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Nevada Bureau of Mines Open-File 99-5 (2nd Edition)

Preliminary Geologic Map of the McTarnahan Hill Quadrangle, Douglas County, Nevada

INTRODUCTION

The preliminary geologic map of the McTarnahan Hill quadrangle, first released in 1999 in PDF format, was originally drafted in Adobe Illustrator. This Second Edition (Revised 2009) was converted and modified slightly in ArcMap Version 9.3. The Quaternary unit descriptions were not significantly changed from the original map. Bedrock unit descriptions were modified and corrected, and sections were added on Mineral Deposits and Structural Geology.

Mineral contents of igneous rocks were estimated visually from thin sections and rock slabs (which were stained for potassium feldspar). Igneous rock names are based on the IUGS classification (e.g., Le Maitre, 1989). Some unit thicknesses were estimated from the geologic map and topographic base map. Strikes and dips were averaged or rounded to the nearest 5° unless accuracy was better than that. Dike widths on the map are commonly exaggerated.

Field work was completed in 1997–1999. Geologic mapping was supported by the U.S. Geological Survey STATEMAP Program (Agreement No. 1434-HQ-97-AG-01766).

UNIT DESCRIPTIONS

Qa **Alluvium** (Holocene) Alluvium occurring along small, normally dry streams and on localized portions of some fan surfaces. Unconsolidated, poorly bedded, poorly to moderately sorted sand and gravelly sand deposited as sheetwash and wash alluvium in Holocene and modern channels. Soil development weak to nonexistent, consisting of a thin, weak, gray-brown, sandy A horizon where present.

Qs **Eolian sand deposits** (Holocene to late Pleistocene?) Deposits of windblown sand occurring as widespread sheets and dunes in valley and other low-lying areas, and as small irregular patches in the foothills of the Pine Nut Mountains. Unconsolidated, moderately sorted, generally fine to medium subrounded sand. Sand consists primarily of quartz, with a variable admixture of rock fragments and other resistant mineral grains such as hornblende and minor magnetite. Occurs in the form of a sheet of sand forming a veneer over much of the eastern side of Carson Valley and the lower slopes of the Pine Nut Mountains and western foothills. Sand sheet thickness varies from a few centimeters to a few meters locally. Generally mapped where thickness exceeds 20 cm. Occurs also as a series of stabilized (vegetated) longitudinal dunes in the large lowland area east and northeast of Hot Springs Mountain. Dunal area appears to be continuous with surrounding area of sheet sands. Occurs also as thin, irregular patches of sand generally along, and at the heads of dry washes and small channels on the western slopes and foothills of the Pine Nut Mountains. Rock outcrops in the vicinity of areas of sand are locally polished and grooved; the grooves indicate a northeast sand-transport direction. Soil development is minimal, consisting of a thin horizon of pale-brown to brown-gray sand a few centimeters thick.

Qf **Flood-plain deposits of the Carson River** (Holocene) Unconsolidated, moderately sorted gray-brown and brown, fine to medium sand and sandy mud interbedded with coarse sand and fine gravel. Occurs as stream channel and overbank deposits along the Carson River. Well-developed soils consisting of deep mollic soils with A–C profiles; the A horizon is typically gray clayey silt up to 70 cm thick.

Qt **Terrace deposits of the Carson River** (Holocene) Unconsolidated, moderately sorted gray-brown to brown sand interbedded with fine gravel. Occurs as a terrace remnant along the west side of the Carson River in northwestern part of the quadrangle on east side of Prison Hill. May be equivalent to the "terrace deposits of the Carson River" of Bingler (1977). Soil generally thin and weakly developed, consisting of a light-grayish-brown to light-brown sandy A horizon up to 20 cm thick.

Qaf **Alluvial fan deposits** (Holocene) Unconsolidated to weakly consolidated, poorly to moderately sorted sand and gravelly sand occurring as relatively small fan-shaped constructional deposits along steeper slopes of Hot Springs Mountain and elsewhere in the quadrangle. Gravel clasts subangular to subrounded and lithologically similar to nearby bedrock. Soil development minimal, consisting of a sandy to gravelly pale-brown A horizon up to 20 cm thick.

Qyc **Flood-plain deposits of Clear Creek** (Holocene) Unconsolidated, moderately sorted dark-brown, silty to clay-rich fine sand (Pease, 1980). Occurs as stream channel deposits along Clear Creek in northwestern-most part of the map area. Well developed soils consisting of deep mollic soils with A–C profiles; the A horizon is typically dark-gray-brown sandy soil up to 50 cm thick.

Qcp **Alluvial-plain deposits of Clear Creek** (Holocene) Weakly consolidated, poorly sorted, yellowish-brown sandy gravel forming low-gradient plain adjacent to Clear Creek in northwestern part of map area (Pease, 1980). Moderately well developed soils with A–C profiles; the A horizon is generally pale-brown sandy soil less than 15 cm thick.

Qpy **Pediment deposits, younger** (Holocene? to late Pleistocene?) Deposits of unconsolidated poorly sorted gravel, sand, and silt forming veneers on erosion surfaces cut into bedrock. Gravel clasts subangular to subrounded and lithologically similar to nearby bedrock. Deposits only slightly dissected and occur on topographically lower slopes of foothills of the Pine Nut Mountains, including Prison Hill, in the northern part of the map area. Soils generally thin (<50 cm) and weakly developed, consisting of a light-brownish-gray gravelly sandy A horizon up to 15 cm thick overlying a slightly darker gravelly, sandy B horizon.

Qpo **Pediment deposits, older** (Pleistocene) Deposits of unconsolidated poorly sorted gravel, sand, and silt forming veneers on erosion surfaces cut into older alluvial deposits or bedrock. Gravel clasts predominantly subrounded and consist of various lithologies, including Mesozoic granodiorite, aplite, metavolcanic rocks, and generally lesser amounts of Mesozoic microdiorite, argillite, and other lithologies. Deposits are moderately dissected and occur on topographically higher slopes along the west side of the Pine Nut Mountains and foothills in the southern part of the quadrangle. Typically formed on top of poorly consolidated Tertiary sedimentary rocks (Tsl). Soils generally thin (<50 cm) but contain a well-developed, brown to yellowish-brown, argillic B horizon up to 40 cm thick.

Qpr **Old alluvium of the Pine Nut Range** (Pleistocene) Unconsolidated, poorly to moderately sorted deposits of sandy fine gravel and gravelly fine to coarse sand (Pease, 1980). Occurs in eastern part of Carson Valley, underlying a thin and irregular veneer of eolian sand (Qs) in the southwestern part of the map area. Alluvium derived from Pine Nut Mountains. Soils relatively deep and well developed, consisting of a light-brownish-gray or pale-brown sandy A horizon up to 20 cm thick, overlying a brown, clay-rich B horizon.

QTg **Alluvial fan and pediment deposits** (Pleistocene and late Pliocene?) Poorly sorted gravel, sand, and silt occurring as alluvial fans along the Carson River in the northernmost part of the quadrangle, and as small, isolated pediment remnants along western slopes of the Pine Nut Mountains in the north-central part of quadrangle. May be equivalent to the “alluvial fan deposits of Mexican Dam Road” of Bingler (1977). Gravel clasts predominantly subrounded and consist of various lithologies, including Mesozoic argillite and minor limestone in northernmost exposures, and Mesozoic granodiorite, aplite, and minor amounts of argillite and other lithologies in the southernmost exposures. Soils moderately deep consisting of a thin, gravelly sandy A horizon, and a brown to yellowish-brown moderately argillic B horizon up to 60 cm thick.

Tsu, Tsl, Tsg **Sunrise Pass Formation** (Pliocene and late Miocene) Lacustrine and fluvial sedimentary rocks, fine- to coarse-grained, and named for exposures near the Sunrise Pass Road in the southeast part of the quadrangle (Trexler and others, 2000; Muntean and others, 2000; Muntean, 2001). Latest Miocene and Pliocene, >7 to ~1.9 Ma (Kelly, 1994, 1997; Trexler and others, 2000; Lindsay and others, 2002). $^{40}Ar/^{39}Ar$ ages for the formation are from sites in quadrangles adjacent to the east and southeast (table 1). A K-Ar age of 9.4±0.8 Ma was reported for hornblende from a hornblende biotite vitric ash in the sedimentary unit, sampled close to sample 97JP71 (7.02 Ma, table 1) in the Mount Siegel Quadrangle (McKee and Klock, 1984); this age suggests the possibility that the maximum age of the unit could be 9 Ma or more.

Tsu **Deltaic and fluvial sands and gravels** Poorly to moderately sorted, grayish-brown and light-brown, semiconsolidated sands, pebbly sands, and less cobble gravel. Plane- and cross-bedded. Clasts are predominantly granitic and metamorphic rocks. Appears to lie conformably on Tsl.

Tsl **Claystone and siltstone** Deposits of poorly to moderately consolidated tuffaceous claystone, siltstone, diatomite, and rhyolitic tephra. Thick beds of fine-grained, nonlaminated to indistinctly laminated, white to light-tan, tuffaceous claystone and siltstone that include minor lenses and beds of sandstone and gravel. The deposits are interpreted to be lacustrine sediments deposited in a paleoenvironment characterized by a valley or flood basin of low relief containing a braided river or streams and small lakes (Kelly, 1994). Fine, white rhyolitic tephra beds crop out north of the Sunrise Pass Road, in Secs. 32 and 33, T14N, R21E. One of these was dated by tephrachronologic correlation at 3.3 Ma (M. Perkins, in Trexler and others, 2000).

Tsg **Sand, gravel, sandstone, and conglomerate** Deposits of unconsolidated sand and gravel, and poorly to well consolidated sand, gravel, sandstone, and conglomerate. Gravel and conglomerate clasts are subangular to subrounded and consist of various lithologic types, including Mesozoic argillite, granodiorite, aplite, metavolcanic rocks, microdiorite, and other rock types. Sands and sandstones are fine- to coarse-grained, locally arkosic, brown to greenish brown, planar- and cross-bedded, and generally strike northwest, and dip southwest. An area within Secs. 29 and 30, T14N, R21E contains exposures of well-indurated coarse sandstone and conglomerate. The deposits are interpreted to be fluvial sediments deposited in a paleoenvironment characterized by lateral accretion of braided streams and vertical accretion during overbank flooding (Kelly, 1994). The unit is found in relatively topographically high positions in the Pine Nut Mountains in the northern and eastern parts of the map area, where it commonly lies unconformably on Mesozoic rocks. It appears to underlie and partly interfinger with the lacustrine facies (Tsl).

Thai **Hornblende andesite dike** (Miocene?) Light-gray dike, ~1–2 m wide, exposed on the southwest flank of Hot Springs Mountain. Contains phenocrysts (~10%) of subequal amounts of elongate, euhedral plagioclase (≤0.2 mm x 0.6 mm) and acicular and elongate hornblende (commonly 0.2 x 2 mm) in a sparsely microvesicular trachytic groundmass of plagioclase microlites and Fe-Ti oxide minerals.

Kap **Aplite** (Cretaceous) Pinkish-gray to white aplite, as dikes (~1–15 m wide) and larger irregular masses. Consists of micrographic quartz and alkali feldspar plus subordinate plagioclase and very sparse biotite. Aplitic to locally pegmatitic. Found within and adjacent to Kph, and probably related. Similar to aplitic border phase of Kph, which was not mapped separately.

Kph, Kphd, Kphb **Prison Hill pluton** (Cretaceous) Very light-gray, medium-grained, granular porphyritic granodiorite containing plagioclase (55%; euhedral to subhedral, commonly ≤3 x 5 mm), hornblende (2%, <3 mm long), biotite (2–3%, 1–2 mm in diameter), quartz (20%, rounded to anhedral gray grains ≤5 mm), and alkali feldspar (21%; both as intergranular grains and as sparse, but nearly ubiquitous, oikocrysts up to 2 x 3 cm). Hornblende and biotite are aligned and randomly oriented microphenocrysts in the oikocrysts. Accessory sphene and Fe-Ti oxide minerals. Aplitic, and locally porphyritic phases are found near pluton margins (not mapped separately). Probably mainly granodiorite (John, 1994), but locally quartz monzodiorite or quartz monzonite (Eisinger, 1960). Scheelite skarns are locally associated in adjacent wall rock (War Bond Mine; NW¼ NW¼ Sec. 17, T14N, R21E; Stager and Tingley, 1988). Age 87.2±0.4 Ma (table 1). **Kphd**, dikes of Kph or granodiorite thought to be related to Kph, including sphene-bearing, subhedral granular granodiorite dikes on the northwest flank of Hot Springs Mountain that are otherwise similar to non-porphyritic Kph. **Kphb**, very light-gray and pinkish-gray, medium-grained, subhedral granular granodiorite containing plagioclase (53%), quartz (30%), alkali feldspar (7%, commonly intergranular), and biotite (10%). Rarely contains 1 cm long alkali feldspar oikocrysts. Accessory Fe-Ti oxide minerals and rare zircon; sphene appears to be absent. Associated with areas of garnet-epidote skarn containing magnetite and, at the Alex Eske Mine (NW¼ SW¼ Sec. 8, T14N, R21E), scheelite (Stager and Tingley, 1988).

Mzgp **Granodiorite porphyry** (Mesozoic) Dikes and small, irregular intrusive bodies of predominantly granodioritic porphyries that are statically to dynamically metamorphosed to greenschist grade. Originally composed of phenocrysts of alkali feldspar, plagioclase, or both (~1 mm to locally 1 cm), quartz (microgranular in groundmass or as 1–3 mm rounded and embayed crystals), and mafic minerals, probably biotite and hornblende, commonly converted to fine biotite ± chlorite ± calcite. Microgranular groundmass; phenocrysts 20–50% of rock. Foliation, if developed, is commonly parallel to dike margins, and defined by fine, aligned biotite.

Jqm **Quartz monzodiorite** (Middle Jurassic) Gray and pinkish-gray, medium-grained, subhedral granular hornblende quartz monzodiorite, containing subhedral plagioclase (45%, ≤1 x 2.5 mm), anhedral green hornblende (15%, mostly ≤1 mm), anhedral alkali feldspar (23%, ~1–2 mm) and quartz (≤1 mm), rare biotite, Fe-Ti oxide minerals, and sphene (~2%). Apparently intrudes Jmd. Believed to be part of the Shamrock (Mt. Siegel) batholith (Stewart and Noble, 1979; John and others, 1994) which is exposed mainly to the southeast of the quadrangle. The Shamrock batholith is 165.8 Ma (Dilles and Wright, 1988).

Jmd **Microdiorite** (Jurassic) Medium-light-gray to greenish-gray, fine grained (≤1 mm), subhedral equigranular dioritic igneous rock with enough quartz locally to be called quartz monzodiorite. Contains variable amounts of plagioclase (50–65%), hornblende (18–35%), interstitial alkali feldspar (8– 20%), quartz (<1–7%), subordinate biotite (<1–3%), Fe-Ti oxide minerals, and commonly, sphene. Rock is commonly somewhat metamorphosed, mainly resulting in the addition of fine-grained biotite. Intruded by Kph and probably by Jqm. Equivalent to the diorite of northern Pine Nut Mountains (John and others, 1994), and believed by them to be Middle Jurassic, based on petrochemical and metallogenic grounds.

Jha **Hornblende meta-andesite** (Jurassic) Medium-dark-gray and greenish-gray rock consisting of plagioclase and hornblende phenocrysts in an originally aphanitic groundmass that is now recrystallized to fine-grained plagioclase, alkali feldspar, biotite, and actinolite. Probably hypabyssal intrusive bodies. Rocks at two outcrop areas in the central Hot Springs Mountain contain phenocrysts (~30%) of 1–4 mm diameter plagioclase and elongate (1 x 5 mm) hornblende; rocks exposed at the northwestern tip of the mountain contain phenocrysts (~20%) of fluidally aligned plagioclase (0.5 x 3) and hornblende (≤2 x 10 mm).

Jhsf, Jhsv, Jhss **Metavolcanic rocks of Hot Springs Mountain** (Jurassic) Greenish-gray to light-gray massive rocks which commonly contain fine relict plagioclase phenocrysts (~1 mm). Other original textures are obscured by greenschist-grade metamorphism, which includes the growth of biotite, actinolite, and lesser epidote and the local development of streaky flaserlike foliation, apparently on relict breccia fragments and fiamme(?). Total thickness unknown, but certainly hundreds of meters. Apparently nonmarine, although a 1 m marble bed was observed at one outcrop area. Jurassic by analogy with other Middle Jurassic nonmarine rocks in this area (e.g., Stewart, 1997). **Jhsf**, predominantly flaser semi-schist which may, in part, have a fragmental pyroclastic andesitic protolith. Dark augenlike bodies range from <1 cm to ~15 cm. **Jhsv**, predominantly massive, fine-grained meta-andesitic rock having probable protoliths of flows or hypabyssal intrusives. **Jhss**, immature feldspathic and volcanic metasandstone and metaconglomerate; commonly bedding features are preserved.

J₸g, J₸gm **Gardnerville Formation** (Late Triassic to Early Jurassic: Stewart, 1997; Wyld and Wright, 1993) Dark gray argillite, locally spotted, calcareous, hornfelsic, or andalusite-bearing. Commonly massive, but rarely displays compositional layering. Marble (**J₸gm**), where mapped separately, is commonly foliated (calc-schist) parallel to compositional layering. Thickness a few hundred meters (partial section), which is probably <10% of total thickness reported from the southern Pine Nut Mountains (Wyld and Wright, 1993).

₸op, ₸opm **Oreana Peak Formation** (Late Triassic) Light-gray and locally dark-greenish-gray rock unit consisting of metatuff, volcaniclastic siltstone, sandstone, and conglomerate, and uncommon metabasalt flows (locally amygdaloidal) and breccias. Tuffs consist of fine, layered ash(?) or contain lapilli (≤1 cm); they are apparently nearly all subaqueous. Volcaniclastic rocks contain plagioclase and, less commonly, mafic volcanic rock fragments. Calcareous units may be converted to garnet-epidote skarn near contacts with igneous intrusive rocks. Regional greenschist-grade metamorphism has converted these rocks into indistinctly foliated semischists and flaser semischists containing fine-grained biotite, muscovite, and tremolite. Thickness in the southern Pine Nut Mountains is ~4,500 m (Wyld and Wright, 1993); the partial section in the McTarnahan Hill quadrangle is probably less than 1,000 m. Age, based on fossil data from nearby areas, is Late Triassic (early to late Norian; Stewart, 1997). Marble units (**Ꞧopm**), 1 m to tens of meters thick and commonly finely foliated subparallel to compositional layering, are mapped separately where thickness and exposure permit. They are recrystallized to white, coarsely crystalline calcite near intrusions.

Mzms **Mica schist** (Mesozoic) Light- to dark-gray, commonly fine-grained, foliated metamorphic rock consisting mainly of a polygonal mosaic of quartz and aligned muscovite or biotite; plagioclase is a minor constituent. Flaser-like textures are locally observed. In addition to the main outcrop area in N½ Sec. 17, T14N, R20E, pendants of hornfels and biotite schist in Kph to the southwest are tentatively included. Protolith indeterminate; possibly pelitic rocks of Triassic or Jurassic age.

Mzmb **Metabasalt and meta-andesite** (Mesozoic) Medium-dark-gray and dark-greenish-gray hornfels and semischist having a probable protolith of porphyritic andesite and amygdaloidal basalt. Meta-andesites contain 1–3 mm, originally subhedral to euhedral plagioclase in a groundmass of actinolite, biotite, clinozoisite, and plagioclase. Metabasalt is fine-grained rock consisting predominantly of plagioclase and biotite, with 1–5 mm elongate areas of polycrystalline quartz (probably amygdules). Rocks are massive to indistinctly foliated. Thickness is indeterminate; possibly correlative with the Oreana Peak Formation.

Ꞧbc **Meta-andesite of Brunswick Canyon** (Triassic) Medium-dark-gray and greenish-gray massive flows which originally contained phenocrysts (5–10%) of plagioclase (1–3 mm, equant to elongate; locally as glomeroporphyritic aggregates) and equant to elongate clots (~2 mm) of fine metamorphic biotite and chlorite at former mafic mineral (pyroxene and hornblende?) sites and, rarely, vesicles. Groundmass originally a felted mass of plagioclase microlites; other groundmass minerals are recrystallized to metamorphic chlorite, biotite, and lesser epidote. Sparse beds of volcanic conglomerate, breccia, feldspathic sandstone, and intermediate-composition pyroclastic(?) rocks. Locally weakly foliated. Equivalent to the metavolcanic rocks of Brunswick Canyon of Bingler (1977). Thickness probably several thousand meters; age poorly constrained.

MINERAL DEPOSITS

The quadrangle is within the Delaware Mining District (Tingley, 1990). Mineral deposits in the McTarnahan Hill area are mainly a result of metasomatic and hydrothermal processes associated with the margins of Mesozoic igneous intrusive rocks. Tungsten skarns are thought to be commonly associated with Cretaceous granitoids (John and others, 1993, p. 36; John and others, 1994, p. 24). Iron mineralization in the region may be more commonly associated with Jurassic plutonic rocks (John and others, 1994, p. 30); however, much of the iron-skarn mineralization in the quadrangle is associated with tungsten skarns, which are commonly spatially associated with the Cretaceous granitic rocks. Polymetallic veins with gold and silver are found in Mesozoic metasedimentary rocks somewhat more distal from igneous intrusions.

Bunker Hill Mine and vicinity: The Bunker Hill Mine is located in SW¼ Sec. 31, T15N, R21E. It had recorded production of gold and copper ($160,000). Copper oxide and sulfide minerals were reported from a low-angle quartz vein (Quade and others, 1990) which dips east parallel to the adjacent thrust(?) fault contact between ₮opm and ₮bc. Garnet and silicified carbonate rocks are present in nearby outcrops, and minor scheelite was observed in a sample from the mine (Quade and others, 1990).

Capital (Eason) Prospect: Reeves and others (1958) described iron mineralization at the Capital prospect in Sec. 36, T15N, R20E. Magnetite and hematite are found in veinlike bodies along a fault zone in Jmd near its contact with marble (J₮gm). Scheelite was also reported from the property (NE¼ SW¼ Sec. 36; Stager and Tingley, 1988, p. 30). There is no recorded production of iron, but 98 units of WO_3 were produced in 1968-69 (Stager and Tingley, 1988).

Valley View Mine: Stager and Tingley (1988, p. 31) reported that the Valley View Mine, in NW¼ Sec. 6, T14N, R21E has been prospected for Pb, Ag, and Hg, but the only recorded production has been W (139 units of WO_3). Scheelite occurs in narrow streaks, parallel to bedding, in skarn bodies 30–120 cm thick that strike northeast and dip about 65°NW. Cinnabar, with jarosite, was reported from a northwest striking, nearly vertical fracture zone (Bailey and Phoenix, 1944; Bailey, ca. 1980).

Allex Eske Mine: A group of underground and surface workings in W½ Sec. 8, T14N, R21E has been called the Alex Eske Mine. Scheelite is found associated with skarn mineralization of calcareous units (Stager and Tingley, 1988, p. 30) of ₮op near the contact with Kphb and Jmd. In addition, small magnetite replacement bodies are found in several areas within ₮op near the igneous rocks. Nine units of WO_3 were reportedly produced in 1955 (Stager and Tingley, 1988, p. 30).

War Bond Mine: The War Bond Mine is in NW¼ Sec. 17, T14N, R21E. Calcareous sedimentary rocks of ₮op have been converted to scheelite-bearing epidote-garnet skarn near their contact with a tongue of Kph. Total production was reported to be 268 units of WO_3 in 1952-53 (Stager and Tingley, 1980, p. 45–46). About 500 m to the east, in NE¼

NW¼ and NW¼ NE¼ Sec. 17, small magnetite replacement bodies are found in Mzms and Ŧop

Nez Perce Claims: A group of underground and surface workings in SE¼ SE¼ Sec. 18, T14N, R21E are associated with a calc-silicate alteration of Ŧop immediately adjacent to Kph. A small magnetite body is exposed, and Quade and others (1990) reported molybdenite. They also reported that a select sample from the property contained 6.3 ppm Au and anomalous Cu.

Tyee and South Mac No. 1 Claims: Argillite of JŦg is strongly silicified at a shaft and prospect pits in NE¼ NW¼ Sec. 19, T14N, R21E. The commodity sought here is unknown; however, anomalous Ba from a sample (Quade and others, 1990) suggests the prospect may be similar to Ag-Cu prospects on Hot Springs Mountain about 4 km to the west (see below).

Hot Springs Mountain Mines: A number of shafts and adits are present on the south flank of Hot Springs Mountain in Sec. 22, T14N, R20E. Workings near the crest of the mountain are along a N40°W quartz vein which contains barite, anomalous Cu and Zn, 6% Pb, and 7.2 ppm Ag (Quade and others, 1990, p. 148). The workings on the lower south slope of the mountain follow a N55°W, 60°NE quartz vein, with barite and Cu-Ag mineralization (Quade and others, 1990, p. 150).

Section 21 prospects: Prospects near the east edge of the quadrangle, in Sec. 21, T14N, R21E are shallow prospect pits in unit Tsg. There are more similar pits just to the east in the Mineral Peak quadrangle. In small inliers, the Tsg overlies deeply weathered Kph, and locally, cobbles of magnetite are found in Tsg. It is not clear why the prospect pits were dug; one possible explanation is the search for paleoplacer gold. Placer gold at the Slater Mine (Johnson, 1973) 21 km to the southeast was derived from similar Neogene gravels. If this explanation is correct, a possible source of gold in unit Tsg here is quartz-tourmaline-copper-gold veins like those at the Utopian Mine (Quade and others, 1990, p. A159; Doebrich and others, 1996) about 3 km to the east.

STRUCTURAL GEOLOGY

Triassic and Jurassic metasedimentary and metavolcanic rocks are dynamically and thermally metamorphosed in the quadrangle. Most of the attitudes in metasedimentary and metavolcanic rocks were measured on metamorphic foliation, which is interpreted to be subparallel to original bedding. Locally, compositional layering that represents original bedding was measured, and is shown on the map by the bedding attitude symbol. Except for one measurement on Hot Springs Mountain, and one in Ŧbc in the northeast part of the quadrangle, no facing directions were observed, making it difficult to determine if most layered units are upright or overturned. In the north part of the quadrangle, in the vicinity of McTarnahan Hill, older Mesozoic layered units are in contact with younger ones along what are interpreted herein as east-dipping reverse faults. The Gardnerville Formation (Ŧop, Ŧopm) is thinned, in places to a single marble unit (Ŧopm) between the younger JŦg and the presumably older Ŧbc. Also, marble beds appear to strike into the proposed reverse faults. To the north, in the New Empire quadrangle, Bingler (1977) showed Gardnerville (his unit Ja) lying with apparent angular unconformity on folded Oreana Peak (his unit Ŧmt). Stewart (1997, p. 11), reported that "an apparent truncation of limestone strata at the base of the Gardnerville has been mapped (J.H. Stewart, unpublished mapping, 1989) in the northern Pine Nut Mountains." Based on interpretations in the McTarnahan Hill quadrangle, this proposed angular unconformity would probably be a reverse or thrust fault. The reverse faults shown on the map are commonly steep, but a 25°E fault was mapped at the Bunker Hill Mine. The age of this faulting is unknown. N20°E, upright, tight antiforms within Oreana Peak Formation northeast of the Bunker Hill Mine could be related. These are similar to N20°W antiforms to the north (Bingler, 1977), and both probably are part of a single phase of tight folds with NNW axial planes that characterize the Pine Nut terrane in western Nevada (Oldow, 1984). Locally, map-unit patterns suggest that the reverse faults are cut by Jmd; however, in one place, 1.2 km southwest of the Bunker Hill Mine, Gardnerville Formation is apparently thrust over Jmd. If this thrust fault is the same age as the postulated reverse faults, the responsible tectonic event probably postdates the Middle Jurassic. Folding and reverse and/or thrust faulting probably predate Kph in the quadrangle, although there is no certain evidence of this. Oldow (1984) suggested that the NNW-trending folds of the Pine Nut terrane are related to Nevadan deformation, which ended by 150 Ma in the Sierra Nevada. Wyld and Wright (1993) reported a Late Jurassic or Early Cretaceous folding event in the southern Pine Nut Mountains. Based on somewhat limited structural data (Bingler, 1977), Mesozoic map units in the New Empire quadrangle to the north appear to be upright and west facing, whereas the same units in the McTarnahan Hill quadrangle dip mainly easterly. These relationships can be explained if the rocks were folded about a N70°E, southeast vergent axis passing through McTarnahan Hill. This explanation requires that most of the Mesozoic rocks of the northeast part of the quadrangle are overturned, and suggests that the mapped reverse faults could have originally been lower angle (thrust) faults. Stewart (1999) showed a similar fold axis, although he located it nearly 1 km to the north. The age of this speculative folding is probably post Middle Jurassic and pre Late Cretaceous; it could be a later part of the event responsible for thrust(?) faults and northerly-trending folds described above.

Numerous northerly striking normal faults cut the Quaternary and Neogene units in the south half of the quadrangle. These are particularly evident in the urbanized area of Johnson and Stephanie Lanes in the southwest part of the quadrangle. These faults have been included in the broad zone of faulting associated with the Sierra Nevada frontal fault system (Adams and Sawyer, 1998), and the zone has been called the east Carson Valley fault zone (dePolo, 1998). The faults form east- and west-facing scarps, locally creating grabens and horsts, or place bedrock against Quaternary units. A fault with significant displacement bounds the east side of an area of bedrock in the south central part of the quadrangle. This fault could continue north under Quaternary units to the vicinity of the Carson River at the north edge of the quadrangle. A normal fault in the east central part of the quadrangle is interpreted to be relatively low angle. The fault trace is sinuous in areas of ridges and valleys, and sparse attitudes in Tertiary rocks near the trace indicate that the beds dip into the fault at moderate to high angles. The most likely interpretation is that the fault has a listric (detachment) geometry, with the bedding that dips toward the fault representing rollover ("reverse drag").

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Table 1. $^{40}Ar/^{39}Ar$ dates, McTarnahan Hill Quadrangle and vicinity.

Sample	Map unit	Rock type	Quad	Mineral	Age method	N. Lat	W. Long.	Age (Ma)	28.02/27.84	±2σ	K/Ca	n**
MT-23	Prison Hill pluton	granodiorite	McTarnahan Hill	hornblende	Plateau	39° 06.55'	119° 39.45'	87.2	–	0.7	–	–
98JP474	Sunrise Pass Fm	pumiceous tuff	Mineral Peak	plagioclase	Single crystal	39° 02.64'	119° 36.65'	3.9	3.93	0.2	0.074	14
97JP83	Sunrise Pass Fm	pumice tuff	Mount Siegel	sanidine	Single crystal	38° 58.17'	119° 34.63'	4.96	4.99	0.01	69.9	14
97JP81	Sunrise Pass Fm	pumice tuff	Mount Siegel	sanidine	Single crystal	38° 57.75'	119° 34.33'	4.96	4.99	0.02	91.2	28
97JP71	Sunrise Pass Fm	reworked tuff	Mount Siegel	sanidine	Single crystal	38° 57.84	119° 30.92'	7.02	7.07	0.05	52.8	10

Except for sample MT-23, $^{40}Ar/^{39}Ar$ ages wre originally reported in Lindsay and others (2002). Age determinations for the listed samples used an age of 27.84 Ma for the neutron flux monitor, sanidine from Fish Canyon Tuff. Recent work suggests an age of 28.02 Ma is more appropriate for Fish Canyon Tuff (Renne and others, 1998). The ages as originally reported are in the Age column. Tertiary ages are recalculated by multiplying them by 28.02/27.84 in the adjacent column. Although not precisely correct, this method gives ages that commonly differ from the correct ages only in the third decimal place, which are not reported.

Table 2. Chemical analyses of rocks of the McTarnahan Hill Quadrangle.

Sample	MT8	MT18	MT19	MT23	MT95	MT100	MT112	MT114	MT132
Map symbol	Ŧbc	Ŧbc	Mzgp	Kph	Jqm	Jhsf	Jha	Jmd	Kph
Rock name	meta-andesite	meta-andesite	granodiorite	granodiorite	qtz-monz-di	metatuff	meta-andesite	microdiorite	granodiorite
W. Long.	119º 38.15'	119º 38.90'	119º 38.34'	119º 39.45'	119º 39.05'	119º 42.66'	119º 43.12'	119º 42.40'	119º 42.40'
N. Lat.	39º 7.60'	39º 7.05'	39º 7.37'	39º 6.55'	39º 3.79'	39º 3.25'	39º 3.94'	39º 3.67'	39º 5.75'
SiO2	66.06	73.93	68.67	68.90	61.62	62.33	66.86	58.78	69.82
TiO2	0.94	0.35	0.37	0.42	0.73	0.70	0.53	1.08	0.37
Al2O3	15.34	14.36	15.90	16.25	17.37	17.04	17.71	16.29	16.15
FeO*	5.71	2.60	3.46	2.53	3.32	5.47	2.64	6.05	2.11
MnO	0.11	0.02	0.03	0.05	0.06	0.11	0.05	0.10	0.04
MgO	2.25	0.43	1.05	0.76	2.78	3.12	0.58	3.78	0.50
CaO	1.57	0.28	0.74	2.95	6.63	5.08	1.63	6.11	2.77
Na2O	4.88	5.32	3.66	4.76	4.19	2.84	5.42	4.24	4.57
K2O	2.82	2.64	5.97	3.22	3.08	3.09	4.44	3.13	3.53
P2O5	0.30	0.06	0.15	0.16	0.21	0.22	0.15	0.43	0.13
LOI	0.81	0.54	0.94	0.29	0.60	0.83	0.59	0.80	0.36
Total**	99.18	99.17	99.13	99.26	99.86	100.06	99.16	99.62	99.40
Sc	24	9	<2	<2	19	11	9	18	2
V	90	17	57	43	128	145	50	142	41
Cr	18	37	25	35	40	32	22	53	17
Ni	5	7	9	5	14	11	4	23	3
Cu	4	<2	<2	<2	2	6	2	71	13
Zn	79	31	29	53	37	51	47	76	61
Ga	15	10	12	14	13	10	12	13	14
Rb	54	36	131	72	64	105	93	42	84
Sr	195	59	98	515	695	210	358	1180	526
Y	29	23	20	16	16	19	19	13	12
Zr	187	183	91	115	157	81	189	155	122
Nb	7	4	9	8	4	15	7	8	8
Ba	1750	923	1640	1340	1530	904	1640	1630	1320
Pb	5	2	2	11	7	9	15	6	17
Th	8	4	8	6	2	3	9	5	7

FeO*, total Fe calculated as FeO; if originally reported as Fe2O3, recalculated as FeO. Ten major oxide values normalized to 100% after recalculation of total Fe to FeO. Trace elements in ppm. Total** is sum of 10 major oxides before normalization; LOI = loss on ignition. Analyzed at NBMG Analytical Laboratory; analytical methods reported in Garside and others (2003, p.4). Sample MT8 location just north of quadrangle, in New Empire Quadrangle.