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Jacek SZCZEPAŃSKI[1], Robert ANCZKIEWICZ[2], Stanisław MAZUR[1], Matthew THIRLWALL[3]

CONSTRAINTS ON TIMING OF ULTRA-HIGH PRESSURE METAMORPHISM IN THE ORLICA-ŚNIEŻNIK DOME, WEST SUDETES

Abstract: The geochronology and P-T conditions of granulites and associated supracrustal rocks from the Orlica-Śnieżnik Dome were investigated. The granulites bear a vestige of ultra-high pressure metamorphism which peak P-T conditions were estimated at c. 36 kbars and 1100 ^{o}C. They were followed by decompression through c. 17 kbars and 600 ^{o}C and by subsequent amphibolite facies conditions. Supracrustal rocks hosting the granulites, recorded significantly lower PT conditions of c. 10 kbars and 700-800 ^{o}C. Lu-Hf garnet dating of mafic and felsic granulites gave c. 380 Ma age, which is interpreted as closely approximating timing of UHP event. 340 Ma Sm-Nd age obtained for the retrograded mafic granulite is interpreted as reflecting late amphibolitisation stage.

Keywords: Bohemian Massif, eclogite facies granulites, UHP metamorphism, exhumation

INTRODUCTION

The eastern part of the Orlica-Śnieżnik Dome in the Sudetes, NE Bohemian Massif, belongs to key areas bearing evidence for UHP metamorphism in the Variscan Belt. The main lithologies cropping out in the area comprise amphibolite-grade Śnieżnik and Gierałtów gneisses intercalated with subordinate staurolite grade metasediments (the Stronie-Młynowiec Formation). These rocks host several inclusions of eclogites (Don et al. 1990). Furthermore, in the Stary Gierałtów region a large body of interlayered felsic and mafic, retrogressed to a variable degree, granulites has been recognized which bear a vestige of ultra-high pressure (UHP) metamorphism (Bakun-Czubarow 1992, Kryza et al. 1996, Bröcker and Klemd 1996, Klemd and Bröcker 1999). The PT conditions for the UHP event were determined as c. 30 kbar and 800-1000°C (Bakun-Czubarow 1992, Bröcker Klemd 1996, Klemd and Bröcker 1999). Kryza et al. (1996), using GASP reaction, estimated extreme conditions for a felsic granulite at 1073°C and 36 kbar. Despite this evidence, Štipska et al. (2004) recently questioned UHP episode and claimed significantly lower pressure conditions of around 20 kbars.

[1] *Institute of Geological Sciences, University of Wrocław, pl. M. Borna 9, 50-204 Wrocław, Poland: js@ing.uni.wroc.pl*
[2] *Institute of Geological Sciences PAN, Cracow Research Centre, ul. Senacka 1, 30-001 Krakow, Poland, ndanczki@cyf-kr.edu.pl*
[3] *Department of Geology, Royal Holloway, University of London, Egham, Surrey TW20 OEX, United Kingdom*

Sm-Nd garnet dating of mafic granulites yielded 341±10 and 343±11 Ma (Klemd, Bröcker 1999). Somewhat older, but concordant within error, Sm-Nd garnet-clinopyroxene-whole rock age of 352±4 Ma was obtained by Brueckner et al. (1991) for the eclogite associated with granulites. U-Pb dating of zircon from felsic granulites show similar age range of c. 340 Ma (Štipska et al. 2004). All these ages were interpreted as reflecting metamorphic peak.

In this study, we focus on evolution of metamorphic conditions revealed by the Stary Gierałtów granulites and on time constraints of UHP event using geothermobarometry combined with Sm-Nd and Lu-Hf garnet geochronology.

P-T CONDITIONS

In order to establish PT conditions of metamorphism, mineral chemistry data from selected 4 thin sections were used. Obtained chemical data were employed for P-T estimates by means of the garnet-biotite (GARB, Holdaway 2000), two-feldspar (2FSP, Fuhrman, Lindsley 1988) thermometers and garnet-aluminosilicate-plagioclase-quartz (GASP, Kozioł, Newton 1989) geobarometer. Additionally, calculations were performed using program THERMOCALC of Powell and Holland (1994).

One sample from granulites and two samples from surrounding supracrustal rocks were selected for PT determination: 1) mafic granulite from vicinity of Gierałtów (sample M20b), 2) mica schist from the Bielice region (sample 99/11) and 3) amphibolite from the vicinity of Nowy Gierałtów (sample 99/12).

Granulite sample M20b consists of kyanite + garnet + feldspar + clinopyroxene ± amphibole + muscovite + biotite. The peak metamorphic conditions were determined using composition of garnet core and re-integrated feldspars (forming inclusions in garnet core) by means of 2FSP geothermometer combined with GASP geobarometer. Calculated PT conditions for the UHP event are approximated at 36±6 kbars and 1150±70 ^{o}C. PT calculations using the rim composition of garnet, biotite and exsolved feldspars provide pressures of 16.9±2.4 kbars at temperatures of 610±60 ^{o}C. These results are interpreted as representing equilibrium during decompression stage.

Sample 99/11 recorded P = 10.7±1.3 kbars and T = 670±50°C for the equilibrium conditions expressed by the paragenesis: quartz + plagioclase + K-feldspar + muscovite + biotite + garnet + ilmenite + rutile. A similar result was obtained for sample 99/12 composed of amphibole + plagioclase + garnet + clinopyroxene + ilmenite + rutile. Peak metamorphic conditions for this sample yielded P = 9.8±1.4 kbars and T = 824±49 °C.

Our PT results indicate that granulites recorded ultra-high pressure metamorphism followed by decompression stage (still at high pressure conditions). On the other hand, the surrounding rocks were metamorphosed at conditions typical of lower crustal level. The pressure difference between granulites and the host rocks suggests their tectonic juxtaposition preceded by the uplift of granulites estimated at minimum 70 km.

SM-ND AND LU-HF GARNET DATING

Both mafic and felsic granulites collected from the same outcrop were subjected to dating. Minimum two garnet fractions were analysed together with two splits of whole rock powder. Sm-Nd dating of retrograded mafic granulite gave 340.4±4.0 Ma age, while Lu-Hf date, obtained for the same garnet fractions, yielded significantly older age of 373.7±0.8 Ma. Felsic granulite gave 319.7±2.5 Ma Sm-Nd age, while preliminary Lu-Hf date is 380±2 Ma. The influence of zircon, Hf-rich accessory mineral, on results of Lu-Hf dating was minimized by hand-picking of inclusion-free garnets and by application of the selective digestion technique that dissolves garnet without dissolving zircon.

The Sm-Nd age obtained for mafic granulite is in a very good agreement with recent U-Pb zircon ages (Štipska et al. 2004) and previous garnet dating of Klemd and Bröcker (1999). Sm-Nd date obtained for the felsic granulite, however, is about 20 Ma younger. This was rather unexpected since there is no tectonic discontinuity between the two lithologies. Most likely, the observed age difference reflects different trace elements diffusion behaviour in garnet in different bulk rock compositions.

As expected in rocks crystallizing under high temperatures (see above), major element zonation in garnet from mafic granulite shows typical diffusional pattern with equilibrated rims. This implies that the Sm-Nd ages reflect cooling. Alternatively, they represent a post-metamorphic peak equilibration under lower (but still high) pressure-temperature conditions as recorded in sample M20b.

Lu-Hf geochronology shows more consistency. Both samples seem to point to an isotopic closure at c. 375-380 Ma. Since Lu-Hf system is believed to have higher closure temperature than Sm-Nd (Scherer et al. 2000), the Lu-Hf ages are interpreted as representing time close to the metamorphic peak.

CONCLUSIONS

Preliminary PT estimates suggest that UHP metamorphism in the Orlica-Śnieżnik Dome occurred at P = 36 and T = 1100 ^{o}C, which agrees well with previous estimates of Bakun-Czubarow (1992), Kryza et al. (1996) and Klemd & Bröcker (1999) and contradicts recent calculations of Štipska et al. (2004). Lu-Hf garnet geochronology suggest the time of metamorphic peak as early as c. 380 Ma. Later stage of amphibolitisation of mafic granulites took place at c. 340 Ma as recorded by Sm-Nd dating. The c. 380 Ma Lu-Hf garnet age is considered to be a close approximation of the UHP event since the same population of garnet crystals yield extreme UHP conditions derived from GASP reaction. It is rather less likely that the Lu-Hf garnet age represents timing of HP retrogressive granulite facies metamorphism and provides, in this case, a minimum time constrain for the UHP event.

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