DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

Prepared in cooperation with the
Manned Spacecraft Center,
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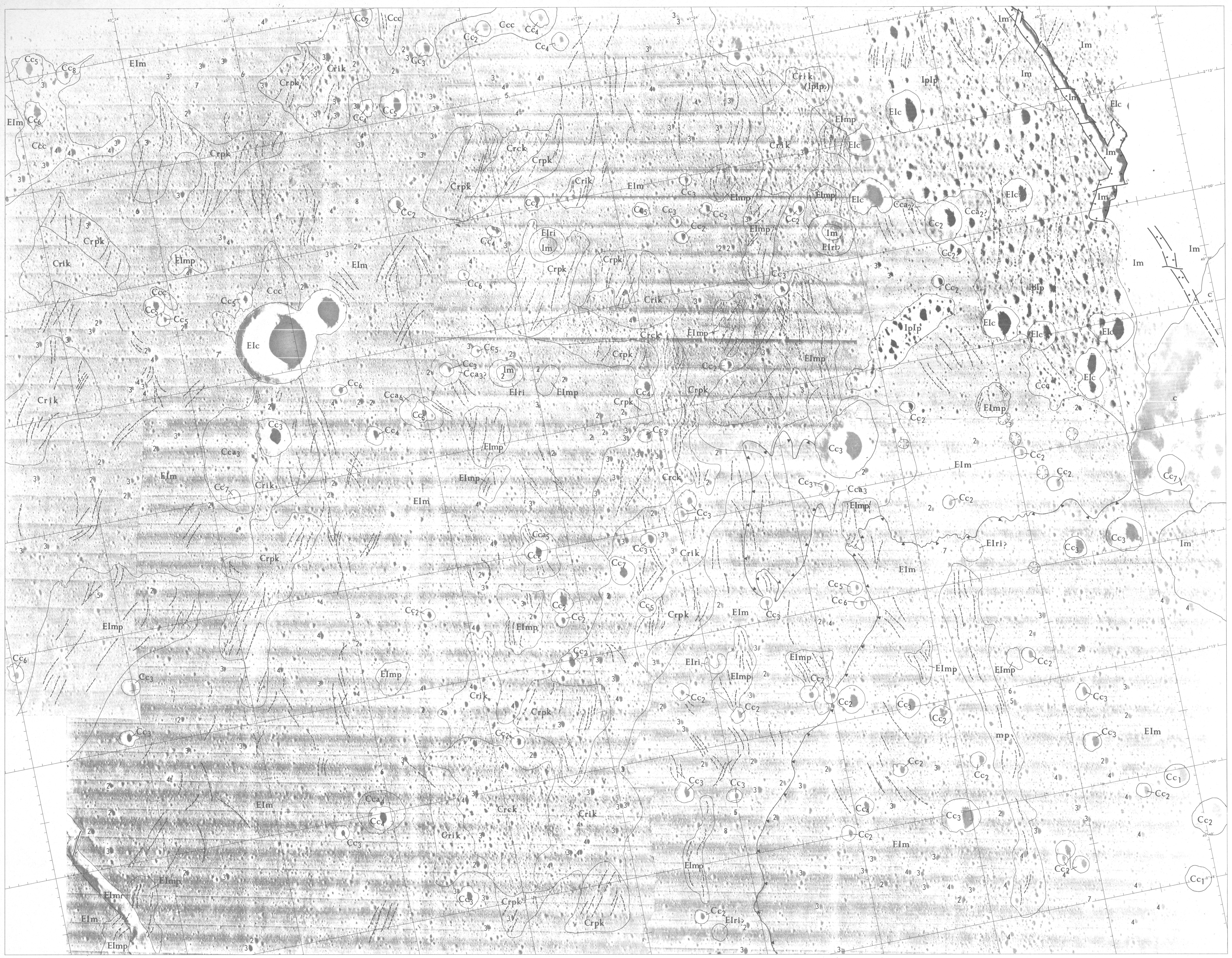
ORB II P-13

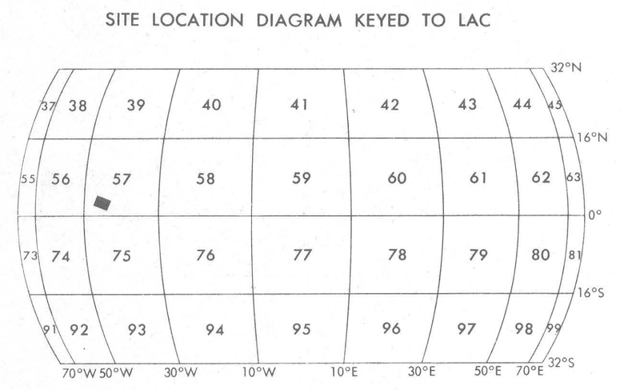


Controlled base prepared by Army Map Service, Corps of Engineers, U.S. Army, Washington, D.C. 20315

SCALE 1:100,000

Principal sources of geologic information: Lunar Orbiter II, III and IV photographs (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.

SITE LOCATION DIAGRAM KEYED TO LAC



PRELIMINARY GEOLOGIC MAP LUNAR ORBITER SITE OF ORB II P-13

By
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1967

Mercator Projection

EXPLANATION

Cca

Crater apron material
[Subscript indicates relative age of parent crater.]

Characteristics
Forms smoothed areas of mare or upland around craters. Some surfaces have high frequency of small fresh craters, and larger craters appear subdued. Unit is not necessarily symmetrical to crater center. Not restricted to any particular crater class although widely present on younger craters.

Interpretation
Mare and upland surfaces that have been smoothed by the crater-forming event. Shaking of an unconsolidated upper layer has resulted in filling of existing craters and smaller secondary craters have formed on the resulting surface.

Ccc

Crater cluster material

Characteristics
Material of groups or clusters of small (mostly <100 m in diameter) craters of similar morphology.

Interpretation
Probably material of groups of secondary craters formed by clots of fragments expelled from craters.

Crck | Crik | Crpk

Kepler ray materials

Characteristics
Modified mare and upland materials coincident with the ray pattern of Kepler. Modification of subjacent surface is primary criteria for division of units. The general trend of lineation and crater elongation is north to northwest. No exotic objects are unequivocally identifiable within the unit.
Crck, cratered ray material. Unit has modified subjacent mare and terra materials to greatest degree. Characterized by high density of elongate Cc_3 craters.
Crik, intermediate ray material. Unit characterized by either a combination of patterned ground and elongate craters or a considerably lower crater density than Crck.
Crpk, patterned ray material. Areas of patterned ground identifiable with Kepler ray pattern. Displays pronounced to subtle surface lineations characterized by dunelike forms or shallow valley-and-ridge morphology.

Interpretation
Mare and terra modified by cratering and scouring by objects ejected from Kepler. The mechanism of scouring is not clear but the consistent close spatial relation of Crpk to the rays suggests a genesis related to ray development. Study of the Orbiter high resolution data suggests that brightening of the rayed surface is more the result of disturbance of the uppermost mare layer than the result of addition of large amounts of exotic material to the mare and upland surface.

Crater materials

NOTE: Crater materials occupying areas larger than 800 meters in lateral extent, including deposits outside the rim crest, are outlined by geologic contacts; materials occupying areas between 400 and 800 meters in lateral extent are assigned numbers only; materials within areas of less than 400 meters are unmapped. Marked topographic break between rim deposits and surrounding surface is characteristic of categories Cc_5-Cc_8.

Characteristics

Cc_8

Crater materials, undivided. Include bright ray material; high density of blocks on wall, rim crest, and rim deposits; probably include much satellitic crater material although satellitic craters are unresolvable on Orbiter photographs; crater rim crest sharp and pronounced. Only occurrence is around small crater in northwest corner of the map.

Cc_7

Crater materials, undivided. Include bright ray material; abundant blocks present on rim deposits; ray pattern less distinct than that of Cc_8; crater rim crest slightly less sharp than that of Cc_8.

6 | Cc_6

6, crater materials, undivided. Rim deposits bright; abundant blocks present on rim deposits; structure abundant in rim; crater rim crest slightly subdued and in some places clearly polygonal.
Cc_6, crater materials, undivided. Rim deposits bright and some occurrences have faint vestigial ray pattern; blocks present on rim crest; generally some craters on rim deposits; density of craters on rim deposits increases with increasing size of crater; crater rim crest slightly subdued.

5 | Cc_5

5, crater materials, undivided. Rim deposits slightly brighter than or same as surroundings; some blocks present on rim deposits; crater rim crest moderately subdued and commonly cratered with small craters.
Cc_5, crater materials, undivided. Rim deposits bright or slightly brighter than surroundings; blocks present on rim; rim deposits preserved but cratered; crater rim crest slightly subdued.

4 | Cc_4

4, crater materials, undivided. Abundant blocks within crater, few blocks on rim deposits; rim deposits generally have moderate to high density of small craters; crater rim crest subdued.
Cc_4, crater materials, undivided. Rim deposits only slightly brighter than surroundings; small blocks present on some rim deposits; crater rim crest slightly to moderately subdued. Topographic break between rim deposits and surroundings less pronounced than that of Cc_5-Cc_8.

3 | Cc_3

3, crater materials, undivided. Rim deposits are cratered; many floors are flat; blocks present on floors; crater rim crest strongly subdued. Little or no topographic break between rim deposits and surroundings.
Cc_3, crater materials, undivided. Few or no blocks present on rim deposits; patterned ground present on some floor material; crater rim crest moderately subdued. Topographic break between rim deposits and surroundings is indistinct.

2 | Cc_2

2, crater materials, undivided. Few blocks present inside of rim; patterned ground present on floor material; crater rim crest largely destroyed; associated crater is pan or shallow-bowl shaped.
Cc_2, crater materials, undivided. Few blocks on rim of larger craters; crater rim crest strongly subdued or associated crater is shallow-bowl shaped.

Cc_1

Crater materials, undivided. Blocks sparse; patterned ground conspicuous on wall; albedo and crater density same as those of surroundings; associated crater is rimless pan-shaped depression.

Interpretation
Materials of both primary and secondary impact craters; oldest are Cc_1 and youngest are Cc_8. Lower numbered craters are modified, and hence older, forms of higher numbered craters. Craters are modified through erosion by impact of meteorites and secondary particles and by gravitative movement of loose materials through seismic shaking. Crater materials include floor material consisting of a mixture of brecciated bedrock and fallback, inner slope or wall material consisting of fallback and broken substrata making up a talus unit and bedrock on higher parts, and rim material consisting of shock-metamorphosed debris heaped at the crater edge and scattered outward to several crater diameters from rim crest. As craters age, they become filled with debris slumped off the walls and from outside the crater; the rim material becomes mixed with the surrounding material until the two are indistinguishable.

COPERNICAN SYSTEM

EImp

Patterned mare material

Characteristics
Unit displays pronounced to subtle surface lineation characterized by linear dunes or shallow valley-and-ridge morphology. Similar to Crpk in most respects except that exposures cannot be related to Kepler ray pattern. Some EImp is strongly subdued.

Interpretation
Most EImp is probably young mare material (EIm) modified by ray-forming processes. Subdued EImp may be mare material modified by rays related to cratering events older than Kepler. Some EImp apparently occurs on slight slopes on the mare and structural features may be developed in the upper layer by downslope movement.

EImr

Mare ridge material

Characteristics
Material of linear positive feature on the generally level mare surface. Transects the southwest corner of the site. Albedo is the same as that of mare material (EIm). Segments are offset; slopes appear to be debris-covered.

Interpretation
Rectilinear outlines suggest ridges are structural features bounded and offset by faults. Probably formed concurrently with the mare and may be related to the process of mare genesis and basin development although origin is obscure.

EIri

Ring material

Characteristics
Material making up the surface of annular ridges enclosing a usually slightly lower floor composed of old mare material (Im). Structural features on the slopes suggest downward movement of material from the crest. Albedo about the same as that of the mare material.

Interpretation
Age of these features is uncertain, but they are at least older than the youngest layer of old mare (Im). They may represent old craters flooded in part by Im or craters formed at the time of flooding of the mare basins.

EIm

Young mare material

Characteristics
Most extensive unit in site. Forms level cratered surface. Is distinctively darker on earth-based full-Moon photographs than mare units surrounding the site.

Interpretation
Probably composed of volcanic flows, the surfaces of which are covered by a fragmental layer. No bedrock is positively identifiable on the surface although some may be present in the floors of craters that penetrate the fragmental layer. The criteria of Eggleton (1967) indicate that the upper layer of debris or poorly consolidated material overlying harder substratum is relatively thin, probably a few tens of meters thick on the average. In the northwest quadrant of the site, EIm breaches a crater whose characteristics suggest that it may be Eratosthenian in age or early Copernican at the youngest. For this reason EIm in its uppermost part may be considerably younger than typical Imbrian mare.

EIc

Crater materials, undivided

Characteristics
Materials of relatively sharp-rimmed craters, most of which are approximately 1 km or more in diameter. Occur in contact with the older terra materials of the site and with the mare in the northeastern part of the site. At two places continuity of crater walls is interrupted by materials of the upper mare layers and mare material occurs within the crater. Albedo of rim deposit about the same as that of mare; albedo of interior greater than mare and some show up on earth-based photographs as bright spots.

Interpretation
Same as Copernican craters but crater materials are older than young mare material (EIm) and younger than terra plains-forming unit (IpIp).

IMBRIAN OR ERATOSTHENIAN SYSTEM

Im

Old mare material

Characteristics
Highly cratered mare surface in contact with older terra plains unit (IpIp) on the northeast edge of the site. Also present in some EIri rings.

Interpretation
Im probably composed of volcanic flows; similar to EIm but probably has thicker surficial layer of fragmental debris because of older age.

IMBRIAN SYSTEM

IpIp

Terra plains-forming material

Characteristics
Forms highly cratered positive area in the northeastern part of the site. Albedo intermediate but higher than that of mare. Generally flat but with considerably greater relief than mare.

Interpretation
Relations shown on Orbiter photograph III S-25 (M 161) suggest that this material occupies the floor of an old breached crater. May be composed of a mixture of older mare material or crater-filling material and material from the Imbrium basin. Clearly older than mare. Owing to its higher elevation was not inundated by mare material that flooded most of the site.

c

Crater material

Characteristics
Material of high ridge in the eastern part of the site. Patterned ground on slopes indicate downslope movement of materials. Possibly a debris apron occurs at base of slope.

Interpretation
Material of crater rim older than terra plains-forming material (IpIp).

PRE-IMBRIAN OR IMBRIAN

Contact
Dashed where indefinitely located.

Fault
Bar and ball on downthrown side; arrows indicate apparent relative horizontal displacement. Displacement direction not shown where uncertain. Dashed where approximately located.

Rimless depression

Mare scarp
Line marks base. Barb points downslope.

Lineament

Site II P-13 is in Oceanus Procellarum, about midway between the craters Kepler to the northeast and Flamsteed to the southwest. Terra materials occur only in the northeast corner of the site. The rest of the area is covered by mare. On full-moon photographs the site appears to be largely an area of dark mare crossed by faint rays radial to Kepler.

The oldest materials in the site occur in the northeast corner, where terra plains-forming materials (IpIp) abut an old ridge (c). The plains-forming unit, which appears to occupy the floor of a large old pre-mare crater, is at a higher elevation than the adjoining mare. A narrow island of terra material southwest of the main exposure of this unit is surrounded by mare. The adjoining mare cover may be thin, therefore, and may be underlain at shallow depth by the terra unit. Vertical and oblique photographs both suggest that the ridge (c) on the eastern edge of the site is the remnant of an old crater rim that predates development of both mare and terra plains units.

Mare within the site is generally uniform in appearance and the dominant mare type is designated "young mare" (EIm). However, within the terra plains unit, along the western edge of the site, and within mapped rings (EIri) patches of distinctive highly cratered mare occur; they are mapped as "old mare" (Im). Elevations of the old mare unit differ from those of the young mare. Fresh-appearing craters (EIc) in the northeast quadrant have been breached and flooded by mare materials. The age of these craters is not known for certain but is apparently not greater than Eratosthenian. Many more blocky craters occur on the young mare unit than on mare units on the eastern side of the Moon. A relatively thin layer of fragmental material covers the young mare unit, as shown by the presence of a hard substratum in numerous craters as small as 20 meters in diameter.

A long serated mare scarp adjoins a northward-trending rille-like depression in the eastern half of the site. The albedo of the mare on one side of the scarp is different from that on the other, and crater size-frequency distribution is also different. Mare material east of the scarp is apparently slightly higher in elevation than mare to the west. The scarp probably marks the contact between mare materials whose ages are approximately the same but whose sources, and perhaps compositions, are different.

Two rays from Kepler cross the region from northeast to southwest. Patches of ray material from Kepler and smaller craters also occur within the site. The Kepler rays have modified the mare and terra in two fashions, and the map shows a three-fold breakdown of modified mare and terra types. At one extreme is the Crck unit, the result of intense cratering by secondary objects. At the other extreme is the Crpk unit, which is characterized by parallel scours and includes areas of patterned mare. Intermediate between these two units is less intensely cratered mare, usually associated with the patterned surface and mapped as Cruk. Since the size-frequency distribution of craters within the rays follows a nearly straight-line log-log distribution, the objects which produced the craters probably varied greatly in size. High-resolution photographs of the site show no recognizable foreign objects within the rayed areas. The brightening effect produced by the rays is interpreted as representing disturbance of the upper layers of the mare and terra rather than gross addition of exotic material.

Superposition relations suggest that craters are degraded with time. Accordingly, all the craters in this site were mapped on the basis of interpreted relative age as deduced from relative "freshness". Relative age of the younger craters (Eratosthenian and Copernican) has been estimated from morphology and rim details, according to the classification shown in figure 1. Complete gradation exists between all categories of younger craters. The older craters consist of the two pre-mare crater types (EIc and c) and crater-like structures occurring in mare areas and mapped as rings (Eri). The genesis and nature of the rings are not clear. They consist of a raised but smooth rim with gentle slopes and a circular floor commonly at a lower level than the surrounding mare. Some floors are covered with old mare (Im). These structures may be craters formed contemporaneously with the mare, or pre-mare craters whose rim crests were at the level of original filling of the mare basin, or igneous intrusions such as ring dikes. Surfaces of anomalous smoothness surrounding many craters have been outlined and termed "crater apron" (Cca). Crater aprons occur on both mare and terra plains units and are characterized by a comparatively smooth surface, pitted to varying degree by small craters. The unit apparently is not restricted to craters of a particular age, nor is it necessarily symmetrically disposed about a crater. It may represent mare material smoothed by impact-induced shaking, and probably consists of a mixture of mare material and crater ejecta. This unit probably has anomalous engineering characteristics; its bearing strength may be higher or lower than that of surrounding materials owing to shaking of a layer of unconsolidated mare material.

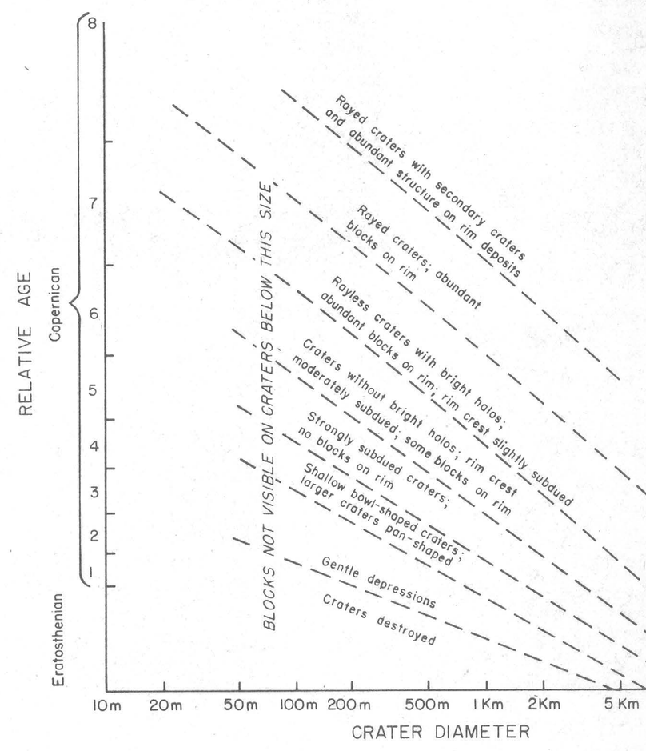

Figure 1

A mare ridge (EImr) transects the southwest corner of the site, and a rille cuts across the old terra plains-forming and mare materials of the northeast corner. Both ridge and rille are bounded by straight scarps that strike northwest and are locally offset by cross faults. The ridge and rille are probably due to structural adjustment of the upper part of the lunar crust. They may provide local exposures of pre-mare material. Other structural features include isolated groups of lineaments and parallel scours or grooves on the mare.

As most of the site is covered by typical mare material, engineering properties should not differ from those of similar surfaces tested by Surveyors I, III, and V. However, the potentially anomalous characteristics of crater aprons are noteworthy as is the mare, which fills collapse basins in the northeastern part of the site.

A number of features within site II P-13 are of scientific interest and importance. Craters predating the time of formation of the upper mare surface occur in the northeastern part of the site and represent important potential sample sites where older material can be collected without leaving the mare. Also of significance is the genesis of the rings, particularly as they may consist of materials representative of the source of mare material.

Materials from the Kepler area are undoubtedly present in the major rays that cross the central part of the site, and pre-mare bedrock may be exposed in the rille and ridge. In addition, the mare scarp in the eastern half of the site may mark the contact between two coeval mare units of different composition.

REFERENCE CITED

Eggleton, R. E., 1967, Depth of lunar "soil" from Orbiter I and II photographs, in Lunar Orbiter Photo Data Screening Group, Preliminary geologic evaluation and Apollo landing analysis of areas photographed by Lunar Orbiter II: Langley Research Center, Langley Working Paper 363, p. 111-112.