XENOLITHS OF THE PTARMIGAN LAKE PLUTON
BUENA VISTA, COLORADO

Rebecca K. Mellinger
Department of Geology
The College of Wooster
Wooster, OH 44691

This project is one of four in the Ptarmigan Lake study area (Buena Vista, Colorado), in the Collegiate Peaks portion of the Sawatch Range. It is accessible by first following the Cottonwood Pass road about 15 miles west of Buena Vista, Colorado, then taking Chaffee County Road 346 to a parking area. A logging road (not open to the public) intersects the San Isabel National Forest Ptarmigan Lake Trail. The area is covered by the Mt. Yale and Tincup 7.5 minute quadrangles, in Colorado. This study is one of eight resulting from the Keck Geology Consortium's Colorado project. The goal of the project is to characterize the metasediments and metavolcanics of central Colorado (Boardman, 1976).

Rocks exposed around Ptarmigan Lake are pelitic metasediments and interlayered mafics and felsics, intruded by a granodiorite pluton. Amphibolite bodies in the pluton are the subject of this paper. In previous work Brock and Barker (1972) have mapped the Ptarmigan Lake Granodiorite as an extension of the Kroenke Lake Granodiorite (1.7 Ga) (Barker, 1974). It is light gray and usually medium grained with a composition ranging from a trondhjemite to a leucoquartz monzonite (Barker, 1974). Barker characterizes a trondhjemite as a leucoquartz diorite with either oligoclase or albite as plagioclase constituents. The mafic silicates are either biotite or hornblende or both, but biotite is typical. One purpose of this study is to compare chemical analyses from the Ptarmigan Lake pluton with published data of the Kroenke Lake Granodiorite (Barker, 1974).

The granodiorite at the Kroenke Lake type locality, approximately 7 miles northeast of Ptarmigan Lake, is coarse-grained, homogeneous, and well foliated. Major minerals are quartz, plagioclase, muscovite, and biotite. Dark bands near the contact are interpreted as swirls of resorbed country rock. The contact reveals the surrounding interlayered mafics and felsics deformed by the pluton. In macroscopic comparison the type locality rock appears very similar to the Ptarmigan Lake Pluton which is also coarse-grained, homogeneous, and foliated. Quartz, plagioclase, biotite, and sphene are present. Information about xenoliths in the Kroenke Lake Pluton was not collected. In the Ptarmigan Lake Granodiorite the amount of mafics varies. This variation may be a result of the presence or absence of amphibolites. Other color variations are attributed to weathering because boulders have broken loose at different times.

Samples collected for the purpose of studying the pluton include both the coarse- and fine-grained xenolithic components along with granodiorite samples. The collection area is along the western extension of the pluton from the boulders in a talus pile at the base of an outcrop cliff (Figure 1). This area was chosen because it offers a representative sampling of xenolith types and behavior for the entire pluton, with other localities exhibiting similar outcrop patterns and xenolith behavior. This made it unnecessary to sample from the entire pluton exposure.

The two distinct types of amphibolite bodies were sampled based on grain size and behavior within the pluton. The first type to be considered was a fine-grained (up to 0.5 mm) amphibolite. A field description includes hornblende and plagioclase, epidote crystals, not veins, and small orange crystals of sphene. Within the pluton the fine-grained amphibolites exhibit ductile behavior indicated by ghost images and swirls of mafic minerals within the granodiorite. This suggests they have been partially or completely resorbed into the pluton. There is some metamorphic fabric but it is difficult to discern because of the small grain size.

The other amphibolite type is a coarse-grained (up to 1mm) rock, with hornblende, plagioclase, and sphene visible in hand sample. Another characteristic of this group of rocks are small (1-5 mm) white blebs. Coarse-grained amphibolites behaved in a brittle manner in the pluton. They are usually very blocky, as opposed to the ductile flow exhibited by the fine-grained amphibolites. Some have been pulled apart or shot through with pegmatites. A minor foliated fabric is present.

Surrounding both types of amphibolite is an almost mafic free band ranging from a few millimeters to several centimeters in width, possibly some type of large scale reaction ring. The boundaries between the band and the amphibolite, and between the band and the host are very sharp in hand sample. Samples were also taken from this leucocratic zone between the amphibolitic and host material

The major questions this study considers are the chemical comparison of granodiorites of the Kroenke Lake type locality (Barker, 1974) and the Ptarmigan Lake study area; if indeed the amphibolites are xenoliths or segregates of the host magma; why they behaved differently in the magma; and the possible significance of leucocratic zones around the amphibolites. Information will be collected through the analysis of thin sections, major and trace elements, and rare earth elements (REE).

Major and trace elements were analyzed at Franklin & Marshall College, Lancaster, PA, with the assistance of Dr. Stanley Mertzman on a Diano 8300 X-ray fluorescence vacuum spectrometer for automated data acquisition and reduction, interfaced with an IBM-AT equipped with a 20 MB hard disk for data calculation and storage. REE analyses for three samples were performed at Kansas State University by Robert Cullers.

Thin section analyses reveal the major constituents of the equigranular, fine-grained xenoliths as hornblende, plagioclase with abundant sericitic alteration, and biotite, some of which has retrograded to cholrite. Accessory minerals are epidote, apatite, and individual crystals of sphene. Foliation is caused by biotite. Coarse-grained samples also contain hornblende, sericitically altered plagioclase, less biotite than the fine-grained samples, diopsitic pyroxene (not in the fine-grained samples), and clumps of sphene. Thin section shows the previously mentioned white blebs to be concentrations of plagioclase which are now mostly sericite and/or epidote. Mild foliation is present with respect to hornblende. Grain size is slightly variable.

The granodiorite samples are equigranular, coarse-grained (up to 2 mm) and contain plagioclase, microcline, perthite, myrmekite, quartz, biotite, and sphene. Minor amounts of hematite and magnetite are present as opaque minerals. Comparison of Barker's chemical analyses of the Kroenke Lake Granodiorite (1974) support inclusion of the Ptarmigan Lake Pluton as an extension of the Kroenke Lake Pluton.

Major and trace element data were studied by plotting components on conventional Harker and ternary diagrams (Cox et al.,1979). Various major element plots show two distinct populations, one of the granodiorites, and one of the amphibolites, both fine- and coarse-grained (Figure 2). From the distinct compositional gap between the two populations, it is concluded the xenoliths were introduced into the granodiorite magma other than being magma segregates. Shelby Boardman had the opportunity to examine the thin sections and stated they looked very much like the amphibolites he has been studying in the Salida, Colorado, area since approximately 1976. Comparison of chemical analyses supports this as well (Boardman, 1976).

Another consideration is if the two types of xenoliths are of one or two different origins. Since the two types are not in two distinct groups when plotted (Figure 2), it is concluded they are of two different origins, not of one now visible at various stages of alteration. If they were at different stages of alteration, there would be more distinct groups grading from one xenolith into the other, instead of the two overlapping populations shown.

No direct reason has been found suggesting why the two types of xenolith behaved differently in the melt. One possibility is that the smaller grains allowed more liquid into the amphibolite because common grain boundaries are overall shorter. This would make it more susceptible to liquid pushing grains apart and causing physical and chemical deformation. Conversely, less liquid was allowed into the coarse-grained xenolith since common grain boundaries are longer. It is difficult to determine if grain size affected behavior, or if grain size is the result of other processes which may have caused the behavior.

With both types of samples, the leucocratic zones around the xenoliths are coarser grained than the xenolith. The main constituents of the zones are quartz, plagioclase, and some potassium feldspar, microcline. In the middle of the zone, there is less potassium feldspar than is present at the xenolith/zone and granodiorite/zone contacts. It is not clear, but for some reason potassium has been removed from this part of the zone. When compared to analyses of gabbros, basaltic volcanics, and basaltic volcaniclastic rocks in the Salida area, xenolith samples are similar overall, but high in potassium. The Salida samples range from 0.31% to 1.79% K2O, and from 1.02% to 2.29% K2O for the Ptarmigan Lake samples (Boardman, et al., 1986).

Rare earth elements were analyzed for one sample from each group; the granodiorites and the two types of amphibolites. Chondrite normalized analyses have been compared to mafic and felsic patterns of the Salida area (Boardman, et al., 1986). None of the Ptarmigan Lake sample patterns fit into groups delineated by Boardman.

Through thin section and chemical analysis, the major questions concerning the granodiorites and the origin of the amphibolites of the Ptarmigan Lake Pluton have been answered. The two granodiorites in question are very similar, and support mapping done by Brock and Barker (1972). The amphibolites are xenoliths and not segregates of the magma, with two types of xenolith of two origins. Comparison of the xenolith data to published data of Boardman (1976), allows the conclusion that local gabbros and basaltic rocks exposed in the Salida area may have been the source. The temperature of the Ptarmigan Lake Pluton was high enough to cause reaction of the magma with the fine-grained amphibolitic xenoliths. The coarse-grained amphibolitic xenoliths retain sharp contacts with the granodiorite and primary minerals (diopside). At some contacts a pre-existing metamorphic fabric of the xenolith is truncated by a metamorphic fabric of biotite in the granodiorite. Since the coarse-grained xenoliths have been only slightly modified, they indicate that metamorphism of gabbro to amphibolites occurred earlier before their introduction into the pluton.

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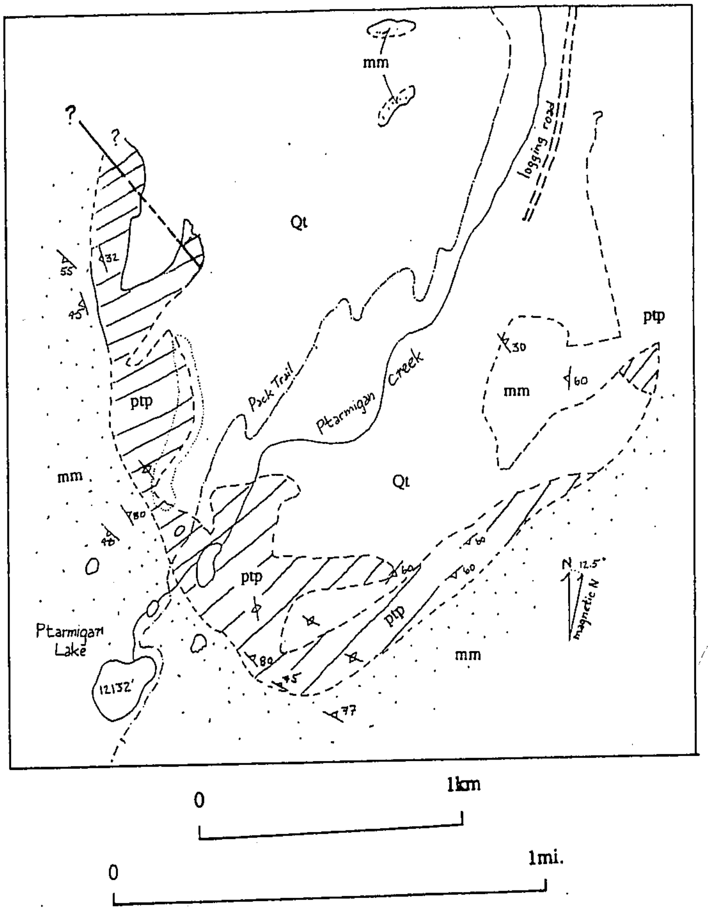

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EXPLANATION OF SYMBOLS

-sample area

-contact, dashed were approximate

-fault, dashed where concealed

-strike and dip of foliation

Quaternary

Qt -glacial till and talus containing ptp and mm

Proterozoic

ptp -Ptarmigan Lake Pluton
(see paper for description)

mm -metasediments and metavolcanics
-sillimanite, muscovite, quartz schist to migmatite
-hornblende-plagioclase gneiss
-interlayered plagioclase,quartz biotite gneisses

Geology by R.A. Wobus,
K. Johnson, and M. Owens

Figure 1-- Sample collection location from Mt. Yale and Tincup quadrangles.

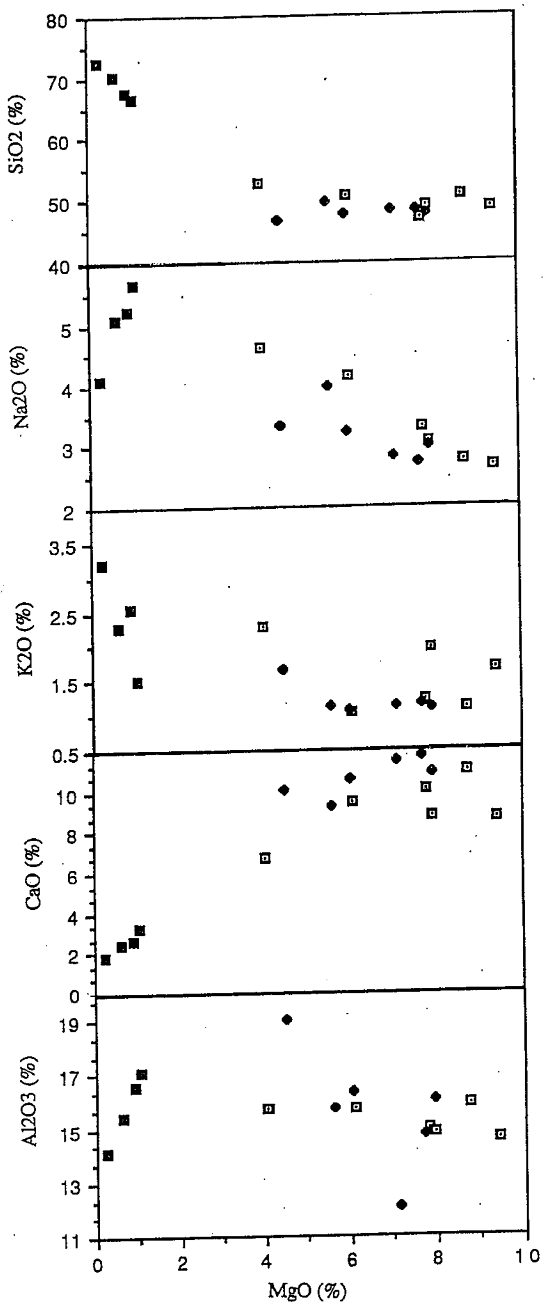

Figure 2-- Harker diagrams of major oxides.

□ fine ◆ coarse ■ granodiorite