Petrology and geochemistry of Tertiary volcanic rocks in the Crawfish Lake Quadrangle, northeastern Oregon

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INTRODUCTION

Crawfish Lake Quadrangle is located in the central Elkhorn Mountains, one of the many mountain ranges that make up the Blue Mountains province in northeastern Oregon. Tertiary volcanic rocks are exposed in the northwestern eight square miles of the quadrangle, as well as in two southwestern outliers (see Pogue et al, this volume). During the summer of 1998 four students from this Keck project mapped these volcanic rocks. We identified eight units, ranging in composition from a reworked rhyolitic tuff to basalt. None of the source vents for these rocks are known. Previous mappers have lumped all of the volcanic rocks of Crawfish Lake Quadrangle together, so they have never been studied in detail. In addition, no ages have been determined for these rocks, so it is unclear how they fit into the regional Tertiary volcanic sequence in the Blue Mountains province. The purpose of this study is to use petrographic and geochemical techniques in order to characterize the individual rock types, test correlations between units made in the field, and attempt to evaluate the petrogenesis of these rocks.

Throughout the Tertiary, the Blue Mountains province was characterized by episodic volcanism whose products varied both geographically and over time. This volcanism was interspersed with periods of erosion and terrestrial sedimentary processes (Walker and Robinson, 1990). Sedimentation and volcanism were largely restricted to local basins of deposition or geographically restricted volcanic piles (Walker, 1990). The resulting rocks are therefore not very regionally extensive and correlations between units are extremely difficult to make. Furthermore, the episodes of rhyolitic to rhyodacitic, andesitic, and basaltic volcanism exhibit subtle variations but overlap with each other spatially and temporally. At times, large volumes of diverse chemical types of rocks were being erupted simultaneously from widely dispersed vent systems (Walker, 1990).

The sequence of Tertiary volcanic rocks in the Blue Mountains province is fairly well established. It is generally divided into three major groups defined largely by age. The first episode occurred in the Paleocene and Eocene and was characterized by major outpourings of calc-alkaline andesitic and basaltic rocks of the Clarno Formation. Oligocene and lower Miocene rocks of the John Day Formation are chiefly rhyolitic and dacitic in composition. The third group is the Columbia River Basalt Group and is characterized by middle Miocene and younger rocks which include large volumes of tholeiitic basalt and moderate volumes of calc-alkaline andesitic and rhyolitic rocks (Walker and Robinson, 1990).

FIELD OBSERVATIONS

Most of the field area consisted of broad areas of low rolling forest land covered in soils and forest litter. In some places, outcrop was more conspicuous, forming cliffs, ridges and summit outcrops. No contacts between units were found during mapping. The best exposed contact consisted of one outcrop spatially above another with dirt and/or a talus slope separating the two. Because there were no clear contacts found in the field, the mapping of contacts was based primarily on changes in topography. The general stratigraphic sequence of these units is fairly easy to discern from the map pattern, however, it is unclear how the outlier units and flow remnants fit into the sequence.

ANALYTICAL TECHNIQUES

Twenty-one samples were selected for petrographic analysis based on freshness and their representation of the unit as a whole. Preparation of rock powders and petrographic analysis were completed at The Colorado College. The analyses include modal abundances based on a 1200 point count and plagioclase compositions determined by the Michel-Levy method. INAA analysis was completed on eighteen samples at the Oregon State University Reactor Laboratory in Corvallis, Oregon. Loss on Ignition and X-ray fluorescence procedure for major, minor, and several trace elements was performed on eighteen samples by Activation Laboratories, Ltd. in Ontario, Canada.

PETROGRAPHY AND STRATIGRAPHY

Tta: Trachytic andesite The oldest volcanic unit in the quadrangle exists only in the southwest corner of the volcanic area and is characterized by abundant float or highly weathered, irregular, hummocky outcrops. Approximately thirty percent of this rock is comprised of aligned plagioclase phenocryst laths with a composition of An_{54}. These laths are relatively fresh, but some resorption is present as evidenced by rounded grains. All of the plagioclase phenocrysts are zoned and in some crystals the calcic cores have been completely dissolved. This unit also contains clinopyroxene and opaque phenocrysts, modally 3% and 1% respectively. Plagioclase microlites in the groundmass display a very prominent trachytic texture.

Tob: One-pyroxene olivine basalt The next oldest identified lava is found almost exclusively as float and forms subdued slopes near the southern and eastern limits of the volcanic outcrop area. This unit is vesicular and amygdaloidal. In thin section, plagioclase and olivine show a poikilitic texture and plagioclase and clinopyroxene display an ophitic texture. Plagioclase comprises approximately 40% of the rock and has a composition of An_{68} in the groundmass. Olivine, modally 15%, occurs as fairly fresh, individual crystals as well as large iddingsitized grains up to 0.5 mm long. Clinopyroxene composes approximately 23% of the total rock mass. Opaque minerals in this rock lack euhedral shape, distinguishing them from all the other units. This rock also contains a small amount of altered glass.

Tpb: One-pyroxene, plagioclase-phyric basalt This unit is predominantly represented by float in the southeast corner of the volcanic outcrop region. It is moderately vesicular and amygdaloidal. Just over 10% of this rock consists of large plagioclase phenocrysts and microphenocrysts ranging in length from 0.1 to 7 mm. Many grains show embayment and resorption textures. Groundmass plagioclase with a composition of An_{64} comprises approximately 36% of this rock. Clinopyroxene in the groundmass, modally 24%, is being weathered to clay and iron oxide minerals. 5% of this rock is composed of olivine grains that are iddingsitized and highly weathered around the edges. Opaque minerals, consisting of euhedral grains and a light dusting between grains, make up 19% of the total rock.

Tep: Mixed epiclastic-pyroclastic deposit This widespread unit forms the southern slopes of Chicken Hill ridge as well as the country south of Chicken Hill ridge. The pyroclastic rocks consist of a variety of materials, including pumiceous tuff, tuffaceous sandstone, conglomerates containing primarily mafic volcanic clasts, lahar breccias and arkosic sandstone (see Hofmann, this volume). Many contain clasts of tuff, hornblende-bearing dacite, tonalite, oxidized scoria, small quartz grains, basalt to mafic andesite with plagioclase phenocrysts, and crystalline basement rock. Near the base of the section outcrops of ash-flow tuff breccia are present. This unit is not included in the geochemical analyses.

Td-ch: Two-pyroxene, plagioclase-phyric dacite The most extensive unit in this quadrangle is the dacite of Chicken Hill, which covers most of the northern half of the volcanic area as well as extensive areas to the southwest. Outcrops display a platy jointing on a centimeter scale, roughly perpendicular to crude columnar jointing. A wide range of rocks are included in the Chicken Hill dacite, represented by variation in abundance and sizes of plagioclase and pyroxene phenocrysts. In thin section, this rock displays a highly trachytic texture of plagioclase laths in the groundmass. At times, these laths flow around microphenocrysts of olivine. Less than two percent of this rock is olivine and it is all highly weathered and iddingsitized. Between 70 and 80% of this rock is composed of groundmass plagioclase with a composition ranging from An_{51} to An_{52}. Very large, oscillatory and progressively zoned plagioclase phenocrysts ranging from 0.5 mm to 5 cm in length make up 1-9% of the total rock mass. They appear embayed and resorbed and in some crystals the calcic cores have been completely dissolved. This unit also contains microphenocrysts of clinopyroxene and orthopyroxene, both modally less than 2%, which occasionally occur in glomeroporphyritic clumps.

Tab: Aphyric, two-pyroxene basalt The youngest unit in this sequence is an aphyric, slightly vesicular basalt which locally forms a cap on the dacite of Chicken Hill just south of Chicken Hill. It forms well developed columnar joints in thin flows that are only a couple of meters thick. The most distinguishing feature of this rock in thin section is its largely aphyric texture and fresh glass. 60% of the rock is composed of trachytic, groundmass plagioclase with a composition of An_{60}. This unit is very fresh and contains just over one percent microphenocrysts including plagioclase, clinopyroxene, orthopyroxene, and olivine.

Tga: Glomeroporphyritic two-pyroxene andesite This unit occurs in three isolated locations in the field area. Therefore its age relationship to the other units is ambiguous. It is believed to post-date the dacite of Chicken Hill (Td-ch) because in at least one location this unit lies on top of Td-ch. In outcrop, this unit displays well developed columnar joints oriented in many different directions. It is characterized by an extremely dark, highly magnetic groundmass with hackly fracture. The most distinguishing characteristic of this unit in thin section is its glomeroporphyritic clumps of plagioclase, clinopyroxene, and orthopyroxene phenocrysts. It also contains a significant amount of fresh glass, up to 20%. Plagioclase crystals, which display a seriate texture in this rock, are all well zoned and some have a spongy cellular texture. Plagioclase in the groundmass has a composition of An_{62}.

Tb: Two-pyroxene, plagioclase- clinopyroxene- olivine-phyric basalt This unit occurs as two outliers southwest of the main volcanic area (see Pogue, this volume). Therefore, its age relationship to the other units is unknown. The unit is visible only as platy fins or as faint columnar joints in road cuts. It is vesicular and amygdaloidal. The basalt has phenocrysts and microphenocrysts of plagioclase, clinopyroxene, and olivine. The relative phenocryst abundaces of olivine and plagioclase vary greatly from sample to sample. Some of the olivine crystals appear fresh whereas others are partially to wholly iddingsitized. Plagioclase crystals are zoned and lack evidence of resorption Clinopyroxene and orthopyroxene occur in the groundmass.

In addition, there are two flow remnants that were discovered while mapping that don't appear to be related to any of the other units in the quadrangle.

GEOCHEMISTRY

Silica content of the units range from 46.74 to 65.07 wt%. The units are classified as basalt, andesite, and dacite based on a SiO_2 vs. Zr/TiO_2 plot (Figure 1). On a plot of FeOt/MgO vs. SiO_2, the units straddle the calc-alkaline and tholeiite fields (Figure 2). LREE are 10-70 times Chondrite enriched, and HREE are 2.5-11 times enriched (Figure 3). All units are an excellent match for continental crust rocks (Figure 4).

DISCUSSION

Map units were correlated as groups such as those found on plots of Sr/Eu vs. SiO_2 (Figure 5) and Zr/Nb vs. SiO_2 (Figure 6). Each unit clearly plots as a distinct cluster that may appear more spread out on one plot and more tightly grouped on another. The individual plot groups also have similar elemental abundances and similar spider and REE slopes. The plots of Sr/Eu vs. SiO_2 and Zr/Nb vs. SiO_2 indicate that these lavas were not derived from a single melt or a single source. They are not simply derived from primitive mantle and related to each other by a processes such as fractionation.

There is strong evidence that suggests that some of these units may have undergone mixing and/or assimilation prior to eruption. The trachytic andesite (Tta), plagioclase-phyric basalt (Tpb), Chicken Hill dacite (Td-ch), and glomeroporphyritic andesite (Tga) all display resorbed plagioclase phenocrysts and some display resorbed pyroxene crystals. Some of the plagioclase phenocrysts have a spongy cellular texture and others have completely replaced calcic cores. This indicates that at some time prior to eruption, these early formed phenocrysts were in disequilibrium with the surrounding melt. Another interesting observation is that the Chicken Hill dacite doesn't contain any visible quartz or potassium feldspar, yet it has an SiO_2 content of 63-65 wt%. This suggests that it may have been contaminated with more felsic melt or possibly granitic crust prior to eruption. In addition, the glomeroporphyritic andesite (Tga) contains sparse highly resorbed quartz grains that may have been incorporated into this lava from the underlying granitic crust or argillite.

These rocks formed in a similar tectonic regime on a preexisting continental margin but they do not share one common source and they are not directly related to one another. Each unit may have a distinct history and evolution. It is difficult to determine relationships between these units because their source vents are unknown. We don't know where they originated or how far they flowed before reaching Crawfish Lake Quadrangle. In addition, these rocks have never been dated so it is unclear how they are related temporally. They may have erupted during several episodes in the Tertiary spanning fifty million years.

REFERENCES CITED

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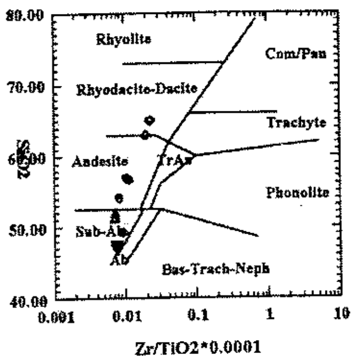

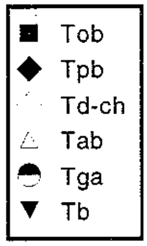

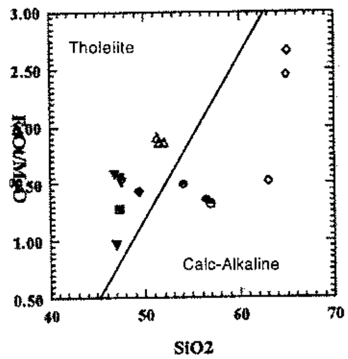

Figure 1. SiO2 vs. Zr/TiO2 discriminant plot after Winchester and Floyd, 1977.

Figure 2. Tholeiite/calc-alkaline classification diagram after Miyashiro, 1974.

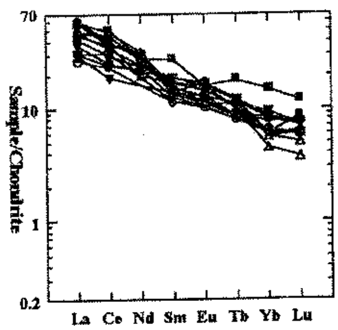

Figure 3. Chondrite-normalized REE plot.

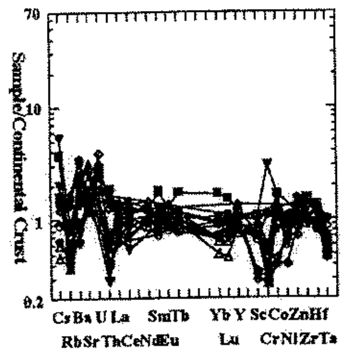

Figure 4. Continental crust-normalized Spider plot.

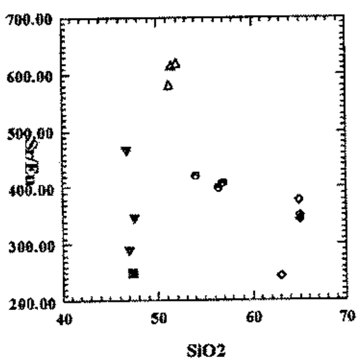

Figure 5. Plot of Sr/Eu vs. SiO2.

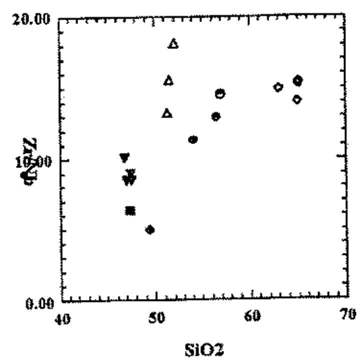

Figure 6. Plot of Zr/Nb vs. SiO2.