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# PETROLOGY OF SPINEL-BEARING MIGMATITES FROM THE SAUWALD, SOUTHERN BOHEMIAN MASSIF

by

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The Sauwald area is located at the southern rim of the Bohemian Massif in Upper Austria and contains S-type granites and migmatites (meta- and diatexites) with some inlayers of high-grade metapelitic paragneisses. These rocks formed during the post-collisional high T/low P stage of the Variscan orogeny (~320–330 Ma). Metapelitic samples from two localities near Kößldorf and Pyret were investigated. They contain the mineral assemblage garnet + cordierite + spinel + sillimanite + K-feldspar + plagioclase + quartz + biotite + muscovite + magnetite + graphite. The peak metamorphic assemblage is: garnet + cordierite + spinel + sillimanite + plagioclase + quartz and occurs either as inclusion assemblage in garnet or in the matrix. The absence of muscovite and the presence of K-feldspar porphyroblasts and sillimanite needles, suggest that the dehydration of muscovite took place already. The biotites show textures indicating partial melting (e.g. biotite-quartz myrmekites) but the absence of orthopyroxene indicates that the P-T conditions did not exceed the thermal limit (e.g. dehydration breakdown) of the biotite stability field.

Garnet exhibits a slight chemical zoning with increasing Fe contents and decreasing Ca and Mg contents towards the rims. Cordierite shows no obvious chemical zoning in Fe and Mg, but shows a slight increase in the Na content from the core to the rims from 0.029 to 0.043 Na a.p.f.u. Within plagioclase analyses, three groups can be distinguished: plagioclase inclusions in garnet show An-contents of 3–65, plagioclase porphyroblasts in the matrix show An-contents of 10–45 and albite rims around the matrix porphyroblasts show An-contents of 0–15. Also, two groups of sillimanite can be distinguished. The texturally older, coarse grained sillimanite needles contain > 1 wt.% FeO, while the younger, finer grained needles show smaller FeO contents of < 1 wt.% Spinel occurs either as green, brown-green or brown grains. The green spinel grains are the only spinels, that contain sillimanite inclusions. The chemical composition of these grains shows differences in the ZnO and $Cr_2O_3$ contents, which increase from the green to the brown spinel. Relictic old biotite grains from the matrix show high $TiO_2$ contents of up to 6.74 wt.% $TiO_2$.

The P-T conditions of the assemblage garnet + cordierite + spinel + sillimanite + quartz were calculated by using (1.) the garnet – cordierite – spinel – sillimanite – quartz thermobarometry as calibrated by NICHOLS et al. (1992), who considered equilibria among the assemblages garnet – spinel – sillimanite – quartz , cordierite – spinel – sillimanite – quartz and garnet – cordierite – sillimanite – quartz for thermobarometric calculations. This yields pressures ranging from 2.9–5.3 kbar and temperatures of 752°C–764°C for calculations in the systems FAS and FASH. (2.) We also used the inverse equilibrium approach (WEBINVEQ) by GORDON (1992) and obtained pressures of 2.8–3.9 kbar and temperatures of 645–814°C. Although these data are in good agreement with the P-T results of KNOP et al. (1999) which yielded P-T conditions of 780°C and 3.8 kbar, these calculations only involved dry cordierite, and thus these results only represent limiting estimates. Thermobarometric calculations involving THERMOCALC (HOLLAND & POWELL, 1998) yield P-T results ranging from 768°C/4.5 kbars ($a_{H2O}$ = 1.0) to 764°C/3.8 kbars ($a_{H2O}$ = 0.5) to 723°C/2.9 kbar ($a_{CO2}$ = 1.0). All these thermobarometric results show that informations about the fluid-content of the cordierites is necessary. Preliminary investigations with microraman spectroscopy yields clear evidence for $H_2O$ and $CO_2$ contents in cordierite porphyroblasts, thus indicating that calculations involving high $a_{(H2O)}$ might not yield correct P-T estimates.

An important part of the evaluation of the P-T-$a_{(H2O)}$ conditions of these high-grade metapelites is the application of thermobarometric techniques involving cordierite. In recent years, an extensive evaluation of cordierite as a petrogenetic indicator in high-grade metapelites was performed (MIRWALD & KNOP, 1995; KNOP & MIRWALD, 2000). These studies focused on the incorporation of sodium in cordierite as a function of temperature, pressure and $a_{(H2O)}$. MIRWALD (1986) and KNOP & MIRWALD (1999, 2000) found an inverse correlation between the sodium content and temperature, allowing a potential application of this relation as a thermometer. Their study also showed that the incorporation of sodium into cordierite is virtually pressure-independent. KNOP & MIRWALD (2000) and SCHEIKL & MIRWALD (1998) showed that the sodium content of cordierite is also a monitor of the presence of fluid or melt in metapelitic rocks. Therefore, the sodium content of cordierites may also serve as a monitor for $a_{(H2O)}$ in the rocks. Our data indicate temperatures of ca. 650–700°C for the cordierite cores in the presence of a fluid phase in an $a_{(H2O)}$ range of 0.5 to 1.0. The Na content of cordierite in the presence of melt would indicate temperatures exceeding 850°C! The frequently observed assemblage cordierite + garnet in migmatites can also be used as a geobarometer based on the divariant reaction (Mg,Fe)-cordierite ⇒ (Mg,Fe)-garnet + aluminiumsilicate + quartz + $H_2O$ (MIRWALD & KNOP, 1995). Using the Mg# of the garnet and cordierite cores yields pressures of ca. 4 kbar for temperatures of 750°C. These data provide important independent P-T estimates in addition to thermobarometric estimates based on multi-equilibrium methods.

Partial melting of metapelites involves reactions that are predictable within the context of a petrogenetic grid. Recently, mineralogical predictions for anatectic pelites were presented by SPEAR et al. (1999). Therefore the observed reaction textures and mineral zoning, produced during partial melting provide important informations about the P-T path of a migmatite sample. Garnet and cordierite coexist and probably form through the reaction biotite + sillimanite + quartz ⇒ garnet + cordierite + K-feldspar + $H_2O$/melt during the prograde portion of the P-T path.

The formation of spinel is also probably due to the reaction biotite + sillimanite ⇒ spinel + cordierite + K-feldspar + $H_2O$/melt. Our observed phase relations indicate heating along a clockwise P-T path into the stability field of the assemblage garnet + cordierite + spinel. During the retrograde portion of the P-T path, the Fe# in garnet increases due to the backreactions of the melt such as: garnet + K-feldspar + melt ⇒ cordierite + biotite and garnet + sillimanite + melt ⇒ cordierite + biotite. These reactions are indicated by resorbed garnets and newly grown cordierite and biotite at the rims of some granets. Based on the very limited growth of retrograde muscovite, it can also be deduced that the rocks were cooled below 3.8 kbar (SPEAR et al. 1999).

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