The role of fluids in the monazite record during successive partial melting events: a textural, chemical and in situ dating study in Grt-Ky gneisses of the Central Rhodope (Bulgaria, Greece)

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Monazite is considered to be resistant to diffusive Pb loss at high temperatures and thus, it is particularly adapted to record various stages during a sequence of high-temperature geological events. This study focuses on Grt-Ky gneisses from the lower part of the metamorphic pile in the central part of the Rhodope Metamorphic Complex, in the areas of Chepelare (Bulgaria) and Sidironero (Greece). The outcrops of both regions have experienced a polycyclic evolution during Alpine times, with at least two stages of high temperature metamorphism. According to P-T estimates, the first event involved granulite facies dehydration melting that produced peritectic garnet and kyanite together with a K-rich melt. The second event relates to widespread fluid-assisted partial melting. The latter is well known in adjacent rocks, where it is dated at ~36-50 Ma, but is poorly expressed in our samples, which well preserve the early granulite facies assemblages. Monazite is present in all samples, included in early porphyroblasts such as garnet and kyanite or in the matrix. Matrix monazites are associated with white mica, rutile and biotite (Greek part) and sillimanite and biotite (Bulgarian part). Matrix monazite grains show fluid-assisted dissolution-recrystallisation features with pronounced Y-zoning correlated to age domains. Y-poor domains, dated by LA-ICPMS method ($^{208}Pb/^{232}Th$ ages) between 130 and 155 Ma, represent the largest part of each grain, while Y-rich domains, dated between 40 and 50 Ma, occur either as thin discontinuous rims (< 15 µm) or as small single grains surrounding the Mesozoic grains or filling white mica cleavages. The low P and REE-content of the surrounding minerals suggests that the Cenozoic domains essentially crystallized at the expense of the Mesozoic domains. In addition, garnet being the Y-richest mineral in the samples, its fluid-assisted resorption is the most likely mean to provide Y involved in the Cenozoic domains. The origin of the fluid is not clearly defined: external fluid infiltration or fluid produced by the recrystallisation of H_2O-bearing minerals. Regardless, this fluid interaction was responsible for the partial dissolution of Mesozoic monazite grains, as well as for garnet resorption, and the precipitation of newly-formed Y-rich monazite during mid-Cenozoic times.

Low-*P*, clockwise metamorphism of the Aus granulite terrane, Namibia

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Introduction

Intermediate *P-T* metamorphism has been inferred to indicate the initiation and operation of collisional orogenesis from the Palaeoproterozoic to the present [1]. However, the Precambrian also preserves examples of anomalously hot, likely collisional, orogenies that do not occur in the Phanerozoic. These orogenies are characterised by low-*P*, high-*T* metamorphism, high apparent geotherms and clockwise or anticlockwise *P-T* paths [2], and have been suggested to form during continental back-arc inversion involving juvenile and weak crust [1].

Regional Geology

The Aus granulite terrane of southern Namibia forms part of the Namaqua metamorphic complex that has been metamorphosed and migmatised in a hot orogenic environment during the Kibaran. The terrane consists of older TTG basement gneisses, a high-grade metamorphic supracrustal sequence, and syn-tectonic garnet leucogranite gneisses formed through anatexis of the surrounding rocks. Residual metapelitic rocks preserve assemblages of g-sill-cd-bi-ksp-pl-q-ilm that equilibrated in the presence of silicate melt. Sillimanite mats occur as large, blocky prisms interpreted as pseudomorphs after prograde andalusite. Sillimanite is included in garnet and rimmed by cordierite, indicating consumption of sillimanite to form garnet and cordierite at prograde to near-peak metamorphic conditions.

Results and Conclusions

Pseudosection modelling of metapelitic and metapsammitic residuum compositions constrain peak *P-T* conditions to 825°C and 5.5 kbar. The replacement of sillimanite by garnet-cordierite suggests that the rocks experienced heating with minor decompression to peak metamorphic conditions. The retrograde path likely involved decompression-cooling, as isothermal decompression would have led to the introduction of orthopyroxene, whereas isobaric cooling would have re-introduced sillimanite, neither of which occurred in these rocks. Pseudosections for melt-reintegrated estimates of the protolith composition show that andalusite stability along the prograde path is restricted to *P* below 4 kbar at 550-600°C. This indicates that prograde metamorphism occurred along a high apparent geotherm of 40°C/km, yet the textures suggest that the rocks evolved along a clockwise path at peak *P-T*. Retrogression occurred along a similar geotherm, suggesting that exhumation was slow, and dominantly occurred through erosion, rather than tectonic processes, and that elevated crustal temperatures outlasted the duration of orogeny.

The origin of such a long-lived heat source is enigmatic, particularly as direct evidence for mantle involvement, such as contemporaneous mafic magmatism, is absent. Metamorphism could have involved initial magmatic underplating that led to widespread crustal melting and the redistribution of melt and heat producing elements to higher crustal levels, thereby maintaining an elevated geotherm during the latter stages of orogeny.

[1] Brown (2006) *Geology*, **34**, 961-964.

[2] Cagnard *et al.* (2007) *Precambrian Res.* **154**, 125-141.