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Digital Geologic Map of the Thirsty Canyon NW Quadrangle, Nye County, Nevada

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DESCRIPTION OF MAP UNITS

[Mapped surficial units are roughly equivalent to those described in a study of surficial deposits in the Nevada Test Site (NTS) region by Hoover and others (1981). Colors of surficial units are from the Rock-Color Chart (Rock-Color Chart Committee, 1951). Descriptions of surficial map units and their inferred ages are based on limited field work in the mapped area and on field work elsewhere in the region.

Volcanic rock names used here are based on the IUGS total alkali-silica classification scheme of Le Bas and others (1986). Phenocryst-content modifiers of volcanic-rock names are based on the modal percentages shown in Table 1. Table 2 shows terms used to indicate median abundances for felsic phenocrysts (quartz, K-feldspar = sanidine + anorthoclase, and plagioclase), for ferromagnesian minerals (biotite, hornblende, orthopyroxene, clinopyroxene, and olivine), and for accessory minerals (chiefly sphene) in intermediate to silicic volcanic rocks. Mineral-abundance terms for basaltic rocks are listed in Table 3, which differ only for mafic phenocrystic abundances; these median abundances include both phenocrysts and microphenocrysts. Generally, mineral contents are listed in order of decreasing abundance. Although the relative abundance terms shown in the tables are appropriate for descriptions of volcanic rocks from the SWNVF, they may be inappropriate when applied to other volcanic fields. Petrographic and chemical analyses of samples of volcanic rock units within the mapped area, as well as their locations, field descriptions, and other characteristics, are reported in Warren and others (in press).

Table 1. Total phenocryst content

Term	(median modal %)
aphyric	<0.5
crystal-poor	0.5-5
(no modifier)	5-15
crystal-rich	15-25
very crystal-rich	>25

Table 2. Phenocrystic mineral abundances in intermediate to silicic volcanic rocks

Term	Felsic minerals (median modal %)	Fe-Mg minerals (median modal %)	Accessory minerals (median ppm/volume)
rare	<0.5	<0.1	<20
sparse	0.5-2	0.1-0.5	20-150
common	2-10	0.5-1	150-300
abundant	10-20	1-2	>300
very abundant	>20	>2	

Table 3. Phenocrystic mineral abundances in basaltic volcanic rocks

Term	Felsics (median modal %)	Mafics (median modal %)	Accessories (median ppm/volume)
rare	<0.5	<0.5	<20
sparse	0.5-2	0.5-2	20-150
common	2-10	2-5	150-300
abundant	10-20	5-10	>300
very abundant	>20	>10	

Stratigraphic nomenclature for regional Tertiary volcanic units is from Sawyer and others (1994) and the Los Alamos National Laboratory database for the southwestern Nevada volcanic field (SWNVF) (Ferguson and others, 1994; Warren and others, in press).

Reported ages of volcanic units are based mainly on new $^{40}Ar/^{39}Ar$ age determinations (Sawyer and others, 1990; Fleck and others, 1991; Sawyer and others, 1994; R.J. Fleck, written commun., 1996). Also reported here are new K/Ar whole-rock basalt ages by R.J. Fleck (Fleck and others, 1996; written commun., 1996) and published K/Ar ages of Kistler (1968) and Marvin and others (1970), recalculated using IUGS constants (Steiger and Jäger, 1977; Dalrymple, 1979). Sources of magnetic polarity data are listed in Minor and others (1993). Additional magnetic polarity data are from Hudson and others (1994).

Ages of surficial units have not been determined by absolute dating techniques within the mapped area. Ages are inferred based on correlations with dated deposits at and near the NTS (see Hoover, 1989). Correlations are largely based on field observations of soil development, local surface dissection, and stratigraphic sequence. The stage of soil carbonate development reported for soils is a visual estimate based on standards defined by Gile and others (1966). Soil horizon terminology follows Birkeland (1984).]

Qay **Young alluvium (Holocene and late Pleistocene)**—Light-brownish-gray to grayish-yellow, poorly sorted, poorly bedded, unconsolidated to weakly consolidated gravel, gravelly sand, and sand. Gravel clasts are angular to rounded and consist mainly of tuff and lava. Sand grains are poorly sorted, fine to very coarse, and locally accompanied by silt. Unit forms channel deposits of active streams, slightly older terrace deposits along some large washes, and extensive alluvial fans that commonly form the lower part of fan aprons that flank bedrock uplands. Locally includes small colluvial deposits along the margins of stream-canyon flood plains. Terrace and fan deposits commonly stand 2 m or less above modern washes and are generally smooth and undissected. Soil development ranges from no visible soil to soils that consist of a thin sandy vesicular A horizon, a slightly cambic B horizon, and a stage I Bk horizon as much as 0.5 m thick. Unit correlates with unit Q1 of Hoover and others (1981). Thickness generally less than 10 m

QTc **Colluvium (Quaternary and Pliocene)**—Unsorted, nonbedded, unconsolidated to moderately consolidated angular pebble to boulder talus and rock-fall debris. Locally includes small landslide deposits and sandy slope-wash and alluvial deposits. Unit present along or at base of moderate to steep bedrock slopes. Thickness generally less than 10 m

Qam **Middle alluvium (middle Pleistocene)**—Yellowish-gray to grayish-brown, poorly sorted, moderately to poorly bedded, moderately consolidated gravel, gravelly sand, and sand. Gravel clasts are angular to rounded, consisting mostly of tuff and lava. Sand grains are poorly sorted, commonly angular, locally silty. Unit forms extensive fans as well as fan and terrace remnants that generally comprise the middle and upper parts of fan aprons flanking bedrock ranges. Depositional surface of unit is largely intact but has been moderately dissected by small washes that head within the fans. Deposits commonly stand 2 to as much as 20 m above through-flowing washes. Upper surface is commonly marked by a moderately to tightly packed stone pavement. Soil development consists of a silty, clayey, sandy vesicular A horizon, a dark-yellowish-orange cambic to slightly argillic B horizon that is rarely preserved, and a stage II Bk horizon to stage III K horizon that is commonly 1.0 to 1.5 m thick. Unit includes deposits from three periods of deposition that were not separated in the mapping. The youngest of the three deposits correlates with unit Q2b and the two older deposits with unit Q2c of Hoover and others (1981). Unit thickness probably exceeds 10 m near southwest corner of mapped area

Basalt of Hidden Cone (middle Pleistocene)—Cinder cone (Hidden Cone), feeder dikes, and lava flows on the north flank of Sleeping Butte in southwestern part of mapped area. Rocks range compositionally from trachybasalt to basalt. Phenocrysts consist of common olivine and plagioclase and rare clinopyroxene. Age (373 ± 42 ka) is statistically indistinguishable from that of the basalt of Little Black Peak (Fleck and others, 1996). Distinguished from Neogene basalts in mapped area by relatively low phenocryst abundance, subequal olivine and plagioclase, by youthful age and geomorphic appearance, and by normal magnetic polarity. Subdivided into:

Qbhl3 **Upper lava flow**—Flow that extends off east flank of cinder cone. Flow has youthful, rubbly (aa) to ropy (pahoehoe) surface geomorphic expression. Maximum flow thickness is about 10 m

Qbhl2 **Middle lava flow**—Flow that extends off northeast flank of cinder cone and laps onto lower lava flow (Qbhl1). Flow has youthful, rubbly (aa) to ropy (pahoehoe) surface geomorphic expression. Maximum flow thickness is about 15 m

Qbhl1 **Lower lava flow**—Flow that extends off northeast flank of cinder cone. Distinguished from younger basalt flows (Qbhl2 and Qbhl3) by smoother, presumably more weathered flow surface. Maximum flow thickness is about 12 m

Qbhc **Cinder cone**—Poorly consolidated scoria and cinders forming cinder cone on north flank of Sleeping Butte. Associated feeder dikes are present in apical vent area and, locally, on flanks of cone. Cone height is 175 m

Basalt of Little Black Peak (middle Pleistocene)—Isolated cinder cone (Little Black Peak) and lava flow straddling western border of mapped area near southwest corner. Rocks are dominantly crystal rich and range compositionally from trachybasalt to basalt. Phenocrysts typically consist of abundant plagioclase, common olivine, sparse clinopyroxene, and rare hornblende. Age (323 ± 27 ka) is statistically indistinguishable from that of the basalt of Hidden Cone (Fleck and others, 1996). Distinguished from Neogene basalts in mapped area by moderate phenocryst abundance, by youthful age and geomorphic appearance of flow and cinder cone vent, and by normal magnetic polarity. Subdivided into:

Qbbl **Lava flow**—Flow that extends off east flank of cinder cone. Flow has youthful, rubbly (aa) to ropy (pahoehoe) surface geomorphic expression. Maximum flow thickness is about 12 m

Qbbc **Cinder cone**—Poorly consolidated scoria and cinders forming a cinder cone. Cone height is about 75 m

QTa **Old alluvium (early Pleistocene and Pliocene?)**—Yellowish-gray to grayish-brown, poorly sorted to unsorted, poorly bedded, moderately consolidated gravel and gravelly sand. Clasts are angular to rounded tuff and lava. Boulders 1 to 2 m across are common. Unit forms fan remnants in westernmost part of mapped area that are generally deeply eroded, have rounded interfluves, and lack their original depositional surface. Generally poorly exposed; surfaces largely covered by a coarse gravel lag that includes abundant fragments of pedogenic carbonate. Soil development typically consists of a partly eroded stage III to stage IV carbonate horizon as thick as 2 m that is locally overlain by a silty, clayey vesicular A horizon similar to that developed on the middle alluvium (Qam). Maximum exposed thickness about 5 m

Tgo **Gravel of Oasis Valley (Pliocene and Miocene)**—Grayish-orange to light-gray, poorly sorted, friable to well cemented, commonly calcareous, locally tuffaceous gravel, conglomeratic sandstone, and sandstone; mostly in uneven medium to thick beds. Sandstone is fine to very coarse grained, locally silty. Gravel clasts are angular to subrounded and as much as 3 m across, consisting mostly of locally derived Miocene tuff and lava. Unit contains local beds of vitric tuff and mudstone, and lenses of monolithologic rock avalanche breccia derived from nearby bedrock. Unit commonly deeply dissected but poorly exposed; erosional slopes typically are covered by a coarse gravel and sand lag. Unit forms strongly dissected alluvial fans that are locally capped by young remnant pediment gravels along interfluves. Present only in southwestern and southeastern parts of mapped area, where unit has a maximum exposed thickness of about 30 m. Age range of unit indicated by stratigraphic relations south of mapped area in Oasis Valley, where basal gravel of the map unit is intercalated with 7.5-Ma Spearhead Member of Stonewall Flat Tuff and upper gravel of the unit laps onto distal flows of the 4.63-Ma basalt of Thirsty Mountain (Typ) (Minor and others, 1997; Wahl and others, 1997). Gravel unit equivalent in part to gravel of Sober-up Gulch of Maldonado and Hausback (1990)

Typ **Basalt of Thirsty Mountain (Pliocene)**—Sequence of basaltic trachyandesite lava flows and associated tephra envelopes forming broad shield volcano at Thirsty Mountain. Includes local scoria deposits and feeder dikes. Phenocryst poor, with common olivine and rare plagioclase. Mean age of flows from various stratigraphic levels of shield sequence is 4.63 Ma (Fleck and others, 1996). Basalt distinguished by marked preservation of constructional volcanic geomorphology, Pliocene age, and characteristic reversed magnetic polarity (Fleck and others, 1996). Linear, northeast-trending, master feeder vent is inferred to be buried beneath Thirsty Mountain basalt flows on the basis of northeast-elongated crest of shield volcano and roughly coincident, pronounced, negative aeromagnetic anomalies (Grauch and others, 1997). Maximum thickness more than 200 m at crest of shield volcano. The following vent-facies map units are locally differentiated:

Typv **Vent-facies scoria deposits**—Basaltic vent deposits near crest of Thirsty Mountain shield volcano (Typ) that consist mostly of locally fused cinders and scoria. Deposits are intruded by numerous basaltic feeder dikes (Typd) and exhibit considerable dissection. Exposed thickness about 30 m

Typd **Feeder dikes**—Compositionally resemble basalt of Thirsty Mountain lavas (Typ). Dikes intrude vent-facies scoria deposits (Typc) along a variety of orientations

Txmr **Gravity-slide breccia of Rainier Mesa Tuff (Miocene)**—Isolated crackle breccia deposit mostly composed of welded Rainier Mesa Tuff (Tmr). Consists of mildly to intensely shattered and fractured (but not disaggregated) tuff, has a sheet-like geometry, and appears to have a basal slip surface that is marked by pulverized, sheared, and fluidized nonwelded tuff. The sheet contains thin internal shear zones that are both subparallel and normal to the basal slip surfaces. Deposit located near west edge of mapped area, where it forms an isolated, resistant mass below a steep escarpment. Inferred to have been emplaced catastrophically due to gravitational sliding of the tuff mass down the limb of a monoclinal fold that is roughly coincident with the steep, erosional escarpment just north of deposit. Monoclinal folding and gravity sliding occurred after 9 Ma following emplacement of the Gold Flat Tuff (Ttg). Exposed thickness about 15 m

Ttf **Black Mountain caldera moat-filling sediments (Miocene)**--Intercalated fan alluvium and subordinate lacustrine deposits and nonwelded tuff. Fan alluvium composed of coarse, poorly sorted and poorly to moderately bedded, angular to rounded gravel and sand in a locally tuffaceous matrix; clasts consist of locally derived volcanic rocks; weakly to well cemented. Lacustrine deposits include interbedded, partly tuffaceous sandstone and mudstone and water-laid tuff. Sediments are present only within the Black Mountain caldera, near northeastern corner of mapped area, where they overlie 9.15-Ma Gold Flat Tuff (Ttg) and underlie 7.5 Ma Spearhead Member of the Stonewall Flat Tuff (exposed about 5 km north of mapped area). In mapped area, maximum thickness about 15 m

Ttb **Thirsty Canyon and younger basalts (Miocene)**--Trachybasalt, basaltic trachyandesite, basalt, and basaltic andesite lava flows and feeder dikes erupted from several centers between about 9.8 and 9.0 Ma (R.J. Fleck, M.A. Lanphere, D.A. Sawyer, and R.G. Warren, written commun., 1996). Basalts concentrated in two areas in western part of mapped area: (1) adjacent to Hidden Cone, and (2) about 5 km north of Hidden Cone. Basalts erupted just prior to, during, and following peralkaline volcanism of the Black Mountain caldera (Thirsty Canyon Group). Rocks are variable in composition from basalt and alkali basalt to trachybasalt and trachybasaltic andesite, and they include subordinate hawaiite, mugearite, and basaltic andesite. Petrography is also variable; phenocryst-rich varieties contain very abundant plagioclase and abundant olivine phenocrysts; subordinate phenocryst-poor varieties contain sparse to common olivine, sparse plagioclase; sparse to rare clinopyroxene, vapor-phase biotite, and orthopyroxene. Rare kaersutitic amphibole and very abundant groundmass apatite are locally present. Olivine and plagioclase contents and stratigraphic range are distinctive. Maximum exposed thickness about 50 m near Hidden Cone

Tbd **Basalt dikes (Miocene)**—Dikes of phenocryst-rich and phenocryst-poor varieties of basalt that compositionally resemble Miocene basalt lavas in mapped area (Ttb, Tte, and Tmt). Although dikes are as much as 20 m thick, most are less than 5 m, in which case they are represented on map by a single magenta line. North-striking basalt dikes are scattered throughout western part of mapped area, where they intrude rocks as young as Rainier Mesa Tuff (Tmr)

Thirsty Canyon Group (Miocene)--Peralkaline assemblage of ash-flow sheets, lavas, and related nonwelded tuffs erupted from Black Mountain caldera between 9.43 and 9.15 Ma (R.J. Fleck, M.A. Lanphere, D.A. Sawyer, and R.G. Warren, written commun., 1996). The Pahute Mesa (Ttp) and Trail Ridge (Ttt) Tuffs likely are the major units associated with caldera collapse (Sawyer and others, 1994). Following caldera collapse, trachytic lavas of Pillar Spring (Tts) and associated rocks and the Gold Flat Tuff (Ttg) accumulated within the caldera; the Gold Flat also overflowed the caldera mainly to the north and south (e.g., Minor and others, 1993). Renewed caldera collapse associated with the Gold Flat is uncertain. Thirsty Canyon Group is distinguished by its peralkaline mineralogy and chemistry; petrographically it is characterized by high alkali feldspar and low plagioclase contents, general absence of biotite and hornblende, and presence of Fe-rich clinopyroxene and fayalitic olivine. Chemically it is distinguished by high iron and low aluminum contents for rhyolitic compositions and anomalously high trace-element concentrations of zirconium, rare-earths, and other elements. Subdivided into:

Ttg **Gold Flat Tuff**—Widespread welded, strongly peralkaline (pantellerite) ash-flow tuff erupted at 9.15 Ma from Black Mountain caldera (R.J. Fleck, M.A. Lanphere, D.A. Sawyer, and R.G. Warren, written commun., 1996). Contains abundant alkali feldspar (anorthoclase and sodic sanidine), sparse plagioclase, Fe-rich clinopyroxene, and fayalitic olivine, and rare biotite, quartz, and hornblende. Arfvedsonite occurs both as sparse phenocrysts and as a devitrification product in groundmass. Contains rare primary fluorite and aenigmatite. Anomalous normal magnetic polarity. Deposited in caldera moat and as outflow facies to south. Maximum thickness of 30 m in caldera

Tts **Trachytic lavas of Pillar Spring** --Crystal-rich to very crystal rich trachyte to rhyolite lava flows and associated tuff and tuff breccia that partly fill Black Mountain caldera in northeastern part of mapped area. Lavas contain abundant to very abundant alkali feldspar (mainly anorthoclase), common plagioclase, sparse clinopyroxene and olivine, and local rare biotite. Magnetic polarity is reversed. Maximum exposed thickness 125 m

Ttt **Trail Ridge Tuff**--Widespread welded, moderately crystal rich, comendite ash-flow tuff erupted from Black Mountain caldera. Contains abundant sodic sanidine, sparse Fe-rich clinopyroxene and fayalitic olivine, and rare plagioclase. Anomalous reversed magnetic polarity. Maximum exposed thickness about 80 m along west fork of Thristy Canyon near eastern edge of mapped area

Ttp **Pahute Mesa Tuff**--Widespread welded, comendite ash-flow tuff erupted from Black Mountain caldera. Contains common alkali feldspar, sparse Fe-rich clinopyroxene and fayalitic olivine, and rare plagioclase and quartz. Strongly zoned, with a crystal-rich top and a crystal-poor base; zoned nature distinguishes tuff from overlying Trail Ridge Tuff (Ttt) and underlying Rocket Wash Tuff (Ttr). Anomalous reversed magnetic polarity. Maximum exposed thickness 35 m. In northern part of mapped area, lower part of map unit locally includes Rocket Wash Tuff (Ttr) where too thin to map separately

Ttr **Rocket Wash Tuff**--Local, moderately crystal-poor, comendite ash-flow tuff erupted at 9.42 Ma, probably from Black Mountain caldera (R.J. Fleck, M.A. Lanphere, D.A. Sawyer, and R.G. Warren, written commun., 1996). Contains common alkali feldspar, sparse Fe-rich clinopyroxene and fayalitic olivine, and rare plagioclase and quartz. Typical reversed magnetic polarity and unzoned nature distinguishes tuff from overlying Pahute Mesa Tuff (Ttp). Recognized only in northwestern part of mapped area, where tuff has a maximum exposed thickness of about 20 m

Ttc **Comendite of Ribbon Cliff**--Pre-caldera, crystal-rich to very crystal rich comendite and trachyte lava flows and domes exposed marginal to the Black Mountain caldera in northeastern part of mapped area. Contains abundant alkali feldspar, local common plagioclase, sparse clinopyroxene and fayalitic olivine, and local rare biotite. Middle of three thick flows has normal magnetic polarity. Maximum exposed thickness 100 m

Tte **Pre-Thirsty Canyon basaltic rocks (Miocene)**—Dominantly trachybasalt and basaltic trachyandesite lava flows, eroded cinder cones, and local feeder dikes erupted between 9.8 and 9.6 Ma (R.J. Fleck, M.A. Lanphere, D.A. Sawyer, and R.G. Warren, written commun., 1996). Flows generally contain very abundant to common plagioclase, common olivine, and rare phlogopite. Overlies, interfingers with, and contains local thin lenses of tuff and tuffaceous sedimentary rocks (Tfu). Distinguished from other Miocene basalt units (Ttb, Tmt, and Tob) by its stratigraphic position immediately beneath Thirsty Canyon Groups. Pre-Thirsty Canyon basaltic rocks are located in a broad northeast-trending belt in western part of mapped area, where the map unit has a maximum exposed thickness of 60 m

Tfu **Tuff and tuffaceous sedimentary rocks, undivided (Miocene)**—White to light-gray, nonwelded, massive to bedded rhyolitic ash-flow and ash-fall tuffs, and subordinate tuffaceous sandstone and siltstone. Includes distal tuff facies of the rhyolite of Fleur-de-lis Ranch and the Beatty Wash Formation erupted between 11.4 and 11.2 Ma from sources south of the mapped area; may also include distal tuff of the rhyolites of Rainbow Mountain, Boundary Butte, and Obsidian Butte that erupted to the southwest, south, and northwest, respectively (Minor and others, 1993; 1997). The rhyolite of Fleur-de-lis Ranch contains abundant plagioclase and biotite, sparse clinopyroxene, and local sparse hornblende, whereas the Beatty Wash Formation contains common sanidine and plagioclase, sparse to common biotite, local sparse hornblende, local rare quartz, and common sphene. Map unit is present in western part of mapped area, where it lies stratigraphically between tuffs of the Timber Mountain and Thristy Canyon Groups, and it interfingers with pre-Thirsty Canyon basaltic rocks (Tte). Maximum exposed thickness about 30 m

Timber Mountain Group (Miocene)--Metaluminous assemblage erupted from the Timber Mountain caldera complex east of the mapped area between about 11.6 and 11.45 Ma (Byers and others, 1976; Sawyer and others, 1994). Group consists predominantly of rhyolite ash-flow tuff. Eruption of the voluminous Rainier Mesa Tuff (Tmr) and Ammonia Tanks Tuff (Tma) resulted in collapse of the Rainier Mesa and younger Ammonia Tanks calderas, respectively, which form the Timber Mountain caldera complex (Fig. 1) (Sawyer and others, 1994). Rocks of the group are distinguished by high quartz phenocryst contents and high concentrations of ferromagnesian minerals in upper parts of zoned ash-flow tuff sheets. Consists of:

Tma **Ammonia Tanks Tuff**—Light- to medium-gray-brown, metaluminous, welded ash-flow tuff erupted at 11.45 Ma from Timber Mountain caldera complex (Sawyer and others, 1994). Compositionally zoned, ranging from a rhyolite (abundant sanidine, common quartz and plagioclase, sparse biotite, rare clinopyroxene, and sparse sphene) to a crystal-rich trachyte (abundant sanidine and biotite, common plagioclase and quartz, and sparse clinopyroxene and sphene); only crystal-rich trachyte observed in mapped area. Chatoyant sanidine and large (as much as 5 mm in diameter) equant quartz phenocrysts are characteristic of the unit. Locally contains basaltic xenoliths as much as several meters across. Tuff is distinguished by high quartz and mafic contents, sparse sphene, and normal magnetic polarity. Exposed only along narrow belt in southwestern part of mapped area, where tuff attains a maximum thickness of 30 m and locally pinches out

Tmt **Basalts in Timber Mountain Group**—Lava flows containing common olivine, common plagioclase, and sporadic sparse clinopyroxene. Exposed in narrow belt in western part of mapped area, where local flows lie stratigraphically between Rainier Mesa (Tmr) and Ammonia Tanks (Tma) Tuffs (basalt of Oasis Valley, Warren and others, in press) as well as directly beneath Rainier Mesa Tuff (basalt of Tierra, Warren and others, in press). Maximum exposed thickness 30 m

Tmr **Rainier Mesa Tuff**—Light- to medium-gray-brown, metaluminous welded ash-flow tuff erupted at 11.6 Ma from Timber Mountain caldera complex (Sawyer and others, 1994). Compositionally zoned from a lower, volumetrically dominant rhyolite (common sanidine and quartz, sparse plagioclase, and rare biotite) to an upper crystal-rich trachyte (abundant biotite, common sanidine, plagioclase, and quartz, sparse clinopyroxene, and rare orthopyroxene and hornblende); only rhyolite observed in mapped area. Large (as much as 5 mm in diameter) equant quartz phenocrysts are characteristic of unit. Distinctive thin (about 10 cm) pyroclastic layers directly beneath the main eruptive unit consist of paired dacite and overlying trachybasalt tuff containing abundant hornblende, common plagioclase, and sparse orthopyroxene. Unit distinguished by high quartz and mafic contents, rare accessory monazite, and reversed magnetic polarity; lower nonwelded to partly welded zones are characteristically salmon pink. Exposed only along escarpment in west-central part of mapped area, where tuff has a maximum thickness of about 125 m

Txqs **Gravity-slide breccia of tuff of Sleeping Butte (Miocene)**—Breccia deposits composed mostly of tuff of Sleeping Butte (Tqsp and Tqsm). Consists of intensely shattered, fractured, and mostly disaggregated welded tuff that has a sheet-like geometry. Deposits located along east flank of north-trending ridge west of Thirsty Mountain in southwest part of mapped area, where they rest stratigraphically below Ammonia Tanks Tuff (Tma) and are interleaved with gravity-slide breccia of hornblende rhyolite lava (Txqh). Inferred to have been emplaced by gravitational sliding during and following development of a large, concealed, geophysically expressed (Grauch and others, 1997), north-striking normal fault located about ½ km east of the deposit. Movement of the slide debris probably occurred down an east-facing escarpment created by this fault following deposition of Tiva Canyon Tuff (Tpc; 12.7-Ma), but before deposition of Rainier Mesa Tuff (Tmr; 11.6-Ma). Maximum exposed thickness of map unit about 15 m

Txqh **Gravity-slide breccia of hornblende rhyolite lava (Miocene)**—Crackle breccia deposits composed mostly of hornblende rhyolite lava (Tqh). Breccia consists of intensely shattered, fractured, and locally disaggregated lava and has a sheet-like geometry. Deposits located along east flank of north-trending ridge west of Thirsty Mountain in southwest part of mapped area, where they rest stratigraphically below Ammonia Tanks Tuff (Tma) and are interleaved with breccia deposits of tuff of Sleeping Butte (Txqs). Inferred to have been emplaced by gravitational sliding during and following development of a large, concealed, geophysically expressed (Grauch and others, 1997), north-striking normal fault located about ½ km east of the deposit. Movement of the slide debris probably occurred down an east-facing escarpment created by this fault following deposition of Tiva Canyon Tuff (Tpc; 12.7-Ma), but before deposition of Rainier Mesa Tuff (Tmr; 11.6-Ma). Maximum exposed thickness of map unit about 30 m

Paintbrush Group (Miocene)--Metaluminous assemblage of alkali rhyolite tuffs and lavas erupted between 12.8 and 12.7 Ma from caldera largely concealed by the younger, overlapping Timber Mountain caldera complex (Sawyer and others, 1994). The Claim Canyon caldera, the well-established source of the Tiva Canyon Tuff (Tpc), is partially preserved just south of the Timber Mountain caldera complex (Byers and others, 1976; Wahl and others, 1997). The Tiva Canyon is the only Paintbrush unit exposed in the mapped area. Rocks of the Paintbrush Group are distinguished by an absence or rarity of quartz phenocrysts in rhyolite units and the general presence of sphene. In mapped area, consists of:

Tpc **Tiva Canyon Tuff**—Light- to medium-gray-brown, metaluminous nonwelded to partly welded ash-flow tuff erupted at 12.7 Ma from Claim Canyon caldera. Compositionally zoned from a lower crystal-poor rhyolite (common sanidine, sparse hornblende, and abundant sphene) to an upper trachyte (common sanidine and plagioclase, sparse biotite and clinopyroxene, rare hornblende, and sparse sphene). Distinguished by dominance of sanidine among felsic phenocrysts, lack of quartz, presence of sphene, and reversed magnetic polarity. Exposed only along escarpment in west-central part of mapped area, where unit has a thickness of about 35 m

Txbg **Gravity-slide breccia of Grouse Canyon Tuff (Miocene)**—Breccia deposits composed mostly of Grouse Canyon Tuff (Tbg). Consists of intensely shattered, fractured, and mostly disaggregated welded tuff blocks that are generally clast supported. Void spaces are occupied by pulverized and comminuted welded and, locally, nonwelded tuff. Unit located in the northwestern part of mapped area, chiefly along the down-thrown side of large normal-oblique faults, suggesting that breccia was emplaced by gravity sliding down fault scarps during or following their development. Stratigraphic relations of breccia indicate that such faulting and landsliding occurred following emplacement of Grouse Canyon Tuff at 13.7 Ma, but before eruption of onlapping Tiva Canyon Tuff (Tpc) at 12.7 Ma. Maximum exposed thickness of map unit about 30 m

Belted Range Group (Miocene)--Peralkaline assemblage of ash-flow sheets, lavas, and related nonwelded tuff erupted from the Grouse Canyon caldera of the Silent Canyon caldera complex, located northeast of the mapped area, between 13.85 and 13.5 Ma (Sawyer and others, 1994). Eruption of the Grouse Canyon Tuff (Tbg and Tbgb), the only Belted Range unit in the mapped area, was the major caldera-forming event. Belted Range Group is distinguished by its peralkaline mineralogy and chemistry; petrographically, it is characterized by high alkali feldspar and low plagioclase contents, absence of biotite and hornblende, and presence of Fe-rich clinopyroxene and fayalitic olivine. Chemically, Belted Range Group is distinguished by high iron and low aluminum in rhyolitic compositions, and anomalous, high concentrations of zirconium and heavy rare-earth elements. In mapped area consists of:

Tbg **Grouse Canyon Tuff**--Widespread peralkaline welded ash-flow sheet erupted at 13.7 Ma from Grouse Canyon caldera of the Silent Canyon caldera complex (Sawyer and others, 1994). Compositionally zoned from lower aphyric comendite to upper, moderately crystal-rich comendite (common alkali feldspar and rare quartz, plagioclase, clinopyroxene, and fayalitic olivine). Groundmass arfvedsonite is common in devitrified, welded upper part. Includes basal aphyric comendite bedded tuff where not mapped separately as the bedded Grouse Canyon tuff (Tbgb). Unit distinguished by high alkali feldspar content relative to other felsic phases, absence of biotite, strong zonation, conspicuous greenish- to bluish-gray color of lower welded tuff and bedded tuff, and anomalous normal magnetic polarity. Exposed in western part of mapped area, where unit has maximum thickness of about 100 m

Tbgb **Bedded Grouse Canyon Tuff**--Greenish- to bluish-gray, aphyric, comendite bedded tuff directly underlying, and comagmatic with, the Grouse Canyon Tuff. Consists of multiple, normally graded, 3-15 m thick beds each containing basal pyroclastic shards and pumice grading upward to fine ash.

Lower part may locally include coerupted rhyolitic nonwelded tuffs. Maximum exposed thickness about 30 m

Tob **Older basalt (Miocene)**--Local basalt and(or) basaltic andesite lava flows beneath Grouse Canyon Tuff (Tbg) in northwestern part of mapped area. Locally very crystal rich, containing very abundant olivine, common clinopyroxene, and common to rare plagioclase. Distinguished from other basalt units by its high phenocryst content and lower stratigraphic position. Maximum exposed thickness about 20 m

Volcanic rocks of Quartz Mountain (Miocene)—Metaluminous assemblage of rhyolitic ash-flow tuffs and lavas and associated tephra envelopes. Volcanic rocks erupted between about 14.9 and 14.2 Ma (M.A. Lanphere, R.J. Fleck, and D.A. Sawyer, written commun., 1998) from mostly unidentified vents within and just north of the mapped area where the assemblage is extensively exposed and forms locally thick stratigraphic sequences (Noble and Christiansen, 1968; Byers and others, 1976; Minor and others, 1993; Grauch and others, 1997). In mapped area the volcanic rocks of Quartz Mountain consist of: (1) lower, local sedimentary rocks (Tqhs), partly welded tuff (Tqht) and Tuff of Tolicha Peak (Tqt); (2) an overlying sequence of rhyolite lavas and associated pyroclastic rocks (Tqh, Tqhb, Tqp, and Tqpb); (3) Tuff of Sleeping Butte (Tqsu, Tqsp, Tqsm, and Tqsl); and (4) a local, upper rhyolite lava (Tqg) (Byers and others, 1976; Ferguson and others, 1994; Warren and others, in press). These units are described individually below:

Tqg **Crystal-poor rhyolite lava (Miocene)**—Flow-foliated and flow-banded, partly vitric, crystal-poor, rhyolite lava flow and associated tephra envelope. Contains sparse alkali feldspar and rare plagioclase and clinopyroxene. Chemically similar to the pyroxene rhyolite lava (Tqp) and the hornblende rhyolite lava (Tqh), but separated from them stratigraphically by the tuff of Sleeping Butte (Tqsu, Tqsp, Tqsm, and Tqsl). Crystal-poor rhyolite exposed only along escarpment in west-central part of mapped area, where unit has a maximum thickness of about 60 m

Tuff of Sleeping Butte (Miocene)--Two genetically related metaluminous rhyolite ash-flow tuff cooling units exposed in Sleeping Butte area in southwestern part of mapped area: (1) an upper nonwelded tuff (Tqsu), and (2) a lower, strongly zoned welded tuff (Tqsp, Tqsm, and Tqsl). Tuffs erupted at 14.27±0.04 Ma (M.A. Lanphere, R.J. Fleck, and D.A. Sawyer, written commun., 1998) from an unknown, nearby (?) source (Byers and others, 1976;

Grauch and others, 1997). Exposed cumulative thickness about 1,000 m. Subdivided into:

Tqsu **Upper nonwelded tuff**—Nonwelded to partly welded, massive, lithic-rich ash-flow tuff, with common alkali feldspar and plagioclase and rare biotite. Includes rare partings. Tuff laps onto lower welded tuff (Tqsp, Tqsm, and Tqsl) east of Sleeping Butte. Maximum exposed thickness more than 250 m

Lower welded tuff—Compositionally zoned welded ash-flow tuff that is distinguished by its high sanidine content, locally abundant granitoid inclusions, stratigraphic position, and normal magnetic polarity. Cumulative exposed thickness about 1,000 m. Subdivided on the basis of degree of welding and crystal composition into three facies (Tqsl, Tqsm, and Tqsp) that generally grade abruptly into one another:

Tqsp **Upper partly welded facies**—Crystal-rich ash-flow tuff containing common sanidine and plagioclase and sparse quartz, biotite, and clinopyroxene. Weathers to a lighter grayish-brown color than the underlying middle welded facies (Tqsm) into which it grades. Locally contains rounded granitoid inclusions as much as 0.5 m in diameter. Maximum exposed thickness about 150 m

Tqsm **Middle welded facies**--Densely welded ash-flow tuff that is strongly zoned from lower mafic-poor rhyolite with common sanidine and quartz, sparse plagioclase, and rare pseudomorphs of clinopyroxene and (or) hornblende, to upper crystal-rich rhyolite with abundant sanidine and plagioclase, sparse pseudomorphs of hornblende and (or) clinopyroxene and biotite, and rare quartz. Black thin (< 5 m) vitrophyre is locally preserved at base where lower crystal-poor welded facies (Tqsl) is absent south of Sleeping Butte. Upper part of facies contains rounded granitoid inclusions as much as 0.5 m in diameter. Maximum exposed thickness about 650 m

Tqsl **Lower crystal-poor welded facies**—Densely welded ash-flow tuff that is welded down to its base. Contains rare quartz, sanidine, plagioclase, and biotite. Present only west of Sleeping Butte, from where it thickens dramatically continuing westward across west border of mapped area. Although no vitrophyre is preserved at its base in mapped area, one is present just west of map border. Distinguished by its crystal-poor nature, its ubiquitous small, hackly fractures, and its susceptibility to erosion. Maximum exposed thickness about 200 m

Tqp **Pyroxene rhyolite lava (Miocene)**--Flow-foliated, flow-banded, and flow-folded, metaluminous rhyolite and lesser dacite lava flows and domes, and related tephra envelopes that are distinguished by the presence of clinopyroxene and the lack of quartz phenocrysts. Contains common sanidine and plagioclase, sparse biotite, rare clinopyroxene, and abundant sphene. Lava is partly vitric. Erupted at about 14.3 Ma from vents near the northwest corner of mapped area (M.A. Lanphere, R.J. Fleck, and D.A. Sawyer, written commun., 1998; Minor and others, 1993); a subvertical east-northeast-striking feeder is present in northwesternmost part of mapped area. Lava flows have reversed magnetic polarity. Exposed in northwest part of mapped area, where map unit has a maximum exposed thickness of more than 250 m

Tqpb **Pyroxene rhyolite pyroclastic rocks (Miocene)**—Bedded tuff and massive tuff breccia that are comagmatic with, and compositionally similar to, the pyroxene rhyolite lavas (Tqp). Bedded tuff is nonwelded, crystal- and lithic-rich, and partly zeolitized. Tuff breccia, inferred to be block-and-ash-flow deposits, contains blocks and fragments of partly vitric pyroxene rhyolite lava. Exposed in northwest part of mapped area, where map unit has a maximum exposed thickness of about 200 m

Tqh **Hornblende rhyolite lava (Miocene)**—Flow-foliated, flow-banded, and flow-folded, metaluminous rhyolite and lesser dacite lava flows and domes, and related tephra envelopes that are distinguished by the presence of hornblende and quartz. Contains common sanidine, plagioclase, and quartz, and sparse hornblende. Erupted at 14.34±0.04 Ma mainly from vents near the northwest corner of mapped area (M.A. Lanphere, R.J. Fleck, and D.A. Sawyer, written commun., 1998; Minor and others, 1993), but lava and associated pyroclastic rocks (Tqhb) presumably also erupted in the area of exposures in the southwest part of mapped area. Lava flows have reversed magnetic polarity. Maximum exposed thickness about 200 m

Tqhb **Hornblende rhyolite pyroclastic rocks (Miocene)**—Bedded tuff and bedded-to-massive tuff breccia that are comagmatic with and compositionally similar to the hornblende rhyolite lavas (Tqh); also includes subordinate tuffaceous sedimentary rocks. Bedded tuff is nonwelded, crystal- and lithic-rich, and partly zeolitized. Tuff breccia, inferred to be block-and-ash-flow deposits, contains blocks and fragments of partly vitric hornblende rhyolite lava. Map unit poorly exposed near northwest and southwest corners of mapped area. Maximum exposed thickness about 200 m

Tqht **Partly welded tuff (Miocene)**—Distinctive purplish-gray, partly welded ash-flow tuff that is compositionally similar to the hornblende rhyolite lavas (Tqh). Exposed at base of hornblende rhyolite pyroclastic rocks (Tqhb) near southwest corner of mapped area. Maximum exposed thickness about 30 m

Tqt? **Tuff of Tolicha Peak (Miocene)**—Distinctive light-to-dark-gray, metaluminous, very-crystal-poor, partly welded rhyolite ash-flow tuff erupted at 14.30±0.10 Ma (M.A. Lanphere, R.J. Fleck, and D.A. Sawyer, written commun., 1998) from unknown, nearby source possibly buried beneath northern part of mapped area (Minor and others, 1993; Grauch and others, 1997). Contains rare plagioclase, sanidine, quartz, and biotite. Exposed only in a small area just south of Sleeping Butte, near the west border of mapped area, where its identity as Tolicha Peak is uncertain. Normal magnetic polarity. Maximum exposed thickness about 100 m

Tqhs **Sedimentary rocks (Miocene)**—Generally poorly exposed, bedded, partly tuffaceous sandstone, siltstone, shale, and limestone. Zeolitic in part. Maximum thickness about 50 m where exposed along south border of mapped area

MAP DATABASE

This map database, identified as the *Digital geologic map of the Thirsty Canyon NW quadrangle, Nye County, Nevada*, has been approved for release and publication by the Director of the USGS. Although this database has been subjected to review and is substantially complete, the USGS reserves the right to revise the data pursuant to further analysis and review. Furthermore, it is released on condition that neither the USGS nor the United States Government may be held liable for any damages resulting from its authorized or unauthorized use.

The map database, which is available in ArcINFO EXPORT and PDF formats, can be downloaded from *http://greenwood.cr.usgs.gov.*

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The Thirsty Canyon NW 7.5' quadrangle is located in southern Nye County about 20 km west of the Nevada Test Site (NTS) and 30 km north of the town of Beatty (fig.1). Access into the mapped area, which is entirely within the Nellis Air Force Bombing and Gunnery Range, is restricted and requires Nellis pre-approval and escort. The area was mapped in support of the U.S. Department of Energy's NTS Weapons Program and, more recently, in support of the Department's NTS Environmental Restoration Program. Understanding the geology of the Thirsty Canyon NW quadrangle is of great importance to the latter program inasmuch as ground water flowing from the nearby Pahute Mesa underground nuclear testing area may travel beneath the mapped area.

COMPILATION METHODS

The current map database incorporates geologic data from: (1) early geologic mapping (1965-1969) by P.P. Orkild and K.A. Sargent of chiefly flat-lying volcanic rocks in the eastern part of the mapped area; (2) more recent field mapping (1991-1995) by S.A. Minor of older, more deformed bedrock terrane (i.e., pre-~12-Ma rocks) in the western part of the mapped area; (3) recent (1994) mapping by S.A. Minor and D.A. Sawyer of part of the Thirsty Mountain shield volcano in the southern part of the mapped area; (4) recent mapping (at 1:100,000-scale detail) of surficial deposits mainly in the southwestern part of the mapped area (Wahl and others, 1997); and (5) new detailed petrographic and geochemical data of Tertiary volcanic units of the southwest Nevada volcanic field obtained by R.G. Warren and D.A. Sawyer (Warren and others, in press). Hand-drafted stable-base layers of the early mapping were scanned and vectorized and

Hand-drafted stable-base layers of the early mapping were scanned and vectorized and then edited using AutoCAD software. New geologic field data, which were mapped on aerial photographs of about 1:24,000 scale, were mainly digitized directly from the photographs using a Kern PG-2 stereographic plotter interfaced with CADMAP digital capturing software. The new map data were also imported into AutoCAD for editing. Geographic Resource Analysis Support System (GRASS), a public-domain GIS, was used to transform the component map files to Universal Transverse Mercator (UTM) projection and coordinate system. The various map data layers were then converted to ArcINFO coverages. ArcINFO was used to conduct final editing and modification of map elements, build and tag polygons, assign attributes to map elements, and generate a plot file of the final geologic compilation.

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