LUNAR SURFACE DYNAMICS: SOME GENERAL CONCLUSIONS AND NEW RESULTS FROM APOLLO 16 AND 17, G. Crozaz, R. Drozd, C. Hohenberg, C. Morgan, C. Ralston, R. Walker, and D. Yuhas, Laboratory for Space Physics, Washington University, St. Louis, Missouri 63130

Historical Flux of Micrometeorites: Based on a comparison of calculated values for various dynamic processes with experimental data, several workers (1,2) have suggested that the flux of micrometeorites averaged over the last several million years was lower by an order of magnitude than present fluxes measured in satellites. Measurements of small craters on fresh glass surfaces has further supported this view (3). However, the mass of the micrometeoroids involved in these latter measurements is smaller than those responsible for the apparent discrepancies that led to the suggestion of a lower average flux. We have performed a critical review of existing data and see no compelling evidence for such a drastic reduction in the micrometeorite flux. Surface exposure ages for rocks based on track data range from $< 10^6$ to $\sim 5 \times 10^7$ yrs. However, most of these ages are maximum ages. True surface exposure ages can be reliably determined only by detailed measurements of track gradients in rocks (4). The original estimates by Gault et al (1) of average lifetimes of 2 to 6 my for rocks in the size range of 1 to 10 kg appear compatible with existing data though occasional rocks with longer ages have been found. Comparison of erosion rates has been complicated by a confusion between micro and mass-wastage erosion (4) and by speciously low (though irrelevant) estimates of microerosion rates $< 10^{-8}$cm/yr. The experimental mass-wastage erosion rates from both track and radionuclide data of ~ 0.5 to 2×10^{-7}cm/yr agree with theoretical estimates. Our best estimates of the rate of production of impact pits > 500μm in size lies in the range 1 to $5/cm^2$ - my. Although this is somewhat lower than theoretical estimates of 8 to $10/cm^2$ - my, most of the reference rock surfaces are $\gtrsim 2$ my old and erosion effects may well account for the difference. The stirring rates originally calculated by Gault et al (1) are much higher than those determined by track studies. However, recent revised estimates by Gault (personal communication) appear to be roughly compatible with the track data.

Ages of Specific Lunar Features: In a recent paper (5) we have discussed the difficulties of associating individual exposure ages with the formation of specific lunar features and emphasized the importance of obtaining concordant ages using different methods on a suite of samples. Part of the problem is that primary ejecta may unearth secondary ejecta that previously lay close to the surface. Such samples give spuriously large spallation ages unrelated to the primary cratering event. A total of seven rocks from North Ray Crater measured by us and by Marti et al (6) by the ^{81}Kr-Kr method give ages of 50 my. Track data are compatible with this age. Although the story for South Ray Crater is more complex, an age of 2 my seems reasonably well established (5,7).

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From the data shown in Table 1 for Apollo 17 samples, we now add the consortium boulder from Station 6 which we date at 21 ± 2 my by ^{81}Kr-Kr. The estimated track age of 22 my and the steep track gradient confirms our measurements of the time-averaged spectrum of galactic cosmic rays (8) and fills in a previously missing gap in time in the cosmic ray record. Although the initial data are poor due to the generation of large amounts of CO_2 (indicating a large carbon content, perhaps in the form of a carbonate mineral), we obtain a tentative ^{81}Kr-Kr age of 83 my for 75035, collected from the rim of Camelot. This agrees with the Ar^{38} spallation age given by Kirsten et al (9). However, the track age of the chip is considerably younger (7.3 my), perhaps indicating that some of the spallation gases accumulated at sub-surface sites.

The coarse-grained layer in the deep drill stem extending from the surface to a depth of 1 m was tentatively associated with Camelot in the geology field report. Our initial track measurements at a level of 30 cm give a model age of 30 to 60 my and tend to confirm this view. Track measurements at deeper depths drop off rapidly indicating that the layer has not been stirred to a depth of 30 cm. As we shall discuss in more detail at the meeting, this section of the deep drill stem appears to us to be one of the most interesting and valuable samples brought back from the moon. It gives an unprecedented opportunity to study the history of galactic cosmic rays as well as the details of surface stirring and deposition.

Figure 1 shows the results of track studies in various soil samples from which model ages for several features can be determined. Sample 70181 taken from the immediate vicinity of the deep drill has a model age (ρ_{min}) of 130-150 my. The results indicate that considerable stirring and probable additions of new material have occurred in the first few cm of the regolith since Camelot was formed. The trench samples are unique among our Apollo 17 samples in having relatively simple track histories. The estimated age since deposition of the first 5 cm is 5 to 20 my ago. If this material comes from the nearby 10 meter crater, it demonstrates that the regolith at this site is not heavily irradiated at even modest depths. Both the shadow sample 76241 and the rock skim sample 76321 appear to be typical relatively mature soils.

Table 1: Exposure Ages of Apollo 17 Rocks in 10^6 Yrs

	Surface Feature	^{81}Kr-Kr Age	Track Age
73275	-	139 ± 11	4.7 ± 1.†
75035	Camelot	83 ± 18	7.3 ± 3.†
76315	Station 6 boulder	21 ± 2	21.5 ± 3.5*
76535	Station 6 not a boulder	195 ± 16	2.0 ± .3†
77135	Station 7 boulder	28 ± 3	5.4 ± .8†

†Single point determination at $\geq$ 0.5 cm depth gives maximum surface age.
*Fit to track gradient demonstrates single stage exposure.

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REFERENCES

(1) D. E. Gault, F. Hörz, and J. B. Hartung (1972), Proc. Third Lunar Sci. Conf., Vol. 3, pp. 2713-2734, MIT Press.

(2) D. A. Morrison, D. S. McKay, G. H. Heiken, and H. J. Moore (1972), Proc. Third Lunar Sci. Conf., Vol. 3, pp. 2767-2791, MIT Press.

(3) For a general review, see F. Hörz, D. E. Brownlee, H. Fechtig, J. B. Hartung, D. A. Morrison, G. Neukum, E. Schneider, and J. F. Vedder (1973), Summary paper at COSPAR Mtg., Konstanz, Germany, Planetary and Space Sciences (to be published).

(4) G. Crozaz, R. Walker, and D. Woolum (1971), Proc. Second Lunar Sci. Conf., Vol. 3, pp. 2543-2558, MIT Press.

(5) R. J. Drozd, C. M. Hohenberg, C. J. Morgan, and C. E. Ralston (to be published).

(6) K. Marti, B. D. Lightner, and T. W. Osborn (1973), Proc. Fourth Lunar Sci. Conf., Vol. 2, pp. 2037-2048, Pergamon.

(7) C. Behrmann, G. Crozaz, R. Drozd, C. Hohenberg, C. Ralston, R. Walker, and D. Yuhas (1973), Proc. Fourth Lunar Sci. Conf., Vol. 2, pp. 1957-1974, Pergamon.

(8) R. Walker and D. Yuhas (1973), Proc. Fourth Lunar Sci. Conf., Vol. 3, pp. 2379-2389, Pergamon.

(9) T. Kirsten, P. Horn, and D. Heymann (1973), Earth Planet. Sci. Lett. 20, 125-130.

TRACK DENSITIES IN APOLLO 17 SOILS