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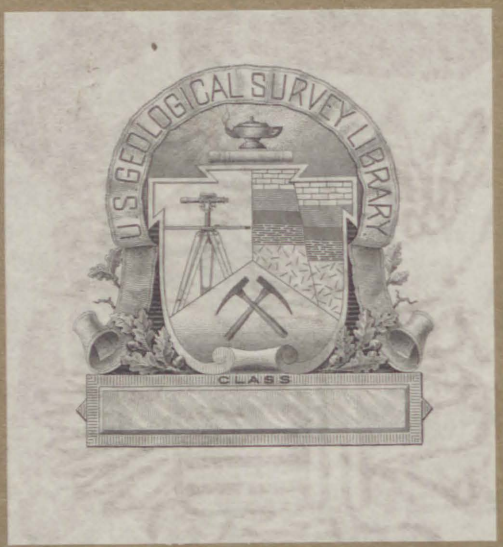
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1. Geologic map of the Fra Mauro region of the Moon—Apollo 13, by R.E. Eggleton. 1 sheet plus 6 p. text. Scale 1:250,000.

2. Geologic map of part of the Fra Mauro region of the Moon—Apollo 13, by T. W. Offield. 1 sheet plus 4 p. text. Scale 1:25,000.

3. Geologic map of the Fra Mauro landing site—Apollo 13, by T. W. Offield. 1 sheet plus 5 p. text. Scale 1:5,000.

* * * * *

To accompany
Geologic Map of Part of the
Fra Mauro Region
of the Moon--Apollo 13
[scale 1:25,000]

By T. W. Offield

The accompanying map shows the geology of the Fra Mauro site--the proposed landing site for the Apollo 13 mission to the Moon. This site lies about 80 km north of the ancient crater Fra Mauro, in a north-south belt of predominantly hummocky uplands terrain geologically distinct from the mare terrains of the earlier Apollo landing sites. The geologic outline of the front face of the Moon is shown by Wilhelms and McCauley (1969); the regional setting around the Fra Mauro site is presented on a 1:250,000-scale map by Eggleton (1970). Detailed geology around the proposed landing ellipse is shown on a 1:5,000-scale map by Offield (1970).

The hummocky textures of the uplands materials become progressively coarser northward from the landing site and are laterally gradational into the rough mountainous terrain forming the rim of the Imbrium basin. Similar hummocky terrain is visible outside the basin rim wherever the uplands have not been inundated by mare or disturbed by younger craters. This terrain, surrounding a circular basin believed to have formed by impact, was interpreted as an ejecta blanket by Gilbert (1893) and many later investigators. The ejecta blanket was named the Fra Mauro Formation by Eggleton (1964). This ejecta interpretation has been strongly reinforced by Lunar Orbiter IV photographs of the Orientale basin, around which similar deposits are better preserved and clearly appear to form an ejecta blanket (McCauley, 1967). Blanket materials around both basins have braided patterns of hummocks and ridges, and partial inundation of craters, suggesting deposition by flow. The Fra Mauro Formation is therefore believed to result principally from radial flowage of material along the surface outward from the Imbrium basin. Such flowage is observed around experimental high-energy explosion craters and some volcanic craters (Masursky, 1968; McCauley and Masursky, 1968). The pattern of flow deposition of the Fra Mauro probably was affected by the topography of the pre-existing ground surface and by contemporaneous ballistic deposition of ejecta, but in general is characterized by ridges oriented radially to the basin, and hummocks either radial or in herringbone patterns whose axes are oriented radially to the basin. In the map area, topographic expression of the Fra Mauro suggests that it is on the order of 200 m thick in the ridges and perhaps 100 m elsewhere. The origin and manner of deposition of the formation can be determined from the composition, texture, structure, and state of consolidation of the materials. The nature of an ejecta deposit of this scale and at this distance from its point of origin is uncertain, but it seems reasonable to expect a chaos of blocks in a flow-structured, finer-grained but variably sorted matrix of particulate debris. A wide range of lithologies is anticipated. The materials may include samples of the full stratigraphic sequence (estimated to be as much as 50 km) excavated from the area of the Imbrium basin. Materials from the original surface in the im-

pact area may include pre-Imbrian mare, plains, and uplands units; these materials may reveal the nature and extent of igneous differentiation processes on the Moon. All of these materials may be shock-metamorphosed to varying degrees, thus extending the range of lithologies that may be present. If blocks originally from great depth can be sampled and dated, they could indicate the time of crystallization of the lunar interior. If blocks that were melted or recrystallized by shock during formation of the Imbrium basin can be identified and dated, the age of the event can be determined. Geologic relations indicate that the Imbrium basin is older than the mare material sampled during the Apollo 11 mission. The age of that mare is 3.7×10^9 years (Lunar Sample Analysis Planning Team, 1970). The age of the Imbrium basin is probably in excess of 4.0×10^9 years.

The Fra Mauro Formation and most other units shown on the map are covered by a relatively thin veneer of unconsolidated particulate debris--the lunar regolith. Compositionally and texturally it is a heterogeneous, poorly sorted mixture of pre-existing regolith and bedrock comminuted, brecciated and shock-metamorphosed to varying degrees by repeated bombardment of the lunar surface by impacting bodies. The regolith is composed largely of materials indigenous to the Moon (derived from both local and distant sources), but probably contains some extra-lunar meteorite debris. Because the upland terrain in this site is older and more disturbed by cratering events than the mare terrain of the Apollo 11 and 12 sites, the regolith is deeper than the 1 to 6 meters observed at the earlier sites. From the depth at which blocky floors appear in fresh craters (Quaide and Oberbeck, 1968), the fragmental surficial layer above the consolidated or semiconsolidated substrate appears generally to be 5 to 12 m thick. In a few places, (for example on the ridges in the Fra Mauro Formation and on crater ejecta), the regolith may be as thin as 1 meter. It is also thin--and may be locally absent--in the walls of the larger young craters.

The projected landing point is within the unit mapped as smooth terrain materials (unit Is). This unit is similar in texture, topographic relief, and albedo (moderately low) to plains units that overlie the Fra Mauro Formation outside the map area. Such plains materials are probably volcanic, but it is also possible that unit Is is a facies of the Fra Mauro, smoother than normal because it was ponded in a topographic low as the formation flowed across the pre-Imbrian surface during deposition.

Individual craters in the site are assigned ages according to the criteria shown in figure 1 (modified after Trask, 1969). The age criteria are based on observed crater superposition relationships which indicate that craters are sharp and fresh in appearance when formed but become increasingly degraded by lunar erosion processes through time. Small craters are degraded faster than large craters so that a small subdued crater may be the same age as a larger less subdued one.

Much of the surface of the map area appears to be covered by ray deposits from the crater Copernicus. The material is probably similar to the apparent ray deposit seen at the Apollo 12 landing site where it consisted of a light-colored fine-grained layer a few centimeters thick (E. M. Shoemaker and others, 1970, written commun.). In walls of craters younger than the Co-

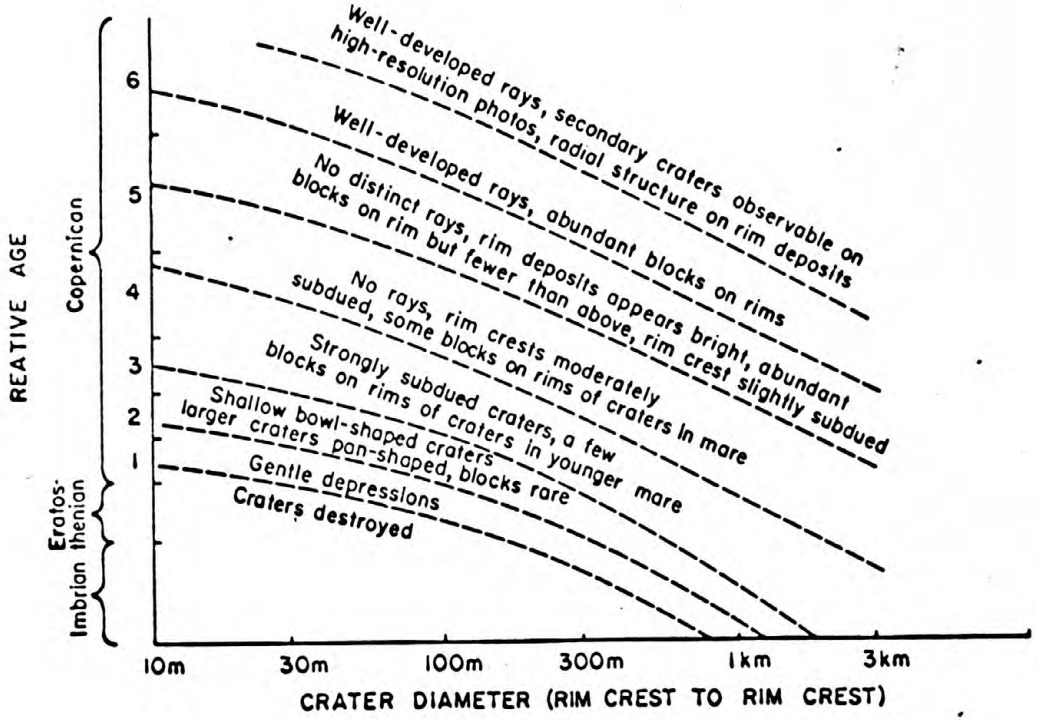

Figure 1.--Relationship between crater morphologies, crater diameters, and postulated ages (modified from Trask, 1969).

pernicus event this light layer may be exposed beneath darker ejecta layers.

Lineaments are not conspicuous in the site, perhaps because they are obscured by the abundance of curved, irregular lines in patterned ground resulting from slumping and downslope creep of unconsolidated surficial materials. Most mapped lineaments trend northeast and northwest coinciding with the lunar tectonic grid system (Strom, 1964) or with the radial pattern of sculpture lines emanating from the Imbrium basin. The large belt of Fra Mauro (unit Ifr) in the site is roughly bounded by lines radial to the basin; the ridge may be defined by Imbrian sculpture or it may be a radial flow ridge or filament in the basin ejecta blanket.

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February, 1970

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