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EARTH RESOURCES SURVEY PROGRAM

SPACE APPLICATIONS PROGRAMS

TECHNICAL LETTER NASA-75

N70-38846
(ACCESSION NUMBER)
10
(PAGES)
CR-85481
(NASA CR OR TMX OR AD NUMBER)
1
(THRU)
(CODE)
13
(CATEGORY)
FACILITY FORM 602

U.S. Geological Survey
Department of the Interior

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WASHINGTON, D.C. 20242

Technical Letter
NASA - 75
April 1967

Dr. Peter C. Badgley
Program Chief,
Code SAR - NASA Headquarters
Washington, D. C. 20546

Dear Peter:

Transmitted herewith is one copy of:

TECHNICAL LETTER NASA-75

USE OF INFRARED IMAGERY AND COLOR PHOTOGRAPHY IN STUDY

OF MISSILE IMPACT CRATERS*

by

H. J. Moore, David Cummings, and D. E. Gault**

Sincerely yours,

William A. Fischer
Research Coordinator
Earth Orbiter Program

*Work performed under NASA Contract No. R-09-020-015
**U.S. Geological Survey, Menlo Park, California

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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

TECHNICAL LETTER NASA-75

USE OF INFRARED IMAGERY AND COLOR PHOTOGRAPHY IN STUDY OF MISSILE IMPACT CRATERS*

by

H. J. Moore, David Cummings, and D. E. Gault**

April 1967

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Prepared by the Geological Survey
for the National Aeronautics and
Space Administration (NASA)

*Work performed under NASA Contract No. R-09-020-015
**U.S. Geological Survey, Menlo Park, California

Use of infrared imagery and color photography in study of missile impact craters

by H. J. Moore, David Cummings, and D. E. Gault

Abstract

Daylight infrared imagery in the 8-13 micron band and color photography obtained from aircraft overflights 2,000 feet above the local terrain were used to study craters produced by missile impacts. Preliminary evaluation gives the following results:

1. The ejecta from the craters were detected using both infrared imaging and color photography during daylight flights.

2. The ejecta from the craters were relatively cool because of high moisture contents resulting from local rain showers, and were paler than their surroundings.

Author

Introduction

A study of craters produced by the impact of missiles is being conducted jointly by the U.S. Geological Survey, the Commanding General of White Sands Missile Range, and the Ames Research Center of the National Aeronautics and Space Administration (NASA). This report is a preliminary description of the results of infrared imagery and color photography of four craters taken by the Natural Resources Program Remote Sensing Aircraft operating from the Manned Spacecraft Center (NASA).

Experimental procedure

In late July 1966 three passes were flown over three craters which were formed several hours prior to the flight and one pass was flown over one crater which was formed a year before the flight at 2,000 feet above the terrain. Daylight infrared imagery at a scale of 1:30,000 using the Reconofax IV infrared scanner (8-13μ band) and photographic imagery at a scale of 1:4,000 using the RC-8 camera with Ectachrome color film were obtained. Several passes were flown using the infrared scanner the following morning. The ground speed of the aircraft ranged between about 145 and 155 knots. The aircraft and camera data are also reported in a flight summary report for Mission 28 (NASA, 1966).

Three test runs were flown the previous day but these are not reported here.

Topographic and geologic maps were prepared at scales of 1/24, 1/48, and 1/3600 during the following few days for use in comparing ground observations with the infrared and photographic imagery. The year-old crater was mapped at a scale of 1/48. The general characteristics of the missile impact craters have been reported previously (Moore et al, 1964, p. 58-92; Moore, 1966, p. 79-105), and the experimental conditions for the missile craters are shown in table 1.

Experimental results

The impact of the missiles produced craters in very pale gray gypsum between 14 and 18 feet across and 3.4 to 4.4 feet deep. The asymmetrical ejecta reflected the oblique trajectory of the missiles. The ejecta was paler than surrounding surface exposures. Geologic mapping showed that ejecta 0.1 of a foot to about 1.0 foot thick was deposited around the craters at right angles to the plane of the trajectory and in forward directions (down range) up to 45 feet from the craters (see fig. 1). A similar pattern was observed for thin to discontinuous ejecta that extended up to 120 feet from the craters. Rare and scattered pieces of ejecta were found as far as 300 feet from the craters.

The craters and their ejecta were detected with difficulty on the color photography. This was principally due to two factors: (1) the ejecta, craters, and surrounding ground were very pale gray so there was little contrast, and (2) the photographs were a little over exposed. However, the ejecta was, in general, paler than the surrounding materials. In only one case, crater 30, could

Table 1.

Crater	Date made	Diameter	Depth	Kinetic energy (ergs)	Angle of impact
28	July 1966	17.2-18 ft.	4.4	1.6×10^{15}	47°
29	July 1966	18-16.2 ft.	3.4	1.6×10^{15}	47°
30	July 1966	14-14.4 ft.	3.5	1.6×10^{15}	47°
18	June 1965	20.1-21.2ft.	5.2	2.4×10^{15}	46°

a line be drawn around a crater with confidence. The results of attempts to delineate ejecta patterns on the color photography are shown in figure 1.

All ejecta from the craters were readily distinguished on the infrared imagery, where they appeared as dark images on the positive transparencies furnished by NASA. Dark images show the craters and their ejecta were cooler than their surroundings, apparently due to a high moisture content. Ejecta up to 1 foot in thickness was sampled and found to range from 4.25 to 5.54 percent in moisture content by the weight loss method. This was found to be the case for ejecta from the three newly-formed craters as well as the year-old crater.

The high moisture content of the ejecta was probably caused by local rain showers that occurred before the craters were photographed. A relatively warm region, probably dry, was detected in the year-old crater.

Early morning infrared imagery was obscured because of rain during the night.

Summary

The ejecta from craters produced by missile impacts were detected in both color photography and infrared imagery. Ejecta from craters shown in the color photographs were lighter than the surrounding terrain. Ejecta from craters shown in the infrared imagery were cooler than the surrounding terrain because the ejecta had high moisture content related to local rain showers.

Recommendations

It is recommended that the experiment be repeated since local rain showers affected the results. In addition, other instrumentation such as the multiband camera, microwave radiometer, and scatterometer should be employed to detect the craters. Finally, the data should be supplemented with temperatures measured on the ground.

References cited

NASA, 1966, Natural Resources Program Remote Sensing Aircraft Flight Data summary report, NASA 926, CV-240A, Mission No. 28, prepared by Flight Research Project Branch Aircraft Operations Officer, Flight Crew Operations Directorate, Manned Spacecraft Center, Houston, Texas.

Moore, H. J., Kachadoorian, Reuben, and Wilshire, H. G., 1964, A preliminary study of craters produced by Missile Impacts, in Astrogeology Studies ann. prog. rept. July 1, 1963-July 1, 1964, Pt. B: U.S. Geol. Survey open-file report, p. 58-92.

Moore, H. J., 1966, Craters produced by Missile Impacts, in Astrogeology Studies ann. prog. rept. July 1, 1964-July 1, 1966, Pt. B: U.S. Geol. Survey open-file report, p. 79-106.

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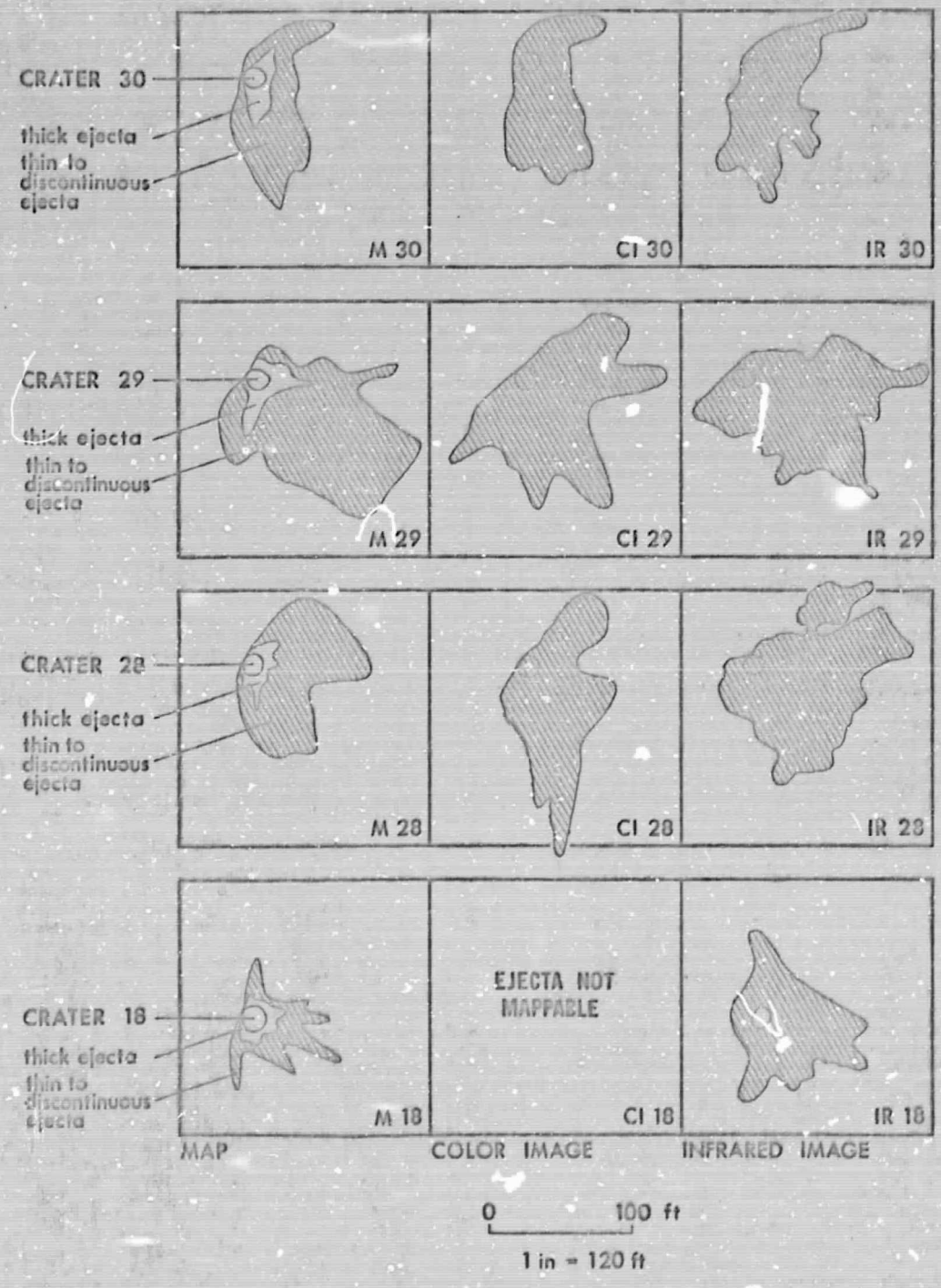

Figure 1. Comparison between geologic mapping, color image, and infrared image of ejecta from missile impact craters.