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Geologic Map of the Lassen Peak, Chaos Crags, and Upper Hat Creek Area, California

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INTRODUCTION

The Lassen Peak, Chaos Crags, and upper Hat Creek map area lies near the southern end of the Cascade Range in northern California (fig. 1, see map). The map area includes parts of the three elements that together form the Lassen volcanic center (Clynne, 1990): the Lassen dacitic dome field, the Central Plateau andesitic lava field, and the underlying deeply eroded and partly altered Brokeoff andesitic stratocone (fig. 2, see map). The Lassen volcanic center is the southernmost active long-lived center of the present-day Cascades volcanic arc. Additionally, andesitic, mafic-andesitic, and basaltic lavas have extruded through regionally distributed monogenetic vents and short-lived shield volcanoes at the edges of the map area. Figure 2 also shows the local setting and the names of localities and other features referred to in the Description of Map Units.

This geologic map contributes to understanding the youngest major volcanic events in the evolution of the Lassen dacitic dome field and provides the basis for a revised assessment of its volcano hazards by emphasizing the youngest eruptive products of the dome field. Although specific interpretation of these youngest events and eruptive products will be undertaken in separate publications, the most significant events are briefly noted here. The most recent eruptive activity, mainly steam-blast eruptions, occurred intermittently between May, 1914, and June, 1917, and climaxed during a week of magmatic eruptions in May, 1915. A separate large-scale geologic map of the Lassen Peak summit area emphasizes some features of the May, 1915 activity. The next youngest eruptions, about 1,100-1,000 years ago, formed the six Chaos Crags volcanic domes (fig. 2) and related pyroclastic deposits; a rapid sequence of major slope failures on the northernmost of these domes about 300 years ago produced a large avalanche deposit known as Chaos Jumbles. The map also shows other, older dacite to rhyolite domes and flows of the Lassen dome field (including Lassen Peak, the largest dome) as well as some mainly andesitic lavas of Central Plateau, Brokeoff, and regional provenance. Also shown are various surficial sedimentary deposits, including moraines and till sheets representing three glaciations of late Pleistocene age, laid down contemporaneously with much of the volcanic activity.

All the dacites in the Lassen dome field belong to a single suite of lavas that formed through a continuum of magma-mixing processes, resulting in the varied appearance and composition of many individual rock units. Thus, lavas with distinct compositions may be quite similar in appearance while different occurrences of the same eruptive unit may appear quite different. Lassen dacitic magmas evolved by the introduction of mafic magma into a silicic reservoir containing felsic phenocrysts. The fundamental variables controlling the character of the erupted magma were relative proportions of mafic and silicic components in the resulting mixtures and the length of time between a mixing event and subsequent eruption. Mixing of hot mafic magma and its phenocrysts with cool host dacitic magma and its phenocrysts caused partial resorption of the host dacitic phenocrysts, quenching of the mixed magma to form undercooled inclusions, and circulation and disaggregation of inclusions back into the host dacitic magma (Clynne, 1999). These processes sometimes created multiple generations of disequilibrium phenocryst assemblages. Because phenocryst abundance, character, and assemblage can vary within individual dacite domes, intradome variation can be greater than some interdome variation.

The following unit descriptions, intended mainly to facilitate use of this map in the field, are based mainly on megascopic criteria. Typically the unit descriptions do not include details of subtle variations in the appearance of the rocks. For example, most Lassen dacites have two populations of dacitic phenocrysts—one normal and a second partly resorbed—but it is usually difficult to distinguish resorbed phenocrysts in hand specimen. The abundance, distribution, and character of undercooled mafic-magma inclusions (called simply "mafic inclusions" below), though commonly varied within individual dacites, can sometimes be used to distinguish units.

Common mineral names are used in the descriptions even though they may not always be compositionally accurate. For example, many orthopyroxenes may actually be bronzite rather than hypersthene; the name hornblende is used for all calcic amphiboles. Mineral rock-name modifiers are given in order of increasing abundance. Phenocryst abundances are estimated, based on the most common lithology or range of lithologies in a unit; "sparse" means less than 1%, and "trace" means much less than 1%. Oxide minerals, primarily titanomagnetite, ubiquitous but generally sparse, are not included in the descriptions.

All units shown on the geologic map are of Quaternary age. All ^{14}C ages referred to in the text are given as reported by the analyst in radiocarbon years BP (relative to 1950), not corrected to calendar years. Symbols in parentheses on the map indicate units buried beneath the unit identified by the color and pattern. The initial letter of each map symbol indicates the dominant lithology of the unit, as follows:

Volcanic units:
- b, basalt (<53% SiO_2); all basalts in the map area are diktytaxitic low-K_2O types designated as tholeiitic
- m, mafic andesite (<57% SiO_2)
- a, andesite (<63% SiO_2)
- d, dacite (<68% SiO_2)
- r, rhyodacite (<72% SiO_2) and rhyolite (72% SiO_2)
- p, pyroclastic deposits (pf, pyroclastic-flow deposits)

Sedimentary units:
- c, colluvium, including talus
- f, fluvial deposits, including most alluvium

l, lacustrine deposits
o, glacial outwash deposits
s, landslide and avalanche deposits
t, till
w, mudflow and other debris-flow deposits

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DESCRIPTION OF MAP UNITS

HOLOCENE

p17 **Pyroclastic deposit of May and June, 1917, from Lassen Peak**—Generally poorly sorted partly indurated thin to thick beds of lithic ash, lapilli, and blocks. Matrix generally very fine, indurated, and pale yellowish-brown. Consists mainly of dacite of Lassen Peak (unit dlp). Thins abruptly from several meters on the crater rim to a few centimeters at the mapped edge of the deposit. Ejected in steam-blast eruptions from a crater in the northwestern part of the Lassen Peak summit area, mainly during May, 1917. Best displayed on the summit-area geologic map

wv22 **Viscous debris-flow deposits of May 22, 1915, from Lassen Peak**—Largely nonsorted unconsolidated nonbedded deposits containing lapilli and blocks, the largest of which are greater than 1 m across, in a sandy to silty matrix. Contain conspicuous clasts of banded pumice of the May 22 eruption (unit p22) in addition to dacite of May 19 (unit d19), dacite of May 14 (unit d14), and dacite of Lassen Peak (unit dlp). Recognized mainly by generally lobate form with scarp-like margins as much as 2 m high; thickness ranges from a few decimeters to about 3 m. Formed by debris flows onto all sides from the steep upper slopes of Lassen Peak after the major pumice eruption of May 22, 1915

p22 **Pumice-fall deposit of May 22, 1915, from Lassen Peak**—65-68% SiO_2. 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. Bedding generally indistinct. Pumice blocks typically banded between dark-gray andesite and light-gray to nearly white dacite; lapilli and coarse ash commonly yellowish-brown with faint banding. Thickness where deposit is distinguished on the map generally exceeds 2 m. Mapped only on the northeast and east side of Lassen Peak; not mapped separately where preserved only in small patches or where thickness is less than a few decimeters

wf22 **Fluid debris-flow deposits of May 22, 1915, from pyroclastic flow**—Largely nonsorted unconsolidated nonbedded deposits containing lapilli and blocks of dacite flow of May 19-20 (unit d19), dacite dome of May 14-19 (unit d14), and dacite of Lassen Peak (unit dlp) as large as 3 m across in a sandy to silty matrix. Also contain conspicuous banded pumice of the May 22 eruption (unit p22) but less abundantly than in the viscous debris-flow deposits of May 22, 1915 (unit wv22). Individual, apparently rootless, small flows emerge from the pyroclastic-flow deposit of May 22 (unit pf22) and merge downslope into a generally sheetlike deposit as thick as 2-3 m, tapering to imperceptibility at the margins. Occur in the Devastated Area (fig. 2) on the northeast side of Lassen Peak and in the drainages of Lost Creek and Hat Creek

pf22 **Pyroclastic-flow deposit of May 22, 1915, from Lassen Peak**—Largely nonsorted unconsolidated nonbedded deposit containing lapilli and blocks of dacite of May 19 (unit d19), dacite of May 14 (unit d14), and dacite of Lassen Peak (unit dlp) as large as 3 m diameter in a sandy to silty matrix. Also contains conspicuous banded pumice of the May 22 eruption (unit p22) and abundant fragments of wood, some of it charred. Ranges in thickness from a feather edge to at least 3 m. Occurs in the Devastated Area on the northeast side of Lassen Peak and grades into fluid debris-flow deposits of May 22 (unit wf22), as noted in description of that unit. The original margins of this deposit

largely coincide with the edge of the trees that were left standing after the eruption of May 22 (magenta dash-dot line on the map)

d19 **Dacite flow of May 19-20, 1915, on Lassen Peak**—64-65% SiO_2. Porphyritic biotite-hornblende dacite with uneroded rough block-lava flow surface having 5-10 m of relief. Groundmass dark-gray to black and typically glassy. Phenocrysts: 20% plagioclase 3-5 mm across, but conspicuous composite crystals as large as 12 mm; 3% hornblende 1-5 mm across, rarely as large as 12 mm; 3% biotite 1-3 mm across; 2% quartz generally 1-3 mm across, rarely as large as 6 mm; trace of ~0.75-mm olivine. Abundant microphenocrysts of augite and hypersthene as much as 0.5 mm across. Plagioclase, biotite, hornblende, and quartz commonly partly resorbed. Mafic inclusions range in size from a few centimeters to about 50 cm, form about 5% of the rock, and contain partly resorbed host-rock phenocrysts (conspicuously, pyroxene-rimmed quartz) and 0.75-mm olivine. Most inclusions have pyroxene and plagioclase microlites containing interstitial glass, are microvesicular, and lack crenulate margins; inclusions that have crenulate margins and lack partly resorbed host-rock phenocrysts are rare. Erupted from vent at the summit of Lassen Peak and flowed about 300 m down the western and northeastern flanks; the northeast lobe was swept away in the eruption of May 22 and incorporated into pyroclastic-flow and fluid debris-flow deposits of May 22 (units pf22 and wf22). Best displayed on the summit-area geologic map

f19 **Flood deposits of May 19-20, 1915, in Hat Creek**—Sorted to nonsorted unconsolidated generally nonbedded sand to boulders and other debris in Hat Creek downstream from the bedrock gorge just north of the Lassen Volcanic National Park Boundary. Scored by numerous braided stream channels, most of them abandoned. The amount of sediment decreases progressively downstream, but the affected area remains complexly scoured and marked by chaotic jams of boulders, logs, and other debris

w19 **Debris-flow deposits of May 19-20, 1915, from avalanche deposit**—Nonsorted unconsolidated generally nonbedded sand to boulders as large as 3 m diameter. Consist almost entirely of dacite of Lassen Peak (unit dlp), dacite dome of May 14-19 (unit d14), and some logs derived from the underlying avalanche deposit of May 19 (unit s19). Deposits occur in the Devastated Area on the northeast side of Lassen Peak (fig. 2), in Lost Creek, and eastward across a low divide into the drainage of Hat Creek. Deposits commonly rooted within the avalanche deposit of May 19 (unit s19); near the margins, numerous standing trees predating the deposits are scarred from collisions with boulders and logs carried in the debris flows

s19 **Avalanche deposit of May 19, 1915, from Lassen Peak**—Nonsorted unconsolidated nonbedded debris consisting of dacite dome of Lassen Peak (unit dlp), dacite dome of May 14-19 (unit d14), pumice of Chaos Crags (unit pc), and much wood debris, including numerous decayed logs lying in positions pointing downslope, away from the summit of Lassen Peak. Generally lies on soil developed in underlying deposits, including pumice of Chaos Crags. Deposited from a mixed snow and debris avalanche originating in cirque at top of northeast face of Lassen Peak. Deposits occur in the Devastated Area on the northeast side of Lassen Peak (fig. 2) and eastward across a low divide into the drainage of Hat Creek. The margins of the avalanche (cyan dash-dot line on the geologic map) were marked by the trees left standing before the eruption of May 22 and recorded in photographs taken on that day before the eruption

p19 **Pyroclastic deposit of May 19, 1915, on Lassen Peak**—Nonsorted unconsolidated nonbedded deposit of blocks to fine lithic ash, consisting entirely of dacite dome of May 14-19 (unit d14) and dacite of Lassen Peak (unit dlp). Ranges in character from a deposit about 4 m thick to a field of discontinuous blocks. Ejected explosively during opening of a summit crater through the dacite dome of May 14-19 and preserved only in summit area of Lassen Peak. Best displayed on the summit-area geologic map

d14 **Dacite dome of May 14-19, 1915, on Lassen Peak**—64-65% SiO_2. Remnants of a small dacite dome of porphyritic biotite-hornblende dacite. Groundmass dark-gray to black and typically glassy. Phenocrysts: 20% plagioclase 3-5 mm across, but conspicuous composite crystals as large as 12 mm; 3% hornblende 1-5 mm across, rarely as large as 12 mm; 3% biotite 1-3 mm across; 2% quartz 1-3 mm across, rarely as large as 6 mm; trace of ~0.75-mm olivine. Abundant

microphenocrysts of augite and hypersthene to 0.5 mm. Partly resorbed plagioclase, biotite, hornblende, and quartz commonly are more abundant than in the slightly younger lava flow (unit d19). Mafic inclusions from a few millimeters to about 50 cm across form about 5% of the rock and contain partly resorbed host-rock phenocrysts (conspicuously, pyroxene-rimmed quartz) and ~0.75-mm olivine. Most inclusions have coarse-grained pyroxene and plagioclase microlites and interstitial glass, are microvesicular, and lack crenulate margins; inclusions having crenulate margins and lacking resorbed host-rock phenocrysts are rare; millimeter- to centimeter-sized inclusions more abundant in the lava dome than in the lava flow (unit d19). The dome, emplaced between about May 14, 1915 and the night of May 19-20, 1915, filled a crater in the summit area of Lassen Peak that had been excavated by earlier steam-blast explosions; the dome was disrupted by a single large explosion on the evening of May 19-20, 1915, to form the slightly younger pyroclastic deposit (unit p19). Remnants of this dome, confined to the summit area of Lassen Peak, are best shown on the summit-area geologic map

scj **Avalanche deposits of Chaos Jumbles, from dome C of Chaos Crags**—Nonsorted unconsolidated nonbedded coarse to fine rubble containing blocks as large as 5 m across. Consists almost entirely of pink oxidized blocks of rhyodacite dome C of Chaos Crags (unit rcc); also contains rare gray prismatically jointed blocks from dome C as well as andesite from Brokeoff volcano (unit abk). Deposit is lobate, has run up onto adjacent topographic highs, and has transverse and longitudinal debris ridges on its surface and scarp-like margins generally 1-5 m high. Formed by catastrophic collapse of dome C of Chaos Crags (unit rcc). Trees drowned by Manzanita Lake, which formed as this avalanche dammed Manzanita Creek, dated as 275±25 ^{14}C years (Clynne and Muffler, 1989)

rcf **Rhyodacite dome F of Chaos Crags**—68% SiO_2. Porphyritic hornblende-biotite rhyodacite; one of 6 lava domes emplaced sequentially (units rca through rcf) that are lithologically nearly identical. Generally dense rhyodacite ranges from white or light-gray and glassy to light- to medium-gray and devitrified. Phenocrysts: 25% plagioclase 2-5 mm across (composite crystals as large as 1 cm); 4% biotite 1-3 mm across (rarely larger); 4% hornblende 2-5 mm across (less commonly as large as 15 mm); 2% quartz 2-5 mm across. Quartz is conspicuous and more abundant than in any other rocks of the Lassen volcanic center except dacite of Lassen Peak (unit dlp); pyroxene-rimmed quartz phenocrysts are particularly conspicuous. Abundances of partly resorbed phenocrysts, millimeter- to centimeter-sized fragments of mafic inclusions, and larger mafic inclusions are much more abundant in the upper four domes (units rcc through rcf) than in the lower domes (units rca and rcb) or the pyroclastic deposits (unit pc). Contains sparse olivine and calcic-plagioclase xenocrysts derived from disaggregated mafic inclusions. Textures of mafic inclusions vary from porphyritic to sparsely phyric; porphyritic inclusions contain phenocrysts inherited from their rhyodacite host, and sparsely phyric inclusions generally contain olivine and calcic-plagioclase phenocrysts 1-2 mm long inherited from their mafic parent. A few are multiple-generation mafic inclusions (inclusions that contain inclusions). Most common inclusions have hornblende-plagioclase groundmasses; others have pyroxene± hornblende-plagioclase groundmasses. Mafic inclusions abundant (to 10% of the rocks) in domes C-F (units rcc-rcf); commonly as large as 20 to 50 cm across, less commonly to 1 m across

ccf **Talus, emplaced hot from dome F of Chaos Crags**—Laterally sorted nonbedded blocks of rhyodacite from dome F of Chaos Crags (unit rcf). Largest blocks, as large as 4 m, are prismatically jointed and commonly disintegrated in place after deposition. Formed by hot rockfalls from dome F during its emplacement

sce **Avalanche deposit from partial collapse of dome E of Chaos Crags**—Nonsorted unconsolidated nonbedded deposit consisting of fine granular matrix to blocks as large as about 2 m, some of them prismatically jointed, consisting entirely of rhyodacite from dome E of Chaos Crags (unit rce); emplaced hot. Many large blocks internally fractured. Formed by partial collapse of dome E of Chaos Crags before emplacement of dome F in the resulting avalanche scar

rce **Rhyodacite dome E of Chaos Crags**—68% SiO_2. Porphyritic hornblende-biotite rhyodacite. Lithologically nearly identical to rhyodacite

dome F (see description of unit rcf) but morphologically distinct; dome F partly fills the scar left by partial collapse of dome E to produce a hot avalanche deposit (unit sce)

cce **Talus, emplaced hot from dome E of Chaos Crags**—Laterally sorted nonbedded blocks of rhyodacite from dome E of Chaos Crags (unit rce). Largest blocks, as large as 4 m across, are prismatically jointed and commonly disintegrated in place after deposition. Formed by hot rockfalls from dome E during its emplacement

scd **Avalanche deposit from partial collapse of dome D of Chaos Crags**—Nonsorted unconsolidated nonbedded deposit consisting of fine granular matrix to blocks as large as about 2 m across, some of them prismatically jointed, consisting mainly of rhyodacite from dome D of Chaos Crags (unit rcd) but containing some pumiceous blocks from dome B (unit rcb). Many large blocks internally fractured. Formed by partial collapse of dome D of Chaos Crags

rcd **Rhyodacite dome D of Chaos Crags**—68% SiO_2. Porphyritic hornblende-biotite rhyodacite. Lithologically nearly identical to rhyodacite dome F (see description of unit rcf)

ccd **Talus, emplaced hot from dome D of Chaos Crags**—Laterally sorted nonbedded blocks of rhyodacite from dome D of Chaos Crags (unit rcd). Largest blocks, as much as 4 m across, are prismatically jointed and commonly disintegrated in place after deposition. Formed by hot rockfalls from dome D during its emplacement

rcc **Rhyodacite dome C of Chaos Crags**—68% SiO_2. Porphyritic hornblende-biotite rhyodacite. Lithologically indistinguishable from rhyodacite dome F (see description of unit rcf). A small area designated as rcc(?) between domes D and E (units rcd and rce) appears to preserve a short segment of an otherwise buried crater rim and dome flank that predate the adjacent domes and is inferred to be part of dome C

ccc **Talus, emplaced hot from dome C of Chaos Crags**—Laterally sorted nonbedded blocks of rhyodacite from dome C of Chaos Crags (rcc). Largest blocks, as much as 4 m across, are prismatically jointed and commonly disintegrated in place after deposition. Formed by hot rockfalls from dome C during its emplacement

rcb **Rhyodacite dome B of Chaos Crags**—70% SiO_2. Porphyritic hornblende-biotite rhyodacite. Lithologically similar to rhyodacite dome F (see description of unit rcf), except as follows: weakly pumiceous; mafic inclusions generally less abundant (generally < 1%) and smaller (10-20 cm across) than in domes C through F

ccb **Talus, emplaced hot from dome B of Chaos Crags**—Laterally sorted nonbedded blocks of rhyodacite from dome B of Chaos Crags (unit rcb). Largest blocks, as much as 4 m across, are prismatically jointed and commonly disintegrated in place after deposition. Formed by hot rockfalls from dome B during its emplacement

rca **Rhyodacite dome A of Chaos Crags**—70% SiO_2. Porphyritic hornblende-biotite rhyodacite. Lithologically indistinguishable from rhyodacite dome B (see description of unit rcb). This small dome is partly mantled by pyroclastic deposits (unit pc) and largely buried by dome B

pc **Pumiceous pyroclastic-flow and fall deposits of Chaos Crags**—Several individually recognized units can be distinguished in stratigraphic sections but cannot be shown separately at the scale of the geologic map. Petrographically the pumice of this unit resembles the dacite of domes A and B (units rca and rcb); present in addition to the predominant pumice are dense glassy blocks and lapilli of rhyodacite that lithologically resemble domes A and B, as well as sparse accidental lithic inclusions. Fall deposits of generally well-sorted unconsolidated medium- to thin-bedded nearly white rhyodacitic pumice typically mantle the surface and are locally reworked as colluvium. Deposits range from near-source blocks as large as about 1 m to distal small lapilli and ash and from as much as 35 m thick at vent cones near south margin of Chaos Crags dome cluster to less than 1 m thick distally. Most pumice fall postdates emplacement of rhyodacite dome A (unit rca) but predates dome B (unit rcb). Beneath these fall deposits are nonsorted unconsolidated pumiceous pyroclastic flows. Three distinct pyroclastic-flow units are recognized. The stratigraphically highest pyroclastic-flow unit is characterized by coarse-celled pumice that forms breadcrusted blocks as large as 4 m across in a white to gray glassy ash matrix. This uppermost pyroclastic flow occurs widely in the area around Chaos Crags and locally in the drainages of Manzanita Creek and Lost Creek,

overlies dome A (unit rca) but underlies dome B (unit rcb), and includes charcoalized wood dated as 1,062±14 ^{14}C years (Clynne and Muffler, 1989). The lower two pyroclastic-flow units resemble one another, each having fine-celled pumice blocks as much as 30 cm across in a pumiceous ash matrix. Each is generally gray to pale yellow but has a pink top as much as 2 m thick. A pink laminated fine-ash deposit commonly 5-20 cm thick overlies the upper of these two flow units. These two lower pyroclastic-flow units predate dome A (unit rca), are exposed mainly in the upper Manzanita Creek and upper Lost Creek drainages, and include charcoalized wood dated as 1,124±15 ^{14}C years (Clynne and Muffler, 1989)

whe **Debris-flow deposits from the northeast side of Lassen Peak**—Poorly sorted, generally unconsolidated, massively bedded rubble ranging from silt-sized to large blocks. Consists entirely of dacite of Lassen Peak (unit dlp). Commonly pinkish in color but ranges from pink to gray, reflecting the lithology of source dacite on different parts of the Lassen Peak dome. Thickness ranges from less than 1 m to as much as 6 m. Formed as mudflows from the steep high northeastern slopes of Lassen Peak (northeast corner of the summit-area geologic map) and deposited in the drainage of upper Lost Creek. Soil underlying the deposit dated as 8,130±100 ^{14}C years; soil developed on the surface of the unit dated as 7,550±50 ^{14}C years (Turrin and others, 1998)

the **Till or protalus-rampart debris of early Holocene age**—Poorly sorted unconsolidated nonbedded diamicton consisting of silt to boulders of dacite of Lassen Peak (unit dlp). Forms two small moraines or ramparts at elevations between 7,800 and 9,000 ft near the base of Lassen Peak on the southeast and northeast sides. Older than 8-ka debris-flow deposits from northeast side of Lassen Peak (unit whe) and younger than probably 12-ka late till of Anklin Meadows (unit tal). This unit is equivalent to unit A_4 of Turrin and others (1998)

fh **Fluvial deposits of Holocene age**—Moderately well-sorted unconsolidated lenticular-bedded sand and gravel in modern stream channels. Age ranges throughout the Holocene

lh **Lacustrine deposits of Holocene age**—Well-sorted unconsolidated silt to fine sand, typically underlying swampy ground within or adjacent to seasonally flooded areas. Mapped only in two small areas: on Table Mountain and near upper Manzanita Creek. Age may range throughout the Holocene

ch **Colluvium and talus of Holocene age**—Nonsorted to laterally sorted unconsolidated nonbedded coarse to fine rubble. Mainly occurs as talus at the base of cliffs or steep slopes of bedrock but locally occurs as slopewash or thin local debris flows. Deposit mapped only where it obscures underlying bedrock completely or consists mainly of different lithology than underlying bedrock. Age ranges throughout the Holocene

(sh) **Landslide deposits of Holocene age**—Nonsorted unconsolidated nonbedded fine to coarse rubble in small slumps on unconsolidated slopes. Shown only as small concealed units east of Chaos Crags and east of Emigrant Pass (fig. 2). Age ranges throughout the Holocene

LATE PLEISTOCENE

tal **Late till of Anklin Meadows**—Diamicton containing boulders as much as 4 m across, consisting of locally derived dacite. Occurs as small moraines at elevations of about 7,600-9,000 ft on the east and south sides of Lassen Peak; also present (buried beneath pumice of Chaos Crags, unit pc) in Crescent Crater and at elevation about 7,600 ft in a small cirque east of Chaos Crags. This unit is equivalent to most of unit A_3 of Turrin and others (1998). It is undated but older than 8-ka debris-flow deposits from northeast side of Lassen Peak (unit whe) and till of early Holocene age (unit the); probably of latest Pleistocene age, about 12 ka

ta **Till of Anklin Meadows**—Widespread diamicton containing boulders commonly as much as 2 m across, locally as large as 4 m, consisting of varied volcanic lithologies. In the valleys of Manzanita Creek and Lost Creek, where the glaciers descended from Lassen Peak, boulders consist largely of 27-ka dacite of Lassen Peak (unit dlp). Occurs as sheetlike till deposits and large moraines at elevations as low as about 6,100 ft in the valleys of Manzanita Creek and Hat Creek and as low as about 5,500 ft in the valley of Lost Creek. Equivalent to most of units A_1 and A_2 of Turrin and others (1998); correlated with last major glacial advance of the Pleistocene (oxygen-

isotope stage 2), probably between about 25 and 17 ka

oa **Outwash deposits coeval with till of Anklin Meadows**—Moderately sorted unconsolidated gravel and sand, commonly containing boulders as large as 1-2 m across consisting of the same lithologies as the till of Anklin Meadows (unit ta) in the same drainages. Occur as partial valley fills and alluvial fan in the drainages of Lost Creek and Hat Creek

fa **Alluvium coeval with till of Anklin Meadows**—Moderately well-sorted unconsolidated lenticular-bedded sand and gravel. Mapped only in a few drainages without permanent streams or in terraces above modern stream channels, adjacent to or between the lower courses of Manzanita, Lost, and Hat Creeks

clp **Talus of Pleistocene age on Lassen Peak**—Generally nonsorted unconsolidated nonbedded coarse to fine rubble. Consists of dacite of Lassen Peak (unit dlp) and covers much of the surface of the Lassen Peak dacite dome. Some of the talus was deposited as hot blocks during emplacement of the dome, recognized by the presence of prismatically jointed blocks of dacite as large as 5 m across. Much was deposited later, during glaciation, weathering, and rockfalls from cliffs and other outcrops on Lassen Peak during the Pleistocene

trl **Post-maximum till of Raker Peak, consisting of Lassen Peak avalanche debris**—Diamicton containing boulders as much as 1.5 m across, consisting virtually entirely of dacite of Lassen Peak (unit dlp) but derived secondarily from avalanche debris that spread across glacial ice (unit slp). Forms a small moraine at the northeast base of Raker Peak. Deposited considerably after maximum advance of ice that deposited most till of Raker Peak (unit tr)

slp **Avalanche debris spread across glacial ice from Lassen Peak**—Nonsorted unconsolidated nonbedded angular rubble containing blocks commonly as large as 1-2 m across, but locally (on the east side of Raker Peak) as large as 6 m; matrix is coarse grit. Consists entirely of dacite of Lassen Peak (unit dlp). Exposed high on the east side of Raker Peak, north of Raker Peak on the west side of the Hat Creek drainage as low as about 5,400 ft, and on the east side of the Hat Creek drainage at the foot of Badger Mountain. Interpreted as having been emplaced on glacial ice in the valley of Hat Creek after partial glacial retreat from terminal moraine of the till of Raker Peak (unit tr)

pflp **Pyroclastic-flow deposit from partial dome collapse of Lassen Peak**—68% SiO_2. Poorly sorted unconsolidated nonbedded volcanic ash to blocks as large as 3 m across, consisting of porphyritic, gray hornblende-biotite dacite petrographically identical to dacite of Lassen Peak (unit dlp); blocks commonly prismatically jointed. Forms incised valley fill in upper Lost Creek, at the northeast base of Lassen Peak. Thickness ranges from feather edge to as much as 50 m. Formed by dome-collapse pyroclastic flows during emplacement of the Lassen Peak dacite dome. Dated by $^{40}Ar/^{39}Ar$ method as 28.3±2.7 ka; paleomagnetic correlation suggests an age of 27±1 ka (Turrin and others, 1998)

dlp **Dacite dome of Lassen Peak**—66-70% SiO_2. Porphyritic hornblende-biotite dacite. Outer portion of the dome commonly oxidized to grayish pink; locally exhibits a breccia carapace. Exposed interior is platy to massively jointed. Phenocrysts: 20% plagioclase 1-5 mm across, some composite crystals as large as 1 cm; 4% quartz, more abundant than in any other dacite in the map area, typically 1-2 mm across, rarely as large as 5 mm; 3% biotite 1-2 mm across; 2% hornblende 1-5 mm across, rarely as large as 15 mm; sparse augite typically 0.25 to about 1 mm across, composite crystals as large as 3 mm; trace olivine generally less than 1 mm. Commonly contains partly resorbed phenocrysts of plagioclase, hornblende, biotite, and quartz. Microlites and microphenocrysts of plagioclase, augite, hypersthene, and hornblende disaggregated from mafic inclusions abundant in light- to medium-gray, glassy to aphanitic groundmass. Mafic inclusions particularly large and abundant, ranging from a few centimeters to 1.5 m across; 20- to 50-cm inclusions more abundant than in any other dacite of the map area. Textures of mafic inclusions range from fine-grained and porphyritic to coarse-grained and aphyric; sparse multiple-generation inclusions (inclusions that contain inclusions). Porphyritic inclusions contain partly resorbed phenocrysts from host dacite; some also contain augite and olivine phenocrysts as large as a few millimeters. Fine-grained inclusions typically have hornblende-plagioclase groundmass but may have pyroxene-hornblende-

plagioclase groundmass. Most inclusions that look aphyric contain remnants of augite and olivine phenocrysts in hornblende-plagioclase groundmass. Fragments of mafic inclusions that range in size from a few millimeters to a few centimeters are abundant. This large (~ 2 km^3) volcanic dome is interpreted as a single emplacement unit because of its single remanent magnetic direction and lack of internal contacts. Glaciated, with a prominent cirque on the northeast side. Contemporaneous with pyroclastic-flow deposit from partial dome collapse of Lassen Peak (unit pflp), of 27±1 ka

tr **Till of Raker Peak**—Widespread diamicton with boulders commonly as large as 2 m, locally to 4 m, of varied volcanic lithologies. Prominent boulder lithologies in drainages of Manzanita Creek and Lost Creek include dacite of hill 8283 (unit d83) and rhyodacite of Eagle Peak (unit re); in drainage of Hat Creek contains prominent andesite of Badger Mountain (unit abm), andesite of Hat Mountain (unit ahm), and dacite of Reading Peak (unit dr). In all drainages notably lacks dacite of Lassen Peak, in contrast to the younger till of Anklin Meadows (unit ta) and, therefore, predates formation of the Lassen Peak dome. Occurs as sheetlike till deposits and moraines at elevations as low as about 5,500 ft. As discussed by Turrin and others (1998), predates 27±1 ka (age of dacite of Lassen Peak, unit dlp) and probably predates 35±1 ka (age of rhyodacite of Kings Creek, unit rk)

or **Outwash deposits coeval with till of Raker Peak**—Moderately to poorly sorted unconsolidated gravel and sand, commonly containing boulders as large as 1-2 m across consisting of the same lithologies as the till of Raker Peak (unit tr). Occurs as a large alluvial fan and downstream deposits in the drainage of Hat Creek

fr **Alluvium coeval with till of Raker Peak**—Moderately to well-sorted unconsolidated lenticular-bedded sand and gravel. Occurs in drainages without permanent streams. Mapped only in 2 small areas on the surface of the andesite flow of Raker Peak (unit arp), in one area adjacent to Lost Creek, and in one area near Manzanita Creek downstream from Manzanita Lake

abw **Andesite flow of Bear Wallow Butte**—57% SiO_2. Thick block-lava flow having margins as high as 40 m. Consists of microvesicular, dark-gray, glassy to aphanitic porphyritic olivine-augite andesite. Phenocrysts: 5% plagioclase generally 0.5 mm across but locally as large as 1.5 mm; 3% olivine 1-2 mm across; 2% augite 0.25-0.5 mm across. Abundant cumulophyric clots ranging in size from 1 to 10 mm consist of all three minerals. The lava flow is unglaciated and generally devoid of soil or vegetation but supports a few mature trees near the margins. Bear Wallow Butte is the southernmost of a youthful alignment of volcanoes north of the map area called Tumble Buttes; the unit is present in the map area only near the north edge. $^{40}Ar/^{39}Ar$ age is 35.1±3.1 ka (M.A. Lanphere, written commun., 2001)

rk **Rhyodacite flow of Kings Creek**—70% SiO_2. Porphyritic hornblende-biotite rhyodacite about 75 m thick, having steep lateral margins; glaciated, but much flow morphology still preserved. Basal and lateral margins glassy, commonly perlitic, in some instances brecciated; flow top pumiceous. Flow layering and spherulitic and lithophysal zones common. Flow breccia preserved locally. Phenocrysts: 15% plagioclase 1-5 mm across, largest are composite grains; 2% biotite 1-2 mm across; 1% hornblende 1-15 mm across; sparse quartz 1-2 mm across; sparse 0.5-mm hypersthene. Contains only sparse partly resorbed equivalents of the dacitic phenocrysts, fragments of inclusions, and crystals derived from disaggregation of mafic inclusions. Mafic inclusions sparse, typically smaller than about 10 cm across (a few to 20 cm). Mafic inclusions have coarse-grained hornblende-plagioclase groundmasses, partly resorbed phenocrysts derived from dacite host magma, and small olivine phenocrysts. Occurs east and southeast of Lassen Peak. Overlies pyroclastic-flow deposit of Kings Creek (unit pfk) and overlain by dacite of Lassen Peak (unit dlp). Inferred to be coeruptive with underlying pyroclastic flows (unit pfk) at 35±1 ka. Erupted from a vent now buried by Lassen Peak

pfk **Pyroclastic-flow deposit of Kings Creek**—Poorly sorted unconsolidated volcanic ash containing pumice blocks as large as about 1 m across. Pumice consists of porphyritic biotite-hornblende rhyodacite petrographically identical to rhyodacite flow of Kings Creek (unit rk); immediately preceded emplacement of that lava flow. Four separate pyroclastic flows or flow units are exposed in the banks of Hat Creek near Emigrant Pass (fig.

2). Similar deposits are exposed downstream in Hat Creek, upstream in the west fork of Hat Creek and, outside the map area, in Kings Creek Meadows. Dated by $^{40}Ar/^{39}Ar$ method as 32.0±17.1 ka; paleomagnetic correlation suggests an age of 35±1 ka (Turrin and others, 1998)

fk **Sediments beneath pyroclastic-flow deposit of Kings Creek**—Well-sorted unconsolidated to partially indurated sands, silts, and interbedded peat. A few beds are pebbly. Thickness about 4 m. Deposited by low-energy streams and quiet-water overbank flows or in ponds. Radiocarbon age calibrated by U-Th is 37.6±0.2 ka (Turrin and others, 1998)

psf **Pyroclastic-flow and proximal fall deposits of Sunflower Flat**—Poorly to moderately sorted unconsolidated volcanic ash containing blocks of porphyritic biotite-hornblende rhyodacite petrographically identical to rhyodacite domes of Sunflower Flat (unit rsf). Maximum thickness greater than 3 m. Occurs as pyroclastic flows from Sunflower Flat to Lost Creek and as proximal fall deposits forming a pumice crater southeast of Sunflower Flat. Underlies most rhyodacite domes of Sunflower Flat (unit rsf) but at least partly overlies oldest dome. Radiocarbon age calibrated by U-Th is 41±1 ka (D.A. Trimble, written commun., 1993)

rsf **Rhyodacite domes of Sunflower Flat**—69% SiO_2. Porphyritic biotite-hornblende-rhyodacite forming 8 domes extruded in an approximately linear northwest trend north of Chaos Crags. Range from dark-gray or black, dense, and glassy to light-gray or pink, microvesicular, microlite-choked, and partially devitrified. Phenocrysts: 12% plagioclase 1-5 mm across, composite crystals as large as 8-10 mm; 2% hornblende 1-12 mm across (large phenocrysts are conspicuous); sparse biotite 1-2 mm across; sparse quartz 1-2 mm across. Microphenocrysts (1-2%) of pyroxene (hypersthene>>augite) abundant but generally smaller than 0.5 mm though a few are as much as 1 mm across. Abundant partly resorbed plagioclase phenocrysts and plagioclase phenocrysts containing vermicular glass inclusions like those in rhyodacite of Krummholz (unit rkr). Common fragments of mafic inclusions range in size from a few millimeters to a few centimeters; rare larger inclusions are as much as 10 cm across. The summits of the domes have not been overridden by glaciers and, although heavily forested, retain their talus-covered primary morphology

ahm **Andesite flow of Hat Mountain**—58-62% SiO_2. Large flow of porphyritic augite andesite, generally about 100 m thick; vent at Hat Mountain, about 3 km east of the map area, is marked by a breached cone of agglutinated cinders and spatter. Generally massively jointed and microvesicular; weathers into rounded boulders 0.5 to several meters in diameter. Contains a disequilibrium phenocryst assemblage of partly resorbed plagioclase, quartz, hornblende, and biotite? and unresorbed augite and calcic plagioclase in varied proportions. Includes two end-member andesite types: a typical type and a less common type. The typical type contains strongly resorbed felsic phenocrysts: 4-8% plagioclase 1-2 mm across, sparse-1% augite as large as 1 mm across, sparse-1% quartz 1-2 mm across rimmed by tiny augite crystals and commonly having black to brownish specks of glass and biotite, and sparse-1% 1-4 mm pseudomorphs of hornblende (and biotite?). The less common andesite type is more porphyritic and has the same phenocryst assemblage but also has many additional less strongly resorbed felsic phenocrysts. Groundmass medium- to dark-gray; typically aphanitic in more porphyritic samples but glassy in less porphyritic samples. Mafic inclusions are generally small (less than about 10 cm across) and sparse, though locally more abundant; they contain the same phenocryst assemblage as in the host rock. Small augite phenocrysts are abundant in mafic inclusions; plagioclase, hornblende, and quartz phenocrysts are sparse and strongly resorbed or rimmed. Chemical composition varied, but typically contains 58-59% SiO_2; more porphyritic rocks contain as much as 62% SiO_2. Mapped only near east edge of the map area. The unit is not precisely dated, but the entire edifice has been glaciated. On the Central Plateau east of the map area it overlies andesite of Fairfield Peak (82 ka) and andesite of Crater Butte (92 ka). Its presence in till of Anklin Meadows demonstrates that andesite of Hat Mountain is older than about 27 ka; presence in till of Raker Peak (unit tr) suggests that andesite of Hat Mountain may be older than about 35 ka. A low-precision K-Ar age of 25±21 ka (A.L. Cook, written commun., 1983) is consistent with the stratigraphy

acr **Andesite scoria deposit on west rim of Crescent Crater**—57% SiO_2. Porphyritic hypersthene-olivine-augite andesite scoria a few meters thick. Phenocrysts: 10% plagioclase ranges from 0.25 to about 1 mm across; 5% augite 0.5-1 mm across; 2% olivine 0.25-0.5 mm across; 1% hypersthene 0.5-1 mm across. Common cumulophyric clots as large as 5 mm contain varied proportions of plagioclase, olivine, augite, and hypersthene. The deposit is present at only one locality, beneath Chaos Crags pumice (unit pc) on west rim of Crescent Crater. The eruptive source is unknown

dcr **Dacite dome and flow of Crescent Crater**—66-69% SiO_2. Porphyritic pyroxene-hornblende dacite in a petrographically and compositionally zoned dome and thick lava flow. The lava flow is typically flow-layered; both the flow and the dome have massive to blocky jointing. Groundmass of the lava flow dark-gray to black, glassy, and typically perlitic; groundmass of the dome medium-gray where fresh but typically oxidized to purplish or light-reddish. Phenocrysts: 15% plagioclase ranges from 2 mm to about 1 cm across (largest are composite crystals); 3% hornblende 1-5 mm across; 1% hypersthene 0.5-1 mm across; sparse biotite 1-2 mm across; trace quartz 1-2 mm across. Hornblende and biotite fresh in the lava flow but strongly oxidized in the dome; partly resorbed plagioclase phenocrysts more abundant in the dome than in the lava flow; abundant augite plus hypersthene microphenocrysts in the dome, only hypersthene microphenocrysts in the flow. Abundant porphyritic mafic inclusions, particularly in the dome, commonly as large as 50 cm across contain 1- to 2-mm olivine, augite, hypersthene, and calcic plagioclase phenocrysts as well as partly resorbed host-lava phenocrysts; some inclusions have hornblende-plagioclase groundmass, others have pyroxene-plagioclase groundmass. Occurs northeast of Lassen Peak; overlies rhyodacite of Krummholz (unit rkr, 43 ka)

rkr **Rhyodacite dome and flow of Krummholz**—69% SiO_2. Thick flow of porphyritic biotite-hornblende rhyodacite and a small vent dome. Groundmass light- to dark-gray and glassy; perlitic and spherulitic varieties occur. Top, bottom, and margins of flow are characteristically dense and glassy but devitrified where flow surface removed by glacial erosion. Massive jointing forms large rectangular blocks. Locally vaguely flow-layered. Phenocrysts: 10% plagioclase mostly 2-3 mm across, common composite crystals as large as 1 cm across, typically with gray cores; 1% hornblende generally 1-2 mm across, sparsely as large as about 1 cm; sparse biotite 1-2 mm across; sparse quartz as large as 2 mm across; sparse hypersthene as large as 0.5 mm across; most plagioclase partly resorbed, with vermicular glass inclusions. Mafic inclusions sparse and small (generally less than about 10 cm across); contain partly resorbed felsic phenocrysts derived from the host and sparse small phenocrysts of olivine and augite. Groundmasses of mafic inclusions contain acicular microphenocrysts of pyroxene, hornblende, and plagioclase. Occurs north of Lassen Peak and east of Chaos Crags. The dome and flow are glaciated and mostly obscured by a thick blanket of pumice from the Chaos Crags eruption (unit pc). Dated by $^{40}Ar/^{39}Ar$ method as 43±2 ka (M.A. Lanphere, written commun., 1998)

r27 **Rhyodacite flow of Section 27 on the north flank of Lassen Peak**—70% SiO_2. Porphyritic biotite-hornblende rhyodacite forms thick lava flows whose original flow morphology and pumiceous carapace are partly preserved; locally spherulitic or flow-layered. Unit has a basal flow breccia. Dark-gray to black and perlitic groundmass where dense; white to colorless where pumiceous. Phenocrysts: 12% plagioclase 1-3 mm across, common composite crystals as large as 6 mm; 3% hornblende 1-3 mm across, rarely larger; 1% hypersthene as large as 1 mm across; sparse biotite generally 1-2 mm across; trace quartz; rare augite xenocrysts. Mafic inclusions generally small and sparse and as large as 10-12 cm across; common fragments of mafic inclusions range in size from a few millimeters to about 1 cm. Inclusions typically contain augite and calcic plagioclase phenocrysts in addition to dacitic phenocrysts derived from host rhyodacite. Extrusive vent probably in the area now occupied by the dacite dome of Lassen Peak (unit dlp). The lava flows are slightly to heavily glaciated. The unit may contain several flows of similar lithologies and ages. Age unknown; much younger than dacite of hill 8283 (unit d83, 261 ka) and older than rhyodacite of Krummholz (unit rkr, 43 ka) and dacite of Crescent Crater (unit dcr)

axe **Andesitic mixed lava of Eagle Peak**—61-68% SiO_2. Mixed lithology of rhyodacite of Eagle Peak (unit re) and augite-hypersthene andesite. Blotchy or color-banded, dark-brownish-gray, microvesicular to pumiceous. The least-mixed material approaches lithology of rhyodacite of Eagle Peak (unit re) but contains sparse mafic phenocrysts in a brownish groundmass. The most-mixed material is porphyritic andesite containing about 10% phenocrysts, mainly plagioclase, hornblende, biotite, and quartz similar to those in rhyodacite of Eagle Peak, though hornblende and biotite are somewhat oxidized; also contains abundant 0.5-mm calcic-plagioclase and sparse 0.5- to 1-mm pyroxene phenocrysts (hypersthene>>augite) from the andesitic magma and cumulophyric clots of pyroxene and plagioclase. Most material is intermediate between the two types. Poorly exposed in a small area of mostly oxidized and altered rock between Ski Heil Peak and Eagle Peak. Precise age unknown but probably contemporaneous with last extrusion of rhyodacite of Eagle Peak (unit re)

re **Rhyodacite dome and flow of Eagle Peak**—71% SiO_2. Thick lava flow and vent dome of porphyritic hornblende-biotite rhyodacite, about 100 m thick; has steep lateral margins and well-preserved flow morphology (despite glaciation). Basal and lateral margins glassy, commonly perlitic, locally brecciated; flow top pumiceous. Commonly flow-layered and spherulitic or lithophysal. Light-colored to white and typically glassy or perlitic groundmass. Phenocrysts: 12% plagioclase 1-3 mm across, sparsely as large as 6 mm; 1-2% biotite 0.5-2 mm across; 1-2% hornblende generally 1-4 mm across, rarely as large as 8 mm; 1% quartz as large as 4 mm across. Sparse partly resorbed plagioclase, hornblende, and biotite phenocrysts. Abundant mafic inclusions have a wide variety of textures; generally fine- to coarse-grained, nearly aphyric, and 10-15 cm across but size may be as great as about 50 cm. Finer-grained inclusions commonly have 0.5- to 1-mm phenocrysts of calcic plagioclase and phenocrysts (some of them partly resorbed) of olivine and sparse augite as well as partly resorbed host-rhyodacite phenocrysts. Inclusion groundmasses generally hornblende-plagioclase; some are pyroxene-hornblende-plagioclase. Abundant fragments of mafic inclusions are as large as a few centimeters across. Nearly contemporaneous with 66-ka pyroclastic-flow deposit of Eagle Peak (unit pfe)

pfe **Pyroclastic-flow deposit of Eagle Peak**—71% SiO_2. Poorly sorted matrix-supported non-indurated white ash, lapilli, and yellowish-weathering pumice blocks; sparse but widespread pumice blocks as large as several meters across. Thickness generally about 2 m. Pumiceous pyroclastic flow erupted from a vent now covered by the Eagle Peak dome. The pumice is porphyritic biotite-hornblende rhyodacite similar to the rhyodacite of Eagle Peak (unit re). Contains matrix-free mafic inclusions as lithic fragments. Occurs mainly west of Manzanita Lake, but a similar deposit several meters thick covers the summit of Ski Heil Peak and also includes dense fragments of rhyodacite of Eagle Peak. Dated by $^{40}Ar/^{39}Ar$ as 66±4 ka (B.D. Turrin, written commun., 1994)

sd **Avalanche deposit from dacite older than pyroclastic-flow deposits of Eagle Peak**—Nonsorted unconsolidated nonbedded angular rubble containing dacite blocks commonly as large as 1-2 m; matrix is coarse grit. Lithology of blocks resembles dacite of hill 8283 (unit d83) and dacite of Vulcans Castle (unit dvc). Crops out locally in upper Manzanita Creek near the west base of Lassen Peak and more abundantly northwest of Manzanita Lake, where the deposit is largely covered by pyroclastic-flow deposit of Eagle Peak (unit pfe) and where only the large avalanche blocks protrude. West of the map area, overlies 199-ka tholeiitic basalt of Eagle Canyon (unit be). At least partly emplaced hot (as indicated by prismatically jointed blocks) by partial collapse of dacite domes in the vicinity of Lassen Peak considerably before the growth of the Lassen Peak dome (unit dlp)

atu **Andesite flow of Tumble Buttes older than Bear Wallow Butte**—58% SiO_2. Porphyritic olivine-augite andesite aa to block lava 5-10 m thick. Black glassy to aphanitic groundmass having large vesicles of irregular shapes and smooth walls, commonly containing opaline silica. Phenocrysts: 2-3% olivine 1-2 mm across; 2-3% plagioclase mostly 0.5-1 mm across but a few as large as 1.5 mm; trace augite as large as about 0.5 mm across. Abundant cumulophyric clots as much as 5 mm across of all three phenocryst minerals, dominated by plagioclase. Present in the

map area only near the north edge. Erupted from a vent subsequently buried by the andesite of Bear Wallow Butte. The flow lies below the limits of glaciation and has a poorly developed soil and forest cover

meh **Mafic andesite flow of Eskimo Hill**—54% SiO_2. Olivine-augite mafic andesite block-lava flow from a scoria cone satellitic to Red Lake Mountain. Microvesicular medium-gray aphanitic groundmass. Phenocrysts: 25% plagioclase generally 0.5-1 mm across, sparsely as large as 1.5 mm; 8% bright green diopsidic augite generally 1 mm across, sparsely as large as 2 mm; 5% olivine mostly 1 mm across, sparsely as large as 2 mm; common small clots of olivine and augite. Rough unglaciated flow surfaces; sparsely vegetated although mature trees are present in some areas. Present near the west edge of the map area, northwest of Manzanita Lake. Underlies pyroclastic-flow deposit of Eagle Peak (unit pfe, 66 ka); overlies mafic andesite of Red Lake Mountain (unit mrl)

mrl **Mafic andesite flows of Red Lake Mountain**—54-59% SiO_2. Older olivine-augite and younger medium-gray microvesicular hypersthene-olivine-augite mafic andesite aa to block-lava flow. Phenocrysts: older flows: 25% plagioclase generally 0.5-1 mm across, sparsely as large as 1.5 mm; 8% diopsidic augite generally less than 1 mm across, sparsely as large as 2 mm; 5% olivine mostly about 1 mm across, sparsely as large as 2 mm; younger flows: 20% plagioclase generally 0.5-1 mm across, sparsely as large as 1.5 mm; 8% diopsidic augite generally less than 1 mm across, sparsely as large as 2 mm; 2% olivine mostly about 1 mm across, sparsely as large as 2 mm; 1% hypersthene to 0.5 mm across. Abundant small clots of olivine and augite. Rough, unglaciated flow surfaces have weak soil and sparse vegetation but some mature trees. Mapped only at west edge of the map area, northwest of Manzanita Lake. Underlies pyroclastic-flow deposits of Eagle Peak (unit pfe, 66 ka)

mrm **Mafic andesite flow of Red Mountain**—54% SiO_2. Olivine-augite mafic andesite aa to block-lava flow. Microvesicular medium-gray aphanitic groundmass. Phenocrysts: 7% diopsidic augite generally less than 1 mm across, sparsely as large as 2 mm; 3% olivine phenocrysts mostly about 1 mm across, sparsely as large as 2 mm. Common small clots of olivine and augite; sparse quartz xenocrysts. About 30% plagioclase microphenocrysts, generally as much as about 0.5 mm across but sparsely as large as 1 mm. Rough unglaciated flow surfaces have considerably better developed soil and more forest cover than the mafic andesite of Red Lake Mountain (unit mrl). Mapped only at northwest edge of the map area. Age unknown but underlies andesite of Red Lake Mountain and overlies andesite of Raker Peak (unit arp) of 270 ka

tb **Till of Badger Mountain**—Diamicton containing boulders as large as 2 m, consisting of varied volcanic lithologies. Prominent boulder lithologies include andesite of Raker Peak (unit arp) and andesite of Badger Mountain (unit abm); less prominent but still relatively common lithologies include basalt of Nobles Trail (unit bnt) and various older dacites, including the dacite of Reading Peak (unit dr). Occurs as sheetlike till deposits and moraines adjacent to the Hat Creek and Lost Creek drainages at elevations as low as about 5,000 ft and in a small area south of Manzanita Lake. Equivalent to units B_2 and B_1 of Turrin and others (1998)

MIDDLE PLEISTOCENE

rdm **Rhyodacite flow of Dersch Meadows**—69% SiO_2. Thick lava flow of porphyritic biotite-hypersthene-hornblende rhyodacite. Interior of flow light-gray to pink, conspicuously flow-layered, generally devitrified; spherulites common; flow base dark-gray, dense, and glassy, typically perlitic, locally brecciated. Phenocrysts: 15% plagioclase 1-3 mm across, sparsely as large as 7 mm; 2% hornblende 1-5 mm across, rarely as large as 8 mm; 1% hypersthene 0.25-1 mm across; sparse biotite as large as 1 mm; trace quartz 1 mm across. Mafic inclusions sparse, rarely exceed 5 cm; contain sparse bright green augite phenocrysts. Partly resorbed phenocrysts and fragments of mafic inclusions sparse. Mapped only at east edge of the map area, south of Emigrant Pass (fig. 2). Vent location unknown, but probably in area east of Paradise Meadows; lava flowed north to Dersch Meadows and the east fork of Hat Creek. Dated by $^{40}Ar/^{39}Ar$ as 193±11 ka (B.D. Turrin, written commun., 1994)

bec **Tholeiitic basalt flow of Eagle Canyon**—48% SiO_2. Thin lava flows of olivine basalt, widespread west of the map area. Medium-gray

holocrystalline, diktytaxitic tube-fed pahoehoe having tumuli on upper surface and consisting of several flow units. Hexagonal-block joint pattern at flow top; massive jointing in interior. Abundant round vesicles at upper and lower surfaces. Phenocrysts: 1-5% olivine 1-3 mm across; 0-5% plagioclase 1-2 mm across; cumulophyric clots of olivine and plagioclase as large as 1 cm. Phenocrysts more abundant in proximal localities, less abundant in distal localities (beyond the map area). Sparse (but locally abundant) distinctive clusters as much as 2 cm across of 2- to 5-mm plagioclase crystals that radiate from an olivine-plagioclase cumulophyric clot. Occurs in only one part of the map area, near west edge, just south of California Highway 44; vent location uncertain, but cinders and agglutinate exposed in roadcuts near there suggest that the vent was nearby. Basalt of Eagle Canyon flowed down the drainage of Manzanita Creek beyond the map. Macdonald (1963) and Macdonald and Lydon (1972) called this flow (and several other tholeiitic basalt flows) Shingletown basalt; Helley and others (1981) established the name "olivine basalt of Eagle Canyon" for this unit but did not recognize its entire distribution or its possible source area. Dated by $^{40}Ar/^{39}Ar$ as 199±2 ka (B.D. Turrin, written commun., 1994)

dr **Dacite domes of Reading Peak**—65-69% SiO_2. Complex of lava domes of porphyritic biotite-hornblende dacite. Light- to medium-gray, aphanitic, massively jointed, devitrified, and locally oxidized. Phenocrysts: 10-12% plagioclase 1-5 mm across, sparse composite crystals as large as 1 cm, 2% hornblende mostly 1-3 mm across, sparsely as large as 5 mm; sparse-1% biotite as large as 1 mm; rare-sparse quartz as large as 2 mm; rare augite as large as 1 mm in small clusters. Pyroxene microphenocrysts (hypersthene>>augite) common but rarely exceed 0.5 mm across and also occur locally as small cumulophyric clots. Most plagioclase phenocrysts are weakly to strongly resorbed, and almost all hornblende and biotite has been pseudomorphed by aggregates of Fe-Ti oxides, plagioclase, and pyroxene. Abundant mafic inclusions contain a wide variety of textures from porphyritic to coarse-grained aphyric; their size and character varies from location to location. Most inclusions <20 cm across but many as large as 50-60 cm. Sparse phenocrysts of calcic plagioclase, augite, and olivine present in some inclusions, as well as partly resorbed host-dacite phenocrysts; mafic inclusions have hornblende-pyroxene-plagioclase groundmasses. Small fragments of mafic inclusions abundant. Only one small area of dacite of Reading Peak occurs within the map area, low on the eastern flank of Lassen Peak; it is similar to and correlated with the glaciated domes exposed on Reading Peak, 2-3 km farther southeast. The age of dacite of Reading Peak was determined by K-Ar to be 212±5 ka (G.B. Dalrymple, written commun., 1991)

dsh **Dacite dome of Ski Heil Peak**—66% SiO_2. Porphyritic augite-hornblende dacite. Light-gray to pinkish, aphanitic, massively jointed, devitrified, and commonly oxidized. Phenocrysts: 10% plagioclase generally 1-5 mm across, composite crystals as large as 1 cm; 1% hornblende 1-3 mm across, sparsely as large as 5 mm; 1% augite 0.5-2 mm across, commonly in small cumulophyric clots; 1% biotite generally 1-2 mm across; sparse quartz generally 1-2 mm across. Hornblende, biotite, and some plagioclase phenocrysts strongly resorbed. Common fragments of mafic inclusions, 1-2 cm across; sparse larger mafic inclusions to 20 cm. Occurs at south end of the map area. Summit area of the dome mainly covered by pyroclastic flow of Eagle Peak (unit pfe). K-Ar age is 244±10 ka (G.B. Dalrymple, written commun., 1991)

bnt **Tholeiitic basalt flow of Nobles Trail**—48% SiO_2. Thin aphyric basalt lava flow with medium-gray coarsely diktytaxitic groundmass of plagioclase, olivine, clinopyroxene, and Fe-Ti oxide microphenocrysts. Consists of multiple flow units of tube-fed pahoehoe. Hexagonal-block joint pattern at top; massive jointing in interior. Abundant spherical vesicles at upper and lower surfaces. Phenocrysts: trace olivine as large as 1 mm across. Occurs near Hat Creek east and northeast of Raker Peak; vent location unknown, probably buried beneath younger lavas in the vicinity of the Central Plateau (fig. 2). Age unknown, but overlies andesite of Raker Peak (unit arp, 270 ka) and underlies till of Badger Mountain (unit tb)

dvc **Dacite dome of Vulcans Castle**—66% SiO_2. Porphyritic biotite-hornblende dacite. Light- to medium-gray but commonly oxidized to pink; aphanitic, massively jointed, devitrified, locally flow-layered. Brecciated and

glassy dome margins preserved along northern flank. Phenocrysts: 10% plagioclase 2-6 mm across, largest are composite; 1% hornblende 1-3 mm across; 1% biotite 1-2 mm across; 1% quartz 1-2 mm across; sparse augite phenocrysts 0.5-1 mm across and small composite augite crystals; sparse 0.5-mm hypersthene microphenocrysts. Abundant mafic inclusions contain a variety of textures; generally less than about 10 cm across. Occurs at southwest edge of the map area. Underlies dacite dome of Ski Heil Peak (unit dsh) of 244±10 ka; includes small area of dome-collapse breccia northwest of Crescent Cliff; highly sculpted by glacial erosion and mass wasting

dpl **Dacite flow of the Lassen Peak Trail Parking Lot**—64% SiO_2. Moderately porphyritic hornblende-augite dacite. Medium-gray, aphanitic, massively jointed, devitrified, and commonly oxidized; commonly flow-layered, especially at the parking lot for the trail up the south side of Lassen Peak (fig. 2). Phenocrysts: 5% plagioclase 1-5 mm across, sparsely as large as 8 mm; 1% augite as large as 3 mm; 1% hornblende 1-2 mm across; sparse biotite generally 1 mm across; trace quartz 1 mm across. Most plagioclase, hornblende, and biotite partly resorbed. Sparse mafic inclusions as much as 10 cm across; most are deformed and partly disaggregated to merge with the groundmass. Abundant small fragments of mafic inclusions a few millimeters to a few centimeters across. Overlain by dacite dome of Ski Heil Peak (unit dsh)

d83 **Dacite dome and flow of hill 8283**—66% SiO_2. Porphyritic pyroxene-hornblende dacite dome and thick lava flow. Light- to medium-gray, aphanitic, having patchy microvesicular areas. Extensively glaciated, but a few remnants of pumiceous carapace preserved. Weakly flow-layered with aligned phenocrysts. Proportions of phenocrysts vary, especially in the lava dome. Phenocrysts: 12% plagioclase 1-6 mm across, sparse composite crystals with dark cores, as large as 1 cm; 1% hornblende 1-5 mm across; sparse biotite generally less than 2 mm across; sparse-1% quartz generally less than 2 mm across. Abundant pyroxene microphenocrysts (augite>>hypersthene) generally less than 0.5 mm across. Felsic phenocrysts both partly resorbed and unresorbed. Augite and olivine xenocrysts common, especially on the western flank of the dome. Abundant mafic inclusions ranging from 10 to about 50 cm across vary from fine- to coarse-grained and are generally sparsely phyric, but some contain sparse to abundant partly resorbed host phenocrysts. Groundmasses of inclusions either pyroxene-plagioclase or hornblende-plagioclase. Abundant fragments of mafic inclusions 5 mm to 2 cm across, commonly contain pyroxene microphenocrysts and cumulophyric clots of microphenocrysts. The hill near the north base of Lassen Peak labeled 8283 ft in elevation marks the vent for lava that emplaced a thick flow northeast toward Lost Creek. Extensively mantled by pumiceous pyroclastic-flow and fall deposits of Chaos Crags (unit pc). K-Ar age 261±5 ka (G.B. Dalrymple, written commun., 1991)

dum **Dacite flow of upper Manzanita Creek**—66-67% SiO_2. Porphyritic pyroxene-biotite-hornblende dacite dome. Light- to medium-gray, splotchy, aphanitic, massively jointed, and devitrified. Phenocrysts: 12% plagioclase 2-5 mm across, sparse composite crystals with dark cores, as large as 1 cm; 2% hornblende 1-5 mm across; 1% biotite as large as 2 mm; rare quartz as large as about 1 mm. Common pyroxene microphenocrysts (hypersthene>>augite) rarely exceed 0.5 mm across, locally as small composite crystals. Mafic inclusions abundant, as large as about 20 cm; include both coarse-grained equigranular inclusions that lack host-lava phenocrysts and fine-grained inclusions that contain partly resorbed host-lava phenocrysts; both types contain sparse 0.5- to 1-mm phenocrysts of augite and olivine; groundmasses are hornblende-plagioclase. Abundant fragments of mafic inclusions a few millimeters to a few centimeters across. Present only at the north base of Lassen Peak. Glacially eroded. Underlies dacite of hill 8283 (unit d83)

arp **Andesite flows of Raker Peak**—57-59% SiO_2. Thick andesite lava flows and lava cone, as well as an agglutinated scoria vent cone at summit of Raker Peak. Typically light-gray, aphanitic, and microvesicular but dark-gray to black where glassy. Typical exposures are rounded boulders or squarish joint-bounded blocks; flow interiors dense and have massive to platy jointing. Lithologically varied, having disequilibrium phenocryst assemblage. Most common lithology consists of lava flows 50-100 m thick of porphyritic olivine-

pyroxene andesite. Phenocrysts: 10-15% plagioclase 1-6 mm across, generally partly resorbed; 4-6% augite 0.5-3 mm across; 2-4% olivine 1-5 mm across; 1-2% hypersthene 0.5-1 mm across; 1% hornblende 0.5-3 mm across; sparse quartz as large as 2 mm, generally having pyroxene rims. Both hypersthene and augite also occur together with plagioclase in cumulophyric clots as large as 5 mm across. Hornblende phenocrysts replaced by dark-colored aggregates of plagioclase, pyroxene, and Fe-Ti oxides; plagioclase strongly resorbed. Flows near the base of the unit contain only sparse phenocrysts of the minerals described above. Mafic inclusions absent, but inclusions of volcanic and metamorphic crustal rocks occur locally. Glaciated except for the northern distal end and the summit area. K-Ar age of a sample collected near the exposed base of the unit is 270±18 ka (G.B. Dalrymple, written commun., 1991)

rmz **Rhyodacite flow of Manzanita Chute**—69% SiO_2. Thick lava flow of moderately porphyritic biotite-hornblende rhyodacite. Largely unglaciated, weathered surface has a well-preserved flow morphology; the upper surface has well defined crescentic flow ridges and a pumiceous carapace; basal part of flow is dense and perlitic. Groundmass ranges from white pumiceous perlitic glass containing spherulites to dark-gray or black dense perlitic glass. Phenocrysts: 10% plagioclase generally 1-3 mm across, sparsely as large as 5 mm; 2% hornblende generally 1-3 mm across, sparsely as large as 5 mm; 1% biotite 0.5-1 mm across. Partly resorbed phenocrysts absent. Mafic inclusions containing a variety of textures generally sparse but locally common; most are 10-30 cm across, aphyric, fine- to coarse-grained, and have hornblende-plagioclase groundmasses; less abundant are smaller porphyritic mafic inclusions containing sparse 1-mm augite and olivine phenocrysts, partly resorbed host-rhyodacite phenocrysts, and fine-grained hornblende-plagioclase groundmasses. Sparse small fragments of mafic inclusions. Mapped only at west edge of the map area, southwest of Manzanita Lake. The vent dome is peak 7241, about 1 km southwest of the map area. The unit overlies rhyodacite flow of Loomis Peak (unit rl), andesite flow of Viola (unit av), and andesite flow and cinder cone of lower Manzanita Creek (unit amc); overlain only by tills of Badger Mountain (unit tb) and Raker Peak (unit tr). $^{40}Ar/^{39}Ar$ age is 297±1 ka (B.D. Turrin, written commun., 1994)

rl **Rhyodacite flow of Loomis Peak**—69% SiO_2. Thick lava flow of porphyritic biotite-hypersthene-hornblende rhyodacite. Varies from white to pink, dense to pumiceous, and devitrified to dense dark-gray or black perlitic glass containing spherulites and lithophysae. Extensively glaciated but locally still exhibits a poorly preserved pumiceous carapace; base of flow dense and perlitic; flow interior massively jointed, flow-layered, and devitrified and having common spherulitic, lithophysal, and oxidized zones. Phenocrysts: 12% plagioclase generally 1-3 mm across (but a few as large as 5 mm and composite crystals as large as 8 mm); 2% hornblende generally 1-3 mm across (but a few as large as 5 mm); 1% hypersthene as large as 0.75 mm; trace biotite 0.5-1 mm across. Particularly abundant mafic inclusions contain a wide variety of textures ranging from fine-grained dark porphyritic and having partly resorbed host-rhyodacite phenocrysts to coarse-grained and aphyric. Most inclusions 10-20 cm across but some as large as 50 cm; coarse-grained aphyric inclusions having hornblende-plagioclase groundmasses are commonly larger; porphyritic mafic inclusions containing sparse 1-mm olivine, augite, and calcic-plagioclase phenocrysts, partly resorbed host-rhyodacite phenocrysts, and fine-grained pyroxene-plagioclase or pyroxene-hornblende-plagioclase groundmasses are commonly smaller. Mafic inclusions that contain older generations of inclusions are relatively common. Fragments of mafic inclusions, partly resorbed phenocrysts, and small crystals disaggregated from inclusions are abundant. Occurs near southwest edge of map area, where it overlies andesites of Brokeoff Volcano (unit abk, about 400 ka) and underlies the rhyodacite flow of Manzanita Chute (unit rmz, 297 ka)

av **Andesite flow of Viola**—57-59% SiO_2. Thick block-lava flow of sparsely porphyritic augite-olivine andesite. Light- to medium-gray, aphanitic. Original flow surface poorly preserved, marked by subrounded vesicular boulders. Flow interior, where exposed, thickly to thinly platy-jointed. Distinctly disequilibrium phenocryst assemblage consisting of olivine, augite, hornblende, plagioclase and quartz. Phenocrysts: 4-8%

plagioclase generally 2-5 mm across, many strongly resorbed; trace-2% augite 0.25-1 mm across; 1% hornblende (+biotite?) 3-5 mm across completely pseudomorphed by fine-grained aggregates of plagioclase, pyroxene, and Fe-Ti oxides; trace olivine 0.1-0.35 mm across, generally corroded and partly converted to iddingsite; trace quartz. Proximal parts of the flow contain twice as many phenocrysts as distal parts. Present in the map area only near west edge, south of Manzanita Creek. The vent is marked by an eroded cinder cone (hill 6924 about 1.5 km southeast of Deep Hole) west of the map area. K-Ar age 313±8 ka (G.B. Dalrymple, written commun., 1991)

rrp **Rhyolite dome of the west side of Raker Peak**—74% SiO_2. Moderately porphyritic hornblende-biotite rhyolite. White to light-gray, glassy, commonly spherulitic. Glacial erosion along the southern margin of the dome exposes prominent columnar joints. Phenocrysts: 10% plagioclase 1-3 mm across, commonly partly resorbed; 2% biotite as large as 1 mm, unresorbed and unoxidized; 1% hornblende as large as 1 mm, unresorbed and unoxidized; sparse quartz as large as 0.25 mm. Abundant coarse-grained equigranular mafic inclusions (57.5% SiO_2) generally 10 to about 30 cm across. Abundant small fragments of mafic inclusions a few millimeters across. Inclusions have pyroxene-hornblende-plagioclase groundmasses and sparse plagioclase phenocrysts; inclusions locally deformed by flowage into even layers a few millimeters thick; these layers commonly extend over several square meters and provide planar discontinuities that separate the rocks into large blocks. Overlain by andesite of Raker Peak (unit arp)

abk **Andesite flows and debris flows of the composite Brokeoff volcano**—61-63% SiO_2. Small areas of various porphyritic augite-hypersthene andesite lavas from the Brokeoff volcano have been mapped together. Lithologies generally similar, typically medium- to dark-gray and aphanitic, containing 10-30% phenocrysts of plagioclase, hypersthene, and augite (generally hypersthene>augite); plagioclase dominates the assemblage. Phenocrysts typically 1-3 mm across, locally as large as 5 mm; olivine sparsely present as partly resorbed phenocrysts. Common cumulophyric clots of plagioclase and pyroxene. Most of these flows are approximately 470 to 400 ka (Clynne and Muffler, 1989), but those in the vicinity of Raker Peak may be older

amc **Andesite flow and cinder cone of lower Manzanita Creek (part of Brokeoff volcano)**—63% SiO_2. Thick lava flow of porphyritic augite-hypersthene andesite. Unglaciated and retains much original flow morphology. Upper surface of the block-lava flow characterized by rounded vesicular boulders 0.5-1 m across. Generally aphanitic, light-gray where weathered (typical), medium- to dark-gray where fresh (rare); distal part of the flow, outside the map area, is commonly flow-layered, partially oxidized, and devitrified. Phenocrysts: 20% plagioclase 1-3 mm across; 6% hypersthene 0.5-2 mm across; 3% augite 0.5-2 mm across; sparse hornblende, generally smaller than 1-2 mm. Abundant cumulophyric clots of plagioclase and pyroxenes 5 mm to 1 cm across. Mafic inclusions sparse and small, generally less than about 5 cm across. Shown only in west part of the map area. Erupted from vent marked by small cinder cone (black-stippled area) near Manzanita Lake campground; the eroded cone of andesitic scoria has a thick soil cover. This unit is overlain by andesite of Viola (unit av, 313 ka); correlation with the later stages of Brokeoff volcano suggests an age between about 470 and 400 ka

EARLY PLEISTOCENE AND EARLY PLEISTOCENE(?)

abm **Andesite flows of Badger Mountain**—57 and 60-63% SiO_2. Moderately to highly porphyritic pyroxene andesite lavas forming a small shield volcano. Flows are generally thin (but locally as thick as 10 m); interflow breccias sparse. Glaciated on the western margins, and cut by normal faults. Generally dark-gray to black, glassy to aphanitic. Lithology varied, including two types corresponding to upper and lower stratigraphic positions. Phenocrysts (upper flows): 20-30% plagioclase as large as 1 mm; 3% hypersthene generally as large as 1 mm, sparsely as large as 2 mm; 2% augite generally as large as 1 mm, sparsely as large as 2 mm. Phenocrysts (lower flows): 15-30% plagioclase; 3-4% augite; sparse-2% hypersthene; sparse-1% olivine 0.5 mm. Abundant cumulophyric clots of plagioclase and pyroxene±olivine generally 2-5 mm across. The two types of lavas correspond to two chemical groups:

the hypersthene-augite andesites low in the section contain about 57% SiO_2, and the augite-hypersthene andesites above contain 60-63% SiO_2. Occurs at northeast edge of the map area. There is a single conventional K-Ar age of 708±21 ka (G.B. Dalrymple, written commun., 1994)

btb **Tholeiitic basalt flows of Twin Bridges**—49% SiO_2. Light-gray, holocrystalline, diktytaxitic. Multiple thin flow units, typically a few decimeters to a few meters thick; vesicular flow tops. Maximum exposed thickness about 30 m, base not exposed. Original flow surfaces poorly preserved. Phenocrysts: sparse to 1% olivine 0.5-1.5 mm across, locally in small glomeroporphyritic clots as large as 3 mm. Present in the map area only near the northeast corner. Location of the vent is unknown. Several small faults and one major fault, all NNW-trending, break this unit. Overlain by andesite flows of Badger Mountain (unit abm) and has normal remanent magnetic polarity; thus probably between 708 and 780 ka

atb **Andesite flows of Table Mountain**—62% SiO_2. Porphyritic augite-hypersthene andesite lava flows forming a small shield volcano. Largely unglaciated but no vent or pyroclastic material preserved. Dark-gray to black, glassy, and vesicular, having conspicuously rubbly flow tops and dense flow interiors; typical exposures consist of vesicular round-weathered boulders. Phenocrysts: 20% plagioclase as large as 0.75 mm; hypersthene generally as large as 0.75 mm, rarely as large as 1.5 mm; augite generally as large as 0.75 mm, rarely as large as 1.5 mm. Abundant cumulophyric clots and crystal clusters consisting of all three phenocryst types, dominated by plagioclase, generally 2-5 mm across. A few small NNW-trending faults cross the edifice. The unit has normal remanent magnetic polarity and probably is younger than 780 ka. Age relations to andesite flows of Badger Mountain (unit abm) uncertain

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