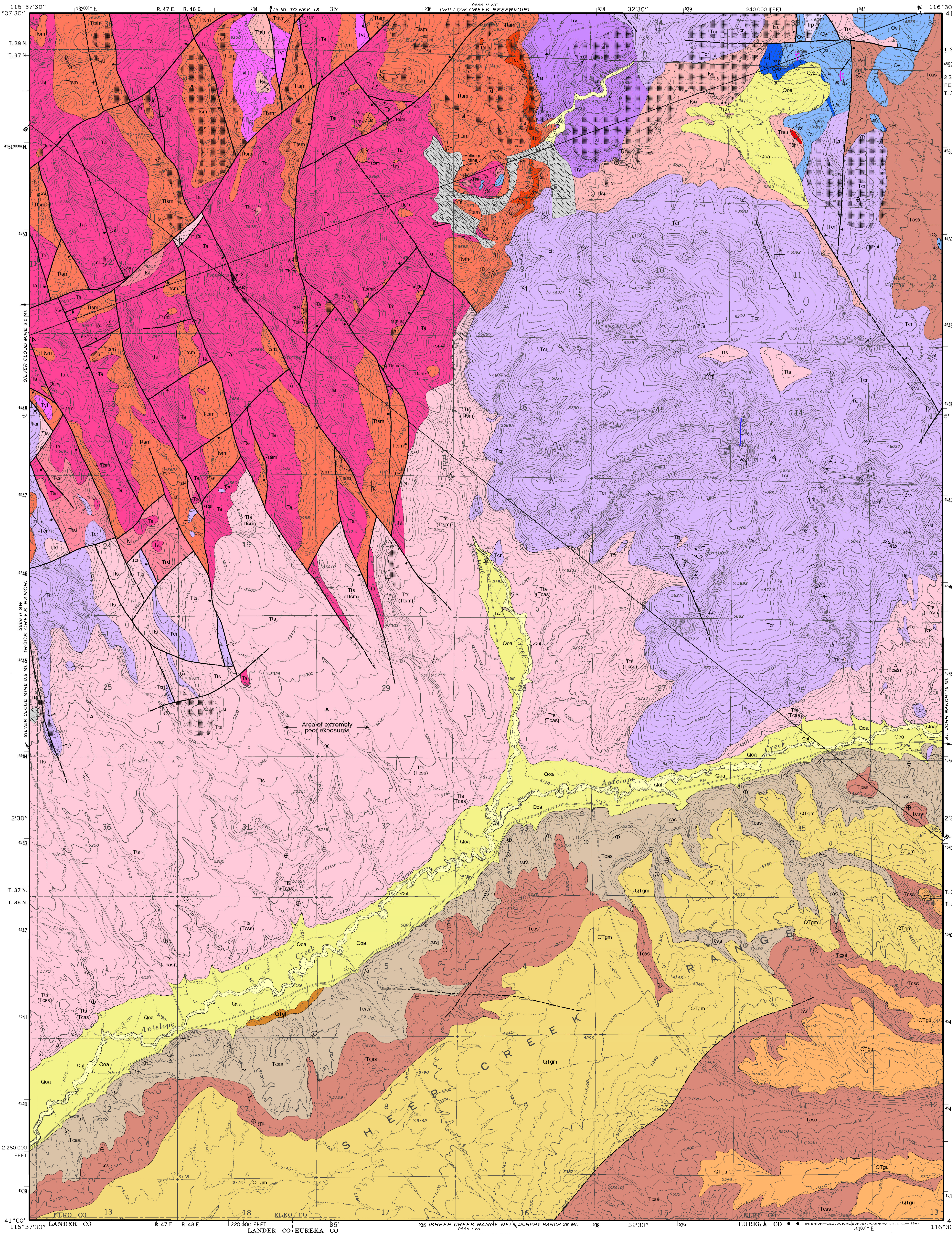
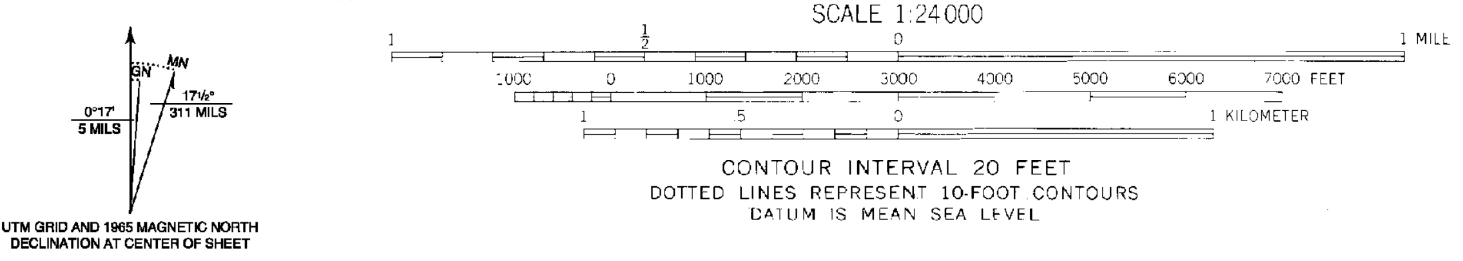
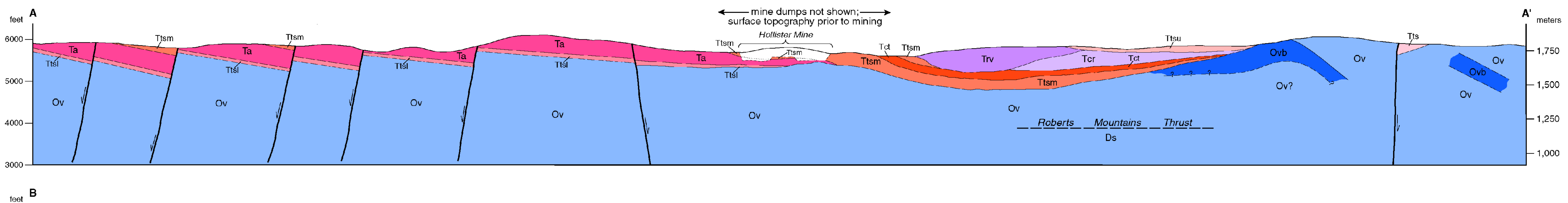
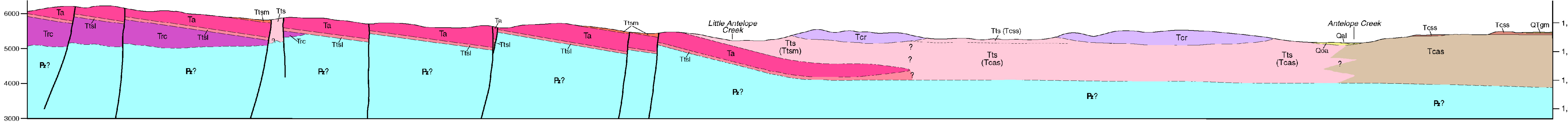


Topographic base from U.S. Geological Survey, Willow Creek Reservoir SE Quadrangle, 1965.
Polyconic projection. 1927 North American datum



See accompanying text for figures, tables, discussion of stratigraphic and structural framework of the quadrangle, and references cited.





# GEOLOGIC MAP OF THE WILLOW CREEK RESERVOIR SE QUADRANGLE, ELKO, EUREKA, AND LANDER COUNTIES, NEVADA

Alan R. Wallace

2003

[Notes: All $^{40}Ar/^{39}Ar$ dates were calculated using a 27.55 Ma age for Fish Canyon Tuff (see table 1). All major-oxide and trace-element data are listed in table 2.].

**Qal** **Alluvium (Quaternary)** Alluvium forms unconsolidated deposits along stream bottoms and is composed of poorly sorted silt, sand, and gravel. Most small streambeds contain thin, narrow alluvial deposits that are not shown on the map. The thickness along Antelope and Little Antelope Creeks is unknown.

**Qoa** **Older alluvium (Quaternary)** Unconsolidated, poorly sorted, gray-brown alluvial deposits are present 1 to 2 m above Antelope and Little Antelope Creeks. Clasts are composed of Paleozoic chert and quartzite and Tertiary volcanic rocks. The deposits generally are concealed by soil and vegetation, and sediments are visible only where creeks have incised into the deposits. The age and correlation of the alluvial deposits in the small basin in the northeastern part of quadrangle are unknown; they may be related to gravel deposits (QTg units).

## Gravel (Quaternary and Pliocene?)

Unconsolidated, poorly sorted gravel and fanglomerate deposits cover two extensive pediment surfaces in the southern part of the quadrangle and form small terrace deposits along Antelope Creek. The deposits may be correlative with similar terrace deposits north of Willow Creek in Willow Creek Reservoir Quadrangle (Wallace, 2003a). Poorly exposed, discontinuous gravel deposits are present locally at three levels on low hills north of Antelope Creek but are not shown on the map. The unit in this area includes:

**QTgl** **Lower gravel deposits** Unconsolidated, poorly exposed gravel deposits are ~5 m above the south side of Antelope Creek. These deposits may be correlative with the older alluvium unit (Qoa) along Antelope and Little Antelope Creeks.

**QTgm** **Middle gravel deposits** Includes unconsolidated, poorly sorted deposits of pebbles to cobbles that cover an extensive, intermediate-level pediment surface south of Antelope Creek. Clasts are subrounded and composed of Paleozoic chert and quartzite, with less-abundant clasts of Tertiary dacite and andesite. Mass wasting of underlying sediments (Tcss, Tcas) has caused substantial downslope redistribution of clasts. Continuous to the east with gravel deposits in the Santa Renia Fields Quadrangle ("fanglomerate" of Carlin Formation in Theodore and others, 1998; stratigraphy revised by T. Theodore, 2001).

**QTgu** **Upper gravel deposits** Identical to middle gravel deposits (QTgm), but it covers surfaces 30 m above those deposits. Continuous to east with gravel ("fanglomerate") deposits in Santa Renia Fields Quadrangle, as described above.

## Carlin Formation (Miocene)

The stratigraphy and age are modified from Theodore and others (1998) and Fleck and others (1998) in the Santa Renia Fields Quadrangle to the east (fig. 1). The members likely are correlative with tuffaceous units north of Antelope Creek (Tts, Ttsu, Tvt, Ttsm), but extremely poor exposures north of creek generally preclude detailed correlation. The Carlin Formation largely is shown south of Antelope Creek where it is better exposed. In this area it includes:

**Tcss** **Siltstone and sandstone member** Poorly exposed, tan siltstone and sandstone beds are composed primarily of quartz and feldspar grains and reworked ash; other identifiable rock fragments are sparse to absent. Thickness is approximately 30 m. The unit designation in the northeastern part of the quadrangle is based on continuity with mapped units to east (Theodore and others, 1998).

**Tcas** **Ash-flow tuff and sedimentary rock member** This member includes nonwelded to partially welded tan rhyolitic ash-flow tuff and tuffaceous sedimentary rocks that were deposited subaqueously and subaerially. Ash-flow tuff sequences are composed of numerous individual beds, each one to several meters thick with no vitrophyres or cooling breaks at contacts between eruptive units. The tuffs are more evenly and thinly bedded to the west, where they are better indurated and locally contain abundant secondary, interstitial calcite. Phenocrysts (percent of rock variable) include quartz, sanidine, plagioclase, biotite, and hornblende. The proportion of tuffaceous sedimentary rocks in the unit increases to the east. Near the east edge of quadrangle, sedimentary units contain abundant granules to cobbles derived from nearby Craig rhyolite (Tcr); to the west, the sedimentary units contain mostly reworked ash. In the south-central part of the quadrangle, leucocratic lacustrine sediments with diagenetic chert are interbedded with tuffs and sediments. The age is 14.41±0.04 to 15.10±0.08 Ma, based on dates from the Santa Renia Fields Quadrangle (table1; Fleck and others, 1998). The thickness is at least 70 m, but the base is not exposed.

## Tuffs and Tuffaceous Sedimentary Rocks North of Antelope Creek (Miocene)

The sequence includes upper, middle, and lower tuffaceous units (Ttsu, Ttsm, Ttsl), a vitric tuff unit (Tvt), and an undifferentiated tuffs and tuffaceous sedimentary rocks unit (Tts). The units represent continuous sedimentation, but divisions were made to facilitate mapping and structural interpretation. The lower tuff is below the andesite (Ta), the middle tuff is between the andesite and vitric tuff (Tvt), and the upper tuff is above the vitric tuff. The upper, middle, and lower tuff units are indistinguishable; the undifferentiated unit (Tts) includes tuffaceous rocks (Ttsl, Ttsm, Ttsu) where neither andesite nor vitric tuff is present to provide stratigraphic divisions. The section that includes upper tuff and vitric tuff units is equivalent laterally to the section that includes the lower two members (Tcss, Tcas) of the Carlin Formation south of Antelope Creek, on the basis of similar lithologies and ages (Fleck and others, 1998; Wallace, 2000). Extremely poor exposures and likely fault repetitions north of Antelope Creek preclude an exact correlation.

**Tts** **Tuffs and tuffaceous sedimentary rocks, undivided** The unit includes tuffaceous rocks in the central part of the quadrangle where poor exposures and the absence of the vitric tuff and andesite preclude division into specific units. The unit may include any or all of the other tuff units exposed in the quadrangle; the possible lithologic unit is shown in parentheses on the map.

**Ttsu** **Upper tuffs and tuffaceous sedimentary rocks** Tan, light-gray, to pinkish-red, very poorly exposed waterlain and subaerially deposited tuffs and tuffaceous sedimentary rocks are exposed in the north part of the quadrangle. The rocks are massive to finely bedded. In the northeastern part of the quadrangle, thin beds of pebble conglomerate locally are present at contacts between the upper tuff unit and the overlying rhyolite porphyry flows; the clasts are composed of Paleozoic chert and quartzite in a quartz-sand matrix. The unit includes all tuffaceous and sedimentary rocks above the andesite in areas where the vitric tuff is not evident. Thickness at least 50 m.

**Tvt** **Vitric tuff** The tuff is fine grained and dark brown, gray, to black. It is exposed along the northern and western edges of the quadrangle. The tuff may have been deposited elsewhere in quadrangle but was modified by subaqueous deposition and hydrothermal alteration (see text insert). Phenocrysts include plagioclase, sanidine, quartz, and pyroxene (pigeonite), with minor opaque minerals (fig. 2). The groundmass is composed of black, porous vitric ash with well-developed compaction foliation. The tuff compositionally is a rhyolite (71% $SiO_2$, $Na_2O+K_2O=8.9\%$). Sanidine in the tuff from the Willow Creek Reservoir Quadrangle, where it is a widespread marker unit (Wallace, 2003a), produced a $^{40}Ar/^{39}Ar$ date of 15.10±0.06 Ma (table 1). The thickness varies from 2 to 10 m, with an irregular basal contact.

**Tct** **Conglomerate and tuff** Massive, coarse conglomerate beds are interbedded with the tuffaceous units east of the Hollister deposit, about 30 m above the andesite and at the approximate contact between the middle and upper tuff units (Ttsm, Ttsu). Clasts are angular to subangular and composed entirely of Vinini Formation quartzite. Conglomerate beds are planar, have little or no internal structure, and are composed of 5 to 50 cm clasts with minor to abundant tuffaceous matrix; interbedded finer-grained beds are composed of sand to pebbles in a tuffaceous matrix. Unit interfingers laterally with sand-and-pebble sandstone beds of middle tuff unit. Base of conglomerate unit forms a sharp, irregular contact with underlying fine-grained tuff beds. Unit grades upward and laterally into finer-grained pebble conglomerates and tuff beds of middle and upper tuffs units (Ttsm, Ttsu). Rare clast imbrication suggests eastward source for clasts. Drilling data show that conglomerate extends east beneath rhyolite of the Velvet area (Trv) (J. Oliver, Great Basin Gold Ltd, written commun., 2000).

**Ttsm** **Middle tuffs and tuffaceous sedimentary rocks** The middle tuff unit includes poorly exposed, fine-grained, thinly bedded, lacustrine to subaerial tuffaceous sedimentary rocks. The rocks were weakly to completely silicified in much of the northern part of the quadrangle. In the Hollister Mine, the basal part of the unit includes very finely laminated and laterally continuous ash-rich sediments, with a basal silicified mafic tuff. The upper part of the unit overlies a gentle, intraformational angular unconformity and contains interbedded sandstone and coarse conglomerates with Paleozoic quartzite clasts in a tuffaceous matrix; the conglomerate beds grade laterally into the conglomerate and tuff unit (Tct). The basal sediments 2 km southwest of the Hollister Mine contain gray, 1-m-thick ostracode-bearing limestone (ls on map) that locally was recrystallized near altered zones. The total thickness of the middle tuff unit varies from 2 to 3 m to more than 20 m.

**Ttsl** **Lower tuffs and tuffaceous sedimentary rocks** The lower tuff unit includes fine-grained, massive to thinly bedded tuffs, reworked tuffaceous material, and crystal-rich vitrophyres. The unit also contains minor amounts of siltstone, sandstone, and local small-pebble conglomerate. The color varies from white, orangish tan, to light green; some minor tuff beds are dark gray to black. The rocks erode easily and usually are poorly exposed except along gullies and in the Hollister Mine. The thickness of the unit is <50 m, and it is absent in parts of the Hollister Mine and areas to east. The lower tuff unit is more extensively exposed in the Willow Creek Reservoir Quadrangle to the north (Wallace, 2003a).

**Trp** **Rhyolite porphyry (Miocene)** Reddish-brown, crystal-rich (20 volume percent phenocrysts) rhyolite flows are exposed in the northeastern corner of the quadrangle. They are much more extensive in the adjacent Willow Creek Reservoir Quadrangle (Wallace, 2003a), where the rhyolite forms exogenous domes erupted at 14.92±0.05 Ma (table 1). Phenocrysts include quartz and sanidine, with subordinate plagioclase and rare pyroxene (pigeonite) (fig. 2).

**Tcr** **Craig rhyolite (Miocene)** Reddish-brown to tan rhyolite flows form large domal masses in the eastern and westernmost parts of the quadrangle. The masses are composed of numerous thin to thick flow units. Basal and flow-top vitrophyres are present locally, but the bases and tops of most of the flow units have only minimal to no quenching, indicating rapid successive emplacement. Individual flow units are planar to extremely flow folded and contorted. Flows contain abundant gas cavities and lithophysal flow tops; vertical, 1- to 10-cm-wide microbreccia zones may indicate milling by escaping gas. East of Little Antelope Creek, the flows dip radially outward from the central part of outcrop area. Flows in the western part of the quadrangle locally interfinger with tuffaceous sediments and have hydrated basal vitrophyres. The western flows are continuous with a thick, extensive mass of rhyolite to the west (A. Wallace, unpub. mapping, 2001). Phenocrysts comprise 11 volume percent of the rock and include sanidine, opaque iron oxide minerals, and quartz, with trace plagioclase, pyroxene, and zircon (fig. 2). Composition: 75% $SiO_2$, $Na_2O+K_2O=7.7\%$. The unit was named informally by Bartlett and others (1991). Flows west of the quadrangle produced dates of 15.17±0.05 and 15.07±0.08 Ma; flows east of Little Antelope Creek were dated at 14.99±0.05 to 15.16±0.05 Ma (table1). Early flows in the northeastern corner of the quadrangle underlie the 15.10±0.05 Ma rhyolite of the Velvet area.

**Tcri** **Feeder dike for Craig rhyolite** Contacts with the enclosing rhyolite flows are vague and gradational. Flow foliation is vertical in the dike and dip gently in the enclosing flows. Dike margins were not quenched adjacent to the flows.

**Trv** **Rhyolite of the Velvet area (Miocene)** Reddish-brown, extremely flow-banded and flow-folded rhyolite flows with abundant small quartz phenocrysts are exposed in the northern part of the quadrangle. Composition: 75% $SiO_2$, $Na_2O+K_2O=9.1\%$. Lithophysal flow tops are common, forming float of small geodes where weathered. The rhyolite overlies early Craig rhyolite flows (Tcr) and conglomerate and tuffaceous units (Tct, Ttsm) and is overlain by the upper tuff unit (Ttsu). Flow tops were intensely replaced by white amorphous silica in some areas, preserving original flow bands and folds and quartz phenocrysts. $^{40}Ar/^{39}Ar$ dating on sanidine from a flow just north of the quadrangle boundary produced an age of 15.10±0.05 Ma (table 1).

**Ta** **Andesite (Miocene)** Reddish to locally black, massive to vesicular andesite flow units are extensively exposed in the western half of the quadrangle. The unit compositionally ranges from low-silica andesite to low-alkali basaltic trachyandesite (56-59% $SiO_2$, $Na_2O+K_2O=3.8$-6.4%; $Na_2O$, $K_2O$ subequal). Phenocrysts are sparse (<2% of the rock) and include plagioclase, olivine, and minor clinopyroxene. Flows are planar to less-commonly flow-folded; as exposed in the Hollister Mine, flows are massive to vesicular and exhibit local columnar joints. The andesite usually is poorly exposed, but it forms a reddish float of small chips to blocks as much as 50 cm in diameter. Exposures in the Hollister Mine show extremely variable depths and degrees of weathering, with preferential weathering along joints and faults. The flows largely were erupted subaerially; the uppermost flow at Hollister interacted with lake water to form hyaloclastic breccias. Mafic tuff breccia units and thin vesicular flows in the basal part of the middle tuff unit (Ttsm) indicate continued nearby eruptions during sedimentation. The unit is thickest (100 m) in the western part of the quadrangle, but the thickness locally varies considerably due to the irregular underlying paleosurface. The unit thins and pinches out to the east and south in this quadrangle, and to the west in areas west and northwest of the quadrangle (A. Wallace, unpub. mapping, 2001). The source of the andesite is unknown; the outward thickening and absence of distal feeders indicate that the flows and poor exposures conceal the feeders.

**Trc** **Rock Creek rhyolite (Miocene)** The unit is shown only in cross section B-B'. There, it shows a possible subsurface extension of the Rock Creek rhyolite (Wallace, 2003a), which thins to the southeast from extensive exposures northwest of the quadrangle and in the western part of the Willow Creek Reservoir Quadrangle. The rhyolite largely underlies the lower tuff sequence and overlies Eocene volcanic and Paleozoic sedimentary rocks in those areas (Wallace, 2003a).

**Tdh** **Dacite (Eocene)** Float and subcrops of a propylitically altered dacite intrusive body are exposed in sec. 2, T37N, R48E in the northeastern corner of the quadrangle, 3.5 km east of the Hollister Mine. The intrusive body is known informally as the Hatter stock (Tewalt, 1998). Drilling data indicate a more extensive, multiple-phase intrusive body in the subsurface west and southwest of the subcrop exposures (Tewalt, 1998; Great Basin Gold Ltd, unpub. data, 2000). Surface samples contain plagioclase and minor quartz and opaque iron-oxide mineral phenocrysts in a sanidine-rich groundmass. Chlorite and carbonate alteration, especially of the mafic minerals, is common in surface samples. The age is reported to be 43 Ma (Hollister and others, 1992).

**P̶z** **Paleozoic rocks, undivided** Shown only on cross section B-B'. The lithologies are unknown and their presence is inferred.

**Ds** **Sedimentary rocks, undivided (Devonian)** Includes the Rodeo Creek Formation, based upon data in Tewalt (1998). Location at depth very approximate from drilling data. The rocks are shown only in cross section A-A'.

**Ov** **Vinini Formation (Ordovician)** Quartzite and chert with subordinate argillaceous sedimentary rocks are exposed in the northeastern part of the quadrangle; minor basalt was reported by Bartlett and others (1991). The quartzite is blue to tan and is composed of well-sorted quartz grains, with local cross bedding. The quartzite contains thin interbeds of pebble conglomerate, with subrounded quartzite and chert pebbles; it also contains discontinuous interbedded breccia zones with angular fragments of quartzite, similar to Vinini Formation(?) breccia (Ovb). The chert is dark brown, and outcrops are massive to strongly bedded. The argillite does not crop out but forms locally abundant float of tan, platy chips. Drilling data (Bartlett and others, 1991; Great Basin Gold Ltd, unpub. data, 2000) indicate that the Vinini underlies Tertiary volcanic rocks at variable depths throughout the northern part of the quadrangle. The unit was named the Orodovician Valmy Formation by Bartlett and others (1991). It is designated here as Vinini to be consistent with mapping, extensive well-exposed sequences, and paleontological data in the adjacent Santa Renia Fields Quadrangle to the southeast (fig. 1; Theodore and others, 1998; see discussion in accompanying text).

**Ovb** **Vinini Formation(?) breccia (Ordovician?)** Crudely bedded sedimentary breccia composed of angular to subangular clasts of quartzite and minor chert, with a lithified quartzite to sandy quartz matrix, is exposed in the northeastern part of the quadrangle. Rare, thin beds of argillite or clay are interbedded with the breccias. Clast size ranges from <1 cm to >20 cm. The beds range from pure quartzite to beds almost entirely composed of breccia clasts. The unit is interbedded with both quartzite and chert beds of the Vinini Formation, and it is folded and sheared along with enclosing quartzite and chert beds in some exposures. The breccia is grossly similar in outcrop to the conglomerate and tuff unit (Tct), and to some pebble conglomerate beds in the upper tuff unit (Ttsu); mapped exposures may include breccias of more than one age, although the majority of the exposed beds are Ordovician in age. Thin sections indicate an interlocking quartzite matrix. Parts of the breccia bodies were weakly to strongly silicified by chalcedonic silica.

**Contact** Dashed where very approximately located due to poor exposures; short dashes indicated approximate location of contacts between Carlin Formation members in Tts, where known; dotted where concealed.

**Fault** Rarely exposed and thus mapped approximately. Dashed where very approximately located; dotted where concealed by younger deposits. Bar and ball on downthrown block. Arrow shows dip of fault. Arrows on cross section show relative movement of fault.

**Lineament** Visible on aerial photographs but of uncertain origin.

**Feeder dike in Craig rhyolite.**

**Strike and dip of bedding**

Inclined ⊕ Horizontal Vertical

**Strike and dip of flow foliation in volcanic flow units**

Inclined Vertical

**Minor overturned anticline** Showing plunge

**Outline of Hollister open-pit mine** Topography shown on map removed by mining. Geology shown as exposed in open pits of mine in 2000.

**Area disturbed by mining-related activities** Bedrock concealed by roads, mine waste piles, leach pads, and buildings. Small mines and waste piles not shown.

**Areas of silicified rocks** Massive chalcedony and opaline silica that formed local surface sinters and extensively replaced volcanic and sedimentary units. Only major areas mapped; usually present in all exposures of middle tuff unit (Ttsm). Predominantly white, but variably also light gray to pink to black. Hard and extremely brittle. Within some silicified zones, massive chalcedony grades into silicified but recognizable tuffaceous rock; elsewhere, silicification front very sharp. Contains abundant cinnabar in and around historical mercury mines.

Field work conducted from 1996-98 by A.R. Wallace.

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