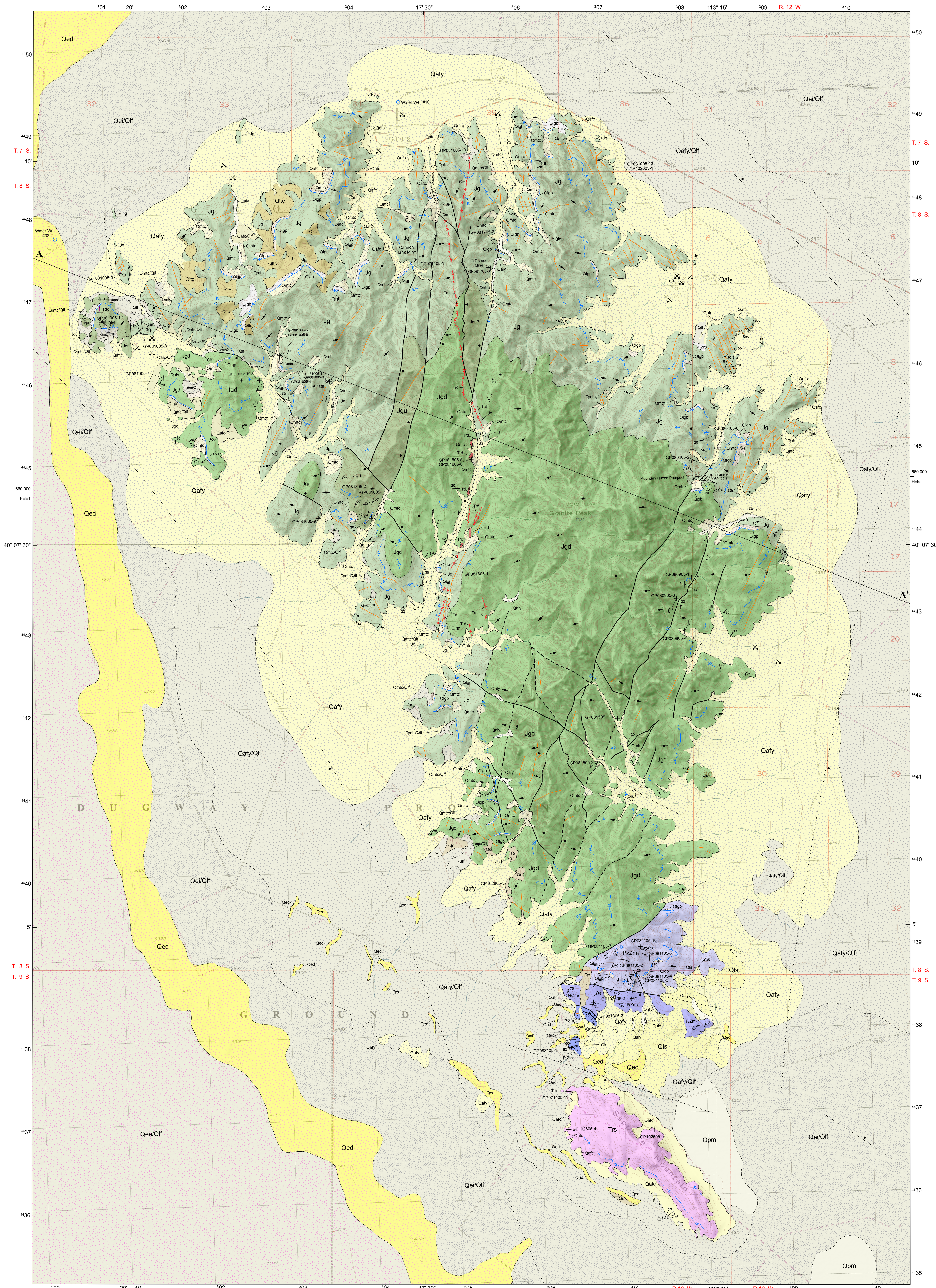

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This geologic map was funded by the Utah Geological Survey.

Granite Peak	Dugway Proving Grounds NW
Granite Peak SE	Dugway Proving Grounds SW

MAP AREA

UTAH

MAP LOCATION

SCALE 1:24,000

1 0.5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0.5 0 1 KILOMETER

TOPOGRAPHIC CONTOUR INTERVAL 40 FEET

GEOLOGIC MAP OF THE GRANITE PEAK AND SAPPHIRE MOUNTAIN AREA, U.S. ARMY DUGWAY PROVING GROUND, TOOELE COUNTY, UTAH

by

Donald L. Clark, Robert F. Biek, Grant C. Willis, Kent D. Brown, Paul A. Kuehne, J. Buck Ehler, and Carl L. Ege

2009

12°41'

TRUE NORTH

MAGNETIC NORTH

APPROXIMATE MEAN DECLINATION, 2009

This basemap is a mosaic of four USGS 7.5' topographic basemaps: Granite Peak, Granite Peak SE, Dugway Proving Grounds NW, and Dugway Proving Grounds SW, 1993.
Shaded relief derived from 5 meter elevation data from the AGRC
Contours derived from 10 meter National Elevation Dataset
Projection: UTM Zone 12
Datum: NAD 1927
Spheroid: Clarke 1886

Field mapping by authors, August 2005
Digital Photogrammetry and Cartography: Donald L. Clark, Robert F. Biek, Kent D. Brown
GIS and Cartography: Jay Hill
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INTRODUCTION

At the request of the U.S. Army Dugway Proving Ground, Special Programs Division (DPG-SPD, now Joint Operational Testing & Training), the Utah Geological Survey (UGS) conducted geologic mapping of the Granite Peak and Sapphire Mountain area. This mapping was performed in August 2005 using standard field mapping methods and aerial photographs provided by Dugway Proving Ground personnel. The aerial photos were 1:24,000 scale, natural color with low sun angle, flown on October 13, 2001, by Towill, Inc., of San Francisco, California. The geologic map-data were placed on a composite topographic base map at 1:24,000 scale that we prepared by combining parts of four U.S. Geological Survey (USGS) 7.5' topographic maps. This map is based on limited field mapping and aerial photograph interpretation. Because the mapping was conducted under a shortened schedule (11 field days) to meet DPG-SPD requirements, the geology depicted does not everywhere meet 1:24,000-scale geologic map standards. Much of this geologic mapping data has been incorporated into smaller-scale geologic maps of Dugway Proving Ground and adjacent areas (Clark and others, 2007; Clark and others, 2008; Clark and others, in preparation). Donald Clark and Robert Biek led the mapping effort and conducted digital photogrammetry and cartography, with Grant Willis, Paul Kuehne, Buck Ehler, and Carl Ege provided substantial field assistance. Kent Brown prepared the base map, set up the digital photogrammetry, and conducted digital cartography.

Granite Peak (see note below) and Sapphire Mountain are range blocks composed of igneous and metamorphic rocks located on the southeast margin of the Great Salt Lake Desert in the northeastern Great Basin. These mountains are unique, in part because they have undergone relatively little detailed geologic study as a result of their location within the U.S. Army Dugway Proving Ground since 1942 (figure 1). Exploration and mining activities for base metals and other commodities occurred on Granite Peak in the late 1800s and early 1900s. Butler and others (1920) originally discussed the geology and mineral resources. The only other detailed geologic study was by Fowkes (1964), who focused on the abundant pegmatite dikes (coarsely crystalline intrusive rocks), an interesting feature of Granite Peak. Douglas Stoeser (USGS, verbal communication, July 2005) also conducted some unpublished geologic work on Granite Peak. Previous geologic mapping in the immediate area includes the Tooele 1° x 2° geologic map (1:250,000 scale) (Moore and Sorensen, 1979), a map of the Dugway Proving Ground SW quadrangle (1:24,000 scale) (Staatz, 1972), and a map and report on the Dugway Range (Staatz and Carr, 1964). Morris (1987) prepared a structural geologic map of the Delta 1° x 2° quadrangle and adjacent areas. Stein and others (1989) reported on geologic data in the Tooele 1° x 2° quadrangle. Steiger and Freethy (2001), and Fitzmayer and others (2004) discussed DPG ground-water studies.

The age of the Granite Peak intrusion has been debated—it has been previously speculated to be from Precambrian to Tertiary (Stokes, 1963; Fowkes, 1964; Moore and Sorensen, 1978, 1979; Hintze, 1980, 1988; Moore and McKee, 1983; Christiansen and others, 1986). Research associated with this mapping project indicates that the intrusion is Late Jurassic in age (149 Ma) (Clark and Christiansen, 2006; Christiansen and others, 2007; Clark and others, 2007, 2008; Jensen and others, 2007; Christiansen and Vervoort, 2009), whereas the volcanic rocks of adjacent Sapphire Mountain are Miocene in age (8 Ma) (Utah Geological Survey and New Mexico Geochronology Research Laboratory, 2007; Clark and others, 2007, 2008).

The age data allow us to place the rock units in their proper geologic context. The igneous intrusions (granite and granodiorite with pegmatite) of Granite Peak appear to coincide with the largely compressional deformation of Middle and Late Jurassic tectonism, which some refer to as the Nevadan orogeny (for example, Armstrong, 1968; DeCelles, 2004). Several intrusions were emplaced in western Utah, Nevada, and California during this time frame (160 to 120 Ma). This Jurassic tectonism, in what some call the hinterland of the Sevier belt (Miller, 1991; DeCelles, 2004), was the precursor to the frontal fold and thrust belt (Sevier orogenic belt of Armstrong, 1968), which significantly affected the western and central parts of Utah from the Early Cretaceous to early Tertiary (120 to 40 Ma) (Miller, 1991; DeCelles, 2004; Hintze and Kowallis, 2009). The granitic rocks of Granite Peak likely intruded a section of Paleozoic or Neoproterozoic marine rocks, as evidenced by the presence of the metasedimentary rocks at the south end. Tertiary magmatism (42 to 6 million years old) subsequently occurred throughout the eastern Great Basin (Best and others, 1989; Christiansen and Yeats, 1992) and led to the emplacement of older dacite and latite dikes, and younger rhyolitic dikes that intruded existing rock units of Granite Peak, and produced the rhyolite of Sapphire Mountain.

The mountains were probably uplifted relative to the adjacent valley floors beginning in the Miocene and continuing into the Quaternary along range-bounding faults that formed during Basin-and-Range extension (see for example, Zoback and others, 1981). The $^{40}Ar/^{39}Ar$ data from the Jurassic pluton suggest that significant exhumation likely associated with extension began about 15 Ma and continued until at least 5 Ma (Utah Geological Survey and New Mexico Geochronology Research Laboratory, 2009). Gravity data suggest a fault with large down-to-the-east displacement along the east margin of the mountains, and other range-bounding faults (Johnson and Cook, 1957; Cook and others, 1989). We found no evidence of Late Quaternary movement on faults along the margins of either Granite Peak or Sapphire Mountain.

Granite Peak was partly submerged by Late Pleistocene Lake Bonneville from about 27,000 to 14,400 years ago (Oviatt and others, 1992), and three of the four primary shorelines of the Bonneville lake cycle are preserved on the flanks of the mountain, including the Stansbury (4440 to 4500 feet [1354–1372 m] in elevation), Provo (4840 to 4880 feet [1476–1488 m]), and Bonneville (5220 to 5260 feet [1591–1604 m]). The Stansbury shoreline is also present on Sapphire Mountain. Surficial deposits—including several generations of stream and alluvial-fan deposits, and sand, gravel, silt, and clay deposited in Lake Bonneville—surround the mountain. Talus and colluvial deposits locally conceal bedrock, especially below the Lake Bonneville shorelines.

Note on Granite Peak:

Granite Peak (elevation 7082 feet [2159 m]) is the highest point of an unnamed mountain of largely granitic rock on Dugway Proving Ground. The name Granite Peak is used on the USGS 7.5' topographic map of this area. This mountain has informally been called by different names, including the Granite Range (Butler and others, 1920), Granite Mountain (Hanley and others, 1950; Stokes, 1963; Moore and Sorensen, 1979), Granite Peak Mountain (Fowkes, 1964; Moore and McKee, 1983), and Granite Peak (Ives, 1946, 1949; Bullock, 1976). Although DPG personnel typically refer to this feature as Granite Mountain (Rachel Quist, U.S. Army DPG, verbal communication, August 2005), some confusion remains since Granite Mountain is the formal name applied to three different mountains in Utah located in Juab, Iron, and Washington Counties (see U.S. Geological Survey Geographic Names Information Systems Web site). The inappropriately named Granite Mountain in Juab County is located about 43 miles (69 km) to the southwest of Granite Peak in the northern Confusion Range and consists largely of carbonate rock! Considering all of the above, we prefer to apply the name Granite Peak to this mountain of granitic rock.

MAP UNIT DESCRIPTIONS

QUATERNARY

Alluvial deposits

Qaly — **Younger stream alluvium** (Holocene) − Moderately sorted sand, silt, clay, and pebble to boulder gravel deposited in ephemeral stream channels; includes minor terraces up to about 15 feet (5 m) above adjacent stream channel; probably less than 20 feet (6 m) thick.

Qafy — **Younger alluvial-fan deposits** (Holocene to upper Pleistocene) − Poorly to moderately sorted, non-stratified, clay- to boulder-size sediment deposited principally by debris flows and debris floods at the mouths of active drainages; forms post-Bonneville, coalesced alluvial-fan apron that encircles Granite Peak; upper part of fans locally deeply incised and commonly characterized by abundant boulders and debris-flow levees that radiate away from the apex of the fan; clast size generally decreases away from the apex of the fans; lowest parts of fans are typically fine grained and of low relief, and thus difficult to distinguish from fine-grained lacustrine deposits; distal contact gradational with lacustrine silt and clay, mostly of the regressional (Provo) phase (Qei/Qlf); believed to overlie older alluvial-fan and Lake Bonneville lacustrine deposits; older alluvial-fan deposits (pre-Lake Bonneville) are not present in map area but are present along flanks of nearby ranges; generally less than 30 feet (9 m) thick.

Eolian deposits

Qed — **Eolian dune sand deposits** (Holocene) − Very fine to medium-grained sand and silt that typically forms dunes locally stabilized by sparse vegetation; commonly overlies fine-grained lacustrine deposits and commonly accumulates on the lee side of blowout depressions; forms long ridge along east margin of Great Salt Lake Desert mud flats and dunes near south end of Granite Peak (also see Dean, 1978); generally less than 15 feet (5 m) thick.

Lacustrine deposits

Deposits of the regressive (Provo) phase of the Bonneville lake cycle (Curry and Oviatt, 1985; Oviatt and others, 1992) are identified with the last map symbol letter 'p', and deposits of the transgressive (Bonneville) phase of the Bonneville lake cycle are identified with the last map symbol letter "b." Deposits lacking the 'p', or 'b' letters are undivided as to phase. Four regionally extensive shorelines of Lake Bonneville are found in the Bonneville Basin, and three (Stansbury, Bonneville, Provo) are located in this map area; the fourth shoreline (Gilbert) was shown by Curry (1982) in this area, but it lacks geomorphic expression so is not mapped (C.G. Oviatt, Kansas State University, verbal communication, March 2006). Ages and elevations of Lake Bonneville shorelines in the study area are included in table 1. Crittenden (1963) reported an elevation of the Bonneville shoreline of 5220 feet (1591 m) on the north end of Granite Peak.

This map does not include detailed mapping of alluvial sand and gravel channels associated with the Old River Bed delta that spread across the flats between Granite Peak and the southern Cedar Mountains as Lake Bonneville regressed from its highstand. For information on and mapping of these deposits refer to Oviatt and others (2003), and Clark and others (2008).

Qlgp, Qlgb — **Lacustrine gravel and sand** (upper Pleistocene) − Moderately to well-sorted, moderately to well-rounded, clast-supported, pebble to boulder gravel and pebbly sand; thin to thick bedded; only larger deposits are mapped where they form tufa-cemented gravel benches on the flanks of Granite Peak; intermediate shorelines are not mapped but are well developed on transgressive Bonneville deposits on the northwest flank of Granite Peak; Qlgp deposited at and below the highest Bonneville shoreline but above the Provo shoreline, and Qlgp deposited at and below the Provo shoreline; Qlgb deposits are also locally mapped on the northern part of Granite Peak at and below the Stansbury shoreline; shorelines are typically partly covered by unmapped talus and colluvium; 0 to several tens of feet thick.

Qls — **Lacustrine sand and silt** (upper Pleistocene) − Fine- to coarse-grained lacustrine sand and silt with minor gravel; typically thick bedded and well sorted; gastropods locally common; grades downslope from sandy nearshore deposits to finer grained offshore deposits; deposited below the Provo shoreline at the south end of Granite Peak; exposed thickness less than 30 feet (10 m).

Qlf — **Lacustrine silt and clay** (upper Pleistocene) − Calcareous silt (marl), clay, and fine-grained sand; laminated to thin bedded; undivided as to Provo or Bonneville phase; also mapped as stacked units partly concealed by alluvial, colluvial, and talus deposits; thickness uncertain, but likely in excess of several tens of feet thick.

Qpm — **Playa mud deposits** (Holocene) − Laminated clay and silt, typically calcareous or saline; mapped in shallow depressions southeast of Sapphire Mountain at areas of local groundwater discharge; probably less than 5 feet (1.5 m) thick where they overlie eolian silt and lacustrine silt and clay, mostly of the regressive (Provo) phase (Qei/Qlf).

Colluvial deposits

Qc — **Colluvial deposits** (Holocene to upper Pleistocene) − Clay- to boulder-size, locally derived sediment deposited by slope wash on the lower flanks of Granite Peak; colluvium is common on many slopes, but only the larger, more prominent deposits are mapped; generally less than 20 feet (6 m) thick.

Mixed-environment deposits

Qafc — **Mixed alluvial-fan and colluvial deposits** (Holocene to upper Pleistocene) − Alluvial-fan and colluvial deposits mapped as mixed unit where difficult to separate along the fringes of Granite Peak and Sapphire Mountain; form small alluvial-fan and colluvial surfaces that spill out onto and grade into younger coalesced alluvial-fan deposits (Qafy); generally less than 20 feet (6 m) thick.

Qmtc — **Mixed talus and colluvial deposits** (Holocene to upper Pleistocene) − Very poorly sorted, angular to subangular cobbles and boulders and finer-grained interstitial sediment deposited principally by rock fall and slope wash on and at the base of steep slopes; locally deeply incised; where present below shoreline deposits includes reworked subrounded gravel and boulders; generally less than 30 feet (9 m) thick.

Qltc — **Mixed lacustrine, talus, and colluvial deposits** (Holocene to upper Pleistocene) − Mapped on the northwest side of Granite Peak where it is mostly derived from and includes lacustrine gravel and sand of the regressive and transgressive phases of Lake Bonneville reworked by rock-fall and slope-wash processes; typically mantles bedrock and fills steep washes, and is locally covered by prominent secondary shorelines; generally less than 10 feet (3 m) thick, but is thicker where it fills paleotopography.

Stacked-unit deposits

Qafy/Qlf — **Younger alluvial-fan deposits over lacustrine fine-grained deposits** (Holocene to upper Pleistocene/upper Pleistocene) − Lacustrine fines locally concealed by veneer of fine-grained, distal alluvial-fan deposits; incised by minor ephemeral washes and locally marked by blowout depressions around which dune sand and silt (Qed) is deposited; gradational with younger, coalesced alluvial-fan deposits; lacks shorelines; fan deposits are generally less than 3 feet (1 m) thick.

Qafc/Qlf — **Mixed alluvial-fan and colluvial deposits over lacustrine fine-grained deposits** (Holocene to upper Pleistocene/upper Pleistocene) − Lacustrine fines locally concealed by veneer of alluvial-fan and colluvial deposits; mapped along the northern fringes of Granite Peak; lacks shorelines, fan and colluvial deposits are generally less than 10 feet (3 m) thick.

Qmtc/Qlf — **Mixed talus and colluvial deposits over lacustrine fine-grained deposits** (Holocene to upper Pleistocene/upper Pleistocene) − Lacustrine silt and clay locally concealed by veneer of talus and colluvial deposits; mapped along lowest slopes of Granite Peak; talus and colluvial deposits are generally less than 10 feet (3 m) thick.

Qei/Qlf — **Eolian silt over lacustrine fine-grained deposits** (Holocene/upper Pleistocene) − Windblown silt overlying lacustrine silt, clay, marl, and some sand; deposited below the Provo shoreline; present along outer periphery of Granite Peak and Sapphire Mountain area; surface commonly contains distinctive vegetation stripes (characteristic landform of sheetflow plains in arid to semiarid regions) (Oviatt and others, 2003); may locally include thicker eolian deposits; includes transgressive deposits at depth; cover unit thickness probably less than 3 feet (1 m).

Qea/Qlf — **Mixed eolian and alluvial deposits over lacustrine fine-grained deposits** (Holocene/upper Pleistocene) − Windblown silt with sheet flow deposits adjacent to and locally covering alluvial sand and gravel in unmapped channels that collectively overlie lacustrine marl and fine-grained deposits and transgressive deposits at depth; locally saline or gypsiferous; form mudflats in west and southwest parts of map area; cover unit thickness probably less than 10 feet (3 m) thick.

unconformity

TERTIARY

Trd — **Rhyolitic dikes** (Miocene) − Grayish-orange, weathering dark-yellowish-brown, porphyritic rhyolite (figure 2, table 2; Clark, 2008); phenocrysts of feldspar and biotite; dikes typically trend nearly north-south and are subvertical, up to roughly 3 miles (5 km) long, and cross-cut granite (Jg) and granodiorite (Jgd); new $^{40}Ar/^{39}Ar$ age of 7.78 ± 0.05 Ma (Utah Geological Survey and New Mexico Geochronology Research Laboratory, 2007; table 4) is similar to rhyolite of Sapphire Mountain, and supercedes prior whole-rock K-Ar age of about 13 million years reported by Moore and McKee (1983). Only larger dikes are mapped; width to 30 feet (10 m).

Not in contact

Trs — **Rhyolite of Sapphire Mountain** (Miocene) − Pale-red, weathering to dark-yellowish-brown and moderate-red, porphyritic, rhyolitic lava flow, and some local flow breccia; phenocrysts (~10%) of quartz and sanidine in an aphanitic groundmass (Clark, 2008; Staatz, 1972; figure 2, table 2); lava flow exhibits subhorizontal flow layering; forms cliffy exposures on Sapphire Mountain; new $^{40}Ar/^{39}Ar$ age of 8.20 ± 0.05 Ma (Utah Geological Survey and New Mexico Geochronology Research Laboratory, 2007; table 4); exposed thickness is 450 feet (140 m).

Not in contact

Tdd — **Dacitic and latitic dikes** (Oligocene? – Eocene?) − Medium-gray to medium-dark-gray porphyritic dacite on northwest side of Granite Peak (only two such dikes are mapped), and uncommon, unmapped medium-light-gray, weathering dark-yellowish-brown latite is also present on the mountain (figure 2, table 2; Clark, 2008); cross-cuts granite (Jg) and granodiorite (Jgd); not dated, but may be related to andesitic and dacitic rocks of Cedar Mountains, which are about 40 Ma (Clark and others, 2008); isotope data presented in table 5; width to 10 feet (3 m).

Intrusive contacts

JURASSIC

Jgu — **Foliated granodiorite and granite of Granite Peak** (Late Jurassic) − Foliated granodiorite with sills and dikes of leucogranite exposed in the central and western part of Granite Peak. Individual leucogranite intrusions were not mapped separately in these exposures. Exposed thickness about 400 feet (120 m).

Jgd — **Foliated granodiorite of Granite Peak** (Late Jurassic) − Medium-light-gray to medium-gray granodiorite; chemical composition varies with decreasing silica to quartz monzonite, monzonite, diorite, and monzodiorite (figure 3, table 2; Clark, 2008; also see Staatz, 1972); primary minerals include plagioclase > quartz > alkali-feldspar > biotite > amphibole > muscovite > (Fowkes, 1964; Jensen and others, 2007); rock is weakly to strongly foliated, contains uncommon dark xenoliths and local feldspar megacrysts as much as 2 inches (5 cm) long; cut by numerous unmapped, white, beryl-bearing pegmatite dikes in various forms (Fowkes, 1964; also see Hanley and others, 1950) (pegmatites to 100 feet [30 m] thick); also includes minor aplite dikes and quartz veins, and is cut by younger dikes (Trd, Tdd); granodiorite is believed to be upper part of the granite intrusion (Jg) (Clark and Christiansen, 2006); some fault and fracture zones in granodiorite are mineralized with hematite and lesser amounts of base metal-bearing minerals; U-Pb zircon age of 149.8 ± 1.3 Ma (table 3; Christiansen and Vervoort, 2009), and step heating $^{40}Ar/^{39}Ar$ age of 15.97 ± 0.04 Ma on biotite and 27.13 ± 0.05 Ma on K-feldspar (table 4; Utah Geological Survey and New Mexico Geochronology Research Laboratory, 2009); the U-Pb age is interpreted to represent the time of emplacement and crystallization, whereas the $^{40}Ar/^{39}Ar$ ages probably record cooling and uplift of the pluton during the late Cenozoic; isotope data provided in table 5. Exposed thickness about 2000 feet (600 m).

Unmapped pegmatite dikes, aplite dikes, and quartz veins: Dikes and veins are typically white to pale-orange in color. In the granodiorite, pegmatites predominate over aplite dikes and quartz veins; one prominent set of pegmatite dikes trends ~N 35° E and dips steeply northwest, and some individual dikes extend up to 0.5 mile (0.8 km) in length; another set of pegmatite dikes is thinner and more anastomosing and appears to cut the aforementioned set; pegmatites occur as stringers, lenses or pods, and tabular bodies with three main zones (based on distribution of minerals and grain size), and contain microcline, quartz, plagioclase, and muscovite with lesser beryl, tourmaline, garnet, and hematite (Fowkes, 1964). We did not directly date the pegmatite dikes, but infer that they are related to the leucogranite intrusion and are Late Jurassic in age (Clark and Christiansen, 2006); a prior K-Ar muscovite age of 30 ± 2 Ma from a pegmatite (Whelan, 1970) is considered unreliable; the cross-cutting relationships between the various types of dikes and veins was not fully investigated. Pegmatite dikes are up to 100 feet (30 m) thick, while aplite dikes and quartz veins are up to 4 feet (1.2 m) thick.

Jg — **Granite of Granite Peak** (Late Jurassic) − White (leucocratic) granite, weathers to pale-orange and moderate-yellowish-brown (figure 3, table 2; Clark 2008); primary minerals include quartz > plagioclase > alkali-feldspar > muscovite > biotite (Fowkes, 1964; Jensen and others, 2007); locally includes dark schistose inclusions and potassium feldspar phenocrysts; generally weakly foliated, except in northeastern exposures where strong flow foliation occurs in upper part near contact with foliated granodiorite; includes a few pegmatite and aplite dikes and quartz veins, and is cut by younger dikes (Trd, Tdd); some fault and fracture zones in granite are mineralized with hematite and lesser amounts of base metal-bearing minerals; U-Pb zircon age determination of 148.2 ± 1.2 Ma (table 3; Christiansen and Vervoort, 2009), and $^{40}Ar/^{39}Ar$ age of 13.69 ± 0.12 Ma on muscovite and 19.14 ± 0.08 Ma on K-feldspar (table 4; Utah Geological Survey and New Mexico Geochronology Research Laboratory, 2009); the U-Pb age is interpreted to be the age of intrusion and is indistinguishable from the age of the granodiorite it intrudes, while the mica and feldspar ages are much younger and are interpreted to be cooling ages possibly related to unroofing of the pluton during the late Cenozoic; isotope data included in table 5. Exposed thickness about 1400 feet (425 m).

Fault contact between $PzZm_1$ and Jgd

Metasedimentary rocks of Granite Peak (Paleozoic? or Neoproterozoic?) − Metasedimentary rocks intruded by granite and granodiorite and abundant pegmatite dikes at the southern end of Granite Peak; divided into three informal units based on lithologies and attitudes; age relations between three units unclear; lithologies suggest these rocks may correspond to some part of the Paleozoic section, to part of the Neoproterozoic McCoy Creek Group or Trout Creek sequence of the southern Deep Creek Range (Misch and Hazzard, 1962; Rodgers, 1984, 1989), or, less likely, to Neoproterozoic units of the Sheeprock Mountains (Christie-Blick, 1982), but correlation with specific units is unclear.

$PzZm_3$ — **Unit 3** − South-dipping package of predominantly metasedimentary rocks (silver-gray muscovite schist and pale-brown quartzite) intruded by granite at the far southern end of Granite Peak; approximately 80% metasedimentary rocks and 20% deeply weathered granite intrusions (not mapped separately), and cut by thin quartz veins; bedding cut by a west-northwest-striking structural cleavage; in fault contact with map unit $PzZm_2$; exposed thickness about 1500 feet (450 m).

Fault

$PzZm_2$ — **Unit 2** − South- to southeast-dipping package of greenish-gray biotite-muscovite schist and quartzite intruded by granodiorite sills and dikes and cut by pegmatite and aplite dikes and quartz veins; intrusions not mapped separately; roughly 50% metasedimentary rocks and 50% weathered intrusions (granodiorite with pegmatite), with eastern exposures entirely granodiorite with pegmatite; in fault contact with map units $PzZm_3$ and $PzZm_1$; U-Pb zircon age determination of 149.9 ± 3.9 Ma on schist probably related to thermal metamorphism (table 3; Christiansen and Vervoort, 2009); isotope data in table 5; exposed thickness about 600 feet (180 m).

Fault

$PzZm_1$ — **Unit 1** − East- to southeast-dipping package of white to light-greenish-gray marble and greenish-gray biotite schist intruded by granodiorite sills and dikes and cut by pegmatite and aplite dikes and quartz veins; approximately 40% metasedimentary rocks and 60% intrusions (granodiorite with pegmatite), with eastern exposures entirely granodiorite with pegmatite; in fault contact with map unit Jgd; exposed thickness approximately 1700 feet (500 m).

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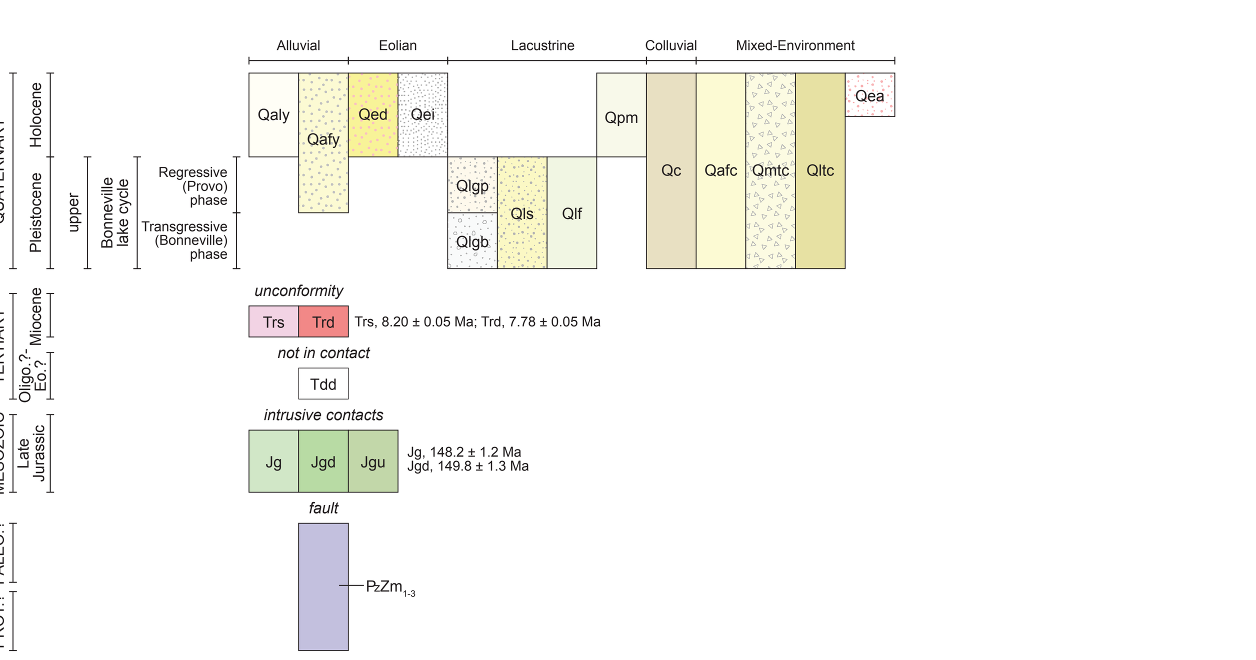
CORRELATION OF MAP UNITS



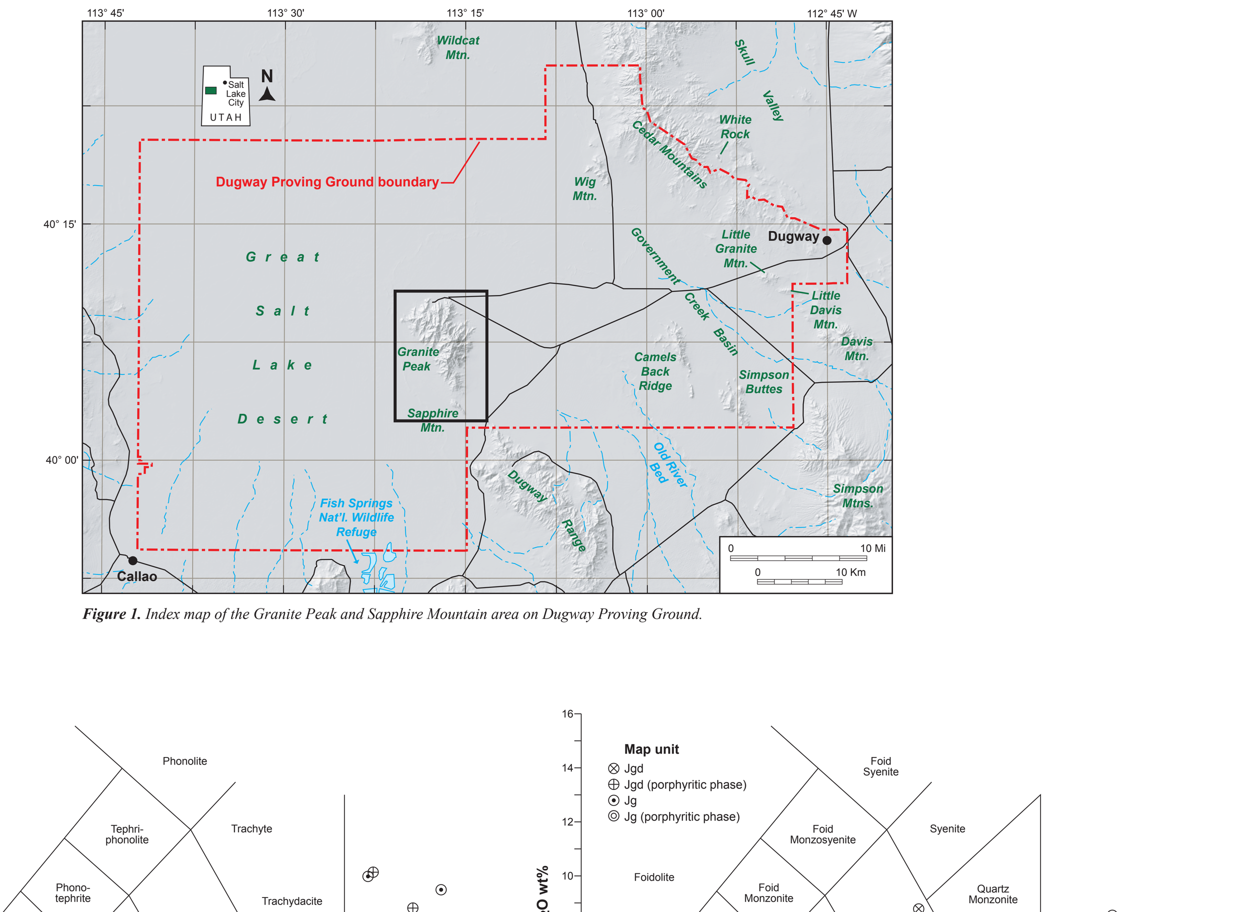


Figure 1. Index map of the Granite Peak and Sapphire Mountain area on Dugway Proving Ground.

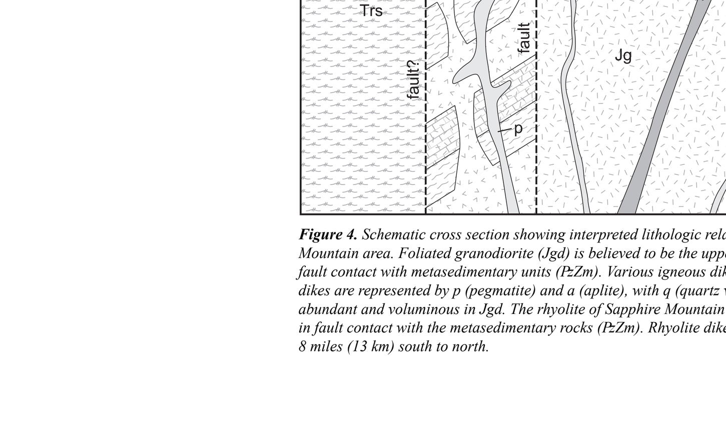


Figure 2. Total alkali-silica plot (after LeBas and others, 1986) with field names for Tertiary dikes and volcanic rocks of the Granite Peak and Sapphire Mountain area.

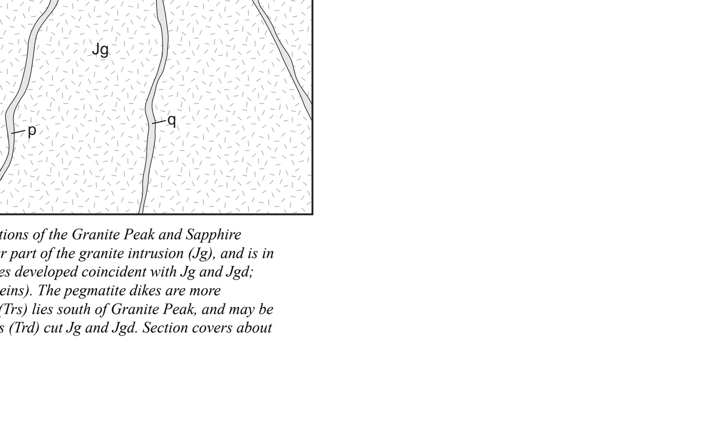


Figure 3. Total alkali-silica plot (after Middlemost, 1994) with field names for Jurassic plutonic rocks of Granite Peak.

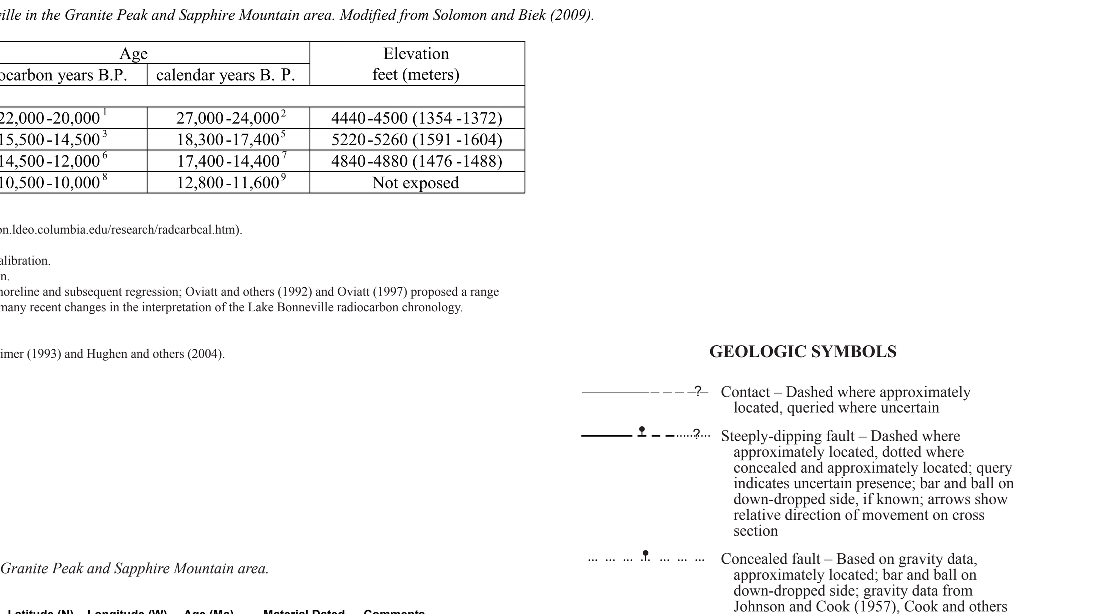


Figure 4. Schematic cross section showing interpreted lithologic relations of the Granite Peak and Sapphire Mountain area. Foliated granodiorite (Jgd) is believed to be the upper part of the granite intrusion (Jg), and is in fault contact with metasedimentary units (PzZm). Various igneous dikes developed coincident with Jg and Jgd; dikes are represented by p (pegmatite) and a (aplite), with q (quartz veins). The pegmatite dikes are more abundant and voluminous in Jgd. The rhyolite of Sapphire Mountain (Trs) lies south of Granite Peak, and may be in fault contact with the metasedimentary rocks (PzZm). Rhyolite dikes (Trd) cut Jg and Jgd. Section covers about 8 miles (13 km) south to north.

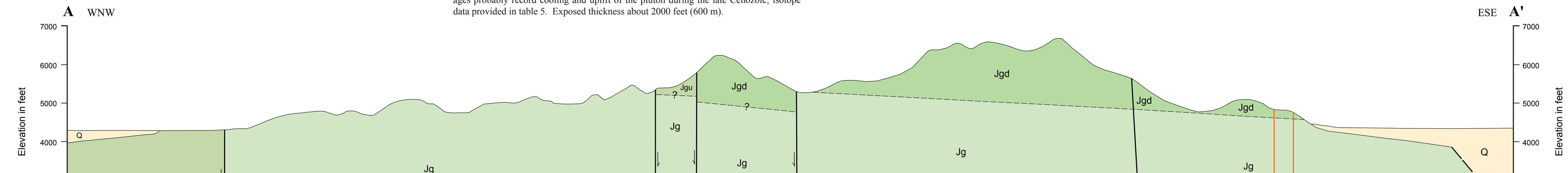


Table 1. *Ages and elevations of major shorelines of Lake Bonneville in the Granite Peak and Sapphire Mountain area. Modified from Solomon and Biek (2009).*

Lake Cycle and Phase	Shoreline (map symbol)	Age: radiocarbon years B.P.	Age: calendar years B.P.	Elevation feet (meters)
Lake Bonneville				
Transgressive Phase	Stansbury (S)	22,000-20,000[1]	27,000-24,000[7]	4440-4500 (1354-1372)
	Bonneville (B)	15,500-14,500[2]	18,300-17,400[8]	5220-5260 (1591-1604)
Regressive Phase	Provo (P)	14,500-12,000[3]	17,400-14,400[9]	4840-4880 (1476-1488)
	Gilbert	10,500-10,000[4]	12,800-11,600[5]	Not exposed

flood (between Bonneville and Provo)

[1] Oviatt and others (1990).
[2] Calendar calibration using Fairbanks and others (2005; http://www.radiocarbon.ldeo.columbia.edu/research/radcarbcal.htm).
[3] Oviatt and others (1992), Oviatt (1997).
[4] Oviatt (written communication, 2009), using Stuiver and Reimer (1993) for calibration.
[5] CRONUS-Earth Project (2005), using Stuiver and others (2005) for calibration.
[6] Godsey and others (2005) revised the timing of the occupation of the Provo shoreline and subsequent regression; Oviatt and others (1992) and Oviatt (1997) proposed a range from 14,500 to 14,000 14C yr B.P. Oviatt and Thompson (2002) summarized many recent changes in the interpretation of the Lake Bonneville radiocarbon chronology.
[7] Godsey and others (2005), using Stuiver and Reimer (1993) for calibration.
[8] Oviatt and others (2005).
[9] Calendar calibration of data in Oviatt and others (2005), using Stuiver and Reimer (1993) and Hughen and others (2004).

GEOLOGIC SYMBOLS

- Contact – Dashed where approximately located, queried where uncertain
- Steeply-dipping fault – Dashed where approximately located, dotted where concealed and queried where uncertain; bar and ball on down-dropped side; if known, arrows show relative direction of movement on cross section
- Concealed fault – Based on gravity data, approximately located; bar and ball on down-dropped side; gravity data from Johnson and Cook (1957), Cook and others (1989)
- Dike of map unit Trd – does not include pegmatite, aplite, and quartz dikes
- Dike of map unit Tdd – does not include pegmatite, aplite, and quartz dikes
- Primary joint or fracture trace from aerial photographs
- Strike of secondary joint or fracture from aerial photographs, vertical to steeply dipping
- Lake Bonneville shorelines – Major shorelines of the Bonneville lake cycle; mapped at the top of the wave-cut platform
  - Bonneville shoreline, highest shoreline of the transgressive (Bonneville) phase; elevation 5220 to 5260 feet (1591–1604 m)
  - Provo shoreline, highest shoreline of the regressive (Provo) phase; elevation 4840 to 4880 feet (1476–1488 m)
  - Stansbury shoreline of the transgressive (Bonneville) phase; elevation 4440 to 4500 feet (1354–1372 m)
- Mineral foliation strike and dip
- Fracture cleavage strike and dip
- Adit
- Prospect
- Sand and gravel pit
- Water well
- Spring
- Rock sample location and number
- Line of cross section

Table 2. *Major- and trace-element whole-rock analyses for the Granite Peak and Sapphire Mountain area.*

Sample #	Map Unit	Rock Name	7.5' Quadrangle	Latitude (N)	Longitude (W)	Major and trace elements
[illegible]	Trd	Rhyolite dike	Granite Peak	[illegible]	[illegible]	[illegible]
[illegible]	Tdd	Dacite dike	Granite Peak	[illegible]	[illegible]	[illegible]
[illegible]	Jgd	Granodiorite	Granite Peak	[illegible]	[illegible]	[illegible]
[illegible]	Jg	Granite	Granite Peak	[illegible]	[illegible]	[illegible]
[illegible]	$PzZm_1$	schist	Granite Peak SE	[illegible]	[illegible]	[illegible]

Notes:
Major oxides reported in weight percent by x-ray fluorescence (XRF); minor and trace elements reported in ppm by inductively coupled plasma-mass spectrometry (ICP-MS).
Analyses performed by ALS Chemex Labs, Inc., Sparks, Nevada.
Most rock names derived from total alkali-silica diagram of LeBas and others (1986).
Location data in NAD27.
LOI is loss on ignition.
Also see Clark (2008) for Dugway Proving Ground area geochemical data.

Table 3. *Summary of U-Pb zircon age analyses from Granite Peak.*

Sample Number	Map Unit	Rock Name	7.5' Quadrangle	Latitude (N)	Longitude (W)	Weighted Average $^{206}Pb/^{238}U$ Age Mean (Ma)
GP102605-3	Jgd	Granodiorite	Granite Peak SE	40°05'16.2"	113°16'45.9"	149.8 ± 1.3
GP081605-9	Jg	Granite porphyry	Granite Peak	40°07'40"	113°18'23"	148.2 ± 1.2
GP081805-3	$PzZm_2$	Schist	Granite Peak SE	40°04'31"	113°16'03"	149.9 ± 3.9

Notes:
Location data in NAD27.
Analyses by laser ablation-inductively coupled plasma mass spectrometry at Washington State University, Pullman, Washington.
See Christiansen and Vervoort (2009) for complete presentation of data.

Table 4. *Summary of $^{40}Ar/^{39}Ar$ age analyses from Granite Peak.*

Sample Number	Map Unit	Rock Name	7.5' Quadrangle	Latitude (N)	Longitude (W)	Age (Ma)	Material Dated	Comments
GP081605-6c	Trd	Rhyolite	Granite Peak	40°07'44"	113°17'04"	7.78 ± 0.05	sanidine	single-crystal laser fusion
SM071405-11	Trs	Rhyolite	Granite Peak SE	40°03'55.4"	113°16'18.5"	8.20 ± 0.05	sanidine	single-crystal laser fusion
GP102605-3	Jgd	Monzonite	Granite Peak SE	40°05'16.2"	113°16'45.9"	15.97 ± 0.04	biotite	step heating, plateau age
GP102605-3	Jgd	Monzonite	Granite Peak SE	40°05'16.2"	113°16'45.9"	27.13 ± 0.05	K-feldspar	integrated age
GP102605-1	Jg	Granite	Granite Peak SE	40°09'58.2"	113°15'56.2"	13.69 ± 0.12	muscovite	step heating, plateau age
GP102605-1	Jg	Granite	Granite Peak SE	40°09'58.2"	113°15'56.2"	19.14 ± 0.08	K-feldspar	integrated age

Notes:
Location data in NAD27.
All analyses performed at the New Mexico Geochronology Research Laboratory, Socorro, New Mexico.
See UGS and NMGRL (2007, 2009) for complete presentation of data.
Age error is ± 2 standard deviations for GP081605-6c and SM071405-11 and ± 1 standard deviation for the remaining samples.

Table 5. *Rb/Sr, Sm/Nd, and Pb isotope analyses for the Granite Peak and Sapphire Mountain area.*

Sample Number	Map Unit	Rock Name	Rb ppm XRF	Sr ppm ID	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$ measured	abs std err (2 sig)	$^{87}Sr/^{86}Sr$ I initial	Sm ppm ID	Nd ppm ID	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$ measured	abs std unc (2 sig)	$^{143}Nd/^{144}Nd$ I initial	eNd today	eNd initial	eNd +/-	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
GP081005-4	Jg	Granite (LREE poor)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GP080405-2a	Jg	Granite	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GP080405-8	Jg	Granite	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GP081005-5a	Jg	Granite porphyry	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GP081005-8a	Jg	Granite porphyry	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GP080905-4	Jgd	Quartz Monzonite	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GP081005-2	Jgd	Diorite	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GP081605-9	Tdd	Dacite dike	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
GP081805-3	$PzZm_2$	Schist	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Analyses performed by Washington State University.
Refer to table 2 for location data.

Technical note on isotope data of table 5 from Eric H. Christiansen, Brigham Young University: The Sr-Nd-Pb isotopic compositions of the igneous and metamorphic rocks of Granite Peak reveal important details about their origin and evolution. [illegible]