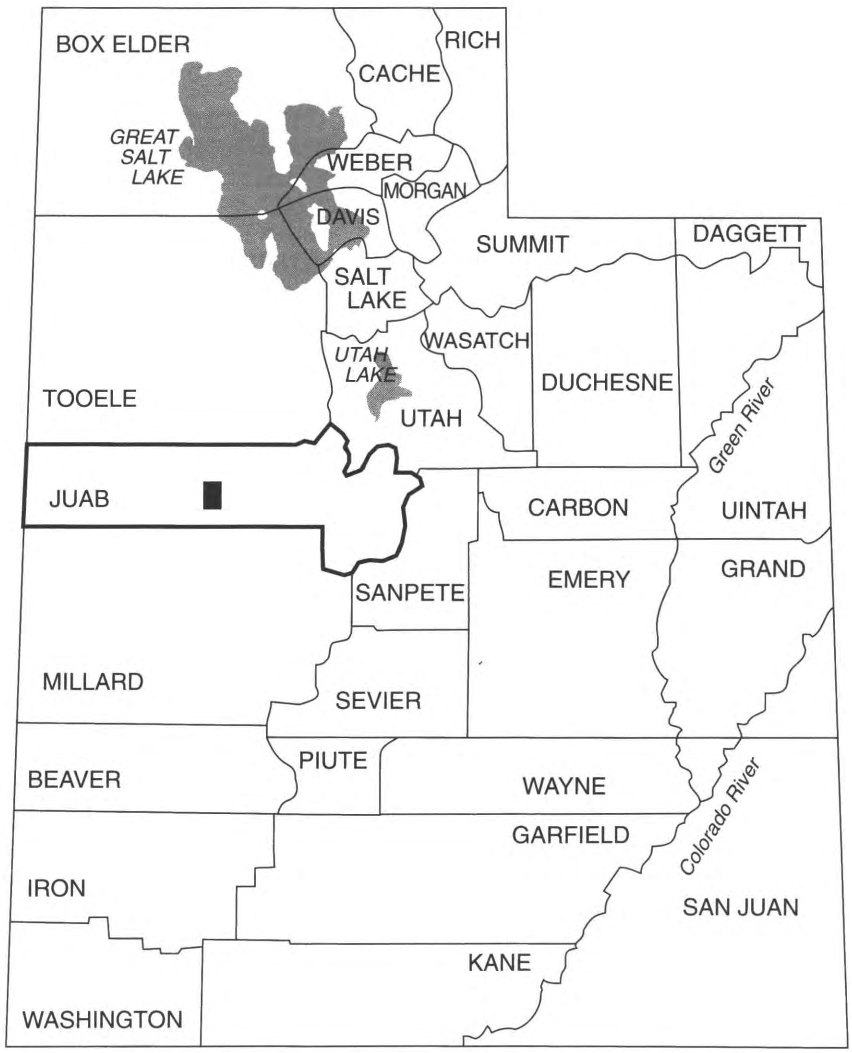
GEOLOGIC MAP OF THE PICTURE ROCK HILLS QUADRANGLE, JUAB COUNTY, UTAH

by
Michael A. Shubat



ISBN 1-55791-636-5

MISCELLANEOUS PUBLICATION 99-3
UTAH GEOLOGICAL SURVEY
a division of
1999 UTAH DEPARTMENT OF NATURAL RESOURCES

1949 · FIFTY YEARS · 1999
UTAH GEOLOGICAL SURVEY

UTAH GEOLOGICAL SURVEY

The **UTAH GEOLOGICAL SURVEY** is organized into five geologic programs with Administration, Editorial, and Computer Resources providing necessary support to the programs. The **ECONOMIC GEOLOGY PROGRAM** undertakes studies to identify coal, geothermal, uranium, hydrocarbon, and industrial and metallic resources; initiates detailed studies of these resources including mining district and field studies; develops computerized resource data bases, to answer state, federal, and industry requests for information; and encourages the prudent development of Utah's geologic resources. The **APPLIED GEOLOGY PROGRAM** responds to requests from local and state governmental entities for engineering-geologic investigations; and identifies, documents, and interprets Utah's geologic hazards. The **GEOLOGIC MAPPING PROGRAM** maps the bedrock and surficial geology of the state at a regional scale by county and at a more detailed scale by quadrangle. The **GEOLOGIC EXTENSION SERVICE** answers inquiries from the public and provides information about Utah's geology in a non-technical format. The **ENVIRONMENTAL SCIENCES PROGRAM** maintains and publishes records of Utah's fossil resources, provides paleontological and archeological recovery services to state and local governments, conducts studies of environmental change to aid resource management, and evaluates the quantity and quality of Utah's ground-water resources.

The UGS Library is open to the public and contains many reference works on Utah geology and many unpublished documents on aspects of Utah geology by UGS staff and others. The UGS has several computer data bases with information on mineral and energy resources, geologic hazards, stratigraphic sections, and bibliographic references. Most files may be viewed by using the UGS Library. The UGS also manages a sample library which contains core, cuttings, and soil samples from mineral and petroleum drill holes and engineering geology investigations. Samples may be viewed at the Sample Library or requested as a loan for outside study.

The UGS publishes the results of its investigations in the form of maps, reports, and compilations of data that are accessible to the public. For information on UGS publications, contact the Natural Resources Map/Bookstore, 1594 W. North Temple, Salt Lake City, Utah 84116, (801) 537-3320 or 1-888-UTAH MAP. E-mail: nrugs.geostore@state.ut.us and visit our web site at http://www.ugs.state.ut.us.

UGS Editorial Staff

J. Stringfellow	Editor
Vicky Clarke, Sharon Hamre	Graphic Artists
Patricia H. Speranza, James W. Parker, Lori Douglas	Cartographers

2/99

GEOLOGIC MAP OF THE PICTURE ROCK HILLS QUADRANGLE, JUAB COUNTY, UTAH

by
Michael A. Shubat[1]

ABSTRACT

The Picture Rock Hills 7.5´ quadrangle is in west-central Utah and encompasses the Picture Rock Hills and the southwestern part of Keg Mountain. Keg Mountain and the Picture Rock Hills are part of a large, late Eocene to early Oligocene igneous center that spans the Thomas Range, Keg Mountain, and northern Drum Mountains. Consequently, the quadrangle is underlain by volcanic and intrusive rocks, and several calderas and cauldrons are in or near the quadrangle. The Eocene and Oligocene ash-flow tuff units (and associated source calderas) in the quadrangle are, in chronological order, the Keg Tuff (Keg cauldron), Mt. Laird Tuff (Thomas caldera), and Joy Tuff (Dugway Valley cauldron). Intrusive rocks are present in the quadrangle that are probably comagmatic with the Keg and Joy Tuffs. Flows, domes, and intrusions of Miocene Topaz Mountain Rhyolite unconformably overlie and intrude the older volcanic rocks. Deposition of sediments during Quaternary time was dominated by Lake Bonneville, which covered most of the quadrangle. Other surficial deposits include stream alluvium, colluvium, and alluvial-fan and eolian deposits. Potential mineral resources in the quadrangle include base and precious metals, uranium, sand and gravel, zeolite minerals, crushed stone, and dimension stone.

INTRODUCTION

The Picture Rock Hills quadrangle is in north-central Juab County, Utah, approximately 30 miles (48 km) northwest of Delta (figure 1) and 44 miles (71 km) west of Eureka. The quadrangle encompasses the Picture Rock Hills and the southwestern part of Keg Mountain. Keg Mountain is a low range in the Great Basin located between the Thomas Range to the west, the Simpson Mountains to the northeast, and Desert Mountain to the east. The Picture Rock Hills mark the southwestern-most extent of Keg Mountain. Geologic mapping of the quadrangle was conducted as part of a joint Utah Geological Survey (UGS)-U.S. Geological Survey (USGS) investigation of the geology and mineral potential of Keg Mountain as part of the Delta 1° x 2° quadrangle study of the Conterminous United States Mineral Assessment Program (CUSMAP). Mapping was done in 1988, 1989, and completed in 1992. This map and report are a refinement of the geology presented in Shubat and Snee (1992).

Previous geologic investigations of the bedrock geology in the area began with Erickson's (1963) description of the volcanic rocks in western Juab County. Staatz and Carr (1964) described the Cambrian stratigraphy, Tertiary volcanic rocks, and mineral deposits of the nearby Thomas and Dugway Ranges. Shawe (1972) first recognized the presence of calderas in central Juab County. Based on his reconnaissance of the region in the 1960s, Shawe (1972) defined the Thomas, Keg, and Desert calderas and outlined three volcanic assemblages. Hintze and Robison (1975) redefined the Cambrian stratigraphy of west-central Utah. Lindsey and others (1975) determined the ages for many of the volcanic rocks in the region by the fission-track method. Lindsey (1975) studied the zeolitic alteration of tuffs at Keg Mountain. Staub (1975) produced the first detailed (1:24,000 scale) geologic map of the Picture Rock Hills 7.5´ quadrangle. Morris (1978) reported hydrothermally altered rocks in the adjacent Keg Pass 7.5´ quadrangle, and conducted a reconnaissance study that included mapping and geochemical sampling. Lindsey (1979) mapped the nearby Thomas Range and northern Drum Mountains, and later Lindsey (1982) presented a detailed account of the regional volcanic stratigraphy and uranium mineralization. Lindsey (1982) was able to document the history of eruptions and collapse of the Thomas caldera and the younger, nested Dugway Valley cauldron. Unpublished reconnaissance mapping of Keg Mountain by Morris, Shawe, and Lindsey exists at a 1:48,000 scale (H.T. Morris, personal communication, 1986). Morris (1987) incorporated much of this unpublished mapping in the geologic map of the Delta 1° x 2° quadrangle (1:250,000 scale). Plavidal (1987) studied the petrology of Miocene igneous rocks in eastern Keg Mountain (Keg Mtn. Ranch 7.5´ quadrangle). Shubat (1987) presented a preliminary report of the geology and mineralization of Keg Mountain. Pampeyan (1989) compiled a 1:100,000 scale map of the Lynndyl 30´ x 60´ quadrangle that includes Keg Mountain and the Picture Rock Hills. Shubat and Snee (1992) provided $^{40}Ar/^{39}Ar$ dates on rocks in Keg Mountain and the Picture Rock Hills, as well as preliminary data on the geology and mineralization. Shubat and Christenson (1999) and Shubat and others (1999) mapped the adjacent Keg Pass and Keg Mtn. Ranch quadrangles, respectively, at 1:24,000 scale.

The Quaternary history and deposits of Keg Mountain, the Picture Rock Hills, and the surrounding Sevier Desert basin were first studied by Gilbert (1890). Subsequent studies were conducted by Varnes and Van Horn (1961), Currey (1982), Currey and others (1983), Oviatt (1984, 1987, 1989), and Oviatt and others (1992, 1994).

[1] *now at 519 Francis Drive, Martinez, California 94553*

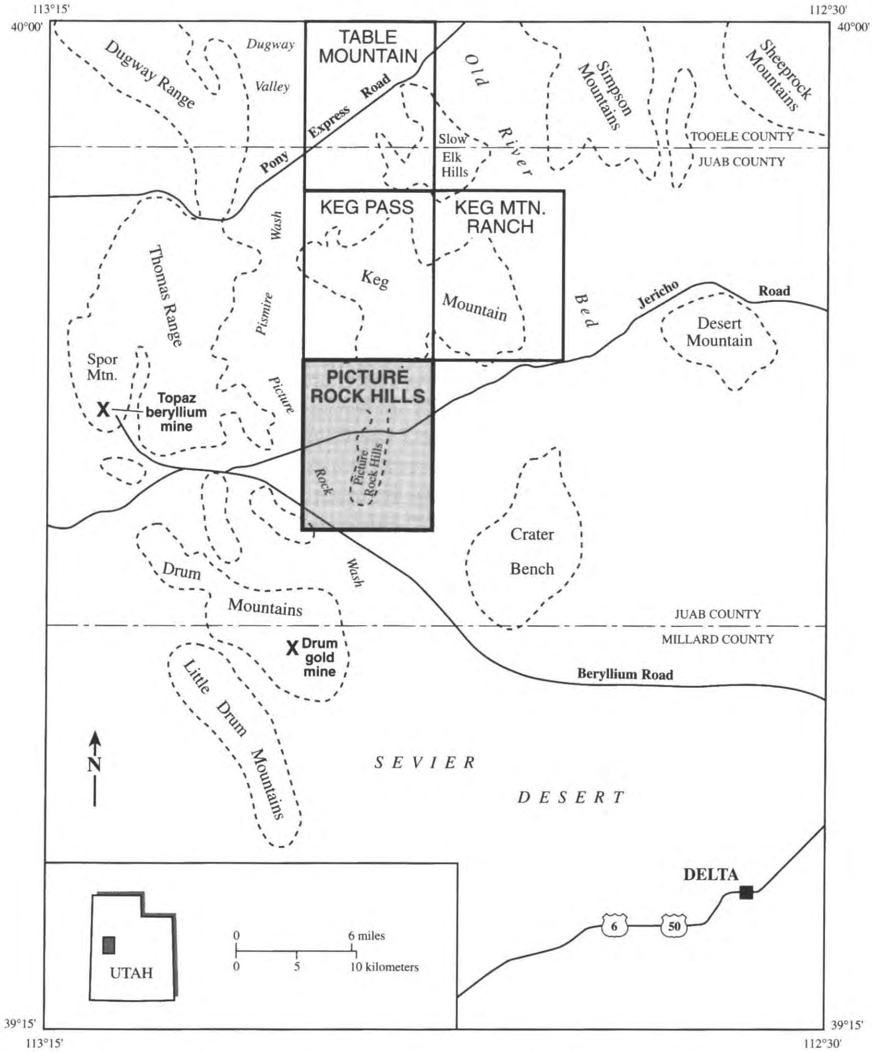


Figure 1. Index map showing the location of the Picture Rock Hills and adjacent quadrangles.

GEOLOGIC SETTING

Pre-Tertiary

Pre-Tertiary sedimentary rocks in the quadrangle are completely covered by volcanic rocks. In the adjacent Keg Pass quadrangle, however, Shubat and Christenson (1999) showed that the Lower Cambrian Prospect Mountain Quartzite was thrust over Middle Cambrian carbonate rocks, probably during the Sevier orogeny. To the south in the Drum Mountains (figure 1), Dommer (1980) mapped Precambrian, Cambrian, and Ordovician rocks cut by high-angle faults of Sevier(?) age. Low-angle faults related to the Sevier orogeny have also been reported in the Drum Mountains (Nutt and others, 1991) and at the Drum mine (Nutt and Thorman, 1992). Similar rocks and structures are probably present beneath the volcanic rocks in the Picture Rock Hills quadrangle. Mineral exploration drilling by The Anaconda Company showed that quartzite, presumably the Cambrian Prospect Mountain Quartzite, underlies volcanic, alluvial, and lacustrine cover at depths ranging from 541 to 3,897 feet (165 to 1,188 m) in the southwest corner of the quadrangle (see metallic minerals section).

Tertiary

The Picture Rock Hills quadrangle lies near the axis of the broad, east-west-trending Deep Creek-Tintic belt, which is defined by Cenozoic volcanic rocks, igneous intrusions, and mineral deposits (Shawe and Stewart, 1976; Stewart and others, 1977). Late Eocene to late Miocene regional extension produced high-angle normal faults that control some of the vents and mineral occurrences in the Picture Rock Hills, at Keg Mountain, and in surrounding ranges.

Volcanism and related mineralization in the Thomas Range and Drum, Keg, and Desert Mountains have been divided into three stages (Shawe, 1972; Lindsey and others, 1975; Lindsey, 1982). The oldest stage (late Eocene to early Oligocene) consisted of emplacement of calc-alkaline, intermediate-composition volcanic rocks and related intrusions. The Dead Ox (present to the north) and Keg Tuffs were probably erupted from cauldrons in Keg Mountain during this stage. In the Thomas Range, this oldest stage culminated with the eruption of the Mt. Laird Tuff and concurrent collapse of the Thomas caldera (Lindsey, 1982). Mineral occurrences related to this stage include copper, manganese, and disseminated gold deposits located in the Drum Mountains district (Nutt and others, 1991) and may include polymetallic vein, polymetallic replacement, and gold occurrences in the adjacent Keg Pass quadrangle (Shubat and Christenson, 1999).

The middle stage (early Oligocene) consisted of eruptions of rhyolitic ash-flow tuffs, caldera subsidence, and intrusion of felsic stocks and plugs. In the Thomas Range, Lindsey (1982) associated the subsidence of the Dugway Valley cauldron with the eruption of the Joy Tuff. The Dell Tuff, present to the north in Keg Mountain, was also erupted (from an unknown source) during this stage. Concealed copper-lead-zinc-silver mineralization in the Picture Rock Hills quadrangle, in part hosted by the Joy Tuff, may be related to this stage.

The youngest stage of activity (Miocene to Pleistocene) consisted of bimodal rhyolite-basalt volcanism. The Topaz Mountain Rhyolite was erupted from numerous vents during this stage. Lithophile mineral deposits formed during this stage include the world-class beryllium orebodies at Spor Mountain (figure 1) (Lindsey, 1977) and a variety of uranium and fluorspar occurrences in the Thomas Range (Staatz and Carr, 1964; Lindsey, 1982).

Quaternary

Deposition of sediments in Quaternary time was dominated by Lake Bonneville, an extensive late Pleistocene lake in the Great Basin in which Keg Mountain and the Picture Rock Hills were islands (Currey and others, 1984). Lake Bonneville began to rise in the Great Salt Lake basin about 30,000 years ago (Oviatt and others, 1992). During this time, an unnamed shallow freshwater lake probably transgressed in the Sevier Desert basin, and began overflowing into the Great Salt Lake basin through the Old River Bed about 27,000 years ago (Oviatt, 1989). The Old River Bed threshold is located just north of the adjacent Keg Mtn. Ranch quadrangle. About 21,000 years ago Lake Bonneville rose to the level of the threshold and then continued to transgress, occupying the Sevier Desert basin and thus the Picture Rock Hills quadrangle (Oviatt, 1989; Oviatt and others, 1994). Lake Bonneville transgressed to a maximum elevation of 5,221 feet (1,592 m) in the Keg Pass quadrangle (present elevation, which includes isostatic rebound)(Currey, 1982), covering most of the Picture Rock Hills quadrangle. This level was controlled by a threshold in southern Idaho where the lake overflowed into the Snake River. The Bonneville shoreline formed about 15,000 to 14,500 years ago (Oviatt and others, 1992). About 14,500 years ago, the threshold failed and the lake dropped catastrophically to the Provo level, at 4,823 feet (1,470 m) in the quadrangle (Currey, 1982), where it once again stabilized and remained until about 14,000 years ago. At that time, Lake Bonneville began a climate-controlled regression (Oviatt and others, 1992). Once the elevation of the Old River Bed threshold was reached, Lake Gunnison occupied the Sevier Desert basin (controlled by the Old River Bed threshold) and Lake Bonneville occupied the Great Salt Lake basin (Oviatt and others, 1994).

Prior to Lake Bonneville, Quaternary deposits were chiefly alluvium, colluvium, and alluvial-fan deposits, though lacustrine deposits in the Sevier Desert basin may be present in subsurface (see Oviatt and others, 1994). During and following the retreat of Lake Bonneville, these sub-aerial processes continued and eolian reworking of the lake deposits occurred.

MAP UNITS

Tertiary

I have classified Tertiary rocks at Keg Mountain on the basis of modal analyses (appendix A) using quartz-alkali feldspar-plagioclase (QAP) trilinear plots of Streckeisen (1976, 1978)(figure 2) and whole-rock, major-element chemical analyses (appendix B) using total-alkali-silica (TAS) plots of Le Bas and others (1986)(figure 3). Some samples and units shown on the figures are from or only exposed in the adjacent Keg Pass and Keg Mtn. Ranch quadrangles. Analyses of samples from these adjacent quadrangles are also included in the appendices. Plate 1 shows the locations of samples collected from the Picture Rock Hills quadrangle for modal and major-element chemical analyses. Informal map-unit names are based on these classifications, lithology, and general outcrop locations. I also define vent areas for several units (see structure section). Dates on Tertiary rocks are summarized in table 1; the most precise and most accurate are the $^{40}Ar/^{39}Ar$ dates from Shubat and Snee (1992).

Erickson (1963) originally described and informally named the oldest igneous rocks in the Picture Rock Hills and Keg Mountain as "Keg Spring andesite and latite." Later, Shawe (1972) included these rocks in his "older assemblage of rocks" that he mapped as latitic, andesitic, and basaltic flows and agglomerates. Shawe (1972) divided this assemblage into an older part, consisting of dark latite, rhyodacite, andesite, and andesitic basalt flows and agglomerates, that corresponds to Erickson's "Keg Spring andesite and latite," and a younger part consisting of flows and agglomerates of andesite and andesitic basalt. Staub (1975) informally referred to Shawe's (1972) "older assemblage" unit as the "Keg Spring andesite." Pampeyan (1989) followed Shawe's division and informally named the lower part the latitic, andesitic, and basaltic flows of Keg Mountain, and the upper part the latitic flows of Keg Mountain.

Mapping in this and adjacent quadrangles (Shubat and Christenson, 1999; Shubat and others, 1999) shows that areas generally mapped as "Keg Spring andesite" by Staub (1975) and Erickson (1963), and the lower part of Shawe's (1972) and Pampeyan's (1989) division, consist of several of my map units: andesite of Keg Pass, Keg Tuff, Mt. Laird Tuff, and several intrusive units. Pampeyan's (1989) upper part of the "Keg Spring andesite" (his latitic flows of Keg Mountain) consist of the Mt. Laird Tuff.

Andesite of Keg Pass (Ta)

In this report, I use the informal name "andesite of Keg Pass" for a heterogeneous sequence of dark-colored dacitic, latitic, and andesitic flows and lahars, following Shubat and Christenson (1999) and suggestions of reviewers. Only two, small, isolated exposures are present in the quadrangle, located on the central north margin (SW1/4 section 26, T. 12 S., R. 10 W.) (all locations in this report are Salt Lake Baseline and Meridian). Flow rocks dominate and contain phenocrysts of andesine, biotite, hornblende, quartz, clinopyroxene, and magnetite in a trachytic matrix. Some flows are coarsely porphyritic, containing plagioclase crystals as long as 0.59 inches (15 mm). Lahars commonly occur at the base of the unit and contain clasts of andesite, quartzite, and limestone. Staub (1975, p. 13-15) apparently described the lahars in more detail.

Modal analysis of one sample (figure 2 and appendix A) shows that, based on phenocryst composition, the rock is an andesite. However, figure 3 shows that whole-rock analyses of three other samples of the unit (appendix B) plot within the dacite and latite compositional fields of Le Bas and others (1986). I continue to use the term andesite for the unit because it is so variable, it is darker than most latites and dacites in the area, and its phenocryst content can be mapped in the field.

Widespread propylitic alteration caused alteration of

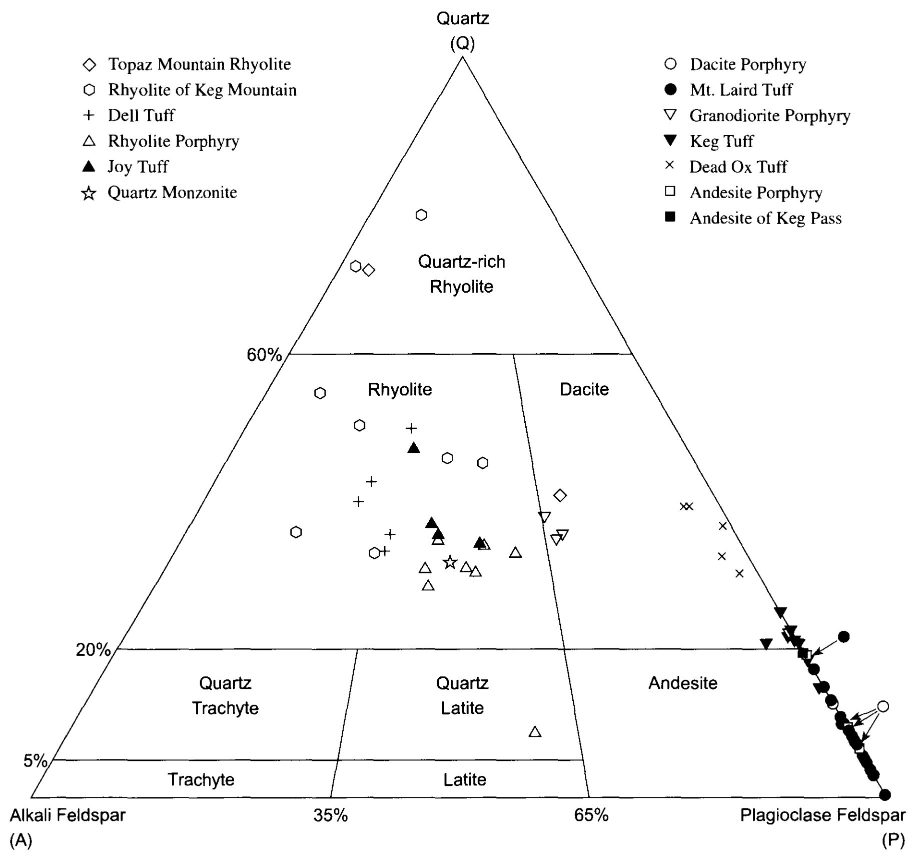


Figure 2. Modal analyses of igneous rocks from Keg Mountain plotted on a trilinear QAP diagram. Q is the quartz content, A is the alkali feldspar content, and P is the plagioclase content determined by point-counting grains in holocrystalline rocks and phenocrysts in aphanitic rocks. Compositional fields from Streckeisen (1976, 1978). Appendix A lists the modal analyses. Not all rock types shown are exposed in this quadrangle (see appendix).

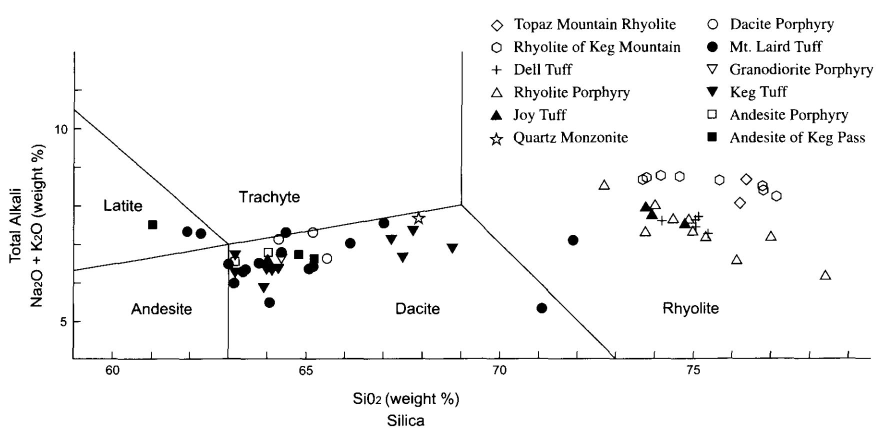


Figure 3. Total alkali (Na_2O+K_2O) versus silica (SiO_2) (TAS) diagram for igneous rocks at Keg Mountain. Compositional fields for volcanic rocks from Le Bas and others (1986). Appendix B lists the major element, whole-rock, geochemical analyses. Not all rock types shown are exposed in this quadrangle (see appendix).

plagioclase to montmorillonite + calcite (unpublished x-ray diffraction data), hornblende and clinopyroxene to chlorite + calcite + epidote, and biotite to chlorite. These minerals, quartz, zeolite (unpublished x-ray diffraction data), and locally pyrite and iron oxides are present in the matrix.

Lindsey (1982) reported an average fission-track age (corrected from an earlier publication) of 39.4 ± 0.7 Ma for samples of what is apparently the andesite of Keg Pass, collected in the western part of the adjacent Keg Pass quadrangle. In the Picture Rock Hills quadrangle, the andesite of Keg Pass appears to occupy the stratigraphic position between the Keg and Mt. Laird Tuffs. However, mapping at Keg Mountain shows that the age of the unit as a whole spans the ages of Keg and Mt. Laird Tuffs and several other units. In the Keg Pass quadrangle, the andesite of Keg Pass underlies the Keg Tuff (Shubat and Christenson, 1999)(36.77 ± 0.12 Ma, table 1). In the Keg Mtn. Ranch quadrangle, clasts of Mt. Laird Tuff (36.54 ± 0.06 Ma, table 1) occur in the lahar facies of the andesite of Keg Pass (Shubat and others, 1999).

No complete section of the andesite of Keg Pass is exposed in the quadrangle. The maximum exposed thickness of the unit is about 20 feet (6 m), far less than that to the north in Keg Mountain, where it is about 200 feet (60 m) thick.

Keg Tuff (Tk)

Shubat and Christenson (1999) named the Keg Tuff and designated a type locality in the Keg Pass quadrangle. Previous mappers (Erickson, 1963; Shawe, 1972; Staub, 1975; Morris, 1987; Pampeyan, 1989) grouped this unit with the oldest igneous rocks of Keg Mountain (see above). Most of the unit Staub (1975) mapped as Keg Spring andesite corresponds to my Keg Tuff.

The Keg Tuff consists of dark-red-brown to black, densely welded, moderately crystal-rich ash-flow tuff of dacitic composition. A black vitrophyre locally occurs at the base of the Keg Tuff. Abundant bronze-weathering biotite is prominent on surfaces parallel to layering. Phenocrysts are 0.04 to 0.24 inches (1 to 6 mm) in size and consist of plagioclase, biotite, quartz, hornblende, and lesser amounts of pyroxene, zircon, and opaque minerals. The matrix of the unit consists of glass or devitrified glass with locally preserved welded and deformed shard outlines. Many quartz and feldspar phenocrysts are broken or shattered, and biotite crystals are bent. Nine modal analyses (figure 2 and appendix A) and whole-rock chemical analyses

***Table 1.** Summary of dates for igneous rocks at Keg Mountain.*

Map Unit	Map Symbol	Sample Number	Mineral/Method	Date (Ma)	Average (Ma)	Reference
Andesite of Keg Pass (?)	Ta	?	?/fission track		39.4 ± 0.7	Lindsey, 1982
		K15-A	zircon/fission track	37.2 ± 1.6		Lindsey & others, 1975
		K15-A	apatite/fission track	39.7		Lindsey & others, 1975
		K50-A	zircon/fission track	38.3 ± 1.5		Lindsey & others, 1975
Keg Tuff	Tk	KP-6-5	biotite/Ar-Ar	36.77 ± 0.12		Shubat & Snee, 1992
Granodiorite porphyry	Tgd	U29B	zircon/fission track	36.6 ± 1.6		Lindsey, 1982
Mount Laird Tuff	Tml	KMR-4-8	biotite/Ar-Ar	36.56 ± 0.11		Shubat & Snee, 1992
		KMR-4-8	hornblende/Ar-Ar	36.59 ± 0.29	36.54 ± 0.06	Shubat & Snee, 1992
		NKM-21-12	biotite/Ar-Ar	36.48 ± 0.14		Shubat & Snee, 1992
		NKM-21-12	biotite/K-Ar	37.1 ± 1.5		Shubat & Christenson, 1999
Dacite porphyry	Tdp	NKM-6-3	biotite/Ar-Ar	36.49 ± 0.15		Shubat & Snee, 1992
		NKM-6-3	biotite/K-Ar	36.2 ± 1.4		Shubat & Christenson, 1999
Joy Tuff	Tj	KMR-1-3	sanidine/Ar-Ar	34.92 ± 0.14	34.88 ± 0.06	Shubat & Snee, 1992
		KMR-1-3	biotite/Ar-Ar	34.84 ± 0.14		Shubat & Snee, 1992
		U240	zircon/fission track	36.9 ± 1.7		Lindsey, 1982
Rhyolite porphyry	Trp	KMR-4-6	sanidine/Ar-Ar	35.04 ± 0.10	35.14 ± 0.15	Shubat & Snee, 1992
		KMR-4-6	biotite/Ar-Ar	35.25 ± 0.13		Shubat & Snee, 1992
		DRS-282-63	zircon/fission track	30.8 ± 1.8		Lindsey & others, 1975
Dell Tuff	Td	various	various/fission track		32.0 ± 0.6	Lindsey, 1982
		K20-A	sphene/fission track	33.6 ± 1.8		Lindsey, 1982
		K48-A	sphene/fission track	32.5 ± 1.6		Lindsey, 1982
		K40-A	zircon/fission track	33.8 ± 1.3		Lindsey, 1982
Rhyolite of Keg Mountain	Tkm	46V	sanidine/K-Ar	6.7 ± 0.3		Plavidal, 1987
		67AFT	sanidine/K-Ar	6.9 ± 0.3		Plavidal, 1987
		105V	sanidine/K-Ar	6.9 ± 0.3		Plavidal, 1987
		K-49-A	zircon/fission track	10.3 ± 0.6		Lindsey & others, 1975
		K-49-B	zircon/fission track	9.6 ± 0.9		Lindsey & others, 1975
Topaz Mountain Rhyolite	Ttm	K47-TR-A	sphene/fission track	7.8 ± 0.6		Lindsey & others, 1975
		K39-TR-A	zircon/fission track	8.2 ± 0.5		Lindsey & others, 1975

of three of these samples and seven other samples (figure 3 and appendix B) indicate that the Keg Tuff is a dacite.

Shubat and Snee (1992) dated biotite crystals from the Keg Tuff at 36.77 ± 0.12 Ma (table 1).

The restricted distribution of the Keg Tuff, known only at Keg Mountain and the Picture Rock Hills, suggests that it was erupted from a local vent. Shubat and Christenson (1999) proposed that it erupted from a poorly defined cauldron, the Keg cauldron (see structure section), located in the north part of the Picture Rock Hills quadrangle and the south part of the Keg Pass quadrangle (figure 4). Shubat and Christenson (1999) considered the Keg Tuff comagmatic with granodiorite porphyry (see following section).

An incomplete section of the Keg Tuff, present in the north-central part of the Picture Rock Hills quadrangle, is about 500 feet (150 m) thick, and a comparable maximum thickness is present in the Keg Pass quadrangle (540 feet [165 m]).

Granodiorite Porphyry (Tgd)

Granodiorite porphyry occurs as a plug in the north-central part of the quadrangle. The plug is similar to and probably correlative with a much larger intrusion of granodiorite porphyry located in the south-central part of the adjacent Keg Pass quadrangle (Shubat and Christenson, 1999). Erickson (1963) and Shawe (1972), in their reconnaissance studies of Keg Mountain, mapped this unit as ignimbrite (tuff) and quartz-latitic, welded ash-flow tuff, respectively. Staub (1975) mapped the plug and referred to the rocks as Keg granodiorite porphyry. Pampeyan (1989) included the stock in the Keg Pass quadrangle in his informally named granodiorite stocks of Keg Mountain.

Granodiorite porphyry consists of light-olive-green

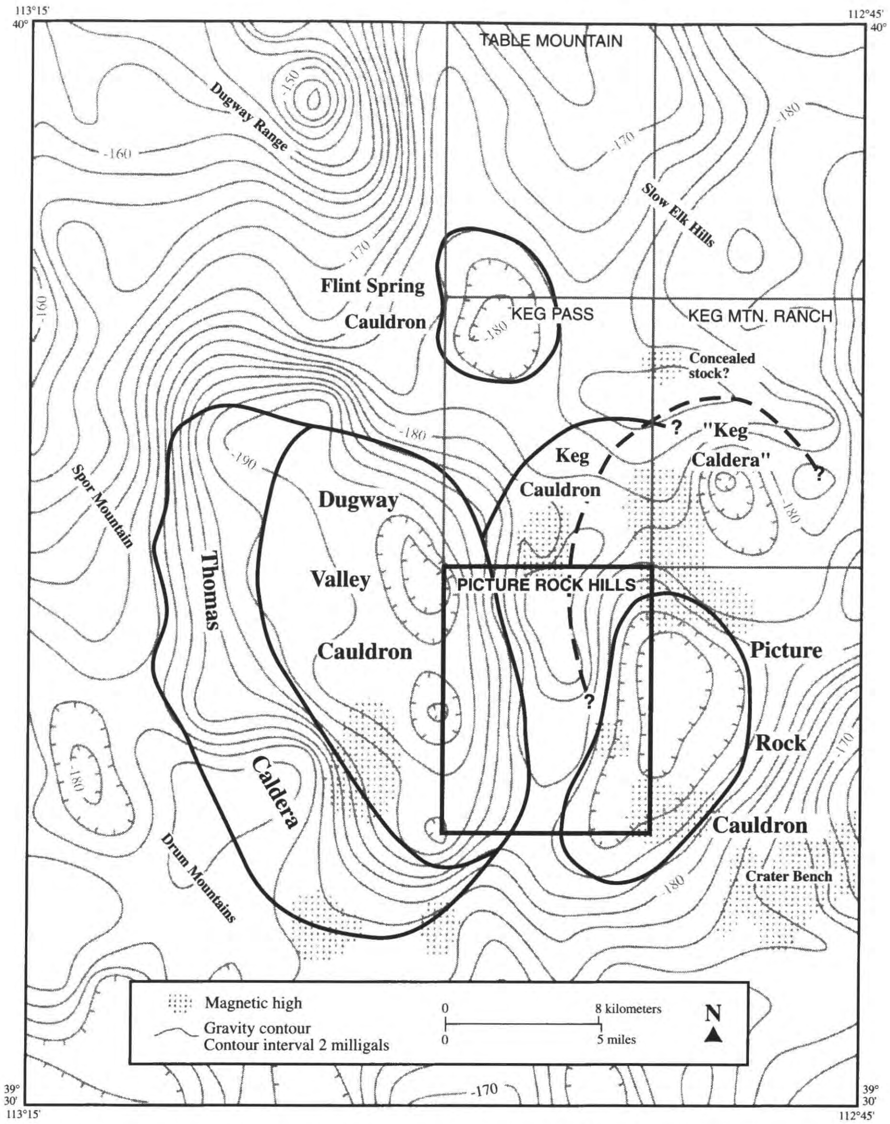


Figure 4. Locations of proposed calderas and cauldrons at Keg Mountain and surrounding areas. Gravity data from Bankey and Cook (1989). Magnetic highs from data in Kucks (1991). Caldera margins in the Thomas Range modified from Lindsey (1982).

to pinkish-green, holocrystalline rock containing large (0.08 to 0.47 inch [2 to 12 mm]) phenocrysts of plagioclase, quartz, biotite, hornblende, and clinopyroxene and lesser amounts of magnetite and zircon set in a fine-grained, subhedral, granular matrix of quartz, plagioclase, and potassium feldspar. Modal analyses of three samples (figure 2 and appendix A) and a whole-rock chemical analysis of one of these samples (figure 3 and appendix B) show these rocks are granodiorite. On figure 3, the dacite compositional field of Le Bas and others (1986) is equivalent to granodiorite for holocrystalline rocks. The unit is pervasively propylitized; plagioclase is altered to clay minerals and calcite, biotite to chlorite and magnetite, and hornblende to chlorite and calcite.

Lindsey (1982) dated the granodiorite porphyry stock in the Keg Pass quadrangle at 36.6 ± 1.6 Ma (table 1). This date agrees well with relationships observed in the Keg Pass quadrangle (Shubat and Christenson, 1999), where granodiorite porphyry intrudes the 36.77 ± 0.12 Ma Keg Tuff (table 1) and is cut by 35.14 ± 0.15 Ma rhyolite porphyry dikes and plugs (table 1).

Because of similarities in whole-rock chemical composition (figure 3, appendix B), age (table 1), and spatial distribution, Shubat and Christenson (1999) considered the granodiorite porphyry to be comagmatic with the Keg Tuff. The stock in the south-central part of the Keg Pass quadrangle may have been intruded into the center of the Keg cauldron (see structure section) after eruption of the Keg Tuff. Modal analyses of Keg Tuff and granodiorite porphyry are different (figure 2, appendix A) because alkali feldspar is in the fine-grained matrix of the Keg Tuff, only counted as matrix, rather than being in phenocrysts.

Mt. Laird Tuff (Tml)

Lindsey (1979) named the Mt. Laird Tuff for exposures near Mt. Laird in the nearby Thomas Range, and reported its presence at Keg Mountain. Shawe (1972) mapped a quartz-latitic, welded, ash-flow tuff at Keg Mountain, some of which corresponds to areas I mapped as Mt. Laird Tuff. Much of the area shown as latitic flows of Keg Mountain by Pampeyan (1989) corresponds to areas I mapped as Mt. Laird Tuff.

Mt. Laird Tuff consists of lavender, pale-green, dark-green, and brown, moderately welded, ash-flow tuff; and in the Keg Pass and Keg Mtn. Ranch quadrangles (Shubat and Christenson, 1999; Shubat and others, 1999), tuff-breccia and lapilli-tuff of dacitic composition. Probable lava flows and hypabyssal intrusions of dacitic composition were mapped with the tuffs in these quadrangles (Shubat and Christenson, 1999; Shubat and others, 1999). A distinctive feature of the Mt. Laird Tuff, and probable flows and intrusions, is the presence of abundant, large (0.08 to 0.47 inch [2 to 12 mm]) phenocrysts of white plagioclase. Other phenocrysts present in the rock are hornblende, biotite, resorbed quartz, clinopyroxene, magnetite, large sphene, and zircon. Ash-flow tuff textures are difficult to distinguish in the field, but are well-defined in thin sections from the Keg Pass and Keg Mtn. Ranch quadrangles (Shubat and Christenson, 1999; Shubat and others, 1999).

Mt. Laird Tuff is propylitically altered in many exposures. The matrix, originally glassy, is altered to a mixture of fine-grained montmorillonite and silica with zeolite minerals filling voids (unpublished x-ray diffraction data). Plagioclase is locally altered to calcite and clay minerals. Ferromagnesian minerals are locally altered to chlorite, epidote, calcite, and magnetite.

Modal analyses of 25 samples (figure 2 and appendix A) indicate that, based on phenocryst content, these rocks would be named andesite. Figure 3, however, shows that whole-rock chemical analyses of eight of these and eight other samples (appendix B) mostly plot within the dacite compositional field of Le Bas and others (1986). Classification as a dacite is more compatible with the ash-flow tuff origin and high silica content of the rocks.

Shubat and Snee (1992) $^{40}Ar/^{39}Ar$ dated hornblende and biotite crystals from two different samples of the Mt. Laird Tuff and obtained an average age of 36.54 ± 0.06 Ma (table 1). Biotite from one of these samples (NKM-21-12, table 1) yielded a K-Ar date of 37.1 ± 1.5 Ma (Shubat and Christenson, 1999). Lindsey (1982) reported a fission-track date of 36.4 ± 1.6 Ma for the Mt. Laird Tuff in the Drum Mountains, but because of field relations and dates on other units he considered its true age to be about 39 million years old. I consider the true age of the Mt. Laird Tuff to be close to 36.54 ± 0.06 Ma because of the consistency of this date with dates (table 1) for the underlying Keg Tuff (36.77 ± 0.12 Ma), the overlying Joy Tuff (34.88 ± 0.06 Ma), and rhyolite porphyry intrusions (35.14 ± 0.15 Ma) that cut Mt. Laird.

Lindsey (1982) associated the eruption of the Mt. Laird Tuff with collapse of the Thomas caldera (see structure section). The eastern margin of the Thomas caldera probably passes through the Picture Rock Hills quadrangle.

North of the Picture Rock Hills quadrangle, two lines of evidence suggest that a concealed pluton underlies an area just south of Keg Pass (figure 4). This pluton is probably related to intermediate-composition igneous rocks. First, deep resistivity audio-magnetotelluric (AMT) soundings collected along a north-south profile across Keg Mountain (Campbell and Visnyei, 1989) show a resistant body at depth beneath the Keg Pass area that has a resistivity signature (200 ohm-meters) typical for many igneous rocks in the region (D.L. Campbell, verbal communication, 1990). Second, regional aeromagnetic data (Kucks, 1991) show a high-amplitude magnetic ridge extending from Keg Pass to a point about 5 miles (8 km) to the south (figure 4). This magnetic signature is consistent with many known intermediate intrusions in the Deep Creek-Tintic belt (Stewart and others, 1977). This postulated intrusion might be a dacitic equivalent of the Mt. Laird Tuff, like the possible stock north of Keg Pass (discussed in Shubat and Christenson, 1999; Shubat and others, 1999) This concealed magnetic and resistant body might alternatively be due to other intermediate-composition rocks, in particular the Keg Tuff and related granodiorite porphyry, or andesite of Keg Pass.

No complete section of the Mt. Laird Tuff is exposed in the quadrangle; the maximum exposed thickness of the Mt. Laird Tuff is 100 feet (30 m). The greatest (intracaldera?) thickness of probable Mt. Laird Tuff, reported in holes drilled by The Anaconda Company in the southwest corner of the quadrangle, is 614 feet (187 m)(see structure section; table 2).

Joy Tuff (Tj)

Lindsey (1979) named the Joy Tuff for exposures near the Joy townsite in the nearby northern Drum Mountains and identified two informal members. Only the lower, crystal tuff member is exposed in the Picture Rock Hills quadrangle.

Erickson (1963) first recognized the presence of rhyolitic ash-flow tuff at Keg Mountain. Shawe (1972) refined the work by Erickson (1963). Some of the rhyolitic, welded, ash-flow tuff mapped by Shawe (1972) corresponds to areas I mapped as Joy Tuff. Staub (1975) mapped an informal "Red Mountain Crystal Tuff" unit in the quadrangle that partly correlates with the Joy Tuff. Lindsey (1979) first reported the presence of Joy Tuff in the southwestern part of Keg Mountain. Some of the area shown as Joy Tuff at Keg Mountain by Pampeyan (1989) corresponds to areas I mapped as Joy, Mt. Laird, and Dell Tuffs.

Joy Tuff consists of red-brown to pink, distinctly red-weathering, moderately to densely welded, rhyolitic ash-flow tuff. A black vitrophyre occurs at the base of the unit and is overlain by a black, fiamme-rich zone. Variations in the degree of welding occur in the Picture Rock Hills quadrangle. The Joy Tuff contains abundant, 0.04 to 0.31 inch (1 to 8 mm) phenocrysts of quartz, sanidine, plagioclase, and biotite, and trace amounts of sphene, zircon, and magnetite. The unit contains as much as 14 percent lithic clasts that consist of volcanic, igneous, and sedimentary rocks. In thin section, many ash-flow tuff textures are well displayed. Most large phenocrysts are shattered, bent, or broken. Small phenocryst fragments occur as lenses of "crystal hash." Some samples contain flattened, welded, Y-shaped shards in the matrix. The matrix is typically devitrified but is locally glassy. Phenocrysts are unaltered. Modal analyses (figure 2 and appendix A) and whole-rock chemical analyses of the same four samples (figure 3 and appendix B) show that these rocks are mostly rhyolite.

Shubat and Snee (1992) dated sanidine and biotite crystals from a sample of basal vitrophyre of the Joy Tuff and obtained an average age of 34.88 ± 0.06 Ma (table 1). This date shows a marked difference with most of the nine fission-track ages (range 34.5 ± 1.3 to 39.7 ± 3.4) reported by Lindsey (1982) that average 38.0 ± 0.7 Ma. I believe that the age of the Joy Tuff is close to the $^{40}Ar/^{39}Ar$ age-spectrum date of 34.88 ± 0.06 Ma because of the greater accuracy of the method. Unpublished $^{40}Ar/^{39}Ar$ age-spectrum dates from the type section of the Joy Tuff (C.J. Nutt, verbal communication, 1992) confirm the date reported by Shubat and Snee (1992). The date by Shubat and Snee (1992) is nearly identical with the date for rhyolite porphyry (Trp)(34.14 ± 0.15 Ma, table 1). For this and other reasons presented in the section on rhyolite porphyry, I consider the Joy Tuff to be comagmatic with the rhyolite porphyry.

Lindsey (1982) believed the source of the Joy Tuff to be the Dugway Valley cauldron, located between Keg Mountain and Topaz Mountain (figure 4). The eastern margin of the Dugway Valley cauldron passes through the Picture Rock Hills quadrangle (see structure section).

No complete section of the Joy Tuff is exposed in the quadrangle. The thickest section of Joy Tuff (540 feet [160 m]) forms a prominent red-colored hill in the north-central part of the quadrangle (SW1/4 section 1, T. 13 S.,

R. 10 W.). The greatest (intracauldron) thickness of probable Joy Tuff, reported in holes drilled by The Anaconda Company in the southwest corner of the quadrangle, is more than 3,000 feet (915 m)(see structure section).

Rhyolite Porphyry (Trp)

Rhyolite porphyry in the Keg Mountain area occurs as many small, hypabyssal dikes and elongate plugs that form at least two linear, subparallel, north- to east-trending zones described by Shubat and Christenson (1999). Only the southwestern end of the southern northeast-trending zone is present in the Picture Rock Hills quadrangle (SW1/4 section 26 and center section 34, T. 12 S., R. 10 W.).

Shawe (1972) first recognized these intrusions and called them intrusive quartz latite. Lindsey and others (1975) depicted some of these intrusions. Morris (1987) mapped the intrusions in greater detail. Pampeyan (1989) informally named the unit the quartz latite stocks of Keg Mountain.

Rhyolite porphyry consists of pale-gray to pink, light-tan-weathering rhyolite porphyry with large (up to 0.4 inch [1 cm]) phenocrysts of sanidine, quartz, plagioclase, and biotite and lesser amounts of zircon and opaque mineral phenocrysts. The matrix consists of aphanitic crystallites, resembling devitrified glass, that are locally altered to zeolite minerals. Near the margins of the intrusions, the rock is nearly aphyric, only containing sparse sanidine crystals, and has a platy parting. This parting grades laterally into massive rhyolite porphyry within 10 feet (3 m) of the contact. In some exposures, rhyolite porphyry shows a "filter pressed" texture (see Best, 1982) that consists of large, cracked crystals of quartz, orthoclase, and plagioclase with minor, interstitial matrix. Modal analyses of nine samples (figure 2 and appendix A) and whole-rock chemical analyses of six of these and four other samples (figure 3 and appendix B) show these rocks are mostly rhyolite.

Shubat and Snee (1992) dated sanidine and biotite from one of these plugs in the Keg Mtn. Ranch quadrangle and obtained an average age of 35.14 ± 0.15 Ma (table 1). Lindsey and others (1975) dated an elongate, rhyolite porphyry plug in the Keg Pass quadrangle at 30.8 ± 1.8 Ma (table 1). I interpret the age of the rhyolite porphyry intrusions to be near the date reported by Shubat and Snee (1992) because of the greater accuracy of the $^{40}Ar/^{39}Ar$ age-spectrum dating method.

The rhyolite porphyry intrusions and the Joy Tuff are similar in many ways. The two units have similar phenocryst assemblages (figure 2, appendix A) and chemical compositions (figure 3, appendix B). Most importantly, they have nearly identical ages (table 1). For these reasons I consider the rhyolite porphyry to be a hypabyssal, comagmatic equivalent of the Joy Tuff.

Topaz Mountain Rhyolite

Erickson (1963) first described and named (informally) the Topaz Mountain Rhyolite and underlying Topaz Mountain Tuff. Lindsey (1979) redefined and formally named the unit, including both lithologies in the Topaz Mountain Rhyolite. Lindsey (1979) identified two informal members: (1) alkali rhyolite and vitrophyre, and (2) stratified tuff. I follow the usage proposed by Lindsey (1979) in this report, but do not use the term "alkali" because alkali as a modifier has several meanings. Many previous workers recognized and mapped the Topaz Mountain Rhyolite at Keg Mountain (Erickson, 1963; Shawe, 1972; Staub, 1975; Morris, 1987; Plavidal, 1987; Pampeyan, 1989). Staub (1975) mapped Topaz Mountain Rhyolite flows, domes and intrusions, and tuff in the quadrangle, informally naming most of them the "Keg Mountains Rhyolite and Tuff" which, unfortunately, is approximately the name given by Shawe (1972) (rhyolite of Keg Mountains) for a different unit in the Keg Mtn. Ranch quadrangle. Staub (1975) mapped other Topaz Mountain Rhyolite rocks as "Picture Rock Quartz Latite Porphyry" and "Drum Mountains Rhyolite."

I mapped two informal members of the Topaz Mountain Rhyolite: (1) stratified tuff; and (2) rhyolite flows, domes, and intrusions. This subdivision is consistent with the mapping by Lindsey (1979; 1982). Beds of stratified tuff occur as discontinuous lenses beneath many rhyolite flows and domes. In part, the stratified tuff was probably explosively erupted from the same vents as, and possibly just before, the rhyolite flows and domes; some stratified tuff was also reworked by water.

Two types of vitrophyre are present in the Topaz Mountain Rhyolite. In many exposures, a black vitrophyre (typically a ledge-forming rock) occurs at the base of flows and represents chilled flow rock. In other exposures, however, stratified tuff beneath a flow has been fused to form a vitrophyre. This rock, called "fused tuff" by Christiansen and Lipman (1966), contains black, collapsed and fused pumice clasts that resemble fiamme. This fused tuff has a glassy texture and strongly resembles ash-flow tuff.

Stratified tuff (Ttmt): Stratified tuff consists of pale-tan to orange, very thick- to thin-bedded, nonwelded, lithic-rich rhyolitic tuff and volcanic sandstone, and local tuff breccia. The unit contains a variety of pyroclastic material, including volcanic rock fragments (lava, tuff, and welded tuff), abundant pumice clasts, and sparse crystal fragments in an ash matrix. Size sorting also varies. Beds of mostly ash with some lithic and pumice clasts are common. In these poorly sorted beds, the clasts are typically much larger than the ash matrix. Other beds mostly contain roughly sand-sized (0.02 to 0.0.12 inch [0.5 to 3 mm]) pyroclasts. The unit was deposited as air-fall, ash-flow, and ground-surge eruptions at Spor Mountain (Bikun, 1980). In the Picture Rock Hills and Keg Mountain, the unit was emplaced as (1) water-lain and air-fall deposits (Lindsey, 1979), (2) vent-clearing deposits, including tuff breccias and poorly sorted, ground-surge deposits (J.K. King, verbal communication, 1995), and (3) reportedly as ash-flow deposits (Staub, 1975). The unit is extensively argillized (montmorillonite), zeolitized, and feldspathically altered throughout Keg Mountain (Lindsey and others, 1974; Lindsey, 1975). Lindsey (1975) showed that glass in the unit was progressively altered, first to clinoptilolite and then to potassium feldspar. Stratified tuff beds range in thickness from 0 to 260 feet (80 m).

Rhyolite flows, domes, and intrusions (Ttm): This unit consists of flows, domes, and dike-like, shallow intrusions of white, gray, and purple rhyolite containing sparse (10 to 15 percent), small (0.08 inch [2 mm]) phenocrysts of quartz and sanidine and lesser amounts of plagioclase, biotite, and opaque mineral phenocrysts. The matrix consists of devitrified glass, and contains irregular voids that constitute as much as 12 percent of the rock. Black to brown vitrophyre occurs at the base of some flows and domes. Breccias with stratified tuff and rhyolite flow clasts in a rhyolite flow matrix are locally exposed at vents (J.K. King, verbal communication, 1995). Staub (1975) described basal flow breccias with the same types of clasts. Rare topaz crystals occur in cavities. In addition to topaz, Staub (1975) identified small crystals of hematite, quartz, bixbyite, and pseudobrookite that line cavities. Two modal analyses (appendix A), and chemical analyses of one of these samples and one other sample (appendix B) from this unit plot as quartz-rich rhyolite, dacite (figure 2), and rhyolite (figure 3).

Flows and domes of rhyolite were probably erupted from several local vents. Shubat and Christenson (1999) noted that in some cases continuous exposures can be followed that show flows at higher elevations changing to dike-like intrusive bodies at lower elevations. Most dike-like bodies and eruptive dome/flow complexes have north-northwest trends (see structure section).

Lindsey and others (1975) reported fission-track dates of 7.8 ± 0.6 and 8.2 ± 0.5 Ma for the Topaz Mountain Rhyolite at Keg Mountain. Lindsey (1982) reported an average date of 6.3 ± 0.1 Ma for five samples of Topaz Mountain Rhyolite from Topaz Mountain. Plavidal (1987) reported K-Ar dates of 6.7 ± 0.3 and 6.9 ± 0.3 Ma for the rhyolite of Keg Mountain, which underlies and is compositionally gradational with the Topaz Mountain Rhyolite in the Keg Mtn. Ranch quadrangle (Plavidal, 1987). I believe that the age of the Topaz Mountain Rhyolite in the Picture Rock Hills quadrangle is close to the date of 6.3 ± 0.1 Ma reported by Lindsey (1982) because it overlies the rhyolite of Keg Mountain. Staub (1975) reported at least two eruptive episodes of Miocene volcanic rocks in the quadrangle.

The maximum exposed thickness of rhyolite flows, domes, and intrusions is 800 feet (240 m). Staub (1975) reported a major erosional unconformity between Miocene (Topaz Mountain Rhyolite) and older igneous rocks in the quadrangle, with almost 400 feet (120 m) of relief east of Kane Spring. Field relations in the Keg Mtn. Ranch quadrangle indicate Topaz Mountain Rhyolite was deposited on a paleotopographic surface that was gently rolling hills.

Quaternary and Tertiary

One Cenozoic bedrock map unit, a Quaternary basalt, is present in the Picture Rock Hills quadrangle. Quaternary and Tertiary deposits were classified primarily by their environment of deposition or origin as interpreted from geomorphic expression. Within each environment/origin, units were subdivided based on grain size (texture) and composition. Unit ages were based on surface morphology, carbonate and soil development, degree of consolidation, and stratigraphic relationships, where exposed. Map-unit symbols reflect this classification scheme. Capital letters show the general age (Q=Quaternary, T=Tertiary); next, lowercase letter(s) show the depositional environment; theses are followed by lowercase letters that show grain size and composition subdivision when necessary. Letters (o=older, y=younger) or a subscripted number at the end of the symbol show the relative age of the unit, with numbers increasing for older deposits.

Quaternary and Tertiary deposits in the quadrangle include alluvial-fan deposits, stream alluvium, alluvium and colluvium, undivided lacustrine and alluvial deposits, eolian deposits, lacustrine deposits, and fill.

Older Alluvial-Fan Deposits (QTaf)

Coarse-grained older alluvial-fan deposits of probable early Pleistocene age, or perhaps Pliocene age (see Christenson and Purcell, 1985 for criteria), occur along the northern edge of the quadrangle on the west flank of Keg Mountain. These deposits are much more extensive in the Keg Pass quadrangle where they occur above the Bonneville shoreline (5,221 feet; 1,592 m). The deposits are undergoing erosion and original fan surfaces have been removed, forming a series of finger-like ridges (commonly called whalebacks or ballenas). The deposits are poorly sorted and consist of clasts of all sizes, from clay to boulders greater than 3 feet (1 m) in diameter. The surface of the deposit is marked by a lag concentrate of the larger clasts. The deposits are at least 60 feet (18 m) thick where exposed. Similar-age deposits of unknown thickness probably underlie lacustrine deposits along the western edge of the quadrangle and fill the valley of Picture Rock Wash.

Quaternary

Basalt of Crater Bench (Qb)

A small exposure of the informally named basalt of Crater Bench (Pampeyan, 1989) occurs in the southeast corner of the quadrangle. Exposures are more numerous to the southeast (figure 5). Previous workers who studied the Crater Bench basalt field are Gilbert (1890), Hogg (1972), Smith (1974), Johnson (1975), Peterson and Nash (1980), Galyardt and Rush (1981), and Oviatt and others (1994).

The basalt is black to dark brown, vesicular, and contains sparse phenocrysts of plagioclase, clinopyroxene, iron-titanium oxides, and orthopyroxene in a matrix of plagioclase, pigeonite, and glass (Peterson and Nash, 1980). Peterson and Nash (1980) described the most extensive rock in the Crater Bench volcanic field as a basaltic andesite.

Peterson and Nash (1980) dated the basalt of Crater Bench at 0.88 ± 0.1 Ma (K-Ar method) and Galyardt and Rush (1981) dated it at 0.95 ± 0.1 Ma (also by the K-Ar method). These dates indicate an early Pleistocene age for the unit.

The unit consists of many flows that form a shield

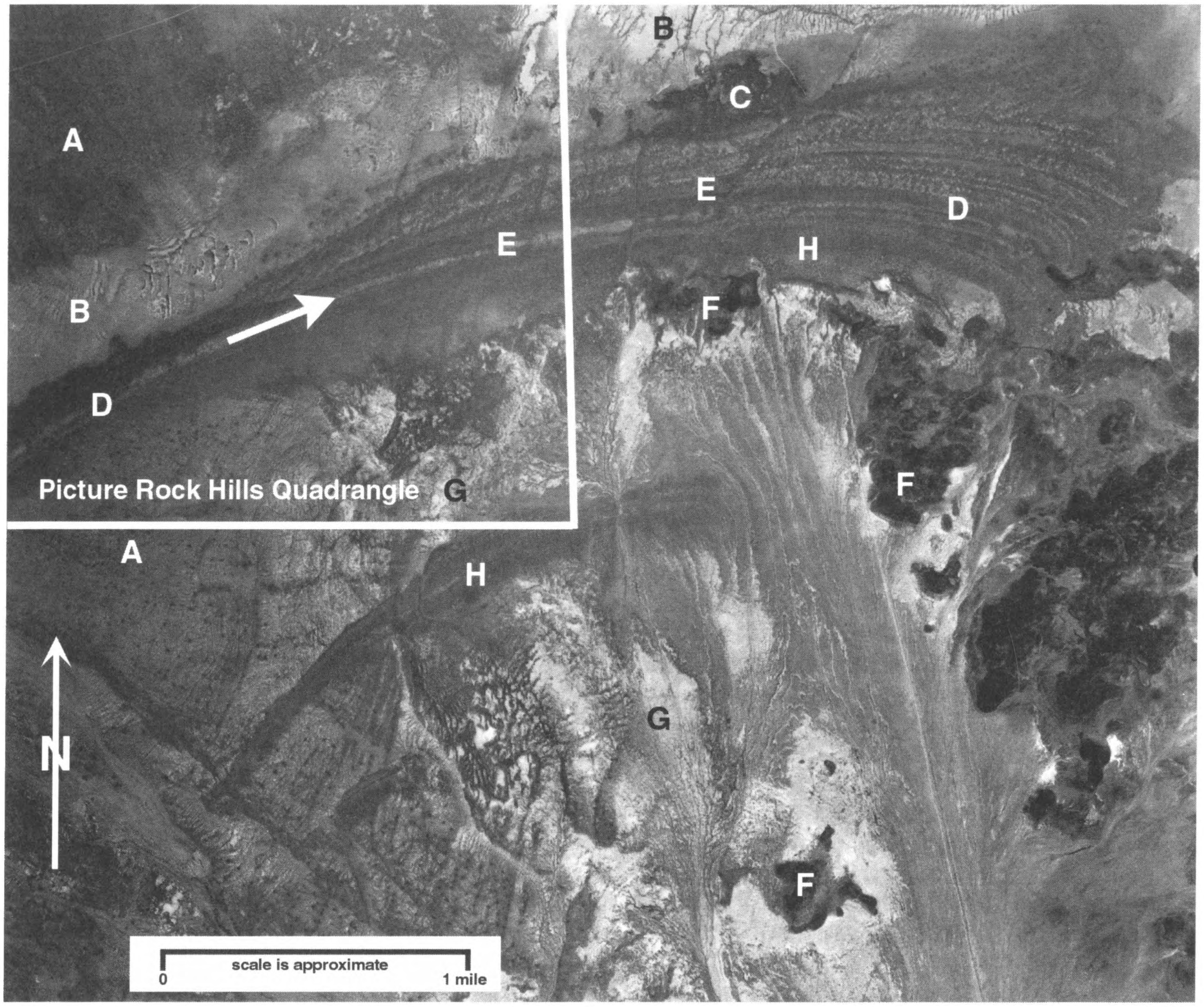


Figure 5. Portion of vertical aerial photograph (UTAH, CSR-F, 59-109, 7-8-79) that covers the southeast corner of the quadrangle. Scale is approximate. A = gravel of lacustrine and/or alluvial origin (Qla); B = fine-grained lacustrine sediments (Qlf); C = eolian dune deposits (Qed); D = lacustrine gravel forming a tombolo at the Provo shoreline that connects piedmont slope to the west with Crater Bench to the east. Arrow indicates direction of sediment transport; E = faults of the Drum Mountains fault zone; F = basalt of Crater Bench (Qb); G = lacustrine marl (Qlm); H = lacustrine carbonate sand (Qlk).

volcano centered on Fumarole Butte. Oviatt and others (1994) noted that the basalt overlies Pliocene-Pleistocene lake beds and that pillows found at the base of the unit indicate that the lava flowed into shallow water. Johnson (1975) estimated the basalt near Fumarole Butte to be 250 to 300 feet (75 to 90 m) thick. Oviatt and others (1994) estimated the thickness of basalt to range from about 500 feet (150 m) near Fumarole Butte to 20 feet (6 m) near the margins of the volcanic field.

Intermediate-Age Alluvial-Fan Deposits (Qaf_2)

Alluvial-fan deposits of middle to late Pleistocene age are present above the Bonneville shoreline (5,221 feet [1,592 m]) in the north part of the quadrangle. These alluvial-fan deposits predate initial occupation of the Bonneville shoreline 15,000 years ago. Fan surfaces are generally 3 to 20 feet (1 to 6 m) above modern channels, and are inactive and undergoing erosion. Erosion has produced an intricate, parallel to pinnate pattern of gullies. The deposits are poorly stratified, poorly sorted mixtures of clay, silt, sand, pebbles, cobbles, and boulders of both debris-flow and stream-flow origin. In mountain-front locations, these deposits are generally less than 20 feet (6 m) thick. They thicken away from the front, however, and similar-age deposits of unknown thickness probably underlie lacustrine deposits in the valley of Picture Rock Wash, in the western part of the quadrangle.

Undifferentiated Lacustrine and Alluvial Deposits (Qla)

These undifferentiated lacustrine and alluvial deposits are latest Pleistocene and Holocene in age, and are present below the Bonneville shoreline (5,221 feet [1,592 m]) (figure 5). Included in the unit are thin, discontinuous eolian sheet sand deposits that are too small to be mapped separately. The undifferentiated deposits consist mostly of sand, pebbles, and cobbles. But locally they include finer grained material and marl, particularly below the tombolo in the southeast corner of the map. The deposits include: (1) Lake Bonneville lacustrine deposits that have been partially reworked by post-lacustrine streams and slope wash; (2) pre-lacustrine alluvial-fan deposits that were partially reworked by waves during the transgression of Lake Bonneville; and (3) interspersed lacustrine and alluvial deposits that can't be differentiated at map scale. A characteristic feature of the second of these types of deposits are the many intermediate-level shorelines that were etched on pre-Bonneville fans. The thickness of these deposits is probably less than 10 feet (3 m) in most places.

Lacustrine Gravel (Qlg)

These shore-zone deposits of sand, gravel (pebbles and cobbles), and silt were deposited as Lake Bonneville transgressed to and occupied the Bonneville shoreline, and during occupation of the Provo shoreline. The unit was deposited as barriers, cuspate barriers ("V-bars" of Gilbert, 1890), spits, tombolos, and beaches. The deposits are generally thin, but may be as much as 30 feet (9 m) thick in some barrier beaches.

A medium-sized (2 square miles [5 km^2]) stacked cuspate barrier complex occupies the northwest corner of the quadrangle. This complex occurs at the drainage divide that separates Pismire Wash to the north from Picture Rock Wash to the south. The location of the cuspate barrier complex suggests that it may have formed by converging longshore currents, in a manner similar to that suggested for other cuspate barriers (Oviatt and others, 1994).

A prominent Provo-level tombolo, located in the southeast corner of the quadrangle, connects the piedmont slope in the southern part of the quadrangle to Crater Bench (figure 5). This tombolo consists of sand-, pebble-, and cobble-sized clasts of Paleozoic quartzite, limestone, and subordinate Tertiary rhyolite indicating a west-to-east transport direction. The source of the clasts was probably alluvial fans shed from the Drum Mountains. The source fans probably lie just south of the quadrangle, on the west side of Picture Rock Wash.

Lacustrine Sand (Qls)

These nearshore deposits of sand with lesser silt and pebbles occur in the west-central part of the quadrangle, midway between the Bonneville and Provo shorelines, on the east side of Picture Rock Wash. The sand is fine to medium grained and consists of silica and volcanic rock fragments. The deposits have the form of flat-topped barrier beaches with little relief. One deposit is a small cuspate barrier that partially encloses lagoon deposits (Qll). The deposits are thin, probably less than 10 feet (3 m) thick.

Lacustrine Marl (Qlm)

This unit consists of white to gray, fine-grained, deep-lake or quiet-water deposits of marl, clay, silt, and sand that are characterized by the presence of abundant ostracodes. The unit was identified by Gilbert (1890) (his "white marl") and redefined by Oviatt (1987). It is present in the southeastern corner of the quadrangle below the Provo shoreline (figure 5), where it is overlain by lacustrine carbonate sand (Qlk) (as shown by exposures just southeast of the southeastern corner of the quadrangle). Deposition occurred in latest Pleistocene time. The Pahvant Butte ash is interbedded near the top of the unit at many localities in the region (Oviatt and others, 1994), but was not found in the quadrangle. Exposed thicknesses of as much as 6 feet (2 m) are found locally, but the total thickness of the unit is unknown. These deposits are locally overlain by thin veneers of alluvial gravel and eolian sand, which comprise adjacent unit Qla.

Lacustrine Carbonate Sand (Qlk)

This calcium carbonate-rich, fine- to medium-grained sand contains coarse-sand- to granule-sized clasts, carbonate pellets and pea-sized, carbonate-coated gastropods (Oviatt and others, 1994). It occurs immediately below the Provo shoreline in the southeast corner of the quadrangle (figure 5). The unit overlies the lacustrine marl (Qlm) and was deposited during and perhaps slightly after the Provo phase of Lake Bonneville (Oviatt and others, 1994). The unit is probably less than 15 feet (5 m) thick (Oviatt and others, 1994).

Fine-Grained Lacustrine Deposits (Qlf)

These fine-grained sediments are located in the southeastern corner of the quadrangle (figure 5), and were deposited on the landward side of a prominent Provo-level tombolo. The unit consists of sandy silt, silty sand, and lesser marl and calcareous clay (Oviatt and others, 1994). These dominantly lacustrine sediments have locally been reworked by alluvial and eolian processes during post-Bonneville time, and thus, locally contain post-Bonneville alluvium and small, stabilized shrub-coppice dunes. The unit is generally less than 10 feet (3 m) thick (Oviatt and others, 1994).

Lacustrine Lagoon Deposits (Qll)

These fine-grained sediments were deposited behind (landward of) Lake Bonneville cuspate barriers in the northwest corner of the quadrangle. The material consists of clay, silt, and sand. Oviatt and others (1994) suggested that these sediments were probably deposited by waves that washed over the barrier beach into a lagoon, and in post-Bonneville time as slope wash from adjacent hills and as eolian material. The thickness of lagoon deposits is probably less than 10 feet (3 m).

Eolian Dune (Qed)

This unit is a single, small, vegetated dune located in the southeastern corner of the quadrangle (figure 5). This dune is the western-most dune of a more extensive area of stabilized dunes in The Hogback quadrangle (Oviatt and others, 1994). The dune consists of well-sorted silica sand and sand-sized lithic clasts. The thickness of the dune is about 6 feet (2 m).

Alluvium and Colluvium (Qac)

Pleistocene- and Holocene-age mixed alluvium and colluvium occur in first-order drainages, sheet-wash deposits below bedrock outcrops, and poorly developed alluvial fans. Deposits are generally less than 30 feet (10 m) thick, and consist of poorly sorted clay, silt, sand, pebbles, cobbles, and boulders. The coarsest deposits occur on the steepest slopes and along drainages.

Younger Alluvial-Fan Deposits (Qaf_1)

These post-Bonneville alluvial-fan deposits are found principally below the Bonneville shoreline and are widely distributed throughout the quadrangle. The fans generally consist of finer grained material than pre-Bonneville fans (QTaf, Qaf_2) and contain mostly sand and gravel, much of it reworked from lake deposits. These fans are generally thin and in their distal parts are commonly a veneer over lake deposits, tapering to a feather edge into the basin. Deposits are thickest near fan apices, but even there they are generally less than 10 feet (3 m) thick.

Stream Alluvium (Qal)

Holocene-age stream alluvium is found in modern stream channels, floodplains, and low terraces 3 to 6 feet (1 to 2 m) above channels. Deposits are generally less than 10 feet (3 m) thick, and range in composition from chiefly clay, silt, and sand at lower elevations to coarser sand, pebbles, cobbles, and boulders in the mountains and along mountain fronts.

Fill (Qf)

This unit consists of locally derived material mounded-up by ranchers to make stock-watering ponds along Picture Rock Wash at and near Picture Rock and Lower Topaz Reservoirs.

STRUCTURE

Two types of structures are present in the Picture Rock Hills quadrangle, volcanism-related structures and high-angle faults. The two names that I use for volcanism-related structures in the quadrangle, caldera and cauldron, require some explanation. Elston (1978) reviewed the definitions of these terms as follows. The term caldera refers to a topographic depression on a volcanic edifice, and thus is a physiographic term. The most common type of caldera is a collapse caldera, where the depression (caldera) formed as a result of the withdrawal of magma from an underlying magma chamber and the subsequent collapse of the chamber's roof. The term cauldron is a structural term that refers to the structures that form when the roof of a magma chamber subsides into its chamber. The term cauldron thus refers to all volcanic subsidence features.

Common usage of the terms caldera and cauldron in the geologic literature, however, has strayed from these definitions. In this report, I use the two terms as follows. The term caldera refers to a volcanic subsidence feature that is bound by a well-defined ring fault(s). The term cauldron refers to all other volcanic subsidence features. Where previous workers have published names for volcanic subsidence features, I use the term assigned by the author for the feature in order to avoid confusion.

Keg Cauldron

Shubat and Christenson (1999) formally proposed the name Keg cauldron for the volcanic subsidence feature that was the source of the Keg Tuff. Because the Keg Tuff has only been recognized at Keg Mountain and the Picture Rock Hills, they suggested that it is a locally derived unit. They proposed that the tuff was erupted from a cauldron centered on a granodiorite porphyry stock located in the south-central part of the Keg Pass quadrangle (figure 4). As defined by Shubat and Christenson (1999), the location of the margin and the ash-flow erupted from the Keg cauldron differs from the "Keg caldera" postulated by Shawe (1972). Shawe's (1972) "Keg caldera" margin is geophysically reasonable, roughly around a gravity low on the southeast flank of the gravity ridge, north and east of the Keg cauldron (figure 4).

Geological evidence for the existence of the Keg cauldron is the ash-flow origin and thickening of the Keg Tuff from 0 to at least 540 feet (0 to 165+ m), from the north-central part of the Keg Pass quadrangle to the south in the Keg Pass and northern Picture Rock Hills quadrangles. Structurally, the distribution and dips of layering measured in the Keg Tuff in the Keg Pass quadrangle outline a broad, low-relief dome centered on the granodiorite porphyry stock (Tgd) in that quadrangle (Shubat and Christenson, 1999). Because of similarities in whole-rock chemical composition, age, and spatial distribution, Shubat and Christenson (1999) considered this stock to be comagmatic with the Keg Tuff and considered it to be a resurgent intrusion that caused doming of the intracauldron Keg Tuff. A paired magnetic high and low, characteristic of shallow intrusions, are near the stock (figure 4; Kucks, 1991). Also, the Mt. Laird Tuff is missing over the resurgent center of the Keg cauldron.

The northern margin of the cauldron shown in figure 4 corresponds (approximately) with the northern limit of the preserved distribution of the Keg Tuff. The southwestern margin of the cauldron probably lies north and/or east of drill holes THC-7 and THC-10 (figure 6), because the Keg Tuff is absent in these and nearby holes (table 2).

Thomas Caldera

Shawe (1972) first recognized the Thomas caldera and Lindsey (1982), working in the Thomas Range, provided a detailed account of the history of the caldera. Lindsey (1982) proposed that the caldera was the source of the Mt. Laird Tuff. The southern and western margins of the caldera were well defined by Lindsey (1982) and Shawe (1972), but the locations of the northern and eastern margins remained ill defined.

Shubat and Christenson (1999) interpreted the Mt. Laird Tuff, where exposed in the Keg Pass quadrangle, to be an outflow facies of the formation, implying that the caldera margin must lie west of bedrock exposures at Keg Mountain. This interpretation was based on the observation that the Mt. Laird Tuff is thin (<100 feet [30 m]), where present, and is missing at several localities, and the absence of large vents and ring fractures. The

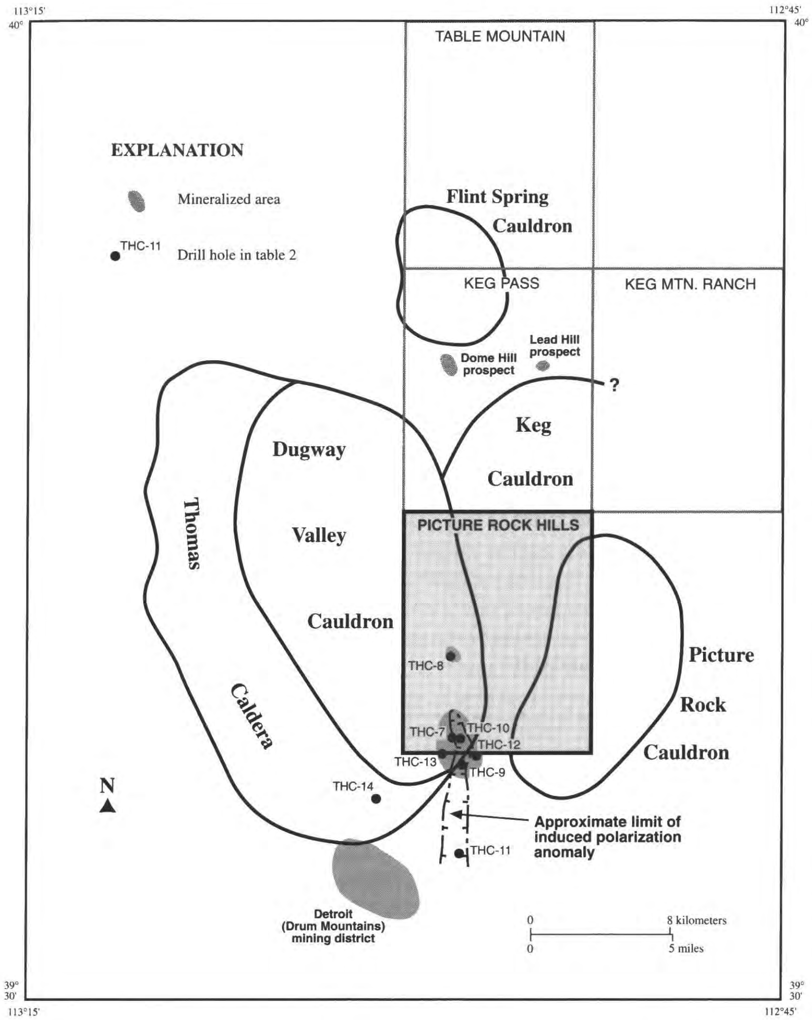


Figure 6. *Locations of Anaconda drill holes, mineralized areas, and caldera and cauldron margins at Keg Mountain. Table 2 summarizes information on the Anaconda drill holes. Caldera margins in the Thomas Range modified from Lindsey (1982).*

outflow interpretation also applies to the northern part of the Picture Rock Hills quadrangle.

A likely place to draw the eastern margin of the Thomas caldera is a persistent gravity gradient along the western margin of Keg Mountain (figure 4), much as Shawe (1972) and Lindsey (1982) did. This gravity gradient may in part represent unconsolidated basin-fill deposits underlying the valley between the Thomas Range, and the Picture Rock Hills and Keg Mountain, but may also represent intracaldera fill of the Thomas caldera and Dugway Valley cauldron.

Results of exploration drilling by The Anaconda Company better constrain the eastern edge of the Thomas caldera, and suggest it is concealed beneath Quaternary deposits and post-Mt. Laird volcanic rocks along the western margin of Keg Mountain (figure 6). Available lithologic logs of the Anaconda holes (table 2) show that the margin of the Thomas caldera could pass between hole THC-9 (outside caldera), and holes THC-7 and THC-10 (inside caldera) (figure 6). This interpretation might be tested by logging the core from these and nearby holes (if core can be found) in order to verify the lithologic assignments made by Anaconda geologists.

Additional data for these holes are available at the American Heritage Center on the University of Wyoming campus in Laramie. Anaconda reports suggest that there are probably several post-caldera high-angle faults in the area that have modified the caldera margin.

Dugway Valley Cauldron

Lindsey (1982) identified and named the Dugway Valley cauldron (figures 4 and 6) and proposed that it was the source of the Joy Tuff. Dugway Valley is actually north of the quadrangle and cauldron (figure 1). Lindsey (1982) defined the location of the southwestern margin of the cauldron by the presence of vent breccia, faults, and landslide breccia. The locations of the remaining margins of this cauldron, however, remained ill defined.

Results of exploration drilling by The Anaconda Company and mapping conducted during this study indicate that the eastern margin of the Dugway Valley cauldron passes through the western part of the Picture Rock Hills quadrangle, concealed beneath Quaternary deposits (figures 4 and 6). Anaconda holes THC-7, THC-8, and THC-10 intercepted thick sections of the Joy Tuff (table 2), suggesting an intra-cauldron setting, whereas hole THC-9 did not intercept the Joy Tuff. These relationships are consistent with the interpretation that the eastern margin of the Dugway Valley cauldron passes between hole THC-9 and holes THC-7 and THC-10, and east of hole THC-8 (figure 6). These relationships and the relationships discussed above for the Mt. Laird Tuff suggest that the margins of the Dugway Valley cauldron and the Thomas caldera are nearly the same in the area of the drill holes (figure 6), and probably to the north along the gravity gradient (figure 4). Staub (1976) noted a north-trending, photo-linear feature east of hole THC-8 that might mark the margins.

Anaconda drill hole THC-8 (table 2) penetrated more than 3,000 feet (915 m) of Joy Tuff without encountering the underlying Mt. Laird Tuff. Geologic mapping showed that the base of the Joy Tuff is exposed, probably outside the cauldron, about 7,000 feet (2,135 m) east of hole THC-8. These relationships are shown in cross section B-B´ (plate 2), which is one possible interpretation of the cauldron margin.

The relationship between rhyolite porphyry intrusions, apparently comagmatic with the Joy Tuff (Shubat and Christenson, 1999), and the Dugway Valley cauldron remains enigmatic. This is because exposures of rhyolite porphyry (Trp), which form north- to east-trending zones at Keg Mountain, are outside the proposed cauldron (Shubat and Christenson, 1999).

Picture Rock Cauldron

The existence of the Picture Rock cauldron is speculative. It is discussed in this report to make the reader aware of its possible presence, and to revise the interpre-

Table 2. Summary of exploration holes drilled by The Anaconda Company in and near the Picture Rock Hills quadrangle. Figure 6 shows the locations of drill holes. All depths and thicknesses given in feet.

hole number	total depth	interval	thickness	lithology	mineralized interval	comments
THC-7	3995	0-380 380-1516 1516-3283 3283-3897 3897-3995	380 1136 1767 614 98	alluvium Topaz Mtn. Rhyolite Joy Tuff Mt. Laird Tuff quartzite	1700-3900	Within this interval are 200 to 300-foot zones containing average values of 0.161 oz./ton Ag, 0.19 % Pb, 0.33 % Zn, and 0.07 % Cu. Carbonate, quartz, and gypsum associated with mineralized rock.
THC-8	4012	0-? ?-4012	? 3000+	alluvium Joy Tuff	?	Sparse Pb-Zn-Cu mineralized rock. Quartz and carbonate associated with mineralized rock.
THC-9	3516	0-495 495-541 541-3516	495 46 2975	alluvium lava flow quartzite	1260-3516	Pyrite along cracks, associated with quartz, hematite, and clay. Sparse galena, chalcopyrite, and sphalerite. Highest Ag values from 1500 to 2600 ppm.
THC-10	3601	0-180 180-1500 1500-2964 2964-3550 3550-3601	180 1320 1464 586 51	alluvium Topaz Mtn. Rhyolite Joy Tuff Mt. Laird Tuff quartzite	1870-3601	Mineralized rock enriched in Pb, Zn, Cu, and Ag. Associated minerals are pyrite, quartz, gypsum, chlorite, and clays.
THC-11	1250	0-? ?-1250	? 750+?	alluvium quartzite	1200-1250	Quartz veins in oxidized quartzite.
THC-12	2608	?	?	quartzite?,	?	Four zones containing as much as 1.7 % sulfides.
THC-13	2440	?	?	Volcanic rocks and quartzite.	?	Three sulfide zones.
THC-14	2430	?	?	Volcanic rocks and quartzite. Joy Tuff is missing	?	Three sulfide zones.

tation of Shubat and Snee (1992). Geologists with The Anaconda Company originally proposed and named the cauldron while exploring for uranium deposits in the area in the late 1970s and early 1980s (see metallic minerals section). Evidence for the existence of the cauldron consists of two geophysical observations: (1) an oval-shaped gravity low (figure 4) may outline the cauldron and (2) the cauldron is coincident with low-resistivity material at depth (Campbell and Visnyei, 1989) that could be intra-cauldron fill. Both of these geophysical features could be produced by unconsolidated basin fill. There is no evidence to suggest which ash-flow tuff was vented from the cauldron. But one possibility is the Dell Tuff which is exposed to the north (Shubat and Christenson, 1999; Shubat and others, 1999).

After looking at the Anaconda drill-hole data and further field examinations, I have revised my previous interpretation (Shubat and Snee, 1992). I no longer think the Picture Rock cauldron (caldera) is the source of the Joy Tuff, and no longer interpret the roughly east-west-trending, arcuate fault in the north-central part of the quadrangle as a structural wall to a cauldron or caldera.

Zones Marked by Rhyolite Porphyry Intrusions

The rhyolite porphyry intrusions (Trp) in the Keg Pass (Shubat and Christenson, 1999), Keg Mtn. Ranch (Shubat and others, 1999), and Picture Rock Hills quadrangles fall into several north- to east-trending zones. All the zones consist of many, small dikes and plugs of rhyolite porphyry that are typically elongate north-south to northeast-southwest. No faults are mapped within these zones, so the control for the rhyolite porphyry distribution is not known. Only the southwest end of the southern northeast-trending zone is present in the Picture Rock Hills quadrangle (SW1/4 section 26 and center section 35, T. 12 S., R. 10 W.).

Shubat and Christenson (1999) inferred the northeast- and east-trending zones (about N. 45° E. and N. 75° E.) were parallel to the maximum principal horizontal stress direction at the time of intrusion of rhyolite porphyry (35.14 ± 0.15 Ma, table 1). This interpretation is in rough agreement with the results (N. 60° to 80° E.) obtained by Best (1988) for Oligocene dikes (32 to 34 million years old) and more westerly orientations shown by Ren and others (1989), derived from Oligocene plutons (31 to 35 million years old), in the eastern Great Basin.

Lineaments Marked by Topaz Mountain Rhyolite

Dike-like intrusions, isolated domes, coalesced flows and domes, and exposures of Topaz Mountain Rhyolite delineate several north-northwest-trending lineaments in the Picture Rock Hills, Keg Pass (Shubat and Christenson, 1999), and Keg Mtn. Ranch (Shubat and others, 1999) quadrangles. Dike-like bodies of Topaz Mountain

Rhyolite in these lineaments trend about north-northwest, and isolated domes are aligned in the same direction. Coalesced flows and domes form ridges and exposures of Topaz Mountain Rhyolite that also trend north-northwest. No mapped faults appear to coincide with the lineaments, but several faults in the Keg Pass quadrangle have this trend (Shubat and Christenson, 1999).

Shubat and Christenson (1999) interpreted the lineaments as being parallel to the maximum principal horizontal stress direction (N. 35° W.) at the time of intrusion and eruption of the Topaz Mountain Rhyolite, between 8 and 6 million years old. This interpretation is in rough agreement with the results (N. 20° to 25° W.) obtained by Zoback and others (1981) in the northern Great Basin for the Miocene (6 to 20 million years ago).

High-Angle Faults

Two ages of high-angle faults are present in the Picture Rock Hills quadrangle. Older faults offset the Eocene and Oligocene Keg and Joy Tuffs (roughly 37 and 35 million years old, respectively), and younger fault scarps are present in late Pleistocene to Holocene sediments. Staub (1976) proposed that a concealed fault bounded the Drum Mountains in the southwest corner of the quadrangle. This fault is not shown on plate 1 because its orientation and location were not determined by Staub (1976).

Only two faults of the older group are present in the quadrangle. One of these faults is arcuate, concave to the south, roughly east-west trending and lies in the north-central part of the quadrangle. This fault has a minimum down-to-the-south stratigraphic separation of 300 feet (90 m) and a more likely separation of 600 feet (180 m) as shown in cross-section A-A´ (plate 2). It probably offsets Keg Tuff (Tk)(36.77 ± 0.12 Ma, table 1) in the footwall and possibly Joy Tuff (Tj)(34.80 ± 0.06 Ma, table 1) in the hanging wall. This fault does not appear related to the cauldrons and caldera in the area. The other fault of this group lies along the north-central edge of the quadrangle, strikes northeast, and has minor separation. It cuts Joy Tuff (Tj)(34.80 ± 0.06 Ma, table 1), and in the Keg Pass quadrangle is apparently overlain by Topaz Mountain Rhyolite (6 to 8 million years old).

In the Thomas Range, Lindsey (1982) determined that high-angle faults largely postdated the 21-million-year-old Spor Mountain Formation. He also noted that only minor block faulting occurred after eruption of the Topaz Mountain Rhyolite (6 to 8 million years old), thus bracketing the age of most of the high-angle faulting in the Thomas Range between 21 and 6 million years old. This age range may well apply to the high-angle normal faults mapped in the Picture Rock Hills quadrangle.

The younger (Quaternary) group of faults constitute the northern tip of the Drum Mountains fault zone, defined and described by Bucknam and Anderson (1979a; 1979b) and studied by many workers (Crone, 1983; Crone and Harding, 1984; Oviatt, 1989; Hintze and Oviatt, 1991; Oviatt and others, 1994). The faults, located in the southeast corner of the quadrangle (figure 5), are closely spaced and strike north-northeast.

The Quaternary fault scarps are best preserved where they cut a prominent Provo-phase tombolo (Qlg). Fault scarps in this area are about 1 to 3 feet (0.3 to 1 m) high. The highest scarp in the fault zone is about 400 feet (120 m) east of the eastern edge of the quadrangle and was profiled by Oviatt and others (1994). Fault-scarp heights diminish from east to west across the zone, with scarps in the western part of the zone being very difficult to locate in the field. Scarps in the western part of the zone face east and scarps in the eastern part of the zone face west, defining a graben.

The faults cut Provo-phase deposits, yielding a maximum age for the scarps of about 14,000 years ago. Some faults cut the younger alluvial-fan deposits (Qaf1) and the fine-grained lacustrine unit (Qlf) that are Holocene and partly Holocene, respectively, in age. This indicates that at least some of the surface rupture in the zone is Holocene in age. Pierce and Colman (1986) performed a morphometric analysis that yielded an age of 9,000 years B.P. for scarps to the south in the Drum Mountain fault zone.

ECONOMIC RESOURCES

Metallic Minerals

Although no mines or prospects are in the quadrangle, much mineral exploration has been done in the quadrangle and at Keg Mountain. Exploration at Keg Mountain has been summarized by Shubat (1987), Shubat and Christenson (1999), and Shubat and others (1999). From 1976 through 1981, The Anaconda Company conducted a major uranium exploration program in the Thomas, Drum, and Keg Mountains (their Thomas Project). As part of this work, they drilled several deep (up to 4,000 feet [1,220 m]) holes in the southwest corner of the quadrangle (table 2). These holes penetrated several hundred feet of basin-fill sediments, hundreds to thousands of feet of volcanic rocks, and terminated in Paleozoic quartzite. Low-grade lead-zinc-silver-copper mineralized rock was encountered in many of the holes (table 2). The following paragraphs summarize the discovery of mineralized rocks made by The Anaconda Company. Additional data on the mineralized rocks exists in the Anaconda Collection at the American Heritage Center on the University of Wyoming campus in Laramie.

The holes drilled by Anaconda were located where a prominent, north-trending induced-polarization anomaly (figure 6) coincided with a structural intersection proposed by company geologists. This structural intersection was arrived at by projecting the ring fracture of the Thomas caldera and northwest-trending faults in the Thomas Range.

Mineralized rock discovered by the drill holes consists of veinlets enriched in lead, zinc, silver, and copper that form a stockwork in quartzite and volcanic rocks. Ore minerals include galena, sphalerite, and chalcopyrite. Gangue minerals are quartz, carbonate, gypsum, hematite, chlorite, and clay. The highest precious-metals content intersected was 20 feet (6 m) of 3.8 troy ounces per ton silver. Some base-metals values are listed in table 2. The highest uranium value intersected was 3 feet (1 m) of 0.147 percent U_3O_8.

Industrial Minerals and Rocks

Sand and Gravel

Abundant sand and gravel are present in the quadrangle in beaches, bars, and tombolos that were deposited near the shores of latest Pleistocene Lake Bonneville. Sand and gravel mapped as sand deposits (Qls) are moderately size sorted and consist of fine- to medium-grained sand with lesser silt and pebbles. Sand grains consist of quartz, volcanic rock fragments, and lesser feldspar. Sand and gravel mapped as gravel deposits (Qlg) are poorly to moderately size sorted, and consist mostly of sand and pebbles with lesser silt and cobbles. The gravel component of the prominent tombolo located in the southeast corner of the quadrangle is dominantly quartzite with lesser limestone and rhyolite. The large cuspate barrier in the northwest corner of the quadrangle has a gravel component that is almost entirely volcanic rocks.

Zeolite Minerals

Significant zeolite mineralization (clinoptilolite) exists in the stratified tuff member of the Topaz Mountain Rhyolite (Ttmt) (Lindsey, 1975). Clinoptilolite makes up between 60 and 90 percent of the rock, and is the only zeolite mineral identified in the area (Lindsey and others, 1974). Mayes and Tripp (1991) summarized the available information on the mineralization. Lindsey (1975) showed that alteration of the tuffs produced feldspathic as well as zeolitic mineral assemblages. The feldspathic assemblage contains potassium feldspar as the dominant mineral. Lindsey (1975) concluded that the alteration was caused by percolating ground water that leached alkalis from glass in the tuff, forming, progressively, the zeolitic and feldspathic assemblages.

Crushed Stone and Dimension Stone

The Joy Tuff (Tj) and the rhyolite flow, dome, and intrusion member of the Topaz Mountain Rhyolite (Ttm) could be used for crushed stone. Crushed devitrified rhyolite could be used for road base material, bituminous aggregate, or possibly cement aggregate.

The Joy Tuff could be used for dimension stone. In exposures in the SW1/4 section 1 and NW1/4 section 12, T. 13 S., R. 10 W., Joy Tuff is massive and very densely welded. The rock contains abundant rock fragments and crystals in a reddish-brown, locally laminated matrix of devitrified glass. Sufficiently large pieces could be quarried and cut for tile or facing stone.

Lapidary Materials

Staub (1975) noted several varieties of lapidary materials in Topaz Mountain Rhyolite (her Keg Mountains Rhyolite). The best known are the topaz crystals, for which Topaz Mountain got its name. In the Picture Rock Hills, these crystals are usually less than 0.6 inches (15 mm) long. Thunder eggs are present in the stratified tuff (Ttmt), and obsidian also is present (Staub, 1975), presumably in vitrophyres in the flow, dome and intrusion member (Ttm). None of the vitrophyres observed were perlitic.

WATER RESOURCES

No perennial streams flow in the quadrangle. Discharge from the lone spring in the quadrangle (Kane Spring; center N1/2 section 35, T. 12S., R. 10W.) is used for livestock. Waddell (1967) reported that a sample contained 1,790 parts/million (~mg/l) evaporated total dissolved solids, and reported other analytical results including metal concentrations.

Bedinger and others (1984) showed the locations of water wells in the region, none are in the quadrangle. The closest well is several miles southwest of the southwest corner of the quadrangle (Bedinger and others, 1984). This well had a reported depth to ground water of 240 feet (73 m). A well located east of the quadrangle, in the adjacent The Hogback quadrangle, had a reported depth to ground water of 365 feet (111 m)(Bedinger and others, 1984). No springs or water wells are shown in the area by Mower and Feltis (1964, 1968).

GEOLOGIC HAZARDS

In general, few significant geologic hazards are present in the quadrangle. Virtually no construction or development has taken place in the quadrangle. No observations or historical records of hazard events are available for the quadrangle.

No earthquakes greater than magnitude 2.0 have been reported in the quadrangle (Goter, 1990). Potentially active faults, however, are present in the southeast corner of the quadrangle. These faults underwent surface rupture in the latest Pleistocene or Holocene. The principal earthquake hazard in the area would be strong ground shaking from a nearby moderate to large earthquake. The quadrangle is near the boundary between seismic zones 2B and 3 (International Conference of Building Officials, 1991) in an area of moderate earthquake hazard.

Slopes in the area are generally stable; no landslides were mapped in the quadrangle. The principal slope-failure hazard is from rock falls below steep, rocky slopes.

Flash flooding is possible along any of the dry washes (Qal) and on active alluvial fans and sheet-wash slopes (Qaf1 and Qac). Cloudburst-generated debris flows are possible in mountain channels (units Qal and Qac) and at the apices of modern alluvial fans (Qaf_1).

Soil conditions should present few problems for building foundations. Soils are generally granular sand and gravel with little clay. It is possible that collapsible soils subject to hydrocompaction may occur on modern alluvial fans (Qaf_1) at mountain fronts, and that expansive, soluble, and erodible materials are present in the fine-grained deep-lake sediments (Qlm) in the southeastern part of the quadrangle.

No shallow ground-water hazards appear to be present in the quadrangle (Hecker and Harty, 1988).

Volcanic rocks in Keg Mountain and the Picture

Rock Hills are locally uranium-rich (see metallic minerals section; Zielinski and others, 1980), and may produce radon gas (Solomon, 1992; Black, 1993). The generally coarse-grained, dry soils are conducive to the movement of radon gas through soil and into structures (Solomon, 1992; Black, 1993).

ACKNOWLEDGMENTS

I thank Dr. Mike Devine of the American Heritage Center at the University of Wyoming in Laramie for allowing me to publish a summary of the mineral exploration activity in the area. Hal Morris of the U.S. Geological Survey contributed the results of his unpublished reconnaissance mapping. Discussions with Fitzhugh Davis, Ken Krahulec, Gary Christenson, Bryce Tripp, David Lindsey, David Campbell, Larry Snee, and Douglas Stoeser greatly enhanced my understanding of the geology of the area. Reviews by Michael Ross, Bill D. Black and Gary E. Christenson of the Utah Geological Survey, and Eric Christiansen of Brigham Young University improved the manuscript. Jon K. King of the Utah Geological Survey combined these reviews with those of the Keg Pass and Keg Mtn. Ranch quadrangles and his own reviews for this final version of the map and report.

REFERENCES CITED

Baedecker, P.A., editor, 1987, Methods of geochemical analysis: U.S. Geological Survey Bulletin 1770, 132 p.

Bankey, Viki, and Cook, K.L., 1989, Complete Bouguer gravity map and related geophysical maps of the Delta 1° x 2° quadrangle, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-2081-A, scale 1:250,000.

Bedinger, M.S., Mason, J.L., Langer, W.H., Gates, J.S., Stark, J.R., and Mulvihill, D.A., 1984, Maps showing ground-water levels, springs, and depth to ground water, Basin and Range province, Utah: U.S. Geological Survey Water Resources Investigations Report WRI 83-4122-B, 12 p., scale 1:500,000.

Best, M.G., 1982, Igneous and metamorphic petrology: New York, W.H. Freeman and Company, 630 p.

Best, M.G., 1988, Early Miocene changes in direction of least principal stress, southwestern United States--Conflicting inferences from dikes and metamorphic core-detachment fault terranes: Tectonics, v. 7, no. 2, p. 249-259.

Bikun, J.V., 1980, Fluorine and lithophile element mineralization at Spor Mountain, Utah: Tempe, Arizona State University, M.S. thesis, 195 p.

Black, B.D., 1993, The radon-hazard-potential map of Utah: Utah Geological Survey Map 149, 12 p., scale 1:1,000,000.

Bucknam, R.C., and Anderson, R.E., 1979a, Map of fault scarps in unconsolidated sediments, Delta 1° x 2° quadrangle, Utah: U.S. Geological Survey Open-File Report 79-366, 21 p., scale 1:250,000.

Bucknam, R.C., and Anderson, R.E., 1979b, Estimation of fault-scarp ages from a scarp-height-slope-angle relationship: Geology, v. 7, no. 1, p. 11-14.

Campbell, D.L., and Visnyei, Andrew, 1989, Audio-magnetotelluric soundings in the Delta Utah 1° x 2° quadrangle: U.S. Geological Survey Open-File Report 89-538, 71 p.

Christenson, G.E., and Purcell, Charles, 1985, Correlation and age of Quaternary alluvial-fan sequences, Basin and Range province, southwestern United States, *in* Weide, D.L., editor, Soils and Quaternary geology of the southwestern United States: Geological Society of America Special Paper 203, p. 115-122.

Christiansen, R.L., and Lipman, P.W., 1966, Emplacement and thermal history of a rhyolite lava flow near Fortymile Canyon, southern Nevada: Geological Society of America Bulletin, v. 77, p. 671-684.

Crone, A.J., 1983, Amount of displacement and estimated age of a Holocene surface faulting event, eastern Great Basin, Millard County, Utah, *in* Gurgel, K.D., editor, Geologic excursions in neotectonics and engineering geology in Utah: Utah Geological and Mineral Survey Special Study 62, p. 49-55.

Crone, A.J., and Harding, S.T., 1984, Relationship of late Quaternary fault scarps to subjacent faults, eastern Great Basin, Utah: Geology, v. 12, p. 292-295.

Currey, D.R., 1982, Lake Bonneville--selected features of relevance to neotectonic analysis: U.S. Geological Survey Open-File Report 82-1070, 30 p.

Currey, D.R., Atwood, Genevieve, and Mabey, D.R., 1984, Major levels of Great Salt Lake and Lake Bonneville: Utah Geological and Mineral Survey Map 73, scale 1:750,000.

Currey, D.R., Oviatt, C.G., and Plyler, G.B., 1983, Lake Bonneville stratigraphy, geomorphology, and isostatic deformation in west-central Utah: Utah Geological and Mineral Survey Special Studies 62, p. 63-82.

Dommer, M.L., 1980, The geology of the Drum Mountains, Millard and Juab Counties, Utah: Brigham Young University Geology Studies, v. 27, pt. 3, p. 55-72, scale 1:40,000.

Elston, W.E., 1978, Mid-Tertiary cauldrons and their relationship to mineral resources, southwestern New Mexico, *in* Chapin, C.E., and Elston, W.E., editors, Field guide to selected cauldrons and mining districts of the Datil-Mogollon volcanic field, New Mexico: New Mexico Geological Society Special Publication no. 7, p. 107-113.

Erickson, M.P., 1963, Volcanic geology of western Juab County, Utah, *in* Sharp, B.J., and Williams, N.C., editors, Beryllium and uranium mineralization in western Juab County, Utah: Utah Geological Society, Guidebook to the Geology of Utah no. 17, p. 23-35.

Galyardt, G.L., and Rush, F.E., 1981, Geologic map of the Crater Springs Known Geothermal Resource Area and vicinity, Juab and Millard Counties, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1297, scale 1:24,000.

Gilbert, G.K., 1890, Lake Bonneville: U.S. Geological Survey Monograph 1, 438 p.

Goter, S.K., compiler, 1990, Earthquakes in Utah--1984-1989: U.S. Geological Survey map, scale 1:500,000.

Hecker, Suzanne, and Harty, K.M., compilers, 1988, Shallow ground water and related hazards in Utah: Utah Geological and Mineral Survey Map 110, 19 p., scale 1:750,000.

Hintze, L.F., and Oviatt, C.G., 1991, Geologic map of the Smelter Knolls West quadrangle, Millard County, Utah: Utah Geological Survey Map 148, 21 p., scale 1:24,000.

Hintze, L.F., and Robison, R.A., 1975, Middle Cambrian stratigraphy of the House, Wah Wah, and adjacent ranges in western Utah: Geological Society of America Bulletin, v. 86, p. 881-891.

Hogg, N.C., 1972, Shoshonitic lavas in west-central Utah: Brigham Young University Geology Studies, v. 19, pt. 2, p. 133-184.

International Conference of Building Officials, 1991, Uniform building code: International Conference of Building Officials, Whittier, California, 1050 p.

Johnson, E.H., 1975, Resistivity and induced polarization survey of a basalt flow in a geothermal environment, western Utah: Salt Lake City, University of Utah, M.S. thesis, 69 p.

Kucks, R.P., 1991, Aeromagnetic anomaly map and related geophysical maps of the Delta 1° x 2° quadrangle, Utah: U.S. Geological Survey Miscellaneous Field Studies Map MF-2081-B.

Le Bas, M.J., Le Maitre, R.W., Streckeisen, Albert, and Zanettin, B., 1986, A chemical classification of volcanic rocks based on the total alkali-silica diagram: Journal of Petrology, v. 27, pt. 3, p. 745-750.

Lindsey, D.A., 1975, The effect of sedimentation and diagenesis on trace element composition of water-laid tuff in the Keg Mountain area, Utah: U.S. Geological Survey Professional Paper 818-C, 35 p.

—1977, Epithermal beryllium deposits in water-laid tuff, western Utah: Economic Geology, v. 72, no. 2, p. 219-232.

—1979, Geologic map and cross sections of Tertiary rocks in the Thomas Range and northern Drum Mountains, Juab County, Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1176, scale 1:62,500.

—1982, Tertiary volcanic rocks and uranium in the Thomas Range and northern Drum Mountains, Juab County, Utah: U.S. Geological Survey Professional Paper 1221, 71 p.

Lindsey, D.A., Buzzard, K.A., Conklin, N.W., and Lee, L.M., 1974, Mineralogical and trace element data for water-laid tuff at Keg Mountain, Juab County, Utah: U.S. Geological Survey report USGS-GD-74-012, available from National Technical Information Service (NTIS) as report PB-231 925/AS, 32 p.

Lindsey, D.A., Naeser, C.W., and Shawe, D.R., 1975, Age of volcanism, intrusion, and mineralization in the Thomas Range, Keg Mountain, and Desert Mountain, western Utah: U.S. Geological Survey Journal of Research, v. 3, no. 5, p. 597-604.

Mayes, B.H., and Tripp, B.T., 1991, Zeolite minerals in Utah: Utah Geological Survey Open-File Report 210, 170 p.

Morris, H.T., 1978, Unprospected zone of pyritic alteration in west-central Utah: U.S. Geological Survey Open-File Report 78-791, 8 p.

—1987, Generalized geologic map of the Delta 2° quadrangle, Tooele, Juab, Millard, and Utah Counties, Utah: U.S. Geological Survey Open-File Report 87-185, scale 1:250,000.

Mower, R.W., and Feltis, R.D., 1964, Ground-water data, Sevier Desert, Utah: Utah Department of Natural Resources, State Engineer (Division of Water Rights) Basic-Data Report no. 9, 34 p., prepared by U.S. Geological Survey.

—1968, Ground-water hydrology of the Sevier Desert, Utah: U.S. Geological Survey Water Supply Paper 1854, 75 p., 7 plates.

Nutt, C.J., and Thorman, C.H., 1992, Pre-late Eocene structures and their control of gold ore at the Drum mine, west-central Utah, *in* Thorman, C.G., editor, Applications of structural geology to mineral and energy resources of the central and western United States: U.S. Geological Survey Bulletin 2012, p. F1-F7.

Nutt, C.J., Thorman, C.H., Zimbelman, D.R., and Gloyn, R.W., 1991, Geologic setting and trace-element geochemistry of the Detroit mining district and Drum gold mine, Drum Mountains, west-central Utah, *in* Raines, G.L., Lisle, R.E., Schafer, R.W., and Wilkinson, W.H., editors, Geology and ore deposits of the Great Basin, Symposium Proceedings: Reno, Geological Society of Nevada, p. 491-509.

Oviatt, C.G., 1984, Lake Bonneville stratigraphy at the Old River Bed and Leamington, Utah: Salt Lake City, University of Utah, Ph.D. dissertation, 122 p.

—1987, Lake Bonneville stratigraphy at the Old River Bed, Utah: American Journal of Science, v. 287, p. 383-398.

—1989, Quaternary geology of part of the Sevier Desert, Millard County, Utah: Utah Geological and Mineral Survey Special Study 70, 41 p.

Oviatt, C.G., Currey, D.R., and Sack, Dorothy, 1992, Radiocarbon chronology of Lake Bonneville, eastern Great Basin, USA: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 99, p. 225-241.

Oviatt, C.G., Sack, Dorothy, and Felger, T.J., 1994, Quaternary geologic map of the Old River Bed [northern Sevier Desert], Millard, Juab and Tooele Counties, Utah: Utah Geological Survey Map 169, 24 p., scale 1:62,500.

Pampeyan, E.H., compiler, 1989, Geologic map of the Lynndyl 30- by 60-minute quadrangle, west-central Utah: U.S. Geological Survey Miscellaneous Investigations Series Map I-1830, 9 p., scale 1:100,000.

Peterson, J.B., and Nash, W.P., 1980, Geology and petrology of the Fumarole Butte volcanic complex, Utah, *in* Studies in late Cenozoic volcanism in west-central Utah: Utah Geological and Mineral Survey Special Studies 52, pt. 2, p. 34-58.

Pierce, K.L., and Colman, S.M., 1986, Effect of height and orientation (microclimate) on geomorphic degradation rates and processes, late glacial terrace scarps in central Idaho: Geological Society of America Bulletin, v. 97, no. 7, p. 869-885.

Plavidal, K.R., 1987, The geology [geochemistry] and petrology of the eastern Keg Mountains, Juab County, Utah: Salt Lake City, University of Utah, M.S. thesis, 137 p.

Ren, Xiaofen, Kowallis, B.J., and Best, M.G., 1989, Paleostress history of the Basin and Range province in western Utah and eastern Nevada from healed microfracture orientations in granites: Geology, v. 17, p. 487-490.

Shawe, D.R., 1972, Reconnaissance geology and mineral potential of the Thomas, Keg, and Desert calderas, central Juab County, Utah: U.S. Geological Survey Professional Paper 800-B, p. B67-B77.

Shawe, D.R., and Stewart, J.H., 1976, Ore deposits as related to tectonics and magmatism, Nevada and Utah: American Institute of Mining, Metallurgical and Petroleum Engineers, Transactions, v. 260, p. 225-232 [presented at Annual Meeting, Las Vegas, Nevada, 1977].

Shubat, M.A., 1987, Geology and mineral occurrences of northern Keg Mountain, Juab County, Utah, *in* Kopp, R.S. and Cohenour, R.E., editors, Cenozoic geology of western Utah: Utah Geological Association Publication 16, p. 451-462.

Shubat, M.A., and Christenson, G.E., 1999, Geologic map of the Keg Pass quadrangle, Juab County, Utah: Utah Geological Survey Miscellaneous Publication 99-4, 28 p., scale 1:24,000.

Shubat, M.A., Felger, T.J., and King, J.K., 1999, Geologic map of the Keg Mtn. Ranch quadrangle, Juab County, Utah: Utah Geological Survey Miscellaneous Publication 99-5, 22 p., scale 1:24,000.

Shubat, M.A., and Snee, L.W., 1992, High-precision $^{40}Ar/^{39}Ar$ geochronology, volcanic stratigraphy, and mineral deposits of Keg Mountain, west-central Utah, *in* Thorman, C.G., editor, Applications of structural geology to mineral and energy re-sources of the central and western United States: U.S. Geological Survey Bulletin 2012, p. G1-G16.

Smith, T.B., 1974, Gravity study of the Fumarole Butte area, Juab and Millard Counties, Utah: Salt Lake City, University of Utah, M.S. thesis, 58 p.

Solomon, B.J., 1992, Geology and the indoor-radon hazard in southwestern Utah, *in* Harty, K.M., editor, Engineering and environmental geology of southwestern Utah: Utah Geological Association Publication 21, p. 165-172.

Staatz, M.H, and Carr, W.J., 1964, Geology and mineral deposits of the Thomas and Dugway Ranges, Juab and Tooele Counties, Utah: U.S. Geological Survey Professional Paper 415, 188 p.

Staub, A.M., 1975, Geology of the Picture Rock Hills quadrangle, Juab County, Utah: Salt Lake City, University of Utah, M.S. thesis, 87p.

Stewart, J.H., Moore, W.J., and Zietz, Isidore, 1977, East-west patterns of Cenozoic igneous rocks, aeromagnetic anomalies, and mineral deposits, Nevada and Utah: Geological Society of America Bulletin, v. 88, no. 1, p. 67-77.

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

Streckeisen, Albert, 1978, Classification and nomenclature of volcanic rocks, lamprophyres, carbonatites, and melitic rocks: Neues Jahrbuch fuhr Mineralogie Abhandlungen, Band (v.) 134, p. 1-14.

Varnes, D.J., and Van Horn, Richard, 1961, Reinterpretation of two of G.K. Gilbert's Lake Bonneville sections, Utah: U.S. Geological Survey Professional Paper 424-C, Geological Survey Research 1961, p. C98-C99.

Waddell, K.M., 1967, Reconnaissance of the chemical quality of water in western Utah, part 1, Sink Valley area, drainage basins of Skull, Rush, and Government Creek valleys, and the Dugway Valley - Old River Bed area: Utah Geological and Mineralogical Survey Water-Resources Bulletin 9, 15 p., 2 oversize tables.

Zielinski, R.A., Lindsey, D.A., and Rosholt, J.N., Jr., 1980, The distribution and mobility of uranium in glassy and zeolitized tuff, Keg Mountain area, Utah, U.S.A.: Chemical Geology, v. 29, no. 1, p. 139-162.

Zoback, M.L., Anderson, R.E., and Thompson, G.A., 1981, Cainozoic evolution of the state of stress and style of tectonism of the Basin and Range province of the western United States: Royal Society of London Philosophical Transactions series A, v. 300, p. 407-434.

APPENDICES

Not all rock types listed in appendix A and B, and shown in figures 2 and 3, are exposed in this quadrangle. Units Tap (andesite porphyry), Tdo (Dead Ox Tuff), Tdp (dacite porphyry), and Tqm (quartz monzonite) are only exposed in the Keg Pass quadrangle (Shubat and Christensen, 1999). Unit Td (Dell Tuff) is not exposed in the Picture Rock Hills quadrangle but might be present in subsurface. Unit Tkm (rhyolite of Keg Mountain) is only exposed in the Keg Mtn. Ranch quadrangle.

Sample number letter prefixes show in which quadrangle the sample was taken. NKM and KP were used for samples from the Keg Pass quadrangle. PRH and KMR were used for samples from the Picture Rock Hills and Keg Mtn. Ranch quadrangles, respectively.

APPENDIX A

Table 1.
Modal analyses of igneous rocks in the Keg Mountain area. Map symbols same as on plates 1 and 2. All values in percent except number of counts, sphene, and zircon. Symbols for sphene and zircon are n = absent and y = present.

sample number	map symbols	no. of counts	matrix	plagio-clase	quartz	alkali feldspar	biotite	horn-blende	clino-pyroxene	opaque minerals	sphene	zircon	lithic & pumice clasts
NKM-22-1	Ta	735	44.08	32.11	7.89	0.00	5.58	3.67	0.14	0.54	n	n	5.99
NKM-17-6	Tap	793	49.81	33.17	2.52	0.00	5.93	5.80	0.38	2.40	n	y	0.00
KP-7-9	Tap	735	45.99	35.24	3.81	0.00	6.39	5.58	1.50	1.50	n	y	0.00
KP-9-8	Tap	639	40.22	33.33	7.98	0.00	8.76	4.85	2.50	2.35	n	y	0.00
NKM-1-15	Tdo	762	70.73	5.64	3.28	0.13	0.79	0.00	0.00	0.13	n	y	19.29
NKM-1-9	Tdo	835	63.35	5.99	4.19	0.48	0.60	0.00	0.00	0.12	n	y	25.27
NKM-15-8	Tdo	756	67.33	6.22	2.78	0.26	0.93	0.00	0.00	0.40	n	y	22.09
NKM-6-6	Tdo	829	65.26	8.69	4.46	0.48	0.72	0.00	0.00	0.72	n	y	19.66
NKM-9-6	Tdo	827	67.11	6.77	4.72	0.48	0.00	0.00	0.00	0.60	n	y	20.31
KMR-4-1	Tk	789	43.73	31.05	9.25	0.25	9.13	3.42	1.77	1.39	n	y	0.00
PRH-13-1	Tk	434	39.40	35.48	9.68	0.23	8.76	3.46	0.69	1.61	n	y	0.69
KP-16-4	Tk	451	45.68	34.37	6.21	0.22	6.21	4.66	1.11	1.55	n	y	0.00
KP-2-2	Tk	780	44.10	31.67	7.44	0.00	10.38	4.36	0.90	1.15	n	y	0.00
KP-8-2	Tk	502	63.94	18.33	5.18	1.00	8.57	1.79	0.20	1.00	n	y	0.00
NKM-16-9	Tk	827	63.72	16.20	4.59	0.24	7.98	3.63	0.97	1.93	n	y	0.73
NKM-2-4	Tk	826	47.22	25.67	7.38	0.36	8.60	5.33	1.69	1.45	y	y	2.30
NKM-2-5	Tk	887	56.93	22.21	6.09	0.00	5.64	5.52	1.13	0.90	n	y	1.58
PRH-2-1	Tk	709	42.74	26.38	9.03	0.00	7.05	1.83	0.85	1.55	n	y	10.58
KP-2-1	Tgd	754	0.00	32.36	30.24	17.11	9.95	8.89	0.00	1.46	n	y	0.00
KP-2-4	Tgd	730	0.00	35.89	28.90	17.81	7.95	6.58	1.10	1.78	n	y	0.00
NKM-18-3	Tgd	792	0.00	38.89	31.57	17.93	6.31	4.17	0.13	0.88	n	y	0.00
KMR-1-4	Tml	668	60.33	26.80	1.50	0.00	5.09	2.84	2.25	1.20	y	y	0.00
KMR-1-5	Tml	774	65.12	22.22	1.94	0.00	4.52	2.20	0.90	2.97	y	n	0.00
KMR-1-6	Tml	821	62.24	20.46	1.95	0.00	6.82	6.58	0.85	0.85	y	n	0.00
KMR-3-21	Tml	717	66.81	18.55	2.23	0.00	4.32	6.42	0.70	0.98	y	n	0.00
KMR-3-9	Tml	790	65.82	20.63	0.76	0.00	4.56	5.32	1.39	1.52	n	n	0.00
KMR-4-4	Tml	749	64.09	20.96	4.94	0.00	4.54	4.14	0.00	1.34	n	y	0.00
KMR-4-8	Tml	835	68.50	17.96	2.75	0.00	3.11	6.59	0.36	0.72	y	y	0.00
KMR-5-1	Tml	707	60.11	25.32	3.95	0.00	7.36	2.26	0.14	0.85	y	y	0.00
KMR-5-13	Tml	517	55.32	29.59	1.55	0.00	6.58	4.26	0.77	1.93	y	y	0.00
KMR-5-2	Tml	799	58.20	24.16	2.63	0.00	6.26	5.63	1.88	1.13	y	y	0.00
KP-12-3	Tml	528	63.07	25.00	1.33	0.00	3.22	4.92	1.70	0.76	y	y	0.00
KP-6-1	Tml	728	56.87	31.59	1.37	0.00	4.40	3.71	1.10	0.96	y	y	0.00
KP-8-7	Tml	730	58.08	25.48	2.19	0.00	4.52	6.99	1.23	1.37	y	y	0.00
NKM-18-13	Tml	694	56.34	27.52	3.17	0.00	6.05	4.76	0.00	2.02	y	y	0.00
NKM-18-15	Tml	808	60.15	24.13	2.60	0.00	5.32	6.81	0.00	0.87	y	y	0.00
NKM-21-1	Tml	814	59.71	22.48	2.83	0.00	4.18	8.85	0.00	1.84	y	y	0.00
NKM-21-12	Tml	725	63.17	22.07	2.07	0.00	2.90	7.72	0.69	1.38	y	y	0.00
NKM-21-14	Tml	791	74.21	14.66	0.51	0.00	2.78	3.67	2.91	1.26	y	y	0.00
NKM-21-5	Tml	808	59.90	22.03	1.86	0.00	4.58	9.78	0.12	1.73	y	y	0.00

Table 1 (continued)

sample number	map symbols	no. of counts	matrix	plagio-clase	quartz	alkali feldspar	biotite	horn-blende	clino-pyroxene	opaque minerals	sphene	zircon	lithic & pumice clasts
NKM-21-8	Tml	767	69.36	19.43	0.13	0.00	2.48	2.61	4.17	1.69	n	y	0.00
NKM-22-4	Tml	772	63.21	22.15	1.30	0.00	7.12	4.79	0.13	1.30	y	y	0.00
NKM-22-5	Tml	754	67.51	16.58	3.58	0.00	5.70	4.51	1.59	0.53	y	y	0.00
NKM-22-6	Tml	746	54.83	28.28	1.88	0.00	5.36	7.51	0.40	1.74	y	y	0.00
NKM-22-7	Tml	819	58.00	22.59	4.15	0.00	5.37	7.81	0.37	1.47	y	y	0.00
NKM-22-8	Tml	794	52.52	31.61	2.14	0.00	6.42	5.67	0.13	1.39	y	y	0.00
KP-8-8	Tdp	793	58.01	24.34	3.66	0.00	5.55	6.81	0.00	1.64	y	y	0.00
NKM-10-2	Tdp	790	68.73	15.06	1.77	0.00	1.77	3.80	7.22	1.65	n	n	0.00
NKM-21-9	Tdp	790	56.84	30.89	2.53	0.00	3.42	5.06	0.25	0.89	n	y	0.00
NKM-7-4	Tdp	784	59.69	24.11	2.55	0.00	5.36	5.99	0.00	2.30	y	y	0.00
KP-12-5	Tqm	366	0.00	30.05	33.06	29.51	4.92	1.91	0.00	0.55	n	y	0.00
KMR-1-2	Tj	796	41.21	13.32	17.46	16.83	2.39	0.00	0.00	0.13	y	n	8.29
KP-13-2	Tj	416	43.27	18.75	18.27	16.35	2.88	0.00	0.00	0.24	y	y	0.00
PRH-1-1	Tj	691	46.74	7.81	17.66	12.01	1.59	0.00	0.00	0.43	y	n	13.75
PRH-2-3	Tj	392	46.94	14.80	17.60	17.60	1.53	0.00	0.00	0.51	y	n	0.77
KMR-3-8	Trp	418	62.20	11.48	10.29	14.35	1.44	0.00	0.00	0.24	n	n	0.00
KMR-4-6	Trp	732	43.44	15.98	16.39	20.63	2.73	0.55	0.00	0.27	n	y	0.00
KMR-5-8	Trp	541	49.72	17.38	14.42	15.71	2.22	0.37	0.00	0.18	n	y	0.00
KP-15-2	Trp	429	71.10	14.45	2.33	9.79	2.33	0.00	0.00	0.00	y	y	0.00
KP-2-3	Trp	805	46.58	20.12	16.77	13.79	2.11	0.00	0.00	0.62	n	y	0.00
KP-3-3	Trp	707	51.06	14.00	16.41	16.83	1.56	0.00	0.00	0.14	n	y	0.00
KP-3-4	Trp	355	58.03	12.39	10.99	15.21	2.82	0.00	0.00	0.56	n	n	0.00
KP-3-5	Trp	457	51.42	16.19	14.22	15.75	2.41	0.00	0.00	0.00	n	n	0.00
KP-8-1	Trp	433	55.66	14.55	13.86	12.47	3.23	0.00	0.00	0.23	y	y	0.00
KMR-3-10	Td	397	31.49	11.08	16.37	18.89	3.02	0.00	0.00	0.25	n	y	18.89
KMR-5-11	Td	490	46.53	9.18	21.43	19.80	2.45	0.00	0.00	0.41	y	y	0.00
KMR-5-9	Td	467	46.47	8.99	20.13	21.41	1.71	0.43	0.00	0.64	y	y	0.00
KP-6-2	Td	386	45.64	12.44	16.84	21.24	3.11	0.26	0.00	0.26	y	y	0.26
NKM-2-2	Td	781	44.94	9.99	26.12	16.26	2.18	0.00	0.00	0.51	y	y	0.00
NKM-1-13	Ttm	652	90.64	0.31	6.44	2.30	0.00	0.00	0.00	0.31	n	n	0.00
KMR-13-3	Ttm	479	54.91	17.33	17.33	7.72	2.51	0.00	0.00	0.21	y	y	0.00

Table 2.
Selected modal analyses of rhyolite of Keg Mountain from Plavidal (1987). Map symbols same as on plates 1 and 2. All values in percent.

symbol number	map symbol	matrix	plagio-clase	quartz	alkali feldspar	biotite	horn-blende	clino-pyroxene	opaque minerals
19V	Tkm	81.4	2.3	8.7	6.5	0.6	0.2	0.1	0.1
48V	Tkm	84.6	0.8	7.1	5.1	1.0	0.4	—	0.9
65V	Tkm	80.7	5.0	7.5	4.2	1.0	0.6	0.6	0.4
66V	Tkm	84.5	2.8	3.9	5.2	0.7	0.9	0.7	1.3
74V	Tkm	59.0	4.6	13.2	18.2	0.9	2.5	0.2	1.3
76V	Tkm	86.9	2.7	4.9	3.1	1.2	0.7	0.1	0.4
84V	Tkm	80.4	0.3	13.5	5.0	0.7	—	—	—
HKV	Tkm	79.4	1.1	15.2	3.1	0.5	0.2	—	0.3

APPENDIX B

Table 1.
Whole rock geochemical data for igneous rocks in the Keg Mountain area. Map symbols same as on plates 1 and 2. $FeTO_3$ refers to total iron reported as Fe_2O_3. Analyses provided by the U.S. Geological Survey; XRF chemical methods described by Baedecker (1987). All values in percent, recalculated to 100 percent after loss on ignition (LOI) subtracted.

sample number	map symbol	SiO_2	Al_2O_3	$FeTO_3$	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	LOI
KP-7-7	Ta	64.82	16.15	5.67	2.15	3.36	3.27	3.49	0.74	0.26	0.09	1.65
KP-15-1	Ta	61.01	16.53	6.47	2.79	4.23	4.24	3.25	1.04	0.39	0.05	3.96
KP-17-1	Ta	65.22	14.94	6.50	1.88	3.64	2.97	3.66	0.84	0.30	0.06	2.24
KP-7-9	Tap	63.16	16.22	5.80	2.21	5.00	3.32	3.21	0.74	0.26	0.08	1.57
KP-9-8	Tap	64.07	15.79	5.67	2.26	4.38	3.44	3.36	0.72	0.24	0.08	1.89
KP-9-4	Tk	67.77	14.77	4.31	1.66	3.19	3.19	4.23	0.57	0.24	0.07	2.31
KP-7-10	Tk	68.77	14.25	4.49	1.58	3.08	2.37	4.56	0.61	0.23	0.05	3.27
KMR-4-3	Tk	67.48	14.56	5.03	1.87	3.40	2.90	3.80	0.66	0.25	0.05	1.75
KP-1-1	Tk	63.99	15.95	5.74	2.10	4.77	3.05	3.34	0.74	0.25	0.07	3.14
KP-11-2	Tk	64.28	15.71	5.61	1.87	5.04	2.95	3.47	0.71	0.26	0.10	2.64
KP-16-3	Tk	63.21	16.01	5.84	1.71	5.89	3.15	3.10	0.74	0.25	0.10	2.59
KP-16-4	Tk	63.21	15.98	5.73	2.31	4.98	3.38	3.37	0.72	0.25	0.08	1.67
KP-2-2	Tk	64.08	15.76	5.63	1.81	5.32	3.06	3.29	0.72	0.25	0.08	3.14
KP-6-5	Tk	63.92	15.85	5.68	2.52	5.11	3.07	2.80	0.73	0.26	0.08	3.00
KP-8-2	Tk	67.19	15.10	4.74	1.82	3.07	2.89	4.26	0.64	0.25	0.05	2.08
KP-2-1	Tgd	64.37	15.68	5.38	2.33	4.55	3.38	3.27	0.71	0.25	0.07	2.65
KMR-1-4	Tml	63.80	15.98	5.90	2.10	4.54	3.11	3.41	0.79	0.28	0.08	3.90
KMR-3-13	Tml	65.15	14.92	5.84	1.42	5.10	2.24	4.21	0.79	0.25	0.08	4.05
KMR-3-21	Tml	71.05	12.92	4.71	1.34	3.75	2.56	2.79	0.58	0.23	0.07	1.90
KMR-3-9	Tml	63.43	15.05	6.56	2.54	4.93	3.11	3.24	0.78	0.28	0.06	3.11
KMR-4-7	Tml	64.38	15.49	5.72	2.55	3.96	3.04	3.75	0.75	0.27	0.09	3.71
KMR-4-8	Tml	63.39	15.67	6.17	2.92	4.33	2.88	3.44	0.82	0.29	0.09	2.61
KMR-5-13	Tml	62.30	15.65	6.72	3.31	3.44	3.72	3.62	0.84	0.29	0.11	2.14
KMR-5-17	Tml	66.14	14.45	5.19	1.94	4.20	2.43	4.64	0.68	0.25	0.06	1.45
KMR-5-18	Tml	64.09	15.66	5.77	2.42	5.46	2.29	3.16	0.78	0.27	0.09	3.84
KMR-5-3	Tml	64.51	15.04	5.88	2.02	4.16	2.67	4.62	0.76	0.26	0.07	1.06
KP-12-1	Tml	66.97	15.44	4.86	1.55	2.73	3.22	4.34	0.62	0.21	0.05	1.71
KP-12-3	Tml	63.03	15.40	6.47	2.65	4.85	3.22	3.20	0.81	0.28	0.10	2.29
KP-14-4	Tml	61.94	16.59	6.87	2.01	3.85	3.67	3.68	0.96	0.39	0.05	1.89
KP-5-22	Tml	71.87	12.11	4.20	1.46	2.52	1.88	5.22	0.46	0.22	0.04	1.16
KP-6-1	Tml	63.18	15.95	6.02	2.23	5.48	2.76	3.16	0.87	0.28	0.08	2.97
KP-8-7	Tml	65.07	15.52	5.60	2.07	4.21	2.99	3.43	0.75	0.27	0.08	2.15
KP-8-8	Tdp	64.31	15.50	5.45	2.29	4.27	3.48	3.64	0.73	0.26	0.07	3.25
KP-9-1	Tdp	65.17	15.57	5.23	2.14	3.58	3.60	3.70	0.68	0.25	0.08	2.99
KP-9-2	Tdp	65.53	15.41	5.20	2.07	4.19	3.00	3.62	0.65	0.24	0.09	4.15
KP-12-5	Tqm	67.88	15.28	4.20	1.55	2.55	2.99	4.71	0.58	0.22	0.04	3.33
KMR-1-2	Tj	73.77	13.85	1.74	0.51	1.78	3.33	4.63	0.24	0.08	0.06	1.55
PRH-2-3	Tj	73.92	13.26	2.12	0.64	1.80	3.49	4.32	0.27	0.11	0.06	0.55
PRH-1-1	Tj	74.77	13.59	1.82	0.47	1.38	3.12	4.42	0.27	0.11	0.04	1.26
KP-13-2	Tj	63.99	15.56	6.17	1.29	4.94	2.89	3.73	1.00	0.38	0.05	3.16
KMR-3-8	Trp	74.83	12.56	1.49	0.47	2.61	3.31	4.37	0.20	0.08	0.06	2.04
KMR-4-6	Trp	73.73	13.73	1.46	0.49	2.82	2.88	4.48	0.23	0.10	0.08	2.44
KP-15-2	Trp	74.01	14.43	1.38	0.60	1.32	3.26	4.68	0.20	0.06	0.06	1.93
KP-16-2	Trp	72.71	15.08	1.84	0.84	0.63	3.53	4.96	0.28	0.09	0.03	2.86
KP-3-1A	Trp	76.16	13.47	1.66	0.63	1.09	1.95	4.66	0.22	0.09	0.07	2.80
KP-3-1B	Trp	78.42	12.10	0.46	0.16	2.53	1.01	5.20	0.05	0.03	0.05	5.07
KP-3-1C	Trp	77.03	12.72	0.82	0.24	1.80	2.15	5.08	0.10	0.03	0.03	3.25
KP-3-4	Trp	74.93	13.81	1.56	0.59	1.43	2.63	4.71	0.21	0.08	0.05	2.19
KP-3-5	Trp	74.44	13.90	1.63	0.63	1.41	2.59	5.07	0.22	0.09	0.03	1.87
KP-8-1	Trp	75.31	13.75	1.60	0.61	1.16	2.31	4.91	0.22	0.09	0.05	2.05
KMR-3-11	Td	75.33	13.27	1.78	0.52	1.49	2.77	4.48	0.23	0.09	0.04	1.34
KMR-5-10	Td	74.15	13.96	1.50	0.52	1.94	2.87	4.74	0.21	0.08	0.03	3.21

Table 1 (continued)

sample number	map symbol	SiO_2	Al_2O_3	$FeTO_3$	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	LOI
KMR-5-11	Td	75.04	13.27	1.65	0.55	1.53	2.77	4.85	0.22	0.08	0.03	1.43
KMR-5-9	Td	75.05	13.38	1.65	0.57	1.54	2.88	4.59	0.22	0.08	0.03	1.20
KP-6-2	Td	75.11	13.23	1.55	0.55	1.53	3.05	4.63	0.23	0.09	0.02	0.94
KP-11-3	Ttm	76.35	12.30	0.85	0.25	1.28	3.43	5.31	0.14	0.03	0.05	1.11
KMR-13-3	Ttm	76.21	12.53	1.22	0.41	1.14	2.29	5.83	0.29	0.06	0.01	2.15

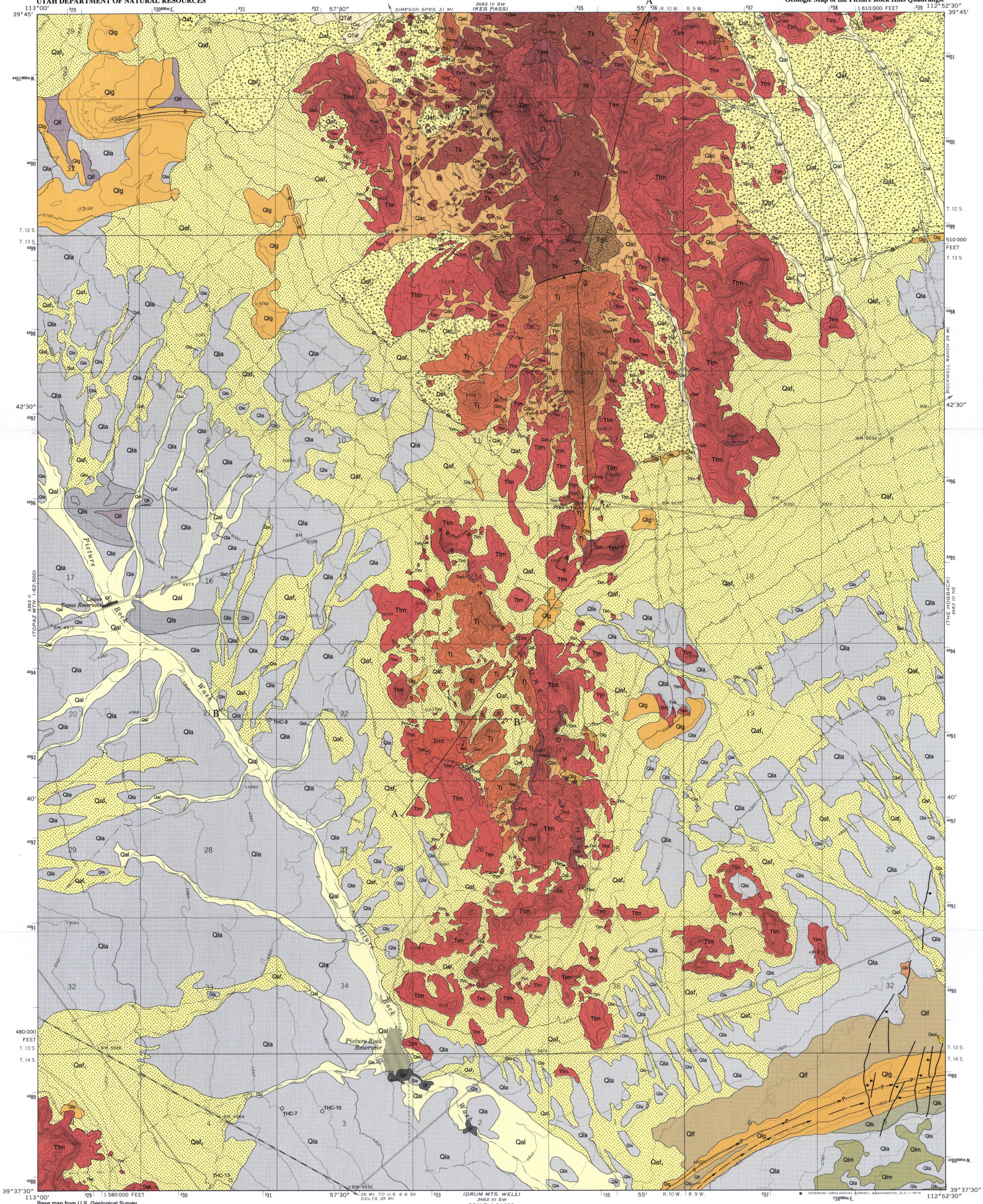
Table 2.

Selected whole-rock geochemical data for rhyolite of Keg Mountain from Plavidal (1987). Map symbols same as on plates 1 and 2. All values in percent.

sample number	map symbol	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	H_2O+	H_2O-	TOTAL
19V	Tkm	71.30	13.10	1.12	0.74	0.37	1.27	2.87	5.52	0.22	0.07	0.06	1.68	0.20	98.5
48V	Tkm	74.90	11.60	0.73	0.48	0.32	0.78	2.79	5.21	0.14	0.03	0.05	1.68	0.15	98.9
65V	Tkm	71.60	12.90	1.07	0.71	0.41	1.07	2.89	5.61	0.21	0.05	0.05	1.68	0.16	98.4
66V	Tkm	72.60	13.00	0.95	0.63	0.33	1.00	3.00	5.53	0.19	0.05	0.05	1.68	0.26	99.2
74V	Tkm	71.70	13.10	0.97	0.64	0.57	1.49	2.94	5.52	0.20	0.06	0.05	1.47	0.13	98.8
76V	Tkm	73.90	12.30	0.98	0.65	0.28	0.88	3.01	5.43	0.19	0.03	0.06	2.16	0.16	100.0
84V	Tkm	74.44	11.90	0.66	0.44	0.23	0.79	2.82	5.41	0.12	0.02	0.05	1.68	0.20	98.8
HKV	Tkm	74.10	12.00	0.70	0.46	0.17	0.71	2.86	5.27	0.12	0.01	0.06	1.80	0.23	98.5

UTAH GEOLOGICAL SURVEY
a division of
UTAH DEPARTMENT OF NATURAL RESOURCES

Plate 1
Utah Geological Survey Miscellaneous Publication MP-99-3
Geologic Map of the Picture Rock Hills Quadrangle



Base map from U.S. Geological Survey
Picture Rock Hills 7.5' Quadrangle, 1971

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

14.0°
249 MILS
1999 MAGNETIC DECLINATION
AT CENTER OF SHEET

UTAH
QUADRANGLE LOCATION

The Miscellaneous Publication Maps provide an outlet for authors who are not Utah Geological Survey staff. Not all aspects of this publication have been reviewed by the UGS.

GEOLOGIC MAP OF THE PICTURE ROCK HILLS QUADRANGLE, JUAB COUNTY, UTAH

by

Michael A. Shubat

1999

DESCRIPTION OF MAP UNITS

Qf Fill (Holocene) - Locally-derived material mounded-up by ranchers to make stock-watering ponds along Picture Rock Wash.

Qal Stream alluvium (Holocene) - Unconsolidated, poorly sorted clay, silt, sand, pebbles, cobbles, and boulders in modern stream channels, floodplains, and terraces 3 to 6 feet (1 to 2 m) above modern channels; generally less than 10 feet (3 m) thick.

Qaf_1 Younger alluvial-fan deposits (Holocene and latest Pleistocene) - Unconsolidated, poorly sorted clay, silt, sand, and gravel found principally below the Bonneville shoreline; generally less than 10 feet (3 m) thick.

Qac Alluvium and colluvium (Holocene and Pleistocene) - Unconsolidated, poorly sorted clay, silt, sand, pebbles, cobbles, and boulders in first-order drainages, on sheet-wash slopes below bedrock outcrops, and in poorly developed alluvial fans; generally less than 30 feet (9 m) thick.

Qed Eolian dune (Holocene and late Pleistocene) - Well-sorted, silica sand and sand-sized, lithic grains in a poorly developed dune; about 6 feet (2 m) thick.

Qll Lacustrine lagoon deposits (Holocene and latest Pleistocene) - Unconsolidated clay, silt, and sand in depressions behind cuspate barrier bars; deposited in Lake Bonneville lagoons, and as slope-wash and eolian material in Holocene time; probably less than 10 feet (3 m) thick.

Qlf Fine-grained lacustrine deposits (Holocene and latest Pleistocene) - Unconsolidated sand, silt, and lesser marl and calcareous clay; deposited in Lake Bonneville and locally contains Holocene alluvial and eolian sediments; generally less than 10 feet (3 m) thick.

Qlk Lacustrine carbonate sand (latest Pleistocene) - Unconsolidated, calcium carbonate-rich, fine- to medium-grained sand, with coarse sand-sized to granule clasts, carbonate pellets and carbonate-coated gastropods; deposited just below the Provo shoreline; maximum thickness less than 15 feet (4.5 m).

Qlm Lacustrine marl (latest Pleistocene) - Poorly consolidated white to gray marl and lesser clay, silt, and sand; characterized by abundant ostracodes; deposited in Lake Bonneville; exposed thickness up to 6 feet (2 m).

Qls Lacustrine sand (latest Pleistocene) - Unconsolidated, moderately sorted, fine- to medium-grained sand with lesser silt and pebbles; grains are silica and volcanic rock fragments; compose barrier beaches between the Bonneville and Provo shorelines; probably less than 10 feet (3 m) thick.

Qlg Lacustrine gravel (latest Pleistocene) - Unconsolidated sand, gravel (pebbles and cobbles), and silt forming beaches, barriers, tombolos, and spits in Lake Bonneville at and just below the Bonneville and Provo shorelines; may be as much as 30 feet (9 m) thick.

Qla Undifferentiated lacustrine and/or alluvial deposits (Holocene and late Pleistocene) - Mostly unconsolidated sand and gravel (pebbles and cobbles) deposited in Lake Bonneville as waves reworked the surfaces of pre-Bonneville alluvial fans, and lacustrine deposits that were partially reworked by post-Bonneville streams and slope-wash; generally less than 10 feet (3 m) thick.

Qaf_2 Intermediate-age alluvial-fan deposits (late to middle Pleistocene) - Unconsolidated, poorly sorted clay, silt, sand, pebbles, cobbles, and boulders above the Bonneville shoreline; fan surfaces are inactive and undergoing erosion, and are up to 20 feet (6 m) above modern drainages; generally less than 20 feet (6 m) thick.

Qb Basalt of Crater Bench (early Pleistocene) - Black to dark-brown, vesicular basaltic andesite flow containing sparse phenocrysts of plagioclase, clinopyroxene, iron-titanium oxides, and orthopyroxene in a matrix of plagioclase, pigeonite, and glass; distal part of Crater Bench, a shield volcano centered on Fumarole Butte; dated at 0.88±0.1 and 0.95±0.1 Ma (Peterson and Nash, 1980; Galyardt and Rush, 1981); less than 20 feet (6 m) thick.

QTaf Older alluvial-fan deposits (early Pleistocene and Pliocene) - Unconsolidated to semi-consolidated, poorly sorted clay, silt, sand, pebbles, cobbles, and boulders above the Bonneville shoreline; exposed thickness 60 feet (18 m) or more.

Topaz Mountain Rhyolite (Miocene) - Divided into:

Ttm Rhyolite flows, domes, and intrusions - White, gray, and purple rhyolite containing sparse (10 to 15 percent), small (0.08 inch [2 mm]) phenocrysts of quartz and sanidine, and lesser plagioclase, biotite, and opaque mineral phenocrysts in a matrix of devitrified glass; black to brown vitrophyre at the base of some flows and domes; less than 6.7±0.3 Ma; maximum exposed thickness 800 feet (240 m).

Ttmt Stratified tuff - Pale-tan to orange, very thick- to thin-bedded, nonwelded, lithic-rich rhyolitic tuff and volcanic sandstone; contains a variety of volcanic rock fragments, abundant pumice clasts, and sparse crystal fragments in an ash matrix; occurs as discontinuous air-fall and water-laid lenses beneath many rhyolite flows and domes; extensively zeolitized and feldspathically altered; 0 to 260 feet (0 to 80 m) thick.

Trp Rhyolite porphyry (Oligocene) - Small, pale-gray to pink, light-tan weathering rhyolite porphyry dikes and plugs with large (up to 0.4 inch [1cm]) phenocrysts of sanidine, quartz, plagioclase, and biotite in an aphanitic matrix; phenocrysts nearly absent near the margins of intrusions and become more abundant toward the interior; dated by Shubat and Snee (1992) at 35.14±0.15 Ma.

Tj Joy Tuff (Oligocene) - Red-brown to pink, moderately to densely welded, rhyolitic ash-flow tuff; black vitrophyre locally present at base of unit and overlain by a black fiamme-rich zone; contains abundant, 0.08- to 0.3-inch (1- to 8-mm) phenocrysts of quartz, sanidine, plagioclase, and biotite, and as much as 14 percent lithic clasts; dated by Shubat and Snee (1992) at 34.88±0.06 Ma; maximum exposed thickness 540 feet (160 m), but more than 3,000 feet (915 m) penetrated in subsurface.

Tml Mt. Laird Tuff (Oligocene and Eocene) - Lavender, pale-green, dark-green, and brown, moderately welded, dacitic ash-flow tuff; characterized by abundant, 0.08 to 0.47 inch (2 to 12 mm) phenocrysts of white plagioclase; other phenocrysts are hornblende, biotite, quartz, and clinopyroxene; dated by Shubat and Snee (1992) at 36.54±0.06 Ma; maximum exposed thickness 100 feet (30 m), but about 600 feet (180 m) penetrated in subsurface.

Tgd Granodiorite porphyry (Oligocene and Eocene) - Light-olive-green plug containing 0.08 to 0.47 inch (2 to 12 mm) phenocrysts of plagioclase, quartz, biotite, hornblende, and clinopyroxene; matrix is fine grained to aphanitic and contains quartz, plagioclase, and potassium feldspar; propylitic alteration common; dated by Lindsey (1982) at 36.6±1.6 Ma.

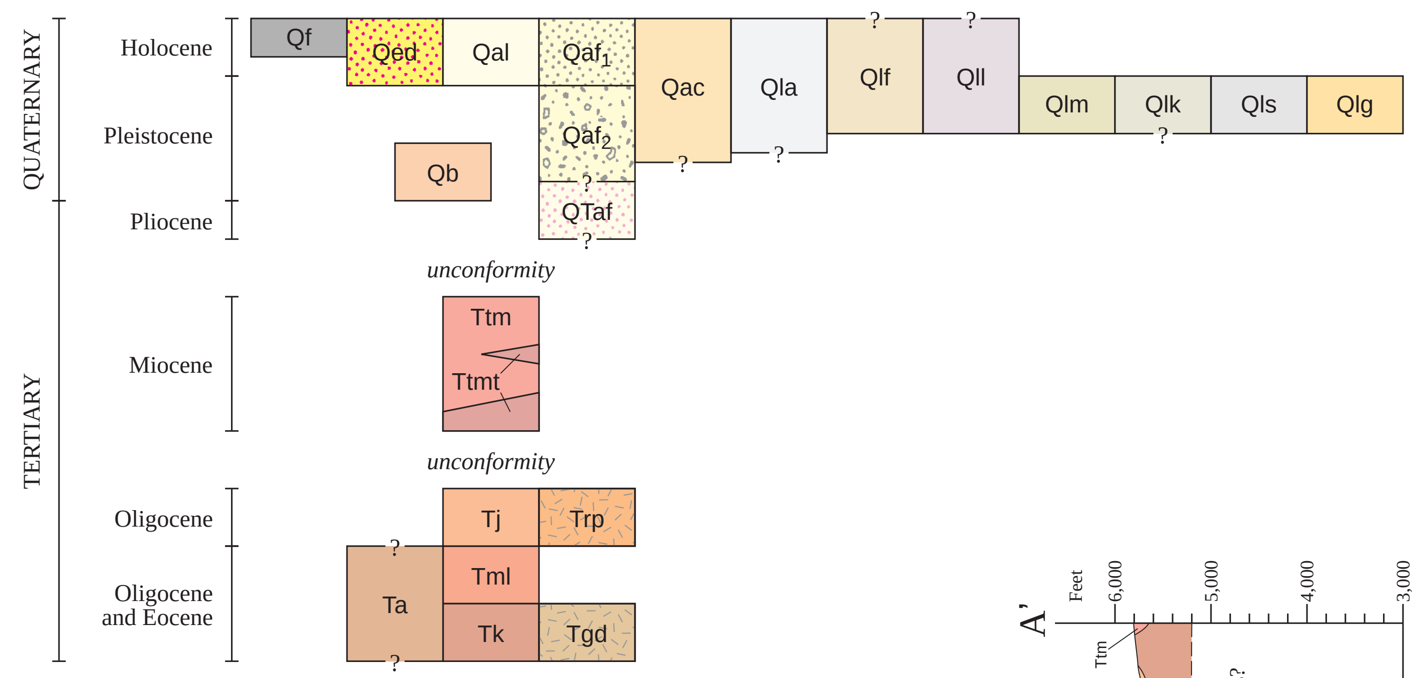
Tk Keg Tuff (Oligocene and Eocene) - Dark-red-brown to black, densely welded, moderately crystal-rich, dacitic ash-flow tuff; black vitrophyre locally present at base; abundant, bronze-weathering biotite prominent on surfaces parallel to layering; also contains plagioclase, biotite, quartz, and hornblende phenocrysts; dated by Shubat and Snee (1992) at 36.77±0.12 Ma; exposed thickness 500 feet (150 m).

Ta Andesite of Keg Pass (Oligocene and Eocene) - Heterogeneous, dark-colored flows and less abundant lahars; flows contain phenocrysts of andesine, biotite, hornblende, quartz, clinopyroxene, and magnetite; lahars commonly at base; lahars contain clasts of andesite, quartzite, and limestone; propylitic alteration common; age variable, but as old as 39 and as young as 37 million years old; exposed thickness about 20 feet (6 m).

STRATIGRAPHIC COLUMN

SYSTEM	SERIES	FORMATION / MAP UNIT		SYMBOL	THICKNESS Feet (Meters)	LITHOLOGY
QUAT.	Holocene	Quaternary deposits		Q	0-30 (0-9)	*unconformity*
	Pleistocene	Basalt of Crater Bench		Qb	0-20 (0-6)	
TERTIARY	Pliocene	Older alluvial-fan deposits		QTaf	0-60+ (0-18+)	*unconformity*
	Miocene	Topaz Mountain Rhyolite	Rhyolite flows, domes, and intrusions	Ttm	0-800 (0-240)	Ttmt
			Stratified tuff	Ttmt	0-260 (0-80)	*unconformity*
	Oligocene	Joy Tuff		Tj	0-540+ (0-160+)	Avg. 34.88 ± 0.06 Ma
	Oligocene and Eocene	Mt. Laird Tuff		Tml	0-100+ (0-30+)	Avg. 36.54 ± 0.06 Ma
		Andesite of Keg Pass		Ta	0-20+ (0-6+)	~37-39 Ma See correlation chart for probable relationships of Andesite of Keg Pass to Mt. Laird and Keg Tuffs.
		Keg Tuff		Tk	0-500+ (0-150+)	36.77 ± 0.12 Ma Ar-Ar

CORRELATION OF MAP UNITS



MAP AND CROSS SECTION SYMBOLS

- Contact, dashed and queried on cross sections where diagrammatic
- High-angle fault, dotted where covered, bar and ball on downthrown side, dashed and queried on cross sections where diagrammatic, arrows show direction of movement on cross section
- B——B Bonneville shoreline
- P——P Provo shoreline
- A——A' Line of cross section on map
- 17 Strike and dip of bedding
- 45 Strike and dip of layering in volcanic rocks
- PRH-1-1 △ Location of sample analyzed in this study (results in table 1 and appendices)
- THC-7 ○ Location of mineral exploration drill hole (see table 2)
- Transport direction on Tombolo