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K-AR AGE OF VOLCANISM AND MINERALIZATION, BODIE MINING DISTRICT AND BODIE HILLS VOLCANIC FIELD, MONO COUNTY, CALIFORNIA[1]

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ANALYTICAL EQUIPMENT AND PROCEDURE

Mineral separates were prepared from 23 rock samples collected by the writers by crushing to 0.1 to 1 mm, depending on the size of the minerals to be analyzed, and then by separating the minerals using electrostatic and magnetic separators, heavy liquids, and an inclined vibrating table. The purified mineral separates were split with a Jones microsplitter into separate aliquots for K_2O and Ar analysis.

K analyses were made by Lois Schlocker by flame photometer, using lithium metaborate fusion; the lithium served as an internal standard. Analytical uncertainty of K content of the samples was approximately 0.5%. Ar analyses were done by M. Silberman, using standard isotope dilution techniques (Dalrymple and Lanphere, 1969). Mass analyses were made with a Neir-type 6-inch, 60 sector, or a Reynolds 4½-inch, 60 sector mass spectrometer, both operated in the static mode. Analytical uncertainty of Ar analysis was approximately 1.7% for samples with more than 30% radiogenic Ar, and increased to 5% for samples with lower radiogenic Ar contents. Many of the ages were determined by duplicate Ar analyses, and the resulting uncertainties were calculated from averaging the data. All uncertainties are quoted at one standard deviation. Constants used in the calculation of ages are: $\lambda_e = 0.585 \times 10^{-10}$ yr^{-1}; $\lambda_\beta = 4.72 \times 10^{-10}$ yr^{-1}; $K^{40}/K_{total} = 1.22 \times 10^{-4}$ gm/gm. Abbreviations used: $\overset{*}{A}r^{40}$ = radiogenic argon; ΣAr^{40} = total argon -40.

The locations of 12 of the samples collected are shown on Figure 1; the other 11 samples were collected elsewhere in the Bodie Hills. Location and analytical data are given in the Sample Descriptions section.

GEOLOGICAL DISCUSSION

This is the first of a series of detailed geochronological studies, using the K-Ar method, of epithermal vein precious metal deposits in volcanic rocks of Nevada and eastern California. The objectives are to determine the absolute age relations of the host rocks, veins, and post-ore volcanics. By applying K-Ar measurements to hypogene vein minerals, and alteration minerals within the wall rocks the time duration of the hydrothermal systems responsible for ore deposition and alteration can be determined.

The Bodie mining district, which produced $30 million worth of gold and silver (Clark, 1970), lies near the eastern margin of a complex massif of Pliocene volcanic rocks which form the southern part of the Bodie Hills (Kleinhampl and others, in press; Chesterman, 1968). The volcanic field covers 80 km^2 and represents approximately 35 km^3 of rock (Gilbert and others, 1968). The volcanics consist of lava flows, tuff breccias, and intrusive plugs and domes, which were erupted from several discrete vent areas, including the mining district itself. The rocks range from rhyolite to alkali basalt in composition; dacite and andesite are the most voluminous rock types. The ages of the volcanic rocks range from 9.5 m.y. to 8 m.y. Geochemical and petrographic data to be presented elsewhere show that these rocks form a related differentiation sequence. The mineralization apparently commenced shortly after the dacitic volcanism ceased in the district. During early stages of ore deposition, some dacitic volcanic rocks were being emplaced west of the district. The hydrothermal system responsible for mineralization and alteration lasted for about 1 m.y., and the cessation of mineralization marked the end of volcanic activity in the Bodie Hills, except for emplacement of a small volume of rhyolite in the western part of the Bodie Hills between 5.3 and

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

5.7 m.y. ago (Chesterman, 1968; F. J. Kleinhampl & others, in press). About 2½ m.y. after mineralization, major volcanic activity began again east and south of the district. These latest volcanic rocks are distinctly alkaline and are not related to those of the Bodie Hills. The regional volcanic geochronology is summarized in Table 1.

Table 1. Range in Age of Volcanic Rocks and Quartz-Adularia Veins, Bodie Mining District and Bodie Hills

Younger post-ore sequence (east of Bodie mining district)	3.6[1] m.y. - 250,000 y.[2]
Younger rhyolitic rocks, western Bodie Hills	5.7 m.y. - 5.3 m.y.[3]
Veins, Bodie mining district	8.0 m.y. - 7.2 m.y.
Dacite intrusive rocks, Bodie mining district	9.2 m.y. - 8.6 m.y.
Silver Hill Volcanic Series of Chesterman and Gray (1966), Bodie mining district	9.4 m.y. - 8.8 m.y.
Other volcanic rocks of Bodie Hills volcanic field (basalts, andesites, dacites, and rhyolites)	9.5 m.y. - 7.8 m.y.[1]

[1]Gilbert and others (1968); [2]Silberman, unpublished data, Aurora mining district; [3]Kleinhampl, unpublished data

The Bodie mining district is underlain by a sequence of lava flows and tuff breccias named by Chesterman and Gray (1966) the Silver Hill Volcanic Series, which is intruded and domed by small hornblende dacite plugs, the largest of which is at Bodie Bluff (Fig. 1). The biotite-hornblende dacite tuff breccia of the district is overlain by two flows, an upper one, referred to as "dacite," and a lower one, referred to as "andesite." Both flows are porphyritic rocks, containing phenocrysts of biotite and hornblende along with some diopsidic augite and sparse quartz in a fine-grained holocrystalline groundmass of plagioclase and potassium feldspar. The plugs, which probably represent apophyses of a larger intrusive mass at depth, are porphyritic hornblende dacites, and are petrographically similar to the flows and tuff breccia except that they contain little or no biotite. Chemically, the tuff breccia, flows, and plugs have similar dacitic compositions.

The structure of the district consists essentially of an irregular, faulted, north-trending anticline intruded by several plugs. Several sets of steeply dipping faults cut all units, including the intrusive rocks. One prominent set strikes north to north-northeast, and another normal to this. The major veins and fractures also strike northeast, parallel to one of the major fault sets. Gold and silver bearing minerals are localized within the quartz veins. The veins occur throughout the district, but are richest and most pervasively developed in the area of the tuff breccia graben on Bodie Bluff (Fig. 1). The dacite intrusive is the center of a wide zone of pervasive potassium silicate alteration (Meyer and Hemley, 1967). Adularia (hydrothermal K feldspar) occurs as a primary gangue mineral in all the veins, and with quartz and K-mica in the altered wall rocks.

The intrusive dacite plug at Bodie Bluff has the largest variation in K-Ar ages of any volcanic rock in the mining district (Fig. 2). The other rocks have concordant mineral pair ages or concordant ages on samples from different parts of the same stratigraphic unit (Fig. 2). Chemical, petrographic, and oxygen isotopic analyses show that with the exception of the dacite plug at Bodie Bluff (see comment, sample 7, Sample Descriptions section), the samples from the district are unaffected by hydrothermal alteration.

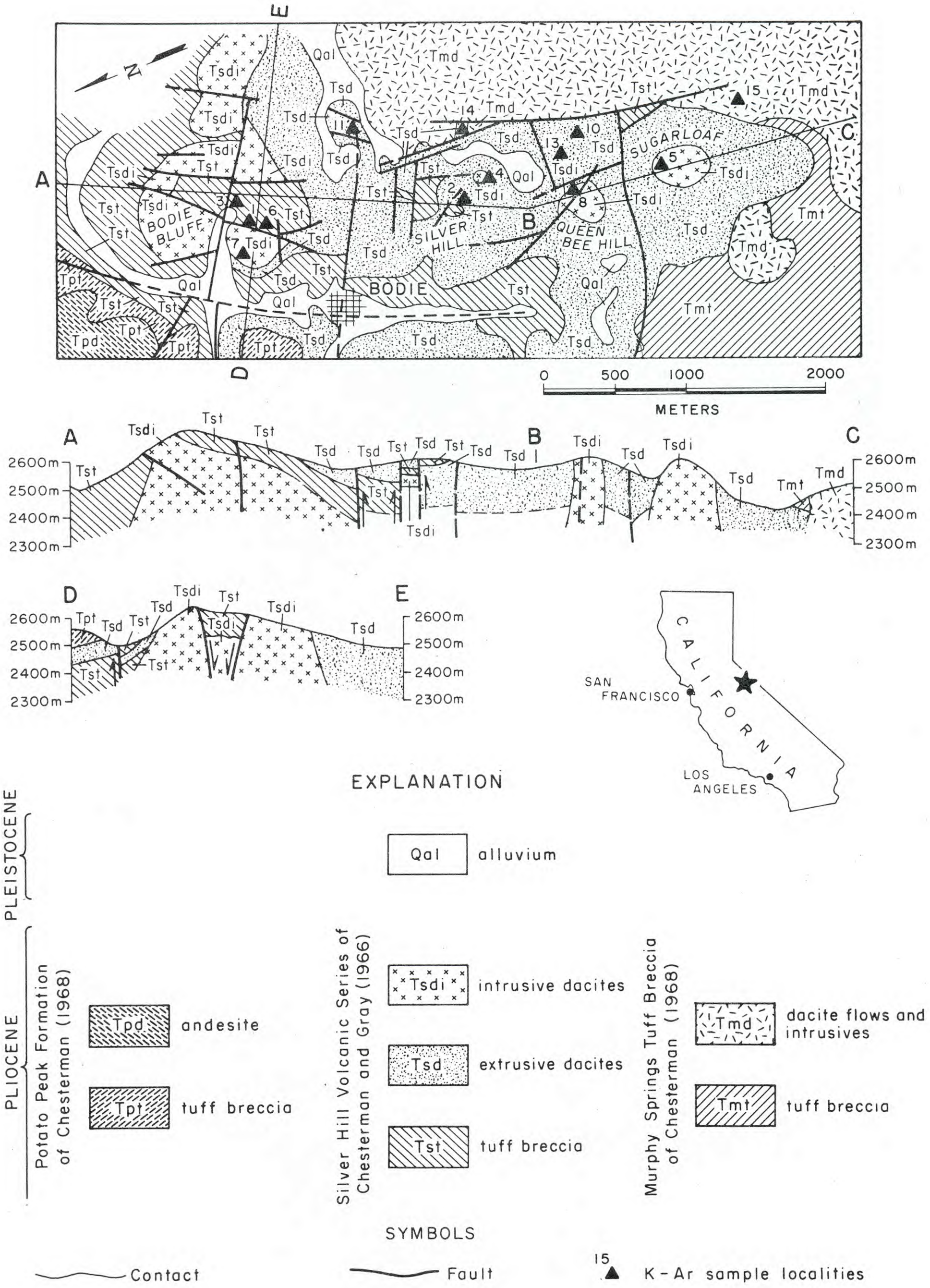
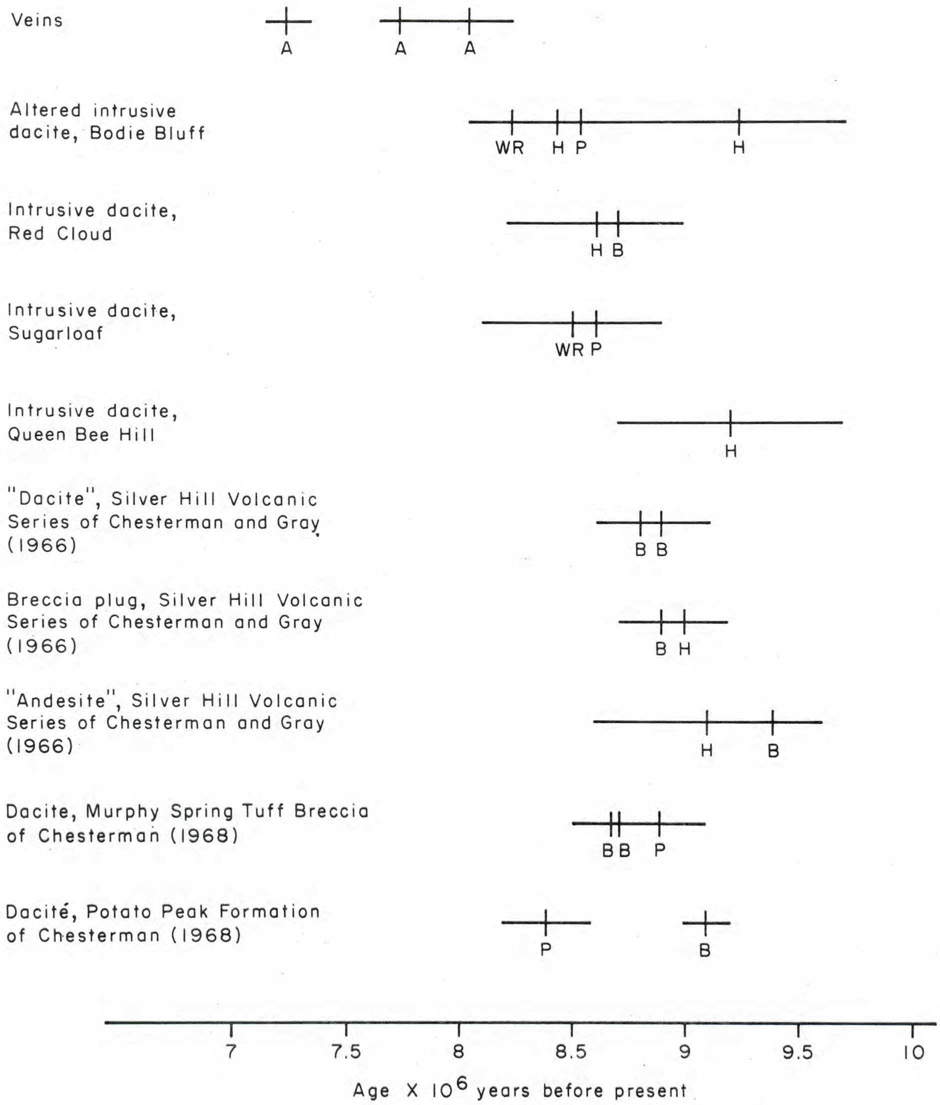


Figure 1. Generalized geologic map and sections of the Bodie mining district, Mono County, California



Horizontal line represents analytical uncertainty

Letter refers to mineral used for K-Ar age determination

- A = Adularia
- B = Biotite
- H = Hornblende
- P = Plagioclase
- WR = Whole rock

Plagioclase ages from Gilbert and others (1968)

Figure 2. K-Ar ages of volcanic rocks and veins of the Bodie mining district, Mono County, California

SAMPLE DESCRIPTIONS

(Rock stratigraphic nomenclature is that of Chesterman and Gray, 1966, and Chesterman, 1968.)

A. Adularia-Quartz Veins, Bodie Mining District

1. USGS(M)-7346-1 K-Ar (adularia) 7.2±0.1 m.y.
7.0±0.1 m.y.

Adularia-quartz vein (S-central Sec. 9, T4N, R27E, just below summit of Standard Hill; Mono Co., CA). Vein intrudes altered dacite of Bodie Bluff and has sharp, clean contacts. It is composed of very fine grained, white intergrowth of quartz and adularia. Irregular banding and vugs are present. Partings and vugs are coated with limonite. It pinches and swells from a few inches to a foot in width. A channel sample taken across the vein averaged 0.2 ppm gold and 20 ppm silver. Analytical data: (adularia contained 37% quartz as fine-grained intergrowth) K_2O = 10.28%; $\overset{*}{Ar}{}^{40}$ = 1.091 x 10^{-10} mole/gm, 1.071 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 81.5, 59.5%. (Second analysis resulted in only partial fusion of the sample, and was not used in calculation.)

2. USGS(M)-RCD1B K-Ar (adularia) 7.7±0.1 m.y.

Adularia-calcite-quartz vein (S-central Sec. 16, T4N, R27E, dump Red Cloud Mine; Mono Co., CA). Very coarse crystalline calcite intergrown with fine-grained adularia and minor quartz. Sample contained 0.1 ppm Au and 0.6 ppm Ag. Analytical data: K_2O = 16.6%; $\overset{*}{Ar}{}^{40}$ = 1.885 x 10^{-10} mole/gm, 1.917 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 80.4%, 89.8%.

3. USGS(M)-B270 K-Ar (adularia) 8.0±0.2 m.y.

Adularia-quartz vein (S-central Sec. 9, T4N, R27E; McClinton shaft dump on Standard Hill; Mono Co., CA). Two to five cm layer of coarse, milky white adularia crystals up to 2 cm across intergrown with quartz coating fracture surfaces of altered dacite of Bodie Bluff. Vein sample contains 8 ppm Au and 8 ppm Ag. Analytical data: K_2O = 15.83%; $\overset{*}{Ar}{}^{40}$ = 1.930 x 10^{-10}, 1.838 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 73.6%, 38.2%. Comment: The reliability of the K-Ar ages of feldspars seems to be related to both chemical composition and structural state (Evernden and Richards, 1962; Evernden and James, 1964). Feldspars consisting of nearly pure orthoclase and having the sanidine structure appear to be highly reliable for K-Ar dating. The adularia used to date mineralization at Bodie falls into this category, according to X-ray data and chemical analyses. Buseck (1966) and Ohmoto and others (1966) reported K-Ar measurements on vein adularia in the Providencia-Concepción del Oro hydrothermal Pb-Zn deposits, which are associated with granodiorite stocks in north-central Mexico. Otherwise, the mineral has not been widely used for isotopic dating.

B. Intrusive Rocks, Bodie Mining District

4. USGS(M)-BH15 K-Ar (hornblende) 8.6±0.4 m.y.
(biotite) 8.7±0.2 m.y.

Porphyritic biotite hornblende dacite (S-central Sec. 16, T4N, R27E; 1,000 ft E of the Red Cloud shaft; Mono Co., CA). Dark-gray to black dacite, with phenocrysts of plagioclase, hornblende, and biotite, and minor pyroxene in an aphanitic groundmass. Hornblende is much more abundant than biotite. Analytical data: (Hornblende, 1% pyroxene) K_2O = 0.924%; $\overset{*}{Ar}{}^{40}$ = 0.1182 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 12.3%. (Biotite, 1% hornblende) K_2O = 6.97%; $\overset{*}{Ar}{}^{40}$ = 0.9026 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 46.1%.

5. USGS(M)-S1 K-Ar (whole rock) 8.5±0.4 m.y.
(plagioclase) (A) 8.3±0.4 m.y.
(plagioclase) (B) 8.9±0.4 m.y.

Porphyritic hornblende dacite intrusive - Sugarloaf (SW/4 Sec. 21, T4N, R27E; top of conical hill; Mono Co., CA). Light-gray porphyritic dacite with plagioclase and hornblende phenocrysts in a fine-grained groundmass. Hornblende is rimmed by iron oxide. Analytical data: (Whole rock) K_2O = 2.63%; $\overset{*}{Ar}{}^{40}$ = 0.3304 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 22.6%. (Plagioclase A) K_2O = 0.847%; $\overset{*}{Ar}{}^{40}$ = 0.1044 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 16.5%. (Plagioclase B) K_2O = 0.709%; $\overset{*}{Ar}{}^{40}$ = 0.0890 x 10^{-10} mole/gm, 0.0971 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 10.1%, 18.2%.

6. USGS(M)-B271 K-Ar (hornblende) 8.4±0.2 m.y.
(plagioclase) 8.5±0.3 m.y.

Altered porphyritic hornblende dacite intrusive of Bodie Bluff (S-central Sec. 9, T4N, R27E; Standard shaft dump, Standard Hill; Mono Co., CA). Reddish-gray porphyritic dacite, with phenocrysts of plagioclase and hornblende in a fine-grained groundmass which shows partial recrystallization and development of chlorite and addition of K-feldspar. The plagioclase has hematite-coating fractures and appears reddish in hand specimen. Some of the hornblende is altered to chlorite. Analytical data: (Hornblende, 2% chlorite, 1% plagioclase) K_2O = 0.739%; $\overset{*}{Ar}{}^{40}$ = 0.0900 x 10^{-10} mole/gm, 0.0928 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 20.1%, 27.4%. (Plagioclase) K_2O = 1.32%; $\overset{*}{Ar}{}^{40}$ = 0.1602 x 10^{-10} mole/gm, 0.1701 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 10.2%, 16.9%. Comment: Same intrusive body as sample USGS(M)-856-8 (below).

7. USGS(M)-856-8 K-Ar (whole rock) 8.2±0.2 m.y.
(hornblende) 9.2±0.5 m.y.

Altered porphyritic hornblende dacite of Bodie Bluff (S-central Sec. 9, T4N, R27E; lowest level of the Rose-clip opencut Mine, S side of Standard Hill; Mono Co., CA). Gray porphyritic dacite with phenocrysts of plagioclase and hornblende in a fine-grained groundmass. Hornblende is sparse, rimmed with iron oxide and partially chloritized. Groundmass shows development of some chlorite and addition of K-feldspar. Analytical data: (Whole rock) K_2O = 5.13%; $\overset{*}{Ar}{}^{40}$ = 0.6262 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 42.0%. (Hornblende, 4% pyroxene) K_2O = 0.760%; $\overset{*}{Ar}{}^{40}$ = 0.1038 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 20.4%. Comment: Same intrusive as sample USGS(M)-B271 (above). The discordant age relations are due to the effect of alteration. The K content is approximately double that of unaltered rock of similar mineralogy, and is due to the addition of adularia to the groundmass. Oxygen isotopic analyses of the whole rock (sample USGS(M)-B271) and the plagioclase and hornblende of sample USGS(M)-856-8 (J. R. O'Neil, written commun., 1971) indicate equilibration with hydrothermal fluids depleted in O^{18}. The hornblende of sample B271 shows normal $O^{18/16}$ for unaltered volcanic rock. The temperature during alteration of sample 856-8 probably did not reach the level required for equilibration of hornblende with the light hydrothermal fluid. Its age is probably the closest to that of crystallization of the Bodie Bluff dacite; however, all ages for this plug should be considered suspect.

8. USGS(M)-BH17 K-Ar (hornblende) 9.2±0.5 m.y.

Porphyritic hornblende dacite of Queen Bee Hill (W-central Sec. 21, T4N, R27E; top of Queen Bee Hill; Mono Co., CA). Greenish-gray porphyritic dacite with plagioclase and hornblende phenocrysts in a fine-grained groundmass. Some hornblende is chloritized. Analytical data: (Hornblende, 4% pyroxene) K_2O = 0.822%; $\overset{*}{Ar}{}^{40}$ = 0.1123 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 22.5%.

C. Extrusive Rocks, Bodie Mining District

9. USGS(M)-7346-1 K-Ar (whole rock) 2.7±0.1 m.y.

Porphyritic hornblende-pyroxene andesite flow, "Wall Andesite" (SE/4 Sec. 10, T4N, R27E; 1300 ft SE of Gray's Mill, near Bodie Canyon road; Mono Co., CA). Dark-gray porphyritic dacite, with phenocrysts of plagioclase, hornblende, and pyroxene in a fine-grained groundmass. Analytical data: K_2O = 3.99%; $\overset{*}{Ar}{}^{40}$ = 0.1608 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 50.7%. Comment: This flow is part of the younger volcanic field erupted to the east of Bodie. It places an upper limit on the age of mineralization as it overlies altered Silver Hill dacite, but is itself unaffected by the alteration that accompanies mineralization.

10. USGS(M)-BH32 K-Ar (biotite) 8.8±0.2 m.y.

Porphyritic biotite-hornblende dacite from Silver Hill Volcanic Series.(center Sec. 21, T4N, R27E; 2500 ft NE of Sugarloaf; Mono Co., CA). Light-gray porphyritic dacite with plagioclase, biotite, and sparse hornblende phenocrysts in a very fine grained, felty groundmass. Hornblendes are mostly oxidized. Analytical data: K_2O = 8.48%; $\overset{*}{Ar}{}^{40}$ = 1.100 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 50.1%.

11. USGS(M)-856-32 K-Ar (biotite) 8.9±0.3 m.y.

Porphyritic biotite-hornblende dacite from Silver Hill Volcanic Series. (E-central Sec. 16, T4N, R27E; old quarry, just N of railroad grade; Mono Co., CA). Porphyritic light-reddish-gray dacite with phenocrysts of plagioclase, biotite, and hornblende in a fine-grained groundmass. Analytical data: K_2O = 8.87%; $\overset{*}{Ar}{}^{40}$ = 1.123 x 10^{-10} mole/gm, 1.204 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 30.1%, 76.1%. Comment: This sample and sample USGS(M)-BH32 (above) are from the upper flow unit or "dacite" of the Silver Hill Volcanic Series.

12. USGS(M)-856-10 K-Ar (biotite) 8.9±0.2 m.y.
(hornblende) 9.0±0.2 m.y.

Porphyritic biotite-hornblende rhyodacite plug from Silver Hill Volcanic Series tuff breccia (W-central Sec. 17, T4N, R27E; 1 mi SW of Bodie townsite; Mono Co., CA). Light-gray porphyritic rhyodacite, with phenocrysts of plagioclase, biotite, and hornblende in an aphanitic groundmass. Analytical data: (Biotite) K_2O = 8.19%; $\overset{*}{Ar}{}^{40}$ = 1.084 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 59.1%. (Hornblende, 4% biotite) K_2O = 1.03%; $\overset{*}{Ar}{}^{40}$ = 0.1371%; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 35.0%. Comment: The tuff breccia was so badly altered within the mining district that none was suitable for dating. This plug occupies one of the vents from which the tuff breccia was erupted and is similar in mineralogy to the tuff breccia.

13. USGS(M)-BH26 K-Ar (hornblende) 9.1±0.5 m.y.

Porphyritic hornblende dacite from Silver Hill Volcanic Series.(NW/4 Sec. 21, T4N, R27E; 2500 ft NNE of Sugarloaf; Mono Co., CA). Light-gray, porphyritic dacite with phenocrysts of plagioclase, hornblende, and minor biotite in a fine-grained groundmass. Analytical data: K_2O = 0.863%; $\overset{*}{Ar}{}^{40}$ = 0.1156 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 24.9%.

14. USGS(M)-BH16 K-Ar (biotite) 9.4±0.2 m.y.

Porphyritic biotite hornblende dacite flow, Silver Hill Volcanic Series, lower flow unit (SE/4 Sec. 16, T4N, R27E; 2000 ft E of Red Cloud shaft; Mono Co., CA). Light-gray porphyritic dacite with phenocrysts of plagioclase, biotite, and hornblende in a fine-grained groundmass. The hornblendes are largely oxidized. Analytical data: (Biotite, 2% adhering groundmass) K_2O = 7.78%; $\overset{*}{Ar}{}^{40}$ = 1.086 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 49.6%. Comment: This sample and sample USGS(M)-BH26 are from the lower flow unit or "andesite" of the Silver Hill Volcanic Series.

D. Volcanic Rocks from Bodie Hills (outside Bodie Mining District)

15. USGS(M)-854-1 K-Ar (biotite) 8.7±0.2 m.y.

Porphyritic biotite dacite flow, Murphy Spring tuff breccia (N-central Sec. 28, T4N, R27E; 3000 ft SE of Sugarloaf; Mono Co., CA). Light-gray porphyritic dacite with phenocrysts of plagioclase and biotite along with small hornblende crystals in a fine-grained groundmass. Analytical data: K_2O = 8.20%; $\overset{*}{Ar}{}^{40}$ = 1.060 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 54.3%.

16. USGS(M)-BH29 K-Ar (biotite) 8.7±0.2 m.y.

Porphyritic biotite-hornblende dacite intrusive, Murphy Spring Tuff Breccia (NE/4 Sec. 23, T4N, R27E; along old railroad grade, 3 mi E of Bodie; Mono Co., CA). Light-gray porphyritic dacite with phenocrysts of plagioclase, biotite, and hornblende in a fine-grained groundmass. Analytical data: K_2O = 8.40%; $\overset{*}{Ar}{}^{40}$ = 1.086 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 56.4%.

17. USGS(M)-BM2 K-Ar (biotite) 9.1±0.1 m.y.

Porphyritic biotite dacite flow of Potato Peak Formation (center Sec. 12, T4N, R26E; 2½ mi WNW of Bodie townsite; Mono Co., CA). Gray to reddish porphyritic dacite with plagioclase and biotite phenocrysts, along with minor hornblende in a fine-grained groundmass. Analytical data: (Biotite, 1% adhering matrix) K_2O = 7.97%; $\overset{*}{Ar}{}^{40}$ = 1.082 x 10^{-10} mole/gm, 1.076 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 57.3%, 57.5%. Comment: Samples USGS(M)-854-1, -BH29, and -BM2 are from volcanic rocks erupted from centers near the Bodie district. These rocks are chemically and petrographically similar to those of the Silver Hill Volcanic Series of the mining district.

E. Volcanic Rocks, Western Bodie Hills

18. USGS(M)-BH9 K-Ar (whole rock) 9.3±0.3 m.y.

Alkali olivine basalt of Mt. Biedeman Formation (NW/4 Sec. 4, T3N, R26E; 7 mi SW of Bodie townsite; Mono Co., CA). Dark gray to black porphyritic basalt with phenocrysts of plagioclase, pyroxene, olivine, and iron oxides in a fine- to medium-grained groundmass. Analytical data: K_2O = 2.60%; $\overset{*}{Ar}{}^{40}$ = 0.3571 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 64.3%.

19. USGS(M)-MTB1 K-Ar (hornblende) 9.5±0.2 m.y.

Hornblende-andesite of Mt. Biedeman Formation (SE/4 Sec. 2, T3N, R26E; 5½ mi SSW of Bodie townsite; Mono Co., CA). Gray porphyritic andesite with large phenocrysts of hornblende (up to 2 cm), and phenocrysts of plagioclase and pyroxene in a fine-grained groundmass. Analytical data: (Hornblende, 6% pyroxene) K_2O = 0.906%; $\overset{*}{Ar}{}^{40}$ = 0.1272 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 48.3%.

20. USGS(M)-BH27 K-Ar (biotite) 9.1±0.2 m.y.

Porphyritic rhyolite of Mt. Biedeman Formation (NE/4 Sec. 12, T3N, R26E; 5½ mi SSW of Bodie townsite; Mono Co., CA). Porphyritic light-gray rhyolite with phenocrysts of biotite, quartz, plagioclase and sanidine in a glassy groundmass. Analytical data: (Biotite, 1% groundmass) K_2O = 8.14%; $\overset{*}{Ar}{}^{40}$ = 1.098 x 10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 43.0%.

21. USGS(M)-BH19A K-Ar (biotite) 8.0±0.2 m.y.

Porphyritic hornblende-biotite dacite flow of Willow Springs Formation (W-central Sec. 12, T4N, R25E; 9 mi W of Bodie townsite; Mono Co., CA). Porphyritic gray dacite with large phenocrysts of plagioclase (up to 8 mm), hornblende, biotite, pyroxene, and quartz in a fine-grained to glassy groundmass. Analytical data: K_2O = 8.13%; $\overset{*}{Ar}{}^{40} = 0.9647 \times 10^{-10}$ mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 47.1%.

22. USGS(M)-BH6 K-Ar (biotite) 5.7±0.2 m.y.

Porphyritic rhyolite intrusive, Mt. Biedeman Formation (NW/4 Sec. 31, T4N, R26E; at junction of Clearwater Road with Cinnabar Canyon, 8 mi WSW of Bodie townsite; Mono Co., CA). Light-gray porphyritic rhyolite with phenocrysts of quartz, biotite, plagioclase and minor sanidine in a glassy, partly devitrified groundmass. Analytical data: K_2O = 8.24%; $\overset{*}{Ar}{}^{40} = 0.6999 \times 10^{-10}$ mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 23.9%. Comment: Originally mapped as part of Mt. Biedeman Formation due to lithologic similarity to rhyolites included with that formation. This plug is one of two intruding tuff breccias of the Willow Springs Formation and pre-Tertiary rocks (Chesterman, 1968). It is part of a series of younger intrusive rhyolites emplaced after the main volcanism of the Bodie Hills.

23. USGS(M)-BH20 K-Ar (biotite) 5.2±0.3 m.y.
(hornblende) 5.4±0.6 m.y.

Porphyritic biotite-hornblende rhyodacite intrusive, Willow Springs Formation (center Sec. 7, T4N, R26E; 300 ft NW of top of 7599′ hill, 7½ mi W of Bodie townsite; Mono Co., CA). Light- to medium-gray porphyritic rock with phenocrysts of biotite, quartz, plagioclase, and hornblende in a glassy, partly devitrified groundmass. Analytical data: (Biotite, 1% hornblende) K_2O = 7.08%; $\overset{*}{Ar}{}^{40} = 0.5451 \times 10^{-10}$ mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 17.2%. (Hornblende, 1% biotite) K_2O = 0.831%; $\overset{*}{Ar}{}^{40} = 0.0665 \times 10^{-10}$ mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 8.9%. Comment: This plug is one of several that intrude the walls and central portion of a volcanic collapse structure termed the Big Alkali Caldera by Chesterman (1968). The walls of the caldera are underlain by dacite flows and are intruded by rhyodacite to rhyolite plugs and irregular dikes along the boundary fault. Tuff breccias and lava flows of the Willow Springs Formation (see no. USGS(M)-BH19A) of approximately 8 m.y. were erupted from this feature. The magma continued to differentiate and to erupt the rhyodacite to rhyolite intrusives in the caldera rim zone and center. USGS(M)-BH6 and -BH20 represent the youngest volcanic rocks of the Bodie Hills field and postdate the mineralization at Bodie by at least 1 m.y. (Chesterman, 1968, p. 63-65).

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