

Petrogenesis and correlation of the mid-Tertiary upper Bonanza tuff, central Colorado

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INTRODUCTION

The Bonanza caldera and the upper Bonanza tuff (UBT) are located between two major mid-Tertiary volcanic fields, the San Juan and the Thirtynine Mile. The San Juan field lies to the west and southwest of the caldera and was active from approximately 35 to 26 Ma (Lipman, 1982). Volcanism began with a period of intermediate composition eruptions which then changed to silicic ash flows from caldera centers at ~30 Ma, shortly after the eruption of the rhyolitic UBT. The Thirtynine Mile volcanic field lies to the northeast of the Bonanza caldera and was active at the same time as the San Juan field, from 37-28 Ma (Shannon, 1988). All the ash flows of this field are suspected to have sources in the Sawatch Range to the west; however, some sources have yet to be discovered. The Wall Mountain tuff, the oldest of the Thirtynine Mile ash flows at 36 Ma, is believed to have been erupted from the Mt. Princeton pluton. The Badger Creek tuff (34 Ma) is believed to be from the Mt. Aetna caldera, which was developed above the Mt. Princeton pluton (Shannon, 1988). The Grizzly Peak caldera lies further to the north but has not yet been correlated with a major ash flow. Varga and Smith (1984) suggested that the Bonanza caldera may be related to these Sawatch calderas to the north, as it is aligned with them along the western edge of the Rio Grande rift. This rift was beginning to form ~30 Ma, just after the eruption of the UBT. This puts the UBT at a time of transition from the earlier compressional tectonic regime to the extensional one that began with the opening of the Rio Grande rift.

The volcanic stratigraphy associated with the Bonanza caldera begins with the Rawley andesite at 37 Ma (Varga and Smith, 1984), composed of andesitic lava flows and lahars. It is overlain by the dacitic lower Bonanza tuff which is itself overlain by the UBT. The latter tuff is lithologically identical to the tuff outside Saguache, dated at ~33 Ma (McIntosh and Chapin, 1994). The sequence is capped by the upper andesite, which is composed of multiple andesitic lava flows and lahars.

The UBT is the only rhyolitic unit associated with the intermediate volcanic rocks of the Bonanza caldera, yet it has not been proven to be outflow from the caldera itself. Therefore, the goals for this project include documenting the petrologic and geochemical characteristics of the UBT and evaluating the petrogenesis of its magma.

FIELD WORK

Most samples of the UBT in this study were collected from a number of drainages located southwest of the caldera and northwest of the town of Saguache, just outside of the Rio Grande National Forest. Samples were gathered here because of the good exposures and because units closer to and within the caldera itself have been hydrothermally altered. Samples of the Spring Creek pluton (a rhyolitic stock east of the caldera) and of the Porphyry Peak rhyolite (an exogenous dome on a ring fracture of the caldera) were also collected for the purpose of comparison.

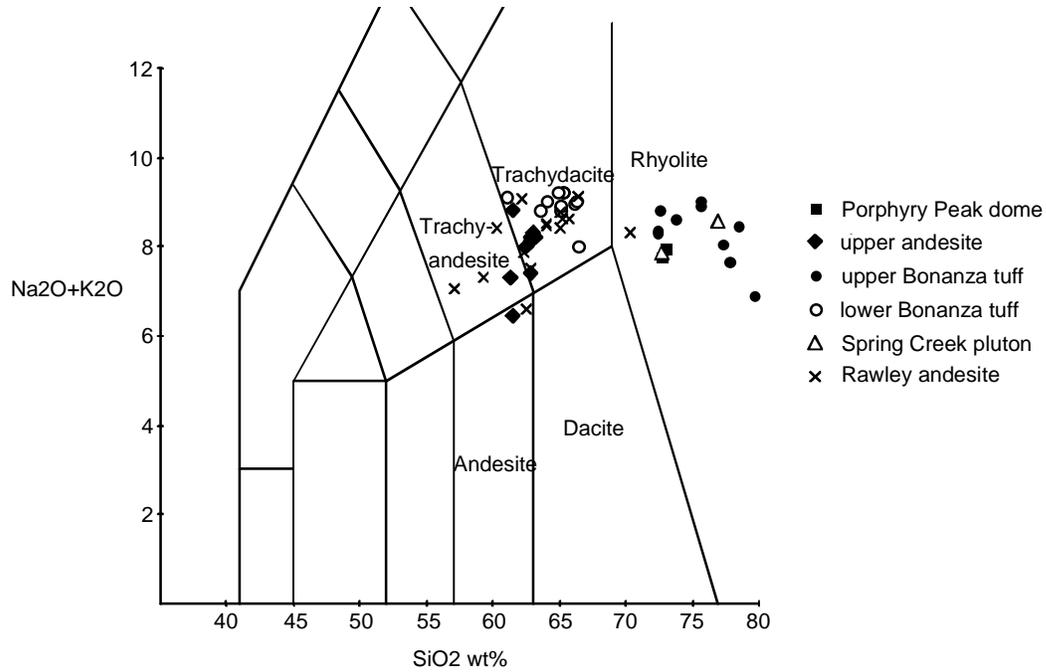
PETROGRAPHY

The UBT is phenocryst poor, with total phenocrysts comprising only 10% of the total rock. Glassy groundmass and vitric fragments (including ~10% pumice) make up ~88%, and lithic fragments comprise only ~2%. Of the phenocrysts, approximately 8% of the total rock is sanidine; the other 2% is divided between plagioclase and biotite, with plagioclase being slightly more abundant. Quartz is notably absent among the phenocryst phases. The texture is vitrophyric and most of the phenocrysts are less than 2 mm. The UBT is distinct from the lower Bonanza tuff, which is dacitic in composition and more crystal rich. The lower tuff has approximately 30% phenocrysts, with 18% plagioclase, 9% sanidine, and 2% biotite (Varga and Smith, 1984).

GEOCHEMISTRY

Whole-rock chemistry (and pumice chemistry in some samples) was obtained for 26 samples using XRF techniques at Michigan State University. Fifteen of those samples were further analyzed using ICP-MS (also at MSU). Major element analyses show that the UBT, Spring Creek pluton, and Porphyry Peak dome are all indeed rhyolites (Fig. 1). The other units of the Bonanza caldera plot as trachyandesites and dacites because of their higher alkali contents relative to silica.

Figure 1. Le Bas diagram and classification of volcanic units associated with the Bonanza caldera.



When trace element compositions are normalized against MORB on spider diagrams, the UBT is 10 to 100 times more enriched in the lighter elements (such as K and Rb) and relatively depleted in the heavier elements (such as Y and Yb). There are troughs at Sr, P, and Ti, which is typical of felsic rocks due to removal of certain mineral phases such as plagioclase, apatite, and biotite or ilmenite (Rollinson, 1993). When normalized against upper crust values (Taylor and McLennan, 1981), the UBT shows a flat trend at approximately one, with troughs at barium, strontium, and titanium. On all spider diagrams, the Spring Creek pluton and Porphyry Peak rhyolite plot similarly to the UBT for most elements. However, they show a wider range for elements such as Sr, P, and Ti, compared to the UBT. Figure 2 shows a plot of the rare earth elements for the UBT, the Spring Creek pluton, and the Porphyry Peak rhyolite. All samples illustrate enrichment in light REEs and fairly flat heavy REEs with a notable negative europium anomaly.

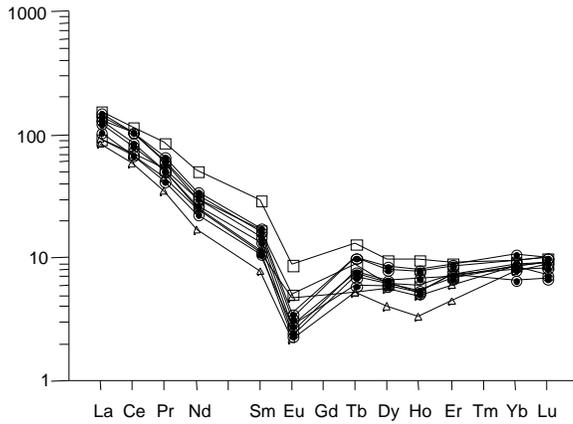


Figure 2. Rare earth elements normalized to chondrites. Triangles = Spring Creek pluton; squares = Porphyry Peak rhyolite; filled circles = UBT.

Figure 3 illustrates two incompatible element ratios for the UBT and other Bonanza units. Even considering analytical errors for these ratios ($\pm 15\%$), there are clear distinctions in Zr/Nb between the UBT and the lower Bonanza tuff and Rawley andesite. However, the UBT is very similar to the Spring Creek pluton and the Porphyry Peak rhyolite. Other ratios (Zr/Yb, La/Nb, Ti/Zr, Ce/Yb) show similar distinctions between the UBT and the andesitic rocks, and similarities between the UBT and the other Bonanza felsic rocks.

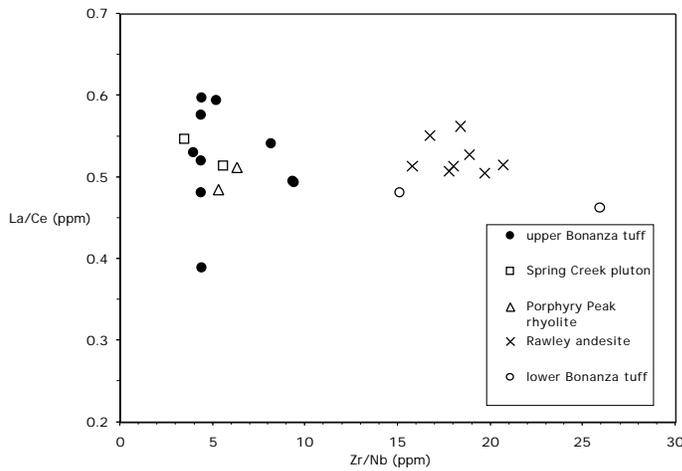


Figure 3. La/Ce vs. Zr/Nb plot

PETROGENESIS OF UBT MAGMA

One possible origin for the UBT magma is by fractionation of a less evolved magma, such as the dacitic lower Bonanza tuff. However, there are several lines of evidence against this model. The distinct separation in incompatible trace element ratios in the dacitic lower Bonanza tuff and the rhyolitic UBT (Fig. 3) argues against a common source for the two magma types. Although individual trace element abundances can vary as a result of fractionation effects, if elements exhibit similar geochemical behavior (e.g., Zr and Nb), they should vary in a constant relationship to each other. Therefore, if two units are from the same source or parental magma, the ratios of geochemically similar trace elements (e.g. Zr/Nb) should be the same. Figure 3 shows that this is not true for the upper and lower Bonanza tuffs.

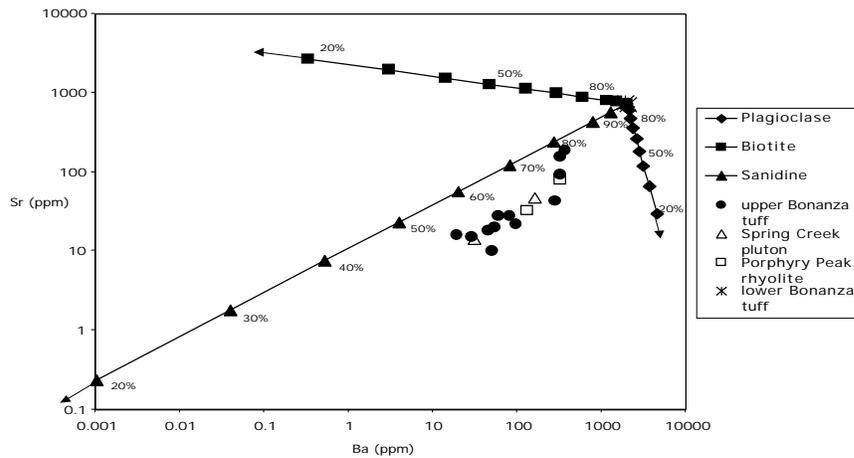


Figure 4. Sr vs. Ba vector plot. Percentages represent amount of remaining liquid (F).

To test the fractionation model further, vectors showing the effects of removal of major phenocrysts are plotted with Sr and Ba data for the UBT and other Bonanza units (Fig. 4). The models assume the lower Bonanza tuff as the parental magma. Figure 4 shows that removal of sanidine appears to be the dominant phase in the fractionating assemblage, which agrees with the petrographic data for the UBT. However, fractionation of assemblages dominated by sanidine does not result in a good match between the major element compositions calculated for liquids that evolve by sanidine fractionation and the observed UBT chemistry. The calculated daughter liquid is too low in SiO_2 whereas most of the other major elements (TiO_2 , Al_2O_3 , MgO , and FeO_T) are too high compared to the average UBT. A final piece of evidence against the fractionation model is the compositional gap between the UBT major element chemistry and that of the lower Bonanza tuff (cf. Fig. 1) instead of a gradual transition in composition, which could be expected from fractionation processes.

SUMMARY AND CONCLUSIONS

The UBT is petrographically and geochemically distinct from the dacitic lower Bonanza tuff and Bonanza andesites. These distinctions plus petrogenetic modeling support the conclusion that the UBT is not derived by simple fractionation of the lower Bonanza tuff. However, the UBT is geochemically similar to the Spring Creek pluton and the Porphyry Peak rhyolite in both major and trace element compositions, which suggests that these three units may have a common origin. If fractionation did not play a major role in the origin of the UBT, then it may be the result of partial melting of the upper crust.

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