# *K-Ar results for silicic volcanics from the Medicine Lake Highland, northeastern California—a summary*

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# K-Ar RESULTS FOR SILICIC VOLCANICS FROM THE MEDICINE LAKE HIGHLAND, NORTHEASTERN CALIFORNIA—A SUMMARY

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The contiguous area including Medicine Lake and Mount Shasta is one that has experienced Holocene volcanism spanning the compositional range from basalt to rhyolite. This volcanism, < 10,000 years old, is symptomatic of the extensive extrusive activity that formed the underlying thick blanket of volcanogenic rocks. The precise area of interest extends from the Double Head—Timber Mountain line on the east to Mount Shasta on the west and from California Highway 89 on the south side to the California-Oregon border on the north. Heretofore little has been known about the absolute chronology of these pre-Holocene rocks; the only published radiometric dates known to the author include those of Mertzman (1977), Hart and others (1979), Brown and Mertzman (1979), Luedke and Lanphere (1980), and Mertzman (1981). The ongoing K-Ar investigation is an outgrowth of a mapping project initiated in 1973 to determine the regional volcanic stratigraphy; the goal was the eventual understanding of the petrology and geochemistry of the region as a function of geologic time. This article reports on the K-Ar geochronology of the silicic rocks that outcrop in this area, herein defined as those extrusives with greater than 67% $SiO_2$. The portion of this region salient to this study is delineated in figure 1. The well known Holocene glass flows, for which the Medicine Lake Highland is well noted, are also depicted. This work was supported by the National Science Foundation (Grant #EAR79-04524) and by research grants from Franklin and Marshall College.

## ANALYTICAL PROCEDURES

Samples were crushed and sieved; the 8-42 mesh fraction was collected and split; one split was for argon analysis and the other for whole rock XRF analysis. The latter split was subsequently crushed to less than 100 mesh and dried overnight. Exactly 0.4 gm of whole rock powder was mixed with 3.6 gm of $Li_2B_4O_7$ in a precise 1:9 dilution and fused into ¾" glass discs. The samples were analyzed in triplicate using a Diano XRD-8300 automated x-ray fluorescence spectrometer. The elemental regression lines (oxide concentration vs line intensity in counts per second) were constructed using 27 USGS, South African, French, and N.B.S. rock standards. Each argon split was cleaned using an ultrasonic apparatus and washed in distilled water and reagent grade acetone. The argon analyses were done at Case Western Reserve University in the Lab of Dr. James Aronson. Each sample was fused in a Mo crucible housed in a silica bell jar and connected en echelon with five other samples housed similarly and connected into the vacuum system. The entire extraction system was degassed by heating and pumping on a Hg diffusion pump between each sample analysis. A $^{38}Ar$ tracer was added to the sample gas from a tracer reservoir through a pipette of known volume. The tracer was added during the fusion process to insure equilibration between it and the sample gas. The extraction system is on line to a MS-10 spectrometer and data was collected with both digital and strip chart output.

## RESULTS

The K-Ar data are reported under "Sample Descriptions," and the whole rock chemical analyses for the dated samples are in table 1. Data concerning three of the samples were previously reported in Mertzman (1981) and are reported herein for the sake of completeness. For two of the samples, SW-75-164 and ML-74-17, a maximum age is assigned because the argon extracted from them could not be distinguished isotopically from atmospheric argon. The latter value was measured at the beginning and end of each batch of six samples. How much radiogenic argon these two samples would require before their extracted argon could be differentiated is a quantity that can be readily calculated. This quantity naturally will vary from sample to sample as a result of the unequal retention of atmospheric argon. This quantity of argon can also be related to a maximum age for the sample; that is, the actual age of the sample lies somewhere between the calculated maximum age and zero.

Ten of the samples, numbered three through twelve, gave Pleistocene ages that range from 1.25 to 0.24 m.y. old. In the region delineated in figure 1, all silicic rocks have now been dated. The conclusion can be drawn that if pre-mid-Pleistocene silicic volcanism did occur, all vestiges of it must have either been removed by erosion or covered by subsequent volcanism. Four of the samples cluster around the 1 m.y. old mark, which in this region coincides with a time of intense volcanism centering in the Haight Mountain—Dry Creek Peak area that produced 1500-2500 feet of two pyroxene-hornblende andesites and dacites. The mineralogy and petrography of these four samples correlates quite well with those from the main region of 1 m.y. old volcanism. Therefore, these samples simply represent satellitic events associated with this pulse of magmatism. The six remaining samples that produced good numbers range from 0.61 to 0.24 m.y. old and are distributed around the base of the Medicine Lake volcano. This distribution pattern has no significance since the extrusives associated with Medicine Lake are substantially younger in age (Mertzman, 1977, 1981), and therefore, these six samples represent islands of older domes and flows. No discernible pattern between sample locations and ages exists for these silicic rocks, a conclusion that sharply contrasts with data from eastern Oregon (MacLeod and others, 1976).

As an addendum, K-Ar dates were attempted on two additional silicic units. Their chemistry is reported in table 2 and their locations are recorded on figure 1. These samples had enormous amounts of atmospheric argon that precluded obtaining any meaningful age data.

Constants used in the age calculation follow: $\lambda_\epsilon = 0.581 \times 10^{-10} yr^{-1}$; $\lambda_\beta = 4.962 \times 10^{-10} yr^{-1}$; $^{40}K/K = 1.167 \times 10^{-4}$ mol/mol.

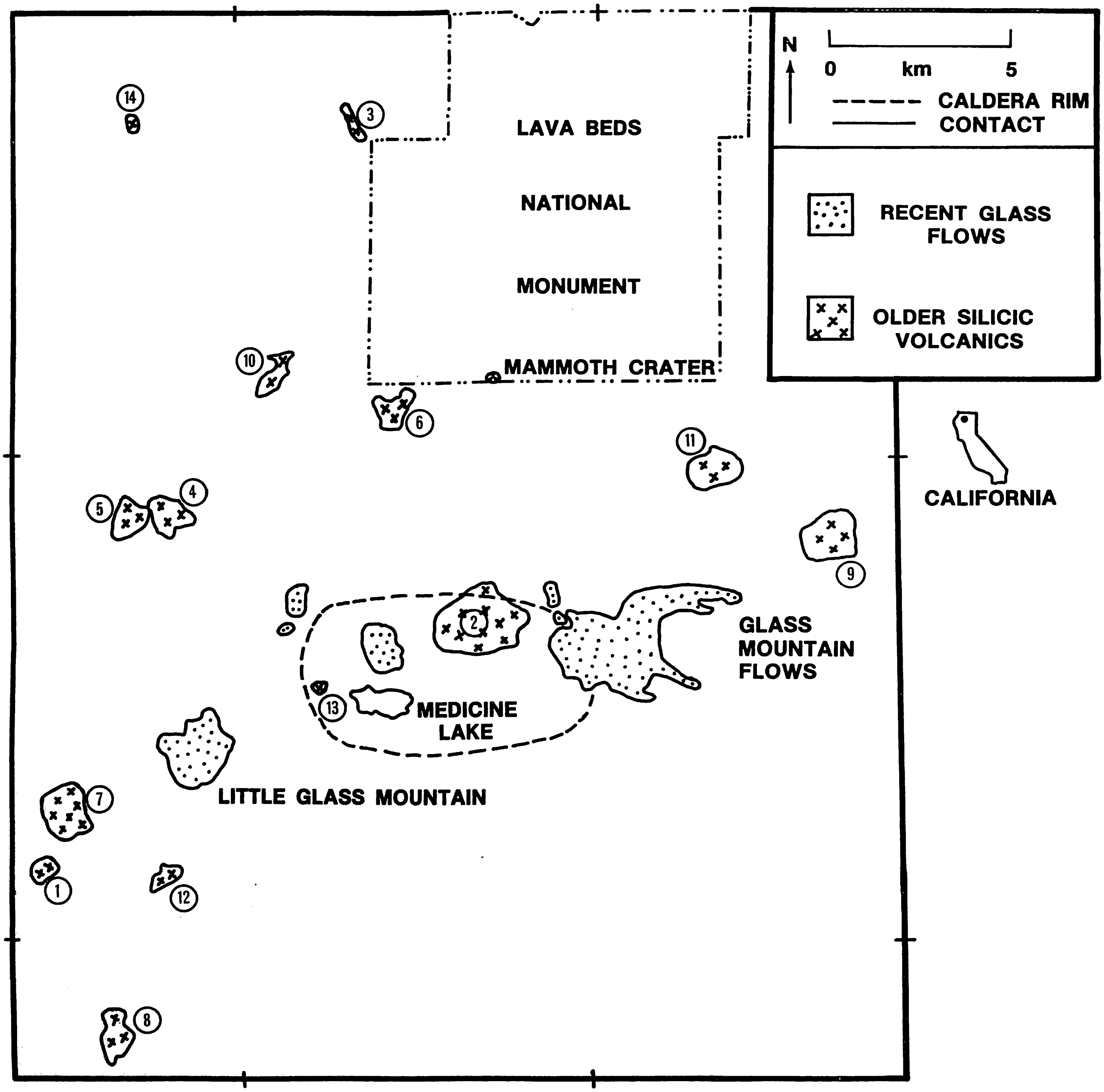


FIGURE 1. Generalized map of the study area. Sample locations are numbered and correspond to the data in the sample description section and table 1.

## SAMPLE DESCRIPTIONS

1. *SW-75-164* K-Ar
Dacite (NE¼ SE¼ S31,T43N,R2E; ¼ mi SE of Lost Spring on Fisk Ridge, Bray quad, CA). Gray vesiculated lava to black obsidian; plagioclase ($An_{40-70}$), orthopyroxene, clinopyroxene, and titanomagnetite phenocrysts set in a trachytic to hyalotrachytic groundmass of fresh brown glass. *Mode*: 27.0% plag, 0.3% cpx, 1.1% Ti-mt, 70.6% groundmass. *Analytical data:* Sample weight = 3.0806 gm; $K_2O$ = 3.42 (wt)%; $^*Ar^{40}$ = 2.7124 x $10^{-13}$ moles/gm; $^*Ar^{40}$ = 0.304%.
**(whole rock)0.05 ± 0.045 m.y.**
**Maximum age 0.15 m.y.**

2. *ML-74-17* K-Ar
Rhyolite (NW¼ SE¼ S31,T44N,R4E; summit dome on Mount Hoffman, Medicine Lake quad, CA). Gray pumiceous lava with unfilled and unlined vesicles; plagioclase ($An_{30-50}$) often oval-shaped from resorption; orthopyroxene, clinopyroxene, and titanomagnetite phenocrysts set in a pilotaxitic groundmass dominated by fresh clear glass. *Mode*: 14.1% plag, 1.4%opx, 0.6% cpx, 0.9% Ti-mt, 73.0% groundmass. *Analytical data*: Sample weight = 3.0066 gm; $K_2O$ = 3.73 (wt)%; $^*Ar^{40}$ (Max.) = 1.386 x $10^{-12}$ moles/gm.
**(whole rock) maximum age 0.08 m.y.**

3. *SM-75-104* K-Ar
Rhyolite tuff (SW¼ NE¼ S34,T46N,R3E; outcrop 0.1 mi S of Lairds Camp—Mount Dome road in the hanging wall of a N10°W striking normal fault, Mt. Dome quad, CA). Gray to buff colored, densely welded, tuffaceous rock; plagioclase ($An_{30-60}$) with strongly developed oscillatory zoning, crystals often broken; hornblende, orthopyroxene, biotite, and titanomagnetite phenocrysts set in a densely welded flow aligned fresh clear glass dominated groundmass. *Mode*: 26.1%plag, 0.6% hornblende, 0.3% opx, 0.3% biotite, 0.6% Ti-mt, 72.1% groundmass. *Analytical data:* Sample weight = 3.209 gm; $K_2O$ = 3.41 (wt)%; $^*Ar^{40}$ = 6.138 x $10^{-12}$ moles/gm; $^*Ar^{40}$ = 4.02%.
**(whole rock) 1.25 ± 0.24 m.y.**

4. *47-B-1* K-Ar
Rhyolite (SE¼ NW¼ S23,T44N,R2E; summit dome that forms hill 5598, Medicine Lake quad, CA). Cream to buff colored lava, often pumiceous; plagioclase ($An_{40-60}$), clinopyroxene, orthopyroxene, hornblende, titanomagnetite phenocrysts set in a trachytic cryptocrystalline groundmass peppered with opaques and plagioclase microlites. *Mode:* 21.9% plag, 1.5% cpx, 1.5% opx, 1.2% Ti-mt, 0.1% hornblende, 73.8% groundmass. *Analytical data:* Sample weight = 4.0128 gm; $K_2O$ = 2.91 (wt)%; $^*Ar^{40}$ = 4.952 x $10^{-12}$ moles/gm; $^*Ar^{40}$ = 51.06%.
**(whole rock)1.18 ± 0.06 m.y.**

5. *56-B-1* K-Ar
Rhyolite (SW¼ SW¼ S23,T44N,R2E; ½ mi SW of hill 5598, on west side of barranca that separates this dome from the one represented by the previous sample, Medicine Lake quad, CA). Gray to buff colored lava, often pumiceous; plagioclase ($An_{30-50}$), orthopyroxene, clinopyroxene, hornblende, and titanomagnetite phenocrysts set in a pilotaxitic cryptocrystalline groundmass dominated by plagioclase microlites and opaques. *Mode:* 17.1% plag, 1.3% opx, 0.8% cpx, 0.7% hornblende, 1.4% Ti-mt, 78.7% groundmass. *Analytical data:* Sample weight = 4.05 gm; $K_2O$ = 3.18 (wt)%; $^*Ar^{40}$ = 4.43 x $10^{-12}$ moles/gm; $^*Ar^{40}$ = 5.55%.
**(whole rock) 0.95 ± 0.14 m.y.**

6. *SM-75-38A* K-Ar
Rhyolite (NW¼ SE¼ S2,T44N,R3E; ½ mi SE of Cinder Butte along the roadbed of the abandoned lumber railroad track, Medicine Lake quad, CA). Cream to pink to buff colored lava, often pumiceous; plagioclase ($An_{30-50}$) with strongly resorbed margins, orthopyroxene, clinopyroxene, and titanomagnetite phenocrysts set in a pilotaxitic partially devitrifed groundmass consisting of plagioclase microlites, opaque granules, and pale brown glass. *Mode:* 8.0% plag, 0.9% opx, 0.2% cpx, 0.8% Ti-mt, 90.1% groundmass. *Analytical data:* Sample weight = 2.7222 gm; $K_2O$ = 4.52 (wt)%; $^*Ar^{40}$ = 2.176 x $10^{-12}$ moles/gm; $^*Ar^{40}$ = 7.35%.
**(whole rock) 0.33 ± 0.04 m.y.**

7. *SW-75-191* K-Ar
Rhyolite (SW¼ SE¼ S28, T43N,R2E; ½ mi SW of summit of Red Cap Mountain along the ridge crest, Medicine Lake quad, CA). Cream to buff colored lava, often platy due to flow jointing; plagioclase ($An_{40}$), orthopyroxene, clinopyroxene, resorbed hornblende, and titanomagnetite as small (< 1 mm) phenocrysts set in a trachytic cryptocrystalline groundmass composed of plagioclase microlites, granular opaques, and devitrified glass. *Mode:* 2.1% plag, 0.1% cpx + opx, 0.2% hornblende, 0.1% Ti-mt, 97.5% groundmass. *Analytical data:* Sample weight = 4.1162 gm; $K_2O$ = 3.36 (wt)%; $^*Ar^{40}$ = 4.877 x $10^{-12}$ moles/gm; $^*Ar^{40}$ = 61.69%.
**(whole rock) 1.01 ± 0.05 m.y.**

8. *AH-80-83* K-Ar
Rhyolite (NW¼ SW¼ S23,T42N,R2E; 3.2 mi SE of the summit of Doe Peak; outcrop is poor and consists of infrequent knockers of obsidian, Hambone quad, CA). Obsidian sample, no phenocrysts; fluidal banding is prominently displayed by alternation of glassy and cryptocrystalline layers, the latter possessing trachytic trains of microlites. *Analytical data:* Sample weight = 2.7635 gm; $K_2O$ = 4.54 (wt)%; $^*Ar^{40}$ = 1.867 x $10^{-12}$ moles½gm; $^*Ar^{40}$ = 23.24%.
**(whole rock) 0.29 ± 0.02 m.y.**

**TABLE 1. Major element chemistry in weight percent together with C.I.P.W. norms.***

| Sample no.<br>Map no. | SW-75-164<br>1 | ML-74-17<br>2 | SM-75-104<br>3 | 47-B-1<br>4 | 56-B-1<br>5 | SM-75-38A<br>6 | SW-75-191<br>7 | AH-80-83<br>8 | 79-61B<br>9 | SM-75-51<br>10 | ML-74-49B<br>11 | AH-80-139<br>12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $SiO_2$ | 68.03 | 70.44 | 70.78 | 70.81 | 71.47 | 71.99 | 72.53 | 74.12 | 74.76 | 74.96 | 76.38 | 76.74 |
| $Al_2O_3$ | 16.01 | 14.18 | 14.30 | 14.65 | 14.48 | 14.11 | 15.00 | 13.35 | 13.27 | 12.93 | 12.13 | 12.82 |
| FeO | 1.89 | 1.68 | 1.06 | 1.60 | 0.91 | 0.60 | 1.17 | 0.83 | 1.36 | 0.82 | 0.70 | 1.00 |
| $Fe_2O_3$ | 1.50 | 0.88 | 1.21 | 1.18 | 1.63 | 2.23 | 0.79 | 0.61 | 0.21 | 0.42 | 0.38 | 0.26 |
| $TiO_2$ | 0.63 | 0.40 | 0.27 | 0.39 | 0.31 | 0.45 | 0.24 | 0.22 | 0.26 | 0.21 | 0.05 | 0.20 |
| MnO | 0.07 | 0.06 | 0.07 | 0.08 | 0.06 | 0.05 | 0.04 | 0.04 | 0.03 | 0.04 | 0.04 | 0.03 |
| MgO | 0.72 | 0.58 | 0.65 | 0.42 | 0.51 | 0.34 | 0.50 | 0.16 | 0.22 | 0.08 | 0.00 | 0.35 |
| CaO | 2.54 | 1.65 | 1.71 | 1.89 | 1.66 | 1.24 | 1.82 | 0.91 | 0.92 | 0.86 | 0.46 | 0.89 |
| $Na_2O$ | 4.71 | 4.68 | 4.03 | 4.66 | 4.78 | 3.91 | 3.51 | 3.84 | 3.60 | 4.06 | 4.46 | 3.67 |
| $K_2O$ | 3.42 | 3.73 | 3.41 | 2.91 | 3.18 | 4.52 | 3.36 | 4.54 | 4.60 | 4.63 | 4.42 | 4.39 |
| $P_2O_5$ | 0.13 | 0.07 | 0.07 | 0.08 | 0.09 | 0.08 | 0.05 | 0.03 | 0.04 | 0.04 | 0.01 | 0.03 |
| L.O.I. | 0.91 | 2.07 | 3.03 | 0.90 | 0.87 | 0.36 | 1.17 | 1.21 | 0.91 | 0.29 | 0.44 | 0.32 |
| TOTAL | 100.56 | 100.42 | 100.59 | 99.57 | 99.95 | 99.88 | 100.18 | 99.86 | 100.18 | 99.34 | 99.47 | 100.70 |
| $FeO^T$ | 3.24 | 2.47 | 2.15 | 2.66 | 2.38 | 2.61 | 1.88 | 1.38 | 1.55 | 1.20 | 1.04 | 1.23 |
| Qz | 20.86 | 24.55 | 30.30 | 27.81 | 27.68 | 24.63 | 34.55 | 32.41 | 33.38 | 31.81 | 32.92 | 35.16 |
| Or | 20.28 | 22.41 | 20.66 | 17.43 | 18.97 | 25.23 | 20.06 | 27.20 | 27.38 | 27.62 | 26.38 | 26.30 |
| Ab | 39.99 | 40.26 | 34.95 | 39.96 | 40.82 | 41.11 | 30.00 | 32.94 | 30.69 | 34.68 | 38.11 | 30.91 |
| An | 11.80 | 6.78 | 8.23 | 8.98 | 7.72 | 3.99 | 8.79 | 4.38 | 4.34 | 3.42 | 0.03 | 4.20 |
| C | 0.25 | 0.00 | 1.06 | 0.60 | 0.37 | 0.00 | 2.42 | 0.54 | 0.80 | 0.00 | 0.00 | 0.40 |
| Di | 0.00 | 0.90 | 0.00 | 0.00 | 0.00 | 1.27 | 0.00 | 0.00 | 0.00 | 0.55 | 1.83 | 0.00 |
| Hy | 3.13 | 2.86 | 2.31 | 2.55 | 1.28 | 0.26 | 2.44 | 1.15 | 2.52 | 0.81 | 0.00 | 2.21 |
| Mt | 2.18 | 1.30 | 1.80 | 1.73 | 2.25 | 0.79 | 1.16 | 0.90 | 0.31 | 0.61 | 0.56 | 0.38 |
| Ilm | 1.20 | 0.77 | 0.53 | 0.75 | 0.59 | 0.85 | 0.46 | 0.42 | 0.50 | 0.40 | 0.10 | 0.38 |
| Hm | 0.00 | 0.00 | 0.00 | 0.00 | 0.09 | 1.68 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Ap | 0.30 | 0.17 | 0.17 | 0.19 | 0.21 | 0.19 | 0.12 | 0.07 | 0.09 | 0.09 | 0.02 | 0.07 |

*The analyses were determined by XRF techniques described in Mertzman (1977); L.O.I. = loss on ignition.

**TABLE 2. Major element chemistry in weight percent together with C.I.P.W. norms.***

| Sample no. | 9-8B | SM-75-80 |
|---|---|---|
| Map no. | 13 | 14 |
| $SiO_2$ | 67.12 | 68.62 |
| $Al_2O_3$ | 15.90 | 14.72 |
| FeO | 2.76 | 1.84 |
| $Fe_2O_3$ | 1.36 | 0.87 |
| $TiO_2$ | 0.71 | 0.42 |
| MnO | 0.10 | 0.09 |
| MgO | 1.20 | 0.96 |
| CaO | 2.76 | 2.13 |
| $Na_2O$ | 4.56 | 3.89 |
| $K_2O$ | 3.14 | 3.07 |
| $P_2O_5$ | 0.20 | 0.10 |
| L.O.I. | 0.39 | 4.08 |
| TOTAL | 100.20 | 100.79 |
| $FeO^T$ | 3.98 | 2.62 |
| Qz | 20.12 | 28.49 |
| Or | 18.59 | 18.76 |
| Ab | 38.66 | 34.04 |
| An | 12.42 | 10.26 |
| C | 0.46 | 1.41 |
| Di | 0.00 | 0.00 |
| Hy | 5.96 | 4.68 |
| Mt | 1.98 | 1.30 |
| Ilm | 1.35 | 0.82 |
| Hm | 0.00 | 0.00 |
| Ap | 0.47 | 0.24 |

*The analyses are for two samples for which K/Ar dates were attempted but were unsuccessful due to large amounts of atmospheric Ar contamination.

9. *79-61B* K-Ar
Rhyolite (NE¼ NE¼ S28,T44N,R5E; 3.7 mi WSW of Tionesta and 1 mi S of the Lava Beds National Monument—State Rte 139 road, Timber Mountain quad, CA). Obsidian sample, no phenocrysts; much of the glass has devitrified along perlitic cracks to a cryptocrstalline felsitic aggregate containing tiny feldspar microlites randomly oriented. *Analytical data:* Sample weight = 3.0717 gm; $K_2O$ = 4.60 (wt)%; $^*Ar^{40}$ = 1.61 x $10^{-12}$ moles/gm; $^*Ar^{40}$ = 7.09%.
**(whole rock) 0.24 ± 0.03 m.y.**

10. *SM-75-51* K-Ar
Rhyolite (NE¼ SE¼ S32,T45N,R3E; 2.4 mi NW of the summit of Cinder Butte, 100 yards west of recent andesite flow front, Medicine Lake quad, CA). Obsidian sample, no phenocrysts; fluidal banding is a conspicuous feature and is delineated by bands of glass and flow aligned crystallite-rich layers. *Analytical data:* Sample weight = 3.1964 gm; $K_2O$ = 4.63 (wt)%; $^*Ar^{40}$ = 4.12 x $10^{-12}$ moles/gm; $^*Ar^{40}$ = 68.04%.
**(whole rock) 0.61 ± 0.03 m.y.**

11. *ML-74-49B* K-Ar
Rhyolite (NE¼ NE¼ S13,T44N,R4E; 0.9 mi NE of Cougar Butte with the best outcrop located along the roadbed of the abandoned lumber railroad, Timber Mountain quad, CA). Obsidian sample, rare, small (< 1 mm) phenocrysts of plagioclase ($An_{30-40}$) in which much of the glass has devitrified along perlitic cracks to a cryptocrystalline felsitic aggregate containing tiny feldspar microlites in a pilotaxitic arrangement. *Mode:* 0.7% plag, 99.3% groundmass. *Analytical data:* Sample weight = 3.128 gm; $K_2O$ = 4.42 (wt)%; $^*Ar^{40}$ = 2.69 x $10^{-12}$ moles/gm; $^*Ar^{40}$ = 11.62%.
**(whole rock) 0.43 ± 0.04 m.y.**

12. *AH-80-139* K-Ar
Rhyolite (NE¼ SE¼ S35,T43N,R2E; 0.5 mi SW of Grasshoper Flat and ½ mi due E of hill 5866, Medicine Lake quad, CA). Obsidian sample, no phenocrysts; fluidal banding is strikingly developed. The banding is made obvious by alternating layers of glass and microlites that are strongly flow aligned. *Analytical data:* Sample weight = 3.0217 gm; $K_2O$ = 4.39 (wt)%; $^*Ar^{40}$ = 2.075 x $10^{-12}$ moles/gm; $^*Ar^{40}$ = 35.90%.
**(whole rock) 0.33 ± 0.02 m.y.**

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