DESCRIPTION OF MAP UNITS FOR THE GEOLOGIC MAP OF THE VIRGINIA CITY QUADRANGLE, NEVADA

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d Mine dumps and tailings

Ql Lake deposits Grayish white, fine-grained Holocene silts and clays deposited in small, closed, fault-controlled basins south of Steamboat Valley. Probably a few to tens of meters thick.

Qs Sand Wind-blown sand blankets a number of areas in the western part of the quadrangle. These well-sorted, medium- to fine-grained quartzose sands are commonly deposited on the east to northeast sides of hills but may extend across some flat areas. The sands are uncemented and loose but most are well stabilized by vegetation, locally including trees. The sands are usually white to tan but locally may be reddish where some alluvial material is intercalated. The sands, which are locally as much as 15 m thick, are probably Pleistocene but may be Holocene in part. Rock outcrops in the vicinity of areas of sand are locally polished and grooved; the grooves indicate a northeast sand-transport direction.

Qt Talus Coarse, angular rock fragments derived from adjacent rock units and deposited on steep slopes. Mapped only locally where it is extensive or conceals contacts between older units.

Qay Young alluvium Poorly sorted Holocene deposits of boulder- to silt-sized material deposited on alluvial fans and as channel deposits. Commonly non-indurated or poorly indurated.

Qa_i Intermediate-age alluvium Poorly sorted Pleistocene deposits of boulder- to silt-sized material deposited on alluvial fans.

Qls Landslide deposits Predominantly deposits resulting from debris flows or rock avalanches, consisting of chaotic mixtures of sand- to boulder-size material derived from steep terrain in hydrothermally altered andesite (Than) in the northwest part of the quadrangle. Also includes deposits ~2 km north of Mt. Abbie that are interpreted to be formed by rotational slump of Tkpu on Taf. Probably Pleistocene; surface is not hummocky and deposits have been dissected and removed by active Holocene streams.

Qfc Ferricrete Iron-oxide-cemented stream channel conglomerate and sandstone which crop out along the canyon adjacent to Toll Road, northwest quadrangle. Up to 5 m thick in exposed remnants along margins of present streams. Probably Pleistocene and formed by acidic surface waters derived from weathering of nearby pyrite-bearing andesite.

Qb Basalt of American Flat Dark-gray, vesicular olivine basalt flows, shallow microvesicular (~0.4 mm) intrusive rocks, and minor scoria. In thin section, a sample from a plug south of the Delaware Mine contained phenocrysts (~30%) of olivine (15%; 0.4-3 mm, rarely 4.5 mm), augite (10%, ≤0.7 mm), and plagoiclase laths (5%; ≤0.1x0.7 mm, rarely to 2 mm), sparse biotite (≤0.1 mm diameter), and Fe-Ti oxides in a intergranular groundmass of fine plagioclase, pyroxene, and glass(?). A flow erupted from this plug on the east flank of McClellan Peak,

apparently flowed across American Flat and down American Ravine. Subsequent erosion has left just remnants of the flow. The vesicular basalt flow contains about 15% phenocrysts of olivine and augite up to 2 mm that grade in size to the matrix. The basalt as a whole contains about 15% olivine, 15% augite, 55% plagioclase, 15% black glass, and 5% opaque minerals. The plagioclase (about An_{65}) forms elongate laths from microlites to 1 mm long. Apatite occurs as microlites in glass and as inclusions in plagioclase Age is 1.17 Ma (new constants) from a flow on Basalt Mesa (SE¼ Sec. 8, T15N, R21E; Doell and others, 1966).

QTa Old alluvium Poorly sorted middle(?) Pleistocene deposits of boulder- to silt-sized material deposited on alluvial fans, which are commonly deeply dissected. Includes a unit exposed in the Overman Pit that consists of moderately bedded fan gravels tilted westward up to 25º toward the Comstock fault. Some old alluvium may be late Tertiary.

Tbd Black Dike Intruded along the footwall of the Comstock fault zone is what Becker (1882) informally referred to as the Black Dike. This basalt dike does not crop out anywhere, but has been encountered in nearly all of the underground workings from the Savage Mine to the Caledonia Mine. It is not shown on the map or in the cross section. The dike, up to 8 m wide, apparently pinches out within 50 or so meters from the surface. Based on a sample from the New Savage Mine, the Black Dike basalt contains about 10% olivine (nearly all altered to clay), 10% augite, 65% plagioclase, 5% opaque minerals, and 10% glass (altered to clay). Crystal sizes are less than 1.5 mm. The plagioclase forms elongate laths with weak oscillatory zoning averaging about An_{65}. Vikre and others (1988) reported whole rock K-Ar ages of 8.6 ± 0.3 Ma and 8.2 ± 0.3 Ma on samples from the New Savage Mine.

Tsvs Volcaniclastic sedimentary rocks of Steamboat Valley Very light-gray to pinkish-gray and yellowish-gray volcanic conglomerate, sandstone, conglomerate, and tuff. Conglomerate contains pebble- to cobble-sized clasts of pale-red to light-gray hornblende andesite, glassy medium-gray pyroxene-hornblende andesite, dark-gray andesite, and pale red glassy hornblende-pyroxene-biotite andesite. In places, the conglomerate contains angular pebble- to boulder-size clasts and probably originated as lahars. The most distinctive rock is generally well sorted, cross-bedded, fine-grained to granule, tuffaceous sandstone. The sandstone contains angular to rounded andesite fragments, glass shards, and grains of plagioclase, hornblende, pyroxene, and opaque. White to very light-gray clayey tuff is a minor constituent.

Tsva Andesitic flows and flow breccias of Steamboat Valley These rocks, which are in the highest part of the Tertiary volcanic section in the Virginia City Quadrangle and just below Tps, are exposed in a relatively small area south of Steamboat Valley. They may be, in part, coeval with other andesitic rocks, and probably intertongue with Tlfu. They are mostly exposed as medium-gray andesite flows, generally dense and not vesicular, with columnar and platy jointing common. Phenocryst composition is variable, but flows are generally distinguished by the presence of olivine that is partially to wholly replaced by glassy orange iddingsite. However, they locally include dark gray flows with relatively abundant hornblende and no olivine. Phenocrysts include 20-30% plagioclase (mostly An_{67}-An_{47}, but some samples with compositions as sodic as An_{29}) to 7 mm; 3-10% green clinopyroxene (diopside-augite) to 2 mm; 1-6% pale brown hypersthene to 1.5 mm; 1-3% opaque to 1 mm; 0-10% hornblende to 5 mm; 0-2% olivine in rounded anhedral to sharply euhedral grains to 2 mm; 0-1% biotite to 3 mm; and

trace stubby gray apatite prisms to 160 microns diameter that generally have brownish rims. The matrix is pilotaxitic to granular, with plagioclase laths that average 20-40 microns, pyroxene, and opaque grains, with or without glass. The flow breccias are poorly exposed but probably comprise 80% of the unit; some laharic breccias may also occur in the unit, but none were observed in outcrop.

Tva Highly vesicular andesite Distinctive medium-gray flow rock that weathers to light-brown to moderate-orange-pink colors and contains as much as 25% void space as irregular frothy vesicles that are locally lined by vapor-phase minerals. Forms a flow as much as 25 m thick and locally has crude columnar jointing. Flow banding is well-developed and commonly has highly variable attitudes. Contains 20-25% plagioclase (average An_{68}) in phenocrysts to 4 mm; 8-9% green clinopyroxene to 1.5 mm; 6-7% brown hypersthene to 1 mm; and 2-3% opaque grains to 0.5 mm. Matrix is pale-brownish-gray devitrified glass that contains plagioclase laths that average about 50 microns long with lesser opaque and pyroxene grains.

Tbbl Big boulder lahar North of Jumbo an extensive lahar or debris flow unit with characteristic large boulders is exposed. The lahar contains clasts up to 3 m in diameter that have varied lithologies; however, the characteristic lithology is dark basalt or basaltic andesite. Perhaps 50% of the unit consists of these dark clasts, some of which have vesicular and pahoehoe textures. Although there are a number of textural varieties, including nearly aphyric rock, in general the basalt is porphyritic with 20-45% phenocrysts up to 3 mm (usually less than 2 mm) across of plagioclase, augite, and minor amounts of hypersthene. Plagioclase phenocrysts tend to have 1:3 elongation but some are equant. They are commonly somewhat castellated with oscillatory-normal zoning averaging about An_{65} with some grains having glassy cellular zones. Stubby euhedral augite (≤ 3 mm) makes up 5-20% of the rock and some of the basaltic rocks contain up to 3% stubby hypersthene; a trace of hornblende is noted in some clasts. In addition, the rocks generally contain about 4% magnetite, variable amounts of plagioclase and pyroxene microlites and up to 20% black glass. Nearly aphyric boulders have strong platy jointing that helps differentiate clasts in this lahar from those in other lahars. Other clasts include andesite and very rare Cretaceous granitic boulders. Up to 15% of the clasts are of highly altered (usually silicified or quartz-alunite) rocks, but such clasts are not evenly distributed. The matrix of the lahar consists of sand and mud, but is rarely exposed (i.e., along the Ophir Grade roadbed). Elsewhere the matrix weathers away easily leaving a boulder-strewn surface. As much as 30 m of this unit is exposed in the quadrangle.

The age of the big boulder lahar is not well constrained. It overlies highly faulted Alta Formation and at the western quadrangle edge overlies Cretaceous granite. The surface that the lahar flowed over was apparently of very low relief. The unit could be as young as Quaternary but is more likely late Miocene or Pliocene because it is offset by faults having Quaternary displacement. The source of the lahar is also unknown. The altered fragments could have easily been derived from the altered area north of Jumbo, the main Comstock district, or the Geiger Grade area. There are, however, no known exposures of Cretaceous granitics in those directions except at the base (west end) of the Geiger Grade. The lack of ash-flow tuff clasts would probably preclude a source to the south. Tabor and Ellen (1975) mapped this unit in the Washoe City Quadrangle east of New Washoe City as part of the Kate Peak Formation but it is lithologically quite distinct from any Kate Peak units.

Tbd Biotite hornblende dacite Light brownish gray weathering, light gray rock consisting of +30% phenocrysts of equant plagioclase (~25%, <5 mm), elongate hornblende (~5%, < 5 mm long), distinctive, large biotite books (~2%, up to 5 mm in diameter and 2 mm thick), and locally, trace bottle-green augite(?) and pinkish quartz, all in a light gray groundmass. The unit is fresh in nearly all outcrops; very minor clay alteration could be either hypogene or supergene. Variable flow banding attitudes and poorly developed columnar jointing suggest it is probably a flow dome which cuts and lies on unit Than. Pervasive hydrothermal alteration and the absence or near absence of biotite in adjacent unit Than serve to distinguish it from Tbd. Crops out in the northeast part of the quadrangle and is overlain to the northeast, by 7.5 Ma olivine basalt flows of the Lousetown Basalt (Schwartz, 2001). Probably equivalent to the 12.1 Ma unit Tkdi of Schwartz (2001) in the Chalk Hills Quadrangle to the northeast.

Thal Hornblende andesite lahars Poorly to well exposed laharic breccias that contain pebble to boulder-sized clasts (to 1 m or more) of andesite with large hornblende phenocrysts. Breccia is mostly matrix supported and clasts are typically subrounded. The matrix is light gray, generally poorly lithified, and consists mostly of sand-size andesitic material. Clasts range from light greenish-gray to pale red and typically contain hornblende phenocrysts as much as 2 cm long. Phenocrysts consist of 20-30% plagioclase (An_{46}-An_{73}) to 1 cm; 3-20% hornblende, in some cases with iron oxide rims; 2-10% pyroxene (wholly to dominantly clinopyroxene), and 1-3% opaque grains. In places, the lahars contain clasts with 1-2% biotite phenocrysts as much as 2 mm across and no pyroxene. Groundmass in the clasts is typically glassy or devitrified glass with microlites or fine laths of plagioclase that average about 30 microns, along with fine pyribole and opaque grains. Probably equivalent to Tkpu of the Mt. Abbie area.

Tlfu Undivided lahars and flows Lahars and flows that underlie a large area in the northwest part of the Virginia City Quadrangle, and generally contain two pyroxenes with or without hornblende, but no olivine. In general, flow rocks are sparsely exposed, and flows probably comprise less than 10% of the sequence. The flows are composed of medium- to dark-gray andesite, some that strongly resembles flows in Taf and some that are more hornblende-rich and resemble flows in Tal. Phenocryst content in the flow rocks is variable: 15-35% plagioclase (An_{47}-An_{70}) to 7 mm; 5-10% pyroxene in grains to 2 mm that are dominantly green clinopyroxene but generally include minor brown hypersthene; trace-10% hornblende, in some cases as crystals to 1 cm long; and 2-5% small opaque grains.

Laharic breccia, which is generally matrix supported, includes angular to subrounded clasts of variable lithology to 2 m or more. Clasts, which are mainly composed of two-pyroxene andesite and commonly highly vesiculated, range from dark-gray scoriaceous rock to light-gray rock that may be strongly flow banded. The matrix ranges from light gray to pinkish gray material composed of pulverized andesite and may contain some shards.

Tha Hornblende andesite flow rock Flows that resemble the dominant clast type in Thal and are typified by phenocrysts of hornblende as much as 2 cm long. The flows are light to medium gray and generally form bold outcrops. Flow foliation is highly variable and commonly oriented at high angles to flow contacts. Phenocrysts include 10-20% plagioclase (average An_{60}) as moderately elongate to blocky, mostly subhedral grains to 5 mm; euhedral to anhedral

hornblende that may be rimmed or wholly replaced by iron oxide; 2-3% pyroxene (dominantly clinopyroxene with minor hypersthene); and 2% opaque grains to 1.6 mm. The matrix consists of flow-aligned plagioclase laths that average 40 microns long with tiny mafic and opaque grains and some devitrified glass. Underlies and intercalated with Thal.

Tad Andesite dike rock Medium- to dark-gray andesite with abundant phenocrysts that include minor biotite. Phenocrysts include 20-25% plagioclase (An_{56} average) as blocky crystals and glomeroporphyritic clusters to 1 cm, and smaller elongate phenocrysts; 10-15% hornblende as subhedral to euhedral crystals to 7 mm; 2-3% opaque as equant grains to 0.7 mm, trace biotite as books to 2mm; trace apatite as clear prisms to 100 microns long; and trace allanite(?) as deep brown grains. The matrix is mostly granular devitrified glass with wispy plagioclase laths and tiny opaque and mafic mineral grains. The dikes are as much as 15 m wide and have dark-gray, glassy borders about 20 cm wide. Probably correlative with Tkpi.

Tbh Andesite of Basalt Hill On Basalt Hill and south of the Haywood Mine, a black andesite flow up to 35 m thick crops out. The andesite contains 20-25% plagioclase phenocrysts less than 1 mm long but a trace up to 6 mm long. The stubby subhedral laths have weak oscillatory normal zoning with an average composition about An_{55}. About 10% of the plagioclase phenocrysts have glassy cellular inner zones. Subhedral augite up to 0.5 mm across makes up about 10% of the rock. The phenocrysts are locally glomeroporphyritic, forming clusters of plagioclase-augite, augite-augite, augite-magnetite, and plagioclase-plagioclase up to 1 mm across. There is up to 1% olivine up to 1 mm and a trace of highly rounded olivine up to 3 mm across. Most of the olivine is altered to iddingsite. The phenocrysts grade in size to a pilotaxitic matrix of plagioclase microlites (with 1:2 to 1:5 elongation), a few augite microlites, and gray glass that makes up 5-25% of the rock. Magnetite up to 0.3 mm across forms about 3% of the rock.

The andesite of Basalt Hill resembles Knickerbocker Andesite but lacks hornblende and lacks the tannish weathered crust. The andesite appears to lie on the same erosional surface as the Knickerbocker Andesite and may be similar in age.

Tka, Tkai - Knickerbocker Andesite The Knickerbocker Andesite (**Tka)** is found as remnants of an extensive flow up to 30 m thick that blankets the southeastern part of the quadrangle. Apparently erupted from a fissure vent (**Tkai**) in the footwall of the Occidental Lode, the Knickerbocker Andesite unconformably overlies the lower member of the Kate Peak Formation and appears to occupy a large erosional window in the upper member of the Kate Peak Formation. Nowhere can a clear contact be seen between the upper member of the Kate Peak Formation and the Knickerbocker Andesite.

The Knickerbocker Andesite is dark gray to black and weathers to a characteristic rust-brown to tannish crust up to 5 mm thick. The rock contains about 50% phenocrysts up to 3 mm long that grade in size to the groundmass of plagioclase microlites and 5-20% glass. Plagioclase phenocrysts form stubby laths with oscillatory zoning and may have cellular zones containing glass and augite. Plagioclase phenocrysts average about An_{55} (in some flows, An_{63}-An_{67}) and make up 35-40% of the rock. Augite makes up 5-15% of the rock along with traces of hypersthene. The pyroxenes tend to form aggregates of crystals and larger pyroxene phenocrysts commonly contain numerous plagioclase inclusions. Aggregates of augite and plagioclase may

be up to 4 mm across. Trace to 1% of hornblende phenocrysts to 3 mm may be partially replaced by magnetite and or augite. A strongly planar flow foliation is commonly observed on weathered surfaces. Red jasper commonly is found in joints as well as in the immediately underlying rocks.

Samples of plagioclase separated from the Knickerbocker Andesite have yielded K-Ar dates of 13.2 ± 1.3 Ma and 13.6 ± 0.8 Ma (Vikre and others, 1988) and 13.6 ± 0.6 Ma (E.H. McKee, written commun., 1987). The five K-Ar dates are within the uncertainty of the method and are essentially concordant. The age of the Knickerbocker Andesite overlaps that of the upper member of the Kate Peak Formation (see Vikre and others, 1988) but is very distinctly a separate magmatic source. It is possible that some rocks we map as Knickerbocker are flow units within the Alta Formation.

Tafl Andesite flows and lahars Relatively minor amounts of pyroxene-hornblende andesite flow rock interbedded in a thick sequence of lahars containing andesitic clasts that range in size from pebbles to boulders as much as 2 m in diameter. They consist of vesicular to dense glassy medium- to dark-gray pyroxene andesite, dark olive green glassy to light greenish-gray devitrified clasts of hornblende andesite, and dense dark-gray finely porphyritic andesite, along with minor amounts of reddish-brown scoria. The matrix is pinkish-gray and the lahars consist of matrix- to clast-supported breccia. The flows are mainly composed of medium- to dark-gray finely porphyritic andesite. Phenocrysts include 15-20% as elongate subhedral to euhedral crystals that grade in size to matrix laths; 5-10% hornblende as crystals to 3 mm long that are partially replaced by iron oxide; 5-10% pyroxene (mostly clinopyroxene) to 1 mm; and opaque grains to 0.3 mm that commonly occur in clusters.

Tbha Biotite hornblende andesite Reddish-brown-weathering, greenish-gray rock consisting of about 15% phenocrysts of equant to elongate, rarely conjoined plagioclase (>10%, 1-4 mm), black to iron-oxide-rimmed hornblende (~3%; mostly 2-3 mm long, but some to 3x9 mm), and euhedral biotite (~1%, <3 mm in diameter). Commonly propylitized, altered to clay minerals, or bleached and stained with iron oxides. Locally, slightly altered to unaltered remnants are observed. Probably a flow dome or intrusive into Than and Taf, although contact relationships are commonly unclear due to destruction of minerals and textures by hydrothermal alteration. Similar in appearance to Tbd, but probably older because Tbd apparently postdates the alteration that affects Tbha.

Than, Thanp, Thanx Hornblende andesite Medium to light gray andesite containing phenocrysts of elongate hornblende (<2x10 mm) and equant, separate and conjoined plagioclase (1x2 to 4x5 mm). Pyroxene can be observed by hand lens in some samples. Biotite is absent or rare in most of the unit, although it is a significant component north of the west end of Toll Road and north of the power-line canyon fork of Bailey Canyon. Most of the unit is strongly hydrothermally altered to white or yellowish gray rocks in which textures are commonly destroyed. Alteration includes epidote + chlorite + albite (propylitic); illite, kaolinite, and other clays (argillic); and local ledges and irregular replacement by silica + alunite. Propylitized rocks commonly appear to be surrounded by or cut by irregular to linear areas of argillized and/or silicified rocks. Mafic minerals are commonly converted to iron oxides in altered rock. **Thanx** is a locally distinguished intrusive or flow(?) breccia portion of the unit. **Thanp** refers to highly altered bedded pyroclastic(?) rocks that were observed at two areas (but only extensive enough to

be mapped at one). These rare bedded rocks are apparently contained within a sequence of lavas. **Than** is exposed over much of the northern part of the quadrangle. The massive nature, rarely preserved steep flow banding, lack of magnetite-rimmed hornblende, and lack of lahars and flow breccias all suggest that at least part of the unit is intrusive or flow domes. Its poorly defined contact with Tkpu north of Long Valley Creek is based mainly on the absence of biotite in **Than**. It is intruded by Tbha, which is similarly affected by hydrothermal alteration. The unit overlies Taf and appears to underlie Thal at the mouth of Bailey Canyon. Also, it underlies or is intruded by Tbd, which is relatively unaltered. Possibly equivalent to the Kate Peak Formation of the Virginia City area.

Tia Andesite porphyry dikes West of Jumbo, andesite dikes of varied composition and texture intrude altered ash-flow tuffs and Davidson Diorite(?).These porphyry dikes contain up to 25% pyroxene phenocrysts up to 10 mm long or up to 20% hornblende phenocrysts up to 7 mm long. They contain variably 20-35% plagioclase phenocrysts up to 3 mm long. The matrices of these dikes are usually very dark and aphanitic but appear to be crystalline.

The dikes cut sericitized ash-flow tuffs but do not appear to be sericitized themselves. They usually are weakly to moderately propylitized with chlorite and very minor epidote. It is unlikely that these are part of the Alta Formation as they intruded along northeasterly faults that also cut the nearby Alta. It is assumed that they are Kate Peak-aged or younger but they do not resemble Kate Peak andesites.

Also included is a hornblende andesite dike which cuts the Guild Mine Member near McClellan Peak. This locally microvesicular dike contains ~3% elongate, magnetite-rimmed hornblende (<2.3 mm long) as well as elongate plagioclase phenocrysts up to 2.5 mm long in a pilotaxitic groundmass of fine plagioclase laths and magnetite.

KATE PEAK FORMATION

Tkpi, Tkpl, Tkpu, Tkpui, Tkpul, Tkpux Kate Peak Formation The Kate Peak Formation consists of andesitic flows, lahars, flow domes, subvolcanic dikes and subvolcanic plugs. Although there are variations in textures and compositions, most of the rocks of the Kate Peak Formation are distinctive from other lithologic units and even when strongly altered can be distinguished by texture. The Kate Peak Formation is herein divided into two informal members. The lower member consists of all hydrothermally altered intrusions and flows in the Comstock district. Unconformably overlying the hydrothermally altered rocks lies the upper member consisting of all extrusives and intrusions that are not hydrothermally altered. Although there is an unconformity between the upper and lower members, lithologically the two members are considered to be part of the same magmatic series based upon composition and texture.

Petrographically the Kate Peak Formation consists of porphyritic andesite. Phenocrysts vary from 25 to 60% of the rock. The size and shape of the plagioclase phenocrysts are characteristic, although in some flows this characteristic is not obvious. They are typically stubby and castellated or poorly formed equant grains. In general, more than half of the plagioclase grains 3-10 mm across are equant aggregates of two to ten crystal fragments that have a castellated appearance in hand sample. Zoning in the plagioclase phenocrysts tends to be highly complex

and variable from phenocryst to phenocryst in the same rock. Cellular zones, generally glassy, were commonly developed throughout crystal growth along with embayed and fluted zones. Plagioclase aggregates commonly show evidence of several periods of aggregation with common growth zones around each stage of aggregation. Aggregates tend to have crystallographic axes at random orientations.

Hornblende is by far the most abundant mafic phenocryst (5-15% of the rock) commonly as broken crystals generally less than 2 mm long. Hornblende in intrusions tends to be greenish to brownish green and may have magnetite rims. Hornblende in extrusions tends to be brown, with magnetite rims or partial to complete replacement by magnetite or hematite. Hornblende phenocrysts commonly have plagioclase inclusions and are in some cases corroded and partially replaced by biotite or pyroxene or both. Brown biotite phenocrysts (0-10% of the rock), commonly with magnetite rims and in some cases corroded are typically less than 2 mm across. Biotite is apparently absent from some of the lower member intrusions but is almost always present in trace quantities or greater in the bulk of the formation. Augite and very rare hypersthene phenocrysts (0-4% of the rock) are found as stubby crystals less than 1 mm long. Pyroxene appears to be absent or in present in trace amounts in roughly half of the Kate Peak Formation in the Comstock district. Round quartz phenocrysts to 1 mm but usually less than 0.5 mm across are found sporadically in the formation, rarely constituting more than 1 or 2% of the rock. Magnetite forms 1-5% of the rock as aggregates or cubes up to 0.5 mm across. The matrix consists of variable proportions of plagioclase microlites, biotite microlites, brown devitrified glass or black glass. There is almost always a sharp break in size between plagioclase phenocrysts and groundmass microlites.

Upper member

The upper member of the Kate Peak Formation (**Tkpu**) was emplaced following a period of hydrothermal activity, faulting and erosion. The earliest phase of the upper member in the Comstock district is an extensive lahar with boulders of Kate Peak andesite up to 2 m across and some pre-Kate Peak rock types. This basal lahar is found north of the Sutro Tunnel and extends to at least Long Valley and around Mt. Abbie, thinning south of the Sutro Tunnel. Overlying the lahar is up to 300 m of interbedded andesite flows with lesser interbedded lahars and a few whitish ash beds near Mount Grosh. A strongly flow-banded plug (**Tkpui**) of upper member intrudes at Mt. Abbie. A somewhat glassy semicircular dike of strongly columnar-jointed upper member intrudes highly altered rocks in Sec. 26, T17N, R20E northeast of Jumbo. A mass of upper member north of the Sutro Tunnel at the east edge of the quadrangle is probably a flow dome. Flow(?) breccia (**Tkpux**) and lahars (**Tkpul**) are mapped separately in a probable flow dome complex exposed north of Long Valley.

Lower member

The lower member of the Kate Peak Formation in the Comstock district is represented mostly by dikes and plugs (**Tkpi**). Dikes are commonly a medium-gray porphyry containing plagioclase (average An_{52}) phenocrysts (30%) as stubby to moderately elongate grains, commonly as complex twins or intergrown crystals to 5 mm, and hornblende phenocrysts (5-10%) to 5 mm, which are totally altered to chlorite and calcite. The dike rocks also contain opaque minerals (2%) in grains to 1 mm; and biotite (1%) as dark brown books to 2 mm across, partly altered to carbonate and chlorite. The matrix consists of plagioclase laths forming felty texture with opaque

and altered mafic grains; the texture is markedly non-seriate. The larger exposed intrusive masses tend to lack a structurally preferred orientation and may represent the earliest phase of intrusion. Apparently coincident with the early phases of faulting that would later become the focus of mineralization in the district, numerous dikes of the lower member were intruded into the structures either within the Comstock, Silver City, and Occidental Lodes or in nearby sympathetic structures. Such structural control is well displayed around Cedar Hill Canyon and in the hanging wall of the Silver City Lode. A small area of flows and a few interbedded lahars (**Tkpl**) occurs in the hanging wall of the Occidental Lode south of the Sutro Tunnel. These are the only known extrusives of the lower member. Apparently, hydrothermal activity affected the district late during the emplacement of the lower member; the lower member of the Kate Peak Formation is considered to have been spatially and temporally associated with the main mineralizing events.

In the footwall of the Comstock Lode and concentrated between Mount Davidson and Orleans Hill are a number of andesite plugs that we group with the lower member of the Kate Peak Formation. The propylitized to sericitized andesite porphyry in these plugs is somewhat different from more typical Kate Peak intrusive rock, in that few of the plagioclase phenocrysts are conjoined and biotite is apparently absent. The margins of these intrusions commonly contain 20-30% plagioclase phenocrysts up to 4 mm. Five to 15 m inward from the contacts very stubby to equant plagioclase phenocrysts (to 5 mm) make up 30% to locally as much as 65% of the rock. The plagioclase is weakly oscillatory-zoned andesine with about one fourth of the plagioclase phenocrysts having broad spongy cellular outer zones. Green to slightly brownish, stubby to fairly elongate euhedral hornblende phenocrysts generally up to 5 mm and rarely to 10 mm long make up 10-15% of the rock. Augite phenocrysts less than 1 mm long make up less than 1% of the rock. Magnetite cubes less than 0.5 mm across make up about 2% of the rock. The matrix consists of plagioclase microlites in 5-15% devitrified brown glass. In the north fork of Cedar Hill Canyon and in several places along Spanish Ravine the andesite porphyry grades within a short distance into small masses of diorite porphyry with a composition similar to the andesite. The diorite contains hornblende laths up to 5 mm in a granular matrix of hornblende, plagioclase, and minor augite with average grain size of about 2 mm but grading into 5-20% matrix with a grain size about 0.3 mm. These intrusions are cut by dikes of more typical, biotite-bearing, phases of the lower member of the Kate Peak Formation.

Age of the Kate Peak Formation

The age of the Kate Peak is middle Miocene. The lower member has never been isotopically dated because it is somewhat altered. The upper member has yielded three K-Ar age determinations from a unit we interpret as a basal flow exposed near the Utah Shaft of 16.9 ± 1.8 Ma to 14.1 ± 0.4 Ma (Vikre and others, 1988): the same basal flow near the Cedar Hill Mine yielded an age of 14.1 ± 0.4 Ma on biotite (E.H. McKee, written commun., 1987). Kate age determinations in the quadrangle appear to be concentrated in the 15-14.1 Ma range; the youngest Kate date from in or very near the quadrangle is 13.2 Ma (recalculated from AD-12 in Bonham and Pakpe, 1969, table 23).

Thp Hornblende andesite porphyry dikes West of Jumbo are several dikes of distinctive hornblende andesite porphyry that contain as much as 20-40% slender hornblende phenocrysts as much as 10 mm long that are commonly sub-parallel to one another. The hornblende has thin

magnetite rims. The dikes also contain 15-25% stubby to equant plagioclase phenocrysts 0.2-1.5 mm long that average approximately An_{50}. About one fourth of the plagioclase phenocrysts have cellular zones and the plagioclase phenocrysts. The rock also contains about 0.5% stubby to rounded augite phenocrysts up to 0.2 mm. There is a fairly sharp break in the size of the phenocrysts to a matrix of lathy plagioclase microlites and some devitrified glass. These weakly propylitized dikes intrude rocks as young as the Alta Formation, but may postdate the Alta.

Tri Rhyolite intrusions A few rhyolite intrusions are found in the Comstock district. A small intrusion exposed south of Cedar Ravine is strongly hydrothermally altered but contains up to 5% relict feldspar and up to 5% quartz phenocrysts less than 1 mm across. Flow foliation is poorly preserved in most outcrops. A rhyolite dike west of Mt. Bullion is very strongly altered but contains a few percent quartz phenocrysts and some discernable flow banding. A highly altered rhyolitic intrusion was intersected by the Sutro Tunnel but does not crop out at the surface. Samples from the Becker Collection (National Museum of Natural History) contain about 15% relict feldspar phenocrysts less than 2 mm across, 0-5% quartz phenocrysts and about 1% biotite phenocrysts less than 1 mm across. The margins of this intrusion have strong lamellar to kink-banded flow foliation while the interior appears to lack flow foliation.

The age of the rhyolite intrusions is unclear. The rhyolites intrude the Alta Formation and are hydrothermally altered. Other intrusive relationships are lacking; however in Ophir Ravine there is a dike of the lower member of the Kate Peak Formation that heads toward but does not cut the rhyolite plug. Thus the youngest likely age for the rhyolites would be that of the lower (altered) member of the Kate Peak Formation. It is also possible that the rhyolites could be a phase of the Alta Formation.

Thbap - Hornblende biotite andesite porphyry A concentration of propylitized hornblende biotite andesite porphyry dikes crops out near the Mahoney Mine at Jumbo. The dikes contain 10-15% subhedral to euhedral green hornblende phenocrysts that are commonly up to 4 mm long (elongation 1:3 to 1:5) but a few are as much as 10 mm long. The hornblende contains many inclusions of plagioclase and some augite. Plagioclase phenocrysts (about An_{40}) up to 3 mm long form about 20% of the rock. The plagioclase phenocrysts include equant to stubby laths and some conjoined grains. About 25% of the plagioclase phenocrysts have cellular zones (commonly several zones) while the rest have non-cellular oscillatory-normal zoning. The rock contains about 0.5% biotite phenocrysts as books up to 0.7 mm thick. There is also about 0.5% anhedral quartz up to 0.2 mm. The phenocrysts grade slightly in size to a matrix of plagioclase and hornblende microlites averaging about 0.05 mm long. The rock also contains about 5% magnetite up to 0.2 mm across.

On the east flank of Basalt Hill an intrusion that is similar to the Mahoney Mine dikes contains large xenoliths (or pendants) of Santiago Canyon Tuff and Alta Andesite. This variably altered intrusion contains 10% euhedral green hornblende (1-4 mm long), 20-25% plagioclase phenocrysts (1-3 mm long), and a trace of brown biotite up to 0.5 mm across. The plagioclase phenocrysts are commonly broken and a few are conjoined. About one fourth have multiple cellular zones while the rest have non-cellular oscillatory-normal zoning. There is also about 3% magnetite and a trace of apatite. There is fairly sharp break in size between the phenocrysts and the matrix of squarish plagioclase microlites and about 20% glass.

Although these intrusions resemble portions of the Alta Formation, the presence of biotite suggests that the dikes are probably a phase of the lower member of the Kate Peak Formation. The zoning in the plagioclase is suggestive of Kate Peak but the general lack of conjoined phenocrysts is atypical of Kate Peak andesites.

Tdd, Tdap, Davidson Diorite The early Miocene Davidson Diorite (**Tdd**), which underlies much of the central part of the Virginia City Quadrangle, intrudes the Alta Formation. This subequigranular rock type crops out on Mt. Davidson and in a few places in the hanging wall of the Comstock Lode. Virtually all exposures are variably hydrothermally altered; essentially unaltered Davidson Diorite is only known from a decline in the footwall of the Comstock Lode in the New Savage Mine. The Davidson Diorite appears to comprise a multi-phased pluton with repeated pulses of magma. Only rarely are internal intrusive contacts observable; some have been noted in drill core. The average grain size of the major constituents varies from place to place; it is generally about 3 mm but locally may be up to 5 mm. Subhedral to anhedral plagioclase is weakly oscillatory-zoned andesine (averaging about An_{47}) with a few grains having spongy cellular outer zones. Anhedral to rarely subhedral pyroxene, nearly always completely actinolized, makes up 10-15% of the rock. In a fresh sample from the New Savage Mine, there is slightly more augite than hypersthene, with augite forming nearly equant grains and the hypersthene having about 2:1 elongation. Calkins (1944) reported hypersthene from the Hale and Norcross Tunnel under Mt. Davidson. The hornblende reported by Gianella (1936) was evidently actinolized hypersthene although a trace of interstitial hornblende occurs in a few thin sections and local phases of the diorite may contain up to 3% hornblende. Although commonly chloritized, the Davidson Diorite contains about 1% brown biotite as poorly formed grains up to 1 mm long. About 7-10% orthoclase and 7-12% quartz occur as an intergranular matrix to the plagioclase and pyroxene. Quartz and orthoclase are typically anhedral equant grains up to 1 mm across but more commonly less than 0.5 mm. Stubby apatite is ubiquitous with traces of zircon and sphene.

An andesite porphyry phase (**Tdap**) of the Davidson Diorite borders exposures of Davidson Diorite as chilled margins in the hanging wall of the Comstock Lode and is also found as numerous dikes. In two places north of the Scorpion Shaft, a gradual change from phaneritic diorite to andesite porphyry is observed over about 3 m. A dike of phaneritic diorite north of Crown Point Ravine grades into andesite porphyry over a vertical extent of about 6 m. In the vicinity of the Scorpion Shaft and the East Yellow Jacket Shaft, the andesite porphyry grades in texture to rock that resembles the upper Alta Formation. Contacts are locally difficult to distinguish, primarily because of alteration. However, most of the dikes in propylitized rocks however, are easily distinguished texturally from the enclosing Alta Andesite. The andesite porphyry may vary considerably in phenocryst content but commonly contains around 35% phenocrysts that grade in size to the matrix. In several dikes near Wakefield Peak, rocks with about 10% phenocrysts near contacts grades to about 60% phenocrysts in dike interiors 3 m from the contact. About 75% of the phenocrysts are oscillatory zoned andesine up to 3 mm across. Most of the plagioclase phenocrysts are only slightly elongate and weakly castellated. About 10% of the plagioclase phenocrysts have glass-rich spongy outer zones. About 15% of the phenocrysts are augite and about 10% are hypersthene up to 2 mm long. These are most commonly actinolized. Traces of oxybiotite occur locally. Magnetite makes up about 2% of the

rock. Stubby apatite occurs as inclusions in plagioclase phenocrysts. The matrix consists of highly variable quantities of plagioclase microlites and devitrified brown glass.

A fine-grained diorite that is similar in composition to the Davidson Diorite is found in the hanging wall of the Comstock Lode. The diorite is subequigranular with average crystal size of about 0.5 mm and some crystals up to 1 mm. The rock contains about 70% plagioclase, 15% altered pyroxene, and small amounts of quartz and orthoclase. It is included with the Davidson Diorite due to similarities in composition, but is distinctly finer grained. This diorite is not exposed on the surface but the Becker Collection contains numerous examples from various underground localities in the Sierra Nevada, Union, Mexican, and Ophir Mines plus a few samples from the footwall of the Comstock Lode in the Yellow Jacket and Crown Point Mines.

A multi-phased plug of fine-grained propylitized diorite that is probably correlative with the Davidson Diorite crops out west of Jumbo. In various textural types, the grain size varies from 0.2 to 0.7 mm. Plagioclase varies in the different types from subhedral to anhedral, making up about 70% of the rock. Anhedral brown biotite makes up about 2% of the rock. The other mafic minerals are completely altered but appear to have consisted of 5 to 10% augite, and one type of the diorite contains highly elongate altered grains as much as 4 mm long of what may have been hypersthene. The rock contains about 5% interstitial anhedral quartz and about 5% interstitial orthoclase. There is also about 4% magnetite and a trace of apatite.

Surface exposures of both the equigranular phase and the andesite porphyry marginal phases plus numerous andesite porphyry dikes extending west past Jumbo indicate that the Davidson Diorite is extensive in the subsurface. Equigranular diorite and andesite porphyry phases occur in a number of places in the Sutro Tunnel to just east of the quadrangle boundary and north of the Sutro Tunnel to the Scorpion Shaft (Becker Collection). Equigranular Davidson Diorite also occurs in the subsurface in the Flowery district to the east of the quadrangle (Becker Collection) and in the Jumbo district (from dump material).

Two zircon samples from the Davidson Diorite yielded fission-track dates of 17.6 ± 2.1 Ma and 16.9 ± 2.1 Ma (Vikre and others, 1988). K-Ar dates for Davidson range from 10.8 to 14.7 (Vikre and others, 1988). These K-Ar age determinations probably do not reflect the age of crystallization, but rather later heating or hydrothermal activity, because some ages are younger than dated post-Davidson rocks, and $\delta^{18}O$ and δD mineral values are too low for unaltered rocks (Vikre and others, 1988).

Thi Hornblende andesite porphyry intrusions Several plugs of frothy andesite that are intruded into the Alta Formation in the western part of the Virginia City quadrangle are very much like the surrounding Alta Andesite flows (Tafh). These are petrographically the same as the surrounding hornblende andesite flows (Tafh) and are clearly the sources of some of the flows and lahars. The intrusions vary in texture and composition but are herein undifferentiated. Some of the plugs are rather uniform throughout. There is a plug of hornblende andesite porphyry that intrudes the thick lahar sequence (Tall) in Sec. 28, T17N, R20E, indicating that the Tafh is, at least in part, younger than those lower member lahars.

Tphap Pyroxene hornblende andesite porphyry Several dikes of gray to greenish pyroxene hornblende andesite porphyry crop out in the vicinity of the Overman Pit. The altered dikes contain 15-30% phenocrysts of plagioclase up to 2 mm long with 1-4% augite and 1-4% hornblende phenocrysts up to 1 mm long. The groundmass is a felted mass of plagioclase microlites and altered devitrified glass. These dikes are probably comagmatic with the Alta Formation

Thpap Hollow hornblende pyroxene andesite porphyry There are several intrusions of hornblende pyroxene andesite porphyry (Thpap) northeast of Silver City. Where relatively fresh, the intrusions are dark brown with 10-20% distinctive "hollow" hornblende phenocrysts up 30 mm long. The brownish-green hornblende phenocrysts typically have a matrix-filled core along a central zone parallel to the c-axis; this texture is generally apparent in hand sample. In thin section, zoning in the hornblendes continues from the outside of the crystals into the long holes on the ends of the crystals. The hornblende phenocrysts are commonly rimmed by magnetite and corroded along the margins, where they may be replaced by microscopic intergrowths of plagioclase, augite, and brown hornblende. Stubby andesine phenocrysts, some with spongy outer zones, are up to 2 mm long and make up 20-40% of the rock. Euhedral augite phenocrysts up to 1 mm make up about 3% of the rock. The plagioclase and augite phenocrysts grade into a matrix of microlites, magnetite, and about 20-30% brown devitrified glass. Most of the mass of the intrusions form a crude ring dike. These intrusions are probably comagmatic with the Alta Formation because a few flows in the upper member of the Alta have hollow hornblende phenocrysts, although they are less than 5 mm long.

Tara American Ravine Andesite The American Ravine Andesite cuts Mesozoic intrusions, Tertiary ash-flow tuffs and the Alta Formation. The usually light gray andesite is porphyritic, with 1-20% slender phenocrysts of hornblende up to 5 mm long. The hornblende is usually rimmed by magnetite. There are also 2-5% plagioclase phenocrysts up to 2 mm long. The groundmass consists of pilotaxitic plagioclase microlites, a few percent glass, and less than 2% opaque minerals. The percentage of phenocrysts varies; rock with more abundant phenocrysts is more commonly found near the interior of larger intrusive masses. In a few marginal exposures west of the Vulcano Mine, the andesite is nearly devoid of phenocrysts and is pale white.

Gianella (1936) stated that the American Ravine Andesite is extrusive and unconformably overlain by the Hartford Hill Rhyolite (Santiago Canyon Tuff); however, in exposures in American Ravine the andesite clearly crosscuts the ash-flow tuffs. The American Ravine Andesite clearly intrudes the Alta Formation in the highway cut near Silver City. The American Ravine may be an intrusive phase of the Alta Formation but this texture and composition is unusual for that unit.

ALTA FORMATION

Tal, Tall, Tals, Tas, Taf, Tafb, Tafs, Tafh, Tafbl Alta Formation The Miocene Alta Formation is the areally most extensive unit exposed in the Virginia City Quadrangle. It includes as much as 1,000 m of andesitic rock, primarily flows and breccias, in the quadrangle. Although several informal members have been mapped, the characteristics of the members overlap and there are local uncertainties in correlation. With a few exceptions, the eruptive source(s) of the

Alta Formation are not known but probably lie, in part, within the quadrangle. Because of the generally fine-grained texture and pervasive hydrothermal alteration of the unit, distinguishing Alta intrusions is difficult.

Upper (Flow) member

The upper, or flow member, of the Alta (**Taf**) overlies the Sutro Member, and locally the lower member directly. The unit is at least 600 m thick. The Sutro Member locally defines the base of the flow member in the eastern part of the quadrangle, but where the Sutro Member is absent, the change in lithology from a dominance by breccias to a dominance by flows approximates the lower contact. Unlike the lower member, the flow member is nearly devoid of lahars and autobreccias. Autobreccias, a few meters thick, very rarely occur at the base of a few of the flows. Only one exposure near Ophir Hill of a somewhat thin lahar is known from the flow member. Rocks of the lower and upper members are petrographically indistinguishable. In isolated exposures without extensive breccias or a contact relationship with the Sutro Member or underlying pre-Alta units, distinguishing the upper and lower members is impossible.

In unaltered exposures (somewhat rare) the flow member consists of hornblende-augite, hornblende, or augite andesite porphyry. Dense andesites are usually black weathering to dark brown or gray crusts, however most of the unit is hydrothermally altered and these rocks lack the weathered crusts. The andesites contain 20-50% plagioclase phenocrysts as stubby laths that rarely exceed 2 mm in length. The plagioclase is weakly to moderately oscillatory-normal zoned with an average composition of about An_{45}. Commonly 10 to 40% of the plagioclase phenocrysts have spongy cellular zones, usually near the outer rim, while the rest lack spongy zones. The andesites contain 2 to 10% augite and very rarely hypersthene phenocrysts. Pyroxene phenocrysts rarely exceed 1 mm in length and are commonly found as clumps of three to ten crystals. The andesites contain 0-10% brown hornblende phenocrysts generally less than 2 mm long, but in some flows as much as 7 mm long. The hornblende phenocrysts typically have thin rims of magnetite, or locally hematite, and commonly are partially to completely replaced by magnetite or, in certain flows, hematite. “Hollow,” matrix-cored hornblende phenocrysts are found in some of the flows. Magnetite crystals (1-5%), commonly up to 0.5 mm, are found in the rocks. Phenocrysts usually grade in size to a matrix consisting mainly of plagioclase microlites in brown glass. Dense glass generally makes up 20-40% of the rock, but in the bulk of the member the glass is devitrified, probably in large part due to hydrothermal alteration. The andesites, where fresh, commonly have a distinct roughly planar, closely spaced jointing. In some cases, this jointing parallels flow foliation defined by alignment of phenocrysts. In other cases, the jointing cannot definitively be linked to flow foliation and may not parallel it. In more altered rocks, this platy jointing is generally absent.

A thick autobreccia (**Tafb**) exposed in Long Canyon on the hanging wall of the Occidental Lode is an apparent exception to the non-brecciated nature of the flow member. This breccia is up to 50 m thick. It is similar to autobreccias in the lower member but because it lies in the hanging wall of the Occidental Lode (apparently above Sutro Member), it is considered part of the flow member.

As much as 4 m of andesitic conglomerate and sandstone (**Tafs**) is in the flow member exposed on Twin Peaks.

In the vicinity of Mt. Abbie, up to 250 m of pyroxene andesite porphyry flows (labeled Tdaf in Hudson and others, 2001) are found in the upper part of the Alta. The flows are dark-brown- to medium-reddish-brown-weathering, commonly with indistinct flow foliation. The andesite contains 40-60% phenocrysts that rarely exceed 3 mm in length. Plagioclase phenocrysts are commonly stubby and weakly zoned andesine laths, some with spongy cellular zones. About 5-10% of the rocks consist of pyroxene phenocrysts, with about equal amounts of augite and hypersthene. Shredy brown biotite makes up less than 1% of the rock as grains usually less than 1 mm. Hornblende is absent from most of the flows, but where present makes up less than 2% of the rock as green hornblende phenocrysts with very thin magnetite rims. The presence of biotite distinguishes these flows from underlying flows in the Alta. However, biotite is locally very difficult to see in hand sample, thus making the flows difficult to distinguish from underlying Alta pyroxene andesites. For that reason, they are not shown separately on the map.

A distinctive massive hornblende andesite porphyry flow (**Tafhp**) is mapped separately north of Jumbo. The rock contains about 50% plagioclase phenocryst up to 5 mm long that grade in size to the matrix. Euhedral hornblende phenocrysts make up 5 to 10% of the rock with nearly all less than 5 mm long. Generally less than 1%, but in some case as much as 10% of the rock consists of euhedral hornblende phenocryst up to 30 mm long. Elongation is usually about 8: 1. The brown hornblende has been partially to almost totally replaced by magnetite. Whether there is one flow or a series of flows is uncertain, but the unit is at least 150 meters thick with the top not exposed.

A sequence at least 200 meters thick of interbedded hornblende andesite flows and lahars (**Tafh**) lies in the western part of the quadrangle and probably overlies the upper Alta units described above., This gently westerly tilted sequence consists of about 75% flows and 25% interbedded lahars. About 90% of the material is hornblende andesite; hornblende-pyroxene andesite is very uncommon. In morphology and abundance the phenocrysts resemble typical Alta Formation, except that plagioclase phenocrysts in some flows tend to be more equant than lathy and the percent of phenocrysts is commonly 15 to 35%. The vast majority of plagioclase phenocrysts are isolated, but a very few may be glomeroporphyritic. Some andesites have no apparent mafic phenocrysts while others may contain hornblende up to 7 mm long. Many of the flows contain hornblende phenocrysts that are strongly embayed by the groundmass or partially replaced by augite; however, in other flows, the hornblendes appear to have been stable. Commonly, brown hornblende has been partially to totally replaced by magnetite. Many of the andesite flows are vesicular, particularly those near the western edge of the quadrangle. Up to 15% very irregular vesicles up to 4 mm across give a frothy appearance to the rock. The groundmass tends to be quite glassy, having tan to brownish glass; locally, it is hematitic. The andesite lahars are similar to the flows, having blocks of glassy andesite up to 50 cm and very rarely 1 meter in a sandy matrix. The hornblende andesites in many respects resemble the main flow member of the Alta Formation and are in fault contact with it. Presumably they lie higher in the sequence. The frothy and glassy nature of the hornblende andesites is unlike that of the main flow member, but nearly all exposures of the lower member are hydrothermally altered, possibly obscuring the original glassy nature.

Basalt or andesitic basalt lahars (**Tafbl**) are locally interbedded with the hornblende andesites (Tafh). These tend to be non-vesiculated and have up to 30% phenocrysts up to 3 mm. The black

basalts contain 10 to 30% stubby plagioclase phenocrysts, up to 10% olivine (often altered to green clay), up to 10%, augite, and up to 5% magnetite.

Tppa Phenocryst-poor andesite Medium-gray to greenish-gray andesite that is distinguished by paucity of phenocrysts. It contains 5-10% plagioclase phenocrysts (approximately An_{50}) to 3 mm, about 2-3% hornblende phenocrysts to 3 mm that are mostly replaced by iron oxide, 1% small opaque grains, and possibly a trace of thoroughly altered pyroxene. The matrix, which makes up 90% of the rock, consists of felty plagioclase laths that average about 5 microns in devitrified glass(?) with tiny opaque and altered mafic grains. This rock type apparently makes up a dome more than 200 m high southwest of the site of Jumbo and a thinner flow that extends to the northwest. Similar phenocryst-poor andesite is found lying on Kgd northeast of Steamboat Valley and in laharic breccias east of Steamboat Valley and southwest of Bailey Creek.

Tphpb Plagioclase-hornblende-pyroxene-biotite flow This unit, distinguished locally within Taf, is dark greenish gray to greenish gray and somewhat resembles a typical Taf flow, but contains large black hornblende phenocrysts and minor altered biotite. Phenocrysts include plagioclase (average about An_{60}) (30-35%) to 5 mm, moderately elongate, with the larger crystals rounded; hornblende to 8 mm long (5-10%) with opaque rims; pyroxene (3-5%) that is partially replaced by calcite; chloritized biotite (2-3%) to 2 mm; and magnetite (3-4%) in small grains. The matrix is a fine mix of randomly oriented plagioclase, altered pyroxene, and opaque minerals, possibly in altered glass. The rock also contains some rounded very fine-grained xenoliths of plagioclase + hornblende + magnetite + pyroxene + altered biotite.

Sutro member

The Sutro Member (**Tas**) locally overlies the lower member of the Alta Formation in the eastern part of the quadrangle. Gianella (1936) originally named the member for exposures in the Sutro Tunnel. The Sutro Member consists of white to tannish pale brown laminated tuffaceous siltstone, mudstone, feldspathic sandstone, and minor gravelly andesitic conglomerate in exposures near the Occidental Lode. The Sutro member is up to 60 m thick in Negro Ravine, thins to the southwest, and is absent near the Woodville Shaft. Gianella (1936) noted that the Sutro member is well exposed in the Sutro Tunnel in several locations between 11000 and 16000 feet from the tunnel portal (both footwall and hanging wall of the Occidental Lode) and a thick section was intercepted in the South Lateral near the East Yellow Jacket Shaft (V.P. Gianella, unpublished notes). In the vicinity of Suicide Rock there are several exposures of the Sutro Member. While similar to the section exposed to the east, the section exposed along the Ophir Grade contains somewhat more gravelly conglomerate and also includes interbedded pumiceous nonwelded tuff. Up to 60 m of Sutro Member is exposed along the Ophir Grade; it thins to 0 m northward near Butler Peak. Up to 4 m of thinly laminated fine-grained white sandstone and gravelly andesitic conglomerate exposed north of Cedar Hill Canyon is considered correlative with the Sutro Member.

Lower member

The lower member (**Tal**) of the Alta Formation unconformably overlies older rocks; in many areas the unit appears to have been deposited on an eroded surface of low relief. However, the unit was deposited locally in channels in the Santiago Canyon Tuff (Tst). **Tal** is at least 200 m thick and may reach a thickness of 450 m in such channels. The member consists of interbedded

andesite autobreccias, some lahars, and unbrecciated flows. The porphyritic andesites typically contain 20-40% phenocrysts less than 3 mm long. Plagioclase phenocrysts are generally stubby laths that are weakly to strongly zoned from about An_{55} to An_{35}. Plagioclase phenocrysts nearly always form isolated grains but a few conjoined phenocrysts in a thin section are not unusual. Augite is the dominant mafic mineral, forming 2 to 15% of the rock. Augite is commonly euhedral and locally is intergrown with magnetite and hornblende. Hornblende is found in some of the flows and very rarely is the dominant mafic mineral; generally it comprises less than 2% of the rock as laths up to 2 mm long. In some cases hornblende makes up 7% of the rock, with laths up to 4 mm long. There are a number of flows that contain distinctly "hollow" hornblende phenocrysts that have matrix filling a core along the c-axis. In some flows, there is strong embayment of hornblende along with partial replacement by augite. Magnetite rims (to complete replacement) are common. Where relatively unaltered (rare in the quadrangle), the andesites have a gray devitrified matrix and a weathered crust that is commonly light gray to locally reddish. The autobreccias contain 20-50% angular but equant clasts of devitrified andesite that are essentially texturally and compositionally like the matrix andesite. The clasts are generally 5-40 cm, but rarely as much as 1 meter across. The andesite of the autobreccias is identical to that of unbrecciated flows. Clasts of the autobreccia are generally gray to greenish while the matrix andesite is devitrified and commonly reddish (hematitic). The lahars contain a variety of andesite clasts up to 40 cm across and rarely up to 1 meter. The matrix of the lahars is usually andesitic sand and silt with both matrix and clast support. Gravel and larger clasts usually make up more than 70% of the rock.

Several sedimentary horizons (**Tals**) are interbedded within the lower Alta member south of Mt. Davidson. Between Bullion Ravine and Crown Point Ravine, 0-17 m of poorly bedded gravelly andesitic conglomerate with interbedded reddish andesitic sandstone are exposed. These are overlain and underlain by lahars. About 30 m below the Sutro Member(**Tas**) between Suicide Rock and Bullion Ravine, 0-15 m of gray laminated tuffaceous siltstone crop out between lahar units.

In Secs. 28 and 27, T17N, R20E northwest of Jumbo, at least 70 m of andesitic lahars (**Tall**) are exposed. The lahars are comprised of andesite clasts typical in texture and composition of the Alta Formation. There are also up to 15% clasts of black basalt, basaltic andesite, or both, not seen elsewhere in the quadrangle. Very similar thick lahars are exposed at the base of the Alta Formation in Brunswick Canyon in the New Empire Quadrangle. The base of these lahars in the Virginia City Quadrangle is not exposed but, based upon similarity, the lahars are assumed to be near the base of the formation and probably part of the lower member of the Alta.

Taph Plagioclase-hornblende andesite flow rock This unit is locally mapped separately within the lower Alta (Tal) near its base. **Taph** is relatively phenocryst-rich, light-greenish-gray flow rock. Phenocrysts include stubby plagioclase (20-25%) to 5 mm, black hornblende (15-25%) to 1 cm, and tiny opaque grains (3%) set in a matrix of plagioclase laths that average 40 microns, granular feldspar, devitrified glass(?), and tiny opaque and hornblende grains. In an outcrop near the Virginia City Reservoir, **Taph** includes a relatively unaltered flow with well-developed columnar jointing perpendicular to its base. The unit may be as much as 75 m thick.

Tah Hornblende andesite Mapped separately within and at the base of the lower Alta (Tal). Distinctive greenish-gray to medium-gray rock with abundant black hornblende phenocrysts to 1 cm or more long and sparse stubby plagioclase phenocrysts to 1 cm. The hornblende phenocrysts commonly form radial rosettes and plagioclase is locally found as glomeroporphyritic clots. In thin section, the rock contains hornblende phenocrysts (10-20%) with thin iron oxide rims; plagioclase (An_{74}-An_{67}, core to rim, for large grains and An_{67}-An_{55}, core to rim, for small grains) phenocrysts (1-5%) partially altered to calcite + chlorite(?); and opaque grains (trace-1%)> The phenocrysts are set in a finely pilotaxitic matrix of plagioclase laths with altered glass(?), intersertal pyroxene, and very fine opaque grains. **Tah** occurs as flows and possible domes as much as 100 m thick at or near the base of the Tal section.

Age of the Alta Formation

The Alta Formation has yielded K-Ar isotopic dates between 20.1 ± 1.4 Ma (Vikre and others, 1988) and 14.8 ± 0.4 Ma (recalculated from Whitebread, 1976). The older dates (i.e., 20.1 and 18.1 Ma in Vikre and others, 1988) probably accurately reflect the age the Alta based on stratigraphic relationships. The Alta overlies the early Miocene Santiago Canyon Tuff (ca. 23 Ma, see below) and is intruded by the early to middle(?) Miocene Davidson Diorite. We consider the Alta Formation to be early Miocene.

Tbr Biotite rhyolite Overlying and possibly interbedded with the unnamed tuff (Tut) northwest of Jumbo is a flow-banded biotite rhyolite. This poorly exposed and altered rhyolite is pink to white with pronounced laminar to slightly undulatory flow banding. It contains about 4% flat, platy biotite phenocrysts up to 1 mm long, and about 5% equant plagioclase phenocrysts 1 to 2 mm long in a groundmass of up to 10% lathy plagioclase microlites less than 0.1 mm long and distinctly banded devitrified and altered glass. Due to the alteration and microcrystalline nature of the unit, the rock composition is unclear; it may be either a latite or rhyolite.

Scattered irregular gray xenoliths up to 70 mm long make up much less than 1% of the rhyolite. The fragments have microgranitic texture, and consist of about 20% biotite, 5% quartz, 20% orthoclase, and 55% plagioclase. All of the grains are anhedral with the exception of biotite; grain size is about 0.07 mm, except that biotite is up to 0.3 mm. These xenoliths may be comagmatic with the rhyolite.

(Tut) Unnamed lithic tuff Disconformably overlying the Santiago Canyon Tuff north of American Flat is an unnamed Miocene lithic ash-flow tuff. This weakly hydrothermally altered tuff is densely welded with about 5% collapsed pumice fragments up to 30 mm long. Phenocrysts include about 5% plagioclase up to 1.5 mm long, about 3% sanidine up to 1 mm across, about 1% quartz up to 0.5 mm, and about 2% biotite up to 0.5 mm long. Lithic fragment, which comprise about 15-30% of the rock, are nearly all <40 mm across. Siltstone and tuff fragments are the most common lithics with lesser quantities of carbonate, andesite and gabbro; all except the tuffs are presumably from Mesozoic units.

The only surface exposure of the tuff is north of the Baltimore Shaft with the lower and upper contacts not exposed. At least 18 m is exposed there. The tuff is absent in the Overman Pit but is found in the subsurface in the Caledonia Mine (Becker Collection) and a small quantity occurs

on the dump of the Forman Shaft. This unnamed tuff overlies the Santiago Canyon Tuff and underlies the Alta Formation, thus an early Miocene age is indicated.

Northwest of Jumbo, at least 70 m of non-welded to poorly welded tuff is exposed that is tentatively correlated with the unnamed tuff. The tuff is mostly poorly exposed with abundant talus from the big boulder lahar (Tbbl) covering it. It contains as phenocrysts about 3% biotite and about 5% plagioclase up to 1.5 mm long, about 2% sanidine up to 1 mm, and a trace of quartz less than 0.5 mm. Uncollapsed to slightly collapsed pumice fragments up to 20 mm long (rarely up to 40 mm) make up 2 -20% of the rock. Lithic fragments that are rarely more than 15 mm across of tuff, gabbro, andesite, and siltstone make up 0-40% of the rock, most commonly about 25%. The base of the tuff is not exposed so the exact stratigraphic position is uncertain, but the lithologic similarity to the unnamed tuff north of the Baltimore Shaft (except for the degree of welding) suggests that they are correlative.

Tst, Tsg Santiago Canyon Tuff Light-gray or brownish-gray, moderately to strongly welded rhyolitic ash-flow tuff. Contains phenocrysts (30-40%) of slightly smoky or rosy, vermicular quartz (10-15%, ≤ 3 mm), sanidine (5-10%, ≤2.5 mm), plagioclase (5-20%, ≤2.5 mm), biotite (1% or more, ≤1 mm), and hornblende (1% or more, ≤1 mm). The unit is particularly distinguished by the presence of rare but ubiquitous euhedral, honey-colored sphene (≤0.5 mm), which is readily altered to yellowish anatase(?) or leucoxene. Sphene cannot commonly be distinguished in hydrothermally altered rocks. Light-gray, moderately to strongly compressed pumice (10-20%, 1-2 cm long) is commonly observed, in addition to sparse pinkish-gray felsite lithic fragments (1-1.5 cm). Locally underlain by a poorly exposed gravel unit, **Tcg** (usually observed as lag), which contains cobbles and boulders of Tnt, Tet, Tlt, and the chatoyant sanidine-bearing crystal tuff (Tct) of the Carson City Quadrangle (Trexler, 1977) to the southwest (which is the tuff of Chimney Spring of the Reno area). The age of the unit, based on recent $^{40}Ar/^{39}Ar$ dating is 22.97±0.05 Ma (C.D. Henry, written commun., 2000). The unit is thickest in a paleochannel north of McClellan Peak

Tet Eureka Canyon Tuff Light-gray, pale-red, or very pale-orange, poorly to moderately welded, phenocryst-poor ash-flow tuff consisting of pheocrysts (5-10%) of sanidine (4-5%, 1-2 mm), strongly vermicular quartz (~4%, 1-2 mm), plagioclase (~3%, ≤1 mm), and sparse thin biotite plates (<1%, ~0.5 mm) in a matrix of slightly welded glass shards and 5-10% gray, lenticular, banded or axiolitic pumice. The age is 24.74±0.06 Ma based on new $^{40}Ar/^{39}Ar$ data (C.D. Henry, written commun., 2000).

Tnt, Tng Nine Hill Tuff Pale-red-purple to medium-gray rhyolitic ash-flow tuff. In a thin section of a sample from Nine Hill, about 2 km southwest of the quadrangle, the rock is seen to consist of sparse phenocrysts (7%) of sanidine (~3%, 0.4-2.5 mm), anorthoclase (~3%, 0.4-1.5 mm), and quartz (~1%, 0.5 mm) in a matrix of strongly welded glass shards and pumice. The pumice (commonly 10-15% of rock but up to 40%) is strongly compressed (aspect ratios of 10:1 or more and up to 15 cm long) and stretching, probably during deposition on walls of paleocanyons, defines a lineation that is commonly subparallel to the strike of compaction foliation in the western part of the quadrangle. Deino (1985) reported that a lower unit of tuff at Nine Hill is somewhat more phenocryst poor (~3%) and all its alkali feldspar is sanidine. Trace biotite is reported (Bingler, 1978; Deino, 1985), but is not commonly observed in rocks affected

by vapor-phase alteration. In the railroad cut southeast of American Flat, there is a white pumice-poor, weakly welded tuff about 5 m thick approximately in the lower third of the unit. In American Ravine, the Nine Hill Tuff appears to have filled a deep paleo-channel that also contains the Lenihan Canyon Tuff. In one exposure there is up to 5 m of gravel (**Tng**) at the base of the Nine Hill Tuff with cobbles of Mesozoic rocks as well as the Guild Mine Member of the Mickey Pass Tuff. The Nine Hill Tuff pinches out against Mesozoic rocks on the northern edge of American Flat. Bingler (1978) indicated an age of about 25 Ma based upon stratigraphic position. New $^{40}Ar/^{39}Ar$ data yield an age of 25.16±0.06 Ma at Nine Hill ~2 km south of the quadrangle (C.D. Henry, written commun., 2000).

Tlt, Tlg Lenihan Canyon Tuff Pale-red, pale-red-purple, or light-brownish-gray (pale greenish-gray near top) welded ash-flow tuff consisting of 25-30% phenocrysts of mostly small plagioclase (12-20%, ~1 mm), rounded, locally smoky quartz(~3%; ≤3 mm, rarely 5 mm), sanidine (3-5%, 2-4 mm), biotite (2-3%, ≤2 mm), and hornblende (~1%, ~1 mm) in a matrix of spherulitically crystallized and axiolitic shards. The hornblende and pumice fragments (to 5 mm long) are rarely visible in hand specimen; rare volcanic lithic fragments (<1%, <5 mm) have a phenocryst content similar to the tuff. Bingler (1978), who defined the type area of the formation west of Lenihan Canyon at the south edge of the quadrangle, listed several distinguishing characteristics, which include: abundant foliation-aligned thin black biotite plates, abundant small plagioclase phenocrysts, rounded quartz, and sparse hornblende. **Tlg** is a local basal gravel that contains clasts of Tgm and granodiorite (up to 1 m long). The age, based on new$^{40}Ar/^{39}Ar$ data, is 26.60±0.06 Ma at the type area near the south margin of the quadrangle (C.D. Henry, written commun., 2000).

Tgm - Guild Mine Member, Mickey Pass Tuff White, light-greenish-gray or pale-red-purple sequence of rhyolitic ash-flow tuff cooling units of variable (15-30%) phenocryst content. The phenocrysts consist of vermicular, bipyramidal quartz (3-10%, 0.4-2 mm), clear to yellowish sanidine (3-10%, 0.4-3 mm), plagioclase (0-10%, mostly ~2 mm), biotite (~1%, ≤1 mm), and iron-titanium oxides (<1%) in a matrix of commonly strongly welded glass shards and compressed pumice. In the upper part of the unit, pumice increases to 10% (Bingler, 1978), as do quartz phenocryst-rich (~15%) varieties. In much of the unit, pumice is found as white, 2-3 cm, vapor-phase altered patches and cavities in reddish tuff. Sparse lithic fragments of dark metaigneous rock and argillite (Gardnerville? Formation) range in size from ≤1 cm to 1x6 cm. The age is about 27 Ma, based on new $^{40}Ar/^{39}Ar$ age determinations of 26.94±0.07 Ma and 27.13 ±0.06 Ma from localities near the south margin of the quadrangle south of McClellan Peak and near Nine Hill, respectively (C.D. Henry, written commun., 2000).

Tg Gravels The oldest Tertiary unit consists of channel-filling gravels that crop out as small exposures just east of McClellan Peak and on the southern end of Hartford Hill near the Drysdale Mine. The gravels consist mainly of unsorted cobbles to boulders, primarily of gabbro. Rounded boulders of granitic rocks up to 1.5 meters across are observed in both exposures. The exposure near McClellan Peak also includes a few cobbles of tuff and metamorphosed Gardnerville Formation. These channel-filling gravels are 0 to perhaps 10 m thick. The exposure near the Drysdale Mine may be younger than some of the tuffs, because the unit is overlain by Santiago Canyon Tuff, but because no tuff fragments are observed in this gravel, it may predate Tgm.

TKp Cretaceous or Tertiary hornblende diorite porphyry Light-gray to greenish-gray porphyry that crops out as two small masses that appear to cut the Gardnerville Formation on the west side of the Jumbo Canyon fault. The porphyry is a seriate-textured rock composed of 70-75% plagioclase to 8 mm that is mostly unaltered (with minor sericite) with oscillatory zoning and some finely sieved zones, 20-25% black hornblende (olive to pale green in thin section) to 6 mm with ragged borders and local epidote alteration, 3% magnetite mostly as fine grains, and a trace of fine apatite prisms. The rock is locally more strongly altered and bleached, with abundant disseminated pyrite. It resembles Tdap somewhat, but is more coarse grained and may be a phase of the Cretaceous granitic complex to the west.

Kgd Biotite-hornblende granodiorite of Steamboat Valley Medium-grained gray hypidiomorphic granular granodiorite with average grain size of 1-2 mm. Contains plagioclase anhedra (An_{34} cores - An_{20} rims) to 7 mm; quartz as interstitial anhedra to 2 mm; weakly perthitic potash feldspar to 4 mm; anhedral to subhedral books of biotite to 3 mm; pale green irregular hornblende grains to 5 mm long with abundant plagioclase and biotite inclusions; opaque grains to 1.5 mm; trace small irregular grains of sphene; and trace small apatite prisms. The rock has weak flow(?) foliation defined by plagioclase, hornblende, and biotite grain alignment.

Ka Granite aplite White to very light-gray and pinkish-gray, fine- to medium-grained, anhedral granular aplite dikes and irregular masses consisting of subequal amounts of alkali feldspar, quartz, and plagioclase, sparse biotite, and accessory Fe-Ti oxides. Pegmatitic phases are locally observed, rarely with black tourmaline. Probably also found as a part of poorly exposed unit Kgr, but not mapped separately in areas of poor exposure.

Kgr Granodiorite Very light-gray to white, commonly poorly exposed, subhedral granular to locally anhedral granular, medium-grained granodiorite, consisting of stubby (some broken) subhedral plagioclase (45-50%, 0.1-2 mm), anhedral quartz (20-30%; 0.2-2 mm), alkali feldspar (15-25%; 1-4 mm), anhedral brown biotite (3-6%; 0.2-2 mm), a trace to ~4% of 5:1 elongate subhedral to anhedral hornblende (0.2-2 mm long), and accessory sphene (0.1-1 mm long), zircon, apatite (≤1 mm), and Fe-Ti oxides (1%, ≤0.1 mm). North of T16N, R20E, hornblende apparently becomes more abundant, the alkali feldspar is found locally as oikocrysts, and about 2% myrmekite (≤0.1 mm) mantles some plagioclase grains. Presence south of Jumbo Grade is mainly interpretative, as actual outcrops are rare and commonly covered by deep grus plus aplite clasts. Probably gradational with Kqm and similar in age (86-88 Ma); a K-Ar date of 74.7 Ma was reported in the Washoe City Quadrangle to the west by Marvin and Cole (1978), but they suggest it is a minimum.

Kqm Leuco monzodiorite Very light gray subhedral granular to porphyritic, medium grained plutonic igneous rock containing plagioclase (>60%), alkali feldspar (>20%), quartz (~10%), hornblende (2-3%), biotite (2-3%), honey-colored sphene (<1%, to 1.5 mm long), and Fe-Ti oxides (~1). The largest hornblende crystals are 4x18 mm. Locally, euhedral alkali feldspar are up to 10 mm and contain small, aligned mafic minerals. Rarely, rounded, dark gray enclaves (up to 8x15 cm) of fine grained hornblende diorite are observed. Weathers to rounded, elongate corestones (≥1 m long). Probably 86-88 Ma based on K-Ar dates in the Washoe City Quadrangle (Marvin and Cole, 1978) and at Virginia City (recalculated from Vikre and others, 1988).

Kfg Foliated granite Light-gray, porphyritic foliated granite, consisting approximately of equant to elongate subhedral plagioclase (~30%, 0.8x1.5 mm to 2x4.5 mm) and hornblende (~10%, 0.8-1.5 mm) in a considerably finer (≤0.1 mm) groundmass of anhedral quartz (~20%), alkali feldspar (~35%), and aligned, shredy biotite. Accessory sphene, apatite, and Fe-Ti oxides (~3%). Igneous foliation is defined mainly by biotite, but elongate hornblende and plagioclase phenocrysts are also aligned.

Kgp Granodiorite porphyry A granitic unit that intrudes the gabbro (Jm) south of Basalt Hill and was referred to as Cretaceous granodiorite porphyry (Kgp) by Bingler (1977), immediately to the south in the New Empire Quadrangle. The pale-pink intrusive rock contains about 60% plagioclase phenocrysts (0.5 to 3.5 mm long) as weakly zoned anhedral laths with 1:2 to 1:3 elongations that are approximately An_{30}. Stubby anhedral completely actinolized stubby pyroxene and or hornblende up to 1.5 mm long make up about 15% of the rock. There is a sharp break in size of the phenocrysts with an interstitial, subhedral-granular matrix that makes up about 25% of the rock. The matrix consists of intergrowths of about 30% quartz and 60% orthoclase with grain size of 0.1 to 0.2 mm. The rock also contains about 0.5% magnetite up to 0.4 mm and a trace of stubby apatite.

Kg Undivided granitic rocks Granitic rocks exposed along American Ravine were not correlated with other granitic units exposed near the southwest edge of the quadrangle, and are herein shown as undivided. We also include in this unit granitic rocks known or interpreted at depth (cross section).

Jm Mafic metaigneous rock Dark-gray and dark-greenish-gray, fine- to medium-grained (1-2 mm), phaneritic, equigranular or porphyritic metagabbro or rarely, metabasalt. The protolith for most of the unit was apparently massive, shallow(?) mafic intrusive rock containing distinctive, stubby, equant phenocrysts (≤1-7 mm) of a mafic mineral that was probably predominantly pyroxene, but has been converted to amphibole. Smaller, elongate or equant plagioclase (2-3 mm) display fluidal textures on weathered surfaces and are locally saussuritized or partially converted to white mica. Original phenocrysts make up 30-40% of the rock; the color index of the metamorphosed rock is 50-60%. Quartz is apparently absent and the groundmass is low in alkali feldspar (based on staining techniques). Rarely, amygdaloidal, fragmental (welded tuff?), or breccia (fragments 1-10 cm) textures are observed. Some samples of fine-grained, porphyritic gabbro are apparently rhythmically banded. Rock is metamorphosed to greenschist facies; finer mafic minerals are converted to biotite, actinolite, and epidote.

Pyroxene and plagioclase are usually found in about equal amounts in the gabbroic rocks, although locally either may be up to 60% of the rock. The pyroxenes have been completely and rarely partially actinolized. The stubby nature of the pyroxene pseudomorphs suggests they were probably augite. Locally larger subhedral pyroxene grains up to 5 mm long may form up to 5% of the rock. There are numerous subtle variations in the texture and composition of the gabbro from outcrop to outcrop but there is no systematic variation recognizable in the intrusive mass. Locally, there are dikes and irregular masses of gabbro porphyry (not mapped separately) intruding the main mass of gabbro. These bodies, up to 30 m across, contain actinolized subhedral pyroxene grains up to 60 mm long with roughly equal amounts of plagioclase up to 2

mm long. These are scattered throughout the exposed mass of gabbro in the Silver City area; the best exposure is in the railroad cut just west of the Vulcano Mine.

The form of the gabbro intrusive body appears to be, in part, that of a sill or possibly a lopolith. On McClellan Peak, near the Tyler Mine and probably south of the Florida Shaft, the gabbro forms a nearly horizontal contact with the underlying Preachers and Gardnerville Formations. Toward Silver City, no sedimentary rocks are exposed under the gabbro and the deepest shafts in the area apparently bottomed in gabbro, based on examination of dump material. The intrusive center of the gabbroic mass is unknown and the source could be buried in any number of concealed locations.

There is a considerable quantity of gabbro on the dump of the Sutro Mine adit west of the Utah Shaft. The adit that goes through the Comstock fault penetrated relatively unaltered gabbro that contains about 60% weakly zoned calcic plagioclase laths, 30% partially actinolized augite, and about 30% brown hornblende. The plagioclase and augite are about 3 mm long with the hornblende forming irregular oikocrysts up to 50 mm across hosting numerous plagioclase and augite poikicrysts. This gabbro is probably a different unit, but may be similar in age to the gabbro described above.

Jrp Foliated lithic rhyolite porphyry Intruded into the Gardnerville Formation on the east flank of McClellan Peak are dikes of foliated lithic rhyolite porphyry (Jrp). The rock contains 10-15% anhedral stubby plagioclase phenocrysts up to 5 mm long. Rounded, commonly highly embayed, and partially recrystallized quartz phenocrysts up to 4 mm long make up 3 to 5% of the rhyolite. Anhedral orthoclase phenocrysts up to 1.5 mm across comprise 7 to 10% of the rock. Slender mafic phenocrysts up to 5 mm long make up 5-7% of the rock. The mafic phenocrysts, probably originally biotite, have been replaced by fine-grained shredy brown biotite and some chlorite. Well-rounded to somewhat jagged, commonly elliptical lithic fragments of Gardnerville clastic rocks usually less than 40 mm long, variably make up 2-30% (commonly ~5%) of the rock. The matrix consists of anhedral intergrowths of about 55% orthoclase, 30% quartz, and 15% shredy biotite (probably metamorphic in origin). There are also traces of apatite and zircon. There is a strong foliation in the rock, mainly defined by the replaced biotite(?) flakes, that parallels the elongation of the lithic fragments.

The rhyolite is probably Jurassic, predating the gabbro (Jm), as it contains a fairly strong cleavage like that in the enclosing Gardnerville Formation but lacking in the overlying gabbro.

Jp Preachers Formation A few very small exposures of quartzite on the east flank of McClellan Peak are correlated with the Lower Jurassic Preachers Formation. The Preachers Formation consists of medium-grained white quartzite with silica cement. Some medium-thick laminations are observed in float samples but not in outcrop. There is a moderate amount of Preachers Formation as clasts in talus (Qt) just west of the few exposures. Less than 10 m of the unit is exposed in the quadrangle.

The Preachers unconformably overlies the Gardnerville Formation in southern Douglas County (Noble, 1962, Hudson, 1983, and unpubl. data) where it is presumed to be Lower Jurassic (Noble, 1962).

Jgs, Jgm Gardnerville Formation The oldest exposed unit in the Virginia City Quadrangle is the Lower Jurassic Gardnerville Formation. At least 300 m of the formation is exposed in the quadrangle. Thinly laminated, medium-gray siltstone and very fine-grained feldspathic sandstone (Jgs) make up nearly all of the exposed section. Locally, thin pebble conglomerate beds are observed. The dominant siltstone contains 10-30% argillaceous matrix. The clastic rocks typically contain a trace to several percent calcite cement. Disseminated authigenic pyrite cubes up to 1 mm across are scattered locally. The unit is locally very carbonaceous, particularly in the NW¼ Sec. 28, T17N, R20E where graphite was mined. On the east flank of McClellan Peak, several interbeds of marbleized limestone (**Jgm**) up to 10 m thick crop out. A thick section of Gardnerville Formation siltstone is also known from the footwall of the Comstock fault in the Crown Point, Yellow Jacket, and Belcher Mines. A very small exposure of the formation just east of Silver City consists of siltstones and fine-grained sandstones containing rounded clasts up to 30 mm across of intermediate composition volcanic rocks. Similar rocks from the upper part of the Gardnerville are exposed east of Little Washoe Lake and on Rocky Hill, just west of the quadrangle. The Gardnerville Formation exposed west and south of Steamboat Valley is similar to rocks from these areas west of the quadrangle. In the vicinity of Steamboat Valley, the unit consists predominantly of pelitic rocks which have been metamorphosed to quartzo-feldspathic sericite schist and biotite spotted hornfels; however, it also includes quartzose sandstone, thin bands of marble, and rare rhyolite-pebble conglomerate and pebbly sandstone. Compositional layering in the Steamboat area appears to be subparallel to metamorphic foliation, and there the sequence appears to be homoclinal. However, to the southwest of Steamboat Valley the rocks are reported to be tightly folded, with the sequence tops mostly to the west (Tabor and others, 1983).

The Gardnerville Formation is thermally metamorphosed near intrusive contacts with Mesozoic plutonic rocks. On the east flank of McClellan Peak, the discernable metamorphic aureole does not appear to be related to the gabbro (unit Jm), as relatively unmetamorphosed siltstones locally underlie the gabbro. Thus, presumably there are other intrusions into the Gardnerville under McClellan Peak. This is partially confirmed by the presence of granodiorite on a dump located in a canyon 500 m southwest of the Delaware Mine. In the most intense metamorphism, the clastic rocks are converted to hornfels or schists that contain up to 40% metamorphic biotite. Locally cordierite is recognizable in hand sample. More distally from the intrusive rocks, sericite schist is common, and in the (originally) more argillaceous beds, andalusite is found. At the Tyler Mine, both spotted cordierite-biotite and sericite-andalusite schists are observed. The thin limestones on the east flank of McClellan Peak have been 70-100% recrystallized to fine-grained, slightly schistose white marble. Specimens from the Becker Collection in the footwall of the Yellow Jacket, Crown Point, and Belcher Mines are weakly hornfelsed, with some epidote-bearing marble below the 2000 level. Specimens from the carbonate in the footwall of the Comstock fault on the 1200 level and in the vicinity of the 2300 level of the Sierra Nevada Mine adjacent to Mesozoic granitic rocks consist of white marble, wollastonite-bearing marble, and epidote-pyroxene-garnet skarn with no siltstone. The dump of the Rock Island Mine in American Flat also contains large volumes of garnet-pyroxene-epidote skarn with no siltstone (as well as Mesozoic granite). The skarn-altered carbonate rocks in the Rock Island and Sierra Nevada Mines might represent the Oreana Peak Formation of Noble (1962), which underlies the Gardnerville, but may be merely limestone interbeds within the Gardnerville Formation.

The age of the Gardnerville Formation cannot be established in the Virginia City area. No fossils were located in this study and the strong metamorphism would probably obscure most fossils. Elsewhere, the Gardnerville Formation is Late Triassic to Early Jurassic (Wyld and Wright, 1993; Stewart, 1997).

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