Geology of the Proterozoic Metamorphic Rocks Along Johnson Gulch, Wet Mountains, Colorado

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INTRODUCTION

The Johnson Gulch area contains outcrops of Proterozoic rocks, similar to those that make up approximately seventy-five percent of the total rock in the Wet Mountains. The geology of this area is dominated by isoclinally folded biotite-hornblende gneisses intruded during multiple episodes of granitoid plutonism ranging in age from 1700 to 1400 Ma. The aim of this project is to characterize the field relations, petrology, structural data, and geochemistry of the rocks in the Johnson Gulch area. These data are useful for constraining the chronology of deformation and plutonism, and determining the conditions of metamorphism during the Proterozoic.

FIELD RELATIONS

Field work was done in a series of loops and traverses covering approximately two square kilometers (Fig. 1). Isoclinal folding is ubiquitous in the biotite-hornblende gneisses and older granitoid intrusions. The first generation of granitoid intrusions (G1) appears as thin felsic wisps with contacts slightly discordant to foliation. The foliation within G1 is parallel to foliation within the biotite-hornblende gneisses, suggesting that the granitic material was emplaced prior to isoclinal folding.

The second granitoid intrusion (G2) appears as a strongly foliated augen gneiss. The augens are 1-3 cm diameter alkali feldspar crystals. The foliation is defined by aligned biotite layers, and contacts between G2 and the biotite-hornblende gneiss are parallel with foliation, suggesting syntectonic emplacement. There are no outcrops showing any crosscutting relationships between the first and second generations of granitoids.

The third generation of granitoids (G3) differs from the previous two in that crystals are equigranular and foliation is faint. Contacts with biotite-hornblende gneisses and other granitoids are both concordant and discordant. Highly strained dikes of this generation are found in the extreme west corner of the field area. Numerous outcrops show the third generation of granitoids crosscutting the second generation.

The fourth granitoid (G4) has no visible foliation and occurs as thick sills in both the higher elevations of the study area, and the low lying center of the gulch. G4 crosscuts G3 along the base of the high elevation sills. West trending dikes of G4 are found on the western side of the area. Pegmatites are associated with both G3 and G4 granitoids.

Two mafic sills are found within the study area. The first is a gabbroic sill with slight foliation around the edges of the intrusion, but no evidence of foliation in the center, where ophitic texture is visible. Pegmatites crosscut the gabbroic intrusion. The second is a commingled sill located eighty meters above the gabbroic sill. The commingled sill shows less viscous mafic material edging around the highly viscous granitoid center. Mutual inclusions are common. G3 is crosscut by the commingled sill along the base of the intrusion.

Lithologies change dramatically across the center of Johnson Gulch. The eastern portion of the study area is dominated by alternately layered thin, biotite-hornbleblende gneisses and felsic metasediments, intruded by all four generations of granitoids. The western portion of the study area is comprised of thicker biotite-hornblende gneisses, with thin intrusions of G2 and G3, and voluminous sills of G4. On the western side of the study area, biotite-hornblende gneiss found above 2800 meters tends to be biotite-rich, while biotite-hornblende gneiss below this elevation is hornblende-rich. On the eastern side of Johnson Gulch, biotite-hornblende gneiss is found below 2870 meters, while most of the rock above this elevation is biotite-rich migmatite. Outcrops along the center of the gulch display cataclasites and slickensides.

STRUCTURAL OBSERVATIONS

The foliation in Johnson Gulch strikes northwest to west and dips to the northeast. However, when the foliations from east Johnson Gulch are compared with those from west Johnson Gulch, two distinct groups appear (Fig. 2). Foliations in the western side of Johnson Gulch dips more steeply to the northeast than the eastern side. Most lineations in Johnson Gulch trend northeast. Measurements are divided into two groups based on their position relative to the center of the Gulch. Lineations from the east portion of the area plunge more shallowly than those in the west.

PETROGRAPHY

Twenty-two thin sections were prepared. Segregated felsic and mafic bands are common features. Crystal size in each type of band is equigranular, although the crystals are much smaller in the mafic bands compared to the felsic bands. Major felsic minerals include microcline, quartz, and albite. Major mafic minerals include biotite and hornblende. Important accessory minerals include garnet, sillimanite (Noblett, 1987), zircon, apatite, sphene, and Fe-Ti oxides. The mafic intrusions are a special case because clinopyroxene and andesine are present. No kinematic indicators were found.

WHOLE ROCK CHEMISTRY

I analyzed twenty-eight samples for major elements using Philips 1800 XRF at Carleton College. The results show two distinct groups: one of samples with silica contents >65 wt. % and the other with silica contents between 48 and 62 wt. %. All samples in the low-silica group are biotite-hornblende gneisses or mafic intrusions, while the high-silica group are granitoids or metasediments. Harker diagrams plotting major oxides against silica content also show distinct trends among the two groups (Fig. 3). The plots of TiO_2, Fe_2O_3, MnO, MgO, and P_2O_5 show clear, well defined groups, while the plots of Al_2O_3, CaO, Na_2O, and K_2O show loosely defined groups. These contrasting distributions demonstrate the varying mobility of oxides during high grade metamorphism. When chemical data from the east side of Johnson Gulch are compared with data from the west, no distinct groups form. Both sides of the gulch contain rocks with widely varying major element components. Therefore, the groups shown in Figure 3 do not correspond to geographic position.

DISCUSSION

Chronology. Field relations indicate biotite-hornblende gneisses are the oldest rocks in the Johnson Gulch area. They have been intruded by at least four episodes of granitoid and mafic plutons. Recent U-Pb zircon work suggest times of 1720 Ma for G1, and 1705 Ma for G2 (Noblett, 1997). These dates, combined with the field relations showing pretectonic and syntectonic emplacement, link both G1 and G2 to Boulder Creek plutonism described by Noblett et al (1987). Both mafic intrusions are mid-Proterozoic in age, and are not part of the Cambrian dikes that appear elsewhere in Colorado (Bickford et al., 1989). The gabbroic sill is crosscut by a pegmatite associated with either G3 or G4, and the commingled sill on the east side of Johnson Gulch has been related to the San Isabel batholith, which is considered the last of the Silver Plume intrusions (Noblett and Staub, 1990). The granitic component of the sill resembles the mineralogic and chemical make up of the nearby batholith, which is dated at 1360 Ma (Thomas et al., 1984). The mafic component of the sill is categorized by its chemistry as a tholeiitic lamprophyre, and plots within the rift related, within-plate field. Because G3 is not found in fold hinges and is discordant to foliation in most outcrops, it is most likely related to 1,400 MA granitoid plutonism. The presence of highly strained dikes of G3 in the western portion of Johnson Gulch supports the hypothesis of synmagmatic strain during emplacement of 1,400 Ma plutons (Nyman et al., 1992). The lack of foliation in G4 suggest that it is also related to the nearby San Isabel batholith.

Conditions of Metamorphism. The conditions of metamorphism can be estimated using petrographic data. The microcline twinning observed in thin sections develops as monoclinic feldspar transforms into triclinic microcline during cooling. The change occurs at 573°C (Klein and Hurlbut, 1993). The presence of sillimanite and garnet suggests a barometric pressure of 3 to 3.5 kilobars and a temperature of 650°C (Noblett, 1987). Both pieces of information place the metamorphic conditions in the amphibolite facies.

Laramide Related Deformation. The combination of lithologic change across the center of Johnson Gulch, the presence of cataclastites and slickensides, and the slightly offset foliations and lineations suggest a fault striking north west through the center of Johnson Gulch. The major element analysis showed no distinct chemical difference on either side of the fault, suggesting both sides of Johnson Gulch may originally have been part of the same lithologic package. If this hypothesis is correct, the package must have been offset after the last foliation was imprinted. Field observations show that there have been no foliation causing events after the emplacement of G4. The only deformation to occur in the Johnson Gulch area since the Proterozoic is Laramide uplift during the Cretaceous. The Johnson Gulch fault is most likely a splay from the nearby Ilse fault, which strikes northwest and runs the length of the Wet Mountains. It was active during the Laramide and experienced large a degree of strain, as shown by the highly brecciated, oxidized, and faulted rock exposures along the roadcuts of Rt.165.

REFERENCES CITED

Bickford et al., 1989, U-Pb zircon geochronology of Proterozoic and Cambrian plutons in the Wet Mountains and southern Front Range, Colorado: Geological Society of America Special Paper No. 235, p. 49-64.

Klein and Hurlbut, 1993, Manual of Mineralogy: New York, John Wiley and Sons, Inc., p.167-168.

Noblett and Staub, 1990, Mid-Proterozoic lamprophyre commingled with late-stage granitic dikes of the anorogenic San Isabel batholith, Wet Mountains, Colorado: Geology, v. 18, p. 120-123.

Noblett, 1997, Personal communication.
Nyman et al., 1992, Mesoproterozoic contractional orogeny in western North America: Evidence from ca. 1.4 Ga plutons: Geology, v. 22, p. 901-904.
Thomas, J.J., Shuster, R.D., and Bickford, M.E., 1984, A terrane of 1,350- to 1,400-m.y.-old silicic volcanic and plutonic rocks in the buried Proterozoic of the mid-continent and in the Wet Mountains, Colorado: Geological Society of America Bulletin, v. 95, p.1150-1152.

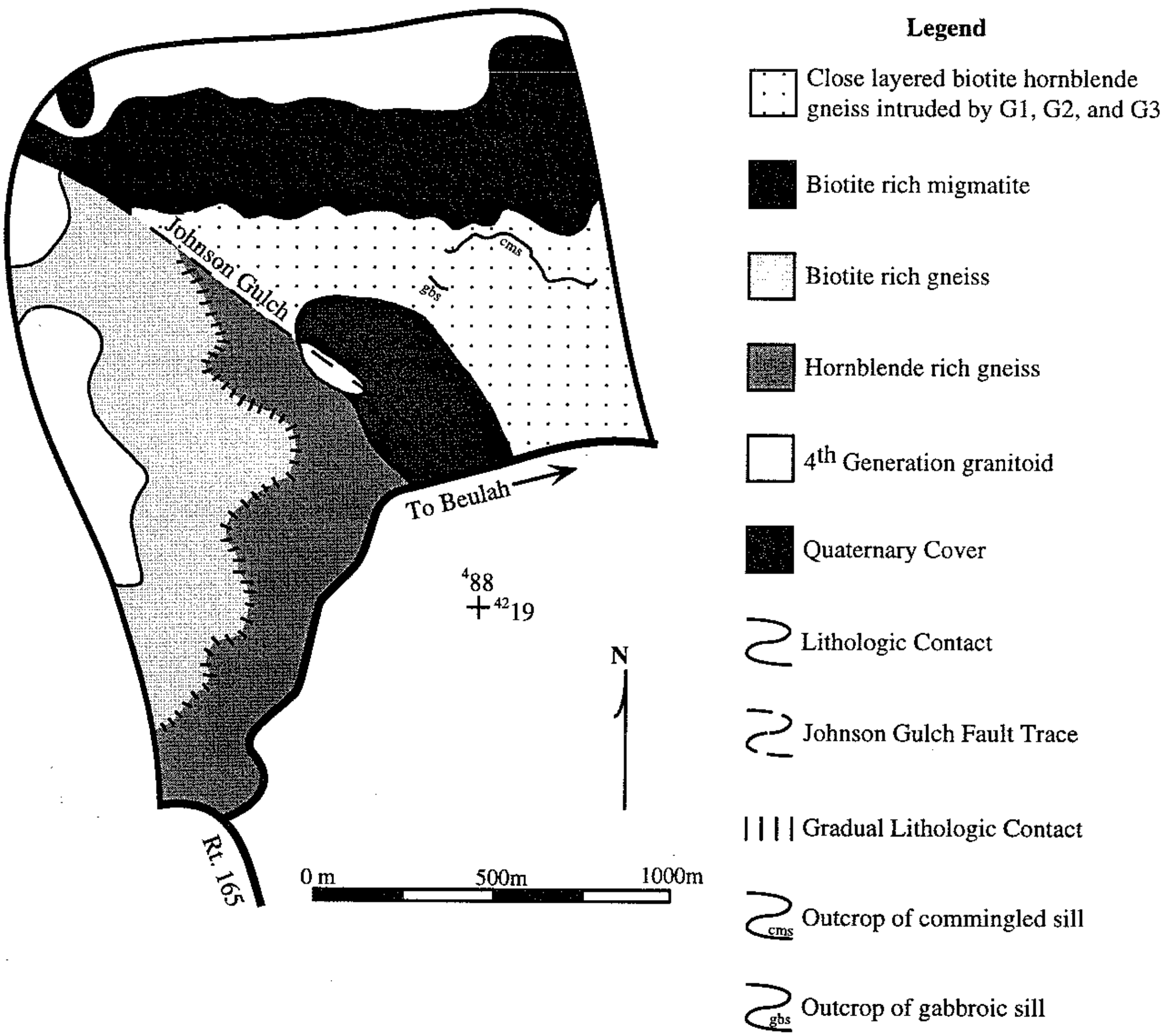

Figure 1. Geologic map of the Johnson Gulch Field Area.

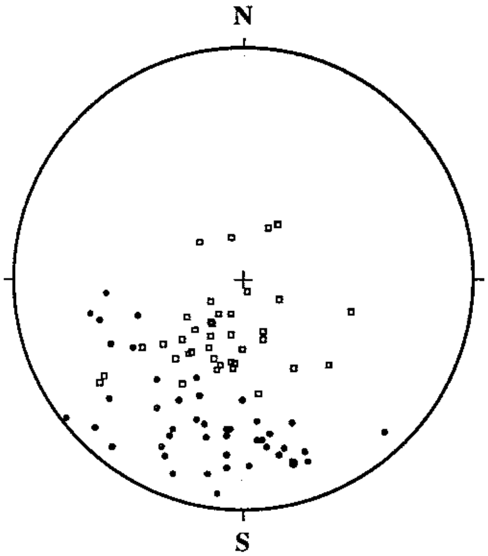

Figure 2. Stereonet of poles to foliation in the Johnson Gulch area. Circles: foliation of west gulch. Boxes: foliation of east gulch.

Figure 3. Harker diagrams plotting major oxides against SiO2 in the litholoies of Johnson Gulch. Dashed circles contain biotite-hornblende gneisses and mafic intrusions. Solid circles contain granitoids and metasediments.