CLEARLAKE HIGHLANDS—THURSTON LAKE AREA

Exposed thickness about 20 m

Basin deposits of Clear Lake (Holocene and Pleistocene)—See descrip-

Rhyolite of Borax Lake (Pleistocene) - Flow of sparsely porphyritic to

coarse pumice blocks. Contains sparse mafic lithic inclusions that were

derived from the underlying dacite of Clearlake Park (dcpk) and basaltic

andesite of Arrowhead Road (bar) or that represent quenched magmas of

intermediate to mafic composition. Age of 0.091±0.013 Ma on obsidian.

bearing dacite. Contains inclusions of baked sandstone of Franciscan

assemblage (KJf) or Great Valley sequence (KJgv) and of the basaltic

cone and small satellitic areas of bomb and block tephra of olivine basaltic

andesite. Overlain by the rhyolite of Borax Lake (rb) and dacite of

Clearlake Park (dcpk). Well data indicate that flank of cinder cone is

overlain by 60 m of alluvium (al) and lacustrine sediments (bcl?) in

SW1/4SE1/4 sec. 16, T. 13 N., R. 7 W. Exposed thickness 10 m

Basaltic andesite of Roundtop Mountain (Pleistocene)—Olivine basaltic

cone and a small area of coarse tephra 1.8 km to the east

tb Terrace deposits of Burns Valley (Pleistocene)—Sand and gravel predom-

high and smaller isolated deposit to east

Maximum thickness probably less than 100 m

brf Flow—Thickness 20 m

thickness 60 m

andesite. Flow erupted from beneath cinder cone and probably from

fissures indicated by east-west vertically sheeted ribs between the cinder

yroclastic deposits—Bomb, block, and lapilli tephra. Cinder cone 200 m

inantly composed of chert and greenstone clasts reworked from the Cache

Formation (QTc) and rare cobbles of early basaltic rocks (beu, beup, beui).

Contains thin fine-grained basaltic tuffs (yp?) in road cuts along State

Route 53 on west edge sec. 14, T. 13 N., R. 7 W. Forms subdued

flat-topped topography that is less dissected than that underlain by the

Cache Formation (QTc). Extensive distribution indicates deposition by a

larger ancestral drainage system that was possibly related to a former

outlet of Clear Lake east of Clearlake Oaks and through Ogelene Canyon.

Gravel deposit east of Pinkeye Lake (Pleistocene)—Stream gravel com-

posed of pebbles and small cobbles in an orange sandy matrix. Contains

clasts of obsidian (rto) from the rhyolite of Thurston Creek, dacite from

nearby dacite units, and chert from the Franciscan assemblage (KJf).

Derived from Manning Flat area and deposited in a former eastward

porphyritic dacite. Overlies the Lower Lake Formation (II) and dacite of

Clearlake Highlands (dhi). Age of 0.40±0.04 Ma. Maximum exposed

porphyritic, quartz-rich dacite. Contains 3–5 percent of 1–5-mm-diameter

quartz that is commonly rimmed by clinopyroxene. Shows steep flow

fronts along shore of Clear Lake. Flows north of Thurston Lake probably

fed by vents or fissures aligned west-northwest in present outcrop area;

other sources at south end of Konocti Bay. Probably overlies the dacite of

and others, 1976) (Pleistocene)—Flows and domes of moderately por-

phyritic dacite. Age of 0.44±0.03 Ma. Maximum thickness about 150 m

porphyritic, hornblende-biotite dacite. Maximum exposed thickness

flows, domes, and minor pyroclastic deposits of moderately porphyritic

dacite. Most specimens contain one or more 1-cm-diameter or larger

phenocrysts of feldspar and diabasic-textured mafic inclusions. Exposed

porphyritic dacite. Base of unit along south margin shows patches of black

glassy porphyritic dacite. Age of 0.48±0.03 Ma. Maximum thickness

Dacite of Clearlake Highlands (Pleistocene)—Flows of moderately por-

phyritic dacite; lacks diabasic-textured mafic inclusions. Interbedded with

and overlain by the Lower Lake Formation (II). Age of 0.52±0.06 Ma.

Rhyodacite of Peacock Point (Pleistocene) — Flow or domes of moderately

Rhyolite of Thurston Creek (Pleistocene) —See description under central

Lower Lake Formation (named by Rymer, 1981; includes basin deposits

of Wildcat Canyon of Hearn and others, 1976) (Pleistocene)—Lacus-

trine, marsh, fluvial, pyroclastic, and volcaniclastic deposits in an ancestral

Clear Lake basin. West of and at Lower Lake, composed of dominantly

sandstone and siltstone and lesser amounts of claystone, diatomaceous

siltstone, conglomerate, and tuff; conglomerate contains pebbles and

cobbles of chert, andesite, dacite, the rhyodacite of Diener Drive (dd),

and, rarely, obsidian. Near Lower Lake, unit contains beds of pebbly

fossiliferous limestone up to 1 m thick and numerous beds of tuff and

lapilli tuff of mafic to silicic composition up to 1.3 m thick (Rymer, 1981).

North of Lower Lake, unit contains siliceous siltstone and mudstone,

which commonly have root casts and diatom and gastropod fossils, and

also contains 0.3-3-m-thick beds of orange limonitic mudstone that are

especially prominent within Redbank Gorge, 0.5–2-m-thick beds of tan to

gray, surgelike lapilli tuff of basaltic andesite, and rare beds of carbona-

ceous mudstone. Unconformably overlies the Cache Formation (QTc);

adjacent to and overlies the rhyodacite of Diener Drive (dd); interbedded

with and overlies the dacite of Clearlake Highlands (dhi); overlain by the

dacites of Thurston Lake (dt), Pinkeye Lake (dpl), and Cache Creek (dcc).

and flow (brf) of the basaltic andesite of Roundtop Mountain. Probable

age range from 0.4 to 0.65 Ma. Thickness 0-25 m in upper Wildcat

Canyon, thickness of tilted sequence at Lower Lake at least 200 m,

Rhyodacite north of Bald Mountain (formerly biotite-hornblende dacite

of Rockledge of Hearn and others, 1976) (Pleistocene)—Small plug of

closely sheeted and foliated biotite-hornblende rhyodacite. Biotite and

hornblende both produce the foliation, which tends to parallel contact

near border of plug. Outcrop is labeled "Rockledge" on atlas sheet 4 of

Becker (1888). Intrudes the Franciscan assemblage (KJf). K/Ar age of

 $1.2\pm0.3$  Ma on biotite; reversed magnetic polarity. Exposed vertical

beu Early basaltic rocks, undivided (Pleistocene and Pliocene)—See descrip-

QTc Cache Formation (Pleistocene and Pliocene)—See description under

NORTHEAST AREA

Martinez Formation (Paleocene)—Marine sandstone and lesser amounts

Basin deposits of Clear Lake (Holocene and Pleistocene)—See descrip-

Basaltic andesite of High Valley (Holocene?)—Quartz-bearing olivine-

tion under central area and Mount Konocti. Shown only in cross section

plagioclase-pyroxene basaltic andesite, comprising cinder cone and five aa

flows mapped separately. Lava flows emerged at the southwest base of

the cone. Major volume of lava blocked the preexisting drainage of High

Valley into North Fork Cache Creek and poured eastward 5.5 km, where

oldest flow (bhvf<sub>1</sub>) overlies highest terrace deposit (t<sub>1</sub>); lesser volume

flowed westward and is partly overlain by alluvium (al) and colluvium (co)

in High Valley. A young age for this unit, probably less than 10,000 yr

B.P., is suggested by young morphology of the cone, its 15-m-deep

summit crater, and chaotic blocky flow surfaces. Aggregate thickness of flows could be as great as 100 m in NW1/4 sec. 25, T. 14 N., R. 7 W.

Pyroclastic deposits—100-m-high cinder cone of Round Mountain and

Young pyroclastic deposits (Holocene and Pleistocene)—See description

Younger basaltic andesite of Clearlake Oaks (Pleistocene)—Sparsely

porphyritic olivine-pyroxene-plagioclase basaltic andesite. Probably over-

lies the andesite of Sulphur Bank (asbf, asbp); overlain by alluvium (al)

proclastic deposits—180-m-high cinder cone of bomb, block, and lapilli

tephra. Called "north crater" by Becker (1888, p. 246). Extensively

Older basaltic andesite of Clearlake Oaks (Pleistocene)—Cinder cone,

eroded and partly buried, of bomb, block, and lapilli tephra of plagioclase-

olivine-clinopyroxene basaltic andesite. Partly concealed by the young

pyroclastic deposits (yp). More eroded and distinctly older than cinder

cone of the younger basaltic andesite of Clearlake Oaks (bycp). Exposed

ritic olivine basaltic andesite. Contains 1 percent inclusions of milky quartz

and Franciscan assemblage rock fragments (KJf) that contain milky quartz

Unit is probably younger than the andesite of Sulphur Bank (asbf, asbp)

because tephra of the basaltic andesite of Rattlesnake Island is absent

beneath the andesite of Sulphur Bank (asbf) in the Sulphur Bank Mine.

Basaltic andesite of Rattlesnake Island (Pleistocene)—Sparsely porphy-

nearby deposits of bomb, block, and lapilli tephra

under central area and Mount Konocti

and the basin deposits of Clear Lake (bcl)

low—Exposed thickness 10 m; small areal extent

modified by quarrying

thickness about 130 m

of mudstone and conglomerate; see Brice (1953) and Swe and Dickinson

northeast area

(1970) for further description

exposed thickness in Redbank Gorge 20 m

Basin deposits of lower Thurston Creek—See description under central area

porphyritic rhyodacite. Probably older than the dacite of Clearlake

Dacite south of Thurston Lake (formerly dacite of Vulture Rock of Hearn

drainage through Pinkeye Lake. Maximum thickness 2–3 m

Dacite of Cache Creek (Pleistocene)—Dome and rubbly flows of sparsely

Dacite of Wheeler Point (Pleistocene)—Domes and flows of moderately

Konocti Bay (dkb). Maximum exposed thickness 200 m

dpf Dacite of Plum Flat (Pleistocene)—Flows and domes of abundantly

Dacite of Thurston Lake (Pleistocene)—Two or possibly three coalesced

Dacite of Pinkeye Lake (Pleistocene)—Flows and domes of moderately

Maximum exposed thickness 50 m

Older basin deposits (Pleistocene)

area and Mount Konocti

Highlands (dhi). Exposed thickness about 20 m

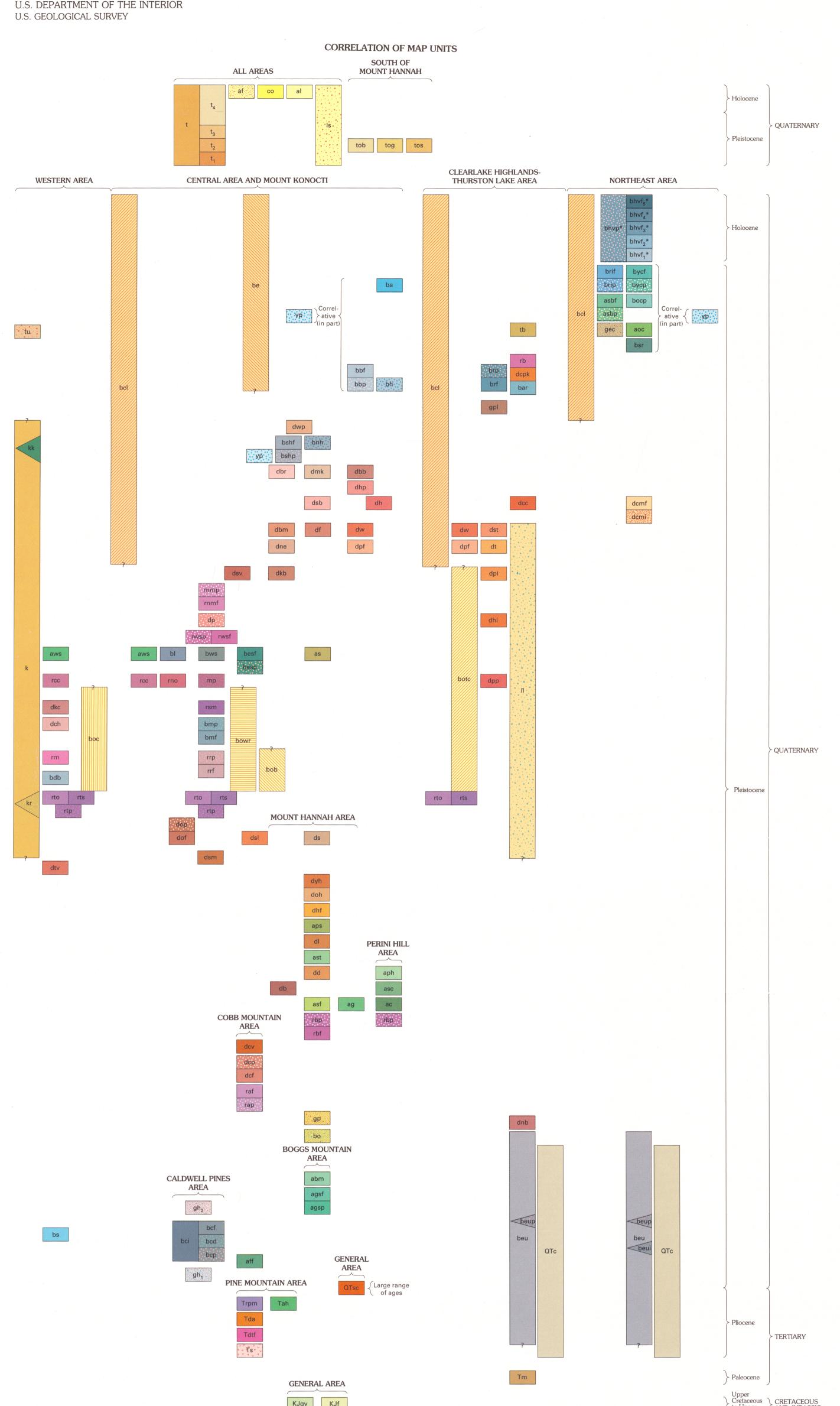
Dacite of Clearlake Park (Pleistocene)—Blocky flow of glassy olivine-

andesite of Arrowhead Road (bar). Exposed thickness 10–15 m

Basaltic andesite of Arrowhead Road (Pleistocene)—Subdued cinder

tion under central area and Mount Konocti. Shown only in cross section

nonporphyritic obsidian and perlite and locally preserved carapace of



**DESCRIPTION OF MAP UNITS** [This map supersedes U.S. Geological Survey Open-File Report 76-751 (Hearn and others, 1976). Descriptions of map units are grouped by geographic area in approximate increasing age. Summaries of the evolution, chemistry, structure, and tectonic setting of the Clear Lake Volcanics are given in Hearn and others (1981) and Donnelly-Nolan and others (1981). The geology of parts of the area underlain by the Cache Formation is based on mapping by Rymer (1981); the geology of parts of the areas underlain by the Sonoma Volcanics, Franciscan assemblage, and Great Valley sequence is based on mapping by McLaughlin (1978). Units are named primarily on the basis of SiO<sub>2</sub> content: basalt less than 53, basaltic andesite 53-59, andesite 59-63.5, dacite 63.5-68, rhyodacite 68–72, and rhyolite greater than 72 percent SiO<sub>2</sub>. A few units that have a range of  $SiO_2$  content are named for the dominant  $SiO_2$  value, or are named according to petrographic criteria that suggest affinity to other units of the same petrologic group. Percentages of minerals are for phenocrysts and are estimated mainly from hand specimens. Size of minerals is maximum dimension. Size of clasts in sedimentary and pyroclastic deposits is maximum dimension. Where vent locations for volcanic units are not shown on the map or discussed, the vent area is assumed to be within or near present outcrops. Known or inferred sequence of units is shown in the correlation chart, in the cross sections, or can be determined from the map. For some key units, position in the sequence is given in the description. Most ages are potassium-argon (K/Ar) ages determined for whole-rock samples by Donnelly-Nolan and others (1981), unless otherwise noted. A few ages are carbon-14 ages or were estimated from geologic relationships. Magnetic polarities are from Mankinen and others (1978, 1981) or were determined in the field by B.C. Hearn, Jr., using a portable fluxgate magnetometer. Maximum thickness of units is unknown unless specified. Thickness for most units is

\* See DESCRIPTION OF MAP UNITS for age assignment

estimated from topographic relief except where drill-hole data was available]

Surficial Deposits Alluvium (Holocene)—Flood-plain, channel, and lake deposits of clay, silt, sand, and gravel. Locally may include youngest part of the basin deposits of Clear Lake (bcl) Colluvium (Holocene)—Slope deposits of silt, sand, and coarser angular clasts. Mapped only where extensive or where covers critical contact of

Alluvial-fan deposits (Holocene)—Coarse deposits of sand and generally angular pebbles and boulders derived from nearby upslope sources Landslide deposits (Holocene and Pleistocene)—Unsorted angular blocks and soil. Largest landslide deposit is on the west side of Mount Konocti; consists of the dacite of Benson Ridge (dbr) and rhyodacite of Soda Bay

(dsb) and has an inferred maximum thickness of at least 250 m. Contact between adjacent landslide deposits on map separates landslides of different age or direction of movement Terrace deposits, undivided (Holocene and Pleistocene) - Dominantly pebble to boulder gravel and minor sand. Four terrace levels mapped in the lower parts of the Kelsey Creek, Sweetwater Creek, Cole Creek, McIntire Creek, and North Fork Cache Creek drainages; terrace levels probably are correlative between adjacent drainages. In the Cole and McIntire Creek drainages, gravel is a mixture of clasts of volcanic rock and resistant components of gravel recycled from the Kelseyville Formation. Maximum thickness about 5 m. Terrace levels differentiated from youngest (lowest) to oldest (highest)

Unit 4 (Holocene and Pleistocene) Unit 3 (Pleistocene) Unit 2 (Pleistocene) Unit 1 (Pleistocene)

SOUTH OF MOUNT HANNAH

Older terrace deposits of upper Kelsey Creek area (Pleistocene) Terrace deposits of Sulphur Creek—Pebble to small boulder-size gravel Contains clasts of the andesite of Boggs Mountain (abm), rhyodacite of Diener Drive (dd), obsidian from the rhyolite of Bonanza Springs (rbp) andesite of Split Top Ridge (ast), rhyodacite of Loch Lomond (dl), and abundant clasts of sandstone and shale of the Great Valley sequence (KJgv). Source local and to east; deposited by an ancestral west-flowing Sulphur Creek whose drainage basin extended farther east than at

present. Maximum thickness 1 m tob Terrace deposits of Bottle Rock Road—Interbedded fluvial sand and pebble-boulder gravel. Contains abundant clasts derived from the Fran ciscan assemblage (KJf), and subordinate clasts of the andesite of Boggs Mountain (abm), rhyodacite of Cobb Mountain (dcf, dcp), dacite of Cobb Valley (dcv), and rhyolite of Alder Creek (raf, rap) that locally are up to 3 m diameter. Source to east and southeast; deposited in an ancestral Kelsey Creek drainage. Maximum thickness 20 m

g Terrace deposits of Glenbrook—Fluvial sand, silt, and gravel of pebble-size to rare small boulder-size clasts. Gravel forms up to 40 percent of some outcrops; gravel consists of 80 percent chert and greenstone clasts of the Franciscan assemblage (KJf), as well as pebbles reworked from Franciscan assemblage conglomerates. 15 percent clasts of the rhyodacite of Cobb Mountain (dcf, dcp), and 5 percent clasts of the rhyolite of Alder Creek (raf, rap). Locally contains a 20- to 30-cm-thick bed of altered tuff or lacustrine diatomite. Similar gravels occur in sec. 5, T. 11 N., R. 8 W. Source to south and southeast; deposited in an ancestral Alder Creek drainage. Maximum thickness 25 m

WESTERN AREA

Basin deposits of Clear Lake (Holocene and Pleistocene)—See descrip tion under central area and Mount Konocti. Shown only in cross section Upland terrace deposits (named by Soil Mechanics and Foundation Engineers, Inc., 1967; termed older alluvium by Rymer, 1978, 1981) (Pleistocene)—Poorly stratified sand, gravel, gravelly clay, and clayey sand. Occurs in Big Valley in a down-faulted block bounded on the south by the Wight Way fault and on the north by an unnamed fault; fault boundaries in part from Soil Mechanics and Foundation Engineers, Inc. (1967). Extent and age poorly known; apparently overlies the Kelseyville Formation (k) and is older than the high terrace deposits  $(t_1)$ . Thickness

cone (dated by Teledyne Isotopes, M.J. Rymer, oral commun., 1975)

found 45 and 3 m below the base of the Kelsey Tuff Member in sec. 26

and sec. 27, T. 13 N., R. 9 W., respectively, are both older than 38,000

yr by the carbon-14 method. Age of the exposed base of the Kelseyville

Formation is approximately 0.60 Ma, based on the average age of the

rhyolite of Thurston Creek (Donnelly-Nolan and others, 1981); age of

dch Rhyodacite of Camels Hump (Pleistocene)—Flows, domes, and shallow 34 to 44 m (Rymer, 1978, p. 85) ntrusions of moderately porphyritic biotite-hornblende rhyodacite. Intrudes the rhyolite of Thurston Creek, intrudes and overlies the basaltic Kelsevville Formation, undivided (named by Rymer, 1981; includes andesite diatreme breccia (bdb) and the rhyolite of Milky Creek (rm), and pyroclastic and lake deposits of Shaul Valley area of Hearn and is overlain by the rhyodacite of Kelsey Creek (dkc) and Kelseyville Forothers, 1976) (Pleistocene)—Well-bedded, lacustrine, deltaic, and fluvial mation (k). Biotite-hornblende dacite of normal magnetic polarity in S1/2 deposits consisting of pebble-cobble conglomerate, pebbly sand, sand, sec. 26, T. 13 N., R. 9 W. tentatively correlated with this unit. Age of silt, diatomaceous siltstone, claystone, pumiceous sandstone, and lapilli 0.59±0.02 Ma on sanidine. Maximum exposed thickness 80 m tuff. Clasts in conglomerates are 80–95 percent Franciscan assemblage rocks (chert, greenstone, graywacke of KJf) and serpentinite (Jsp), and Rhyolite of Milky Creek (Pleistocene)—Flow or flows, coarse blocks and 5-20 percent volcanic rocks from the dacite of Cobb Valley(?) (dcv), bombs, coarse pumice breccia, nonbedded and poorly bedded pyroclasrhyolite of Alder Creek (raf, rap), andesite of Boggs Mountain (abm), and tic breccia, minor lapilli tuff, and minor mudflow deposits of commonly obsidian (rto) from the rhyolite of Thurston Creek. Clasts are derived perlitic, crystal-rich biotite rhyolite; locally, massive pyroclastic breccia from terrain to the south, southeast, or southwest. The formation was consists of mainly biotite-free crystal-rich pumice; locally pyroclastic brecdeposited in an ancestral Clear Lake basin. The Kelseyville Formation is cia is rich in brown scoria derived from the basaltic andesite diatreme probably co-extensive with similar deposits concealed at depth in Big breccia (bdb), fragments of glassy dacite, fragments of chert, greenstone,  $^{\prime}$ alley and beneath Clear Lake. Wood (sample number W-3420, U.S and graywacke derived from the Franciscan assemblage (KJf), and frag-Geological Survey Radiocarbon Laboratory, Reston, Va.) and a conifer ments of serpentinite (Jsp). Intrudes and contains inclusions of the basal-

exposed top of the Kelseyville Formation is estimated to be 0.13 Ma by Rymer (1981), but is more likely 0.35 to 0.45 Ma based on ages of probable sources of the Kelsey Tuff Member on or south of Mount Konocti. Upper part of the Kelseyville Formation is eroded and lowest

part is unexposed; thickness in map area about 390 m; minimum total thickness about 500 m (Rymer, 1981) Kelsey Tuff Member (named by Rymer, 1981; formerly aquifer ash of Hearn and others, 1976)—Upper part consists of 40–170 cm of poorly bedded, unsorted, gray to light-tan ash, lapilli, lapilli tuff, and tuff of crystal-poor, slightly vesicular basaltic andesite; lower part consists of 10-40 cm of interbedded tuff, claystone, and siltstone. Upper part is composed of 95 percent basaltic andesite fragments, and 5 percent lithic fragments (dacite, greenstone, chert, graywacke, and, rarely, diabasictextured mafic fragments); average basaltic andesite fragment 0.5 cm diameter, maximum generally 6 cm diameter; basaltic andesite fragments contain about 1 percent small Franciscan assemblage inclusions. Lower part typically contains several gray to rusty 2–15-cm-thick beds of 1–3mm-diameter basaltic andesite fragments; in Shaul Valley, lower part contains angular to rounded blocks up to 0.3 m diameter of several varieties of dacite. The Kelsey Tuff Member was deposited subaqueously from airfall into lake basin; locally shows features of soft-sediment slump or redeposition, causing variable thickness. Source vent was probably one of the cinder cones on, beneath, or south of Mount Konocti. Kelsey

tic andesite diatreme breccia (bdb); contains inclusions of, and probably

overlies, the rhyolite of Thurston Creek; intruded by, and overlain by, the

rhyodacite of Camels Hump (dch). Closely resembles the rhyolite of Cole

Creek (rcc), but the rhyolite of Milky Creek is apparently older based on

a K/Ar age of  $0.60\pm0.02$  Ma on sanidine. Maximum exposed thickness

Tuff Member occurs 30-40 m below eroded top of the Kelseyville Formation (Rymer, 1981), and it is a major aguifer as deep as 70 m beneath much of southern Big Valley (Soil Mechanics and Foundation Engineers, dne Dacite north of Ely Flat (formerly older hornblende dacite of Mt. Konocti Inc., 1967). Beneath northern Big Valley, it is known to be as deep as 120 m and probably is present at greater depth. Total thickness 40–190 cm in outcrop, generally decreasing away from Mount Konocti Rhyolite-rich facies—Local facies occurring in secs. 2, 10, and 11, T. 12 N.,

elevation on Mount Konocti in NE1/4 sec. 20, T. 13 N., R. 8 W. Maximum exposed thickness about 300 m R. 9 W. Present either at the base or as much as 25 m above the base of dkb Dacite of Konocti Bay (Pleistocene)—Flows and domes of moderately the Kelseyville Formation; consists of as much as 40 m of pumice-rich porphyritic dacite. Source vent concealed, probably located north of Ely sandstone and conglomerate. Lies immediately above, or is laterally close to a section as much as 5 m thick of mudflow-deposited, massive, Flat, in sec. 21, T. 13 N., R. 8 W. Exposed thickness about 200 m rhyolitic pumice conglomerate and lapilli tuff (rtp) of the rhyolite of dsv Dacite of Shaul Valley (Pleistocene)—Domal flows of sparsely porphyritic Thurston Creek

ornblende-biotite dacite. Probably overlies the basaltic andesite east of kc Rhyodacite of Kelsey Creek (Pleistocene)—Flows and minor pyroclastic Shaul Valley (besf, besp); overlain by the dacite of Benson Ridge (dbr). deposits of biotite rhyodacite. Thickness in Kelsey Creek gorge about Maximum thickness at least 130 m

Speckled andesite (Pleistocene)—Shown only in cross section A-A'. Andesite has distinctive speckled texture due to the presence of 10–15 percent of 0.25–2-mm plagioclase phenocrysts. No outcrops of the speckled andesite are known, but occurs as inclusions in the young pyroclastic deposits (yp) between Soda Bay and Fraser Point and at 120-m depth in a water well in NE1/4SE1/4 sec. 9, T. 13 N., R. 8 W. Inferred to underlie much of the low part of the eastern flank of Mount Konocti. Probably older than the rhyodacites of Horseshoe Bay (dh) and Soda Bay (dsb) and the dacites of Fraser Point (df) and Henderson Point (dhp). Thickness unknown Older basin deposits (Pleistocene)

Basin deposits southeast of Camel Back Ridge—Poorly exposed lacustrine, alluvial, and minor pyroclastic deposits in small local basin. Consists of silty claystone, diatomaceous siltstone, and lapilli tuff of rhyolitic pumice. Unit contains fragments of black obsidian and of pink and gray dacite, sparse 1-3-cm-diameter pebbles of vesicular gray dacite, abundant 1-3-mmdiameter quartz, and sparse 1-mm-diameter biotite flakes. Lapilli tuff of crystal-rich biotite rhyolite pumice is locally cemented by siliceous sinter. Probably overlies obsidian (rto) of the rhyolite of Thurston Creek and steeply tilted beds of the Kelseyville Formation (k) on the north side of basin. Exposed thickness about 2 m; maximum thickness probably about

bowr Basin deposits of Wildcat Road—Poorly exposed claystone, siltstone, diatomaceous siltstone, pumiceous sandstone, and conglomerate. Conglomerate contains pebbles of obsidian, andesite or dacite, and chert. Overlies obsidian (rto) of the rhyolite of Thurston Creek, andesites of Split Top Ridge (ast) and Glenview (ag), rhyodacite of Diener Drive (dd), and older dacite of Mount Hannah (doh). Exposed thickness about 15 m

Basaltic andesite diatreme breccia (Pleistocene) - Altered, coarse, non-

edded to poorly bedded diatreme breccia and derivative pyroclastic

breccia of gray-to-brown basaltic andesite scoria. Breccia contains blocks

up to 30 cm diameter of black, glassy, crystal-poor dacite and serpentin-

ite, as well as blocks up to several m diameter of conglomerate containing

clasts of chert, graywacke, and serpentinite. Breccia also contains

rounded chert pebbles; angular fragments of obsidian (rto) from the

rhyolite of Thurston Creek; angular fragments of chert, graywacke, and

shale from the Franciscan assemblage (KJf); and a 2-m-diameter block of

schistose amphibolite. Unit in part hydrothermally altered in SW corner

sec. 36, T. 13 N., R. 9 W. Maximum exposed thickness about 35 m

area and Mount Konocti. Subdivided into three map units

rts Stony rhyolite

rtp Pyroclastic deposits

Rhyolite of Thurston Creek (Pleistocene)—See description under central

Dacite of Tyler Valley (Pleistocene)—Isolated, irregular to dikelike shallow

intrusions of sparsely porphyritic dacite west of the main Clear Lake

volcanic field. Intrudes the Franciscan assemblage (KJf). Ages of

 $0.86\pm0.02$  Ma and  $0.82\pm0.02$  Ma on sanidine do not fit normal magnetic

polarity; however, age of  $0.711\pm0.011$  Ma on sanidine by the 40/39

argon method (J.D. Obradovich, oral commun., 1994) fits normal

Olivine basalt north of Sweetwater Creek (Pleistocene)—Poorly exposed

mall diatreme composed of light-brown, partly weathered tuff and lapilli

tuff of olivine basalt and sparsely porphyritic andesite. Consists of 80–100

percent of 1–25-mm-diameter subrounded fragments of vesicular olivine-

rich basalt that, in part, have cores of olivine phenocrysts, and 0-20

percent of separate olivine crystals and fragments of vesicular or solid,

phenocryst-poor andesite of unknown derivation that become more

abundant at top of exposure. Overlain by basal part of the Kelseyville

Formation (k). Possibly similar in age to the olivine basalt of Caldwell

Pines (bcf, bci, bcd, bcp) based on similar abundance of olivine. Exposed

Basin deposits of Clear Lake—Shown only in cross section. Deltaic,

lacustrine, marsh, and marginal fluvial deposits composed of gravel, sand,

silt, clay, mud, peat, and volcanic ash (Sims, Adam, and Rymer, 1981).

Age ranges from present to greater than 0.175 Ma based on paleomag-

netic and preliminary pollen analyses (core CL-80-1, Sims, Rymer, and

Perkins, 1981). Lower part may overlie or grade into the Kelseyville (k)

and Lower Lake (II) Formations. Maximum thickness greater than 177 m

composed of clay, silt, sand, and gravel in subsidence basin surrounding

Sugarloaf. Contains fragments of the dacite of Plum Flat (dpf) and various

dacites from the Mount Konocti volcanic edifice. Deposits derived from

surrounding slopes and ancestral upper drainage basin of Thurston Creek.

Age ranges from present to probably less than 0.5 Ma. Exposed thickness

coarse ash and tuff, lapilli tephra, and lapilli tuff; blocks and bombs are

locally abundant; commonly weathered to dark-orange soil. Typically

exhibits alternating coarse-grained (0.5-15 cm) and fine-grained (<2

mm) layers that are 1-15 cm thick and show graded bedding or, rarely,

reverse-graded bedding. Dominant fragments are white, yellow, and

brown hydrothermally altered scoria, or gray-to-black fresh scoria mainly

of andesite and basaltic andesite and, rarely, of dacite. Unit contains 1–20

percent of 1–100-cm-diameter fragments of older units of the Clear Lake

Volcanics, and fragments of chert, serpentine, greenstone, graywacke,

and shale from the Franciscan assemblage (KJf) and Great Valley

sequence (KJgv). Unit consists dominantly of airfall deposits (rarely

reworked by water or by slumping) and contains lesser amounts of maar

deposits from underwater or phreatic eruptions (based on presence of

mud-armored lapilli and distinct bomb sags) and base-surge deposits.

Sources are: (1) inferred vents suggested by arcuate segments of the Clear

pyroclastic deposits along the lake shore; (2) vent beneath Little Borax

Lake maar; (3) inferred vent north-northwest of the Bell Mine; and (4)

cinder cones east of Clearlake Oaks. Wide age range; probably correlates

in part with ash beds in sediments beneath Clear Lake; youngest ash bed

beneath Clear Lake is in core 7 taken midway between Fraser Point and

Pirates Cove and is about 11,000 years old (Sims, Adam, and Rymer,

1981); oldest part is near Bell Mine, is apparently overlain by the basaltic

andesite south of Howard Peak (bshf, bshp), and is about 0.35 Ma.

Basaltic andesite of Anderson Island (Pleistocene)—Flow(?) of blocks up

1–2 percent black, cuspate, partially melted inclusions of the phenocryst-

rich rhyodacite of Horseshoe Bay (dh). Covers area 10x10 m above lake

level; source close to outcrop on north shore of Anderson Island. Exposed

Basaltic andesite of Buckingham Peak (Pleistocene)—Olivine basaltic

andesite. Unit is partly removed by landslide that may be related to

eruptions which produced the maar at Little Borax Lake; fragments of this

Rhyodacite of Wright Peak (Pleistocene)—Flows and dome of coarsely

and abundantly porphyritic biotite rhyodacite. Contains 1–5 percent of

3-10-mm pyroxene-plagioclase mafic inclusions having a granular tex-

ture. Surfaces of flows on east slope of Wright Peak show arcuate flow

ridges, which are known locally as the upper "lava rings" (Mauldin, 1960).

Overlies the basaltic andesites south of Howard Peak (bshf, bshp) and

north of Howard Peak (bnh). Youngest of the rhyodacite and dacite units

on Mount Konocti; age of  $0.35\pm0.02$  Ma on sanidine. Maximum thick-

Basaltic andesite south of Howard Peak (Pleistocene) - Olivine-

clinopyroxene basaltic andesite. Contains 0–0.25 percent of inclusions of

1-5-mm-diameter potassium feldspar, plagioclase, and quartz and 0-1

percent of 2-40-mm-diameter inclusions of solid, or frothy, partially

melted dacite and biotite rhyolite. Forms eroded pyroclastic blanket on

high south slope of Mount Konocti. Overlies the dacites of Benson Ridge

the young pyroclastic deposits (yp) 1 km west of Bell Mine. Maximum

low—Subordinate part of unit; forms ledge. Maximum thickness 5 m

Basaltic andesite north of Howard Peak (Pleistocene)—Phenocryst-poor

yroclastic deposits—Dominant part of unit; bomb, block, and lapilli tephra

pasaltic andesite. Coarse bomb, block, and lapilli tephra, and thin ves-

icular flow covering a 50x20 m area. Contains rare inclusions of 1–2-mm-

diameter plagioclase, potassium feldspar, and quartz and 0.5–1 percent of

2-mm- to 30-cm-diameter solid or frothy, partially melted inclusions of

dacite and biotite rhyolite. Forms pair of eroded ridges that are subdued

remnants of low cinder cone. Probably contemporaneous with the basaltic

andesite south of Howard Peak (bshf, bshp); overlain by the rhyodacite of

Wright Peak (dwp) and probably overlain by the basaltic andesite of Buckingham Peak (bbf, bbp). Maximum exposed thickness about 130 m

erately porphyritic dacite, commonly spherulitic. Most feldspar and quartz

phenocrysts are 1-3 mm in size, in contrast with the larger phenocrysts in

other dacite and rhyodacite units high on Mount Konocti. Probable source

is 0.2 km west-northwest of Wright Peak, at or close to the vent symbol;

vent is a partially caved, near-vertical passage reported to be of great

vertical extent (Mauldin, 1960, p. 53–55) and is surrounded by blocks of

oxidized dacite and welded dacite spatter. Maximum thickness less than

abundantly porphyritic biotite dacite. Contains 1-2 percent of diabasic-

textured pyroxene-plagioclase mafic inclusions as much as 1.2 m diame-

itic dacite. Contains 0.5 percent of granular-textured pyroxene-

plagioclase mafic inclusions. Source vent concealed near present summit

of Buckingham Peak. Youngest dacite unit on Buckingham Peak. Maxi-

otite dacite. Similar in appearance to the rhyodacite of Soda Bay (dsb),

but dacite of Henderson Point contains fewer large sanidine phenocrysts.

Probable vent area just south of present summit of Buckingham Peak.

abundantly porphyritic biotite rhyodacite. Additional extent concealed

beneath Big Valley and Clear Lake. Unit may represent more than one

eruption; source vents lie beneath Wright Peak and possibly 0.8 km

north-northwest of Howard Peak. Major flow moved west and north

forming Clark Peak and Dali-Dona; smaller flow shows prominent arcuate

flow ridges, known locally as lower "lava rings" (Mauldin, 1960) on the

east slope of Wright Peak. Average of 2 ages is 0.42 Ma; probably

younger than the dacite north of Ely Flat (dne) and older than the

rhyodacite of Wright Peak (dwp), which is dated at 0.35 Ma. Maximum

hyodacite; perlitic on Anderson Island and shore of Horseshoe Bay,

probably caused from flowing into water. On Anderson Island, this

rhyodacite was formerly the biotite dacite of Kamdot of Hearn and others

(1976). Contains abundant diabasic-textured mafic inclusions, up to 0.5

m diameter, that make up as much as 25 percent of flow on Anderson

Island: contains sparse 5-25-cm-diameter inclusions of the dacite of

Fraser Point (df). Source concealed above 3,300-ft elevation on Bucking-

ource vent located near western limit of unit's outcrop area, at about

3,300-ft elevation on east side of ridge that joins Howard Peak and

Buckingham Peak. Probably overlain by the rhyodacite of Horseshoe Bay

altered to white opalized dacite at Bell Mine. Source vent now mostly

buried at about 3,300-ft elevation southeast of South Peak. Maximum

of Hearn and others, 1976) (Pleistocene)—Flows of moderately porphy-

ritic hornblende dacite. Probable source vent concealed near 3,000-ft

ham Peak. Age of 0.35±0.02 Ma on sanidine. Maximum exposed

**Dacite of Fraser Point (Pleistocene)**—Flows of sparsely porphyritic dacite.

**Dacite of Bell Mine (Pleistocene)**—Flow of moderately porphyritic dacite;

Rhyodacite of Horseshoe Bay (Pleistocene)—Flow of coarsely porphyritic

Dacite of Henderson Point (Pleistocene)—Flows of coarsely porphyritic

Rhyodacite of Soda Bay (Pleistocene)—Flows and domes of coarsely and

Ridge and east of Shaul Valley. Maximum exposed thickness 300 m

dbr Dacite of Benson Ridge (Pleistocene)—Flows and domes of coarsely and

dbb Dacite of Buckingham Bluffs (Pleistocene)—Flow of moderately porphy-

mum thickness 150 m

thickness about 400 m

thickness 230 m

(dh). Exposed thickness 200–300 m

exposed thickness 120 m

Maximum exposed thickness 200 m

Dacite of Mount Konocti (Pleistocene) — Flows of medium-grained, mod-

(dbr) and Mount Konocti (dmk); may be interbedded with or grade into

1.7 m diameter of slightly vesicular olivine basaltic andesite; contains

Maximum exposed thickness about 60 m

east of Buckingham Peak

lapilli tephra. Maximum thickness 50 m

of pyroclastic deposits about 80 m

exposed thickness about 50 m

bbf Flow—Maximum thickness 10 m

Basin deposits of Ely Flat—Lacustrine, fluvial, and coarse alluvial deposits

magnetic polarity. Exposed vertical extent about 60 m

CENTRAL AREA AND MOUNT KONOCTI

Younger basin deposits (Holocene and Pleistocene)

about 25 m; drilled thickness about 120 m

Young pyroclastic deposits (Holocene and Pleistocene)—Well-bedded

Basin deposits of lower Thurston Creek—Well-bedded lacustrine and deltaic deposits composed of clay, silt, diatomaceous siltstone, pumiceous sandstone, and pyroclastic tuff and lapilli tuff. Rarely contains gastropod molds, and some beds are rich in silicified plant debris, or are locally rich in iron oxide, causing them to weather orange or red. Locally contains pebbles of chert, greenstone, graywacke, shale, and the glassy rhyodacite of Diener Drive (dd). North of Manning Flat, basal part contains locally derived boulder conglomerate of obsidian (rto) and pumice (rtp) from the rhyolite of Thurston Creek in tuffaceous matrix; boulder conglomerate is overlain by 30-60 cm of evenly bedded, light-gray dacitic(?) pumice of 0.25-1.5 cm diameter. Exposed thickness about 30 m

Basin deposits of Bonfield Flat (formerly basin deposits of Konocti Conservation Camp of Hearn and others, 1976)—Poorly exposed, white, rhythmically layered beds of diatomaceous claystone and siltstone, finegrained tuffaceous sandstone, and a few beds of tuffaceous sandstone containing pebbles and cobbles of obsidian and dacite. Overlies the rhyodacite of Diener Drive (dd) and obsidian (rto) of the rhyolite of Thurston Creek; may be contemporaneous with the basin deposits of lower Thurston Creek (botc) and upper part of the Lower Lake Formation (II). Thickness at least 40 m Rhyolite north of McIntire Creek (formerly dacite of Cleft Hill of Hearn and others, 1976) (Pleistocene) — Moderately crystal-rich, locally perlitic, biotite rhyolite. Youngest unit in complex sequence east of Mount Olive;

deposits (rwsp) of the rhyolite west of Sugarloaf, obsidian (rto) of the rhyolite of Thurston Creek, and rhyolite northeast of Mount Olive (rno). Maximum thickness about 25-40 m Pyroclastic deposits—Coarse bomb and block tephra and lapilli tuff. Contain sparse obsidian fragments and, close to source vent, contain blocks of vesicular biotite rhyolite up to 1.5 m in diameter

rnmf Flows—Small lateral extent

overlies flows (bmf) of the basaltic andesite of McIntire Creek, pyroclastic

dp Dacitic pyroclastic deposit north of McIntire Creek (Pleistocene)—Lighttan pyroclastic breccia. Contains blocks of biotite dacite and biotitehornblende dacite up to 60 cm diameter, sparsely porphyritic obsidian fragments up to 5 cm diameter derived from the rhyolite of Thurston Creek (rto) or the rhyolite south of McIntire Creek (rsm), and rare small fragments of chert; blocks of biotite rhyolite absent. Overlies the rhyolite west of Sugarloaf (rwsp), basaltic andesite west of Sulphur Mound Mine (bws), mixed pyroclastic deposit west of Sulphur Mound Mine (mp), and obsidian (rto) of the rhyolite of Thurston Creek. Maximum thickness about

> Rhyolite west of Sugarloaf (formerly biotite rhyolite pyroclastic deposits west of Sugarloaf of Hearn and others, 1976) (Pleistocene)—Crystalrich biotite rhyolite. Exposed area is 1 km<sup>2</sup>, but concealed extent may exceed 3 km<sup>2</sup>; present in both Magma 1 Watson and in Getty 1 Kettenhofen drill holes. Source probably near present outcrops northwest or west of Sugarloaf. Scattered fragments of this rhyolite occur on top of the obsidian (rto) of the rhyolite of Thurston Creek as much as 3 km east-southeast of Ely Flat. Overlain by the dacites of Konocti Bay (dkb) and north of Ely Flat (dne). Age of  $0.54\pm0.02$  Ma on sanidine. Maximum exposed thickness 65 m

rwsf Flow—Perlitic glassy crystal-rich biotite rhyolite. West of Ely Flat rwsp: Pyroclastic deposits—Pyroclastic breccia and lapilli tuff; mostly nonbedded to poorly bedded, only locally well bedded. Biotite rhyolite pumice lapilli and blocks of pumice and lithic biotite rhyolite, both up to 1 m diameter, make up 90–95 percent of deposit. Also contains lithic fragments and blocks up to 70 cm diameter of biotite-hornblende dacite resembling the rhyodacites of Sugarloaf (dsl) or Mount Olive (dof, dop), diabasic-textured mafic inclusions up to 40 cm diameter, fragments of basaltic andesite, and rare fragments and blocks up to 15 cm diameter of the black glassy deposits, locally reworked by water; local well-bedded airfall layers 1–15 cm thick contain pumice fragments up to 12 cm diameter, fragments of chert and graywacke averaging 6 mm diameter, and abundant clear quartz grains of 1–3 mm diameter

locks and bombs, and pyroclastic breccia of sparsely porphyritic basaltic andesite. Overlies and contains partially melted inclusions of the rhyodacite of Mount Olive (dop, dof) and rhyolite northeast of Mount Olive (rno). Maximum exposed thickness 50 m Basaltic andesite east of Shaul Valley (Pleistocene) - Basaltic andesite Contains vesicular, partially melted blocks of crystal-rich dacite that lack visible biotite or hornblende. Source near main exposure. Overlain by the

Basaltic andesite of Lower Lake Road (Pleistocene)—Flows, coarse

dacites of Benson Ridge (dbr) and Shaul Valley (dsv); possibly contemporaneous with the basaltic andesite of Lower Lake Road (bl). Exposed thickness about 50 m

unit are common in young pyroclastic deposits (yp) northwest, north, and Pyroclastic deposits—Bomb, block, and lapilli tephra Basaltic andesite west of Sulphur Mound Mine (Pleistocene) - Porphyritic plagioclase-olivine basaltic andesite. Small flow, vent plug(?), and pyroclastic deposits of bomb, block, and lapilli tephra containing coarse bbp Pyroclastic deposits—Eroded cinder cone composed of bomb, block, and scoriaceous bombs and blocks up to 3 m diameter. Contains partially fused inclusions of the rhyodacite of Sulphur Mound Mine (dsm) up to 30 Basaltic andesite of Horseshoe Bend (Pleistocene)—Blocky flow, bombs, cm diameter. Small area of oxidized basalt and massive fresh basalt in and scoria of porphyritic olivine basaltic andesite. Deposited on flank of its SW1/4SE1/4 sec. 32, T. 13 N., R. 8 W. may be a small flow and vent plug. Overlies the mixed pyroclastic deposit west of Sulphur Mound Mine (mp), cinder-cone source that was subsequently destroyed by the explosive eruption that shaped Horseshoe Bay. Maximum thickness of flow 5 m and apparently overlies obsidian (rto) of the rhyolite of Thurston Creek and

> Andesite west of Shaul Valley (formerly basalt west of Shaul Valley of Hearn and others, 1976) (Pleistocene)—Bomb and block tephra, small flow(?), and dikes of sparsely porphyritic andesite. Vented from dikes that cut the rhyolite of Cole Creek (rcc) and rhyodacite of Mount Olive (dof, dop). Also vesicular blocks of this andesite up to 30 cm diameter (containing partially melted inclusions of the biotite rhyolite of Cole Creek (rcc)) are 5–10 percent of a mudflow(?) deposit of mixed biotite rhyolite and andesite that overlies the rhyolite of Cole Creek (rcc) in center N1/2 sec. 26, T. 13 N., R. 9 W. Maximum thickness about 5 m

(dp). Maximum thickness about 10 m

rhyodacite of Sulphur Mound Mine (dsm); overlain by the rhyolite west of

Sugarloaf (rwsp) and dacitic pyroclastic deposit north of McIntire Creek

Rhyolite of Cole Creek (Pleistocene)—Lapilli tuff, pumice breccia, and flows of predominantly perlitic, crystal-rich biotite rhyolite. Area of unit in center of N1/2 sec. 26, T. 13 N., R. 9 W. includes an overlying mudflow(?) deposit 1-3 m thick, composed of 90-95 percent biotite rhyolite fragments up to 30 cm diameter and 5–10 percent scoria from the andesite west of Shaul Valley (aws). Biotite rhyolite occurs in drill holes beneath Gunn Flat and at 123-m depth in NE1/4 sec. 15, T. 13 N., R. 9 W. in Big Valley. Apparently overlies the rhyodacite of Mount Olive (dof, dop); overlain by the Kelseyville Formation (k) and dacite of Benson Ridge (dbr); cut by dikes of the andesite west of Shaul Valley (aws). Age of

0.54±0.02 Ma on sanidine. Maximum exposed thickness 80 m Rhyolite northeast of Mount Olive (Pleistocene)—Bomb, block, and lapilli tephra, pyroclastic breccia, lapilli tuff, and tuff of crystal-rich biotite rhyolite. Poorly exposed, mostly nonbedded. Consists of pumice lapilli, pumice blocks, and lithic blocks up to 70 cm diameter; locally contains biotite-free rhyolitic pumice, blocks of crystal-poor biotite dacite up to 50 cm diameter, and fragments of chert up to 2 cm diameter; obsidian fragments absent. Closely similar to the rhyolites west of Sugarloaf (rwsp), of Milky Creek (rm), and of Cole Creek (rcc). Occurs as inclusions in, and is overlain by, the basaltic andesite of Lower Lake Road (bl). Maximum exposed thickness 25 m

mp Mixed pyroclastic deposit west of Sulphur Mound Mine (Pleistocene)— Bomb, block, and lapilli tephra, pyroclastic breccia, and lapilli tuff composed of mixed fragments of rhyolite, dacite, Franciscan assemblage (KJf), and Great Valley sequence (KJgv) in variable proportions in a clayey matrix. Poorly bedded; deposited mainly by airfall from explosive rhyolitic eruption. Contains beds rich in biotite-free, sparsely porphyritic rhyolitic pumice of average diameter 10 mm; largest blocks or bombs of that pumice, up to about 1 m diameter, occur in beds in western part of unit. Unit contains abundant 1–3-mm-diameter quartz grains. Unit also contains blocks of biotite-hornblende dacite and biotite dacite up to 25 cm diameter, sparsely porphyritic obsidian fragments up to 5 cm diameter, abundant light-gray altered fragments, rare black glassy fragments possibly of the rhyodacite of Diener Drive (dd), and abundant angular 2-10-mm-diameter fragments of shale, siltstone, sandstone, and chert from the Franciscan assemblage (KJf) and the Great Valley sequence (KJgv). Erupted either from the vent for the rhyolite south of McIntire

Creek (rsm) or another nearby source. Maximum thickness about 65 m Rhyolite south of McIntire Creek (formerly rhyolite of Hildebrand Springs of Hearn and others, 1976) (Pleistocene)—Vent breccia of pumice lapilli, pumice blocks, fused pumice breccia, and obsidian composed of sparsely porphyritic rhyolite. Fused pumice breccia outlines part of border of vent. Obsidian closely resembles obsidian (rto) of the rhyolite of Thurston Creek. Cuts flow (bmf) of the basaltic andesite of McIntire Creek. Exposed thickness 25 m

Basaltic andesite of McIntire Creek (Pleistocene)—Sparsely porphyritic basaltic andesite. Maximum thickness about 80 m in eastern part of unit, about 10 m in western part of unit bmp Pyroclastic deposits—Bomb, block, and lapilli tephra forming subdued, eroded cinder cone; basaltic andesite in cinder cone is slightly more olivine rich than in flows

Rhyolite of Red Hill Road (Pleistocene) - Porphyritic biotite-feldspar rhyolite. Age of  $0.50\pm0.02$  Ma on sanidine Pyroclastic deposits—Coarse bomb and block tephra composed of pumice and perlitic blocks as much as 1.5 m diameter and diabasic-textured andesitic inclusions as much as 0.5 m diameter (Stimac and others, 1991). Unit contains more abundant phenocrysts than flow and is slightly younger(?) than flow. Exposed thickness 40 m

rrf Flow—Biotite- and feldspar-bearing obsidian. Exposed thickness 20 m Rhyolite of Thurston Creek (Pleistocene)—Sparsely porphyritic rhyolite. Contains less than 1 percent of andesitic inclusions, most of which are less than 10 mm diameter (Stimac and others, 1991). Pyroclastic deposits (rtp), obsidian (rto), and stony rhyolite (rts) mapped separately in most of area. Dominant exposed lithology is obsidian; however, stony rhyolite is

dominant in total thickness of flows. Pumiceous carapace largely eroded from surface of flows, but locally preserved where initially thicker or where previously covered by younger deposits. Rhyolite in Camel Back Ridge area may be separate flow erupted from local vents, but probably is contemporaneous with rhyolite farther east. Ages on obsidian samples are  $0.479\pm0.015$  Ma north of Manning Flat,  $0.56\pm0.02$  Ma in unit rtp at Sulphur Mound Mine, 0.551±0.016 Ma in Bottle Rock Road road cut on Camel Back Ridge, and 0.64±0.03 Ma in SW1/4NE1/4 sec. 12, T. 12 N., R. 9 W. on Camel Back Ridge; estimated actual age of about 0.60 Ma is on the basis of ages on underlying and overlying units. Maximum exposed thickness 130 m; thickness in Republic 77–1 Boggs drill hole northwest of Mount Hannah is 300 m

Obsidian—Outer part of flow(s) rts Stony rhyolite—Devitrified inner part of flow(s) Pyroclastic deposits—Bomb, block, and lapilli tephra, pyroclastic breccia, apilli tuff, and tuff, locally present beneath flow(s). Near-vent deposits at Sulphur Mound Mine contain pumice, obsidian, and altered fragments of the rhyodacite of Sulphur Mound Mine (dsm) up to 30 cm diameter

Rhyodacite of Sugarloaf (Pleistocene)—Dome and flows(?) of abundantly nd coarsely porphyritic biotite-hornblende rhyodacite. Probable source vent is faulted dome at Sugarloaf. Maximum exposed thickness 100 m dsm Rhyodacite of Sulphur Mound Mine (Pleistocene)—Flow or dome of noderately porphyritic biotite rhyodacite, mostly altered to opalized white dacite. Oldest unit in Sulphur Mound Mine area; ages of 0.60±0.02 Ma on sanidine from altered rock sample and 0.57±0.02 Ma on sanidine from fresh rock sample. Minimum thickness 100 m

Rhyodacite of Mount Olive (Pleistocene) - Abundantly porphyritic biotitehornblende rhyodacite. Overlain by obsidian (rto) and stony rhyolite (rts) of the rhyolite of Thurston Creek, Kelseyville Formation (k), basaltic andesite of Lower Lake Road (bl), pyroclastic deposits (rwsp) of the rhyolite west of Sugarloaf, and rhyolite northeast of Mount Olive (rno); probably overlain by the rhyolite of Cole Creek (rcc) and dacite of Benson Ridge (dbr); cut by dikes of the andesite west of Shaul Valley (aws). Age of  $0.53\pm0.02$  Ma on sanidine is too young; true age must be older than the overlying rhyolite of Thurston Creek dated at about 0.60 Ma. Maximum exposed thickness 180 m

Pyroclastic deposits—Block tephra, lapilli tephra, and pyroclastic breccia

Basaltic andesite south of Round Mountain (Pleistocene)—Eroded remnant of cinder cone of block, bomb, and lapilli tephra of olivineplagioclase-pyroxene basaltic andesite. Contains up to 10 percent of 2–20-mm-diameter inclusions of Franciscan assemblage rocks (KJf). Low semicircular ridge is vestige of breached cone that is the oldest cinder cone east of Clearlake Oaks evidenced by its deeply eroded condition. Maximum thickness 50 m

> Dacite of Chalk Mountain (Pleistocene)—Slightly vesicular hypersthene dacite and soft white opalized dacite; sugary to trachytic groundmass. Dacite intrudes contorted graywacke and shale of the Franciscan assemblage (KJf) on south side of Chalk Mountain. Groundmass texture and lack of oxidized basal breccia suggest that all dacite at Chalk Mountain could be a shallow intrusive mass. At Chalk Mountain, dacite is extensively altered by recent and current H<sub>2</sub>S fumarolic activity. Source vents located at Chalk Mountain and at Stony Top. Horizontal flow foliation indicates that part of Stony Top may be a flow remnant, similar to other isolated dacite outcrops east, west, and northwest of Stony Top. Normal magnetic polarity and extensive erosion suggest age of unit is equivalent to older part of the Brunhes Normal-Polarity Chron (0–0.7 Ma) or to the Jaramillo Normal-Polarity Subchron (0.90-0.97 Ma) (of the Matuyama Reversed-Polarity Chron). Maximum thickness 60 m

dcmf Flow(s)—Erosional remnants Intrusion—In part hydrothermally altered

> Early basaltic rocks (Pleistocene and Pliocene)—Olivine basalt and olivine basaltic andesite. Abundance and size of phenocrysts vary in some individual exposures. Most occurrences contain very sparse (less than 0.1 percent) of 1–3-mm-diameter quartz inclusions. Flows are dominant and appear to be erosional remnants. Interbedded with and overlie upper part of the Cache Formation (QTc) near Clearlake Highlands; interbedded with and intrusive into middle or lower part of the Cache Formation near Bartlett Springs fault zone. Unit correlates in part with intrusions and more extensive flows of olivine basalt and basaltic andesite outside map area, such as southeast of Lower Lake 5–12 km near Spruce Grove Road and 17 km at Hell's Half Acre (Brice, 1953); east-southeast of Lower Lake 21 km at Manhattan Mine-McLaughlin Mine; southeast of Middletown 3 km at Snelly Peak, 6 km at Maguire Peak, and 10 km at Table Mountain; and east of Clearlake Oaks 23 km at Coyote Peak. Erupted from many vents scattered to the northeast, east, southeast and south of the main outcrop area of the Clear Lake Volcanics. In the map area, age of  $1.66\pm0.10~\mathrm{Ma}$ at Schoolteacher Hill; outside map area, ages of 1.33±0.53 Ma and  $1.34\pm0.29$  Ma along Spruce Grove Road,  $1.66\pm0.08$  Ma at Coyote Peak (McLaughlin and others, 1990), 1.45±0.12 Ma at Hell's Half Acre, 2.2±0.2 Ma at Manhattan Mine-McLaughlin Mine (D.H. Sorg, oral commun., 1984), and 1.96±0.06 Ma at Table Mountain. Part of this unit near the Bartlett Springs fault zone may be older on the basis of interbedded occurrence in the middle or lower part of the Cache Formation (QTc). Most flows have reversed magnetic polarity; Snelly Peak and one flow at Hell's Half Acre have normal magnetic polarity; and Maguire Peak and basalt 5.9 km southeast of Chalk Mountain have intermediate(?) magnetic polarity. Maximum thickness about 60 m

beu Undivided—Dominantly flows; lesser pyroclastic deposits and intrusive rocks Pyroclastic deposits—Bomb, block, and lapilli tephra, pyroclastic breccia,

beui Intrusive rocks—Dikes and plugs Cache Formation (revised by Rymer, 1981) (Pleistocene and Pliocene)—Siltstone, sandstone, conglomeratic sandstone, and tuff. Fluvial and locally lacustrine origin; deposited in fault-bounded basin that is older than and separate from the Clear Lake basin. In map area, contains 5–15 percent of 1-5-cm-diameter pebbles mainly of chert, vein quartz, and greenstone, and contains 1 percent or less of pebbles of graywacke, shale, and serpentinite. Contains late Pliocene mammalian fossils (Rymer, 1981). Blackeye Canyon section (Rymer, 1981) contains rhyolitic(?) tuff as much as 3.5 m thick and lapilli tuff and pyroclastic breccia (beup) of the early basaltic rocks unit as much as 2.7 m thick. Generally lacks pebbles of the Clear Lake Volcanics, except from the early basaltic rocks units (beu, beup) from nearby sources. See Anderson (1936), Brice (1953), and Rymer (1981) for more detailed descriptions of this unit. Forms dissected topography with grass-covered slopes and lag gravel on the surface. Probably derived mainly from the north and east. As mapped here, the upper part contains interbedded early basaltic rocks (beu) near Clearlake Highlands, and the lower or middle part contains interbedded and intrusive early basaltic rocks (beui, beu) near the Bartlett Springs fault zone; also intruded by and overlain by the early basaltic rocks (beu, beup, beui). Age of unit is late Pliocene and early Pleistocene (Rymer, 1981). Maximum thickness unknown, but minimum thickness is 1,600 m (Rymer, 1981)

ds Rhyodacite of Seigler Mountain (Pleistocene) - Domes and flows of abundantly porphyritic hornblende-biotite-quartz-feldspar rhyodacite. Both size and abundance of hornblende phenocrysts distinguish this unit from all other feldspar-phyric dacite and rhyodacite units in the Clear Lake

**MOUNT HANNAH AREA** 

volcanic field. Age of  $0.61\pm0.02$  Ma on sanidine; normal magnetic polarity. Maximum thickness about 350 m Younger dacite of Mount Hannah (Pleistocene)—Flows of moderately porphyritic dacite containing medium-size plagioclase phenocrysts. Mainly vented near summit of the edifice built by the older dacite of Mount Hannah (doh); may be partly intrusive where exposed northwest of summit. Age of  $1.03\pm0.16$  Ma is too old; true age of about 0.90 Ma, in the Jaramillo Normal-Polarity Subchron (of the Matuyama Reversed-Polarity Chron), is suggested by intermediate magnetic polarity of this unit and ages of underlying units. Maximum exposed thickness about

doh Older dacite of Mount Hannah (Pleistocene)—Flows and domes of moderately porphyritic dacite containing coarse plagioclase phenocrysts, which distinguish this dacite unit from the overlying younger dacite of Mount Hannah (dyh). Intermediate magnetic polarity. Maximum exposed thickness of 420 m, plus an additional 280 m observed in drill hole USGS 1 Mt. Hannah on the northern flank of Mount Hannah, indicate a total thickness of at least 700 m for this unit close to its source vent

Dacite of Harrington Flat (Pleistocene)—Flows of moderately porphyritic dacite. Vents concealed beneath Mount Hannah. Average age is 0.90±0.04 Ma. Maximum exposed thickness about 70 m; drilled 60 m without reaching base of unit on northern flank of Mount Hannah Andesite of Poison Smith Spring (Pleistocene)—Flows of pyroxene andesite that has a distinctive texture of abundant (15–20 percent) clots of clinopyroxene and orthopyroxene. Ages of  $0.84\pm0.05$  and  $0.86\pm0.04$ Ma determined for unit are too young, because age by stratigraphic position is 0.90±0.03 Ma; reversed magnetic polarity indicates age is probably younger than the Jaramillo Normal-Polarity Subchron (of the Matuyama Reversed-Polarity Chron). Maximum thickness about 80 m

Rhyodacite of Loch Lomond (Pleistocene)—Flows and domes of modertely porphyritic rhyodacite containing coarse feldspar phenocrysts. Probable vent west of Loch Lomond; other vents are concealed beneath Mount Hannah. Age is  $0.90\pm0.03$  Ma. Intermediate magnetic polarity. Maximum exposed thickness 150 m Andesite of Split Top Ridge (Pleistocene)—Flows of andesite that has a distinctive texture of sparse large (15-mm-long) phenocrysts and abun-

dant small (0.25-1-mm-long) phenocrysts of plagioclase. Widespread unit that has been correlated by texture and mineralogy. Ages of  $0.88\pm0.06$  Ma at Split Top Ridge,  $0.88\pm0.02$  Ma 0.3 km south of Loch Lomond, and 0.86±0.03 Ma on northwest side of Boggs Lake are all slightly too young. Age from stratigraphic position and intermediate magnetic polarities is about 0.90 Ma. Small differences in polarity may imply small age difference between exposures east and west of Mount Hannah. Maximum exposed thickness southeast of Boggs Lake 80 m; maximum thickness at Split Top Ridge about 150 m Rhyodacite of Diener Drive (Pleistocene)—Extensive flow or flows of sparsely porphyritic pyroxene rhyodacite that is locally spherulitic.

Groundmass rich in subparallel 0.2-mm-long plagioclase and pyroxene. Similar to the dacite of Boggs Lake (db) but less porphyritic. Age is 0.92±0.03 Ma. Minimum thickness on Split Top Ridge 50 m db Dacite of Boggs Lake (Pleistocene)—Flows of sparsely porphyritic dacite. Groundmass rich in subparallel 0.2-mm-long plagioclase and pyroxene. Age is 0.98±0.09 Ma. Reversed magnetic polarity. Maximum exposed thickness 20 m

Andesite of Glenview (Pleistocene)—Flow and scoriaceous bombs of andesite that has a distinctive speckled appearance due to presence of 25–30 percent of 1–2-mm-long single crystals and 1–2-mm-diameter clots of plagioclase. Partly covered by the older (doh) and younger (dyh) dacites of Mount Hannah. Age is 1.00±0.05 Ma. Reversed magnetic polarity. Maximum exposed thickness about 200 m Andesite of Salmina Flat (Pleistocene)—Flows of ilmenite-bearing and site. Contains 0.25 percent of conspicuous 0.25–0.5-mm-diameter steelgray ilmenite in a sugary to aphanitic groundmass. Reversed magnetic polarity. Maximum thickness about 250 m

Rhyolite of Bonanza Springs (Pleistocene)—Very sparsely porphyritic rhyolite. Age is 1.02±0.04 Ma. Reversed magnetic polarity in drill-core sample of flow. Maximum exposed thickness 70 m near Seigler Springs; thickness 1-2 m west of Mount Hannah; drilled thickness 110 m in Republic 77–1 Boggs northwest of Mount Hannah

oclastic deposits—White pumiceous tuff, lapilli tuff, and, locally, coarse pyroclastic breccia; upper 3–4 m in road cut of State Route 175 in W1/2 sec. 26, T. 12 N., R. 8 W. is reworked and contains boulders of the andesite of Salmina Flat (asf). Shows rhythmic layering of coarse and fine layers of widely varying thickness. Mainly deposited by airfall, locally into quiet water and, in places, reworked by water. Grades into chaotic pyroclastic breccia near a concealed vent northwest of Seigler Springs; another probable vent is concealed northwest of Mount Hannah

lows—Not exposed; shown only in cross section A-A'. Three rhyolitic obsidian flows, which are 29, 17, and 15 m thick, are present in the Republic 77–1 Boggs drill hole northwest of Mount Hannah

Gravel deposit east of Poison Smith Spring (Pleistocene)—Eroded remnant of coarse pebble-boulder fluvial gravel in light-yellow soil and lag gravel. Contains clasts of the andesite of Boggs Mountain (abm) up to 20 cm diameter and smaller clasts of graywacke, blueschist, and chert from the Great Valley sequence (KJgv) and the Franciscan assemblage (KJf); lacks clasts of the andesite of Poison Smith Spring (aps). Overlies graywacke and shale that are probably of the Great Valley sequence (KJgv); overlain by the andesite of Poison Smith Spring. Thickness 1–2 m

Old basin deposits (Pleistocene)—Shown only in cross section. Conglomerate, sandstone, and silty claystone. Contains clasts of graywacke and serpentinite; in part rich in detrital serpentinite(?). Known only from Republic 77–1 Boggs drill hole northwest of Mount Hannah. Occurs beneath the rhyolite of Bonanza Springs (rbp, rbf); overlies lapilli tuff (bcp) of olivine-rich basalt probably derived from the olivine basalt of Caldwell Pines. Possibly deposited in a graben. Thickness 60 m

Maximum thickness about 200 m

thickness of flow 30 m

Hannah area

rbp Pyroclastic deposits

PERINI HILL AREA

rounded to tabular inclusions of metasedimentary rocks that have high-

grade mineral assemblages (garnet+spinel+cordierite and plagioclase

+quartz+orthopyroxene±biotite). Also rich in inclusions of clear to

amethyst quartz, known locally as "Clear Lake diamonds," that are up to

15 cm in diameter and have an irregular to rounded shape, resorbed

margins, and an elongate splintery fracture. Normal magnetic polarity.

Andesite of Seigler Canyon (Pleistocene) — Dome and surrounding flow of

indesite. Resembles the andesite of Split Top Ridge (ast), but contains

smaller feldspar phenocrysts and more pyroxene phenocrysts. Ages of

 $1.03\pm0.04$  Ma and  $0.97\pm0.03$  Ma; latter age fits intermediate magnetic

polarity at beginning of the Jaramillo Normal-Polarity Subchron (of the

Matuyama Reversed-Polarity Chron). Maximum thickness about 120 m

liatreme composed of fragments of vesicular, gray to light-yellow ande-

site, rhyolitic pumice (rbp) from the rhyolite of Bonanza Springs, and

sparse fragments of chert, graywacke, and serpentinite. Flow probably

tilted down to south; diatreme is a possible source vent. Dated at

0.93±0.05 Ma, but true age is probably greater than 0.97 Ma (predating

the Jaramillo Normal-Polarity Subchron of the Matuyama Reversed-

Polarity Chron) to fit tilt-corrected reversed magnetic polarity and to

preserve the easily eroded pyroclastic deposits (rbp) of the rhyolite of

Bonanza Springs that underlie the andesite of Childers Peak. Maximum

Rhyolite of Bonanza Springs (Pleistocene)—See description under Mount

Dacite of Cobb Valley (Pleistocene)—Flow and minor coarse pyroclastic

deposits of sparsely porphyritic dacite. Source is probably near spinelike

Cobb Mountain. Average of three ages is 1.08±0.03 Ma. Magnetic

polarity reversed, but 40 degrees from axial dipole. Maximum thickness

COBB MOUNTAIN AREA

ac Andesite of Childers Peak (Pleistocene)—Flow remnant of andesite and

Exposed thickness above lake level is 20 m Pyroclastic deposits—Cinder cone and associated deposits of bomb, block, aph Andesite of Perini Hill (Pleistocene)—Flows and minor pyroclastic deposits and lapilli tephra and agglutinate. Low cone at south end of island is of porphyritic quartz- and cordierite-bearing andesite. Contains rare source of flow to northeast and northwest 1–2-mm-diameter lavender cordierite. Rich in 1-mm to 15-cm-diameter

brif Flow—Scoriaceous aa flow erupted above lake level Andesite of Sulphur Bank (Pleistocene) - Sparsely porphyritic andesite and basaltic andesite. Variable abundance of plagioclase phenocrysts: less than 1 percent near the cinder cone, up to 2 percent near Sulphur Bank Mine. Cinder cone (called "south crater" by Becker, 1888, p. 246) is main source of flow(s); small satellitic crater 100 m in diameter on south flank of main cone. Isolated outcrops of bombs and welded spatter, such as in NW1/4NW1/4 sec. 5, T. 13 N., R. 7 W. and sec. 32, T. 14 N., R. 7 W., may represent secondary source vents or interaction with lake water or wet sediments. Total areal extent of 4 km<sup>2</sup> is now partly buried by the basin deposits of Clear Lake (bcl). Age is younger than the 44,500±800 yr B.P. carbon-14 age (Donnelly-Nolan and others, 1981) of a log found

ow(s)—In part hydrothermally altered at Sulphur Bank Mine (White and Roberson, 1962). Exposed thickness of flow about 20 m, maximum thickness 30 m Pyroclastic deposits-Cinder cone, 200 m high, and associated deposits of

in landslide(?) deposits 1.7 m beneath the flow

bomb, block, and lapilli tephra gec Gravel deposit east of Clearlake Oaks (Pleistocene)—Pebble-cobble gravel consisting predominantly of chert and subordinate amounts of greenstone and graywacke, derived from the Franciscan assemblage (KJf), and scoriaceous basaltic andesite. Occurs at low elevation in valley east of Clearlake Oaks. Possibly deposited in ancestral eastward outlet of Clear Lake (Hodges, 1966, p. 135). Overlain by the younger basaltic andesite of Clearlake Oaks (bycp, bycf) and the basaltic andesite of Sulphur Bank (asbf, asbp). May correlate with part of the terrace deposits of Burns Valley (tb). Thickness about 5 m

Andesite of old cinder cone (Pleistocene)—Bomb, block, and lapilli tephra composed of plagioclase andesite and lesser amounts of olivine basalt; dominant rock type is sparsely porphyritic andesite. Contains sparse blocks of a distinctive, relatively porphyritic olivine basalt. Exposure is limited to small area 15x35 m along State Route 20 east of Clearlake Oaks. Remnant of buried cinder cone of unknown extent. Exposed thickness 7 m

CALDWELL PINES AREA

Mankinen and Grommé (1982), and Gillot and others (1979). Time scale is that of U.S. Geological Survey. Vertical wavy line separates units of unknown relative age.

MAJOR UNCONFORMITY AND UPLIFT

Notes: Diagrammatic correlation chart is organized generally by geographic areas (see index) from western areas on the left to eastern areas on the right. In addition, because volcanism

decreases in age northward, geographic distribution of units is south to north from bottom to top of chart. Surficial map units al, af, co, ls, t, and bcl at the top, and bedrock units QTsc,

KJgv, KJf, and Jsp at the bottom are widespread. Size of box is not proportional to volume of unit. Units bcl, bo, bcp, rbf, and as are shown only in cross section. Units dated by

potassium-argon or carbon-14 are indicated by shading in upper left corner of box. Asterisk indicates dated sample is from site outside of map area; see description of map units for age

assignment. Brackets enclose age that does not fit stratigraphic sequence, magnetic polarity, or other ages on the same unit. Magnetic polarity scale is from Mankinen and Dalrymple (1979),

**BOGGS MOUNTAIN** 

PINE MOUNTAIN AREA

Olivine basalt of Caldwell Pines (Pleistocene)—Olivine basalt that is particularly rich in olivine (7–15 percent). Least evolved of the Clear Lake volcanic rocks. Lacks quartz inclusions found in most occurrences of the early basaltic rock units (beu, beup, beui). Diatreme (bcd) is probable source of flow. Steeply sheeted exposures (bci) in NW1/4NW 1/4 sec. 36, T. 12 N., R. 9 W. are probable dikes. Age is 1.66±0.12 Ma. Maximum

Gap in time scale; period of no volcanism

DIAGRAMMATIC CORRELATION OF MAP UNITS

CENTRAL AREA AND MOUNT KONOCTI

MOUNT

**HANNAH** 

CLEARLAKE HIGHLANDS-

NORTHEAST AREA and

CLEARLAKE HIGHLANDS

THURSTON LAKE AREA

THURSTON LAKE AREA NORTHEAST AREA

WEST -

> Period of no volcanism

> Period of no volcanism

CALDWELL PINES

**WESTERN AREA** 

age is 1.12±0.02 Ma. Intermediate magnetic polarity in the Cobb Mountain Normal-Polarity Subchron (of the Matuyama Reversed-Polarity Chron) (Mankinen and others, 1978; Mankinen and Grommé, 1982) Maximum exposed thickness about 400 m in the southeastern cliffs of Cobb Mountain; thickness as much as 150 m in down-faulted blocks southeast of Cobb Mountain (Goff and McLaughlin, 1976)

Rhyolite of Alder Creek (Pleistocene)—Crystal-rich biotite rhyolite. Three

ages of  $1.15\pm0.02$ ,  $1.11\pm0.02$ , and  $1.11\pm0.02$  Ma on sanidine; average

Rhyodacite of Cobb Mountain (Pleistocene) — Coarsely porphyritic biotite

magnetic polarity. Maximum thickness about 400 m

cite close to vent

dcf Flows and domes

Pyroclastic deposits—Coarse blocks of pumiceous, oxidized biotite rhyoda-

rhyodacite. Ages of  $1.05\pm0.02$  and  $1.06\pm0.02$  Ma on sanidine. Reversed

raf Flows—Thick, mostly devitrified, stony. Vesicular vitric blocks occur locally at top and base of unit rap Pyroclastic and volcaniclastic deposits—Pyroclastic breccia, lapilli tuff, tuff nd tuffaceous sedimentary rocks. Minor extent, occurs on top of and beneath the main group of flows (raf). In the extreme SW corner sec. 14, T. 11 N., R. 8 W., tuffaceous sedimentary rocks are 5 m thick, contain biotite rhyolite pumice, blocks of the andesite of Ford Flat (aff), and Franciscan assemblage rocks (KJf); rap unit represents an early pyroclastic

aff Andesite of Ford Flat (Pleistocene)—Isolated remnants of fragmental deposits of olivine andesite. Most occurrences consist of bombs, spatter, and cinders, plus 5 percent or less of fragments of Franciscan assemblage rocks (KJf). Includes interbedded lake sediments in the NE1/4NE1/4 sec. 22, T. 11 N., R. 8 W. Olivine andesite below the southeastern cliffs of Cobb Mountain appears to have filled gullies in an erosion surface. In sec. 24, T. 11 N., R. 8 W., a 35-m-thick mudflow deposit consists of 90-95 percent of poorly sorted lapilli and scoriaceous blocks of olivine andesite of Ford Flat and 5–10 percent of blocks of Franciscan assemblage (KJf) graywacke; this mudflow has lobate tongues about 5 m long and 1 m thick, which suggest that the mudflow moved toward the southeast. Olivine andesite cinders are locally abundant beneath the rhyolite of Alder Creek (raf, rap) in exposures too small to map at this scale. Source vent probably concealed beneath Cobb Mountain. Age is 1.71±0.21 Ma. Maximum exposed thickness 35 m

abm Andesite of Boggs Mountain (Pleistocene)—Flows, 10–15 m thick, and are dikes(?) of andesite that has a distinctive speckled appearance due to abundant small plagioclase phenocrysts. Contains about 10 percent of -3-mm-diameter clots of clinopyroxene and orthopyroxene. Flows are ypically sheeted near base and margins. Two probable dikes in sec. 2, T 11 N., R. 8 W. are close to one vent. Ages are  $1.47\pm0.06$  and  $1.51\pm0.04$ Ma; latter age from longer fusion of sample is more accurate. Reversed magnetic polarity. Maximum thickness about 150 m

BOGGS MOUNTAIN AREA

Andesite of Grouse Spring (Pleistocene)—Hornblende-bearing andesite. Typically contains 5-10 percent of 0.1-10-cm-diameter inclusions of netasedimentary rocks and sparse 0.5–1-cm-diameter inclusions of sievetextured plagioclase that contains altered hornblende needles. Reversed magnetic polarity

agsp Pyroclastic deposits—Small patches of lapilli tuff and pyroclastic breccia of

nornblende-bearing andesite scoria. Maximum exposed thickness 5 m

bcf Flow and minor amount of underlying bomb and lapilli tephra bci Intrusive rocks—Dikes and irregular small bodies

Diatreme breccia—Nonbedded, in part well-cemented. Average diameter of fragments is 0.5-2 cm. Contains 40-60 percent of altered fragments of vesicular and massive olivine basalt and 40-60 percent of fragments of Franciscan assemblage (KJf) rocks that are up to 1 m diameter, are predominantly graywacke and argillite, and are only about 1 percent each of red chert, greenstone, and serpentinite

bcp Pyroclastic deposits—Lapilli tuff beneath flow and in Republic 77–1 Boggs drill hole. Shown only in cross sections A-A' and B-B' High-level gravels (Pleistocene)—Coarse deposits gh<sub>2</sub> Unit 2—Younger deposit; composite waterlaid and lag deposit of resistant, rounded, pebble- to boulder-size clasts of Franciscan assemblage (KJf) graywacke, chert, and blueschist mainly derived from unit 1 (gh<sub>1</sub>), as well as angular fragments derived from the olivine basalt of Caldwell Pines (bcf,

bci, bcd). Maximum thickness 2 m Unit 1—Older deposit; waterlaid deposit of rounded pebbles, cobbles and boulders up to 1 m in diameter of Franciscan assemblage (KJf) graywacke, chert, and blueschist; lacks clasts of the Clear Lake Volcanics or Sonoma Volcanics; cut by intrusive rocks (bci) and overlain by flows (bcf) of the olivine basalt of Caldwell Pines. Maximum thickness about 10 m PINE MOUNTAIN AREA Andesite of Helen Mine (Pliocene)—Small flow(?) and dikelike and

regular intrusions of sparsely porphyritic olivine andesite. Occurs at the Helen Mine as four small remnants totalling 1,000 m<sup>2</sup> at the surface and as several small underground masses. Intruded near and along a fault that separates Franciscan assemblage mélange from serpentinite (Yates and Hilpert, 1946, pl. 46 and 47). Three of the four surface exposures are extensively altered by hydrothermal activity. Mercury mineralization postdates andesite according to Yates and Hilpert (1946). Average age of andesite is  $2.05\pm0.33$  Ma. Vertical extent at least 100 m Rhyolite of Pine Mountain (Pliocene)—Dome and flow of white, hydrothermally altered, crystal-rich rhyolite and rare blocks of black glassy biotite rhyolite. In most samples, groundmass and feldspar phenocrysts are pervasively altered, possibly due to proximity of mercury mineraliza-

tion in the Helen Mine area to the north. Overlies the rhyodacite of Appletree Creek (Tda). Age of 2.06±0.02 Ma on sanidine. Thickness about 110 m in summit area Rhyodacite of Appletree Creek (Pliocene)—Eroded small flow of hydrothermally altered, moderately porphyritic rhyodacite. Eroded condition, small phenocryst size, and lack of quartz phenocrysts indicate possible affinity of this unit with the Sonoma Volcanics. Maximum thickness about

(Tda). Eroded condition and paucity of quartz phenocrysts indicate possible affinity of this unit with the Sonoma Volcanics. Exposed thickness

Sonoma Volcanics (Pliocene)—Flow(?) of silicified dacite(?) that contains 5–10 percent feldspar phenocrysts in SW1/4 sec. 18 and NW1/4 sec. 19, T. 10 N., R. 7 W. Erosional remnants of dacitic(?) welded ash-flow tuff that contains 5 percent feldspar phenocrysts in sec. 13, T. 10 N., R. 8 W. Source of welded tuff probably at Mount St. Helena 6.5 km to the southeast. Map contacts taken in part from McLaughlin (1978). Remnants of Sonoma Volcanics in map area probably are part of youngest member, the rhyolite of Calistoga (Fox and others, 1985). The only K/Ar age for the rhyolite of Calistoga is 3.0±0.2 Ma (Mankinen, 1972) for sample collected at the summit of Mount St. Helena. Fission-track age of  $2.6\pm0.3$  Ma on zircon from the lowermost part of the rhyolite of Calistoga (Fox and others, 1985) is probably too young. Overall age range for the Sonoma Volcanics is late Miocene to late Pliocene; however, age in area of this report is considered Pliocene only. Maximum thickness in map

> **GENERAL AREA Bedrock Units**

Silica-carbonate rock (Quaternary? and late Tertiary)—White, tan, redprown to dark-gray, locally porous, resistant rocks composed of quartz, chalcedony, opal, and magnesium carbonate minerals. Formed by hydrothermal alteration of serpentinite. Associated with thermal springs and altered zones along faults. Common host rock for mercury deposits Great Valley sequence (Upper Cretaceous to Upper Jurassic)-Shale, siltstone, graywacke, conglomerate, greenstone, and chert. See Brice (1953), Swe and Dickinson (1970), and McLaughlin and others (1990) for more detailed descriptions and subdivisions of this unit

Franciscan assemblage (Upper Cretaceous to Upper Jurassic)—Structurally complex assemblage of varied rock types, such as chert, greenstone, graywacke, shale, and metamorphic rocks of blueschist grade. See Brice (1953), McNitt (1968a, b, c), McLaughlin (1978, 1981), and

INTERIOR - GEOLOGICAL SURVEY, RESTON, VA - 1995

McLaughlin and others (1990) for detailed descriptions and subdivisions erpentinite (Jurassic? and older?)—Serpentinized mafic and ultramafic rocks. Locally has tectonically intruded the Clear Lake Volcanics along major fault zones

diameter, of rhyodacite. Contains fewer sanidine and plagioclase phenocrysts than the rhyodacite of Appletree Creek (Tda). Probably older than the rhyolite of Pine Mountain (Trpm) and rhyodacite of Appletree Creek

GEOLOGIC MAP AND STRUCTURE SECTIONS OF THE CLEAR LAKE VOLCANICS, NORTHERN CALIFORNIA

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