PRELIMINARY EVIDENCE FOR SYNTECTONIC EMPLACEMENT OF MESOPROTEROZOIC PLUTONS IN THE SOUTHERN WET MOUNTAINS, COLORADO

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INTRODUCTION

As outlined by Siddoway (this volume), a growing body of work in the southwestern US supports syntectonic emplacement and dynamic metamorphism of Mesoproterozoic granite. Alternatively, the geochemical signatures of these plutons have long been attributed to anorogenic events (Cullers, et al, 1992).

The area around Bear Creek and Williams Creek in the southwestern Wet Mountains, Colorado, is situated in a key geologic setting, capable of adding considerably to the “anorogenic” debate. This area is composed of Paleoproterozoic gneiss, in close proximity to two Mesoproterozoic plutons—the Bear Creek Granite, isotopic age of 1486+/-36 Ma (Bickeford, et al, 1989), and the San Isabel Granite, 1360 Ma (Cullers, et al, 1992). Additionally, two lines of evidence from the southern Wet Mountains suggest retrogression through amphibolite grade conditions circa 1365 Ma. Siddoway et al (2000) support regional overprinting of 500°C between 1369+/-4 Ma and 1342+/-6 Ma using 40Ar/39Ar Hbl closure from amphibolite north of the San Isabel pluton. Titanite in granite from the Bear Creek field area likewise records temperatures between 450-500°C at 1364 Ma (unpublished U-Pb titanite age, Jones and Connelly, UT Austin 2002). The evidence suggests that the southern Wet Mountains were heavily affected by Mesoproterozoic events.

The month of July 2001 was spent mapping structural relationships and sampling in this rugged yet promising area with George Perkins of Colorado College. The common mineral textures and fabrics shared by metamorphic and plutonic units, coupled with the temperature and temporal constraints established by earlier workers, led to the hypothesis that dynamic metamorphism and subsequent retrogression through amphibolite conditions at 1365 Ma was synchronous with Mesoproterozoic plutonism. Work is currently underway to test this hypothesis through in-situ monazite geochronology and petrologic analysis.

FIELD METHODS and DESCRIPTIVE ANALYSIS

The Bear Creek field area is located on the southwestern flank of the Wet Mountains, just north of the junction of Bear and Williams creeks. The area is composed of Proterozoic units up-thrown against Phanerozoic sedimentary and volcanic rocks along the Wet Mountain Fault, a SE-NW striking Laramide feature. The fault scarp is heavily dissected, with local relief on the order of 500m, providing good access to the Proterozoic units. Detailed structural mapping and sampling of this 2 km by 3 km region was completed during July 2001, and added to a regional reconnaissance level map completed by Boyer in 1962.

Unit Descriptions and Contact Relationships

The lithologies are described below in near chronological order, where it could be inferred through crosscutting relationships, though the relationships between these units are complex.

The oldest units consist of amphibolite, biotite gneiss, and quartz-feldspathic gneiss. The amphibolite was most common in the southwestern region of the field area. Extensive epidote mineralization of amphibolite was observed in association with brittle faults on the western edge of the research area. Calc-silicates and potential pillow structures were also observed in this unit. Compositional banding of and deformed dikes in the amphibolite show small scale rootless, ptygmatic, and isoclinal folds with hinges parallel to lineation.

The biotite gneiss is found throughout the field area, often in association with a quartz-rich fine grained gneiss. Both of these units are occasionally migmatitic, and host many small scale folds.

The amphibolite, biotite gneiss, and quartz-feldspathic units host at least three generations of intrusions, including a hornblende diorite; a megacrystic granite with contacts concordant with foliation; and a fine grained granite with discordant contacts. The biotite gneiss, quartz-feldspathic gneiss, and amphibolite, are also found as xenoliths in large bodies of hornblende diorite gneiss and coarse granite gneiss.

The medium to coarse-grained hornblende diorite gneiss is found in the central and northwestern parts of the research area. These isolated bodies may relate to the quartz-diorite describe by Boyer (1962)and likely represents G1 in the Siddoway (2000) classification. This unit is cross-cut by the coarse granite gneiss.

The coarse, megacrystic granite gneiss is the dominant rock type in Bear Creek. There are two phases of this granitoid, marked by a textural difference, with a slightly finer grained phase semi-concordant to foliation, but folded with the coarser material. The coarse grained unit contains large (1-2cm) feldspar crystals, and is alternately enriched in biotite or, around pegmatite bodies, in hornblende. Boudins of this unit in amphibolite have necks parallel to lineation. This granitoid appears to correlate with the Bear Creek granite of Boyer (1962), and the G2 granite of Siddoway (2000).

The fine grained leucocratic granite is found regionally as sills and dikes but is not as dominant as the megacrystic granite. The fine grained granite sills are found both discordant with and parallel to foliation in host granite and amphibolite. The fine granite also shares the lineation of its host rocks, defined by elongate quartz grains. Several centimeters of offset are present at one location along a vertical offshoot of a large fine grained granite sill. This granite correlates with the Williams Creek Granite mapped by Boyer (1962), and G3 of Siddoway (2000).

Several generations of variably deformed aplite and pegmatite dikes, from isoclinally folded, ptygmatic and concordant, to planar and discordant, are found throughout the field area. The planar dikes (roughly (252, 45), n=19) occasionally show reverse offset on the order of tens of centimeters.

All of the units show similar fabric development and gneissic layering with southwest-northeast striking, northwest dipping foliation being the most common (S=(216, 45)). All units show a moderate to

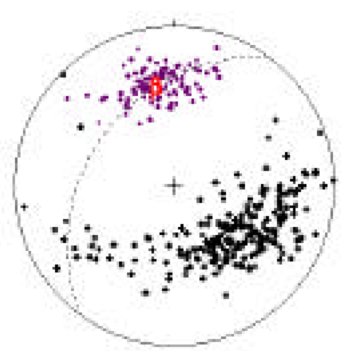

Figure 1: Equal area projection, Bear Creek, CO. S=(216, 45) n=231; L=(35, 350) n=96

well-developed mineral lineation plunging north (L=(35, 350)). (Fig. 1).

Structural Petrology

Microstructural petrology of 26 oriented thin sections revealed heterogeneous textures in quartz and feldspar. Quartz grains typically show 2:1 to 3:1 length to width ratios defining foliation and lineation. Grains were observed with undulose extinction, deformation banding, and progressive subgrain development and recrystallization, with resultant grain size reduction and dramatic grain boundary bulging. Quartz grains with triple point junctions were observed in the strain shadow of one feldspar phenocrysts. Feldspar likewise shows variable states of deformation. The majority of feldspars are heavily twinned. Tartan twin lamellae vary from straight, to kinked, to poorly preserved. Some feldspars show undulose extinction, minor subgrain development, and rare mantle structures accompanied by grain boundary migration. Symplectite is common in all felsic units.

While field observations of shear sense were contradictory and inconclusive, thin section observations of C-S fabrics, subgrain shapes in quartz, and brittle garnet trails indicate top to the southeast shear.

For a detailed description of the amphibolite mineralogy and textures refer to Perkins, this volume.

WORK IN PROGRESS

Monazite geochronology

Monazite ((Ce, La, Nd, Th, Y)PO_4) is an accessory mineral common in many igneous and metamorphic rocks (Williams and Jercinovic, *in press)*. In recent years the refinement of in-situ monazite chemical geochronology has dramatically improved the temporal resolution of complicated geologic events. Slow diffusion of major and minor elements, abundant Th and U, and little common Pb, make monazite an excellent tool for recording multiple metamorphic events (Williams and Jercinovic, *in press).*

Three samples from Bear Creek were selected for detailed monazite mapping - a) for their structural relationships and relative age, and b) to test for the presence of monazite in several rock types. These samples represented quartz-feldspathic gneiss, coarse grained granite gneiss, and fine grained granite. Polished thin sections were scanned for Ce, to locate potential monazite grains, and Mg, to record thin section setting, using a Cameca SX50 electron microprobe. Selected monazite grains were then mapped at high magnification for Y, Th, U, and Ca concentrations, to identify potential age domains. Major and minor element analysis of sites within these domains reveal quantified abundances of U, Th, and Pb, which are then used to iteratively calculate age and statistical significance.

Initial Monazite Results

Abundant monazite grains were found in all samples, however, alteration and deterioration of grain edges and inadequate polishing left grains in samples 21-1 and 22-3 unworkable. Maps of grains in 18-OC4 (fine grained granite) revealed distinct domains, marked by low Th cores with concordant high Th rims (Fig. 2). Probe work is continuing on this sample.

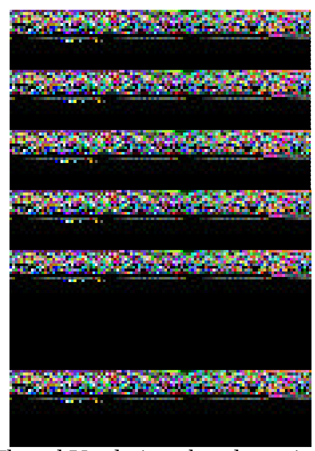

Figure 2: Th and Y relative abundance in monazite grain from fine grained granite, showing distinct low Th core, and presumed age domains.

INTERPRETATIONS and CONCLUSIONS

The field and textural observations contribute to a growing body of work supporting retrogression through amphibolite grade metamorphic conditions at ≈1365 Ma in southern Colorado. The observed deformation of quartz, with grain boundary migration and grain boundary bulge, heterogeneous subgrain development, and limited recrystallization, suggests temperatures between 350 and 700°C (Gapais, 1989; Passchier and Trouw, 1998). Limited zones of dynamic recrystallization along beautifully twinned feldspar phenocrysts, with variable undulose extinction, suggest temperatures above 500°C (Passchier and Trouw, 1998). This range is further supported by hornblende and titanite geothermometry and geochronology (Siddoway et al., 2000; Jones and Connelly, UT Austin 2002, unpublished titanite age). However, given the limited mineralogical assemblages, constraining peak temperature is rough at best. The textures observed in thin section are problematic, ranging from wormy symplectite, to feldspars with undulose extinction, and even phenocrysts with heavy, straight twin lamellae. Any high P and T estimate must take into account the lack of extensive recrystallisation and limited mantle development. It is quite possible that these heterogeneous rocks have experienced multiple deformations and substantial strain partitioning. Again, monazite geochronology currently in progress will illuminate the timing of metamorphism, and place plutonism in a temporal context with respect to deformation. Monazite ages confirming coeval plutonism and deformation would support a dynamic setting for these Mesoproterozoic granites.

Future Research

The strength of monazite geochronology is the placing of time on well-constrained P-T-D paths, by accurately dating inclusions in porphyroblasts. The granitoid assemblages in Bear Creek do not allow for such a refined application of this method. Other mineralogical and metamorphic assemblages from the Mesoproterozoic in the Wet Mountains and Arkansas River Valley are prime candidates for such research (Acevedo, Clark, Tellio, this volume). Within these assemblages there is the potential to further constrain the timing of multiple deformation events, and contribute to an emerging understanding of the 1365 Ma event and its role in southern Colorado basement development.

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