The Petrology of Mafic Dikes and Their Relationship to Talc Formation in the Ruby Range Southwestern Montana

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Introduction

The goal of the Montana project was to form a complete petrogenetic model for the formation of economic talc deposits in the Ruby Range, southwestern Montana. Many workers (e.g. Anderson et al., 1990 and Garihan, 1973) have studied the genesis of the talc bodies and possible mechanisms for their formation. However, the exact age and the corresponding thermal event for talc formation have not yet been determined.

Based on chronological associations, one thermal source proposed by Anderson et al., (1990) is the intrusion of mafic dikes at 1455 Ma and 1130 Ma. Mafic dikes are observed cutting across talc deposits in two locations at the Regal-Keystone talc mine and one location at the Smith-Dillon mine. These locations, while undocumented by previous workers, seem the ideal places to determine the thermal and chronological relationship between the dikes and the talc deposits. A study of the mafic dikes of the Ruby Range was undertaken to A) chemically and petrographically characterize the mafic dikes of the Ruby Range and B) determine the relationship between the talc deposits and the dikes.

Field work and Petrography

Based on field and petrographic observations, the dikes were divided into two general groups: 1) Archean amphibolite dikes, and 2) Proterozoic diabase dikes. The group 2 rocks were divided into two separate sub groups consisting of a) fresh dikes and b) very altered dikes. In hand sample the group 1a rocks appeared to be fresh amphibolite while the group 1b rocks had obviously undergone extensive alteration. The group 2 rocks all appeared to be fresh except for localized epidotization.

In thin section, however, all of the dike samples taken showed varying degrees of alteration. While the original mineralogy may still be intact, alteration rims can be seen even on the freshest of samples. Chlorite and sericite are present in varying amounts in all of the dikes.

The group 1a rocks consist predominately of amphibole (>40%) and plagioclase, with varying amounts of chlorite, sericite and quartz. Accessory minerals included epidote, biotite, opaques and garnet. These rocks are amphibolites and have been subjected to high grade regional metamorphism. They are therefore considered to be Archean age because no high grade regional event is beleived to have occurred in the Proterozoic.

The group 1b rocks consist of chlorite (80-90%) quartz and opaques. Minor amounts of talc are seen as well. The presence of talc suggests that the hydrothermal event responsible for the alteration of these dikes was also responsible for talc formation.

The group 2 rocks are diabasic in texture and consist of predominately plagioclase and clinopyroxene. Accessory minerals include quartz, opaques, and biotite. The plagioclase is commonly altered to sericite and the pyroxene to chlorite and more rarely amphibole. These rocks lack the high grade mineral assemblage seen in the group 1 rocks.

Geochemistry

Twenty four of the samples selected for thin section analysis were analyzed for major and trace element geochemistry by x-ray flourescensce on a Rigaku 3070 x-ray spectrometer. Eighteen of these samples were submitted for Rare Earth Element (REE) analysis by Induced Nuetron Activation Analysis techniques.

Major element chemistry for the group 1a and group 2 rocks is very similar. They both have about 50 weight percent $SiO2$, 6 to 7 weight percent MgO, and 1.5 to 2.5 weight percent $Na2O$. They all plot as high Fe tholeiites on a Jensen cation diagram (1976) (Fig. 1). In fact, they plot overwhelmingly as tholeiites on every classification diagram used in this study. The group 1b rocks, however, show distinct enrichment of MgO (20 to 30 weight percent MgO) and depletion in $SiO2$ (42to44 weight percent), $Na2O$ (0 weight percent) and Calcium (< 2 weight percent) (Fig.2).

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Trace element and REE chemistry is interesting for these rocks. MORB normalized (Pearce, 1983) trace element plots for the group two rocks show a hump in the K, Rb and Ba area (Fig. 3). Ta values seem higher than expected and Y,and Yb are lower than expected. REE plots show a generally flat profile with a slight light REE enrichment (Fig. 4).

Discussion

All of the dikes seen in contact with the talc deposits are Archean amphibolites. Nowhere were Proterozoic dikes seen in contact with the talc. Given this observation, the relationship between the formation of the talc bodies and the Proterozoic dikes remains a mystery.

The extent of alteration in the group 1b rocks (Fig 5) and the size of the adjacent talc deposits indicates a fluid alteration of the rocks. The fluid responsible for the talc formation and the group 1b alteration was certainly enriched in magnesium (Fig.2). The fluid was also likely depleted in calcium, sodium and silica. However, no mineral phase exists in these rocks to house sodium. Investigations into the exact nature of the fluid involved are currently in progress.

The high values for K, Sr, and Ba on the MORB normalized trace element plot for the group 2 rocks (Fig. 4) suggests slight crustal contamination. The group 2 samples plot on a Ti,Zr discriminant diagram in two groups (Fig. 6). One group plots in the within plate-morb overlap area suggesting a rift type environment. The other group plots in the area of a typical back arc basin plot. The flat profile of the REE plot (Fig. 5) supports the data on the discriminant diagram suggesting a tensional environment for the dike formation.

Conclusions

1) Only Archean dikes are seen in contact with the talc, so the nature of the relationship between the Proterozoic dikes and talc formation remains a mystery.
2) The talc and alteration done to the group 1b rocks was done by a fluid that was rich in magnesium and possibly depleted in calcium, sodium and silica.
3)The Proterozoic dikes were formed in a tensional setting. Whether this is a rift or back arc basin is not known.

References

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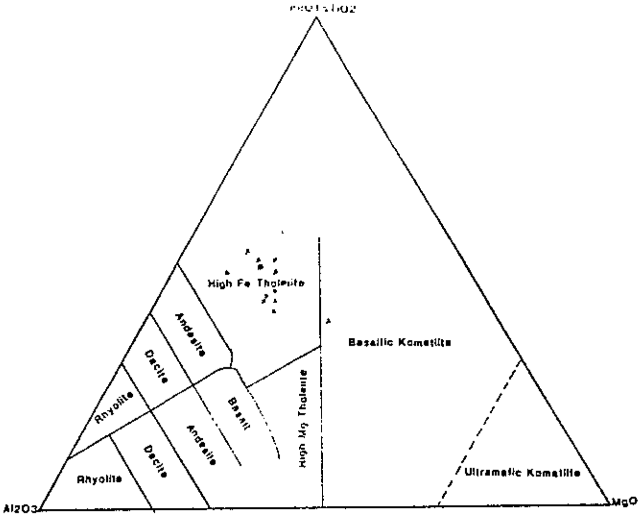

Figure 1. Dike samples from the Ruby Range plotting as High Iron Tholeiites on a Jensen Cation Diagram (1976).

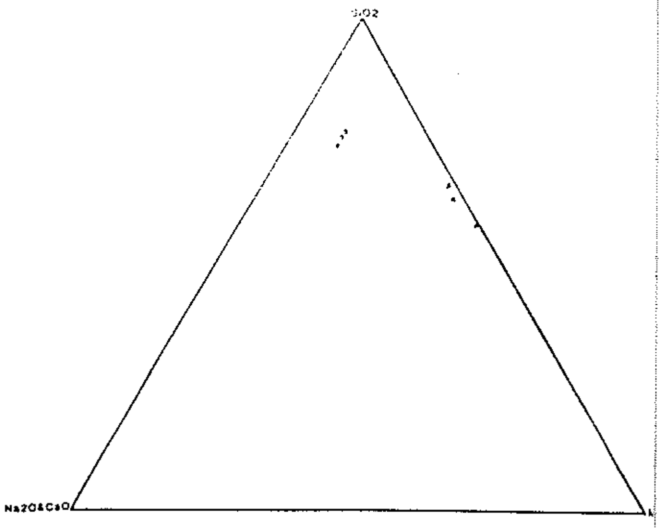

Figure 2. Triangle variation diagram showing MgO enrichment and CaO, Na_2O, and S depletion for fresh (circles) and altered (crosses) Archean dikes in the Ruby Range.

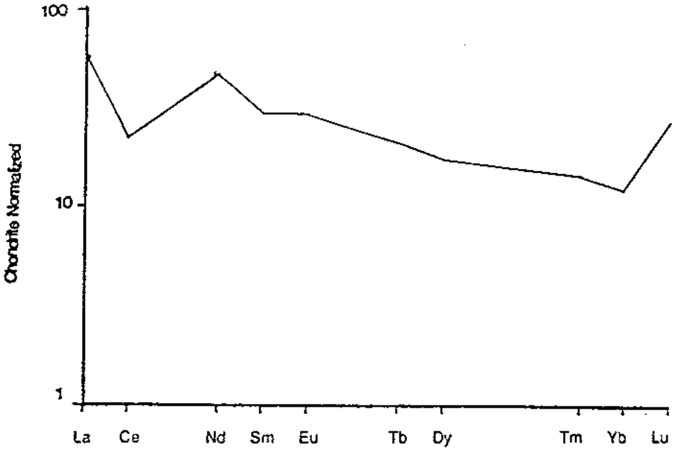

Figure 4. Rare Earth Element plot showing a flat or slight LREE enriched profile.

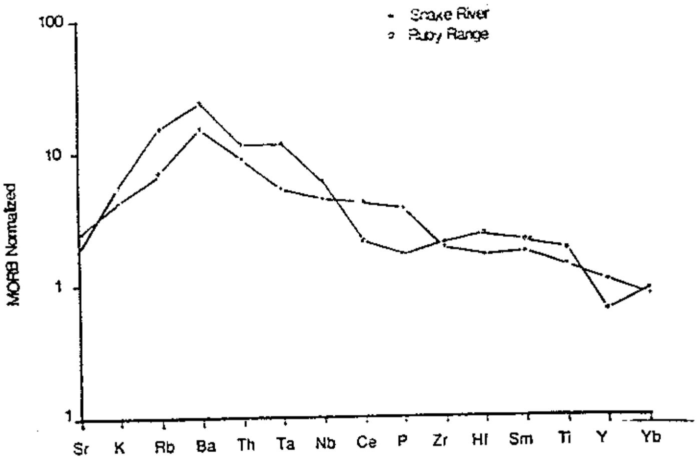

Figure 3. MORB (Pearce 1983) Normalized trace element diagram showing Snake River Plain Continental Tholeiites and Ruby Range samples. Note the slight hump in K, Rb and Ba for the Ruby Range Samples.

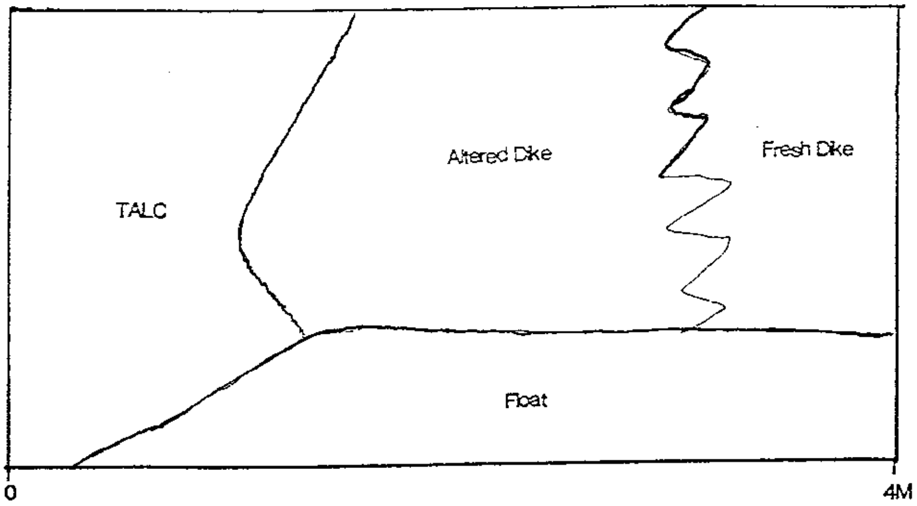

Figure 5. Field sketch showing the area of alteration in q dikes near the talc deposits.

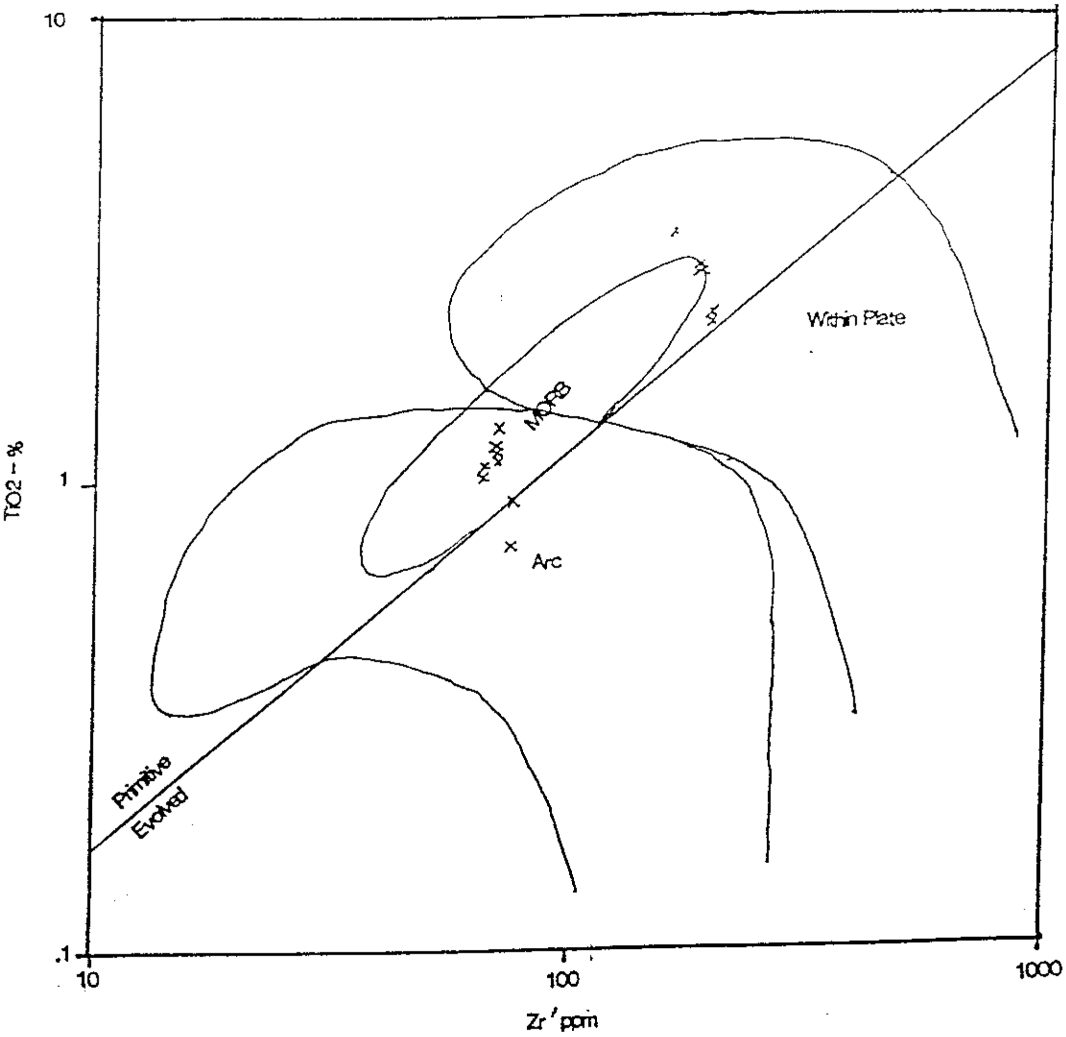

Figure 6. Discriminant diagram showing the two groups of Proterozoic dikes. One plots as a rift and the other as a back arc basin.

The Influence of Major Faults in Retrograde Metamorphism and Talc Formation in the Ruby Range, Southwestern Montana

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The Archean Wyoming province lies in north-western Wyoming and south-western Montana. The Wyoming province is characterized by a variety of metamorphic and structural styles. In the western part of the province, high-grade metasedimentary sequences comprise most of the rocks. These have undergone isoclinal folding, nappe emplacement, and metamorphism to granulite facies at 2.75 Ga (Mogk, Henry, 1986).

Archean plutons of calc-alkaline granitoid dominate the eastern Wyoming province. Emplaced at about 2.75 b.y. ago, these plutons contain older, supracrustal xenoliths, which were metamorphosed to granulite grade 3.4- 3.2 b.y. ago. (Mogk, Henry, 1986)

The discontinuity between these distinct geologic regions appears in the western Beartooths as a mobile belt. The mobile belt consists of lithologic sequences of different metamorphic grades, structural types, and isotopic ages. These sequences have been juxtaposed by transverse and thrust faults (Mogk, Henry, 1986).

The Ruby Range occupies the north-west portion of the Archean Wyoming Province. The structural makeup of the Ruby Range varies between the central one-third of the range and the outer terrain. In the middle of the range, one finds two or three fold generations on a mesoscopic and macroscopic scale. Outside of this region, the rocks exhibit four fold generations. Karasevich et al. interpret this discrepancy as evidence that the rocks of the central Ruby Range originated in the Cherry Creek area, and were emplaced as nappes in their present locale. The emplacement would have occurred between 2750 my and 1450 my ago. (Karasevich et al., 1981)

Granulite-facies rocks in the north of the Ruby Range give dates of 2.75 Ga. Temperatures associated with this 2.75 Ga. event range from 745 degrees C in the north of the range to 675 degrees C in the central range. Anomalously low temperature conditions measured by oxygen isotope data may result from retrograde metamorphism, or later, low grade metamorphic events, such as the 1800 my emplacement of granitic dikes. (Karasevich et al.) James (1990) proposes another low grade, regional thermal rise at 1650 m.y., as well as a later (post 1.425 Ga.) hydrothermally driven event associated with the emplacement of mafic dikes. This last hydrothermal event is cited as the probable formative source of the talc reserves in the Ruby Range, which are valued for their large bodies of pit-minable, tremolite free talc (Olson, 1976).

The Ruby Range talc deposits have formed in dolomitic marbles. The structure of the host rocks seems to have influenced the location of formation of talc bodies. Talc occurs discontinuously along layer parallel fractures (Anderson et al., 1990). The maximum conditions for formation of the talc have been calculated as 2 kbar and 400 degrees C. (Anderson et al., 1990)

Okuma (1971), Garihan (1973), and Berg (1979) have suggested that talc formation resulted from fluid movement along the major North-west trending faults in the Ruby Range area. (Anderson et al., 1990). The volume of fluid required to produce this talc would be more than 600 times the volume of the talc. Because talc reserves in the Ruby Range have been estimated at a hefty, one million tons, formation of the ore requires enormous quantities of fluid (Anderson et al., 1990). If the major faults served as the main conduit for the circulation for a vast volume of hot fluids, rocks on or near the faults should display the effects of hydrothermal retrograde metamorphism and of metasomatism.

The identification of the talc forming event is complicated by the effects of several other low grade events; however, talc producing activity was widespread and significant, and, if the faults acted as conduits, retrograde effects beyond the scope of later hydrothermal events should be preserved. I have begun to distinguish non-fluid related, retrograde events. This distinction has helped to clarify the relationship between metasomatic, talc related alteration minerals, and other, regional, retrograde assemblages. They may have resulted from two separate events, or the same event.

In undertaking this project I compared of fluid altered rocks adjacent to major faults to the background metamorphic rocks collected near faults, as well as samples of the same rock types, collected at locations distant from major faults. I collected 160 samples from the northern, southern, and central parts of the Ruby Range according to the above criterion. 48 samples have been thin-sectioned and examined under a petrographic microscope. In addition to petrographic examination, the Amherst College scanning electron microscope has supplied chemical composition data, useful for mineral identification, and geothermometry and barometry.