ALKALIC INTRUSIVE CENTERS, PIKES PEAK BATHOLITH, COLORADO

Submitted by

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Introduction

The Proterozoic Pikes Peak Granite (1080 Ma) is exposed along the Front Range and Rampart Range from about the latitude of Colorado Springs north to Castle Rock; the granite is visible in outcrop for 65 kilometers west of Colorado Springs with a total surface exposure of about 3840 square kilometers (Figure 1). The Pikes Peak batholith is a complex pluton composed mostly of granite and granodiorite but containing more than a half dozen late-stage alkalic intrusive centers with compositions ranging from gabbro to syenite to fayalite granite and riebeckite granite.

At the Keck winter workshop on the Pikes Peak granite, Professor Lawford Anderson from the University of Southern California, held forth eloquently on the significance of this batholith. The Proterozoic 'red' granites represent a unique event in earth history as part of the anorogenic association of anorthosites, charnockites and granites. Anderson suggested that these plutons formed between "pulses" of orogeny and production of new crust during the Proterozoic and that this new, "juvenile" crust is the source rock for the anorogenic granitic magmas. Due to thermal instability, the underlying mantle, isolated from orogenic or subduction processes, might rise adiabatically to the base of this crust and through a variety of assimilation -fractional crystallization processes (AFC) yield these anorogenic granites. Such an event could occur only in newly formed continental crust and thus studies of the origin of anorogenic granites like the Pikes Peak batholith acquire significance in their ability to shed light on this process.

Geologic Setting

The Pikes Peak batholith is widely cited as an example of anorogenic granitic magmatism (Barker and others, 1975). This conclusion is based on the lack of internal deformation, the absence of contemporaneous tectonic boundaries in the region, and the presence of several late alkalic intrusive centers which are similar to those produced during crustal doming, extension and rifting in other parts of the world (e.g., New England, Nigeria).

More than 90 percent, by volume, of the exposed rocks in the Pikes Peak batholith are typical hornblende- and biotite granites and granodiorites with textures varying from inequigranular to porphyritic, fine-grained equigranular to pegmatitic. Hutchinson (1960, 1976) mapped primary flow structures in the batholith (based on planar parallelism of feldspars, flow layers, parallelism of xenoliths, long dimensions of feldspar, biotite, and quartz mosaics) and primary fracture systems (based on cross-joints normal to lineation, a-c normal to planar-flow structures, longitudinal joints parallel to planar flow sturctures, marginal fissures filled with aplite or pegmatite). His studies revealed three major intrusive channels within the main batholith. Since these centers are at different but overlapping altitudes, Hutchinson was able to create a three-dimensional model of the main batholith with a vertical relief of over two kilometers.

However, it is the unusual late-stage intrusive centers, which comprise only about 10 percent of the exposed batholith, which led earlier workers to hypothesize a complex, mantle-derived anorogenic origin for the Pikes Peak batholith. Wobus (1976) described two chemically distinct trends within this group of small plutons. A potassic trend, exemplified by the Windy Point and other late fine-grained granites, is found in plutons on Pikes Peak and in the Rampart Range, at West Creek and Lake George, and near Tarryall. These were interpreted as late-stage, rapidly-cooled variants of the Pikes Peak Granite. A sodic trend, recognized by compositions ranging from gabbro to syenite, fayalite granite and riebeckite granite, is found in seven small intrusive centers in the batholith. Four of these centers show ring dike-like patterns.

Geochemical analyses of samples from a few of these centers were used to propose a model for the origin of the Pikes batholith (Barker and others, 1975, 1976). Barker and others argued that mantle-derived alkali olivine basalt magma interacted with a lower crust that was depleted in K_2O due to generation of large volumes of granitic magmas during two previous Proterozoic events (1700 Ma Boulder Creek event and 1400 Ma Silver Plume event). The soda-enriched rocks of the alkalic centers were believed to be derived from those contaminated magmas. This model has been widely cited in the literature as one explanation for such rocks; however, his model was based primarily on major-element data. Trace element and isotopic compositions corroborated the model but were obtained for only a few of the alkalic centers.

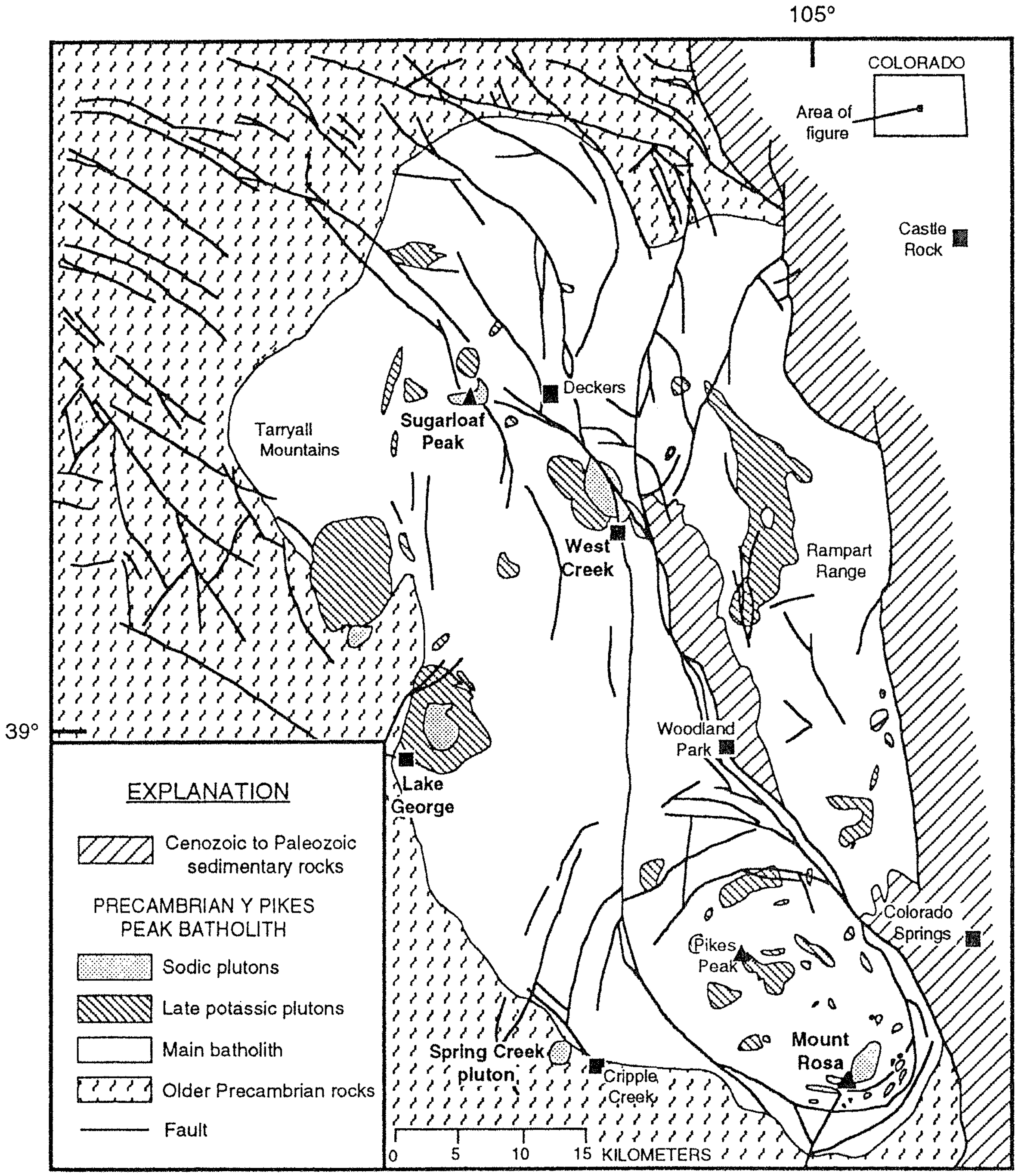

Figure 1. Geologic index map of the Pikes Peak batholith showing locations of sodic and late potassic plutons. From Bryant and Wobus (1975) and Scott and others (1976).

The Keck project students and faculty made field observations and sampled extensively in all the alkalic centers and in the associated granitic rocks. The geochemical data they generated include major, minor, trace element and isotopic compositions from all the major rock types involved. At the winter workshop, students began developing computer models to test Barker et al.'s and other hypotheses for the origin of magmas emplaced in the batholith. Fractional crystallization, combined assimilation-fractional crystallization (AFC), and partial melting processes were evaluated with the geochemical data collected during this project.

Student Projects

Four students elected to study the rock types found in the sodic centers. With the exception of one previously unmapped center (Sugarloaf), field work for these projects consisted of careful sampling from several centers, along with observations of contacts and textures, but not re-mapping. Collection of coarse-grained plutonic samples presented some challenges because unweathered samples needed to be at least twenty times larger than the largest grain size to ensure homogeneity in the splits of powders for geochemical analysis.

Chase Davis pursued gabbro and syenite occurrences from the Lake George, Tarryall and Spring Creek plutons. The gabbros are mantle-derived rocks which provide a starting point for tests of AFC origins for the rest of the sodic trend rocks. Preliminary data show these gabbros are fairly evolved with low Mg-numbers and are unlikely to be direct products of melting from the mantle. **Rachel Beane** studied the syenites of the Sugarloaf pluton. Sugarloaf was the only center not mapped by U.S.G.S. workers so Rachel first focussed on defining the textural variants and rock types in the Sugarloaf pluton. If Barker and others' hypothesis is correct, the geochemical data should show derivation from the gabbros and links to the fayalite granites via AFC processes. **Ben Saltoun** studied the fayalite granites, primarily from the Mount Rosa body. His first goal was to sort out terminology because these rocks actually varied in composition from syenites to granites. His geochemical data will test the continuity from Rachel's syenite compositions to the final step in the sodic series of riebeckite granite. **Greg Kay** worked on the Na-amphibole (riebeckite) granites in the Mount Rosa body. A wide variety of textural variants need to be explained. His geochemical data provide the final point for testing the continuity of the sodic series.

Emily Giambalvo noted the unusual compositions of the amphiboles throughout the Pikes Peak batholith. She sampled rocks from several of the alkalic plutons including West Creek, Sugarloaf and Mount Rosa, and then worked with Beane and Kay to obtain SEM/EDAX compositions on the amphiboles in rocks which were also being analyzed for whole-rock geochemistry. Emily has characterized the amphibole chemistry and showed that many of the old microscope identifications of riebeckite are incorrect. Her data will also allow approximations for distribution coefficients of trace elements between amphibole and whole rock compositions that will refine fractionation models.

Jill Douglass undertook the study of Rb-Sr and Sm-Nd isotope systematics representing the spectrum of compositions in the Pikes Peak batholith. She collected isotopic data from 16 carefully screened samples which were also analyzed for major and trace elements by other students. The data (in combination with additional Pikes Peak data provided by Dan Unruh of the U.S.G.S.) are crucial in evaluating magma-crust interactions and the geochemical nature of source rocks in the mantle and/or crust.

Jen Stewart selected a group of intermediate composition rocks to study. These granodiorites contain biotite and hornblende as well as megacrysts of labradorite. The latter have been inferred to be relicts from lower crust anorthosite, a lithology which is commonly associated with anorogenic granites and may possibly be related to a small body of anorthosite in the Spring Creek pluton.

Britta Gustavson studied the Windy Point granite, a fine-grained variant of the potassic portion of the batholith which occurs throughout the exposed area of rocks, often forming resistant knobs such as the summit of Pikes Peak itself. Geochemical analysis of these rocks provides the standard for comparison of the sodic suite trend against the potassic trend. Britta's data may reveal the relationship between these rocks and the coarse-grained granites that characterize the bulk of the batholith.

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.

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