IRRADIATION RECORDS IN ORANGE GLASS AND TWO BOULDERS FROM APOLLO 17.

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Orange glass from subsurface samples 74220 and 74261 - The possibility that the bright orange material at station 4 represented recent lunar volcanism drew widespread interest to this sample. We have measured particle track densities, diameter distributions and annealing behavior as well as uranium concentration in the orange glass.

The major particle track features of the glass are: (1) In 74220 the total measured track density in individual spheres ranges between $1.5x10^5$ and 10^8 (median $5x10^5$) for 16 spheres. For 15 spheres from 74261 the range is $2.2x10^5$ to $1.3x10^7$ (median $4.5x10^5$). (2) Roughly 10% of the spheres in each sample have track density gradients indicative of unshielded exposure on the lunar surface. (3) For fixed etching conditions, the measured track diameter distributions in individual spheres vary depending upon track density. Spheres with low track densities ($(1-3)x10^5$ cm^{-2}) have the largest track diameters (see Fig. 1). (4) Annealing experiments show that iron nuclei tracks are partially erased by heating at 200°C for 1 hour, and that fission tracks (both spontaneous and induced) are completely erased by heating at 450°C for 1 hour. These conclusions were drawn from measured track density distributions for groups of spheres heated at various temperatures between 150 and 500°C for 1 hour. Relative to the distribution for unheated spheres, samples heated at 150 and 200° show a progressive shift toward lower track densities (fading of cosmic ray Fe tracks); between 200 and 300° the distribution is relatively stable (mostly unaffected fission tracks) while at 350° and above another progressive shift toward lower track densities is noted (fading of fission tracks). No natural tracks remain after 1 hour at 450°C; neutron-induced fission tracks also anneal under these conditions. (5) The uranium concentration in the glass, measured by counting induced fission tracks in an adjacent mica detector, is quite homogeneous with an area-weighted average (15 spheres) of 155 ppb for 74220 and 159 ppb (15 spheres) for 74261.

From the above the following conclusions can be drawn. The diameter distributions and annealing data indicate that most (50-100%) tracks in spheres with densities of $(1-3)x10^5$ tracks cm^{-2} are fission tracks. This is also borne out by the fact that neutron-induced fission tracks in the same spheres have a diameter distribution similar to (but on the average ~10% larger than) the natural tracks. This slight size difference may indicate minor annealing (up to ~20% based on typical calibration curves (1)) of the spontaneous fission tracks at lunar surface temperatures. The expected fission track density for 0.16 ppm uranium and an age of $3.7x10^9$ y (2) is $2x10^5$ tracks/cm^2, taking into account the experimentally determined etching efficiency of 0.6. A 20% annealing correction would reduce this to $1.6x10^5$. Thus, contrary to some other interpretations (3) we believe the fission track record in the orange spheres to be compatible with the $^{40}Ar-^{39}Ar$ age.

Soil 74220 was collected from a distinct layer extending from approximately 5 to 7.5 cm below the lunar surface. Soil 74261 was collected from the gray soil zone at the end of the same trench. Both samples may include

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material from the overlying surface soil; in fact this is the probable source for the ~10% of solar flare irradiated orange glass in each sample. Since the soil is well stratified with distinct upper and lower boundaries, it has probably never been vigorously mixed. Using the median track density, the in-situ galactic cosmic ray exposure age is 2.5×10^6 yrs for soil 74220. (A correction of $2 \times 10^5/cm^2$ has been subtracted from the median density given above in view of the fission track contribution.) Because of the much longer (~30 My) Ne exposure age (4) the orange glass must have been within ~1 m of the lunar surface but below ~15 cm for ~30 My at some time in its history, and at its present position for only 2.5×10^6 yrs.

Apollo 17 boulders - Our interest in the Apollo 17 boulders has been directed toward an understanding of individual boulder history through determination of particle track exposure ages, erosion rates, etc., and also toward a search for pre-compaction irradiation effects and breccia formation effects in general through the use of high voltage electron microscopy. The data presented below were gleaned for the most part from small, sometimes undocumented chips in a preliminary allocation. It is expected that much more comprehensive information will be available at the time of the Fifth Lunar Science Conference.

One unexplained phenomenon which has hindered the track studies up to the present is the peculiar etching behavior of many of the feldspar grains, particularly in our samples of 72255. After standard etching procedures (using an etching solution of $1gNaOH:2gH_2O$) feldspar surfaces are frequently irregular and 'bumpy', presumably due to non-uniform dissolution of the surface, making track observations difficult and perhaps introducing errors if track etching is as irregular as is surface dissolution. Optical microscope observations are possible in areas of low track density if surfaces are lightly polished to remove irregularities after etching; however, scanning electron microscopy of areas with densities $\gtrsim 10^8 cm^{-2}$ is very difficult. Although we have not noticed this effect in feldspars from other missions, it is apparently widespread among Apollo 17 samples as we have observed similar behavior in numerous surface soil samples, in other boulder samples, in basalt 71055 and occasionally in Apollo 17 deep core samples. The peculiar etching behavior may be related to small-scale chemical irregularities. Shock would appear to be ruled out as an explanation since shock effects are common in feldspars of similar bulk composition from other missions, yet the etching abnormality seems restricted to Apollo 17 samples.

Boulder 1, Station 2 - 72255: Preliminary studies of two interior pieces from this sample indicate an upper limit to the track exposure age of 15-20 My. Exposure ages determined by track methods, in the context of the large boulders, require some explanation. They do not necessarily bear any relation to the time at which the boulder rolled to its present location. Lunar surface photographs show considerable debris, including large fragments, surrounding the boulders. Because of the steep depth dependence of the particle track production rate, the surface under a spalled off fragment of typical thickness 10 cm is essentially virgin from a track point of view. Thus we expect that particle track exposure ages determined at different locations on the same large boulder will reflect the local rate of large-scale discontin-

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uous erosion, and will not necessarily be the same.

Boulder 2, Station 2 - 72315: Our measurements of a steep track density profile in a single feldspar crystal from this sample are documented in an accompanying abstract (5). An exceptionally young solar flare track exposure age of 10^5 y has been calculated. 72335: We have examined only a 60 mg undocumented chip, supposedly a surface sample, although without a discernible track density gradient at the edges examined. However, a gradient typical of solar flare track gradients was observed to extend over several feldspar grains in the chip interior. Maximum observed track densities were $>5x10^8$ cm^{-2}, falling to a minimum of $\sim 3x10^7$ and rising again. We have observed large variations ($\tilde{>}$a factor of 6) in track density between adjacent olivine grains and variations in track density of more than 20 x between adjacent olivine and feldspar grains. Possible explanations: (i) 72335 might contain a few pre-compaction irradiated grains. (ii) The interior track density gradient and the occasional high track density feldspar may be due to an unusual exposure geometry created by the presence of numerous nearby vugs in the exposed surface. (iii) Track density differences among adjacent olivines may be due to shock or thermal annealing. 72395: We have examined a documented interior slab that was cut roughly parallel to and ~3 cm below the exposed boulder surface. Track densities in feldspar range between $2\text{-}5x10^6$ cm^{-2}. A tentative exposure age of 10-20 My for this part of the boulder can be assigned.

High voltage electron microscope studies of the boulder samples will proceed as soon as the refurbishment of the 650kV microscope is completed.

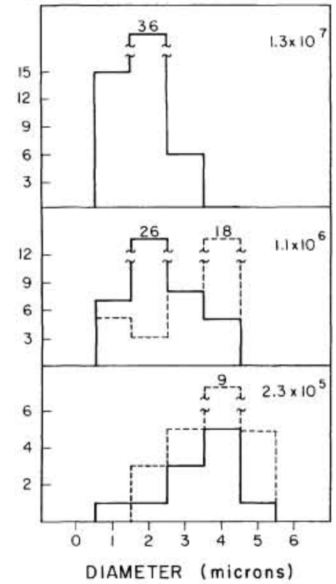

Fig. 1 - Track diameter histogram for spheres of varying track densities from 74220. Neutron-induced fission track diameters for the same spheres are shown as dotted lines.

References

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