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Petrogenesis of Eocene-Oligocene magmatism of the Sulphur Springs Range, central Nevada: The role of magma mixing

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PETROGENESIS OF EOCENE-OLIGOCENE MAGMATISM OF THE SULPHUR SPRINGS RANGE, CENTRAL NEVADA: THE ROLE OF MAGMA MIXING

by

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ABSTRACT

PETROGENESIS OF EOCENE-OLIGOCENE MAGMATISM OF THE SULPHUR SPRINGS RANGE, CENTRAL NEVADA: THE ROLE OF MAGMA MIXING

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Widespread base- and precious-metal anomalies, altered porphyry intrusions and oxidized veins occur in a portion of the Sulphur Springs Range, Nevada (adjacent to the Au-producing Carlin Trend). Some of the Eocene-Oligocene intrusions and cogenetic volcanic rocks in the range exhibit evidence of magma mixing and invite comparisons with other mineralized, Eocene mixed magma systems like the Bingham porphyry Cu deposit 300 km farther to the east. The Sulphur Springs igneous suite ranges compositionally through rhyolite, dacite, andesite and basaltic andesite but is less alkaline than the Bingham volcanic suite. However, the alkali content of the Sulphur Springs suite is similar to other Eocene igneous rocks along the Carlin

trend. The unusual geochemical signature of the Bingham igneous suite, enrichment in Cr, Ni, and Ba, is generally not found in the unaltered Sulphur Springs suite, with the exception of a set of altered mafic and intermediate dikes found in the core of the Sulphur Springs Range. TheBingham and Sulphur Springs volcanic suites both show extensive mixing of mafic magma with more silicic magma to create magma with intermediate compositions. The Bingham suite demonstrates mixing mineralogically by the presence of altered olivine and pyroxene in intermediate composition rocks. One of the disequilibrium Sulphur Springs rocks vividly expresses magma mixing as “andesite” – containing plagioclase, biotite, clinopyroxene, orthopyroxene, olivine, and amphibole coexisting with heavily resorbed megacrysts of quartz and K-feldspar. The Sulphur Springs mixed magma also contains abundant late-stage accessory magnetite and resorbed and oxidized garnet. The most likely parental magmas for this rock are a garnet-bearing quartz porphyry and olivine-bearing basaltic andesite which are both present in the range.

Questions these data raise include: 1) Was there an unusual tectonic setting during the Eocene of the western United States that promoted both magma mixing and base- and precious-metal mineralization? 2) How vital might mixing processes and mafic magma be in delivering large amounts of S and chalcophile metals from deeper magmas to the shallow crust and eventual ore deposits?

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Introduction

The Sulphur Springs Range is approximately 80 km south of Carlin, a small mining town in northeastern Nevada (Figure 1). This area, including Mineral Hill - on the west side of the range, and Union Pass – on the east side of the range, was mined in the late 1800's for gold, silver, and copper (Lincoln, 1923). This historic mining largely predates mining along the Carlin trend to the north, a northwest-southeast line of the most productive gold mines in North America. Carlin type gold deposits are characterized by disseminated ore in carbonate rocks deposited by hydrothermal fluids. They appear to be related to regional Eocene volcanism (Johnston and Ressel, 2004; Henry and Ressel, 2000a; Henry and Ressel, 2000b; Seedorff, 1991). More recently, grass-roots exploration has been conducted in the Sulphur Springs Range in hopes of identifying a Carlin-style target or deposit.

The Sulphur Springs Range has extensive outcrops of volcanic and intrusive rocks that exhibit some key characteristics of porphyry deposits. These include substantial amounts of hydrothermal alteration, pebble dikes, disseminated and vein-related mineralization, as well as geochemical anomalies of As, Ba, Cr, Cu, F, Ni, Pb, Sb, Zn in some of the altered mafic and intermediate dikes found within the range (Abbott, 2003 written communication).

The Bingham porphyry Cu deposit, an Eocene mixed magma system, 300 km farther inboard (east) is a possible comparison to the characteristics we see in the Sulphur Springs volcanic suite. However, the unusual geochemical signature of the Bingham igneous suite – enrichment in Cr, Ni, and Ba as observed by Maughan et al. (2002) – is generally not found in the unaltered Sulphur Springs igneous volcanic suite, but an altered intrusive suite is rich in both Cr and Ni.

Geological Setting

During the late Proterozoic, central Nevada lay on the western-most edge of the North American continental margin (Wooden et al., 1998; Grauch et al., 1998). Igneous rocks in this region illustrate that the continental margin, as shown by the I_{Sr} = 0.706 line, is located to the northwest of both the Carlin and Battle Mountain-Eureka mineralization trends, then swings southeastward before it curves to the southwest (Figure. 2; Grauch et al. 2003; Tosdal et al., 2000). Through the Paleozoic, there was regional extension in this area that created a miogeocline, a basin to the east of an emergent source area, in which there was extensive deposition from the Ordovician through the Devonian (Madrid, 1987 cited in Finney et al., 1993). Important stratigraphic units formed in this setting include the Ordovician Vinnini Formation (mainly shale), the Devonian Devil's Gate Limestone, as well as other Devonian carbonate rocks.

In late Devonian through late Mississippian time, the Antler Orogeny affected the western margin of the North American plate (Carpenter et al., 1994). The result of this tectonic episode, in the area of study, is the Roberts Mountain Thrust (Figure 2). This thrusting event pushed the Ordovician Vinnini Shale over the Devonian group, which is typically capped by the Devil's Gate Limestone – the uppermost unit of the lower plate. This thrust contact is seen in various locations throughout the Sulfur Springs Range (Abbott, 2003; Carlisle and Nelson, 1990). This contact of carbonate rocks with the

Roberts Mountain thrust fault is the typical setting for the host rock of mineralization along the Carlin Trend, as it is generally fractured and is a conduit for fluids.

Between 40 and 36 Ma, there was a period of extension throughout much of northern Nevada (Figure 3; Seedorff, 1991). The extensional units, including the Elko Conglomerate, are evidence of Eocene extension (Hayes et al., 2002). Extension may be time progressive from north to south, corresponding to a similar pattern for volcanism in the region (Figure. 3; Seedorff, 1991). Magmatism generally pre-dates the onset of upper crustal extension; however, some of the early crustal extension is believed to be accommodated by intrusion of magma (Seedorff, 1991; Gans et al., 1989). This extension may have been crucial in opening up space within the crust for magmas to penetrate to shallow levels.

Cenozoic magmatism in this region began in the Eocene, with most data pointing to ages of 40-36 Ma (Henry and Ressel, 2006; Henry and Ressel, 2000a; Henry and Ressel, 2000b). This magmatism ranged in composition between andesite, dacite, granodiorite, and rhyolite, and was widespread throughout northern Nevada (Henry and Ressel, 2000a; Henry and Ressel, 2000b). Concurrent volcanism was happening at similar latitudes in Utah, including the magmatism responsible for the Bingham, Clayton, and Alta stocks (Vogel et al., 2001). Apparently there were several large magma chambers episodically present beneath the area of the Carlin Trend and the Emigrant Pass Volcanic field during the Eocene (Grauch et al., 2003; Grauch et al., 1998; Henry and Ressel, 2000a; Henry and Ressel, 2000b). These chambers were creating more felsic magma through processes of differentiation, crustal assimilation, or most likely a combination of both (Henry and Ressel, 2000a; Henry and Ressel, 2000b). The Eocene volcanism of the Carlin Trend may be genetically associated with the mineralization that occurs along the trend. Although the close spatial and temporal relationships of Eocene igneous rocks to Carlin Trend mineralization has suggested a probable link (Ressel et al., 2000; Ressel et al., 2001), other workers remain skeptical and have proposed alternate models related to fluid flow focused by the edge of the craton (Hofstra and Rye, 1998). The Bingham porphyry copper system is well removed from the craton margin, but is comparable in age to the main pulse of Carlin mineralization (Ressel et al., 2000) and has associated Carlin-type Au mineralization.

Basin and Range extension of the western North American continent has been happening for the last 15-25 million years (Henry and Ressel, 2000a; Henry and Ressel, 2000b). The Sulphur Springs Range has two prominent normal faults, the West Graben Fault and the East Graben Fault, both of which have throw of hundreds of feet, see cross section in Figure 4.b (Carlisle and Nelson, 1990; Abbott, 2003).

Sampling and Analytical Methods

One hundred and eighty-five samples of igneous rocks were collected for this study of Sulphur Springs Range magmatism. Care was taken to gather the freshest, least altered samples. Standard or polished thin sections were examined for 25 samples which represented the main lithologic units (Appendix A). Complete hand sample descriptions and locations are available in Appendix B.

Analytical data was collected from Brigham Young University Geological Science labs on 145 of these samples, with replicate analyses commercially from ALS Chemex for 48 samples. Both major and trace element analyses were completed at

Brigham Young University (BYU) using a Siemans 303 X-ray florescence spectrometer (Appendix C). Multiple analyses of international standards assured precision and accuracy of the analyses.

Rare earth element (REE) abundances were determined by ALS Chemex Labs for 49 samples, using inductively coupled plasma mass spectrometry (Appendix D). Gold abundances were also determined at ALS Chemex by fire assay and atomic absorption methods. ALS Chemex data for major were obtained in similar fashion to BYU data, using X-ray florescence spectrometry, and trace elements were obtained by using the four acid "near-total" digestion method.

U-Pb age determinations were conducted on zircon mineral separates in the GeoAnalytical Lab at Washington State University (Appendix E). All laser work in this study was performed using a New Wave UP-213 laser ablation system in conjunction with a ThermoFinnigan Element2 single collector double-focusing magnetic sector ICP-MS. Fixed 30 or 40 µm diameter spots were used with a laser frequency of 10 Hz. The ablated material is delivered to the torch by He and Ar gas. For a more comprehensive overview of the techniques used, refer to Chang et al., (2006).

Garnet and olivine phenocryst compositions were determined with a Cameca SX50 electron microprobe that has been upgraded to SX100 standards. A 20 nA beam and a 15 kV acceleration voltage were used for analyses (Appendix F).

Results

Unit Descriptions

Elko Conglomerate

The Elko Conglomerate is a primarily red-brown pebble to cobble conglomerate, and locally arkosic sandstone. The conglomerate clasts are predominantly quartzite with subordinate green chert in some locations (Smith and Kenter, 1978). This unit outcrops just east of the East Graben Fault on the east side of the range (Figure 4). On the eastern most exposures of the Elko there is locally an igneous member, the tuff at Union. The tuff at Union, the upper member of the Elko Conglomerate, is an orange to maroon ash-flow tuff. It is difficult to pin down the makeup of this rock with only two samples which are in general compositionally a ferroan, calc-alkalic, metaluminous, shoshonitic, latite (Figure 5). This unit includes fragments of quartzite cobbles, which are the dominant clast in the Elko, as well as well rounded cobbles of the square quartz porphyry. The square quartz porphyry is rhyolitic and contains bipyramidal quartz phenocrysts along with plagioclase, potassium feldspar, and sparse biotite.

The age of the Elko Conglomerate is Eocene to Oligocene according to Smith and Kenter (1978). The age of the tuff at Union is not known. However, within the tuff at Union, our new U-Pb zircon age on a square quartz porphyry cobble is 155.2 ± 3.5 Ma (Appendix E.5.). This suggests that eroded cobbles from Jurassic plutons were being transported across the paleo-surface of the Eocene. The square quartz porphyry cobbles are only found in the tuff at Union and not in the lower part of the Elko Conglomerate. An intrusion very similar to these clasts outcrops in the southeastern region of the Sulphur Springs Range.

Flow Banded Rhyolite and Latite Flow

The flow banded rhyolite consists of alternating dark grey flow bands with light grey to pink flow bands in the crystal-poor lava flow. This rhyolite straddles the metaluminous and peraluminous fields, as well as the ferroan and magnesium fields, and is calc-alkalic and high-K (Figure 5). This rhyolite is only found in one location (Figure 4), but has a very similar composition to a rhyolite flow that outcrops approximately 11 km to the south.

In thin section, the banded rhyolite has extremely small phenocrysts caught in the flowing matrix. These phenocrysts include quartz, plagioclase and oxides. The matrix is composed of very finely banded devitrified glass.

This flow is possibly older than the nearby plagioclase dacite lava domes, as it is on the western edge of the volcanic sequence – near the East Graben Fault – and might be correlative with the Elko Conglomerate. There are subcrops of the Elko Conglomerate to the east of the banded rhyolite (Figure 4).

In close proximity to this flow banded rhyolite is a compositionally metaluminous, calc-alkalic, magnesian, shoshonitic, latitic lava flow (Figure 4 and 5). In the field this latite flow is a crystal-poor, black scoriaceous lava, which in some locations appear to flow down paleo-streambeds. In other locations they appear to have wrapped around the flow banded rhyolite and likely are of similar age.

Biotite Porphyry

The biotite porphyry unit occurs as light tan cobbles of a phenocryst-rich porphyritic rock. It has a medium to fine-grained matrix with abundant phenocrysts of biotite, plagioclase, and quartz. The biotite porphyry is a metaluminous, calc-alkalic, magnesian, shoshonitic dacite (Figure 5).

Phenocryst content includes large phenocrysts of biotite, along with quartz, plagioclase, and potassium feldspar, as well as an Fe-Ti oxide (obscured by alteration). Phyllic alteration has converted most potassium feldspar to muscovite. The quartz phenocrysts sometimes show resorption and often exhibit gas-rich or leaked fluid inclusions. The matrix consists of intergranular quartz, plagioclase, biotite and small amounts of glass.

The biotite porphyry is found in only one location and may be a dike or vent-fill (Figure 4). However, this porphyry appears to be closely related in texture, composition, and location, to the biotite dacite ash fall.

The U-Pb age found for one sample of this rock type is 35.9 ± 0.5 Ma, which is very similar to the age of the biotite porphyry ash (Figure 6). This data affirms the possibility that this is an altered intrusive dike, related to the biotite dacite ash fall.

Biotite Dacite Ash Fall and Flows

The biotite dacite ash outcrops poorly as light colored soil horizons, with porphyritic dacite pebbles and cobbles littering the ground. Roadcuts provide better exposures of this unit showing it to be an altered, non-welded, whitish-yellow ash laced with small oxidized veins. The ash altered to a swelling clay in most locations. The ash was possibly emplaced as a caldera-filling ash, or an ash fall (and in some location a flow) located above the tuff at Union in the Elko Conglomerate (Figure 4). Often times subcrop is only distinguished from the surrounding alluvium by the occurrence of porphyry fragments.

The biotite dacite ash has phenocrysts of biotite, plagioclase, quartz, garnet, and some megacrysts of quartz. Plagioclase is the most abundant phenocryst, but biotite is large and abundant as well, with only minimal oxidized rims. The least altered samples of this unit are metaluminous, calcic, magnesian, high-K, dacite, similar to the biotite porphyry (Figure 5). Altered samples fall into the rhyolite field as a result of silicification.

Outcrops of this unit near the north-end of the mapped area are ash flows and have small crystals of biotite, bipyramidal quartz and abundant lithic fragments. Alteration in this vicinity is dominantly argillic with sparse pyrite (oxidized). These altered outcrops may be part of the Indian Wells Formation, which is a series of ash flow tuffs in a sedimentary environment found in the valley east of the Pinion Range to the north of the Sulphur Springs Range (Smith and Kenter, 1978).

The U-Pb zircon age of a porphyry clast within the biotite dacite ash is 35.4 ± 0.4 Ma (Figure 6). The age of the ash fall is thus constrained between the age of this clast and the age of the overlying plagioclase dacite (35.1 Ma). The biotite dacite ash is the basal unit for all subsequent volcanic rocks which are present in the volcanic series in the eastern Sulphur Springs Range, as it is the most unit pervasive throughout the section.

Plagioclase Dacite Lava Domes

The most voluminous surficial unit in the Sulphur Springs igneous suite is the plagioclase dacite lava domes. This unit consists of a pink or orange phenocryst-rich rock, outcropping as low-relief flow foliated or brecciated lava domes. An unaltered vitrophyre is found in some locations directly below the dome's margins. The plagioclase dacite domes comprise the majority of the knolls in the eastern portion of the volcanic field (Figure 4). The dacite usually exhibits flow foliation (it also occurs as a matrix supported breccia), which is the Tertiary igneous unit mapped by Carlisle and Nelson (1990). However, they amalgamated the plagioclase dacite with nearly all other rock types described in this paper.

The plagioclase dacite unit is a peralumious, calc-alkalic, magnesian, high-K dacite based on the least altered vitrophyre samples (Figure 5). Slightly altered samples have a much broader range of composition depending on the alteration type. They range from rhyolite in silicically altered regions to trachyte in propylitically and argillically altered areas (Figure 5).

Plagioclase is the primary phenocryst with lesser quartz and clinopyroxene, and sparse amphibole, and biotite in some domes. The plagioclase dacite vitrophyre has a very fine-grained matrix that is almost entirely glass, with some areas which have been devitrified. In more altered samples, chlorite, clay minerals and other iron-staining are observed.

A U-Pb zircon age determined for this unit is 35.1 ± 0.5 Ma (Figure 6). The field relationships correlate well with this age as the plagioclase dacite appears to overlie the biotite porphyry ash, and the ash has been somewhat altered proximal to the domes. This signifies that it intruded in through and onto the biotite porphyry ash.

Mixed Magma Andesite Dike and Lava Flows

The mixed magma andesite is unique in various textural aspects. It is a dark grey, crystal-rich volcanic rock found both as near-surface dikes and near-vent flows (Figure 4). Where argillically altered, it has a pink colored rind on fractures. Dike or flow margins have some perlitic glass in their matrices. These outcrops also have sporadic zones of vesicular rock.

On the whole rock IUGS classification scheme, this rock falls in the upper right portion of the andesite field, with some analyses straddling the dacite field (Figure 5). Compositionally it is metaluminous, calc-alkalic, magnesian, and shoshonitic (Figure 5). Two samples of the mixed magma andesite are more mafic than the others at 57% silica and fall in the latite field (Figure 5). This pair may represent a separate unit altogether or provide a less evolved fraction of the andesite unit.

The disequilibrium phenocryst assemblage makes this rock unique. Rounded sieved-textured plagioclase is the dominant phenocryst. Other prominent phenocrystic phases include biotite, clinopyroxene, orthopyroxene, and olivine, as well as heavily resorbed megacrysts of quartz and potassium feldspar (Figure 7). The megacrystic potassium feldspar and quartz are up to 3.5 cm across. In thin section, the potassium feldspar is best characterized as sanidine and the quartz is unstrained. The mixed magma andesite also contains abundant accessory magnetite and resorbed and oxidized garnet (Figure 8). Thin section examination reveals substantial resorption of quartz phenocrysts (Figure 7 and 8). Olivine averages Fo_{77} and is partially to completely altered to iddingsite or other fine-grained phases.

The mineral assemblage denotes mixing of a silicic magma (containing quartz and sanidine megacrysts) with a mafic magma (containing olivine and pyroxene). Other indicators of magma mixing include clinopyroxene halos around the resorbed quartz (Figure 7 and 8; Coombs and Gardner, 2004).

The most likely parental magmas for this rock are a garnet-bearing biotite quartz rhyolite (possibly similar to porphyry fragments found in the biotite dacite ash) and an olivine-bearing latite or basaltic andesite, both of which are present in the volcanic field.

The garnets found in the Sulphur Springs suite fall into two distinct categories – garnet in the mixed magma andesite is almost completely Fe-Mn and a little Ca and Mg, but garnet in the biotite dacite ash contains more Mg with substantially less Mn but similar amounts of Ca (Figure 9). This likely signifies that a more evolved garnet-bearing silicic magma (in addition to the biotite dacite ash) contributed to form the mixed magma andesite.

The mixed magma andesite has a U-Pb zircon age of 32.0 ±0.6 Ma. The 2 sigma error bar for this age does not overlap with that of the older garnet-bearing lithologies, i.e. the biotite dacite ash (Figure 6). Stratigraphic relationships also imply that this is the youngest unit in the volcanic field (Figure 4).

Basaltic Andesite Flows and Dikes

The basaltic andesite flows and dikes are dense, black, and porphyritic. They are compositionally metaluminous, calcic, magnesian, and medium-K (Figure 5). Field relations suggest that these were emplaced as possible dikes or mafic flows into or onto the biotite dacite ash (Figure 4). The biotite dacite ash has an alteration zone that extends

5 meters into the ash adjacent to the contact with the basaltic andesite flows and dikes. This also implies that the basaltic andesite is younger than the basin filling ash.

The basaltic andesite flows and dikes have clinopyroxene, orthopyroxene, and olivine, with very sparse phenocrysts of plagioclase. There is some alteration of olivine to iddingsite, but pyroxenes remained fresh. Olivine averages Fo_{80}. The matrix is composed of mainly plagioclase and pyroxene along with small zones of glass. The matrix also shows distinct flow foliation of the elongated plagioclase microphenocrysts.

The basaltic andesite flows and dikes are the most mafic of the Eocene igneous rocks found in the Sulphur Springs area. (True basalts are found approximately 12 km to the south; however, they are believed to be Miocene in age – due to their location and structure and composition.)

Mafic to Intermediate Dikes

In the core of the Sulphur Springs Range, out of the mapped area, there is a series of moderately-to-extremely altered dikes of varying composition and unknown age. The subcrop is usually composed of a light orange colored drape of altered rock, identifiable as igneous by the porphyritic-aphanitic texture and small phenocrysts. Several propyllitically altered dikes have preserved the phenocryst assemblage of olivine and clinopyroxene.

Dikes with the most elevated Cr and Ni contents are generally the least silicic, averaging around 55% SiO_2 (Figure 4). There are, however, dikes with anomalously high SiO_2, up to 65%; this might be accounted for as silicic alteration or it could suggest a dike suite that is more evolved because of slightly elevated rare earth concentrations in several samples, yet anomalously rich in Cr and Ni (500 ppm Cr and 230 ppm Ni at 65% SiO_2) possibly due to magma mixing.

Unit Age Relations

U-Pb ages of zircons confirm stratigraphic relationships inferred from poorly exposed contacts in the Sulphur Springs volcanic field. The basal volcanic unit is the tuff at Union, a member of the Elko conglomerate. Within the tuff at Union, there are fragments of the older square quartz porphyry, which has a U-Pb zircon age of 156 Ma (Appendix E). This suggests that before the eruption of the tuff at Union, Eocene volcanism had not significantly covered this Jurassic pluton or pediment cobbles derived from the pluton.

The biotite porphyry and the biotite dacite ash are indistinguishable in age and composition (Figure 5). U-Pb ages of these units are 35.9 and 35.4 Ma respectively (Figure 6). There are no clear field relations demonstrating which is older. These two units are possibly comagmatic with the one being an explosive product, the ash, followed by a vent-filling dome or intrusion, the porphyry. The actual extent of these units is not constrained on the east because they are buried by younger volcanic units and Quaternary sediments, but it is unlikely that they are large as similar extrusive units are not found in the adjacent ranges.

The U-Pb age of the plagioclase dacite is also indistinguishable from that of the biotite dacite ash, with an age of 35.1 Ma. However, field relations show that the plagioclase dacite overlies the biotite dacite ash in at least two locations. Hence, after the initial eruption of the ash, close behind was the dome forming flows and breccias of the plagioclase dacite.

Unconstrained by a U-Pb age is the emplacement of the basaltic andesite. Its younger age is known only due to field relations where the basaltic andesite appears to intrude through the biotite dacite ash and along contacts it has propyllitically altered the matrix of the ash to a bright green color.

The youngest of the Eocene-Oligocene volcanic units in this area is the mixed magma andesite, having an age of 32.0 Ma. Within the phenocryst assemblage, the presence of the megacrystic quartz and garnet give proclivity to the idea that the felsic component of the mixing magmas is related to a rhyolite magma that might be similar to the biotite dacite ash. This could denote a long sustained magma chamber into which a more mafic magma was injected and mixed, or more likely a later chamber distinct from the biotite dacite ash with similar composition and phenocryst content, including garnet. Eruption, however, must have taken place a short time after mixing because the quartz and potassium feldspar megacrysts were not entirely assimilated and reaction rims are found on some phenocrysts (Coombs and Gardner, 2004).

Discussion

Comparison with Bingham igneous suite

The Sulphur Springs volcanic field is about the same age, but about 300 km west of the Bingham porphyry Cu deposit in northern Utah. Major and trace element compositions of the Sulphur Springs suite form a trend that is distinct from that of the Bingham suite (Figure 10; Maughan, 2001). Compositionally, the older volcanic series (related to mineralization) in the Bingham suite have high alkali contents and range from rhyolite to trachyte, latite, shoshonite, and minette (Maughan et al, 2002), whereas the Eocene Sulphur Springs suite includes rhyolite, dacite, andesite and basaltic andesite on the IUGS chemical classification diagram (The basalt in the Sulphur Springs Range is generally thought to be Miocene in age). Bingham volcanic suite ranges across peraluminous and metaluminous values, through calk-alkalic to alkalic, is generally magnesian, with high-K to shoshonitic compositions.

The characteristically high Cr, Ni, and Ba contents of the Bingham suite are not present in the main unaltered Eocene rocks of the Sulphur Springs suite (Figure 11). The older volcanic suite at Bingham suite has elevated concentrations of Cr and Ni across the full range of silica content. Sulphur Springs shows the more common trend of high values for Cr and Ni in mafic samples, but following a trendline that decreases quickly to very low values (>50 ppm) as the samples become more silicic. The only exception in the Sulphur Springs suite is the set of mafic and intermediate dikes found generally within the range. These dikes have relatively high Cr and Ni contents regardless of silica content, but do not have the high Ba content as seen at Bingham. The Ba content of the Bingham suite is high throughout the silica range, but is the highest in the mafic and intermediate composition rocks. In the Sulphur Springs suite Ba increases as SiO_2 increase, while the Bingham suite decreases in Ba as SiO_2 increases (Figure 11c). Both suites have Ba contents of between 1000-2500 ppm at about 65% SiO_2. This might be due to the introduction of Ba with alteration.

Both the Bingham and Sulphur Springs volcanic suites show evidence of mixing of mafic magma with a more silicic magma to create volcanic rocks with intermediate compositions. The Bingham suite demonstrates mixing of mafic alkaline magma with more silicic magma mineralogically by the presence of altered olivine and pyroxene rimmed by amphibole in intermediate composition rocks (Pulsipher, 2000). Other evidences for magma mixing include elevated Cr and Ni concentrations in intermediate composition rocks, dacite clasts that contain mafic clots, large resorbed potassium feldspar phenocrysts in silicic rocks with elevated Cr and Ni content, as well as minette dikes and quartz latite dikes of the same age intruding side by side in the open pit mine at Bingham (Pulsipher, 2000; Maughan et al., 2002).

One of the Sulphur Springs rocks, which is in disequilibrium, vividly expresses magma mixing is "andesite," containing plagioclase, biotite, clinopyroxene, orthopyroxene, olivine, and amphibole, along with strongly resorbed megacrysts of quartz and potassium feldspar. The Sulphur Springs mixed magma andesite also contains abundant late-stage accessory magnetite and resorbed and oxidized garnet. The most likely parental magmas for this rock are a garnet-bearing rhyolite and an olivine-bearing latite or basaltic andesite, all of which are present in the volcanic field. We suspect that magma mixing may be operative in the genesis of other Sulphur Springs rocks as well, although in a less dramatic fashion.

The Sulphur Springs volcanic suite is Eocene to early Oligocene in age and is slightly younger than the magmatism related to mineralization at Bingham. The Sulphur Springs suite ranges from 32 – 36 Ma. Comparing that to the older volcanic series at Bingham, which ranges from 37 – 39 Ma, the Sulphur Springs suite is approximately 1-4 Ma younger (Figure 5; Maughan et al., 2002, Pulsipher, 2000).

Comparison with other Carlin Trend igneous rocks

The Sulphur Springs range is just south and east of the main northern Carlin trend-Emigrant Pass igneous complex. The main Carlin trend is from NW to the SE, then heads toward the south to include Rain and Bullion deposits (Figure 1). Continuing this southward trend another 40 km would include the Sulphur Springs Range and the Mineral Hill and Union Pass mineral deposits. The structure of the Sulphur Springs region is similar to the intensely mineralized localities to the north along the Carlin Trend. This structure includes Paleozoic limestone and dolomite in lower plate of the Roberts Mountain Thrust fault, creating an area of brecciated rock which readily accepts mineralization fluids (Henry and Ressel, 2000a; Henry and Ressel, 2000b). This contact in the Sulphur Springs region was subsequently cut by NNW and N trending normal faults.

The rock types in the Sulphur Springs igneous suite are comparable to those found farther to the north in the Northern Carlin trend – Emigrant Pass igneous complex and the Tuscarora volcanic field (Figure 12). The Carlin trend – Emigrant Pass volcanic field includes rhyolite, dacite, andesite, and basaltic andesite in the IUGS chemical classification diagram (Henry and Ressel, 2006; Henry and Ressel, 2000a; Henry and Ressel, 2000b; Ressel, 2005). Similarly the Tuscarora volcanic field erupted sub-alkaline magma, but does include minor latite and trachyte (Henry and Ressel, 2000a; Henry and Ressel, 2000b; Henry et al., 1999). Both the Carlin trend – Emigrant Pass and Tuscarora volcanic field are metaluminous, calc-alkalic, magnesian, and high-K. The Sulpur Springs suite appears to be the slightly younger southward continuation of this calc-alkaline magmatism that is strongly correlated with the mineralization along the main

Carlin trend (Figure 6; Ressel and Henry, 2006). The Carlin and Tuscarora volcanic fields show concentrations of Cr, Ni, and Ba similar to those of the Sulphur Springs suite with higher Cr and Ni in more mafic rocks, but low in the intermediate and felsic rocks, and lower Ba throughout than that of Sulphur Springs.

Tectonic regime for petrogenesis of the Sulphur Springs suite

The magmas erupted in the Sulphur Springs igneous suite are clearly a product of changing tectonic conditions in western North America during the Eocene. During the early Cenozoic, the Farallon Plate subducted at a very low angle under the North American Plate (Lipman et al., 1972; Severinghaus and Atwater 1990). During the late Eocene, the Farallon Plate apparently detached from the lithosphere in a southward sweeping motion allowing hot asthenospheric mantle to flow between the subducting slab and the relatively colder lithospheric mantle (Best and Christiansen, 1991). Concurrent with this southward sweeping volcanism, or shortly thereafter, extension, crustal thinning, and relaxation occurred in western North America; these are manifest by Eocene grabens and rapidly accumulated conglomerate facies, such as the Elko Conglomerate (Seedorff, 1991; Hayes, 2002). The heating of the lithospheric mantle with hot asthenospheric mantle, subduction and dewatering of the Farallon Plate, and decompression of hot lithospheric mantle associated with minor extension may all be responsible in various degrees for the small amounts of partial melting of the lithospheric and asthenospheric mantle (Maughan et al., 2002). Collapse of the thickened hinterland may have followed in the wake of southward-sweeping volcanism seen throughout the Great Basin (Figure 3).

The tectonic setting for north central Nevada, as revisited recently in Grauch et al. (2003), shows the complexity of the tectonic structure of the region (Figure 2). The 0.706 Sr isopleth marks the western most edge of the Precambrian continental crust, which is juxtaposed against the accreted terrain and oceanic crust to the west. The eastern limits of the Roberts Mountain allocthon as well as the Golconda allocthon are near the mineralization trends, with Sulphur Springs very near the eastern limit. These are the regional expressions of the Antler Orogeny (Figure 2; Grauch et al., 2003). Also note the location of the younger - middle Miocene - Northern Nevada rift (Zoback et al., 1994).

A similar tectonic regime existed in the region of the Bingham porphyry deposit. Apart from the fact that it is not nearly as close to the edge of the Precambrian craton, it too went through the detachment of the Farallon Plate, which created a Tertiary volcanic arc setting. Tectonic discrimination diagrams for silicic and mafic rocks show that both the Bingham and the Sulphur Springs volcanic/intrusive centers are overwhelmingly continental arc-related magmas (Figure 13; Maughan et al, 2002). The Bingham porphyry deposit is possibly located near the edge of a structural boundary; according to Nelson et al. (2002) it is near the hypothetical accretionary boundary between the Farmington Canyon Complex and the Santaquin Complex.

Magma Mixing

Hattori and Keith (2001) showed that porphyry (and Carlin-style) mineralization at Bingham could not have occurred without the involvement of mafic alkaline magmas that were rich in S and Cu (and Au). The intermediate "calc-alkaline" magmas at

Bingham were simply too poor in these elements for any reasonable volume of magma to serve as a source of metal in the deposits. Although only trivial amounts of mafic magma are seen at the surface around Bingham, evidence of magma mixing involving alkaline olivine-bearing magmas is universal. Perhaps the inception of extension during the Eocene allowed mafic magmas to intercept and mix with evolved magmas in shallow sub-volcanic settings beneath the deposit. The geochemical signature of this mixing is elevated Cr and Ni concentrations in intermediate rocks (Figure 11).

High concentrations of Cr and Ni in all Eocene igneous suites along the Carlin trend and in the unaltered Sulphur Springs suite are not evident, with the exception of the mafic and intermediate dike set found in the Sulphur Springs Range. Additionally, alkaline olivine-bearing Eocene magmas in the Carlin trend are apparently rare. However, the Cr and Ni-rich mafic dikes, the olivine-bearing basaltic andesite, and mixed magma andesite of the Sulphur Springs area are clear evidence that mafic magmas were involved in the magma system. (Although few workers would deny the involvement of mantle-derived magmas at deeper levels in the Carlin trend).

Nonetheless, the question remains as to whether deep mafic magmas, richer in S and chalcophile metals, mixed with more silicic magma and in the process degassed and contributed a flux of volatiles and metals to ore horizons during the Eocene. Some might be tempted to limit the role of Carlin trend Eocene magmas to simple heat sources to drive fluid flow – particularly fluids from basinal brines (Tosdal, 1998). However, the mixed magma andesite from the Sulphur Springs Range is clear evidence that magma mixing did occur at this time. The magma mixing that produced the Sulphur Springs andesite appears to have utilized a less mafic magma than Bingham – perhaps already fractionated and thus lower in Cr and Ni (Figure 11). Extension may have promoted intrusion and eruption of mafic magmas from deeper mafic sources, as well as magma mixing, although evidence of this process is not abundant.

Degassing of underplated and mixed magma may contribute large proportions of sulfur, volatiles, and metals to an ore-forming system (Waite et al., 1997). This idea of mixing associated with degassing to supply additional sulfur to the magmatic system it is mixing with is proposed in various locations to account for the enrichment of metals, including the porphyry Cu mineralization at Santa Rita in New Mexico (Audetat and Pettke, 2006), Questa deposit in New Mexico, Nukay deposit in Mexico, and Las Bambas porphyry deposit in Peru (Jones, 2002), and in the Farallón Negro Volcanics in Argentina (Halter et al., 2005), as well as the Bingham deposit in Utah (Pulsipher, 2000; Maughan et al. 2000).

Conclusions

In summary there appears to be a unique tectonic environment during the middle Cenozoic that promoted the eruption and intrusion of mafic and silicic magmas, and mixing of these magmas. Magmatism encouraged mineralization throughout the region of northern Nevada and Utah. This environment included:

1. The rollback of the Farallon Plate, as it apparently detached from the lithosphere in a southward sweeping motion allowing hot asthenospheric mantle to flow between the subducting slab and the relatively colder lithosheric mantle

2. The presence of structural boundaries, including lithosphere – penetrading structures and thrust faults, promoted hydrothermal fluid flow and movement of magma through the upper lithosphere.

3. Distinctly continental arc-related magmas as seen in tectonic discrimination diagrams

4. The pooling of mafic magma within the lithosphere to promote partial melting of the crust and the mixing of the mafic magma with the more silicic magma, as well as the intrusion and eruption of mafic magma.

The eruption of mixed magmas and mafic magmas in both the Sulphur Springs Range and at the Bingham deposit suggests that there is a more mafic magma may have delivered sulfur and chalcophile metals to the shallow crust. The Bingham suite demonstrates magma mixing by the presence of altered olivine and pyroxene in intermediate composition rocks, elevated Cr and Ni concentrations, volcaniclastic units with dacite clasts that contain mafic clots, and minette dikes and quartz latite dikes of the same age intruding side by side in the Bingham pit (Maughan et al., 2002).

The Eocene volcanic rocks of the Sulphur Springs Range exhibit magma mixing as disequilibrium phenocryst assemblages (plagioclase, biotite, clinopyroxene, orthopyroxene, amphibole, and olivine with resorbed megacrysts of quartz and potassium feldspar; along with accessory magnetite and resorbed and oxidized garnet). This suite of rocks generally does not display an association with the large amounts of sulfur and chalcophile metal mineralization as at the Bingham suite. However, sulfur and chalcophile metals may have been introduced from the mafic and intermediate dikes and possibly the basaltic andesite, which are higher in Cr and Ni concentrations and likely contained high concentrations of sulfur. The mafic and intermediate dikes may have been involved in magma mixing as there are some dikes that have intermediate compositions with elevated Cr and Ni values – similar to the Bingham suite. Gossan veins throughout the area and the historically mined Union Pass and Mineral Hill districts indicate large quantities of S, Au, Ag, and Cu were mobilized.

The comparison between mineralization seen at Bingham and the mineralization seen in the Carlin trend region has been made before. Johnson and Ressel (2004) suggested that porphyry Cu-Au deposits, Carlin type deposits, and distal disseminated deposits are all related as a continuum with the differences in the deposit type, depending on the spatial relationship to the magmatic hydrothermal system.

The Sulphur Springs igneous suite and the Bingham system are similar in tectonic regime and the presence of magma mixing; however the strong presence of high Cr and Ni as seen at Bingham is seen only in an altered suite of mafic and intermediate dikes in the Sulphur Springs Range. Like Bingham and Sulphur Springs, other Carlin-related Eocene magmatic systems may have experienced similar underplating of mafic magma vital to generating large chalcophile (Au) and volatile (S) budgets.

References

Abbott, J., 2003, personal communication.

Audetat, A., and Pettke, T., 2006, Evolution of sulphur and copper in the magmas associated with porphyry-Cu mineralization at Santa Rita in New Mexico, U.S.A.: International Mineralogical Association Abstracts and Programs, v.19, p.185.

Best, M.G., and Christiansen, E.H., 1991, Limited extension during peak Tertiary volcanism, Great Basin of Nevada and Utah: Journal of Geophysical Research, B, Solid Earth and Planets, v. 96, n. 8, p. 13,509-13,528.

Carlisle, D., and Nelson, C.A., 1990, Geologic Map of the Mineral Hill Quadrangle, Nevada: Nevada Bureau of Mines and Geology Map 97, scale 1:48,000.

Carpenter, J.A., Carpenter, D.G., and Dobbs, S.W., 1994, Antler orogeny: Paleostructural analysis and constraints on plate tectonic models with a global analogue in southeast Asia, *in* Dobbs, S.W., and Taylor, W.J., eds., Structural and stratigraphic investigations and petroleum potential of Nevada, with special emphasis south of the Railroad Valley producing trend, Nevada Petroleum Society – 1994 Conference volume II, p.187-240.

Chang, Z., Vervoort, J.D., McClelland, and W.C., Knaack, C., 2006, U-Pb dating of zircon by LA-ICP-MS: Geochemistry Geophysics Geosystems, v. 7, p. 1-14.

Coombs, M.L., and Gardner, J.E., 2004, Reaction rim growth on olivine in silicic melt: Implication for magma mixing: American Mineralogist, v. 89, p. 748-759.

Ewart, A., 1979, A review of the mineralogy and chemistry of Tertiary-Recent dacitic, latitic, rhyolitic, and related salic volcanic rocks, *in* Barker, F., ed. Trondhjemites, dacites, and related rocks: Amsterdam, Elsevier, p. 13–21.

Finney, S.C., Perry, B.D., Emsbo, P., and Madrid, R.J., 1993, Stratigraphy of the Roberts Mountain allochthon, Roberts Mountain and Shoshone Range, Nevada, *in* Lahren, M.M., Trexler, J.H., Jr. and Spinosa, C., eds., 1993, Crustal evolution of the Great Basin and Sierra Nevada: Cordilleran / Rocky Mountain section, Geological Society of America Guidebook, Department of Geological Sciences, University of Nevada, p. 197-230.

Frost, B.R., Barnes, C.G., Collins, W.J., Arculus, R.J., Ellis, D.J., and Frost, C.D., 2001, A geochemical classification for granitic rocks: Journal of Petrology, v. 42, no. 11, p. 2033-2048.

Gans, P. B., Mahood, G. A., and Schermer, E., 1989, Synextensional magmatism in the Basin and Range province; A case study from the eastern Great Basin: Geological Society of America Special Paper 233, p.1-53.

Grauch, V.J.S., Klein, D.P., Rodriguez, B.D., and Wooden, J.L., 2003, Geophysical and isotopic constraints on crustal structure related to mineral trends in north-central Nevada and implications for tectonic history: Economic Geology, v. 98, p. 269-286.

Grauch, V.J.S., 1998, Crustal structure and its relation to gold belts in northern-central Nevada: Overview and progress report, *in* Tosdal, R.M., ed., Contributions to the Au metallogeny of northern Nevada: U.S. Geological Survey Open-File Report, 98-338, p. 34-37.

Grauch, V.J.S., Klein, D.P., and Rodriguez, B.D., 1998, Progress on understanding the crustal structure near the Battle Mountain-Eureka mineral trend form geophysical constraints, *in* Tosdal, R.M., ed., Contributions to the Au metallogeny of northern Nevada: U.S. Geological Survey Open-File Report 98-338, p. 8-14.

Halter, W.E., Heinrich, C.A., and Pettke, T., 2005, Magma evolution and the formation of porphyry Cu–Au ore fluids: evidence from silicate and sulfide melt inclusions: Mineralium Deposita, v. 39, n. 8, p. 845-863.

Hattori, K.H., and Keith, J.D., 2001, Contributions of mafic melt to porphyry copper mineralization: evidence from Mout Pinatubo, Philippines, and Bingham deposit, Utah: Mineralium Deposita, v. 36, p. 799-806.

Hayes, S.R., Hickey, K.A., Mortensen, J.K., and Tosdal, R.M., 2002, Onset of extension in the basin and range: Basin analysis of the Eocene Elko Formation, northeast Nevada: Geological Society of America Abstracts with programs, v. 34, p. 83.

Henry, C.D., and Boden, D.R., 1998, Eocene magmatism: The heat source for Carlin-type gold deposits of northern Nevada: Geology, v. 12, p.1067-1070.

Henry, C.D., Boden, D.R., Henry, C.D., Boden, D.R., and Castor, S.B., 1999, Geologic map of the Tuscarora Quadrangle, Nevada: Nevada Bureau of Mines and Geology Map 116, scale 1:24,000.

Henry, C.D., and Ressel, M.W., 2000a, Eocene magmatism of northeastern Nevada: The smoking gun for Carlin-type gold deposits, *in* Cluer, J.K., Price, J.G., Struhsacker, E.M., Hardyman, R.F., and Morris, C.L., eds., Geology and Ore Deposits 2000: The Great Basin and Beyond: Geological Society of Nevada Symposium Proceedings, May 15-18 2000, p. 365-388.

Henry, C.D., and Ressel, M.W., 2000b, Interrelation of Eocene magmatism, extension, and Carlin-type gold deposits in northeastern Nevada, *in* Lageson, D.R., Peters, S.G., and Lahren, M.M., eds., Great Basin and Sierra Nevada: Boulder, Colorado, Geological Society of America Field Guide 2, p. 165-187.

Hofstra, A.H., and Rye, R.O., 1998, Deuterium and ^{18}O data from Carlin-type gold deposits-implications for genetic models, *in* Tosdal, R.M., ed., Contributions to the Au metallogeny of northern Nevada: U.S. Geological Survey Open-File Report 98-338, p. 202-204.

Johnston, M.K., and Ressel, M.W., 2004, Carlin-type and distal disseminated Au-Ag deposits: related distal expressions of Eocene intrusive centers in north central Nevada: Society of Economic Geologists Newsletter, n.59, p. 12.

Jones, D.M., 2002, Magma mixing and mineralization: Empirical evidence from Questa (Mo), New Mexico, USA; Nukay (Au-Cu), Gerrero, Mexico; Las Bambas (Cu-Au), Peru: Geological Society of America Abstracts with programs, v. 34, p. 87.

Le Maitre, R. W., 1989, A classification of igneous rocks and glossary of terms: Blackwell, Oxford, p. 1-193.

Lincoln, F.C., 1923, Mining districts and mineral resources of Nevada, Reno, Nevada Newsletter Publishing Co., p. 1-95.

Lipman, P.W., Prostka, H.J., and Christiansen, R.L., 1972, Cenozoic volcanism and plate-tectonic evolution of the Western United States. I. Early and Middle Cenozoic: Philosophical Transactions of the Royal Society of London. Series A, Mathematical and Physical Sciences, v. 271, p. 217-248.

Madrid, 1987, Stratigraphy of the Roberts Mountain allochthon in north-central Nevada [unpublished dissertation]: Stanford, California, Stanford University, p. 1-336.

Maughan, D.T., 2001, Mafic to intermediate alkaline rocks of the Bingham district, Utah: MS Thesis, Brigham Young University, Provo, Utah, p. 1-238.

Maughan D.T., Keith, J.D., Christiansen, E.H., Pulsipher, T., Hattori, K., and Evans, H.J., 2002, Contributions from mafic alkaline magmas to the Bingham porphyry Cu-Au-Mo deposit, Utah, USA: Mineralium Deposita, v. 37, p. 14-37.

Miyashiro, A., 1974, Volcanic rock series in island arc and active continental margins: American Journal of Science, v. 28, p. 451-472.

Muller, D., and Groves, D.I., 2000, Potassic igneous rocks and associated gold-copper mineralization: 3rd Edition, Springer, Berlin Heidelberg New York, p. 1-240.

Nelson, S.T., Harris, R.A., Dorais, M.J., Heizler, M., Constenius, K.N., and Barnett, D.E., 2002, Basement complexes in the Wasatch Fault, Utah, provide new limits on crustal accretion: Geology , v. 30, n. 9, p. 831-834.

Pearce, J.A., Harris, N.B., and Tindle, A.G., 1984, Trace element discrimination diagrams for the tectonic interpretation of granitic rocks: Journal of Petrology, v. 25, p. 956-983.

Pulsipher, T., 2000, The correlation of Eocene extrusive block and ash flows to intrusions in the Bingham copper porphyry system, Utah: MS Thesis, Brigham Young University, Provo, Utah, p. 1-104.

Ressel, M.W., 2005, Igneous Geology of the Carlin Trend, Nevada: The Importance of Eocene Magmatism in Gold Mineralization: PhD Dissertation, University of Nevada-Reno. p. 1-276.

Ressel, M.W., and Henry, C.D., 2006, Igneous geology of the Carlin trend, Nevada: Development of the Eocene plutonic complex and significance for Carlin-type gold deposits: Economic Geology, v. 101, p. 347–383.

Ressel, M.W., Noble, D.C., Henry, C.D., and Trudel, W.S., 2000, Dike-hosted ores of the Beast deposit and the importance of Eocene magmatism in gold mineralization of the Carlin trend, Nevada: Economic Geology, v. 95, p. 1417-1444.

Ressel, M.W., Noble, D.C., Henry, C.D., and Trudel, W.S., 2001, Dike-hosted ores of the Beast deposit and the importance of Eocene magmatism in gold mineralization of the Carlin trend, Nevada-A reply: Economic Geology, v. 96, p. 666-668.

Seedorff, E., 1991, Magmatism, extension, and ore deposits of Eocene to Holocene age in the Great Basin--Mutual effects and preliminary proposed genetic relationships, in Raines, G. L., Lisle, R. E., Schafer, R. W., and Wilkinson, W. H., eds., Geology and ore deposits of the Great Basin: Geological Society of Nevada, Symposium, Reno/Sparks, April 1990, Proceedings, v. 1, p. 133-178.

Severinghaus, J., and Atwater, T., 1990, Cenozoic geometry and thermal state of the subducting slabs beneath western North America: Geological Society of America, Memoir, v. 176, p. 1-22.

Smith, J.F., and Kenter, K.B., 1978, Geologic map of the Carlin-Piñon Range area, Elko and Eureka counties, Nevada: USGS Map I-1028. Smith, J.F., and Kenter, K.B., 1978, Geologic map of the Carlin-Piñon Range area, Elko and Eureka counties, Nevada: USGS Map I-1028, scale 1:62500.

Stewart, J.H., and Carlson, J.E., 1976, Geologic Map of northern-central Nevada: Nevada Bureau of Mines and Geology Map 50, scale 1:250,000.

Tosdal, R.M., Wooden, J.L., and Kistler, R.W., 2000, Geometry of the Neoproterozoic continental break-up, and implications for location of Nevadan mineral belts, *in* Cluer, J.K., Price, J.G., Struhsacker, E.M., Hardyman, R.F., and Morris, C.L., eds., Geology and Ore Deposits 2000: The Great Basin and Beyond: Geological Society of Nevada Symposium, Reno, 2000, Proceedings, p. 451–466.

Tosdal, R.M., 1998, Contributions to the gold metallogeny of northern Nevada-preface, *in* Tosdal, R.M., ed., Contributions to the Au metallogeny of northern Nevada: U.S. Geological Survey Open-File Report 98-338, p. 1-7.

Vogal, T.A., Cambray, F.W., and Constenius, K.N., 2001, Origin and emplacement of igneous rocks in the central Wasatch Mountains, Utah: Rocky Mountain Geology, v. 36, p119-162.

Waite, K.A., Keith, J.D., Christiansen, E.H., Whitney, J.A., Hattori, K., Tingey, D.G., and Hooks, C.J., 1997, Petrogenesis of the volcanic intrusive rocks associated with Bingham Canyon porphyry Cu-Au-Mo deposit, Utah: Society of Economic Geology Guidebook 29, p. 69-90.

Wooden, J.L., Kistler, R.W., and Tosdal, R.M., 1998, Pb isotopic mapping of crustal structure in the northern Great Basin and relationships to Au deposit trends, *in* Tosdal, R.M., ed., Contributions to the Au metallogeny of northern Nevada: U.S. Geological Survey Open-File Report 98-338, p. 20-33.

Zoback, M.L., McKee, E.H., Blakely, R.J. and Thompson, G.A., 1994, The northern Nevada rift: regional tectono-magmatic relations and middle Miocene stress direction: Geological Society of America Bulletin, v. 106, p. 371-382.

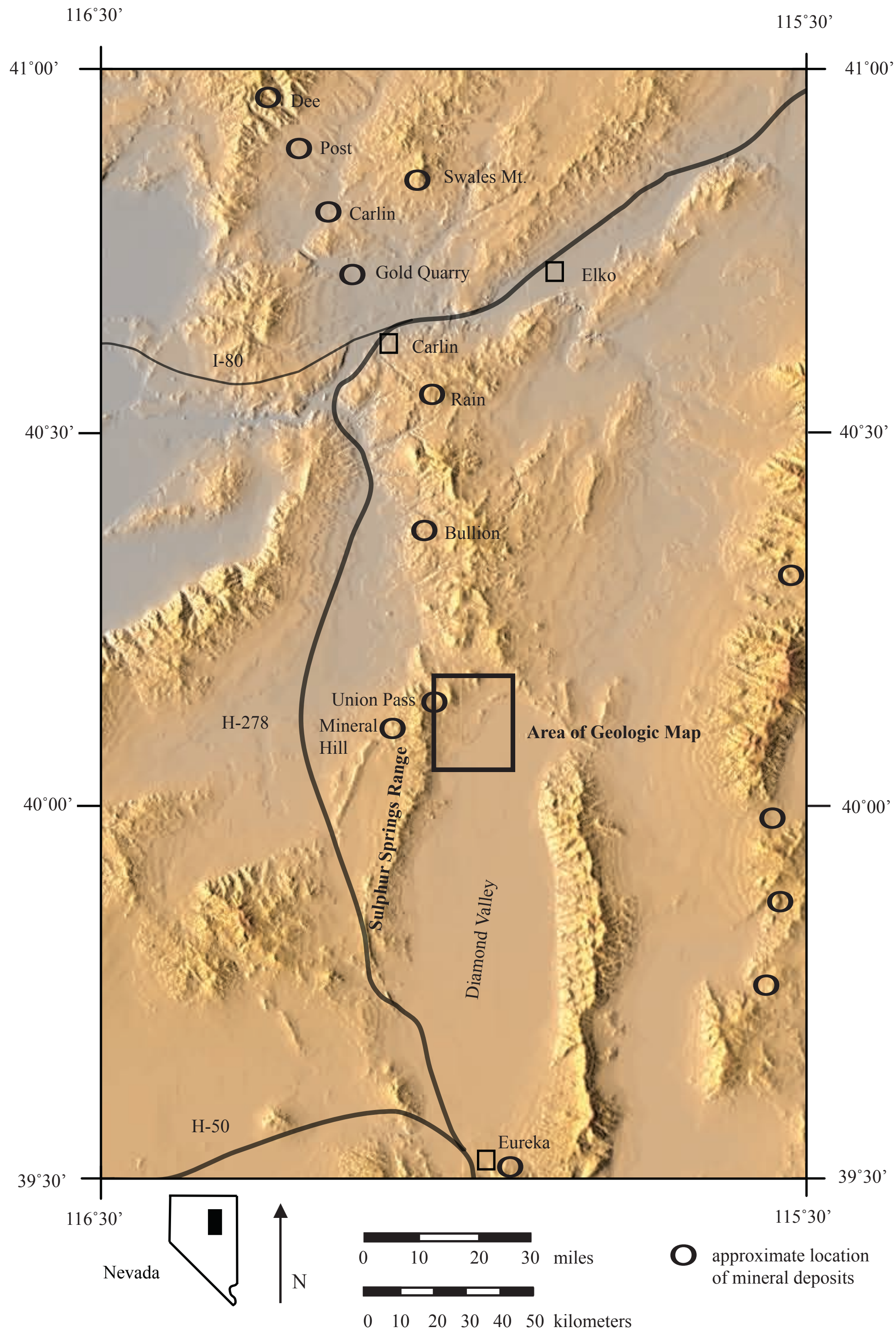


Figure 1. Shaded relief map of central Nevada, indicating the location of the Sulphur Springs Range in relation to the Carlin Trend. The large square shows the area of the volcanic rocks mapped. Circles represent locations of known mineral deposits. Base map from Chalk Butte, Inc.

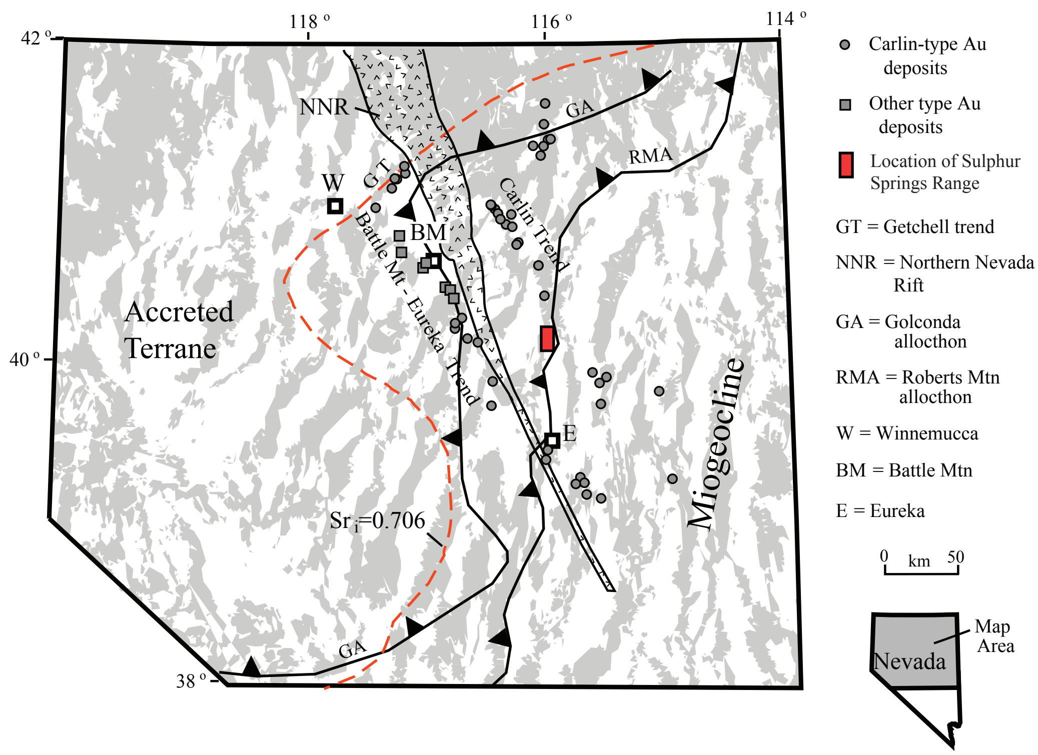


Figure 2. Central Nevada is underlain by a complex tectonic structure. This figure illustrates the area of continental crust as the location of the .706 line (red dashed line), the eastern edges of the allocthons in the region, and the location of the northern Nevada rift - which is middle Miocene. Modified from Grauch et al. (2003)

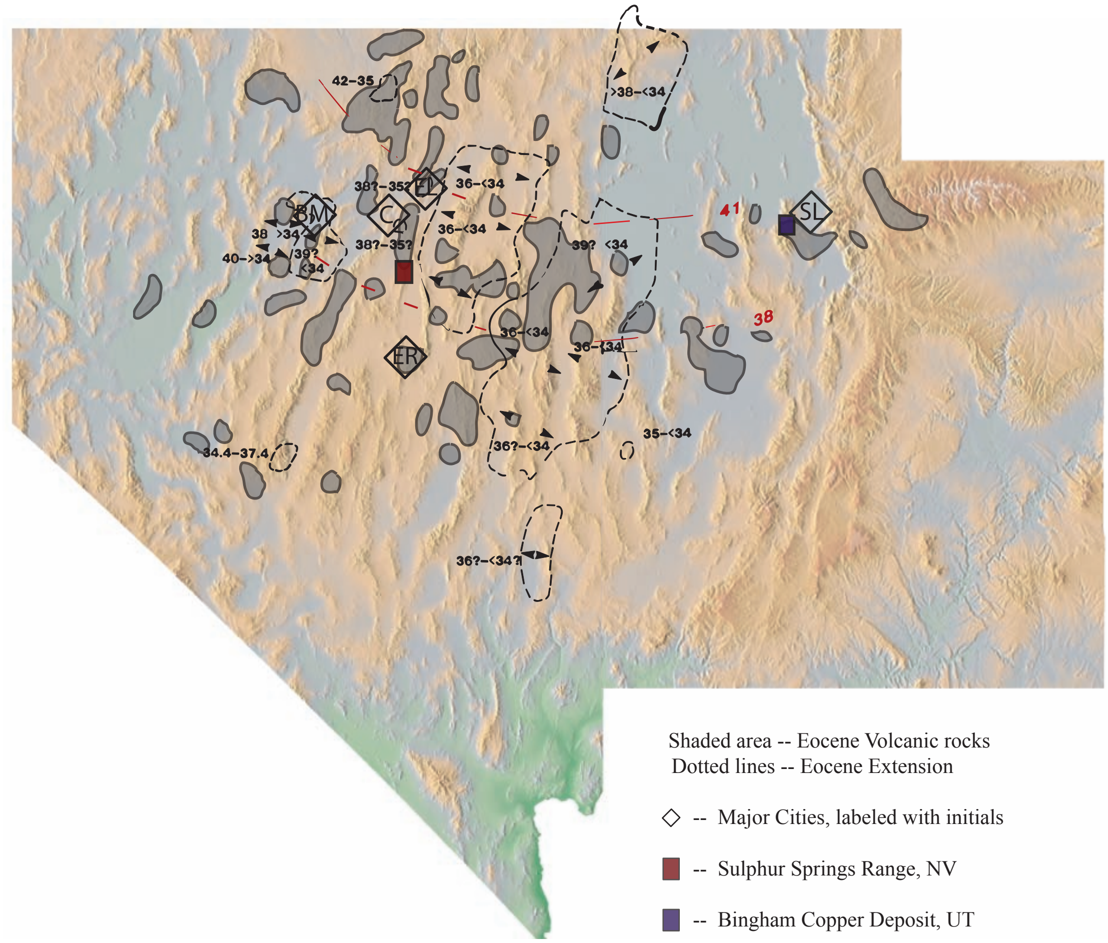


Figure 3. Volcanism and extension which occurred during the Eocene in Nevada-Utah region. The trend of ages getting younger to the south is expressed as the numbers in Ma. Dashed red lines and numbers represent the average volcanism age, and black lines and numbers represent average extensional ages. EL – Elko, C – Carlin, BM – Battle Mountain, SL – Salt Lake City, ER – Eureka. As modified from Seedorff (1991).

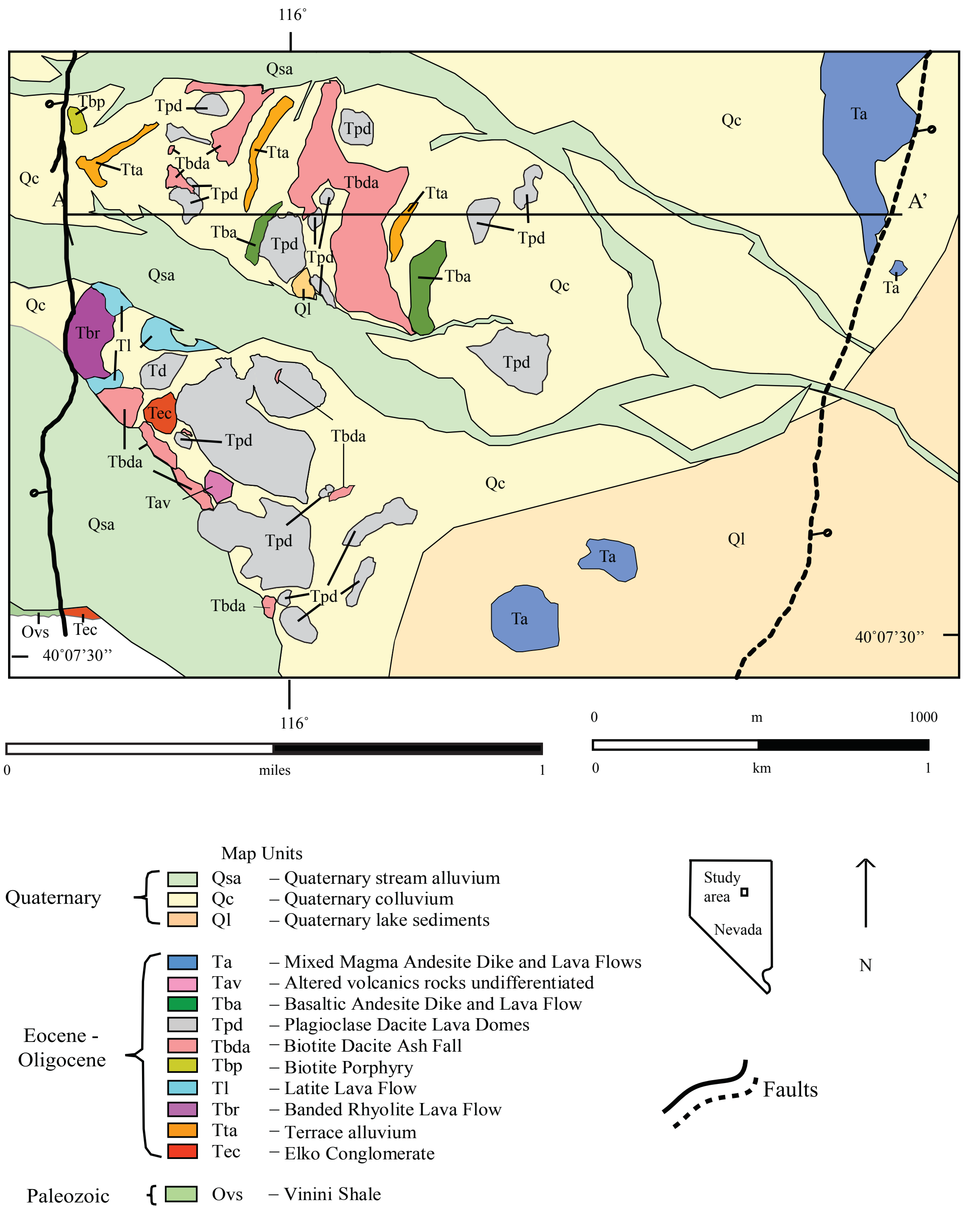


Figure 4.a. Geology of a portion of the Sulphur Springs Range, Nevada.

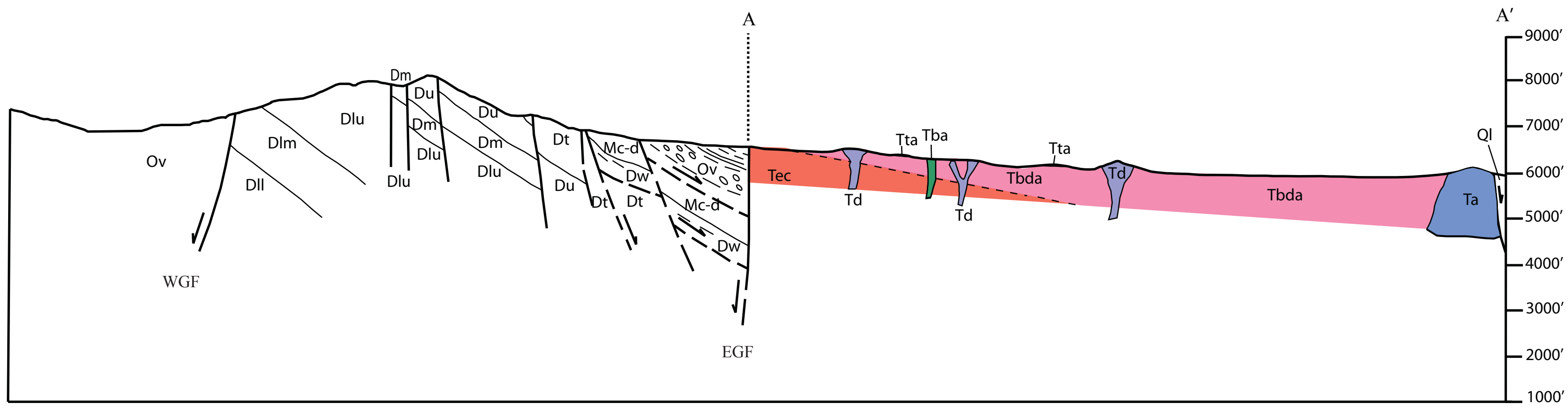


Figure 4.b. Geology and cross section of a portion of the Sulphur Springs Range, Nevada. West side of cross section is modified from Carlisle and Nelson (1990). EGF - East Graben Fault, WGF - West Graben Fault.

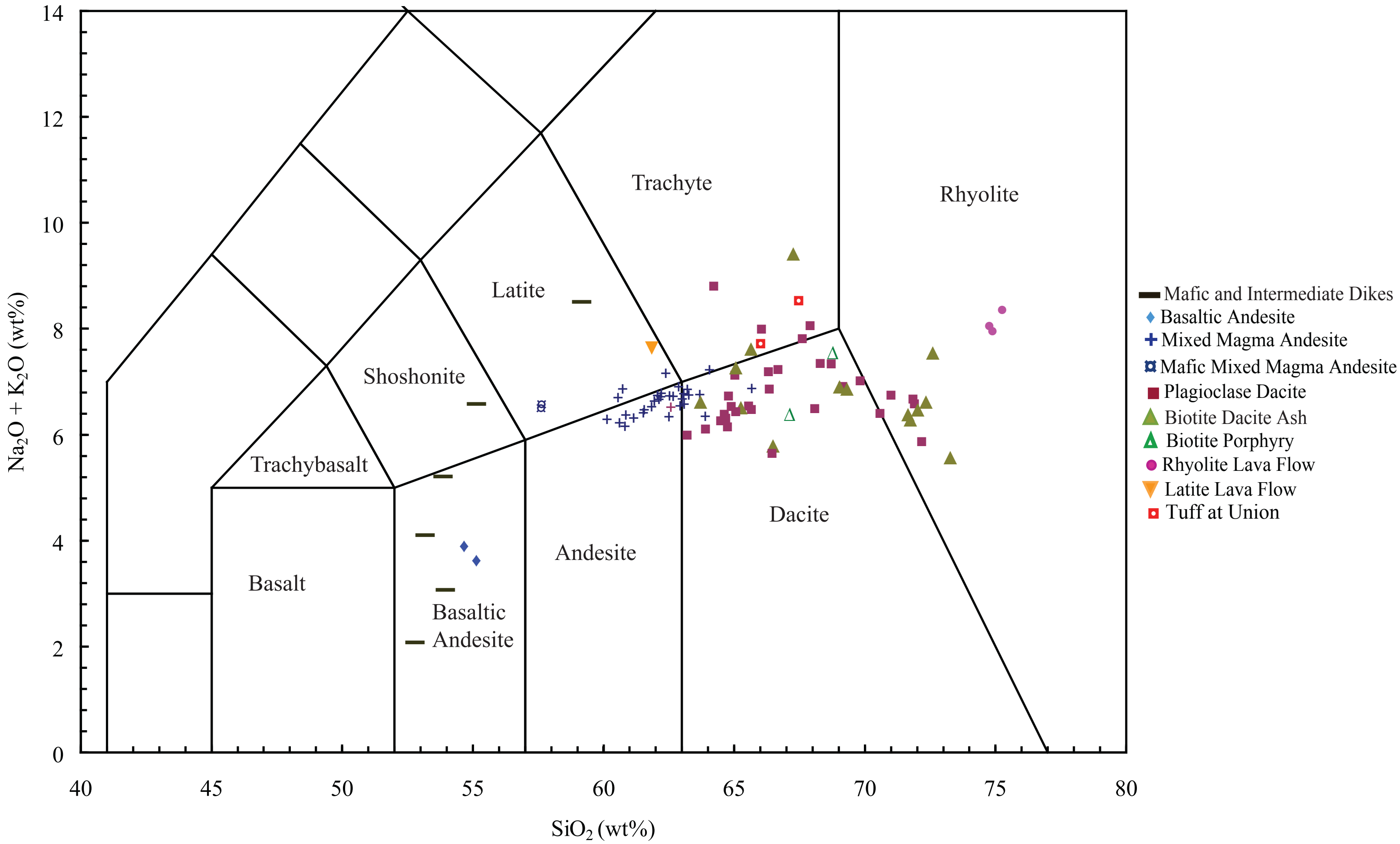


Figure 5. a. IUGS chemical classification of volcanic rocks (Le Maitre, 1989) for rocks from the Sulphur Springs Range. Rock compositions normalized to 100% on a volatile-free basis.

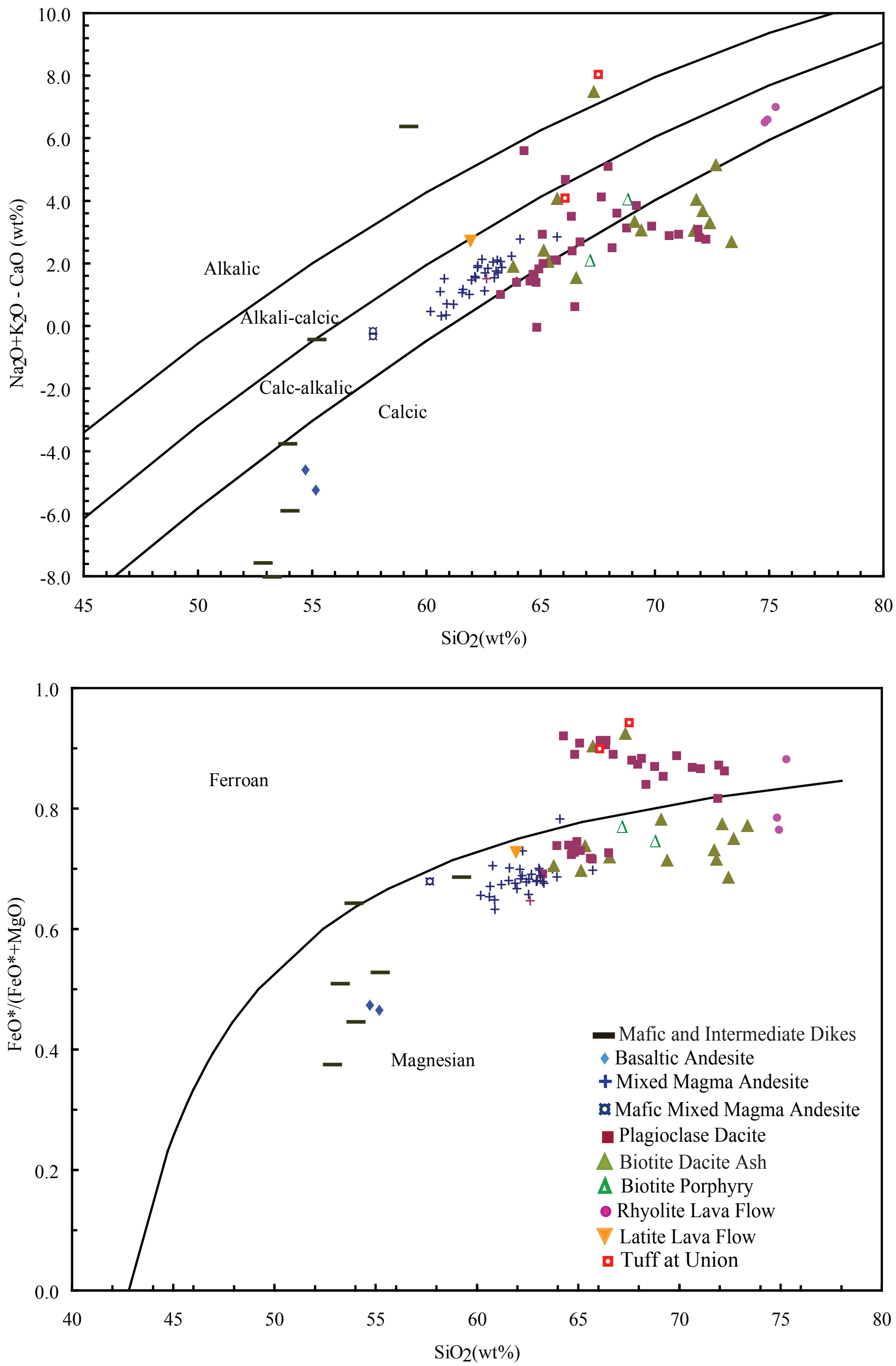
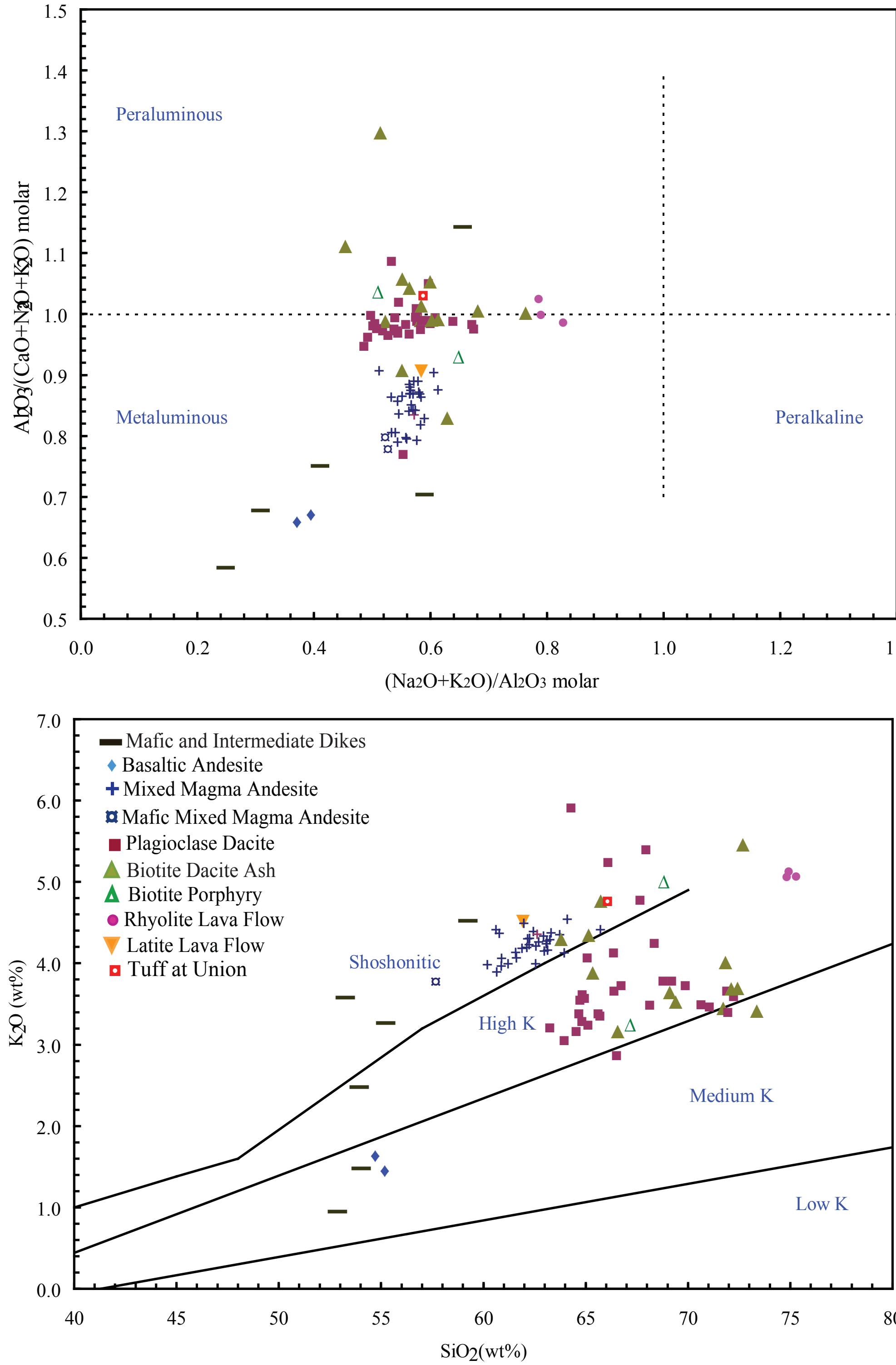


Figure 5. b. Major element discrimination diagrams for the middle Cenozoic Suphur Springs igneous suite. A. Modified alkali lime index after Frost et al. (2001). B. FeO/(MgO+FeO) discriminant from Miyashiro (1974) using terminology of Frost et al. (2001). C. Discrimination diagram between peraluminous and metaluminous. D. SiO_2 vs K_2O fields from Ewart et al.(1979).



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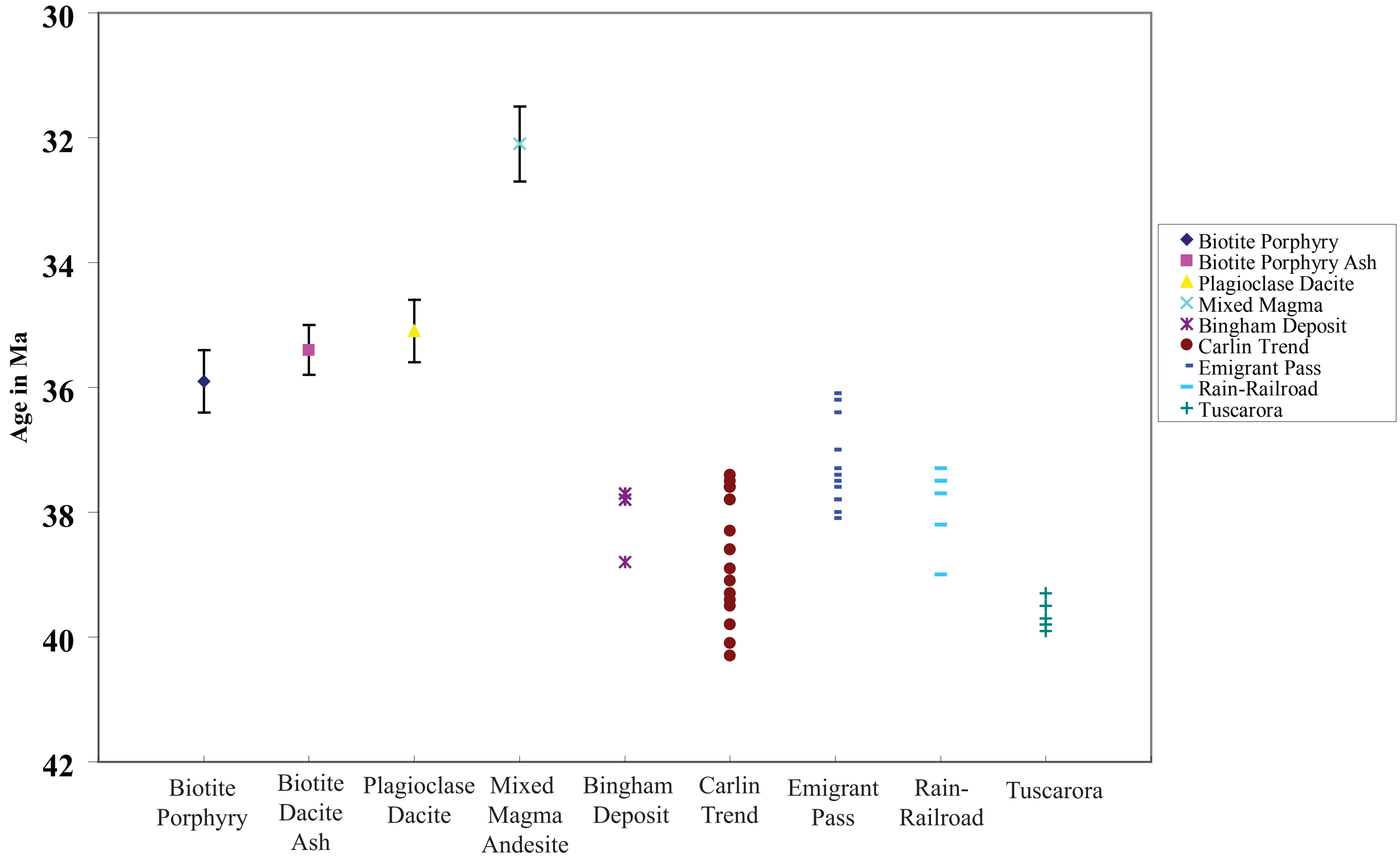
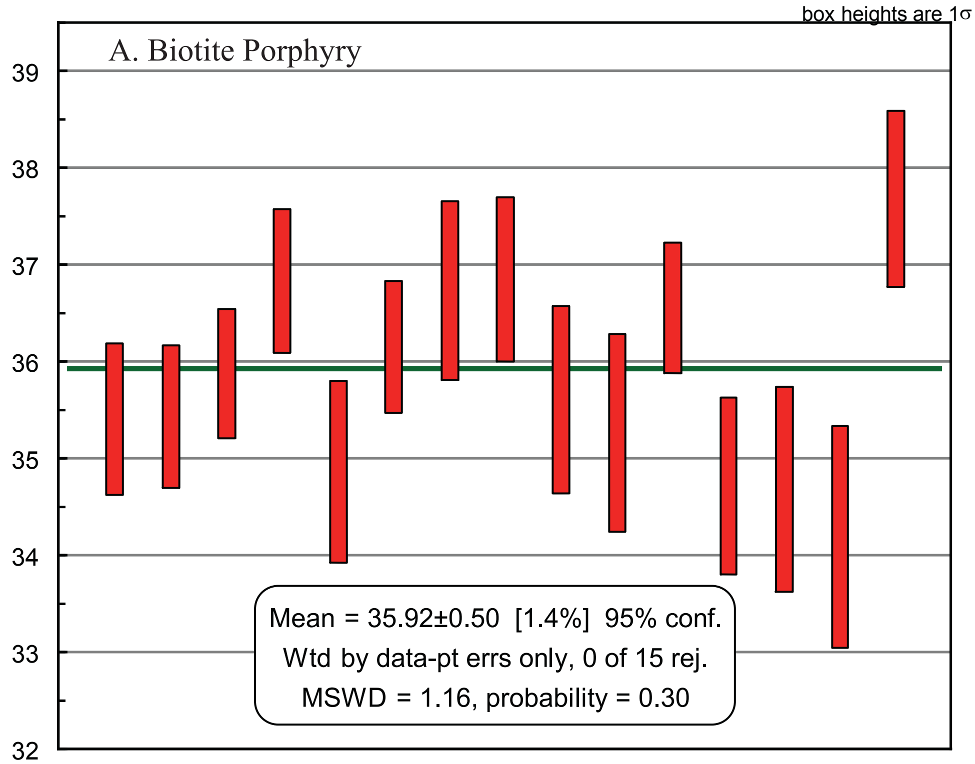


Figure 6.a Ages of Eocene igneous rocks from the Sulphur Springs, Bingham, Carlin, and Tuscarora suites. U/Pb age determinations were conducted on zircon grains for the Sulphur Springs suite, error bars indicate 1σ. Bingham deposit ages taken from Maughan et al. (2002), Carlin Trend, Emigrant Pass, and Rain-Railroad Pass ages taken from Ressel and Henry (2006), Tuscarora ages taken from Henry and Boden (1998).



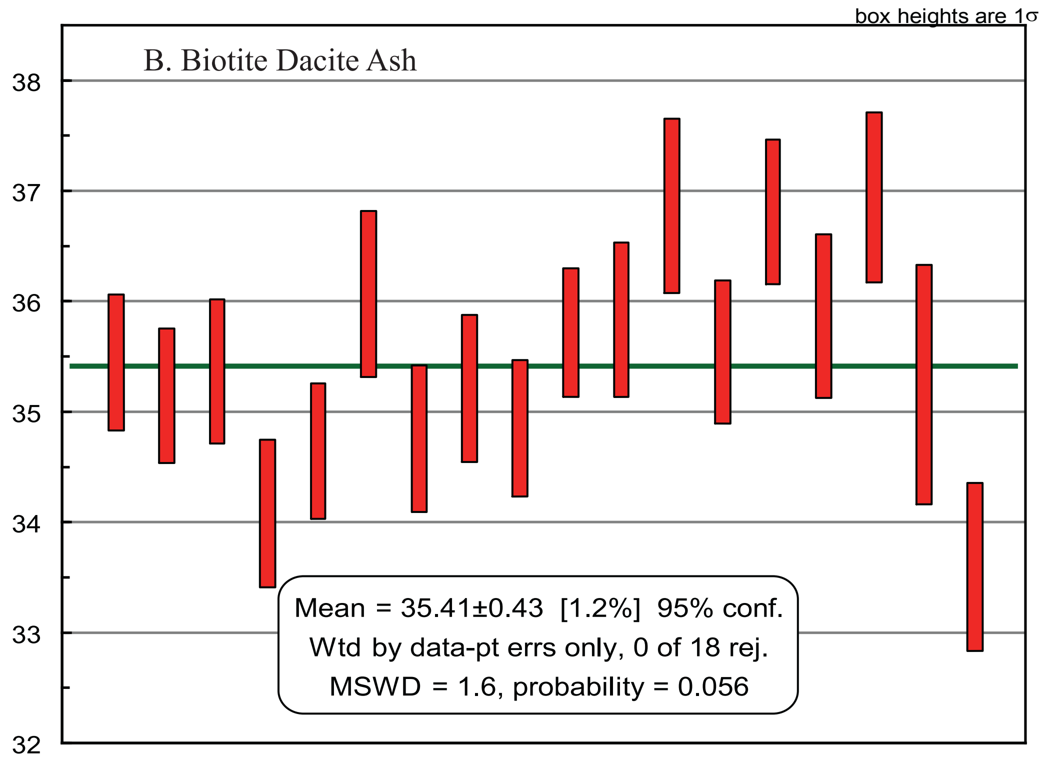
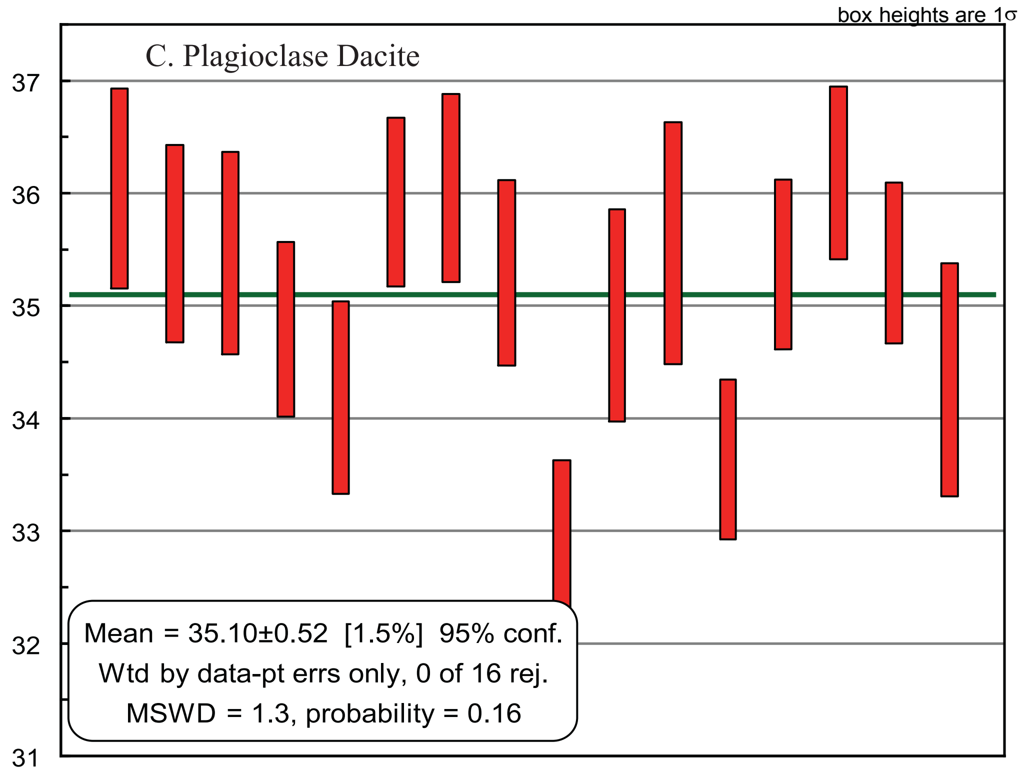


Figure 6.b. U-Pb analyses that were used in calculating ages for A. biotite porphyry, B. biotite dacite ash, C. plagioclase dacite, D. mixed magma andesite.



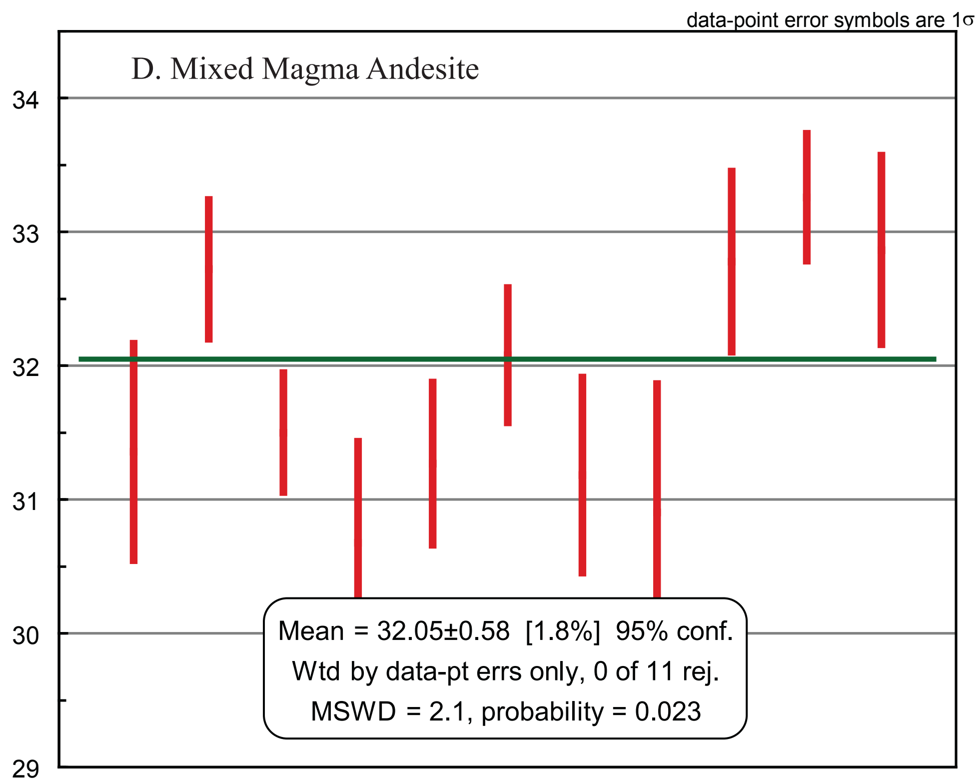


Figure 6.b. U-Pb analyses that were used in calculating ages for A. biotite porphyry, B. biotite dacite ash, C. plagioclase dacite, D. mixed magma andesite.

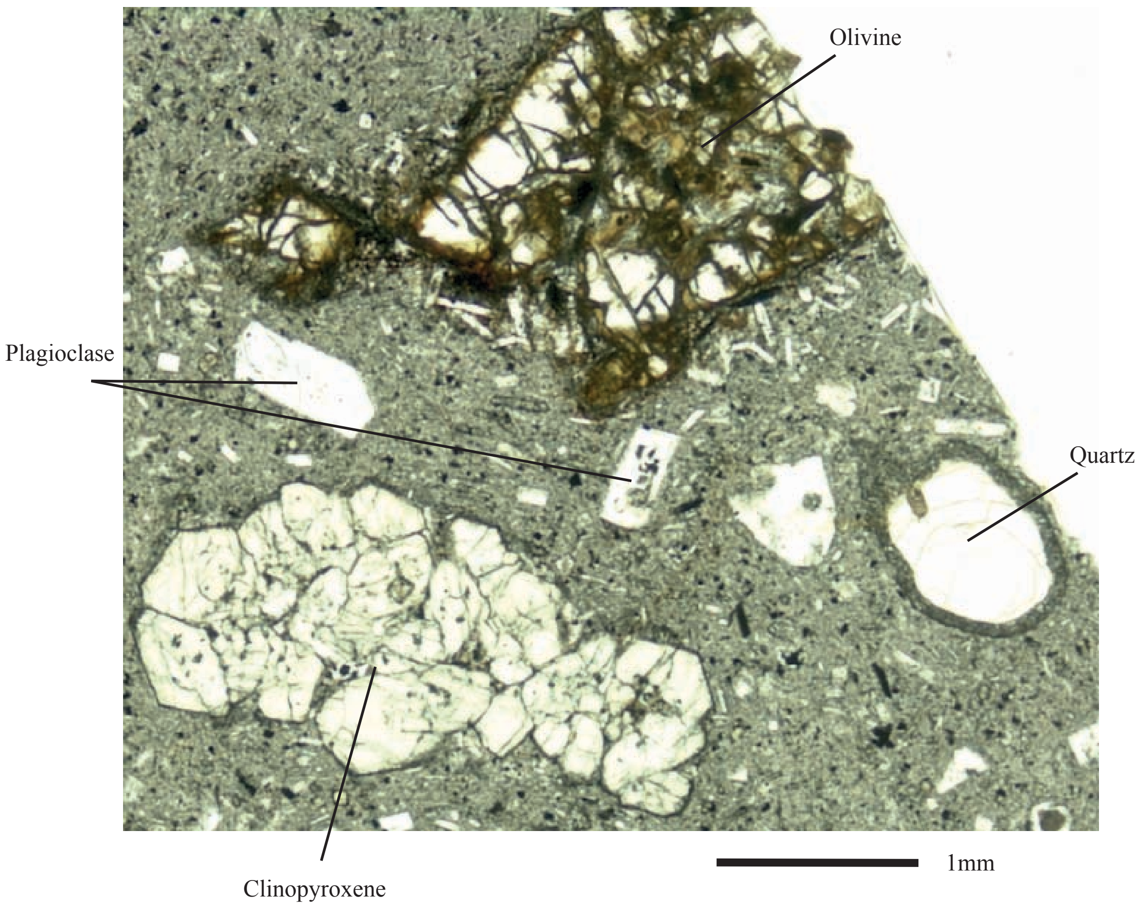


Figure 7. Photomicrograph of mixed magma andesite in transmitted light, from sample 04 EB 064. Photo shows sieved plagioclase, oxidized olivine, clinopyroxene, and quartz with an extensive resorption rim.

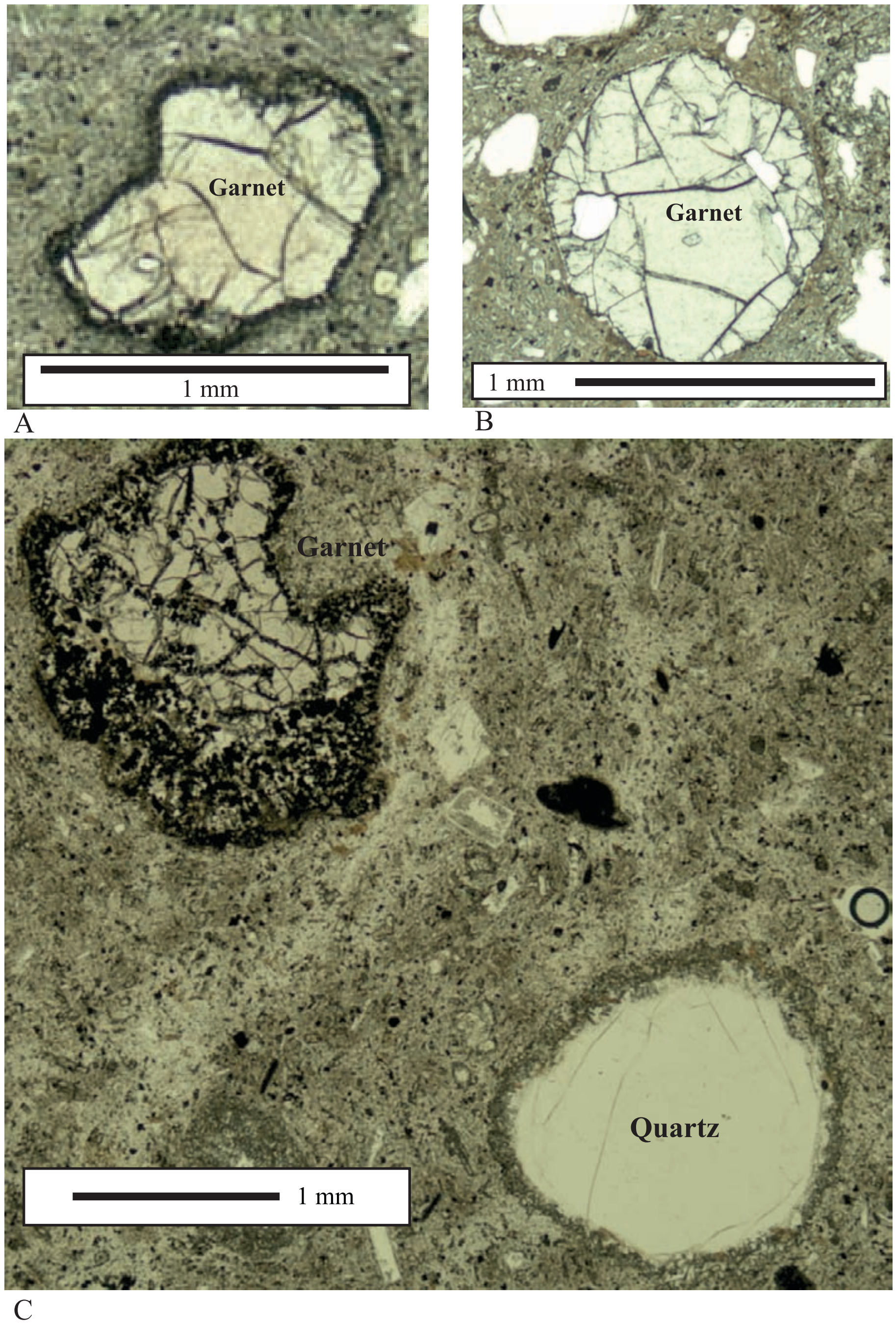


Figure 8. Photomicrograph of garnet found in mixed magma andesite as seen in transmitted light. A is from sample 04 EB 064 and shows replacement to magnetite around the rim. B is from sample 04 EB 168, is euhedral, and shows no rim, this sample is a flow sample. C is from sample 04 EB 123 and shows replacement with magnetite through half of the crystal as well as replacement around the rim and along fractures in the other half. C also shows a rounded and rimmed quartz crystal.

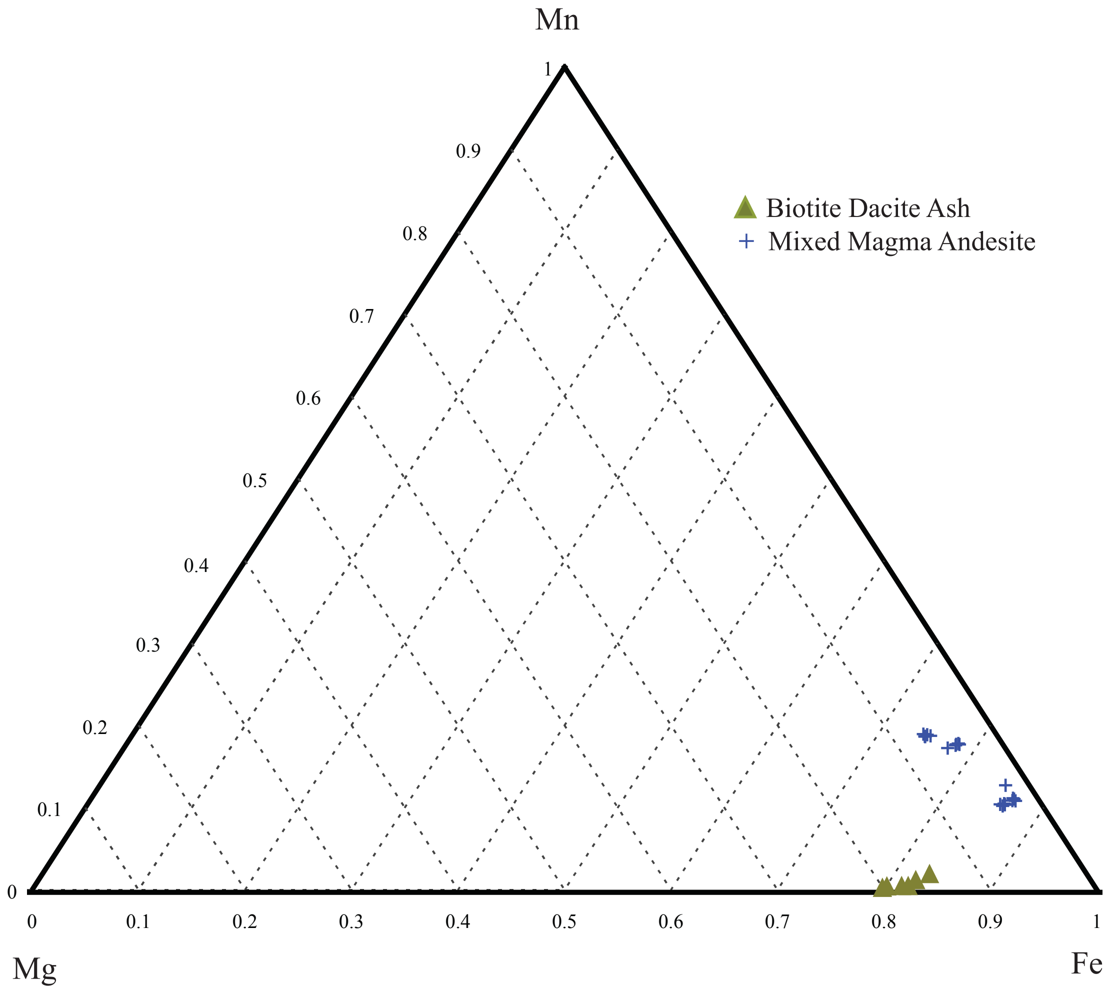


Figure 9. Compositions of garnet found in the biotite dacite ash and the mixed magma andesite of the Sulphur Springs suite. Older more felsic biotite dacite ash contains garnets higher in Mg than the garnets found in the mixed magma andesite.

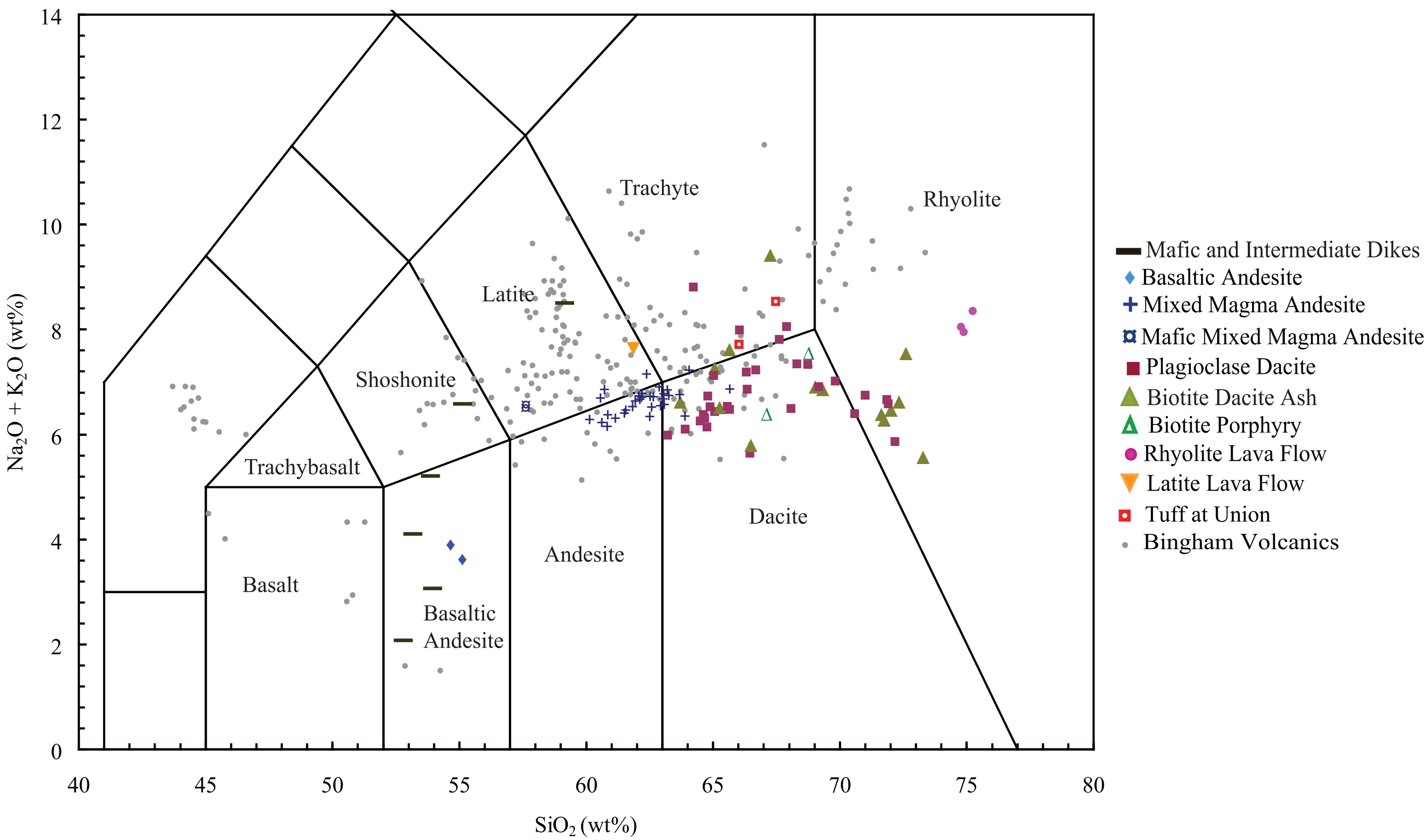


Figure 10. IUGS chemical classification of volcanic rocks (Le Maitre, 1989) for the Sulphur Springs and Bingham igneous suites. Rock compositions normalized to 100% pn a volatile-free basis. The Sulphur Springs suite falls mainly in the lower half of the diagram, while the Bingham suite is more alkaline and falls mainly in the upper half of the diagram. Bingham analyses as taken from Maughn (2001).

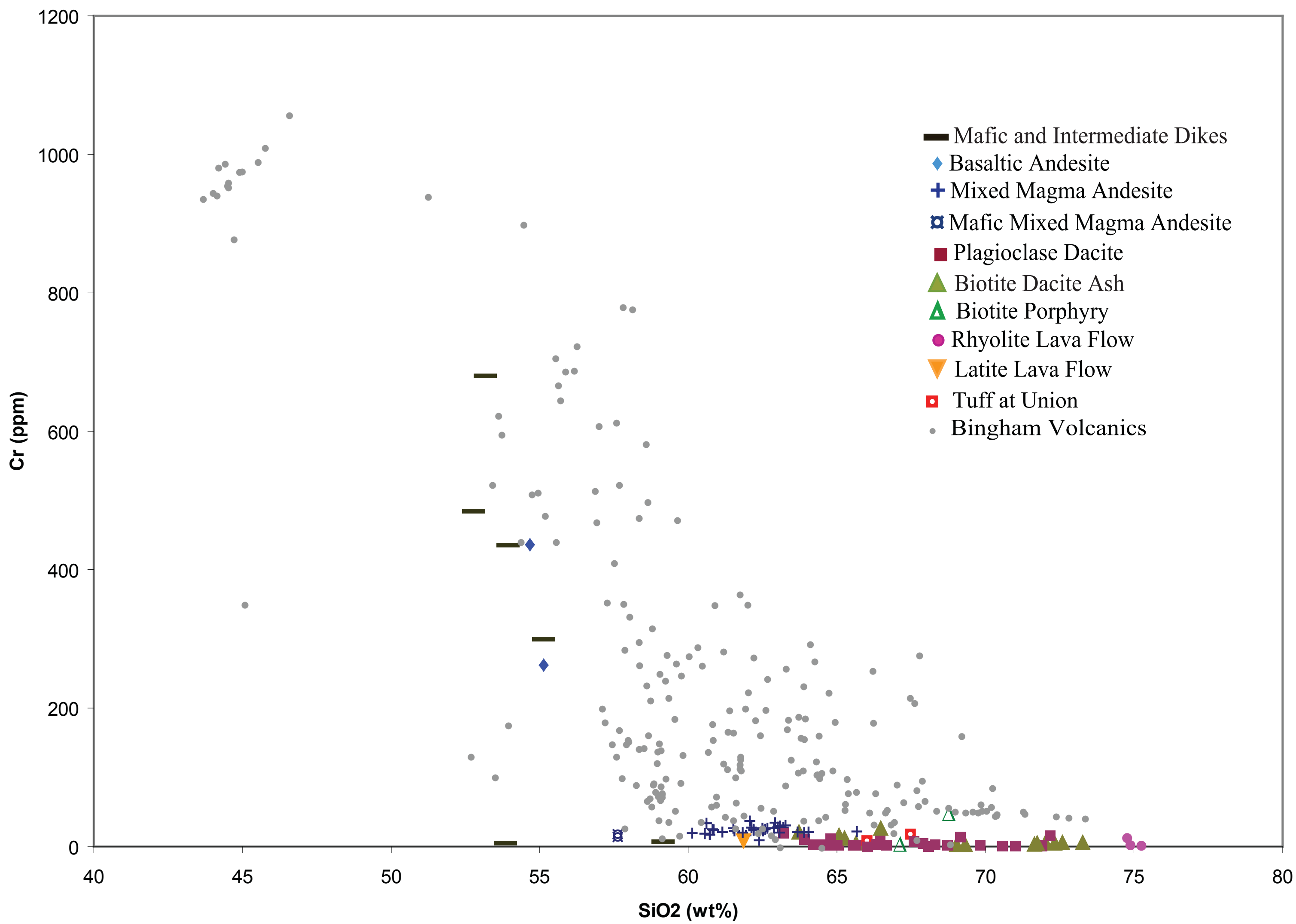


Figure 11a. Variation diagram comparing Cr concentrations of the Bingham and Sulphur Springs igneous suites.

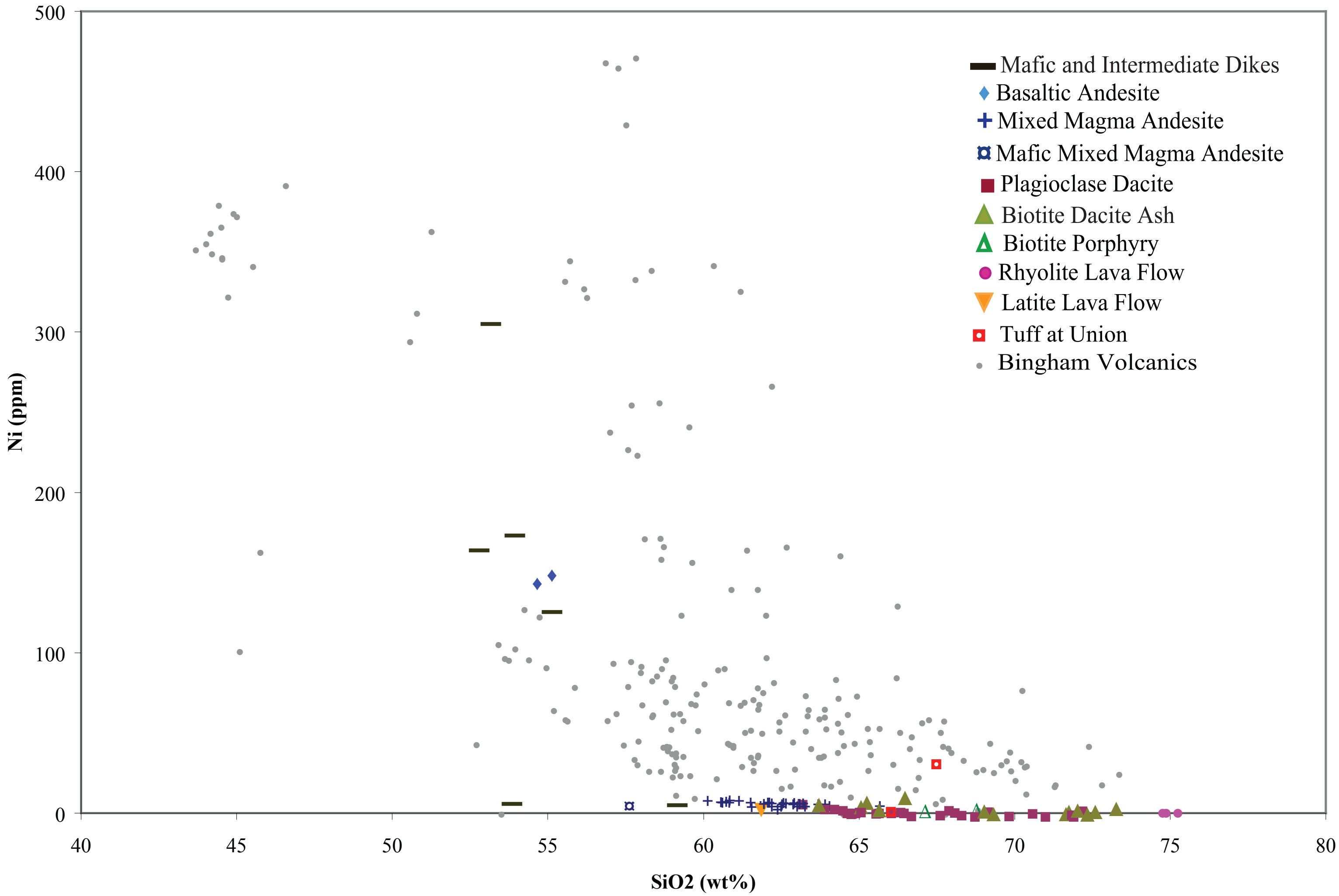


Figure 11b. Variation diagram comparing Ni concentration of the Bingham and Sulphur Springs igneous suites.

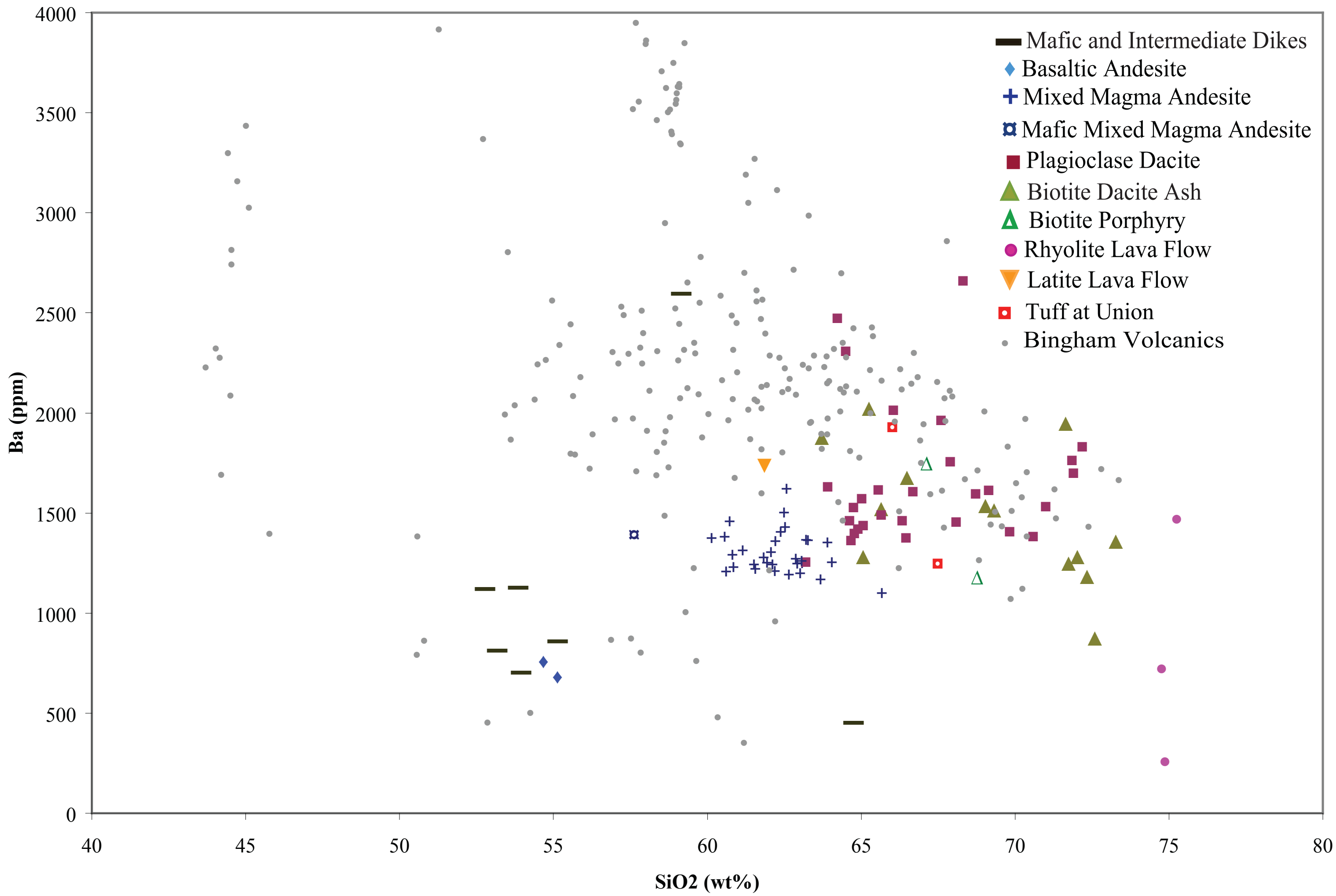


Figure 11c.Variation diagram comparing the Ba Concentrations of the Bingham and Sulphur Springs igneous suites.

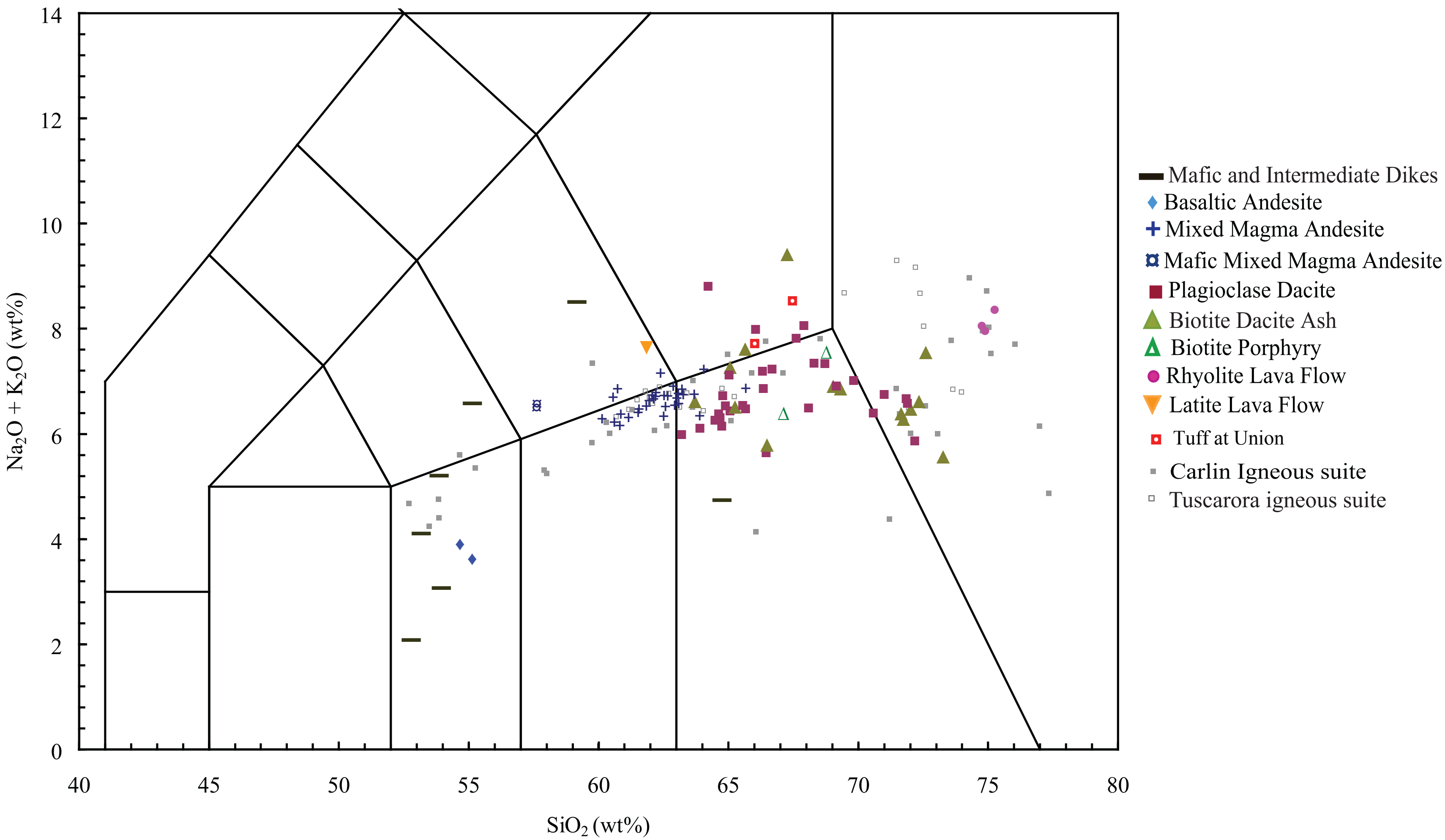


Figure 12. IUGS chemical classification of volcanic rocks (Le Maitre, 1989) for the Sulphur Springs, Carlin, and Tuscarora igneous suites. Rock compositions normalized to 100% on a volatile-free basis. Carlin analyses as taken from Ressel (2005). Tuscarora analyses as taken from Henry et al. (1999).

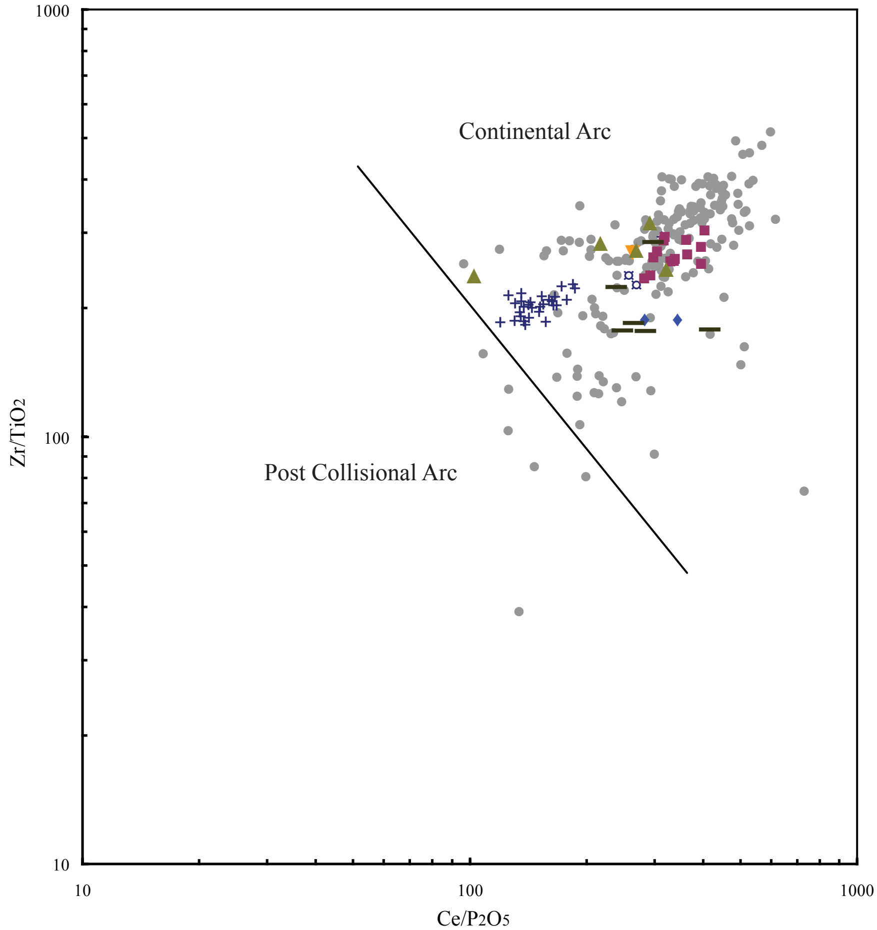
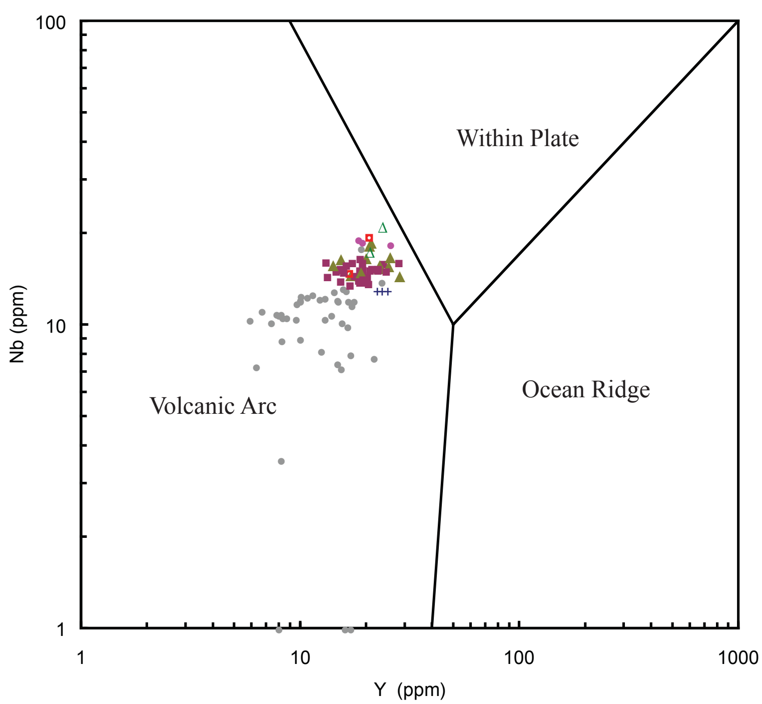


Figure 13. Tectonic discrimination diagrams (Muller and Groves, 2000; Pearce et al., 1984) for rocks from the Sulphur Springs and Bingham volcanic suites. Both display arc related magmas. A. is for mafic rocks only.B. is for silicic rocks only. Bingham samples from Maughan et al. (2001).

A.



- Mafic and Intermediate Dikes
- Basaltic Andesite
- Mixed Magma Andesite
- Mafic Mixed Magma Andesite
- Plagioclase Dacite
- Biotite Dacite Ash
- Biotite Porphyry
- Rhyolite Lava Flow
- Latite Lava Flow
- Bingham Volcanics

B.

Appendix A

Thin section descriptions, sample number in bold, followed by unit abbreviation.

04 EB 019 Tmd Lamprophyre dike. Phenocrysts include biotite, muscovite, plagioclase, clinopyroxene, and olivine. Accessory minerals include oxides. The matrix is composed of glass and muscovite, biotite, chlorite, and plagioclase. This sample appears altered with chlorite. Flow foliation in elongated mica grains.

04 EB 025 Tmd Mafic dike. Phenocrysts include olivine, pyroxene, biotite, and accessory oxides. The matrix is composed of glass, plagioclase, and clinopyroxene. This sample is altered – matrix and phenocrysts. No flow foliation present.

04 EB 041 Tbda Biotite dacite ash fall. Phenocrysts include plagioclase, biotite, and quartz. Accessory minerals include oxides, zircon and apatite. The matrix is composed of fine-grained intergrowths of mainly plagioclase, quartz and biotite. The largest plagioclase phenocrysts express growth zoning. There are recrystallization halos around the quartz grains. Some of the biotite is recrystallized or deteriorated. There are zircon and apatite needles found in the plagioclase. No flow foliation present.

04 EB 044 Tpd Plagioclase dacite lava dome. Phenocrysts include plagioclase, pyroxene, and biotite. Accessory minerals include oxides, apatite, and zircon. The matrix is composed of glass, some of which is devitrified. Some plagioclase crystals are extremely zoned while others are not. There are zircon and apatite needles found in the plagioclase. No flow foliation present.

04 EB 045 Tba Basaltic andesite lava flow or dike. Phenocrysts include olivine, clinopyroxene, orthopyroxene, and oxides. The matrix is composed mainly of plagioclase intergrowths and contains some pyroxene and glass. Olivine altered to chlorite and iddingsite. Pyroxene crystals form small cumulophyric clumps. Flow foliation is prevalent throughout matrix, but phenocrysts are not aligned.

04 EB 049 Ta Mixed magma andesite dike. Phenocrysts include pyroxene, quartz, plagioclase, and accessory oxides. The matrix is composed of mainly plagioclase and quartz intergrowths, with some glass. Quartz phenocrysts are fractured with recrystallization halos surrounding each grain, and contain gas fluid inclusions. Some plagioclase exhibit zoning. No flow foliation present, with the exception of some matrix grain orientation around phenocrysts.

04 EB 050 Tba Basaltic andesite lava flow or dike. Phenocrysts include olivine, clinopyroxene, orthopyroxene, and oxides. The matrix is composed mainly of large plagioclase intergrowths and contains some pyroxene and glass. Olivine is recrystallized or altered. Pyroxene shows some zoning. Pyroxene crystals grow together to form small cumulates. Flow foliation is prevalent throughout matrix, but phenocrysts are not aligned.

04 EB 061 Tpd Plagioclase dacite lava dome. Phenocrysts include zoned plagioclase, biotite, amphibole, and very few quartz grains. Accessory minerals include oxides, apatite and zircon. The matrix is composed of glass, with areas of devitrification. Iron staining is found in fractures and possible cavities. No flow foliation present.

04 EB 063 Ta Mixed magma andesite lava flow. Phenocrysts include clinopyroxene, orthopyroxene, plagioclase, and quartz. Accessory minerals include oxides. The matrix is composed of glass, some of which is devitrified, as well as very small plagioclase and pyroxene. Pyroxenes are the dominant phenocryst and are much larger than other phenocrysts. There are very few quartz phenocrysts, all of which are partially resorbed. No flow foliation present.

04 EB 064 Ta Mixed magma andesite lava flow or dike. Phenocrysts include clinopyroxene, quartz, olivine, plagioclase, amphibole, biotite, and orthopyroxene. Accessory minerals include oxides, garnet, apatite, and rutile. The matrix is composed of devitrified glass, along with very small plagioclase and pyroxene crystals. Phenocrysts are out of equilibrium. Quartz is deeply embayed and has reaction rims. Quartz contains some gas fluid inclusions as well as needles of apatite and rutile. Amphibole is resorbed around the edges. Olivine has iddingsite alteration on edges. Garnet is resorbed and has a reaction halo containing oxides and the inner zone contains melt or fluid inclusions. No flow foliation present.

04 EB 081 Ta Mixed magma andesite lava flow. Phenocrysts include quartz, clinopyroxene, plagioclase, orthopyroxene, and biotite. Accessory minerals include oxides. The matrix is composed of glass, some of which is devitrified, as well as very small plagioclase and pyroxene. Quartz is embayed and fractured, with iron strain in the fractures near the edges. Biotite is resorbed to form pyroxene and oxide halos. There is a feather-like pyroxene pattern that is possibly filling a cavity. The centers of some large plagioclase crystals are resorbed or recrystallized. Very subtle flow foliation present in matrix grains.

04 EB 086 Tbp Biotite porphyry dike. Phenocrysts include biotite, quartz, plagioclase, and potassium feldspar. Accessory minerals include oxides, apatite and zircon. The matrix is composed of plagioclase, quartz, and small biotite. Some quartz crystals have resorption halos while others do not. Some quartz also has empty fluid inclusions. Biotite is in good condition, but anhedral. A single potassium feldspar crystal was found that was altered to muscovite. No flow foliation present.

04 EB 089 Tbda Biotite dacite ash fall. Phenocrysts include plagioclase, biotite, and quartz. Accessory minerals include oxides, zircon, apatite, and possibly potassium feldspar. The matrix is composed of fine-grained intergrowths of mainly plagioclase, quartz and biotite. Most plagioclase phenocrysts express growth zoning. There are recrystallization halos around the quartz grains. Some quartz grains contain fluid inclusions. Some of the biotite is recrystallized. There are zircon and apatite needles found in the plagioclase. Pyroxene or amphibole crystals are entirely recrystallized, but leave behind a crystal shadow filled in with oxides and a grunge mineral. No flow foliation present.

04 EB 096 Tmd Mafic dike. Possible phenocrysts include amphibole, plagioclase, quartz, and pyroxene. Accessory minerals include oxides. Alteration minerals include muscovite and chlorite. The matrix is composed of quartz or plagioclase intergrowths. This sample appears altered. No flow foliation present.

04 EB 097 Tbr Banded rhyolite lava flow. Within the flow bands, small phenocrysts of quartz, plagioclase, and oxides can be found. The matrix is composed of devitrified glass. There are cavities within the bands. Flow foliation, or banding, is the main texture.

04 EB 105 Tl Latite lava flow. Phenocrysts include pyroxene, plagioclase, quartz, potassium feldspar, and oxides. The fine grained matrix is composed mainly of glass with flow oriented grains of plagioclase and some pyroxene. Plagioclase is highly sieved. Quartz has resorption rims and potassium feldspar is deteriorating from core toward rim. Flow oriented grains.

04 EB 108 Tpd Plagioclase dacite lava dome vitrophyre. Phenocrysts include plagioclase, biotite, amphibole, orthopyroxene, clinopyroxene, and quartz. Accessory minerals include oxides and small inclusions of rutile and apatite in the plagioclase crystals. The matrix is glassy. Plagioclase is zoned. Amphibole is euhedral and shows excellent 60/120 cleavage. No flow foliation present.

04 EB 121 Tpd Plagioclase dacite lava dome. Phenocrysts include plagioclase and clinopyroxene. The matrix is composed of glass. This sample is quite altered. Alteration minerals include chlorite and muscovite. No flow foliation present.

04 EB 123 Ta Mixed magma andesite dike. Phenocrysts include quartz, clinopyroxene, plagioclase, sanidine, garnet, olivine, orthopyroxene, and amphibole. Accessory minerals include zircon, apatite, and oxides. The matrix is composed of glass and small unoriented crystals of plagioclase, clinopyroxene, and quartz. Plagioclase is sieved. Quartz has reaction rims that are splays of orthopyroxene. Most quartz is clear, however a few samples show slight undulation. There are inclusions in some quartz that might be fluid inclusions or vapor crystals. Garnet is resorbed – sometimes only around the rim, and sometimes it is being replaced throughout with magnetite cubes. One clot of plagioclase with sanidine was found. No flow foliation present.

04 EB 135 Tpd Plagioclase dacite lava dome. Phenocrysts include plagioclase, altered clinopyroxene, and quartz. Accessory minerals include oxides. The matrix is composed of mostly devitrified and altered glass. Alteration minerals include chlorite and an iron–staining. Plagioclase is often fractured and sometime sieved. No flow foliation present.

04 EB 143 Tbda Biotite dacite ash flow. Phenocrysts include plagioclase, quartz, amphibole, biotite, and pyroxene. Accessory minerals include oxides. The matrix is composed of glass and small plagioclase crystals. Plagioclase is sieved. Quartz is clear, however some are embayed. No flow foliation present.

04 EB 149 Ta Mixed magma andesite flow. Phenocrysts include plagioclase, remnant biotite, altered clinopyroxene, and orthopyroxene. Accessory minerals include oxides. The matrix is composed of glass, plagioclase and clinopyroxene. Sample is altered including chlorite alteration. Plagioclase is sieved. Quartz is filling voids and rimmed with clinopyroxene. No flow foliation present.

04 EB 154 Ta Mixed magma andesite dike. Phenocrysts include quartz, plagioclase, clinopyroxene, and orthopyroxene. Altered minerals include olivine, biotite, and amphibole. Accessory minerals include oxides. The matrix is composed of glass, with small amounts of plagioclase and clinopyroxene. Quartz has varying degrees of embayment and possibly is filling voids. No flow foliation present.

04 EB 167 Ta Mixed magma andesite lava flow. Phenocrysts include clinopyroxene, orthopyroxene, plagioclase, quartz, and olivine. Accessory minerals include oxides. The matrix is composed of plagioclase and both orthopyroxene and clinopyroxene. Muscovite is found in alteration splays. All phenocrysts are quite small. Plagioclase is sieved. Matrix grains are flow aligned.

04 EB 168 Ta Mixed magma andesite flow. Phenocrysts include quartz, plagioclase, garnet, clinopyroxene, orthopyroxene, biotite, and sanidine. Accessory minerals include oxides. The matrix is composed of glass, plagioclase, quartz, and clinopyroxene. Quartz has small resorption rims and often an undulating texture. Garnet is euhedral and exhibit very little resorption in the form of small oxides around the rim. Slight orientation of matrix grains around phenocrysts.

Appendix B

Hand sample and field notes description for each sample, sample number in bold, followed by unit abbreviation, followed by location of sample in UTM – Nad27 datum.

03EB-11 Tmd, 583600 E, 4446500 N – mafic dike, found only in float, contains up to 2 cm long plagioclase phenocrysts, vein intensity pyrite alteration, 70 meters long - 1.5 meters wide, on a fault structure.

03EB-12 Tmd, 583323 E, 4446546 N – mafic dike or volcanic neck-vent, strongly altered, some clasts contain small phenocrysts, the matrix is brick red, and the surface above it includes a rhyolite tuff.

03EB-13 Tr, 583259 E, 4445523 N – rhyolite, 13a- margin, 13b- center, white/pink weathered, 3 meters wide - pinches and swells, phenocryst poor, very flattened air vesicles – possibly flattened pumice. Strike and dip - N56, 87°W.

03EB-14 Tr, 583181 E, 4445614 N – small rhyolite dikes, 14a- dark magma, 14b- possible red arkose, multiple small dikes, contains all kinds of lithic fragments, variation of texture, altered.

03EB-15 Tr, 583181 E, 4445620 N – rhyolite, dike along the fault, very altered, yellow/orange.

03EB-16 582949 E, 4445474 N – pebble dike, sample includes porphyry clasts - two types 1- fine-grained, 2-contains broken quartz phenocrysts, quartz-pyrite-sericite alteration, silicified.

03EB-17 Tr, 582621 E, 4450423 N – rhyolite tuff or possible vent, very altered - mixed argillic/phyllic alteration, pumice lapilli, and vug-filling, quartz phenocrysts, 100-150 ft long.

03EB-18a Tr, 582680 E, 4449984 N – rhyolite plug, very altered, phenocrysts - quartz, feldspars (cavities due to alteration), biotite, a few with pumice lapilli, 80% silica-silicified, phyllic, argillic, silicic alteration, similar to 03 EB-17, no vegetation with in area of plug.

03EB-18b Tr, 582728 E, 4449984 N – rhyolite plug, less silicified than 18a, iron stained feldspars, smoky and regular quartz.

03EB-19 Tmd, 580989 E, 4452049 N – lamprophyre dike, green, variety of sample types - some mica rich, some oxidized, fine-grained ground mass with clasts (xenocrysts). Phenocrysts include biotite, muscovite, plagioclase, clinopyroxene, and olivine. Accessory minerals include oxides. The matrix is composed of glass and muscovite, biotite, chlorite, and plagioclase. Dikes striking 350 NNW.

03EB-20 Tmd, 577000 E, 4445000 N – mafic dike, center and southern margin of the dike is mica rich, mica gradually changes- increases from center to southern/bottom margin of dike - zonation present. Contains mineralization including tetrahedrite, malachite/azurite.

03EB-21 Tmd, 577000 E, 4445000 N – mafic dike, 21a- from outcrop, 21b- from prospect pit pile, 21c- from carbonate vein - banded grey calcite – previous sample containing 20 ppm Au and barium, found outcropping below prospect pit, very altered. Strike and dip of dike is 091 EW, 80°S.

03EB-22 Tmd, 577188 E, 4446853 N – porphyry sill, altered, disseminate pyrite, green mica- rocolite/fuchsite, sill-like outcrop on Devonian unconformity, cherty underlying rock chaotic, pods of green weathered-sulfide rich quartz sulfide veins, stratigraphic relationship changes to the south between this location and Mineral Hill block - but remains the same to the north.

03EB-23 Tmd, 578685 E, 4450924 N – mafic dike, altered, tan colored, tuff-like, see description for 24.

03EB-24 Tmd, 578685 E, 4450924 N –mafic dike, 60% silica, a few flattened fiame-pumice, intrusive, phyllic/argillic alteration, clay-rich -orange color, phenocrysts destroyed except broken quartz phenocrysts <1%, possible dacite origin, obvious slickensides, sulfides in intrusion - rust brown color, possible amphiboles, plagioclase crystals up to 1-2 cm, more dikes along trend of canyon/fault.

03EB-25 Tmd, 579092 E, 4450253 N – mafic dike, less-unaltered, phenocrysts include olivine, pyroxene, biotite, and accessory oxides. The matrix is composed of glass, plagioclase, and clinopyroxene. It is very heavy – high specific gravity. Found as float on east slope of hillside.

03LB-26 Tmd, 579092 E, 4450253 N – mafic dike, similar to 03 EB-25 contains clinopyroxene - green, possible that this sample represents the whole dike - margin to margin.

04EB 030 Tr, 582645 E, 4450805 N – East pass volcanic rocks, rhyolite, cavities in argillically altered rhyolite - quartz and altered plagioclase, within 100 ft of the margin some rock is more iron stained (argillized) others quite white, possible block and ash flow, quartz phenocrysts appear euhedral, large blocks of various lithologies suggest an eruptive vent, smoky and clear pink quartz, 8% quartz phenocrysts, iron staining, secondary silica alteration.

04EB 031 Tpd, 582565 E, 4450831 N – plagioclase dacite lava dome, contains quartz fragments, dominant clear quartz phenocrysts, rectangular cavities from argillic weathering and alteration of plagioclase.

04EB 032 Tbda, 584400 E, 4444780 N – biotite dacite ash, garnet-bearing float sample, magnetite inclusions, angular quartz-rich, feldspar-rich, biotite, 25-30% total phenocrysts, found on hillside east flank, appear as angular non-rounded cobbles, possibly subcrop, some cobbles are more altered.

04EB 033 Tpd, 584326 E, 4444732 N – plagioclase dacite lava dome, breccia clasts, microcrystalline, manganese dendrites, chert xenoliths, zoned some areas are more crystal rich.

04EB 034 Tbda, 584220 E, 4444591 N – mineral samples, float mineral samples, 34a- possible alunite mineral similar to sample 032 biotite dacite ash, 34b- possible magmatic sulfide, spherical - in magma, fine-grained igneous rock, 34c- possibly coarser-grained equivalent, extremely crystal rich, margin that appears like 04 EB-033. Flow banding breaking up in breccia.

04EB 035 Tpd, 584100 E, 4444515 N – plagioclase dacite lava dome, 035a- glassy with plagioclase-rich phenocrysts dark color- dacite vitrophyre, 035b- flow banded (one intruding the other) altered but similar to 035a.

04EB 036 Tba, 583988 E, 4444664 N – Basaltic andesite, thought to be a mafic-shoshonite before analytical data refuted that hypothesis, mafic - clinopyroxene and olivine, plagioclase, possible dike or shoshonite flow, olivine should increase Cr and Ni numbers, surface alteration of olivine to iddingsite while clinopyroxene are fresh green.

04EB 037 Tta, 583912 E, 4444751 N – minnette, float sample taken from old alluvial surface, biotite rich with sulfides, yellow sulfur in fractures, fresh glass.

04EB 038 Tec, 583475 E, 4446142 N – square quartz porphyry, pebble cobbles of the quartz porphyry, altered.

04EB 039 Tec, 583414 E, 4446117 N – square quartz porphyry, different porphyry lithologies, 039a- quartz porphyry with large bipyramidal quartz phenocrysts, 039b- quartz porphyry with smaller phenocrysts of quartz, 039c- fine grained quartz porphyry, all silicically altered.

04EB 040 Tpd, 583756 E, 4445308 N – plagioclase dacite lava dome, dacite vitrophyre, glassy dacite much like that of the others taken from the hill top - compare to 04 EB-035 - contains plagioclase, quartz, vitrophyre - possibly on the edge of a vent or dome.

04EB 041 Tbda, 583770 E, 4445122 N – biotite dacite ash, 041a- biotite rich, possibly same as sample 032, phenocrysts include plagioclase, biotite, and quartz.

Accessory minerals include oxides, zircon and apatite. 041b- all rounded cobbles-quartz porphyry as found in the tuff at Union, in the Elko conglomerate. Light colored soil around location possibly a weathering tuff containing 041a. Weathering tuff also seen in road cut and barrow pit where angular fragments like 041a are weathering out. Tuff is altered to a white yellow color and has iron rich small veins running through it. It is possibly an extensive cover throughout low lying regions of the valley.

04EB 042 Tbda, 584409 E, 4444987 N – biotite dacite ash, sample with megacrysts of quartz, ash in road cut, sample taken from the north side of the road, possible magmatic origin consists of high fluid water pressure - forming megacrysts, rather deep and saturated with water - possibly 10% wt%, 50% volume in magma.

04EB 043 Ql, 584277 E, 4444228 N – marl, carbonate rock, mainly limestone, trees growing on a light patch of soil, chippy, no phenocrysts, carbonate lake sediments, likely near the high point of a lake filling the playa.

04EB 044 Tpd, 584268 E, 4444275 N – plagioclase dacite lava dome, dacite vitrophyre, glassy, containing mostly phenocrysts of plagioclase, pyroxene, and biotite. Accessory minerals include oxides, apatite, and zircon. More sample added as we walked to the north.

04EB 045 Tba, 583990 E, 4444547 N – Basaltic andesite, first thought to be mafic-shoshonite before analyzed. Phenocrysts include olivine, clinopyroxene, orthopyroxene, and oxides. Mafic rock is the same as 04 EB-036, it is possibly a flow – in-situ with a dip-slope to the east, really glassy.

04EB 046 Tut, 578156 E, 4451883 N – tuff at Union, igneous rock possibly dacite, also possibly tuff at Union, red dacite with distinct alteration.

04EB 047 Ta, 586720 E, 4441223 N – mixed magma andesite, containing phenocrysts of biotite, plagioclase, quartz, K-feldspar, oxides, pyroxene, olivine, dike like, dense and chippy. Possibly a dike with 346 NW strike and 78 NE dip.

04EB 048 Ta, 585724 E, 4441075 N – mixed magma andesite, very similar to 04 EB-047 including plagioclase, quartz, biotite and others, not very altered. Strike 231 SW, dip 70 NE.

04EB 049 Ta, 585512 E, 4441380 N – mixed magma andesite, from near the top of hill on the east side, phenocrysts include pyroxene, quartz, plagioclase, and accessory oxides. Distinct foliation, large fracture type foliation, top possible flow foliation in similar direction - but also possible a vertical fracture system or flow foliation. Strike 160 S, dip 28 NE.

04EB 050 Tba, 584894 E, 4444416 N – basaltic andesite, first thought to be mafic – shoshonite, rind alteration only, hard to get a good foliation surface. Phenocrysts include olivine, clinopyroxene, orthopyroxene, and oxides. Strike 320 NW, dip 60.

04EB 051 Tpd, 585279 E, 4444664 N – plagioclase dacite lava dome, very altered, volcanic, green propyllitic alteration, dipping due east – strike 0 NS, dip 010 E.

04EB 052 Tbda, 584664 E, 4445686 N – biotite dacite ash, biotite rich ash possibly caldera fill, larger clasts intact on side and top of the hill, not in bulldozed pit. Sample taken from weathering clasts in pit, in place. One clast not as biotite rich.

04EB 053 Tut, 587520 E, 4449637 N – biotite porphyry clast, sample contains square quartz porphyry, biotite rich quartz porphyry pebble found, tuff at Union or equivalent to the north, all clasts very altered.

04EB 054 Tut, 587477 E, 4449789 N – plagioclase dacite lava dome, or similar to plagioclase dacite lava dome, in tuff at Union or equivalent to the north, fragmental quartz, plagioclase altered white, possible oxides, altered orange, large cavities filled with clay, presumably large feldspar phenocrysts, alteration heavy on sedimentation lines, poor bedding near the top. Strike, 33 NNE, dipping 61 W.

04EB 055 Tut, 587477 E, 4449776 N – jarosite alteration, thick bed type alteration, bedding layers strike 60 NE, dipping 20 NW.

04EB 056 Tut, 587526 E, 4449706 N – similar to plagioclase dacite lava dome, alteration, sample with the plagioclase less altered, matrix is filled with jarosite.

04EB 057 Tut, 587516 E, 4449690 N – biotite-rich porphyry, biotite rich cobble found in tuff at Union or equivalent to the north, pink colored alteration; fairly – not entirely absent of square quartz porphyry, biotite pervasive.

04EB 058 Tut, 587528 E, 4449635 N – similar to plagioclase dacite lava dome, large feldspars, little quartz, no biotite, altering, another type of volcanic – but it weathers faster than the matrix, cobble surrounded by jarosite rind.

04EB 059 Tpd, 585622 E, 4444829 N – plagioclase dacite lava dome, dacite breccia, altered, silicified matrix, plagioclase rich with amphibole/biotite, and quartz. Two types of cobbles 2nd has less dark minerals and appears more altered with as green mineral, very poor flow foliation, striking 69 NE, dipping 25 W.

04EB 060 Tpd, 585387 E, 4444778 N – plagioclase dacite lava dome, sample from brecciated block on northeast side of hill.

04EB 061 Tpd, 585383 E, 4444779 N – plagioclase dacite lava dome, basal vitrophyre of flow likely connected with sample 051, glassy though somewhat altered, good biotite, plagioclase, amphibole, and quartz. Glassy vitrophyre follows in float around hill to north and can be seen on bottom of outcrop 04 EB-051.

04EB 062 Ta, 586122 E, 4442664 N – mixed magma andesite, appears to be a black scoriaceous flow forming the entire hill, one block has quartz forming on a fracture, another cobble contains a xenolith.

04EB 063 Ta, 586110 E, 4442647 N – mixed magma andesite, dense non-vesicular basalt-like subcrop – no outcrop. Phenocrysts include clinopyroxene, orthopyroxene, plagioclase, and quartz. Locally distinct, no foliation or flow direction. Possible trend 342 N-S.

04EB 064 Ta, 585644 E, 4442444 N – mixed magma andesite, slope sample – float – phenocrysts include clinopyroxene, quartz, olivine, plagioclase, amphibole, biotite, and orthopyroxene, along with garnet. Lighter rind on the porphyry samples. Garnet-bearing sample found 20 steps to the north west of gps reading.

04EB 065 Ta, 585617 E, 4442450 N – mixed magma andesite, freshest sample, likely same as 04 EB-064 without alteration (red chippy rock appears similar – litters the hillside - not sampled).

04EB 065add Ta, 585617 E, 4442450 N – mixed magma andesite, additional sample taken at same location

04EB 066 Ta, 585497 E, 4442296 N – mixed magma andesite flow, only possible outcrop, red chippy, thin bedded/foliated. Top of hill. Strike 315NW, dip 29 SW.

04EB 067 Ta, 585434 E, 4442378 N – mixed magma andesite, random float- similar to 04 EB-064 various types, not red chippy, about the same elevation as 04 EB-064

04EB 067add Ta, 585422 E, 4442393 N – mixed magma andesite, additional sample taken at same location

04EB 068 Ta, 585712 E, 4442133 N – mixed magma andesite, sample of outcrop – possibly a breccia pipe, glassy margin of flow, possible flow foliation inside, strike 355 NS, dip 57 E.

04EB 069 Tr, 583908 E, 4432658 N – rhyolite, vitrophyre of rhyolite/andesite flow, south end of valley, glassy- dark- perlitic, plagioclase rich, quartz, possible biotite, and reddish-oxidizing mineral – hematite. Vitrophyre at the top of the flow.

04EB 070 Tb, 582261 E, 4430594 N – basalt, south of study area, olivine bearing, fine-grained, no vesicles, dense, rind mineral alteration.

04EB 071 Tmd, 578848 E, 4438674 N – igneous dike, Same as 04 JA 186 for chemistry, sample out of road side, this sample for reference only, extremely altered, somewhat high density, pink areas appear less altered – mostly caliche covered.

04EB 072 Tb, 578228 E, 4434754 N – basalt, west side high in the first cliff – bottom outcrop of basalt flow- contains vesicles and large plagioclase crystals, and lots of red hematite - after something else, flow could continue from east side of range to west – perhaps this is the toe of the farthest flow. Top of flow broken and vesicle rich, as well as what is beneath. Likely younger flow – sits near the top of the range.

04EB 073 Tb, 575821 E, 4442113 N – basalt, west valley, lighter – glassy – devitrified, phenocrysts of brown weathering mineral, possibly part of younger basalt flows. Strike and dip of flow surface is 0 N-S, 12 E

04EB 074 Tbda, 588266 E, 4447445 N – biotite dacite ash, biotite rich dacite ash only found as float – covering mound north of the road, near lake bar feature, other lake sediments in float.

04EB 075 Tbda, 588351 E, 4447512 N – biotite dacite ash, contains larger clasts of distinctly altered ash with good biotite. 075B – going up hill toward bar feature, biotite porphyry slowly disappears from float and large cobbles of dark lava appear – same happens along bar feature, b is a cobble – for reference only.

04EB 076 Tpd, 584624 E, 4442873 N – plagioclase dacite lava dome, contains alteration vein, altered sample.

04EB 077 Ta, 587822 E, 4444377 N – mixed magma andesite lava flow, mafic in appearance, well layered appear similar to 04 EB-047, contains phenocrysts of plagioclase, olivine, and clinopyroxene, south side of outcrop has flow foliation – strike 81 EW, dip 86 N, north side has flow foliation – strike 62 EW, dip 79 NNW. Core of outcrop not so foliated. 2nd outcrop more vesicular.

04EB 078 Ta, 587641 E, 4444499 N – mixed magma andesite, vesicular flow, contains bomb-like clasts, very broken up, plagioclase crystals with inclusions, areas where it is altered pink.

04EB 079 Ta, 587611 E, 4444542 N – mixed magma andesite breccia flow, brecciated in appearance, pink altered sample.

04EB 080 Tbda, 587444 E, 4446019 N – biotite dacite ash, biotite and quartz bearing dacite clasts in float, very angular, cobbles are larger, all biotite dacite ash.

04EB 081 Ta, 587939 E, 4446654 N – mixed magma andesite, float sample, containing phenocrysts of quartz, clinopyroxene, plagioclase, orthopyroxene, and biotite, and contains some sulfur alteration.

04EB 082 Ta, 587860 E, 4446447 N – mixed magma andesite flow, outcrop of thin foliated lava, quartz, plagioclase feldspar, dark mineral, smoky quartz. Flow foliation strike 39 NE, dip 16 ESE

04EB 083 Ta, 587919 E, 4446007 N – mixed magma andesite flow, blocky fragments sampled from top of hill – also has quartz filled fractures and vesicles – possibly altered.

04EB 084 Ta, 587905 E, 4445769 N – mixed magma andesite flow, good outcrop of what is happening in other places, basic trend is 334, flow feature wrapping around and twisting as it flows.

04EB 085 582889 E, 4445651 N – pebble dike, resample pebble dike, two types of porphyry.

04EB 086 Tbp, 582881 E, 4445278 N – biotite porphyry, 100 meter long subcrop, biotite porphyry, location at southern end of subcrop, large phenocrysts of biotite, quartz, plagioclase, and potassium feldspar – altered Fe-rich mineral – weathering, possible dike or vent.

04EB 087 Tpd, 583553 E, 4445156 N – plagioclase dacite lava dome, vitrophyre – glassy contains plagioclase, biotite crystals amphibole and quartz

04EB 088 Tpd, 583442 E, 4445086 N – plagioclase dacite lava dome, has distinctly different alteration, includes biotite, propyllitic alteration – green, no good foliation, rubble-like.

04EB 089 Tbda, 583490 E, 4444959 N – biotite dacite ash, phenocrysts include plagioclase, biotite, and quartz. Biotite dacite clasts in float, large cobbles, pristine biotite, follows in float to next sample locality – still in float.

04EB 090 Tpd, 583562 E, 4444901 N – plagioclase dacite lava dome, appears to be plagioclase dacite lava dome-type feature, very altered.

04EB 091 Tpd, 583578 E, 4444827 N – plagioclase dacite lava dome, vitrophyre appears glassy and similar to 04 EB-087 containing biotite, plagioclase, and quartz.

04EB 092 Tbda, 583441 E, 4444979 N – biotite dacite ash, reference only- found in float, finer grained biotite dacite nodule within biotite dacite, float continues to here. Then turns into a gravel cap hill on the other side of wash – gravel cap continues.

04EB 093 Tmd, 579380 E, 4442956 N – mafic dike, sample of dike good plagioclase laths some quartz, matrix altered orange. Very altered.

04EB 094 Tmd, 580394 E, 4442664 N – mafic dike, red, is igneous, orange color, appears to be calcite rich – altered – oxidizing, pink alteration preserves some crystalline texture, contains black secondary mineral – possibly manganese, green alteration in some samples.

04EB 095 Tmd, 580149 E, 4442600 N – mafic dike, not a very fresh sample, altered, one piece has remnant crystal form - possible biotite phenocrysts, all very altered.

04EB 096 Tmd, 579886 E, 4442672 N – mafic dike, dike much less altered than all other samples. Sample is propyllitically altered green and more igneous in appearance, mostly aphanitic matrix, a few possible phenocrysts of amphibole, plagioclase, quartz, and pyroxene.

04EB 097 Tbr, 582972 E, 4444027 N – banded rhyolite, light grey crystal-poor, well banded flow, no outcrop, float sample. Within the flow bands, small phenocrysts of quartz, plagioclase, and oxides can be found.

04EB 098 Tbr, 582944 E, 4443804 N – banded rhyolite lava flow, outcrop, pinkish crystal-poor – possible xenolith circled in hand sample, B – flow beneath – whiter, contact of the two flows – 34 dip to the N with strike of 90 EW, flow foliation for the upper flow.

04EB 099 Tbr, 582962 E, 4443765 N – banded rhyolite, breccia and flow pipe, with some flow foliation virtually vertical and some chaotic, appears altered.

04EB 100 Tec, 583010 E, 4443648 N – porphyry terrace, hillside containing several types of porphyry – all sub rounded in float – possibly an old alluvial terrace of various porphyries.

04EB 101 Tl, 583051 E, 4443758 N – dark latite, vesicular lava flow – in contact with 04-EB-099 (rhyolite).

04EB 102 Tut 583333 E, 4443679 N – tuff at Union, fair outcrop of red- maroon plagioclase-bearing tuff. Phenocrysts include plagioclase, quartz, pyrite crystals-hematite squares. Outcrop continues across drainage up hill until it comes in contact with latite cobbles.

04EB 103 Tpd, 583437 E, 4443312 N – plagioclase dacite lava dome, glassy vitrophyre – phenocrysts include plagioclase, quartz, biotite, biotite dacite ash found in float near outcrop.

04EB 104 Tba, 583653 E, 4443429 N – biotite dacite ash, appears to be small subcrop, subcrop rubble of 104B. Possible trend to the N-S, near vertical dip.

04EB 105 Tl, 583285 E, 4443989 N – dark latite, vesicular and non-vesicular lava flow – usually together, non-vesicular has more angular fragments. Phenocrysts include pyroxene, plagioclase, quartz, potassium feldspar, and oxides

04EB 106 Tpd, 584185 E, 4443750 N – plagioclase dacite lava dome, vitrophyre, glassy, plagioclase, not altered, dark grey matrix, subcrop- large plagioclase, large amphibole.

04EB 107 Tpd, 583987 E, 4443824 N – plagioclase dacite lava dome, from the side of hill – possibly biotite ash looks different – biotite and amphibole, possibly similar to 108.

04EB 108 Tpd, 583781 E, 4443784 N – plagioclase dacite lava dome, slightly different, glassy – phenocrysts include plagioclase, biotite, amphibole, orthopyroxene, clinopyroxene, and quartz. Covers less vegetated surface.

04EB 109 Tpd, 583727 E, 4443427 N – plagioclase dacite lava dome, various alteration styles – green (propyllitic) and Fe mineral to hematite.

04EB 110 Tpd, 583738 E, 4443381 N – plagioclase dacite lava dome, possibly christobalite-bearing. What appears to be christobalite as possible fracture fill, or possibly alteration and quartz.

04EB 111 Tpd, 583809 E, 4443351 N – plagioclase dacite lava dome, propyllitic alteration -green, contains lithic fragments and plagioclase and quartz phenocrysts, brecciated, possible biotite.

04EB 112 Tpd, 583888 E, 4443374 N – plagioclase dacite lava dome, propyllitic alteration, a piece of the plagioclase dacite lava dome with slickensides.

04EB 113 Tpd, 583930 E, 4443392 N – plagioclase dacite lava dome, possibly christobalite-bearing, altered.

04EB 115 Tpd, 584113 E, 4443539 N – plagioclase dacite lava dome, plagioclase changing due to propyllitic alteration and red Fe mineral.

04EB 116 Tpd, 584388 E, 4443050 N – plagioclase dacite lava dome, out of outcrop – looks similar to 04 EB-108 – but altered, phenocrysts include biotite, quartz, plagioclase, and altered amphibole, part sampled from nearby subcrop.

04EB 117 Tbda, 584484 E, 4443032 N – biotite dacite ash, altered, in float sample.

04EB 118 Tpd, 585429 E, 4443807 N – plagioclase dacite lava flow, breccia flow, three types of igneous rock in sample, quartz, plagioclase, biotite, possibly weathered and altered. Subcrop likely continues under NE part of older alluvium.

04EB 119 Tpd, 585596 E, 4443844 N – plagioclase dacite lava flow, porphyritic, phenocrysts include plagioclase, biotite, quartz, green mineral fairly unaltered, apparent strike and dip 45 NE dipping 42 NW.

04EB 120 Tbda, 585207 E, 4444062 N – biotite dacite ash, A - unknown. B- is altered biotite quartz porphyry, altered very green (comes from up the streambed) where it is in contact with the basaltic andesite.

04EB 121 Tpd, 585100 E, 4444056 N – plagioclase dacite lava dome, altered, phenocrysts include plagioclase and clinopyroxene, apparent strike - 0 NS, dipping 64 W.

04EB 122 Ql, 582752 E, 4445225 N – marl, sample of marly limestone, megascopic – looks like other marl within tertiary section, no bedding, no black chert, likely correlative with Quaternary lake sediments.

04EB 123 Ta, 586722 E, 4441219 N – mixed magma andesite, rounded and sieved plagioclase, reaction rims around quartz phenocrysts, biotite, clinopyroxene, sanidine, garnet, olivine, orthopyroxene, and amphibole, orange spots are altered olivine or magnetite. Large megacrysts of K-feldspar and quartz, magma mixing, megacrysts of K-feldspar are approximately 3.5 cm long; quartz phenocrysts are up to 2-3 cm, clot of orthopyroxene 30+ being total 3mm across, one crystal of K-feldspar with quartz inclusion was 3 cm long.

04EB 124 Ta, 586724 E, 4441238 N – mixed magma andesite, cavities that could have been amygdaloids, possibly volatiles or weathered feldspars, clot of olivine or sulfides.

04EB 125 Ta, 586717 E, 4441302 N – mixed magma andesite, this simple contains a 3 cm biotite megacryst.

04EB 126 Ta, 586652 E, 4441368 N – mixed magma andesite, flow foliation absent, very distinct – likely a flow – still have K-feldspar and quartz, olivine is much fresher – still red, but crystal form preserved, much more glassy matrix.

04EB 127 Ta, 586691 E, 4441528 N – mixed magma andesite, more of the dike-type, denser, outcrop (not flow type) possible strike 349 N, dip 68 SW.

04EB 128 Tpd, 584277 E, 4443412 N – plagioclase dacite lava dome, green - propyllitic mineralization/alteration, possibly siliceous mineral in a more finely brecciated dacite, or possibly a volcaniclastic. Utm coordinates are off somewhat.

04EB 129 Tpd, 583783 E, 4443778 N – plagioclase dacite lava dome, sample is glassy containing quartz, biotite, plagioclase, amphibole, with small magnetite crystals, similar to sample 04 EB-108.

04EB 130 Tmh, 572498 E, 4406886 N – near Mt Hope, square quartz porphyry, N and E of Mt. Hope (50 km to the south of Sulphur Springs volcanic field) likely separated from Mt. Hope by a fault . 50/50 crystals to matrix, contains quartz, biotite, slight quartz-pyrite-sericite alteration, fractures – iron stained from possible pyrite veins, apparent dip – low angle.

04EB 131 Tmh, 568361 E, 4409976 N – Mt. Hope porphyry (50 km to the south of Sulphur Springs volcanic field), rhyolite flows to the north of mine, smoky black quartz – due to deuteric uranium alteration, along with fresher piece ¼ mile down the road, likely topaz bearing, with amount of uranium for smoky quartz; Mt Hope – (no sample taken at the mine) quartz porphyry, quartz-pyrite-sericite alteration, bleached white, with some staining from pyrite, quartz crystals still present, cavities in the rock due to pumice, rhyolite to the north – flow banded with quartz-pyrite-sericite alteration.

04EB 132 Trr, 595890 E, 4445059 N – railroad pass dacite, north side of Diamond Valley, dacite flows by Railroad Pass, quartz and feldspar megacrysts, welded vitrophyre, however it is very possible this is a extrusive expression of the mixed magma andesite to the south. (Railroad Pass volcanic rocks to the east, valley fill of tertiary volcanic rocks - one clast weathering out appears similar to dacite on out side of the valley, light bed appears very well bedded - valley fill - fluvial/lucustrine, possibly related to the Indian Wells Formation to the northwest. Possibly all of which is capped by a mafic rock of sorts – altered.)

04EB 133 Tpd, 583683 E, 4443137 N – plagioclase dacite lava dome, altered volcanic rocks, sample of slightly less altered greenish volcanic rocks, plagioclase, quartz, biotite, weathered amphiboles - possibly sulfides or magnetite crystals, glassy matrix, outcrop weathers different than dacite, propyllitic and quartz-pyrite-sericite alteration.

04EB 134 Tpd, 583655 E, 4443062 N – plagioclase dacite lava dome, altered volcanic rocks, largest outcrop of propyllitic alteration, large cavities forming possibly copper-green, sample taken of greenish portion, pieces of weathering biotite mistaken for copper, may contain sulfide blebs.

04EB 135 Tpd, 583677 E, 4442929 N – plagioclase dacite lava dome, altered volcanic rocks, small outcrop propyllitic mineralization. Phenocrysts include plagioclase, altered clinopyroxene, and quartz.

04EB 136 Tpd, 583742 E, 4442795 N – plagioclase dacite lava dome, propyllitic alteration in dacite domes.

04EB 137 Tpd, 583699 E, 4440880 N – plagioclase dacite lava dome, sample of dacite vitrophyre, possibly similar to 04 EB-108, plagioclase, biotite, quartz, amphibole.

04EB 138 Tpd, 583195 E, 4438199 N – breccia pipe, breccia of sorts, kind of like a pebble dike, angular clasts, very altered green clasts, matrix slightly green with orange quartz-pyrite-sericite alteration, weathers distinctly as pipe shaped outcrop.

04EB 139 Tpd, 584102 E, 4442398 N – plagioclase dacite lava dome, well banded dacite, looks similar to the rhyolite flow to the west, but chemically plagioclase dacite lava dome, flow foliation strike 22 NE, dipping 22 SE.

04EB 140 Tpd, 584158 E, 4442339 N – plagioclase dacite lava dome, quartz-pyrite-sericite alteration, possibly contains xenoliths.

04EB 141 Tpd, 584209 E, 4442258 N – plagioclase dacite lava dome, dacite breccia, plagioclase quartz and green propyllitic alteration mineral.

04EB 142 Tpd, 589386 E, 4449565 N – plagioclase dacite like vitrophyre, in the northeast volcanic rocks on the west side of Garcia Flats, spring surfacing along the SW side of knoll where A. is located - possible dacite vitrophyre with lots of plagioclase, quartz, and a little biotite, in glassy matrix- perlitic, likely due to presence of the spring. B-looks to be a dacite breccia, it has an outcrop/subcrop with breccia in place with the vitrophyre above it, and possibly it is a volcaniclastic with a flow above it.

04EB 143 Tbp, 589451 E, 4449738 N – biotite porphyry, outcrop of biotite quartz porphyry, large biotite, quartz crystals, plagioclase, amphibole, and pyroxene. Feldspars altered to clays, argillic alteration type, matrix weathering and possible manganese dendrites. Each high point is a small ridge of biotite dacite ash possibly each is a subsequent ash flow.

04EB 144 Tbda, 589334 E, 449985 N – biotite dacite ash flow, outcrop of biotite with quartz - smoky and square with bipyramids, plagioclase weathered, apparent quartz-pyrite-sericite alteration with orange pyrite staining on fractures, pumice altered, and possibly some lithics, and some broken quartz. Likely an ash flow.

04EB 145 Tbda, 589534 E, 4450355 N – biotite dacite ash flow, the incline marks the trend of the flow of the biotite dacite ash, outcrops all along the way, 145 is a jarosite vein found in the pile of subcropping porphyry, no distinct pattern or direction, found scattered, first vein type found.

04EB 146 Tbda, 589537 E, 4450478 N – biotite dacite ash flow, not to be analyzed. It has biotite clusters.

04EB 147 Tbda, 589469 E, 4450692 N – biotite dacite ash flow, biotite, quartz porphyry flow, includes pumice shards and vesicles, biotite and quartz, weathered or altered.

04EB 148 Tav, 590073 E, 4449966 N – altered volcanic rocks undifferentiated, appears to contain quartz, biotite, plagioclase, K-feldspar, possibly amphibole, in a very glassy matrix, (green propyllitic alteration 10 m to the E of glassy sample) second part of sample is not nearly as phenocryst rich as surrounding rocks.

04EB 149 Tav, 590050 E, 4449949 N – altered volcanic rocks undifferentiated, dark and light, dark – some parts look like 04 EB-148, possibly dark magma mixing with lighter pink magma, or just alteration zones. Pink region contains quartz, biotite, plagioclase – small laths, clinopyroxene and orthopyroxene, not crystal-rich, maybe 10%

crystals, all small – except the biotite. You can still find pebbles of the biotite dacite ash up here.

04EB 150 Tbda, 589995 E, 4449891 N – biotite dacite ash flow, 3 distinctive types of flows, vertical flow foliation with E-W trend, sample of biotite ash.

04EB 151 Tav, 590007 E, 4449898 N – altered volcanic rocks undifferentiated, very possibly similar to 04 EB-149 – but matrix is dark grey, has biotite, plagioclase laths, and quartz, within 5 meters of sample 04 EB-150.

04EB 152 Ql, 589554 E, 4449241 N – marl, fine to microcrystalline limestone with very small white shells, light in color, some places have a manganese coat, most likely associated with the Quaternary lake sediments.

04EB 153 Ta, 589945 E, 4448942 N – mixed magma andesite, more silica rich – very little clinopyroxene, no visible olivine, includes quartz, plagioclase and biotite.

04EB 154 Ta, 589910 E, 4448966 N – mixed magma andesite, top of hill, phenocrysts include quartz, plagioclase, K-feldspar, garnet, clinopyroxene, and orthopyroxene. Halos around quartz, quartz filling vugs, large clinopyroxene crystals, and K-feldspar megacryst upto 3 cm long.

04EB 155 Ta, 589724 E, 4448676 N – mixed magma andesite, from the top of hill – no good foliation. Possibly more silica rich, but more chippy, weathered red rind. Contains quartz, K-feldspar, plagioclase, and clinopyroxene.

04EB 156 Ta, 589581 E, 4448927 N – mixed magma andesite, more mafic, finer grains – few large crystals, smaller crystals present in fine-grained matrix.

04EB 157 Ta, 589508 E, 4448766 N – mixed magma andesite, crystal-poor, fine grained, weathered, rounded, appears to be more mafic, containing altering olivine, clinopyroxene, and plagioclase, with a rind that appeared to be sulfur rich.

04EB 158 Ta, 589542 E, 4448576 N – mixed magma andesite, taken from the top of hill – appears vesicular, however cavities are forming from weathering feldspars. Foliation appears much more vertical, possibly fracturing, but pervasive throughout summit of hill.

04EB 159 Ta, 589119 E, 4448391 N – mixed magma andesite, quartz has weathered – mostly is not present, feldspar is present, but lot of cavities.

04EB 160 Barite, 581042 E, 4444529 N – barite vein, in mine prospect zone, see chemistry.

04EB 161 Ta, 585403 E, 4442357 N – mixed magma andesite, new sample taken near adds from 065 and 067.

04EB 162 Tsqp, 583114 E, 4445061 N – square quartz porphyry, A – square quartz porphyry from terrace – bipyramidal, garnet, biotite, plagioclase, K-feldspar – whole rock altered to reddish brown; B – sericitic alteration on square quartz porphyry, bipyramidal quartz, appears to be the same rock as A just different alteration types.

04EB 163 Tpd, 584116 E, 4441388 N – plagioclase dacite lava dome, breccia of flow banded plagioclase dacite lava dome, plagioclase, quartz, Fe-rich mineral altering to hematite - very altered – yellow – red pyrite staining, from outcrop in bottom of drainage.

04EB 164 Tut, 583029 E, 4443174 N – tuff at Union, altered volcanic rocks in what appears to be Elko conglomerate – possibly younger, contains plagioclase, quartz, altered Fe mineral, possible K-feldspar, matrix altered to lavender color.

04EB 165 Tsqp, 588786 E, 4450649 N – porphyry gravels, various igneous porphyry cobbles, A – porphyry plagioclase rich biotite poor, B – biotite quartz porphyry – has mostly plagioclase, some blocks more tuffaceous, others more blocky and cohesive – could be alteration types, C – apparently the square quartz porphyry with bipyramidal quartz, no biotite, but weathers similar to clasts found in the tuff at Union, D– Mafic type with clinopyroxene and quartz crystals, in a dark grey glassy matrix. Each type has variation on the alteration, or perhaps there are more varieties, could be a weathering volcaniclastic or just an ancient non-welded stream channel or terrace.

04EB 166 Ta, 590567 E, 4448737 N – mixed magma andesite, large clinopyroxene clot, with quartz, plagioclase, and maybe some amphibole, large crystals of plagioclase and quartz, strike 342, dip 34 W.

04EB 167 Ta, 590391 E, 4449258 N – mixed magma andesite lava flow, phenocrysts include quartz, plagioclase, clinopyroxene, and orthopyroxene. Last outcrop from the hills on the north end of Diamond valley, steep dip- looks vesicular – possibly cavities, small crystals and a lot less abundant than previous sample, more mafic, strike 314, dip 76 NE.

04EB 168 Ta, 591587 E, 4449021 N – mixed magma andesite, on the north slope of the valley, phenocrysts include quartz, biotite, plagioclase, clinopyroxene, orthopyroxene, and sanidine along with garnet. Strike, 311, Dip, 28 NE.

04EB 169 Tbda, 590680 E, 4450992 N – biotite dacite ash flow, linear trend 2 N, altered. Orange pyrite staining, feldspar altered to clay from argillic alteration, small crystals of biotite and quartz, and contain lithic fragments.

04EB 170 Tbda, 590657 E, 4451685 N – biotite dacite ash flow, outcrop/subcrop, biotite dacite ash – top capped with gravels, likely a flow.

Appendix C: Major and trace element whole rock XRF analyses

Sample #	03EB 11	03EB 12	03EB 13a	03EB 13b	03EB 14a	03EB 14b	03EB 15	03EB 16
Unit Name	Tmd	Tmd	Tr	Tr	Tr	Tr	Tr	Tvpd
Alteration		Alt	Alt	Alt	Alt	Alt	Alt	Alt
wt.%								
SiO2	52.96	66.32	80.66	81.16	86.51	83.03	72.91	90.54
TiO2	1.08	0.73	0.08	0.07	0.27	0.54	0.08	0.35
Al2O3	17.47	14.57	10.58	9.87	9.00	11.12	11.11	7.05
Fe2O3	8.27	4.93	0.32	0.47	0.64	1.44	0.97	0.39
MnO	0.13	0.09	0.02	0.01	0.00	0.01	0.04	0.00
MgO	4.09	0.24	0.14	0.10	0.21	0.45	0.13	0.15
CaO	8.83	5.32	0.30	0.16	0.37	0.18	6.73	0.14
Na2O	2.72	0.26	1.12	1.16	0.30	0.28	0.26	0.31
K2O	2.46	0.28	7.17	6.57	0.56	1.20	0.18	0.32
P2O5	0.33	0.25	0.05	0.07	0.10	0.06	0.06	0.04
LOI	1.49	10.16	0.97	0.81	3.59	3.69	8.98	2.72
Total	99.83	103.15	101.41	100.45	101.55	102	101.45	102.01
ppm								
F	0	1141	3	154	108	289	694	293
S	-	-	-	-	-	-	-	-
Cl	0	0	0	0	0	0	0	0
Sc	19	11	0	0	0	0	1	0
V	202	147	7	56	58	58	15	56
Cr	10	19	0	30	28	61	2	32
Co	-	-	-	-	-	-	-	-
Ni	8	9	0	8	7	16	4	3
Cu	15	11	0	6	7	6	0	1
Zn	134	51	11	27	27	36	61	24
Ga	20	21	10	11	11	15	18	9
As	-	-	-	-	-	-	-	-
Rb	73	16	213	31	31	66	14	19
Sr	655	37	80	55	55	71	17	140
Y	25	23	19	21	21	19	20	13
Zr	207	171	82	116	115	173	67	160
Nb	14	18	15	17	16	17	20	14
Ba	1142	258	962	1255	1257	361	1047	1362
La	30	38	10	20	10	26	8	26
Ce	89	80	59	28	39	52	14	31
Nd	31	35	0	17	0	23	0	21
Sm	8	19	3	10	9	12	16	9
Pb	13	46	26	29	29	27	26	5
Th	3	23	18	28	30	20	36	26
U	4	0	8	3	3	0	10	0

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks

Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	03EB 17	03EB 18a	03EB 18b	03EB 19	03EB 20	03EB 21a	03EB 21b	03EB 22
Unit Name	Tr	Tr	Tr	Tmd	Tmd	Tmd	Tmd	Tmd
Alteration	Alt	Alt	Alt		Alt	Alt	Alt	Alt
wt.%								
SiO2	72.18	80.26	79.93	56.98	48.25	49.89	59.89	60.56
TiO2	0.70	0.49	0.52	1.10	1.13	0.75	0.92	1.00
Al2O3	14.98	14.03	14.69	17.00	10.83	13.71	15.97	13.89
Fe2O3	5.58	0.75	0.58	7.36	7.93	6.69	8.03	6.98
MnO	0.01	0.01	0.01	0.11	0.08	0.04	0.06	0.06
MgO	0.12	0.08	0.06	2.99	6.79	10.73	1.27	2.42
CaO	0.88	0.23	0.19	2.05	11.01	7.59	3.38	3.40
Na2O	0.21	0.30	0.23	3.87	0.51	0.00	0.28	0.31
K2O	0.12	0.06	0.04	4.38	3.27	1.30	4.04	4.18
P2O5	0.79	0.14	0.17	0.48	0.94	0.15	0.21	0.72
LOI	6.47	5.27	5.52	3.53	11.30	10.74	6.52	7.04
Total	102.04	101.62	101.94	99.85	102.04	101.59	100.57	100.56
ppm								
F	868	183	211	0	0	0	1389	1380
S	-	-	-	-	-	-	-	-
Cl	0	0	0	0	0	0	0	0
Sc	9	0	0	19	25	31	28	18
V	142	70	67	163	198	210	228	365
Cr	32	4	6	13	685	839	769	508
Co	-	-	-	-	-	-	-	-
Ni	23	3	3	7	307	267	237	236
Cu	21	1	5	13	206	40	97	42
Zn	44	41	23	83	6941	73	287	1690
Ga	18	18	17	20	22	18	21	22
As	-	-	-	-	-	-	-	-
Rb	10	0	0	143	179	55	184	108
Sr	56	18	34	605	165	49	16	44
Y	56	21	19	27	36	20	20	21
Zr	204	206	204	261	363	105	147	339
Nb	18	19	17	20	14	0	10	16
Ba	765	446	498	2613	828	175	374	468
La	55	61	63	35	158	7	11	80
Ce	102	105	100	119	308	45	46	190
Nd	47	43	41	40	129	0	0	71
Sm	15	13	13	7	30	5	4	11
Pb	17	18	22	17	115	0	102	18
Th	31	54	54	11	13	5	0	23
U	2	0	0	4	11	0	2	9

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	03EB 23	03EB 24	03EB 25	03LB 26	04EB 038	04EB 039a	04EB 039b	04EB 039c
Unit Name	Tmd	Tmd	Tmd	Tmd	Tsqp	Tsqp	Tsqp	Tsqp
Alteration	Alt	Alt			Alt	Alt	Alt	Alt
wt.%								
SiO2	53.99	72.61	51.83	51.06	84.30	76.34	83.64	81.37
TiO2	1.64	0.93	1.09	1.04	0.49	0.14	0.80	0.47
Al2O3	23.97	25.69	11.81	13.29	10.04	15.73	10.64	12.67
Fe2O3	3.89	1.43	8.68	8.26	0.74	0.52	0.20	0.78
MnO	0.08	0.00	0.13	0.11	0.01	0.01	0.01	0.01
MgO	1.60	0.21	12.86	9.14	0.09	0.32	0.07	0.08
CaO	10.13	0.24	9.48	8.50	0.03	0.06	0.11	0.05
Na2O	0.00	0.00	1.14	1.54	0.26	0.25	0.22	0.23
K2O	0.74	0.12	0.96	1.42	0.17	1.40	0.11	0.14
P2O5	0.55	0.05	0.21	0.29	0.05	0.04	0.26	0.05
LOI	13.96	5.61	8.19	6.14	3.93	5.01	4.23	5.26
Total	110.55	106.9	106.38	100.79	100.12	99.81	100.29	101.1
ppm								
F	1044	394	0	0	439	946	466	284
S	-	-	-	-	1673	103	465	441
Cl	0	0	0	0	49	97	37	36
Sc	23	0	27	25	0	0	0	0
V	204	122	194	182	34	17	41	36
Cr	366	18	490	441	54	12	77	47
Co	-	-	-	-	8	6	0	4
Ni	84	1	166	175	5	4	4	8
Cu	37	2	41	41	0	3	0	3
Zn	59	3	84	74	8	7	8	10
Ga	22	20	17	16	9	23	12	12
As	-	-	-	-	5	2	9	8
Rb	36	13	39	38	9	114	5	8
Sr	51	34	691	689	60	23	951	201
Y	32	13	27	26	7	16	11	18
Zr	220	220	202	198	182	83	278	178
Nb	17	17	13	13	16	27	18	16
Ba	260	114	1135	719	5676	426	1060	1595
La	101	35	35	36	18	0	68	30
Ce	163	64	90	87	0	11	84	29
Nd	72	25	33	34	0	0	57	22
Sm	22	11	9	6	0	0	4	0
Pb	8	13	8	7	0	0	24	8
Th	15	35	9	9	5	6	21	11
U	1	0	2	3	0	0	4	0

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash,
Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry,
Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt,
Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

				AlsChemex	AlsChemex			
Sample #	04EB 040	04EB 041a	04EB 041b	04 EB 044	04 EB 045	04EB 046	04EB 047	04EB 048
Unit Name	Tpd	Tbda	Tsqp	Tpd	Tba	Tut	Ta	Ta
Alteration			Alt					
wt.%								
SiO2	62.73	68.82	77.59	64.77	53.75	66.70	62.09	62.55
TiO2	0.80	0.59	0.38	0.75	0.93	1.20	0.85	0.85
Al2O3	16.57	16.03	14.04	16.92	13.74	18.05	15.11	15.01
Fe2O3	4.60	2.82	0.66	3.45	8.14	3.47	6.19	6.32
MnO	0.07	0.03	0.01	0.05	0.13	0.02	0.08	0.08
MgO	1.43	0.70	0.27	1.17	8.36	0.18	2.38	2.57
CaO	4.70	3.58	0.16	4.48	8.67	0.49	4.88	4.87
Na2O	3.05	3.28	3.17	3.16	2.15	0.38	2.43	2.42
K2O	3.10	3.63	0.51	2.89	1.42	8.12	4.18	4.12
P2O5	0.23	0.21	0.02	0.27	0.23	0.25	0.36	0.37
LOI	2.20	0.82	3.68	1.85	2.49	4.08	1.18	1.07
Total	99.49	100.51	100.49	99.76	100.01	102.93	99.72	100.23
ppm								
F	226	485	526	-	-	523	425	420
S	330	66	462	-	-	59	535	71
Cl	158	89	47	-	-	65	85	77
Sc	10	0	0	-	-	0	13	14
V	86	54	30	50	172	118	130	130
Cr	8	6	13	7	266	24	30	32
Co	18	14	0	16	39	16	21	25
Ni	4	2	1	3	150	33	5	6
Cu	4	2	0	6	39	9	6	7
Zn	81	36	11	72	80	53	64	63
Ga	21	19	18	24	18	18	19	18
As	4	3	4	3	2	13	3	2
Rb	100	111	29	72	69	176	143	142
Sr	802	696	225	770	711	107	585	572
Y	25	14	39	18	23	21	24	23
Zr	219	204	180	165	181	326	181	183
Nb	15	16	35	17	13	20	13	13
Ba	2326	1540	1675	1400	690	1266	1203	1256
La	51	45	26	44	36	18	31	31
Ce	81	87	23	83	67	34	64	63
Nd	32	34	16	-	-	16	27	26
Sm	10	4	0	-	-	0	7	8
Pb	17	21	0	17	8	6	18	17
Th	14	16	15	14	9	15	9	8
U	5	4	0	3	1	0	5	5

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	04EB 049	04EB 050	04EB 051	04EB 052a	04EB 053	04EB 054	04EB 055	04EB 057
Unit Name	Ta	Tba	Tpd	Tbda	Tut	Tut	Tut	Tut
Alteration					Alt	Alt	Alt	Alt
wt.%								
SiO2	60.14	53.49	67.54	71.09	76.30	82.39	77.86	73.60
TiO2	0.99	1.04	0.71	0.40	0.47	0.09	0.12	0.49
Al2O3	15.09	13.83	16.99	14.52	15.12	12.07	13.46	14.37
Fe2O3	7.22	8.50	1.28	1.65	1.62	0.19	0.62	2.73
MnO	0.10	0.14	0.01	0.02	0.02	0.01	0.04	0.02
MgO	3.19	8.45	0.17	0.68	0.50	0.10	0.30	0.51
CaO	5.89	8.34	4.13	3.28	0.29	0.67	0.60	1.50
Na2O	2.34	2.25	3.54	2.90	0.28	0.28	0.26	0.18
K2O	3.86	1.61	3.74	3.63	0.53	0.15	0.23	0.41
P2O5	0.41	0.21	0.19	0.11	0.13	0.09	0.29	0.16
LOI	1.05	1.82	0.80	2.01	5.64	5.34	5.97	6.48
Total	100.28	99.68	99.09	100.27	100.9	101.39	99.75	100.45
ppm								
F	394	0	203	216	733	318	199	611
S	24	11	967	141	57	2747	385	233
Cl	83	214	70	71	80	72	48	76
Sc	16	22	11	6	0	0	0	0
V	142	181	84	37	60	13	13	77
Cr	36	440	8	8	5	3	5	5
Co	18	27	5	8	0	0	20	0
Ni	7	144	0	0	5	0	4	5
Cu	8	39	2	0	2	0	7	4
Zn	74	88	32	30	43	10	22	29
Ga	19	18	20	17	19	15	17	20
As	2	2	5	4	4	21	12	11
Rb	132	49	120	114	28	5	13	18
Sr	671	649	760	390	19	30	77	28
Y	25	28	16	81	21	25	25	18
Zr	186	202	216	182	250	114	133	216
Nb	13	14	16	16	20	24	26	19
Ba	1214	767	1615	1186	450	135	1289	412
La	29	35	43	37	51	28	29	37
Ce	65	74	82	65	74	43	35	54
Nd	25	33	34	29	40	25	23	29
Sm	9	6	6	5	0	0	0	2
Pb	14	9	17	21	3	4	18	9
Th	7	10	16	20	24	21	26	19
U	4	3	5	5	0	0	0	0

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	04EB 059a	04EB 061	04EB 062	04EB 063	04EB 064	04EB 065	04EB 066	04EB 067
Unit Name	Tpd	Tpd	Ta	Ta	Ta	Ta	Ta	Ta
Alteration								
wt.%								
SiO2	70.63	63.58	60.25	60.54	62.74	62.82	61.59	61.13
TiO2	0.67	0.69	0.90	0.95	0.82	0.82	0.90	0.88
Al2O3	16.06	16.18	14.66	14.59	15.24	15.17	15.19	15.75
Fe2O3	1.19	4.77	7.03	7.33	5.89	5.90	6.59	5.51
MnO	0.01	0.08	0.10	0.10	0.09	0.09	0.09	0.09
MgO	0.16	1.55	3.68	3.58	2.51	2.54	2.55	2.59
CaO	3.79	4.33	5.65	5.82	4.79	4.87	5.15	5.14
Na2O	3.30	3.17	2.32	2.21	2.57	2.39	2.55	2.32
K2O	3.48	3.19	4.02	3.95	4.25	4.34	4.16	3.91
P2O5	0.22	0.21	0.41	0.47	0.35	0.37	0.47	0.51
LOI	0.72	1.50	0.68	0.40	0.82	0.95	0.93	2.51
Total	100.22	99.24	99.69	99.93	100.09	100.25	100.16	100.32
ppm								
F	68	354	371	233	310	289	408	388
S	59	44	32	145	62	134	99	91
Cl	47	105	207	192	210	213	74	176
Sc	5	10	17	17	13	13	15	14
V	47	80	154	171	126	128	138	112
Cr	8	8	26	27	30	33	39	28
Co	18	3	14	29	24	24	22	17
Ni	0	3	9	7	7	5	7	5
Cu	3	6	12	14	7	7	11	6
Zn	18	73	79	71	67	69	72	79
Ga	18	21	19	17	18	19	18	19
As	5	4	2	3	2	3	3	3
Rb	103	114	140	132	147	147	140	141
Sr	710	814	660	617	599	609	603	676
Y	15	19	24	22	23	23	23	27
Zr	211	219	179	177	189	187	183	195
Nb	15	14	12	11	14	14	13	14
Ba	1550	1454	1236	1296	1372	1369	1311	1508
La	45	51	30	30	31	29	30	33
Ce	76	87	63	66	66	65	65	65
Nd	32	35	25	25	27	27	27	29
Sm	4	12	9	6	7	8	8	8
Pb	17	20	17	16	18	19	19	19
Th	15	16	8	8	9	10	9	10
U	4	6	4	4	4	5	4	4

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	04EB 068	04EB 069	04EB 070	04EB 072	04EB 073	04EB 074	04EB 075b	04EB 076
Unit Name	Ta	Tr	Tb	Tb	Tb	Tbda	Tbda	Tpd
Alteration								
wt.%								
SiO2	60.95	73.64	55.41	50.40	50.26	63.59	63.92	68.74
TiO2	0.90	0.14	1.21	1.74	2.12	0.74	0.59	0.70
Al2O3	15.41	12.91	15.99	16.84	16.19	16.06	14.99	16.11
Fe2O3	6.70	1.83	8.68	11.44	11.90	4.56	4.62	1.71
MnO	0.09	0.07	0.12	0.16	0.17	0.05	0.07	0.01
MgO	2.83	0.50	4.18	4.78	5.07	1.46	1.80	0.19
CaO	5.33	1.36	7.00	8.13	8.29	4.35	4.79	3.76
Na2O	2.28	2.82	2.31	3.33	3.38	2.59	2.90	3.28
K2O	4.09	5.06	4.03	1.50	1.55	3.78	4.26	3.69
P2O5	0.50	0.05	0.57	0.59	0.89	0.27	0.29	0.28
LOI	1.45	1.93	0.19	0.58	-0.27	2.67	2.59	1.15
Total	100.54	100.3	99.68	99.49	99.53	100.1	100.81	99.62
ppm								
F	603	362	331	531	370	479	511	261
S	1866	40	0	23	0	311	232	369
Cl	175	106	187	73	79	120	166	79
Sc	15	0	19	22	22	10	11	8
V	126	21	217	260	220	85	96	47
Cr	29	7	22	44	71	15	19	8
Co	10	12	23	20	27	9	12	3
Ni	7	1	4	30	38	7	5	0
Cu	9	2	8	24	28	9	8	6
Zn	73	48	82	125	135	63	68	31
Ga	19	16	20	22	22	20	19	20
As	3	12	2	3	3	5	10	6
Rb	133	190	127	22	19	120	179	112
Sr	637	109	707	757	671	568	552	726
Y	25	26	28	32	41	26	25	16
Zr	189	131	227	182	258	208	173	215
Nb	13	19	14	12	20	17	16	15
Ba	1247	270	1573	1013	1010	2027	1288	1425
La	32	33	34	32	39	45	36	37
Ce	66	67	82	75	100	75	64	71
Nd	27	28	30	32	36	31	27	31
Sm	9	5	7	10	11	6	9	5
Pb	17	28	15	8	9	21	24	17
Th	10	29	8	1	2	20	16	16
U	5	8	4	3	3	5	5	5

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	04EB 077	04EB 078	04EB 079	04EB 080	04EB 081	04EB 082	04EB 083	04EB 084
Unit Name	Ta	Ta	Ta	Tbda	Ta	Ta	Ta	Ta
Alteration								
wt.%								
SiO2	60.26	61.44	58.60	61.98	62.01	62.02	60.11	60.84
TiO2	0.93	0.94	1.04	0.78	0.91	0.93	1.02	1.06
Al2O3	14.49	14.88	14.73	15.09	14.44	14.75	14.80	15.27
Fe2O3	7.30	6.65	7.21	5.58	6.49	6.55	7.09	7.34
MnO	0.10	0.09	0.10	0.08	0.09	0.08	0.10	0.09
MgO	3.19	2.99	3.41	2.09	3.19	2.75	3.38	2.77
CaO	5.57	5.15	5.70	4.60	5.00	5.03	5.59	5.39
Na2O	2.31	2.15	2.27	2.29	2.17	2.52	2.29	2.52
K2O	3.94	4.45	3.88	4.17	4.32	4.18	4.38	4.37
P2O5	0.47	0.46	0.52	0.61	0.47	0.41	0.51	0.53
LOI	0.88	1.37	1.45	2.02	1.12	0.87	0.66	0.80
Total	99.43	100.57	98.89	99.28	100.21	100.09	99.92	100.99
ppm								
F	481	277	445	594	322	584	312	669
S	97	38	503	253	104	65	134	25
Cl	103	223	105	161	223	91	260	117
Sc	17	14	15	13	14	15	15	16
V	163	140	144	111	144	137	158	161
Cr	23	18	21	24	27	25	21	19
Co	25	16	15	13	26	22	23	21
Ni	8	6	8	6	7	6	8	8
Cu	9	8	13	8	6	10	11	12
Zn	70	71	82	70	67	66	77	74
Ga	18	19	19	18	18	19	19	18
As	3	3	3	3	3	3	3	2
Rb	137	144	126	144	139	139	139	144
Sr	618	671	729	618	640	655	722	717
Y	22	24	27	29	24	24	25	26
Zr	178	191	199	193	192	190	198	199
Nb	12	13	13	15	13	12	13	13
Ba	1318	1258	1381	1881	1628	1436	1388	1464
La	29	32	34	37	30	33	32	29
Ce	65	67	64	64	64	63	69	69
Nd	25	28	28	27	26	26	27	26
Sm	6	9	10	8	7	8	7	8
Pb	15	17	13	20	17	18	17	17
Th	8	10	9	9	8	8	9	9
U	4	4	4	4	4	4	4	4

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	04EB 086	04EB 087	04EB 088	04EB 089	04EB 090	04EB 091	04EB 093	04EB 094
Unit Name	Tbp	Tpd	Tpd	Tbda	Tpd	Tpd	Tmd	Tmd
Alteration							Alt	Alt
wt.%								
SiO2	66.76	62.74	64.29	68.05	65.26	63.18	51.36	66.21
TiO2	0.43	0.81	0.77	0.63	0.82	0.79	1.55	1.79
Al2O3	14.47	16.61	17.36	15.80	17.26	16.50	17.31	21.34
Fe2O3	3.40	4.41	4.57	2.17	2.45	4.54	4.03	0.93
MnO	0.05	0.06	0.03	0.03	0.03	0.07	0.06	0.01
MgO	1.04	1.39	0.40	0.78	0.26	1.53	1.70	0.29
CaO	3.41	4.60	4.16	3.75	4.45	4.62	10.77	0.92
Na2O	2.50	2.72	3.07	3.30	3.47	2.98	0.00	0.23
K2O	4.86	3.47	4.05	3.46	3.67	3.33	0.88	0.60
P2O5	0.15	0.21	0.21	0.21	0.22	0.24	0.43	0.49
LOI	4.12	2.71	1.29	0.64	0.57	2.37	15.31	7.73
Total	101.19	99.73	100.18	98.8	98.46	100.16	103.4	100.52
ppm								
F	584	391	298	591	344	297	0	695
S	17	59	26	52	61	64	167	59
Cl	92	195	51	100	63	194	87	68
Sc	9	11	10	5	11	10	24	0
V	51	97	97	42	99	97	199	188
Cr	51	8	8	5	8	9	348	471
Co	11	6	8	7	11	11	0	0
Ni	3	2	3	0	0	2	68	38
Cu	4	4	3	1	3	5	43	46
Zn	63	67	53	30	42	80	69	15
Ga	19	20	21	19	20	20	22	18
As	3	4	3	4	8	5	222	129
Rb	211	100	86	111	112	103	57	42
Sr	285	759	750	676	742	747	35	45
Y	24	21	13	15	19	23	43	42
Zr	186	217	221	201	226	221	261	355
Nb	21	16	15	17	17	16	21	26
Ba	1184	1382	1589	1519	1626	1479	118	79
La	35	44	46	50	46	47	79	66
Ce	66	85	85	82	85	90	124	111
Nd	28	34	33	35	33	35	63	65
Sm	7	9	4	5	6	9	13	0
Pb	27	18	17	24	17	19	5	6
Th	21	16	16	15	14	15	14	18
U	8	5	4	3	5	5	2	4

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	04EB 095	04EB 096	04EB 097	04EB 099	04EB 102	04EB 103	04EB 104a	04EB 104b
Unit Name	Tmd	Tmd	Tbr	Tbr	Tut	Tpd	Tbda	Tbda
Alteration	Alt							
wt.%								
SiO2	53.79	53.25	74.58	74.55	64.73	63.34	67.85	64.87
TiO2	1.29	1.34	0.13	0.15	0.76	0.80	0.74	0.81
Al2O3	16.58	14.91	13.16	13.25	16.91	16.43	15.04	16.01
Fe2O3	2.34	7.48	1.33	1.65	3.85	4.38	5.10	5.22
MnO	0.13	0.09	0.03	0.04	0.02	0.07	0.04	0.04
MgO	0.48	5.95	0.16	0.40	0.37	1.33	0.37	0.50
CaO	12.14	6.78	1.35	1.55	3.55	4.59	1.97	3.52
Na2O	0.32	3.24	3.29	3.01	2.94	2.93	2.02	2.85
K2O	1.21	3.18	5.04	5.06	4.69	3.51	7.50	4.70
P2O5	0.33	0.37	0.07	0.06	0.23	0.27	0.24	0.30
LOI	14.49	6.02	0.93	1.12	1.95	2.19	0.81	0.71
Total	103.08	102.6	100.06	100.84	99.99	99.83	101.68	99.51
ppm								
F	0	1568	0	670	472	248		455
S	72	72	341	1267	33	64		54
Cl	67	104	37	99	50	187		46
Sc	20	22	0	0	10	10		8
V	164	146	6	20	95	94		83
Cr	270	305	5	16	14	8		8
Co	1	14	10	13	5	5		14
Ni	30	127	2	1	3	2		3
Cu	37	41	5	1	5	3		4
Zn	61	73	34	41	47	76		52
Ga	19	19	16	16	20	21		19
As	22	6	5	5	4	4		7
Rb	63	106	224	216	121	98		112
Sr	88	610	231	217	675	764		590
Y	41	35	19	19	17	23		19
Zr	240	250	116	124	212	215		203
Nb	20	15	19	19	15	15		15
Ba	328	874	1482	735	1945	1439		1525
La	54	50	31	28	45	47		48
Ce	84	95	53	56	79	93		97
Nd	43	49	22	23	30	38		33
Sm	13	12	3	3	5	8		6
Pb	13	5	34	29	17	19		17
Th	12	10	22	21	14	16		14
U	0	3	7	4	4	5		5

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks

Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	04EB 105	04EB 106	04EB 107	04EB 108	04EB 109	04EB 110	04EB 111	04EB 112
Unit Name	Tl	Tpd	Tpd	Tpd	Tpd	Tpd	Tpd	Tpd
Alteration								
wt.%								
SiO2	61.04	62.25	63.91	63.86	65.49	67.28	66.61	69.76
TiO2	0.79	0.75	0.73	0.69	0.79	0.74	0.72	0.64
Al2O3	17.09	16.35	15.44	16.10	16.03	15.69	15.07	14.88
Fe2O3	5.15	5.40	4.08	4.22	4.88	3.93	4.03	3.02
MnO	0.04	0.09	0.06	0.07	0.03	0.03	0.08	0.03
MgO	1.74	1.69	1.36	1.47	0.40	0.45	0.51	0.40
CaO	4.90	4.59	4.83	4.32	3.28	3.96	2.90	3.48
Na2O	3.11	3.02	2.71	3.12	2.77	3.02	2.66	2.92
K2O	4.46	3.00	2.78	3.32	5.22	3.47	5.32	3.47
P2O5	0.36	0.30	0.29	0.27	0.30	0.29	0.22	0.26
LOI	1.79	2.15	2.63	1.68	0.72	0.65	1.26	1.12
Total	100.47	99.58	98.82	99.11	99.9	99.49	99.38	99.98
ppm								
F	471	267	212	149	300	417	120	290
S	106	127	26	99	12	63	138	38
Cl	86	147	181	158	52	59	56	60
Sc	13	8	8	9	9	10	10	9
V	130	78	65	79	81	76	94	89
Cr	10	16	14	8	6	6	10	8
Co	12	5	4	4	13	12	12	14
Ni	3	5	2	2	2	3	4	2
Cu	5	4	3	4	3	4	6	2
Zn	84	83	73	69	48	47	68	49
Ga	21	21	22	21	19	19	18	18
As	4	3	5	5	3	3	4	4
Rb	170	102	90	106	139	106	168	114
Sr	725	836	876	790	565	678	542	621
Y	24	19	19	19	17	21	20	19
Zr	218	214	224	212	204	205	194	202
Nb	17	15	16	14	14	14	14	14
Ba	1744	1651	1394	1634	2033	1471	1776	1403
La	44	45	48	43	44	46	39	40
Ce	95	93	95	90	87	87	84	78
Nd	34	36	37	35	30	34	31	32
Sm	8	9	7	7	7	5	8	5
Pb	22	18	19	19	17	18	18	17
Th	17	14	15	16	14	14	13	13
U	7	5	6	5	4	4	4	5

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	04EB 114	04EB 117	04EB 118	04EB 119	04EB 120a	04EB 120b	04EB 121
Unit Name	Tpd	Tbda	Tpd	Tpd	Tbda	Tbda	Tpd
Alteration							
wt.%							
SiO2	67.01	71.06	71.17	71.08	67.72	71.92	63.24
TiO2	0.69	0.46	0.64	0.64	0.68	0.43	0.85
Al2O3	16.07	14.24	15.56	15.54	16.15	13.01	16.18
Fe2O3	2.66	2.79	1.03	0.96	2.51	3.39	3.38
MnO	0.02	0.03	0.01	0.02	0.02	0.03	0.09
MgO	0.44	0.73	0.20	0.12	0.18	0.90	0.36
CaO	3.67	2.77	3.54	3.72	3.99	2.84	6.61
Na2O	3.08	2.78	3.03	3.19	3.30	2.14	3.08
K2O	4.19	3.63	3.65	3.39	3.49	3.35	3.56
P2O5	0.28	0.17	0.24	0.23	0.23	0.14	0.28
LOI	1.15	0.95	0.83	0.70	0.85	2.14	3.62
Total	99.27	99.61	99.9	99.59	99.13	100.28	101.25
ppm							
F	433	545	214	102	201	695	62
S	396	100	79	88	68	125	46
Cl	61	108	40	53	77	97	53
Sc	9	7	8	7	9	8	15
V	70	56	49	77	90	63	111
Cr	9	8	8	7	12	9	17
Co	13	16	9	13	10	11	4
Ni	1	2	1	0	2	3	2
Cu	4	0	2	3	4	3	6
Zn	29	43	35	46	34	50	55
Ga	19	17	17	17	19	17	20
As	5	5	4	5	10	2	5
Rb	121	140	105	103	108	126	124
Sr	702	384	647	673	724	387	629
Y	18	23	15	15	15	17	28
Zr	210	194	203	204	199	169	208
Nb	15	16	15	16	15	15	16
Ba	2678	1287	1782	1719	1647	1363	1415
La	41	39	39	39	43	33	44
Ce	72	68	70	74	76	53	81
Nd	28	29	28	32	29	24	32
Sm	5	5	3	3	5	4	11
Pb	17	22	16	17	19	10	18
Th	13	20	13	14	14	17	14
U	5	5	5	3	4	2	4

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	04EB 123	04EB 124	04EB 125	04EB 126	04EB 127	04EB 129	04EB 130	04EB 131
Unit Name	Ta	Ta	Ta	Ta	Ta	Tpd	Tmh	Tmh
Alteration								
wt.%								
SiO2	61.76	61.37	61.04	60.89	62.58	64.94	66.44	75.27
TiO2	0.87	0.90	0.95	0.88	0.87	0.71	0.49	0.01
Al2O3	15.19	15.26	15.36	14.82	14.91	16.24	15.73	13.43
Fe2O3	6.26	6.48	6.90	6.57	6.35	4.39	3.40	1.00
MnO	0.09	0.08	0.09	0.09	0.09	0.07	0.05	0.09
MgO	2.52	2.64	2.65	2.74	2.68	1.53	0.85	0.17
CaO	4.84	4.82	5.29	5.06	5.01	4.33	3.79	0.68
Na2O	2.45	2.48	2.41	2.35	2.41	3.13	2.80	3.49
K2O	4.20	4.17	4.03	4.22	4.12	3.35	3.50	4.68
P2O5	0.41	0.48	0.46	0.43	0.45	0.26	0.15	0.02
LOI	1.03	1.02	0.91	0.69	0.91	1.39	3.55	0.93
Total	99.61	99.7	100.08	98.72	100.37	100.33	100.74	99.75
ppm								
F	223	202	318	133	278	226	392	1047
S	114	66	106	260	42	47	10	0
Cl	73	80	85	180	72	169	74	53
Sc	15	14	16	14	14	9	6	0
V	132	139	146	133	138	85	43	0
Cr	28	25	24	29	37	8	5	2
Co	19	20	18	13	19	4	2	11
Ni	7	5	5	7	7	2	1	0
Cu	7	8	8	5	7	2	1	0
Zn	68	70	70	72	65	69	73	52
Ga	19	19	19	20	19	20	22	21
As	3	2	2	2	3	6	2	8
Rb	142	137	133	140	139	107	122	363
Sr	592	594	644	631	585	775	583	18
Y	23	23	24	24	24	19	12	25
Zr	180	180	183	184	179	211	194	69
Nb	13	13	12	13	12	15	17	42
Ba	1198	1217	1226	1248	1252	1509	949	10
La	35	27	29	30	31	52	32	0
Ce	70	66	66	67	63	95	68	28
Nd	26	26	27	27	25	35	28	0
Sm	6	6	7	10	7	8	7	2
Pb	16	18	17	19	18	19	19	43
Th	9	8	8	8	9	15	10	21
U	4	4	5	4	4	5	4	0

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	04EB 132	04EB 133	04EB 135	04EB 136	04EB 137	04EB 138	04EB 139	04EB 140
Unit Name	Trr	Tpd	Tpd	Tpd	Tpd	Tpd	Tpd	Tpd
Alteration		Alt						Alt
wt.%								
SiO2	65.30	62.01	66.59	66.03	62.71	63.22	67.27	62.77
TiO2	0.70	0.73	0.72	0.74	0.77	0.78	0.76	0.80
Al2O3	14.57	14.55	15.98	16.09	16.20	16.58	16.87	15.14
Fe2O3	5.46	4.52	3.67	5.09	4.64	5.29	2.46	3.55
MnO	0.08	0.05	0.02	0.04	0.07	0.04	0.04	0.05
MgO	2.13	0.48	0.29	0.46	1.54	0.39	0.29	0.30
CaO	4.03	3.28	3.70	3.66	4.61	3.15	3.68	3.78
Na2O	2.46	2.06	2.98	3.08	2.81	2.89	3.07	1.66
K2O	4.39	8.71	4.29	4.14	3.21	5.85	4.78	9.25
P2O5	0.33	0.34	0.26	0.28	0.30	0.28	0.31	0.36
LOI	0.53	2.52	0.67	0.67	2.83	1.59	0.88	3.08
Total	99.98	99.25	99.15	100.27	99.69	100.06	100.4	100.73
ppm								
F	331	188	283		216	258	175	238
S	41	1684	20		106	174	205	194
Cl	124	60	57		192	68	74	47
Sc	11	9	8		10	8	9	8
V	112	100	59		90	106	65	90
Cr	24	6	13		8	8	14	7
Co	19	14	8		8	16	12	15
Ni	5	2	1		2	5	1	2
Cu	5	4	4		4	5	4	8
Zn	65	65	34		74	87	35	56
Ga	18	17	19		20	20	19	17
As	3	11	3		5	4	5	5
Rb	167	160	119		99	162	125	188
Sr	493	317	702		735	543	684	302
Y	22	19	16		21	15	17	23
Zr	170	170	205		214	208	218	172
Nb	15	12	15		15	14	16	13
Ba	1107	2327	2003		1545	2490	1981	1528
La	33	36	42		44	39	42	38
Ce	68	82	88		93	92	92	77
Nd	28	26	31		35	30	33	28
Sm	5	7	5		7	4	2	6
Pb	19	17	16		18	19	18	16
Th	11	10	12		16	14	12	11
U	5	3	4		5	4	4	3

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash,
Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry,
Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt,
Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	04EB 141	04EB 142a	04EB 142b	04EB 142c	04EB 143	04EB 147	04EB 148	04EB 149
Unit Name	Tpd	Tpd	Tpd	Tpd	Tbp	Tbda	Tav	Tav
Alteration					Alt		Alt	Alt
wt.%								
SiO2	65.17	62.28	69.84	68.00	65.64	71.63	62.96	70.75
TiO2	0.81	0.89	0.76	0.65	0.70	0.43	0.77	0.70
Al2O3	17.07	16.38	14.08	15.46	16.78	13.64	16.44	15.38
Fe2O3	3.44	5.46	2.68	3.57	2.99	2.26	5.00	0.85
MnO	0.02	0.23	0.09	0.02	0.04	0.03	0.09	0.01
MgO	0.28	2.15	0.37	0.53	0.80	0.68	1.44	0.20
CaO	4.38	4.92	2.99	3.02	4.22	2.38	4.46	3.80
Na2O	3.19	2.79	2.24	3.12	3.10	2.09	3.18	3.03
K2O	3.62	3.18	3.50	3.74	3.17	5.38	3.36	3.10
P2O5	0.27	0.30	0.22	0.23	0.35	0.14	0.26	0.28
LOI	1.29	1.99	3.05	1.63	3.24	1.22	1.87	1.95
Total	99.54	100.56	99.83	99.98	101.02	99.88	99.82	100.04
ppm								
F	376	0	210	391	375	206	183	288
S	22	115	199	279	1222	708	42	230
Cl	66	205	42	48	89	84	150	46
Sc	11	13	9	7	10	0	9	10
V	92	101	71	77	65	47	76	62
Cr	9	26	21	20	7	9	6	5
Co	2	5	12	12	6	12	5	0
Ni	3	8	3	3	2	2	2	0
Cu	5	6	3	5	3	3	4	0
Zn	47	74	39	27	60	35	80	24
Ga	21	21	16	18	20	16	21	17
As	4	4	9	4	5	10	4	5
Rb	109	122	99	118	127	164	134	95
Sr	718	651	438	543	689	313	734	630
Y	19	24	20	13	21	23	24	23
Zr	218	219	196	204	234	161	259	242
Nb	15	16	15	16	17	15	16	16
Ba	1479	1273	1850	1631	1755	880	1513	1887
La	48	41	39	36	43	51	49	44
Ce	91	88	64	74	88	87	105	87
Nd	34	35	27	27	34	36	39	34
Sm	7	9	4	3	3	3	7	2
Pb	17	17	14	21	20	19	19	16
Th	15	14	11	18	18	21	17	15
U	4	5	3	4	5	5	5	4

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	04EB 150a	04EB 150b	04EB 151	04EB 153	04EB 154	04EB 155	04EB 156	04EB 157
Unit Name	Tbda	Tbda	Tav	Ta	Ta	Ta	Ta	Ta
Alteration								
wt.%								
SiO2	63.90	70.22	67.85	62.59	62.48	63.51	56.80	61.30
TiO2	0.68	0.60	0.74	0.80	0.88	0.85	0.96	0.71
Al2O3	16.58	15.02	15.92	14.55	15.27	15.07	16.51	15.88
Fe2O3	3.66	1.74	1.65	5.93	6.11	6.12	7.47	5.56
MnO	0.06	0.02	0.08	0.10	0.10	0.09	0.12	0.09
MgO	1.28	0.58	0.27	2.44	2.39	2.36	3.17	2.38
CaO	4.10	3.29	4.07	4.85	4.66	4.54	6.67	4.97
Na2O	2.55	2.90	3.11	2.21	2.50	2.43	2.78	2.75
K2O	3.04	3.38	3.24	4.04	4.23	4.34	3.72	4.31
P2O5	0.27	0.26	0.28	0.44	0.46	0.44	0.40	0.32
LOI	3.74	1.35	1.35	1.78	0.50	0.70	0.89	1.08
Total	99.84	99.36	98.55	99.73	99.59	100.43	99.48	99.33
ppm								
F	354	355	283	80	233	211	221	0
S	149	203	395	1525	18	21	31	16
Cl	161	65	55	141	134	103	88	136
Sc	10	6	10	13	13	14	18	13
V	82	62	70	125	136	135	171	123
Cr	29	6	4	22	22	23	20	11
Co	5	5	10	17	22	25	21	20
Ni	10	0	0	6	6	6	5	3
Cu	7	0	4	6	6	8	9	8
Zn	76	30	33	65	67	65	91	75
Ga	22	17	18	18	19	18	20	19
As	4	6	10	3	4	2	2	3
Rb	107	107	105	132	150	152	128	162
Sr	757	563	707	585	592	553	771	643
Y	21	20	26	22	23	23	25	23
Zr	224	202	241	179	184	180	223	213
Nb	18	17	16	13	13	12	15	17
Ba	1682	1952	2459	1359	1267	1175	1397	1411
La	48	40	43	30	28	32	42	43
Ce	82	78	95	61	66	70	108	101
Nd	34	32	36	26	26	27	38	37
Sm	6	3	6	6	7	5	8	7
Pb	21	19	15	18	18	18	16	21
Th	19	15	15	8	8	7	14	17
U	5	4	5	4	4	4	4	7

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	04EB 158	04EB 159	04EB 160	04EB 161	04EB 162a	04EB 162b	04EB 163	04EB 164
Unit Name	Ta	Ta	Barite	Ta	Tsqp	Tsqp	Tpd	Tut
Alteration			Alt			Alt	Alt	
wt.%								
SiO2	61.39	60.93	70.41	63.08	74.59	77.15	67.08	62.59
TiO2	0.89	0.87	0.02	0.85	0.07	0.06	0.81	0.85
Al2O3	15.41	15.26	0.16	15.44	14.26	16.05	16.33	16.41
Fe2O3	6.72	6.31	0.66	6.07	1.42	0.77	2.75	5.45
MnO	0.09	0.09	0.20	0.09	0.05	0.01	0.02	0.04
MgO	2.24	2.72	6.89	2.58	0.23	0.28	0.30	0.58
CaO	4.82	5.48	9.65	4.90	0.48	0.03	2.57	3.41
Na2O	2.47	2.33	0.00	2.60	3.59	0.18	2.45	2.69
K2O	4.25	4.12	0.00	4.35	4.69	2.13	7.31	6.12
P2O5	0.42	0.43	0.05	0.36	0.08	0.04	0.23	0.26
LOI	1.19	1.65	15.40	0.81	1.19	4.47	0.95	1.54
Total	99.88	100.18	103.44	101.13	100.64	101.17	100.77	99.93
ppm								
F	331	17	0	157	748	1465	326	233
S	172	1506	305	40	20	189	149	78
Cl	59	196	60	209	62	56	40	51
Sc	15	14	7	11	0	9	7	9
V	136	132	9	121	5	9	87	90
Cr	27	23	10	28	2	2	5	9
Co	19	20	0	17	18	1	17	15
Ni	7	5	0	6	3	4	1	7
Cu	9	8	0	7	0	1	2	6
Zn	74	67	44	67	23	9	37	69
Ga	19	18	3	18	19	25	17	19
As	3	3	178	3	5	4	7	3
Rb	146	133	0	147	272	188	166	141
Sr	639	619	18	605	61	55	434	526
Y	23	24	2	23	31	19	20	18
Zr	184	185	12	189	60	55	195	197
Nb	13	13	2	14	45	33	14	14
Ba	1364	1284	38	1278	231	1225	2112	1814
La	30	31	0	30	13	0	41	43
Ce	71	71	0	67	38	10	85	95
Nd	26	28	0	27	0	0	31	31
Sm	8	6	5	6	2	0	3	4
Pb	17	17	9	18	18	0	16	18
Th	9	9	1	9	10	9	12	14
U	5	4	0	4	4	0	3	4

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash,
Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry,
Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt,
Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rock XRF analyses

Sample #	04EB 165a	04EB 165b	04EB 165c	04EB 165d	04EB 167	04EB 168	04EB 169	04EB 170
Unit Name	Tsqp	Tsqp	Tsqp	Tsqp	Ta	Ta	Tbda	Tbda
Alteration			Alt				Alt	
wt.%								
SiO2	65.32	62.12	79.67	61.64	56.94	63.33	70.63	70.66
TiO2	0.79	0.82	0.14	0.82	0.92	0.81	0.52	0.53
Al2O3	15.62	15.96	10.90	16.13	16.21	15.16	14.39	15.61
Fe2O3	5.02	5.29	0.44	5.78	7.75	5.97	2.57	2.35
MnO	0.05	0.08	0.00	0.09	0.11	0.09	0.02	0.02
MgO	1.42	1.75	0.12	2.20	3.30	1.50	0.62	0.84
CaO	4.48	4.82	0.33	5.33	6.78	4.43	1.93	2.23
Na2O	2.87	2.78	0.43	3.46	2.72	2.68	2.01	2.26
K2O	3.30	3.39	7.96	2.80	3.73	4.48	7.05	3.95
P2O5	0.22	0.25	0.09	0.29	0.38	0.43	0.14	0.05
LOI	1.27	2.04	0.98	1.19	0.80	1.43	1.15	2.68
Total	99.09	99.3	101.05	99.73	99.64	100.32	101.03	101.16
ppm								
F	342	243	507	118	120	284	398	515
S	48	202	247	631	20	39	72	91
Cl	93	146	114	71	131	58	90	94
Sc	10	10	0	12	15	14	0	0
V	94	100	30	92	155	117	83	75
Cr	13	15	4	82	16	23	6	8
Co	15	12	12	13	20	19	14	6
Ni	9	11	2	37	6	5	2	1
Cu	8	7	0	16	9	7	3	1
Zn	69	73	6	88	81	64	35	54
Ga	19	20	11	20	20	18	17	20
As	4	4	4	4	3	3	8	3
Rb	117	104	143	81	124	150	208	108
Sr	590	637	95	825	767	572	259	352
Y	24	28	13	25	24	23	25	21
Zr	204	209	67	226	223	175	168	203
Nb	16	17	25	15	15	13	14	19
Ba	1375	1887	1918	3379	1401	1261	985	1253
La	43	45	0	54	43	30	46	53
Ce	91	84	22	106	99	67	83	88
Nd	35	33	0	36	36	25	34	38
Sm	6	7	0	6	9	5	3	5
Pb	21	20	0	15	15	18	21	23
Th	16	16	8	14	14	9	19	24
U	6	5	0	5	4	4	2	5

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix C: Major and trace element whole rockXRF analyses

Sample #	04EB 173	04EB 175
Unit Name	Unknown	Unknown
Alteration		
wt.%		
SiO2	68.30	71.14
TiO2	0.38	0.58
Al2O3	14.35	14.63
Fe2O3	3.29	1.73
MnO	0.07	0.02
MgO	1.11	0.52
CaO	2.96	3.34
Na2O	2.55	2.66
K2O	4.81	3.18
P2O5	0.17	0.23
LOI	3.44	2.38
Total	101.42	100.39
ppm		
F	241	362
S	41	331
Cl	149	67
Sc	7	11
V	42	56
Cr	43	5
Co	10	7
Ni	3	0
Cu	0	0
Zn	45	59
Ga	19	16
As	3	5
Rb	212	70
Sr	258	575
Y	26	20
Zr	180	200
Nb	21	15
Ba	1183	2316
La	37	40
Ce	62	69
Nd	26	29
Sm	6	5
Pb	25	19
Th	22	16
U	8	3

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks
Altered Rocks do not appear on figures

Appendix D: Rare earth element analyses, from Als Chemex

Sample #	04EB 039a	04EB 039b	04EB 039c	04EB 040	04EB 041a	04 EB 044	04 EB 045	04EB 046
Unit Name	Tsqp	Tsqp	Tsqp	Tpd	Tbda	Tpd	Tba	Tut
ppm								
La	6.7	64.8	28.1	54.3	53.1	55.1	36.7	18.5
Ce	13.4	144.5	56.6	92.7	95.2	98.7	70.5	37.7
Pr	1.4	17.6	6.9	11	10.8	11.4	8.2	4.9
Nd	5.3	74.8	25.7	37.3	36.4	38.7	30.1	18
Sm	1.2	14.2	4.8	6.7	6	6.7	6	3.9
Eu	0.3	3.3	1	1.5	1.4	1.6	1.3	1
Gd	1.3	10.8	4	5.9	4.7	5.8	5	3.5
Tb	0.3	1.2	0.5	0.7	0.6	0.7	0.7	0.5
Dy	2	3.6	2.9	4	2.6	3.7	4.2	2.8
Ho	0.5	0.5	0.6	0.8	0.5	0.7	0.9	0.5
Er	1.6	1.5	2	2.3	1.3	2	2.5	1.6
Tm	0.3	0.2	0.3	0.3	0.2	0.3	0.4	0.2
Yb	1.7	1.2	2.1	2	1.2	1.7	2.2	1.3
Lu	0.3	0.2	0.3	0.3	0.2	0.3	0.4	0.2

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks

Appendix D: Rare earth element analyses, from Als Chemex

Sample #	04EB 047	04EB 049	04EB 050	04EB 053	04EB 054	04EB 063	04EB 065	04EB 068
Unit Name	Ta	Ta	Tba	Tav	Tav	Ta	Ta	Ta
ppm								
La	36.1	32.9	36.5	55.9	25.4	30.5	35.6	38.2
Ce	69.7	72.8	74.3	106.5	48.2	62.9	69.4	78
Pr	8.5	8.2	8.4	12	5.9	7.6	8.3	9.3
Nd	30.9	34.5	31.4	43	20.7	29.4	30.7	35.9
Sm	6.7	6.8	5.9	7.3	5.2	6.1	6.3	7.1
Eu	1.3	1.5	1.4	1	0.4	1.4	1.3	1.5
Gd	5.3	5.5	5.4	6	4.5	5.1	5.3	6
Tb	0.7	0.8	0.8	0.7	0.7	0.7	0.7	0.9
Dy	4.1	4.1	4.4	3.5	3.8	3.8	4	4.4
Ho	0.8	0.9	0.9	0.6	0.7	0.7	0.8	0.8
Er	2.1	2.4	2.6	1.6	2	2	2.1	2.4
Tm	0.3	0.3	0.4	0.2	0.3	0.3	0.3	0.3
Yb	1.9	2.2	2.4	1.1	1.8	1.8	1.9	2.1
Lu	0.3	0.3	0.4	0.2	0.3	0.3	0.3	0.3

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks

Appendix D: Rare earth element analyss, from Als Chemex

Sample #	04EB 069	04EB 070	04EB 072	04EB 073	04EB 086	04EB 096	04EB 097	04EB 102
Unit Name	Tr	Tb	Tb	Tb	Tbp	Tmd	Tbr	Tut
ppm								
La	42.1	39.7	33.2	43.7	52	53.2	35.1	54.4
Ce	78.6	77.2	70.1	93.8	94.4	111	61.4	95.9
Pr	8.9	10	9.1	12.6	10.2	13.2	6.8	11.4
Nd	29.7	36.7	37.6	50.5	33.9	50	22.5	38.5
Sm	5.7	7.8	8.1	10.8	6.1	9	4.1	6.8
Eu	0.5	1.8	1.8	2.5	1.1	2.2	0.6	1.5
Gd	4.7	6.6	6.3	9.5	5.1	7.4	3.6	5.3
Tb	0.7	0.9	1	1.4	0.7	1	0.5	0.6
Dy	3.9	5	5.5	7.8	3.5	4.8	2.5	3.1
Ho	0.8	0.9	1.2	1.5	0.7	0.9	0.5	0.6
Er	2.2	2.8	3	4.3	1.9	2.6	1.4	1.5
Tm	0.4	0.4	0.5	0.6	0.3	0.4	0.2	0.2
Yb	2.3	2.3	2.7	3.8	1.8	2.2	1.4	1.2
Lu	0.4	0.4	0.4	0.6	0.3	0.3	0.2	0.2

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks

Appendix D: Rare earth element analyses, from Als Chemex

				AlsChemex	AlsChemex			
Sample #	04EB 105	04EB 107	04EB 121	04EB 123	04EB 124	04EB 125	04EB 126	04EB 127
Unit Name	Tl	Tpd	Tpd	Ta	Ta	Ta	Ta	Ta
ppm								
La	52.9	53.8	45.8	35.8	34.1	35.2	33.2	35
Ce	97.9	95.7	90.6	69.6	70.6	69.5	69	68.9
Pr	11.3	10.9	10.6	8.7	8.6	8.6	8.3	8.4
Nd	39.6	37.5	38.2	30.7	32.7	32.4	32.1	31.3
Sm	7.2	6.2	6.6	6.8	6.7	7.1	6.4	6.6
Eu	1.5	1.5	1.7	1.4	1.5	1.5	1.5	1.4
Gd	5.9	5.2	6.9	5.5	6	5.8	5.9	5.3
Tb	0.8	0.6	0.9	0.7	0.8	0.8	0.8	0.8
Dy	3.9	3.2	4.7	4.1	4.2	4.3	4.3	4.2
Ho	0.7	0.6	0.9	0.8	0.8	0.8	0.8	0.8
Er	2.1	1.7	2.9	2.1	2.3	2.2	2.4	2.2
Tm	0.3	0.2	0.4	0.3	0.3	0.3	0.3	0.3
Yb	1.8	1.5	2.4	1.8	2	2	2.1	2
Lu	0.3	0.2	0.4	0.3	0.3	0.3	0.3	0.3

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks

Appendix D: Rare earth element analyses, from Als Chemex

Sample #	04EB 130	04EB 131	04EB 132	04EB 135	04EB 137	04EB 138	04EB 142b	04EB 143
Unit Name	Tmh	Tmh	Trr	Tpd	Tpd	Tpd	Tpd	Tbp
ppm								
La	38.1	9	34.8	48.5	50.8	51.7	46.4	58.1
Ce	68.8	21.1	70.9	92.7	91.8	91.9	83.3	100.5
Pr	8.3	2.4	8.5	10.5	10	9.2	9.3	10.7
Nd	27.3	8.5	31.5	36.5	37.4	34.7	35.1	38.9
Sm	5.3	2.8	6	6	5.8	5	5.8	6.1
Eu	1.2	0.1	1.3	1.6	1.5	1.3	1.4	1.4
Gd	4.1	2.9	5.5	5.4	5.6	4.4	5.3	5.4
Tb	0.5	0.6	0.8	0.7	0.7	0.5	0.7	0.7
Dy	2.3	3.7	3.7	3.1	3.7	2.4	3.6	3.6
Ho	0.4	0.7	0.7	0.6	0.7	0.4	0.7	0.7
Er	1.1	2	2.1	1.6	2	1.2	1.9	1.9
Tm	0.1	0.3	0.3	0.2	0.2	0.1	0.2	0.2
Yb	0.9	1.8	1.8	1.3	1.9	1.2	1.8	1.8
Lu	0.1	0.3	0.3	0.2	0.2	0.1	0.2	0.2

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash,
Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry,
Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt,
Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks

Appendix D: Rare earth element analyses, from Als Chemex

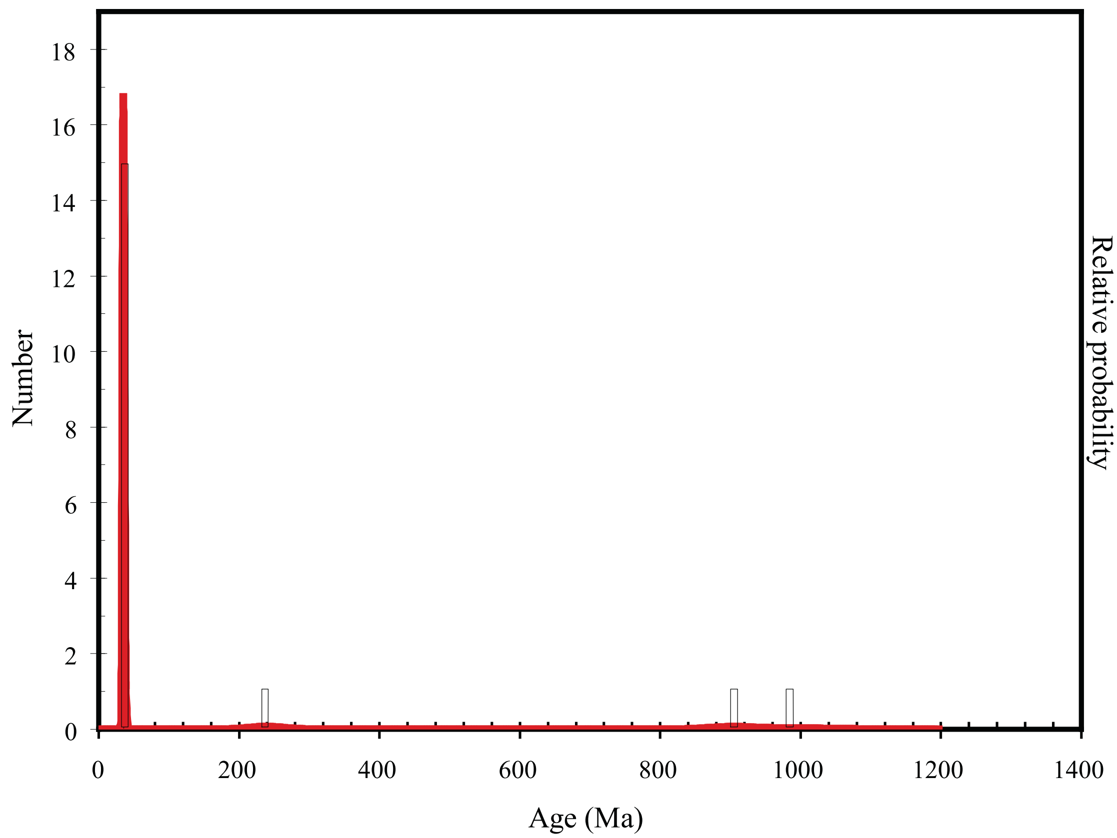
Sample #	04EB 148	04EB 149	04EB 154	04EB 156	04EB 159	04EB 162a	04EB 163	04EB 168
Unit Name	Tav	Tav	Ta	Ta	Ta	Tav	Tpd	Ta
ppm								
La	57.3	54.8	35	53.2	35.7	12.6	54.7	37.1
Ce	104	94.9	65.2	98	67	25.9	95.7	70.1
Pr	11.4	10.6	8.1	11.8	8	3.2	10.5	8.3
Nd	41.9	38.7	31.4	42.6	32.2	11	37.9	32.8
Sm	6.5	6.3	6.2	7.2	6.1	3.2	6	6.3
Eu	1.6	1.6	1.5	1.9	1.5	0.3	1.4	1.4
Gd	6.2	5.7	5.8	7.4	5.7	3.6	5.3	5.5
Tb	0.8	0.7	0.8	0.9	0.7	0.6	0.6	0.7
Dy	4.1	3.8	4.3	4.9	4.2	4.5	3.2	4
Ho	0.7	0.7	0.7	0.9	0.8	0.8	0.5	0.8
Er	2.3	2.1	2.2	2.6	2.2	2.5	1.7	2.1
Tm	0.2	0.3	0.3	0.3	0.2	0.3	0.2	0.2
Yb	2.1	2	1.9	2.3	2	2.7	1.4	1.9
Lu	0.3	0.3	0.3	0.3	0.2	0.4	0.2	0.2

Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks

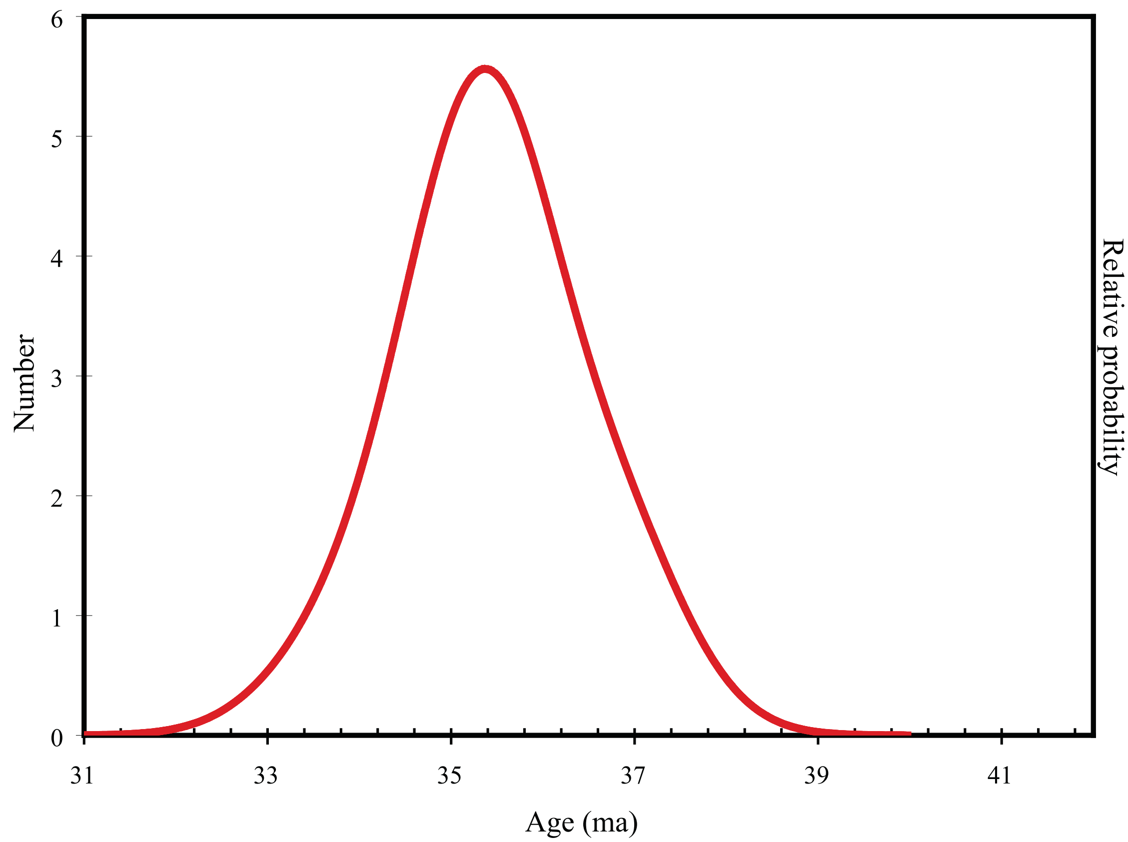
Appendix D: Rare earth element analyses, from Als Chemex

Sample #	04EB 170
Unit Name	Tbda
ppm	
La	57.4
Ce	100
Pr	11.2
Nd	39
Sm	6.4
Eu	1.5
Gd	6.1
Tb	0.8
Dy	3.9
Ho	0.6
Er	1.9
Tm	0.2
Yb	1.7
Lu	0.2

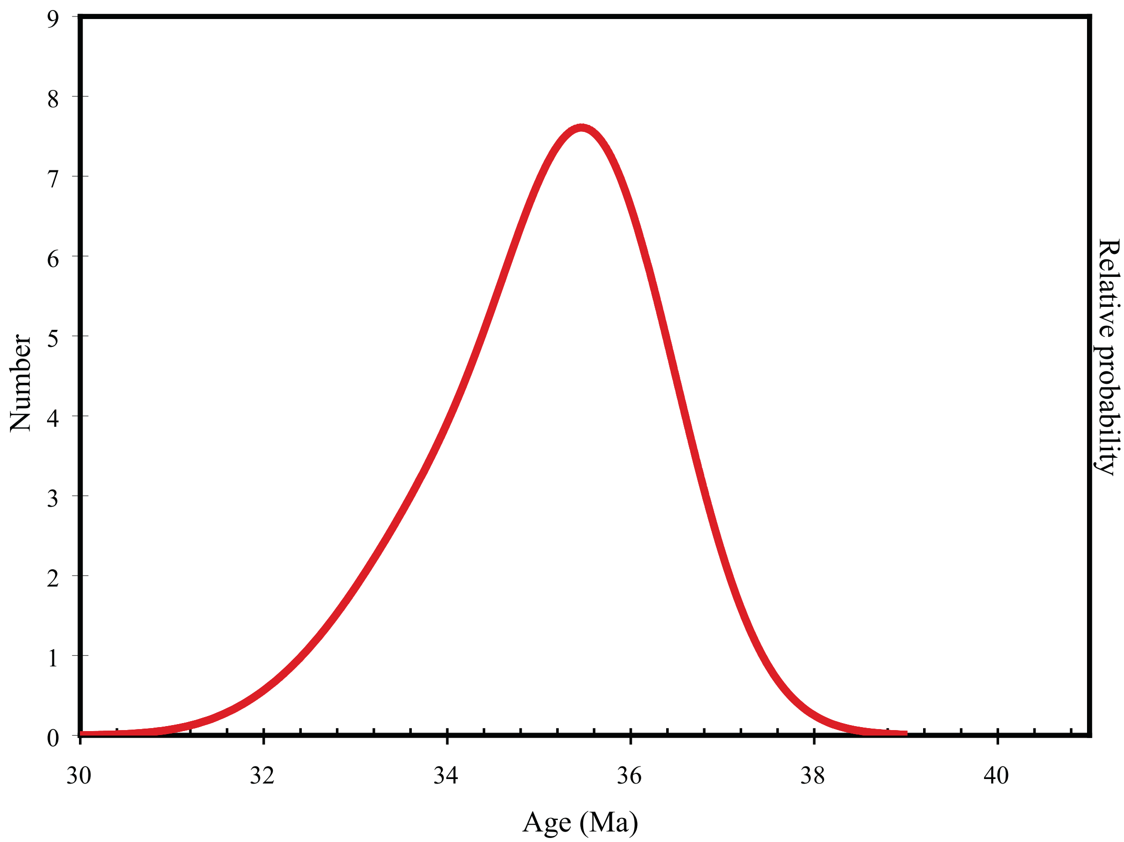
Ta – Mixed Andesite, Tba– Basaltic Andesite, Tpd – Plagioclase Dacite, Tbda– Biotite Porphyry Ash, Tbp – Biotite Porphyry, Tl – Latite Flow, Tbr – Banded Rhyolite, Tsqp - Square Quartz Porphyry, Tr – Rhyolite, Tmd – Mafic and Intermediate Dikes, Trr – Railroad Pass Rhyolite, Tb - Basalt, Tmh – Mount Hope Porphyry, Tut – Tuff at Union, Tav - Altered Volcanic rocks



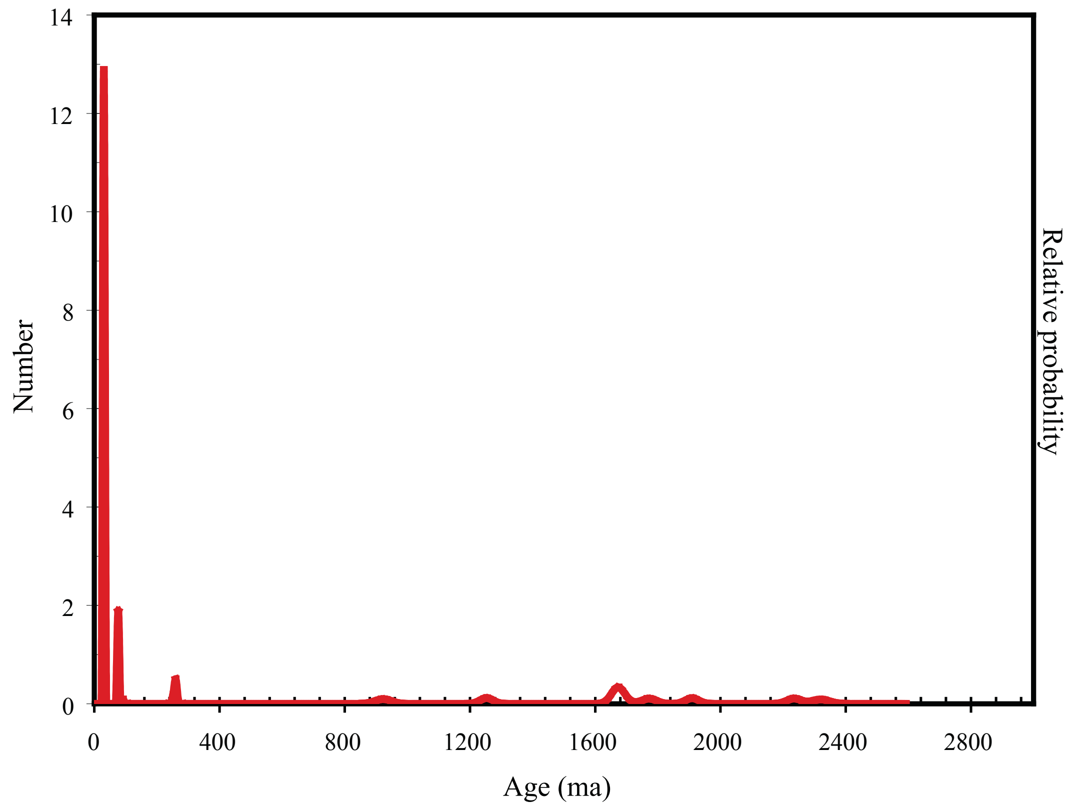
Appendix E.1. U-Pb ages of Biotite Porphyry. Relative propbability diagram of all analyses.



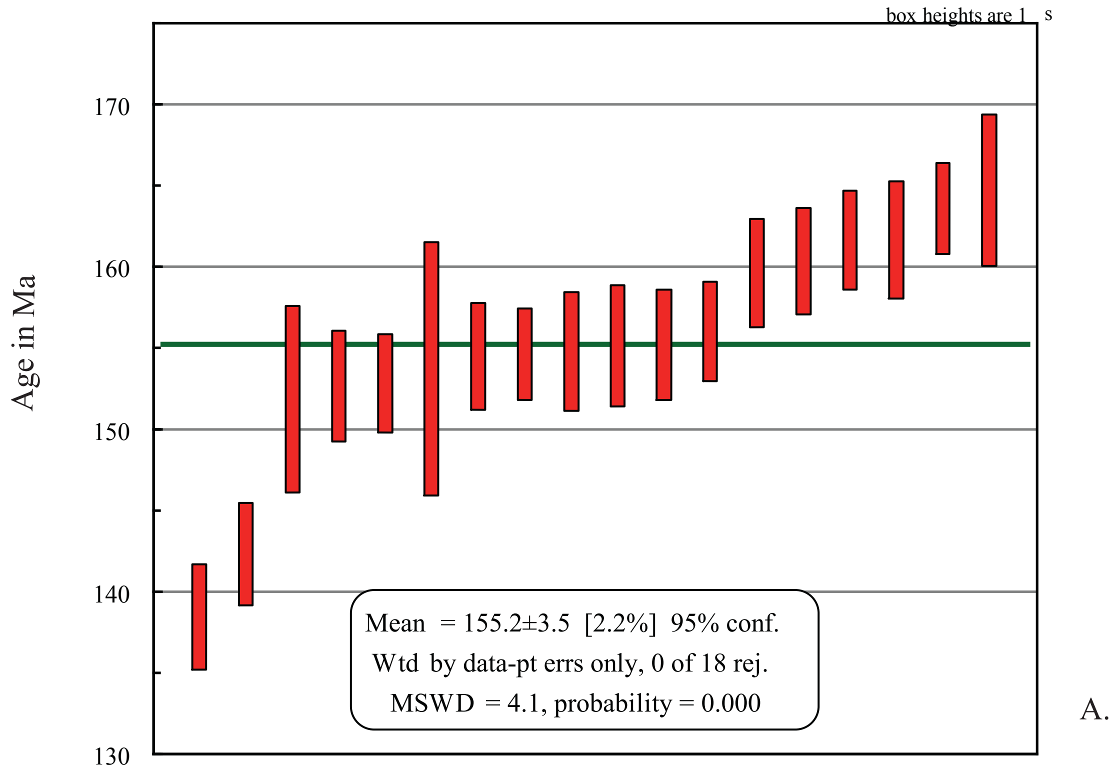
Appendix E.2 U-Pb ages of Biotite Dacite Ash. Relative probability diagram of all analyses.

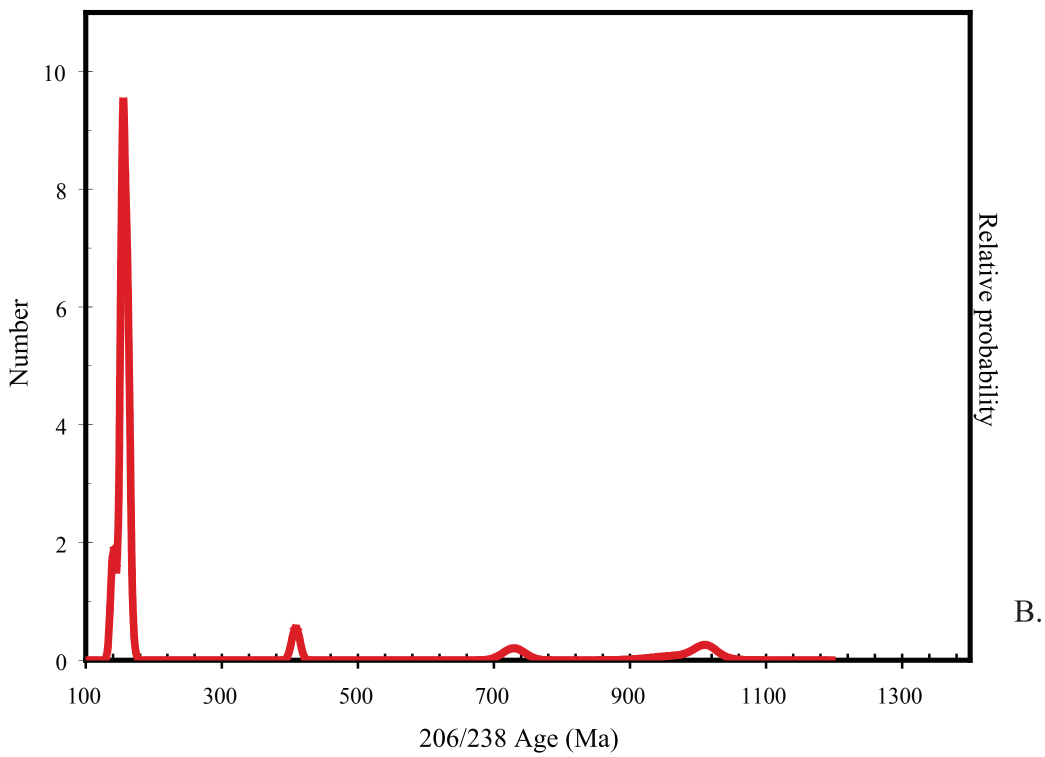


Appendix E.3. U-Pb ages of Plagioclase Dacite. Relative probability diagram of all analyses.



Appendix E.4. U-Pb ages of Mixed Magma Andesite Relative probability diagram of all analyses.





Appendix E.5. U-Pb ages of Square Quartz Porphyry. A. is a graph of the used analyses. B. is a relative probability diagram of all analyses.

Appendix E. Table 1. LA-ICP-MS Data and calculated ages.

Sample # 04EB086
Biotite porphyry

Spot Analysis	Ratios						Ages					
	$^{207}Pb/^{235}U$	±1 σ	$^{206}Pb/^{238}U$	±1 σ	$^{207}Pb/^{206}Pb$	±1 σ	$^{207}Pb/^{235}U$	±1 σ	$^{206}Pb/^{238}U$	±1 σ	$^{207}Pb/^{206}Pb$	±1 σ
04EB86_1a	0.03736	0.00130	0.00551	0.00012	0.04922	0.00096	37.2	1.3	35.4	0.8	158.2	44.9
04EB86_1b	0.03546	0.00111	0.00551	0.00011	0.04669	0.00079	35.4	1.1	35.4	0.7	33.6	39.8
04EB86_1c	0.03582	0.00088	0.00558	0.00010	0.04659	0.00051	35.7	0.9	35.9	0.7	28.0	25.9
04EB86_2a	0.03819	0.00097	0.00573	0.00012	0.04837	0.00052	38.1	1.0	36.8	0.7	117.3	25.1
04EB86_3a	0.03586	0.00120	0.00542	0.00015	0.04801	0.00068	35.8	1.2	34.9	0.9	99.6	33.0
04EB86_3b	0.03664	0.00104	0.00562	0.00011	0.04730	0.00071	36.5	1.0	36.2	0.7	64.3	35.6
04EB86_3c	0.03784	0.00165	0.00572	0.00015	0.04806	0.00126	37.7	1.6	36.7	0.9	102.3	60.8
04EB86_4a	0.04044	0.00154	0.00573	0.00013	0.05122	0.00114	40.3	1.5	36.9	0.8	250.7	50.3
04EB86_4b	0.04726	0.00223	0.00554	0.00015	0.06195	0.00177	46.9	2.2	35.6	1.0	672.5	60.1
04EB86_4c	0.03685	0.00158	0.00549	0.00016	0.04878	0.00113	36.7	1.5	35.3	1.0	137.1	53.7
04EB086_6a	0.03970	0.00100	0.00569	0.00011	0.05063	0.00060	39.5	1.0	36.6	0.7	224.2	27.3
04EB086_6b	0.03963	0.00123	0.00540	0.00014	0.05323	0.00060	39.5	1.2	34.7	0.9	338.6	25.5
04EB086_7a	0.03398	0.00136	0.00539	0.00017	0.04569	0.00087	33.9	1.3	34.7	1.1	0.0	26.6
04EB086_7b	0.03459	0.00132	0.00532	0.00018	0.04718	0.00060	34.5	1.3	34.2	1.2	58.5	30.3
04EB086_8a	0.04797	0.00130	0.00586	0.00014	0.05933	0.00046	47.6	1.3	37.7	0.9	579.4	16.7
Ages not used												
04EB086_5a	0.51153	0.05312	0.03775	0.00390	0.09827	0.00101	419.5	35.1	238.9	24.2	1591.6	19.1
04EB086_5b	2.74402	0.17826	0.16446	0.01025	0.12101	0.00167	1340.5	47.2	981.5	56.5	1971.2	24.3
04EB086_5c	2.28614	0.08580	0.14983	0.00531	0.11066	0.00092	1208.0	26.2	900.0	29.7	1810.3	15.1

Appendix E. Table 1. LA-ICP-MS Data and calculated ages.

Sample # 04EB041
Biotite dacite ash

	Ratios						Ages					
Spot Analysis	$^{207}Pb/^{235}U$	±1 σ	$^{206}Pb/^{238}U$	±1 σ	$^{207}Pb/^{206}Pb$	±1 σ	$^{207}Pb/^{235}U$	±1 σ	$^{206}Pb/^{238}U$	±1 σ	$^{207}Pb/^{206}Pb$	±1 σ
04EB041_1a	0.03625	0.00104	0.00551	0.00010	0.04758	0.00082	36.2	1.0	35.5	0.6	78.2	40.3
04EB041_1b	0.03858	0.00090	0.00547	0.00010	0.05107	0.00058	38.4	0.9	35.2	0.6	244.1	25.8
04EB041_2a	0.03579	0.00110	0.00550	0.00010	0.04709	0.00088	35.7	1.1	35.4	0.7	53.7	43.8
04EB041_2b	0.03614	0.00115	0.00530	0.00011	0.04935	0.00094	36.0	1.1	34.1	0.7	164.4	44.1
04EB041_3a	0.03416	0.00091	0.00539	0.00010	0.04588	0.00068	34.1	0.9	34.6	0.6	0.0	26.5
04EB041_3b	0.03913	0.00121	0.00561	0.00012	0.05046	0.00086	39.0	1.2	36.1	0.8	216.4	39.1
04EB041_3c	0.03593	0.00096	0.00541	0.00010	0.04809	0.00066	35.8	0.9	34.8	0.7	103.7	32.0
04EB041_4a	0.03915	0.00120	0.00548	0.00010	0.05172	0.00094	39.0	1.2	35.2	0.7	273.1	41.2
04EB041_4b	0.03502	0.00093	0.00542	0.00010	0.04673	0.00068	34.9	0.9	34.9	0.6	35.5	34.6
04EB041_5a	0.03744	0.00089	0.00556	0.00009	0.04874	0.00062	37.3	0.9	35.7	0.6	135.4	29.6
04EB041_5b	0.03560	0.00104	0.00558	0.00011	0.04617	0.00077	35.5	1.0	35.8	0.7	5.3	40.8
04EB041_6a	0.04574	0.00140	0.00574	0.00012	0.05765	0.00095	45.4	1.4	36.9	0.8	516.3	36.0
04EB041_7b	0.03638	0.00099	0.00553	0.00010	0.04756	0.00072	36.3	1.0	35.5	0.7	77.4	35.4
04EB041_8a	0.04080	0.00092	0.00573	0.00010	0.05149	0.00051	40.6	0.9	36.8	0.7	262.8	22.4
04EB041_9a	0.03955	0.00131	0.00558	0.00012	0.05123	0.00103	39.4	1.3	35.9	0.7	251.0	45.5
04EB041_9b	0.03733	0.00102	0.00575	0.00012	0.04692	0.00063	37.2	1.0	37.0	0.8	45.3	31.6
04EB041_10a	0.03719	0.00154	0.00548	0.00017	0.04900	0.00107	37.1	1.5	35.3	1.1	147.9	50.2
04EB041_11a	0.03796	0.00120	0.00522	0.00012	0.05250	0.00089	37.8	1.2	33.6	0.8	307.1	38.3

Appendix E. Table 1. LA-ICP-MS Data and calculated ages.

Sample # 04EB044
Plagioclase dacite

	Ratios						Ages					
Spot Analysis	$^{207}Pb/^{235}U$	±1 σ	$^{206}Pb/^{238}U$	±1 σ	$^{207}Pb/^{206}Pb$	±1 σ	$^{207}Pb/^{235}U$	±1 σ	$^{206}Pb/^{238}U$	±1 σ	$^{207}Pb/^{206}Pb$	±1 σ
04EB044_2a	0.04171	0.00147	0.00561	0.00014	0.05391	0.00099	41.5	1.4	36.1	0.9	367.4	40.8
04EB044_2b	0.03862	0.00130	0.00553	0.00014	0.05061	0.00084	38.5	1.3	35.6	0.9	223.2	38.0
04EB044_3a	0.03632	0.00126	0.00552	0.00014	0.04771	0.00082	36.2	1.2	35.5	0.9	84.9	40.5
04EB044_4a	0.03657	0.00126	0.00541	0.00012	0.04898	0.00095	36.5	1.2	34.8	0.8	147.1	44.7
04EB044_4b	0.03898	0.00176	0.00532	0.00013	0.05314	0.00150	38.8	1.7	34.2	0.9	334.9	62.6
04EB044_5a	0.03624	0.00121	0.00559	0.00012	0.04701	0.00090	36.2	1.2	35.9	0.8	49.6	45.3
04EB044_5b	0.03612	0.00152	0.00561	0.00013	0.04668	0.00123	36.0	1.5	36.1	0.8	33.1	61.6
04EB044_6b	0.03539	0.00108	0.00549	0.00013	0.04673	0.00066	35.3	1.1	35.3	0.8	35.7	33.4
04EB044_7b	0.03459	0.00119	0.00510	0.00013	0.04920	0.00082	34.5	1.2	32.8	0.8	157.3	38.8
04EB044_8a	0.03569	0.00126	0.00543	0.00015	0.04765	0.00079	35.6	1.2	34.9	0.9	82.0	38.9
04EB044_9a	0.04207	0.00162	0.00553	0.00017	0.05514	0.00095	41.8	1.6	35.6	1.1	417.8	38.1
04EB044_11a	0.03441	0.00105	0.00523	0.00011	0.04769	0.00077	34.4	1.0	33.6	0.7	84.1	37.6
04EB044_11b	0.03555	0.00106	0.00550	0.00012	0.04684	0.00070	35.5	1.0	35.4	0.8	41.2	35.2
04EB044_11c	0.03632	0.00112	0.00563	0.00012	0.04678	0.00075	36.2	1.1	36.2	0.8	36.7	39.1
04EB044_13a	0.03683	0.00120	0.00551	0.00011	0.04851	0.00092	36.7	1.2	35.4	0.7	124.4	44.0
04EB044_12b	0.03546	0.00153	0.00534	0.00016	0.04814	0.00111	35.4	1.5	34.3	1.0	105.9	53.6

Appendix E. Table 1. LA-ICP-MS Data and calculated ages.

Sample # 04EB123
Mixed magma andesite

	Ratios						Ages					
Spot Analysis	$^{207}Pb/^{235}U$	±1 σ	$^{206}Pb/^{238}U$	±1 σ	$^{207}Pb/^{206}Pb$	±1 σ	$^{207}Pb/^{235}U$	±1 σ	$^{206}Pb/^{238}U$	±1 σ	$^{207}Pb/^{206}Pb$	±1 σ
04EB123_1a	0.04245	0.00239	0.00488	0.00013	0.06315	0.00248	42.2	2.3	31.4	0.8	713.2	81.2
04EB123_1b	0.03361	0.00107	0.00509	0.00008	0.04790	0.00104	33.6	1.1	32.7	0.5	94.3	50.4
04EB123_1c	0.03475	0.00148	0.00510	0.00011	0.04945	0.00145	34.7	1.5	32.8	0.7	169.0	66.9
04EB123_2a	0.03382	0.00098	0.00490	0.00007	0.05008	0.00099	33.8	1.0	31.5	0.4	198.8	45.2
04EB123_2b	0.03196	0.00136	0.00477	0.00012	0.04860	0.00132	31.9	1.3	30.7	0.8	128.5	62.8
04EB123_2c	0.03169	0.00105	0.00486	0.00009	0.04727	0.00100	31.7	1.0	31.3	0.6	63.1	49.5
04EB123_3a	0.03241	0.00096	0.00499	0.00008	0.04711	0.00093	32.4	0.9	32.1	0.5	54.9	46.5
04EB123_3b	0.03511	0.00094	0.00517	0.00007	0.04923	0.00087	35.0	0.9	33.3	0.5	158.9	41.0
04EB123_7a	0.03260	0.00103	0.00485	0.00011	0.04876	0.00081	32.6	1.0	31.2	0.7	136.2	38.4
04EB123_7b	0.03289	0.00124	0.00481	0.00015	0.04963	0.00082	32.9	1.2	30.9	1.0	177.8	38.1
04EB123_7c	0.03395	0.00099	0.00511	0.00011	0.04817	0.00074	33.9	1.0	32.9	0.7	107.5	36.1
Ages not used												
04EB123_9a	0.07794	0.00138	0.01176	0.00019	0.04807	0.00022	76.2	1.3	75.4	1.2	102.8	10.6
04EB123_5a	0.08034	0.00142	0.01224	0.00019	0.04761	0.00029	78.5	1.3	78.4	1.2	79.9	14.4
04EB123_9b	0.09217	0.00151	0.01386	0.00019	0.04823	0.00032	89.5	1.4	88.7	1.2	110.4	15.4
04EB123_5b	0.45339	0.00942	0.04095	0.00076	0.08029	0.00055	379.7	6.6	258.7	4.7	1204.2	13.4
04EB123_5c	1.93054	0.06193	0.15394	0.00470	0.09096	0.00066	1091.7	21.2	923.0	26.2	1445.7	13.8
04EB123_4a	2.66601	0.06131	0.21453	0.00404	0.09013	0.00091	1319.1	16.8	1252.9	21.4	1428.3	19.2
04EB123_10b	4.41561	0.06603	0.29604	0.00409	0.10818	0.00041	1715.3	12.3	1671.6	20.3	1769.0	7.0
04EB123_8b	4.49031	0.06768	0.29611	0.00409	0.10998	0.00045	1729.2	12.4	1672.0	20.3	1799.1	7.5
04EB123_8a	4.51883	0.08536	0.29734	0.00523	0.11022	0.00053	1734.4	15.6	1678.1	25.9	1803.1	8.8
04EB123_10a	4.74985	0.07864	0.31641	0.00484	0.10888	0.00048	1776.1	13.8	1772.2	23.7	1780.7	8.0
04EB123_6a	9.45801	0.13477	0.34473	0.00454	0.19899	0.00070	2383.5	13.0	1909.4	21.7	2817.9	5.7
04EB123_6c	11.51088	0.15632	0.41434	0.00519	0.20149	0.00068	2565.5	12.6	2234.7	23.6	2838.3	5.5
04EB123_6b	12.02090	0.19266	0.43329	0.00636	0.20122	0.00090	2606.0	14.9	2320.5	28.5	2836.1	7.3

Appendix E. Table 1. LA-ICP-MS Data and calculated ages.

Sample # 04JA156
Square quartz porphyry

Spot Analysis	Ratios						Ages					
	$^{207}Pb/^{235}U$	±1 σ	$^{206}Pb/^{238}U$	±1 σ	$^{207}Pb/^{206}Pb$	±1 σ	$^{207}Pb/^{235}U$	±1 σ	$^{206}Pb/^{238}U$	±1 σ	$^{207}Pb/^{206}Pb$	±1 σ
04JA156_4b	0.17684	0.00590	0.02170	0.00052	0.05915	0.00098	165.3	5.1	138.4	3.3	572.6	35.8
04JA156_4a	0.16614	0.00512	0.02232	0.00050	0.05405	0.00080	156.1	4.4	142.3	3.2	373.0	33.0
04JA156_1a	0.16463	0.00938	0.02384	0.00092	0.05009	0.00154	154.8	8.1	151.9	5.8	199.1	69.7
04JA156_9a	0.16560	0.00707	0.02397	0.00055	0.05011	0.00131	155.6	6.1	152.7	3.4	200.3	59.5
04JA156_5b	0.17292	0.00506	0.02399	0.00048	0.05228	0.00074	162.0	4.4	152.8	3.1	297.5	32.2
04JA156_1b	0.15275	0.01023	0.02414	0.00124	0.04589	0.00144	144.3	9.0	153.7	7.8	3.5	62.7
04JA156_9b	0.16321	0.00647	0.02425	0.00052	0.04880	0.00117	153.5	5.6	154.5	3.3	138.4	55.1
04JA156_8a	0.16306	0.00456	0.02428	0.00045	0.04871	0.00069	153.4	4.0	154.6	2.8	134.0	33.0
04JA156_1c	0.16565	0.00561	0.02430	0.00058	0.04944	0.00084	155.6	4.9	154.8	3.7	169.0	39.2
04JA156_4c	0.16681	0.00706	0.02436	0.00059	0.04972	0.00126	156.6	6.1	155.1	3.7	182.0	57.8
04JA156_3b	0.18921	0.00646	0.02437	0.00054	0.05635	0.00105	176.0	5.5	155.2	3.4	466.3	40.9
04JA156_4d	0.17230	0.00585	0.02450	0.00049	0.05100	0.00099	161.4	5.1	156.0	3.1	240.8	43.9
04JA156_7b	0.19110	0.00601	0.02507	0.00053	0.05528	0.00088	177.6	5.1	159.6	3.3	423.4	35.2
04JA156_7a	0.18191	0.00611	0.02519	0.00052	0.05237	0.00097	169.7	5.2	160.4	3.3	301.5	41.7
04JA156_8b	0.17515	0.00574	0.02540	0.00049	0.05002	0.00093	163.9	4.9	161.7	3.1	195.9	42.7
04JA156_3a	0.18294	0.00703	0.02540	0.00057	0.05227	0.00118	170.6	6.0	161.7	3.6	297.2	50.6
04JA156_8c	0.17899	0.00568	0.02571	0.00045	0.05049	0.00094	167.2	4.9	163.6	2.8	217.7	42.4
04JA156_5a	0.22250	0.01030	0.02589	0.00074	0.06233	0.00164	204.0	8.5	164.8	4.7	685.6	55.0
Ages not used												
04JA156_11a	0.50373	0.01169	0.06547	0.00100	0.05580	0.00062	414.2	7.9	408.8	6.0	444.6	24.6
04JA156_2a	1.19528	0.03415	0.11979	0.00287	0.07240	0.00076	798.4	15.7	729.3	16.5	997.3	21.2
04JA156_6a	1.84120	0.11209	0.16350	0.00752	0.08167	0.00238	1060.3	39.3	976.2	41.5	1237.7	56.1
04JA156_6b	1.70584	0.04204	0.16986	0.00299	0.07284	0.00080	1010.7	15.7	1011.3	16.5	1009.4	22.0

Appendix F: Table 1 Electron microprobe analyses of olivine

Sample #	04 EB 050					
Analysis #	EB 050 oli1b	EB 050 oli2a	EB 050 oli5a	EB 050 oli5d	EB 050 oli5e	EB 050 oli6b
Unit Name	Tba	Tba	Tba	Tba	Tba	Tba
wt. %						
SiO2	38.53	38.87	40.09	39.88	40.68	39.79
TiO2	0.04	0.01	0.00	0.01	0.00	0.03
Al2O3	0.10	0.41	0.56	0.35	0.12	0.34
FeO	16.31	13.53	14.00	13.47	13.33	16.52
MnO	0.26	0.20	0.17	0.20	0.17	0.22
MgO	42.47	44.51	45.32	45.59	46.04	44.10
CaO	0.17	0.13	0.14	0.12	0.15	0.18
Total	97.88	97.66	100.27	99.60	100.50	101.18
Cations						
Si	1.00	0.99	1.00	1.00	1.01	0.99
Ti	0.00	0.00	0.00	0.00	0.00	0.00
Al	0.00	0.01	0.02	0.01	0.00	0.01
Fe	0.35	0.29	0.29	0.28	0.28	0.35
Mn	0.01	0.00	0.00	0.00	0.00	0.01
Mg	1.64	1.70	1.68	1.70	1.70	1.64
Ca	0.01	0.00	0.00	0.00	0.00	0.01
Total	3.00	3.00	2.99	3.00	2.99	3.00
End Members						
%Fo	82.23	85.40	85.24	85.74	86.05	82.63
%Fa	17.72	14.57	14.77	14.21	13.98	17.37

Ta – Mixed Magma Andesite, Tba– Basaltic Andesite

Appendix F: Table 1 Electron microprobe analyses of olivine

Sample #	04 EB 064				04 EB 125	
Analysis #	EB 064 oli1b	EB 064 oli1c	EB 064 oli1f	EB 064 oli3b	EB 125 oli1c	EB 125 oli1d
Unit Name	Ta	Ta	Ta	Ta	Ta	Ta
wt. %						
SiO2	38.00	38.35	39.21	40.13	37.64	38.23
TiO2	0.04	0.01	0.02	0.01	0.00	0.00
Al2O3	0.14	0.17	0.09	0.34	4.63	1.24
FeO	21.02	21.25	20.89	21.22	20.16	20.75
MnO	0.25	0.29	0.27	0.24	0.26	0.27
MgO	39.41	39.75	41.04	39.50	38.38	39.23
CaO	0.14	0.18	0.18	0.23	0.14	0.17
Total	98.98	99.99	101.70	101.67	101.21	99.88
Cations						
Si	0.99	0.99	1.00	1.02	0.95	0.99
Ti	0.00	0.00	0.00	0.00	0.00	0.00
Al	0.00	0.01	0.00	0.01	0.14	0.04
Fe	0.46	0.46	0.44	0.45	0.43	0.45
Mn	0.01	0.01	0.01	0.01	0.01	0.01
Mg	1.54	1.53	1.55	1.49	1.45	1.51
Ca	0.00	0.01	0.01	0.01	0.00	0.01
Total	3.00	3.00	3.00	2.98	2.98	2.99
End Members						
%Fo	76.91	76.87	77.75	76.89	77.17	77.07
%Fa	23.01	23.05	22.21	23.17	22.74	22.87

Ta – Mixed Magma Andesite, Tba– Basaltic Andesite

Appendix F: Table 1 Electron microprobe analyses of olivine

Sample #	04 EB 126			
Analysis #	EB 126 oli1b	EB 126 oli1c	EB 126 oli2b	EB 126 oli3b
Unit Name	Ta	Ta	Ta	Ta
wt. %				
SiO2	37.73	40.07	38.71	38.10
TiO2	0.03	0.00	0.04	0.02
Al2O3	0.27	0.14	2.10	0.03
FeO	19.58	19.20	19.43	19.96
MnO	0.26	0.28	0.26	0.26
MgO	39.83	42.18	40.51	40.54
CaO	0.18	0.17	0.21	0.19
Total	97.88	102.04	101.26	99.08
Cations				
Si	0.99	1.00	0.98	0.99
Ti	0.00	0.00	0.00	0.00
Al	0.01	0.00	0.06	0.00
Fe	0.43	0.40	0.41	0.43
Mn	0.01	0.01	0.01	0.01
Mg	1.56	1.58	1.53	1.57
Ca	0.01	0.00	0.01	0.01
Total	3.00	2.99	2.99	3.01
End Members				
%Fo	78.36	79.60	78.81	78.34
%Fa	21.61	20.33	21.20	21.64

Ta – Mixed Magma Andesite, Tba– Basaltic Andesite

Appendix F: Table 2 Electron microprobe analyses of garnet

Sample #	04 EB 032				04 EB 064		
Analysis#	eb032 garn1a	eb032 garn1b	eb032 garn3a	eb032 garn4a	eb064 garn1a	eb064 garn1f	eb064 garn1l
Unit Name	Tbda	Tbda	Tbda	Tbda	Ta	Ta	Ta
wt. %							
SiO2	37.24	38.43	37.12	37.21	35.76	35.60	37.12
TiO2	0.14	0.16	0.05	0.14	0.00	0.00	0.02
Al2O3	21.92	22.44	21.09	21.25	21.09	22.13	22.03
FeO	31.09	32.22	31.42	31.08	31.61	30.95	31.05
MnO	0.33	0.61	0.87	0.32	7.33	7.12	7.18
MgO	6.86	6.37	5.51	6.57	1.62	1.56	1.69
CaO	1.67	1.76	1.76	1.61	1.78	1.68	1.70
Y	0.01	0.02	0.00	0.00	0.03	0.06	0.11
Total	99.25	102.00	97.83	98.18	99.22	99.10	100.88
Cations							
Si	5.89	5.93	5.99	5.95	5.89	5.84	5.95
Ti	0.02	0.02	0.01	0.02	0.00	0.00	0.00
Al	4.11	4.16	4.24	4.16	4.35	4.24	4.16
Fe	4.09	4.08	4.01	4.01	4.09	4.28	4.16
Mn	0.04	0.08	0.12	0.04	1.02	0.99	0.98
Mg	1.62	1.46	1.33	1.57	0.40	0.38	0.40
Ca	0.28	0.29	0.31	0.28	0.32	0.30	0.29
Y	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Total	16.05	16.02	16.00	16.02	16.07	16.02	15.96
End members							
Andradite	0.24	0.28	0.10	0.25	0.00	0.00	0.04
Grossular	4.28	4.39	4.94	4.16	5.17	4.99	4.94
Pyrope	26.76	24.48	22.14	25.98	6.52	6.45	6.93
Spessartine	0.72	1.34	1.99	0.73	16.79	16.73	16.71
Almandine	68.00	69.51	70.84	68.89	71.52	71.83	71.38

Ta – Mixed Magma Andesite, Tbda– Biotite Dacite Ash

Appendix F: Table 2 Electron microprobe analyses of garnet

Sample #	04 EB 154				04 EB 168		
Analysis#	eb154 garn1b	eb154 garn1c	eb154 garn1f	eb154 garn1g	eb168 garn	eb168 garn1b	eb168 garn1c
Unit Name	Ta	Ta	Ta	Ta	Ta	Ta	Ta
wt. %							
SiO2	38.02	36.55	36.02	37.31	36.71	35.32	34.59
TiO2	0.00	0.01	0.02	0.01	0.00	0.00	0.01
Al2O3	21.82	21.22	21.73	22.28	23.10	21.76	21.91
FeO	35.25	35.75	35.93	35.81	35.88	35.85	35.76
MnO	4.40	4.42	4.51	4.46	4.74	4.59	4.60
MgO	1.54	1.39	1.40	1.38	0.91	0.87	0.98
CaO	0.67	0.64	0.61	0.63	0.74	0.60	0.70
Y	0.10	0.03	0.00	0.06	0.02	0.00	0.01
Total	101.80	100.01	100.21	101.93	102.11	98.98	98.56
Cations							
Si	6.05	5.97	5.88	5.95	5.86	5.85	5.77
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al	4.69	4.88	4.90	4.78	4.79	4.97	4.99
Fe	4.09	4.08	4.18	4.19	4.34	4.25	4.31
Mn	0.59	0.61	0.62	0.60	0.64	0.64	0.65
Mg	0.37	0.34	0.34	0.33	0.22	0.21	0.25
Ca	0.11	0.11	0.11	0.11	0.13	0.11	0.12
Y	0.01	0.00	0.00	0.01	0.00	0.00	0.00
Total	15.90	15.99	16.03	15.95	15.97	16.03	16.08
End members							
Andradite	0.00	0.02	0.04	0.02	0.00	0.00	0.02
Grossular	1.98	1.86	1.70	1.83	2.21	1.79	2.03
Pyrope	6.35	5.67	5.69	5.64	3.73	3.61	4.07
Spessartine	10.28	10.29	10.43	10.36	11.11	10.85	10.83
Almandine	81.38	82.16	82.13	82.16	82.96	83.75	83.05

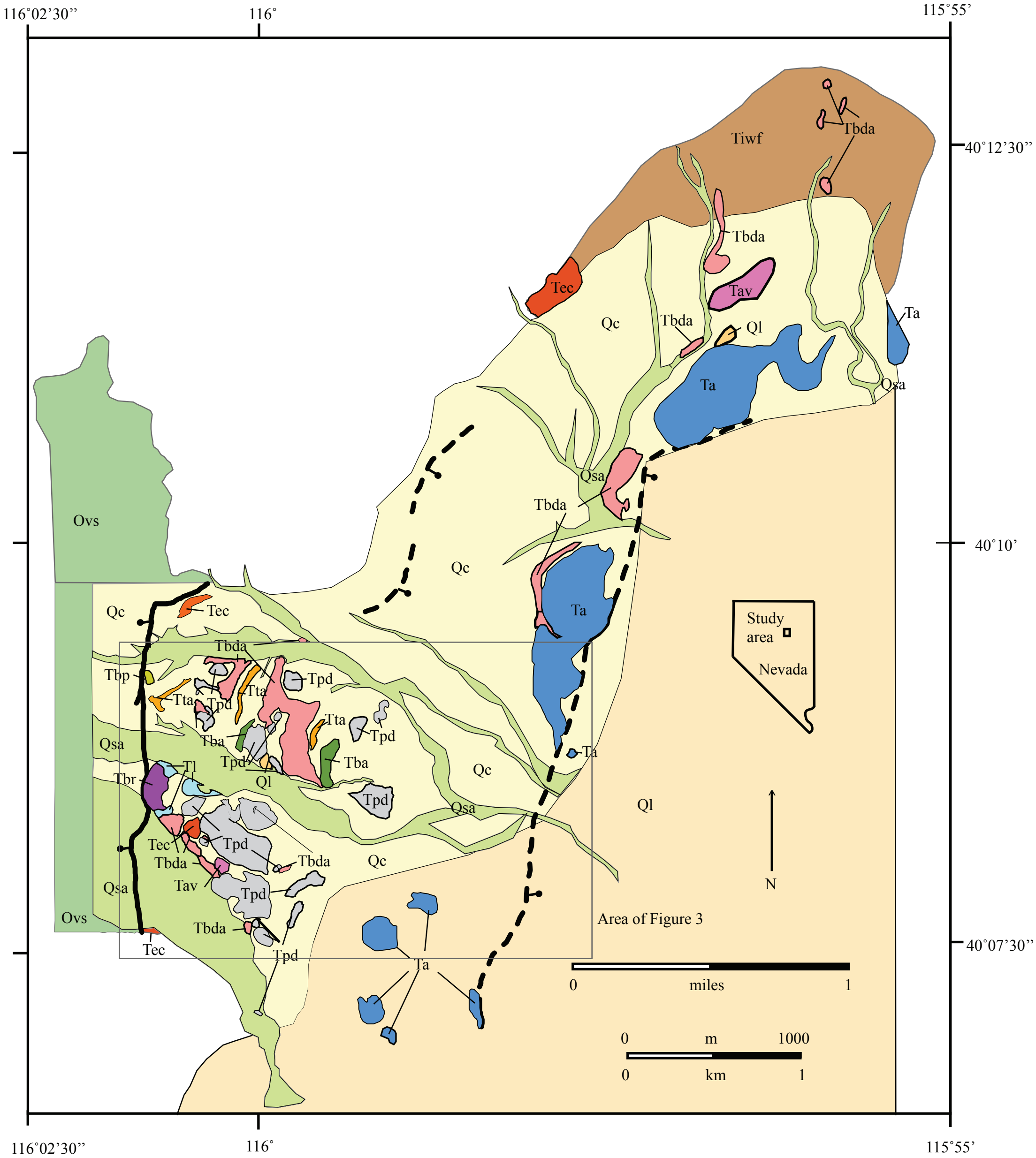
Ta – Mixed Magma Andesite, Tbda– Biotite Dacite Ash

Appendix F: Table 2 Electron microprobe analyses of garnet

Sample #	04 EB 168						
Analysis#	eb168 garn1d	eb168 garn2a	eb168 garn3c	eb168 garn3d	eb168 garn3e	eb168 garn3f	eb168 garn3g
Unit Name	Ta	Ta	Ta	Ta	Ta	Ta	Ta
wt. %							
SiO2	36.37	37.09	35.99	37.64	37.58	35.24	37.48
TiO2	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Al2O3	21.59	22.21	21.18	22.34	22.22	20.66	21.99
FeO	35.94	35.37	30.76	30.54	30.75	30.44	30.43
MnO	4.70	5.42	7.81	7.76	7.84	7.82	7.89
MgO	0.88	0.87	2.52	2.74	2.77	2.60	2.75
CaO	0.71	0.88	0.80	0.81	0.87	0.82	0.79
Total	0.01	0.04	0.00	0.00	0.00	0.00	0.00
	100.20	101.89	99.05	101.83	102.03	97.58	101.32
Cations							
Si	5.94	5.94	5.90	5.95	5.94	5.88	5.96
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Al	4.91	4.74	4.22	4.04	4.06	4.25	4.05
Fe	4.15	4.19	4.09	4.16	4.14	4.06	4.12
Mn	0.65	0.74	1.08	1.04	1.05	1.11	1.06
Mg	0.21	0.21	0.62	0.65	0.65	0.65	0.65
Ca	0.13	0.15	0.14	0.14	0.15	0.15	0.13
Y	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	15.99	15.96	16.05	15.97	15.99	16.09	15.98
End members							
Andradite	0.00	0.05	0.00	0.00	0.00	0.00	0.00
Grossular	2.11	2.50	2.32	2.34	2.50	2.38	2.27
Pyrope	3.64	3.57	10.16	11.03	11.03	10.54	11.06
Spessartine	11.03	12.61	17.90	17.74	17.74	17.99	18.03
Almandine	83.23	81.28	69.62	68.89	68.74	69.10	68.64

Ta – Mixed Magma Andesite, Tbda– Biotite Dacite Ash

Appendix G. Geologic Map of Sulphur Springs Volcanic Field.



Map Units

Quaternary	Qsa	– Quaternary stream alluvium	
	Qc	– Quaternary colluvium	
	Ql	– Quaternary lake sediments	
Eocene - Oligocene	Tiwf	– Indian Wells Formation	
	Ta	– Mixed Magma Andesite Dike and Lava Flows	
	Tau	– Altered volcanics rocks undifferentiated	
	Tba	– Basaltic Andesite Dike and Lava Flow	
	Tpd	– Plagioclase Dacite Lava Domes	
	Tbda	– Biotite Dacite Ash Fall	
	Tbp	– Biotite Porphyry	
Eocene - Oligocene	Tl	– Latite Lava Flow	
	Tbr	– Banded Rhyolite Lava Flow	
	Tta	– Terrace alluvium	
	Tec	– Elko Conglomerate	
Paleozoic	Ovs	– Vinini Shale	

Faults

Appendix G Unit Descriptions

Qsa – Quaternary stream alluvium – recently deposited channel and floodplain alluvium of small, ephemeral streams. Consists of poorly sorted, rounded cobbles of various compositions, sand, and clay.

Qc – Quaternary colluvium – unsorted, unstratified, subrounded to subangular pebble to cobble sized clasts of various compositions depending on location, in a matrix of tan sand and clay. General term for lack of outcropping units.

Ql – Quaternary lake sediments – playa and lake sediments composed of sand bars and shoreline deposits, as well as silt, clay and salt deposits.

Tiw – Indian Wells Formation – layers of extrusive rock - as an ash flow tuff alternating with sedimentary type environment. Outrcrops locally as a light tan ash flow tuff including porphyritic fragments and lithics. Composition of the tuff is dacitic to rhyolitic, with phenocrysts of biotite, quartz, and plagioclase. Correlated with Indian Wells Formation found in the volcanic sequence in the Pinion Range to the north, which is Oligocene in age.

Tva – Mixed magma andesite – Dark grey, crystal rich andesite, pink colored rind where altered. Rounded plagioclase is the dominant phenocryst; however other minerals are abundant, including quartz, biotite, clinopyroxene, olivine, potassium feldspar, orthopyroxene, and garnet with accessory magnetite.

Reaction rims form around quartz phenocrysts, plagioclase is sieved, olivine and magnetite are altered to iddingsite or hematite, megacrystic potassium feldspar and quartz up to 3.5 cm in length. Dense dike-like appearance with occasional flow-type outcrops, which are more vesicular. It is 32.0 Ma derived by U-Pb zircon analysis.

Tav – Altered volcanic rocks undifferentiated – extrusive rocks which are very altered.

Tba – Basaltic andesite – Dense, black, porphyritic basaltic andesite. Mineral assemblage includes clinopyroxene, orthopyroxene, olivine, with sparse plagioclase. Surface alteration of olivine to iddingsite while clinopyroxene is fresh green. Possibly emplaced as a dike or mafic flow.

Tpd – Plagioclase dacite – generally altered to a pink to orange matrix, but dark grey when found as unaltered, glassy vitrophyre. Emplaced as lava domes, seen as prominent knolls throughout the mapped region. Composition is dacite in unaltered samples, but altered samples range from andesite to rhyolite and dacite to trachyte. Plagioclase is the primary phenocryst quartz, amphibole, and biotite. These domes usually have flow foliation, but also a matrix supported breccia. It is 35.1 Ma derived by U-Pb zircon analysis.

Tbda – Biotite dacite ash fall – Outcrops as light colored soil horizons, with porphyry pebbles and cobbles littering the ground. Alters to swelling clays in most locations. It is a biotite rich, dacite which includes quartz and sometimes quartz megacrysts and garnet. Possibly a caldera filling ash, or a layer above the Elko Conglomerate, often times outcrop is only distinguished by porphyry pebbles found on light colored surfaces. Roadcuts show whitish – yellow ash writhed with iron rich veins. At the northern end of valley biotite dacite outcrops as ash flow tuff. It is 35.4 Ma derived by U-Pb zircon analysis.

Tbp – Biotite porphyry – Light tan colored, biotite rich dacite porphyry. Large phenocrysts of biotite, with quartz and plagioclase, potassium feldspar and an altered iron-rich mineral. Subcrop denotes possible dike or vent-fill. It is 35.9 Ma derived by U-Pb zircon analysis.

Tl – Latite –crystal-poor, black scoriaceous lava flow, in some locations seems to have flowed down paleo streambeds.

Tbr – Banded rhyolite – light and dark flow banded rhyolite lava flow, crystal-poor. Subcrop to outcrop of alternating dark gray with light grey to pink flow bands.

Tta – Terrace alluvium – tertiary age terraces composed of alluvial gravel. Contains cobbles of materials found in the Elko conglomerate, Vinini Shale, as well as rock types not found in any other unit – including quaternary units. Terraces do not contain cobbles from surrounding volcanic outcrops.

Tec – Elko Conglomerate – Red-brown pebble to cobble conglomerate, and in some locations an arkosic sandstone. Conglomerate makeup is predominantly quartzite and in some places contains green chert. The tuff at Union is the upper member of the Elko, described as a latite that is orange to maroon in color due to alteration, which includes fragments of quartzite cobbles (as found in the Elko Conglomerate) as well as cobbles of the square quartz porphyry. The square quartz porphyry is rhyolitic in composition and contains bipyramidal quartz phenocrysts along with plagioclase, K-feldspar, and some biotite. The square quartz porphyry is 156 Ma derived by U-Pb zircon analysis. The Elko Conglomerate is Eocene in age.

Ovs – Vinini Shale – predominantly gray platey shale, black chert beds, silty gray to light tan limestone beds. It is Ordovician in age.