Fluid-mediated mineral consumption and growth in polymetamorphosed metapelites of the Black Hills, South Dakota

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Regional Metamorphism in the Black Hills

Late Archean and Early Proterozoic continental margin pelites, graywackes, and quartzites were regionally metamorphosed during collision of the Archean Wyoming and Superior Provices beginning ~1760 Ma [1]. The metamorphism reached at least garnet-biotite grade conditions. This assemblage occurs in much of the middle portion of the Precambrian core of the Black Hills. It is characterized by inclusion-rich (graphite, quartz, and other phases) unzoned garnets that are $Sps_{44}Alm_{44}Pyr_3Grs_9$. Mn-ilmenite (up to 47% pyrophanite component) also occurs. The broad distribution of the grt-bt assemblage is attributed to the stabilizing effect of Mn.

Mineral growth during contact metamorphism

During late stages of the collision, the rocks were intruded by the Harney Peak leucogranite (HPG) at 1720-1705 Ma. Vigorous fluid flow, evidenced by abundant quartz veins, metasomatic aureoles, and consumption of graphite from metapelites, occurred around the granite. The lowest-grade aureole assemblage includes chlorite that overgrows regional foliaton and new, clear, Sps-poor, Alm-rich rims on garnet. Higher-grade facies include staurolite, then sillimanite, and finally second-sillimanite. Mineral compositions suggest 4-4.5 kbar pressure. Within the sillimanite zone, garnet is mostly inclusion free and ~1720 Ma old[1]. Textures suggest that this new garnet grew after dissolution of the old garnet, for which the only remaining evidence may be remnant inclusions or quartz-biotite clots in which biotite is coarser then in the matrix. Andalusite typically occurs as euhedral crystals in quartz veins or as poikiloblasts along foliations planes, where it appears to have grown as Si-rich fluids passed through. Most andalusite probably grew during decompression of the fault-bounded HPG block.

Reference

[1] Dahl, P. S. *et al.* (2002) *GSA Abstracts* **34**, 68

Equilibrium and fractional crystallization during prograde metamorphism revisited

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The use of forward thermodynamic modeling to constrain the nature of P-T paths during prograde metamorphism, and in phase equilibrium calculations in general, has become a widely utilized technique. Many studies utilizing this technique to model individual rock samples assume an equilibrium crystallization model with a constant effective bulk rock composition even though it is clear that in many samples, such as garnet-bearing pelites, equilibrium crystallization and constant effective bulk rock composition are not the norm. This study revisits the concept of equilibrium and fractional crystallization in relation to effective bulk rock composition in low-pressure garnet-bearing pelites experiencing isobaric heating paths. The methodology and results from 3 different approaches of modeling fractional crystallization during prograde metamorphism are presented.

Thermodynamic modeling of phase diagram sections in the MnKFMASH and MnNCKFMASHT systems indicate that fractional crystallization of garnet does not, generally, have a significant effect on the stability of non-fractionated phases. However, the results also indicate that it can be extremely important to consider the effect of fractional crystallization on effective bulk rock composition in relation to the stability of the fractionating phase itself. For example, an equilibrium crystallization model along an isobaric heating path for an average low-Al pelite composition from the Nelson Batholith contact aureole, British Columbia, predicts garnet growth, followed by coupled staurolite growth and garnet consumption, in turn followed by coupled staurolite consumption and garnet growth. However, if the effect of garnet fractional crystallization is considered, and garnet is not consumed during staurolite growth, then garnet will not grow during and after staurolite consumption along the prograde heating path. This has important implications on the derivation of garnet-growth P-T paths utilizing garnet chemistry and inferred reaction history. Finally, the effects of fractional crystallization of more than one phase during prograde metamorphism are presented.