2.3.3 Micrometeorite Impact Craters on Skylab Experiment S 149

K. Nagel, H. Fechtig, E. Schneider, G. Neukum
Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Abstract

During the Skylab experiment S 149 three different sets of areas were exposed. 71.5 cm^2 were facing the sun for 46 days, and 36 cm^2 for 33 days, whereas 77.5 cm^2 were exposed in anti-solar direction for 34 days. A fourth set is currently being exposed with the hope of future recovery. The exposed surfaces consisted of stainless steel, aluminium, platinum, glass, and pyroxene. The recovered targets have been investigated with a light microscope and a scanning electron microscope. We found two groups of possible impact structures:

1.) Five craters between 1 and 30 μm. These craters show clear signs of hypervelocity impact. Measurements yielded diameter to depth ratios between 2 and 3. Chemical investigations in the craters yielded an enhancement in aluminium in one case.

2.) 44 crater-like structures between 1 and 4 μm in diameter. These features have been found on 4 cm^2 of pyroxene exposed in solar direction. They show diameter to depth ratios between 5 and 8. Chemical measurements of the interior of these structures indicate the elements of the pyroxene composition.

The five impacts of the first group correspond to a cumulative flux of the order of 10^{-4} $(m^{-2}s^{-1})$ for masses of about 10^{-12} g. The second group may indicate a fragmentation process at altitudes around 450 km. Considering these 44 crater-like structures having been produced by fragments of one projectile, the impact rate could be comparable to that calculated for the first group. If individual projectiles had produced these structures, the corresponding flux could be 2 orders of magnitude higher.

Introduction

The Skylab experiment S 149 was designed to measure the interplanetary dust flux near the earth (altitude approximately 430 km). As a result of a kind invitation by Dr. Hemenway, Dudley Observatory, Albany, N.Y., surfaces were exposed in three missions. The exposure areas consisted of stainless steel, pyroxene, phosphate glass, and foils of aluminium, and platinum. One set of 77.5 cm^2 was looking for 34 days in the antisolar direction; in solar direction there has been one set of 71.5 cm^2 exposed for 46 days, and another one of 36 cm^2 for 33 days. Fig. 1 shows a model of the spacecraft and the position of the solar and antisolar positions.

Methods

The exposed surfaces have been scanned for micron-sized impact craters or penetration holes, respectively. All areas have been investigated

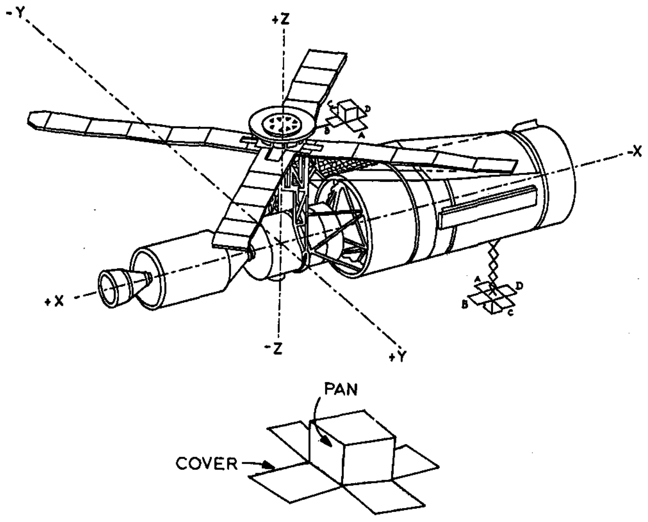

Fig. 1: Model of Skylab with the exposure positions of the collection surfaces.

with a light microscope (detectable crater size 5 µm diameter), and a scanning electron microscope to detect craters .5 µm in diameter. In addition, depth measurements of the individual craters have been performed. Chemical investigations in the interior of the detected craters have been done using a solid state detector Si(Li) and X-ray spectrometers in order to detect projectile residues.

Results

A total area of 52 cm^2 has been investigated with a scanning electron microscope. Five craters have been found between 1 µm and 30 µm in diameter and they all show clear signs of hypervelocity impact. In Table 1, data from the five craters are listed. In addition 44 crater-like features were found on 4 cm^2 of spodumen surface which are interpreted as possible fragmentation products of a low-density projectile near the collection surfaces.

Table 1: List of Impact Craters

Material	Number of craters	Diameter (µm)	Diameter to depth ratio	Exposure direction	Exposure position
stainless steel	1	3.1	2 to 3	solar	pan
pyroxene	1	1.0		solar	pan
phosphate glass	1	2.0		solar	pan
aluminium foil	1	30.0		solar	cover
stainless steel	1	16.0x22.0		antisolar	pan
pyroxene	44	1.0-4.0	5 to 8	solar	cover

Fig. 2 shows the larger crater on stainless steel, the penetration hole in aluminium foil, and one of the 44 craters on pyroxene.

The ratios of crater diameter to crater depth of some of the 44 craters vary between 5 and 8 (Table 1). A comparison with simulated craters suggests low density projectiles (Nagel et al., 1975). If we assume that these 44 craters were produced by fragments of one projectile (total of 6 projectiles) the calculated particle flux is $10^{-4}m^{-2}s^{-1}$ for particle masses of about 10^{-12} g. If we assume that each crater was produced by a primary projectile (total of 49 projectiles) the corresponding flux is two orders of magnitude higher.

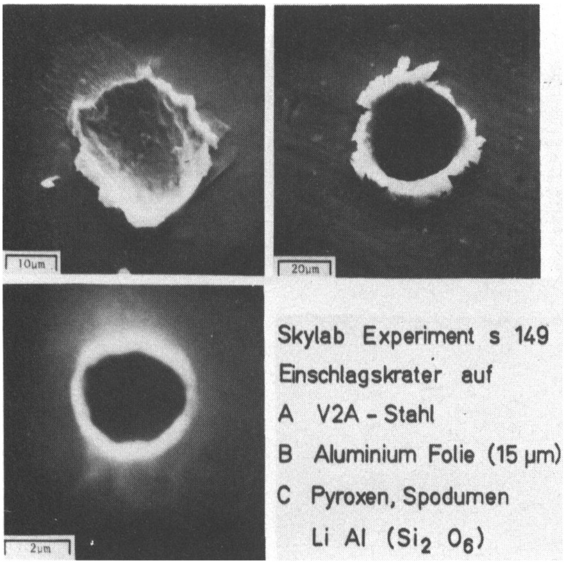

Fig. 2: Scanning electron micrographs of three craters detected on exposed areas.

Chemical measurements in some of the 44 craters yielded the pyroxene composition and no indication of other materials. Investigations of the interior of the larger crater in stainless steel showed an enhancement in aluminium. Chemical analysis of the crater in phosphate glass revealed Al, Si, P, Ca, and Fe, but since all these elements are present in the target it is difficult to measure the residues of the projectile if it had stony meteorite composition. However, we can still exclude the possibility that the projectile was composed of FeNi since these elements were not recorded in the crater.

Discussion of results

The results given here are in a good agreement with the results of the experiment S 149 of Hemenway at al. (1974).

The evidence for fragmentation processes near the collection surfaces as reported in the previous section has also been found by Hemenway et al. (1975). These fragmentation effects have been observed by the satellite experiments Prospero (Bedford et al., 1975) and HEOS 2

(Hoffmann et al., 1975b). In a separate paper (Fechtig and Hemenway, 1976) possible fragmentation mechanisms are discussed.

The location of 4 (out of 5) craters on the pans (cf. Fig. 1, Table 1) suggests that they represent the "apex"-population of the meteoroids, since most of them are found in apex direction (Hoffmann et al., 1975a).

The results for the fluxes are also in good agreement with the results reported from the HEOS 2 dust experiment S 215. The reported fluxes are close to the so-called "apex"-fluxes from the HEOS 2 results.

Acknowledgments

We like to thank Dr. C.L. Hemenway and Dr. D.S. Hallgren for the invitation to participate in their experiment S 149 and for their efforts in mounting and in handling our samples. Mrs. Papp has done a great part of the scanning work.

References:

Bedford, D.K., Adams, N.G., and Smith, D. (1975), "The Flux and Spatial Distribution of Micrometeoroids in the Near-Earth Environment", Planet. Space Sci. 23, 1451.

Fechtig, H., and Hemenway, C.L. (1976), "Near Earth Fragmentation of Cosmic Dust", this Volume.

Hemenway, C.L., Hallgren, D.S., and Tackett, C.D. (1974), "Near Earth Cosmic Dust Results from S-149", AIAA/AGU Conference on Scientific Experiments of Skylab, Huntsville, Alabama.

Hoffmann, H.-J., Fechtig, H., Grün, E., and Kissel, J. (1975a), "First Results of the Micrometeoroid Experiment S 215 on the HEOS 2 Satellite", Planet. Space Sci. 23, 215.

Hoffmann, H.-J., Fechtig, H., Grün, E., and Kissel, J. (1975b), "Temporal Fluctuations and Anisotropy of the Micrometeoroid Flux in the Earth-Moon System Measured by HEOS 2", Planet. Space Sci. 23, 981.

Nagel, K., Neukum, G., Eichhorn, G., Fechtig, H., Müller, O., and Schneider, E. (1975), "Dependencies of Microcrater Formation on Impact Parameters", VIth Lunar Science Conference, Houston, 1975. To be published in the Proceedings of the VIth Lunar Science Conference, Vol. 3, p. 3417.