Petrology and Geochemistry of the Fayalite-bearing Granitoids, Mount Rosa Intrusive Center, Front Range, Colorado

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Introduction

In order to better understand the origin of the Pikes Peak batholith, it is useful to understand the petrogenesis of the fayalite-bearing granitoids. These granitoids are part of a composite intrusive center that represents a late-stage peralkaline intrusion of the Pikes Peak batholith. The fayalite granitoids have a unique accessory mineral assemblage that is not often found in silicic igneous rocks. The purpose of studying the fayalite-bearing granitoid is to determine: (1) its field relations with adjacent igneous bodies, (2) to determine the petrologic characteristics of the fayalite granitoid and (3) the geochemical characteristics of the granitoid. Extensive sampling of the fayalite granitoid bodies from around the Mount Rosa intrusive center allows for the determination and reevaluation of the petrology of these rocks. Geochemical studies of the fayalite-bearing granitoids allows for a geochemical comparison among these unusual rocks. Also, these studies provide insight for causes of heterogeneity among the fayalite granitoids and to the other rocks in the Pikes Peak batholith.

Analytical Techniques

The study of the fayalite-bearing granitoids involved the use of several descriptive petrologic and geochemical techniques. The granitoid was characterized petrologically through thin section analysis and mineralogical point counting. Geochemical analysis of the fayalite-bearing granitoid involved four separate procedures, three of which were performed at Franklin and Marshall College under the direction of Stan Mertzman. X-ray Fluorescence was used to determine both major and trace elements characteristics of these unique rocks. However, due to the objectives of this thesis, a more intensive geochemical analysis was needed. The Inductively Coupled Plasma technique was used to determine the abundance of certain trace elements that XRF was unable to measure. Fourteen trace element concentrations were determined through the combined XRF and ICP techniques. Three samples that represented the petrologic spectrum of the fayalite granitoids were sent to a commercial lab to conduct radiochemical neutron activation analysis. The INAA technique provided data on twenty additional trace elements, including several rare earth elements (REE).

Petrology

Mesoscopic characteristics

The fayalite-bearing granitoid is a coarse grained plutonic rock with average grain size ranging from 0.5cm to 3cm. Mineralogically, the rock is predominantly composed of alkali feldspar, quartz and plagioclase, with few mafic phases apparent in hand sample. The fayalite-bearing granitoid is generally a dark gray-green color on a fresh surface, but weathers to a flat brown color. Microcline is the dominant feldspar phase and occupies 53-79% of the total volume of the granitoids. A modal analysis of these rocks indicates that approximately 60% of the exposed fayalite-bearing granitoid is granitic as defined by the IUGS classification scheme.

Microscopic characteristics

The fayalite-bearing granitoid is mineralogically and texturally homogenous throughout the Mount Rosa intrusive center. The texture is almost entirely hypidiomorphic-granular, yet there are occasional pockets of allotriomorphic granitic granular texture.

The dominant mineral phases that comprises the fayalite granitoids are quartz, microcline-perthite and plagioclase. Microcline is generally subhederal, perthitized and occupies approximately 55% to 80% of the total volume of the granitoid. There are two occurrences of plagioclasewithin the fayalite-bearing granitoids. Oglioclase is principally developed between the irregular intersticies of the perthitized microcline and there is the occurrence of low-set tabular plagioclase crystals which exhibits normal albite twinning. The tabular plagioclase exhibits a compositional range of An_{23-27} as determined by the Michel-Levy method. The total volume of plagioclase in the fayalite granitoid varies from 3% to 24%. These plagioclase crystals can occur as single isolated subhedral to euhedral tabular crystals or as small anhedral allotriomorphic pockets along alkali feldspar interfaces. Quartz is typically anhedral and occupies 20% of the granitoid.

Of all the mafic mineral phases that are constituents of the fayalite-bearing granitoids, biotite-annite is the most common. Under crossed-polars, biotite varies in color from light brown to red-brown to dark brown with increasing Fe^{2+} content. There are two separate modes of growth exhibited by these iron rich biotites. One growth mode resulted in the development of small anhedral annite which was associated with other mafic minerals in clots. The other growth mode resulted in larger euhedral crystals of annite. However, there are no petrographic relations between the euhedral annite and other minerals in the rocks.

The dark-brown biotite commonly has inclusions of zircon and allanite. Other accessory minerals which commonly occur as inclusions in the biotite-annite are magmatic epidote, flourite, hornblende, fayalite and iddingsite. Fayalite only occurs in samples which are lower in quartz content and is generally associated with iddingsite.

Geochemistry

The fayalite granitoids are chemically homogenous. They are characterized by high SiO_2 (67 to 74 wt.%), high Na_2O (≈4 wt.%), high K_2O (≈5.5 wt. %), high amounts of rare earth elements (except Eu), and a high FeO/MgO ratios. FeO concentrations range from 3 to 5 wt.% with less than 0.1 wt.% MgO present. Also, they have low amounts of CaO (<1.8%) and low Sr values (≈23 ppm). The fayalite granitoids straddle the boundary between alkalic and subalkalic, so they can be considered marginally alkalic. Also, these granitoids are strongly peralkaline with Al_2O_3/ ($CaO+Na_2O+K_2O$) ratios varying from 1.2 to 1.4. Another chemical characteristic of the fayalite granitoid is a strong tholeiitic affinity, which is representative of its low CaO and MgO. The fayalite granitoids are consistent with the chemical definition of an A-type granite as determined by Loiselle and Wones (1979). Using a tectonic discrimination diagram of Pearce et al. (1984) and the chemical discrimination diagram modified from Whalen et al. (1987a), the fayalite granitoids can accurately be classified as an A-type granitoid (figs. 1 and 2).

Discussion

Geochemical analysis of the fayalite granitoids allows for the determination of the physical conditions present during crystallization. The zircon solubility formula of Watson and Harrison (1983) can be used as a geothermometer. The interpretation of the temperatures requires the use of petrography. The zircon in the fayalite granitoids is typically euhedral and included in biotite-annite. The zircon is not restitic and consequently represents an early forming phase. Therefore, the temperatures calculated from the solubility formula of Watson and Harrison (1983) can be interpreted as liquidus or near liquidus temperatures. The fayalite granitoids exhibit a range of near liquidus temperatures ranging from 865°C to 966°C (fig. 3).

The presence of magmatic epidote has implications on possible pressures at which the melt began to crystallize. According to Zen and Hammarstrom (1984b), the presence of magmatic epidote in an igneous rock indicates that the melt crystallized at pressures no less than 8 Kbars. However, the exact phase petrology of magmatic epidote in a silicic system is poorly understood. Therefore caution must be utilized when using magmatic epidote as an indication of pressure conditions (Tulloch, 1986; Moench, 1986). Yet, the possibility of the melt crystallizing at elevated pressures must be considered. Barker et al. (1974) proposed that the Pikes Peak batholith crystallized within the epizonal crust at pressures of 1.5 Kbars. However, the presence of magmatic epidote suggests that the pressure cited by Barker et al. (1974) may be low.

Geochemical analysis indicates that there are fractionation trends among the fayalite granitoids. These fractionation trends were modeled by using the distribution coefficients of various trace elements and creating vectors based on 100% fractionation of a specific mineral. This technique allows for the determination of distinct phases that were fractionated. All vectors have been plotted from the most primitive sample. The primitive sample was selected on the following basis: it has the lowest SiO_2 content, highest amount of FeO and MgO, the highest concentration of trace elements, the highest liquidus temperature and is a xenolith that is a fined grained textural variant of the fayalite granitoid. It is apparent that the fayalite granitoids underwent simultaneous fractionation of biotite, opx and amphibole (figs. 4 and 5). However, this result is not concordant with the REE data. The REE data indicates that there is a distinct negative europium anomaly (fig. 6). This europium anomaly reflects the fractionation of alkali feldspar and plagioclase. It is suggested that the magma of the fayalite granitoids initially fractionated anorthite, opx, amphibole, biotite and some orthoclase. Once the melt was depleted in CaO, the anorthite ceased to crystallize. At this point the most primitive sample cooled while other portions of the melt continued to fractionate opx, amphibole and biotite to differing degrees before eventually crystallizing.

References

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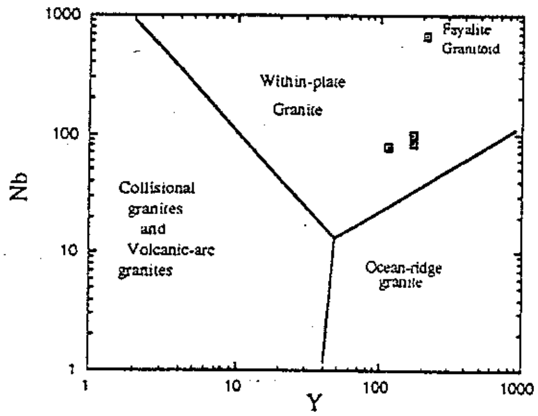

Fig. 1. Y-Nb tectonic discrimination diagram of Pearce et al. (1984) Trace element concentrations in ppm.

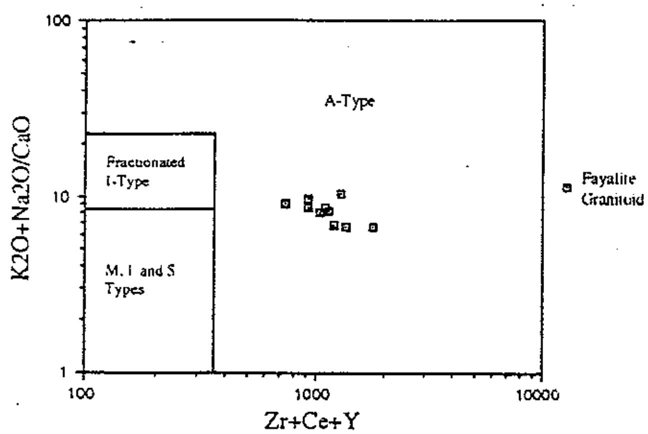

Fig. 2. Zr+Ce+Y vs. K_2O+Na_2O/CaO chemical discrimination diagram modified from Whalen et al. (1987a).

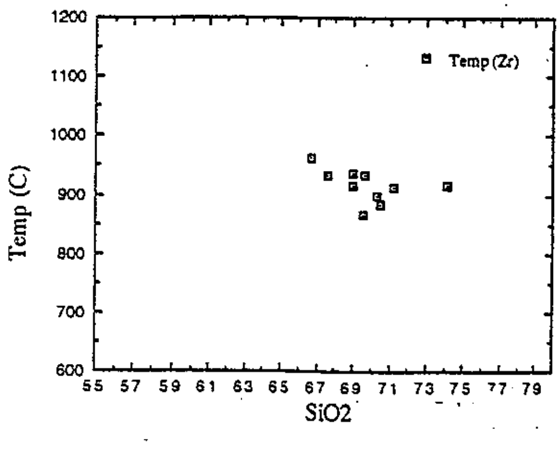

Fig. 3. Silica vs. Temp (°C) zircon saturation temperature diagram illustrating the range of near liquidus temperatures of the fayalite granitoid.

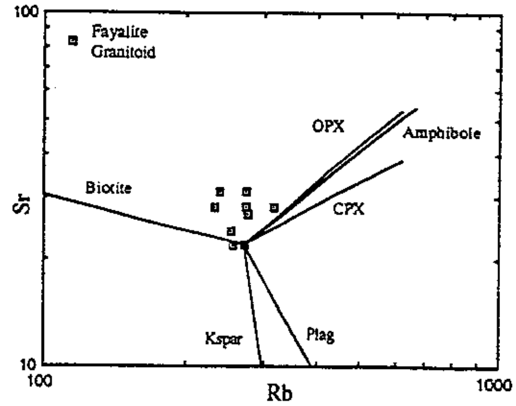

Fig. 4. Rb vs. Sr. Illustrates the fractionation that occured among the fayalite granitoids.

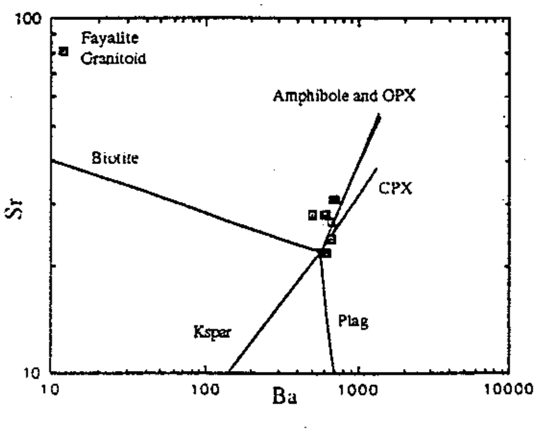

Fig. 5. Ba vs. Sr. Illustrates the fractionation that occured among the fayalite granitoids.

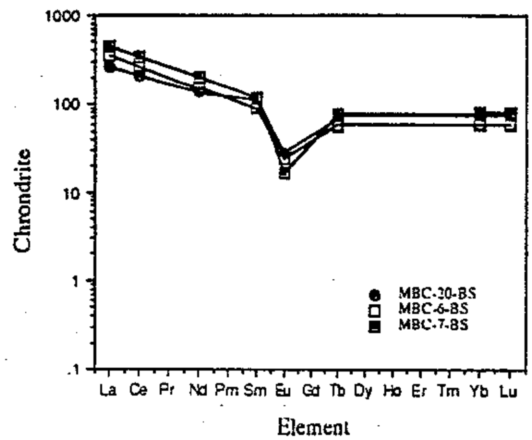

Fig. 6. REE vs. rock chrondrites. The negative europium anomaly represents fractionation of plagioclase and alkali feldspar.