A Geochemical and Petrographic Analysis of quartzofeldspathic gneisses in the the Pony Middle Mountain Metamorphic Suite and Indian Creek Metamorphic Suite, Tobacco Root Mountains, Southwestern Montana

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INTRODUCTION

The Indian Creek Metamorphic Suite (ICMS), located in the west-central and southern areas of the Tobacco Root Mountains contains quartzofeldspathic gneiss, hornblende gneiss, dolomitic marble, aluminous schists, quartzite and iron formation. The Pony Middle Mountain Metamorphic Suite (PMMMS), located in the north and northwest Tobacco Root Mountains, is dominated by quartzofeldspathic gneiss with lesser amounts of hornblende-plagioclase gneiss and amphibolite.

The ICMS and PMMMS quartzofeldspathic gneisses occur within notably differing rock associations. Generally, quartzofeldspathic gneisses of the ICMS include a large amount of isoclinally folded marbles and quartzites along with a variable amount of hornblende gneiss. The PMMMS quartzofeldspathic gneiss includes only a very minor amount of these marbles, quartzites and hornblende gneisses. The presence of marble and quartzite in the ICMS, suggests it is more likely to be of sedimentary origin than the PMMMS. This lithologic discrepancy provides the question addressed in this study. The goal of this project is to determine the protolith of these quartzofeldspathic gneisses and to make a geochemical comparison between the ICMS and PMMMS assemblages.

METHODS

Eighty-two samples of quartzofeldspathic gneiss were collected in the field for geochemical and petrogaphic analysis. From these eighty samples thirty thin sections were cut for petrographic analysis. Fifteen samples were analyzed for major, minor and trace element data; six from the ICMS, and nine from the PMMMS. These sample localities were chosen based on their proximity to other mapped lithologic units, such as marbles, quartzites, hornblende gneisses. Major and minor element data were analyzed using Inductively Coupled Plasma (ICP) methods performed by ACT Labs in Ontario, Canada. Trace elements were analyzed by using Instrumental Neutron Activation Analysis (INAA) performed at Oregon State University.

PREVIOUS WORK

Several attempts have been made at determining the origin of the quartzofeldspathic gneisses in the Tobacco Root Mountains. Unfortunately, the interpretations are generally conflicting and inconclusive. Several high grade metamorphic and folding events have obliterated the primary textures and structures that might provide a clue to the origin of these rocks.

The ICMS quartzofeldspathic gneisses contain a significant amount of interfoliated and folded marble and quartzite. Due to the spatial relationship, the rocks have generally been interpreted as sedimentary (Mogk et al., 1992). In addition, grain shape studies on zircons performed by Cordua (1973) and Hess (1967) indicate that 72-100% of the zircons found in these gneisses are rounded. The rounded shape of these zircons suggested they could be detrital grains of sedimentary origin.

In contrast, geochemical analysis of quartzofeldspathic gneisses in the ICMS conducted by Jacob (1984) suggests that the quartzofeldspathic gneisses of this region are igneous in origin based on discrimination functions of Shaw (1972). Also, Wilson and Hyndman (1990) conducted studies on four gneisses from the Copper Mountain and Kelley area. From these studies they concluded that these gneisses show calc-alkaline affinities similar to granitic rocks enclosing synplutonic basaltic dikes found in the Cretaceous Idaho Batholith and could have developed in a similar setting. In addition, Clark and Mogk (1986) found that REE evidence for quartzofeldspathic gneisses in the nearby Blacktail range are consistent with tonalitic and granitic source areas.

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Looking north from Noble Lake at terrain underlain by SPMS rocks believed to represent allochthonous oceanic crust.

PETROGRAPHY

As analyzed in thin section, the ICMS and the PMMMS granofeldspathic gneisses generally consist of similar mineral assemblages. These assemblages include: 50-60% quartz, 15-20% orthoclase, 5% microcline, 10-15% plagioclase with lesser amounts of biotite (5-10%). Accessory minerals are hornblende, garnet, apatite, zircon, monazite, sphene, epidote, clinopyroxene, titanite, calcite and opaques (< 3%). Rocks found near the Tobacco Root Batholith generally contain chlorite replacing biotite. This chloritization was a local retrograde event probably caused by an increase in temperature of host rocks during the intrusion of the Cretaceous Tobacco Root Batholith.

Grain shapes and sizes are variable. Generally, most grains tend to be euhedral to subhedral, however, it is not uncommon to find completely anhedral grains. Minerals are medium to coarse grained. Foliation in thin section is defined by mineral segregation layers and elongation of biotite and quartz crystals.

Zircons are more abundant in the ICMS. These zircons all appear to be rounded. The few zircons found in the PMMMS are generally larger and much more euhedral than those found in the ICMS.

All thin section billets were stained to detect the presence of potassium feldspar. Rocks from the ICMS contain close to 10% more potassium feldspar than those from the PMMMS. In thin section, the ICMS contains around 5% more microcline than the PMMMS.

GEOCHEMISTRY

Fifteen quartzofeldspathic gneisses from the PMMMS and ICMS were analyzed geochemically. The geochemistry of the quartzofeldspathic gneisses from these assemblages is highly variable. It appears that each sample has its own chemical signature dissimilar to gneisses from neighboring areas.

Generally, REE patterns indicate that these gneisses are slightly LREE enriched and slightly HREE depleted. The slope of the REE pattern is almost flat when normalized to continental crust. This pattern, however, does indicate an overlap between the ICMS and PMMMS. In general, the ICMS, appears to have lower REE abundances than the PMMMS **(Figure 1).**

Discrimination diagrams based on Shaw (1972) suggest that all but one study sample had an igneous protolith. This discrimination diagram is based on the following equation:

$$DF = 10.44 - 0.21SiO_2 - 0.32Fe_2O3 - 0.98MgO + 0.55CaO = 1.46\ Na_2O + 0.54\ K_2O$$

If the equation is > 0, then the rock is most reasonably interpreted as having an igneous protolith. If this equation is < 0 when major element oxide values are used in each sample, then the rock is interpreted as having a sedimentary protolith **(Figure 2).**

DISCUSSION

The quartzofeldspathic gneisses from the Tobacco Root Mountains have undergone several high-grade metamorphic events. These metamorphic events could have played a large role in altering the chemical signature of the rocks that we see today. Therefore, it might not be possible to determine protolith based on geochemistry alone. The geochemical signatures of these gneisses are distinctly different from one another- arguing that these rocks have been through a significant amount of metasomatism and alteration. It is therefore very important to use extreme caution in evaluating the geochemistry of these rocks. Discrimination functions are a way of approaching the protolith problem, however one must also use caution in relying too heavily on these diagrams because their validity is questionable. Rounded zircons found in the ICMS have previously been interpreted as detrital (Cordua, 1973), but metamorphic zircons typically are rounded, so the validity of that interpretation is questionable (Cherniak et al, 1997).

Therefore , the task of protolith determination is extremely difficult when addressing metamorphic rocks. However, large potassium feldspar porphyroblasts found frequently in the field within the ICMS and PMMMS assemblages are probably too large to have formed during metamorphism (Siddoway, personal comm. 1997). **(Figure 3).** These porphyroblasts are very likely to be primary features, indicative of a coarse-grained or pegmatitic igneous rock that intruded some host. Thus, the protolith for the PMMMS assemblages could have been arkosic sandstones, greywackes, weathered granites, granites or felsic volcanics intruded by pegmatite.

The textural observations together with the results of discrimination functions following Shaw, (1972) may support an igneous protolith for the gneisses of the PMMMS and ICMS assemblages. The one sample, that did plot as sedimentary (# 72 Figure 2), contains cordierite, which typically forms in meta-pelitic rocks. This discrimination diagram doesn't address the problem that marbles and quartzites are interfoliated within the ICMS assemblages. An igneous rock with the chemical composition observed, that could have been emplaced in a sedimentary sequence, would most likely have been a felsic volcanic rock. The REE diagram does however indicate the chemistry of the PMMMS and ICMS assemblages overlap somewhat. However, the differences in the ICMS and PMMMS REE abundances are still visible. In addition, the chemistry of these gneisses is strikingly similar to known Archean granitoid rocks of the neighboring Beartooth Mountains. The quartzofeldspathic gneisses of the Tobacco Root Mountains have very similar Na_2O and K_2O signatures to the Long Lake Granite in the eastern Beartooth Mountains. **(Figure 4)** (Mogk, 1988).

Therefore, based on field data, discrimination diagrams, geochemistry and comparisons to rocks of known origin, it appears that these rocks of the PMMMS and ICMS are both of igneous and sedimentary origin, although they appear to have more igneous than sedimentary affinity.

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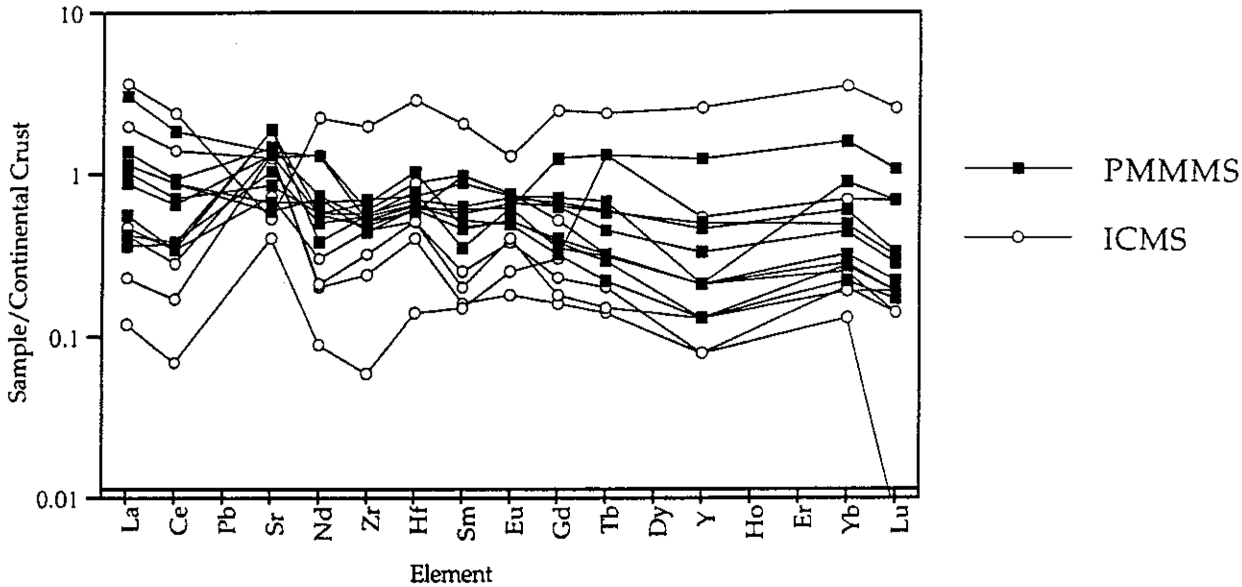

Figure 1. Rare earth element spider plot for samples of the PMMMS and ICMS metamorphic assemblages.

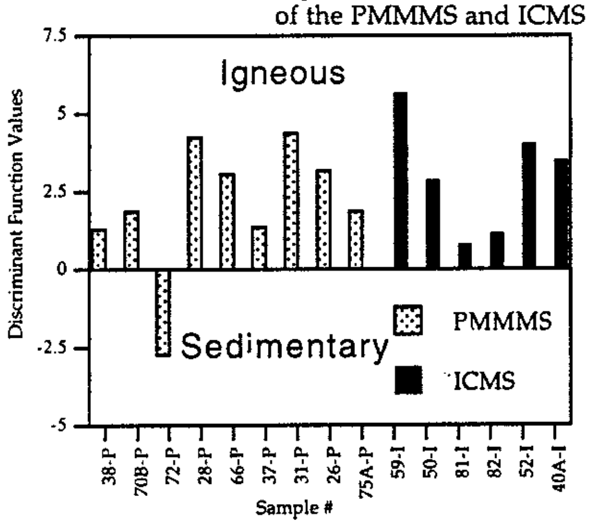

Figure 2. Discrimination diagram based on Shaw (1971), indicating that most of the samples of the PMMMS and ICMS assemblages plot as igneous.

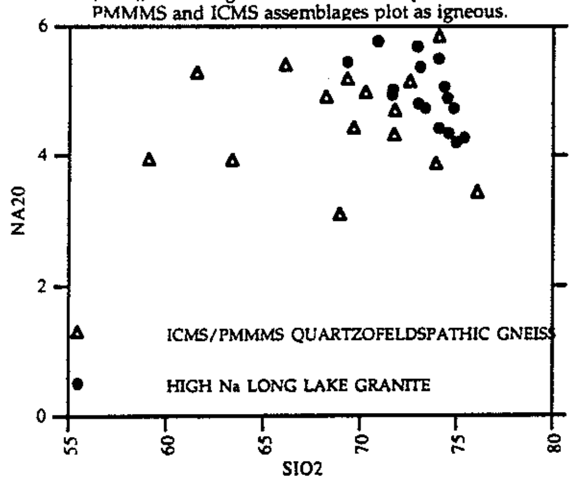

Figure 4. Comparison of PMMMS and ICMS assemblages to high Na Long Lake Granite from the nearby Beartooth Mountains (Mogk,1988)

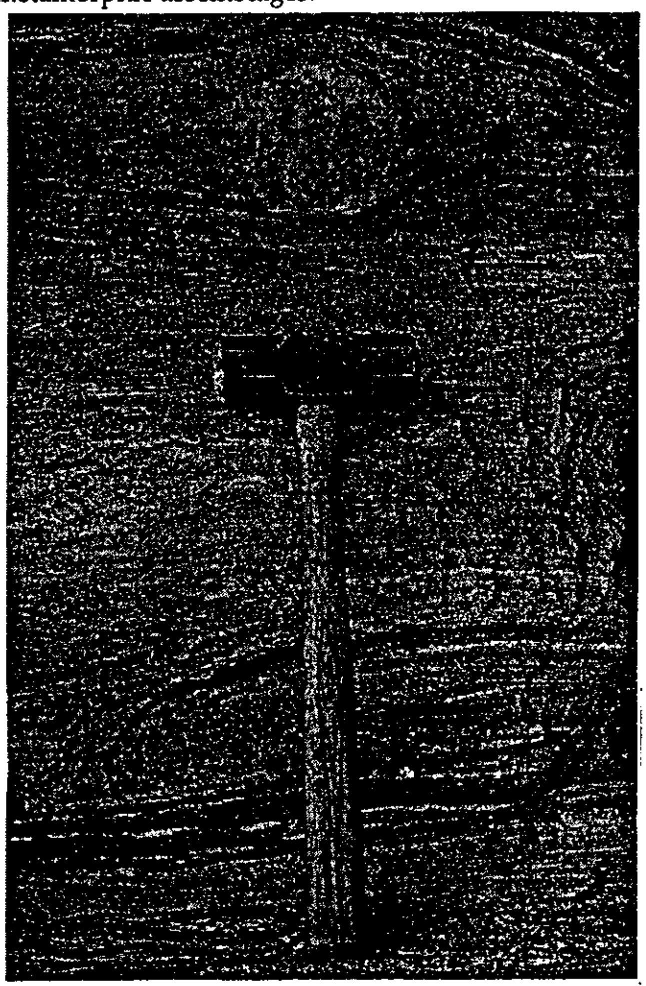

Figure 3. Large potassium feldspar porpyroblast found in the ICMS assemblage representative of those found throughout thePMMMS and ICMS assemblages.

Ductile deformation in the Tobacco Root Mountains of Southwest Montana

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INTRODUCTION

The Spuhler Peak Metamorphic Suite (SPMS) lies between the Indian Creek Metamorphic Suite (ICMS) and the Pony-Middle Mountain Metamorphic Suite (PMMMS) in the Tobacco Root Mountains of southwest Montana. The SPMS is a distinct lothologic assemblage consisting of amphibolite, horneblende-plagioclase gneiss, gedrite-garnet-plagioclase gneiss, sillimanite schist, and quartzite (Burger et. al., this volume). The rocks of the PMMMS and ICMS vary greatly from the SPMS rocks as they are dominated by quartzofeldspathic gneiss and marbles, with much lesser amounts of amphibolite. The contact between the SPMS and the gneisses of the ICMS and PMMMS is currently folded in a km-scale, possibly non-cylindrical fold (Burger et. al., this volume). Burger (1969) hypothesized that the contact may have originally been a regional scale fault. The fault model for the contact explains the juxtaposition of the contrasting lithologic assemblages of the SPMS and the ICMS and PMMMS. In contrast, Gillmeister (1971) hypothesized that the contact was originated as a depositional contact. This distinction is critical to the tectonic and metamorphic history of the Tobacco Root Mountains. Accordingly, it is necessary to test these interpretations of the SPMS/ICMS-PMMMS contact by determining if shear occurred along this contact; and, if so, identifying the direction and sense of that shear.

METHODS

In this study, 40 oriented samples were taken from 30 outcrops of quartz rich rocks at the SPMS contact and up to 0.5 km from the contact on either side. The samples consisted primarily of fuchsitic quartzite from the SPMS and quartzofeldspathic gneiss from the ICMS and PMMMS. Microscopic analysis of quartz deformation fabrics requires a large number of grains to be analyzed in thin section, thus requiring the selection of fine grained samples. In order to sample a broad range of fine grained, quartz-rich rock, samples were taken from many points along the SPMS contact. Locations were chosen not only from the nose of the fold, as in the Kranenberg (1996) study, but also down both limbs of the fold. This enabled comparison between the deformed rocks of the nose and the deformed rocks along each limb. Each sample was cut to produce two mutually perpendicular thin sections: both perpendicular to foliation, one parallel to lineation.

In order to provide sufficient evidence for the strain history of these rocks, both textural analysis of samples in thin section as well as quartz C-axis analysis were completed. Initial petrographic analysis of these samples was followed by C-axis analysis in which the orientations of quartz C-axes were measured using a universal stage to determine if lattice preferred orientation (LPO) exists. The data were then plotted on a lower hemisphere projection and interpreted.