was unable to show any elements with atomic numbers greater than 11 (sodium); thus, it is unlikely that the brown contamination is composed of lunar soil.

(2) The pitting is due to lunar material blasted toward the Surveyor 3 spacecraft by the Apollo 12 LM as it landed. This possibility cannot be discounted, as has been shown previously for the camera housing. Experiments have shown that parts of the tube are visible from the LM. Two problems arise with this hypothesis. One is that the pitting on the tube seems to be more intense than on the camera; the other is that the camera seems to have been brown before the LM landed (and in a somewhat uniform fashion). However, the pitted side of the tube was darkened.

(3) The pitting is due to lunar material blasted toward the tube by the vernier engines; the contamination is due to incompletely burned propellant (unsymmetrical dimethyl hydrazine monohydrate fuel combined with nitrogen tetroxide oxidizer, with some nitrous oxide added as a catalyst). This also is a possible source, as the contaminated side of the tube could point down toward the lunar surface and somewhat in toward the Surveyor spacecraft if the tube is rotated 180° about the astronaut's cutter axis relative to possibility (2).

The Surveyor strut seems to have been pitted by lunar material disturbed by either the LM descent stage or the Surveyor 3 vernier engines. The brown contamination also could have come from either source, as the propellants used are nearly identical. We feel that the Surveyor 3 vernier engines are the more logical source.

Conclusions

The general conclusions arising from the MSC examination of the Surveyor 3 television camera housing and polished tube are—

(1) Meteoroid flux at the lunar surface is as expected from near-Earth measurements.

(2) Lunar ejecta flux related to meteoroid impacts on the lunar surface could not be specifically identified. However, other non-natural sources of low-velocity impacts by lunar surface material were evident.

(3) Lunar surface experiments and hardware must be shielded from the effects of spacecraft jet-exhaust-induced impacts.

Although additional analysis of the data obtained from the samples is continuing, it is not expected that the results given at this time will be altered significantly.

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PART F

MICROCRATER INVESTIGATIONS ON SURVEYOR 3 MATERIAL

E. Schneider, G. Neukum, A. Mehl, and H. Fechtig

Two screws from the Surveyor 3 spacecraft recovered during the Apollo 12 mission have been investigated for micrometeorite impact features. A general description of the scientific investigations of Surveyor 3 material is given in reference 1.

The positions of the screws on the Surveyor 3 spacecraft are shown in figure 1. From this pho-

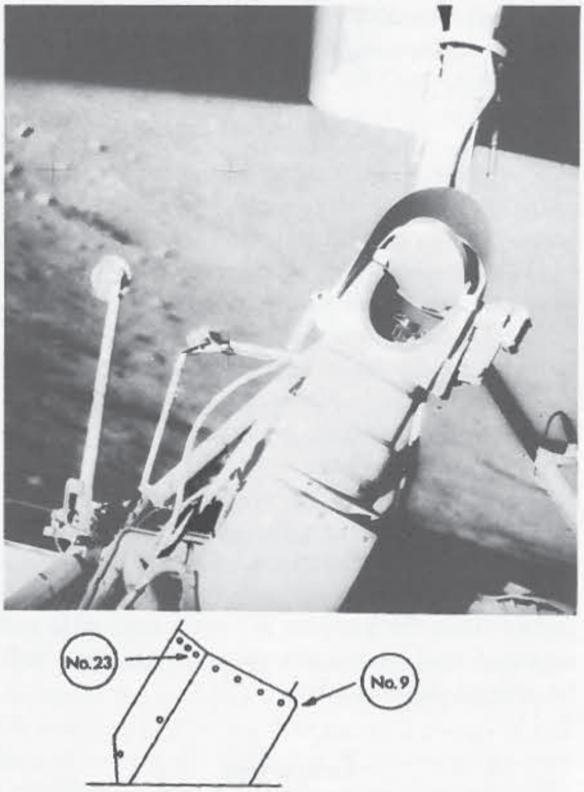


FIGURE 1.—Positions of screws 9 and 23 on the Surveyor 3 spacecraft.

tograph, screw 23 can be seen to point above the Moon's horizon at an angle of 66.6° with respect to the local upward vertical direction. Screw 9 points toward the lunar surface at the same angle with respect to the local downward vertical direction (ref. 2). Therefore, impact craters from extra-lunar particles may be expected primarily on screw 23, possibly together with low-velocity impact craters from secondary lunar debris. Screw 9 should show low-velocity impacts of secondary lunar debris.

Figure 2 shows the two screws including the washers. The investigations were made using a scanning electron microscope (Stereoscan). The scanning magnification was chosen to be 5000 ×, which allowed the identification of craters down to about 0.5 μm in diameter.

The original surfaces of the screws and washers were not specially prepared in any way for scientific investigations. They are rough and probably inadequate to yield reliable results. On screw 2[1] (see fig. 3), strange features could be observed. Figure 4 shows six interesting objects on screw 1; these objects can be considered as impact phenomena.

The crater objects found on the screws can be compared with artificially produced micrometer-sized impact craters on metal targets. Rudolph (ref. 3) has published photographs of microcraters produced in the laboratory using a 2-MV Van de Graaff dust accelerator. Figure 5 shows some craters produced by impacts of iron projectiles on various metal targets with an impact velocity of 5.2 km/sec. The six objects on screw 1 (shown in fig. 4) appear to be low-velocity impact craters ($\leq$ 5 km/sec). They may have been produced either by interplanetary dust particle impacts or by secondary lunar debris from larger impacts on the lunar surface. The three objects on the surface of screw 2 (fig. 3), however, are considered to be manufacturing artifacts rather than impact craters.

[1] The identification numbers of the screws have been lost. Therefore, we have arbitrarily assigned the numbers 1 and 2 to the screws.

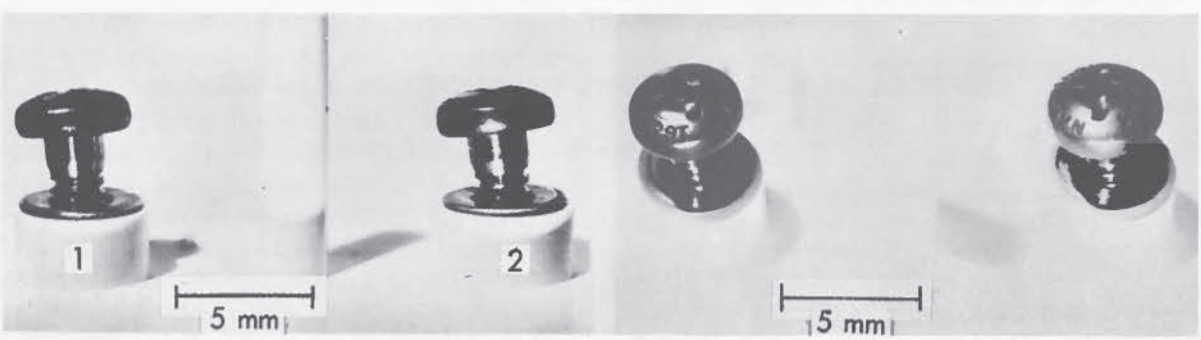
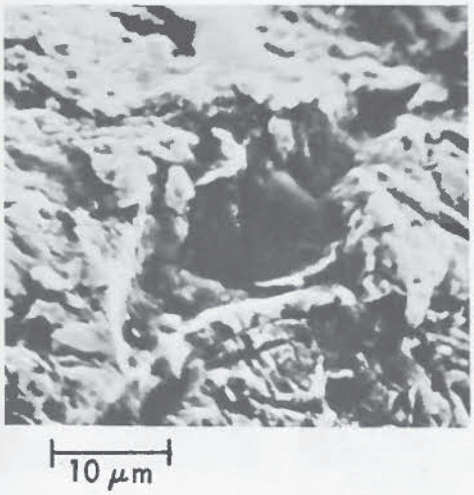
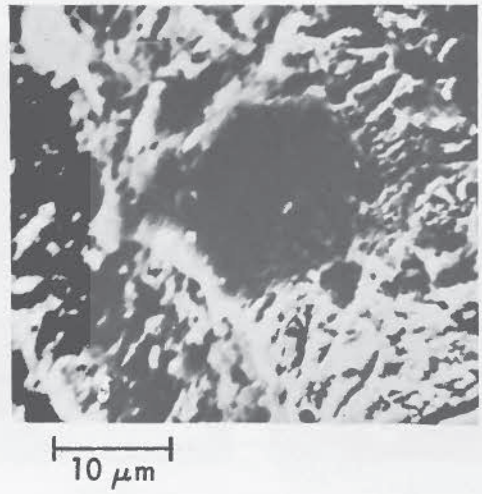


FIGURE 2.—Surveyor 3 screws with washers.





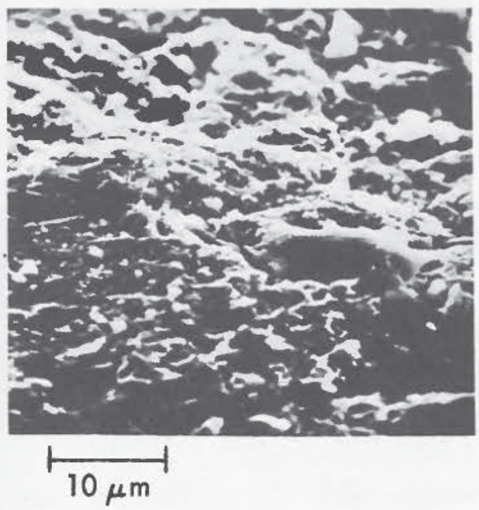


FIGURE 3.—Stereoscan photographs of objects found on the surface of screw 2 (probably not microcraters).

Assuming that the six craters on one of the screws are a result of primary impacts, it is possible to calculate a flux, Φ, for the 31-month exposure time and the surface area of about 0.12 cm^2:

$$\Phi = \frac{N}{Ft}$$

where

Φ = cumulative flux, $m^{-2}\ sec^{-1}$
N = number of particles/crater
F = exposed surface area, m^2
t = exposure time, sec

With the data involved in these investigations, one obtains a flux of $\Phi = 5 \times 10^{-3}\ m^{-2}\ sec^{-1}$.

It seems doubtful to regard this result as interplanetary cosmic dust flux. By comparing this result with the flux obtained from the studies of lunar surface samples (refs. 4 and 5),[2] one should be aware that the particle number density in the interplanetary space at 1 AU shows a deviation in the microcrater distribution in the pit diameter range around 50 μm. This corresponds to a deviation in the microparticle distribution in the particle diameter range of about 25 μm. However, even submicrometer-sized particles exist in the interplanetary space, as indicated by Weinberg (ref. 6) and Hanner[3] from

[2] F. Hörz, J. B. Hartung, and D. E. Gault, Lunar Science Institute Contribution 09, unpublished.
[3] M. Hanner, private communication, 1970.

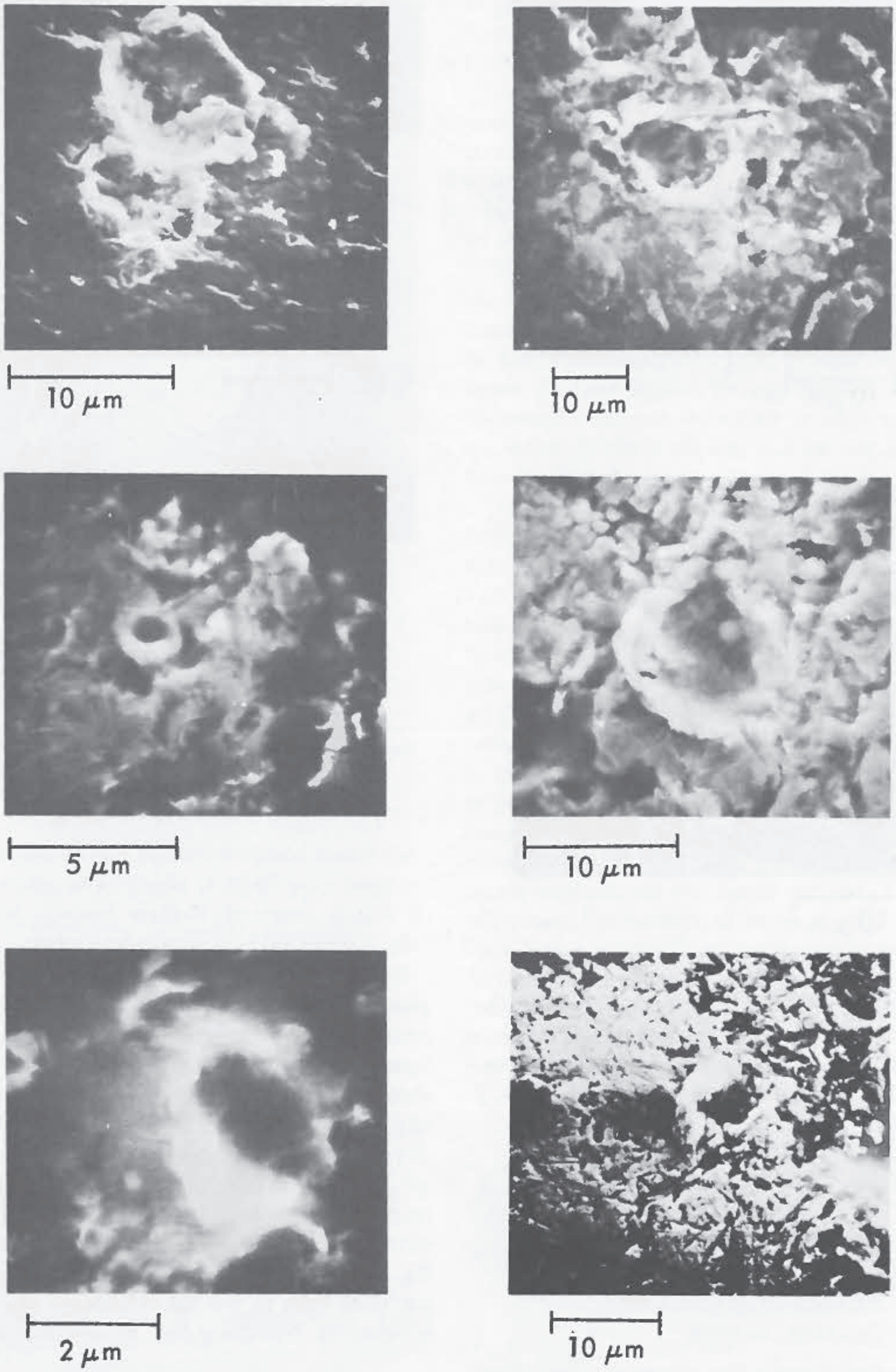


FIGURE 4.—Stereoscan photographs of objects on screw 1; most of the objects are assumed to be microcraters.

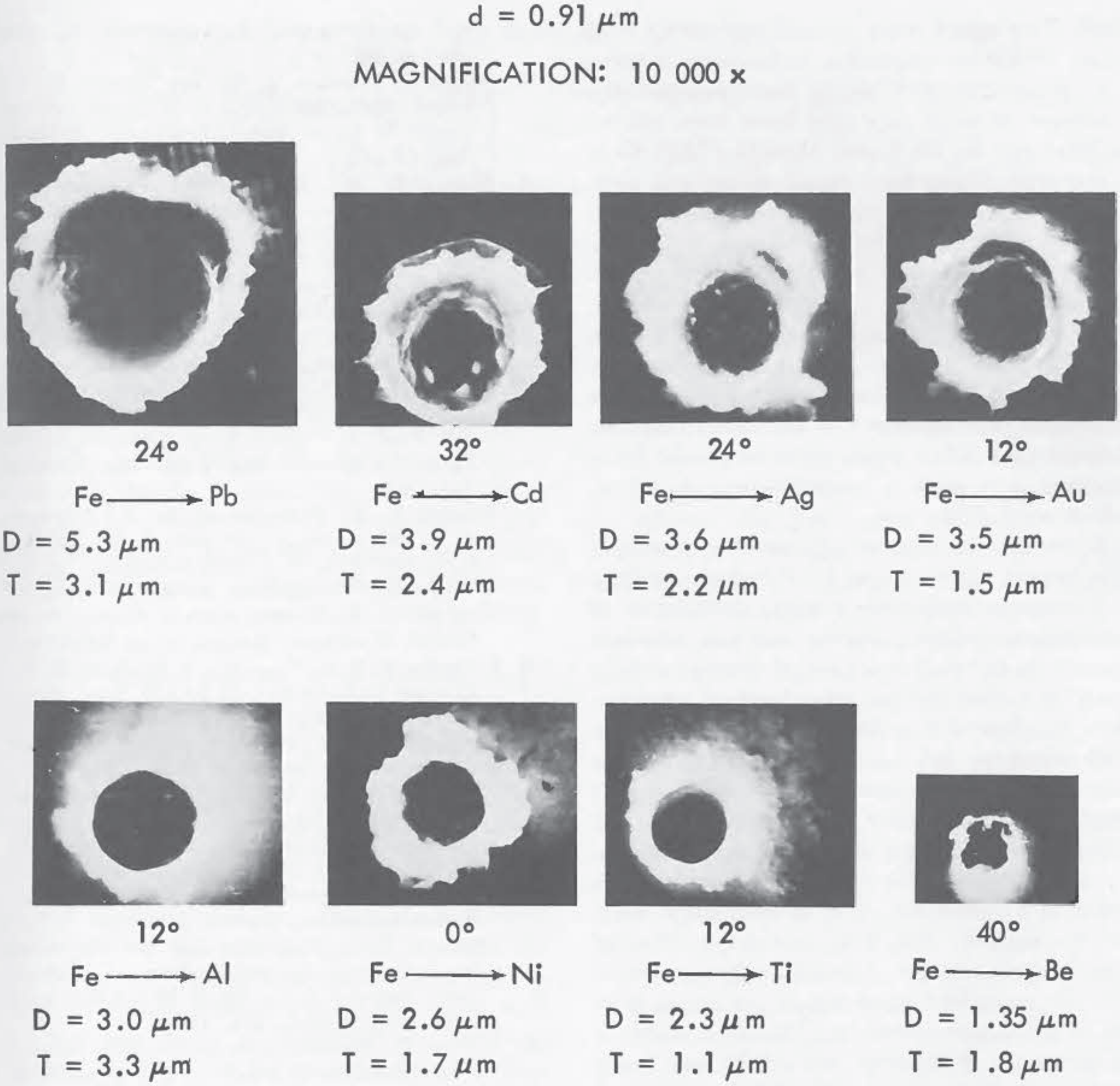


FIGURE 5.—Stereoscan photographs of simulated microcraters caused by iron projectiles on several metal targets at constant impact conditions. Velocity of the projectiles is 5.2 km/sec. d=projectile diameter; D=crater diameter; and T=crater depth. Data from V. Rudolph (see ref. 3).

zodiacal light measurements. Carter (ref. 7) reported the existence of microcraters on lunar glassy spherules down to 300-Å crater diameter. He interprets these craters as produced by secondary particle debris from larger meteoroid impacts on the lunar surface, although these craters found in this investigation can be produced by primary and/or secondary particles. Therefore, we consider the flux of primary particles of

$$\Phi = \frac{N}{Ft} = 5 \times 10^{-3}\ \mathrm{m^{-2}\,sec^{-1}}$$

for particle diameter ≥ 1 μm to be an upper limit. This result is in general agreement with other similar investigations on Surveyor 3 material. Benson et al. (ref. 8) have reported the existence of many dips that have been quoted as produced by the Lunar Module (LM). Only a few craters have been found; none were identified as hypervelocity impact craters. Cour-Palais et al. (ref. 9; also see ch. VI, pt. E, of this report) and Brownlee et al. (ref. 10) have reported a low number of impacts with conclusions similar to those given in this article. Buvinger (ref. 11) has published less than 0.2 hypervelocity impact/cm^2, which suggests our results to be considered as secondary impacts. Zernow (ref. 12) reports negative results for a scanned area with a magnification of 315 ×, which seems to be low.

In conclusion, one can summarize that only few impact craters could be detected. As little is known concerning the velocity distribution of interplanetary dust particles, one can interpret the results in two ways. First, the impacts could have been produced by interplanetary particles, then the flux of 5×10^{-3} m^{-2} sec^{-1} for particles with diameter $\geqq 1$ μm would indicate that a deviation from the normal distribution can exist only for particles below 1 μm in diameter. The alternative interpretation is that most of the craters found by different investigators on Surveyor 3 material are due to secondary lunar debris impacts. In this case, the flux of 5×10^{-3} m^{-2} sec^{-1} for particles with a diameter $\geqq 1$ μm must be interpreted as an upper limit for interplanetary particles. This final result is in agreement with recent flux results from lunar samples (refs. 4 and 5) and with the results of the Pioneer dust experiment (ref. 13).

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