STUDIES OF CHARGED PARTICLE IMPACTS ON THE LUNAR SURFACE

H.A. Khan*, G.W. Dorling, R.K. Bull, A. Aframian, S.A. Durrani and J.H. Fremlin. Physics Department, Birmingham University, Birmingham B15 2TT, England.

INTRODUCTION A number of studies have already been made of the latent damage trails formed in lunar materials by the constant bombardment of solar and galactic charged particles, in order to obtain some information about these particles[1-3].

This abstract describes attempts to find the hardness of the solar flare spectrum and to distinguish tracks due to it and galactic particles from those due to spallation products. Supporting experiments carried out on terrestrial minerals are also described.

ANALYSIS OF LUNAR FELDSPARS Fig. 1 shows the track density distributions in feldspar grains from various lunar samples. Almost all the samples were found to have been exposed to both solar and galactic particles. Apollo 14 samples 14321,147 and 14163,113 seem to have been heavily exposed while samples 61282,3 and 68502,13 from Apollo 16, and 72501,49 and 75082,18 from Apollo 17 show almost identical track densities with an average value of 10^7 tracks/cm^2. The greatest track density variation was found in sample 78421,22; thus suggesting the least soil mixing.

SOLAR FLARE ENERGY SPECTRUM Samples with sharp track gradients have been found to have been exposed to solar flares. The track density , at a depth D was found to obey $\rho_D = \rho_0 D^{-\alpha}$ power law. The parameter 'α', an index of hardness of the spectrum was found to vary widely, between 0.25 to 1.5 (compared with the Surveyor III value of 2.5(1)). However, a complicated exposure history as well as a plane of study not in the direction of irradiation may both lead to experimental values for 'α' lower than expected. We have tried a different approach. Tracks in a feldspar crystal, showing no apparent gradient, have been classified according to their projected direction on the plane under investigation. The procedure was repeated for a sequence of parallel planes by grinding, polishing and re-etching. Figure 2 shows a contour diagram. A refers to the top face while B, C, ... etc. refer to faces lying successively below A. Assuming isotropic etching (at present being checked), the contours suggest that the crystal was exposed to solar flares from 'top south' and 'bottom east' directions. The α-values obtained from these are 2.15 and 1.92, quite close to the 2.5 value obtained for the Surveyor III glass filter.

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* On leave from Pakistan Institute of Nuclear Science and Technology, (PINSTECH), Nilore, Islamabad, Pakistan.

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SPALLATION PRODUCT TRACKS Fig. 3 shows etched track densities obtained by both scanning electron microscope (SEM) and optical microscope in various Apollo 16 and 17 samples. It has been observed that SEM counts are always higher than the optical counts(2). The origin of these "extra" tracks is not very well understood. A feldspar crystal when heated at 250°C for ten minutes, loses all its "extra" tracks. In a different experiment, we found that spallation product tracks behave remarkably similarly to these "extra" tracks. Crystals exhibiting track gradients showed fewest extra tracks which is consistent with the above view. Being close to the surface at one time, the high temperatures could well have annealed them out.

SUPPORTING EXPERIMENTS Terrestrial crystals similar to those commonly found in lunar material have been irradiated with ^{252}Cf fission fragments to establish some of their track registration characteristics. Samples of feldspar, olivine and pyroxene have been investigated for variation of track registration efficiency with crystal plane when etched respectively in boiling 60% NaOH solution, WN solution and 48% HF. Some significant variations in track registration have been found. Experimental work is continuing in this field.

The geometry of projected track lengths on to the crystal surface leads to the formula $x/R = \cos\theta - \sin\theta_c \cot\theta$(4). Irradiation of labradorite at angles of 30° and 60° led to a critical angle for etching, θ_c of $5.5 \pm 2°$ and a maximum etchable range for fission fragments of $9.9 \pm 0.8\mu$m.

The measured mean projected track length under conditions of 2π irradiation depends on the extent to which short tracks are lost. Theoretical relationships between $\bar{x}$, R and θ_c appropriate to the experimental conditions have been obtained by integrating the above formula between limits corresponding to the shortest and longest lengths measured. Such a measured value for R for labradorite gave a value of 10.6 ± 1.0 µm.

It has also proved possible to quantify the number of tracks lost in counting against the crystal background as a percentage relative to the ratio of the shortest length measured to the longest.

The relationship between range and critical angle is currently being applied to a study of the range and critical angle of other ion tracks in crystals and their subsequent behaviour on annealing.

Also, measurements of track length for Ar, Fe and Kr on glass have been made and these are related to (dE/dx) crit.and etchable track length of these ions in feldspars and olivines.

References

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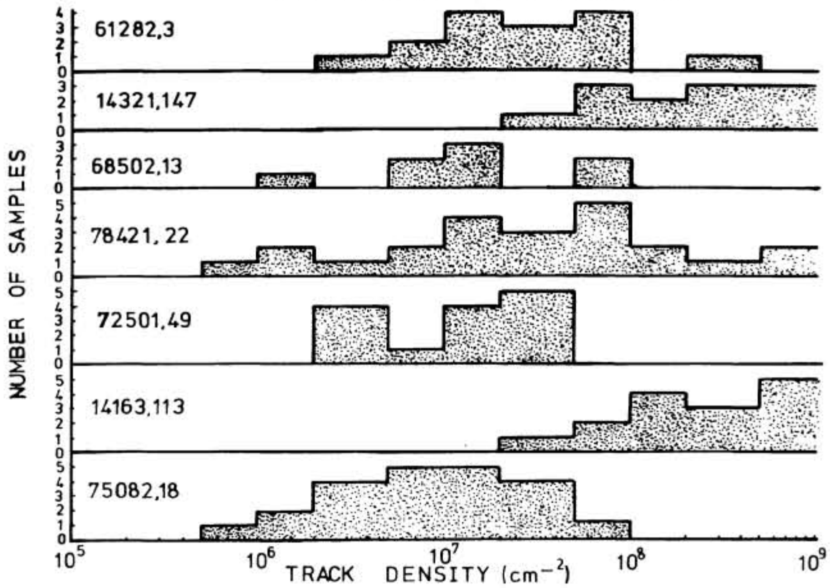

Fig.1.

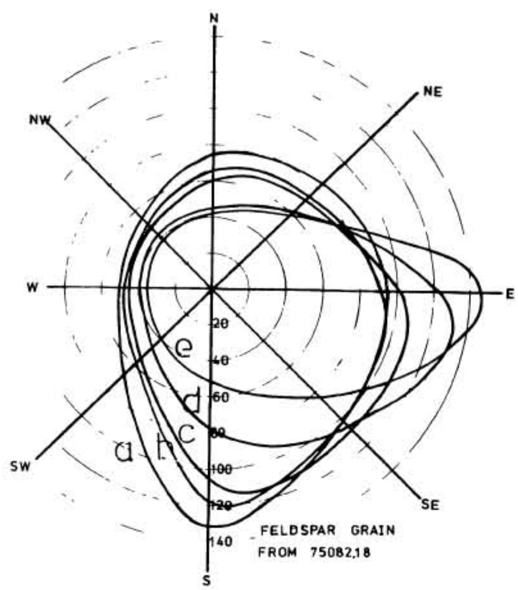

Fig 2.

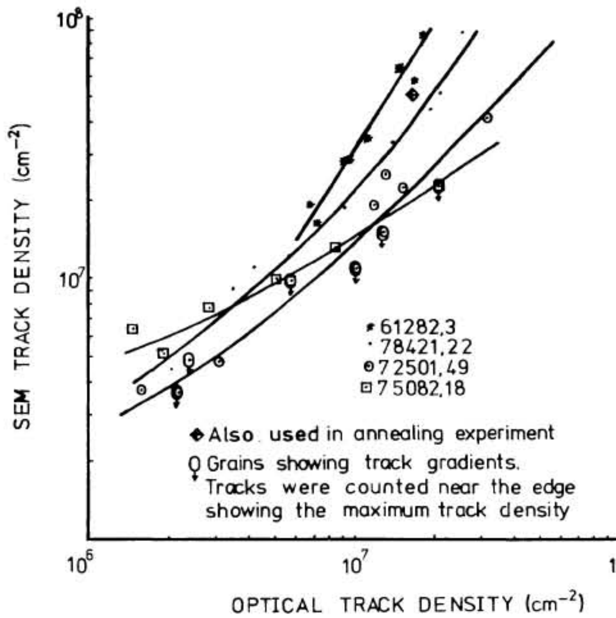

Fig 3.