TRACK PARAMETERS OF APOLLO 16 LUNAR GLASSES

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A number of parameters of general interest in fission track analysis of lunar glasses have been measured, using in all about twenty light-brown and colourless glass spherules and fragments selected microscopically from the fines samples 66081, 9 and 61281, 2. The procedures follow those described in refs. 1-3.

General Velocity of Etching, V_g The 'spherules' were mounted individually in epoxy resin on to a piece of quartz, and slightly ground and polished to yield plain initial surfaces. They were then etched under identical conditions for either 150 or 50 sec, using fresh 48.0 volume %HF at a temperature of 21.0 $\pm$ 0.05°C controlled to within $\pm$ 0.1°C. The thickness of glass removed was measured with an optical microscope (at 450 x). The results for six light-brown spherules are shown in Table 1. The mean value of V_g = 0.144 $\pm$ 0.008 μm/sec is to be compared with 0.128 $\pm$ 0.002 μm/sec found for some Apollo 15 glasses[3].

Critical Angle of Etching, θ_c This important parameter was measured for 12 glass spherules or fragments (light brown to transparent) from samples 66081, 9 and 61281, 2, using the 'comparison method'[1]. The lunar glasses as well as a piece of 'reference glass' (U-2) were first annealed at high temperatures (~500°C for 1 hr); they were then exposed to a Cf-252 spontaneous-fission source in '2π geometry' for known lengths of time (60 sec for U-2, 120 sec for lunar glasses). This was followed by simultaneous etching under standard conditions. The critical angle for the reference glass ($\theta_{c,r}$) having previously been determined[1] (= 31°45'), $\theta_{c,l}$ for the lunar glasses is calculated from

$$\rho(\text{lunar})/\rho(\text{ref}) = (1 - \sin\theta_{c,l})/(1 - \sin\theta_{c,r}) \quad \ldots 1$$

where ρ is the track density per unit area in each case. The values of θ_c so obtained are listed in Table 2.

Prolonged Etching Factor f(t) The prolonged etching factor is defined[2] as

$$f(t) = \rho(t)/\rho(o) \quad \ldots 2$$

where $\rho(t)$ and $\rho(o)$ are the (internally produced) track densities, in a given material, for etching times t and o under specified etching conditions. Fig. 1 shows the results for two light-brown spherules 1604 and 1607 (from 66081, 9); the values of f(t) at t=100 sec are 1.47 and 1.50. As shown in ref. 2, the values of f(t), V_g and θ_c for a material can be used to calculate R, themean range of fission fragments in it, from:

$$R = V_g . t/([f(t) - 1](1 + \sin\theta_c)) \quad \ldots 3$$

Using the values of V_g and θ_c from Tables 1 and 2, R is found to be 19.4 and 17.6 μ for 1604 and 1607, respectively (the errors are large as f(t) - 1 is small).

Uranium Content and Age The uranium content of five light-brown lunar

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spherules has been determined by the 'auxiliary detector' method. The five spherules (annealed and polished flat) as well as a piece of reference glass (with 43 $\pm$ 1 ppm of U-content) were placed in contact with a Makrofol plastic detector and irradiated in a reactor (fluence = 8.352 x 10^{15} thermal neutrons /cm^2). The values of U-content, found by comparing the track densities, are shown in Table 3; variation by a factor of up to 6 between individual glasses is observed (as noted - also by other workers). The apparent age of spherule 1608 has been found by counting the number of fossil fission tracks in it (under 'hump F' in the companion paper[4]) and assuming its U-content (not yet measured directly) to be the same as in 1609, i.e. 0.5 ppm. This age (since last severe heating or melting; and ignoring any fission track fading in the meanwhile, for reasons given in ref. 4) is found to be $\sim$7 x 10^8 yr, which is very similar to that found for an Apollo 15 glass[3]. (Changes in U content could easily alter this by a factor of several times either way.) In the above calculation we have assumed all fossil fission tracks to be due to spontaneous fission in U-238. It is interesting to note that a cosmic-ray fast neutron flux of 1/cm^2sec on the moon's surface would lead to a fluence of $\sim$3x10^{16}/cm^2 over 10^9 yr, which is comparable to the (thermal neutron) fluence imparted by us to 1609 (yielding an induced-fission track density of 6.5 x $10^4 cm^{-2}$). Since the macroscopic cross sections for (respectively fast and slow) induced fission of U-238 and U-235, mixed in their natural proportions, differ only by a factor of $\sim$4, a fair amount of induced fission may be expected to have taken place (even ignoring fast fission in Th). The thermalized neutron flux on the moon, when the very much higher initial natural abundance of U-235 ($\tau_{\frac{1}{2}} \sim 7 \times 10^8$ yr) is taken into account, would further contribute to induced natural fission. All these factors would bring down the calculated age.

References

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Table 1. General velocity of etching, V_g, in glasses from sample 66081, 9

Spherule No	1604	1605	1606	1607	1608	1609
Time of etching (sec)	150	150	150	150	50	50
V_g(μm/sec)	0.147	0.143	0.150	0.140	0.130	0.144

Weighted Mean $V_g = 0.144 \pm 0.008$ μm/sec

Table 2. Critical angle of etching, θ_c, for glasses from samples 66081, 9 (marked (a)) and 61281, 2 (marked (b)).

No.	θ_c	No.	θ_c	No.	θ_c
1604(a)*	36°42'	1614(a)	38°32'	1618(b)*	36°42'
1607(a)*	35°36'	1615(b)*	36°09'	1619(b)	39°08'
1612(a)	37°44'	1616(b)*	35°52'	1620(b)	38°32'
1613(a)	39°08'	1617(b)*	36°42'	1621(b)	37°22'

Mean for 12 particles: 37°22' ± 0°22'

* Those marked thus(*) are light brown glasses. The rest are colourless.

Table 3. Unanium content (ppm) in glasses from sample 66081, 9

Spherule No.	1604	1605	1606	1607	1609
U-content	1.13(ppm)	0.43	3.16	1.40	0.50