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

GEOLOGIC ATLAS OF THE MOON
J. HERSCHEL QUADRANGLE
I-604 (LAC-11)

NOTES ON BASE

The base chart was prepared by ACIC 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 Report 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 geocentric 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 photo-clinometric methods 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 of the face of the moon.

Lengths of Radius Vectors to control points.....⊕ or △ 1741.9

Depths 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.

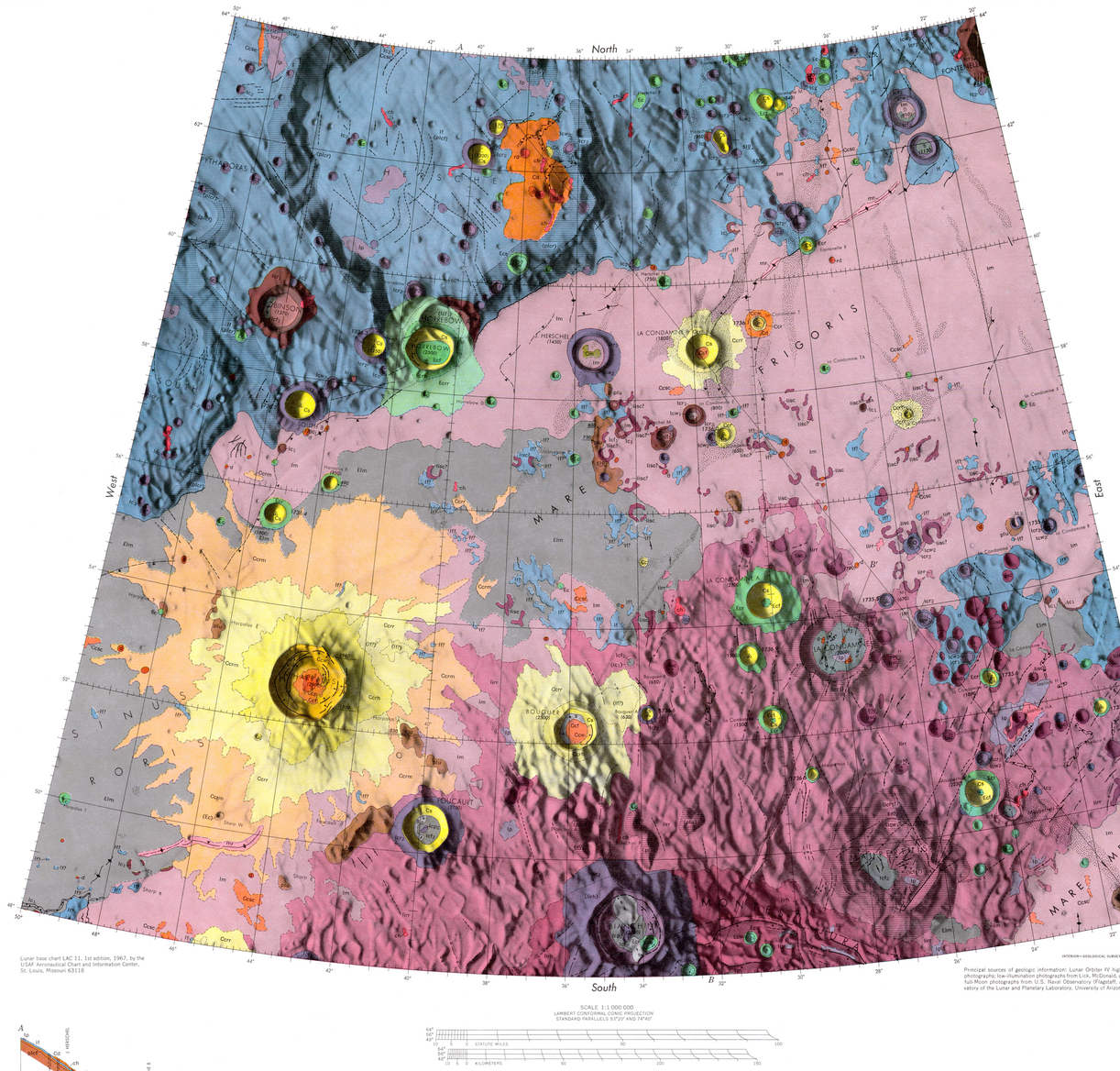
Supplementary features are associated with the named features through the addition of identifying letters. Craters are identified by capital letters. Eminences are identified by Greek letters.

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

A block-dot is included, where 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 Pic du Midi, Lick, McDonald, Mount Wilson, Yerkes, Arcetri, Lick, McDonald, Mount Wilson, Yerkes, Pic du Midi and Kottamia Observatories. Supplementary visual observations using the 25 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.

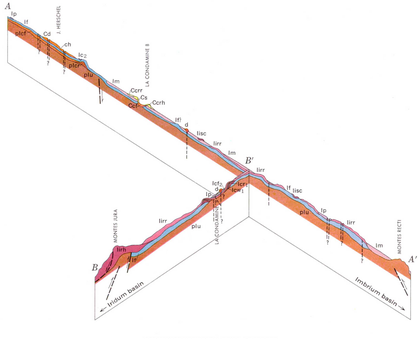


Lunar base chart LAC 11, 1st edition, 1967, by the USAF Aeronautical Chart and Information Center, St. Louis, Missouri 63118

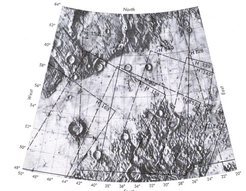
Principal sources of geologic information: Lunar Orbiter IV high-resolution (100 -150 m) photographs; low-illumination photographs from Lick, McDonald, and Pic du Midi Observatories; full-Moon photographs from U.S. Naval Observatory (Flagstaff, Arizona) and Catalina Observatory of the Lunar and Planetary Laboratory, University of Arizona

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1969—685345

SCALE 1:1 000 000
LAMBERT CONFORMAL CONIC PROJECTION
STANDARD PARALLELS 5.720° AND 7.440°



APPROXIMATE HORIZONTAL SCALE 1:2 500 000
VERTICAL SCALE GREATLY EXAGGERATED



LUNAR ORBITER IV HIGH-RESOLUTION COVERAGE OF J. HERSCHEL QUADRANGLE

GEOLOGIC MAP OF THE J. HERSCHEL QUADRANGLE OF THE MOON

By
G. E. Ulrich
1969

EXPLANATION

Mare material

Gm

Characteristics
Smooth dark material in floor of crater J. Herschel F which appears in transect ray material from crater Aristarchus (northeast of quadrangle).
Interpretation
Very young lava flows from source beneath J. Herschel F superposed on ray material of Copernican age. Other mare material in quadrangle is probably of similar age although superposition on Copernican units is not evident

Bright ray materials

Characteristics
Albedo generally less than unmodified (Ec unit) surface pattern; around freshest craters and for regional rays (in north-central and northeastern parts of quadrangle) which are related to craters Anaxagoras and Carpenter (both north of the quadrangle). Albedo locally intermediate around slightly subdued Copernicus craters Bouguer and La Condamine B (light stipple pattern) and around Herpalus, not mapped around Harpalus where unit corresponds closely with distribution of crater rim materials (Ccrh, Ccrr, Ccrm)
Interpretation
Fresh bright materials of small, closely spaced secondary craters. The interpreted part of these bright patches of ray material gives the rays a higher albedo than that of surrounding, less cratered material or of older stabilized crater surfaces

Dark terra material

Cd

Characteristics
Forms smooth, very dark surface on east side of floor of crater J. Herschel. Surrounded by irregular, subdued to well-developed depressions, rilles, chain craters, and domes
Interpretation
Pyroclastic material probably derived from several types of depressions believed to be volcanic vents

Bright edge material

Cs

Characteristics
Has highest albedo of any lunar material. Occurs on steep slopes on the inner walls of craters
Interpretation
Exposed rock scarp and talus. Most talus is derived from bedrock underlying steep slopes, especially near top of crater walls

Materials of rayed craters

Cc Ccr Ccrh Ccrr Ccrm Ccw Ccf Ccp

Characteristics
Cc, *crater materials, undivided. The small to be subdivided into individual units. Craters smaller than 2 km set shown. In craters larger than 4 km, divided into:*
Ccr, *rim material, undivided. Forms surface sloping outward from very sharp rim crest of craters La Condamine F and La Condamine T. In larger craters divided into:*
Ccrh, *rim material, hummocky. Forms rough slopes adjacent to rim crest. Around Herpalus, surface has high local relief; discontinuous ridges and valleys grade outward from sharp uncultured rim to unit Ccrr. Around Bouguer, topography is smoother*
Ccrr, *rim material, radial. Low ridges subradial to crater. Braided "birdfoot" texture formed by irregular subdued craters lying between tangential ridges that trend obliquely away from the primary crater. Contacts with units Ccrh and Ccrm are gradational*
Ccrm, *mixed satellitic crater and mare materials. Abundant patches and stringers of small craters exhibiting braided texture (as in Ccrr) subradial to crater Harpalus. Craters sharper in appearance and less densely distributed than in unit Ccrr. Mare surface is visible between craters. Unit is distinguishable on Lunar Orbiter photography and corresponds generally with distribution of moderately bright ray materials on telescopic photographs*
Ccw, *wall material. Forms hummocky terraces on lower inner slopes of craters Herpalus and Bouguer; smooth in La Condamine T. Darker than unit Cs*
Ccf, *floor material. Forms relatively level, hummocky or smooth surface in central part of crater*
Ccp, *ejecta material. Forms irregular hills with local relief of 250 to 350 meters in floor of crater Herpalus*
Interpretation
Fresh bright ejecta (on rim) and fallback (on wall) of small impact craters
Ccr, *ejecta from impact (La Condamine F) or volcanic crater (La Condamine T)*
Ccrh, *ejecta, decreasing thickness away from crater rim. Contains overturned and thrusted rocks derived from underlying units and overlain by fragmental layer of mixed rock debris*
Ccrr, *like ejecta deposits forming nearly continuous blanket*
Ccrm, *this to discontinuous field of secondary impact craters, not completely masking mare material*
Ccw, *talus and slump blocks on slopes which have become stable, allowing exposed material to darken*
Ccf, *volcanic materials or brecciated debris and fallback covering true crater floor to variable depths. Includes some mixed wall materials*
Ccp, *materials probably uplifted from below present crater floor. May be locally intrusive or volcanic*

Materials of ray craters

Cc Ccr Ccrh Ccrr Ccw Ccf

Characteristics
Materials of craters having predominantly sharp rim crests and locking bright halo and ray material. Albedo generally intermediate; locally high to low
Cc, *crater materials, undivided. Sharp rim crest and smooth inner wall if intermediate to high albedo. Crescent with adjacent wall shown at outer limit of continuous ray material. Craters smaller than 2 km not shown. In craters larger than 4 km, divided into:*
Ccr, *rim material, undivided. Forms gentle inward-sloping surface from rim crest to adjacent units. Generally has sharp rim crest and less density of small craters. In crater Herschel, divided into:*
Ccrh, *rim material, hummocky. Outer slope of moderate relief forming narrow ring around rim crest*
Ccrr, *rim material, radial. Moulding material having slight radial lineation (visible only on Orbiter photography) and delineated most easily where it overlies mare material. Similar to unit Ccrr but lettered detail less sharp. Contacts with units Ccrh and Ccrm are gradational. Albedo low to intermediate*
Ccw, *wall material. Forms smooth wall surface of intermediate albedo*
Ccf, *floor material. Forms smooth, flat surface in crater bottom. Of small areal extent except in crater Herschel where it is topographically similar to unit Ccf*
Interpretation
Crater rim freshness and lack of rays and bright halos are criteria for age assignment
Ec, *small impact or volcanic crater*
Ecr, *ejecta from impact or volcanic eruption from associated crater*
Ecrh and Ecrr, *similar to units Ccrh and Ccrr*
Ecw, *fallback, talus, and bedrock on relatively stable slopes. Probably darkened by age*
Ecf, *brecciated debris and fallback covering true crater floor and being encroached on by material transported downslope from wall. In Herschel unit may reflect built-up volcanic materials or structurally unsurveyed original crater floor*

Mare materials

Elm
Im

Characteristics
Comparatively smooth dark plains materials of Sinus Roris, Mare Frigoris, Sinus Iridum (south of the quadrangle), and Mare Imbrium. Minor positive relief is produced by scarps and ridges trending predominantly northeast
Elm, *material having low albedo*
Im, *material having low albedo and higher density of small craters than unit Elm*
Interpretation
Series of volcanic flows which have filled the mare basins and crater floors and are thus younger than the basins, Scarps and ridges may reflect subsidence, faulting and (or) lower intrusive and extrusive features. This deposits of mare material appear to overlie the low-lying Iridum crater ejecta blanket and remnants of the Fra Mauro Formation on the south and extreme northeast; thick deposits overlie deeply-faulted terra on the north
Elm, *lava flows probably younger than those of unit* Im
Im, *lava flows*

Plains-forming material

Ip

Characteristics
Smooth, nearly level material occupying low-lying areas of the terra. Crater density and albedo are slightly higher than those of mare units, slightly lower than Iridum crater rim materials, and substantially lower than the Fra Mauro Formation. Areal extent increases toward the distal margins of the Fra Mauro Formation in the northwestern part of the quadrangle. Quarried where buried beneath Bouguer rim materials (Ccrr); may be mare material instead
Interpretation
Probably volcanic flows extruded into topographically low areas from local sources. Upper surface may be comminuted fine material or pyroclastic cover. Higher crater density and embayment by mare material indicate that unit is older than mare materials

Crater materials

Ic$_2$ Icr$_2$ Icw$_2$ Icf$_2$ Icg$_2$

Characteristics
Slightly to moderately subdued crater rim and interior materials. Most occurrences are superposed on Iridum crater radial rim material (Iir); other occurrences are morphologically similar. Less to moderate crater density and subdued terraces in larger craters
Ic$_2$, *crater materials, undivided. Craters are 2 to 4 km in diameter, and are commonly more irregular and shallower than Ec craters. Too small for units to be subdivided. Contact with adjacent units placed slightly outside rim crest to include rim materials. Morphologically sharper than* Ic$_1$ *and more subdued than* Ec
Icr$_2$, *rim material. Forms outward-sloping generally smooth surface from rim crest to adjacent units; hummocky and irregular in areal plan*
Icw$_2$, *wall material. Forms smooth inner wall surface similar to* Ecw. *On steep wall in crater Bianchini (40 km in diameter), unit is concentrically terraced and apparently faulted*
Icf$_2$, *floor material. Forms smooth or hummocky, generally level surface. Lower depressions in the floors of craters La Condamine C (in) and Marapertius (Ic$_1$f) are intrinsic to the unit and do not reflect the structural grain which dominates the crater rims*
Icg$_2$, *peak material. Forms irregular hills in floors of craters Bianchini (unit has local relief of 800-850 meters) and Foucault (local relief 125-150 meters)*
Interpretation
Ic$_2$, Icr$_2$, and Icw$_2$, *ejecta deposited by impact and locally by volcanic events. The mechanisms of explosion, eruption, and collapse all may have contributed to the formation of the original crater. Where mapped on terra north of Sinus Roris and Mare Frigoris, unit may be locally equivalent to unit* Iisc
Icf$_2$, *volcanic or possibly impact breccia floor-filling materials. In craters La Condamine and Marapertius, unit is younger than the original crater rim, wall, and floor material (may even be younger than Imbrian) as well as younger than the post-crater tectonic deformations caused by the Imbrium and subsequent Iridium impacts; in these occurrences unit probably formed by later volcanic floor-filling. Lesser depressions result from tectonic collapse pseudoconspicuous with volcanism*
Icg$_2$, *uplifted subfloor materials, possibly intrusive and partly volcanic*

Rim materials of Iridium crater

Iirh Iirr

Characteristics
Positive units surrounding Sinus Iridum (south of quadrangle)
Iirh, *rim material, hummocky. Forms multiple ridges and scarps concentric with Sinus Iridum. Scarps face toward Sinus Iridum, are discontinuous, and have generally steep slopes. Maximum local relief is 500 meters in the quadrangle but exceeds 2500 meters at Promontory Cliffs (southeast of quadrangle). Rim of Sinus Iridum crater and material (Iw) as mapped in Sinus Iridum quadrangle (Schaber, 1969)*
Iirr, *rim material, radial. Hummocky material with moderate relief, distributed radially on terra around Sinus Iridum. Subjacent topographic features are decreasingly subdued for approximately the first 140 km from the rim crest; rim of crater Maupertuis and unnamed crater remnant northeast of Bianchini are very subdued, and rim of crater La Condamine is moderately subdued and crossed by northeast lineaments radial to Sinus Iridum. Distribution of fresh small craters (<2 km, not mapped) on surface of unit is nonuniform; those larger than 2 km in diameter are abundant in east half and sparse in west half. Ridged pattern indicates areas where formation may be thin and underlying unit exposed*
Interpretation
Materials of crater formed by impact before filling by mare material of Sinus Iridum
Iirh, *disturbed basement material from inner part of original Iridium crater, partly thrust outward and partly ejected by the impact. Inward-facing scarps reflect collapse of former highly unstable slopes*
Iirr, *ejecta blanket derived from Iridium crater. Unit appears to thin outward as suggested by subdued older crater materials. Probably overlies Fra Mauro Formation. Radially distributed lineaments, rilles, and ridges may reflect either surficial depositional patterns or subsurface structures. Big either interpretation the features have a genetic relationship to the Iridium crater*

Crater materials

Ic$_1$ Icf$_1$ Icw$_1$ Icf$_1$

Characteristics
Crater materials which are subdued and highly lineated or obscured, having substantially filled floors and moderately high density of craters (some 2-4 km in diameter) on rims. Materials of Iridium crater rim, Bouguer, Maupertuis and Marapertius C mapped as buried
Ic$_1$, *crater material undivided. Rim crests and arcuate remnants are too subdued to differentiate rim and wall units*
Icr$_1$, Icw$_1$, *and* Icf$_1$ *are similar to corresponding upper Imbrian units except they are more irregular and densely cratered, and walls, terraces, and floors are more subdued*
Interpretation
Ic$_1$, *crater materials of early Imbrian age cut by structural patterns and buried by ejecta deposits of the Iridium crater. Origin uncertain*
Icr$_1$, Icw$_1$, *and* Icf$_1$, *reworked, eroded, and locally volcanically covered ejecta and breccia of original crater materials. Quarried buried units of Maupertuis contain strong northeast lineaments of Iridium structure and weak northwest lineaments of possible Imbrian structure; fault scarp on southeast wall is much younger than original crater wall; crater may be as old as pre-Imbrian*

Fra Mauro Formation

If

Characteristics
Forms undulating hummocky surface occupying most of terra north, and some south,of Sinus Roris and Mare Frigoris. Pronounced lineated texture trends north and northwest on a regional scale. Curvilinear, roughly concentric lineaments occur on floors of craters South and J. Herschel. Isolated irregular hummocks in more areas (queried) are mapped on basis of relief which is intermediate between that of units plu and Iirr but identification as Fra Mauro is uncertain. Ruled pattern indicates areas where formation may be thin and pre-Imbrian material locally exposed
Interpretation
Ejecta mantle of varying thickness derived from the Imbrium basin south of the quadrangle. Probably deposited as base-surge deposits from large source area. Unit appears in this regionally to the north and is mappable 100 to 150 km north of the quadrangle boundary. Lineaments in unit reflect both primary depositional patterns or subsurface structural elements possibly resulting from Imbrium or Iridium impact events. The curvilinear patterns in craters South and J. Herschel are generally concentric to the old crater rims and probably reflect structures in the buried crater floor material (plcf)

Undivided terra material

plu

Characteristics
Forms rugged ranges such as Montes Recti (1050-1100 meters relief) in Mare Imbrium, Foucault A (1450-1500 meters relief) on the southern edge of Sinus Roris, and small areas of Montes Jura
Interpretation
Montes Recti is part of a discontinuous inner rim around the Imbrium basin, probably composed of deformed basement rock. Unit in other areas may represent similar basement rocks exposed through or buried by younger deposits. Whether these are tectonically related to the Imbrium or Iridium basins cannot be determined. May be covered by thin layer of Fra Mauro Formation

Buried crater materials

plcr plcf

Characteristics
plcr, *rim material. Forms outer and inner slopes of large subdued arcuate to polygonal ridges enclosing craters of northern terra that are very broad relative to their depth and that have many subdued craters*
plcf, *floor material. Forms broad level plains with high crater density, subdued hummocks, and curvilinear ridges and rilles*
Interpretation
Origin unknown. Floor material probably includes materials both contemporaneous with and younger than the rim material. Subsurface structure of floors possibly is reflected through the thin overlying Fra Mauro Formation

Mare ridge

mr

Characteristics
Curvilinear or sinuous ridge; locally flat or irregular on top. Line marks approximate crest. Arrow indicates plunge direction of crest. Largest segments with lobe-shaped outlines are shown as geologic unit (mr)
Interpretation
Structurally controlled fissure volcanic complex. May be substantially younger than units Im and Elm

Contact

Solid where well defined; long dashed where approximately located; short dashed where predominantly queried where indefinitely located

(plcf) Concealed contact
Buried unit indicated by symbol in parentheses

Fault

Dashed where approximately located. Bar and ball on approximately downthrown side; barbless where fault scarp against which younger rocks were deposited (on side with hachures)

Iridium crater rim crest
Approximate crest line of Iridium crater rim formed by Montes Jura

Rilles

Narrow depression with straight or meandering pattern. In places feature terminates at crater edge. Where well exposed, walls are steep and smooth
Interpretation: Straight rilles: graben or volcanic collapse reflecting subsurface structural control. Meandering rilles: possibly erosion channels produced by high-velocity volcanic flows. Locally subdued by overlying deposits

Scarp

Curvilinear break in slope, generally continuous over many kilometers. Line marks base. Barb points downslope. Dashed where slope change is gentle or gradational
Interpretation: Formed by buried fault or intrusion

Terra ridge

Linear hill, 5 to 10 km long. Irregular or asymmetric in profile. Commonly occurs in groups of parallel ridges and intervening valleys. Line marks approximate crest
Interpretation: Buried structural blocks or possibly basin-related depositional and structural ridges

Lineament

Gentle linear depression in terra; average length 10 to 20 km. Commonly discontinuous and relatively straight
Interpretation: Surface expression of structural feature, reflecting fracturing or faulting along zones of crustal weakness

Concealed crater

Symbol indicates rim crest. Queried where interpretation of feature is uncertain

Dome material

d

Characteristics
Forms very smooth domical hills, 100 to 200 meters high. Most common on mare plains. Sparse occurrence on terra; notable example is in unit Cd on buried floor of crater J. Herschel. Locally occurs in crater floors, but too small to map except in La Condamine
Interpretation
Volcanic cone or lucolithic body

Slump material

sl

Characteristics
Forms irregular crescent-shaped or lobate terrace near crater floor
Interpretation
Landslide or talus deposits at base of steep crater walls resulting from mass wasting

Chain-crater material

ch

Characteristics
Unit forms linear depression having scalloped edge and consisting of rimless to low-rimmed sliced or composite overlapping craters, 6 km or less in diameter
Interpretation
Volcanic craters or collapse depressions which reflect structural zones in the subsurface. Some may be secondary impact craters

Rimless or low-rimmed depression

rd

Characteristics
Smooth circular depression having very subdued rounded rim or no rim expression at all. Occurs within low albedo area on floor of crater J. Herschel (unit Cd) and on mare. Unit occurs locally along scarp or rille trends
Interpretation
Possibly explosion or collapse calderas. May be vents from which unit Cd in J. Herschel was erupted. Unit appears to be structurally controlled by scarps or rilles

INTRODUCTION

Lunar surface materials are classed into units on the basis of visual observations and data from telescopic and Lunar Orbiter photographs. Each unit has a distinctive range of physical characteristics, such as topography and albedo (reflectivity under full-Moon illumination), and is considered analogous to a terrestrial rock-stratigraphic formation. These characteristics rather than lithologic properties must, of necessity, suffice to define the units; however, the morphologic nature of most mappable units on the Moon is, of itself, suggestive of a certain lithologic composition, based on analogous terranes on Earth. Superposition and cross-cutting relations and degree of crater density are used to arrange the units in chronologic sequence. These units according to relative age; they can then be grouped into time-stratigraphic units. Following terrestrial convention, the major time-stratigraphic units are designated systems, each of which corresponds to a period of geologic time (Shoemaker, 1962; Shoemaker and Hackman, 1962; McCauley, 1967; Wilhelms, 1966). Each unit is given either a descriptive designation or a formal stratigraphic name and a letter symbol composed of an abbreviation of its age assignment (capital) and name (lowercase). Mappable units are referred to as materials, recognizing that their lithologic compositions are not presently known and probably complex in larger scales. Features such as ridges, inferred faults, and lineaments (indistinct linear features) are indicated by symbols similar to those used on terrestrial geologic maps. The units are described in chronologic order in the map explanation, and their observed characteristics and an interpreted origin that seems consistent with these characteristics are briefly summarized.

GEOLOGIC SUMMARY

The J. Herschel quadrangle in the northwest quadrant of the Moon's earthside hemisphere includes parts of four major provinces, whose surface characteristics are a basis for interpreting the geologic history of the region. The first province is the terra in the north; its surface textures are grossly radial to the large, circular, multi-ring Imbrium basin centered 300 km southeast of the quadrangle, and it appears to be largely covered by ejecta from that basin. Second is the rougher terra in the south, composed of Imbrium basin materials that are structurally modified and extensively mantled by younger materials derived from the smaller crater (or basin) underlying Sinus Iridum (220 km in diameter, just south of the quadrangle). The third is the mare province, occupying the low-lying areas of the terra between the northern and southern terra and roughly symmetric with the Imbrium basin. The fourth province is represented by very small areas of Sinus Iridum at the south edge of the quadrangle and the small part of Mare Imbrium in the southeast corner of the quadrangle surrounding Montes Recti. The mare plains materials of the third and fourth provinces probably vary in age but they overlie and therefore are younger than the partly buried Imbrium and Iridum basins.

The oldest recognizable materials of the J. Herschel quadrangle are in the northern terra, whose dominant features are densely cratered and faulted remnants of large polygonal craters such as J. Herschel (155-175 km in diameter). The origin of these craters and the history of the region prior to their development is unknown. Their degradation by subsequent cratering, tectonic deformation, and mantling by younger impact and volcanic deposits is inferred to have occupied a longer period of time than the formation of any other features in the region. The crater J. Herschel is covered by earliest Imbrian units and thus is of pre-Imbrian age, probably early pre-Imbrian considering its extreme degradation.

The first discernible event of regional magnitude was the formation of the generally circular multiring Imbrium basin. This event, which marks the beginning of the Imbrian Period, produced structural and depositional features that dominate a large part of the earthside hemisphere. In the J. Herschel quadrangle, the troughlike depression filled by the mare plains of Sinus Roris and Mare Frigoris, the rugged inner basin rim represented by Montes Recti, and the terra between the Roris-Frigoris and Imbrium-Iridum maria are all roughly concentric—and structurally related—to the Imbrium basin. Presumed Imbrium basin ejecta (Fra Mauro Formation) blankets the northern terra of the quadrangle, including the rims of the polygonal pre-Imbrian craters. This thin mantling deposit is near the periphery of the Imbrium ejecta, grading northward from hummocky to smooth, and is considered equivalent to the transition zone of the Fra Mauro Formation south of the Imbrium basin (Eggleton, 1964, p. 82; 1965; Wilhelms, 1966, p. 268; 1968). The oldest craters superposed on it, Horrebow A and Robinson, are early Imbrian in age.

The next event of regional significance was the formation of the large (250 km) partly rimmed Iridium crater which forms the basin embayed by the mare material of Sinus Iridum (Schaber 1969). The exposed segment of the hummocky crater rim (Iirh) forms the Montes Jura and grades outward into a radial facies (Iirr) that blankets most of the terra in the southern and central parts of the quadrangle. Within and outside the outer portions of the radial facies are irregular satellitic craters (Iisc), 5-10 km across, which are generally radial to the Iridium crater. Iridium deposits overlie the Fra Mauro Formation, indicating that the Iridium crater-forming event was a discrete, post-Imbrian occurrence, contrary to Urey's proposal (1962, 1968) that the Iridium and Imbrium basins are products of the same event. The Iridium basin is considered to be younger than the Imbrium by only a small interval. Several early Imbrian craters including La Condamine, Maupertuis C, and possibly Maupertuis were formed after Fra Mauro Formation but before Iridium, and several late Imbrian craters including Bianchini and Foucault overlie Iridium ejecta.

After the Iridium event, smooth plains material (Ip) was deposited in depressions within the terra, so that it now embays the rougher Imbrian and Iridium deposits. It resembles the Apennine Bench Formation of Hackman (1966) and the Cayley Formation of Morris and Wilhelms (1967), both units of Imbrian age.

Most smooth mare plains material with low albedo has been regarded as latest Imbrian in age because mare material underlying deposits of the crater Eratosthenes and overlying those of Archimedes is considered that age by informal definition (Wilhelms, written comm., 1969). One unit in the J. Herschel quadrangle has similar overlap relations; crater material of J. Herschel F, a little younger than Archimedes, is overlain by mare material (Im), and the mare material in turn is overlain by ejecta from the crater Horrebow, a little older than Eratosthenes. The other regional mare unit in the quadrangle (Elm) is darker, smoother, and apparently younger and is assigned Imbrian or Eratosthenian age. A third, local mare unit (Cm) in the floor of J. Herschel F crosscuts Copernican ray material and is thus Copernican in age.

The mare material of Sinus Roris and Mare Frigoris appears to be thickest near its northern border, where the mare-terra contact is abrupt and generally rectilinear. Toward the southern border, the mare material only partly inundates the subjacent floors of remnant craters (Ic$_2$ and Ic$_1$), northern outliers of Iridium ejecta (Iirr), and secondary craters (Iisc) from the Iridium crater.

The period of regional mare filling was followed by a series of cratering events and deposition of ejecta on both mare and terra which has continued at varying rates through the most recent geologic history of the region. The oldest of these events produced the now-denuded radial ejecta (Ecrr) from Horrebow superposed on the mare surface and possibly the partly degraded rim materials of craters superposed on the terra, including La Condamine A and Maupertuis A. These craters are assigned an Eratosthenian age.

The youngest craters are those that are fresh-appearing, have sharp rim crests and well-preserved radial ejecta facies, and are surrounded by rays. Tycho, Copernicus, Harpalus, Bouguer, La Condamine B, and several smaller bright-halo craters have rays that cross mare and locally on the terra. La Condamine T has dark radial ejecta which overlies Copernican ray material and is thus Copernican in age.

On the eastern side of the floor of the crater J. Herschel, a smooth, dark, presumably pyroclastic deposit (unit Cd) is associated with several rilles, low-rimmed-to-rimless craters, chain craters, and a steep-sided dome (Ulrich, 1966). This unit is considered to be Copernican in age because it apparently covers part of a bright-halo crater.

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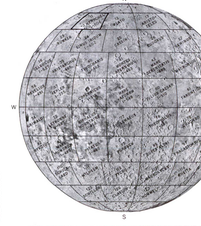
COPERNICAN SYSTEM
ERATOSTHENIAN SYSTEM
IMBRIAN SYSTEM
PRE-IMBRIAN
Upper
Lower



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

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