FIELD, PETROGRAPHIC, & GEOCHEMICAL CHARACTERISTICS OF THE PRICE CREEK VOLCANICS, SOUTHEAST BLACKTAIL MOUNTAINS, MONTANA

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ABSTRACT

Geologic mapping in the SE portion of the Blacktail Mountains has revealed a more diversified stratigraphic sequence than previously documented (Muller & Krol, 2004). Prior mapping of this area has shown it as a single volcanic unit composed of a maroon rhyolite tuff, possibly erupted from the Eocene Dillon volcanic center located ~50 km to the northwest. Our mapping allowed us to further subdivide this unit, which we term the Price Creek unit (PCu), into two distinct lithologies based on mesoscopic characteristics; 1) a basal volcanic breccia and 2) a rhyolitic tuff.

This study focuses on petrographic and geochemical analyses of the PCu in an effort to better define and elucidate its petrogenesis. The lowermost unit of the PCu is a maroon, coarse-grained, matrix-supported breccia that unconformably overlies Archean gneiss. It contains subangular clasts (1-100 cm) of predominately granitic gneiss with crystal fragments of quartz and feldspar. The contact between the basal breccia and the gneiss is sharp and highly irregular. Locally, maroon, aphanitic veinlets cross-cut and intrude parallel to the gneissic foliation in basement outcrops. The breccia is overlain by an aphanitic, maroon rhyolitic tuff. Petrographic analysis reveals angular to subrounded lithic and dominantly quartz crystal fragments with rare euhedral quartz phenocrysts set in a microcrystalline groundmass. Preliminary XRF analysis of several PCu tuff samples shows a very high SiO_2 content (84-87%) and a severe depletion of all other major element oxides with the exception of aluminum and iron (<1 wt% K_2O, Na_2O, CaO, MgO). The extreme enrichment of silica, depletion in other elements, and hematitic staining strongly suggests major geochemical alteration and modification following the formation of the rhyolite. The precise timing and nature of this alteration event is poorly constrained but may be related to the development and hydrothermal activity associated with post-Laramide normal movement on the Jake Canyon fault. The Jake Canyon fault, which forms the range front at Price Creek, is highly silicified with large masses of vein quartz (locally 10s meters in thickness) found along its trace. Hydrothermal fluids permeated footwall and hanging wall rocks causing hydrothermal alteration 100s of meters from the fault (Tysdal et al., 1990).

INTRODUCTION

Southwest Montana is characterized by a number of magmatic centers that erupted throughout the Eocene. Rocks that occur at the southeastern end of the Blacktail Mountains in the Price Creek stream drainage have previously been mapped as a single stratigraphic unit composed of rhyolite tuff and lava flows sitting on top of Archean gneiss (Lonn et al., 2000). These workers speculated that these rhyolite tuff/lava units may be related to magmatic activity associated with the Eocene-age Dillon volcanic center located ~ 50 km away. In an effort to elucidate the origins and geologic history of volcanic rocks in the Price Creek drainage we performed detailed geologic mapping in conjunction with petrographic and geochemical analysis.

Our mapping in the southern end of the Blacktail range has revealed a more complex and distinctive stratigraphic sequence than previously recognized. On the basis of mesoscopic characteristics we have subdivided this unit, which we term the Price Creek unit into; 1) a basal volcanic breccia; and 2) an overlying sequence of rhyolitic tuff and lava flows. The basal volcanic breccia contains clasts of Archean granitic gneiss and possesses contacts that are intrusive. The rhyolite tuff and lava flows are stratigraphically above the breccia and characterized by an aphanitic texture with minor flow banding and vesicles. Petrographic analysis reveals the Price Creek volcanic rocks contain phenocrysts and phenoclasts of predominantly quartz set in a glassy and hematite-rich matrix. In contrast, field observations of Dillon volcanic rocks show that these rocks are commonly deformed into overturned flow folds characteristic of a highly viscous lava. The Dillon volcanic rocks contain abundant plagioclase, often zoned, biotite, and minor quartz set in a cryptocrystalline matrix.

Preliminary geochemical analysis has revealed that the Dillon volcanic rocks are rhyolite and display typical volcanic chemistry. The Price Creek rocks however, display unusually high silica contents and a depletion of most major oxides. We interpret this signature to be the result of post-emplacement hydrothermal activity. Tysdal et al. (1990) documented a period of major hydrothermal activity along the trace of the Jake Canyon fault during Late Cretaceous time. We suggest this event may have affected rocks of the Price Creek unit resulting in the silicification of these rocks and the depletion of major oxides. If the alteration of the PCu is related to hydrothermal activity along the Jake Canyon fault, then the PCu must be at least Late Cretaceous in age, and could not be the result of the magmatic activity associated with the Dillon volcanic center.

LOCAL GEOLOGIC SETTING

The Blacktail Mountains occur within the Rocky Mountain Basin and Range province of the western U.S. Cordillera. The Blacktail range extends approximately 50 kilometers along a northwest-southeast trend and is between 5-6 kilometers wide (Fig. 1A). The Blacktail Mountains are one of numerous basement-cored uplifted blocks that occur throughout southwest Montana. These uplifted blocks and associated cover rocks are the result of Cenozoic extension during the last ~50 Ma. The front of the Blacktail range is marked by the Jake Canyon and the younger Blacktail Deer Creek faults (Tysdal, 1988). These faults are responsible for the uplift of the range and the present day topography.

The core of the Blacktail range consists of 2.7 Ga Archean (~2.7 billion years old) metamorphic granitic gneiss and interlayered amphibolite and are intruded by several Proterozoic (?) (1.4 Ga) mafic bodies. In the northwestern portion of the Blacktail Mountains, the basement rocks are overlain by a thick sequence of Paleozoic and Mesozoic sedimentary rocks with Cenozoic volcanic rocks at the extreme northern end (Fig. 1B). However, in the southern portion of the mountain range these rocks have been eroded and striped away and only Cenozoic volcanic and sedimentary rocks rest unconformably on top of Archean gneiss. Following deposition of the sedimentary and volcanic rocks this region experienced several phases of deformation with the development of several large-scale faults (Fig. 1C; Muller & Krol, 2004).

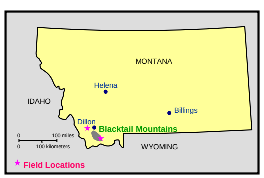


Figure 1A. Location of Blacktail Mountains and field locations for Price Creek and Dillon volcanic units.

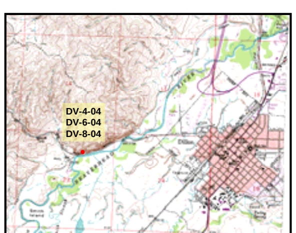


Figure 1B. Portion of the 1:24,000 Dillon West 7½ minute quadrangle showing sample locations of Dillon volcanic lava flow used in comparison with Price Creek volcanic rocks.

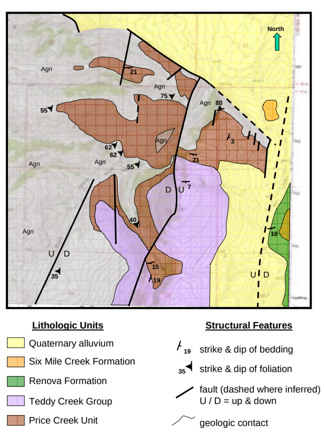


Figure 1C. Geologic map of the SE portion of the Blacktail Mountains, Montana. Mapping of the Price Creek volcanic unit based on work of Muller & Krol, 2004; Rofe & Krol, 2004.

CHARACTERISTICS - PRICE CREEK UNIT (PCu)

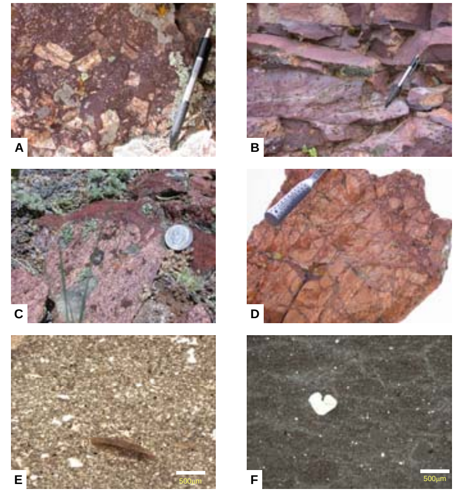


Figure 2. A) Typical basal, maroon colored breccia of the Price Creek unit. Clasts consist mainly of granitic gneiss and crystal fragments. B) Fine-grained volcanic tuff and lava flow unit that overlies the breccia unit. Note the possible presence of vesicles. C) Small aphanitic veins intruding basement gneiss. D) Contact between Archean gneiss and Price Creek breccia is nearly subvertical. E) Photomicrograph of Price Creek tuff. Note small lithic fragment and angular quartz crystal fragments (PPL). F) Embayed quartz phenocryst in a darkened glassy matrix from a lava flow layer (XPL).

Field Observations

Geologic mapping has delineated two distinct volcanic units in the Price Creek-Teddy Creek drainages. These include a basal, coarse-grained, maroon colored volcanic breccia overlain by a sequence of fine-grained, maroon rhyolite tuffs and lava flows.

Volcanic Breccia

- *Unconformably overlies Archean gneiss*
- *Contains abundant granitic gneiss clasts (1-100 cm) and crystal fragments (Fig. 2A)*
- *Displays intrusive relationship with Archean gneiss. Near contact with basement gneiss, small veinlets of maroon rhyolite cross-cut and intrude parallel to metamorphic foliation (Figs. 2C & 2D)*

Rhyolite tuff and lava flows

- *Stratigraphically lies above the volcanic breccia*
- *Fine-grained tuffs and lava flows (locally vesicular) (Fig. 2B)*
- *Contains lithic fragments as well as quartz phenocrysts and fragments*

Petrographic Analysis

- *Price Creek tuffs/lava flows are highly siliceous and contain abundant quartz phenocrysts and lithic fragments ranging in size from 10 to 500 µm (Fig. 2E).*
- *Quartz phenocrysts commonly embayed and euhedral to subhedral (Fig. 2F).*
- *Matrix is glass or ultra fine-grained quartz*
- *Price Creek volcanic rocks are devoid of hydrous phases like biotite or hornblende*

CHARACTERISTICS - DILLON VOLCANICS

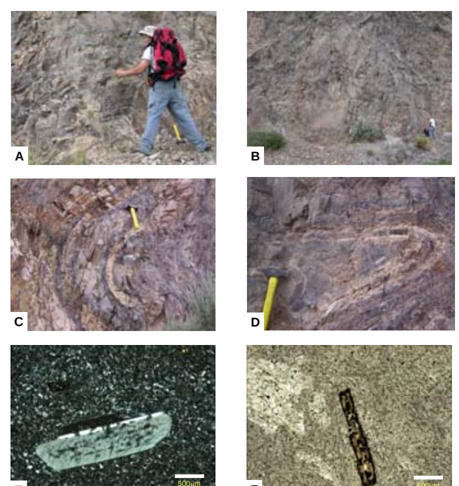


Figure 3. A) Flow banding in Dillon lava flow. B) Layering and large overturned flow folds in Dillon lava. C & D) Recumbent flow folds in Dillon lava flows. E) Zoned plagioclase phenocryst within a finer-grained groundmass of plagioclase, quartz, and biotite (XPL). F) Biotite phenocryst set in a glassy matrix and finer-grained biotite groundmass. Note the radiating nature of crystallites in matrix (PPL).

Field Observations

Rocks of the Dillon volcanics extruded from a localized magmatic center approximately 41 Ma (Fritz et al., 1989). These rocks consist of a series of lava flows that display a variety of textures and a distinctive mineralogy than rocks of the Price Creek unit.

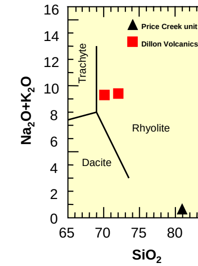
Dillon Rhyolite Lava Flows

- *Commonly displays flow banding (Fig. 3A)*
- *Dillon volcanic consist of lava flows of rhyolitic composition (Fig. 3B).*
- *Lava flows are commonly deformed into overturned and recumbent folds (Fig. 3 C & D).*
- *Biotite and feldspar phenocrysts are abundant within Dillon volcanics.*

Petrographic Analysis

- *Dillon rhyolite flows are also highly siliceous*
- *Contain abundant plagioclase (sometimes zoned) and biotite phenocrysts (Figs. 3E & F).*
- *Matrix composed of ultra fine-grained quartz and glass (cryptocrystalline)*
- *Matrix commonly consists of crystallites (Fig. 3F).*

PRELIMINARY GEOCHEMISTRY



Whole-rock geochemistry was applied to rocks of the Price Creek unit and the Dillon volcanics in an effort to characterize and compare or contrast their chemical compositions.

On a total alkali content versus silica plot (LeBas et al., 1986), the Dillon volcanics fall within the rhyolite field and reflect typical igneous chemistry. However, volcanic rocks from the Price Creek unit display an unusually high SiO_2 content and are largely depleted in total alkalis.

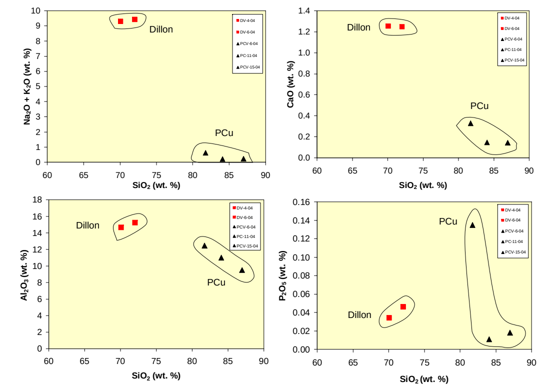


Figure 4. Major oxide versus SiO_2 diagrams for the Dillon volcanic rocks and the Price Creek unit. Dillon rocks display typical igneous chemical signatures whereas, the Price Creek unit displays a significant depletion in most major oxides and much higher concentrations in SiO_2 content.

The extremely high SiO_2 content found within rocks of the PCu, coupled with a severe depletion in all major oxides (with the exception of Al_2O_3) suggest the Price Creek rocks were affected by a post-emplacement hydrothermal event. Major hydrothermal activity has been documented along the Jake Canyon fault (Tysdal et al., 1990). Tysdal et al. (1990) mapped the presence of large deposits of hydrothermal quartz bodies (up to 20 meters thick) along the Jake Canyon fault as well as significant alteration of the adjacent basement gneiss. On the basis of apatite fission track dates from altered and unaltered rocks (ranging between 60 to 74 Ma). The authors interpret that the hydrothermal event can be no younger than the apatite dates. In addition, they obtained a $^{40}Ar/^{39}Ar$ whole-rock date of 48.1 ± 0.3 Ma from an unaffected basalt flow that caps the altered gneiss, which they interpret as a minimum age for hydrothermal activity.

CONCLUSIONS

1) On the basis of field and petrographic observations as well as geochemical analyses, we interpret the Price Creek unit as a separate and distinct volcanic unit from the Dillon rhyolite. Field evidence shows that the basal unit of the PCu represents an intrusive breccia into Archean granitic gneiss. Overlying the breccia unit is a sequence of fine-grained volcanic tuff and lava flows. The breccia contains clasts of Archean gneiss suggesting a localized magmatic center. Additionally, small aphanitic veinlets cross-cut and intrude parallel to gneissic layering and indicate basement rocks were invaded by a molten phase and not simply a location of deposition of pyroclastic material.

2) Compositionally, volcanic rocks from the Price Creek unit and the Dillon rhyolite are different. The PCu contains abundant quartz phenocrysts that are commonly embayed, indicating a still molten groundmass, and devoid of hydrous phases. In contrast, the Dillon rhyolite contains hydrous phase like biotite and abundant zoned plagioclase suggesting a more calcium rich parental magma than the Price Creek magma.

3) The age of magmatic activity in the southern end of the Blacktail range is uncertain. However, if the hydrothermal activity associated with movement along the Jake Canyon fault is correlative, then the PCu is Late Cretaceous in age. In contrast, volcanism responsible for the Dillon rhyolite occurred at approximately 41 Ma (Fritz et al., 1989). If our hypothesis is correct, then the Price Creek unit represents a previously unknown and undocumented magmatic center in this portion of the Rocky Mountains.

REFERENCES CITED

Fritz, W.J., Matthews, J.M. & Satterfield, D.A., 1989, Age, chemistry, and sedimentology of Late Cretaceous and Tertiary volcanic and volcanoclastic rocks in the Beaverhead and upper Ruby River Basin, southwestern Montana: A preliminary report, Northwest Geology, v. 18, p. 67-84.
LeBas, M.J., LeMaitre, R.W., Streckeisen, A. & Zanettin, B., 1986, A chemical classification of volcanic rocks based on the total alkali-silica diagram, Journal of Petrology, v. 27, p. 745-750.
Lonn, J.D., Skipp, B., Ruppel, E.T., Janecke, S.U., Perry, Jr., W.J., Sears, J.W., Bartholomew, M.J., Stickney, M.C., Fritz, W.J., Hurlow, H.A. & Thomas, R.C., 2000, Geologic Map of the Lima 30'x 60' Quadrangle, southwest Montana, Montana Bureau of Mines and Geology, Open File Report 408.
Muller, P.D. & Krol, M.A., 2004, Early Cenozoic volcanism, sedimentation, and faulting, southeast Blacktail Mountains, Montana, Geological Society of America Abstracts with Programs, vol. 36, no. 5.
Rofe, N.Q. & Krol, M.A., 2004, Geologic mapping of volcanic rocks in the Blacktail Mountains, Montana, National Conference for Undergraduate Research Meeting, p. 157.
Tysdal, R.G., Zimmermann, R.A., Wallace, A.R. & Snee, L.W., 1990, Geologic and fission-track evidence for Late Cretaceous faulting and mineralization, northeastern flank of Blacktail Mountains, southwest Montana, United States Geological Survey Bulletin 1922, 20 p.

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