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Fluids and Melts in Lower Crustal Granulites: The Inclusion Evidence

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Chemical composition, P-T conditions of mineral equilibration, experimental evidence, a number of arguments identify lower crustal granulites as a major source of mid-crustal granites. The formation of granitic melts occurs by partial melting of pre-metamorphic, mostly meta-sedimentary fertile protoliths, in the presence of internally or externally-generated fluids.

By the example of metapelites from the West Uusimaa granulite dome (Southern Finland), it is shown that traces of these melt- and fluid-related processes are still present in the rocks in the form of inclusions: melt inclusions, only occurring in the core of some garnets, and fluid inclusions, widespread in most rock-forming minerals in the form of primary (syn-metamorphic) or secondary (post-metamorphic) inclusions. Two major fluids are identified: CO_2-rich (carbonic) and high-salinity aqueous (brines), which have coexisted without significant mixing during a large part of the metamorphic evolution. Both inclusion types are strikingly different in their appearance and relative abundance: CO_2-rich inclusions are relatively large, well preserved, very abundant, whereas saline aqueous inclusions are very small, rare, partly or wholly imploded (collapsed inclusions, Touret and Huizenga, 1999).

Carbonic inclusions were generated at peak metamorphic conditions, during the limited period of time when melts were present in the rocks. They were later redistributed by incremental fracturing and healing of rock-forming minerals, without significant influence of the mineral composition. Saline aqueous fluids, on the other hand, percolated through grain mineral boundaries, initiating a number of spectacular microstructures: K-feldspar microveins at plagioclase-quartz and K-feldspar-quartz boundaries, plagioclase microveins at quartz-garnet boundaries, quartz-plagioclase (myrmekite)- and quartz-cordierite symplectites in K-feldspar and cordierite, respectively, elongated quartz porphyroblasts (ribbons) growing at the expenses of most other minerals, notably feldspars.

Most of these microstructures and inclusion types have been described elsewhere (Touret, 1985, Perchuk and Gerya, 1993, Harlov et al., 1998), and, even if overlooked in many regional studies, they appear to be typical for granulites in general. Mineral thermometry (mostly based on coexisting feldspars) places some limits on the temperatures at which fluid-induced microstructures have been formed, from peak metamorphic temperature for the K-feldspar veins to less than 500 degree C for final quartz growth. These microstructures indicate significant element mobility at the scale of the mineral grain (in first instance alkalis and silica, to a lesser extent Fe and Mg), which must have had a profound influence on the granulite overall geochemical signature.

In conclusion, it appears that partial melting is far to be the only process responsible for the making of a granulite. Most of the rock evolution has occurred in the presence of two fluids, one (CO_2) indicated by the remnants that it has left in inclusions, the other one (aqueous brine) by the mineralogical evidence that it has left on the granulite mineral assemblage.

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