Petrology of dioritic intrusives, Trail Creek Pluton, Wyoming

Marie Knotwell
Department of Geology, The Colorado College, 902 N. Cascade Ave., Colorado Springs, CO 80946
Faculty sponsors: David P. Hawkins; Jeffrey B. Noblett, The Colorado College

INTRODUCTION

The Heart Mountain Fault area in northwestern Wyoming is a province with an unusual structural and igneous history. More than 3400 km^2 of sedimentary and volcanic materials have been displaced over 30 km. Normal faulting (Pierce, 1960), gravity settling accompanied by volcanism (Hauge, 1985), and volcanic fluidization (Beutner and Craven, 1996) are the most recent and well received tectonic models for this region.

Unusual plutons of shoshonitic and dioritic compositions lie along the fault. Volcanic fluidization, proposed by Edward Beutner and Amy Craven in 1996, is the only model that accounts for the emplacement of these plutonic rocks. The authors of this model interpreted the plutons to represent a "hot spot" trace in the upper plate of the Heart Mountain detachment. Beutner and Craven suggested that the source of dioritic and shoshonitic plutons is presently located below the Crandall Intrusive Complex. The string of 14 plutons that trend S 60 E from the proposed source were emplaced in the upper plate of the detachment as it moved over the intrusive source during faulting.

Kudo and Broxton (1985) conducted a petrogenetic study of the Crandall ring-dike complex. They were successful in demonstrating that the dioritic, monzodioritic, and gabbroic rocks were genetically related. Elizabeth Stone (1997) provided evidence that the string of plutons, extending from the Crandall Intrusive Complex were petrochemically related. However, processes such as crustal contamination may have effected these magmas as well. The goal of this project is to use field, petrographic, and geochemical relationships to accurately describe the high potassium, dioritic rocks of the Trail Creek Pluton. These observations will then be used to constrain the various magmatic models for high potassium intrusive rock sequences.

METHODS

Field observations were made, a geologic map was prepared, and samples for chemical and petrographic analysis were collected from the Trail Creek Pluton, northwestern Wyoming. Fifteen samples were analyzed using inductively coupled plasma by Activation Laboratories Ltd. Instrumental neutron activation analysis was performed by the Oregon State University Radiation Center on five samples. Twenty-five thin sections were prepared by Wagner Petrographic, Provo, Utah. The thin sections were then examined for mineral assemblages and textures.

FIELD AND PETROGRAPHY RELATIONS

The rock types in the pluton are: a shoshonitic diorite porphyry, a phenocryst-poor phase of the diorite, and a monzodiorite. The southeastern-most end of the Trail Creek Pluton displays an abundance of shoshonitic diorite porphyry. This is where some of the most crucial intrusive relationships were recorded. Shoshonitic diorite porphyry has been intruded by a phenocryst poor diorite dike; plagioclase phenocrysts in the shoshonitic diorite porphyry show a flow orientation only at the contact of the two rock types. The contact is wavy and irregular. A fine-grained monzodiorite dikelet intrudes both the porphyritic diorite and the phenocryst-poor diorite. This intrusion truncates plagioclase phenocrysts in the porphyry on a sharp contact.

Coarse-grained, hypidiomorphic to shoshonitic diorite porphyry contains phenocrysts of plagioclase, clinopyroxene, olivine, and lesser amounts of brown-green magmatic biotite. The groundmass of this diorite consists of plagioclase, clinopyroxene, sanidine, biotite, apatite, and opaque oxides. All phenocryst phases have resorbed rims. Sanidine nucleates on plagioclase laths. Olivine and clinopyroxene rims have been deuterically altered at high temperatures and replaced with opaque oxides, red-brown biotite, and chlorite. Clinopyroxene is found to poikilitically enclose olivine and shows a subophitic texture with plagioclase. Red-brown biotite radiates from deeply embayed ilmenite crystals.

A chronology of intrusive events for the rocks at the Trail Creek Pluton was constructed from the observations made in the field (Figure 1). Shoshonitic diorite porphyry, phenocryst-poor diorite, and monzodiorite intruded Tertiary volcanoclastic and andesitic flows. Dikes of phenocryst-poor diorite and monzodiorite intruded the pluton at different stages of its development. While the bulk of the pluton was still plastic, a phenocryst-poor member of diorite intruded, allowing for flow alignment of plagioclase phenocrysts in the porphyritic diorite near the contact. Monzodiorite intrusion must have occurred after the porphyritic stock had solidified significantly, in order to truncate plagioclase phenocrysts at the contact of the intrusion.

Growth relationships were interpreted from microscopic observations. Olivine crystals solidified first, followed by the contemporaneous crystallization of clinopyroxene and plagioclase. Plagioclase, olivine, and clinopyroxene are clearly in disequilibrium with the melt, despite evidence of a preliminary anhydrous melt that produced anhydrous phenocryst phases. Hydrous phases of red-brown biotite, opaque oxides, and chlorite were last to form. The magma must have become hydrous to allow for the deuteric alteration of the anhydrous phenocryst phases by these late stage minerals.

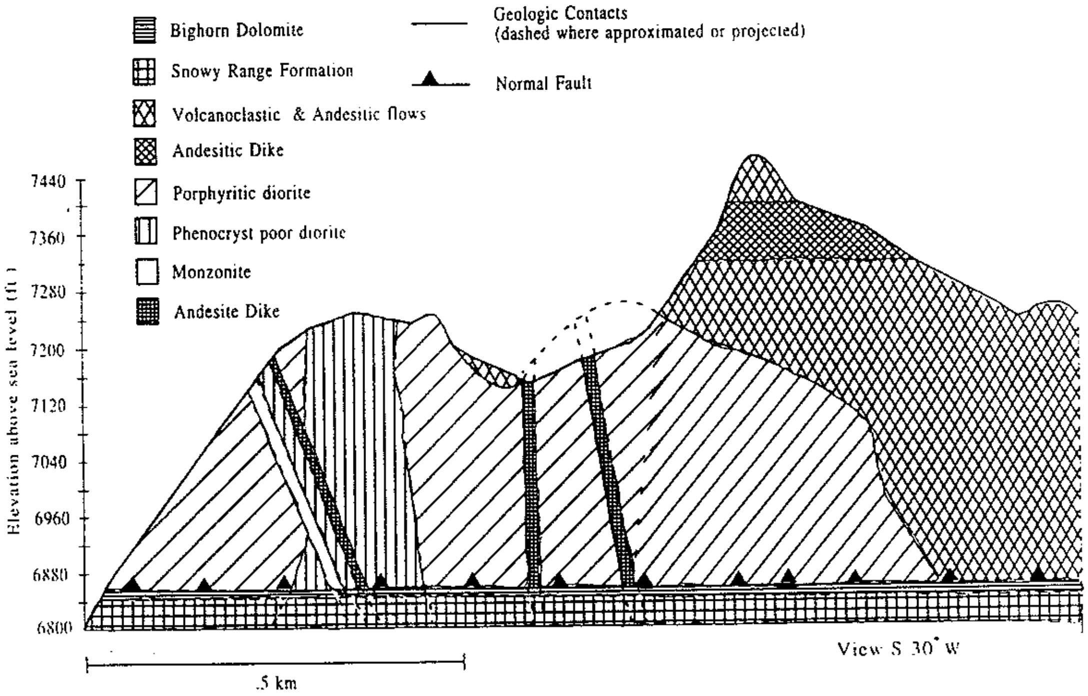

Figure 1. Cross section of map area, showing intrusive relationships.

GEOCHEMISTRY

Binary plots of major oxides versus silica and MgO are similar for all samples. A variation diagram of K_2O versus SiO_2 subdivides subalkaline rocks, and classifies the porphyritic and phenocryst-poor diorite as shoshonite and high-K andesite (Figure 2). Other discrimination plots classify the composition of this rock suite with calc-alkaline basalts, volcanic-arc granites, and intraplate granites; based on concentrations of TiO_2, MnO, P_2O_5, Na_2O+K_2O, MgO, Rb, and Y+Nb.

Concentrations of trace and rare earth element data from INAA, were normalized to C1 chondrite, continental crust, and primitive mantle compositions. Spider plots were composed using these same normalized values (Figure 3). The best match occurs with continental crust values, with the exception of Cr, Co, and Ni which show negative anomalies. The spider plot for normalized primitive mantle displays a good match with middle and heavy rare earth elements. Compared to continental crust compositions this rock suite is modestly enriched in light and middle rare earth elements. The porphyritic and phenocryst-poor diorite are ten to one hundred times enriched relative to chondrite. Cr, Co, and Ni are ten to one hundred times depleted.

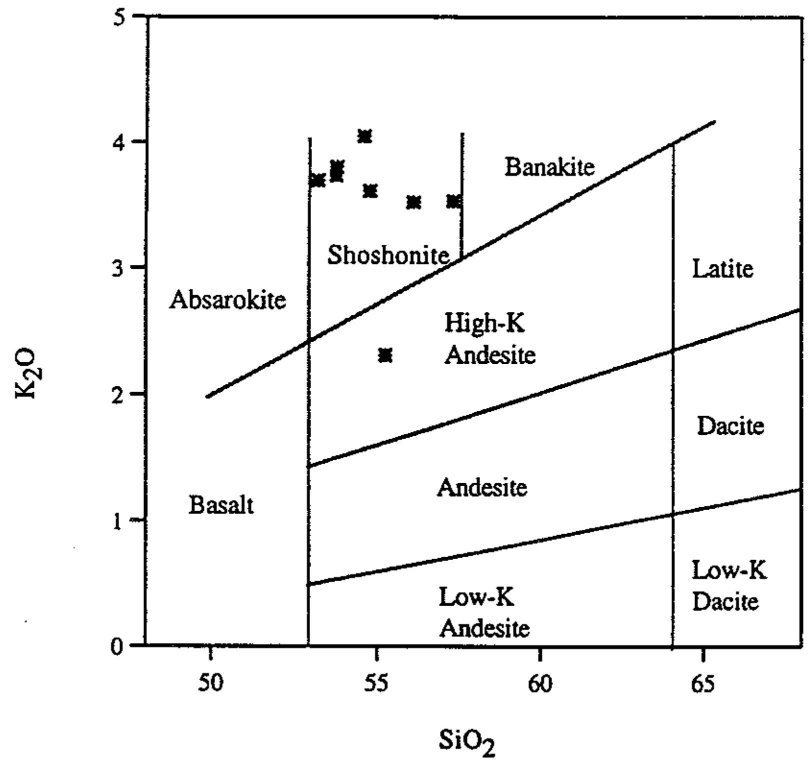

Figure 2. K_2O vs. SiO_2 diagram for the subdivision of the subalkaline series classifies Trail Creek porphyritic and phenocryst poor diorite as shoshonites (McBirney, 1993).

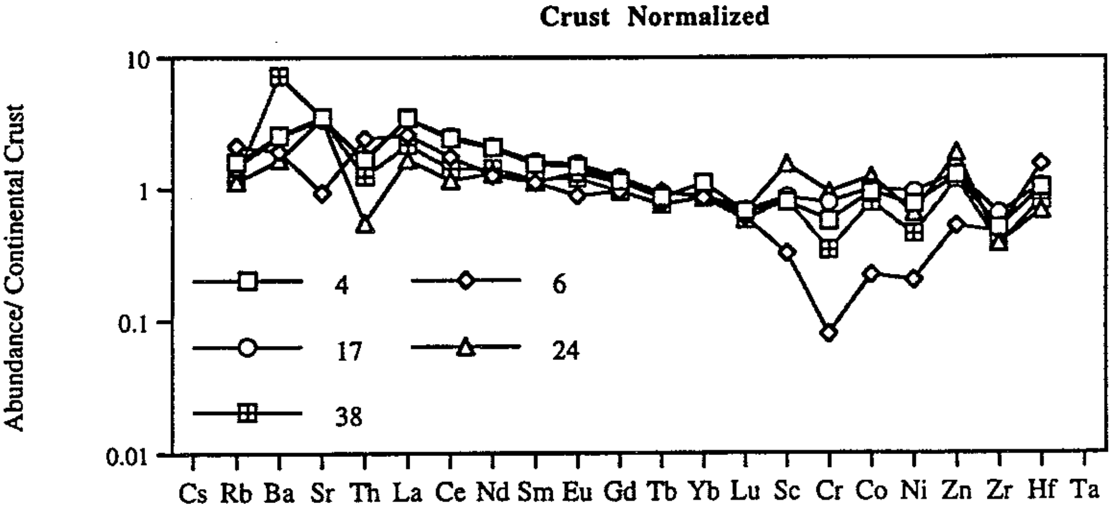

Figure 3. Spider diagram for shoshonites.

DISCUSSION

Despite cross cutting relationships seen in the field, no geochemical evidence suggests that the phenocryst-poor diorite was fractionated from the porphyritic magma. It is more likely however that the two rock types are from the same parent but represent individual degassing events within the pluton. Trace element plots indicate Cr, Co, and Ni have been removed from the melts, regardless of the source. These elements were probably lost during fractional crystallization of olivine. The lack of Eu anomalies suggests plagioclase was neither fractionated from the melt nor added to a melt. Plagioclase phenocrysts appear out of equilibrium; a case can be made that plagioclase was fractionated out of the melt and that xenocrystic plagioclase was later incorporated into the magma.

POSSIBLE PETROGENETIC MODELS

Petrogenetic models for high potassium, orogenic shoshonites include some or all of the following stages: 1) direct partial melting of a hydrous peridotite, 2) continental partitioning of a peridotite at depth and re-equilibration with the surface peridotite during ascent through the upper mantle, 3) partial melting of metamorphosed abyssal tholeiite near the top of a descending slab in a subduction zone setting, 4) contamination of a melt by assimilation of middle continental crust, and 5) fractional crystallization of a parent liquid with basaltic compositions. Preliminary examination of trace element data provides evidence for contamination to the melt by assimilation of continental crust and fractional crystallization of a parent liquid of basaltic compositions. Further investigation of trace, rare earth, and isotope element data will provide a more in depth explanation for the petrogenesis of these rocks and an interpretation of the source of potassium in these shoshonites.

CONCLUSION

Cross-cutting relationships determined in the field and geochemistry obtained in the lab for the shoshonitic diorite porphyry and phenocryst-poor diorite proved to be inconclusive on the matter of chronology for the distinct rock types. Evidence for rapid emplacement of the Trail Creek Pluton, as suggested in Beutner and Craven's hypothesis (1996), is mixed. It is possible that both rock types were emplaced previous to movement away from the magmatic source or that the phenocryst-poor diorite intruded the fault detachment and the previously emplaced shoshonitic diorite porphyry.

REFERENCES CITED

Beutner, E.C., and Craven, A.E., 1996, Volcanic fluidization of the Heart Mountain detachment, Wyoming: Geology, v. 24, no. 7, p. 595-598.

Hauge, T. A., 1985, Gravity-spreading origin of the Heart Mountain allochthon, northwestern Wyoming: Geological Society of America Bulletin, v. 96, p. 1440-1456.

Kudo, A.M., and Broxton, D.E., 1985, High-potassium intrusive rocks of the Crandall ring-dike complex, Absaroka Mountains, Wyoming: Geological Society of America Bulletin, v. 96, p. 522-528.

McBirney, A.R., 1993, Igneous Petrology. Boston: Jones and Bartlett Publishers, p.319.

Pierce,W.G., 1960, The "break-away" point of the Heart Mountain detachment fault in northwestern Wyoming: in Geological Survey Research 1960: U.S. Geological Survey Professional Paper 400-B, p. B236-B237.

Stone, E.M., 1997, Petrochemistry of the plutons in the Heart Mountain allochthon, northwestern Wyoming: Department of Geosciences, Franklin and Marshall College, Lancaster, PA.