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Geologic Map of Lassen Volcanic National Park and Vicinity, California

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Pamphlet to accompany

Scientific Investigations Map 2899

Lassen Peak and the Devastated Area

Aerial view of Lassen Peak and the proximal Devastated Area looking south. Area with sparse trees marks the paths of the avalanche and debris-flow deposits of May 19–20, 1915 (unit sw9) and the pyroclastic-flow and fluid debris-flow deposits of May 22, 1915 (unit pw2) (Clynne and others, 1999; Christiansen and others, 2002). Small dark crags just to right of the summit are remnants of the May 19–20, 1915, lava flow (unit d9). The composite dacite dome of Lassen Peak (unit dl, 27±1 ka) dominates the upper part of the view. Lithic pyroclastic-flow deposit (unit pfl) from partial collapse of the dome of Lassen Peak is exposed in the canyon of the headwaters of Lost Creek in center of view. Ridges flanking central area are glacial moraines (unit Qta) thinly covered by deposits of the 1915 eruption of Lassen Peak (Christiansen and others, 2002). Small permanent snowfield is seen on the left lower slope of Lassen Peak. Area east of the snowfield is the rhyodacite lava flow of Kings Creek (unit rk, 35±1 ka, part of the Eagle Peak sequence). Dacite domes of Bumpass Mountain (unit db, 232±8 ka), Crescent Crater (unit dc, 236±1 ka), hill 8283 (unit d82, 261±5 ka), and Loomis Peak (unit rlm, ~300 ka) are part of the Bumpass sequence. *Photograph by Michael A. Clynne.*

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Introduction

The geologic map of Lassen Volcanic National Park (LVNP) and vicinity encompasses 1,905 km^2 at the south end of the Cascade Range in Shasta, Lassen, Tehama, and Plumas Counties, northeastern California (fig. 1, sheet 3). The park includes 430 km^2 of scenic volcanic features, glacially sculpted terrain, and the most spectacular array of thermal features in the Cascade Range. Interest in preserving the scenic wonders of the Lassen area as a national park arose in the early 1900s to protect it from commercial development and led to the establishment in 1907 of two small national monuments centered on Lassen Peak and Cinder Cone. The eruptions of Lassen Peak in 1914–15 were the first in the Cascade Range since widespread settling of the West in the late 1800s. Through the printed media, the eruptions aroused considerable public interest and inspired renewed efforts, which had languished since 1907, to establish a national park. In 1916, Lassen Volcanic National Park was established by combining the areas of the previously established national monuments and adjacent lands.

The southernmost Cascade Range is bounded on the west by the Sacramento Valley and the Klamath Mountains, on the south by the Sierra Nevada, and on the east by the Basin and Range geologic provinces. Most of the map area is underlain by middle to late Pleistocene volcanic rocks; Holocene, early Pleistocene, and late Pliocene volcanic rocks (<3.5 m.y.) are less common. Paleozoic and Mesozoic rocks are inferred to underlie the volcanic deposits (Jachens and Saltus, 1983), but the nearest exposures of pre-Tertiary rocks are 15 km to the south, 9 km to the southwest, and 12 km to the west. Diller (1895) recognized the young volcanic geology and produced the first geologic map of the Lassen area. The map (sheet 1) builds on and extends geologic mapping by Williams (1932), Macdonald (1963, 1964, 1965), and Wilson (1961). The Lassen Peak area mapped by Christiansen and others (2002) and published in greater detail (1:24,000) was modified for inclusion here. Figure 2 (sheet 3) shows the mapping credit for previous work; figure 3 (sheet 3) shows locations discussed throughout the text.

A CD-ROM entitled Database for the Geologic Map of Lassen Volcanic National Park and Vicinity, California accompanies the printed map (Muffler and others, 2010). The CD-ROM contains ESRI compatible geographic information system data files used to create the 1:50,000-scale geologic map, both geologic and topographic data and their associated metadata files, and printable versions of the geologic map and pamphlet as PDF formatted files. The 1:50,000-scale geologic map was compiled from 1:24,000-scale geologic maps of individual quadrangles that are also included in the CD-ROM. It also contains ancillary data that support the map including locations of rock samples selected for chemical analysis (Clynne and others, 2008) and radiometric dating, photographs of geologic features, and links to related data or web sites. Data contained in the CD-ROM are also available at http://pubs.usgs.gov/sim/2899/.

The southernmost Cascade Range consists of a regional platform of basalt and basaltic andesite, with subordinate andesite and sparse dacite. Nested within these regional rocks are "volcanic centers", defined as large, long-lived, composite, calc-alkaline edifices erupting the full range of compositions from basalt to rhyolite, but dominated by andesite and dacite. Volcanic centers are produced by the focusing of basaltic flux from the mantle and resultant enhanced interaction of mafic magma with the crust. Collectively, volcanic centers mark the axis of the southernmost Cascade Range. The map area includes the entire Lassen Volcanic Center, parts of three older volcanic centers (Maidu, Dittmar, and Latour), and the products of regional volcanism (fig. 4, sheet 3). Terminology used for subdivision of the Lassen Volcanic Center has been modified from Clynne (1984, 1990).

Regional Volcanism

Regional volcanism built a broad platform that covers the southernmost Cascade Range (fig. 4*A*, *B*). Two distinct parental magmas and their derivatives contribute to the suite of regional lavas in the Lassen area: calc-alkaline basalt and tholeiitic basalt (Clynne, 1993; Borg and others, 2002). Calc-alkaline compositions are related to Cascade Arc magmatism and dominate the regional suite in both volume and abundance. Small calc-alkaline volcanoes are cinder cones with fields of lava flows, and large calc-alkaline volcanoes are steep-sided cones or shields with gentle slopes. Low-potassium olivine tholeiitic basalt (LKOT; also called high-alumina olivine tholeiitic or HAOT) is a volumetrically minor but widespread component of the regional volcanism and is related to the Basin and Range geologic province. LKOT erupts from fissures between the shield volcanoes and the fluid lavas flood intervening valleys. Edifices containing both the calc-alkaline and LKOT suites are not found. On this map, LKOT is distinguished from calc-alkaline lavas by color and by including tholeiitic in the unit names. The overall result of regional volcanism is a broad platform of overlapping mafic to intermediate volcanoes. A seismic-refraction experiment reported by Berge and Stauber (1987) indicates that the young volcanic platform is about 4 km thick in the active southernmost Cascade Arc.

Calc-alkaline Volcanoes

Calc-alkaline regional volcanoes have a wide range of sizes and forms. They comprise a continuum of sizes from cinder cones with lava flows through steep-sided lava cones to broad shield volcanoes. Typically, lava flows from regional volcanoes have blocky vesicular lava surfaces, although aa surfaces are also observed. Interiors have thick, slabby to thin, platy joint patterns; aphanitic textures are typical, and holocrystalline textures are generally confined to thick or ponded flows.

The smallest and most abundant volcanoes are cinder cones. Cinder cones are composed of bedded cinders or scoria and bombs piled up around a vent. Typically they have an associated lava flow that erupts from the base of the cone. Cinder cones have a single period of activity (monogenetic) and erupt small-volume aa to blocky lava flows. These small calc-alkaline volcanoes are usually compositionally and mineralogically homogeneous and tend to occur in groups of similar age and lithology. We use the term "sequence" for groups of volcanoes related by lithology and age and the term "chain" for sequences displaying a conspicuous linear geometry.

Lava cones and shield volcanoes are bigger than cinder cones and are more or less circular in plan view. Lava cones and shield volcanoes are constructed by eruptions from a central vent or flank vents high on the edifice to build a steep-sided lava cone or flatter shield volcano. They are usually capped by a cinder cone but generally lack widely distributed fragmental deposits. Typically they are active for a short period of decades to a few millennia and build a variety of edifice sizes of as much as a few cubic kilometers in volume. West Prospect Peak and the complex of Red Lake Mountain and Red Mountain are examples of lava cones in the map area. Sugarloaf Peak, mostly outside the map area, is another very symmetric lava cone. Prominent shield volcanoes in the map area are Prospect Peak, Sifford Mountain, Mount Harkness, Badger Mountain, and Table Mountain.

Rocks from the longer-lived, larger regional volcanoes (shields or lava cones) are composed of a single composition or display minor ranges throughout the lifetime of the edifice. When heterogeneous, they typically evolve with time to higher silica and crystal contents with accompanying changes in phenocryst assemblage. These ranges are discussed in the unit descriptions, but the larger regional volcanoes are usually considered single entities and are generally mapped as single units.

The calc-alkaline regional suite is dominated by a continuum of olivine basalt, olivine-augite basaltic andesite, and two-pyroxene andesite; rocks more silicic than andesite are rare. Phenocryst assemblages in calc-alkaline regional lavas are relatively simple. Primitive basalts contain olivine, commonly without a second phase. Evolved basalts add augite and plagioclase to the fractionating assemblage, and most basaltic andesites contain a combination of olivine, augite, and plagioclase phenocrysts. Complex zoning patterns, multiple populations of phenocrysts, and resorption or reaction features in phenocrysts are generally absent in mafic calc-alkaline rocks, but they are present in some andesites. Hypersthene replaces olivine in the fractionating assemblage in the range 56–58 percent SiO_2, and most andesites contain two pyroxenes. Glomeroporphyritic clots of crystals, generally of the same phases as present in the rock, are common in evolved rocks of the calc-alkaline suite. Individual calc-alkaline volcanoes erupt from a single or small number of compositionally similar magma batches with relatively little fractionation or evolution.

The calc-alkaline lava suite displays significant geochemical diversity but has geochemical characteristics typical of arc volcanic rocks erupted through continental crust, for example, the Japan or Kamchatka Arcs (Gill, 1981; Thorpe, 1982). Geochemical diversity is greatest in the most primitive compositions, and fractionation reduces the range of geochemical diversity in more evolved rocks through interaction with the lower crust and mixing within the suite. Evolution of mafic magmas is dominated by crystal fractionation, but addition of a small-degree partial melt of mafic lower crust is also an important process (Clynne, 1993). Assimilation of upper crust plays a role in determining the geochemical composition of some andesitic regional volcanoes.

Low-Potassium Olivine Tholeiite (LKOT)

Erupted volumes of LKOT are relatively large; volumes of as much as a few cubic kilometers are typical. LKOT flows erupt from fissures that build spatter ramparts and rarely construct cinder cones. These vents are inconspicuous in the geologic record because they are composed of glassy scoria that is easily weathered and eroded, and the low-relief vent profiles are often buried by younger volcanism. Vents for LKOT flows older than a few hundred thousand years are difficult to identify. LKOT lava flows form widespread sheets that have a characteristic surface morphology. The upper and lower surfaces of flow units contain abundant spherical vesicles, and flow tops are often ropy (pahoehoe) and have a characteristic joint pattern of crudely hexagonal blocks. Flow-unit interiors are generally holocrystalline and diktytaxitic and are massive with a widely spaced blocky joint pattern. The upper surfaces have little relief except for common to abundant tumuli. These characteristics are rapidly obscured by weathering and soil-forming processes so that within about 400 to 500 ka, LKOT flows in the Lassen area become flat surfaces with thick soil.

LKOT displays remarkable chemical and petrographic homogeneity. Most units contain 48 to 50 percent SiO_2 and are olivine basalts. LKOT lava typically contains sparse olivine phenocrysts accompanied by plagioclase in slightly more evolved examples. Augite phenocrysts and multiple phenocryst populations are rare, as are phenocrysts with strong zoning or resorption textures. Glomeroporphyritic clots of crystals like those found in calc-alkaline rocks are uncommon and generally confined to near-vent parts of lava flows. Borg and others (2002) summarized the lithologic, petrographic, and distinctive geochemical characteristics of LKOT.

Volcanic Centers

Intercalated within the regional volcanic rocks are a few voluminous (as much as a few hundred cubic kilometers) long-lived (0.5–1 m.y. or longer) foci of volcanism called volcanic centers. Volcanic centers erupt calc-alkaline compositions. The fundamental differences between regional calc-alkaline volcanoes and volcanic centers are the latter’s longevity, volume, and range of compositions in a single edifice or geographic locale. Five volcanic centers younger than about 3.5 Ma are recognized along the Cascade axis in the Lassen area (fig. 4*A*). Each volcanic center experienced a unique evolution but generally consists of an initial phase of silicic volcanism followed by construction of a large composite cone dominated by andesite, which is flanked by a variety of younger, more silicic rocks. Late in the evolution of each volcanic center, an acidic hydrothermal system driven by heat from cooling subvolcanic silicic magma bodies caused alteration of the permeable rocks of the composite cone. Subsequent glacial and fluvial erosion of the altered interiors of the composite cones resulted in bowl-shaped depressions surrounded by more-resistant rims of thick, unaltered, flank lava flows. The Yana, Maidu, Dittmar, and Latour Volcanic Centers have reached this stage, and their hydrothermal systems are extinct. The Lassen Volcanic Center hosts continuing silicic volcanism and an active hydrothermal system (Muffler and others, 1982b; Muffler and others, 1983; Ingebritsen and Sorey, 1985; Clynne and others, 2003; Janik and McLaren, 2010).

Volcanic centers contain a diverse assemblage of rock types from basalt or basaltic andesite to rhyolite but are dominated by intermediate calc-alkaline compositions (andesite–dacite). Rocks in the volcanic centers are petrographically much more complex than rocks from regional volcanoes, and geochemical and petrographic evidence for magma mixing is abundant (Bullen and Clynne, 1990). Multiple phenocryst populations, reverse and strong normal zoning, compositional spikes in phenocryst compositions, and resorbed and disequilibrium phenocryst assemblages are typical of volcanic-center rocks. Phenocrysts commonly are larger and more abundant than in regional lavas of equivalent silica content. Glomeroporphyritic clots of crystals, which we interpret to be derived from bodies of cumulate material fractionated from parental and evolved mafic magmas, are abundant in volcanic-center andesites and attest to efficient recycling of crystals in the magmatic system.

Volcanic centers result from a local increase in the amount of basaltic magma intruded into the crust from the mantle relative to the background calc-alkaline regional volcanism (Guffanti and others, 1996). Increased basaltic intrusion heats the crust and promotes interaction between mafic magma and the crust. A complex vertically zoned magmatic system with localized bodies of magma develops in the crust beneath the volcanic center. Magma mixing between andesitic magma batches is common, and eventually the additional heat causes crustal melting beneath volcanic centers leading to eruption of silicic lavas (Borg and Clynne, 1998) and interaction between mafic and silicic magma bodies. Geochemical diversity of rocks decreases with time in volcanic centers, attesting to the increasing importance of homogenization in the magmatic systems during their evolution (Clynne, 1990; Bullen and Clynne, 1990; Feeley and others, 2008).

Volcanic centers are the surface expression of a magmatic cycle driven by a local increase in regional magmatic flux that waxes as the crust is heated and wanes as the easily fusible component of the lower crust is depleted. Early in the evolution of volcanic centers, magmatic fractionation is dominated by crystal fractionation of basalt with a relatively small contribution from the crust. As the evolution of volcanic centers proceeds, the crustal component becomes increasingly important until, in the later stages, it dominates the magmatic system. The origin of increased magmatic flux is unclear; it may be caused by structures that focus magma at the base of the crust or within the lower crust (Blakely and others, 1997). Alternatively, it could be related to inhomogeneities of magma production in the mantle wedge or even to heterogeneities at the slab-wedge interface. Volcanic centers do not significantly overlap in space, possibly as a result of the depletion of the easily fusible component in the lower crust that is required for production of large volumes of silicic magma. Given the uncertainties in dating the early volcanic centers, we believe that volcanism in volcanic centers has been nearly continuous somewhere in the Lassen area over the past 3.5 m.y. Typically, a single volcanic center is active and becomes extinct before or as the next center begins. However, during the late Pliocene to early Pleistocene, the life spans of the Maidu and Dittmar Volcanic Centers coincided (fig. 4*A*).

Tectonic Setting

Figure 5 (sheet 3) illustrates the tectonic setting of the Lassen segment (Guffanti and Weaver, 1988) of the Cascade Volcanic Arc from the Sacramento Valley on the west to the California-Nevada border on the east. Volcanism in the area is a result of oblique subduction of the Juan de Fuca oceanic plate beneath the North American continental plate offshore of northern California. About 12 Ma, the axis of the Lassen segment was near the California-Nevada border. Since then, the arc axis has migrated westward to its present position (Guffanti and others, 1990). Simultaneously, the width of the arc narrowed, probably due to slab steepening. The southern terminus of active volcanism retreated roughly parallel to the northward extension of the San Andreas Fault system and migration of the Mendocino Triple Junction off the northern California coast. Also at 12 Ma, the south limit of Cascade volcanism was in the Sierran block approximately at the latitude of Lake Tahoe, 180 km southeast of the Lassen area. At 3 Ma, the south limit of active volcanism was in the area of the Yana Volcanic Center, 30 km south of Lassen Peak near Lake Almanor (fig. 5). At present, the south limit of active volcanism approximately corresponds to the south boundary of LVNP, and the youngest dated regional volcano in the area is Sifford Mountain at about 170 ka. These relations suggest a long-term migration rate for the southern terminus of Cascade Arc volcanism of 15 to 20 km per m.y. (1.5 to 2 cm per yr) and a rate for at least the last 3 m.y. of about 10 km per m.y. (1 cm per yr).

Two adjacent tectonic regimes affect the Lassen area. The extensional Basin and Range Province is expanding westward into the Cascade Arc (Guffanti and others, 1990), and the active Hat Creek and Lake Almanor Grabens are the westernmost major Basin and Range structures in the area (fig. 5). This impingement is manifested in numerous normal faults, which commonly provide pathways for magma to reach the surface. Some magmas traverse the crust rapidly, and relatively primitive mafic lavas are widespread, albeit not abundant (Borg and others 1997). Many regional volcanoes are aligned along fault traces and partially to completely bury them. The Lassen area also sits astride the Walker Lane, a broad linear zone of distributed strike-slip faulting, parallel to and inboard of the San Andreas Fault System, that accommodates about 20 percent of the relative motion between the North American and Pacific Plates (Blakely and others, 1997; Faulds and Henry, 2008). At the latitude of the Lassen area, the Walker Lane regime generally manifests itself as a small strike-slip component on the normal faults. On the map, faults are shown only where offset of volcanic stratigraphy can be documented in the field. Although the Hat Creek Graben-Lake Almanor Graben structure crosses the east half of LVNP, few faults are mapped there.

Expression of the grabens is obscured by a combination of young volcanism and glaciation, and additional faults are likely present in the subsurface.

Eruptive History of the Lassen Area

Regional Volcanic Rocks

Over the last 3 Ma, regional calc-alkaline volcanism in the Lassen segment (fig. 4*A*, *B*) of the Cascade Arc (Guffanti and Weaver, 1988) constructed a broad platform of volcanic rocks in a band straddling the arc axis. A variety of mostly older lavas erupted from shield volcanoes, lava cones, and cinder cones are exposed in the mostly unglaciated terrain surrounding the Lassen Volcanic Center. North of the Lassen Volcanic Center, these older rocks commonly are broken into linear blocks bounded by faults. The volume of regional volcanic rocks diminishes with distance in both directions from the arc axis, so that there are lesser volumes of fore-arc and back-arc volcanism. On a short time scale, regional volcanism is concentrated in local areas, for example, in the last 75,000 years regional volcanism produced the Tumble Buttes and Sugarloaf chains (fig. 4*B*). The Red Lake Mountain and Red Cinder areas were active in the interval from 75,000 to 100,000 years ago and the Poison Lake area from 100,000 to 110,000 years ago. Prior to that time regional volcanism was concentrated in different areas. Regional volcanism does not occur within the boundaries of active volcanic centers. There, rising regional magmas are intercepted and processed and contribute to the magmatic system of the volcanic center. Return of regional volcanism within the confines of a volcanic center indicates solidification of that part of its magmatic system.

Within the regional lavas of the map area, young alignments of monogenetic cones and flows that share spatial, chemical, and lithologic characteristics are noteworthy. These are illustrated by the Tumble Buttes and Sugarloaf chains (discussed in the following paragraph) and several alignments in the Caribou Volcanic Field (discussed below). The Tumble Buttes chain consists of 13 units of monogenetic flows and cones (additional vents and flows occur north of the map area) correlated on the basis of similar spatial, temporal and compositional characteristics. Although not offset by faults, the Tumble Buttes chain forms a linear array of vents 15 km long and parallel to the pattern of regional faulting, and their location is clearly controlled by faults in the subsurface. Tumble Buttes lavas are olivine and pyroxene basaltic andesite and andesite. The Tumble Buttes chain is mostly about 10–15 to ~50 ka in age and is probably the youngest zone of concentrated mafic volcanism in the Lassen area.

The Sugarloaf chain consists of four units of monogenetic cones and flows in the area south of Sugarloaf Peak, the lava cone of Sugarloaf Peak, and a few additional units north of the map area. The units are correlated on the basis of similar spatial, temporal, and compositional characteristics. Lavas of the Sugarloaf chain are sparsely porphyritic olivine and pyroxene basaltic andesite and andesite. Although not offset by faults, this 12 km linear array of vents coincides with and obscures the western boundary fault of the Hat Creek Graben. The Sugarloaf chain is mostly about 45 to ~75 ka in age.

LKOT is related to Basin and Range tectonics (Clynne, 1993), and it erupted across the Lassen region in a wave progressing from east to west that approximately coincides with progressive impingement of Basin and Range extension on the Cascade Arc (Guffanti and others, 1990). Although they produce relatively large volumes of lava, LKOT eruptions are relatively infrequent; only 13 are found in the map area, and all are less than about 1 m.y. Older tholeiites are common in the areas east and north of the map (Grose and others, 1991, 1992; Macdonald 1963, 1964, 1965; Macdonald and Lydon, 1972), and, because they are readily buried by younger volcanism, some are likely present in the subsurface.

Pliocene–Early Pleistocene Volcanic Centers

The oldest volcanic rocks in the vicinity of the present-day axis of the Cascade Range in the Lassen area were mapped as the Tuscan Formation by Anderson (1933) and Lydon (1968). The Tuscan Formation consists of a broad volcanic and volcanoclastic wedge of fragmental material, primarily volcanic conglomerate, volcanic sandstone, siltstone, and minor pumiceous tuff, emplaced on the west slope of the southernmost Cascade Range. The Tuscan Formation deposits were emplaced by a number of mechanisms, but lahars and debris flows dominate. Pyroclastic flows and interbedded lava flows are sparse. A few major ash-flow sheets and tuffs are also present (Helley and others, 1981). Adjacent to the Cascade Range, the Tuscan Formation is ~500 m thick (Lydon, 1968) where it interfingers with proximal deposits of the Latour and Yana Volcanic Centers. It thins dramatically toward the east margin of Sacramento Valley where it is intercalated with fluvial sediments (Harwood and others, 1981). Much of the Tuscan Formation was reworked by fluvial processes, especially in distal areas near the Sacramento Valley. In the Lassen area, these deposits were mostly derived from the Latour and Yana Volcanic Centers. The Tuscan Formation ranges in age from ~3,500 ka (Helley and others, 1981) to perhaps as young as 2,500 ka. Similar, but older, deposits related to the Miocene to Pliocene Cascade Arc are found south of the Yana Volcanic Center and are called the Mehrten Formation (Curtis, 1954).

Rocks of the Latour Volcanic Center (>3 Ma) are present along the northwest boundary of the map area. Rocks of the Yana Volcanic Center (~3.4–2.4 Ma) dominate the area southwest of Lake Almanor but do not crop out within the boundaries of the map area. Little is known about the evolution of the Yana Volcanic Center and even less is known about the Latour Volcanic Center.

The next important volcanic events in the Lassen area were growth of the Dittmar (2.4–1.3 Ma) and Maidu (2.4–1.2 Ma) Volcanic Centers (fig. 4*A*). Rocks of the Dittmar Volcanic Center are abundant in the southeastern part of LVNP and the adjacent area. The Maidu Volcanic Center is better preserved and its evolution is known in more detail, but it is mostly located beyond the southwest boundary of the map.

Dittmar Volcanic Center

The Dittmar Volcanic Center lies in the area of the intersection between the Hat Creek Graben and Lake Almanor Graben (figs. 3, 4*A*), and the volcanic center has been chopped into a number of fault blocks. Many more faults probably exist than have been shown on the map. The detailed stratigraphy of the volcanic center cannot generally be traced across these faults or correlated between blocks. Consequently, the details of its evolution are poorly known. The largest preserved remnants of the Dittmar Volcanic Center are Mount Hoffman, Saddle Mountain, Pilot Mountain, Kelly Mountain, and Wild Cattle Mountain (fig. 3). The Dittmar Volcanic Center hosted a hydrothermal system in its waning stages of activity; thus many of the early Dittmar rocks are hydrothermally altered. Glaciation of weak, hydrothermally altered rocks has deeply eroded the central area, and rocks are generally poorly exposed. Radial dips of lava flows and fragmental deposits indicate that the Dittmar Volcanic Center was centered in the area southwest of Saddle Mountain. Deposits of the Dittmar Volcanic Center are grouped into three stratigraphic stages: Stage 1, early growth of the composite cone; Stage 2, later growth of the composite cone; and Stage 3, late silicic volcanism.

Stage 1 of the Dittmar Volcanic Center consists of generally thin lava flows and interbedded fragmental deposits ranging from flow breccias, lithic fall deposits, and block and ash deposits to lahars. These lavas and volcanic deposits erupted from a central vent whose position was in the vicinity of Warner Valley between Kelly and Saddle Mountains but which has been completely removed by erosion. Best exposures of relatively fresh Stage 1 rocks are found on the north flank of Kelly Mountain, on the cliffs below Juniper Lake, on Mount Hoffman, and on Wild Cattle Mountain. Strongly altered lavas are well exposed in the valleys of Kings and Hot Springs Creeks on both sides of Flatiron Ridge. Olivine-bearing basaltic andesite and hypersthene-augite andesites dominate Stage 1, and pyroxene±hornblende dacite to rhyolite are subordinate. Lavas are generally porphyritic, typically containing 15–30 percent phenocrysts, although some sparsely porphyritic and a few nearly aphyric lavas are present. The duration and age of Stage 1 is poorly constrained; three K-Ar ages from near the top and bottom of the unaltered parts of the stratigraphic section are 1,650±35 and 1,785±35 ka, and 2,315±29 ka, respectively.

A debris avalanche derived from Stage 1 of the Dittmar Volcanic Center is exposed in roadcuts along Calif. Hwy 36 near Inskip Hill (Muffler and others, 1989). Rocks in the debris avalanche are correlated to Stage 1 lithologies present on the north flank of Kelly Mountain above Warner Valley and are nearly 50 km from their source area. The age of this debris avalanche is poorly known. It postdates deposition of the Tuscan Formation in the Inskip Hill area and is probably younger than about 2,500 ka and probably older than the intervening Maidu Volcanic Center and, thus, younger than ~2,200 ka.

Ingebritsen and Rojstaczer (1983) suggested from satellite imagery that several old calderas might be present in the area around Sifford Mountain. One of these is just south of LVNP in the area of Wild Cattle Mountain and Feather River Meadows. The area was partially filled by younger rocks from the Lassen Volcanic Center but contains rocks correlated with Stage 1 of the Dittmar volcanic center. A geothermal exploration well in Feather River Meadows penetrated several hundred feet of ash-flow tuff that is similar to tuffs exposed on Kelly Mountain. It is likely that the thick tuff ponded in a small caldera, and it is possible that the eruption was related to the debris avalanche exposed at Inskip Hill.

Stage 2 of the Dittmar Volcanic Center consists of generally thick lava flows with sparse interbedded fragmental deposits. Good exposures of relatively fresh Stage 2 rocks are found on the south flank of Kelly Mountain and the upper parts of Saddle and Pilot Mountains. Stage 2 lavas erupted from flank vents whose locations are not preserved. Hypersthene-augite andesites dominate Stage 2; olivine-bearing andesite and pyroxene±hornblende dacite are subordinate. Lavas are porphyritic, typically containing 20–30 percent phenocrysts, and some contain small mafic inclusions. The duration and age of Stage 2 is poorly constrained; a single K-Ar age is 1,398±42 ka.

Stage 3 of the Dittmar Volcanic Center consists of a few lava flows and domes of hornblende-biotite rhyodacite and rhyolite that overlie Stage 2 lavas. No vents for these units are known, and the best exposures are in the Grassy Swale area and at the summit of Pilot Mountain. Additional Stage 3 lava flows and related deposits probably were buried beneath younger rocks of the Central Plateau of LVNP. The duration and age of Stage 3 is poorly constrained; a rhyolite lava flow exposed in Summit Creek is 1,273±7 ka.

Maidu Volcanic Center

The Maidu Volcanic Center is located south of LVNP, and a small part of it lies within the southeast corner of the map area (fig. 4*A*). The largest preserved remnants of the Maidu Volcanic Center in the map area are Hampton Butte, Blue Ridge, and North Stover Mountain (fig. 3). Within the map area, Maidu Volcanic Center unconformably overlies the Tuscan Formation and, outside the map area, it unconformably overlies rocks of the Yana Volcanic Center. Its base is exposed in the canyons of Battle, Mill, and Deer Creeks. The core of the Maidu Volcanic Center was hydrothermally altered and deeply eroded and is well exposed in the cliffs surrounding Battle Creek Meadows. The summit and vent areas have been completely obscured by a combination of hydrothermal alteration and glacial and fluvial erosion. The preserved parts of the Maidu Volcanic Center dip radially away from Battle Creek Meadows, which is therefore presumed to have been the center of activity. Wilson (1961) attributed the depression of Battle Creek Meadows to explosive eruption of the Rockland tephra and formation of a small caldera at this site. The Rockland tephra, however, is much younger than the Maidu Volcanic Center, and no other widespread deposit of the appropriate age is known that could have come from the area (Clynne, 1984). It is more likely that the Battle Creek Meadows depression has an erosional origin. Although deeply eroded, the Maidu Volcanic Center is, in general, structurally intact. The total volume erupted at the Maidu

Volcanic Center was in excess of 200 km^3 and it was active from 2.4 to ~1.2 Ma.

Despite its age, hydrothermal alteration, and deep erosion, the stratigraphy of the Maidu Volcanic Center is fairly well understood. Deposits of the Maidu Volcanic Center are grouped into three stratigraphic stages: Stage 1, early growth of the composite cone; Stage 2, later growth of the composite cone; and Stage 3, late silicic volcanism. Stage 1 is mostly composed of thin lava flows and fragmental deposits erupted from a central vent during the period from ~2.4 to ~2.15 Ma.. Lithologies and compositions are diverse; olivine-augite, olivine-augite-hypersthene, augite-hypersthene, and hypersthene-augite assemblages occur. Hypersthene-augite andesites dominate, and olivine-bearing basaltic andesite and pyroxene±hornblende dacite are subordinate. Stage 1 contains considerable intercalated pyroclastic material. Fragmental deposits are not mapped separately; they range from fallout to block-and-ash flow deposits, and lahar deposits are common. The permeable fragmental deposits and brecciated flow carapaces are particularly susceptible to hydrothermal alteration. Hydrothermal alteration was especially intense in the area between Christie Hill, Little Round Valley, and Mineral Summit.

Stage 2 of the Maidu Volcanic Center is dominated by a small number of thick porphyritic augite-hypersthene dacite lava flows erupted from flank vents. These lava flows generally lack interbedded fragmental deposits. Stage 2 was active from ~2.15 to ~2.05 Ma, and possibly later. Stage 3 consists of five large, very thick felsic lava flows erupted between ~1.3 and ~1.2 Ma. One is composed of porphyritic rhyodacite, and the other four are sparsely porphyric rhyolite and are some of the largest silicic lava flows in the Cascade Range; the largest, the Blue Ridge rhyolite flow, has a volume of ~15 km^3.

Lassen Volcanic Center

Recently acquired geochronology (Lanphere and others, 1999) and reinterpretation of rock units surrounding the Brokeoff Volcano provoked reorganization of the three-stage stratigraphic description of the Lassen Volcanic Center presented in previous publications (Clynne, 1984, 1990; Muffler and others, 1989). Herein, the major stratigraphic divisions of the Lassen Volcanic Center are designated the Rockland caldera complex, Brokeoff Volcano, and Lassen domefield (fig. 4*C*). These eruptive stages represent a continuum of lithologically correlated volcanism distinctly different from one another but linked by a common magmatic system. The Rockland caldera complex consists of a group of dacite to rhyolite domes, flows, and pyroclastic deposits and the Rockland tephra. Brokeoff Volcano was previously called Stages 1 and 2 of the Lassen Volcanic Center. The Lassen domefield consists of the dacite domefield and surrounding hybrid andesite lava flows on the Central Plateau area of LVNP and surrounding areas that we previously called Stage 3 of the Lassen Volcanic Center. Clynne (1990) and Bullen and Clynne (1990) discussed the geochemistry and magmatic evolution of the Lassen Volcanic Center using the old stage terminology. The total erupted volume of the Lassen Volcanic Center was estimated by Sherrod and Smith (1990) to be about 200 km^3.

Rockland Caldera Complex

The Rockland caldera complex consists of the Rockland tephra and a group of geographically, stratigraphically, and lithologically correlative silicic volcanic units ranging in age from ~825 to 609 ka. Dacite to rhyolite domes and flows exposed peripheral to Brokeoff Volcano (fig. 4*C*) erupted during this approximately 215,000-year-long period of silicic volcanism, which culminated in eruption of the Rockland tephra at 609±7 ka (Lanphere and others, 1999, 2004). Total erupted volume of the Rockland caldera complex is at least 60–70 km^3.

The Rockland tephra was first recognized by Wilson (1961) as the "Rockland rhyolite pumice tuff breccia". The name derives from the Rockland School, which was then located 0.5 mile northwest of Camp Forward along the western margin of the map area. A coeval distal ash-fall deposit is widely distributed in northern and central California and northeast to Idaho and in deep-sea cores taken off the northern California coast (Sarna-Wojcicki and others, 1985). Meyer and others (1991) defined the term "Rockland tephra" to refer to both distal and proximal exposures, and this usage was continued in recent papers specifying the age of the unit (Lanphere and others, 1999, 2004). We accept the term as defined by Meyer and others (1991).

Wilson (1961), Helley and others (1981), and Meyer and others (1991) attributed the Rockland deposits to the Maidu Volcanic Center; indeed, Helley and others (1981) called the unit the "ash of Mount Maidu". Clynne (1984) recognized that the Rockland deposits were younger than the Maidu Volcanic Center and, based on a fission-track age of about 400 ka (Meyer and others, 1980, 1991), attributed the Rockland tephra to the Lassen Volcanic Center. This age was younger than Brokeoff Volcano, and thus the Rockland tephra was thought possibly to be the initial eruption of the Lassen domefield stage of the Lassen Volcanic Center. Subsequent precise dating determined the Rockland tephra to be 609±7 ka (Lanphere and others, 1999; 2004), slightly older than the Brokeoff Volcano. The calculated volume of the Rockland tephra is ~50 km^3 (dense rock equivalent; Sarna-Wojcicki and others, 1985), which is similar to that of the Mazama ash from Crater Lake (Bacon, 1983). An eruption of this magnitude must have formed a collapse caldera. Projection of outcrop pattern of proximal deposits points toward Brokeoff Volcano, and it seems likely that eruption of the Rockland tephra produced a small caldera that has subsequently been filled by Brokeoff Volcano and younger products of Lassen Volcanic Center.

Clynne (1984) also recognized a number of silicic rock units older than Brokeoff Volcano and the Rockland tephra, and he assigned them to the Maidu and Dittmar Volcanic Centers. Subsequent radiometric dating and improved understanding of the evolution of the Maidu and Dittmar Volcanic Centers showed these silicic rock units to be inconsistent with those centers. Instead, these silicic rock units form a ring around the inferred source of the Rockland tephra and thus are now grouped with the Rockland tephra as the Rockland caldera complex. Lithic fragments from several of these silicic rock units are present in the Rockland tephra. These relations support our hypothesis that the Rockland tephra was erupted from a caldera located at the present site of Brokeoff Volcano. The nature and sources of rocks occupying the area of the Rockland caldera complex prior to its formation are incompletely known, but the presence of lithic clasts of unit acs and possibly unit rd3 in the Rockland tephra suggests that a small andesitic composite volcano and a silicic domefield possibly related to the Dittmar Volcanic Center occupied the area before emplacement of the Rockland caldera complex and eruption of the Rockland tephra.

Brokeoff Volcano

Brokeoff Volcano is the second of the major stratigraphic divisions of the Lassen Volcanic Center. Brokeoff Volcano, also designated "Mount Tehama" by the National Park Service, consists of a large, ~80-km^3, composite volcano. Almost immediately after eruption of the Rockland tephra, the caldera began to fill as renewed activity formed Brokeoff Volcano. The stratigraphy of Brokeoff Volcano is described as two sequences of deposits: the Mill Canyon sequence and the Diller sequence.

The Mill Canyon sequence consists of dozens of small-volume basaltic andesite to dacite lava flows and interbedded fragmental deposits erupted from a central vent between about 590 and 470 ka. The sequence is dominated by packages of thin andesite lava flows and breccias of a single lithology. Adjacent flow packages are different lithologies, and a wide variety of porphyritic olivine and pyroxene basaltic andesites and andesites to pyroxene-hornblende dacites are present. Although mapped here as a single unit, the andesites of Mill Canyon were shown in more detail by Clynne (1984). Vent or near-vent facies of Brokeoff Volcano andesites are found along the ridge between Mount Diller and Brokeoff Mountain, on Diamond Peak, and on the ridge south of Bumpass Hell and demonstrate that the position of the central vent varied as the volcano grew. The Mill Canyon sequence is capped by thick dacite lava flows erupted at 470 ka and mapped as the dacite of Twin Meadows. The dacite of Twin Meadows is the only rock unit of significant lateral extent in the Brokeoff Volcano and provides a convenient stratigraphic boundary between the Mill Canyon sequence and the overlying Diller sequence.

The Diller sequence consists of thick, large-volume, lithologically similar lava flows erupted between 470 and 385 ka. These flows erupted from flank vents and generally lack interbedded pyroclastic deposits. The most extensive exposures of Diller sequence lava flows are on the south and west flanks of Brokeoff Mountain, on the ridge to the west of Mount Diller, and in the drainage of Rice Creek. Six large augite-hypersthene andesite to silicic andesite lava flows are mapped, and remnants of additional lava flows are combined as an additional unit. No volcanism is recognized in the Lassen Volcanic Center between about 385 and 300 ka. After extinction of the Brokeoff Volcano, the character and locus of volcanism in the Lassen Volcanic Center changed dramatically.

Brokeoff Volcano rocks, especially the Mill Canyon sequence, have undergone variable degrees of hydrothermal alteration. Rocks exposed near the eroded core of Brokeoff Volcano are strongly altered, and the degree of alteration generally decreases away from the core. Permeable fragmental deposits and flow breccias tend to be more altered than dense lava flow cores. The most extensive sections of fresh Mill Canyon sequence andesites are found in the cliffs of Bailey Creek (between Brokeoff Mountain and Mount Diller) and in Mill Creek. Williams (1932) proposed that the eroded core of Brokeoff Volcano was a collapse caldera. However, no large-volume pyroclastic deposit of the appropriate age has been found in the Lassen area and no significant stratigraphic offsets between lavas in the core and flanks of Brokeoff Volcano have been found. The eviscerated core of Brokeoff Volcano is the product of enhanced glacial and fluvial erosion of weak, hydrothermally altered rock, and much of the core area now consists of material emplaced by landslides. The largest remnants of the Brokeoff Volcano (Mount Diller and Brokeoff Mountain) were protected from erosion by thick, unaltered, lava flows of the Diller sequence on their outer flanks.

Lassen Domefield

The silicic rocks in the northwest corner of LVNP and hybrid andesite lavas on the Central Plateau (fig. 3) comprise the Lassen domefield, the final stage of the evolution of the Lassen Volcanic Center. The silicic rocks of the Lassen domefield erupted along the northern flank of Brokeoff Volcano and are divided on the basis of age into the Bumpass (~300–190 ka) and Eagle Peak (~70–0 ka) sequences. The hybrid andesite units erupted in two groups called the older (~310–~240 ka) and younger (~90–0 ka) Twin Lakes sequence and are contemporaneous with the Bumpass and Eagle Peak sequences, respectively. No volcanism is known in the Lassen Volcanic Center during the period 190–90 ka. The erupted volumes of the silicic rocks of the Lassen domefield total ~40–50 km^3 and the hybrid andesites ~10 km^3.

The Bumpass sequence is a group of 15 dacite to rhyodacite lava domes, flows, and a lithic pyroclastic flow deposit that comprise the older part of the dacite domefield. These were emplaced in the southern part of the Lassen domefield on the north flank of Brokeoff Volcano in a broad curvilinear array between about 300 and 190 ka. Repeated glaciation has removed glassy dome carapaces and most of the fragmental deposits associated with domes and flows. Bumpass sequence lavas are mostly porphyritic pyroxene and hornblende dacites; quartz and biotite are generally sparse. A few are porphyritic biotite-hornblende rhyodacite. Mafic inclusions are sparse to abundant. The Bumpass sequence rock units are characterized by weakly disequilibrium phenocryst assemblages that originated by mixing of a small proportion of regional mafic magma with rhyodacite of the Lassen domefield magmatic system.

The Eagle Peak sequence consists of a group of seven dacite and rhyodacite lava domes and flows and their associated pyroclastic deposits erupted in the northern part of Lassen domefield between 66 and 1.1 ka. Vents are concentrated in a small area in the central part of the Lassen domefield. These include the most prominent young volcanic features in LVNP: Lassen Peak (27 ka) and Chaos Crags (1.1 ka) and the products of five older eruptions. Most units of the Eagle Peak sequence are glaciated, but the degree of glacial erosion is much less than on domes of the Bumpass sequence, and significant portions of glassy carapaces, primary hot talus, and pyroclastic deposits are preserved. Lavas of the Eagle Peak sequence are porphyritic hornblende and biotite dacite and rhyodacite; some also contain quartz. The rocks are characterized by weakly disequilibrium phenocryst assemblages and mafic inclusions that originate by mixing of a small proportion of regional mafic magma with rhyodacite of the active Lassen domefield magmatic system.

The Twin Lakes sequence consists of two time-stratigraphic groups of mostly andesite and basaltic andesite lava flows and agglutinate cones erupted around the periphery of the Lassen domefield but primarily on the Central Plateau of LVNP. An older group of lava flows is correlative with the Bumpass sequence, and a younger group of lava flows is correlative with the Eagle Peak sequence. The two youngest eruptions in LVNP, the basaltic andesites of Cinder Cone and deposits of the 1914–17 eruption of Lassen Peak, are included in the younger Twin Lakes sequence. Rocks of the Twin Lakes sequence have strongly disequilibrium phenocryst assemblages that are characterized by coexistence of magnesian olivine and quartz. They originate by mixing of subequal proportions of regional mafic magma and rhyodacite of the Lassen domefield magmatic system.

The Bumpass, Eagle Peak, and Twin Lakes sequences belong to a suite of lavas formed by a continuum of magma-mixing processes that cause many rock units to be variable in appearance and composition. Thus, chemically different lavas may have a similar macroscopic appearance, or the same lava may range in appearance. Lassen dacites evolve by introduction of regional mafic magma into a silicic reservoir containing felsic melt and phenocrysts. Mixing of hot mafic magma and its phenocrysts with cool host dacite and its phenocrysts, partial resorption of the host dacite phenocrysts, quenching of the resultant mixed magma to form undercooled inclusions, and circulation and disaggregation of inclusions back into the host dacite create complex disequilibrium phenocryst assemblages (Clynne, 1999). Phenocryst abundance, character, and even assemblage can vary within individual dacite domes, and intradome variability can be as large as interdome variability. The two fundamental factors controlling the character of the erupted magma are the relative proportions of mafic and silicic components in the mixture and the length of time between the mixing event(s) and eruption. When the relative proportions of mafic and silicic components approach unity, inclusions are no longer formed, and the magmas mix homogeneously to form hybrid magmas. Hybrids are typically andesitic and are usually characterized by strongly resorbed phenocrysts and the coexistence of magnesian olivine and quartz as phenocrysts.

Holocene Activity

The Lassen Volcanic Center is still active, and three eruptions of Holocene age occurred at Chaos Crags, Cinder Cone, and Lassen Peak. No other eruptions documented to be Holocene have occurred in the area covered by the map.

Chaos Crags

The Chaos Crags erupted northwest of Lassen Peak about 1,103±13 yr B.P. (Clynne and others, 2002) and is the youngest unit of the Eagle Peak sequence. The eruptive sequence consists of a group of six rhyodacite lava domes and associated pyroclastic deposits that define a typical silicic eruption in the Lassen Volcanic Center. The depiction of map units follows that of Christiansen and others (2002). Initial pyroclastic deposits are mapped as a single unit, and subsequent lava domes and collapse deposits are mapped separately.

The Chaos Crags eruption began with a vent-opening phase followed by explosive eruption and emplacement of the lower and middle pyroclastic flow that cooled as a single unit. Fallout of pumice around the vent built a small tuff cone at the north end of the Chaos Crags. Extrusion of a small lava dome A and cooling of magma in the conduit then plugged the vent. Reopening of the conduit and explosive eruption of rhyodacite as the upper pyroclastic flow followed a short hiatus in the eruptive sequence and was much larger than the eruption that produced the lower and middle pyroclastic flows. This eruption partially destroyed dome A. Subsequent to eruption of the upper pyroclastic flow, domes B through F were emplaced. Although the relative ages of these domes are clear, the time interval over which they erupted is not. However, similar paleomagnetic direction for all units indicate that the entire eruption probably took less than a few decades (D.E. Champion, written commun., 2003). Domes D and E had small hot collapse events that emplaced short run-out lithic pyroclastic avalanches. Talus emplaced hot from the lava domes as they grow is also mapped. At a later time, dome C partially collapsed as a series of three, cold, rockfall avalanches that emplaced the Chaos Jumbles at 278±28 yr BP.

Chaos Crags lavas are porphyritic hornblende-biotite rhyodacite that contain a complex disequilibrium phenocryst assemblage characteristic of Lassen dacites (Clynne, 1999) and variable amounts of mafic inclusions. Early erupted lava contrasts with later erupted lava. Mafic inclusions are sparse to rare in the early rhyodacites (generally less than 1 percent to a few percent), whereas they form up to nearly 20 percent of late rhyodacites. The proportion of reacted phenocrysts and groundmass microphenocrysts disaggregated from inclusions mirrors the proportion of inclusions in the rocks. Bulk rock compositions (macroscopically inclusion-free) also reflect the proportion of disaggregated inclusions; early rhyodacites are a homogeneous group at about 69–70 percent SiO_2, whereas late rhyodacites are heterogeneous and contain 67–68.5 percent SiO_2.

Cinder Cone

Cinder Cone is the youngest mafic volcano in the map area and consists of five lava flows, two cinder cones, and a widespread mafic ash fall deposit; it is the second youngest eruption in the Twin Lakes sequence. The calibrated radiocarbon age of Cinder Cone is 264±28 yr B.P., and stratigraphic and paleomagnetic data indicate that the lava and tephra erupted over a short interval about 1650 C.E. (Clynne and others, 2000;

Clynne and others, 2002). Tree-ring dendrochronology indicates that Cinder Cone erupted in 1666 C.E. (Sheppard and others, 2009). Subdivision of Cinder Cone deposits is based on eruptive sequence and composition; two compositional groups are present. An early cone, now a remnant, produced the Old Bench flow (olivine basaltic andesite) and the two Painted Dunes flows (olivine basaltic andesite and olivine andesite, respectively). Painted Dunes flows contain blocks of welded cinders and agglutinate from several to tens of meters across that were rafted from the remnant cinder cone, which was almost completely destroyed by their eruption. Painted Dunes flows blocked drainage from Central Plateau of LVNP and created Snag Lake. Renewed eruptions built Cinder Cone and emplaced the two Fantastic Lava Beds flows (augite-olivine basaltic andesite). A widespread ash deposit as much as 2.5 m thick is composed of ash of both the Painted Dunes and Fantastic Lava Beds compositions and has no discernable time break between them. Thickness of the ash is shown on the map as isopachs in centimeters. The isopachs were adapted from those presented by Heiken (1978) by combining the isopachs of his three units and showing them as total thickness. The map does not show a 0-cm isopach because ash extends locally for at least several kilometers beyond the 0-cm isopach as shown by Heiken (1978). Old Bench and Painted Dunes 1 flows have a thick cover of colorfully oxidized ash, and Painted Dunes 2 flow has a thin cover of ash with Fantastic Lava Beds composition. Oxidation of ash demonstrates that Old Bench and Painted Dunes lava flows were still hot when the ash that formed Cinder Cone erupted. Little ash was erupted during or after Fantastic Lava Beds flows were emplaced, and their surfaces are nearly ash free. Painted Dunes and Fantastic Lava Beds flows have rough, block-covered surfaces with considerable relief and many flow levees. Lava flows completely lack soil and are nearly devoid of vegetation; only a few mature but stunted trees grow on Painted Dunes ash deposits. Deposits of diatomite around the base of the Fantastic Lava Beds flows indicate that Butte Lake was considerably larger before the eruption of Cinder Cone and was partially filled in by the lava flows.

1914–1917 Eruption of Lassen Peak

The 1914–17 eruption of Lassen Peak is the most recent eruption in the Twin Lakes sequence and is a complex eruptive sequence consisting of a dacite dome and lava flow; dacite pyroclastic flow and fall deposit; and phreatic, avalanche, debris-flow, and flood deposits. Magmatic activity was confined to the period from about May 14 to 22, 1915, and affected primarily the northeast flank and slope of Lassen Peak (now called the Devastated Area) and the valleys of Lost and Hat Creeks as far as about 50 km downstream. Division of deposits of the 1914–1917 eruption is based on stratigraphy and mode of emplacement and generally follows the depiction of Christiansen and others (2002). Rock types range from olivine andesite to several varieties of hornblende-biotite dacite with abundant mafic inclusions and complex mineralogy. The presence of spectacularly banded pumice blocks erupted on May 22 serves to distinguish May 22 from May 14–19 deposits. See Clynne (1999) for more detailed description and interpretation of these rocks and Clynne and others (1999) for additional description of the 1915 eruption.

The eruptive sequence began on May 30, 1914, with a phreatic explosion at the summit of Lassen Peak. By mid-May of 1915, more than 180 steam explosions had blasted out a 300-m-wide crater at the summit. Deposits of this precursory activity are thin and were mostly confined to the immediate vicinity of Lassen Peak or were buried by subsequent deposits and are not shown on the map. In the week before May 19, 1915, a small dacite lava dome (d4) filled the crater. On the late evening of May 19, 1915, the growing dacite dome was disrupted by a large phreatic explosion. Hot blocks of lava were thrown onto the snow-covered upper flanks and summit of Lassen Peak (p9), which initiated an avalanche of snow and rock that swept down the steep northeast face of Lassen Peak, over the low ridge northeast of Emigrant Pass, and into Hat Creek (sw9). The avalanche was quickly followed by a debris flow formed from melting of snow by hot lava blocks and underlying loose rock debris (f9). The debris flow followed the same path as the avalanche until it encountered the low ridge northeast of Emigrant Pass, where it was deflected west into Lost Creek. The debris flow continued down Lost Creek for another 7 km before coming to rest in the large flat area 3 km west of Twin Bridges. During the early morning hours of May 20, 1915, the debris-flow and avalanche deposits released large volumes of water that caused a flood along Hat Creek north of Old Station (f9). Also in the late evening and early morning of May 19–20, 1915, dacite lava, which was more fluid than that erupted during the previous week, welled up into and filled the newly excavated crater. It spilled over two low areas on the rim and emplaced two short lava flows (d9) on the steep west and northeast flanks of Lassen Peak.

The eruptive sequence culminated two days later at approximately 4:00 pm on May 22, 1915. A vertically directed column of pumice and gas blasted through the May 19–20 lava flow, created a new crater, and rose to 30,000 ft. Partial collapse of the column initiated a pyroclastic flow on the northeast slope of Lassen Peak, which rapidly incorporated and melted snow in its path. By the time it reached the lower Devastated Area, the pyroclastic flow transformed into a fluid debris flow (pw2) that traveled down Lost Creek to beyond Twin Bridges, where it released water and caused a second flood along Hat Creek north of Old Station. Continued fallout from the eruption cloud emplaced a pumice deposit on the upper slopes of Lassen Peak (p2). Pumice that fell on remaining snow-covered areas high on Lassen Peak generated six viscous debris flows that were emplaced on the west, north, and east flanks of Lassen Peak (w2). The May 19 lava flow on the northeast flank of Lassen Peak was removed in this eruption and incorporated into May 22 deposits, and the still-hot lava at the summit partially slumped back into the May 22 crater. For several years after this eruption, spring snowmelt percolating into Lassen Peak encountered hot rock and triggered steam explosions. Particularly vigorous phreatic explosions in May 1917 blasted out the western of the two craters at the summit of Lassen Peak and emplaced phreatic deposits (p17).

Caribou Volcanic Field

The Caribou Volcanic Field is an area of intense, young regional volcanism located 20–30 km east of the Lassen Volcanic Center (figs. 4*A*, 6; sheet 3). The field is composed of monogenetic cinder cones, flows, and small- to medium-sized lava cones, generally of mafic composition, and is distinguished from older regional mafic lavas around its periphery by substantial constructional morphology and the absence of significant structural disruption. The Caribou Volcanic Field (~425–0 ka) is contemporaneous with the later part of the Lassen Volcanic Center and is the result of a higher flux of magma from the mantle compared to the Lassen segment of the arc as a whole, but not as high as that at the Lassen Volcanic Center (Guffanti and others, 1996). The Caribou Volcanic Field may represent an incipient volcanic center that is not quite vigorous enough to initiate crustal melting and silicic volcanism. No single edifice has a long history of activity; Caribou volcanoes, however, tended to erupt in arrays that were probably active for periods as long as 100–200 ka. Emplacement of arrays is generally structurally controlled; that is, linear arrays of vents bury active or inactive faults that provided pathways exploited by ascending magma and acted to focus volcanism at the surface.

The volcanoes of the Caribou Volcanic Field were mapped in three larger and six smaller arrays that share similar spatial, temporal, and compositional characteristics. The major arrays are the Red Cinder chain, the Poison Lake chain, and the Caribou chain. The Caribou chain is further subdivided into the Triangle Lake sequence, the Echo Lake sequence, and the Caribou sequence. The six smaller arrays are the Tuya chains, the Bidwell Spring chain, the Cone Lake chain, the Sunrise Peak sequence, the Island Lake sequence, and the Beauty Lake sequence.

Red Cinder Chain

The Red Cinder chain includes 18 closely spaced vents whose eruptive products overlapped to build the substantial edifice of Red Cinder along the boundary between LVNP and the Caribou Wilderness Area. The edifice is nearly circular, but vents show a northwest–southeast alignment parallel to regional structure. Many vents are preserved as cinder cones. Several of the older units are cut by small faults, but in general the edifice is intact. The Red Cinder chain is dominated by porphyritic olivine basalt and olivine-augite basaltic andesite; one unit is pyroxene andesite. Only the andesite of Red Cinder (69±20 ka) is dated, but the Red Cinder chain is probably all less than ~100 ka; the youngest units are ~25 ka. Volcanoes of the Red Cinder chain are not as heavily glaciated as the nearby Caribou chain; many lava flows partially retain their original surfaces.

Poison Lake Chain

A broad zone of 39 young basalt and basaltic-andesite cinder cones and lava flows forms the Poison Lake chain. The entire chain lies outside the area of glaciation, and cinder cones and flow surfaces are well preserved. The cones and flows in the Poison Lake chain are combined into nine groups based on shared lithologic, chemical, and spatial characteristics. The vents are arranged in two parallel arrays only a kilometer apart, but no temporal or compositional differences can be discerned that are specific to one or the other of the lines of volcanoes. The chain coincides with and buries faults with small offsets that can be seen at the ends of the zone (south end off the map area). These faults have been used repeatedly as conduits for magma to erupt at the surface. Rocks that form these volcanoes are dominated by sparsely porphyritic to porphyritic olivine basalts that include some of the most primitive lavas in the Lassen area (Borg and others, 1997; Clynne and Borg, 1997). Eight of the nine groups have $^{40}Ar/^{39}Ar$ dates between ~100 and ~110 ka; the ninth is undated.

Caribou Chain

The Caribou chain is the dominant constructional feature in Caribou Volcanic Field. The chain extends 14 km from Star Butte in the south to Triangle Lake in the north. Lavas of the Caribou chain are dominated by porphyritic olivine basaltic andesite and augite–olivine basaltic andesite with little lithologic and compositional diversity.

The central part of the Caribou chain is designated the Caribou sequence and includes the large edifices of North, middle, and South Caribou, the platform of slightly older rocks upon which the edifices rest, and younger lava flows northwest of Silver Lake. The Echo Lake and Triangle Lake sequences, respectively south and north of the Caribou sequence, are similar but younger rocks. The Caribou sequence was active from ~425 ka to ~325 ka; the Echo Lake and Triangle Lake sequences extend the eruptive period of the entire Caribou chain to ~275 ka. The three Caribou edifices were high points throughout the late Pleistocene glacial episodes; the upper parts of the edifices are deeply eroded, exposing several intrusive masses. Vents, when found, are poorly preserved agglutinate cones, and the surfaces of lava flows are stripped of their block carapaces.

Other Chains and Sequences in the Caribou Volcanic Field

The smaller groups are the Tuya chains, the Bidwell Spring chain, the Cone Lake chain, the Sunrise Peak sequence, the Island Lake sequence, and the Beauty Lake sequence. Each has been correlated on the basis of shared similar spatial, temporal, and compositional characteristics.

Two arrays of unusual olivine basaltic-andesite volcanoes called tuyas exposed in the Caribou Wilderness Area are mapped as the Tuya chains. Tuyas have a distinctive shape that is steep-sided and flat-topped like a silicic lava dome and are interpreted to have erupted beneath glacial ice. Rock exposed on the sides of the tuyas has a distinctive pattern of closely spaced joints so that the rock breaks into angular roughly cubic blocks with slightly curved to almost conchoidal planar surfaces. Both chains erupted along distinct linear arrays, probably controlled by faults in the subsurface. The older chain probably erupted during a glacial advance at either 120–130 ka or about 60 ka. The younger chain probably erupted during the latest major glacial episode at 18–35 ka and is among the youngest volcanoes in the Caribou Volcanic Field.

A line of small monogenetic mafic volcanoes that extends from Black Butte for about 5 km north is designated the Bidwell Spring chain. They are mostly outside the area of glaciation, but some have been weakly glaciated or partially covered by till. One radiometric date and the age of overlying glacial deposits indicate the vents in this chain to be between about 20 and 70 ka.

The Cone Lake chain comprises a group of basalt and basaltic andesite lava and cinder cones near Cone Lake. Although generally similar to flows of the Poison Lake chain, they are older (~200 to ~250 ka) and partially buried by units of Poison Lake chain and Bidwell Spring chain. The Cone Lake chain is mostly beyond the limit of glaciation, and the cinder cones are fairly well preserved.

The Sunrise Peak sequence comprises a group of basalt and basaltic andesite lava flows and vents near Butte Lake. Although generally similar to the Red Cinder chain, they are older (~300–400 ka), more heavily glaciated, and cut by a prominent, old, till-covered fault that is part of the discontinuous fault zone between Lake Almanor Graben and Hat Creek Graben.

The Island Lake sequence comprises two spatially and temporally related basalt lava flows near Bonte Peak. The Island Lake sequence is ~350 ka, heavily glaciated, and cut by faults along the discontinuous fault zone between the Lake Almanor Graben and the Hat Creek Graben.

The Beauty Lake sequence includes glaciated lava flows lacking preserved vents south of Red Cinder. They are lithologically similar to mafic rocks in Caribou chain, but spatially offset from them, and approximately coeval with oldest rocks in Caribou chain (~425 ka).

Glacial Geology

Five episodes of Pleistocene glaciation are recognized in the Lassen area (Crandell, 1972; Kane, 1982; Colman and Pierce, 1992; Turrin and others, 1998). In most parts of the map, however, glacial deposits are divided simply into younger and older tills. In general, till, younger glaciations (Qty) has well-preserved moraines, whereas till, older glaciations (Qto) has only moderately to poorly preserved moraines. The boundary between the two tills corresponds to the boundary between middle Wisconsin and early Wisconsin glacial stages as defined by Colman and Pierce (1992) or approximately to the Tioga and Tahoe glacial advances as these terms are used by Kane (1982). Our depictions of this boundary are based on our field observations, and our interpretations do not always agree with those of Crandell (1972) and Kane (1982). For example, in the Bailey Creek drainage northwest of Brokeoff Mountain, our contact lies between that shown by Crandell (1972) and that shown by Kane (1982). A comparison of different workers' depictions of the Lassen area glacial geology is presented in table 1.

In the Lost, Hat, and Manzanita Creek drainages, Christiansen and others (2002) recognized and mapped six ages of glacial deposits, which were adapted for this map without modification. Tills designated late till of Anklin Meadows (Qtal), till of Anklin Meadows (Qta), and till of Raker Peak (Qtr) by Christiansen and others (2002) correspond to late Tioga, middle Tioga, and early Tioga tills of Kane (1982), respectively. These tills are equivalent to Qty in the rest of the map area. Post-maximum till of Raker Peak consisting of Lassen Peak avalanche debris (Qtrl) (Christiansen and others, 2002) is present only in the Lost and Hat Creek drainages. Till designated till of Badger Mountain (Qtb) in the Hat and Manzanita Creek drainages by Christiansen and others (2002) corresponds to the Tahoe advance of Kane (1982) and is included in Qto in all other drainages on this map. In the Lost, Hat, and Manzanita Creek drainages, the subdivided glacial units are intercalated with volcanic rocks of the Eagle Peak sequence. Use of the detailed glacial unit terminology was partially extended to the Bailey and Digger Creek drainages. In all areas other than the Hat, Manzanita, Lost, Bailey, and Digger Creek drainages, the contacts between Qty and Qto should be considered preliminary and approximate. Extension of the detailed glacial stratigraphy from the Lost, Hat, and Manzanita Creek drainages to the rest of the map area represents the most important remaining geologic mapping problem in the Lassen area.

A similar scheme was adopted in mapping outwash gravels. Some till and outwash gravel mapped as Qto and outwash gravel (Qoo and Qou), particularly in the distal part of the Bailey Creek drainage in the northwestern part of the map and along the south boundary of the map area, is probably Illinoian in age.

Methods

Unit Names

We base most volcanic rock unit names on SiO_2 content of the dominant lithology. Rock units that were not chemically analyzed are named based on their phenocryst assemblage, the morphology of the rock unit, and the geologist's experience with similar rock units. Because the composition of many rock units varies, we use the dominant composition to name the rock. However, the chemical composition of volcanic rocks is a continuum from basalt to rhyolite. When a lithology straddles or is close to a boundary, a future analysis may indicate a slightly different composition; thus, the name of some units is subject to revision. Major-element chemical analyses for samples from most rock units were published in Clynne and others (2008). Location of samples for chemical analysis and radiometric dating are included in the digital database on the accompanying CD-ROM (Muffler and others, 2010). Chemical analyses of Lassen rocks also were published by Clynne (1984), Bullen and Clynne (1990), Bacon and others (1997), Borg and others (1997), Borg and Clynne (1998), Clynne (1999), and Tepley and others (1999).

Mineral Names

Common mineral names, such as hornblende, hypersthene, and augite, are used for mafic minerals in the map descriptions even though they may not be compositionally precise. All magnesian orthopyroxenes are called hypersthene, and all magnesian clinopyroxenes are called augite. Hornblende is used for all calcic amphiboles, and biotite for all Fe–Mg micas. We use abbreviations for common minerals: pl, plagioclase; ol, olivine; aug, augite; hyp, hypersthene; pyr, pyroxene; hbl, hornblende; bt, biotite; and qtz, quartz. Mineral rock-name modifiers are used conventionally, in order of increasing abundance. Phenocryst abundances are estimated: the term "sparse" means less than about 1 percent and "trace" means much less than 1 percent. When the rock type is variable, the most common lithology is estimated or ranges are given. Oxide minerals, primarily titanomagnetite, are ubiquitous but are not included in the names or lithologic descriptions.

Reacted Phenocrysts and Mafic Inclusions

The unit descriptions commonly do not take into account subtle variations in the macroscopic appearance of these rocks. For example, most Lassen dacites and many andesites have two populations of phenocrysts, one that is normal and a second that is reacted, but it may be difficult to distinguish reacted phenocrysts in hand specimen. Reacted crystals were subjected to significant thermal or chemical disequilibrium, usually as a result of mixing magmas. The terms resorbed, fritted, or sieved are used commonly in the literature to describe the resulting texture and are generally synonymous with our use of the term "reacted."

Most Lassen dacites, and also some andesites and rhyolites, contain inclusions of more mafic chilled magma, ranging from a few millimeters to about 1.5 m in size. These are usually subrounded with sharp margins that are often crenulate against the host. In some dacites, many of the inclusions are broken and have angular margins. Inclusions have a fine-grained, highly microvesicular texture in which plagioclase and hornblende or pyroxene form a network of acicular crystals with variable proportions of interstitial glass. Many rocks also contain partly recrystallized inclusions with a range of coarser-grained, weakly microvesicular to dense textures. Inclusions generally are formed from hybridized magma and commonly contain weakly to strongly reacted felsic phenocrysts derived from the host dacite. They may also contain mafic phenocrysts retained from their parental mafic magma. In addition to mafic inclusion, the terms "enclave," "quenched inclusion," "undercooled inclusion," and "andesitic inclusion" are used in the literature to describe this type of inclusion (Bacon, 1986). See Clynne (1999) for additional explanation and discussion of mafic inclusions and reacted phenocrysts and their significance. The abundance, distribution, and character of mafic inclusions, although commonly variable in individual dacites, can be used to distinguish dacite units. When useful, information on the mafic-inclusion population of rock units is provided in the unit descriptions. The abundance of inclusions is described semi-quantitatively: the term "abundant" means more than about 5 percent inclusions, "common" means from 1 percent to about 5 percent, and "sparse" means less than about 1 percent.

Unit Ages

Ages of rock units reported in the Description of Map Units and Correlation of Map Units were acquired through a variety of radiometric dating techniques including radiocarbon, potassium-argon (K-Ar), and argon-argon ($^{40}Ar/^{39}Ar$). Age boundaries are based on Gradstein and others (2005) and Walker and others (2009). Paleomagnetic polarity boundaries are based on Berggren and others (1995). Ages for a few units are constrained by paleomagnetic directional data. References are given for published radiometric and paleomagnetic data, but most ages are unpublished. They are compiled in table 2 and details will be published elsewhere. Uncertainties given for all ages are 1 sigma. A few ages are weighted averages of several determinations. Ages of undated rock units are estimated using a variety of information, including stratigraphic position relative to dated units, preservation of volcanic morphology, degree of glacial erosion and relation to glacial deposits, degree of faulting, extent of soil development, and magnetic polarity; these ages are subject to revision.

Unit Labels

We construct unit labels in the following order: age, rock type, unit name. An initial capital letter T is used for the known or inferred age of Tertiary map units and the capital letter Q for Quaternary surficial and glacial units (except hydrothermally altered rocks and travertine deposits). For Quaternary volcanic units, the initial Q is omitted.

Volcanic units:
- b, basalt (<53% SiO_2)
- m, basaltic andesite (53–57% SiO_2)
- a, andesite (57–63% SiO_2)
- d, dacite (63–68% SiO_2)
- r, rhyodacite (68–72% SiO_2) and rhyolite (>72% SiO_2)
- p, pyroclastic flow and fall deposits

Glacial and sedimentary units:
- c, colluvium, including talus
- d, diatomite
- f, fluvial deposits, including all alluvium
- h, hydrothermally altered rocks and travertine deposits
- o, glacial outwash deposits
- s, landslide and avalanche deposits
- t, till
- w, mudflow and other debris-flow deposits

Second (third for Tertiary units) and subsequent letters specify the individual rock units on the map. Rock units placed in groups and given similar names followed by a number, for example basaltic andesites of Silver Lake, units 1–11, are assigned numbers in known or inferred stratigraphic order, from oldest (unit 1) to youngest (unit 11). For example, unit bb10 represents Quaternary basalts and basaltic andesites of Bogard Buttes, unit 10.

The Correlation of Map Units is organized into five major groups as follows: glacial and sedimentary deposits, rocks of volcanic centers including the Tuscan Formation, and three groups of regional volcanic rocks. Rocks of each volcanic center and the Caribou Volcanic Field are enclosed in colored boxes to indicate all units belonging in those groups. Rock units related to regional volcanism are shown according to location; Regional volcanic rocks north and west of Lassen Volcanic Center: Regional volcanic rocks south and east of Lassen Volcanic Center, and Regional volcanic rocks of the Caribou area. Table 3 gives the page number of each unit's description in the Description of Map Units and assistance in finding individual units on the Correlation of Map Units. Table 3 also gives the 1:24,000 quadrangle(s) within which each map unit occurs together with radiometric dates.

Acknowledgments

Our work builds on that of previous geologists (fig. 2) and would have been considerably more difficult without the context they provided. The mapping and publications of Howel Williams were, by far, the most insightful in this regard. His *Geology of the Lassen Volcanic National Park* (Williams, 1932) stands as a seminal work in interpretation of the geologic history of the Lassen area and the Cascade Range.

A project of the scope and size of this geologic map cannot possibly be completed without the assistance and consultation of colleagues. We particularly acknowledge the significant collaborations of Robert L. Christiansen and Marianne Guffanti in successful completion of this geologic map. Clynne and Muffler were ably assisted over the course of geologic mapping by a number of field assistants: Lars Borg, Miranda Fram, Marianne Guffanti, Gordon Keating, Jacob Madden, Charles Melancon, and Deborah Trimble.

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DESCRIPTION OF MAP UNITS

[Note that **not all map units are labeled on the map**. To identify units that are not labeled, because they are too small for color identification and (or) labeling will obscure data, see database (accompanying CD-ROM). See **table 3** for an alphabetical listing of map unit labels, as well as unit name, page number of unit description in pamphlet, radiometric age, location by heading in Correlation of Map Units, and quadrangle location in database. See **Methodology** section for detailed information on methods used to describe and name map units. **Unit labels** are abbreviations for age (all units without a capital letter are Quaternary), rock type, and unit name: unit bb10 represents Quaternary basalts and basaltic andesites of Bogard Buttes, unit 10. **Rock type abbreviations (volcanic units)**: b, basalt (<53% SiO_2); m, basaltic andesite (53–57% SiO_2); a, andesite (57–63% SiO_2); d, dacite (63–68% SiO_2); r, rhyodacite (68–72% SiO_2) and rhyolite (>72% SiO_2); p, pyroclastic flow and fall deposits. **Rock type abbreviations (glacial and sedimentary units)**: c, colluvium, including talus; d, diatomite; f, fluvial deposits, including all alluvium; h; hydrothermally altered rocks and travertine deposits; o, glacial outwash deposits; s, landslide and avalanche deposits; t, till; w, mudflow and other debris-flow deposits. **Common mineral abbreviations**: pl, plagioclase; ol, olivine; aug, augite; hyp, hypersthene; pyr, pyroxene; hbl, hornblende; bt, biotite; and qtz, quartz. **Abbreviations in brackets** at end of unit description represent 1:24,000-scale quadrangle(s) where unit is mapped (see fig. 3)]

GLACIAL, SEDIMENTARY, AND HYDROTHERMAL DEPOSITS

NONVOLCANIC SEDIMENTARY DEPOSITS

Alluvium and Colluvium

Qf **Alluvium (Holocene and Pleistocene)**—Moderately well sorted, unconsolidated, lenticular-bedded sand and gravel in modern stream channels. Includes stream terraces and reworked glacial outwash in some areas. Dominantly Holocene, but includes some older Pleistocene alluvium. Includes extensive marsh deposits at northeast end of Lake Almanor. [BB, CH, CM, GP, LP, MH, MN, MZ, OS, PL, PP, RC, RP, ST, SW, TH, VI, WP]

Qc **Colluvium and talus (Holocene and Pleistocene)**—Nonsorted to laterally sorted, unconsolidated, nonbedded, coarse to fine rubble. Consists mainly of talus at the base of cliffs or steep slopes of bedrock, but locally occurs as slopewash or thin, local debris flows. In northern Caribou Volcanic Field, includes flat, generally internally drained areas of windblown ash related to eruption of nearby cinder cones. Older colluvium generally has well-developed soil. Mapped only where it obscures underlying bedrock completely or is different lithology than underlying bedrock. Does not include debris emplaced hot from growing dacite domes. Age ranges throughout Holocene and, in areas outside the limits of glaciation, into Pleistocene. [BB, CH, LP, LY, MH, MN, MZ, OS, PL, PP, RC, RP, ST, SW, WP]

Qcl **Talus on Lassen Peak (late Pleistocene)**—Generally nonsorted, unconsolidated, nonbedded, coarse to fine rubble. Covers much of surface of the Lassen Peak dacite dome (dl). Some of talus was deposited as hot blocks during emplacement of dome and is recognized by presence of prismatically jointed blocks of dacite as large as 5 m across. Much talus was deposited later, during glaciation, weathering, and rockfalls from cliffs and other outcrops on Lassen Peak during late Pleistocene. [LP, MZ, RP]

Mass-Wasting Deposits

Qsh **Landslide deposits in hydrothermally altered core of Brokeoff Volcano (Holocene)**—Nonsorted, unconsolidated, nonbedded, fine to coarse rubble in small slumps, debris flows, and landslides on slopes underlain by unconsolidated or hydrothermally altered rocks. Mapped only where unit obscures bedrock or deposit is thick. Much of hydrothermally altered core of Brokeoff Volcano is unstable and subject to small landslides and debris flows, dozens of which occurred in East and West Sulphur Creek. Some slides subject to reactivation during spring snowmelt. Several major landslides of postglacial age originated from high, interior parts of eroded Brokeoff Volcano; largest landslide (not mapped separately) broke away from scarp above Forest Lake and flowed nearly 7 km down Mill Creek. It contains bedrock blocks as much as 100 m long and has radiocarbon date of 3,310±55 yr B.P. (Clynne and others, 2002). Another large landslide originated from northwest side of

Pilot Pinnacle and flowed north into Blue Lake Canyon. Major rockfall of Holocene age originated from south face of Pilot Pinnacle. [LP, RP]

Qsj **Avalanche deposits of Chaos Jumbles (Holocene)**—Nonsorted, unconsolidated, nonbedded deposit of coarse to fine rubble with angular blocks as much as 5 m across. Consists almost entirely of pink, oxidized rhyodacite of Chaos Crags, dome C (rcc). Trains of blocks of weakly altered andesite of Brokeoff Volcano from septum between dome C and dome B (rcb) can be found in Chaos Jumbles. Deposit has lobate margins (with run-up on adjacent topographic highs, especially Table Mountain), transverse and longitudinal debris ridges on surface, and scarp-like margins generally 1–5 m high (see Eppler and others, 1987, for more details). Formed by catastrophic collapse of dome C as three rockfall avalanches were emplaced in quick succession (Crandell and others, 1974). Soils and forest are much better developed near margins of deposit relative to interior. Radiocarbon age of 278±28 yr B.P. was obtained from trees drowned by Manzanita Lake, which formed when first avalanche dammed Manzanita Creek (Clynne and others, 2002). Tree-ring correlation age for emplacement of Chaos Jumbles is 1644±14 C.E. [MZ]

Qwh **Debris-flow deposits from the northeast side of Lassen Peak (Holocene)**—Poorly sorted, generally unconsolidated, massively bedded rubble ranging from silt to large subrounded blocks. Consists entirely of dacite of Lassen Peak (dl). Commonly pink in color, but ranges from pink to gray, reflecting lithology of source dacite on different parts of Lassen Peak dome. Thickness, <1–6 m. Formed as mudflows from steep, high, northeast slopes of Lassen Peak and deposited in drainage of upper Lost Creek. Soil underlying deposit has radiocarbon age of 8,130±100 yr B.P. and soil developed on surface of deposit has radiocarbon age of 7,550±50 yr B.P. (Turrin and others, 1998; Clynne and others, 2002). Thus, the age of the deposit is ~8,000 yr B.P. [LP, MZ, RP, WP]

Qsl **Avalanche debris from Lassen Peak spread across glacial ice (late Pleistocene)**—Nonsorted, unconsolidated, nonbedded, angular rubble with blocks commonly as large as 1–2 m across, locally (on the east side of Raker Peak) to 6 m; coarse grit matrix. Consists entirely of material derived from Lassen Peak (dl). Occurs high on east side of Raker Peak, north of Raker Peak on west side of Hat Creek drainage to as low as ~5,400 ft elev, and on east side of Hat Creek drainage at foot of Badger Mountain. Interpreted as debris spread across surface of glacier in valley of Hat Creek after partial glacial retreat from terminal position of Raker Peak glaciation (Qtr). [WP]

Qs82 **Avalanche deposit from dacite of hill 8283 (middle Pleistocene)**—Nonsorted, unconsolidated, nonbedded, angular rubble with blocks commonly as much as 1–2 m across in coarse grit matrix. In proximal areas, consists almost entirely of dacite of hill 8283 (d82). Occurs in valley of Manzanita Creek from west base of Lassen Peak to as low as ~4,000 ft elev. Best exposed near intersection of Calif. Hwys. 44 and 89, just west of park entrance at Manzanita Lake. West of this exposure, deposit is largely covered by pumiceous pyroclastic-flow deposits (pe) from Eagle Peak, and only large avalanche blocks protrude to surface. In area of McCumber Reservoir, deposit is mostly covered by outwash gravel and by tholeiitic basalt of Eagle Canyon (bec). In distal areas, deposit contains abundant fragments of andesite of Manzanita Creek (amz), which were probably picked up as avalanche crossed amz. Qs82 contains some prismatically jointed blocks, but it is unclear whether or not unit was emplaced hot by partial collapse of the d82 dacite dome. Age of deposit is uncertain, although Qs82 must be equivalent to or younger than d82 (261±5 ka) and older than bec (199±22 ka). [MZ, VI]

Qwb **Debris-flow deposit from Brokeoff Volcano (middle Pleistocene)**—Sheetlike fragmental deposit, primarily in drainages of Rock and Digger Creeks, found only beyond limit of glaciation. Outcrops are sparse; good exposures occur only in road and stream cuts. Thickness is variable; thickest section measured is 8 m in Digger Creek. Deposit is matrix supported and light orange in color, weathering to dark orange. Matrix is composed of comminuted rock fragments, silt, and mud and is compacted but unconsolidated. Unweathered exposures of matrix are scarce. Debris flow contains as much as 20% angular to rounded clasts from a few millimeters to several meters in size. Clasts have dark-orange-brown weathering rinds as thick as 3 mm and are predominantly porphyritic aug-hyp andesite (andesite of Digger Creek, adc). Fragments of adc from all parts of lava flow (for example, vesicular, dense, platy, glassy, massive) can be found together. Matrix weathers away to leave a lag of clasts on ground surface. Distribution of debris flow and prominent lithologies indicate an origin from slopes of Brokeoff Volcano. Deposit surmounts topography in Blue Ridge area and may have been emplaced by a debris avalanche. Age of debris flow is unclear but may be related to eruption of adc, probably 350–450 ka. [GP]

Hydrothermal Deposits

h **Hydrothermally altered rocks in active thermal areas (Holocene)**—Rocks exposed in areas of active hydrothermal alteration and so intensively altered that their original lithology and stratigraphy are indeterminable. Typically, light-gray or orange-brown, altered andesite and dacite, without preserved mafic phenocrysts. Occasionally, areas of kaolinite and silica with scattered blocks of intensely altered rock. Mapped only in areas of intense active hydrothermal alteration at Bumpass Hell, Devils Kitchen, and Sulphur Works. [LP, RP]

ht **Travertine (Holocene)**—Deposits of calcium carbonate deposited on ground surface by flowing hot water. Around active hot-spring vents, forms mounds 1–4 m diam; commonly streaked with brightly colored green and orange algae. Deposits around modern but inactive vents are white, sometimes forming multiple terraces each 0.4 m high. Older travertine deposits are brown and commonly disaggregated by surface processes into 0.1 m angular blocks. In addition to two areas of dominantly old travertine mapped in upper Little Hot Springs Valley, springs currently depositing travertine occur on east bank of West Sulphur Creek at 6,850 ft elev, 550 ft at 176° azimuth from the roadcut at Sulphur Works, and on the east side of Little Hot Springs Valley at 7,360 ft elev, 4,600 ft at 79° azimuth from the summit of Diamond Peak. A travertine deposit too small to show at map scale occurs on the south side of Hot Springs Creek about 800 ft along trail from Warner Valley picnic area. Travertine deposits are all younger than till, younger glaciations (Qty). [LP]

Glacial Deposits

Two groups of glacial deposits are mapped: generalized deposits of glacial advances that apply to most of the map area and deposits intercalated with volcanic rocks in Hat, Manzanita, and Bailey Creeks that are subdivided and mapped separately.

Till

Qth **Till or protalus-rampart debris (Holocene)**—Poorly sorted, unconsolidated, nonbedded diamicton consisting of silt to boulders of dacite of Lassen Peak (dl). Equivalent to unit of Christiansen and others (2002). Forms small moraines or ramparts at ~7,800–9,000 ft elev near south and east base of Lassen Peak. Similar deposits on the north-facing upper slopes of Reading Peak and around several tuyas (basaltic andesite of Turnaround Lake, mtt) are not mapped. [RP]

Qty **Till, younger glaciations (late Pleistocene)**—Diamicton with boulders commonly as large as 2 m across, locally to 4 m, and occasionally larger, consisting of a range of volcanic lithologies. Occurs as sheetlike deposits and large moraines as low as ~5,900–6,200 ft elev in Mineral area, 5,400 ft in valley of Warner Creek, 5,600 ft in area around Feather River Meadows and in valleys of Butte Creek and Bailey Creek (Chester quadrangle), 5,200 ft in Bunchgrass Valley, and 6,000–6,500 ft around Caribou Wilderness. Generally mapped only in areas where it obscures bedrock lithology or forms moraines. Typified by moraine complexes with well-preserved morphology and weakly oxidized soil zone ~50 cm thick. Subdivided as late till of Anklin Meadows (Qtal), till of Anklin Meadows (Qta), and till of Raker Peak (Qtr) in the Lost Creek, Hat Creek, and Manzanita Creek drainages (Christiansen and others, 2002) and in Bailey Creek (Viola quadrangle) and Digger Creek drainages. Equivalent in part to deposits of the early, middle, and late Tioga-age glaciations in Lassen area as defined by Kane (1982) and generally correlative with deposits of Tioga glaciations (late Wisconsin) in Sierra Nevada. [BB, CH, CM, LP, MH, MZ, PP, RC, RP, ST, TH, VI, WP]

Qtal **Late till of Anklin Meadows (Holocene to late Pleistocene)**—Diamicton with boulders of locally derived dacite as much as 4 m across. Occurs as small moraines at ~7,600–9,000 ft elev on east and south sides of Lassen Peak. Also found buried beneath pumiceous pyroclastic-flow and fall deposits (rhyodacite of Chaos Crags, pc) in Crescent Crater and at ~7,600 ft elev in small cirque east of Chaos Crags. Equivalent to deposits of late Tioga age in Lassen area as defined by Kane (1982) and Crandell (1972). Unit overlain by debris-flow deposits from the northeast side of Lassen Peak (Qwh, ~8,000 yr B.P.). [LP, MZ, RP, WP]

Qta **Till of Anklin Meadows (late Pleistocene)**—Heterolithologic diamicton with boulders commonly as much as 2 m across, locally to 4 m, and occasionally larger. Occurs as sheetlike deposits and large moraines as low as 5,500–5,600 ft elev in Lost Creek, 6,100–6,200 ft in Hat Creek, 6,100 ft in Manzanita Creek, 5,600 ft in Bailey Creek (Viola quadrangle), and 5,600–5,700 ft in Digger Creek. Generally mapped only in areas where unit obscures the bedrock lithology or forms moraines. Typified by moraine complexes with well-preserved morphology and a weakly oxidized soil zone ~50 cm thick. In Hat, Lost, and Manzanita Creek drainages, Qta is dominated by material derived from Lassen Peak and is distinguished from till of Raker Peak (Qtr) by presence of dacite of Lassen Peak (dl; Christiansen and others, 2002). Equivalent to deposits of middle Tioga glaciation in the Lassen area as defined by Kane (1982). [GP, LP, MZ, RP, WP]

Qtrl **Post-maximum till of Raker Peak consisting of Lassen Peak avalanche debris (late Pleistocene)**—Diamicton, with boulders as large as 1.5 m across, consisting almost entirely of dacite derived from avalanche debris from Lassen Peak spread across glacial ice (Qsl). Forms a small moraine at northeast base of Raker Peak. [WP]

Qtr **Till of Raker Peak (late Pleistocene)**—Heterolithologic diamicton containing boulders commonly as much as 2 m across, locally to 4 m, and occasionally larger. Occurs as sheetlike deposits and large moraines as low as ~5,800 ft elev in Manzanita Creek valley and 5,500 ft in Hat Creek valley. Typified by moraine complexes with well-preserved morphology and weakly oxidized soil zone ~50 cm thick. Generally mapped only where it obscures bedrock lithology or forms moraines. In Manzanita Creek drainage, prominent boulder lithologies include dacite of hill 8283 (d82) and rhyodacite of section 27 (r27). In Hat Creek drainage, Qtr contains abundant andesite of Hat Mountain (ah), dacite of Reading Peak (dr), and rhyodacite of Dersch Meadows (rd). Distinguished from till of Anklin Meadows (Qta) by lack of clasts derived from Lassen Peak (dl; Christiansen and others, 2002). Equivalent to deposits of early Tioga glaciation in Lassen area (Kane, 1982). [GP, MZ, WP]

Qto **Till, older glaciations (late Pleistocene)**—Heterolithologic diamicton with boulders commonly as large as 2 m across, locally to 4 m, and occasionally larger. Occurs as sheetlike deposits and subdued moraines preserved beyond limits of till, younger glaciations (Qty) in the areas around Mineral and North Fork Feather River and valleys of Digger, Bailey (Grays Peak quadrangle), and Warner Creeks. Qto is extensive in area south and east of Caribou Wilderness, 5,500–6,500 ft elev. Younger part equivalent in age to till of Badger Mountain (Qtb) as mapped in Hat, Lost, and Manzanita Creek drainages (Christiansen and others, 2002). Generally mapped only in areas where it obscures bedrock lithologies or forms moraines. Qto is typified by moderately to poorly preserved and eroded moraines and strongly oxidized soil zone >1 m thick. Equivalent to Tahoe and pre-Tahoe glaciations in Lassen area (defined by Kane, 1982) and generally correlative with Tahoe and older glaciations (early Wisconsin and older) in Sierra Nevada. [BB, CH, CM, GP, LP, LY, MH, MN, MZ, PP, RC, RP, ST, VI]

Qtb **Till of Badger Mountain (late Pleistocene)**—Heterolithologic diamicton with boulders commonly as large as 2 m across, locally to 4 m, and occasionally larger. Occurs as sheetlike till deposits and subdued moraines preserved beyond the limits of younger tills (till of Anklin Meadows, Qta, and till of Raker Peak, Qtr) in the Hat, Lost, and Manzanita Creek drainages. Generally mapped only in areas where it obscures bedrock lithology. Occurs at 5,500–6,500 ft elev. Typically has oxidized soil zone >1 m thick. Prominent boulder lithologies include andesite of Raker Peak (arp) and andesites of Badger Mountain (abm); less prominent but relatively common lithologies include tholeiitic basalt of Nobles Trail (bn) and various older dacites, including dacite of Reading Peak (dr). Equivalent to deposits of Tahoe glaciation in Lassen area (defined by Kane, 1982) and ~60 ka in age. [MZ, WP]

Outwash

Qoy **Outwash gravel, younger glaciations (late Pleistocene)**—Moderately sorted, unconsolidated gravel and sand, commonly containing boulders as much as 1–2 m across consisting of same lithologies as the correlative till, younger glaciations (Qty). Occurs as partial valley fills, thick sheets or alluvial fans in drainages of Butte Creek, Warner Creek, Willow Creek, Box Canyon, Bunchgrass Valley, Feather River Meadows, and North Fork Feather River.

Equivalent to outwash gravel of Anklin Meadows (Qoa) and outwash gravel of Raker Peak (Qor) in Hat Creek and to part of outwash gravel, undivided (Qou) in Manzanita Creek and Battle Creek Meadows. Probably includes older outwash in some areas. [BB, CH, CM, LP, MH, MN, MZ, OS, PP, RC, RP, ST, TH, VI, WP]

Qou **Outwash gravel, undivided (late Pleistocene)**—Moderately sorted, unconsolidated gravel and sand, commonly containing boulders as much as 1–2 m across consisting of same lithologies as the correlative till, younger glaciations (Qty) and till, older glaciations (Qto). Occurs as partial valley fills and thick sheets in valleys of South Fork Battle Creek and Manzanita Creek where outwash gravels are not divided. Age is equivalent to Qty and Qto. [GP, LY, MN, PP, SW, VI]

Qoa **Outwash gravel of Anklin Meadows (late Pleistocene)**—Moderately sorted, unconsolidated gravel and sand, commonly containing boulders as much as 1–2 m across consisting of the same lithologies as the correlative till of Anklin Meadows (Qta). Occurs as partial valley fill, thick sheets, or alluvial fans in Hat Creek drainage. Distinguished from outwash gravel of Raker Peak (Qor) by presence of clasts derived from Lassen Peak (dl). Collectively, Qor and Qoa are equivalent to outwash gravel, younger glaciations (Qoy) and form part of outwash gravel, undivided (Qou) in other drainages. [MZ, OS, WP]

Qor **Outwash gravel of Raker Peak (late Pleistocene)**—Moderately sorted, unconsolidated gravel and sand, commonly containing boulders as much as 1–2 m across consisting of the same lithologies as the correlative till of Raker Peak (Qtr). Occurs as partial valley fill, thick sheets, or alluvial fans in Hat Creek drainage. An extensive fan of Qor in Emigrant Ford area may, in part, be related to floods generated by the emplacement of Lassen Peak at 27 ka. In area between Twin Bridges and Big Spring, Qor is covered but not completely obscured by thin pyroclastic-flow and associated fluid debris-flow deposits, May 22 (pw2) from the 1915 eruption of Lassen Peak (Christiansen and others, 2002). Qor is distinguished from outwash gravel of Anklin Meadows (Qoa) by the absence of clasts derived from Lassen Peak (dl). Collectively Qor and Qoa are equivalent to outwash gravel younger glaciations (Qoy) and comprise part of outwash gravel, undivided (Qou) in other drainages. [MZ, OS, WP]

Qoo **Outwash gravel, older glaciations (late Pleistocene)**—Moderately sorted, unconsolidated gravel and sand, commonly containing boulders as large as 1–2 m across consisting of the same lithologies as till, older glaciations (Qto). Occurs in valley of Gurnsey Creek and as partial basin fill south of Wilson Lake. Age is equivalent to the younger part of Qto. [CM, MN]

Sedimentary Deposits

Qd **Diatomite (Holocene)**—Deposits of diatomite occur peripheral to Cinder Cone lava flows for about 2 km west from present shores of Butte Lake, as kipukas in Fantastic Lava Beds flows from Cinder Cone, and on east shore of Butte Lake. Diatomite occurs primarily as disturbed sediment bulldozed by lava flows. Deposited in ancient Butte Lake; pattern of the deposits indicates that a much larger lake existed prior to eruption of Cinder Cone (Clynne and others, 2000). Many additional deposits of diatomite present in Butte Lake area are too small to show at map scale. [PP]

VOLCANIC CENTERS OF SOUTHERNMOST CASCADES

LASSEN VOLCANIC CENTER

Lassen domefield

Twin Lakes sequence, younger

Deposits of 1914–1917 eruption of Lassen Peak (Holocene)—Complex eruptive sequence consisting of a dacite dome and lava flow, dacite pyroclastic flow and fall deposit, and phreatic, avalanche, debris-flow, and flood deposits. Magmatic activity was confined to the period from about May 14 to 22, 1915, and affected primarily the northeast flank and slope of Lassen Peak (now called the Devastated Area) and the valleys of Lost and Hat Creeks as far as about 50 km downstream. Division of deposits of the 1914–1917 eruption is based on stratigraphy and mode of emplacement and generally follows the depiction of Christiansen and others (2002). Rock types range from ol andesite to several varieties of hbl-bt dacite with abundant mafic inclusions and complex mineralogy. The presence of spectacularly banded pumice erupted on May 22 serves to distinguish May 22 from May 19 deposits. See Clynne (1999) for more detailed description and interpretation of these rocks. [LP, MZ, OS, RP, WP]

1917 C.E.

p17 **Phreatic deposit, May–June**—Generally poorly sorted, partly indurated, thin to thick beds of lithic ash, lapilli, and blocks deposited in 1917. Matrix is generally very fine, indurated, and pale-yellowish-brown ash. Consists mainly of material derived from dacite dome of Lassen Peak (dl); thins abruptly from several meters on crater rim (north edge of Lassen Peak summit) to a few centimeters at mapped edge of deposit. Ejected in steam-blast eruptions from crater in the northwestern part of the Lassen Peak summit, mainly during May and June of 1917. [LP]

1915 C.E.

w2 **Viscous debris-flow deposits, May 22**—Largely nonsorted, unconsolidated, nonbedded debris-flow deposits with lapilli and blocks to >1 m and rarely to 2 m in a sandy to silty matrix. Dominated by banded and light-colored pumice of the May 22, 1915, eruption but also contains fragments of d9, d4, and dacite of Lassen Peak (dl). Generally lobate with scarp-like margins as high as 1–2 m; thickness ranges from a few decimeters to ~3 m. Formed by debris flows from steep upper slopes of Lassen Peak after major pumice eruption of May 22, 1915. The two largest debris flows are found in lower Devastated Area and upper Manzanita Creek. [LP, MZ, RP, WP]

p2 **Pumice-fall deposit, May 22**—Generally well sorted, unconsolidated, thick-to-thin beds consisting of blocks, lapilli, and ash of dacitic pumice; blocks prismatically fractured and commonly disintegrated in place. Erupted from Lassen Peak on afternoon of May 22, 1915. Bedding generally indistinct. Pumice blocks weakly banded, typically with yellowish-brown and light-gray to nearly white dacitic layers; lapilli and coarse ash commonly yellowish brown with faint color banding. Mapped only on north and east sides of Lassen Peak, where thickness generally exceeds ~2 m. Not mapped where preserved only in small patches or where thickness is only a few decimeters or less. Narrow lobe of scattered pumice lapilli can be traced from LassenPeak directly over Hat Mountain to vicinity of Cinder Cone. [LP, RP, WP]

pw2 **Pyroclastic-flow and associated fluid debris-flow deposits, May 22**—Consists of pyroclastic-flow and associated debris-flow deposits erupted on the afternoon of May 22, 1915, that grade into each other in middle Devastated Area (mapped separately in Christiansen and others, 2002). Pyroclastic-flow deposit is largely nonsorted, unconsolidated, nonbedded material with lapilli and blocks of d9, d4, and dacite of Lassen Peak (dl) as large as 3 m in a sandy to silty matrix. Blocks of banded pumice with dark-gray andesitic (59.7–61.0% SiO_2) and light-gray to nearly white dacitic (64.2–66.8% SiO_2) layers are conspicuous and diagnostic. Rhyodacite pumice from Chaos Crags eruption (pc) is minor compared to its abundance in sw9. Deposit contains abundant fragments of wood, some charred, including numerous decayed logs lying in positions pointing downslope away from summit of Lassen Peak. Ranges in thickness from feather edge to at least 3 m. Occurs in upper to middle Devastated Area on northeast side of Lassen Peak.

The fluid debris-flow deposits derived from the pyroclastic flow are largely nonsorted, unconsolidated, nonbedded deposits containing lapilli and blocks of d9, d4, and dl as large as 3 m in a sandy to silty matrix. Banded pumice blocks are conspicuous and diagnostic. Individual, apparently rootless, small flows emerge from pyroclastic-flow deposit and merge downslope into generally sheetlike deposit as thick as 2–3 m, with margins tapering to imperceptibility. Exposed in the middle to lower Devastated Area on northeast side of Lassen Peak and in drainages of Lost Creek and Hat Creek to near Old Station. [LP, MZ, OS, RP, WP]

d9 **Dacite flow, May 19–20**—Porphyritic bt-hbl dacite (64–65% SiO_2) erupted from vent at summit of Lassen Peak that was reopened by phreatic explosion on evening of May 19, 1915. Lava filled crater and flowed through notch on west side of summit and ~300 m down west flank. Another similar flow on northeast flank was removed during pyroclastic eruption of May 22. Lava flow was still fluid enough to partially slump back into crater created by pyroclastic eruption two days later on May 22. Lava flow has uneroded, spiny aa surface with 5–10 m of relief. Phenocrysts: 20% pl, from 3–5 mm, but composite crystals to 12 mm are conspicuous; 3% hbl, 1–5 mm, rarely to 12 mm; 3% bt, 1–3 mm; 2% qtz, 1–3 mm, rarely to 6 mm; trace ol, 0.75 mm. Contains abundant microphenocrysts of pl, aug, and hyp to 0.5 mm. About 40% of pl, bt, hbl, and qtz phenocrysts are reacted. Groundmass is dark gray to black and typically glassy. Mafic inclusions from a few cm to ~50 cm form ~5% of rock. They contain reacted host-rock phenocrysts (large pyr-rimmed qtz particularly conspicuous) and ol to 0.75 mm. Most inclusions have fine-grained microvesicular texture of pyr and pl microphenocrysts with interstitial glass, are subangular, and lack crenulate margins. See Clynne (1999) for detailed description and interpretation of 1915 rocks. [LP]

f9 **Flood deposits, May 19–20**—Sorted to nonsorted, unconsolidated, generally nonbedded sand to boulders and other debris in Hat Creek between the bedrock gorge just north of Lassen Volcanic National Park boundary and Twin Bridges that were deposited by dewatering of the May 19–20, 1915, debris flows (sw9). Scoured by numerous braided stream channels, most abandoned. Amount of sediment decreases progressively downstream, but affected area remains complexly scoured and marked by chaotic jams of boulders, logs, and other debris. [WP]

sw9 **Avalanche and debris-flow deposits, May 19–20**—Composite unit mapped as two separate units by Christiansen and others (2002). Avalanche deposit is composed of nonsorted, unconsolidated, nonbedded debris from d4, dacite of Lassen Peak (dl), Chaos Crags pumice (pc), and much wood debris. Generally lies on soil developed in underlying deposits, including pumice from Chaos Crags (pc). Deposited from a mixed snow-and-debris avalanche originating in cirque at top of east face of Lassen Peak late in the evening of May 19 and (or) the early morning of May 20. Deposits occur in Devastated Area on northeast side of Lassen Peak and across low divide northeast of Emigrant Pass in Hat Creek drainage.

Debris-flow deposits from Lassen Peak are composed of nonsorted, unconsolidated, generally nonbedded sand to boulders as much as 3 m diam. They consist almost entirely of fragments of d4, dl, pc, and logs derived from underlying avalanche deposit of May 19–20 or adjacent areas of forest. Deposits occur in Devastated Area on northeast side of Lassen Peak and down Lost Creek drainage to a few kilometers east of Twin Bridges. Deposits commonly are rooted within avalanche deposit of May 19–20. Emplaced during late evening of May 19 and (or) early morning of May 20 immediately following the avalanche. Near margins, numerous standing trees predating deposits are scarred from collisions with boulders and logs carried in debris flows. Piles of boulders and logs behind large trees or boulders are common along margins of deposit. [WP]

p9 **Pyroclastic deposit, May 19**—Nonsorted, unconsolidated, nonbedded deposit of blocks to fine lithic ash, consisting entirely of dense clasts of d4 and dacite of Lassen Peak (dl), emplaced late in evening of May 19, 1915. Ranges from layer ~4 m thick to a field of discontinuous blocks. Ejected by phreatic explosion that opened summit crater through the dacite dome of May 14–19 and preserved only in Lassen Peak summit area. [LP]

d4 **Dacite dome, May 14–19**—Porphyritic bt-hbl dacite (64–65% SiO_2), which forms remnants of a small dacite lava dome at summit of Lassen Peak, emplaced between about May 14 and evening of May 19, 1915. Dome filled crater excavated by phreatic explosions that began on May 30, 1914, and was partially disrupted by single large phreatic explosion on evening of May 19, 1915. Phenocrysts: 20% pl, from 3–5 mm, but composite crystals to 12 mm are conspicuous; 3% hbl, 1–5 mm, rarely to 12 mm; 3% bt, 1–3 mm; 2% qtz, 1–3 mm, rarely to 6 mm; trace ol, 0.75 mm. Contains abundant microphenocrysts of pl, aug, and hyp to 0.5 mm. Pl, bt, hbl, and qtz phenocrysts are commonly reacted and more abundant than in d9. Groundmass is dark gray to black, typically glassy and microvesicular. Mafic inclusions from a few mm to ~50 cm form ~5% of rock and contain reacted host-rock phenocrysts (large pyr-rimmed qtz is particularly conspicuous) and ol to 0.75 mm. Most inclusions have fine-grained microvesicular texture of pyr and pl microphenocrysts and interstitial glass, are subangular, and lack crenulate margins. Millimeter- to centimeter-sized inclusions are more abundant in lava dome than lava flow (d9). [LP]

Basaltic andesites of Cinder Cone (Holocene)—Complex eruptive sequence consisting of two cinder cones (Cinder Cone and remnant cone at same location) and five block-lava flows south of Prospect Peak and west of Butte Lake on Central Plateau. Subdivision is based on eruptive sequence and composition; two compositional groups are present. Old Bench flow (mo) and Painted Dunes flows (mp1, mp2) erupted from remnant cone and comprise an early group of ol basaltic andesite to andesite deposits having the Painted Dunes composition. Painted Dunes flows (especially mp2) contain blocks of welded cinders and agglutinate from several to tens of meters across that were rafted from remnant cinder cone, which was almost completely destroyed by eruption of the flows. Painted Dunes flows blocked drainage into Butte Lake from south and created Snag Lake. Fantastic Lava Beds flows (mf1, mf2) erupted from Cinder Cone and form a late group of ol basaltic andesites having the Fantastic Lava Beds composition. Painted Dunes composition has higher MgO and lower K_2O and TiO_2 at similar SiO_2 content than Fantastic Lava Beds composition. A widespread ash deposit as much as 2.5 m thick is composed of ash of both compositions, Fantastic Lava Beds overlying Painted Dunes with no discernable time break between; thickness is shown on the map as isopachs in centimeters (adapted from Heiken, 1978). Ash thinner than 5 cm extends locally for at least several kilometers beyond the 5 cm isopach. Old Bench flow and Painted Dunes flow 1 have thick cover of colorfully oxidized ash, and Painted Dunes flow 2 has thin cover of ash; both ashes have Fantastic Lava Beds composition. Oxidation of ash demonstrates that Old Bench and Painted Dunes lava flows were still hot when the ash that formed Cinder Cone erupted. Little ash was erupted during or after Fantastic Lava Beds flows were emplaced, and their surfaces are nearly ash free. Painted Dunes and Fantastic Lava Beds flows have rough, block-covered surfaces with considerable relief and many flow levees. Lava flows completely lack soil and are nearly devoid of vegetation; only a few mature but stunted trees grow on Painted Dunes ash deposits.

Painted Dunes composition is sparsely porphyritic ol basaltic andesite and andesite, and Fantastic Lava Beds composition is sparsely porphyritic aug-ol basaltic andesite. Fantastic Lava Beds rocks also contain small pl phenocrysts, but the two types are difficult to discriminate in the field. Groundmasses are dark gray to black and strongly microvesicular and are typically glassy, but aphanitic lava is also common. Inclusions of clear and milky qtz, generally a few mm to 1 cm in size, are common to abundant in both Painted Dunes and Fantastic Lava Beds compositions; rare qtz inclusions to 10 cm have rhombohedral cleavage. Two additional types of inclusions are rare; one type consists of a variety of partially melted mafic to felsic granitic rocks, and the second type consists of mafic inclusions of basaltic andesite (53.3–53.4% SiO_2). Stratigraphic, paleomagnetic, and radiocarbon data indicate that the lava and tephra erupted over a short interval about 1650 C.E. (Clynne and others, 2000; Clynne and others, 2002). Tree-ring dendrochronology indicates that Cinder Cone erupted in 1666 C.E. (Sheppard and others, 2009). Cinder Cone is the youngest mafic volcano in the map area. [PP]

Fantastic Lava Beds

mf2 **Flow 2**—Thin to thick, block-lava flow of sparsely porphyritic aug-ol basaltic andesite (55.1–56.2% SiO_2) erupted from south base of Cinder Cone. Lava flowed in a channel across mf1 and entered Butte Lake. Phenocrysts: 5% ol, 0.25–1 mm, few larger; 2–3% pl, 0.5 mm, few larger, mostly reacted; sparse aug, 0.25–0.5 mm. Groundmass is dark gray to black, glassy, and microvesicular. [PP]

mf1 **Flow 1**—Block-lava flow as thick as 20 m of sparsely porphyritic aug-ol basaltic andesite (56.4–57.3% SiO_2) erupted from south base of Cinder Cone. Lava flowed south over Painted Dunes flows toward Snag Lake then veered north to Butte Lake and crops out in the area between Cinder Cone and Butte Lake. Small outcrop on east shore of Butte Lake demonstrates that mf1 lava underlies much of lake basin. Phenocrysts: 5% ol, 0.25–1 mm, few larger; 2–3% pl, 0.5 mm, few larger, mostly reacted; sparse aug, 0.25–0.5 mm. Groundmass is dark gray to black, glassy, and microvesicular. Xenocrysts of feldspar to 5 mm disaggregated from granitic inclusions are sparse. Cinder Cone is constructed of scoria bombs, lapilli, and ash of Fantastic Lava Beds composition. Cone has a double rim, but there is no discernable difference in lithology or composition between inner and outer rims. Also includes a ring of dense agglutinate bombs as large as 3 m across at base of cone. Light-colored vesicular inclusions of partially melted felsic granitic rocks are rare but conspicuous in scoria. [PP]

Painted Dunes

mp2 **Flow 2**—Thick (to 30–40 m) block-lava flow of sparsely porphyritic ol andesite (57.1–59.7% SiO_2) erupted from remnant cone at base of Cinder Cone. Lava flowed south from base of remnant cone over Painted Dunes flow 1 toward Snag Lake then veered north toward Butte Lake and is mapped primarily south of base of Cinder Cone to shore of Snag Lake. Ash-covered kipukas in area of Fantastic Lava Beds flows near Butte Lake indicate that Painted Dunes flow 2 is more extensive than present outcrop area and was partially buried by Fantastic Lava Beds flows. Ash from Cinder Cone is poorly preserved on surface of this flow, because it has sifted between jumbled blocks on surface. Phenocrysts: 5% ol, 0.25–1 mm, few larger. Groundmass is medium to dark gray, aphanitic, and dense to black, glassy, and microvesicular. Commonly contains sparse feldspar xenocrysts. [PP]

mp1 **Flow 1**—Thick (to 30–40 m) block-lava flow of sparsely porphyritic ol basaltic andesite (54.1–56.1% SiO_2) erupted from remnant cone at south base of Cinder Cone. Lava flowed south toward Snag Lake then veered north toward Butte Lake and is mapped primarily around south base of Cinder Cone. Characterized by a cover of ash as thick as several meters called the Painted Dunes. Ash-covered kipukas in area south of continuous outcrop indicate that flow is more extensive and was partially buried by the younger flows (mp2, mf1, mf2). Phenocrysts: 5% ol, 0.25–1 mm, few larger. Groundmass is medium to dark gray, aphanitic or dense, black, glassy, and microvesicular. Commonly contains sparse feldspar xenocrysts. One large and one small remnant of a cinder cone constructed of scoria bombs, lapilli, and ash are found under south flank of Cinder Cone. Most of cone was destroyed by eruption of the Painted Dunes lava flows, and much of remainder was buried by construction of Cinder Cone. Cone remnants are recognized by their irregular shape and Painted Dunes composition. [PP]

mo **Old Bench flow**—Relatively thin, as thick as 10 m, lava flow of sparsely porphyritic ol basaltic andesite (53.5–54.1% SiO_2) erupted from remnant cone for the Painted Dunes flows. Found at the east base of Cinder Cone and is almost completely covered with a several-meter-thick deposit of weakly oxidized ash from later eruptions of Cinder Cone; only a few pinnacles of lava extend through the ash. Flow was more extensive than mapped and is mostly buried by Painted Dunes and Fantastic Lava Beds flows. Phenocrysts: 5% ol, 0.25–0.5 mm, few larger. Groundmass is black and glassy with abundant flattened to stretched vesicles. Qtz grains are less abundant and smaller than in Painted Dunes and Fantastic Lava Beds flows. [PP]

a74 **Andesite of hill 7416 (late Pleistocene)**—Thick (to 50 m) block-lava flow of porphyritic ol-aug andesite (57.5% SiO_2) erupted from a vent marked by a scoria cone on the upper east flank of West Prospect Peak. Lava flowed northward down crease between Prospect Peak and West Prospect Peak and partially buried trace of Hat Creek Fault on north flank of Prospect Peak. Flow has not been glaciated, is unforested, and is completely lacking in soil; its original block surface is well preserved. Contains a disequilibrium phenocryst assemblage consisting of strongly reacted sodic pl, qtz, hbl, and bt (?) and unreacted ol, aug, and calcic pl. Phenocrysts: 12% pl, 0.5–6 mm, mostly 1–3 mm; 1–2% qtz, 1–3 mm; 1% aug, 0.5–2 mm, aggregates of small crystals; 1% ol, to 2 mm, mostly 0.5–1 mm; trace hbl to 1 cm. Fragments of andesitic inclusions 5 mm to a few centimeters in diameter are abundant; larger inclusions to 10 cm are sparse. Groundmass is dark gray to black, glassy, and dense to vesicular. Unit not dated, but its age is well constrained by stratigraphy. Flow is not offset by Hat Creek Fault, which offsets 15–18 ka glacial deposits farther north (Muffler and others, 1994). Unit erupted into a glacial cirque 18–25 ka but is older than Chaos Crags pumice (1.1 ka). It may be Holocene, but estimated to be about 12–15 ka. [OS, PP, SW]

ah **Andesite of Hat Mountain (late Pleistocene)**—Porphyritic aug andesite (58.0–61.6% SiO_2) forming generally ~100-m-thick lava flows. Vent is marked by breached cone of agglutinated cinder and spatter. Entire edifice has been glaciated; original block surface of lava flows was removed by erosion. Lava is generally massively jointed and typically weathers into rounded boulders 0.5 to several meters in diameter. Flow contains a disequilibrium phenocryst assemblage consisting of reacted group of felsic phenocrysts (pl, qtz, hbl, and bt?) and group of mafic phenocrysts (aug, calcic pl). These groups of phenocrysts are present in variable proportions. Typical flow contains strongly reacted felsic phenocrysts: 4–8% pl, 1–2 mm; sparse–1% aug to 1 mm; sparse–1% qtz, 1–2 mm rimmed by tiny aug crystals and often containing black to brownish specks of glass and bt; sparse–1%, 1–4 mm pseudomorphs of hbl (and bt?). Less-common type of flow found primarily around Twin Lakes is more porphyritic (~15% total phenocrysts) and contains same phenocryst assemblage but with many felsic phenocrysts less strongly reacted. Medium- to dark-gray groundmass is aphanitic (less porphyritic samples) to glassy (more porphyritic samples), and both types are microvesicular. Mafic inclusions are generally small, less than ~10 cm and sparse, although more common locally. They contain same phenocryst assemblage found in host rock, but pl, hbl, and qtz phenocrysts are sparse and strongly reacted or rimmed, whereas small aug phenocrysts are abundant. Chemical composition is variable; typical samples have 58–59% SiO_2, and more porphyritic samples have as much as ~62% SiO_2. Flow overlies rhyolites of Dittmar Volcanic Center, Stage 3 (rd3), basalt of Badger Flat (bbf), and rhyodacite of Dersch Meadows (rd). Attempts to date this unit failed, and its precise age is unknown. Unit overlies and therefore must be younger than basaltic andesite of Fairfield Peak (mfp, 82±14 ka) and andesite of Crater Butte (ac, 93±13 ka). Clasts of ah are not present in till of Badger Mountain (Qtb) suggesting that ah is younger than ~60 ka. Clasts of ah in till of Anklin Meadows (Qta) and till of Raker Peak (Qtr) demonstrate that it is older than ~27 ka and suggest that it is older than ~35 ka. The flow is estimated to be ~40–50 ka. [MH, PP, RP, WP]

ae **Andesite of Eagle Peak (late Pleistocene)**—Macroscopically heterogeneous unit formed by mixing of rhyodacite of Eagle Peak (re) and aug-hyp andesite magmas. Color-banded and compositionally banded to blotchy, microvesicular to pumiceous rock of variable lithology (61–68% SiO_2) is poorly exposed in small area of mostly oxidized and altered rock between Ski Heil Peak and Eagle Peak. The most mafic lithology is porphyritic andesite, containing phenocrysts of pl, hbl, bt, and qtz that are similar in character to those in re, although hbl and bt tend to be slightly oxidized. Also contains a few percent of 0.5–1 mm hyp and aug (hyp>aug) and abundant 0.5-mm calcic pl phenocrysts from andesitic magma. Total phenocryst content is ~10%. Also contains glomeroporphyritic clots of aug+hyp+pl. Groundmass is dark brownish gray, glassy, and microvesicular. Least mafic lithology resembles re but contains sparse phenocrysts from andesite contaminant and has brownish, glassy groundmass. Majority of the unit is intermediate between the two lithologies. Precise age is unknown, but it is probably contemporaneous with the end of the eruption of re at 66±4 ka. [LP]

mfp **Basaltic andesite of Fairfield Peak (late Pleistocene)**—Short stubby lava flow of sparsely porphyritic, ol basaltic andesite (54.4% SiO_2) erupted from vent marked by agglutinate cone of Fairfield Peak. Original block surface of flow has been removed by glaciation. Outliers along base of Prospect Peak demonstrate that till, younger glaciations (Qty) and ash and lava from Cinder Cone bury part of mfp. Cone is composed of scoria, cinders, and blocks of vesicular lava armored by agglutinated surface. Phenocryst assemblage is in strong disequilibrium; pl is reacted and has thick overgrowths of more calcic pl, and qtz is rimmed by aug. Phenocrysts: 3% ol, 0.5–2 mm, mostly 0.5 mm; 2% pl, 0.5–5 mm, mostly 1–3 mm; sparse qtz, 1–3 mm. Trace pseudomorphs of hbl to 1 cm but generally only a few millimeters. Groundmass is usually light to medium gray and aphanitic but is often oxidized. Dominant joint pattern is thick and slabby. Overlies andesite and basaltic andesite of Cluster Lakes (acl) and andesite of Crater Butte (ac), and is overlain by andesite of Hat Mountain (ah). K-Ar age is 82±14 ka. [PP]

ac **Andesite of Crater Butte (late Pleistocene)**—Lava flow as much as 150 m thick of porphyritic aug-ol andesite (60.4–60.5% SiO_2) between Hat Mountain and Fairfield Peak. Erupted from vent marked by agglutinate cone; lobes of lava flowed northeast to Butte Lake and south to Horseshoe Lake. Original block surface of flow has been removed by glaciation, exposing the massively jointed interior. Phenocryst assemblage is in weak to strong disequilibrium; pl is reacted, hbl and bt are pseudomorphed by pl, pyr, and oxide, and qtz is rimmed by aug. Abundance of phenocrysts is variable: a lighter-colored, relatively phenocryst-rich phase has weakly reacted felsic phenocrysts, and a darker-colored, relatively phenocryst-poor phase has more strongly reacted felsic phenocrysts. Phenocrysts: 5–10% pl, 0.5–5 mm, mostly 1–3 mm; 1–2% ol, 0.5–2 mm; sparse–2% qtz, 1–2 mm; 1–2% aug, 0.5–3 mm; sparse pseudomorphs of hbl and bt to 1 cm, but generally a few millimeters. Groundmass is light to dark gray and aphanitic. Small andesitic inclusions to 10 cm are uncommon, but sporadically present, especially in lighter-colored phase. The darker-colored phase is often somewhat oxidized, massively jointed, and breaks into large blocks; lighter-colored phase is fresher, often platy jointed, and breaks into blocks with rough, uneven surfaces. Variety of lithologically distinct, fresh and oxidized, vesicular and dense blocks of lava and scoria form the agglutinate cone. Both phases of the lava flow, as well as composite blocks, are present. Lower part of north rim of cone is composed of a variant of the lighter phase that is porphyritic hbl-bt dacite (65% SiO_2); it is glassy and contains 20% phenocrysts, andesitic inclusions to 30 cm, and abundant small fragments of andesitic inclusions. Cone is capped by sparsely porphyritic, more mafic lava (56.7% SiO_2) with aphanitic groundmass and small aug, reacted ol, hbl, and pl, and pyr-rimmed qtz phenocrysts. Composition is similar to the andesitic inclusions and probably represents hybridized inclusion-forming magma. Overlies rhyolites of Dittmar Volcanic Center, Stage 3 (rd3), andesite of section 22 (a22), and basaltic andesites and basalt of Snag Lake (msn), and underlies basaltic andesite of Fairfield Peak (mfp). K-Ar age is 93±13 ka. [MH, PP]

Twin Lakes sequence, older

acl **Andesite and basaltic andesite of Cluster Lakes (middle Pleistocene)**—Two lava flows of porphyritic ol andesite and ol-aug andesite (56.6–57.9% SiO_2) erupted from vent marked by agglutinate cone. Original block surfaces have been removed by glaciation. Two mapped lava flows, one near vent and another in Box Canyon, are slightly different. Phenocryst assemblage is in strong disequilibrium; pl is resorbed and thickly rimmed, and qtz is rimmed by aug. Phenocrysts (flow near vent, 56.6% SiO_2): 8% pl, 0.5–6 mm, mostly 1–3 mm; 4–5% ol, 0.5–2 mm, mostly 0.5–1 mm; 1% qtz, 1–3 mm. Phenocrysts (flow in Box Canyon, 57.9% SiO_2): 6% pl, 0.5–5 mm, mostly 0.5–2 mm; 1% ol, 0.5–2 mm; 1–2% aug, 0.5 mm; sparse qtz, 1–2 mm. Pseudomorphs of hbl to 1 cm, but generally a few millimeters, are trace component of both flows. Groundmass of both flows is light gray and aphanitic; dominant joint pattern is slabby. Overlies basalt of Badger Flat (bbf) and andesites of West Prospect Peak (awp) and underlies basaltic andesite of Fairfield Peak (mfp). Age unknown, but underlies and must be older than andesite and basaltic andesite of Prospect Peak (ap, 247±56 ka) and is estimated to be 250–300 ka. [PP, WP]

arp **Andesite of Raker Peak (middle Pleistocene)**—Thick hyp-ol-aug andesite (57.4–58.7% SiO_2) lava flows forming a lava cone with agglutinated scoria cone at vent. Nearly entire unit, except northern distal portions of lava flows and summit area, has been glaciated. Unit has a disequilibrium phenocryst assemblage and is lithologically heterogeneous. Most common rock type consists of thick lava flows (50–100 m) of porphyritic hyp-ol-aug andesite. Phenocrysts: 10–15% pl, 1–6 mm, usually reacted; 4–6% aug, 0.5–3 mm; 2–4% ol, 1–5 mm; 1–2% hyp, 0.5–1 mm; 1% hbl 0.5–3 mm; sparse qtz to 2 mm generally with pyr rim. Aug and hyp also occur with pl in 5-mm and smaller glomeroporphyritic clots. Hbl phenocrysts are replaced by dark-colored aggregates of pl, pyr, and Fe-Ti oxide; pl is strongly reacted. Groundmass is light gray and microvesicular when aphanitic and dark gray to black when glassy. Typical exposures of flow surfaces are rounded boulders or angular joint-bounded blocks, whereas flow interiors are dense with massive to platy jointing. A few earlier flows at base of volcano are much less porphyritic than stratigraphically higher flows and contain same phenocryst assemblage as later flows but only 2–3% total phenocrysts. Groundmass is medium gray, dense, and aphanitic. Mafic inclusions are absent in both flow types, but xenoliths of volcanic and metamorphic crustal rocks are found in several places. Unit is much younger than underlying rhyolite of Raker Peak (rr). A sample of earlier flows yielded a K-Ar age of 270±18 ka. [MZ, WP]

av **Andesite of Viola (middle Pleistocene)**—Thick block-lava flow of sparsely porphyritic aug-ol andesite (57.3–59.0% SiO_2). Vent is marked by eroded agglutinate cone at hill 6924 ~1.5 km southeast of Deep Hole. Lava flowed northwest ~7 km from vent. Original, poorly preserved flow surface is marked by subrounded vesicular boulders. Flow cores, where exposed, are slabby to platy jointed. Good exposures are present along Calif. Hwy 44 in Manzanita Creek. Lava flow has been glaciated in vent area and along its south margin. It has a variable composition and distinctly disequilibrium phenocryst assemblage consisting of ol, aug, hbl, pl, and qtz. Phenocrysts: 4–8% pl, generally 2–5 mm, many strongly reacted; trace–2% aug, 0.25–1 mm; 1% hbl (+bt?), 3–5 mm, completely pseudomorphed by fine-grained aggregate of pl, pyr, and Fe-Ti oxide; trace ol, 0.1–0.35 mm, usually corroded and partially converted to iddingsite; trace qtz to a few millimeters usually has pyr rims. Proximal portions of flow contain higher abundances of phenocrysts, whereas distal portions have lower abundances.

Groundmass is light to medium gray and aphanitic. Flow is covered with thick orange soil. Overlies andesites of Diller sequence, undivided (ad), andesite of Digger Creek (adc), andesite of Manzanita Creek (amz), and rhyodacite of Manzanita Chute (rmz), and underlies basaltic andesite and andesite of Red Lake Mountain (mrd) and lithic tephra from Deep Hole (pdh). K-Ar age is 313±8 ka. [LP, MZ, VI]

Eagle Peak sequence

Rhyodacite of Chaos Crags (Holocene)—Chaos Crags is composed of porphyritic hbl-bt dacite and rhyodacite (67–70% SiO_2) erupted as two tuff cones, three pumiceous pyroclastic-flow deposits, a fall deposit, six lava domes, and two lithic pyroclastic-flow deposits. Lava domes (rca, rcb, rcc, rcd, rce, rcf) and lithic pyroclastic-flow deposits (pcd, pce) are mapped individually, whereas the other pyroclastic deposits are mapped as a single unit (pc). Talus emplaced hot from growing domes is also mapped (cc). The eruption initiating the sequence was explosive and emplaced a thin fall deposit (mostly buried by later deposits), two pyroclastic-flow deposits, and a 40-m-high tuff cone at the south end of Chaos Crags. Effusive eruption of lava filled the tuff cone and built a small lava dome A (rca). Renewed explosive activity blasted away most of dome A, emplaced a third pyroclastic flow deposit, and built a second tuff cone 20 m high adjacent to the first cone. Pumice from the eruptive cloud formed a widespread fall deposit. Effusive activity constructed five additional domes (rcb, rcc, rcd, rce, rcf), emplaced sequentially B through F, two of which had hot collapses that resulted in emplacement of lithic pyroclastic-flow deposits (pcd, pce).

Rhyodacite of Chaos Crags has a slightly variable lithology. Phenocrysts: 25% pl, 2–5 mm (composite crystals as much as 1 cm); 4% bt, 1–3 mm (rarely larger); 4% hbl, 2–5 mm, occasionally as much as 1.5 cm; 2% qtz, 2–5 mm. Qtz is conspicuous and more abundant than in all Lassen Volcanic Center units except dacite of Lassen Peak (dl). Rhyodacite ranges from white or light gray and glassy to light to medium gray and devitrified. Abundance of reacted phenocrysts, millimeter- to centimeter-sized fragments of mafic inclusions, and larger mafic inclusions increases systematically from the early pumiceous pyroclastic-flow and fall deposits through domes A–F. Pyr-rimmed qtz phenocrysts are particularly conspicuous in younger domes. Ol and calcic pl xenocrysts from disaggregation of quenched inclusions are sparse. Mafic inclusions are texturally variable; both porphyritic and sparsely phyric varieties are present. Sparsely phyric inclusions generally contain 1–2 mm ol and calcic pl phenocrysts from mafic parent. Inclusions with hbl+pl groundmasses are most common, but inclusions with aug+hyp+hbl+pl groundmasses are also present. Mafic inclusions sparse in the lower and middle pyroclastic flows of unit pc; slightly more abundant in the upper pyroclastic flow and domes A (rca) and B (rcb); abundant in domes C (rcc), D (rcd), E (rce), and F (rcf), forming as much as 20% of the rock. Inclusions generally small, rarely >10–20 cm in the pyroclastic flows (pc) and domes A and B; often as large as 20–50 cm and occasionally as much as 1 m in domes C, D, E, and F. Pumice in pyroclastic flows of unit pc and domes A and B contains 69.5 to 70% SiO_2. Domes C through F are more variable and slightly less felsic (67–69% SiO_2). Domes A and B have weakly pumiceous outer carapaces; domes C, D, E, and F are composed of denser rock. Chaos Crags domes have the same paleomagnetic direction as pyroclastic deposits (pc, pcd, pce) and, thus, are essentially the same age, 1,103±13 yr B.P. (Clynne and others, 2002). [MZ, OS, VI, WP]

cc **Talus, emplaced hot from domes B–F**—Laterally sorted deposits of nonbedded blocks from Chaos Crags domes B–F, (rcb, rcc, rcd, rce, and rcf). Largest blocks, ~4 m across (rarely as large as 10 m), are prismatically jointed and commonly disintegrated in place after deposition. Formed by hot rockfalls from domes during emplacement. Locally includes some talus formed by normal mass-wasting processes. [MZ]

rcf **Dome F—**Lava dome of porphyritic hbl-bt rhyodacite (67–68% SiO_2). Dome F erupted into the scar created by partial collapse of dome E (rce) and covered its vent. [MZ]

pce **Lithic pyroclastic-flow deposit from partial collapse of dome E**—Nonsorted, unconsolidated, nonbedded deposit of fine rubble to blocks commonly as large as ~2 m across, a few as large as 10 m. Deposit on east side of Chaos Crags consists entirely of fragments from dome E (rce). Deposit was emplaced hot; many large blocks are prismatically jointed or internally fractured. Formed by partial collapse of rce before emplacement of dome F (rcf) in resulting avalanche scar. Radiocarbon ages are 230±40 and 730±40 yr B.P. (Clynne and others, 2002), but paleomagnetic direction is similar to other Chaos Crags deposits, and pce is probably the same age (see discussion of pumiceous pyroclastic-flow and fall deposits, unit pc). [MZ, WP]

rce **Dome E**—Lava dome of porphyritic hbl-bt rhyodacite (67–68% SiO_2). Dome E erupted from a vent that it now covers. Partial collapse of dome E produced a hot lithic pyroclastic flow (pce). [MZ]

pcd **Lithic pyroclastic-flow deposit from partial collapse of dome D**—Nonsorted, unconsolidated, nonbedded deposit of fine rubble to blocks as large as about 2 m, a few to 10 m. Deposit on west side of Chaos Crags consists of material derived from dome B (rcb) and dome D (rcd). Deposit was emplaced hot; many large blocks are prismatically jointed. Formed by partial collapse of dome D (rcd). Resultant avalanche swept across surface and incorporated pumiceous blocks from underlying dome B (rcb). Blocks derived from rcb were either still hot from emplacement of the dome or were reheated to above the Curie Point in the hot deposit. Radiocarbon date of 430±30 yr B.P. was obtained from deposit (Clynne and others, 2002), but paleomagnetic direction is similar to other Chaos Crags deposits, and pcd is probably same age (see unit pc). [MZ]

rcd **Dome D**—Lava dome of porphyritic hbl-bt rhyodacite (69% SiO_2). Dome D of the Chaos Crags erupted from a vent now covered by the dome and has the highest elevation of the six lava domes. Partial collapse of dome D produced a hot lithic pyroclastic flow (pcd). [MZ]

rcc **Dome C**—Lava dome of porphyritic hbl-bt dacite (68% SiO_2). Dome C of the Chaos Crags erupted from a vent now covered by the dome. A septum of Brokeoff Volcano andesites (andesites of Diller sequence, undivided, ad) several tens of meters wide is present along southwest boundary with dome B lava; Brokeoff Volcano rocks at summit of dome C indicate dome grew as a solid plug. Small area of partially welded hot talus just east of saddle between domes D and E is inferred to be related to dome C (Christiansen and others, 2002). Nearly vertical, northwest-facing cliff of dome C breakaway scar of Chaos Jumbles avalanche deposits (Qsj) exposes strongly oxidized pink dacite of the dome interior. [MZ]

rcb **Dome B**—Lava dome of porphyritic hbl-bt rhyodacite (69.5–70% SiO_2). Dome B erupted from and partially filled and buried the tuff cone of upper pyroclastic flow of unit pc. This relatively flat-topped dome flowed sluggishly north. In contrast to other domes, lava of dome B often shows crude or vague flow layering and, locally, thin sheets of smeared mafic inclusions. [MZ]

pc **Pumiceous pyroclastic-flow and fall deposits**—Deposits of three pumiceous pyroclastic flows, a coignimbrite fall deposit, and two tuff cones are combined on the map. Fall deposits at the surface are generally well-sorted unconsolidated beds of nearly white rhyodacite pumice ranging in size from blocks as large as ~1 m across near the source vent to lapilli and ash farther away. The deposit mantles the ground surface and is locally reworked as colluvium. Thickness ranges from <1 m distally, through several meters near Chaos Crags, to as much as 35 m in the vent cones at south margin of Chaos Crags dome cluster. Mostly postdates emplacement of dome A (rca) but predates dome B (rcb). Fall deposits underlie and are intercalated with nonsorted, unconsolidated, pumiceous pyroclastic flows. Three distinct pyroclastic-flow units are recognized: lower and middle flow units are similar and have fine-celled pumice blocks as much as ~30 cm across in a pumiceous ash matrix, each generally gray to pale yellow in color but with a pink top ~1–2 m thick. A pink, laminated, fine-ash cloud deposit ~5–20 cm thick locally overlies the middle flow unit. Lower and middle pyroclastic flows cooled as a single unit and predate rca; charcoal samples yielded weighted average radiocarbon age (n=7) of 1,118±17 yr B.P. (Clynne and others, 2002). Upper pyroclastic-flow unit is characterized by coarse-celled pumice in breadcrust blocks as large as 2 m across (rarely to 4 m); glassy ash matrix is white to gray. This flow unit postdates emplacement of rca but predates rcb; incorporated charcoal samples yielded a weighted average (n=6) radiocarbon age of 1,083±19 yr B.P. (Clynne and others, 2002). Eruption of upper pyroclastic flow partially destroyed dome A, and blocks of that dome are common in proximal exposures of the pyroclastic flow. Two radiocarbon ages discussed above are not statistically distinguishable; although there may be a short hiatus between eruption of dome A and upper pyroclastic flow, a weighted average of all ages, 1,103±13 yr B.P., is used for the Chaos Crags eruption.

Unit pc occurs widely in area around Chaos Crags. Exposures of lower and middle pyroclastic flows are confined to vicinity of Lost and Manzanita Creeks within a few kilometers of Chaos Crags. Upper pyroclastic flow traveled down Lost Creek nearly to Twin Bridges, a distance of ~20 km. In Manzanita Creek, upper pyroclastic flow transformed into a lahar by incorporation of water and flowed nearly to McCumber Reservoir; the transition from pyroclastic flow to lahar is gradual, and a boundary was not mapped, but occurs in area of Deer Flat. Scattered pumice lapilli, mostly coignimbrite debris associated with eruption column that produced upper pyroclastic flow, can be found scattered over most of Lassen Volcanic National Park and east to Bogard Buttes area, but unit pc is mapped only where it masks underlying units. Lithology and composition of pc is identical to rca and rcb. [MZ, OS, VI, WP]

rca **Dome A**—Lava dome of porphyritic hbl-bt rhyodacite (69.5–70% SiO_2). Dome A erupted into and partially filled tuff cone from which the lower and middle pyroclastic flows (pumiceous pyroclastic-flow and fall deposits, unit pc) erupted. Dome A was mostly destroyed by the eruption of upper pyroclastic flow (pc), and only a remnant of the original dome is preserved. Fragments of dome A are abundant in the upper pyroclastic flow within ~1–2 km of vent. [MZ]

Dacite of Lassen Peak (late Pleistocene)—Dome and pyroclastic flow of porphyritic hbl-bt dacite and rhyodacite (63.5–70.2% SiO_2). Phenocrysts: 20% pl, 1–5 mm with some composite crystals to 1 cm; 4% qtz (more abundant than in other dacites in map area), typically 1–2 mm, rarely to 5 mm; 3% bt, 1–2 mm; 2% hbl, 1–5 mm, rarely to 15 mm; sparse aug, typically 0.25–1 mm, composite crystals to 3 mm; trace ol, generally 1 mm. Ol is more prominent in the most silicic rock from the northeast ridge and is often obscure or absent elsewhere. Combination of abundant qtz and aug phenocrysts is diagnostic of dacite of Lassen Peak. Partially reacted phenocrysts of pl, hbl, bt, and qtz are common. Microphenocrysts of pl, aug, hyp, and hbl (disaggregated from inclusions) and tiny microlites are abundant in light- to medium-gray, glassy to aphanitic groundmass. Fragments of mafic inclusions from a few millimeters to a few centimeters are abundant. Mafic inclusions are particularly large and abundant, as large as 1.5 m; inclusions in 20–50 cm range are more abundant than in any other dacite in the map area except dacite of Mount Helen (dh). Mafic inclusions have a wide range of textures from fine grained and porphyritic to coarse grained and aphyric; multiple-generation inclusions are sparse. Porphyritic mafic inclusions contain resorbed phenocrysts from host dacite; some also contain aug and ol phenocrysts to a few millimeters. Fine-grained inclusions typically have hbl-pl groundmass but may have pyr-hbl-pl groundmass. Most aphyric inclusions contain remnants of aug and ol phenocrysts in hbl-pl groundmass. $^{40}Ar/^{39}Ar$ age of pfl is 28.3±2.7 ka; paleomagnetic correlation suggests 27±1 ka (Turrin and others, 1998). [LP, MZ, RP, WP]

pfl **Lithic pyroclastic-flow deposit from partial collapse of dome**—Poorly sorted, unconsolidated, nonbedded volcanic ash to blocks as large as 3 m across, consisting of dense, porphyritic, gray, hbl-bt dacite (68.0% SiO_2) lithologically identical to the dacite dome of Lassen Peak (dl); blocks commonly prismatically jointed. Matrix-supported, block-rich deposit with matrix of comminuted dacite. Forms sheet at northeast base of Lassen Peak, incised by upper Lost Creek. Also exposed in the north-facing toe of Survivors Hill and present in subsurface at Emigrant Pass (north of the Devastated Area parking lot). Thickness ranges from feather edge to as much as 50 m. Formed by hot, dome-collapse, pyroclastic flows during emplacement of Lassen Peak dacite dome. [WP]

dl **Dome**—Large (2 km^3) volcanic dome of porphyritic hbl-bt dacite that covers its vent. Where exposed, the dome interior is platy to massively jointed. Single magnetic direction (Turrin and others, 1998) and lack of internal contacts suggest a single emplacement unit. Outer part of dome is commonly oxidized to grayish-pink. Parts of dome are covered by breccia carapace; few areas of primary hot talus are preserved, recognized by presence of prismatically jointed blocks of dacite as much as 5 m across. Large spines are prominent on south flank of dome, and a prominent cirque formed on northeast side during glaciation of Lassen Peak (Christiansen and others, 2002). Dome composition ranges considerably from ~70% SiO_2 in northeast-projecting ridge to ~63.5% SiO_2 in spine low on northwest side above upper Manzanita Creek, but bulk of dome is 66–68% SiO_2. Despite chemical heterogeneity, petrography of dome is nearly uniform. Chemical range is attributed to varying amount of disaggregated andesitic inclusions not readily apparent in hand specimen. [LP, MZ, RP]

Rhyodacite of Kings Creek (late Pleistocene)—A sequence of at least four pumiceous pyroclastic flows, tuff cone, and thick lava flows of porphyritic hbl-bt rhyodacite (69.1–70.3% SiO_2) erupted from vent now partially buried by Lassen Peak. Phenocrysts: 15% pl, 1–5 mm (largest are composite grains); 2% bt, 1–2 mm; 1% hbl, 1–15 mm; sparse qtz, 1–2 mm; sparse hyp, 0.5 mm. The sparse 1–1.5 cm hbl phenocrysts are distinctive of this rock unit. Resorbed equivalents of dacitic phenocrysts, broken fragments of inclusions, and crystals derived from disaggregation of mafic inclusions are sparse. Mafic inclusions are rare and typically smaller than ~10 cm, although a few are as large as 20 cm. Inclusions have coarse-grained hbl-pl groundmass and contain reacted phenocrysts derived from host magma and small ol phenocrysts derived from mafic parent. Age of pk is 35±1 ka (paleomagnetically calibrated radiocarbon age, Clynne and others, 2002; Turrin and others, 1998) and coeval with the lava flows (rk). [LP, RP, WP]

rk **Flows**—Thick lava flows of porphyritic hbl-bt rhyodacite (69.1–70.3% SiO_2). Small, poorly preserved tuff cone (pk) at east end of Lassen Peak parking lot marks vent. Lava flowed eastward toward Reading Peak, where a ridge divided it into two lobes. One lobe flowed southeast down Kings Creek drainage for 2 km to Kings Creek Meadows, and the second lobe flowed northeast down headwaters of Hat Creek for ~3 km. Lobe in Kings Creek is approximately 75 m thick with steep lateral margins; lobe in Hat Creek is somewhat thinner. Although glaciated, flow morphology is well preserved. Basal and lateral margins are glassy, typically perlitic, and locally brecciated; top of flow is variably pumiceous. Flow banding, spherulitic zones, and lithophysal zones are common. Devitrified interior of flow is rarely exposed. Lava flow overlies the pyroclastic flow deposits (pk) and is in turn overlain by dacite of Lassen Peak (dl). [LP, RP]

pk **Pumiceous pyroclastic-flow deposits**—Poorly sorted, unconsolidated volcanic ash, with pumice blocks to ~1 m across. Pumice is light gray to white, glassy, coarsely pumiceous, and weathers to pale yellow. Pumice consists of porphyritic bt-hbl rhyodacite (69.1-70.6% SiO_2) lithologically identical to rk. Tuff cone just east of Lassen Peak parking lot marks the vent. Pumiceous pyroclastic flows inundated the Kings Creek and West Fork Hat Creek valleys. Flows immediately preceded the emplacement of lava flows (rk). Four separate pyroclastic flows or flow units emplaced in rapid succession are exposed in banks of Hat Creek just southeast of Emigrant Pass; total thickness ~10 m. Similar deposits are exposed in West Fork Hat Creek and Kings Creek Meadows and may have been emplaced by separate flows. Original extent of pk was markedly reduced by glacial erosion. Age of pk is 35±1 ka. [LP, RP, WP]

Rhyodacite of Sunflower Flat (late Pleistocene)—Pumiceous pyroclastic-flow deposits and domes of porphyritic bt-hbl rhyodacite (68.3–70.0% SiO_2) north of Chaos Crags. Phenocrysts: 12% pl, 1–5 mm, a few to 8–10 cm are composite crystals; 2% hbl, 1–12 mm (large phenocrysts sparse but conspicuous); sparse bt, 1–2 mm; sparse qtz, 1–2 mm. Microphenocrysts of hyp and aug (hyp>aug) are abundant but generally <0.5 mm, although a few as large as ~1 mm are present. Reacted pl phenocrysts and pl phenocrysts with vermicular glass inclusions are abundant and distinctive. Groundmass is dark gray to black when dense and glassy to light gray or pink when microvesicular or partially devitrified. Broken fragments of mafic inclusions from a few millimeters to a few centimeters in size are common, but larger inclusions (10 cm max) are rare. Age is 41±1 ka (calibrated radiocarbon age from psf, Turrin and others, 1998). [MZ, WP]

rsf **Domes**—Overlapping complex of eight domes of porphyritic bt-hbl rhyodacite (68.3–70.0% SiO_2) that erupted in a linear trend north of Chaos Crags. Domes overlie the associated pyroclastic-flow deposits mapped as psf. On north flank, overlain by lateral moraines of till of Anklin Meadows (Qta) but not glaciated; domes are heavily forested and retain talus-covered, primary morphology. Interiors of domes are not exposed. [MZ, WP]

psf **Pumiceous pyroclastic-flow deposits**—Poorly to moderately sorted, unconsolidated, volcanic ash with pumice blocks as large as ~50 cm. Occurs as pyroclastic flows from Sunflower Flat to Lost Creek and as proximal fall deposits (not mapped separately) forming a pumice crater southeast of Sunflower Flat. Pumice is porphyritic, bt-hbl rhyodacite (69.0–69.3% SiO_2) lithologically identical to rsf. Pumice blocks with coarse cell structure; lithic blocks of dense dome or conduit rock sparse. Fresh pumice is white, and matrix weathers to pale yellow; blocks often oxidized to pink and yellow. Calibrated radiocarbon age is 41±1 ka (Turrin and others, 1998). [MZ] rkr **Rhyodacite of Krummholz (late Pleistocene)**—Thick flow of porphyritic bt-hbl rhyodacite (68.3–69.3% SiO_2); small dome marks the vent. Dome and flow are glaciated and mostly obscured by thick blanket of pumice from Chaos Crags eruption (pc). Outer parts of flow are characteristically dense and glassy, although devitrified rock is present where flow surface was removed by glaciation. Dome rock is massively jointed and weathers into large rectangular blocks. Lava flow locally displays vague flow banding and abundant thin platy jointing. Phenocrysts: 10% pl, mostly 2–3 mm (composite crystals as large as 1 cm common); 1% hbl, generally 1–2 mm (sparse hbl to ~1 cm); sparse bt, 1–2 mm; sparse qtz, to 2 mm; sparse hyp, to 0.5 mm. Reacted pl phenocrysts and pl phenocrysts with vermicular glass inclusions are abundant. Groundmass is light to dark gray and glassy, although perlitic and spherulitic varieties occur. Distal and deeply eroded parts of flow have an aphanitic groundmass. Mafic inclusions are sparse and small, generally <10 cm in size. Inclusions contain reacted felsic phenocrysts derived from host, sparse small ol phenocrysts, and sparse aug phenocrysts. Groundmasses of mafic inclusions contain acicular microphenocrysts of pyr, hbl, and pl, with glass. $^{40}Ar/^{39}Ar$ age of 43±2 ka is consistent with its unusual transitional remanent magnetic direction (Laschamp Geomagnetic Excursion, D.E. Champion, written commun., 1998). [MZ, WP]

r27 **Rhyodacite of section 27 (late Pleistocene)**—Thick lava flows of porphyritic bt-hbl rhyodacite (69.7–69.8% SiO_2) on the north flank of Lassen Peak. Vent was probably in area now occupied by Lassen Peak. Flows are slightly to moderately glaciated, and original flow morphology and pumiceous carapace are preserved locally. Flows are spherulitic, flow banded, and brecciated at the base. Several flow lobes fill canyons on tributaries of upper Manzanita Creek south of hill 8283. Phenocrysts: 12% pl, 1–3 mm (composite crystals to 6 mm common); 3% hbl, 1–3 mm (rarely larger); 1% hyp, to 1 mm; sparse bt, generally 1–2 mm; trace qtz, 0.5–2 mm. Aug xenocrysts are rare. Rock is dark gray to black with perlitic groundmass where dense and white to colorless where vesicular or pumiceous. Broken fragments of mafic inclusions a few millimeters to ~1 cm in size are common. Mafic inclusions are generally small and sparse, ranging to 10–12 cm in size, typically containing aug and calcic pl phenocrysts in addition to phenocrysts derived from host rhyodacite. Age is not closely constrained. Unit overlies but is much younger than dacite of Crescent Crater (dc, 236±1 ka) and dacite of hill 8283 (d82, 261±5 ka); r27 is overlain by and slightly older than rhyodacite of Krummholz (rkr, 43±2 ka). Age estimated to be ~50-60 ka. [MZ, WP]

Rhyodacite of Eagle Peak (late Pleistocene)—Pumiceous pyroclastic-flow deposits and thick lava flow and summit dome of porphyritic hbl-bt rhyodacite (71.0–71.6% SiO_2). Phenocrysts: 12% pl, 1–3 mm (few to 6 mm); 1–2% bt, 0.5–2 mm; 1–2% hbl, generally 1–4 mm (rarely to 8 mm); 1% qtz, to 4 mm. Reacted pl, hbl, and bt phenocrysts are sparse. Groundmass is light gray to white and typically glassy or perlitic with sparse to abundant spherulites. Mafic inclusions are abundant and have a wide variety of textures, although majority are fine to coarse grained and nearly aphyric. Most are 10–15 cm in size, but range to ~50 cm. Finer-grained inclusions often contain small 0.5–1 mm phenocrysts of calcic pl and phenocrysts or remnants of resorbed phenocrysts of ol and aug, as well as reacted host rhyodacite phenocrysts. The inclusions generally have hbl+pl groundmasses, although inclusions with aug+hyp+hbl+pl groundmasses are also present. The unit overlies but is much younger than dacite of Ski Heil Peak (ds, 244±10 ka) and dacite of Vulcans Castle (dv). $^{40}Ar/^{39}Ar$ age of 66±4 ka indicates that re is probably the oldest unit in Eagle Peak sequence. [GP, LP, MZ]

re **Dome and flow**—Thick lava flow with summit dome of porphyritic hbl-bt rhyodacite (71.0–71.6% SiO_2) that overlies its vent. Lava flow exposed at Crescent Cliff is ~100 m thick with steep lateral margins. Although glaciated, flow morphology is well preserved. Basal and lateral margins are glassy and locally brecciated; top of the flow is weakly pumiceous. Flow banding, spherulitic zones, and lithophysal zones are common. The devitrified interior of dome and flow not exposed. $^{40}Ar/^{39}Ar$ age is 66±4 ka. [LP]

pe **Pumiceous pyroclastic-flow deposits**—White, poorly sorted, matrix-supported, unconsolidated ash, lapilli, and pumice blocks. Erupted from a vent now covered by dome and lava flow (re) and preserved only beyond limits of late Pleistocene glaciation. Most extensive area of outcrop is west of Manzanita Lake, where deposit occurs as a single ~2-m-thick bed. A several-meter-thick, similar deposit, including dense fragments of re, occurs on summit of Ski Heil Peak. Several small areas of pumiceous pyroclastic-flow deposit correlated with pe are found in Digger Creek drainage in the area east of Camp Forward. Pumice blocks as large as several meters in size are sparse but widespread. Contains loose mafic inclusions as lithic fragments. Pumice is porphyritic bt-hbl rhyodacite (70.9% SiO_2) similar to re. The pyroclastic flows immediately preceded eruption of and are same age as the associated dome and flow (re). [GP, LP, MZ]

Bumpass sequence

rd **Rhyodacite of Dersch Meadows (middle Pleistocene)**—Thick lava flow of porphyritic bt-hyp-hbl rhyodacite (69.4% SiO_2). Vent location is unknown but probably east of Paradise Meadows; lava flowed north to Dersch Meadows. Five discrete outcrop areas are separated by extensive till cover. Phenocrysts: 15% pl, 1–3 mm, few to 7 mm; 2% hbl, 1–5 mm, rarely to 8 mm; 1% hyp, 0.25–1 mm; sparse bt, to 1 mm; trace qtz, 1 mm. Reacted phenocrysts and fragments of mafic inclusions are uncommon. Mafic inclusions are sparse, rarely exceed 5 cm, and contain sparse, bright-green aug phenocrysts. Pumiceous upper surface of flow has been removed by glacial erosion, and massively jointed core of flow is exposed. Interior of lava flow is light gray, locally pink when oxidized, strongly flow banded, and usually devitrified. Base of flow is well exposed just east of Hat Lake and is dark gray to black, dense and glassy, often perlitic and spherulitic, and brecciated. Overlies andesites of Diller sequence, undivided (ad) in Hat Creek. $^{40}Ar/^{39}Ar$ age of 193±11 ka indicates that rd was the last unit of Bumpass sequence to be emplaced. [RP, WP]

dr **Dacite of Reading Peak (middle Pleistocene)**—Complex of porphyritic bt-hbl dacite (64.9–68.9% SiO_2) lava domes that have been extensively glaciated; massive-jointed, devitrified, and locally oxidized interiors are exposed. Includes protalus ramparts and small moraines on north-facing upper slopes of domes. Includes small area of dacite on east flank of Lassen Peak that is of generally similar lithology. Several dacite domes are present in the complex, but contacts between them could not be located. When emplaced, dome complex rivaled Lassen Peak in volume. Lithology and composition of dacite is slightly variable. Phenocrysts: 10–12% pl, 1–5 mm, few composite crystals to 1 cm; 2% hbl, mostly 1–3 mm, few to 5 mm; sparse–1% bt, to 1 mm; rare–sparse qtz, to 2 mm; rare aug, to 1 mm in small clusters. Hyp and aug microphenocrysts are common but rarely exceed 0.5 mm in size and are sometimes found as small glomeroporphyritic clots. Most pl phenocrysts are weakly to strongly reacted, and almost all hbl and bt has been pseudomorphed by aggregates of Fe-Ti oxide, pl, and pyr. Fragments of mafic inclusions are abundant. Groundmass is light to medium gray, dense and aphanitic. Mafic inclusions are abundant and display a wide variety of textures from porphyritic to coarse-grained aphyric; size and character vary. Most inclusions are <20 cm, but inclusions to 50–60 cm are common. Sparse phenocrysts of calcic pl, aug, and ol, as well as reacted host dacite phenocrysts, are present in some inclusions. Mafic inclusions have hbl-pyr-pl groundmasses. A sample from the National Park Service quarry at east end of the easternmost dome yielded a K-Ar age of 212±5 ka. [RP]

db **Dacite of Bumpass Mountain (middle Pleistocene)**—Dome and lava flow of porphyritic hbl-aug dacite (64.1–64.4% SiO_2). A thick lava flow (>100 m) emerged from beneath the dome at Bumpass Mountain and flowed southeast for several kilometers, covering ~12 km^2. Smaller flow extended northwest from Bumpass Mountain. Extensively glaciated, original glassy carapace of dome was completely stripped, and only massively jointed, devitrified, and locally oxidized interior of dome is exposed. Phenocrysts: 5% pl generally 1–5 mm, composite crystals to 8 mm; 1% aug, 0.5–5 mm, often in small glomeroporphyritic clots; 1% hbl, 1–3 mm, few to 5 mm; sparse bt, generally 1–2 mm; sparse hyp, 0.5–1 mm; rare qtz, generally 1–2 mm. Hbl, bt, and some pl phenocrysts are strongly resorbed and often difficult to see. Some qtz phenocrysts have rims of fine-grained aug. Groundmass is light to medium gray and aphanitic. Fragments of broken inclusions, 1–2 cm across, are common, but larger mafic inclusions are notably sparse and generally <20 cm. Inclusions have a pyr+pl groundmass and contain resorbed host-lava phenocrysts and sparse 0.25–1 mm ol and aug phenocrysts. Joint pattern is thickly platy to massive; columnar jointing is locally present in dome. Thick zones of thinly platy-jointed rock are exposed in glaciated margins of lava flow. Unit is younger than all Brokeoff Volcano rocks, dacite of Ski Heil Peak (ds), and dacite of Mount Helen (dh) and older than dacite of Reading Peak (dr). K-Ar age is 232±8 ka.

Remnants of a fragmental deposit related to dacite of Bumpass Mountain are preserved in area south and west of Bumpass Mountain. Deposit is nonsorted, nonbedded, and composed of subrounded blocks of dense dacite of Bumpass Mountain in moderately consolidated matrix of comminuted dacite and ash. Matrix supported; blocks generally 10–50 cm in size, but some larger. Deposit is several tens of meters thick on south side of Bumpass Hell and thins rapidly away from Bumpass Mountain. Original extent of breccia was greatly reduced by glacial erosion. Deposit probably represents phreatic explosive disruption of small growing dome by magmatic gas or heated groundwater. The Bumpass Hell thermal area occupies the area of the Bumpass Mountain vent. Lithology of dacite blocks is identical to db, and eruption of the explosion breccia probably occurred early in the emplacement of db. In area of most intense hydrothermal activity at Bumpass Hell thermal area, explosion breccia is almost completely altered. [LP, RP]

dc **Dacite of Crescent Crater (middle Pleistocene)**—Lithologically and compositionally zoned unit composed of porphyritic hyp-hbl dacite dome (65.6% SiO_2) and thick porphyritic bt-hyp-hbl rhyodacite lava flow (68.9% SiO_2). Dome covers the vent. Depression at the summit is a cirque that exposes devitrified interior of dome. Lava flow at north base of dome probably predates it. Layer of ol-aug basaltic andesite scoria and ash that overlies dome and underlies pumiceous pyroclastic-flow and fall deposits (pc) from Chaos Crags is exposed at summit (Christiansen and others, 2002) but is too small to be depicted at the map scale. Origin of scoria and ash deposit is unknown. Phenocrysts: 15% pl, 2 mm to ~1 cm (largest are composite crystals); 3% hbl, 1–5 mm; 1% hyp, 0.5–1 mm; sparse bt, 1–2 mm; trace qtz, 1–2 mm. Hbl and bt are fresh in lava flow but strongly to completely oxidized in dome. Reacted pl phenocrysts are more abundant in dome than in lava flow; dome contains abundant aug in addition to hyp microphenocrysts. Broken fragments of ol- and aug-bearing mafic inclusions are abundant, especially in dome. Groundmass of lava flow is dark gray to black, glassy, and typically spherulitic or perlitic. Where fresh, groundmass of dome is medium gray and aphanitic, but in most places it is oxidized to purplish pink. Lava flow locally displays flow banding; both flow and dome exhibit massive to blocky jointing. Abundant mafic inclusions as large as 50 cm are porphyritic and contain an assemblage of 1–2 mm ol, aug, hyp, and calcic pl, as well as reacted host-lava phenocrysts. Inclusions have hbl+pl or pyr+pl groundmasses. Another type of porphyritic inclusion contains 50% millimeter-sized phenocrysts of pl, hyp, aug, and hbl in a glassy groundmass. Overlain by dacite of Lassen Peak (dl), rhyodacite of section 27 (r27), and rhyodacite of Krummholz (rkr). $^{40}Ar/^{39}Ar$ age is 236±1 ka. [MZ, WP]

ds **Dacite of Ski Heil Peak (middle Pleistocene)**—Dome of porphyritic aug-hbl dacite (64.2–66.5% SiO_2) that covers its vent. Extensively glaciated; only massively jointed, devitrified, and commonly oxidized interior of dome is exposed. Summit area of dome is covered by pumiceous pyroclastic-flow deposits (pe) from Eagle Peak. Phenocrysts: 10% pl, generally 1–5 mm, composite crystals to 1 cm; 1% hbl, 1–3 mm, few to 5 mm; 1% aug, 0.5 to 2 mm, often in small glomeroporphyritic clots; 1% bt, generally 1–2 mm; sparse qtz, generally 1–2 mm. Hbl, bt, and some pl phenocrysts are strongly reacted. Groundmass is light gray to pinkish, dense, and aphanitic. Fragments of 1–2 cm mafic inclusions are common; larger mafic inclusions to 20 cm are sparse. West and south margins of dome are less oxidized and more mafic (64.2% SiO_2) than interior (66.5% SiO_2) and contain conspicuous aug phenocrysts to 5 mm. Unit is younger than dacite of Mount Helen (dh), dacite of Lassen Peak parking lot (dpl), and dacite of Vulcans Castle (dv) and older than dacite of Bumpass Mountain (db). K-Ar age is 244±10 ka. [LP]

dh **Dacite of Mount Helen (middle Pleistocene)**—Large dacite dome of porphyritic bt-hbl dacite (65.5% SiO_2) forming Mount Helen. Vent was beneath Mount Helen on steep flank of Brokeoff Volcano, and some lava flowed eastward towards Kings Creek Meadows to produce short, thick lava flow. Extensively glaciated, original glassy carapace was almost completely stripped; massive-jointed, devitrified, and locally oxidized interior is exposed. Small area of original glassy carapace is locally preserved beneath rhyodacite of Kings Creek (rk) just below summit of Calif. Hwy 89 (near Lassen Peak parking lot). This remnant has a different composition (69.3% SiO_2) and lithology and grades into dominant lithology, but has not been mapped separately. Small area of porphyritic bt-hbl dacite exposed in roadcut on Calif. Hwy 89 under rk is mapped as dh; although lithologically similar, this dacite lacks inclusions and may not be related. Phenocrysts (dome interior): 10% pl, generally 1–5 mm, composite crystals to 8 mm; 1–2% hbl, 1–3 mm, few to 5 mm; 1% bt, generally 1–2 mm; sparse qtz, generally 0.5–2 mm; sparse hyp, 0.5–1 mm. Rock also contains 1 mm aug (often in small glomeroporphyritic clots) and 0.5 mm ol crystals derived from disaggregation of mafic inclusions. Hbl, bt, and some pl phenocrysts are strongly reacted, and some qtz phenocrysts have rims of aug. Groundmass is light to medium gray, dense, and aphanitic. Joint pattern is massive to thick tabular and columnar. Characteristic are abundant sparsely porphyritic mafic inclusions (59% SiO_2) that locally form as much as 20% of rock. Inclusions are generally to ~20 cm, locally larger, and contain reacted host-lava phenocrysts and sparse 0.25–1 mm ol and aug phenocrysts in pyr+pl groundmass. Broken fragments of inclusions, 1–2 cm in size, are also abundant. Phenocrysts (dome margin): 15% pl, generally 1–5 mm, composite crystals to 1 cm; 3–4% hbl, 1–3 mm, few to 5 mm; 1–2% qtz, 0.5–2 mm; 1% bt, generally 0.5–1 mm; sparse hyp, 0.5–1 mm. Hbl and bt phenocrysts are generally fresh, a few pl phenocrysts are reacted, and qtz phenocrysts lack aug rims. Groundmass is medium gray, dense, and glassy and perlitic. Inclusions in dome margin are similar to those in dome interior. Fragments of inclusions, 1–2 cm in size, are also abundant. Joint pattern is massive. Unit overlies dacite of Lassen Peak parking lot (dpl) and dacite under Mount Helen (duh) and underlies dacite of Bumpass Mountain (db). K-Ar age of 249±12 ka is consistent with stratigraphy. [LP, RP]

duh **Dacite under Mount Helen (middle Pleistocene)**—Sparsely porphyritic aug-hbl dacite (64.2% SiO_2) forming small remnant of dome on north flank of Mount Helen. Dacite of Mount Helen (dh) mostly buried duh, and only a small area of extensively glaciated, massively jointed, and devitrified interior of dome is exposed. Phenocrysts: 5% pl, generally 0.5–5 mm, a few larger grains are composite crystals; 1–2% hbl, 1–3 mm, reacted; sparse bt, generally 1 mm; sparse qtz, 1 mm. Small ol crystals and clots of ol and pl are conspicuous accessories. Groundmass is light to medium gray, aphanitic, and dense. Fragments of inclusions, 1–2 cm, and larger mafic inclusions to ~20 cm are common. Precise age is unknown, but unit is older than dh (249±12 ka), probably similar in age to nearby Bumpass sequence domes, and is estimated to be 250–260 ka. [RP]

dsc **Dacite of Summit Creek (middle Pleistocene)**—Thick flow and associated fragmental deposits of porphyritic hyp-hbl dacite (65.0% SiO_2) exposed in Kings Creek drainage. Source is unknown but is probably located near Reading Peak, buried beneath glacial deposits or younger dacites. Flow was extensively glaciated; its original form is poorly preserved. Massively jointed, devitrified, and somewhat oxidized interior of thick flow is exposed. In Summit Creek, fragmental deposits of similar lithology that underlie lava flow are poorly sorted, vaguely reversely graded, weakly to strongly consolidated, locally vaguely bedded deposits of subrounded to angular, dense blocks in a sand- to pebble-sized matrix of comminuted dacite. These deposits are monolithologic and clast supported, with blocks as large as 2 m. Largest blocks are slightly pumiceous, some blocks are pink, and some show vague prismatic jointing. The fragmental deposit is probably a lithic (dome-collapse) pyroclastic flow or hot talus from a nearby dome. Phenocrysts: 8–10% pl, generally 0.5–6 mm, larger crystals are composite; 2–4% hbl, 0.5–4 mm, mostly 1–3 mm; sparse–1% hyp, 0.5–2 mm, often in small glomeroporphyritic clots. Some pl crystals are reacted in both lava flow and fragmental deposits, but hbl is reacted only in lava flow. Lava has a light gray aphanitic groundmass; fragmental deposits are light to dark gray and glassy. Small, generally aphyric mafic inclusions and fragments of inclusions are abundant, and larger inclusions to 20–30 cm are sparse. Unit unconformably overlies hydrothermally altered rocks related to the Dittmar Volcanic Center (Tad) and dacite of Bench Lake (dbl, 679±14 ka). Precise age unclear; correlated with Bumpass sequence, but could belong to Rockland caldera complex. Estimated to be ~250–260 ka. [RP]

dpl **Dacite of Lassen Peak parking lot (middle Pleistocene)**—Moderately porphyritic hbl-aug dacite lava dome (63.7% SiO_2). Extensively glaciated, massive-jointed, devitrified, and typically oxidized interior is exposed. Flow banding is common, especially in exposures at Lassen Peak parking lot. Phenocrysts: 5% pl, 0.5–5 mm, few to 8 mm are generally composite crystals; 1% aug, to 3 mm, often in small glomeroporphyritic clots; 1% hbl, 1–2 mm, few to 5 mm; sparse bt, generally 1 mm; trace qtz, 1 mm. Most pl, hbl, and bt show reaction textures. Groundmass is medium gray, dense, and aphanitic and typically has splotches of vapor-phase devitrification. Broken fragments of mafic inclusions are abundant and range from a few millimeters to a few centimeters; most are smeared and merge with groundmass through disaggregation. Whole mafic inclusions to ~10 cm are sparse. Age is only partially constrained; older than dacite of Ski Heil Peak (ds, 244±10 ka), probably older than dacite of Mount Helen (dh, 249±12 ka), and estimated to be 250–260 ka. [LP]

dv **Dacite of Vulcans Castle (middle Pleistocene)**—Dome of porphyritic bt-hbl dacite (65.6-66.5% SiO_2). Dome was highly sculpted by glacial erosion and mass wasting; massively jointed, devitrified, locally strongly flow banded, and oxidized interior is exposed. Brecciated and glassy margins are preserved along north flank, and a small area of partially welded dome-collapse breccia is northwest of Crescent Cliff. Phenocrysts: 10% pl, 2–6 mm, largest are composite; 1% hbl, 1–3 mm; 1% bt, 1–2 mm; 1% qtz, 1–2 mm; sparse aug, 0.5–1 mm, as phenocrysts and small glomeroporphyritic clots of crystals; sparse hyp, 0.5 mm, as microphenocrysts. Groundmass is light to medium gray, often oxidized to pink, and is aphanitic and dense. Mafic inclusions with a variety of textures are abundant and generally <10 cm. Age is poorly constrained, but dv is clearly younger than Brokeoff Volcano (extinct at ~390 ka). Unit is older than dacite of Ski Heil Peak (ds, 244±10 ka) and probably younger than rhyodacites of Loomis Peak (rlm) and Manzanita Chute (rmz, 297±1 ka) and is estimated to be 250–260 ka, but could be slightly older. [LP]

d82 **Dacite of hill 8283 (middle Pleistocene)**—Dome and thick lava flow of porphyritic pyr-hbl dacite (65.7–66.4% SiO_2). Hill 8283 marks vent for thick lava flow 3.5 km long that flowed to north toward Lost Creek. Flow is heavily glaciated; carapace is entirely stripped, and massively jointed interior is exposed. Dome is also heavily glaciated, but remnants of its pumiceous carapace are preserved. Weak banding shown by aligned phenocrysts is common. Relative proportion of phenocrysts is somewhat variable, especially in lava dome. Phenocrysts: 12% pl, 1–6 mm, few composite crystals with dark cores to 1 cm; 1% hbl, 1–5 mm; sparse bt, generally ~2 mm; sparse–1% qtz, generally ~2 mm. Hyp and aug microphenocrysts generally <0.5 mm are abundant. Both reacted and unreacted felsic phenocrysts are present. Aug and ol xenocrysts are common, especially on west flank of dome. Fragments of broken mafic inclusions 5 mm–2 cm across are abundant and often contain pyr microphenocrysts and glomeroporphyritic clots of pyr microphenocrysts. Groundmass is light to medium gray and aphanitic with local patchy microvesicular areas. Mafic inclusions from 10 to ~50 cm are abundant. They have variable textures from fine to coarse grained and contain sparse to common, reacted host phenocrysts; sparsely porphyritic inclusions are most common. Hyp and aug microphenocrysts generally <1 mm are abundant. Both pyr-pl and hbl-pl groundmasses are present. K-Ar age is 261±5 ka. [MZ, WP]

dmz **Dacite of upper Manzanita Creek (middle Pleistocene)**—Dome of porphyritic pyr-bt-hbl dacite (66.0–67.0% SiO_2). Dome is heavily glaciated, and the massively jointed and devitrified interior is exposed. Glacial and fluvial erosion along Manzanita Creek cut the single dome into several remnants. Phenocrysts: 12% pl, 2–5 mm, few composite crystals with dark cores to 1 cm; 2% hbl, 1–5 mm; 1% bt, to 2 mm; rare qtz, to 1 mm. Hyp and aug microphenocrysts (hyp>aug) are common but rarely exceed 0.5 mm and are sometimes found as small glomeroporphyritic clots. Groundmass is light to medium gray and aphanitic, with splotchy areas of devitrification. Fragments of mafic inclusions a few millimeters to a few centimeters in size are abundant. Larger mafic inclusions are abundant and to ~20 cm in diam. Contains coarse-grained inclusions that lack host-lava phenocrysts and fine-grained inclusions that contain resorbed host-lava phenocrysts. All inclusions contain sparse 0.5–1 mm phenocrysts of aug and ol and have hbl-pl groundmasses. Age is unknown, but dmz underlies dacite of hill 8283 (d82, 261±5 ka) and is one of oldest domes of Bumpass sequence. Estimated to be ~265–280 ka. [MZ]

rmz **Rhyodacite of Manzanita Chute (middle Pleistocene)**—Thick lava flow and dome of moderately porphyritic bt-hbl rhyodacite (69.3% SiO_2). Erupted from vent beneath summit dome and flowed downhill toward northwest ~3 km. Although it is older than several glacial advances (Christiansen and others, 2002), flow is unglaciated and has well-preserved flow morphology; upper surface has well-defined crescentic flow ridges and a pumiceous carapace, whereas basal part is dense and perlitic. Phenocrysts: 10% pl, generally 1–3 mm, few to 5 mm; 2% hbl, generally 1–3 mm, few to 5 mm; 1% bt, 0.5–1 mm. Reacted phenocrysts are absent, and fragments of mafic inclusions are sparse. Groundmass ranges from white, pumiceous, perlitic glass with spherulites to dark-gray to black, dense perlitic glass. Mafic inclusions with variety of textures are generally sparse but locally common; majority are 10–30 cm, aphyric, and fine to coarse grained with hbl-pl groundmasses. Porphyritic mafic inclusions are smaller, contain sparse 1-mm aug and ol phenocrysts and reacted host rhyodacite phenocrysts, and have fine-grained hbl+pl groundmasses. Unit overlies andesite of Manzanita Creek (amz), rhyodacite of Loomis Peak (rlm), andesite of Viola (av, 313±8 ka), and basalt of Onion Springs (bo) and underlies lithic tephra from Deep Hole (pdh). $^{40}Ar/^{39}Ar$ age is 297±1 ka. [LP, MZ]

rmc **Rhyodacite of Mount Conard (middle Pleistocene)**—Thick lava flows of porphyritic hyp-hbl rhyodacite (69.1-71.0% SiO_2) on north, west, and southeast flanks of Mount Conard, including remnant of lava flow at Terrace Lake. No vent has been located for these lava flows, but they appear to have flowed southward for an unknown distance from a vent that was high on east flank of Brokeoff Volcano. The 100-m-thick flow that forms a prominent cliff on the west face of Mount Conard is not part of Brokeoff Volcano but filled a canyon cut in its upper flank. Phenocrysts: 10–12% pl, 0.5–5 mm, generally 1–3 mm; 2–3% hbl, to 5 mm, generally 1–3 mm; sparse–2% hyp, 0.5–2 mm; sparse–1% bt, 0.5–1 mm. Fragments of mafic inclusions and mafic inclusions to ~10 cm with a variety of textures are common. Groundmass is generally glassy and light colored, although some parts of thick flows are aphanitic. Flow banding is typically well developed, and spherulitic zones are common; flow margins are pumiceous or perlitic. Flows on Mount Conard overlie andesite of Rice Creek (ar) and are probably younger than all of Brokeoff Volcano. Flow remnant at Terrace Lake is overlain by dacite of Reading Peak (dr) and is probably older than all Bumpass sequence units except, perhaps, rhyodacite of Manzanita Chute (rmz) and rhyodacite of Loomis Peak (rlm). $^{40}Ar/^{39}Ar$ age of 298±9 ka for thick flow on west flank of Mount Conard indicates lava flows are associated with early part of the Bumpass sequence. [LP, RP]

rlm **Rhyodacite of Loomis Peak (middle Pleistocene)**—Thick lava flow of porphyritic bt-hyp-hbl rhyodacite (68.6% SiO_2). Erupted from vent approximately located at Loomis Peak and flowed northwest. Upper surface has poorly preserved pumiceous carapace, whereas basal part is dense and perlitic. Extensive glacial erosion of flow margins exposed massively jointed, flow-banded, and devitrified interior where spherulitic, lithophysal, and oxidized zones are common. Phenocrysts: 12% pl, generally 1–3 mm, few to 5 mm, composite crystals to 8 mm; 2% hbl, 1–3 mm, few to 5 mm; 1% hyp, to 0.75 mm; trace bt, 0.5–1 mm. Fragments of mafic inclusions, reacted phenocrysts, and small crystals disaggregated from inclusions are abundant. Groundmass is variable: white to pinkish, dense to pumiceous, and devitrified to dark-gray to black, dense perlitic glass with spherulites and lithophysae. Mafic inclusions are abundant. Textures range from fine grained porphyritic, with resorbed host-rhyodacite phenocrysts, to coarse grained aphyric. The majority are 10–20 cm, but inclusions up to 50 cm occur. Coarse-grained aphyric inclusions are typically larger and have hbl+pl groundmasses, whereas porphyritic inclusions are smaller, contain sparse 1-mm ol, aug, calcic pl, and reacted host-rhyodacite phenocrysts, and have fine-grained pyr+pl or pyr+hbl+pl groundmasses. Mafic inclusions enclosing older generations of inclusions are relatively common. Age is poorly constrained. Unit conformably overlies basalt of Onion Springs (bo) and andesite of Mount Diller (amd) and, therefore, can be no older than ~390 ka. It is overlain by rhyodacite of Manzanita Chute (rmz) and, therefore, must be older than 297 ka. Age is estimated to be ~300 ka; it is one of oldest units of Lassen domefield stage of Lassen Volcanic Center. [LP, MZ]

Brokeoff Volcano

Diller sequence

amd **Andesite of Mount Diller (middle Pleistocene)**—Thin (10–30 m) lava flows of porphyritic aug-hyp andesite (61.2–63.0% SiO_2) erupted from vent, which is not preserved, high on north flank of Brokeoff Volcano. Andesite of Mount Diller is the youngest lava of the Diller sequence and forms the uppermost slopes of Brokeoff Volcano on its west, north, and northeast flanks. Thickness is 300–400 m on ridge trending northwest from Mount Diller. Flows often have thick basal breccias and tops composed of subrounded vesicular blocks. Flow interiors usually have blocky joint patterns. Includes lava flows at the summit of Brokeoff Mountain with similar lithology but slightly more mafic composition (60.2% SiO_2).

Phenocrysts: 20-30% pl, 0.5–4 mm; 5% hyp, 0.5–2 mm; 3% aug, 0.5–2 mm. Xenocrystic ol is usually present in trace amounts. Glomeroporphyritic clots of pl+aug+hyp±ol generally 5 mm–1 cm are abundant and characteristic of amd. Mafic inclusions containing pl and pyr phenocrysts are small and rare. Groundmass is typically dark gray to black and hyalopilitic but ranges to light gray and aphanitic. Flows bordering core of Brokeoff Volcano are hydrothermally altered to varying degrees. Overlies andesites of Mill Canyon (amc) and dacite of Twin Meadows (dt) on Brokeoff Mountain, andesite of Digger Creek (adc) in Blue Lake Canyon area, and andesite of Rice Creek (ar) in Cold Boiling Lake area. Flow near middle of amd section on Mount Diller yielded K-Ar age of 387±10 ka. This age is consistent with known stratigraphy of Lassen Volcanic Center but is ~50 ka younger than any other dated Brokeoff Volcano unit and may not be accurate. Overlain by rhyodacite of Loomis Peak (rlm) and younger Bumpass sequence dacites along north flank of Brokeoff Volcano. [LP, RP]

ad **Andesites of Diller sequence, undivided (middle Pleistocene)**—Small outcrop areas of porphyritic aug-hyp andesite lava flows (60–63% SiO_2) on north and west sides of Lassen domefield are correlated with Brokeoff Volcano on the basis of similar lithology and age. Younger glacial and volcanic deposits obscure sources and extents of these lava flows. Includes two small outcrops of a moderately welded aug-hyp andesite ash-flow tuff in South Fork Bailey Creek (unit Qapf of Clynne, 1984). Andesites are generally similar, typically medium to dark gray aphanitic rocks containing 10–30% phenocrysts of pl, hyp, and aug (generally hyp>aug); pl dominates assemblage. Phenocrysts typically 1–3 mm, locally as large as 5 mm; ol sparsely present as partly resorbed crystals. Glomeroporphyritic clots of pl+pyr common in some flows. Unit is overlain by andesite of Viola (av, 313±8) and younger rocks of the Lassen domefield. Age estimated to be 400–470 ka. [GP, MZ, VI, WP]

adc **Andesite of Digger Creek (middle Pleistocene)**—Thick (30–60 m) lava flows of porphyritic aug-hyp andesite (61.3–61.9% SiO_2) erupted from vent that is not preserved but was higher on west flank of Brokeoff Volcano than hill 8198. Unit is part of Diller sequence and forms the upper slopes of Brokeoff Volcano on its west flank. Lava flowed west and was diverted around dome of Red Rock Mountain. Lava flows underlie andesite of Mount Diller (amd) in Blue Lake Canyon area. Typical outcrops are glaciated cliffs exposing thinly platy jointed flow interiors. Flow tops are usually composed of oxidized and vesicular rounded blocks. Phenocrysts: 20–30% pl, mostly 1–3 mm but to 5 mm; 5–6% hyp, 0.5–2 mm; 3–4% aug, 0.5–2 mm. Xenocrystic ol is locally present in trace amounts. Hbl is also present in trace amounts and is usually found as oxidized relict grains but occasionally as euhedral, Fe-Ti oxide-rimmed crystals. Glomeroporphyritic clots of pl+aug+hyp±ol generally 5 mm–1 cm are abundant and characteristic. Mafic inclusions containing pl and pyr phenocrysts are small and very sparse. Xenoliths of metamorphic and metavolcanic rocks occur in area of hill 8198. Groundmass is typically light gray and aphanitic with pl, pyr, and Fe-Ti oxide microlites but black and glassy at flow margins. Samples from flow interiors are aphanitic and usually show splotchy devitrification of glass to cryptofelsite. Overlies basaltic andesite of Hootman Ranch (mhr, 562±12 ka), dacite of Red Rock Mountain (drr, 672±20 ka), andesite of Cabin Spring (acs, 690±34 ka), andesites of Mill Canyon (amc, 591–472 ka), and dacite of Twin Meadows (dt, 470±10 ka) and other older rocks. It is overlain by andesite of Viola (av, 313±8 ka) and rhyodacite of Manzanita Chute (rmz, 297±1 ka). Sample from hill 8198 yielded K-Ar age of 451±10 ka. [GP, LP, MZ, VI]

amz **Andesite of Manzanita Creek (middle Pleistocene)**—Thick block-lava flow of porphyritic aug-hyp andesite (62.6% SiO_2) correlated on basis of lithology and age with Diller sequence and erupted from vent marked by small cinder cone south of Manzanita Lake. Eroded cinder cone is built of andesite scoria and has a thick soil cover. Lava flowed from cone to west for 8 km. Lava flow is unglaciated and retains considerable original flow morphology. Upper surface is characterized by 0.5–1 m rounded vesicular boulders. Distal part of flow is locally flow banded, partially oxidized, and devitrified. Phenocrysts: 20% pl, 1–3 mm; 6% hyp, 0.5–2 mm; 3% aug, 0.5–2 mm. Sparse hbl phenocrysts, generally <1–2 mm are locally present. Glomeroporphyritic clots of pl+aug+hyp from 5 mm to 1 cm are abundant. Mafic inclusions are sparse and small, generally <5 cm. Groundmass, when fresh, is medium to dark gray and aphanitic; it generally weathers to light gray. Age poorly constrained by stratigraphy. Overlies basaltic andesite of Hootman Ranch (mhr, 562±12 ka; Lanphere and others, 2004) and is overlain by andesite of Viola (av, 313±8 ka) and rhyodacite of Manzanita

Chute (rmz, 297±1 ka). Unit is probably older than andesite of Mount Diller (amd, 387±10 ka) and about the same age to somewhat younger than andesite of Digger Creek (adc, 451±10 ka); estimated to be ~425–450 ka. [MZ, VI]

ag **Andesite of Glassburner Meadows (middle Pleistocene)**—Thick (30–60 m) lava flows of porphyritic aug-hyp andesite (61.4–61.7% SiO_2) erupted from unpreserved vent on south flank of Brokeoff Volcano. Part of Diller sequence and forms uppermost slopes of Brokeoff Volcano on part of its south flank. Lava flowed south over area covered by dacite of Twin Meadows (dt) and andesite of Bluff Falls quarry (abf). Upon reaching lower slopes, flow ponded against dacite of Rocky Peak (drp). Lava flow was glaciated, and typical outcrops are small cliffs exposing flow interiors that are thinly platy jointed. When exposed, flow tops are typically composed of oxidized, vesicular, rounded blocks. Phenocrysts: 25% pl, mostly 1–3 mm, but to 5 mm; 4–5% hyp, mostly 0.5–1, but to 2 mm; 3–4% aug, mostly 0.5–1, but to 2 mm. Xenocrystic ol is locally present in trace amounts. Hbl also present in trace amounts and found as oxidized relict grains. Glomeroporphyritic clots of pl+aug+hyp±ol generally 5 mm–1 cm are abundant. Mafic inclusions containing pl and pyr phenocrysts are present but small and very sparse. Groundmass is typically light gray and aphanitic with pl, pyr, and Fe-Ti oxide microlites. Samples from flow interiors are aphanitic, dense, and usually show devitrification of glass to cryptofelsite. Unit not dated, but is slightly younger than andesite of Bluff Falls quarry (abf, 467±10 ka) and probably similar in age to andesite of Digger Creek (adc, 451±10 ka). Overlain by basaltic andesite of Huckleberry Lake (mhl), a post-Brokeoff Volcano lava flow that is ~300 ka in age. [LP]

abf **Andesite of Bluff Falls quarry (middle Pleistocene)**—Thick (30–60 m) lava flows of porphyritic aug-hyp andesite (59.0–59.1% SiO_2) erupted from unpreserved vent on south flank of Brokeoff Volcano. Lava flowed south over lava flows of Mill Canyon sequence. Typical outcrops are glacial cliffs exposing flow interiors with thin platy jointing. Large exposure at Bluff Falls quarry exhibits the jointing patterns of thick silicic andesite flows particularly well (Muffler and others, 1989). These thick flows typically have brecciated and oxidized zone at base, overlain progressively by zones of flow-banded and massively jointed rock, thinly platy jointed rock, and columnar-jointed rock. Where exposed, flow tops are typically composed of oxidized and vesicular, rounded blocks. Phenocrysts: 20% pl, mostly 1–3 mm, but to 5 mm; 4–5% hyp, mostly 0.5–1 mm, but to 2 mm; 3–4% aug, mostly 0.5–1 mm, but to 2 mm. Xenocrystic ol is usually present in trace amounts. Hbl is also present in trace amounts and is typically found as oxidized relict grains. Glomeroporphyritic clots of pl+aug+hyp±ol generally 5 mm–1 cm are abundant. Mafic inclusions containing pl and pyr phenocrysts are small and uncommon. Groundmass is typically light gray and aphanitic with pl, pyr, and Fe-Ti oxide microlites. K-Ar age is 467±10 ka. Overlain by basaltic andesite of Huckleberry Lake (mhl), a post-Brokeoff Volcano lava flow that is ~300 ka in age. [LP]

ar **Andesite of Rice Creek (middle Pleistocene)**—Thick (30–60 m) lava flows of porphyritic aug-hyp andesite (62.4–63.0% SiO_2) erupted from unpreserved vent on east flank of Brokeoff Volcano. Unit is oldest of Diller sequence lavas. On east flank of Brokeoff Volcano, ar lava flowed east and then south and covered 50 km^2 of Mill Canyon sequence lavas and older rocks. Outlier of ar is found beneath dacite of Bumpass Mountain (db) at Kings Creek Falls. Typical outcrops are glacial cliffs exposing flow interiors that are thinly platy jointed. When exposed, flow tops are usually composed of oxidized, vesicular, rounded blocks. Phenocrysts: 20% pl, 0.5–2 mm; 4-5% hyp, mostly 0.5–1 mm, but up to 2 mm; 3–4% aug, mostly 0.5–1 mm, but up to 2 mm. Xenocrystic ol is locally present in trace amounts. Glomeroporphyritic clots of pl+aug+hyp±ol generally 5 mm–1 cm across are abundant. Mafic inclusions containing pl and pyr phenocrysts are small and very sparse. Groundmass is typically light gray, but often pinkish gray. Flow interiors are aphanitic and usually show devitrification of glass to cryptofelsite. Few flow remnants in Twin Meadows and Spencer Meadows areas are less porphyritic and have lower SiO_2 (59–60%); they are similar to andesite of Bluff Falls quarry (abf), but are not mapped separately. Two different samples from north of Feather River Meadows yielded K-Ar ages of 485±12 and 477±14 ka. [CM, LP, RP]

Mill Canyon sequence

dt **Dacite of Twin Meadows (middle Pleistocene)**—Thick lava flows of porphyritic pyr-hbl dacite (66.1–68.0% SiO_2) that cap Mill Canyon sequence and form the most important widespread stratigraphic marker of Brokeoff Volcano. Vent area(s) not preserved. Flows are generally 100 m, but to 200 m, thick and massively to thickly platy jointed. Basal vitrophyres are locally exposed. Flows are found high on southwest flank of Brokeoff Mountain and form most of upper part of mountain. Another thick flow is found in Blue Lake Canyon (North Fork Bailey Creek). Flows in area below Mount Diller and Pilot Pinnacle are strongly altered, as are flows near Cold Boiling Lake. Unit is one of few rocks of Brokeoff Volcano that contains hbl as an essential phenocryst. Phenocrysts (Brokeoff Mountain flows): 8–10% pl, 1–3 mm, but mostly 1–2 mm; 2% hbl, 0.5–1.5 mm; 1% pyr, 0.5–1 mm (hyp>aug). Where fresh, groundmass is light to dark gray and aphanitic, but typical dacite of Twin Meadows is oxidized. Glomeroporphyritic clots of pl, hyp, and aug as much as 5 mm are common. Inclusions to 20 cm are abundant in flows exposed on Brokeoff Mountain and sparse in the flows at Blue Lake Canyon and near Cold Boiling Lake. Flows at Blue Lake Canyon and near Cold Boiling Lake are generally less porphyritic and contain less hbl than Brokeoff Mountain flows. Unit exposed in north face of Brokeoff Mountain has K-Ar age of 470±10 ka. [LP, RP]

amc **Andesites of Mill Canyon (middle Pleistocene)**—Variety of generally thin ol basaltic andesite to pyr andesite lava flows and sparse dacite lava flows (55–65% SiO_2) forming older part of Brokeoff Volcano. These flows and associated fragmental deposits erupted from central vents that cannot be located precisely. Overwhelming majority of lavas contain 57–61% SiO_2, and the average of 40 Mill Canyon sequence andesites contains 58.5% SiO_2. Base of Brokeoff Volcano section is exposed in Mill and Blue Lake Canyons, where flows tend to be more mafic (basaltic andesite to andesite) and are often ol-bearing. Higher in section, hyp+aug andesite lava flows are dominant, and flows containing ol are less common. Pyr±hbl dacites are sparse. Mill Canyon sequence andesites are generally porphyritic, typically containing 15–30% phenocrysts, although some sparsely porphyritic and a few nearly aphyric lavas are present. Phenocryst size is variable, but tends to be 0.5–2 mm. Phenocrysts typically are less abundant and smaller than in Diller sequence lavas. Mafic phenocryst assemblages are variable; ol-aug, ol-aug-hyp, hyp-aug, and aug-hyp assemblages occur. Pl is ubiquitous and typically dominates phenocryst assemblage, but pl-poor lavas also are present. Glomeroporphyritic clots of pl and mafic minerals are common. Many pyr andesite lavas contain ol xenocrysts, and a few contain hbl. In lower part of Mill Canyon sequence, it is common for adjacent flows to have different phenocryst assemblages and (or) abundances. Stratigraphically higher in volcano, andesites typically occur as packages of several similar flows, but adjacent packages are different. Groundmasses are generally medium to dark gray and aphanitic to glassy; aphanitic textures are most common.

Includes a thick (to 150 m) lava flow of porphyritic pyr-hbl dacite (63.4% SiO_2) at base of Brokeoff Volcano exposed in cliff of Mill Canyon overlying dacite of Morgan Mountain (dmm). This flow (dacite of Growler Spring of Clynne, 1984) and another at the base of Brokeoff Volcano in South Fork Bailey Creek are correlated with amc but could be related to Rockland caldera complex. Phenocrysts (Mill Canyon lava flow): 20% pl, mostly 0.5–2 mm, some to 5 mm; 2% aug, 0.5 mm, few to 2 mm; 2% hyp, 0.5 mm, few to 2 mm; 1% oxidized hbl, 0.5–1 mm; sparse ol, 0.5–2 mm; rare qtz rimmed with aug. Groundmass is light gray, aphanitic, and dense to sparsely microvesicular. Small inclusions and glomeroporphyritic clots of pl+aug+hyp are common.

In contrast to Diller sequence, Mill Canyon sequence lavas contain considerable pyroclastic material intercalated with the lavas. Fragmental deposits, not mapped separately, include fallout and lithic pyroclastic flow deposits; lahar deposits are common, and pumiceous pyroclastic-flow deposits are sparse in Mount Conard area. Thick accumulations of fragmental deposits are notable in East Fork Sulphur Creek area and area between Brokeoff Mountain and Mount Diller and probably mark proximity to vent areas. Core of Brokeoff Volcano is variably hydrothermally altered, and fresh rock is rare. Permeable fragmental deposits and brecciated flow carapaces are particularly susceptible to hydrothermal alteration. In areas of intense active hydrothermal alteration, rocks are so extensively altered that their original lithology is difficult to determine; typically, these are light-gray or orange-brown, altered andesite with no preserved mafic phenocrysts, but locally there are areas of kaolinite and silica with scattered blocks of intensely altered rock. The most extensive areas of unaltered to relatively unaltered Mill Canyon sequence rocks are exposed in walls of Mill Canyon, on lower slopes of Mount Conard, and in canyons of North and South Fork Bailey Creek. Mill Canyon sequence is capped by dacite of Twin Meadows (dt, 470±10 ka). Six samples of amc yielded K-Ar ages of 591±13, 555±18, 534±27, 506±14, 473±10, and 472±9 ka and date the entire age span of the Mill Canyon sequence. [LP, RP,WP]

Rockland caldera complex

pr **Rockland tephra (middle Pleistocene)**—Consists of poorly exposed deposits of hyp-hbl rhyolite pumice (71.0–74.5% SiO_2) emplaced as fallout facies and ash-flow facies in the area of Onion Creek, Canyon Creek, and Digger Creek near Camp Forward. Additional deposits of the ash-flow facies are exposed in the extreme southwest corner of map area in roadcuts along Calif. Hwy 36 and outside the map area along the east bank of Guernsey Creek west of Deer Creek Meadows. Deposits are characterized by intense dissection and white to light-orange soil. Much better exposures occur west of the map area in the adjacent Manton quadrangle.

The ash-flow facies is nonsorted, nonwelded, and friable, although vapor-phase crystallization locally has weakly indurated the deposit. White to tan ash forms bulk of ash flows. Pumice lapilli and bombs to 20 cm form 10–20% of deposit. Lithic fragments are abundant, especially near base. Deposit weathers quickly, and fresh outcrops are limited to roadcuts and quarries. Thickness is poorly known; no complete section is exposed. Helley and others (1981) suggest thickness of at least 60 m near Manton. Incomplete exposures in Canyon Creek and Onion Creek areas are 30–80 m thick.

Phenocrysts: 8% pl, 1–3 mm; 1% hbl, 1–2 mm; sparse hyp, 0.1 mm; sparse qtz, 1–2 mm. Pumice has characteristic silky texture and very elongate vesicles. Small mafic inclusions are locally common; larger ones to 20 cm are sparse. Many types of fresh to weathered or hydrothermally altered, mafic to silicic volcanic rocks occur as lithic fragments in ash-flow deposits, but most of their sources have not been identified; however, a distinctive porphyritic, qtz-bearing, flow-banded, and devitrified rhyolite (possibly the type of rhyolites of Dittmar Volcanic Center, Stage 3 from Summit Creek, rd3) is ubiquitous and identifies Rockland tephra deposits. Clasts of the distinctive andesite of Cabin Spring (acs) are also occasionally found. Most abundant lithic types are porphyritic aug-hyp andesites similar to those found on large composite volcanoes in the region.

The fallout facies of the Rockland tephra is composed of beds of ash and pumice lapilli that are from a few millimeters to a few centimeters in size; lithic fragments are sparse. Exposures of fallout facies are limited to isolated roadcuts and quarries west of the map area around Manton. Thickness is at least 2 m in exposures along Forwards Mill Road and 5 m or more in the quarries around Manton where the deposit has been thickened by reworking (Helley and others, 1981). $^{40}Ar/^{39}Ar$ age is 609±7 ka (Lanphere and others, 1999; 2004). [GP, LY, VI]

rr **Rhyolite of Raker Peak (middle Pleistocene)**—Steep-sided lava dome of moderately porphyritic hbl-bt rhyolite (73.5% SiO_2) erupted from an underlying vent. Glacial erosion along south margin of dome exposed prominent columnar joints, and dome has been stripped of pumiceous and blocky carapace. Phenocrysts: 10% pl, 1–3 mm, many resorbed; 2% bt, to 1 mm; 1% hbl, to 1 mm; sparse qtz, to 0.25 mm. Groundmass is white to light gray and glassy but often spherulitic. Coarse, even-grained mafic inclusions (57.5% SiO_2) are common, generally 10–30 cm. Small fragments of mafic inclusions a few millimeters in size are abundant. Inclusions have a pyr+hbl+pl mineral assemblage and sparse pl phenocrysts. In some places inclusions are smeared in thin, even layers a few millimeters thick giving appearance of flow banding in rhyolite. These layers commonly provide planar discontinuities upon which rock separates into large flat blocks. Overlain by much younger lava flows of andesite of Raker Peak (arp, 270±18 ka). K-Ar age is 588±69 ka, but it is probably older than the Rockland tephra. It is chemically very similar to Rockland tephra (pr) and may represent a pre-caldera leak of the Rockland magma chamber. [WP]

drr **Dacite of Red Rock Mountain (middle Pleistocene)**—Lava dome of porphyritic hyp-hbl dacite (63.7% SiO_2) on west flank of Brokeoff Mountain. Tentatively correlated with Rockland caldera complex, although it may be unrelated. Red Rock Mountain was glaciated, and pumiceous and glassy carapace of the dome was completely removed; thinly platy jointed core of dome is exposed. Phenocrysts: 8% pl, 0.5–4 mm; 2% hbl, 1–2 mm; sparse qtz with aug rims, 1–2 mm; sparse hyp, 0.5 mm. Fresh rock is light gray, but it is typically oxidized to shades of red. Mafic inclusions to a few centimeters across are common. Overlies andesite of Cabin Spring (acs); predates Brokeoff Volcano and formed barrier to advancing Brokeoff andesites. K-Ar age is 672±20 ka. [GP, LP]

dbl **Dacite of Bench Lake (middle Pleistocene)**—Several small domes of porphyritic hyp-hbl dacite (65.7% SiO_2) related to Rockland caldera complex are poorly exposed under glacial deposits and younger rocks in Kings Creek. Original pumiceous carapaces or hot talus covers were completely removed by erosion, exposing their crystalline, thick platy- to massive-jointed interiors. Lithology of domes is slightly variable; the following description is of the largest dome (hill 800 meters southeast of Kings Creek Falls). Phenocrysts: 8–10% pl, generally 0.5–6 mm, mostly 1–3 mm, larger crystals generally composite; 2–3% hbl, mostly 1–3 mm, few to 6 mm; sparse hyp, 0.5 mm; traces of 1–3 mm bt and qtz. Some pl phenocrysts are strongly reacted. Groundmass is light to medium gray and glassy to aphanitic. Large quenched andesitic inclusions are sparse, but broken fragments of andesitic inclusions are common and generally <1–2 cm. Unit underlies rocks of Brokeoff Volcano (andesite of Rice Creek, ar, 477±14 and 485±12 ka) and overlies hydrothermally altered rocks of Dittmar Volcanic Center. K-Ar age is 679±14 ka. [RP]

dbc **Dacite of Bailey Creek (middle Pleistocene)**—Small body of porphyritic bt-hbl dacite (64.2% SiO_2) with domical outcrop and massive jointing poorly exposed in the canyon of South Fork Bailey Creek. Dacite was tentatively correlated with the Maidu Volcanic Center by Clynne (1984), but it is now recognized as part of the Rockland caldera complex. Phenocrysts: 10% pl, to 5 mm; 2% oxidized hbl, 0.5–4 mm; 1% oxidized bt, 0.5–2 mm; 1% qtz, 0.5–1 mm; sparse hyp, 0.5–1 mm; trace corroded ol, 1 mm; trace aug, 0.5 mm. Where fresh, groundmass is light gray and aphanitic, but typically it is oxidized pinkish. Age unknown, but dbc is overlain by andesites of Mill Canyon (amc) and, thus, is older than Brokeoff Volcano. Estimated to be ~700–825 ka. [LP]

drp **Dacite of Rocky Peak (early Pleistocene)**—Thick lava flow of porphyritic pyr-hbl dacite (66.6% SiO_2) with a dome at Rocky Peak marking the vent. Extensive glaciation removed most of original carapace of glassy and vesicular rock. Dome has massive jointing and lacks flow structure. Upper part of lava flow is glassy and massively jointed and has vague flow structure marked by aligned phenocrysts and often zones of microvesicles, brecciation, oxidation, and devitrification. Interior of lava flow is more crystalline and has thin platy jointing. Phenocrysts: 15–20% pl, 1–4 mm; 1–3% oxidized hbl, 1–4 mm; 1–2% hyp, 0.5 mm; trace–3% aug, 0.5–1 mm. Lava flow is hyp-hbl dacite, whereas the dome is primarily hbl-aug dacite; transition between lithologies is gradational. Mafic inclusions to ~20 cm are abundant. Groundmass is light to medium gray and glassy to aphanitic. Unit overlies andesite of Martin Creek (amr) and basaltic andesite of Grays Peak (mgp, 1,080±26 ka) and is overlain by andesites of Mill Canyon (amc, <591±13 ka), andesite of Digger Creek (adc, 451±10 ka), and andesite of Glassburner Meadows (ag). K-Ar age is 803±27 ka. [GP, LP]

dfr **Dacite of Flatiron Ridge (early Pleistocene)**—Thick lava flow (>100 m) of porphyritic hbl-pyr dacite (65.9% SiO_2) erupted from vent now buried by younger domes of Lassen Volcanic Center. Lava flowed southeast and filled a paleovalley of Warner Creek. Subsequently, Kings Creek and Hot Springs Creek were re-excavated by glaciers along north and south margins of flow to create Flatiron Ridge, and original carapace of flow was completely stripped. Phenocrysts: 8–10% pl, generally 1–3 mm, few to 6 mm; 1–2% hbl, 1–3 mm, few to 5 mm; sparse hyp, 0.5–1 mm; rare aug, 0.5–1 mm. Hbl and some pl phenocrysts are strongly reacted. Groundmass is medium to dark gray, dense, and aphanitic. Abundant 1–2 cm broken fragments of andesitic inclusions with pyr+pl groundmass are characteristic; larger inclusions are rare. Thick zones of thinly platy jointed rock are exposed in glaciated margins of lava flow, and top is covered with till. In Kings Creek, unconformably overlies much older hydrothermally altered rocks of Dittmar Volcanic Center (Tad) and dacite of Panther Creek (dp, 827±18 ka). K-Ar age is 812±6 ka. [MH, RP]

dp **Dacite of Panther Creek (early Pleistocene)**—Small group of porphyritic hyp-hbl dacite domes (65.3% SiO_2) exposed around and south of Devils Kitchen. Domes were eroded so that original pumiceous carapaces or hot talus covers were completely removed and crystalline thick platy to massive jointed interiors exposed. At Devils Kitchen, rocks are strongly altered. Largest of domes erupted from vent centered under hill 7139. Dome(s) and sparse dome-collapse or other breccia deposits exposed in canyon wall north of Devils Kitchen are similar. Phenocrysts: 12–15% pl, 0.5–6 mm, mostly 1–3 mm, larger crystals generally composite; 2–4% hbl, mostly 1–3 mm, few to 1 cm; sparse hyp, 0.5 mm; rare 1 mm crystals of ol and aug. Hbl and some pl phenocrysts are strongly reacted. Groundmass is light to medium gray and aphanitic. Porphyritic mafic inclusions are abundant but generally <15–25 cm, and 1–2 cm fragments of mafic inclusions are abundant. Unit underlies rocks of Brokeoff Volcano and overlies hydrothermally altered rocks of Dittmar Volcanic Center. K-Ar age of sample from hill 7139 is 827±18 ka. [RP]

dpg **Dacite of Plantation Gulch (early Pleistocene)**—Dome of porphyritic bt-hbl dacite (66.9% SiO_2) that forms twin-peaked ridge east of Plantation Gulch. Dome was probably emplaced as a solid mass that uplifted and distorted lava flows of the underlying andesite of Martin Creek (amr). Phenocrysts: 10–15% pl, 1–5 mm, mostly about 2 mm; 0–5% hbl, 1–6 mm; 1–3% qtz, 1–3 mm; 1% oxidized bt, 1–2 mm; 1% hyp, 0.5 mm. Inclusions to 20–30 cm and fragments of disaggregated inclusions containing aug are abundant. Groundmass is light gray and aphanitic but often oxidized, and rock is massively jointed. Located between Brokeoff Volcano and Maidu Volcanic Center and related to earliest part of Rockland caldera complex. Age is poorly known and estimated to be about same age to slightly older than dacite of Rocky Peak (drp, 803±27 ka). [LP, MN]

dch **Dacite of Christie Hill (early Pleistocene)**—Porphyritic hyp-hbl dacite (67.3% SiO_2) lava dome at Christie Hill and thick flow extending south. Phenocrysts: 20% pl, 1–3 mm; 4% hbl, 0.5–3 mm; 1% hyp, 0.5–1 mm; 1–2 % qtz, 1–5 mm. When fresh, rock is medium gray with devitrified aphanitic groundmass, but typically it is oxidized from pink to deep red. Inclusions to 20–30 cm with hbl-pl groundmass and aug and ol phenocrysts are abundant, and fragments of inclusions and 1 mm aug and ol disaggregated from them are common. Qtz more abundant, but inclusions, fragments of inclusions, and aug and ol much less abundant in lava flow than in dome. Dome is dense and massively jointed; flow is microvesicular and commonly flow banded. Unit overlies much older altered rocks of Maidu Volcanic Center, but is itself unaltered. Located between Brokeoff Volcano and Maidu Volcanic Center and related to earliest part of Rockland caldera complex. Age is poorly known and estimated to be about same age to slightly older than dacite of Rocky Peak (drp, 803±27 ka). [LP, MN]

dmm **Dacite of Morgan Mountain (early Pleistocene)**—Large, heterogeneous lava dome of porphyritic pyr-hbl dacite (66.6% SiO_2) at Morgan Mountain. Glaciated steep-sided dome has no original surface morphology preserved, is massively jointed, and lacks internal flow structure. Much of it is covered with talus and colluvium and, on lower slopes, till. Phenocrysts: 15–20% pl, 0.5–2 mm, few to 5 mm; 0–3% oxidized hbl, 1–4 mm; 1–2% aug, 0.5–1 mm, few larger; sparse–1% hyp, 0.5–1 mm; 1–3% qtz, mostly 1 mm, few larger. Inclusions to ~20 cm, both pyr-pl and hbl-pl groundmasses are abundant. Fresh rock is medium gray to pink with aphanitic, dense to sparsely microvesicular groundmass, but generally weathered. Located between Brokeoff Volcano and Maidu Volcanic Center and related to earliest part of Rockland caldera complex. Age is poorly known and estimated to be about same age to slightly older than dacite of Rocky Peak (drp, 803±27 ka). [LP, MN]

dcy **Dacite of Canyon Creek (early Pleistocene)**—Porphyritic pyr-hbl dacite (68.0% SiO_2) buried by early Brokeoff Volcano lavas and exposed by erosion in Canyon Creek. Dacite has domical outcrop and massive to thick platy jointing and is probably a lava dome. Lacks an obvious vent. Phenocrysts: 10–12% pl, 0.5–4 mm, mostly 1–2 mm, many reacted and with gray cores; 1–2% hbl, 1–3 mm, mostly pseudomorphed by pyr and Fe-Ti oxide; 1–2% hyp, 0.25–0.5 mm. Groundmass is dark gray, aphanitic, and dense and contains spherulites. Located between Brokeoff Volcano and Maidu Volcanic Center and related to earliest part of Rockland caldera complex. Age is poorly known and estimated to be about same age to slightly older than dacite of Rocky Peak (drp, 803±27 ka). [LP, RP]

MAIDU VOLCANIC CENTER

Rocks of Maidu Volcanic Center rest unconformably on Tuscan Formation (Tt) and are abundant in southern and southwestern parts of map; most of the center lies south and west of map area. Maidu Volcanic Center is moderately well preserved, and its evolution is known in general. However, the interior of Maidu Volcanic Center is hydrothermally altered and deeply eroded; consequently, details of its evolution are poorly known. Three stages of Maidu Volcanic Center rocks correspond to early and late stages of growth of an andesitic stratovolcano (Stages 1 and 2) and subsequent silicic volcanism (Stage 3) peripheral to the andesitic stratocone. Several Stage 3 lava flows (rb, rmp, rlp, rsm) are among the largest rhyolite lava flows in the Cascade Range; their combined volume is ~37 km^3. Maidu Volcanic Center was active 2.4–1.2 m.y.

Stage 3

rb **Rhyolite of Blue Ridge (early Pleistocene)**—Thick (to 150 m) flow of sparsely porphyritic hyp-hbl rhyolite lava (75.4-75.5% SiO_2) that forms extensive plateau covering ~90 km^2 on northwest flank of Maidu Volcanic Center. Lava flowed west from vent in vicinity of Rocky Peak or Grays Peak, but precise location of vent is unknown. Phenocrysts: 5% pl, to 4 mm, mostly 1–2 mm; 1% hbl, to 2 mm, mostly 0.5–1 mm; 1% hyp, 0.5–1 mm. Mafic inclusions absent. Where glassy, rb is light gray to black, flow banded, and perlitic, but more typical rock is devitrified, white to tan and deeply weathered, often strongly flow banded, spherulitic, and lithophysal. Flow morphology of surface and pumiceous carapace were completely obliterated by erosion. Flow is covered by thick, very light colored soil. Volume of lava flow is ~15 km^3. K-Ar ages of 1,150±70 ka (whole rock) and 1,240±110 ka (pl) reported by Gilbert (1969) are consistent with known stratigraphic relations. [GP, LY]

rmp **Rhyolite of Mill Creek Plateau (early Pleistocene)**—Thick (to 150 m) lava flow of sparsely porphyritic hbl-bt rhyolite (75.1-75.9% SiO_2). Erupted from buried vent near west margin of flow. Flowed southeast to form extensive plateau covering ~55 km^2 on east flank of Maidu Volcanic Center; mostly south of map area. Surface flow morphology and pumiceous carapace completely removed by erosion. Flow is covered by a thick, very light colored soil. Includes two small remnants of hbl-bt rhyolite lava flow exposed just south of Morgan Mountain; no vent is apparent. Also includes small body of strongly flow banded and deeply weathered hbl rhyolite lava exposed 0.4 km northwest of Christie Hill, which is almost completely buried beneath younger rocks and till. Phenocrysts (Mill Creek Plateau): 5% pl, to 5 mm, mostly 1–2 mm; 1% bt, 0.5–1 mm; sparse hbl, 1–2 mm, a few larger. Xenocrysts of 1–2 mm hyp disaggregated from crystal clots of hyp+pl are present: mafic inclusions are absent. Locally, rmp is light gray to black, flow-banded, and perlitic, but typically is devitrified, white to tan, deeply weathered, generally strongly flow-banded, spherulitic, and lithophysal. Rare exposures of base of flow reveal light gray vitrophyre. Phenocrysts (flow remnants at Morgan Mountain): 6-8% pl, 0.5–2 mm, few larger; 1–2% bt, 0.5–1 mm; sparse hbl, 1–2 mm, few to 5 mm; sparse qtz, 0.5–1 mm. Groundmass is white to light gray, microvesicular, and glassy to devitrified. Phenocrysts (flow remnant northwest of Christie Hill): 6% pl, 0.5–2 mm; 4% hbl, 0.5–1 mm. Groundmass is flow banded, white to dark gray, and aphanitic. Volume of lava flow is ~7 km^3. Unit overlies andesites of Maidu Volcanic Center, Stage 1, undivided (Tam), andesites of Wild Catle Mountain (Taw), and rhyodacite of Gurnsey Creek (rg); overlain by tholeiitic basalts of Mill Creek Plateau (bmc). Similar in age to rhyolite of Lost Creek Plateau (rlp, 1,305±10 ka) and rhyolite of Blue Ridge (rb, ~1,200 ka). [CM, LP, MN]

rlp **Rhyolite of Lost Creek Plateau (early Pleistocene)**—Thick (to 150 m) lava flow of sparsely porphyritic bt-hbl rhyolite (74.3% SiO_2). Erupted from vent near Wilson Lake and flowed east. Forms extensive plateau covering ~30 km^2 on east flank of Maidu Volcanic Center; mostly south of map area. Surface flow morphology and pumiceous carapace completely removed by erosion. Flow was weakly glaciated, primarily on north flank and has sparse till cover. Flow is covered by a thick, very light colored soil. Phenocrysts: 10% pl, to 5 mm, few larger grains generally composite crystals; 2–3% hbl, to 4 mm; sparse bt, 0.5 mm. Mafic inclusions are absent. When glassy, lava flow is light gray to black, flow banded, and perlitic, but typically it is devitrified, white to tan, deeply weathered, generally strongly flow banded, spherulitic, and lithophysal. Volume of lava flow is ~5 km^3. Unit overlies andesites of Wild Cattle Mountain (Taw) and rhyodacite of Gurnsey Creek (rg); overlain by tholeiitic basalt of Ice Cave Mountain (bic). $^{40}Ar/^{39}Ar$ age is 1,305±10 ka. [CM]

rsm **Rhyolite of North Stover Mountain (early Pleistocene)**—Thick (to 150 m) lava flow of sparsely porphyritic bt-hbl rhyolite (74.1% SiO_2). Erupted from vent near Ice Cave Mountain and flowed southeast. Forms extensive plateau covering ~50 km^2 on east flank of Maidu Volcanic Center; partly south of map area. Surface flow morphology and pumiceous carapace completely removed by erosion. Flow was glaciated, primarily on north side;

covered by a thick, very light colored soil. Cut by major fault associated with Lake Almanor Graben. Phenocrysts: 5% pl, to 5 mm, mostly 1-3 mm; 1% hbl, 1-4 mm; trace bt, 0.5-1 mm. Xenocrysts of aug and hyp, 1-2 mm, are disaggregated from crystal clots of pyr+pl. Mafic inclusions are absent. When glassy, lava flow is light gray to black, flow banded, and perlitic, but typically it is devitrified, white to tan, deeply weathered, generally strongly flow banded, spherulitic, and lithophysal. Rare exposures of flow margins reveal light-gray vitrophyre. Volume of lava flow is ~8.5 km^3. Unit overlies andesites of Dittmar Volcanic Center, Stage 2, undivided (ad2) and andesites of Wild Cattle Mountain (Taw); overlain by tholeiitic basalt of Warner Valley (bwv), basalts and basaltic andesites of Sifford Mountain (bsm), tholeiitic basalts of Buzzard Springs (bbz), and tholeiitic basalt of Ice Cave Mountain (bic). Similar in age to rhyolite of Lost Creek Plateau (rlp, 1,305±10 ka) and rhyolite of Blue Ridge (rb, ~1,200 ka). [CM, ST]

rg **Rhyodacite of Gurnsey Creek (early Pleistocene)**—Small exposure of thick lava flow of coarsely porphyritic aug-hyp rhyodacite at southeast end of Wild Cattle Mountain; bulk of flow is south of map area across Gurnsey Creek. Erupted from vent buried by rhyolite of Mill Creek Plateau (rmp) and flowed east from east flank of Maidu Volcanic Center. Includes small exposure of similar rock in Nanny Creek that probably represents a different flow. Phenocrysts: 15% pl, to 3 mm, mostly 1–2 mm; 2–3% hyp, 0.5–2 mm; sparse–1% aug, 0.5–2 mm, mostly 0.5–1 mm; rare hbl, 0.5 mm. Glomeroporphyritic clots of pl+aug+hyp 5 mm to 5 cm are common; small mafic inclusions are present. Groundmass is nearly white to light gray, aphanitic, and dense. Splotchy areas of spherulites and flow banding are common; jointing is massive. Base of flow dark gray, perlitic, and brecciated. Covered by thick tan to light-orange soil. Volume of lava flow is ~2 km^3. Unit overlies andesites of Wild Cattle Mountain (Taw) and is overlain by rhyolite of Lost Creek Plateau (rlp). Age is similar to slightly older than rlp (1,305±10 ka). [CM, LP]

Stage 2

Tah **Andesites of Hampton Butte (late Pliocene)**—Two thick lava flows of coarsely porphyritic hyp-aug-ol andesite (58.2% SiO_2) form summit of Hampton Butte and cap Stage 2 section of Maidu Volcanic Center in map area. Flowed toward northwest from vent on flank of Maidu Volcanic Center that is not preserved. Deeply weathered flow breccia separates two flows. Flow tops display massive, rounded blocks that contain abundant rounded to flattened elongate vesicles. Flow cores display thick slabby jointing. Unit has well-developed, deep-reddish soil; thin cover of glacial till is common, especially on north slope of Hampton Butte. Relative proportions of mafic phenocrysts are variable in both flows, so descriptions are generalized. Phenocrysts (lower flow): 20% pl, to 3 mm, mostly 1–2 mm; 1–3% ol, 0.5–2 mm, few larger are composite; 4–5% hyp, 0.5–2 mm; 2–3% aug, 0.5–2 mm. Phenocrysts (upper flow): 20% pl, to 3 mm, mostly 1–2 mm; 5–7% ol, 0.5–2 mm, few larger are composite; 2–3% aug, 0.5–2 mm; sparse hyp, 0.5–2 mm. Pl phenocrysts with dark-gray reacted cores are present in both flows but are more abundant in upper flow. Glomeroporphyritic clots of pl+ol+aug+hyp to 1 cm are common in both flows. Ol-bearing mafic inclusions to ~5 cm are sparse but widely distributed in upper flow. Groundmasses are medium to dark gray and glassy to aphanitic. Splotchy areas of vapor-phase crystallization are common, especially in upper part of flows. Unit overlies andesites of Maidu Volcanic Center, Stage 1, undivided (Tam, ~2,150–2,375 ka), andesite of South Fork Battle Creek (Tab, 2,166±67 ka) and dacites of Maidu Volcanic Center, Stage 2, undivided (Tdm, ~2,100–2,150 ka). Unit underlies basaltic andesite of South Fork Battle Creek (mbc, 1,738±46 ka), andesites of Cowslip Campground (acc, 1,320±40 ka), and basaltic andesite of Grays Peak (mgp, 1,080±26 ka). Estimated to be ~2,050–2,100 ka. [GP, LY]

Tdm **Dacites of Maidu Volcanic Center, Stage 2, undivided (late Pliocene)**—Thick (30–100+ m) porphyritic aug-hyp dacite (63.3–65.8% SiO_2) lava flows erupted from vents on upper flanks of the composite volcano that are not preserved. In the map area, flows occur on the north and east flanks of Maidu Volcanic Center. Typical outcrops are glacial cliffs exposing thinly platy jointed flow interiors. Flow tops are composed of oxidized and vesicular, rounded blocks. Phenocrysts: 20–30% pl, mostly 1–3 mm, but to 5 mm; 3–6% hyp, mostly 0.5–1 mm, but to 2 mm; 2–4% aug, mostly 0.5–1 mm, but to 2 mm. Xenocrystic ol is often present in trace amounts, and a few flows contain sparse hbl. Glomeroporphyritic clots of pl+aug+hyp±ol, generally 5 mm to 1 cm, are abundant. Small mafic inclusions containing pl+pyr phenocrysts are rare. Groundmass typically light gray and aphanitic and shows devitrification of glass to cryptofelsite. Unit overlies Tuscan Formation (Tt), basaltic andesite of Lassen Lodge (Tml), andesites of Maidu Volcanic Center, Stage 1, undivided (Tam, ~2,150–2,375 ka), and andesite of South Fork Battle Creek (Tab, 2,166±67 ka). Unit is overlain by andesites of Hampton Butte (Tah), basaltic andesite of South Fork Battle Creek (mbc, 1,738±46 ka), basalt of Panther Creek (bpa, 1,105±49 ka), rhyolite of Blue Ridge (rb, ~1,200 ka), basaltic andesite of Grays Peak (mgp, 1,080±26 ka), dacite of Morgan Mountain (dmm), and basaltic andesite of Huckleberry Lake (mhl). K-Ar age of sample from near Hampton Butte is 2,120±46 ka. K-Ar ages from samples collected outside map area are 2,105±25, 2,140±42, and 2,259±46 ka. Best estimate for the age of Tdm is ~2,100–2,150 ka. [GP, LY, MN]

Stage 1

Tam **Andesites of Maidu Volcanic Center, Stage 1, undivided (late Pliocene)**—Variety of basaltic andesite, andesite, and dacite lava flows forming the older part of Maidu Volcanic Center. Flows and associated fragmental deposits erupted from central vents that cannot be precisely located. Analyzed samples range in composition from 55–65% SiO_2; most are andesite. In the map area, flows are exposed in the cliffs surrounding Battle Creek Meadows, in the canyon of South Fork Battle Creek. Outside the map area, base of unit is exposed in Mill Creek and Deer Creek canyons. Stage 1 andesites are generally porphyritic, typically containing 15–30% phenocrysts, although some sparsely porphyritic and few nearly aphyric lavas are present. Phenocryst size is variable but tends to be 0.5–2 mm. Phenocrysts typically less abundant and smaller than in dacites of Maidu Volcanic Center, Stage 2, undivided (Tdm). Phenocryst assemblages are variable; ol-aug, ol-aug-hyp, aug-hyp, and hyp-aug assemblages occur. Pl is nearly ubiquitous and typically dominates phenocryst assemblage. Glomeroporphyritic clots of pl and mafic minerals are common. Many pyr-andesite lavas contain ol xenocrysts, and hbl or pseudomorphs of hbl are occasionally present. Groundmasses are generally medium to dark gray and aphanitic to glassy; aphanitic textures are most common. In contrast to later Maidu Volcanic Center deposits (Tdm), unit contains considerable intercalated pyroclastic material. Fragmental deposits are not mapped separately; they range from fallout to block-and-ash flow deposits, and lahar deposits are common. Permeable fragmental deposits and brecciated flow carapaces are particularly susceptible to hydrothermal alteration, which was especially intense in area around Christie Hill, Little Round Valley, and Mineral Summit. Unit unconformably overlies Tuscan Formation (Tt). Unit is overlain by andesite of South Fork Battle Creek (Tab, 2,166±67 ka), dacites of Maidu Volcanic Center, Stage 2, undivided (Tdm, ~2,100–2,150 ka), andesites of Hampton Butte (Tah), basaltic andesites of South Fork Battle Creek (mbc, 1,738±46 ka), andesites of Wild Cattle Mountain (Taw), andesites of Cowslip Campground (acc, 1,320±40 ka), andesite of Martin Creek (amr), basalt of Panther Creek (bpa, 1,105±49 ka), dacite of Christie Hill (dch), Rockland tephra (pr, 609±7 ka), basaltic andesite of Huckleberry Lake (mhl), and basalts of Cold Creek Butte (bcc). K-Ar ages of two samples from incipiently hydrothermally altered rock near the top of unit on mountain just north of Mineral are 2,045±42 and 1,905±42 ka, which are probably slightly too young. Four additional K-Ar ages from south of map area are 2,375±49, 2,325±49, 2,250±49, and 2,152±47 ka. Best estimate for the age of Tam is ~2,150–2,375 ka. [LP, LY, MN]

Tab **Andesite of South Fork Battle Creek (late Pliocene)**—Thick complex of finely porphyritic hyp-aug andesite (62.6% SiO_2) lava flows from younger part of Maidu Volcanic Center Stage 1. Lava flow section ~300 m thick where exposed in cliffs above South Fork Battle Creek. Lava probably erupted from a flank vent, flowed generally northwest, and filled a canyon cut into the composite volcano. Flow contacts and interflow breccias are scarce. Flow interiors display thick slabby to thin platy jointing. Phenocrysts: 30% pl, to 1 mm; 7% aug, 0.5–2 mm; 3% hyp, 0.5–1 mm; sparse ol, 1–2 mm. Aphanitic groundmass often has bluish cast but otherwise is very light to medium gray. Unit is youngest Stage 1 lava on northwest flank of the composite volcano. Unit overlies andesites of Maidu Volcanic Center, Stage 1, undivided (Tam, ~2,150–2,375 ka) and is overlain by dacites of Maidu Volcanic Center, Stage 2, undivided (Tdm, ~2,100-2,150 ka), andesites of Hampton Butte

(Tah), basalt of Panther Creek (bpa, 1,105±49 ka), basaltic andesite of Grays Peak (mgp, 1,080±26), and rhyolite of Blue Ridge (rb, ~1,200 ka). K-Ar age is 2,166±67 ka. [GP, LY]

Tml **Basaltic andesite of Lassen Lodge (late Pliocene)**—Porphyritic aug-ol basaltic andesite lava flows probably erupted from Maidu Volcanic Center are located ~5–6 km west of town of Mineral. Near Lassen Lodge, Tml comprises the lowermost lava flows of the volcano in this area. Similar flows outside map area near Judd Creek (Finley Butte and Lyonsville quadrangles) may be related. Phenocrysts: 10–15% pl, 0.5–3 mm, mostly 0.5–1 mm; 3–5% ol, 0.5–2 mm, few larger; 4% aug, 0.5–2 mm, few larger. Groundmass is dark gray to black, aphanitic to glassy, and microvesicular. Some flows have more abundant and larger phenocrysts: 15–20% pl, 0.5–5 mm, mostly 0.5–1 mm; 8% aug, 0.5–5 mm, mostly 0.5–1 mm, few larger; 4% ol, 0.5–3 mm, few larger. These contain abundant glomeroporphyritic clots of ol+pl+aug to 1 cm and probably owe their more abundant crystals to disaggregation of clots. Groundmass is medium gray, aphanitic, and microvesicular. Aug phenocrysts in both lithologies are bright green, indicating a chromian diopside composition. Age is very poorly constrained. Unit overlies Tuscan Formation (Tt), is at the base of Maidu Volcanic Center, and could be equivalent to the oldest part of andesites of Maidu Volcanic Center, Stage 1, undivided (Tam, ~2,150–2,375 ka); estimated to be ~2,350–2,375 ka. [LY]

DITTMAR VOLCANIC CENTER

Rocks of Dittmar Volcanic Center are abundant in southeastern Lassen Volcanic National Park and adjacent Lassen National Forest. Dittmar Volcanic Center sits astride the area connecting the Lake Almanor Graben and Hat Creek Fault and has been structurally dismembered by faulting. Interior of Dittmar Volcanic Center is hydrothermally altered and deeply eroded; consequently, details of its evolution are poorly known. Rocks of Dittmar Volcanic Center are divided into three stages corresponding to early and late stages of the growth of an andesitic stratovolcano (Stages 1 and 2) and subsequent silicic volcanism (Stage 3) peripheral to andesitic stratocone. Dittmar Volcanic Center was active from at least 2.4 to 1.3 m.y. and probably somewhat earlier.

Stage 3

rd3 **Rhyolites of Dittmar Volcanic Center, Stage 3 (early Pleistocene)**—Isolated erosional remnants or buried lava domes and flows of porphyritic bt-, hbl-, and hyp-bearing rhyolite and rhyodacite (70.9–75.0% SiO_2) on north flank of Dittmar Volcanic Center. Includes bodies on Pilot Mountain, in Summit Creek and Grassy Swale, and just east of Hidden Lake. Rocks related to this unit must have been more abundant prior to glaciation, and similar rocks undoubtedly lie buried beneath younger rocks of Lassen Volcanic Center on Central Plateau of LVNP and in Caribou Volcanic Field.

Small area of porphyritic, qtz-bearing, hbl rhyolite (75.0% SiO_2) is exposed in wall of tributary to Summit Creek ~1.6 km north of its juncture with Kings Creek. This rhyolite is strongly flow banded and is probably a thick lava flow; location of vent is unknown. Extent of lava flow is also unknown, but it likely covers large area in subsurface. Phenocrysts: 8% pl, 1–3 mm; 2–3% qtz, 1–2 mm; 1–2% hbl, 1–3 mm; sparse bt, 1 mm. Groundmass is aphanitic and medium gray, sometimes pinkish in color, and spherulitic. Small, fine-grained, aphyric inclusions and fragments of inclusions are common. Flow is mostly buried beneath glacial deposits and probably by andesite of Hat Mountain (ah) lava flows. Lithology is similar to qtz-bearing rhyolite ubiquitously found as lithic fragments in Rockland tephra (pr).

Small body of porphyritic bt-hbl rhyodacite (70.9% SiO_2) caps Pilot Mountain. This rhyodacite has massive to thick platy jointing and is a thick lava flow or lava dome; location of vent is unknown but, perhaps, is buried beneath flow. Phenocrysts: 12% pl, 0.5–3 mm, mostly 0.5–1 mm; 2–3% hbl, 0.5–2 mm; sparse bt, 0.5–1 mm. Rock has a light-gray, almost white, glassy groundmass. Contains abundant inclusions of basaltic andesite composition (54% SiO_2), 5–30 cm in long dimension, although most are 5–15 cm. Some inclusions have distinctive texture of as much as 30% clots of pl+ol+aug in a fine-grained matrix; others lack clusters but contain isolated crystals of same mineral phases. Fragments of inclusions are common in rhyolite, and 0.5–2 mm crystals of pl, ol, and aug were derived from disaggregation of mafic inclusions.

Body of porphyritic bt-hbl rhyodacite (71.6% SiO_2) is exposed on ridge just north of Grassy Swale. This rhyodacite is generally flow banded and has perlitic glassy base with massive to thick platy jointing and appears to be a thick lava flow dipping north; location of vent is unknown, and flow is mostly buried beneath andesite of Hat Mountain (ah) lava flows. Phenocrysts: 10–12% pl, 1–3 mm; 2–3% hbl, 1–3 mm; 1% bt, 1 mm; sparse qtz, 1–2 mm. Groundmass is glassy and very light gray to white, except where perlitic or spherulitic. Small, fine-grained, aphyric inclusions and fragments of inclusions are common.

Small body of porphyritic bt-hyp-hbl rhyolite or rhyodacite is exposed on ridge just east of Hidden Lake. This body has massive to thick platy jointing and is probably a thick lava flow; location of vent is unknown but perhaps is buried beneath flow. Some areas are flow banded, oxidized, and devitrified. Phenocrysts: 10% pl, 1–5 mm, mostly 1–2 mm; 3% hbl, 1–5 mm, mostly 2–4 mm; 2% hyp, 1–2 mm; sparse bt, 0.5–2 mm. Small sparsely porphyritic inclusions and fragments of inclusions are common. Groundmass is glassy and very light gray to white.

K-Ar age of rhyolite lava flow exposed in Summit Creek is 1,273±7 ka. Ages of other rhyolites in this unit are unknown, but they overlie andesites of Dittmar Volcanic Center, Stage 2, undivided (ad2) conformably and are probably 1,250–1,400 ka. [MH, RP]

Stage 2

ad2 **Andesites of Dittmar Volcanic Center, Stage 2, undivided (early Pleistocene)**—Thick (30–60 m) lava flows of porphyritic aug-hyp andesite (58–63% SiO_2) and sparse dacite (63–64% SiO_2) that covered the flanks of the volcano. Flows exposed in south face of upper part of Saddle Mountain are generally thinner (10–20 m). Erupted from vents probably located on upper slopes or at the summit of volcano and not preserved. These flows dip radially away from core area of Dittmar Volcanic Center, which was centered just southwest of Saddle Mountain. Intercalated pyroclastic material generally is lacking. Largest exposures are in fault blocks of Kelly Mountain and the ridge southwest of Willow Creek, and on north slopes of Saddle Mountain. Typical outcrops are glacial cliffs exposing flow interiors that are thinly platy jointed and locally columnar jointed. Flow tops are composed of oxidized and vesicular, rounded blocks. Phenocrysts: 20% pl, 0.5–2 mm; 6–8% hyp, mostly 0.5–1, but to 2 mm; 2–4% aug, mostly 0.5–1, but to 2 mm. Xenocrystic ol locally present in trace amounts. Glomeroporphyritic clots of pl+aug+hyp±ol generally 5 mm–1 cm are abundant and diagnostic. Mafic inclusions containing pl+pyr phenocrysts are present in some flows but are generally small and sparse. Groundmass is typically light gray, but often pinkish. Samples from flow interiors are aphanitic and usually show devitrification of glass to cryptofelsite. Three related units, andesite of Benner Creek (ab), andesite of Doe Mountain (adm), and andesite of Domingo Spring (ads) are correlated with ad2. K-Ar age of one sample is 1,398±42 ka. [MH, PP, RP, ST]

adm **Andesite of Doe Mountain (early Pleistocene)**—Small dome-shaped mass of porphyritic aug-hyp andesite correlated with andesites of Dittmar Volcanic Center, Stage 2, undivided (ad2). Probably erupted from a vent now buried by dome. Glaciation and erosion modified original morphology of dome. Phenocrysts: 15% pl, 1–5 mm; 4% hyp, mostly 0.5–1, but to 2 mm; 2% aug, mostly 0.5–1, but to 2 mm. Glomeroporphyritic clots of pl+aug+hyp, generally ~5 mm, are abundant. Mafic inclusions containing pl+pyr phenocrysts are present but generally small and sparse. Groundmass is light gray, glassy to aphanitic, and dense. Unit overlies andesites of Maidu Volcanic Center, Stage 1, undivided (Tam), andesites of Wild Cattle Mountain (Taw), and dacites of Maidu Volcanic Center, Stage 2, undivided (Tdm). Although correlated with Dittmar Volcanic Center, that relation is not clear, and adm may be associated with Maidu Volcanic Center. Age is similar to ad2 (1,398±42 ka) and probably 1,400–1,600 ka. [CM, MN]

ads **Andesite of Domingo Spring (early Pleistocene)**—Small dome-shaped mass of porphyritic aug-hyp andesite (61.9% SiO_2) probably correlates with andesites of Dittmar Volcanic Center, Stage 2, undivided (ad2). Probably erupted from a vent now buried by dome. Faulting and glaciation modified original morphology of dome. Phenocrysts: 20% pl, 0.5–2 mm; 6% hyp, mostly 0.5–1, but to 2 mm; 4% aug, mostly 0.5–1, but to 2 mm. Glomeroporphyritic clots of pl+aug+hyp, generally 5 mm–1 cm are abundant. Mafic inclusions containing pl+pyr phenocrysts are present but generally small (to 10 cm) and sparse. Groundmass is light gray, glassy to aphanitic, and sparsely microvesicular. Age is similar to ad2 (1,398±42 ka) and probably 1,400–1,600 ka. [MH, ST] ab **Andesite of Benner Creek (early Pleistocene)**—Thick (30–60 m) block lava flows of porphyritic hyp-aug andesite exposed in north end of graben occupied by Lake Almanor. Exposures are unglaciated and have conspicuous rounded vesicular boulders forming carapace of flow. Base of flow is black, glassy, dense vitrophyre. Small scattered exposures beneath till north of mapped exposures indicate additional flow is buried beneath till. Phenocrysts: 10–15% pl, 0.5–4 mm, mostly 1–2 mm; 3% aug, 0.5–1 mm, few to 2 mm; 1% hyp, 0.5–1 mm. Groundmass is medium to dark gray and glassy to aphanitic. Glomeroporphyritic clots of pl+aug+hyp to 5 mm are common; small andesitic inclusions are sparse. Correlated with andesites of Dittmar Volcanic Center, Stage 2, undivided (ad2, 1,398±42 ka) and is probably similar age (1,400–1,600 ka). [CH, ST]

Stage 1

Tad **Andesites of Dittmar Volcanic Center, Stage 1, undivided (late Pliocene to early Pleistocene)**—Early part of Dittmar composite cone is composed of lithologically diverse, generally thin, basaltic andesite to andesite lava flows and fragmental deposits and sparse rhyodacite pyroclastic deposits. Flows range in composition from 55.7 to 68% SiO_2, but the majority contain 55.7–58.4 SiO_2. Rhyodacite ash flow (68.4% SiO_2) is exposed on north flank of Kelly Mountain. Base of Dittmar Volcanic Center section may be exposed in Hot Springs Creek and at base of Saddle Mountain, where andesite flows overlie hydrothermally altered, thick dacite and rhyodacite lava flows and domes(?) that may be older than Dittmar Volcanic Center. Relations among these rocks are obscure, and they have not been mapped separately. Andesite flows are generally porphyritic, typically containing 10–20% phenocrysts, although some sparsely porphyritic and a few nearly aphyric lavas are present. Phenocryst size is variable but tends to be 0.5–2 mm; ol-aug, ol-aug-hyp, aug-hyp, and hyp-aug assemblages are present. Pl is nearly ubiquitous and typically dominates the phenocryst assemblage, but pl-poor lavas also are present. Glomeroporphyritic clots of pl and mafic minerals are common. Many pyr andesite lavas contain ol xenocrysts; hbl is rare. Rhyodacite ash flow is sparsely porphyritic, contains aug, hyp, and pl phenocrysts, and is variably welded. In lower part of section, it is common for adjacent flows to have different phenocryst assemblages and (or) abundances. Groundmasses are generally medium to dark gray and aphanitic to glassy. Higher in section, andesites typically occur as packages of similar flows, but adjacent packages have different lithologies. Hydrothermal alteration and poor exposure limit recognition of fragmental deposits (which are not mapped separately). These range from fallout to lithic pyroclastic flow deposits; lahar deposits are common, and pumiceous pyroclastic flows are sparsely present in Kelly Mountain area. K-Ar ages of three samples are 1,650±35 ka, 1,785±35 ka and 2,315±29 and indicate a long eruptive history for early phase of Dittmar Volcanic Center. [MH, PP, RP, ST]

Taw **Andesites of Wild Cattle Mountain (late Pliocene)**—Variety of thin, porphyritic, hyp-aug-ol, hyp-ol-aug, and hyp-aug andesite (59.6% SiO_2) lava flows correlated with Dittmar Volcanic Center. Wild Cattle Mountain comprises a series of south-dipping andesite lava flows; vent locations are unknown but presumably were to the northeast and are not preserved. Flow contacts and interflow breccias are rarely exposed. Includes bedded pyroclastic rocks near base of section on Wild Cattle Mountain. Abundance and size of phenocrysts is variable; composition more variable than single analysis indicates. Includes coarsely porphyritic, propylitically altered aug andesite lava flows north of Feather River Meadows. Phenocrysts (Wild Cattle Mountain): 6–12% pl, 0.5–5 mm, mostly 0.5–2 mm; 2–4% aug, 0.5–2 mm, mostly 0.5–1 mm; 1–3 % ol, 0.5–2 mm, mostly 0.5–1 mm; 1–3 % hyp, 0.5–2 mm, mostly 0.5–1 mm. A few flows lack larger pl phenocrysts; some lack ol. Glomeroporphyritic clots of pl+aug+hyp±ol are common to abundant. In some flows, many phenocrysts were derived from disaggregated glomeroporphyritic clots. Small quenched andesitic inclusions are sparse in some flows. Groundmass is light to medium gray, aphanitic, and dense. Cores of lava flows generally have thin platy jointing, but some are massive. Phenocrysts (Feather River Meadows): 8–12% pl, 0.5–6 mm, mostly 0.5–3 mm; 2–3% aug, 0.5–2 mm, few to 5 mm. Glomeroporphyritic clots of pl+aug to 5 mm are common. Rock is weakly altered; groundmass and some phenocrysts are partially replaced by chlorite, calcite, and qtz. Groundmass is greenish dark gray, aphanitic and dense. Unit overlies andesites of Maidu Volcanic Center, Stage 1, undivided (Tam). Unit is overlain by rhyodacite of

Gurnsey Creek (rg), rhyolite of Lost Creek Plateau (rlp, 1,305±10 ka), rhyolite of North Stover Mountain (rsm), andesite of Rice Creek (ar, 477±14 and 485±12 ka), and tholeiitic basalt of Ice Cave Mountain (bic). The lithology and composition are similar to lava flows exposed in cliffs of Saddle Mountain mapped as andesites of Dittmar Volcanic Center, Stage 1, undivided (Tad). Unit is interpreted to correlate with upper part of Tad and to be southwest flank of Dittmar Volcanic Center. Age is poorly constrained but is likely to be ~1,600–2,000 ka. [CM, LP, MN, RP]

LATOUR VOLCANIC CENTER

Small part of Latour Volcanic Center (mostly outside map area north and west of North Battle Creek Reservoir) is located in north part of Viola quadrangle. Latour Volcanic Center appears to consist of an andesitic volcano at Latour Butte and flanking silicic rocks similar to other volcanic centers in Lassen area.

Tlv **Rocks of Latour Volcanic Center (late Pliocene)**—Dominated by porphyritic hbl-bt rhyolite, bt-hbl dacite, and hyp-aug andesite. Constructional morphology is poorly preserved, and vents have not been located. Obscured by thick soils. In area west of North Battle Creek Reservoir, most abundant rock is porphyritic hbl-bt rhyolite (74.9% SiO_2); most of Latour Volcanic Center in map area consists of this lithology. Rhyolite is a thick flow that erupted from vicinity of Buck Butte (Viola quadrangle) and flowed south into map area. Phenocrysts: 12% pl, 0.5–3 mm, mostly 1 mm; 6% qtz, 0.5–2 mm; 1% bt, 0.5–2 mm, mostly 0.5 mm; sparse hbl, 1 mm. Small, quenched magmatic inclusions containing 1 mm aug phenocrysts are common. Groundmass is light gray, glassy, and dense when fresh, but typically light to medium gray, devitrified, and locally spherulitic. Often flow banded, massively jointed, and usually deeply weathered.

Underlying rhyolite north of North Battle Creek Reservoir is poorly exposed porphyritic bt-hbl dacite. Phenocrysts: 15% pl, 0.5–4 mm, larger crystals are composite; 2–3% hbl, 1–3 mm; 1% qtz, 0.5–1 mm; sparse bt, 1 mm; sparse hyp, 0.5–1 mm. Most hbl and bt are reacted and pseudomorphed by pyr, oxides, and pl; qtz crystals are rounded. Small quenched magmatic inclusions are common. Groundmass is aphanitic and microvesicular. When fresh, rock is light gray, but often it is oxidized to a pinkish-gray cast.

Most common andesitic lithology is porphyritic hyp-aug andesite that probably underlies other Latour Volcanic Center rocks in map area. Phenocrysts: 15–25% pl, 0.5–4 mm, many with gray cores; 3–5% hyp, 0.5–1 mm; 2-4% aug, 0.5–2 mm. Glomeroporphyritic clots of pl+hyp+aug are common. Groundmass is dark gray to black, glassy to aphanitic, and dense. K-Ar age of andesite lava flow is 3,140±67 ka and indicates that Latour Volcanic Center is much older than the overlying lavas mapped as older regional andesites and basaltic andesites, undivided (am). [VI]

TUSCAN FORMATION

Tt **Tuscan Formation (late Pliocene)**—Within the map area, the Tuscan Formation is exposed only in extreme southwest corner, where the deposits were derived from Yana Volcanic Center (fig. 4*A*, south of map area). Deposits are predominantly debris-flow breccias composed of angular to subrounded fragments of volcanic rock, as much as 3 m in diam but mostly from a few to 20 cm, in a matrix of gray-tan volcanic sand and silt. Individual debris flows 0.5 to 10 m thick deposited as sheets over gently sloping terrain or as lenses in drainages. Debris-flow deposits are poorly sorted and often reversely graded, and upper and lower contacts are usually sharp. Thin weathered zones occur between some debris-flow deposits. Tuscan debris-flow deposits are strongly to weakly consolidated. Most debris flows were generated as direct result of eruptive processes, and many were probably emplaced hot or warm. Consolidated debris-flow deposits are resistant to erosion and form benches on steep canyon walls. A variety of clasts are present, but porphyritic ol and ol-aug basaltic andesites and pyr andesites are most common. In and just south and west of map area, unit consists of only uppermost part of Tuscan Formation and is overlain by rocks of Maidu Volcanic Center. Equivalent rocks in Yana Volcanic Center range in age from ~3,300 to ~2,700 ka; overlying Maidu Volcanic Center rocks are as old as ~2,400 ka. Tuscan Formation in map area was probably deposited close to 2,700 ka. [LY]

REGIONAL VOLCANIC ROCKS

NORTH AND WEST OF LASSEN VOLCANIC CENTER

Includes rocks related to regional volcanism (calc-alkaline and tholeiitic) erupted from monogenetic volcanoes and small- to moderate-sized lava cones and shield volcanoes of all ages in axis of Cascade Arc in area north and west of Lassen Volcanic Center. Area approximately bounded on east by trace of Hat Creek Fault-Lake Almanor Graben system. Major features include Tumble Buttes and Sugarloaf chains of monogenetic cones and Prospect Peak, West Prospect Peak, Badger Mountain, Table Mountain, and Red Lake Mountain shield volcanoes.

Late Pleistocene volcanic rocks

Late Pleistocene volcanic rocks (11.7–125 ka) in the areas north and west of Lassen Volcanic Center. Includes the Tumble Buttes and Sugarloaf chains of small, monogenetic cinder cones and lava flows, a few larger lava cones and shield volcanoes like Red Mountain and Red Lake Mountain, and the voluminous tholeiitic Hat Creek Basalt lava flow. These young volcanoes are well-preserved constructional features that are not disrupted by faults and are unglaciated to weakly glaciated.

bhc **Hat Creek Basalt (late Pleistocene)**—Sparsely porphyritic, tholeiitic, ol basalt (48.1–49.0% SiO_2) lava-flow complex. This tube-fed pahoehoe lava field consists of many flow units erupted from a 3 km-long fissure capped by spatter cones, just south of Old Station. Lava flowed north into and filled Hat Creek Graben for 20 km to Cassel area (north of map area; fig. 1). Phenocrysts: trace–2% ol, 0.5–2 mm, few larger; 0–5% pl, 0.5–2 mm, few larger. Bulk of lava is sparsely porphyritic; phenocrysts are more abundant in earliest-erupted lava found near vent fissure, and this lava locally contains glomeroporphyritic clots of ol+pl to 5 mm. Groundmass is light to medium gray and holocrystalline and is typically a coarsely diktytaxitic intergrowth of pl, ol, pyr, and Fe-Ti oxide microphenocrysts. Lava typically has hexagonal block-joint pattern at top and massive jointing in interior of flow units. Flow has abundant round vesicles at upper and lower surfaces. Surface of flow is rough and sparsely vegetated, and tumuli and pahoehoe surfaces are common. Cut by most recent episode of movement on Hat Creek Fault, but scarps as high as 30 m high do not expose the base of the flow (Muffler and others, 1994). Unsubstantiated information from local water-well drillers suggests that flow may be as thick as 50 m in center of Hat Creek Graben; its volume is substantial, perhaps as much as 5 km^3. Outwash gravel of middle Wisconsin age (outwash gravel of Anklin Meadows, Qoa) overlies lava flow (Muffler and others, 1994). Outwash gravels related to older glacial advances are not present, and flow is constrained to between 15 and ~40 ka. North of map area, flow overlies andesite of Sugarloaf Peak (ass, 46±7 ka) and lavas from Cinder Butte (north of map area) that were dated as 38±7 ka (Turrin and others, 2007). $^{40}Ar/^{39}Ar$ age of 24±6 ka (Turrin and others, 2007) is consistent with the stratigraphy. [OS]

Tholeiitic basalts of Big Lake (late Pleistocene)—Two units comprise a zoned porphyritic ol basalt lava-flow and cinder-cone complex (48.6–50.6% SiO_2), partly north of map area. Unit 1 (bk1) erupted from a vent in the vicinity of hill 6051. Subsequently, scoria of unit 2 (bk2) built cinder cones and buried bk1 vent; followed by emplacement of several lava flows. Lava flows fill a small graben and dammed drainage to form Big Lake (just north of map area; see fig. 3). One flow crossed basin now filled by North Battle Creek Reservoir and flowed 2 km down North Fork Battle Creek. Lava flows cross several regional faults but are not offset by them. Cinder cones have a soil several meters thick. Both units overlie older regional andesites and basaltic andesites, undivided (am), but age is otherwise poorly constrained. Age is estimated to be 50–75 ka. [MZ, TH, VI]

bk2 **Unit 2—**Moderately thick lava flows (10–30 m) and cinder cones of porphyritic ol basalt (48.6% SiO_2). Phenocrysts: 5% ol, 0.5–1 mm, few larger; 5% pl, 0.5–2 mm, mostly ~1 mm. Most phenocrysts are part of glomeroporphyritic clots of 0.5–1 mm ol+pl, which are abundant and as large as 1 cm. Groundmass is dark gray, aphanitic, and extremely microvesicular; jointing is blocky to massive. [MZ, TH, VI]

bk1 **Unit 1—**Moderately thick flow (10–20 m) and cinder cone of sparsely porphyritic ol basalt (50.6% SiO_2). Phenocrysts: 5% ol, 0.5–1 mm, few larger; 2% pl, 0.5–1 mm. Glomeroporphyritic clots of 0.5–1 mm ol+pl are present and as large as 5 mm, but are much less abundant than in bk2. Groundmass is dark gray, aphanitic, and microvesicular; jointing is blocky. [MZ, VI] meh **Basaltic andesite of Eskimo Hill (late Pleistocene)**—Porphyritic, ol-aug basaltic andesite (54.5% SiO_2) lava flow and cinder cone satellitic to Red Lake Mountain. Lava flowed from cinder cone south for 1 km. Aa flow surface is unglaciated and sparsely vegetated. Phenocrysts: 25% pl, generally 0.5–1 mm, a few to 1.5 mm; 8% bright-green diopsidic aug, generally 1 mm, a few to 2 mm; 5% ol, mostly 1 mm, a few to 2 mm. Small clots of ol+aug are common. Groundmass is medium gray, glassy to aphanitic, and microvesicular. Unit is presumed to be coeval with lithologically identical early stage of basaltic andesite and andesite of Red Lake Mountain (mrd). It is slightly older than pumiceous pyroclastic-flow deposits (pe, 66±4 ka) from Eagle Peak and is estimated to be ~75 ka. [MZ]

mrd **Basaltic andesite and andesite of Red Lake Mountain (late Pleistocene)**—Thin aa to block-lava flows and large scoria cone of porphyritic ol-aug basaltic andesite (54.0–54.4% SiO_2). Relatively small volume of late-stage hyp-ol-aug andesite (58.8% SiO_2) forms bocca on northwest side of cone (not mapped separately). Lava erupted from cone and flowed nearly 10 km west, buried faults in older terrane, and filled topography. Flow surfaces are rough and unglaciated with weakly developed soil and sparse vegetation. Phenocrysts (early stage): 25% pl, 0.5–1 mm, few to 1.5 mm; 8% bright green diopsidic aug, 1 mm, few to 2 mm; 5% ol, 1 mm, few to 2 mm. Phenocrysts (late stage): 20% pl, 0.5–1 mm, few to 1.5 mm; 8% bright green diopsidic aug, 1 mm, few to 2 mm; 2% ol, 1 mm, few to 2 mm; 1% hyp, < 0.5 mm. Small clots of ol+aug are common. Groundmass is medium gray, glassy to aphanitic, and microvesicular. Overlies older regional andesites and basaltic andesites, undivided (am), andesite of Table Mountain (at), andesite of Manzanita Creek (amz), tholeiitic basalt of Eagle Canyon (bec, 199±22 ka), avalanche deposit from dacite of hill 8283 (Qs82), basalt of Cherry Thicket (bct), andesite of Viola (av, 313±8 ka), and basaltic andesite of Red Mountain (mrm) and is overlain by slightly younger pumiceous pyroclastic-flow deposits (pe, 66±4 ka) from Eagle Peak; age estimated to be ~75 ka. [MZ, VI]

mrm **Basaltic andesite of Red Mountain (late Pleistocene)**—Thick aa to block-lava flows and scoria cone of porphyritic ol-aug basaltic andesite (54.5% SiO_2). Lava flows have rough, unglaciated flow surfaces that have considerably better developed soil and more forest than overlying basaltic andesite and andesite of Red Lake Mountain (mrd). Lava erupted from cone of Red Mountain and flowed for as much as 6 km east. Lava buried faults in older regional andesites and basaltic andesites, undivided (am) and filled topography. Phenocrysts: 7% bright green diopsidic aug, 1 mm, few to 2 mm; 3% ol, 1 mm, few to 2 mm. Small clots of ol+aug are common; qtz xenocrysts are sparse. Pl microphenocrysts, generally to 0.5 mm, but with a few to 1 mm, compose ~30% of rock. Groundmass is medium gray, aphanitic, and microvesicular. Unit overlies andesite of Grayback Ridge (agr), andesite of Table Mountain (at), andesite of Ashpan Butte (aa), and andesite of Raker Peak (arp, 270±18 ka). Unit is overlain by basaltic andesite and andesite of Red Lake Mountain (mrd) and pumiceous pyroclastic-flow deposits (pe, 66±4 ka) from Eagle Peak. Its relation with andesite of Tumble Buttes (att) is unclear, but it is probably older. Age is estimated to be ~75–100 ka. [MZ]

Tumble Buttes chain

The Tumble Buttes chain comprises a linear zone of cinder cones and lava flows 12 km long trending N. 15° W., approximately coincident with the Cascade Arc axis a few kilometers north of the Lassen Volcanic Center. The linear array of vents is parallel to nearby faults and probably reflects an underlying fault that served as a conduit for magma. Ten mapped units of basaltic andesite and andesite occur on the map, and three additional units are present north of the map area. The Tumble Buttes chain lies mostly outside the area of the youngest glaciation, and cinder cones and flow surfaces are well preserved. The similar lithology and composition of Tumble Buttes chain units suggest that the chain represents a relatively short lived episode of volcanism. Based on a $^{40}Ar/^{39}Ar$ age for the andesite of Bear Wallow Butte (abt, 35.1±3.1 ka), 9 of the 13 units are estimated to be 35–50 ka in age. A few units are interpreted to be slightly older, 50–75 ka, and andesite of Mud Lake (mtm) may be as old as about 100 ka. The youngest unit, andesite of Devils Rock Garden (atd), is one of the youngest regional lava flows in the Lassen area and is probably 10–15 ka. The interpreted eruptive order of the Tumble Buttes chain units is based on known stratigraphic relations. However, some units do not have definitive stratigraphic relations, and the eruptive order may be subject to revision.

atd **Andesite of Devils Rock Garden (late Pleistocene)**—Thick (to 60 m), sparsely porphyritic ol-aug andesite (58.2% SiO_2) block-lava flow. Flow has conspicuous irregular flow levees and rugged surface with significant relief. Vent marked by small parasitic cinder cone on south flank of southern of two cones called Tumble Buttes, just north of map boundary. Phenocrysts: 3% pl, 0.5–1 mm; 1% aug, 0.5–1 mm; sparse ol, 0.5–1 mm. Glomeroporphyritic clots of all three phenocryst phases, dominated by pl, are sparse and as large as a few millimeters across. Groundmass is medium gray, glassy to aphanitic, and sparsely microvesicular. Rock has flow layering defined by thin oxidized zones of vapor-phase crystallization. Age is unknown, but it is one of youngest flows in Lassen area as indicated by lack of soil and forest cover; Macdonald (1963) suggested that it might be Holocene. Overlies all adjacent lava flows including andesite of Logan Mountain (alg) and basaltic andesites of Magee Volcano (mm), and other flows of Tumble Buttes chain: basaltic andesite of hill 6770 (mt67), basaltic andesite of Tumble Buttes (mtu), basaltic andesite of Mud Lake (mtm), basaltic andesite of section 5 (mt5), and basaltic andesite of hill 6138 (mt61). Relation to glacial deposits is unclear, but unit probably is younger than till, younger glaciations (Qty, ~17–35 ka) and outwash gravel, younger glaciations (Qoy, ~15–18 ka in this area). Estimated to be 10–15 ka. [TH]

atb **Andesite of Bear Wallow Butte (late Pleistocene)**—Thick block-lava flow with as much as 40-m-high flow fronts of porphyritic aug-ol andesite (57.0% SiO_2). Unit is southernmost of youthful Tumble Buttes chain of volcanoes. Scoria cone marks vent, and lava flowed mostly to south and east for as much as 3 km. Lava flow is unglaciated and, although it supports a few mature trees near margins, is generally devoid of soil or vegetation. Phenocrysts: 5% pl, generally 0.5 mm but occasionally to 1.5 mm; 3% ol, 1–2 mm; 2% aug, 0.25–0.5 mm. Glomeroporphyritic clots of pl+ol+aug, 1–10 mm, are abundant. Groundmass is microvesicular, dark gray, and glassy to aphanitic. Overlies all adjacent lava flows including older regional andesites and basaltic andesites (am), tholeiitic basalt of Twin Bridges (btb), andesite of Ashpan Butte (aa), and basaltic andesite of Red Mountain (mrm). Overlies other Tumble Buttes chain flows including basaltic andesite of Mud Lake (mtm), basaltic andesite of section 5 (mt5), basaltic andesite of hill 6138 (mt61), basaltic andesite of Bear Wallow Butte (mtb), basaltic andesite of hill 5410 (mt54), and andesite of Tumble Buttes (att). $^{40}Ar/^{39}Ar$ age is 35.1±3.1 ka. [MZ, OS, TH, WP]

mt67 **Basaltic andesite of hill 6770 (late Pleistocene)**—Thick (20–40 m) aa to block lava flow of porphyritic ol-aug basaltic andesite (56.3% SiO_2). Vent marked by the northern of two cinder cones labeled Tumble Buttes (hill 6770; off map area to north). Lava from cone flowed 4 km southwest. Has well-defined marginal flow levees and a rugged surface with significant relief. Phenocrysts: 7% pl, 0.5–1 mm, few to 2 mm; 1–2% ol, 0.5–1 mm; 1–2% aug, 0.5–1 mm. Glomeroporphyritic clots of all three phenocryst phases, but dominated by pl, are sparsely present and as large as 5 mm. Groundmass is medium gray, glassy to aphanitic, and microvesicular. Irregular vesicles are abundant. Age is not well constrained, but it underlies andesite of Devils Rock Garden (atd) and overlies basaltic andesite of Tumble Buttes (mtu). Lack of well-developed soil and forest cover indicates relative youth; estimated to be 35–50 ka. [TH]

mtu **Basaltic andesite of Tumble Buttes (late Pleistocene)**—Thin aa to block-lava flow (5–15 m) of porphyritic ol basaltic andesite (55.7–56.3% SiO_2). Vent was in area of northern of two cinder cones labeled Tumble Buttes (hill with elevation 6770, north of map area) and was probably buried by basaltic andesite of hill 6770 (mt67). Lava flowed for 2 km from vent and has a rugged, sparsely forested surface. Phenocrysts: 5% ol, 0.5–3 mm; 3% pl, 0.5–2 mm; sparse aug, 0.5–1 mm. Many phenocrysts occur as small glomeroporphyritic clots of ol+pl. Groundmass is dark gray to black, glassy to aphanitic, and sparsely microvesicular. Age is unknown, but lack of well-developed soil or forest cover indicates relative youth. It is clearly older than andesite of Devils Rock Garden (atd) and basaltic andesite of hill 6770 (mt67) and is probably slightly older than andesite of Bear Wallow Butte (atb). Estimated age is 35–50 ka. [TH]

mt54 **Basaltic andesite of hill 5410 (late Pleistocene)**—Thin (5–10 m) aa to block-lava flow of porphyritic ol-aug basaltic andesite. Vent marked by cinder cone just east of Bear Wallow Butte. Second cone lies ~300 m to east. Lava flowed northeast for ~1 km and partially buried older faulted terrane of older regional andesites and basaltic andesites (am). Part of flow probably buried by andesite of Bear Wallow Butte (atb). Phenocrysts: 10% pl, 0.5–1 mm, few to 2 mm; 6% aug, 0.5–2 mm; 2% ol, 0.5–1 mm, few to 2 mm. Glomeroporphyritic clots of all three phenocryst phases, dominated by pl, are common and as large as 5 mm. Groundmass is medium gray, glassy to aphanitic, and microvesicular. Vesicles with irregular shapes are abundant. Overlies older regional andesites and basaltic andesites (am), basaltic andesite of section 5 (mt5), and andesite of Tumble Buttes (att). Age is poorly constrained, but unit is overlain by atb (35.1±3.1 ka). Lack of well-developed soil and forest cover indicates relative youth; estimated to be 35–50 ka. [TH]

mtb **Basaltic andesite of Bear Wallow Butte (late Pleistocene)**—Thin (5–10 m), aa to block-lava flow of sparsely porphyritic aug-ol basaltic andesite (56.5% SiO_2). Vent marked by cinder cone just north of Bear Wallow Butte. Lava flowed from vent to both east and west for ~3 km. Andesite of Bear Wallow Butte (atb) partly buries the flow. Phenocrysts: 2% ol, 0.5–2 mm; 2% pl, 0.5–2 mm; sparse aug, as large as ~0.5 mm. Glomeroporphyritic clots of all three phenocryst phases, dominated by pl, are common and as large as 5 mm. Groundmass is dark gray, glassy to aphanitic, and microvesicular. Vesicles with irregular shapes and smooth walls are abundant. Overlies basaltic andesite of Mud Lake (mtm), basaltic andesite of section 5 (mt5), and basaltic andesite of hill 6138 (mt61). Age is not well constrained, but unit is overlain by atb. Nevertheless, lack of well-developed soil and forest cover indicates relative youth; estimated age is 35–50 ka. [TH]

mt61 **Basaltic andesite of hill 6138 (late Pleistocene)**—Thin (5–15 m) aa to block lava flow of porphyritic ol-aug basaltic andesite (55.2–55.6% SiO_2). Vent marked by cinder cone just north of Bear Wallow Butte. Lava flowed for ~2 km southeast and was subsequently partially buried by andesite of Devils Rock Garden (atd). Phenocrysts: 14% pl, 0.5–2 mm; 4% aug, 0.5–2 mm; 2% ol, 0.5–1 mm, few to 2 mm. Glomeroporphyritic clots of all three phenocryst phases, dominated by pl, are common and as large as 5 mm across. Groundmass is medium gray, glassy to aphanitic, and microvesicular. Irregular vesicles are abundant. Lava flow buries faulted older regional andesites and basaltic andesites (am) and is unglaciated. Overlies basaltic andesite of Mud Lake (mtm) and basaltic andesite of section 5 (mt5) and is overlain by basaltic andesite of Bear Wallow Butte (mtb), andesite of Bear Wallow Butte (atb), and andesite of Devils Rock Garden (atd). Lack of well-developed soil and forest cover indicates relative youth, and unit is estimated to be ~50 ka. [TH]

mt5 **Basaltic andesite of section 5 (late Pleistocene)**—Thick (20–30 m) aa to block lava flow of porphyritic aug-ol basaltic andesite (55.9% SiO_2). Flow has well-defined marginal flow levees and rugged oxidized and clinkery surface with significant relief. Vent marked by cinder cone kipuka surrounded by andesite of Devils Rock Garden (atd). Lava from vent emerges from beneath atd and can be traced for 2 km southeast. Phenocrysts: 12% pl, mostly 0.5–2 mm, few to 4 mm; 6% ol, 0.5–2 mm; 2–3% aug, 0.5–2 mm. Majority of phenocrysts occur in glomeroporphyritic clots of all three phenocryst phases, dominated by pl, and are as large as 8–10 mm. Groundmass is dark gray, aphanitic, and microvesicular. Unit overlies andesite of Logan Mountain (alg) and is overlain by andesite of Devils Rock Garden (atd), basaltic andesite of Bear Wallow Butte (mtb), and basaltic andesite of hill 6138 (mt61). Lack of well-developed soil and forest cover indicates relative youth; estimated to be ~50 ka. [TH]

att **Andesite of Tumble Buttes (late Pleistocene)**—Thin (5–10 m), porphyritic ol-aug andesite (57.7% SiO_2) aa to block-lava flow erupted from vent subsequently buried by andesite of Bear Wallow Butte (atb). Lava flowed southeast for ~4 km. Large irregular vesicles that commonly contain opaline silica are characteristic. Flow is unglaciated and has a poorly developed soil and forest cover. Phenocrysts: 2–3% ol, 1–2 mm; 2–3% pl, mostly 0.5–1 mm, with a few to 1.5 mm; trace aug to ~0.5 mm. Glomeroporphyritic clots of all three phenocryst phases, dominated by pl, are abundant and as large as 5 mm across. Groundmass is black and glassy to aphanitic. Overlies older regional andesites and basaltic andesites (am) and basalt of Twin Bridges (btb) and is overlain by andesite of Bear Wallow Butte (atb) and basaltic andesite of hill 5410 (mt54). Probably younger than basaltic andesite of Red Mountain (mrm). Age is poorly constrained, but lack of well-developed soil and forest cover indicates relative youth. Unit is probably not substantially older than atb (35.1±3.1 ka); estimated to be 50–75 ka. [MZ, OS, TH, WP]

mtm **Basaltic andesite of Mud Lake (late Pleistocene)**—Thin (5–10 m) aa to block-lava flow of porphyritic, aug-ol basaltic andesite. Vent unlocated, probably buried beneath andesite of Devils Rock Garden (atd). Phenocrysts: 2% pl, 0.5–1 mm; 1% ol, 0.5–1 mm; sparse aug, 0.5–1 mm. Glomeroporphyritic clots of all three phenocryst phases, dominated by pl, are sparse and as large as 5 mm across. Groundmass is medium gray, glassy to aphanitic, and microvesicular. Vesicles with irregular shapes are abundant. Unit overlain by all adjacent rock units: andesite of Devils Rock Garden (atd), basaltic andesite of hill 6138 (mt61), basaltic andesite of Bear Wallow Butte (mtb), and andesite of Bear Wallow Butte (atb). Unit is unglaciated. Age is poorly constrained, but better-developed soil indicates one of oldest lavas in Tumble Buttes chain. Estimated to be 75–100 ka. [TH]

Sugarloaf chain

The Sugarloaf chain comprises a linear zone of cinder cones and lava flows 12 km long trending N. 15° W. approximately coincident with the west boundary of the Hat Creek Graben. The linear array of vents is parallel to nearby faults and probably reflects an underlying fault that served as a conduit for magma. Five mapped units of basaltic andesite and andesite occur on the map, and three additional units are present north of the map area. The Sugarloaf chain lies mostly outside the area of the youngest glaciation, and cinder cones and flow surfaces are well preserved; some smaller cones are partly buried by the basalt of Hat Creek. The Sugarloaf chain is a young volcanic feature, and the similar lithology and composition of the eight units suggest that the chain represents a relatively short-lived episode of volcanism. $^{40}Ar/^{39}Ar$ ages (Turrin and others, 2007) are available for andesite of Sugarloaf (ass, 46±7 ka), basaltic andesite of Little Potato Butte (msl, 67±4 ka), and andesite of Potato Butte (asp, 77±11 ka). The remaining units are estimated to be slightly older, perhaps as old as 100 ka. The interpreted eruptive order of units of the Sugarloaf chain is based on the $^{40}Ar/^{39}Ar$ ages and known stratigraphic relations. However, some units do not have definitive stratigraphic relations, and the eruptive order may be subject to revision.

ass **Andesite of Sugarloaf Peak (late Pleistocene)**—Thick block-lava flows of sparsely porphyritic aug-hyp andesite (59.3–60.6% SiO_2) erupted from steep-sided lava cone of Sugarloaf Peak near Old Station. Flow fronts are steep and as high as 100 m. Scoria cone at the summit marks vent just north of map area (see fig. 3). Phenocryst content is variable from ~2–10%. Phenocrysts: 1–5% pl, mostly 0.5 mm, few larger; 1–3% hyp, mostly 0.5 mm, few larger; sparse–2% aug, 0.5 mm. Most phenocrysts form glomeroporphyritic clots of pyr+pl as large as 1 cm. Groundmass is black and glassy to dark gray and aphanitic. Vesicular flow tops have flattened and elongated or irregular-shaped vesicles. Flow interiors are dense with blocky jointing. Flows have little or no soil and support only sparse forest. Flow buries faults along the west side of the Hat Creek Graben, but is unfaulted. $^{40}Ar/^{39}Ar$ age is 46±7 ka (Turrin and others, 2007). [OS]

msl **Basaltic andesite of Little Potato Butte (late Pleistocene)**—Thick (25 m), short, block-lava flow of porphyritic ol-aug andesite (54.8% SiO_2) near Old Station; two cinder cones mark vent. Scoria in both cones is mostly oxidized; one cone is partly buried by lava flow. Lava flowed to north for ~1 km. Unit is partly buried by vents and lava of Hat Creek Basalt (bhc). Erupted along west side of Hat Creek Graben, but flow is unfaulted. Phenocrysts: 5% aug, 0.5–1.5 mm, mostly <1 mm; 5% pl, 0.5–1.5 mm, mostly <1 mm; 1% ol, 0.5–1.5 mm, mostly <1 mm. Most phenocrysts occur in 3–8 mm glomeroporphyritic clots of ol+aug+pl. Groundmass is light to medium gray and aphanitic and contains abundant flat amoeboid vesicles. Unit overlies basaltic andesite of hill 4709 (ms47), is overlain by andesite of Potato Butte (asp), and has a thin soil. $^{40}Ar/^{39}Ar$ age is 67±4 ka (Turrin and others, 2007). [OS]

asp **Andesite of Potato Butte (late Pleistocene)**—Thick (to 60 m) block-lava flows of porphyritic ol-aug andesite (57.9–58.4% SiO_2) with two cinder cones that mark vent. Two flows are distinguished by phenocryst content and morphology. Older flow, exposed along north boundary of outcrop area, has less relief and fewer phenocrysts but composition similar to later flow. Younger flow forms most of outcrop area. Few small outcrops around east and south periphery of younger flow may be similar-appearing older lavas. Erupted along west side of Hat Creek Graben, but flow is unfaulted. Phenocrysts (older flow): sparse–2% ol, 0.5–2 mm; mostly <1 mm; sparse–2% aug, 0.5–1 mm; sparse–2% pl 0.5–1, mm. Phenocrysts (younger flow): 3–5% pl, 0.5–2 mm; 2–3% ol, 0.5–2 mm; 2–3% aug, 0.5–1 mm. Most phenocrysts present as abundant small glomeroporphyritic clots of ol+aug+pl, 2–5 mm in size. Groundmass is dark gray to black and glassy with abundant, flat, irregular vesicles. Block-lava flows have little or no soil and support only sparse forest. Unit overlain by Hat Creek Basalt (bhc, 24±6 ka). $^{40}Ar/^{39}Ar$ age is 77±11 ka (Turrin and others, 2007). [OS]

ms47 **Basaltic andesite of hill 4709 (late Pleistocene)**—Thin (10 m), short, block-lava flow of porphyritic aug-ol basaltic andesite (56.0% SiO_2) near Old Station. Cinder cone, consisting mostly of unoxidized scoria and dense blocks and bombs, marks vent. A deep orange soil is ~1 m thick on cone; block lava flows covered with a thin soil. Much of the lava flow is buried by flows of Hat Creek Basalt (bhc) and basaltic andesite of Little Potato Butte (msl). Erupted along west side of Hat Creek Graben, but flow is unfaulted. Phenocrysts: 3% ol, 0.5–2 mm; mostly <1 mm; 1% aug, 0.5–1 mm; sparse pl, 0.5–1 mm. Majority of phenocrysts occur in small (to 5 mm) glomeroporphyritic clots of ol+aug+pl. Groundmass is dark gray to black and glassy to aphanitic. Unit underlies andesite of Potato Butte (asp) but has not been dated; it is probably only slightly older than asp (77±11 ka), (msl, 67±4 ka), and andesite of Sugarloaf Peak (ass, 46±7 ka). [OS]

aso **Andesites of Old Station (late Pleistocene)**—Small group of poorly exposed, sparsely porphyritic ol-aug andesite block lava flows and scoria cones near Old Station that are mostly buried by Hat Creek Basalt (bhc). Description is for the largest flow in unit, but others are similar. Vent is small cinder cone cut by Calif. Hwy 44. Erupted along west side of Hat Creek Graben, but lava flows are unfaulted and have little or no soil cover. Phenocrysts: 2–3% pl, 0.5–1 mm, few larger; 1–2% aug, 0.5–1 mm; sparse ol, 0.5–1 mm. Glomeroporphyritic clots of ol+aug+pl to 5 mm in size are sparse. Flow has a black glassy to dark gray aphanitic, dense to microvesicular groundmass. Age is probably similar to or slightly older than basaltic andesite of Little Potato Butte (msl, 67±4 ka), andesite of Potato Butte (asp, 77±11 ka), and andesite of Sugarloaf Peak (ass, 46±7 ka) and is estimated to be 75–100 ka. [OS]º

Middle Pleistocene and older volcanic rocks

Middle Pleistocene and older volcanic rocks (125–1,800 ka) in the areas north and west of the Lassen Volcanic Center. Major middle Pleistocene features include Prospect Peak, West Prospect Peak, Badger Mountain, and Table Mountain shield volcanoes. Includes monogenetic cinder cones and lava flows and several tholeiitic basalt lava flows. These are mostly glaciated and are more likely to be faulted with increasing age. Early Pleistocene rocks are mostly preserved in fault blocks, including the Hat Creek Fault.

mbg **Basaltic andesite of Little Bunchgrass Meadow (middle Pleistocene)**—Thick lava flow and eroded cinder cone of porphyritic ol-aug basaltic andesite (54.2% SiO_2). Lava flowed north from cone and filled a deep canyon cut by glacial erosion through andesite and basaltic andesite of Cluster Lakes (acl) and basalt of Badger Flat (bbf) and into andesites of Badger Mountain, (abm) and andesites of West Prospect Peak (awp). Original surface of proximal part of lava flow was removed by glacial erosion; dense core is exposed. Distal part of flow retains oxidized, clinkery upper surface; basal breccia is occasionally exposed. Phenocrysts: 10% aug, 0.5–6 mm, larger are composite; 5% ol, 0.5–2 mm, mostly 1 mm; 1% pl, 0.5–3 mm, mostly 1 mm. Aug is distinctive bright green, and xenocrysts of qtz to 3–4 mm are ubiquitous accessory. Groundmass is light to dark gray and aphanitic. Jointing ranges from thin platy to massive. Small cliff of similar but older, sparsely porphyritic, aug-ol basaltic andesite (55.9% SiO_2) is exposed on south side of cinder cone by glacial erosion but is not mapped separately from cinder cone. Phenocrysts: 5% ol, 0.5–2 mm; 2% aug, 0.5–1 mm. Rock contains abundant pl microphenocrysts (few as large as 1 mm) and has medium gray, aphanitic groundmass. Unit is younger than bbf and acl. $^{40}Ar/^{39}Ar$ age is 143±6 ka. [WP]

mbx **Basaltic andesite of Box Canyon (middle Pleistocene)**—Small cinder cone and short, thick lava flow of porphyritic ol-aug basaltic andesite (53.7% SiO_2) on lower northwest flank of West Prospect Peak. Cinder cone of red to brown oxidized cinders and bombs. Lava flow erupted from west base of cone and flowed 1 km down flank of West Prospect Peak into Box Canyon. Lava filled an old glacial canyon, which was recut during late Wisconsin glaciation. Phenocrysts: 15% aug, 0.5–2 mm, composite crystals to 4 mm; 10% ol, 0.5–2 mm. Groundmass is light gray, aphanitic, and dense. Small qtz xenocrysts with aug rims are sparse. Age is poorly constrained but is probably slightly older than basaltic andesite of Little Bunchgrass Meadow (mbg) and is estimated to be ~150 ka. [WP]

b44 **Tholeiitic basalt of Calif. Hwy 44 (middle Pleistocene)**—Thin lava flow of sparsely porphyritic, tholeiitic, ol basalt (49.6% SiO_2) erupted from fissure north of Prospect Peak. This extensive lava flow was fed by lava tubes and flowed north out of map area along base of Butte Creek Rim for >15 km. It also flowed to west and barely spilled over Hat Creek Rim. Well-preserved spatter rampart of welded cinders and agglutinate and sparse scoria was built over vent at hill 5885. Surface of flow is relatively flat and has low relief, although punctuated by widely spaced tumuli. Phenocrysts: 3–5% ol, 0.5–1 mm; trace pl, 0.5–1 mm. Few small glomeroporphyritic clots of ol+pl are locally present. Flow lobe to northwest is slightly more porphyritic than main part of lava flow and may be oldest part of flow. Groundmass is light to medium gray and is typically holocrystalline and diktytaxitic. Upper surface of flow is strongly vesicular and commonly ropy; top layer of flow breaks along joints into equant hexagonal blocks. Thick orange soil covers flow over much of its extent. Unit overlies andesites, basaltic andesites, and basalts of Hat Creek Rim (ahc), basaltic andesite of Signal Butte (msg), and andesite and basaltic andesite of Prospect Peak (ap, 247±56 ka). Unit is overlain by much younger andesite of hill 7416 (a74). $^{40}Ar/^{39}Ar$ age of 190±18 ka is consistent with its excursional magnetic direction (D.E. Champion, written commun., 2006). [OS, PP, SW]

b18 **Tholeiitic basalt of hill 1879 (middle Pleistocene)**—Short, thin pahoehoe lava flow and small cinder cone of sparsely porphyritic, tholeiitic ol basalt (49.2% SiO_2) east of Butte Creek. Lava flowed north for ~2 km from cinder cone located ~5 km north of Twin Buttes. Surface of flow is relatively flat and has low relief. Short flow is unusually small for tholeiitic basalt in Lassen area. Phenocrysts: 3–5% ol, 0.5–1 mm; trace pl, 0.5–1 mm. Few small glomeroporphyritic clots of ol+pl locally present. Groundmass light to medium gray, typically holocrystalline, and weakly to strongly diktytaxitic. Upper surface of flow is vesicular and often ropy, and top layer of flow breaks along joints into equant hexagonal blocks. Thick orange soil covers flow over much of its extent. Age is poorly constrained. Unit overlies basalts and basaltic andesites of Swains Hole (bsh), basalt of section 30 (bl30), and basalt of hill 2109 (bl21). Probably older than Poison Lake chain, but probably not older than basalt of hill 2232 (bl22, 220±14 ka); chemically similar to tholeiitic basalt of Calif. Hwy 44 (b44, 190±18 ka) and may be similar in age. [BB, PL, PP, SW]

bec **Tholeiitic basalt of Eagle Canyon (middle Pleistocene)**—Thin, widespread lava flows of sparsely porphyritic ol basalt (48.6% SiO_2). Like other tube-fed pahoehoe lava flows, unit has tumuli on its upper surface and is composed of a number of flow units. Location of vent is unclear, but cinder and agglutinate exposed in roadcuts along U.S. Forest Service road 17, slightly south of Calif. Hwy 44, and at east limit of outcrop of bec, suggest that vent was in that area. Lava flowed down Manzanita Creek drainage into North Fork Battle Creek and subsequently over and along base of Battle Creek Fault scarp for a total of ~40 km. MacDonald (1963) and MacDonald and Lydon (1972) called this and several other, much older, tholeiitic basalt flows “Shingletown Basalt”. Helley and others (1981) separated out the basalt of Eagle Canyon but did not recognize its entire distribution or source. Phenocrysts: 1–5% ol, 1–3 mm; 0–5% pl, 1–2 mm. Phenocryst abundance is higher in proximal localities. Locally contains distinctive clusters of 2–5 mm pl crystals to 2 cm diam that radiate from small ol+pl glomeroporphyritic clots. Groundmass is medium gray, holocrystalline, and diktytaxitic. Flows exhibit hexagonal-block joint pattern at top of flows and blocky jointing in interiors. Upper and lower portions of individual flow units contain abundant round vesicles. Unit overlies older regional andesites and basaltic andesites (am), Rockland tephra (pr), andesite of Manzanita Creek (amz), andesite of Viola (av), and probably rhyodacite of Manzanita Chute (rmc). Unit is overlain by avalanche deposit from dacite of hill 8283 (Qs82), pumiceous pyroclastic-flow deposits (pe) from Eagle Peak, and pumiceous pyroclastic-flow and fall deposits (pc) from Chaos Crags. $^{40}Ar/^{39}Ar$ age is 199±22 ka. [GP, MZ, VI]

mm **Basaltic andesites of Magee Volcano (middle Pleistocene)**—Thin lava flows of porphyritic aug-ol basaltic andesite (56.3% SiO_2) exposed on south flank of Magee Volcano. Most of lower south slopes of andesitic composite Magee Volcano (Borg, 1989), located north of map area, are obscured by till. However, two rock types are present beyond limits of glaciation and in stream valleys, roadcuts, and small fault scarps. Vents for these lava flows are unknown, but they must have been upslope on Magee Volcano, and probably were removed by glacial erosion. Phenocrysts (outcrop area adjacent to andesite of Devils Rock Garden, atd): 25% pl, 0.25–1 mm, mostly <0.5 mm; 3% ol, 0.5–1 mm; 1% aug, 0.5–1 mm. Few strongly resorbed pl (3–5 mm) and aug megacrysts (to 5 mm) are present. Groundmass is light to medium gray, aphanitic, and microvesicular. Phenocrysts (remaining outcrop areas including analyzed sample): 4% ol, 0.5–1 mm, few larger; 4% pl, 0.5–1 mm, mostly 0.5 mm; 1% aug, 0.5–1 mm, few larger. Most crystals are present as small clots of ol+pl+aug. Groundmass is dark gray to black, glassy to aphanitic, and microvesicular. Single low-precision K-Ar date of 210±120 ka is from the youngest part of Magee Volcano (L.E. Borg, written commun., 1989); flows in map area are probably slightly older. [TH]

bn **Tholeiitic basalt of Nobles Trail (middle Pleistocene)**—Thin, aphyric basaltic (48.0% SiO_2) lava flow in Hat Creek northeast of Raker Peak. Location of vent is unknown, but it is probably buried beneath younger lava flows of andesite of Hat Mountain (ah) on Central Plateau of LVNP. Unit consists of multiple flow units of tube-fed pahoehoe with hexagonal-block joint pattern at their tops and massively jointed interiors. Lava flow is weakly glaciated but well preserved, with abundant spherical vesicles at upper and lower surfaces. Phenocrysts: trace ol, to about 1 mm. Groundmass is medium gray, coarsely diktytaxitic, and consists of pl, ol, aug, and Fe-Ti oxide microlites. Age is poorly constrained, but unit overlies andesites of Badger Mountain (abm) and andesite of Raker Peak (arp, 270±18 ka) and underlies till of Raker Peak (Qtr). May be similar in age to tholeiitic basalt of Eagle Canyon (bec) and is estimated to be ~200–250 ka. [WP]

ap **Andesite and basaltic andesite of Prospect Peak (middle Pleistocene)**—Block-lava flows of porphyritic ol basaltic andesite, aug-ol andesite, and aug-hyp andesite (53–58% SiO_2) forming Prospect Peak shield volcano. Shield is capped by cinder cone with several flank vents near summit. Summit crater contains pumice from 1.1 ka Chaos Crags eruptions. Lower flanks on south and west sides of volcano are buried by till and moraines. Three types of lava flows erupted to build Prospect Peak. Late-stage hyp-aug andesite lava flows that erupted from summit crater cover some flanks of volcano. Porphyritic aug-ol andesite lavas form bulk of edifice and area beyond north flank of volcano, north of Hat Creek Fault. Exposures of early-stage sparsely porphyritic ol basaltic-andesite lava are confined to extreme northwest outcrop area. Phenocrysts (late aug-hyp andesite): 25% pl, 0.5–2 mm, mostly 1 mm; 4% hyp, 0.5–2 mm, mostly <1 mm; 2% aug, to 2 mm, mostly <1 mm; trace ol, <1 mm. Phenocrysts (aug-ol andesite): 35% pl, 0.5–2 mm, mostly 1 mm; 4% aug, 0.5–2 mm, mostly <1 mm; 3% ol, 0.5–2 mm, mostly <1 mm. Phenocrysts (early ol basaltic andesite): 3% ol, 0.5–2 mm, mostly <1 mm; sparse pl, 0.5–2 mm. Groundmass of all flows is dark gray to black and glassy to aphanitic. Surfaces of lava flows consist of rounded vesicular blocks. Jointing is massive, forming rounded blocks, but interior of flows is rarely exposed. Hat Creek Fault slightly offsets lavas on north flank of Prospect Peak. Unit overlies andesites of Badger Mountain (abm), andesites of West Prospect Peak (awp), and andesite and basaltic andesite of Cluster Lakes (acl); overlain by tholeiitic basalt of Calif. Hwy 44 (b44, 190±18 ka). K-Ar age of sample of late hyp-aug andesite is 247±56 ka; volcano was probably active for, at most, a few thousand years. [PP, SW, WP]

pdh **Lithic tephra from Deep Hole (middle Pleistocene)**—Nonsorted, nonbedded, unconsolidated, and ungraded deposit of lithic debris from andesite of Viola (av) and sparse fragments of andesite of Digger Creek (adc). Forms raised rim on the west, south, and east sides of Deep Hole explosion crater, located ~3 km west of Manzanita Lake. Fragments are angular to subrounded and from all parts of lava flows. Deposit is dominated by 0.5- to 10-cm-sized fragments, but blocks to 2 m are found. Matrix is comminuted ash-sized andesite. Deposit has thick orange soil; exposures of unweathered deposit were not found. Deposit was formed by one or more phreatic explosions, probably when an unknown magma body approached the surface and encountered groundwater. Explosion(s) was directed north. Walls of Deep Hole expose av and adc, and floor is covered with thick deposit of sand derived from rhyodacite of Manzanita Chute (rmc) lava flow. Deposit also found as thin sheet overlying av north of Deep Hole, but mapped only where it has geomorphic expression. Area surrounding Deep Hole has been extremely disturbed by bulldozing manzanita thickets into windrows; no undisturbed surface was found. Roadcut on U.S. Forest Service road 17 just south of Calif. Hwy 44 exposes 80–100 cm of weakly sorted, nonbedded, ungraded, and unconsolidated deposit. Clasts are mostly 1–2 cm; maximum clast size is 7 cm. Clasts are mostly dense, angular fragments of av; clasts of adc are rare. Matrix is comminuted ash-sized andesite, and deposit is deeply weathered. Age is unknown, but it is younger than av (313±8 ka) and rmc (297±1 ka) and much older than pe (66±4 ka); it underlies unmapped dacite pyroclastic flow exposed in road 17 roadcut, which is probably related to Bumpass sequence. Unit may be related to eruption of tholeiitic basalt of Eagle Canyon (bec, 199±22 ka), the basalt lava thought to have vented near toe of rmc lava flow, although relation to bec is unclear; estimated to be ~200 ka. [MZ]

bct **Basalt of Cherry Thicket (middle Pleistocene)**—Poorly exposed lava flow of porphyritic ol basalt (51.2% SiO_2) west of Red Lake Mountain. Vent has not been located and is probably buried by overlying basaltic andesite and andesite of Red Lake Mountain (mrd). Phenocrysts: 3% ol, 0.5–3 mm, mostly 0.5–1 mm; 1% pl, 0.5–2 mm, mostly 0.5–1 mm. Small glomeroporphyritic clots of pl+ol to 3 mm are common. Groundmass is light to medium gray, aphanitic, and microvesicular. Large round to ovoid vesicles are abundant in blocks at surface of flow; interior jointing is blocky. Age is poorly constrained as younger than andesite of Manzanita Creek (amz, 400–450 ka) and older than mrd (75–100 ka) and is estimated to be ~300 ka. [VI]

bo **Basalt of Onion Springs (middle Pleistocene)**—Obscure, porphyritic aug-ol basalt (51.7% SiO_2) lava flow and eroded cinder cone at toe of lava flow of rhyodacite of Loomis Peak (rlm). Small volume of lava erupted from cone in saddle between Loomis Peak and rhyodacite of Manzanita Chute (rmc) dome and puddled in saddle. Phenocrysts: 6% ol, 0.5–2 mm; 4% pl, 0.5–5 mm, mostly 0.5–1 mm; 2% aug, 0.5–1 mm. Some pl phenocrysts have dark-gray cores; small glomeroporphyritic clots of pl+ol to 3 mm are abundant. Groundmass is medium gray, aphanitic and microvesicular. Large, round to ovoid vesicles are abundant in blocks at surface of flow; interior jointing is massive. Unit is younger than andesite of Mount Diller (amd, 387±10), but older than rlm and rmc (297±1 ka) and is estimated to be ~300–325 ka. [LP, MZ]

awp **Andesites of West Prospect Peak (middle Pleistocene)**—Lava flows of porphyritic aug-hyp andesite and aug-ol andesite (59.3–61.2% SiO_2) forming steep-sided lava cone. Small cirque occupies northwest flank just below the summit; summit area is eroded cinder cone. Most of volcano has thick mantle of colluvium and soil. Two rock types are present: most of outer surface of cone is composed of aug-hyp lava flows; porphyritic aug-ol andesite (59.3% SiO_2) is exposed along base and part of north flank of lava cone and probably represents early phase of volcano's evolution. Phenocrysts: (porphyritic aug-hyp andesite): 3–4% hyp, 0.5–1 mm; 1–2% aug, 0.5–1 mm; 1–2% pl, 0.5–1 mm. Phenocrysts (porphyritic aug-ol andesite): 5–7% pl, 0.5–1 mm, mostly 0.5 mm; 2–3% ol, 0.5–1 mm; sparse aug, 0.5–1 mm; trace hyp, 0.5 mm. Small glomeroporphyritic clots, 1–5 mm across, of aug+hyp+pl are abundant in aug-hyp andesite; similar but smaller and sparser clots are present in aug-ol andesite. Groundmasses are dark gray to black, glassy to aphanitic, and dense to vesicular. Flow surfaces are composed of massively jointed, rounded blocks. Vague flow banding is common, and smeared-out fragments of welded, oxidized lava are locally present. Age of West Prospect Peak is poorly constrained. It is older than andesite and basaltic andesite of Prospect Peak (ap, 247±56 ka) but unfaulted and is estimated to be 300–400 ka. [OS, PP, SW, WP]

bbf **Basalt of Badger Flat (middle Pleistocene)**—Lava flow and cinder cone of porphyritic ol basalt (51.3–52.2% SiO_2), near Badger Flat. Flow and cone were glaciated, and much till was deposited on flow. Lava flowed down Box Canyon to Potato Butte area and is ~10 m thick. Phenocrysts: 10–12% ol, 0.5–2 mm, mostly 1 mm; 6–8% pl, 0.5–2 mm, mostly 1 mm. Xenoliths of qtz to 2 cm are sparse. Groundmass is variable; in proximal areas, glacial erosion exposed core of flow, and lava is light gray, finely holocrystalline, and microvesicular to weakly diktytaxitic (although not tholeiitic). At distal end of flow, original flow surface is preserved, although weathered, and groundmass is dark gray and glassy. Flow top is vesicular, and jointing is thick slabby to massive in flow interior. Age poorly constrained. Unit overlies andesites of Badger Mountain (abm, 708±21 ka) and is overlain by andesites of West Prospect Peak (awp), andesite and basaltic andesite of Cluster Lakes (acl), basaltic andesite of Little Bunchgrass Meadow (mbg), and andesite of Hat Mountain (ah). It is slightly older but close in age to awp (300–400 ka). [OS, WP]

mhr **Basaltic andesite of Hootman Ranch (middle Pleistocene)**—Thick lava flow of porphyritic ol-aug basaltic andesite (55.5–56.2% SiO_2). Location of vent is unknown but is probably in area between Red Rock Mountain and Red Lake Mountain. Macdonald (1963), Helley and others (1981), and Blake and others (1999) attributed this unit to Brokeoff Volcano, but based on the lithology and composition of the lava, this correlation is unlikely. Proximal part of flow is buried by glacial deposits, lavas of Lassen Volcanic Center, and regional lavas. Lava flowed westward and was focused into two narrow streams near Canyon Creek and

Rock Creek. Rock Creek lava stream flowed along base of Battle Creek Fault scarp almost to Sacramento River (west of map area) for a total distance of ~28 km (Blake and others, 1999). Unit is slightly offset by displacement on Battle Creek Fault scarp near Volta powerhouse (west of map area in Manton quadrangle; see fig. 3). Phenocrysts: 30% pl, 0.5–6 mm, mostly 1–2 mm; 7% aug, to 2 mm, distinctive bright-green color; 4% ol, 1–2 mm; 3% hyp, 0.5–1 mm. Glomeroporphyritic clots, dominated by ol, but containing pyr and pl, to several centimeters but generally ~5 mm, are abundant and characteristic. Groundmass is dark gray and glassy to aphanitic. Flow tops contain abundant, large, spherical to ovoid vesicles. Joint pattern is massive; weathering forms rounded boulders. Thick, dark-orange to red soil covers most of flow. Unit overlies older regional andesites and basaltic andesites, undivided (am), basaltic andesites of Camp Forward (mcf), and andesite of Onion Creek (ao) and is overlain by andesite of Digger Creek (adc), andesite of Viola (av), and basalt of Eagle Canyon (bec). Unit directly overlies Rockland tephra (pr, 609±7 ka), an important regional stratigraphic marker. $^{40}Ar/^{39}Ar$ age is 562±12 ka (Lanphere and others, 2004), and is consistent with an excursional magnetic direction that was correlated with Big Lost paleomagnetic event at ~575 ka (Champion and others, 1996; Lanphere and others, 1999). [GP, VI]

aw **Andesite of Wilcox Peak (middle Pleistocene)**—Complex of thin, porphyritic, aug-hyp andesite (58.2% SiO_2) lava flows from lava cone of Wilcox Peak (north of map area, fig. 3); only the southernmost part of unit appears on map. Phenocrysts: 20–25% pl, 0.5–1 mm, few larger; 5% hyp, 0.5–2 mm, a few larger; sparse–1% aug, 0.5–1 mm. Glomeroporphyritic clots of pyr+pl are common and to 5 mm in size. Relative abundance of hyp and aug and general size of phenocrysts are variable among flows. Groundmass is medium gray, dense, glassy to aphanitic. Blocks on top of lava flows are vesicular with flattened and stretched vesicles. Rock displays thin-platy to thick-slabby jointing. Unit overlies older regional andesites and basaltic andesites, undivided (am), but age is otherwise poorly constrained. Wilcox Peak lava cone is less severely faulted than underlying am and has well-developed soil and mature forest. Has normal magnetic polarity and is estimated to be 500–700 ka. [OS]

alg **Andesite of Logan Mountain (middle Pleistocene)**—Complex of thin, porphyritic aug-hyp andesite (57.6% SiO_2) lava flows from lava cone of Logan Mountain (vent is north of map area, fig. 3). Phenocrysts: 25% pl, 0.5–2 mm, few larger; 3–4% hyp, 0.5–1 mm, few larger; 1–2% aug, 0.5–1 mm, few larger. Glomeroporphyritic clots of pyr+pl are generally present and to 5 mm. Relative abundance of hyp and aug and general size of the phenocrysts is variable. Groundmass is medium gray, glassy to aphanitic and dense, and rock displays thick-slabby to blocky jointing. Flow tops are vesicular with flattened and stretched vesicles. Unit overlies older regional andesites and basaltic andesites, undivided (am), but age is otherwise poorly constrained. Unit is less severely faulted than the underlying am and has well-developed soil and mature forest. It has normal polarity, and its age is estimated to be 500–700 ka. [TH]

agr **Andesite of Grayback Ridge (middle Pleistocene)**—Thin lava flow of porphyritic aug-ol andesite. Partially eroded cinder cone at hill 6122 on Grayback Ridge marks vent. Lava flowed south, where it was confined by and partially filled fault-bounded valley between Grayback Ridge and adjacent unnamed ridge to southwest. Lava flow has a scoria-covered surface, but flow core is dense. Phenocrysts: 4% ol, 0.5–2 mm, mostly 0.5 mm; 4% pl, 0.5–2 mm, mostly 0.5 mm; sparse aug, 0.5–1 mm. Glomeroporphyritic clots of ol+pl or pyr+pl to 5 mm in size are common. Groundmass is medium gray, aphanitic, and sparsely microvesicular. Age is poorly constrained but is considerably younger than underlying older regional andesites and basaltic andesites, undivided (am). Lava flow buries old faults that cut am terrane into blocks but is not faulted itself. Vent is poorly preserved, and soil development is much less extensive than on am. Unit overlain by basaltic andesite of Red Mountain (mrm) and tholeiitic basalts of Big Lake, units 1 and 2 (bk1, bk2). Unit has normal magnetic polarity, and age is estimated to be 600–700 ka. [MZ]

acs **Andesite of Cabin Spring (middle Pleistocene)**—Lava flow of porphyritic hyp-aug andesite (61.6% SiO_2) that crops out west of Red Rock Mountain. This lava flowed westward from source subsequently obscured by dacite of Red Rock Mountain (dr) and (or) lavas of Brokeoff Volcano. Eastern part of lava flow was glaciated and stripped of its block carapace; western part of lava flow is beyond limit of glaciation, and thick soil obscures its surface. Phenocrysts: 5% pl, 0.5–1 mm; 5% aug, 1–2 mm; 5% hyp, 1–2 mm. Many aug phenocrysts are strongly zoned with light-green cores and dark-green rims and give rock a distinctive appearance. Much of pyr occurs as monomineralic or 2-pyr glomeroporphyritic clots to 5 mm. Groundmass is medium gray, aphanitic, and microvesicular, with irregular bands and zones of devitrification. Joint pattern is thick-slabby to blocky. Inclusions of milky-white vein qtz are common. Unit is overlain by dacite of Red Rock Mountain (drr, 672±20 ka) and andesite of Digger Creek (adc, 451±10 ka). K-Ar age is 690±34 ka. [GP]

mr **Basaltic andesite of Rock Spring (middle Pleistocene)**—Small outcrop of vesicular flow front of porphyritic ol-aug basaltic andesite (55.8% SiO_2) exposed at Rock Spring, ~5.5 km northeast of Camp Forward. It is almost completely buried by andesite of Digger Creek (adc) and debris-flow deposit from Brokeoff Volcano (Qwb). Little is known about source or affinity of this lava flow, but its lithology and composition suggest that it is a regional volcanic unit and not related to Lassen Volcanic Center. Phenocrysts: 2% aug, 1–4 mm; 2% ol, 1–2 mm; 6% pl, 1 mm. Glomeroporphyritic clots of aug+pl and ol+pl are common. Groundmass is light to medium gray and aphanitic. Age is very poorly constrained. It is older than late Brokeoff Volcano lavas (andesite of Digger Creek, adc) and probably older than andesite of Cabin Spring (acs, 690±34 ka). It may be slightly younger than or similar in age to andesite of Onion Creek (ao) and is estimated to be ~700 ka. [GP]

ao **Andesite of Onion Creek (middle Pleistocene)**—Porphyritic ol-aug andesite (58.3% SiO_2) lava flow. Emerges from beneath andesite of Digger Creek (adc) and forms a low cliff along south bank of Onion Creek. Flow is unglaciated and little eroded; its source is unknown. Lava flowed west following pre-existing drainage, burying a terrane of older regional andesites and basaltic andesites, undivided (am) and basaltic andesites of Camp Forward (mcf). Blocky vesicular flow top grades downward into a massively jointed flow core. Phenocrysts: 25% pl, 0.5–2 mm; 4% aug, to 2 mm; 1% ol, to 1 mm; trace hyp, to 0.5 mm. Groundmass is dark gray and glassy. Flow is not dated, but is overlain by Rockland tephra (pr, 609±7 ka), basaltic andesite of Hootman Ranch (mhr, 562±12 ka), andesite of Digger Creek (adc, 451±10 ka), and debris-flow deposit from Brokeoff Volcano (Qwb). It has normal magnetic polarity and is probably slightly older than andesite of Cabin Spring (acs, 690±34 ka). Estimated to be 700–780 ka. Clynne (1984) inferred ao to be part of Mill Canyon sequence of Brokeoff Volcano, but that interpretation now appears to be incorrect. [GP]

at **Andesite of Table Mountain (middle Pleistocene)**—Porphyritic aug-hyp andesite (61.4% SiO_2) lava flows forming small shield volcano. Vent area is poorly preserved; edifice was not glaciated. Several faults oriented north-northwest slightly offset the edifice. Flow tops are conspicuously rubbly, whereas flow interiors are dense; typical exposures consist of rounded boulders. Phenocrysts: 20% pl, to 0.75 mm; 5% hyp, to 0.75 mm, few to 1.5 mm; 3% aug, to 0.75 mm, few to 1.5 mm. Glomeroporphyritic clots and crystal clusters consisting of all three phenocryst phases but dominated by pl are abundant and generally 2–5 mm in size. Groundmass is dark gray to black, glassy, and vesicular. Unit is older than all adjacent units. It has not been dated, but has normal polarity and is probably similar in age to andesites of Badger Mountain (abm, 708±21 ka), ~700 ka. [MZ]

abm **Andesites of Badger Mountain (middle Pleistocene)**—Moderately porphyritic to very porphyritic aug-hyp andesite and ol-hyp-aug andesite lava flows forming a small shield volcano. Flows are generally thin (to 10 m); interflow breccias are sparse. Shield is glaciated on northwest margin and cut by normal faults; vent area is poorly preserved. Two types of lava flows corresponding to upper (59.7–62.7% SiO_2) and lower (56.9–57.3 SiO_2) stratigraphic positions in Badger Mountain can be distinguished but are not mapped separately. Phenocrysts (upper): 10–20% pl, 0.5–1 mm, few larger to 2 mm; 3% hyp, 0.5–1 mm, few 2 mm; 2% aug, 0.5–1 mm, few 2 mm. Phenocrysts (lower): 25–30% pl, 0.5–1 mm; 3–4% aug, 0.5–1 mm; sparse–2% hyp, 0.5–1 mm; sparse–2% ol, 0.5–1 mm. Some lower flows contain more ol than hyp. Glomeroporphyritic clots of pl+aug+hyp±ol are common to abundant in both upper and lower flows, generally 2–5 mm. Groundmasses are dark gray to black and glassy to aphanitic. The two types of lavas correspond to two chemical groups: ol-hyp-aug andesites in lower section contain 56.9–57.3 SiO_2; upper aug-hyp andesites in remainder of volcano contain 59.7–62.7% SiO_2. Unit overlies older regional andesites and basaltic andesites, undivided (am) and tholeiitic basalt of Twin Bridges (btb); overlain by adjacent units basalt of Badger Flat (bbf), andesite and basaltic andesite of Cluster Lakes (acl), andesite and basaltic andesite of Prospect Peak (ap), tholeiitic basalt of Nobles Trail (bn), andesite of Potato Butte (asp), and avalanche debris from Lassen Peak spread across glacial ice (Qsl).

K-Ar age of 708±21 ka for upper flow is consistent with its normal magnetic polarity; entire volcano is probably about that age. [OS, WP]

btb **Tholeiitic basalt of Twin Bridges (middle Pleistocene)**—Nearly aphyric tholeiitic basalt (49.0% SiO_2) flow forming flat surface north of Badger Mountain. Multiple thin flow units are typically from a few tens of centimeters to a few meters thick; flow tops are vesicular. Maximum exposed thickness is ~30 m in fault scarp near Big Spring, but base of unit is not exposed. Original flow surfaces are poorly preserved, and location of vent is unknown. One large and several smaller faults oriented north-northwest break flows into north-northwest-trending linear blocks. Phenocrysts: typically, sparse–1% ol, 0.5–1.5 mm, sometimes in small glomeroporphyritic clots to 3 mm. Groundmass is light gray, holocrystalline, and diktytaxitic. Unit overlies older andesites and basaltic andesites, undivided (am). Unit has not been dated, but is overlain by andesites of Badger Mountain (abm, 708±21 ka), basaltic andesite of Red Mountain (mrm), andesite of Tumble Buttes (att), and andesite of Potato Butte (asp). It has normal magnetic polarity, and is probably 730–780 ka. [OS, WP]

aa **Andesite of Ashpan Butte (early Pleistocene)**—Sparsely porphyritic aug-hyp andesite (60.8% SiO_2) lava flow and lava cone at Ashpan Butte. Eroded scoria cone at summit marks vent. Phenocrysts: 1–4% hyp, mostly 0.5 mm, few larger; sparse aug, 0.5–1 mm; 1–4% pl, mostly 0.5 mm, few larger. Phenocryst content is variable from 3–8%; most phenocrysts are in glomeroporphyritic clots of pyr+pl to 5 mm across. Flow has black glassy to medium-gray, dense, aphanitic groundmass and thin platy to thick slabby jointing. Groundmass is commonly mottled by thin, oxidized zones of vapor-phase crystallization. Vesicular flow tops have flat stretched vesicles and zones of roundish vesicles. Age is poorly constrained. Unit overlies older regional andesites and basaltic andesites, undivided (am) and is surrounded by much younger basaltic andesite of Red Mountain (mrm) and andesite of Bear Wallow Butte (atb). Lava cone was significantly modified by erosion; scoria cone is poorly preserved. Both have thick, well-developed soil. Although Ashpan Butte lava cone buried a major fault, it appears to be unfaulted. It has reversed polarity, and its age is estimated to be 800–1,000 ka. [MZ]

msg **Basaltic andesite of Signal Butte (early Pleistocene)**—Thin lava flow of sparsely porphyritic ol basaltic andesite with large cinder cone marking vent. Cinder cone contains both fresh and oxidized cinders and has orange soil to 1 m thick. Lava from cone flowed as much as 3 km north and west toward, but not as far as, Hat Creek Fault scarp. Lava flow is cut by small faults oriented parallel to Hat Creek Fault. Flow has thick well-developed soil that obscures surface morphology. Phenocrysts: 5–8% pl, 0.5–3 mm, most weakly to strongly reacted; sparse ol, 0.5–1 mm. Contains sparse small andesitic inclusions, small glomeroporphyritic clots dominated by pl, reacted hbl, and qtz xenocrysts with rims of aug. Groundmass is medium gray, aphanitic to holocrystalline, and dense to microvesicular; jointing is massive. Age is very poorly constrained. Unit overlain by tholeiitic basalt of Calif. Hwy 44 (b44, 190±18 ka), which is much younger. Unit has reversed magmatic polarity. It overlies andesites, basaltic andesites, and basalts of Hat Creek Rim (ahc, 924±24 ka) and is probably about the same age as initiation of movement on Hat Creek Fault (estimated to be ~900–1,000 ka). [OS, SW]

ahc **Andesites, basaltic andesites, and basalts of Hat Creek Rim (early Pleistocene)**—Variety of thin ol and pyr basalt, basaltic andesite, and andesite (mostly 60–63% SiO_2) lava flows and vent material exposed in Hat Creek Fault scarp. Lavas exposed in scarp face have small lateral extent and interfinger and are probably broadly equivalent to rocks mapped as older regional andesites and basaltic andesites, undivided (am) and younger rocks on west side of Hat Creek and in Grayback Ridge area. Similar andesite lava flows in Butte Lake area are mapped as andesite of Butte Lake (abl) and andesite of section 22 (a22). Variety of lavas with phenocryst assemblages ranging from ol to 2 pyr-pl are present; most common are sparsely phyric to porphyritic ol andesite (5% ol, 0.5–1 mm), sparsely phyric to porphyritic pyr andesite (5% aug), and porphyritic aug-hyp andesite (3–4% hyp, 0.5–1 mm; 1–2% aug, 0.5–1 mm; 5–15% pl, 0.5–2 mm, few glomeroporphyritic clots). Groundmasses are typically dark gray and aphanitic. K-Ar ages of 924±24 ka on basalt lava flow from top of Hat Creek Fault and 1,645±35 ka from flow within the section but north of map area, suggest a considerable age range for the unit. Estimated to be ~900 to >1,645 ka. [OS, PP, SW]

abl **Andesite of Butte Lake (early Pleistocene)**—Porphyritic aug-hyp andesite (60.5% SiO_2) lava flow(s), exposed in upthrown fault scarp east of Butte Lake and mostly buried by till. Lava flows were heavily glaciated; surface features are not preserved. Vent location is unknown. Phenocrysts: 15% pl, 0.5 mm; 4% hyp, 0.5–1 mm; 1% aug, 0.5–2 mm. Groundmass is dark gray to black, aphanitic to glassy, and dense. Some flows have sparse glomeroporphyritic clots of pyr+pl to a few millimeters. Thin platy to massively jointed flow interiors are exposed. Similar lithologically and in stratigraphic position to andesites, basaltic andesites, and basalts of Hat Creek Rim (ahc), suggesting that it may be related to lavas exposed in Hat Creek Rim north of Prospect Peak. Nearby units basalt of Bathtub Lake (bsb) and basalts of Sunrise Peak, units 1 and 2 (bss1, bss2) that are interpreted to be much younger, drape over old fault scarp exposing abl. Age is estimated to be similar to youngest part of the ahc section, ~900–1,000 ka. [PP]

a22 **Andesite of section 22 (early Pleistocene)**—Nearly aphyric ol andesite lava (59.9% SiO_2) flows exposed in downthrown fault block just east of flows from Cinder Cone; mostly buried by till. Lava flows were heavily glaciated; surface features are not preserved. Thin, platy to massively jointed flow interiors are exposed. Outcrops are probably small fault blocks. Location of vent area is unknown. Phenocrysts: sparse ol, 0.5–1 mm; sparse pl, 0.5–1 mm. Groundmass is dark gray to black and aphanitic to glassy, locally with irregular flow banding or banding defined by vapor-phase crystallization. Inclusions of partially melted granitic rocks and milky qtz xenocrysts from few millimeters to 1 centimeter are common. Similar lithologically and in stratigraphic position to andesites, basaltic andesites, and basalts of Hat Creek Rim (ahc); may be related to lavas exposed in Hat Creek Rim north of Prospect Peak. Age is estimated to be similar to youngest part of ahc, ~900–1,000 ka. [PP]

dhm **Dacite of Huckleberry Mountain (early Pleistocene)**—Complex of thick, porphyritic, aug-hbl-hyp dacite (63.4% SiO_2) lava flows erupted from vent near Huckleberry Mountain, (northwest of map area in Jacks Backbone quad, fig. 3). Flow complex was glaciated, and flow-margin features removed; vent is not preserved. Lithology is slightly variable; some flows may be andesites. Phenocrysts: 30–45% pl, 0.5–1 mm, few larger; 3–5% hyp, 0.5–1 mm; sparse–1% hbl, 2 mm–1 cm. Sparse aug, generally 0.5–1 mm, is present in some flows. Amount of hbl is variable, and it is usually strongly reacted and replaced by an aggregate of Fe-Ti oxide, pyr, and pl. Mafic inclusions, generally <1 cm, present in some flows. Groundmass is light gray to almost white, glassy to aphanitic, and sparsely microvesicular. Rock has thick-slabby to blocky jointing. Age is unknown. Unit overlies rocks of Latour Volcanic Center (Tlv) and older regional andesites and basaltic andesites, undivided (am) suggesting it is younger than ~1,400 ka; age is otherwise poorly constrained. Exposure is poor, and colluvium and thick soil suggest that unit is relatively old. Unit has reversed magnetic polarity and is estimated to be 800–1,200 ka. [TH, VI]

am **Older regional andesites and basaltic andesites, undivided (early Pleistocene)**—Variety of older volcanic rocks exposed in swath across northwest edge of map area. Includes wide variety of lithologies and compositions from ol basaltic andesite to pyr andesite (55.2–58.3% SiO_2) related to regional volcanism. Intercalated pyroclastic material and vent facies are locally present. East of Hat Creek, lavas mapped as andesites, basaltic andesites, and basalts of Hat Creek Rim (ahc) have similar lithology and stratigraphic position.

In Viola, Manzanita Lake, Thousand Lakes Valley, and Old Station quadrangles, composed of rocks that form platform of normally faulted and eroded lava flows. Largest exposure is between Grayback Ridge and North Battle Creek Reservoir at northwest corner of map. Lavas were erupted from numerous small centers; only a few vents are shown. Faulting and erosion disrupted these volcanoes and obscured their original constructional morphology. Range of their ages and relation to other units are poorly known; single K-Ar date of 1,400±37 ka was obtained from lava flow near top of pile southwest of North Battle Creek Reservoir. Some rocks may be late Pliocene in age. Wide variety of sparsely phyric to porphyritic ol basaltic andesite, ol-pyr basaltic andesite, and 2-pyr andesite lava flows are present. Three analyzed samples contained 55.2%, 56.7%, and 58.3% SiO_2, but range of compositions present is certainly broader. Groundmasses are medium to dark gray, aphanitic to glassy, and dense. Most outcrops are deeply weathered. In Little Logan Butte and Hat Creek Hill area, sparsely porphyritic pyr andesite and ol basaltic andesite are most common rock types. Groundmasses are generally dark gray to black, aphanitic, and microvesicular. Thick, well-developed, orange to red soils are common.

In Grays Peak quadrangle, patches of pyr andesite exposed beneath Rockland tephra (pr) in Canyon Creek area and basaltic andesites of Camp Forward (mcf) in Digger Creek represent eroded terrane covered by younger units. Flows that appear to come from north may be related to similar lavas in Viola, Manton, and Shingletown quadrangles. Their source, age, and relation to other units is poorly known. Most common lithology is porphyritic hyp-aug andesite (58.3% SiO_2) containing 20–40% phenocrysts, dominantly pl to 5 mm, and occasionally sparse ol. Other lithologies similar to those from Grayback Ridge and North Battle Creek Reservoir areas are also present. [GP, MZ, OS, TH, VI]

mcf **Basaltic andesites of Camp Forward (early Pleistocene)**—Thin flows of porphyritic, aug-ol and ol-aug basaltic andesite (54.3% SiO_2) that form deeply eroded remnants of small shield volcano at west boundary of map area. Lava flows 5–10 m thick dip gently away from vent (near hill 4110) that is not preserved. Rocks are deeply weathered; thick cover of bright-red soil covers most of flows. Two rock types are present. Lower flows are aug-ol basaltic andesite (54.3% SiO_2). Phenocrysts: 10% ol, 1 mm; sparse pl, 1 mm; sparse aug, 1 mm. Upper flows are ol-aug basaltic andesite; they have not been analyzed but may be less mafic than lower flows. Phenocrysts: 8–10% aug, 1–2 mm; 5% ol, 1 mm; 2% pl, 1 mm. Glomeroporphyritic clots of aug+ol and pl are abundant in upper flows; xenoliths of milky white vein qtz are common in all flows. Flow lineation and vapor-phase crystallization are common in light- to medium-gray groundmass. Age is poorly known. Unit overlies rocks assigned to older regional andesites and basaltic andesites, undivided (am, 1,400±37 ka), but the age of am in this area is probably older than date. Unit is overlain by rhyolite of Blue Ridge (rb, ~1,200 ka) but was already eroded before partial burial by rb lava. Unit has reversed magnetic polarity and is estimated to be 1,400–1,600 ka. [GP]

SOUTH AND EAST OF LASSEN VOLCANIC CENTER

Includes rocks related to regional volcanism and erupted from monogenetic volcanoes and small- to moderate-sized lava cones and shield volcanoes of all ages in axis of Cascade Arc south and east of Lassen Volcanic Center. Area approximately bounded on east by trace of Hat Creek Fault-Lake Almanor Graben system. Prominent features include Sifford Mountain and Mount Harkness shield volcanoes.

bbz **Tholeiitic basalts of Buzzard Springs (late Pleistocene)**—Thin, sparsely porphyritic tholeiitic ol and aug-ol basalt (48.7–49.6% SiO_2) lava flows erupted from line of at least six unnamed cinder cones south-southwest of Sifford Mountain. Related flow, tholeiitic basalt of Ice Cave Mountain (bic), is the southernmost and largest flow in this group, slightly older, and is mapped separately. Some lava mapped as bbz may belong to underlying, lithologically similar bic. Alignment of vents for bbz probably reflects a north-northwest-trending fault in subsurface. These flows are among youngest regional lavas in map area, are unfaulted, have little or no soil, and support only sparse forest. Ponding of these flows in North Fork Feather River channel partially blocked river and created Feather River Meadows. Phenocryst content 1–10%. Near-vent samples tend to be more porphyritic than those away from vents. Phenocrysts: 0–6% pl, mostly 0.5–1 mm, few larger; sparse–3% ol, mostly 0.5–1 mm, few larger; rare aug, 0.5 mm. Many phenocrysts are in glomeroporphyritic ol+pl clots as large as 5 mm in size. Flows have aa surfaces, rarely pahoehoe, and medium-gray, aphanitic to holocrystalline and microvesicular to weakly diktytaxitic groundmasses. Vesicular flow tops have rounded to irregular-shaped vesicles. Flows overlie basaltic andesite of Small Butte (msm) and basalts and basaltic andesites of Sifford Mountain (bsm); glacial drift partially buries north end of cinder cone chain. K-Ar age of 65±45 ka is consistent with stratigraphy and probably more meaningful than implied by the analytical uncertainty. [CM, RP, ST]

bic **Tholeiitic basalt of Ice Cave Mountain (late Pleistocene)**—Lava flow of nearly aphyric to sparsely porphyritic tholeiitic basalt (48.6–48.8% SiO_2) erupted from vent at summit of Ice Cave Mountain and flowed south out of map area. Vent is largest and southernmost of chain of at least six vents of similar age; the other vents and flows are mapped as tholeiitic basalts of Buzzard Spring (bbz). Lava on Ice Cave Mountain is mostly remobilized spatter and contains sparse small lava tubes. Large volume of pahoehoe basalt lava from this vent entered Lost Creek drainage and flowed south and west to Deer Creek Meadows and south and east to Soldier Meadows (both south of map area; see fig. 3). Small stream of lava flowed north and is buried by bbz. Phenocrysts: rare–2% ol, 0.5–2 mm; rare–6% pl, 0.5–2 mm. Phenocryst content variable; lava near vent is most porphyritic and contains sparse to common glomeroporphyritic clots of ol+pl to ~1 cm. Lava has light- to medium-gray aphanitic to holocrystalline, typically diktytaxitic groundmass; flow tops contain abundant round vesicles; jointing is blocky. Unit lies on much older rocks of Maidu and Dittmar (and south of the map area, Yana) Volcanic Centers, occupies present-day drainages, and is minimally incised. Although it is faulted in Deer Creek Meadows, flow lacks significant soil cover and has well-preserved flow features. Unit overlies till, older glaciations (Qto) and outwash gravel, older glaciations (Qoo). Age is equivalent to bbz (65±45 ka). [CM]

bcc **Basalts of Cold Creek Butte (late Pleistocene)**—Thick (30–60 m) block lava flows of early aug-ol basalt (52.4% SiO_2) and late ol basalt (50.9% SiO_2) erupted from cinder cone of Cold Creek Butte at west end of Battle Creek Meadows. Lava flowed down South Fork Battle Creek for 8 km and ponded in canyon. Backflow of early lava from vent flowed 3 km toward Mineral, blocked drainage of South Fork Battle Creek, and created Battle Creek Meadows. Outer part of cinder cone is composed of scoria and bombs of late ol basalt lithology. Abundance of phenocrysts is variable in both lithologies. Phenocrysts (early aug-ol basalt): 8% ol, 0.5–2 mm, mostly 1 mm; 3–8% pl, 0.5–2 mm, mostly 0.5–1 mm; sparse–2% aug, 0.5–1 mm. Glomeroporphyritic clots of ol+aug+pl are abundant and as large as ~1 cm in early flows but absent from late flows. Early flows have medium-gray, aphanitic to holocrystalline groundmass and tend to have vesicular flow tops. Phenocrysts (late ol basalt): 5–8% ol, 0.5–2 mm, mostly 0.5 mm. Late flows have light- to dark-gray, aphanitic to glassy groundmasses. Age is poorly constrained. One of youngest lava flows south of LVNP, it is exposed in South Fork Battle Creek canyon but was completely incised by creek along most of its length. Creation of Battle Creek Meadows by trapping of sediment indicates that bbc erupted before latest glacial advances. It is estimated to be 75–100 ka. [LY, MN]

bmc **Tholeiitic basalts of Mill Creek Plateau (middle to late Pleistocene)**—Lava flows of porphyritic tholeiitic basalt (48.5% SiO_2) erupted through rhyolite of Mill Creek Plateau (rmp). Spatter ramparts are preserved at four vents aligned north-south. Three southern vents and two southern flows are south of map area. Small volume of lava from two southern vents produced localized flows, whereas larger volume of lava from two northern vents produced more extensive flows. Lava from northernmost vent entered Mill Creek drainage and forms a discontinuous bench as much as 20 m thick for 10 km downstream, including bench on which the community of Mill Creek is located. Lava from second northernmost vent entered Guernsey Creek drainage and flowed 8 km downstream; most of flow is buried beneath alluvium and colluvium. Phenocrysts: 2–4% ol, 0.5–2 mm; 2–6% pl, 0.5–2 mm, mostly 0.5–1 mm. Phenocryst content is variable; lava from northernmost vent is especially porphyritic. Glomeroporphyritic clots of ol+pl are sparse to abundant and as large as ~1 cm. Lava has light- to medium-gray, holocrystalline, often diktytaxitic groundmass; flow tops contain abundant round vesicles; jointing is massive to blocky. Age is poorly constrained. Unit lies on much older rocks of Maidu Volcanic Center and occupies present drainages. Significant post-emplacement erosion in Mill Creek indicates that bmc is pre-glacial. Estimated age is 100–140 ka. [CM, MN]

bsm **Basalts and basaltic andesites of Sifford Mountain (middle Pleistocene)**—Variety of lithologically distinct, porphyritic, aug-ol basalt and basaltic andesite (51.5–57.4% SiO_2) block-lava flows that form the small shield volcano of Sifford Mountain. Eroded scoria cone at summit marks vent. Lava from Sifford Mountain flowed at least 10 km south and east and partially blocked North Fork Feather River. More Sifford lava may be present under till east of Domingo Spring. Contacts between flows are not mapped. Includes three common and two less-common lava types.

(1) Porphyritic ol-hyp-aug basaltic andesite (55.8–57.4% SiO_2). Phenocryst size and abundance is variable, especially pl and pyr. Phenocrysts: 5–15% pl, mostly 0.5 mm, few larger to 2 mm; 1–4% aug, 0.5 mm; 1–2% hyp, 0.5–1 mm; 1–2% ol, 0.5–4 mm, few larger. Rock is dark gray to black with a glassy to aphanitic groundmass and massive jointing. This lava covers much of south flank of Sifford Mountain and probably constitutes youngest flows on volcano. (2) Porphyritic aug-ol basalt (51.5% SiO_2). Phenocrysts: 10% pl, 0.5–2 mm, mostly 0.5 mm; 7% ol, 0.5–2 mm; 3% aug, 0.5–2 mm. Glomeroporphyritic

clots as large as ~5 mm composed of all three phenocryst phases are sparse. Groundmass is medium gray and holocrystalline; the joint pattern is massive. This lava is exposed in North Fork Feather River valley and Domingo Spring area and is probably intermediate in age. One of these flows is at least 20 m thick where it is cut by young fault near Domingo Spring. Higher on north flank of Sifford Mountain, these flows are buried by younger lava flows. (3) Porphyritic ol basalt. Phenocrysts: 25% pl, mostly 0.5 mm, few larger; 3–4% ol, 0.5–4 mm, few larger; sparse aug, 0.5 mm. Medium- to dark-gray, aphanitic to holocrystalline groundmass; massive jointing. This lava forms most of west flank of volcano and is probably intermediate in age. (4) Porphyritic ol-aug basalt (53.0% SiO_2). Phenocrysts: 20% pl, mostly 0.5 mm, few larger to 1 mm; 8% aug, 1–5 mm, most as glomerocrysts to 8 mm; 2% ol, 0.5–1 mm. The lava also contains common glomeroporphyritic clots as large as 5 mm composed of all three phenocryst minerals. Groundmass is medium gray and holocrystalline and displays thick slabby to massive jointing. This basalt is exposed only in fault scarp along Hot Springs Creek and is probably oldest of exposed Sifford lavas. (5) Porphyritic ol basalt. Phenocrysts: 10% pl, 1–6 mm, mostly 2–3 mm; 8% ol, 0.5–4 mm, few larger are composite crystals. Groundmass is medium to dark gray and aphanitic; rock contains sparse glomeroporphyritic clots of pl+ol. This lava is found only in small area northeast of Domingo Spring. It is poorly exposed; its age relative to other Sifford lavas is unclear.

Sifford Mountain shield is weakly glaciated and little eroded. Except for porphyritic ol-aug basalt, only flows forming surface of volcano are exposed; however, vesicular and rubbly upper surfaces of lava flows are mostly stripped. Several young faults with little displacement cut edifice. Faults near Boiling Springs Lake and along Hot Springs Creek offset late Wisconsin glacial deposits (not visible at map scale).

Sifford Mountain is youngest regional shield volcano south of Lassen Volcanic Center and marks southern limit of young regional volcanism in Cascade Arc. $^{40}Ar/^{39}Ar$ ages are 172±23 ka for aug-ol basalt lava flow exposed near Domingo Spring and 167±4 ka for porphyritic ol-aug basalt exposed in fault scarp along Hot Springs Creek. Entire shield volcano was probably emplaced within span of few thousand years. [CM, MH, RP, ST]

msm **Basaltic andesite of Small Butte (middle Pleistocene)**—Thick flow (>60 m) of porphyritic aug-ol basaltic andesite (55.6% SiO_2). Small plug of partially oxidized lava and remnants of agglutinated cinder cone mark glaciated vent. Lava surrounds eroded vent for ~1 km, but more is probably buried beneath tholeiitic basalts of Buzzard Springs (bbz). Flow surface is heavily glaciated; thickly jointed core of flow is exposed. Phenocrysts: 10% pl, 0.5–2 mm, few larger; 3% ol, 0.5–1 mm, few larger; sparse aug, 0.5–1mm. Some phenocrysts are small glomeroporphyritic clots, 2–4 mm. Groundmass is medium to dark gray, aphanitic, and microvesicular. Age is poorly constrained. It overlies andesite of Rice Creek (ar, 477±14 and 485±12 ka) and is overlain by bbz (65±45 ka). It is probably same age or somewhat older than basalts and basaltic andesites of Sifford Mountain (bsm, 172±23 and 167±4 ka). [CM, RP]

amh **Andesite and basalt of Mount Harkness (middle Pleistocene)**—Thin lava flows of porphyritic ol basalt (51.8% SiO_2) and aug-ol andesite (57.9% SiO_2) erupted from Mount Harkness shield volcano. Scoria cone at summit marks youngest vent. Mount Harkness volcano consists of older ol basalt lava flows and younger aug-ol andesite lava flows. The aug-ol andesite lava flows represent some of youngest regional volcanism in southern LVNP. These lavas cascaded over glacial cliffs of Warner Valley and partly filled valley bottom. Upper slopes of volcano are mantled by fields of boulders transported short distances from their original flow-top locations by periglacial action. Blocky-jointed lava on northeast margin of mountain indicates confinement of flowing lava by ice. A small cirque on the north side of summit exposes vent complex. Ol basalt lava flows are best exposed on glacially eroded north flank of volcano above Juniper Lake. Basaltic and andesitic parts of volcano are probably, but not necessarily, closely related in time. Phenocrysts (ol basalt): 5% ol, 0.5-3 mm, mostly 1 mm; sparse aug, 0.5 mm. Flows have black to medium- to dark-gray, aphanitic, microvesicular groundmasses and blocky jointing. Phenocrysts (aug-ol andesite): 5% ol, mostly 0.5 mm, few to 1 mm; 3% aug, 0.5–1 mm; 3% pl, mostly 0.5 mm, few larger to 1 mm; sparse hyp, 0.5–1 mm. Glomeroporphyritic clots to 5 mm of pl+ol+aug are common. Flows have block-lava surfaces and black to dark-gray, aphanitic, groundmasses and thick platy jointing. Vesicular flow tops have rounded to irregular-shaped vesicles. K-Ar age of 188±32 ka for younger ol-aug andesite is consistent with stratigraphy. Older ol basalt flows overlie rocks of

Dittmar Volcanic Center and probably tholeiitic basalt of Warner Valley (bwv, 610±22 ka) and may be somewhat older than aug-ol andesite. [MH]

mhl **Basaltic andesite of Huckleberry Lake (middle Pleistocene)**—Thin lava flows of aug-ol basaltic andesite 53.1–54.0% SiO_2) erupted from vent high on south flank of Brokeoff Volcano. This regional mafic lava is unrelated to Lassen Volcanic Center magmatic system, and its presence on flank of Brokeoff Volcano marks the end of a viable Brokeoff Volcano magmatic system. Flows covered at least 18 km^2 of south flank of Brokeoff Volcano and flowed down stream courses into Battle Creek Meadows nearly to Mineral. Individual flow units near the vent are separated by layers of scoria. Vent is marked by small plug intruded into a cinder cone, most of which was removed by glacial erosion. Dikes intruded and partially melted underlying dacite of Twin Meadows (dt); contaminated basaltic andesite (not visible at map scale) is exposed in cliffs south of Forest Lake. Lava flows are heavily glaciated; typically, only flow interiors crop out. Lithology is variable. Phenocrysts: 5–7% ol, 0.5–2 mm, mostly 1 mm; 2–5% pl, 0.5–2 mm, mostly 0.5–1 mm; sparse aug, 0.5–1 mm. These early lava flows contain only ol, pl, and sparse aug phenocrysts. Most lava, however, has less ol but contains abundant xenocrysts of pl (to 5 mm), aug, and hyp, as well as glomeroporphyritic clots of same minerals, all derived from underlying Brokeoff Volcano dacite and andesite lava flows. Aug-ol basaltic andesite has light-gray holocrystalline groundmass, whereas contaminated basaltic andesite has medium- to dark-gray, aphanitic groundmass. Rarely preserved flow surfaces are blocky with stretched vesicles; flow interior is typically thick platy to massively jointed. Unit overlies andesite of Glassburner Meadows (ag) and andesite of Bluff Falls quarry (abf, 467±10 ka), but is significantly younger and estimated to be ~300 ka. [LP, MN]

bwv **Tholeiitic basalt of Warner Valley (middle Pleistocene)**—Extensive sheet of sparsely porphyritic, tholeiitic, ol basalt (48–49% SiO_2). Erupted from vent or vents in vicinity of and possibly under Mount Harkness. One stream of lava flowed southward through Lake Almanor Graben and into North Fork Feather River canyon (south of map area and fig. 3; see fig. 1) for at least 60 km. Second stream of lava flowed down Butt Creek (also south of fig. 3) into North Fork Feather River canyon. In Warner Valley, flows are offset at least 100 m by faults extending northwest from Lake Almanor Graben. West of Lake Almanor, cut by many faults with small offsets. Lava flows are tube-fed. In proximal area at cliffs of Warner Valley, at least 11 flow units are present. Unit is glaciated and has extensive till cover east of Warner Valley. Phenocrysts: rare to 2% ol, generally 0.5–2 mm, sparse ol to 5 mm in few flow units. Lava has light- to medium-gray, aphanitic to holocrystalline, often diktytaxitic, groundmass. Flow tops contain abundant round vesicles; jointing is massive to blocky. Vesicle sheets and cylinders are common where thick flow units are exposed. Groundmass of thick flow units often has greenish splotchy appearance caused by growth of large poikilitic aug. Flow interiors have thick blocky to massive joint pattern. Thin flow units and flow-unit tops often have crudely hexagonal, blocky joint pattern. Beyond limits of till cover, bwv has a well-developed orange to reddish soil; flow-top features are rarely observed. Unit overlies much older rocks of Dittmar and Maidu Volcanic Centers including andesites of Dittmar Volcanic Center, Stage 2, undivided (ad2), andesite of Benner Creek (ab), and rhyolite of North Stover Mountain (rsm), and it is overlain by Rockland tephra (pr, 609±7 ka) and the much younger andesite and basalt of Mount Harkness (amh, 188±32 ka). $^{40}Ar/^{39}Ar$ age is 610±22 ka. [CH, MH, ST]

mgp **Basaltic andesite of Grays Peak (early Pleistocene)**—Sparsely porphyritic, ol basaltic andesite (56.1% SiO_2) lava flows near Hampton Butte with a poorly preserved cinder cone at vent. Lava flowed down Panther Creek at least 6 km. Upper surface has well-developed orange soil cover; flow morphology is poorly preserved. Phenocrysts: 1–2% ol, to 1 mm. When fresh, groundmass is light to medium gray and aphanitic to holocrystalline, but typical rock is slightly vesicular and weakly oxidized to pinkish-gray. Unit overlies andesites of Cowslip Campground (acc, 1,320±40 ka) and rhyolite of Blue Ridge (rb, ~1,200 ka) and is overlain by dacite of Rocky Peak (drp) and debris-flow deposit from Brokeoff Volcano (Qwb). K-Ar age is 1,080±26 ka. [GP, LY]

bpa **Basalt of Panther Creek (early Pleistocene)**—Porphyritic aug-ol basalt (52.7% SiO_2) found on ridge above intersection of Panther Creek and South Fork Battle Creek is an erosional remnant of canyon-filling lava flow that is much younger than underlying Maidu Volcanic

Center rocks. Location of vent is unknown; relation to other regional mafic lavas is unknown. Phenocrysts: 10–12% ol, 0.5–1 mm, few larger; 2–3% pl, 0.5–2 mm; 1–2% bright-green chromian aug, 0.5–3 mm. Groundmass is medium gray, aphanitic, and microvesicular. K-Ar age is 1,105±49 ka. [LY]

amr **Andesite of Martin Creek (early Pleistocene)**—Thick lava flows of porphyritic hyp-aug andesite (61% SiO_2) and eroded volcanic neck that forms hill 6869. Lava flows dip gently south, indicating that they flowed toward Maidu Volcanic Center or were deformed by emplacement of younger dome. Phenocrysts: 25% pl, 0.25–1 mm; 6% aug, 0.5–3 mm; 4% hyp, 0.5–2 mm. Much of pyr occurs as small glomeroporphyritic clots to 3–4 mm. Milky qtz xenocrysts surrounded by pyr reaction rims are common; pseudomorphs of hbl are present but rare. Groundmass is light to medium gray. Vague flow lineation is sometimes apparent. Flow tops are moderately vesicular, flow cores are characterized by closely spaced platy joints, flow margins have massive jointing, and base is brecciated and oxidized. Unit is undated but overlies andesites of Maidu Volcanic Center, Stage 1, undivided (Tam) and underlies dacite of Rocky Peak (drp, 803±27 ka). Unit is reversely magnetized, and it appears to have been uplifted by intrusion of dacite of Plantation Gulch (dmg). Lithology is similar to nearby andesites of Cowslip Campground (acc, 1,320±40 ka), and amr may be of similar age. Estimated age 1,100–1,300 ka. [LP, MN]

acc **Andesites of Cowslip Campground (early Pleistocene)**—Thick lava flows of porphyritic hyp-aug andesite (58.1% SiO_2). Lavas form crest of ridge culminating at hill 6964 east of Hampton Butte and are exposed as dip slopes northwest to Hazen Flat, indicating they came from vent located to south, probably on southwestern flank of Maidu Volcanic Center, that is not preserved. Lack of interflow breccias, massive jointing, and coarsely crystalline groundmass support interpretation that unnamed hill between Dry Lake and Cowslip Campground is thickly ponded flow. Contains two types of porphyritic hyp-aug andesite: one with small and another with large pl phenocrysts. Phenocrysts (large pl): 15% pl, 0.5 to 4 mm: 8–10% aug, 0.5–5 mm; 3–5% hyp, 0.5–3 mm; sparse ol, 1–4 mm. Phenocrysts (small pl): 30% pl, to 1 mm; 8–10% aug, 0.5–5 mm; 3-5% hyp, 0.5–3 mm; sparse ol, 1–4 mm. Much of pyr occurs in glomeroporphyritic clots of aug and hyp to 1 cm. Ol is altered to iddingsite and is rimmed with pyr crystals. Large aug phenocrysts are color-zoned from light-green cores to dark-green rims. Groundmass is light to medium gray. Inclusions of milky vein qtz, 1–3 cm, are common in some flows, as well as altered fragments of volcanic and sedimentary rocks. Originally named andesite of Turner Mountain by Wilson (1961) and Clynne (1984) based on its superficial resemblance to lavas near summit of Turner Mountain (south of map area). Rocks in the Turner Mountain area are part of the Maidu Volcanic Center, but acc overlies and is much younger than the Maidu Volcanic Center. K-Ar age is 1,320±40 ka. [GP, LP, LY, MN]

mbc **Basaltic andesites of South Fork Battle Creek (early Pleistocene)**—Three erosional remnants of sparsely porphyritic ol basaltic andesite lava flows in South Fork Battle Creek. No vent areas are preserved; relation to other regional mafic lavas is unknown. Three outcrop areas are just west of Hampton Butte (55.5% SiO_2), just north of Hampton Butte, and 5 km south of Hampton Butte on south side of South Fork Battle Creek. There is some lithologic variability among the three outcrop areas; they may not be same eruptive unit. Each of these lava flows overlies rocks of Maidu Volcanic Center. Phenocrysts: 4–6% ol, 0.5–1 mm, few larger; 4–6% pl, 0.5–1 mm. Few larger pl and pyr crystals occur singly or in clots and are probably xenocrysts derived from underlying, coarsely porphyritic andesites of Maidu Volcanic Center. Groundmass is light gray, aphanitic, and microvesicular. K-Ar age is 1,738±46 ka for a sample from area just west of Hampton Butte. [LY]

REGIONAL VOLCANIC ROCKS OF THE CARIBOU AREA

Includes rocks of monogenetic volcanoes and small- to moderate-sized lava cones and shield volcanoes of all ages in Caribou area. Area approximately bounded on west by trace of Hat Creek Fault-Lake Almanor Graben system. Regional volcanic rocks of Caribou area are divided into two major groups based on age and character of volcanism: Caribou Volcanic Field, and older volcanic rocks in Caribou area. Volcanism in Caribou area was particularly intense during last 450,000 years and produced Caribou Volcanic Field, which dominates easternmost Lassen Volcanic National Park and adjacent areas to east and northeast. Before 450 ka, volcanism in Caribou area was typical of dispersed regional volcanism; rocks of this period are generally buried by rocks of Caribou Volcanic Field and obscured by glacial deposits.

Tuya chains

mtt **Basaltic andesite of Turnaround Lake (late Pleistocene)**—Porphyritic ol basaltic andesite (55.6–56.3% SiO_2) lava flows erupted subglacially (tuyas) and aligned north-south, presumably reflecting subsurface fault control of vent locations. Includes tuyas at Turnaround Lake (55.6% SiO_2) and hills 7576 (56.3% SiO_2) and 7353 southwest of South Divide Lake. Forms steep-sided, oval to roughly circular, relatively flat-topped piles of lava as much as ~1 km diam and 100–200 m high. Sides of tuyas have characteristic curved and polygonal joint patterns that indicate chilling against ice. Phenocrysts: 10–20% pl, 0.5–2 mm, mostly 0.25–1 mm; 2% ol, 0.25–1 mm, mostly 0.5 mm. Few small glomeroporphyritic clots of ol+pl are present. Groundmass is black, glassy, and coarsely microvesicular. Unit overlies basalts of Triangle Lake, unit 1 (brt1) and basalt of hill 8030 (br80). Unit erupted during last major glacial episode, probably 17–35 ka, and is one of youngest units in Caribou Volcanic Field. [BB, RC]

mte **Basaltic andesites of Evelyn Lake (late Pleistocene)**—Porphyritic, aug-ol and ol-aug basaltic andesite (53.1–55.1% SiO_2) lava flows erupted subglacially (tuyas) in southern Caribou Volcanic Field. Includes hills 7275 (53.1% SiO_2) and 7299 west of Evelyn Lake and hill 7436 (55.1% SiO_2) slightly farther west. Forms steep-sided, oval to elongate, relatively flat-topped piles of lava 0.5–1 km long and as high as 100 m. Sides of tuyas have characteristic curved and polygonal joint patterns that indicate chilling against ice. Hill 7436 contains an intrusive plug and subaerial flows near summit. Phenocrysts (hills 7275 and 7299): 5% pl, 0.5–2 mm, mostly 0.5–1 mm; 2% aug, 0.5–1 mm, few composite grains to 2 mm; 1% ol, 0.5–1 mm. Groundmass is dark gray, glassy, and dense to microvesicular. Phenocrysts (hill 7436): 5–10% pl, 0.25–1 mm, mostly <0.5 mm; 2% ol, 0.5–2 mm, mostly <1 mm; sparse aug, 0.5–1 mm. Groundmass of lava is dark gray, glassy, and coarsely microvesicular. Groundmass of plug is medium gray, aphanitic, and dense. Unit overlies basaltic andesite of Black Cinder Rock (mb, 667±24 ka) and basalt of Posey Lake (bbp). Evelen Lake tuyas are more eroded and older than Turnaround Lake (mtt) tuyas and probably erupted during early Wisconsin or Illinoian glaciation. Therefore, mte is estimated to be either ~60 ka or 120–130 ka. [RC]

Red Cinder chain

The Red Cinder chain comprises a zone of vents 11 km long and 2.5 km wide trending N. 10° W. across the west-central part of the Caribou Volcanic Field, congruent with two young faults that cut several of the older units in the chain. The Red Cinder chain is dominated volumetrically by the complex edifice centered on Red Cinder (at 2,553 m the highest elevation in the eastern part of map area). Units of the Red Cinder chain are not as heavily glaciated as other nearby parts of the Caribou Volcanic Field, and many lava flows retain their original surfaces.

mrc **Basaltic andesite of Red Cinder Cone (late Pleistocene)**—Thin block-lava flows of porphyritic ol basaltic andesite (53.1% SiO_2) erupted from northerly of pair of vents collectively called Red Cinder Cone, 1 km northwest of Red Cinder. Lava flowed ~1 km northwest. Flows were only slightly eroded by glaciers. Phenocrysts: 3% ol, 0.5–1 mm; 3% pl, 0.5–2 mm. Small glomeroporphyritic clots of ol+pl to 5 mm are present but not abundant; qtz xenocrysts are sparse. Groundmass is medium gray, aphanitic, and microvesicular to dense. Jointing is thick slabby to massive; flow tops are vesicular. Unit mrc overlies basalt of Red Cinder Cone (brc), basaltic andesite of Red Cinder (mrr), andesite of Red Cinder (arr, 69±20 ka), and andesites of Dittmar Volcanic Center, Stage 1, undivided (Tad). Age is not well constrained; estimated to be 20–25 ka. [MH, PP]

brc **Basalt of Red Cinder Cone (late Pleistocene)**—Lava flow of porphyritic aug-ol basalt (52.1% SiO_2) erupted from southerly of pair of vents collectively called Red Cinder Cone. Flow is short and thick and may have been confined by glacial ice. Lava flow was only slightly eroded by glaciers. Most of cinder cone built over vent was destroyed by eruption of lava flow and by glaciation. Phenocrysts: 8% ol, mostly 0.5–2 mm, few larger; 6% aug, 0.5–3 mm; 4% pl, 0.5–2 mm. Small glomeroporphyritic clots of ol+aug+pl to 5 mm are abundant. Groundmass is black when glassy and medium to dark gray and aphanitic in dense flow cores. Flow surfaces are vesicular and oxidized. Unit brc is overlain by basaltic andesite of Red Cinder Cone (mrc) and overlies basaltic andesite of Red Cinder (mrr), andesite of Red Cinder (arr, 69±20 ka), and andesites of Dittmar Volcanic Center, Stage 1, undivided (Tad). Age is not well constrained; estimated to be 25–40 ka. [MH, PP]

mrr **Basaltic andesite of Red Cinder (late Pleistocene)**—Thin block-lava flows and large cinder cone of porphyritic ol basaltic andesite (53.3 % SiO_2) erupted from Red Cinder. Lava flowed 3 km west-northwest and 3.5 km southwest from vent. Lava flow was glaciated, but surface morphology is mostly preserved. Flow tops are very vesicular to scoriaceous and often oxidized. Phenocrysts: 10% pl, 0.5–2 mm, mostly <1 mm; 5% ol, 0.5–1 mm. Glomeroporphyritic clots of pl+ol, 2–5 mm in size, are present but not abundant. Groundmass is typically light to medium gray, aphanitic, and sparsely microvesicular, but black where glassy; commonly flow banded. Unit mrr is overlain by basaltic andesite of Red Cinder Cone (mrc) and basalt of Red Cinder Cone (brc) and overlies basalt of hill 8030 (br80), basalt of Cameron Meadow (brm), andesite of Red Cinder (arr, 69±20 ka), basaltic andesites of Long Lake, unit 3 (mrg3), andesites of Dittmar Volcanic Center, Stage 2, undivided (ad2), and andesites of Dittmar Volcanic Center, Stage 1, undivided (Tad). Unit mrr is older than last glacial maximum; estimated to be 25–40 ka. [BB, MH, PP, RC]

br80 **Basalt of hill 8030 (late Pleistocene)**—Thin lava flows of porphyritic aug-ol basalt (52.1–52.3 % SiO_2) erupted from vent marked by cinder cone 1 km southeast of Red Cinder at hill 8030. Lava flowed 4 km west and 3 km southeast. Flows are offset by small N. 10° W. faults along discontinuous fault zone between Lake Almanor Graben and Hat Creek Graben. Glaciated but not deeply eroded, although little original surface morphology is preserved. Phenocrysts: 10% pl, 0.5–2 mm; 5% ol, 0.5–1 mm; sparse aug, 0.5–1 mm. Glomeroporphyritic clots of pl+ol, 2–5 mm in size, are abundant. Groundmass is dark gray, aphanitic, and microvesicular. Unit br80 overlies basalt of Cameron Meadow (brm), andesite of Red Cinder (arr, 69±20 ka), basaltic andesites of Long Lake, units 1, 2, and 3 (mrg1, mrg2, mrg3), and andesites of Dittmar Volcanic Center, Stage 2, undivided (ad2). Unit br80 is overlain by basaltic andesite of Turnaround Lake (mtt) and basaltic andesite of Red Cinder (mrr). Unit br80 is older than last glacial maximum; estimated to be 25–40 ka. [MH, RC]

brm **Basalt of Cameron Meadow (late Pleistocene)**—Thin lava flows of porphyritic ol basalt erupted from vent to east now buried by younger lavas. Lava fills valley floor between Cameron Meadow and younger lavas from Red Cinder. Glaciated; crops out as small rounded hills of dense, thickly jointed, flow cores. Phenocrysts: 8–10% ol, mostly 0.5–1 but up to 2 mm; sparse pl, 1 mm; sparse aug, 1–2 mm. Groundmass is medium to dark gray and aphanitic with pink vapor-phase crystallization along flow planes. Unit brm overlies the much older basaltic andesite of Jakey Lake (mj) and andesites of Dittmar Volcanic Center, Stage 2, undivided (ad2) and is overlain by basalt of hill 8030 (br80) and basaltic andesite of Red Cinder (mrr). Unit brm is older than last glacial maximum; estimated to be 25–40 ka. [MH]

bra **Basalt of Ash Butte (late Pleistocene)**—Short, thick lava flow of porphyritic aug-ol basalt (52.0% SiO_2) erupted from cinder cone of Ash Butte at north-northwest end of Red Cinder chain. Cone and lava flow were glaciated but generally are free of thick till deposits. Rubbly surface of flow and shape of cone are well preserved, although cone is sufficiently eroded to expose agglutinated core in some places. Cinders are generally oxidized; part of cone was rafted away by lava flow. Phenocrysts: 6% pl, 0.25–1.5 mm, mostly <1 mm; 4% ol, 0.5–1 mm, mostly 0.5 mm. Glomeroporphyritic clots of ol+pl to a few millimeters and small xenocrysts of qtz are sometimes present. Groundmass is dark gray, aphanitic, and dense to microvesicular. Unit bra overlies andesite of Red Cinder (arr, 69±20 ka), basalt east of Ash Butte (bre), and basalt of Widow Lake (brw). Unit bra is older than last glacial episode and estimated to be 40–70 ka. [PP]

br22 **Basalt of hill 2283 (late Pleistocene)**—Relatively thin lava flow (to 20 m) of sparsely porphyritic ol basalt (52.5% SiO_2) erupted from well-preserved cinder cone at hill 2283. Cone is composed of agglutinated cinders that are mostly oxidized. Cone and lava flow glaciated, extensively buried by till, and poorly exposed, but cone shape is well preserved. Lava from cone flowed ~1 km west. Phenocrysts: 3% ol, 0.5–1 mm, mostly 0.5 mm. Groundmass is light to medium gray and aphanitic. Rafted, agglutinated cinders cover parts of flow; in other places, massively jointed flow interior is exposed. Unit br22 overlies basalt of section 25 (br25), andesite of Red Cinder (arr, 69±20 ka), and basalt of Widow Lake (brw). Age is poorly constrained but is clearly older than last glacial episode; estimated to be 40–70 ka. [BB, PP]

br25 **Basalt of section 25 (late Pleistocene)**—Thin lava flow of porphyritic ol basalt (52.9% SiO_2) erupted from cinder cone that forms hill 7711 at north-northwest end of Red Cinder chain. Lava flowed north for 3 km. Cone and lava flow were only weakly glaciated; brecciated surface of flow and conical shape of cone are fairly well preserved. Phenocrysts: 4% ol, 0.5–1 mm, mostly 0.5 mm; 6% pl, 0.25–1.5 mm, mostly <1 mm. Groundmass is light to medium gray, holocrystalline, and microvesicular. Glomeroporphyritic clots of ol+pl to a few millimeters and small xenocrysts of qtz are sometimes present. Unit br25 is overlain by basalt of hill 2283 (br22) and overlies andesite of Red Cinder (arr, 69±20 ka) and basalt of Widow Lake (brw). Age is not well constrained, but is older than last glacial episode; estimated to be 40–70 ka. [PP]

arr **Andesite of Red Cinder (late Pleistocene)**—Thin, block-lava flows of porphyritic aug-hyp andesite (59.6–60.3% SiO_2) that comprise the largest-volume unit of the Red Cinder chain. Erupted from vent now buried by younger lavas of basaltic andesite of Red Cinder (mrr). Lava flows were glaciated but are not significantly eroded. Phenocrysts: 10% pl, 0.5–1 mm, few to 2 mm; 3% hyp, 0.5–1 2 mm; 2% aug, mostly 0.5–1, few to 2 mm. Glomeroporphyritic clots of pl+hyp+aug, 2–5 mm in size, are abundant. Groundmass is dark-gray, dense, and aphanitic. Flattened vesicles are common in upper parts of flows. Unit arr is overlain by basaltic andesite of Red Cinder Cone (mrc), basalt of Red Cinder Cone (brc), basaltic andesite of Red Cinder (mrr), basalt of hill 8030 (br80), basalt of Ash Butte (bra), basalt of hill 2283 (br22), and basalt of section 25 (br25). Unit arr overlies basalt east of Ash Butte (bre), basalts of Triangle Lake, units 1 and 2 (brt1, brt2), basaltic andesites of Silver Lake, unit 4 (mc4), and andesites of Dittmar Volcanic Center, Stage 1, undivided (Tad). Oldest exposed unit of the complex edifice centered at Red Cinder; K-Ar age is 69±20 ka. [BB, MH, PP, RC]

bre **Basalt east of Ash Butte (late Pleistocene)**—Short, thick (20–30 m) lava flow of sparsely porphyritic ol basalt erupted from cinder cone 500 m east of Ash Butte. Cone and lava flow were glaciated and are partially covered by thick deposits of till. Cone is sufficiently eroded to expose its agglutinated core; cinders are generally oxidized. Phenocrysts: 3% pl, 0.25–1.0 mm, many with overgrowth rims; 1% ol, 0.5–1 mm. Glomeroporphyritic clots of ol+pl to 4 cm, but mostly 5 mm or less, are common, and small qtz xenocrysts are sometimes present. Groundmass is medium gray, aphanitic to holocrystalline, and microvesicular. Flow top is vesicular; large stretched vesicles occur throughout unit. Unit bre is overlain by basalt of section 25 (br25), basalt of Ash Butte (bra), and andesite of Red Cinder (arr, 69±20 ka). Age is poorly constrained; estimated to be 70–100 ka. [PP]

brw **Basalt of Widow Lake (late Pleistocene)**—Relatively thin lava flows (to 10 m) of porphyritic ol basalt (52.1% SiO_2) at north-northwest end of Red Cinder chain. Erupted from two cinder cones (7,232 ft and 2,213 m elev) 0.5 km northeast of Widow Lake. The cones are aligned west-northwest and composed of agglutinated, mostly oxidized cinders. Both cones and lava flows were glaciated, are extensively buried by till, and are very poorly exposed. Third cone, ~0.75 km southwest of Widow Lake, is completely buried by till, but outcrop 300 m farther west suggests that this cone is also brw. Phenocrysts: 5% ol, 0.5–2 mm; rare pl, 0.25–1.0 mm. Groundmass is medium gray and aphanitic but commonly oxidized. Unit brw is overlain by basalt of Ash Butte (bra), basalt of hill 2232 (br22), and basalt of section 25 (br25). Age is poorly constrained; estimated to be ~100 ka. [BB, PP]

Basaltic andesites of Long Lake (late Pleistocene)—Thick lava flows of porphyritic ol basaltic andesite and ol-aug basaltic andesite (53.2-56.3% SiO_2) on south flank of Red Cinder edifice. Age is poorly constrained, but flows are among oldest in Red Cinder chain; estimated to be ~100 ka. [MH, RC]

mrg3 **Unit 3**—Thick lava flow of porphyritic aug-ol basaltic andesite (53.2% SiO_2) erupted from poorly preserved cinder cone that forms hill 7602, 5 km west-northwest of Posey Lake. Lava flowed 2.5 km west and is offset by two small faults along discontinuous fault zone between Lake Almanor Graben and Hat Creek Graben. Flow was heavily glaciated and is partly buried by till; surface features are not preserved. Phenocrysts: 8% pl, 0.5–1 mm, few larger; 6% ol, 0.5–1 mm, few larger; 3% aug, 0.5 mm. Groundmass is light to medium gray, aphanitic to holocrystalline, and dense. Unit mrg3 overlies unit mrg1, unit mrg2, basaltic andesite of Black Cinder Rock (mb, 667±24 ka), and andesite of Dittmar Volcanic Center, Stage 2, undivided (ad2) and is overlain by basaltic andesite of Red Cinder (mrr) and basalt of hill 8030 (br80). [MH, RC]

mrg2 **Unit 2**—Thick lava flow of porphyritic aug-ol basaltic andesite (55.5–56.3% SiO_2) erupted from poorly preserved vent at hill 7603 north-northwest of Posey Lake. Lava flowed several kilometers west and is offset by one of two small faults along discontinuous fault zone between Lake Almanor Graben and Hat Creek Graben. Another outcrop is 1.5 km farther west; intervening area is buried by unit mrg3. Flow was heavily glaciated and is partly buried by till; surface features are not preserved. Lithology is somewhat variable. Phenocrysts: 8–12% pl, 0.5–3 mm; 4–8% ol, 0.5–3 mm; sparse to 2% aug, 0.5–2 mm. Many crystals occur in glomeroporphyritic clots of ol+pl±aug generally to 2–5 mm in size. Groundmass is light to medium gray, aphanitic to holocrystalline, and dense to microvesicular. Unit mrg2 overlies unit mrg1 and is overlain by unit mrg3 and basalt of hill 8030 (br80). [MH, RC]

mrg1 **Unit 1**—Thick lava flows of porphyritic ol basaltic andesite (53.6% SiO_2) in area l–2 km north-northwest of Posey Lake. Vent not preserved; flows probably erupted from vent now buried by mrg2 vent or by younger lavas of Red Cinder chain. Lava flowed south from vent area ~3 km. Flows were heavily glaciated and are partly buried by till; surface features are not preserved. Lithology is somewhat variable. Phenocrysts: 4–8% ol, 0.5–3 mm, few larger; 1–3% pl, 0.5–1 mm. Small glomeroporphyritic clots of ol+pl are sparse in some flows and common in others. Groundmass is medium gray, usually aphanitic and dense, but occasionally holocrystalline and microvesicular. Lava is massive to thick platy-jointed. Unit mrg1 is overlain by unit mrg2, unit mrg3, and basalt of hill 8030 (br80). [RC]

mrb **Basaltic andesite of Caribou Wilderness (late Pleistocene)**—Porphyritic, aug-ol basaltic andesite lava flows in six small outcrop areas southwest of Triangle Lake. Vent location uncertain, but probably located to southwest and buried by younger lavas. Flows were mostly stripped by glaciers; only a few remnants of flow cores are preserved. Somewhat variable in lithology. Phenocrysts: 4–6% ol, 0.5–2 mm; 5–8% pl, 0.5–1 mm; 4–6% aug, 0.5–1 mm. Small glomeroporphyritic clots of ol+pl+aug are common. Groundmass is medium to dark gray, holocrystalline, and dense; usually has abundant vapor-phase crystallization splotches and, generally, some purplish oxidation. Unit mrb overlies basalts of Triangle Lake, Units 1 and 2 (brt1, brt2) but has not been dated; estimated to be ~100 ka, but could be older. [BB]

Basalts of Triangle Lake (late Pleistocene)—Lava flows of sparsely porphyritic and porphyritic ol basalt (52.4% SiO_2) located immediately southwest of Triangle Lake. Vents not preserved, but probably erupted from vents located to southwest and buried by younger lava flows. Flows were heavily glaciated and are poorly exposed, typically only as flow cores. Basalts of Triangle Lake are not dated; estimated to be ~100 ka, but could be older. [BB]

brt2 **Unit 2**—Lava flows of porphyritic ol basalt displaying a limited range of lithologic variability. Phenocrysts: 5% ol, 0.5–2 mm; sparse to 2 % pl, 0.5–1 mm; rare aug, 0.5–1 mm. Few samples contain glomeroporphyritic clots of ol+pl+aug. Most pl and aug may be from disaggregated glomeroporphyritic clots. Groundmass is light to medium gray and usually holocrystalline, but locally aphanitic and dense to microvesicular. Unit brt2 overlies unit brt1 and is overlain by basaltic andesite of Caribou Wilderness (mrb) and andesite of Red Cinder (arr, 69±20 ka). [BB]

brt1 **Unit 1**—Lava flows of sparsely porphyritic ol basalt (52.4% SiO_2) displaying a range of lithologic variability. Phenocrysts: 5–15% ol, 0.5–4 mm, mostly <2 mm (most flows have ~5% ol, 0.5–2 mm). Groundmass is light to medium gray and usually holocrystalline, but locally is aphanitic and dense to microvesicular. Unit brt1 is overlain by unit brt2, basaltic andesite of Caribou Wilderness (mrb), andesite of Red Cinder (arr, 69±20 ka), and basaltic andesite of Turnaround Lake (mtt). [BB]

Bidwell Spring chain

The Bidwell Spring chain comprises a zone of vents 8.5 km long and ~2 km wide trending N. 25° W. across the north-northwest part of the Caribou Volcanic Field, ~2 km northeast of Butte Lake. Units of the Bidwell Spring Chain erupted at the northern margin of young glaciation; only parts of the flows are overlain by till and outwash deposits, and the cinder cones are only slightly eroded. Age of units in the Bidwell Spring chain ranges from ~25 ka to ~70 ka.

adb **Andesite of Bidwell Spring (late Pleistocene)**—Thin, block-lava flow of nearly aphyric andesite (59.0% SiO_2) with small cinder cone forming its vent. Flow is displaced slightly to the southwest from the main N. 25° W. orientation of the Bidwell Spring chain. Proximal portion of lava flow is overlain by till, younger glaciations (Qty), whereas distal portion of flow is beyond extent of young glaciation, and a rough scoriaceous block-surface is preserved. Small cinder cone is surrounded by thin, marginal deposits of unit Qty, but only weakly eroded. Phenocrysts: trace ol, 0.5 mm. Contains a few large xenocrysts of pl. Groundmass is black and glassy; lava contains abundant irregularly shaped stretched vesicles. Age is constrained by overlying glacial deposits which indicate that it is older than ~25 ka, and it is probably younger than basalt of Twin Buttes (bdt, 46.3±3.4 ka). [PP, SW]

mdp **Basaltic andesite of Pole Spring Road (late Pleistocene)**—Short, thick, aa to block-lava flow of sparsely porphyritic ol basaltic andesite (53.7% SiO_2) in northwest part of Bidwell Spring chain; vents are marked by two small cinder cones aligned north-northeast. Lava flowed 2 km northwest. Southwest edge of lava flow is overlain by till, younger glaciations (Qty), whereas distal portion and east side of lava flow are beyond glacial limit, and a rough scoriaceous surface is preserved. Phenocrysts: 1–2% ol, 0.25–1 mm; 1–2% pl, 0.25–1mm. Groundmass is dark gray to black, glassy to aphanitic, and coarsely microvesicular. Sparse xenocrysts of pl and qtz to 5 mm are present. Lava blocks on upper surface have stretched to irregularly shaped vesicles; flow interior is microvesicular. Lava flow has poorly developed soil. Unit overlies much older basalts and basaltic andesites of Swains Hole (bsh) and basalt of hill 2109 (bl21). Age is well constrained; weakly affected by 18–25 ka glacial advance, but overlies basalt of Twin Buttes (bdt, 46.3±3.4 ka). Estimated age is between ~25 and 45 ka. [PP]

md36 **Basaltic andesite of section 36 (late Pleistocene)**—Short, thick, block-lava flow of porphyritic, ol basaltic andesite (53.6% SiO_2) in northwest part of Bidwell Spring chain; vent area marked by two cinder cones aligned north-south. Scoria and bombs in cones are oxidized; agglutinate rafted from cones covers flow in some places. Lava flowed ~2 km northwest of cones. Phenocrysts: 12% pl, 0.5–2 mm; 2% ol, 0.5–2 mm, mostly 1 mm. Glomeroporphyritic clots of pl+ol are present. Groundmass is medium gray, aphanitic, and microvesicular. Blocks at flow surface contain abundant stretched vesicles. Unit md36 is younger than basalt of Twin Buttes (bdt, 46.3±3.4 ka) but older than basaltic andesite of Pole Spring Road (mdp); estimated age is 25–40 ka. [BB, PP]

bdt **Basalt of Twin Buttes (late Pleistocene)**—Block lava flows and two large well-preserved north-northwest-aligned cinder cones of sparsely porphyritic ol basalt (52.8% SiO_2) in central part of Bidwell Spring chain. Lava from cinder cones flowed in two separate streams as far as 7 km north. Lava flows cover nearly 25 km^2 and have as much as 10 m of relief at their margins. Blocky flow tops are vesicular; interiors are dense. Cinders and ash from the cones of Twin Buttes blanket area east of cones. Flow has orange soil in some areas, but outcrop is still abundant. Phenocrysts: 3–4% ol, 0.5–1 mm; sparse pl, 0.5 mm. Small xenoliths (1–2 cm) of coarsely crystalline qtz are occasionally found. Groundmass is black to medium gray, glassy to aphanitic, and dense to microvesicular. Unit bdt overlies basaltic andesites of Black Butte, unit 1 (mdb1) and is probably older than all other units of Bidwell Spring chain except basaltic andesites of Black Butte. $^{40}Ar/^{39}Ar$ age is 46.3±3.4 ka, which is slightly older than last major glacial advance (18–25 ka). [BB, PL, PP]

Basaltic andesites of Black Butte (late Pleistocene)—Thick, block-lava flow and associated complex of cinder cones at southeast end of Bidwell Spring chain. Flows and cinder cones are all basaltic andesite. Age is probably 50–70 ka. [BB, PP]

mdb2 **Unit 2**—Prominent, well-preserved cinder cone that forms Black Butte (elev, 2437 m). Cinders are basaltic andesite identical in composition to unit mdb1. [BB]

mdb1 **Unit 1**—Thick, block-lava flow of sparsely porphyritic ol basaltic andesite (55.8–56.1% SiO_2). Lava flowed as far as 3 km from vent, and additional lava is probably buried beneath basalt of Twin Buttes (bdt). Associated cinder cone 0.5 km west of Black Butte was partially destroyed when lava flows were extruded from its base; some areas of lava flow are covered by cinders and agglutinate rafted from the cone. Surface of lava flow has unusual topography characterized by fissures a few meters across and a few meters deep, oriented at various angles. These features were probably caused by a shallow underlying intrusion, perhaps related to aborted rise of magma that produced the later cone (unit mdb2). Phenocrysts: 2% ol, 0.5–1 mm. Groundmass is dark gray, aphanitic, and dense to microvesicular, with vapor-phase crystallization along planar fractures. Lava flow is partially buried by till, younger glaciations (Qty), but majority of lava flow is beyond the limits of glaciation. Unit mdb1 is overlain by the basalt of Twin Buttes (bdt, 46.3±3.4 ka); fresh flow surfaces suggest that unit mdb1 is only slightly older than unit bdt. [BB, PP]

Poison Lake chain

The Poison Lake chain comprises a zone of cinder cones and lava flows 18 km long and 2 km wide trending N. 40° W. across the northeast part of the Caribou Volcanic Field. Vents in the chain are concentrated in two rows that probably reflect underlying faults that served as conduits for magma. Thirty-nine mapped units of basalt and basaltic andesite are divided into nine groups based on shared lithologic, chemical, and spatial characteristics. The Poison Lake chain lies outside the area of glaciation, and cinder cones and flow surfaces are well preserved. Ten $^{40}Ar/^{39}Ar$ ages and one K-Ar age range from 110.8 ka to 97.6 ka, indicating that the Poison Lake chain units erupted during a short-lived episode of volcanism. The eruptive order of the Poison Lake chain units is based on known stratigraphic relations and the $^{40}Ar/^{39}Ar$ ages. However, some of the groups do not have definitive stratigraphic relations, and the uncertainties of many of the $^{40}Ar/^{39}Ar$ ages overlap. Consequently, the eruptive order may be subject to revision.

Basalts of Cone Lake Road (late Pleistocene)—Group of two ol basalt (49.0–49.5% SiO_2) lava flows and cinder cones 3.5 km southwest of Bogard Buttes. Interpreted to be the youngest group in the Poison Lake chain based on $^{40}Ar/^{39}Ar$ age of 97.6±9.8 ka for unit bc2. [BB]

bc2 **Unit 2**—Thin, short, stubby block lava flow of porphyritic ol basalt (49.3–49.5% SiO_2); vents marked by row of small cinder cones aligned north-south. Lava flowed ~2 km north and 1 km south. Phenocrysts: 10% ol, 0.5–3 mm, mostly 1 mm; trace pl, 1 mm. Groundmass is light to medium gray, aphanitic, and dense to microvesicular. Blocks on upper surface of flow contain abundant, large, rounded to irregular-shaped vesicles. Unit bc2 overlies basalts of Stephens Campground, units 2 and 3 (bs2, bs3) and unit bc1. $^{40}Ar/^{39}Ar$ age is 97.6±9.8 ka. [BB]

bc1 **Unit 1**—Thick, short, lobate lava flow of porphyritic ol basalt (49.0% SiO_2); large, well-preserved cinder cone marks vent. Cinders and ash in cone are oxidized; aa surface of lava flow is covered in some places with thick layer of rafted cinders and agglutinate. Phenocrysts: 10–12% ol, 0.5–5 mm, mostly 1–2 mm; sparse–2% pl, 0.5–3 mm, mostly ~1 mm. Small glomeroporphyritic clots of ol or pl and ol+pl are present. Groundmass is medium gray, aphanitic to holocrystalline, and extremely microvesicular. Unit overlies basalts of Stephens Campground, units 2 and 3 (bs2, bs3) and basalt of hill 2088 (bl20); overlain by unit bc2. [BB]

Basalts of old railroad grade (late Pleistocene)—Group of six cinder cones and three lava flows of porphyritic ol basalt (50.0–51.5% SiO_2) in northwestern Poison Lake chain. Basalts of old railroad grade overlie basalts of Poison Butte, but their relation to other units is unclear. $^{40}Ar/^{39}Ar$ age of unit bg4 is 102.1±11.4 ka. [BB, PL, SW]

bg4 **Unit 4**—Cinder cone (hill 1791) and lava flow of sparsely porphyritic aug-ol basalt (51.2–51.5% SiO_2). Lava flowed as far as 1 km northwest and south. Top of flow is composed of vesicular aa and is covered by deep orange soil. Interior of flow is dense and flow banded. Phenocrysts: 5% ol, 0.5–3 mm, mostly <1 mm; 2% pl, 0.5–1 mm, mostly 0.5 mm; trace aug, 0.5 mm. Groundmass is medium gray, aphanitic, and microvesicular. Unit bg4 overlies basalts and basaltic andesites of Swains Hole (bsh) and basalts of Poison Butte, unit 3 (bp3). $^{40}Ar/^{39}Ar$ age is 102.1±11.4 ka. [PL]

bg3 **Unit 3**—Cinder cone (hill 1784) and thick lava flow of porphyritic ol basalt (50.0% SiO_2) located 2–3 km west of Poison Lake. Lava flowed northwest from cone ~3 km, mostly beyond north boundary of map area. Phenocrysts: 15% ol, 0.5–6 mm, mostly <3 mm; 5% pl, 0.5–3 mm, mostly <1 mm. Groundmass is dark gray, aphanitic, and microvesicular. Unit bg3 overlies basalts and basaltic andesites of Swains Hole (bsh) and basalts of Poison Butte, units 1 and 3 (bp1, bp3). [PL, SW]

bg2 **Unit 2**—Large, well-preserved cinder cone (hill 1816) and short stubby aa lava flow of porphyritic ol basalt (50.2% SiO_2). Flow has thick ash cover from eruption of nearby cones. Phenocrysts: 10% ol, 0.5–3 mm, mostly 1 mm; sparse pl, 0.5–1 mm. Small glomeroporphyritic clots of ol+pl are present. Groundmass is medium-gray, aphanitic, and dense. Unit bg2 overlies basalts and basaltic andesites of Swains Hole (bsh) and basaltic andesite of hill 1868 (ml18). [PL] bg1 **Unit 1**—Three small cinder cones of porphyritic ol basalt (52.9% SiO_2) aligned N. 40° W. and located 3.2–3.7 km south of Poison Lake; no associated lava flows. Phenocrysts: 4–5% ol, 0.5–2 mm, mostly 0.5–1 mm; 1–2% pl, 0.5–2 mm, mostly 0.5–1 mm. Small glomeroporphyritic clots of ol+pl are common. Where fresh, groundmass of dense blocks is dark gray, aphanitic, and microvesicular, but most blocks and scoria are oxidized to shades of red. Unit bg1 overlies basaltic andesite of hill 1868 (ml18). [BB, PL]

Basalts of Poison Butte (late Pleistocene)—Group of cinder cones and lava flows of sparsely porphyritic ol basalt (51.4–52.8% SiO_2). Most units also contain sparse pl and (or) aug. Basalts of Poison Butte are older than basalts of old railroad grade and younger than basalts of Pittville Road. They are approximately the same age as basalts and basaltic andesites of Bogard Buttes, but there are no contact relations between the two groups. $^{40}Ar/^{39}Ar$ age of bp6 is 105.0±6.0 ka. [PL]

bp6 **Unit 6**—Short, thick, block lava flow of sparsely porphyritic aug-ol basalt (52.8% SiO_2). Lava flowed ~1.5 km north from well-preserved but partially buried cinder cone between hill 1925 and hill 1919. Phenocrysts: 2% ol, 0.5–2 mm, mostly 0.5–1 mm; 1% pl, 0.5–1 mm; sparse aug, 0.5–1 mm. Groundmass is medium gray, aphanitic, and microvesicular. Unit bp6 overlies basalts of Pittville Road, units 1 and 2 (bt1, bt2), basalts of Robbers Spring, unit 2 (br2), unit bp4, and unit bp5. $^{40}Ar/^{39}Ar$ age is 105.0±6.0 ka. [PL]

bp5 **Unit 5**—Well-preserved cinder cone (hill 1925) of sparsely porphyritic aug-ol basalt (52.3–52.4% SiO_2). Cone is younger than most surrounding cinder cones and lava flows; it probably does not have associated lava flow. Includes remnant of older, largely buried cinder cone on its northeast flank. Both cones have similar composition, but slightly different petrography. Phenocrysts (main cone): 2–3% ol, 0.5–2 mm, mostly 0.5–1 mm; sparse aug, 0.5–1 mm; rare pl, 0.5 mm. Groundmass is medium to dark gray, glassy to aphanitic, and microvesicular. Phenocrysts (older cone): 2–3% ol, 0.5–2 mm, mostly 0.5–1 mm; trace aug, 0.25–0.5 mm. Groundmass is medium gray, glassy to aphanitic, and microvesicular. Unit bp5 overlies basalts of Pittville Road, unit 2 (bt2) and basaltic andesite of hill 1868 (ml18); overlain by unit bp6. [PL]

bp4 **Unit 4**—Short and thin lava flow of sparsely porphyritic ol basalt (52.6% SiO_2) erupted from large, well-preserved cinder cone (hill 1942, ~1.5 km south of Poison Lake). Cone has multiple craters and is composed of oxidized scoria. Flow has oxidized, scoriaceous, and rubbly top. Phenocrysts: 3% ol, 0.5–1 mm; sparse aug, 0.5 mm. Groundmass is dark gray, aphanitic, and microvesicular. Unit bp4 overlies basaltic andesite of hill 1868 (ml18); overlain by unit bp6. [PL]

bp3 **Unit 3**—Lava flow of sparsely porphyritic ol basalt (52.8% SiO_2); large cinder cone of Poison Butte marks vent. Most cinders in cone are oxidized to bright red. Lava erupted from cone flowed ~2 km, mostly west. Lava flow is cut by N. 40° W. fault with 10 m offset. Top of lava flow is composed of rubbly and vesicular aa and is covered by deep orange soil. Phenocrysts: 3% ol, 0.5–2 mm, mostly <1 mm. Fresh groundmass is medium gray, glassy to aphanitic, and microvesicular. Unit bp3 overlies basalts and basaltic andesites of Swains Hole (bsh), basaltic andesite of hill 1868 (ml18), and unit bp1; overlain by basalts of old railroad grade, units 3 and 4 (bg3, bg4). [PL]

bp2 **Unit 2**—Short, thick (15 m) lava flow of sparsely porphyritic ol basalt (51.4% SiO_2) just north-northwest of Poison Lake. Lava flow erupted from same vent as bp1 but apparently with little or no additional pyroclastic activity, because no cinders of bp2 lithology were found on cone. Lava flowed only ~1 km from vent; most of unit is north of map area. Flow has rubbly and vesicular aa top and is often strongly oxidized. In some places, it is covered by cinders rafted from bp1 cone and by deep reddish soil. Phenocrysts: 2% ol, 0.5–2 mm; sparse pl, 0.5 mm. Groundmass is light to medium gray, glassy to aphanitic, and microvesicular. Unit contains fewer, but larger, ol phenocrysts than bp1. Unit bp2 overlies unit bp1. [PL]

bp1 **Unit 1**—Thick (15 m) lava flow and cinder cone of sparsely porphyritic ol basalt (52.2–52.3% SiO_2). Vent is at large, well-preserved cinder cone (hill 1882) northwest of Poison Lake, just north of map area (see fig 3). Lava flowed north and northeast as far as 3 km; most of unit is north of map area. Lava bench on southwest side of cone is covered by 2-m-thick blanket of cinders; most cinders on bench and in cone are oxidized. Flow is covered by deep reddish soil. Phenocrysts: 4% ol, 0.5–2 mm, mostly <1 mm; sparse pl, 0.5 mm. Groundmass is light to medium gray, glassy to aphanitic, and microvesicular. Unit bp1 is overlain by basalts of old railroad grade, unit 3 (bg3), unit bp2, and unit bp3. [PL]

Basalts and basaltic andesites of Bogard Buttes (late Pleistocene)—Group of 12 thick (10–15 m), short aa and block lava flows and cinder cones of sparsely porphyritic ol basalt and basaltic andesite (52.1–53.2% SiO_2), comprising the largest group of flows and cinder cones in the Poison Lake chain. One cinder cone (just northwest of hill 2092, fig. 3) and associated flow (bb7) are east of map area in Pine Creek Valley quadrangle. Most cinders in cones are oxidized, but sporadic unoxidized blocks are found locally. Rough upper flow surfaces are well preserved but in some places covered by poorly developed orange soil and sparse forest. Some flows have distinct lateral flow levees. Flows fall into two lithologic groups: bb1–bb7 are slightly more mafic than bb8–bb12, tend to be less porphyritic, and have ol>pl. In contrast, bb8–bb12 have ol<pl and are usually slightly more porphyritic. Phenocrysts (both groups): sparse–4% pl, 0.5–2 mm; 1–2% ol, 0.5–2 mm. Small glomeroporphyritic clots of ol+pl and rarely aug are sparse in most flows. Groundmasses are medium to dark gray, aphanitic, and generally microvesicular. $^{40}Ar/^{39}Ar$ ages of units bb12 and bb6 are 107.5±3.8 and 100.1±8.5 ka, respectively; all twelve units are approximately the same age. [BB, PL]

bb12 **Unit 12**—Large, composite cinder cone and lava flow of sparsely porphyritic ol basaltic andesite (53.1–53.2% SiO_2) located on upper west flank of Bogard Buttes. Early cone is primarily oxidized scoria, but also contains a few dense bombs. Small, well-preserved late cone was built on top of early cone; thick, short aa lava flow erupted through it and flowed down steep flank of Bogard Buttes ~1 km and constructed prominent flow levees. Phenocrysts: 1–2% pl, 0.5–2 mm, mostly 0.5–1 mm; sparse ol, 0.5–2 mm, mostly 0.5–1 mm. Small glomeroporphyritic clots of ol+pl are sparse. Unit overlies dacite of Bogard Buttes (Tdb), unit bb4, and unit bb8. $^{40}Ar/^{39}Ar$ age is 107.5±3.8 ka. [BB]

bb11 **Unit 11**—Thick, aa lava flow of sparsely porphyritic ol basaltic andesite (53.1% SiO_2) that erupted from well-preserved cinder cone (hill 2023, 3.2 km south of Bogard Buttes). Lava flowed east ~2 km out of map area. Phenocrysts: 2% pl, 0.5–2 mm, mostly 0.5–1 mm; sparse ol, 0.5–2 mm, mostly 0.5–1 mm. Small glomeroporphyritic clots of pl+ol are sparse. Groundmass is medium to dark gray, aphanitic, and microvesicular. Unit bb11 overlies units bb1, bb2, bb6, and bb9. [BB]

bb10 **Unit 10**—Thick, short aa lava flow of sparsely porphyritic ol basalt (53.0% SiO_2) erupted from cinder cone 2.5 km south-southwest of Bogard Buttes, just south of hill 2106, and flowed west and south ~1 km. Phenocrysts: 1–2% pl, 0.5–2 mm, mostly 0.5–1 mm; sparse ol, 0.5–2 mm, mostly 0.5–1 mm. Small glomeroporphyritic clots of ol+pl are sparse. Groundmass is medium to dark gray, aphanitic, and dense to microvesicular. Unit bb10 overlies basalt of section 11 (b11), basalts of Stephens Campground, unit 2 (bs2), and units bb3, bb8, and bb9. [BB]

bb9 **Unit 9**—Thick, short aa lava flow of sparsely porphyritic ol basalt (52.8% SiO_2) that erupted from small, well-preserved cinder cone 3.2 km south of Bogard Buttes, 0.6 km west of hill 2023. Lava flowed west ~0.5 km, rafting part of cinder cone. Phenocrysts: 1–2% pl, 0.5–2 mm, mostly 0.5–1 mm; sparse ol, 0.5–2 mm, mostly 0.5–1 mm. Small glomeroporphyritic clots of ol+pl are sparse. Groundmass is medium to dark gray, aphanitic, and dense to microvesicular. Unit bb9 overlies units bb1, bb2, and bb3 and is overlain by units bb10 and bb11. [BB]

bb8 **Unit 8**—Thick, short block lava flow of sparsely porphyritic ol basalt (52.8% SiO_2) erupted from small well-preserved cinder cone (hill 2106) on south flank of Bogard Buttes. Lava flowed 1 km west. Phenocrysts: 1–2% pl, 0.5–1 mm; sparse ol, 0.5–1 mm. Small glomeroporphyritic clots of pl are sparse. Groundmass is medium gray, aphanitic, and microvesicular. Unit bb8 overlies dacite of Bogard Buttes (Tdb), basalt of hill 2088 (bl20), and unit bb3; overlain by units bb10 and bb12. [BB]

bb6 **Unit 6**—Thick, short aa lava flow of sparsely porphyritic ol basalt (52.8% SiO_2) erupted from small, well-preserved cinder cone (hill 2008) 4 km south of Bogard Buttes. Lava flowed east ~2 km out of map area. Phenocrysts: 1% ol, 0.5–2 mm, mostly 0.5–1 mm; sparse pl, 0.5–1 mm. Groundmass is medium to dark gray, aphanitic, and dense to microvesicular. Unit bb6 overlies basaltic andesites of Susan River (Tmsr), basalt of section 11 (b11), and unit bb2; overlain by unit bb11. $^{40}Ar/^{39}Ar$ age is 100.1±8.5 ka. [BB]

bb5 **Unit 5**—Thick, aa lava flow of porphyritic ol basalt (52.4% SiO_2) erupted from vent marked by cinder cone at hill 2096 on northwest flank of Bogard Buttes. Lava flowed north 4 km.

Phenocrysts: 4% pl, 0.5–1 mm; 2% ol, 0.5–2 mm, mostly 0.5–1 mm. Unit is more porphyritic than other bb units, but most crystals occur in small glomeroporphyritic clots of pl+ol. Groundmass is medium to dark gray, aphanitic, and microvesicular. Unit bb5 overlies dacite of Bogard Buttes (Tdb), basalts of Robbers Spring, unit 2 (br2), basalts of Stephens Campground, unit 5 (bs5), and unit bb4. [BB, PL]

bb4 **Unit 4**—Thick, short aa lava flow of sparsely porphyritic ol basalt (52.5% SiO_2) that erupted from small, well-preserved cinder cone on west flank of Bogard Buttes and flowed west ~1 km. Phenocrysts: 1–2% ol, 0.5–2 mm, mostly 0.5–1 mm; sparse pl, 0.5–1 mm. Small glomeroporphyritic clots of ol+pl and aug+pl are very sparse. Groundmass is medium gray, aphanitic, and dense to microvesicular. Unit bb4 overlies dacite of Bogard Buttes (Tdb) and basalts of Stephens Campground, units 4 and 5 (bs4, bs5); overlain by units bb5 and bb12. [BB]

bb3 **Unit 3**—Thick, short block lava flow of sparsely porphyritic ol basalt (52.3% SiO_2) erupted from small well-preserved cinder cone just east of hill 2106 on south flank of Bogard Buttes and flowed east ~2 km just out of map area. Phenocrysts: 1–2% ol, 0.5–2 mm, mostly 0.5–1 mm; sparse pl, 0.5–1 mm. Small glomeroporphyritic clots of aug are very sparse. Groundmass is medium to dark gray, aphanitic, and dense to microvesicular. Unit bb3 overlies dacite of Bogard Buttes (Tdb) and unit bb1; overlain by units bb8, bb9, and bb10. [BB]

bb2 **Unit 2**—Thick, short aa lava flow of sparsely porphyritic ol basalt (52.1% SiO_2) located 3.5 km south of Bogard Buttes. No obvious vent, although the flow may have erupted at site of bb9 cone. Phenocrysts: 1–2% ol, 0.5–2 mm, mostly 0.5–1 mm; sparse pl, 0.5–1 mm. Small glomeroporphyritic clots of ol+pl and rarely aug are sparse. Groundmass is medium gray, aphanitic, and microvesicular. Unit bb2 is overlain by units bb6, bb9, and bb11. [BB]

bb1 **Unit 1**—Short, thick aa lava flow of sparsely porphyritic ol basalt (52.1% SiO_2) located 2.9 km south-southwest of Bogard Buttes. No obvious vent, although the flow may have erupted at site of bb10 cone south of Bogard Buttes. Lava flowed east ~1.5 km out of map area. Phenocrysts: 1–2% ol, 0.5–2 mm, few larger. Also contains few small glomeroporphyritic clots of aug and is only Bogard Buttes unit that lacks pl. Groundmass is dark gray, aphanitic, and microvesicular. Unit bb1 is correlated with other Bogard Buttes units based on its spatial relationship, similar lithology and composition, and similar apparent age; however, it is slightly different in lithology and composition and could be older or unrelated to them. Unit bb1 is overlain by units bb3, bb9, and bb11. [BB]

Basalts of Pine Creek (late Pleistocene)—Group of three cinder cones and lava flows of sparsely porphyritic aug-ol basalt (52.2–52.5% SiO_2) located 4.5 to 6 km south of Bogard Buttes. Soil and forest are weakly developed on the lava flows. Basalt of Pine Creek units overlie much older rocks and are not in contact with any other Poison Lake chain units. They are placed stratigraphically below basalts and basaltic andesites of Bogard Buttes primarily based on their lithologic and compositional similarity and $^{40}Ar/^{39}Ar$ age of 106.2±3.6 ka for unit bpc1. [BB]

bpc3 **Unit 3**—Two short, thick (10–20 m), aa to block lava flows of sparsely porphyritic aug-ol basalt (52.2% SiO_2) that erupted from small cinder cone (hill 2023, just north of Pine Creek) and flowed only a few hundred meters from vent. Phenocrysts: 1–2% ol, 0.5–1 mm, few larger; trace aug, 0.5–1 mm; trace pl, 0.5–1 mm. Lava has vesicular flow top and contains abundant microphenocrysts (to 0.25 mm) of pl and mafic minerals. Groundmass dark gray, aphanitic, and microvesicular. Unit bpc3 overlies basalt of section 11 (b11) and no other rock units. Relation to units bpc1 and bpc2 is unclear. [BB]

bpc2 **Unit 2**—Short, thick (10–20 m) aa to block lava flow of sparsely porphyritic aug-ol basalt (52.5% SiO_2) that erupted from small cinder cone (hill 1986) and flowed 1 km northeast out of map area. Phenocrysts: 1–2% ol, 0.5–1 mm, few larger; trace aug, 0.5–1 mm; trace pl, 0.5–1 mm. Lava has vesicular flow top and contains abundant microphenocrysts (to 0.25 mm) of pl and mafic minerals. Groundmass dark gray, aphanitic, and microvesicular. Unit bpc2 overlies basalt of section 11 (b11) and unit bpc1. [BB]

bpc1 **Unit 1**—Short, thick (10–20 m) aa to block lava flow of sparsely porphyritic aug-ol basalt (52.4% SiO_2) that erupted from small cinder cone (hill 2060) and flowed 1 km north and west. Phenocrysts: 1–2% ol, 0.5–1 mm, few larger; trace aug, 0.5–1 mm; trace pl, 0.5–1 mm. Lava has vesicular flow top and contains abundant microphenocrysts (to 0.25 mm) of pl and mafic minerals. Groundmass dark gray, aphanitic, and microvesicular. Unit bpc1 overlies basaltic andesites of Susan River (Tmsr) and is overlain by unit bpc2. $^{40}Ar/^{39}Ar$ age is 106.2±3.6 ka. [BB]

Basalts of Pittville Road (late Pleistocene)—Group of cinder cones and lava flows of sparsely porphyritic aug-ol basalt (50.3–50.6% SiO_2). Basalts of Pittville Road are older than basalts of old railroad grade, unit 4 (bg4, 102.1±11.4 ka) and younger than basalts of Stephens Campground, units 4 and 5 (bs4, 110.8±3.8 ka and bs5, 108.6±2.1 ka); $^{40}Ar/^{39}Ar$ age of unit bt4 is 101.0±1.9 ka and K-Ar age of unit bt1 is 108±14 ka. [BB, PL]

bt4 **Unit 4**—Thick, short stubby lava flow and complex of large, well-preserved cinder cones (hill 1974 and hill just to south) of aug-ol basalt (50.4% SiO_2), located 5 km south-southeast of Poison Lake. Flow moved ~1 km north and may be partly buried beneath younger units. Phenocrysts: 2% ol, 0.5–2 mm; 1–2% aug, 0.5–2 mm. Contains sparse, small glomeroporphyritic clots of aug. Groundmass is medium gray, aphanitic to holocrystalline, and dense to microvesicular. Unit bt4 overlies basalts and basaltic andesites of Swains Hole (bsh), basalts of Robbers Spring, units 1 and 2 (br1, br2), basalts of Stephens Campground, units 2 and 4 (bs2, bs4), and units bt2 and bt3. $^{40}Ar/^{39}Ar$ age is 101.0±1.9 ka. [BB, PL]

bt3 **Unit 3**—Short, thick, block-lava flow and large cinder cone of sparsely porphyritic aug-ol basalt (50.3% SiO_2). Lava flowed north ~1.5 km from vent at hill 2001, 3.3 km northwest of Bogard Buttes. Phenocrysts: 2% ol, 0.5–1 mm; 1% aug, 0.5–1 mm; rare pl, 0.5 mm. Most of phenocrysts are in small glomeroporphyritic clots of ol or aug. Groundmass is medium gray, aphanitic, and microvesicular. Unit bt3 overlies basalts of Stephens Campground, unit 5 (bs5), basalts of Robbers Spring, unit 1 (br1), and unit bt2; overlain by unit bt4. [BB]

bt2 **Unit 2**—Short, 10-m-thick, block lava flow and small but well-preserved cinder cone of sparsely porphyritic ol basalt (50.4–50.6% SiO_2), 3.5 km south-southeast of Poison Lake just southwest of hill 1919. Lava flowed west and east in two, 1-km-long, broad lobes. Western lobe has steep front, and top of flow is composed of microvesicular blocks. East lobe has more subdued flow front and is separated from cinder cone by basalts of Pittville Road, unit 4 (bt4). Phenocrysts: 1–2% ol, 0.5–2 mm; sparse aug, 0.5–2 mm, mostly 0.5 mm. Contains sparse, small glomeroporphyritic clots of aug. Groundmass is dark gray, aphanitic to holocrystalline, and microvesicular. Unit bt2 overlies basalts and basaltic andesites of Swains Hole (bsh), basaltic andesite of hill 1868 (ml18), and basalts of Robbers Spring, unit 2 (br2); overlain by basalts of Poison Butte, units 5 and 6 (bp5, bp6) and unit bt4. [BB, PL]

bt1 **Unit 1**—Lava flow of sparsely porphyritic aug-ol basalt (50.3% SiO_2) located 1.5 km southeast of Poison Lake, mostly buried by younger deposits. Vent probably lies buried beneath younger basalts of Pittville Road (bt) or basalts of Poison Buttes (bp). Phenocrysts: 2% ol, 0.5–2 mm; rare aug, 0.5–1 mm. Groundmass is medium gray, aphanitic, and microvesicular. Unit bt1 is overlain by basalts of Poison Butte, unit 6 (bp6) and overlies basalts of Robbers Spring, unit 2 (br2). K-Ar age is 108±14 ka. [PL]

m20 **Basaltic andesite west of hill 2078 (late Pleistocene)**—Cinder cone of sparsely porphyritic ol basaltic andesite (53.5% SiO_2) located just west of hill 2978, 3.5 km west of Bogard Buttes. Correlated with the Poison Lake chain on the basis of geography and stratigraphy, but distinguished from the other units on the basis of petrographic and chemical characteristics. No associated lava flow, although one may be buried by basalts of Stephens Campground lava flows. Scoria in cone is mostly oxidized. Phenocrysts: 1–2% ol, 0.5–2 mm; rare aug, 1–2 mm; sparse pl, 0.5 mm. Groundmass of unoxidized bombs is dark gray, glassy, and microvesicular to dense. Unit m20 overlies basalts of Stephens Campground, units 4 and 5 (bs4, bs5), but stratigraphic relation to other Poison Lake units is uncertain. Age is poorly constrained, but probably similar to other units of Poison Lake chain. [BB]

Basalts of Stephens Campground (late Pleistocene)—Group of cinder cones and lava flows of porphyritic ol basalt (50.4–51.5% SiO_2). Compared to other units of Poison Lake chain, this group is characterized by abundant pl (except bs1) and relatively thin, large-volume, far-traveled lava flows. Some flows (bs3, bs4, bs5) also contain aug phenocrysts. Basalts of Stephens Campground are older than basalts of Pittville Road and younger than basalts of Robbers Spring. $^{40}Ar/^{39}Ar$ ages of unit bs5 and unit bs4 are 108.6±2.1 ka and 110.8±3.8 ka, respectively. [BB, PL]

bs5 **Unit 5**—Thick (15–20 m) lava flow and large, well-preserved cinder cone (hill 2078) of porphyritic aug-ol basalt (51.4% SiO_2), located 3 km west of Bogard Buttes. Lava flowed ~3 km north. Phenocrysts: 8% ol, 0.5–3 mm; 4% pl, 0.5–1 mm; 1% aug, 0.5–1 mm. Glomeroporphyritic clots of ol+pl+aug to 5 mm are common. Groundmass is medium gray, aphanitic, and microvesicular. Top of flow is vesicular aa and is covered by poorly developed orange soil. Unit bs5 overlies dacite of Bogard Buttes (Tdb), basalts of Robbers Spring, unit 2 (br2), and unit bs4; overlain by basalts of Pittville Road, units 2 and 3 (bt2, bt3), basaltic andesite west of hill 2078 (m20), and basalts and basaltic andesites of Bogard Buttes, units 4 and 5 (bb4, bb5). $^{40}Ar/^{39}Ar$ age is 108.6±2.1 ka. [BB, PL]

bs4 **Unit 4**—Short lava flow of porphyritic aug-ol basalt (50.6% SiO_2) with small, well-preserved cinder cone marking vent on west flank of Bogard Buttes. Lava flowed west and north ~3 km and is separated from its cone by younger lava flows of basalts and basaltic andesites of Bogard Buttes, unit 4 (bb4). Phenocrysts: 8% pl, 0.5–2 mm, mostly 0.5–1 mm; 5% ol, 0.5–2 mm; sparse aug, 0.5–1 mm. Small glomeroporphyritic clots of pl+ol+aug to 5 mm are common. Groundmass is medium gray, aphanitic to holocrystalline, and microvesicular. Large, round to ovoid vesicles are abundant in blocks at flow surface; flow has massively jointed interior. Unit bs4 overlies dacite of Bogard Buttes (Tdb), basalt of section 2 (bl2), basalts of Robbers Spring, unit 1 (br1), and unit bs2; overlain by basaltic andesite west of hill 2078 (m20), bb4, and unit bs5. $^{40}Ar/^{39}Ar$ age is 110.8±3.8 ka. [BB]

bs3 **Unit 3**—Thin (5 m) block lava flow of porphyritic aug-ol basalt (51.4–51.5% SiO_2). Small cinder cone at hill 2146 marks vent location, 3.7 km southwest of Bogard Buttes. Lava flowed northwest and south as far as 3 km from vent area; small lobe flowed few hundred meters east. Phenocrysts: 6–10% pl, 0.5–2 mm, mostly 0.5 mm; 4–5% ol, 0.5–2 mm, mostly 0.5–1 mm; 1–2% aug, 0.5–1 mm. Glomeroporphyritic clots of ol+pl to 5 mm are common. Groundmass is medium gray, aphanitic to holocrystalline, and microvesicular. Blocks on flow surface are very vesicular; joint pattern is massive and flow has only thin soil cover. Unit overlies basalt of section 11 (b11), basalt of hill 2232 (bl22), and units bs1 and bs2; overlain by basalts of Cone Lake Road, units 1 and 2 (bc1, bc2). [BB]

bs2 **Unit 2**—Thin, block lava flow of porphyritic ol basalt (50.5–50.8% SiO_2). Small cinder cone adjacent to bs3 cone, 3.7 km southwest of Bogard Buttes, marks vent location. Lava flowed west and north from vent area as far as 6 km and east for a few hundred meters. Phenocrysts: 5–7% ol, 0.5–5 mm; mostly 0.5–1 mm; 2–3% pl, 0.5–2 mm, mostly 0.5–1 mm. Small glomeroporphyritic clots of ol+pl are present. Groundmass is medium to dark gray, aphanitic to holocrystalline, and microvesicular. Large, round to ovoid vesicles are abundant in blocks at surface of flow; joint pattern is massive. Unit bs2 overlies basalt of section 11 (b11), basalts and basaltic andesites of Swains Hole (bsh), basalt of hill 2232 (bl22), basalt of section 2 (bl2), and basalts of Robbers Spring, unit 1 (br1); overlain by basalts of Pittville Road, unit 4 (bt4), basalts of Cone Lake Road, units 1 and 2 (bc1, bc2), basalt of Twin Buttes (bdt), basalts and basaltic andesites of Bogard Buttes, unit 10 (bb10), unit bs3, and unit bs4. [BB]

bs1 **Unit 1**—Thin (5 m) block lava flow of porphyritic ol basalt (50.4% SiO_2) located 6 km southwest of Bogard Buttes. Vent was probably to north near vents for units bs2, bs3, bc1, and bc2 and is now buried by younger lavas of Poison Lake chain. Lava flowed at least 3 km from inferred vent area. Phenocrysts: 5% ol, 0.5–3 mm; trace pl with dark-gray cores. Small glomeroporphyritic clots of ol are also present. Groundmass is medium gray, aphanitic, and microvesicular. Lava at flow surface contains abundant large, rounded to flattened vesicles; lava breaks along joints into thick tabular to squarish slabs. Flow has thin soil. Unit bs1 overlies basalt of section 11 (b11); overlain by unit bs3. [BB]

Basalts of Robbers Spring (middle Pleistocene)—Group of two cinder cones and lava flows of sparsely porphyritic to porphyritic ol basalt (51.1–51.4% SiO_2). Oldest group of vents and flows in Poison Lake chain; overlain by basalts of Poison Butte, basalts of Pittville Road, and basalts of Stephens Campground. $^{40}Ar/^{39}Ar$ age of unit br2 is 101.5±8.7 ka. [BB, PL]

br2 **Unit 2**—An extensive, 10-m-thick, aa and block-lava flow and large cinder cone (hill 1919) of porphyritic ol basalt (51.1–51.4% SiO_2), located 3.5 km south-southeast of Poison Lake. Lava flowed northeast and east 3 km and emplaced a broad lava flow. Top of flow composed of microvesicular blocks. Phenocrysts: 6% ol, 0.5–2 mm, mostly 0.5–1 mm. Groundmass is dark gray, aphanitic, and microvesicular. Unit br2 overlies tholeiitic basalt of Grays Valley (bgv) and is overlain by basalts of Stephens Campground, unit 5 (bs5), basalts of Pittville Road, units 1, 2, and 4 (bt1, bt2, bt4), basalts of Poison Butte, unit 6 (bp6), and basalts and basaltic andesites of Bogard Buttes, unit 5 (bb5). $^{40}Ar/^{39}Ar$ age is 101.5±8.7 ka. [BB, PL] br1 **Unit 1**—Thin lava flow and well-preserved cinder cone (hill 1921) of porphyritic ol basalt ($51.3\% \ SiO_2$), located 3.8 km west-northwest of Bogard Buttes. Lava has aa surface and flowed northwest for at least 1 km, but it is largely buried by younger lava flows of Poison Lake chain. Phenocrysts: 10% ol, 0.5–3 mm, largest generally composite grains; sparse pl, 0.5 mm. Few small glomeroporphyritic clots of ol present. Groundmass medium to dark gray, aphanitic, and strongly microvesicular. Unit br1 is overlain by basalts of Stephens Campground, units 2 and 4 (bs2, bs4) and by basalts of Pittville Road, units 3 and 4 (bt3, bt4). [BB]

Cone Lake chain

Cone Lake chain comprises a group of spatially and temporally related basalt and basaltic andesite lava and cinder cones in the north part of the Caribou Volcanic Field 4–5 km west of Bogard Buttes. Units assigned to the Cone Lake chain form two parallel arrays approximately coincident with the Poison Lake chain. Four of the eight units constitute a zone of vents 8 km long and ~1.5 km wide trending N. 30° W. from Cone Lake. The other four units form a parallel 8-km-long array displaced 3.5 km to the east. Although generally similar in character to the Poison Lake chain, the Cone Lake chain is older (~200–250 ka) and is partially buried by units of the Poison Lake and the Bidwell Spring chains. Units of the Cone Lake chain are mostly beyond the north limit of glaciation; cones are fairly well preserved.

bl35 **Basalt of section 35 (middle Pleistocene)**—Short block-lava flow and large, poorly preserved cinder cone of sparsely porphyritic ol basalt ($52.5\% \ SiO_2$) located 2.9 km west-southwest of Bogard Buttes, just southeast of hill 2091. Phenocrysts: 2–3% ol, 0.5–1 mm. Small glomeroporphyritic clots of ol are common. Groundmass is medium gray, aphanitic to holocrystalline, and microvesicular and has vague flow lineation and interstitial vapor-phase silica. Unit bl35 overlies unit bl2. $^{40}Ar/^{39}Ar$ age is 202.0±2.2 ka. [BB]

bl2 **Basalt of section 2 (middle Pleistocene)**—Short block-lava flow and large, well-preserved cinder cone (hill 2091) of sparsely porphyritic ol basalt ($51.5\text{–}52.5\% \ SiO_2$) located 3.2 km west-southwest of Bogard Buttes. Lavas in Poison Lake chain may bury much of lava flow. Phenocrysts: 2–3% ol, 0.5–1 mm. Small glomeroporphyritic clots of ol are common. Groundmass is medium gray, aphanitic to holocrystalline, and microvesicular and has a vague flow lineation and interstitial vapor-phase silica. Unit bl2 is overlain by basalts of Stephens Campground, units 2 and 4 (bs2, bs4) and by basalt of section 35 (bl35). [BB]

bl20 **Basalt of hill 2088 (middle Pleistocene)**—Cinder cone (hill 2088) of porphyritic ol basalt ($52.2\% \ SiO_2$) located 3.2 km southwest of Bogard Buttes. Large, well-preserved cone is composed of oxidized cinders and ash and has thick orange soil cover. It has no apparent lava flow, but one could be buried by younger flows and cones of Poison Lake chain. Phenocrysts: 4% ol, 0.5–3 mm, mostly 1 mm. Sparse, fresh bombs in cinder cone have black to dark-gray, glassy to aphanitic groundmass and are dense to microvesicular. Unit bl20 is overlain by basalts of Cone Lake Road, unit 1 (bc1) and basalts and basaltic andesites of Bogard Buttes, unit 8 (bb8). [BB]

bl30 **Basalt of section 30 (middle Pleistocene)**—Short, thin lava flow of porphyritic ol basalt at northwest end of Cone Lake chain, with small, well-preserved cinder cone just east of hill 1879. Scoria in cinder cone is mostly oxidized. Lava flowed ~1 km north. Phenocrysts: 3–4% ol, 0.5–2 mm, few larger; sparse pl, 0.25–0.5 mm. Small glomeroporphyritic clots of ol+pl to 5 mm are common. Groundmass is medium to dark gray, glassy to aphanitic, and microvesicular. Unit overlies basalts and basaltic andesites of Swains Hole (bsh) and basalt of hill 2109 (bl21); overlain by tholeiitic basalt of hill 1879 (b18) and basalt of Twin Buttes (bdt). Unit bl30 is not dated, nor is its relation to any dated unit known. It is, however, somewhat older than the Poison Lake chain and probably older than ~200 ka. It is probably younger than unit bl21, which is estimated to be 225–250 ka, and is probably younger than basalt of hill 2232 (bl22, 220±14 ka). Estimated to be 200–220 ka. [BB]

bl22 **Basalt of hill 2232 (middle Pleistocene)**—Small shield volcano in southeastern part of Cone Lake chain, composed of lava flows of porphyritic ol basalt ($51.2\% \ SiO_2$), with eroded cinder cone marking vent. Lava flowed in all directions from vent to produce small shield at least 4 km diam. Younger flows and glacial deposits buried much of this flow. Phenocrysts: 10% pl, 0.5–2 mm, mostly 0.5–1 mm; 4% ol, 0.5–1 mm. Glomeroporphyritic clots of ol+pl to 1 cm are common. Groundmass is medium gray, holocrystalline, and microvesicular. Locally contains xenoliths of milky vein qtz to 2–3 cm. Flows are massively jointed. Unit bl22 overlies basaltic andesites of Cone Lake (mlc); overlain by basalts of Stephens Campground, units 2 and 3 (bs2, bs3) and basalt of Twin Buttes (bdt). K-Ar age is 220±14 ka. [BB]

bl21 **Basalt of hill 2109 (middle Pleistocene)**—Relatively thin, short, aa lava flow of porphyritic ol basalt (50.8% SiO_2) with large cinder cone marking vent. Located in northwest part of Cone Lake chain. Small lava tubes are present; flow top is vesicular. Lava flowed northwest from vent ~3 km. Younger units have buried much of this flow. Cinder cone has at least two craters, neither of which is well preserved. Phenocrysts: 3% ol, 0.5–2 mm, mostly 0.5–1 mm; sparse pl, 0.5–1 mm, mostly in clots. Groundmass is medium gray, aphanitic, and microvesicular. Small glomeroporphyritic clots of ol+pl are sparse. Unit bl21 overlies basalts and basaltic andesites of Swains Hole (bsh); overlain by basalt of section 30 (bl30), tholeiitic basalt of hill 1879 (b18), basaltic andesite of Pole Spring Road (mdp), and basalt of Twin Buttes (bdt, 46.3±3.4 ka). Unit not dated and is much older than unit bdt. It is somewhat older than Poison Lake chain and appears to be slightly older than nearby basalt of hill 2232 (bl22, 220±14 ka). Estimated to be about 225–250 ka. [BB, PP]

mlc **Basaltic andesites of Cone Lake (middle Pleistocene)**—Two large and two small cinder cones of similar age located in southeast part of Cone Lake chain. Lava flows from these cones may exist buried beneath till, younger glaciations (Qty), basalt of Twin Buttes (bdt), or basalt of hill 2232 (bl22). Cones are moderately well preserved but have well-developed, thick, orange soils. Phenocrysts (big cone just east of Cone Lake): 2–3% ol, 0.25–1 mm, mostly <0.5 mm; sparse pl, 0.5 mm. Phenocrysts (big cone just northwest of Cone Lake): 15% pl, 0.25–1 mm, mostly 0.5 mm; 2–3% ol, 0.25–2 mm, mostly 1.0 mm; trace aug, 0.5 mm. Phenocrysts (small cone 1 km north of Cone Lake): 2–3% ol, 0.5–1 mm, mostly ~1 mm; sparse pl, 0.5 mm. Phenocrysts (small cone north of Twin Buttes): 2% ol, 0.5–2 mm; sparse–2% pl, 0.5 mm. All have dark gray, glassy, microvesicular groundmasses. Unit mlc is overlain by basalt of hill 2232 (bl32) and basalt of Twin Buttes (bdt, 46.3±3.4 ka). Age is poorly constrained; considerably older than unit bdt and may be slightly older than unit bl22 (220±14 ka). Estimated to be about 225–250 ka. [BB]

ml18 **Basaltic andesite of hill 1868 (middle Pleistocene)**—Lava flow and cinder cone of porphyritic aug-ol basaltic andesite (54.1–54.4% SiO_2), located 2.5 km south of Poison Lake. Lava flow has very vesicular and scoriaceous top and is covered by deep soil. Edifice cut by small faults and mostly buried by younger lava flows of Poison Lake chain. Phenocrysts: 15% pl, 0.5–3 mm, mostly 0.5–1 mm; 8% ol, 0.5–2 mm, mostly 0.5–1 mm; aug 2%, 0.5–2 mm, mostly 0.5–1 mm. Most crystals present as glomeroporphyritic clots from few millimeters to 1 cm. Groundmass is medium to dark gray, aphanitic to holocrystalline, and dense to microvesicular. Flow interior is dense to microvesicular and massively jointed. Unit ml18 overlies basalts and basaltic andesites of Swains Hole (bsh); overlain by basalts of old railroad grade, units 1 and 2 (bg1 and bg2), basalts of Pittville Road, unit 2 (bt2), basalts of Poison Butte, units 3, 4, and 5 (bp3, bp4, bp5), and basalt of Twin Buttes (bdt, 46.3±3.4 ka). Age is poorly constrained; considerably older than bdt and considerably younger than bsh. It is older than Poison Lake chain and probably older than basalt of hill 2232 (bl22, 220±14 ka). Estimated to be about 225–250 ka. [BB, PL]

Caribou chain

The Caribou chain comprises a zone of vents l4 km long and 1.5 km wide trending N. 25° W. across the east part of the Caribou Volcanic Field, extending from Star Butte in the southeast to Triangle Lake in the northwest. Rocks of the Caribou chain are primarily eroded lava flows of ol basaltic-andesite and aug–ol basaltic andesite with little lithologic or chemical diversity. Small gabbroic inclusions are distinctive. The Caribou chain has been highly glaciated. Cinder cones are generally absent, although some vents are marked by resistant agglutinate cones or plugs. The Caribou chain was active about 425–275 ka.

The Caribou chain is divided into three sequences: (1) The Triangle Lake sequence to the north, (2) the Echo Lake sequence to the south, and (3) the Caribou sequence. The Caribou sequence comprises the highlands of the Caribou Wilderness and is dominated by the large North, middle, and South Caribou lava cones but includes many smaller volcanoes and lava flows.

Triangle Lake sequence

A few basaltic andesite lava flows and cinder cones near Triangle Lake at the northern end of the Caribou chain are younger than the Caribou sequence. These lavas are heavily glaciated and obscured by a cover of drift. Their relation to other units is poorly known, but they are included in the Caribou chain on the basis of age and lithology.

mtr **Basaltic andesite of Triangle Lake (middle Pleistocene)**—Short, thick lava flow of sparsely porphyritic aug-ol basaltic andesite (55.4% SiO_2). Poorly preserved agglutinate cone at small hill east of Triangle Lake marks location of vent. Flows are heavily glaciated; typically, only flow cores crop out. Block carapaces and vesicular material generally are not found. Phenocrysts: 2% ol, 0.5–2 mm, mostly 0.5 mm; 1% pl, 0.5–2 mm, mostly 0.5 mm; trace aug, 0.5–1 mm. Variety of small inclusions and xenocrysts are common, including gabbroic clots of ol+aug+pl to 1 cm, qtz xenocrysts, and partially melted crustal inclusions. Many phenocrysts are disaggregated from gabbroic clots. Groundmass is medium to dark gray, aphanitic, and dense; jointing is massive. Unit mtr is completely surrounded by till, younger glaciations (Qty). K-Ar age is 277±22 ka. Unit mtr is thus one of youngest units in the Caribou chain. [BB]

mt20 **Basaltic andesites of section 20 (middle Pleistocene)**—Thick, short, porphyritic ol basaltic andesite lava flows in northwest part of Caribou chain. Poorly preserved vents are located at hill 2221 just southeast of Triangle Lake and at unnamed hill just northeast of Triangle Lake. Lava flows are heavily glaciated and mostly buried by till. Block carapaces or vesicular material generally are not found. Two flows have slightly different lithologies. Phenocrysts (hill 2221): 3–5% pl, 0.5–2 mm, few larger crystals usually composite; 3–4% ol, 0.5–3 mm. Glomeroporphyritic clots of ol+pl to 1 cm are present. Groundmass is light gray, holocrystalline, and dense to weakly microvesicular. Phenocrysts (unnamed hill): 5–7% pl, 0.5–2 mm, few larger crystals often composite; 3–4% ol, 0.5–1 mm, few larger; 1–2% aug, 0.5–1 mm. Small glomeroporphyritic clots of ol+pl+aug are common; xenocrysts of qtz and hbl are rare. Most of pl and aug may have been derived from disaggregated glomeroporphyritic clots. Groundmass is medium to dark gray, holocrystalline, microvesicular, and often weakly oxidized. Unit mt20 overlies basalt of Caribou Wilderness (bcw) but is otherwise surrounded by till, younger glaciations (Qty). Unit mt20 has not been dated, but it is probably one of the younger units of the Caribou chain; it is estimated to be ~300 ka. [BB]

Echo Lake sequence

The Echo Lake sequence consists of a small group of lithologically similar basalt and basaltic andesite lava flows, domes, and cinder cones at the southeast end of the Caribou chain. The units are lithologically similar to rocks in the Caribou sequence but are slightly younger (~300 ka). Thick cover of till obscures most stratigraphic relations among units of Echo Lake sequence.

Basalts of Bond Valley (middle Pleistocene)—Three poorly preserved cinder cones and lava flows of porphyritic ol basalt just northeast and southeast of Star Butte. Age is approximately equivalent to basaltic andesites of Echo Lake, unit 1 (mee1, 302±36 ka). The stratigraphic relationship among the three lava flows can be seen in the adjoining Swain Mountain quadrangle (off map to east). [RC]

beb3 **Unit 3—**Thick lava flow of porphyritic ol basalt (52.9 % SiO_2). Cinder cone marking vent is very poorly preserved and mostly buried by till, older glaciations (Qto). Flow is heavily glaciated and mostly buried by till; flow top is scoriaceous. Lava flowed south ~0.3 km from vent along faulted margin of Swain Mountain. Phenocrysts: 10% pl, 0.5–2 mm, mostly <1 mm, many reacted; 2% ol, 0.5–1 mm. Small glomeroporphyritic clots of ol+pl are common. Groundmass is medium gray, aphanitic, and microvesicular. Unit beb3 overlies unit beb2. [RC]

beb2 **Unit 2**—Poorly preserved cinder cone partly buried by till marks vent for thick lava flow of porphyritic ol basalt. Lava flow is buried by till, older glaciations (Qto) and beb3 in the map area. Lava from this cone flowed south along faulted margin of Swain Mountain volcano for at least 6 km and crops out in adjacent Swain Mountain quadrangle. Lava flow may be slightly offset by faults along east margin of Swain Mountain. Phenocrysts: 4–6% ol, 0.5–2 mm, mostly <1 mm; 4–6% pl, 0.5–2 mm, mostly <1 mm. Glomeroporphyritic clots of pl+ol are abundant and as large as 1 cm; most phenocrysts occur in clots or were disaggregated from clots. Groundmass is light gray, holocrystalline, and coarsely microvesicular. Flow top is scoriaceous. Unit beb2 overlies unit beb1 and is overlain by unit beb3. [RC] beb1 **Unit 1**—Poorly preserved cinder cone partly buried by till marks vent for thick lava flow of porphyritic ol basalt. Most cinders in cone are oxidized. Lava flow is buried by till, older glaciations (Qto) and by unit beb3 and crops out only east of map area in Swain Mountain quadrangle. Lava flowed south from this cone along west margin of Swain Mountain volcano for 6 km, where it is faulted. Phenocrysts: 8–10% ol, 0.5–4 mm; sparse pl, 1–2 mm; rare aug, 1–2 mm. Small glomeroporphyritic clots of pl+aug are rarely present. Groundmass is dark gray, aphanitic, and dense. Unit beb1 overlain by unit beb2. [RC]

Basaltic andesites of Echo Lake (middle Pleistocene)—Complex of lava domes, flows, and cinder cone of sparsely porphyritic ol basaltic andesite (53.9–55.6% SiO_2) near Echo Lake. K-Ar age of unit mee1 is 302±36 ka; unit mee2 is approximately the same age. [RC]

mee2 **Unit 2**—Thick lava flow (30 m) of sparsely porphyritic ol basaltic andesite (55.2–55.6% SiO_2). Cone of mostly oxidized cinders marks vent. Lava from cone flowed south in two thick lobes, west lobe ~3 km, and east lobe ~1 km. Lava flow outcrops along the contact between till, older glaciations (Qto) and till, younger glaciations (Qty) and is overlain by both. West lobe is weakly modified by glaciers but extensively buried by till; typically only steep flow margins crop out. East lobe is less extensively buried by till. Flow has a rough oxidized surface and is partially covered by agglutinate, probably rafted from cinder cone. Phenocrysts: 3–4% pl, 0.5–1 mm, mostly 0.5 mm; 1–2% ol, 0.5–1 mm, mostly 0.5 mm; rare aug, 0.5 mm. Small qtz xenocrysts are sparse; some pl phenocrysts are strongly reacted. Groundmass is dark gray, glassy to aphanitic, and dense to microvesicular. Unit mee2 overlies older basalts and basaltic andesites south of Caribou Volcanic Field (boc) and unit mee1. [RC]

mee1 **Unit 1**—Lava domes and short, thick, lava flows of porphyritic, ol basaltic andesite (53.9% SiO_2). Rocks are heavily glaciated; typically only dome and flow cores crop out. Five domes mark vents for lava flows; another vent is mostly buried by till. Some compositional variation is present. Phenocrysts: 10% pl, 0.5–2 mm, mostly 1 mm; 3–4% ol, 0.5–1 mm; sparse aug, 0.5–1 mm. Groundmass is medium gray, aphanitic, and dense to microvesicular. Unit mee1 is overlain by unit mee2. K-Ar age is 302±36 ka. [RC]

mes **Basaltic andesite of Star Butte (middle Pleistocene)**—Thick lava flow and cinder cone of sparsely porphyritic ol basaltic andesite near Echo Lake. Location of vent is marked by large cinder cone of Star Butte. Lava flowed ~1 km west, was heavily glaciated, and is almost completely buried by till. Phenocrysts: 4% ol, 0.25–1 mm; 1% pl, 0.25–1 mm. Contains few small glomeroporphyritic clots of ol+pl. Groundmass is medium gray, aphanitic to holocrystalline, and dense. Flow cores display thick slabby jointing. Unit mes overlies older basalts and basaltic andesites south of Caribou Volcanic Field (boc); overlain by basalts of Bond Valley, unit 2 (beb2), and by till, older glaciations (Qto). Approximately the same age as basalts of Bond Valley (beb) and basaltic andesites of Echo Lake (mee; 302±36 ka). [RC]

Caribou sequence

The Caribou sequence consists of the volcanoes in the central part of the Caribou chain including the large edifices of North, middle, and South Caribou.

Vents and lava flows northwest of Silver Lake and south of South Caribou form a platform upon which the three large Caribou edifices were built. Glaciers flowing from the Caribou edifices covered this platform during several episodes. Glacial erosion, lithologic homogeneity, textural variability, and abundant disaggregated inclusions combine to make these flows difficult to discriminate in the field. Although the stratigraphy is generally correct, there may be mistakes in mapping detail. In addition, some flows of relatively small volume or extent have been combined with larger flows.

mce **Basaltic andesite of Eleanor Lake (middle Pleistocene)**—Thick lava flow of porphyritic aug-ol basaltic andesite (54.3% SiO_2) just east of Turnaround Lake. Lava erupted from poorly preserved vent at hill 2234 and flowed north and east ~1.5 km. Lava flow heavily glaciated; typically only flow cores crop out. Till and poorly developed soil cover much of flow. Phenocrysts: 20% pl, 0.5–2 mm, mostly 0.5–1 mm, many resorbed; 4% ol, 0.5–2 mm; sparse aug, 0.5–1 mm. Small glomeroporphyritic clots of ol+pl are abundant. Contains a variety of small (to 4–5 cm) coarse-grained granitic- to cumulate-textured inclusions, fragments of inclusions, and individual crystals derived from inclusions, which are more abundant than in similar units (basaltic andesite of Jewel Lake, mcj, and basaltic andesite of Rim Lake, mcr).

Two most common types are fresh, but recrystallized, 2-pyr gabbro and partially melted gabbro containing pseudomorphs of hbl. Small xenoliths of metamorphic rock and qtz are also present. Black pseudomorphs of hbl are sparse. Groundmass is light to medium gray, generally holocrystalline and dense. Upper part of flow is microvesicular, oxidized, and massively jointed; interior of flow has thick tabular to platy jointing. Relation to similar units basaltic andesite of Jewel Lake (mcj) and basaltic andesite of Rim Lake (mcr) is unknown. Unit mce overlies basalt of Caribou Peak (bcp), basalt of Caribou Wilderness (bcw), basalt of Cowboy Lake (bcb), and basaltic andesites of Silver Lake, unit 8 (mc8, 400±14 ka). Age uncertain but probably younger than basaltic andesite of middle Caribou (mcm, 362±33 ka); estimated to be ~325–350 ka. [BB]

mcj **Basaltic andesite of Jewel Lake (middle Pleistocene)**—Thick lava flow of porphyritic aug-ol basaltic andesite (54.6–54.7% SiO_2) 2.5 km west of Silver Lake. Lava erupted from poorly preserved vent at hill 2213 and flowed east ~2 km. Lava flow heavily glaciated; typically only flow cores crop out. Drift and poorly developed soil cover much of flow. Phenocrysts: 8–10% pl, 0.5–2 mm, mostly 1 mm, few larger and many reacted; 2–3% ol, 0.5–1 mm; sparse–1% aug, 0.5–1 mm. Contains variety of small coarse-grained, granitic- to cumulate-textured inclusions, fragments of inclusions, and individual crystals derived from inclusions. These are generally partially melted or recrystallized, gabbroic in composition, and composed of pl+ol+pyr. Groundmass is light to medium gray, generally holocrystalline and dense. Upper part of flow is microvesicular, oxidized, and massively jointed; interior has thick tabular to platy jointing. Relation to similar units basaltic andesite of Rim Lake (mcr) and basaltic andesite of Eleanor Lake (mce) is unknown. Unit mcj overlies basaltic andesites of Silver Lake, units 6, 8, and 9 (mc6, mc8, mc9). Age uncertain but probably younger than basaltic andesite of middle Caribou (mcm, 362±33 ka); estimated to be ~325–350 ka. [BB, RC]

mcr **Basaltic andesite of Rim Lake (middle Pleistocene)**—Thick lava flow of porphyritic aug-ol basaltic andesite (55.7% SiO_2) 2 km west of Silver Lake. Lava erupted from vent at unnamed hill in western part of outcrop area and flowed east ~1.5 km. Lava flow heavily glaciated; typically only flow cores crop out. Till and poorly developed soil cover much of flow. Phenocrysts: 10% pl, 0.5–3 mm, mostly 1 mm, few larger composite grains; 2% aug, 0.5–1 mm; 1% ol, 0.5–1 mm, few larger composite grains. Small glomeroporphyritic clots of aug+pl are present. Contains abundant, small, coarse-grained inclusions, fragments of inclusions, and individual crystals derived from inclusions. These are partially melted and microvesicular, gabbroic in composition, and composed of pl and pseudomorphs of hbl. Black pseudomorphs of resorbed hbl from a few millimeters to nearly 1 cm, derived from disaggregated gabbroic inclusions, are abundant and conspicuous. Groundmass is light to medium gray, aphanitic, and dense. Upper part of flow is microvesicular, oxidized, and massively jointed; interior of flow has thick tabular to platy jointing. Relation to similar units basaltic andesite of Jewel Lake (mcj) and basaltic andesite of Eleanor Lake (mce) is unknown. Unit mcr overlies basaltic andesites of North Caribou, units 3 and 6 (mcn3, mcn6) and basaltic andesites of Silver Lake, units 6, 8, and 10 (mc6, mc8, mc10). Age uncertain but probably younger than basaltic andesite of middle Caribou (mcm, 362±33 ka); estimated to be ~325–350 ka. [RC]

Basaltic andesites of North Caribou (middle Pleistocene)—Thick lava flows of porphyritic aug-ol basaltic andesite (54.4–56.9% SiO_2). Flows erupted from North Caribou and several associated vents and built large lava cone of North Caribou. Lava flows were heavily glaciated; typically only flow cores crop out. Till and poorly developed soil cover much of these flows. Flows contain a variety of small (to 4–5 cm) coarse-grained, granitic to cumulate-textured inclusions, fragments of inclusions, and individual crystals derived from inclusions. Also contain pseudomorphs of hbl, hbl pseudomorph-bearing inclusions, and qtz. Units overlie a number of basaltic andesites of Silver Lake units including mc8 (400±14 ka) and are probably slightly younger than basaltic andesite of middle Caribou (mcm, 362±33 ka). Estimated to be ~350 ka. [RC]

mcn8 **Unit 8**—Plug of porphyritic aug-ol basaltic andesite (55.0% SiO_2) intruded into vent agglutinate and lava flows of mcn3 at older and northern of two vents at North Caribou. Phenocrysts: 20% pl, 0.5–2 mm, mostly 1 mm; 3–4% ol, 0.5–2 mm; sparse aug, 0.5–1 mm. Unoxidized ol displays unusual dark-green color. Contains variety of coarse-grained (to 10–12 cm), granitic to cumulate-textured inclusions, fragments of inclusions, and individual crystals derived from inclusions. Light-colored granitic inclusions lacking ol and pyr and containing qtz and potassium feldspar are also found. Pseudomorphs of hbl and hbl pseudomorph-bearing inclusions are also present, but not common. Groundmass light to medium gray, aphanitic at margins, and holocrystalline and dense in interior of plug. Interior of plug is massively jointed; margins have vertically oriented, widely spaced joints. Younger than units mcn1, mcn2, and mcn3; relation to other basaltic andesites of North Caribou is unknown. [RC]

mcn7 **Unit 7**—Small dome-like mass of aug-ol basaltic andesite lava 1.8 km north of North Caribou. Erupted through basaltic andesite of Silver Lake, unit 10 (mc10) from vent at small unnamed hill. Entire outcrop is oxidized and reddened. Phenocrysts: 10% pl, 0.5–3 mm, mostly 0.5–1 mm; 2–3% ol, 0.5–2 mm, mostly <1 mm; 1% aug, 0.5–1 mm. Small glomeroporphyritic clots are common. Groundmass is weakly oxidized, aphanitic, and microvesicular. [RC]

mcn6 **Unit 6**—Small dome-like mass of porphyritic aug-ol basaltic andesite at small hill 1 km north of North Caribou. Hill is an eroded and partially oxidized agglutinate cone intruded by a small plug of similar rock (not mapped separately). Phenocrysts: 15% pl, 0.5–2 mm, mostly 0.5–1 mm, few larger and reacted; 4% ol, 0.5–2 mm, mostly <1 mm; sparse aug, 0.5 mm. Glomeroporphyritic clots of ol+pl up to 5 mm are present. Small pseudomorphs of hbl are sparse, and qtz xenocrysts are rare. Groundmass is light to medium gray, aphanitic to holocrystalline, and microvesicular to dense. Jointing is typically massive to thick platy. Unit mcn6 overlies unit mcn3 and is overlain by basaltic andesite of Rim Lake (mcr). [RC]

mcn5 **Unit 5**—Thick lava flows of porphyritic aug-ol basaltic andesite (55.0% SiO_2) erupted at younger and southern of two vents at North Caribou; lava flowed east ~2 km. Forms summit of cone of North Caribou. Phenocrysts: 20% pl, 0.5–5 mm, mostly 1–3 mm; 2–4% ol, 0.5–2 mm. Inclusions much less common than in basaltic andesite of middle Caribou (mcm) and in most other basaltic andesites of North Caribou. Hbl pseudomorphs and hbl pseudomorph-bearing inclusions are absent. Groundmass is light to medium gray, aphanitic to generally holocrystalline, and typically dense. Flow interior is thickly platy jointed. Unit mcn5 overlies basaltic andesites of Silver Lake, unit 3 (mc3) and units mcn4 and mcn1. [RC]

mcn4 **Unit 4**—Thick lava flows of porphyritic aug-ol basaltic andesite (56.9% SiO_2) erupted at younger and southern of two vents at North Caribou; lava flowed east ~3 km. Phenocrysts: 5–8% pl, 0.5–2 mm, mostly 1 mm; 1% ol, 0.5–2 mm; sparse aug, 0.5–1 mm. Pseudomorphs of hbl to 1 cm and small hbl pseudomorph-bearing inclusions are particularly abundant (1–2%) and characteristic. Groundmass is light to medium gray, aphanitic to holocrystalline, and usually dense. Flow interior is thickly platy jointed; the flow top is massively jointed and often oxidized. Unit mcn4 overlies basaltic andesites of Silver Lake, units 1, 2, 3, and 8 (mc1, mc2, mc3, mc8), basaltic andesite of middle Caribou (mcm), and units mcn1, mcn2, and mcn3. [RC]

mcn3 **Unit 3**—Thick lava flows of porphyritic aug-ol basaltic andesite erupted at older and northern of two vents at North Caribou; lava flowed both east and west. Lava flows were deeply eroded, exposing plug (mcn8) intruded into vent agglutinate. Phenocrysts: 20% pl, 0.5–2 mm, mostly 1 mm; 3–4% ol, 0.5–2 mm; sparse aug, 0.5–1 mm. Contains light-colored granitic inclusions lacking ol and pyr and containing qtz and potassium feldspar. Groundmass is light to medium gray, aphanitic to holocrystalline, and dense. Flow interior has thick slabby jointing. Unit mcn3 overlies basaltic andesites of Silver Lake, unit 8 (mc8) and unit mcn4; overlain by units mcn6 and mcn8 and by basaltic andesite of Rim Lake (mcr). [RC]

mcn2 **Unit 2**—Thick lava flows of porphyritic aug-ol basaltic andesite (54.4% SiO_2) probably erupted at older and northern of the two vents at North Caribou; lava flowed east. Phenocrysts: 12% pl, 0.5–2 mm, mostly 1 mm; 2–3% ol, 0.5–2 mm; sparse aug, 0.5–1 mm. Glomeroporphyritic clots of ol+pl are present. Groundmass is light to medium gray, aphanitic to holocrystalline, and dense. Interior of flow has thick slabby jointing; top of flow is massively jointed and microvesicular. Unit mcn2 overlies unit mcn1; overlain by unit mcn4. [RC]

mcn1 **Unit 1**—Thick lava flows of porphyritic aug-ol basaltic andesite (54.5% SiO_2) probably erupted at older and northern of two vents at North Caribou; lava flowed east. Phenocrysts: 10% pl, 0.5–2 mm, mostly 1 mm; 2–3% ol, 0.5–2 mm; sparse aug, 0.5–1 mm. Groundmass is light to medium gray, aphanitic to holocrystalline, and dense. Interior of flow has thick slabby jointing; top of flow is massively jointed and microvesicular. Unit mcn1 overlies basaltic andesites of Silver Lake, units 3 and 8 (mc3 and mc8); overlain by units mcn2, mcn4, and mcn5. [RC]

bcs **Basalt of South Caribou (middle Pleistocene)**—Lava flows and plug of ol basalt (50.0–50.2% SiO_2) located in southeastern Caribou Volcanic Field. Lava flows are heavily glaciated; typically only flow cores crop out. Erupted from vent at summit of South Caribou and covers most of west flank of South Caribou; vent is partially preserved as agglutinated cinders in summit area and is intruded by small plug. Phenocrysts: 3–5% ol, 0.5–2 mm, mostly <1 mm. Groundmass of lava flows is light to medium gray, holocrystalline, and microvesicular. Plug has a dark gray to black, aphanitic, and dense quenched margin and light gray, coarsely holocrystalline, and dense interior**.** Jointing in flows is variable from blocky to thick platy; plug is blocky to columnar jointed. Both plug and lava flow contain sparse, small qtz xenoliths. Unit bcs overlies basaltic andesite of middle Caribou (mcm, 362±33 ka) and basaltic andesite of Hay Meadow (mch). Estimated to be ~350 ka, but could be as young as ~300 ka. [RC]

mcm **Basaltic andesite of middle Caribou (middle Pleistocene)**—Thick lava flows of porphyritic aug-ol basaltic andesite (54.0% SiO_2). Flows are heavily glaciated, and typically only flow cores crop out; till and poorly developed soil cover much of these flows. Lavas vented at both hill 7643 (informally designated middle Caribou; 0.5 km south of North Caribou) and at South Caribou (vent now covered by basalt of South Caribou, bcs). Minimal lithologic and compositional variation in lavas. Outlier, 1 km east of main outcrop area, has a similar but slightly different lithology and indicates that additional flow is buried by till. Phenocrysts: 12–15% pl, 0.5–2 mm, mostly 1 mm; 2–4% ol, 0.5–2 mm; sparse aug, 0.5–1 mm. Contains a variety of small (to a few centimeters) coarse-grained, granitic- to cumulate-textured inclusions, fragments of inclusions, and individual crystals derived from inclusions. These gabbroic inclusions are pl-dominated, typically ol and (or) aug bearing, and partially melted. Light-colored granitic inclusions lacking ol and pyr are also found. Inclusions are common in flows from middle Caribou vent and more abundant than in flows from South Caribou vent. Resorbed pseudomorphs of hbl to 5 mm are locally common; qtz xenocrysts are found. Groundmass is light to medium gray, aphanitic to typically holocrystalline, usually dense, but locally microvesicular. Flow interiors are thickly platy jointed; flow tops are massively jointed and oxidized. Unit mcm overlies basalt of Hidden Lakes (bbh), basaltic andesites of Silver Lake, unit 1 (mc1), basalt of Indian Meadow (bci), basaltic andesite of hill 7114 (mc71), and basaltic andesite of Hay Meadow (mch); overlain by basalt of South Caribou (bcs) and basaltic andesite of North Caribou, unit 4 (mcn4). K-Ar age is 362±33 ka. [RC]

mch **Basaltic andesite of Hay Meadow (middle Pleistocene)**—Thick lava flow of ol basaltic andesite. Lava erupted from vent marked by poorly preserved cinder cone (hill 7143) at south end of Caribou sequence and flowed south over 3 km to near Heckle Ranch. Cone is composed of oxidized agglutinated cinders and has dike-like spine of oxidized and sheared basaltic andesite oriented north-northwest extending length of hill. Flow is heavily glaciated; typically only flow core crops out; till cover is abundant. Some compositional and lithologic variation is present. Phenocrysts: 5–8% ol, 0.5–2 mm, mostly 1 mm; sparse–1% pl, 0.5–1 mm, mostly 0.5–1 mm. Groundmass is medium gray, aphanitic, and microvesicular; few glomeroporphyritic clots of ol+pl are present. Unit mch is overlain by basalt of South Caribou (bcs) and basaltic andesite of middle Caribou (mcm, 362±33 ka), and overlies basalt of Indian Meadow (bci). It is probably younger than the basaltic andesites of Silver Lake, units 1–11 (mc1–mc11; ~400 ka). It is estimated to be 375–400 ka. [RC]

mc71 **Basaltic andesite of hill 7114 (middle Pleistocene)**—Thick lava flow of sparsely porphyritic ol basaltic andesite (55.5% SiO_2) 1.5 km west-southwest of South Caribou. Although somewhat off the axis of the Caribou chain, mc71 correlates with it based on apparent age and lithology. Unit probably erupted from deeply eroded vent located at hill 7114 and flowed southwest only ~1 km. Flows are heavily glaciated; typically only flow cores crop out. Phenocrysts: 1% ol, 0.5–1 mm. Groundmass is dark gray, aphanitic, and dense with abundant microphenocrysts of pl. Unit mc71 is overlain by basaltic andesite of middle Caribou (mcm, 362±33 ka) and probably overlies the basaltic andesites of Silver Lake, units 1–11 (mc1–mc11, ~400 ka). Like the basaltic andesite of Hay Meadow (mch), it is estimated to be 375–400 ka. [RC] bci **Basalt of Indian Meadow (middle Pleistocene)**—Thick lava flow of aug-ol basalt (52.8% SiO_2) in southwestern Caribou Volcanic Field. Vent location unknown but probably buried by basaltic andesite of middle Caribou (mcm). Flow is heavily glaciated; typically only flow core crops out. Phenocrysts: 8–10% ol, 0.5–3 mm, mostly 1–2 mm; 5–6% aug, 0.5–3 mm, mostly 1 mm; 3–4% pl, 0.5–2 mm, mostly 0.5–1 mm, few larger are composite. Most crystals are in glomeroporphyritic clots of ol+pl+aug to 1 cm. Groundmass is medium gray, aphanitic, and dense. Unit bci is overlain by basaltic andesite of Hay Meadow (mch) and unit mcm (362±33 ka) and is probably younger than the basaltic andesites of Silver Lake, units 1–11 (mc1–mc11, ~400 ka). It estimated to be 375–400 ka. [RC]

Basaltic andesites of Silver Lake (middle Pleistocene)—Thick lava flows of porphyritic ol basaltic andesite and aug-ol basaltic andesite (53.4–54.8% SiO_2) in southern Caribou Volcanic Field. Flows are heavily glaciated; typically only flow cores crop out. Vent locations for most flows are unknown. Forms a platform upon which basaltic andesite of middle Caribou (mcm), basaltic andesites of North Caribou (mcn1–8), basaltic andesite of Eleanor Lake (mce), basaltic andesite of Jewel Lake (mcj), and basaltic andesite of Rim Lake (mcr) were emplaced. Lava flows grouped in some units are slightly variable and did not necessarily erupt from common vent. Flows overlie basalt of Cowboy Lake (bcb) and are younger than older basalts and basaltic andesites south of Caribou Volcanic Field (boc, 650±20 ka); overlain by unit mcm (362±33 ka). K-Ar age of mc8, 400±14 ka, approximates age of other units in basaltic andesites of Silver Lake. [BB, RC]

mc11 **Unit 11**—Thick lava flow of sparsely porphyritic ol basaltic andesite (53.8% SiO_2) exposed near South Divide Lake. Erupted from poorly preserved vent at unnamed hill 0.5 km south of North Divide Lake and flowed south ~2 km. Phenocrysts: 2–3% ol, 0.5–3 mm, larger grains composite; sparse–1% pl, 0.5–1 mm, few larger, many reacted. Groundmass is medium gray, holocrystalline, and dense. Overlies units mc10 and mc8. [RC]

mc10 **Unit 10**—Thick lava flows of porphyritic ol basaltic andesite (53.5% SiO_2) exposed southeast of North Divide Lake and probably erupted from vent at small hill 1 km southeast of North Divide Lake. Outlier forms another small hill just south of North Divide Lake. Lithology is somewhat variable. Phenocrysts: 5–10% ol, 0.5–4 mm, mostly 1 mm; sparse–1% pl, 0.5–2 mm, generally 0.5–1 mm. Some flows, especially those in outlier, contain small, coarse-grained, granitic-textured inclusions, fragments of inclusions, and individual crystals derived from inclusions. These are gabbroic in composition and are composed of pl+pyr. Inclusions of qtz are also present. Groundmasses are light to dark gray, aphanitic to holocrystalline, and dense. Unit mc10 overlies units mc7 and mc8; overlain by unit mc11, basaltic andesite of North Caribou, unit 7 (mcn7), and basaltic andesite of Rim Lake (mcr). [RC]

mc9 **Unit 9**—Thick lava flows of ol basaltic andesite near Emerald Lake. Vent locations are uncertain, but one may be at small hill southwest of Emerald Lake. Phenocrysts: 10% ol, 0.5–1 mm, few to 2 mm; sparse–1% pl, 0.5–1 mm. Groundmass is dark gray to black, aphanitic to holocrystalline, and dense. Unit mc9 overlies units mc8, mc6, and mc5; overlain by basaltic andesite of Jewel Lake (mcj). [BB, RC]

mc8 **Unit 8**—Thick lava flows of porphyritic aug-ol basaltic andesite (53.5–54.8% SiO_2) occurring as continuous outcrop over substantial area. Unit probably erupted from several vents, but none were located with certainty. One may be beneath the vent for mcj (hill 2213) and another in the vicinity of mcr and mcn6. Lava flows have similar compositions and lithologies, although some variation is present. Phenocrysts: 10–15% pl, 0.5–2 mm, few larger are xenocrysts; 3–5% ol, 0.5–2 mm, sparse larger crystals are composite; sparse–1% aug, 0.5 mm. Groundmasses are light to medium gray, aphanitic to holocrystalline, and typically dense. Contains small glomeroporphyritic clots, gabbroic xenoliths, and crystals (including pseudomorphs of hbl) disaggregated from them. Unit mc8 overlies units mc3, mc6, and mc7; overlain by units mc9, mc10, and mc11 and by basaltic andesite of Eleanor Lake (mce), basaltic andesite of Jewel Lake (mcj), and basaltic andesite of Rim Lake (mcr). K-Ar age is 400±14 ka. [BB, RC]

mc7 **Unit 7**—Thick lava flows of sparsely porphyritic ol basaltic andesite underlying mc8 and mc10 near North Divide Lake. Phenocrysts: 2–3% ol, 0.5–3 mm, larger crystals are composite; sparse–1% pl, 0.5–1 mm, few larger with gray cores. Groundmass is medium to dark gray, aphanitic, and dense. Unit mc7 is overlain by units mc8 and mc10. [RC] mc6 **Unit 6**—Lava flows of porphyritic ol basaltic andesite occurring as small outcrop underlying mc8 and mc9 southeast of Gem Lake and east of Emerald Lake. Phenocrysts: 3–4% ol, 0.5–3 mm, mostly 0.5–1 mm; 1% pl, 0.5–1 mm. Few small glomeroporphyritic clots of ol+pl are present. Groundmass is medium gray, aphanitic, and dense. Unit mc6 overlies unit mc5; overlain by units mc8, mc9, and basaltic andesite of Rim Lake (mcr). [RC]

mc5 **Unit 5**—Lava flow of porphyritic ol basaltic andesite occurring as small outcrop 0.2 km southeast of Gem Lake. Phenocrysts: 3–4% ol, 0.5–3 mm, mostly 0.5–1 mm; 1% pl, 0.5–1 mm. Few small glomeroporphyritic clots of ol+pl are present. Groundmass is dark gray, aphanitic, and dense. Unit mc5 is overlain by units mc6 and mc9. [RC]

mc4 **Unit 4**—Lava flow of sparsely porphyritic ol basaltic andesite erupted from poorly preserved agglutinate cone at hill 2294, ~1.5 km southwest of Turnaround Lake. Lava flowed northeast ~2.5 km to beyond Turnaround Lake. Cone is mostly buried by andesite of Red Cinder (arr); small plug is exposed at its summit. Rocks are heterogeneous, because of a large, and variable component of disaggregated xenolithic material. Phenocrysts: 1–2% ol, 0.5–2 mm, mostly 0.5 mm; 1–3% pl, 0.5–2 mm, mostly 0.5 mm; trace–sparse aug, 0.5–1 mm. Variety of small inclusions and xenocrysts are common, including gabbroic clots to 1 cm of ol+aug+pl, qtz and hbl xenocrysts, small andesitic inclusions, and partially melted crustal inclusions. Many phenocryst-sized crystals are disaggregated from gabbroic clots or other inclusions; many pl are partially reacted. Groundmass is medium to dark gray, aphanitic and dense; jointing is massive. Unit mc4 is overlain by unit arr. [BB]

mc3 **Unit 3**—Thick lava flows of porphyritic ol basaltic andesite occurring as small outcrop 1 km southwest of Silver Lake. Phenocrysts: 5% pl, 0.5–1 mm, few with gray cores; 2–3% ol, 0.5–2 mm, mostly 1 mm. Groundmass is light gray, aphanitic to holocrystalline, and dense. Unit mc3 is overlain by unit mc8 and by basaltic andesites of North Caribou, units 1, 4, and 5 (mcn1, mcn4, mcn5). [RC]

mc2 **Unit 2**—Lava flows of sparsely porphyritic ol basaltic andesite occurring as bench 1–1.5 km south of Silver Lake. Phenocrysts: 1% ol, 0.5–2 mm, mostly 0.5 mm; 1% pl, 0.5–2 mm, mostly 0.5 mm. Groundmass is light gray, aphanitic, and dense. Unit mc2 overlies unit mc1 and is overlain by basaltic andesites of North Caribou, unit 4 (mcn4). [RC]

mc1 **Unit 1**—Lava flows of porphyritic ol basaltic andesite (53.4% SiO_2) occurring as benches and isolated outcrops 1.6 km south of Silver Lake. All flows have ol>pl, although some variation is present. Phenocrysts: 5–8% ol, 0.5–4 mm, mostly 1–2 mm; sparse–3% pl, 0.5–2 mm, mostly 0.5–1 mm, some with gray cores. Glomeroporphyritic clots of ol+pl and occasionally aug from a few millimeters to a few centimeters are present. Groundmasses are light to medium gray, aphanitic to holocrystalline, and microvesicular to dense. Jointing is typically massive to thick platy. Unit mc1 is overlain by unit mc2, basaltic andesite of North Caribou, unit 4 (mcn4), and basaltic andesite of middle Caribou (mcm). [RC]

bcw **Basalt of Caribou Wilderness (middle Pleistocene)**—Small group of thick, porphyritic, ol basalt (49.7–50.4% SiO_2) lava flows in northern Caribou chain, ~1.5 km east of Triangle Lake. Flows are heavily glaciated; typically only flow cores crop out. Poorly preserved vents are located at the till-covered hill 2213 (east of Triangle Lake) and a small unnamed hill to northeast. Small outcrop areas l km northeast of Triangle Lake may have erupted from another vent that is not preserved. Phenocrysts: 5–8% ol, 0.5–4 mm, mostly 0.5–2 mm; rock from hill 2213 has fewer ol phenocrysts. Groundmass is light to medium gray, aphanitic to holocrystalline, and dense to microvesicular. Unit bcw overlies basalt of Caribou Peak (bcp) and is overlain by basaltic andesite of Eleanor Lake (mce) and basaltic andesites of section 20 (mt20). Age is probably older than unit mce and is estimated to be 375–400 ka. [BB]

bcp **Basalt of Caribou Peak (middle Pleistocene)**—Thick lava flows of sparsely porphyritic ol basalt in northern part of Caribou chain. Flows are heavily glaciated; typically only flow cores crop out. Poorly preserved vent of weakly agglutinated cinders is exposed at Caribou Peak, and other vents are probably buried by basaltic andesite of Eleanor Lake (mce). Phenocrysts: 4–6% ol, 0.5–2 mm, a few larger crystals are composite; sparse pl, 0.5 mm. Groundmass is medium to dark gray, aphanitic to finely holocrystalline, and dense to weakly microvesicular with blocky to thick platy jointing. Unit bcp overlies basalt of Cowboy Lake (bcb) and is overlain by basalt of Caribou Wilderness (bcw) and by unit mce. Age is similar to possibly somewhat older than basaltic andesites of Silver Lake, unit 8 (mc8, 400±14 ka) and is estimated to be 400–425 ka. [BB] bcb **Basalt of Cowboy Lake (middle Pleistocene)**—Poorly exposed thick lava flows of porphyritic ol basalt (52.2% SiO_2) between Silver Lake and Caribou Peak in central Caribou Volcanic Field. Lava flows are heavily glaciated; typically only flow cores are exposed, and they are mostly covered by extensive sheet of till. Flow morphology is better preserved than older basalts and basaltic andesites south of Caribou Volcanic Field (boc, 650±20 ka). Vents not located and probably buried beneath till or basaltic andesites of Silver Lake, units 1–11 (mc1–11). Consists of unknown number of flows with similar lithology and composition to other lavas of Caribou Volcanic Field. Phenocrysts: 3–8% ol, 0.5–1 mm, mostly 0.5 mm; sparse–5% pl, 0.5–2 mm, mostly 0.5–1 mm. Ol is generally more abundant than pl, but is of subequal abundance in some flows. Few flows contain sparse, larger ol and (or) pl phenocrysts to 3 mm; some contain trace of aug. Most flows have small glomeroporphyritic clots of ol+pl, some to a few centimeters across. Groundmasses are light to medium gray and generally aphanitic, but occasionally holocrystalline and weakly microvesicular to dense. Small xenoliths of qtz, commonly with thin aug rims, are widely distributed. Unit is overlain by basaltic andesites of Silver Lake, unit 8 (mc8, 400±14 ka), and is estimated to be 400–425 ka. [BB, RC]

Sunrise Peak sequence

The Sunrise Peak sequence comprises a group of spatially and temporally related basalt and basaltic andesite lava flows and vents east and north of Butte Lake in the northwest Caribou Volcanic Field. Although generally similar to the Red Cinder chain, the Sunrise Peak sequence is older (~300–400 ka), more heavily glaciated, and cut by a prominent, old, till-covered fault that is part of the discontinuous fault zone between Lake Almanor Graben and Hat Creek Graben.

bsl **Basalt of Lost Spring (middle Pleistocene)**—Porphyritic aug-ol basalt (52.7–53.0% SiO_2) lava flow and cinder cone. Exposed near Duck Lake, north of Butte Lake. Vent is 1 km southeast of Duck Lake. Lava from vent flowed at least 1.5 km northwest. Lava was heavily glaciated, surface features are not preserved, and it is mostly buried by till, younger glaciations (Qty). Cinder cone, located on edge of glaciated area, is partially eroded and buried by Qty. Phenocrysts: 8% pl, 0.5–2 mm, few larger; 5% ol, 0.5–2 mm, mostly 1 mm; 2% aug, 0.5–2 mm, mostly 1 mm. Most crystals occur in glomeroporphyritic clots of ol+pyr+pl to 1 cm. Groundmass is light gray, holocrystalline, and dense. Massively jointed flow interiors are exposed. Unit bsl probably overlies basalt of Duck Lake (bsd) and is overlain by the much younger basalt of Twin Buttes (bdt, 46.3±3.4 ka). $^{40}Ar/^{39}Ar$ age is 302±7 ka. [PP]

bsd **Basalt of Duck Lake (middle Pleistocene)**—Sparsely porphyritic ol basalt lava flow exposed around Duck Lake, in northern Caribou Volcanic Field. Lava flow was heavily glaciated and is mostly buried by till; surface features are not preserved. Vent location is unknown. Phenocrysts: 5% ol, 0.5–2 mm. Groundmass is light gray, aphanitic, and dense. Thick, slabby-jointed flow interiors are exposed. Locally displays flow banding defined by vapor-phase crystallization. Unit bsd is probably overlain by basalt of Lost Spring (bsl), but is otherwise completely surrounded by till, younger glaciations (Qty). Estimated to be ~300 ka. [PP]

bs72 **Basalt of hill 7243 (middle Pleistocene)**—Cinder cone of porphyritic ol basalt in northwestern Caribou Volcanic Field. Cone is almost completely buried by till; associated lava flow may exist beneath till. Exposed part of cone is composed of agglutinated, strongly oxidized scoria and bombs. Phenocrysts: 7–8% ol, 0.5–2 mm; sparse aug, 0.5–2 mm. When fresh, groundmass is dark gray, glassy to aphanitic, and microvesicular. Age is very poorly constrained, but it is probably slightly younger than basalts of Sunrise Peak, unit 1 (bss1, 393±4 ka). [PP]

Basalts of Sunrise Peak (middle Pleistocene)—Porphyritic aug-ol basalt lava flows (51.4–52.3% SiO_2) and agglutinated scoria cones, exposed in the prominent fault scarp east of Butte Lake. Vent located at Sunrise Peak. Eruptions built two overlapping scoria cones with bss1 cone buried by bss2 cone. The bss2 cone was eroded by glaciers and is mostly covered by till, younger glaciations (Qty). Lithologically similar, but distinct, lava flows were erupted from the scoria cones. Lava flows were heavily glaciated, and surface features are not preserved. $^{40}Ar/^{39}Ar$ age of unit bss1 is 393±4 ka; unit bss2 is slightly younger. [PP]

bss2 **Unit 2**—Porphyritic aug-ol basalt (52.3% SiO_2) lava flows and agglutinated scoria cone. Thin platy to massively jointed flow interiors are exposed. Phenocrysts: 6% ol, 0.5–2 mm, mostly

1–2 mm; 2% aug, 0.5–1 mm; 2% pl, 0.5–1 mm. Groundmass is dark gray to black, aphanitic to glassy, and dense to microvesicular. Some flows have sparse glomeroporphyritic clots of ol+aug+pl to few millimeters. Xenocrysts of qtz are present. Unit bss2 overlies unit bss1, but is otherwise completely surrounded by till, younger glaciations (Qty). Age is slightly younger than bss1 (393±4 ka) [PP]

bss1 **Unit 1**—Porphyritic aug-ol basalt (51.4% SiO_2) lava flows and agglutinated scoria cone. Phenocrysts: 3% ol, 0.5–2 mm, mostly 0.5–1 mm; 2% aug, 0.5–1 mm; 5% pl, 0.5–2 mm, few larger. Groundmass is dark gray to black, aphanitic to glassy, and dense to microvesicular. Glomeroporphyritic clots of ol+aug+pl to few millimeters are common. Sparse xenocrysts of qtz are present. Unit bss1 overlies basalt of Bathtub Lake (bsb); overlain by bss2, but is otherwise completely surrounded by till, younger glaciations (Qty). $^{40}Ar/^{39}Ar$ age is 393±4 ka. [PP]

bsb **Basalt of Bathtub Lake (middle Pleistocene)**—Sparsely porphyritic ol basalt lava flows in Butte Creek, north of Butte Lake. Lithologies of several flows are somewhat variable. Flows were heavily glaciated; outcrops are discontinuous; and surface features are not preserved, being mostly buried by till or by ash from Cinder Cone eruption. Only massively jointed flow interiors are exposed. Vents are unknown and probably were removed by glaciation. Cut by small faults extending southeast from Hat Creek Fault. Phenocrysts: sparse to 5% ol, 0.5–2 mm, larger in some flows; 0–2% pl, 0.5–1 mm. Groundmasses are light to dark gray and holocrystalline to aphanitic. Unit bsb is overlain by basalt of Sunrise Peak, unit 1 (bss1, 393±4 ka), but is otherwise completely surrounded by till, younger glaciations (Qty). Age is probably ~400 ka. [PP]

Island Lake sequence

Island Lake sequence comprises two spatially and temporally related basalt lava flows near Bonte Peak, in the southwest part of the Caribou Volcanic Field. Generally similar to other rocks in Caribou Volcanic Field, the Island Lake sequence is ~350 ka, heavily glaciated, and cut by one of the small N. 10° W. faults along the discontinuous fault zone between Lake Almanor Graben and Hat Creek Graben. K-Ar age of unit bie is 331±45 ka; unit bii is probably slightly younger.

bii **Basalt of Island Lake (middle Pleistocene)**—Thick lava flow of porphyritic aug-ol basalt (52.7% SiO_2) erupted from eroded vent at hill 7470, 2.2 km north-northeast of Bonte Peak and flowed southwest for ~2 km. Lava flow was heavily glaciated and is partially buried by till. Surface features are not preserved, and only flow cores crop out. Phenocrysts: 15% pl, 0.5–2 mm, mostly 1 mm; 10% ol, 0.5–2 mm, mostly 1 mm; 2% aug, 0.5–2 mm, mostly 1 mm. Glomeroporphyritic clots of pl+ol+aug to 8 mm are abundant. Groundmass is light to medium gray, aphanitic to glassy, and dense. Thick platy to massively jointed flow interiors are exposed. Unit bii overlies older rock units: andesites of Dittmar Volcanic Center, Stage 2, undivided (ad2), basaltic andesites and basalt of Snag Lake (msn), basalt of Bonte Peak (bnt), and basaltic andesite of Black Cinder Rock (mb, 667±24 ka). Age is poorly constrained but probably slightly younger than basalt of East Lake (bie, 331±45 ka). Estimated to be 300–350 ka. [MH]

bie **Basalt of East Lake (middle Pleistocene)**—Lava flows of porphyritic ol basalt (52.9% SiO_2) erupted from poorly preserved vent at hill 7321, 1 km northeast of Bonte Peak. Lava flowed 4.5 km south. Heavily glaciated. Typically only flow cores crop out; till obscures much of southern part of unit. On east boundary, faulted against much older basaltic andesite of Black Cinder Rock (mb). Phenocrysts: 5% pl, 0.5–2 mm, mostly 0.5–1 mm; 3% ol, 0.5–1 mm, few larger. Glomeroporphyritic clots of pl+ol are abundant. Groundmass is light gray, holocrystalline, and microvesicular; lava near south limit of outcrop area is coarsely holocrystalline. Unit bie overlies basalt of Bonte Peak (bnt) and basaltic andesite of Black Cinder Rock (mb, 667±24 ka), and is probably slightly older than basalt of Island Lake (bii). K-Ar age is 331±45 ka. [MH, RC]

Beauty Lake sequence

The Beauty Lake sequence consists of highly glaciated lava flows immediately northwest of Hay Meadow in the southern part of the Caribou Volcanic Field. The flows are lithologically similar to mafic rocks in the Caribou chain, but are spatially offset from them. The Beauty Lake sequence is approximately coeval with the oldest rocks of the Caribou chain, ~425–450 ka.

bbb **Basalt of Beauty Lake (middle Pleistocene)**—Thick lava flows of porphyritic aug-ol basalt (52.6% SiO_2). Flows are heavily glaciated; typically only flow cores crop out. No vent is preserved. Phenocrysts: 9% ol, 0.5–2 mm, few larger; 5% aug, 0.5–2 mm, few larger; 1% pl, 0.5–1 mm. Small glomeroporphyritic clots of ol+aug+pl are sparse. Groundmass is light gray, holocrystalline, and microvesicular. Jointing is blocky to thick platy. Unit bbb overlies basalt of Hidden Lakes (bbh) and basalt of Posey Lake (bbp) and is youngest unit of Beauty Lake sequence. Absolute age is poorly constrained. It is probably older than basaltic andesites of Silver Lake, unit 8 (mc8, 400±14 ka) and is estimated to be ~425–450 ka. [RC]

bbp **Basalt of Posey Lake (middle Pleistocene)**—Thick lava flows of porphyritic ol basalt (51.7% SiO_2). Flows are heavily glaciated; typically only flow cores are exposed. Location of vent is unknown but was probably north of Posey Lake. Phenocrysts: 6% ol, 0.5–2 mm, mostly <1 mm; 2% pl, 0.5–1 mm, few larger. Small glomeroporphyritic clots of ol+pl are sparsely present. Groundmass is light to medium gray, holocrystalline, and dense. Jointing is blocky to thick platy. Unit bbp is overlain by basalt of Beauty Lake (bbb) and overlies basalt of Hidden Lakes (bbh). Absolute age is poorly constrained. It is probably older than basaltic andesites of Silver Lake, unit 8 (mc8, 400±14 ka) and is estimated to be ~425–450 ka. [RC]

bbh **Basalt of Hidden Lakes (middle Pleistocene)**—Thick lava flows of ol basalt (51.5–51.9% SiO_2) between Posey Lake and Hidden Lakes and south to Hay Meadow. Probably erupted from vent near Posey Lake that is not preserved and flowed south. Flows are heavily glaciated; typically only flow cores are exposed. Flows have similar lithologies, although some variation is present. Phenocrysts: 8–10% ol, 0.5–2 mm, mostly <1 mm, few larger to 4 mm. Groundmass is medium gray, holocrystalline, and dense. Unit bbh is overlain by basalt of Beauty Lake (bbb), basalt of Posey Lake (bbp), and basaltic andesite of middle Caribou (mcm, 362±33 ka). Absolute age is poorly constrained, but is probably older than basaltic andesites of Silver Lake, unit 8 (mc8, 400±14 ka) and is estimated to be 425–450 ka. [RC]

Older volcanic rocks

Older volcanic rocks (mostly >650 ka) surround the Caribou Volcanic Field on north, east, and south and form a base on which the volcanic field is built. Immediately south of the Caribou Volcanic Field, the rocks are heavily glaciated, mostly buried by till, and exposed only as obscure bits of lava flows. They are disrupted by faults extending northwest from the Lake Almanor Graben. A better-exposed group of old volcanoes occurs at higher elevations at Black Cinder Rock and Bonte Peak.

Much older rocks are exposed around the Caribou Volcanic Field beyond the limits of glaciation. To the south, these include several extensive sheets of tholeiitic basalt, a thick stack of 2.2–2.7 Ma calc-alkaline regional lavas exposed in Mud Creek Rim, and the west edge of the Swain Mountain shield volcano (fig. 3). In the north, these older rocks include the tholeiitic basalt sheet filling Grays Valley and the shield volcanoes of Bogard Buttes, Cal Mountain, and Cone Mountain (fig. 3).

bgv **Tholeiitic basalt of Grays Valley (middle Pleistocene)**—Thin, extensive sheet of nearly aphyric, tholeiitic, ol basalt (48.4–48.6% SiO_2) erupted from spatter rampart just west of Bogard Buttes Ranger Station (east of map area in Pine Creek Valley quadrangle). Multiple flow units of tube-fed pahoehoe flowed north-northwest and filled valley between Bogard Buttes, Cal Mountain, Cone Mountain, and Crater Lake Mountain (fig. 3). Phenocrysts: sparse pl, 1–2 mm; sparse ol, 0.5–2 mm. Few small glomeroporphyritic clots of ol+pl are present. Groundmass is light gray and coarsely diktytaxitic. Upper flow surface contains abundant spherical vesicles and has hexagonal-block, joint pattern with massively jointed flow interior. Age poorly constrained, but normal magnetic polarity indicates that unit bgv is <780 ka. Well-developed soil and obscure flow-surface features suggest that unit bgv is older than ~500 ka; estimated to be ~600 ka. [BB, PL]

bsh **Basalts and basaltic andesites of Swains Hole (middle Pleistocene)**—Group of lithologically similar, sparsely porphyritic ol basalt and basaltic andesite (52.1–53.3% SiO_2) lava flows poorly exposed 4.5 km southwest of Poison Lake. Buried to south by younger rock units. Much of unit is covered by a thick blanket of windblown dust and ash from eruptions in Poison Lake chain. Vents were located to south and east and are now buried by younger lavas from Caribou Volcanic Field. North of map area, these same rocks are well exposed in Butte Creek Rim (fig. 3). Lithologically variable. Phenocrysts: 2–8% ol, 0.5–1 mm; 1–3% pl, 0.5–1 mm in most flows. One flow 1 km southwest of Poison Lake, has ~15% 0.5–1 mm phenocrysts of ol and pl with pl>>ol. Groundmasses are generally medium to dark gray, glassy to aphanitic; most are microvesicular. Many flows have vesicular tops. Age poorly constrained; clearly much older than Poison Lake chain, tholeiitic basalt of Calif. Hwy 44 (b44, 190±18 ka), and andesite and basaltic andesite of Prospect Peak (ap, 247±56 ka) and therefore much older than ~300 ka. Broadly equivalent to older basalts and basaltic andesites south of Caribou Volcanic Field (boc, 650±20 ka). Unit bsh has normal polarity and thus is probably younger than 780 ka. Estimated to be ~600–725 ka. [BB, PL, PP, SW]

boc **Older basalts and basaltic andesites south of Caribou Volcanic Field (middle Pleistocene)**—Sparsely porphyritic to porphyritic ol basalt and basaltic andesite (52.3–52.7% SiO_2) lava flows scattered through southern Caribou Volcanic Field. Exposed in 60 small outcrops, mostly in Red Cinder quadrangle. These older flows are heavily glaciated, and constructional morphology is subdued or absent; typically, only small areas of flow core crop out beneath thick till cover. Vents are generally not located, and affinities of these flows to other units cannot be determined. Largest outcrop is lava flow of sparsely porphyritic ol basalt in extreme southeast part of map that filled canyon cut in basalt of Rock Creek (brk). Proximal part of this lava flow is buried by till, older glaciations (Qto); distal part has thick soil cover. Location of vent is unknown, but it was probably somewhere to northwest of flow near Bailey Creek. Four analyses are all basaltic, but some rocks probably are basaltic andesites. In general, these older basalts and basaltic andesites have compositions and lithologies similar to younger lavas in Caribou Volcanic Field. Typically, they contain sparse to ~5% small phenocrysts of ol, often accompanied by small pl crystals and more rarely by aug. Some are more porphyritic and contain subequal amounts of larger ol and pl phenocrysts and glomeroporphyritic clots of ol and pl. Groundmasses are light to dark gray, aphanitic to holocrystalline, and microvesicular to dense. Lava flows are older than Caribou Volcanic Field, for example basaltic andesites of Silver Lake, unit 8 (mc8, 400±14 ka). Unit boc overlies tholeiitic basalt of Rock Creek (brk, 989±49 ka). A number of measurements suggest all lavas have normal polarity. K-Ar age of larger outcrop area ~3 km south of Heckle Ranch is 650±20 ka. Age of unit boc is estimated to be ~600 to ~725 ka, broadly stratigraphically equivalent to basaltic andesite of Black Cinder Rock (mb), basaltic andesites and basalt of Snag Lake (msn), basalt of Bonte Peak (bnt), basalts and basaltic andesites of Swains Hole (bsh), and a few other units. [BB, CH, MH, RC]

bhr **Basaltic plug near Heckle Ranch (middle Pleistocene)**—Sparsely porphyritic ol basalt (52.3% SiO_2) plug in southern part of Caribou Volcanic Field. Plug intruded cinder cone of older basalts and basaltic andesites south of Caribou Volcanic Field (boc), which was subsequently heavily glaciated and mostly eroded away. Part of unit consists of dikes intruded into welded, agglutinated, and oxidized cinders. Adjacent lava flow of unit boc may be related to plug and (or) cinder cone. Phenocrysts: 5% ol, 0.5–1 mm, mostly 0.5 mm. Groundmass is medium gray, holocrystalline with light-green patches of poikilitic groundmass pyr, and sparsely microvesicular. Rock is massively jointed. Age poorly constrained but similar to older basalts and basaltic andesites south of Caribou Volcanic Field (boc, 650±20 ka). [RC]

mj **Basaltic andesite of Jakey Lake (middle Pleistocene)**—Thick lava flow of porphyritic ol basaltic andesite erupted from vent at hill 7741, 2.6 km northeast of Juniper Lake in southern Caribou Volcanic Field. Lava flowed ~1 km north from poorly preserved vent. Lava was heavily glaciated; surface features are not preserved; flow is partially buried by till. Phenocrysts: 8–10% ol, 0.5–3 mm, mostly 1 mm. Groundmass is light to medium gray, aphanitic to holocrystalline, and dense. Jointing is massive to thick platy. Age is poorly constrained. Unit mj overlies much older rocks of Dittmar Volcanic Center but is probably younger than basaltic andesites and basalt of Snag Lake (msn) and similar in age to basalt of Bonte Peak (bnt) and basaltic andesite of Black Cinder Rock (mb, 667±24 ka). Estimated to be ~650 ka. [MH]

bcg **Basalt of Butte Creek Campground (middle Pleistocene)**—Cinder cone of ol basalt in the Butte Creek drainage in the northern part of the Caribou Volcanic Field. A related lava flow may be buried beneath till or younger volcanic units. Phenocrysts: 10% ol, 0.5–2 mm, mostly 0.5 mm; sparse pl, 0.5–2 mm, mostly 0.5 mm. The groundmass is dark-gray to black and aphanitic. Age poorly constrained; much older than the overlying andesite and basaltic andesite of Prospect Peak (ap, 247 ± 56 ka). Probably equivalent to the younger part of basalts and basaltic andesites of Swains Hole (bsh), and estimated to be about 600–650 ka. [PP] mb **Basaltic andesite of Black Cinder Rock (middle Pleistocene)**—Lava flows of sparsely porphyritic ol basaltic andesite (54.2–55.0% SiO_2), south of Caribou Volcanic Field, that erupted from vent marked by scoria cone at Black Cinder Rock and at least one other vent. Lava flows are heavily glaciated; typically only flow cores crop out. Edifice of Black Cinder Rock was cut by faults of the discontinuous fault zone between Lake Almanor Graben and Hat Creek Graben. Lithology of lava flows is slightly variable. Phenocrysts: 1–5% ol, 0.5–1 mm, mostly <0.5 mm, some flows with a few to 2 mm; rare–sparse pl, 0.5–1 mm, mostly <0.5 mm. Few small glomeroporphyritic clots of ol or ol+pl are present in some flows. Few larger, ragged crystals of pl are locally found and are probably xenocrysts. Groundmass is light to dark gray, aphanitic to holocrystalline, and typically dense. Unit mb overlies parts of older basalts and basaltic andesites south of Caribou Volcanic Field (boc, 650±20 ka), but is generally equivalent in age to that unit. K-Ar age is 667±24 ka. [MH, RC]

msn **Basaltic andesites and basalt of Snag Lake (middle Pleistocene)**—Ol basaltic andesite and ol basalt in five isolated areas near Juniper and Snag Lakes, southwest of Caribou Volcanic Field. Rocks are probably not directly related but are combined because of similar lithology and age. Lava flows are heavily glaciated; typically only flow cores crop out; vent locations are unknown. Outcrops have deep soil and thick cover of till. Most of the five outcrop areas consist of sparsely porphyritic ol basaltic andesite. Phenocrysts: 3–5% ol, 0.5–2 mm, few larger; sparse to 5% pl, many with dark cores. Many ol phenocrysts are weakly oxidized. Groundmasses are dark to medium gray, aphanitic, and dense to weakly microvesicular. Area 1 km northeast of Glen Lake contains ~10% ol and glomeroporphyritic clots of ol+pl. Southern part of area southwest of Snag Lake contains 5% pl and only 1–2% ol. Area 1 km east of Mount Hoffman contains fragmental material and may be a deeply eroded vent. Age of unit msn is very poorly constrained, but older than Caribou Volcanic Field. Unit msn directly and unconformably overlies much older rocks of Dittmar Volcanic Center and is overlain by younger lava flows of Caribou Volcanic Field. Age is probably similar to older part of older basalts and basaltic andesites south of Caribou Volcanic Field and is estimated to be ~675–725 ka. [MH, PP]

bnt **Basalt of Bonte Peak (middle Pleistocene)**—Lava flows of sparsely porphyritic ol basalt (51.6–53.1% SiO_2) south of Caribou Volcanic Field. Vent was probably near summit of Bonte Peak. Lava flows are heavily glaciated; typically only flow cores crop out. Flanks of Bonte Peak were oversteepened by glacial erosion; much of lava away from summit is buried by till. Faulting along the discontinuous fault zone between Lake Almanor Graben and Hat Creek Graben may cut lavas, but relations are obscured by glacial erosion and till deposits. Phenocrysts: 2-4% ol, 0.5–1 mm, mostly 0.5 mm; sparse pl, 0.5–1 mm, mostly 0.5 mm. Few larger, ragged crystals of pl found in some flows are probably xenocrysts. Groundmass is variable from medium to dark gray and aphanitic to light gray and holocrystalline. Aphanitic lava is often oxidized to purplish or pinkish shades and holocrystalline lava to light brown or tan. Unit bnt is overlain by basaltic andesite of East Lake (bie, 331±45 ma) and probably by basaltic andesite of Black Cinder Rock (mb, 667±24 ka). Unit bnt overlies parts of older basalts and basaltic andesites south of Caribou Volcanic Field (boc, 650±20 ka), but is generally equivalent in age to it, and is estimated to be 675–700 ka. [MH, RC]

bcr **Basalt of Butte Creek Ranch (early Pleistocene)**—Porphyritic ol basalt lava and cinder cone in Butte Creek valley, 6.5 km southwest of Poison Lake. Cinder cone is somewhat eroded, leaving remnant of small crater-filling lava flow exposed at summit. Additional lava may be buried by younger lava flows of basalts and basaltic andesites of Swains Hole (bsh) and glacial outwash. Cinder cone is composed of oxidized scoria and blocks and bombs of ol basalt; covered by thick orange soil. Phenocrysts: 20% ol, 0.5–2 mm, few larger are composite grains; 5% pl, 0.5–1 mm. Small glomeroporphyritic clots of ol+pl are common. Groundmass is medium gray, aphanitic and microvesicular. Most of lava at summit is weakly oxidized. Age is very poorly constrained, but unit bcr has reversed magnetic polarity and must be older than 780 ka; estimated to be 800–850 ka. [SW]

a16 **Andesite of section 16 (early Pleistocene)**—Thin lava flow of porphyritic aug-hyp andesite 2.4 km east of Black Butte. Heavily glaciated and poorly exposed; only a small area of flow core crops out. Vent location is unknown. Phenocrysts: 15% pl, 0.25–1 mm; 5% hyp, 0.25–1 mm; 2% aug, 0.5–1 mm. Glomeroporphyritic clots of pl+pyr are abundant. Groundmass is dark gray and glassy to aphanitic. Unit a16 is older than all nearby units and is interpreted to be broadly equivalent to rocks exposed in upper part of Hat Creek Fault scarp. Unit not dated but is probably similar in age to andesite of Butte Lake (abt) and andesite of section 22 (a22); estimated to be ~900–1,000 ka. [BB]

brk **Tholeiitic basalt of Rock Creek (early Pleistocene)**—Extensive sheet of sparsely porphyritic, tholeiitic ol basalt (48.9% SiO_2) erupted from vent now buried beneath glacial till or younger rocks, probably near center of Red Cinder quadrangle. Number of small outcrops are southwest of Hay Meadow; larger continuous outcrops are beyond limit of till in southeast corner of map area. Lava flow extends southward into Lake Almanor Graben and down North Fork Feather River canyon, a distance of ~40 km. Lava sheet is at least 30 m thick near Lake Almanor. Offset at least 100 m east of Manzanita Mountain by faults extending northwest from Lake Almanor Graben; offset ~60 m by Clear Creek Fault in area south of Swain Mountain (out of map area; Westwood West quadrangle). Phenocrysts: sparse–2% ol, 0.5–2 mm. Lava has light to medium gray, aphanitic to holocrystalline, often coarsely diktytaxitic groundmass; flow tops contain abundant round vesicles; jointing is massive to blocky, often crudely hexagonal near upper surface of individual flow units. Lava flow has a well-developed orange to reddish soil; flow-top features are rarely observed. Unit brk can be discriminated from nearly identical but younger tholeiitic basalts by its reverse magnetic polarity. Paleomagnetic directional data (D.E. Champion, written commun., 1996) indicate that unit brk was emplaced as single eruptive unit. $^{40}Ar/^{39}Ar$ age is 989±49 ka. [CH, RC]

msw **Basaltic andesites of Swain Mountain (early Pleistocene)**—Shield volcano composed of porphyritic ol basaltic andesite (53.2–56% SiO_2) lava flows. Only westernmost part is in map area; most is in adjacent Swain Mountain quadrangle. Generalized description applies to entire Swain Mountain shield volcano. Volcano is ~8 km long and 6 km wide, and overall is well preserved. West flank of volcano (in map area) was oversteepened by faulting and glacial erosion; part of edifice is buried by till. Cirque is present on northeast side of summit; north flank is weakly glaciated. Scattered outcrops of agglutinated scoria in summit area are remnants of poorly preserved summit cone. Much of flanks of volcano, especially north flank, is covered by till and (or) thick soil. Volcano composed of two types of ol basaltic andesite, with and without pl phenocrysts, respectively. Phenocrysts (ol basaltic andesite, 53.2% SiO_2, northeast base of volcano): 5–8% ol, 0.5–3 mm, mostly 0.5–1 mm; rare–sparse pl, 0.5–1 mm. Groundmass is light to medium gray, aphanitic to holocrystalline, and dense to microvesicular. Cores of thick flow units, where ponded at north base of volcano, are very light gray and coarsely holocrystalline. Phenocrysts (ol-pl basaltic andesite, 56.3% SiO_2, near summit): 2–4% ol, 0.5–3 mm, mostly 0.5–1 mm; 2–4% pl, 0.5–2 mm. Small glomeroporphyritic clots of ol+pl are common. Jointing is slabby in flow interiors. A number of much younger units are adjacent to the west flank of Swain Mountain, but till obscures contacts. Basaltic andesite flow from summit has K-Ar age of 1,570±35 ka. [RC]

b11 **Basalt of section 11 (early Pleistocene)**—Lava flows of porphyritic ol basalt (52.2% SiO_2) 5 km south of Bogard Buttes, with eroded lava cone marking vent. Lava flowed ~3 km southeast and is partly buried by younger units. Outcrop is sparse; flow is deeply weathered and covered by thick gravelly soil containing subrounded boulders of weathered lava. Phenocrysts: 10% pl, 0.5–2 mm, mostly 0.5–1 mm; 5% ol, 0.5–2 mm, usually oxidized. Glomeroporphyritic clots of ol+pl to 1 cm are common. When fresh, groundmass is light gray, holocrystalline, and microvesicular. Rock is generally weathered, is brownish gray to pinkish gray, and has blocky jointing. Unit b11 is overlain by number of units from the much younger Poison Buttes chain. K-Ar age is 1,710±42 ka. [BB]

Tbm **Basalts and basaltic andesites of Mud Creek Rim (late Pliocene)**—Thick (>400 m) section of regional mafic lava flows and sparse interbedded pyroclastic material. Section is exposed primarily in fault scarps that form east boundary of north part of Lake Almanor Graben. Although variety of rocks is present, most abundant are ol basalts and basaltic andesites (51.6–57.2% SiO_2). These lavas erupted from unknown number of small overlapping shield volcanoes north of Lake Almanor. In general, these lavas are sparsely to moderately porphyritic ol basalt to basaltic andesite with 1–10% ol, 0.5–2 mm; some flows contain aug and (or) pl and may lack ol. Groundmasses are generally light to medium gray and aphanitic. $^{40}Ar/^{39}Ar$ age of 2,785±16 ka and three K-Ar ages of 2,455±49 ka, 2,307±32 ka, and 2,200±49 ka indicate significant range in age. [CH, RC]

Tdb **Dacite of Bogard Buttes (late Pliocene)**—Shield volcano composed of porphyritic aug-hyp dacite (63.4–63.5% SiO_2) lava flows. Bogard Buttes volcano is ~5 km diam; its general form is preserved, although several small normal faults cut edifice and form small graben. Vent area(s) are not preserved. Rock is devitrified and (or) altered to light brown to tan. Phenocrysts: 15% pl, 0.5–2 mm, mostly 0.5–1 mm; 4% hyp, 0.5–2 mm, mostly 0.5–1 mm; 4% aug, 0.5–2 mm, mostly 0.5–1 mm. Small glomeroporphyritic clots of pl+aug+hyp are common. Fresh groundmass is medium to dark gray, aphanitic, and dense and is locally flow banded. Jointing in flow interiors is slabby to platy. Unit Tdb is overlain on west flank by much younger vents and flows of Poison Lake chain. K-Ar ages of 2,350±70 ka and 2,225±49 ka were obtained, but volcano was probably constructed over a shorter time interval than suggested by these ages. [BB]

Tac **Andesite of Cal Mountain (late Pliocene)**—Shield volcano composed of lava flows of sparsely porphyritic ol andesite (58.2–59.1% SiO_2). This volcano is ~4 km diam and is well preserved; only south half lies within map area. Two samples, both from south flank of volcano, exhibit subtle variation in phenocryst content. Phenocrysts: 2% ol, 0.5–3 mm, mostly 0.5–1 mm, sparse–trace pl, 0.5 mm. Groundmass is medium greenish gray, aphanitic, and dense. Splotchy vapor-phase crystallization parallel to flow banding is common in some flow interiors. Jointing is slabby in flow interiors. K-Ar age is 2,345±49 ka. [PL]

Tmc **Basaltic andesite of Cone Mountain (late Pliocene)**—Shield volcano composed of lava flows of sparsely porphyritic ol basaltic andesite (56.0–56.1% SiO_2), north of Grays Valley at northeast corner of map area. Only extreme south flank of volcano is in map area. Volcano is ~6 km diam and was somewhat dissected by erosion. Lava flows exhibit subtle variation in phenocryst content. Phenocrysts (south flank): 2% ol, 0.5–2 mm, mostly 0.5–1 mm. Groundmass is medium gray, contains abundant microlithic feldspar, and is microvesicular. K-Ar age is 2,575±57 ka. [PL]

Tmsr **Basaltic andesites of Susan River (late Pliocene)**—Sparsely to moderately porphyritic ol basaltic andesite (54.7% SiO_2) lava flows forming extensive block-faulted terrane northeast of Silver Lake, mostly east of map area in Pine Creek Valley and Swain Mountain quadrangles. Constructional morphology is poorly preserved; individual lava flows and cones are not distinguished. Several poorly preserved vents are exposed east of map area. Rocks are generally deeply weathered and covered by extensive blanket of till and thick soil; outcrop is very sparse. Phenocrysts (ol basaltic andesite from map area): 10–12% pl, 0.5 mm; 3–4% ol, 0.5–1 mm. Groundmass is dark gray, aphanitic, and weakly microvesicular to dense. Age is very poorly constrained. Unit Tmsr is probably older than basaltic andesites of Swain Mountain (msw, 1,570±35 ka), basalt of section 11 (b11, 1,710±42 ka), and dacite of Bogard Buttes (Tdb, 2,225±49 ka and 2,350±70 ka). Flows in map area have normal magnetic polarity and probably fall into Gauss Chron of magnetic-polarity time scale and thus are probably older than 2,580 ka. [BB]

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Table 1. Correlation of glacial terminology, age assignments, and depiction of glacial deposits in Lassen Volcanic National Park and vicinity, California.

[Map unit labels in parentheses; **- - -**, not indicated. Ages of glacial deposits for the Christiansen and others (2002) units and this map follow those of Turrin and others (1998): Tioga is Late to Middle Wisconsin in age and equivalent to Marine Oxygen Isotope Stage 2; Tahoe is Early Wisconsin in age and equivalent to Marine Oxygen Isotope Stage 4; and pre-Tahoe is Late Illinoian and older and equivalent to Marine Oxygen Isotope Stage 6 and older stages]

<table>
<tr><th>Crandell, 1972</th><th>Kane, 1982</th><th>Turrin and others, 1998</th><th>Christiansen and others, 2002, and detailed areas of this map</th><th>Additional generalized units on this map</th><th>Estimated age</th></tr>
<tr><td>- - -</td><td>- - -</td><td>Till of Anklin Meadows A4</td><td>- - -</td><td>- - -</td><td>200–300 yrs</td></tr>
<tr><td rowspan="3">Moraines of late Tioga age</td><td rowspan="3">Late Tioga till</td><td rowspan="2">Till of Anklin Meadows A3</td><td>Till or protalus-rampart debris (Qth)</td><td rowspan="6">Till, younger glaciations (Qty)</td><td rowspan="2">8–12 ka</td></tr>
<tr><td>Late till of Anklin Meadows (Qtal)</td></tr>
<tr><td>Till of Anklin Meadows A2</td><td rowspan="2">Till of Anklin Meadows (Qta)</td><td rowspan="2">17–25 ka</td></tr>
<tr><td>Tioga Drift</td><td>Middle Tioga till</td><td>Till of Anklin Meadows A1</td></tr>
<tr><td rowspan="4">Tahoe Drift</td><td rowspan="2">Early Tioga till</td><td rowspan="2">“Early Tioga” till</td><td>Post-maximum till of Raker Peak consisting of Lassen Peak avalanche debris (Qtrl)</td><td>~27 ka</td></tr>
<tr><td>Till of Raker Peak (Qtr)</td><td>27–35 ka</td></tr>
<tr><td rowspan="2">Tahoe till</td><td>Till of Badger Mountain B2</td><td rowspan="2">Till of Badger Mountain (Qtb)</td><td rowspan="3">Till, older glaciations (Qto)</td><td rowspan="2">60–70 ka</td></tr>
<tr><td>Till of Badger Mountain B1</td></tr>
<tr><td>pre-Tahoe drift</td><td>pre-Tahoe till</td><td>- - -</td><td>- - -</td><td>>130 ka</td></tr>
</table>

Table 2. K-Ar and $^{40}Ar/^{39}Ar$ Ages obtained for the geologic map of Lassen Volcanic National Park and vicinity, California

[Unit labels are listed in the same order as shown in table 3 and Description of Map Units. See accompanying CD-ROM or files online (http://pubs.usgs.gov/sim/2899/) for sample locations, given here as latitude and longitude in decimal degrees. A few samples were collected outside of the map area and are not included in the CD-ROM. Ages taken from published sources and discussed in the Description of Map Units are not repeated here. Abbreviations: gl, glass; gm, groundmass; pl, plagioclase; wr, whole rock. USGS analysts: ATC, A.T. Calvert; BDT, B.D. Turrin; GBD, G.B. Dalrymple; MAL, M.A. Lanphere. LEB, (L.E. Borg, written commun., 1989). WDP, samples analyzed for William D. Page of Pacific Gas and Electric Company at Berkeley Geochronology Center, Berkeley, Calif., under the supervision of Paul Renne (W.D. Page, written commun., 1995)]

Unit label	Map unit	Sample No.	Latitude	Longitude	Material dated	Method	Age (ka)	Analyst
				Lassen Volcanic Center				
mfp	Basaltic andesite of Fairfield Peak	LC86-928	40.5230°	-121.3618°	wr	K-Ar	82±14	GBD
ac	Andesite of Crater Butte	LC86-922	40.4915°	-121.3527°	wr	K-Ar	93±13	GBD
arp	Andesite of Raker Peak	LC85-748	40.5268°	-121.4528°	wr	K-Ar	270±18	GBD
av	Andesite of Viola	LC80-391	40.4976°	-121.6086°	wr	K-Ar	313±8	GBD
rkr	Rhyodacite of Krummholz	LC81-733	40.5036°	-121.5003°	wr	$^{40}Ar/^{39}Ar$	43±2	MAL
re	Rhyodacite of Eagle Peak, Dome and flow	LC92-1752	40.4758°	-121.5147°	gl	$^{40}Ar/^{39}Ar$	66±4	BDT
rd	Rhyodacite of Dersch Meadows	LC86-997	40.5099°	-121.4619°	gl	$^{40}Ar/^{39}Ar$	193±11	BDT
dr	Dacite of Reading Peak	LC81-683	40.4685°	-121.4415°	wr	K-Ar	212±5	GBD
db	Dacite of Bumpass Mountain	B-331	40.4605°	-121.4600°	wr	K-Ar	232±8	GBD
dc	Dacite of Crescent Crater	LC87-1230	40.5073°	-121.4900°	gm	$^{40}Ar/^{39}Ar$	236±1	BDT
ds	Dacite of Ski Heil Peak	LC83-355	40.4695°	-121.5164°	wr	K-Ar	244±10	GBD
dh	Dacite of Mount Helen	B-160	40.4707°	-121.5048°	wr	K-Ar	249±12	GBD
d82	Dacite of hill 8283	LC89-1514	40.5072°	-121.5130°	wr	K-Ar	261±5	GBD
rmz	Rhyodacite of Manzanita Chute	LC92-1754	40.5325°	-121.5935°	gl	$^{40}Ar/^{39}Ar$	297±1	BDT
rmc	Rhyodacite of Mount Conard	LM80-899	40.4307°	-121.5094°	pl	$^{40}Ar/^{39}Ar$	298±9	ATC
amd	Andesite of Mount Diller	LC80-449	40.4677°	-121.5553°	wr	K-Ar	387±10	GBD
adc	Andesite of Digger Creek	LC80-527	40.4497°	-121.5797°	wr	K-Ar	451±10	GBD
abf	Andesite of Bluff Falls quarry	80G101	40.4144°	-121.5319°	wr	K-Ar	467±10	GBD
ar	Andesite of Rice Creek	B-316	40.4336°	-121.4497°	wr	K-Ar	477±14	GBD
		80G112	40.3955°	-121.4721°	wr	K-Ar	485±12	GBD
dt	Dacite of Twin Meadows	LC82-865	40.4465°	-121.5552°	wr	K-Ar	470±10	GBD
amc	Andesites of Mill Canyon	B-338	40.4399°	-121.5122°	wr	K-Ar	472±9	GBD
		LC84-605	40.4357°	-121.5068°	wr	K-Ar	473±10	GBD
		LM80-884	40.4123°	-121.5117°	wr	K-Ar	506±14	GBD
		80G107	40.4749°	-121.5624°	wr	K-Ar	534±27	GBD
		LM80-854	40.4223°	-121.4971°	wr	K-Ar	555±18	GBD
		B-51	40.4657°	-121.5738°	wr	K-Ar	591±13	GBD
rr	Rhyolite of Raker Peak	LC82-210	40.5250°	-121.4762°	wr	K-Ar	588±69	MAL
drr	Dacite of Red Rock Mountain	80G105	40.4704°	-121.6181°	wr	K-Ar	672±20	GBD
dbl	Dacite of Bench Lake	LC86-879	40.4597°	-121.4258°	wr	K-Ar	679±14	GBD
drp	Dacite of Rocky Peak	80G102	40.4117°	-121.5967°	wr	K-Ar	803±27	GBD

Table 2. K-Ar and $^{40}Ar/^{39}Ar$ Ages—continued

Unit label	Map unit	Sample No.	Latitude	Longitude	Material dated	Method	Age (ka)	Analyst
dfr	Dacite of Flatiron Ridge	LC81-629	40.4364°	-121.3586°	gm	K-Ar	812±6	ATC
dp	Dacite of Panther Creek	LC88-1427	40.4337°	-121.4273°	wr	K-Ar	827±18	GBD
				Maidu Volcanic Center				
rlp	Rhyolite of Lost Creek Plateau	LC93-1863	40.2798°	-121.3993°	wr	$^{40}Ar/^{39}Ar$	1,305±10	WDP
Tdm	Dacites of Maidu Volcanic Center, Stage 2, undivided	LM93-3087	40.1962°	-121.6313°	wr	K-Ar	2,105±25	MAL
		LC91-1611	40.3603°	-121.6578°	wr	K-Ar	2,120±46	GBD
		LC88-1393	40.2542°	-121.5447°	wr	K-Ar	2,140±42	GBD
		LC88-1372	40.2687°	-121.6018°	wr	K-Ar	2,259±46	GBD
Tam	Andesites of Maidu Volcanic Center, Stage 1, undivided	LC80-504	40.3600°	-121.6247°	wr	K-Ar	1,905±42	GBD
		LC79-54	40.3753°	-121.5935°	wr	K-Ar	2,045±42	MAL
		LM93-2959	40.2422°	-121.4737°	wr	K-Ar	2,152±47	GBD
		LC93-1814	40.2637°	-121.4498°	wr	K-Ar	2,250±49	GBD
		LC88-1391	40.2733°	-121.5395°	wr	K-Ar	2,325±49	GBD
		LC88-1382	40.2893°	-121.5658°	wr	K-Ar	2,375±49	GBD
Tab	Andesite of South Fork Battle Creek	LC91-1578	40.3562°	-121.6573°	wr	K-Ar	2,166±67	GDB
				Dittmar Volcanic Center				
rd3	Rhyolites of Dittmar Volcanic Center, Stage 3	LC86-865	40.4790°	-121.4145°	wr	K-Ar	1,273±7	ATC
ad2	Andesites of Dittmar Volcanic Center, Stage 2, undivided	LC81-576	40.3839°	-121.3547°	wr	K-Ar	1,398±42	GBD
Tad	Andesites of Dittmar Volcanic Center, Stage 1, undivided	LC86-886	40.4777°	-121.3057°	wr	K-Ar	1,650±35	GBD
		LC88-1413	40.4947°	-121.2900°	wr	K-Ar	1,785±35	GBD
		LC93-1866	40.4273°	-121.3322°	wr	K-Ar	2,315±29	MAL
				Latour Volcanic Center				
Tlv	Rocks of Latour Volcanic Center	LC92-1696	40.6284°	-121.6825°	wr	K-Ar	3,140±67	GBD
				Regional volcanic rocks				
atb	Andesite of Bear Wallow Butte	LC83-263	40.6157°	-121.5043°	wr	$^{40}Ar/^{39}Ar$	35.1±3.1	MAL
mbg	Basaltic andesite of Little Bunchgrass Meadow	LC83-276	40.5745°	-121.4023°	gm	$^{40}Ar/^{39}Ar$	143±6	ATC
b44	Tholeiitic basalt of Calif. Hwy 44	LC84-569	40.6338°	-121.3343°	pl	$^{40}Ar/^{39}Ar$	190±18	ATC
bec	Tholeiitic basalt of Eagle Canyon	LC84-563	40.5388°	-121.7082°	wr	$^{40}Ar/^{39}Ar$	199±22	BDT
mm	Basaltic andesites of Magee Volcano	LB88-32	40.6895°	-121.6182°	wr	K-Ar	210±120	LEB
ap	Andesite and basaltic andesite of Prospect Peak	LM87-1443	40.5740°	-121.3414°	wr	K-Ar	247±56	MAL
acs	Andesite of Cabin Spring	80G104	40.4614°	-121.6303°	wr	K-Ar	690±34	GBD
abm	Andesites of Badger Mountain	LC83-380	40.5755°	-121.4013°	wr	K-Ar	708±21	GBD
ahc	Andesites, basaltic andesites, and basalts of Hat Creek Rim	LM87-1381	40.8295°	-121.4557°	wr	K-Ar	924±24	GBD
		LM87-1378	40.7485°	-121.4137°	wr	K-Ar	1,645±35	GBD

Table 2. K-Ar and $^{40}Ar/^{39}Ar$ Ages—continued

Unit label	Map unit	Sample No.	Latitude	Longitude	Material dated	Method	Age (ka)	Analyst
am	Older regional andesites and basaltic andesites, undivided	LC92-1717	40.5723°	-121.6842°	wr	K-Ar	1,400±37	MAL
bbz	Tholeiitic basalts of Buzzard Springs	B-306	40.4025°	-121.4301°	wr	K-Ar	65±45	GBD
bsm	Basalts and basaltic andesites of Sifford Mountain	LC81-720	40.4357°	-121.3743°	wr	$^{40}Ar/^{39}Ar$	167±4	WDP
		LC81-649	40.3575°	-121.3569°	wr	$^{40}Ar/^{39}Ar$	172±23	WDP
amh	Andesite and basalt of Mount Harkness	LC82-928	40.4099°	-121.3071°	wr	K-Ar	188±32	GBD
bwv	Tholeiitic basalt of Warner Valley	LC93-1970	40.2845°	-121.2652°	wr	$^{40}Ar/^{39}Ar$	610±22	MAL
mgp	Basaltic andesite of Grays Peak	LM90-2422A	40.3790°	-121.6592°	wr	K-Ar	1,080±26	GBD
bpa	Basalt of Panther Creek	LM92-2438	40.3598°	-121.7118°	wr	K-Ar	1,105±49	GBD
acc	Andesites of Cowslip Campground	80G108	40.3844°	-121.6228°	wr	K-Ar	1,320±40	GBD
mbc	Basaltic andesites of South Fork Battle Creek	LC91-1613	40.3613°	-121.6508°	wr	K-Ar	1,738±46	GBD
	Caribou Volcanic Field							
arr	Andesite of Red Cinder	LM87-1487	40.5200°	-121.2693°	wr	K-Ar	69±20	MAL
bdt	Basalt of Twin Buttes	LC86-831	40.6267°	-121.2278°	wr	$^{40}Ar/^{39}Ar$	46.3±3.4	ATC
bc2	Basalts of Cone Lake Road, unit 2	LM03-4010	40.5573°	-121.1708°	gm	$^{40}Ar/^{39}Ar$	97.6±9.8	ATC
bg4	Basalts of old railroad grade, unit 4	LM91-2116	40.6410°	-121.2268°	gm	$^{40}Ar/^{39}Ar$	102.1±11.4	ATC
bp6	Basalts of Poison Butte, unit 6	LM03-4004	40.6370°	-121.1740°	gm	$^{40}Ar/^{39}Ar$	105.0±6.0	ATC
bb12	Basalts and basaltic andesites of Bogard Buttes, unit 12	LC08-2433	40.5832°	-121.1600°	gm	$^{40}Ar/^{39}Ar$	107.5±3.8	ATC
bb6	Basalts and basaltic andesites of Bogard Buttes, unit 6	LM90-1938	40.5565°	-121.1260°	gm	$^{40}Ar/^{39}Ar$	100.1±8.5	ATC
bpc1	Basalts of Pine Creek, unit 1	LM07-4339	40.5350°	-121.1313°	gm	$^{40}Ar/^{39}Ar$	106.2±3.6	ATC
bt4	Basalts of Pittville Road, unit 4	LM90-2070	40.6255°	-121.1748°	gm	$^{40}Ar/^{39}Ar$	101.0±1.9	ATC
bt1	Basalts of Pittville Road, unit 1	LM90-2078	40.6490°	-121.1798°	gm	K-Ar	108±14	GBD
bs5	Basalts of Stephens Campground, unit 5	LM90-2027	40.6205°	-121.1475°	gm	$^{40}Ar/^{39}Ar$	108.6±2.1	ATC
bs4	Basalts of Stephens Campground, unit 4	LM90-1983	40.5937°	-121.1742°	gm	$^{40}Ar/^{39}Ar$	110.8±3.8	ATC
br2	Basalts of Robbers Spring, unit 2	LM90-2076	40.6374°	-121.1711°	gm	$^{40}Ar/^{39}Ar$	101.5±8.7	ATC
bl35	Basalt of section 35	LM90-1981	40.5837°	-121.1737°	gm	$^{40}Ar/^{39}Ar$	202.0±2.2	ATC
bl22	Basalt of hill 2232	LC85-655	40.5802°	-121.2168°	wr	K-Ar	220±14	GBD
mtr	Basaltic andesite of Triangle Lake	LM87-1351	40.5278°	-121.2140°	wr	K-Ar	277±22	GBD
mee1	Basaltic andesites of Echo Lake, unit 1	LM91-2233	40.4460°	-121.1562°	wr	K-Ar	302±36	GBD
mcm	Basaltic andesite of middle Caribou	LC88-1327	40.4653°	-121.1770°	wr	K-Ar	362±33	GBD
mc8	Basaltic andesites of Silver Lake, unit 8	LC82-898	40.4903°	-121.1622°	wr	K-Ar	400±14	GBD
bsl	Basalt of Lost Spring	LM87-1467	40.5766°	-121.2828°	gm	$^{40}Ar/^{39}Ar$	302±7	ATC
bss1	Basalts of Sunrise Peak, unit 1	LM87-1548	40.5590°	-121.2787°	gm	$^{40}Ar/^{39}Ar$	393±4	ATC
bie	Basalt of East Lake	LM87-1777	40.4417°	-121.2454°	wr	K-Ar	331±45	MAL
	Older volcanic rocks							
boc	Older basalts and basaltic andesites south of Caribou Volcanic Field	LM91-2392	40.3970°	-121.1735°	wr	K-Ar	650±20	GBD

Table 2. K-Ar and $^{40}Ar/^{39}Ar$ Ages—continued

Unit label	Map unit	Sample No.	Latitude	Longitude	Material dated	Method	Age (ka)	Analyst
mb	Basaltic andesites of Black Cinder Rock	LG92-50	40.3970°	-121.1735	wr	K-Ar	667±25	GBD
brk	Theoleiitic basalt of Rock Creek	LC39-1980	40.4368°	-121.2199	wr	$^{40}Ar/^{39}Ar$	989±49	MAL
msw	Basaltic andesites of Swain Mountain	LM92-2746	40.4242°	-121.1013°	wr	K-Ar	1,570±35	GBD
b11	Basalt of section 11	LM90-1942	40.5478°	-121.1325°	wr	K-Ar	1,710±42	GBD
Tbm	Basalts and basaltic andesites of Mud Creek Rim	LM91-2379	40.3828°	-121.2178°	wr	K-Ar	2,200±49	GBD
		LC82-879	40.3543°	-121.2031°	wr	K-Ar	2,307±32	GBD
		LM91-2367	40.3348°	-121.1770°	wr	K-Ar	2,455±49	GBD
		LM93-3150	40.2888°	-121.1565°	wr	$^{40}Ar/^{39}Ar$	2,785±16	MAL
Tdb	Dacite of Bogard Buttes	LM90-1956	40.5777°	-121.1333°	wr	K-Ar	2,225±49	GBD
		LM90-2018	40.5973°	-121.1370°	wr	K-Ar	2,350±70	GBD
Tac	Andesite of Cal Mountain	LM92-2802	40.6525°	-121.1753°	wr	K-Ar	2,345±49	GBD
Tmc	Basaltic andesite of Cone Mountain	LB90-85	40.6987°	-121.1137°	wr	K-Ar	2,575±57	GBD

Table 3. Alphabetical list of map unit names, labels, and ages.

[Correlation of Map Units (CMU) group abbreviations—CVF, Caribou Volcanic Field, may include additional abbreviations: D, Bidwell Spring chain; B, Beauty Lake sequence; C, Caribou chain; CL, Cone Lake chain; I, Island Lake chain; P, Poison Lake chain; R, Red Cinder chain; S, Sunrise Peak sequence; T, Tuya chains. DVC, Dittmar Volcanic Center. LVC, Lassen Volcanic Center, may include additional abbreviations: B, Bumpass sequence; BV, Brokeoff Volcano; E, Eagle Peak sequence; R, Rockland caldera complex; TO, Twin Lakes sequence; older, TY, Twin Lakes sequence, younger. LtVC, Latour Volcanic Center. MVC, Maidu Volcanic Center. RNW, regional volcanic rocks north and west of Lassen Volcanic Center, may include additional abbreviations: T, Tumble Buttes chain, S, Sugarloaf chain. ROC, older regional volcanic rocks in Caribou area. RSE, regional volcanic rocks south and east of Lassen Volcanic Center. Other units: G, glacial, sedimentary, and hydrothermal deposits; TF, Tuscan Formation. Ages from Table 2 or the Description of Map Units. See figure 3 (sheet 3) for quadrangle locations and abbreviations]

Unit label	Unit name	Text page	CMU group*	Age of dated units	Quadrangle(s)
a16	Andesite of section 16	90	ROC		BB
a22	Andesite of section 22	60	RNW		PP
a74	Andesite of hill 7416	22	LVC-TY		OS, PP, SW
aa	Andesite of Ashpan Butte	59	RNW		MZ
ab	Andesite of Benner Creek	46	DVC		CH, ST
abf	Andesite of Bluff Falls quarry	36	LVC-BV	467±10 ka	LP
abl	Andesite of Butte Lake	59	RNW		PP
abm	Andesites of Badger Mountain	58	RNW	708±21 ka	OS, WP
ac	Andesite of Crater Butte	23	LVC-TY	93±13 ka	MH, PP
acc	Andesites of Cowslip Campground	65	RSE	1,320±40 ka	GP, LP, LY, MN
acl	Andesite and basaltic andesite of Cluster Lakes	24	LVC-TO		PP, WP
acs	Andesite of Cabin Spring	57	RNW	690±34 ka	GP
ad	Andesites of Diller sequence, undivided	35	LVC-BV		GP, MZ, VI, WP
ad2	Andesites of Dittmar Volcanic Center, Stage 2, undivided	45	DVC	1,398±42 ka	MH, PP, RP, ST
adb	Andesite of Bidwell Spring	70	CVF-D		PP, SW
adc	Andesite of Digger Creek	35	LVC-BV	451±10 ka	GP, LP, MZ, VI
adm	Andesite of Doe Mountain	45	DVC		CM, MN
ads	Andesite of Domingo Spring	45	DVC		MH, ST
ae	Andesite of Eagle Peak	23	LVC-TY		LP
ag	Andesite of Glassburner Meadows	36	LVC-BV		LP
agr	Andesite of Grayback Ridge	57	RNW		MZ
ah	Andesite of Hat Mountain	22	LVC-TY		MH, PP RP, WP
ahc	Andesites, basaltic andesites, and basalts of Hat Creek Rim	59	RNW	924±24 ka 1,645±35 ka	OS, PP, SW
alg	Andesite of Logan Mountain	57	RNW		TH
am	Older regional andesites and basaltic andesites, undivided	60	RNW	1,400±37 ka	GP, MZ, OS, TH, VI
amc	Andesites of Mill Canyon	37	LVC-BV	472±9 ka 473±10 ka 506±14 ka 534±27 ka 555±18 ka 591±13 ka	LP, RP, WP

Table 3. Alphabetical list of map unit names, labels, and ages—continued

Unit label	Unit name	Text page	CMU group*	Age of dated units	Quadrangle(s)
amd	Andesite of Mount Diller	34	LVC-BV	387±10 ka	LP, RP
amh	Andesite and basalt of Mount Harkness	63	RSE	188±32 ka	MH
amr	Andesite of Martin Creek	65	RSE		LP, MN
amz	Andesite of Manzanita Creek	35	LVC-BV		MZ, VI
ao	Andesite of Onion Creek	58	RNW		GP
ap	Andesite and basaltic andesite of Prospect Peak	55	RNW	247±56 ka	PP, SW, WP
ar	Andesite of Rice Creek	36	LVC-BV	477±14 ka 485±12 ka	CM, LP, RP
arp	Andesite of Raker Peak	24	LVC-TO	270±18 ka	MZ, WP
arr	Andesite of Red Cinder	68	CVF-R	69±20 ka	BB, MH, PP, RC
aso	Andesites of Old Station	53	RNW-S		OS
asp	Andesite of Potato Butte	52	RNW-S	77±11 ka	OS
ass	Andesite of Sugarloaf Peak	52	RNW-S	46±7 ka	OS
at	Andesite of Table Mountain	58	RNW		MZ
atb	Andesite of Bear Wallow Butte	50	RNW-T	35.1±3.1 ka	MZ, OS, TH, WP
atd	Andesite of Devils Rock Garden	49	RNW-T		TH
att	Andesite of Tumble Buttes	51	RNW-T		MZ, OS, TH, WP
av	Andesite of Viola	24	LVC-TO	313±8 ka	LP, MZ, VI
aw	Andesite of Wilcox Peak	57	RNW		OS
awp	Andesites of West Prospect Peak	56	RNW		OS, PP, SW, WP
b11	Basalt of section 11	91	ROC	1,710±42 ka	BB
b18	Tholeiitic basalt of hill 1879	54	RNW		BB, PL, PP, SW
b44	Tholeiitic basalt of Calif. Hwy 44	53	RNW	190±18 ka	OS, PP, SW
bb1	Basalts and basaltic andesites of Bogard Buttes, unit 1	74	CVF-P		BB
bb2	Basalts and basaltic andesites of Bogard Buttes, unit 2	74	CVF-P		BB
bb3	Basalts and basaltic andesites of Bogard Buttes, unit 3	74	CVF-P		BB
bb4	Basalts and basaltic andesites of Bogard Buttes, unit 4	74	CVF-P		BB
bb5	Basalts and basaltic andesites of Bogard Buttes, unit 5	73	CVF-P		BB, PL
bb6	Basalts and basaltic andesites of Bogard Buttes, unit 6	73	CVF-P	100.1±8.5 ka	BB
bb8	Basalts and basaltic andesites of Bogard Buttes, unit 8	73	CVF-P		BB
bb9	Basalts and basaltic andesites of Bogard Buttes, unit 9	73	CVF-P		BB
bb10	Basalts and basaltic andesites of Bogard Buttes, unit 10	73	CVF-P		BB
bb11	Basalts and basaltic andesites of Bogard Buttes, unit 11	73	CVF-P		BB
bb12	Basalts and basaltic andesites of Bogard Buttes, unit 12	73	CVF-P	107.5±3.8 ka	BB
bbb	Basalt of Beauty Lake	88	CVF-B		RC
bbf	Basalt of Badger Flat	56	RNW		OS, WP
bbh	Basalt of Hidden Lakes	88	CVF-B		RC
bbp	Basalt of Posey Lake	88	CVF-B		RC
bbz	Tholeiitic basalts of Buzzard Springs	61	RSE	65±45 ka	CM, RP, ST

Table 3. Alphabetical list of map unit names, labels, and ages—continued

Unit label	Unit name	Text page	CMU group*	Age of dated units	Quadrangle(s)
bc1	Basalts of Cone Lake Road, unit 1	71	CVF-P		BB
bc2	Basalts of Cone Lake Road, unit 2	71	CVF-P	97.6±9.8 ka	BB
bcb	Basalt of Cowboy Lake	86	CVF-C		BB, RC
bcc	Basalts of Cold Creek Butte	62	RSE		LY, MN
bcg	Basalt of Butte Creek Campground	89	ROC		PP
bci	Basalt of Indian Meadow	84	CVF-C		RC
bcp	Basalt of Caribou Peak	85	CVF-C		BB
bcr	Basalt of Butte Creek Ranch	90	ROC		SW
bcs	Basalt of South Caribou	83	CVF-C		RC
bct	Basalt of Cherry Thicket	56	RNW		VI
bcw	Basalt of Caribou Wilderness	85	CVF-C		BB
bdt	Basalt of Twin Buttes	70	CVF-D	46±3 ka	BB, PL, PP
beb1	Basalts of Bond Valley, unit 1	80	CVF-C		RC
beb2	Basalts of Bond Valley, unit 2	79	CVF-C		RC
beb3	Basalts of Bond Valley, unit 3	79	CVF-C		RC
bec	Tholeiitic basalt of Eagle Canyon	54	RNW	199±22 ka	GP, MZ, VI
bg1	Basalts of old railroad grade, unit 1	72	CVF-P		BB, PL
bg2	Basalts of old railroad grade, unit 2	71	CVF-P		PL
bg3	Basalts of old railroad grade, unit 3	71	CVF-P		PL, SW
bg4	Basalts of old railroad grade, unit 4	71	CVF-P	102.1±11.4 ka	PL
bgv	Tholeiitic basalt of Grays Valley	88	ROC		BB, PL
bhc	Hat Creek Basalt (tholeiitic)	48	RNW	24±6 ka	OS
bhr	Basaltic plug near Heckle Ranch	89	ROC		RC
bic	Tholeiitic basalt of Ice Cave Mountain	61	RSE		CM
bie	Basalt of East Lake	87	CVF-I	331±45 ka	MH, RC
bii	Basalt of Island Lake	87	CVF-I		MH
bk1	Tholeiitic basalts of Big Lake, unit 1	48	RNW		MZ, VI
bk2	Tholeiitic basalts of Big Lake, unit 2	48	RNW		MZ, TH, VI
bl2	Basalt of section 2	77	CVF-CL		BB
bl20	Basalt of hill 2088	77	CVF-CL		BB
bl21	Basalt of hill 2109	78	CVF-CL		BB, PP
bl22	Basalt of hill 2232	77	CVF-CL	220±14 ka	BB
bl30	Basalt of section 30	77	CVF-CL		BB
bl35	Basalt of section 35	77	CVF-CL	202.0±2.2 ka	BB
bmc	Tholeiitic basalts of Mill Creek Plateau	62	RSE		CM, MN
bn	Tholeiitic basalt of Nobles Trail	55	RNW		WP
bnt	Basalt of Bonte Peak	90	ROC		MH, RC
bo	Basalt of Onion Springs	56	RNW		LP, MZ
boc	Older basalts and basaltic andesites south of Caribou Volcanic Field	89	ROC	650±20 ka	BB, CH, MH, RC

Table 3. Alphabetical list of map unit names, labels, and ages—continued

Unit label	Unit name	Text page	CMU group*	Age of dated units	Quadrangle(s)
bp1	Basalts of Poison Butte, unit 1	72	CVF-P		PL
bp2	Basalts of Poison Butte, unit 2	72	CVF-P		PL
bp3	Basalts of Poison Butte, unit 3	72	CVF-P		PL
bp4	Basalts of Poison Butte, unit 4	72	CVF-P		PL
bp5	Basalts of Poison Butte, unit 5	72	CVF-P		PL
bp6	Basalts of Poison Butte, unit 6	72	CVF-P	105.0±6.0 ka	PL
bpa	Basalt of Panther Creek	64	RSE	1,105±49 ka	LY
bpc1	Basalts of Pine Creek, unit 1	74	CVF-P	106.2±3.6 ka	BB
bpc2	Basalts of Pine Creek, unit 2	74	CVF-P		BB
bpc3	Basalts of Pine Creek, unit 3	74	CVF-P		BB
br1	Basalts of Robbers Spring, unit 1	77	CVF-P		BB
br2	Basalts of Robbers Spring, unit 2	76	CVF-P	101.5±8.7 ka	BB, PL
br22	Basalt of hill 2283	67	CVF-R		BB, PP
br25	Basalt of section 25	68	CVF-R		PP
br80	Basalt of hill 8030	67	CVF-R		MH, RC
bra	Basalt of Ash Butte	67	CVF-R		PP
brc	Basalt of Red Cinder Cone	66	CVF-R		MH, PP
bre	Basalt east of Ash Butte	68	CVF-R		PP
brk	Tholeiitic basalt of Rock Creek	91	ROC	989±49 ka	CH, RC
brm	Basalt of Cameron Meadow	67	CVF-R		MH
brt1	Basalts of Triangle Lake, unit 1	69	CVF-R		BB
brt2	Basalts of Triangle Lake, unit 2	69	CVF-R		BB
brw	Basalt of Widow Lake	68	CVF-R		BB, PP
bs1	Basalts of Stephens Campground, unit 1	76	CVF-P		BB
bs2	Basalts of Stephens Campground, unit 2	76	CVF-P		BB
bs3	Basalts of Stephens Campground, unit 3	76	CVF-P		BB
bs4	Basalts of Stephens Campground, unit 4	76	CVF-P	110.8±3.8 ka	BB
bs5	Basalts of Stephens Campground, unit 5	75	CVF-P	108.6±2.1 ka	BB, PL
bs72	Basalt of hill 7243	86	CVF-S		PP
bsb	Basalt of Bathtub Lake	87	CVF-S		PP
bsd	Basalt of Duck Lake	86	CVF-S		PP
bsh	Basalts and basaltic andesites of Swains Hole	88	ROC		BB, PL, PP, SW
bsl	Basalt of Lost Spring	86	CVF-S	302±7 ka	PP
bsm	Basalts and basaltic andesites of Sifford Mountain	62	RSE	167±4 ka 172±23 ka	CM, MH, RP, ST
bss1	Basalts of Sunrise Peak, unit 1	87	CVF-S	393±4 ka	PP
bss2	Basalts of Sunrise Peak, unit 2	86	CVF-S		PP
bt1	Basalts of Pittville Road, unit 1	75	CVF-P	108±14 ka	PL
bt2	Basalts of Pittville Road, unit 2	75	CVF-P		BB, PL

Table 3. Alphabetical list of map unit names, labels, and ages—continued

Unit label	Unit name	Text page	CMU group*	Age of dated units	Quadrangle(s)
bt3	Basalts of Pittville Road, unit 3	75	CVF-P		BB
bt4	Basalts of Pittville Road, unit 4	75	CVF-P	101.0±1.9 ka	BB, PL
btb	Tholeiitic basalt of Twin Bridges	59	RNW		OS, WP
bwv	Tholeiitic basalt of Warner Valley	64	RSE	610±22 ka	CH, MH, ST
cc	Rhyodacite of Chaos Crags, Talus, emplaced hot from Domes B–F	25	LVC-E		MZ
d4	Deposits of 1914–1917 eruption of Lassen Peak, Dacite dome, May 14–19	20	LVC-TY	1915 C.E.	LP
d82	Dacite of hill 8283	33	LVC-B	261±5 ka	MZ, WP
d9	Deposits of 1914–1917 eruption of Lassen Peak, Dacite flow, May 19–20	19	LVC-TY	1915 C.E.	LP
db	Dacite of Bumpass Mountain	30	LVC-B	232±8 ka	LP, RP
dbc	Dacite of Bailey Creek	39	LVC-R		LP
dbl	Dacite of Bench Lake	39	LVC-R	679±14 ka	RP
dc	Dacite of Crescent Crater	31	LVC-B	236±1 ka	MZ, WP
dch	Dacite of Christie Hill	40	LVC-R		LP, MN
dcy	Dacite of Canyon Creek	40	LVC-R		LP, RP
dfr	Dacite of Flatiron Ridge	39	LVC-R	812±6 ka	MH, RP
dh	Dacite of Mount Helen	31	LVC-B	249±12 ka	LP, RP
dhm	Dacite of Huckleberry Mountain	60	RNW		TH, VI
dl	Dacite of Lassen Peak, Dome	27	LVC-E		LP, MZ, RP
dmm	Dacite of Morgan Mountain	40	LVC-R		LP, MN
dmz	Dacite of upper Manzanita Creek	33	LVC-B		MZ
dp	Dacite of Panther Creek	39	LVC-R	827±18 ka	RP
dpg	Dacite of Plantation Gulch	40	LVC-R		LP, MN
dpl	Dacite of Lassen Peak parking lot	32	LVC-B		LP
dr	Dacite of Reading Peak	30	LVC-B	212±5 ka	RP
drp	Dacite of Rocky Peak	39	LVC-R	803±27 ka	GP, LP
drr	Dacite of Red Rock Mountain	38	LVC-R	672±20 ka	GP, LP
ds	Dacite of Ski Heil Peak	31	LVC-B	244±10 ka	LP
dsc	Dacite of Summit Creek	32	LVC-B		RP
dt	Dacite of Twin Meadows	36	LVC-BV	470±10 ka	LP, RP
duh	Dacite under Mount Helen	32	LVC-B		RP
dv	Dacite of Vulcans Castle	33	LVC-B		LP
f9	Deposits of 1914–1917 eruption of Lassen Peak, Flood deposits, May 19–20	20	LVC-TY	1915 C.E.	WP
h	Hydrothermally altered rocks in active thermal areas	16	G		LP, RP
ht	Travertine	16	G		LP
m20	Basaltic andesite west of hill 2078	75	CVF-P		BB
mb	Basaltic andesite of Black Cinder Rock	90	ROC	667±24 ka	MH, RC
mbc	Basaltic andesites of South Fork Battle Creek	65	RSE	1,738±46 ka	LY
mbg	Basaltic andesite of Little Bunchgrass Meadow	53	RNW	143±6 ka	WP

Table 3. Alphabetical list of map unit names, labels, and ages—continued

Unit label	Unit name	Text page	CMU group*	Age of dated units	Quadrangle(s)
mbx	Basaltic andesite of Box Canyon	53	RNW		WP
mc1	Basaltic andesites of Silver Lake, unit 1	85	CVF-C		RC
mc2	Basaltic andesites of Silver Lake, unit 2	85	CVF-C		RC
mc3	Basaltic andesites of Silver Lake, unit 3	85	CVF-C		RC
mc4	Basaltic andesites of Silver Lake, unit 4	85	CVF-C		BB
mc5	Basaltic andesites of Silver Lake, unit 5	85	CVF-C		RC
mc6	Basaltic andesites of Silver Lake, unit 6	85	CVF-C		RC
mc7	Basaltic andesites of Silver Lake, unit 7	84	CVF-C		RC
mc8	Basaltic andesites of Silver Lake, unit 8	84	CVF-C	400±14 ka	BB, RC
mc9	Basaltic andesites of Silver Lake, unit 9	84	CVF-C		BB, RC
mc10	Basaltic andesites of Silver Lake, unit 10	84	CVF-C		RC
mc11	Basaltic andesites of Silver Lake, unit 11	84	CVF-C		RC
mc71	Basaltic andesite of hill 7114	83	CVF-C		RC
mce	Basaltic andesite of Eleanor Lake	80	CVF-C		BB
mcf	Basaltic andesites of Camp Forward	61	RNW		GP
mch	Basaltic andesite of Hay Meadow	83	CVF-C		RC
mcj	Basaltic andesite of Jewel Lake	81	CVF-C		BB, RC
mcm	Basaltic andesite of middle Caribou	83	CVF-C	362±33 ka	RC
mcn1	Basaltic andesites of North Caribou, unit 1	82	CVF-C		RC
mcn2	Basaltic andesites of North Caribou, unit 2	82	CVF-C		RC
mcn3	Basaltic andesites of North Caribou, unit 3	82	CVF-C		RC
mcn4	Basaltic andesites of North Caribou, unit 4	82	CVF-C		RC
mcn5	Basaltic andesites of North Caribou, unit 5	82	CVF-C		RC
mcn6	Basaltic andesites of North Caribou, unit 6	82	CVF-C		RC
mcn7	Basaltic andesites of North Caribou, unit 7	82	CVF-C		RC
mcn8	Basaltic andesites of North Caribou, unit 8	81	CVF-C		RC
mcr	Basaltic andesite of Rim Lake	81	CVF-C		RC
md36	Basaltic andesite of section 36	70	CVF-D		BB, PP
mdb1	Basaltic andesites of Black Butte, unit 1	70	CVF-D		BB, PP
mdb2	Basaltic andesites of Black Butte, unit 2	70	CVF-D		BB
mdp	Basaltic andesite of Pole Spring Road	70	CVF-D		PP
mee1	Basaltic andesites of Echo Lake, unit 1	80	CVF-C	302±36 ka	RC
mee2	Basaltic andesites of Echo Lake, unit 2	80	CVF-C		RC
meh	Basaltic andesite of Eskimo Hill	49	RNW		MZ
mes	Basaltic andesite of Star Butte	80	CVF-C		RC
mf1	Basaltic andesites of Cinder Cone, Fantastic Lava Beds, Flow 1	21	LVC-TY	1666 C.E.	PP
mf2	Basaltic andesites of Cinder Cone, Fantastic Lava Beds, Flow 2	21	LVC-TY	1666 C.E.	PP
mfp	Basaltic andesite of Fairfield Peak	23	LVC-TY	82±14 ka	PP
mgp	Basaltic andesite of Grays Peak	64	RSE	1,080±26 ka	GP, LY

Table 3. Alphabetical list of map unit names, labels, and ages—continued

Unit label	Unit name	Text page	CMU group*	Age of dated units	Quadrangle(s)
mhl	Basaltic andesite of Huckleberry Lake	64	RSE		LP, MN
mhr	Basaltic andesite of Hootman Ranch	56	RNW	562±12 ka	GP, VI
mj	Basaltic andesite of Jakey Lake	89	ROC		MH
ml18	Basaltic andesite of hill 1868	78	CVF-CL		BB, PL
mlc	Basaltic andesites of Cone Lake	78	CVF-CL		BB
mm	Basaltic andesites of Magee Volcano	54	RNW	210±120 ka	TH
mo	Basaltic andesites of Cinder Cone, Old Bench flow	22	LVC-TY	1666 C.E.	PP
mp1	Basaltic andesites of Cinder Cone, Painted Dunes, Flow 1	22	LVC-TY	1666 C.E.	PP
mp2	Basaltic andesites of Cinder Cone, Painted Dunes, Flow 2	21	LVC-TY	1666 C.E.	PP
mr	Basaltic andesite of Rock Spring	58	RNW		GP
mrb	Basaltic andesite of Caribou Wilderness	69	CVF-R		BB
mrc	Basaltic andesite of Red Cinder Cone	66	CVF-R		MH, PP
mrd	Basaltic andesite and andesite of Red Lake Mountain	49	RNW		MZ, VI
mrg1	Basaltic andesites of Long Lake, unit 1	69	CVF-R		RC
mrg2	Basaltic andesites of Long Lake, unit 2	69	CVF-R		MH, RC
mrg3	Basaltic andesites of Long Lake, unit 3	68	CVF-R		MH, RC
mrm	Basaltic andesite of Red Mountain	49	RNW		MZ
mrr	Basaltic andesite of Red Cinder	67	CVF-R		BB, MH, PP, RC
ms47	Basaltic andesite of hill 4709	52	RNW-S		OS
msg	Basaltic andesite of Signal Butte	59	RNW		OS, SW
msl	Basaltic andesite of Little Potato Butte	52	RNW-S	67±4 ka	OS
msm	Basaltic andesite of Small Butte	63	RSE		CM, RP
msn	Basaltic andesites and basalt of Snag Lake	90	ROC		MH, PP
msw	Basaltic andesites of Swain Mountain	91	ROC	1,570±35 ka	RC
mt20	Basaltic andesites of section 20	79	CVF-C		BB
mt5	Basaltic andesite of section 5	51	RNW-T		TH
mt54	Basaltic andesite of hill 5410	50	RNW-T		TH
mt61	Basaltic andesite of hill 6138	51	RNW-T		TH
mt67	Basaltic andesite of hill 6770	50	RNW-T		TH
mtb	Basaltic andesite of Bear Wallow Butte	51	RNW-T		TH
mte	Basaltic andesites of Evelyn Lake	66	CVF-T		RC
mtm	Basaltic andesite of Mud Lake	51	RNW-T		TH
mtr	Basaltic andesite of Triangle Lake	79	CVF-C	277±22 ka	BB
mtt	Basaltic andesite of Turnaround Lake	66	CVF-T		BB, RC
mtu	Basaltic andesite of Tumble Buttes	50	RNW-T		TH
p17	Deposits of 1914–1917 eruption of Lassen Peak, Phreatic deposit, May–June	19	LVC-TY	1917 C.E.	LP
p2	Deposits of 1914–1917 eruption of Lassen Peak, Pumice-fall deposit, May 22	19	LVC-TY	1915 C.E.	LP, RP, WP
p9	Deposits of 1914–1917 eruption of Lassen Peak, Pyroclastic deposit, May 19	20	LVC-TY	1915 C.E.	LP
pc	Rhyodacite of Chaos Crags, Pumiceous pyroclastic-flow and fall deposits	26	LVC-E	1,103±13 yr B.P	MZ, OS, VI, WP

Table 3. Alphabetical list of map unit names, labels, and ages—continued

Unit label	Unit name	Text page	CMU group*	Age of dated units	Quadrangle(s)
pcd	Rhyodacite of Chaos Crags, Lithic pyroclastic-flow deposit from partial collapse of dome D	26	LVC-E		MZ
pce	Rhyodacite of Chaos Crags, Lithic pyroclastic-flow deposit from partial collapse of dome E	25	LVC-E		MZ, WP
pdh	Lithic tephra from Deep Hole	55	RNW		MZ
pe	Rhyodacite of Eagle Peak, Pumiceous pyroclastic-flow deposits	29	LVC-E		GP, LP, MZ
pfl	Dacite of Lassen Peak, Lithic pyroclastic-flow deposit from partial collapse of dome	27	LVC-E	27±1 ka	WP
pk	Rhyodacite of Kings Creek, Pumiceous pyroclastic-flow deposits	28	LVC-E	35±1 ka	LP, RP, WP
pr	Rockland tephra	38	LVC-R	609±7 ka	GP, LY, VI
psf	Rhyodacite of Sunflower Flat, Pumiceous pyroclastic-flow deposits	28	LVC-E	41±1 ka	MZ
pw2	Deposits of 1914–1917 eruption of Lassen Peak, Pyroclastic-flow and associated fluid debris-flow deposits, May 22	19	LVC-TY	1915 C.E.	LP, MZ, OS, RP, WP
Qc	Colluvium and talus	14	G		BB, CH, LP, LY, MH, MN, MZ, OS, PL, PP, RC, RP, ST, SW, WP
Qcl	Talus on Lassen Peak	14	G		LP, MZ, RP
Qd	Diatomite	18	G		PP
Qf	Alluvium	14	G		BB, CH, CM, GP, LP, MH, MN, MZ, OS, PL, PP, RC, RP, ST, SW, TH, VI, WP
Qoa	Outwash gravel of Anklin Meadows	18	G		MZ, OS, WP
Qoo	Outwash gravel, older glaciations	18	G		CM, MN
Qor	Outwash gravel of Raker Peak	18	G		MZ, OS, WP
Qou	Outwash gravel, undivided	18	G		GP, LY, MN, PP, SW, VI
Qoy	Outwash gravel, younger glaciations	17	G		BB, CH, CM, LP, MH, MN, MZ, OS, PP, RC, RP, ST, TH, VI, WP
Qs82	Avalanche deposit from dacite of hill 8283	15	G		MZ, VI
Qsh	Landslide deposits in hydrothermally altered core of Brokeoff Volcano	14	G	3,310±55 yr B.P.	LP, RP
Qsj	Avalanche deposits of Chaos Jumbles	15	G	278±28 yr B.P.	MZ
Qsl	Avalanche debris from Lassen Peak spread across glacial ice	15	G		WP
Qta	Till of Anklin Meadows	17	G		GP, LP, MZ, RP, WP
Qtal	Late till of Anklin Meadows	16	G		LP, MZ, RP, WP
Qtb	Till of Badger Mountain	17	G		MZ, WP
Qth	Till or protalus-rampart debris	16	G		RP
Qto	Till, older glaciations	17	G		BB, CH, CM, GP, LP, LY, MH, MN, MZ, PP, RC, RP, ST, VI
Qtr	Till of Raker Peak	17	G		GP, MZ, WP
Qtrl	Post-maximum till of Raker Peak consisting of Lassen Peak avalanche debris	17	G		WP

Table 3. Alphabetical list of map unit names, labels, and ages—continued

Unit label	Unit name	Text page	CMU group*	Age of dated units	Quadrangle(s)
Qty	Till, younger glaciations	16	G		BB, CH, CM, LP, MH, MZ, PP, RC, RP, ST, TH, VI, WP
Qwb	Debris-flow deposit from Brokeoff Volcano	15	G		GP
Qwh	Debris-flow deposits from the northeast side of Lassen Peak	15	G	~8,000 yrs B.P.	LP, MZ, RP, WP
r27	Rhyodacite of section 27	29	LVC-E		MZ, WP
rb	Rhyolite of Blue Ridge	41	MVC	1,150±70 ka 1,240±110 ka	GP, LY
rca	Rhyodacite of Chaos Crags, Dome A	27	LVC-E	1,103±13 yr B.P.	MZ
rcb	Rhyodacite of Chaos Crags, Dome B	26	LVC-E		MZ
rcc	Rhyodacite of Chaos Crags, Dome C	26	LVC-E		MZ
rcd	Rhyodacite of Chaos Crags, Dome D	26	LVC-E		MZ
rce	Rhyodacite of Chaos Crags, Dome E	26	LVC-E		MZ
rcf	Rhyodacite of Chaos Crags, Dome F	25	LVC-E		MZ
rd	Rhyodacite of Dersch Meadows	30	LVC-B	193±11 ka	RP, WP
rd3	Rhyolites of Dittmar Volcanic Center, Stage 3	44	DVC	1,273±7 ka	MH, RP
re	Rhyodacite of Eagle Peak, Dome and flow	29	LVC-E	66±4 ka	LP
rg	Rhyodacite of Gurnsey Creek	42	MVC		CM, LP
rk	Rhyodacite of Kings Creek, Flows	28	LVC-E		LP, RP
rkr	Rhyodacite of Krummholz	29	LVC-E	43±2 ka	MZ, WP
rlm	Rhyodacite of Loomis Peak	34	LVC-B		LP, MZ
rlp	Rhyolite of Lost Creek Plateau	41	MVC	1,305±10 ka	CM
rmc	Rhyodacite of Mount Conard	34	LVC-B	298±9 ka	LP, RP
rmp	Rhyolite of Mill Creek Plateau	41	MVC		CM, LP, MN
rmz	Rhyodacite of Manzanita Chute	33	LVC-B	297±1 ka	LP, MZ
rr	Rhyolite of Raker Peak	38	LVC-R	588±69 ka	WP
rsf	Rhyodacite of Sunflower Flat, Domes	28	LVC-E		MZ, WP
rsm	Rhyolite of North Stover Mountain	41	MVC		CM, ST
sw9	Deposits of 1914–1917 eruption of Lassen Peak, Avalanche and debris-flow deposits, May 19–20	20	LVC-TY	1915 C.E.	WP
Tab	Andesite of South Fork Battle Creek	43	MVC	2,166±67 ka	GP, LY
Tac	Andesite of Cal Mountain	92	ROC	2,345±49 ka	PL
Tad	Andesites of Dittmar Volcanic Center, Stage 1, undivided	46	DVC	1,650±35 ka 1,785±35 ka 2,315±29 ka	MH, PP, RP, ST
Tah	Andesites of Hampton Butte	42	MVC		GP, LY

Table 3. Alphabetical list of map unit names, labels, and ages—continued

Unit label	Unit name	Text page	CMU group*	Age of dated units	Quadrangle(s)
Tam	Andesites of Maidu Volcanic Center, Stage 1, undivided	43	MVC	1,905±42 ka 2,045±42 ka 2,152±47 ka 2,250±49 ka 2,325±49 ka 2,375±49 ka	LP, LY, MN
Taw	Andesites of Wild Cattle Mountain	46	DVC		CM, LP, MN, RP
Tbm	Basalts and basaltic andesites of Mud Creek Rim	91	ROC	2,200±49 ka 2,307±32 ka 2,455±49 ka 2,785±16 ka	CH, RC
Tdb	Dacite of Bogard Buttes	92	ROC	2,225±49 ka 2,350±70 ka	BB
Tdm	Dacites of Maidu Volcanic Center, Stage 2, undivided	42	MVC	2,105±25 ka 2,120±46 ka 2,140±42 ka 2,259±46 ka	GP, LY, MN
Tlv	Rocks of Latour Volcanic Center	47	LtVC	3,140±67 ka	VI
Tmc	Basaltic andesite of Cone Mountain	92	ROC	2,575±57 ka	PL
Tml	Basaltic andesite of Lassen Lodge	44	MVC		LY
Tmsr	Basaltic andesites of Susan River	92	ROC		BB
Tt	Tuscan Formation	47	TF		LY
w2	Deposits of 1914–1917 eruption of Lassen Peak, viscous debris-flow deposits, May 22	19	LVC-TY	1915 C.E.	LP, MZ, RP, WP