

Textural studies of migmatitic granulites: solid–melt reactions and the role of fluids

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Introduction

A common feature of migmatites in granulite-facies terrains is the presence of megacrysts of anhydrous ferromagnesian minerals in the leucosomes. These have been taken to indicate dehydration-melting by reactions such as



(Tracy and Robinson 1983; Waters and Whales 1984). These processes are potentially important agents for the dehydration of high-grade terrains, since water formerly combined in hydrous phases is partitioned into the melt, and might be removed from the system. The degree of melt extraction, the fate of dissolved water, and the possibilities for retrograde reaction have been much debated. This contribution describes textures in the migmatitic metapelites of Namaqualand, South Africa, which illuminate some of these questions.

Petrography

The migmatitic metapelites consist of coarse-grained leucosomes rich in K-feldspar and garnet set in a finer-grained palaeosome which generally contains residual, aligned biotite. Their more general features were described by Waters (1988). Two textures, largely restricted to the leucosomes, are noteworthy here. The first is attributable to high-T retrograde processes, and consists of skeletal intergrowths of quartz with biotite, sillimanite, or garnet, forming at the expense of coarse leucosome phases, most commonly K-feldspar. The intergrowths show parallel ribs or

vermicules 5–40 μm across. They rarely constitute more than 5% of the leucosome. Typical examples, with volume proportions, are given in Table 1.

The second notable textural feature is the strong positive association between quartz and the large leucosome garnets which are believed to be solid products of the melting reaction. Quartz occurs as large oval inclusions, fills deep marginal embayments, or forms a canal around the exterior such that garnet commonly makes little direct contact with other phases. This texture is not immediately reconcilable with the inferred melting reactions, in which quartz is invariably a reactant, not a product.

Mass balance

The bulk compositions of the high-T retrograde intergrowths have been compared with the composition of the phase they appear to be replacing. The choice of reference frame is not self-evident, yet the involvement of quartz strongly suggests relative immobility of SiO_2 . When calculated on a constant Si basis, the net flux of Al is generally also small. The biotite-bearing replacements then proceed at approximately constant volume, whereas those involving denser sillimanite or garnet show a volume reduction.

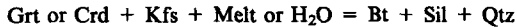
Discussion

It is common to find more than one type of high-T retrograde texture in a single sample, so that they can be coupled with each other or with simpler

TABLE 1. Representative intergrowth textures

No	Sample No	Reactant	Products (with vol%)
1	DWN-274	Crd	Sil (55.2%) + Qtz (44.8%)
2	DWN-274	Kfs	Sil (40.4%) + Qtz (59.6%)
3	DWN-244	Kfs	Bt (60.1%) + Qtz (39.9%)
4	SK-6	Kfs	Bt (73.3%) + Qtz (26.7%)
5	DWN-601	Kfs	Grt (66.7%) + Qtz (33.3%)

mineral replacements (such as broad biotite laths invading cordierite or garnet) to be consistent with the overall retrograde reactions



However, the textures are not consistent with the direct participation of aqueous fluid, in which silica, because of its solubility, would behave as a mobile species. They are similar to those described as 'primary replacement' textures by Ashworth and McLellan (1985). Although there is no direct evidence of melt involvement, the intergrowth textures are almost entirely restricted to leucosome domains, and the phases involved are those which would be stable on melt crystallisation.

The prograde Grt-Qtz association provides evidence that quartz-bearing intergrowths may form in the presence of melt. Similar Grt + Qtz associations are also found in run products in dehydration-melting experiments (e.g. Vielzeuf & Montel, in press). Si and Al are predicted to be the least mobile major species in siliceous liquids, so that local mineral textures forming in the presence of melt may also be expected to conserve Si and Al. The formation of garnet (which has high Al, but lower Si than melt and bulk rock) could thus result in a build-up of silica against the growing surface.

It is concluded that the intergrowth textures reflect local Si-conserving reactions forming part of the retrograde interaction between residual melt and solids, and their limited extent confirms that effective physical separation of solids and melt is generally achieved. An important remaining point

concerns the degree of separation which is necessary to prevent back-reaction and rehydration. Our own mass balance studies (D.J. Waters, F.J. Baars and J. Burton, unpublished data) suggest that most of the studied leucosomes have lost at least some melt. Nevertheless, leucogranitic stringers and sheets presumed to represent segregated melt are themselves almost devoid of rehydration textures. If a water-undersaturated melt is prevented by sluggish kinetics, slow diffusion of rate-determining species, or mantling by crystallised products from fully interacting with anhydrous peritectic phases, the release of stored fluid occurs rapidly in the last stages of crystallisation. Sudden volume increase will promote fracturing, conducting the volatiles away with little further opportunity for local retrograde reaction.

References

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