DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PREPARED IN COOPERATION WITH THE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AND THE
USAF AERONAUTICAL CHART AND INFORMATION CENTER

NOTES ON BASE

The base chart was prepared with advisory assistance from Dr. Gerard P. Kuiper and his collaborators, D. W. G. Arthur and E. A. Whitaker.

DATUM

The horizontal and vertical positions of features on this chart are based on selenocentric measurements made by ACIC and published in ACIC Technical Paper No. 15, "Coordinates of Lunar Features", March 1965. The assumed lunar figure is that of a sphere corresponding to the mean lunar radius of 1738 kilometers. Supplementary positions are developed in the chart area as an extension of the primary control.

Primary Control Positions .... ⊕
Supplementary Control Positions .... △

ELEVATIONS

Radius vector lengths are the distances from the geometrical center of the moon to the plane of the crater rim or the designated position of the feature measured. The lengths of the radius vectors are expressed in kilometers.

The relative elevations of crater rims and other prominences above the surrounding terrain and depths of craters are in meters. They were determined by the shadow measuring techniques as refined by the Department of Astronomy, Manchester University, under the direction of Professor Zdenek Kopal. The probable error of the localized relative elevations is 100 meters in the vicinity of the center of the moon with the magnitude increasing to 300 meters at 70° from the center due to foreshortening.

Lengths of Radius Vectors to control points ...... ⊕ or △ 1741.9
Depth of craters (rim to floor) .... (400)
Relative Elevations (referenced to surrounding terrain) with direction and extent of measured slope indicated 300

NAMES

Feature names were adopted from the 1935 International Astronomical Union nomenclature system as amended by Commission 16 of the I.A.U., 1961 and 1964.

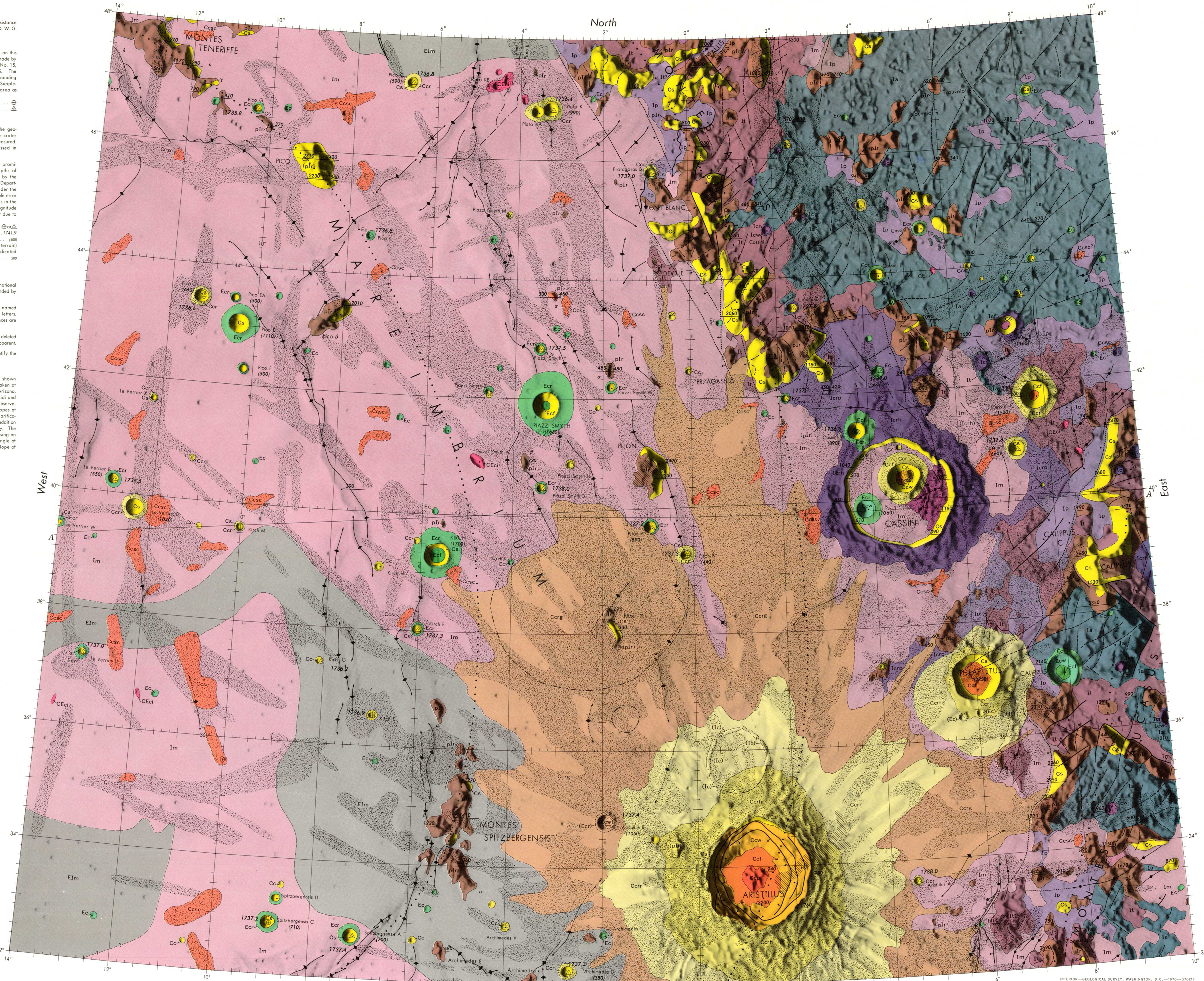
Supplementary features are associated with the named features through the addition of identifying letters. Craters are identified by capital letters. Eminences are identified by Greek letters.

Names of the supplementary lettered features are deleted when the association with the named feature is apparent.

A black dot is included, when necessary, to identify the exact feature or features named.

PORTRAYAL

The configuration of the lunar surface features shown on this chart is interpreted from photographs taken at Lowell, U.S. Navy, Catalina Station-University of Arizona, Lick, McDonald, Mount Wilson, Yerkes, Pic du Midi and Kottomia Observatories. Supplementary visual observations with the 20 and 24 inch refracting telescopes at Lowell Observatory provide identification and clarification of indistinct photographic imagery and the addition of minute details not recorded photographically. The pictorial portrayal of relief forms is developed using an assumed light source from the West with the angle of illumination maintained equal to the angle of slope of the features portrayed.



INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1970—G70217

Lunar base chart LAC, 1st. edition, 1966, by the USAF Aeronautical Chart and Information Center, St. Louis, Missouri 63118

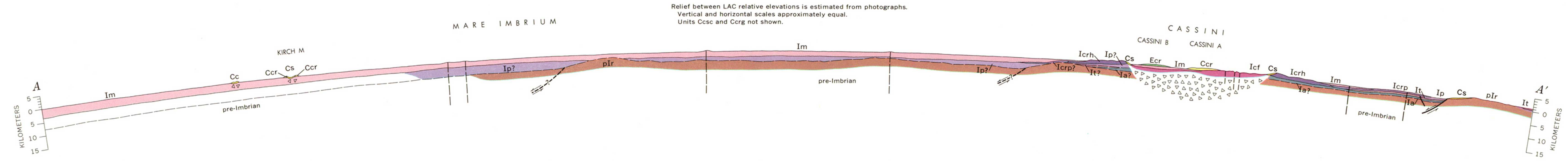
SCALE 1:1 000 000
LAMBERT CONFORMAL PROJECTION
AT 21°20' AND 42°40'

STATUTE MILES
KILOMETERS

Principal sources of geologic information:
Originally prepared 1966–67 on the basis of unpublished photographs from Lick Observatory and the Catalina Observatory of the Lunar and Planetary Laboratory, University of Arizona. Modified 1968–69 on the basis of Lunar Orbiter photography (see index map) by author, Don E. Wilhelms, and Donald L. Wilson. Brightness data from full-Moon photographs from the U.S. Naval Observatory, Flagstaff, Arizona. Color data from Whitaker (1966).

Prepared on behalf of the National Aeronautics and Space Administration under contract No. R-66.

Relief between LAC relative elevations is estimated from photographs.
Vertical and horizontal scales approximately equal.
Units Ccsc and Ccrg not shown.



GEOLOGIC MAP OF THE CASSINI QUADRANGLE OF THE MOON

By

N. J. Page

1970

E X P L A N A T I O N

Cs — Slope material

Characteristics
Occurs on steep slopes, mostly on inner crater walls and on the steepest slopes of rugged pre-Imbrian material. Appears smooth at Orbiter resolution. Albedo very high; in all cases brighter than surrounding materials
Interpretation
Probably fresh fragmental debris and freshly exposed bedrock

Dark covering material

Characteristics
Dark material with no visible topographic features of its own
Interpretation
Probably very young volcanic flows and pyroclastics. Where surrounds a crater, could be dark impact ejecta

COPERNICAN SYSTEM

Ccsc — Material of clustered small craters

Characteristics
Material of small, irregular, low-rimmed craters occurring in chains or clusters commonly radial or subradial to large craters including Aristillus and craters outside the quadrangle. Queried where relation to a large crater is uncertain
Interpretation
Material of craters formed by the impact of ejecta from large primary impact craters

Cc Ccr Ccrh Ccrr Ccrg Ccw Ccf Ccp — Materials of rayed craters

Characteristics
Cc, *crater materials, undivided. Materials of small craters having bright rays or halos. Divided in large craters as follows:*
Ccr, *rim, undivided. Material outside rim crest standing above surrounding terrain. Albedo intermediate to high. In the larger craters divided into:*
Ccrh, *rim, hummocky. Has high, hilly topography adjacent to rim crest; in Aristillus inner half consists of concentric terraces. Grades into:*
Ccrr, *rim radial. Has lower, smoother relief than hummocky rim material; mostly forms very low, subradial ridges; small elongate satellitic craters present on surface. Grades into:*
Ccrg, *rim, grooved. Occurs in and around discontinuous, groovelike, radial satellitic craters of Aristillus which are more abundant than on radial rim material. Outer contact marks limit of abundant topographically negative features, but some occur beyond contact*
Ccw, *wall. Occurs on steep terraced inner walls of Aristillus and in slump block in Cassini A. Albedo intermediate, not as high as that of unit* Cs
Ccf, *floor. Smooth-appearing material, locally with small hills. Abedo intermediate, lower than that of wall material*
Ccp, *central peak. Material of rugged cluster of peaks in central part of crater Aristillus. Albedo high*
Interpretation
Larger craters are of impact origin but some small ones may be of volcanic origin
Ccr, *ejecta, either impact or volcanic*
Ccrh, *impact ejecta of variable thickness and fragment size at the surface, grading downward to outward-thrust and brecciated bedrock*
Ccrr, *impact ejecta deposited on low trajectories*
Ccrg, *formed by secondary impact, mostly upon mare material, of fragments ejected at low trajectories*
Ccw, *fragmental debris and masses of rim material that have moved downslope*
Ccf, *shock-crushed breccia, mass-wasted material, and (or) post-crater volcanic material*
Ccp, *lens of fractured bedrock either uplifted by impact process or formed by later rebound of crater floor*

Ray material

Characteristics
Light material which forms radial to subradial streaks around Copernican craters. No visible relief. Associated with mapped and unmapped clustered small craters. Albedo intermediate to high and patchy or streaky
Interpretation
Fine ejecta from primary and secondary impact craters or fresh bright material on inner walls of small, closely spaced, unresolved secondary craters

CEci — Material of irregular and chain craters

Characteristics
Elongate single crater or a chain of three or more craters. Sharp rim topography
Interpretation
Volcanic craters. Superposition of some examples on mare material and freshness indicate relative youth

ERATOSTHENIAN SYSTEM

Ec Ecr Ecw Ecf — Materials of rayless craters

Characteristics
Topographically similar to units Cc, Ccr, Ccw, *and* Ccf *or slightly more subdued. Albedo low to intermediate*
Interpretation
Origin similar to corresponding units of rayed craters

IMBRIAN OR ERATOSTHENIAN SYSTEM

EIm / Im — Mare material

Characteristics
Material of extensive dark plains that is topographically level and smooth except for low ridges and scarps, and for undulations NE of crater Cassini, where surface resembles Cassini rim material but is darker and more subdued. Subunits distinguished by differences in albedo, crater density, and color as follows:
EIm, *darker, less cratered, and bluer*
Im, *lighter, more cratered, and redder*
[Color differences are faint but can be enhanced by compositing ultraviolet and infrared photographs; see Whitaker (1966).]
Interpretation
Volcanic materials, either pyroclastic debris or lava flows; probably mixed in the upper layers with impact debris. Undulating, dark surface near Cassini apparently results from incomplete burial of Cassini rim material by thin, probably pyroclastic, mare material. Unit EIm *believed younger than unit* Im *because of lower crater density and could be as young as some rayless craters of Eratosthenian age that are superposed on unit* Im

IMBRIAN SYSTEM

Ic Icr Icrh Icrp Icw Icf — Crater materials

Characteristics
Ic, *crater materials, undivided*
Icr, *rim. Has lower relief, smoother surface and lower albedo than units* Ccr *and* Ecr
Icrh, *rim, hummocky. Similar to unit* Ccrh *but topographically less sharp; also includes some low, smooth topography in distal parts*
Icrp, *rim, pitted. Occurs near Cassini. Topography flat overall with abundant small subdued hills and elongate pits. Albedo intermediate*
Icw, *wall. Occurs on moderately steep inner walls of craters. Albedo intermediate*
Icf, *floor. Hummocky material occurring on part of the floor of Cassini. Albedo intermediate*
Interpretation
Ic, Icr, Icrh, Icw, *origin similar to units* Cc, Ccr, Ccrh, Ccw; *more subdued because exposed to erosion longer*
Icrp, *probably formed by deposition and secondary impact of fragments ejected from the crater Cassini upon plains-forming material*
Icf, *probably structurally uplifted equivalent of wall and floor materials of Cassini*

Ip — Plains-forming material

Characteristics
Smooth, flat or rolling topography; a moderate number of small round craters are present on the surface, more than on mare material. Albedo low to intermediate, but higher than mare material. Similar to Apennine Bench Formation of Hackman (1966) but exact correlation uncertain
Interpretation
Probably consists of volcanic materials filling low areas

It — Hilly terra material

Characteristics
Topography rolling, with subdued hills and ridges; rougher than plains-forming material but smoother than Alpes Formation. Albedo intermediate
Interpretation
Volcanic materials or material "eroded" from other units. Alternatively, could be Imbrium basin ejected. Some near Cassini may have Cassini ejecta superposed

Ia — Alpes Formation (new name)

Characteristics
Blocky or knobby irregular hills, approximately equidimensional or elongate, mostly below 5 km long. Gradational in appearance with rugged pre-Imbrian material and hilly terra material; individual hills generally smaller than in the former unit and more rugged than in the latter. Albedo generally intermediate with many small bright patches on local steep slopes. Type area is between lat. 47° and 48° N. and long. 5° and 8° E
Interpretation
Material ejected from the Imbrium basin at the time of its formation by impact or bedrock structurally deformed by this event or, most probably, a mixture of these

PRE-IMBRIAN

pIr — Rugged material

Characteristics
Massive rugged hills with generally smooth-appearing slopes. Albedo high; where very high, mapped as unit Cs
Interpretation
Represents part of the rim or ring materials produced by formation of the Imbrium basin. May be thinly covered with Alpes Formation and hilly terra material. The bare appearance of the hills may be caused by shedding of any thin layers of material which may have originally covered them; freshest of such exposures are represented by unit Cs

Contact
Dashed where approximately located or gradational

(pIr)
Concealed contact
Indicates limit of topographic expression of buried unit. Buried unit indicated by symbol in parentheses

Fault scarp
Dashed where inferred; dotted where concealed. Bar and ball on apparent downthrown side. Fault either offsets unit or forms scarp against which younger rocks were deposited (shown as exposed where borders slope covered by unit Cs*, probably a thin unit)*

Very narrow trough
Interpretation: *Probable graben*

Lineament
Gentle linear scarp or depression
Interpretation: *Fault or surface expression of buried fault*

Mare ridge
Line marks crest. Arrow indicates tapered end. Dotted where buried by younger materials
Interpretation: *Fracture-controlled intrusion or extrusion of mare material*

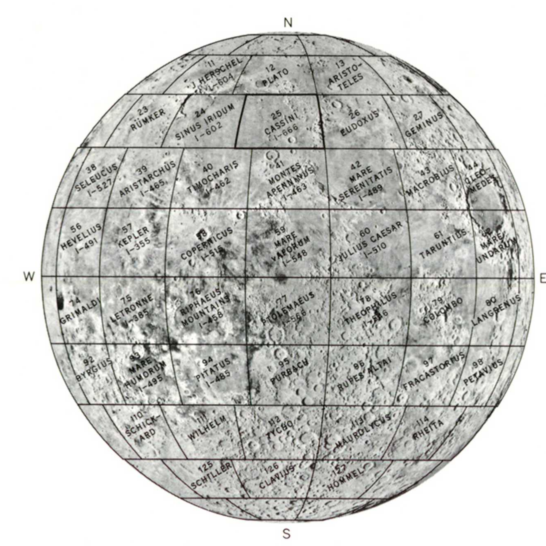
Concealed crater
Symbol indicates rim crest

Sinuous rille
Circle at end represents crater

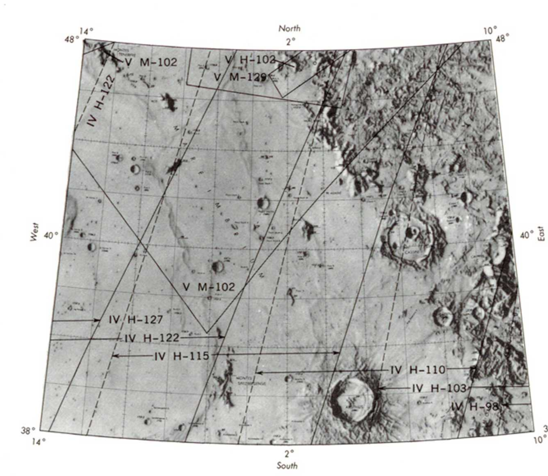
Imbrium basin structure
Characteristics
Generalized crests of the major ragged, discontinuous, approximately circular concentric mountain rings of Imbrium basin
Interpretation
Partly covered complex fault blocks resulting from the formation of the Imbrium basin

Landslide
Arrows indicate direction of probable movement

Fractured rock
Shown on cross section beneath crater floors
Interpretation: *Rock extensively fractured by impact*



INDEX MAP OF THE EARTHSIDE HEMISPHERE OF THE MOON
Number above quadrangle name refers to lunar base chart (LAC series); number below refers to published geologic map



LUNAR ORBITER PHOTOGRAPHIC COVERAGE OF CASSINI QUADRANGLE
Roman numerals (IV and V) refer to Orbiter mission. Arabic numerals refer to photo frame number. Letters refer to high (H) or moderate (M) resolution. V H-102 has 20 to 30 m resolution; others, 90 to 150 m.

GEOLOGIC SUMMARY

The Cassini quadrangle is in the north-central part of the nearside lunar disk and includes most of the northeast quadrant of Mare Imbrium. Lunar geologic units in the area have been distinguished according to topographic expression, albedo, and inferred stratigraphic relations, and the distribution of each unit is portrayed on the accompanying map. The nature and disposition of geologic units in the area was largely controlled by the formation of the Imbrium basin and its subsequent filling by mare material. Four principal classes of geologic units can be distinguished: (1) material of three rugged arcuate mountain ranges circumferential to the Imbrium basin; (2) terra materials superposed on these ranges; (3) mare materials; and (4) crater materials. An additional unit, bright slope material, indicates fragmental debris from, and fresh exposures of, these units. The relative ages of the units are determined by a variety of criteria, including superposition and transection relations, density of superposed craters and, in the case of craters, apparent topographic freshness. Age designations are assigned according to the lunar stratigraphic scheme devised as a result of studies of the geologically similar Copernicus region south of the quadrangle (Shoemaker, 1962; Shoemaker and Hackman, 1962; later revisions are reported by McCauley, 1967, and Wilhelms, in press).

The formation of the Imbrium basin, which marked the beginning of the Imbrian Period, is the earliest decipherable event in the Cassini quadrangle. With the basin, at least three concentric mountain rings of rugged pre-Imbrian terra materials (pIr) formed, largely by uplift along arcuate faults (Hartmann and Kuiper, 1962). The isolated mountains that resemble islands in the mare—Montes Teneriffe, Pico, and Montes Spitzbergensis—mark the innermost ring, which is almost completely covered by mare material. Montes Alpes and Montes Caucasus form the second and third rings, respectively.

Superposed on the rugged pre-Imbrian material are one or possibly two widespread geologic units that appear to have formed at the same time as the Imbrium basin. The more distinctive of these units, here named the Alpes Formation, occurs predominantly in the low-lying region between Montes Alpes, from which it is named, and Montes Caucasus. Its surface is generally characterized by numerous closely spaced, equidimensional low hills up to 5 km across; in the Montes Caucasus, some larger and more rugged blocks are also included in the unit. Similar materials occur in the Montes Apenninus quadrangle (Hackman, 1966), in the Rümker quadrangle on the northwest side of the Imbrium basin (Eggleton and Smith, 1967), and in the Kepler, Copernicus, and western Montes Riphaeus quadrangles south of the basin (Wilhelms and McCauley, 1969). The distribution of the Alpes Formation and similar material around the Imbrium basin suggests that the unit is either a blanket of ejecta derived from the basin or material shattered essentially in place during basin formation, or both. The Alpes Formation thus may be correlative in time, but not necessarily in exact mode of origin, with the Fra Mauro Formation, a unit which is also circumferential to the Imbrium basin and which is commonly interpreted as basin impact ejecta (Wilhelms, in press). The Fra Mauro Formation in its type area south of the Imbrium basin (Eggleton, 1964; Wilhelms, in press) is characterized by a radially braided to subdued hummocky topography that is quite distinct from the closely spaced equidimensional hills that typify the Alpes Formation. The materials in the Montes Apenninus and Rümker quadrangles were mapped as Fra Mauro Formation, although Eggleton and Smith (1967) recognized the resemblance of the Rümker quadrangle material to the material here named the Alpes Formation and interpreted it as a tremendous slump breccia. The second widespread unit, hilly terra material (It), is smoother than the Alpes Formation and resembles parts of the smooth member of the Fra Mauro Formation in the region around Mare Vaporum (Wilhelms, 1968). It may consist of impact ejecta or rocks that were fluidized or more highly shattered than those of the Alpes Formation. However, the alternative and preferred explanation, in view of its mantling appearance, is that the hilly terra unit consists of volcanic material that overlies the Alpes Formation.

The terra is traversed by two principal sets of structures: one radial to the Imbrium basin, the other circumferential to it. The radial structures are part of the Imbrian sculpture which extends outward from the basin around its entire periphery (Hartmann, 1963). In the Montes Caucasus, and to a lesser extent in the Montes Alpes, large blocks are downfaulted along the radial structures, whereas in the intervening terrain the sculpture consists only of indistinct lineaments. There is little or no evidence of strike slip movement along the Imbrian sculpture, contrary to the opinion (Fielder, 1965, p. 107) that the Alpes and Caucasus are offset parts of the same structure. The most prominent circumferential structures in the area are the arcuate faults along the basinward scarps of Montes Alpes and Montes Caucasus. These faults appear to be normal and downthrown on the basin side, and the blocks they bound slope eastward away from the basin. A similar inferred major fault, now buried by mare material, is believed to lie just inside the Montes Teneriffe-Montes Spitzbergensis arc (shown only on cross section). Additional faint lineaments parallel these major faults throughout the terra. The extent and regularity of the concentric mountain rings and the radial faults, and the distribution of the Alpes Formation, all of which resemble features of the younger Orientale basin (Lunar Orbiter IV photograph M-187), suggest that the Imbrium basin was formed by a single catastrophic impact event.

A third Imbrian terra unit younger than the rugged concentric ranges, plains-forming material (Ip), consists of topographically smooth and rolling material that fills low areas of the terra. This unit is clearly younger than the Alpes Formation, probably younger than the hilly terra material, and younger than most of the faults and lineaments. However, it appears to be older than the mare material, because it is more heavily cratered than the mare material and appears to be embayed by it.

Mare materials, divided into two units on the basis of albedo and color, form widespread dark plains. The relatively smooth surface of these units closely follows the curvature of the Moon and fills in most preexisting depressions to approximately the same level. The mare material is believed to be an interbedded mixture of lavas and ash flows.

Between the time of formation of the Imbrium basin and the deposition of the latest mare material of Imbrian age, the crater Cassini and several smaller craters assigned to the Imbrian System were formed in the quadrangle. Cassini is distinguished by being partly buried by mare material yet being unaffected by the Imbrian sculpture and related fractures. If Cassini and the other Imbrian craters had been present when the basin formed, they would be intersected by basin-related structures and overlain by the Alpes Formation or broken up and incorporated into it. Such post-basin pre-mare craters show that the basin did not fill immediately after it formed but after an intervening period of crater formation. The similarity of unburied parts of Cassini to younger impact craters, discussed below, suggests that it also is of impact origin.

Post-mare crater materials, assigned Copernican and Eratosthenian ages, include those of Aristillus and many smaller craters. Aristillus is similar in its morphology, stratigraphy, and ray and satellitic-crater system to Copernicus, for which an impact origin has been deduced (Shoemaker, 1962; see also detailed mapping by Schmitt, Trask, and Shoemaker, 1967). Most of the smaller craters are similar in form, suggesting that they are also of impact origin, but some of them and all the irregular and chain craters could be of volcanic origin.

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