K-Ar ages of granitic plutons of north-central Nevada

Miles L. Silberman and Edwin H. McKee

Isochron/West, Bulletin of Isotopic Geochronology, v. 1, pp. 15-32

This page is intentionally left blank to maintain order of facing pages.

K-Ar AGES OF GRANITIC PLUTONS IN NORTH-CENTRAL NEVADA[1]

Miles L. Silberman and Edwin H. McKee
U. S. Geological Survey

The following list contains analytical data for K-Ar isotopic age determinations on 26 plutons from north-central Nevada, along with notes on the geology.

Mineral separates from samples of the granitic rocks were prepared by crushing and sizing the fresh rock samples to 0.1 to 1 mm. Electrostatic and magnetic separators, heavy liquids, an inclined vibrating table, and in some cases hand-picking were used to prepare mineral concentrates used for K_2O and Ar analyses. The mineral separates were split with a Jones microsplitter and separate aliquots were analyzed for argon and potassium. Estimates of mineral purity are given where available.

Argon analyses were performed by the writers in the Isotope Geology Laboratory of the U.S. Geological Survey, Menlo Park, Calif., using standard isotope dilution procedures (Dalrymple and Lanphere, 1970). A Neir type, 6-inch, 60° sector mass spectrometer or a Reynolds type, 4 1/2-inch, 60° sector mass spectrometer, both operated in the static mode, were used for mass analysis. Potassium analysis was performed by Lois Schlocker by flame photometer using lithium metaborate fusion, the lithium serving as an internal standard. Analytical precision of the reported ages is 2 percent unless otherwise noted and is based on statistical analysis of a large number of replicate potassium and duplicate argon determinations (McKee and Silberman, 1970; Silberman, unpublished data).

Constants used in the calculation of K-Ar age are: $\lambda_e = 0.585 \times 10^{-10}\ yr^{-1}$; $\lambda\beta = 4.72 \times 10^{-10}\ yr^{-1}$; K^{40}/K total = 1.22×10^{-4} gm/gm.

Abbreviations used: $\overset{*}{A}r$ = radiogenic argon-40; $\Sigma\ \overset{*}{A}r^{40}$ = total argon-40; # = age calculated from mean of two argon analyses.

1 Publication authorized by Director, U.S. Geological Survey.

GEOLOGIC DISCUSSION

The area covered by the listed samples, approximately 50,000 square kilometers, includes Lander and Eureka Counties and parts of Elko, Humboldt, Pershing, and Nye Counties, Nevada (fig. 1). Within the region are approximately 50 granite, quartz monzonite, granodiorite, and monzonite plutons of medium- to coarse-grained equigranular to prophyritic texture. They range in outcrop area from less than 1 to more than 150 square kilometers. Some, like Buffalo Mountain and French Creek, are large composite plutons, of varying composition. More than 50 K-Ar age determinations have been run on 34 of the plutons in this area. The age relations of the plutons were summarized by Silberman and McKee (1971), but the following list contains the analytical data for the K-Ar ages and notes on the geologic occurrence of each pluton that have not been published previously.

The age data are presented range by range. Where appropriate, a short discussion of the age relations indicated by the K-Ar results from each range follows the last determination for each group.

The ages of the plutons discussed in the list are plotted on a frequency diagram in Figure 2, grouped in intervals of five million years. Average ages were used for concordant mineral pairs. For discordant mineral pairs, the older age (hornblende) was used, as it probably more nearly represents the age of emplacement. For the large pluton complexes of Frenchy Creek and Buffalo Mountain, several ages were used because these complex bodies were emplaced over an interval of time.

Table 1 lists the data used in Figure 2 and includes K-Ar ages from sources other than our own. R. L. Armstrong has provided valuable data on the geochronology of plutonic rocks in the eastern part of the area of Figure 1. Paul Damon's data on the Laramide plutonic epoch in the southwest Basin and Range province, and data by Evernden and Kistler on the Sierra Nevada batholith has allowed us to compare the ages of the plutonic rocks in north-central Nevada to those in adjacent regions.

We consider the ages of the 34 plutons in north-central Nevada to represent the times of plutonism in central Nevada. The distribution of the ages shows that plutonism in north-central Nevada was episodic and occurred in four pulses: Jurassic (168 to 143 m.y.); middle Cretaceous (105 to 87 m.y.); Late Cretaceous (71 to 68 m.y.); and middle Tertiary (49 to 30 m.y.). The best represented of the intrusive epochs are those of the Jurassic and Tertiary ages. In total area of intrusive rock exposed at the present erosion surface, the Jurassic epoch is the dominant one. With only one exception, that of the small pluton northwest of Carlin, all of the ages fall within the four time intervals.

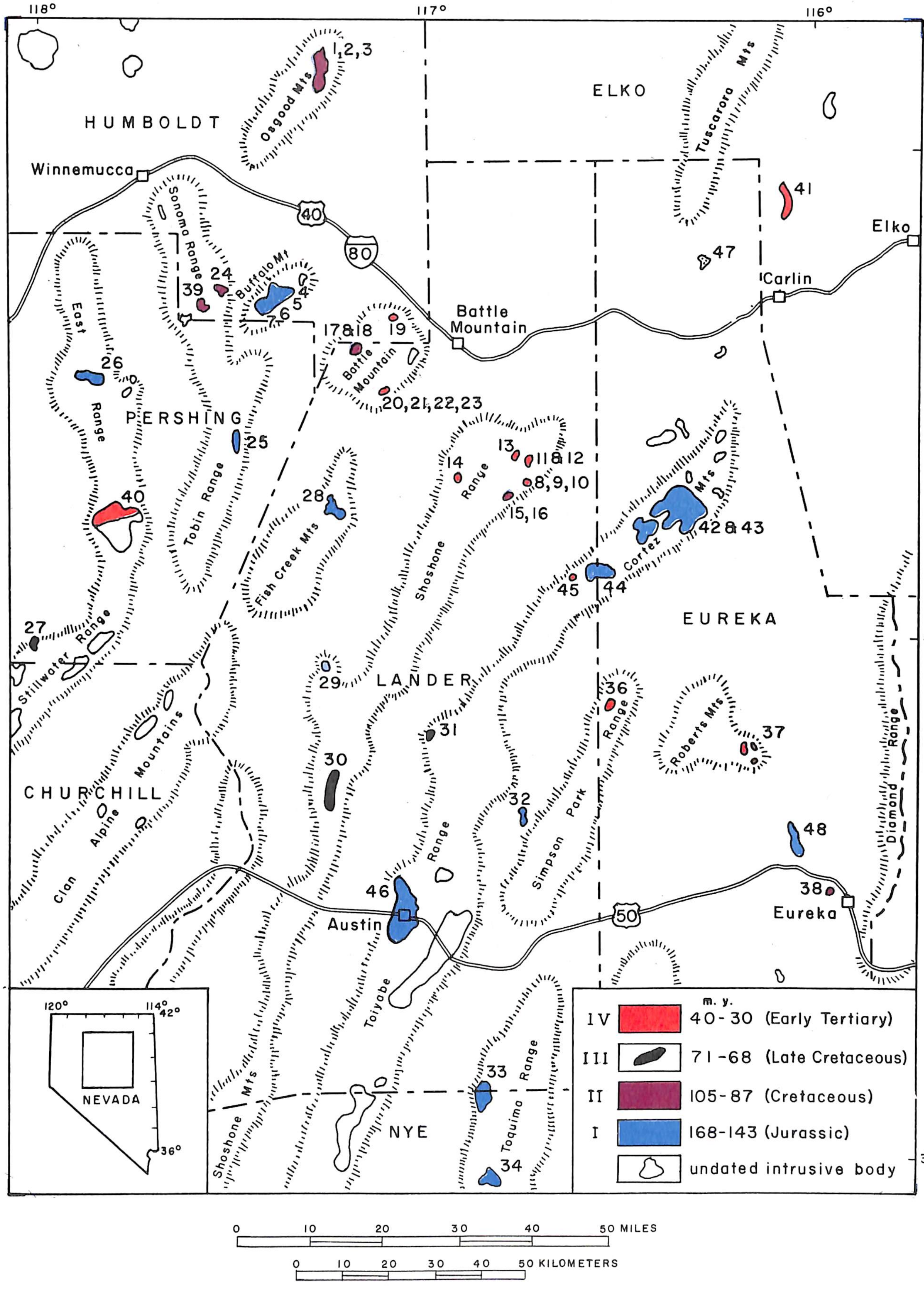

Figure I. Plutons in North Central Nevada modified from Wilson and Paul (1965)

Table 1. K-Ar Ages of North-Central Nevada Plutons

I. Included in area of Figure 1, from List #1.

Sample no.	Range - Pluton	Age in m.y.
1,2	Osgood Mountains, Osgood	90
4	Buffalo Mountain, quartz-monzonite	146
5	Buffalo Mountain, monzonite	159
6	Buffalo Mountain, monzonite	153
7	Buffalo Mountain, quartz-monzonite	151
8	Northern Shoshone, Tenabo dike	35
9,10	Northern Shoshone, Tenabo stock	38
11,12	Northern Shoshone, Granite Mountain	37
13	Northern Shoshone, Hilltop	38
14	Northern Shoshone, Goat Ridge	35
15	Northern Shoshone, Gold Acres	99
17,18	Antler Peak (Battle Mountain) Range, Trenton Canyon	87
19	Antler Peak (Battle Mountain) Range, Elder Creek	37
20,21	Antler Peak (Battle Mountain) Range, Copper Canyon	38
24	Sonoma Range, Gregg Canyon	104
25	Tobin Range, Tobin	153
26	East Range, Lee Peak	149
27	Stillwater Range, New York Canyon	69
28	Fish Creek Mountains, McCoy	153
29	Shoshone Mountains, Cain Creek	155
30	Shoshone Mountains, Ravenswood	71
31	Toiyabe Range, Iowa Creek	68
32	Toiyabe Range, Grass Valley	168
33	Toquima Range, Clipper Gap	151
34	Toquima Range, Northumberland	154
36	Simpson Park Range, Walti	33
37	Roberts Mountains, Mount Hope	36
38	Fish Creek Range, Ruby Hill	100
II. Included in area of Figure 1, from sources other than List #1.		
39	Sonoma Range, Stony Basin	105[1]
40	East Range, Granite Mountain	30[2]
41	Independence Range, Swales Mountain	39[3]
42	Cortez Range, Frenchy Creek	143[4]
43	Cortez Range, Frenchy Creek	153[4]
44	Cortez Range, Mill Canyon	150[4]
45	Cortez Range, Cortez Dike	34[5]
46	Toiyabe Range, Austin (West)	157[6]
47	Tuscarora Mountains	121[7]
48	Whistler Mountain	152[4]

Source of data:

[1] Gilluly (1967)
[2] D. B. Tatlock (written commun., 1970)
[3] Coats and others (1965)
[4] Armstrong (1970)
[5] Wells and others (1969)
[6] Krueger and Schilling (this journal)
[7] Hausen and Kerr (1968)

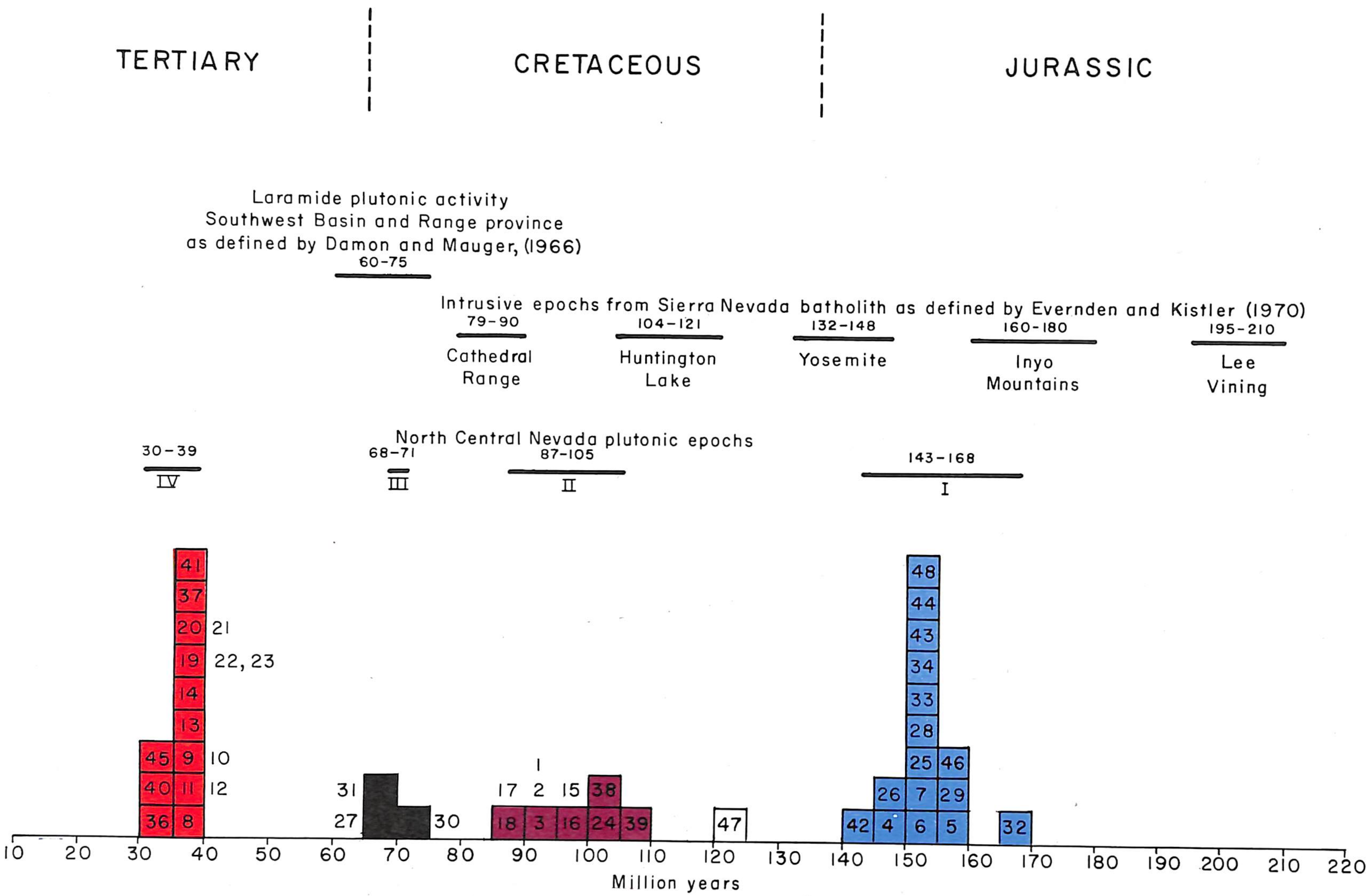

Figure 2. Histogram of KAr Ages of North Central Nevada Plutons
(Grouped in 5 million year intervals)

Also plotted in Figure 2 are the intrusive epochs defined by Evernden and Kistler (1970) for the Sierra Nevada batholith and the age of major Laramide plutonic activity defined by Damon and Mauger (1966) for the southwestern Basin and Range province. The two older plutonic pulses in north-central Nevada overlap in time the Inyo Mountains, Yosemite, and Huntington Lake intrusive epochs of the Sierras, but the peaks of the pulses in Nevada are out of phase with those in the Sierras. The Laramide pulse in north-central Nevada is represented by only three plutons, and these probably mark the northernmost extension of Laramide plutonism which is much more intense in the southwestern Basin and Range province. Neither the Laramide nor the middle Tertiary plutonic episodes of Nevada are represented in the Sierra Nevada, which suggests that these pulses are not related to the Sierran plutonic activity.

The data from north-central Nevada confirm the episodic nature of plutonism discussed by Gilluly (1967). Both Damon and Mauger (1966) and Evernden and Kistler (1970) also show that plutonic activity was episodic for the areas that they studied. However, when the data for north-central Nevada, the Sierra Nevada, and the southwestern Basin and Range are viewed as a whole, they suggest that plutonism was essentially continuous from Jurassic through middle Tertiary time for the Cordillera. It is only when areas of smaller size, of the order of the 50,000 square kilometers of north-central Nevada (fig. 1) are considered, that plutonism appears to be episodic. As additional data for the rest of the Cordillera are compiled in succeeding issues of this journal, the model for episodic plutonism developed from north-central Nevada and the surrounding regions should be re-evaluated.

SAMPLE DESCRIPTIONS

Intrusive Rocks--North-Central Nevada

Osgood Mountains

1. USGS(M)-MB33B — K-Ar — (biotite) 89.9 ± 1.8 m. y.

Osgood Mountains stock, north lobe. Medium-grained biotite-hornblende granodiorite (south-central part of sec. 6, T. 38 N., R. 42 E.; 1,000 feet northeast of Alpine mine, at saddle; Humboldt Co., NV). Analytical data: (Biotite, 1% chlorite) K_2O = 8.88%, $\overset{*}{A}r^{40} = 1.208 \times 10^{-9}$ mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 89.1%. Collected by: Ralph Roberts and M. L. Silberman, U.S. Geological Survey. Comment: Intrudes Cambrian Preble Formation. Reference: Silberman and McKee (1971).

2. USGS(M)-MB34 — K-Ar — (biotite) 92.2 ± 1.8 m. y.; (hornblende) 88.3 ± 1.8 m. y.

Osgood Mountains stock, south lobe. Medium-grained biotite-hornblende granodiorite (east-central part of sec. 29, T. 38 N., R. 42 E.; 3,000 feet south of Mountain View mine; Humboldt Co., NV). Analytical data: (Biotite, pure) K_2O = 8.73%, $\overset{*}{A}r^{40} = 1.219 \times 10^{-9}$ mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 86.1%. (Hornblende, 3% pyroxene) K_2O = 0.694%, $Ar^{40} = 9.272 \times 10^{-11}$ mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 62.1%. Collected by: Ralph Roberts and M. L. Silberman, U.S. Geological Survey. Comment: Intrudes Cambrian Preble Formation. Reference: Silberman and McKee (1971).

3. USGS(M)-MB32 — K-Ar — (biotite) 89.9 ± 1.8 m. y.

"Andesite dike." Porphyritic biotite dacite (SE/4 sec. 29, T. 38 N., R. 42 E.; on east wall of the north pit, Getchell mine; Humboldt Co., NV). Analytical data: (Biotite, pure) K_2O = 8.52%, $\overset{*}{A}r^{40} = 1.159 \times 10^{-9}$ mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 91.7%. Collected by: Ralph Roberts and M. L. Silberman, U.S. Geological Survey. Comment: The dike intrudes Cambrian Preble Formation. It is chemically identical to the Osgood Mountains stock and is probably a porphyritic offshoot of the main pluton. Its K-Ar age is the same as the stock. It outcrops on a bench to the east of the main ore zone. The dike is unaltered except for some surface oxidation.

Buffalo Mountain

4. USGS(M)-MB1 — K-Ar — (biotite) 146 ± 3 m. y.; (hornblende) 145 ± 3 m.y.

Plutonic complex of Buffalo Mountain. Medium-grained biotite-hornblende quartz monzonite (SW/4 sec. 15, T. 33 N., R. 41 E.; Humboldt Co., NV). Analytical data: (Biotite, 1% chlorite) K_2O = 8.08%, $\overset{*}{A}r^{40}$ = 1.813 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 89.2%. (Hornblende, 1% pyroxene) K_2O = 0.780%, $\overset{*}{A}r^{40}$ = 1.737 x 10^{-10} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 74.3%. Collected by: Thomas Neff, Weber State College, Ogden, Utah. Reference: Silberman and McKee (1971).

5. USGS(M)-MB3 K-Ar (biotite) 157±3[#] m.y.
(hornblende) 160±3 m.y.

Plutonic complex of Buffalo Mountain. Medium-grained biotite-hornblende monzonite (NE/4 sec. 26, T. 33 N., R. 40 E.; Humboldt Co., NV). Analytical data: (Biotite, pure) K_2O = 9.05%; (a) $\overset{*}{A}r^{40}$ = 2.197 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 95.0%; (b) Ar^{40} ≐ 2.190 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 94.8%. (Hornblende, 5% pyroxene, 1% biotite) K_2O = 0.641%, $\overset{*}{A}r^{40}$ = 1.582 x 10^{-10} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 77.9%. Collected by: Ralph Roberts, U.S. Geological Survey. Reference: Silberman and McKee (1971).

6. USGS(M)-MB4 K-Ar (biotite) 153±3 m.y.

Plutonic complex of Buffalo Mountain. Very coarse grained porphyritic biotite monzonite (NW/4 sec. 26, T. 33 N., R. 40 E.; Humboldt Co., NV). Characterized by perthite crystals as much as 2 inches across. Analytical data: (Biotite, 1.0% chlorite) K_2O = 7.87%, $\overset{*}{A}r^{40}$ = 1.857 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 66.9%. Collected by: Ralph Roberts and M. L. Silberman, U. S. Geological Survey.

7. USGS(M)-MB27 K-Ar (biotite) 151±3 m.y.

Plutonic complex of Buffalo Mountain. Medium-grained biotite-hornblende quartz monzonite (north-central, sec. 23, T. 33 N., R. 40 E.; Humboldt Co., NV). Analytical data: (Biotite, pure) K_2O = 9.16%, $\overset{*}{A}r^{40}$ = 2.120 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 92.0%. Collected by: Ted Theodore, U.S. Geological Survey. Comment: The plutonic complex crops out over an area of more than 80 square kilometers. It is composed of plutons of syenite porphyry to quartz monzonite and intrudes the Permian Havallah and Pennsylvanian Pumpernickel Formations. Quartz monzonite intrudes syenite in the northern part of the complex. The age relations between the other rock types are not everywhere known. The K-Ar ages of 146, 145, and 151 m.y. on quartz monzonite relative to the older ages of 160, 157, and 153 m.y. on monzonite and monzonite porphyry suggest that the quartz monzonite is the youngest phase. A rhyolite porphyry and quartz latite porphyry dike swarm cuts the pluton, however, the concordant biotite and hornblende ages of USGS MB-1 and MB-3 suggest that the ages quoted are the ages of crystallization. No dikes were found in the vicinity of the samples that are listed above.

Northern Shoshone Range

8. USGS(M)-M125 K-Ar (biotite) $34.8 \pm 0.7^{\#}$ m.y.
(sanidine) 34.7 ± 0.7 m.y.

Rhyolite porphyry dike (NW/4 sec. 16, T. 28 N., R. 47 E.; at Altenberg Hill; Lander Co., NV). Analytical data: (Biotite, pure) K_2O = 8.24%; (a) $\overset{*}{A}r^{40} = 4.218 \times 10^{-10}$ mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 80.3%; (b) $\overset{*}{A}r^{40} = 4.332 \times 10^{-10}$ mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 83.7%. (Sanidine, pure) K_2O = 11.60%, $\overset{*}{A}r^{40} = 6.003 \times 10^{-10}$ mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 97.5%. Collected by: C. T. Wrucke and T. J. Armbrustmacher, U.S. Geological Survey. Comment: Intrudes Tenabo stock and the Devonian Slaven chert. These dikes are spatially associated with gold-quartz veins. Reference: McKee and Silberman (1970, table 1, no. 1).

9. USGS(M)-M124 K-Ar (biotite) $38.2 \pm 0.8^{\#}$ m.y.

Tenabo stock. Porphyritic biotite-hornblende granodiorite (SE/4 sec. 8, T. 28 N., R. 47 E.; Lander Co., NV). Analytical data: (Biotite, pure) K_2O = 8.79%; (a) $\overset{*}{A}r^{40} = 4.888 \times 10^{-10}$ mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 78.3%; (b) $\overset{*}{A}r^{40} = 4.877 \times 10^{-10}$ mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 55.3%. Collected by: C. T. Wrucke and T. J. Armbrustmacher, U.S. Geological Survey. Reference: McKee and Silberman (1970, table 1, no. 2).

10. USGS(M)-M123 K-Ar (biotite) $37.4 \pm 0.8^{\#}$ m.y.
(hornblende) 38.2 ± 0.8 m.y.

Tenabo stock. Porphyritic biotite-hornblende granodiorite (SE/4 sec. 8, T. 28 N., R. 47 E.; Lander Co., NV). Analytical data: (Biotite, 5% chlorite) K_2O = 7.99%; (a) $\overset{*}{A}r^{40} = 4.436 \times 10^{-10}$ mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 81.4%; (b) $\overset{*}{A}r^{40} = 4.472 \times 10^{-10}$ mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 83.0%. (Hornblende, 1% biotite, 1% pyroxene) K_2O = 1.077%, $\overset{*}{A}r^{40} = 6.133 \times 10^{-11}$ mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 71.3%. Collected by: C. T. Wrucke and T. J. Armbrustmacher, U.S. Geological Survey. Reference: McKee and Silberman (1970, table 1, no. 3).

11. USGS(M)-MB7 K-Ar (biotite) 38.0 ± 0.8 m.y.
(hornblende) 36.7 ± 0.7 m.y.

Granite Mountain stock. Medium-grained biotite-hornblende granodiorite (SE/4 sec. 14, T. 29 N., R. 46 E.; at Gray Eagle mine; Lander Co., NV). Analytical data: (Biotite, 5% chlorite) K_2O = 7.66%, $\overset{*}{A}r^{40} = 4.338 \times 10^{-10}$ mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 62.6%. (Hornblende, 4% biotite) K_2O = 0.953%, $\overset{*}{A}r^{40} = 5.223 \times 10^{-11}$ mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 55.2%. Collected by: M. L. Silberman, U.S. Geological Survey. Reference: McKee and Silberman (1970, table 1, no. 5).

12. USGS(M)-M119 K-Ar (biotite) 37.0±0.7 m.y.
(hornblende) 36.0±0.7 m.y.

Granite Mountain stock. Medium-grained biotite-hornblende granodiorite (NW/4 sec. 12, T. 29 N., R. 46 E.; near Coral Canyon, Lander Co., NV). Analytical data: (Biotite, 2% chlorite) K_2O = 7.25%, $\overset{*}{A}r^{40}$ = 4.003 x 10^{-10} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 37.6%. (Hornblende, <1% biotite) K_2O = 0.892%, $\overset{*}{A}r^{40}$ = 4.796 x 10^{-11} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 62.6%. Collected by: C. T. Wrucke, U. S. Geological Survey. Reference: McKee and Silberman (1970 table 1, no. 6).

13. USGS(M)-MB8 K-Ar (hornblende) 38.1±0.8 m.y.

Hilltop stock. Medium-grained hornblende granodiorite (SE/4 sec. 3, T. 29 N., R. 46 E.; Humboldt Co., NV). Analytical data: (Hornblende, 4% pyroxene, 2% chlorite) K_2O = 1.021%, $\overset{*}{A}r^{40}$ = 5.809 x 10^{-11} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 40.0%. Collected by: Ralph Roberts, C. T. Wrucke, U.S. Geological Survey. Reference: Silberman and McKee (1971).

14. USGS(M)-M103B K-Ar (biotite) 35.1±0.7 m.y.

Goat Ridge stock. Porphyritic biotite granodiorite (NW/4 sec. 28, T. 29 N., R. 45 E.; Lander Co., NV). Analytical data: (Biotite, 7% chlorite) K_2O = 7.61%, $\overset{*}{A}r^{40}$ = 3.983 x 10^{-10} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 70.9%. Collected by: C. T. Wrucke, T. J. Armbrustmacher, U.S. Geological Survey. Reference: McKee and Silberman (1970, table 2, no. 4).

15. USGS(M)-MGW72 K-Ar (sericite) 92.8±1.9 m.y.
(biotite) 98.8±2.0 m.y.

Porphyritic biotite-quartz monzonite (east-central part of sec. 36, unsurveyed T. 28 N., R. 46 E.; from drill core, 500 feet below Gold Acres pit, Gold Acres open-pit mine; Lander Co., NV). Analytical data: (Sericite, pure) K_2O = 9.97%, $\overset{*}{A}r^{40}$ = 1.401 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 88.8%. (Biotite, 12% chlorite) K_2O = 8.22%, $\overset{*}{A}r^{40}$ = 1.232 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 85.9%. Collected by: C. T. Wrucke from Union Pacific drill core. Comment: The pluton is not exposed at the present ground surface. The biotite is partially altered to chlorite and sericite. The sericite age represents the age of alteration and the biotite age may be reduced from the true age of the pluton.

16. USGS(M)-M5 K-Ar (sericite) 94.3±1.9 m.y.

Altered felsite sill, quartz sericite and limonite (east-central part of sec. 36, T. 28 N., R. 46 E., unsurveyed; Gold Acres open-pit mine; Lander

Co., NV) intruded along Roberts Mountain thrust, breccia zone. Analytical data: (Sericite, pure) K_2O = 8.34%, $\overset{*}{A}r^{40}$ = 1.191 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 94.9%. Collected by: M. L. Silberman. U.S. Geological Survey. Comment: This felsite sill is mineralized. The sericite alteration probably occurred during deposition of the ore. If so, this age and the sericite age of GW72 indicate a strong episode of quartz-sericite alteration accompanied by gold deposition in the Late Cretaceous. The Gold Acres fine-gold deposit is thus Late Cretaceous in age.

Discussion: The K-Ar ages for granitic rocks of the northern Shoshone Range show that the bulk of plutonic activity in the range was Tertiary. However, pre-Tertiary granitic rocks also occur as indicated by the Late Cretaceous alteration ages obtained at Gold Acres. The true ages of the igneous rocks at Gold Acres are, however, still uncertain, but they may be related to the Jurassic plutons in the nearby Cortez Mountains to the east.

Antler Peak (Battle Mountain) Range

17. USGS(M)-MB25 K-Ar (biotite) 87.2±1.7 m.y.

Trenton Canyon stock. Medium-grained, biotite-hornblende granodiorite (SW/4 sec. 24, T. 32 N., R. 42 E.; elevation 6,500 ft, along Trenton Canyon; Lander Co., NV). Analytical data: (Biotite, 3% chlorite) K_2O = 7.38%, $\overset{*}{A}r^{40}$ = 9.729 x 10^{-10} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 79.1%. Collected by: Ted Theodore, U.S. Geological Survey. Reference: Silberman and McKee (1971).

18. USGS(M)-M26 K-Ar (biotite) 87.0±1.7 m.y.

Trenton Canyon stock. Medium-grained biotite-hornblende granodiorite (SW/4 sec. 24, T. 32 N., R. 42 E.; elevation 6,750 ft, along Trenton Canyon, 1/4 mi upstream from MB25; Lander Co., NV). Analytical data: (Biotite, pure) K_2O = 8.20%, $\overset{*}{A}r^{40}$ = 1.078 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 76.2%. Collected by: Ted Theodore, U.S. Geological Survey. Comment: Rock is fresh, except for pyrite along fracture surfaces. Reference: Silberman and McKee (1971).

19. USGS(M)-MB12 K-Ar (biotite) 37.3±0.7 m.y.

Elder Creek pluton. Porphyritic biotite granodiorite (center of sec. 2, T. 32 N., R. 43 E.; Humboldt Co., NV). Analytical data: K_2O = 8.45%, $\overset{*}{A}r^{40}$ = 4.690 x 10^{-10} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 66.3%. Collected by: M. L. Silberman, U.S. Geological Survey. Reference: Silberman and McKee (1971).

20. USGS(M)-MB23 K-Ar (biotite) 38.2±0.8 m.y.

Copper Canyon stock. Porphyritic biotite-quartz monzonite (drill core samples from depth of 250-430 ft; (SW/4 sec. 22, T. 31 N., R. 43 E.; Lander Co., NV). Analytical data: (Biotite, pure) K_2O = 9.05%, $\overset{*}{A}r^{40}$ = 5.155 x 10^{-10} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 82.0%. Collected by: D. Blake, Duval Corporation; Ted Theodore, U.S. Geological Survey. Comment: The sample contains minor disseminated pyrite and has undergone potassic alteration. Reference: Silberman and McKee (1971).

21. USGS(M)-M18 K-Ar (biotite) 38.5±0.8 m.y.

Copper Canyon stock. Porphyritic biotite-quartz monzonite (SW/4 sec. 22, T. 31 N., R. 43 E.; Lander Co., NV). Analytical data: K_2O = 8.54%, $\overset{*}{A}r^{40}$ = 4.900 x 10^{-10} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 86.5%. Collected by: D. Blake, Duval Corporation; Ted Theodore, U.S. Geological Survey. Comment: The sample has undergone potassic alteration similar to that of sample MB23. Reference: Silberman and McKee (1971).

Discussion: The alteration has resulted in recrystallization of the matrix to quartz, K-feldspar and white mica; some potassium was introduced during this process. The biotites occur as phenocrysts about 1 mm long, are optically homogeneous and do not appear to have been affected by the alteration.

22. USGS(M)-MRB6500 K-Ar (whole rock minus sulfides) 37.2±0.7 m.y.

Recrystallized matrix of Battle Conglomerate from ore zone in Battle Conglomerate (Copper Canyon pit, 6,500-foot bench; SW/4 sec. 22, T. 31 N., R. 43 E.; Lander Co., NV). Analytical data: K_2O = 9.51%, $\overset{*}{A}r^{40}$ = 5.283 x 10^{-10} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 81.4%. Collected by: D. Blake, Duval Corporation. Comment: Rock has recrystallized to fine-grained biotite-sericite-K feldspar-quartz assemblage with pyrite, chalcopyrite, and other sulfides. The sulfides were removed by sinking them in methyline iodide, and the light fraction was ground to -100+150 mesh and used for Ar and K analyses.

23. USGS(M)-MB52 K-Ar (whole rock minus sulfides) 37.2±0.7 m.y.

Recrystallized matrix of Battle Conglomerate from ore zone in Battle Conglomerate (Copper Canyon mine, 6,500-foot bench; SW/4 sec. 22, T. 31 N., R. 43 E.; Lander Co., NV). Analytical data: K_2O = 2.55%, $\overset{*}{A}r^{40}$ = 1.411 x 10^{-10} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 52.1%. Collected by: D. Blake, Duval Corporation; M. L. Silberman, U.S. Geological Survey. Comment:

Except for some relict plagioclase, rock has recrystallized to biotite-sericite-quartz assemblage with pyrite and chalcopyrite. Same mineral separation procedure as sample MRB6500.

Discussion: The Copper Canyon stock has undergone pervasive potassic alteration, and peripheral to it are base and precious metal deposits in a zonal arrangement (Roberts and Arnold, 1965). The biotites of samples MB23 and M18 are magmatic and do not appear to have been affected by the alteration as their ages are the same as the biotite from the petrographically similar unaltered Elder Creek stock.

The principal ore fluid at Copper Canyon appears to have been a concentrated brine. Copper mineralization is restricted in extent to the area in which the concentrated brine occurs in fluid inclusions (Nash and Theodore, 1970). The mineral assemblage in the ore zone is similar to the potassic alteration assemblage of the stock, and alteration of the stock and the Battle matrix were both primarily caused by this concentrated hydrothermal fluid. The average ages of the ore zone matrix (37.2 m.y.) and the biotites from the stock (38.3 m.y.) differ statistically at the 95% confidence level. However, the slightly lower age of the ore zone may be due to a grain size effect. The very fine grained potassium-bearing phases in the ore zone probably lost argon at lower temperatures than the coarse biotites of the stock during the time that the stock and the surrounding rocks cooled. The data interpreted in this manner agree with Damon and Mauger (1966) conclusion that the processes of ore deposition in the porphyry-type copper deposits is restricted in time to the cooling history of the host rock. A more detailed study of the age relations in the Battle Mountain Range, including the Copper Canyon area, is in progress.

Sonoma Range

24. USGS(M)-MB42 K-Ar (biotite) $104 \pm 2^{\#}$ m.y.

Gregg Canyon stock. Biotite-hornblende granodiorite (SW/4 sec. 18. T. 33 N., R. 40 E.; Humboldt Co., NV). Analytical data: (Biotite, pure) K_2O = 6.91%; (a) $\overset{*}{A}r^{40}$ = 1.089 x^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 78.1%; (b) $\overset{*}{A}r^{40}$ = 1.083 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 82.0%. Collected by: Ralph Roberts and M. L. Silberman, U.S. Geological Survey. Comment: Intrudes Cambrian Preble and Harmony Formations. Reference: Silberman and McKee (1971).

Tobin Range

25. USGS(M)-MB41 K-Ar (biotite) $153 \pm 3^{\#}$ m.y.

Tobin stock. Medium-grained biotite-hornblende granodiorite (NW/4 sec.

4, T. 29 N., R. 40 E.; Pershing Co., NV). Analytical data: (Biotite, pure) K_2O = 9.15%; (a) $\overset{*}{A}r^{40}$ = 2.168 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 88.9%; (b) $\overset{*}{A}r^{40}$ = 2.148 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 91.6%. Collected by: Ralph Roberts and M. L. Silberman, U.S. Geological Survey. Comment: Intrudes Pennsylvanian(?) Pumpernickel and Permian Havallah Formations. Reference: Silberman and McKee (1971).

East Range

26. USGS(M)-MB45 K-Ar (biotite) 131±3 m.y.
(hornblende) 149±3 m.y.

Lee Peak stock. Medium- to fine-grained biotite-hornblende granodiorite (south-central part of sec. 8, T. 31 N., R. 37 E.; Pershing Co., NV). Analytical data: (Biotite, 2% chlorite) K_2O = 9.20%, $\overset{*}{A}r^{40}$ = 1.842 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 92.6%. (Hornblende, 2% pyroxene, 2% biotite) K_2O = 1.078%, $\overset{*}{A}r^{40}$ = 2.474 x 10^{-10} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 82.8%. Collected by: Ralph Roberts, D. H. Whitebread, and M. L. Silberman, U.S. Geological Survey. Comment: Intrudes Mississippian or older Leach Formation and Triassic(?) sedimentary rocks. The biotite and hornblende ages are discordant, and may indicate resetting by a later thermal event. The hornblende age is probably closer to the true age of crystallization. Reference: Silberman and McKee (1971).

Stillwater Range

27. USGS(M)-M333 K-Ar (biotite) 69.1±1.4 m.y.

New York Canyon stock. Granodiorite (approximate location only, New York Canyon, Stillwater Range, 20 mi E of Lovelock; Pershing Co., NV). Analytical data: K_2O = 6.60%, $\overset{*}{A}r^{40}$ = 6.86 x 10^{-10} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 83%. Collected by: R. C. Speed, Northwestern University. Reference: Silberman and McKee (1971). Comment: Same as NKS7-3, Speed and Armstrong (this journal).

Fish Creek Mountains

28. USGS(M)-M273 K-Ar (biotite) 153±3 m.y.

McCoy stock. Biotite granodiorite (sec. 5 unsurveyed, T. 28 N., R. 42 E.; Lander Co., NV). Analytical data: K_2O = 9.32%, $\overset{*}{A}r^{40}$ = 2.196 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 91%. Collected by: E. H. McKee, U.S. Geological Survey. Comment: Intrudes Triassic Osobb Formation, overlain by Tertiary Caetano and Bates Mountain Tuffs. Reference: Silberman and McKee (1971).

Shoshone Mountains (Lander County)

29. USGS(M)-M272 K-Ar (biotite) 155±3 m.y.

Cain Creek stock. Biotite granodiorite (sec. 29, T. 25 N., R. 42 E.; Lander Co., NV). Analytical data: K_2O = 7.35%, $\overset{*}{A}r^{40}$ = 1.755 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 89%. Collected by: E. H. McKee, U.S. Geological Survey. Reference: Silberman and McKee (1971).

30. USGS(M)-M274 K-Ar (biotite) 71.4±1.4 m.y.

Ravenswood stock. Quartz monzonite (north-central part of sec. 5, T. 21 N., R. 42 E.; Lander Co., NV). Analytical data: K_2O = 7.63%, $\overset{*}{A}r^{40}$ = 8.19 x 10^{-10} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 77%. Collected by: E. H. McKee, U.S. Geological Survey. Comment: Intrudes Cambrian quartzite of lower plate of Roberts Mountains thrust. Reference: Silberman and McKee (1971).

Toiyabe Range

31. USGS(M)-M335 K-Ar (biotite) 67.9±2.7 m.y.

Iowa Creek stock. Granodiorite (south part of secs. 25 and 26, T. 23 N., R. 44 E.; Lander Co., NV). Analytical data: K_2O = 8.73%, $\overset{*}{A}r^{40}$ = 8.92 x 10^{-10} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 23%. Collected by: E. H. McKee, U.S. Geological Survey. Reference: Silberman and McKee (1971).

32. USGS(M)-M050 K-Ar (biotite) 168±3 m.y.

Grass Valley stock. Granodiorite (NW/4 sec. 11, T. 21 N., R. 46 E.; Lander Co., NV). Analytical data: K_2O = 8.32%, $\overset{*}{A}r^{40}$ = 2.165 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 76%. Collected by: E. H. McKee, U.S. Geological Survey. Comment: Probably related to the nearby Austin pluton (157 m.y.) dated by Armstrong (1970) and Geochron Laboratory (see Krueger and Schilling, this journal). Reference: Silberman and McKee (1971).

Toquima Range

33. USGS(M)-M275 K-Ar (biotite) 151±3 m.y.

Clipper Gap stock. Fine- to medium-grained quartz monzonite (sec. 12, T. 15 N., R. 45 E.; just west of the SW corner of R. 45½ E.; Lander Co., NV). Analytical data: K_2O = 6.63%, $\overset{*}{A}r^{40}$ = 1.539 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 90%. Collected by: E. H. McKee, U.S. Geological Survey. Comment: Intrudes western facies Paleozoic rocks.

34. USGS(M)-M3-13 K-Ar (biotite) 154±3# m.y.

Northumberland stock. Medium-grained biotite-hornblende granodiorite (NW/4 sec. 19, T. 13 N., R. 46 E.; Nye Co., NV). Analytical data: K_2O = 8.27%; (a) $\overset{*}{Ar}{}^{40} = 1.980 \times 10^{-9}$ mole/gm, $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 96.7%; (b) $\overset{*}{Ar}{}^{40} = 1.950 \times 10^{-9}$ mole/gm, $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 88.3%. Collected by: F. J. Kleinhampl, U.S. Geological Survey. Reference: Silberman and McKee (1971).

35. USGS(M)-M25-5 K-Ar (muscovite) 78.2±1.6# m.y.

Belmont pluton. Porphyritic granite (center of sec. 18, T. 9 N., R. 45 E., 4½ mi NW of Belmont; Nye Co., NV). Analytical data: (Muscovite, pure) K_2O = 10.20%; (a) $\overset{*}{Ar}{}^{40} = 1.206 \times 10^{-9}$ mole/gm, $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 84.0%; (b) $\overset{*}{Ar}{}^{40} = 1.200 \times 10^{-9}$ mole/gm, $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 74.7%. Collected by: F. J. Kleinhampl, U.S. Geological Survey. Comment: Concordant with biotite ages determined on other phases of the pluton (see G-B0553/NBM AD-11 and G-B0836/NBM AD-19 of Krueger and Schilling, this journal). This pluton crops out south of the area of Figure 1, and is not included in the histogram.

Simpson Park Range

36. USGS(M)-M14 K-Ar (biotite) 33.4±0.7 m.y.

Walti pluton. Porphyritic biotite-hornblende granodiorite (NW/4 sec. 34, T. 24 N., R. 48 E.; Eureka Co., NV). Analytical data: (Biotite, pure) K_2O = 8.70%; (a) $\overset{*}{Ar}{}^{40} = 4.316 \times 10^{-10}$ = mole/gm, $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 31.8%; (b) $\overset{*}{Ar}{}^{40} = 4.353 \times 10^{-10}$ mole/gm, $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 36.4%. Collected by: M. L. Silberman, U.S. Geological Survey. Comment: Intrudes Silurian and Devonian sedimentary rocks. Reference: Silberman and McKee (1971).

Roberts Mountains

37. USGS(M)-66B87 K-Ar (biotite) 35.6±0.7 m.y.

Mount Hope pluton. Rhyolite porphyry (sec. 7 unsurveyed, T. 22 N., R. 52 E.; Eureka Co., NV). Analytical data: K_2O = 8.64%, $\overset{*}{Ar}{}^{40} = 4.587 \times 10^{-10}$ mole/gm, $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 77.0%. Collected by: M. C. Blake, Jr., U.S. Geological Survey. Reference: Silberman and McKee (1971).

Fish Creek Range

38. USGS(M)-AD39 K-Ar (biotite) 99.8±2.0 m.y.

Ruby Hill stock. Quartz-monzonite porphyry (NW/4 sec. 22, T. 19 N., R. 53 E.; 1388-98 ft in drill hole RH-713 collared 150 ft N of Rogers Tunnel portal; Eureka Co., NV). Analytical data: (Biotite, 13% chlorite), K_2O = 6.76%, $\overset{*}{A}r^{40}$ = 1.023 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 85.0%. Collected by: W. P. Johnson, Reno, Nev. Comment: Core used for dating contains pyrite-quartz-calcite veinlets and shows propylitic alteration. The alteration and especially high percentage of chlorite in the biotite suggests that the age may not be the magmatic age. Reference: Silberman and McKee (1971).

Santa Rosa Range

39. USGS(M)-SA1 K-Ar (biotite) 97.8±3.5 m.y.
(hornblende) 99.5±5.0 m.y.

Santa Rosa stock. Leucogranodiorite (SW/4 sec. 25, T. 42 N., R. 43 E.; approximately 1½ mi SE of Paradise Peak; Humboldt Co., NV). Analytical data: (Biotite) K_2O = 9.11%, $\overset{*}{A}r^{40}$ = 1.350 x 10^{-9} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ 90%. (Hornblende) K_2O = 0.485%, $\overset{*}{A}r^{40}$ = 7.30 x 10^{-11} mole/gm, $\overset{*}{A}r^{40}/\Sigma Ar^{40}$ = 56%. Collected by: J. Smith, U.S. Geological Survey. Comment: Intrudes Upper Triassic and Jurassic shales and sandstones. This pluton crops out north of the area of Figure 1 and is not incurred in the histogram.

REFERENCES

Armstrong, R. L. (1970) K-Ar dating using neutron activation for Ar analysis: Comparison with isotopic dilution analysis: Geochim. et Cosmochim. Acta, v. 34, p. 233-236.

Coats, R. R., Marvin, R. F., and Stern, T. W. (1965) Reconnaissance of mineral ages of plutons in Elko County, Nevada, and vicinity, in Geological Survey Research 1965: U.S. Geol. Survey, Prof. Paper 525-D, p. D11-D15.

Dalrymple, G. B., and Lanphere, M. A. (1970) Potassium-argon dating, principles, techniques, and applications to geochronology: San Francisco, W. H. Freeman Co., 258 p.

Damon, P. E., and Mauger, R. L. (1966) Epierogeny-orogeny viewed from the Basin and Range province: Amer. Inst. Mining Metall. Petroleum Engineers, Trans., v. 235, p. 99-112.

Evernden, J. F., and Kistler, R. W. (1970) Chronology of emplacement of Mesozoic batholithic complexes in California and western Nevada: U.S. Geol. Survey, Prof. Paper 623, 42 p.

Gilluly, James (1967) Geologic map of Winnemucca quadrangle, Pershing and Humboldt Counties, Nevada: U. S. Geol. Survey, Geol. Quad. Map GQ-656.

Hausen, D. M., and Kerr, P. F. (1968) Fine gold occurrence at Carlin, Nevada, in Ridge, J. D., ed., Ore deposits in the United States, 1933-1967 (Graton-Sales Vol. 1): New York, Amer. Inst. Mining Metall. Petroleum Engineers, p. 909-940.

Krueger, H. W., and Schilling, J. H. (1971) Geochron/Nevada Bureau of Mines K-Ar age determinations--List 1: Isochron/West, v. 1 (Jan. 1971).

McKee, E. H., and Silberman, M. L. (1970) Geochronology of Tertiary igneous rocks in central Nevada: Geol. Soc. America Bull., v. 81, p. 2317-2328.

Nash, J. T., and Theodore, T. G. (1970) Ore fluids in a contact copper deposit, Copper Canyon, Nevada: Econ. Geology.

Neff, T. R. (1970) The Buffalo Mountain pluton dike swarm (abs.): Hayward, Calif., Geol. Soc. America, Cordilleran Sec. Mtg., program, v. 2, p. 124.

Roberts, Ralph, and Arnold, D. C. (1965) Ore deposits of the Antler Peak quadrangle, Humboldt and Lander Counties, Nevada: U. S. Geol. Survey, Prof. Paper 459B, 94 p.

Silberman, M. L., and McKee, E. H. (1971) Periods of plutonism in north-central Nevada, in Roberts, R. J., Radtke, A. S., and Coats, R. R., Gold-bearing deposits in north-central Nevada and southwestern Idaho: Econ. Geology.

Wells, J. D., Stoiser, L. R., and Elliot, J. E. (1969) Geology and geochemistry of the Cortez gold deposit: Econ. Geology, v. 64, p. 526-537.