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 in and around potential early Apollo landing site 1 in the lunar equatorial belt. The Maskelyne DA region, at the southeastern edge of Mare Tranquillitatis, is in an area transitional between mare and terra. Patches of typical terra material occur on northwest-trending ridges, and typical heavily cratered mare material occurs only in the east-central part of the region. The terrain in the rest of the region, including the potential landing site, is exceptionally smooth and deficient in craters more than 50 m (meters) in diameter. A large cratered dome, possibly indicative of late-stage volcanism, occurs in the southern part of the region. Telescopically, the terrain over most of the region resembles that of mare areas with intermediate albedo; hence, at a scale of 1:1,000,000 the materials here were mapped as unit Ipm_2 of the Procellarum Group (Wilhelms, 1965).

The terra materials in the central part of the region are part of a low circular plateau approximately 35 km across. The plateau lies just to the north of the cratered dome, and the edge is marked by arcuate ridges and scarps best seen on moderate-resolution Orbiter V photographs. Most of the smoothest unit in the region (Ctm) lies on the plateau, and a number of low domes and irregular craters (Eci) are associated with the structure.

The terra comprises five units. Hilly terra material (IpIth) forms features with the greatest relief: intersecting large craters (> 500 m), low hills, and northwest-trending ridges. Few smaller craters are present. A second unit, terrace material (Cte), occurs at the bases of the more prominent ridges and probably is an accumulation of debris that has moved down the steep slopes of the ridges. The unit is separated from hilly terra (IpIth) by a sharp break in slope. A third terra unit, smooth terra material (IpIts), resembles unit IpIth but has less relief. The terrain consists of low rounded hills, shallow depressions, and faint ridges. Large (> 500 m) degraded craters are common. Unit IpIts grades imperceptibly into unit IpIth as the positive relief elements become more prominent and into a fourth terra unit, terra-mantling material (Ctm), as the relief elements disappear and craters become less numerous. A fifth unit, cratered terra material (IpItc), resembles the smooth terra unit but is more densely cratered. The hilly, smooth, and cratered terra units appear to be the oldest geologic units in the region. They may consist of ejecta from the impacts that formed the Tranquillitatis and Nectaris basins. However, the morphologic characteristics typical of ejecta blankets have long since been erased by erosion and faulting. Movement along northwest-trending faults produced ridges and valleys, probably long after the Tranquillitatis and Nectaris basins formed. The ridges are radial to Mare Imbrium and could have formed contemporaneously with the Imbrium basin. All three of the oldest units are deficient in small craters and are probably covered with a thick impact-generated fragmental layer. They may be thinly covered locally by unit Ctm.

The terra-mantling unit (Ctm) is the smoothest unit in the area and combines many of the features of both terra and mare. Almost flat and level like the mare, the unit is distinguished by slightly higher albedo and very low positive relief features (vestiges of old craters and linear ridges). It has less relief than the other terra units and fewer craters than any other unit. The few large craters (> 500 m) are very shallow and have flat floors. The unit is interpreted to consist of a slightly cohesive mixture of fragmental volcanic debris, colluvium, and impact ejecta. Colluvium may predominate around positive relief features; volcanic debris elsewhere. The paucity of craters may result partly from the youth of the material and partly from its lack of cohesion; because of the latter, impacts produce rounded, subdued craters that are rapidly degraded. The unit is thin where remnants of old craters and ridges protrude above the surface.

The mare material has been divided into two principal units: heavily cratered mare (Im) and moderately cratered mare (CEm). In addition to being more heavily cratered, unit Im has a greater proportion of sharp, fresh craters (50-200 m), and its crater population includes all gradations between fresh craters and shallow subdued ones. In contrast, few fresh-appearing craters occur in the moderately cratered mare, and nearly all the large ones (> 500 m) are shallow pan-shaped depressions; very few rimmed bowl-shaped craters are present. Differences in the crater frequencies of the two mare units probably result largely from difference in age. However, lithology may also affect crater frequencies. The lower frequency of very fresh, blocky rayed craters in unit CEm would not result solely from an age difference unless unit CEm were extremely young, younger even than many of the fresh blocky craters, which is unlikely. Unit CEm may be less cohesive than unit Im, so that new craters in the former are more rounded and more rapidly eroded. The large pan-shaped craters in unit CEm may be thinly covered craters of an older terrain.

Two mare ridges occur within the region. The one in the east half is bordered by very smooth, sparsely cratered material with low albedo. Mapped as dark apron material (Cad), the terrain around the ridge resembles that on unit Ctm except that the albedo is lower.

Two domes occur within the region. Associated with the broad, low dome in the south-central part of the region are the remnant of a crater chain and a dense cluster of craters. The smaller dome in the north-central part of the region has a central cleft. Both domes probably represent near-surface laccolithic intrusion, and the associated craters are probably volcanic in origin.

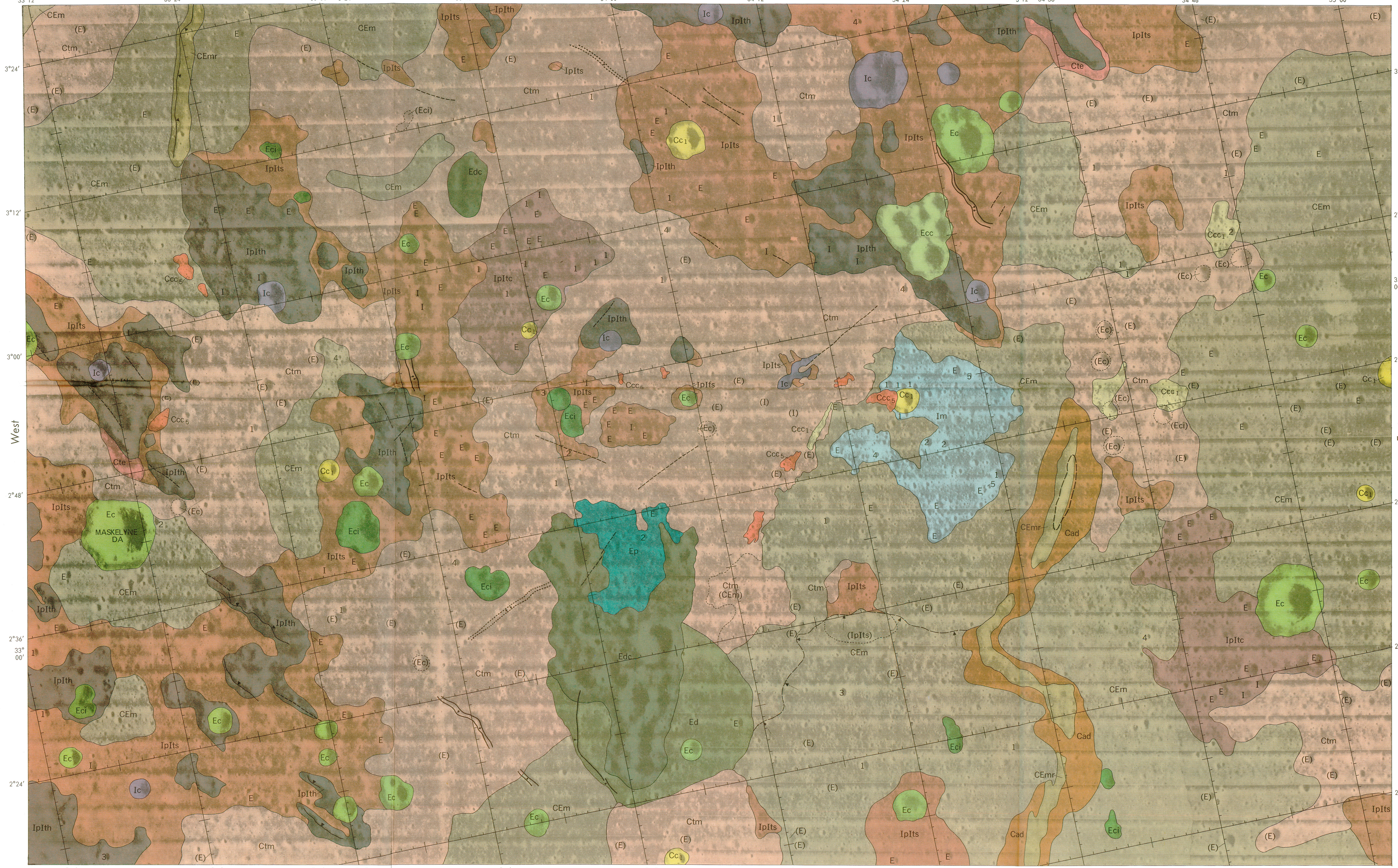
The potential Apollo landing site in this region is unique in two respects. Firstly, unit Ctm is the smoothest, least cratered unit observed anywhere in the equatorial belt and presents problems in interpretation. The extremely low crater frequency indicates a very young age, and the unit may be largely volcanic in origin. Examination of the material would shed light on the nature of the processes resulting in deposition of widespread regional units on the terra. Secondly, several young volcanic features are present in the site, the cratered dome in the south-central part being the most prominent example. Such features may aid in understanding lunar volcanism

REFERENCES

Pohn, H.A., and Wildey, R.L., in press, A photoelectric-photographic map of the normal albedo of the Moon: U.S. Geol. Survey Prof. Paper 599-E.

Wilhelms, D.E., 1965, Preliminary geologic map of the Taruntius quadrangle of the Moon, *in* Astrogeol. Studies Ann. Prog. Rept., July 1964-July 1965, map supp.: U.S. Geol. Survey open-file report.

——— 1969, Geologic map of the Apollo landing site 1 [scale 1:25,000]: U.S. Geol. Survey Misc. Geol. Inv. Map I-617.



Controlled base is Photomap ORB II-2 (100) prepared by Army Map Service, Corps of Engineers, U.S. Army, Washington, D.C. 20315

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1970—G69476

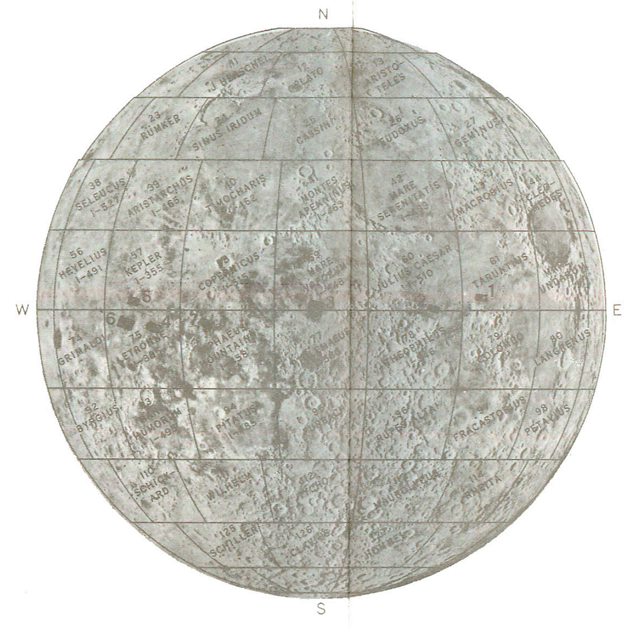
Principal sources of geologic information: Lunar Orbiter moderate-resolution photographs: I-M48 and M49; II-M35-42; III-M5, M9 and M11; V-M55-62; albedo data from Pohn and Wildey (in press) and from near full-Moon plates 5818 and 5819 taken at U.S. Naval Observatory, Flagstaff, Ariz.

Work performed on behalf of the National Aeronautics and Space Administration under contract No. T-66353 G

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

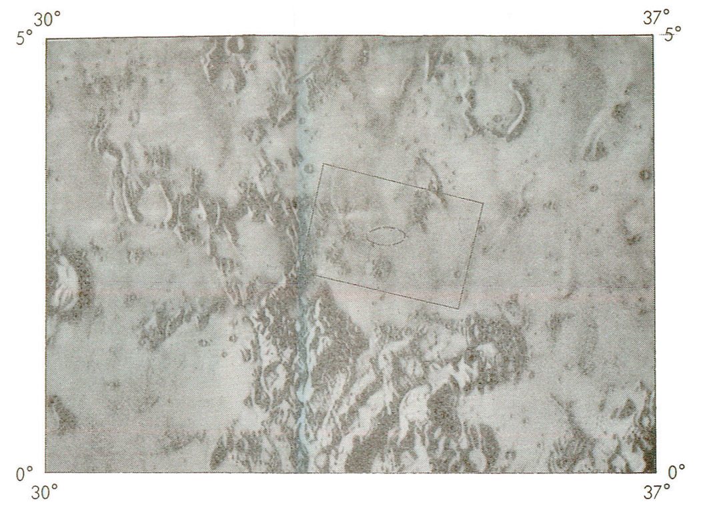
SCALE 1:100 000

MERCATOR PROJECTION

NAUTICAL MILES

STATUTE MILES

KILOMETERS



MAP OF PART OF THE MASKELYNE D QUADRANGLE OF THE MOON
(AIC SERIES)

Area of this report shown by solid line; dashed line indicates LM landing dispersion ellipse (99% landing probability). Approximate scale 1:3,000,000

GEOLOGIC MAP OF THE MASKELYNE DA REGION OF THE MOON

LUNAR ORBITER SITE II P-2, SOUTHEASTERN MARE TRANQUILLITATIS INCLUDING APOLLO LANDING SITE 1

By
Michael H. Carr
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 craters in each age group are not outlined; such craters are indicated by number or letter symbol only. For example, materials mapped as Cc_1, outlined, and colored are associated with a relatively old Copernican crater more than 600 m (meters) in diameter; materials designated simply 1 are the same age but are associated with craters from 400 to 600 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_5 — Crater-cluster material

Characteristics: *Material in and around clusters of sharp craters. Most craters are small (< 50 m). Albedo is higher than that of surrounding materials*

Interpretation: *Material of clusters of craters probably formed by the impact of ejecta from Tycho although other clusters mapped as part of the Tycho field in some other map areas are slightly more subdued and are assigned ages equivalent to Cc_3 and Cc_4*

5 — Crater material

Characteristics: *Material of rayed craters having block-strewn hummocky rims. Terraces and blocks present on wall. Crater rim crest sharp*

4 — Crater material

Characteristics: *Material of craters having rim deposits that appear brighter than surroundings. Scattered blocks on rim. Terraces may be present on walls. Slightly subdued rim crest*

3 — Crater material

Characteristics: *Material of crater having rim deposits that appear only as bright or slightly brighter than surroundings. Few blocks on rim. Rim crest rounded and moderately subdued*

2 — Crater material

Characteristics: *Material of craters having smooth rim deposits that appear only as bright as the surroundings. Blocks sparse on rim. Rim crest moderately subdued*

Ctm — Terra-mantling material

Characteristics: *Largest extent in the west half of the region. Albedo intermediate; higher than that of unit CEm. Unit forms a low undulating surface having areas of low positive relief. Grades imperceptibly into unit IpIts as the positive relief elements become more numerous and into mare material as the positive elements decrease in number and craters become more common. Fewer craters between 50 and 200 m than in the mare materials. Fresh blocky craters larger than 100 m are absent and craters larger than 500 m are mostly shallow rimless depressions. Smoothest unit in the region and one of the smoothest recognized anywhere on the Moon*

Interpretation: *Slightly cohesive fresh volcanic debris mixed with colluvium and impact ejecta. Overlies an old cratered terrain. Some of the large shallow craters are partly buried craters of the underlying terrain and some areas of positive relief are areas where the unit is thin. The paucity of craters results from the youth of the unit and the lack of small blocky craters results from the low cohesion*

Cte — Terrace material

Characteristics: *Occurs at the base of steep slopes. Mapped only where contact is clearly defined. Unit gently sloping with well developed patterned ground (irregular anastomosing ridges and troughs approximately 10 m wide and several meters high). Unit terminates abruptly against adjacent units with sharp break in slope*

Interpretation: *Apron of debris that has accumulated at the base of steep slopes as a result of mass wasting. Consists of fragmental debris. Process of formation still continuing*

Cad — Dark apron material

Characteristics: *Occurs around a mare ridge in the east half of the region. Has smooth topography, very low crater density, and very low albedo. Resembles unit Ctm but albedo is much lower*

Interpretation: *Origin obscure. In part may be debris derived by downslope movement from the ridge*

Ccc_1 — Crater-cluster material

Characteristics: *Material in and around clusters of subdued craters. Craters range in size from 80 to 300 m. Albedo similar to that of surrounding material*

Interpretation: *Material of clusters of craters probably formed by the impact of ejecta from Theophilus. Numerical subscript indicates inferred age of cluster*

Cc_1, 1 — Crater material

Characteristics:
Cc_1, *material of rayless craters having smooth rim deposits. Blocks sparse on rim, but more common on wall of some craters. Crater rim crest rounded and moderately subdued*
1, *materials of rayless craters having smooth moderately to strongly subdued rims. No terraces present on wall. Crater rim crest rounded*

COPERNICAN OR ERATOSTHENIAN

CEmr — Mare ridge material

Characteristics: *Forms low linear ridges on the mare. Flanks of ridges smooth and less cratered than the surrounding mare*

Interpretation: *Site of volcanic intrusion or extrusion. Low north-trending ridge in southeast corner of the site may be thinly covered terra ridge*

CEm — Moderately cratered mare material

Characteristics: *Has largest extent in the east half of the region. Albedo low to intermediate, lower than that of units Ctm and Im. More craters between 50 and 200 m than on unit Ctm. Fewer total craters and fewer fresh blocky craters in the same size range than in unit Im. Craters larger than 500 m are mostly pan-shaped depressions. Divided into moderately cratered mare material and smooth mare material by Wilhelms (1969)*

Interpretation: *Probably volcanic flow material or tuff. Large pan-shaped craters are probably remnants of craters that formed in the underlying terrain. E and Ec craters shown as buried where shallow and pan-shaped but shown as exposed where bowl-shaped. Unit not everywhere the same age but ranges from Eratosthenian to Copernican. Paucity of blocky craters suggests material is less cohesive than unit Im. Burial of older craters indicates thickness ranges from 50 to 90 m*

ERATOSTHENIAN SYSTEM

Ep — Pitted material

Characteristics: *Only occurrence is just north of the dome craters (Edc) in the south-central part of the region. Forms gently rolling topography and low hills as wide as 250 m. Many subdued craters mostly less than 200 m. Divided into hilly and gently hilly subunits by Wilhelms (1969)*

Interpretation: *Probably indurated ash and lava of volcanic hills and craters covered with a thin fragmental layer. Volcanism related to formation of dome*

Ed — Dome material

Characteristics: *Material occurs on broad low dome in the south-central part of the region. The surface of the dome resembles that of unit Ctm. Contact is drawn at the break in slope between the dome and the surrounding terrain*

Interpretation: *May represent volcanic extrusion or near-surface intrusion. If extruded, the near-surface fragmental layer may differ in composition from the surrounding material; if intruded the material exposed at the surface is identical to the surrounding material*

Edc — Dome-crater material

Characteristics: *Materials associated with a crater chain and cluster of large craters on the dome in the south central part of the region. Also includes a dome-like structure with central cleft in the north-central part of the region. Craters have low rounded rims. Patterned ground on steep slopes*

Interpretation: *Materials from volcanic craters. Probably volcanic debris reworked by successive impact*

Eci — Irregular-crater material

Characteristics: *Materials associated with craters that have irregular outlines*

Interpretation: *Craters may be remnants of mutually intersecting secondary craters or may be volcanic craters*

Ecc — Crater-cluster material

Characteristics: *Material in and around cluster of large bowl-shaped craters in the east-central part of the region. Albedo same as that of surrounding materials*

Interpretation: *Origin uncertain. Size precludes secondary impact origin. May be volcanic*

Ec, E — Crater material

Characteristics:
Ec, *material of rayless crater with smooth rim and rounded rim crest. Rim distinctly subdued but still stands well above surrounding terrain*
E, *material of rayless crater with smooth rim, rounded rim crest, and shallow internal slopes. Rim barely stands above surrounding terrain*

IMBRIAN SYSTEM

Im — Heavily cratered mare material

Characteristics: *Only occurrence near the center of the region just south of a prominent terra ridge (IpIth). Albedo intermediate; slightly higher than unit CEm. The low hills and shallow slopes that characterize Ctm are absent; all relief features are craters. More heavily cratered and has a higher proportion of fresh blocky craters in the 50 to 200 m size range than unit CEm*

Interpretation: *Old mare material. Probably strongly cohesive volcanic tuff deposits or flows covered by a layer of fragmental debris. Blocks are visible around craters as small as 40 m suggesting that the near-surface fragmental layer is less than 15 m thick*

Ic, I — Crater material

Characteristics:
Ic, *material of subdued bowl-shaped craters having smooth low rim and rounded rim crest. Craters have gentler internal slopes and shallower depth than Ec craters of comparable size*
I, *material of gentle depressions. No discernible rim*

PRE-IMBRIAN OR IMBRIAN

IpIth, IpIts, IpItc — Terra material

Characteristics:
IpIth, *hilly terra material. Forms most of the high ground in the region and occurs most extensively in the west half. Terrain characterized by northwest trending ridges and low rounded hills. Patterned ground occurs in most areas. Large craters (> 500 m) more common than on mare units*
IpIts, *smooth terra material. Similar to unit IpIth but has less relief. Has low rolling topography and large shallow rounded craters. Occurs mostly adjacent to areas of unit IpIth and grades imperceptibly into unit Ctm*
IpItc, *cratered terra material. Similar to unit IpIts but more craters in the size range 100 to 500 m*

Interpretation:
Oldest materials exposed in the region. May be remnants of ejecta blankets around Nectaris and Tranquillitatis basins. Thick surficial fragmental layer results in relatively rapid downslope movement of near-surface material with consequent destruction of small craters and filling of depressions
IpIth *includes the features with most positive relief. Relief caused by cratering or faulting*
IpIts *and* IpItc, *most of the depressions have been filled, probably with debris from adjacent slopes, so both units have low relief. They may be covered in part by unit* Ctm

Interpretation of Crater Materials
(Cc_1, Ec, Ic; 5-1, E, I)

Materials of craters that are probably mostly of impact origin. Craters are assigned letters or numbers according to relative age. Numbered craters are the youngest and the higher the number the younger the crater. Since the rate of crater destruction and the initial crater morphology may be different in different units the assigned ages are only approximate. In younger craters, shock-metamorphosed fragmental debris forms rims and walls. Highly shocked bedrock may be exposed on walls. Material associated with older craters indistinguishable from surrounding materials

Contact

(Ec) Buried contact
Contact evident from surface topography. Buried unit shown in parentheses

Fault
Dotted where buried. Bar and ball on apparent downthrown side

Lineament
Gentle linear depression. Probable fault or fracture

Scarp
Barbs point downslope. Marks sharp break in slope within geologic unit

Gentle sinuous scarp
Arrows point downslope. Marks gentle north-facing scarp in unit CEm in south-central part of the site. Albedo slightly lower south of scarp. Material immediately south of scarp resembles unit Cad. Probable flow front

Block field
Area where blocks not associated with craters are particularly numerous on the surface. Blocks also occur around mapped craters with numbers higher than 2 but are not shown at this scale

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