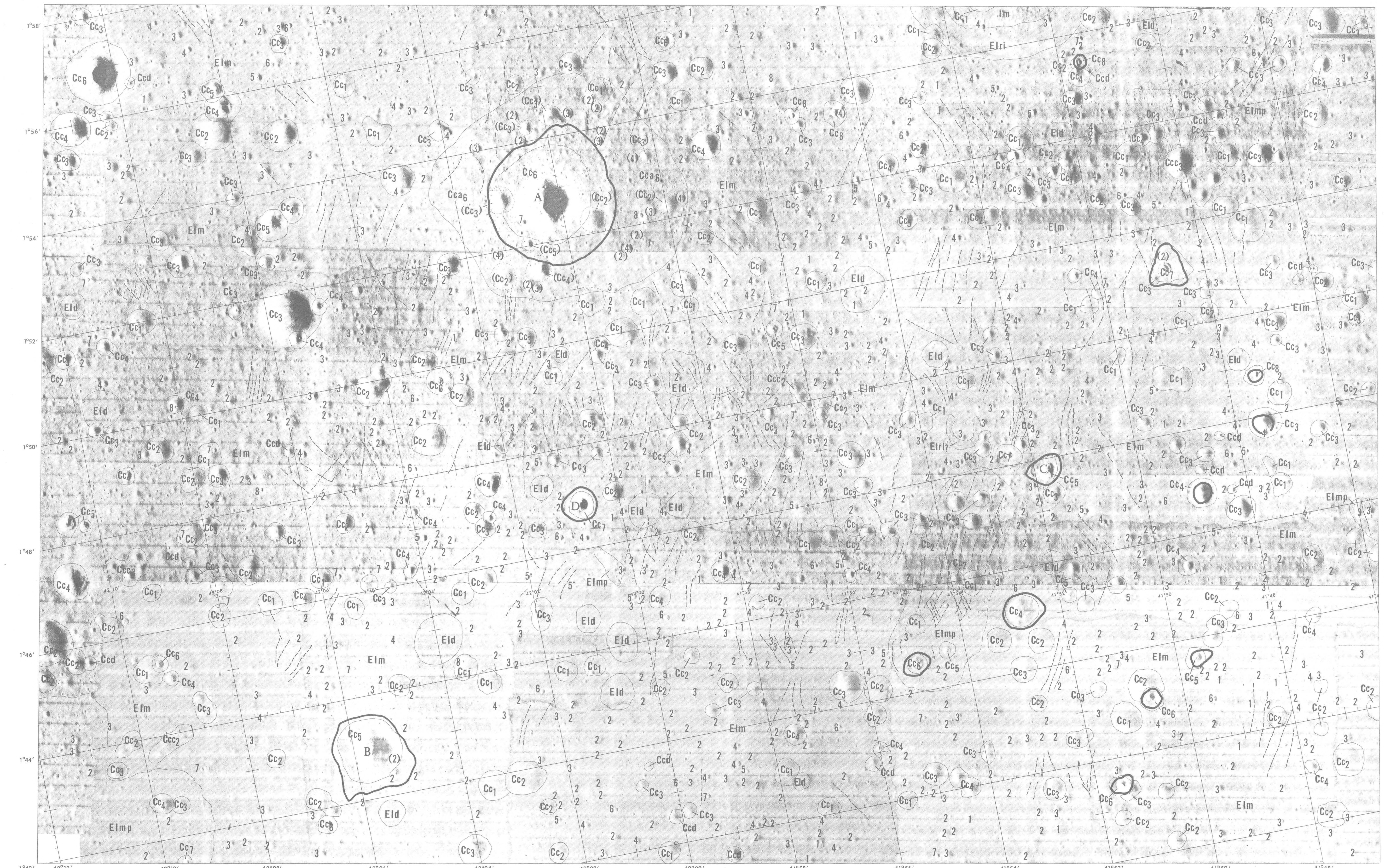
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY
OPEN FILE REPORT

ORB II-13-2

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
Manned Spacecraft Center,
National Aeronautics and Space Administration



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

Sources of geologic information: photographs returned by Lunar Orbiter II, frames H-198 through 200, H-205 through 207, M-197 through 212; and Lunar Orbiter III, frames H-165 through 167.

SCALE 1:25,000

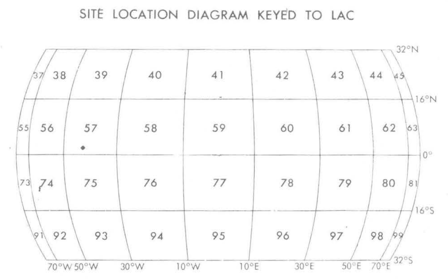
METERS — KILOMETERS — NAUTICAL MILES

PRELIMINARY GEOLOGIC MAP OF ELLIPSE II-13-2 AND VICINITY

By
S.R.Titley

1967
Mercator Projection

SITE LOCATION DIAGRAM KEYED TO SAC



General Geology

Ellipse II-13-2 is in Oceanus Procellarum approximately midway between the crater Kepler to the northeast and Flamsteed to the southwest. The map area is occupied entirely by mare materials. Full-Moon photographs of the area show dark mare materials and two faint rays from Kepler.

The oldest materials of the area are 1) blocks of ejecta and 2) bedrock exposed in the floors of some young craters. Almost all the mare materials, that cover the area, are apparently of one age. Superposed on these materials are craters and their deposits, the youngest of which are fresh and bright and the oldest--smooth depressions. At the north edge of the area, older mare material, lower in elevation than the rest of the mare, is enclosed by an annular ridge.

Superposition relations indicate that fresh craters are degraded with time. Accordingly, all craters are mapped on the basis of interpreted relative age. Crater morphology and details of the rim and floor are used to estimate age according to the diagram shown below (fig. 1). Complete gradation is present between adjacent categories.

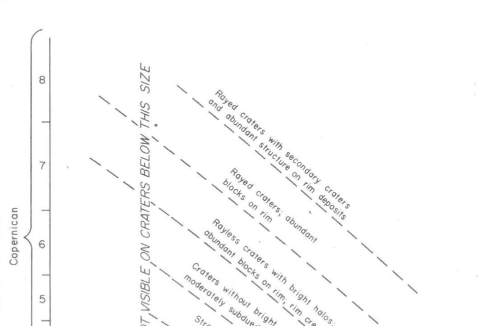


Figure 1.--Assumed relations among crater diameter (from rim crest to rim crest), crater properties and crater age. Width of intervals on ordinate carries no implication as to lengths of intervals of lunar geologic time.

Engineering Geology

Similarities in crater size-frequency distribution and albedo strongly suggest that mare materials of this area are nearly identical with those of the area to the southwest where Surveyor I landed (Lunar Orbiter Photo Data Screening Group, 1967). In addition to these criteria, the evidence from crater morphology (see below) suggesting comparatively thin soil layers in both areas indicates further similarity. Thus the dynamic resistance of 4 to 7 x 10^5 dynes per cm^2 indicated by Surveyor I (Jaffe and others, 1966) for lunar soils of the dark mare in site III P-12 may closely approximate a general value of similar dark-mare soils of this area.

Relatively fresh craters in the southern and western parts of the area are surrounded by ejected blocks as much as 500 meters from the crater rim. North of crater A (lat 1°53' N., long 42°00' W.) and west of crater B (lat 1°43' N., long 42° 06' W.), blocks as large as 10 meters lie on the mare surface. In the central part of the area a few blocks near the limit of resolution in size (2 meters) are visible on the mare near craters C (lat 1°46' N., long 41°52' W.) and D (long 42°01' W.).

Inasmuch as the mare materials here appear to constitute a single fairly uniform unit, and as the aforementioned craters are in or near the ellipse, data derived from evaluation of blocks as natural penetrometers should be applicable in general to the entire ellipse. All resolvable blocks occur on crater rims or interiors. However, blocks below the limit of resolution, derived from the numerous small fresh craters, are probably abundant throughout the area.

The technique evolved by Oberbeck and Quaide (1967) was used to estimate the thickness of the fragmental layer in the area. The curves in figure 2 show the relative percentage of total craters of normal, flat-bottomed, and concentric geometry. The area studied is considered a representative sample. Only fresh craters (Cc_{4-8}) were included in the analysis. Sixty-five percent of the 40-meter craters are flat bottomed; thus, if the theory of Oberbeck and Quaide is correct, about 65 percent of the area is covered by a fragmental layer about 4 to 7 meters thick. (See fig. 2.)

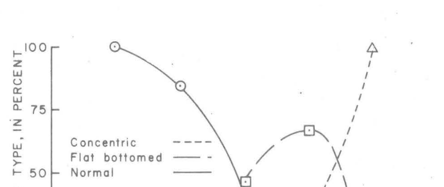


Figure 2.--Apparent geometry of small fresh craters as a function of crater diameter. Depth to cohesive substrate for

normal craters, $> \frac{D}{5.5}$ (approximately);

flat-bottomed craters, $> \frac{D}{5.5}, < \frac{D}{10.0}$ (approximately);

concentric craters, $> \frac{D}{10.0}$ (approximately).

Sun angle 20°.

A few dimple craters (unit Ccd) of uncertain genesis and significance are present. They may have formed by processes related to collapse. In general, however, the widespread and generally uniform distribution of small craters which expose bedrock and the presence of widespread relatively thin fragmental material suggest that collapse features, if present, are local rather than widespread. The dimple craters appear to be randomly distributed.

Features of Scientific Interest

Because the upper mare surface has breached and flooded apparently young craters in the northeastern part of site II P-13 (Titley, 1967), mare of this region may very well be younger than most mare on the east side of the Moon. This possibility is further strengthened by the presence of a comparatively thin and thus probably youthful fragmental layer in this area. Collection of rock samples will probably be easy, therefore, because of probably widespread distribution on the surface. Furthermore, shallow depth to bedrock may facilitate proper placement of geophysical instruments.

Of considerable scientific interest is the ring north of the ellipse. The unusual morphology and questionable genesis of this feature, one of at least six in site II P-13 (Titley, 1967), make it worthy of investigation. The fact that its albedo is the same as the surrounding mare material suggests that it may be an old crater covered by mare material which has differentially compacted over the rim crest. Such an origin would imply that the mare material at this location had behaved more like an ignimbrite capable of extensive differential compaction than a lava flow. This is a fundamental question of lunar geology which can be attacked by study of this feature. The ring might also be an extrusive feature younger than the surrounding material, in which case, rock samples from it may provide information concerning lunar differentiation history. The mare material inside the ring appears to be more heavily cratered than the mare outside it.

Patterned mare in and near the ellipse may represent ray materials and thus may contain materials from the crater Kepler.

REFERENCES

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Jaffe, L. A., and others, 1966, Surveyor I mission report, pt. II, Scientific data and results: California Inst. Technology, Jet Propulsion Lab. Tech. Rept. 32-1023.

Lunar Orbiter Photo Data Screening Group, 1967, Preliminary geologic evaluation and Apollo landing analysis of areas photographed by Lunar Orbiter II: U.S. Natl. Aeronautics and Space Adm., Langley Research Center, Langley Working Paper 363.

Oberbeck, V. R., and Quaide, W. L., 1967, Estimated thickness of a fragmental surface layer of Oceanus Procellarum: Jour. Geophys. Research, v. 72, p. 4697-4704.

Titley, S. R., 1968, Preliminary geologic map of Lunar Orbiter site ORB II P-13 [scale 1:100,000]: U.S. Geol. Survey ~~map (in prep.)~~ open-file report.

Crater materials

NOTE: Crater materials occupying larger areas, including deposits outside the rim crest, are outlined by geologic contacts; materials occupying smaller areas are assigned numbers only.

Characteristics

COPERNICAN SYSTEM

8 | Cc_8

8, crater materials, undivided. Rim crest diameter 50-100 meters. Includes bright ray material; wall, rim crest, and rim deposits have high density of blocks, particularly on craters showing structure within craters and in rim; may include satellitic crater material that in the small size range is not resolved on Orbiter photographs; crater rim crest very sharp and pronounced.

Cc_8, crater materials, undivided. Rim crest diameter greater than 100 meters. Include bright ray material; resolvable blocks present in rim deposits of one crater 50 meters in diameter; blocks probably abundant in rim deposits of others; interiors sharply blocky with well-developed terraces.

7 | Cc_7

7, crater materials, undivided. Rim crest diameter 50-100 meters. Unit is bright; distinguished from age 8 by fewer blocks in rim deposits and on rim crest and absence of ray material; abundance of blocks is related to thickness of layer impacted; most craters have structured floor; fewer sharp structures in rim than age 8; crater rim crest may be somewhat subdued.

Cc_7, crater materials, undivided. Rim crest diameter 100-400 meters. Unit is bright, abundant blocks present on rim crest and in rim deposits; considerably fewer blocks than in Cc_8 deposits outside of mapped area; pronounced break in slope from rim deposits to mare; crater rim crest sharp.

6 | Cc_6

6, crater materials, undivided. Rim crest diameter 75-100 meters. No halo material; considerably fewer blocks present on rim than on age 7; crater rim crest moderately subdued.

Cc_6, crater materials, undivided. Rim crest diameter 100-400 meters. Includes bright halo material; abundant blocks present in rim deposits and on rim crest; some structure occurs in rim; crater rim crest slightly subdued and cratered, and some are clearly polygonal.

5 | Cc_5

5, crater materials, undivided. Rim crest diameter 75-100 meters. Few or no blocks present in rim deposits, but blocks are abundant within crater; change in slope from rim deposits to mare material is gradual; structure in wall and rim generally absent; crater rim crest subdued.

Cc_5, crater materials, undivided. Rim crest diameter 100-400 meters. Unit is not bright; some blocks present in rim deposits; a few small craters present on the rim; crater rim crest moderately subdued.

4 | Cc_4

4, crater materials, undivided. Rim crest diameter 75-100 meters. No blocks present in rim deposits; rim material is markedly flattened, generally level, and commonly cratered; change in slope from rim deposits to mare material is gradual; crater interior is smooth; associated crater is shallow-bowl shaped; crater rim crest strongly subdued.

Cc_4, crater materials, undivided. Rim crest diameter 100-400 meters. Blocks absent in rim deposits but common in wall material; "normal" crater shape preserved in craters of larger size, but floor is progressively flattened toward lower size limit; crater rim crest is strongly subdued, well rounded, smooth, and shows numerous small craters.

3 | Cc_3

3, crater materials, undivided. Rim crest diameter 75-100 meters. Associated crater is gentle, shallow cup-shaped depression having little or no remnant of original rim crest.

Cc_3, crater materials, undivided. Rim crest diameter 100-400 meters. Floor of larger craters is flat; many show creep structures in floor-filling material; a few large blocks in center of many craters.

2 | Cc_2

2, crater materials, undivided. Rim crest diameter 75-150 meters. Associated crater ranges from flat bottomed at upper size limit to cup shaped at lower size limit.

Cc_2, crater materials, undivided. Rim crest diameter 150-400 meters. Little or no structure occurs in floor; wall material has gentle slope; associated crater is pan-shaped depression.

1 | Cc_1

1, crater materials, undivided. Rim crest diameter 100-200 meters. Associated crater is gentle depression; crater rim crest commonly polygonal or irregular.

Cc_1, crater materials, undivided. Rim crest diameter 200-400 meters. Associated crater is gentle depression; crater rim crest commonly polygonal or irregular.

Interpretation
Materials of both primary and secondary impact craters; youngest Cc_8, oldest Cc_1. Craters with lower numbers are modified forms of higher numbered craters. Craters are modified through erosion by impacting micrometeorites, small meteorites and secondary particles and by gravitative movement of loose materials caused by seismic shaking.

Interpreted engineering properties
All craters except Cc_1, Cc_2, 2, and 3 craters have blocks either visible or inferred on their rims and thus constitute landing hazards. On large subuded craters depth to cohesive substrate greater than average on floors and less than average on rims. Fragmental layer on mare probably has anomalous engineering properties around youngest craters as the result of impact-induced disturbances; the anomalous character probably diminishes as aging progresses.

Scientific interest
The freshest samples of ejected materials will be found aroung the youngest craters. Samples from craters of all ages may shed light on radiation histories. Soil profiles sampled around rim of youngest craters may provide evidence of age of cratering and provide information on radiation histories.

Cca_6

Crater apron material

Characteristics
Smoothed mare material around crater. Surface has fewer small craters than on surrounding craters. At smaller scale, Cc_1 craters occur at apron edge and Cc_1 and Cc_2 craters within apron.

Interpretation
Mare material that has been smoothed by the energy of the crater-forming event and, to a lesser extent, by the covering of the mare surface by ejecta. The disturbance resulted in the filling of pre-existing craters on the older surface.

Interpreted engineering properties
Unit probably has anomalous engineering properties. Loose fragmental material shaken into a pre-existing crater may not have the bearing strength of similar materials on a surface beyond the apron. Materials overlying flatter surfaces have probably been shaken and, depending upon the vibration frequencies, may assume either greater or lesser bearing strength properties.

Scientific interest
Disturbed mare materials. Soil profiles may not be representative of radiation histories found in less disturbed lunar soils. Smooth surface may be overlain by abundant small rocks ejected from the parent crater.

Ccd

Dimple crater material

Characteristics
Material of small craters with distinctive geometry. They lack rims and their inner slopes are slightly to markedly convex upward. Except for their greater depth and the absence of blocks they resemble small Cc_3 craters.

Interpretation
Origin and significance unknown. They may be slump or collapse features or eroded impact craters.

Interpreted engineering properties
As they may be collapse features they may be potential hazards to trafficability. Slopes appear potentially unstable.

Scientific interest
Materials are of interest because origin of craters is uncertain. If of collapse origin there may be no blocks near their centers. If of exogenous origin, numerous blocks may be circumferentially distributed around them.

Ccc_3

Crater cluster material

Characteristics
Material in and around cluster of 4 shallow bowl-shaped craters.

Ccc_2

Crater cluster material

Characteristics
Similar to Ccc_3 but craters more subdued.

Interpretation
Probably secondary impact craters.

Interpreted engineering properties
High slopes and probable subresolution blocks are engineering hazards.

Scientific interest
Material relatively old and not of high scientific priority.

IMBRIAN OR ERATOSTHENIAN SYSTEMS

Eld

Mare dome material

Characteristics
Materials of very low, irregular domes 100-400 meters in diameter. A few domes have shallow valleys part way around them but such features are less evident and the domes are more irregular in shape than in ellipse III-12-1 (Harbour, 1967). Crater density same as on surroundings.

Interpretation
Tumuli or volcanic pipes and vents that have been eroded to the same textural appearance as the surroundings. If domes are sources of surrounding mare materials, low topographic relief indicates that ejection probably was not explosive.

Interpreted engineering properties
Same as adjacent mare material, but layer of fragmental debris may be slightly thinner.

Scientific interest
May provide relatively fresh volcanic materials and may give information on process of mare extrusion.

Elmp

Patterned mare material

Characteristics
Mare material that displays subtle to pronounced lineation of surface form characterized by shallow linear valley-and-ridge morphology. Trend of the lineation generally NNW to NNE. Detail of the surface is variable, ranging from pronounced to very subtly subdued. Albedo same as unit Elm.

Interpretation
Some appears, by analogy, to result from ray-forming processes although other characteristics of rays such as brightening and the presence of elongate craters are absent. Some appears to be the result of debris movement down low-angle slopes.

Interpreted engineering properties
Represents a potential landing hazard because of slope variability over short distances and because of unknown bearing strengths.

Scientific interest
If related to rays, may contain exotic fragments derived from primary impact craters. May yield information on fine scale lunar tectonic processes.

Elm

Mare material

Characteristics
Level cratered material making up the surface of the ellipse and surrounding region. On Earth-based full-Moon photographs, unit Elm is among the darker mare units recognizable.

Interpretation
Probably represents volcanic flows, the surfaces of which are covered by a fragmental layer. No layer of bedrock is positively identifiable at the general level of the surface although some may be present on the floors of craters. The criteria of Eggleton (Lunar Orbiter Photo Data Screening Group, 1967, p. 111) indicate that the upper layer is relatively thin in the site. Results of experiments on Surveyor V indicate similar fragmental mare material in Mare Tranquillitatis is basaltic in chemical composition.

Interpreted engineering properties
See text discussion. The large number of blocky craters suggests a relatively thin upper fragmental layer. Similarity of observable characteristics of this mare with mare of landing sites of Surveyors I and III suggests similar engineering properties.

Scientific interest
Composition of the mare should reflect differentiation histories on the Moon. Mare material of this site is apparently younger than that of many other sites; hence may be of particular interest. Soil profiles should reveal data on radiation history of the Moon.

Elri

Ring material

Characteristics
Material making up the surface of an annular ridge at north edge of map enclosing a mare-covered floor at a slightly lower elevation. Slopes covered with patterned ground. Albedo about the same as unit Elm.

Interpretation
An old crater inundated by mare material (possibly ignimbrite) which compacted differentially to preserve the structure in subdued form. Alternatively may be a ring-shaped extrusion, or regional mare material upwarped by a younger subsurface ring dike. Patterned ground on slopes caused by downhill creep of surficial debris.

Interpreted engineering properties
Debris-covered slopes and creep textures indicate potentially hazardous surface.

Scientific interest
Of great interest for information it may provide on the origin of the mare material, whether ignimbrite or lava flow. If feature is an extrusive ring, samples from it may represent a late stage of differentiation. Samples of soil from the ring can be obtained from the toe of the debris apron.

IMBRIAN SYSTEM

Im

Cratered mare material

Characteristics
Occurs within the ring (mapped as Elri) at north edge of the map. Topographically lower than Elm and more densely cratered. Albedo is apparently about the same as unit Elm.

Interpretation
An older mare unit but probably similar in all other respects to unit Elm.

Interpreted engineering properties
Unknown. It may be similar to unit Elm but owing to a greater age may have a thicker regolith layer than Elm.

Scientific interest
Older than unit Elm and thus may reflect rocks derived from earlier stages in the differentiation history of the mare.

Contact
Dashed where approximately located.

(Cc_4)
Buried contact
Buried unit shown in parentheses.

(3)
Buried small crater

Lineament
Shallow groove or subdued scarp. In areas of patterned ground the general trend and extent of the troughs and scarps are indicated by several lineament symbols.

Block field
Line outlines continuous or semicontinuous field of resolvable blocks. Subresolution blocks are probably abundant within line and probably extend beyond it.