Petrology of mafic and felsic gneisses of the Indian Creek Metamorphic Suite, Tobacco Root Mountains, southwestern Montana

Jennifer Martin
Department of Geology, Franklin and Marshall College, P.O. Box 3003, Lancaster, PA 17604
Faculty sponsor: Robert A. Wiebe, Franklin and Marshall College

INTRODUCTION

The Indian Creek Metamorphic Suite (ICMS) consists of units of quartzofeldspathic gneiss, marble, aluminous schist, hornblende gneiss, iron formation, and quartzite. Most of the units in this suite of rocks are sedimentary in origin. The quartzofeldspathic gneiss, however, can be further subdivided into sections containing metasedimentary rocks as well as granitic gneiss and amphibolite which probably had igneous origins. The purpose of this study is to attempt to determine if these granitic gneiss and amphibolite sequences are igneous in origin, whether they are volcanic or plutonic, and whether they provide information on tectonic setting.

FIELD RELATIONS

Rock classification. Vitaliano *et al* (1979) describe the quartzofeldspathic gneiss unit of the ICMS as four distinct lithologies: quartzofeldspathic gneiss, amphibolite, quartzite, and sillimanite schist. Vitaliano *et al* also subdivides the quartzofeldspathic gneiss lithology into four rock types with somewhat variable mineralogy. The other three lithologies are described as being found in thin interlayers with the quartzofeldspathic gneisses. Granitic gneiss is light gray to pinkish-gray with a color index less than ten and a dominant mineralogy of quartz, feldspar, and biotite. Amphibolite is dark gray to black with a color index greater than fifty and a dominant mineralogy of hornblende and plagioclase feldspar.

Field observations. The quartzofeldspathic unit consists of approximately 50% granitic gneiss and 20% amphibolite with the remaining 30% being quartzite and sillimanite schist. Locally, however, there are areas in which the percentages of granitic gneiss and amphibolite are more equal, particularly close to the contact between the ICMS and the Spuhler Peak Metamorphic Suite. The granitic gneiss layers range in width from 10 cm to 50 m while the amphibolite layers range from 10 cm to 6 m. The gneissose layering within the granitic gneiss and amphibolite layers is always parallel to the contacts between the two lithologies. The contacts between the two lithologies are typically sharp and planar. No non-planar contacts between the granitic gneiss and the amphibolite were observed.

PETROGRAPHY

Approximately 80 samples were collected; however, it was necessary to eliminate a number of samples to achieve a more manageable set to analyze. The least weathered and most homogeneous samples were chosen and 32 were cut for thin-sections. The following petrologic descriptions are based on a set of 18 thin-sections (12 amphibolites and 6 granitic gneisses). The set of samples was limited due to the availability of corresponding geochemical data.

Amphibolites. Four of the 12 sections (3, 16B, 26A, 33A) studied are fine-grained, the remaining 8 are a medium-grained. The mineralogy of these samples is predominantly hornblende and plagioclase feldspar with some samples containing minor amounts of clinopyroxene, quartz, orthopyroxene, garnet, biotite and other accessory minerals such as apatite. Alteration of the rocks produced secondary minerals such as sericite and chlorite in some of the samples.

<u>Hornblende</u> is the dominant mineral in all of the amphibolite samples. The pleochroism of the hornblende is predominantly green-brown; however, two samples (3 and 21) display tan-brown pleochroism. Quite a wide variety of grain size and shape was observed ranging from 0.2 mm sub-rounded crystals to 2 mm elongate sub-rectangular crystals. Some crystals are also twinned. Hornblende replaced clinopyroxene in several of the samples, and some of the hornblende crystals are pseudomorphs of clinopyroxene crystals. Where clinopyroxene crystals are present, hornblende crystals are always found surrounding them.

<u>Plagioclase</u> is the second most abundant mineral in the samples. Approximately 40% of the plagioclase crystals are twinned. The grain size is quite variable. The majority of the grains are 0.2 mm and sub-rounded. The remaining crystals include 1-2 mm sub-rounded crystals as well as more elongate, 2-3 mm, crystals which are often sub-rectangular. Typically the smaller crystals are not as frequently twinned

as the larger crystals. Plagioclase crystals often meet at 120° angles. Alteration to sericite is common in the plagioclase crystals in many of the samples.

Clinopyroxene occurs in 7 of the 12 sections. Remnant crystals, replaced by hornblende occur in a couple of the other samples. The grain size varies from 0.2 mm irregularly shaped crystals to 2 mm elongate crystals.

Quartz occurs in 3 of the 12 sections. Quartz occurs as 0.15 mm interstitial crystals between hornblende and plagioclase, as 0.2 mm sub-rounded crystals, and in veins of 0.2 mm sub-rounded crystals concordant to the gneissose banding. Many of the crystals display undulatory extinction. Where the sample has strong compositional layering, quartz occurs in plagioclase-rich layers.

Orthopyroxene occurs as 1-2 mm irregularly shaped crystals. These original orthopyroxene crystals are found altered to cummingtonite in one sample (16B).

Garnet crystals occur in one sample (21). The crystals range in size from 0.2 mm and 0.7 mm and are irregularly shaped. Some crystals contain inclusions of the other minerals present in the section such as quartz and hornblende.

Biotite crystals also occur only in sample 21. They are 0.15 mm rectangular, dark brown pleochroic crystals that occur in irregular clumps.

Granitic gneiss. Of the six granitic gneiss samples, only one (16A) is fine-grained; the rest are medium-grained. The mineralogy of these samples is predominantly quartz and plagioclase feldspar and/or K-feldspar with biotite, garnet, muscovite, and other accessory minerals. As with the amphibolites, alteration minerals such as chlorite and sericite are also present.

Plagioclase crystals occur in all of the samples. They make up approximately 50% of each sample. Approximately 50% of the crystals exhibit twinning of some type. The grain size varies from 0.2 mm sub-rounded to 2-3 mm and sub-rectangular. The grain boundaries typically meet at 120° angles. Sericite alteration is common in these samples.

K-feldspar crystals occur in 3 of the 6 granitic gneiss samples (15A, 30, 33B). They are always found in smaller percentages than plagioclase crystals. These crystals all display cross-hatch twinning. The crystals are normally 0.2 mm and sub-rounded. They occur irregularly throughout the samples, but are most often in groups with plagioclase crystals.

Quartz crystals occur in all of the samples and are nearly equal to the feldspars in abundance. There is a variation in grain sizes from 0.2-2 mm, but the shapes of the grains are usually sub-rounded. Some of the grains exhibit undulatory extinction.

Biotite crystals occur as a small percentage of all of the granitic gneiss samples. In 4 of the six samples (26B, 30, 33A, 53A), biotite exhibits brown pleochroism. In the remaining two samples the pleochroism is green. The crystals are 0.2-0.5 mm and euhedral. They are often aligned parallel to each other and to the banding if it is present.

Muscovite crystals occur in a small amount in 2 of the 6 samples (16A and 33B). The crystals are 0.1 mm and typically occur interstitially.

Garnet crystals occur in sample 26B. They occur intermittently as 0.2-0.7 mm irregularly shaped crystals.

GEOCHEMISTRY

Twenty-four samples were analyzed for major and trace element concentrations using x-ray fluorescence spectroscopy. The samples chosen to be analyzed were the least weathered and most homogeneous of the group. The results from eighteen of the samples will be considered at this time. The remaining samples include those analyzed for comparison between the metamorphic suites, those collected outside the main map area, and those yielding poor results. Of the 18 samples, 11 were chosen for rare earth element (REE) analysis.

Results. Compositions of the rocks fall into two distinct groups (Fig. 1). The first group is lower in silica and higher in calcium and consists of the 12 amphibolite samples. The second group is higher in silica and lower in calcium and consists of the remaining 6 granitic gneiss samples. The silica content of the amphibolites ranges from 48% to 52%. The silica content of the granitic gneisses ranges from 63% to 73% with the exception of sample 16A which contains 83% silica.

Amphibolites. The most notable variation in major elements of the amphibolites can be found in Al_2O_3, MgO, and total iron. The AFM diagram (Fig. 2) illustrates some of the variation in MgO and total iron. These samples plot along a fairly clear line that might indicate the beginning of a tholeiitic trend driven by fractionation. Geochemically the amphibolites have typical basaltic compositions; however, they are not completely consistent with any one type of basalt (Raymond, 1995)

Discriminant trace element plots illustrate the problem of grouping these samples as a specific type of basalt (Fig. 3). These samples do not consistently plot within a certain type of basalt; and, it is notable that five of the samples do not even plot within this diagram's range of basalts. This variation in conjuction with preliminary REE graphs showing a positive Eu anomoly for several of the samples suggest crystal accumulation.

Granitic gneisses. Geochemically these samples resemble granitic compositions. They fall within the limits of variation of some typical granites; however, they are not completely consistent with any one type (Raymond, 1995). All of the granitic gneiss samples are corundum normative. Figure 4 plots the samples in terms of normative percent quartz, albite, and orthoclase. It is notable that the majority of these samples plot along the cotectic. They also display a range in ratio of albite to orthoclase. It is apparent from this plot as well as figure 1 that one sample does not fall within the normal variation of the group. Sample 16A contains more silica and significantly less total iron than the rest of the samples.

DISCUSSION

Petrographically the samples do not obviously retain any primary igneous textures. It is possible that some of the plagioclase crystals could have been recrystallized from a formerly larger crystal. There are examples of areas in the thin-sections of both types of rocks where mosaics of small grains have the shape of a larger subhedral feldspar.

Geochemically the amphibolites resemble basalts; however, they do not plot consistently as one type of basalt on discrimination diagrams (Fig. 3). Plagioclase accumulation indicated by negative Eu anomolies shown in graphs of the REE data could be an explanation for the variation in the lower end of the tholeiitic trend in the AFM diagram (Fig. 2). These facts might be evidence against a volcanic protolith for some of the samples.

In the granitic gneiss group, sample 16A does not geochemically resemble an igneous rock. Its percentage of silica is too high and the rest of its chemistry is not consistent with the other samples. The most reasonable explanation would be that this rock is sedimentary in origin.

REFERENCES CITED

Raymond, Lauren A., 1995, Petrology: The Study of Igneous, Sedimentary, and Metamorphic Rocks (1st ed.): Dubuque, Wm. C. Brown Communications, Inc., 742 p.

Vitaliano, C.J., Burger, H.R., W. S., Hanley, T. B., Hess, D. F., and Root, F.K., 1979, Explanatory text to accompany the geologic map of the southern Tobacco Root Mountains, Madison County, Montana: Geological Society of America Map and Chart Series MC-31, p. 1-8.

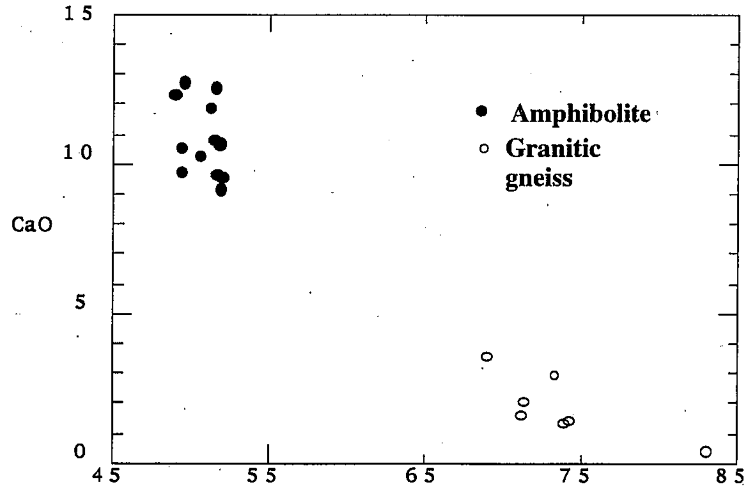

Figure 1. Plot of SiO2 v. CaO.

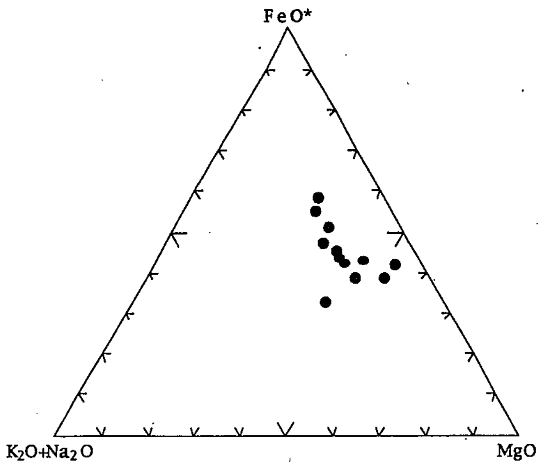

Figure 2. AFM plot of amphibolite samples.

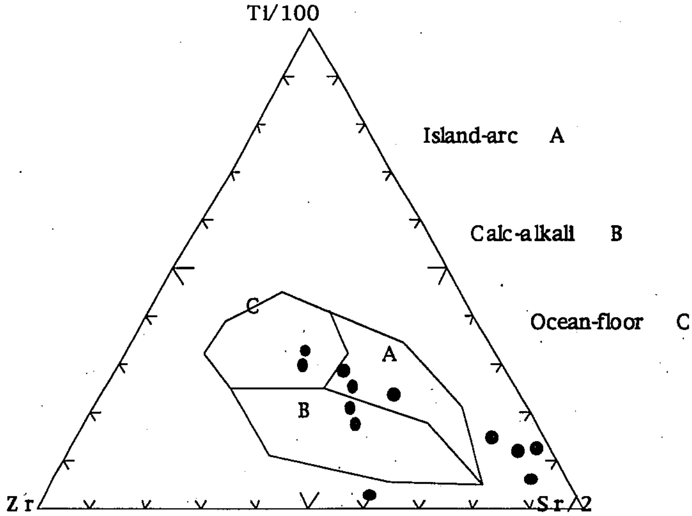

Figure 3. Amphibolite geochemical data plotted on a basaltic discrimination diagram (Pearce and Cann, 1973)

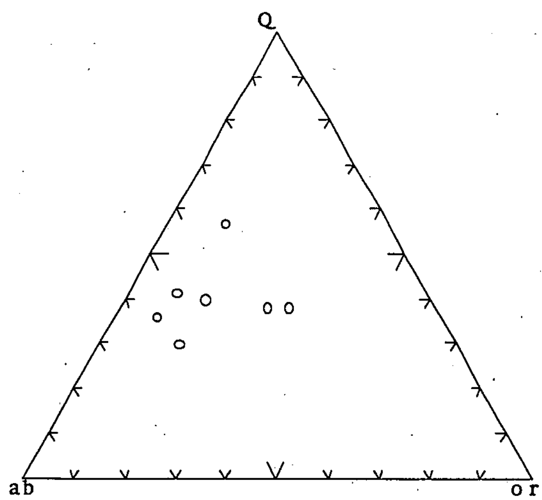

Figure 4. Granitic gneiss samples plotted on the quartz-albite-orthoclase triangle.