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Mining District File Summary Sheet

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QUAD_NAME	Sulphur 7½'
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COMMODITY If not obvious	gold; silver
NOTES	Geology; correspondence; Contains 5 copyrighted articles - SEE LIST ON BACK 19 p (scanned part) NOTE: Do not scan copyright articles

Keep docs at about 250 pages if no oversized maps attached
(for every 1 oversized page (>11x17) with text reduce
the amount of pages by ~25)

SS: DP Initials 8/1/08 Date

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Revised: 1/22/08

1 Pyroclastis Rocks and Calderes Associated With Strongly Peralkaline Magmatism; by G. A. Mahood; in Journal of Geophysical Research, vol 89 no. B10, p 8540-8552, September 1984

2 Correlation of Ash-flow Tuffs; by W. Hildreth and G.A. Mahood; in Geological Society of America Bulletin vol. 96, p 968-974, July 1985

3 Geology of the Peralkaline Volcano at Pantelleria, Strait of Sicily; by G. A. Mahood and W. Hidreth; in Bulletin of Volcanology, vol 48 p143-172, 1986

4 Large Partition Coefficients for Trace Elements in High-silica Rhyolites; by G. Mahood and W. Hildreth; in Geochimica et Cosmochimica, vol 47, p 11-30, 1983

5 A Summary of the Geology and Petrology of the Sierra La Primavera, Jalisco, Mexico; by G A. Mahood; in Journal of Geophysical Research, vol 86 no B11 p 10137-10152, November 1981

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December 7, 1998

Scan these

Peter Mitchell
Newmont Gold Company
861 West 6th Street
Winnemucca, Nevada 89445

Dear Peter:

I've enclosed a five reprints that relate to things that we discussed on the field trip.

(1) The summary paper in JGR on La Primavera gives some idea about the map scale you'd expect most silicic lava flows and domes to occur on.

(2) I send the paper on partition coefficients solely for Table 1, which illustrates the difference in composition between a typical metaluminous "calc-alkaline" mid-continental rhyolite (the Bishop Tuff) and and weakly peralkaline rhyolites (Primavera). If you have some analyses of the Dozer, for example, you could compare them. Even if the rocks are slightly altered so that the alkalies are shot and the silica contents are too high due to silicification, you still should be able to tell whether it's a typical metaluminous rock or an alkalic one by comparing the relative abundances of some of the relatively immobile elements. Note that in the alkalic rocks the ratio of Fe to Ca is high, about 8 taking the raw % and is lower in the Bishop Tuff, less than 2. The HREE, Y, Zr, Hf, Nb, and Ta all tend to be higher in alkalic rocks. (Ignore LREE because they are more easily mobilized and they show a much wider magmatic range due to fractionation processes.) Even if the rocks are silicified, you can get back at magmatic contents crudely by correcting these elements for "dilution" by added silica, assuming that magmatic values for rhyolites should be in the range 72-77%.

(3) I enclose the review paper on pyroclastic rocks and caldera associated with stongly peralkaline magmatism because it has a section talking about how to distinguish welded fall deposits from welded ignimbrites. Although you don't have stongly peralkaline rocks at Rosebud, weakly alkalic rocks will show some of the characteristics I describe--sort of tending in that direction.

(4) Similarly, the paper on the geology of Pantelleria illustrates the map scales (Fig. 1) and edifice shapes (Fig. 14) of these more alkalic lavas, talks about rheomorphic ignimbrites, and illustrates how to recognize caldera walls.

(5) The review paper on correlation of ash-flow tuffs (you can tell I had a USGS co-author, my dear husband) might be of use if you get involved in somewhat more regional scale mapping, where we picked up ignimbrites.

I've also enclosed some receipts, most importantly the one for the Gold Country Inn, which I forgot to include along with my invoice(s).

I've done a quick look-see at the thin sections. Thank goodness you sent the section billets--they are often more useful in identifying the rocks than the sections due to alteration! Any chance I could get a list that said what units each of the sections belongs to? On some, I can figure it out from the location, but on most I can't because I don't have that detailed a memory. I think if I'm going to suggest some appropriate (from a volcanologist's viewpoint) names, I'd like to know which units we are dealing with so that, in a case that's borderline or ambiguous I choose something most consistent with prior usage. Also, if you've got any chemical analyses, they would be a help.

Best regards,

Gail Mahood

Gail Mahood

cc R. Vance

TOPICS IN VOLCANIC GEOLOGY RELATED TO THE ROSEBUD MINE

Gail A. Mahood
Professor, Geological and Environmental Sciences, Stanford University

This report is based on a brief geologic field visit to the area surrounding the Rosebud mine on October 3-6, 1998. Specific questions regarding individual units were answered on the outcrop or in the core shed. Hence this report addresses the broader issues of identifying and naming volcanic rocks that had proved problematic, which required a more systematic and extended response.

Contents

TERMINOLOGY FOR WELDED PYROCLASTIC DEPOSITS

Internationally, the term "ignimbrite" is now the most widely used term for the deposits of hot pumice- and ash-rich pyroclastic flows[1], and I would recommend using it in the Rosebud district for the appropriate rocks. The synonymous term "ash-flow tuff" dominates the older U.S. literature because of its persistent use by USGS geologists up until quite recently. It is no longer preferred because, by formal definition, a tuff should consist of greater than 75% ash (i.e., pyroclastic particles <2mm in size), and many deposits have much more than 25% lapilli- or block-size pumice and lithics. (A less scientific reason for the demise of the term "ash-flow tuff" is related to the increasing prominence of studies of volcanoes in Italian- and Spanish-speaking countries, and it is that it is not nearly as euphonious as "ignimbrite" when translated.)

Another term seen commonly in the older literature on the western U.S. or in modern literature written by nonvolcanologists is "welded tuff". Although it is usually meant by most people to mean welded ignimbrite, the term is both sloppy and ambiguous because, again, tuff has a formal definition, and welded tuffs can form from other than ignimbrites (e.g., near-vent fallout deposits, or fallout deposits fused by the heat of an overlying lava flow).

Pumice fall deposits (sometimes called "air fall deposits" but not preferred because it isn't the air that's falling) can weld in near-vent localities where accumulation rate is high. Generally, these localities are within a kilometer of the vent. The deposit will appear crudely stratified and there will be rapid vertical variations in the degree of welding over distances of meters (depending on the momentary accumulation rate), whereas a welded ignimbrite will show gradual vertical changes in the degree of welding over tens of meters. Fall deposits can be fused where they are overlain by lava flows. Generally this happens when the still-warm fall deposit is over-run by a related lava flow from the same vent. Both welded fall deposits and fused fall deposits are volumetrically trivial. Their value in reconstructing older volcanic terrains is that if you find them, you know you are in a near-vent setting.

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[1] It is important to recognize that an ignimbrite, welded or not, can consist of numerous pyroclastic flows emplaced within a period of hours, days, or weeks. As such, different emplacement units can have different phenocryst abundances or lithic assemblages, and there can be pumice fall deposits, surges, or reworked intervals between them. In large ignimbrites, individual emplacement units can have different spatial distributions, which can initially lead to difficulties in correlation in pre-Quaternary, faulted terrains.

DISTINGUISHING DENSELY WELDED IGNIMBRITES FROM LAVAS

Some units in the Rosebud district have been identified as densely welded ignimbrites and as lava flows or domes by successive groups of exploration geologists. All the units in question that I examined I found to be lavas (with a high degree of certainty). The field evidence in the case of the "Dozer", for example, is the lack of lithics, the continuity of the flow banding, the thinness of the flow bands, the lack of any gradation to what would be nonwelded material, and the presence of marginal autobreccia.

The following set of criteria outline how to distinguish densely welded ignimbrites from lava flows and domes.

Textures Characteristic of Densely Welded Ignimbrites

Eutaxitic: streaky banding caused by flattening of pumice lapilli on compaction due to moderate to dense welding. Visible at the outcrop, hand lens and thin section scales. Flattened pumice ("fiamme" from Italian for flame, referring to their wispy curved margins) typically are darker in color than the surrounding ashy matrix, because the pumice lapilli retain more heat than the smaller ash particles during emplacement, making it possible for the pumice to weld more densely than the matrix.

Vitriclastic: glass shards. Visible in hand lens in weakly and moderately welded rocks, occasionally even in densely welded rocks that have been silicified; visible in thin section at all degrees of welding unless obliterated by devitrification. Usually visible even in very densely welded ignimbrites due to the fact that fine ash dust accumulates on the surface of shards in the eruption cloud, outlining the shards in thin section. Autobrecciation at the base of lava flows can produce textures that in hand specimen and thin section mimic vitriclastic texture. This results from the production of fine ash by the grinding of autobreccia blocks against one another. This ash usually can be distinguished from the the ash in ignimbrites by its shape. Nearly all the ash in ignimbrites is produced by the bursting of bubble walls in a pumiceous froth; hence, the glass shards preserve the curved bubble-wall shapes and are typically Y-shaped. Shards produced by the grinding of autobreccia blocks will have a much higher percentage of blocky or angular shards, rather than the delicate bubble-wall shapes.

Axiolitic: crystallization of needle-like quartz and alkali feldspar perpendicular to the center line of a fiamme (flattened pumice lapilli); is useful in devitrified rocks in which the vitriclastic texture is otherwise obscured.

Other Features Used in Distinguishing Welded Ignimbrites from Lavas

Lithics

Lavas: usually absent; may be present in feeders.

DW Igs: always present but can be very sparse in some peralkaline examples in which the eruptions weren't very explosive. Individual emplacement units within an ignimbrite tend to have a constant concentration of lithics and proportion of various lithologies of lithics, making lithics a useful correlation tool. This is because the great preponderance of lithics are derived from the vent (and this fact can be used to determine likely source areas). The pyroclastic flows that form densely welded ignimbrites do not pick up and entrain significant amounts of lithic debris from the underlying ground, except where they are funneled through canyons. These ground-derived clasts are generally easy to identify, because they will be entrained only within 1-2 meters of the base, they are commonly much larger than the vent-derived lithics, they commonly occur in lithic trains, and they match the underlying ground lithology. Very high concentrations of lithics (>30%) are generally associated with an intracaldera setting, the lithics derived from collapse of the caldera walls. Large lithics (>10 cm diameter) are restricted to intracaldera ignimbrites or near-vent settings in outflow facies, because the pyroclastic flows are incapable of transporting such large clasts very far due to their rapid settling velocities in the fluidized flows.

Layering/banding

Lavas: continuous over many meters; individual bands can be very thin (mm) and constant thickness for meters.

DW Igs: discontinuous; streaky; eutaxitic; bands usually at least several mm thick. In rheomorphic ignimbrites (i.e., those that undergo lava-like flow following dense welding) banding can be continuous over meters, but it isn't as regular as in a lava flow, and usually one can trace a unit to some less rheomorphic part that shows unequivocal evidence of being an ignimbrite.

Mafic enclaves/blobs

Lavas: Can be present; distinguished from lithics by crenulate margins of spheroidal or ovoid overall shapes; usually chilled at their margins therefore finer grained; may cause secondary vesiculation in the lava around them, resulting in some void space around the enclave. Although more mafic than their host, many are not truly mafic in the sense of being basaltic; many are trachytic or andesitic.

DW Igs: Not present. Equivalent thing in igs appears as more-mafic looking pumice lapilli (or their flattened equivalent, fiamme, which generally aren't as flattened as the more silicic pumice.

Broken crystals

Lavas: Can be present; usually quartz or plagioclase that have "exploded" on vesiculation of melt inclusions. Commonly pieces will still be adjacent. Usually associated with some resorbtion textures.

DW Igs: Common. All phenocryst types except bio will show breakage, and the matching pieces commonly are not adjacent. Some look shard-like. Not associated with absorbtion textures.

Basal and marginal autobreccia

Lavas: Very common.

DW Igs: Very rare; only in rheomorphic types and only locally.

Outcrop pattern

A characteristic feature of ignimbrites is that they are sheet-like in outcrop pattern at the map scale. They typically have aspect ratios on the order of 1:1000 (thickness:lateral extent) whereas silicic lava flows are typically 1:20. Silicic lava domes (i.e., units that spread out concentrically around the vent) rarely exceed 3 km in diameter; if outcrops extend farther than this it is generally a lava flow (i.e., a unit that flows away from the vent in a single direction) and will have a toungue-like shape in plan view. There are some extraordinary dacite lava flows that have flowed tens of kilometers due to being channeled in pre-existing river valleys, but most silicic lava flows are less than 5-7 km in length. In well-exposed areas not subject to significant faulting, the sheet-like outcrop pattern of an ignimbrite will make its identification easy. But in poorly exposed areas or terrains disrupted by faulting this may be harder to establish. Additionally, although individual lava flows are generally not extensive, they can be parts of dome fields where multiple lava flows and domes can coalesce to give the appearance of an extensive stratigraphic unit in an area of poor exposure. Finally, there are a few occurrences of voluminous and/or high-temperature rhyolite lava flows that mimic the sheet-like behavior of ignimbrites to the point that they have fooled even volcanologists. The prime example of this in the U.S. are some lava flows in the Bruneau-Jarbidge district.

The difference in aspect ratio manifests itself at the outcrop scale. Lava flows will have steep margins that younger deposits will lap. Lava flow margins can sometimes be identified by mapping flow foliations. They tend to dip concentrically toward the vent near the vent, to be more or less horizontal (or parallel to the underlying surface) in the main flow lobe, and to dip steeply toward the vent near the margins. Obviously, there is abundant local variation, so these are general trends. Ignimbrites, on the other hand, don't have "edges". The products of near-newtonian pyroclastic flows, they spill into low-lying areas. As a result, they tend to lap pre-existing topography and have more or less horizontal upper surfaces. Silicic lava flows, being Bingham fluids, can drape over topography and have significant initial dips.

Welding

Lavas: The weight and heat of the overlying flow can result in fusing and flattening of ash and blocks at the autobrecciated base of the flow, but true pumice lapilli are generally absent.

DW Igs: Variations in the degree of welding vertically is the feature that is usually diagnostic in young deposits that are well-exposed. In older deposits where poorly welded tops have been removed by erosion, this variation may only be apparent at the base of an ignimbrite. The lessening of welding toward the base in an ignimbrite and the common presence of autobreccia at the base of lava flows makes the base the best place to examine an ambiguous unit.

Textural Features That Are Only Weakly Diagnostic

Vesicles

Lavas: When first erupted, silicic lava flows generally have a pumiceous carapace on the margins and top. This is readily eroded so is generally not preserved in mid-Tertiary lava flows. As a result, most of the remaining material will be dense. When vesicles are present, they commonly show evidence of deformation by the flow process, being elongate in the direction of flow.

DW Igs: Rare. Caused by secondary vesiculation of high-temperature igs that accumulated so rapidly that they still had magmatic gases to lose after thorough compaction. In these cases, vesicles are present at the few % level and are spherical, because they formed after compaction.

Devitrification

Lavas: Yes. Flow bands will often be characterized by different grain sizes of devitrification.

DW Igs: Yes. Primary (i.e., high-temperature, near the time of eruption) devitrification commonly preserves textures in thin section that are indicative of an ignimbrite: vitriclastic texture, axiolitic texture. In very thick (usually intracaldera) sections, primary devitrification can be granophyric, totally obliterating vitriclastic texture.

Spherulites and lithophysae

Spherulites are devitrification textures that form at high degrees of undercooling in dense glass. They can form in both lava flows and in densely welded ignimbrites where there is both dense glass (in the latter case, due to welding) and fairly rapid cooling (near the base in densely welded ignimbrites and near the base or lateral margins of lava flows). They are not as common in densely welded ignimbrites as in lavas, probably because zones of such complete welding as to homogenize the material to a dense glass yet of sufficiently rapid cooling to prevent primary devitrification are generally thin in ignimbrites and make up a smaller volumetric proportion of the unit than in lavas. Lithophysae are essentially large spherulites (usually walnut-sized) that "exploded" leaving a jagged interior that is often coated with well-formed crystals of tridymite, alkali feldspar, pyroxene, magnetite or fayalite that crystallized from a vapor.

Perlitic texture

Visible in hand specimen and thin section, this onion-skin-like concentric cracking is produced by the strain set up by the volume increase induced by secular hydration of dense glass. It occurs in both lava flows and densely welded ignimbrites in zones of dense glass. In densely welded ignimbrites, perlitic texture can be seen to crosscut vitriclastic texture. In rocks that undergo secular devitrification or low-grade alteration after hydration, the perlitic texture is often preserved to some extent, and is useful because it indicates that the rock was once glassy.

Well-developed perlitic texture is generally restricted to phenocryst-poor rocks. In rocks with more than about 10% phenocrysts, cracking due to stresses set up during initial cooling due to the different thermal expansion of crystals and glass and the presence of crystals to focus stress on hydration of glass disrupts the development of true perlitic texture and instead arcuate cracks radiating irregularly from crystals break the rock into mm-sized pieces.

What If You're Still in Doubt?

When in doubt whether a unit is a welded ignimbrite or a lava flow, the most conservative approach is to call it a lava flow. This is because a welded ignimbrite has stratigraphic significance that all but the largest lava flows do not have. As the products of particulate flows with low yield strength, most ignimbrites are restricted to topopgraphic lows and their top surfaces are paleohorizontal indicators because original dips rarely 4 degrees. (The exceptions to this rule are ignimbrites that form from highly inflated pyroclastic flows, which are not restricted to topographic lows and can have significant primary dips. However, as the deposits of highly inflated flows, they are cool and never weld; hence, their preservation potential is low and are not likely to be found in mid-Tertiary or older rocks.) Because flattening in welded ignimbrite is produced by compaction under the force of gravity, eutaxitic textures will be paleohorizontal except immediately adjacent (within cms) to canyon walls or if the ignimbrite is rheomorphic. In contrast, the surfaces of lava flows need not be horizontal if they are filling complex topography; the flow banding in rhyolitic lava flows is not a good indicator of paleohorizontal; and in many rhyolitic centers similar-looking lava flows erupt at different times and from different vent locations, so they cannot be used for structural reconstructionsin the same way that sheet-forming ignimbrites can. Additionally, most ignimbrites of any size (those thick enough to weld and to be preserved extensively in mid-Tertiary rocks) are associated with caldera collapse and commonly with resurgent doming (both with characteristic styles of faulting) and subsequent ring-fracture eruptions of lava domes, often in a lakeside setting. That is, calling something a welded ignimbrite brings with it the likelihood of a particular volcanic setting, styles of faulting, a persistent heat source in a relatively large subjacent magma chamber, multiple intrusion events, and a set of potential mineralizing settings. Calling something a lava flow, doesn't carry with it all this "geologic baggage" (although on further mapping, one might show that any particular lava flow was related to a caldera).

CLASSIFYING AND NAMING VOLCANIC ROCKS

There is no widely accepted classification system for volcanic rocks based on hand specimen identification. Most modern textbooks present the TAS classification system of Le Maitre et al. (1989) as the standard way to classify volcanic rocks. This uses the concentration of total alkalies (wt.% $Na2O$ + $K2O$) versus wt % $SiO2$. The main advantage of this system is that the nomenclature is based upon a system of root names with additional qualifiers to be used when necessary. It makes the relationships between adjacent fields apparent from the names themselves, so relationships are communicated to nonspecialists. Although widely quoted it has several serious drawbacks. First, whole-rock chemical analyses aren't always available. Second, the alkalies are some of the elements most easily disturbed by weathering or low-temperature alteration. Fortuitously for the classification system, mild hydration of volcanic glass and some forms of hydrothermal alteration tend to replace lost $Na2O$ with $K2O$, more or less, mole for mole, so the total wt.% of the alkalies is little changed. However, the classification system is totally obviated by silicification.

Another problem with this classification system is that many continental suites, whether arc-related or in the interior tend to cross from the subalkaline suite at low silica contents (basalt-basaltic andesite-andesite-dacite) to the alkaline suite (trachybasalt-basaltic trachyandesite-trachyandesite-trachyte) at higher silica contents, suggesting that the authors of this scheme gave this boundary too low a slope (perhaps based on their greater familiarity with non-convergent-margin settings in Europe).

An additional problem for folks working with silicic rocks is that the field for rhyolite spans a very wide range compositionally and mineralogically (probably reflecting the authors greater interest in the mafic end of the spectrum). Because different ore deposits (Au, Cu, Sn, Mo) are associated with felsic rocks of varying levels of silica content and degrees of alkalinity, I think it is worthwhile in an exploration context to split the rhyolite field. I think it is useful to use the term "rhyodacite" for quartz-bearing rocks intermediate between dacite and rhyolite. It is also useful to indicate whether a silicic rock is peralkaline or, if not peralkaline, is close to it.

A Simplified Classification Scheme for Rocks in the Western U.S.

I have included as Table 1 a simplified classification system based on hand-specimen identification designed to be applicable to most rocks in the western U.S. It will work straightforwardly on rocks with typical phenocryst contents, i.e., between 5 and 25%. At lower phenocryst concentrations, some of the characteristic phases may not yet have reached the liquidus, and at higher phenocryst concentrations you start to pick up additional phases; I've noted how this may result in variations from the "normal" situation. In classifying a rock in this system, the first distinction is made on the presence or absence of quartz phenocrysts, because of the ease of identifying quartz in hand specimen in both fresh and altered volcanic rocks. The only caution is that because much of the western U.S. is underlain by granitic or gneissic basement, basalts and basaltic andesites fairly frequently contain xenocrystic quartz. It is usually easy to identify because it looks "unhappy", showing evidence of resorbtion or of being rimmed by pyroxene. After determining whether quartz phenocrysts are present, the classification is based on the proportion of alkali feldspar to plagioclase (AF:P) in silicic rocks and on the type of mafic phenocrysts in intermediate and mafic rocks.

Alkalic Rocks

This simplified scheme does not fully account for rock suites that lie at higher total alkalies in the TAS system (trachyte, trachyandesite, trachybasalt, alkali basalt) that are a minor component of extension-related terrains in the Great Basin. Being more alkalic and more feldspathic, there is a tendency to have a higher proportion of feldspar in the phenocryst assemblage and for the mafic phenocrysts, at any given silica saturation to be K-bearing; i.e., phlogopite and hornblende exist to lower silica contents into trachyandesites, rather than being restricted to dacites as in subalkalic rocks. The higher feldspar content also tends to make the groundmass of the mafic rocks, if cryptocrystalline, grey rather than the black of typical basalts. For the same reason, the groundmass of these alkalic mafic rocks on weathering and weak alteration tends to develop a grey mottling that is very characteristic. It would be appropriate to use these terms if you have some indication from mineralogy or from chemical analyses that the suite is alkalic.

Peralkaline Silicic Rocks

Most of the mid-Tertiary rocks of Nevada are somewhat potassic versions of the basalt-andesite-dacite-rhyodacite-rhyolite suite, but Miocene rocks in northwestern Nevada and in the Nevada Test Site do cross over into the alkalic side, and the most silicic rocks they produce are peralkaline. The peralkaline condition (molecular Na2O + K20 > Al2O3) is reflected mineralogically in the absence of plagioclase and biotite, and the presence of Na-rich and Fe-rich cpx and amphibole, and/or Fe-rich olivine. The nomenclature for peralkaline silicic rocks is an unwieldy mess, but given that my quick visit to the Rosebud district provided no positive evidence for peralkaline rocks in the area, I won't belabor it here other than to say that one could define three series based on peralkalinity and degree of silica saturation:

trachydacite - alkali rhyolite (metaluminous rocks near the peralkaline field);
comenditic trachyte - comendite (mildly peralkaline);
pantelleritic trachyte - pantellerite (strongly peralkaline).

The first two suites have phenocrystic quartz and sodic sanidine in their most differentiated members. The pantelleritic suite lacks phenocrystic quartz, and the alkali feldspar approaches true anorthoclase. Its higher Fe content is manifest in conspicuous mafic phenocrysts that reflect the strongly peralkaline character of the rock (sodic pyroxene and amphibole, and the Na-Ti accessory mineral cossyrite).

Difficulty in Classifying Extremely Phenocryst-Poor Volcanic Rocks

Classifying extremely phenocryst-poor volcanic rocks in the absence of chemical analyses of more or less fresh rocks is difficult. For example, a rock like the "Dozer", brown to light grey in outcrop with the less than 1% plagioclase phenocrysts potentially could be a rhyolite, rhyodacite, dacite, andesite (albeit on the high-silica end), or trachyte. This is a case where a chemical analysis, even recognizing that the rock is altered, would be helpful. Knowing that the rock is silicified, it would be best to look at the absolute and relative abundances of elements that are most stable in this setting: Fe, Ti, Ca (as long as there's no calcite in thin section), P, Zr, Hf, Ta, Nb, Th, HREE. Lacking such analyses, one is forced to use much less diagnostic characteristics that result in accurate field calls only when employed by field geologists with an abundance of experience in volcanic rocks: color of the fully crystallized groundmass; heft as a measure of density; nature of vesicularity; character of flow banding; nature of jointing.

Miscellaneous Comments Regarding Nomenclature

Latite

This term was originally used for ultrapotassic intermediate rocks of Latium, Italy. It was applied by many of the early workers in the western U.S. to intermediate rocks with somewhat elevated K2O contents relative to typical "arc-related" andesites and dacites. (Similarly "quartz latite" was used for potassic versions of rhyolite or rhyodacite.) It occupies a specific field in the classification of Steckeisen (1980): on the QAPF diagram it is the volcanic equivalent of a monazite, with less than 5% quartz in the QAPF system. Few intermediate rocks in the Great Basin would have such low levels of silica saturation, so it is technically a misnomer as commonly applied in the western U.S. Because of this ambiguity in usage, it tends not to be used today, and it is probably best not to use the term for the rocks in the Rosebud district. Preferred terms for somewhat alkalic intermediate rocks are trachyandesite and trachydacite. (These also have the advantage of transparency to nonspecialists because of the use of a modifier on familiar rock names). And if there is no independent evidence of how alkalic they are, stick to the simpler terms andesite or dacite.

Porphyry

This term gets applied widely by those working in ore deposits, presumably because of the association with mineralization in small intrusions in volcanic settings. "Porphyry" has a very specific meaning: a phaneritic rock with abundant and prominent phenocrysts in a fine-grained groundmass (i.e., finer than 1 mm). This means that you should be able to resolve the groundmass with the naked eye and be able to identify at least some of the individual groundmass grains with your handlens. Because the rocks are phaneritic, they should be given a phaneritic modifying name (e.g., granite porphyry, monzonite porphyry). Associated with this definition is a specific implication regarding the emplacement depth of the porphyry intrusion: below the level of the volcanic edifice but not as deep as the several kilometers or more of typical medium- to coarse-grained phaneritic granitic (s.l.) rocks.

Economic geologists often apply the term "porphyry" to any strongly porphyritic rock--rocks that in a non-ore-deposit setting geologists would simply refer to as volcanic rocks. This is unfortunate because the term loses its value as a signifier of emplacement depth when applied so broadly, and the term when so applied can be misleading to subsequent geologists. For example, what I as a volcanologist would call a strongly porphyritic dacite is refered to as a diorite porphyry in some epithermal gold deposits. My name indicates the very shallow level of the mineralization--essentially within the volcanic edifice--whereas the diorite porphyry brings to mind intrusions (even though they may be lavas) and potentially greater depths. A strongly porphyritic rock with an aphanitic groundmass (i.e., you cannot resolve the grains with the naked eye, and though you can see that there are individual grains with a handlens, you can't identify them) should be given a volcanic rock name with a modifier to indicate that it is porphyritic (e.g., porphyritic rhyolite, glomeroporphyritic andesite).

In an ore deposit setting, where one might feel constrained by prior usage, it would be acceptable to call strongly porphyritic rocks with aphanitic groundmasses porphyries, as long as the modifier is a volcanic name (e.g., rhyolite porphyry, andesite porphyry) to indicate the aphanitic nature of the groundmass and to give an accurate sense of the final crystallization pressure. But one should remain true to the correct definition--that the rock has "abundant and prominent" phenocrysts--and only apply it to rocks with good-sized phenocrysts making up at least 25% of the rock. In this context, none of the rocks in the Rosebud district that I examined should be termed "porphyry".

IS THERE A CALDERA AT ROSEBUD?

During my short visit to the Rosebud district, I did not see any positive evidence for a caldera. In the mining district itself, the absence of any thick ignimbrites argues against it as does the stratigraphy of the deep exploratory hole we examined in the core shed. If there were a caldera in the area of the drill hole, we should have seen a thick (hundreds to thousands of meters) section of densely welded intracaldera ignimbrite lying beneath the sequence of lava flows and sediments exposed at the surface. Instead, going downward these surface units passed into sediments (without a conspicuous contribution of densely welded ignimbrite clasts) and then Auld Lang Syne "basement". The small number of dikes/sills found in the core is significant because intracaldera sections are commonly cut by an abundance of dikes related to emplacement of postcaldera lavas and to "leaks" (that may not breach the surface) from a subjacent chamber.

Although the wide extent of similar-looking silicic lavas leaves open the possibility that there might be a caldera somewhere nearby, if I were asked to interpret the geologic setting of the mine area, I would venture that it is a silicic lava dome and flow field with ancillary intermediate lavas. The shallowing of eastward dips upward in the section suggests that the volcanism was concurrent with ongoing Basin-and-Range extensional faulting. The intercalated sediments suggest the presence of shallow lakes, perhaps in fault-bounded basins. A younger analog with an active hydrothermal system would be the Coso volcanic field in southeastern California.

AGE OF VOLCANISM IN THE ROSEBUD REGION

Sparked by my initial surprise about how little there seemed to be in the literature about the volcanic rocks in the Rosebud area and out of curiosity and a desire to scope out a potential student thesis project (but not on the company's "dime"), I conducted a fairly extensive search of the literature to see if there were any discussions of the volcanic rocks in the district or information on the age of the volcanic rocks and their relationship to Basin-and-Range faulting.

The following summarizes the little information I did find. The nearest volcanic rocks, in the Jackson Range, have not been dated radiometrically. Sediments that contain diatoms that are late middle Miocene to early Pliocene in age (Willden, 1963) have intercalated basaltic lavas, and they are overlain by rhyolitic lavas(?) associated with quicksilver mineralization. At the Ragged Top caldera in the Trinity Range southwest of Lovelock, the silicic lavas and ignimbrites are 15 Ma (Thole, 1991). Northwest of the Rosebud district in NW Nevada and NE California there are rhyolitic ignimbrites and lava flows ranging in age from about 26 Ma to about 15 Ma (Duffield and McKee, 1986; Noble et al., 1970). Like the rocks of the Rosebud district, the rocks in the Trinity and Jackson Ranges appear to be high-K metaluminous suites, whereas the silicic rocks in NW Nevada are weakly alkalic to moderately peralkaline. My notes on relevant references are appended as Appendix A, in case they are of any use or interest.

TABLE 1

Classification System for Hand-Specimen Identification of Volcanic Rocks

Contains Quartz Phenocrysts

Alkali Rhyolite	AF:P > 2:1 (plag may be absent) Fe-rich cpx and/or Fe-rich ol mafics sparse (≤1%)
Rhyolite	2:1 > AF:P >1:2 (alk fsp may be absent in pheno-poor rocks) bi > px (opx and cpx); px may be absent mafics sparse (≤1%)
Rhyodacite	AF:P < 1:2 (alk fsp present only in pheno-rich rocks) bi > hb; hb may be absent; ± opx, cpx mafics conspicuous (1-3%)

No Quartz Phenocrysts

Name	Must have	May have	Absent
Trachyte	anorthoclase or sodic sanidine	cpx, amph, bi, Fe-ol	
Dacite	plag	hb, bi, cpx, opx; mafics 3-5%; qtz in very strongly porphyritic rocks	san
Andesite	plag	hb, cpx, opx	san, bi, ol
Basaltic andesite	plag, cpx	opx	hb, ol
Basalt	plag, Mg-ol	cpx	hb, opx

APPENDIX A

Notes on Referenes Related to Ages of Volcanism in the Rosebud Region

Willden, R. (1963) General Geology of the Jackson Mountains, Humboldt County, Nevada. USGS Bull 1141-D, D1-D65.

Map N of 41'00 only.
All pre geochron, therefore no real ages.
Tertiary basalts on east side of range. Lower part is distinctive porphyritic unit with 15-20% plag phenos up to 2 inches long and 1 inch wide. [These are similar to some described by Peter from somewhere N of the Rosebud mine.] Basalts in upper part of section are aphyric or sparsely aug phenos: and to bas.
Interbedded sed rocks have fossil leaves and diatoms.
Tertiary seds: shale, water-laid tuff, shaly ss, diat shale and chert. Diatoms are late middle Miocene to early Pliocene.
Above seds and intercalated basalts are rhyolite lava flows with 15-20% phenos of quartz, san, bio, plag. Overlies dacite "flow breccia" with large class of chert, hornfels, qtzite, ls. Dacite has phenos of qtz, plag, bio, amph. Assoc. with Bottle Creek quicksilver district.

Duffied, WA, McKee EH (1986) Geochronology, structure, and basin-range tectonism of the Warner Range, northeastern Californa. GSA Bull 97:142-146

Most of section consists of volcanic rocks, ranging from about 32 my near the base to about 14 my at the top. Rocks older than about 26 my are principally andesite lahars; 26-17 my are andesite lavas flows and rhyolitic welded igs, younger than about 17 my are principally basaltic and andesitic lava flows, [though also bi-bearing rhyolite lavas, so bimodal].
Horst that dips homoclinally 20-25°W-SW. So B-R faulting younger than the youngest rocks--14 my
[32 my dates on lahars may be suspect because they are on hb taken from andesitic ash. Could be contaminated. Oldest igs are 26 my.]
40 miles north of area, near CA-OR border, they got WR obsidian dates of 7-9 my, which they attribute to the W-NW trend [which others have said is the Yellowstone mirror].

Noble DC, McKee EH, Smith JG, Korringa MK (1970) Stratigraphy and geochronology of Miocene volcanic rocks in northwestern Nevada. USGS Prof pap 700-D, D23-32.

Ashdown Tuff: 25.3 + .9, 23.7 + .7 on split of same san sep; 23.9 + .7 on san. W and S flanks of Pine Forest Range (where it underlies Steens Basalts) and locally in N, Central and S parts of Black Rock Range. Densely welded and devit. 15-25% phenos of anorthoclase (as large as 1 cm), bio, and rare cpx.
Vent? suggest 5 miles E of Summit Lake in the N part of Black Rock Range. subalkaline.

Craine Creek: 15.7 + 5 on sanidine. dw ig, green when glassy. 10% phenos of sodic san, qtz, and distinctive pheos of micrograpically intergrown qtz and san plus trace mafics. Vapor phase arfvedsonite therefore peralkaline.
K-Ar on sanidine = 16 my.

Tuff of the Mesa: SE Pine Forest and locally E flank of BRR. Similar to Craine Creek but have notieable, 1%, mafics of Fe-rich cpx, fayalite, and mt.

Idaho Canyon Tuff: dw, granophyric, locally lithophysal. Na-san, qtz and rare micrographically intergrown qtz and san are usually a few percent but as much as 5-15 % at top. Comendite. Center of distribution is Virgin Valley.

Summit Lake Tuff: K-Ar on anorthoclase - 15.1 + .5 my K-Ar. Directly overlies Idaho Canyon Tuff. W-central Pine Forest to southernmost BRR and to southern part of Calico Mtns. Dw, devit. 20-25 phenos of anorthoclase, bio, cpx, amphibole. subalkaline.

Soldier Meadow Tuff: K-Ar on san = 14.7 + .5 ; 15.6 + 1.7 nonhydrated glass = From Calico Mtns to just south of Big Mountain and W and NE of Badger Mtn. Erosional remnants in central BRR. Most localities weather to a very deep brown. Dw, granophyric, v.p. arfv, Na-amph and cpx - peralkaline - comendite. 20-25 phenos of smoky qtz and na-rich san, arfvedsonite, Fe-rich cpx.

Both subalkaline and peralkaline present. The peralkaline rocks all contain <4% FeO therefore comendites.

Range bounding fault on W side of BRR offsets Soldier Meadow Tuff > 3,000'. Faulting has continued from the late Miocene through the Quaternary. The oldest fulting so far recognized was contemporaneous with the deposition of the late Miocene ash-flow sheets. In SW Pine Forest R by angular discordance and progressive offlap relations between the Ashdown Tuff, the tuff of Craine Creek, the Idaho Canyon Tuff, and the Summit Lake Tuff.

Thole, J. T. (1991) Ragged Top caldera: geology and geochemistry of a Miocene volcanic center, Pershing County, Nevada. Unpub. M.S. thesis, Washington State University, 108 p.

Trinity Range.
Precaldera dacite and rhyolite lavas; intracaldera ig and breccias; postcaldera dikes. High-K, calc-alkaline suite 62-76% SiO2.

Youngest unit is a basaltic andesite dike (53% SiO2), which may not be genetically related. Has xenocrystic quartz rimmed by glass and cpx.

Caldera first recognizd by Willden, R. and Speed, R.C. (1974) Geology and mineral deposits of Churcill County, Nevada. Nevada Bur. Mines and Geol. Bull. 83. They got a hb K-Ar date of 12.0 Ma on a rhyolite south of I-80 on the road to Jessup, which is thought to be outflow from RTC. Also got bio K-Ar date on "latite" dike in the caldera of 12.7 Ma.

Quote ages from McKee, E. H., and Marvin, R.F. (1974) Summary of radiometric ages of Tertiary volcanic rocks in Nevada. Part IV: northwestern Nevada. Isochron/West 10:1-6 on a rhyolite and a quartz latite flow from just northwest of Lovelock in the Trinity Range, which he interprets as possible outflow from RTC.
Bi from rhyolite flow = 14.4 + 0.7
Hb and bi from quartz latite flow are 13.7 + 1.7 and 14.8 + 0.7, respectively.
Consistent with his own dates, below.

5 WR dates in this study:
14.31 + 0.18 Ma on 2PD (dacite).
13.83 + 0.14 Ma, 13.65 + 0.17 on GR (rhyolite) which unconformably overlies 2PD (but both samples are propyliticly altered, so the age is probably too young)
14.73 + 0.26 on cross-cutting dacite dike HD, which is also postcaldera.
So concludes that the caldera is about 14.5 Ma.
9.08 + 0.18 on basaltic andesite dike BA. No cross-cutting relationships with other dike sets. "Probably associated with other late Miocene basalts present in other areas of the western Great Basin (Noble, D. C., (1988) Cenozoic volanic rocks of the northwestern Great Basin: An overview. In, Buffa, R., Cuffney, R. and Seedorff, E. (eds.) Hot-spring gold deposits of northwesten Nevada and southeastern Oregon. Geol. Soc. Nevada Spec. Pub. 7:31-42)". [Sampled dike trends NNE, as do nearly all the other dikes in the area.]

Largely a geochemical study (ME, TE, O isotopes), but remaps and is different from earlier mapping by:

Heggeness, J.O. (1982) The geology of Ragged Top caldera. Unpub. M.S. thesis, University of Nevada, Reno. 107 p.

[Neither Thole nor Heggeness say anything about age of B-R faulting versus volcanism. Some moderate (45-50 degree) southward dips on presumed intracaldera stuff. But both the 14.7 dacite dike and 9.1 Ma basaltic andesite dike trend NNE.]