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K-AR AGES OF TERTIARY IGNEOUS AND SEDIMENTARY ROCKS OF THE MINA-CANDELARIA REGION, MINERAL COUNTY, NEVADA

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We report 17 new K-Ar ages from Tertiary rocks of the Candelaria Hills, Garfield Hills, Excelsior Mountains, and Pilot Mountains, southeastern Mineral County, NV (Fig. 1). Sample description sites are shown on fig. 1.

Five major Cenozoic rock sequences are recognized in this area and are described below in order of increasing age. The youngest sequence consists of Pliocene basalt with ages of about 3 to 4 m.y. (nos. 1 and 2, this paper, no. 9, Silberman and others, 1975). The second sequence consists of volcanogenic and terrigenous sedimentary rocks of the type previously classed as Esmeralda Formation (Ferguson and others, 1954); two samples (nos. 3 and 4) gave ages of 5.7 and 7.3 m.y. (latest Miocene). Similar rocks east of the Pilot Mountains are as old as 12 m.y.

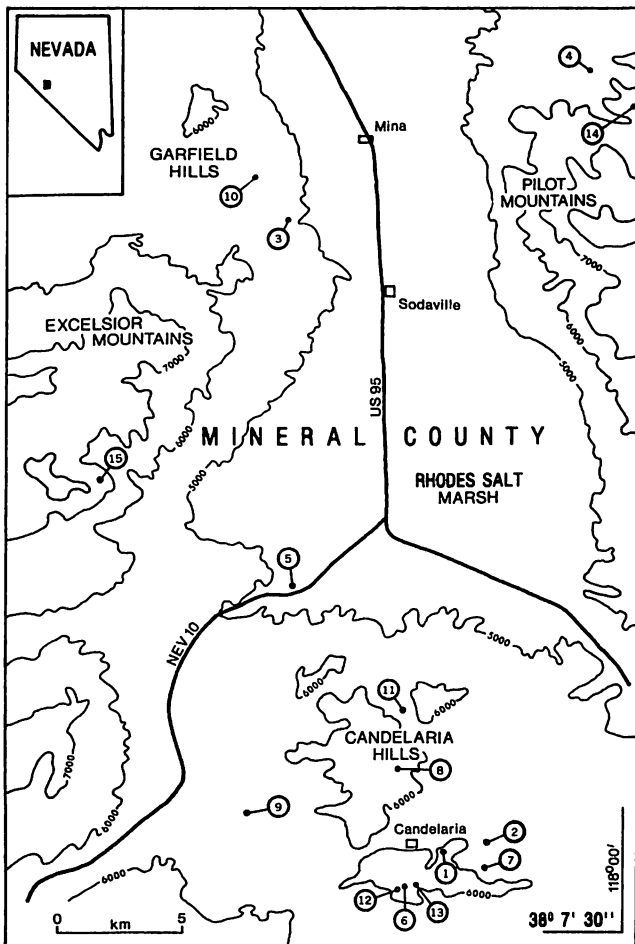


FIGURE 1 — Map showing sample localities of dated rocks in Mineral County, Nevada. Contours show elevation in feet.

according to Evernden and others (1964). The third sequence consists of widespread andesite, included in the Gilbert Andesite by Ferguson and others (1954). The three ages given here (nos. 5 and 6) range from 15.7 to 17.4 m.y. (Miocene) and are consonant with ages on similar rocks in this area recently reported by Silberman and others (1975) and Albers and Stewart (1972).

The fourth sequence comprises siliceous ash-flow tuffs and intercalated sedimentary rocks and basaltic lava. We have given this sequence the informal name, Miocene tuffs of the Candelaria Hills, and divided it into ten units, numbering from the bottom up. Seven ages were obtained for tuffs of the fourth sequence (nos. 7 through 13), ranging from 21.4 to 24.7 m.y. (early Miocene).

The lowest or fifth sequence consists of older ash-flow tuffs upon which strata of the fourth sequence locally rest unconformably. Three ages (nos. 14 and 15), ranging from 26.3 to 27.1 m.y., date the older tuffs in the Excelsior and the Pilot Mountains as very late Oligocene or very early Miocene.

All but two of the 17 ages were determined in the U.S. Geological Survey laboratories at Denver, Colorado; the other two were determined by Krueger Enterprises, Inc. (Geochron Laboratories). All ages were obtained using techniques described by Dalrymple and Lanphere (1969) and calculated using the following constants: $\lambda_{\beta} = 4.72 \times 10^{-10} \text{ yr}^{-1}$, $\lambda_{\epsilon} = 0.585 \times 10^{-10} \text{ yr}^{-1}$, and $K^{40}/K = 1.19 \times 10^{-4}$. The quoted uncertainties represent the estimated analytical error at two standard deviations (2σ).

SAMPLE DESCRIPTIONS

1. USGS-D2391R K-Ar
Olivine basalt (E. side of mouth of Pickhandle Gulch; T. 4 N., R. 35 E. [unsurveyed]; $38^{\circ}09'27''\text{N}$., $118^{\circ}04'54''\text{W}$.; Candelaria quad., Mineral Co., NV). Lava composed of phenocrysts of olivine, plagioclase, and clinopyroxene in a groundmass of feldspar, pyroxene, ore, and unhydrated brown glass. Analytical data: $\text{K}_2\text{O} = 2.64\%$, 2.63% ; $^* \text{Ar}^{40} = 0.1072 \times 10^{-10}$ mole/gm; $^* \text{Ar}^{40} / \Sigma \text{Ar}^{40} = 35\%$; collected by: R. C. Speed, Northwestern Univ.; dated by: R. F. Marvin, H. H. Mehnert, and V. M. Merritt, U.S. Geological Survey. Comment: Silberman and others (1975) obtained a K-Ar whole-rock age of 3.8 ± 0.6 m.y. on basalt from the same sequence but from a site on Candelaria Mountain about 1 km to the southwest. (whole-rock) 2.8 ± 0.1 m.y.

2. **USGS-D2392R** K-Ar
Olivine basalt (approx. 3.5 km E. of Candelaria townsite; T. 4 N., R. 35 E. [unsurveyed]; 38°09'47"N., 118°03'00"W.; Candelaria quad., Mineral Co., NV). Lava consists of olivine, plagioclase, and clinopyroxene phenocrysts in a groundmass of feldspar, pyroxene, ore, and unhydrated brown glass. Analytical data: K₂O = 2.56%, 2.52%; *Ar⁴⁰ = 0.1074 x 10⁻¹⁰ mole/gm; *Ar⁴⁰/ΣAr⁴⁰ = 35%; collected by: R. C. Speed, Northwestern Univ.; dated by: R. F. Marvin, H. H. Mehnert, and V. M. Merritt, U. S. Geological Survey. Comment: Same sequence as sample 1.
(whole-rock) 2.9±0.1 m.y.
3. **USGS-D2466B** K-Ar
Volcanogenic sedimentary rock (mouth of Douglas Canyon; NE1/4 sec. 24, T. 6 N., R. 34 E.; 38°21'55"N., 118°08'17"W.; Camp Douglas quad., Mineral Co., NV). Lithic-quartz-feldspar-biotite sandstone with ashy matrix in a succession of thin-bedded pumiceous sedimentary rocks. Analytical data: K₂O = 7.42%, 7.45%; *Ar⁴⁰ = 0.6310 x 10⁻¹⁰ mole/gm; *Ar⁴⁰/ΣAr⁴⁰ = 51%; collected by: R. C. Speed, Northwestern Univ.; dated by: R. F. Marvin, H. H. Mehnert, and V. M. Merritt, U. S. Geological Survey. Comment: Age may be maximum age as contamination by extraneous biotite is a possibility.
(biotite) 5.7±0.2 m.y.
4. **USGS-D2466B** K-Ar
Volcanogenic sedimentary rock (lower Cinnabar Canyon, Pilot Mountains; NE1/4 SE1/4 sec. 36, T. 7 N., R. 35 E.; 38°25'05"N., 118°01'26"W.; Mineral Co., NV). Pumice-hornblende-plagioclase-pyroxene sandstone with ash matrix; hornblende grains are unaltered. Analytical data: K₂O = 1.13%, 1.14%; *Ar⁴⁰ = 0.1219 x 10⁻¹⁰ mole/gm; *Ar⁴⁰/ΣAr⁴⁰ = 44%; collected by: A. H. Cogbill, Northwestern Univ.; dated by: R. F. Marvin, H. H. Mehnert, and V. M. Merritt, U. S. Geological Survey. Comment: Specimen is from the upper 5 m of Tertiary sediment succession in the valley at northern margin of the Pilot Mountains. Age may be maximum age as contamination by extraneous femics is a possibility.
(hornblende) 7.3±0.2 m.y.
5. **USGS-D2405H** K-Ar
USGS-D2405P1
Hornblende andesite (top of cliff on N. side of Nevada Highway 10; SE1/4 SE1/4 sec. 36, T. 5 N., R. 34 E. [unsurveyed]; 38°14'31"N., 118°08'38"W.; Belleville quad., Mineral Co., NV). Porphyritic andesite lava composed of plagioclase phenocrysts (95%) with minor brown hornblende and clinopyroxene phenocrysts in a felsic groundmass (5%) of feldspar, pyroxene, ore, and various felsic devitrification products. Analytical data: (hornblende) K₂O = 0.73%, 0.72%; *Ar⁴⁰ = 0.1856 x 10⁻¹⁰ mole/cm; *Ar⁴⁰/ΣAr⁴⁰ = 57%; (plagioclase) K₂O = 2.33%, 2.31%; *Ar⁴⁰ = 0.5980 x 10⁻¹⁰ mole/cm; *Ar⁴⁰/ΣAr⁴⁰ = 80%; collected by: R. C. Speed and A. H. Cogbill, Northwestern Univ.; dated by: R. F. Marvin, H. H. Mehnert, and V. M. Merritt, U. S. Geological Survey. (hornblende) 17.3±1.1 m.y. (plagioclase) 17.4±0.6 m.y.
6. **USGS-D2390R** K-Ar
Andesite (T. 3 N., R. 35 E. [unsurveyed]; approx. 1.5 km S. of Candelaria townsite; 38°08'40"N., 118°05'32"W.; Candelaria quad., Mineral Co., NV). Pyroxene basalt with phenocrysts of orthopyroxene and plagioclase in a groundmass of pyroxene, plagioclase, and ore. Analytical data: K₂O = 2.44%, 2.46%, 2.45%, and 2.52%; *Ar⁴⁰ = 0.5741 x 10⁻¹⁰ mole/cm; *Ar⁴⁰/ΣAr⁴⁰ = 76%; collected by: R. C. Speed, Northwestern Univ.; dated by: R. F. Marvin, H. H. Mehnert, and V. M. Merritt, U. S. Geological Survey. Comment: This basalt is map unit Tv8 of Page (1959).
(whole-rock) 15.7±0.5 m.y.
7. **USGS-D2381B** K-Ar
Crystal tuff, unit 9 of the Miocene tuffs of the Candelaria Hills (approx. 2.5 km ESE. of Candelaria townsite; T. 3 N., R. 35 E. [unsurveyed]; 38°09'04"N., 118°03'38"W.; Candelaria quad., Mineral Co., NV). Specimen from strongly compacted zone in ash-flow tuff about 100 m thick. It has crystals of quartz (15%), sanidine and plagioclase (10%), and biotite (<1%); ash and pumice matrix are largely vitric in this specimen. Analytical data: K₂O = 6.85%, 6.86%; *Ar⁴⁰ = 2.262 x 10⁻¹⁰ mole/gm; *Ar⁴⁰/ΣAr⁴⁰ = 29%; collected by: R. C. Speed, Northwestern Univ.; dated by: R. F. Marvin, H. H. Mehnert, and V. M. Merritt, U. S. Geological Survey. Comment: This tuff is correlated with map unit Tv18 of Page (1959) and is correlated lithologically with tuff 20 km southwest of Candelaria on Nevada Highway 10 which gave the following ages: sanidine 22.2±0.6 (2σ) m.y., plagioclase 22.9±1.3 (2σ) m.y. (Gilbert and others, 1968). Unit 9 is also known, informally, as the tuff of Candelaria Junction.
(biotite) 22.2±0.8 m.y.
8. **USGS-D2550S** K-Ar
Crystal tuff, unit 9 of the Miocene tuffs of the Candelaria Hills (approx. 3 km NE. of Candelaria townsite; T. 4 N., R. 35 E. [unsurveyed]; 38°11'09"N., 118°06'00"W.; Candelaria quad., Mineral Co., NV). Specimen taken from poorly compacted vitric base in ash-flow tuff which has crystals of quartz (15%), sanidine and plagioclase (10%), and biotite (<1%); ash and pumice matrix are largely vitric. Analytical data: K₂O = 9.68%, 9.69%; *Ar⁴⁰ = 3.299 x 10⁻¹⁰ mole/gm; *Ar⁴⁰/ΣAr⁴⁰ = 92%; collected by: R. C. Speed,

8. (continued)
Northwestern Univ.; dated by: R. F. Marvin, H. H. Mehnert, and V. M. Merritt, U. S. Geological Survey.
Comment: Same as for sample 7.
(sanidine) 22.9 ± 0.5 m.y.
9. USGS-D2404B K-Ar
Crystal tuff, unit 9 of the Miocene tuffs of the Candelaria Hills (T. 4 N., R. 34 E. [unsurveyed]; $38^{\circ}10'01''$ N., $118^{\circ}09'45''$ W.; Belleville quad., Mineral Co., NV). Specimen is from a strongly compacted zone of ash flow with fresh crystals in a highly devitrified matrix. Analytical data: $K_2O = 7.57\%, 7.50\%$; $*Ar^{40} = 2.758 \times 10^{-10}$ mole/gm; $*Ar^{40}/\Sigma Ar^{40} = 53\%$; collected by: A. H. Cogbill, Northwestern Univ.; dated by: R. F. Marvin, H. H. Mehnert, and V. M. Merritt, U. S. Geological Survey. Comment: The ages obtained for samples 7 and 8 of this paper agree with those of Gilbert and others (1968) from unit 9. However, it appears that the biotite age for this tuff sample is too old. Since the stratigraphic assignment of this sample seems indisputable, the determined age may have been caused by sample contamination, excess argon, or analytical error. Unit 9 is also known, informally, as the tuff of Candelaria Junction.
(biotite) 24.6 ± 0.9 m.y.
10. USGS-D2436P1 K-Ar
Crystal tuff, unit 7 of the Miocene tuffs of the Candelaria Hills (NE1/4 SE1/4 sec. 14, T. 6 N., R. 34 E.; $38^{\circ}22'37''$ N., $118^{\circ}09'10''$ E.; Mina NW quad., Mineral Co., NV). Ash-flow tuff with crystals of plagioclase (15%), clinopyroxene (2%), and trace amounts of biotite, quartz, and hornblende. Ashy matrix is vitric in analyzed specimen but strong devitrification is widespread in unit 7. Analytical data: $K_2O = 0.85\%, 0.84\%$; $*Ar^{40} = 0.2684 \times 10^{-10}$ mole/gm; $*Ar^{40}/\Sigma Ar^{40} = 84\%$; collected by: R. C. Speed, Northwestern Univ.; dated by: R. F. Marvin, H. H. Mehnert, and V. M. Merritt, U. S. Geological Survey. Comment: Because this tuff lies below the unit 9 (22-23 m.y. old), the 21.4 m.y. age is apparently a bit too young. Unit 7 is also known as the tuff of Belleville.
(plagioclase) 21.4 ± 0.9 m.y.
11. R3476 K-Ar
Olivine basalt, unit 6 of Miocene tuffs of the Candelaria Hills (approx. 4.5 km N. of Candelaria townsite in T. 4 N., R. 35 E. [unsurveyed]; $38^{\circ}12'04''$ N., $118^{\circ}05'45''$ W.; Candelaria quad., Mineral Co., NV). Olivine basalt lava with phenocrysts of altered olivine, fresh clinopyroxene, and plagioclase in a groundmass of pyroxene, plagioclase, ore, and unaltered brown glass. Analytical data: $K_2O = 1.41\%, 1.36\%$; $*Ar^{40} = 0.4481 \times 10^{-10}$, 0.5254×10^{-10} mole/cm; $*Ar^{40}/\Sigma Ar^{40} = 34.5\%, 44.5\%$; collected by: J. S. Oldow, Northwestern Univ.; dated by: Geochron Laboratories Inc., Cambridge, Mass. (whole-rock) 24.1 ± 1.9 m.y.
12. USGS-D2380B K-Ar
Crystal tuff, unit 5 of the Miocene tuffs of the Candelaria Hills (T. 3 N., R. 35 E. [unsurveyed]; approx. 2 km SSW. of Candelaria townsite; $38^{\circ}08'36''$ N., $118^{\circ}05'56''$ W.; Candelaria quad., Mineral Co., NV). Ash-flow tuff with crystals of sanidine and plagioclase (15%), quartz (15%), biotite (10%) in a vitric matrix of pumice and ash. Analytical data: $K_2O = 8.08\%, 8.08\%$; $*Ar^{40} = 2.908 \times 10^{-10}$ mole/gm; $*Ar^{40}/\Sigma Ar^{40} = 62\%$; collected by: R. C. Speed, Northwestern Univ.; dated by: R. F. Marvin, H. H. Mehnert, and V. M. Merritt, U. S. Geological Survey. Comment: A tuff exposed on Nevada Highway 10, 20 km SW. of Candelaria is correlated by lithology and stratigraphy with unit 5. Gilbert and others (1968) report the following ages for this tuff: sanidine 22.1 ± 0.4 (2σ) m.y., plagioclase 22.8 ± 0.6 (2σ) m.y., and biotite 24.0 ± 1.0 (2σ) m.y. This tuff is map unit *Tv12* of Page (1959) and is also known as the tuff of Metallic City.
(biotite) 24.2 ± 0.9 m.y.
13. USGS-D2379B K-Ar
Crystal tuff, unit 1 of Miocene tuffs of the Candelaria Hills (near Metallic City site; T. 3 N., R. 35 E. [unsurveyed]; $38^{\circ}08'46''$ N., $118^{\circ}05'13''$ W.; Candelaria quad., Mineral Co., NV). Ash-flow tuff with crystals of plagioclase and sanidine (15%), quartz (5-10%), and biotite (10%) in a moderately devitrified ashy matrix. Analytical data: $K_2O = 7.93\%, 7.96\%$; $*Ar^{40} = 2.913 \times 10^{-10}$ mole/gm; $*Ar^{40}/\Sigma Ar^{40} = 38\%$; collected by: R. C. Speed, Northwestern Univ.; dated by: R. F. Marvin, H. H. Mehnert, and V. M. Merritt, U. S. Geological Survey. Comment: This unit correlates with map unit *Tv1* of Page (1959).
(biotite) 24.7 ± 0.8 m.y.
14. USGS-D2464S K-Ar
USGS-D2464B
Crystal tuff, tuff of Pilot Mountains (T. 6 N., R. 36 E., 10 km ENE. of Mina; $38^{\circ}24'20''$ N., $117^{\circ}59'30''$ W.; Mineral Co., NV). Strongly compacted ash-flow tuff with crystals of quartz (20%), feldspar (25%), and biotite (5%) in a totally devitrified ash-pumice matrix. Analytical data: (sanidine) $K_2O = 10.25\%, 10.10\%$; $*Ar^{40} = 3.979 \times 10^{-10}$ mole/gm; $*Ar^{40}/\Sigma Ar^{40} = 83\%$; (biotite) $K_2O = 8.07\%, 8.14\%$; $*Ar^{40} = 3.220$ mole/gm; $*Ar^{40}/\Sigma Ar^{40} = 57\%$; collected by: A. H. Cogbill, Northwestern Univ.; dated by: R. F. Marvin, H. H. Mehnert, and V. M. Merritt, U. S. Geological Survey.
(sanidine) 26.3 ± 0.4 m.y.
(biotite) 26.7 ± 0.9 m.y.

15. B-3462 K-Ar
 Crystal tuff, tuff on Moho Mountain (SE. side of Excelsior Mountains; T. 5 N., R. 34 E. [unsurveyed]; 38° 16' 51" N., 118° 13' 05" W.; Camp Douglas quad., Mineral Co., NV). Ash-flow tuff with crystals of feldspar (18%), quartz (5%), and biotite (3%) in a largely devitrified ash matrix. Analytical data: $K_2O = 7.733\%, 7.627\%$; $*Ar^{40} = 3.095 \times 10^{-10}, 2.970 \times 10^{-10}$ mole/gm; $*Ar^{40}/\Sigma Ar^{40} = 23.9\%, 22.0\%$; collected by: R. C. Speed, Northwestern Univ.; dated by: Geochron Laboratories Inc., Cambridge, Mass. (biotite) 27.1 ± 1.5 m.y.

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