Field Relations, Petrology and Geochemistry of Sugarloaf Complex , Pikes Peak Batholith, Colorado

Rachel J. Beane, Williams College, Williamstown, MA 01267

Sugarloaf is one of seven sodic intrusive centers that lie within or adjacent to the 1,040-m.y.-old Pikes Peak Batholith in central Colorado. Major element and modal analyses from six centers have previously been published: Lake George, Tarryall and Rampart Range by R.A. Wobus (1976), and West Creek/Deckers, Mt. Rosa and Cripple Creek by Barker and others (1975). This study presents field relations, petrography, and major and trace element analyses for the seventh intrusive center.

FIELD RELATIONS

Sugarloaf is a north-north west trending pluton of syenite (1x3 km) located in the Green Mountain 7 1/2-minute quadrangle (T9S, R71W). Outcrops and float were used to determine the contact between the syenite and the Pikes Peak granite. The contact was plotted on a forty-foot contour interval topographic map using an altimeter and Brunton compass (figure 1). Granite with abundant milky quartz, found in the south west portion of the map area, suggests local shearing and later mineralization.

Four textures of syenite were identified: fine, medium, coarse and pegmatitic syenite. The various textures of syenite were not mappable and generally occured throughout Sugarloaf. The fine grained syenite appears to cut the medium and coarse grained syenite in several places. Much of the syenite was weathered; the freshest samples were found near the top of Sugarloaf. Samples of syenite were also taken from a Jefferson County Highway 126 roadcut approximately three miles to the east of Sugarloaf (T9S, R70W).

PETROGRAPHY

Point counts of four stained slabs locate the samples within the syenite range on a QAP diagram (recalculated counts: quartz <5%, plagioclase ≈20%, K-spar ≈75%). Twenty -five samples were examined in thin section. Thin section petrography showed the syenites were primarily perthite (70 - 80%), with amphiboles (10 - 20%), quartz (<5%), opaques (<5%) and trace amounts of fluorite, apatite, plagioclase and biotite.

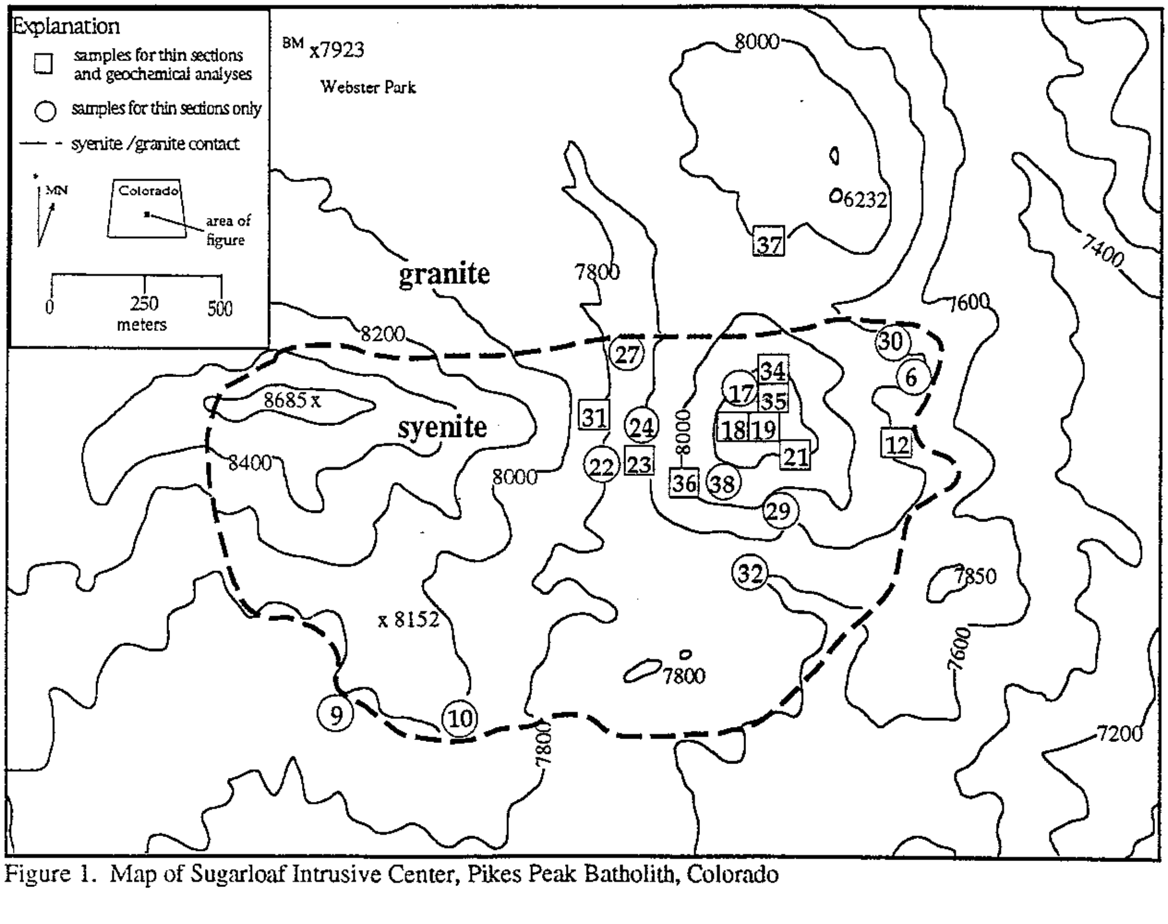

Figure 1. Map of Sugarloaf Intrusive Center, Pikes Peak Batholith, Colorado

Sami Goldman studied a series of unusual lamprophyric dikes located around the south margin of the Mount Rosa center. Her field observations constrained several of these as Pikes Peak in age while other dikes in the region may be younger. These rocks are the most primitive yet found in the batholith and are essential in understanding the nature of the underlying mantle and interaction of mantle-derived melts with crust.

Marnie Sturm undertook a study of the overall geochemical trends in the batholith. Other workers have shown that there are several geochemical varieties of "A-type" granites found around the world (e.g., Eby, 1992), and for some, their geochemistries correlate with tectonic setting. Marnie will compare major and trace element data for the Pikes Peak rocks with other global occurrences of A-type granitoids on various types of discrimination diagrams in order to establish geochemical characteristics of the Pikes Peak batholith in the overall scheme of A-type (and anorogenic) granites.

Acknowledgments

All of the student's advisors participated actively in this project. Visitors to the field site included Shelby Boardman (Carleton) and Peter Crowley (Amherst). Assisting in the computer modelling at the winter workshop were Lori Bettison-Varga (Wooster), Sam Kozak (Washington and Lee) and Steve Weaver (Beloit). In the field, Dan Unruh of the U.S.G.S. and Bob Shuster from the University of Nebraska-Omaha provided guidance and background materials. Special thanks go to Marnie Sturm, our super field assistant from Trinity University and to Darren Cameron and Maggie Jastremsky, our excellent camp tenders from Colorado College. Access to labs was generously provided by Franklin and Marshall College (XRF and ICP), the University of Massachusetts at Amherst (XRF), and Rice University (Sm-Nd and Sr isotope analysis). We are especially grateful to lab directors Stan Mertzman, Mike Rhodes and Pete Dawson, and Jim Wright for their help at these labs. Finally, our thanks to the students in our group whose ability to collaborate on and share research was a joy.

References Cited

Barker,F., Millard,H.T., Hedge,C.E., and O'Neill,J.R., 1976, Pikes Peak batholith -- Geochemistry of some minor element and isotopes, and implications for magma genesis, in Epis,R.C., and Weimer,R.J.,eds., *Studies in Colorado Field Geology: Colorado School of Mines. Prof. Contr.* 8, p.44-56.

Barker,R., Wones,D.R., Sharp,W.N., and Desborough,G.A., 1975, The Pikes Peak batholith, Colorado Front Range, and a model for the origin of the gabbro-anorthosite-syenite-potassic granite suite: *Precambrian Research*, v.2, p.97-160.

Bryant,B., Barker,F., Wobus,R.A., and Hutchinson,R.M., 1976, Road Log, Pikes Peak batholith field trip, in Epis,R.C., and Weimer,R.J.,eds., *Studies in Colorado Field Geology: Colorado School of Mines. Prof. Contr.* 8, P.17-31.

Eby, G., 1992, Chemical subdivision of the A-type granitoids: petrogenetic and tectonic implications, *Geology*, 20, p.641-644.

Hutchinson,R.M., 1960, Structure and petrology of north end of Pikes Peak batholith, Colorado, in *Guide to the Geology of Colorado*: Rocky Mountain Association of Geologists, Denver, Colorado, p.170-180.

Hutchinson,R.M., 1976, Granite-tectonics of Pikes Peak batholith, in Epis,R.C., and Weimer,R.J., eds., *Studies in Colorado Field Geology: Colorado School of Mines. Prof. Contr.* 8, p.32-43.

Scott,G.R., Taylor,R.B., Epis,R.C., and Wobus,R.A., 1978, Geologic map of the Pueblo 1° x 2° quadrangle, south-central Colorado: *U.S.Geol.Survey Map I-1022.*

Wobus,R.A., 1976, New data on potassic and sodic plutons of the Pikes Peak batholith, central Colorado, in Epis,R.C., and Weimer,R.J., eds., *Studies in Colorado Field Geology: Professional Contributions of the Colorado School of Mines*, no.8, p.57-67.

Perthite textures varied and included both stringer and bleb-like forms. The perthite often interfingered with adjoining grains of perthite or quartz. Perthite stringers generally extended across Carlsbad twin boundaries although a few terminated at the boundary. Quartz and plagioclase are anhedral and interstitial, suggesting they are late in crystallization history. Amphibole and fluorite textures also imply late crystallization. The amphiboles are pleochroic brown to green and support occasional blue threads within the amphibole or along its rim. Amphiboles were probed with an SEM and identified as ferro-richterite (Giambalvo, this volume). Apatite is sub- to euhedral and sometimes appears within other minerals suggesting it underwent an early crystallization. SEM probe of the opaques revealed they were of the ilmenite series.

GEOCHEMISTRY

Major and trace elements of eleven samples were determined using the XRF lab at the University of Massachusetts, Amherst. Major elements for Sugarloaf syenite averaged: 62% SiO_2, 15% Al_2O_3, 7% total Fe, 6-7% Na_2O, 5% K_2O, 1%CaO, and less than one percent of TiO_2, MgO, MnO and P_2O_5. The AFM diagram shows all samples have high total alkalies and relatively little iron or MgO (figure 2). The one sample of granite (number 37 on map), contained: 73% SiO_2, 13% Al_2O_3, 2% total Fe, 3% Na_2O, 6%K_2O, 1%CaO and less than one percent of TiO_2, MnO, MgO and P_2O_5. SEM probe of amphiboles (sample GM18RB, Giambalvo this vol.) indicated the amphiboles were enriched in TiO_2,FeO, CaO, MgO, and MnO when compared to whole rock analyses.

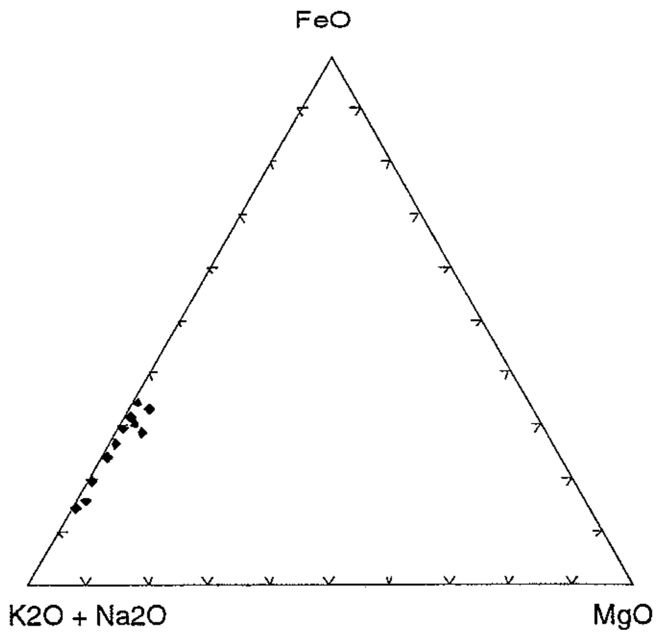

Figure 2. AFM diagram for samples from Sugarloaf intrusive center.

Trace element data show the syenites are enriched in incompatible and rare earth elements (REE) when compared to MORB (figure 2). The syenites are highly enriched in Ba and Rb, both of which are likely substitutes in the feldspars of the abundant perthite. They are also notably enriched in Th, Ta and Nb. All the syenites are depleted in Sr, Ti, Sc, Cr and Ni.

REE were determined for five samples using INAA (by XRAL Laboratories). The REE plot of rock/chondrites shows the syenites are strongly enriched in REE which is expected for rocks in the A-type granite suite. The light REE elements are enriched more than the heavy REE. There is a definite Eu anomaly which reflects plagioclase fractionation and indicates there has been at least one fractionation event in the petrogenesis of the Sugarloaf syenite.

Errors for analytical methods were determined by doing statistical analyses of the standard samples run. Errors for major and trace element determined by XRF were less than or equal to 1% of the amount present. Mean error for samples determined by INAA was approximately 5% of the amount present.

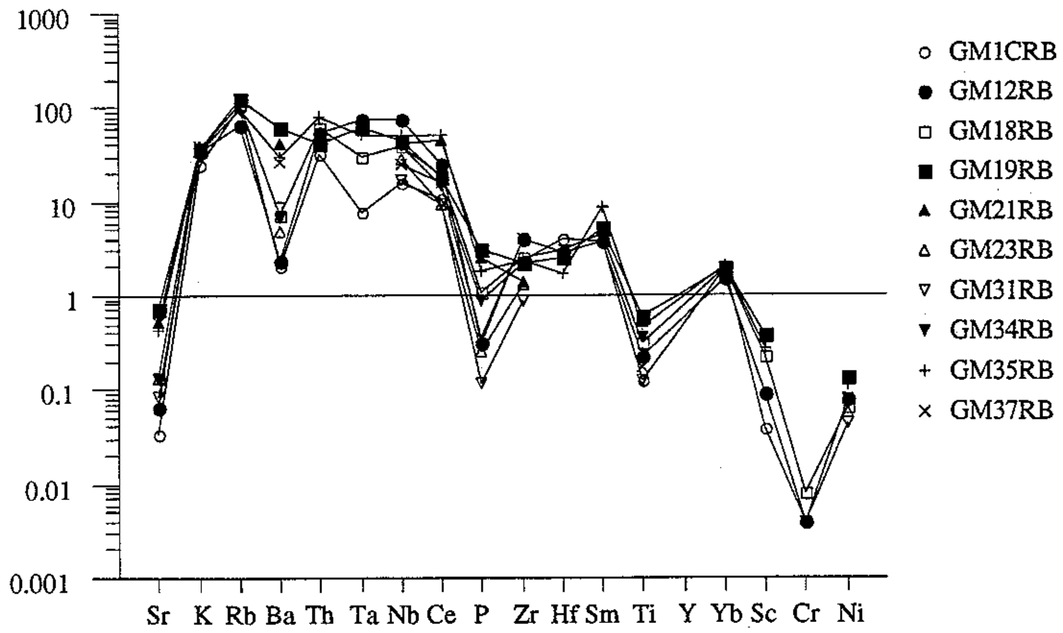

Figure 3. Pearce plot with samples normalized to MORB.

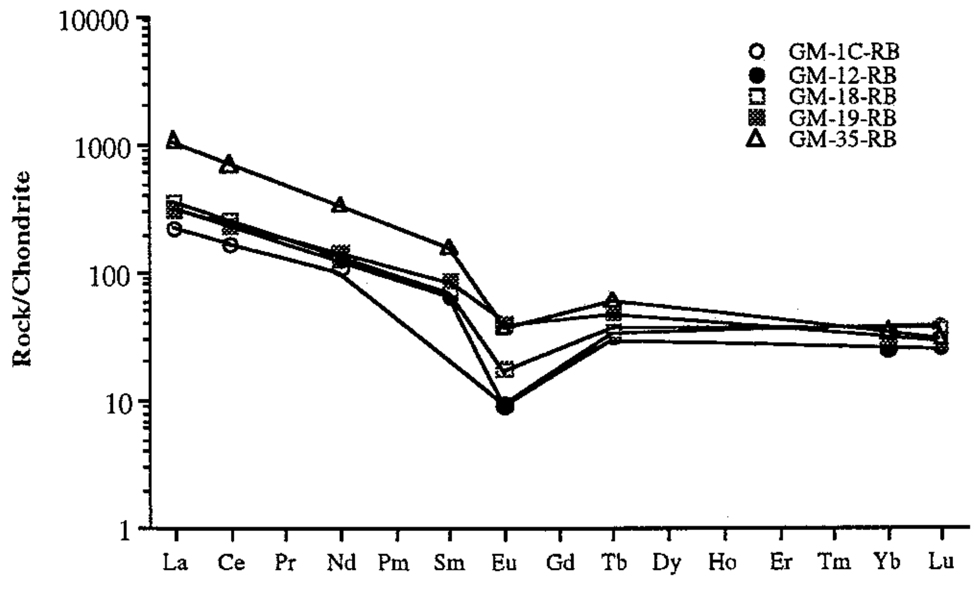

Figure 4. Rare earth element (REE) plot with samples normalized to chondrite (Taylor & McLennan 1985)

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.

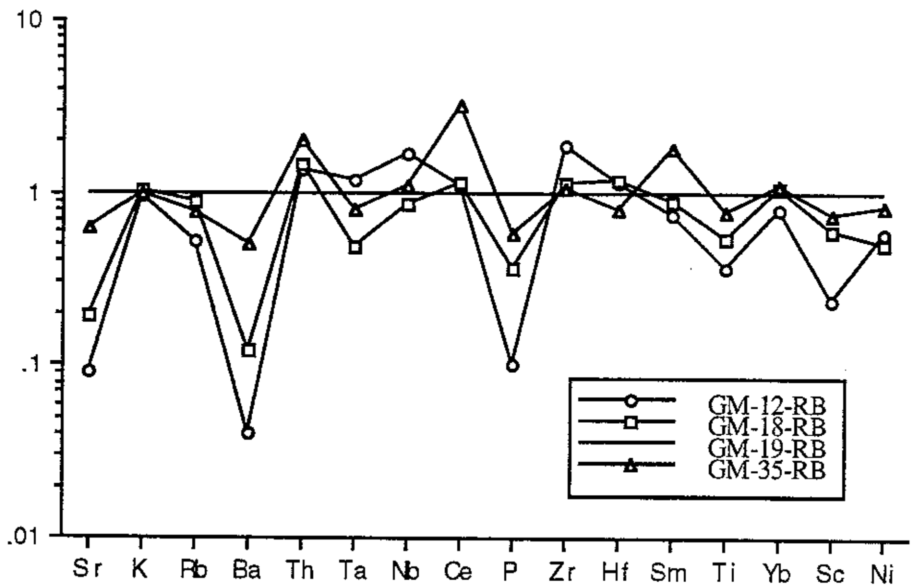

Figure 5. Samples from Sugarloaf normalized against sample GM19RB.

REFERENCES

Barker, F. , Wones, D.R., Sharp, W.N., and Desborough, G.A., 1975, The Pikes Peak Batholith, Colorado Front Range, and a model for the origin of the gabbro-syenite-potassic granite suite: Precambrian Research, v. 2, p. 97-160.

Eby, G.N., 1990, The A-type granitoids: a review of the occurrence and chemical characteristics and speculations on their petrogenesis: Lithos, v. 26, p.115-134.

Taylor, S.R., and McLennan, S.M., 1985, The Continental Crust: its Composition and Evolution.

Wobus, R.A., 1976, New data on potassic and sodic plutons of the Pikes Peak batholith, central Colorado, in studies in Colorado Field Geology: Col. School of Mines Prof. Contr. no. 8, p. 57-67.

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

Chase C. Davis
Department of Geology
Washington and Lee University
Lexington, VA 24450

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