IRRADIATION HISTORY OF LUNAR CORES AND THE ACCUMULATION OF THE REGOLITH, G. Crozaz and S. Dust, McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130 USA.

The irradiation and depositional histories of individual lunar cores vary greatly. The development of a typical portion of the lunar regolith proceeds along two modes. The first is the accumulation of distinct layers a few cm thick which have remained largely undisturbed (with the exception of their very surface or skin) since they were deposited. These units are characterized by a decrease in the minimum track densities with depth in agreement with the expected track production from galactic cosmic rays. Their surface exposures are found to vary widely (1-100 m.y.). The presence of crystals with high track densities (> 10^8/cm^2) is a typical feature and means that the units contain material irradiated before burial by solar flare particles within the upper mm of the lunar regolith. The deposition of a unit thicker than 10 cm is a rare event (the only known is the coarse-grained layer of the Apollo 17 deep drill). Visually identified stratigraphic units frequently do not appear distinctive from the track standpoint. The second and dominant mode of regolith formation proceeds through the accumulation of smaller increments of heavily irradiated material that do not result in distinct layers. Typical accumulation rates are on the order of 1 cm/m.y. We report here fossil track measurements for a number of core sections including 60007 (top of the Apollo 16 deep drill stem), 60010 and 60009 (respectively top and bottom sections of a double drive tube collected at the Apollo 16 LEM station), 70009 and 70008 (top sections of the Apollo 17 deep drill stem). New data are shown in Figs. 1-3. Data for 70009 and 70008 were previously published by Crozaz and Plachy (1). It is interesting to note that the Apollo 16 cores, which were taken within 50 m of each other, show similar trends in their track records although with different intensities of irradiation.

70009 and 70008--The upper 80 cm section of the Apollo 17 deep drill stem consists of a coarse-grained layer (~19-79 cm) covered by some 19 cm of highly irradiated finer grained material. Using a combination of track, thermoluminescence, rare gas, ^22Na and ^26Al studies (1), we inferred that the most likely source of the thick coarse-grained layer appears to be either Camelot Crater or the Central Cluster craters which were emplaced ~100 m.y. ago (2). The layer was subsequently re-excavated (~2 m.y. ago) and the resulting depression was gradually filled in. The uniform high track densities in the top 19 cm reflect this recent addition of material whose grains apparently remained so close to the surface that they accumulated large quantities of solar flare tracks prior to their deposition at their present locations. Low track densities in core samples are exceptional. The overwhelming majority of lunar core samples exhibit high track densities similar to those observed in the upper 19 cm of 70009.

60007--This section contains five stratigraphic units as identified by visual observations (3). However, the track data show that these visually identified units do not correspond to distinct depositional events of fresh, unirradiated material. We studied 8 samples: 4 from unit IV and one from each of the other units. The section as a whole shows a high level of irradiation. About 94% of the crystals have track densities in excess of 10^8/cm^2 (as opposed to
IRRADIATION HISTORY

Crozaz, G. et al.

only 32% in the top 19 cm of 70009). The upper part of 60007 (units V and IV) is distinctly more irradiated than the lower half but apart from this obvious difference, we find no evidence for distinct units. As in the case of the upper part of 70009, we propose that 60007 represents the accumulation of largely preirradiated material from a number of local events. The number of these greatly exceeds the number of recognized stratigraphic units. This is certainly true in the case of unit IV where all 4 samples show very similar track distributions. If the unit had been deposited as a whole and had lain undisturbed since, a marked decrease of the minimum track density would be observed. An accumulation rate of a few mm/m.y. is inferred for the bottom of section 60007 using the minimum track density method. This method cannot be applied to the top part of this section due to the ubiquity of solar flare tracks.

60010--The double drive tube 60010-60009 was taken on the edge of a 1 m crater rim in the vicinity of the ALSEP site. Seven distinct strata seem to be present in 60010 (3). We sampled 26 different locations. Although less heavily irradiated than 60007, which represents the same depth interval sampled at a point only 50 m away, 60010 shows the same general characteristics, the upper half being distinctly more irradiated than the lower half (83% as opposed to 23% of the crystals with track densities in excess of $10^8$/cm$^2$). Unit 1 (below 23 cm) resulted from the accumulation of a number of thin layers whereas unit 2 (18.5-23 cm) corresponds to a single depositional event. Unit 2 was exposed at the surface for a maximum of $\sim$6 m.y. before being covered up by the material constituting units 3 and 4 (11.5-18.5 cm) which in turn resided at the surface for a maximum of $\sim$22 m.y. In contrast, units 5, 6 and 7 (upper 11.5 cm) were added in thin increments. All levels include a component irradiated prior to its deposition at the sampling site. The average accumulation rate of the lower half of 60010 is $\sim$0.4 cm/m.y. The minimum track density method again cannot be applied to estimate the accumulation rate of the top part of this section.

60009-60009 includes 10 stratigraphic units (4). Material was analyzed at 19 locations. Compared to other sections, 60009 is most unusual, being characterized by a low level of irradiation (i.e. low track density), independently confirmed by its low concentration of agglutinates (3) and its weak FMR signal (5, 6). Compared to "typical soils" (which include all the soils discussed above with the exception of the Apollo 17 deep drill coarse-grained layer), all soils in 60009 can be considered as immature or submature. Most layers in 60009 are the result of the mixing of soils of different preirradiation histories. A number of units, a few cm thick, which remained undisturbed since they were deposited, can be recognized. Even these units, however, contain admixtures of previously irradiated material. Only 4 distinct track units (4-1 with boundaries at 20.5, 25 and 31 cm) are recognized between 12 cm and the bottom of this 31.5 cm section in contrast with the 7 units described by Nagle et al. (4). Units 2 through 4 were exposed at the surface for a maximum of 3, 1 and 7 m.y., respectively, leading to a minimum accumulation rate of the lower part of 60009 (below 12 cm) of $\sim$1.7 cm/m.y. Above 12 cm, the mode of accumulation suddenly changed and accumulation proceeded in much thinner layers whose number exceeds the 3 units defined from the visual stratigraphy. No decrease of the minimum track density with depth is observed in this region.
IRRADIATION HISTORY

Crozaz, G. et al.

where at least 6 peaks in the agglutinate content can be recognized. Assuming that at least some of the grains analyzed in the upper part of the section were devoid of tracks when they were deposited, a maximum accumulation time of 13 m.y. is deduced for the upper 12 cm leading to an average deposition rate of $\geq 1.3$ cm/m.y. for the whole section.

REFERENCES


Fig. 1 - Fig. 2 - Fig. 3

Figures 1-3:
Track densities as a function of depth in core sections 60007, 60010 and 60009.