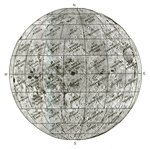
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

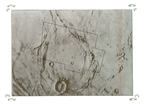
PREPARED IN COOPERATION WITH THE
MANNED SPACECRAFT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



INDEX MAP OF THE EARTHSIDE HEMISPHERE OF THE MOON

Large numbers 1-7 refer to regions that include early Apollo landing sites:
1. Mare Ivorum (PA region - 1418)
2. Sea of Tranquillity (PA region - Apollo 11)
3. Oceanus P region - 1625
4. Wichmann C4 region - 1424
5. Descartes R region - 1627
6. Flamsteed A region - this report
7. Lansberg P region - 1623 (Apollo 12)

Small number above quadrangle name refers to lunar chart (LAC series).
Small number below refers to published geologic map (scale 1:1,000,000).



MAP OF PART OF THE FLAMSTEED QUADRANGLE OF THE MOON (AIC SERIES)

Area of this report shown by solid line; dashed circle indicates early Apollo landing site. Approximate scale 1:3,700,000

GEOLOGIC SUMMARY

The Flamsteed K region is in the southern part of Oceanus Procellarum, approximately 65 km (kilometers) north of the crater Flamsteed and 320 km southwest of the crater Kepler. The region was photographed by Lunar Orbiter III on its 100th revolution, and was visited by the crew of a potential early Apollo landing site. The area is included in a 1:1,000,000-scale map by Marshall (1962).

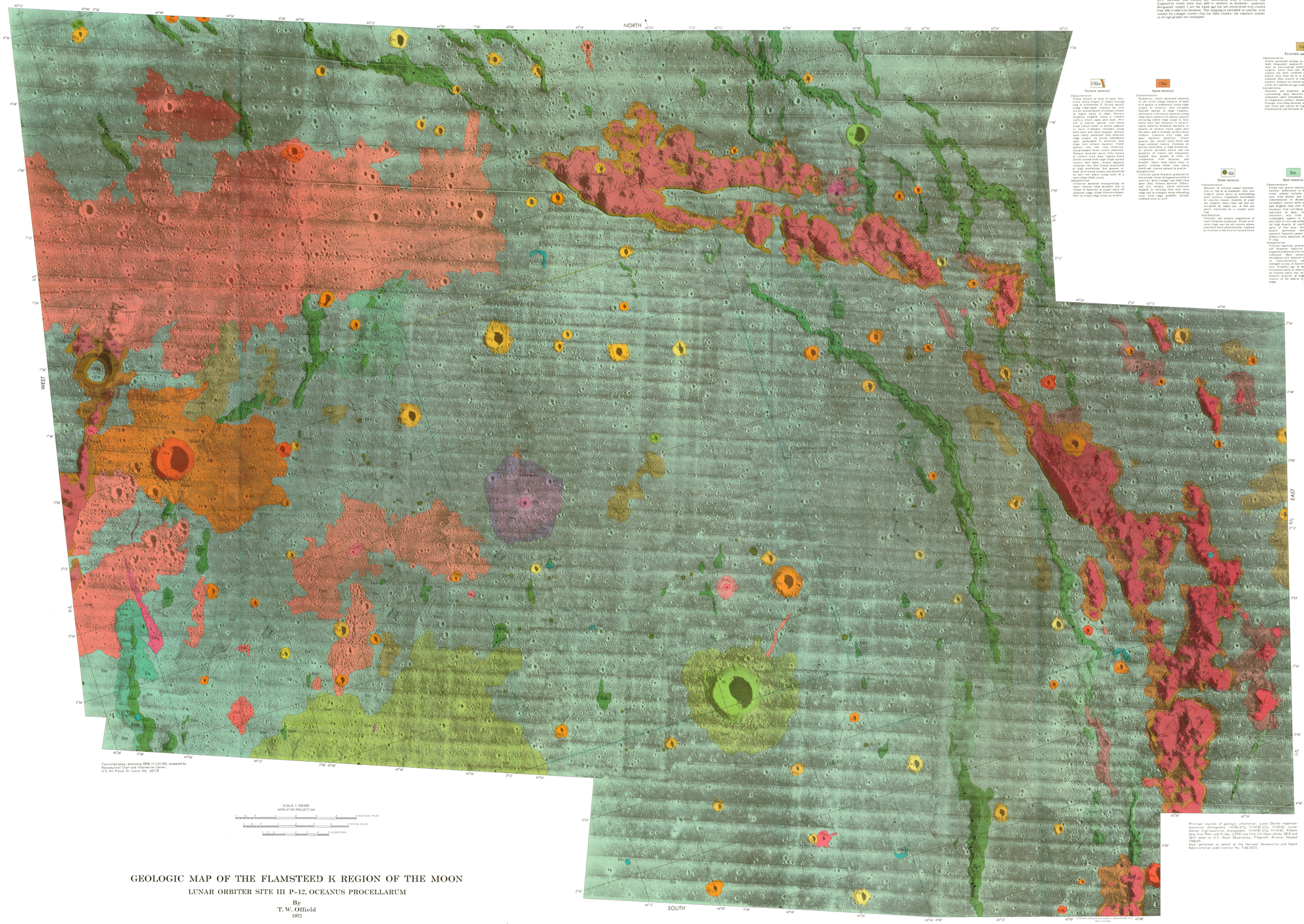
Terra material (plt) in the region forms the ridges of Flamsteed P, an incomplete circular structure constituted to be the rim or concentric ridge of a very large impact structure. Subjacent bedrock of this material is highly lineated. Fractured bedrock appears to be exposed at places, but the surface is interpreted to consist mainly of patterned fragmental debris. The paucity of craters on the ridges is ascribed to destruction by downslope movement of the surface material. This process is evidenced by the numerous lineations, terraces, and benches (CEds) and apron deposits (CEa) along the bases of the ridges.

Aside from craters, the mare surface is generally flat but has numerous elevated patches, low scarps, and irregular areas of patterned ground. The mare material is brighter in the western half than in the eastern half because of the presence of ray materials and secondary crater clusters from the crater Kepler. Structural lineaments are uncommon in the mare; they are relatively uniformly oriented (northeast, north, and northwest) in both mare and terra materials, and probably reflect bedrock fractures related to the lunar grid system. An Eratosthenian age for the surface mare unit in the map area is suggested by the fact that the mare is less cratered than the Eratosthenian-age material of Kepler and younger than the Eratosthenian crater Flamsteed (south of the area), ejecta from which is partly covered by this same unit of mare material. Probably more than one episode of deposition of the presumably volcanic mare material was involved.

Craters are relatively concentric on the ridge system of Flamsteed P and partly transverse to it. Near the relatively fresh 2.3-km Cr4 crater southeast of Flamsteed $_2$P, the mare ridge appears to be older than the crater because domes of ejecta are piled along the base of the ridge. An adjacent area of patterned ground embays the ejecta and then appears younger than the crater. The ejecta of the crater is embayed by patterned ground probably are volcanic in origin and may represent vent areas which were the sources of the surrounding material.

Craters in the region range in diameter from the limit of resolution (0.5 km, and vary in form from sharp-rimmed bright craters to shallow depressions with subdued rims. The youngest crater has three distinguishable facies of ejecta conventionally distributed successively outward a hummocky to fairly smooth raised facies, a hummocky ejecta blanket consisting of irregularly interwoving radial and concentric lineation ridges, and an array of secondary craters and discontinuous ejecta. Blocks are very abundant around this crater and occur as much as 2 crater diameters from the rim. Because of the paucity of secondary craters, secondary craters are difficult to recognize, and resolvable blocks are less abundant and do not extend as far from the crater rim.

The principal object of scientific interest in the region is the ring structure Flamsteed P. Bare rock appears to be exposed on scarps formed by the innermost concentric ridge of the structure. The relative position of these stratigraphic relationship to the adjacent mare should indicate whether the ring is an old crater rim or a volcanic feature (Fielder, 1967; O'Keefe and others, 1967; Milton, 1967). Other features of scientific interest are the mare ridges, patterned ground in the mare, the embayment of Kepler ejecta, and hummocky domes which may be of volcanic origin.



Controlled base, photomap ORB III-12(100), prepared by Aeronautical Chart and Information Center, U.S. Air Force, St. Louis, Mo. 63118

SCALE 1:500 000
(MERCATOR PROJECTION)
5 NAUTICAL MILES
5 STATUTE MILES
5 KILOMETERS

GEOLOGIC MAP OF THE FLAMSTEED K REGION OF THE MOON

LUNAR ORBITER SITE III P-12, OCEANUS PROCELLARUM

By
T. W. Offield
1972

Principal sources of geologic information: Lunar Orbiter moderate-resolution photographs I-0182-2(12), III-0182-2(12), IV-0142-2; Lunar Orbiter high-resolution photographs III-0182-2(12), IV-0142-2; Albedo data from Pohn and Wildey (1970) and from full-moon photos 3818 and 3819 taken at U.S. Naval Observatory, Flagstaff, Arizona. Mapped 1969 to 1971.

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LITHOGRAPH GEOLOGICAL SURVEY, WASHINGTON, D.C. 1972—L71044

EXPLANATION

NOTE: A crater's materials are mapped and given symbols according to the size (rim-crest diameter) and interpreted relative age of the crater. The apparent freshness of the crater on Orbiter photographs is used to determine its age, and allowance is made for an inverse relation between crater size and rate of degradation (Soderblom and Lebofsky, 1968; Soderblom, 1970). The larger craters in each age group are mapped in color (mappable materials extend relatively farther from the rim crests of older craters than of younger craters). Craters too small to be mapped individually are included with the surrounding material. The map symbols that identify these materials consist of a capital letter to designate lunar time-stratigraphic division (system), lowercase letter(s) to designate rock unit, and, in the Copernican System, a subscript number to designate relative age within that system. To the extent that the crater materials are mappable, the rock units in each age group are not subdivided; such craters are indicated by number or letter symbol only. For example, materials designated as $C_1$1, undivided, and colored are associated with a relatively old Copernican crater (more than 400 m (meters) in diameter); materials designated as $C_3$3 are associated with a younger crater (less than 400 m to 400 m in diameter). The mapping is extended to smaller size classes for younger craters than for older craters; the smallest craters in all age groups are unmapped.

Copernican System

Cm_c, Crr_c, Cm_c — Crater material

Characteristics
Material of craters having very bright ray material; abundant blocks extend outward from rim to four crater diameters beyond rim crest; rims rim crest sharp and polygonal
Cm, *material of craters having conspicuous facies of radial and concentric lineation or elongate hummocks; outer limit of resolvable blocks may coincide with outer edge of facies or occur within it.*
Crr, *material of craters having rough, undivided, discontinuous ejecta; linear strips of craters present. Preserved only around one 220 m diameter crater near center of site*
Interpretation
Material of craters forming multidirectional ejecta; abundant blocks present on walls and rim; rim crest very slightly subdued
Cm, *material of craters forming array of lineation or elongate hummocks; limit of occurrence of blocks marks outer edge of ejecta*
Crr, *material of craters having rough, discontinuous ejecta; blocks abundant in crater interiors and on rim crest; interior shadow sharp but commonly irregular in shape because of rough crater interiors; rim crest sharp to very slightly subdued*

Ccr_c — Crater clusters material

Characteristics
Unit characterized by concentrations of slightly subdued, to pale elongate, craters whose morphology and characteristics are similar to those of Cr3 craters; includes subdued hummocky material between craters. Appears different from other Cr3 craters in Orbiter photographs
Interpretation
Ray material and material of secondary craters. Primary crater unknown but could possibly be Tycho

Cch_c — Chain crater material

Characteristics
Material in string of interrupted elongate or coalescent craters; rim crest of Cr4 material of Flamsteed Q and on rim forms southeast part of map
Interpretation
Material in and around line of probable secondary craters

Cpr_c — Patterned mare material

Characteristics
Fairly patterned texture in isolated patches; topographic more irregularly undulatory and albedo possibly lower than in surrounding mare material; craters in patterned areas are slightly lower than surrounding surface. Embays or covers unit Crk and ejecta of 2.2 km crater Cr4 (Copernican crater southeast of Flamsteed Q)
Interpretation
Possibly ash deposits; may mark source vents for mare material. Material may be patterned result lineaments and in downslope movement of fragmental surface material on flank-wall topography. Embays or covers unit Crk and ejecta of Copernican crater southeast of Flamsteed Q and because of lower crater density

Crk_c — Kepler ray and crater cluster material

Characteristics
Consists of material of moderately subdued, elongate 100-1000 m craters; similar to Cr3 craters, includes subdued hummocky material between craters. Patch west of Cr4 crater near center of site, and patch SE km southeast of Cr4 crater have elongate craters or strings of craters that are parallel to ray material from Kepler; craters in patch southeast are in irregular patterns that appear different bright on full-Moon photographs. Lies within Kepler rays
Interpretation
Material of secondary craters of Kepler, and depositional ray materials; patches with lineated topography probably reflect downslope movement of ray material; ejecta, ejecta materials, interpreted to have light cover on mare ridge (Emp) and terra (plt) materials in southwest part of area; crater trends slightly have been subdued or destroyed by downslope movement of surficial material

Cr_c3 — Crater material

Characteristics
Cr3, *material of craters having moderately subdued rims; some blocks on rims; shadow sharp and broadly curved in larger craters, bounded by zone of darkening at low angle illumination in small craters*
Interpretation
3, *same as Cr3 but occurs in smaller craters*

Cr_c2 — Crater material

Characteristics
Cr2, *material of craters having moderately subdued rim crests; some blocks on rims; shadow sharp and broadly curved in larger craters, bounded by zone of darkening at low angle illumination in small craters*
Interpretation
2, *same as Cr2 but occurs in smaller craters*

Cr_c1 — Crater material

Characteristics
Cr1, *material of craters having moderately subdued rim crests; shadow sharp and broadly curved in larger craters, bounded by zone of darkening at low angle illumination in small craters*
Interpretation
1, *same as Cr1 but occurs in smaller craters*

Cr_c4 — Crater material

Characteristics
Cr4, *material of craters that commonly have vestiges of radial lineation; material commonly abundant on rims; rim crest slightly subdued*
Cr4r, *radial rim material; forms partly radial discontinuous ridges on rim crest*
4, *same as Cr4, but occurs in smaller craters*

Cd_c — Dome material

Characteristics
Material of circular domal features, 120 to 700 m in diameter; rim rim slightly above level of surrounding mare; domes have concentric fractures; no relative crests. Centers of some are slightly lower than rim and are marked by pits; domes are partly restricted by a raised outer ring
Interpretation
Possibly the surface expression of small plugdome intrusions. These with pits may be volcanic vents; domes with rim have been protectively subdued by erosion in the form of raised floors

Em — Mare material

Characteristics
Forms very gently undulatory to level surface; topographic more irregularly undulatory and albedo possibly lower than in surrounding patterned mare material; craters in patterned areas are slightly lower than surrounding surface. Embays or covers unit Crk and ejecta of 2.2 km crater Cr4 (Copernican crater southeast of Flamsteed Q)
Interpretation
Possibly ash deposits; may mark source vents for mare material. Material may be effusivelike spread laterally from vents marked by ridges and domes. Embays or covers unit Crk because of lower crater density

Emp — Patterned mare material

Characteristics
Fairly patterned texture in patches; topographic more irregularly undulatory than in surrounding mare material; ridges; topographic more irregularly undulatory and albedo possibly lower than in surrounding mare material. Ridges are commonly wider than those in adjacent mare. Number density of superimposed craters similar to that of mare. Not higher than ridges in Emp
Interpretation
Possibly ash deposits; may mark source vents for mare material. Material may be effusivelike spread laterally from vents marked by ridges and domes. Ridges may represent swarms and/or ridges. Especially irregular mare craters larger than 20 m in diameter; rim crests of craters are less rounded than those in mare. Boundary between ridge material and mare material is commonly a zone of transition, marked by change from patterned to unpatterned ground. Unit also includes isolated irregularly shaped, raised patches surrounded by patterned ground; unit Emp and Ecr specifically identified.
Interpretation
Possibly the lava of volcanic material involved over composite faults within stage of Flamsteed P and over faults within stage of Flamsteed P. Ridge systems are most stage of mare in older than 2.2-km Cr4 crater southeast of Flamsteed Q; ridges are along straight segments of ray ridges probably were produced by downslope movement of ejecta; possibly is exposed in ray ridges, but most of the ridge surface is covered by patterned ground. Unit also includes isolated irregularly shaped, raised areas may be uplifted blocks or small domes; unit Emp specifically identified as mare ridges near the crater Kepler ejecta and as an incompletely buried groundmass of the ring (and vice versa)

Emr — Mare ridge material

Characteristics
Forms low, somewhat sinuous ridges; topographically more irregular than commonly made up of short linear segments. In essence, part of site ridges are subequal to ridges of Emp; ridges are wider than those of Emp; irregularity of surface of Flamsteed ridges. Stones are generally irregular and are bounded in places by straight edges. Ridges are commonly wider than those of Emp. Especially irregular mare craters larger than 20 m in diameter; rim crests of craters are less rounded than those in mare. Boundary between ridge material and mare material is commonly a zone of transition, marked by change from patterned to unpatterned ground. Unit also includes isolated irregularly shaped, raised patches surrounded by patterned ground; unit Emr specifically identified.
Interpretation
Possibly the lava of volcanic material involved over composite faults within stage of Flamsteed P and over faults within stage of Flamsteed P. Ridge systems are most stage of mare in older than 2.2-km Cr4 crater southeast of Flamsteed Q; ridges are along straight segments of ray ridges probably were produced by downslope movement of ejecta; possibly is exposed in ray ridges, but most of the ridge surface is covered by patterned ground. Unit also includes isolated irregularly shaped, raised areas may be uplifted blocks or small domes; unit Emr specifically identified as mare ridges near the crater Kepler ejecta and as an incompletely buried groundmass of the ring (and vice versa)

Ec, Ecrr, E — Crater material

Characteristics
Ec, *material of craters having moderately subdued rim crests; shadow sharp and broadly curved in larger craters, bounded by zone of darkening at low angle illumination in small craters*
Ecrr, *radial rim material. Faintly resource, continuous, subdued hummocky material*
E, *material of craters that are nearly subdued; shallow depressions or have the shape of shallow pans. Commonly lineated. Patterned ground on walls*

Interpretation of crater materials
(Cm-Ec, E-E)
Material of both primary and secondary impact craters. Cr3 (younger) (Cr4 (older) craters are mapped; material is result of microtectonic fracturing and downslope movement of material from rim crest. Material of craters in lunar maria (mare craters) is mapped; rim to mare elsewhere may be gouged out by ejecta from younger craters. Craters in the 400-m to 2-km size range

Elr — Ring material

Characteristics
Subdued hummocky topography; rounded hills and depressions; mostly 200 to 2,000 m in diameter. Some have slightly raised floors and are commonly surrounded by double rim
Interpretation
Probably materials of subdued old craters; some may be volcanic (magmatic) developed during one or more episodes of mare material emplacement. If the material is volcanic, related to mare material, probable depth-diameter ratios would suggest that the material is not pyroclastic material if the craters were markedly subdued prior to burial; a thickness of 50 to 100 m of mare material is likely. An alternative interpretation is ring-dike structures or other concentrical volcanic features

Imbrian or Eratosthenian System

plt — Terra material

Characteristics
Forms ridges as high as 500 m which make up ring of Flamsteed P; slopes of more than 20° present. Area in ridges is commonly lineated, showing linear and curved edges and trends in highly patterned or fractured rock. Ridges are commonly at 10 to 15 m scale on outer slopes. Highly lineated; commonly in rectilinear patterns, some of which are groundmass; other unidentified fracture systems. Blocks common on steep crests and slopes. Less common on gentler slopes. Some craters are as large as 100 m; most craters unidentifiable 20 m and subdued or larger craters are very sparse; craters are commonly subdued and low in numerous density of 2-100 m fresh to very subdued craters
Interpretation
Highly fractured bedrock; exposed at places but mostly mantled by fragmental material; some of material may be surface texture due to downslope movement of fragmental material. Ridges are probably part of a large impact crater. Constitutes rim of 212 km crater Flamsteed P; largely buried by mare material; exposed at places in place in the northern segment of the ring suggests uplifted block of old crater rim rather than crater rim. This circular ridge system concerned by Fielder (1967; p. 33) to be a crater rim, but to be a pre-mare ring-dike complex; the evident pre-mare sculpturing of ridge and embayment of ridge by mare indicates ridge is older than the mare. Lineations and other structures served in tectonic lava release is indicated by spatially associated mare ridges and patches of patterned ground

plts — Subdued terra material

Characteristics
Forms low, irregular, low topographic mound; adjacent to isolated terra hills in vicinity of terra ridge complex. Unit is part of ring of Flamsteed P; gradational with extensive apron material (CEa). Distinguished from apron material by lineations and lower albedo and more obvious vestige of surface materials
Interpretation
Low material of old crater rim, embayed or surrounded by mare material; but high enough to have escaped inundation

plc — Crater material, undivided

Characteristics
Forms ridges of steep-walled crater in south end of ridge designated Flamsteed P. Floor of crater occupied by mare
Interpretation
Material of old impact crater

Pre-Imbrian

Contact
Long dashed where approximate (sealed; short dashed where gradational)

(Ec)
Buried contact
Buried unit indicated by symbol in parentheses

(3)
Buried crater
Stone buried crater diameter less than 400 m in lateral extent

BRIGHT
DARK
Albedo boundary, showing relative brightness

Lineament

Scarp
Line marks foot of scarp; hatch points downslope

Ridge
Crest of sharp mare ridge or ray ridge; arrp broad mare ridge

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Explanatory pamphlet accompanies map