A SUMMARY OF RADIOMETRIC AGE DETERMINATIONS ON TERTIARY
VOLCANIC ROCKS FROM NEVADA AND EASTERN CALIFORNIA:
PART II,¹ WESTERN NEVADA²

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The radiometric age determinations summarized comprise 73 previously published and 32 unpublished dates on samples collected from various localities in western Nevada. Sample descriptions, given here by locality number (keyed to map, fig. 1), include field or laboratory number, age, rock type, location, and for new ages, the analytical data used for their calculation. Short discussions of the geologic significance of many of the ages are included under comments. For some areas, groups of ages precede a short discussion of their topical significance.

All ages were determined by the K-Ar method. For the published ages, details of analytical procedure may be found in the literature sources given. Ages not published were determined by procedures used in Isotope Geology Laboratories of the U. S. Geological Survey (McKee and others, 1971) or by Geochnron Laboratories of Krueger Enterprises, Cambridge, Mass. (Krueger and Schilling, 1972).

GEOLOGIC DISCUSSION

The area of rocks sampled covers 19,000 square miles, including Lyon, Douglas, Ormsby, Storey, Mineral, and Esmeralda Counties, and parts of Nye and Churchill Counties, and is shown in Figure 1 with the sample localities.

Samples are concentrated in several areas, in particular western Mineral County, Storey County, and the Goldfield area of Nye and Esmeralda Counties. There are large areas of western Nevada that have little or no radiometric geochronology, notably all of eastern Mineral County and the northeastern and northern areas of the region outlined, yet these are areas of extensive volcanic fields of various composition. The distribution of dates reflects in part detailed geochronologic studies of the U. S. Geological Survey in the mining districts of Aurora, Goldfield, Silver Peak, Tonopah, and Comstock, and those of Gilbert and others (1968) in Mono Basin.

Although widespread ash-flow tuffs occur in western Nevada, it also contains numerous local volcanic fields. The stratigraphy of most of the volcanic fields in western Nevada is poorly understood, as radiometric dating has not yet attained the geographic distribution necessary to correlate events across the region.

The volcanic rocks of the western Nevada can be divided into two groups that contrast both in overall composition and in mode of origin or emplacement: (1) ash-flow sheets of rhyolite and quartz latite, mostly emplaced between 28 and 20 m.y. ago; and (2) younger calc-alkalic rocks consisting of separate flows, tuffs, and intrusive plugs. The ash-flow sheets of the first group, though widespread, probably are not as voluminous as those of central Nevada, and none as old as the oldest central Nevada sheets have been found. Source areas, presumably calderas from which these sheets erupted, have not been located. The source for some of the ash-flow sheets may have been to the east (the central and eastern Nevada ignimbrite province of Cook, 1965). The northern Gillis and Gabbs Valley Ranges, which are composed largely of middle Miocene ash flows, in some places several thousand feet thick may be the source for some of the more westerly ash-flow sheets. Voluminous rhyolitic ash-flow activity ceased in western Nevada about 20 m.y. ago; volcanism has since been characterized by local lava flows, ash flows, and shallow intrusive rocks.

The younger volcanic rocks that form the second group are more varied in composition than the earlier ash-flow sheets. These rocks compose volcanic fields of calc-alkaline rocks, which generally are predominantly andesitic and dacitic in composition but range from rhyolite to alkali-olivine basalt. Separate flows, ash flows, flow breccias, air-fall tuffs, and intrusive plugs generally are of small volume compared with the earlier ash-flow sheets, but aggregate thicknesses of volcanic piles commonly exceed several thousand feet. Volcanic fields of this type occur in the Virginia and Carson Ranges

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Figure 1. Map showing location of dated rock samples. Published dates are indicated by dots, new dates by “x.” The numbers are keyed to the sample descriptions.
The calc-alkaline volcanic rocks in many areas intertongue with, or are superseded by, tuffaceous sedimentary rocks and air-fall tuffs locally named the Siebert, Coal Valley, Aldrich Station, or Esmeralda Formations. These rocks appear to have formed in separate, restricted basins and probably are the result of Basins and Range faulting that began in the period 15 to 20 m.y. ago. In some areas, notably the Virginia Range and the Anchorite Hills (southeast of the Wasuuk Range), extensive fields of alkali-olivine basalt or trachyandesite (as much as 50 km³ in volume) were erupted late in the Tertiary and Quaternary, particularly in the late Pliocene and Pleistocene. In other areas, such as the region surrounding Aurora, fields of alkaline andesites and dacites accompanied by rhyolite and alkali-olivine basalt or trachyandesite were erupted in late Cenozoic time.

A histogram of the ages summarized here, Figure 2, illustrates the nature of volcanism in the region through time. Comparison of this histogram with that in McKee and others (1971, fig. 2) shows the differences in volcanism between western and central Nevada. In central Nevada, ash-flow sheets erupted before 20 m.y. ago are the most voluminous rocks. Relatively little volcanism of any type has occurred in this region since that time. In western Nevada, in contrast, post-20-m.y. volcanism is dominant, although it is possible that future geologic studies may show that the overall volume of the older ash-flow sheets is, or once was, comparable to that of the younger andesitic, dacitic, and basaltic volcanism.

Another difference in the volcanism of central and western Nevada is the relation of basalts to other petrologic types. In western Nevada, basaltic and andesitic rocks intertongue, although in any one area the basalts tend to be younger. In central Nevada, basalts are at most places considerably younger than andesitic or rhyolitic rocks. In central Nevada, the andesitic volcanism precedes and in part overlaps the period of emplacement of the ash-flow sheets, whereas in western Nevada, andesitic volcanism in any one area generally occurs after the end of ash-flow emplacement.

The histograms indicate that no Tertiary volcanic rocks older than 30 m.y. occur (or have been identified yet) in western Nevada. Ash-flow sheets from about 28 to 20 m.y. form the earliest volcanic activity. Although a great volume of volcanic rock was erupted during this pre-20-m.y. period, only a small number of ages have been determined. Between about 20 and 18 m.y., little volcanism occurred, or has yet been identified. A hiatus in volcanic activity at this time is found at other places in the Great Basin; its significance is discussed by McKee and others (1970) and McKee (1971). Andesitic-dacitic volcanism was greatest in the period between 17 and 8 m.y., although some older andesites are present (includes data from adjacent eastern California [Kleinhampel and others, 1972; Silberman and Chesterman, 1972; Gilbert and others, 1968]). Local basins filled with tuffaceous sediments and air-fall tuffs have developed within the past 15 m.y. In some areas, flows of alkaline-olivine basalt and trachyandesite erupted during this 15-m.y. interval. Some of these are interbedded with the sedimentary rocks. Since about 5 m.y. ago, alkaline andesites and dacites have erupted from scattered vents in the region.

The histogram (fig. 2) illustrates the relative increase in importance of the basaltic volcanism with decreasing geologic age and shows that there is a general overlap of andesitic and basaltic-rhyolite volcanism in time for the whole region. The available data, however, suggest that in any one area andesite tends to precede sedimentary rocks and basalts.

Western Nevada has been of major economic importance because of its large epithermal gold- and silver-bearing quartz veins. Metal districts in the region that produced ore worth $30 million or more are Aurora (Mineral County), Tonapah (Nye County), Goldfield (Esmeralda County), and the Comstock Lode (Storey County). Bodie (Mono County) in eastern California, just west of Aurora, produced a similar amount. Numerous smaller districts produced less but significant quantities of gold and silver (Bonham, 1969, 1967; Koschmann and Bergendahl, 1968). Recent study of the geochronology of the large districts (Bonham, 1969; Silberman and Ashley, 1970; Silberman and Chesterman, 1972) suggests some significant similarities. All districts mentioned are in Tertiary volcanic rocks, and in all of them the host rocks are the calc-alkaline andesite-dacite suite. K-Ar ages of the ore deposits based on measurements on vein and alteration minerals, including adularia and analcite (Silberman and Ashley, 1970; Bonham, 1969; Silberman and Chesterman, 1972; Silberman and F. J. Kleinhampel, unpublished data), indicate that mineralization occurred during the end stages of, or shortly after, the end of the calc-alkaline volcanism. The postore volcanic rocks, either basalt-rhyolite association as at Goldfield or alkalic volcanics as at Bodie-Aurora, are in general not mineralized or affected by major hydrothermal alteration.

Paleozoic metasedimentary rocks, Mesozoic plutonic rocks, and Tertiary volcanic rocks are host rocks for epithermal mineralization. The relation of many of these deposits to Tertiary volcanism remains to be demonstrated. The large areas of volcanic rocks in western Nevada of only vaguely known age should be of interest for exploration targets. Knowledge of their ages and the age patterns of the mineralization in the region will yield a better evaluation of their mineral potential.

[Isochron/West, no. 4, August 1972]
Figure 2. Summary of K-Ar ages of volcanic rocks in western Nevada.

[Isochron/West, no. 4, August 1972]
SAMPLE DESCRIPTIONS

1. Evernden and James (1964)  
Sample KA1244  
K-Ar (plagioclase) 12.4 m.y.


2. Bonham (1969)  
Sample AD-16  
K-Ar (plagioclase) 15.2±2.4 m.y.


3. Evernden and James (1964)  
Sample KA1286  
K-Ar (plagioclase) 5.7 m.y.


4. Evernden and James (1964)  
Sample KA1259  
K-Ar (whole rock) 11.0 m.y.


5. Bonham (1969)  
Sample AD-15  
K-Ar (whole rock) 14.5±1.5 m.y.


6. Evernden and James (1964)  
Sample KA1288, KA1289  
K-Ar (sanidine) 22.8 m.y.  
(plagioclase) 22.7 m.y.


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7. Dalrymple and others (1967) Sample W-22


8. G/UCD-GAX17

Coal Valley Formation (Bonham, 1969); Truckee Formation (Thompson and White, 1964). Pumiceous tuff breccia, rhyolite (Central Sec. 30, T18N, R22E; 39°23′32″N, 119°33′12″W; Storey Co., NV). Analytical data: K$_2$O = 6.93%; $\frac{\Delta Ar^{40}}{\Sigma Ar^{40}} = 1.575 \times 10^{-10}$, $1.630 \times 10^{-10}$, $1.500 \times 10^{-10}$, $1.415 \times 10^{-10}$ mole/gm; $\frac{\Delta Ar^{40}}{\Sigma Ar^{40}} = 18.7\%$, 18.9%, 15.8%, and 15.2%. Collected by: D. Axelrod, Univ. Calif. Davis, and H. F. Bonham, Nev. Bur. Mines; dated by: Geochron Laboratories, Inc. Comment: Mineral separated from large pumice block. Date considered tentative—subject to additional work in progress. It supports the essentially equivalent age of upper part of Kate Peak Formation which is interbedded with the Truckee Formation in this area (Thompson and White, 1964). See sample 9.

9. USGS(M)-C1

Kate Peak Formation. Vitrophyre member, glassy rhyolite flow, upper part of formation (W central Sec. 29, T18N, R22E; 39°23′32″N, 119°32′32″W; Storey Co., NV). Analytical data: K$_2$O = 8.09%; $\frac{\Delta Ar^{40}}{\Sigma Ar^{40}} = 1.492 \times 10^{-10}$ mole/gm; $\frac{\Delta Ar^{40}}{\Sigma Ar^{40}} = 48.0\%$. Collected by: M. L. Silberman, U. S. Geological Survey; dated by: M. L. Silberman, U. S. Geological Survey. Comment: This age is the same within analytical uncertainty as that of no. 8 on the Truckee Formation and supports Thompson and White's (1964) conclusion of the essentially equivalent age of the Truckee and upper part of the Kate Peak.


11. USGS(M)-C9

Alta Formation. Porphyritic pyroxene andesite (SW/4 SE/4 Sec. 4, T16N, R21E; 39°16′27″N, 119°37′41″W; along Storey Co.—Lyon Co. boundary, NV). Analytical data: K$_2$O = 0.359%; $\frac{\Delta Ar^{40}}{\Sigma Ar^{40}} = 0.0878 \times 10^{-10}$ mole/gm; $\frac{\Delta Ar^{40}}{\Sigma Ar^{40}} = 38.9\%$. Collected by: M. L. Silberman, U. S. Geological Survey; dated by: M. L. Silberman, U. S. Geological Survey. Comment: The Alta, like the overlying Kate Peak, is a complex unit of lava flows, tuff breccias, and interbedded sedimentary units. The Sutro member yielded a fels suggesting an early Miocene age (Axelrod, 1966). Due to complexities of structure, the relation of the sample to the Sutro member is not known, although its lithology suggests that it is stratigraphically above the Sutro (Calkins, 1944).

12. Evernden and James (1964) Sample KA1267

Hartford Hill Rhyolite Tuff. Rhyolitic welded tuff (NW/4 Sec. 31, T17N, R21E; Storey Co., NV). Collected by: R. Rose, San Jose State College; dated by: J. F. Evernden, Univ. Calif. Berkeley. Comment: Rhyolite conformably underlying Alta Formation in which shales containing Sutro flora are interbedded. The location does not check out with geology as no Alta occurs in vicinity—probably incorrect location.

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13. Doell and others (1966)  
Sample S18  

14. Wilden and Speed (in press)  
Sample 67WS6  
Dacite flow (SW/4 NE/4 Sec. 21, T24N, R28E; 39°56'24"N, 118°50'24"W; Pershing Co., NV). Analytical data: \( K_2O = 0.748\%; \frac{\text{Ar}^{40}}{\text{Ar}^{39}} = 0.932 \times 10^{-11} \text{ mole/gm}; \frac{\text{Ar}^{40}}{\text{Ar}^{39} + \text{Ar}^{40}} = 33\% \). Collected by: R. W. Willden, U. S. Geological Survey; dated by: R. W. Kistler, U. S. Geological Survey.

15. Evernden and James (1964)  
Sample KA1261  

16. Wilden and Speed (in press)  
Sample 66CH22  
Hornblende andesite lapilli tuff (SW/4 NW/4 Sec. 29 (unsurveyed), T16N, R29E; 39°13'21"N, 118°45'24"W; Pershing Co., NV). Analytical data: \( K_2O = 0.517\%; \frac{\text{Ar}^{40}}{\text{Ar}^{39}} = 0.932 \times 10^{-11} \text{ mole/gm}; \frac{\text{Ar}^{40}}{\text{Ar}^{39} + \text{Ar}^{40}} = 33\% \). Collected by: R. W. Willden, U. S. Geological Survey; dated by: R. W. Kistler, U. S. Geological Survey.

17. Wilden and Speed (in press)  
Sample 66CH159  
Hornblende dacite (NW/4 SW/4 Sec. 2, T14N, R29E; 39°06'00"N, 118°42'36"W; Pershing Co., NV). Analytical data: \( K_2O = 0.742\%; \frac{\text{Ar}^{40}}{\text{Ar}^{39}} = 0.932 \times 10^{-11} \text{ mole/gm}; \frac{\text{Ar}^{40}}{\text{Ar}^{39} + \text{Ar}^{40}} = 36\% \). Collected by: R. W. Willden, U. S. Geological Survey; dated by: R. W. Kistler, U. S. Geological Survey.

18. Wilden and Speed (in press)  
Sample 66CH213  
Hornblende andesite (SE/4 Sec. 24, T15N, R31E; 39°08'48"N, 118°27'42"W; Churchill Co., NV). Analytical data: \( K_2O = 0.558\%; \frac{\text{Ar}^{40}}{\text{Ar}^{39}} = 1.46 \times 10^{-11} \text{ mole/gm}; \frac{\text{Ar}^{40}}{\text{Ar}^{39} + \text{Ar}^{40}} = 34\% \). Collected by: R. W. Willden, U. S. Geological Survey; dated by: R. W. Kistler, U. S. Geological Survey.

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Slate Mountain Area

19. Willden and Speed (in press) K-Ar (hornblende) 27.0 m.y.
   Sample 67W152
   Andesite (SE/4 Sec. 8, T14N, R35E; 39°05'24"N, 118°03'30"W; Churchill Co., NV). Analytical data: \( K_2O = 0.644\% \); \( \Delta Ar^{40} = 2.58 \times 10^{-11} \) mole/gm; \( \Delta Ar^{40}/\Sigma Ar^{40} = 39\% \). Collected by: R. W. Willden, U. S. Geological Survey; dated by: R. W. Kistler, U. S. Geological Survey.

Wassuk Range

20. Bingler (1972) K-Ar (biotite) 25.2±1.0 m.y.
   Sample G-B1945/NBM AD45

   Sample GB-1788/NBM AD43

Aurora-Cedar Hill-Trench Canyon

Alkali Valley Area

22. USGS(M)-711-67 K-Ar (hornblende) 13.5±0.3 m.y.
   Porphyritic hornblende andesite of Aurora mining district (E border, Sec. 13, T5N, R27E; 38°17'22"N, 118°54'33"W; in Aurora Creek Valley; Mineral Co., NV). Analytical data: Hornblende (4% pyroxene) \( K_2O = 0.708\% \); \( \Delta Ar^{40} = 1.413 \times 10^{-11} \) mole/gm; \( \Delta Ar^{40}/\Sigma Ar^{40} = 49.4\% \). Collected by: M. L. Silberman, U. S. Geological Survey; dated by: M. L. Silberman, U. S. Geological Survey. Comment: This is a relatively unaltered part of the andesitic host rock sequence of the Aurora mining district. It is overlain by rhyolite, correlative with sample no. 28.

23. USGS(M)-668-G10 K-Ar (hornblende) 14.4±0.3 m.y.
   Hornblende andesite of Aurora mining district (NE corner Sec. 6, T4N, R28E; 38°14'25"N, 118°53'30"W; approximately 1 mi E of Calif. Border; Mineral Co., NV). Analytical data: Hornblende (4% pyroxene) \( K_2O = 0.658\% \); \( \Delta Ar^{40} = 1.403 \times 10^{-11} \) mole/gm; \( \Delta Ar^{40}/\Sigma Ar^{40} = 43.0\% \). Collected by: F. J. Kleinhampl and M. L. Silberman, U. S. Geological Survey; dated by: M. L. Silberman, U. S. Geological Survey. Comment: Altered, mildly propylitized andesite, correlative with the mineralized andesite of the Aurora mining district. The hornblende occurs as large phenocrysts and apparently is not affected by the hydrothermal alteration which usually destroys the ferro-magnesium minerals. Chemical analysis suggests this rock has not suffered gain or loss of major elements.

24. USGS(M)-711-8 K-Ar (plagioclase) 15.4±0.3 m.y.
   Intrusive, porphyritic pyroxene-andesite of Aurora mining district (NE/4 NE/4 Sec. 30, T5N, R28E; 38°16'05"N, 118°53'30"W; Mineral Co., NV). Analytical data: \( K_2O = 0.993\% \); \( \Delta Ar^{40} = 7.144 \times 10^{-11} \) mole/gm; \( \Delta Ar^{40}/\Sigma Ar^{40} = 42.6\% \). Collected by: M. L. Silberman, F. J. Kleinhampl, U. S. Geological Survey; dated by: M. L. Silberman, U. S. Geological Survey. Comment: Intrusive phase of the andesitic host rock sequence of the Aurora mining district. This rock is unaltered. It may be a volcanic neck from which flows of the Aurora mineralized andesites were erupted.

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25. Gilbert and others (1968)  
Sample KA2048


26. USGS(M)-712-1

Intrusive biotite hornblende andesite porphyry of west Brawley Peak. Felsporphyritic andesite of Al-Rawi (1970) (center N/2 Sec. 36, T5N, R27E; 38°15'08"N, 118°55'03"W; Mineral Co., NV).  
Analytical data: (Biotite) K2O = 8.47%; Ar40 = 1.405 x 10^-10 mole/gm; Ar40/ΣAr40 = 50.1%. (Hornblende) K2O = 0.690%; Ar40 = 0.962 x 10^-11 mole/gm; Ar40/ΣAr40 = 44.8%. Collected by: M. L. Silberman and F. J. Kleinhampl, U. S. Geological Survey; dated by: M. L. Silberman, U. S. Geological Survey.

Comment: Flows from the west Brawley intrusive inass overlie altered andesites of the Aurora mining district. Sample no. 25 is from approximately the same area as no. 26. This rock is characterized by large plagioclase phenocrysts (up to 1 cm across). A more felsic variety with the same large plagioclase phenocrysts crops out in Bodie Canyon to the west (see sample no. 27).

27. USGS(M)-710-7

Rhyolite porphyry of Bodie Canyon (NE corner Sec. 23, T5N, R27E; 38°16'56"N, 118°55'41"W; Mineral Co., NV).  
Analytical data: (Biotite) K2O = 8.36%; Ar40 = 1.393 x 10^-10 mole/gm; Ar40/ΣAr40 = 55.7%. Collected by: M. L. Silberman, U. S. Geological Survey.

Comment: This rock is a more felsic variety of the biotite hornblende andesite porphyry of west Brawley. It shows the large feldspar phenocrysts and is approximately the same age.

28. USGS(M)-NTS 1OB

Porphyritic rhyolite flow (NW/4 SE/4 Sec. 7, T5N, R28E; 38°18'04"N, 118°53'48"W; Mineral Co., NV).  
Analytical data: (Sanidine) K2O = 11.40%; Ar40 = 1.357 x 10^-10 mole/gm; Ar40/ΣAr40 = 55.7%. (Plagioclase) K2O = 0.693%; Ar40 = 0.1048 x 10^-10 mole/gm; Ar40/ΣAr40 = 23.4%. Collected by: M. L. Silberman and F. J. Kleinhampl, U. S. Geological Survey; dated by: M. L. Silberman, U. S. Geological Survey. Comment: This flow is part of a rhyolitic complex cropping out in Bodie Canyon, west and north of the Aurora mining district. Parts of the rhyolite are altered, but no mineralization occurs within it. The age of this rhyolite (see sample no. 29 also) overlaps the age of mineralization of the Aurora mining district (F. J. Kleinhampl and M. L. Silberman, unpublished data).

29. USGS(M)-Baghdad

Porphyritic rhyolite intrusive (E central Sec. 22, T5N, R27E; 39°16'43"N, 118°56'48"W; Mineral Co., NV).  
Analytical data: (Sanidine) K2O = 11.40%; Ar40 = 1.668 x 10^-10 mole/gm; Ar40/ΣAr40 = 33.1%. (Plagioclase) K2O = 0.6093%; Ar40 = 0.1048 x 10^-10 mole/gm; Ar40/ΣAr40 = 23.4%. Collected by: M. L. Silberman and F. J. Kleinhampl, U. S. Geological Survey; dated by: M. L. Silberman, U. S. Geological Survey. Comment: Part of 10 to 11 m.y.-old rhyolite complex outcropping north and east of the Aurora mining district (see also sample no. 28). The rhyolitic complex is the same age as the mineralization of Aurora, and may be genetically related to the ore deposits (F. J. Kleinhampl and M. L. Silberman, unpublished data).
30. **USGS(M)-670G4**  
**K-Ar**  
**(biotite) 2.5±0.1 m.y.**  
Glassy, porphyritic rhyolite plug (NE/4 NW/4 Sec. 20, T5N, R28E; 38°16'52"N, 118°53'03"W; Mineral Co., NV).  
Analytical data: K\textsubscript{2}O = 8.75%; \textit{Ar\textsubscript{40}} = 3.252 x 10\textsuperscript{-11} mole/gm; \textit{Ar\textsubscript{40}}/\textit{Ar\textsubscript{40}} = 24.9%. Collected by: F. J. Kleinhampl and M. L. Silberman, U. S. Geological Survey; dated by: M. L. Silberman, U. S. Geological Survey. Comment: This small plug intrudes altered mineralized andesite of the Aurora mining district. Several large veins are cut off at the contact.

31. **USGS(M)-610-1B**  
**K-Ar**  
**(biotite) 2.5±0.2 m.y.**  
Porphyritic biotite-hornblende andesite intrusive (SE/4 NE/4 Sec. 21, T5N, R28E; 38°16'40"N, 118°51'31"W; Mineral Co., NV). Analytical data: (Biotite) K\textsubscript{2}O = 7.65%; \textit{Ar\textsubscript{40}} = 2.844 x 10\textsuperscript{-11} mole/gm; \textit{Ar\textsubscript{40}}/\textit{Ar\textsubscript{40}} = 25.0%. Collected by: J. F. Kleinhampl, M. L. Silberman, U. S. Geological Survey; dated by: M. L. Silberman, U. S. Geological Survey. Comment: This plug is east of the Aurora mining district and is not in contact with the host rocks. It is overlain by younger basalts of Mount Hicks (no. 34).

32. **USGS(M)-672-2**  
**K-Ar**  
**(whole rock) 0.25±0.05 m.y.**  
Basaltic andesite of Aurora-Crater (NE/4 NW/4 Sec. 8, T5N, R28E; 38°18'46"N, 118°52'57"W; Mineral Co., NV). Analytical data: (Whole rock) K\textsubscript{2}O = 3.27%; \textit{Ar\textsubscript{40}} = 1.205 x 10\textsuperscript{-12} mole/gm; \textit{Ar\textsubscript{40}}/\textit{Ar\textsubscript{40}} = 6.6%. Collected by: M. L. Silberman, F. R. Glass, U. S. Geological Survey; dated by: M. L. Silberman, U. S. Geological Survey. Comment: The Aurora-Crater volcano is a complex of lavas and dikes with a central partly collapsed core within which the cinder cones have been built. It has suffered minimal erosion and retains geomorphic features common to very young volcanoes (Kleinhampl and others, 1972). It occupies about 8 square miles, north of the Aurora mining district. Its age is the youngest isotopic age on volcanic rock from this area.

33. **USGS(M)-611-5**  
**K-Ar**  
**(whole rock) 2.2±0.1 m.y.**  
Hornblende andesite flow (SE/4 SE/4 Sec. 28, T5N, R28E; 38°15'28"N, 118°51'21"W; Mineral Co., NV). Analytical data: (Whole rock) K\textsubscript{2}O = 4.48%; \textit{Ar\textsubscript{40}} = 1.451 x 10\textsuperscript{-11} mole/gm; \textit{Ar\textsubscript{40}}/\textit{Ar\textsubscript{40}} = 29.1%. (Hornblende) K\textsubscript{2}O = 1.09%; \textit{Ar\textsubscript{40}} = 3.989 x 10\textsuperscript{-12} mole/gm; \textit{Ar\textsubscript{40}}/\textit{Ar\textsubscript{40}} = 21.4%. Collected by: M. L. Silberman, F. J. Kleinhampl, U. S. Geological Survey; dated by: M. L. Silberman, U. S. Geological Survey. Comment: This volcanic flow overlies altered andesite south of the main part of the Aurora mineral district.

34. Gilbert and others (1968)  
**K-Ar**  
**Sample KA2089**  
**(whole rock) 1.6±0.1 m.y.**  

35. Gilbert and others (1968)  
**K-Ar**  
**Sample KA2066**  
**(sanidine) 3.6±0.1 m.y.**  

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36. Gilbert and others (1968)
Sample KA2003
K-Ar (plagioclase) 2.7±0.8 m.y.

37. Gilbert and others (1968)
Sample KA1859
K-Ar (plagioclase) 2.8±0.4 m.y.

38. Gilbert and others (1968)
Sample KA1912
K-Ar (biotite) 2.7±0.2 m.y.
Biotite-pyroxene pumice of Cedar Hill (center Sec. 30, T4N, R29E; 38°11'23"N, 118°49'12"W; Mineral Co., NV). Collected by: C. K. Gilbert, M. N. Christensen, K. R. LaJoie, Y. Al·Rawi, Univ. Calif. Berkeley; dated by: K. R. LaJoie, Univ. Calif. Berkeley. Comment: The last three samples are in stratigraphic order with no. 36 being the youngest. The preceding 9 samples (nos. 30 through 38) are a complex of young, alkaline volcanic rocks ranging from 3.6 to 0.25 m.y. in age and consist of sub-alkaline olivine basalt, basaltic andesite, andesite, dacite and rhyolite flows, domes and plugs. These young volcanics represent a fundamental change in the chemical nature of volcanism in the Mono Basin area, from an earlier calc-alkaline volcanic suite to one of alkali-calcic or alkaline nature (Kleinhamp and others, in press). Their estimated volume is 30 km³ (Gilbert and others, 1968).

Anchorage Hills-Excelsior Mountains
Huntoon Valley Area

39. Dalrymple and others (1967)
Sample W19, nos. 1 and 2
K-Ar #1 (sanidine) 3.32±0.10 m.y.
(biotite) 3.39±0.24 m.y.
#2 (sanidine) 3.19±0.10 m.y.
(biotite) 3.45±0.17 m.y.

40. Gilbert and others (1968)
Sample KA1813
K-Ar (sanidine) 3.5±0.1 m.y.

41. Dalrymple and others (1967)
Sample W20
K-Ar (biotite) 3.46±0.14 m.y.
(plagioclase) 3.77±0.34 m.y.

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43. Dalrymple and others (1967)  
Sample W21  

44. Gilbert and others (1965)  
Sample KA1567  

45. Gilbert and others (1968)  
Sample KA1876  

46. Gilbert and others (1968)  
Sample KA1866  

47. Gilbert and others (1968)  
Sample KA2016  

48. Gilbert and others (1968)  
Sample KA2015  
Olivine basalt (SW/4 Sec. 9, T2N, R31E; 38°02'46"N, 118°31'46"W; Mineral Co., NV). Collected by: C. K. Gilbert, M. N. Christensen, Y. Al-Rawi, K. R. Lajoie, Univ. Calif. Berkeley; dated by: K. R. Lajoie, Univ. Calif. Berkeley. Comment: This and the preceding 5 samples (nos. 43-48) are part of an extensive field of thin, alkali-olivine basalt flows which cover nearly 300 square miles east and south of Mono Lake in Nevada and California. The basalts, which are intercalated with small volumes of rhyolite, andesite and latite, were erupted from numerous local centers between 2.6 and 4.5 m.y. ago. The aggregate thickness of these flows locally exceeds 600 feet. Their volume is estimated as 65 km³ (Gilbert and others, 1968).
49. Dalrymple and others (1967)  
Sample W23


50. Gilbert and others (1968)  
Sample KA1852


51. Gilbert and others (1968)  
Sample KA1916, 1918

Sanidine-bearing latite ignimbrite (Sec. 35, unsurveyed, T3N, R30E; 38°04'32"N, 118°36'11"W; 0.4 mi W of Huntoon Spring, bottom of creek; Mineral Co., NV). Collected by: C. K. Gilbert, M. N. Christensen, Y. Al-Rawi, K. R. LaJoie, Univ. Calif. Berkeley; dated by: K. R. LaJoie, Univ. Calif. Berkeley. Comment: The sample and the previous two were collected in stratigraphic order. The youngest is sample 50.

52. Gilbert and others (1968)  
Sample KA1860

Sanidine-bearing latite ignimbrite (Sec. 35, unsurveyed, T3N, R30E; 38°04'50"N, 118°35'23"W; 0.3 mi N16°W of Huntoon Spring; Mineral Co., NV). Collected by: C. K. Gilbert, M. N. Christensen, Y. Al-Rawi, K. R. LaJoie, Univ. Calif. Berkeley; dated by: K. R. LaJoie, Univ. Calif. Berkeley. Comment: The sample and the previous two were collected in stratigraphic order. The youngest is sample 50.

53. Gilbert and others (1968)  
Sample KA1911

Sanidine-free latite ignimbrite (Center N boundary Sec. 24, T3N, R29E; 38°06'44"N, 118°43'44"W; Mineral Co., NV). Collected by: C. K. Gilbert, M. N. Christensen, Y. Al-Rawi, K. R. LaJoie, Univ. Calif. Berkeley; dated by: K. R. LaJoie, Univ. Calif. Berkeley. Comment: This and the preceding 4 samples are from a sequence of widespread welded latite ignimbrites which crop out in a broad belt crossing Mono Basin in a northwesterly direction. They fall into two age groups, an older one from 11.1 to 11.9 m.y., and a younger one from 9.0 to 9.8 m.y. The older of the two groups crops out in the southeastern part of the area, and the younger to the NW. The Anchorite Hills is the dividing line. The two age groups are probably from different eruptive centers (Gilbert and others, 1968). The thickest exposures, 700', occur in Huntoon Valley (locations 50, 51, 52), but generally the ignimbrites are relatively thin and extensive.

54. Gilbert and others (1968)  
Sample KA2047


55. Gilbert and others (1968)  
Sample KA2000

Sanidine-free latite ignimbrite (Center N boundary Sec. 24, T3N, R29E; 38°06'44"N, 118°43'44"W; Mineral Co., NV). Collected by: C. K. Gilbert, M. N. Christensen, Y. Al-Rawi, K. R. LaJoie, Univ. Calif. Berkeley; dated by: K. R. LaJoie, Univ. Calif. Berkeley. Comment: This and the preceding 4 samples are from a sequence of widespread welded latite ignimbrites which crop out in a broad belt crossing Mono Basin in a northwesterly direction. They fall into two age groups, an older one from 11.1 to 11.9 m.y., and a younger one from 9.0 to 9.8 m.y. The older of the two groups crops out in the southeastern part of the area, and the younger to the NW. The Anchorite Hills is the dividing line. The two age groups are probably from different eruptive centers (Gilbert and others, 1968). The thickest exposures, 700', occur in Huntoon Valley (locations 50, 51, 52), but generally the ignimbrites are relatively thin and extensive.

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Aldrich Station (Coal Valley)

56. Evernden and others (1964) K-Ar
Sample KA552


57. Evernden and others (1964) K-Ar
Sample KA414


58. Evernden and others (1964) K-Ar
Samples KA482, 482II


59. Evernden and others (1964) K-Ar
Sample KA500


60. Evernden and others (1964) K-Ar
Sample KA551


Smith Valley

61. Evernden and others (1964) K-Ar
Sample KA485


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Gilbert and others (1968)
Samples KA1970, 1988, 2009

Gilbert and others (1968)
Samples KA1979, 1989

Robinson and others (1968)
Sample 14

Evernden and others (1964)
Sample KA480

Evernden and others (1964)
Sample KA499

Albers and Stewart (1972)
Sample Gilbert

Evernden and others (1964)
Sample KA577

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69. Evernden and others (1964) K-Ar (biotite) 10.7 m.y. Sample KA452


Toiyabe Range

70. F. J. Kleinhampl (written communication, 1971) K-Ar (biotite) 21.5±0.4 m.y. Sample Z15326-9a


Silver Peak Range

71. Evernden and James (1964) K-Ar (biotite) 12.7 m.y. Sample KA1268


72. Robinson and others (1968) K-Ar (biotite) 21.5±1.0 m.y. Sample 12

Rhyolite welded tuff (Sec. 31, T2N, R37E; 37°95'N, 117°54'W; Silver Peak Range; Esmeralda Co., NV). Collected by: R. J. Moiola, Mobil Oil Corp.; dated by: J. F. Evernden, Univ. Calif. Berkeley.

73. Robinson and others (1968) K-Ar (biotite) 6.0±0.5 m.y. Sample 6


74. Robinson and others (1968) K-Ar (whole rock) 4.8±0.6 m.y. Sample 7


75. Robinson and others (1968) K-Ar (biotite) 5.9±0.2 m.y. Sample 8


76. Robinson and others (1968) K-Ar (biotite) 6.1±0.3 m.y. Sample 5

77. Robinson and others (1968)
Sample 13
K-Ar (biotite) 6.9±0.3 m.y.

Rhyolite air-fall tuff (Sec. 15, T1S, R39E; 37°51'N, 117°38'W; on the Monocline between Big Smokey and Clayton Valleys; Esmeralda Co., NV). Collected by: R. J. Moiola, Mobil Oil Corp; dated by: J. F. Evernden, Univ. Calif. Berkeley.

78. McKee (1968)
Sample Pigeon Spring
K-Ar (biotite) 4.5±0.2 m.y.

Rhyolite tuff breccia (Sec. 16, T6S, R39E; 37°25'N, 117°40'W; Esmeralda Co., NV). Analytical data: $K_2O = 5.79\%$, $\text{Ar}^{40} = 3.81 \times 10^{-11}$ mole/gm; $\text{Ar}^{40}/\Sigma\text{Ar}^{40} = 42\%$. Collected by: E. H. McKee, U.S. Geological Survey; dated by: J. D. Obradovich, U. S. Geological Survey. Comment: Cited as Pliocene, no date published.

San Antonio Mountains

79 USGS(M)-12789-75
K-Ar (biotite) 16.7±0.5 m.y.
(hornblende) 16.8±0.5 m.y.

Porphyritic biotite-hornblende dacite flow (center Sec. 34, T6N, R42E; 38°20'09"N, 117°15'00"W; Nye Co., NV). Analytical data: (Biotite) $K_2O = 8.41\%$, $\text{Ar}^{40} = 2.088 \times 10^{-10}$ mole/gm; $\text{Ar}^{40}/\Sigma\text{Ar}^{40} = 79.4\%$. (Hornblende) $K_2O = 0.815\%$, $\text{Ar}^{40} = 2.057 \times 10^{-11}$, $2.001 \times 10^{-11}$ mole/gm; $\text{Ar}^{40}/\Sigma\text{Ar}^{40} = 42.6\%, 41.6\%$. Collected by: F. J. Kleinhampl, U. S. Geological Survey; dated by: M. L. Silberman, U. S. Geological Survey. Comment: Part of extensive unit of porphyritic dacite as much as 1,500 feet thick which overlies Tertiary tuffs (Davis and others, 1971).

80. Armstrong and others (1972)
Sample 57233
K-Ar (whole rock) 17.9±3 m.y.


81. Armstrong and others (1972)
Sample 5780
K-Ar (whole rock) 15.8±2 m.y.


82. Armstrong and others (1972)
Sample D-3-13
K-Ar (whole rock) 18.9±1.5 m.y.


83. Bonham and others (1972)
Sample USGS(M)T1219
K-Ar (biotite) 20.4±0.6 m.y.

84. USGS(M)-11549-1

Fraction breccia, rhyolitic welded tuff (NE/4 Sec. 2, T2N, R42E; 38°03'38"N, 117°13'37"W; at Heller Butte; Nye Co., NV). Analytical data: (Biotite) $K_2O = 8.74\%$; $\Delta^40 = 2.222 \times 10^{-10}$ mole/gm; $\Delta^40/\Sigma\Delta^40 = 62.3\%$. Collected by: F. J. Kleinhampl, U.S. Geological Survey; dated by: M. L. Silberman, U.S. Geological Survey. Comment: The fraction breccia is the oldest postore unit in the Tonopah district. The age of 17 m.y. places an upper limit and the previous one (sample no. 83) places a lower limit of 20.4 m.y. on the time of mineralization. Age of mineralization at Tonopah has been estimated as 19.1 m.y. based on a single date on adularia from one of the veins (Bonham and others, 1972, this issue).

85. L. J. Garside (written communication, 1972)

Siebert Tuff. Rhyolite tuff (SW/4 SE/4 Sec. 20, T2N, R42E; 38°00'57"N, 117°17'01"W; Esmeralda Co., NV). Analytical data: (Sanidine) $K_2O = 11.11\%$; $\Delta^40 = 2.782 \times 10^{-10}$ mole/gm; $\Delta^40/\Sigma\Delta^40 = 53.9\%$. Collected by: L. J. Garside, Nev. Bur. Mines; dated by: Geochron Laboratories, Inc.

86. Albers and Stewart (1972)


87. Armstrong and others (1972)


88. Armstrong and others (1972)


89. Armstrong and others (1972)


91. Armstrong and others (1972) K-Ar (whole rock) 6.8±1.5 m.y.
Sample B-1-2


92. Armstrong and others (1972) K-Ar (whole rock) 8.7±1.5 m.y.
Sample B-1-1

Malpais Basalt. (NW/4 NE/4 SE/4 Sec. 10, T3S, R42E; 37°41'45"N, 117°14'40"W; Esmeralda Co., NV). Collected by: C. J. Vitaliano, Ind. Univ.; dated by: R. L. Armstrong and H. Dick, Yale Univ. Comment: Basal flow. The last 4 samples were collected from 2 flows of the Malpais Basalt.

93. Armstrong and others (1972) K-Ar (whole rock) 13.5±3.0 m.y.
Sample 5813


94. Armstrong and others (1972) K-Ar (whole rock) 12.0±0.5 m.y.
Sample 58441


95. Armstrong and others (1972) K-Ar (whole rock) 12.9±1.2 m.y.
Sample B-2-3

Labradorite andesite from Black Cap Mountain, lower flow (SE/4 SW/4 NE/4 Sec. 9, T1S, R43E; 37°41'45"N, 117°09'20"W; Nye Co., NV). Collected by: C. J. Vitaliano, Ind. Univ.; dated by: R. L. Armstrong and H. Dick, Yale Univ. Comment: See sample 96, collected from same outcrop, 18 meters above no. 95.

96. Armstrong and others (1972) K-Ar (whole rock) 11.8±0.4 m.y.
Sample B-2-7


97. USGS(M)-164-69 K-Ar (biotite) 14.2±0.3 m.y.

Siebert Tuff. Pumiceous rhyolite air-fall tuff (NW/4 NE/4 Sec. 18, T3S, R43E; 37°41'17"N, 117°11'38"W; Esmeralda Co., NV). Analytical data: K$_2$O = 8.57%, $^{40}$Ar/$^{36}$Ar = 1.807 x 10$^{-10}$ mole/gm; $^{40}$Ar/$\Sigma$Ar$^{40}$ = 62.7%. Collected by: R. P. Ashley and M. L. Silberman, U. S. Geological Survey; dated by: M. L. Silberman, U. S. Geological Survey. Comment: Biotite separated from pumice fragments in the tuff to avoid contamination from lithic fragments.

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98. **USGS(M)-164-15**

Meda Rhyolite. Rhyolite welded tuff (NE corner Sec. 18, T3S, R43E; 37°41′10″N, 117°11′23″W; Esmeralda Co., NV). Analytical data: $K_2O = 7.83\%$; $^{40}\text{Ar}/^{39}\text{Ar} = 2.069 \times 10^{-10}$ mole/gm; $^{40}\text{Ar}/^{39}\text{Ar} = 37.5\%$. Collected by: R. P. Ashley and M. L. Silberman, U. S. Geological Survey; dated by: M. L. Silberman, U. S. Geological Survey.


Sample 288-I

K-Ar (biotite) 17.8±0.4 m.y.

100. Armstrong and others (1972)

Sample 58N260

K-Ar (plagioclase) 21.6±1.1 m.y.

101. Kistler (1968)

Sample 644-3B

K-Ar (biotite) 21.1 m.y.

102. Albers and Stewart (1972)

Sample 97VV-5

K-Ar (biotite) 21.6±0.5 m.y.

103. Silberman and Ashley (1970)

Sample 203-11

K-Ar (biotite) 21.4±0.4 m.y.

104. Silberman and Ashley (1970)

Sample Y-47

K-Ar (biotite) 21.2±0.4 m.y.

105. Albers and Stewart (1972)

Sample 97VV-299

K-Ar (hornblende) 21.5±0.5 m.y.

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REFERENCES


[Isochron/West, no. 4, August 1972]


