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FINAL REPORT

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STUDY AND INTERPRETATION OF LUNAR CLOSE-UP STEREO PHOTOGRAPHY

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FINAL REPORT

STUDY AND INTERPRETATION OF LUNAR CLOSE-UP STEREO PHOTOGRAPHY

I. INTRODUCTION

The lunar close-up stereoscopic camera which was built by Kodak to the specifications of Dr. T. Gold was used successfully on Apollo 11, 12 and 14. It functioned without any technical faults and was judged convenient to use by all three crews. It recorded a variety of surface textures in the lunar soil, both distrubed and undisturbed, a number of rock surfaces in the undisturbed condition, and a number of surface samples of materials brought to the moon whose interaction with the lunar soil was to be tested. A resolution of approximately 80 microns was aimed for in the design of the camera and was indeed obtained on all pictures. Stereoscopy played a major part in interpreting surface textures and small scale structure.

The interpretation of the pictures led to several significant conclusions concerning processes on the lunar surface and to interesting results concerning the interaction of lunar soil with manmade objects. Undisturbed, partially imbedded lunar rocks were found to be usually completely free from lunar soil on most of the exposed surface. Glazed micrometeorite impact holes and other fine detail of the rock could be recognized, making clear that any tendency of general scattering of the lunar dust by meteorite impacts must be opposed by some other surface transportation process that tends to remove fine material from the surfaces of the stones. Some remarkable small scale features were seen in the undisturbed lunar soil which can be reproduced in the laboratory under conditions of electron bombardment. Glass deposits were photographed, some of which are difficult to understand in terms of impact phenomena, and the origin of these is not yet known. The characteristic patterns of lunar soil as disturbed by the astronauts' boots were seen and one recognizes a preponderance of clumps, presumably due to electrostatic effects. Imprints of the astronauts' boots and of the wheels of the MET show the extraordinary perfection with which the lunar soil allows itself to be molded due to the small particle size and the degree of cohesion between the grains.

The test samples of man-made materials show clearly the great importance of electrostatic effects in attracting dust grains and the differences of different substances in this regard. It was also seen that brushing with a soft brush cleaned most surfaces satisfactorily.

The number of pictures taken on all three missions was not as large as had been hoped. The number of stereo pairs from Apollo 11 was 17, from Apollo 12 it was 15, and from

Apollo 14 it was 17. The fact that interesting small scale structure can be seen on the undisturbed lunar soil on a scale that the astronauts could not discern makes clear that many more shots of undisturbed soil would be valuable.

II. PURPOSE OF THE CAMERA

The purpose of the camera was to record on the moon features of interest that were on too small a scale to be recorded by the Hasselblad photography and that could not be transported back to earth without significant disturbance. The condition of the surfaces of rocks, the nature of the junction line between rocks and soil, and the detailed structures and textures of the soil are in that category. For unexpected features the close-up photography may contribute clues essential for an understanding. Man-made disturbances in the soil, such as by rocket exhaust, footprints or wheel imprints, may need to be investigated for technological reasons. Thus the following priority list for photography was supplied as a guidance to the astronauts before the Apollo 11 mission.

a. Unexpected Features. Any small scale feature on the lunar surface which is totally unexpected from the Surveyor photography. A crack in the ground or a deep hole whose edges could be photographed would be in this category. Any area suggesting that gases or liquids have come from the interior, such as by changing the surface color or texture would be another high priority item. Any very unusual looking object lying on the ground should be photographed *in situ* first, even if it were planned to bring it back. In the observation of the unexpected features, the high definition pictures may contain essential clues that lead to an understanding of the phenomena that were responsible.

b. The Deposition of the Lunar Soil. The photography should include representative areas of ordinary undisturbed ground the relationship between the soil and rocks, i.e., the details at the junction line; a comparison of the junction line on the uphill and downhill side of a rock which is lying on an inclined slope; details of the soil lying on top of a rock; any unusual looking structures or features in the soil material; any patterns, striations or markings in the soil, especially on steeply inclined areas (even if these steeply inclined areas are only a few inches in size); any trench or depression adjacent to or surrounding a rock; any place that is suggestive of rock material having become disintegrated and added to the neighboring soil; small fresh looking craters on the ground that may be seen, in the size range from the smallest perceptible up to tens of centimeters (for the case of the larger ones a number of representative areas in and around the crater should be photographed).

This photography will assist in gaining an understanding of the manner in which lunar soil has been produced and transported. Surface erosion processes have taken place on the moon but their detailed nature is not understood. A tendency exists for the soil material to be deposited level, and this photography may shed light on the mechanism responsible for this.

c. Surface Details Visible on the Rocks. Photography should include fissures, apparent cleavage planes, any structure suggestive of bedding, and structure suggestive of crystallization, holes or porous structures, junction lines between two different substances, any areas showing a color or albedo differentiation.

This investigation may shed light on the origin of the rocks, perhaps on the manner in which they were formed or the depth from which they were excavated by impacts. Features on the rocks may contain information concerning processes that took place in the subsurface layers related possibly to volcanism or to the percolation of water or the formation of ice or the percolation by other volatiles. They also may contain information concerning the manner in which the subsurface material was laid down, i.e. whether by a magmatic process or the settling down of small particles, etc. It may also be possible to discern whether there are any similarities between such rocks and any of the meteorites.

d. <u>Interaction of Soil with the Astronauts</u>. The footprints of the astronauts should be photographed, in different locations if there is any variability of the depth to which they sink in, in order to facilitate the design of vehicles for lunar use. Any clumping or adhesion of lunar soil on any part of the vehicle or on the astronauts should be photographed so as later to minimize problems from this cause.

For Apollo 12, 13 and 14 this was updated to the following headings:

1. Unexpected Features
2. Glassy Objects on the Surface
3. Rock-Soil Junction
4. Inclined, Undisturbed Soil Surface
5. Top Surfaces of Rocks
6. Footprints.

Dr. Gold discussed these priorities and details of the management of the camera with the crew of Apollo 13 and of Apollo 14.

III. RESULTS

The following reports regarding the close-up stereoscopic photography have been prepared.

(1) In the preliminary science report for Apollo 11 a report prepared by the staff at MSC, Houston entitled "Lunar Surface Close-Up Stereoscopic Photography";

(2) In the same volume and also in Science, 165, 1345 (1969) a paper by T. Gold, "Apollo 11 Observations of a Remarkable Glazing Phenomenon on the Lunar Surface,"

(3) In Science, 1 May, 1970, 168, 608-611, a discussion by various authors of the Origin of Glass Deposits in Lunar Craters;

(4) in the Preliminary Science Report for Apollo 12, a paper by T. Gold, F. Pearce and R. Jones "Lunar Surface Stereoscopic Photography;

(5) in Icarus, 12, a paper by T. Gold "Apollo 11 and 12 Close-Up Photography";

(6) in the Preliminary Science Report for Apollo 14, a paper by T. Gold "Lunar Surface Close-Up Stereoscopic Photography".

These papers discuss many aspects and details of the observations. Different surface textures can be distinguished, and one can recognize different types of undisturbed ground and distinguish it clearly from ground that has been modified either by the rocket exhaust or by the spray of the astronauts' boots. In the undisturbed ground features are seen that point to an as yet unknown surface activity. Thus one sees ridges and valleys with a width less than 1 mm extending over distances of several centimeters. A surface transportation process evidently takes place which has a tendency of distributing material in that particular way. Similar phenomena are seen in the laboratory when dust is transported electrostatically.

Top surfaces of rocks in their undisturbed condition were found to be completely free from lunar dust. Since the time scale for coating with secondaries of meteorite impacts would be much shorter than a time scale for imbedding them by the same process to the depth to which they are imbedded, it is clear that a surface transportation process other than meteorite bombardment has been active. The extreme cleanliness on the surfaces of such rocks can be gauged from the fact that glossy surfaces, no doubt for the most part caused by impacts, are clearly seen and that enclosures in the rock of different color are not obscured.

In the observations of surface samples contaminated with lunar dust and then cleaned off, various interesting effects are observed. The dust is differently attracted to various surfaces and in particular it is very strongly preferentially attracted to small indentations of the surface. This has to be ascribed to strong electrostatic effects from the edges of these indentations acting on a significantly charged dust.

The examination of the photographs included a microscopic examination up to the full resolution of the film used, and the fine detail discovered in this way included such features as "icicles" of glass hanging down over an edge. Many very clean and shiny surfaces were discovered, again pointing to a process that prevents the settling down of very fine particles on them or that removes those on a short time scale.

Two models were made of two Apollo 11 photographs using the methods of photogrammetry. These models enabled one firstly to appreciate better the real materials and texture of the material *in situ*. They also allowed one to determine whether particular demarkation lines could be due to differences in the ground that suffered solar irradiation and that which did not. One picture in the Apollo 11 series shows such a line, and it is indeed likely that one side of the line represents ground which is permanently shielded from the sun. This greatly strengthens the hypothesis that solar irradiation or solar wind exposure causes the surface to change its albedo. The models have a size of 44 x 45 cm and will now be available as exhibits in a museum.

IV. PUBLIC DISPLAYS OF LUNAR CLOSE-UP STEREOSCOPIC PHOTOGRAPHY

Display units have been manufactured for showing a set of selected pictures in 3-D in museum circumstances. These displays utilize the "Vectograph" principle developed by the Land Polaroid Corporation and the transparencies were made available free of charge by Dr. Land. Units of five pictures are at present on exhibit in the following locations.

1. Paris, Palais de la Decouverte
2. Smithsonian, Washington
3. NASA Headquarters
4. Space Museum, MSC, Houston
5. Space Museum, Cape Kennedy

In addition, such units have been exhibited at two COSPAR Meetings, one in Leningrad in May 1970 and one in Seattle in May 1971. These exhibits appear to be of great interest to the public.