Microtectonic and Metamorphic Evidence for a Decompression Phase of the “Triple Point” Terrane of Northern New Mexico

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Metamorphic rocks from Cerro Colorado in the southern Tusas Mountains of northern New Mexico provide insights on the origin of the high T/low P metamorphism that is widespread across northern New Mexico. The metamorphism involves reactions amongst andalusite, kyanite, and sillimanite at pressures close to those of the Al_2SiO_5 invariant point. An outstanding problem in Proterozoic metamorphism of the southwest is how regional temperatures of 500-600 deg C were achieved at the relatively shallow depth of 3.5-4.0 kbar. Many explanations have been put forth, and in this paper we propose one based on detailed study of metamorphic rocks at Cerro Colorado in the Southern Tusas Mountains where there are no nearby plutons to have provided a source of heat. The Tusas Mountains represent a tilted upper crustal section with low grade metamorphic rocks exposed in the northern part of the range, and sillimanite grade rocks occurring in the southern Tusas Mountains. The area has been studied by Williams (e.g. Williams, 1991). We were guided in the field by data provided by Williams and by the unpublished MS thesis of Bishop (1997). We here propose that a phase of isothermal decompression occurred during the metamorphic history of the area. Daniel and Pyle (2005) also describe a phase of decompression for correlative rocks in the Picuris Range, east of Cerro Colorado.

In northern New Mexico, southern Colorado, and Arizona, it is widely recognized that there was an orogenic event between 1.7-1.6 Ga associated with the accretion of juvenile crust of the Mazatzal province to the Yavapai province (e.g., Bowring and Karlstrom, 1993). In addition to this orogenic event, the basement rocks of the Tusas and surrounding mountain ranges were affected by a 1.4-1.3 thermal event, which is the approximate age of “post-tectonic” plutons, of U/Pb/Th monazite dates, and of hornblende Ar cooling ages (Shaw, et al., 2005). Which of these two events, at 1.7-1.6 Ga or at 1.4 Ga, produced the triple point metamorphic assemblages remains debated.

Based on mineral texture, mineral zoning, and P-T estimates made with TWQ (Berman, 1991; Berman and Aranovich, in prep), we present a model for the evolution of the metamorphic rocks of the Cerro Colorado area. The following structural summary is based on the work of Bishop (1997). The earliest foliation developed (S1) is preserved as inclusion patterns within garnet. These garnets continued to grow as a second foliation (S2) developed. S2 surfaces are folded into open to tight upright folds with fold hinges that trend E-W and plunge shallowly (F3). Related to this folding, an axial planar cleavage developed (S3). These upright folds attest to a period of N-S shortening that followed the development of S2. Field and petrographic data show that kyanite was deformed by D2 and sillimanite growth began at the end of D2 and continued into D3. The sillimanite that began to grow at the end of D2 formed synchronously with preserved decompression reactions (Figure 1). The key decompression reaction was garnet + muscovite = sillimanite + biotite (Davidson et al., 1997) and is well preserved in one sample. This reaction is nearly horizontal in P-T space. The petrographic evidence for this reaction (Figure 1) is a preserved reaction texture in which garnet fragments are partially replaced by sillimanite, which is surrounded by halos of biotite rich matrix, and muscovite further away in the matrix.

Based on examination of multiple samples, we found evidence for two episodes of almandine garnet growth. The first was the garnet involved in the decompression reaction. Where still present, this garnet is anhedral and homogeneous in all elements (Figure 1); the absence of growth zoning implies the garnet was held at high temperature (but < 600 deg C) for a long time. A second episode of garnet growth occurred post D2 and produced euhedral garnets. Outer zones (rims) of all garnets show growth zoning. This second phase of garnet growth appears to have been formed by the reverse of the decompression reaction, suggesting this growth was due to a slight increase of pressure. We attribute this late garnet growth to thickening of the crust during the formation of the upright folds (F3).

We ascribe the S2 fabric to tectonic thinning and flattening in the stability field of sillimanite. The thinning is supported by top to south shear bands and symmetric, tight folding of crosscutting veins. Previous interpretation of the S2 fabric is that it was due to thrusting in a fold and thrust belt (e.g., Williams, 1991). In our model, the flattening fabric and associated decompression preceded the top to north convergent structures. We conclude that the heat source for the 1.4 metamorphism is inherited from a time when the rocks were deeper, in the kyanite stability field at temperature above the triple point and less than 600 deg C. Since then, the rocks decompressed from 4-6 kbar to 3-4 kbar during thinning of the crust and were held at about 550 deg C at 3 kbar for long enough for the garnet to homogenize and to re-equilibrate to those conditions. At the end of the thinning episode, crustal thickening during the D3 folding produced additional reaction and distinct growth zoning at the rims of the garnets, and set the cooling thermochronometers.

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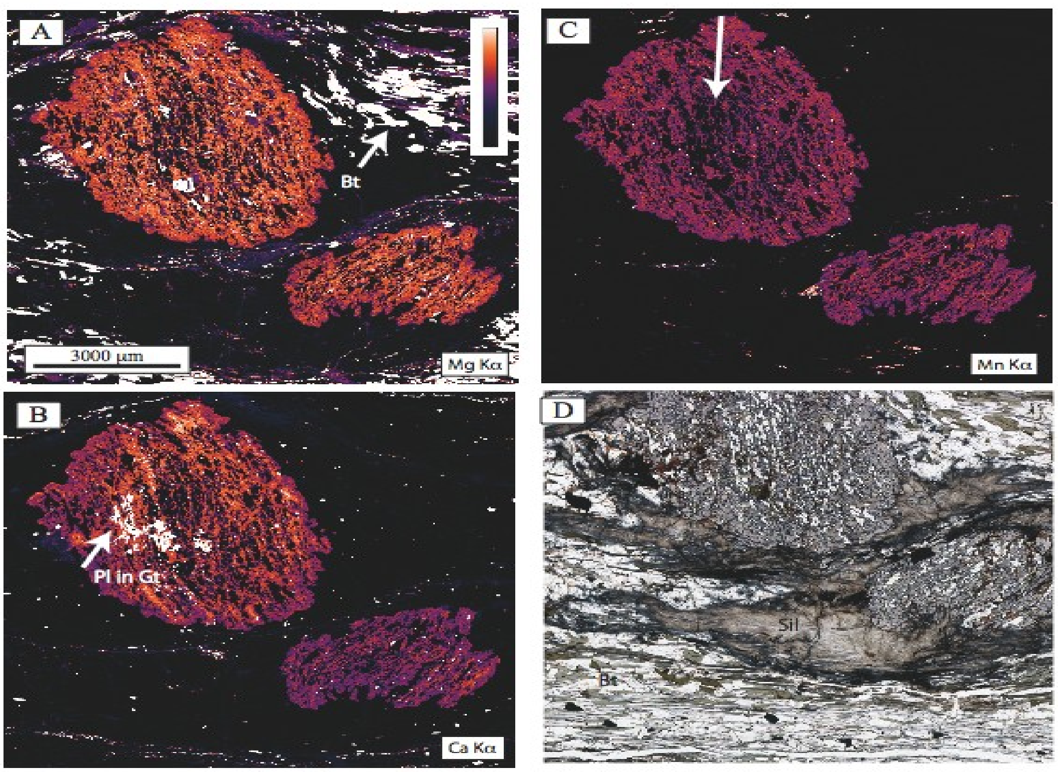

Figure 1. A,B,C x-ray maps for Mg, Ca, Mn on partially resorbed garnet. Note lack of zoning except for a decrease of Mg toward the edge, and splotchy variations of Ca in the interior. There is also a slight decrease of Mn toward the edges, in contrast to typical Mn kick-ups for retrograde zoning. White of A is biotite; white of C is plagioclase. Photomicrograph D shows foliation in garnet, massive sillimanite in tails extending from garnet, and S2 foliation of matrix.