THE APOLLO 17 DEEP DRILL CORE: A POSSIBLE DEPOSITIONAL MODEL;
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We have measured rare gas contents of nine grain-sized soil samples spaced
along the Apollo 17 deep drill string, and of one surface soil sample from the
drill core site. Abundances and isotopic compositions of all five rare gases,
plus concentrations of Ca, K, Sr, Rb, and Ba were determined in each of six
sized fractions of each sample. Only the Ar analysis, reported here, has been
more or less completed at present; other rare gas results will be presented
later. Some of the chemical data appear in another abstract in this volume (1).

Concentrations of cosmic-ray produced $^{38}$Ar, calculated from ordinate-
intercept correlations over grain-sized fractions of individual samples (2,3),
are plotted vs. depth below lunar surface in Fig. 1. Similar studies of Apollo
15 drill core material suggested, as a best-fit depositional model, that all
but the upper $\approx 45$ g/cm$^2$ of the section consists of rapidly deposited, uniformly
preirradiated soil which was subsequently irradiated in situ for $\approx 450$ m.y.
before burial by a recently deposited surface layer (2,3). The spallogenic
signature of long-term in situ cosmic-ray irradiation is a depth profile for
$^{38}$Ar$_{sp}$ which has the general shape of the dashed curves in Fig. 2, derived from
Stoemmer et al.'s measured $^{37}$Ar profile in the Apollo 16 and 17 drill cores (4).
While the spallation Ar data from the Apollo 15 drill core soils follow this
simple type of depth profile very well (2,3), it is clear from Fig. 1 that this
is not the case for the Apollo 17 deep core, and thus that the bulk of this
regolith section was not emplaced and subsequently irradiated as a single mas-
scopic unit.

Despite the apparent complexity of the measured $^{38}$Ar$_{sp}$ profile in Fig. 1,
however, it is in fact consistent with a relatively simple depositional history
for the regolith at this site. If the lower $\approx 220$ g/cm$^2$ ($\approx 120$ cm) of material
were rapidly emplaced and subsequently irradiated without vertical mixing,
spallation Ar$_{sp}$ produced in situ would follow a profile similar in shape to the
lower dashed curve in Fig. 2; during this time, the ancient regolith surface
would have been located very near the present 70004/70005 junction depth in
the drill core. Later, a second, massive, relatively rapid deposition of
$\approx 160$ g/cm$^2$ ($\approx 90$ cm) of material formed a new regolith surface now located $\approx 10$
cm above the 70006/70007 junction depth, and subsequent $^{38}$Ar$_{sp}$ production in
both the new and older deposits accumulated along a profile similar to the
upper dashed curve in Fig. 2. Finally, a rapid and recent emplacement of $\approx 160$
g/cm$^2$ ($\approx 80$ cm) of uniformly preirradiated material completed the present
regolith section.

A model fit derived by postulating a young preirradiated surface layer and

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superimposed $^{38}\text{Ar}_{sp}$ production profiles of appropriate amplitude in the lower depositional units is consistent, within error, with all ten data points in the observed profile; the fit is shown by the solid curve in Fig. 2. On the assumption that soils in the lower units were not irradiated prior to emplacement, this model fit yields unique values for the ancient surface locations relative to the present regolith surface - at $\sim 160$ g/cm$^2$ (-80 cm) and $\sim 320$ g/cm$^2$ (-170 cm) - and for the quantities $T_P$s, where $T$ is the in situ irradiation time for a depositional unit and $P_s$ is the surface production rate of spallogenic $^{38}\text{Ar}$. With $P_s = 8.75 \times 10^{-9}$ ccSTP/g(Ca) (3), and $\text{Ca} = 8.4\%$ for the appropriate grain size fractions (1), the in situ irradiation times are $\sim 550$ m.y. for the lower unit prior to deposition of the overlaying material, followed by an additional $\sim 570$ m.y. for both units. Assuming the surface unit to be recent, the base of the drill core was therefore deposited $\sim 1100$ m.y. ago.

It is clear, simply from the fact that trapped solar wind rare gases are present in all samples, that the lower depositional units in the drill core section have experienced at least some level of preirradiation. Assuming that the preirradiation was uniform, there are now three parameters for each unit that must be fixed by the data points: position of the unit surface, ($^{38}\text{Ar}_{sp}$)$_0$ concentrations arising from preirradiation, and irradiation time $T$. Since there currently exist only two data points in the postulated middle unit (Fig. 2), the model as presently constrained by the data cannot yield unique parameter values. In examining solutions for arbitrary choices for ($^{38}\text{Ar}_{sp}$)$_0$ in the middle layer, however, we found that the depths of the ancient unit surfaces were very stable at $162 \pm 3$ g/cm$^2$ and $321 \pm 4$ g/cm$^2$, and that the total irradiation time for the lower unit fell consistently in the range $920 \pm 65$ m.y. Since a model which allows preirradiation is more general and more reasonable than one which does not, the stratification "age" of the soil at the base of the drill core is probably closer to 920 m.y. than to the 1100 m.y. value derived above.

As a further refinement, we reconsider the assumption of approximately zero deposition age for the $\sim 160$ g/cm$^2$ surface layer. Although track evidence suggests that the section of this unit within stem 70008 has not been irradiated in place for longer than $\sim 10$ m.y. (5), and the agglutinate content in 70008 is that of an immature soil (6), the observation of low track density is puzzling in view of both the substantial preirradiation of the surface layer given by the horizontal fit in Fig. 2, and the suggestion that this layer is associated with Camelot ejecta (7), the age of which appears to lie between 70 and 85 m.y. (5). From the spallation Ar point of view, the depositional age of the entire surface layer could be $\sim 0$, within error. However, the data from 70008 are fit somewhat better...
by a spallation Ar profile, shown in Fig. 3, which implies preirradiation, a deposition age of ~90 m.y., and an upper layer boundary just above the 70008/70009 junction depth, ~44 g/cm² below the surface. In this reading of the data, this layer could well be Camelot ejecta. By implication, the top ~44 g/cm² of the core now comprises another distinct surface layer, a possibility suggested earlier on the basis of agglutinate evidence (6). We note that if this interpretation is adopted, and the model fits for the deeper layers recalculated to take contributions from this ~90 m.y. late irradiation into account, the depositional unit boundaries remain virtually unchanged and the total stratification age of the basal layer rises to 950 ± 65 m.y.

Several different kinds of experimental evidence could eventually rule on the validity of this depositional model. Depth profiles of other spallogenic gases, and additional rare gas measurements on samples from the middle regions of stems 70004, 5, 6, 7 (Fig. 2) would constitute a critical cross-check of the predicted Fig. 2 profile, and remove the current ambiguity in specifying model parameters for the individual units. These stems have not been opened, and the required samples may not be available for some time. The model prediction of two ancient, long-term regolith surfaces at deep locations in the core seems to be qualitatively supported by existing X-radiography evidence: the upper surface, at 162 ± 3 g/cm², is coincident with Nagle's estimate (7) for the base of Unit 59 ('Camelot ejecta'), while the lower surface, at 321 ± 4 g/cm², is near the top of a series of units which are highly depleted in large basaltic rock fragments, perhaps implying extensive comminution. The ancient surfaces are also significant in terms of the track and agglutinate profiles and discontinuities which should characterize such interfaces; here the principal caveat is that preirradiation effects, if very high, may mask in situ production records. Unfortunately, no samples (except from 70008) of these drill core materials have yet been allocated for either track or soil studies (7). The neutron capture record in Gd and Sm will provide a critical check on this spallation model; the data, which exist but are not yet published, suggest that the neutron capture and Ar spallation models for the Apollo 17 drill core may not be in agreement (8).