INTERIM GEOLOGIC MAP OF THE KEG PASS QUADRANGLE JUAB COUNTY, UTAH

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ABSTRACT

The Keg Pass 7½ minute quadrangle is in west-central Utah and includes the western part of Keg Mountain. The oldest rocks in the quadrangle are Cambrian quartzite and limestone. These rocks were deformed during the Sevier orogeny, which produced at least two thrusts in the quadrangle. Keg Mountain was an igneous center during the Tertiary Period and most of the quadrangle is underlain by volcanic and intrusive rocks. The major igneous events in the quadrangle were (1) eruption of the Dead Ox Tuff and subsidence of the associated Flint Spring cauldron, (2) eruption of the Keg Tuff and subsidence of the associated Keg cauldron, (3) eruption of the Mt. Laird Tuff and collapse of the associated Thomas caldera, (4) eruption of the Joy Tuff and collapse of the associated Dugway Valley cauldron, (5) eruption of the Dell Tuff from an unknown source, and (6) eruption of late Miocene alkali rhyolite. The caldera and cauldron margins in the Keg Pass quadrangle represent the eastern part of a large, late Eocene to early Oligocene igneous center that spans the Thomas Range, Keg Mountain, and northern Drum Mountains area. Mineral occurrences in the quadrangle probably formed during this igneous activity and consist of volcanic-hosted gold prospects, polymetallic veins, and precious metals-enriched jasperoid bodies. Deposition of sediments during late Pleistocene time was

dominated by Lake Bonneville, which covered much of the northern and western parts of the quadrangle. The lake transgressed to a maximum elevation of 5,221 feet (1,592 m), forming the Bonneville shoreline.

INTRODUCTION

The Keg Pass quadrangle is in north-central Juab County, Utah, approximately 38 miles (61 km) northwest of the town of Delta and 44 miles (71 km) west of Eureka (figure 1). The quadrangle includes the western part of Keg Mountain. Keg Mountain is a low range located between the Thomas Range to the west, the Simpson Mountains to the northeast, and Desert Mountain to the east. This report presents some of the results of a joint Utah Geological Survey-U.S. Geological Survey 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).

FIGURE 1 NEAR HERE

Previous geologic investigations at Keg Mountain 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 1960's, Shawe 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) mapped the Picture Rock Hills 7½ quadrangle, which covers the southwestern portion of Keg Mountain. Morris (1978) discovered hydrothermally altered rocks at northern Keg Mountain, and conducted a reconnaissance study of the area 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. As a result of this work, Lindsey 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. Pampeyan (1989) complied a 1:100,000 scale map that includes the quadrangle.

GEOLOGIC SETTING

Sedimentary rocks at Keg Mountain record an Early Cambrian marine transgression and Middle Cambrian deposition of miogeoclinal carbonate strata. Emplacement of thrust plates during the Cretaceous Sevier orogeny resulted in the Lower Cambrian Prospect Mountain Quartzite being thrust over Middle Cambrian carbonate rocks. Cenozoic volcanic rocks, igneous intrusions, and mineral deposits define the broad, east-west-trending Deep Creek-Tintic mineral belt (Shawe and Stewart, 1976; Stewart and others, 1977). Keg Mountain lies near the axis of this mineral belt. Regional extension produced late Eocene to late Miocene high-angle normal faults that control many of the mineral occurrences at Keg Mountain and in surrounding districts.

Tertiary Volcanic Rocks

Shawe (1972), Lindsey and others (1975), and Lindsey (1982) divided volcanism and related mineralization in the Thomas Range, Drum, Keg, and Desert Mountains into three stages. Their oldest stage (late Eocene to early Oligocene) consisted of eruptions of calc-alkaline, intermediate-composition volcanic rocks and related intrusions. In the Thomas Range, this oldest stage culminated with the eruption of the Mt. Laird Tuff and coincident 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 and may include polymetallic vein, polymetallic replacement, and gold occurrences at Keg Mountain.

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 middle stage apparently lacks associated mineral deposits.

The youngest stage of activity (Miocene to Pleistocene) consisted of bimodal alkali rhyolite-basalt volcanism. Lithophile mineral deposits formed during this stage include the world-class beryllium ore-bodies at Spor Mountain (figure 1) (Lindsey, 1977) and a variety of uranium (Lindsey, 1982) and fluorspar occurrences in the Thomas Range.

Quaternary Deposits

Deposition in Quaternary time was dominated by Lake Bonneville, an extensive late Pleistocene lake in the Great Basin in which Keg Mountain was an island (Currey and others, 1984). The lake began to rise in the Great Salt Lake basin about 32,000 years ago, and transgressed from the north and west into the Keg Pass quadrangle beginning in the northwest corner, probably about 20,000 years ago based on elevation-time relationships of Currey and Oviatt (1985). The lake transgressed to a maximum elevation of 5,221 feet (1,592 m) (present elevation, including isostatic rebound; Currey, 1982) at the Bonneville shoreline. This level was controlled by a threshold in southern Idaho where the lake overflowed into the Snake River. The Bonneville shoreline was occupied from about 16,000 to 14,500 years ago. At 14,500 years ago, the threshold failed and the lake dropped to the Provo level (4,838 feet; 1,476 m; Currey, 1982) where it once again stabilized and remained until about 13,500 years ago (Currey and Oviatt, 1985). At that time, the lake began a climate-controlled regression and was gone from the quadrangle shortly after 13,500 years ago, based on the present lowest elevation of 4,640 feet (1,415 m) in the northwest corner of the quadrangle, only 200 feet (60 m) below the Provo shoreline.

Prior to Lake Bonneville, Quaternary deposits were chiefly restricted to alluvium, colluvium, and alluvial-fan deposits. During and following the retreat of the lake, these processes continued as did eolian reworking of the lake deposits.

MAP UNITS

Cambrian Rocks

Prospect Mountain Quartzite (Cpm)

The Prospect Mountain Quartzite consists of pinkish-gray to tan, rusty-weathering, medium-grained, thick-bedded quartzite with small-scale crossbedding. In the Keg Pass quadrangle, the unit constitutes the upper plate of a thrust such that neither the upper or lower contacts of the unit are exposed. Just north of the quadrangle (in the Slow Elk Hills), however, Prospect Mountain Quartzite conformably underlies the Pioche Formation. Most exposures of Prospect Mountain Quartzite in the quadrangle are pervasively brecciated, presumably as a result of thrusting. Hintze and Robison (1975), following the recommendations of earlier workers, assigned a Lower Cambrian age to the unit. Unpublished drill-hole information indicates that the minimum thickness of the Prospect Mountain Quartzite in the Keg Pass quadrangle is 1,200 feet (366 m) (unpublished data, Getty Minerals Company). The drill hole that penetrated this thickness lies in the NW¼, section 34, T. 11 S., R. 10 W.

Pioche Formation

The Pioche Formation consists of two members, the informally designated lower member and the overlying Tatow Member (Hintze and Robison, 1975).

Lower member (Cpl): The lower member consists of intercalated horizons of medium-bedded, dark-green to black, ledgy quartzite, thin-bedded, dark-olive-green to black phyllitic quartzite, and dark-olive-green phyllite. Quartzite dominates in the lower parts of exposed sections and phyllite in the upper parts. Phyllite beds locally contain trilobite tracks. Rusty weathering is common. Hintze and Robison (1975) assign a Lower Cambrian age to the member. The base of the unit is not exposed in the Keg Pass quadrangle, but minimum thicknesses of 140 feet (43 m), 122 feet (37 m), and 287 feet (88 m) (figure 2) were measured to the north in the Table Mountain quadrangle. Hintze and Robison (1975) place the lower boundary of the unit at the first occurrence of siltstone in the section. The lower member occurs as thin slivers between thrusts in the northeast part of the quadrangle.

FIGURE 2 NEAR HERE

Tatow Member (Cpt): The Tatow Member (Hintze and Robison, 1975) consists of mottled orange-brown, oncolytic dolomite and white to gray oncolytic limestone. Exposures of the unit occur along the northern edge of the quadrangle in the north half of section 13, T. 11 S., R. 10 W., where it sits in the upper plate of a thrust fault. Excellent exposures of the unit occur north of the quadrangle in the Slow Elk Hills. There, the unit consists of thick-bedded, cliff-forming, orange-brown dolomite, which locally changes along strike to white to gray limestone. The Tatow Member is bound above and below by dark-olive-green phyllite, which mark the upper and lower contacts. Hintze and Robison (1975) assign a Middle Cambrian age to the unit. Three measured sections in the Table Mountain quadrangle contained complete sections of the Tatow Member that are 94 feet (29 m), 86 feet (26 m), and 58 feet (18 m) (figure 2) thick.

Howell Limestone (Ch)

The Howell Formation consists of light- to medium-gray, medium- to thick-bedded biosparite. It overlies the Pioche Formation on the upper plate of a thrust in the north half of section 13, T. 11 S., R. 10 W. We define the base of the formation in the Keg Pass quadrangle as the first massive, gray limestone overlying orange-weathering dolomite of the Pioche Formation. North of the quadrangle, in the Table Mountain quadrangle, the base of the Howell Formation is well exposed. There, the base of the Howell consists of intercalated olive-green-gray phyllite and carbonate rock (figure 2). Two measured sections in the Table Mountain quadrangle showed that the basal phyllite of the Howell is 56 feet (17 m) and 84 feet (26 m) (figure 2) thick. No complete section of the Howell Formation exists in the Keg Pass quadrangle, but folded, discontinuous exposures indicate a thickness in excess of 400 feet (120 m).

Ordovician and Cambrian Rocks

Undifferentiated Carbonate Rocks (OCl)

Undifferentiated Ordovician and Cambrian carbonate rocks (OCl) consist of light- to dark-gray, medium- to thick-bedded biosparite with minor shale and intraformational conglomerate interbeds. These rocks form the lower plates of thrusts in the northwestern part of the Keg Pass quadrangle and the adjacent Slow Elk Hills. The maximum exposed thickness of a continuous section is 200 feet (60 m) in the NW¼, section 31, T. 11 S., R. 9 W. At this location, a drill hole intersected a minimum of 500 feet (150 m) of carbonate rock. Insufficient exposures of the unit exist to permit positive identification, but it is probably the Howell Formation. The reason for this tentative identification is the presence of tan boundstone at the top of the exposed carbonate section in the southeast part of the Table Mountain quadrangle (northwest corner of section 8, T. 11 S., R. 9 W.). It is possible that this unit contains carbonate rocks belonging to the Chisholm Formation, Dome Limestone, Whirlwind Formation, or Swasey Limestone.

Tertiary Rocks

Unnamed Conglomerate (Tcg)

The unnamed conglomerate consists of well-rounded pebbles and cobbles of quartzite, chert, and limestone in a gray-green, sandy to silty matrix. The unit is very poorly exposed and occurs only in the center of the Keg Pass quadrangle (southwest part of section 25, T. 11 S., R. 10 W., and northwest part of section 36, T. 11 S., R. 10 W.). The distinguishing characteristic of the unit is the absence of volcanic rock fragments. The unnamed conglomerate unconformably overlies Paleozoic rocks. We infer that the unnamed conglomerate underlies volcanic rocks and presume that it represents the base of the Tertiary section, although its age is not known. The maximum exposed thickness of the unnamed conglomerate is 40 feet (12 m).

Andesite of Keg Spring (Ta)

Erickson (1963) originally described this unit and informally named it the "Keg Spring andesite and latite." Later, Shawe (1972) described these rocks as consisting of dark latite, rhyodacite, andesite, and andesitic basalt flows and agglomerates. Shawe mapped these rocks as a single unit and assigned them to his "older assemblage of rocks." In his report, Shawe divided his older assemblage into an older part corresponding 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 this unit as the "Keg Spring andesite." Pampeyan (1989) mapped these rocks according to Shawe's division into an upper and lower part. Pampeyan informally named the lower part the latitic, andesitic, and basaltic flows of Keg Mountain. Pampeyan informally named the upper part the latitic flows of Keg Mountain.

Our mapping shows that areas generally mapped as "Keg Spring andesite" by Staub and Erickson, and the lower part of Shawe's and Erickson's division, consist of several units: andesite, the Keg Tuff (a sub-regional ash-flow tuff that we define below), Mt. Laird Tuff (another sub-regional ash-flow tuff defined by Lindsey, 1979), and several intrusive units. Pampeyan's upper part of the "Keg Spring andesite" (his latitic flows of Keg

Mountain) consist of the Mt. Laird Tuff. In this report, we adopt the informal name "andesite of Keg Spring" and restrict its usage to andesitic flows and intercalated mudflow breccia. We retain the geographic part of the name (Keg Spring) even though the andesite of Keg Spring is not exposed at Keg Spring. The unit is best exposed in the SW¼, section 31, T. 11 S., R. 9 W.

The andesite of Keg Spring consists of a heterogeneous sequence of dark-colored andesite flows and andesitic mudflow breccia. Flow rocks dominate and contain phenocrysts of andesine, biotite, hornblende, quartz, clinopyroxene, and magnetite set in a trachytic matrix. Some flows are coarsely porphyritic, containing plagioclase crystals as long as 15 millimeter. Mudflow breccia commonly occurs at the base of the unit and contains clasts of andesite, quartzite, limestone, and Mt. Laird Tuff. Some of the basal mudflow breccia is deeply weathered, and contains rounded clasts of Paleozoic rocks and subangular Mt. Laird Tuff, suggestive of fossilized colluvium.

Modal analyses (figure 3 and appendix A) confirm the classification of these rocks as andesite. Figure 4 shows that whole-rock analyses (appendix B) of three samples of the unit plot within the dacite and trachyandesite compositional fields of Le Bas and others (1986).

Widespread propylitic alteration (in varying degrees of intensity) of the unit caused many mineralogic changes. Propylitic alteration caused alteration of plagioclase to montmorillonite + calcite, hornblende and clinopyroxene to chlorite + calcite + epidote, and biotite to chlorite. Magnetite rims commonly surround altered ferromagnesian minerals. Alteration of the matrix produced montmorillonite + chlorite + calcite + quartz + zeolite + pyrite.

Lindsey (1982) reported an average fission-track age (corrected from an earlier publication) of 39.4±0.7 Ma for samples of the andesite of Keg Spring collected in the eastern part of the quadrangle. Our mapping, however, shows that the age of the unit as a whole spans the ages of several other units in the quadrangle, and in places is younger than 36.5 Ma. In the NW¼, section 6, T. 12 S., R. 9 W. the Keg Tuff (dated at 36.77±0.12 Ma by Shubat and Snee, in press) clearly overlies the andesite of Keg Spring, indicating the minimum age of the unit at this location. In the adjacent Keg Mtn. Ranch quadrangle, however, clasts of Mt. Laird Tuff (dated at 36.54±0.06 Ma by Shubat and Snee, in press) occur in the andesite of Keg Spring, indicating the maximum age of the unit at this location. The andesite of Keg Spring is at least in part older than the Dead Ox Tuff (defined below) because clasts of andesite occur in the Dead Ox Tuff.

No complete section of the andesite of Keg Spring is exposed in the quadrangle. The maximum exposed thickness of the unit is 200 feet (60 m) in the NW¼, section 6, T. 12 S., R. 9 W.

FIGURES 3 AND 4 NEAR HERE

Andesite Porphyry (Tap)

Andesite porphyry occurs as small sub-volcanic intrusions that previous workers (Erickson, 1963; Shawe, 1972; Morris, 1987; Pampeyan, 1989) grouped with the andesite of Keg Spring (see above). We do not give this unit an informal name because of its limited extent and the small likelihood that it will be correlated with rocks in adjacent ranges. Andesite porphyry consists of dark brown to black, brown-weathering andesite with abundant phenocrysts (0.2 to 5 mm) of plagioclase, quartz, hornblende, biotite, and augite, and lesser amounts of zircon and magnetite in an aphanitic matrix. Flow features in the rock include bent biotite crystals and a weakly developed trachytic texture. Modal analyses (figure 3 and appendix A) confirm the classification of these rocks as andesite. Figure 4 shows that whole-rock analyses (appendix B) of two samples of the unit plot within the dacite compositional field of Le Bas and others (1986).

Andesite porphyry occurs as small plugs, less than 2,300 feet (700 m) in diameter, in the center of the quadrangle. Field relationships in the north half of section 6, T. 12 S., R. 9 W., show that the plugs intrude the andesite of Keg Spring and are overlain by the Keg Tuff, which is 36.77±0.12 Ma (Shubat and Snee, in press).

Pebble Dike (Tpd)

A pebble dike occurs in the north half of section 8, T. 12

S., R. 9 W., located 3,500 feet (1,070 m) north of Keg Pass. The pebble dike is small, only 100-foot (30-m) diameter. The pipe contains argillized and iron-stained clasts of volcanic rocks, Paleozoic rocks, and intrusive rocks. The matrix is not well exposed. We interpret that the unit has a pipe-like shape because it crops out in a circular area. The pebble dike cuts the andesite of Keg Spring, indicating the maximum age of the unit. This pebble dike is similar to two pebble dikes located in the adjacent Keg Mtn. Ranch quadrangle (section 33, T. 11 S., R. 9 W. and section 4, T. 12 S., R. 9 W.), both of which cut the Mt. Laird Tuff.

Dead Ox Tuff

We propose the formal geologic name, Dead Ox Tuff, for a lithostratigraphic unit at the formational rank. We name the unit for exposures of lithic-crystal tuff located near Dead Ox Wash. We designate the type locality as the northwest bank of a stream cut in the SE¼SW¼SW¼, section 29, T. 11 S., R. 9 W. (in the northeast part of the Keg Pass quadrangle). The Dead Ox Tuff consists of three informally named lithostratigraphic members: 1) a lithic-crystal tuff member (present at the type locality), 2) a megabreccia member, and 3) a stratified tuff member. Lithic-crystal tuff occurs as distinct beds, as at the type locality, as well as forming the matrix of megabreccia. We designate a stream cut in the NW¼SE¼SW¼, section 26, T. 11 S., R. 10 W. as a reference section for the megabreccia member of the

Dead Ox Tuff. This is one of the few locations where the matrix of the megabreccia is exposed. Exposures of the stratified tuff member occur in the SE¼SE¼, section 30, T. 11 S., R. 9 W. The Dead Ox Tuff is known to occur only at Keg Mountain. Many previous workers mapped the megabreccia member as Paleozoic rocks (Erickson, 1963; Shawe, 1972; Morris, 1987; Pampeyan, 1989) and did not recognize the other members. Staub (1975) mentioned the presence of coarse breccia with a possible igneous matrix at Keg Mountain, which may be our megabreccia member.

Lithic-crystal tuff member (Tdo): The lithic-crystal tuff member of the Dead Ox Tuff consists of tan, orange, and pale-green, thick-bedded, moderately to poorly welded, dacitic ash-flow tuff. It contains abundant lithic fragments, ranging from 1 millimeter to 40 centimeters in diameter, of quartzite, limestone, black phyllite, andesite, and pumice. The slightly flattened pumice clasts impart a crude layering to the rock. Phenocrysts consist of plagioclase, quartz, biotite, and lesser amounts of zircon and opaque minerals. Coarsely lithic portions (20-40 cm diameter clasts) resemble "mesobreccia" described by Lipman (1976) and weather to form cobble- and boulder-strewn slopes, with little exposed matrix.

Petrographic and chemical analyses indicate that the lithic-crystal tuff member is a dacite. Modal analyses (figure 3 and appendix A) of lithic-crystal tuff plot within the dacite compositional field of Streckeisen (1978). Figure 4 shows that whole-rock analyses (appendix B) of two samples of the lithic-crystal tuff plot within the dacite compositional field of Le Bas and others (1986).

Most exposures of the lithic-crystal tuff member in the Keg Pass quadrangle show the effects of argillic alteration. Pumice clasts alter to an illite-group clay (possibly celadonite) and minor kaolinite. Plagioclase crystals alter to kaolinite + calcite. Biotite alters to montmorillonite + calcite. The matrix of the tuff alters to the above mentioned clay minerals, calcite, and pyrite.

The contact between the lithic-crystal tuff member and underlying units has been identified at two localities. Near the type locality, drill-hole cuttings show that the tuff overlies Paleozoic limestone (unpublished data, American Gold Minerals Corporation). In the center of the quadrangle, the tuff overlies the unnamed conglomerate described above. Contacts between the lithic-crystal tuff member and overlying units are poorly exposed.

The age of the lithic-crystal tuff member has not been directly determined by radiometric dating. We interpret the age of the lithic-crystal tuff member to be about the same as the megabreccia member because lithic-crystal tuff forms the matrix of megabreccia. We bracket the age of the megabreccia member between about 36.5 and 39.4 Ma (see below).

The maximum exposed thickness of the lithic-crystal tuff member is about 60 feet (20 m).

Megabreccia member (Tdom): The megabreccia member consists of clasts of Prospect Mountain Quartzite, Pioche Formation, undifferentiated lower Paleozoic limestone, conglomerate, andesitic mudflow breccia, and andesite. Clast sizes range from less than 1 foot to 800 feet (20 cm to 240 m) in diameter. Most clasts are 10 to 200 feet (3 to 60 m) in diameter. The matrix of the megabreccia member consists of the poorly welded lithic-crystal tuff member of the Dead Ox Tuff (described above). The matrix was observed at two localities. One locality is a stream cut in the NW¼SE¼SW¼, section 26, T. 11 S., R. 10 W. (the reference section for the megabreccia member), where highly altered, poorly exposed, poorly welded tuff occurs between clasts. A thin rind of ash-flow tuff coats the megabreccia clasts at this locality. Another exposure of megabreccia in the SE¼NE¼NW¼, section 31, T. 11 S., R. 9 W. contains several low, rubbly outcrops of lithic-crystal tuff that we interpret to be matrix. This exposure is one of the few areas of megabreccia that sits above the Lake Bonneville level. We speculate that mantling of megabreccia by lake sediments accounts for the paucity of exposed matrix.

An interesting property of the megabreccia is that nearly all of the quartzite clasts, and some of the limestone clasts, are intensely and pervasively brecciated. Clasts in the megabreccia display two types of breccia textures. The first (and most abundant) texture displayed by clasts consists of monolithologic, angular, entirely matrix-supported breccia with a fine-grained matrix of comminuted material. Figure 5 shows a typical clast, consisting of a quartzite breccia. This texture indicates that a period of intense and pervasive brecciation affected the quartzite and limestone prior to their incorporation into the megabreccia. The second texture displayed by clasts consists of a network of many small fractures and faults, which are restricted to the clast. This textures could represent rocks that were deformed during thrusting and later incorporated into the megabreccia. Andesite clasts, which consist of flow and debris-flow lithologies, are not brecciated.

FIGURE 5 NEAR HERE

We bracket the age of the megabreccia member between about 36.5 and 39.4 Ma. The megabreccia member is older than 36.49±0.15 Ma (Shubat and Snee, in press), which is the age of one of the dacite porphyry intrusions that cut the megabreccia member. The megabreccia member is younger than the oldest part of the andesite of Keg Spring, because andesite clasts occur in the megabreccia. Lindsey (1982) reported an age of 39.4±0.7 Ma for the andesite of Keg Spring. We interpret the age of the megabreccia member to be the same as the lithic-crystal tuff member because lithic-crystal tuff forms the matrix of megabreccia

The megabreccia member unconformably overlies Paleozoic rocks. The upper contact of the unit is not preserved and no complete sections of the megabreccia member are present. The largest exposed thickness of megabreccia is 280 feet (85 m).

Stratified tuff member (Tdow): The stratified tuff member consists of tan to orange, poorly exposed, thin-bedded to laminated (1 cm to less than 1 mm) volcanic sandstone, siltstone, and ash-rich tuff. Sand-sized crystal fragments consist of quartz, plagioclase, and biotite. Lithic fragments consist of quartzite, limestone, and volcanic rock. The unit is restricted to the southeast part of section 30, T. 11 S., R. 9 W. The unit is intruded by a dacite porphyry plug and as a result is pervasively altered. One sample contained an alteration assemblage consisting of quartz, calcite, potassium feldspar, biotite, and pyrite. The unit overlies the andesite of Keg Spring. Its age is bracketed between 36.49±0.15 Ma (Shubat and Snee, in press), the age of a dacite porphyry intrusion similar to the one that cuts the stratified tuff member, and 39.4±0.7 Ma, the age of the andesite of Keg Spring (Lindsey, 1982). The unit appears to be less than 40 feet (12 m) thick.

Origin of the Dead Ox Tuff: The origin of the megabreccia member of the Dead Ox Tuff is equivocal. The megabreccia member may have originated by one of two processes (or a combination of both): (1) eruption of megabreccia from a vent (Shawe and Snyder, 1988) or (2) collapse of caldera walls during caldera subsidence (Lipman, 1976). We favor the first of these processes, eruption from a vent, because of the textures present in the intensely brecciated clasts of quartzite and limestone (figure 5). We interpret this brecciation to have originated in the subsurface by a process similar to that described by Shawe and Snyder (1988) as deep-level, subvolcanic "explosion-breccia." Nutt and others (1991) describe similar breccias in the Detroit district (in the nearby Drum Mountains). Nutt and others interpret breccia complexes there to have formed in the subvolcanic environment, near the roof of an inferred igneous intrusion. If the intensely brecciated clasts in the megabreccia at Keg Mountain did originate in a subvolcanic environment, then they must have been transported to the surface during eruption of the enclosing Dead Ox tuff. The presence of andesitic debris-flow clasts in the megabreccia indicates, if the megabreccia was erupted, that the erupted material picked-up and incorporated surficial rocks during emplacement. We envision an eruption similar to that which produced the Aira caldera in Japan (Aramaki, 1984) as a model for the Dead Ox Tuff eruption. The Aria eruption produced a depression filled with megabreccia and tuff that lacks distinct ring-faults.

The source of the Dead Ox Tuff cannot be unequivocally identified. However, the presence of large clasts in the megabreccia member argues for a nearby vent. Also, the absence of a thick section of Dead Ox Tuff argues against a large source caldera. With these constraints in mind, we speculate that the source was an unexposed, ill-defined cauldron, which we name the

Flint Spring cauldron (see later section), located in the north-central part of the quadrangle (figure 6).

FIGURE 6 NEAR HERE

Keg Tuff (Tk)

We propose the formal geologic name, Keg Tuff, for a lithostratigraphic unit at the formational rank. We name the unit the Keg Tuff because exposures of it cover much of the western part of Keg Mountain. We designate the type locality as the SW¼SW¼, section 1, T. 12 S., R. 10 W. (in the center of the Keg Pass quadrangle). To date, the Keg Tuff is known to occur only at Keg Mountain. Previous mappers grouped this unit with the andesite of Keg Spring (see above)(Erickson, 1963; Shawe, 1972; Staub, 1975; Morris, 1987; Pampeyan, 1989).

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. Vitrophyre also locally occurs above the base, indicating that at least two cooling units are locally present. Abundant bronze-weathering biotite, prominent on surfaces parallel to layering, characterize the unit. Phenocrysts are 1 to 6 millimeters in diameter 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 welded and deformed shard outlines locally preserved. Many quartz and feldspar phenocrysts are broken or shattered. Biotite crystals are bent. Figure 7 shows the typical textures and mineralogy present in the Keg Tuff.

FIGURE 7 NEAR HERE

Petrographic and chemical analyses indicate that the Keg Tuff is a dacite. Modal analyses (figure 3 and appendix A) of Keg Tuff plot within the dacite compositional field of Streckeisen (1978). Figure 4 shows that whole-rock analyses (appendix B) of eight samples of Keg Tuff plot within the dacite compositional field of Le Bas and others (1986).

No complete section of the Keg Tuff exists in the Keg Pass quadrangle, however, the lower and upper contacts are exposed at many locations. The Keg Tuff overlies the andesite of Keg Spring over much of Keg Mountain. Irregularities in the contact, as shown in the east half of section 11, T. 12 S., R. 10 W., indicate that the tuff erupted onto an irregular paleotopographic surface. Map units that overlie the Keg Tuff are the Mt. Laird Tuff and the Joy Tuff. Irregular contacts between the Keg Tuff and overlying units indicate that the overlying units likewise erupted onto an irregular paleotopographic surface developed on the Keg Tuff. Map units that intrude the Keg Tuff are granodiorite porphyry, dacite porphyry, and rhyolite porphyry.

Shubat and Snee (in press) dated biotite crystals from the Keg Tuff at 36.77±0.12 Ma (table 1). The dated sample was collected from locality 1, figure 8, in the southeast part of the Keg Pass quadrangle. We consider this date to be a good representation of the true age of the formation because it is older than the date for the rhyolite porphyry intrusions (35.14±0.15 Ma, table 1) that cut the Keg Tuff and younger than the date for the underlying andesite of Keg Spring (39.4±0.7 Ma) reported by Lindsey (1982). The date for the Keg Tuff is also slightly older than the stratigraphically younger Mt. Laird Tuff (36.54±0.06 Ma, table 1) and a dacite plug that cuts the Keg Tuff (36.49 ± 0.15 Ma, table 1). Shubat and Snee (in press), however, noted that the differences between the dates for the Keg Tuff, Mt. Laird Tuff, and dacite plug are not statistically significant.

The origin of the Keg Tuff is poorly understood. Its restricted distribution (known only to occur at Keg Mountain) suggests that it erupted from a local vent. We propose that it erupted from a poorly defined cauldron, the Keg Cauldron (see later section on the Keg cauldron), located in the southwest part of the Keg Pass quadrangle (figure 6).

No complete section of the Keg Tuff is exposed in the quadrangle. The maximum exposed thickness of the Keg Tuff is 540 feet (165 m), near the type section in the center of the quadrangle. Map relations suggest that there was a period of tilting and erosion after eruption of the Keg Tuff and before eruption of the Mt. Laird Tuff. Thus, the original thickness and distribution of the Keg Tuff may have been greater than what is preserved.

TABLE 1 NEAR HERE

FIGURE 8 NEAR HERE

Granodiorite Porphyry (Tgd)

Granodiorite porphyry occurs as a stock and a plug in the south-central part of the Keg Pass quadrangle and in the north-central part of the adjacent Picture Rock Hills quadrangle (Shubat, unpublished data), respectively. We do not give this unit an informal name because of its limited extent and the small likelihood that it will be correlated with rocks in adjacent ranges. Erickson (1963) and Shawe (1972), in their reconnaissance studies of Keg Mountain, mapped these rocks as tuff and quartz-latitic welded ash-flow tuff, respectively. Staub (1975) referred to these rocks as the Keg granodiorite porphyry. Pampeyan (1989) informally named the stock in the Keg Pass quadrangle the granodiorite stocks of Keg Mountain.

Granodiorite porphyry consists of light olive-green to pinkish-green, holocrystalline porphyry containing coarse (2 to 12 mm) phenocrysts of plagioclase, quartz, biotite, hornblende, and clinopyroxene and lesser amounts of magnetite and zircon set in a fine-grained hypidiomorphic-granular matrix of quartz, plagioclase, and potassium feldspar. Modal analyses (figure 3 and appendix A) confirm the classification of these rocks as granodiorite. Figure 4 shows that a whole-rock analysis (appendix B) of the unit plots within the dacite compositional field of Le Bas and others (1986). The unit is pervasively propylitized in the Keg Pass quadrangle. 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. This date agrees well with cross-cutting relationships observed in the field. Granodiorite porphyry intrudes the 36.77±0.12 Ma Keg Tuff and is cut by 35.14±0.15 Ma rhyolite dikes and plugs.

Because of similarities in whole-rock composition, age, and spatial distribution, we consider the granodiorite porphyry to be comagmatic with the Keg Tuff. The stock in the southeast part of the Keg Pass quadrangle may have been intruded into the center of the Keg cauldron (see below) after eruption of the Keg Tuff.

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 ash-flow tuff unit at Keg Mountain, some of which corresponds to areas we mapped as Mt. Laird Tuff. Much of the area mapped as latitic flows of Keg Mountain by Pampeyan (1989) corresponds to areas we mapped as Mt. Laird Tuff.

Mt. Laird Tuff consists of lavender, pale green, dark green, and brown, moderately welded, ash-flow tuff, tuff-breccia, lapilli-tuff, and probable flows and hypabyssal intrusions of dacitic composition (figure 9). A distinctive feature of the Mt. Laird Tuff is the presence of abundant, coarse (2 - 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 often difficult to distinguish in the field, but are well-defined in thin section. Vitrophyre locally occurs at the base of the unit. A volumetrically minor facies consists of accretionary lapilli-block tuff with a distinctive black, aphyric matrix that contains the accretionary lapilli (figure 9).

In thin section, observable ash-flow textures consist of shattered plagioclase phenocrysts and ragged and bent biotite grains. Many samples show moderate propylitic alteration. The matrix, originally glassy, is altered to a mixture of fine-grained clay (montmorillonite) and silica with zeolite minerals filling voids. Plagioclase is locally altered to calcite and clay minerals. Ferromagnesian minerals are locally altered to chlorite, epidote, calcite, and magnetite.

Modal analyses (figure 3 and appendix A) indicate that, based on phenocryst content, these rocks should by named andesite. Figure 4, however, shows that whole-rock analyses (appendix B) of the unit plot within the dacite compositional field of Le Bas and others (1986). We prefer the name dacite as opposed to andesite because of the high silica content of the rocks.

Shubat and Snee (in press) dated hornblende and biotite crystals from two different samples of the Mt. Laird Tuff at 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 (Geochron Laboratories). Lindsey (1982) reported a fission-track date of 36.4±1.6 Ma for the Mt. Laird Tuff, but because of field relations and other dates he considered its true age to be about 39 Ma. We consider the true age of the Mt. Laird Tuff to be close to the $^{40}Ar/^{39}Ar$ date of 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 cross-cutting rhyolite porphyry intrusions (35.14±0.15 Ma).

The Mt. Laird Tuff closely resembles the dacite porphyry unit described below in many ways. The two map units are similar in hand sample appearance, spatial distribution, modal analyses (figure 3), chemical analyses (figure 4), and nearly identical in age (table 1). For these reasons we consider the Mt. Laird Tuff and dacite porphyry to be comagmatic. The difference between the two map units is this: rock bodies mapped as dacite porphyry are clearly intrusive in origin.

Lindsey (1982) associated the eruption of the Mt. Laird Tuff with collapse of the Thomas Caldera (figure 6). Over most of the Keg quadrangle, the unit appears to be outflow from the Thomas Caldera. Evidence supporting this interpretation is that, where top and bottom contacts are exposed, the unit is thin. Its maximum exposed thickness in the Keg Pass quadrangle is 220 feet

(67 m). In the northeast part of the quadrangle, however, a vent facies of the Mt. Laird may be present (figure 6). Evidence for a Mt. Laird Tuff vent in this area consists of the presence of pebble dikes containing Mt. Laird clasts, coarse fragmental textures in the tuff, an accretionary lapilli-block tuff facies, probable hypabyssal intrusions, and steeply dipping layering.

No complete section of the Mt. Laird Tuff is exposed in the quadrangle. The maximum exposed thickness of the Mt. Laird Tuff is 220 feet (67 m)

Dacite Porphyry (Tdp)

Dacite porphyry occurs as several small, hypabyssal plugs, less than 3,000 feet (900 m) in diameter, located in the center of the Keg Pass quadrangle. We do not give this unit an informal name because of its limited extent in the quadrangle. Rocks mapped as dacite porphyry in this study probably correlate with similar rocks in the Thomas Range that Lindsey (1979) informally named "intrusive porphyry" and included within the definition of the Mt. Laird Tuff. Previous workers that mapped at Keg Mountain did not recognize this unit.

Dacite porphyry contains abundant coarse (2 to 10 mm) phenocrysts of plagioclase, quartz, biotite, hornblende, and magnetite set in a matrix of plagioclase, quartz, and sanidine microphenocrysts and aphanitic material. Modal analyses (figure 3 and appendix A) indicate that, based on phenocryst content, these rocks should by named andesite. Figure 4, however, shows that whole-rock analyses (appendix B) of the unit plot within the dacite compositional field of Le Bas and others (1986). We prefer the name dacite as opposed to andesite because of the high silica content of the rocks. The unit is pervasively propylitized in the Keg Pass quadrangle. Plagioclase is altered to clay minerals and calcite, biotite to chlorite and magnetite, and hornblende to chlorite and calcite.

Shubat and Snee (in press) dated biotite from the unit at 36.49±0.15 Ma (table 1). This date closely corresponds to our date of 36.2±1.4 Ma (K-Ar on biotite, Geochron Laboratories). For the reasons given above, we consider the dacite porphyry and the Mt. Laird Tuff and to be comagmatic.

Regional aeromagnetic data (Kucks, 1991) show a circular, high-amplitude magnetic high (with a paired dipole low to the north) that straddles the northern part of the east-central edge of the Keg Pass quadrangle (figure 6). We interpret this anomaly as representing a buried dacite porphyry stock because of its proximity to several mapped dacite porphyry plugs and a possible Mt. Laird vent area described above (figure 6). AMT resistivity data (D. Campbell, verbal communication, 1990) support this interpretation. Dacite porphyry plugs are of economic interest because of the presence of anomalous amounts of gold in the argillic/pyritic alteration halo around some of the intrusions.

Quartz Monzonite (Tqm)

Quartz monzonite occurs as one or two plugs, less than 2,000 feet (610 m) in diameter, in the central part of the Keg Pass quadrangle. We do not give this unit an informal name because of its limited extent and the small likelihood that it will be correlated with rocks in adjacent ranges. Previous workers that mapped at Keg Mountain did not recognize this unit.

Quartz monzonite is a gray, rusty-weathering, porphyritic rock containing phenocrysts (0.3 to 10 mm) of plagioclase, biotite, quartz, hornblende, potassium feldspar, magnetite, and zircon set in a fine-grained matrix of potassium feldspar and quartz. The rock contains sparse dark-green xenoliths. A modal analysis (figure 3 and appendix A) of the phenocrysts in the rock indicate that it would be classified as a quartz diorite. Considering the large amount of potassium feldspar in the matrix, however, we feel that a more appropriate name is quartz monzonite. Figure 4 shows that a whole-rock analysis (appendix B) of the unit plots within the dacite compositional field of Le Bas and others (1986).

Quartz monzonite is locally argillized, silicified, and pyritically altered. Plagioclase is altered to calcite + clays and hornblende to chlorite + calcite. Potassium feldspar and biotite crystals are mostly unaltered. Faint thin silica overgrowths occur on quartz phenocrysts. Margins of the intrusions show strong pyritic alteration.

The age of quartz monzonite is poorly constrained. It has not been dated and map relations only show that it is younger than the Mt. Laird Tuff (see above).

Joy Tuff (Tj)

Lindsey (1979) named the Joy Tuff for exposures near the Joy townsite in the nearby Thomas Range and identified three informal members. Only the lowermost of his members, the crystal tuff member, is present at Keg Mountain. Erickson (1963) first recognized the presence of rhyolitic ash-flow tuff at Keg Mountain. Shawe (1972) refined the mapping by Erickson. Some of the rhyolitic ash-flow tuff mapped by Shawe corresponds to areas we mapped as Joy Tuff. Staub mapped an informal "Red Mountain Crystal Tuff" unit in the adjacent Picture Rock Hills quadrangle that 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 mapped as Joy Tuff at Keg Mountain by Pampeyan (1989) corresponds to areas we mapped as Joy Tuff, Mt. Laird Tuff, and Dell Tuff (see below).

Joy Tuff consists of red-brown to pink, moderately to densely welded, rhyolitic ash-flow tuff. A black vitrophyre locally 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 adjacent Picture Rock Hills quadrangle, suggesting the presence of multiple cooling units. The Joy Tuff contains abundant, 1 to 8 millimeter 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.

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 3 and appendix A) confirm the classification of these rocks as rhyolite. Whole-rock analyses of the unit (appendix B) plot within the rhyolite compositional field of Le Bas and others (1986).

Shubat and Snee (in press) dated sanidine and biotite crystals from a sample of basal vitrophyre of the Joy Tuff at 34.88±0.06 Ma (table 1). This date shows a marked discordance with 9 fission-track ages reported by Lindsey (1982) that average 38.0±0.7 Ma. The improved accuracy of the $^{40}Ar/^{39}Ar$ age spectrum dating method is responsible for this discrepancy. Unpublished data from the type section of the Joy Tuff (C. J. Nutt, verbal communication., 1992) confirm the date obtained for the unit by Shubat and Snee. We believe that the date by Shubat and Snee represents the true age of the unit because it is consistent with the observation that Joy Tuff overlies Mt. Laird Tuff. The date by Shubat and Snee (in press) is nearly identical with the date for rhyolite porphyry (see below) that we consider to be comagmatic with the Joy Tuff.

Lindsey (1982) believed the source of the Joy Tuff to be the Dugway Valley cauldron, located between Keg Mountain and Topaz Mountain. The small thickness of the Joy Tuff in the Keg Pass quadrangle suggests that it is outflow from the cauldron. It is possible, however, that the Joy Tuff in the quadrangle was deeply eroded and was once much thicker.

No complete section of the Joy Tuff is exposed in the quadrangle. The maximum exposed thickness of the Joy Tuff is 80 feet (24 m). In the adjacent Picture Rock Hill quadrangle it is more than 600 feet (180 m) thick.

Rhyolite Porphyry (Trp)

Rhyolite porphyry occurs as many small, hypabyssal dike-like plugs that lie along two linear, subparallel, northeast-trending zones (lineaments) described below. We do not give this unit an informal name because of its limited extent in the quadrangle and the small likelihood that it will be correlated with rocks in adjacent ranges. Shawe (1972) first recognized these intrusions and named them intrusive quartz latite. Lindsey and others (1975) dated the unit. 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 pinkish, light-tan weathering rhyolite porphyry with coarse (as large as 1 cm) phenocrysts of orthoclase, quartz, plagioclase, and biotite and lesser zircon and opaque minerals. The matrix consists of patches of aphanitic crystallites, resembling devitrified glass, that is locally altered to zeolite minerals. A variety of textures are present in the rock. Near the margins of the intrusions, the rock is nearly aphyric, contains sparse sanidine crystals, and has a platy parting. This fabric grades laterally into massive rhyolite porphyry within 10 feet (3 m) of the contact. Some exposures show a "filter pressed" texture that consists of large, cracked crystals of quartz, orthoclase, and plagioclase with minor, interstitial matrix.

Modal analyses (figure 3 and appendix A) confirm the classification of these rocks as rhyolite. Whole-rock analyses (figure 4 and appendix B) of the unit plot within the rhyolite compositional field of Le Bas and others (1986).

Shubat and Snee (in press) dated sanidine and biotite from one of these plugs in the Keg Mountain Ranch quadrangle at 35.14±0.15 Ma (table 1). Lindsey and others (1975) dated a rhyolite porphyry plug in the Keg Pass quadrangle at 30.8±1.8 Ma. We interpret the true age of the rhyolite porphyry intrusions to be near the date given by Shubat and Snee (in press) because they cut the Joy Tuff (in the Picture Rock Hills Quadrangle) but do not appear to cut the 32.0 Ma Dell Tuff (see below).

The rhyolite porphyry intrusions and the Joy Tuff are similar in many ways. The two units have similar phenocryst assemblages (figure 3) and chemical analyses (figure 4). Most importantly, they have nearly identical dates (table 1). For these reasons we consider the rhyolite porphyry to be the hypabyssal, comagmatic equivalent of the Joy Tuff.

Two lines of evidence suggest that a concealed pluton underlies the Keg Pass area. Deep resistivity (AMT) soundings collected along a north-south profile across Keg Mountain (Campbell and Visnyei, 1989) show a resistive body at depth beneath Keg Pass that has a resistivity signature (> 200 ohm-meters) typical for many igneous rocks in the region (D. Campbell, verbal communication, 1990). 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 6). This magnetic signature is consistent with many known intrusions in the Deep Creek-Tintic mineral belt. These data support our interpretation that a granitic body lies at depth beneath the Keg Pass area. The rhyolite porphyry plugs exposed at the surface in the area may be related to such an intrusion.

Dell Tuff (Td)

Lindsey (1979) formally named the Dell Tuff for exposures near the Dell in the nearby Thomas Range and reported the presence of the unit in the Keg Pass quadrangle. Staatz and Carr (1964) first identified the unit in the Thomas Range and called it a quartz-sanidine crystal tuff. At Keg Mountain, Erickson (1963) mapped Dell Tuff as part of his informal "Keg Mountain Ignimbrite." Shawe (1972) mapped a rhyolitic ash-flow tuff at Keg Mountain that in part corresponds to the Dell Tuff. Part of the area mapped by Morris (1987) as the Dell Tuff corresponds to areas we mapped as the Dell Tuff. Plavidal (1987) mapped the Dell Tuff in the Keg Mountain Ranch quadrangle. Pampeyan (1989) mapped the Dell Tuff as the Joy Tuff.

The Dell Tuff is a pink to tan, poorly to moderately welded, crystal-rich, rhyolitic ash-flow tuff. It contains abundant phenocrysts of quartz, sanidine, plagioclase, and biotite that range in size from 2 to 10 millimeter. Trace amounts of hornblende, opaque minerals, zircon, and large sphene crystals are also present. Phenocrysts are shattered, broken, and bent. The matrix consists of glass that is locally devitrified and spherulitic. Shard structures are preserved in the matrix. Lithic fragments (volcanic) constitute as much as 19 percent of the rock. The rock is unaltered.

Modal analyses (figure 3 and appendix A) confirm the classification of these rocks as rhyolite. Whole-rock analyses of the unit (appendix B) plot within the rhyolite compositional field of Le Bas and others (1986).

Lindsey and others (1975) dated three samples from Keg Pass, ranging in age from 32.5±1.6 to 33.8±1.3 Ma. Lindsey (1982) established an average age of 32.0 ± 0.6 Ma for the formation. We believe that this date is close to the true age because it is consistent with field relations. The Dell Tuff overlies 35.14±0.15 Ma rhyolite porphyry intrusions and is overlain by upper Miocene alkali rhyolite.

Recent paleomagnetic work by J.L. Hanna (verbal communication, 1989) showed that the Dell Tuff at the type locality ("The Dell," in the Thomas Range) has a normal magnetic polarity and that the Dell Tuff at Keg Pass has a reverse polarity, indicating that the Dell Tuff consists of at least two cooling units. Multiple cooling units, however, were not observed in the field.

The source caldera of the Dell Tuff has not been found. Lindsey (1982) speculated that the source should lie in or near Keg Mountain or the Thomas Range.

The greatest thickness of Dell Tuff at Keg Mountain is in the Keg Mountain Ranch quadrangle where it is 490 feet (150 m) thick. In the Keg Pass quadrangle, its thickness ranges from 0 to 350 feet (110 m). It unconformably overlies older rocks and is unconformably overlain by the Topaz Mountain Rhyolite.

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. We follow the usage proposed by Lindsey (1979) in this report. Many previous workers recognized and mapped the Topaz Mountain Rhyolite at Keg Mountain (Erickson, 1963; Shawe, 1972; Morris, 1987; Plavidal, 1987; and Pampeyan, 1989). Staub (1975) mapped alkali rhyolite in the area but informally named the unit the "Keg Mountains Rhyolite," which (unfortunately) is approximately the name given by Shawe (1972) (rhyolite of Keg Mountain) for a different unit present in the

Keg Mountain Ranch quadrangle. Following Shawe, Morris (1987) distinguished two alkali rhyolite units, the older rhyolite of Keg Mountain and the younger Topaz Mountain Rhyolite. Pampeyan (1989) introduced a new informal nomenclature for alkali rhyolite in the area that we do not use.

We mapped two informal members of the Topaz Mountain Rhyolite: (1) alkali rhyolite and vitrophyre, and (2) stratified tuff. This subdivision is consistent with the usage by Lindsey (1979; 1982). In general, stratified tuff underlies alkali rhyolite flows. In many areas, however, stratified tuff occurs as discontinuous, wedge-shaped intercalations between flows.

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, the stratified tuff beneath a flow has been fused to form a vitrophyre. This rock, called "fused tuff" by Christiansen and Lipman (1966), contains collapsed pumice clasts and strongly resembles ash-flow tuff.

Alkali rhyolite and vitrophyre (Ttm): This unit consists of flows, domes and dike-like, shallow intrusions of alkali rhyolite. Alkali rhyolite consist of white, gray, and purplish rhyolite containing sparse (10 to 15 percent), small (2 mm) phenocrysts of quartz and sanidine and lesser plagioclase, biotite, and opaque minerals. 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. Rare topaz crystals occur in cavities as a vapor-phase crystals. In addition to topaz, Staub (1975) identified small crystals of hematite, bixbyite, and pseudobrookite that line cavities.

Flows and domes of alkali rhyolite were probably erupted from local vents. In some cases continuous exposures can be followed from flow rock at higher altitudes to dike-like intrusive bodies at lower altitudes. Most dike-like bodies and eruptive masses have north-northwest trends, forming several lineaments in the quadrangle (see below).

Lindsey and others (1975) reported 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 dates of 6.7±0.3 and 6.9±0.3 Ma for the Keg Mountain Rhyolite, which underlies and is compositionally gradational with the Topaz Mountain Rhyolite. We believe that the true age of the Topaz Mountain Rhyolite at Keg Mountain is close to the date of 6.3±0.1 Ma reported by Lindsey (1982).

No complete section of flows of Topaz Mountain Rhyolite is present in the quadrangle. Its maximum exposed thickness is 590 feet (180 m). Field relations in the Keg Mountain Ranch quadrangle indicate that it was deposited on a paleotopographic surface consisting of gently rolling hills.

Stratified tuff (Ttmt): Stratified tuff consists of pale tan to orange, massive- to thin-bedded, nonwelded, lithic-rich rhyolitic tuff and volcanic sandstone. The rock contains a variety of volcanic rock fragments, abundant pumice clasts, and sparse crystal fragments in an ash matrix. The unit was deposited as air-fall, ash-flow, and ground-surge eruptions (Bikun, 1980) and as water-lain deposits. The unit is extensively zeolitized and feldspathically altered throughout Keg Mountain (Lindsey, 1975). Lindsey showed that glass in the unit was progressively altered to clinoptilolite and potassium feldspar.

Beds of stratified tuff range in thickness from 0 to 140 feet (43 m).

Quaternary and Tertiary Deposits

Older Alluvial-Fan Deposits (QTaf)

Coarse-grained older alluvial-fan deposits of probable early Pleistocene age, perhaps Pliocene age (Christenson and Purcell, 1985), are found on the west flank of Keg Mountain between the mountains and the Bonneville shoreline (5,221 feet; 1,592 m). Deposits are undergoing erosion and original fan surfaces have been removed, forming a series of finger-like ridges (commonly termed whalebacks or ballenas) up to 60 feet (18 m) above modern streams. These older alluvial fans are now beheaded or detached from their original source areas as the less erosion-resistant volcanic rock of the mountain front is removed. Deposits are at least 60 feet (18 m) thick, and perhaps more, where exposed. Similar-age deposits of unknown thickness may underlie lacustrine deposits along the northern and western edges of the quadrangle in Dugway Valley. The deposit is poorly sorted and consists 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, and where the deposit has been eroded and reworked by Lake Bonneville (unit Qlg/QTaf), the surface is strewn with large, weathered, case-hardened boulders.

Quaternary Deposits

Intermediate-Age Alluvial-Fan Deposits (Qaf_2)

Alluvial-fan deposits of middle to late Pleistocene age are found at various levels above the Bonneville shoreline surrounding Keg Mountain. These alluvial-fan deposits predate initial occupation of the Bonneville shoreline 16,000 years ago. Fan surfaces are inactive and undergoing erosion as streams cut down following the regression of Lake Bonneville. Fan surfaces are generally 3-20 feet (1-6 m) above modern channels, and a gradation in morphology (degree of dissection), level, and presumably age is apparent from the youngest of these intermediate-age fans back to the older Quaternary and Tertiary alluvial-fan deposits (QTaf). In mountain-front locations, 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 Dugway Valley to the north and west. Deposits are poorly stratified, poorly sorted mixtures of clay, silt, sand, gravel, cobbles, and boulders of both debris-flow and stream-flow origin, and are generally less coarse than adjacent older alluvial-fan deposits (QTaf) at similar mountain-front positions.

Lacustrine Marl (Qlm)

Fine-grained deep-lake sediments of marl, clay, silt, and sand, including ostracode- and gastropod-rich layers, are found in the northwest corner of the quadrangle. Deposition occurred in latest Pleistocene time, chiefly while Lake Bonneville occupied the Bonneville shoreline. Exposed thicknesses of up to 6 feet (2 m) are found locally, but total thickness is unknown. These deposits are locally overlain by thin veneers of alluvial gravel and eolian sand.

Lacustrine Sand (Qls)

Sandy shore-zone and offshore deposits with clay, silt, and gravel are found below the Bonneville shoreline and are most extensive in the northern part of the quadrangle between the Bonneville and Provo shorelines. These deposits are of latest Pleistocene age, deposited chiefly while Lake Bonneville occupied the Bonneville shoreline, and may be up to 30 feet (9 m) thick in the zone between the two shorelines. Below the Provo shoreline, these deposits are probably much thinner.

Lacustrine Gravel (Qlg)

Coarse-grained shore-zone deposits, chiefly sand and gravel with cobbles, are found at and just below the Bonneville shoreline. These gravels were deposited as the lake transgressed to and occupied the Bonneville shoreline during latest Pleistocene time. They are generally thin, but may be up to 30 feet (9 m) thick in some barrier beaches.

Colluvium (Qmc)

Colluvium of Pleistocene and Holocene age occurs on steep mountain slopes below rock outcrops. It generally consists of coarse cobble and boulder talus, and commonly grades downslope into wash slopes of mixed alluvium and colluvium (Qac). Colluvium may reach thicknesses of 30 feet (9 m) or more near the bases of slopes, but is generally less than 10 feet (3 m) thick.

Alluvium and Colluvium (Qac)

Pleistocene- and Holocene-age mixed alluvium and colluvium occurs in first-order drainages and wash slopes below colluvium. Deposits are generally less than 10 feet (3 m) thick, and are generally poorly sorted clay, silt, sand, gravel, cobbles, and boulders. The coarsest deposits occur on the steepest slopes and along drainages.

Undifferentiated Lacustrine and Alluvial Deposits (Qla)

In the zone between the Bonneville and Provo shorelines, undifferentiated alluvial and lacustrine deposits of latest Pleistocene and Holocene age occur. These are mostly sand and gravel with cobbles, and include lacustrine deposits reworked by streams and slope wash, alluvial deposits reworked by the lake, and alluvial and lacustrine deposits which cannot be differentiated at the map scale. Thickness probably rarely exceeds 10 feet (3 m), although the unit may be underlain by great thicknesses of other unconsolidated alluvial and lacustrine deposits.

Younger Alluvial-Fan Deposits (Qaf_1)

Post-Bonneville alluvial-fan deposits are found principally below the Bonneville shoreline in the northern and western parts of the quadrangle. These fans usually have apices at either the Bonneville or Provo shoreline scarps. Post-Bonneville fans in general are finer grained than pre-Bonneville fans and contain mostly sand and gravel, much of it reworked from lake deposits. These fans are generally very thin and in distal parts are commonly a veneer over lake deposits, tapering to a feather edge into the basin. Deposits are thickest near apices, but even there are generally less than 10 feet (3 m) thick.

Eolian deposits (Qes)

Post-Bonneville (Holocene) wind-blown sand in stabilized dunes, now being eroded, is found below the Bonneville shoreline. The well-sorted sand is derived from lacustrine deposits, and is most extensive in the northwest corner of the quadrangle overlying marl and deep-lake deposits below the Provo shoreline. Eolian sands are generally less than 10 feet (3 m) thick.

Alluvium in Channels and Low Terraces (Qal)

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

STRUCTURE

Thrust Faults and Folds

Morris (1987) first reported the presence of Sevier-age thrusts in the northern Keg Mountain area and Slow Elk Hills. Our mapping shows that at least two thrusts are present in the Keg Pass quadrangle. One thrust, possibly the older of the two, places rocks of the Pioche Formation over undifferentiated carbonate rocks. It is exposed only in the northern half of sec. 13, T. 11 S., R. 10 W. Stratigraphic separation across the thrust may be as little as 600 feet (180 m) or as great as 2,000 feet (610 m). Rocks on either side of the thrust have similar strikes and dips, suggesting that the thrust consists of a hanging wall flat over a footwall flat. Thickness variations in both members of the Pioche Formation (in the hanging wall of the thrust) suggest local attenuation of upper-plate rocks near the thrust.

The other thrust, possibly the younger of the two thrusts, places rocks of the Prospect Mountain Quartzite over undifferentiated carbonate rocks. Thin thrust-bound slivers of the Pioche Formation locally occur between upper-plate quartzite and lower-plate carbonate rocks. The thrust may represent as little as 1,200 feet (360 m) or as much as 6,500 feet (2,000 m) of stratigraphic separation. Brecciation of upper-plate quartzite is pervasive throughout the area. Local alteration of lower-plate carbonate rocks to jasperoid occurs immediately beneath the thrust. White calcite veinlets are ubiquitous in lower-plate carbonate rocks and may have been produced by the thrusting event. The thrust surface is sharp and well-exposed, consisting of a thin (<4 cm) cataclasite zone. No ductile deformation was observed in the footwall. The thrust is nearly flat-lying and occurs within an altitudinal range of 5,100 to 5,400 feet (1,555 to 1,647 m) in the northeast quarter of the quadrangle (Plate 1). Subsurface data show that the thrust occurs at a depth greater than 1,250 feet (380 m) beneath Dome Hill (figure 8), suggesting that the thrust dips gently to the west.

The relationship between these two thrust faults is uncertain. Construction of restorable cross sections suggests that the relationship is not as simple as that of a horse or imbricate splay. One possible history is (1) emplacement of the first thrust, placing the Pioche Formation over carbonate rocks, (2) folding, and (3) emplacement of the second thrust, placing quartzite over carbonate rocks. In this scenario, the second thrust must cut down section through the hanging wall and footwall of the first thrust. The direction of tectonic transport for both thrusts would be to the east. Another possibility is that the thrusts formed as back thrusts with the direction of tectonic transport to the west.

Correlation of the thrusts mapped at Keg Mountain to regional thrust faults is uncertain. Based on the general similarities of the Cambrian sections in the House, Dugway, and Drum Mountains, Morris (1983) considered all these ranges to belong to the Wah Wah-Frisco thrust plate and interpreted the Wah Wah-Frisco thrust to pass beneath Keg Mountain. The limited stratigraphic separations across the thrusts at Keg Mountain suggest that neither of the exposed thrusts are the Wah Wah-Frisco thrust.

Folds in carbonate rocks, lying beneath the thrusts, occur in the northeastern quarter of the quadrangle. Most of these are small-amplitude (less than 200 feet; 60 m) folds that plunge gently to the northeast. Calcite veinlets are abundant in the hinge zones of these folds, with sets of veinlets oriented parallel to bedding and subparallel to the axial planes of minor folds. The largest fold in the quadrangle, a syncline, occurs in the north half of section 13, T. 11 S., R. 10 W. The syncline is west verging, plunges gently to the north, and has an amplitude of about 1,000 feet (300 m). The syncline appears to deform the first (possibly older) thrust described above.

Caldera and Cauldron Structures

The terms caldera and cauldron refer to the depressions formed during eruptions of volcanic ash. We apply the term caldera to well-defined depressions bound by ring faults. We apply the term cauldron to poorly defined depressions that either do not have faulted margins or are too poorly exposed to see the margins.

Flint Springs Cauldron

The source of the Dead Ox Tuff is not known, but our interpretation of an eruptive origin (or at least an eruptive component) for the megabreccia member of the Dead Ox Tuff suggests a nearby vent. We propose that the Dead Ox Tuff erupted from the Flint Spring cauldron located in the northwest part of the quadrangle (figure 6). The term caldera does not apply because of the absence of clearly defined margins. Two lines of evidence support this view: (1) the presence of a subtle gravity low in this area, and (2) the absence of a plausible, mappable caldera margin (structural or topographic wall) bounding the megabreccia terrain. The absence of a thick section of Dead Ox Tuff, pronounced gravity low near the megabreccia terrain, or recognizable ring-faults argue against the presence of a large source caldera for the Dead Ox Tuff.

Keg Cauldron

To date, the Keg Tuff has only been recognized at Keg Mountain, suggesting that it is a locally derived unit. We propose that it was erupted from a cauldron, here termed the Keg cauldron, centered on the granodiorite porphyry stock located in the south-central part of the Keg Pass quadrangle (figure 6). The term caldera does not apply because of the absence of clearly defined margins. As defined here, the Keg cauldron differs substantially from the "Keg caldera" defined by Shawe (1972). The only evidence for the existence of the Keg cauldron is the thickening of the Keg Tuff from 0 feet in the north-central part of the quadrangle to more than 540 feet (165 m) at the center of the quadrangle. Structurally, the distribution of (and dips measured in) the Keg Tuff outlines a broad, low-relief dome centered on the granodiorite porphyry stock. Because of similarities in whole-rock composition, age, and spatial distribution, we consider this stock to be comagmatic with the Keg Tuff and view it as a resurgent intrusion that caused doming.

Thomas Caldera

We place the eastern edge of the Thomas caldera along the western margin of Keg Mountain (figure 6), as originally drawn by Shawe (1972) and Lindsey (1982), for stratigraphic and geophysical reasons. Stratigraphically, we interpret the Mt. Laird Tuff at Keg Mountain to be a outflow facies of the formation, implying that the caldera margin must lie west of Keg Mountain. Detailed mapping has shown that, where top and bottom contacts are exposed, only thin sections of Mt.Laird Tuff are present between the Keg and Joy Tuffs and that over the center of the proposed Keg cauldron the Mt. Laird tuff is missing. Mapping revealed no stratigraphic or structural evidence for the margin of the Thomas Caldera passing through or east of Keg Mountain. Geophysically, 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 6). This gravity gradient probably in part represents unconsolidated basin-fill deposits but may also represent intracaldera fill of the Thomas Caldera.

Lineaments marked by Rhyolite Porphyry Intrusions

The distribution of rhyolite porphyry intrusions in the Keg Pass, Keg Mountain Ranch (M. Shubat, unpublished mapping), and Picture Rock Hills (M. Shubat, unpublished mapping) quadrangles delineates two northeast-trending lineaments at Keg Mountain. Both lineaments consist of many small, dike-like bodies of rhyolite porphyry, each of which have a northeasterly trend. No faults appear to coincide with the lineaments.

The northern-most of the lineaments is 3.1 miles (5.0 km) long, trends northeast, and lies entirely within the Keg Pass quadrangle. The lineament cuts the northern end of the granodiorite porphyry intrusion in the southeastern part of the quadrangle. The lineament bifurcates at its southwestern end.

The southern-most lineament is 7.2 miles (11.6 km) long, also trends northeast, and traverses the Picture Rock Hills, Keg Pass, and Keg Mountain Ranch quadrangles. The lineament is interrupted, approximately at its midpoint, by the granodiorite porphyry intrusion in the southeastern part of the Keg Pass quadrangle.

We interpret the lineaments to represent the least principal horizontal stress direction at the time of intrusion of rhyolite porphyry (35.14±0.15 Ma, table 1). The direction of the least principal horizontal stress axis was N45°W. This interpretation is in excellent agreement with the results obtained by Best (1988) for the Oligocene.

High-Angle Faults

High-angle faults in the Keg Pass quadrangle occur in all orientations and amounts of stratigraphic separation across these faults, where demonstrable, are small (less than 200 feet; 60 m). Examination of striated surfaces on some faults yielded a normal sense of slip.

Well-exposed field relations and geochronology tightly constrain the onset of at least some of the high-angle faulting. One north-striking fault in the center of the Keg Pass quadrangle drops the base of the Keg Tuff 50 feet (15 m) down to the west. A dacite porphyry dike-like plug then intruded the fault. Dates for the Keg Tuff and the dacite porphyry intrusions indicate that the age of this fault is between 36.77±0.12 and 36.49±0.15 Ma.

Two observations bracket the minimum age of faulting. Mapping in the adjacent Keg Mountain Ranch quadrangle (M. Shubat, unpublished mapping) demonstrated that high-angle faults cut alkali rhyolite flows, the youngest of which Plavidal (1987) dated at 6.7±0.3 Ma. No high-angle faults cut Quaternary units in the Keg Pass quadrangle.

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

Lineaments marked by Alkali Rhyolite Intrusions

The distribution of dike-like intrusions and isolated domes of Topaz Mountain Rhyolite delineates several north-northwest-trending lineaments in the Keg Pass quadrangle. The dike-like bodies of Topaz Mountain Rhyolite in these lineaments each trend north-northwest. No faults appear to coincide with the lineaments.

One of these lineaments is 2.0 miles (3.2 km) long and trends N34°W. The southeastern end of this lineament is at the east-central edge of section 11, T. 12 S., R. 10 W. (in the south-central part of the Keg Pass quadrangle). Another lineament is 1.5 miles (2.4 km) long and trends N35°W. The southeastern end of this lineament in the southwestern corner of section 13, T. 12 S., R. 10 W. (also in the south-central part of the Keg Pass quadrangle).

We interpret the lineaments to represent the least principal horizontal stress direction at the time of intrusion and eruption of the Topaz Mountain Rhyolite between 8 and 6 Ma. The direction of the least principal horizontal stress axis was N55°E. This interpretation is in excellent agreement with the results obtained by Best (1988) for the Miocene.

ECONOMIC RESOURCES

Metallic Mineral Resources

Exploration at Keg Mountain since 1978 resulted in discoveries of lead-, silver-, copper- and gold-bearing mineral occurrences (figure 8). Occurrences fall into three categories, volcanic-hosted gold, sediment-hosted polymetallic (lead-zinc-silver dominated) vein and replacement, and carbonate-hosted jasperoid prospects.

Volcanic-hosted Gold Occurrences

The best explored volcanic-hosted gold occurrence at Keg Mountain lies about 3,300 feet (1 km) west of the Copper Hill prospect (figure 8). Industry geologists discovered the prospect in 1987 and explored it with 14 drill holes in 1988 and 1989. Gold enrichment occurs along a high-angle, northwest-striking, southwest-dipping normal fault that juxtaposes the Mt. Laird Tuff (hanging wall) against the lithic-crystal tuff member of the Dead Ox Tuff. Alteration consists of intense argillization and pyritization of the Dead Ox Tuff within a few meters of the fault. The highest values obtained to date average 1.02 ppm Au over a 20-foot (6 m) interval. Other areas with anomalous gold shown in figure 8 occur adjacent to pebble dikes cutting the Mt. Laird Tuff, adjacent to dacite porphyry plugs, and along high-angle faults.

Dome Hill Prospect

The Prospect Mountain Quartzite hosts the polymetallic vein and replacement occurrence (Cox and Singer, 1986) at Dome Hill (figure 8). Structurally, the hill constitutes the southwestern half of a dome that is cut by several high-angle faults, the most prominent of which consists of a silicified rib along the elongate northwest-trending axis of the hill. Mineralized rock at Dome Hill consists of highly oxidized stockwork and replacement occurrences containing concentrations of silver, lead, copper, gold, and bismuth. Primary sulfide minerals are pyrite, galena, tetrahedrite-tennantite, and rare chalcopyrite. Analyses of mineralized samples show high concentrations of silver (as much as 27 oz/ton in bulk samples) and bismuth (as much as 3.7 percent) and locally high values of gold (6.5 ppm), base metals, arsenic, and antimony.

Faults and fractures control the exposed distribution of mineralized rock at Dome Hill and geochemical sampling showed that highly anomalous samples spatially coincide with the dominant northwest-trending fault along the crest of the hill. Mineralized rock apparently extends over 3,000 feet (900 m) to the northwest from the top of the hill to an area of buried mineralized rock discovered by drilling (figure 8). Drill holes in this area tested a northeast-trending self-potential responder coincident with northeast-striking air-photo lineaments. Drill core showed the presence of quartz veinlets in carbonate host rock containing pyrite, galena, and sphalerite, and several intercepts of disseminated sulfides in silicified breccia zones. One stockwork zone contained 0.70 oz/ton silver, 0.55 percent lead, and 0.54 percent zinc over a 10-foot (3 m) interval.

Lead Hill Prospect

Two types of mineralized rock occur at Lead Hill: (1) carbonate-hosted gold-, silver-, zinc-, and molybdenum-bearing jasperoid, and (2) small, massive pods of galena replacing limestone. Mineralized jasperoid bodies occur along high-angle faults and fracture zones, forming resistant, dark-brown masses about 7 to 30 feet (2 to 9 m) in length and 3 to 10 feet (1 to 3 m) in width. Ore minerals in jasperoid consist of sparse, fine-grained pyrite and galena. Gangue mineralogy consists almost entirely of microcrystalline, chalcedonic silica with a ubiquitous iron-oxide stain and trace amounts of sericite. Geochemical analyses of jasperoid samples show an enrichment in lead, silver, molybdenum, gold and zinc. The highest values obtained from jasperoid samples are 1.89 percent lead, 7.88 oz/ton silver, 450 ppm molybdenum, 0.59 ppm gold, and 280 ppm zinc. The second type of mineralized rock at Lead Hill consists of small (30 cm diameter) pods of nearly massive galena replacing limestone adjacent to a granodiorite dike exposed in a prospect trench at the north end of Lead Hill. Analyses of the galena-rich pods showed the presence of silver (0.66 oz/ton) and trace amounts of zinc in addition to lead.

Industrial Rock and Mineral Resources

Sand and gravel

Abundant sand and gravel resources are present in the quadrangle, which we mapped as lacustrine gravel (Qlg) on plate

1. The sand and gravel deposits are moderately well sorted and were deposited near the shore of Lake Bonneville in beaches and tombolos. well-sorted, fine- to medium-grained sand is also present in dunes (Qes). Sand and gravel are abundant in alluvial and alluvial-fan deposits of all ages, although they are less well sorted, more angular, and contain more fines than lacustrine gravel deposits.

Cement rock

Several of the Paleozoic rock units in the quadrangle may have potential for cement production. Silty limestone in the Howell Limestone may have desirable concentrations of calcium carbonate, alumina, and iron for cement. The Pioche Formation could be a source of shale. Gypsum could be imported from the Nephi area.

High-calcium limestone

Some limestone units in the quadrangle may have potential for high-calcium limestone production. Continental Lime, Incorporated has a plant in the Cricket Mountains that produces high-calcium lime from the Dome Formation (Tripp, 1991). Rocks of the Dome Formation may be present in the Ocl map unit.

Zeolite minerals

Significant zeolite mineral (clinoptilolite) resources exist in the stratified tuff member of the Topaz Mountain Rhyolite in the Keg Mountain area (Lindsey, 1975). Mayes and Tripp (1991) summarized the available information on the deposit. Lindsey (1975) showed that alteration of the tuff produced two mineral assemblages: zeolitic and feldspathic. The zeolitic assemblage contains clinoptilolite, constituting between 60 and 90 percent of the rock, and is the only zeolite mineral identified in the area. The feldspathic assemblage contains potassium feldspar as the dominant mineral. Lindsey 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

The Prospect Mountain Quartzite and some volcanic rocks in the quadrangle could be used for crushed stone.

WATER RESOURCES

Two springs are present in the quadrangle, Keg Spring and Flint Spring. Gates and Kruer (1981) report that the total dissolved solids in water from the springs is 1,810 and 1,910 milligrams per liter, respectively. Discharge from both springs has been diverted to storage tanks for livestock watering. There are no perennial streams in the quadrangle.

There are no wells in the quadrangle. Bedinger and others

(1984) indicate that the nearest well is 1.5 miles (2.4 km) west-northwest of the northwest corner of the quadrangle, in section 12, T. 11 S., R. 11 W. They report a depth to water in this well of 270 feet (82 m). Unconsolidated deposits in the northwestern corner of the quadrangle may likewise contain ground water, but the potential for production from wells is not known. Gates and Kruer (1981) indicate that any ground water in this unconsolidated aquifer is probably moderately saline (3,000-10,000 milligrams per liter dissolved solids).

GEOLOGIC HAZARDS

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

No earthquakes larger than magnitude 4 have occurred in historical time within 30 miles (50 km) of the quadrangle (Goter, 1990). No active or potentially active (Quaternary) faults are found in the quadrangle, and the nearest faults with evidence for displacements in post-Bonneville time are the Drum Mountains and Crater Bench faults about 5 miles (8 km) to the south (Hecker, 1992). Faults with possible late Quaternary events are also found southwest of the Simpson Mountains about the same distance to the east. The principal earthquake hazard would be from strong ground shaking in a moderate to large earthquake. The quadrangle is at the boundary between 1991 Uniform Building Code seismic zones 2B and 3 in an area of moderate earthquake hazard.

Slopes in the area are generally stable and no landslides were mapped in the quadrangle. The principal slope-failure hazard is from rock falls (figure 10) below steep, rocky slopes, and possible cloudburst-generated debris flows in mountain channels (geologic units Qal, Qac) and at the apices of modern alluvial fans (Qaf_1). Flash flooding is possible along any of the dry washes (Qal) and on active alluvial fans and wash slopes (Qaf_1, Qac).

Soil and ground-water 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 northwest corner of the quadrangle. Shallow ground water is probably not present anywhere in the quadrangle. The volcanic rocks of Keg Mountain are possibly uranium-bearing and may produce radon gas (Sprinkel, 1988). The generally coarse-grained, dry soils are conducive to the movement of radon gas through soils and into structures.

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FIGURE CAPTIONS

FIGURES

Figure 1. Index map showing the location of the Keg Pass quadrangle.

Figure 2. Measured stratigraphic section of Paleozoic rocks near Table Mountain (SW¼ section 18, T. 10 S., R. 9 W.).

Figure 3. 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. Compositional fields from Streckeisen (1978). Compositional field for dacite is the same as the field for granodiorite, its plutonic equivalent. Appendix A lists the modal analyses.

Figure 4. Silica versus total alkali (Na_2O+K_2O) diagram for igneous rocks at Keg Mountain. Compositional fields from Le Bas and others (1986). Appendix B lists the major element analyses.

Figure 5. Megabreccia member of the Dead Ox Tuff. (A) Exposure in the NW¼SE¼SW¼, section 26, T. 11 S., R. 10 W. (the reference section for the megabreccia member) showing two clasts in the megabreccia. Clast to the left consists of pervasively brecciated quartzite. Clast to the right consists of unbrecciated andesite. Ash-flow tuff matrix is poorly exposed and consists of light-colored, poorly welded lithic-crystal tuff.

(B) Close-up of the pervasively brecciated quartzite clast shown above. Breccia consists of angular quartzite clasts (gray) in a fine-grained matrix of comminuted quartzite (light gray). This brecciation may have originated by a process similar to that described by Shawe and Snyder (1988) as deep-level, subvolcanic "explosion-breccia."

Figure 6. Locations of proposed calderas and cauldrons at Keg Mountain and surrounding areas (modified from Shubat and Snee, in press). Gravity data from Bankey and Cook (1989). Magnetic data (diagonal lines) from Kucks (1991). Caldera margins for the western part of the Thomas caldera and the Dugway Valley cauldron from Lindsey (1982).

Figure 7. Photomicrograph showing typical textures and minerals present in the Keg Tuff. Phenocrysts are quartz (Q), plagioclase (P), and biotite (B). Field of view is 7 millimeters.

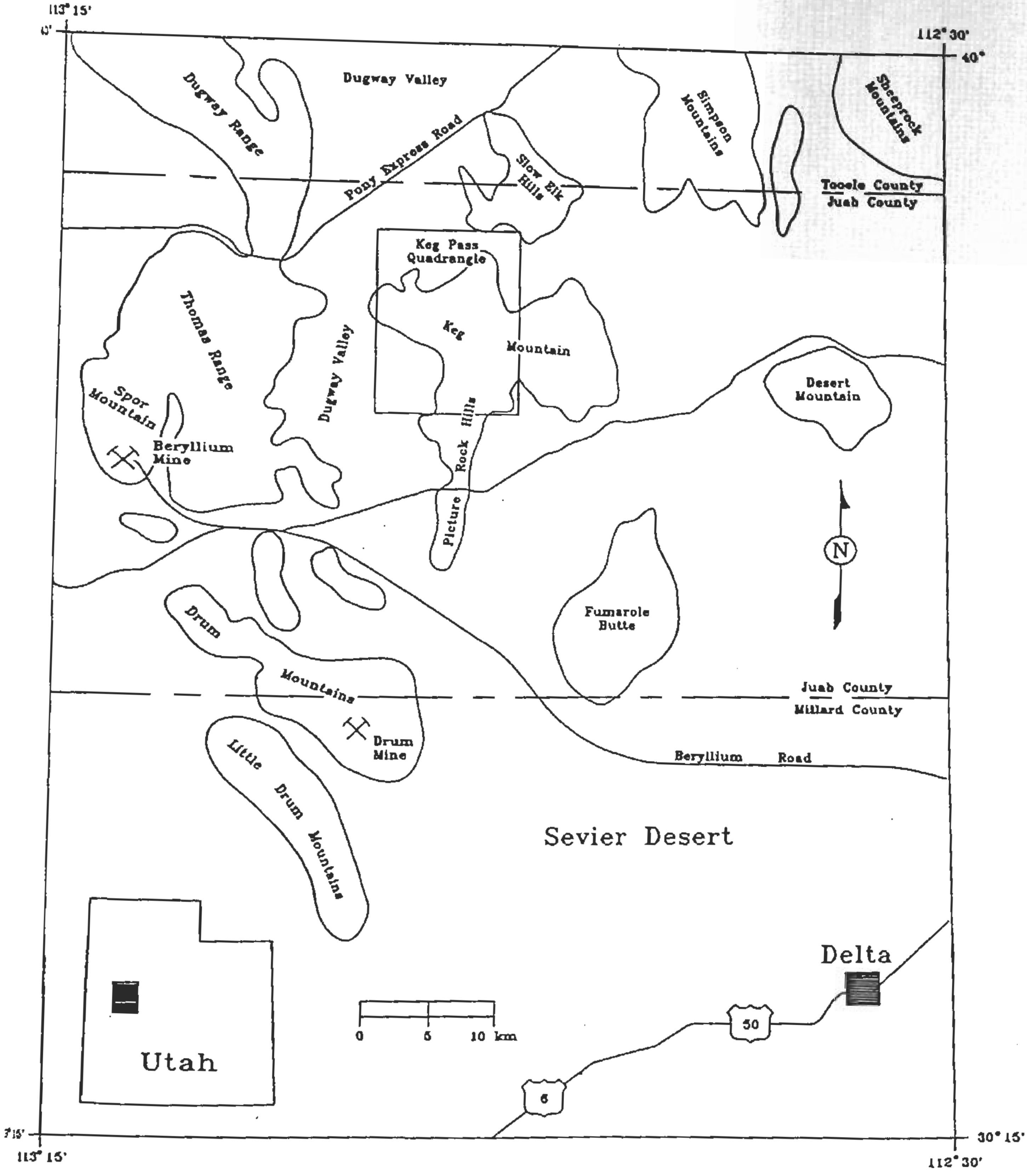
Figure 8. Locations of samples dated by the $^{40}Ar/^{39}Ar$ method by Shubat and Snee (in press) and locations of mineral occurrences in the Keg Pass quadrangle. Diamonds, polymetallic vein and replacement deposits; triangles, mineralized jasperoids; small stars, volcanic-hosted gold occurrences; numbered circles, locations of dated samples listed by number in table 1; large star, possible vent area for the Mt. Laird Tuff.

Figure 9. Lithologies present in the Mt. Laird Tuff in the northeast part of the Keg Pass quadrangle. (A) Exposure of the tuff-breccia facies of the Mt. Laird Tuff. Clasts range in size from less than 1 to 20 centimeters in diameter and consist of the ash-flow tuff facies of the Mt. Laird Tuff. The matrix consists of poorly to moderately welded tuff. (B) Photomicrograph of an accretionary lapillus from the accretionary lapilli-block tuff facies of the Mt. Laird Tuff. Lapillus consists of fine crystal fragments and ash. Accretionary lapilli may form as "moist aggregates of ash in eruption clouds", or by "rain that falls through dry eruption clouds" (Fisher and Schmincke, 1984). Field of view is 7 millimeters.

Figure 10. Rock-fall clasts of Topaz Mountain Rhyolite that have rolled from the hillside in the background onto unconsolidated deposits at the base of the slope (SE¼, section 29, T. 11 S., R. 10 W.).

TABLES

Table 1. Summary of $^{40}Ar/^{39}Ar$ age-spectrum dates for igneous rocks at Keg Mountain (from Shubat and Snee, in press). Figure 8 shows the locations of dated samples.



113° 15'
112° 30'
40°
Dugway Valley
Dugway Range
Pony Express Road
Slow Elk Hills
Simpson Mountains
Sheeprock Mountains
Tooele County
Juab County
Keg Pass Quadrangle
Keg
Mountain
Thomas Range
Dugway Valley
Spor Mountain
Beryllium Mine
Rock Hills
Picture
Desert Mountain
N
Fumarole Butte
Drum
Mountains
Juab County
Millard County
Drum Mine
Beryllium Road
Little Drum Mountains
Sevier Desert
Delta
50
0
5
10 km
Utah
6
30° 15'
113° 15'
112° 30'

Figure 1

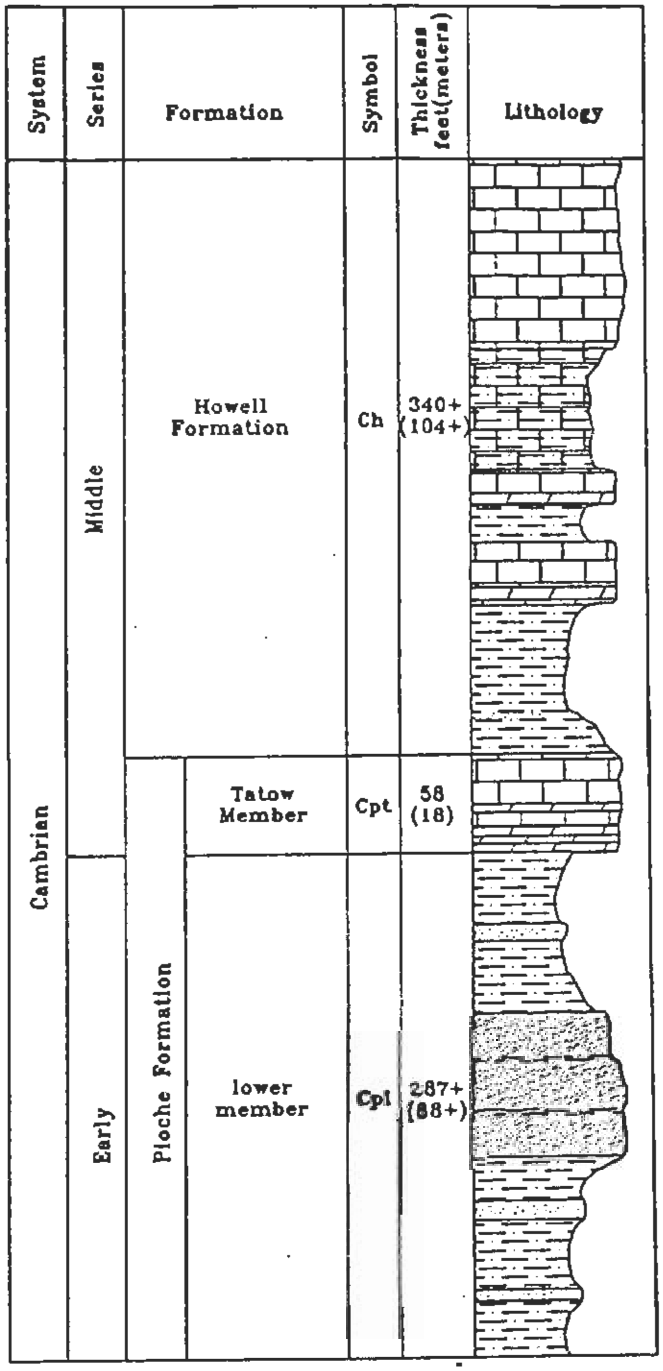


Figure 2 [redacted]

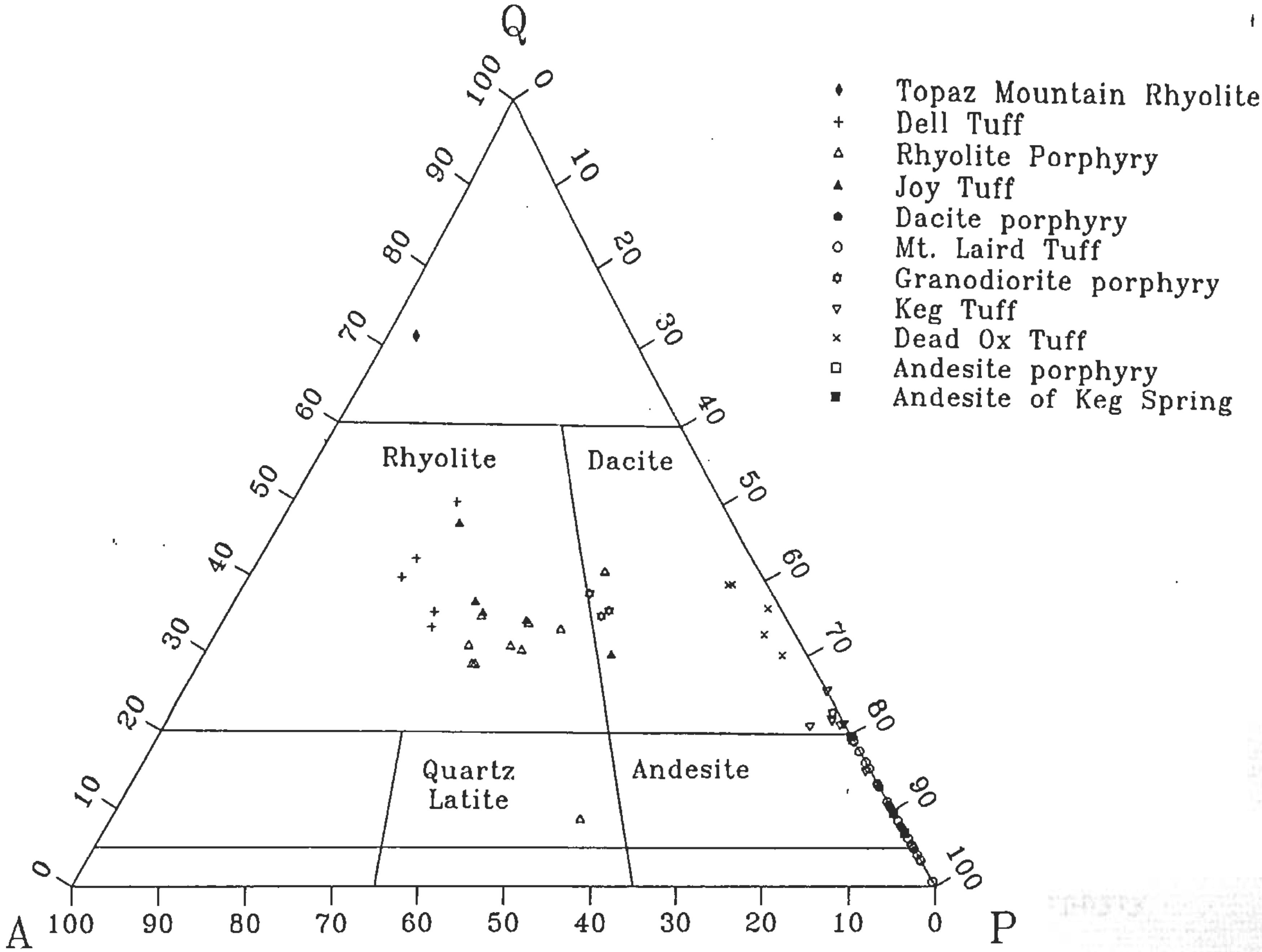

Q
A
P
Topaz Mountain Rhyolite
Dell Tuff
Rhyolite Porphyry
Joy Tuff
Dacite porphyry
Mt. Laird Tuff
Granodiorite porphyry
Keg Tuff
Dead Ox Tuff
Andesite porphyry
Andesite of Keg Spring
Rhyolite
Dacite
Quartz Latite
Andesite

Figure 3

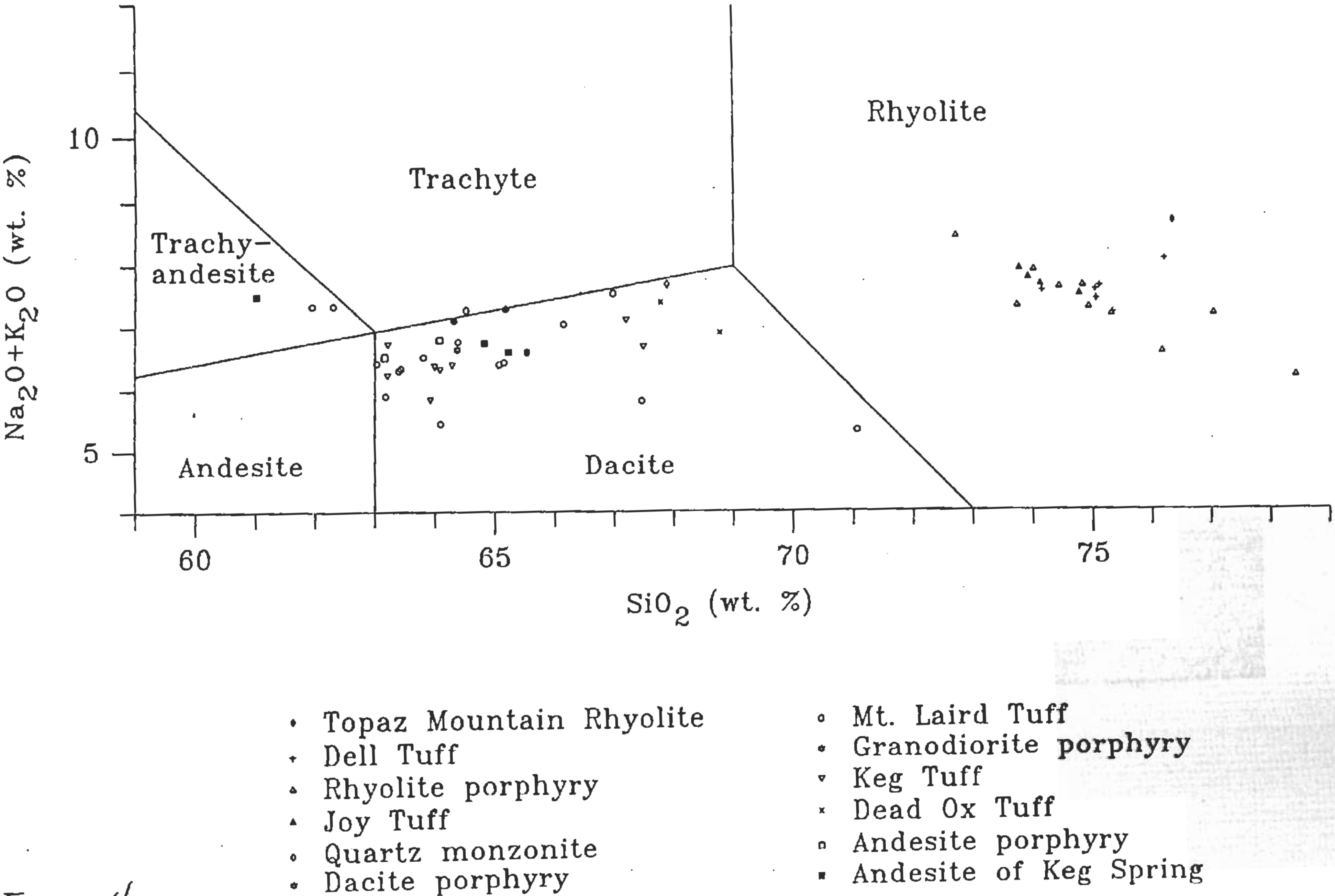

Na2O+K2O (wt. %)
10
5
SiO2 (wt. %)
60
65
70
75
Trachy-
andesite
Andesite
Trachyte
Dacite
Rhyolite
Topaz Mountain Rhyolite
Dell Tuff
Rhyolite porphyry
Joy Tuff
Quartz monzonite
Dacite porphyry
Mt. Laird Tuff
Granodiorite porphyry
Keg Tuff
Dead Ox Tuff
Andesite porphyry
Andesite of Keg Spring

Figure 4

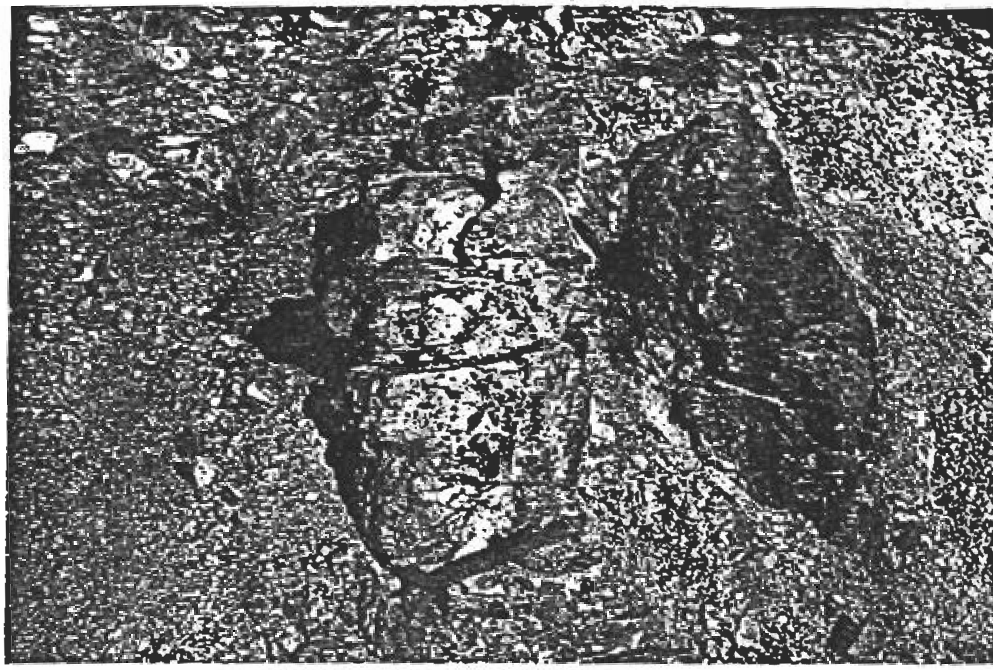


Figure 5a

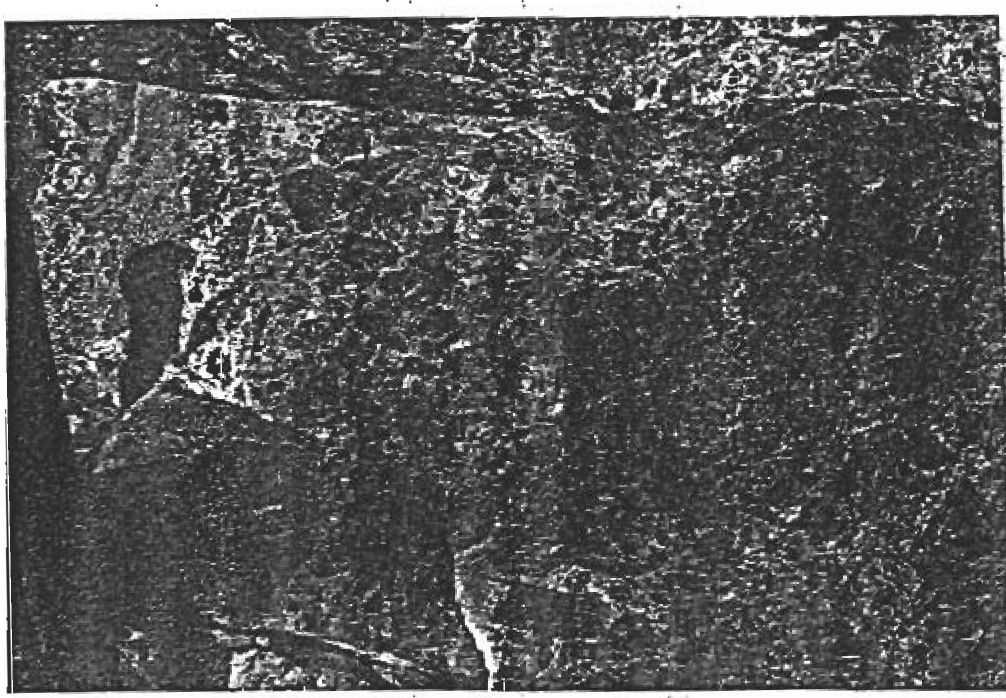
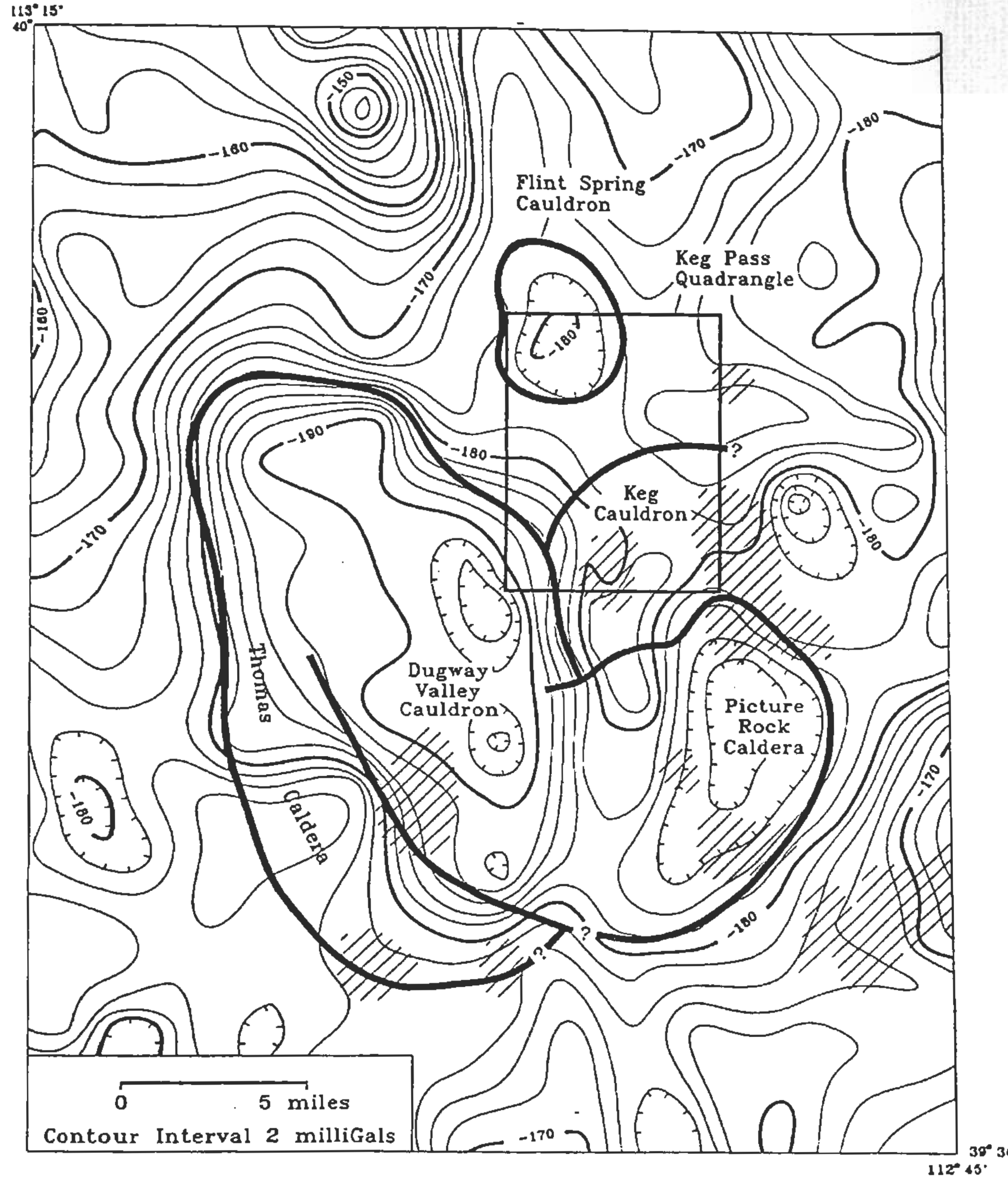


Figure 5b



113° 15'
40°
-150
-160
-170
-180
Flint Spring
Cauldron
Keg Pass
Quadrangle
-190
Keg
Cauldron
?
Dugway
Valley
Cauldron
Thomas
Caldera
Picture
Rock
Caldera
0
5 miles
Contour Interval 2 milliGals
39° 30'
112° 45'

Figure 6

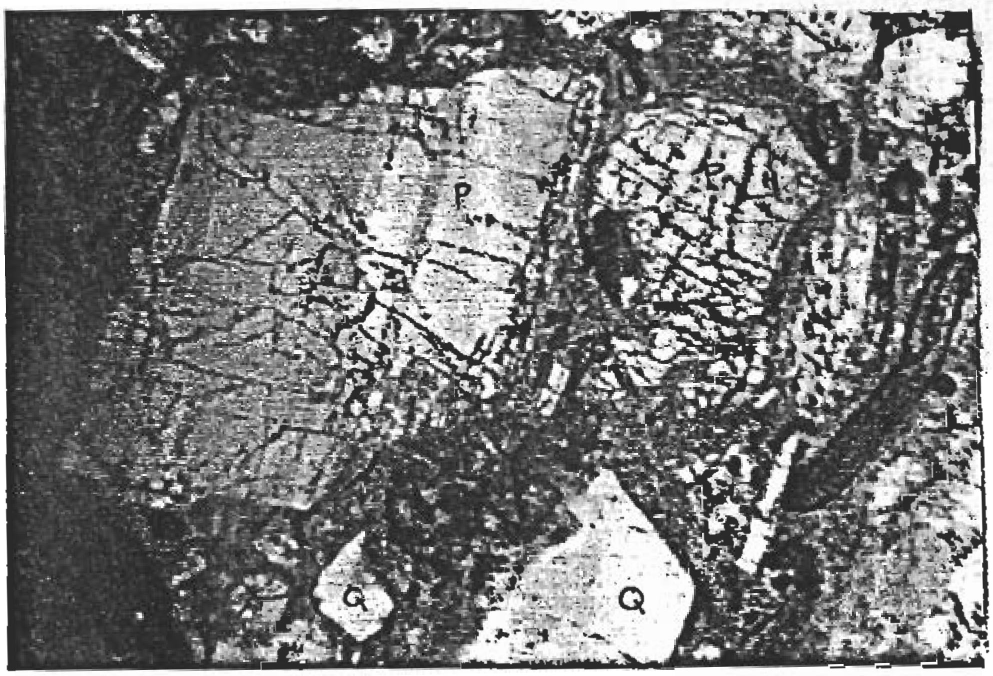
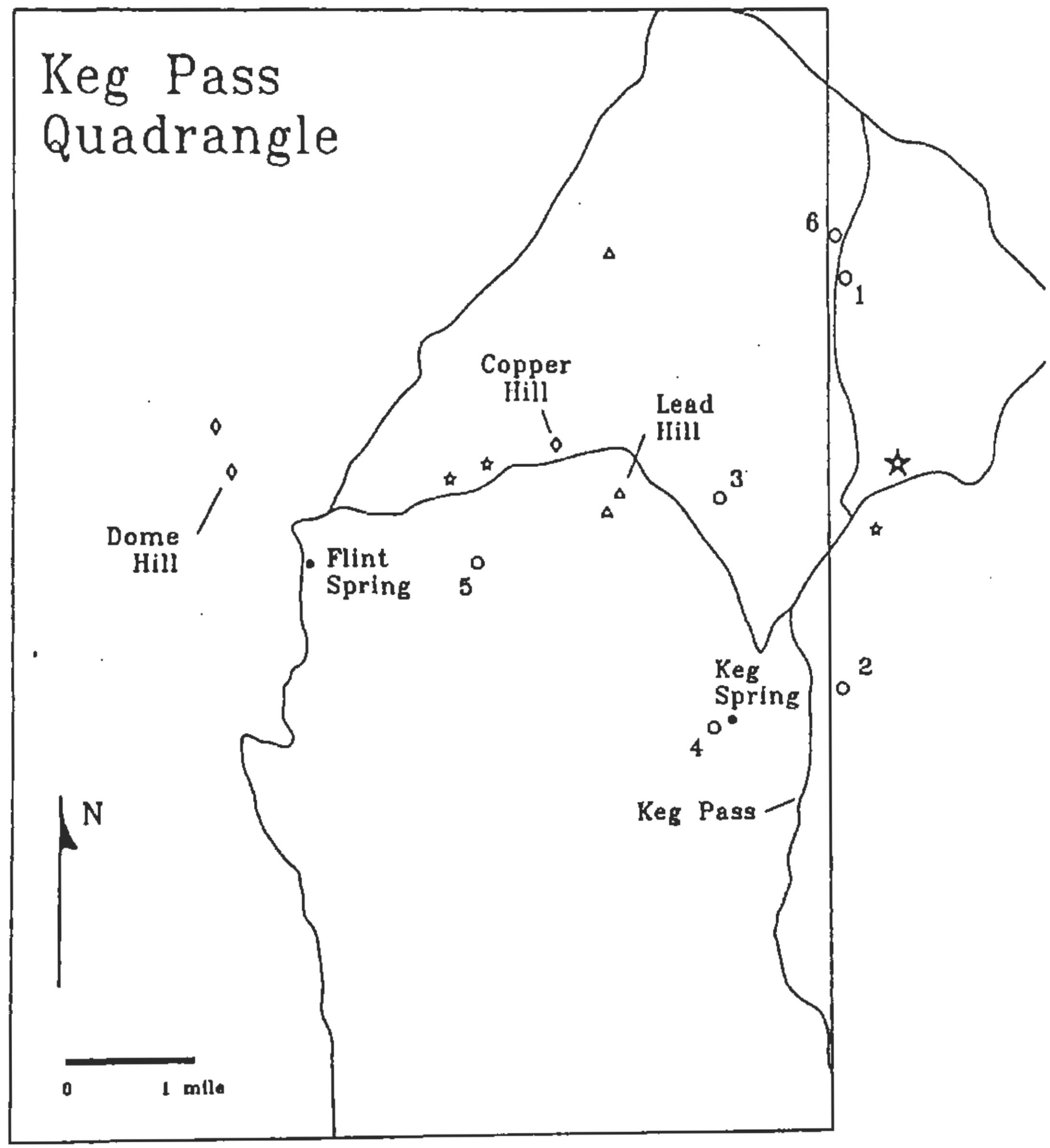


Figure 7



Keg Pass
Quadrangle
Copper Hill
Lead Hill
Dome Hill
Flint Spring
Keg Spring
Keg Pass
1
2
3
4
5
6
N
0
1 mile

Figure 8

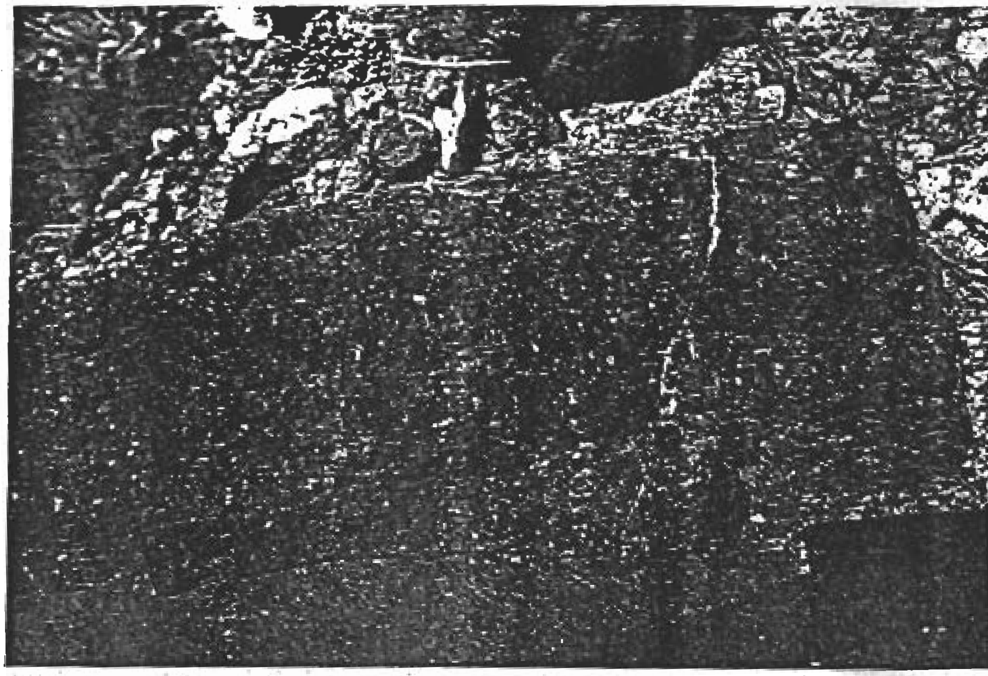


Figure 9a

Figure 9 b

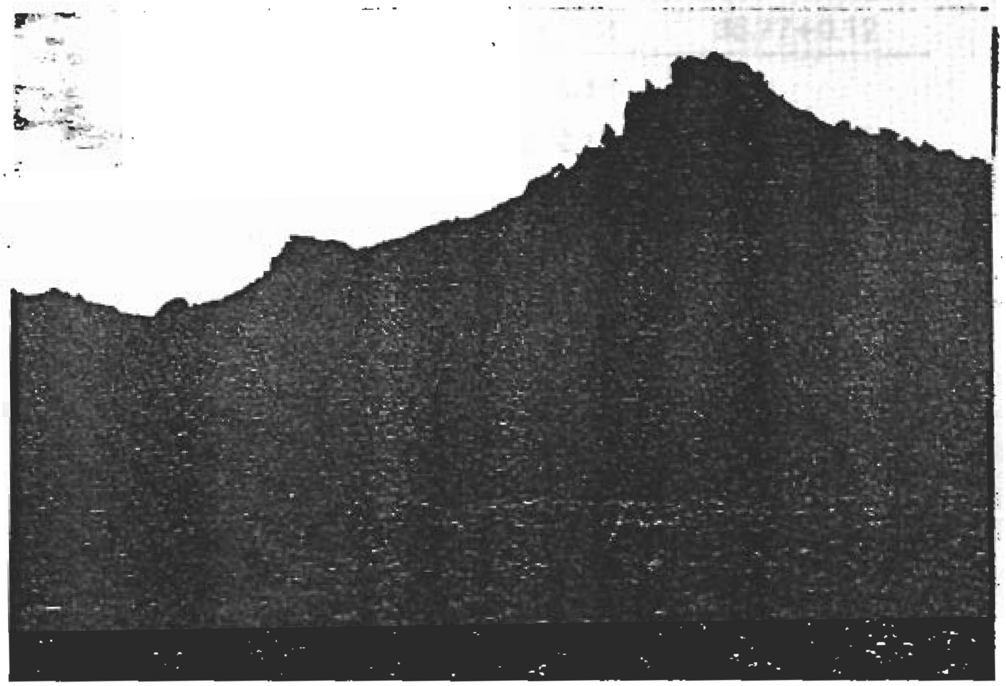


Figure 10

Table 1. Summary of $^{40}Ar/^{39}Ar$ age-spectrum dates for igneous rocks at Keg Mountain (from Shubat and Snee, in press). Figure 8 shows the locations of dated samples.

number	map unit	mineral	date (Ma)	average (Ma)
4	Tk	biotite	36.77+0.12	36.77+0.12
5	Tml	biotite	36.48+0.14	
6	Tml	biotite	36.56+0.11	36.54+0.06
		hornblende	36.59+0.29	
3	Tdp	biotite	36.49+0.15	36.49+0.15
1	Tj	sanidine	34.92+0.14	34.88+0.06
		biotite	34.84+0.14	
2	Trp	sanidine	35.04+0.10	35.14+0.15
		biotite	35.25+0.13	

Appendix A. Modal analyses of igneous rocks in the Keg Mountain area. Map units same as plates 1 and 2. All values in percent except no. of counts, sphene, and zircon. Symbols for sphene and zircon are n = absent and y = present.

sample number	map unit	no. of counts	matrix	plagio-clase	quartz	sanidine	biotite	horn-blende	clino-pyroxene	opaque minerals	sphene	zircon	lithic clasts
NKM-17-6	Ta	793	49.81	33.17	2.52	0.00	5.93	5.80	0.38	2.40	n	y	0.00
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
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
KP-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	3.96	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

sample number	map unit	no. of counts	matrix	plagio-clase	quartz	sanidine	biotite	horn-blende	clino-pyroxene	opaque minerals	sphene	zircon	lithic clasts
NKM-18-1	Tml	694	56.34	27.52	3.17	0.00	6.05	4.76	0.00	2.02	y	y	0.00
NKM-18-1	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-21-1	Tml	725	63.17	22.07	2.07	0.00	2.90	7.72	0.69	1.38	y	y	0.00
NKM-21-1	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
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
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-13-3	Trp	479	54.91	17.33	17.33	7.72	2.51	0.00	0.00	0.21	y	y	0.00
KMR-3-8	Trp	418	62.20	11.48	10.29	14.35	1.44	0.00	0.00	0.24	y	y	0.00
KMR-4-6	Trp	732	43.44	15.98	16.39	20.63	2.73	0.55	0.00	0.27	n	n	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
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-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	45.34	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

Appendix B. Whole rock geochemical data for igneous rocks at Keg Mountain. Map units same as plates 1 and 2. FET03 refers to total iron. Analyses provided by the U.S. Geological Survey. Recalculated to 100 percent.

sample number	map unit	SIO2	AL2O3	FETO3	MGO	CAO	NA2O	K2O	TIO2	P205	MNO
KP-7-7	Ta	64.82	16.15	5.67	2.15	3.36	3.27	3.49	0.74	0.26	0.09
KP-15-1	Ta	61.01	16.53	6.47	2.79	4.23	4.24	3.25	1.04	0.39	0.05
KP-17-1	Ta	65.22	14.94	6.50	1.88	3.64	2.97	3.66	0.84	0.30	0.06
KP-7-9	Tap	63.16	16.22	5.80	2.21	5.00	3.32	3.21	0.74	0.26	0.08
KP-9-8	Tap	64.07	15.79	5.67	2.26	4.38	3.44	3.36	0.72	0.24	0.08
KP-9-4	Tdo	67.77	14.77	4.31	1.66	3.19	3.19	4.23	0.57	0.24	0.07
KP-7-10	Tdo	68.77	14.25	4.49	1.58	3.08	2.37	4.56	0.61	0.23	0.05
KMR-4-3	Tk	67.48	14.56	5.03	1.87	3.40	2.90	3.80	0.66	0.25	0.05
KP-1-1	Tk	63.99	15.95	5.74	2.10	4.77	3.05	3.34	0.74	0.25	0.07
KP-11-2	Tk	64.28	15.71	5.61	1.87	5.04	2.95	3.47	0.71	0.26	0.10
KP-16-3	Tk	63.21	18.01	5.84	1.71	5.89	3.15	3.10	0.74	0.25	0.10
KP-16-4	Tk	63.21	15.98	5.73	2.31	4.98	3.38	3.37	0.72	0.25	0.08
KP-2-2	Tk	64.08	15.76	5.63	1.81	5.32	3.06	3.29	0.72	0.25	0.08
KP-6-5	Tk	63.92	15.85	5.68	2.52	5.11	3.07	2.80	0.73	0.26	0.08
KP-8-2	Tk	67.19	15.10	4.74	1.82	3.07	2.89	4.26	0.64	0.25	0.05
KP-2-1	Tgd	64.37	15.68	5.38	2.33	4.55	3.38	3.27	0.71	0.25	0.07
KMR-1-4	Tml	63.80	15.98	5.90	2.10	4.54	3.11	3.41	0.79	0.28	0.08
KMR-3-13	Tml	65.15	14.92	5.84	1.42	5.10	2.24	4.21	0.79	0.25	0.08
KMR-3-21	Tml	71.05	12.92	4.71	1.34	3.75	2.56	2.79	0.58	0.23	0.07
KMR-3-9	Tml	63.43	15.05	6.56	2.54	4.93	3.11	3.24	0.78	0.28	0.06
KMR-4-7	Tml	64.38	15.49	5.72	2.55	3.96	3.04	3.75	0.75	0.27	0.09
KMR-4-8	Tml	63.39	15.67	6.17	2.92	4.33	2.88	3.44	0.82	0.29	0.09
KMR-5-13	Tml	62.30	15.65	6.72	3.31	3.44	3.72	3.62	0.84	0.29	0.11
KMR-5-17	Tml	66.14	14.45	5.19	1.94	4.20	2.43	4.64	0.68	0.25	0.06
KMR-5-18	Tml	64.09	15.66	5.77	2.42	5.46	2.29	3.16	0.78	0.27	0.09
KMR-5-3	Tml	64.51	15.04	5.88	2.02	4.16	2.67	4.62	0.76	0.26	0.07
KP-12-1	Tml	66.97	15.44	4.86	1.55	2.73	3.22	4.34	0.62	0.21	0.05

sample number	map unit	SIO2	AL2O3	FETO3	MGO	CAO	NA2O	K2O	TI02	P205	MNO
KP-12-3	Tml	63.03	15.40	6.47	2.65	4.85	3.22	3.20	0.81	0.28	0.10
KP-14-4	Tml	61.94	16.59	6.87	2.01	3.85	3.67	3.68	0.96	0.39	0.05
KP-5-22	Tml	71.87	12.11	4.20	1.46	2.52	1.88	5.22	0.46	0.22	0.04
KP-6-1	Tml	63.18	15.95	6.02	2.23	5.48	2.76	3.16	0.87	0.28	0.08
KP-8-7	Tml	65.07	15.52	5.60	2.07	4.21	2.99	3.43	0.75	0.27	0.08
KP-8-8	Tdp	64.31	15.50	5.45	2.29	4.27	3.48	3.64	0.73	0.26	0.07
KP-9-1	Tdp	65.17	15.57	5.23	2.14	3.58	3.60	3.70	0.68	0.25	0.08
KP-9-2	Tdp	65.53	15.41	5.20	2.07	4.19	3.00	3.62	0.65	0.24	0.09
KP-12-5	Tq	67.88	15.28	4.20	1.55	2.55	2.99	4.71	0.58	0.22	0.04
KMR-1-2	Tj	73.77	13.85	1.74	0.51	1.78	3.33	4.63	0.24	0.08	0.06
PRH-2-3	Tj	73.92	13.26	2.12	0.64	1.80	3.49	4.32	0.27	0.11	0.06
PRH-1-1	Tj	74.77	13.59	1.82	0.47	1.38	3.12	4.42	0.27	0.11	0.04
KP-13-2	Tj	63.99	15.56	6.17	1.29	4.94	2.89	3.73	1.00	0.38	0.05
KMR-3-8	Trp	74.83	12.56	1.49	0.47	2.61	3.31	4.37	0.20	0.08	0.06
KMR-4-6	Trp	73.73	13.73	1.46	0.49	2.82	2.88	4.48	0.23	0.10	0.08
KP-15-2	Trp	74.01	14.43	1.38	0.60	1.32	3.26	4.68	0.20	0.06	0.06
KP-16-2	Trp	72.71	15.08	1.84	0.84	0.63	3.53	4.96	0.28	0.09	0.03
KP-3-1A	Trp	76.16	13.47	1.66	0.63	1.09	1.95	4.66	0.22	0.09	0.07
KP-3-1B	Trp	78.42	12.10	0.46	0.16	2.53	1.01	5.20	0.05	0.03	0.05
KP-3-1C	Trp	77.03	12.72	0.82	0.24	1.80	2.15	5.08	0.10	0.03	0.03
KP-3-4	Trp	74.93	13.81	1.56	0.59	1.43	2.63	4.71	0.21	0.08	0.05
KP-3-5	Trp	74.44	13.90	1.63	0.63	1.41	2.59	5.07	0.22	0.09	0.03
KP-8-1	Trp	75.31	13.75	1.60	0.61	1.18	2.31	4.91	0.22	0.09	0.05
KMR-13-3	Td	76.21	12.53	1.22	0.41	1.14	2.29	5.83	0.29	0.06	0.01
KMR-3-11	Td	75.33	13.27	1.78	0.52	1.49	2.77	4.48	0.23	0.09	0.04
KMR-5-10	Td	74.15	13.96	1.50	0.52	1.94	2.87	4.74	0.21	0.08	0.03
KMR-5-11	Td	75.04	13.27	1.65	0.55	1.53	2.77	4.85	0.22	0.08	0.03
KMR-5-9	Td	75.05	13.38	1.65	0.57	1.54	2.88	4.59	0.22	0.08	0.03
KP-6-2	Td	75.11	13.23	1.55	0.55	1.53	3.05	4.63	0.23	0.09	0.02
KP-11-3	Ttm	76.35	12.30	0.85	0.25	1.28	3.43	5.31	0.14	0.03	0.05

DESCRIPTION OF MAP UNITS

Qal Alluvium in channels and low terraces (Holocene) - Unconsolidated, poorly sorted, stream-flow deposits of clay, silt, sand, gravel, cobbles and boulders found in modern stream channels, flood plains, and terraces 3-6 feet (1-2 m) above modern channels.

Qes Eolian sand (Holocene) - Unconsolidated, well-sorted deposits of wind-blown sand in stabilized dunes that are now being eroded. Post-Bonneville in age and found below the Bonneville shoreline; derived from lacustrine deposits.

Qaf_1 Younger alluvial-fan deposits (Holocene and latest Pleistocene) - Unconsolidated, poorly sorted, chiefly stream-flow deposits of clay, silt, sand, and gravel found principally below the Bonneville shoreline. Fans are thin and, in distal parts, form a veneer over lake deposits that taper to a feather edge.

Qla Undifferentiated lacustrine and alluvial deposits (Holocene and latest Pleistocene) - Unconsolidated deposits of sand, gravel, and cobbles consisting of lacustrine deposits reworked by streams and slope wash, alluvial deposits reworked by the lake, and alluvial and lacustrine deposits which cannot be differentiated at the map scale. Unit occurs chiefly between the Bonneville and Provo shorelines.

Qac Alluvium and colluvium (Holocene and Pleistocene) - Unconsolidated deposits of clay, silt, sand, gravel, cobbles, and boulders in first-order drainages and wash slopes below colluvium.

Qmc Colluvium (Holocene and Pleistocene) - Unconsolidated deposits of coarse cobble and boulder talus found on steep mountain slopes below rock outcrops.

Qlg Lacustrine gravel (latest Pleistocene) - Unconsolidated, coarse-grained shore-zone deposits of sand, gravel, and cobbles found at and just below the Bonneville shoreline.

Qls Lacustrine sand (latest Pleistocene) - Unconsolidated, sandy shore-zone and offshore deposits, with clay, silt, and gravel, found below the Bonneville shoreline. Most extensive in the northern part of the quadrangle between the Bonneville and Provo shorelines.

Qlm Lacustrine marl (latest Pleistocene) - Unconsolidated, fine-grained, deep-lake deposits of marl, clay, silt, and sand, including ostracode- and gastropod-rich layers.

Qaf_2 Intermediate-age alluvial-fan deposits (middle to late Pleistocene) - Unconsolidated, poorly sorted, debris-flow and stream-flow deposits of clay, silt, sand, gravel, cobbles, and boulders found above the Bonneville shoreline. Fan surfaces are inactive and undergoing erosion.

QTaf Older alluvial-fan deposits (early Pleistocene and Pliocene) - Unconsolidated to semi-consolidated, poorly sorted deposits of clay, silt, sand, gravel, cobbles, and boulders on the west flank of Keg Mountain above the Bonneville shoreline. Designated as Qlg/QTaf where the deposit has been eroded and reworked by Lake Bonneville.

---------- Unconformity ----------

Topaz Mountain Rhyolite (Miocene) - Divided into:

Ttm Flows, domes, and intrusions of alkali rhyolite - White, gray, and purplish rhyolite containing sparse (10 to 15 percent), small (2 mm) phenocrysts of quartz and sanidine and lesser plagioclase, biotite, and opaque minerals. The matrix consists of devitrified glass. Black to brown vitrophyre occurs at the base of some flows and domes. Lindsey and others (1975) dated two samples of the unit at 7.8±0.6 and 8.2±0.5 Ma. Plavidal (1987), however, reported dates of 6.7±0.3 and

6.9±0.3 Ma for an underlying unit, indicating that the true age of the Topaz Mountain Rhyolite is probably close to Lindsey's (1982) date of 6.3±0.1 Ma for the unit in the Thomas Range.

Ttmt Stratified tuff - Pale tan to orange, massive- to thin-bedded, nonwelded, lithic-rich rhyolitic tuff and volcanic sandstone. The rock contains a variety of volcanic rock fragments, abundant pumice clasts, and sparse crystal fragments in an ash matrix. The unit was deposited as air-fall, ash-flow, and ground-surge eruptions, and water-lain deposits. Extensively zeolitized and feldspathically altered.

---------- Unconformity ----------

Td Dell Tuff (Oligocene) - Pink to tan, poorly to moderately welded, crystal-rich, rhyolitic ash-flow tuff. Contains abundant phenocrysts of quartz, sanidine, plagioclase, and biotite that range in size from 2 to 10 millimeters. Lithic fragments constitute as much as 19 percent of the rock. Lindsey (1982) dated the unit at 32.0 ± 0.6 Ma (average).

---------- Unconformity ----------

Trp Rhyolite porphyry (Oligocene) - Small plugs of pale gray to pinkish, light-tan weathering rhyolite porphyry with coarse (as large as 1 cm) phenocrysts of orthoclase, quartz, plagioclase, and biotite. Matrix is aphanitic. Rock is nearly aphyric near the margins of plugs and coarsely porphyritic toward the interior. Dated by Shubat and Snee (in press) 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 that is overlain by a black fiamme-rich zone. Contains abundant, 1- to 8-millimeter phenocrysts of quartz, sanidine, plagioclase, and biotite. Contains as much as 14 percent lithic clasts. Dated by Shubat and Snee (in press) at 34.88±0.06 Ma.

Tqm Quartz monzonite (Oligocene and Eocene) - Small plugs of gray, rusty-weathering, porphyritic rock containing phenocrysts (0.3 to 10 mm) of plagioclase, biotite, quartz, hornblende, and potassium feldspar in a fine-grained matrix of potassium feldspar and quartz. Contains sparse dark-green xenoliths. Silicification and pyritic alteration common.

Tpd Pebble dike (Oligocene and Eocene) - Small, pipe-shaped body containing argillized and iron-stained clasts of volcanic rocks, Paleozoic rocks, and intrusive rocks. Matrix poorly exposed.

Tdp Dacite porphyry (Oligocene and Eocene) - Small plugs of olive green dacite porphyry containing abundant, coarse (2 to 10 mm) phenocrysts of plagioclase, quartz, biotite, and hornblende in a fine-grained to aphanitic matrix. Propylitic alteration common. Dated by Shubat and Snee (in press) at 36.49±0.15 Ma.

Tml Mt. Laird Tuff (Oligocene and Eocene) - Lavender, pale green, dark green, and brown, moderately welded, dacitic ash-flow tuff, tuff-breccia, lapilli-tuff, and probable flows and hypabyssal intrusions of dacitic composition. Characterized by the presence of abundant, coarse (2 to 12 mm) phenocrysts of white plagioclase. Other phenocrysts present are hornblende, biotite, quartz, and clinopyroxene. Vitrophyre locally present at base of unit. A minor facies consists of accretionary lapilli-block tuff with a distinctive black, aphyric matrix. Dated by Shubat and Snee (in press) at 36.54±0.06 Ma.

Tgd Granodiorite porphyry (Oligocene and Eocene) - Light olive-green to pinkish-green, holocrystalline porphyry containing coarse (2 to 12 mm) phenocrysts of plagioclase, quartz, biotite, hornblende, and clinopyroxene. Matrix consists of quartz, plagioclase, and potassium feldspar. Propylitic alteration common. Forms a stock in the south-central part of the quadrangle. 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. Vitrophyre also locally present within the unit, separating cooling units. Abundant, bronze-weathering biotite prominent on surfaces parallel to layering. Other phenocrysts consist of plagioclase, biotite, quartz, and hornblende. Dated by Shubat and Snee (in press) at 36.77±0.12 Ma.

Dead Ox Tuff* (Oligocene and Eocene) - Divided into:

Tdo Lithic-crystal tuff member - Tan, orange, and pale-green, thick-bedded, moderately to poorly welded, dacitic ash-flow tuff. Contains abundant lithic fragments, ranging from 1 millimeter to 40 centimeters in diameter, of quartzite, limestone, black phyllite, andesite, and pumice. The slightly flattened pumice clasts impart a crude layering to the rock. Phenocrysts consist of plagioclase, quartz, and biotite. Lithic-rich parts weather to form cobble- and boulder-strewn slopes, with little exposed matrix. Argillic alteration common.

Tdom Megabreccia member - Consists of clasts of Prospect Mountain Quartzite, Pioche Formation, undifferentiated Lower Paleozoic limestone, conglomerate, andesitic mudflow breccia, and andesite in a matrix of poorly welded, dacitic lithic-crystal tuff (see lithic-crystal tuff member above). Clast sizes range from less than 1 foot to 800 feet (20 cm to 240 m) in diameter. Most clasts are 10 to 200 feet (3 to 60 m) in diameter. Matrix poorly exposed. Nearly all quartzite clasts and some limestone clasts in the megabreccia are intensely and pervasively brecciated. Brecciated clasts consists of monolithologic, angular, entirely matrix-supported breccia with a fine-grained matrix of comminuted material.

Tdow Stratified tuff member - Tan to orange, poorly exposed, thin-bedded to laminated (1 cm to less than 1 mm) volcanic sandstone, siltstone, and ash-rich tuff. Sand-sized crystal fragments consist of quartz, plagioclase, and biotite. Lithic fragments consist of quartzite, limestone, and volcanic rock. Argillic alteration common.

Tap Andesite porphyry (Eocene) - Small plugs of andesite porphyry containing phenocrysts of plagioclase, biotite, hornblende, and quartz. Dacitic composition.

Ta Andesite of Keg Spring (Oligocene and Eocene) - Dark-colored andesite flows and andesitic mudflow breccia. Flow rock dominates and contains phenocrysts of andesine, biotite, hornblende, quartz, clinopyroxene, and magnetite. Some coarsely porphyritic flows contain plagioclase crystals as long as 15 millimeters. Mudflow breccia contains clasts of andesite, quartzite, limestone, and (locally) Mt. Laird Tuff. Propylitic alteration common. Lindsey (1982) reported an average fission-track age of 39.4±0.7 Ma, but in places the unit is younger than 36.5 Ma.

Tcg Unnamed conglomerate (Eocene) - Conglomerate consisting of well-rounded pebbles and cobbles of quartzite, chert, and limestone in a gray-green, sandy to silty matrix. Poorly exposed.

---------- Unconformity ----------

OCl Undifferentiated carbonate rocks (Ordovician and Cambrian) - Light- to dark-gray, medium- to thick-bedded biosparite with minor shale and intraformational conglomerate interbeds. Unit constitutes the lower plates of thrusts. Correlation uncertain, but probably consists mostly of the Howell Formation. Unit may contain parts of the Chisholm Formation, Dome Limestone, Whirlwind Formation, or Swasey Limestone.

Ch Howell Limestone (Cambrian) - Light- to medium-gray, medium- to thick-bedded biosparite. Contains intercalations of olive-green-gray phyllite at or near the base of the unit. Also contains minor interbeds of oncolytic, dolomitic limestone.

Pioche Formation (Cambrian) - Divided into:

Cpt Tatow Member - Thick-bedded to medium-bedded, mottled orange-brown, oncolytic dolomite and white to gray oncolytic limestone. Forms low cliffs.

Cpl Lower member - medium-bedded, dark-green to black, ledgy quartzite, thin-bedded, dark-olive-green to black phyllitic quartzite, and dark-olive-green phyllite. Quartzite dominates in the lower part and phyllite in the upper part. Phyllite beds locally contain trilobite tracks.

Cpm Prospect Mountain Quartzite (Cambrian) - Pinkish-gray to tan, rusty-weathering, medium-grained, thick-bedded quartzite with small-scale crossbedding. Constitutes the upper plate of a thrust. Most exposures pervasively brecciated.

MAP SYMBOLS

CONTACT

HIGH–ANGLE FAULT

Dashed where location inferred, dotted where covered
bar and ball on downthrown side; dip indicated

THRUST FAULT

Dashed where location inferred, dotted where covered
teeth on upper plate

AIR PHOTO LINEAMENT

Probable locations of faults

BONNEVILLE SHORELINE

B B B

STRIKE AND DIP OF BEDDING

10

STRIKE AND DIP OF LAYERING
IN VOLCANIC ROCKS

10

ANTICLINE

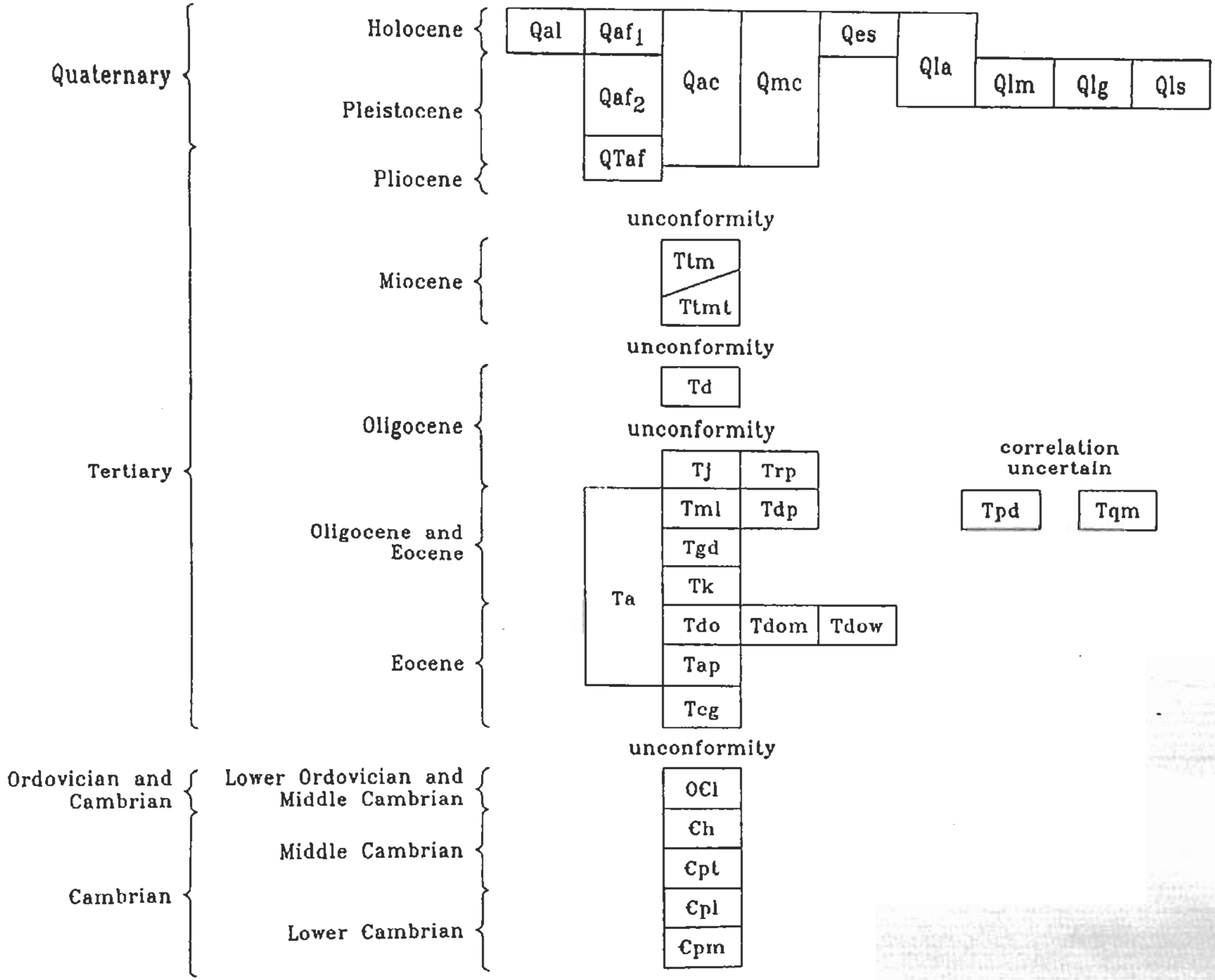
SYNCLINE

PROVO SHORELINE

P P P

Plate 2

Correlation of Map Units



System	Series	Formation		Symbol	Thickness feet(meters)
Tertiary	Miocene	Topaz Mountain Rhyolite	alkali rhyolite and vitrophyre	Ttm	0-590 (0-180)
			stratified tuff	Ttml	0-140 (0-43)
	Oligocene	Dell Tuff		Td	0-360 (0-110)
		Joy Tuff		Tj	0-50 (0-20)
	Oligocene and Eocene	Mt. Laird Tuff		Tml	0-220 (0-67)
		Keg Tuff		Tk	0-640 (0-190)
	Eocene	Dead Ox Tuff	stratified tuff member	Tdow	0-40 (0-12)
			megabreccia member	Tdom	0-250 (0-80)
			lithic-crystal tuff member	Tdo	0-60 (0-18)
		andesite of Keg Spring		Ta	0-200+ (0-60+)
		unnamed conglomerate		Tcg	0-40 (0-12)
Ordovician and Cambrian	Lower Ordovician and Middle Cambrian	undifferentiated carbonate rocks		OCu	500+ (150+)
Cambrian	Middle Cambrian	Howell Limestone		Ch	340+ (104+)
		Pioche Formation	Tatow Member	Cpt	60(18)
	Lower Cambrian		lower member	Cpl	287+ (88+)
		Prospect Mountain Quartzite		Cpm	1230+ (375+)

Lithology