ORIGIN OF THE APOLLO 17 DEEP DRILL COARSE-GRAINED LAYER, G. Crozaz and A. L. Plachy, McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130 USA.

The upper 80-centimeter section of the Apollo 17 deep drill stem consists of a coarse-grained layer (~18-79 cm) covered by some 18 cm of finer-grained material. Our previous work on seven samples from section 70008 (25 to 63 cm below the lunar surface) showed a very low density of particle tracks and a systematic decrease with depth as would be expected if the coarse-grained material had been deposited as a single layer and had lain undisturbed since. The assumption that the entire layer to 79 cm, including the 18 cm of finer-grained capping material, had been deposited simultaneously led to a track model age of ~10 my.

This model age is difficult to reconcile with other data from the Apollo 17 site. From the local geologic setting it has been suggested that the coarse-grained layer may have been emplaced in a single event associated with the formation of either Camelot Crater (the deep drill sampling site is located at ~1 crater diameter E of this 700-m crater) or the Central Cluster craters (the sampling site lies at the northwestern edge of this complex). However, as discussed in an accompanying abstract from our group (1), the bulk of evidence indicates that the ages of these potential source craters is probably ~100 my.

The importance of investigating this problem stems from the potential association of the Central Cluster craters with Tycho ejecta (1-4).

We report here both thermoluminescence (TL) and track studies of samples from 70009, the uppermost part of the deep drill stem. The basic data are shown in Figs. 1 and 2.

Analysis of the data is complicated by the fact that the teflon plug in this drill stem became loose, allowing the material to move and homogenize to an unknown extent (5). Measurements of the short-lived isotope ^{22}Na ($t_{1/2}$=2.6 yr) also suggest that some material (up to ~2 cm) from the top of the stem may have been lost in the sampling process (Rancitelli, private communication). However, the TL results show clearly that the homogenization was very incomplete; the amount of material lost from the top of the core must also have been modest. Plotted for comparison with the 70009 TL data are data that we previously obtained for the drive tubes 12025/28. The TL in both cases shows a characteristic rapid rise with depth followed by a slow decrease at deeper depths. This profile results from the combined effects of temperature and ionization as a function of depth (6,7) and is established with a time scale of ~5 x 10^3y. Surprisingly the maximum occurs at a deeper depth in 70009 than in 12025/28. This is possibly due to a difference in thermal conductivity permitting a deeper penetration of the diurnal heat wave. The difference in the profiles cannot be explained by an important loss of material from 70009, since such loss would produce a shift in the maximum <u>towards</u> and not <u>away</u> from the surface. Taking the extremes of thermal conductivity that have been quoted by Keihm and Langseth (8), we calculate the maximum value of N/A of the TL to be at 17 to 19 cm; as the data show the peak to be between 15 and 19 cm

APOLLO 17 DEEP DRILL

Crozaz, G. and Plachy, A. L.

in 70009, we estimate a maximum loss of material of ∿2 cm.

The main features of the track data are as follows: down to ∿34 cm in the core (∿19 cm from the surface), corresponding to units II through VI, the track densities are uniformly high, well in excess of $10^7 cm^{-2}$. Since 70009 was not homogenized in handling, the uniformity must have been produced on the moon; we therefore find no evidence for distinct units II-VI in the track data. In unit I, with the exception of sample 170, there is a very marked decrease of the track densities with the depth. We have reasons to believe that sample 170 which is anomalously high in both track densities and thermoluminescence in fact comes from a location adjacent to sample 165 (Duke, private communication). Such a location would remove the anomaly observed by both methods. The track data are thus in agreement with the preliminary description of this section which includes only unit I in the coarse-grained layer (5).

In Fig. 3, the average minimum track densities in unit I of 70009 and in 70008 are shown as a function of the depth expressed in $g \cdot cm^{-2}$. The experimental track data are compared with theoretical curves for the expected depth dependence for a simply irradiated layer. The production curves have been calculated to best accommodate the upper 3 points which are known with a much better accuracy than those previously used from the 40 to 60 cm interval. The model exposure age so deduced is 30 my., provided that the top 18 cms of material were deposited simultaneously with or shortly after the coarse-grained layer. If this were not the case, the exposure age would be lower. As the coarse-grained layer extends no nearer than ∿18 cm from the surface with a maximum track density of only $\sim 10^6 cm^{-2}$ for the previously unirradiated material, we have now lost the hope we entertained of measuring the ancient record of cosmic rays at much higher energies than previously observed. Even allowing for a loss of material of 2 cms the age cannot be pushed beyond ∿40 my. if a density of 1.75 for 70009 is assumed or ∿60 my. if a density of 1.90 is used.

Further, data on the radioactive isotope ^{26}Al indicate that the fine-grained material in the top 18 cm has a net excess of activity suggesting that it may represent recent (∿1 my.) infill of surface irradiated material into a small crater that reached down to the top of unit 1.

The enigma of the young model track age of the coarse-grained layer can be removed by assuming that the average amount of material covering the coarse-grained layer was significantly more than the 18 cm currently found. Assuming that the total exposure time was 100 my., we require a capping of some 45 gm/cm^2 of material during this time. This result is consistent with what is now known about the rare-gas (9) and neutron effects in the core (10). The most promising approach to the final resolution of this issue appears to be careful track and rare-gas studies on individual fragments from the coarse-grained layer.

REFERENCES

(1) Arvidson, et al., 1976, Abstracts, Lunar Sci. Conf. 7th.

(2) Muehlberger, et al., 1973, Apollo 17 Preliminary Sci. Report, NASA SP-330, p. 6-1 to 6-91.

(3) Howard, 1973, Science 180, p. 1052-1055.

APOLLO 17 DEEP DRILL

Crozaz, G. and Plachy, A. L.

(4) Lucchitta, 1975, Trans. Amer. Geophys. Union 56, p. 389.
(5) Duke and Nagle, Lunar Core Catalog.
(6) Hoyt, et al., 1971, Proc. Lunar Sci. Conf. 2nd, p. 2245-2263.
(7) Hoyt, et al., 1972, Proc. Lunar Sci. Conf. 3rd, p. 2997-3007.
(8) Keihm and Langseth, 1973, Proc. Lunar Sci. Conf. 4th, p. 2503-2513.
(9) Pepin, et al., 1975, Proc. Lunar Sci. Conf. 6th, p. 2027-2055.
(10) Curtis and Wasserburg, 1955, The Moon 13, p. 185-227.

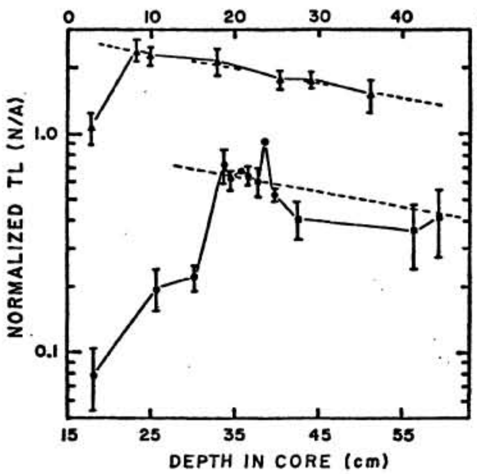

Fig. 1. Normalized TL (N/A) as a function of depth in the Apollo 12 double core 12025/12028 (▲) and in the Apollo 17 drill core 70009 (●)/70008 (■). For the Apollo 12 single grains N/A ≡ N(peak)/A(peak); for the Apollo 17 bulk samples (~1.5 mg) N/A ≡ N(250°C)/A(peak). The error bars are one S.D. The lunar surface for 12025/12028 is at 0 cm and for 70009 at 14.9 cm.

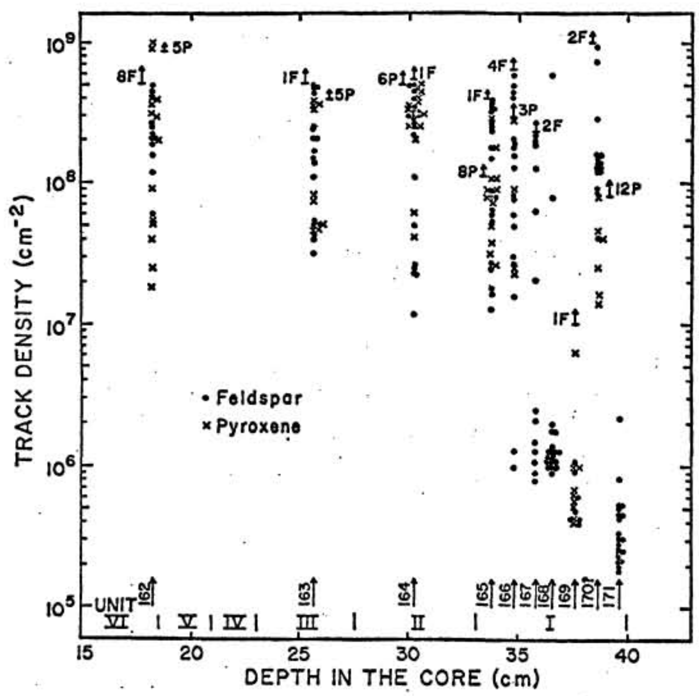

Fig. 2. Track densities in individual feldspar and pyroxene grains of section 70009 of the Apollo 17 deep drill core. The top of core 70009 is at 14.9 cms.

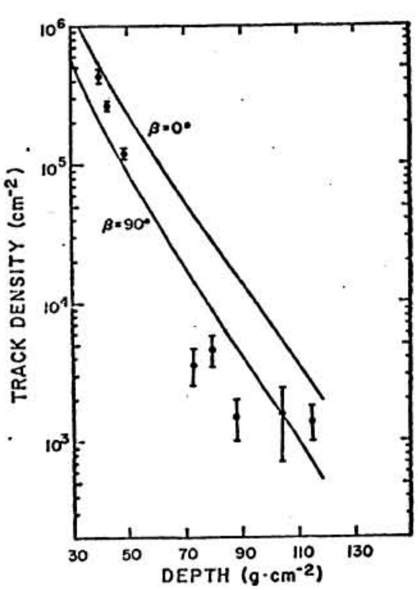

Fig. 3. Track densities in the coarse-grained layer of sections 70009 and 70008 of the Apollo 17 deep drill core. The two smooth curves correspond to the track production as a function of depth for two extreme orientations of the grains with respect to the surface and an exposure time of 30 my. The error bars are ± 1σ.