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WOLLASTONITE + SCAPOLITE IN CALC-SILICATE ROCKS OF THE ANÁPOLIS-ITAUÇU COMPLEX, GOIÁS: ADDITIONAL EVIDENCE OF ULTRA-HIGH TEMPERATURE METAMORPHISM

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INTRODUCTION

Ultra-high temperature (UHT) refers to crustal metamorphism where temperatures exceed 900 °C (Harley, 1998). Such extreme granulites were previously described in Brazil from the Itabuna-Salvador-Curaça Belt in Bahia (Barbosa et al., 2005, Leite, 2002), and from the Niquelândia Complex (Ferreira Filho et al., 1998), Barro Alto Complex (Moraes & Fuck, 2000) and Anápolis-Itauçu Complex (Moraes et al., 2002, Baldwin et al., 2005) in Goiás. In Brazil, UHT granulites occur as isolated outcrops within "common" granulites, in similar fashion to those described from Antarctica (Harley & Hensen, 1990) and India (Brown & Raith, 1996). Most commonly, UHT granulites are recognized by the diagnostic mineral assemblages that occur in pelites, which are sapphirine + quartz, aluminous orthopyroxene + sillimanite + quartz, hercynite-rich spinel + quartz, and osumilite + garnet (Harley, 1998). However, calc-silicate rocks also may contain diagnostic UHT mineral assemblages, e.g. where wollastonite and scapolite occur together as a stable mineral assemblage. Here we describe the first occurrence of wollastonite + scapolite from the Anápolis-Itauçu Complex.

THE ANÁPOLIS-ITAUÇU COMPLEX

The Brasília Fold Belt borders the western margin of the São Francisco Craton. The two tectonic divisions of the belt are as follows (Fuck et al., 1994): the eastern, external zone comprises sedimentary and metasedimentary cratonic cover sequences that are progressively more deformed and metamorphosed to the west; the inner zone is constituted of the Araxá Group, the Anápolis-Itauçu Complex, and the Goiás Magmatic Arc. The Araxá Group is composed of turbidite-type sediments, volcanic rocks, ophiolitic mélange and granite intrusions, with metamorphism ranging from greenschist to amphibolite facies conditions, whereas the Anápolis-Itauçu Complex comprises granulites, volcano-sedimentary sequences and intrusive granites. The Goiás Magmatic Arc consists of Neoproterozoic juvenile arc rocks, comprising volcano-sedimentary rocks, and tonalite and granodiorite gneisses; arc magmatism extended between 900 and 800 Ma, and pre-collisional calc-alkaline magmatism lasted until ca. 640 Ma (Pimentel et al., 2000).

The Anápolis-Itauçu Complex (AIC) occupies a NNW-oriented area (260 km x 70 km) and is bounded on both sides by mylonite zones separating the complex from the Araxá Group on the east, and from the Goiás Magmatic Arc on the west. The AIC comprises an orthogneiss unit derived from tonalite, granodiorite, and mafic-ultramafic layered bodies; a paragneiss unit, including aluminous granulite, garnet-sillimanite gneiss, calc-silicate rocks, marble, and quartzite; other rocks include volcano-sedimentary sequences and a large number of elongate, NW-SE-oriented granite intrusions (Lacerda Filho et al., 1991). Recent geochronological data from the AIC indicate that magmatism and metamorphism occurred ca. 650–620 Ma, related to final ocean closure between the São Francisco and Amazon continents (Piuzana et al., 2003; Pimentel et al., 2004; Laux et al., 2004).

UHT granulites in the AIC have been identified at three localities (Moraes et al., 2002). North of Goiânia (ML-67), an impure quartzite preserves sapphirine + quartz and aluminous orthopyroxene + sillimanite + quartz assemblages; reaction microstructures and high Al_2O_3 in orthopyroxene (12.9 wt. %) allowed the inference of a composite P–T path, with decompression followed by a near-isobaric cooling stage from T >1,000°C at >9 kbar to <900°C (Moraes et al., 2002, Baldwin et al., 2005). Near Damolândia (PT-62) and in the Monjolo stream (ANA-287), sapphirine occurs in both quartz-rich and quartz-poor rocks. In both rocks a succession of complex reaction microstructures of symplectites and coronae allows inference of a composite P-T path involving a decompression segment to <8 kbar at >1000°C, followed by a near-isobaric cooling to <600°C at <6 kbar (Moraes et al., 2002).

CALC-SILICATE ROCKS FROM ANÁPOLIS-ITAUÇU COMPLEX

The study outcrop is located at the neighborhood of Goianira, where a single outcrop of calc-silicate rock occurs. The main rock is a white medium grained, foliated calc-silicate rock, which includes lenses of different bulk compositions, with sharp contacts. All rocks have calcite, clinopyroxene, ternary feldspar (orthoclase with plagioclase exsolution), titanite, quartz, and wollastonite or scapolite; wollastonite + scapolite is scarce and where they occur together grossular-rich garnet is also present. Most rocks have a granoblastic fabric with silicates surrounded by calcite. Wollastonite may have a thin corona of calcite + quartz. Some scapolite grains are replaced by plagioclase + calcite. Where wollastonite and scapolite occur in the same sample, the first is surrounded by a thin corona of calcite + quartz and scapolite is separated from wollastonite by a complex granular intergrowth of grossular-rich garnet + quartz + plagioclase ± calcite. These microstructures indicate that the rocks may have crossed one or more of the following reactions during cooling and/or decompression and cooling, according to the different equilibration volumes:

1) $Wo + CO_2 = Cc + Qtz$;
2) $Wo + Scp + Cc = Grt + CO_2$;
3) $Wo + Scp = Grt + Qtz + CO_2$;
4) $Wo + Scp = Grt + An + CO_2$;
5) $Scp + Qtz = Grt + An + CO_2$.

MINERAL CHEMISTRY

Mineral chemistry is simple: calcite is pure Ca end-member. Scapolite has Eq An (equivalent An content) between 0.69 and 0.75, with most grains >0.75, which is the value that limits mizzonite from meionite; Cl and SO_3 concentrations are very low, < 0.01 % and < 0.02%, respectively, which is typical of high-Ca scapolite. Garnet is Ca rich, with composition dominated by grossular (grs98adr2). Ternary feldspar is present, with orthoclase (or95ab15) as host grain and exsolved plagioclase (an37); the reintegrated composition is (or74ab19an7) Clinopyroxene has XMg around 0.70 and is zoned, with decrease of Al from core to rim and increase of Fe.

P-T CONDITIONS

Clinopyroxene is the only Fe-Mg phase present in the rock, as garnet is almost pure grossular and all other phases are Ca-rich phases. Consequently, no conventional thermobarometers can be used to calculate P-T conditions. Therefore, P-T conditions must be constrained from phase equilibria in the CASCH model system. We used the T vs. XCO_2 projection drawn for 10 kbar by Moecher & Essene (1990). The presence of wollastonite with abundant calcite and wollastonite + scapolite is sufficient to infer T >900-950°C. High XCO_2 is also inferred from the lack of epidote-group minerals or any other hydrous phase in the rock. In domains where wollastonite occurs, it is surrounded by a thin corona of quartz + calcite, indicating that reaction 1 was crossed during cooling and/or decompression and cooling. In the domains with wollastonite + scapolite a corona of grossular-rich garnet + quartz + anorthite in the presence of calcite was most likely formed by crossing reactions 2 and 3, and as quartz started to be available after reaction was crossed; anorthite may have been formed by reactions 4 or 5. These reactions form two possible paths. Crossing reactions 2 and 4 implies decreasing XCO_2 with almost no cooling, and crossing reactions 2, 3, and 5 implies cooling with a small decrease in XCO_2. We prefer the second interpretation, because it implies a similar P-T path to those inferred for other portions of the Anápolis-Itauçu Complex (Moraes et al., 2002; Baldwin et al., 2005). The T >900-950°C inferred from the mineral assemblages (mainly the coexistence of wollastonite + scapolite) might be overestimated, as the diagram was calculated for the CASCH system, and the scapolite composition is at the lower extreme of the meionite composition range, which will expand the scapolite stability field to lower T. However, this shift is not large, and the presence of ternary feldspar also suggests high T, around 1000°C.

CONCLUSION

The presence of wollastonite + calcite, wollastonite + scapolite and ternary feldspar is sufficient to define one more occurrence of ultra-high temperature mineral parageneses in the Anápolis-Itauçu Complex, albeit in a different bulk composition than in Al-Mg rich rocks. Recent U-Pb dating has shown that some mafic rocks have crystallization ages similar to or a bit younger than the metamorphic peak in the Anápolis-Itauçu Complex (Laux et al., 2004). In some locations where UHT mineral assemblages have been described, as in Damolândia, mafic rocks are recognized and they could be an indicator of the additional heat necessary for UHT conditions to be attained. The calc-silicate rocks described here are close to another mafic intrusion, the Goianira intrusion, but up to now, it has not been possible to determine the structural relationship between them. Independent of the heat source, it is clear that UHT conditions were attained in several locations within the Anápolis-Itauçu Complex.

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