Lunar soil has had a long and complex history at and near the lunar surface. For soil columns with obvious, visible layers the historical particle track record left by heavy cosmic ray nuclei may be divided into two periods: (A) The time prior to final deposition in layers, for which the history can be derived only in a statistical manner by considering the distribution of track densities and track density gradients in individual grains and correlating these distributions with calculations of the effects of soil excavation, redeposition, and mixing. (1-3) (B) The period of the final layering process itself, for which surface times can be derived if grains are identified that have acquired tracks at known depths only since the layer was deposited. One hypothesis assumed that no tracks formed prior to layering but that each layer was well mixed after deposition; exposure ages were calculated from a statistical measure of the distribution of track densities, the 25th percentile values(4). An alternative(5) makes use of the minimum track densities in each layer to infer its maximum exposure time(6). It is useful to note further that if track erasure occurs at the time a soil is deposited, either by heating(7) or shock-induced deformation erasure(5), the minimum density gives the actual surface residence time rather than an upper limit.

In two soil columns that have been searched extensively for evidence of shock deformation(8,9) we have found that shock effects are frequent, so that the upper limits should often be close to the true exposure times of layers.

Fig. 1 shows schematically how by purely mechanical deformation tracks may be made optically unrecognizable by being fragmented into submicroscopic lengths. In ~60% of the pyroxenes we examined from the Apollo 12 double core, deformation markings were recognizable optically. The correlation between minimum and 25th percentile track densities in Fig. 2 imply that both measure real effects - but not always the same effects since they do not always correlate. There are stratigraphic layers within visible layers (for example V-G and V-E) that have been detected only by particle tracks. Both Fig. 2 and Fig. 3 show that there is no regular correlation between minimum and median track densities. These apparently measure
two independent quantities that can be used to characterize a soil - the recent surface exposure and the integrated effect of prior surface exposure. For layers in Apollo 15 core 15005 we infer variable surface ages ranging from 0.1 to 20 m.y. with an average deposition rate of \( \leq 0.4 \text{ cm/m.y.} \)\(^{(9)} \). For the Apollo 12 double core individual ages range from 0.2 to 36 m.y. with an average deposition rate of \( \leq 0.35 \text{ cm/m.y.} \)\(^{(8)} \).

Sample 15401 has the shortest surface exposure yet measured for a soil (~500,000 years) as inferred from the track density distribution data of Fig. 4. The long tail extending to the right can be interpreted in terms of a soil mixing model \((1-3)\), as implying at least one mix or possibly a few mixes, but not many. This conclusion may be inferred qualitatively by comparing Fig. 4 with the schematic diagram in Fig. 5, which shows how the mixing and continued near surface irradiation of grains shift the resulting track density distributions.

REFERENCES:


Figure 1
Fig 1

Fig 2

Fig 3

Fig 4

Fig 5

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