U.S. DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Digital Geologic Map Database of the Nevada Test Site Area, Nevada

By

Ronald R. Wahl[1], David A. Sawyer[1], Scott A. Minor[1], Michael D. Carr[4], James C. Cole[1], WC Swadley[1], Randell J. Laczniak[2], Richard G. Warren[3], Katryn S. Green[1], and Colin M. Engle[1]

Open-File Report 97-140

[1]Denver, Colorado [2]Las Vegas, Nevada [3]Los Alamos National Laboratory, New Mexico [4]Menlo Park, California

1997

INTRODUCTION

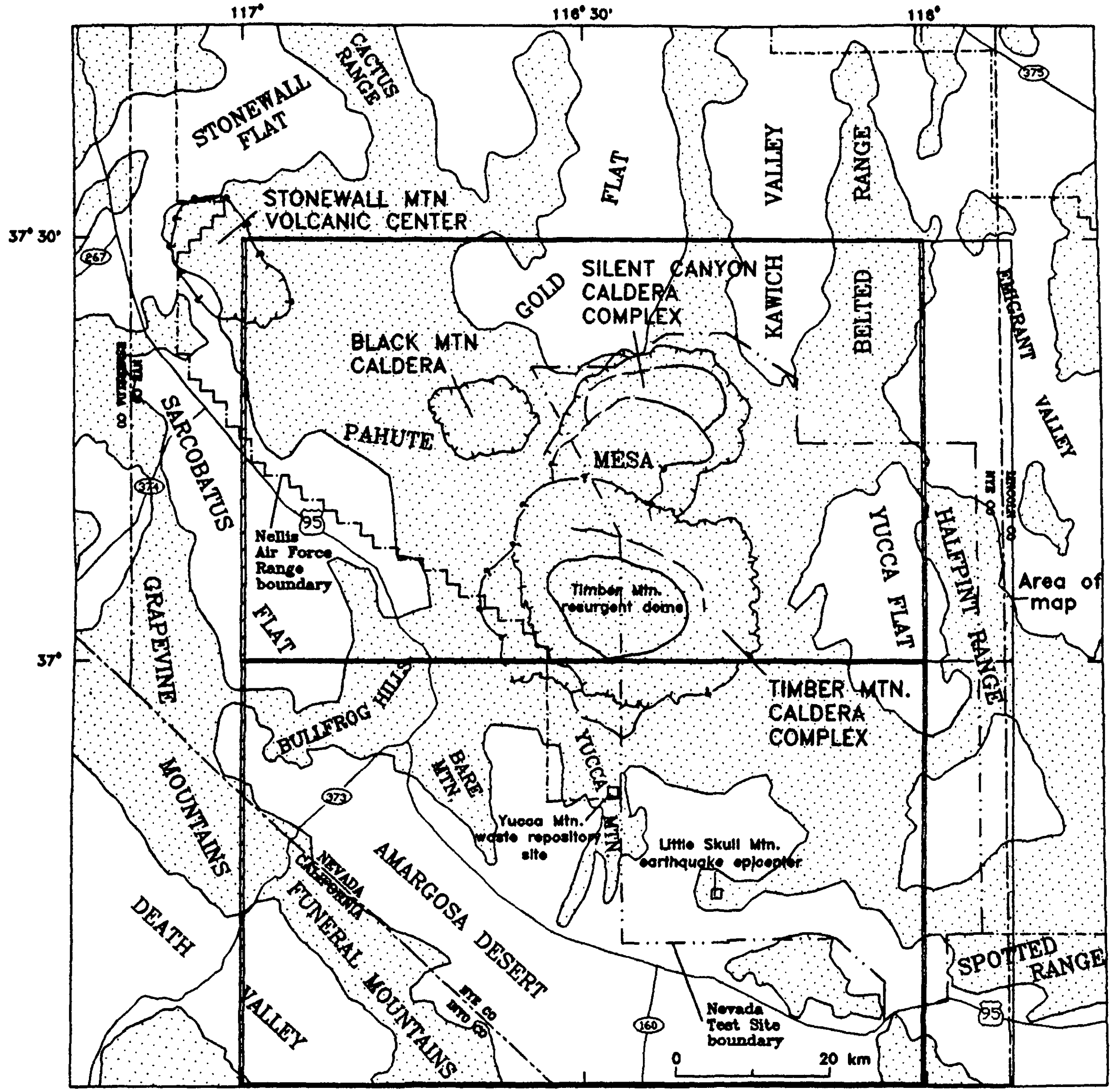
Work on geologic compilation of the Nevada Test Site (NTS) map and Pahute Mesa 30' x 60' quadrangle was conceptually proposed in 1984 as part of a U.S. Geological Survey (USGS) programmatic initiative to conduct a geologic synthesis of the southern Great Basin in Nevada. One of the central objectives of the program was to compile the geology of four contiguous 1:100,000-scale, 30' x 60' minute quadrangles that cover the region of interest (Pahute Mesa, Beatty, Pahranagat Range, and Indian Springs quadrangles), and to produce a separate 1:100,000-scale geologic map of the NTS that overlaps all four quadrangles. Digital compilation of the Pahute Mesa quadrangle began in 1990, with support coming entirely from the USGS Radioactive Waste Program. Work on the digital compilation of the NTS has largely been funded by the Department of Energy (DOE) NTS Program. Three of the other proposed 1:100,000-scale geologic maps have been completed, the NTS map (Frizzell and Shulters, 1990) and the Pahranagat Range quadrangle map (Jayko, in press), and the Beatty quadrangle map (Carr and others, 1995). A preliminary digital geologic map of the Pahute Mesa 30' x 60' quadrangle has been released (Minor and others, 1993), and a preliminary version of this map was released (Sawyer and others, 1995). A derivative map by Minor and others, 1996 was made from this database to portray the seismicity of the Pahute Mesa 30’ x 60’ quadrangle.

The Nevada Test Site/Pahute Mesa/Beatty digital geologic map database allows for accurate and rapid updating of geologic information, generation of derivative maps at various scales, and layering with other Geographic Information System (GIS) databases and thematic map layers to produce integrated interpretive maps and 3-D models. The digital database is available, in Geographic Resource Analysis Support System (GRASS) ASCII vector, DLG-3 (optional), SDTS, and in Arc/Info ASCII (Generate) and export formats, from the USGS, Denver, on-line repository on Internet (via 'anonymous ftp') at greenwood.cr.usgs.gov [136.177.21.122], path (/pub/open-file-reports/ofr-97-140). Figure 1 shows the area of coverage for this database.

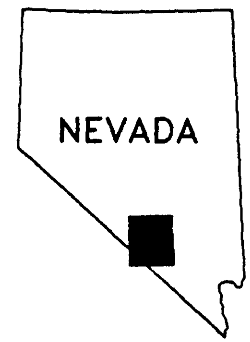
COMPILATION METHODS

This map database incorporates geologic data from the following sources): (1) digitized (by SCITEX scan) polygon, fault, and structural attitude layers of the published 1:100,000-scale geologic map of the Nevada Test Site (Frizzell and Shulters, 1990) as a starting point; (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), (4) the digital 1:100,000-scale geologic compilation of the Beatty 30' by 60' quadrangle (Carr and others, 1995);), (5) the preliminary digital 1:100,000-scale geologic compilation of the Indian Springs 30' by 60' quadrangle (unpublished data); and (6) recent field studies of stratigraphy and structure by the authors and others (Figure 2a).

Sawyer was lead compiler for the NTS part of the combined database; Minor was lead compiler of the Pahute Mesa sheet outside of the NTS area; Carr was lead compiler of the



Location map showing the regional and cultural setting of the NTS digital geologic database.



MAP DATABASE LOCATION

Figure 1._ Location Maps for the Nevada Test Site and the Surrounding Region

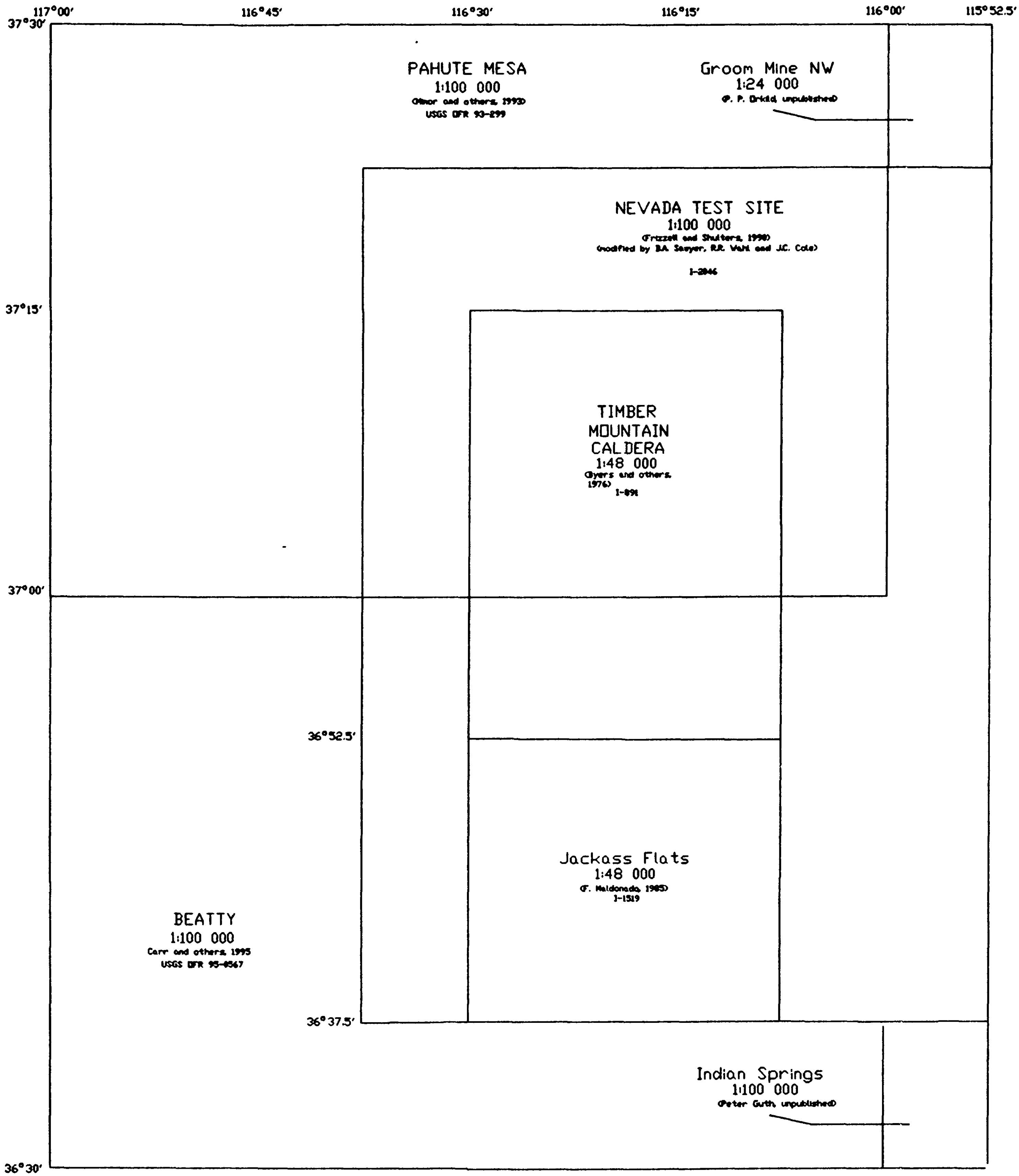


Figure 2a._ Sources of Compiled Geologic Data for the Nevada Test Site Area

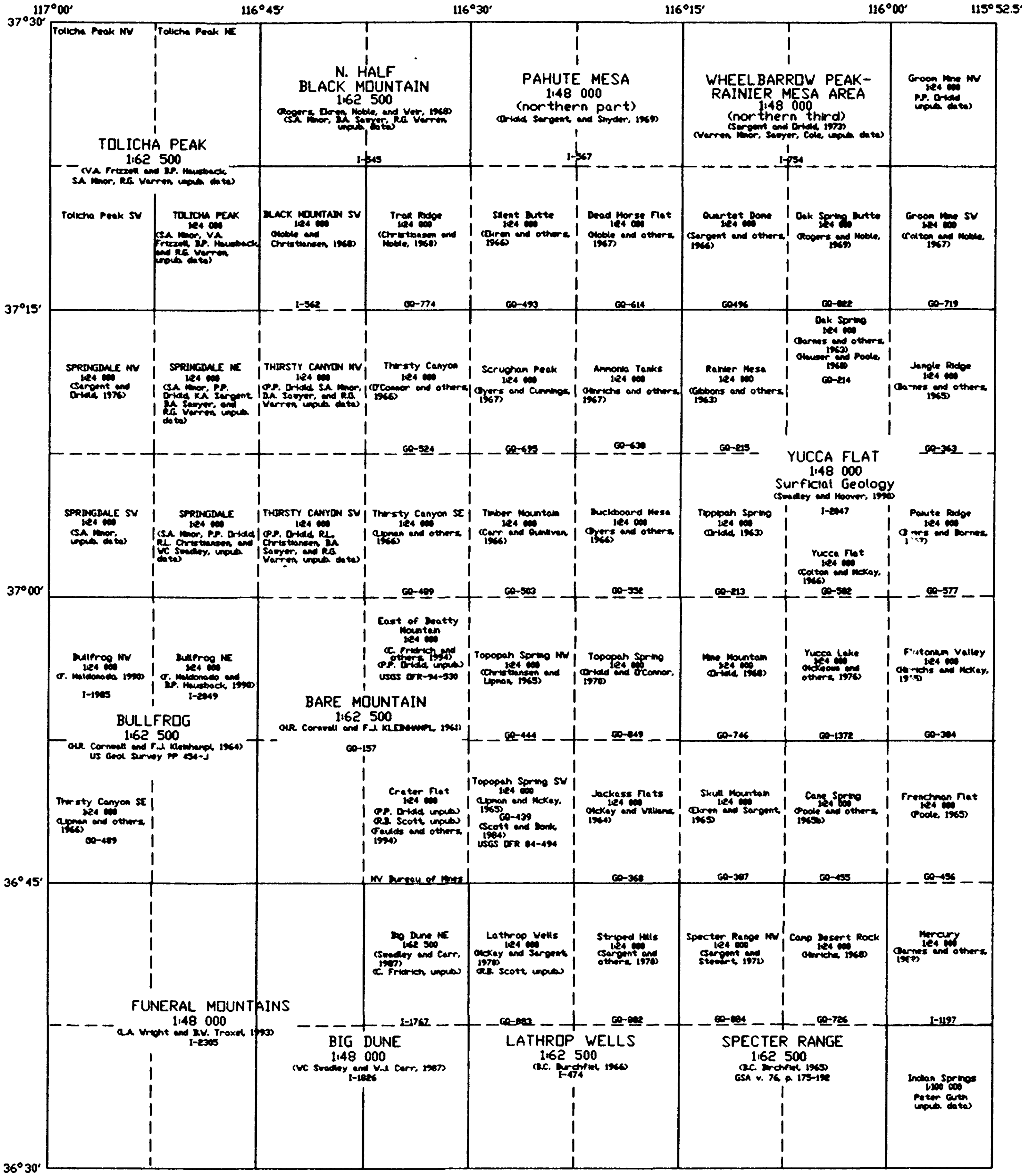


Figure 2b._ Sources of Original Geologic Data for the Nevada Test Site

Beatty sheet outside of the NTS area; Swadley compiled the new surficial geology and stratigraphy in the NTS area and Cole compiled the new geology and stratigraphy of the pre-Tertiary sedimentary rocks in the NTS area.

New geologic field data were digitized directly from field-annotated aerial photographs using a digital photogrammetric plotter or from scale-stable author-prepared maps using a digitizing tablet or scanner. 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 (Figure 2b). All new digital files as well as the pre-existing Pahute Mesa, Beatty, Indian Springs, surficial geology, and NTS geologic map files were imported into the raster processing software LT4X for cleaning, editing, and, in the case of scan files, vectorization. The new map data were also imported into AutoCAD from the digital photogrammetric plotters for editing and simplification for depiction at a scale of 1:100,000. The Geographic Resource Analysis Support System (GRASS), a public domain GIS developed by the U. S. Army Corps of Engineers, was used to integrate all of the new component map files to perform tranforming, as needed to the Universal Transverse Mercator projection, Zone 11, merge the files in the appropriate composite map-data layers, conduct final editing and modification of map elements, and build and tag polygons.

The map dataset may produce some minor display conflicts when displayed in full because of limitations of the algorithms used to automatically generate the unit labels (labels of some narrow polygons extend into adjoining polygons), and faults or fault decorations (for example, ball and bar symbols) locally overlap map unit labels or structural attitude symbols. These labeling conflicts were not resolved for this 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 differences in polygon contacts or structural features compared to data captured at larger scales of resolution.

DESCRIPTION OF MAP UNITS

GENERAL

The Tertiary map unit descriptions were largely compiled using recent petrographic, chemical, stratigraphic, and geochronologic data by Sawyer, Minor, and Warren. The pre-Tertiary unit descriptions were largely compiled by Cole, and descriptions of Quaternary and other surficial units were based on information contributed by Cole and Swadley.

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 table 1 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. Phenocrystic 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 from the SWNVF, they may be inappropriate when applied to other volcanic fields.

Table 1._ Total Phenocryst Content

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

Table 2._ Phenocrystic Mineral Abundances in Intermediate to Silicic Volcanic Rocks

Term	Felsics (median modal %)	Mafics (median modal %)	Accessories (median ppm/V)
rare	<0.5	<0.1	<20
sparse	0.5-2	0.1-0.5	20-150
common	2-10	0.5-1	150-300
abundant	10-20	1-2	>300
very abundant	>20	>2	

Table 3. Phenocrystic Mineral Abundances in Basaltic Volcanic Rocks

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

Tertiary volcanic stratigraphic nomenclature is from Sawyer and others (1994), Warren and others (1989, in press), and Ferguson and others, 1994. Some map unit descriptions and informal unit names cited within them are derived from descriptions in published USGS Geologic Quadrangle (1:24,000-scale) and Miscellaneous Investigations (1:48,000-scale) Series maps (figure 2b) or, in the case of central Nevada volcanic units, from Scott and others (1995). 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 Cole and others (1989), Guth (1986, 1990), Cashman and Trexler (1994), Minor and others (1993), and Trexler and others (1996), and is based on many published studies cited by them. Descriptions of these units are largely summarized from published geologic map descriptions (figure 2b), 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). Metamorphic facies and structures are mapped in the Funeral Mountains and in the Bare Mountain area are based on recent studies by Hoisch and Simpson (1993) and Hoisch (1995).

Reported ages for volcanic units are based mainly on 40Ar/39Ar age determinations (Best and others, 1989; Fleck and others, 1991; Noble and others, 1991; Sawyer and others, 1994). Published 40Ar/39Ar 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). 40Ar/39Ar ages are supplemented by published K/Ar results of Kistler (1968) and Marvin and others (1970, 1973, 1979, 1989), recalculated using current IUGS constants (Steiger and Jaeger, 1977; Dalrymple, 1979). 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 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 maps 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.

DESCRIPTIONS

Qay **Young alluvium** (Holocene and late Pleistocene)-- Gravel, gravelly sand, and sand, light-brownish-gray to grayish-yellow, poorly sorted, poorly bedded, unconsolidated to weakly consolidated. Gravel is angular to rounded; consists of ash-flow tuff, lava, limestone, dolomite, quartzite, and sandstone. Sand is poorly sorted, fine to very coarse, locally silty. Unit forms channel deposits of active streams, terrace deposits along some of the larger washes, and extensive fans that commonly form the lower part of fan aprons that flank mountain ranges. Terrace and fan deposits commonly stand 2 m or less above modern washes and are generally smooth and undissected. Soil varies from no visible soil development to soils consisting of a thin sandy vesicular A horizon, a slightly cambic B horizon, and a stage I Bk horizon as much as 0.5 m thick. Unit correlates with unit Q1 of Hoover and others (1981).

Qey **Young Quaternary eolian deposits** (Holocene)--Young eolian sand and silt. Wind-blown sand and silt forming dunes, sheet deposits, mounds stabilized by vegetation, and ramp deposits.

QTc **Colluvium** (Quaternary and Tertiary)--Compilation unit consisting of unsorted, non-bedded, weakly consolidated rock debris near the interface between bedrock and surficial deposits of various ages; may locally enclose areas of bedrock too small to depict. Unit not compiled in areas of steep terrain, although it is widespread.

Qp **Playa and lake 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, Kawich Lake, Gold Flat Lake, Frenchman Lake, and Death Valley.

Qs **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; Troxel and Wright, 1989).

Qlb **Lacustrine beach deposits** (Holocene and late Pleistocene)--Two ages of beach deposits are recognized. Deposits of late Pleistocene pluvial lakes form low discontinuous sand ridges near the four playas within the map area. Sand is yellowish gray, moderately sorted, mostly medium to coarse, weakly consolidated, slightly pebbly. Ridges are 1-3 m high, commonly covered with a pebble to coarse sand lag; surface clasts have a weakly developed desert varnish. One Holocene beach ridge was mapped at the east edge of the Gold Flat playa. Deposit consists of grayish-orange, thinly crossbedded, unconsolidated, slightly pebbly, calcareous sand. Ridge is about 2 m high and is sparsely covered with a pebble gravel lag. Soil development limited to a thin vesicular A horizon on some late Pleistocene deposits.

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

Qam **Middle alluvium** (middle Pleistocene)--Gravel, gravelly sand, and sand, yellowish-gray to grayish-brown, poorly sorted, moderately to poorly bedded, moderately consolidated. Gravel is angular to rounded, includes ash-flow tuff, lava, limestone, dolomite, quartzite, and sandstone. Sand is poorly sorted, commonly angular, locally silty. Unit forms extensive fans and fan and terrace remnants that generally comprise the middle and upper parts of fan aprons flanking bedrock ranges. Depositional surface of unit is largely intact but has been, moderately dissected by small washes that head within the fans. Deposits commonly stand 2 to as much as 20 m above through-flowing washes. A moderately to tightly packed stone pavement is common. Soil development consists of a silty, clayey sand vesicular A horizon, a dark-yellowish-orange cambic to slightly argillic B horizon that is rarely preserved, and a stage II Bk horizon to stage III K horizon commonly 1.0 to 1.5 m thick. Unit includes deposits from three periods of deposition that were not mapped separately because of map scale. The youngest of the three deposits correlates with unit Q2b and the two older deposits with unit Q2c of Hoover and others (1981).

Qem **Middle eolian deposits** (middle Pleistocene)--Sand, very pale orange to light-grayish-brown, poorly to moderately sorted, fine to coarse, weakly consolidated, no bedding preserved. Unit commonly includes varying amounts of eolian sand that has been reworked by slope wash and intermittant streams. These reworked deposits contain scattered gravel clasts and lenses and locally are capped by well-developed paleosols. Unit forms large sand ramps flanking bedrock hills adjacent to Sarcobatus Flat. No exposures of soil were observed within the quadrangle; regionally the surface soil typically consists of a partly eroded 0.5- to 1.0-m-thick stage III K horizon. Correlates with unit Q2e of Hoover and others (1981). Compiled unit locally includes suspected young Quaternary eolian deposits.

QTa **Quaternary surficial deposits**--undivided (Holocene, Pleistocene, and Pliocene?)-- Unit represents undivided surficial deposits, chiefly in the southern and eastern parts of the database area, where studies to classify the surficial materials have not been completed. Unit chiefly consists of materials similar to Middle alluvium.

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; Pexton, 1984). 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). Unit locally contains possible younger playa deposits that were not specifically identified.

QTu **Undifferentiated surficial deposits** (Holocene, Pleistocene, and Pliocene?)--Includes younger, middle, and older alluvium; younger and older eolian deposits in Emigrant Valley, and colluvial deposits. Alluvial deposits consist of unconsolidated gravel, gravelly sand, silty sand, and sandy silt. Clasts are locally derived. Angular to subrounded, poorly to moderately consolidated gravel, generally with sparse sand and silt in matrix. Light gray to light brownish gray to yellowish brown to grayish brown, poorly to moderately well sorted, poorly to well bedded. Alluvium is 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. Middle and older alluvium form terraces in washes and dissected alluvial fans, and fan remnants. Colluvium is unconsolidated 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. This unit is mapped only in areas where the information about the surfical geology is incomplete.

Qby **Younger Quaternary basalt** (Pleistocene)--Isolated cinder cones, lava flows, and feeder dikes at Little Black Peak and on the flank of Sleeping Butte about 12 km north of Oasis Mt., and south of Crater Flat, about 10 km northwest of the town of Amargosa Valley (formerly known as Lathrop Wells). Rock compositions are mainly phenocryst-poor trachybasalt and basalt, although more sodic compositions, including hawaiite, are known. Phenocrysts consist of common olivine and sparse plagioclase. Distinguished by a low phenocryst abundance, predominance of olivine, by young ages [about 350 Ka for Sleeping Butte area basalts (Fleck and others, 1996) and about 130 Ka for Lathrop Wells basalt (Turrin and others 1991)] 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, 1996). 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 at Buckboard Mesa (2.87 +/-0.06 Ma; normal magnetic polarity), rocks in southeastern Crater Flat (3.73 +/- 0.02 Ma; reverse polarity), and at the broad shield volcano at Thirsty Mountain about 10 km north of Oasis Valley (4.63 +/- 0.02 Ma; reverse polarity). The ages are from Fleck and others, 1996. Lithologies consist of lava flows and scoria mounds of dark gray to dark-reddish-brown basalt. Phenocrysts vary from common to abundant olivine, sparse plagioclase, and sparse clinopyroxene in Buckboard Mesa area; to common to abundant olivine in southeast Crater Flat; to phenocryst poor with rare plagioclase in Thirsty Mountain area. Distinguished by marked preservation of constructional volcanic geomorphology, Pliocene age, and characteristic magnetic polarity of each center. Maximum thickness more than 200 m at the Thirsty Mountain shield volcano; as much as 100 m thick at other localities.

Tgf **Funeral Formation** (Pliocene and Late Miocene?)--Mostly fanglomerate derived from Funeral Mountains. Clasts derived predominantly from Cambrian and Precambrian quartzose sedimentary rocks. Locally intertongues with unconsolidated silty lacustrine deposits (Troxel and Wright, 1989). A whole rock potassium-argon age of about 4.1 Ma was obtained from basalt outside the database area (McAllister, 1973), and on this map may be younger. The Funeral Formation is tilted and is unconformably overlain by alluvial-fan deposits that retain their most of their original fan morphology. Base of unit is local angular unconformity.

Tgy **Younger sedimentary deposits** (Pliocene and Miocene)--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. Unit locally contains interbedded, partly tuffaceous sandstone and mudstone and layers of nonwelded vitric tuff and limestone; such interbedded, fine-grained deposits are 65 m thick within gravel deposits north of Beatty Wash. Clasts consist of locally derived Tertiary volcanic rocks and lesser pre-Tertiary sedimentary rocks, and are as large as 3 m across. Monolithologic landslide breccia derived from nearby bedrock is locally present within unit. Unit forms deeply dissected alluvial fans in Oasis Valley, Beatty Wash, northern Crater Flat, and northwest of Tolicha Wash that disclose complex internal stratigraphy due to repeated pedimentation Unit may be deposited over a span of at least 3 m.y.and is possibly diachronous in different areas; in northern Crater Flat, contains beds of volcanic ash that are 8.2 Ma (Monsen and others, 1992); farther north, the 7.5-Ma Spearhead

Member of Stonewall Flat Tuff is within the basal part of these sedimentary deposits; and 4.63-Ma basalt from the Thirsty Mountain shield volcano is interbedded with gravels in lower Thirsty Canyon. Maximum thickness about 180 m in Oasis Valley area. Equivalent in part to gravel of Sober-up Gulch of Maldonado and Hausback (1990) and the gravels of Oasis Valley mapped by Minor and others (1993).

Tgfc **Furnace Creek Formation** (Late Miocene)--Mostly fanglomerate, derived from reworked older Tertiary gravels similar to those in the upper plate of the Boundary Canyon fault, Funeral Mountains. Locally intertongues with unconsolidated silty lacustrine sediments (Troxel and Wright, 1989). 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 both older and younger volcanic units 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.

Tsc **Civet Cat Canyon Member of Stonewall Flat Tuff** (Miocene)--Comendite welded ash-flow tuff erupted from Stonewall Mountain caldera at 7.45 Ma. Compositionally zoned from lower comendite, containing common alkali feldspar (anorthoclase and sodic sanidine) and rare clinopyroxene, plagioclase, and fayalitic olivine, to upper crystal-rich trachyte containing abundant alkali feldspar, common plagioclase, sparse biotite and clinopyroxene, and rare orthopyroxene; acmite or arfvedsonite is present in groundmass. Magnetic polarity reverse. Maximum exposed thickness 180 m.

Tsp **Spearhead Member of Stonewall Flat Tuff** (Miocene)--Welded ash-flow tuff erupted from Stonewall Mountain caldera at 7.5 Ma. Lithology 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.

Tsr **Rhyolite of Stonewall Mountain** (Miocene)-- Lava flows and domes adjoining Stonewall Mountain caldera (Weiss and Nobel, 1989). Rhyolite is crystal-rich, containing abundant biotite and common sanidine, plagioclase, and clinopyroxene; flow laminated and flow folded. Maximum preserved dome height exceeds 200 m.

Tyb **Thirsty Canyon and younger basalts** (Miocene)-- Lava flows, cinder cones, and local feeder dikes erupted between 9.9 and 6.3 Ma in widespread locations generally north and west of Timber Mountain, near the Black Mountain caldera and Stonewall Mountain volcanic center, and in northern Pahute Mesa at Basalt Ridge. Basalts erupted before, during, and following peralkaline rhyolitic eruptions of the Black Mountain caldera. Variable crystal content; phenocryst-rich varieties contain very abundant plagioclase and abundant olivine; 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. Maximum exposed thickness about 100 m. See Carr and others (1995) for details of units compiled.

Tys **Andesite of Sarcobatus Flat (Miocene)**--Andesitic lava flows and subordinate interflow tuffaceous sedimentary rocks exposed in low hills along edge of Sarcobatus Flat in western part of map area. Andesitic flows contain common plagioclase and sparse to common orthopyroxene and hornblende. Includes intermediate-composition rocks of peralkaline affinity, probably close in age to rocks of Thirsty Canyon Group, east of Black Mountain. Maximum exposed thickness about 100 m.

Tyr **Rhyolite of Obsidian Butte** (Miocene)--Flow-laminated and -folded spherulitic rhyolite lava flows (8.8 Ma; Noble and others, 1991) and subordinate related pyroclastic and sedimentary rocks near Obsidian Butte. Generally aphyric, but some flows contain sparse plagioclase, biotite, or olivine, or rare clinopyroxene. Pyroclastic rocks mainly consist of variously bedded, pumice- and lithic-rich tuff, tuff breccia, and reworked tuff; sedimentary rocks are generally well-bedded tuffaceous sandstone and conglomerate; clasts chiefly consist of locally derived rhyolite. Intertongues with basalt flows of unit Tyb. Maximum exposed thickness about 375 m.

Tgm **Late synvolcanic sedimentary rocks** (Miocene)--Compilation unit consisting of weakly to moderately consolidated, generally well-bedded pebble to cobble conglomerate, breccia, sandstone, siltstone, nonwelded tuff, and locally reworked tuff, in various locations. Clasts are mostly Miocene volcanic rocks, but Proterozoic/Paleozoic debris is conspicuous in Halfpint Range. Matrix generally tuffaceous, and thin ash-fall beds (less than 1 m) are commonly vitric and contain pumice lapilli. Late synvolcanic sedimentary rocks deposited in local paleobasins and paleochannels in northwestern part of area, in the Halfpint Range, and in the Little Skull Mountain area. Deposition post-dates eruption of Timber Mountain Group but overlaps with the Thirsty Canyon Group and associated basalts. Maximum exposed thickness about 125 m.

Tgc **Caldera moat-filling sedimentary deposits** (Miocene)--Interbedded 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. Moat-filling sedimentary deposits distinguished from other deposits by position within the Timber Mountain caldera complex and the Black Mountain caldera. Maximum thickness about 300 m in Timber Mountain caldera complex.

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; compiled only in the Bullfrog Hills, in isolated exposures north of Tolicha Peak, and along the south margin of Crater Flat. At Bullfrog Hills, unit 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. Thin basal zones of slide sheets are subparallel to local bedding and consist of sheared and comminuted tuff. Conglomerate is variably bedded, matrix-supported, poorly sorted, and contains locally well-rounded pebbles, cobbles, and rare boulders. Fanglomerate is polymictic, poorly sorted, and commonly has matrix of tuffaceous sandstone. 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 and have a maximum exposed thickness exceeding 400 m. Unit in southern Crater Flat consists of blocks and sheets of monolithologic breccia derived from Paleozoic carbonate rocks, designated "landslide blocks" (part) of Swadley and Carr (1987) that overlie Timber Mountain Group.

Thirsty Canyon Group (Miocene)--Peralkaline volcanics erupted as ash-flow sheets, lavas, and related nonwelded tuffs from Black Mountain between 9.4 and 9.15 Ma. The Pahute Mesa and Trail Ridge Tuffs likely are the major units associated with caldera collapse. The younger Pillar Spring, Yellow Cleft, and Hidden Cliff lavas and associated rocks chiefly accumulated within the caldera depression, while the Gold Flat Tuff filled the caldera and overflowed to the north and south. Thirsty Canyon Group is distinguished by its peralkaline mineralogy (high alkali feldspar and low plagioclase contents, general absence of biotite and hornblende, and presence of Fe-rich clinopyroxene and fayalitic olivine) and chemistry (high iron, low alumina, and anomalously high trace-element concentrations of zirconium, rare-earths, and other elements). Subdivided into:

Ttg **Gold Flat Tuff**--Strongly peralkaline (pantellerite) welded ash-flow tuff erupted at 9.15 Ma from Black Mountain caldera. Contains abundant anorthoclase and sodic sanidine, sparse plagioclase, Fe-rich clinopyroxene, and fayalitic olivine, and rare biotite, quartz, and hornblende. Arfvedsonite occurs both as sparse phenocrysts and as a devitrification product in groundmass. Contains rare primary fluorite and aenigmatite. Anomalous normal magnetic polarity. Chiefly preserved in caldera moat; thickness outside caldera unknown.

Tth **Trachyte of Hidden Cliff**--Very crystal-rich trachyte lavas containing very abundant plagioclase(distinctive) and common to very abundant olivine and clinopyroxene. Normal magnetic polarity. Extruded within Black Mountain caldera (exposed part exceeds 500 m).

Tts **Trachytic rocks of Pillar Spring and Yellow Cleft**--Crystal-rich trachyte to rhyolite lava flows, associated tuff and tuff breccia, and porphyritic syenite intrusive rocks within Black Mountain caldera. Lavas contain abundant to very abundant alkali feldspar (mainly anorthoclase), common plagioclase, sparse clinopyroxene and olivine, and local rare biotite; phenocrysts in syenite consist of abundant anorthoclase and sodic plagioclase and lesser olivine and clinopyroxene. Reverse magnetic polarity; maximum exposed thickness 180 m.

Ttt **Trail Ridge Tuff**--Widespread welded, moderately crystal rich, comendite ash-flow tuff erupted from Black Mountain caldera. Contains abundant sodic sanidine, sparse Fe-rich clinopyroxene and fayalitic olivine, and rare plagioclase. Anomalous reverse magnetic polarity. Maximum exposed thickness about 65 m.

Ttp **Pahute Mesa and Rocket Wash Tuffs**--Widespread comendite ash-flow tuffs erupted from Black Mountain caldera. Pahute Mesa Tuff is welded, moderately crystal-poor, and 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. Rocket Wash Tuff, a local subjacent cooling unit erupted 9.4 Ma, has slightly more common alkali feldspar and nonanomalous reverse magnetic polarity; maximum exposed thickness about 50 m.

Ttc **Comendite of Ribbon Cliff**--Pre-caldera crystal-rich to very crystal rich comendite and trachyte lava flows and domes exposed marginal to the Black Mountain caldera. Contains abundant alkali feldspar, common plagioclase, sparse clinopyroxene and fayalitic olivine, and local rare biotite. Normal magnetic polarity. Maximum exposed thickness 320 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; and isolated lava and associated tephra in the lower Thirsty Canyon drainage and in Oasis Valley. Age ranges from about 10.5 Ma to 9.5 Ma. Maximum exposed thickness about 175 m.

Tft **Post-Timber Mountain basaltic rocks** (Miocene)--Lava flows erupted between 11.45 Ma and approximately 10 Ma; composition ranges from basalt, basaltic andesite, trachybasalt, to basaltic trachyandesite. Flows generally contain common olivine, sparse plagioclase, and rare clinopyroxene. See Carr and others (1995) for specific local units included in this compilation unit. Maximum exposed thickness about 30 m.

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

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

Tfd **Lavas of Dome Mountain (Miocene)**--Interstratified trachybasalt, basaltic trachyandesite, and trachyandesite lava flows that overlap the southern topographic wall of Timber Mountain caldera complex. Lavas are compositionally and mineralogically varied; 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. Rhyoite that intrudes the Rhyolite of Rainbow Mountain in the Bullfrog Hills is compiled with 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. In the northern part of the Bullfrog Hills unit 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 Tgx. 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. Rhyolite of Chukar Canyon subunit contains petrographically similar tephras and mixed basalt-rhyolite pumice in upper part. Quartz-poor character and abundance of sphene are diagnostic. Unit 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. Phenocrysts include common plagioclase, sparse sanidine, hornblende, and clinopyroxene. Tuff contains as much as 20 percent red-brown fragments 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)--Calc-alkaline assemblage erupted from the Timber Mountain caldera complex between about 11.6 and 11.45 Ma. Group is chiefly 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 (11.6 Ma) and Ammonia Tanks Tuff (11.45 Ma) resulted in collapse of the Rainier Mesa and Ammonia Tanks calderas (Christiansen and others, 1977), which together form the Timber Mountain caldera complex. The younger caldera is centered about Timber Mountain, which is a resurgent dome of the Ammonia Tanks Tuff.

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:

Tmay **Trachyte of East Cat Canyon**--Immediately post-caldera, very crystal-rich trachyte lavas erupted prior to resurgence on margin of Timber Mountain resurgent dome. Contains very abundant plagioclase and biotite, abundant clinopyroxene, sparse sanidine and orthopyroxene, rare quartz and hornblende, and abundant apatite. Close temporal and compositional association with Ammonia Tanks Tuff is distinctive, as is the presence of sanidine and quartz, which is unusual for an intermediate lava. Maximum thickness about 125 m. Includes rhyolite of Parachute Canyon.

Tmaw **Tuff of Buttonhook Wash**--Post-caldera, crystal-rich rhyolite ash-flow tuff and subordinate bedded tuff erupted immediately after Ammonia Tanks caldera subsidence, within Timber Mountain caldera complex. Contains common sanidine, plagioclase, and quartz, sparse biotite and clinopyroxene, local rare hornblende, and abundant sphene. Very similar to intracaldera Ammonia Tanks Tuff, but separated 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 metaluminous, welded ash-flow tuff sheet erupted at 11.45 Ma from Ammonia Tanks caldera 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 rhyolitic tuff but contains sparse hornblende and rare orthopyroxene, clinopyroxene, and Mg-rich olivine with basaltic lapilli. Distinguished by high quartz and mafic 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 that grades downward into megabreccia. Composed of angular clasts as much as 6 m across and variable amounts of coarse-grained tuffaceous matrix; clasts locally derived from volcanic rock units exposed on topographic wall of Rainier Mesa caldera. Lower part of unit locally intertongues with upper Rainier Mesa Tuff; top is overlain by Ammonia Tanks Tuff. Breccia emplaced as debris flows and rock avalanches shed from topographic wall following Rainier Mesa caldera collapse. Thickness exceeds 300 m. Unit may locally include similar breccia emplaced following Ammonia Tanks caldera collapse.

Tmat **Rhyolites of Tannenbaum Hill/Buried Canyon**--Rhyolite lavas and related subordinate nonwelded tuff erupted between emplacement of Rainier Mesa Tuff and Ammonia Tanks Tuff within the Rainier Mesa caldera; chemically and petrographically similar to Ammonia Tanks Tuff. Contains common quartz and sanidine, rare plagioclase and biotite, and common sphene. Distinguished by sphene content, normal magnetic polarity, and stratigraphic position between major ash-flow tuff units. Isotopic age of 11.54 +/- 0.03 Ma (Fridrich, Sawyer, Fleck, and Lanphere, unpublished data) Thickness greater than 180 m.

Tmt **Basalts in Timber Mountain Group**--Flows emplaced before and after eruption of Rainier Mesa Tuff; see Carr and others (1995) for details of specific basalts compiled with this unit. Both normal and reverse magnetic polarity units are included. Maximum exposed thickness less than 30 m.

Tmr **Rainier Mesa Tuff**--Widespread metaluminous welded ash-flow tuff sheet erupted at 11.6 Ma from Rainier Mesa caldera. 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). Locally underlain by thin (about 10 cm) distinctive layers of dacite and overlying trachybasalt tephra that contain abundant hornblende, common plagioclase, and sparse orthopyroxene. Unit distinguished by high quartz and mafic 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 but locally accumulated as much as about 400 m thick in topographic lows. 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**--Rhyolite lava and nonwelded tuff erupted prior to formation of Rainier Mesa caldera. 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. Erupted at 11.62 +/- 0.03 Ma (Fridrich, Sawyer, Fleck, and Lanphere, unpublished data). Includes Rhyolite of Pinnacles Ridge south of Beatty Wash.

Tgnx **Transitional Timber Mountain breccia and sedimentary rocks** (Miocene)--Volcaniclastic sedimentary rocks deposited near 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 that represent the initial eruptions of the Timber Mountain Group, but chiefly preserved within the 12.5 Ma Claim Canyon caldera. 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).

Paintbrush Group (Miocene)--Metaluminous assemblage of alkali rhyolite tuffs and lavas erupted between 12.8 and 12.7 Ma from calderas that were largely obliterated by the younger Timber Mountain caldera complex. The Topopah Spring Tuff and Tiva Canyon Tuff are the major ash-flow units of the Group. The Tiva Canyon formed the Claim Canyon caldera, which is partially preserved on the south margin of the Timber Mountain caldera complex; location of the caldera formed during eruption of the Topopah Spring Tuff is uncertain. Paintbrush Group rocks are distinguished from Timber Mountain units by absent or scarce quartz phenocrysts in rhyolite units and by typical 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 in northern topographic wall of Ammonia Tanks caldera. Contains common sanidine and common to sparse plagioclase and biotite. Includes rhyolite of Scrugham Peak, rhyolite of Benham, and 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. Includes the former tuff of Chocolate Mountain (Christiansen and Lipman, 1965), which is intracaldera Tiva Canyon in the Claim Canyon caldera, an upper separate cooling unit (tuff of Pinyon Pass) in the same area. Maximum exposed thickness about 110 m.

Tpx **Paintbrush caldera-collapse breccias**--Caldera-collapse landslide breccias emplaced in the Claim Canyon caldera with intracaldera Tiva Canyon. Clasts consists of varied pre-Tiva Canyon volcanic rocks.

Tpy **Yucca Mountain Tuff**--Welded aphyric rhyolite ash-flow tuff that forms a simple cooling unit in the vicinity of the Claim Canyon caldera. Distinguished by its extremely low phenocryst content, stratigraphic position immediately beneath the Tiva Canyon Tuff, and reverse magnetic polarity. 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 emplaced between eruptions of the major Tiva Canyon and Topopah Spring ash-flow tuff units. 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, 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. Unit also includes the rhyolite of Black Glass Canyon and rhyolite of Z. Distinguished reverse magnetic polarity. 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 near 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 90 m.

Tpt **Topopah Spring Tuff**--Widespread metaluminous welded ash-flow tuff sheet erupted at 12.8 Ma from uncertain caldera source located near the younger 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). Unit distinguished by high sanidine content but lower sanidine/plagioclase ratio than that of Tiva Canyon Tuff, and by trace quartz content, absence of sphene, and normal magnetic polarity. Maximum exposed thickness about 350 m.

Tac **Calico Hills Formation** (Miocene)--Metaluminous rhyolite lavas and related tuff erupted at 12.9 Ma from the Calico Hills area and the buried Area 20 caldera beneath Pahute Mesa (Sawyer and Sargent, 1989). Lavas postdate caldera collapse associated with Crater Flat Group tuffs, but are interpreted to be magmatically related to the Crater Flat cycle. 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). Unit includes crystal-rich rhyolites of Pool (sparse biotite and hornblende) and Inlet (common biotite and sparse hornblende) in subsurface of Pahute Mesa. Calico Hills distinguished by normal magnetic polarity, high relative quartz content, Fe-rich mafic minerals, and bedded pyroclastic character and local zeolitic alteration. Maximum exposed thickness approximately 200 m; but drilling indicates more than 2200 m thick within Area 20 caldera. Where unit is compiled west of Yucca Flat, at Rainier Mesa, in the southern Belted Range area, and north of Silent Canyon, may include undivided bedded tuff of various ages.

Tio **Older intrusive rocks** (Miocene)--Mixed unit of andesitic, hydrothermally altered, hypabyssal bodies in Bullfrog Hills and granitic-rhyolitic plutons that intrude the Wahmonie volcanic center. Andesite contains common plagioclase and clinopyroxene phenocrysts and predates or is coeval with overlying older basalt unit.

Tw **Wahmonie Formation** (Miocene)--Metaluminous crystal-rich andesite and dacite lavas, tephra, and related volcaniclastic deposits erupted at 13.0 Ma from the Wahmonie volcano, located outside the main cluster of SWNVF calderas in the area west of Frenchman Flat and south of Shoshone Mountain. Informally divided into compositionally distinct units (Warren and others, in press) that are not compiled in this database. Contains abundant to very abundant plagioclase (increases upward in the sequence of lavas), very abundant to common biotite (decreases upward), abundant to sparse hornblende, rare to very abundant orthopyroxene (increases upward), very abundant clinopyroxene in middle and upper part, abundant olivine in the middle part, and sparse quartz. Distinguished by mafic-rich mineralogy, and dominance of plagioclase, and complete absence of sanidine.

Tws **Salyer Member (Miocene)**--Volcaniclastic facies of lower Wahmonie Formation that includes laharic breccia, bedded and reworked tuff, "tuff breccia" and other volcaniclastic breccia deposits.

Crater Flat Group (Miocene)--Calc-alkaline assemblage of ash-flow sheets, lavas, and related nonwelded tuff erupted between about 13.5 and 13.1 Ma from Area 20 caldera and possibly from the northern Crater Flat area vicinity (Prospector Pass caldera of Carr and others, 1986). The Bullfrog Tuff, the principal Crater Flat ash-flow tuff unit, was erupted from the buried Area 20 caldera beneath Pahute Mesa. The Crater Flat Group is distinguished by high relative quartz content among the felsic minerals and Fe-rich mafic mineralogy. Subdivided into:

Tcp **Prow Pass Tuff** (Miocene)--Rhyolite welded ash-flow tuff sheet erupted at about 13.1 Ma from an unknown source caldera. 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. Outcrops chiefly in a small area just northwest of Yucca Mountain, but known from drilling to be much more extensive in the subsurface.

Tcg **Latite of Grimy Gulch**--Local intermediate-composition, crystal-poor lava flows erupted on flank of Silent Canyon caldera complex at south end of Kawich Valley. Contains common plagioclase and olivine, sparse clinopyroxene, and rare sanidine and quartz (both with reaction rims). Normal magnetic polarity. Maximum thickness 76 m

Tcb **Bullfrog Tuff**--Widespread metaluminous, variably welded, rhyolite ash-flow tuff sheet erupted at about 13.25 Ma. Lithic content varies widely across the area from lithic-poor welded tuff south of Timber Mountain to thick, compositionally zoned, lithic-rich nonwelded tuff in the buried Area 20 caldera. Stockade Wash outflow lobe east of Timber Mountain, 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 (known only from subsurface data) 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); contains local landslide breccia deposits, and is locally as thick as about 680 m. Bullfrog Tuff is hydrothermally altered and locally brecciated in Bullfrog Hills. Distinguished by high relative quartz content among the felsics, sparse to rare biotite and hornblende, Fe-rich mafic minerals, general absence of sphene, and normal magnetic polarity. Where unit is compiled west of Yucca Flat, at Rainier Mesa, and in the southern Belted Range area, may include undivided bedded tuff of various ages.

Tcr **Rhyolites in the Crater Flat Group** (Miocene)--Thick rhyolitic flows and minor related breccia and tephra. Includes rhyolite of Prospector Pass west of Yucca Mountain (Fridrich and others, 1994), and various local flow units known only from the subsurface of Pahute Mesa (Warren and others, in press). These rhyolites typically contain common phenocrysts of plagioclase, quartz, and sanidine; common biotite and sparse hornblende.

Tct **Tram Tuff** (Miocene)--Widespread welded rhyolite ash-flow tuff, possibly erupted from source in the northern part of Crater Flat (proposed Prospector Pass caldera of Carr and others, 1986). Age about 13.4 Ma, stratigraphically bracketed between the Bullfrog Tuff and the Deadhorse Flat Formation rhyolite lava flows. Distinguished by phenocryst composition (subequal common quartz, plagioclase, and sanidine; sparse biotite as the only mafic mineral) and reverse magnetic polarity.

Tgp **Rocks of Pavits Spring and older synvolcanic sedimentary deposits, undivided** (Miocene)--Combined compilation unit that encompasses Tertiary sedimentary deposits that are older than the Timber Mountain Group and younger than any demonstrable Oligocene unit. Generally consists of bedded fluvial and lacustrine clastic deposits, limestone, and 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 southeastern part of database, includes Rocks of Pavits Spring that contain ash-flow tuff as old as 15.8 Ma (J. C. Yount, oral commun., 1989) and conglomerate clasts from Lincoln County, Nevada, sources as young as about 18.3 Ma.). Consists of nonwelded tuff and fluvial to lacustrine, locally tuffaceous sedimentary rocks in the Mt. Helen area and north of Black Mountain. Ash-fall tuffs are mineralogically similar to late and early rhyolites of Quartz Mountain, and to tuff of Tolicha Peak. Unit includes tuffaceous breccia derived from dacite of Mt. Helen. Locally zeolitized. Unit also includes rocks of Joshua Hollow (Monsen and others, 1990) and minor deposits south of Crater Flat that contain 14.9 Ma ash (J.C. Yount, oral commun., 1989). See Carr and others (1995) for additional units in the Bullfrog Hills and on the flanks of the Grapevine and Funeral Mountains compiled with this unit.

Tgox **Older landslide breccias and sediments** (Miocene)-- Monolithologic breccia, heterolithic angular gravel, and coarse sandstone. Breccia debris is typically dolomite or Precambrian quartzite, depending on local source rock. Base of unit is local unconformity. Unit directly overlies Grouse Canyon Tuff (13.7 Ma) south of Quartz Mt. Well-bedded boulder conglomerate and sandstone directly overlies Redrock Valley Tuff (15.3 Ma) at north end of Mine Mountain.

Belted Range Group (Miocene)--Peralkaline rhyolite ash-flow sheets, lavas, and related nonwelded tuff erupted between 13.85 and 13.5 Ma from the Grouse Canyon caldera of the Silent Canyon caldera complex. Grouse Canyon Tuff is the major Belted Range caldera-forming unit and forms a widespread ash-flow in the region. Following Grouse Canyon caldera collapse, thick peralkaline lavas and related tuff of the Deadhorse Flat Formation accumulated in the caldera and overflowed northward into the Saucer Mesa area. Belted Range Group is distinguished by its peralkaline mineralogy (high alkali feldspar and low plagioclase contents, absence of biotite and hornblende, and presence of Fe-rich clinopyroxene and fayalitic olivine) and chemistry (high iron and low alumina; high concentrations of zirconium and rare-earth elements). Subdivided into:

Tbd **Deadhorse Flat Formation**--Post-caldera lavas and related tuff erupted within Grouse Canyon caldera between 13.7 and 13.5 Ma. Mineralogy is variable among the different subunits of formation, and ranges from crystal-rich comendite and trachyte to crystal-poor and aphyric comendite. Phenocrysts include common sodic sanidine as well as clinopyroxene and fayalitic olivine. Unit includes comendite of Lambs Canyon (with common quartz), aphyric comendite of Kaw Station, comendite and low-silica comendite of Saucer Mesa, comendite of Basket Valley, comendite of Chartreuse (with sparse quartz and rare plagioclase), and trachyte of Muenster (with abundant alkali feldspar and rare plagioclase). Comendite of Lambs Canyon has reverse magnetic polarity, and has been dated at 13.5 Ma; comendite of Saucer Mesa has normal polarity. Maximum thickness about 1600 m in subsurface of Pahute Mesa; maximum exposed thickness about 150 m.

Tbdb **Comendite of Basket Valley**--Subunit of Dead Horse Flat Formation compiled separately only in the area northeast of Grouse Canyon caldera where it is mappable at base of formation; subsurface data indicate the comendite of Chartreuse is older. Comendite lava and welded to nonwelded tuff; distinguished by abundant alkali feldspar and rare quartz, clinopyroxene, and fayalitic olivine, by strong light rare-earth element enrichment, and rheomorphic character of lava. Unit includes low-silica comendite lava north of Apache Tear Canyon. Normal magnetic polarity. Maximum exposed thickness about 150 m.

Tbg **Grouse Canyon Tuff**--Widespread peralkaline welded ash-flow tuff sheet erupted at 13.7 Ma from Grouse Canyon caldera of Silent Canyon caldera complex. Compositionally zoned from lower aphyric comendite to upper moderately crystal-rich comendite (common alkali feldspar and rare quartz, plagioclase, clinopyroxene, and fayalitic olivine). Groundmass arfvedsonite is common in devitrified, welded upper part. Basal aphyric bedded tuff is a distinctive marker and is more widely distributed to east and southeast than ash-flow tuff. Unit distinguished by high alkali feldspar content relative to other felsic phases, strong geochemical zonation, conspicuous greenish- to bluish-gray color, and anomalous normal magnetic polarity. Maximum intracaldera thickness about 575 m (subsurface data); maximum exposed outflow thickness about 110 m; maximum thickness of bedded tuff 150 m. Welded tuff thins markedly to the south through the Yucca Flat area.

Tbgs **Comendite of Split Ridge**--Pre-caldera aphyric comendite and porphyritic trachyte lava flows and related tuff erupted at 13.85 Ma. Comendite exposed at Split Ridge southeast of Silent Canyon caldera complex; includes trachyte lavas locally exposed along western margin of Kawich Valley and Saucer Mesa. Trachytes contain common sanidine, olivine, and clinopyroxene. Comendite lava has normal magnetic polarity; maximum thickness about 380 m.

Trl **Lithic Ridge Tuff** (Miocene)--Regional, partly welded to welded metaluminous ash-flow tuff erupted at 14.0 Ma from unknown caldera source (possibly near northern Crater Flat). 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 30 m.

Trd **Dikes of Tram Ridge** (Miocene)-- Intrusive conduits for rhyolite of Picture Rock and local related tuff erupted at 14.0 Ma. Dikes best exposed in Paleozoic rocks at Bare Mountain but have also been identified 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)--Combined compilation unit that encompasses mineralogically similar lavas that seem to occupy a similar stratigraphic position in widespread localities. Metaluminous, crystal-rich rhyolite to dacite lava flows, intrusive feeders, and related tuff erupted at 14.0 Ma. Dacitic phases contain abundant plagioclase and biotite, sparse sanidine, hornblende, and sphene, and rare quartz; reverse magnetic polarity seems typical. Partly equivalent to andesites and dacites and tuff of Units B and C in subsurface of Yucca Mountain south of quadrangle, and correlates with metaluminous tephra in bed 4JK of Tunnel Formation (Carroll, 1989, fig. 2). Unit includes rhyolitic lavas near Quartz Mountain and Tolicha Peak and intermediate, hydrothermally altered lavas in Bullfrog Hills. Maximum exposed thickness about 450 m.

Tn **Tunnel Formation** (Miocene)--Diverse sequence of multicolored red, orange, and white bedded and nonwelded rhyolite tuff and subordinate reworked tuff. Tunnel Formation is a mappable unit mainly in eastern part of map area, most notably at Rainier Mesa, but also on west side and in the subsurface of Yucca Flat where it fills valleys and basins in pre-existing topography. Top of unit is defined as base of Grouse Canyon Tuff or Lithic Ridge Tuff; base of formation is top of Tub Spring Tuff. Upper beds (4JK) [see Carroll (1989) for details of subunits of formation] consist of interlayered tephra associated with peralkaline sources (comendite of Quartet Dome) and metaluminous sources (rhyolite of Picture Rock; tuff of Sleeping Butte may be metaluminous source of bed 4GH). Sources of non-peralkaline middle beds (3D, 4A-F) and lower beds (3A-C) not decisively identified. Compiled unit may locally include Lithic Ridge Tuff in northwestern Yucca Flat; unit compiled in Belted Range may consist largely of bedded Comendite of Quartet Dome.

Tbq **Comendite of Quartet Dome** (Miocene)--Peralkaline crystal-rich comendite lava domes and related tephra mainly exposed around south margin of Kawich Valley. Contains abundant sanidine, common quartz, sparse fayalitic olivine, and rare clinopyroxene. Distinguished by peralkaline mineralogy, high relative quartz content, and normal magnetic polarity. Maximum exposed thickness 250 m. Correlates with bed 4J of Tunnel Formation and is interpreted to belong to the Grouse Canyon magmatic cycle.

Tqc **Tuff of Cache Cave Draw / Rhyolite of Coyote Cuesta** (Miocene)--Combined compilation unit defined for mineralogically similar rhyolite flows and related tuffs that post-date Tuff of Sleeping Butte in widespread locations. Unit includes the upper rhyolite of Quartz Mountain (not separately compiled). Tuff of Cache Cave Draw consists of aphyric ash-flow tuff with reverse magnetic polarity.

Tqs **Tuff of Sleeping Butte** (Miocene)--Two metaluminous rhyolite ash-flow tuffs and associated bedded tephra erupted at 14.3 Ma from a probable caldera source near the Sleeping Butte area, about 12 km north of Oasis Valley. 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. Upper tuff apparently laps onto lower densely welded tuff east of Sleeping Butte. 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 may correlate with beds 4GH of Tunnel Formation. Tuff of Sawtooth Mountain of Maldonado (1990) and Maldonado and Hausback (1990) is tentatively correlated with the tuff of Sleeping Butte.

Tqh **Middle rhyolite of Quartz Mountain** (Miocene)--Calc-alkaline rhyolite to dacite lava flows and related tephra, reworked tuffs, and local sedimentary rocks; exposed in northwestern part of database area. Rocks of this unit contain phenocrysts of common sanidine and plagioclase, with either sparse biotite, rare clinopyroxene, and abundant sphene, or common quartz and sparse hornblende. Bedded rhyolite tuff is nonwelded, crystal- and lithic-rich, and partly zeolitized, and locally includes tuff breccia. Lava flows have reverse magnetic polarity. May locally include distal tuff of Sleeping Butte. Maximum exposed thickness of lava flows more than 250 m; bedded tuffs locally exceed 300 m.

Tqt **Tuff of Tolicha Peak** (Miocene)--Distinctive metaluminous, very crystal poor, welded rhyolite ash-flow tuff erupted at 14.3 Ma from unknown source; chiefly exposed in northwestern area of database. Contains rare plagioclase, sanidine, and quartz, and no mafic minerals (except local rare biotite). Conspicuous platy to hackly, orangish- to pinkish-brown appearance in outcrop; typically forms a colluvial scree. Normal magnetic polarity. Maximum exposed thickness exceeds 300 m. May correlate in part with beds 3BC of Tunnel Formation.

Tqe **Early rhyolite of Quartz Mountain** (Miocene)--Calc-alkaline rhyolite to dacite lava flows, compositionally similar pyroclastic deposits, and tuffaceous sedimentary rocks; exposed in northwestern database area, stratigraphically below tuff of Tolicha Peak. Rocks contain phenocrysts of either common quartz, plagioclase, sanidine, and biotite, rare hornblende, and sparse sphene, or sparse alkali feldspar and biotite. Hydrothermal alteration common

Tqm **Dacite of Mt Helen** (Miocene)--Lava flows and intrusive masses exposed in Mt Helen area in northwestern part of map area; crystal-rich with abundant plagioclase, biotite, and hornblende, and common large (more than 1 cm) quartz phenocrysts.

Tuo **Comendite of Ochre Ridge** (Miocene)--Peralkaline lava flows and related tephra present at Ocher Ridge and along western margin of the southern Belted Range. Lavas are moderately crystal-poor, but contain common sanidine and quartz, and rare clinopyroxene. Distinguished from comendite of Emigrant Valley by stratigraphic position above Tub Spring Tuff. Normal magnetic polarity.

Tub **Tub Spring Tuff** (Miocene)--Widespread peralkaline welded ash-flow tuff erupted at 14.9 Ma from unknown caldera source, possibly in eastern Pahute Mesa or southern Kawich Valley. Present in Belted Range and northeast side of Yucca Flat; Compositionally zoned from lower crystal-poor comendite (common sanidine and quartz, and rare plagioclase and biotite) to upper crystal-rich comendite (abundant sanidine, common quartz, and sparse clinopyroxene and fayalitic olivine). Distinguished from peralkaline Grouse Canyon Tuff and younger peralkaline units by stratigraphic position and high relative quartz content. Normal magnetic polarity. Maximum exposed outflow thickness 90 m.

Tue **Comendite of Emigrant Valley** (Miocene)--Peralkaline lava flows and related tephra exposed along eastern flank of Belted Range. Lavas are moderately crystal poor, containing common sanidine and quartz, and rare clinopyroxene. Distinguished from comendite of Ocher Ridge by stratigraphic position below the Tub Spring Tuff.

Ton **Older tunnel beds** (Miocene)--Zeolitized, dominantly white, bedded and nonwelded rhyolite tuff and reworked 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 position beneath Tub Spring Tuff. Includes tunnel beds 1 and 2 of Carroll (1989) and may locally include nonwelded tuff equivalent to older calc-alkaline tuffs of the region (tuff of Yucca Flat, Redrock Valley Tuff, tuff of Twin Peaks, or 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. Tuff of Buck Spring of

Maldonado (1990) and Hausback (1990) is tentatively correlated with the tuff of Yucca Flat based on petrography and stratigraphic position. Maximum thickness 80 m.

Tor **Redrock Valley Tuff** (Miocene)--Subregional, welded, metaluminous, crystal-rich rhyolite ash-flow sheet erupted at 15.3 Ma from unknown source, probably in the Timber Mountain vicinity; unit chiefly exposed along west and north margins of Yucca Flat. Contains common plagioclase, sanidine, and biotite, rare quartz and hornblende, and sparse sphene. Distinguished by high relative plagioclase and low relative quartz contents, reverse magnetic polarity, common dense welding (atypical of older ash-flow tuff units), and red color where altered. Maximum exposed thickness about 125 m.

Tot **Tuff of Twin Peaks** (Miocene)--Crystal-rich rhyolite ash-flow tuff erupted at about 15.5 Ma from unknown source; chiefly exposed around northern margin of Yucca Flat. Phenocrysts include common plagioclase, sanidine, quartz, and biotite, sparse hornblende, rare clinopyroxene, and very abundant sphene. Formerly called the Fraction Tuff, but mineralogy does not support correlation with the type Fraction Tuff in the Tonopah district. Tuff of Twin Peaks is distinctly younger than the mapped Fraction Tuff in the Cathedral Ridge area of the Kawich Range. Unit includes the tuff of Whiterock Spring. Reverse magnetic polarity; maximum thickness is 475 m in Test Well 1 and Test Well 8; outcrop thickness generally less than 150 m.

Tob **Older basalt** (Miocene)--Local basalt and basaltic andesite lava flows exposed beneath Tuff of Twin Peaks at north end of Yucca Flat and beneath Grouse Canyon Tuff in the area west of Black Mountain. Locally very crystal rich, containing common olivine and clinopyroxene, and common to rare plagioclase. Distinguished from other basalt units by low stratigraphic position. Basalt near Yucca Flat has normal magnetic polarity. Maximum exposed thickness exceeds 50 m.

Tkr **Rhyolites of Belted Peak** (Miocene)--Combined compilation unit of calc-alkaline lava flows and related tephra exposed in various localities in the Belted Range. Contains variable phenocryst abundances of quartz, alkali feldspar, plagioclase, biotite, and hornblende. Variable magnetic polarity; includes rhyolites of Belted Peak (normal polarity) and Johnnies Water (reverse polarity). Distinguished from rhyolites of Wheelbarrow Peak by stratigraphic position and petrographic characteristics. Maximum exposed composite thickness about 600 m.

Tka **Rhyolites of Wheelbarrow Peak** (Miocene)--Alkalic lava flows and related tephra exposed in Belted Range. Contains variable phenocryst abundances of quartz, alkali feldspar, plagioclase, biotite, and hornblende. Distinguished from rhyolites of Belted Peak by stratigraphic position.

Tkl **Latite of Kawich Valley** (Miocene)--Crystal-rich lava flows containing abundant plagioclase and common biotite and hornblende. Some flows contain quartz, clinopyroxene, and hornblende and lack biotite. Present along margin of Kawich Valley. Maximum exposed thickness about 250 m; normal magnetic polarity.

Tqo **Older rhyolite tuffs and lavas** (Miocene)--Rhyolite of Gold Flat and other units on the northern Black Mountain quadrangle. Three or more, probably unrelated, rhyolitic welded ash-flow tuff sheets exposed in Gold Flat area. Contains variable phenocryst abundances of plagioclase, alkali feldspar, quartz, biotite, hornblende, clinopyroxene, and sphene. Includes tuff of Wilsons Camp, tuff of Gold Flat, and rhyolite of O'Briens Knob.

Tge **Prevolcanic sedimentary rocks** (Oligocene-Early Miocene)--Combined compilation unit that includes various sedimentary rocks in different areas of the database, but all appear to predate SWNVF volcanic activity. Conglomerates are typically poorly bedded and weakly cemented and contain poorly sorted angular to subrounded pebbles, cobbles, and boulders of durable pre-Tertiary rock, chiefly quartzite; lack of volcanic clasts is diagnostic. Unit is more than 100 m thick west of Mt. Helen and is overlain by tuff of Antelope Spring, which indicates Oligocene or older (equivalent to fanglomerate unit of Ekren and others, 1971). Compiled unit on the north side of the Spotted Range includes Rocks of Winapi Wash (J.C. Yount, oral commun., 1991) that includes hundreds of meters of fluvial gravels, lacustrine limestone, sandstone-siltstone, with interbedded tuff as old as 30.2 Ma (Marvin and others, 1970), These rocks were formerly designated Horse Spring Formation (Hinrichs, 1965; Barnes and others, 1982) but are clearly older than the Miocene type Horse Spring Formation of the Lake Mead area (Bohannon, 1984).

Tep **Pahranagat tuff** (Miocene)--Calc-alkaline, crystal-rich, rhyolite welded ash-flow tuff sheet erupted at 22.65 Ma from probable caldera source in Kawich Range in central Nevada caldera complex. Contains abundant quartz, common sanidine, plagioclase, and biotite, rare hornblende, and common sphene. Locally includes basal bedded tuff. Reverse magnetic polarity. Exposed near northeastern corner and in the Belted Range where maximum thickness is about 200 m. Equivalent to tuff of White Blotch Spring and to part of tuff of Antelope Springs of Ekren and others (1971).

Tes **Shingle Pass Tuff** (Oligocene)--Widespread metaluminous rhyolite ash-flow tuff sheet erupted at 26.7 Ma, probably from caldera source in Quinn Canyon Range in central Nevada. Contains common sanidine, plagioclase, and pyroxene, sparse quartz and biotite, and rare hornblende and fayalitic olivine. Normal magnetic polarity measured in Belted Range and west of Groom Pass indicates that only the lower cooling unit of the type Shingle Pass is present; maximum exposed thickness about 200 m.

Tem **Monotony Tuff** (Oligocene)--Widespread metaluminous, very crystal-rich dacite welded ash-flow tuff sheet erupted at 27.31 Ma from caldera source in southern Pancake and northern Reveille Ranges in central Nevada. Contains very abundant plagioclase and biotite, abundant hornblende, and common quartz, sanidine, and clinopyroxene. Extremely crystal-rich nature, anomalous normal magnetic polarity, and brownish, hummocky outcrop appearance are distinctive. Exposed in Belted Range and west of Groom Pass; maximum exposed thickness about 200 m.

Tgt **Titus Canyon Formation** (part) (Oligocene)--Heterolithic conglomerate present only on the flank of the Funeral Mountains. Equivalent to the "variegated and brown conglomerate facies" of Reynolds (1969) that contains tuff dated at about 27 Ma (biotite) and 29 Ma (plagioclase). Base of unit is a regional unconformity that is commonly faulted.

TKd **Diorite dikes** (Oligocene-Cretaceous?)--Dusky green, fine- to medium-grained porphyritic diorite dikes that cut foliation in metamorphosed country rock at Chloride Cliffs and Bare Mountain. Dikes contain approximately 75 percent plagioclase, 10 percent hornblende, 7 percent clinopyroxene, 5 percent biotite, 3 percent opaque oxide minerals, and traces of epidote. 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). Similar dikes (not compiled) cut Paleozoic rocks near northern Yucca Flat and produce 40Ar/39Ar plateau ages of about 102 Ma (Cole and others, 1993).

Kg **Granitic rocks** (Cretaceous)--Equigranular and porphyritic intrusive rocks, chiefly hornblende-biotite granodiorite and biotite monzogranite, and minor leucocratic granite. Includes the zoned, porphyritic Climax stock (101 Ma; Naeser and Maldonado, 1981) north of Yucca Flat, the equigranular Gold Meadows stock (93.6 Ma; Naeser and Maldonado, 1981) north of Rainier Mesa, and granite north of Bare Mountain (about 98 Ma; Monsen and others, 1992). Small, poorly-exposed bodies of undated muscovite-bearing leucogranite crop out in the southern Kawich Range and in the northern Halfpint Range.

P*Pt **Tippipah Limestone** (Early Permian and Pennsylvanian)--Limestone, calcareous mudstone, and minor chert-pebble conglomerate and sandy limestone; forms well-bedded, ledgy, medium-gray outcrop; diverse fauna preserved in biohermal middle and upper parts of the unit. Base marked by an indistinct erosional paraconformity on top of Chainman Shale that cuts out variable amounts of the Scotty Wash Quartzite; top not preserved. Unit exposed in the cores of moderately to strongly overturned synclines at CP Hills and Syncline Ridge, west and southwest of Yucca Flat. Maximum thickness 1250 m (Miller, 1989).

***PMcs** **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, but is known from subsurface data in the CP Hills to be disconformable on Guilmette Formation (Trexler and others, 1996); top of the unit is irregular due to erosion prior to deposition of Tippipah Limestone. Unit is exposed around Syncline Ridge, in the CP Hills, and in the southern Calico Hills. Thickness indeterminate due to structural complications, but probably exceeds 900 m (Cashman and Trexler, 1994; Trexler and others, 1996).

Mm **Monte Cristo Group and equivalents** (Mississippian)--Limestone, clayey-silty limestone, and quartzite; heterogeneous unit of shelf- and inner-slope-facies calcareous deposits that were defined (bottom to top) as the Narrow Canyon Limestone, Mercury Limestone, limestone of Timpi Canyon, and overlying shale and quartzite beds attributed to the "Chainman Shale" in the Spotted Range east of Mercury (Barnes and others, 1982). These shale and quartzite units are Late Mississippian and probably correlate with the Indian Springs Formation (Trexler and others, 1996). Top of unit truncated by Spotted Range thrust; combined thickness of limestone section about 250 m.

MDe **Eleana Formation** (Mississippian and Late Devonian)--Chert-rich sandstone and pebble conglomerate, siliceous siltstone, and minor bioclastic limestone and bedded chert; laterally variable unit containing thick-bedded lenticular sandstone-conglomerate turbidite complexes, laminated bioturbated siltstone, and discrete carbonate turbidite beds in the upper part. Informally described as 9 subunits by Poole and others (1961); base of type section in Carbonate Wash is disconformable on Late Devonian slope-facies carbonate rocks. Lower 100 m consists of debris-flow limestone breccia beds and sandy limestone and quartzite; middle 1700 m consists of chert litharenite sand, conglomerate, and siltstone; upper 150 m consists of bioclastic limestone in thin tabular beds and chert litharenite sand; top is everywhere faulted against Chainman Shale. Strata compiled as Eleana Formation at Bare Mountain and in the Calico Hills are generally thinner and finer grained than the type Eleana and contain older limestone beds, but show similar stratigraphic organization.

Strata compiled as Eleana Formation at Shoshone Mountain and Mine Mountain are distinct but have not been formally defined. They differ from Eleana in that they are deposited on karst-weathered shelf-facies Devonian Guilmette Formation and they are consistently finer-grained and contain clasts from more heterogeneous sources (Trexler and others, 1996).

Dsf **Slope-facies rocks** (Late, Middle, and Early Devonian)--Moderately resistant, light to dark gray limestone, dolomite, and silty carbonate rocks. Moderately well-bedded, locally laminated or fossiliferous, and typified by debris flows with clasts of quartzite, limestone, dolomite, and coarse fossil fragments; some debris flows have quartzose matrix sand. Laminated intervals commonly contain intraformational breccia beds. Exposed at Carbonate Wash, eastern Rainier Mesa, northern Calico Hills, and at Bare Mountain (Rocks of Tarantula Canyon of Monsen and others, 1992); maximum thickness in map area about 300 m; base not exposed; top is eroded slightly below base of Eleana Formation.

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; basal beds are yellow and silty above an apparently conformable contact with Simonson Dolomite. Quartzite beds in upper part at Shoshone Mountain and Mine Mountain are brecciated by post-depositional collapse over karst features. Karst not developed in Guilmette in the Spotted Range. Thickness approximately 350 m.

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. Basal contact is distinct where yellow platy-silty beds of lower Simonson rest on sandy upper Sevy Dolomite. Maximum thickness in map area about 300 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, 19 86). Thickness approximately 490 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 others, 1977); upper contact is paraconformable at base of Simonson Dolomite. Lower part equivalent to units A to C of dolomite of Spotted Range; upper part equivalent to units D to F of dolomite of Spotted Range (Poole, 1965; Barnes and others 1982). Thickness not well defined in many areas due to complex structure, but approximately 450 m in Spotted Range.

Sr **Roberts Mountain 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. Variable bed thickness, commonly flaggy splitting; dark gray chert layers and nodules occur locally. Base is regionally disconformable on the Ely Springs Dolomite. Occurs only in northern Bare Mountain where the thickness is 198 m (Monsen and others, 1992).

Oes **Ely Springs Dolomite** (Late Ordovician)--Medium- to dark-gray, fine- to medium-grained dolomite and limy dolomite; conspicuously fossiliferous. Moderately thick bedded; contains sparse to abundant irregular layers and nodules of dark-gray chert. Basal contact conformable on 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. 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.

Cn **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 (Middle and Late Cambrian)--Well bedded, varicolored dolomite and limestone; everywhere subdivided into:

Cbb **Banded Mountain Member**--Medium to thick beds of light to dark gray dolomite and limestone. Alternation of 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. Thickness about 580 m.

Cbp **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 birds-eye texture. Basal contact is conformable and gradational to Carrara Formation. Thickness variable, but about 700 m.

Cc **Carrara Formation** (Middle and Early Cambrian)--Limestone, siltstone, and shale; clastic rocks predominate in lower 350 m, limestone becomes more prominent in the upper 120 m. Lower contact is conformable on the Zabriskie Quartzite; 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 about 470 m in northern Halfpint Range, indeterminate in the CP Hills due to complex structure, and about 350 m at Bare Mountain. The partial section compiled as Carrara on the west side of the Belted Range is chiefly limestone and sandy limestone and may be a deeper water facies than Carrara elsewhere in the database.

Cz **Zabriskie Quartzite** (Early Cambrian)--Orthoquartzite; massive, white to pink, laminated and cross-bedded, densely cemented orthoquartzite with conspicuous tubular trace fossils (burrows); locally intensely brecciated. Basal contact is conformable on micaceous siltstone of the Wood Canyon Formation. Thickness varies regionally from about 350 m at Bare Mountain to about 150 m in the Striped Hills, to less than 30 m in the Halfpint Range and Belted Range.

CZw **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 varies regionally from about 1150 m at Bare Mountain to about 700 m northeast of the Halfpint Range.

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 4 units based on relative proportions of micaceous siltstone and shale and on presence of sparse limestone beds (Barnes and Christiansen, 1967). Total thickness varies regionally from about 700 m at Bare Mountain to more than 1500 m in the Belted Range.

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. Thickness is estimated to exceed 900 m (Barnes and Christiansen, 1967) near the Halfpint Range, but may be as thick as 2000 m in the Funeral Mountains (Wright and Troxel, 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; estimated thickness 700 m (Wright and Troxel, 1993).

Yb **Beck Spring Dolomite** (Middle? Proterozoic)--Strongly laminated calcitic marble; estimated thickness 70 m (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 staurolite and biotite-bearing pelitic schist containing abundant tabular bodies of amphibolite and several distinctive marker beds of calcitic marble; estimated thickness 1000 m (Wright and Troxel, 1993).

Xmi **Metamorphic and intrusive rocks** (Early? Proterozoic)--Biotite schist, biotite-hornblende schist, and biotite-epidote schist, intruded by gneissic monzogranite in Trappman Hills just north of western Gold Flat. Muscovite from schist in this area yielded K-Ar age of 14.0 Ma (McKee, 1983), which is interpreted to date uplift and cooling resulting from Miocene regional crustal extension. Sillimanite-grade metamorphic rocks in the Funeral Mountains are intruded by pegmatite and granite that contain 1700 Ma zircon (Wright and Troxel, 1993).

ACKNOWLEDGMENTS

We wish to acknowledge several individuals from the U.S. Geological Survey for their contributions to this compilation. We thank R.E. Sabala for methodically and carefully drafting numerous tracings of geologic map layers prior to scanning, and J.R. Estabrook for his persistent, successful efforts in locating and supplying archival map materials used in the compilation. Staff of the U.S. Geological Survey Central Region GIS laboratory provided expert assistance in operating Tektronics and Anatech scanners. A preliminary digital polygon coverage of the NTS geologic map was generated under the direction of D.S. Aitken of the Western Region GIS laboratory. V.S. Williams kindly developed and shared custom software to transfer GS Map files to AutoCAD. Discussions in the field and office with U.S. Geological Survey colleagues M.D. Carr, F. Maldonado, P.P. Orkild, 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 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 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 the Eleana Range, 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. Paul Williams and G.N. Green provided timely and helpful reviews of the manuscript and database. This work was prepared in cooperation with the Department of Energy under interagency agreement DE-AI08-91NV11040.

REFERENCES

Armstrong, R.L., 1970, Geochronology of Tertiary igneous rocks,eastern Basin and Range Province, western Utah, eastern Nevada, and vicinity, U.S.A.: Geochimica et Cosmochimica Acta, v. 34, p. 203-232.

Barnes, Harley, and Christiansen, R.L., 1967, Cambrian and Precambrian rocks of the Groom district, Nevada, southern Great Basin: U.S. Geological Survey Bulletin 1244-G, p. G1-G34.

Barnes, Harley, Christiansen, R.L., and Byers, F.M., Jr., 1965, Geologic map of the Jangle Ridge quadrangle, Nye and Lincoln Counties, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-363, scale 1:24,000.

Barnes, Harley, Ekren, E.B., Cleaves, and Hedlund, D.C., 1982, Geologic and tectonic maps of the Mercury quadrangle, Nye and Clark Counties, Nevada: U.S. Geological Survey Miscellaneous Investigations Map I-1327, scale 1:24,000

Barnes, Harley, Houser, F.N., and Poole, F.G., 1963, Geologic map of the Oak Spring quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-214, scale 1:24,000.

Bath, G.D., 1968, Aeromagnetic anomalies related to remnant magnetism in volcanic rock, Nevada Test Site, in Eckel, E.B., ed., Nevada Test Site: Geological Society of America Memoir 110, p. 135-146.

Berry, W.B.N., and Boucot, A.J., 1970, Correlation of the North American Silurian rocks: Geological Society of America Special Paper 102, 289 p.

Best, M.G., Christiansen, E.H., Denio, A.L., Gromme, C.S., McKee, E.H., and Noble. D.C., 1989, Eocene through Miocene volcanism in the Great Basin of the western United States: New Mexico Bureau of Mines and Mineral Resources Memoir 47, p. 91-133.

Brogan, G.E., Kellogg, K.S., Slemmons, D.B., and Terhune, C.L., 1991, Late Quaternary faulting along the Death Valley-Furnace Creek fault system, California and Nevada: U.S. Geological Survey Bulletin 1991,23 p.

Burchfiel, B.C., 1966 Reconnaissance geologic map of the Lathrop Wells 15-minute quadrangle, Nye County, Nevada, U.S. Geological Survey Miscellaneous Geologic Investigations Map I-474, scale 1:62,500.

Burchfiel, B.C., 1966, change to:Burchfiel, B.C. , 1964, Precambrian and Paleozoic stratigraphy of the Specter Range quadrangle, Nye County, Nevada. American Association of Petroleum Geologists Bulletin, v. 48, p. 40-56.

Burchfiel, B.C. , 1965, Structural geology of the Specter Range quadrangle, and its regional significance: Geological Society of America Bulletin, v. 76, p. 175-192.

Burchfiel, B.C., 1964 Precambrian and Paleozoic stratigraphy of the Specter Range quadrangle, Nye County, Nevada, American Association of Petroleum GeologistsBulletin, v. 48, p. 40-56.

Byers, F.M., Jr., and Barnes, Harley, 1967, Geologic map of the Pahute Ridge quadrangle, Nye and Lincoln Counties, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-577, scale 1:24,000.

Byers, F.M., Jr., Carr, W.J., Christiansen, R.L., Lipman, P.W., Orkild, P.P., and Quinlivan, W.D., 1976a, Geologic map of the Timber Mountain caldera area, Nye County, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I-891, scale 1:48,000.

Byers, F.M., Jr., Carr, W.J., Orkild, P.P., 1989, Volcanic centers of southwestern Nevada: evolution of understanding, 1960-1988: Journal of Geophysical Research, v. 94, no. B5, p. 5908-5924.

Byers, F.M., Jr., Carr, W.J., Orkild, P.P., Quinlivan, W.D., and Sargent, K.A., 1976b, Volcanic suites and related cauldrons of Timber Mountain-Oasis Valley caldera complex, southern Nevada: U.S. Geological Survey Professional Paper 919, 70 p.

Byers, F.M., Jr., and Cummings, David, 1967, Geologic map of the Scrugham Peak quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-695, scale 1:24,000.

Byers, F.M., Jr., Rogers, C.L., Carr, W.J., and Luft, S.J., 1966, Geologic map of the Buckboard Mesa quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-552, scale 1:24,000.

Carr, M.D., Sawyer. D.A., Nimz, K., Maldonado, F., and Swadley, WC, 1995, Digital bedrock geologic map database of the Beatty 30 x 60 minute quadrangle, Nevada and California, U.S. Geological Survey Open-File Report 96-0291, scale 1:100,000.

Carr, M.D., Waddell. S.J., Vick, G.S., Stock, J.M., Monsen, S.A.,Harris, A.G., Cork, B.W., and Byers, F.M., Jr., 1986, Geology of drill hole UE25p#1: a test hole into pre-Tertiary rocks near Yucca Mountain, southern Nevada: U.S. Geological Survey Open-file Report 86-175, 87 p.

Carr, W.J., 1984, Regional structural setting of Yucca Mountain, southwestern Nevada, and late Cenozoic rates of tectonic activity in part of the southwestern Great Basin, Nevada and California: U.S. Geological Survey Open-File Report 84-854, 109 p.

Carr, W.J., Byers, F.M., Jr., and Orkild, P.P., 1986, Stratigraphic and volcano-tectonic relations of Crater Flat Tuff and some older volcanic units, Nye County, Nevada: U.S. Geological Survey Professional Paper 1323, 28 p.

Carr, W.J., and Quinlivan, W.D., 1966, Geologic map of the Timber Mountain quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-503, scale 1:24,000.

Carr, W.J., 1982, Volcano-tectonic history of Crater Flat, southwestern Nevada, as suggested by new evidence from drill-hole USW-VH- 1 and vicinity: U.S. Geological Survey Open-file Report 82-457, 25 p.

Carroll, R.D., 1989, Density logging and density of rocks in Rainier Mesa area, Nevada Test Site: U.S. Geological Survey Open-File Report 89329, 72 p.

Cashman, P.H., and Trexler, J.H., Jr., 1991, The Mississippian Antler foreland and continental margin in southern Nevada: the Eleana Formation reinterpreted, in Cooper, J.D., and Stevens, C.H., eds., Paleozoic paleogeography of the western United States II: Society of Economic Paleontologists and Mineralogists, Pacific Section, v. 67, p. 271-280.

Cashman. P.H., and Trexler, J.H., Jr., 1994, The case for two coeval Mississippian sections at the Nevada Test Site, in McGill, S.F. and Ross, T.M., eds., Geologic Investigations of an Active Margin: Geological Society of America Cordilleran Section Guidebook, San Bernadino, California, p. 76-81.

Cemen, Ibrahim, Wright, L.A., Drake, R.E., and Johnson, F.C., 1985, Cenozoic sedimentation and sequence of deformational events at the southeastern end of the Furnace Creek strike-slip fault zone, Death Valley region, California: Society for Economic Mineralogists and Petrologists Special Publication 37, p. 127-141.

Christiansen, R.L., and Lipman, P.W., 1965, Geologic map of the Topopah Spring NW quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-444, scale 1:24,000.

Christiansen, R.L., and Noble, D.C., 1968, Geologic map of the Trail Ridge quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-774, scale 1:24,000.

Christiansen, R.L., Lipman, P.W., Carr, W.J., Byers, F.M., Jr., Orkild, P.P., and Sargent, K.A., 1977, Timber Mountain-Oasis Valley caldera complex of southern Nevada: Geological Society of America Bulletin, v. 88, p. 943-959.

Cole, J.C., 1991, Pre-drilling geologic summary for characterization well "E-Tunnel access" ER-12-1: U.S. Geological Survey Administrative Report, 9 p.

Cole, J.C., Wahl, R.R., and Hudson, M.R., 1989, Structural relations within the Paleozoic basement of the Mine Mountain block: implications for interpretation of gravity data in Yucca Flat, Nevada Test Site, in Olsen, C.W., and Carter, J.A., eds., Proceedings of the Fifth Symposium on the Containment of Underground Nuclear Explosions, Santa Barbara, California: Lawrence Livermore National Laboratory Report CONF-8909163, v. 2, p. 431-455.

Cole, J.C., Trexler, J.H., Jr., Cashman, P.H., and Hudson, M.R., 1994, Structural and stratigraphic relations of Mississippian rocks at the Nevada Test Site, in McGill, S.F. and Ross, T.M., eds., Geologic Investigations of an Active Margin: Geological Society of America Cordilleran Section Guidebook, San Bernadino, California, p. 66-75.

Colton, R.B., and McKay, E.J., 1966, Geologic map of the Yucca Flat quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-582, scale 1:24,000.

Colton, R.B., and Noble, D.C., 1967, Geologic map of the Groom Mine SW quadrangle, Nye and Lincoln Counties, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-719, scale 1:24,000.

Cornwall, H.R., 1972, Geology and mineral deposits of southern Nye County, Nevada: Nevada Bureau of Mines and Geology Bulletin 77, 49 p.

Cornwall, H.R., and Kleinhampl, F.J., 1961, Geologic Map of the Bare Mountain quadrangle, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ- 157, scale 1:62,500.

Cornwall, H.R., and Kleinhampl, F.J., 1964, Geology of Bullfrog quadrangle and ore deposits related to Bullfrog Hills Caldera, Nye County, Nevada and Inyo County, California: U.S. Geological Survey Professional Paper 454-J, 25 p.

Crowe, B.M., Vaniman, D.J., and Carr, W.J., 1983, Status of volcanic hazard studies for the Nevada Nuclear Waste Storage Investigations: Los Alamos National Laboratory Report LA-9325, Los Alamos, New Mexico.

Dalrymple, G.B., 1979, Critical table for conversion of K-Ar ages from old to new constants: Geology, v. 7, p. 558-560.

Dalrymple, G.B., Izett, G.A., Snee, L.W., and Obradovich, J.D., 1993, 40Ar/39Ar age spectra and total fusion ages of tektites from Cretaceous-Tertiary rocks in the Beloc Formation, Haiti: U.S. Geological Survey Bulletin 2065, 20 pp.

Dalrymple, G.B., and Lanphere, M.A., 1969, Potassium-argon dating: Principles, Techniques, and Applications to Geochronology: W.H. Freeman, New York, 258 p.

Ekren, E.B., Anderson, R.E., Orkild, P.P., and Hinrichs, E.N., 1966, Geologic map of the Silent Butte quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-493, scale 1:24,000.

Ekren, E.B., Anderson, R.E., Rogers, C.L., and Noble, D.C., 1971, Geology of northern Nellis Air Force Base Bombing and Gunnery Range, Nye County, Nevada: U.S. Geological Survey Professional Paper 651, 91 p. (map scale 1:125,000).

Ekren, E.B., Rogers, C.L., Anderson, R.E., and Botinelly, Theodore, 1967, Geologic map of the Belted Peak quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-606, scale 1:62,500.

Ekren, E.B., and Sargent, K.A., 1965, Geologic map of the Skull Mountain quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-387, scale 1:62,500.

Ferguson, J.F., Cogbill, A.H., and Warren, R.G., 1994, A geophysical-geological transect of the Silent Canyon caldera complex: Journal of Geophysical Research, v. 99, p. 4323-4339.

Fleck, R.J., 1970, Tectonic style, magnitude, and age of deformation in the Sevier orogenic belt in southern Nevada and southeastern California: Geological Society of America Bulletin, v. 81, p. 1705-1720.

Fleck, R.J., Lanphere, M.A., Turrin, Brent, and Sawyer, D.A., 1991, Chronology of late Miocene to Quaternary volcanism and tectonism in the southwest Nevada volcanic field [abs.]: Geological Society of America Abstracts with Programs, v. 23, n. 2, p. 25.

Fleck, R.J., Turrin, B.D., Sawyer, D.A.,Warren, R.G., Champion, D.E., Hudson, M.R., Minor, S.A., 1996, Age and character of basaltic rocks of the Yucca Mountain region southern Nevada: Journal of Geophysical Research

Faulds, J.E., Bell, J.W., Feuerbach, D.L., and Ramelli, A.R., 1994, Geologic map of the Crater Flat area: Nevada Bureau of Mines and Geology Map 101.

Fridrich, C. J., Orkild, P.P., Murray, M., and Scott, R. B. 1994, Preliminary geologic map of the East of Beatty Mountain: U.S. Geological Survey Open-file Report 94-530.

Frizzell, V.A., Jr., and Shulters, Jacqueline, 1990, Geologic map of the Nevada Test Map, southern Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I-2046, scale 1:100,000.

Gibbons, A.B., Hinrichs, E.N., Hansen, W.R., and Lemke, R.W., 1963, Geology of the Rainier Mesa quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-215, scale 1:24,000.

Guth, P.L., 1986, Bedrock geologic map of the Black Hills 1:24,000 quadrangle, Nevada: U.S. Geological Survey Open-File Report 86-438, scale 1:24,000.

Guth, P.L., 1990, Superposed Mesozoic and Cenozoic deformation, Indian Springs quadrangle, southern Nevada, in Wernicke, B.P., ed., Basin and range extensional tectonics near the latitude of Las Vegas, Nevada: Geological Society of America Memoir 176, p. 237-249.

Hausback, B.P., Deino, A.L., Turrin, B.T., McKee, E.H., Frizzell, V.A., Jr., Noble, D.C., and Weiss, S.I., 1990, New 40Ar/39Ar ages for the Spearhead and Civet Cat Canyon

Members of the Stonewall Flat Tuff, Nye County, Nevada--evidence for systematic errors in standard K-Ar determinations on sanidine: Isochron/West, n. 56, p. 3-7.

Hay, P.L., Pexton, R.E., Teague, T.T., and Kyser, T.K., 1986, Spring related carbonate rocks, Mg clays, and associated minerals in Pliocene deposits of the Amargosa Desert, Nevada and California: Geological Society of America Bulletin, v. 97, p. 1488-1503.

Hinrichs, E.N., 1968, Geologic map of the Camp Desert Rock quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ726, scale 1:24,000.

Hinrichs, E.N., Krushensky, R.D., and Luft, S.J., 1967, Geologic map of the Ammonia Tanks quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-638, scale 1:24,000.

Hinrichs, E.N., and McKay, E.J., 1965, Geologic map of the Plutonium Valley quadrangle, Nye and Lincoln Counties, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-384, scale 1:24,000.

Hoisch, T. D., 1995, "Report on metamorphic petrology and uplift of Bare Mountain area: Report for Yucca Mountain Project Tectonics Project. DOE Adminstrative report"

Hoisch, T.D., and Simpson, C., 1993, Rise and tilt of metamorphic rocks in the lower plate of a detachment fault in the Funeral Mountains, Death Valley, California: Journal of Geophysical Research, v. 98, p. 6805-6827.

Hoover, D.L., Swadley, WC, and Gordon, A.J., 1981, Correlation characteristics of surficial deposits with a description of stratigraphy in the Nevada Test Site Region: U.S. Geological Survey Open-File Report 81-512, 27 p.

Houser, F.N., and Poole, F.G., 1960, Preliminary geologic map of the Climax stock and vicinity, Nye County, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I-328, scale 1:5,000.

Hudson, M.R., 1992, Paleomagnetic data bearing on the origin of arcuate structures in the French Peak-Massachusetts Mountain area of southern Nevada: Geological Society of America Bulletin, v. 104, p. 581-594.

Hudson M.R., Sawyer, D.A., and Warren, R.G., 1994, Paleomagnetism and rotation constraints for the middle Miocene southwestern Nevada volcanic field: Tectonics, v. 13, p. 258-277.

Hunt, C.B., and Mabey, D.R., 1966, Stratigraphy and structure, Death Valley, California: U.S. Geological Survey Professional Paper 494-A, 162 p.

Jayko, A.S., in press, Geologic Map of the Pahranagat Range 30' by 60' minute quadrangle, Nevada: Nevada Bureau of Mines and Geology Map, scale 1:100,000.

Kistler, R.W., 1968, Potassium-argon ages of volcanic rocks in Nye and Esmeralda Counties, Nevada, in Eckel, E.B., ed., Nevada Test Site: Geological Society of America Memoir 110, p. 251-273.

Lanphere, M.A., Dalrymple, G.B., Fleck, R.J., and Pringle, M.S., 1990, Intercalibration of mineral standards for K-Ar and 40Ar/39Ar age measurements [abs.]: Eos, American Geophysical Union Transactions, v. 71, p. 1658.

Le Bas, M.J., Le Maitre, R.W., Streckeisen, A., and Zenettin, B., 1986, A chemical classification of volcanic rocks based on the total alkali-silica diagram: Journal of Petrology, v. 27, p. 82-133.

Lipman, P.W., Quinlivan, W.D., Carr, W.J., and Anderson, R.E., 1966, Geologic map of the Thirsty Canyon SE quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-489, scale 1:24,000.

Lipman, P.W. and McKay, E.J., 1965, Geologic map of the Topopah Spring NW quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-439, scale 1:24,000.

Maldonado, Florian, 1985, Geologic map of the Jackass Flats area, Nye County, Nevada: U.S. Geological Survey Miscellaneous Investigations Map I-1519, scale 1:48,000

Maldonado, Florian, 1990, Geologic map of the northwest quarter of the Bullfrog 15-minute quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I-1985, scale 1:24,000.

Maldonado, Florian, and Hausback, B. P., 1990, Geologic map of the northeast quarter of the Bullfrog 15-minute quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I-2049, scale 1:24,000.

Marvin, R.F., Byers, F.M., Jr., Mehnert, H.H., Orkild, P.P., and Stern, T.W., 1970, Radiometric ages and stratigraphic sequence of volcanic and plutonic rocks, southern Nye and western Lincoln Counties, Nevada: Geological Society of America Bulletin, v. 81, p. 2657-2676.

Marvin, R.F., and Cole, J.C., 1979, Radiometric ages--Compilation "A", U.S. Geological Survey: Isochron West no. 22, p. 3-14.

Marvin, R.F., Mehnert, H.H., and McKee, E.H., 1973, A summary of radiometric ages of Tertiary volcanic rocks in Nevada and eastern California: Part III--southeastern Nevada: Isochron/West no. 6, p. 1-30.

Marvin, R.F., Mehnert, H.H., and Naeser, C.W., 1989, U.S. Geological Survey radiometric ages--Compilation "C," Part three--California and Nevada: Isochron/West no. 52, p. 3-11.

McAllister, J.F., 1970, Geology of the Furnace Creek borate area, Death Valley, Inyo County, California: California Division of Mines and Geology, Map Sheet 14, 9 p. + map, scale 1:24, 000.

McAllister, J.F., 1973, Geologic map and sections of the Amargosa Valley borate area--southeast continuation of the Furnace Creek area--Inyo County, California: U.S. Geological Survey Miscellaneous Investigations Series Map I-782, scale 1:24,000.

McAllister, J.F., 1974, Silurian, Devonian, and Mississippian Formations of the Funeral Mountains in the Ryan quadrangle, Death Valley region, California: U.S. Geological Survey Bulletin 1386, 35 p.

McKay, E.J. and Williams, W.P., 1964, Geologic map of the Jackass Flats Quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-368, scale 1:24,000.

McKay, E.J. and Sargent, K.A., 1970, Geologic map of the Jackass Flats Quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-883, scale 1:24,000.

McKee, E.H., 1983, Reset K-Ar ages: evidence for three metamorphic core complexes, western Nevada: Isochron/West, n. 38, p. 17-20.

McKeown. F. A., Healey, D.L., and Miller, C.H., 1976, Geologic map of the Yucca Lake Quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-1327, scale 1:24,000.

Metcalf, L.A., 1982, Tephrostratigraphy and potassium-argon age determinations of seven volcanic ash layers in the Muddy Creek Formation of southern Nevada: Water Resources Center, Desert Research Institute, University of Nevada, Publication 45023, 187 p. (available from National Technical Information Service, U.S. Department of Commerce, Springfield VA 22161)

Miller, R.H., 1976, Revision of Upper Ordovician, Silurian, and Lower Devonian stratigraphy, southwestern Great Basin: Geological Society of America Bulletin, v. 87, p. 961-968.

Miller, R. P., 1989, Late Pennsylvanian - Early Permian depositional facies and paleogeographic significance of a mixed-clastic outer-shelf-to-basin sequence, east-central California and western Nevada: Laramie, University of Wyoming M.S. thesis, 154 p.

Minor, S.A., Vick G.S., Carr M.D., and Wahl, R.R., 1996, Faults, lineaments, and earthquake epicenters digital map of the Pahute Mesa 30 x 60 minute quadrangle, Nevada, U.S. Geological Survey Open-File Report 96-0262, scale 1:100,000.

Minor, S.A., 1995, Superposed local and regional paleostresses—fault slip analysis of Neogene extensional faulting near coeval caldera complexes, Yucca Flat, Nevada: Journal of Geophysical Research, v. 100, p. 10507-10528.

Minor, S.A., Sawyer, D.A., Wahl, R.R., Frizzell, V.F., Jr., Schilling, S.P., Warren, R.G., Orkild, P.P., Cole, J.A., Hudson, M.R., Fleck, R..J., Lanphere, M.A., Swadley, WC, and Cole, J.C., 1993, Preliminary geologic map of the Pahute Mesa 30' x 60' quadrangle, Nevada: U.S. Geological Survey Open-File Report 93-299.

Monsen, S.A., Carr, M.D., Reheis, M.C., and Orkild, P.P., 1990, Geologic map of Bare Mountain, Nye County, Nevada: U.S. Geological Survey Miscellaneous Investigations Map I-2201, scale 1:24,000.

Naeser, C.W., and Maldonado, Florian, 1981, Fission-track dating of the Climax and Gold Meadows stocks, Nye County, Nevada: U.S. Geological Survey Professional Paper 1199-E, p. E45-E47.

Noble, D.C., and Christiansen, R.L., 1968, Geologic map of the southwest quarter of the Black Mountain quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I562, scale 1:24,000.

Noble, D.C., Krushensky, R.D., McKay, E.J., and Ege, J.R., 1967, Geologic map of the Dead Horse Flat quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-614, scale 1:24,000.

Noble, D.C., Vogel, T.A., Weiss, S.I., Erwin, J.W., McKee, E.H., and Younker, L.W., 1984, Stratigraphic relations and source areas of ash-flow sheets of the Black Mountain and Stonewall Mountain volcanic centers, Nevada: Journal of Geophysical Research, v. 89, p. 8593-8602.

Noble, D.C., Weiss, S.I., and McKee, E.H., 1991, Magmatic and hydrothermal activity, caldera geology, and regional extension in the western part of the southwestern Nevada volcanic field, in Raines, G.L., Lisle, R.E., Schaefer, R.W., and Wilkinson, W.H., eds., Geology and ore deposits of the Great Basin: Geological Society of Nevada, symposium proceedings, Reno, p. 913-934.

O'Connor, J.T., Anderson, R.E., and Lipman, P.W., 1966, Geologic map of the Thirsty Canyon quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-524, scale 1:24,000.

Orkild, P.P., 1963, Geologic map of the Tippipah Spring quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-213, scale 1:24,000.

Orkild, P.P., 1968, Geologic map of the Mine Mountain quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-746, scale 1:24,000.

Orkild, P.P. and O'Connor, J.T., 1970, Geologic map of the Topopah Spring quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-849, scale 1:24,000.

Orkild, P.P., Sargent, K.A., and Snyder, R.P., 1969, Geologic map of Pahute Mesa, Nye County, Nevada: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I-567, scale 1:48,000.

Poole, F.G., 1965, Geologic map of the Frenchman Flat quadrangle, Nye, Lincoln, and Clark Counties, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-456, scale 1:24,000.

Poole, F.G., Elston, D.P., and Carr, W.J., 1965, Geologic map of the Cane Spring quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-455, scale 1:24,000.

Poole, F. G., Houser, F. N., and Orkild, P. P., 1961, Eleana Formation of Nevada Test Site and vicinity, Nye Canyon, Nevada: U.S. Geological Survey Professional Paper 424-D, p. D104-D111.

Poole, F.G., and Sandberg, C.A., 1977, Mississippian paleogeography and tectonics of the Western United States, in Stewart, J.H., Stevens, and Fritsche, A.E., eds., Paleozoic paleogeography of the Western United States: Society of Economic Paleontologists and Mineralogists, Pacific Section, Pacific Coast Paleogeography Symposium 1, p. 67-85.

Reynolds, M. W., 1969, Stratigraphy and structural geology of the Titus and Titanothere Canyons area, Death Valley, California: Ph.D. dissertation, University of California, Berkeley, California, 310 p.

Rogers, C.L., Ekren, E.B., Noble, D.C., And Weir, J.E., 1968, Geologic map of the northern half of Black Mountain quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I-545, scale 1:62,500.

Rogers, C.L., and Noble, D.C., 1969, Geologic map of the Oak Spring Butte quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-822, scale 1:24,000.

Rosenbaum, J.G., and Snyder, D.B., 1984, Preliminary interpretation of paleomagnetic and magnetic property data from drill holes USW G-1, G-2, GU-3, G-3, and VH-1 and surface localities in the vicinity of Yucca Mountain, Nye County, Nevada: U.S. Geological Survey Open-File Report 85-49, 73 p.

Rosenbaum, J.G., Hudson, M.R., and Scott, R.B., 1991, Paleomagnetic constraints on the geometry and timing of deformantion at Yucca Mountain, Nevada: Journal of Geophysical Research, v. 96, p. 8801-8841.

Sargent, K.A., Luft, S.J., Gibbons, A.B., and Hoover, D.L., 1966, Geologic map of the Quartet Dome quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-496, scale 1:24,000.

Sargent, K.A., McKay, E.J., and Burchfiel, B.C., 1970, Geologic map of the Striped Hills quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-882, scale 1:24,000.

Sargent, K.A. and Stewart, J.H., 1971, Geologic map of the Specter Range NW quadrangle, Nye County, Nevada: U.S. Geological Survey Geologic Quadrangle Map GQ-884, scale 1:24,000.

Sargent, K.A., and Orkild, P.P., 1973, Geologic map of the Wheelbarrow Peak-Rainier Mesa area, Nye County, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I-754, scale 1:48,000.

Sargent, K.A., and Orkild, P.P., 1976, Preliminary geologic map of the northwest quarter of the Springdale quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Field Studies Map MF-751, scale 1:24,000.

Sawyer, D.A., Fleck, R.J., Lanphere, M.A., Warren, R.G., and Broxton, D.E., 1994, Episodic caldera volcanism in the Miocene southwestern Nevada volcanic field: revised stratigraphic framework, 40Ar/39Ar geochronology, and implications for magmatism and extension: Geological Society of America Bulletin, v. 106, p.1304-1318.

Sawyer, D.A., and Sargent, K.A., 1989, Petrologic evolution of divergent peralkaline magmas from the Silent Canyon caldera complex: Journal of Geophysical Research, v. 94, p. 6021-6040.

Sawyer, D.A., Wahl, R.R, and others, 1995, Preliminary digital geologic map database of the Nevada Test Site area, Nevada: U.S. Geological Survey Open-File Report 95-0567.

Scott, R.B., 1990, Tectonic setting of Yucca Mountain, southwest Nevada, in Wernicke, B.P., ed., Basin and Range extensional tectonics near the latitude of Las Vegas, Nevada: Geological Society of America Memoir 176, p. 251-282.

Scott, R.B., and Bonk, J., 1984, Preliminary geologic map of Yucca Mountain, Nye County, Nevada, with geologic sections: U.S. Geological Survey Open-File Report 84-494, scale 1:12,000.

Scott, R.B., Gromme, C.S., Best, M.G., Rosenbaum, J.G., and Hudson, M.R., 1995, Chapter A, Stratigraphic relationships of Tertiary volcanic rocks in central Lincoln County, southeastern Nevada, in Scott, R.B., and Swadley, WC, eds., Geologic studies in the Basin and Range Colorado Plateau transition in southeastern Nevada, southwestern Utah, and northwestern Arizona, 1992: U.S. Geological Survey Bulletin 2056.

Steiger, R.H., and Jaeger, E., 1977, Subcommission on Geochronology: Convention on the use of decay constants in geo- and cosmochronology: Earth and Planetary Science Letters, v. 36, p. 359-362.

Streckeisen, A.L., 1976, To each plutonic rock its proper name: Earth Science Reviews, v. 12, p. 1-33.

Stock, Chester, and Bode, F.D., 1935, Ocurrence of lower Oligocene mammal-bearing beds near Death Valley, California: National Academy of Sciences Proceedings, v. 21, p. 571-579.

Suhr, N.H., and Ingamells, C.O., 1966, Solution technique for analysis of silicates: Analytical Chemistry, v. 38, p. 730-734.

Swadley, WC, and Carr, W.J., 1987, Geologic map of the Quaternary and Tertiary Deposits of the Big Dune quadrangle, Nye County, Nevada and Inyo County, California: U.S. Geological Survey Miscellaneous Investigations Series Map I-1767, scale 1:48,000.

Swadley, W C, and Parrish, L.D., 1988, Surficial geologic map of the Bare Mountain quadrangle, Nye County, Nevada: U.S. Geological Survey Miscellaneous Investigations Series Map I-1826, scale 1:48,000.

Turrin, B.D., Champion, D.E., and Fleck, R.J., 1992, Measuring the age of the Lathrop Wells volcanic center at Yucca Mountain, Response to Wells and others: Science, v. 257, p. 555-558.

Weiss, S.I., and Noble, D.C., 1989, Stonewall Mountain volcanic center, southern Nevada: Stratigraphic, structural, and facies relations of outflow sheets, near-vent tuffs, and intracaldera units: Journal of Geophysical Research, v. 94, n. B5, p. 6059-6074.

Wells, S.G., McFadden, L.D., Renault, C.E., and Crowe, B.M., 1990, Geomorphic assessment of late Quaternary volcanism in the Yucca Mountain area, southern Nevada: Implications for the proposed high-level radioactive waste repository: Geology, v 18, p. 549-553.

Wright, L.A., and Troxel, B.W., 1993, Geologic map of the central and northern Funeral Mountains and adjacent areas, Death Valley region, southern California: U.S. Geological Survey Miscellaneous Investigations Map 1-2305, scale 1:48,000.

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

Low-Angle fault—Hachures on upper plate

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

Oblique-slip fault—Bar and ball and opposing arrows indicate sense of dip and strike components of slip, respectively

Strike-slip fault—Opposing arrows indicate slip sense

Quaternary fault—Known to offset Quaternary deposits

Faults ruptured in response to nuclear weapons tests (shown in red)

Fault in bedrock—Existence of fault known prior to nuclear test but reactivation occurred in response to testing

Fault in Quaternary deposit—Existence of fault first recognized on the basis of s'rface rupture due to nuclear testing. Includes new bedrock or Quaternary deposits resulting from test-induced reactivation of subsurface faults

Lineament in bedrock

Lineament in Quaternary deposits

Tertiary(?) landslide slip-surface trace—Hachures on slide block

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—Hachures point toward topographic depression

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 **Subgreenschist 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, chlorite and garnet. In the central Funeral Mountains, the Johnnie Formation also commonly contains chlorite and garnet and the Stirling Quartzite commonly contains kyanite and chlorite. 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

Strike and dip of bedding

Inclined

Vertical

Horizontal

Overturned

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

Inclined

Vertical

Horizontal

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