USGS Open-File Report 96-261

Digital Bedrock Geologic Map Database of the Beatty 30 x 60-minute quadrangle, Nevada and California

Geologic Explanation

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DESCRIPTION OF MAP SYMBOLS

Contact

Fault—Solid where certain; long dash where approximately located; short dash where inferred, dotted where concealed

Normal fault—Bar and ball on down-thrown side

Thrust fault—Barbs on upper plate

Attenuation fault—Hachures on upper plate

Recently active fault—Fault displaying evidence of movement during the Quaternary Period (past 2 Ma); distinguished only in database

Metamorphic boundaries (shown in green)

Depositional contact—Contact between overlying alluvium and underlying metamorphic rocks

Fault—Juxtaposing rocks of different metamorphic grade

Metamorphic facies boundary—Approximately located

Description of metamorphic facies:

SG S**ubgreenschist facies**-—Includes non-metamorphosed sedimentary strata or weakly metamorphosed strata. Pelitic rocks are shales or slates and carbonate rocks are limestone, dolomite, or marble equivalents. Carbonate rocks lack metamorphic phyllosilicates

G **Greenschist facies—**Pelitic rocks are phyllites or fine-grained schist and commonly contain muscovite and chlorite. At Bare Mountain, the Stirling Quartzite also contains one or more of staurolite, chloritoid and garnet. In the central Funeral Mountains, the Johnnie Formation also commonly contains chloritoid and garnet and the Stirling Quartzite commonly contains kyanite and chloritoid. Carbonate rocks are marbles and may contain one or more of talc, clinochlore, and muscovite

gar n **First occurrence of garnet**

LA **Lower amphibolite facies—**Pelitic schist commonly contains muscovite, biotite and chlorite. At Bare Mountain, the Wood Canyon Formation also contains garnet and staurolite. Carbonate rocks of the Wood Canyon Formation may contain muscovite and tremolite

MA **Middle amphibolite facies—**Applies to rocks in the northern Funeral Mountains and southern Bullfrog Hills. Pelitic schist of the Kingston Peak Formation, Johnnie Formation, Crystal Spring Formation and 1.7 Ga basement rocks contains muscovite and biotite and one or more of garnet, staurolite and kyanite

UA **Upper amphibolite facies—**Applies to rocks in the northern Funeral Mountains. Pelitic schist of the Crystal Spring Formation and 1.7 Ga basement rocks contains muscovite, biotite, and one or more of kyanite, sillimanite and garnet. Rocks lack or contain little staurolite

Metamorphic isograd—Defined by mineral reaction of first occurrence of index mineral

Caldera boundaries (shown in turquoise)—Solid where certain; dashed where approximately located

Inferred caldera margin—Nature of margin uncertain

Structural caldera margin

Topographic caldera wall—Hatcheries point toward topographic depression

Strike and dip of bedding

Inclined

Vertical

Overturned

Strike and dip of foliation—Defined by fiamme in Tertiary volcanic rocks, metamorphic foliation in Paleozoic and Proterozoic metasedimentary rocks

Inclined

Vertical

Axial trace of fold—Solid where certain; dashed where approximately located. (Major and minor fold map-scale folds distinguished in database. Direction of plunge indicated in database by line direction)

Anticline

Upright

Overturned

Syncline

Upright

Overturned

COMPILATION METHODS

The current map database incorporates geologic data from: (1) digitized (by scanning) polygon, fault, and structural attitude layers of the published 1:100,000-scale geologic map of the Nevada Test Site (NTS) (Frizzell and Shulters, 1990, and Figure 1a, Sources of Compiled Geologic Data); (2) the digital 1:100,000-scale geologic compilation of the Pahute Mesa 30' by 60' quadrangle (Minor and others, 1993); (3) the digital database compilation of the NTS by Sawyer and others (1995), and (4) recent field studies of stratigraphy and structure by the authors and others. Numerous revisions of the NTS area were also made by adding new field and stratigraphic data to the published 1:24,000- scale geologic data (see Figure 1b; Sources of Original Geologic Data).

The map dataset may produce some minor display conflicts that reflect limitations of the algorithms used to automatically generate the labels; unit labels of some narrow polygons extend into adjoining polygons, and faults or fault decorations (e.g., ball and bars) locally overlap map unit labels or structural attitude symbols. These labeling conflicts were not resolved for this version of the map because they do not affect the quality or resolution of the database when used in a GIS. The reader is referred to published copies of the component U.S. Geological Survey base maps (Pahute Mesa, Beatty, Indian Springs, Pahranagat Lakes 1:100,000-scale maps) for clarification of place names and other geographic base map features. The geologic map dataset is considered an accurate compilation at the line-width and simplified polygon geometry depicted at 1:100,000-scale level of detail. Enlarging or viewing the dataset at scales greater than about 1:50,000 (in particular with comparison to 1:24,000-scale topographic or published geologic maps) will in some cases show polygon contacts or structural features to be inaccurately located at the larger scales of resolution.

DESCRIPTION OF MAP UNITS

The descriptions for Tertiary map units were largely compiled using recent petrographic, chemical, stratigraphic, and geochronologic data by D. A. Sawyer, S. A. Minor, and R. G. Warren. The pre-Tertiary unit descriptions were largely compiled by M.D. Carr, and descriptions of Quaternary and other surficial units were based on information contributed by WC Swadley (USGS, 1994, written communication). Volcanic rock names 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 Tables 1 to 3 below; in basaltic rocks the modifiers "phenocryst- rich" and "-poor" are substituted for "crystal- rich" and "-poor", respectively, to distinguish phenocrysts and microphenocrysts from coarse groundmass crystals common in those rocks. Phenocryst mineral abundances are from unpublished median data compiled for individual Southwest Nevada Volcanic Field (SWNVF) units by R. G. Warren. Table 2 below shows terms used to indicate median abundances for felsic phenocrysts (quartz, K-feldspar=sanidine + anorthoclase, and plagioclase), for mafic minerals (biotite, hornblende, arfvedsonite, orthopyroxene, clinopyroxene, acmite, 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 below, 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 fro the SWNVF, they may be inappropriate when applied to other volcanic fields.

Tertiary volcanic stratigraphic nomenclature is from Sawyer and others (1994) and the Los Alamos National Laboratory GEODES database (Ferguson and others, 1994). Some map unit descriptions and informal unit names cited within those reports are derived from descriptions in published USGS Geologic Quadrangle (1:24,000-scale) and Miscellaneous Investigations (1:48,000-scale) Series maps (see Sources of Geologic Data figures), from the GEODES data, or, in the case of central Nevada volcanic units, from Scott and others (in press). The revised SWNVF stratigraphic framework used in this report builds upon the reports of Ekren and others (1971), Byers and others (1976b, 1989), and Carr and others (1986), and from the regional compilation maps of Orkild and others (1969), Sargent and Orkild (1973), Byers and others (1976a), and Minor and others (1993).

Stratigraphic nomenclature used for the pre-Tertiary sedimentary units is outlined in Monsen and others (1992), Cole and others (1989), Guth (1986, 1990), Cashman and Trexler (1994), and Minor and others (1993), and is based on many published studies cited by them. Descriptions of these units are largely summarized from published geologic map descriptions (see Sources of Geologic Data figures), and supplemented by Cole and others (1989, 1994), Miller (1989), Monsen and others (1992), Cole (1991), Cashman and Trexler (1991, 1994), and some unpublished data. Plutonic rock names are based on the IUGS classification scheme of Streckeisen (1976).

Reported ages for volcanic units are based mainly on ^{40}Ar/^{39}Ar age determinations (Best and others, 1989; Fleck and others, 1991; Noble and others, 1991; Sawyer and others, 1994). Published ^{40}Ar/^{39}Ar ages from Hausback and others (1990) were recalculated using a 513.9 Ma monitor age for MMHB-1 (Lanphere and others, 1990; Dalrymple and others, 1993). ^{40}Ar/^{39} ages are supplemented by published K/Ar results of Kistler (1968) and Marvin and others (1970, 1973, 1989), and Marvin and Cole (1979) recalculated using current IUGS constants (Steiger and Jaeger, 1977; Dalrymple, 1979). Asterisk [*] denotes isotopic age from literature corrected for decay and abundance constants recommended by Steiger and Jaeger (1977) using conversion tables of Dalrymple (1979). Previously unpublished conventional K-Ar ages for basalt flows east of Beatty Mountain and various volcanic units in the Bullfrog Hills are included in Appendices 1 and 2, respectively. Additional sources of radiometric ages are cited specifically in the map unit descriptions.

Magnetic polarity data are from published sources (Bath, 1968; Byers and others, 1976a and 1976b; Rosenbaum and Snyder, 1984; Noble and others, 1984; Carr and others, 1986; Rosenbaum and others, 1991; Hudson, 1992; Hudson and others, 1994). Normal polarity magnetizations have northerly declinations and moderate downward inclinations. Reverse polarity magnetizations have southerly declinations and moderate upward inclinations. Anomalous normal and reverse polarity magnetizations have downward or upward inclinations, respectively, but their directions lie at great (>45°) angles to the time-averaged late Tertiary expected direction for the area.

Some geographic place names mentioned in the descriptions are not labeled on the 1:100,000-scale topographic base map but are present on the larger-scale component topographic and geologic quadrangle maps that have been published. Where cited place names are not labeled on the base maps, locations of the named geographic features are described with respect to features that are labeled on these maps.

Metamorphic facies are mapped in the Funeral Mountains and in the Bare Mountain area and are based on studies by Hoisch and Simpson (1993) and Hoisch (1995).

QTa **Alluvial-fan, fluvial, and colluvial deposits, undivided**—Includes: Young alluvial-fan deposits (Holocene)—Gravel, gravelly sand, silty sand, and sandy silt. Light gray to light brownish gray to grayish brown, poorly to moderately well sorted, poorly to well bedded. Deposited as discontinuous beds and lenses forming alluvial-fan aprons adjacent to range fronts, thin sheet-like deposits on valley floors, low terraces in large washes, and bottoms of active washes. Includes Q1 deposits of Hoover and others (1981), flood-plain deposits and unit 4 of the alluvial-fan gravel of Wright and Troxel (1993)

Young fluvial deposits (Holocene)—Gravel, gravelly sand, silty sand, and sandy silt. Mainly deposits in channel and on flood plain of Amargosa River. Consists mainly of sheetflood sand deposits derived in part through reworking of wind-blown material (Swadley and Parrish, 1988). Equivalent, in part, to units Q1s and Q1ab (part) of Swadley and Parrish (1988)

Deposits of Lake Manly (Pleistocene)—Mostly shore line gravel, locally includes some ponded silt (probably of Tioga age 10 to 30 ka). Base of unit is disconformity or local unconformity

Intermediate alluvial fan deposits (Pleistocene)—Gravel, gravelly sand, and silty sand. Clasts are locally derived. Yellowish brown to grayish brown, poorly to moderately well sorted, and poorly to well bedded. Forms terraces in washes and dissected alluvial fans. Commonly contains stage II or III calcrete horizon less than 1 m thick. Desert pavement is well developed on most deposits. Includes units Q2b, Q2bc, and Q2c of Hoover and others (1981) and units 2 and 3 of alluvial fan gravel of Wright and Troxel (1993)

Intermediate fluvial deposits (Pleistocene)—Unconsolidated to moderately consolidated gravel, gravelly sand, silty sand, and sandy silt. Mainly deposits in the channel and on the flood plain of the Amargosa River. Consists mainly of sheetflood sand deposits derived in part through reworking of wind blown material (Swadley and Parrish, 1988). Equivalent, in part, to unit Q2s of Swadley and Parrish (1988)

Old alluvial fan deposits (Pleistocene and Pliocene)—Poorly to moderately consolidated gravel, generally with sparse sand and silt in matrix. Clasts are locally derived. Angular to subrounded, poorly sorted, and nonbedded to well bedded. Forms dissected alluvial fans and fan remnants. Typically has well developed stage IV calcrete horizon as much as 2 m thick. Commonly has moderate desert pavement and numerous weathered stones on deflated surface of deposit. Includes QTa deposits of Hoover and others (1981); unit 1 of alluvial fan gravel of Wright and Troxel (1993); and locally, may contain deposits equivalent to gravels of Oasis Valley (Tog below). Base of unit is disconformity or local angular unconformity.

Colluvial deposits (Holocene to Pliocene)—Angular boulders, gravel, and sand of local derivation, forming talus aprons and thin surficial veneers that obscure bedrock. Commonly also contains admixtures of wind-blown sand and silt. Older deposits have strong desert varnish

Qe **Eolian sand and silt, undivided—**Includes:

Young eolian sand and silt (Holocene)—Wind-blown sand and silt forming dunes, sheets, mounds stabilized by vegetation, and ramps. Includes Q1e deposits of Hoover and others (1981)

Intermediate eolian sand and silt (Pleistocene)—Wind-blown sand and silt forming dunes, sheets, mounds stabilized by vegetation, and ramps. Includes Q2e deposits of Hoover and others (1981)

Qp**Playa deposits—**Includes:

Playa deposits (Holocene)—Compacted, poorly to moderately consolidated clay, silt, and fine sand; thinly bedded; calcareous; light grayish brown. Locally contains sparse thin beds or lenses of pebbly coarse sand. Deposited in intermittently flooded bottoms of closed drainage basins such as Yucca Lake in the southern part of Yucca Flat

Saline playa deposits (Holocene)—Evaporitic playa and paludal deposits in Cotton Ball Basin (floor of north-central Death Valley). Includes sand sheets indurated by carbonate or sulfate salts; massive gypsum capped by anhydrite and/or bassinite; sulfate salts; sodium carbonate and other carbonate salts; slabby rock salt forming an irregular surface capped by silt containing sulfate salt; reworked silty rock salt; rock salt having a smooth surface capped by silt containing sulfate and borate salts; rock salt having a rough surface capped by silt containing sulfate and borate salts (Hunt and Mabey, 1966; Wright and Troxel (1993)

Qt **Travertine (Holocene and Pleistocene)—**Spring generated travertine deposits, mostly along the southwest base of the Funeral Mountains

QTp **Older playa, marsh, and spring deposits (Pleistocene? and Pliocene)—**Pale yellowish-brown, white to very light- gray weathering marl and yellowish-gray to grayish-orange silt, which locally is calcareous and locally contains clayey zones. Contains beds as much as 1 m thick of limestone, as well as discontinuous zones containing small limestone nodules. (Swadley and Carr, 1987). Unit contains ash beds that have yielded isotopic dates of 3.2 and 2.1 Ma, and is interpreted as Pliocene in age (Hay and others, 1986). Exposed thicknesses as much as 50+ m (Hay and others, 1986). As much as 10 m of Pleistocene and/or Late Pliocene limestone, marl, and silt unconformably overlie the Pliocene deposits locally (Hay and others, 1986) and are included in this unit. Pleistocene and/or Late Pliocene beds locally are fossiliferous (Swadley and Carr, 1987). Base of unit is local angular unconformity

Qby **Younger Quaternary basalt (Pleistocene)—**Isolated cinder cone and lava flow, and feeder dikes at Lathrop Wells, about 10 km northwest of the town of Amargosa Valley (formerly known as Lathrop Wells). Well-preserved cone of very-dark-red, unconsolidated, basalt cinders and related ash deposits; contains some basalt blocks and bombs. Spatter cone deposits, having associated with them extruded, pillow- shaped masses of vesicular basalt and deposits of moderate-red basalt cinders, are aligned along, and partly buried beneath, the east side of the main cinder cone. The cinder cone and the spatter-cone deposits rest on black scoriaceous olivine basalt flows. Magnetic polarity of the basalt flows is normal

(Swadley and Carr, 1987). The age of the cinder cone has been interpreted as Holocene or latest Pleistocene by some workers on the basis of its morphology (Wells and others, 1990). Rock compositions are mainly phenocryst-poor trachy basalt and basalt; more sodic samples, including hawaiite, are uncommon. Phenocrysts consist of common olivine and sparse plagioclase. Distinguished by a low phenocryst abundance, predominance of olivine, by young age [about 130 Ka for Lathrop Wells basalt (Turrin and others, 1992)] and geomorphic appearance of cinder cone vents, and by normal magnetic polarity

Qbo **Older Quaternary basalt (Pleistocene)—**Basalt flows and moderately dissected scoria mounds of black to dark reddish- brown olivine basalt. Includes volcanic centers at Red, Black, and Little Cones in Crater Flat (Faulds and others, 1994). Basalt has yielded whole-rock potassium-argon dates of about 1.1 Ma (Fleck and others, in press). Magnetic polarity is reverse (Rosenbaum and Snyder, 1984)

Typ**Pliocene and youngest Miocene basalt (Pliocene)—**Basaltic trachyandesite cinder cones, lava flows, and feeder dikes erupted from volcanic centers in southeastern Crater Flat (3.73 ± 0.02 Ma; reverse polarity; Fleck and others, in press]. Consists of lava flows and eroded scoria mounds of dark gray to dark-reddish-brown basalt. Phenocrysts vary from common to abundant olivine in southeast Crater Flat. Distinguished by marked preservation of constructional volcanic geomorphology, Pliocene age, and reverse magnetic polarity. Maximum exposed thickness of 100 m

Tgf**Funeral Formation (Pliocene and Late Miocene?)—** Mostly fanglomerate derived from Funeral Mountains. Clasts derived predominantly from Wood Canyon Formation and Stirling Quartzite with sparse clasts from Johnnie Formation. Locally intertongues with unconsolidated silty lacustrine deposits (Wright and Troxel, 1993). A whole rock potassium-argon age of about 4.1 Ma* was determined for a sample of basalt collected from the upper part of the Funeral Formation approximately 4.4 km north-northeast of Ryan, California (McAllister, 1973). The fanglomerate assigned to the Funeral Formation on this map may be younger than the basalt-bearing upper part of the Funeral dated in the Ryan area. The Funeral Formation is tilted and is unconformably overlain by alluvial-fan deposits that retain their original, albeit degraded, fan morphology. Base of unit is local angular unconformity

Tgy**Younger sedimentary deposits (Pliocene and Miocene)—**General designation for Tertiary sedimentary deposits that are older than "old alluvial fan deposits" (QTa), are younger than the Paintbrush Tuff, and are not demonstrably deposits of Oasis Valley sedimentary basin or Timber Mountain caldera moat. Consists mainly of poorly consolidated, poorly sorted, subrounded to well-rounded gravel and sand forming strongly dissected alluvial surfaces in northwestern Crater Flat, Mercury Valley ("older alluvium" of Hinrichs, 1968), and west of Point of Rocks. Monolithologic breccia derived from Paleozoic carbonate rocks and other nearby bedrock locally occurs at the base of, and within, the unit. Deposits in northern Crater Flat contain beds of volcanic ash that yielded conventional potassium-argon ages of 7.7 to 8.7 Ma (Monsen and others, 1992); deposit west of Point of Rocks contains bed of volcanic ash that yielded fission-track zircon age of 11.5 Ma (Metcalf, 1982). Includes tilted alluvial fan deposits such as "older gravels" (part) of Cornwall and Kleinhampl (1964) and "sedimentary rocks" of Wright and Troxel

(1993) in northern Amargosa Desert along the east edge of the Funeral Mountains. These deposits rest on Timber Mountain Tuff or older units. "Thirsty Canyon and younger basalts" (Tyb) are intercalated with or overlie these deposits; "younger basalt" flow dated at 7.5 Ma (Appendix 2) rests on "young sedimentary deposits" east of Porter Mine. Unit includes Pliocene and Miocene "alluvium and colluvium" and "sedimentary rocks" of Swadley and Carr (1987) in southern Crater Flat. Pumice from a tuffaceous sandstone bed within "sedimentary rocks" unit yielded zircon dated at about 6 Ma by the fission-track method (Swadley and Carr, 1987). Also includes Tcg-Specter Range NW, Striped Hills, Topopah Spring 7.5; Tgs-Topopah Spring NW, Toa- Skull Mountain; Tac-Skull Mountain, Cane Spring 7.5. Consists of basin-fill deposits and fan alluvium composed mainly of poorly sorted, poorly to moderately bedded, angular to rounded gravel and sand in a locally tuffaceous matrix; typically weakly cemented. Clasts in unit composed of locally derived Tertiary volcanic rocks and lesser Pre-Tertiary sedimentary rocks, and include boulders as much as 3 m in diameter. Unit forms very strongly dissected alluvial fans in northern Crater Flat that include several levels of younger gravel deposits comprising small pediment remnants. Unit distinguished from temporally overlapping caldera moat-filling sedimentary deposits by extracaldera distribution of unit, and from younger landslide and sedimentary breccias and late synvolcanic sedimentary deposits by the higher stratigraphic position of the unit

Tgfc **Furnace Creek Formation (Late Miocene)—**Mostly fanglomerate, derived mainly from reworking of older Tertiary gravels similar to those still exposed along the flanks of the Funeral Mountains in the upper plate of the Boundary Canyon fault. Locally intertongues with unconsolidated silty lacustrine sediments (Wright and Troxel, 1993). A minimum age of about 5.5 Ma* and a maximum age of about 6.5 Ma* were reported for the Furnace Creek Formation on the basis of conventional potassium-argon dates for volcanic units above and below the Furnace Creek in the Dante's View area, approximately 25 km south of the map (Fleck, 1970); a similar maximum age was reported by Cemen and others, 1985). Diatoms of Hemphillian age were reported from the upper part of the formation in the Furnace Creek area (McAllister, 1970), placing the top of the unit in the Early Pliocene or Late Miocene and consistent with isotopic ages. Base of unit is local angular unconformity

Tgo **Gravel of Oasis Valley (Pliocene and Late Miocene)—**Poorly to well consolidated, poorly sorted, subrounded to well-rounded gravel and conglomeratic sandstone. Forms very strongly dissected alluvial- fans in Oasis Valley and Beatty Wash. Contains locally derived clasts of Tertiary volcanic and upper Proterozoic to Paleozoic sedimentary rocks; boulders as large as 3 m in diameter. Broken, well-rounded pebble- to cobble-sized clasts of quartzite and chert are recycled from older Tertiary deposits. Monolithologic breccia (Tyx) derived from Paleozoic carbonate rocks locally occurs at the base of, and within, the unit. Includes the "older gravels" (part) of Cornwall and Kleinhampl (1961, 1964) in the Bullfrog and Bare Mountain 15' quadrangles, "Miocene gravel and sandstone" (part) of Swadley and Parrish (1988), and "tuffaceous sandstone and gravel" (part) of Christiansen and Lipman (1965). Equivalent in part to gravel of Sober-up Gulch of Maldonado and Hausback (1990). Unit locally contains interbedded, partly tuffaceous sandstone and mudstone and layers of nonwelded vitric tuff and limestone; such interbedded, finer grained deposits form a 65-m-thick interval within gravel deposits north of Beatty Wash described as "interbedded sandstone and mudstone" unit of Swadley and Parrish (1988). This interval consists of light-gray to grayish- yellow, fine-grained, moderately to well-sorted, thin- to medium-bedded tuffaceous sandstone and grayish-yellow to greenish-gray, thinly bedded mudstone, locally containing pumice fragments. North of map area, basalt flows of the 4.63-Ma Thirsty Mountain shield volcano intertongue with gravels in lower Thirsty Canyon (Minor and others, 1993). Spearhead Member of the Stonewall Flat Tuff (isotopically dated as 7.6 Ma by Hausback and others, 1990) intertongues with lower part of the gravel and sand unit near mouth of Beatty Wash and in Bullfrog Hills. Rests in angular unconformity on older units. Thickness 0 to 180 m (Swadley and Parrish, 1988). Base of unit is local angular unconformity

Tsp**Spearhead Member of Stonewall Flat Tuff (Miocene)—**Welded ash-flow tuff erupted from Stonewall Mountain caldera at 7.6 Ma. Consists of grayish-pink, nonwelded to partly welded ash-flow tuff containing abundant glass shards. Compositionally zoned from lower crystal-poor comendite, containing common alkali feldspar, sparse clinopyroxene, and rare fayalitic olivine, plagioclase, and quartz, to upper comendite containing abundant alkali feldspar, sparse plagioclase, clinopyroxene, and fayalitic olivine, and rare quartz, biotite, and hornblende; upper zone is only locally present. Magnetic polarity normal. Maximum exposed thickness about 50 m

Tyb**Thirsty Canyon and younger basalts (Miocene)—**Widespread trachybasalt, basaltic trachyandesite, basalt, and basaltic andesite lava flows, eroded cinder cones, and feeder dikes erupted from several centers between 9.9 and 6.3 Ma. General designation for basalts equivalent in age to, or younger than, silicic volcanic rocks of the Thirsty Canyon Group. Dark gray, dense to vesiculated basalt flows. Distribution is generally north and west of Timber Mountain in areas adjoining Black Mountain caldera and Stonewall Mountain volcanic center. Basalts erupted just prior to, during, and following the peralkaline volcanic rocks (Thirsty Canyon Group) of the Black Mountain caldera. Basalts adjoining Black Mountain caldera in west part of map area are variable in composition from basalt and alkali basalt to trachybasalt and trachybasaltic andesite, and 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, biotite, and orthopyroxene, rare kaersutitic amphibole, and very abundant apatite are locally present. Numerous basalt feeder dikes (unmapped at 1:100,000-scale) were emplaced southwest of Black Mountain caldera. Olivine and plagioclase contents, and stratigraphic range are distinctive. Maximum exposed thickness about 100 m. Basalts of this group yield whole rock potassium-argon ages between about 5.3 and 9.15 Ma. Includes: basalt near Currie Well yielding age of 8.1 ± 0.4 Ma (Maldonado, 1990; Appendix 2); basalt between Hooligan mine and Daylight Pass yielding age of 7.5 ± 0.3 Ma (Appendix 2); "basalt lava flows" (Tb3) of Maldonado (1990); "basalt" (part) of Cornwall and Kleinhampl (1964); Pliocene or Miocene basalt flows intercalated with "younger sedimentary deposits" (Tys) and associated feeder dikes intruding older Tertiary deposits in hills northeast of Funeral Mountains (Wright and Troxel, 1993). Included in "older rift basalts" by Crowe and others (1983)

Tgm **Late synvolcanic sedimentary rocks (Miocene)**—Weakly to moderately consolidated, generally well-bedded pebble to cobble conglomerate, breccia, sandstone, siltstone, and locally reworked nonwelded tuff. Variously rounded clasts, predominantly of Miocene volcanic and Proterozoic/Paleozoic sedimentary provenance, supported in tuffaceous matrix; tuffs form thin (less than 1 m), generally isolated beds, are commonly vitric, and contain pumice lapilli. Unit distinguished from younger landslide and sedimentary breccias by higher stratigraphic position, typically smaller size and greater rounding of clasts, and higher proportion of tuffaceous clasts and matrix, and from caldera moat-filling sedimentary deposits by extracaldera distribution. Late synvolcanic sedimentary rocks deposited in local paleobasins and paleochannels in the Little Skull Mountain area; deposition of unit occurred following eruption of Timber Mountain units but before, during, and after eruption of the Thirsty Canyon Group and temporally associated basalts with which unit is locally interlayered. Maximum exposed thickness about 125 m

Tgc**Caldera moat-filling sedimentary deposits (Miocene)**—Consists of intercalated fan alluvium and subordinate lacustrine deposits and nonwelded tuff. Fan alluvium composed of coarse, poorly sorted, unevenly bedded, angular to rounded gravel, sand, and minor silt in a locally tuffaceous matrix; clasts, as large as 1 m, consist of locally derived volcanic rocks; weakly to moderately cemented. Lacustrine deposits include interbedded, partly tuffaceous sandstone and mudstone and water-laid tuff. Tuff beds, as much as 0.5 m thick, consist of pumice-bearing ash-fall and ash-flow tuff. Unit poorly exposed; most slopes mantled by gravelly sand. Caldera sedimentary deposits distinguished from younger sedimentary deposits by the limited extent within the Timber Mountain caldera complex. Timber Mountain deposits overlie intracaldera 11.45 Ma Ammonia Tanks Tuff, intertongue with Pahute Mesa and Trail Ridge Tuffs, and underlie 2.82 Ma basalt at Buckboard Mesa. Maximum thickness about 300 m in Timber Mountain caldera complex (Minor and others, 1993)

Tgyx **Younger landslide and sedimentary breccias (Miocene)**—Brecciated slide blocks and sheets, sedimentary breccia and conglomerate, and subordinate finer-grained tuffaceous sedimentary rocks and tuff. Unit present only in southern and western parts of the map area. In Bullfrog Hills area largely consists of crudely bedded to massive, polymictic, matrix- and block-supported breccia containing lenses, blocks, and sheets of monolithologic breccia up to 1 km or more in length. Slide sheets commonly bounded along lower contacts by thin zones of sheared and comminuted tuff that are subparallel to local bedding. Conglomerate is poorly to well bedded and contains matrix- supported, poorly sorted, locally well-rounded pebbles, cobbles, and rare boulders. Fanglomerate is polymictic, poorly sorted, and commonly has matrix of tuffaceous sandstone. Sedimentary breccia and conglomerate clasts, locally derived from competent Miocene volcanic rocks and pre-Tertiary sedimentary rocks, are enclosed in partly tuffaceous, sandy to silty matrix. Breccia and conglomerate probably deposited syntectonically as landslide debris, colluvium, and proximal fan alluvium adjacent to uplifted fault blocks. In

Bullfrog Hills, breccias are concordantly(?) overlain by rhyolite of Rainbow Mountain tuff and have a maximum exposed thickness exceeding 400 m. Unit also includes blocks and sheets of monolithologic breccia largely derived from Paleozoic carbonate rocks. These breccias locally occur at the base of, and rarely within, "young sedimentary deposits" (Tgy), particularly in Crater Flat. Includes Miocene "landslide blocks" (part) of Swadley and Carr (1987) in southern Crater Flat. Base of unit is local angular unconformity

Thirsty Canyon Group (Miocene)—Peralkaline assemblage of ash-flow sheets, lavas, and related nonwelded tuffs erupted from Black Mountain caldera in north-central part of map area between 9.4 and 9.15 Ma. The Pahute Mesa and Trail Ridge Tuffs likely are the major units associated with caldera collapse. 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:

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 reverse magnetic polarity. Maximum exposed thickness about 65 m

Ttp **Pahute Mesa and Rocket Wash Tuffs—**Widespread Pahute Mesa Tuff consists of welded, moderately crystal-poor, 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. Pahute Mesa has anomalous reverse magnetic polarity; maximum thickness about 60 m. Unit locally includes the Rocket Wash Tuff, a subjacent cooling unit erupted 9.4 Ma that has slightly more common alkali feldspar and a typical reverse magnetic polarity; maximum exposed thickness about 50 m

Tfu **Upper Fortymile rhyolite lavas (Miocene)—**Lava flows containing abundant sanidine, sparse biotite, and rare clinopyroxene. Includes rhyolite flows, domes, plugs, and associated tephra overlying trachyte of Donovan Mountain in northernmost Bullfrog Hills, rhyolite of Boundary Butte lava on the south rim of the Ammonia Tanks caldera of the Timber Mountain caldera complex, and isolated lava and associated tephra exposures along the lower Thirsty Canyon drainage. Age ranges from about 10.5 Ma to 9.5 Ma. Maximum exposed thickness about 175 m

Tft **Post-Timber Mountain basaltic rocks (Miocene)—**Basalt, basaltic andesite, trachybasalt, and basaltic trachyandesite lava flows and dikes erupted between 11.45 and approximately 10 Ma. Includes rocks mapped as trachyandesite in the northwest moat of the Timber Mountain caldera complex. Flows generally contain common olivine, sparse plagioclase, and rare clinopyroxene. Maximum thickness of flows approximately 30 m (Minor and others, 1993). Includes: Basalt of Kiwi Mesa (potassium-argon date of 9.7 Ma in Carr, 1984); Basalt of Skull Mountain, Tb2-N

1/2 Bullfrog 10.3 Ma (Appendix 2); Tb1-3-Bare Mtn. 10.7 Ma (Appendix 1); Tb-Big Dune, 10.5 Ma (R.J. Fleck, written commun. 1979); Tbo- Topopah Spring 7.5. A dark-gray to black basalt flow as thick as 10 m that occurs locally between the latitic lava flows and the underlying rhyolite lava flows and tuffs of Rainbow Mountain on the southeast slope of Rainbow Mountain belongs to this category of basalts but is included in map unit Tfn because it is too thin to map show separately at this map scale. Included in "basalts of the silicic cycle" (part) by Crowe and others (1983)

Tfn **Trachyte of Donovan Mountain (Miocene)—**Crystal-rich trachyte lava flows and subordinate feeder dikes, sills, and flow-margin tephra present in Bullfrog Hills area. Flows contain abundant plagioclase, common sanidine, biotite, and clinopyroxene, and sparse olivine. Flow foliations and laminations locally conspicuous. Lava flows have normal magnetic polarity; age 10.4 Ma. Maximum exposed thickness exceeds 200 m. Flows overlie rhyolite of Rainbow Mountain with local angular discordance and locally are overlain by some upper Fortymile rhyolite lava

Tfs **Rhyolite of Shoshone Mountain (Miocene)—**Generally aphyric rhyolite lavas and minor related tuffs containing rare plagioclase, sanidine, clinopyroxene, and biotite. Erupted from center southeast of Timber Mountain caldera complex; normal magnetic polarity; age 10.3 Ma. Maximum exposed thickness in map area 150 m

Tfd **Lavas of Dome Mountain (Miocene)—**Interstratified trachybasalt, basaltic trachyandesite, and trachyandesite lava flows overlapping southern moat of Timber Mountain caldera complex. Different lava types are petrographically distinguishable; basaltic rocks contain abundant plagioclase, common olivine, and sparse clinopyroxene; trachyandesites contain sparse to common clinopyroxene, rare olivine and orthopyroxene, and local rare hornblende. Normal magnetic polarity; age older than 10.35 Ma, younger than about 11 Ma. Maximum exposed thickness in map area about 200 m

Tiy **Younger intrusive rocks (Miocene)—**Intrusive rhyolite and microgranite porphyry emplaced in the southeast flank of Timber Mountain dome following collapse of Ammonia Tanks caldera. Intrusive rhyolite is crystal-rich and contains abundant alkali feldspar, common quartz, sparse biotite and plagioclase, and sphene; strongly resembles rhyolite compositional zone of Ammonia Tanks Tuff. Unit termed microgranite porphyry (Byers and others, 1976a) is very crystal rich syenite and contains very abundant sanidine, abundant biotite, and common plagioclase and clinopyroxene. Rhyolite that intrudes the rhyolite of Rainbow Mountain in the Bullfrog Hills is compiled in this unit

Tfr **Rhyolite of Rainbow Mountain (Miocene)—**Intercalated rhyolite and minor dacite/trachyte nonwelded ash-flow tuff and subordinate lava flows, ash-fall tuff, and tuffaceous sedimentary rocks. Present in the northern part of the Bullfrog Hills where it is a thick (150 m), crystal-rich ash-flow tuff containing common plagioclase, quartz, sanidine, and biotite. Lava flows are predominant in the southern Bullfrog Hills and contain common plagioclase and biotite, sparse quartz, and local rare hornblende and clinopyroxene. The lowest lava flow is equivalent to tuff in the northern Bullfrog Hills and contains sparse sanidine. Rests with angular discordance upon older volcanic units; concordantly(?) overlies proximal sedimentary rocks (breccia) of unit Tgyx. Lavas have normal magnetic polarity; age about 11 Ma. Maximum exposed thickness in map area about 250 m. Equivalent to rhyolite lava flows and tuffs of Rainbow Mountain of Maldonado and Hausback (1990)

Tfb**Beatty Wash Formation (Miocene)—**Post-caldera rhyolite lavas and related tuff erupted from 11.4 to 11.2 Ma within moat of Timber Mountain caldera complex. Includes rhyolite of Beatty Wash (normal magnetic polarity) and tuff of Cutoff Road (anomalous reverse magnetic polarity), which contain common sanidine and plagioclase, sparse to common biotite, local sparse hornblende, local rare quartz, and common sphene. Petrographically similar tephras are white and very pumice-rich in lower part and consist of brown basalt-rhyolite mixes in rhyolite of Chukar Canyon subunit of upper part. Rare quartz and abundant sphene are diagnostic. Also includes overlying rhyolites of Max Mountain (reverse magnetic polarity) and Boundary Butte, which contain sparse quartz phenocrysts. Lavas as much as 300-430 m thick; tuff layers as much as 60 m thick

Tfl**Tuff of Leadfield Road—**Grayish-orange-pink, nonwelded to partly welded ash-flow tuff. Tuff contains 3 to 10 percent phenocrysts consisting of plagioclase (60 to 80 percent), sanidine (5 to 10 percent), hornblende (2 to 5 percent), and clinopyroxene (2 to 3 percent). Also contains as much as 20 percent red-brown rock fragments consisting of rhyolitic lava, ash-flow tuff, siltstone, and mudstone. Unit only occurs in the western Bullfrog Hills (Maldonado, 1990). Thickness 275 m

Tff**Rhyolite of Fleur-de-lis Ranch (Miocene)—**Post-caldera rhyolite lavas and welded ash-flow tuff erupted at about 11.4 Ma on west side of Timber Mountain caldera complex. Contains abundant plagioclase and biotite, sparse clinopyroxene, and local sparse hornblende. Distinguished by abundance of plagioclase and lack of sphene, especially in welded ash-flow subunits. Magnetic polarity normal. Stacked lavas and welded tuffs as much as 300 m thick. Includes rhyolite of West Cat Canyon

Timber Mountain Group (Miocene)—Metaluminous assemblage erupted from the Timber Mountain caldera complex between about 11.6 and 11.45 Ma. Group consists predominantly of rhyolite ash-flow tuff and includes subordinate, related rhyolite lava flows and domes that erupted before, between, and after emplacement of ash-flow units. Eruption of the voluminous Rainier Mesa Tuff and Ammonia Tanks Tuff resulted in collapse of the Rainier Mesa and younger Ammonia Tanks calderas (Christiansen and others, 1977), respectively, which form the Timber Mountain caldera complex. The latter caldera is centered about Timber Mountain, which consists of the Ammonia Tanks resurgent dome. Rocks of this group are distinguished by high content of quartz phenocrysts in rhyolite units and high mafic contents in upper parts of zoned units. Subdivided into:

Tmaw **Tuff of Buttonhook Wash—**Post-caldera, crystal-rich rhyolite ash-flow tuff and subordinate bedded tuff erupted immediately after Ammonia Tanks subsidence, and confined within Timber Mountain caldera complex. Contains common sanidine, plagioclase, and quartz, sparse biotite and clinopyroxene, local rare hornblende, and abundant sphene. Virtually identical to intracaldera facies of unit Tma, but separated from it by a cooling break. Magnetic polarity normal.

Maximum exposed thickness about 250 m. Includes petrographically indistinguishable tuff of Crooked Canyon

Tma **Ammonia Tanks Tuff**—Widespread welded ash-flow tuff sheet erupted at 11.45 Ma from younger Ammonia Tanks caldera of Timber Mountain caldera complex, and resurgently domed to form Timber Mountain. Compositionally zoned from lower, volumetrically dominant rhyolite (abundant sanidine, common quartz and plagioclase, sparse biotite, rare clinopyroxene, and sparse sphene) to upper crystal-rich trachyte (abundant sanidine and biotite, common plagioclase and quartz, and sparse clinopyroxene and sphene). Local basal bedded tuff unit resembles lower rhyolite but contains sparse hornblende and rare orthopyroxene, clinopyroxene, and Mg-rich olivine in association with basaltic lapilli. Distinguished by high quartz and mafic mineral contents, sparse sphene, and normal magnetic polarity. Maximum intracaldera thickness more than 900 m on Timber Mountain resurgent dome; outflow widely distributed in all directions, with a typical thickness of less than 150 m

Tmx **Timber Mountain landslide breccia**—Thickly bedded, poorly sorted breccia grading downward into megabreccia. Composed of angular, mainly pre-Ammonia Tanks volcanic clasts as much as 6 m across and variable proportions of coarse-grained tuffaceous matrix; clasts locally derived from rock units exposed on topographic wall of Timber Mountain caldera complex. Lower part of unit locally intertongues with upper Rainier Mesa Tuff, and breccia is overlain by intracaldera Ammonia Tanks Tuff. Breccia, limited to caldera moat and base of caldera wall, emplaced as debris flows and rock avalanches shed off topographic wall of caldera(s) following Rainier Mesa and, perhaps, Ammonia Tanks collapse. Maximum thickness exceeds 300 m

Tmc **Rhyolite of Buried Canyon**—Rhyolite lavas and related subordinate nonwelded tuff erupted between emplacement of Rainier Mesa Tuff and Ammonia Tanks Tuff in Timber Mountain caldera complex moat; chemically and petrographically similar to Ammonia Tanks. Contains common quartz and sanidine, rare plagioclase and biotite, and common sphene. Distinguished by sphene content, normal magnetic polarity, and stratigraphic position between major tuff units. Isotopic age of 11.54 ± 0.03 Ma (Fridrich, Sawyer, Fleck, and Lanphere, unpublished data). Maximum thickness greater than 180 m

Tmt **Basalts in Timber Mountain Group**—Flows containing common olivine, common plagioclase, and local sparse clinopyroxene. Includes pre-Rainier Mesa basalt of Tierra [normal magnetic polarity (Lawrence Livermore National Lab, unpublished data)] and basalt of Oasis Valley (reverse magnetic polarity) that occurs stratigraphically between Rainier Mesa and Ammonia Tanks Tuffs. Includes: Tb1 of Maldonado (1990) and Maldonado and Hausback (1990) occurs between Ammonia Tanks and Rainier Mesa Members in north one-half of Bullfrog [includes pre-Timber Mountain in Topopah Spring 7.5 and Mine Mountain, as well as Tb1 and Tb in N 1/2 of Bullfrog—not all are parts of a single continuous flow unit]. Included in "basalts of the silicic cycle" (part) by Crowe and others (1983). A thin basalt was mapped locally below the Paintbrush Tuff in Topopah Spring 7.5' quadrangle by Lipman and McKay (1965). Flow is too thin to show at scale of map and is included in Paintbrush Tuff. Maximum exposed thickness less than 30 m

Tmr **Rainier Mesa Tuff**—Widespread welded ash-flow tuff sheet erupted at 11.6 Ma from older Rainier Mesa caldera of Timber Mountain caldera complex. Compositionally zoned from lower, volumetrically dominant rhyolite (common sanidine and quartz, sparse plagioclase, and rare biotite) to upper crystal-rich trachyte (abundant biotite, common sanidine, plagioclase, and quartz, sparse clinopyroxene, and rare orthopyroxene and hornblende). Distinctive thin (about 10 cm) tephra layers directly beneath main eruptive unit consist of paired dacite and overlying trachy basalt tuff containing abundant hornblende, common plagioclase, and sparse orthopyroxene. Unit distinguished by high quartz and mafic mineral contents, rare accessory monazite, and reverse magnetic polarity; lower nonwelded to partly welded zones are characteristically salmon pink. Maximum intracaldera thickness more than 500 m; outflow, which is widely distributed in all directions, has a typical maximum thickness of 150 m and locally is ponded to a thickness of as much as about 400 m. Includes minor overlying bedded Rainier Mesa Tuff locally; in Bullfrog Hills unit may include some Ammonia Tanks Tuff where distinction could not be made due to brecciation and alteration

Tmrf **Rhyolite of Fluorspar Canyon**—Pre-caldera rhyolite lava and nonwelded tuff that predate eruption of Rainier Mesa Tuff. Contains common quartz and sanidine, sparse plagioclase, and rare biotite. Locally consists of thick nonwelded tuff deposits. Distinguished by high quartz content, reverse magnetic polarity, and rare accessory monazite, and from petrographically similar mafic-poor Rainier Mesa Tuff by lower lithic content. Maximum thickness about 200 m. Includes tuff of Holmes Road, a distinctive interlayered brown and pink to white phreatomagmatic deposit. Isotopic age 11.62 ± 0.03 Ma (Fridrich, Sawyer, Fleck, and Lanphere, unpublished data). Includes Rhyolite of Pinnacles Ridge, on the divide between Beatty Wash and Yucca Wash

Tgnx **Transitional Timber Mountain breccia and sedimentary rocks (Miocene)**—Volcaniclastic sedimentary rocks associated with the Transitional Timber Mountain rhyolite lava flows

Tmn **Transitional Timber Mountain rhyolites (Miocene)**—Widespread crystal-rich to very crystal-rich rhyolite lavas and related nonwelded tuffs, ponded in the Claim Canyon caldera at 12.5 Ma, but representing the initial eruptions of Timber Mountain-type petrography (common quartz and biotite, but lacking in monazite). Contains common to abundant sanidine and plagioclase, and common quartz and common biotite. Includes the rhyolites of Windy Wash and Waterpipe Butte, which contain rare to common hornblende and abundant sphene, and the rhyolite of the Loop which lacks both. Rhyolite of the Loop is dated at 12.49 ± 0.03 Ma (Fridrich, Sawyer, Fleck, and Lanphere, unpublished data). Small-volume rhyolite lava flows, related breccia and intrusive dikes and tephra are included

Paintbrush Group (Miocene)—Metaluminous assemblage of alkali rhyolite tuffs and lavas was erupted from the vicinity of the Timber Mountain caldera complex between 12.8 and 12.7 Ma. The Claim Canyon caldera, well-established source of the Tiva Canyon Tuff, adjoins the southern part of the Timber Mountain caldera complex and is exposed in the south of the map area, whereas the source of the older Topopah Spring Tuff is uncertain. The westernmost exposures of thick Pah Canyon and Yucca Mountain Tuffs, located just south of the intersection of the Transvaal Hills and Beatty Wash, are interpreted by some to be a part of the southwest outer topographic wall of the Topopah Spring caldera. Paintbrush Group rocks are distinguished by an absence or rarity of quartz phenocrysts in rhyolite units and the presence of sphene, except in the lower Topopah Spring. In addition to biotite, units in the upper part of the Paintbrush contain hornblende, whereas the lower units contain clinopyroxene. Subdivided into:

Tpu**Post-Tiva Canyon rhyolites—**Post-caldera rhyolite lavas and related nonwelded tuff exposed on northern topographic wall of Timber Mountain caldera complex. Contains common sanidine and common to sparse plagioclase and biotite. Includes the rhyolite of Scrugham Peak, which also contains abundant sphene, and the younger rhyolite of Benham, which additionally contains rare quartz and hornblende. Unit also includes the rhyolites of Vent Pass and Comb Peak. Erupted immediately after the Tiva Canyon Tuff; reverse magnetic polarity. Maximum exposed thickness 300 m

Tpc**Tiva Canyon Tuff—**Widespread metaluminous welded ash-flow tuff sheet erupted at 12.7 Ma from Claim Canyon caldera. Compositionally zoned from lower crystal-poor rhyolite (common sanidine, sparse hornblende, and abundant sphene) to upper trachyte (common sanidine and plagioclase, sparse biotite and clinopyroxene, rare hornblende, and sparse sphene). Distinguished by dominance of sanidine among felsic phenocrysts, presence of sphene, and reverse magnetic polarity; lower part commonly is conspicuously platy. Locally hydrothermally altered and brecciated in Bullfrog Hills. Exposures consist of outflow in Pahute Mesa map area, where unit is widely distributed with maximum exposed thickness about 110 m. Intracaldera Tiva Canyon was called the tuff of Chocolate Mountain on the Topopah Spring NW quadrangle (Christiansen and Lipman, 1965). In the Claim Canyon caldera area and in northern Crater Flat there is an upper separate cooling unit, the tuff of Pinyon Pass, which shows a similar compositional zonation to the Tiva Canyon

Tpx**Paintbrush caldera-collapse breccias—**Caldera collapse landslide breccias interfingering with the intracaldera Tiva Canyon Tuff on and adjoining the Chocolate Mountain resurgent caldera dome. Consists of varied pre-Tiva Canyon volcanic rock types

Tpy**Yucca Mountain Tuff—**Welded aphyric rhyolite ash-flow tuff, present as a simple cooling unit in the vicinity of the Claim Canyon caldera and Yucca Mountain. Distinguished by its virtually phenocryst-free composition and reverse magnetic polarity; and stratigraphic position immediately beneath the Tiva Canyon Tuff, to which it appears to be related as a precursory eruption. Maximum thickness of 335 m within the Claim Canyon caldera, and 75 m outside

Tpm **Middle Paintbrush Group rhyolites—**Lava flows and related nonwelded tuff present at Pahute Mesa that were erupted between deposition of the two major Paintbrush ash-flow tuff units (Tiva Canyon Tuff and Topopah Spring Tuff). Lavas contain common sanidine, common to rare plagioclase and biotite, and rare quartz. The lowest unit, the rhyolite of Silent Canyon, has the highest plagioclase content, common biotite as the only mafic mineral, and lacks sphene; overlying rhyolite of Echo Peak is characterized by sparse to common biotite, rare clinopyroxene, and abundant sphene; uppermost crystal-poor rhyolite of Delirium Canyon has sparse plagioclase, rare hornblende and biotite, and abundant sphene. Additional units include the rhyolite of Black Glass Canyon and rhyolite of Z. Distinguished by stratigraphic position both above and below the Pah Canyon Tuff and by reverse magnetic polarity of lava flows. Maximum thickness for individual flow units ranges from 140 to 390 m

Tpp**Pah Canyon Tuff**—Partly welded to welded rhyolite ash-flow tuff, erupted in the vicinity of the Claim Canyon caldera. Contains common plagioclase, sanidine, and biotite, and rare clinopyroxene and sphene. Distinguished by stratigraphic position and reverse magnetic polarity; maximum thickness of 90 m

Tpt**Topopah Spring Tuff**—Widespread metaluminous welded ash-flow tuff sheet erupted at 12.8 Ma from as yet uncertain caldera source located in general vicinity of Timber Mountain caldera complex. Compositionally zoned from lower crystal-poor rhyolite (sparse plagioclase and rare sanidine, biotite, and quartz) to upper trachyte (common sanidine and plagioclase, sparse biotite and clinopyroxene, and local rare quartz). Local overlying bedded tuff is zoned in similar fashion. Unit is distinguished by high sanidine content but lower sanidine/ plagioclase ratio than that of Tiva Canyon Tuff, trace quartz content, absence of sphene, and normal magnetic polarity. Exposures are entirely outflow; no intracaldera tuff has been recognized. The tuff is widely distributed in southern part of map area, including the Yucca Mountain repository area; it has a maximum exposed thickness of about 350 m

Tac**Calico Hills Formation (Miocene**)—Sequence of metaluminous rhyolite lavas and related tuff erupted from vents in the Calico Hills area and in the Area 20 caldera in subsurface of Pahute Mesa (Sawyer and Sargent, 1989) at 12.9 Ma. Lavas represent post-collapse eruptions generally related to Crater Flat Group magmatism. Lava sequence is compositionally zoned from lower rhyolite (contains common quartz, plagioclase, and sanidine and sparse biotite) to upper crystal-poor rhyolite (contains sparse quartz and sanidine, and rare plagioclase and biotite). Also includes crystal-rich rhyolites of Pool (sparse biotite and hornblende) and Inlet (common biotite and sparse hornblende) in subsurface of Pahute Mesa. On the west side of Yucca Flat, in the Rainier Mesa/southern Belted Range area, and north of Silent Canyon the map unit may include undivided bedded tuff associated with the Bullfrog Tuff, the Wahmonie Formation, the Paintbrush Group, and (or) pre-Rainier Mesa rhyolites. Normal magnetic polarity, high relative quartz content, Fe-rich mafic mineral chemistry, common bedded tuff character, and local zeolitization are distinctive. Maximum exposed thickness approximately 200 m; ponded to more than 2200 m within Area 20 caldera

Tio**Older intrusive rocks (Miocene**)—Andesitic, hydrothermally altered, hypabyssal intrusion poorly exposed in Bullfrog Hills. Contains common plagioclase and clinopyroxene phenocrysts. Intrudes pre-Tertiary basement rocks and predates or is coeval with overlying older basalt unit. Unit also includes the granitic and rhyolitic plutons that intrude the Wahmonie volcanic center

Tw **Wahmonie Formation (Miocene)**—Metaluminous very crystal-rich andesite and crystal-rich dacite lavas, tephra, and related volcaniclastic deposits erupted at 13.0 Ma from the Wahmonie volcano, located southeast of the main cluster of SWNVF calderas. Contains abundant to very abundant plagioclase (increasing upward in the sequence of lavas), very abundant to common biotite (decreasing upward), abundant to sparse hornblende (except where rare in lower tuff of Mara Wash), rare to very abundant orthopyroxene (increasing upward), very abundant clinopyroxene in middle and upper members, abundant olivine in the middle member, and sparse quartz in the lower Member and tuff of Mara Wash. Distinguished by mafic-rich mineralogy and dominance of plagioclase, and complete absence of sanidine. Includes widespread Wahmonie tephra distributed throughout Yucca Flat and most of Rainier Mesa that is similar in mineralogy to lower Member

Tws **Salyer Member (Miocene)—**Volcaniclastic facies of lower Wahmonie, including lahars, bedded and reworked tuffs, "tuff breccia" and other volcaniclastic breccia layers

Crater Flat Group (Miocene)—Metaluminous assemblage of ash-flow sheets, lavas, and related nonwelded tuff erupted from Area 20 caldera and possibly from the vicinity of the proposed Prospector Pass caldera in the northern Crater Flat area (Carr and others, 1986) between about 13.5 and 13.1 Ma. The Bullfrog Tuff, the major exposed Crater Flat unit, erupted from Area 20 caldera where it is ponded to a thickness of more than 600 m in the subsurface of Pahute Mesa; the larger part of the caldera may have been obliterated by younger Timber Mountain caldera complex. The Crater Flat Group is distinguished by high relative quartz contents among the felsic minerals and Fe-rich mafic minerals. Subdivided into:

Tcp**Prow Pass Tuff (Miocene)—**Youngest welded ash-flow tuff sheet in Crater Flat Group, erupted from an unknown source at about 13.1 Ma. Rhyolite tuff contains common plagioclase and sanidine, sparse quartz, and rare orthopyroxene and biotite. Distinguished by orthopyroxene content and relatively low biotite, and normal magnetic polarity. Principal surface exposures are in a small area just northwest of the "Prow" of Yucca Mountain, but much more extensive in the subsurface of Yucca Mountain

Tcb**Bullfrog Tuff—**Widespread metaluminous, variably welded, rhyolite ash-flow tuff sheet. Regional variations in lithic content from lithic-poor welded tuff south of quadrangle at Yucca Mountain to thick, compositionally zoned, lithic-rich nonwelded tuff in central part of map area in the buried Area 20 caldera. Outflow Stockade Wash lobe east of caldera, previously called Stockade Wash Tuff, has common sanidine, quartz, plagioclase, and biotite, rare hornblende, and maximum thickness of 120 m. Intracaldera facies in Area 20 caldera is compositionally zoned, from lower rhyolite (common sanidine and quartz, sparse plagioclase, and rare biotite) to upper rhyolite (common sanidine, plagioclase and quartz, sparse biotite, and rare hornblende); it has a high lithic content, is intercalated with landslide breccia deposits, and has maximum thickness of about 680 m. Bullfrog Tuff is hydrothermally altered and locally brecciated in Bullfrog Hills. Distinguished by high relative quartz content sparse to rare biotite and hornblende, Fe-rich mafic minerals, general absence of sphene, and normal magnetic polarity. About 13.25 Ma in age. Includes a related subunit (tuff of Rickey) in subsurface of Pahute Mesa. On the west side of Yucca Flat, and in Rainier Mesa/southern Belted Range area may include undivided bedded tuff of Deadhorse Flat Formation, Wahmonie Formation, Calico Hills Formation, the Paintbrush Group, and (or) the rhyolite of Fluorspar Canyon

Tcr**Rhyolites in the Crater Flat Group (Miocene)—**Thick rhyolitic flows and minor related breccia and tephra. Includes rhyolite of Prospector Pass on the East of Beatty Mountain quadrangle (Fridrich and others, 1994). Petrographically very similar to rhyolite of Inlet: common felsic phenocrysts of plagioclase, quartz, and sanidine; common biotite and sparse hornblende. Unit also includes rhyolite lava and related tuffs of Jorum (rare biotite and hornblende), Sled (crystal-poor, and having rare quartz, biotite, and hornblende), and Kearsarge (crystal-rich, having common biotite and clinopyroxene, sparse orthopyroxene, and rare quartz); these units are known only from the subsurface of Pahute Mesa

Tct**Tram Tuff (Miocene)—**Widespread welded rhyolite ash-flow tuff, possibly erupted from source in the northern part of the Prospector Pass caldera complex. Age about 13.4 Ma, stratigraphically bracketed between the Bullfrog Tuff and the Deadhorse Flat Formation rhyolite lava flows. Distinguished by mineralogy of subequal common quartz, plagioclase, and sanidine; sparse biotite as the only mafic mineral, and reverse magnetic polarity

Tgp**Rocks of Pavits Spring and older sedimentary deposits, undivided (Miocene)—**General designation for Tertiary sedimentary deposits that are older than the Timber Mountain Tuff and younger than any demonstrable Oligocene unit. Consists of bedded fluvial and lacustrine sedimentary deposits with intercalated nonwelded ash-fall tuff beds. Sedimentary rocks largely consist of volcaniclastic conglomeratic sandstone, siltstone, shale, and sandy limestone; contains fossil fish and plants. Base of unit is unconformity. In eastern part of quadrangle, includes Rocks of Pavits Spring and equivalent deposits that intertongue with or contain ash-fall tuff correlated with the Calico Hills Formation tuff and older volcanic units of the southwest Nevada volcanic field (most volcanic interbeds are of the Crater Flat Group (13.5-13.1 Ma) or older. Ash bed from near the base of rocks of Pavits Spring in the Hampel Wash area (Camp Desert Rock 7.5) yielded a potassium-argon age on biotite of 15.8 Ma (Yount, oral comm. 7/18/89). Clasts derived from the Hiko, Blotch Spring, Shingle Pass, and Monotony Tuffs occur in the lower part of the Pavits Spring (Barnes and others, 1982). The Hiko Tuff, youngest of the units represented by clasts in the Pavits Spring, yielded an isotopic age of about 18.3 Ma for samples from Lincoln County, Nevada (Armstrong, 1970). If the correlation of clasts is correct, then the maximum age for the Pavits Spring is about 18.3 Ma. Includes gravel, sandstone, and siltstone interlayered with "older landslide and sedimentary breccia" (Tgox) in Point of Rocks area (J.L. Zigler, written commun., 1995). In the western part of the quadrangle, "older sedimentary deposits" generally are older than Crater Flat Group. Most sections are in part equivalent in age and lithology to rocks of Pavits Spring. In Bullfrog Hills divided by Maldonado (1990) into: Tba—Bedded pyroclastic deposits and tuffaceous sedimentary rocks and Tas—Ash-fall tuff and tuffaceous sedimentary rocks. Base of unit is local unconformity. Some sections on the flanks of the Grapevine and Funeral Mountains may contain lower Miocene deposits that are missing farther to the east at unconformity at base of rocks of Pavits Spring. Unit includes isolated exposures of gravel, sandstone and siltstone along the rim of Crater Flat (Tts and Tbr of Swadley and Carr, 1987; rocks of Joshua Hollow of Monsen and others, 1992). An intercalated tuff bed in one of these exposures southeast of Black Marble Mountain yielded conventional potassium-argon date of 14.9 Ma (J.C. Yount, pers. commun.) flanks of the eastern Grapevine and northern Funeral Mountains unit includes a crystal-lithic tuff, "unnamed tuff sequence," and "green conglomerate facies" of Reynolds (1969) (latter was included in Titus Canyon Formation of Stock and Bode, 1935). Crystal-lithic tuff marker bed in "green conglomerate facies" of Reynolds (1969) yielded potassium-argon date of about 17 Ma (M.W. Reynolds, oral comm., 1983). Includes deposits in Death Valley that have yielded potassium-argon dates of about 20 Ma on sanidine and 23 Ma on biotite (M.W. Reynolds, oral comm., 1983). Also includes conglomerate in southern Funeral Mountains containing intercalated layers of tuff, as well as monolithologic breccia derived mainly from the Wood Canyon and Bonanza King Formations (Tcs of Swadley and Carr, 1987). Biotite from tuff intercalated with conglomerate near west-central boundary of Big Dune 15' quadrangle yielded a potassium-argon age of 14.9 Ma (Swadley and Carr, 1987)

Tgox **Older landslide and sedimentary breccias (Miocene)—**Breccia, gravel, and sandstone. Breccia typically is matrix-supported and monolithologic, consisting of debris derived from Paleozoic sedimentary units. Gravel is poorly sorted with angular clasts. Commonly grades into breccia. Intercalated with Rocks of Pavits Springs in the Point of Rocks area. Base of unit is local unconformity

Trl**Lithic Ridge Tuff (Miocene)—**Regional, partly welded to welded metaluminous ash-flow tuff erupted at 14.0 Ma from unknown caldera source possibly in vicinity of Crater Flat south of quadrangle. Contains common plagioclase and sanidine, and sparse quartz, biotite, and sphene. Distinguished by high plagioclase content relative to other felsic phases and anomalous reverse magnetic polarity. Maximum exposed thickness in map area 30 m

Trd**Dikes of Tram Ridge (Miocene)—**Intrusive feeders for rhyolite of Picture Rock and local related tuff erupted at 14.0 Ma. Dikes occur widely over the region from Bare Mountain to north of Timber Mountain. Contains abundant plagioclase and biotite, sparse sanidine, hornblende and sphene, and rare quartz. Distinguished by abundant plagioclase and biotite, and reverse magnetic polarity

Trr**Rhyolite of Picture Rock (Miocene)—**Widespread metaluminous, crystal-rich dacite lava flows, intrusive feeders, and local related tuff erupted at 14.0 Ma. Contains abundant plagioclase and biotite, sparse sanidine, hornblende and sphene, and rare quartz. Distinguished by abundant plagioclase and biotite, and reverse magnetic polarity. Partly equivalent to units in subsurface of Yucca Mountain south of quadrangle (andesites and dacites in drill holes G-1 and G-2, and tuff of Units B and C). Correlative with metaluminous tephra in bed 4JK (Carroll, 1989, fig. 2) of Tunnel Formation. Includes rhyolitic lavas near Quartz Mountain and Tolicha Peak which contain very abundant to abundant plagioclase and biotite, common to sparse alkali feldspar and hornblende, rare quartz, and very abundant to sparse sphene. Also includes intermediate, hydrothermally altered lavas in Bullfrog Hills that probably correlate with Unit B in the subsurface of Yucca Mountain. Maximum exposed thickness about 450 m

Tn **Tunnel Formation (Miocene)—**Diverse sequence of dominantly red and white bedded and nonwelded rhyolite tuff; possibly includes subordinate, reworked, epiclastic tuff. It is a mappable unit where it ponded in local paleobasins mainly in eastern part of map area, most notably at Rainier Mesa, but also on west side and in the subsurface of Yucca Flat. Upper beds (4JK) (see Carroll [1989, fig. 2] for stratigraphic context of number/letter-designated subunits of formation] consist of interfingering metaluminous and peralkaline tephra; peralkaline, aphyric comendite tuff is apparently related to comendite of Quartet Dome, whereas metaluminous 4K tuff is associated with the rhyolite of Picture Rock, or the tuff of Sleeping Butte as a slightly older metaluminous source (bed 4GH). Non-peralkaline middle beds (3D, 4A-F) contain common sanidine and sparse quartz and plagioclase and are very mafic-poor (rare clinopyroxene and biotite); crystal content of middle beds increases slightly down section. Bed 3D includes rare hornblende. Lower beds consist of crystal-poor tuff (sparse plagioclase and rare sanidine, quartz, and biotite [bed 3BC]) underlain by crystal-rich tuff (common plagioclase, sanidine, quartz, and biotite, and rare hornblende [bed 3A]). Top of unit is defined as base of Grouse Canyon Tuff or Lithic Ridge Tuff; base of formation is top of Tub Spring Tuff. Formation distinguished by its significant local thickness (as much as 200 m), typical zeolitic alteration, and internal variations in petrography and chemistry

Tqs**Tuff of Sleeping Butte (Miocene)—**Sequence of two metaluminous rhyolite ash-flow tuffs and associated bedded tephra predominantly exposed in Sleeping Butte area about 12 km north of Oasis Valley; tuffs erupted at 14.3 Ma probably from caldera source in this area. Upper tuff is partly welded, massive, lithic rich, and crystal poor, with sparse alkali feldspar and rare biotite. Underlying, more densely welded tuff 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. Lower welded tuff distinguished by high sanidine content, locally abundant granitoid inclusions, stratigraphic position, and normal magnetic polarity. Maximum exposed cumulative thickness about 400 m. Unit may include tuff related to rhyolite of Picture Rock, and possibly correlative with beds 4GH of Tunnel Formation. Tuff of Sawtooth Mountain of Maldonado (1990) and Maldonado and Hausback (1990) is tentatively correlated with tuff of Sleeping Butte

Ton**Older tunnel beds (Miocene)—**Lower sequence of zeolitized, dominantly white, bedded and nonwelded rhyolite tuff and reworked epiclastic tuff. Limited exposures around north end of Yucca Flat and southern Kawich Valley; extensive in subsurface of Rainier Mesa and Yucca Flat. Distinguished from overlying Tunnel Formation by stratigraphically intervening Tub Spring Tuff. Includes tunnel beds 1 and 2 of Carroll (1989, fig. 2), and may locally include nonwelded tuff equivalent to tuff or Yucca Flat, Redrock Valley Tuff, tuff of Twin Peaks, and tuff of Whiterock Spring

Toy**Tuff of Yucca Flat (Miocene)—**Subregional, nonwelded to partly welded, metaluminous rhyolite ash-flow sheet erupted at 15.05 Ma from unknown source. Present in subsurface and along margins of Yucca Flat. Contains common plagioclase, sanidine, and biotite, and sparse quartz and hornblende; typically zeolitized. Reverse magnetic polarity. Maximum thickness 80 m. Tuff of Buck Spring of Maldonado (1990) and Maldonado and Hausback (1990) is tentatively correlated with the tuff of Yucca Flat

Tge**Prevolcanic sedimentary rocks (Oligocene-Early Miocene)—**Weakly cemented, poorly bedded and poorly exposed fanglomerate containing poorly sorted, angular to subrounded pebbles, cobbles, and boulders composed of quartzite and subordinate sedimentary rocks of pre-Tertiary age. Absence of Tertiary volcanic clasts is diagnostic. Present only in the eastern part of quadrangle. Compiled unit includes Rocks of Winapi Wash of Yount (USGS, oral communication, 1991) on the north side of the Spotted Range that were formerly correlated with the Horse Spring Formation (Hinrichs, 1965; Barnes and others, 1982). However, biotite from bedded tuff in the Winapi Wash section yielded a biotite potassium-argon age of 30.2 Ma (Marvin and others, 1970), a better temporal and mineralogic correlative to the Needles Range Group

Tgt**Titus Canyon Formation, lower part (Oligocene)—**Present only in western part of quadrangle. Equivalent to the "variegated and brown conglomerate facies" of Reynolds (1969). Includes only the Oligocene lower part of the Titus Canyon as originally defined by Stock and Bode (1935). Sample of intercalated tuff from Daylight Pass 7.5-minute quadrangle (near Boundary Canyon) yielded potassium-argon ages of about 27 Ma (biotite) and 29 Ma (plagioclase) (M.W. Reynolds, oral commun., 1983). Base of unit is a regional unconformity that commonly is faulted

TKd **Diorite dikes (Oligocene-Cretaceous?)—**Dusky green, fine- to medium-grained porphyritic diorite. Contains approximately 75 percent plagioclase, 10 percent hornblende, 7 percent clinopyroxene, 5 percent biotite, 3 percent opaque oxide minerals, and traces of epidote. Forms dikes that cut foliation in metamorphosed country rock at Chloride Cliffs and Bare Mountain. Inferred crystallization age is based on conventional potassium-argon ages for hornblende of 26.1 ± 1.7 Ma from Bare Mountain (Monsen and others, 1992) and 28.3 ± 0.7 Ma from Chloride Cliffs (Wright and Troxel, 1993)

Kg**Granitic rocks (Cretaceous)—**Equigranular leucocratic granite. Weakly foliated, very pale orange to pale yellowish-orange, medium-grained. Contains 50 percent quartz, 30 percent potassium feldspar, and 15 percent plagioclase, as well as 5 percent muscovite and opaque iron oxide minerals as alteration products. Contacts of granite of Fluorspar Canyon are faulted wherever exposed (Monsen and others, 1992). Crystallization age based on uranium-lead dating of zircon 98 ± 27 Ma (younger intercept age) (Monsen and others, 1992). Similar granitic rocks in surrounding region include Climax stock north of Yucca Flat (101 Ma; Naeser and Maldonado, 1981) and Gold Meadows stock north of Rainier Mesa (93.6 Ma; Naeser and Maldonado, 1981)

dPt **Tippipah Limestone (Early Permian and Pennsylvanian)—**Light to dark gray, well-bedded limestone; silty intervals weather light brown. Shaly and platy-splitting, silty limestone forms uppermost beds, which are underlain by ledge-forming interval, 30-m-thick, of thick-bedded limestone containing tuberous chert nodules along bedding planes. Thick-bedded interval underlain, in turn, by platy fossiliferous limestone containing spherical chert nodules 2 to 5 cm in diameter. Rests concordantly on Eleana Formation. The only exposures of this partial section, 200+ m thick, are in the lower plate of CP thrust fault in the CP Hills (McKeown and others, 1976)

dMcs **Chainman Shale and Scotty Wash Quartzite (Early Pennsylvanian and Mississippian)—**Homogeneous black shale with sparse siltstone, fine quartz sandstone, quartzite, and bioclastic limestone; Scotty Wash forms upper part of unit and is distinguished by abundance of lensoid and tabular quartz sand bodies with local gray fossiliferous limestone beds. Base of Chainman Shale is not exposed in the map area; top of unit is irregular due to erosion prior to deposition of Tippipah Limestone. Unit is exposed in CP Hills and in southern Calico Hills. Thickness unknown, but probably exceeds 900 m (Cashman and Trexler, 1994)

MDe **Eleana Formation (Mississippian and Late Devonian)—**Siliceous siltstone, shale, and bedded chert with intervals containing beds of bioclastic limestone and (or) chert-pebble conglomerate and sandstone. Most complete section is in Tarantula Canyon at Bare Mountain. There, upper third is predominantly siliceous siltstone and shale with sparse limestone in uppermost few meters; middle third is siliceous siltstone and shale with abundant interbeds of bioclastic limestone and sandstone (gravity-flow deposits); lower third is siliceous siltstone and shale overlying Upper Devonian? siltstone and slightly calcareous siltstone that forms lowermost 65 m of Eleana (Cornwall and Kleinhampl, 1964; Monsen and others, 1992). Maximum exposed thickness is 976 m. At Bare Mountain and in the Calico Hills siltstone at base of Eleana rests on slope-facies Devonian limestone and dolomite debris-flow beds, which contain Middle Devonian conodonts in Tarantula Canyon (Monsen and others, 1990). Basal Eleana at Mine Mountain and Shoshone Mountain is shale and rests on karst-weathered, shelf-facies Devonian Guilmette Formation (Cole and others, 1994)

Dsf**Slope-facies rocks (Devonian)—**Moderately resistant, light- to dark-gray dolomite, limestone, silty dolomite, and silty limestone. Crops out in Tarantula Canyon and northern Calico Hills. Moderately well-bedded, laminated limestone and dolomite (and silty limestone and dolomite) with debris flows of detrital carbonate rock as much as 10 m thick. Laminated intervals commonly contain intraformational breccia beds. Debris flows contain sand-, cobble-, and boulder-sized clasts of limestone, dolomite, quartzite, limy quartzite, and individual coral heads. Upper fourth of unit is mostly limestone, whereas lower three quarters are predominantly dolomite. Upper contact concordant and abruptly gradational below light brownish gray limy siltstone assigned to lower part of Eleana Formation. Fossils of probable late Middle Devonian age were reported from "near the top" of the unit by Cornwall and Kleinhampl, 1961). A conodont fauna from 15 m below top of unit is middle Middle Devonian (latest Eifelian to early Givetian). Basal contact concordant and defined by gradational change from light- to dark-gray, moderately well-stratified dolomite and cherty dolomite to light gray, poorly stratified, vuggy dolomite of the Lone Mountain Dolomite. Moderately distinct break in slope at basal contact. Maximum thickness 300 ft (92 m) (Cornwall and Kleinhampl, 1961). Formerly included in Fluorspar Canyon and Nevada Formations (Cornwall and Kleinhampl, 1961; Cornwall, 1972). Lithologically similar to outer continental-shelf or continental-slope facies rocks such as the

Vaughn Gulch Limestone, but Tarantula Canyon has a more restricted stratigraphic range

Dg**Guilmette Formation (Late and Middle Devonian)—**Predominantly thick-bedded, dark- to light-gray, coarse-crystalline limestone. Contains sandy limestone and thick beds of tan quartzite in upper part; biohermal beds are common in middle section; medium-bedded light- to olive-gray dolomite interbedded with limestone near base; while basal beds are yellow and silty above an apparently conformable contact with Simonson Dolomite. Contains interbeds of dark gray dolomite throughout, some with concentrations of stromatoporoid *Amphipora* and some containing sparse chert blebs. Stromatoporoid, brachiopod, and mollusk debris commonly is present. Forms massive cliffs and steep ledgey slopes in upper part and ledgey slopes in lower part. Quartzite beds in upper part at Shoshone Mountain and Mine Mountain are brecciated by collapse over karst features. Formerly mapped as the Devils Gate Limestone (see Burchfiel, 1965, 1966; Orkild, 1968). Approximately 345 m thick

Ds **Simonson Dolomite (Middle Devonian)—**Dolomite and local sandy dolomite; medium-to dark-gray, conspicuously bedded, ledge-forming unit that includes a distinctive yellow, silty, cherty dolomite at the base; distinguished by uniform bedding, alternating dark and light layers, and by common dolomitized relics of brachiopods, tubular corals, and stromatoporoids. Contains brachiopod *Stringoecephalus* sp. in upper part. Locally contains concentrations of stromatoporoid *Amphipora* in upper part. Contains beds of sandy dolomite and thin beds of dolomitic sandstone near base. Basal contact is sharp but conformable and distinctive where yellow platy-silty beds of lower Simonson rest on sandy upper Sevy Dolomite; it may be a hiatus (Poole and Sandberg, 1977). Formerly mapped as the Nevada Formation, upper part (see Burchfiel, 1965, 1966; Orkild, 1968). Maximum thickness in map area about 355 m

DSlm **Lone Mountain Dolomite (Early Devonian? and Late Silurian)—**Dolomite, very light-gray with a distinct interval of medium-gray dolomite, approximately 60 m thick, near the middle of the unit. Dolomite is fine- to medium-grained, indistinctly bedded, and commonly brecciated; forms craggy exposures. Unit is sparsely fossiliferous with poorly preserved crinoid debris being moderately common. Lower contact gradational and marked by a gradual downward darkening of the gray dolomite and an increased definition of the layering toward the underlying unit. Drill hole UE25p#1 at Yucca Mountain intersected rocks that were assigned to the Lone Mountain Dolomite and yielded Late Silurian conodonts (M.D. Carr and others, 1986). Thickness approximately 1600 ft (488 m) (Cornwall and Kleinhampl (1961)

DSsl **Sevy Dolomite and Laketown Dolomite, undivided (Early Devonian and Silurian)—**Dolomite, thick bedded, strongly brecciated in many areas; sandy in uppermost part; light- to medium-gray in middle part; lower part contains two conspicuous dark gray bands. Basal contact is sharp and conformable, but may be a hiatus (Poole and Sandberg, 1977); upper contact is paraconformable at base of Simonson Dolomite. Well bedded where not brecciated; fine- to medium-grained dolomite tends to be thinly bedded, whereas coarsely crystalline dolomite is thick bedded. Lower part consists of alternating intervals of light- and dark-gray dolomite. Light-gray is dolomite similar to that forming upper part; dark-gray dolomite is thin to thick bedded, finely to coarsely crystalline, and contains abundant chert nodules. Dark-gray dolomite forms bands 5 to 30 m thick in lower part of unit. May include Sevy Dolomite, which is equivalent to unit F Dolomite of Spotted Range (see Poole, 1965; Barnes and others 1982), units D and E of dolomite of Spotted Range, and Laketown Dolomite, which is equivalent to units A to C of dolomite of Spotted Range. Thickness not well defined in many areas due to complex structure, but approximately 450 m in Spotted Range; may be as much as 695 m. Unit includes the Hidden Valley Dolomite that crops out only in southeastern Funeral Mountains. Upper part of Hidden Valley is poorly bedded, light gray, coarse-grained dolomite. Contains some sandy, silty, or muddy intervals. Lower part, 520 ft (158.5 m) thick in reference section, consists of well bedded, medium- to dark-gray dolomite containing nodular chert and, in some intervals, thin layers of chert (McAllister, 1974). Rests concordantly on Ely Springs Dolomite. Partial section exposed in lower plate of Schwaub Peak thrust fault; complete reference section, 1440 ft (438.9 m) thick, measured northwest of Pyramid Peak in the southeastern Funeral Mountains, 5 km south of the map boundary (McAllister, 1974). Late Emsian fossils were recovered from the upper part of reference section; Wenlockian to possibly Late Llandorverian fossils were collected from the lower 100 ft (30.5 m) of the formation (McAllister, 1974)

Sr **Roberts Mountains Formation (Silurian)**—Slope-forming, light brownish-gray to medium gray dolomite and limestone, with interbedded silty and sandy dolomite and sparse beds of dolomite-pebble conglomerate. Thin to thickly bedded, commonly flaggy splitting. Upper part predominantly thin to medium beds of light to medium gray dolomite, with sparse silty partings and layers of dolomite-cobble conglomerate. Middle and lower parts contain thin, platy beds to medium beds of dolomite, limestone, dolomitic mudstone, and calcarenite. Dark gray chert layers and nodules and layers of dolomite-pebble conglomerate occur locally. Distinctive bed of dolomite-pebble conglomerate, 0.3 m thick, occurs at base of unit which is disconformable. Early to Late Silurian fossils including brachiopods, corals, graptolites, and conodonts are common (Cornwall and Kleinhampl, 1961; Berry and Boucot, 1970; Miller, 1976; M.D. Carr and others, 1986). Latest Llandoverian to very earliest Wenlockian, (*Amorphognathoides* zone) conodonts were collected 8 m above the base of formation at Bare Mountain; Middle Llandovery, (*Spathognathodus* zone) conodonts were reported from the basal 10 m of the unit in the Bullfrog Hills (Miller, 1976). Ludlovian conodonts were collected from the upper part to the formation (Miller, 1976). Thickness 183 m (Carr and others, 1986) to 335 m (Miller, 1976)

Oes**Ely Springs Dolomite (Late Ordovician)**—Medium- to dark-gray, fine- to medium-grained dolomite and limy dolomite, conspicuously fossiliferous. Thin- to medium-bedded; moderately well bedded in west to poorly bedded in east. Contains sparse to abundant irregular layers and nodules of dark-gray chert, 5 to 20 cm thick. Basal contact conformable and grades abruptly downward into Eureka Quartzite. Thickness 30 to 130 m

Oe **Eureka Quartzite (Late and Middle Ordovician)**—Orthoquartzite, conspicuous white to pale-orange unit that appears massive in outcrop but is internally laminated and locally cross bedded; fine-grained, well-sorted quartz sand with variable silica cement. Light-gray to pale-red, medium- to thick-bedded, fine- to medium-grained, well-sorted quartzite. Thin intervals of limy or dolomitic sandstone are present at base and top of formation. Bed of medium-gray dolomite is present approximately 10 m above base of formation in east part of quadrangle. Moderately resistant unit; forms ledges. Basal contact at first appearance of limestone downward in section. Contact is conformable and abruptly gradational with Pogonip Group. Thickness 75 to 145 m

Op **Pogonip Group (Middle and Early Ordovician)**—Silty limestone, dolomite, and subordinate chert and siltstone; well-bedded, unit marked by medium- to dark-gray carbonate beds and brown-orange silty or cherty zones; fossil content is variable, but brachiopods, oncolites, and corals are locally conspicuous. Unit consists of thin-bedded silty Goodwin Limestone at the base (about 350 m), an indistinct silty zone in the middle (time-equivalent of the Ninemile Formation), and the Antelope Valley Limestone (about 550 m) at the top that contains distinct sandy beds near the contact with overlying Eureka Quartzite

fn **Nopah Formation (Late Cambrian)**—Limestone, dolomite, and subordinate chert, shale, and siltstone; well-bedded, light- to dark-gray, massive-weathering carbonate beds with yellow to brown, fissile silty partings. The basal red-brown Dunderberg Shale Member (about 100 m) is overlain by the middle Halfpint member of thin-bedded cherty limestone (about 320 m), which is overlain by the Smoky member of thick-bedded dark-gray limestone (about 200 m) at the top (Barnes and Christiansen, 1967)

Bonanza King Formation (Late and Middle Cambrian)—Divided into:

fbb **Banded Mountain Member**—Medium to thick beds of light to dark gray dolomite and limestone. Alternating light-, medium- and dark-hued beds produce distinctive banded appearance; upper part of unit shows more massive color banding of medium gray, pale yellow, and dark gray dolomite in descending order. In western part of quadrangle, upper 180 m of member appear as three prominent color bands of approximately equal thickness, which in descending order are medium-, very light-, and dark-gray. These thick color bands become less distinguishable eastward across the quadrangle. Resistant unit; forms ridges and cliffs. Basal contact of member at top of uppermost distinctive interval of nonresistant, yellowish-orange calcareous siltstone and silty limestone and dolomite in formation, which forms upper 20 to 25 m of Papoose Lake Member. Thickness 560 m to 580 m; and

fbp **Papoose Lake Member**—Dark-gray limestone and light gray dolomite with thin zones of yellowish-orange silty limestone and dolomite. Spotty dolomitization of lower massive limestone beds produces distinctive birdseye texture. Most of unit is medium to thick beds of fine-grained limestone and dolomite alternating in thin, discontinuous interlayers and interlaminations, which give rock a mottled appearance. Also contains sparse thick beds of massive, finely crystalline, white limestone or dolomite, particularly near base of unit in western part of quadrangle. Resistant unit; forms ridges and cliffs. Basal contact is conformable and gradational to Carrara Formation. Thickness 360 to 580 m

fc **Carrara Formation (Middle and Early Cambrian)**—Limestone, siltstone, and shale; upper part, 200 m thick, consists of thinly bedded, dark greenish-gray phyllite or schist and micaceous quartzite with sparse but conspicuous beds of medium dark-gray limestone. Intervals of medium bedded algal limestone form resistant ribs near top and middle of upper part. Middle part, 60 m thick, is thickly bedded, dark-gray limestone, characteristically containing *Girvenella*. Lower part, 90 m thick, also consists of thinly bedded, dark greenish-gray phyllite or schist and micaceous quartzite with sparse but conspicuous beds of medium dark-gray limestone. Lowermost part contains beds of orthoquartzite and abruptly grades into Zabriskie Quartzite; basal contact is conformable. upper contact is gradational into overlying Bonanza King Formation. Lower shale-siltstone section is thin-bedded, micaceous, and contains several distinctive limestone beds; trilobite debris is locally conspicuous. Limestone beds in upper Carrara show common oncolites, oolites, and stromatoliths and wavy silty partings of orange calcareous silt. Total thickness indeterminate in the CP Hills due to complex structure. Thickness 350 m to 505 m

fz **Zabriskie Quartzite (Early Cambrian)—**Pale-red to dusky-red, fine- to medium-grained orthoquartzite. Massive, white to pink, laminated and cross-bedded, densely cemented orthoquartzite with conspicuous tubular trace fossils (burrows), most notably *Scolithus*, in lower part; locally intensely brecciated. Basal contact is conformable on micaceous siltstone of the Wood Canyon Formation. Resistant unit; forms ridges and shear cliffs. Basal contact is conformable and abruptly gradational to pelitic rocks of Wood Canyon Formation and is marked by a sharp break in slope. Maximum thickness about 150 m in the Striped Hills, but less than 30 m in the Halfpint Range and Belted Range

fZw**Wood Canyon Formation (Early Cambrian and Late Proterozoic)—**Orthoquartzite, micaceous quartzite, arkosic sandstone, siltstone, and subordinate dolomite. Upper third of unit consists of interbedded red orthoquartzite and brown-green micaceous siltstone with several prominent orange dolomite beds; middle third contains distinctive beds of arkosic granule conglomerate in micaceous quartzite and siltstone; lower third is similar to the upper third. Total thickness variable across the region, but generally 1100 m to 700 m. From the Funeral Mountains to Bare Mountain (Monsen and others, 1992; Wright and Troxel, 1993), upper part, 605 m thick, consists of interbedded quartzite, micaceous quartzite, and siltstone with sparse dolomite and limestone beds. Thick-bedded, pale-red, fine-grained quartzite predominates near top, yielding downward to grayish-green, thin- to medium-bedded siltstone and micaceous quartzite. Conspicuous marker interval, 60 m thick, of dark-yellowish-gray, thick-bedded dolomite and limestone begins 255 m below the top of the formation. Middle part, 210 m thick, consists of pale-green, very coarse-grained, poorly sorted, gritty orthoquartzite, containing beds of quartz-pebble conglomerate and sparse beds of pale green siltstone. Lower part, 335 m thick, consists of thickly bedded, brownish-black to moderate-brown very fine-grained micaceous quartzite and quartzite containing sparse interbeds of light-green siltstone. Also contains three conspicuous marker beds of pale-orange dolomite and limestone. Tops of these carbonate beds are 285 m (25 m thick), 205 m (20 m thick), and 100 (10 m thick) above base of formation. Metamorphosed to amphibolite-grade schist and quartzite locally at Bare Mountain and in eastern Bullfrog Hills. Basal contact conformable and gradational to Stirling Quartzite. Total thickness from 1150 m at Bare Mountain to 700 m in northwesternmost Spring Mountains

Zs **Stirling Quartzite (Late Proterozoic)**—Micaceous quartzite, siltstone, and orthoquartzite. Unit chiefly consists of medium-grained red and purple quartz-rich sandstone, arkosic sandstone, and pebbly sandstone. Informally divided into 5 units based on relative proportions of micaceous siltstone and shale and on presence of sparse limestone beds (Barnes and Christiansen, 1967). Total thickness variable across the region, but generally 700 m to more than 1500 m; no complete sections are preserved in the map area. From the Funeral Mountains to Bare Mountain (Monsen and others, 1992; Wright and Troxel, 1993), Member E, 90 m thick, consists of white to pale yellowish-brown, medium- to thick-bedded, fine-grained orthoquartzite. Quartzite commonly is laminated or cross laminated. Member D, 630 m thick, consists of medium-to-thick interbeds of light brownish-gray, fine-grained quartzite and micaceous quartzite, yellowish-brown dolomite, and pale-green siltstone in upper two thirds, while lower third is pale-gray to pale-orange, medium- to thick-bedded dolomite and limestone, which commonly are laminated. Member C is pale-green siltstone, phyllite, or schist containing sparse beds of micaceous quartzite, limestone and dolomite. Siltstone is thinly bedded and platy splitting where only slightly metamorphosed. Member B contains fine-grained arkosic sandstone, micaceous siltstone, and beds of laminated dolomite. Member A consists of fine- to coarse-grained sandstone, varying from quartz arenite to arkose and containing abundant beds of quartz-pebble conglomerate and platy siltstone. A distinctive interval in upper part contains interbeds of pale-orange dolomite and limestone. Siltstone in Members A and B is metamorphosed to garnet-bearing schist in northern Funeral Mountains

Zj **Johnnie Formation (Late Proterozoic)**—Brown and red quartzite, variegated siltstone, limestone, and calcareous siltstone; quartzites are thick-bedded and indistinctly cross-bedded and locally pebbly; siltstones are laminated and conspicuously micaceous. Upper part contains numerous limestone beds in calcareous siltstone; base is not exposed in the map area; thickness is estimated to exceed 900 m (Barnes and Christiansen, 1967). In Funeral Mountains (Wright and Troxel, 1993), upper part consists of alternating layers of pelitic schist and quartzite (and pebbly quartzite). Distinctive marker unit of metalimestone in upper part probably equivalent to Rainstorm Member. Middle part is mainly of greenish-weathering pelitic schist grading downward into pelitic schist commonly containing orangish-weathering layers of calcareous siltite. Lower part is pelitic schist containing amphibolite layers near top of interval and calcitic marble and pebbly quartzite layers near bottom. Metamorphic grade of Johnnie Formation in the Funeral Mountains increases from upper greenschist in southeast to at least middle amphibolite (variably retrograded to greenschist) in northwest (Hoisch and Simpson, 1993)

Yk**Kingston Peak Formation (Middle Proterozoic)**—Upper part is metaconglomerate containing clasts of quartzite and calcitic marble supported in a matrix of staurolite- and biotite-bearing pelitic schist. Lower part is staurolite- and biotite-bearing pelitic schist containing subordinate layers of laminated calcitic marble

Yb**Beck Spring Dolomite (Middle Proterozoic)**—Strongly laminated calcitic marble (Wright and Troxel, 1993)

Yc **Crystal Spring Formation (Middle Proterozoic)—**Upper part is staurolite- and biotite-bearing pelitic schist and micaceous quartzite containing subordinate layers of calcitic marble and amphibolite. Middle part is calcitic marble containing subordinate layers of staurolite- and biotite-bearing pelitic schist. Lower part is staurolite- and biotite-bearing pelitic schist containing abundant tabular bodies of amphibolite and several distinctive marker beds of calcitic marble (Wright and Troxel, 1993)

Xmi **Metamorphic and intrusive rocks (Early? Proterozoic)—**In Monarch Canyon (northwest Funeral Mountains) consists of pelitic gneiss and migmatite intruded by pegmatite dikes, small granitic bodies, and small amphibolite bodies. Zircons from two-mica granitic rocks included in unit yielded a U-Pb age of 1.7 Ga (Wright and Troxel, 1993). In Bullfrog Hills, consists of pelitic schist and gneiss, as well as sparse marble, intruded by pegmatite and amphibolite dikes. Rocks are sillimanite grade in Monarch Canyon and kyanite grade in Bullfrog Hills

ACKNOWLEDGMENTS

The compilers are indebted to numerous earth scientists from the U. S. Geological Survey and the academic community whose work over many decades has provided the basis for this map. Scott A. Minor of the U. S. Geological Survey and Richard G. Warren of Los Alamos National Laboratory engaged in extended discussions of the volcanic stratigraphy and provided access to unpublished data and preliminary manuscripts. Mitchell W. Reynolds of the U. S. Geological Survey, Beverly Z. Saylor of the Massachusetts Institute of Technology, and S. John Caskey of the University of Nevada, Reno, provided unpublished mapping or mapping available only in unpublished Master's theses. A preliminary digital polygon coverage of the NTS geologic map by Frizzell and Shulters (1990) was generated under the direction of D.S. Aitken of the Western TRU, and modified and provided to the authors by Randell J. Laczniak. Geoffery A. Phelps, Tracey J. Felger, Donna Knifong, and Todd T. Fitzgibbon provided valuable training and assistance necessary for creating the digital database. Discussions in the field and office with U. S. Geological Survey colleagues P.P. Orkild, J.C. Cole, S.A. Minor, R.R. Wahl, R.J. Laczniak, M.A. Lanphere, R.J. Fleck, M.R. Hudson, V.A. Frizzell, Jr., R.E. Anderson, W.B. Hamilton, C.J. Fridrich, D.W. O'Leary, F.W. Simonds, J. C. Yount, as well as B.P. Hausback (Calif. State Univ., Sacramento), and S.I. Weiss (Univ. of Nevada, Reno) were helpful in developing an understanding and appreciation of the varied geology of the area. C.J. Fridrich, T.D. Hoisch, and R.B. Scott generously provided unpublished map data and extensive input on parts of the digital map compilation in the Yucca Mountain-Crater Flat-Bare Mountain area. Collaborative work in the Mississippian and Devonian rocks by P.H. Cashman and J.H. Trexler, Jr., both of the University of Nevada at Reno, has been critical to understanding the complex structure and stratigraphy in Mine Mountain and the Calico Hills. Air Force Sgt. D. Welch, Capt. R. Durham, and Shelby Friend kindly arranged access and served as escorts on several trips into geologically critical areas of Nellis Air Force Bombing and Gunnery Range. David Miller and Todd Fitzgibbon provided helpful reviews of the manuscript and database. This work was prepared in cooperation with the Department of Energy under interagency agreement DE-AI08-91NV11040.

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Table 1. Total phenocryst content (crystal=xl)

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

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

rare	**sparse**	**common**	**very abundant**	**abundant**
Felsic minerals (median modal %)				
<0.5	0.5-2	2-10	10-20	>20
Mafic minerals (median modal %)				
<0.1	0.1-0.5	0.5-1	1-2	>2
Accessory minerals (median ppm/Volume)				
<20	20-150	150-300	>300	

Table 3. Phenocrystic mineral abundances in basaltic volcanic rocks

rare	**sparse**	**common**	**abundant**	**very abundant**
Felsic minerals (median modal %)				
<0.5	0.5-2	2-10	0-20	>20
Mafic minerals (median modal %)				
<0.5	0.5-2	2-5	5-10	>10
Accessory minerals (median ppm/Volume)				
<20	20-150	150-300	>300	

Appendix 1

Table 1. *Conventional potassium-argon ages for Tertiary basalt flows east of Beatty Mountain in the Bare Mountain 15' quadrangle*

[Analyses by U.S. Geological Survey, Menlo Park, California. Potassium measured by flame photometry following lithium metaborate fusion (Suhr and Ingamells, 1966). Argon measurements using standard techniques of isotope dilution (Dalrymple and Lanphere, 1969). Decay and abundance constants as recommended by Steiger and Jäger (1977). Sample locations: 102887-3--lat 36^{o}54'55"N., long 116^{o}41'44"W.; 102889-2--lat 36^{o}54'44"N., long 116^{o}43'22"W.; 102889-5A--lat 36^{o}54'50"N., long 116^{o}43'10"W.; 102889-6--lat 36^{o}55'22"N., long 116^{o}42'57"W. Bare Mountain, Nevada 15' quadrangle]

Sample No. Laboratory (Field)	**Percent Material**	**Percent K_2O**	**mol^{40}Ar*/g**	**^{40}Ar***	**Age (Ma)[1]**
-- (102887-3)	Whole rock	1.79 1.83	2.799x10^{-11}	69	10.7±0.2
90I271A (102889-2)	Whole rock	1.543 (n=4)	2.346x10^{-11}	47.6	10.5±0.1
91I332A (102889-5A)	Whole rock	1.439 (n=4)	2.297x10^{-11}	43.4	11.1±0.1
91I329A (102889-6) Back split	Whole rock	1.83 (n=4)	2.793x10^{-11}	63.1	10.6±0.1

^{40}Ar* = radiogenic ^{40}Ar

[1]Uncertainties given at one standard deviation. Error determinations follow Cox, Allen, and Dalrymple, 1967 [Statistical analysis of geomagnetic reversal data and precision of potassium-argon data: Journal of Geophysical Research, v. 72, p. 2603-2614].

102887-3: Basalt Tb_1 of Monsen and others (1990); age previously reported by Monsen and others (1990)

102889-2: Basalt Tb_1 of Monsen and others (1990)

102889-5A: Basalt Tb_2 of Monsen and others (1990)

102889-6: Basalt Tb_3 of Monsen and others (1990)

Table 2. Conventional potassium-argon ages for selected Tertiary volcanic rocks in the Bullfrog 15' quadrangle by Florian Maldonado. [Analyses by U. S. Geological Survey, Denver, Colorado. Analysts: R.F. Marvin, H.H. Mehnert, and E.L. Brandt. Potassium measured by flame photometry following lithium metaborate fusion (Suhr and Ingamells, 1966). Argon measurements using standard techniques of isotope dilution (Dalrymple and Lanphere, 1969). Decay and abundance constants as recommended by Steiger and Jaeger (1977). Sample locations: D3270R--lat 36°46'15"N., long 116°51'15"W.; D3271R--lat 36°48'45"N., long 116°55'45"W.; D3272R--lat 36°57'45"N., long 116°55'25"W.; D3273R--lat 36°50'35"N., long 116°56'25"W.; D3300R--lat 36°55'20"N., long 116°48'00"W. Bullfrog, Nevada-California 15' quadrangle]

Sample No. Laboratory (Field)	**Material**	**Percent K_2O**	**mol^{40}Ar*/g**	**Percent ^{40}Ar***	**Age (Ma)[1]**
D3270R (BF-379)	Whole rock	2.35 2.33	0.2538x10-10	53	7.5±0.3
D3271R (BF-380)	Whole rock	1.29 1.29	0.1912x10-10	29	10.3±0.4
D3272R (BF-380A)	Whole rock	1.25 1.28	0.1478x10-10	37	8.1±0.4
D3273R (BF-383)	Whole rock	1.78 1.78	0.2317x10-10	60	9.0±0.3
D3300R (BF-383)	Biotite	7.49 7.50	1.080x10-10	54	10.0±0.4

^{40}Ar* = radiogenic ^{40}Ar

[1] Uncertainties given at one standard deviation.

D3270R: Basalt overlying Tertiary gravel in SE 1/4 of Bullfrog 15' quadrangle
D3271R: Basalt Tb_2 of Maldonado (1990)
D3272R: Basalt Tb_3 of Maldonado (1990)
D3273R: Basalt overlying Tuff of Leadfield road in SW 1/4 of Bullfrog 15' quadrangle
D3300R: Latite of Donovan Mountain (Unit Tl of Maldonado, 1990)