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Disequilibrium melting of plagioclase during the generation of S-type granite magma

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This study has investigated the behaviour of plagioclase during fluid-absent biotite melting in a metapelitic source from which peraluminous granite magma segregated. The study focused on the Bandelierkop Quarry (South Marginal Zone of the Limpopo belt), where stromatic and discordant nebulous leucosomes contain peritectic garnet crystals produced by the following simplified melting reactions, respectively: Bt + Sil + Qtz + Pl = Grt + Ilm + Melt; and, Bt + Qtz + Pl = Grt + Ilm + Opx + Crd + Melt. In rare cases, large (10 to 20 mm) garnet crystals within both leucosome types are compositionally growth zoned. These garnet crystals host plagioclase inclusions, which are commonly euhedral and occur as single crystals, clusters of crystals and as polymineralic inclusions, which typically also include biotite, rutile and orthopyroxene. Euhedral quartz crystals are attached to the plagioclase crystals in some cases. The plagioclase inclusions display considerable chemical heterogeneity. Matrix plagioclase in both leucosome types ranges in composition from An_{27} to An_{35}, whilst that in the residuum adjacent to the leucosomes ranges from An_{32} to An_{39}. Euhedral plagioclase inclusions are considerably more calcic, with compositions that range from An_{50} to An_{83}. An content of the inclusions shows no relationship with position within the garnet crystal, nor with size of the plagioclase crystal. These crystals are also significantly zoned, yet their zoning is not systematic, with inclusions displaying both Na- and Ca-enriched rims. Garnet zonation around the inclusions was investigated in detail and demonstrates that, as expected, the Ca-rich nature of the inclusions is not a consequence of Ca-uptake from garnet. This was expected because there are no viable solid-solution exchange possibilities within a chemically isolated system consisting of only plagioclase and garnet. In contrast, anhedral plagioclase within large amoeboid polymineralic inclusions displays compositions similar to the matrix plagioclase. These inclusions are interpreted to reflect magma inclusions (melt + an assemblage of crystals), allowing for exchange of Ca between plagioclase and garnet. Garnet also hosts very fine-grained (≤ 10µm) isometric inclusions of quartz + plagioclase ± biotite. These have a microgranitic texture and are interpreted to represent crystalized melt inclusions.

The complexity of plagioclase behaviour recorded within the peritectic garnet crystals is interpreted to reflect disequilibrium during anatexis due to slow diffusion in plagioclase. It is proposed that during biotite fluid-absent melting, only the outer portions of the reactant plagioclase crystals participate in the melting reaction and they do so by combined dissolution and precipitation of new, Ca-rich crystals. Phase equilibrium modelling demonstrates that the Ca-content of peritectic plagioclase is inversely proportional to the amount of plagioclase that participates in the reaction. Consequently, the euhedral plagioclase inclusions are interpreted to be peritectic with restricted availability of reactant plagioclase.

The preservation of these unique garnet crystals, possibly due to rapid and efficient melt loss from the leucosome structures, provides a rare insight into the details of the anatectic process. In the vast majority of migmatitic granulites, these are lost due to comprehensive syn- to post-anatectic recrystallization and homogenization of mineral compositions.