A Petrological and Geochemical Study of the Gabbros and Associated Rocks from the Pikes Peak Batholith, southern Front Range, Colorado

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Introduction

The gabbros of the Pikes Peak Batholith occur in three small ring complexes and one other intrusive center in and adjacent to the pluton. Each complex is located on the western edge of the batholith with the exception of the intrusive center at West Creek which is more centrally located. Samples of gabbro were selected from the following areas for which maps have been published: Cripple Creek (Sage, 1966), Lake George (Anderson and Wobus, 1978), Tarryall (Hawley and Wobus, 1977), and West Creek (Barker et al., 1975). The gabbros were examined in light of preexisting emplacement theory (Barker et al., 1975). It was hypothesized that modern geochemical work would serve to incorporate the gabbros more significantly into the model of genesis for this pluton.

Field Description

In addition to the gabbros, these intrusive centers contain a common association of quartz syenite, quartz monzonite, and anorthosite. With few exceptions the previously published maps were extremely accurate. The oval shaped Cripple Creek body is about 1.7 by 3 kilometers in diameter with gabbro forming the outer rim. Samples from this location were obtained from mining pits since there were no outcrops in place. Most exposures of the gabbro were weathered. The anorthosite found here is pegmatitic (Barker et al., 1975) and it could possibly have evolved from the gabbro as plagioclase fractionated from the magma. Quartz syenite forms the core of this stock. The elliptical Lake George body is approximately 6.5 by 8 kilometers in diameter with outcrops of relatively fresh gabbro situated throughout its core. Quartz syenite is also present here. The Tarryall pluton is an oval shaped body about 2 by 2 kilometers in size, and is cut by the Redskin Stock. It consists of an outer rim of gabbro surrounding an inner zone of quartz monzonite and a core of quartz monzonite porphyry. The gabbro from West Creek is from one outcrop that also contains syenite and granite, both of which are younger based on field relationships.

Petrography

Petrographic analysis of eight representative samples of the medium to coarse-grained gabbros reveals common assemblages dominated by plagioclase. Augite and biotite are also abundant. In lesser amounts the assemblages contain olivine, apatite, magnetite, and quartz. The plagioclase crystals are commonly large, altered, typically Labradorite (An_{60}), and vary in texture from anhedral and equant to subhedral and tabular. Some samples exhibit albite twinning and oscillatory zoning. The augite is anhedral to subhedral and is distinguished by its length fast orientation. The biotite generally surrounds the magnetite. A significant amount of the olivine crystals are altered to biotite and apatite is common in all samples, whereas quartz is present in relatively few. The sample of the associated rock, quartz syenite, is weathered and highly altered. It consists of quartz, potassium feldspar, plagioclase (An_{55}), and lesser amounts of hornblende and biotite. The quartz monzonite is medium-grained with a mineral assemblage similar to that of the syenite. The quartz monzonite porphyry is distinguished by phenocrysts (2mm) of blue-grey quartz, large feldspar phenocrysts, and higher percentages of quartz and potassium feldspar than the

DISCUSSION

The Pikes Peak batholith is composed predominantly of A-type granites under the classification developed originally by Chappell and White (1974). A-type granitic rocks are described as a suite of syenites to granites characterized by sub-aluminous to peralkaline chemical trends, higher alkalies and lower CaO than other granitoids, high FeO/MgO, high halogens, and enrichment in mafic silicates and high field strength (HFS) elements (Eby 1990). The Sugarloaf syenites follow these trends and fall in the A-type suite.

Barker and others (1975, 1976) did major element and isotopic analyses of the Pikes Peak batholith and proposed the only existing model for its petrogenesis. The assimilation-fractional crystallization (AFC) model proposes that the sodic rocks were differentiated from alkali basaltic magma contaminated by reaction melting in the lower crust. Preliminary AFC modeling, suggested by isotopic study (Douglass, this vol.), imply the Sugarloaf syenites may be derived from fractional crystallization of gabbroic rocks and crustal contamination. Not all elements support this model, however, and additional consideration is needed to further restrict a petrogenetic model for the syenites.

Trace element variation among the syenites may also be generated by fractional crystallization. Three samples were normalized to GM19RB, a medium grained syenite that appears the most primitive according to trace element data (figure 5). The samples are relatively enriched in the incompatible elements: Th, Nb, Ce, Zr and Hf; and depleted in the more compatible elements, like Sr and Ba. Sample GM12RB, a fine grained syenite, is more enriched in incompatible elements and more depleted in the compatible elements than the other three medium grained syenites. This implies GM12RB is the most evolved and may support the field observation that the fine grained syenite intrudes the medium and coarse grained syenites within Sugarloaf intrusive center.

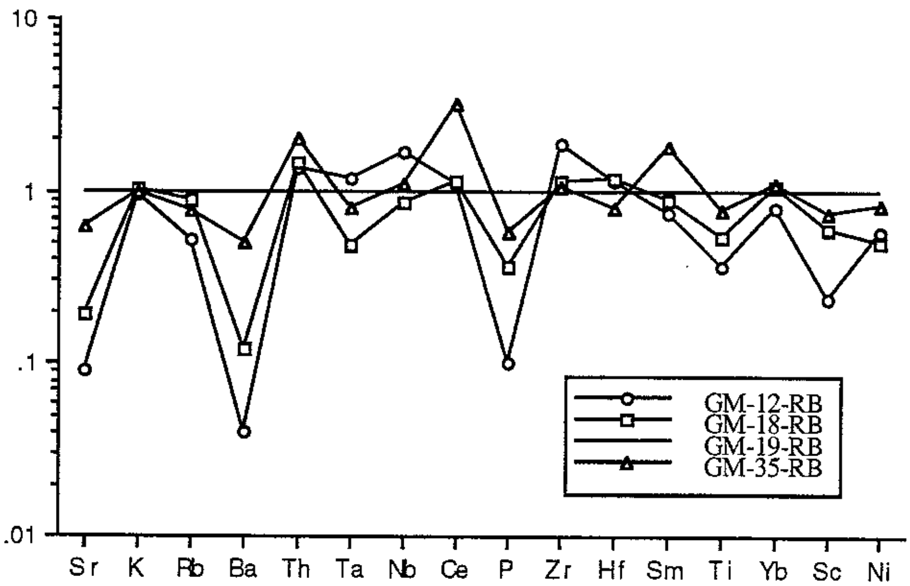

Figure 5. Samples from Sugarloaf normalized against sample GM19RB.

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quartz monzonite. The anorthosite contains plagioclase in the Labradorite range and its crystals are large and euhedral to anhedral.

Geochemical Data

The representative samples of the gabbro and associated rocks were analyzed at Franklin and Marshall College for major and trace element composition using X-ray fluorescence. Inductively coupled plasma analysis provided additional trace and rare earth element data. Four gabbro samples were also analyzed using instrumental neutron activation. The accuracy levels for major element analysis show percent error to be 5% or less and for trace elements it is generally below 8%.

The silica content for the gabbros ranges from a low of 44.27% to a high of 51.95%. The MgO values are also significantly different, sample CCN-19 has 11.82% and T-34 contains only 2.59%. FeO values range from 6.24% (CCN19) to 13.76% (CCN19B). The total alkali contents for the gabbros are all above 5%, with the exception of sample CCN-19, suggesting an alkali gabbro classification (Anderson and Wobus,1978). This is confirmed by an AFM diagram based on the Irvine-Baragar (1971) classification system. The gabbros have relatively high concentrations of alumina ranging from 13.35% to 16.84%. As expected, a ternary plot of TiO_2, K_2O, and P_2O_5 modeled from continental origins of basalts (Pearce et al., 1975) determines the gabbros to be of continental origin.

The REE plot in figure 1 shows a high light-REE enrichment and relatively low concentrations of heavy REE. The graph shows a linear trend and sample CCN-19 shows a very slight Europium anamoly suggesting plagioclase fractionation.The high concentrations of LREE also imply the possibility of partial melting or a LREE enriched source (Wilson, 1989). The presence of apatite could also strongly fractionate the REE (Le Marchand, et al., 1987).

Discussion

An attempt was made to find relationships between the gabbros of the Pikes Peak batholith in an effort to affirm the model of genesis (Barker et al., 1975) involving the starting or parent mantle-derived magma that evolves through lower crust contaminattion and fractional crystallization into the rocks of the sodic suite of this pluton. In a plot of Nd versus Sr (epsilon values) based on INAA data, it was determined that sample CCN-19 had an enriched mantle composition (Douglas, 1993). It showed the most enriched crustal Nd signature and had the most primitive major element composition, low SiO_2 and high MgO. According to the same Nd values, samples CCN-19B, T-34, and WC-38 suggest a depleted mantle source that had assimilated continental crust. WC-38, containing the highest SiO_2 content, was the most evolved gabbro. Attempts were made to model the fractionation of the three depleted gabbros from CCN-19. These modeling studies have been unsuccessful to date, but work is continuing.

No major elements of the gabbros appear to behave incompatibly, further trace element work is needed to verify this. Harker diagrams of major elements plotted against SiO_2 reveal similar trends. It is evident from these diagrams that several of the samples consistently plot together. Figure two, MgO against SiO_2, shows how the pairs of T-30 and T-34, LG-22 and LG-23, and T-26 and CCN-19B group with one another. WC-38 either plots away from the first pair or close to them as seen in Figure 2. CCN-19 either plots either away from the last pair or in some cases it simply switches positions with CCN-19B. Further research of the gabbros is necessary; modeling involving trace elements may assist in developing a possible theory relating the gabbros to separate source compositions.

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Figure 2: Harker Diagram of Magnesium versus Silica.

Explanation: CCN-19B - open triangle, T-26 - solid triangle, LG-22 - open square, LG-23 - solid square, T-30 - open diamond, T-34 - solid diamond, CCN-19 - open circle, WC-38 - solid circle.

Figure 1: Spider Diagram for Samples Using INAA Analysis. (Chondrite Values from Leedy)