p. 3

POST-METAMORPHIC FLUID INFILTRATION INTO GRANULITES FROM THE ADIRONDACK MTS., USA; J. Morrison and J.W. Valley, University of Wisconsin- Madison.

The Adirondack Mountains of New York (USA) are a classic granulite facies metamorphic terrane and as such have been the focus of many studies concerning the role of fluids in the development of granulites. Most studies to date in both the Adirondack and the S. India granulites have addressed the nature of processes that operate during metamorphism as well as pre-metamorphic has been conducted on post-metamorphic retrogressive processes, which recent studies have shown to have important implications for granulite petrogenesis as well as geochronology and geophysical properties of the crust.

During the Grenville Orogeny at ~ 1.1 Gyr, metamorphic grade in the Adirondacks varied from amphibolite facies in the NW Lowlands (6.5-7.0 Kb, 650-700 °C) to the granulite facies (7.5-8.0 Kb, 750-800 °C) in the Highlands[1]. The Marcy anorthosite massif, a major lithologic unit in the granulite facies of the Adirondacks, is a large (~12,000 km^3), homogeneous batholith composed predominantly of plagioclase (~ An_{45}) with lesser amounts of pyroxene, garnet and Fe-Ti oxides. Approximately 90% of 150 anorthosite samples contain post peak-metamorphic alteration assemblages of calcite, chlorite, sericite, quartz, pyrite, pyrrhotite, epidote, scapolite and prehnite. The percentage of alteration is variable and ranges from a trace to 10 volume%.

Two distinct textures characterize the alteration assemblages: veins and disseminated phases. The veins are discrete and cross-cut plagioclase megacrysts, garnet, orthopyroxene, clinopyroxene and Fe-Ti oxide. The larger veins (>0.5 mm wide) are often symmetrically zoned with calcite cores surrounded by chlorite then sericite. Smaller veins (<0.5mm wide) are generally composed of either chlorite or calcite. In addition to the veins, alteration minerals occur disseminated throughout both plagioclase and the mafic minerals, and as 'clots' within the interstitial mafics. These assemblages, which document post metamorphic fluid infiltration, are readily visible by normal petrographic techniques. However, transmitted light microscopy alone does not reveal all of the manifestations of the retrograde fluid infiltration. Cathodoluminescence of apparently unaltered samples reveals anastomosing veins of calcite (<<0.05 mm wide) that lie along cleavage or partings in mineral grains, along cross-cutting fractures and along grain boundaries. These calcite veins indicate that the retrograde fluid infiltration was more extensive than indicated by transmitted light petrography alone[2].

This widespread retrograde fluid infiltration has important implications for studies of granulite genesis. Substantial controversy surrounds the relative importance of the four mechanisms that have been proposed to account for the low water activities (aH_2O) that characterize granulites: 1) partial melting which would cause a preferential partitioning of water into the melt phase, 2) passage of dry magmas through the crust, 3) pervasive infiltration of deep-seated CO_2 which would dilute the metamorphic fluid and reduce the aH_2O, or 4) metamorphism of already dry rocks. In particular, controversy surrounds the importance of CO_2-flooding[3,4,5]. The presence of high density CO_2-rich fluid inclusions in granulites is often interpreted as evidence for infiltration of massive amounts of CO_2 during metamorphism. Lamb et al.[6] have shown that some high density CO_2-rich inclusions in samples from the Adirondacks must have been trapped after the peak of metamorphism, yet the origin and nature of the retrograde fluids has been poorly understood. In some samples textural relations between high density CO_2-rich inclusions and secondary minerals indicate that entrapment of the inclusions is concurrent with mineralogic alteration. For example, veins of sericite and chlorite crosscut clinopyroxene and where they intersect quartz, trails of high density CO_2-rich fluid inclusions are developed. We interpret this texture to indicate that the fluid inclusions have trapped the same fluids that caused the mineralogic alteration. This textural association of high density CO_2-rich fluid inclusions and retrograde minerals is particularly important in light of the cathodoluminescence results which indicate that many apparently pristine samples have been infiltrated by retrograde CO_2-H_2O fluids.

We have analyzed the carbon and oxygen isotope composition of calcite in 30 altered anorthosite samples in order to evaluate the provenance of the retrograde fluids. Values of $\delta^{18}O$ (SMOW) range from 11.1 to 15.0 ‰ and values of $\delta^{13}C$ (PDB) range from 0.2 to -4.0 ‰. Coexisting calcite and the host plagioclase have been analyzed for $\delta^{18}O$ to evaluate whether the isotopic composition of the calcite is controlled by the host rock or the hydrothermal fluid. Values of Δ_{cc-pl} range from 0.9 to 5.8 which we interpret to indicate that the oxygen isotope composition of the calcite was controlled primarily by the hydrothermal fluids. Mixed H_2O-CO_2 fluid inclusions provide minimum temperatures for the alteration of $\sim$350°C. The calcite values are intermediate between those of igneous rocks and marbles, which suggests that the hydrothermal fluids exchanged with both meta-igneous and supracrustal lithologies.

The precises timing of the hydrothermal vein formation is not yet known. If the fluid infiltration occurred during uplift from granulite facies pressures and temperatures (maximum depths = 24-26 km at $\sim$ 1.1 Ga), then the alteration assemblages and associated fluid inclusions will provide important constraints on pressure-temperature-time paths of uplift as well as the nature of mid crustal fluid movements. Alternatively, if the fluid infiltration occurred during the Phanerozoic then these veins provide important information about large scale fluid movements associated with the Taconian or Acadian orogenies as suggested by Oliver[7].

REFERENCES

1. Bohlen, S.R., Valley, J.W. and Essene, E.J. (1985) J. Petrol., 26, 971-992.

2. Morrison, J. and Valley, J.W. (1987) Geology, in submission.

3. Newton, R.C. (1986) Advances in Physical Geochemistry, 5, 36-59.

4. Lamb, W.M. and Valley, J.W. (1985) The Deep Proterozoic Crust in the N. Altantic Provinces, 119-131.

5. Valley, J.W. (1985) The Deep Proterozoic Crust in the N. Atlantic Provinces, 217-235.

6. Lamb, W.M., Valley, J.W. and Brown, P.E. (1987) Contrib. Mineral. Petrol., 96, 485-495.

7. Oliver, J. (1986) Geology, 14, 99-102.