
The Apollo 15 green-glass spherules have been studied by examining charged-particle tracks and micrometeorite-impact craters on these samples. It is hoped that these studies will lead to a reconstruction of the exposure and thermal history of these soils. Micrometeorite craters, solar-flare tracks and galactic cosmic-ray tracks give information on the exposure of samples within the top few microns, top \(\simeq 100\) microns, and top \(\simeq 10-20\) cm, respectively. Fission tracks can be used to date the time of formation or of the last severe heating of the glasses.

Impact craters were studied by mounting the spherules on epoxy resin and examining them under a scanning electron microscope (SEM) using magnifications between 1k and 5k. Polished surfaces were etched in 5\% aqueous solution of HF for 2 minutes to reveal tracks. Again, these were generally studied using an SEM. A study of 24 spherules in which \(\simeq 50\%\) of the surface of each spherule was scanned revealed a low abundance of microcraters. Only 2 large high-velocity impact craters were observed (each was on a different spherule). These had central raised rims \(\simeq 3\mu m\) across and were surrounded by spall zones of \(\simeq 100\) \(\mu m\) diameter. Another sphere showed a number (\(\simeq 20\)) of pits, without associated spall zones, with diameters of \(\simeq 1-5\) \(\mu m\).

Etched tracks were studied in 15 spherules. No significant track-density gradients were observed in any of them. Total track densities varied from \(\simeq 8 \times 10^5\) to \(2 \times 10^7\) tracks.cm\(^{-2}\). The quartile track density \(p_{0.25}\) (such that 25\% of the spheres have a lower track density than it) is \(\simeq 1.5 \times 10^6\) tracks.cm\(^{-2}\). For pyroxene and feldspar crystals from the same sample, 15301,104, a value for \(p_{0.25}\) of \(3 \times 10^7\) tracks.cm\(^{-2}\) was obtained. An increase by a factor of \(\simeq 10-20\) would be necessary to bring the glass track-densities into agreement with the crystal data. This could reflect the lower efficiency of revelation and/or sensitivity of these glasses. Alternatively, it may be due either to some thermal event which was sufficient to wipe out the previous track record in the glasses but not in the crystals, or to the effect of sustained solar heat on the lunar surface which would be expected to affect the track retentivity of the glasses more than that of crystals.

A major part of our work so far has centred on the identification of fission tracks in the spherules. Durrani et al. (1) showed that fission tracks in certain lunar glasses give rise to etch pits of greater diameter than those due to cosmic-ray particles.

Figures 1a,b represent some typical diameter-distributions obtained for glasses from this sample. Many spherules show track-diameter distributions similar to that in Fig. 1a, with a broad peak extending up to \(\simeq 1.5\) \(\mu m\). Some
show a subsidiary peak centred on a diameter of ~2 \(\mu\)m. In one case (Fig. 1b) the whole of the distribution is centred about this value.

A full analysis of these distributions requires detailed calibration of the lunar glasses with Fe and other ions of different residual ranges and also with fission tracks from internal fission. Such studies are being carried out at present. However, some preliminary remarks may be made. By irradiating man-made soda-lime glass with Fe ions of energy 9.6 MeV/amu from the Manchester LINAC, and on correcting for the slightly different bulk etch rates in 5% HF (which were found to be 0.014 \(\mu\)m.sec\(^{-1}\) in soda-lime and 0.015 \(\mu\)m.sec\(^{-1}\) in the lunar green glass), it is possible to get an estimate of the range of diameters likely to be found for Fe ions in the lunar glass. These are estimated to be \(\approx 1 \mu\)m for Fe ion tracks etched for 2 minutes in 5% HF.

A green-glass spherule was annealed for 48 hours at 600\(^\circ\)C to remove fossil tracks. It was then irradiated with fission fragments from a \(^{252}\)Cf source and etched in the usual manner. Track diameters of 2.24 (\(\pm 0.21\)) \(\mu\)m were obtained. We therefore tentatively ascribe the broad peak in the fossil-track distribution to cosmic ray ions and the 2 \(\mu\)m peak in Figs. 1a,b to fission-tracks. Some data on the etching characteristics of the glass is summarised in Table 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>(V_g) (bulk etch velocity)*</td>
<td>0.015 (\mu)m.sec(^{-1})</td>
</tr>
<tr>
<td>(V_T) (track velocity for fission fragments)</td>
<td>0.03 (\mu)m.sec(^{-1})</td>
</tr>
<tr>
<td>(\theta_c) (mean critical angle)</td>
<td>30.3(^\circ)</td>
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*For 5% aqueous solution of HF.

The fractional area under the postulated fission peak in Fig. 1a yields a fission-track density of \(~1.5 \times 10^5\) tracks.cm\(^{-2}\). If a uranium content of 50 ppb is assumed (2), then a fission-track age of \(~2 \times 10^9\) years is obtained. Using the same assumption, the spherule for which Fig. 1b was obtained would yield a fission-track age of \(~10^{10}\) years, which is clearly invalid. Possibly this spherule has a much higher uranium content, and this is obviously an area which requires further study, and in particular exact uranium-content determinations of individual spherules.

In conclusion, then, the lack of solar-flare track-density gradients and of large numbers of microcraters indicates that the Apollo 15 green glass has not had an extended exposure on the top surface of the regolith. Diameter distributions suggest that a significant number of fission tracks are present.

References
(1) Durrani S.A., Khan H.A., Malik S.R., Aframian A., Fremlin J.H., and

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TRACKS AND MICROMETEORITES

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Fig. 1a) Typical track diameter distribution in green glass spherule.

Sample 15301,104

Fig. 1b) Track diameter distribution in green glass spherule showing only one peak.

Sample 15301,104