DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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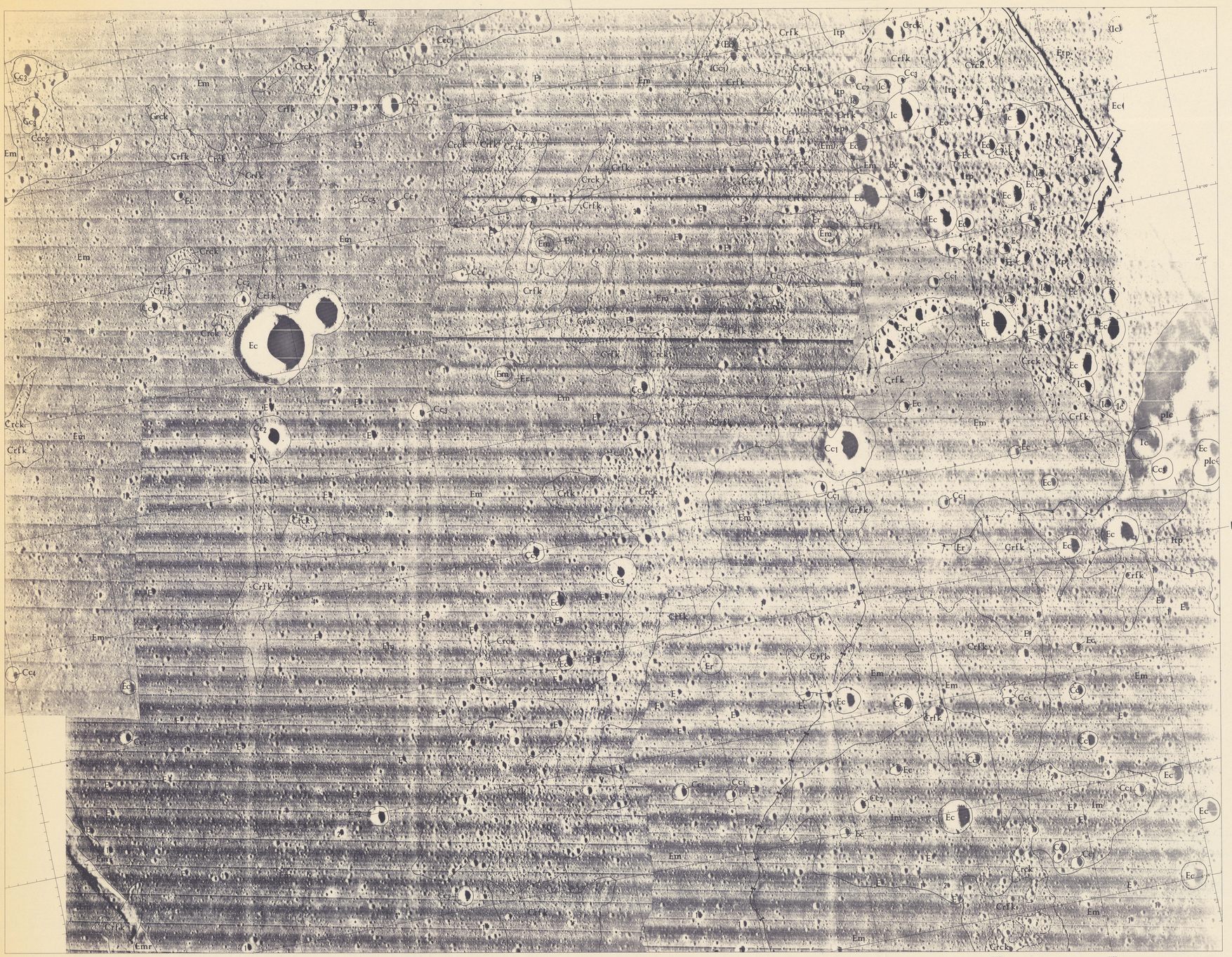


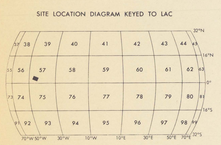
Controlled base prepared by Army Map Service, Corps of Engineers, U.S. Army, Washington, D.C. 20315

SCALE 1:100,000

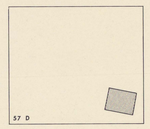
1000 0 1 2 3 4 5 6 7 8 9 10 15 20 KILOMETERS
1 ½ 0 1 2 3 4 5 6 7 8 9 10 NAUTICAL MILES

Principal sources of geologic information: Lunar Orbiter moderate-resolution photographs: I—M197-212; III—M161. Lunar Orbiter high-resolution photograph: IV—H144 (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



SITE LOCATION DIAGRAM KEYED TO AIC



GEOLOGIC MAP OF LUNAR ORBITER SITE II P-13
OCEANUS PROCELLARUM, NORTH OF EQUATOR

By
M.H. Carr and S.R. Titley

November 1968

Mercator Projection

EXPLANATION

Contact

Long dashed where two facies of same unit are separated.

(Ic) Concealed contact

Buried unit indicated by symbol in parentheses.

Fault

Bar and ball on downthrown side.

Gentle sinuous scarp

Line marks base of slope and arrows point downslope. Interpretation: Eroded flow front.

Gentle linear depression

Interpretation: May be buried sinuous rille or may mark edge of flow front.

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

	Outlined	Numbered only	Unmapped
Cc_5 (youngest)	>200 m	100-200 m	<100 m
Cc_3, Cc_4	>500 m	300-500 m	<300 m
Cc_1, Cc_2	>600 m	400-600 m	<400 m
Ec	>700 m	400-700 m	<400 m
Ic (oldest)	>700 m	Not shown	<700 m

COPERNICAN SYSTEM

Cc_5	5

Crater materials

Characteristics
Cc_5, materials of rayed craters having block-strewn hummocky rims; abundant blocks present on wall. Faint concentric ridges occur on rim; terraces on wall. Crater density on rim lower than that of surroundings. Crater rim crest sharp. Many secondary craters present.
5, materials of craters with well-developed rays. Abundant blocks on rim and within craters. Terraces on wall. Rim crest sharp.

Cc_4	4

Crater materials

Characteristics
Cc_4, materials of rayed craters having block-strewn, faintly hummocky rims. Abundant blocks present on wall. Terraces occur on wall. Crater density on rim lower than that of surroundings. Crater rim crest sharp.
4, materials of craters with bright halos and few or no rays. Abundant blocks on rim and within crater. Terraces on walls. Rim crest slightly subdued.

Cc_3	3

Crater materials

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

Crck	Crfk

Kepler ray materials

Characteristics
Materials in and around densely cratered areas of mare and terra. Faint to strong linear grooves occur approximately radial to Kepler. Albedo higher than surrounding terrain.
Crck, coarsely cratered ray material. More craters larger than 100 meters present compared to surrounding terrain. Many craters occur in chains radial to Kepler or overlap to form grooves. Some craters are elongate but many are circular and resemble non-ray craters.
Crfk, finely cratered ray material. Surface almost completely saturated with craters smaller than 100 meters in diameter but density of larger craters is comparable to non-ray terrain. Craters occur in chains or overlap to form fine lineations on the surface. Albedo slightly lower than Crck. Commonly Crfk occurs adjacent to patches of Crck on southwest side away from Kepler.

Interpretation
Mare and terra material modified by craters formed by objects ejected from Kepler. Surface materials mostly are reworked pre-existing debris. Some exotic material from Kepler may be present. Age equivalent to Cc_2 craters.

Ccc_2

Crater-cluster material

Characteristics
Materials associated with clusters of Cc_2 craters. Cluster resembles cratered Kepler ray material but lacks the linear structures and numerous small craters that characterize the rays.

Interpretation
Cluster of impact craters secondary to some crater other than Kepler.

Ccc_1

Crater-cluster material

Characteristics
Materials associated with clusters of Cc_1 craters. Host craters are larger than 100 meters in diameter. Unit occurs only at the northern boundary of the site.

Interpretation
Material of cluster of secondary impact craters.

Cc_2	2

Crater materials

Characteristics
Cc_2, materials of rayless craters having block-strewn smooth rims. Blocks and subdued terraces on walls. Crater rim crest moderately subdued.
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

Characteristics
Cc_1, materials of rayless crater having smooth rim. Scattered blocks present in rim and wall materials. Faint terraces occur on wall. Crater density of rim same as that of surroundings. Crater rim crest moderately rounded.
1, materials of rayless crater having smooth rim. Scattered blocks present in rim and wall materials. No terraces on walls. Crater rim crest strongly subdued and rounded.

ERATOSTHENIAN SYSTEM

Emr

Mare ridge material

Characteristics
Material forming the mare ridges in the southwest corner of the site.

Interpretation
Site of volcanic intrusion or extrusion. Position of ridge controlled by underlying structure.

Em

Young mare material

Characteristics
Most extensive unit in the site. Forms level cratered surface. Is distinctly 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 walls of young craters. The surface debris layer is relatively thin and is estimated as less than 8 meters thick over 70 percent of the unit (Quaide and Oberbeck, 1968). The thin surface layer, lack of Imbrian craters on the surface, and covering of the flanks of large Eratosthenian craters in the north-central part of the site all suggest a young age.

Etp

Smooth terra plains-forming material

Characteristics
Occurs within an old large crater in the northeast part of the site. Generally level terrain having intermediate albedo. Fewer craters more than 400 meters in diameter than on Itp. Most craters are very subdued and flat floored. Fewer small (<200 meters in diameter) sharp craters than on the mare. Because of the high density of subdued craters, no age designation is given to craters too small to be outlined.

Interpretation
Probably composed largely of fragmental debris of both volcanic and impact origin. Lack of small fresh-appearing craters and lack of blocks suggests that a much thicker surficial fragmental layer has developed on this unit than on the mare.

Er

Ring material

Characteristics
Material associated with faint ring structures in the mare. Ring comprises a low circular ridge enclosing material having a slightly lower elevation than the surrounding mare. Some rings are partly enclosed by a shallow circular depression. Albedo same as surrounding mare material.

Interpretation
May be remnants of old craters thinly covered with mare material or may be volcanic ring structures that formed at the time of deposition of the mare material.

Ec	E

Crater materials,

Characteristics
Ec, materials of rayless craters having smooth rims. Scattered blocks present on rim and wall. No terraces occur on wall. Crater rim crest moderately to strongly subdued and rounded.
E, materials of shallow rayless crater having smooth low rim. No blocks present in some craters; a few isolated blocks present in rim or interior of others. Crater rim crest rounded. Strongly subdued rim that barely stands above surrounding terrain.

IMBRIAN SYSTEM

Im

Old mare material

Characteristics
Occurs in the southeast corner of the site. Resembles Im except that it is more densely cratered and has a slightly higher albedo.

Interpretation
Probably volcanic flows similar to Em but has more craters and a thicker debris layer because of its older age. May be merely Em modified by ray material, but lacks the radial streaks characteristics of rays.

Itp

Cratered terra plains-forming material

Characteristics
Forms highly cratered generally level terrain in floor of large crater in northeast corner of site. Surface is saturated with subdued craters 200-500 meters in diameter. Few fresh blocky craters present. Has slightly higher elevation than the mare. Albedo intermediate. Because of the high crater density, no age designation is given to craters too small to be outlined.

Interpretation
Similar to Etp but older and more cratered. Probably composed largely of fragmental debris of both volcanic and impact origin. Lack of small fresh blocky craters suggests that a much thicker surficial fragmental layer has developed on this unit than on the mare.

Ic

Crater materials,

Characteristics
Materials of shallow bowl-shaped or pan-shaped craters having smooth low rims. No blocks present in either rim or wall materials. Crater rim crest rounded.

PRE-IMBRIAN

plc

Crater rim material

Characteristics
Forms part of the rim of an old crater 40 km in diameter that lies mostly outside the map area. Rugged sparsely cratered terrain has patterned ground over entire unit.

Interpretation of Crater Materials

Materials of craters that are probably mostly of impact origin. Craters are assigned numbers or letters according to relative age. Numbered craters are the youngest and the higher the number the younger the crater. Interior slopes of youngest craters are probably fragmental and brecciated debris which may include blocks of highly shocked rock. Highly shocked bedrock may also be exposed in youngest craters. Material around older craters is indistinguishable from surrounding materials.

General Geology

This map shows the geology of Lunar Orbiter site II P-13, within which lies ellipse West One, a potential early Apollo landing site in the lunar equatorial belt. The site is in Oceanus Procellarum, about midway between the crater 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 dark mare, and the entire site is crossed by rays from Kepler. Materials in the site have been mapped according to their interpreted relative age and assigned to positions in the standard lunar stratigraphic column used for small-scale reconnaissance mapping (Hackman, 1962; Wilhelms, 1966). Numbers have been added to the symbols used for Copernican crater units in order to provide a finer breakdown by relative age. The highest numbers are for the youngest units.

The oldest materials in the site occur in the northeast corner, where cratered terra plains-forming materials (unit Itp) abut a ridge (unit plc). The ridge is a remnant of the rim of an old crater that predates development of both mare and terra plains units. The terra plains units occupy the floor of the old crater and are slightly higher than the adjoining mare.

Mare within the site is generally uniform in appearance, and the dominant mare type is designated "young mare" (unit Em). However, a small area of more heavily cratered mare in the southeast corner of the site is called "old mare" (unit Im). The young mare appears to be younger than typical mare of most other areas of the lunar equatorial belt; it has a slightly lower albedo, is less densely cratered, and covers the flanks of two fresh-appearing craters in the west-central part of the site. The two craters are Eratosthenian in age; thus, the mare is at least that young.

Blocks and terraces occur in mare craters as small as 20 meters in diameter, suggesting that the surface debris layer is thin compared with that of most other mare areas.

In the southeast part of the site are two faint structural features: a north-south linear depression and a subdued east-west scarp. In several places these features separate mare materials with slightly different albedos. The linear depression may be the remnant of an old sinuous rille. Alternatively, both features may be related and may mark the edge of a flow front that has been largely destroyed by erosional processes.

Rays from Kepler cross the region from northeast to southwest and modify the pre-existing terrain. The rays have been divided into two units: coarsely cratered Kepler ray (Crck) and finely cratered Kepler ray (Crfk). The coarsely cratered ray material has significantly more craters in the 100-600 meters diameter size range than the surrounding materials. Within the finely cratered ray unit, craters less than 100 meters in diameter are much more numerous than in surrounding materials. Both types of rays are characterized by linear depressions approximately radial to Kepler. Although the rays are mapped as separate geologic units, little exotic material from Kepler is believed to be present. The distinctive features of the rays result largely from reworking of pre-existing surface materials.

Superposition relations suggest that craters are degraded with time. Accordingly, all the larger craters in the site are mapped on the basis of interpreted age as inferred from "relative freshness." The relative ages have been estimated from rim details according to the classification shown in figure 1. Because the rate of crater destruction may vary from place to place on the Moon, all craters with the same designation in this and other areas may not be strictly equivalent in age.

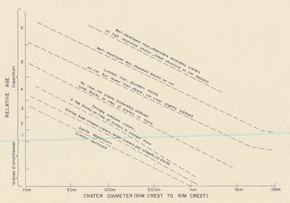


Figure 1.--Relation between diameters, properties, and ages of craters. Categories are intergradational).

One type of crater-like feature not mapped according to the aforementioned scheme is the "ring" (unit Er)--a low circular ridge with gentle slopes enclosing an area that is commonly slightly lower than the surrounding mare. Such structures may be premare craters thinly covered by mare material, or they may be igneous intrusions similar to ring dikes.

Very few linear structures are present in the area. In addition to those in the southeast part of the site, a northwest-trending mare ridge (unit Emr) occurs in the southwest corner. The boundary between the mare and terra plains-forming units also follows this trend, and the contact may mark the position of a buried fault. Faint linear grooves trending northwest and northeast are visible over much of the mare; many of the northeast-trending grooves may be caused by secondary craters from Kepler, but some are probably structurally controlled.

Engineering Properties

The crater size frequency distribution and albedo of the young mare in this area is similar to that of the mare at the Surveyor I landing site, and the engineering properties at the two locations should be similar. Quaide and Oberbeck (1968) estimated that the thickness of the fragmental layer is 8 meters or less over 70 percent of the mare. The fragmental layer on the terra plains-forming materials may be considerably thicker. Blocks occur around all craters Cc_2 or younger.

Scientific Interest

Several features of the site are of scientific interest. Because most of the mare material is young, the surface debris layer must be thin and blocks will be plentiful around small fresh craters. It should be relatively easy, therefore, to sample bedrock underlying the debris layer. The mare scarp, the subdued linear trough, and the ring structures may all be volcanic features that formed by the same volcanic processes that resulted in the deposition of the mare material. The rays are of interest in that material from Kepler may be identifiable in the ray areas and would provide a sample of material from deep within the crust. Finally, comparison of the mare material and terra plains-forming material could demonstrate whether the differences between these units result from age, composition, or lithology.

References

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