Deducing Metamorphic Histories
First Step: Garnet Zoning in Metapelites and Pyroxene Analyses from Bedded Iron Formation

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Introduction

The metapelites in the Indian Creek Metamorphic Suite (ICMS), Spuhler Peak Formation (SPF), and Pony-Middle Mountain Metamorphic Suite (PMMMS) contain fantastic, and useful, mineral associations and textures. The mineral assemblages, mineral chemistry, and textures of the three units may put bounds on their metamorphic histories. If all the minerals were euhedral and similarly zoned, this task might be straightforward. Complex crystal forms and chemical zoning patterns, especially in the garnets, have led me to search for clues to growth histories prior to the application of geothermobarometers.

In these rocks, garnets hold the best records of growth history. Traces of chemical zoning either produce bell-shaped curves or flat lines, where bell shaped curves reflect typical prograde conditions and flat lines infer homogenization due to reheating or growth after tectonism (Spear,1993).

Bedded iron formation, also present in the southern Tobacco Root Mountains, has been studied by Immega and Klein (1976). Magnetite gneiss from a previously unsampled locality contains orthopyroxene-clinopyroxene pairs that correlate with previously published results.

Methods

Samples used in this report were taken from the ICMS, SPF and the Middle Mountain Gneiss member of the PMMMS (Gillmeister,1971). In the field I chose the broadest variety of bulk compositions with the idea that the broadest range of compositions might be necessary to reconstruct their histories. In the lab, extensive petrographic study was used to choose distinctive textures and individual grains for study; modal analyses for 30 thin sections were also approximated. I chose three thin sections, one from each unit, each with the mineral assemblage quartz-garnet-biotite-aluminosilicate-plagioclase-rutile-ilmenite in similar modes.

Since either bulk compositional layering or tectonic evolution might have controlled the evolution of the garnet forms, I have attempted to minimize the compositional variable by choosing thin sections with similar modes.

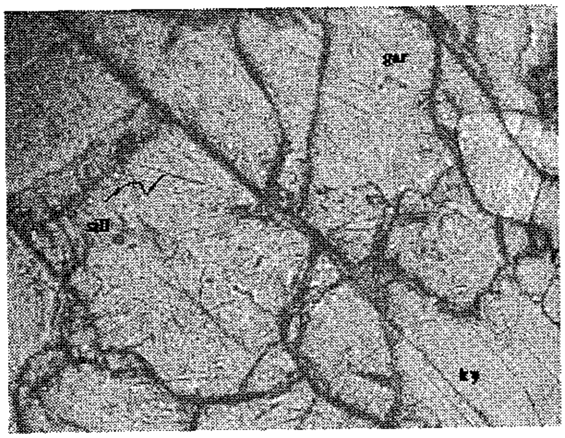
Changes in chemistry across the diameters of elongate and small anhedral and idioblastic garnets were determined using a Jeol 6400 Electron Microscope, Energy Dispersive X-Ray Spectroscopy (EDS), and the Kevex 8000 Microanalyst's Advanced Imaging software. Chemical analyses for orthopyroxene and clinopyroxene from magnetite gneiss were determined and averaged using EDS and the Kevex Microanalyst.

Results

Interesting textural features exist within and between garnets and aluminosilicates. Mineral form in garnet is variable, from inclusion-rich poikiloblasts (Figure 1) to elongate minerals (Figure 3) to small crystals with inclusion rings (See Figure 4) to elongate, fractured garnets (Figure 5). The poikiloblasts and the elongate porphyroblasts in the SPF have jagged edges, except in the quartzite of Figure 3. The same size garnets in the ICMS have smooth edges. The Pony-Middle Mountain Metamorphic Suite contains generally euhedral to subhedral poikiloblasts; it displays no distinct fracturing or elongation.

Kyanite as well as fibrolitic and prismatic sillimanite are in each of the units and coexist in the same thin section. Kyanite and sillimanite were never found in contact; in hand specimen, however, sillimanite was found pseudomorphing kyanite. Sillimanite is produced during a net transfer reaction, the garnet-aluminosilicate-plagioclase geobarometer (GASP), in all three units as well as growing off biotite and quartz (Figure 2). Both forms of sillimanite are present; kinked fibrolite surrounds prismatic sillimanite. Occurrence of relict kyanite is greatest in the PMMMS, but kyanite can be found in the ICMS in trace amounts. Sillimanite replaces garnet in the Middle Mountain Gneiss.

One of the more intriguing relationships between garnets and aluminosilicates is in an ICMS poikiloblastic garnet (Figure 1). Here, prismatic sillimanite crystals trace out parts of the curved internal foliation of the garnet; only part of the garnet is visible, thus descriptors such as synkinematic are not applied. Anhedral kyanite inclusions concentrate in the rims of the garnet. The garnet itself participates in a discontinuous reaction with prismatic sillimanite, plagioclase, and quartz.



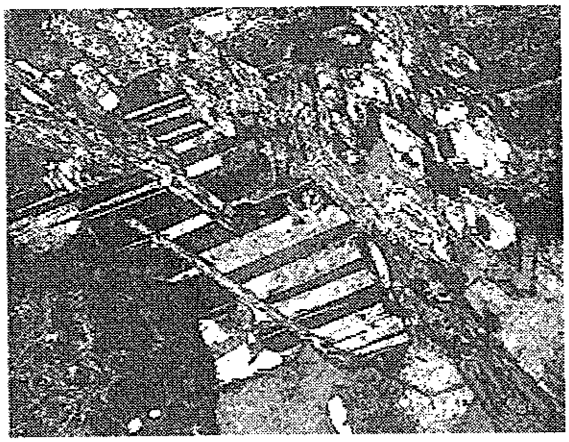


Figure 1: Poikiloblastic garnet from ICMS (8.0.3) in plain light. The fine sillimanite outline a synkinematic growth pattern; kyanite occurs only in the rim. Figure 2: Net transfer reaction from SPF (6.1.4) under crossed polars. Sillimanite, garnet and quartz grow at the expense of plagioclase.

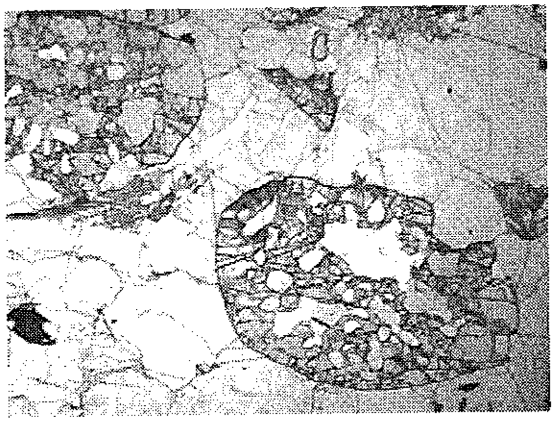
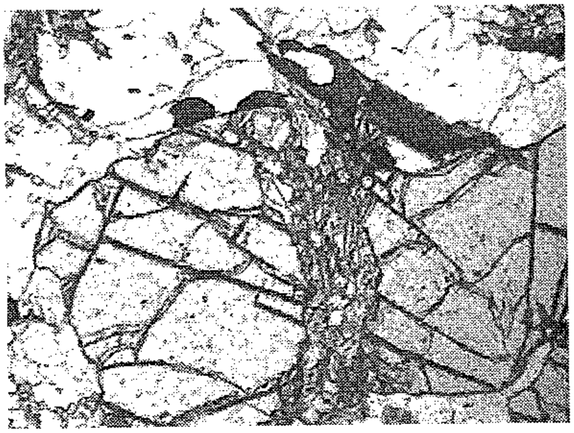


Figure 3: Elongate garnet from SPF (19.1.1) Quartzite. Note smooth edges and dissolved interior. Figure 4: Small garnet with ringed inclusion from PMMMS (18.4.1). (Results, 7e) Both in plain light.



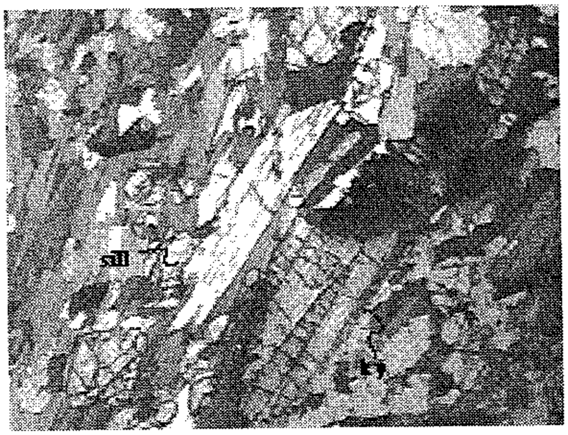
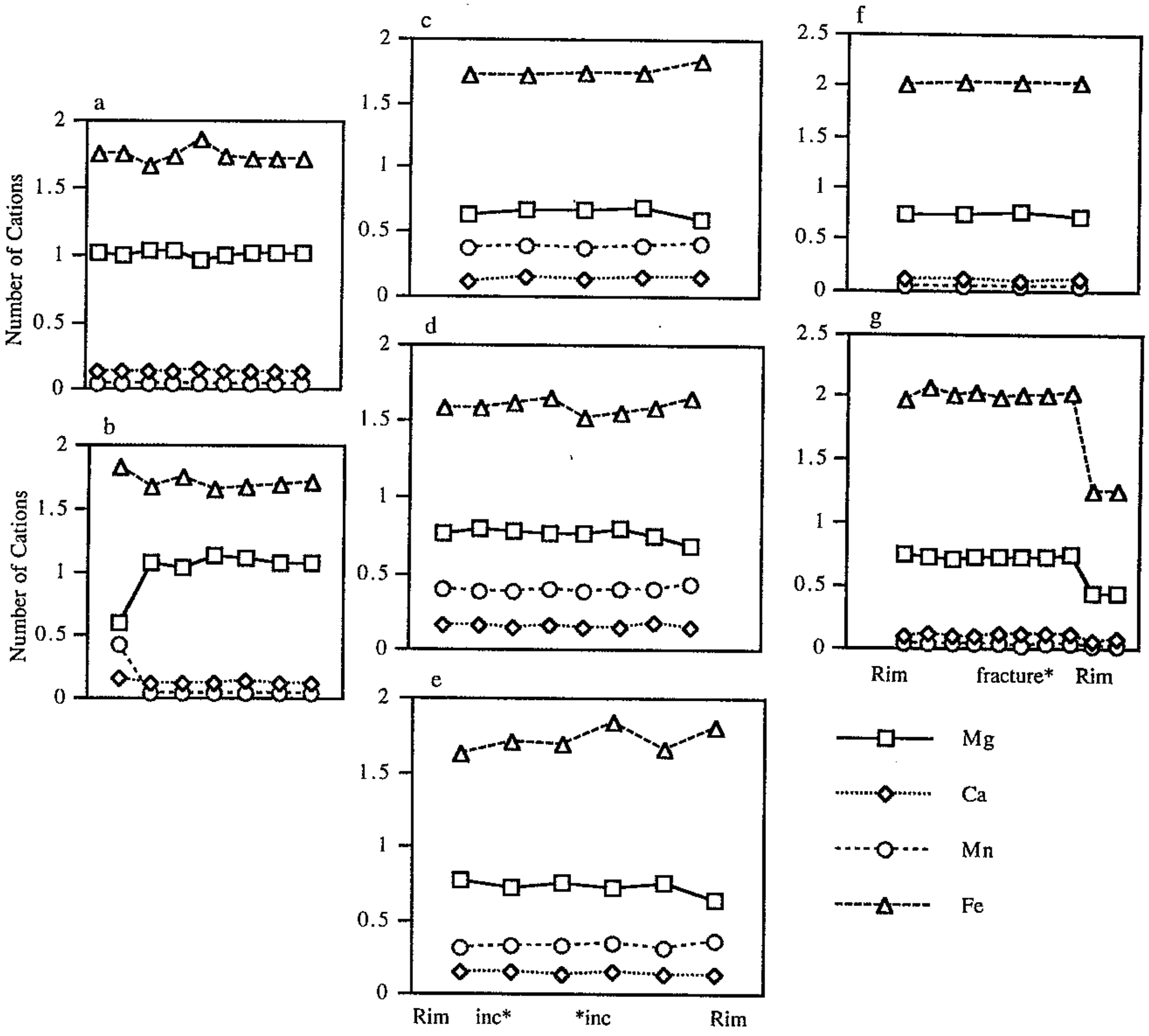


Figure 5: Elongate and fractured garnet from ICMS (14.4.1) in plain light. Sillimanite and quartz frequently grow out of these fractures. (Results, 7g) Figure 6: Idioblastic sillimanite and kyanite from PMMMS (18.4.1).

*Field of view for above figures is two millimeters.

Figure 7: Garnet Traces. [a,c,f] anhedral inclusion-free crystals. [b,g] elongate garnets; [g] fractured. [d] euhedral crystal. [e] inclusion ring, anhedral garnet; note inclusions are marked.[a,b] SPF; [c,d,e]PMMMS; [f,g]ICMS



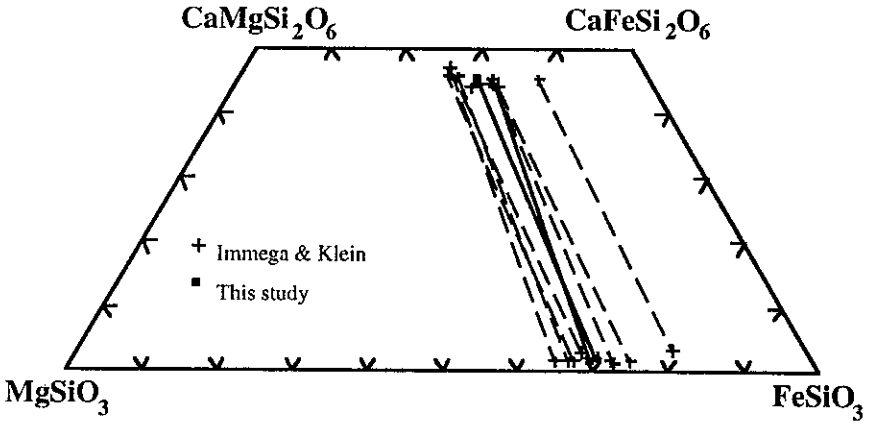


Figure 8: Quadrilateral plot of clinopyroxene-orthopyroxene pairs. Data taken from the magnetite gneiss at Johnson Creek fit samples taken at other localities in the southern Tobacco Root Mountains.

Discussion and Conclusion

The examples from the Indian Creek Metamorphic Suite are puzzling. The anhedral crystal [7f] and half of the elongate garnet [7g] have the same iron content. Yet the other half of the garnet has half that amount of iron. I might say that this low iron half is a remnant there exists high differential bulk composition even on the thin section level, and, therefore, composition is an agent in textural difference in garnets. On the other hand, I might use the different iron ratios to postulate that the garnets grew at different times. A plausible scenario includes initial elongate garnet growth with nucleation of the anhedral crystal following the deformative/metamorphic event that caused the fracture and partial homogenization in the elongate garnet. Bulk composition might be enriched in iron from the exposure of the broken garnet's iron-rich core.

Traces from the Spuhler Peak Formation [7f,g] are remarkably similar to those just mentioned, except that the iron core of the SPF anhedral crystal has not been completely homogenized. In both examples of anhedral crystals from above, no iron resorbtion was found in the rims, while intense iron rims are interpreted in the elongate garnet traces from both units.

Metamorphic history seems best preserved in the Pony-Middle Mountain Metamorphic Suite, with clear bell-shaped profiles and retrograde iron-rich, magnesium-poor rims. Most striking though is trace 7e of the anhedral crystal with an inclusion ring (Figure 4). Here, I might use this as evidence for an homogenous high-grade garnet or post-tectonic garnet that was later zoned in a typical prograde/ retrograde zoning pattern. If I assume that inclusions are picked up during relatively high rates of growth, then I can explain the sudden jump to high iron levels surrounding this garnet. Alternatively, I might suggest that an influx of iron into the system accomplishes the same ends. It is important to remember that this garnet is approximately 1 mm in diameter. How fast can a garnet homogenize? Also I must stress that controls on inclusion patterns are not well understood.

What is still at question is whether compositional changes in the garnets were due to growth zoning or diffusion, or both. The distinction directly affects what assumptions I make in applying geothermobarometers to reconstruct pressure and temperature. A two-dimensional x-ray scan of larger garnets should highlight any distinct concentric zoning or more subtle variations.

References

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