DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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

GEOLOGIC ATLAS OF THE MOON
APOLLO LANDING SITE 1
I-617 [ORB II-2(25)]

GEOLOGIC SUMMARY

This map shows the geology of a potential early Apollo landing site in the lunar equatorial belt. The Maskelyne DA region lies near the southern edge of the southeastern embayment of Mare Tranquillitatis. Unlike all other landing sites, which are covered almost entirely with mare material, the gently undulating terrain of about two-thirds of this site has characteristics transitional between mare and terra: more relief than the mare but less than the typical rugged terra; albedo intermediate between the two (see also 1:100,000-scale map of the Maskelyne DA region by Carr, 1970). The undulating topography is observable telescopically at low Sun illumination (Wilhelms, 1964, p. 27-28); the material in some areas of this terrain was mapped as an intermediate-albedo member (Ipm2) of the Procellarum Group on a preliminary 1:1,000,000-scale map of the Taruntius quadrangle (Wilhelms, 1965).

The transitional material of the site is in the southeastern part of a low, circular domelike plateau approximately 35 km in diameter (seen best on moderate-resolution Orbiter V photographs). The plateau resembles some volcanic domes, and a volcanic origin is further suggested by the numerous domes, ridges, craters, and low hills that occur within it and at its margins. These include part of the dome in the southwestern corner of the map area, which has been mapped as dome-crater material (Edc and Edcw) and pitted material (Eph and Epg). Numerous irregular probably volcanic craters occur nearby in the area mapped by Carr (1970). The rugged hill mapped as hilly terra material (IpIth) is either volcanic or an island of old material that is elsewhere covered.

Most of the smooth, undulating moderate-albedo material in the map area is called terra-mantling material (unit Ctm); small patches of similar material that has more relief owing to craters and low positive features are labeled smooth terra material (IpIts). Like mare material, the terra-mantling material has a fairly flat surface. Like terra material, it has large (>300 m) subdued craters and few small (approximately 75-200 m) craters. The material differs from typical mare material in that its surface is slightly undulating and from typical terra material in that it lacks large areas of patterned ground (irregular, anastomosing ridges and troughs several meters high and approximately 10 m wide). The properties of the terra-mantling material are consistent with a relatively young material that incompletely erases the topography of old cratered terra and has had little time to be cratered itself.

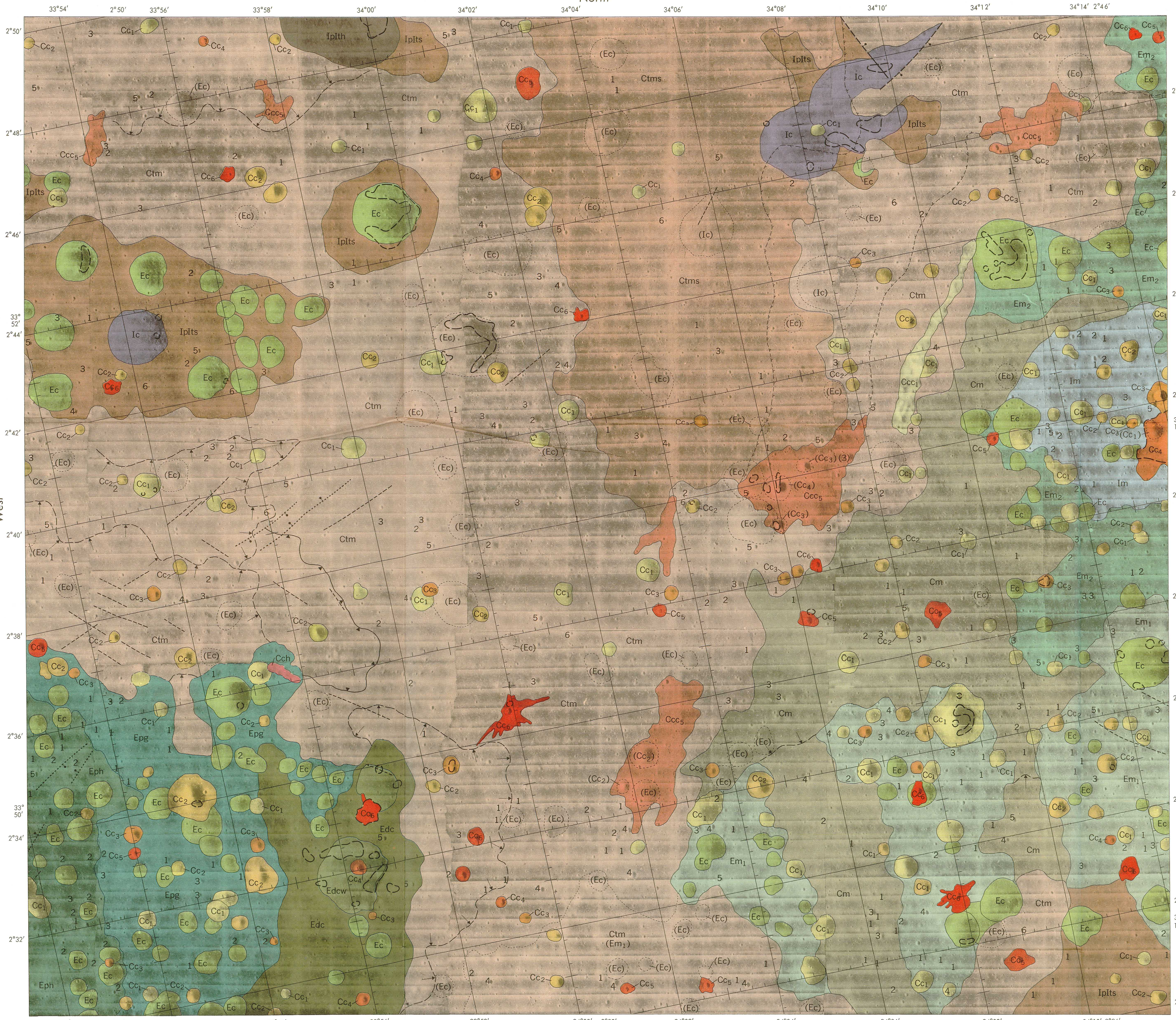
The material may be of volcanic origin. If so, its composition and (or) lithology are probably different from that of mare material, because the youngest mare materials have a lower albedo. The association with probable volcanic features discussed above and the presence of numerous apparent flows that seem to cover the mare near its border with successive lobes favor a volcanic origin. Alternatively, the unit may consist of a thick mobile fragmental layer; it appears to be gradational with more rugged terra (units IpIts and IpIth) and could be erosional debris derived from higher ground. On a fragmental layer of this sort, craters might be destroyed rapidly and, in addition, when first formed, they might have rounded features; thus, craters of equivalent age could appear older in unit Ctm than in the mare. Another possibility is that the mantling material may be mare material; its intermediate character may result from the nearness of terra material to the surface. The mare material is thin in the entire southeastern part of Mare Tranquillitatis, as shown by the large number of terra "islands" (Wilhelms, 1965). The moderate albedo may therefore result merely from mixing of a surficial mantle of dark mare materials with underlying light terra materials.

The remainder of the area, the eastern part, is occupied by mare material, some of which is similar to that in other parts of the Moon, but most of which has a subdued appearance that may result from mantling. Mare materials are divided into four units (Im, Em1, Em2, and Cm) according to the density and age of their superposed craters. The moderately cratered mare material (unit CEm) mapped by Carr (1970) comprises three of these (units Em1, Em2, and Cm). At the south edge of the present area the mapping convention shows terra-mantling material (unit Ctm) burying mare material of unit Em1. This means that although the surface characteristics are those of unit Ctm, the gross cratering characteristics of unit Em1 are also visible, in subdued form. Moderately cratered mare materials in other parts of the area may also be thinly mantled because they have a subdued appearance and possibly a slightly bimodal crater population with intermediate ages and sizes lacking. The oldest mare unit, heavily cratered mare material (unit Im), has a crater distribution typical for lunar mare material and thus does not appear to be mantled by younger material. It has more craters, and in particular more sharp blocky craters, than terra-mantling material and other mare materials in the map area. The frequency of sharp blocky craters suggests that the old mare is more cohesive than the younger units (see also Carr, 1970). The youngest mare unit, smooth mare material (Cm), has only a few old large craters, all of which are subdued, and its smooth surface appears to be the result of relatively recent emplacement.

This potential Apollo landing site is unique in that 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. It may be a distinct type of lunar volcanic material, absent in other landing sites, that is intrinsically lighter than mare material. If on the other hand it is entirely fragmental debris, its nature will elucidate the processes of downslope movement. Examination of the material should shed light on the nature of the processes resulting in deposition of widespread regional units on the terra.

REFERENCES

Carr, M.H., 1970, Geologic map of the Maskelyne DA region of the Moon [scale 1:100,000]: U.S. Geol. Survey Misc. Geol. Inv. Map I-616.
Wilhelms, D.E., 1964, Progress in mapping the Taruntius quadrangle, *in* Astrogeol. Studies Ann. Prog. Rept., August 1962-July 1963, pt. A: U.S. Geol. Survey open-file report, p. 24-30.
——— 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.



SCALE 1:25 000
MERCATOR PROJECTION

1 NAUTICAL MILE
1 STATUTE MILE
1 KILOMETER

Controlled base, part of photomap ORB II-2(25) prepared by Army Map Service, Corps of Engineers, U.S. Army, Washington, D.C. 20315

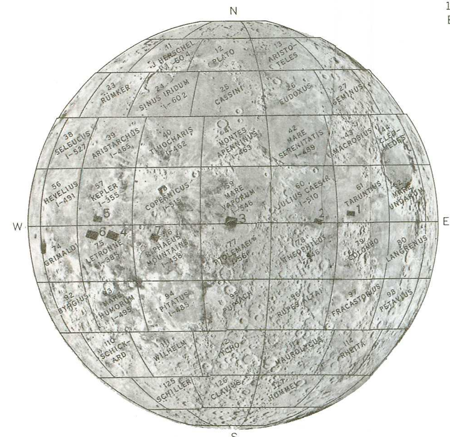
Principal sources of geologic information: Lunar Orbiter moderate-resolution photographs: II-M35-42; III-M5 and M9; V-M55-62. Lunar Orbiter high-resolution photographs: II-H38-40; and convergent stereoscopic high-resolution pairs V-H56, H60 and H57, H61; albedo data from near full-Moon photograph 5818 taken at U.S. Naval Observatory, Flagstaff, Ariz.

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

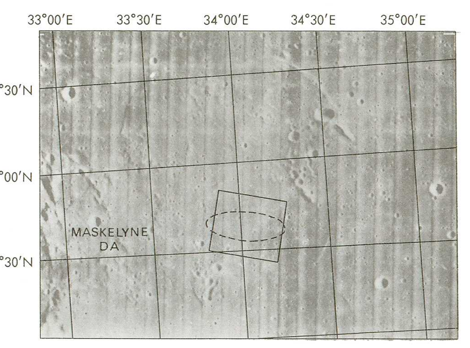
Large numbers 1-7 refer to regions that include early Apollo landing sites:

1. Maskelyne DA region - I-616
2. Sabine D region - I-618
3. Oppolzer A region - I-620.
4. Wichmann CA region - I-624
5. Maestlin G region - I-622
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-M58
Area of this report shown by solid line; dashed line indicates LM landing dispersion ellipse (99% landing probability). Approximate scale of photograph 1:900,000

GEOLOGIC MAP OF APOLLO LANDING SITE 1

PART OF MASKELYNE DA REGION, SOUTHEASTERN MARE TRANQUILLITATIS

By
Don E. Wilhelms
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 Cc1, 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

Cm — Smooth mare material

Characteristics
Unit is flatter and darker than terra-mantling material (Ctm), having the low to intermediate albedo of typical lunar mare material. Surface and crater characteristics resemble those of terra-mantling material, except slightly more pitted by small (unmapped) subdued craters. (Included by Carr (1970) in moderately cratered mare material of Copernican and Eratosthenian age, CEm)

Interpretation
Young flows with same composition as other mare materials

Ctm / Ctms — Terra-mantling material

Characteristics
Forms smooth, gently undulating surface; few craters or relief features of any kind. Especially deficient in craters of intermediate size (50-200 m) and age (Ec-Cc1). Also deficient in blocky craters of all sizes except the smallest (<40 m). Most large craters are very subdued (Ic and Ec). Forms part of a large domelike plateau that is higher than the mare. Some patterned ground (irregular anastomosing ridges and troughs approximately 10 m wide and and several meters high) on walls of subdued craters and other slopes. Albedo intermediate between that of mare and terra
Ctms *is smoother and described crater deficiencies are especially pronounced. Smoothest unit in the site and one of the smoothest recognized to date on the Moon*

Interpretation
Young volcanic material overlying terra and mostly subduing its relief. Alternatively, may be debris eroded from terra, or possibly terra debris mixed with volcanics. Assigned Copernican age because Eratosthenian and early Copernican (Cc1) crater materials appear to be less numerous than in most other units, suggesting that many have been buried; all craters with the appearance of Eratosthenian craters (Ec) are mapped as buried. If the material is terra debris and not young volcanics, the debris was recently mobilized
Ctms, *probably young discrete flow or flows of mantling material. Determination of origin of terra-mantling material is prerequisite to understanding the mechanism of accumulation of material in areas of low relief. If volcanic, the reason for its high albedo relative to mare materials of the same age is of interest; such albedo differences may result from compositional differences*

Ccc5 — Crater cluster material

Characteristics
Material in and near irregular clusters of closely spaced small (<40 m) sharp round craters. (Additional adjacent areas of lesser crater density are outlined by a diagonally hachured dashed line)

Interpretation
Craters formed by impact of ejecta from Tycho although craters mapped as Tycho secondaries in some map areas closer to Tycho are more subdued and assigned ages of Cc3 and Cc4. Round shape and apparent freshness of Tycho secondaries in this area may be caused by the greater impact velocities that result from the large distance from Tycho. Fresh exposures and blocks of the country rock and fragmented material of the projectiles may be present.

Cch — Chain-crater material

Characteristics
Material in and around a chain of craters; the individual craters have gentle bowl-shaped interiors but slightly raised rim crests. Only occurrence is at long 33° 55'W., lat 2°36'N.

Interpretation
Material of volcanic craters

Ccc1 — Crater cluster material

Characteristics
Material of linear cluster of round to slightly elongate craters (<100 m) having very low, subdued rims. Cluster elongate in a direction radial to the crater Theophilus

Interpretation
Material of craters formed by impact of ejecta from Theophilus

Cc6 / 6 — Crater material

Characteristics
Cc6, *material of craters having abundant bright ray material. Abundant resolvable blocks (>2 m in diameter) present in rim deposits. Walls are steep and internal detail is very sharp. Crater rim crest very sharp*
6, *similar to* Cc6 *except that no blocks are visible probably because crater is small*

Cc5 / 5 — Crater material

Characteristics
Cc5, *material of craters having bright ray material. Abundant blocks present in rim deposits. Walls are steep and interiors are rugged and blocky. Crater rim crest raised and sharp*
5, *material of craters commonly having bright halos or some ray material. Internal detail includes well-defined central mound or mounds. Crater rim crest slightly to moderately subdued*

Cc4 / 4 — Crater material

Characteristics
Cc4, *material of craters having bright ray or halo material. Blocks abundant in rim deposits of largest occurrence (at east edge of map). Internal detail includes sharp mounds or clusters of blocks. Crater rim crest raised and slightly to moderately subdued*
4, *material of craters whose rim crests are raised but somewhat subdued. Internal detail includes subdued mounds and small concentric rings*

Cc3 / 3 — Crater material

Characteristics
Cc3, *material of craters having distinctly raised but partly rounded rim crests, moderately to strongly subdued. Interior conical. Many craters have a rounded mound or several small mounds in center of crater*
3, *material of craters having raised but very subdued rim crest. Interior conical. Some craters have small, flat or slightly convex floors*

Cc2 / 2 — Crater material

Characteristics
Cc2, *material of craters having raised but strongly rounded rim crest. Interior bowl-shaped*
2, *material of rimless, bowl-shaped or conical depressions*

Cc1 / 1 — Crater material

Characteristics
Cc1, *material of craters whose rim crests are low but discernibly higher than surroundings; some craters near lower limit of size range have no raised rim. Interior bowl-shaped*
1, *material of gentle depressions*

ERATOSTHENIAN SYSTEM

Em2 / Em1 — Moderately cratered mare material

Characteristics
Forms nearly flat terrain overall, 25-75 percent of which is occupied by craters larger than 30 m. Locally is nearly as smooth as unit Cm. Fewer total craters and fewer blocky craters of all sizes except the smallest (<40 m) than on unit Im. Albedo about same as that of unit Cm and typical for lunar maria. Included in unit CEm of Carr (1970). Em2 *and* Em1 *distinguished by crater density; that of* Em2 *is lower and flat intercrater areas correspondingly more extensive. Crater density of* Em1 *is intermediate between that of Im and* Em2

Interpretation
Mare material younger than unit Im and covering it. Possibly consists of a thin layer of unit Cm covering Im

Eph / Epg — Pitted material

Characteristics
Eph, *pitted and hilly. Forms terrain of considerable relief at a lateral scale of 50-250 m. Surface is smooth at fine scale. Terrain consists of apparently randomly distributed round, elliptical, and irregular hills and intervening depressions (many mapped as unit Ec); almost no level surfaces*
Epg, *pitted and gently hilly. Similar pattern of hills and craters as in unit Eph, but relief is less and there is considerable gently undulating terrain between hills and craters. (Units combined on map by Carr (1970) as pitted material, Ep)*

Interpretation
Field of volcanic cones and craters related to nearby large dome craters, and probably including material erupted from them. Thus many craters mapped as Ec may be volcanic, and their greater density than on other units may be due to mode of volcanism and not age. Unit Epg could be unit Eph covered by layers of terra-mantling material

Edc / Edcw — Dome-crater material

Characteristics
Edc, *dome-crater material, undivided. Rounded hills and ridges on which circular to elongate craters having rounded rim crests occur. Only occurrence is adjacent to a large dome just south of the map area. Similar craters outside the map area are irregular in shape and (or) occur in chains*
Edcw, *wall material. Forms steep or gentle inner wall of craters of unit Edc. Grades into unit Edc at rounded rim crest*

Interpretation
Volcanic origin is suggested by high but rounded, convex-upward rim crests

Ec — Crater material

Characteristics
Craters less than 250 m are rimless gentle, bowl-shaped or pan-shaped (nearly flat-bottomed) depressions. Some craters larger than 250 m have a raised rim and deposits outside the rim crest; rim crest of these craters is strongly subdued. Patterned ground on walls. Blocks on wall and on rim crests of a few craters. Shown as buried by terra-mantling material (Ctm, Ctms) and smooth mare material (Cm)

IMBRIAN SYSTEM

Im — Heavily cratered mare material

Characteristics
Pitted by more craters of all sizes and ages, except the oldest (Ic) and the youngest Cc5, Cc6*), than any other unit in the area. Crater distribution typical of lunar mare material. Approximately 50-75 percent of terrain consists of slope surfaces associated with large craters (>150 m) in various degrees of preservation. Albedo intermediate--slightly higher than that of moderately cratered mare material and nearly as high as that of terra-mantling material*

Interpretation
Volcanic flows and (or) tuffs, probably basaltic like those analyzed at the Surveyor V and VI landing sites. Heavily fragmented by impact and covered by fragmental regolith

Ic — Crater material

Characteristics
Material of large gentle depressions. Those occurrences that are mapped as exposed have patterned ground and blocks on the walls

PRE-IMBRIAN OR IMBRIAN

IpIth / IpIts — Terra material

Characteristics
IpIth, *hilly terra material. Gross relief elevated and hilly; fine relief of typical lunar patterned ground.*
IpIts, *smooth terra material. Surface has low relief and is fairly smooth, but has more patterned ground than terra-mantling material (unit Ctm). Occurs on terrain with 100-500 m craters of Eratosthenian and Imbrian age*

Interpretation
IpIth, *either terrain predating mare material or young volcanic constructional features*
IpIts, *old terra material of undetermined age and origin, thinly mantled by young, possibly Copernican volcanic material (possibly unit Ctm) or erosional debris*

Interpretation of crater materials
(Cc_6- Cc_1, 6 - 1, Ec, and Ic)

Mostly materials of both primary and secondary impact craters. Sequence of craters in column results from different ages of craters. Craters low in column derived from craters similar to those high in column by micrometeorite erosion and gravity mass wasting. Some round volcanic craters may be present and because these may have had a different initial morphology from the impact craters, their age assignments may be in error. Many craters mapped as Ec in units Eph and Epg are likely to be such volcanic craters. The subdued morphology of some older-appearing craters may result from covering by younger materials, both recognized materials such as units Ctm and Ctms and currently unrecognized materials; age designations of these craters may therefore also be in error

Contact
Dashed where does not match base because of incorrect assembly of base mosaic

(Ec) Buried contact
Outlines a unit covered by younger unit but still topographically expressed. Buried unit shown by symbol in parentheses

Probable fault
Dashed where forms scarp against which younger materials were deposited. Dotted where buried. Bar and ball on apparent downthrown side

Lineament
Linear groove or albedo change of unknown origin

Scarp

Gentle sinuous scarp
Arrows point downslope. Commonly coincides with slight albedo differences. Interpretation: Most probably a flow front. Some may be structurally controlled or the limit of thick subsurface rock units

Cratered area
Very approximate limit of area more densely cratered by fresh small (<40 meter in diameter) craters than typical, but less densely cratered than unit Ccc5. *Hachures point toward cratered area*

Block field
Area where blocks >2 m diam. are abundant. (Blocks as large as those mapped on westward slopes are also to be expected on many sun-facing slopes, where poor lighting prevents their detection)

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