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 USAF-ACIC with advisory assistance from Dr. Gerald P. Kuiper and his collaborators, D. W. G. Arthur and E. A. Whitaker.

CONTROL

The position of features on this 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. Gerald 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 techniques 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 measuring technique used, relative height determinations in general E-W direction are more accurate than in the N-S direction.

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

CONTOURS

All contours are approximate
Contour interval is 300 meters
Approximate contour —— 600 ——
Depression contour
NOTE: Contour information is not currently available beyond 63° West.

NAMES

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

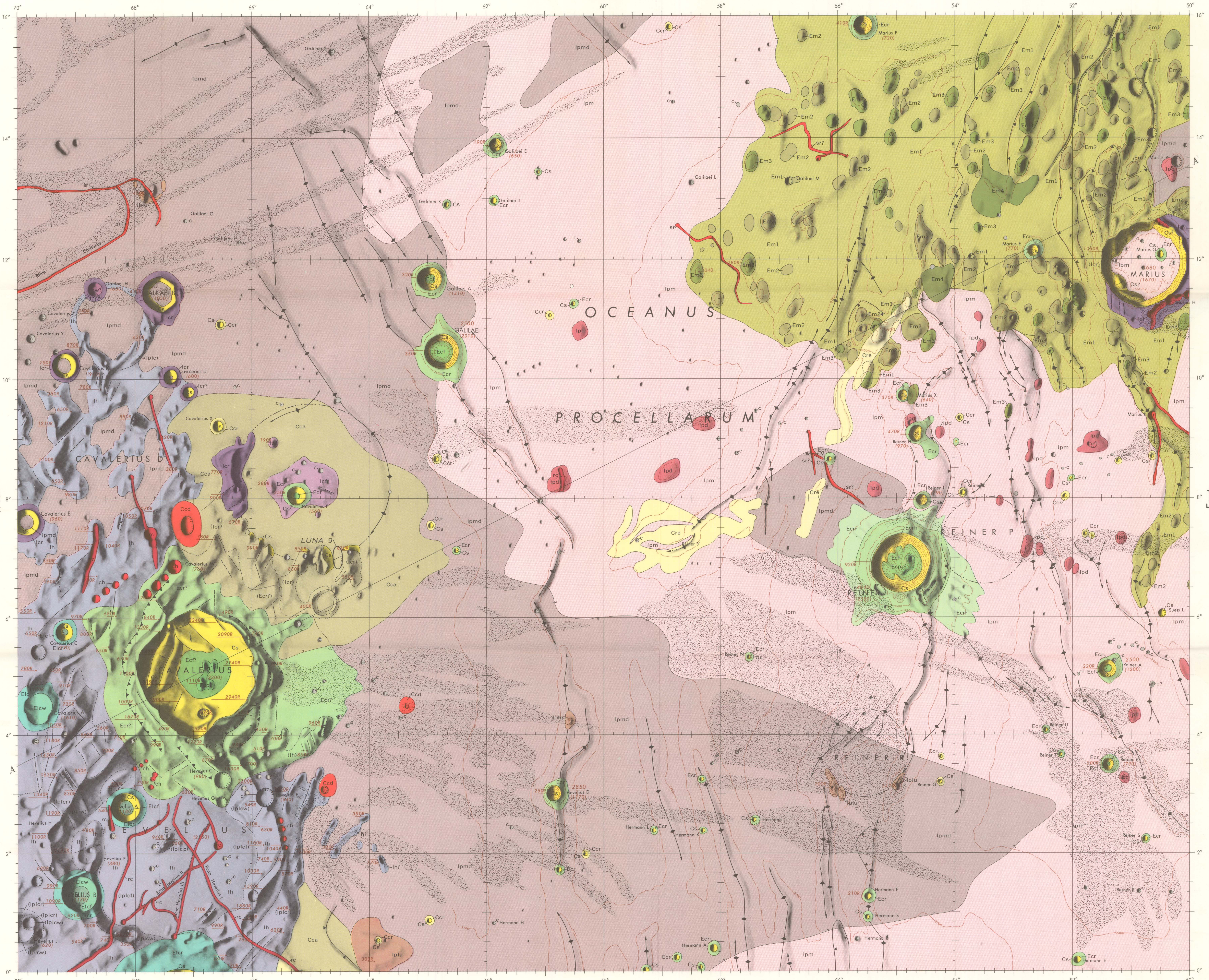
Craters designated by capital letters were selected from the IAU list of Named Lunar Formations. Supplementary lettered formations have been added in accordance with the criterion suggested by Blagg and Müller. They are designated by lower case letters.

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 unpublished photographs from the Lunar and Planetary Laboratory, University of Arizona and Department of Astronomy, University of Manchester. Visual observations made with the 24 inch Lowell refracting telescope, Flagstaff, Arizona, 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.

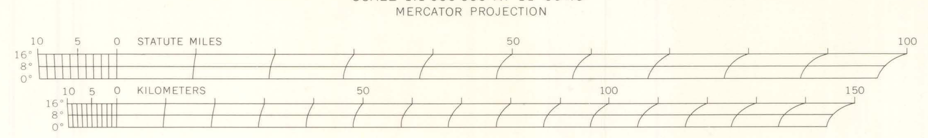


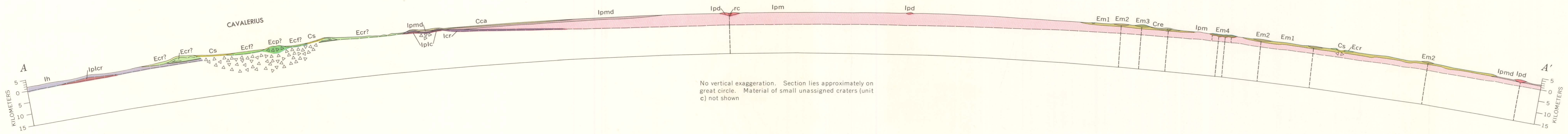
Lunar base chart LAC 56, 1st edition, 1963, by the Aeronautical Chart and Information Center, United States Air Force, St. Louis, Missouri 63118

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1967—G66415

Sources of geologic information: Photographs from Photographic Lunar Atlas (Kuiper, 1960); unpublished photographs from Lick Observatory, Catalina Observatory, and Lowell Observatory, taken by USAF-ACIC; visual observations by John F. McCauley made at the 36 in. refractor, Lick Observatory, the 30 in. reflector of the USGS Observatory, and the McMath Solar Telescope of Kitt Peak Natl. Observatory

SCALE 1:1 000 000 AT 11°00′45″
MERCATOR PROJECTION





No vertical exaggeration. Section lies approximately on great circle. Material of small unassigned craters (unit c) not shown

GEOLOGIC MAP OF THE HEVELIUS REGION OF THE MOON

By

John F. McCauley

1967

EXPLANATION

COPERNICAN SYSTEM

Cs

Slope material

Characteristics
Albedo very high; typically 0.13–0.14 and greater than adjacent crater floor or rim material. Present mostly on relatively smooth interior crater slopes ranging from 20 to 40 degrees

Interpretation
Partly sorted, relatively fresh rock fragments ranging in size from dust to large blocks. Derived principally by slumping and spalling of the steep inner walls of craters

Ccd

Dark-halo crater material

Characteristics
Albedo very low, same as that of Cca. *Forms craters and surrounding halos or aprons having little or no detectable relief. Appears to interrupt Copernican rays*

Interpretation
Volcanic craters surrounded by pyroclastic ejecta

Cca

Cavalerius Formation (new name)

Characteristics
Albedo very low (<0.06). Present on flanks of crater Cavalerius where it subdues but does not conceal subjacent topography; extends over parts of the adjacent mare surface. Has no intrinsic relief. Appears to interrupt rays radial to the Copernican crater Olbers A approximately 250 km northwest of Cavalerius. Type area is north flank of crater Cavalerius, 7°N., 66°W

Interpretation
Pyroclastic material for the most part but may include flows on the mare plain

Cre

Reiner Gamma Formation (new name)

Characteristics
Albedo intermediate, typically about 0.08–0.09. Appears superposed on surrounding units with no topographic expression of its own. Occurs in three patches: the largest has an irregular outline and surrounds two cresent-shaped areas of mare material; the others are linear and trend northeastward. Type area is Reiner γ, 7½° N., 58° W

Interpretation
The unit is unique on the visible hemisphere of the Moon, and no certain earth analogues are known. It could represent a felsic glowing avalanche (nuée ardente) deposit that originated in the Marius hills area

Ccr

Crater rim material

Characteristics
Albedo generally high (>0.10); detectability depends on the albedo of the background material. Surrounds craters 2–3 km in diameter; topography appears smooth at the limit of resolution. Rim material grades outward from some craters to small patches of ray material

Interpretation
Impact crater ejecta. Poorly sorted crushed rock possibly containing scattered large blocks. Block size and thickness are maximum near the crater rim

Ray material

Characteristics
Albedo generally high (>0.10); detectability depends on the albedo of the background material. Distribution generally patchy. Appears superposed on other units with no discernible topographic expression of its own

Interpretation
Small, telescopically unresolvable, closely spaced, secondary craters with fresh, bright materials on the inner walls. The integrated effect of these bright patches of slope material gives the rays a higher albedo than that of surrounding less cratered material or of older stabilized cratered surfaces

ERATOSTHENIAN SYSTEM

Ecr | Ecrh | Ecrr | Ecf | Ecp

Crater material

Ecr, *rim, undifferentiated*
Ecrh, *rim, hummocky*
Ecrr, *rim, radial*
Ecf, *floor*
Ecp, *peak*

Characteristics
Albedo low and uniform, typically 0.06–0.08. Ecr *generally around craters less than 20 km in diameter where topography appears smooth; some fine texture can be detected around the craters Galilaei and Galilaei A; hummocky and radial topography and possible faint rays not differentiated in* Ecr? *around Cavalerius.* Ecrh *surrounds the crater Reiner and extends about 10 km from the rim crest; the topography is hummocky with subordinate concentric ridges.* Ecrr *consists of subdued ridges radial to Reiner to the northwest and southeast.* Ecf *is smooth to slightly hummocky.* Ecp *forms smooth but steep hills near center of crater*

Interpretation
The rim materials are genetically similar to Ccr. *The concentric ridges of* Ecrh *and* Ecr *are interpreted to be the surface expression of slices thrust radially outward from the crater during its formation by impact, and* Ecrr *and parts of* Ecr *consist of ballistically deposited ejecta (inferred contact between thrust slices and ballistic ejecta of* Ecr *is shown on cross section).* Ecf *is brecciated bedrock and fine impact ejecta that has fallen back into the crater and may also include slumped wall material; breccia may form a relatively deep lens beneath the crater.* Ecp *may consist of brecciated bedrock uplifted during or after impact or may be the volcanic material produced later than the crater*

Em4 | Em3 | Em2 | Em1

Marius Group (new name)

Em4, *material of small-dome clusters*
Em3, *material of steep domes*
Em2, *material of low domes*
Em1, *smooth undulating material*

Characteristics
Occurs on south-dipping plateau surface several hundred meters higher along its northern edge (in the adjacent Seleucus region) than the adjacent maria. Em1 *consists of smooth undulating terrain with ridges, small scarps, and plateaus present locally; albedo low and uniform.* Em2 *consists of domes of convex profile and gentle slopes, typically 2–3 degrees, similar in general form to mare dome material* (Ipd). Em3 *consists of domes of concave profile and fairly steep slopes, typically 6–7 degrees; several are superimposed on the lower* Em2 *domes. Many domes of both types are elongated NNE-SSW, and some appear to be steeper on the east side. Many domes have small summit pits (most too small to plot on the map) and fine rille-like structures on the flanks.* Em4 *consists of clusters of domes or cones too small to be mapped individually, most of which appear to be similar in form to* Em2 *domes. Type area is region within 150 km west and north of the genetically unrelated crater Marius, from which the name is derived*

Interpretation
Complex series of volcanic flow materials intercalated with some pyroclastic deposits, both derived from the pits at the crests of many of the domes. The difference in form between Em2 *and* Em3 *domes may result from a difference in composition, with* Em2 *materials mafic and* Em3 *intermediate to possibly felsic, or from a difference in eruptive processes with lavas of the same composition. The ring of* Em2 *and* Em3 *domes directly west of the crater Marius may result from collapse along ring fractures with the subsequent formation of rim volcanoes, the deposits from which nearly fill the original depression.* Em1 *is the oldest unit, and* Em2 *is older than* Em3 *where these units are in contact. The relation of* Em4 *to* Em2 *and* Em3 *is indeterminate*

IMBRIAN AND (OR) ERATOSTHENIAN

Elcr | Elcw | Elcf

Crater material

Elcr, *rim*
Elcw, *wall*
Elcf, *floor*

Characteristics
Albedo uniform, generally greater than 0.10. Occurs as fresh-appearing crater material of the terrae. The topography of Elcr *and* Elcf *is similar to that of corresponding Eratosthenian units.* Elcw *is present on the inner slopes of craters but unlike* Cs *is not brighter than the adjacent rim and floor materials*

Interpretation
Elcr *and* Elcf *are similar genetically to* Ecr *and* Ecf. Elcw *is similar to* Cs *but rests on lower slopes that are now generally stable*

IMBRIAN SYSTEM

Procellarum Group

Ipmd

Mare material, dark

Characteristics
Albedo typically very low (<0.06); lower than that of Ipm. *Topographic characteristics are similar to those of* Ipm *except for a lower frequency of domes; generally exhibits a lower crater density and a lower incidence of superposed ray material than* Ipm. *Occurs along the west margins of Oceanus Procellarum and in small isolated patches in the northeastern part of the region*

Interpretation
Similar genetically to Ipm *but probably forms a thin blanket of younger material (possibly Eratosthenian or in part Copernican) covering the older* Ipm. *Locally, however, it could be contemporaneous with* Ipm *but be composed of darker, more mafic material*

Ipm | Ipd

Mare material

Ipd, *dome*
Ipm, *smooth*

Characteristics
Albedo generally low and uniform; indeterminate where rays are superposed. Ipm *forms extensive relatively smooth dark areas marked by elongate broad low ridges; terminates abruptly against higher topographic features.* Ipd *occurs as domes generally elliptical in plan, 3–15 km across, and as high as 300 meters; small craters occur on the flanks of many domes; some domes exhibit a cleft along their crests with a small crater at one end*

Interpretation
Ipm *is a thick complexly overlapping series of volcanic materials locally covered by a discontinuous thin layer of relatively fine-grained material formed by impact; the wide extent and low relief suggest either mafic flows or ash-flow deposits (ignimbrites) as the principal materials; maximum thickness near the crater Galilaei near the center of the region; grades to a thin veneer over buried topography. Topographic form and the low albedo suggest that the* Ipd *domes may be small shield volcanoes of mafic composition, consisting mostly of volcanic flows but perhaps including intercalated volcanic ash*

Icr | Icw | Icf

Crater material

Icr, *rim*
Icw, *wall*
Icf, *floor*

Characteristics
Topography and albedo, except for Icf, *similar to Eratosthenian and Eratosthenian or Imbrian crater material.* Icf *is rough, densely cratered, and has numerous small rilles; it occupies the central tumescence of the large mostly flooded crater north of Cavalerius. The crater floors are generally buried and the rim units embayed by* Ipmd

Interpretation
Impact crater material genetically similar to that of Copernican and Eratosthenian craters. Includes all crater material overlying the Hevelius Formation (Ih) *and overlain by dark mare material of late Imbrian* (Ipm) *or possible post-Imbrian* (Ipmd) *age. Also includes rim material of crater Marius which does not overlie Hevelius Formation and may be older than the material of the other craters*

Ih

Hevelius Formation (new name)

Characteristics
Relatively smooth material with a fine hummocky to braided texture (hummocks less than ½ km across); texture is progressively coarser in the direction of Mare Orientale (the center of which lies about 1,000 km to the southwest of the Hevelius region). Fine texture, including numerous small pits, best seen visually, but coarser hummocky texture about 100 km to the southwest is photographically resolvable. Albedo not uniform; generally intermediate to high. Type area is western part of the floor of the crater Hevelius near 2°N., 68°W

Interpretation
Ejecta from the impact that formed the Orientale basin. Consists of poorly sorted crushed rock with scattered blocks less than ½ km in size. May contain patches of smooth material of local derivation in small depressions; mantles the crater Hevelius

PRE-IMBRIAN OR IMBRIAN

Iplc | Iplcr | Iplcw | Iplcf | Iplcp

Crater material

Iplc, *undifferentiated*
Iplcr, *rim*
Iplcw, *wall*
Iplcf, *floor*
Iplcp, *peak*

Characteristics
Not exposed; shown on map only as concealed. Physiographic form similar to that of corresponding exposed crater materials but subdued; albedo and surface texture are those of superposed unit

Interpretation
Older buried crater units genetically similar to corresponding exposed units

Iplu

Undifferentiated material

Characteristics
Albedo intermediate and uniform. Forms small islands surrounded by mare material. The flanks of the smaller islands such as those within the crater Reiner R rise to 700 meters above the mare and appear to be relatively smooth. The lower, more extensive islands to the east of the crater Hevelius are rough; numerous small craters may be seen visually under good seeing conditions

Interpretation
Older crater ramparts and highland surfaces which may be thinly buried by material of the Hevelius Formation (Ih) *or be exposed remnants of Imbrian or pre-Imbrian craters* (Iplc)

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ch

Chain-crater material
Rimless to low-rimmed alined craters, 6 km in diameter or less, that either overlap or are closely spaced. Interpretation: Volcanic craters of the maar type, collapse depressions, or possibly satellitic craters

rc

Rille and chain-crater material
Material in straight to gently curving narrow depressions with crater-like enlargements as much as 5 km in diameter along their length. Albedo low to intermediate. Interpretation: Volcano-tectonic depressions and craters

sr

Sinuous rille
Narrow depressions. Commonly with a meandering pattern; in places have associated small craters. Albedo of inner walls intermediate to high. Interpretation: May be erosion channels cut by fluidized volcanic ejecta or very large lava channels

c

Crater
Crater whose position has been noted on photographs but whose form cannot be determined. Mostly 1–2 km in diameter. Interpretation: May be small nonrayed primary impact crater or satellitic crater

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

(Iplcr)
(Iplcw)
Concealed contact
Formation concealed by younger deposits indicated by symbols in parentheses

Fault
Bar and ball on apparent downthrown side. Dashed where approximately located; dotted where concealed

Thrust fault
Sawteeth on upper plate. Interpretation: Sole of blocks thrust from crater at low angle and thinly buried by ballistically deposited ejecta

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

Ridge
Line marks crest. Arrow indicates tapered end. Dotted where concealed

Scarp
Line marks base. Barb points downslope

Slump block
Arrow shows direction of movement. Dotted where concealed

Concealed crater
Symbol marks rim crest

Rimless depression
Irregular to circular. Interpretation: Collapse feature

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

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 topographic and other physical properties such as 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. Correlation of many of the rock-stratigraphic units of the Hevelius region with the rock-stratigraphic units in the Mare Imbrium region is still uncertain.

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, for example, rim material, are informal members. Features such as ridges, inferred faults, and lineaments (indistinct linear negative features) are indicated by symbols similar to those of terrestrial geology.

The descriptions of the units are arranged in chronologic order and include brief summaries of the characteristics and interpreted origin of each. The numerical data on albedo are from an unpublished albedo map by M. N. West, U.S. Geological Survey.

HEVELIUS REGION

The Hevelius region is in the west-central part of Oceanus Procellarum approximately 1,200 km (kilometers) from the center of Mare Imbrium. Three distinct topographic and geologic provinces are recognized in the region.

The first province, west of Oceanus Procellarum and at the west edge of this region, is part of an extensive cratered terra that extends to Mare Orientale, at the extreme west edge of the visible hemisphere of the Moon and approximately 1,000 km southwest of the Hevelius region. The surface material of this terra (Hevelius Formation) is of intermediate to high albedo and within the crater Hevelius is relatively smooth with a faintly braided to fine hummocky texture and numerous superposed small pits. Westward from the Hevelius region, towards Mare Orientale, the old craters of this terra appear to be progressively more deeply buried, and the terrain is more hummocky (McCauley, 1964). Apparently this terra is covered by a blanket of material that extends continuously from the edge of Mare Orientale, where it is thickest, into the Hevelius region, where it is relatively thin and only partly subdues the larger subjacent topographic features such as the crater Hevelius. This blanketing material is interpreted to be ejecta produced by an impact that formed the Orientale basin, believed to be the youngest of the large mare basins. Numerous northeast-trending lineaments and mare-embayed troughs in the region appear to be part of a structural pattern radial to the Orientale basin (Hartman and Kuiper, 1962).

The second province, in the center of the map area, is a mare plain. The mare material is thickest in the north-central part of the map area near the crater Galilaei, where a series of northwest-trending mare ridges is present but no trace of subjacent features is seen. The mare material thins to the west, where it embays older craters and northeast-trending troughs; it also appears to thin to the south and southeast, where ghost craters such as Reiner P and Reiner R can be seen. The depression now occupied by the mare plain probably resulted from structural subsidence of an old cratered terra like that of the first province. In the mare plain two stratigraphic units have been recognized. The first (unit Ipm) has an intermediate albedo, contains numerous domes, and is correlated with the mare material of the Procellarum Group in the Kepler region to the east (Hackman, 1962). The second (unit Ipmd) is generally darker, less cratered than unit Ipm, and occurs mostly along the west margins of Oceanus Procellarum; it is interpreted as a thin, younger unit covering the older mare material. Both units are probably volcanic. Numerous dark-rimmed craters assigned to the Eratosthenian System, 2–5 km in diameter, occur on the mare plain; about one-third of these lie on mare ridges. Bright-rimmed craters assigned to the Copernican System also occur throughout the area but are generally smaller, 2–3 km in diameter, and about half as numerous as the dark-rimmed craters. Most or all bright-rimmed craters and the majority of the dark-rimmed craters are probably of impact origin, with the darker of the impact type inferred to be older. The large number of dark-rimmed craters on ridges, however, suggests that many of these may be of internal origin; for these, relative albedo cannot be used as an age criterion. One of the youngest units recognized in the region is the Cavalerius Formation, a dark blanketing unit probably composed of pyroclastic material.

The third province, in the northeastern part of the region, is a large southward-dipping plateau, several hundred meters higher than the adjacent mare, with numerous superimposed domes 3–10 km in diameter. The Marius Group, which forms the plateau surface (Em1) and two types of domes, low (Em2) and steep (Em3), is interpreted to be a volcanic complex consisting of intercalated lava and ash deposits originating in numerous vents at the crests of both types of domes (McCauley, 1965). The Marius Group is clearly superimposed on the mare material of the Procellarum Group along a sinuous scarp marking its contact in the adjacent Seleucus region. The crater density is markedly lower than that for the Procellarum Group in the Kepler region to the east (craters 1–2 km in diameter are almost 10 times less numerous). Its lower crater density and superposition on the Procellarum Group are strong evidence for assigning the Marius Group a post-Imbrian age. The Marius Group is in turn locally overlain by faint Copernican ray material and is, therefore, assigned an Eratosthenian age.

In summary, the oldest recognizable event in the Hevelius region was extensive cratering of the old terra surface; Hevelius is an example of such a crater. The western part of the area was then covered by a thin blanket of impact ejecta (Hevelius Formation) from the Orientale basin, and this new surface was again cratered. The earlier of these craters were partly flooded and the entire central and northwestern parts of the region subsided and were inundated by mare material, first of the Procellarum Group, later by darker material which may be younger than the Procellarum Group. Volcanism of a different type occurred later in the northeastern part of the region and produced numerous domes of two different types with smooth undulating local deposits between (Marius Group). After these events, cratering by impact, and probably volcanic cratering, continued throughout the entire region, during the Eratosthenian and Copernican Periods. Deposition of the pyroclastic material of the Cavalerius Formation is among the most recent events of the region.

LUNA 9

Luna 9, a surface probe of the USSR, soft landed in the Hevelius region on February 3, 1966, at 2145 hours (Moscow time), and during the following 2½ days transmitted a series of high-resolution panoramic television pictures. The best current estimate of the Luna 9 landing site is the vicinity of 7°00′N. and 64°33′W.; the inferred dispersion ellipse is plotted on the map. The probe probably landed on young, dark volcanic material of the Cavalerius Formation (Cca), either in the plains where it covers mare material or on one of the broad hills nearby where it covers older crater rim deposits. Alternatively, the probe could have landed on one of the local occurrences of Copernican slope material (Cs) on the flanks of the hills. The pictures released to date show an intricate, undulating, rubbly surface with fragments ranging in size from the limit of resolution (several millimeters) to angular blocks about 25 centimeters across. Numerous craters, most of which are rimless, can also be recognized; these range from a few centimeters to several meters across. The sharply angular nature of the blocks suggests that they are composed of material at least weakly cohesive (Moore, 1966) and that they have not undergone significant erosion either by micrometeorites or sputtering since deposition on this surface.

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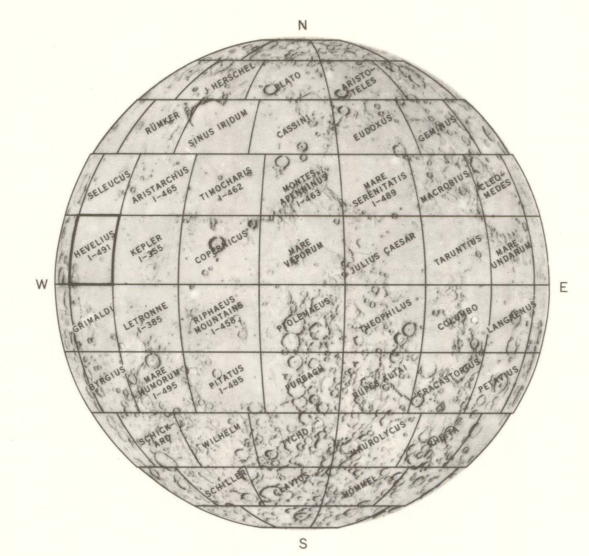

INDEX MAP OF THE SUBTERRESTRIAL HEMISPHERE OF THE MOON
Published maps are indicated by series number

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