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Isochron/West, Bulletin of Isotopic Geochronology, v. 3, pp. 23-28

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K-AR DATES AND STRONTIUM ISOTOPE INITIAL RATIOS OF SOME CENOZOIC VOLCANIC ROCKS FROM WEST-CENTRAL NEVADA

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We report 16 new K-Ar dates for volcanic rocks from the Goldfield-Tonopah region in Nye and Esmeralda Counties, Nevada. The samples were collected by Vitaliano during an investigation of the Cenozoic volcanics of west-central Nevada, supported by NSF Grant G3990, aimed at establishing a workable stratigraphic sequence for these rocks (Vitaliano, 1963). The K-Ar determinations and Sr isotopic analyses were made by Armstrong and Dick in the geochronology laboratory of Yale University. (The geochronology laboratory of Yale University was supported by NSF Grant GA 1964. Paul N. Taylor assisted with the K and Ar analyses.)

The K-Ar data were obtained using standard analytical techniques as described by Armstrong (1970). Argon was determined by isotope dilution, potassium by atomic absorption spectrophotometry. The dates were computed using the following constants: $K^{40} = 0.0119$ atom percent; $\lambda_\beta = 4.72 \times 10^{-10}$ yr^{-1}, $\lambda_e = 0.584 \times 10^{-10}$ yr^{-1}. Analyses of standards indicate that calibrations are accurate within 2%. Uncertainties reported are for analytical error only and represent one standard deviation, or the standard error for averaged dates. K and Ar analytical data are given in the sample descriptions. Strontium isotopic analyses were done on a six-inch Nier-type mass spectrometer equipped with expanded scale recorder. On this instrument the E & A Sr standard gives $Sr^{87}/Sr^{86} = .7080$.

In all but one case (Y-58N260) the modal percentages of the rock constituents given in the petrographic descriptions are based on measurement of 250 to 500 points per rock, by the Chayes point-count method. The petrographic identifications are based on the Rittman classification.

SAMPLE DESCRIPTIONS

1. Y-B1-14 K-Ar (whole rock) 7.6±1.7 m.y.

Malpais Basalt, top of uppermost flow. (NW/4 NE/4 SE/4 Sec. 10, T3S, R42E; 37°41′45″N, 117°14′50″W; top of Malpais Mesa about 28 m above, and about 140 m SSW of Y-B1-2; Esmeralda Co., NV). A black porphyritic rock with plagioclase phenocrysts up to 3 mm long, with weakly developed flow structure. Slightly vesicular, with vesicles partly to completely filled with carbonate. Zoned plagioclase phenocrysts (An_{43-51}) constitute 30% of the rock, olivine (thoroughly iddingsitized) 10%, and groundmass the remainder. The plagioclase phenocrysts have a 0.05-mm rim of more sodic plagioclase and contain numerous inclusions of phlogopite, olivine, and magnetite. Plagioclase microlites constitute more than half the trachytic groundmass; the rest is olivine (iddingsitized), magnetite, hematite, and pyroxene, with accessory phlogopite and apatite. Analytical data: K = 0.963, 0.967%; $\bar{A}r^{40} = 0.294 \times 10^{-6}$ cc/gm (4% Σ Ar^{40}). Comment: See Y-B1-1 below.

2. Y-B1-17 K-Ar (whole rock) 8.0±2 m.y.

Malpais Basalt, base of the uppermost flow. (NW/4 NE/4 SE/4 Sec. 10, T3S, R42E; 37°41′45″N, 117°14′45″W; mesa above Pozo Canyon; about 24 m above, and about 65 m W of Y-B1-2; Esmeralda Co., NV). A black vesicular rock with very large phenocrysts of plagioclase (68% of the rock). In thin section, pyroxene and olivine microphenocrysts are also visible. The zoned plagioclase (An_{46-79}) phenocrysts are up to 7.8 mm long

and contain poicilitic inclusions of augite, titanaugite, and iddingsitized olivine microlites and occasional grains of phlogopite and magnetite. The exceedingly fine grained groundmass is trachytic and consists of plagioclase, euhedral diopside, and granular olivine (iddingsitized), with magnetite, hematite, and scattered grains of apatite and phlogopite. A small amount of secondary carbonate is present in the groundmass. Analytical data: K = 0.993, 1.00%; $\overset{*}{A}r^{40} = 0.265 \times 10^{-6}$ cc/gm (1% Σ Ar^{40}), 0.361×10^{-6} cc/gm (5% Σ Ar^{40}). Comment: See Y-B1-1 below.

3. Y-B1-2 K-Ar (whole rock) 6.8±1.5 m.y.

Malpais Basalt, basal flow. (NW/4 NE/4 SE/4 Sec. 10, T3S, R42E; 37°41′45″N, 117°14′40″W; NW wall of Pozo Canyon; Esmeralda Co., NV). A fine-grained porphyritic rock differing from Y-B1-1 mainly in the pronounced trachytic texture of the groundmass and different proportions of the phenocryst minerals (labradorite 85-90%, olivine 10-15%, with an occasional grain of diopside), and the presence of scattered grains of phlogopite in the groundmass. The plagioclase phenocrysts are remarkably unaltered, whereas the plagioclase microlites are partly replaced by green fibrous chlorite. Chlorite is also developed in interstitial patches of phlogopite and orthoclase representing the final of crystallization. Analytical data: K = 1.04, 1.01%; $\overset{*}{A}r^{40} = 0.278 \times 10^{-6}$ cc/gm (4% Σ Ar^{40}). Comment: See Y-B1-1 below.

4. Y-B1-1 K-Ar (whole rock) 8.7±1.5 m.y.

Malpais Basalt, basal flow. (NW/4 NE/4 SE/4 Sec. 10, T3S, R42E; 37°41′45″N, 117°14′140″W; NW wall of Pozo Canyon; Esmeralda Co., NV). A fine- to medium-grained, slightly vesicular, porphyritic rock with vesicles sparsely lined with calcite. Phenocrysts of labradorite (An_{50}), olivine, and diopside comprise 40% of the rock. The phenocrysts are mostly (98%) plagioclase. The olivine is extensively iddingsitized and the pyroxene slightly altered to serpentine. Andesine, olivine, and pyroxene microlites plus accessory phlogopite, magnetite, and apatite can be identified in the groundmass, which is exceedingly fine-grained. A small amount of carbonate has been developed in the olivine, a small amount of palagonite and clay in the labradorite phenocrysts, and a notable quantity of clay in the labradorite microlites. Analytical data: K = 0.999, 0.977%; $\overset{*}{A}r^{40} = 0.325 \times 10^{-6}$ cc/gm (5% Σ Ar^{40}), 0.363×10^{-6} cc/gm (5% Σ Ar^{40}). Comment: Samples Y-B1-1, B1-2, B1-14, and B1-17 are from two flows of the 30 m thick Malpais Basalt (Ransome et al, 1909, p. 72) which caps the mesa. The average date for the basalt (∿7.7 m.y.) is greater than the more precise age of 6.7±.1 m.y. obtained for the underlying Spearhead "Rhyolite." The errors are so large that the discrepancy is not significant; but the excess age suggests that the basalt may have been slightly contaminated with radiogenic argon at the time of eruption. It seems reasonable to assume that the flows constituting the Malpais Basalt were extruded not long after deposition of the Spearhead, and within a relatively brief time interval.

5. Y-Tsp K-Ar (feldspar) 6.7±0.10 m.y.
(whole rock) 6.8±0.14 m.y.

Spearhead "Rhyolite," from type locality (Ransome et al, 1909, p. 71) (NW/4 SE/4 NE/4 Sec. 10, T3S, R42E; 37°41′40″N, 117°14′20″W; quarry near Rabbit Spring at the foot of Malpais Mesa, just S of Spearhead Point; Esmeralda Co., NV). Actually a welded ash flow tuff, not a rhyolite flow forming vertical cliffs 10 to 12 ft high, particularly where overlain by the resistant Malpais Basalt. It is a brown to gray-brown porphyroclastic rock, with quartz and feldspar grains up to 2 mm long in an aphanitic matrix. Fragments of volcanic rock up to 1.25 cm square are scattered sparsely throughout, along with lenticular streaks of gray devitrified pumice and dark brown glassy *fiamme*. Parallelism of the pumice and *fiamme* gives the rock a streaky appearance which is further enhanced by flattened vesicles up to 5 cm long. In thin section, fragmented quartz and sanidine constitute up to 95% of the crystals, clinopyroxene the remainder. The matrix consists predominantly of flattened glass shards with a few grains of accessory apatite and magnetite. Eutaxitic texture is common throughout the rock. Analytical data: (Sanidine) K = 5.60, 5.62%; $\overset{*}{A}r^{40} = 1.48 \times 10^{-6}$ cc/gm (56% Σ Ar^{40}), 1.52×10^{-6} cc/gm (69% Σ Ar^{40}). (Whole rock) K = 4.15, 4.22%; $\overset{*}{A}r^{40} = 1.14 \times 10^{-6}$ cc/gm (62% Σ Ar^{40}). Comment: See Y-58N264 below.

6. Y-58N264 K-Ar (whole rock) 7.1±0.5 m.y.

Spearhead "Rhyolite." (SE/4 SW/4 NW/4 Sec. 25, T3S, R43E; 37°39′10″N, 117°06′40″W; low cliff on SE side of a wash about 7 mi ESE of Rabbit Springs; Nye Co., NV). Very fine-grained dark reddish-brown, densely welded ash flow tuff forming bold cliff-like outcrops even when not protected by a capping of more resistant rock. It consists largely of glass shards with sparse sanidine crystals and lithic fragments; occasional flattened vesicles are seen. The slightly devitrified glassy matrix contains grains of magnetite and hematite and needles of rutile(?). The lithic fragments are largely collapsed pumice in the form of *fiamme.* The presence of tiny tridymite crystals throughout the rock and lining the vesicles indicates that the ash flow cooled in the vapor phase. Analytical data: K = 4.02, 4.08%; $\overset{*}{A}r^{40} = 1.16 \times 10^{-6}$ cc/gm (13% ΣAr^{40}). Comment: According to Ransome et al (1909, p. 70-71) the Spearhead at Malpais Mesa consists of two distinct flows, with no evidence of any interval of erosion or deposition between them. Noble et al (1964, p. D26) found Ransome's Spearhead Rhyolite to be a simple cooling unit, part of a large composite sheet forming the lower part of the Thirsty Canyon Tuff; traced southward from Malpais Mesa, this cooling unit incorporates additional ash flows to become a thick compound cooling unit and is underlain by another compound cooling unit of similar composition and inasmuch as the break between the two compound cooling units becomes less distinct and disappears, they reassigned both to the Spearhead Member of the Thirsty Canyon Tuff. Kistler (1968, p. 254) has obtained a potassium-argon date of 7.5 m.y. for a sample of the basal member of the Thirsty Canyon Tuff from the Black Mountain region, about 40 miles southeast of Goldfield. For the uppermost member of the Thirsty Canyon Tuff Kistler obtained a date of 6.2 m.y. This neatly brackets our result of 6.7 m.y. for the stratigraphically intermediate Spearhead member. Discrepant dates of 7.8 and 9.5 m.y. were reported for glass from the Gold Flat member that overlies the Spearhead by Marvin and others (1970).

7. Y-B2-7 K-Ar (whole rock) 11.8±0.4 m.y.
Sr^{87}/Sr^{86} initial ratio: .7043±.0007

Upper labradorite andesite flow of the capping of Blackcap Mountain. (SE/4 SW/4 NE/4 Sec. 9, T1S, R43E; 37°41′45″N, 117°09′20″W; 18 m above Y-B2-3 in the cliff face; Nye Co., NV). Dark gray to black, noticeably porphyritic andesite, consisting of 0.5-cm phenocrysts of zoned labradorite (An_{50-66};68% of the rock), 1 - mm olivine (8%), augite (16%), magnetite (6%), and phlogopite (3%) in a groundmass of microlites of these same minerals plus accessory apatite. The plagioclase phenocrysts are very slightly altered to clay, whereas the plagioclase microlites are unaltered. All the olivine is iddingsitized. There is a little interstitial glass in the groundmass. Analytical data: K = 1.30, 1.28, 1.31%; $\overset{*}{A}r^{40} = 0.633 \times 10^{-6}$ cc/gm (27% ΣAr^{40}), 0.589×10^{-6} cc/gm (36% ΣAr^{40}). Comment: See Y-58441 below.

8. Y-B2-3 K-Ar (whole rock) 12.9±1.2 m.y.

Lower labradorite andesite flow of the capping of Blackcap Mountain. (SE/4 SW/4 NE/4 Sec. 9, T1S, R43E; 37°41′45″N, 117°09′20″W; cliff face about 8 m above the base of the flow; Nye Co., NV). Dark gray to black, meagerly porphyritic with aphanitic groundmass. Phenocrysts are of zoned plagioclase (An_{50-70}) up to 0.5 mm long, titanaugite, and iddingsitized olivine. In addition to microlites of plagioclase, pyroxene, and olivine, the groundmass contains accessory magnetite, phlogopite, and apatite. Minor amounts of secondary carbonate are present in the plagioclase. The plagioclase constitutes 70% of the rock, pyroxene 14%, and olivine 4%. Analytical data: K = 1.40, 1.39%; $\overset{*}{A}r^{40} = 0.67 \times 10^{-6}$ cc/gm (8% ΣAr^{40}), 0.78×10^{-6} cc/gm (6% ΣAr^{40}). Comment: See Y-58441 below.

9. Y-5813 K-Ar (whole rock) 13.5±3 m.y.

Pigeonite-labradorite andesite (NE/4 NW/4 NE/4 Sec. 12, T2S, R42E; 37°47′10″N, 117°12′40″W; low knoll 2 mi N of Kendall Mountain; Esmeralda Co., NV). A remarkably fresh, black, fine-grained, meagerly porphyritic rock consisting of plagioclase (An_{52}), olivine, and pigeonite phenocrysts in a groundmass of the same minerals plus abundant iron oxide (magnetite?) and accessory apatite and phlogopite. The plagioclase phenocrysts

are slightly altered to clay. Analytical data: K = 0.617, 0.632%; $\overset{*}{A}r^{40}$ = 0.26 x 10^{-6} cc/gm (2% Σ Ar^{40}), 0.42 x 10^{-6} cc/gm (3% Σ Ar^{40}). Comment: See Y-58441 below.

10. Y-58441 K-Ar (whole rock) 12.0±0.5 m.y.

Olivine trachyandesite flow overlying dacite vitrophyre equivalent to Y-58N260. (SE/4 NW/4 NW/4 Sec. 11, T2S, R43E; 37°52′15″N, 117°17′45″W; low ridge about 4 mi SW of Mud Lake; Nye Co,, NV). A black fine-grained rock microporphyritic to aphyric, with texture varying from markedly trachytic to intergranular. The microphenocrysts, when present, are up to 1 mm in size and constitute less than 5% of the rock. They are of plagioclase (An_{55}), intensely iddingsitized olivine, clear diopside, and magnetite. The groundmass consists of microlites of the same plagioclase (60% of the groundmass), iddingsitized olivine (20%), diopside in clear laths (10%), and clouds of magnetite grains, plus occasional flakes of phlogopite and grains of apatite. All the plagioclase is slightly altered to clay along fractures and, in some crystals, in the cores. Analytical data: K = 1.74, 1.72, 1.74%; $\overset{*}{A}r^{40}$ = 0.83 x 10^{-6} cc/gm (16% Σ Ar^{40}), 0.85 x 10^{-6} cc/gm (8% Σ Ar^{40}). Comment: Blackcap Mountain is a small butte in the Goldfield volcano-tectonic depression in Nye County, ½ mile east of the Esmeralda County line. The butte has been preserved from erosion by a capping consisting of two flows which Ransome et al (1909, p. 73 and pl. 2) identified with the Malpais Basalt. The dates obtained for these flows, 11.8 and 12.9 m.y., correspond to the Barstovian-Clarendonian boundary (Evernden and others, 1964); correlation with the Malpais Basalt is ruled out. The date for sample Y-5813 from a petrographically similar rock four miles northwest of Blackcap Mountain is consistent with the interpretation that it could be a part of the Blackcap Mountain flows. Likewise, the trachyandesite flow that supplied sample Y-58441 is probably part of the same volcanic episode, although not one of the other flows dated.

11. Y-5780 K-Ar (whole rock) 15.8±2 m.y.

Olivine trachyandesite flow (NE/4 NE/4 NW/4 Sec. 23, unsurveyed T4N, R43E; 38°11′35″N, 117°07′10″W; on the W drainage of a small valley 2-½ mi W of the Rye Patch pump station near Tonopah; Nye Co., NV). A black, aphanitic, slightly vesicular rock. Microphenocrysts (<1 mm) constitute 55% of the rock. Zoned plagioclase (An_{55-61}) is the predominant microphenocryst mineral (about 5/6 of the microphenocrysts); some of the crystals are corroded and replaced by glass. Augite forms euhedral crystals, occasionally showing zones of resorption. Olivine (completely iddingsitized) is extremely rare as microphenocrysts. The groundmass consists of plagioclase, completely iddingsitized olivine, and augite microlites; minute grains of magnetite; and glass (5%). Vesicles are sometimes lined with cristobalite. Analytical data: K = 2.03, 2.00, 2.02%; $\overset{*}{A}r^{40}$ = 1.24 x 10^{-6} cc/gm (5% Σ Ar^{40}), 1.32 x 10^{-6} cc/gm (5% Σ Ar^{40}). Comment: See Y-B3-13 below.

12. Y-57233 K-Ar (whole rock) 17.9±3 m.y.

Labradorite trachyandesite flow. (SE/4 SE/4 unsurveyed T4N, R42E; 38°09′45″N, 117°12′35″W; approx. 8 mi NW of Tonopah; Nye Co., NV). A black, fine-grained, meagerly porphyritic rock. Dark green olivine and pyroxene crystals as well as sparse colorless plagioclase phenocrysts up to 1.5 mm in diameter constitute less than 10% of the rock, and are embedded in an aphanitic slightly vesicular groundmass. Under the microscope the rock is distinctly microporphyritic with marked flow structure. Phenocrysts consist of diopside, olivine (slightly iddingsitized) and plagioclase (An_{60}), and are set in a trachytic to intergranular groundmass. Plagioclase microlites constitute 70% of the groundmass, the remainder is granular olivine (slightly more iddingsitized than the phenocrysts) (10%), iron ore (10%), clear diopside laths (5%), interstitial glass (about 5%), and grains of apatite and zircon (less than 1%). The cores of plagioclase phenocrysts also show evidence of very mild attack by the groundmass. Except for one vesicle partly lined with carbonate the sample was unaltered. Analytical data: K = 2.06, 2.03%; $\overset{*}{A}r^{40}$ = 1.46 x 10^{-6} cc/gm (6% Σ Ar^{40}), 1.49 x 10^{-6} cc/gm (3% Σ Ar^{40}). Comment: See Y-B3-13 below.

13. Y-B3-13 K-Ar (whole rock) 18.9±1.5 m.y.
Sr^{87}/Sr^{86} initial ratio: .7052±.0007

Uppermost olivine trachyandesite flow of the series forming Thunder Mountain, 322 feet above the base of the series (NE/4 NE/4 SE/4 Sec. 28, T4N, R44E; 38°10′15″N, 117°02′21″W; NE of Tonopah, Nye Co., NV). A black, fine-grained slightly vesicular rock. Under the microscope it is seen to be microporphyritic, with small (<1 mm) microphenocrysts of zoned plagioclase (An_{45-51}) constituting 20% of the rock, iddingsitized olivine (10%), augite (10%), hornblende rimmed with iron oxide (about 5%), and magnetite (about 5%). The groundmass (50%) consists of microlites of the above minerals with a small amount (about 3% of the groundmass) of brown glass. Less than 0.1% of the vesicles are lined with carbonate. Analytical data: K = 1.56, 1.58%; $\overset{*}{Ar}^{40}$ = 1.15 x 10^{-6} cc/gm (8% Σ Ar^{40}), 1.23 x 10^{-6} cc/gm (9% Σ Ar^{40}). Comment: The trachyandesites represented by samples Y-5780, Y-57233, and Y-B3-13 are Miocene and definitely older than the Black Cap Mountain and related flows. A consistent decrease in age of capping mafic lavas southeastward from central Nevada was shown by Armstrong (1970). The mafic capping lavas in the Tonopah-Goldfield region show a similar southward decrease in age. The southward decrease in initial Sr^{87}/Sr^{86} ratios from central Nevada that was observed by Scott and others (1971) is paralleled by the two results we report here (samples Y-B2-7 and Y-B3-13).

14. Y-58N260 K-Ar (feldspar) 21.6±1.1 m.y.
(biotite) 21.8±0.3 m.y.

Dacite vitrophyre. (NW/4 SW/4 NE/4 Sec. 15, T1S, R43E; 37°51′20″N, 117°08′25″W; along primitive road leading from Goldfield to Mud Lake, 2 mi E of Mud Lake; Esmeralda Co., NV). A dark gray porphyritic rock with large phenocrysts of feldspar (up to 1 cm) and smaller biotite (up to 1.5 mm) in a glassy groundmass. The visible phenocrysts constitute 60% of the rock. In thin section, the very fresh euhedral plagioclase phenocrysts, zoned (An_{39-44}) and fractured, constitutes 25% of the rock, and biotite 15%. Phenocrysts of clear unaltered pyroxene (diopside, 11%; augite, 5%), equally fresh orthoclase (3%), and quartz (3%), although as large or even larger than the biotite phenocrysts, are not conspicuous in hand specimen against the glassy groundmass. The glassy to cryptocrystalline groundmass, with perlitic fracture, contains clots of fine-grained aggregates of the constituent minerals which may represent broken and engulfed crust of the lava flow. Analytical data: (Plagioclase) K = 0.650, 0.660%; $\overset{*}{Ar}^{40}$ = 0.574 x 10^{-6} cc/gm (20% Σ Ar^{40}). (Biotite) K = 6.90, 6.90%; $\overset{*}{Ar}^{40}$ = 6.12 x 10^{-6} cc/gm (54% Σ Ar^{40}), 5.92 x 10^{-6} cc/gm (63%) Σ Ar^{40}). Comment: The dates obtained on feldspar and biotite are in excellent agreement, not only with each other, but also with the date of 21.1 m.y. reported by Kistler (1968, p. 255) for a dacite vitrophyre collected about four miles southeast of Goldfield (Henry Cornwall, written communication, 1971). Kistler's dacite vitrophyre is a welded ash flow tuff; Y-58N260, on the other hand, is distinctly a flow. Nevertheless the field relations and the similarity in composition, as reflected in the petrography, leave no room for doubt that these are merely two phases of the same or closely related volcanic units.

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