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K-Ar AGES OF LATE CENOZOIC BASALTIC ROCKS IN THE NORTHERN PART OF THE MORMON VOLCANIC FIELD, NORTH-CENTRAL ARIZONA

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The Mormon volcanic field is a basaltic province of approximately 3,000 km² that straddles the boundary of the southern Colorado Plateau and the northern Arizona Transition Zone (fig. 1). The field developed in the late Cenozoic as part of the regional northeast to east migration of basaltic volcanism from the Transition Zone onto the Colorado Plateau (Luedke and Smith, 1978; Smith and Luedke, 1984). Volcanism in the field was concurrent with mild extensional stress and normal faulting that were probably distal and late-stage events of the Basin and Range disturbance that strongly deformed southern Arizona in the middle to late Miocene (Shafiqullah and others, 1980; Holm and others, 1991). Most of the known vent structures occur on the Colorado Plateau within the southeast projection of the Cataract Creek fault system of Shoemaker and others (1978).

The volcanic, structural, and geomorphic histories of the Mormon field are known in general (Holm and others, 1989), and details are emerging from on going geologic mapping (1:24,000 and 1:6,000 scales) and study of the field's petrology, geochemistry, and geochronology by us and other scientists at Northern Arizona University and the U.S. Geological Survey. The field is dominated by basalt that occurs principally as sheet lavas, shield volcanoes, scoria cones, and small flows from the cones; small volumes of andesite and dacite form thick flows and lava domes locally, most notably at Mormon Mountain (fig. 1). Over 200 vent structures have been identified in the volcanic field on SLAR photo mosaics, and ground-based mapping in the northern part indicates the total number of vent structures in the entire field is probably closer to 400.

Late Miocene eruptions from vents on the Colorado Plateau produced sheet basalts that cover large areas of eroded Permian and

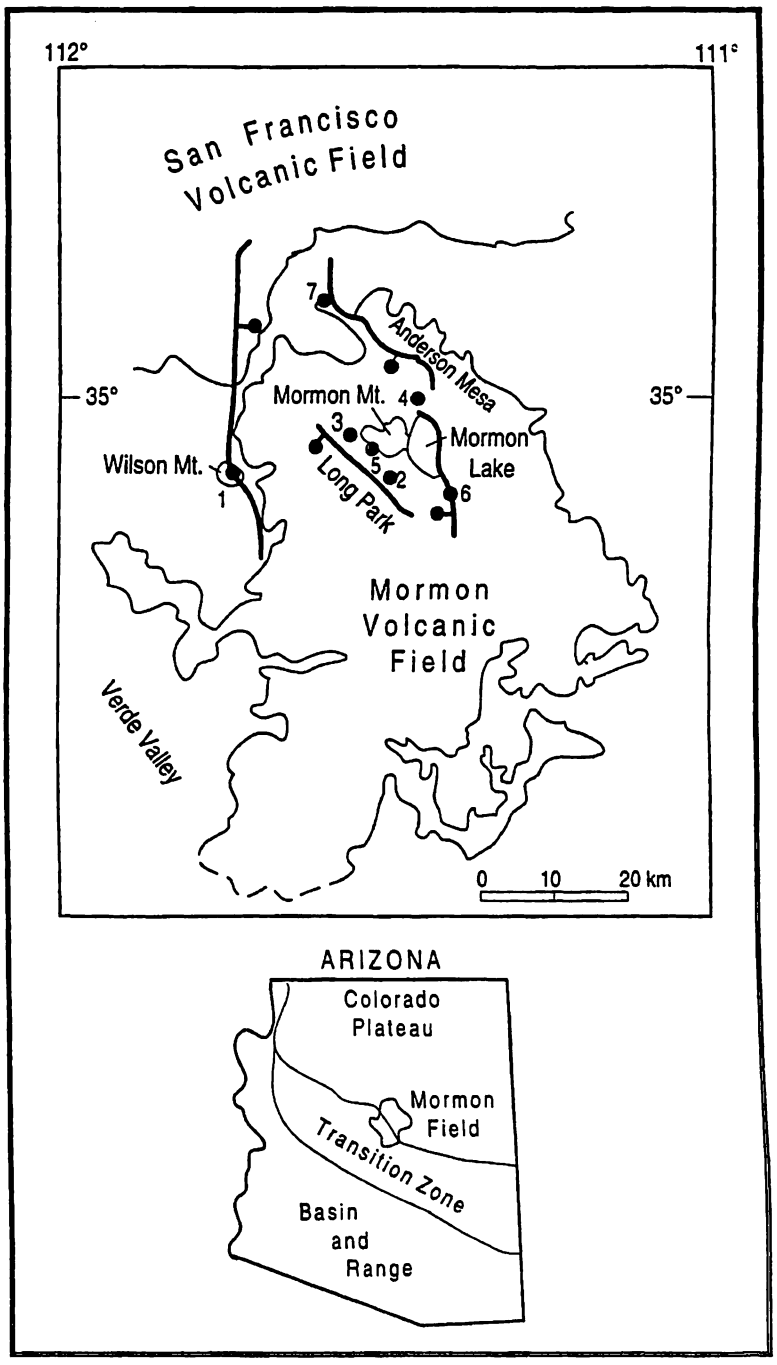

FIGURE 1. Map showing general boundary of Mormon volcanic field, locations of samples analyzed (dots with numbers), and geographic features referred to in this report. Faults are heavy lines with bar and ball on down-thrown side.

Triassic strata (6.11 ± 0.30 m.y., Damon and others, 1974) and intracanyon flows and "ramp basalts" in canyons and valleys that led down into the Verde Valley (8.10 ± 0.3 m.y., McKee and McKee, 1972; to 6.02 ± 0.91 m.y., Damon and others, 1974; Peirce and others, 1979; Elston, 1984; Peirce and Nations, 1986; Holm and Cloud, 1990). Except for four Pleistocene cones on the extreme northern edge of the field (fig. 1, sample 7), volcanism apparently ended in the early to late Pliocene after shield volcanoes and scoria cones were constructed on top of the sheet lavas, and lava domes of dacite and andesite were emplaced on or very near the shields. The youngest dacite in the composite lava dome at the Mormon Mountain silicic center records the last known major eruption; Luedke and Smith (1978) list its age as 3.1 ± 0.6 m.y.

Seven new K-Ar dates by the University of Arizona Laboratory of Isotope Geochemistry are reported here. Most of the samples were selected to date the post-sheet-lava volcanism, and to constrain the timing of volcanism and faulting in the northern part of the volcanic field. In the sample descriptions, the lithologic terms are based principally on the geochemical classification of Wilkinson (1986). Hybrid basalts, relatively common in the highly faulted parts of the Cataract Creek fault system, incorporated crustal granitic rocks. Hybrid compositions are characterized by quartz xenocrysts with clinopyroxene reaction rims in the mode, and by relatively high Mg-numbers but low normative An contents. Vent structures are identified according to field location with the 4-digit numbering system described by Wolfe and others (1987); the first digit is the second integer of the township, the second digit is the second integer of the range, and the last two digits identify the section. If two or more structures are in a section, suffixes (A, B, etc.) are added.

The K-Ar dates reported here for the northern part of the Mormon volcanic field indicate that after extrusion of late Miocene sheet lavas, eruption of shield volcanoes, scoria cones, and cone-related lava flows occurred during a relatively brief period in the early Pliocene. Faulting in the northern part of the field was broadly coeval with volcanism. The youngest known volcanic structures, however, postdate the faults with which they are associated, which suggests that volcanism may have outlasted faulting. Except for the Pleistocene cones (sample 7) on the north edge of the field, basaltic volcanism younger than the main-stage dacite of Mormon Mountain has not been identified.

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SAMPLE DESCRIPTIONS

1. *UAKA 90-002 (Field WM109-4)* K-Ar
Plagioclase-clinopyroxene-olivine transitional basalt dike in vent 8629 (34°55′02″N, 111°45′01″W; elev. 2170 m; SW/4,SE/4,NE/4, S29,T18N,R06E; Wilson Mountain quad., Coconino Co., AZ). *Analytical data:* %K = 1.196, 1.199, 1.175, 1.198, 1.224; $^{40}Ar^* \times 10^{-12}$mol/g = 12.351, 12.481, 12.674, 12.347, 12.444; $^{40}Ar^*/\Sigma^{40}Ar$ = 30.4%, 29.6%, 28.5%, 30.4%, 29.8%. *Comments:* Feeder dike in scoria cone at the summit of Wilson Mountain. The cone was the source for the youngest intracanyon lava flow on Wilson Mountain. Both the lava flow and the cone were displaced by the Oak Creek fault. Petrography and geochemistry suggest the rock is a hybrid. Approximately 20 km north of Wilson Mountain, a nonfaulted benmoreite cone overlies the Oak Creek fault; the lava flow from this cone has a K-Ar age of 1.16 ± 0.04 m.y. (Wolfe and others, 1987). *Collected by:* R. F. Holm.
(feldspar concentrate) 5.99 ± 0.14 m.y.

2. *UAKA 90-005 (Field MM134-2)* K-Ar
Clinopyroxene-olivine transitional basalt dike in vent 8836B (34°54′03″N,111°30′11″W; elev. 2316 m; NE/4,SW/4,NW/4,S36,T18N,R08E; Mormon Mountain quad., Coconino Co., AZ). *Analytical data:* %K = 0.685, 0.680, 0.680; $^{40}Ar^* \times 10^{-12}$mol/g = 5.468, 5.199, 5.498, 5.156; $^{40}Ar^*/\Sigma^{40}Ar$ = 53.9%, 58.3%, 56.0%, 60.4%. *Comments:* Feeder dike in nonfaulted scoria cone that overlies a fault associated with Long Park graben; cone is parasitic on a shield volcano cut by the fault and Long Park graben. Petrography and geochemistry suggest the rock is a hybrid. *Collected by:* R. F. Holm.
(feldspar concentrate) 4.51 ± 0.13 m.y.

3. *UAKA 90-006 (Field MM146-2)* K-Ar
Plagioclase-clinopyroxene-olivine transitional basalt lava flow from vent 8804A (34°57′49″N,

111°33′10″W; elev. 2387 m; SE/4,SE/4,SW/4, S04,T18N,R08E; Mormon Mountain quad., Coconino Co., AZ). *Analytical data:* %K = 0.507, 0.515, 0.511, 0.505, 0.515; $^{40}Ar^* \times 10^{-12}$mol/g = 3.883, 3.973, 3.966, 3.747; $^{40}Ar^*/\Sigma^{40}Ar$ = 65.6%, 64.8%, 64.9%, 66.9%. *Comments:* The lava flow erupted from a scoria cone that is the principal vent structure at the summit of a shield volcano partly covered by the Mormon Mountain silicic center. *Collected by:* R. F. Holm.

(feldspar concentrate) 4.39 ± 0.15 m.y.

4. *UAKA 90-003 (Field ML125-2)* K-Ar
Olivine alkali basalt lava flow from Pine Grove Hill scoria cone, vent 9931B (34°59′30″N,111°28′24″W; elev. 2218 m; NE/4,NE/4,NE/4,S31,T19N,R09E; Mormon Lake quad., Coconino Co., AZ). *Analytical data:* %K = 0.427, 0.417, 0.429, 0.432, 0.431; $^{40}Ar^* \times 10^{-12}$mol/g = 3.334, 3.180, 3.331, 3.140; $^{40}Ar^*/\Sigma^{40}Ar$ = 76.4%, 78.5%, 76.9%, 78.2%. *Comments:* Lava flow fills grabens in 6.11 Ma sheet lavas of Anderson Mesa, and was faulted by reactivation of the faults of Mormon Lake and Anderson Mesa. *Collected by:* R. F. Holm.

(feldspar concentrate) 4.38 ± 0.20 m.y.

5. *UAKA 90-004 (Field MM130-2)* K-Ar
Clinopyroxene-olivine subalkaline basalt plug in scoria cone 8810A (34°56′53″N,111°32′11″W; elev. 2355 m; SW/4,SE/4,SW/4,S10,T18N,R08E; Mormon Mountain quad., Coconino Co., AZ). *Analytical data:* %K = 1.071, 1.100, 1.064; $^{40}Ar^* \times 10^{-12}$mol/g = 7.917, 7.549, 7.552, 7.966, 7.757; $^{40}Ar^*/\Sigma^{40}Ar$ = 53.0%, 52.8%, 57.9%, 52.8%, 54.0%. *Comments:* The scoria cone is parasitic on a shield volcano. The cone is one of the youngest basaltic units beneath the Mormon Mountain silicic center. Petrography and geochemistry suggest the rock is a hybrid. *Collected by:* R. F. Holm.

(feldspar concentrate) 4.14 ± 0.11 m.y.

6. *UAKA 91-057 (Field ML18-3)* K-Ar
Clinopyroxene-olivine basanitic alkali basalt plug in scoria cone 7902B (34°52′53″N,111°25′07″W; elev. 2402 m; SW/4,NW/4,SW/4,S02,T17N,R09E; Mormon Lake quad., Coconino Co., AZ). *Analytical data:* %K = 0.390, 0.388, 0.379, 0.374, 0.381; $^{40}Ar^* \times 10^{-12}$mol/g = 2.627, 2.485, 2.583, 2.634, 2.564; $^{40}Ar^*/\Sigma^{40}Ar$ = 57.1%, 57.2%, 64.2%, 57.0%, 58.2%. *Comments:* The scoria cone overlies the normal fault that bounds the east side of Mormon Lake. This sample and sample 4 bracket the time of latest movements of the fault. Field relationships indicate the scoria cone probably postdates the eruption of a nearby dacite dome that is nearly identical in petrography and geochemistry to the oldest volcano-stratigraphic unit in the Mormon Mountain silicic center (Holm and others, 1989). *Collected by:* R. F. Holm.

(feldspar concentrate) 3.89 ± 0.10 m.y.

7. *UAKA 89-036 (Field FE112-2)* K-Ar
Plagioclase-clinopyroxene-olivine transitional basalt lava flow from scoria cone 0711B (35°07′45″N,111°36′04″W; elev. 2070 m; SE/4, NW/4,SE/4,S12,T20N,R07E; Flagstaff East quad., Coconino Co., AZ). *Analytical data:* %K = 1.005, 1.006, 1.003; $^{40}Ar^* \times 10^{-12}$mol/g = 1.432, 1.457, 1.586, 1.515; $^{40}Ar^*/\Sigma^{40}Ar$ = 66.9%, 67.7%, 55.3%, 63.3%. *Comments:* The lava flow erupted from the northwestern-most cone in a row of four cones. The flow entered the incised drainage of Walnut Creek along the Anderson Mesa fault, and also flowed into the northwest end of the Lake Mary graben. The lava flow is not faulted, and therefore gives the youngest possible time of movement on the faults. The flow is partly dissected by Walnut Creek. Quaternary age and field position suggest the lava may be affiliated with the San Francisco volcanic field. Geochemistry indicates the rock is a hybrid. *Collected by:* R. F. Holm.

(feldspar concentrate) 0.859 ± 0.055 m.y.

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