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

VERTICAL DATUM

The assumed lunar figure is that of a sphere corresponding to the mean lunar radius of 1738 kilometers. Elevations are referred to a spherical datum 2.6 kilometers below the mean radius to minimize minus elevation values.

CONTROL

The horizontal and vertical positions of features on this chart are based primarily on the positions of 150 lunar features measured by J. Franz and computed by Schrutka-Rechtenstamm. This control network is supplemented by ACIC extensions in localized areas. Additional horizontal positions have been selected from the Consolidated Catalog of Selenographic Positions by D. W. G. Arthur and the coordinates of 696 lunar features by R. Baldwin. The probable error of the control is evaluated at 1000 meters.

ELEVATIONS

All elevations are in meters. They are referenced to the assumed vertical datum unless indicated as relative elevations. The relative elevations of crater rims and other prominences above the surrounding terrain and depths of craters are determined by the shadow measuring technique 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 lunar disk with the magnitudes increasing to 300 meters at 70° departure from the center due to foreshortening.

Elevations (referenced to datum) 1100
Depth of crater (rim to floor) .... (400)
Relative elevations (referenced to surrounding terrain) with direction and extent of measured slope indicated 300R

CONTOURS

All contours are approximate
Contour interval is 300 meters
Approximate contour ——— 600 ———
Depression contour

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.

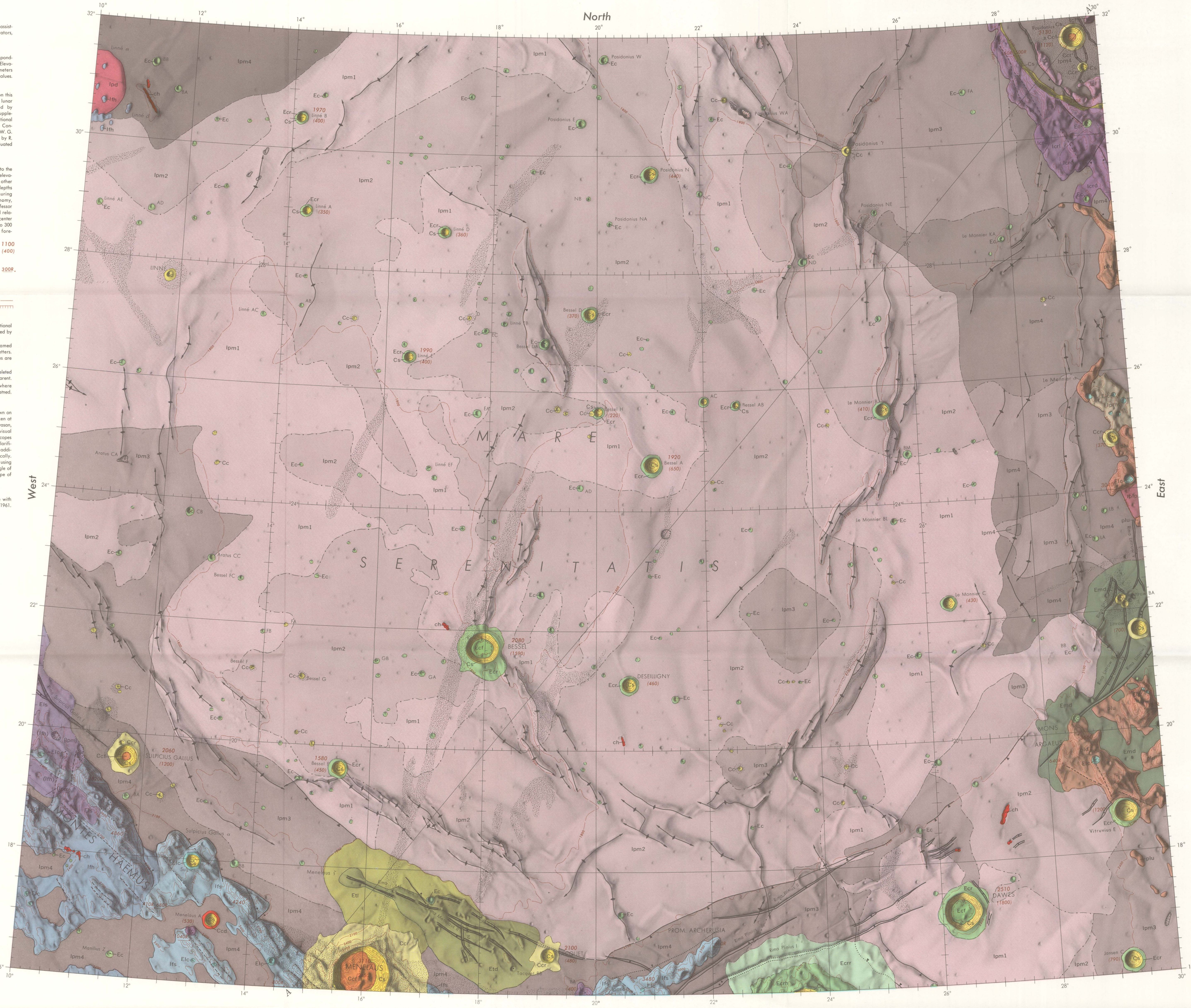
A black dot or black dotted outline is included, where necessary, to identify the exact feature or features named.

RELIEF PORTRAYAL

The configuration of the lunar surface features shown on the base chart is interpreted from photographs taken at Lick, McDonald, Mt. Wilson, Yerkes, Stony Ridge, Kwasan, and Pic du Midi 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.

EAST-WEST DIRECTION

Orientation of cardinal directions is in accordance with resolution adopted by the I. A. U. General Assembly, 1961.



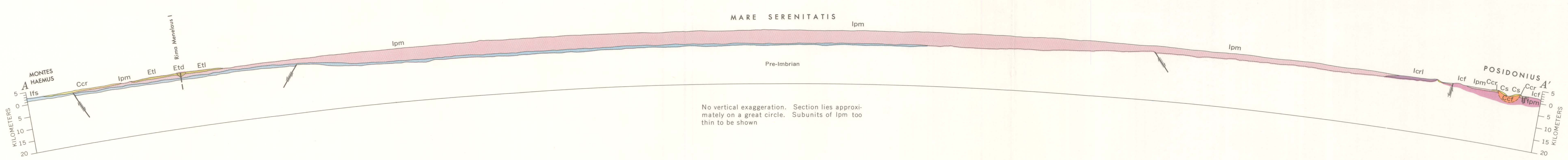
Lunar base chart LAC 42, 1st edition, 1965, by the Aeronautical Chart and Information Center, United States Air Force, St. Louis, Missouri 63118

SCALE 1:1 000 000
LAMBERT CONFORMAL PROJECTION
STANDARD PARALLELS 21°20′ AND 42°40′

STATUTE MILES
KILOMETERS

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1966—G66391

Principal sources of geologic information: photographs from Mt. Wilson, Lick, and Yerkes Observatories published in Photographic Lunar Atlas, G. P. Kuiper, ed., 1960, University of Chicago Press; photographs taken by G. H. Herbig at the 120 in. reflector, Lick Observatory; visual observations by M. H. Carr at the 36 in. refractor, Lick Observatory, 1965



No vertical exaggeration. Section lies approximately on a great circle. Subunits of Ipm too thin to be shown

GEOLOGIC MAP OF THE MARE SERENITATIS REGION OF THE MOON

By
M. H. Carr

1966

The surface of the Moon is heterogeneous. Surface materials are classed on the basis of telescopic observations into map units, each having lateral continuity and a limited range of physiographic characteristics and optical properties (mainly polarization and albedo, the reflectivity under fullmoon illumination). Such units are analogous to the rock-stratigraphic formations of terrestrial geology. By application of the principles of superposition and intersection, these formations are arranged in order of relative age and grouped into time-stratigraphic units. Following terrestrial convention, the major time-stratigraphic units are designated systems, and their subdivisions series; corresponding to these are periods and epochs of time (Shoemaker, 1962; Shoemaker and Hackman, 1962). The periods and epochs recognized at present, with major geologic events of each (most recent at the top, oldest at the bottom) are:

PERIOD	EPOCH	EVENTS
Copernican		Formation of ray craters.
Eratosthenian		Formation of craters whose rays are no longer visible.
Imbrian	*Archimedian*	Deposition of the extensive mare material of the Procellarum Group. Formation of craters and regional deposits younger than the Apenninian Series and older than at least part of the Procellarum Group.
	Apenninian	Excavation by impact of the Mare Imbrium basin and deposition of its ejecta. Formation of most of the faults subradial to the Imbrium basin.
pre-Imbrian time (not yet formally divided)		Excavation by impact of many or all of the mare basins in the east half of the Moon.

Each formation is given either a descriptive designation or a formal stratigraphic name, and a symbol composed of an abbreviation of its age assignment (capital) and name (lower case). Formations exposed at the surface are outlined on the map by solid or dashed contacts. Dotted contacts and symbols in parentheses refer to buried units whose characteristic topographic expression influences the topography at the surface. The descriptions of the formations are arranged below in stratigraphic order and include brief summaries of the visual characteristics and interpreted origin of each.

Structures such as graben and single faults, and certain distinctive lunar features of questionable origin, are mapped with symbols analogous to those of terrestrial geology.

The geologic mapping has been carried out to the precision obtainable with existing telescopic techniques. As more detailed information is acquired through lunar exploration, greater precision in discrimination, location, and interpretation of geologic units and structures and further refinement of their chronologic sequence is to be expected.

Microdensitometer tracings of fullmoon photographs and unpublished albedo measurements by H. A. Pohn and R. L. Wildey, U.S. Geological Survey, were used to subdivide the mare material. Albedo values for other units are approximate and based on data from Rowan and West (1965).

REFERENCES CITED

Rowan, L. C., and West, Mareta, 1965, A preliminary albedo map of the lunar equatorial belt, *in* Astrogeologic studies ann. prog. rept., July 1, 1964 to July 1, 1965, pt. A: U.S. Geol. Survey open-file rept., p. 101–113.

Shoemaker, E. M., 1962, Interpretation of lunar craters, *in* Kopal, Zdenek, ed., Physics and Astronomy of the Moon: London, Academic Press, p. 283–359.

Shoemaker, E. M., and Hackman, R. J., 1962, Stratigraphic basis for a lunar time scale, *in* Kopal, Zdenek, and Mikhailov, Z. K., eds., The Moon—Symposium 14 of the International Astronomical Union: London, Academic Press, p. 289–300.

COPERNICAN SYSTEM

Cs — Slope material
Characteristics
Occurs on steep slopes, mostly on the inner walls of craters. High albedo (>0.11)
Interpretation
Freshly generated talus or freshly exposed bedrock. Process of talus formation may still be continuing

Ccd — Dark-halo crater rim material
Characteristics
Forms dark halos around craters. Smooth topography. Very low albedo (0.05–0.06)
Interpretation
Pyroclastic material from a volcanic crater or possibly dark ejecta from an impact crater

Cc — Crater material, undifferentiated
Characteristics
Material of ray craters too small for individual crater units to be distinguished. High albedo (>0.10)
Interpretation
Craters probably are mostly of impact origin but some volcanic craters may be included, especially where location of craters appears to be structurally controlled, e.g., small crater on Posidonius γ

Ccr — Crater rim material
Characteristics
Forms the rims of bright-rayed craters. Around larger craters (>8 km diam.), near the rim crest consists of low irregularly shaped hillocks and shallow depressions, with little or no preferred orientation, and farther out consists of low sub-radial ridges and grooves. Around smaller craters (<8 km diam.) topography appears smooth. High albedo (>0.10)
Interpretation
Around most craters probably poorly sorted impact ejecta. May be stratified volcanics around some small craters, especially those lying on rilles or ridges, such as Sulpicius Gallus and Tacquet

Ccf — Crater floor material
Characteristics
Occurs on the floors of rayed craters with a sharp break in slope at the base of the inner walls. Topography generally smooth but includes some low hills on the floor of Menelaus. High albedo (>0.10), but commonly slightly lower than that of Cs *on the crater inner walls*
Interpretation
In most craters probably is the top of a shock-crushed breccia lens but may include some slumped wall material. May be volcanic in some small craters, especially those lying on ridges and rilles

Ray material
Characteristics
Forms radial and subradial rays around Copernican craters. No observable relief. High albedo (>0.10). Distinguished by very high albedo where superimposed on Ccr
Interpretation
Fine ejecta from primary and secondary craters

ERATOSTHENIAN SYSTEM

Ec — Crater material, undifferentiated
Characteristics
Material of small rayless craters that are younger than Ipm. *Craters too small for individual crater units to be distinguished. Low to medium albedo (0.06–0.08)*
Interpretation
Craters probably are mostly of impact origin but some volcanic craters may be included

Ecr, Ecrh, Ecrr — Crater rim materials
Ecr, *undifferentiated*
Ecrh, *hummocky*
Ecrr, *radial*
Characteristics
Occur on the rims of rayless craters that are younger than Ipm. *The topography of* Ecr *appears smooth around most craters, but low sub-radial ridges and depressions are visible around Bessel. Albedo of* Ecr *is low to medium (0.06–0.08), generally the same or slightly lower than that of the surrounding* Ipm. Ecrh *and* Ecrr, *mapped around Plinius, have medium to high albedo (0.08–0.10).* Ecrh, *near the rim crest, has a rough hummocky topography.* Ecrr, *farther from the rim crest, is characterized by low radial ridges and depressions*
Interpretation
Around most craters probably poorly sorted impact ejecta but some volcanic materials may be included. Higher albedo of Ecrh *and* Ecrr *suggests a late Eratosthenian age for Plinius. Some craters mapped as Eratosthenian may be dark-rimmed Copernican craters*

Ecf — Crater floor material
Characteristics
Occurs on the floors of craters with a sharp break in slope at the base of the inner walls. Generally smooth and level, but some low hills on the floors of Bessel and Dawes are included. Low albedo (0.06–0.07) sharply differentiates unit from Cs *on the inner crater walls*
Interpretation
Similar to Ccf

Emd — Mare material, dark
Characteristics
Occurs in the region of Rimae Littrow. Between the rilles the topography is smooth and level. The edge of the unit is in places marked by a low scarp. Very low albedo (0.05–0.06), one of the darkest geologic units on the moon
Interpretation
Volcanic material: probably mostly flows but may include some pyroclastic materials. Formed during the final stages of the filling of the Serenitatis basin

Etd, Etl — Tacquet Formation (new name)
Etd, *dark member*
Etl, *light member*
Characteristics
Occurs only in the region of Rimae Menelaus. Surface of dark member characterized by low hills and irregular depressions except at the western end of Rima Menelaus I, where surface appears smooth and dome-like. Surface of light member has very low ridges 3 km across, approximately at right angles to Rima Menelaus I or radial to Menelaus ζ. Boundaries of both members marked by low scarps. Etd *has very low albedo (0.05–0.06) except for scattered small areas up to 2 km across with albedos as high as 0.10. Albedo of* Etl *same as that of* Ipm3. *Named for the crater Tacquet. Type locality of dark member, area between latitudes 16°30′ N and 17°00′ N and longitudes 17°30′ E and 18°00′ E. Type locality of light member, area between latitudes 18°00′ N and 18°20′ N and longitudes 15°40′ E and 16°00′ E*
Interpretation
Volcanic flows and pyroclastics derived in part from the Menelaus rilles

Elc — Crater material, undifferentiated
Characteristics
Material of rayless craters whose ages relative to Ipm *are indeterminate but which are younger than* Ifh *and* Ifs. *Medium albedo (0.07–0.10)*
Interpretation
Similar to Ec

Els — Sulpicius Gallus Formation (new name)
Characteristics
Occurs near Rimae Sulpicius Gallus. Forms the high rims of the rilles but has no observable relief away from the rilles. Overlies Ifh *and may overlie* Ipm. *Low albedo (0.06–0.07). Named for Rimae Sulpicius Gallus. Type locality, area between latitudes 20°00′ N and 20°30′ N and longitudes 10°00′ E and 10°30′ E*
Interpretation
Layer of pyroclastic deposits, mostly less than 50 meters thick. Volcanic flows may be present locally, especially near the rilles

IMBRIAN SYSTEM

Archimedian Series

Procellarum Group

Ipm1, Ipm2, Ipm3, Ipm4 — Mare material
Characteristics
Topography generally smooth and level with low ridges and scarps. Unit as a whole terminates abruptly against older units. Subunits are differentiated on basis of albedo: Ipm1, *0.064–0.066;* Ipm2, *0.062–0.064;* Ipm3, *0.061–0.062;* Ipm4, *0.060–0.061*
Interpretation
Volcanic materials; probably includes both ash-flow tuffs and lava flows. In general, the higher the albedo, the older the subunit. Some subunits may represent zones of alteration

Ipd — Dome material
Characteristics
Forms broad low dome, 200–300 meters high and approximately 20 km across, northwest of Linné. Albedo similar to that of Ipm3
Interpretation
Shield volcano. Probably mostly lava flows and pyroclastics

Ic — Crater material, undifferentiated
Characteristics
Material of small craters younger than Ifh *but partly inundated or embayed by* Ipm. *Medium albedo (0.07–0.10)*
Interpretation
Craters probably are mostly of impact origin

Icrl, Icrd — Crater rim materials
Icrl, *light*
Icrd, *dark*
Characteristics
Occur on the rim of Posidonius, a well preserved crater that is partially filled with Ipm. *Hummocky disordered topography.* Icrl *has medium albedo (0.08–0.10).* Icrd *has lower albedo (0.07–0.08)*
Interpretation
Poorly sorted impact ejecta from a crater older than the present mare surface

Icf — Crater floor material
Characteristics
Forms the inner ring, central peak, and intervening hilly areas in the floor of the crater Posidonius. Medium albedo (0.07–0.10)
Interpretation
Probably crushed and brecciated bedrock. Peaks and ring may have formed by rebound at time of impact or by subsequent isostatic adjustment

Iplp — Plains-forming material
Characteristics
Occurs in low-lying areas in the terra east of Mare Serenitatis. Smooth and level surface. Medium albedo (0.07–0.10)
Interpretation
Probably mare-like material but older than the Procellarum Group

Iplhf — Hummocky material, fine
Characteristics
Occurs in low-lying areas in the terra east of Mare Serenitatis. Undulating topography with low elongate hillocks up to 300 meters high. Medium albedo (0.08–0.10)
Interpretation
Material of unknown origin

Apenninian Series

Ifh, Ifs — Fra Mauro Formation
Ifh, *hummocky facies*
Ifs, *smooth facies*
Characteristics
Ifh *occurs principally in Montes Haemus and grades laterally into* Ifs *to the east. Numerous low hummocks ½–1 km across on surface of* Ifh *but surface of* Ifs *is smooth. Larger topographic features reflect topography of underlying terrain. Medium albedo (0.07–0.10)*
Interpretation
Materials ejected from Mare Imbrium basin at the time of its formation by impact. Hummocky facies is thicker and closer to the basin than smooth facies

PRE-IMBRIAN

plu — Undifferentiated materials
Characteristics
Occur in the terra east of Mare Serenitatis. Rugged topography. Medium albedo (0.08–0.10)
Interpretation
Materials of unknown origin

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ch
Chain craters
Line of contiguous craters. Interpretation: Probably volcanic craters

Albedo boundary in Ipm
Long-dashed where distinct; short-dashed where gradational. Interpretation: May represent contact between beds of different age or between zones of alteration

(Ipm)
(Ifh)
Contact
Long-dashed where approximately located; short-dashed where laterally gradational; queried where doubtful; dotted where concealed; buried formations shown by symbols in parentheses

Fault
Dotted where concealed. Downthrown side shown by bar and ball or only by ball where faults closely spaced. Faults too close together to be mapped separately shown by single heavy line

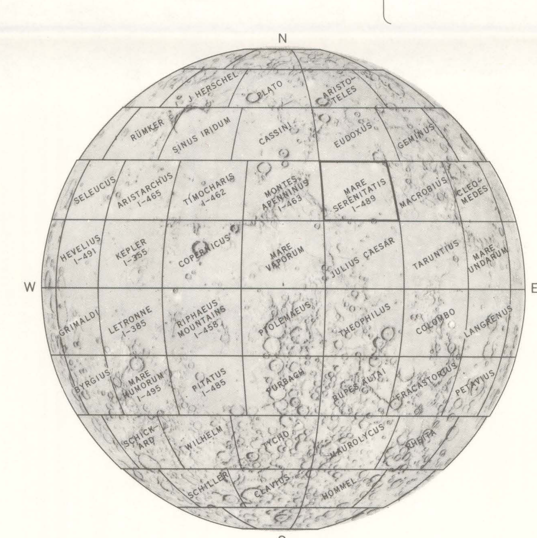
Lineament
Linear trough, scarp, or ridge. Interpretation: May be single fault, horst, or graben

Mare ridge
Line marks ridge crest. Arrows mark tapered ends. Dotted where concealed. Interpretation: May be anticline or site of volcanic intrusion or extrusion

Mare scarp
Marks base of scarp. Barbs point downslope. Dotted where concealed. Interpretation: May be fault, monocline, or flow front

Ridge marking rim crest of buried crater

Irregular depression
Rimless or with low rim. Interpretation: May be secondary impact crater or collapse feature



INDEX MAP OF THE SUBTERRESTRIAL HEMISPHERE OF THE MOON
Published maps are indicated by series number