THE CHARGED-PARTICLE TRACK RECORD OF SOME LUNAR SOILS AND ITS INTERPRETATION. R.K. Bull and S.A. Durrani, Dept. of Physics, University of Birmingham, Birmingham B15 2TT, England.

Track-density distributions have been studied in mineral grains from five soil samples and inferences drawn as to their exposure history. A dependence of track density on grain size is noticed, and some track-density gradients are discussed.

1. Track-density distributions and exposure ages of some soils

Five soil samples (75081, 62281, 15601, 15301, and 15021) have been examined in some detail, mainly using crystals of d > 180 μm. The crystals were generally divided into a light and a dark fraction. The light fraction, assumed to be feldspars, was etched in boiling 60% NaOH for 2-5 min, while the dark fraction, presumed to be pyroxenes, was etched for 20-40 min. Further refinements were introduced for sample 15601 (see below). Track-density measurements were made by SEM at magnifications of 2-5 K.

The surface exposure ages of the above samples have been calculated, using the model of Arrhenius et al.[1]. This model involves the parameters $\rho_{0.25}$ and N_H/N. Here, the fraction of grains with track densities between ρ_{min} and $\rho_{0.25}$ is 0.25; and N_H/N is the fraction of crystals with $\rho > 10^8$ cm^{-2}. The ages have been calculated assuming scoop depths D of 3 cm and 5 cm (the only depth firmly known is for sample 75081,61, being 5 cm). The relevant data are shown in Table 1.

Table 1. Exposure ages of soil samples

Sample	No. of crystals	Location	$\rho_{0.25}$ (10^6tr .cm^{-2})	N_H/N	Surface exposure age (m.y.) D = 3cm	D = 5cm
75081,61	33	Camelot Crater	60	0.64	56	97
62281,11	26	Buster Crater (edge)	5	0.04	4.7	8
15601,98	60	Nr. Hadley Rille	80	0.70	75	128
15301,104	10	Spur Crater	30	0.60	28	48
15021, 205	14	L M site	50	0.50	47	80

2. Grain-size dependence of track density

Crystals from soil sample 15601 were sorted into mineral types by colour, x-ray analysis, and etching properties. Track densities in feldspar, pyroxene and olivine grains of over 250 μm were compared (Fig. 1a). Olivines (etched in WN solution at pH = 7) showed systematically lower track densities (presumably owing to lower mean etchable ranges of the VH ions). Pyroxenes were further subdivided into grain-size intervals 38-63; 63-150; 150-180; and > 250 μm. A systematic increase in track density is observed (Fig. 1b) as the grain size decreases. These observations are replotted in Fig. 2 in terms of parameters N_H/N (Fig. 2a) and $\rho_{0.25}$ (Fig. 2b) as defined earlier. (The median grain size for the > 250 μm fraction is taken as 400 μm.)

For the smallest grains $N_H/N = 1$, implying irradiation by solar flares in the top ~0.1 cm of the regolith. This is compatible with prolonged micro-erosion of initially large grains by, e.g., solar-wind sputtering[2] or

TRACK RECORD OF LUNAR SOILS

Bull and Durrani

micrometeoritic bombardment[3], resulting in both smaller sizes and high track densities. It must be noted, however, that no marked track-density gradients (variation of > 2 in ρ from one edge to another) were observed in any of these small crystals. The larger grains are assumed to have remained buried deeper down for long periods, thus escaping erosion by micrometeoritic and sputtering processes.

3. Track-density gradients

Only a small fraction ($\lesssim$ 5%) of the grains studied from the above five soil samples showed marked track-density gradients. The measured values of α, an index of the hardness of the solar-flare spectrum, in the relation $\rho_D = \rho_o D^{-\alpha}$ (where ρ_o is the track density at the top surface, and ρ_D that at depth D), ranged from 0.4 to 0.8 in these grains. These values are considerably smaller than that found[4] for the Surveyor 3 glass filter ($\alpha \simeq$ 2.5). The low observed values of α can easily result from either shielding, erosion, or churning; or from the fact that the direction of polishing is not the original direction of irradiation.

Of particular interest are two large (~500 μm) grains from sample 15301,104. They showed low track densities, but with distinct track gradients, viz. $\alpha \simeq 0.4$ and 0.5. The low track-density edge of one of these crystals gives $\rho \simeq 2 \times 10^6$ tr.cm^{-2}. If the simplest assumption is made, namely that the flattening of the track profile is due to an original shielding of the crystal, a shielding thickness of ~500 μm is sufficient to restore the value of α to 2.5. The initial depth of the lowest track-density edge of the crystal then corresponds to D ~ 1000 μm. The Surveyor 3 data represent[4] a track production rate $\dot{\rho}$ vs depth given by:

$$\dot{\rho}(D) = 1.9 \cdot 10^{14} \times D^{-2.6} \text{ cm}^{-2} \cdot (\text{m.y.})^{-1},$$ where D is in microns.

With D = 1000 μm, we obtain the exposure interval of ~0.7 m.y., which may be further reduced because of solid-angle considerations, etc. If the flattened profile of track density with depth is due to random orientation, or erosion of the crystals, then the required shielding depth is smaller, and even smaller exposure intervals are indicated. All these values are much smaller than those calculated for the soil sample 15301,104 as a whole, viz. ~28-48 m.y.

References

1. Arrhenius, G., et al. (1971). Proc. Lunar Sci. Conf. 2nd, p.2583-2598.
2. Phakey, P.P., Hutcheon, I.D., Rajan, R.S., and Price, P.B. (1972). Proc. Lunar Sci. Conf. 3rd, p.2905-2915.
3. Crozaz, G., et al. (1972). Proc. Lunar Sci. Conf. 3rd, p.2917-2931.
4. Fleischer, R.L., Hart, H.R., Jr., and Comstock, G.M. Science, 171, 1240-1242 (1971).

TRACK RECORD OF LUNAR SOILS

Bull and Durrani

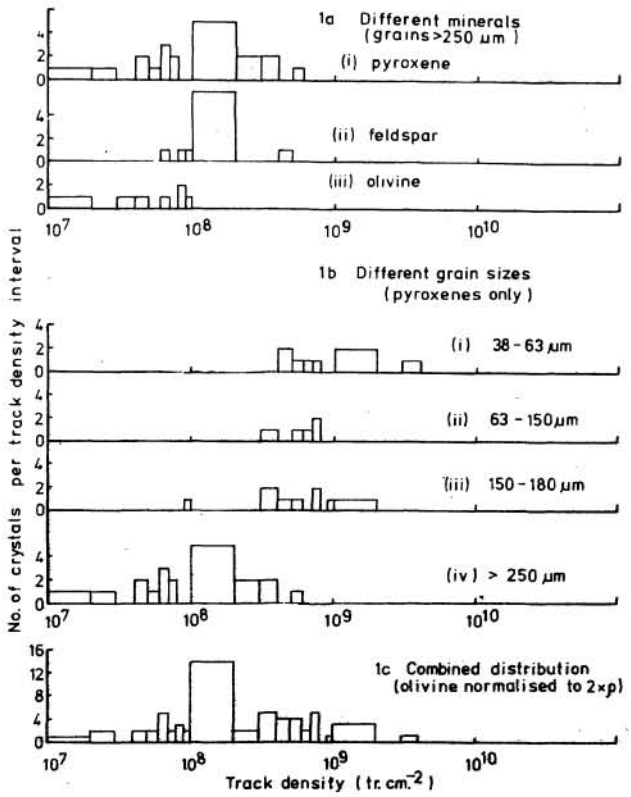
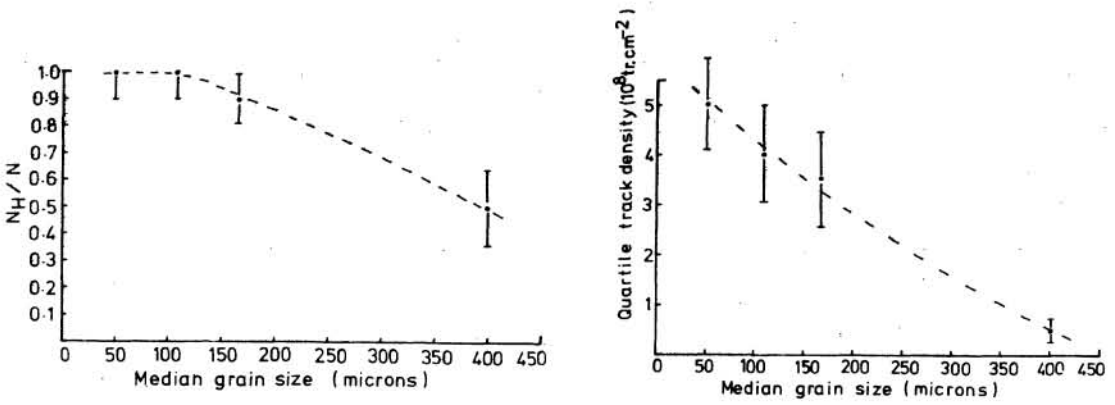


Fig. 1. Frequency distribution of track densities in crystals from sample 15601,98. (a) The d > 250 μm fraction of different minerals. Olivine grains show systematically lower ρ values. (b) Pyroxene grains divided into grain-size intervals. The track densities increase as grain size falls. (c) Combined distribution (after having multiplied the olivine ρ values by 2; cf. (a)).



2(a) 2(b)

Fig. 2. Grain-size dependence of track densities in pyroxene crystals from sample 15601,98. (a) N_H/N, i.e. the fraction of crystals with $\rho > 10^8$ cm^{-2}. (b) Quartile track density $\rho_{0.25}$; the fraction of crystals with track densities between ρ_{min} and $\rho_{0.25}$ is 0.25. The smaller grains are richer in tracks cm^{-2}.