DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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

GEOLOGIC SUMMARY

This map shows the geology of two potential early Apollo landing sites in the lunar equatorial belt. The large, elliptical landing site 3 shown on the index map is a possible landing site for the first Apollo mission; the smaller, circular site 3R is an area of higher scientific interest that may be visited on an early mission after the first.[1]

The Oppolzer A region is in south-central Sinus Medii, slightly to the west of the subterrestrial point of the lunar disk. A map of the region at a scale of 1:100,000 (Rowan, 1970) includes the landing sites and shows their regional geologic setting. It shows a large number of crater clusters superposed on relatively heavily cratered mare material. Many of the crater clusters lie along well-defined rays from Copernicus and Tycho and probably belong to the widespread fields of secondary impact craters around these large craters. The area of this map lies between the large crater clusters and includes a small patch of mare material with below-average crater density.

Imbrian mare materials make up the oldest geologic unit in the sites; they are not exposed at the surface but are covered with a layer of fragmental debris such as shown on all of the Surveyor photographs. The mare material was probably originally a series of lava flows, possibly with some pyroclastics. Subsequent cratering has comminuted and stirred the original surface material so that original volcanic landforms and boundaries between individual flows are no longer discernible. A small tract of mare material in the western part of the area, shown as Eratosthenian mare material (Em), has fewer fresh craters larger than 50 m (meters) and fewer subdued craters larger than 100 m than the Imbrian mare material, and it has fewer sharp craters than typical mare material elsewhere on the Moon. It is either an area where a layer of younger material, possibly pyroclastics, has covered an older cratered surface or an area where the mechanical properties of the original mare material were different from those of mare material elsewhere, so that craters have not been as well preserved on it. If the area of anomalous mare material includes a layer of relatively young material, some of the larger Eratosthenian craters mapped as superposed on the unit may in fact be buried beneath the younger layer. Surveyor VI landed (arrow) on Eratosthenian mare material at a spot surrounded on three sides by mare ridge material (Morris and others, 1968, p. 17).

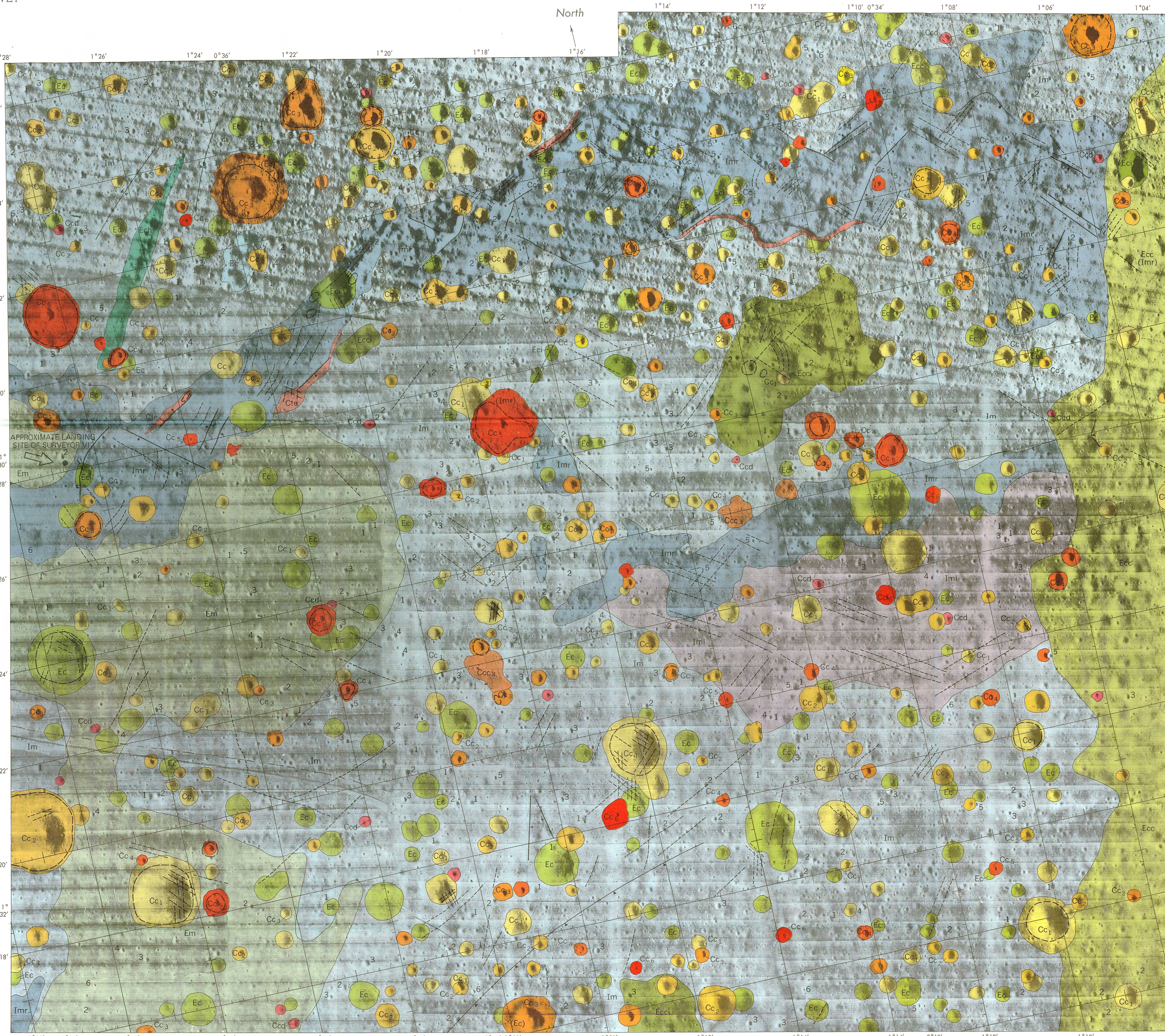
Two well-defined mare ridges occur in the area. They are interpreted as lava flows that were extruded along fissures at the close of deposition of the Imbrian mare material. Mare ridges in some other areas have been interpreted as portions of originally flat mare material passively uplifted along faults; such an origin is also possible for the ridges here. The relatively low, narrow ridge running approximately east-west in the eastern part of the map area is of interest as the only mare ridge within a potential landing site for the first mission, but it will be difficult to study during a short stay time. A better defined, higher mare ridge with a zigzag pattern crosses the northern part of the map area and is the goal of a mission to the relocated landing site, 3R, which may be visited after the first mission. A 1-km traverse from the center of the relocated site reaches a well-defined terrace (unit Cte) at the contact between the ridge and the mare material. The convex-upward terrace is similar to many other lunar terraces at the base of moderate to steep slopes. It is probably an accumulation of mass-wasted debris from the upper parts of the slope. Patches of lunar patterned ground (irregular, anastomosing ridges and troughs several meters high and approximately 10 m wide) on the mare ridge material and on the terrace are probably the result of downslope creep of fragmental material.

REFERENCES

Rowan, L.C. 1970, Geologic map of the Oppolzer A region of the Moon [scale 1:100,000]: U.S. Geol. Survey Misc. Geol. Inv. Map I-620.

Morris, E.C., Batson, R.M., Holt, H.E., Rennilson, J.J., Shoemaker, E.M., and Whitaker, E.A., 1968, Television observations from Surveyor VI, *in* Surveyor VI: A preliminary report: Natl. Aeronautics and Space Adm. Spec. Pub. 166, p. 11-40.

[1] Since this map was prepared, two Apollo landings have been made at sites 2 and 7 (see index map). There is little likelihood that a landing will be made at sites 3 and 3R.



Controlled base, part of photomap ORB II-8 (25) prepared by Aeronautical Chart and Information Center, U.S. Air Force, St. Louis, Mo. 63118. Northern portion of base map made from lower sun angle photographs (Orbiter III) than southern portion (Orbiter II). Hence craters appear deeper and more numerous in northern portion

SCALE 1:25 000
MERCATOR PROJECTION

1 NAUTICAL MILE
1 STATUTE MILE
1 KILOMETER

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1970—G70028

Principal sources of geologic information: Lunar Orbiter moderate-resolution photographs III-M94-100. Lunar Orbiter high resolution photographs; II-H121-123; and convergent stereoscopic high-resolution pairs V-H109, H113 and H110, H114

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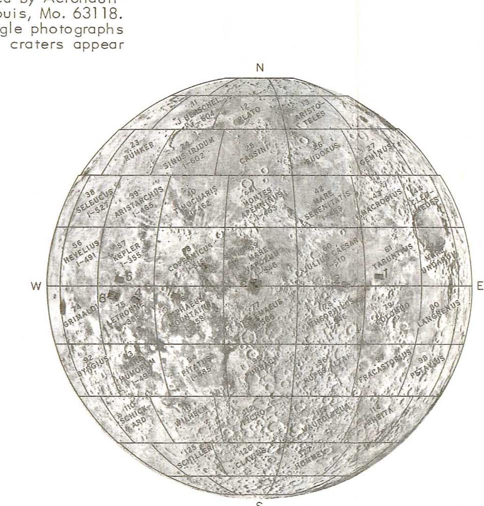
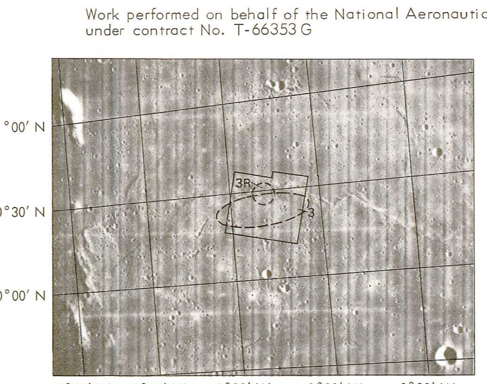
Large numbers 1-7 refer to regions that include early Apollo landing sites:

1. Maskelyne DA region
2. Sabine D region
3. Oppolzer A region
4. Wichmann CA region
5. Maestlin G region
6. Flamsteed K region
7. Lansberg P region

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



INDEX MAP OF THE EARTHSIDE HEMISPHERE OF THE MOON



PART OF LUNAR ORBITER PHOTOGRAPH V-M110
Area of this report shown by solid line; long-dashed ellipse indicates LM landing dispersion area (99% landing probability) on early mission (site 3); short-dashed circle indicates relocated landing site (3R) for possible use on a later mission. Approximate scale 1:980,000

GEOLOGIC MAP OF APOLLO LANDING SITES 3 AND 3R
PART OF OPPOLZER A REGION, SINUS MEDII

By
N.J. Trask

1970

EXPLANATION

NOTE: A crater's materials are mapped 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 the sizes and rates of degradation of craters (see enclosed pamphlet). The larger craters in each age group are mapped in color (mappable materials extend relatively farther from the rim crests of young craters than from the rim crests of old craters of comparable size). The map symbols that identify these materials consist of a capital letter to designate lunar time-stratigraphic division (system), lower case letters to designate rock unit, and, in the Copernican System, a subscript number to designate relative age within that system. To keep the map from becoming crowded, materials of the smaller Copernican craters are not outlined but are indicated by a number only For example, materials mapped as Cc_1 outlined, and colored are associated with a relatively old Copernican crater more than 100 m (meters) in diameter; materials designated simply 1 are the same age but are associated with craters from 75 to 100 m in diameter. The mapping is extended to smaller size craters for younger craters than for older craters; the smallest craters in all age groups are unmapped.

COPERNICAN SYSTEM

Ccc_4 — Crater cluster material

Characteristics

Material in areas having a distinctly higher density of craters 5-20 m in diameter than surrounding areas. Craters are moderately subdued and slightly elongate north-south

Interpretation

Material of field of secondary impact craters perhaps formed by Tycho ejecta. One of the few fields of craters that are confidently interpreted as secondary impact craters and are accessible on early missions if landing site is nearby. Fragments of the projectiles which made the craters may be present

Cte — Terrace material

Characteristics

Forms narrow terrace at base of moderately steep slopes along mare ridge (Imr). *A few resolvable blocks on unit. Surface convex upward. Patterned ground with ridges and troughs mostly at an angle to the topographic contours. Both upslope and downslope contacts are relatively sharp; lower contact cuts across an* Ec *crater*

Interpretation

Loose rock debris mass wasted from mare ridge. Formation has continued into relatively recent time. One of the few terraces mapped along a mare ridge in an early Apollo site. Ground examination and photography may provide evidence for or against proposed origin as mass wasted material derived from higher ground; information would have bearing on origin of larger terraces occurring at the base of steep slopes in the terra

Ccd — Dimple crater material

Characteristics

Material of craters having subdued rim crests. Walls are steeper at base than near crest (convex upward). No visible blocks in rim deposits

Interpretation

Material of eroded impact craters in which extensive creep of material on walls has built up an oversteepened front near base. Alternatively, may be a collapse feature in which loose material has drained downward into a subsurface fracture

Cc_6 / 6 — Crater material

Characteristics

Cc_6, *material of craters with well-developed bright-appearing rays. No resolvable (>2 m) blocks in rim deposits probably because all such craters in this area are small; subresolution blocks probably abundant. Interiors of craters sharply structured and rough with well-developed concentric terraces. Crater rim crest very sharp*

6, *material of craters with intensely bright rays. Small craters with less well developed rays would be included in this class but confident identification is not possible*

Cc_5 / 5 — Crater material

Characteristics

Cc_5, *material of craters with weak to well-developed rays. A few blocks resolvable in rim deposits of most craters and moderately abundant blocks on craters larger than 100 m. Crater interiors are rough and terraced. Floors of some craters flat. Crater rim crest sharp*

5, *material of craters having slightly subdued rim crests. Crater interiors smooth. Few details visible*

Cc_4 / 4 — Crater material

Characteristics

Cc_4, *material of craters whose rim deposits appear as bright or slightly brighter than surroundings. Flat or terraced floors of craters slightly subdued. A few blocks resolvable in rim deposits of larger craters. Crater rim crest moderately subdued*

4, *material of craters whose rim deposits appear only as bright as surroundings. Floors of craters flat or terraced. Crater rim crest moderately subdued*

Cc_3 / 3 — Crater material

Characteristics

Cc_3, *material of craters whose rim deposits appear only as bright as surroundings. A few blocks in rim deposits of larger craters. Crater interiors subdued; central mound in some craters. Crater rim crest distinctly raised but moderately to strongly subdued*

3, *material of craters having strongly subdued rims; many have double rim crests a few meters apart. Floors of craters flat or slightly convex upward*

Cc_2 / 2 — Crater material

Characteristics

Cc_2, *material of craters having strongly subdued rim crests. A few blocks in rim deposits of larger craters; sparse blocks and patterned ground (irregular anastomosing ridges and troughs several meters high and approximately 10 m wide) on walls of large craters. Crater interiors cup-shaped to flat*

2, *materials of craters having the shape of a shallow bowl. Crater rim crest raised but strongly rounded*

Cc_1 / 1 — Crater material

Characteristics

Cc_1, *diameter 100-250 m. Material of craters having the shape of a shallow bowl. Patterned ground on walls. Crater rim crest raised but broadly rounded. Diameter >250 m. Strongly subdued rim crests. No blocks on rims; blocks on walls especially near the tops of slopes.*

1, *material of craters that are gentle depressions*

ERATOSTHENIAN SYSTEM

Ech — Chain-crater material

Characteristics

Material in northeast-trending shallow linear depression with crater-like enlargements along it. One occurrence in site

Interpretation

Probably a chain of secondary impact craters

Em — Mare material

Characteristics

Forms level cratered plain in western part of area due south of mare ridge (Imr). *Has fewer fresh craters >50 m and fewer subdued craters >100 m than unit* Im. *Few lineaments except near large craters. Appears topographically lower than unit* Im *to west and slightly higher than unit* Im *to east*

Interpretation

Basaltic pyroclastic material and possibly some lava flows. Impact-produced surficial debris covers surface. Material appears to have lower cohesion than unit Im *so that fresh craters are not as well preserved on it. Lower density of* Ec *craters suggests unit is younger than* Im; *hence it may be a young mantle of largely pyroclastic material covering* Im. *Some large* Ec *craters shown superposed on unit may be buried by it. Lunar regolith developed on this unit probably consists of a mixture of unit* Em *and underlying* Im. *Alternatively, unit may be the same age as* Im *but simply have different mechanical properties. Under either hypothesis, samples of unit may have different chemical and mineralogical properties from those of more typical mare material in this and other sites*

Eci / Ecci — Material of irregular craters

Characteristics

Material of craters with one or more straight segments of wall parallel to local lineament directions. Craters highly subdued; form pan-shaped and gentle depressions. Most have slightly raised rims. Patterned ground abundant both on walls and exterior rims. Resolvable blocks on walls common

Eci, *single irregular craters*

Ecci, *clusters of irregular craters*

Interpretation

Material of craters mostly of internal origin but some may be primary or secondary impact craters whose shape was influenced by fractures in the lunar crust or which have been tectonically modified. If of internal origin, craters may be surrounded by volcanic ejecta mixed into lunar regolith

Ecc — Crater-cluster material

Characteristics

Material in terrain covered with shallow 100 to 400 m craters; craters contiguous in much of unit. Intercrater areas gently undulating and relatively smooth; density of small 10 to 20 m craters the same as on mare material (Im). *Patterned ground on the slopes of craters; other lineaments sparse. No resolvable blocks around craters*

Interpretation

Debris in and around a cluster of secondary impact craters. Origin of crater-forming projectiles uncertain. Relatively fine-grained material with no blocks greater than 2 m in diameter

Ec — Crater material

Characteristics

Material of craters that are gentle depressions or have shape of shallow bowls; larger craters are pan shaped with a distinct break in slope at rim crest. Blocks and patterned ground on walls of larger craters

Interpretation of Crater Materials

Cc_6–Ec; 6–1

Materials of both primary and secondary impact craters; youngest Cc_6, *oldest* Ec. Ec *craters and those with lower numbers were once similiar in appearance to craters with higher numbers but with time have been subdued by micrometeorite erosion and by slumping and downhill creep caused by seismic shaking. Crushed rock, poorly sorted debris, and impactite occur in rim deposits of all but the oldest craters; materials were probably shock metamorphosed to varying degrees but shock phases, if originally present, may have reverted to unshocked forms in oldest craters. Individual blocks probably angular around youngest craters, becoming progressively more rounded and more deeply buried in older craters. Walls and floors of younger craters probably consist of highly fractured bedrock possibly with shatter cones; impactite may be present on floors and walls of younger small craters. These features are progressively obliterated in older craters whose floors and walls are covered with fragmental debris much like the ground outside the crater rims. Closely spaced ridges and troughs of patterned ground on walls of older craters caused by downhill creep of fragmental debris*

IMBRIAN SYSTEM

Im / Iml — Mare materials

Characteristics

Level to very gently rolling materials, highly cratered with abundant subdued craters. Percentage of area covered by craters ranges from 15 to 25

Iml, *lineated. Has more lineaments and fewer subdued craters than unit* Im

Interpretation

Basaltic lava flows and pyroclastics stirred and comminuted by impact. Units probably made up of many over-lapping flows but individual flows are not traceable. Typical of mare material in much of the equatorial belt of the Moon. Iml *same as* Im *but may have been more active seismically so that subdued craters have been destroyed by shaking and slight movement along numerous lineaments*

Imr — Mare ridge material

Characteristics

Forms positive topographic features in places bounded and transected by northeast and northwest trending scarps and lineaments. Contact with mare material (Im *and* Em) *an abrupt scarp in places and a gentle transitional slope in others. Most slopes less than 20°. Subdued 50-200 m craters fewer than on mare material; density of 10-20 m craters the same as on mare material except where patterned ground is well developed. Ridge in east-central part of area is lower and has fewer pronounced scarps than ridge in northern part of area*

Interpretation

Lava flows extruded along nearly vertical fissures and faults in central part of ridge. Scarps probably the site of most recently active faults. Peripheral parts mainly flows that have spread from feeder dikes and sills along the faults; may also be monoclines or aprons of colluvium similar to Cte. *Alternatively, ridges may simply be mare material passively uplifted along faults. Lower crater density in areas of patterned ground caused by eroding effects of downslope movement of material. Surficial fragmental material probably thinner on ridges than on adjacent mare material (Morris and others, 1968, p. 33). Low mare ridge in central part of area older than higher ridge to north*

Contact

(Imr)
Buried contact
Buried unit shown in parentheses

Probable fault
Bar and ball on apparent downthrown side. Mapped along relatively sharp scarps

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

Scarp
Line marks base; barb points downslope. Probably the front of small debris flow

Gentle linear depression
Barbs point downslope. May be fracture trace or volcanic vent

Block field
Line outlines continuous or semicontinuous field of resolvable blocks in and around craters or along mare ridge. Subresolution blocks probably abundant within line and probably extend beyond it

For sale by U.S. Geological Survey, price $1.00
Explanatory pamphlet accompanies map