by LARRY J. GARSIDE
Nevada Bureau of Mines and Geology

208
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GEOLOGY OF THE CAMP DOUGLAS QUADRANGLE, MINERAL COUNTY, NEVADA[1].

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INTRODUCTION

The Camp Douglas 7 1/2-minute quadrangle is located just to the southwest of the town of Mina at the eastern end of the Excelsior Mountains. The quadrangle includes one peak over 8500 feet (2590 m), and Thunder Mountain, in the central part of the area, has a maximum elevation of 7990 (2435 m). Two mining districts, Douglas (Camp Douglas) and Silver Dyke are present in the quadrangle. Mining in the area was begun in 1893, and a signigicant amount of tungsten ore was mined at Silver Dyke during and after World War I; mining at Silver Dyke was carried on by leasors as recently as 1972.

The geology of the area has been described by Ferguson, Muller, and Cathcart (1954), and Muller and Ferguson (1939). Vanderburg (1937), and Hill (1915) described the geology and mineral deposits of Camp Douglas, and Kerr (1936) has reported on the tungsten mineralization at Silver Dyke. Nielsen (1963) mapped two small portions of the quadrangle during his study of the Pilot Mountains, 10 km to the east. Speed (1977a) has named two new formations (the Mina and Gold Range Formations) which have type areas within the quadrangle. The Bibliography section of this report lists additional articles which contain information pertinent to the quadrangle.

Geologic mapping for this map was done on color aerial photographs having a scale of approximately 1:24,000 available from IntraSearch, Denver, CO. The contacts and faults were transferred to the topographic base by inspection with the aid of an optical enlarger-reducer.

Rock names used in this report are based on megascopic and thin-section estimates of rock and mineral content. For aphanitic porphyritic igneous rocks, the rock names are predominantly based on phenocryst mineralogy, and may vary somewhat from rock names based on chemical analyses. Phenocryst contents were visually estimated from thin sections and stained slabs. Precious metal values are reported in oz/ton; the conversion factor to gm/metric ton (ppm) is 34.286.

ACKNOWLEDGEMENTS

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LITHOLOGY

Approximately one-third of the area within the Camp Douglas quadrangle is underlain by Permian and Mesozoic rocks, one-third by Tertiary volcanic and sedimentary rocks, and the remaining third consists of Quaternary alluvial deposits. The Permian Mina Formation, consisting mainly of marine cherts and grawackes, is exposed in the northeast and south-central parts of the quadrangle,

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1. This report is a preliminary, more-detailed version of the text to NBMG Map 63.

and is highly deformed. The Cretaceous Gold Range Formation, a sequence of volcanic and volcaniclastic rocks is exposed in the western and central portions of the quadrangle. A few outcrops of Jurassic Dunlap? Formation are present in the northwest corner of the map area. Several Mesozoic intrusive rocks, including diorite, quartz monzonite, and granite, intrude most of the older units.

The Tertiary rocks lie unconformably on pre-Tertiary rocks. The oldest Tertiary rocks are felsic, which have been removed by erosion in many areas, leaving only remnants to crop out irregularly below a younger sequence of andesite flows and lahars. The youngest Tertiary rocks in the area are tuffaceous sedimentary rocks which crop out in the northeast part of the quadrangle.

The Quaternary alluvial deposits consist of fan and basin deposits of local derivation, plus sand dunes at the east edge of Garfield Flat (a playa lake near the northwest corner of the mapped area).

QUATERNARY DEPOSITS

DUNES AND EOLIAN SAND

This map unit is found only in the northwest corner of the quadrangle. The area of outcrop is slightly over 1 km^2 located at the northeast corner of the Garfield Flat playa, and contains a variety of vegetation-stabilized (shrub coppice) dunes as well as drift sand. The sand deposits are accumulating on a slightly sloping alluvial surface; dune forms include barchan and transverse. The source of the sand is probably Garfield Flat and the alluvial apron to the west of the Flat. This would suggest a northeast direction of prevailing wind transport.

LANDSLIDE DEPOSITS

Two small outcrops of landslide material occur near the west edge of the quadrangle about 1-1.5 km southeast of Pepper Spring. These deposits have formed in an area of steep slopes and consist of blocks of hornblende andesite with or without blocks of Tertiary ash-flow tuff, contained in a reddish, earthy matrix. In addition, a landslide block of approximately 0.25 km^2 area is present near the southwest corner of the quadrangle. This block is made up of older gravel deposits which have moved a short distance downslope over Tertiary andesite laharic deposits. This slide may have been facilitated by uplift and consequent erosion of supporting bedrock along a relatively young east-west trending fault located nearby. Also, a small outcrop of landslide material derived from an outcrop of Mina Formation is present in a canyon about 1.5 km west of the mouth of Silver Dyke Canyon.

ALLUVIUM

This unit occupies the lower relief areas adjacent to steeper alluvial fan complexes. It consists of poorly sorted gravel, sand and silt deposited from ephemeral streams in the lower areas of the valleys. It is distinguished on aerial photographs by its uniform texture and light color in contrast to the alluvial fan deposits.

ALLUVIAL FAN DEPOSITS

The most extensive unit of Quaternary deposits in the quadrangle is the coarse, poorly sorted boulder gravels and pebbly sands in alluvial fans. The major areas of large, coalescing fans (bajadas) are in the northwest and southeast parts of the quadrangle. Some colluvium is included in the unit in areas near bedrock outcrops. The fan deposits are a heterogeneous mixture of silt, sand, and gravel from local sources; their make-up varies with the rock types in the source areas and the extent and gradient of the intermittent streams supplying them. Fan deposits are thickest near the source areas; some of the fan slopes are up to 7° near the mountain front. Also, it was noted during the mapping that the alluvial fan deposits adjacent to Soda Springs Valley on the east margin of the quadrangle appear to be somewhat more dissected by the present washes than those in other areas. This recent downcutting in the fan deposits there may be related to recent changes in base level due to faulting.

OLDER GRAVEL DEPOSITS

Older gravel deposits are present only at the north and south edges of the Camp Douglas quadrangles, and consist mainly of fan and pediment deposits of poorly sorted, boulder- to silt-size material. The older gravel deposits are commonly more consolidated or caliche-cemented than the younger alluvial units and they may be more dissected by recent washes. The source area for the coarse detritus within the older gravel deposits is not, in some cases, readily identifiable. The older gravel deposits in the northern part of the quadrangle were probably deposited in alluvial fans, while those along the south margin are pediment deposits. Usually, they contain a heterogeneous mixture of material eroded from the surrounding highlands, but the pediment gravels exposed along the south edge of the quadrangle consist of over 95% material from the underlying Tertiary andesite laharic deposits. The absence of fragments of Mina Formation, for example, probably indicates a source area to the west of the older gravel deposits or lateral offset by the east-west trending fault just to the north.

TERTIARY ROCKS

TUFFACEOUS SEDIMENTARY ROCKS

Exposures of this rock unit are present only in the northeast corner of the quadrangle near the mouth of Douglas Canyon. They consist of up to 100 m of light-colored volcaniclastic rocks, including tuff, and tuffaceous shale, sandstone, and conglomerate. The unit unconformably overlies Mina Formation, and in western or upland areas of exposure consists mostly of tuffaceous conglomerate which contains boulders, cobbles and pebbles of several nearby Tertiary volcanic units as well as chert (probably from the underlying Mina Formation) and pink granite, which was probably eroded from outcrops 7-8 km to the northwest. The rounding and sorting are poor, and the beds are poorly exposed. The finer material in these conglomerates consists of sand, silt, and bentonitic clays.

The more easterly exposures of the tuffaceous sedimentary unit include beds of tuffaceous sandstone with calcareous cement, bentonite shale, and pebbly conglomerate. Coarse ash, present in some sandstones, is glassy. *Chara* oogonia (algal remains) were tentatively identified at one locality.

The tuffaceous sedimentary rock unit appears to include both fluvatile and lacustrine sedimentary environments. The boulder conglomerate to the west could represent a former stream channel, while the well-bedded tuffaceous sandstones and shales may have been deposited at the margin of a local lake. Marvin and others (1977) report K-Ar age of 5.7±0.2 m.y. for biotite collected from a tuffaceous sandstone exposed near the mouth of Douglas Canyon. However, they suggest this age may be a maximum, as contamination with extraneous, older biotite is a possibility.

BIOTITE-HORNBLENDE-ANDESITE

The unit here designated as biotite-hornblende andesite is the youngest part of a group of flows, lahars and hypabyssal intrusive rocks which is present in greater thickness to the west in the Moho Mountain quadrangle. The source was an andesitic stratavolcano which is probably located in the higher peaks of the central Excelsior Mountains 7 km to the west.

The biotite-hornblende andesite is mainly exposed in the northern part of the quadrangle, and is predominantly composed of flow rocks, although some laharic breccias of similar lithology are also included. A hypabyssal intrusive phase is also recognized, especially in S29,T6N,R34E. The unit unconformably overlies a great variety of older Tertiary and Mesozoic rocks; its top is an erosional unconformity within the quadrangle. The andesite is at least 100 m thick locally. The biotite-hornblende andesite consists of numerous flows which are not readily differentiated in the field; it is usually easily separated from underlying rocks, except in S35,36,T6N,R34E where it overlies flows of hornblende andesite.

The biotite-hornblende andesite is light- to medium-gray, or, less commonly, reddish brown or dark gray. It contains equant white plagioclase phenocrysts as well as hornblende, pyroxene, and sparse biotite. Rarely it exhibits local flow banding.

In thin section, the biotite-hornblende andesite consists of 5-25% phenocrysts, mainly plagioclase and hornblende, in a pilotaxitic matrix. Equant plagioglase phenocrysts are usually 0.5-5 mm, commonly exhibit oscillatory zoning, and have inclusion- or glass-filled rims or cores. Hornblende phenocrysts (usually oxyhornblende) are elongate, idiomorphic crystals that may be up to 1 cm in length, although they are usually 1-7 mm in length. They are pleochroic in various shades of brown and have opaque, recrystallized borders or are completely replaced by iron-oxide minerals, finely crystalline pyroxene and indeterminate opaque matter. Dark brown flakes of biotite, 0.3-2 mm, are sparse, but their presence usually serves to separate this andesite map unit from the older, darker colored hornblende andesite. A few grains of quartz were recognized in two thin sections. These appear as rounded, xenocrysts(?) rimmed by fine crystals of pyroxene. The groundmass consists of microlites of most of the phenocryst minerals, in addition to potassium feldspar, and glass. Magnetite is a common accessory mineral.

The following analysis was done on K-Ar age date sample CD-31 (M. L. Silberman, written communication, 1975), collected at NW/4 S26,T6N,R34E.

	Percent
SiO_2...............	58.9
Al_2O_3..............	16.2
Fe_2O_3..............	4.9
FeO................	1.1
MgO................	3.2
CaO................	5.6
Na_2O..............	3.3
K_2O...............	2.8
H_2O+..............	0.40
H_2O-..............	1.5
TiO_2..............	0.39
P_2O_5..............	0.42
MnO................	0.09
CO_2...............	0.05
SUM	99

The biotite-hornblende andesite has been K-Ar dated at 15.7$\pm$0.5 and 16.1$\pm$ 0.7 m.y. on biotite and plagioclase, respectively, from a sample collected about 1.5 km south of Douglas Canyon (Silberman and others, 1975a; Garside and Silberman, 1978). This 16 m.y. andesite is part of a large volume of andesitic volcanic rocks erupted from numerous centers along the Walker Lane fault zone in western Nevada between about 17 and 12 m.y. ago (Silberman and others, 1975b).

RHYOLITE PORPHYRY DIKES

Two narrow rhyolite dikes cut micromonzonite 1.7 km east of Silver Dyke Canyon. These dikes are several hundred meters in length, 2-3 m wide, and vertical. The longer dike is along a portion of a major east-west fault.

The rhyolite is yellowish gray and contains feldspar phenocrysts, 1-3 mm in length, biotite phenocrysts up to 1 mm, and ovoid vermicular, embayed quartz phenocrysts, 1-3 mm in length, biotite phenocrysts up to 1 mm. In thin section the rock consists of approximately 20% phenocrysts of quartz (40%), plagioclase 30%, potassium feldspar (20%), and biotite (1%) in a finely crystalline matrix.

The rhyolite porphyry dikes are present only within the micromonzonite. If the 16 m.y. age on the micromonzonite is correct, the dikes must be somewhat younger.

MICROMONZONITE

Two small micromonzonite intrusive masses of 1.1.5 km^2 outcrop area are exposed 1-2 km west of the mouth of Silver Dyke Canyon. They intrude Mina Formation and the lower unit of the Gold Range Formation, and also appear to cut Tertiary ash-flow tuffs. Age- and contact-relations between the micromonzonite and Tertiary hornblende andesite are amibguous. The southern intrusive body also cuts a Mesozoic? thrust fault and is emplaced in the nose of a syncline, both present in the Mina Formation. Most of the micromonzonite is greenish gray, although border and dike porphyry phases are usually light gray. The color index of the rock is 10-15. The main mass of the intrusive bodies is porphyritic micromonzonite, consisting of plagioclase and pyroxene phenocrysts in a fine-grained phaneritic hypidiomorphic-granular matrix. Light-colored hornblende-plagioclase porphyry dikes both cut and extend out from the main micromonzonite mass.

In thin section the micromonzonite consists of approximately 50% plagioclase, 35% potassium feldspar, 10% pyroxene, less than 5% quartz, and 1% biotite. Accessory minerals include magnetite (up to 5%), apatite and zircon. Phenocryst minerals in the porphyry phase are approximately 25% of the rock, predominantly plagioclase and hornblende with sparse biotite. Plagioclase occurs as 1-3 mm long euhedral crystals and as smaller subhedral crystals usually less than .5 mm. Potassium feldspar occurs predominantly as automorphic crystals less than about .4 mm in length. Subhedral pyroxene crystals 0.4-1.2 mm in diameter, exhibit poikilitic texture, enclosing small crystals of magnetite, plagioclase, potassium feldspar, and quartz(?). Some pyroxene phenocrysts appear to be complete replacements of hornblende. Biotite plates are usually 0.2-0.4 mm in diameter. Quartz occurs mainly as subhedral crystals less than 1 mm, although it is present in porphyry phases as embayed and corroded phenocrysts 1-1.5 mm in diameter. Hornblende is common only in the porphyry phases, as euhedral phenocrysts up to 1 by 7 mm in dimension. Alteration minerals in the micromonzonite include minor amounts of epidote, chlorite, calcite, tremolite, saussurite, and a fiberous zeolite in one sample.

The micromonzonite has been dated at 16.2 m.y. by K-Ar methods (Speed and Kistler, in press). This date is close to those from andesitic lavas in this area. This age similarity, coupled with the generally similar rock composition, makes it appear likely that the micromonzonite is a hypabyssal intrusive rock related to the Miocene andesitic volcanism of this region.

ANDESITE LAHARIC DEPOSITS

A poorly sorted sequence of laharic andesitic volcanic breccias is exposed at the south edge of the Camp Douglas quadrangle. These deposits consist predominantly of light gray clasts of porphyritic flow rock in a fine-grained matrix of silt- and sand-sized material. The clasts are angular to subrounded and vary in size from a few cm to over 1 m and average approximately 25 cm. Crude bedding is recognizable in some places, and a few minor, interbedded epiclastic volcanic sandstones and conglomerates were noted. These epiclastic beds are also high in andesitic material, and probably represent fluvial deposits. More than 95% of the clasts are light-colored andesitic flow rocks, similar to those present in the northern part of the quadrangle as well as further west in the Excelsior Range and near Nevada Highway 10 to the south. A few clasts are andesitic scoria and cinders, and a very small number of clasts are chert and welded tuff.

The andesitic laharic deposits are up to approximately 200 m in thickness within the quadrangle. The total thickness of the laharic deposits is unknown since their base is not exposed within the map area. The unit is not exposed to the north of a major east-west strike-slip(?) fault.

In thin section the major type of clast consists of phenocrysts of plagioclase, hornblende, and minor pyroxene and biotite in a pilotaxitic, partially glassy groundmass. Accessory magnetite, apatite, and zircon are also present. Phenocrysts are generally up to 2 mm in diameter. Potassium feldspar is common in the matrix.

Approximately 2 km to the south of the quadrangle the laharic deposits overlie mineralogically similar andesite flows which have been dated by K-Ar methods at 17.3 and 17.4 m.y. on hornblende and plagioclase respectively (Marvin and others, 1977). Within the quadrangle and to the south, the andesite laharic deposits are often overlain by Quaternary older gravel deposits. Similar laharic breccias of unknown, but probably equivalent age, are also present in the Excelsior Range about 9 km to the west.

INTRUSIVE LATITE AND ASSOCIATED VENT BRECCIA

An elongate, hypabyssal latite intrusive mass (Tl) with minor associated breccia (Tlv) is exposed in S35 and 36,T6N,R34E, east of the Kernick Mine. The intrusive cuts latite breccia, which is interpreted to be an associated vent breccia, as well as rhyolitic welded tuff and hornblende andesite. It is unconformably overlain by biotite-hornblende andesite. The elongate shape of the latite may be related to a possible structural weakness which is a continuation of the east-west trending faults and veins in the Camp Douglas mining district to the west.

The latite ranges from pale brown to very pale orange, and is associated with a larger, enclosing aureole of argillization and silicification. This alteration makes distinction of units difficult. The vent breccia is mineralogically similar to the intrusive phase, but consists mainly of latite pumice fragments, usually less than 30 cm in diameter. Flow banding and an obviously glassy matrix are present only at a few localities, mainly near the margins of the dike-like latite intrusive body.

Thin sections of the least-altered samples show that the latite intrusive consists of approximately 15 percent plagioclase and sparse biotite phenocrysts in a glassy matrix. Flow textures in the volcanic glass range from actual flow banding, to the alignment of phenocrysts and microlites. The glass ranges from light brown to clear, and may appear black in hand specimen. In some samples, the matrix is devitrified to a fine mixture of cristobalite and potassium feldspar, which exhibits spherulitic texture. Plagioclase phenocrysts are only rarely larger than 1 mm; biotite plates and flakes are usually only 0.2 mm in diameter, although some may be as large as 1.2 mm. Some biotite phenocrysts are rimmed and variably replaced by iron oxide minerals.

Hydrothermal alteration of the latite and latite vent breccia consists of strong silicification and argillization; this alteration also extends into the surrounding hornblende andesite. In addition, iron-staining and opalization are present locally, and Papke (1970) detected montmorillonite, kaolinite, illite, quartz, cristobalite, potassium feldspar, jarosite, and gypsum at the Sodaville montmorillonite deposits near the southeast end of the latite intrusive body.

Pyrite(?), often converted to iron oxide minerals, is present in variable amounts. This hydrothermal alteration and associated mineralization (at the Kernick Mine, for example) may be related to the mineralization at Camp Douglas to the northwest.

A K-Ar age of 18.9±0.8 m.y. was obtained on plagioclase from a glassy latite sample taken near the northwest end of the intrusive body (Garside and Silberman, 1970).

HORNBLENDE ANDESITE

The Hornblende andesite unit consists of a sequence of flows (Ta) and a few minor dikes and small, irregular intrusive bodies (Tai). It is exposed throughout much of the quadrangle and normally underlies biotite-hornblende andesite and overlies older Tertiary ash-flow tuffs or pre-Tertiary rocks. It is over 100 m thick in several places, and is usually light gray, light brownish gray, medium dark gray, or dark greenish gray, often weathering to pale brown. It is not noticeably flow banded, although it often exhibits platy jointing. Because it consists of numerous flows, it is somewhat variable, and may be difficult to distinguish from other andesite units in the quadrangle. In most areas it is differentiated from the younger biotite-hornblende andesite by its darker color, acicular hornblende phenocrysts, absence of biotite, and lower percentage and smaller size of phenocrysts, especially plagioclase. In the east central part of the quadrangle certain parts of the unit may resemble rocks included in the biotite-hornblende andesite.

In thin section, the hornblende andesite is often quite fine-grained. Phenocrysts of hornblende, pyroxene, and plagioclase usually make up less than 15 percent of the rock. The matrix is finely crystalline, with pilotaxitic fluidal or, less commonly, felted texture, and consists of small plagioclase laths, magnetite grains, and variable amounts of small pyroxene crystals. Phenocrystic hornblende, usually basaltic hornblende, often occurs only as "ghosts" of finely crystalline iron-oxide minerals and pyroxene. The hornblende phenocrysts are acicular crystals from 0.5 to 3 mm long, rarely they reach 1 cm in length. Plagioclase is often not present as phenocrysts, but when present is usually less than 2.5 mm in length. Subhedral to euhedral pyroxene phenocrysts are usually present, although in varying amounts, and are usually less than 1 mm in diameter. The amount of potassium feldspar in the matrix is also somewhat variable. Accessory magnetite and sparse apatite were recognized. Rare xenocrystic quartz grains up to several millimeters in diameter were observed in a few basal flows in the western part of the quadrangle, and sparse olivine also occurs in a few of the lowermost flows of the unit. Propylitization of the hornblende andesite is common in flows exposed to the west of the Silver Dyke Fault; mafic minerals are partially altered to chlorite, epidote, and calcite and plagioclase is slightly altered to fine sericite. In the eastern part of the quadrangle the unit is strongly argillized and silicified in an alteration aureole surrounding an intrusive latite. Alteration minerals recognized include mont-montmorillonite, kaolinite, illite, quartz, jarosite, and gypsum (Papke, 1970).

Some of the hornblende andesite flows are at least 19 m.y. old, as they are intruded by latite of this age east of the Kernick Mine. Because of the variety of flows included in this unit, some portions may be younger. In the northeast corner of the quadrangle the unit overlies the Belleville Tuff that has a K-Ar age of 22 m.y. Thus, most if not all of the hornblende andesite unit is between 19 and 22 m.y. old.

OLIVINE BASALT

Olivine basalt is present near the north edge of the quadrangle, occupying a total area of less than 2 km^2. It lies below the Tertiary andesite units and overlies pre-Tertiary Mina and Dunlap Formations. The olivine basalt is medium dark gray to brownish gray; it is usually less than 100 m thick. The basal contact is somewhat irregular, probably due to deposition in low areas on a surface of relatively high relief. At some localities hornblende andesite may be absent above the olivine basalt, allowing biotite-hornblende andesite to directly overlie the olivine basalt. The absence of the hornblende andeiste is more likely due to non-deposition in an area of high relief, rather than pre-biotite-hornblende andesite erosion. The olivine basalt is often vesicular, and consists in part of scoria and blocks as well as massive flow rock. Small olivine phenocrysts (converted to iddingsite) are often visible in hand specimen.

In thin section, the basalt contains only olivine as phenocrysts, in a vesicular, pilotaxitic, fine-grained matrix of calcic plagioclase, pyroxene, and magnetite. The olivine phenocrysts are 0.4-1.2 mm in diameter, and are rimmed and replaced by iddingsite and altered to serpentine. Small, anhedral grains of biotite are also present, possibly as an alteration product of other mafic minerals. Secondary calcite occurs locally in vesicles.

The olivine basalt is undated, but it is probably the lower part of the overlying Tertiary andesite sequence. It is older than 19 m.y., but a lower age limit cannot be placed with certainty. The relationship of the olivine basalt to the ash-flow tuffs exposed in the quadrangle is not known. A less-likely interpretation is that the olivine-basalt is related to basalts similar to the 24 m.y. flow exposed near Candelaria, 25 km to the south (Marvin and others, 1977), where basalt flows are interlayered with rhyolitic ash-flow tuffs.

CONGLOMERATE

A very small outcrop of conglomerate occurs in NW/4 S25,T6N,R34E, about 1.5 km south of Douglas Canyon. It is nearly surrounded by Permian Mina Formation, but contains pebbles of Tertiary(?) andesite and thus is interpreted to be Tertiary. It consists mainly of sub-rounded pebbles of hornblende andesite and chert, and is usually poorly exposed. Within this outcrop, a few very small areas of the Tertiary hornblende andesite(?) unit and a flow banded rhyolite (not seen elsewhere in the quadrangle) are also present but were not mapped separately. Because of the presence of pebbles of chert, probably derived from the Mina Formation and hornblende andesite, the conglomerate appears to be a local accumulation at or near the base of the Tertiary section in the area. The single outcrop is separated from the Mina Formation on both the north and the south by low-angle, calcite-filled faults. These faults also cut Tertiary andesite and basalt and Mina Formation in the immediate vicinity, and are probably detachment faults of small displacement.

BELLEVILLE TUFF

This unit consists of welded rhyodacite ash-flow tuff (Ttb) and a thin underlying gravel (Ttbg). It was named for approximately 200 m of ash-flow tuff exposed 2.3 km S20E of the site of Belleville (Speed and Cogbill, 1979b); this locality is about 5 km south of the Camp Douglas quadrangle boundary. The unit is present only as a few small exposures in the northeast corner of the quadrangle.

The Belleville Tuff is a rhyodacite ash-flow tuff with a discontinuous basal sedimentary gravel. It unconformably overlies the Tuff of Metallic City and Permian Mina Formation. It is up to 60 m thick but thins to 10 m or less in some areas below the overlying hornblende andesite. The tuff is strongly compacted and largely devitrified; only a single cooling unit is recognized in the mapped area. A vitrophyre is locally present near the base.

The basal gravel unit, where present, consists of no more than a few meters of rounded to well-rounded pebbles, cobbles and boulders in a poorly exposed, white, tuffaceous matrix. The clasts are mainly resistant pre-Tertiary rocks, including Mina Formation graywacke and chert, and conglomerate and hornfels of the Gold Range Formation. The tuffaceous matrix material was probably derived by erosion from the underlying Metallic City Tuff.

The rhyodacite ash-flow tuff portion of the unit is light gray to pale brown, contains up to 25% strongly compacted pumice, 12-15% plagioclase phenocrysts, 1-2% lithic fragments, and very sparse mafic minerals and quartz in a devitrified to glassy matrix of moderately deformed glass shards and dust. Rare biotite and pyroxene are usually not observed in portions of the tuff which have been subjected to vapor phase alteration. The matrix is often devitrified to potassium feldspar and cristobalite, and tridymite is commonly present in cavities and areas of former pumice lapilli as a result of vapor-phase alteration. Tabular plagioclase phenocrysts are usually 1-3 mm in length, and the sparse lithic fragments are small (0.5 mm-1 cm) and consist of chert, andesite and welded tuff. The unit is distinguished from other tuff units in the quadrangle mainly by the presence of plagioclase as the main phenocryst mineral, rare mafic minerals, virtual absence of quartz, and presence of strongly compacted pumice.

The age of the Belleville Tuff is approximately 22 m.y., based on 2 K-Ar ages determined on plagioclase (Marvin and others, 1979; Garside and Silberman, 1978) from samples collected just north of the quadrangle border. Stratigraphic relations in the vicinity of Candelaria suggest that these ages may be somewhat too young, as the Belleville Tuff underlies tuffs dated as old as approximately 23 m.y. (Speed and Cogbill, 1979b). According to Speed and Cogbill (1979b), Belleville Tuff includes units Tr13, Tr14, Tr15, and Tr16 of Page (1959) at Candelaria, and is present in the Miller Mountain area of southern Mineral County.

METALLIC CITY TUFF

The Metallic City Tuff is a rhyolite crystal ash-flow tuff named for exposures in the Candelaria area 2.5 km S64W of Metallic City (Speed and Cogbill, 1979b). In the northern part of the Camp Douglas quadrangle it is exposed in a few areas as erosional remnants, less than 20 m thick, underlying either hornblende andesite or the Belleville Tuff. Where the base is exposed, the unit overlies Permian Mina Formation.

In outcrop, the Metallic City Tuff is very light gray to light olive gray, and contains small, dark gray lithic fragments (2 mm-5 cm) and white, slightly compacted pumice (2-5 mm). In thin section, the tuff usually consists of 20-30%

phenocrysts, 10-30% pumice, and less than 5% lithic fragments in a matrix of glass shards and dust. The phenocrysts are often broken and angular, and consist of approximately 40% quartz, 20% plagioclase, 25% potassium feldspar, and 15% biotite. Generally the phenocrysts are less than 2 mm in diameter; biotite plates are somewhat aligned along the compaction foliation and quartz phenocrysts are often somewhat larger than other minerals, ovoid, and slightly corroded. A very few hornblende phenocrysts were seen in one thin section. Pumice is poorly to moderately compacted, and usually smaller than 5 mm, although rarely 1 cm or larger. Shards are moderately compressed and are usually glassy. The matrix is glassy to slightly devitrified and spherulitic. Lithic fragments are usually less than 1 cm in dimension, although considerably larger fragments are present locally, such as at a small outcrop of probable unwelded Metallic City Tuff exposed southeast of Garfield Flat.

A sample of the Metallic City Tuff from exposures in S14,T6N,R34E gave K-Ar ages of 24.2±0.7 and 24.8±1.0 m.y. on biotite and plagioclase respectively (Garside and Silberman, 1979). Marvin and others (1977, sample USGS-D2380B) report a similar age from the type section. However, Gilbert and others (1968) describe K-Ar ages as young as approximately 22 m.y. for this unit at a locality 20 km southwest of Candelaria (Marvin and others, 1978). Based on the available evidence, an age of 24-25 m.y. seems the most likely. The Metallic City Tuff correlates with map unit Tvl2 of Page (1959) at Candelaria (Speed and Cogbill, 1979b).

CRYSTAL TUFF

A sequence of 3 ash-flow tuff units is locally preserved as erosional remnants below hornblende andesite in the higher part of the Excelsior Mountains to the south and west of Thunder Mountain. The uppermost unit is a very pale purple rhyolite crystal tuff containing white, compacted pumice (Tct). It is usually less than 30 m thick. An underlying gravel unit (Tctg) is present at one locality. The crystal tuff generally overlies rhyodacite tuff, but may directly overlie pre-Tertiary rocks, suggesting local erosion of the underlying tuffs. The gravel, where present, is up to 10 m thick in local channels in pre-Tertiary rocks, and contains cobbles and boulders of the older, underlying rhyolite tuff as well as several pre-Tertiary rock types. The presence of the rhyolite tuff cobbles provides additional evidence for the erosion of part of the underlying tuffs before the crystal tuff was deposited. Boulders in this gravel are commonly 15-30 cm in diameter, but may be as large as 1.5 m.

Phenocrysts compose about 20-30% phenocrysts of the crystal tuff and consist of about 40% quartz, 35% potassium feldspar, 20% plagioclase and 5% biotite in a largely devitrified matrix. White moderately compacted pumice makes up 10-20 cm locally near the base of the tuff. Sparse lithic fragments up to 1 cm in diameter may be present. Subhedral, equant to ovoid quartz phenocrysts are vermicular, slightly pinkish, and usually 1-3 mm or rarely up to 4 mm in diameter. Feldspar phenocrysts, 1-2 mm long, are commonly broken and have been slightly sericitized. Biotite flakes, approximately 2 mm in diameter, are nearly always altered to iron-oxide and clay minerals.

The age of the crystal tuff is approximately 27 m.y. based on a K-Ar age (27.1±1.5 m.y.) on biotite from a sample collected on Moho Mountain in the southwest part of the Camp Douglas quadrangle (Marvin and others, 1977, sample B-3462). The crystal tuff resembles the Weed Heights Member of the Mickey Pass Tuff, named in the Yerington area (Prøffitt and Proffitt, 1976) and present in the Luning NW 7 1/2-minute quadrangle, approximately 30 km to the north (Ekren and Byers, 1978). Also, it is of approximately the same age (Proffitt and Proffitt, 1976).

OLDER ANDESITE

Two very small outcrops of andesite occur below the crystal tuff in the western part of the quadrangle. The andesite lies unconformably below the crystal tuff and, at one locality, above the rhyolite tuff, stratigraphically equivalent to the rhyodacite tuff, which is absent. The andesite is up to 25 m thick.

In thin section, the older andesite consists of phenocrysts of basaltic hornblende, pyroxene, plagioclase, and accessory magnetite having a pilotaxitic texture in a finely crystalline groundmass of plagioclase, alkali feldspar, pyroxene, and magnetite. The euhedral basaltic hornblende phenocrysts are 1-3 mm, commonly zoned, and are rimmed or completely replaced by fine-grained iron oxide minerals and pyroxene. Pyroxene phenocrysts are 1-1.5 mm in diameter, while plagioclase laths are smaller, 0.2-8 mm in length.

The older andesite is at least as old as 27 m.y., as it underlies the crystal tuff. It appears to be nearly equivalent in age to the rhyodacite tuff, which was not age dated.

RHYODACITE TUFF

A thin (5-10 m) rhyodacite ash-flow tuff is present in the eastern part of the quadrangle below the crystal tuff and above rhyolite tuff (described below). It is commonly a distinctive pale red purple, and contains approximately 10% small, white plagioclase phenocrysts, rare biotite and pyroxene?, and 5-20% strongly compacted pumice in a thoroughly recrystallized matrix containing moderately to strongly deformed, recrystallized shards. Sparse lithic fragments (less than 5 mm) of older volcanic rocks are also present and are more abundant near the base of the unit in a few areas. Plagioclase phenocrysts are usually 0.5-1.5 mm in length, and pumice lapilli are strongly compressed disks up to 2-3 mm by 5-7 cm.

The rhyodacite tuff is commonly hydrothermally altered. Plagioclase and other minerals are altered to sericite and minor calcite, and pumice is often completely replaced by finely crystalline silica. Iron-oxide minerals occupy, in part, the sites of former mafic minerals.

The rhyodacite tuff appears to be stratigraphically equivalent to the older andesite, described above, and is older than the overlying 27 m.y. old crystal tuff.

RHYOLITE TUFF

The lowermost Tertiary unit exposed in the western part of the quadrangle is a white to very light gray or pinkish gray, altered, rhyolite ash-flow tuff (Trt), 10 m to approximately 150 m thick. The unit also includes a few exposures of an underlying gravel (Trtg) up to 10 m thick which consists of rounded to angular pebbles and cobbles of pre-Tertiary rocks, including Gold Range Formation and quartz monzonite porphyry. The rhyolite tuff lies with angular unconformity on several pre-Tertiary units, and is generally overlain by rhyodacite tuff. Micromonzonite intrudes the rhyolite tuff 2 km west of Silver Dyke Canyon. In places, the basal contact appears to have been an irregular erosional surface. The rhyolite tuff and overlying tuffs crop out sporadically beneath hornblende andesite flows. In several areas, the younger crystal tuff lies directly on pre-Tertiary basement, indicating the probable local erosional removal of the rhyolite tuff.

In thin section the rhyolite tuff is normally quite altered. It appears to have originally consisted of approximately 15-20% phenocrysts in a thoroughly altered and recrystallized matrix; the few ghosts of former glass shards noted show only slight deformation. Phenocrysts consist of approximately 40% quartz, 55% plagioclase and potassium feldspar and 1-4% biotite. The quartz phenocrysts are commonly slightly vermicular and embayed, 0.5-2 mm in diameter, and are ovoid or broken and angular. Feldspars are approximately the same size as quartz, and are usually completely replaced by alteration minerals. Pumice (up to several cm) is moderately compacted. Lithic fragments, often from the Gold Range Formation, are normally sparse and small (<1 cm), but are relatively abundant near the base of the tuff in a few areas. The rhyolite tuff may be difficult to distinguish from the younger crystal tuff; however, the former usually is more altered, has less biotite and quartz, and contains quartz phenocrysts that are smaller and more angular.

Pervasive alteration present in the unit consists of the conversion of feldspar, pumice, and much of the matrix to a mixture of quartz, kaolinite, pyrophyllite, calcite, and sericite. Biotite is often entirely altered to sericite plus iron-oxide minerals. Some rocks, when analyzed by x-ray diffraction, are found to consist almost entirely of quartz, kaolinite, and pyrophyllite or quartz and 2M mica (Keith Papke, personal communication, 1976). Iron oxide pseudomorphs of pyrite are also present in some samples.

The rhyolite tuff is probably the oldest Tertiary unit in the quadrangle. Silicified pyroclastic and tuffaceous sedimentary rocks, described below, may be correlative with the lowermost part of the tuff. It resembles parts of the Mickey Pass Tuff (the Guild Mine Member?) present several tens of kilometers to the north, but is too altered for any certain correlation.

SILICIFIED PYROCLASTIC AND TUFFACEOUS SEDIMENTARY ROCKS

Outcrops of strongly silicified rocks in the east-central part of the quadrangle which occupy slightly more than 1 km^2 have been included in a single map unit, although they are often too altered to permit identification of rock type. They consist of probable pyroclastic and tuffaceous sedimentary rocks which now consist of over 95% cryptocrystalline silica. In most samples, it is impossible to recognize any original mineral or rock constituents or sedimentary features. However, in a few outcrops, silicified volcaniclastic conglomerates, sandstones, and felsic(?) lapilli tuffs can be tentatively identified. The pebbles appear in some cases to be andesite(?) and dark chert, and "ghosts" of similar pebbles can be seen elsewhere in the unit as dark blebs in a pinkish-gray mass of very hard, porous-to-dense silica. In addition to cryptocrystalline silica, a small amount of potassium feldspar jarosite hematite were recognized.

The exact stratigraphic position of this unit of silicified rocks is not known with certainty. The unit is probably less than 40 m thick, and appears to lie on Tertiary hornblende andesite as well as Permian Mina Formation. However, several smaller outcrop areas of the silicified unit which overlie andesite appear to be slide blocks. In addition, the largest mass of the silicified unit, when viewed from a distance, resembles a giant slide block, and low-angle gouge zones are present along the basal contacts in a few places near the south edge of outcrop. The only possible correlative unit in the Camp Douglas quadrangle is a thin unit of poorly welded tuffs and tuffaceous sedimentary rocks which is present at the base of the lowest Tertiary ash-flow tuff about 2 km northwest of the mouth of Silver Dyke Canyon.

It is proposed that the silicified pyroclastic and tuffaceous sedimentary rocks are part of a large slide block or blocks which have moved eastward from the Thunder Mountain area over hornblende andesite and Mina Formation. When this movement took place is not known. The unit is probably correlative with thin, discontinuous pyroclastic and sedimentary rocks that are mapped with the lower part of the rhyolite tuff unit described above.

MESOZOIC ROCKS

QUARTZ-EYE GRANITE PORPHYRY

Numerous small- to medium-sized dikes and irregular intrusive bodies of quartz-eye granite porphyry intrude the Mina and lower Gold Range Formations and diorite in the southwestern part of the Camp Douglas quadrangle. The largest of these intrusive bodies is no wider than 300 m, although they may be up to 2 km in length. The quartz-eye granite porphyry is light-colored, generally light gray to pinkish gray, and commonly contrasts sharply with the generally dark-colored rocks which it intrudes. The porphyry is unconformably overlain by Tertiary welded tuffs and andesite lavas. It is not foliated, but does exhibit marginal grain-size changes in both phenocrysts and groundmass. One intrusive body which intrudes diorite just to the south of Thunder Mountain is aplitic at its margins and nearly phaneritic porphyritic in its interior. Some samples of this intrusive are also somewhat iron-stained, possibly due to small amounts of oxidized pyrite.

In thin section the quartz-eye granite porphyry consists of phenocrysts of quartz, plagioclase, potassium feldspar and sparse biotite in a fine-grained groundmass of quartz and feldspar. The phenocrysts normally constitute 10-20% of the rock, and may exhibit glomeroporphyritic texture. The approximate phenocryst percentages are: quartz, 40%; potassium feldspar, 35%; plagioclase, 25%; biotite usually less than 1%. The groundmass is somewhat variable in grain size, but usually consists of approximately 0.01-0.02 mm grains of quartz, potassium feldspar, and plagioclase having a xenomorphic granular or, rarely, micrographic texture. Distinct, ovoid quartz phenocrysts, 1-5 mm in diameter are somewhat corroded and vermicular. Equant potassium feldspar phenocrysts are microperthitic and usually 3-6 mm in size, although they can be up to 1 cm. Plagioclase is 1.5-2 mm in diameter, and sparse biotite flakes are usually 1-1.5 mm. A few faint "ghosts" of hornblende (now fine-grained chlorite and biotite), 0.8-1.5 mm in diameter, were seen in one thin section. Most of the alteration of the quartz-eye porphyry consists of the partial alteration of feldspars, and sometimes biotite, to sericite.

The quartz-eye granite porphyry is approximately 90 m.y. old, based on a biotite K-Ar age (89.5 ± 2.7 m.y.); more data on K-Ar determinations of this and other rocks in the quadrangle are presented in Garside and Silberman (1978). The geologic and K-Ar age relations suggest that this quartz-eye granite porphyry is related to the biotite quartz monzonite and, probably, the quartz monzonite porphyry.

QUARTZ MONZONITE PORPHYRY

Two small outcrops of quartz monzonite porphyry are present adjacent to a mass of biotite quartz monzonite in the southwest part of the quadrangle. The quartz monzonite porphyry intrudes both the Mina and Gold Range Formations, and is locally overlain by Tertiary volcanic rocks. Contact relations of the quartz monzonite porphyry with the biotite quartz monzonite are not well exposed, but the porphyry is probably related to the main biotite quartz monzonite mass, either as a border phase or a separate comagmatic intrusive body.

The quartz monzonite porphyry contains large, white plagioclase, phenocrysts in a medium dark gray to grayish black, fine-grained matrix. However, where hydrothermally altered, the porphyry is pale greenish yellow. The plagioclase phenocrysts are up to 4 cm in diameter, although most are 0.5-1 cm, and are equant to somewhat rectangular in outline. Biotite, hornblende, and quartz phenocrysts are usually smaller than 1-2 mm in diameter. A few 2-3 mm long potassium feldspar phenocrysts were noted, although most potassium feldspar is present in the matrix.

In altered quartz monzonite porphyry plagioclase and matrix minerals are converted to a fine mosaic of quartz and sericite; biotite and hornblende are altered to hydrobiotite(?) or are replaced by specular hematite intergrown with magnetite and having Fe:Ti in the ratio of 4:1 (L. C. Hsu, written communication, 1978). Disseminated pyrite is present locally in light-colored rock containing strong quartz-sericite alteration; where oxidized, the rock surfaces may contain iron oxide or sulfate minerals. In areas where the altered quartz monzonite porphyry is in contact with very light gray cherts of the Mina Formation, the two units are often difficult to distinguish in outcrop.

The age of the quartz monzonite porphyry is not known, except that it is younger than the Gold Range Formation which it intrudes and older than the Tertiary felsic ash-flow tuffs overlying it. If the assumed close relationship to the biotite quartz monzonite is correct, the quartz monzonite porphyry is approximately 90 m.y. old.

BIOTITE QUARTZ MONZONITE

Two large areas (1-3 km^2 each) of biotite quartz monzonite crop out in the southwest part of the quadrangle. In addition, a small portion of another pluton is present near the southeast corner of the quadrangle, and two small outcrops were mapped adjacent to one of the larger plutons. The biotite quartz monzonite intrudes rocks of the Black Dyke(?), Mina, and Gold Range Formations and is nonconformably overlain by Tertiary and Quaternary units. Contacts of the quartz monzonite with the intruded rocks are usually sharp, and because the pre-Tertiary rocks are usually quite dark-colored, the intrusive contact is usually easily distinguished on aerial photographs.

The biotite quartz monzonite is light gray to grayish pink, medium-grained (2-5 mm), equigranular, and has a typical granitic (hypidiomorphic-granular) texture. It is not foliated, but often exhibits two distinct sets of steeply dipping joints which are at approximately right angles to each other.

In thin-section the rock is seen to consist of potassium feldspar, plagioclase, quartz, and biotite with accessory apatite, zircon, and sometimes, pyrite. Hornblende occurs in samples from a pluton present just to the southwest of the quadrangle, which is exposed at the extreme southern edge of the mapped area. Plagioclase is often oscillatory zoned, usually subhedral, and may contain numerous inclusions and be somewhat sericitized. Potassium feldspar grains are usually subhedral to anhedral, and somewhat smaller than those of plagioclase. Quartz is anhedral; biotite is commonly partially chloritized. The potassium feldspar is generally 40-60% of the total feldspar present, and is often pink.

K-Ar ages were determined on plagioclase, potassium feldspar and biotite from a sample collected from the large pluton at the mountain front in the southeast part of the quadrangle (Garside and Silberman, 1978). These ages are 70.3±2.1, 78.5±2.4, and 92.8±2.8 m.y., respectively. The biotite determination is probably the most reliable, although it, too, should be considered a minimum age. It is very close in age to a 92.4 m.y. determination on a quartz monzonite porphyry in the Moho Mt. quadrangle to the west of the Camp Douglas quadrangle (Marvin and Cole, 1978), and somewhat older than K-Ar ages on biotite (84.1 m.y.) and hornblende 78.8 m.y.) from a pluton exposed at Marietta Summit, 2.5 km southwest of the SW corner of the Camp Douglas quadrangle.

The biotite quartz monzonite in the Camp Douglas quadrangle is part of a number of large granitic bodies in this part of western Nevada. These plutons are generally considered to be part of the Sierra Nevada batholithic complex (Ross, 1961), possibly near its eastern margin (Speed and Kistler, in press).

DIORITE

A pluton of hornblende-biotite diorite is exposed in Silver Dyke Canyon. The main outcrop is nearly two square kilometers, with virtually all the exposures located on the southwest side of the Silver Dyke Fault. The diorite has intruded the lower and middle units of the Gold Range Formation, and has been intruded by quartz-eye porphyry. Except for a small dike or sill at the south end of the pluton, it appears to be a single mass, now somewhat offset by the Silver Dyke Fault.

The diorite is dark gray to dark greenish gray, generally medium grained, somewhat coarsely jointed, and quite uniform in appearance. It has a color index of about 25, and in thin section consists predominantly of plagioclase, about An_{50} (65%), hornblende (25%), and biotite (5%). A small amount of interstitial quartz and potassium feldspar are present, along with accessory magnetite, apatite, and rare zircon. The plagioclase is predominantly subhedral, and is generally coarser grained than the other minerals; crystals are somewhat lath-shaped, generally 1-3 mm in length, and polysynthetically twinned. The amounts of hornblende and biotite are variable among samples; crystals are generally subhedral to anhedral and usually less than 2 mm in diameter. Magnetite, usually less than 0.08 mm in diameter, is a common accessory mineral.

In the thin sections examined, alteration minerals are always present, but in variable amounts. Plagioclase is altered to sericite and saussurite, biotite is altered to chlorite, and hornblende is altered to actinolite?, epidote and calcite. In addition, hydrothermal alteration has affected the diorite near the Silver Dyke Vein; this mainly consists of quartz-adularia alteration and, according to Kerr (1936), kaolinization.

Kerr (1936) reports a chemical analyses of unaltered diorite, as:

	Percent
SiO_2..............	55.05
TiO_2..............	0.12
Al_2O_3.............	18.94
Fe_2O_3.............	2.88
FeO...............	5.01
MnO...............	0.7
MgO...............	3.62
CaO...............	7.02
Na_2O..............	3.93
K_2O...............	2.28
H_2O...............	0.21
H_2O (at 105° C.)...	0.04
P_2O_5..............	0.38
CO_2...............	0.09
SO_3...............	Trace
S.................	0.06
SUM	99.80

K-Ar ages on the diorite include dates of 91.5 ± 4.6 m.y. (hornblende concentrate), 96.8 ± 2.9 m.y. (biotite) and 101 ± 4 m.y. (biotite). More data on these age determinations is reported in Garside and Silberman (1978). The biotite ages (97-101 m.y.) are believed to more closely represent the true age, as the hornblende concentrate was contaminated with biotite and magnetite.

GOLD RANGE FORMATION

The Gold Range Formation was originally named by Nielsen (1963) for exposures in the central Excelsior Mountains a few km north of the mining camp of Marietta, although the name was never formalized. This type area was approximately 8 km west of the edge of the Camp Douglas Quadrangle. Nielsen also mapped the Gold Range Formation in the vicinity of Camp Douglas. The formation name is derived from the Gold Range Mining District, which has often been considered to include the mining areas at Camp Douglas (The Douglas or Silver Star Mining District), Silver Dyke, Marietta, the Moho Mine, and various other prospects in this part of the Excelsior Mountains. Speed (1977a) has discussed the history of the informal usage of the Gold Range Formation and formally redefined the formation, using Nielson's original name but excluding some rocks that were included in the original definition.

The Gold Range Formation is exposed in the west-central part of the quadrangle. Thunder Mountain and Camp Douglas are within an area of exposure where a 1-2 km-thick continuous section is present. The formation has been divided into three informal map units in the quadrangle; a lower volcaniclastic unit, a middle volcanic unit and an upper conglomerate and sandstone unit. The volcaniclastic and flow rocks indicate the presence of a complex volcanic pile in the early Mesozoic.

The lower unit of the Gold Range Formation consists of sedimentary breccias, and volcaniclastic sandstones, siltstones, and conglomerates. Bedding in the unit ranges from good to poor, and in some outcrop areas, no definite bedding features can be distinguished. Many of the rocks of the lower member are gray-weathering, dense, black, fine-grained rocks which in thin-section consist of a fine mass of partly recrystallized quartz, plagioclase, sanidine? and biotite (now chlorite). These rocks appear to be reworked or water-laid tuffs. Interbedded rocks are primarily poorly sorted epiclastic volcanic- and chert-pebble mudstones, sandstones, conglomerates and breccias. The chert fragments are commonly gray- or reddish-colored, and may have been derived from chert beds in the Mina Formation. Volcanic fragments in the conglomerates are usually finely-crystalline felsic to intermediate rocks of flow or ash-flow origin. Some units in the lower part of the Gold Range Formation are probably of ash-flow origin, and appear to be mostly lithic and vitric tuffs; after alteration and recrystallication, they are difficult to distinguish from epiclastic and reworked pyroclastic deposits. The lower part of the Gold Range Formation has been extensively affected by thermal metamorphism in the northwestern part of the quadrangle. Clots and irregular patches of garnet and epidote are the most obvious effects, although the rocks are also more recrystallized and contain more sericite in this area. Most of the rocks are altered to hornfels. The area of strong garnet-epidote alteration is shown by a pattern in the Gold Range Formation on the geologic map.

The middle unit of the formation is well exposed in a synclinal nose that is centered on Thunder Mountain. It is often more massive and more of a cliff-former than the upper and lower units, and consists predominantly of grayish purple to light bluish gray welded tuffs and a few obvious flow rocks. The composition of the volcanic middle member is predominantly quartz latitic to rhyodacitic. Lesser amounts of rhyolite and andesite flows are also present, and thin sedimentary interbeds of volcaniclastic sandstone are present locally. A small outcrop in S25,T6N,R33E has also been tentatively included in the middle unit, as it appears to be somewhat similar to the middle unit or Thunder Mountain.

There, plagioclase phenocrysts up to 2.5 by 5 cm occur locally in felsic flow(?) or hypabyssal intrusive(?) rocks.

Although the rocks of the middle volcanic unit have been somewhat metamorphosed, certain textural features are often visible in outcrop or thin section. Pilotaxitic textures are visible in andesites, and compaction foliation and shard and pumice outlines can sometimes be seen in quartz latite welded tuffs. These tuffs commonly have large, (2-4 mm) phenocrysts of quartz and feldspar. The original mafic minerals have usually been altered to epidote, chlorite, or other metamorphic minerals. Flow banding can be seen in some rhyolitic units near the top of the volcanic unit, although the majority of the felsic volcanic rocks are probably welded tuffs. The middle unit is 500-700 m thick.

The upper unit of the Gold Range Formation is present in the quadrangle only on the top of Thunder Mountain and in the vicinity of Camp Douglas. It is a well-bedded sequence of dark-colored conglomerates, pebbly-sandstones, and siltstones. The pebbles are predominantly gray, light green, brown or black chert with lesser amounts of volcanic rock fragments, while sand grains are often chert and quartz. Plagioclase is a common minor sand-size constituent, and detrital biotite can sometimes be recognized. The conglomerate pebbles average 2 mm-2 cm in diameter (with some up to 9 cm) and are sub-angular to subrounded. Silica is the cementing agent for most of the sandstones and conglomerates. A few scour-and-fill structures were seen, but they are rare. No fossils were noted in the unit, although a sample of silicified wood in float at one locality probably came from the upper part of the Gold Range Formation. Only 100-200 m of the upper unit of the formation is present on Thunder Mountain, and no overlying units are present in the quadrangle.

The lower and middle units of the Gold Range Formation in the vicinity are overlain with angular unconformity by Tertiary andesite flows. The relationship of the Gold Range to the Dunlap(?) Formation exposed to the north is unknown, as the intervening area is covered by Tertiary andesite. The base of the formation is a thrust fault in Silver Dyke Canyon; however, an apparently unconformable contact with the underlying Mina Formation is present about 3 km to the west of the canyon. The geologic relations there are not completely clear, however, and the contact could be a fault.

The Gold Range contains subaerial units, such as ash-flow tuffs, and the sedimentary beds do not appear to be marine. It would seem that at least most of the formation in the Camp Douglas Quadrangle was deposited subaerially.

When Speed (1977a) redefined the Gold Range Formation, he tentatively assigned a Triassic to Lower Jurassic age to it, based in part on fossil evidence from rocks which he believed were correlative in the Pilot Mountains. However, an Rb-Sr age date of 103 ± 5.7 m.y. was later obtained from volcanic rocks of the Gold Range Formation on Thunder Mountain in the Camp Douglas Quadrangle and that is believed to be the age of extrusion (Speed and Kistler, in press). According to R. W. Kistler and R. C. Speed (oral communication, 1978) a 6-point whole rock Rb-Sr isochron yielded the above age date from 6 samples collected at two localities on Thunder Mountain. These localities are: NW/4 SE/4 SW/4 S33,T6N,R34E and unsurveyed (projected from the north and east), NE/4 NW/4 NE/4 and NW/4 NE/4 NW/4 S3,T5N,R34E. Thus it appears that at least part of the Gold Range Formation is mid-Cretaceous (Albian, van Hinte, 1976), in age although older rocks might be present in the formation, separated from the dated section by unrecognized faults or unconformities. The only known potential correlatives at the present time are volcanic rocks found in the central Sierra Nevada in California.

DUNLAP(?) FORMATION

The Dunlap Formation was named by Muller and Ferguson (1936) for exposures in Dunlap Canyon in the Pilot Mountains about 10 km east of the Camp Douglas Quadrangle. In west central Nevada, the Dunlap Formation is highly variable in lithology between and within mountain ranges (Ross, 1961, p. 26), and consists of quartz sandstones, chert-pebble conglomerates, andesite breccias and flows, andesitic volcaniclastic sedimentary rocks, siltstones, and minor limestones. Many of the clastic units are prominently colored red by iron oxide minerals. The rocks are believed to have been deposited in alluvial fans which extended into the marine environment (Stanley, 1971). It has been suggested (Stanley, 1971) that the Dunlap intertongues with the underlying Sunrise Formation, which is mainly marine limestones and mudstones. The age of the Dunlap Formation is Lower Jurassic (Pliensbachian and Lower Toarcian), based on pelecypods and ammonites found within it.

Rocks tentatively assigned to the Dunlap(?) Formation in the Camp Douglas Quadrangle crop out only in the northwest part of the area, in S17 and 20,T6N, R34E. The outcrops here are small inliers surrounded by Tertiary andesite and old Quaternary gravel. The rocks consist of chert- and andesite-pebble conglomerate, epiclastic volcanic sandstone and pebbly siltstones, feldspathic sandstone, and minor fossiliferous limestone. With the exception of the limestone, which is yellowish gray, the predominant color of the rocks is moderate red to grayish red or grayish red purple. No definite flow rocks were noted, although small amounts may be present. Pebbles and cobbles of intermediate volcanic rocks or chert may predominate in a particular unit. Sandstone interbeds usually are feldspathic and contain some chert or andesite pebbles. Bedding and sorting are usually poor, and the pebbles are often sub-angular. Epiclastic andesitic sandstones are usually distinctive, as the plagioclase grains appear as distinct white grains in a reddish matrix.

The limestone beds contain a large amount of poorly preserved fossil hash, including possible brachiopod fragments. Limestone pebble conglomerates are exposed just north of the quadrangle border, and lenses of limestone are present a few km to the north of the quadrangle, in a more extensive outcrop area of Dunlap(?). Stanley (1971, figs., 2, 5) included these rocks in the Dunlap Formation, but the assignment of them to that formation is queried here, because of their poorly understood age and stratigraphic relations to the Dunlap(?). Muller and Ferguson (1939) report an Early Jurassic (Pliensbachian) pelecypod, *Plicatostylus gregarius* and an Early Jurassic (Lower Toarcian) ammonite, *Harpoceras sp.* from the Dunlap(?) Formation in an unspecified area of Garfield Hills to the north of the quadrangle. These zones would fall in the 176-183 m.y. range, according to a recent revision of the Jurassic time scale (van Hinte, 1976).

PERMIAN ROCKS

MINA FORMATION

The Mina Formation was named by Speed (1977a), who designated lower Douglas Canyon in the northeast corner of the Camp Douglas Quadrangle as the type area. The base of the formation is nowhere exposed, and a probable angular unconformity with the overlying Gold Range Formation is reported by Speed. Where stratigraphic tops can be determined from graded bedding, the azimuth, dip, and the stratigraphic up direction of individual beds may vary greatly between outcrops a few tens to hundreds of meters apart. Isoclinal folding and/or thrust faulting must be present in these rocks, and therefore, no true stratigraphic thickness can be determined. Speed (1977a) suggests that the formation is 1 km or more thick.

In addition to the exposures in the type area, the Mina Formation crops out over approximately 15 km^2 of the southwestern part of the quadrangle. In this area, in the vicinity of Silver Dyke Canyon, the Mina Formation has been thrust over part of the Gold Range Formation. Approximately 3 km to the southwest of the thrust fault in Silver Dyke Canyon, an apparently unconformable contact between the Mina and Gold Range Formations is exposed. Attitudes in the Gold Range there indicate that the contact may be overturned or vertical.

The Mina Formation consists of interbedded, massive- to well-bedded feldspathic graywackes, chert and siltstones. The graywackes often show features indicative of deposition from turbidity currents. Normal gradded bedding is quite common, and is often useful for determining the stratigraphic up direction; in addition, poor sorting, lithic clasts of mafic volcanic rocks and feldspathic mudstone, plane lamination, and convolute lamination are present. A number of the dark colored, more massive units resemble mafic igneous rocks, from which they were no doubt derived. The igneous rock fragments are usually andesites and dacites, similar in composition to the feldspathic graywackes in which they are included. Sand grains are commonly in the medium to coarse sand size range, although single turbidite units may grade upward into feldspathic siltstones. The graywackes commonly consist of approximately one-third silt-size, recrystallized matrix; the sand-size portion contains plagioclase, hornblende, pyroxene, quartz and lithic fragments, in order of decreasing abundance. Plagioclase may make up over 60% of the rock, hornblende and minor pyroxene approximately 10%, and quartz and rock fragments 1-3%, and the remainder a fine matrix, which may consist in part of silt-size plagioclase. Individual turbidite beds range from approximately 1 cm to several meters in thickness.

Siltstone units are gray to olive and reddish-brown rocks which consist of interbedded feldspathic and quartzose units, some of which show features indicating deposition by turbidity currents. Many of the siltstones are silicified, and are interbedded with more massively bedded, gray to reddish-brown cherts. A thick sequence of cherts with minor interbedded turbidities is present about 1 km south of Douglas Canyon. Dark silicified siltstones and cherts are also present in Silver Dyke Canyon. The massive and graded feldspathic graywackes are best exposed just north of Douglas Canyon and in the southwest part of the quadrangle.

Speed (1977a) suggests that the probable depositional site was proximal to the source of the sediment and was probably a subsea fan. The volcanic composition of the graywackes and included clasts indicates a volcanic source which was apparently an andesitic island arc. The volcanic rocks of this island area may be represented by the apparently contemporaneous Black Dyke Formation described below.

The age of at least part of the Mina Formation is Permian on the basis of K-Ar dating and fossil evidence (Speed, 1977a). K-Ar ages of detrital hornblende believed to be essentially equivalent in age to the enclosing turbidites indicate a minimum age of 255 m.y.; also, poorly preserved fusulinids from near the Moho Mine at the southwest corner of the quadrangle are suggestive of <u>Schwagerina</u> sp., an early Permian form (Speed, 1977a).

BLACK DYKE(?) FORMATION

The Black Dyke Formation was named by Speed (1977a), who designated the type area as Black Dyke Mountain, approximately 8 km to the north of the Camp Douglas Quadrangle. It consists there of mafic volcanic breccia together with minor intervals of related volcanogenic sedimentary rocks, lava flows, and mafic intrusive rocks. It is also present in the central Excelsior Mountains just north of Marietta, about 5 km west of the Camp Douglas Quadrangle (Speed, 1977a).

In the Camp Douglas Quadrangle, only one small outcrop area of approximately 0.25 km^2 in the southwest corner of the map area has been tentatively assigned to the Black Dyke Formation. The exposures of Black Dyke(?) Formation extend only a short distance to the south of the quadrangle boundary before being cut off by biotite quartz monzonite. Both the Black Dyke(?) and the quartz monzonite are overlain in the vicinity, by Tertiary andesite laharic deposits and Quaternary older gravels. Similar rocks, included in the Black Dyke Formation by Speed (1977a) near Marietta, are only 6 km to the east of this exposure in the Camp Douglas Quadrangle.

Samples of Black Dyke(?) Formation from the Camp Douglas Quadrangle show that the unit consists of mafic volcanic rocks and minor epiclastic graywackes derived from them. The mafic volcanic rocks are essentially andesite flow(?) breccias consisting of dark gray to dark greenish gray rocks composed mainly of pyroxene, hornblende, and plagioclase phenocrysts in a dark, fine-grained matrix of chlorite and plagioclase. Accessory magnetite is common, making most hand samples noticeably magnetic. The color index of the volcanic rocks is usually 30 to 40, and their texture ranges from aphanatic to porphyritic phaneritic. Some breccia fragments contain plagioclase and hornblende phenocrysts up to 2 cm, although a phenocryst size of 3-4 mm is more common. Fragments of quartz-bearing dacite are rare, but present. The interbedded graywacke units are quite similar to many graywackes in the Mina Formation. They consist of sand-sized grains of plagioclase, pyroxene, and hornblende in a silt-sized matrix; some beds show graded bedding and plane lamination, features which were probably produced during turbidity-current deposition. Determinations of the stratigraphic up direction appear to vary greatly within short distances, similar to variations found in the Mina Formation. This structural complexity in the Mina and Black Dyke Formations is probably related to tectonic transport in the late Paleozoic or early Mesozoic (Speed, 1977a, 1977b).

Speed (1977a) suggests that the source of the volcanic rocks and clasts in the Black Dyke Formation was an andesitic volcano or volcanic complex associated with a volcanic arc in a marine environment. The interbedded turbidites indicate that at least part of the formation was deposited below wave base, although not necessarily at great depth.

The Black Dyke Formation has been age dated (Speed and Armstrong, 1971) by potassium-argon methods as Permian both at the type area (252$\pm$3 m.y., 253$\pm$3 m.y.) and in the central Excelsior Mountains 5 km west of the Camp Douglas Quadrangle (253$\pm$3 m.y., 218$\pm$3 m.y.). The concordance of three of the four dates indicates a probable minimum age of 253 m.y. for the formation, which is essentially equivalent to the age of the Mina Formation.

STRUCTURAL GEOLOGY

The Camp Douglas Quadrangle lies at the northeastern end of the Excelsior Mountains, an east- to southeast-trending range whose form is controlled by high-angle faults of similar trend. The Excelsior Mountains, with adjacent ranges to the north and south, comprise a structurally anomalous zone of east- to southeast-trending faults which is surrounded by the more typical north- to northwest-trending faults common to the Basin and Range in extreme western Nevada. This area has been called the Mono Basin-Excelsior Mountains structural zone (Gilbert and Reynolds, 1973; Shaw, 1965).

The quadrangle lies just to the west of a major tectonic zone, the Walker Lane (Locke and others, 1940), which is believed to have a combined right lateral displacement of 20-40 km along several northwest-trending fault strands (Nielson, 1965; Hardyman and others, 1975).

Pre-Tertiary folds and faults in the late Paleozoic and Mesozoic rocks of this part of Nevada represent several periods of deformation. Because the age of the rocks affected is not always well known, regional interpretations of the pre-Tertiary structural history are difficult to make. More detailed mapping is needed in this part of the State to clearly define the pre-Tertiary tectonism of the region. Recent interpretations (Speed, 1977b; Rogers and others, 1974) of the structural history of the region have emphasized plate-tectonic models, especially the closing of behind-the-arc basins, to explain folds and thrust faults in late Paleozoic and Mesozoic rocks.

FOLDS AND THRUST FAULTS

The oldest deformation in the quadrangle is apparently recorded only in the Mina and Black Dyke(?) Formations. In these rocks, the stratigraphic up direction often changes radically from outcrop to outcrop, even in essentially homoclinal sequences; often, most of the beds are overturned. This deformation is apparently due to either isoclinal folding or multiple thrust faulting. The Gold Range Formation is not similarly deformed, indicating that this deformation is pre-Gold Range, and is probably Triassic or Permian in age. The Mina Formation is believed to be allochthonous, and was strongly folded and probably thrust to its present site before the deposition of the Gold Range Formation (Speed, 1977a).

A younger period of deformation is represented by several folds and a thrust fault involving the Gold Range Formation. An antiform and adjacent synform exposed near the mouth of Silver Dyke Canyon are in the upper plate of a thrust fault that has emplaced Mina Formation over the Gold Range Formation. The axes of these folds are generally north-trending, are slightly overturned to the west, and plunge about 45 degrees to the south. An upright syncline is present in the Gold Range Formation on Thunder Mountain. Beds on the limbs of this syncline have dips of up to 90°, and the axis trends northerly and plunges to the north at approximately 40°. This axial trend is essentially parallel to the folds in the upper plate of the thrust in Silver Dyke Canyon, and the trend may be related to the direction of motion on the thrust. The amount of displacement due to the thrust fault is not known. This thrust faulting is younger than the lower part of the Gold Range Formation, and if this lower part is mid-Cretaceous, as the volcanic unit is, then the deformation is younger than approximately 100 m.y.

DETACHMENT FAULTS

Several low-angle faults cut Tertiary andesite units and Permian Mina Formation about 1.5 km south of Douglas Canyon. A minor east-west-trending synform in the Mina Formation is present just to the north of the area of faults, and might be somehow related. These faults generally parallel the Tertiary-Mina Formation contact, are filled with light to medium gray, coarsely crystalline calcite and brecciated wall rock, but are otherwise unmineralized. The calcite veins along the faults are up to 5 m wide, and the dip of the faults is generally 25°-35° (rarely 50°-70°) to the south. A geochemical sample of the calcite gave no anomalous base of precious metal values. The low-angle faults often preserve small areas of older Tertiary rocks under upper-plate Mina Formation. For example, a small outcrop of Tertiary conglomerate (Tcg), unknown elsewhere in the quadrangle, is separated from the Mina Formation on both the north and south, by calcite-filled, low-angle faults. The mechanism of formation of these fualts is not known, but it appears that displacement is not large. The large, open spaces which are filled by later calcite probably indicate a relatively shallow depth during the faulting. Since rocks as young as 16 m.y. are cut by these faults, the age of faulting must be somewhat younger than that. Hardyman and others (1975) have described low-angle detachment faults in Tertiary rocks of the Gillis and Gabbs Valley Ranges 30 km to the north. They believe that the mechanism producing these faults is intimately associated with the strike-slip faulting along the Walker Lane. A similar relationship might also exist in the Camp Douglas quadrangle.

A thin unit of silicified pyroclastic and tuffaceous sedimentary rocks exposed in the east-central part of the quadrangle apparently slid eastward from a higher elevation, in the Thunder Mountain area, to its present position overlying Permian Mina Formation and Tertiary hornblende andesite. This unit is highly altered, but may be correlative with the older ash-flow tuffs exposed in the quadrangle. The age of the proposed sliding is not known, but must be younger than the hornblende andesite (about 20(?) m.y.) and older than high-angle faults which cut the block. The amount of movement is probably 1-2 km. The largest outcrop of the silicified pyroclastic and tuffaceous sedimentary rocks, when viewed from a distance, has a jumbled surface appearance reminiscent of landslide blocks. In addition, low-angle gouge zones (detachment faults are present at the basal contact along the south edge of exposure. Several smaller blocks in this area have a more obvious slide origin, and could have separated from the main slide mass as it came to rest.

HIGH-ANGLE FAULTS

As mentioned previously, the Camp Douglas Quadrangle is in an area of east-west trending, high-angle faults. This trend is anomalous with respect to northerly-trending Basin-and-Range faults of the surrounding region. Many of the high-angle faults in the quadrangle strike east-west, although a few strike north and northwest. Strike-slip or oblique slip movement has been suggested for a number of these east-west faults (Gilbert and Reynolds, 1973; Ekren and others, 1976; Shaw, 1965; Speed and Cogbill, 1979a), and left-lateral movement was reported on an east-west 1934 earthquake fault north of Marietta, 10 km west of the quadrangle (Callaghan and Gianella, 1935). The major high-angle faults in the quadrangle are described below in sequence from north to south.

In the vicinity of Douglas Canyon, several east-west faults cut rocks as young as the Tuff of Belleville (22 m.y.). Speed and Cogbill (1979a) report left-oblique slip, as indicated by fault striae, on one of these faults. They state that the strike-slip component is approximately twice the dip slip.

A number of generally easterly-trending faults are also present in the vicinity of Camp Douglas; a quartz-adularia vein along one of these faults was dated at about 15 m.y. (Silberman and others, 1957a). Also, a linear latite dike and associated alteration zone which is subparallel to the main Camp Douglas vein is present several kilometers east of Camp Douglas. The faults and veins of the Camp Douglas mining area generally have dips of 50°-70°, either north or south; veins having dips of 35°-40° were observed near the Grassi Mine in the western part of the Camp Douglas District; oblique-slip is indicated by low rake angles of slickensides on some of these fault surfaces. Also, there is an apparent left separation of at least 0.7 km along the main Camp Douglas fault, and Speed and Cogbill (1979a) report that striae on the fault surface indicate left-oblique slip, with strike movement of 2-5 times dip slip. However, some faults, such as the one east of the Bounce Mine, have slickensides which rake approximately 75°NW, indicating that there, at least, the last movement was predominantly dip-slip.

The Silver Dyke Vein follows a major N60°W fault which is over 6 km long. This fault is high-angle, and dips both to the northeast and southwest along its length. It is somewhat sinuous, and splays into several more obscure faults at its southern end. Adularia from the vein has been dated at approximately 17 m.y. (Morton and others, 1977). An apparent left separation of about 1 km is indicated by displacement of the diorite-Gold Range Formation contact. Smaller left separations are indicated by other offset features. The fault separates into two or more strands in a few places, and the vein material filling the fault zone is up to 60 m wide locally. Evidence of relative movement, as estimated from slickensides, is somewhat conflicting. The slickensides observed in a near vertical portion of the southern end of the Silver Dyke Fault on an eastward-trending splay, indicate left oblique slip in part, having rake angles of 20°-35° E-SE, and 65°W. However, slickensides in the middle and northern part of the fault rake near 90°, indicating dip-slip movement. The amount of vertical displacement here is not known.

A number of major, high-angle faults cut Tertiary hornblende andesite and older rocks in the western part of the quadrangle. Although their strikes vary, the longer faults generally trend east-west. At least one fault in this area appears to cut Tertiary ash-flow tuffs, but does not displace hornblende andesite which overlies it. Presumably therefore, some faulting is older than the hornblende andesite. No obvious features indicating horizontal offset were observed. However, a major east-west fault (at approximately 38°18') lies along a line of disrupted stream drainage, photo lineaments, and faults (L. Garside, unpublished mapping) extending 10 km west of the quadrangle to a fault near the Endowment Mine in the Marietta Mining District which had left-oblique slip during a 1934 earthquake (Callaghan and Gianella, 1935).

A major east-west fault is also present near the south border of the quadrangle, where it cuts Quaternary alluvial fan deposits. This fault is a part of a major fault zone which forms the boundary of the Excelsior Mountains, and is probably essentially continuous with a northeast-trending fault along the north side of Huntoon Valley, 25 km to the southwest. Speed and Cogbill (1979a) report that measurements of striae on a bedrock scarp of this fault indicate it is oblique-slip, with the strike-slip component approximately 3 times the dip-slip. Based on this measurement, and an estimated southerly throw of over 300 m in the past 15 m.y., they estimate left-lateral offset of a kilometer or more.

MINERAL DEPOSITS

Hydrothermal alteration and mineral deposits and occurrences are quite widespread in the quadrangle, ranging in age from Mesozoic to Tertiary. The deposits have been described by a number of authors, and the following discussion combines that published information with unpublished data and information collected during this study. A complete study of the ore deposits of the quadrangle was not attempted during the quadrangle mapping.

Mines and propsects in the area are normally included within the Gold Range Mining District, which is usually considered to include the Camp Douglas and Silver Dyke mining areas. The Gold Range Mining District has been included in the Silver Star District, which may include the mines in the vicinity of Marietta. Production figures for these districts are often intermingled. Mineralized veins, areas of hydrothermal alteration and silication are generalized on the map and described more fully below, generally from north to south.

DOUGLAS CANYON

A number of small prospects are present in the Mina Formation in the vicinity of Douglas Canyon. The workings are usually pits or short adits, and they generally explore narrow (30-60 cm), milky quartz veins, although several barite veins are also present (Tafuri, 1973, p. 39-40; Archbold, 1966, p. 18). The quartz veins are generally east- and northeast-trending, and a few select samples contain up to 10 oz/ton Ag and several thousand parts per billion Hg. The barite veins contain white barite with included wallrock fragments, usually average about 30 cm in width, and are less than 100 m long. Also stibnite is present in a quartz vein at the Antimony Blossom prospect in S14,T6N,R34E, approximately 300 m north of the quadrangle boundary (Lawrence, 1963).

EAST OF GARFIELD FLAT

A few small prospects are present just east of Garfield Flat and south of the main county road. These prospect pits are along a few 12-15 cm quartz veins which contain minor iron- and copper-oxide minerals. The veins are found only in the Dunlap(?) Formation, and may be older than the overlying Tertiary hornblende andesite, indicating a different period of mineralization from that at Camp Douglas and Silver Dyke.

CAMP DOUGLAS MINING AREA

Veins carrying gold and silver were discovered in 1893, and mining activity centered on the Camp Douglas area between 1893 and 1903 (Vanderburg, 1937), and continued through the 1930's. Production is believed to be about $2 million, mainly in gold (Ferguson and others, 1954). The workings consist of numerous shafts and horizontal workings, generally less than 120 m deep. The main mineralization is associated with a nearly 3 km long, N85°W, 40-70°SW, branching quartz vein in the Gold Range Formation, and numerous, steeply inclined, subparallel veins located just to the north of the main vein. Northerly-trending silicified and sericitized zones and spotty quartz veins apparently with free gold (Hill, 1915), occur in Tertiary andesite 1.5 km to the northeast of Camp Douglas. The main east-west system of veins and faults appears to extend from the Camp Douglas area southeast to the east edge of the quadrangle along a linear zone of alteration and latite-dike intrusion.

The veins at Camp Douglas, in the central and most productive part of the district, consist of sugary, white quartz with some comb and cockade structure. Finely crystalline adularia is apparent in thin-sections and on slabs stained (with sodium coblatinitrite solution) to detect potassium feldspar. Iron-staining is present locally, and a platy or lamellar structure in the vein quartz, apparently a cleavage-plane replacement of calcite, is present in many areas. Except for minor pyrite, no sulfide minerals were noted in the central part of the district. The values were mainly in gold and silver (Vanderburg, 1937), and free gold and pyrite are the principal metallic constituents, although a little scheelite has been reported from the deeper levels of one mine (Ferguson and others, 1954). The veins are generally well-defined, and 2-5 m wide.

In the vicinity of the Grassi Mine, at the western end of the district, the quartz-adularia veins contain minor amounts of pyrite, chalcopyrite, galena, and tetrahedrite, as well as oxidation products of these minerals. At the eastern end of the district, stibnite is present at the Kernic Mine in a quartz vein with reported gold values (Lawrence, 1963). And near the eastern edge of the quadrangle, a zone of silicification and argillization (quartz, montmorillonite, kaolinite, illite, jarosite, and gypsum) in a southeast-trending latite dike, the surrounding hornblende andesite, and pyroclastic and sedimentary rocks, may be the continuation of alteration and mineralization at Camp Douglas. Papke (1970) and Archbold (1966) have described the Sodaville montmorillonite deposit, which is located at the southeastern end of this altered zone. It has produced over 25,000 tons of bentonite, mostly before the early 1930's.

The age of the Camp Douglas veins is approximately 15.4 m.y. (Garside and Silberman, 1978; Silberman and others, 1975) based on a K-Ar age determination on adularia from a quartz vein in the central part of the Camp Douglas District. This age is similar to that of much of the andesitic volcanism of this area, and a genetic relationship may be indicated. In the vicinity of the Gem and Maryann Mines, it appears that a thin laharic(?) unit of the biotite-hornblende andesite overlies the veins, suggesting that the veins are older than part of the biotite-hornblende andesite. The evidence, however, is not conclusive.

SILICATED GOLD RANGE FORMATION, PEPPER SPRING AREA

Rocks of the lower unit of the Gold Range Formation are erratically silicated in an area between Pepper Spring and the Grassi Mine. The silicated rocks contain quartz, garnet, epidote, and minor tremolite. This silication may be related to an unexposed pre-Tertiary(?) intrusion. A few minor occurrences of copper-oxide minerals in fractures are present locally in the Gold Range Formation in this area.

SILVER DYKE VEIN SYSTEM

Tungsten was discovered in 1916 along the Silver Dyke Vein on claims originally located for silver (Vanderburg, 1937). Several thousand feet of workings on several levels are present, which are mainly accessible from adits. In Silver Dyke Canyon mining was continued to depths of over 150 m. A few workings are also present at Tungsten Dyke, near the north end of the vein. Production of tungsten is estimated to be about 50,000 units (450,000 kg) of WO_3. The total value of production, mainly tungsten, is approximately $1.5 million (Muller and others, 1954), mostly before 1938. The ore mined reportedly averaged about 1% WO_3, with local values up to several percent.

The Silver Dyke vein trends N60°W, and is about 6 km long. It is steeply inclined (70°-90°), and contains fine-grained, white quartz with comb and cockade structure near the surface, becoming more massive at depth. Platy or lamellar quartz is present, apparently as a cleavage-plane replacement of calcite, similar to that noted at Camp Douglas. The vein is at least 60 m wide in some areas, but is generally 5-10 km. Propylitic alteration is present in hornblende andesite for a considerable distance west of the vein, which cuts the Gold Range Formation, diorite, and Tertiary volcanic rocks, and may have had left-oblique slip along the zone.

The vein material consists of inclusion-filled, quartz, finely crystalline adularia, scheelite (some containing molybdenum), and, according to Sigurdson (1974b), albite, pyrite, chalcopyrite and the Au-Ag tellurides hessite and petzite. Free gold is also reported (Muller and others, 1954). Precious metal values in a few ore shoots are up to 100 oz/ton Ag and 1 oz/ton Au; a rough average of some unpublished values indicates an Ag:Au ratio of about 200:1. Supergene oxidation, producing iron- and manganese-oxide minerals, gypsum, and kaolinite, has extended to depths of at least 130 m along certain zones. Fluid inclusion homogenization studies (Sigurdson, 1974a, b) indicate the crystallization temperature of the main phase of tungsten mineralization at Silver Dyke was slightly over 300°C. Adularia from quartz vein material in the Silver Dyke Mine area gave a K-Ar age of 17.3 ± 0.2 m.y., about 2 m.y. older than the Camp Douglas vein age (Garside and Silberman, 1978; Morton and others, 1977). Kerr (1936, p. 47) suggests that some of the Silver Dyke veins may be older than the hornblende andesite, although some clearly cut it.

Several short northeast-trending veins about 1 km northeast of the Silver Dyke Mine contain sporadic manganese-, copper-, and iron-oxide minerals in dense, vitreous quartz. The relationship of these veins to the Camp Douglas or Silver Dyke vein systems is unknown.

In addition, several narrow veins containing quartz, pink potassium feldspar, pyrite, chalcopyrite, bornite, and molybdenite cut the diorite west of the Silver Dyke vein in the lower adit of the Silver Dyke Mine and along a northwest-trending canyon which intersects Silver Dyke Canyon about 250 m upstream of the old mill and housing area. Quite narrow quartz-eye granite porphyry dikes also cut the diorite in this area, are mineralogically somewhat similar to the quartz-potassium feldspar veinlets, and become more numerous near a larger porphyry mass. This porphyry mass, 0.5 km northwest of the Silver Dyke Mine, should be further investigated for the possible presence of more extensive molybdenum mineralization. Pink potassium feldspar from one of these veinlets present in the lower adit of the Silver Dyke Mine gave a K-Ar age of 75.9 ± 23 m.y. (Garside and Silberman, 1978; Morton and others, 1977). This age should probably be considered a minimum, and clearly indicates an older period of mineralization, possibly associated with the quartz-eye granite porphyry. Molybdenum in scheelite present in the younger veins at Silver Dyke may have been remobilized from those older veins.

SOUTHEASTERN CAMP DOUGLAS QUADRANGLE-MOHO MINE

The Tertiary ash-flow tuffs exposed in the southeast part of the quadrangle are often quite altered to an advanced argillic assemblage of quartz, kaolinite, and pyrophyllite or quartz and a 2M mica. This alteration is predominantly in the rhyolite tuff, the lowest of the Tertiary units. It does not appear to affect the overlying hornblende andesite, suggesting that the alteration is older than that unit.

A few minor quartz veins cut the Mina Formation near the intrusive contact with the biotite quartz monzonite pluton which is exposed at the mountain front 3 km southwest of the mouth of Silver Dyke Canyon. These veins usually consist of dense, vitreous quartz, variable amounts of sericite, and galena, pyrite, chalcopyrite, and specular hematite as well as their oxidized equivalents. Silver is reported in some assays.

The Moho Mine consists of about 1000 m of underground workings along a N30°-45°E altered zone and quartz-vein system about 1200 m long, and is located almost entirely outside the quadrangle, to the west of the southwest corner of the map area. The chief values are free gold with some silver and also lead in the form of cerrusite (Vanderburg, 1937, p. 40-42; Ross, 1961, Table 6.1).

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