76535: AN OLD LUNAR ROCK? D.D. Bogard and L.E. Nyquist, NASA Johnson Space Center, Houston, TX 77058; B.M. Bansal and H. Wiesmann, Lockheed Electronics Corporation, Houston, TX 77058.

The suggestion by Gooley et al. (1) that lunar sample 76535 formed at considerable depth as a result of crystal accumulation makes a determination of its radiometric age extremely important. We have carried out Rb-Sr measurements on separated minerals and K-Ar measurements on plagioclase separates and on a whole rock sample. We have not been able to obtain a completely unambiguous age at this time, apparently because of inherent complexities of the rock.

K-Ar Results. Plagioclase comprises 58% of the rock, olivine 37%, pyroxene ~4%, and minor phases ≲1% (1). Two plagioclase separates (>99% pure) were prepared by Frantz and hand-picking from a coarsely crushed (~0.5-1 mm grain size) portion of an original 4 gr sample; spits were prepared for K and Ar analyses (Table 1). An aliquot of the whole rock sample weighing 1.3 gr had been previously ground to fine grain size (~50μ) and used for major and trace element chemistry by XRF and isotope dilution (2). Portions of this sample were used for K and Ar analyses (Table 1). Potassium was measured by isotope dilution. Argon was measured mass spectrometrically by a standard addition technique using a gas pipette delivering calibrated amounts of atmospheric Ar. Argon was extracted from plagioclase #1 in a single melting stage. To insure that no significant amounts of adsorbed atmospheric Ar were contributing to the total ^{40}Ar, the second plagioclase and the whole rock were extracted in three stages: 150°C, 350°C, and 1640°C. Only 1.7% and 3.3% of the total ^{40}Ar released by the plagioclase and whole rock, respectively, were released in the two lower temperatures (with a larger amount released at 150°C) and this Ar was nearly atmospheric in composition.

The plagioclase and whole rock K-total ^{40}Ar ages of 76535 are 4.40-4.54x 10^9 yrs (Table 1). However, this lunar sample apparently contains ^{40}Ar which is not the result of *in situ* decay of ^{40}K, as well as ^{36}Ar and ^{38}Ar which are not the result of cosmic ray interactions during its exposure age. Evidence for this is contained in Fig. 1, which plots ^{40}Ar/^{36}Ar against ^{38}Ar/^{36}Ar. The value for trapped ^{38}Ar/^{36}Ar shown (0.187) would be approximately correct for solar wind, atmospheric, or trapped meteoritic ("planetary") Ar. The value for cosmogenic ^{38}Ar/^{36}Ar (1.43) is that measured by Eberhardt et al. (3) in a feldspar concentrate of 10003. The three samples analyzed all show ^{38}Ar/^{36}Ar less than 1.43 (Fig. 1), and show a linear correlation within analytical uncertainties which intercepts the trapped ^{38}Ar/^{36}Ar line at ^{40}Ar/^{36}Ar=36.6±2, and the cosmogenic ^{38}Ar/^{36}Ar line at ^{40}Ar/^{36}Ar=104±1. Such a linear correlation could represent mixing of an excess component with ^{36}Ar:^{38}Ar:^{40}Ar= 1:0.187:37 and argon of composition ^{36}Ar:^{38}Ar:^{40}Ar=1:1.43:104 produced *in situ* by radioactive decay and cosmic-ray interactions. Both plagioclase and the whole rock have Ca/K ratios of about 335 (1), so that a mixing line would be generated if the composition of the excess argon remains constant. (Actually, radiogenic ^{40}Ar and cosmogenic ^{36,38}Ar production in the whole rock are both heavily dominated by the plagioclase.) The correlation of Fig. 1 can be used in two equivalent ways to correct for the apparent excess Ar: i) the intercept value of ^{40}Ar*/^{36}Ar=104 can be multiplied by the cosmogenic ^{36}Ar to give the radiogenic ^{40}Ar*; ii) ^{40}Ar/^{36}Ar=37 for the excess argon can be

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multiplied by the excess ^{36}Ar (total ^{36}Ar minus cosmogenic ^{36}Ar) to determine the excess ^{40}Ar, which is subtracted from the total ^{40}Ar to yield the radiogenic $^{40}Ar^*$. Corrections to ^{40}Ar for the plagioclase #1, plagioclase #2, and whole rock amounted to 9.5%, 2.2% and 21% respectively. "Corrected" $^{40}Ar^*$ contents and the corresponding K-^{40}Ar ages are given in Table 1.

Corrections for excess ^{40}Ar lower the plagioclase age to ~4.34×10^9 yrs, and the whole rock age to 4.14x10 yrs. The latter is considered least reliable because it is more sensitive to the correction and because the ratio of measured cosmogenic ^{38}Ar in the whole rock to that in the plagioclase is only 53%, whereas the ratio ought to be ~58% if the whole rock sample contained a "normal" amount of plagioclase. If one increases the corrected ^{40}Ar content of the whole rock sample by a corresponding factor (10%) the corrected K-^{40}Ar age becomes 4.30×10^9 yrs, in agreement with the plagioclase values. If the excess argon interpretation is correct, the plagioclase gas retention age of the rock is $4.34 \pm .08 \times 10^9$ yrs. The ^{38}Ar cosmic ray exposure age is 200×10^6 yrs.

Rb-Sr Results. Several factors combine to make Rb-Sr dating of this rock difficult: (a) the Rb concentration of the whole rock is only 0.2 ppm; (b) almost all of the trace elements are concentrated in the plagioclase, and trace element abundances in the other major mineral, olivine, are very low; (c) plagioclase and olivine make up at least 95% of the rock (1), while minor phases which might concentrate trace elements are rare (<1% of the total rock). (d) The rock went through an extended period of annealing and recrystallization (1). It further appears from our data (Table 2) that the Rb-Sr systematics have been disturbed. The data do not uniquely define an isochron. Tie lines between the plagioclase/whole rock point and the three olivine data yield apparent ages of 5.9±0.5 AE, 8±2 AE, and 5.1±0.4 AE, respectively. Thus either we have unsuspected analytical difficulties or the system does not fulfill the criteria for a Rb-Sr age. We do not completely exclude the first possibility, but feel it is highly unlikely.

The olivine 2 and 3 data (Table 2) allow an interesting calculation. The olivine 3 separate is estimated to contain at least 95% olivine by weight. If olivine 3 is viewed as a two component mix of "pure" olivine (#2) and a "residue", $^{87}Rb/^{86}Sr$ in the residue can be obtained with only slightly greater uncertainty than for the analytical precision of olivine 3. The corresponding $^{87}Sr/^{86}Sr$ ratio may also be calculated. This calculated point ($^{87}Rb/^{86}Sr$ = 0.0666, $^{87}Sr/^{86}Sr$ = 0.7033, +.0005, -.0003) together with the plag/whole rock data yields an apparent age of 4.4+0.6/-0.5 AE, consistent with the K-Ar age. The initial $^{87}Sr/^{86}Sr$ (I) obtained from the plag/whole rock is relatively insensitive to the age ambiguity. Assuming the K-Ar age (4.3 AE) yields I = 0.69913±6, i.e., essentially our BABI value. For T=3.7-4.6 AE, I=0.69923-0.69905. Thus the I values accomodate the old age found by K-Ar but could also be consistent with (T,I) for a mare basalt like 70035.

References:
(1) Gooley R. et al (1974) Sample 76535, A Deep Lunar Crustal Rock, Submitted to Geochim. Cosmochim. Acta.
(2) Haskin L.A. et al (1974) this volume.
(3) Eberhardt P. et al (1971) Earth Planet. Sci. Lett. 11, 245-247.

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Table 1. K-Ar Results.

	K (ppm)	K Blank (%)	Total ^{40}Ar 10^{-8} cm^3/g (a)	Total K-^{40}Ar AGE 10^9 yrs.	Excess ^{36}Ar 10^{-8} cm^3/g.	Corrected ^{40}Ar 10^{-8} cm^3/g.	Corrected K-^{40}Ar AGE 10^9 yrs.	Cosmogenic ^{36}Ar 10^{-8} cm^3/g.	Cosmogenic ^{38}Ar 10^{-8} cm^3/g.
Plag. #1	394	6.7	2870	4.47	7.62	2596	4.30	24.7	36.4
Plag. #2	403	0.3	2831	4.40	1.75	2765	4.37	26.6	38.0
Whole Rock	237	7.1	1803	4.54	10.5	1425	4.14	13.6	19.4

^{40}Ar concentrations have an analytical uncertainty of approximately 3-4% and $^{40}Ar/K$ ratios of approximately 5%, which would generate an uncertainty in the K-^{40}Ar ages of approximately 0.08×10^9 yrs.

(a) Blank corrections to ^{40}Ar were 2-3%.

Table 2. Rb-Sr Results.

Sample	wt. (mg.)	Rb (ppm)	Sr (ppm)	$\frac{^{87}Rb}{^{86}Sr}$	$\frac{^{87}Sr}{^{86}Sr}$ $2\sigma m$
Whole Rock (a)	53.9	0.238	113.9	0.00605±28	0.69950 ± 5
Plag A (b)	18.8	0.431	216.1	0.00577±7	0.70012 ± 46
Plag B (b)	42.5	0.407	198.1	0.00594±27	0.69949 ± 12
Olivine 1 (c)	48.9	0.0294	0.681	0.125±8	0.70962 ± 25
Olivine 2 (d)	102.4	0.0100	0.817	0.0354±.0039	0.70289 ± 18
Olivine 3 (e)	56.1	0.0490	2.50	0.0567±17	0.70320 ± 15

(a) As for the Ar analysis the sample was an aliquot of that prepared for XRF analysis (2).
(b) Hand picked Frantz separate containing no visible olivine or large dark phases.
(c) Hand picked Frantz separate prepared to obtain ~50 mg of olivine plus minor phases, excluding only plagioclase bearing grains.
(d) Hand picked Frantz separate prepared to obtain ~100 mg of "pure" olivine.
(e) The plag-free rejects from olivine 2, thus significantly enriched in minor phases.

Concentrations of REE in the whole rock, plag B and olivine 2 samples may be found in Haskin et al. (2).

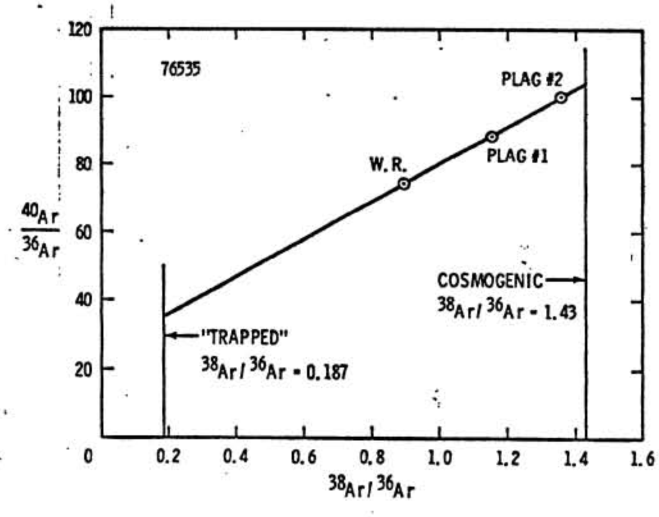

Fig 1. $^{40}Ar/^{36}Ar$, $^{38}Ar/^{36}Ar$ correlation plot for two plagioclase and one whole rock analyses. Verticle lines indicate "trapped" and cosmogenic $^{38}Ar/^{36}Ar$.