LITHOLOGY

QUATERNARY DEPOSITS

Qal Alluvium and eolian sand. This unit crops out only in a 1 km^2 area in the northwest corner of the quadrangle, and consists of eolian deposits (Qsd: coppice) dunes and drift sand. The sand is accumulating on a slightly sloping surface; dune forms include barchan and transverse. The source area is probably Garfield Flat and the alluvial apron to the west of the Flat, suggesting that the prevailing winds are from the southwest.

Landslide deposits. Two small outcrops of landslide material occur in the southeastern corner of Pepper Spring. These deposits are in an area of steep slopes and consist of blocks of rhyolitic and andesitic rock in a sandy silt-clay matrix, of a reddish, earthy matrix. A third landslide block of 0.25km^2 area is present near the southeastern corner of the quadrangle; it is made of very old gravel deposits which have moved a short distance and contain very large andesite breccia. This slide may have been facilitated by uplift and erosion of supporting bedrock along a fault. Other small landslides occur along other small quaternary of landslide material are present about 1.5km west of Silver Dyke Canyon.

Alluvium Alluvium occupies the lower relief areas adjacent to steeper alluvial fan complexes; it consists of poorly sorted gravel, sand and silt deposited from ephemeral streams. On aerial photographs it has a uniform texture and light color in contrast to the alluvial fans.

Alluvial fan deposits. The most extensive Quaternary unit in the quadrangle is this. Most of the large, coalescing fans (Ibajadas) are in the northwest and southeast parts of the quadrangle. Some colluvium is included in the unit, near bedrock outcrops. The fan deposits are poorly-sorted mixtures of silt, sand, and gravel from local sources. The deposits are thickest near the source areas; fan slopes range up to 7° near the mountain front. The alluvial fans adjacent to Soda Springs Valley on the east margin of the quadrangle are somewhat more dissected than those in other areas; this downcutting may be related to recent faulting.

Qsg Older gravel deposits. Older gravel deposits are present only at the north and south edges of the quadrangle. This unit is commonly more calcite-cemented and more dissected than younger alluvial units. The source area for the coarse detritus within the older gravel deposit is not, in most instances, readily identifiable. The older gravel deposits in the northern part of the quadrangle were probably deposited in alluvial fans, rather than along the south margin as on pediments. Usually, they contain a poorly-sorted heterogeneous mixture of boulders, to silt-sized material eroded from the surrounding highlands, but the pediment gravels exposed in Pepper Spring are composed of well-sorted gravel and sand derived from the underlying Tertiary laharic deposits. The absence of fragments of Mina Formation (Fm.) there, for example, probably means that the source area is to the west or lateral offset by the east-trending fault just to the north.

TERTIARY ROCKS

Tcg Tertiary sedimentary rocks. This poorly-exposed unit crops out only in the northwest corner of the quadrangle near the Gold Range Fm. It consists of a section of up to 100m of light-colored volcaniclastic rocks, including tuff, and tuffaceous shale, sandstone, and conglomerate. The sedimentary overlies Mina Fm. in western or upland areas this unit consists mostly of poorly-sorted tuffaceous conglomerate containing boulders, cobbles and pebbles of nearby Tertiary volcanic units, chert (probably from an underlying Mina Fm.), and pink granite (probably eroded from outcrops 7-8km to the northwest). Some tuffaceous sandstone is also present. The more easterly exposures include tuffaceous sandstone with calcareous cement, bentonite shale, and pebble conglomerate. Glassy, coarse ash is present in some sandstones.

Both fluviatile and lacustrine environments appear to be represented in this unit. Intraformational conglomerates may represent a stream channel, while the well-bedded tuffaceous sandstones and silty mudstones represent deposits far the margin of a lake. Marvin and others (1977) report a K-Ar age of 5.7±0.2 $m.y._{(1)}$ for a tuffaceous sandstone in sec. 6,T.6N.,R.34E. However, they suggest this age may be a maximum, as contamination with younger material is considered a possibility.

Tbt Biotite-hornblende andesite. This unit is the youngest of a group of dark-colored lava flows, sills, and hypabyssal intrusive rocks, probably from an andesitic stratovolcano located just south of the area of the Excelsior Mts. 7km to the west; it is mainly exposed in the northern part of the quadrangle, and is intermediate between the dominantly laharic breccias of similar lithology. A hypabyssal intrusive phase is also present, especially in Sec.5,T.5N.,R.34E.

The unit unconformably overlies a great variety of older rocks. Locally, it is exposed at the contact of the 100m thick, and consists of numerous light gray, or less commonly, reddish-brown or darker gray flows which are difficult to tell apart; it is usually easily distinguished from underlying rock flows.

The unit consists of 5-25% phenocrysts, mainly equant (0.5-6mm) plagioclase and elongate (up to 1cm) hornblende, in a pilotaxitic matrix. Brown flakes of biotite (0.2-2mm) are sparse, but usually serve to distinguish this andesite unit from the older, darker colored hornblende andesite. The groundmass consists of microlites of the phenocryst minerals, in addition to K-feldspar, glass, magnetite, and apatite.

The unit was K-Ar dated as 15.7±0.5 and 16.1±0.7$m.y._{(2)}$ on biotite and hornblende, respectively, from a sample (Sp-33) collected in NW/4 sec.16,T6R,R34E (Garside & Silberman, 1978). This 16$m.y._{(2)}$ andesite is the youngest dated lava flow or intrusive rock exposed in western Nevada (Evernden & others, 1975). The dated sample gave a whole rock analysis of: SiO_2=58.6%, Al_2O_3=16.2%, Fe_2O_3=4.0%, FeO=1.1%, MgO=1.7%, CaO=5.6%, Na$_2$O=3.3%, K$_2$O=2.8%, H$_2$O+=0.40%, H_2O-=0.16%, TiO_2=0.7%, P_2O_5=0.4%, MnO=0.09%, CO_2=0.05%, S=0.09%.

Tbp Rhyolite porphyry dikes. Two yellowish-gray rhyolite dikes cut micromonzonite 1.7km east of Silver Dyke Canyon. The dikes are approximately 1.5km long, 2.2m wide, trend N60°E and are vertical. The longer is along a major east-west fault. The dikes contain 10-20% phenocrysts, 2-3% biotite, plagioclase 30%, K-feldspar 20%, and biotite 1%) in a finely crystalline groundmass.

Tmp Micromonzonite porphyry (11.1 km^2) micromonzonite stocks intrude Mina Fm., and have been mapped in the Gold Range Fm. and in the Tertiary ash-flow tuffs. Age and contact-relations between the micromonzonite and Tertiary volcanic rocks are unclear. The micromonzonite intrusive body also cuts a Mesozoic? thrust fault and is emplaced in the nose of the fault which forms the thrust. The intrusive mass is porphyritic, with plagioclase and pyroxene phenocrysts in a fine-grained groundmass of K-feldspar, plagioclase, and biotite. Hornblende-plagioclase porphyry dikes cut and extend out from the main micromonzonite mass. Most of the micromonzonite is greenish-gray, although border and dike phases are usually light gray.

The phenerictic micromonzonite contains 50% plagioclase, 35% K-feldspar, 10% pyroxene, 2% biotite, 1% biotite, and accessory magnetite (up to 5%), apatite and zircon. Phenocryst sizes are 0.5-2mm and the groundmass is microcrystalline with sparse biotite; pyroxene and hornblende with sparse biotite; and are 25% of the rock. Hornblende is common only in the porphyry phenocrysts up to 1cm long. Some pyroxene phenocrysts appear to be complete replacement of hornblende. Alteration minerals include chlorite, epidote, K-feldspar, calcite, tremolite, and sausurite.

The micromonzonite has been dated at 16.2±0.5m.y. by K-Ar methods (Speed & Kistler, in press). This age is close to that of the andesite lava flows in the Gold Range Fm. and 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.

Tmpl Intrusive breccia. A coarse, sorted sequence of laharic andesitic volcanic breccia is exposed at the south edge of the quadrangle. This unit consists predominantly of light gray clasts of porphyritic flow rock in a matrix of silt- and sand-sized material. Clasts are commonly angular and vary in size from a few cm to more than 1m, and average ~25cm. Locally, crude bedding has been small. Intercalated epiclastic volcanic sandstones and conglomerates are present. These epiclastic beds probably represent the lower part of the Gold Range Fm. similar to the andesitic flow rocks present in the northern part of the quadrangle in further west in the vicinity of Excelsior Range and near Nevada Hwy. 10 to the south. A few clasts are andesitic lava flows similar to those in the Gold Range Fm., but most are rhyolitic. The unit is up to 200m thick in the quadrangle. The total thickness is unknown as the base is not exposed.

The andesitic clasts consist of phenocrysts (up to 2mm in diam.) of plagioclase, hornblende, lesser pyroxene and biotite and accessory magnetite, apatite, and zircon, in a pilotaxitic, partially glassy groundmass containing abundant K-feldspar.

Two km to the south in the quadrangle the laharic deposits overlie mineralogically similar andesite flows which have been dated by K-Ar methods at 21.0±0.7$m.y._{(3)}$ (Marvin & others, 1977). The laharic andesite is overlain by the Quaternary older gravel deposits. Similar relations of gravel and probably equivalent age are present in the Excelsior Range, about 9km to the west.

Tmt Intrusive latite and associated vent breccia. An intrusive, hypabyssal latite intrusive mass (TT) with minor associated breccia (TTv) is exposed in S35 & 36,T6N, R34E. The intrusive cuts latite breccia (which appears to be an associated vent breccia) rhyolite welded tuff, and hornblende andesite; it is unconformably overlain by biotite-hornblende andesite. The latite may be intruded along a structural weakness which is a continuation of the east-trending faults and veins in the Camp Douglas mining district to the west.

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

The least-altered latite intrusive consists of 15% plagioclase and sparse biotite phenocrysts in a glassy matrix. The matrix commonly is devitrified to a fine mixture of cristobalite and K-feldspar, often with a spherulitic texture.

The latite intrusive, latite vent breccia and surrounding hornblende andesite, are strongly silicified and argillized (quartz, montmorillonite, kaolinite, illite, jarosite, and gypsum). Ironstaining and sulfur-oxidation are present locally; pyrite?, often converted to iron oxide, is also present.

A K-Ar age of 18.9±0.8$m.y._{(4)}$ was obtained on plagioclase from glassy latite taken near the northwest end of the intrusive body (Garside & Silberman, 1978).

Tb Hornblende andesite. Hornblende andesite flows (Tb) and a few minor dikes and small, irregular intrusive bodies (Tb) are exposed throughout the quadrangle. The flows underlie the Gold Range Formation and are overlain by Tertiary ash-flow tuffs or by Tertiary volcanic rocks. This unit is more than 100m thick and is various shades of gray, brownish-gray, or pale brown, is non-porphyritic, fine-textured, and often exhibits flow banding. Because it consists of numerous flows, it is somewhat variable, and may be difficult to distinguish from other andesite units. In most areas it is differentiated from the younger biotite-hornblende andesite by its darker color, angular hornblende phenocrysts, absence of biotite, and lower percentage and smaller size of phenocrysts, especially plagioclase. In the easternmost part of the quadrangle certain parts of the unit may resemble rocks included in the biotite-hornblende andesite.

The hornblende andesite is often fine-grained. Phenocrysts of basaltic hornblende, pyroxene, and plagioclase (usually <15% of the rock) are present in a fine-grained groundmass. The pilotaxitic fluidal or less commonly, felted texture. Acicular hornblende phenocrysts are 0.5-2mm in size and may reach 1cm in length. Plagioclase is often absent as phenocrysts, but when present is usually <1mm in diameter. Accessory magnetite and sparse biotite were recognized. Pyroxene phenocrysts are present in several mm in diameter, were observed in a few basal flows in the western part of the quadrangle, and sparse olivine was once in a few of the lowermost flows. Propylitization is common in flows west of the Silver Dyke Fault. Mafic minerals are partially altered to chlorite, epidote, and calcite; plagioclase is slightly altered to sericite and clay minerals. The groundmass of the unit is strongly argillized and silicified in an alteration aureole surrounding the Mina Fm. intrusive.

Some of the hornblende andesite flows are at least 10m.y. old since they are intruded by latite of the age of the Mina Fm. intrusive. Because of the variety of flows in this unit, some may be younger. In the northeast corner of the quadrangle the unit overlies Bellevile Tuff that has a K-Ar age of 22m.y. This most if not all of the hornblende andesite unit is between 19 and 22m.y. old.

Tb Olivine basalt. Gray, olivine basalt is present near the north edge of the quadrangle, occupying a total area of ~2km^2; it lies below the Tertiary andesite units and overlies pre-Tertiary rocks and Mina Fm. and Gold Range Fm. The basal contact is irregular, and basalt may have been originally topographic relief on the surface when it was first erupted. The basalt is often vesicular, and consists of part or scoria and blocks as well as massive flows. It contains abundant olivine phenocrysts in a granular, pilotaxitic, fine-grained matrix of calcic plagioclase, pyroxene, and opaque minerals. Olivine is altered to a pale brown and are rimmed and replaced by iddingsite and altered to serpentine. Small, anhedral grains of native copper are present, possibly as an alteration product of other mafic minerals.

The basalt is exposed in the western part of the overlying Tertiary andesite sequence, and thus is older than 19m.y. A less likely interpretation is that the basalt is younger than the 24m.y.-old flow exposed near Candelaria, 25km to the south (Marvin & others, 1977).

Tg Conglomerate. A small, poorly exposed outcrop of conglomerate was exposed at the extreme southern edge of the quadrangle in sec.3,T.6N,R34E. It is nearly surrounded by Permian Mina Fm., but contains pebbles of Mina Fm. and Tertiary volcanic rocks. The age of this unit is unknown. It consists mainly of subrounded pebbles of hornblende andesite and chert. Within this outcrop, the pebbles are mainly hornblende andesite and subordinate rhyolite (not seen elsewhere) are also present but were not mapped separately. Because of the presence of pebbles of chert, probably derived from the Mina Fm., and hornblende andesite, the conglomerate appears to be a local accumulation at or near the base of the Tertiary section. The outcrop is bound on both the north and south by low-angle, east-west-trending faults of small displacement.

Tbt Belleville Tuff. This unit consists of welded rhyodacite ash-flow tuff (Tbt), and a thin discontinuous rhyolite flow (Tbr) which is exposed in a small area in the northeast corner of the quadrangle. The Belleville Tuff was K-Ar dated at 22.0±0.7$m.y._{(5)}$ (Garside & Silberman, 1978; Cogbill, 1979b), about 5km south of the Camp Douglas quadrangle. Petrographically, it is similar to the Tuff of Metallic City and Permian Mina Fm. The tuff is 10-60m thick, and is strongly compacted and welded; it is thicker in single cooling units and recognized in the mapped area, with vitrophyre locally present at the base.

The basal gravel unit consists of no more than a few m of rounded pebbles in a white, tuffaceous matrix. The clasts are mainly resistant Mina Fm. graywacke and chert and Tertiary tuff, and Mesozoic? intrusive rocks. The matrix was probably derived by erosion from the underlying Metallic City Tuff.

The rhyodacite ash-flow tuff is light gray to pale brown, moderately to densely welded, and has 5-15% phenocrysts, 1-2% lithic fragments, and very sparse mafic minerals and quartz in a devitrified glassy matrix of deformed glass shards and dust. Rare biotite and pyroxene are observed in thin section. The tuff shards are moderately compacted to vapor-phase alteration. The matrix is often devitrified to K-feldspar and quartz, and is locally argillized and silicified. Quartz and areas of former pumice are flattened and stretched. Albite plagioclase phenocrysts are usually 1-3mm in length, and are fractured and broken. Lithic fragments are usually brown andesite or dacite welded tuff.

The age of the Belleville Tuff is 22m.y., based on 2 K-Ar determinations on plagioclase (Marvin & others, 1977; Garside & Silberman, 1978) from samples collected just north of the quadrangle. Stratigraphic relations near Candelaria suggest these ages may be too old for the tuff, because the tuff underlies ash flows dated as old as ~23m.y. (Speed & Cogbill, 1979b). According to Cogbill (1979b), the Belleville Tuff is correlative to present Tvt3, Tvt4, Tvt5, and Tvt6 of Page (1959) at Candelaria, and is present in the Tertiary section in Silver Dyke Canyon.

Tt Metallic City Tuff. This unit is a rhyolite crystal-poor welded tuff which has been mapped in Metallic City in S8, T.3N.,R32E, 15km south of the quadrangle (Speed & Cogbill, 1979b). In the area of the quadrangle it is exposed as erosional remnants, ~20m thick, overlying Mina Fm. and underlying either rhyodacite ash-flow tuff or the Belleville Tuff. The Metallic City Tuff is light gray and contains dark gray lithic fragments (2mm-5cm) and widely scattered crystal pumice (2-5mm), and consists of 20-30% phenocrysts, 10-20% pumice, and 1-2% lithic fragments in a matrix of glass shards and dust. The phenocrysts are often broken and angular and consist of 40% quartz, 50% plagioclase, 5% sanidine, 5% biotite, and rare hornblende. Pumice is poorly to moderately compacted, and usually smaller than 5mm, although rarely 1cm or larger. Shards are moderately compressed. The matrix is glassy to slightly devitrified and spherulitic. Lithic fragments are usually less than 1cm, although larger fragments are present locally.

The Metallic City Tuff exposed in S14,T6N,R34E gave K-Ar ages of 24.2±0.7 (biotite) and 24.8±1.0$m.y._{(6)}$ (plagioclase) (Garside & Silberman, 1978). Marvin and others (1977, sample USGS-Cn-1) report a similar age from the same locality. The Metallic City Tuff correlates with map unit Tvt2 of Page (1959) at Candelaria (Speed & Cogbill, 1979b).

Tvt Tuff of Metallic City. A sequence of 2-3 ash-flow tuffs (Tvt) is exposed as an erosional remnant between Metallic City and rhyodacite ash-flow tuffs in the Excelsior Mts. to the south and west of Thunder Mtn. The uppermost unit, ~30m thick, is a very pale purple to pale brown, densely welded, crystal-poor, compacted pumice (Tc). The crystal tuff generally overlies rhyodacite tuff, but in one locality it is underlain by two dark-colored rocks, suggesting local erosion of the underlying tuffs. An underlying gravel unit (Tctg) present at one locality, is up to 10m thick in local channels in pre-Tertiary rocks, and contains cobbles and boulders (15-30cm) of the older rhyolite tuff as well as 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.

Phenocrysts compose about 20-30% of the crystal tuff, consisting of 40% quartz, 35% K-feldspar, 20% plagioclase, and 5% biotite in a largely devitrified matrix. White, moderately compacted pumice makes up 10-20% of the rock, and sparse lithic fragments up to 1cm may be present.

The crystal tuff is ~27$m.y._1$ old based on a K-Ar date (27.1 ±1.5$m.y._1$) on biotite from a sample collected on Moho Mtn. in the southwest part of the quadrangle (Marvin & others, 1977; sample B-3462). The crystal tuff resembles the Weed Heights Member of the Mickey Pass Tuff of about the same age, named in the Yerington area (Proffett & Proffett, 1976) and present in the Luning NW 7½-minute quadrangle, ~30km to the north (Ekren & Byers, 1978).

Tdr Older andesite. Two small outcrops of andesite up to 25m thick occur in the western part of the quadrangle, lying unconformably below the crystal tuff and above the rhyolite tuff, stratigraphically equivalent to the absent rhyodacite tuff. 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, K-feldspar, pyroxene, and magnetite, and is at least 27m.y. old, as it underlies the crystal tuff; it appears to be nearly equivalent in age to the rhyodacite tuff (not dated).

Trd Rhyodacite ash-flow tuff. A distinctive pale red-purple rhyodacite ash-flow tuff is present in the eastern part of the quadrangle below the crystal tuff and above the rhyolite tuff. This tuff contains 10% small (0.5-1.5mm long), white plagioclase phenocrysts, rare biotite and pyroxene?, and 5-20% strongly compacted pumice in a thoroughly recrystallized matrix containing deformed, recrystallized shards. Sparse lithic fragments (<5mm) of older volcanic rocks are also present and locally are more abundant near the base. Pumice lapilli are strongly compressed disks, up to 2-3mm by 5-7cm. The tuff is commonly hydrothermally altered: plagioclase and other minerals to sericite and minor calcite, pumice to finely crystalline silica, and mafic minerals to iron oxide. It appears to be stratigraphically equivalent to the older andesite, and older than the overlying 27$m.y._1$-old crystal tuff.

Trt Rhyolite tuff. The lowermost Tertiary unit exposed in the western part of the quadrangle is a white to gray, altered, rhyolite ash-flow tuff (Trt), 10-150m thick. The unit also includes a few exposures of an underlying gravel (Trtg) up to 10m thick, which consists of rounded to angular pebbles and cobbles of pre-Tertiary rocks, including Gold Range Fm. and quartz monzonite porphyry. The rhyolite tuff lies with angular unconformity on pre-Tertiary units, and is overlain by rhyodacite tuff. In places, the basal contact appears to have been an irregular erosional surface. In several areas, the younger crystal tuff lies directly on pre-Tertiary basement, indicating the probable local erosional removal of the rhyolite tuff.

This unit consists of 15-20% phenocrysts in a thoroughly altered and recrystallized matrix; the former glass shards show only slight deformation. Phenocrysts consist of 40% quartz, 55% plagioclase and K-feldspar, and 1-4% biotite; quartz phenocrysts are 0.5-2mm in diameter. Feldspars are the same size as quartz, and usually completely replaced by alteration minerals. Pumice (up to several cm) is moderately compacted. Lithic fragments, often from the Gold Range Fm., are normally sparse and small (<1cm), but locally are relatively abundant near the base of the tuff. The rhyolite tuff may be difficult to distinguish from the younger crystal tuff; however, the former is usually altered more, has less biotite and quartz, and contains quartz phenocrysts that are smaller and more angular.

Pervasive alteration in the unit consists of the conversion of feldspar, pumice, and much of the matrix to quartz, kaolinite, pyrophyllite, calcite, and sericite. Biotite is often entirely altered to sericite and iron oxide. Some rocks consist almost entirely of quartz, kaolinite, and pyrophyllite or quartz and 2M mica.

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 part of the Mickey Pass Tuff (the Guild Mine Member?) present several tens of km to the north, but is too altered for any certain correlation.

Tv Silicified pyroclastic and tuffaceous sedimentary rocks. Outcrops of strongly silicified rocks in the east-central part of the quadrangle, which occupy slightly more than 1km^2, have been included in a single map unit, although they are often too altered to permit identification of rock type. They are probable pyroclastic and tuffaceous sedimentary rocks which now consist of more than 95% cryptocrystalline silica. Usually, it is impossible to recognize any original constituents or sedimentary features; however, in a few outcrops, silicified volcaniclastic conglomerate, sandstone, and silicified lapilli tuffs can be tentatively identified. The pebbles appear to be andesite? and dark chert, and "ghosts" of similar pebbles can be seen elsewhere as dark blebs in a pinkish-gray mass of silica. In addition to cryptocrystalline silica, small amounts of K-feldspar, jarosite and hematite are present.

The exact stratigraphic position of this unit of silicified rocks is not known; it is probably younger than the rhyodacite ash-flow Tertiary hornblende andesite as well as Permian Mina Fm. Several smaller outcrop areas appear to be blebs blocks. From a distance, the largest mass of the silicified unit resembles a giant dike block. Low-angle faults are present locally along the basal contacts near the south edge of outcrop. The only possible correlative of the Tertiary rocks is the east-west trending silicified and tuffaceous sedimentary rocks at the base of the lowest Tertiary ash flow tuff in the Gold Range Formation. There is an apparent left separation of at least 0.7km along the main Camp Douglas fault; strike-indicator left-oblique slip, with strike movement of 2.5-1mm dip slip (Speed & Cogbill, 1979a). However, some faults, such as the one east of the Bounce Mine, have gickenedges which rake ~75° NW, indicating that the last movement there was predominantly dip-slip.

The Silver Dyke Vein follows a major N60°W fault which is more than 6km long. This fault is high-angle, separates into two or more strands in a few places, and dips both to the northeast and southwest along its length. It is sinuous, is filled with quartz vein material locally up to 60m wide, and splays into several branches at its southern end. An apparent left separation of about 1km is indicated by displacement of the diorite-Gold Range Fm. contact. Evidence of relative movement is somewhat conflicting. The slickensides near the southern end of the Silver Dyke Fault on an eastward-trending splay, indicate left oblique slip, having rake angles of 20°-35° E to SE, and 65° N. However, slickensides in the middle and northern part of the fault rake near 90°, indicating dip-slip movement.

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. One south fault appears to cut Tertiary andesite, but not the overlying hornblende andesite. No obvious features indicating horizontal offset were observed. The lowest of the Tertiary units, a tuff (at ~38° 18') lies along a line of disrupted stream drainage with abrupt changes in direction. The topographic feature upon which extend 10km west of the quadrangle to a fault near the Endowment Mine in the Mountain Spring Quadrangle, is a left-oblique slip during a 1934 earthquake (Callaghan & Gianella, 1935).

An east-west fault, cutting Quaternary alluvial fan deposits, is also present near the south boundary of the quadrangle. This fault is a part of a major fault zone which forms the south margin of the Excelsior Mts., and is probably an extension of Thunderbolt with a northeast-trending fault along the east side of Huntoon Valley, ~25km to the west (Speed and Cogbill 1979a) report that strike on the south side of the Huntoon Valley fault is with a strike-slip component 3 times the dip-slip; they estimate left-lateral offset of a kilometer.

MINERAL DEPOSITS

Hydrothermal alteration and mineral occurrences are widespread in the quadrangle, ranging in age from Mesozoic to Tertiary. The following discussion supplements published information with unpublished data and information collected during this study. A detailed study was not undertaken.

Mines and prospects in the area are normally included within the Gold Range Mining District, which also includes parts of the adjacent quadrangles. Include the Camp Douglas and Silver Dyke mining areas. The Gold Range Mining District has also been included in the more inclusive Silver Star District. Published production figures for the district are combined with those for the adjacent districts. Mineral veins and areas of hydrothermal alteration and silication are generalized on the map and described in more detail below, generally from north to south.

Douglas Canyon. A number of small prospects are present in the Mina Fm. in the vicinity of Douglas Canyon. The workings are usually pits or short adits exploring narrow (30-60 cm) milky quartz and more-rusty quartz veins, and often exhibit two sets of steeply dipping joints at right angle to each other. The rock adjacent to the veins, particularly on the north side, contains accessory apatite, zircon, and sometimes, pyrite. Hornblende crystals are abundant in the rock immediately adjacent to the mapped area. Pink K-feldspar is 40-60% of the total feldspar present.

K-Ar ages were determined on plagioclase (70.3±2.1$m.y._1$), biotite (65.7±2.4$m.y._1$), and biotite (92.6±2.9$m.y._1$) from a sample of the large pluton at the mountain front in the southeast part of the quadrangle (Garside & Silberman, 1978). The biotite determination is probably the most reliable, although it is possibly a minimum age. The pluton is similar in age to a quartz monzonite porphyry in the Mono Mtn. quadrangle to the west (92.4m.y. on biotite; Marvin & Cole, 1978) and some other dikes and intrusive masses in the Yerington area, to the southwest of the SW corner of the quadrangle (biotite 84.1m.y., hornblende 89.2m.y., Speed & Kistler, in press). The biotite quartz monzonite in this quadrangle, as well as many other large granitic bodies in the western Nevada Plutonic-Metamorphic Belt, is considered to be part of the Sierra Nevada batholithic complex (Rose, 1961), probably near its eastern edge (Bateman & Clark, 1974).

Tqd Diorite. A hornblende-biotite diorite pluton (2km^2) is exposed in Silver Dyke Canyon and in a small area west side of the Silver Dyke Fault; it intrudes part of the Gold Range Fm., and has been mapped in the Gold Range Formation. Except for a small dike or sill at the south end, the pluton appears to be a single mass, approximately 1.5km long and 1km wide.

The pluton is dark gray, medium-grained, coarsely jointed, and unlike the Mesozoic? quartz monzonite porphyry (Tqp) plagioclase, about An$_{35}$ (65%), hornblende (25%), and biotite (10). A small amount of interstitial quartz and hornblende is present; along with accessory magnetite, apatite, and rare zircon. Variable amounts of secondary minerals are present. Plagioclase is altered to sericite and saussurite, biotite to chlorite, and hornblende to actinolite, chlorite, and epidote. Magnetite is altered and kaolinization (Kerr, 1936) occur along the Silver Dyke Fault. The diorite is 93-94% felsic (Q+Or+Ab+An), hornblende, 96.8-2.9m.y. (biotite) and 101±4m.y. (biotite) (Garside & Silberman, 1978). The biotite age (97±10m.y.) is probably closer to the true age more accurately.

Tqp Gold Range Quartz Monzonite Porphyry Formation. The Gold Range Formation is exposed in the Excelsior Mts., a few km north of Mono Mtn. in the southeast quadrangle. Rocks are grouped in the Gold Range Fm. in the vicinity of Camp Douglas. The formation is named after the Gold Range Mining District. Speed (1973a) discussed the history of the informal usage of the Gold Range Fm. and Gold Range Mining District. Kerr (1936) used the original name but excluding some rocks that were included in the original definition.

The formation is exposed in the west-central part of the quadrangle. Fm. consists of a quartz monzonite stock and a contact aureole. The stock is fine-grained, and is divided into three varieties, the most common section is present; it was divided into three varieties, the most common section is present, a medium-grained, biotite-rich (Kgrm), and an upper conglomerate and sandstone unit (Kgcs). The rocks present suggest a complex volcanic pile in the area of Mesozoic.

The lower unit consists of sedimentary breccias, and volcaniclastic sandstones, siltstones, and conglomerates. Bedding ranges from poorly to well-defined. Rocks are usually well-weathering, dense, black, fine-grained rocks consisting of a fine mass of partly recrystallized quartz, plagioclase, sandine? and biotite (now chlorite); these rocks appear to be reworked or water-laid tuffs. Interbedded rocks are coarser and contain recrystallized volcanic- and chert-pebble mudstones, sandstones, conglomerate and breccias. The chert fragments are commonly gray or reddish-colored, and may have been derived from chert beds in the Mina Fm. Volcanic fragments in the conglomerate are usually ferromagnesian-rich felsic to intermediate rocks of flow origin. Some units in the lower part of the section contrasts sharply with the generally dark-colored rocks which it intrudes. The lowermost unit is composed of light gray, well-welded tuffs and andesite lavas. One body which intrudes diorite just in the south of the quadrangle, is a dacite porphyry, and a nearly phanetic porphyritic interior. Locally the porphyry is iron-stained, possibly due to oxidized pyrite.

The age of at least part of the Mina Fm. is Permian on the basis of K-Ar dating and biostratigraphy (Speed, 1973a). K-Ar ages of detrital hornblende believed to be essentially equivalent to the age of the source rocks, indicate a minimum age of 255m.y., and poorly preserved fusulinids from near the Mono Mine at the southeast corner of the quadrangle are suggestive of Schwagerina sp. an early Permian form (Speed, 1973a).

Black Dyke? Formation. The Black Dyke Fm. was named by Speed (1973a); the type area is Black Dyke Mtn., 8km to the north of the quadrangle. The formation consists there of dialic volcanic breccia together with minor interval of relatively coarse-grained sedimentary rocks, tuffaceous and mafic intrusive rocks. The Black Dyke is also present in the central Excelsior Mts., just north of Marietta, about 5km west of the quadrangle (Speed, 1973a).

Only one small outcrop area of 0.25km^2 in the southwest corner of the quadrangle has been tentatively assigned to the Black Dyke Fm. The exposure extends only a short distance to the south of the quadrangle before it is cut off by biotite quartz monzonite. Both the Black Dyke? and the quartz monzonite are overlain in the vicinity by Tertiary laharic andesite breccia and Quaternary older gravels. Similar exposures of Black Dyke Fm. occur near Marietta, 6km to the east of this exposure (Speed, 1973a).

The Black Dyke? Fm. in the quadrangle consists of mafic volcanic rocks and minor epiclastic graywackes derived from them. The mafic volcanic rocks are dark greenish-gray aphanitic to porphyritic phenetic andesite flow? breccias composed mainly of pyroxene, hornblende, and plagioclase phenocrysts in a dark, fine-grained matrix of chlorite and plagioclase. Accessory magnetite is common, making the rock noticeably magnetic. Rare fragments of quartzite are present in the rock. The interbedded graywackes are similar to parts of the Mina Fm. They consist of sand-sized grains of plagioclase, pyroxene, and hornblende in a silt-sized matrix; some beds show graded bedding and plane parallel laminations, and are usually poorly sorted. The stratigraphic up-direction appears to vary greatly within short distances; the variations are similar to those found in the Mina Fm.

Speed (1973a) suggests the source of the volcanic rocks and clasts in the Black Dyke Fm. 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.

Hornblende from the Black Dyke? Fm. has been age dated (Speed & Armstrong, 1971) by K-Ar methods as Permian, both at the type area (252.3m.y.$_{(7)}$) and in the mine (230m.y.$_{(8)}$ Excelsior Mts. 5km west of the quadrangle (253.3m.y.; 218-3m.y.). The conformable contact with the Mina Fm. is considered probable age of 253m.y., essentially equivalent to the age of the Mina Fm.

STRUCTURAL GEOLOGY

The Camp Douglas quadrangle lies at the northeastern end of the Excelsior Mts., a range whose form is controlled by high-angle faults. The range, approximately 30km long, trends north-south, comprise a structurally anomalous zone of east- to southeast-trending faults surrounded by the more typical north- to northwest-trending faults common to the Basin and Range in extreme western Nevada. The Excelsior Mts. lies within the Basin-Excelsior Mtns. structural zone (Gilbert & Reynolds, 1973; Stewart, 1980).

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

The Walker Lane is a major feature of Nevada represent several periods of deformation; regional interpretations of the pre-Tertiary structural history are therefore difficult to make. Recent investigations (Speed, 1977b; Rogers & Lumm, 1974) have emphasized plate-tectonic models, especially the closing of behind-the-arc basins, to explain the structural history of these faults. More detailed mapping is needed in this part of Nevada to clearly define the Tertiary structures in the region.

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

A younger period of deformation is represented by folds and a thrust fault involving the Gold Range Fm. An anticlinorium and synclinorium exposed near the mouth of Silver Dyke Canyon are in the upper plate of a thrust fault that has emplaced Mina Fm. over the Gold Range Fm. The folds in the folds are generally north-trending, are slightly overturned to the west, and plunge about 45° south. The anticline is present in the Gold Range Fm. on Thunder Mtn.; limbs have dips of up to 80°, and the axis plunges to the north at 40°. This axial trend is parallel to the folds in the upper plate of the thrust in Silver Dyke Canyon, and suggests a common direction of movement for the folds. The thrust fault is younger than the lower part of the section, as it cuts the lowermost Tertiary ash flow tuff in the volcanic unit is, then the deformation is younger than ~10m.y.

Detachment faults. Several detachment faults are present in andesite units and Permian Mina Fm. about 1.5km south of Camp Douglas Canyon. These faults generally parallel the Tertiary-Mina Fm. contact, and are filled with light gray, coarsely crystalline calcite and brecciated wall rock. The calcite veins along the faults are up to 5m wide, and the dip of the faults is generally 25°-30° toward 270°. These low-angle faults often preserve small areas of older Tertiary rocks under upper-plate Mina Fm. Displacements usually are small, but one fault can be as young as 16m.y. are cut by these faults, their age must be somewhat younger than. Hardyman and others (1975) described low-angle detachment faults in Tertiary rocks of the Gillis and Gabbs Valley Ranges 30km to the north. They believe the mechanism producing these faults is related to strike-slip faulting along the Walker Lane. A similar relationship might also exist here.

A thin unit of silicified pyroclastic and tuffaceous sedimentary rocks in the east-central part of the quadrangle apparently dip eastward from a higher elevation, in the Thunder Mtn. area, to its present position overlying Permian Mina Fm. and