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 by the Aeronautical Chart and Information Center, United States Air Force, with advisory assistance from Dr. Gerard P. Kuiper and his collaborators, D. W. G. Arthur and E. A. Whitaker.

CONTROL

The position of features on the base chart was determined through the use of selenographic control established primarily from the measures of J. Franz and S. A. Saunder as compiled by D. W. G. Arthur and E. A. Whitaker in the Orthographic Atlas of the Moon, edited by Dr. Gerard P. Kuiper, 1960.

VERTICAL DATUM

Vertical datum is based on an assumed spherical figure of the Moon and a lunar radius of 1738 km. The datum plane was subsequently adjusted to 2.6 km below the surface described by the 1738-km radius to minimize the extent of lunar surface of minus elevation value. Gradients of major surface undulations were established by interpolating Schrutka-Rechtenstamm computations of J. Franz's measurements of 150 lunar craters. The probable error of comparative elevation values is evaluated at 1000 meters. Vertical datum, so established, is considered interim and will be refined as soon as a more accurate figure of the Moon is determined.

ELEVATIONS

All elevations are shown in meters. The relative heights of crater rims and other prominences above the maria and depths of craters were determined by the shadow-measuring technique as refined by the Department of Astronomy, University of Manchester, under the direction of Professor Zdenek Kopal. Relative heights, thus established, have been referenced to the assumed vertical datum and have been integrated with the gradients of the surface undulations. The probable error of the localized relative heights is 100 meters. Inherent with the measuring technique used, relative height determinations in general E-W direction are more accurate than in the N-S direction.

Elevations (referenced to datum) 2700
Relative elevations (referenced to surrounding terrain) 550R
Depth of crater (rim to floor) .... (1300)

CONTOURS

All contours are approximate.
Contour interval is 600 meters.
Approximate contour ——— 6000 ———
Depression contour 600

NAMES

The feature names selected were adopted from the 1935 International Astronomical Union nomenclature system with minor changes introduced in the Photographic Lunar Atlas, edited by Dr. Gerard P. Kuiper, 1960.

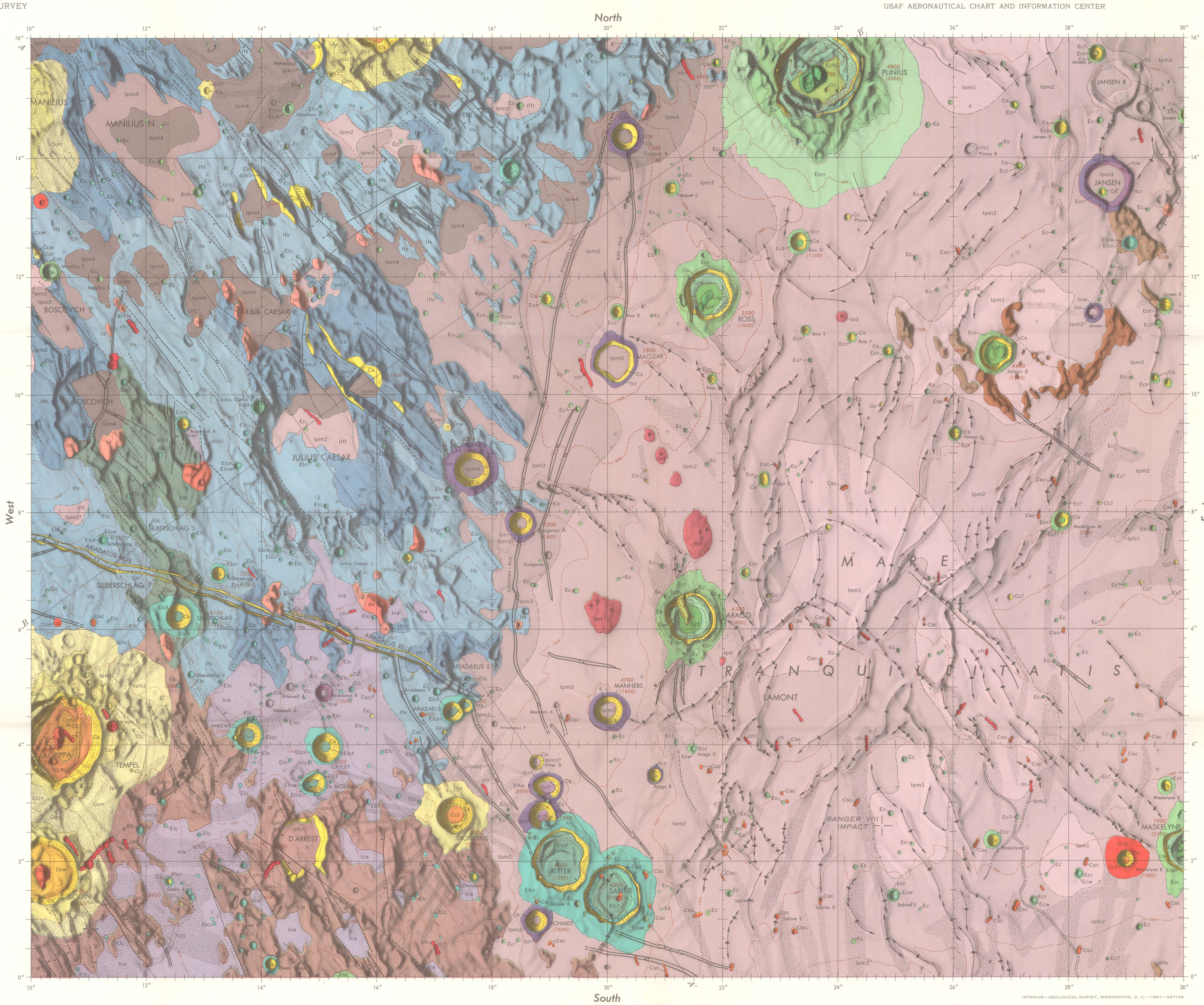
Craters designated by capital letters were selected from the IAU list of Named Lunar Formations. Supplementary lettered formations have been added in accordance with the criterion suggested by Blagg and Müller. They are designated by lower case letters.

RELIEF PORTRAYAL

The configuration of the relief features shown on the base chart was interpreted from photographs taken at Lick, McDonald, Mt. Wilson, Yerkes, and Pic du Midi observatories and published in the 1960 edition of the USAF Lunar Atlas and from unpublished photographs from the Lunar and Planetary Laboratory, University of Arizona, and Department of Astronomy, University of Manchester. Visual observations made with the 24 in. Lowell refracting telescope, Flagstaff, Ariz., have also been used to add and clarify details. The pictorial portrayal of relief forms was 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. Cast shadows were eliminated to enable complete interpretation of relief forms.

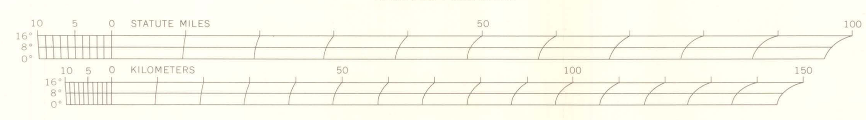
EAST-WEST DIRECTION

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

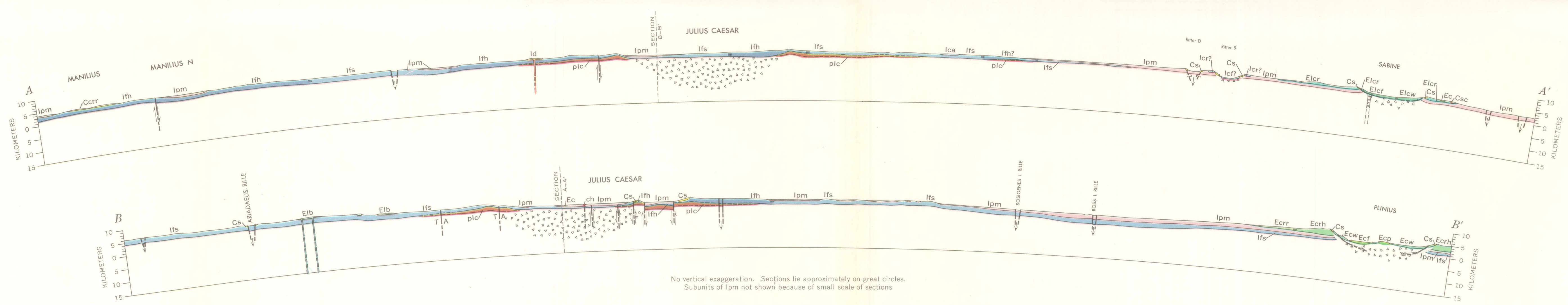


Lunar base chart LAC 60, 1st edition, 1962, by the USAF Aeronautical Chart and Information Center, St. Louis, Missouri 63118

SCALE 1:1 000 000 AT 11°00'45"
MERCATOR PROJECTION



Sources of geologic information: Published low-illumination photograph from Lick Observatory (number L–24 in catalog); unpublished photographs from Lick Observatory; unpublished high-illumination photographs from U.S. Naval Observatory, Flagstaff, Ariz., photographs of the south-central region from Ranger VIII; and visual observations by E. C. Morris with the 36 in. refractor, Lick Observatory, and the 30 in. reflector, USGS Observatory, Flagstaff, Ariz.



No vertical exaggeration. Sections lie approximately on great circles.
Subunits of Ipm not shown because of small scale of sections

GENERAL INFORMATION

The surface of the Moon is heterogeneous. Surface materials are classed on the basis of telescopic observations into units, each having a limited range of physical properties such as topography, visible under low-illumination, and albedo, the reflectivity under full-Moon illumination. Such units are considered analogous to the rock-stratigraphic formations of terrestrial geology. By application of the principles of superposition and intersection, these rock units 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 units are periods and epochs of time, respectively (Shoemaker, 1962; Shoemaker and Hackman, 1962). The type localities of most of the systems and series recognized to date are in the vicinity of Mare Imbrium. The assignment of the various mappable rock-stratigraphic units to time-stratigraphic units is somewhat uncertain except in the type areas.

Each unit is given either a descriptive designation or a formal stratigraphic name, and the letter symbol for each unit is composed of an abbreviation of its age assignment (capital) and name (lower case). Materials of each crater are together considered an informal formation, and the subunits, rim material, for example, are informal members. Features such as structural troughs, ridges, faults, and lineaments (indistinct linear negative features) are indicated by symbols similar to the structural symbols of terrestrial geology.

The descriptions of the units are arranged in chronologic order and include brief summaries of the visual characteristics and interpreted origins of each. Albedos are given in qualitative terms, which correspond to preliminary figures of Rowan and West (1965) as follows: very low, <0.06; low, 0.06-0.08; intermediate, 0.08-0.10; high, 0.10-0.12; very high, >0.12.

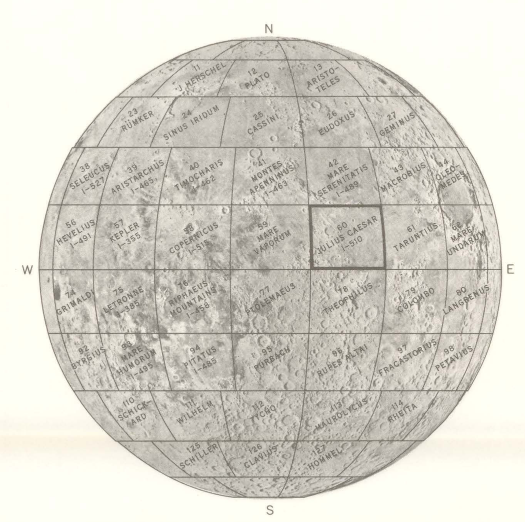
The geologic mapping has been carried out to the precision obtainable with existing telescopic techniques; it has been aided in a small area near the southern map boundary by Ranger VIII photography. As more detailed information is acquired through lunar exploration, greater precision in discrimination and location of geologic units and structures and further refinement of their chronologic sequence is to be expected.

REFERENCES CITED

Rowan, L. C., and West, M. N., 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 report, 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—Internat. Astron. Union Symposium 14: London, Academic Press, p. 289-300.



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

EXPLANATION

COPERNICAN SYSTEM

Cs — Slope material

Characteristics
Albedo highest of any lunar material except some light domes. Occurs on steep slopes, mostly on the inner walls of craters
Interpretation
Freshly exposed rock, probably both talus and bedrock uncovered during talus formation. Process of talus formation may still be continuing

Ccd — Dark-halo crater material

Characteristics
Albedo very low, same as Procellarum Group or lower. Smooth topography
Interpretation
Volcanic material or unusually dark impact ejecta

Materials of rayed craters (Cc; Ccw; Ccr; Ccrh; Ccrr; Ccf; Ccfs; Ccfh; Ccp)

Characteristics
Cc, *undifferentiated material of sharp-rimmed, rayed, or bright-halo craters too small to permit identification of individual crater units. In large craters, divided into:*
Ccr, *rim, undifferentiated. Raised rim around crater. Grades outward to ray material. Albedo intermediate to high*
Ccrh, *rim, hummocky. Surface has high local relief; discontinuous hills and valleys roughly concentric with the crater in the inner part grading outward to a branching pattern. Albedo intermediate to high*
Ccrr, *rim, radial. Surface has moderate local relief of low ridges subradial to the crater; difficult to detect on rough subjacent topography. Albedo intermediate to high, somewhat patchy*
Ccw, *wall. Hummocky topography on steep to moderate slopes inside crater; locally crossed by narrow benches roughly concentric to the crater rim. Includes all materials inside small craters. Albedo intermediate*
Ccf, *floor, undifferentiated. Mapped in craters whose floors are too small to distinguish units. Albedo intermediate to high. Also shown in the dark-halo crater Maskelyne B*
Ccfs, *floor, smooth. Albedo intermediate to high*
Ccfh, *floor, hummocky. Forms low irregular hills on crater floors*
Ccp, *peak. Forms high ground or peaks at or near center of crater. Albedo high*
Interpretation
Cc, *small craters of uncertain origin*
Ccr, *ejecta from crater of impact origin*
Ccrh, *impact-produced ejecta of variable thickness and fragment size at the surface grading downward to overturned and fractured bedrock*
Ccrr, *stringers of impact-produced ejecta*
Ccw, *darkened talus and slumped rim material*
Ccf, *probably the top of shock-crushed breccia lens*
Ccfs, *either a smoothed and eroded part of an impact-produced breccia lens or a later volcanic cover*
Ccfh, *mostly slump material from walls*
Ccp, *lens of intensely brecciated bedrock uplifted just subsequent to impact; possibly volcanic in some craters*

Csc — Satellitic crater material

Characteristics
Material of shallow craters with low rims. Outlines irregular or composed of two or more merging round craters. Most occurrences in quadrangle are outlying members of a swarm around the large ray crater Theophilus to the south
Interpretation
Secondary craters excavated by material ejected from large primary impact craters

Ray material (Light; Dark)

Characteristics
Streaks and patches approximately radial to Copernican craters or in halos around them. Superimposed on parts of all other units except Cs and Ccd. Most rays are lighter than surroundings. Rays west of crater Dionysius are darker than surroundings; light rays to the east, on Procellarum Group, may have dark central stripes
Interpretation
Probably consists of many small secondary impact craters and a thin layer of fragmental rock ejected from both primary and secondary craters. Dark rays of Dionysius may result from excavation of dark bedrock

ERATOSTHENIAN SYSTEM

Materials of rayless craters (Ec; Ecw; Ecr; Ecrh; Ecrr; Ecf; Ecfs; Ecp)

Characteristics
Topographically similar to materials of rayed craters. Albedo generally lower but rim materials include patches as bright as corresponding materials of rayed craters and brighter than adjacent Procellarum Group
Interpretation
Similar to corresponding materials of rayed craters. Albedos, atypically high for Eratosthenian materials, may indicate late Eratosthenian ages. Ridgelike peak in crater Arago is probably volcanic feature younger than crater

IMBRIAN SYSTEM

Archimedian Series

Crater materials (Elc; Elcw; Elcr; Elcf)

Characteristics
Similar to corresponding Eratosthenian crater units but stratigraphic assignment indeterminate. Elcf *in Sabine and Ritter has hills and arcuate ridges on level plains which are higher and broader than floors of Eratosthenian and Copernican craters of comparable size*
Interpretation
Materials of impact origin except possibly those of Sabine and Ritter. Age of Sabine and Ritter relative to mare material unknown; rim material is extensive and not visibly embayed, but no satellitic craters are visible. Craters may be calderas because of lack of satellitic craters, high floors, arcuate internal ridges, and close resemblance to each other

Elsc — Satellitic crater material

Similar to Csc. *Individual craters are smaller than* Csc

Elb — Boscovich Formation (new name)

Characteristics
Rough hummocky surface with prominent straight or curving narrow stringy ridges mostly from 5 to 30 km long. Associated with conical and low flat domes. Albedo high, with some intermediate patches. Type area is around the southeast rim of the crater Boscovich and within 40 km of the crater
Interpretation
Volcanic complex. Material extruded from fissures and associated volcanic cones. Some Boscovich transects Ipm4 *and therefore is younger*

Procellarum Group (Ipm4; Ipm3; Ipm2; Ipm1; Ipd)

Characteristics
Ipm *units, flat mare material. Albedo low compared with most other units; units* Ipm1 *through* Ipm4 *have successively lower albedo. Surface level and relatively smooth at telescopic resolution; relief features such as ridges and scarps have very low slopes. Subunits not shown on cross section*
Ipd, *mare dome material. Albedo like that of* Ipm. *Forms domes, height low in proportion to width, with circular to irregular outlines. Many domes have summit craters. Large ones appear composite*
Interpretation
Ipm, *volcanic materials: flows or ash beds, or both. Uppermost layer may be fragmental debris. Albedo differences probably reflect difference in age or composition of the uppermost layer only*
Ipd, *probably shield volcanoes. Some subdued domes without summit craters may be laccoliths*

Crater materials (Ic; Icw; Icr; Icf)

Characteristics
Ic, *crater materials, undifferentiated. Forms small subdued rings; shown only as buried unit*
Icr, *rim. Topography is gently hummocky or smooth. Albedo low*
Icw, *wall. Similar to* Ecw *and* Ccw
Icf, *floor. Apparently smooth. Albedo low*
Interpretation
Similar to corresponding Eratosthenian and Copernican units. Subdued topography of Ic *suggests burial.* Icf *may be mare material* (Ipm *unit*)

Ica — Cayley Formation (new name)

Characteristics
Surface generally flat and smooth. Apparently lacks ridges and rilles. Appears to mantle subjacent terrain; buried (or ghost) craters evident in some areas (3°30′ N., 14°40′ E.). Albedo intermediate, about the same as that of Fra Mauro Formation, higher than Procellarum Group. Crater density greater than on Procellarum Group. Type area is east of the unrelated crater Cayley for which the formation is named; 3½°-4½° N., 15½°-16¼° E
Interpretation
Volcanic materials; may be ash-flow or ash-fall tuff with intercalated ballistically deposited layers

Apenninian Series

Fra Mauro Formation (If; Ifh; Ifs)

Characteristics
Forms rolling surface which is laterally continuous with similar material adjacent to the Imbrium basin in Montes Apenninus region. Progressively smoother to southeast; members (Ifh, Ifs) *represent gradational facies. Ruled pattern indicates areas where formation may be thin and pre-Imbrian material locally exposed*
If, *undifferentiated. Shown only as buried unit*
Ifh, *hummocky member. Has surface studded with low subequidimensional hummocks, 1-3 km across, with low crests. Albedo intermediate with spots of high albedo on hummocks*
Ifs, *smooth member. Has no hummocks at best telescopic resolution obtained, but has undulating or rolling surface, commonly with fine lineations mostly radial to the center of the Imbrium basin. Albedo intermediate to high, higher than in Mare Vaporum quadrangle to the west*
Interpretation
Thick blanket of debris ejected from the Imbrium basin by the impact of a large solid body. Deposited along low-angle trajectories; completely or partly mantles subjacent topography, such as the large crater Julius Caesar. Material embanked against the northwest rim of Julius Caesar, was largely blocked from the northeastern interior by the rim, but filled the crater to greater depths southeastward and embanked on the south inner wall. Ifs *is smoother and thinner than* Ifh *mainly because of greater distance from the Imbrium basin. Patches of possible* Ifh *farther from basin than some* Ifs *may represent local thick accumulations against obstacles*

It — Terra material, undifferentiated

Characteristics
Undulating to rugged topography; dominant linear pattern in western part of exposure; ridges and peaks appear to be mantled or smoothed; flatter areas are highly cratered and pitted with irregular depressions and grooves. In most places in sharp contact with Cayley Formation. Albedo intermediate. Ruled pattern indicates areas where formation is believed thin and underlying material may be locally exposed
Interpretation
Various materials mantling pre-Imbrian rocks, including volcanic materials, slump debris, thin ballistically deposited crater ejecta from distant sources, and possibly some Fra Mauro Formation

PRE-IMBRIAN

plc — Crater material, undifferentiated

Characteristics
Forms areas of circular and elliptical outlines having rugged to moderately rugged relief. Cut by lineaments radial to Imbrium basin
Interpretation
Rim and wall material of craters older than the Fra Mauro Formation

plu — Undifferentiated material

Characteristics
Forms rugged islands in Mare Tranquillitatis
Interpretation
May be part of rim of Tranquillitatis basin, thinly covered by Fra Mauro Formation

Id, dd — Terra dome material

Characteristics
Id, *light domes. Outline round, elliptical or irregular. Rougher and much steeper than mare domes. Albedo high to very high; some domes extremely bright in all illuminations*
dd, *dark domes. Forms domes with convex profile, broader and lower than light domes; appear to be composed of several lobes. Albedo intermediate*
Interpretation
Volcanoes composed of relatively viscous volcanic deposits. Imbrian or younger. Some light domes may be structural blocks

ch — Chain-crater material

Characteristics
Undifferentiated rim, wall, and floor material of partly overlapping or alined craters with either high or low rims. Distinguished from Csc *and* Elsc *by greater length of chain in proportion to width*
Interpretation
Volcanic craters. Imbrian or younger

Contact
Long dashed where approximately located; short dashed where gradational; queried where doubtful

Buried contact (If)
Shows limit of topographically expressed part of buried units. Buried unit indicated by symbol in parentheses

Laterally gradational contact
Shown only on cross section. Corresponds to short dashed contact on map

Fault
Solid line at base of sharp scarp; dashed and dotted at base of gentle scarp; dashed where inferred and exposed; dotted where inferred and buried. Bar and ball on downthrown side. Arrows indicate apparent horizontal movement. Hachures indicate fault scarp against which younger rocks were deposited (on side with hachures); shown also where material on scarp is Cs. *On cross sections,* T *and* A *indicate apparent horizontal movement toward and away from observer, respectively*

Lineament
Gentle narrow trough or very gentle scarp in terra. Interpretation: May be single fault, graben, buried graben, or depositional texture

Sinuous rille
Narrow depressions with a meandering pattern; in places have associated small craters. Interpretation: Channel eroded by ash flow or other volcanic materials

Ridge
Line marks crest. Arrows mark tapered ends. Interpretation: May be pressure ridge or site of volcanic intrusion or extrusion; arcuate ridge in crater Sabine possibly over intrusive dike

Gentle mare scarp
Line marks base of scarp. Interpretation: May be fault, buried scarp or flow-front

Concealed crater
Symbol indicates rim crest

Irregular depression
Interpretation: Collapse feature or secondary impact crater

Rimless round crater
Round crater with steep walls but without raised rim. Interpretation: Collapse feature or volcanic crater

Igneous intrusion (interpretation)
Shown only in cross section, surface expression shown by ridge symbol

Breccia lens
Shown on cross section beneath crater floors. Interpretation: Impact-produced breccia

GEOLOGIC MAP OF THE JULIUS CAESAR QUADRANGLE OF THE MOON

By
Elliot C. Morris and Don E. Wilhelms
1967

For sale by U. S. Geological Survey, price $1.00