THE FLUX OF METEOROIDS AT THE MOON IN THE MASS RANGE 10^{-8} TO 10^{-12} G FROM THE APOLLO WINDOW AND SURVEYOR III TV CAMERA RESULTS. Burton Cour-Palais NASA Johnson Space Center, Houston, TX 77058

A total of $3.5m^2$ of external surfaces of the command module heat-shield windows of Apollo 7 through 17, excluding 11, were examined for meteoroid impacts using an optical microscope. Ten meteoroid impacts with spall diameters ranging from 25 to 445μm have been identified and described in Refs. 1 and 2. Three 1.7cm diameter cores were removed from an Apollo 14 window for SEM scans at magnification levels of 1000x and 10,000x. Approximately $1cm^2$ was scanned at 1000x with a resolution of 200 Angstroms. Of an additional 693 fields of view examined 429, each $10^2\mu m^2$, were at 10,000x with a minimum detectable crater diameter of 0.2μm, and 264, each $10^4\mu m^2$, were at 1000x with a minimum detectable crater diameter of 2μm. No hypervelocity impact craters (remelted lipped pits with or without a concentric spall zone) were seen in either the scan or the individual fields. However, five pits between 5 and 20μm diameter were observed to have fractured central pits and a spall zone. Large numbers of pits averaging 5μm diameter were seen in the coating layer in both examinations, but 90% of them did not penetrate into the glass surface. These craters were cylindrical in section and were presumably caused by debris from the reaction control system or explosive devices.

The meteoroid mass associated with the spall and pit diameters observed in the Apollo window examinations was derived from the results of an experimental hypervelocity impact program performed on the TRW linear accelerator using Apollo window targets. The projectiles used were iron ($\rho=7.8g/cm^3$), silicon ($\rho=2.3g/cm^3$), and lanthanum hexaboride ($\rho=2.6g/cm^3$) ranging from 0.3 to 5μm in diameter, while the impact speeds varied between 1 and 27 Km/sec. In Fig. 1 the experimental results are shown with the best-fit straight line equation in each case for the pit diameter (D_p) and the inner and outer spall diameters D_{si} and D_{so}. The aluminum projectile (ref. 3) is included to provide a projectile of a different density. Apparently the pit diameter is not a dependable means of arriving at the meteoroid mass after spallation begins. For the silicon projectiles, which have approximately the same mass density as the average meteoroid, the departure from the line to the equation occurs at approximately 1 erg; for the iron projectile this occurs at about 10 ergs. In both cases the measured diameter exceeds the predicted diameter by about 20% due to removal of the pit lips in the spallation process. However, both the inner and outer spallation diameters provide a very dependable source for the mass correlation.

The equations used to derive the masses corresponding to the observed Apollo craters were: (1) $D_{so} = 2.8\ d_m \cdot \rho_m^{0.5} \cdot E_m^{0.31}$, for pits with spallation where D_{so} is outer spall diameter (cm); ρ_m is meteoroid mass density (g/cm^3): E_m is meteoroid energy (ergs): and d_m is meteoroid diameter (cm) and (2) $D_p = 1.8\ \rho_m^{-0.18} \cdot E_m^{0.33}$; for pits without spallation where D_p is pit diameter (μm) and ρ_m and E_m are as in (1). The results of the mass and flux determinations are given in Table 1 for each Apollo mission.

The cumulative Apollo window results are plotted in Fig. 2 along with the recalibrated results of the Surveyor III TV camera housing pits, ref. 4. In addition, the lunar rock crater curve labeled Hartung et al. (1972) and

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Morrison et al. (1973) in ref. 5 is shown on the plot for comparison. Both the Surveyor III data and the lunar rock curve have been modified to a meteoroid density of $2 g/cm^3$ to be compatible with the Apollo window mass determination. The Pioneer 8/9 front film grid data point from ref. 6 is also included.

The consistency between the Apollo window and Surveyor III data is evident, but there is a difference of about a factor of 6 compared with the lunar rock curve. If the Pioneer 8/9 point is considered with the window data, the shape of the possible current flux at the Moon shows an upturn in the low masses similar to that for the rocks.

References:
1. B. G. Cour-Palais et al; NASA SP-315, 1973.
2. B. G. Cour-Palais et al; Lunar Science III, 1972.
3. R. Block et al; Max Planck Institute für Kernphysik, 1971.
4. B. G. Cour-Palais et al; Space Research XII, 1972.
5. F. Hörz et al; Plan and Earth Sciences (to be published).
6. O. E. Berg and E. Green; Space Research XIII, 1973.

TABLE I: APOLLO CRATER CHARACTERISTICS

Apollo	Exposure (m^2sec.)	Number of impacts	Limiting crater dia. (μm)	Minimum mass (g)	Nom. flux at moon per m^2sec.
7 (Earth Orb.)	1.39×10^5	5	125	1.8×10^{-10}	1.87×10^{-5}
8	1.13×10^5	1	65	5.7×10^{-11}	1.70×10^{-5}
9 (Earth Orb.)	1.18×10^5	1	200	3.3×10^{-10}	4.43×10^{-6}
10	1.25×10^5	0	40	2.7×10^{-11}	-
12	1.53×10^5	0	40	2.7×10^{-11}	-
13	1.01×10^5	1	445	1.1×10^{-4}	1.89×10^{-5}
14	1.48×10^5	2	25	1.3×10^{-11}	2.60×10^{-5}
15	1.81×10^5	0	100	1.1×10^{-10}	-
16	1.68×10^5	0	100	1.1×10^{-10}	-
17	1.86×10^5	0	100	1.1×10^{-10}	-

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