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Neil Suneson and Ivo Lucchitta

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K/AR AGES OF CENOZOIC VOLCANIC ROCKS WEST-CENTRAL ARIZONA

NEIL SUNESON — *Department of Geological Sciences, University of California, Santa Barbara, CA 93106*
IVO LUCCHITTA — *U.S. Geological Survey, 2255 North Gemini Drive, Flagstaff, AZ 86001*

INTRODUCTION

Recently completed mapping of the Castaneda Hills 15′ quadrangle, located north of the Bill Williams River in west-central Arizona (fig. 1), has yielded a detailed picture of volcanism and tectonism along the eastern margin of the southern Basin and Range province. When compared with other parts of this province, the area is somewhat anomalous tectonically because low hills rising above valleys floored by either basement rocks or thin alluvial veneers are present instead of deep basins bordered by mountain ranges. The quadrangle also includes a northwest-trending lineament that separates mountain ranges with anomalous northeast trends (Harquahala, Harcuvar, Buckskin) from ranges with more normal north-northwest trends (Hualapai, Black). This lineament also separates a linear array of Tertiary metamorphic core complexes located to the southwest (Rehrig and Reynolds, 1977) from basement rocks of Precambrian age located to the northeast of the lineament. The exact nature of this northwest-trending lineament is poorly understood, but the lineament is aligned with the southeast extension of the Stewart Valley right-lateral fault (Stewart and others, 1968) and it marks a concentration of late-Miocene silicic volcanic centers in the Castaneda Hills quadrangle.

Petrographic and chemical evidence indicates that the volcanic rocks in this part of Arizona are strongly bimodal (Suneson and Lucchitta, 1978). A systematic program of isotopic dating has established a regional stratigraphy for the volcanic rocks, the age of inception and termination of major basin-range faulting, and the synchronous nature of rhyolite and basalt volcanism. In addition, approximate age limits have been assigned to a period of regional thrusting and/or gravity gliding that was originally recognized by Lasky and Webber (1949). This paper reports 17 new K/Ar ages from the Castaneda Hills 15′ quadrangle and one new K/Ar age from the adjacent Artillery Peak 15′ quadrangle.

This work was carried out under the auspices of the Western Arizona Tectonics project of the U.S. Geological Survey and was supported in part by Geological Society of America Penrose Grant No. 2398-78 to N. H. Suneson. Argon extraction and isotopic analysis for many of the samples was carried out by Suneson at the U.S. Geological Survey laboratory in Menlo Park, Calif. The authors wish to thank B. Myers, J. C. Von Esson, and E. H. McKee, all of the U.S. Geological Survey in Menlo Park, for their assistance in helping with the extraction and analysis procedures. The interpretation of the dates and the discussion of the geology of the Castaneda Hills quadrangle is entirely the authors' responsibility, however.

GEOLOGICAL DISCUSSION

Rocks exposed in the Castaneda Hills 15′ quadrangle include Precambrian granitic and gneissic rocks, Tertiary(?) gneiss, diorite, and schist, Cenozoic continental clastic and volcanic rocks, and Quaternary alluvial and colluvial deposits (Lucchitta and Suneson, 1977a). Locally, the Tertiary sedimentary and volcanic rocks unconformably overlie the Precambrian and Tertiary(?) metamorphic rocks; elsewhere, these rocks are separated by subhorizontal tectonic surfaces. Thrust and/or gravity glide masses composed of Precambrian(?) or Tertiary(?) schist, quartzite, marble, metavolcanic and plutonic rocks (Lucchitta and Suneson, 1977b; Shackelford, 1977) are locally interbedded in the sedimentary and volcanic sequence. Tertiary gneiss complexes have only recently been recognized in western Arizona (Rehrig and Reynolds, 1977). The westward extent of these complexes has not been established, but there seems to be little doubt that much of the "Precambrian" basement southwest of the lineament described previously and shown on the geologic map of Arizona (Wilson and others, 1969) may, in fact, be Tertiary. Until more detailed studies on the presedimentary gneiss and schist have been completed, we shall refer to the basement rocks in the Castaneda Hills quadrangle as Precambrian(?) or Tertiary(?).

All of the volcanic rocks for which we have isotopic ages (16.5–6.8 m.y.) are younger than a widespread breccia that was eroded from the front of an advancing surface thrust or gravity glide mass (Lucchitta and Suneson, 1977b). Deposition of this chaotic breccia, composed of angular fragments of schistose metavolcanic and metasedimentary rocks, marks a period of intense thrusting or gravity gliding in the Castaneda Hills quadrangle. The breccia is in part overridden by the thrust and in part represents a highly fractured thrust sheet. The absence of any regional unconformities between the breccia and the oldest dated basalt (CH-61, 16.5 m.y.) suggests that deposition of the breccia is not much earlier than eruption of the basalt. We believe, therefore, that a period of major thrust faulting involving Tertiary(?) metavolcanic rocks over Precambrian(?) of Tertiary(?) gneiss occurred slightly before 16.5 m.y. ago. This thrust faulting is similar to, but slightly older than, a period of thrust faulting involving similar rocks described by Davis and others (1977). Davis and others suggest that a heterogeneous assemblage of Precambrian basement, Paleozoic metasedimentary, Mesozoic(?) plutonic, and Tertiary sedimentary and volcanic rocks was thrust northeastward over Mesozoic and/or lower Tertiary quartzo-feldspathic gneisses approximately 13–15 m.y. ago.

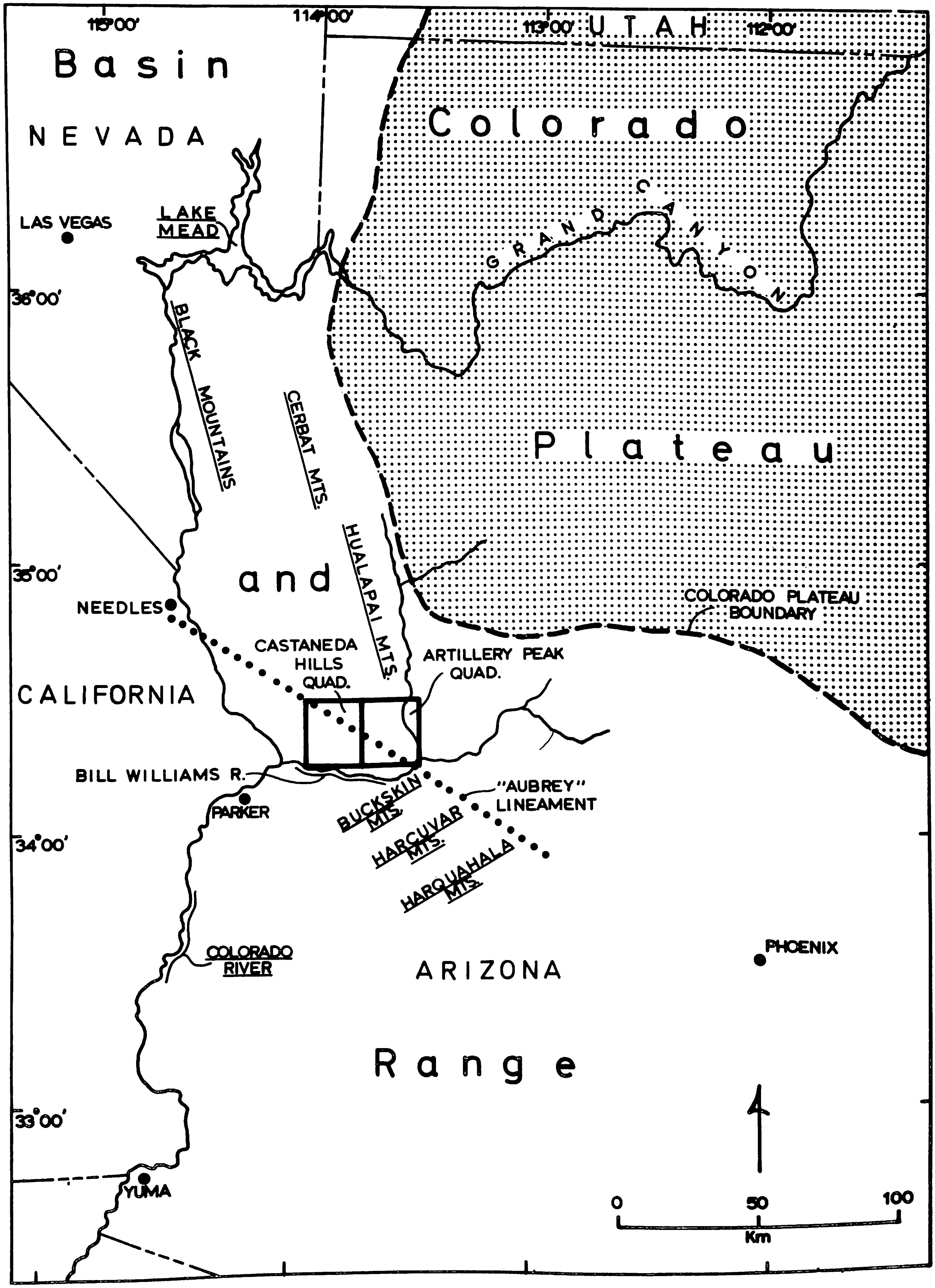

FIGURE 1. Location map.

In the northern third of the quadrangle, silicic volcanic rocks, dated at 15.1–10.3 m.y., overlie and are interbedded with a distinctive red arkosic conglomerate. The conglomerate is present in plates that represent a second period of thrusting or gravity gliding in the southern part of the quadrangle. This second period of thrusting or gravity gliding appears to have affected a smaller area than the earlier event and involves relatively small plates of Tertiary(?) quartzite, marble, and plutonic rocks over red conglomerate; basalt that is too altered to date locally underlies these plates. If this basalt correlates with the basalt that overlies the breccia, this later period of thrusting and gravity gliding occurred between 16.5 and 15.1 m.y. ago.

Estimates of the age of major normal faulting in the study area are based on two lines of evidence: (1) the amount of tilting undergone by volcanic units of different age, and (2) the degree to which individual volcanic units are cut by normal faults. In general, the older volcanic units are more steeply tilted and cut by a greater number of faults that show more displacement than are younger units. The oldest dated unit (CH-61, basalt, 16.5±0.2 m.y.) is steeply tilted; we believe, therefore, that most basin-range faulting occurred after 16.5 m.y. The absence of thick accumulations of basin beds beneath the basalt suggests that little, if any, basin-range deformation occurred before eruption of the basalt. The rhyolites and quartz-bearing basalts, 15.1–10.3 m.y. old, dip less steeply than the 16.5 m.y. basalt. Megacryst-bearing basalt flows, which are about 8–7 m.y. old, are only slightly faulted and follow present drainage patterns; normal faulting had largely ceased in this area by about that time. Quaternary alluvial deposits are unfaulted.

The volcanic rocks in the Castaneda Hills quadrangle are an example of a bimodal volcanic suite as described by Christiansen and Lipman (1972). Basalts were erupted from 16.5 to 6.8 m.y. ago and rhyolites were erupted from 15.1 to 10.3 m.y. ago. In areas where basalt and rhyolite were erupted approximately simultaneously, the basalt contains quartz "xenocrysts". Basalts erupted at the same time as the rhyolites (for example, CH-47 and CHSE-164) but in different areas contain no quartz.

ANALYTICAL METHODS

Rhyolite ages were determined using sanidine and biotite, crushed to either the 60–100 or 60–140 mesh fraction. Basalt ages were determined using crushed whole rock samples (60–100 mesh) which were decanted and cleaned in hydrofluoric and nitric acids, as well as in an ultrasonic bath. Crushed samples were loaded into the extraction line within eight hours of preparation. Potassium was analyzed by a lithium metaborate fusion-flame photometer procedure (Ingamells, 1962) with lithium as the internal standard (analyst, P. Klock); one K_2O determination was made for each sample.

Argon extraction and purification techniques are similar to those described by Dalrymple and Lanphere (1969). Argon content was determined using standard isotope dilution techniques (Dalrymple and Lanphere, 1969). Argon composition was determined using a Nier-type 60°-sector 15.24 cm radius mass spectrometer operated in the static mode. Sample CHNE-152 was analyzed on a 5-collector first-order direction-focussing, 22.9 cm radius mass spectrometer controlled by a PDP8/C minicomputer that takes peak heights simultaneously from the three Ar collectors. The constants used in the age calculation are: $\lambda_\beta = 4.963 \times 10^{-10}$ yr^{-1}, $\lambda_\epsilon + \lambda_\epsilon' = 0.581 \times 10^{-10}$ yr^{-1}, $^{40}K/\Sigma K = 1.167 \times 10^{-4}$ mole/mole. The estimated analytical uncertainly represents the precision of the K (σ_K = 0.5%) (Cox and Dalrymple, 1967) and Ar (σ^{40}_{38} = 0.2%) (Cox and Dalrymple, 1967) analyses and is reported at the 1σ level.

SAMPLE DESCRIPTIONS

1. *CH-61* K-Ar
Basalt. (NW/4 SW/4 S30,T13N,R16W; 34°26′05″N, 113°58′57″W; Castaneda Hills 15′ quad., Mohave Co., AZ). K_2O = 2.403%, $^*Ar^{40} = 5.750 \times 10^{-11}$ mole/gm, $^*Ar^{40}/\Sigma Ar^{40}$ = 73.3%; *Collected by:* N. Suneson; *dated by:* N. Suneson. *Comment:* Upper part of trachybasalt, alkali-olivine basalt, trachyandesite sequence of Suneson and Lucchitta (1978) that underlies Peach Springs Tuff (Young, 1966). The Peach Springs Tuff has been dated by Damon and others (1966, p. 28) at 16.9±0.4 m.y.
(whole rock) 16.5±0.2 m.y.

2. *CHNE-152* K-Ar
Rhyolite. (SE/4, NE/4 S22,T13N,R15W; 34°27′09″N, 113°48′43″W; hill 2422′; Castaneda Hills 15′ quad., Mohave Co., AZ). K_2O = 10.18%, $^*Ar^{40}$ = 2.226 x 10^{-10} mole/gm, $^*Ar^{40}/\Sigma Ar^{40}$ = 45.7%. *Collected by:* N. Suneson; *dated by:* E. H. McKee. *Comment:* Dome intruding poorly consolidated conglomerate.
(sanidine) 15.1±0.1 m.y.

3. *CH-26* K-Ar
Quartz-bearing basalt or basaltic andesite. (SW/4 NE/4 S21,T12N,R15W; 34°22′08″N, 113°49′24″W; Castaneda Hills quad., Mohave Co., AZ). K_2O = 2.320%, $^*Ar^{40}$ = 4.575 x 10^{-11} mole/gm, $^*Ar^{40}/\Sigma Ar^{40}$ = 49.8%. *Collected by:* N. Suneson; *dated by:* N. Suneson. *Comment:* Referred to as a quartz-bearing "basalt" by Suneson and Lucchitta (1978); is intruded by CHNE-151.
(whole rock) 13.7±0.3 m.y.

4. *CH-47* K-Ar
Basalt. (NW/4 SW/4 S1,T13N,R17W; 34°29′31″N, 113°59′52″W; Castaneda Hills 15′ quad., Mohave Co., AZ). K_2O = 1.288%, $^*Ar^{40}$ = 2.43 x 10^{-11} mole/gm, $^*Ar^{40}/\Sigma Ar^{40}$ = 55.4%. *Collected by:* N. Suneson; *dated by:* N. Suneson. *Comment:* Referred to as mesa-capping basalt by Suneson and Lucchitta (1978).
(whole rock) 13.1±0.2 m.y.

5. *CHNW-159* K-Ar

Rhyolite. (NW/4 SW/4 S10,T12N,R16W; 34°23'46"N, 113°55'12"W; hill 1981'; Castaneda Hills 15' quad., Mohave Co., AZ). K_2O = 11.87%, $*Ar^{40}$ = 2.238 x 10^{-10} mole/gm, $*Ar^{40}/SAr^{40}$ = 84.8%. *Collected by:* N. Suneson; *dated by:* N. Suneson.

(sanidine) 13.1±0.1 m.y.

6. *CHSE-164* K-Ar
Basalt. (SW/4 SW/4 S19,T11N,R15W; 34°16'30"N, 113°52'07"W; Castaneda Hills 15' quad., Mohave Co., AZ). K_2O = 1.153%, $*Ar^{40}$ = 2.158 x 10^{-11} mole/gm, $*Ar^{40}/SAr^{40}$ = 33.1%. *Collected by:* N. Suneson; *dated by:* N. Suneson. *Comment:* Referred to as mesa-capping basalt by Suneson and Lucchitta (1978).

(whole rock) 13.0±0.5 m.y.

7. *CHNW-156* K-Ar
Rhyolite. (SW/4 SE/4 S24,T13N,R17W; 34°26'42"N, 113°59'30"W; hill 2130'; Castaneda Hills quad., Mohave Co., AZ). K_2O = 12.10%, $*Ar^{40}$ = 2.214 x 10^{-10} mole/gm, $*Ar^{40}/SAr^{40}$ = 72.3%. *Collected by:* N. Suneson; *dated by:* N. Suneson. *Comment:* Intrudes CH-61 and Peach Springs Tuff.

(sanidine) 12.7±0.1 m.y.

8. *AP-04A* K-Ar
Rhyolite. (SW/4 NW/4 S21,T12N,R14W; 34°22'12"N, 113°43'44"W, Potts Mtn.; Artillery Peak 15' quad., Mohave Co., AZ). K_2O = 11.44%, $*Ar^{40}$ = 2.079 x 10^{-10} mole/gm, $*Ar^{40}/SAr^{40}$ = 75.7%. *Collected by:* N. Suneson; *dated by:* N. Suneson.

(sanidine) 12.6±0.1 m.y.

9. *CH-58B* K-Ar
Quartz-bearing basalt or basaltic andesite. (NW/4 SE/4 S21,T13N,R16W; 34°27'01"N, 113°56'10"W; hill 2425'; Castaneda Hills 15' quad., Mohave Co., AZ). K_2O = 1.849%, $*Ar^{40}$ = 3.311 x 10^{-11} mole/gm, $*Ar^{40}/SAr^{40}$ = 53.5%. *Collected by:* N. Suneson; *dated by:* N. Suneson. *Comment:* Referred to as quartz-bearing "basalt" by Suneson and Lucchitta (1978).

(whole rock) 12.4±0.1 m.y.

10. *CHNE-153* K-Ar
Rhyolite. (SE/4 SE/4 S33,T13N,R15W; 34°25'03"N, 113°49'48"W; hill 2533'; Castaneda Hills 15' quad., Mohave Co., AZ). K_2O = 9.17%, $*Ar^{40}$ = 1.638 x 10^{-10} mole/gm, $*Ar^{40}/SAr^{40}$ = 60.4%. *Collected by:* N. Suneson; *dated by:* N. Suneson. *Comment:* Rhyolite lava flow in Aubrey Hills.

(sanidine) 12.4±0.2 m.y.

11. *CHNE-151* K-Ar
Rhyolite. (SW/4 SW/4 S15,T12N,R15W; 34°22'40"N, 113°48'40"W; Castaneda Hills 15' quad., Mohave Co., AZ). K_2O = 10.19%, $*Ar^{40}$ = 1.821 x 10^{-10} mole/gm, $*Ar^{40}/SAr^{40}$ = 86.2%; *Collected by:* N. Suneson; *dated by:* N. Suneson. *Comment:* Intrudes quartz-bearing basalt (CH-26).

(sanidine) 12.4±0.1 m.y.

12. *CHNW-155* K-Ar
Rhyolite. (NW/4 NW/4 S19,T13N,R16W; 34°27'28"N, 113°58'43"W; Castaneda Hills 15' quad., Mohave Co., AZ). K_2O = 9.89%, $*Ar^{40}$ = 1.670 x 10^{-10} mole/gm, $*Ar^{40}/SAr^{40}$ = 54.0%. *Collected by:* N. Suneson; *dated by:* N. Suneson.

(biotite) 11.7±0.2 m.y.

13. *CHSW-158* K-Ar
Rhyolite. (NW/4 NW/4 S12,T11N,R17W; 34°18'50"N, 113°59'18"W; Castaneda Hills 15' quad., Mohave Co., AZ). K_2O = 6.52%, $*Ar^{40}$ = 9.708 x 10^{-11} mole/gm, $*Ar^{40}/SAr^{40}$ = 77.7%. *Collected by:* N. Suneson; *dated by:* N. Suneson. *Comment:* Rhyolite dike in Bill Williams Mountains; contains abundant basalt xenoliths.

(sanidine) 10.3±0.1 m.y.

14. *CH-111* K-Ar
Basalt. (SE/4 SE/4 S23,T11N,R17W; 34°16'38"N, 113°59'39"W; Castaneda Hills 15' quad., Mohave Co., AZ). K_2O = 2.380%, $*Ar^{40}$ = 3.151 x 10^{-11} mole/gm, $*Ar^{40}/SAr^{40}$ = 39.8%. *Collected by:* N. Suneson; *dated by:* N. Suneson. *Comment:* Referred to as "mesa-capping" basalt by Suneson and Lucchitta (1978). Age similar to that reported by Armstrong and others (1976) for geomorphically similar basalt.

(whole rock) 9.2±0.2 m.y.

15. *CHSE-166* K-Ar
Basalt. (SE/4 SE/4 S3,T11N,R15W; 34°19'12"N, 113°48'05"W; Castaneda Hills 15' quad., Mohave Co., AZ). K_2O = 0.698%, $*Ar^{40}$ = 7.717 x 10^{-12} mole/gm, $*Ar^{40}/SAr^{40}$ = 13.4%. *Collected by:* N. Suneson; *dated by:* N. Suneson. *Comment:* Referred to as "megacryst-bearing" basalt by Suneson and Lucchitta (1978).

(whole rock) 7.7±0.5 m.y.

16. *CH-78* K-Ar
Basalt. (SW/4 SE/4 S12,T12N,R17W; 34°23'33"N, 113°58'55"W; Castaneda Hills 15' quad., Mohave Co., AZ). K_2O = 1.985%, $*Ar^{40}$ = 2.157 x 10^{-11} mole/gm, $*Ar^{40}/SAr^{40}$ = 51.4%. *Collected by:* N. Suneson; *dated by:* N. Suneson. *Comment:* Referred to as "megacryst-bearing" basalt by Suneson and Lucchitta (1978).

(whole rock) 7.5±0.2 m.y.

17. *IL-CH-77-8* K-Ar
Basalt. (SW/4 SE/4 S16,T13N,R16W; 34°27'44"N, 113°56'11"W; Castaneda Hills 15' quad., Mohave Co., AZ). K_2O = 1.135%, $*Ar^{40}$ = 1.225 x 10^{-11} mole/gm, $*Ar^{40}/SAr^{40}$ = 39.7%. *Collected by:* I. Lucchitta; *dated by:* N. Suneson. *Comment:* Referred to as "megacryst-bearing" basalt by Suneson and Lucchitta

(1978).

(whole rock) 7.5±0.2 m.y.

18. *CH-92* K-Ar
Basalt. (SW/4 SW/4 S36,T13N,R16W; 34°25'03"N, 113°53'33"W; Castaneda Hills 15' quad., Mohave Co., AZ). K_2O = 1.592%, $*Ar^{40}$ = 1.555 x 10^{-11} mole/gm, $*Ar^{40}/\Sigma Ar^{40}$ = 38.1%. *Collected by:* N. Suneson; *dated by:* N. Suneson. *Comment:* Referred to as "megacryst-bearing" basalt by Suneson and Lucchitta (1978).

(whole rock) 6.8±0.2 m.y.

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