Granulite Microfabrics and Deformation Mechanisms in Southern Madagascar

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Quartzo-feldspathic granulites are probably the most intensely studied deep-seated rocks with respect to quartz textures. Few microfabric studies explain crystallographic preferred orientation (CPO) of plagioclase as a result of dislocation motion on the (010)[001] and (010)[100] (Ji and Mainprice 1988) in granulite facies conditions. Diffusion-accomodated grain boundary sliding was described from very fine-grained quartzofeldspathic high-grade mylonites (Behrman and Mainprice 1987). The diffusional creep is also enhanced by the presence of granitic melt (Dell'Angelo and Tullis 1988).

The well equilibrated microstructure of granulite matrix is commonly interpreted by petrologists as a product of extensive solid state static annealing (Spry 1969). Emphasis is placed on the geometrical and morphological characteristics as the lack of like/like contacts between constituent minerals (Mc Lellan 1983) and presence of excellent triple point junction network between constituent phases. Rarely, the grain shape fabric and optical microstructures such as morphology of quartz-feldspar boundaries, grain indentations and grain overgrowths in coarse-grained quartzo-feldspathic high-temperature tectonites are explained as a result of combination of diffusional and dislocation creep (Gower and Simpson 1992).

Only few studies combining petrographic and microstructural observation in mechanistic models exist in natural granulites. We use a complex quantitative textural analysis approach developed recently at the Institute of Petrology and Structural Geology, Prague, in combination with detailed microfabric analysis to develop a model of mechanical behaviour of naturally deformed granulites. High-temperature microstructures of quartzo-feldspathic rocks have been studied in granulitic rocks of southern Madagascar. Granulites show strongly oriented crystallographic fabrics in both feldspar and quartz. The microstructures in weakly deformed granulite are characterized by diffusional mass transfer of quartz-feldspar. The texture in this rocks reflects a load-bearing structure (LBF). The deformation of alkali feldspar within the shear zones starts by perthitic exsolution domain reorganization and proceeds to complete recrystallization of feldspar by subgrain rotation mechanisms. Dynamic recrystallization of feldspar leads to the production of considerable amount of recrystallized K-feldspar-plagioclase matrix considered as a weak phase. An increase in weak phase content is related also with the decrease in stress concentration in neck zones and is responsible for persistence of LBF structure in recrystallized granulites. In fully recrystallized granulite typical „platten quartz" texture develops always in LBF structures. Our microstructural observations suggest that these rocks behaved as a polyphase system where quartz never forms an interconnected matrix (even for 50% of weak matrix). In such recrystallized quartzo-feldspathic granulites, the bulk creep strength approaches that of quartz rich tectonites. These data are finally used to discuss the rheology of the lower continental crust under high thermal regime.

For stress estimates we use an analogy with porous sintered metals, where a small amount of a weak phase within a strong phase produces a large degree of weakening relative to the strength of the strong phase (Tharp 1983). In polyphase materials where the stronger phase is dominant, the bulk strength s is given by Eudier's (1962) formula modified by Tharp (1983) for rocks

$$\sigma_{rock} = \sigma_s (1 - k\phi w^{2/3}) \quad (2)$$

where srock is the strength of porous aggregate and ss the strength of strong phase, fw is the volume proportion of weak phase and k is an experimentally derived factor corresponding to the configuration and the shape of pores. Using the Eudier-Tharp model we show the role of fine-grained recrystallized matrix on the stability of LBF structure under extreme thermal conditions and high temperature conditions.

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