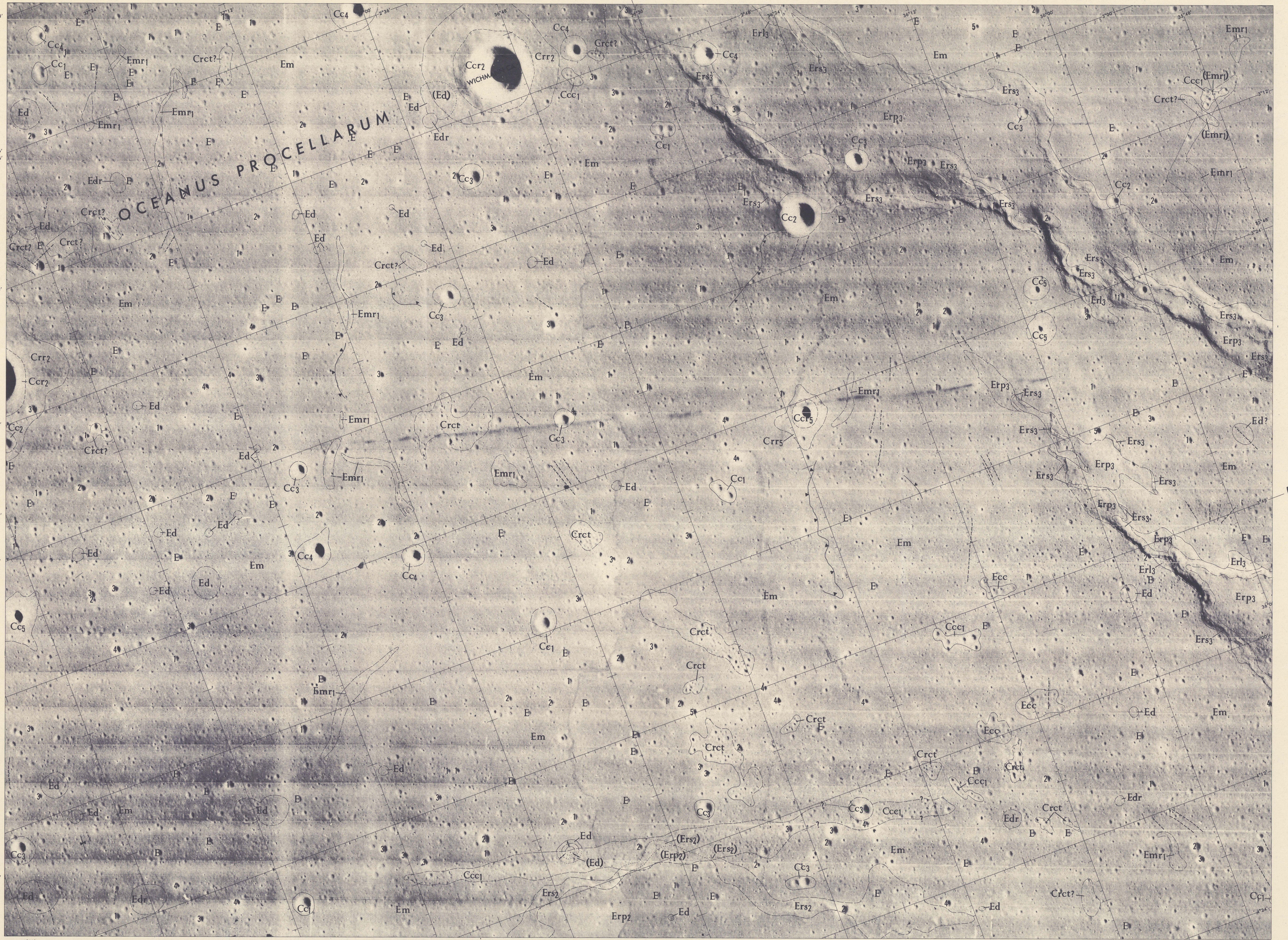
DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
Manned Spacecraft Center,
National Aeronautics and Space Administration
(under NASA contract No. T-66353)



Controlled base prepared by Army Map Service, Corps of Engineers, U.S. Army, Washington, D.C. 20315

SCALE 1:100,000

Principal sources of geologic information: Lunar Orbiter moderate resolution photographs: III--M173-180; V--M169-176. Lunar Orbiter high resolution photographs: V--H169-176 (Langley Research Center, NASA, 1966, 1967); albedo data from Pohn and Wildey (1966) and from full-Moon plates 5818 and 5819 taken at U.S. Naval Observatory, Flagstaff, Ariz.

GEOLOGIC MAP OF LUNAR ORBITER SITE III P-11
OCEANUS PROCELLARUM, SOUTH OF EQUATOR

By
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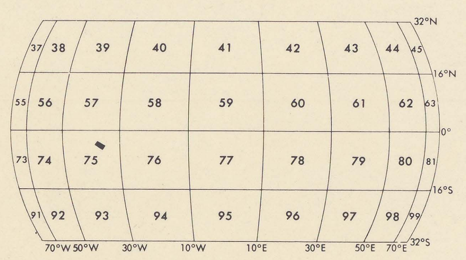
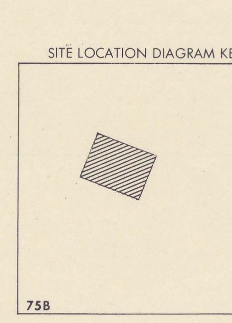
November 1968

Mercator Projection

SITE LOCATION DIAGRAM KEYED TO LAC



SITE LOCATION DIAGRAM KEYED TO AIC



EXPLANATION

Contact

Long dashed where approximate. Short dashed where gradational. Queried where uncertain.

Lineament

Gentle scarp, or trough. Interpretation: Fracture or fault.

(Emr1) Buried contact

Buried unit indicated by symbol in parentheses.

Ridge crest of dome

Scarp

Barbs point downslope. Interpretation: Flow front or flow lobe.

Gentle linear depression

Barbs point downslope. Interpretation: Fault; fracture, or volcanic vent.

Crct

Tycho ray material

Characteristics
Material in and around clusters of elongate craters approximately 50 meters in diameter that have the same characteristics as Cc_{3-4}-type craters; albedo high. Queried where uncertain.

Interpretation
Material of secondary impact craters and ejecta probably from the crater Tycho.

Ccc_1

Crater cluster material

Characteristics
Materials in and around clusters of nearly circular craters approximately 50 meters in diameter that have the same characteristics as Cc_1-type craters; albedo moderately high; oriented east-west; queried where uncertain.

Interpretation
Material of secondary impact craters and ejecta. Origin unknown.

Ecc

Crater cluster material

Characteristics
Materials of highly subdued craters (E type) approximately 50-100 meters in diameter; albedo and crater density similar to those of surroundings.

Interpretation
Materials of secondary impact craters subdued by cratering and mass wasting. Origin unknown.

Erp_3 | Ers_3 | Erl_3

Mare ridge material

Characteristics
Materials of clearly visible broad, sinuous mare ridge. Crater density approximately the same as on surrounding mare areas. Craters older than Cc_1 more than 400 meters in diameter are absent. Albedo low. Divided into morphologic subunits as follows:
Erp_3, plateau. Broad generally undulatory surface that comprises major part of the ridge.
Ers_3, spine. Narrow, sharp-crested ridge projecting above the plateau surface. In form and position spines appear to be analogous to natural levees of terrestrial lava flows.
Erl_3, lobe. Lobate protrusion of the mare ridge extending outward from the base of a spine.

Interpretation
Probably volcanic flows. Several flows may be present in a single ridge as suggested by the apparent overlapping of plateaus and spines. Erp_3 probably represents the major part of the surface of the flow; Ers_3 may define natural flow levees; and Erl_3 may define subsidiary flows that broke through the levees, or aprons of erosional debris from the levees.

Erp_2 | Ers_2

Mare ridge material

Characteristics
Materials of sinuous mare ridge. Grossly similar in form to younger ridges but are more subdued; spines are less well developed, and lobes are not visible. Crater density and albedo approximately same as on surrounding mare.
Erp_2, plateau.
Ers_2, spine.

Interpretation
Similar to corresponding units of younger mare ridge.

Emr_1

Mare ridge material

Characteristics
Material of highly subdued sinuous mare ridges. Morphologic subunits (plateaus, spines, and lobes) cannot be distinguished. Crater density approximately the same as on surrounding mare material.

Interpretation
Probably old volcanic flows, subdued and partly covered by erosional debris.

Crater materials

NOTE: Craters are outlined with geologic contacts or simply numbered according to their relative age and approximate rim crest diameter as shown in the following table.

	Outlined	Numbered only
Cc_5	>200 m	100-200 m
Cc_3, Cc_4	>500 m	300-500 m
Cc_1, Cc_2	>600 m	400-600 m
Ec	>700 m	400-700 m

Characteristics

Cc_5 | Ccr_5 | Crr_5 | 5

Crater materials

Cc_5, materials of rayed craters having block-strewn, hummocky rims. Abundant blocks on wall. Crater density on rim lower than that of surroundings. Crater rim crest sharp.
Ccr_5, inner rim and wall materials, undivided. Rim materials have concentric dune-like structures and are brighter than surroundings.
$Ccrr_5$, outer radial rim material. Both concentric and elongate dune-like hummocks brighter than surroundings.
5, materials of craters with limited to well-developed rays. Abundant blocks on rims and within craters. Crater rim crest slightly subdued.

Cc_4 | 4

Crater materials, undivided

Cc_4, materials of craters with limited to well-developed rays. Abundant blocks. Crater rim crest sharp. Crater density on rim lower than that of surroundings.
4, materials of craters with bright halos and few or no rays. Abundant blocks on rims and within craters.

Cc_3 | 3

Crater materials, undivided

Cc_3, materials of craters with limited rays and block-strewn smooth rims. Abundant blocks on walls. Crater rim crest slightly subdued.
3, materials of rayless craters having smooth rims. Scattered blocks on rim and within crater. Rim crest moderately subdued.

Cc_2 | Ccr_2 | Crr_2 | 2

Crater materials

Cc_2, materials of craters with no rays to limited rays. Some blocks on rims and walls. Rim crest moderately to slightly subdued.
Ccr_2, rim and wall material undivided. Abundant blocks. Rim crest slightly subdued.
$Ccrr_2$, radial rim material. Weakly developed dune-like hummocks.
2, materials of rayless craters having smooth low rims. Scattered blocks on rim and within craters. Rim crest moderately to strongly subdued.

Cc_1 | 1

Crater materials, undivided

Cc_1, materials of rayless craters having smooth rims. Crater density on rim same as that of surroundings. Scattered blocks on rims and walls. Rim crest moderately subdued. Patterned ground conspicuous.
1, materials of rayless craters having smooth rims. Crater rim crest strongly subdued and rounded. Scattered blocks on rims and within craters.

COPERNICAN SYSTEM

E

Crater materials, undivided

E, materials of craters with strongly subdued rims that barely stand above surroundings. Many craters pan shaped. No blocks.

Interpretation of Crater Materials

Materials of craters that are probably mostly of impact origin. Numbers from E to 5 indicate decreasing relative age of materials. Interior slope of youngest craters is probably fragmental and brecciated debris which may include blocks of highly shocked rock. Rim material is impact ejecta of finely pulverized and brecciated rock. Interior slope of many of the oldest craters may have a blanket of material deposited over the original crater surface.

Ed | Edr

Dome material and ringed dome material

Characteristics
Ed, dome material, circular features 100-1,600 meters across that rise slightly above level of surrounding mare surface. In some, center is slightly lower than rim and occupied by a small pit. A few partly encircled by raised outer ring.
Edr, ringed dome material. Same as Ed but surrounded by a circular depression.

Interpretation
Surface expression of small plug-like intrusions or laccoliths. Those partly enclosed by a raised outer ring may be a form of degraded crater. Edr may be surface expression of plug or laccolith around which differential subsidence has occurred.

Em

Mare material

Characteristics
Albedo predominantly low. Generally flat to very gently undulatory surface. Lineaments in mare are not common. No ghost craters or partially buried craters can be seen through the mare. Old craters (E) most numerous in western half of site.

Interpretation
Probably volcanic tuffs or flows. Area appears to be covered by a single mare unit. Based on the age and distribution of craters on the mare, the mare is approximately the same age (Eratosthenian) throughout the area. The uniform appearance of the surface may in part be the result of a blanket of material which mantles different mare units, if any are present.

ERATOSTHENIAN SYSTEM

General Geology

This map shows the geology of Lunar Orbiter site III P-11 within which lies landing ellipse West Two, a potential early Apollo landing site in the lunar equatorial belt. The area is in Oceanus Procellarum, south of the equator, approximately 320 km south of the crater Kepler. It is covered by mare material and the evenness of the mare surface is broken only by mare ridges and some low domes. Relatively few of the many superposed impact craters are larger than 200 m across. Terra material is absent.

Although there are no obvious differences in geology of topography between the eastern and western halves of the area, and no obvious criteria for differentiating mare units, the oldest craters (E) are somewhat more numerous in the western half, suggesting that the mare there may be slightly older. Alternatively, the oldest craters may be evenly distributed throughout the site but, owing to differences in the thickness of a blanket of surficial material, many more craters have been buried in the eastern half than in the western. Because of the general paucity of large, subdued Eratosthenian craters and the relative freshness of the low domes and prominent mare ridges, the age of the mare is probably Eratosthenian on the lunar geologic time scale (Wilhelms, 1966). On an earlier, small-scale reconnaissance geologic map of the Letronne region (Marshall, 1963), mare in this area was mapped as Imbrian.

The most striking geologic features in the area are three sets of mare ridges. Although they all appear to be Eratosthenian, degradation and(or) burial of certain distinctive topographic features indicate that the three sets were not formed contemporaneously. These distinctive topographic features are best preserved in the youngest set of ridges, which occurs in the northeastern part of the area, where the ridges strike northwest. The plateau (Erp_3) occupies the central part of the ridge. On either side of it, and projecting above its surface, are spines (Ers_3). In one place, a lobate protrusion (Erl_3) extends beyond the spine. Even though these features display distinctly different, topographic expression, they probably consist of the same material. Their interrelationships resemble those in recent terrestrial lava flows, such as the SP Crater flow, in the San Francisco volcanic field, north of Flagstaff, Ariz. If the analogy is valid, the mare ridges in this site are probably lava flows. (However, this interpretation by no means implies that all mare ridges on the Moon are lava flows. There are several types of mare ridges, and each may have a different origin.) Block fields occur on or around mare ridges elsewhere on the Moon, but the available photographs show none in this site. The second oldest mare ridge set occurs at the southern edge of the map area and strikes almost east-west. The plateau (Erp_2) and spine (Ers_2) are preserved but moderately subdued. The oldest ridge set (Emr_1) occurs throughout the area. This set may be represented only by remnants of the spine, the plateaus having been buried or completely eroded. These oldest mare ridges seem to strike generally northward, with variations. (Such strike variations are not uncommon in lava flows, and strike variations of spines are clearly shown in units Ers_3 and Ers_2.)

Two types of domes are present--normal (Ed) and ringed (Edr). The ringed domes are characterized by a circular depression surrounding the raised, central area. Both types range from approximately 100 to 1,500 m in diameter, and they appear to be more numerous in the western part of the map area, but the individual types are randomly distributed. They may both be volcanic: both may represent surface expressions of small plug-like intrusions or laccoliths, and the ringed depression (of unit Edr) may result from differential magmatic subsidence. Alternatively, the two types may have different origins: the normal domes may be plug-like intrusions or laccoliths and the ringed ones may be ring-dike complexes.

All the aforementioned units (mare, mare ridges, and domes) have been cratered by impact. Superposition relations indicate that craters are degraded with time. Ages have been assigned to craters according to their apparent freshness with respect to size; small craters are degraded faster than large ones, so that a small subdued crater may be the same age as a large sharper one. Figure 1 shows the general morphological criteria used to assign relative ages. The more detailed descriptions in the chronologic column apply specifically to site III P-11. Craters assigned to the Copernican system are given a number to provide a finer breakdown by relative age; the higher numbers are for younger craters. The rate of crater degradation may be different on the various units because, in part, the units may be composed of different materials. Therefore, craters assigned the same age may not belong to exactly the same time period, and age designations are only approximate.

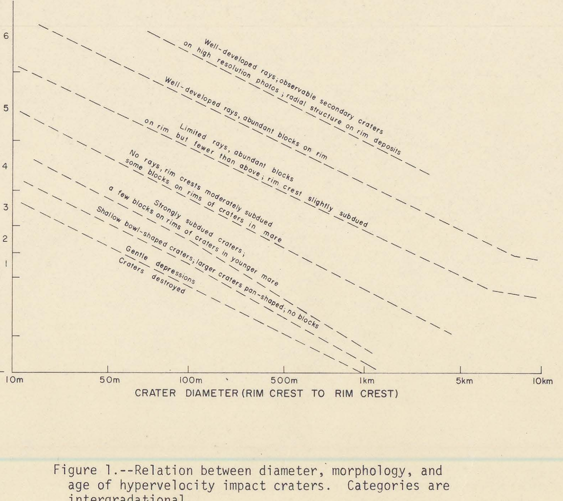


Figure 1.--Relation between diameter, morphology, and age of hypervelocity impact craters. Categories are intergradational.

The area also contains two sets of secondary impact fields. One set (Crct) trends northwest and was probably produced by the impact of ejecta from Tycho. The other set (Ccc_1), in the southern part of the area, trends east-west, and its source is unknown. Some of the material in the Tycho secondary fields may have been derived from the southern highlands--several thousand kilometers away.

A thin blanket of fragmental material (the lunar regolith) probably covers most of the area. It may consist of ejecta from meteorite impacts, or it may be volcanic debris such as ash-fall tuff. Lineaments, possible evidence of faulting, are not conspicuous, perhaps because faulting has not recently occurred or because faults are buried by a mantle of younger material.

Engineering Properties

Data from Surveyor I can probably be extrapolated to site III P-11 because of the proximity of the spacecraft and the similar appearance of the mare material. The static bearing strength of the surface on which Surveyor I landed is approximately 3×10^5 dynes per cm^2 (5 psi) (Natl. Aeronautics and Space Adm., 1966, p. 20). The mechanical properties of the lunar surface at the Surveyor III landing site appear to be similar to those at the Surveyor I landing site (Natl. Aeronautics and Space Adm., 1967, p. 118). The static bearing strength of the surface at the Surveyor III site is also about 3×10^5 dynes per cm^2 (5 psi). The crushing strength of a block picked up by the Surveyor III soil sampler is about 2×10^7 dynes per cm^2 (100 psi). Materials at site III P-11 that resemble those at the Surveyor sites may have similar physical properties. The engineering properties of the mare ridges are not known. The regolith on the youngest mare ridge may be anomalously thin.

Scientific Interest

The mare material in this site is relatively young and may differ in composition from older mare material in sites to the east. Bedrock appears to be near the surface, and blocks should be plentiful around small fresh craters. Features of special interest in the site are the Tycho ray and the mare ridges but the landing ellipse would have to be relocated for these to be studied. Material in and around the cluster of Tycho secondaries may have come from the southern lunar highlands. Samples of this material might provide data that would establish the age of Tycho, one of the youngest large bright-rayed craters on the Moon. As noted above, the ridges in this site are probably volcanic features; thus, they might yield important new information on the age and nature of lunar volcanism.

References

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