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# POTASSIUM-ARGON AGES OF LATE MIOCENE TO LATE QUATERNARY VOLCANIC ROCKS IN THE SUSANVILLE-EAGLE LAKE AREA, LASSEN COUNTY, CALIFORNIA

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## INTRODUCTION

Twenty-nine K-Ar age determinations on late Cenozoic volcanic rocks from northeastern California are presented. The region centers on Susanville and Eagle Lake in Lassen County, and includes the junction of three major geologic provinces—the Sierra Nevada, the Cascade Range, and the basin and range (southern part of Modoc Plateau subprovince) (fig. 1). Most of the dated rocks occur within the Walker Lane fault system northwest of Honey Lake.

Prior to this work, no radiometric ages on volcanic rocks were available in the region. The ages reported here result from support work for regional geologic mapping by T.L.T. Grose and four graduate students from the Colorado School of Mines, under the U.S. Geological Survey Geothermal Research Program, Grant No. 14-08-001-G-624 during the years 1979–1981.

## REGIONAL SETTING

The Susanville–Eagle Lake region lies at the north end of the Sierra Nevada granitic terrane, at the southeastern corner of the High Cascade volcanic terrane, and along the western boundary of the basin and range province. The latter includes two subprovinces: the Modoc Plateau and the Walker Lane. Nearly all of the rocks exposed in the region are volcanic types, locally derived, and of late Miocene to Quaternary age (Lydon and others, 1960; Durrell, 1966; Macdonald, 1966; Grose and others, 1981; Luedke and Smith, 1981; Grose, 1986). Eruptive centers of many kinds and ages occur scattered throughout the region. They include small shield volcanoes, low stratovolcanoes, cinder and flow cones, and elliptical and tubular dikes. Rock compositions range from basaltic (tholeiitic) to rhyolitic with a preponderance of mafic andesitic types. Numerous normal and diagonal-slip faults occur in the region. Some are clearly associated with eruptive activity.

## INTERPRETATION

The ages reveal a progression of eruptive activity starting about 12 m.y. on the east and ending about 200,000 years ago on the west (Grose and McKee, 1982). This age progression is reflected well by the degree of erosional degradation of the numerous eruptive features in the region—moderately destructional on the east and freshly constructional on the west. Also, associated with the westward progression of eruptions is a compositional change from silicic and intermediate to basaltic. The older volcanic centers appear to be fewer, more widely scattered, and larger central-volcano types. The younger centers are more abundant and are smaller cone-types.

The ages support field relationships and indicate that faulting has been continuous in the region from late Miocene to the present. Extensional strain rates and directions calculated from faulted dated rocks suggest that rates are an order of magnitude less at the northern part of the Sierra Nevada than in the central and southern parts (Roberts and Grose, 1982).

Ages and volcanic conduit geometries suggest a 90° change in least principal stress direction from NW-SE in late Miocene to SW-NE in the Quaternary (Grose, 1985).

Temporal volcanic relationships in the Susanville–Eagle Lake region agree well with those documented in other parts of the western margin of the basin and range province (Christiansen and McKee, 1978; McKee and others, 1983; Smith and Luedke, 1984).

## SAMPLE DESCRIPTIONS

- BAD-5** K-Ar  
Olivine basalt lava flow (40°50.8'N, 120°57.3'W; NE/4 NE/4 NW/4 S3, T34N, R9E; Hayden Hill 15' quad.; elevation 5,360 ft; NW slope of Ashurst Mountain–Slate Mountain volcanic upland; Lassen Co., CA) from nearly horizontal flow underlain by about 200 feet of similar flows plus minor pyroclastic interbeds and overlain by about 30 ft (9 m) of flow breccia, in turn overlain disconformably by mafic andesite flow dated  $2.9 \pm 0.2$  m.y. (sample 2). Light to dark gray, vesicular to dense, sparsely microporphyrific with olivine and labradorite euhedral phenocrysts set in intergranular and hyalo-ophitic matrix; from unit called "Twin Lakes Basalt" by Bean (1980). *Analytical data:* K<sub>2</sub>O = 1.55%; <sup>40</sup>Ar\* =  $7.04474 \times 10^{-12}$  mol/gm; <sup>40</sup>Ar\* = 13.7%.  
(whole rock)  $3.2 \pm 0.1$  m.y.
- BAD-1** K-Ar  
Mafic andesite lava flow (40°50.7'N, 120°57.2'W; NW/4 NW/4 NE/4 S3, T34N, R9E; Hayden Hill 15' quad.; elevation 5,440 ft; on NW slope of Ashurst Mountain–Slate Mountain volcanic upland; Lassen Co., CA) from nearly horizontal flow disconformably underlain by several hundred feet of interbedded flows and tuffs (sample 1). Source of flow is monogenetic cone, Lava Peak, in S7, T34N, R10E. Medium gray, aphanitic to sparsely microporphyrific with olivine and andesine in pilotaxitic groundmass; from unit called "Lava Peak Basaltic Andesite" by Tuppan (1981). *Analytical data:* K<sub>2</sub>O = 1.46%; <sup>40</sup>Ar\* =  $6.05506 \times 10^{-12}$  mol/gm; <sup>40</sup>Ar\* = 12.4%.  
(whole rock)  $2.9 \pm 0.2$  m.y.
- BAD-3** K-Ar  
Olivine basalt lava flow (40°47.7'N, 120°57.4'W; NW/4 NW/4 SW/4 S22, T34N, R9E; Hayden Hill 15' quad.; elevation 5,800 ft; in Ashurst Mountain–Slate Mountain volcanic upland; Lassen Co., CA) from nearly horizontal flows filling several square miles of a paleotopographic low. Source of flow is small volcano in S26, T34N, R9E. Light to medium gray, abundantly finely glomeroporphyritic with olivine and calcic plagioclase set in intergranular matrix of plagioclase and pyroxene; from unit termed "McClure Basalt" by Bean (1980) and Tuppan (1981). *Analytical data:* K<sub>2</sub>O = 0.846%; <sup>40</sup>Ar\* =  $3.97102 \times 10^{-12}$  mol/gm; <sup>40</sup>Ar\* = 11.2%.  
(whole rock)  $3.3 \pm 0.2$  m.y.

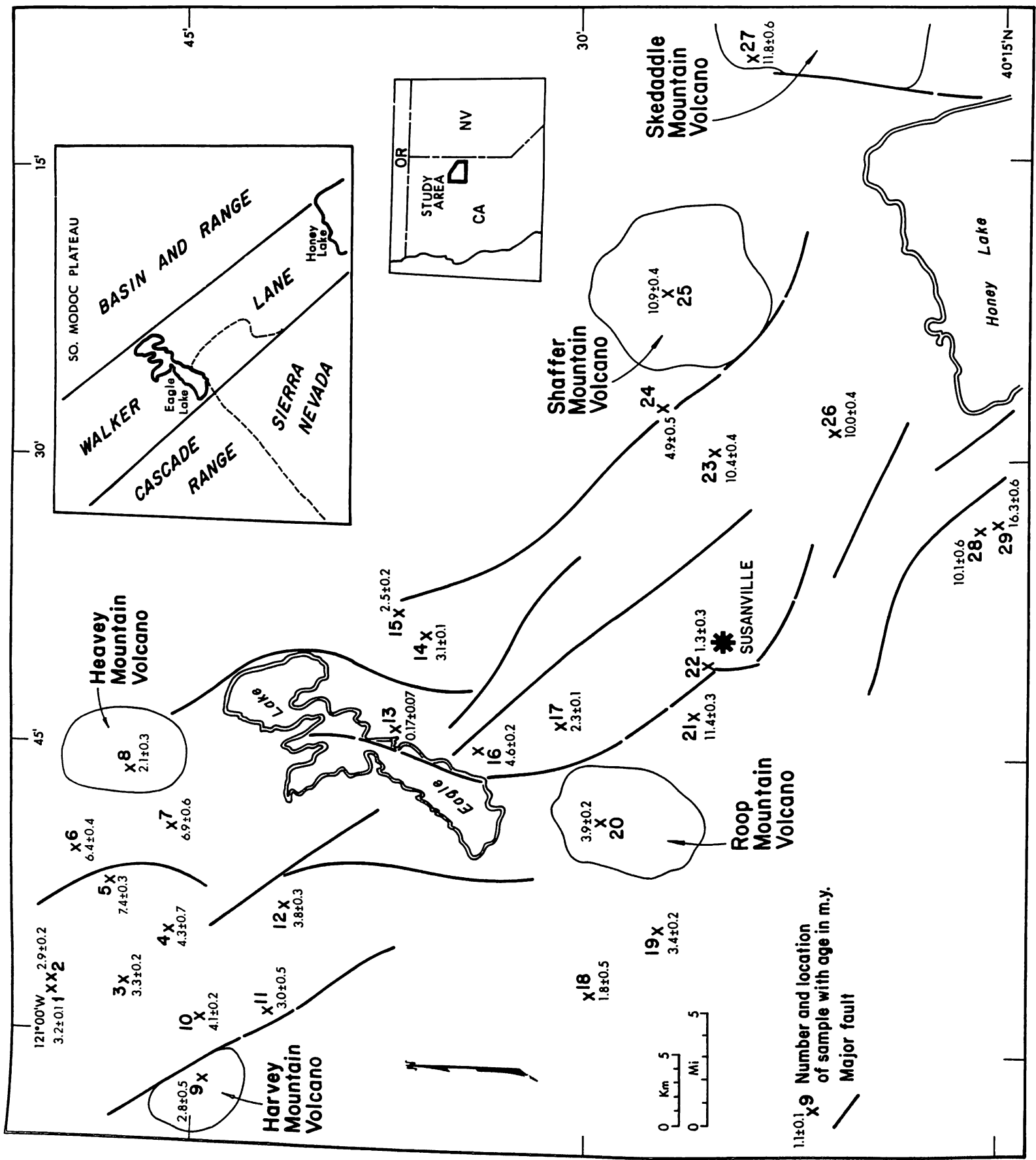


FIGURE 1. Map showing locations and K-Ar ages in m.y. of volcanic rocks in the Susanville-Eagle Lake area, Lassen County, California.

4. **TAD-3** K-Ar  
Diktytaxitic basalt (40°45.8'N, 120°54.3'W; SW/4 NE/4 SE/4 S36, T34N, R9E; Hayden Hill 15' quad.; elevation 6,220 ft; in Ashurst Mountain-Slate Mountain volcanic upland; Lassen Co., CA) from highest elevation of this unit which covers several square miles with maximum preserved thickness of 300 ft (92 m). It underlies 4.1 ± 0.2 m.y. Ashurst Mountain Basalt of Bean (1980) (sample 10) and overlies 6.4 ± 0.4 m.y. Slate Mountain Andesite of Tuppen (1981) (sample 6) and 6.9 ± 0.6 m.y. Cave Mountain Andesite of Grose and others (1981) and Tuppen (1981) (sample 7). Light to medium gray and weathered to orange-red, strongly finely diktytaxitic with olivine, augite, and plagioclase; massive with remarkably uniform texture and composition. Unit is one of the most distinctive and oldest diktytaxitic high-alumina basalts in the Susanville-Eagle Lake region, it is called "Golden Basalt" by Tuppen (1981). *Chemical analysis:* SiO<sub>2</sub> 48.82, Al<sub>2</sub>O<sub>3</sub> 17.05, FeO 9.24, MgO 9.83, CaO 11.11, Na<sub>2</sub>O 2.41, K<sub>2</sub>O 0.23, TiO<sub>2</sub> 0.87, P<sub>2</sub>O<sub>5</sub> 0.10, MnO 0.17. *Analytical data:* K<sub>2</sub>O = 0.228%; <sup>40</sup>Ar\* = 1.40342 × 10<sup>-12</sup> mol/gm; <sup>40</sup>Ar\* = 3.8%.  
**(whole rock) 4.3 ± 0.7 m.y.**
5. **TAD-5** K-Ar  
Olivine mafic andesite (40°47.9'N, 120°52.0'W; NW/4 NE/4 NE/4 S20, T34N, R10E; Hayden Hill 15' quad.; elevation 6,165 ft; in Ashurst Mountain-Slate Mountain volcanic upland; Lassen Co., CA) from lava flow, dipping 5° east, overlying and interbedded with andesitic tuff, both exposed in a 1.5 square mile area and underlying 6.4 ± 0.4 m.y. Slate Mountain Andesite of Tuppen (1981) (sample 6). White to light gray, moderately microporphyritic with olivine in subophitic groundmass of calcic plagioclase and augite. Unit is one of the oldest in surrounding 200 square miles, is called "Loveland Gulch Basalt" by Tuppen (1981). *Chemical analysis:* SiO<sub>2</sub> 52.19, Al<sub>2</sub>O<sub>3</sub> 16.67, FeO 8.59, MgO 7.36, CaO 8.31, Na<sub>2</sub>O 2.98, K<sub>2</sub>O 0.81, TiO<sub>2</sub> 0.86, P<sub>2</sub>O<sub>5</sub> 0.23, MnO 0.14. *Analytical data:* K<sub>2</sub>O = 0.635%; <sup>40</sup>Ar\* = 6.77799 × 10<sup>-12</sup> mol/gm; <sup>40</sup>Ar\* = 15.6%.  
**(whole rock) 7.4 ± 0.3 m.y.**
6. **TAD-1** K-Ar  
Porphyritic andesite flow (40°49.5'N, 120°50.6'W; NW/4 NW/4 SW/4 S10, T34N, R10E; Hayden Hill 15' quad.; elevation 6,430 ft; midway on E flank of Slate Mountain; Lassen Co., CA) from oldest exposed flow 600 ft (168 m) below eroded top of sequence of andesite flows interbedded with minor volcaniclastic layers. The sequence, exposed over 40 square miles, overlies the 7.4 ± 0.3 m.y. Loveland Gulch mafic andesites (sample 5) and underlies the 6.9 ± 0.6 m.y. Cave Mountain Andesite of Tuppen (1981) (sample 7). Dark gray to black, abundantly finely porphyritic with calcic plagioclase, pipersthene, and augite phenocrysts set in hyalo-ophitic groundmass. From unit called "Slate Mountain Andesite" by Tuppen (1981). *Chemical analysis:* SiO<sub>2</sub> 62.44, Al<sub>2</sub>O<sub>3</sub> 16.79, FeO 5.64, MgO 2.75, CaO 5.27, Na<sub>2</sub>O 3.91, K<sub>2</sub>O 2.48, TiO<sub>2</sub> 0.82, P<sub>2</sub>O<sub>5</sub> 0.24, MnO 0.11. *Analytical data:* K<sub>2</sub>O = 1.888%; <sup>40</sup>Ar\* = 1.73702 × 10<sup>-11</sup> mol/gm; <sup>40</sup>Ar\* = 11.1%.  
**(whole rock) 6.4 ± 0.4 m.y.**
7. **TAD-4** K-Ar  
Porphyritic andesite flow (40°45.6'N, 120°49.0'W; NW/4 SE/4 SW/4 S35, T34N, R10E; Hayden Hill 15' quad.; elevation 6,440 ft; SE side of Ashurst Mountain-Slate Mountain volcanic upland; Lassen Co., CA) from middle part of sequence of andesite flows at least 400 ft thick disposed in gently east-tilted fault blocks exposed over about 30 square miles. Dark gray to black, locally speckled, moderately finely porphyritic with olivine and plagioclase phenocrysts set in intergranular to hyalo-ophitic groundmass; from unit called "Cave Mountain Andesite" by Grose and others (1981) and Tuppen (1981). *Chemical analysis:* SiO<sub>2</sub> 57.30, Al<sub>2</sub>O<sub>3</sub> 17.46, FeO 6.86, MgO 4.30, CaO 7.21, Na<sub>2</sub>O 3.61, K<sub>2</sub>O 1.57, TiO<sub>2</sub> 0.90, P<sub>2</sub>O<sub>5</sub> 0.32, MnO 0.12. *Analytical data:* K<sub>2</sub>O = 1.530%; <sup>40</sup>Ar\* = 1.51848 × 10<sup>-11</sup> mol/gm; <sup>40</sup>Ar\* = 5.5%.  
**(whole rock) 6.9 ± 0.6 m.y.**
8. **TAD-2** K-Ar  
Mafic andesite flow (40°47.2'N, 120°45.6'W; SE/4 NW/4 SW/4 S20, T34N, R11E; Hayden Hill 15' quad.; elevation 6,400 ft; from summit area of Heavey Mountain shield N of Eagle Lake; Lassen Co., CA) from bomb fragment from cinder cone that represents the youngest eruptive activity on Heavey Mountain (Tuppen, 1981). Medium gray, sparsely microporphyritic with olivine in intersertal to intergranular matrix containing labradorite, clinopyroxene, magnetite, and glass. *Chemical analysis:* SiO<sub>2</sub> 53.67, Al<sub>2</sub>O<sub>3</sub> 18.35, FeO 7.40, MgO 5.22, CaO 7.51, Na<sub>2</sub>O 4.16, K<sub>2</sub>O 1.69, TiO<sub>2</sub> 1.62, P<sub>2</sub>O<sub>5</sub> 0.50, MnO 0.13. *Analytical data:* K<sub>2</sub>O = 1.459%; <sup>40</sup>Ar\* = 4.48176 × 10<sup>-12</sup> mol/gm; <sup>40</sup>Ar\* = 3.6%.  
**(whole rock) 2.1 ± 0.3 m.y.**
9. **BAD-4** K-Ar  
Mafic andesite (40°44.5'N, 121°2.1'W; NW/4 SW/4 NW/4 S12, T33N, R8E; Harvey Mountain 15' quad.; elevation 7,325 ft; summit of Harvey Mountain shield volcano; Lassen Co., CA) from blocky flow just east of main vent at summit. Medium to dark gray, moderately microporphyritic with calcic plagioclase, hypersthene and olivine phenocrysts set in pilotaxitic to intergranular and microdiktytaxitic groundmass. Unit is called "Andesite of Harvey Mountain" by Macdonald (1965) and "Harvey Mountain Andesite" by Bean (1980). *Analytical data:* K<sub>2</sub>O = 2.143%; <sup>40</sup>Ar\* = 8.67206 × 10<sup>-12</sup> mol/gm; <sup>40</sup>Ar\* = 6.8%.  
**(whole rock) 2.8 ± 0.5 m.y.**
10. **BAD-2** K-Ar  
Olivine basalt (40°44.5'N, 120°58.8'W; NE/4 SE/4 NE/4 S8, T33N, R9E; Antelope Mountain 15' quad.; elevation 7,085 ft; summit of Ashurst Mountain; Lassen Co., CA) from elongate ridge crest that represents eroded eruptive fissure dike, one of several nearby that supplied lava to adjacent flows. These flows, exposed over 20 square miles, overlie the Gordon Basalt (sample 4), are probably correlative with the Twin Lakes Basalt (sample 1), and underlie the Long Lake Mafic Andesite and the McClure Basalt (sample 3) of Bean (1980). Medium to dark gray, moderately finely porphyritic and glomeroporphyritic with olivine and calcic plagioclase phenocrysts set in

intergranular matrix of plagioclase, augite, and magnetite; unit has been called the "Ashurst Mountain Basalt" by Bean (1980), and is equivalent to "Basalt" as mapped by Macdonald (1965). *Analytical data*:  $K_2O = 1.197\%$ ;  $^{40}Ar^* = 7.06812 \times 10^{-12}$  mol/gm;  $^{40}Ar^* = 19.6\%$ .

(whole rock)  $4.1 \pm 0.2$  m.y.

11. **GAD-8** K-Ar  
Diktytaxitic basalt ( $40^\circ 41.6'N, 120^\circ 58.6'W$ ; NW/4 NW/4 SW/4 S28, T31N, R9E; Antelope Mountain 15' quad.; elevation 5,610 ft; low on S flank of Ashurst Mountain-Slate Mountain volcanic upland; Lassen Co., CA) from relatively deeply eroded mass of flows that are continuous with flows of  $4.3 \pm 0.7$  m.y. "Gordon Basalt" (sample 4) of Tuppen (1981), that underlie  $4.1 \pm 0.2$  m.y. "Ashurst Mountain Basalt" (sample 10) of Bean (1980), and that appear to be continuous (Grose and others, 1981) with Burney Basalt of Macdonald (1965). Light to medium gray, strongly finely diktytaxitic with olivine, augite, and plagioclase in intergranular matrix, massive with uniform texture and composition. *Chemical analysis*:  $SiO_2$  48.32,  $Al_2O_3$  17.69,  $FeO$  9.04,  $MgO$  9.27,  $CaO$  11.35,  $Na_2O$  2.44,  $K_2O$  0.17,  $TiO_2$  0.87,  $P_2O_5$  0.14,  $MnO$  0.17. *Analytical data*:  $K_2O = 0.189\%$ ;  $^{40}Ar^* = 8.0421 \times 10^{-13}$  mol/gm;  $^{40}Ar^* = 2.3\%$ .  
(whole rock)  $3.0 \pm 0.5$  m.y.
12. **GAD-7** K-Ar  
Rhyolite flow ( $40^\circ 41.2'N, 120^\circ 52.8'W$ ; SW/4 SW/4 SW/4 S29, T33N, R10E; Antelope Mountain 15' quad.; elevation 5,480 ft; in hills on E side of Champs Flat; Lassen Co., CA) from an isolated rhyolite flow dome(?) mass exposed over about one square mile and mostly in fault contact with adjacent units. It is the only Pliocene rhyolite known within a radius of 25 miles (40 km) (Grose, 1986). Light gray, weathered white, moderately microvitrophyric with euhedral phenocrysts of sanidine, sodic plagioclase, and biotite in hyalopilitic groundmass. *Chemical analysis*:  $SiO_2$  72.20,  $Al_2O_3$  14.12,  $FeO$  1.38,  $MgO$  0.50,  $CaO$  1.86,  $Na_2O$  3.13,  $K_2O$  4.13,  $TiO_2$  0.17,  $P_2O_5$  0.10,  $MnO$  0.04. *Analytical data*:  $K_2O = 3.05\%$ ;  $^{40}Ar^* = 1.6551 \times 10^{-11}$  mol/gm;  $^{40}Ar^* = 6.9\%$ .  
(whole rock)  $3.8 \pm 0.3$  m.y.
13. **YAD-2** K-Ar  
Olivine mafic andesite ( $40^\circ 36.8'N, 120^\circ 43.5'W$ ; SW/4 SW/4 SW/4 S22, T32N, R11E; Fredonyer Peak 15' quad.; elevation 5,160 ft; from W portal of the Bly Tunnel near level of Eagle Lake W side of Black Mountain; Lassen Co., CA) from a lower flow unit of blocky lava derived from the Black Mountain volcano where it is downfaulted into the Eagle Lake basin. It is overlain by basalt flows estimated to be younger than 75,000 years. Gray to black, moderately finely porphyritic and glomeroporphyritic with calcic plagioclase and olivine phenocrysts set in intersertal to intergranular groundmass, vesicular with well preserved flow structures. Unit has been called "Black Mountain Olivine Basaltic Andesite" by Youngkin (1980). *Analytical data*:  $K_2O = 1.712\%$ ;  $^{40}Ar^* = 4.21724 \times 10^{-13}$  mol/gm;  $^{40}Ar^* = 0.79\%$ .  
(whole rock)  $0.17 \pm 0.07$  m.y.
14. **YAD-1** K-Ar  
Andesite flow ( $40^\circ 36.0'N, 120^\circ 38.5'W$ ; SE/4 SE/4 SE/4 S29, T32N, R12E; Fredonyer Park 15' quad.; elevation 5,455 ft; from low volcanic fault blocks N of Willow Creek Valley; Lassen Co., CA) from upper part of several-hundred-foot-thick sequence of andesitic flows tilted gently eastward. Light brown and gray, sparsely finely porphyritic with olivine and hypersthene phenocrysts in pilotaxitic flow banded matrix, strong platy jointing. Unit is called "Dry Lake Hypersthene Andesite" by Youngkin (1980). *Analytical data*:  $K_2O = 2.344\%$ ;  $^{40}Ar^* = 1.04312 \times 10^{-11}$  mol/gm;  $^{40}Ar^* = 28.9\%$ .  
(whole rock)  $3.1 \pm 0.1$  m.y.
15. **YAD-3** K-Ar  
Mafic andesite flow ( $40^\circ 37.1'N, 120^\circ 37.6'W$ ; NW/4 NW/4 SE/4 S21, T32N, R12E; Fredonyer Peak 15' quad.; elevation 5,730 ft; S flank of Fredonyer Peak N of Willow Creek Valley. Sample is from sequence, several hundred feet thick, of interbedded flows, tuffs, lahars, and volcanoclastic rocks that are disposed in gently east-tilted fault blocks. Source of lava sample is small lava cone  $\frac{1}{2}$  mile to the southeast. This sequence overlies the Dry Lake Hypersthene Andesite (sample 14) of Youngkin (1980). Dark gray, sparsely microporphyritic with olivine and calcic plagioclase phenocrysts set in mainly intergranular and weakly diktytaxitic groundmass. This unit was called the "Stone Ranch Olivine Basaltic Andesite" by Youngkin (1980). *Analytical data*:  $K_2O = 1.117\%$ ;  $^{40}Ar^* = 4.00146 \times 10^{-12}$  mol/gm;  $^{40}Ar^* = 6.6\%$ .  
(whole rock)  $2.5 \pm 0.2$  m.y.
16. **YAD-5** K-Ar  
Mafic andesite plug ( $40^\circ 33.9'N, 120^\circ 44.5'W$ ; SW/4 SE/4 NW/4 S9, T31N, R11E; Fredonyer Peak 15' quad.; elevation 6,920 ft; summit of Gallatin Peak S of Eagle Lake; Lassen Peak, CA) from small volcanic plug flow rock associated with cinder breccia at one of two similar plugs or necks intruding Cretaceous quartz diorite of the Gallatin horst block at northernmost exposure of Sierran granitic basement in the region. Gray-brown, sparsely microporphyritic with calcic plagioclase plus olivine phenocrysts set in ophitic matrix with abundant clinopyroxene, strong platy jointing, microlitic cavities. Unit was called "Mahogany Peak Olivine Basaltic Andesite" by Youngkin (1980). *Analytical data*:  $K_2O = 0.906\%$ ;  $^{40}Ar^* = 5.9652 \times 10^{-12}$  mol/gm;  $^{40}Ar^* = 31.6\%$ .  
(whole rock)  $4.6 \pm 0.2$  m.y.
17. **GAD-2** K-Ar  
Mafic andesite flow ( $40^\circ 30.7'N, 120^\circ 43.0'W$ ; SW/4 SW/4 SE/4 S27, T31N, R11E; Fredonyer Peak 15' quad.; elevation 6,440 ft; from Gallatin horst S of Eagle Lake; Lassen Co., CA) from flow interior 20 ft above base resting horizontally on Sierran quartz diorite. Unit is down-faulted over 1200 ft (362 m) into Eagle Lake depression. Medium to dark gray, sparsely microporphyritic and glomeroporphyritic with olivine and calcic plagioclase set in uniform intergranular groundmass of clinopyroxene, olivine, and plagioclase, locally mildly diktytaxitic. Unit was referred to as "Colman Lake Olivine Basaltic Andesite" by Youngkin (1980). *Chemical analysis*:  $SiO_2$  54.26,  $Al_2O_3$  17.92,  $FeO$  7.44,  $MgO$  5.53,  $CaO$  7.89,  $Na_2O$  3.70,  $K_2O$  1.70,  $TiO_2$  1.39,  $P_2O_5$  0.57,  $MnO$  0.13. *Analytical data*:  $K_2O = 1.830\%$ ;  $^{40}Ar^* = 5.96907 \times 10^{-12}$  mol/gm;  $^{40}Ar^* = 26.9\%$ .  
(whole rock)  $2.3 \pm 0.1$  m.y.

18. *GAD-4* K-Ar  
Mafic andesite bomb (40°30.0'N, 120°57.2'W; SW/4 NW/4 NW/4 S2, T30N, R9E; Westwood 15' quad.; elevation 5,800 ft; from volcanic lowland SW of Eagle Lake; Lassen Co., CA) from N30W-trending cinder-scoria eruptive linear over one mile in length typical of others variously geomorphically degraded in region (Grose and others, 1981). Black, gray, red, sparsely microporphyrific with pyroxene and calcic plagioclase euhedral phenocrysts set in hyalopilitic microvesicular matrix. *Chemical analysis*: SiO<sub>2</sub> 52.69, Al<sub>2</sub>O<sub>3</sub> 17.67, FeO 8.03, MgO 6.38, CaO 8.11, Na<sub>2</sub>O 3.39, K<sub>2</sub>O 1.02, TiO<sub>2</sub> 1.33, P<sub>2</sub>O<sub>5</sub> 0.29, MnO 0.14. *Analytical data*: K<sub>2</sub>O = 1.151%; <sup>40</sup>Ar\* = 2.96412 × 10<sup>-12</sup> mol/gm; <sup>40</sup>Ar = 2.5%.  
(whole rock) 1.8 ± 0.5 m.y.
19. *GAD-9* K-Ar  
Mafic andesite flow (40°26.9'N, 120°53.9'W; NW/4 SW/4 NE/4 S19, T30N, R10E; Westwood 15' quad.; elevation 5,532 ft; from slightly tilted and weakly faulted flows comprising volcanic lowland SW of Eagle Lake; Lassen Co., CA) from over 20 square miles of andesitic flows that "fill in" area between major volcanoes (Grose and others, 1981). The source is local small elliptical vents and dikes. Medium gray, sparsely microporphyrific with olivine phenocrysts set in pilotaxitic matrix, dense. *Chemical analysis*: SiO<sub>2</sub> 55.23, Al<sub>2</sub>O<sub>3</sub> 17.56, FeO 7.33, MgO 5.06, CaO 7.76, Na<sub>2</sub>O 3.38, K<sub>2</sub>O 1.67, TiO<sub>2</sub> 0.99, P<sub>2</sub>O<sub>5</sub> 0.40, MnO 0.14. *Analytical data*: K<sub>2</sub>O = 1.645%; <sup>40</sup>Ar\* = 8.1139 × 10<sup>-12</sup> mol/gm; <sup>40</sup>Ar\* = 18.5%.  
(whole rock) 3.4 ± 0.2 m.y.
20. *GAD-3* K-Ar  
Mafic andesite dike (40°29.2'N, 120°46.9'W; NE/4 SW/4 SE/4 S1, T30N, R10E; Westwood 15' quad.; elevation 7,340 ft; NE part of summit area of Roop Mountain shield volcano; Lassen Co., CA) from a large dike with strike of N10E within an eruptive cinder-scoria-flow fissure zone, a part of the vent complex, and probably one of the youngest eruptives associated with Roop volcano (Grose and others, 1981). Medium gray, light gray-mottled, rarely microporphyrific with olivine in microvesicular intergranular matrix of clinopyroxene and calcic plagioclase. *Chemical analysis*: SiO<sub>2</sub> 56.31, Al<sub>2</sub>O<sub>3</sub> 17.74, FeO 6.68, MgO 4.47, CaO 7.12, Na<sub>2</sub>O 3.50, K<sub>2</sub>O 1.61, TiO<sub>2</sub> 0.90, P<sub>2</sub>O<sub>5</sub> 0.34, MnO 0.12. *Analytical data*: K<sub>2</sub>O = 1.615%; <sup>40</sup>Ar\* = 9.15235 × 10<sup>-12</sup> mol/gm; <sup>40</sup>Ar\* = 37.5%.  
(whole rock) 3.9 ± 0.2 m.y.
21. *GAD-5* K-Ar  
Dacite (40°25.8'N, 120°43.1'W; NW/4 NW/4 SW/4 S26, T30N, R11E; Susanville 15' quad.; elevation 4,690 ft; in bottom of Piute Creek Canyon 3 miles W of Susanville; Lassen Co., CA) typical of intermediate flows in complex unit of intermediate and silicic flows, pyroclastic rocks, and interbedded conglomerate lenses that underlie Late Miocene, Pliocene and Quaternary volcanic rocks in the region (Grose and others, 1981). White to medium gray, abundantly finely porphyritic and glomeroporphyritic with sodic plagioclase, sanidine, and minor hornblende, clinopyroxene, and biotite set in pilotaxitic matrix. Unit probably correlates with the Antelope Mountain  
Andesite of Roberts (1985) (sample 23). *Chemical analysis*: SiO<sub>2</sub> 63.39, Al<sub>2</sub>O<sub>3</sub> 16.92, FeO 5.01, MgO 1.31, CaO 4.39, Na<sub>2</sub>O 3.48, K<sub>2</sub>O 2.06, TiO<sub>2</sub> 0.50, P<sub>2</sub>O<sub>5</sub> 0.11, MnO 0.09. *Analytical data*: K<sub>2</sub>O = 2.209%; <sup>40</sup>Ar\* = 3.62413 × 10<sup>-11</sup> mol/gm; <sup>40</sup>Ar\* = 82.4%.  
(whole rock) 11.4 ± 0.3 m.y.
22. *GAD-1* K-Ar  
Diktytaxitic basalt (40°25.3'N, 120°40.4'W; SE/4 NE/4 NW/4 S31, T30N, R12E; Susanville 15' quad.; elevation 4,680 ft; from lava flow capping up-faulted bench ½ mile W of Susanville; Lassen Co., CA) typical of mildly faulted flows northeast and east of Susanville, at least 180 ft thick, that probably underlie the alluvium and lake beds of the northwestern part of the Honey Lake Valley (Grose and others, 1981; Roberts, 1985). Dark gray, sparsely microporphyrific with olivine phenocrysts set in intergranular and ophimottled matrix of calcic plagioclase, clinopyroxene, and olivine, finely diktytaxitic. Unit is called "Susanville Basalt" by Roberts (1985). *Chemical analysis*: SiO<sub>2</sub> 48.39, Al<sub>2</sub>O<sub>3</sub> 17.08, FeO 9.78, MgO 9.84, CaO 10.83, Na<sub>2</sub>O 2.48, K<sub>2</sub>O 0.26, TiO<sub>2</sub> 0.91, P<sub>2</sub>O<sub>5</sub> 0.15, MnO 0.18. *Analytical data*: K<sub>2</sub>O = 0.291%; <sup>40</sup>Ar\* = 5.53954 × 10<sup>-13</sup> mol/gm; <sup>40</sup>Ar\* = 1.3%.  
(whole rock) 1.3 ± 0.3 m.y.
23. *RAD-2* K-Ar  
Mafic andesite (40°25.1'N, 120°29.7'W; SE/4 SW/4 NE/4 S34, T30N, R13E; Litchfield 15' quad.; elevation 4,160 ft; from bottom of slope on SE flank of Antelope Mountain; Lassen Co., CA) from numerous mafic andesite and andesite flows over 300 ft thick that occur on Antelope Mountain and that underlie at least 1,100 ft of andesite breccia. Light gray, abundantly finely porphyritic with plagioclase, sanidine, hornblende, augite phenocrysts in pilotaxitic matrix. Unit is called "Antelope Mountain Andesite" by Roberts (1985), and it correlates with similar intermediate flow complexes in areas west of Susanville (Grose and others, 1981) (sample 21). *Chemical analysis*: SiO<sub>2</sub> 56.31, Al<sub>2</sub>O<sub>3</sub> 17.86, FeO 8.18, MgO 3.34, CaO 6.43, Na<sub>2</sub>O 3.66, K<sub>2</sub>O 1.29, TiO<sub>2</sub> 0.88, P<sub>2</sub>O<sub>5</sub> 0.21, MnO 0.12. *Analytical data*: K<sub>2</sub>O = 1.237%; <sup>40</sup>Ar\* = 1.85914 × 10<sup>-11</sup> mol/gm; <sup>40</sup>Ar\* = 26.9%.  
(whole rock) 10.4 ± 0.4 m.y.
20. *GAD-3* K-Ar  
Mafic andesite dike (40°29.2'N, 120°46.9'W; NE/4 SW/4 SE/4 S1, T30N, R10E; Westwood 15' quad.; elevation 7,340 ft; NE part of summit area of Roop Mountain shield volcano; Lassen Co., CA) from a large dike with strike of N10E within an eruptive cinder-scoria-flow fissure zone, a part of the vent complex, and probably one of the youngest eruptives associated with Roop volcano (Grose and others, 1981). Medium gray, light gray-mottled, rarely microporphyrific with olivine in microvesicular intergranular matrix of clinopyroxene and calcic plagioclase. *Chemical analysis*: SiO<sub>2</sub> 56.31, Al<sub>2</sub>O<sub>3</sub> 17.74, FeO 6.68, MgO 4.47, CaO 7.12, Na<sub>2</sub>O 3.50, K<sub>2</sub>O 1.61, TiO<sub>2</sub> 0.90, P<sub>2</sub>O<sub>5</sub> 0.34, MnO 0.12. *Analytical data*: K<sub>2</sub>O = 1.615%; <sup>40</sup>Ar\* = 9.15235 × 10<sup>-12</sup> mol/gm; <sup>40</sup>Ar\* = 37.5%.  
(whole rock) 3.9 ± 0.2 m.y.

21. **GAD-5** K-Ar  
 Dacite (40°25.8'N, 120°43.1'W; NW/4 NW/4 SW/4 S26, T30N, R11E; Susanville 15' quad.; elevation 4,690 ft; in bottom of Piute Creek Canyon 3 miles W of Susanville; Lassen Co., CA) typical of intermediate flows in complex unit of intermediate and silicic flows, pyroclastic rocks, and interbedded conglomerate lenses that underlie Late Miocene, Pliocene and Quaternary volcanic rocks in the region (Grose and others, 1981). White to medium gray, abundantly finely porphyritic and glomeroporphyritic with sodic plagioclase, sanidine, and minor hornblende, clinopyroxene, and biotite set in pilotaxitic matrix. Unit probably correlates with the Antelope Mountain Andesite of Roberts (1985) (sample 23). *Chemical analysis:* SiO<sub>2</sub> 63.39, Al<sub>2</sub>O<sub>3</sub> 16.92, FeO 5.01, MgO 1.31, CaO 4.39, Na<sub>2</sub>O 3.48, K<sub>2</sub>O 2.06, TiO<sub>2</sub> 0.50, P<sub>2</sub>O<sub>5</sub> 0.11, MnO 0.09. *Analytical data:* K<sub>2</sub>O = 2.209%; <sup>40</sup>Ar\* = 3.62413 × 10<sup>-11</sup> mol/gm; <sup>40</sup>Ar\* = 82.4%.  
**(whole rock) 11.4 ± 0.3 m.y.**
22. **GAD-1** K-Ar  
 Diktytaxitic basalt (40°25.3'N, 120°40.4'W; SE/4 NE/4 NW/4 S31, T30N, R12E; Susanville 15' quad.; elevation 4,680 ft; from lava flow capping up-faulted bench ½ mile W of Susanville; Lassen Co., CA) typical of mildly faulted flows northeast and east of Susanville, at least 180 ft thick, that probably underlie the alluvium and lake beds of the northwestern part of the Honey Lake Valley (Grose and others, 1981; Roberts, 1985). Dark gray, sparsely microporphyritic with olivine phenocrysts set in intergranular and ophimottled matrix of calcic plagioclase, clinopyroxene, and olivine, finely diktytaxitic. Unit is called "Susanville Basalt" by Roberts (1985). *Chemical analysis:* SiO<sub>2</sub> 48.39, Al<sub>2</sub>O<sub>3</sub> 17.08, FeO 9.78, MgO 9.84, CaO 10.83, Na<sub>2</sub>O 2.48, K<sub>2</sub>O 0.26, TiO<sub>2</sub> 0.91, P<sub>2</sub>O<sub>5</sub> 0.15, MnO 0.18. *Analytical data:* K<sub>2</sub>O = 0.291%; <sup>40</sup>Ar\* = 5.53954 × 10<sup>-13</sup> mol/gm; <sup>40</sup>Ar\* = 1.3%.  
**(whole rock) 1.3 ± 0.3 m.y.**
23. **RAD-2** K-Ar  
 Mafic andesite (40°25.1'N, 120°29.7'W; SE/4 SW/4 NE/4 S34, T30N, R13E; Litchfield 15' quad.; elevation 4,160 ft; from bottom of slope on SE flank of Antelope Mountain; Lassen Co., CA) from numerous mafic andesite and andesite flows over 300 ft thick that occur on Antelope Mountain and that underlie at least 1,100 ft of andesite breccia. Light gray, abundantly finely porphyritic with plagioclase, sanidine, hornblende, augite phenocrysts in pilotaxitic matrix. Unit is called "Antelope Mountain Andesite" by Roberts (1985), and it correlates with similar intermediate flow complexes in areas west of Susanville (Grose and others, 1981) (sample 21). *Chemical analysis:* SiO<sub>2</sub> 56.31, Al<sub>2</sub>O<sub>3</sub> 17.86, FeO 8.18, MgO 3.34, CaO 6.43, Na<sub>2</sub>O 3.66, K<sub>2</sub>O 1.29, TiO<sub>2</sub> 0.88, P<sub>2</sub>O<sub>5</sub> 0.21, MnO 0.12. *Analytical data:* K<sub>2</sub>O = 1.237%; <sup>40</sup>Ar\* = 1.85914 × 10<sup>-11</sup> mol/gm; <sup>40</sup>Ar\* = 26.9%.  
**(whole rock) 10.4 ± 0.4 m.y.**
24. **RAD-1** K-Ar  
 Glomeroporphyritic basalt (40°26.9'N, 120°27.3'W; NW/4 SW/4 S18, T30N, R13E; Litchfield 15' quad.; elevation 4,320 ft; from lava plateau W of Shaffer Mountain in canyon of Willow Creek; Lassen Co., CA) from distinctive glomerocrystic flows in middle part of flow-on-flow sequence that probably originated from a low shield volcano in the western part of Secret Valley. They are uplifted, tilted, and faulted on the Gallatin horst, and they overlie tuffaceous and lacustrine beds (Grose and others, 1981; Roberts, 1985). Dark gray, moderately coarsely glomeroporphyritic with snowflake-like glomerocrysts of calcic plagioclase up to 15 mm in diameter and small olivine phenocrysts set in diktytaxitic intergranular matrix of augite and plagioclase. Unit is called "Secret Valley Basalt" by Roberts (1985). *Chemical analysis:* SiO<sub>2</sub> 49.38, Al<sub>2</sub>O<sub>3</sub> 17.69, FeO 9.31, MgO 9.29, CaO 10.69, Na<sub>2</sub>O 2.85, K<sub>2</sub>O 0.42, TiO<sub>2</sub> 1.04, P<sub>2</sub>O<sub>5</sub> 0.25, MnO 0.16. *Analytical data:* K<sub>2</sub>O = 0.391%; <sup>40</sup>Ar\* = 2.73145 × 10<sup>-12</sup> mol/gm; <sup>40</sup>Ar\* = 6.4%.  
**(whole rock) 4.9 ± 0.5 m.y.**
25. **GAD-10** K-Ar  
 Andesite flow (40°26.7'N, 120°21.4'W; NW/4 SW/4 NW/4 S24, T30N, R14E; Litchfield 15' quad.; elevation 6,730 ft; from summit of Shaffer Mountain composite volcano; Lassen Co., CA) from the highest preserved flow and located about 1,500 ft to the southeast of the central vent plug, hence it represents one of the youngest eruptives on Shaffer Mountain volcano. Dark gray, abundantly glomeroporphyritic and seriate on plagioclase phenocrysts with sparse clinopyroxene microphenocrysts set in intersertal matrix. *Chemical analysis:* SiO<sub>2</sub> 58.32, Al<sub>2</sub>O<sub>3</sub> 17.04; FeO 6.50, MgO 3.61, CaO 6.50, Na<sub>2</sub>O 3.44, K<sub>2</sub>O 2.28, TiO<sub>2</sub> 0.85, P<sub>2</sub>O<sub>5</sub> 0.34, MnO 0.10. *Analytical data:* K<sub>2</sub>O = 2.155%; <sup>40</sup>Ar\* = 3.40326 × 10<sup>-11</sup> mol/gm; <sup>40</sup>Ar\* = 34.8%.  
**(whole rock) 10.9 ± 0.4 m.y.**
26. **RAD-5** K-Ar  
 Andesite flow (40°21.0'N, 120°28.5'W; NW/4 NE/4 NE/4 S26, T29N, R13E; Litchfield 15' quad.; elevation 4,360 ft; from low on NW side of Bald Mountain in Honey Lake Valley; Lassen Co., CA) from small lava flow interbedded within lower part of sequence, over 1000 ft or 330 m thick, of heterolithic debris flows (lahars) and monolithic flow breccias. This sequence overlies the "Antelope Mountain Andesite" of Roberts (1985) (sample 23) and underlies Pliocene(?) tuff (Roberts, 1985). It correlates with thick laharc and breccia units southwest of Susanville (Grose and others, 1981). Medium gray, finely porphyritic with plagioclase and pyroxene in pilotaxitic matrix. *Chemical analysis:* SiO<sub>2</sub> 60.45, Al<sub>2</sub>O<sub>3</sub> 16.93, FeO 6.74, MgO 2.55, CaO 5.30, Na<sub>2</sub>O 3.47, K<sub>2</sub>O 2.03, TiO<sub>2</sub> 0.74, P<sub>2</sub>O<sub>5</sub> 0.13, MnO 0.12. *Analytical data:* K<sub>2</sub>O = 1.789%; <sup>40</sup>Ar\* = 2.57517 × 10<sup>-11</sup> mol/gm; <sup>40</sup>Ar\* = 34.8%.  
**(whole rock) 10.0 ± 0.4 m.y.**
27. **GAD-11** K-Ar  
 Andesite flow (40°24.0'N, 120°9.8'W; SW/4 NE/4 SW/4 S3, T29N, R16E; Wendel 15' quad.; elevation 5,160 ft; from flow low on NW flank of Hot Springs Peak in the Skedaddle Mountains; Lassen Co., CA) from flow dipping about 8° NW that projects to the summit of the Skedaddle Mountain volcano complex. It represents one of the youngest flows derived from the central vent area. Dark gray, abundantly finely seriate porphyritic with plagioclase and minor augite and sanidine set in pilotaxitic groundmass. *Chemical*



*analysis:* SiO<sub>2</sub> 60.72, Al<sub>2</sub>O<sub>3</sub> 17.53, FeO 5.99, MgO 2.27, CaO 5.00, Na<sub>2</sub>O 3.85, K<sub>2</sub>O 2.20, TiO<sub>2</sub> 0.70, P<sub>2</sub>O<sub>5</sub> 0.24, MnO 0.08. *Analytical data:* K<sub>2</sub>O = 1.954%; <sup>40</sup>Ar\* = 3.32114 × 10<sup>-11</sup> mol/gm; <sup>40</sup>Ar\* = 27.1%.

(whole rock) 11.8 ± 0.6 m.y.

28. *GAD-6* K-Ar  
Olivine-augite basalt flow (40°15.6'N, 120°33.3'W; SE/4 NW/4 NE/4 S30, T28N, R13E; Susanville 15' quad.; elevation 7,780 ft; summit of Thompson Peak; Lassen Co., CA) from uppermost part of uniform nearly horizontal basalt flows, 915 ft thick, that rest on older flows (sample 29) and Sierran quartz monzonite. Light to medium gray, diktytaxitic, mildly ophimottled, intergranular, with labradorite, augite, and olivine in uniform fabric. Unit is called "Thompson Peak Basalt" by Roberts (1985). *Chemical analysis:* SiO<sub>2</sub> 48.58, Al<sub>2</sub>O<sub>3</sub> 16.91, FeO 10.51, MgO 7.94, CaO 9.65, Na<sub>2</sub>O 2.80, K<sub>2</sub>O 0.49, TiO<sub>2</sub> 1.07, P<sub>2</sub>O<sub>5</sub> 0.21, MnO 0.17. *Analytical data:* K<sub>2</sub>O = 0.542%; <sup>40</sup>Ar\* = 7.9244 × 10<sup>-12</sup> mol/gm; <sup>40</sup>Ar\* = 18.4%.

(whole rock) 10.1 ± 0.6 m.y.

29. *RAD-3* K-Ar  
Basalt flow (40°15.3'N, 120°33.3'W; SE/4 NW/4 SE/4 S30, T28N, R13E; Susanville 15' quad.; elevation 7,280 ft; near summit on S flank of Thompson Peak; Lassen Co., CA) from upper part of multiple flow sequence, 230 ft, overlain on high-relief erosional surface by Thompson Peak Basalt (sample 28) and underlain by "Sierran quartz monzonite" of (Roberts, 1985). The flows preserved in the Thompson Peak area accumulated in a paleovalley cut in Sierran granitic rocks. Black, sparsely finely porphyritic with labradorite and olivine in hyalo-ophitic matrix, uniformly dense. *Chemical analysis:* SiO<sub>2</sub> 50.06, Al<sub>2</sub>O<sub>3</sub> 15.09, FeO 12.06, MgO 4.52, CaO 8.31, Na<sub>2</sub>O 3.36, K<sub>2</sub>O 1.48, TiO<sub>2</sub> 2.31, P<sub>2</sub>O<sub>5</sub> 0.97, MnO 0.23. *Analytical data:* K<sub>2</sub>O = 1.448%; <sup>40</sup>Ar\* = 3.41972 × 10<sup>-11</sup> mol/gm; <sup>40</sup>Ar\* = 46.5%.

(whole rock) 16.3 ± 0.6 m.y.

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