New K-Ar ages of volcanic and plutonic rocks and ore deposits in western Nevada

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NEW K-AR AGES OF VOLCANIC AND PLUTONIC ROCKS AND ORE DEPOSITS IN WESTERN NEVADA

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The ages reported here are a product of the program of dating hydrothermal mineral deposits and volcanic and plutonic rocks in Nevada being done jointly by the U. S. Geological Survey and the Nevada Bureau of Mines and Geology. This paper presents new K-Ar ages of some plutonic and volcanic rocks and mineral deposits in the Gilbert, Candelaria, Klondike, Rawhide (Regent), and Silver Star mining districts; ages from two hydrothermally altered copper-molybdenum-bearing stocks in the Hall and Rock Hill mining districts; three ages from the Lone Mountain pluton; and the age of basalt in the Garfield Hills (Fig. 1). Brief geologic descriptions of the mining districts and ore deposits are given. Some of the mineralization ages were previously given in tabular form in Silberman and McKee (1974) and O'Neil and Silberman (1974).

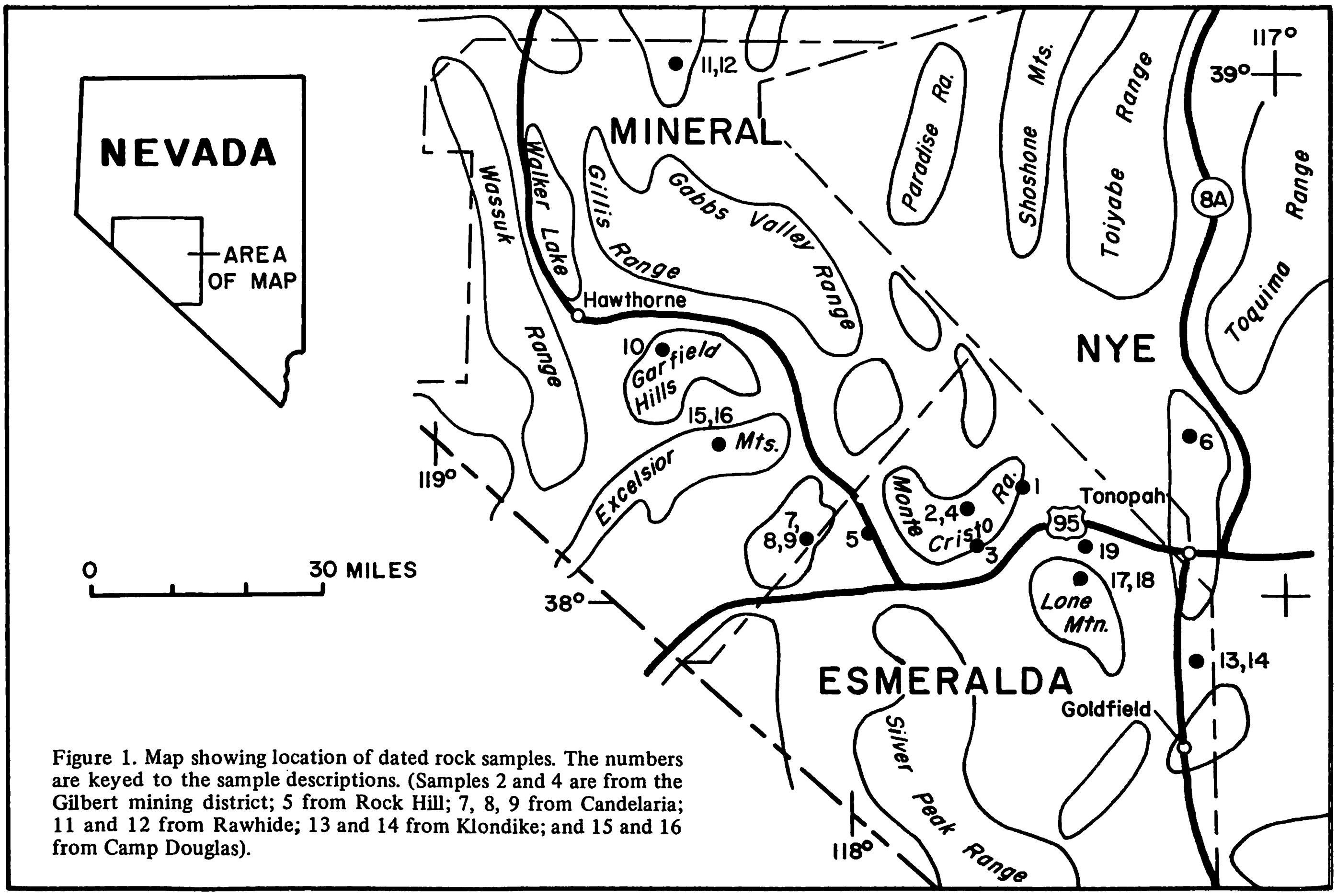

Figure 1. Map showing location of dated rock samples. The numbers are keyed to the sample descriptions. (Samples 2 and 4 are from the Gilbert mining district; 5 from Rock Hill; 7, 8, 9 from Candelaria; 11 and 12 from Rawhide; 13 and 14 from Klondike; and 15 and 16 from Camp Douglas).

Analytical procedure and equipment are the same as those described in Silberman and McKee (1971). Plus-and-minus figures after the ages represent estimated analytical uncertainty in the age determination at the one Sigma level. Constants used for K-Ar age calculations are: $\lambda_\epsilon = 0.585 \times 10^{-10}$ yr^{-1}, $\lambda_\beta = 4.72 \times 10^{-10}$ yr^{-1}, $K^{40}/K_{total} = 1.22 \times 10^{-4}$ gm/gm.

GEOLOGIC DESCRIPTIONS

Gilbert Mining District

The Gilbert mining district is in the central part of the Monte Cristo Mountains, 30 miles west of Tonopah (Fig. 1). Production from the district amounted to $105,000 (Albers and Stewart, 1972). The following description of the geology of the Monte Cristo Mountains and ore deposits is modified from Albers and Stewart (1972). The oldest rocks in the Monte Cristo Mountains consist principally of shale, siltstone, and some limestone of the Palmetto Formation of Ordovician age. These rocks are intruded by granitic rocks of Triassic and Jurassic age. Most of the Monte Cristo Mountains are underlain by volcanic and sedimentary rocks of Tertiary age. Rhyolitic welded ash-flow tuffs and breccias, the oldest Tertiary rocks, are overlain by shale, siltstone, sandstone, and limestone. Rhyolite flows, plugs, and domes overlie and intrude the sedimentary rocks in the central and eastern parts of the Monte Cristo Mountains. Andesitic rocks, termed the Gilbert Andesite by Ferguson and others (1953), cover most of the higher parts of the Monte Cristo Mountains. The youngest volcanic rocks in the Monte Cristo Mountains are thin flows of olivine basalt that crop out north of the mining district.

The welded ash-flow tuffs are altered but presumably belong to the group of rhyolitic to quartz latitic ash-flow tuffs of Miocene age common in western Nevada (Silberman and McKee, 1971). Two K-Ar ages of 15.1 m.y. on the Gilbert Andesite (this paper, sample 3; Albers and Stewart, 1972) establish it as at least partly middle Miocene in age (time scale of Berggren, 1972). The rhyolite plugs, domes and flows are very fine grained or glassy, and it was not possible to obtain mineral separates from them. An age of 7 m.y. (sample 2) was obtained from nonhydrated obsidian from a rhyolite plug. This age should probably be considered a minimum, without additional confirmation. Both the rhyolitic rocks and the Gilbert Andesite crop out over wide areas and probably were erupted over a considerable time span.

The ore deposits at Gilbert are of two types and are probably related to two separate events. The first and probably oldest deposit consists of quartz veins, containing silver-lead ores with molybdenite that cut limestone of the Palmetto Formation close to a small quartz-monzonite intrusion. The second consists of gold-bearing quartz veins, both in volcanic rocks of Tertiary age and shale and siltstone of the Palmetto Formation near masses of intrusive rhyolite. An age of 7.9 m.y. (sample 2) was obtained from hydrothermal potassium feldspar from one of these gold-bearing veins. The mineralization at Gilbert appears to be related to the rhyolite complex even though the single obsidian age on the sample of rhyolite dated was slightly younger than the reported age of mineralization.

An age of 194 m.y. (sample 4) was obtained from sericite separated from altered quartz monzonite porphyry in the western part of the district. This age is close to the Triassic age of 202 m.y. of biotite from quartz monzonite at Crow Spring to the northeast of Gilbert (Speed and Armstrong, 1971). Both quartz monzonite samples were collected several miles from the location of the silver- and lead-bearing quartz veins, and the relation of the quartz monzonite to the older mineralization is uncertain. No material suitable for dating was found in these older veins.

Redlich

At Redlich, just west of Highway 95 near Rock Hill (Fig. 1), a small quartz monzonite mass veined by quartz intrudes sedimentary rocks of the Palmetto Formation. Molybdenite, pyrite, chalcopyrite, and fluorite are visible in some specimens at the outcrop. Muscovite, separated from a sample of the quartz monzonite, gave a 78-m.y. age (sample 5). The Late Cretaceous age of the molybdenum-bearing stock is the same as that of the Hall property to the east.

Hall Property

At the Hall property in the northwestern San Antonio Mountains (Fig. 1), a small (outcrop area approximately one-half mi^2) alaskite-quartz monzonite stock intrudes mica-schist, sericitic quartzite, and silicified limestone. These strata are either Paleozoic or Mesozoic (Davis and others, 1971). They may be related to sedimentary and metasedimentary rocks of Mississippian to Permian(?) age that make up part of the same inlier of pre-Tertiary rocks in the vicinity of Florence Canyon in which the Hall property is located. Overlying the pre-Tertiary metasedimentary rocks are felsic volcanic rocks, principally rhyolite tuffs, domes, and flows. Porphyritic dacite, partly intrusive as well as extrusive, lies on and is faulted against the pre-Tertiary rocks, as well as against the felsic volcanic rocks, and underlies most of the northwestern San Antonio Mountains (Davis and others, 1971). Concordant age determinations of 16.7±0.5 and 16.8±0.5 m.y. were previously reported from biotite and hornblende, respectively, from porphyritic dacite, northeast of the Hall property (Silberman and McKee, 1972).

At the Hall property, a large tonnage of low-grade molybdenite ore occurs near the surface, both in the stock and in the adjacent metamorphosed clastic strata (Kirkemo and others, 1965).

Biotite, from sulfide-bearing quartz monzonite collected from the dump of the shaft at the Hall property, yielded a K-Ar age of 77.4±2.3 m.y. (sample 6).

Candelaria Mining District

The Candelaria mining district, which produced $15 to $20 million worth of silver (Page, 1959), is in the Candelaria Hills (Fig. 1). The geology of the district is summarized from Page (1959). Chert and dolomite of the Palmetto Formation of Ordovician age are the oldest rocks in the district. These are overlain by the Diablo Formation of Permian age. The youngest pre-Tertiary rocks are shale of the Candelaria Formation of Early Triassic age, which contain most of the mineral deposits (Page, 1959). The Ordovician to Triassic sedimentary rocks are cut by serpentine, which crops out as a large mass in Pickhandle Gulch and as smaller lenses elsewhere. The serpentine is part of a complex of metamorphosed sedimentary and mafic to ultramafic igneous rocks that crops out in Pickhandle Gulch (Page, 1959).

Dikes of felsite, quartz monzonite porphyry, and quartz diorite porphyry, all partly altered hydrothermally, cut the older sedimentary and metamorphosed sedimentary and igneous rocks. In general, they are alined east-west and may reflect an elongate intrusion at depth that arched the older rocks. Dikes were injected into fissures in the arched wallrocks. A positive aeromagnetic anomaly of approximately 100 gammas magnitude corresponds roughly to the east-west trend of the dikes (U. S. Geol. Survey, 1971).

Overlying the pre-Tertiary sedimentary and altered igneous rocks is a Tertiary volcanic section as much as 2,000 feet thick, composed largely of rhyolite to dacite ash-flow tuffs, a few silicic lava flows and breccias, interbedded sedimentary rocks, and several basalt flows. This section of volcanic rocks is overlain unconformably by flat-lying Pliocene olivine basalt (time scale of Berggren, 1972).

Two major pre-Tertiary orogenies affected the sedimentary rocks. One was post-Ordovician and pre-Permian in age because it occurred prior to the deposition of the Diablo Formation. The second was Jurassic(?) in age, affecting the Diablo and Candelaria Formations. Mineralization occurred after most of the folding and faulting of the second orogeny. The crosscutting silicic dikes were formed before mineralization occurred as they are displaced by steep reverse faults and minor thrusts that localize most of the ore deposits (Page, 1959). All of the pre-Tertiary rocks, including the silicic dikes, are hydrothermally altered. The Tertiary volcanic rocks are considered to be postmineralization in age as they are unaltered and are not displaced by either the reverse or minor thrust faults. Steep normal faults of late Cenozoic age offset the youngest Tertiary basalts and alluvium (Page, 1959).

Ore, consisting of argentiferous jamesonite, galena, pyrite, arsenopyrite, sphalerite, and minor chalcopyrite, is largely oxidized near the surface and locally to depths of as much as 700 feet. The veins that contain the ore minerals are in faults, and are composed of brecciated wallrock cemented with iron and manganese oxides and small to moderate amounts of quartz. Other gangue minerals include dolomite and very minor rhodochrosite. Silver was the predominant metal mined, but the ore also contained commercial amounts of gold, lead, antimony, copper, and zinc. Veins occur principally in north-dipping, steep cross faults and steep, bedding plane faults and are best developed in the lower part of the Candelaria Formation.

Alteration consists of dolomitization and silicification of the sedimentary and meta-igneous rocks and strong quartz-sericite alteration of the felsic igneous dike rocks.

An age of 126 m.y. (sample 7) was obtained from muscovite, separated from hydrothermally altered quartz monzonite porphyry that was collected southeast of the Mount Diablo mine. The porphyry consists of quartz, sericite, K-feldspar, and some disseminated sulfides that apparently contain a small amount of silver (partial analyses reported under sample description). Alteration is probably related to the silver mineralization. The age of mineralization appears to be post-Jurassic and pre-Tertiary as suggested by the geological relations. Further study, including evaluation of stable isotope analyses, is required to relate the fluids active in ore deposition in the veins and in the alteration of the nearby igneous rocks. An age of 23 m.y. (sample 8) was obtained on sanidine separated from a rhyolite tuff (unit 6 of Page, 1959), which is fairly low in the Tertiary volcanic sequence.

A whole-rock K-Ar age of approximately 4 m.y. (sample 9) was obtained from the young basalt sampled from outcrops west of Pickhandle Gulch. The basalt has been cut by normal faults. Its age indicates that at least 300 feet of vertical offset has occurred on the Candelaria fault since Miocene or Pliocene time (time scale of Berggren, 1972).

Rawhide (Regent) Mining District

Very little published geologic information is available for the Rawhide (Regent) district. The following description of the geology of the district is modified from Schrader (1947). Rawhide, which produced approximately $1.5 million worth of gold and silver (Schrader, 1947) is located on the northwest rim of Gabbs Valley in an unnamed group of mountains whose highest point is Rawhide Peak. The district is underlain by a complex assemblage of volcanic rocks of Tertiary age that is probably more than 1,000 feet thick. The volcanic rocks are of local origin and occupy a basin or structural depression in older pre-Tertiary rocks; the volcanic rocks include dacite, rhyolite, andesite, and basalt as flows, tuffs, and small plugs. The andesite and basalt and some of the rhyolite are younger than the principal ore-bearing rocks. None of the Tertiary rocks, with the exception of a rhyolite dike approximately midway in the volcanic section, has been dated.

Most of the principal ore deposits occur in a flow rhyolite underlying Balloon Hill and vicinity; some other Tertiary volcanic units also are mineralized. Ore deposits occur as replacement veins and irregular bodies along zones of sheeting and faulting. The oxidized zone extends to a depth of about 500 feet. Widespread areas of hydrothermal alteration occur in the wallrocks (Schrader, 1947). Some altered areas are found in association with large porphyry dikes, as at the Black Eagle Mine.

Schrader (1947) lists 42 ore and alteration minerals from the deposits in the district. The chief ore minerals in the oxidized zone are cerargyrite, pyrite, native gold, silver, and electrum. In the sulfide zone ore minerals consist of argentite, proustite, pyrite, native gold, and electrum. Hydrothermal alteration of the wallrocks resulted in the formation of adularia, alunite, jarosite, kaolinite, pyrite, pyrrhotite, quartz, and calcite.

Two samples were collected for age determination from widely separated areas in the district. The first, sample 11, was obtained from the dump of an adit of the Black Eagle Mine at the head of Black Eagle Gulch (Fig. 1). Ore at the mine occurs in a persistent vein that strikes N. 25° W., dips steeply, and is made up largely of quartz and brecciated, crushed, altered, and mineralized rhyolite. The footwall of the vein is a rhyolite dike intruded into the rhyolite and, according to Schrader, may be genetically related to the ore deposits. This dike, traced up the hill south of Black Eagle Gulch, has glassy selvages. Biotite and sanidine, separated from a sample of the rhyolite, yielded ages of 14.6 and 14.7 m.y., respectively. Adularia is reported as a constituent of the vein (Schrader, 1947), but material suitable for age determination was not found at the Black Eagle Mine during this initial reconnaissance. Chemical analyses and petrography of sample 11 indicates no alteration or mineralization of the dike sample.

The second sample, sample 12, was from the portal of the Yellowstone tunnel at the east end of Hooligan Hill. The hill consists of rhyolite which intrudes a dacite. Schrader (1947) considers this rhyolite to be older than the rhyolite at the Black Eagle Mine. Ore is best developed at Hooligan Hill as small but rich veins in the rhyolite along fractures, faults, and joint plane intersections. The sampled rhyolite has been altered to an assemblage of quartz, sericite, and K-feldspar. An age of 15.5 m.y. was obtained from hydrothermal muscovite separated from this altered rhyolite.

On the basis of the limited isotopic dating done at Rawhide, it appears that mineralization occurred within the interval 14.5 to 15.5 m.y. ago. Since only two samples from this very complex district were collected for age determination, it is by no means certain that the true range in age of mineralization has been determined. Further work should yield conclusive results as the district contains three datable alteration or vein minerals – alunite, sericite, and adularia (Schrader, 1947). Detailed isotopic studies, including both stable isotopes and additional K-Ar dating, should yield more complete definition of the period of time and extent of the hydrothermal alteration and mineralization.

Klondike Mining District

The Klondike mining district is located about 10 miles south of Tonopah (Fig. 1). Most of the ore deposits occur in limestone of the Emigrant Formation of Middle and Late Cambrian age, which is intruded by dikes and irregular bodies of rhyolite. A small muscovite granite mass occurs as an intrusive body along a zone of thrust faulting. According to Ball (1906), ore deposits consist of three sets of veins: (1) quartz veins, predominantly silver-bearing, parallel to bedding in the limestone; (2) quartz veins, predominantly gold-bearing, along contacts of the sedimentary rocks and rhyolite dikes; (3) quartz veins carrying argentiferous galena and cerussite in granite, along joint fractures parallel to bedding of surrounding rocks. The recorded production of the district was about $67,000 (Albers and Stewart, 1972).

Two samples were collected for dating. A sample of muscovite from the muscovite granite, believed to be related to the silver-lead veins (type 3, above), yielded an age of 104 ± 2 m.y. (sample 14). A sample of sanidine from crystal-poor rhyolite, possibly related to the gold mineralization described by Ball (1906), yielded an age of 10.5 ± 0.3 m.y. (sample 13). The rhyolite is distinctly younger than the Oddie Rhyolite at Tonopah to the north (H. F. Bonham, L. J. Garside, and M. L. Silberman, unpub. data) and is approximately the same age as rhyolite of Cactus Peak, which crops out to the south of Klondike in the northern part of the Goldfield Hills (Ashley and Silberman, 1975).

Garfield Hills

Thin flows of olivine basalt in the northwestern part of the Garfield Hills overlie Triassic and Jurassic sedimentary rocks, Cretaceous(?) granitic rocks, and Tertiary intermediate volcanic rocks. The olivine basalt is intruded by a small crystal-poor flow-banded rhyolite plug at the Carol R. Mine, a uranium prospect north of La Panta (Garside, 1973). The uranium mineralization occurs as carnotite in pebbly sand, cobble conglomerate, and basaltic tuffs beneath the olivine basalt, as well as in altered olivine basalt at the contact between the basalt and rhyolite. The age of mineralization, which appears to be related to the rhyolite, is fixed as younger than the 8.5-m.y. age (sample 10) of the basalt. A larger mass of rhyolite to the west, which appears to be petrographically similar to that at the Carol R. Mine, intrudes the dated olivine basalt and older Mesozoic sedimentary rocks.

Camp Douglas

Camp Douglas (in the Silver Star district) is in the eastern part of the Excelsior Mountains. The district is underlain by Permian and Mesozoic sedimentary and volcanic rocks that have been referred to the Excelsior and Dunlap Formations by Ferguson, Muller, and Cathcart (1953).

Gold and silver occur in quartz veins that cut the Excelsior and Dunlap Formations. Gold-bearing veins also occur in altered Tertiary intermediate volcanic rocks in the eastern part of the district.

K-Ar ages of 15.3 and 15.7 m.y. (sample 15) have been obtained from biotite and plagioclase, respectively, separated from hornblende-biotite andesite collected east of the district. The sample locality is near the base of a series of distinctive porphyritic andesite flows. These flows overlie a complex sequence of finely crystalline hornblende andesites (L. J. Garside, unpub. data). An age of 15.0 m.y. (sample 16) was obtained from adularia separated from a vein cutting silicified conglomerate of the Dunlap Formation. The age relations indicate that mineralization at Camp Douglas is probably related to the Miocene intermediate volcanic activity in the vicinity.

Lone Mountain

Lone Mountain consists of a mass of granite, cropping out over 28 mi^2, intruded into Precambrian and Cambrian sedimentary rocks (Albers and Stewart, 1972). At least two other petrographic types of granitic plutonic rocks are present on the northeast flank of Lone Mountain, as well as dikes and an irregular mass of altered felsic porphyritic intrusive rock. Roof pendants of Cambrian sedimentary rocks and masses of an older gabbro occur in these granitic rocks. Thin diabase dikes cut the main pluton and sedimentary rocks near their mutual contact.

Two K-Ar ages were obtained from separate samples taken close together in the main mass of the pluton (Fig. 1). Biotite from coarse-grained biotite granite yielded an age of 69.2 m.y. (sample 18A), and muscovite from a late-stage pegmatite segregation in the biotite granite yielded an age of 71.1 m.y. (sample 18). The ages overlap within analytical uncertainty. Edwards and McLaughlin (1972) report a 63 ± 7-m.y. age on biotite from this pluton. No samples of the felsic porphyritic rocks suitable for K-Ar dating were found, and the other granitic units were not dated. Hornblende separated from a gabbro mass yielded an age of 113 m.y. (sample 17).

Albers and Stewart (1972) report three K-Ar ages from the Lone Mountain pluton, 367 ± 18 m.y. on hornblende from one of a series of hornblende-bearing dikes cutting the pluton, and 67 ± 3 and 20 ± 1 m.y., respectively, from biotite separated from different samples of the pluton. Their sample localities were not specified. The 67-m.y. age agrees within analytical uncertainty with those reported here. Concordance between the biotite and muscovite ages (this report) suggests they they have recorded reasonably accurately the crystallization age of the main granitic part of the pluton. It is not possible to evaluate the other ages reported previously without accurate information or sample locations. Further work is necessary to define adequately the age of all phases of the igneous rocks in the pluton.

An age of 14.7 m.y. (sample 19) was obtained from sanidine separated from altered, flow-banded rhyolite that intrudes the Cambrian sedimentary rocks, as well as Mesozoic(?) granitic rocks and rhyolite ash-flow tuffs at the northernmost outcrops of Lone Mountain.

SAMPLE DESCRIPTIONS

1. Black Balls — K-Ar — (obsidian) 7.0±0.2 m.y.
Obsidian (sec. 5, unsurveyed, T4N, R39E; 38°13′53″N, 117°36′21″W, Esmeralda Co., NV). Black obsidian occurring as glassy round cores in perlite. The perlite formed as balls 1 to 3 inches (3 to 10 cm) in diameter and probably resulted from emplacement of a rhyolite plug in wet lake sediments. Analytical data: K_2O = 4.52%, $*Ar^{40} = 0.4672 \times 10^{-10}$ moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 36.8%. Collected by: M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey.

2. GLA-1 — K-Ar — (adularia, sanidine) 7.9±0.2 m.y.
Quartz-adularia vein (approx. center, T4N, R38E; 38°11′08″N, 117°42′12″W, Esmeralda Co., NV), breccia vein consisting of dark-gray fragments of siltstone in a white matrix of medium- to fine-grained quartz and fine-grained adularia and chalcedony. Analytical data: K_2O = 12.09%, $*Ar^{40} = 1.405 \times 10^{-10}$ mole/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 69.3%. Collected by: M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey. Comments: The sample contained 0.015 ppm Au and 1.9 ppm Ag. X-ray diffraction analysis according to the three-reflection method of Wright (1968) indicated a sanidine structure for the feldspar.

3. GL-2 — K-Ar — (biotite) 15.1±0.5 m.y.; (plagioclase) 13.6±0.4 m.y.
Porphyritic biotite-pyroxene andesite (sec. 9, T3N, R38E; 37°07′58″N, 117°42′29″W, Esmeralda Co., NV). Phenocrysts of plagioclase, biotite, and pyroxene in a fine-grained groundmass of feldspar, iron oxides, and glass. Analytical data: (Biotite) K_2O = 8.39%, $*Ar^{40} = 1.884 \times 10^{-10}$ moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 66.4%. (Plagioclase) K_2O = 0.81%, $*Ar^{40} = 0.1639 \times 10^{-10}$ mole/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 62.8%. Collected by: M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey. Comment: The plagioclase and biotite ages are discordant. The plagioclase has thin coatings of iron oxide on fractures and partings, giving them a reddish appearance in hand specimen. They also contain some glass inclusions. Plagioclases with glass inclusions frequently give ages discordant with coexisting minerals (M. L. Silberman, unpub. data). The biotite age agrees with an age of biotite from another sample of Gilbert Andesite reported by Albers and Stewart (1972).

4. GL-15 — K-Ar — (sericite) 194±4 m.y.
Altered quartz monzonite porphyry (sec. 28, T4N, R38E; 38°10′39″N, 117°42′26″W, Esmeralda Co., NV). Quartz-sericite alteration of porphyritic rock with quartz and feldspar phenocrysts. Biotite and feldspars are altered to muscovite. Stringers and veins of quartz are present. The rock consists of quartz, sericite, and minor limonite after pyrite. Analytical data: K_2O = 6.75%, $*Ar^{40} = 2.037 \times 10^{-9}$ moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 98.0%. Collected by: M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey. Comment: This age is only slightly younger than that of unaltered biotite from a granodiorite pluton, 10 miles northeast of Gilbert, near Crow Springs (Speed and Armstrong, 1971).

5. Redlich — K-Ar — (muscovite) 78.3±2.3 m.y.
Altered quartz monzonite (sec. 34, T4N, R36E; 38°09.8′N, 117°57.4′W, Esmeralda Co., NV). Partially oxidized rock consisting of intergrowths of cloudy perthite, quartz, muscovite, which appears to be primary, and minor biotite and molybdenite. Analytical data: K_2O = 10.94%. $*Ar^{40} = 1.292 \times 10^{-9}$ moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 85.4%. Collected by: D. Osborne, Minerals Exploration Company, and M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey. Comment: Thin quartz stringers are present in the sample, which contains 700 ppm Mo and 40 ppm Cu.

6. Hall-B K-Ar (biotite) 77.4±2.3 m.y.
Porphyritic quartz monzonite (east central sec. 6, T5N, R42E; 38°19.1′N, 117°17.7′W, dump of shaft at the Hall Mine, Nye County, NV). Phenocrysts of cloudy, partially sericitized K-feldspar and plagioclase in a granitic textured groundmass of feldspar and quartz. Sparse primary biotite phenocrysts are partially chloritized and have minor sericite lamellae. Pyrite is disseminated and also occurs in discontinuous streaks. Analytical data: K_2O = 6.95%, $*Ar^{40}$ = 8.103 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 94.7%. Collected by: H. F. Bonham, Jr., Nevada Bureau of Mines and Geology, and M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey. Comment: The biotite is primary, and has been affected by some recrystallization due to hydrothermal alteration. In general, studies have shown that alteration takes place shortly after time of crystallization in mineralized stocks (Theodore and others, 1973), and the age is considered to be both age of emplacement (crystallization) and mineralization.

7. CAN-1 K-Ar (muscovite) 126±4 m.y.
Altered quartz monzonite porphyry (north-central, T3N, R35E; 38°08.8′N, 118°04.8′W, approx. 500 ft SE of Mount Diablo Mine, Mineral Co., NV). The rock was a medium-grained porphyry with phenocrysts of feldspar and mica. The feldspars and groundmass have been thoroughly recrystallized to quartz, sericite, and K-feldspar. Groundmass sericite is very fine grained. The micas have recrystallized to a felty mass of coarser grained muscovite. Minor disseminated sulfides are present. Analytical data: K_2O = 9.28%, $*Ar^{40}$ = 1.782 x 10^{-9} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 96%. Collected by: M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey. Comment: Chemical and petrographic analysis shows strong K-silicate alteration, with some probable enrichment of potassium (based on assuming original quartz monzonite composition) and is strongly anomalous in Ba. Trace analysis shows 7.4 ppm Ag, and the following amounts of other elements: K = 4.6%, Rb, 171 ppm, Sr, 86 ppm, Cu, 37 ppm, Au, 2.8 ppb, Ba = 15,000 ppm. Whole-rock X-ray analysis indicates quartz-sericite-K-feldspar composition.

8. CAN-3 K-Ar (sanidine) 22.8±0.7 m.y.
Porphyritic rhyolite (north-central sec. 3, unsurveyed, T3N, R35E; 38°09.0′N, 118°04.3′W, approx. 800 ft NW of Mount Diablo Mine, top of small white hill, Mineral Co., NV). The rock consists of broken phenocrysts of sanidine, quartz, minor plagioclase, and sparse oxidized biotite in a microcrystalline groundmass of divitrified glass. Eutaxitic structure is absent, but ghostlike relicts of glass shards are present. The rock is probably an ash flow. Analytical data: K_2O = 11.18%, $*Ar^{40}$ = 3.788 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 98%. Collected by: M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey. Comment: TV-6 unit of Page (1959).

9. CAN-2 K-Ar (whole rock) 3.9±0.4 m.y.
Porphyritic olivine basalt (SE¼ sec. 33, unsurveyed, T4N, R35E; 38°09.25′N, 118°05.0′W, above Pickhandle Gulch, E end of Candelaria Mountain, Mineral Co., NV). Phenocrysts of olivine in a groundmass of plagioclase, with interstitial olivine, pyroxene, iron oxides, and a very small amount of brownish glass. The glass has largely crystallized to very fine grained feldspars. Analytical data: K_2O = 2.12%, $*Ar^{40}$ = 0.1251 x 10^{-10}, 0.1211 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 15.0, 19.6%. Collected by: M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey. Comment: The presence of a small amount of interstitial glass suggests the age should be considered a minimum.

10. 2701-2 K-Ar (whole rock) 8.5±0.3 m.y.
Porphyritic olivine basalt (NE¼ sec. 36, T8N, R31E; 38°30.9′N, 118°28.0′W, Mineral Co., NV). Phenocrysts of olivine, largely unaltered except on fractures in a completely crystalline groundmass of plagioclase laths, with smaller interstitial olivine, pyroxene and iron oxides. Analytical data: K_2O = 1.69%. $*Ar^{40}$ = 0.2135 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 50.6%. Collected by: M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey.

11. R-11 K-Ar (biotite) 14.6±0.4 m.y.
(sanidine) 14.7±0.4 m.y.
Porphyritic rhyolite (north-central, T13N, R31½E, 39°01.0′N, 118°25.9′W; dump of portal, Black Eagle Mine, Mineral Co., NV). (See Schrader, 1947, fig. 52.) Phenocrysts of rounded and embayed quartz, plagioclase and sanidine with smaller biotite flakes in a very fine grained groundmass of feldspars and devitrified glass. The rock is unaltered. Analytical data: biotite, K_2O = 8.09%, $*Ar^{40}$ = 1.750 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 68.7%. Sanidine, K_2O = 8.93%, $*Ar^{40}$ = 1.943 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 90.2%.

Collected by: M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey. Comment: The sample is from dike which follows and forms the footwall of the vein at the Black Eagle Mine. Hydrothermal alteration affects the dike, but this sample is unaltered. The vein was from 2 to 20 ft in width and consisted chiefly of quartz and crushed, brecciated, altered rhyolite and other rock.

12. R-7 K-Ar (muscovite) 15.5±0.5 m.y.
Altered rhyolite (sec. 5, T13N, R32E; 39°01.0'N, 118°23.6'W; portal of adit, Yellowstone tunnel, E end of Hooligan Hill within Rawhide townsite, Mineral Co., NV – location approximate). The rock consists of altered porphyritic rhyolite, recrystallized to an assemblage of sericite, quartz, K-feldspar and limonite (after pyrite). K-feldspar occurs largely in groundmass with quartz and fine-grained mica. Feldspar phenocrysts are now largely sericite and quartz. Original mica flakes, probably biotite, now consist of muscovite lamellea, with iron oxides – coarser than the groundmass K-mica. Analytical data: K_2O = 6.07%, $*Ar^{40}$ = 1.398 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 70.0%. Collected by: M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey.

13. K-1 K-Ar (sanidine) 10.5±0.3 m.y.
Porphyritic rhyolite (NW¼NW¼ sec. 31, T1N, R43E; 37°54.1'N, 117°12.2'W, Esmeralda Co., NV). Crystal-poor columnar-jointed rhyolite with sparse phenocrysts of quartz and sanidine with rare iron oxides in a fine-grained groundmass of feldspars and quartz. Analytical data: K_2O = 11.66%, $*Ar^{40}$ = 1.818 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 79.3%. Collected by: H. F. Bonham, Nevada Bureau of Mines and Geology, and M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey.

14. Mg-1 K-Ar (muscovite) 104±2 m.y.
Muscovite granite (SW¼NW¼NE¼ sec. 25, T1N, R42E, 37°54.92'N, 117°12.93'W, Esmeralda Co., NV). Medium- to coarse-grained intergrowth of quartz, K-feldspar, and muscovite. Muscovite is primary, apparently not an alteration product. Analytical data: K_2O = 10.26%, $*Ar^{40}$ = 16.25 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 88.0%. Collected by: H. F. Bonham, Nevada Bureau of Mines and Geology, and M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey.

15. CD-31 K-Ar (biotite) 15.3±0.5 m.y.
(plagioclase) 15.7±0.7 m.y.
Porphyritic hornblende-biotite andesite (NW¼NE¼SW¼NW¼ sec. 26, T6N, R34E; 38°21.07'N, 118°10.05'W, Mineral Co., NV). Phenocrysts of plagioclase, hornblende and biotite in a fine-grained, reddish-brown groundmass. Analytical data: biotite, K_2O = 9.10%, $*Ar^{40}$ = 2.068 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 46.9%. Plagioclase, K_2O = 1.17%, $*Ar^{40}$ = 0.2727 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 33.7%. Collected by: L. J. Garside, Nevada Bureau of Mines and Geology. Dated by: M. L. Silberman, U. S. Geological Survey. Comment: Rocks probably correlative with this unit are altered and mineralized about 1 mile to the southwest of the collection locality. Presumably the mineralization is related to that dated at 15.0 m.y. (see sample 16).

16. CD-8 K-Ar adularia (orthoclase structure) 15.0±0.5 m.y.
Adularia (center, NW¼NE¼NW¼ sec. 33, T6N, R34E; 38°20.45'N, 118°12.03'W, Mineral Co., NV). Medium-grained quartz intergrown with fine-grained adularia both in part replacing lamellar calcite. Fractures and vugs which are common are coated with limonite and Mn oxides. Analytical data: K_2O = 9.80%, $*Ar^{40}$ = 2.187 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 70.8%. Collected by: L. J. Garside, Nevada Bureau of Mines and Geology. Dated by: M. L. Silberman, U. S. Geological Survey. Comment: X-ray diffraction analysis according to the three reflection method of Wright (1968) indicated an orthoclase structure for the feldspar. The date probably indicates the age of gold-silver mineralization in the Camp Douglas mining district.

17. GB-1 K-Ar (hornblende) 113±3 m.y.
Gabbro (NE¼SE¼SE¼ sec. 35, T3N, R40E; 38°04.08'N, 117°26.55'W, Esmeralda Co., NV). Medium-grained intergrowth of plagioclase, pyroxene, green pleochroic hornblende, and minor chloritized biotite. Analytical data: K_2O = 0.84%, $*Ar^{40}$ = 1.446 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 85.4%. Collected by: H. F. Bonham, Nevada Bureau of Mines and Geology, R. P. Ashley and M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey.

18. SPR-1 K-Ar (muscovite) 71.1±1.4 m.y.
Pegmatite (SE¼NW¼ sec. 15, unsurveyed, T2N, R40E; 38°01.88′N, 117°28.23′W, Esmeralda Co., NV). Coarse-grained intergrown of K-feldspar, plagioclase, quartz, muscovite, adjacent to a 1- to 2-inch quartz vein. The pegmatite occurs as a segregation within biotite granite with quartz filling the central part. Analytical data: K_2O = 11.06%, $*Ar^{40}$ = 11.83 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 79.5%. Collected by: H. F. Bonham, Nevada Bureau of Mines and Geology, R. P. Ashley and M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey.

18A. SPR-1A K-Ar (biotite) 69.2±1.4 m.y.
Biotite granite (SE¼NW¼ sec. 15, unsurveyed, T2N, R40E; 38°01.88′N, 117°28.23′W, Esmeralda Co., NV, approximately 300 ft SW of no. 18). Medium-grained granite consisting of microcline quartz, plagioclase, and green pleochroic biotite. Analytical data: K_2O = 9.16%, $*Ar^{40}$ = 9.548 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 82.0%. Collected by: H. F. Bonham, Nevada Bureau of Mines and Geology, R. P. Ashley and M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey.

19. MILLER-1 K-Ar (sanidine) 14.7±0.3 m.y.
Porphyritic flow-banded rhyolite (SE¼SW¼ sec. 13, T3N, R40E; 38°06.58′N, 117°26.12′W; Esmeralda Co., NV). Quartz and sanidine phenocrysts in a fine-grained groundmass of similar composition. Phenocrysts are banded and partially embayed. Some feldspars have been partially or wholly replaced by quartz as aggregate crystals. Secondary quartz as aggregate crystals similar to those replacing feldspars (originally plagioclase?) has also crystallized as irregular stringers and blebs in the groundmass, which contains some carbonate. FeOX present probably after altered mafics. Analytical data: K_2O = 11.60%, $*Ar^{40}$ = 2.477 x 10^{-10} moles/gm, 2.582 x 10^{-10} moles/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 83.4%, 77.8%. Collected by: H. F. Bonham, Nevada Bureau of Mines and Geology, R. P. Ashley and M. L. Silberman, U. S. Geological Survey. Dated by: M. L. Silberman, U. S. Geological Survey. Comment: The rock has been altered, and the age should be considered a minimum.

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