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MORPHOLOGIC STUDIES OF THE MOON AND PLANETS (NSG-7188)

FINAL TECHNICAL REPORT

to

Planetary Geology Program
Division of Solar System Exploration
Office of Space Science and Applications
National Aeronautics and Space Administration

Period Covered: July 1, 1976 - August 31, 1984

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Morphologic Studies of the Moon and Planets (NSG-7188)

Final Technical Report

ABSTRACT

Investigations of the impact, volcanic and tectonic history of the Moon and planets were carried out over an eight year period from July 1, 1976 to August 31, 1984. These studies resulted in numerous reports published in the scientific literature, including papers on: the interpretation of lunar orbital geochemical data, terrain effects on the morphology of lunar craters, structural development of flooded impact basins, the setting and style of eruption of lunar volcanic features, comparison of eolian features on Earth and Mars, and the detection of previously unknown impact basins on Mars. In addition, summary papers were published on lunar stratigraphy and the exploration of the Moon.

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Morphologic Studies of the Moon and Planets (NSG-7188)

Final Technical Report

INTRODUCTION

This final report covers research conducted under National Aeronautics and Space Administration Grant NSG-7188, titled "Photogeology of Lunar Impact and Volcanic Features" (July 1, 1976 - May 31, 1979), and "Morphologic Studies of the Moon and Planets" (June 1, 1979 - August 31, 1984). Numerous research tasks were completed under these proposal periods, concentrating on lunar data analysis and synthesis during the 1976-79 grant period, and on broader aspects of comparative planetology from 1979 to 1984. The changes in grant titles and administrative responsibilities are covered in the Administrative Summary below.

Research under the auspices of this grant consisted of analysis of Apollo lunar photography and orbital geochemical data to better understand the impact, volcanic and tectonic history of the Moon. Investigations of terrestrial analogs to martian eolian features were undertaken to provide a better understanding between erosional and depositional desert landforms seen in Viking Orbiter images of the surface of Mars. In addition, spectral reflectance measurements of terrestrial desert surface sediments provided information on the origin and changes of sand grain coatings resulting from eolian transport. These investigations have provided a firm scientific basis for further analysis of orbital photography and images, particularly for their use in constraining geophysical models of planetary crustal deformation and geochemical models for the formation and modification of sand grain coatings.

ADMINISTRATIVE SUMMARY

Originating in the period following the Apollo missions, NASA Grant NSG-7188 was first entitled "Geologic Mapping from Apollo Data" and was under the direction of Dr. Farouk El-Baz, Research Director of the Center for Earth and Planetary Studies, National Air and Space Museum, Smithsonian Institution. A final report on the Apollo investigations was submitted to NASA on June 30, 1976, and a follow-up proposal was submitted for consideration by the new Lunar Data Analysis and Synthesis Program of the Lunar Programs Office. This proposal, entitled "Photogeology of Lunar Impact and Volcanic Features," was given the same grant number for ease in funding, but included significantly different tasks from those of the earlier lunar data analysis. Research funding under this program remained effective until May 30, 1979.

With the changes from NASA's lunar emphasis to planetary data analysis, a renewal proposal was submitted in August, 1978 to the Planetary Geology Program. This proposal, "Morphologic Studies of the Moon and Planets," was still under the direction of Farouk El-Baz, and covered the period June 1, 1979 to June 30, 1982. During this time, research emphasis shifted from lunar mapping and synthesis studies to comparison of eolian features on Mars with similar features in the Western Desert of Egypt. On March 1, 1980, a previously separate proposal ("Analogs of Martian Eolian Features in Southwestern Egypt," NSG-7486) was combined with NSG-7188, and received funding through 1982.

In July 1982, Dr. El-Baz left the Smithsonian, and two no-cost extensions to the grant were issued to complete studies under the direction of Dr. Ted Maxwell. Utilization of carry-over funding from this grant allowed enhancements of the Center's Image Processing facilities and completion of research tasks on the volcanic flooding of

martian craters.

A summary of personnel supported by NASA Grant NSG-7188 is presented in Table 1. In addition to those listed, several interns supported by the National Air and Space Museum were involved in research during the grant period.

Table 1. Personnel Supported under NSG-7188

Personnel	Period of Support	Major Tasks
Farouk El-Baz*	July 1, 1976-July 1, 1982	Director of Research
Ted A. Maxwell**	July 1, 1976-August 30, 1984	Structural Analyses Comparative Studies Director of Research (1982-1984)
R. W. Wolfe*	July 1, 1976-September 1, 1977	Lunar Calderas
P. L. Strain***	July 1, 1976-August 30, 1984	Lunar Rilles and Geochemistry
A. S. Walker	May 4, 1978-May 31, 1979	Lunar volcanism
A. W. Gifford	October 27, 1976-February 28, 1981	Comparative studies
C. A. Wood	September 1, 1979-August 31, 1980	Mars: Basins
A. L. Chaikin	August 30, 1978-February 28, 1979	Comparative studies
L. S. Manent	March 1, 1980-February 28, 1983	Desert studies
K. Stamm	December 1, 1980-October 1, 1981	Desert sediments
V. L. Avery	May 16, 1983-August 23, 1983	Mars: Flooded craters
E. E. Lettvin	September 14, 1981-August 20, 1982	Desert studies
A. H. Hamdan	December 8, 1980-June 5, 1981	Desert studies

*Salaries and wages supported by Smithsonian Institution

**Effective October 1, 1977, salary supported by Smithsonian Institution.

***Effective June 18, 1979, salary supported by Smithsonian Institution.

SCIENCE SUMMARY

Lunar Farside Craters

Since few studies had been made of craters in the farside lunar highlands, the craters King and Aitken were investigated in detail to determine the origin of smooth dark material north of King, and the unique domical structures and linear scarps associated with Aitken. Investigations of these craters suggested that the domes may represent the viscous last stages of volcanic eruption (Walker and El-Baz, 1979).

Relationships of Lunar Craters to Substrate

Instigated by a study of the lunar farside crater Necho (Gifford et al., 1979), several other craters on the lunar far side were determined to have distinctly asymmetric terracing. Gifford and Maxwell (1979) investigated these craters, and found that the asymmetry was related to pre-existing structure and topography of the impact site. Using Necho as the type example of an asymmetrically slumped crater, 30 other highland craters were found to have similar morphology, in which the direction of major slumping is away from an older crater rim.

Lunar Basins

Studies of both the Smythii basin and the Serenitatis basin were undertaken during the period of research. Comparisons of the partially flooded Smythii basin to Orientale by Strain and El-Baz (1979) indicated that differences in the thickness, composition and physical properties of the lunar crust existed between the time of the two impacts.

Investigations of structural features in the Serenitatis basin concentrated on estimating the origin and amount of stress needed to deform the basaltic mare layers into ridges. Using a finite-element model (Maxwell, 1978) to simulate the lunar elastic lithosphere, the amount of strain due to subsidence of the basin was found to be insufficient to cause that observed from photogeologic investigations. Consequently, global-scale lunar contraction, possibly due to cooling of the Moon, is necessary to account for the structural deformation.

Additional studies comparing compressional features in the Caloris basin on Mercury to those of lunar basins suggested that those in Caloris resulted from basin subsidence alone. In contrast to the ridge systems of lunar multi-ring basins, the orientations within Caloris support previous studies that have suggested a post contraction/despinning(?) time of formation for structural features within the Caloris basin (Maxwell and Gifford, 1980).

Lunar Volcanic Features

The geology and morphology of Ina, a unique volcanic depression southeast of the Imbrium basin was described in a paper by Strain and El-Baz (1980). The floor of the "caldera" was found to contain four separate units, including smooth, sparsely cratered protrusions or mounds ranging in height from 5 to 25 m. The unusual morphology of the Ina structure may have been influenced by its location in a highly fractured region between two of the largest nearside impact basins, and by the composition of the magma that erupted to form the feature.

A study of the topography of rilles in the Harbinger Mountains region of the Moon using detailed topography from Apollo metric photography was completed by Strain and El-Baz (1977). The southern ends of the rilles are characterized by circular to elongate depressions that occur on a 30 km diameter dome of probable volcanic origin. Structural studies indicate that slope rather than regional structural pattern is the dominant factor controlling rille direction.

The thicknesses of lunar mare flow fronts as measured from Apollo topography were studied by Gifford and El-Baz (1981). Height measurements of flow scarps were found to range from 1 to 96 m, with 57% less than 15 m. Data for 20 areas, including 15 previously unmeasured regions were summarized.

The distribution and age of basaltic mare units on the far side of the Moon were investigated by Walker and El-Baz (1982), and the thickness of mare units were calculated for three farside craters. Crater frequency distributions on these mare units indicate ages of 3.7 and 3.8 billion years, suggesting that the units are distributed over a narrow time period of about 100 million years. These results indicated that mare basalt emplacement on the lunar far side ceased before it did on the near side.

Correlation of Apollo Geochemical Data

Several studies of the east side of the Moon were undertaken to correlate Apollo orbital geochemical data with photogeologic mapping. Analysis of Apollo 15 low altitude X-ray fluorescence data over Mare Crisium indicated that despite the relative homogeneity of Crisium mare material, small regions of dark mare in the eastern part of the basin

have a lower Al/Si ratio than average Crisium mare. Using Apollo 17 bulk soil analyses, a factor for converting measured Al/Si intensity ratios to soil concentrations was calculated for the Apollo 15 orbital data. Application of this conversion factor suggested that aluminum concentrations in the dark mare units in Crisium were 5% lower than the average mare, and may be compositionally similar to Apollo 17 basaltic regolith (Maxwell et al., 1977).

As part of investigations of the Luna 24 samples, the nature of rays and possible sources of highland material in the vicinity of the landing site were studied by Maxwell and El-Baz (1978). This study indicated that no single source would be responsible for highland fragments in the drill core, and that only a minimal amount of material from the farside crater Giordano Bruno would be present.

Correlation of Earth-based spectral interpretation of Mare Crisium with the subsurface interface detected by the Apollo Lunar Sounder experiment was published by Maxwell and Phillips (1978). Based on these correlations, it is likely that the spectrally distinct surface units are on the order of several hundred meters thick, and that the crater Peirce excavated a subsurface basalt unit.

Lunar Geology - Summary Papers

A summary of lunar stratigraphy by El-Baz (1977) was published as part of the critical lunar questions sections of the Royal Society monograph on the Moon. The major successes and failures of photogeologic interpretations were discussed, as well as the importance of orbital geochemical and geophysical data.

Emphasizing the interdisciplinary nature of lunar studies, El-Baz (1979) used the scientific exploration of the Moon to depict the complex relationships between astronomers, cartographers, geologists, geochemists, geophysicists, physicists, mathematicians and engineers, all of whom are essential to the present-day understanding of the Moon. Although the lunar missions have not yet answered all the questions posed, they have provided lessons that are being applied successfully to planetary missions.

Comparative Studies of Desert Landforms

Although much of the work comparing desert landforms of Mars with those in the Western Desert of Egypt was performed under a previous grant (NSG-7486), several tasks were continued under NSG-7188 after consolidation of the grants. El-Baz and Maxwell (1979) compared eolian wind streaks in southwestern Egypt to those in the Cerberus region of Mars. The size range of streaks in southwestern Egypt was found to be consistent with those on Mars; streaks range from a few kilometers to 40 km in length, and about half those values in width. Detailed studies of streaks in Egypt allowed more definitive hypotheses for the martian eolian regime. Additional comparisons of wind streaks were made using Landsat images of China (El-Baz and Manent, 1981).

Additional studies of desert surfaces concentrated on the nature and composition of coatings on sand grains from the Western Desert as a possible analog to Mars. Kaolinite and montmorillonite were found to be the dominant clays on the grains, and hematite staining was found to be responsible for the red color of the grains, despite active transport.

Mars Impact Basins

Cooperative studies with C. A. Wood resulted in the identification of several new impact basins on Mars from Viking Orbiter images (1980). Eighteen previously unknown basins were detected, the smallest with diameters 50 to 100 km less than the smallest basins on Mercury or the Moon. The diameter distribution of the martian basins was found to exhibit three distinct slope segments, with inflections at the same diameters at which morphologic changes occur. Features within the basins suggested that as on the Moon, Mars basins were the sites of igneous extrusions.

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