio (w/r) was rather low. For that reason, the constant δ^{18}_{O} value of seawater can not be accepted, especially at the deeper part of ocean crust. Nonetheless, it can be expected that some variations of chemical composition of the gabbroic rocks correspond to the evidenced gabbro-seawater reaction. Thus, one may propose that, the whole-rocks dating of the Ślęża gabbro can be based with significant error, representing mean age of ocean floor metamorphism and emplacement than crystallisation of the mafic magma. It may significantly implicate geological age estimated due to isotope techniques. This problem could be solved by means of isotope mass balance based on oxygen isotope microanalysis of albite and the other products of saussuritisation.

Conclusions

1. Oxygen isotope analysis suggests that the main metamorphic processes took place before the main tectonic events i.e. emplacement of the Ślęża ophiolite.
2. Whole rock isotope dating of Ślęża gabbroic rocks may represent the ocean floor metamorphism rather than crystallisation of the gabbro.

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