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POTASSIUM-ARGON AGES OF IGNEOUS ROCKS AND ALTERATION MINERALS ASSOCIATED WITH MINERAL DEPOSITS, WESTERN AND SOUTHERN NEVADA AND EASTERN CALIFORNIA[1]

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Seventeen new potassium-argon ages on Tertiary and Mesozoic igneous rocks and alteration minerals associated with mineral deposits are reported here (fig. 1). Seven of the samples are from unaltered rocks and include analyses of biotite, hornblende, and whole rock material. These ages help establish the regional framework for some mineral deposits or date the host rock of a mineral deposit. Ten samples (five adularia, four alunite, and one sericite) are from mines or mining districts and provide information about the time of alteration and possible mineralization at these sites. The samples were dated as part of mineral resource and geologic quadrangle mapping studies by the Nevada Bureau of Mines and Geology.

ANALYTICAL METHODS

The K-Ar sample preparation was done at the Nevada Bureau of Mines and Geology, University of Nevada, Reno. Argon and potassium analyses were done in the U.S. Geological Survey laboratories, Menlo Park, California. Analyses were by standard isotope dilution procedures as described by Dalrymple and Lanphere (1969). The mineral concentrations were made using heavy-liquid, magnetic, electrostatic, and hand-picking procedures. The whole-rock sample was ground to 80-100 mesh, and leached in HNO_3 and HF solution. Potassium analyses were performed by lithium metaborate flux fusion flame photometry techniques, the lithium serving as an internal standard (Ingamells, 1970). Argon analyses were performed using a 15.2-cm-radius, Neir-type mass spectrometer or a five-collector mass spectrometer (Stacy and others, 1981). The precision of the data, shown as the ± value, is the estimated analytical uncertainty at one standard deviation. It represents uncertainties in the measurement of radiogenic ^{40}Ar and K_2O based on experience with hundreds of replicated analyses in the Menlo Park laboratories. Mass discrimination of the spectrometer is routinely determined on the basis of multiple analyses of purified air. The constants used in the age determination are those from the subcommission on Geochronology (Steiger and Jaeger, 1977).

1. *RR-32* K-Ar
Kate Peak Formation; biotite-hornblende andesite flow (39°33′35″N, 119°49′17″W; NE$1/4$, NE$1/4$ SW$1/4$ NW$1/4$ S35,T20N,R19E; N of Reno, Reno 7.5' quad., Washoe County, NV). *Analytical data*: $K_2O = 8.53\%$; $^{40}Ar^* = 1.7609 \times 10^{-10}$ mol/gm; $^{40}Ar^*/\Sigma^{40}Ar = 0.643$. *Collected by*: L. J. Garside. *Analyzed by*: E. H. McKee. *Comment*: Fresh, dated flow overlies advanced argillic alteration in the underlying Alta Formation, providing an upper limit on the age of hydrothermal alteration. This age is in the midpoint of the known range of Kate Peak ages of 12-16 Ma (e.g., Vikre and others, 1988). Alteration here must thus be at least 14.3 Ma, reinforcing a 14.6-Ma age on alteration from a sample (19-30M) taken on the flank of Peavine Peak, 5 km to the west (D. M. Hudson and M. L. Silberman, unpub. data, 1993) and suggesting that an alunite age determination of 11.8 Ma from the same area (sample 19-30E) is either too young or dates a somewhat later period of hydrothermal alteration (or supergene oxidation). Similar alunite ages (about 11 Ma) are recorded from altered Tertiary andesite in the northern Carson Range about 15 km to the southwest (Russell and others, 1989).
(biotite) 14.3 ± 0.5 Ma

2. *V-34* K-Ar
Alunite (39°33′52″N, 119°44′21″W; SE$1/4$ SE$1/4$ S28, T20N,R20E; NE of Reno in the Wedekind mining district, Vista 7.5' quad., Washoe County, NV). *Analytical data*: $K_2O = 5.09\%$; $^{40}Ar^* = 1.1973 \times 10^{-10}$ mol/gm; $^{40}Ar^*/\Sigma^{40}Ar = 0.549$. *Collected by*: H. F. Bonham, Jr. *Analyzed by*: E. H. McKee. *Comment*: Alunitic hydrothermal alteration of Alta Formation associated with mineralization at the Wedekind mining district.

[1] Age determinations done under the U.S.Geological Survey-Nevada Bureau of Mines and Geology cooperative program.

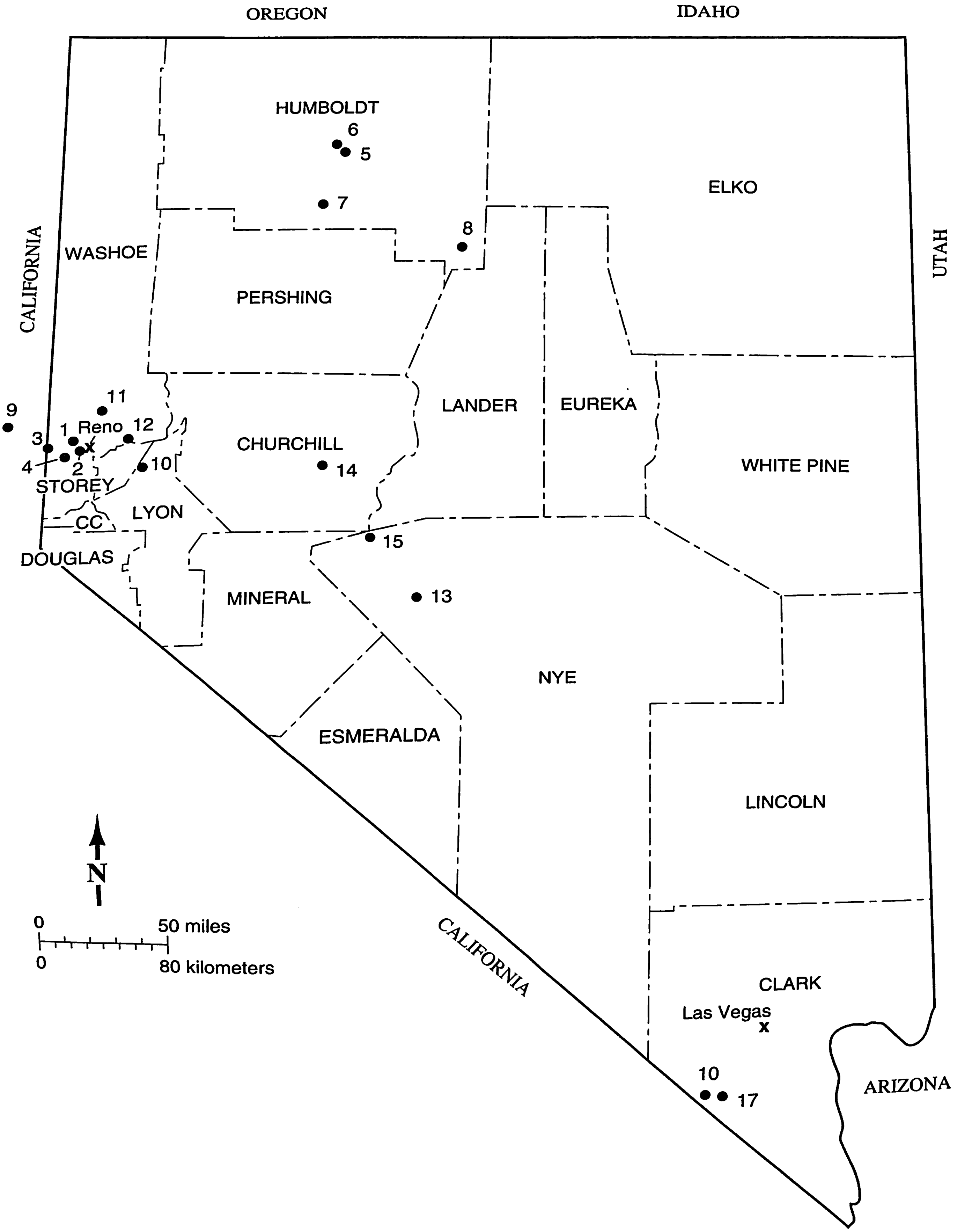

FIGURE 1. Locations of sample collection sites for radiometric age-determinations in this paper. The numbers refer to descriptions in the text.

Extensive areas of quartz-alunite alteration in the Reno-Virginia City area have an age range of 11-16 Ma and are related to multiple hydrothermal events. This Wedekind district alunite date is comparable to an older group of ages from the Virginia City and Geiger Grade areas 25-40 km to the south (see Vikre and others, 1988). Alteration and mineralization of similar character to that at Wedekind extends westward from the Wedekind district for 20-25 km to the Peavine mining district. If most or all of this hydrothermal alteration is approximately of the same age, our best estimate of that age is 15-16 Ma, based on presently available data (see the discussion on sample RR-32 above).

(alunite) 16.3 ± 0.5 Ma

3. *V-205* K-Ar

Hornblende-biotite andesite (39°35′29″N, 119°59′51″W; NW1/4 NW1/4 NE1/4 NE1/4 S19,T20N,R18E; NW flank of Peavine Peak, Verdi 7.5' quad., Washoe County, NV). *Analytical data*: K_2O = 8.10%; $^{40}Ar^*$ = 1.8734 × 10^{-10} mol/gm; $^{40}Ar^*/\Sigma^{40}Ar$ = 0.572. *Collected by*: L. J. Garside. *Analyzed by*: E. H. McKee. *Comment*: The andesite flow unit superficially resembles flows of the Kate Peak Formation (and was mapped as such in the Reno NW quad by Soeller and Nielsen, 1980). It lies on Cretaceous granodiorite (Bell and Garside, 1987) and is present at the base of a middle Miocene sequence of andesite flows and lahars exposed mainly to the west in California along the east flank of the Sierra Nevada (see discussion for sample GD-1, below); this sequence is probably age equivalent to the Kate Peak Formation and at least part of the Alta Formation of the Virginia City quadrangle. Because sample V-205 is from the basal part of the sequence, the sampled unit is not likely to be a direct correlative of the Kate Peak, which has an age of 14.3 Ma at the nearest dated locality (sample RR-32 above).

(biotite) 16.0 ± 0.5 Ma

4. *V-189* K-Ar

Olivine basalt (39°30′51.5″N, 119°56′53.5″W; SW1/4 NW1/4 SE1/4 NW1/4 S15,T19N,R18E; E of Verdi, Verdi 7.5' quad., Washoe County, NV). *Analytical data*: K_2O = 0.770%; $^{40}Ar^*$ = 1.4031 × 10^{-11} mol/gm; $^{40}Ar^*/\Sigma^{40}Ar$ = 0.582. *Collected by*: L. J. Garside. *Analyzed by*: E. H. McKee. *Comment*: The dated basalt flow appears to be near the base of the sandstone of Hunter Creek (Bell and Garside, 1987). Its stratigraphic relationship to a Hemphillian flora (Axelrod, 1958) located just to the east (and interbedded with a 5.9-Ma andesite tuff; Evernden and James, 1964) is uncertain; the basalt may be separated from the fossiliferous beds by an unrecognized fault. Possibly the basalt flow unit is the same as one reported to be 11.3 Ma (using new constants) by Evernden and James (1964); if so, the reason for the age discrepancy is unknown.

(whole rock) 8.6 ± 0.3 Ma

5. *AJ-1* K-Ar

Adularia (41°18′10″N, 118°00′00″W; NW1/4 S36,T40N,R35E; main pit of the Jumbo (Austin Jumbo) Mine, Awakening (Slumbering Hills) mining district, Awakening Peak and Jackson Well 7.5' quads., Humboldt County, NV). *Analytical data*: K_2O = 14.45%; $^{40}Ar^*$ = 3.6157 × 10^{-10} mol/gm; $^{40}Ar^*/\Sigma^{40}Ar$ = 0.866. *Collected by*: R. J. Roberts. *Analyzed by*: E. H. McKee. *Comment*: Quartz-adularia veins and stockworks cut sandstone and argillite of the Mesozoic Auld Lang Syne Group (Calkins, 1938) at the mine, which is the major producer in the district. Iron-stained adularia rhombohedria, 1-3 mm in diameter are present in veinlets having open-space textures. See also the comment on sample Sleeper (below) and Conrad and others (1993).

(adularia) 17.3 ± 0.5 Ma

6. Sleeper K-Ar

Alunite (41°20′07″N, 118°03′05″W; C N1/4 N1/4 S21, T40N,R35E; Sleeper Mine, Awakening (Slumbering Hills) mining district, Jackson Well 7.5' quad., Humboldt County, NV). Analytical data: K_2O = 8.62%; $^{40}Ar^*$ = 6.7156 × 10^{-11} mol/gm; $^{40}Ar^*/\Sigma^{40}Ar$ = 0.246. *Collected by*: D. E. Ranta. *Analyzed by*: E. H. McKee. *Comment*: Nash and others (1991) and Conrad and others (1993) report that 5.4 Ma acid leaching (with associated opal-kaolinite-alunite deposition) occurs along post-ore faults, and is thus later than the main-stage mineralization. They suggest that it may be shallow, solfataric alteration associated with a geothermal system that is considerably later than the main-stage gold-silver mineralization. The hypogene gold-silver mineralization and a mineralized rhyolite porphyry at the mine are reported to be approximately 16 Ma (Nash and Bartlett, 1991; Conrad and others, 1993). This age is relatively close to the 17.3-Ma mineralization at the Jumbo Mine 5 km to the southeast (see sample AJ-1 above).

(alunite) 5.4 ± 0.2 Ma

7. *Blue Mtn* K-Ar

Alunite (40°59′17″N, 118°07′45″W; SW1/4 SW1/4 SE1/4, S14,T36N,R34E; west flank of Blue

Mountain, Gaskell 7.5' quad., Humboldt County, NV). *Analytical data*: $K_2O = 1.68\%$; $^{40}Ar^* = 9.3342 \times 10^{-12}$ mol/gm; $^{40}Ar^*/\Sigma^{40}Ar = 0.151$. *Collected by*: H. F. Bonham, Jr. *Analyzed by*: E. H. McKee. *Comment*: The Blue Mountain prospect, located 35 km south of the Sleeper Mine, has gold and silver mineralization in Triassic metasedimentary rocks. Alunite at the property is probably associated with solfataric acid leaching, and thus apparently dates only the latest hydrothermal alteration. The precious-metal mineralization is probably older, and may be of more than one age. The alunite age is close to an alunite age at the Sleeper Mine (sample Sleeper, above), and may record the same later geothermal system.

(alunite) 3.9 ± 0.2 Ma

8. *STONEH* K-Ar

Stonehouse porphyry body (40°49′53″N, 117°12′07″W; SW¼ SW¼, S12,T34N,R42E; SE flank of Lone Tree Hill, Valmy 7.5' quad., Humboldt County, NV). *Analytical data*: (biotite) $K_2O = 8.73\%$; $^{40}Ar^* = 5.00678 \times 10^{-10}$ mol/gm; $^{40}Ar^*/\Sigma^{40}Ar = 0.77$; (hornblende) $K_2O = 1.082\%$; $^{40}Ar^* = 5.70628 \times 10^{-11}$ mol/gm; $^{40}Ar^*/\Sigma^{40}Ar = 0.42$. *Collected by*: L. B. Gustafson. *Analyzed by*: E. H. McKee. *Comment*: The biotite-hornblende mineral pair was separated from an unaltered granodiorite porphyry dike that closely resembles other, hydrothermally altered dikes on Lone Tree Hill. We interpret the dike to represent a late phase of the mineralizing porphyry system. Thus, the age of the dike sets an upper limit on alteration, and represents in a general way the age of intrusion and mineralization. The sericitized dikes are believed associated with Pb-Zn and Zn-Cu skarn mineralization observed at the Lone Tree Mine just to the west of Lone Tree Hill (Bloomstein and others, 1993). The skarn mineralization is similar to other 36-Ma skarns in the Battle Mountain area (Bloomstein and others, 1993; Theodore, 1991). The mesothermal and epithermal gold mineralization at the Lone Tree Mine is post-skarn, but otherwise undated. The age determinations for the mineral pair do not overlap within their error limits, and biotite (normally considered less retentive of radiogenic argon) has the older age. The reason for this discrepancy is unknown.

(biotite) 39.4 ± 1.2 Ma
(hornblende) 36.3 ± 1.2 Ma

9. *GD-1* K-Ar

Alunite (39°38′43.6″N, 120°17′34″W; SW¼ NW¼, S27,T21N,R15E; approximately 300 m N of the Antelope Mine in Antelope Valley, 3 km SW of Loyalton, Sierra County, CA). *Analytical data*: $K_2O = 4.52\%$; $^{40}Ar^* = 4.94492 \times 10^{-11}$ mol/gm; $^{40}Ar^*/\Sigma^{40}Ar = 0.191$. *Collected by*: L. J. Garside, H. F. Bonham, Jr., and M. W. Brady. *Analyzed by*: E. H. McKee. *Comment*: Date on coarse, hypogene alunite from quartz-alunite alteration of Tertiary andesite and dacite flows. A sample of alunite collected from near the Antelope Mine also yielded an age of 7.6 Ma (P. G. Vikre and E. H. McKee, unpub. data, 1993). Alteration is associated with enargite-gold type mineralization at the Golden Dome property. Similar mineralization is noted to the southeast in Nevada in the Peavine, Wedekind, Castle Peak, Comstock Lode, and Ramsey districts. Andesitic rocks similar to the wall rock at Golden Dome are dated at 10.4 and 13.3 Ma at two localities 20 and 10 km to the southeast and northeast, respectively (Saucedo and Wagner, 1992). Unaltered flows in the vicinity of the mineralized area are interpreted by Young and Cluer (1992) to be younger than the alteration. If this interpretation is correct, there are intermediate-composition flows in this area younger than 7.6 Ma.

(alunite) 7.6 ± 0.2 Ma

10. *R-3* K-Ar

Quartz and adularia (39°26′37.1″N, 119°22′41.2″W; SW¼ NW¼, S11,T18N,R23E; 1.5 km southeast of Ramsey townsite, Martin Canyon 7.5' quad., Lyon County, NV). *Analytical data*: $K_2O = 0.782\%$; $^{40}Ar^* = 1.21517 \times 10^{-11}$ mol/gm; $^{40}Ar^*/\Sigma^{40}Ar = 0.072$. *Collected by*: Larry McMaster. *Analyzed by*: E. H. McKee. *Comment*: Quartz-adularia alteration associated with precious metal mineralization in the Ramsey district. An alteration age of 9.3 Ma is reported on alunite from the district (Vikre and others, 1988).

(adularia) 10.8 ± 0.3 Ma

11. *AD-SS-25* K-Ar

Tuff of Axe Handle Canyon; moderately welded rhyolite vitric ignimbrite (39°45′31″N, 119°38′25″W; SE¼ S20,T22N,R21E; Pah Rah Range north of Reno, Fraser Flat 7.5' quad., Washoe County, NV). *Analytical data*: (biotite) $K_2O = 8.18\%$; $^{40}Ar^* = 3.7789 \times 10^{-10}$ mol/gm; $^{40}Ar^*/\Sigma^{40}Ar = 0.758$; (sanidine) $K_2O = 10.32\%$; $^{40}Ar^* = 4.5683 \times 10^{-10}$ mol/gm; $^{40}Ar^*/\Sigma^{40}Ar = 0.984$. *Collected by*: H. F. Bonham, Jr. *Analyzed by*: E. H. McKee. *Comment*: The tuff is present as a local erosional remnant below the tuffs of Whiskey Springs (Garside and Bonham, 1992) and it rests on

Mesozoic granodiorite. The age places a lower limit on the middle Tertiary section of ignimbrites in this region.

(biotite) 31.8 ± 1.0 Ma
(sanidine) 30.5 ± 0.8 Ma

12. *OG-54* K-Ar
Rhyolite ignimbrite (39°38′05″N, 119°25′59″W; NE1/4 NE1/4 S6,T20N,R23E near mouth of Pierson Canyon, Olinghouse 7.5′ quad., Washoe County, NV). *Analytical data*: K_2O = 6.47%; $^{40}Ar^*$ = 1.09020 × 10^{-11} mol/gm; $^{40}Ar^*/\Sigma^{40}Ar$ = 0.73. *Collected by*: L. J. Garside and H. F. Bonham, Jr. *Analyzed by*: E. H. McKee. *Comment*: The sample is from a vitrophyre at the top of a thin rhyolitic unit consisting of basal air-fall tuff and volcaniclastic sandstone overlain by unwelded grading to welded, white rhyolitic ignimbrite. The rhyolitic unit is intercalated with basalt flows of the Pyramid sequence. The Pyramid sequence is a general term for the predominantly basaltic and andesitic unit in the Pyramid Lake area of western Nevada which lies above 22- to 31-Ma silicic ignimbrites (and locally above the 20- to 17-Ma Alta Formation), and below Kate Peak Formation (ca. 12-16 Ma in the Reno-Virginia City area - see Vikre and others, 1988). About 1 km to the east of locality OG-54, a rhyolite air-fall tuff associated with a late Barstovian or early Clarendonian flora is intercalated in the Pyramid sequence. Biotite from that tuff is dated at 13.3 Ma (H. F. Bonham, Jr. and D. I. Axelrod, unpubl. data). Eight km to the north, in Fort Defiance Canyon, basal flows of the Pyramid sequence (Chloropagus Formation of Axelrod [1956] according to Bonham, 1969) are dated at 14.9 Ma (Bonham, 1969, p. 30; Krueger and Schilling, 1971, sample G-R0674/NBM-AD15). Elsewhere in the Pyramid Lake area, K-Ar age determinations on flows of the Pyramid sequence and related rocks have a range ages from about 13 Ma to about 16 Ma (Bonham, 1969; Krueger and Schilling, 1971; Silberman and McKee, 1972, p. 11; Evans and others, 1981). All ages discussed above are based on new constants or have been converted to new constants (Dalrymple, 1979). The 11.7-Ma age reported here appears to be quite young based on adjacent dates of presumed age-equivalent strata. If correct, the date suggests that the Pyramid sequence is in part younger than heretofore thought, and may overlap in age Kate Peak volcanism of the Reno-Virginia City area. The Kate Peak Formation overlies the Pyramid sequence in the nearby Olinghouse mining district, but has not been dated there.

(biotite) 11.7 ± 0.4 Ma

13. *2699* K-Ar
Adularia (38°39′00″N, 117°31′30″W; NE1/4 NE1/4 NW1/4, S18,T9N,R40E; southern Shoshone Mountains east of the old camp of Golden, Mount Ardivey 7.5′ quad., Nye County, NV). *Analytical data*: K_2O = 14.92%; $^{40}Ar^*$ = 4.3108 × 10^{-10} mol/gm; $^{40}Ar^*/\Sigma^{40}Ar$ = 0.914. *Collected by*: J. V. Tingley. *Analyzed by*: E. H. McKee. *Comment*: The sample is from a quartz-cemented breccia in the footwall of a wide northwest-trending fracture zone in rhyolitic welded ash-flow tuff at the East Golden Mine, Cloverdale mining district. Quartz and adularia crystals, along with clots of limonite and minor manganese oxide, coat fracture surfaces and line vugs in the brecciated, silicified rock. All of the mineralized areas within the Cloverdale district are located along a general northwest trend which parallels the southwestern margin of the Peavine caldera (Snyder and Healey, 1983). The mining areas lie outside the defined caldera margin, but mineralization is postulated to occur along structures related to the ring fracture zone of the caldera. A sample of adularia from the Golden King Mine yielded an age of 20.9 ± 0.5 Ma reported by McKee and John (1987).

(adularia) 20.0 ± 0.6 Ma

14. *3925* K-Ar
Adularia (39°28′49″N, 118°04′59″W; SW1/4 NW1/4 SE1/4, S30,T19N,R35E; northwest of Geiger Gap in the northern Louderback Mountains, Wonder Mountain 7.5′ quad., Churchill County, NV). *Analytical data*: K_2O = 7.68%; $^{40}Ar^*$ = 2.5559 × 10^{-10} mol/gm; $^{40}Ar^*/\Sigma^{40}Ar$ = 0.855. *Collected by*: J. V. Tingley *Analyzed by*: E. H. McKee. *Comment*: The sample is from an irregular-striking vein that generally follows the northwest-trending Gold King Group fault (Schrader, 1947), Gold King Mine, Wonder mining district. Vein material consists of vuggy, limonite-stained, cream-colored quartz and adularia, white quartz, and specks of black silver sulfide. Northeast-trending quartz-adularia veins in this area have been cut and offset by the major northwest-trending structure; both sets of structures cut the Wonder rhyolite unit of Schrader (1947).

(adularia) 23.0 ± 0.7 Ma

15. *3477* K-Ar

Adularia (39°03′52″N, 117°46′25″W; SE$^1/_4$ SW$^1/_4$ NW$^1/_4$ S24,T14N,R37E; south of Burnt Cabin Summit in the northern Paradise Range, Burnt Cabin Summit 7.5' quad., Nye County, NV). *Analytical data*: K_2O = 7.25%; $^{40}Ar^*$ = 1.73229 × 10^{-10} mol/gm; $^{40}Ar^*/\Sigma^{40}Ar$ = 0.77. *Collected by*: J. V. Tingley *Analyzed by*: E. H. McKee. *Comment*: Sample was collected from a vuggy quartz-adularia vein exposed in a northeast-trending drift intersected by the upper adit of the Duluth Mine, Bruner mining district. The district is underlain by Tertiary volcanic rocks, chiefly silicic domes, plugs and irregularly-shaped intrusive bodies (Kleinhampl and Ziony, 1984). A sample of biotite rhyolitic porphyry from the Bruner Mine, located about 1 mile northeast of the Duluth Mine, yielded a biotite age of 19.3 Ma by K-Ar analysis (Kleinhampl and Ziony, 1984). Ore deposits in the Bruner district are free-gold-bearing quartz veins that formed along fractures, faults, and breccia zones in the rhyolitic volcanic rocks. At the Duluth Mine, vuggy, lenticular quartz-adularia veins occur along a wide, N20°E-striking sheeted, zone in brecciated, silicified rhyolite tuff. Breccia fragments are kaolinized and cemented with quartz; cavities in the breccia are lined with quartz and adularia crystals and some crystals are stained amber by limonite and jarosite. Some quartz vein material exhibits a lamellar texture believed to represent pseudomorphic replacement of calcite by quartz.

(adularia) 16.5 ± 0.5 Ma

16. *CHA-MIN* K-Ar

Sericitized granite porphyry (35°50′24″N, 115°25′55″W; SW$^1/_4$ SE$^1/_4$ SE$^1/_4$, S24, T24S,R57E; south of Keystone Wash in the southern Spring Mountains, Shenandoah Peak 7.5' quad., Clark County, NV). *Analytical data*: K_2O = 9.02%; $^{40}Ar^*$ = 2.736984 10^{-9} mol/gm; $^{40}Ar^*/\Sigma^{40}Ar$ = 0.976. *Collected by*: H. F. Bonham, Jr., J. V. Tingley, and L. J. Garside. *Analyzed by*: E. H. McKee. *Comment*: Sericite obtained from pyritic, sericitized quartz-eye granite porphyry collected from the dump of the Chaquita Mine, Goodsprings mining district. The sample is from the Keystone dike which intrudes rocks in the upper plate of the Keystone thrust. Carr and others (1986) reported ages of 183 ± 6 and 189 ± 6 Ma for the Yellow Pine sill, a porphyry body that intrudes rocks in the lower plate of the Keystone thrust at the Yellow Pine Mine, about two miles northeast of the Chaquita Mine. Hewett (1931) and Albritton and others (1954) observed that the porphyry dikes and sills of the district were, in many cases, intruded along preexisting thrusts and that the porphyry intrusions preceded dolomitization and the deposition of ore minerals. Many of the porphyry contacts, however, show evidence of continued movement subsequent to crystallization of the porphyries (Hewett, 1931). See sample CP-HB below.

(sericite) 199.3 ± 6.0 Ma

17. *CP-HB* K-Ar

Granite porphyry of Crystal Pass (35°47′45″N, 115°25′09″W; SE$^1/_4$ SW$^1/_4$ SE$^1/_4$, S1,T25S,R58E; one mile southeast of Crystal Pass, south of the town of Goodsprings in the southern Spring Mountains, Goodsprings 7.5 quad., Clark County, NV). *Analytical data*: K_2O = 1.582%; $^{40}Ar^*$ = 4.571196 × 10^{-10} mol/gm; $^{40}Ar^*/\Sigma^{40}Ar$ = 0.878. *Collected by*: H. F. Bonham, Jr., J. V. Tingley, and L. J. Garside. *Analyzed by*: E. H. McKee. *Comment*: Hornblende was separated from an essentially unaltered hornblende granodiorite porphyry dike exposed near the head of a small basin southeast of Crystal Pass. This dike is one of a number of related granitic porphyries having somewhat different mineralogies and textures. Intrusive rocks with ages in this range are known only from the Goodsprings district in southern Nevada, but latest Triassic (and Early Jurassic) plutons of the Lee Vining intrusive epoch occur in the central Sierra Nevada (Evernden and Kistler, 1970), Inyo batholith (McKee and Nash, 1967), and near Tonopah (John and McKee, 1987; John and Robinson, 1989). The date obtained from this sample is comparable to (within the analytical reproducibility limits) the date obtained from the sample of altered, mineralized porphyry from the Chaquita Mine and with dates reported by Carr and others (1986) from the Yellow Pine sill (see sample CHA-MIN, above). If the Keystone thrust has a displacement of at least 10 km (Burchfiel and others, 1974), the presence of porphyry dikes in both plates of the thrust within a relatively limited area seems to preclude a pre-thrust age of intrusion. The zonation of metal deposits within the district, and the association of this zonation with the intrusive rocks (Hewett, 1931) suggest that the deposits have not been displaced much by thrust faults, and probably formed after thrust faulting. These dates thus provide evidence that porphyry intrusion and mineralization in the Goodsprings district are coeval and that both apparently postdate the major period of thrust faulting.

(hornblende) 190.3 ± 6.0 Ma

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The 1983 revision of this geologic time chart was prepared by the Geologic Names Committee for U.S. Geological Survey use. It supersedes the 1980 chart. Numerical ages of chronostratigraphic boundaries are subject to many uncertainties besides the analytical precision of the dating. The placement of boundary stratotypes and the achievement of international agreements on these ages is a slow process subject to much revision and review. Recent studies and revisions of the geologic time scale of especial interest are reported in *A geologic time scale,* by W. B. Harland, A. V. Cox, P. G. Llewellyn, C. A. G. Pickton, A. G. Smith, and R. Walters, 1982: Cambridge University Press, 132 p.; *The decade of North American geology 1983 geologic time scale,* by A. R. Palmer, 1983: Geology, v. 11, p. 503–504; and *The chronology of the geological record,* N. J. Snelling (ed.), 1985: Blackwell Scientific Publishers, The Geological Society, Memoir No. 10, 343 p.

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