

## FLOWERY PEAK QUADRANGLE

### QUATERNARY DEPOSITS

#### Anthropogenic Deposits

**Qt Mine waste and mill tailings (latest Holocene)** Discarded broken rock from mining activity, mostly from recent open-pit mining in the Flowery district. Includes small areas of light-colored, fine mill tailings along the Six Mile Canyon drainage.

**Qx Extensively disturbed areas (latest Holocene)** Disturbed ground including excavations and product piles at gravel pits and earthworks around water and sewage ponds. Does not include excavations for residential construction.

#### Eolian Deposits

Extensive deposits of wind-blown and reworked sand on the flat platform ('Dayton Flat') between the entrenched valley of the Carson River (the Carson Plains) and the piedmonts of the Virginia Range and Pine Nut Mountains.

**Qed Eolian dunes (latest Holocene to latest Pleistocene)** Deposits of well sorted medium to fine-grained sand that form irregular dune fields and longitudinal dunes along the crest of bluffs that enclose the entrenched valley of the Carson River. Also includes local, dune-like accumulations of eolian sand within the Carson River valley. Only areas with well discernible dune-like topography are included in this unit. Unit Qes contains extensive lower and less well-defined dune forms.

**Qes Eolian sand sheet (latest Holocene to late Pleistocene)** Deposits of poorly to moderately well sorted fine to coarse-grained sand. Unit has a generally flat to broadly undulate surface and forms an extensive but locally discontinuous veneer on the flat, platform-like surface that spans much of the quadrangle between bounding alluvial fans and the entrenched valley of the Carson River. Unit is likely to include fine alluvial gravel and sand, particularly along its outer margins. Small areas of sand dunes, pans, and blowouts are common in this unit. Respectively, these areas contain deposits of well-sorted fine to medium sand; flat-lying typically mud-cracked deposits silt and clay; or may reveal discontinuous patches of underlying units (in particular Qew and Qfl)

#### Piedmont Alluvial Deposits

Deposits of alluvial fans and washes that drain the Virginia Range, the Pine Nut Mountains, and minor local sources. Includes sediments ranging in size from large boulders to fine sand. Debris flow deposits and bouldery flood deposits are common in steep interior mountain drainages and in proximal parts of alluvial fans.

**Qau Undivided piedmont alluvium (latest Holocene to Pleistocene)** Deposits of silt, sand, and gravel that occur in various settings throughout the quad including stream channels, fluvial terraces, and alluvial fans.

**Qay Undivided young alluvium (latest Holocene to latest Pleistocene)** Deposits of silt, sand, and gravel on active alluvial fans, in stream channels, and on broad piedmont slopes. Includes some fluvial terraces flanking stream channels and bouldery debris flow deposits in narrow valleys in the Virginia Range front.

**Qay<sub>3</sub> Youngest active alluvium (latest Holocene)** Deposits of silt, sand and gravel in active single-thread stream channels and principal distributary channels on active alluvial fans. Includes some bouldery debris flow deposits in the Virginia Range interior and upper piedmont. No soil development. Map pattern of Qay<sub>3</sub> in Six Mile Canyon and its alluvial fan reflects channel shifts, erosion, and deposition associated with flooding in the winter of 2006.

**Qay<sub>2</sub> Young active alluvium, (latest to middle Holocene)** Deposits of predominantly sand and gravel associated with active alluvial fans, low, channel-flanking terraces, and broad alluvial slopes in areas of coalescing alluvial fan toes. Includes bouldery debris flow deposits in interior mountain drainages and proximal to medial alluvial fan areas. Includes Qay<sub>3</sub> deposits where they are too small or widely dispersed to be divided. Qay<sub>2</sub> surfaces are characterized by well defined bar-and-channel to bar- and-swale depositional topography, particularly in proximal and medial alluvial fan areas. Surface morphology of distal fans and alluvial slopes is flat to broadly undulate. Soil development is generally nil to weak. Some surface clasts on older Qay<sub>2</sub> surfaces are moderately weathered. In Six Mile Canyon, this unit includes terraces underlain by alluvial strata that contain reworked mine tailings.

**Qay<sub>1</sub> Young inactive alluvium (middle? Holocene to latest Pleistocene)** Deposits of sand and gravel associated with inactive alluvial fans. Includes bouldery debris flow deposits in interior mountain drainages and proximal to medial alluvial fan areas. Associated alluvial fan surfaces are characterized by weakly to moderately subdued bar-and-swale morphology to planar morphology with protruding gravel bar crests. Coarser-grained deposits have the best preserved depositional morphology. Moderate surface weathering includes sparse cracked and split rocks; weak to moderate varnish patina on some clasts; and sparse lichen cover. Soil development is weak to moderate and includes Bw and stage I Bk horizon development. In some areas, Qay<sub>1</sub> surfaces are mantled with a thin veneer of medium to coarse-grained eolian sand.

**Qw Alluvial and eolian deposits of the Wyemaha Alloformation (Morrison, 1964, 1991) (late Pleistocene)** Deposits of poorly to moderately well-sorted sand, mud, and minor gravel. Extensive surficial outcrops restricted to the interface between the lower piedmont/alluvial slope of the Virginia Range and the valley flat astride the entrenched valley of the Carson River. Elsewhere, unit occurs as thin stratum overlying unit Qfl in

bluff exposures on the margin of the Carson River floodplain. We interpret this unit as a distal alluvial fan/alluvial slope deposit that contains intermixed eolian sand. It is likely correlative to younger parts of piedmont unit Qai. Qw overlies Qfl along an unconformity and is characterized by a moderately well-developed soil with a strong Bw horizon, a weak to moderate Bt horizon, and a stage I to II Bk horizon. Surface outcrops of Qw in the south-central part of the quadrangle are characterized by brown clayey soils with extensive networks of cracks likely owing to shrink-swell processes.

**Qai Intermediate-age alluvium (late to middle? Pleistocene)** Deposits of silt, sand, and gravel on inactive alluvial fans at the foot of the Virginia Range and in isolated patches within the range. Surface morphology ranges from bar and swale (mainly in bouldery proximal and medial fan areas) to planar with protruding coarse gravel clasts. Surface weathering is moderate to strong and includes abundant split rocks, moderate to dark varnish patina, and moderately dense lichen cover on some clasts. Soil development is moderately strong and includes argillic (Bt) horizon and stage II-III calcic (Bk) horizon development.

**Qao Old alluvium (middle to early Pleistocene)** Deposits of coarse sand and gravel on inactive alluvial fans and terraces near the Virginia Range front. Moderate to strong soils characterized by strong stage III calcic (Bk) and strong argillic (Bt) horizon development. Surface morphology is planar but with abundant protruding boulders and exhumed(?) boulders on the surface locally.

### **Carson River Alluvial Deposits**

**Qry Carson River alluvial deposits, undivided (Holocene)** Gravel, sand, and mud associated with active and abandoned meander-belt and floodplain surfaces of the Carson River. The unit is divided into three subunits that are discriminated on the basis of inset topographic relations and surface morphology.

**Qry<sub>4</sub> Active channel and bars of the Carson River (latest Holocene)** Well-sorted deposits of gravel, sand, and silt associated with the active channel of the Carson River. Unit includes sand splays, gravel bars and includes areas of bank erosion associated with floods in 1997 and 2006 and thus does not correspond precisely with the channel trace shown on the base map.

**Qry<sub>3</sub> Young mud, sand, and gravel deposits of the Carson River (latest to late Holocene)** Unit includes intermittently active and recently abandoned meander-belts, floodplain surfaces, and some channel bars/islands. These areas are inundated with moderate to low frequency and are generally part of the active channel-floodplain environment. Abandoned channel segments and overflow channels are commonly associated with oxbow lakes and marshy area and are marked in places by sinuous tracts of riparian trees and shrubs. Floodplain surfaces that flank these meander-belts are generally flat and characterized by overlapping and crosscutting paleochannels that are evident in aerial imagery. Several agricultural fields are situated on this surface.

**Qry<sub>2</sub> Intermediate age mud, sand, and gravel deposits of the Carson River (late to middle? Holocene)** Includes meander-belt and floodplain deposits and related surfaces. Morphology typically characterized a flat floodplain surface that is commonly exploited for agriculture. Let disturbed areas typically characterized by a series of relatively high-standing floodplain surface remnants dispersed amidst overlapping, sinuous paleochannel complex. Agricultural activity in the Carson River valley is concentrated primarily on this surface.

**Qry<sub>1</sub> Older Carson River alluvial deposits (middle to early? Holocene)** Includes the highest fluvial terrace remnants within the incised valley of the Carson River, typically composed of sand, silt, and mud. Distribution of this deposit limited primarily to the outer margins of the Carson River valley in the form of inset terraces and small, isolated floodplain remnants. Unit may include more than one generation of fluvial terraces.

### **Hillslope and Mass-Wasting Deposits**

**Qc Holocene and Pleistocene colluvium** Slope-mantling deposits of coarse gravel. Unit is particularly common in areas downslope from surfaces underlain by unit QTa. May include weathered bedrock locally.

**Qls Landslide deposits** Two landslide deposits have been mapped. The largest, southeast of Mount Grosh, is mainly composed of T<sub>fma</sub>. A small deposit consisting of Tertiary andesite debris occurs in the east half of the quadrangle north of the Mark Twain Estates.

**Qtb Basalt talus** Talus composed exclusively of angular fragments of Lousetown Basalt (T<sub>lb</sub>). The talus covers slopes that are underlain by T<sub>cs</sub>, T<sub>fha</sub>, and T<sub>fba</sub>.

### **Fluvial and Lacustrine Deposits of Lake Lahontan**

**Ql Undivided lacustrine deposits (latest to middle Pleistocene)** Deposits of sand, silt, and mud associated with pluvial Lake Lahontan. May also include interrelated fluvial deposits of the Carson River (Q<sub>fl</sub>). This unit may include deposits of the Sehoo and Eetza Alloformations, and possibly older lacustrine units associated with Lake Lahontan (Morrison, 1965; 1991). Only very small outcrops of Q<sub>l</sub> are found in the quadrangle in isolated areas of the upper piedmont of the Virginia Range.

**Qfl Fluvio-lacustrine deposits (late to middle Pleistocene)** Deposits of well-sorted fluvial sand and silt and interbedded lacustrine mud. Elaborate cross-stratification and soft-sediment deformation features common in sand, silt, and gravel; muds generally flat-lying and massively bedded. Unit contains abundant granite-rich sand and silt indicating Carson River source. Q<sub>fl</sub> is extensively exposed along the bluffs bordering the Carson River floodplain and locally exposed in deeply incised washes that flow to the Carson

River. In section, unit Qfl is characterized by interstratification of complexly structured fluvial silt, sand, and pea gravel with beds of massive lacustrine clay. Some sand and pea-gravel beds are strongly oxidized to dark yellowish orange color and commonly indurated. Qfl strata indicate an overall upward-coarsening trend with some marked by relatively thin fining-upward intervals. We interpret this unit as a deltaic deposit from the Carson River into Lake Lahontan. Qfl is unconformably overlain by unit Qw and units Qed and Qes, and because of scale limitations of the map the latter units may be included in Qfl except where they are extensively exposed. Relation with Qw indicates that this unit is probably correlative to the Eetza Formation (Morrison, 1964; 1991). It may also include older units.

### **Other Late Cenozoic Units**

**Qsp Spring deposits (latest Holocene to late Pleistocene)** Deposits of silt and fine sand with some pebbles occur adjacent to some of the active highland springs along the south slope of the Flowery Range. Deposit morphology typically includes terraces or mounds of fine-grained sediment, commonly dark gray to brown organic-rich silt and sand. These sediments and related terraces and mounds may occur on steeply sloping terrain, as is the case in the Sutro Springs area.

### **Deposits of the Naturalite Dome Area**

**Qns Sedimentary deposits of the Naturalite dome area** Nearly flat-lying friable diatomaceous sedimentary strata that consist mostly of white to very-light-brownish-gray, pale-olive-green, or pale-ochre, poorly stratified, fine-grained sand to granule beds. Diatoms, mainly pennate species, make up major to minor amounts of Qns. Mineral grains include quartz, feldspar, hornblende, biotite, and pyroxene. Glass shards are absent to abundant. Larger detritus consists of scattered pebbles and local accumulations of pebbles. Most of the detritus is of andesitic composition; however, to the southwest of the Naturalite dome the material is dominated by rhyolitic material from the dome, and may largely have been derived from explosive material from the dome. A tephra bed from this area contains abundant glass shards with refractive index (RI) of 1.496.

**Qnw Welded rhyolite airfall** A small exposure of resistant rhyolite pyroclastic rock occurs on the northwest side of the Naturalite dome. This rock mainly consists of lapilli and bombs of glassy hydrated (RI = 1.496) rhyolite (QPr) that are welded together. In addition, the rock contains as much as 20% of andesitic lithic fragments and minor amounts of nonhydrated glass with RI = 1.484. A few small granitic clasts were identified in thin section. Small fragmental crystals of feldspar, biotite, hornblende, and quartz were also noted in thin section. The westernmost (and basal) portion of the exposure is crudely stratified, and these strata form a shallow syncline with its axis plunging shallowly west.

**Qnr Glassy rhyolite** White to very light-gray, nearly aphyric glassy rhyolite forms the core of the Naturalite dome on the basis of surface exposures and excavations. Similar material forms a smaller exposure in a pit to the west, where it intrudes andesitic

rock along nearly vertical intrusive contacts. Both rhyolite masses have been mined as aggregate for use in lightweight concrete and concrete block. The rock is commonly flow-banded, and weakly to strongly vesicular. It is nearly aphyric macroscopically, but sparse oligoclase phenocrysts are as much as 1 mm long, and smaller quartz and sanidine phenocrysts are generally present, along with traces of black biotite flakes. Feldspar microlites and small spherulites commonly comprise minor amounts of the rock, but some flowage bands contain as much as 50% microlites and spherulites. Flow-stretched vesicles make up as much as 40% of the rhyolite. RI of the glass is 1.496. K/Ar ages of rock from the Naturalite dome reported by Silberman and others (1979), who referred to the feature as the Sutro rhyolite dome, are  $1.55 \pm 0.22$  Ma on alkali feldspar, and  $1.55 \pm 0.06$  Ma on obsidian (recalculated from the original ages).

**Qnb Rhyolite breccia** Breccia comprised completely of loose angular fragments of rhyolite comprise a discontinuous carapace or envelope around the QPr core of Naturalite dome. This breccia was either produced by crushing during dome intrusion or by breakup by explosive activity on the surface of the dome. Similar, but strongly welded, breccia is present in the southeast part of the small western pit, where the nearly vertical contacts suggest an intrusive origin. QPr itself is moderately to strongly shattered, and the contact between it and QPbx is not sharp in many places.

**Qnt Tuff ring deposits** Poorly indurated, stratified to massive pyroclastic deposits that we have interpreted as tuff ring deposits occur around the QPr and QPbx core of the Naturalite dome. In general the strata dip shallowly inward toward the rhyolitic core and probably represent intracrater deposition. In places, the core rhyolite seems to overlie these deposits, and the relatively resistant rhyolite may have filled the crater, thus protecting the loose pyroclastic material from removal by erosion. For the most part, the tuff ring deposits are covered by QPr talus and soil, but mine workings and access roads have produced some excellent exposures. The stratified material, which includes some well sorted ash to lapilli beds, was probably formed as bedded falls or as surge, but some deposition may have taken place in water. Well sorted volcanic breccias are common and unsorted pyroclastic flows occur in places. Most of the detritus is of accessory QPr, but accidental andesitic and granitic clasts are common in some beds. Juvenile bombs of friable perlite containing cores and kernels of nonhydrated glass occur in some beds. Refractive index of the nonhydrated glass is 1.484.

## QUATERNARY AND TERTIARY DEPOSITS

**QTa Pleistocene to Pliocene alluvium** Deposits of coarse alluvium, typically occurring as high-standing fan and pediment remnants in the foothills of the Virginia Range. Commonly present as coarse gravelly veneers on eroded bedrock surfaces or pediments. Strong soil development (strong Bt and/or stage III Bk horizon) present in many exposures. Many QTa surfaces are stripped to a lag of coarse gravel, and may include weathered bedrock locally where underlying unit composition is similar to the alluvial deposit.

**QTs Spring deposits** White to light gray, locally limonite stained, sandy to silty material in small range front exposures northwest of Sutro. The age of this material, which appears to be hydrothermally altered in places, is unknown. It was probably deposited during hot spring activity along a range front fault. It may be of late Tertiary or early Quaternary age.

## **MIOCENE ROCKS**

**Tlb Lousetown Basalt** Gray fine-grained basalt with seriate texture forms the top of gently northwest dipping mesas in the northwest part of the quadrangle. Crystals of labradorite-bytownite, olivine, and clinopyroxene are generally less than 1 mm long. The plagioclase and pyroxene range in size down to groundmass grains with an average size of 30  $\mu$ . The groundmass also contains opaque microlites and brown glass. The rock is locally vesicular and has distinct flow foliation in places that yields north to northwest dips that are more steeply dipping than the overall dip of the unit. An  $^{40}\text{Ar}/^{39}\text{Ar}$  date of  $7.54 \pm 0.08$  Ma was obtained on groundmass in a sample from about 2 km north of the Flowery Peak Quadrangle (Schwartz and Faulds, 2002).

**Tcs Sedimentary rocks of the Chalk Hills** Poorly exposed white, light-gray, very-pale-orange, pale-greenish-yellow, and light-brown pebble conglomerate, sandstone, fine-grained tuff, lapilli tuff, and diatomaceous siltstone occur near the north border of the quadrangle. The sandstone ranges from very fine to coarse and is dominated by andesitic and dacitic rock fragments and mineral grains derived from such rock. The tuffs are mainly crystal-lithic tuffs of dacitic composition. In many places, white chips of diatomaceous rock provide the only indication of the extent of this unit, which is better exposed in the Chalk Hills Quadrangle to the north (Schwartz and Faulds, 2002). The unit probably provided stream-polished pebbles of volcanic rock that are locally mixed with basalt talus (Qtb) directly below basal outcrops of the Lousetown Basalt. An  $^{40}\text{Ar}/^{39}\text{Ar}$  date of  $12.63 \pm 0.14$  Ma was obtained on hornblende from tuffaceous rock in this unit from a site about 1 km north of the Flowery Peak Quadrangle (Schwartz and Faulds, 2002).

**Tod Dacite of Occidental Quarry** Biotite hornblende dacite that was quarried for building stone at the Occidental Quarry forms a nearly circular exposure more than 0.5 km in diameter near the west edge of the Flowery Peak Quadrangle. It is typified by large phenocrysts, containing commonly conjoined, plagioclase phenocrysts to 1.5 cm; hornblende phenocrysts to 1 cm; and minor biotite as books to 6 mm across. The rock is distinguished by quartz that occurs in minor amounts as rounded and embayed grains to 2 mm. Very minor opaque grains are found along with traces of apatite as tiny, clear prisms. The matrix is dominated by plagioclase laths that average about 50  $\mu$  long and form pilotaxitic texture in a field of granular potash feldspar, hornblende, and opaque microlites. Tod contains more than 64%  $\text{SiO}_2$ ; it is relatively silica-rich compared with other intermediate rocks in the Virginia City area. An  $^{40}\text{Ar}/^{39}\text{Ar}$  date of  $12.91 \pm 0.18$  Ma on hornblende further distinguishes this rock from other intermediate rocks in the area.

## Intrusive Rocks

**Tbhi Biotite-hornblende intrusive rocks** Dikes and larger intrusions of biotite-hornblende andesite or dacite occur widely in the quadrangle. They are typically gray to light-gray rocks with abundant andesine phenocrysts to 1 cm, sparse to moderately abundant hornblende to 1 cm, and minor biotite to 3 mm. Quartz is generally present as rounded and weakly embayed phenocrysts to 3 mm. Pyroxene is absent. In thin section, the hornblende ranges from brown to olive green and the biotite is typically brown. The mafic minerals are generally not replaced by iron oxide. The matrix ranges from very finely microgranular (average grain 20  $\mu$ ) to finely felty (average grain 75  $\mu$ ) or weakly pilotaxitic (average microlite 100  $\mu$ ). Phenocrysts are distinctly larger than matrix grains. Intrusions of Tbhi, which mostly cut rocks of the 15.2- to 15.8-Ma Virginia City magmatic suite, may be part of the 14.2- to 14.9-Ma Flowery Peak magmatic suite, but some may be related to the younger (12.9 Ma) dacite of Occidental Quarry. Tbhi dikes in the Flowery mining district are altered, and thus older than mineralization there, which has been dated at 13.4 Ma (Castor and others, 2005).

## Rocks of the Flowery Peak Magmatic Suite

Rocks of the Flowery Peak magmatic suite range in age from about 14.2 to 14.9 Ma, and typically contain relatively abundant hornblende. In addition, sparse to moderately abundant biotite is common, and plagioclase phenocrysts are mostly stubby grains more than 3 mm long. Rocks of this suite are mostly IUGS andesites on the basis of alkali/silica plots of samples from the Virginia City Quadrangle. A few have trachyandesitic compositions.

**Tfa Andesites of Flowery Peak, undivided** We map most of the rocks in the Flowery Peak magmatic suite in this unit, which is dominantly composed of hornblende-orthopyroxene andesite and hornblende-biotite andesite flows. Some related debris-flow deposits are also included.

Phenocryst content of the andesite of Flowery Peak varies from 20 to 50%. Andesine phenocrysts, which are as much as 1 cm long, are commonly stubby, poorly formed, conjoined grains. Hornblende is the most abundant mafic phenocryst, mostly as brown crystals less than 4 mm long, but locally as much as 1.2 cm long. The hornblende is typically brown and commonly has opaque iron oxide rims or has been completely replaced by iron oxide. Brown biotite phenocrysts, where present, generally have magnetite rims, are corroded, and are less than 3 mm across. Hypersthene, as small prisms that are rarely more than 1 mm long, is commonly the dominant or only pyroxene. Some rocks contain minor clinopyroxene and olivine. Quartz is rarely present. Opaque oxide forms equant or irregular grains to 1 mm. The matrix consists of variable proportions of plagioclase, mafic minerals, and opaque microlites in devitrified glass or glass. The plagioclase phenocrysts and matrix microlites are generally distinctly different in size.

Rock that we have mapped as andesite of Flowery Peak was previously included in the Kate Peak Formation by Thompson (1956) and Hudson (2003). Hornblende



$^{40}\text{Ar}/^{39}\text{Ar}$  ages on specimens from the Virginia City Quadrangle are  $14.75 \pm 0.22$  and  $14.39 \pm 0.20$  Ma (Hudson and others, in prep.).

**Tfba Biotite hornblende andesite** Light-brownish-gray-weathering, light-gray rock containing about 30% phenocrysts occurs in the north part of the quadrangle. Phenocrysts consist of moderately abundant stubby andesine as much as 5 mm long, elongate hornblende to 2 mm long, distinctive large biotite books as much as 5 mm in diameter and 2 mm thick, minor bottle-green augite, and locally, traces of rounded pinkish quartz grains and rounded olivine. The matrix is light gray. It is assigned to the Flowery Peak magmatic suite on the basis of  $^{40}\text{Ar}/^{39}\text{Ar}$  ages of  $14.20 \pm 0.43$  Ma on plagioclase and  $14.58 \pm 0.12$  Ma on hornblende from specimens in the Virginia City Quadrangle.

**Tfha Hornblende andesite** Medium- to light-gray andesite containing phenocrysts of elongate hornblende to 1 cm long and equant, moderately abundant to abundant, separate and conjoined plagioclase to 4x5 mm occurs in the north part of the quadrangle. Plagioclase phenocrysts are calcic andesine; some have growth zones near the rims with fine cellular sieve texture. Biotite is rare and quartz is absent in most specimens. Brown hornblende phenocrysts that are variably rimmed with opaque material are moderately abundant, and in some samples minor pyroxene and traces of biotite. Pyroxene can be observed by hand lens in some samples; only orthopyroxene was identified in thin section. The matrix is pilotaxitic and consists of plagioclase microlites that average 50 to 100  $\mu$  in length, opaque grains, and devitrified glass. A clast of hornblende andesite from a related unit in the Virginia City Quadrangle gave an  $^{40}\text{Ar}/^{39}\text{Ar}$  age on hornblende of  $14.51 \pm 0.12$  Ma (Hudson and others, in prep.).

**Tfsa Biotite-hornblende andesite of Sugarloaf** Light brownish-gray to light gray biotite-hornblende andesite with local traces of quartz comprises a rock mass that forms an imposing landmark in Sixmile Canyon. On the basis of the mapped surface shape, it is considered to be an intrusive dome. It contains abundant blocky andesine to sodic bytownite phenocrysts as much as 7 mm long, mottled reddish-brown and olive-green hornblende to 1.5 cm long, and biotite books to 3 mm. In thin section, the hornblende is mottled reddish-brown and olive-green with thin iron oxide rims, and the biotite is locally altered to chlorite. Quartz occurs as rare irregular grains to 2 mm across. Pyroxene is absent or present in trace amounts. An  $^{40}\text{Ar}/^{39}\text{Ar}$  age on hornblende is  $14.53 \pm 0.11$  Ma.

**Tfra Biotite-hornblende-pyroxene andesite of Rocky Peak** Gray, coarsely porphyritic pyroxene-biotite-hornblende andesite with traces to minor accessory quartz forms three domes in the north part of the map area. The largest, on Rocky Peak, seems to have a nearly horizontal lower contact on the south, but steeply dipping contacts to the northeast. Two smaller bodies of similar rock occur to the south. The rock contains moderately abundant stubby andesine phenocrysts to 1.2 cm. Mafic phenocrysts include hornblende to 8 mm, sparse biotite to 3 mm, and trace to minor clinopyroxene to 1.5 mm. Orthopyroxene is rare or absent, occurring in only one out of seven specimens examined petrographically. Minor amounts of olivine were found in two such specimens. In thin section, the hornblende ranges from oxidized orange-red to relatively unoxidized olive-green colors and is locally replaced by iron oxide. The biotite is deep reddish brown to

brown. Quartz phenocrysts range from small anhedral to rounded, wormy, equant grains to 2 mm. The matrix contains weakly flow-aligned to felty plagioclase microlites, along with hornblende, clinopyroxene, and opaque microlites.

**Tfma Biotite-hornblende-pyroxene andesite of Mount Grosh** Coarsely porphyritic gray to pale red pyroxene-biotite-hornblende andesite with minor quartz comprises a dome in the southwest part of the quadrangle. It contains abundant andesine-labradorite phenocrysts commonly as masses of conjoined grains to 1.2 cm across. Hornblende is present as wholly altered (iron oxide+pyroxene+plagioclase) phenocrysts as much as 1 cm long, biotite as slightly rounded reddish-brown books to 8 mm across, and clinopyroxene as unaltered grains to 1.5 mm. The rock contains trace to minor quartz as rounded, vermiform, equant phenocrysts to 3 mm. The rock commonly contains very fine-grained biotite-hornblende diorite xenoliths.

**Tfd Debris flows with biotite-hornblende andesite clasts** Debris-flow breccias that contain biotite-hornblende andesite occur in and at the base of Tfa. In places, such debris flows form sequences as much as 150 m thick. Particularly thick sequences occur beneath Tfa on the south side of Rocky Peak, on the northeast side of Flowery Peak, and on the east side of Emma Peak. The breccia contains subrounded light-gray biotite-hornblende andesite and gray hornblende andesite clasts to 2 m. It is mostly matrix supported and locally contains relatively fine-grained sandy to pebbly beds. It lies, without notable angular discordance, on Tva.

**Thai Hornblende andesite intrusive rocks** Dikes and larger intrusions of hornblende andesite with little or no biotite occur widely in the quadrangle, and are particularly abundant in and near the Flowery mining district. The rock is typically gray or dark gray with sparse to abundant stubby plagioclase phenocrysts to 1 cm long. In some dikes, border zones can be seen to contain less plagioclase phenocrysts than core rock. In some examples, hornblende phenocrysts are abundant and large, as much as 1.5 cm long. Biotite is typically lacking, but may be present as rare corroded grains. Quartz is also generally absent. Where present, pyroxene occurs as small grains of clinopyroxene and hypersthene. A hornblende andesite dike in the Virginia City Quadrangle has been dated at  $14.53 \pm 0.42$  Ma by  $^{40}\text{Ar}/^{39}\text{Ar}$  on hornblende (Hudson and others, in prep.), so at least some of these dikes are part of the Flowery Peak magmatic suite.

**Ts Sedimentary rocks** A thin sequence of bedded, fine to coarse volcaniclastic sedimentary rocks and tuffs lies between andesitic rocks of the Silver City and Flowery Peak magmatic suites in two small exposures in the northeast part of the quadrangle. These rocks include white to very-light-gray, thin-bedded to laminated, very fine- to medium-grained sandstone, pale-olive massive to bedded fine-grained to lithic tuff, and heterolithic volcaniclastic conglomerates. Clasts in the conglomerates, which are pebble to boulder size, are mostly finely porphyritic rock with variable amounts of hornblende considered to be from the underlying Silver City andesites, but many are more coarsely porphyritic hornblende andesite and some contain biotite, suggesting a source as young as the Flowery Peak andesites.

## **Rocks of the Virginia City Magmatic Suite**

Rocks of the Virginia City magmatic suite range in age from 15.2 to 15.8 Ma on the basis of  $^{40}\text{Ar}/^{39}\text{Ar}$  ages on specimens from the Virginia City Quadrangle (Hudson and others, in prep.). They have variable phenocryst assemblages, ranging from pyroxene andesite, through hornblende andesite, to biotite-hornblende andesite and include flows and debris flow deposits. Rocks of this suite are mostly andesites in the IUGS classification on the basis of alkali/silica plots, but a few have basaltic andesite and trachyandesite compositions.

**Tva Virginia City andesites, undivided** This is a mineralogically and texturally variable unit. It is mostly composed of flows but includes some breccias. It includes biotite-hornblende andesite, pyroxene-hornblende andesite, and two-pyroxene andesite. Phenocrysts, which make up 25-40% of the rock, are dominantly plagioclase, with subordinate pyroxene and hornblende, and rare biotite. Plagioclase phenocrysts are calcic andesine to labradorite and generally less than 3 mm long, although grains to 7 mm long occur in some rocks. Hornblende, as traces to as much as 10%, is generally less than 4 mm long, but prisms to 8 mm occur in some rocks. Hornblende is commonly partly to wholly replaced by iron oxide. Pyroxene phenocrysts are less than 2 mm long. Clinopyroxene is generally more abundant than hypersthene. Biotite, as small grains to 2 mm across, is rarely present. Tiny opaque grains, which commonly occur in clusters, make up as much as 3.5% of the rock. Apatite, present in some rocks in trace amounts, occurs as stubby, gray to light brown prisms to 400  $\mu\text{m}$  long. The matrix in most rocks contains flow-aligned plagioclase microlites that average 50-100  $\mu\text{m}$  long and are distinctly smaller than phenocryst plagioclase. Mafic and opaque microlites are also present. Tva is commonly altered, with plagioclase partially replaced by albite and calcite, and mafic minerals replaced by chlorite and opaque or sericite and sphene. This alteration is particularly strong in and near the Flowery mining district. In and to the east of the Flowery mining district, Tva is strongly altered to silica + sericite.

**Tvka Andesites of the Kate Peak series** Pyroxene andesite and hornblende-pyroxene andesites in the Kate Peak area in the southwestern corner of the map have been mapped separately from Tva as andesites of the Kate Peak series. They are typified by distinctly flow-aligned calcic andesine phenocrysts to 1 cm long and several percent black and pale green pyroxene phenocrysts to 2 mm long. Some flows contain no hornblende, but others contain sparse hornblende phenocrysts as much as 1 cm long. The lowest flows contain as much hornblende as pyroxene. Traces of brown apatite prisms to 300  $\mu\text{m}$  long were noted in thin section, and rare olivine and biotite to 1 mm were noted in one specimen. Matrix and phenocryst plagioclase typically have seriate size distributions. Flow rock on the west side of Kate Peak in the Virginia City Quadrangle gave a hornblende  $^{40}\text{Ar}/^{39}\text{Ar}$  age of  $15.43 \pm 0.26$  Ma (Hudson and others, in prep.).

**Tvkp Olivine-pyroxene andesite** Flows of pyroxene andesite with minor olivine occur near the top of the Kate Peak series andesites. Light gray to white bedded tuffs that contain clinopyroxene, hypersthene, and rare hornblende occur just above this unit.

**Tvkdb Biotite-bearing debris flows** A unit of debris flows containing biotite-bearing andesite caps a ridge southwest of Kate Peak. The debris includes subrounded clasts as much as 1.5 m in diameter in gray matrix. The andesite contains abundant plagioclase phenocrysts to 4 mm, sparse hornblende to 4 mm, and subordinate brown biotite phenocrysts to 2 mm in a black glassy to gray devitrified groundmass. There are also some reddish-brown oxidized hornblende andesite clasts. The unit locally contains lapilli tuff and granule sand to silt beds.

**Tvkb Biotite-hornblende andesite flows** A flow or a sequence of flows of hornblende biotite andesite occurs in the Tvka sequence. This flow rock contains minor biotite phenocrysts to 2 mm, a few percent hornblende to 3 mm, and stubby plagioclase phenocrysts to 3 mm.

**Tvkd Andesite debris flows** There are several debris flow units, most less than 10 m thick, interbedded with Tvka. Most are too thin or poorly exposed to show on the geologic map. These lahars are typically heterolithic and contain subrounded clasts less than 30 cm and rarely up to 50 cm of several types of andesite. The matrix consists of gray silt, sand, and mud.

**Tvba Biotite-hornblende andesite flows** On the east flank of Kate Peak in the southern part of the quadrangle, the lower part of the Virginia City andesites is dominated by biotite-bearing flows and associated breccias. These rocks are gray to light reddish-brown or pale red with 20-35% phenocrysts, mostly andesine phenocrysts to 1 cm long. Mafic phenocrysts include moderately abundant olive green or oxidized reddish brown hornblende prisms to 8 mm long, rare to minor biotite books to 2 mm across, and sparse small clinopyroxene phenocrysts. Trace amounts of olivine are present in some flows. Orthopyroxene is absent or very rare. Small opaque grains to 0.5 mm and traces of brown apatite to 300 $\mu$  are also present.

**Tvbd Biotite-hornblende andesite debris flows.** Sequences of clast- to matrix-supported debris flows as much as 90 m thick, dominated by biotite-hornblende andesite clasts, are interbedded with Tvba. The clasts are angular to rounded pebbles to boulders as much as 3 m in diameter. In addition to pale-red and light-gray biotite-hornblende andesite, clasts of very fine-grained microdiorite are locally common and clasts of finely porphyritic pyroxene andesite and fine-grained sedimentary rock are present in small amounts locally. The matrix is mostly light gray to pink fragmental material. Rare sandy to pebbly layers are also present.

**Tvpa Pyroxene andesite flows** Flows of pyroxene andesite with little or no hornblende occur in the Virginia City andesite section, commonly at or near its base but also higher in the section above Tvba flows. These rocks are commonly altered, with plagioclase partly replaced by calcite and mafic minerals wholly replaced by chlorite  $\pm$  calcite  $\pm$  albite. Plagioclase phenocrysts are abundant, generally small but as much as 5 mm long, and range from andesine to labradorite in composition. Where unaltered the rock is nearly black and contains clinopyroxene with subordinate hypersthene.

**Tvs** Sedimentary rocks occur at the base of the Virginia City andesite unit and within it. They consist of well-lithified siltstone, fine- to coarse-grained sandstone, and coarser beds that range from pebble to boulder conglomerates. Most occurrences are too small to map; however, a lens of sedimentary rocks 700 m long and nearly 200 m wide lies just northwest of the Kg exposure in the Flowery mining district. This relatively large mass of Tvs contains basal conglomerate with rounded boulders of granitic rock and likely represents the local base of the Tertiary section. Above the coarse conglomerate are beds of siltstone, sandstone, and pebble breccia.

### **Rocks of the Silver City Magmatic Suite**

Rocks of the Silver City magmatic suite range in age from 17.4 Ma to 18.3 Ma on the basis of  $^{40}\text{Ar}/^{39}\text{Ar}$  ages on specimens from the Virginia City Quadrangle (Hudson and others, in prep.). They are dominated by heterolithic debris flow breccias, but include some flow rock. Flow rocks and debris flow clasts mostly range from nearly aphyric andesite, through pyroxene andesite to hornblende andesite. A few debris flows have biotite-bearing clasts. Rocks of this suite are mostly basaltic trachyandesites and trachyandesites in the IUGS classification on the basis of alkali/silica plots.

**Tsfa Fine-grained andesite** We have mapped distinctive andesite that contains minor fine hornblende phenocrysts and very rare plagioclase phenocrysts in the upper part of the Silver City suite in the northeast part of the quadrangle. Thompson (1956) mapped this rock type as an intrusive equivalent to the Lousetown basalt; however, we found no evidence of intrusive origin, and believe that the unit is extrusive on the basis of its consistent stratigraphic location. The mineral assemblage is different from that of the Lousetown basalt. The hornblende, which occurs as moderately abundant phenocrysts to 4 mm, is mostly replaced by clinopyroxene+iron oxide+plagioclase. The plagioclase phenocrysts are mostly unaltered, but so sparse that An content could not be determined by optical methods. Quartz, sparsely present as grains to 4 mm, is surrounded by clinopyroxene reaction rims and probably xenocrystic. The matrix is mostly fine, flow-aligned labradorite laths with lesser amounts of clinopyroxene and opaque grains.

**Tsdu Upper debris flow unit** Heterolithic, clast-supported breccia occurs beneath Tkva in the southwest part of the quadrangle. The clasts are angular to subrounded pebbles to boulders of Tspa and hornblende andesite. Biotite-hornblende andesite clasts are locally present near the top of the unit.

**Tspa Pyroxene andesite flows** Resistant, dark-gray pyroxene basaltic andesite flow rock that weathers reddish brown lies between Tsdu and Tsdm. It is mostly dense, finely porphyritic rock with 20-25% labradorite phenocrysts to 4 mm, fine pyroxene phenocrysts, and little or no hornblende. Some flows contain as much as 3 percent olivine phenocrysts to 1 mm that are mostly serpentinized. In places the flows have vesicular tops, and locally they include flow breccia.

**Tsa Silver City andesite flows, undivided** Flows of finely porphyritic to aphyric two-pyroxene basaltic andesite occur within or above Tsdm in the southwest part of the

quadrangle. These flows are mostly similar to Tspa, but they include a distinctive flow breccia with clasts of andesite with abundant flow-aligned coarse plagioclase plates as much as 1 cm across. In the northeast part of the quadrangle, finely porphyritic andesites that contain sparse to abundant hornblende are common in this unit. Clinopyroxene is the only or dominant pyroxene in many of these hornblende-bearing rocks, but two pyroxene andesite is also present. Biotite is lacking or extremely rare.

**Tsd Undivided debris flows** In the northeast part of the quadrangle, debris flows that mostly resemble Tsdm lie above below or within Tsa. These debris flows are generally heterolithic, but mostly consist of pebbles to boulders of finely porphyritic andesite. Typically they have gray to dark-gray clasts in gray matrix, but locally the matrix is light gray to nearly white. Thin unmapped flows, generally of finely porphyritic pyroxene andesite, with or without hornblende, occur in places in the unit.

**Tsdm Middle debris flow unit** Heterolithic, clast-supported, debris-flow breccia dominated by dark gray volcanic clasts occurs in the southwest part of the quadrangle. The clasts are mostly angular, but some are subrounded, and range from pebbles to boulders. They include nearly aphyric dark gray basaltic andesite, reddish-brown to dark gray scoria, gray hornblende-bearing andesite, and white pumice. The hornblende-bearing andesite contains subequal amounts of hornblende, clinopyroxene, and hypersthene phenocrysts. The debris flow matrix is generally gray, but is locally locally light brownish gray or light brown, and consists of sand to granule fragmental material. The unit includes some medium-grained to granule sandstone and pebble gravel beds in sequences as much as 2 m thick, particularly in the upper part of the unit. Locally these gravel beds contain opalized wood. A few 2- to 3-m-thick flows of dark gray, aphyric to sparsely porphyritic basaltic andesite are locally present. The porphyritic flow rock has bytownite phenocrysts to 3 mm, sparse hypersthene to 1.5 mm, lesser amounts of small clinopyroxene and opaque grains, and traces of hornblende.

**Tsdb** Light colored breccias that contain biotite-hornblende andesite clasts occur locally in Tsdm near the top of the unit.

**Tsdl Lower debris flow unit** Light-colored, heterolithic, clast-supported debris flows occur beneath Tsdm in a small area along the east flank of the Virginia Range near the south end of the quadrangle. Most of the clasts, which are generally subrounded and range from pebbles to boulders as much as 1 m in diameter, are mostly composed of light gray to gray hornblende andesite. A few well-rounded clasts occur locally. Clasts of plagioclase-rich andesite with little or no hornblende are also present. The matrix is light gray to light brownish gray.

**Tsha Hornblende andesite flow rock** Gray andesite with relatively sparse plagioclase phenocrysts to 8 mm and a few percent hornblende phenocrysts to 4 mm underlies debris flows of Tsdl and Tsdm. The rock ranges from dense to vesicular and is locally cut by well-developed columnar joints.

**Tst    Santiago Canyon Tuff** Light-gray to pinkish-gray, moderately to strongly welded rhyolitic ash-flow tuff crops out near the southwest corner of the quadrangle. It contains abundant phenocrysts of plagioclase, quartz, and sanidine to 4 mm, minor biotite and hornblende phenocrysts to 1.5 mm, and rare sphene. Light-gray, moderately to strongly compressed pumice to 2 cm and sparse pinkish-gray felsite lithic fragments to 1.5 cm are present. The age of the Santiago Canyon Tuff is early Miocene,  $23.12 \pm 0.05$  Ma, on the basis of  $^{40}\text{Ar}/^{39}\text{Ar}$  dating (C.D. Henry, personal commun., 2004).

## OLIGOCENE ROCKS

**Tgm    Guild Mine Member, Mickey Pass Tuff(?)** White to pinkish-gray, moderately to strongly welded rhyolitic ash-flow tuff overlies metamorphosed volcanic rock in the northeast part of the quadrangle. It contains 4-19% phenocrysts of plagioclase, sanidine, and quartz. The quartz phenocrysts are pale gray, and some are wormy. It also has trace to minor biotite and opaque grains, rare hornblende, and traces of zircon. The upper part of this unit consists mostly of pinkish-gray devitrified tuff with white collapsed pumice fragments as large as 2x10 cm. This rock is commonly resistant, forming grossly spheroidal outcrops with nubby surfaces. The matrix is mainly composed of glass shards. Lithic fragments comprise traces to a few percent of the rock, and include fragments of intermediate volcanic rock, dark metavolcanic rock and fine-grained Mesozoic sedimentary rock. The devitrified tuff is as much as 70 m thick, and is underlain in places by gray vitrophyre. A thin lower unit of less strongly lithified, white tuff is present locally. It is similar to the overlying resistant tuff but is unwelded to weakly welded and contains more biotite and more abundant lithic fragments, mostly of intermediate volcanic rock. At one locality, granitic boulders were found at the base of this tuff. A poorly exposed thin layer of similar tuff is exposed between Kg and overlying Tsd near the east border of the quadrangle. On the basis of its overall lithology, this tuff has been speculatively correlated with the Guild Mine Member of the Mickey Pass Tuff, which has yielded ages between  $26.94 \pm 0.07$  Ma and  $27.13 \pm 0.06$  Ma (C.D. Henry, written commun., 2000).

## PRE-TERTIARY ROCKS

**Klg    Leucogranitic rock** Light colored, quartz-rich granitic rock with minor amounts of biotite and granodioritic to granitic composition occurs as small northeast trending dikes and large elongate masses in association with Kgd in the largest area of granitic rock in the quadrangle. Texturally, this rock ranges from aplitic to pegmatitic, but most of the large masses are granitic with average grain size of 1 mm or more. Much of this rock is partially altered to chlorite, white mica, calcite, and albite, and it is commonly limonitized. Opaque grains are sparse. Hornblende may have been present in very minor amounts prior to alteration.

**Kqd    Hornblende-biotite quartz diorite to granodiorite** Granitic rock of probable Cretaceous age is exposed in the east part of the Flowery mining district, and in several

places in the northeast part of the quadrangle. In the Flowery district, much of it is friable light-colored rock that has been altered to a mixture of sericite and quartz with pyrite or limonite. However, less altered gray rock occurs in the south-flowing drainage just west of the Bonanza (east) pit, and has granodioritic mineralogy, with slightly more hornblende than biotite. Similar rock to the east ranges from quartz dioritic mineralogy with hornblende  $\geq$  biotite, to granodioritic with biotite  $>$  hornblende. The rock is mostly equigranular with average grain size slightly  $< 1$  mm to 1.5 mm, but some potash feldspar grains are as much as 3 mm long. Minor opaque grains are present, and trace minerals are sphene and zircon. In some areas, the rock has been deeply weathered to grus.

**Jm Metamorphic rocks** Exposures of metamorphic rocks are restricted to the northeast part of the quadrangle. Most of these rocks are metamorphosed mafic to intermediate volcanic rocks. Near contacts with granitic rocks, the metamorphic rocks are fine-grained amphibolite gneiss or massive pyroxene-amphibole-zoisite-sphene hornfels. Away from such contacts, such as in the large exposure in the northeast part of the quadrangle where they are overlain by the Mickey Pass(?) Tuff, they are mostly massive hornblende-hornfels rocks (amphibole+albite+diopside+sphene). Rocks mapped as Jm west of the largest area of granitic rocks in the quadrangle are composed of intermixed intrusive rocks (mostly leucogranitic rock) and metavolcanic rocks of the greenschist facies (chlorite+calcite+albite+quartz). Locally, these greenschist facies rocks include breccias with clasts of porphyry and granitoid rock in fragmental matrix. A large mappable Jm xenolith within the same granitic mass has amphibolitic borders and cores of greenschist facies rock (chlorite+calcite+albite+quartz+pyrite).

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