Geologic Map of the Lake Tahoe Basin, California and Nevada

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Introduction

In 1997 President Clinton issued an executive order instructing federal agencies to establish an interagency partnership to coordinate and manage activities within the Lake Tahoe Basin. The Executive Order also called for the establishment of a linked natural resources Geographic Information System (GIS) database. Subsequently the U.S. Geological Survey (USGS) established a Lake Tahoe multi-agency data clearinghouse. At the time, the only digital geologic coverage available contained inconsistencies. Geologic units and contacts did not match across quadrangle boundaries, geologic structures such as faults and folds were not shown, and in some areas more up-to-date mapping was available.

A project to prepare a new digital geologic map and database was proposed to the California Geologic Mapping Advisory Committee who, along with the State Geologist, determines geologic mapping priorities for the California Geological Survey. The proposal was approved by the committee and submitted to the USGS for funding through the STATEMAP component of the National Cooperative Geologic Mapping Program. The immediate objective of this project was to compile the most recent and representative geologic mapping and establish a seamless geologic database to be used by planning and decision-making agencies in the Lake Tahoe Basin. These types of digital data can provide an important component for performing GIS analyses throughout the basin.

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Compilation

The ***Geologic Map of the Lake Tahoe Basin, California and Nevada*** was compiled and digitized from existing, published and unpublished, geologic maps covering the area. The initial compilation of the California portion was completed in 2002 with revisions and the addition of the Nevada geology taking place in 2004. Copies of existing geologic maps, on stable base material, were obtained where possible with flat paper copies being the second choice. In some cases folded paper maps were the only option. The geologic maps were put into digital format by hand, either by scanning and on-screen digitizing or by placing the map on a tablet and digitizing. For the most part, this compilation retains the level of detail shown on the original source maps. However, the structural data had to be simplified extensively to be shown at 1:100,000 scale.

The digital work was completed using ArcInfo® 8.3, a commercial GIS software package by Environmental Systems Research Institute (ESRI). The compilation was prepared in segments using 7.5-minute quadrangle boundaries. The various geologic coverages for each quadrangle along with the base layers and shaded-relief image were combined using the ArcMap application within ArcInfo® 8.3 (ESRI).

For the most part, faults were compiled from the original geologic source maps. Selected faults from the preliminary fault map of Schweickert and others (2000b) were used for traces in the lake bottom and additional traces on land. Only those faults classified by Schweickert and others (2000b) as cutting latest Pleistocene or Holocene deposits were considered. During the review of this compilation, concerns were raised regarding the existence and continuation of some of these faults, especially traces through Quaternary deposits. For this reason fault traces from Schweickert and others (2000b) are not shown through Quaternary deposits and the remainder are shown as inferred with questionable continuation or existence. The evaluation of fault activity in the Lake Tahoe Basin is ongoing. The age and location of the faults in the lake bottom and cutting

Quaternary deposits should be considered preliminary interpretations.

Geologic Summary

Located high in the Sierra Nevada, Lake Tahoe offers some of the most picturesque scenery in the world. Elevations in the basin range from 1,897 meters (6,225 feet) at lake level to 3,320 meters (10,891 feet) at Freel Peak. Nestled between the Sierra Nevada on the west and the Carson Range to the east, Tahoe's cold, clear water and surrounding rugged, snow-capped mountain peaks contribute to its natural beauty. Over millions of years, a complex interaction of geologic processes has shaped and carved the landscape into the vistas we see today. The geologic history of the area records periods of marine deposition, granitic intrusion, tectonic uplift, volcanic eruptions, glacial scouring, and erosion that have been repeated over a vast expanse of time.

The oldest rocks in the area are seen as isolated remnants of metamorphosed Paleozoic and Mesozoic volcanic and sedimentary rocks that were intruded by the Jurassic and Cretaceous granitic rocks of the Sierra Nevada batholith. These metamorphic remnants are the products of ancient volcanic arcs and related submarine sedimentary deposits (Harwood and Fisher, 2002).

Prior to the main uplift of the Sierra Nevada ancient Tertiary (Eocene?) rivers passed through the area carving channels and depositing accumulations of gravel, sand and silt derived from the erosion of the older metamorphic basement rocks. These rivers also provided the channels that carried the volcanic flows and debris from the early volcanic centers that developed locally and to the east (Harwood and Fisher, 2002; Schweickert and others, 2000a).

Volcanism was widespread during the Tertiary. The earliest deposits were Oligocene and possibly early Miocene age rhyolitic ash-flow tuffs, that originated from the east (Harwood and Fisher, 2002). This early volcanic episode was followed by a period that extended through most of the Miocene and into the Pliocene, characterized by large accumulations of andesitic mudflow breccia and andesite and basaltic andesite flows. Volcanic eruptions continued into the Pleistocene and consisted mainly of basalt and latite flows that were deposited on the older volcanic sequences (Harwood and Fisher, 2002; Schweickert and others, 2000a).

During the Pleistocene, glaciation played a major role in the shaping of the landscape. Birkeland (1964) recognized four glacial episodes in the northern part of the basin. He established their relative ages and correlated them in part with other known glacial stages in the Sierra Nevada. Evidence of glacial activity is apparent throughout most of the basin. The most commonly recognized glacial feature are the moraines, the long narrow ridges composed of granitic and volcanic debris scoured from the local rocks. They can be seen around Fallen Leaf Lake, Emerald Bay and Meeks Bay on the west and southwestern shore of the lake.

It has generally been known, since the first geologists explored the area, that faulting has played a part in the formation of Lake Tahoe. Studies related to the distribution and types of faults in and around the area have led to a better understanding of how and to what extent faults have played in the development of the basin. It is now recognized that basin-and-range type faulting has extended into the area creating a series of west-tilted blocks bounded by east-dipping faults that produce the north south-trending basin that Lake Tahoe now occupies. It is generally accepted that Lake Tahoe was formed by a combination of block faulting and damming of the outlet, at the north end of the basin, by repeated episodes of volcanic activity and glacial advances.

In 1998, using the latest-generation imaging equipment and technology, the U.S.G.S. (Western Region Coastal and Marine Geology Branch) in cooperation with the University of New Brunswick, Canada (Ocean Mapping Group), were able to image the lake bottom in stunning detail (Gardner and others, 1998). This new imagery not only provided a detailed picture of known features on the lake bottom, it also revealed some previously unidentified geologic features. Linear features seen on the lake bottom were interpreted to be relatively young faults offsetting recent sediments. McKinney Bay, the large embayment on the western shore and large blocks scattered on the lake bottom, were attributed to a large debris-avalanche that was originally thought to have occurred within the last 11,000 years (Gardner and others, 2000; Karlin and others, 2001). Recent studies indicate this slide may have occurred around 55,000 to 60,000 years ago (written communication, G.M. Kent, 2004). These features, as well as the faults and landslides exposed above lake level, raise questions as to the earthquake potential in the area as well as the possibility of a seismically-triggered, tsunami-type wave that could cause considerable damage and loss of life around the lake (Ichinose and others, 2000). Investigations to evaluate these hazards and their potential are ongoing.

Base material

The base for this geologic map was prepared by scanning mylar separates of the various layers (culture, hydrography, hypsography and roads) that make up the Placerville, Truckee and Smith Valley 30' x 60' USGS topographic quadrangle maps. The scanned images were then vectorized, registered, digitally combined, and edited to remove unnecessary lines. The base for the Carson City 30' x 60'quadrangle was obtained in digital format as Digital Line Graphics (DLG's) and edited for continuity with the other base maps. The shaded-relief and bathymetric image was obtained from the USGS Lake Tahoe data clearinghouse (http://tahoe.usgs.gov/DEM.html) which was derived in part from Gardner and others (1998) (http://tahoe.usgs.gov/openfile.html; also see Dartnell and Gardner, 1999).

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DESCRIPTION OF MAP UNITS

Unit descriptions are taken from geologic map sources; see Correlation of Map Units (Figure 1) for stratigraphic relationships.

af	**Artificial fill (late Holocene) –** Man-made deposits of varying composition.
Qb	**Beach deposits (Holocene) –** Moderately sorted, fine- to very coarse-grained to gravelly arkosic sand.
Qfp	**Flood-plain deposits (Holocene) –** Gravelly to silty sand and sandy to clayey silt. Locally includes lacustrine and delta deposits. In part may be Pleistocene.
Qt	**Talus deposits (Holocene) –** Accumulations of coarse angular blocks to gravelly and sandy granitic and volcanic debris. In part may be Pleistocene. Extensive deposits along the Truckee River.
Ql	**Lake deposits (Holocene) –** Thin-bedded sandy silt and clay.
Qyg	**Younger glacial deposits (Holocene) –** Unsorted sandy to clayey, boulder to cobble till; forms undissected moraines. Locally may include talus and alluvial fan deposits.
Qc	**Colluvium (Holocene) –** Unsorted, poorly consolidated granitic colluvium, decomposed granite, soil, matrix supported debris flow material, sand and cobble to boulder gravel.
Qls	**Landslide deposits (Holocene and Pleistocene) –** Unsorted angular boulder- to clay-size debris; locally may include talus, colluvium, rockfall and avalanche deposits. Includes accumulations of poorly sorted, disrupted materials transported by debris flows.
Q	**Alluvium (Holocene and Pleistocene) –** Unconsolidated, moderately to poorly sorted sand, silt and gravel. Locally includes alluvial fan deposits, glacial outwash and lacustrine deposits.
Qf	**Alluvial fan deposits (Holocene and Pleistocene) –** Poorly sorted bouldery sand and gravel. Locally includes older fan deposits and alluvium.
Qm	**Mudflow deposits of Birkeland (1961) (Holocene and (or) Pleistocene) –** Cobbles and boulders of local bedrock in a mud matrix deposited as a debris flow or flows at the confluence of Deer Creek and the Truckee River.
Qob	**Older beach deposits (Pleistocene) –** Moderately sorted gravelly, coarse arkosic sand in the South Lake Tahoe quadrangle.
Qol	**Older lake deposits (Pleistocene) –** Thin-bedded sandy silt and clay.

Qlt **Lacustrine terrace deposits (Pleistocene) –** Poorly to moderately sorted silt, sand and gravel forming broad low terraces 5-10 meters above lake level. Locally includes delta deposits.

Tioga glacial deposits (Pleistocene) – Approximate age 9,990 – 25,500 YBP (Yount and LaPointe, 1997)

Qti **Till –** Unconsolidated, gray to light-tan, bouldery polymict till characterized by large granitic boulders, generally unweathered; preserved as sharp-crested moraines. Locally may include outwash deposits.

Qtio **Outwash deposits –** Unconsolidated boulder and cobble gravel, sand and silt; generally unweathered.

Tahoe glacial deposits (Pleistocene) – Approximate age 56,000 – 118,000 YBP (Yount and LaPointe, 1997)

Qta **Till –** Unconsolidated bouldery till with distinct yellow-brown weathered matrix; preserved as larger moraines with more rounded and broader crests. Locally may include outwash deposits.

Qtao **Outwash deposits –** Unconsolidated polymict boulder to cobble gravel, sand and silt; distinguished from Tioga outwash deposits by higher terrace position and greater degree and depth of soil development.

Tahoe and Tioga glacial deposits – undivided (Pleistocene)

Qgt **Till –** Unsorted to very poorly sorted, bouldery to clayey gravel; surface granitic boulders slightly to moderately weathered. Associated with undissected to moderately dissected moraines. Locally may include outwash deposits.

Older glacial deposits (Pleistocene) – Pre-Tahoe deposits. Includes Sherwin deposits of Birkeland (1961) and Donner Lake deposits of Harwood and Fisher (2002)

Qog **Till –** Deeply weathered bouldery deposits generally without morainal form; surface granitic boulders are weathered with stained, pitted and knobby surface; granitic boulders within the deposit are decomposed. Locally may include outwash deposits.

Qogo **Outwash deposits –** Poorly sorted boulder and cobble gravel, sand and silt.

Glacial deposits undivided (Pleistocene and Holocene?) – Includes Tioga and Tahoe age deposits as well as pre-Tahoe and possibly younger (Holocene) glacial deposits

Qg **Till –** Includes Tioga and Tahoe age deposits as well as pre-Tahoe and possibly younger (Holocene) glacial deposits.

Qgo **Outwash deposits –** Poorly sorted boulder and cobble gravel, sand and silt.

Qvbm **Bald Mountain olivine latite of Birkeland (1961) (Pleistocene) –** Dark-gray olivine latite flow erupted from vents at and southwest of Bald Mountain. Qvbmcc – cinder cone deposits. Includes olivine shoshonite flows, scoria and tuff of Latham (1985). K/Ar whole-rock age of 1.2±0.1 Ma (recalculated from Dalrymple, 1964).

Qjf **Juniper Flat alluvium of Birkeland (1961) (Pleistocene) –** Interfingering lenses of silt, sand and gravel; gravel is mainly andesitic. Includes Union Valley sediments of Latham (1985)

Qpc **Prosser Creek alluvium of Birkeland (1961) (Pleistocene) –** Indurated polymict boulder to pebble gravel, sand and silt; partly alluvial and partly lacustrine. Deposited when Truckee River drainage was blocked by Hirschdale olivine latite flows.

Qvh **Hirschdale olivine latite of Birkeland (1961) (Pleistocene) –** Dark-gray to dark-green porphyritic olivine latite flows containing pillow structures near base; erupted from vents near Juniper Flat. Qvhcc – cinder cone deposits, Qvht – basaltic tuff. Includes Juniper Flat flow of Latham (1985). K-Ar whole-rock age of 1.3±0.1 Ma (recalculated from Dalrymple, 1964).

QPot **Older talus deposits (Pliocene and (or) Pleistocene) –** Moderately weathered, lichen-encrusted, bouldery deposits in the Mt. Tallac area. Interpreted to be the dissected remnants of a previous land surface (Fisher, 1989).

QPvd **Dry Lake volcanic flows of Birkeland (1961) and Wise and Sylvester (2004) (Pliocene and (or) Pleistocene) –** Consists of at least four aphyric and porphyritic flows of potassium-rich andesite and dacite from domes south and southeast of Dry Lake in the Martis Peak quadrangle. QPvd1 – QPv4 (oldest to youngest). A whole-rock age of 1.34 Ma is reported from a flow west of Klondike Meadow in the Martis Peak quadrangle (written communication, A.G. Sylvester, 2004). Birkeland (1961) originally mapped five latite and basalt flows; Latham (1985) mapped six hornblende and pyroxene andesite flows.

QPvbc **Big Chief basalt of Birkeland (1961) (Pliocene and (or) Pleistocene) –** Dark-gray hypocrystalline basalt with sparse olivine phenocrysts; probably erupted from fissures along northwest-trending faults. Deer Creek trachybasaltic andesite flow of Wise and Sylvester (2004).

QPvpm **Page Meadow basalt of Wise and Sylvester (2004) (Pliocene and (or) Pleistocene)** Olivine basalt flows and dikes along south side of Truckee River and under Page Meadows. Also occurs as dikes in the Sunnyside area.

QPs **Unnamed gravels, sand and alluvium (Pliocene and (or) Pleistocene) –** Undivided gravels and alluvial deposits. Includes Cabin Creek alluvium of Birkeland (1961) in the Truckee quadrangle - weathered andesitic cobble gravel and interstitial andesitic sand overlain by the Bald Mountain flow. Also includes the Fir Crags gravel of Birkeland (1961) in the Tahoe City quadrangle - andesitic cobble gravel that underlies the Page Meadow basalt. Locally may include lacustrine deposits.

QPvbu **Burton Creek basalt of Wise and Sylvester (2004) (Pliocene and (or) Pleistocene)** Olivine basalt flows south of Burton Creek.

QPvlf **Lake Forest basalt of Wise and Sylvester (2004) (Pliocene and (or) Pleistocene) –** Olivine basalt flows northwest of Lake Forest.

QPvb **Unnamed volcanic rocks (Pliocene and (or) Pleistocene) –** Basalt flows**,** flow breccia and basaltic ash. Includes maar at Lake Forest near Dollar Point.

QPi **Unnamed intrusive rocks (Pliocene and (or) Pleistocene) –** Irregular-shaped intrusions and dikes of andesite, latite and basalt. May include local flows. QPia – intrusive andesite and latite; QPib – intrusive basalt.

Pvta **Tahoe City trachyandesite of Wise and Sylvester (2004) (Pliocene) –** Thick trachyandesite flows northwest of Tahoe City. Pvtcc - cinder cone deposits.

Pvtb **Tahoe City basalt of Wise and Sylvester (2004) (Pliocene) –** Dark-gray olivine basalt and palagonitic basalt flows with local pillow structures at the base; underlies Tahoe City and forms a bench along Truckee River. Tahoe City olivine latite of Birkeland (1961). K-Ar whole-rock age of 2.0±0.1 Ma (recalculated from Dalrymple, 1964).

Pvp **Polaris olivine latite of Birkeland (1961) (Pliocene) –** Small olivine latite flow overlying latite tuff and tuff breccia. Pvpt – latite tuff and tuff breccia. K-Ar whole-rock age of 1.68±0.05 Ma (recalculated from Doell and others, 1966).

Pvah **Alder Hill basalt of Birkeland (1961) (Pliocene) –** Three olivine basalt flows probably erupted from vent on Alder Hill. Pvahcc - cinder cone deposits. Includes Alder Creek and Beacon flows of Latham (1985). K-Ar whole-rock age of 2.4±0.1 Ma (recalculated from Dalrymple, 1964).

Ps **Fluvial and lacustrine deposits (Pliocene) –** Fluvial and lacustrine deposits of shale, sandstone and ash. Includes deposits mapped as Truckee and Coal Valley formations. North of the map area, in the Boca quadrangle, Ar/Ar and tephrochronologic data on ash beds on the west side of Boca Reservoir give ages of between 3 and 4 Ma (Henry and Perkins, 2001).

Unnamed volcanic and intrusive rocks (Pliocene) – consists of:

Pva **Andesite and basaltic andesite flows (Pliocene) –** Light- to dark-gray, fine-grained porphyritic, massive to locally flow-banded andesite and basaltic andesite flows. Occurs as continuous flows and isolated remnants of larger flows deposited in channels eroded in older Tertiary volcanic deposits. Includes lava domes in the Agate Bay area (Wise and Sylvester, 2004). Harwood and Fisher (2002) report K-Ar whole-rock ages that range from 3.3±0.09 to 4.7±0.1 Ma on andesite flows in the Homewood, Tahoe City, and adjacent quadrangles to the west. Basaltic andesite flows along the northwest corner of the Martis Peak quadrangle have been dated north of the map area in the Boca quadrangle. Samples at Boca Hill and from a flow to the north give Ar/Ar whole-rock ages of 4.09±0.40 Ma and 3.95±0.15 Ma respectively (written communication, C.D. Henry, 2004). K-Ar whole-rock ages of 2.3±0.1 Ma (recalculated from Dalrymple, 1964) on an upper andesite flow and 2.53±0.07 Ma (recalculated from Doell and others, 1966) on a lower andesite flow along the highway south of Watson Creek in the Kings Beach quadrangle.

Pval **Andesite lahars (Pliocene) –** Deposits of blocky, light- to dark-gray tuff breccia derived from and interbedded with hornblende- and hypersthene- bearing flows.

Pvb **Basalt flows (Pliocene) –** Dark-gray to black, fine-grained, sparsely porphyritic to glomeroporphyritic olivine basalt flows occurring as small, widely separated, columnar-jointed masses deposited on older Tertiary volcanic rocks and granitic rocks. K-Ar whole-rock ages on basalt flows, west of the map area, range from 7.6± 0.2 to 4.0±0.1 Ma (Harwood and Fisher, 2002). Includes the Boca Ridge flows of Latham (1985) - porphyritic olivine basaltic andesite, shoshonite, latite and mugearite flows. North of the map area, in the Boca quadrangle, Latham (1985) reports a K-Ar whole-rock age of 2.8 Ma on a flow north of Rocky Canyon on Boca Ridge. Henry and Perkins (2001) report an Ar/Ar whole-rock age of 2.61±0.03 Ma on the same basaltic andesite flow.

Pi **Dikes and intrusives (Pliocene) –** Pia - Flow-banded to massive, fine- to coarse-grained hornblende andesite dikes and altered intrusive andesite and andesite breccia in vent areas; Pib - Black, fine-grained olivine basalt dikes and intrusives. Harwood and Fisher (2002) report a K-Ar whole-rock age of 3.0±0.08 Ma on an andesite plug in the Ellis Peak area and 4.0±0.1 and 4.1±0.1 Ma ages on andesite dikes in the Ward Peak area. Andesite dikes, to the west of the map area, have K-Ar whole-rock ages that range from 3.6±0.05 to 4.3±0.1m.y (Harwood and Fisher, 2002). Basalt dikes, in the same area, have K-Ar whole-rock ages that range from 3.9±0.1 to 4.4±0.1 Ma (Harwood and Fisher, 2002).

Unnamed volcanic and intrusive rocks (Miocene) – consists of:

Mva **Undivided andesitic and dacitic lahars, flows, breccia and volcaniclastic sediments (Miocene) –** Undivided andesite, trachyandesite, basaltic andesite and dacite lahars, flows, breccia and volcaniclastic sediments; local basalt flows. In part, may include rocks of Pliocene age. Locally includes rhyolite tuff. Includes Mehrten, Relief Peak and Kate Peak formations. An andesite block from a block and ash flow tuff west of Kirkwood Valley in the Caples Lake quadrangle gives a preliminary Ar/Ar plagioclase age of 6.0±0.2 Ma (DeOreo, 2004). An andesite block from a block and ash flow tuff east of Kirkwood Valley in the Caples Lake quadrangle gives an Ar/Ar biotite age of 14.70±0.06 Ma and a preliminary plagioclase age of 14.0±0.5Ma (DeOreo, 2004). An andesite peperite dike that intrudes debris flow deposits east of Kirkwood Valley in the Caples Lake quadrangle gives an Ar/Ar whole rock age of 10.6±0.2 Ma and a preliminary plagioclase age of 10.4±0.2 Ma (DeOreo, 2004).

Mvaf **Andesite and dacite flows (Miocene) –** Massive to platy andesite, includes hornblende- and pyroxene-andesite flows and dacite flows. Locally includes andesite and dacite domes; in part may be Pliocene. May locally include trachybasalt and basalt flows. An andesite flow west of the map area in the Norden quadrangle gives an Ar/Ar hornblende age of 6.33± 0.25 Ma (written communication, C.D. Henry, 2004).

Mvbf **Basalt flows (Miocene) –** Grey to black, aphyric to coarsely crystalline basalt flows. A basalt flow at Red Lake Peak in the Carson Pass quadrangle gives an Ar/Ar whole rock age of 6.75±0.15 Ma (DeOreo, 2004). May locally include andesite and trachyandesite flows.

Mvs **Fluvial deposits (Miocene) –** Well-stratified, clast-supported deposits composed of mafic to intermediate volcanic clasts in the Caples Lake and Carson Pass quadrangles. Includes interstratified coarse-grained fluvial and volcanic debris flow deposits at Castle Point in the Caples Lake quadrangle and volcanic lithic sandstones and cobble conglomerate-breccia at Elephants Back in the Carson Pass quadrangle.

Mi **Intrusive rocks (Miocene) –** Local dikes and intrusions of andesite, latite, basaltic andesite, basalt and rhyolite; in part may be Pliocene. Mia – andesite, basaltic andesite and latite; Mib – basalt and basaltic andesite; Mir – rhyolite. An Ar/Ar age of 6.32 Ma on hornblende is reported from a hornblende andesite intrusion in the Martis Peak quadrangle at Martis Peak (written communication, W.S. Wise, 2004). A basaltic andesite intrusion on the west side of Little Valley in the Marlette Lake quadrangle and a basalt dike west of Donner Lake in the Norden quadrangle, west of the map area, give Ar/Ar whole-rock ages of 13.9±0.9 Ma and 8.4±0.4 Ma respectively (written communication, C.D. Henry, 2004). Armin and others (1984) report a K-Ar age of 5.2±0.8 Ma on a hornblende andesite neck at Stevens Peak and a K-Ar age of 13.4±1.5 Ma on an andesite dome at Elephants Back in the Carson Pass quadrangle.

Mvg **Glenbrook volcanic center (Miocene) –** Porphyritic hornblende-sanidine latite in irregular-shaped intrusive masses and dikes, local vitric-crystal tuff and associated hornblende trachyte flows and vent fill in the Glenbrook quadrangle (Grose, 1985). Mvgi – latite intrusions; Mvgt – vitric-crystal tuff; Mvgf – trachyte flows and vent fill. Morton and others (1977) report a K-Ar age of 8.7±0.3 Ma.

Upper lahar sequence of Harwood and Fisher (2002) (Miocene) – consists of:

Mvul **Andesitic lahars (Miocene) –** Light- to dark-gray lahars composed primarily of hornblende andesite blocks mixed with basalt and dacite fragments.

Mvula **Andesite flows (Miocene) –** Light-gray weathering, dark-gray, fine-grained, porphyritic hornblende andesite flows.

Mvulp **Pumiceous tuff (Miocene) –** White to yellow-tan, hornblende-rich pumice lapilli air-fall tuff; pumice lapillae up to 2 cm in diameter mixed with generally minor amounts of dark-gray to brick-red scoria; massive to thick-bedded, locally graded layers.

Mvulr **Rockslide-avalanche deposits (Miocene) –** Mottled gray, tan, brick-red and yellow, nonstratified, heterolithologic chaotic mixture of huge volcanic blocks and matrix; blocks consist of intensely fractured and altered, aphanitic dacite(?), scattered blocks of andesite and andesitic lahar in a matrix of volcanic mudstone and ash. Forms a widespread debris blanket south and southwest of Squaw Valley.

Lower lahar sequence of Harwood and Fisher (2002) (Miocene) - consists of:

Mvll **Andesitic lahars (Miocene) –** Gray to brick-red, blocky, massive locally flow-banded lahars composed of chaotic mixtures of andesitic fragmental debris in a volcaniclastic muddy matrix; minor interbedded volcanic conglomerate and sandstone; sparse andesite flows.

Mvlla **Andesite flows (Miocene) –** Light-gray weathering, dark-gray, fine-grained, porphyritic hornblende andesite flows. Harwood and Fisher (2002) report a K-Ar whole-rock age of 5.4±0.07 Ma on an andesite flow west of the map area in the Granite Chief quadrangle.

Unnamed volcanic and sedimentary rocks

ϕMvr **Rhyolite tuff (Oligocene and Miocene?) –** Crystal-rich to crystal-poor, welded and non-welded rhyolite tuff from sources in central and western(?) Nevada. Includes the Valley Springs Formation, Lenihan Canyon Tuff and the Mickey Pass Tuff. Ar/Ar ages for the Lenihan Canyon Tuff (26.60±0.06 Ma) and the Mickey Pass Tuff (26.94±0.07 Ma) were obtained from samples collected at McClellan Peak in the Virgina City quadrangle, Nevada (written communication, C.D. Henry, 2004). Other isotopic ages determined for rhyolite tuffs exposed to the east and west of the map area range from 21.6 to 33.9 Ma (Harwood and Fisher, 2002; Stewart, 1999).

ϕc **Conglomerate and breccia (Oligocene and (or) older Tertiary) –** Conglomerate consisting of angular to rounded boulders of Tertiary volcanic rocks and pre-Tertiary metavolcanic and mafic plutonic rocks.

Granitic rocks

ap **Aplite and pegmatite dikes (Cretaceous) –** Medium- to fine-grained; in places altered and iron-stained.

Kelg **Echo Lake granodiorite (Cretaceous) –** Very light-gray, medium- to coarse-grained, weakly porphyritic hornblende-biotite granodiorite; locally includes quartz monzonite. Commonly weathers to pale-orangish-gray grus. Characterized by small microcline phenocrysts 0.5 to 1.5 cm long and abundant flattened mafic inclusions. Mafic inclusions are common and are locally abundant near contacts. Similar to and probably correlative with the Freel Peak granodiorite. Armin and John (1983) report a K-Ar age of 91.7±0.8 Ma (hornblende) and 72.8±1.0 Ma (biotite) from a sample collected on the north side of Waterhouse Peak in the Freel Peak quadrangle.

Intrudes the Keiths Dome quartz monzonite and is intruded by the Bryan Meadow granodiorite.

Kppg **Phipps Pass granodiorite (Cretaceous) –** Medium- to coarse-grained, equigranular hornblende-biotite granodiorite. Texturally similar to the more potassic granodiorite phases of the Bryan Meadow granodiorite.

Kbmg **Bryan Meadow granodiorite (Cretaceous) –** Light-gray, medium-grained locally porphyritic hornblende-biotite granodiorite typically containing about 5 percent subhedral and euhedral hornblende crystals as large as 1 cm, and similar amounts of biotite in a groundmass of feldspar and quartz. Intrudes the Echo Lake granodiorite, Burnside Lake adamellite, granodiorite of Freel Peak, Lovers Leap granodiorite, quartz diorite of Jobs Canyon, Keiths Dome quartz monzonite, and the Desolation Valley granodiorite. Armin and John (1983) report K-Ar ages of 89.3±2 and 89.6±2 Ma (biotite) for a sample collected in Horsethief Canyon in the Freel Peak quadrangle.

Kllg **Lovers Leap granodiorite (Cretaceous) –** Light-gray, fine- to medium-grained porphyritic hornblende-biotite granodiorite with abundant 10- to 15-mm-long poikilitic potassium feldspar phenocrysts and fairly abundant clots of fine-grained biotite and hornblende 3 to 10 mm in diameter. Intruded by the Wrights Lake granodiorite and Bryan Meadow granodiorite.

Kgag **Glen Alpine granodiorite (Cretaceous) –** Hornblende-biotite granodiorite; foliated throughout; mafic inclusions commonly less than 16 mm. Hornblende crystals define a vertical lineation near the contacts.

Ktlg **Tyler Lake granodiorite of Sabine (1992) (Cretaceous) –** Medium-grained, equigranular granodiorite. Plagioclase forms equant or tabular euhedral to subhedral crystals 1 to 3 mm across. Biotite is the principal mafic mineral occurring as discrete grains or in small clusters. Intrudes the Pyramid Peak granite and the Desolation Valley granodiorite.

Kwlg **Wrights Lake granodiorite (Cretaceous) –** Medium- to coarse-grained hornblende-biotite granodiorite with poikilitic potassium feldspar; distinguished by euhedral hornblende 8 to 15 mm long. Randomly distributed mafic inclusions are common. A general planar orientation of hornblende and plagioclase defines a subtle foliation. Intrudes the Pyramid Peak granite, Camper Flat granodiorite, and the Lovers Leap granodiorite.

Kdlg **Dicks Lake granodiorite (Cretaceous) –** Medium- to coarse-grained hornblende-biotite granodiorite; foliated and lineated subvertically near the contact. Intrudes the Camper Flat granodiorite and the quartz diorite of Azure Lake.

Krpa **Alaskite at Rubicon Point (Cretaceous) –** Medium- to coarse-grained alaskite. Consists of quartz, plagioclase, microcline, and biotite. Foliate structure indicates it is younger than the Phipps Pass granodiorite.

Krvg **Rockbound Valley granodiorite (Cretaceous) –** Hornblende-biotite granodiorite; distinguished by the consistent and relatively fine grain size of the mafic minerals. Intrudes the Camper Flat granodiorite.

Kwpg **Granodiorite of Waterhouse Peak (Cretaceous) –** Dark-gray, fine-grained, equigranular hornblende-biotite granodiorite to quartz monzodiorite exposed on the northeast flank of Waterhouse Peak. Flattened diorite inclusions are locally abundant. Intrudes the Echo Lake granodiorite and the Bryan Meadow granodiorite.

Kgqd **Quartz diorite of Grass Lake (Cretaceous) –** Medium- to dark-gray, medium-grained, strongly foliated hornblende-biotite quartz diorite. Local protoclastic gneissic bands parallel the dominant foliation defined by preferred orientation of biotite. Intrudes the Bryan Meadow granodiorite.

Kkgg **Granodiorite of Kingsbury Grade (Cretaceous) –** Medium-grained hornblende-biotite granodiorite characteristically containing 5 to 10 percent of large (7-10 mm) anhedral biotite flakes. Contains plagioclase laths, microcline patches as much as 15 mm in diameter, quartz, and 2- to 5-mm-long hornblende laths. Strongly foliated along northern and western contacts where a fine-grained chilled margin indicates that this rock intruded both the granodiorite of Daggett Pass and the granodiorite of East Peak.

Kwpt **Tonalite West of Waterhouse Peak (Cretaceous) –** Dark-gray, medium-grained, locally strongly foliated hornblende-biotite tonalite that crops out on the west side of Waterhouse Peak. Characterized by clots of anhedral fine-grained biotite and hornblende as long as 1 cm. Intrudes the Freel Peak granodiorite.

Keg **Granodiorite of East Peak (Cretaceous) –** Fine- to medium-grained, well-foliated, equigranular to weakly porphyritic hornblende-biotite granodiorite to quartz monzodiorite. Contains potassium feldspar that locally forms subhedral phenocrysts to 1.5 cm long, and hornblende which occasionally form needles as long as 15 mm. Foliation is defined by sub-parallel alignment of biotite, hornblende, and locally feldspars. Intruded by the Bryan Meadow granodiorite and the granodiorite of Kingsbury Grade, and it intrudes the granodiorite of Daggett Pass. Equivalent to quartz monzodiorite and granodiorite of Zephyr Cove of Grose (1985).

Ksgr **Monzogranite of Spooner Summit of Grose (1985) (Cretaceous) –** White to light-gray, medium-grained idiomorphic, slightly porphyritic with hornblende laths locally to 10 mm long. Massive to weakly foliated with rare dioritic inclusions 1 to 20 cm long.

Ktcg **Granodiorite of Thornburg Canyon (Cretaceous) –** Light-gray, medium-grained, porphyritic biotite granodiorite; contains blocky potassium feldspar phenocrysts to 3 cm in a salt-and-pepper textured groundmass.

Kcvg **Granodiorite of Charity Valley (Cretaceous) –** Light-gray, medium- to fine-grained, porphyritic biotite granodiorite; contains tabular potassium feldspar phenocrysts up to 2 cm. Mafic minerals are euhedral and subhedral biotite books and less common euhedral hornblende. Sphene is an abundant accessory mineral.

Kcld **Diorite of Caples Lake (Cretaceous) –** Dark-gray, medium-grained, strongly foliated, weakly porphyritic hornblende-biotite diorite. Characterized by a strong biotite-hornblende foliation, abundant flattened mafic inclusions and sparse plagioclase phenocrysts 5 to 8 mm long. Intrudes the granodiorite of Caples Lake.

Kclg **Granodiorite of Caples Lake (Cretaceous) –** Pinkish-gray, medium-grained, sparsely porphyritic, moderately well foliated hornblende-biotite granodiorite. Characterized by subhedral to anhedral subparallel biotite and hornblende crystals and sparse blocky potassium feldspar phenocrysts 5 to 10 mm long. McKee and Howe (1981) reported a K-Ar age of about 94 Ma (biotite).

Kfpg **Freel Peak granodiorite (Cretaceous) –** Light orangish-gray-weathering, medium-grained, weakly porphyritic biotite granodiorite characterized by abundant ovoid quartz aggregates, small potassium feldspar phenocrysts 0.5 to 1.5 cm long, and ragged biotite crystals. Flattened mafic inclusions are abundant. Lithologically similar to Ebbetts Pass granodiorite of Wilshire (1957). Intrudes the quartz diorite of Jobs Canyon and is intruded by the tonalite west of Waterhouse Peak, the Burnside Lake adamellite, and the Bryan Meadow granodiorite. Armin and others (1984) report a K-Ar age of 93.2±3.0 Ma (hornblende) and 82.9±1.5 Ma (biotite) from a sample collected at Armstrong Pass in the Freel Peak quadrangle.

Kbla **Burnside Lake adamellite of Parker (1961) (Cretaceous) –** Light pinkish-gray, pale-pinkish-orange-weathering, porphyritic biotite granite containing microcline phenocrysts 1 to 3 cm long in a medium-grained groundmass. Intrudes both the Echo Lake granodiorite and the Freel Peak granodiorite and is intruded by the Bryan Meadow granodiorite. Armin and John (1983) report a K-Ar age of 86.5±0.5 Ma (biotite) for a sample collected at Scotts Lake in the Freel Peak quadrangle.

Kdpg **Granodiorite of Daggett Pass (Cretaceous) –** Medium- to coarse-grained, well-foliated hornblende-biotite granodiorite that grades into a mafic quartz monzodiorite about 1 km east of Daggett Pass. Hornblende crystals define a strong protoclastic foliation in the monzodiorite. Intruded by the granodiorite of Kingsbury Grade and the Bryan Meadow granodiorite. Armin and John (1983) report a K-Ar age of 92.1±2 Ma (hornblende) and 88.3±2 Ma (biotite) for a sample collected at Daggett Pass and a K-Ar age of 85.6±2 Ma (biotite) for a sample collected near the bottom of Daggett Creek, near the junction of the old Kingsbury Grade Road and Foothill Road east of the map area in the Minden quadrangle.

Kcpt **Carson Pass tonalite of Parker (1961) (Cretaceous) –** Brownish-gray to bluish-gray, medium-grained, moderately foliated hornblende- and biotite-bearing granitic rock, ranging from granodiorite to quartz diorite. Oriented mafic minerals and flattened mafic inclusions define the foliation. Intrudes the Burnside Lake adamellite of Parker (1961). Armin and others (1984) report a K-Ar age of 90.9 ±2 Ma (biotite) for a sample collected at Carson Pass.

Kfvg **Granodiorite of Faith Valley (Cretaceous) –** Medium-gray, fine- to medium-grained, equigranular hornblende-biotite granodiorite.

Kepg **Ebbetts Pass granodiorite of Wilshire (1957) (Cretaceous) –** Light-gray, medium- to moderately coarse-grained biotite granodiorite. Anhedral biotite is the main mafic mineral, and anhedral hornblende is rare to locally common. Quartz characteristically occurs in ovoid aggregates. Locally the texture is prophyritic with microcline phenocrysts averaging 1.5 cm long. Mafic inclusions are common to locally abundant. Armin and others (1984) report a K-Ar age of 94.6±2.0 Ma (hornblende) from a sample collected on the south side of the Mokelumne River.

Kklg **Granodiorite of Kinney Lakes (Cretaceous) –** Light-gray, medium-grained hornblende-biotite granodiorite. Biotite occurs as euhedral elongated books and subhedral flakes and is more abundant than subhedral and euhedral hornblende prisms. Euhedral sphene is ubiquitous. Abundant mafic inclusions and a strong mineral foliation are usually present near contacts between this and older plutons. Mapped previously as Ebbetts Pass granodiorite by Wilshire (1957) and Curtis (1951). Evernden and Kistler (1970) reported a K-Ar age of 83.9±2 Ma (biotite) for this pluton.

bd **Basalt dikes (Cretaceous) –** Most were intruded into east-west vertical joint sets. Dikes intrude the older diorite and gabbros (Jdg), Pyramid Peak granite, Keiths Dome quartz monzonite, Desolation Valley granodiorite and the Camper Flat granodiorite (Loomis, 1983). In places remapped as microdiorite dikes (Jmd) by Sabine (1992).

Kdqd **Quartz monzodiorite north of Daggett Pass (Cretaceous?) –** Dark-blue-gray, medium-grained, equigranular, locally strongly foliated hornblende-biotite quartz diorite; exposed north of Daggett Pass.

Kbp **Breccia pipe (Cretaceous?) –** Angular fragments of metamorphic rock enclosed in a fine-grained granitic groundmass in the Carson Pass quadrangle.

Kcfg **Camper Flat granodiorite (Cretaceous or Jurassic?) –** Coarse-grained, equigranular hornblende-biotite granodiorite locally with oligoclase phenocrysts to 20 mm long. Contains numerous randomly distributed inclusions, most are mafic and larger than those in other local intrusive bodies. Intruded by the Rockbound Valley and Phipps Pass granodiorites. Intrudes the Pyramid Peak granite.

Kdvg **Desolation Valley granodiorite (Cretaceous or Jurassic?) –** Hornblende-biotite granodiorite; contains a large number of randomly distributed mafic inclusions and a complex internal foliation. Intrudes the Pyramid Peak granite and the Keiths Dome quartz monzonite.

Kkqm **Keiths Dome quartz monzonite (Cretaceous or Jurassic?) –** Mafic quartz monzonite averaging 16 percent dark minerals.

Unnamed granitic rocks of the Sierra Nevada batholith

Kgr **Granite and granodiorite, undivided (Cretaceous) –** Undivided fine- to coarse-grained granite and granodiorite; locally may include alaskite, quartz diorite and diorite. Includes biotite granite west of Round Mound of Armin and John (1983) and the hornblende-biotite granodiorite of Millberry Canyon of Armin and others (1984).

Kqd **Quartz diorite and diorite (Cretaceous) –** Undivided fine- to locally coarse-grained quartz diorite and diorite; locally well foliated. Includes hornblende-biotite quartz diorite of Jobs Canyon of Armin and John (1983). Some of these rocks may be large mafic inclusions within more silicic intrusive rocks, while others are apparently intrusive.

Kdg **Diorite and gabbro (Cretaceous) –** Dioritic and gabbroic rocks with minor quartz diorite.

KJgr **Granite (Cretaceous and (or) Jurassic) –** Light-gray, medium-grained biotite granite gradational into granodiorite. Includes monzogranite of North Logan House of Grose (1985).

KJgd **Granodiorite (Cretaceous and (or) Jurassic) –** Light- and dark-gray hornblende-biotite granodiorite with minor aplite and pegmatite.

KJdg **Diorite and gabbro (Cretaceous and (or) Jurassic) –** Medium- to coarse-grained hornblende and biotite diorite to quartz diorite; foliated in part, locally pegmatitic; includes gabbro and metagabbro. Includes diorite of Montreal Canyon of Grose (1985).

Jurassic intrusive rocks

Jaqd **Quartz diorite at Azure Lake (Late? and Middle Jurassic) –** Quartz diorite with fine- to medium-grained seriate texture containing 17 percent quartz. Forms a northwest-trending, dike-like intrusion; cumulate layering and comb structure are locally present. Considered to be related and in part coeval with Jdg and Ja (Fisher, 1989).

Jpgr **Pyramid Peak granite (Jurassic) –** White to pale buff, coarse-grained, equigranular biotite granite; locally includes quartz monzonite. Consists of approximately equal proportions of quartz, microcline perthite and sodic oligoclase with generally less than 5 percent biotite. Euhedral microcline crystals 5 to 20 mm long. Sabine (1992) reports a U-Pb age of 164±7 Ma (zircon).

Jdi **Diorite (Jurassic?) –** Dark-gray, gray-green to mottled green and white, rusty-weathering, variably altered and deformed hornblende-rich diorite.

Jdg **Diorite and gabbro (Late? and Middle Jurassic) –** Dark-gray weathering, hypabyssal, medium-grained intrusive bodies and dikes of diorite and gabbro, typically with clinopyroxene and local plagioclase phenocrysts. Considered to be related and in part coeval with Jaqd and Ja (Fisher, 1989).

Jmd **Microdiorite dikes of Sabine (1992) (Jurassic) –** Fine-grained, equigranular to seriate, locally porphyritic consisting of calcic plagioclase, hornblende and biotite. All trend east-northeast, approximately perpendicular to the foliation and alignment of the local diorite bodies.

Jmib **Mafic intrusive breccia (Late? and Middle Jurassic) –** Dark-gray weathering, polylithologic intrusive breccia, intermediate to mafic clasts, typically with extensive sulfidic hydrothermal alteration.

Ja **Anorthosite (Late? and Middle Jurassic) –** Undifferentiated noritic anorthosite through hypersthene diorite intrusive suite. Cumulate layering and comb structure common. Considered to be related and in part coeval with Jaqd and Jdg (Fisher, 1989).

Metamorphic rocks

Tuttle Lake Formation of Harwood (1992) (Late? and Middle Jurassic) – consists of:

Jtlf **Lava flows –** Dark-gray weathering, basaltic to andesitic, locally pillowed amygdular lava flows. Massive flows without amygdules are dominant and are commonly associated with basal flow breccia.

Jtlb **Volcanic breccia –** Gray-weathering, polylithologic and monolithologic, intermediate to mafic volcanic breccia. Monolithologic breccia fragments surrounded by matrix of same composition. Polymict breccia contains volcanic clasts of variable texture and composition and sparse sedimentary clasts. Clasts up to a meter in diameter.

Jtls **Tuffaceous sandstone and conglomerate –** Gray-weathering volcaniclastic sandstone and minor siltstone. Conglomerate is poorly organized, multicolored polymict, with sandstone interlayered with pebble and cobble conglomerate.

Jtld **Diamictite –** Multicolored diamictite composed primarily of pebbly sandstone containing clasts of fine- to medium-grained volcanic and hypabyssal rocks, very coarse grained quartzofeldspathic sandstone and quartzite.

Jsc **Sailor Canyon Formation (Middle and Early Jurassic) –** Quartzose and feldspathic sandstone and siltstone; locally calcareous.

JTrm **Metamorphic rocks (Jurassic and (or) Triassic) –** Undivided metasedimentary and metavolcanic rocks.

JTrms **Metasedimentary rocks (Jurassic and (or) Triassic) –** Metamorphosed sandstone, calcareous siltstone and silty limestone. Includes metaconglomerate in the Glenbrook quadrangle.

JTrmv **Metavolcanic rocks (Jurassic and (or) Triassic) –** Metamorphosed dacitic and andesitic pyroclastic deposits and flows.

Trls **Limestone (Late Triassic?) –** Bluish-gray weathering calcarenite and dolomite interbedded with 1- to 2-cm-thick beds or thin lenses of rusty to bluish, dark-gray weathering, very fine grained siliceous sandstone and siltstone.

Lake Tahoe Sequence of Harwood (1992) – consists of:

Jlp **Pelite unit (Jurassic?) –** Rusty-weathering, black sulfidic slate and andalusite-bearing pelitic hornfels with sparse lenses of fine-grained feldspathic and volcanic-lithic sandstone.

Jle **Ellis Peak Formation (Jurassic) –** Alternating beds of medium- to fine-grained quartz arenite and dark-gray quartzose metasiltstone. Quartz arenite beds range in thickness from 1 to 30 cm, are commonly graded and parallel-laminated. Locally contains poorly sorted conglomerate and breccia composed of quartz arenite and limestone fragments in a quartz sand matrix.

Jlb **Blackwood Creek Formation (Jurassic) –** Black sulfidic slate and hornfels interbedded with light-gray weathering, dark-gray, sandy limestone and feldspathic sandstone in variable proportions. Sandy limestone beds range in thickness from 10 to 30 cm, are graded and locally cross-laminated. Feldspathic sandstone beds are fine grained and from 1 to 10 cm thick.

Mls **Serena Creek Formation (Mississippian? or younger) –** Light-gray to tan metamorphosed ribbon chert with thin partings of black siliceous argillite.

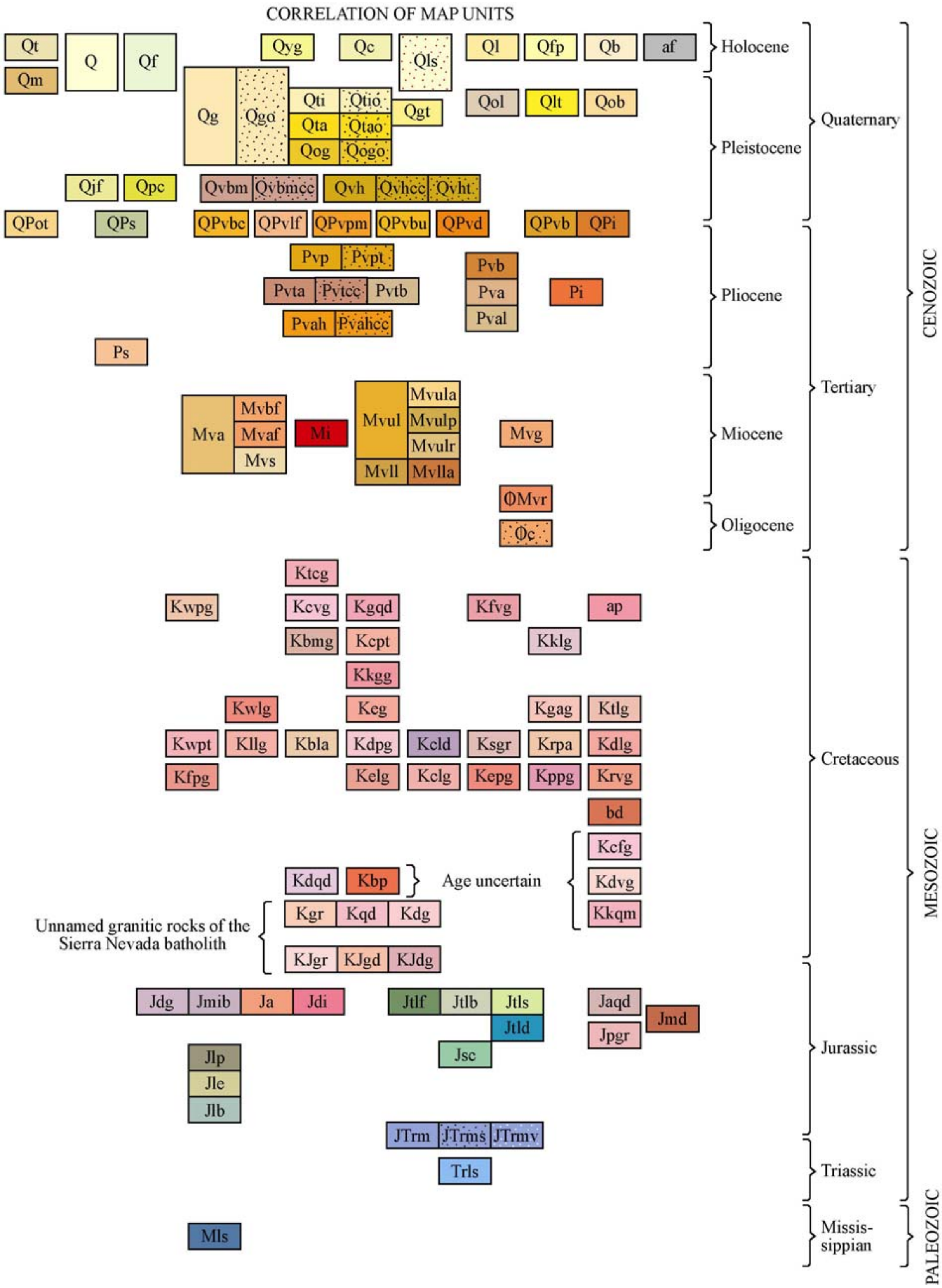

Figure 1. Correlation of map units for the Geologic Map of the Lake Tahoe Basin, California and Nevada.

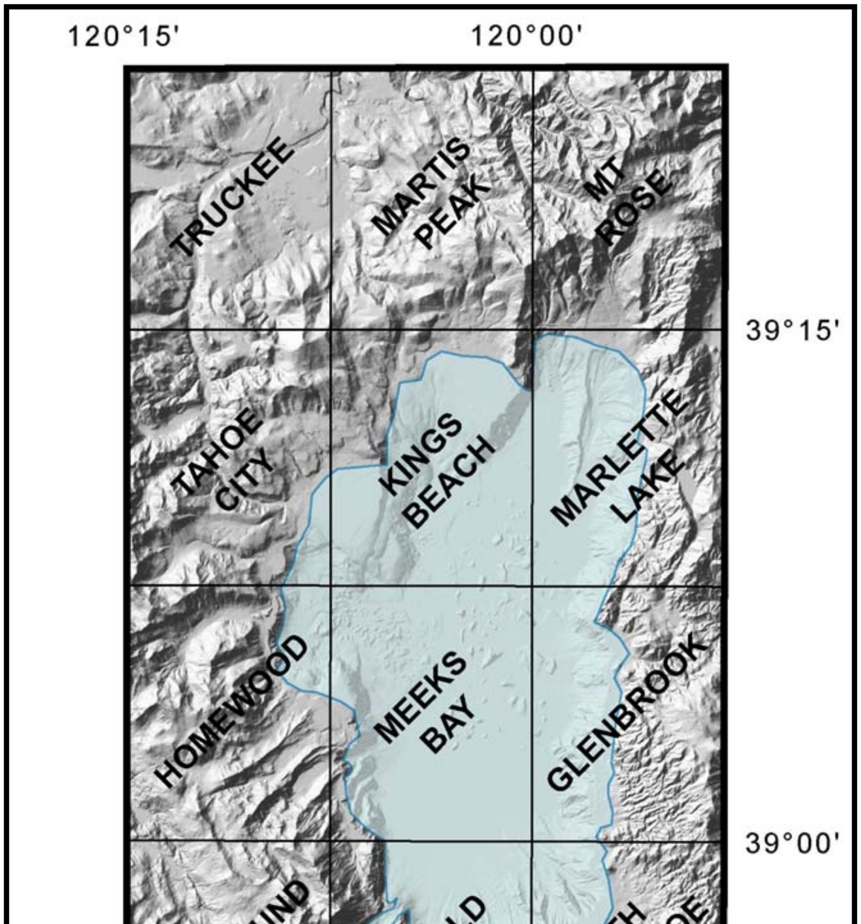

Figure 2. Index to 7.5-minute quadrangles in the Lake Tahoe Basin, California and Nevada. DEM from U.S. Geological Survey.

Sources of mapping in the Lake Tahoe Basin listed by 7.5-minute quadrangle (*primary compilation sources shown in bold type*). For complete citation see the reference section following this list.

Caples Lake Quadrangle*

Bedrossian, T.L., 1979; Burnett, J.L., 1982; **DeOreo, S.B., 2004**; **John, D.A., Armin, R.A. and Moore, W.J., 1981**; **McKee, E.H. and Howe, R.A., 1981**.

Carson Pass Quadrangle

Armin, R.A., John, D.A. and Moore, W.J., 1984; Burnett, J.L., 1982; **DeOreo, S.B., 2004;** John, D.A., Armin, R.A. and Moore, W.J., 1981.

Echo Lake Quadrangle*

Burnett, J.L., 1982; Connelly, S.F., 1988; Fisher, G.R., 1989; **John, D.A., Armin, R.A. and Moore, W.J., 1981**; **Loomis, A.A., 1983**; **McCaughey, J.W., 2003**.

Emerald Bay Quadrangle*

Burnett, J.L., 1982; **Fisher, G.R., 1989**; Loomis, A.A., 1983; **McCaughey, J.W., 2003**; U.S. Department of Agriculture, 1974.

Freel Peak Quadrangle*

Armin, R.A. and John, D.A., 1983; John, D.A., Armin, R.A. and Moore, W.J., 1981.

Glenbrook Quadrangle*

Grose, T.L.T., 1985; Stewart, J.H., 1999.

Homewood Quadrangle*

Harwood, D.S. and Fisher, G.R., 2002; Higgins, C.T., 1977.

Kings Beach Quadrangle*

Burnett, J.L., 1982; Franks, A.L., 1980; **Wise, W.S. and Sylvester, A.G., 2004**.

Marlette Lake Quadrangle*

Grose, T.L.T., 1986; Stewart, J.H., 1999.

Martis Peak Quadrangle*

Birkeland, P.W., 1961; Burnett, J.L., 1982; Franks, A.L., 1980; Gates, W.C.B., 1994; **Latham, T.S., Jr., 1985;** Matthews, R.A., 1968; **Wise, W.S. and Sylvester, A.G., 2004**.

Meeks Bay Quadrangle*

Burnett, J.L., 1982.

Mount Rose Quadrangle*

Lewis, R.L, 1988; Stewart, J.H., 1999.

Pyramid Peak Quadrangle

Connelly, S.F., 1988; John, D.A., Armin, R.A. and Moore, W.J., 1981; **Loomis, A.A., 1983**; **Sabine, C., 1992**; Wagner, D.L. and Spittler, T.E., 1997.

Rockbound Valley Quadrangle

Fisher, G.R., 1989; **Loomis, A.A., 1983; Sabine, C., 1992**.

South Lake Tahoe Quadrangle*

Armin, R.A. and John, D.A., 1983; **Bonham, H.F., Jr. and Burnett, J.L., 1976**.

Tahoe City Quadrangle*

Birkeland, P.W, 1961; Gates, W.C.B., 1994; **Harwood, D.S. and Fisher, G.R., 2002**; Higgins, C.T., 1977; **Wise, W.S. and Sylvester, A.G., 2004**.

Tragedy Spring Quadrangle

Bedrossian, T.L., 1979.

Truckee Quadrangle*

Birkeland, P.W, 1961; Burnett, J.L., 1982; Franks, A.L., 1980; Gates, W.C.B., 1994; **Harwood, D.S. and Fisher, G.R., 2002**; Hawkins, F.F., LaForge, R. and Hansen, R.A., 1986; Latham, T.S., Jr., 1985; **Wise, W.S. and Sylvester, A.G., 2004**.

*Fault additions from: **Schweickert, R.A., Lahren, M.M., Karlin, R.E., Smith, K.D. and Howle, J.F., 2000b.**

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