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
MAUROLYCUS QUADRANGLE
I-695 (LAC 113)

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 Paper No. 15, "Coordinates of Lunar Features", March 1965. The assumed lunar figure is that of a sphere corresponding to the mean lunar radius of 1738 kilometers. Supplementary positions are developed in the chart area as an extension of the primary control.

Primary control positions .... ⊕
Supplementary control positions .... △

ELEVATIONS

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

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

Lengths of radius vectors to control points .... ⊕ or △ 1741.9
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.

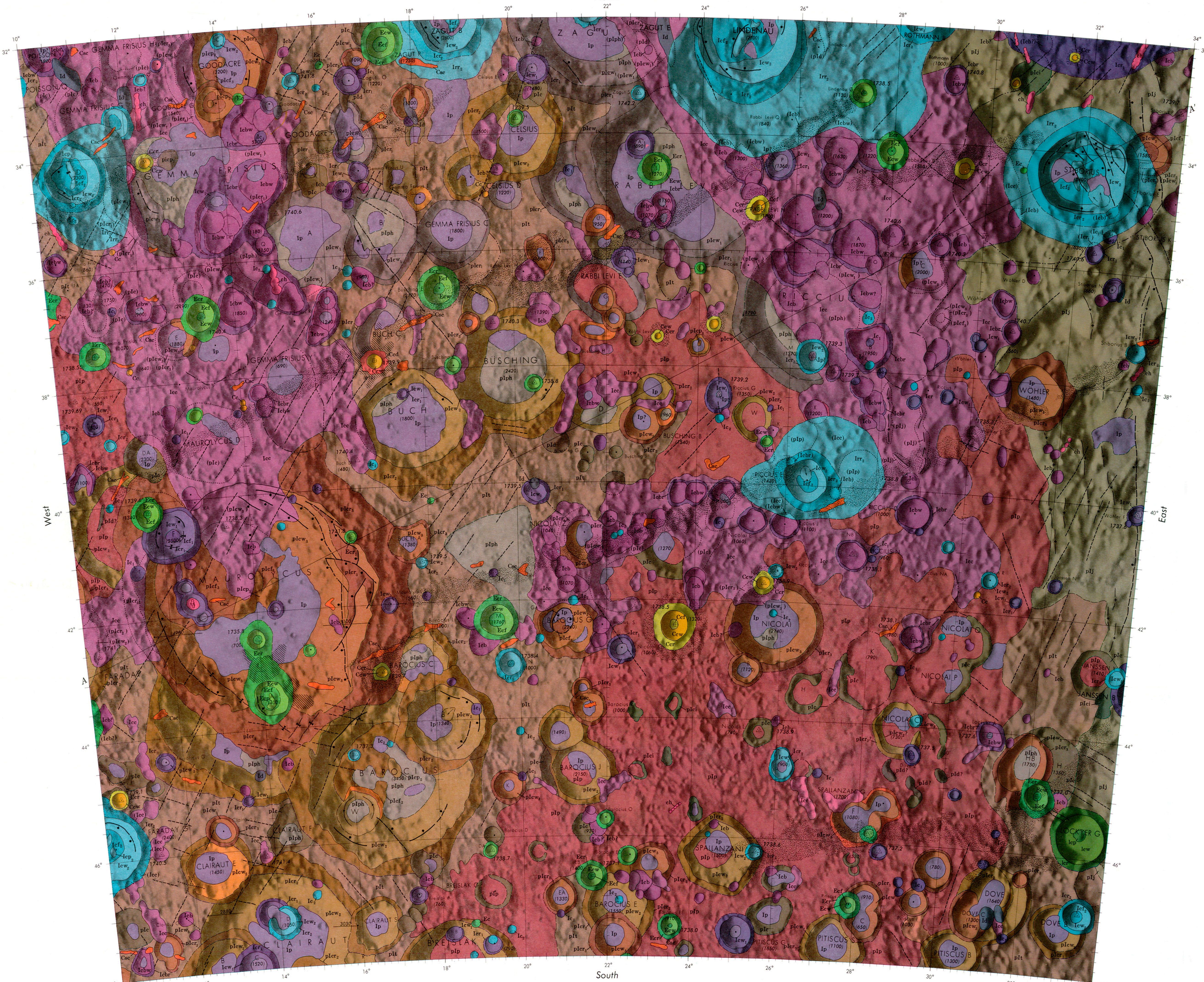
Supplementary features are associated with the named features through the addition of identifying letters. Craters are identified by capital letters. Eminences are identified by Greek letters.

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

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



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

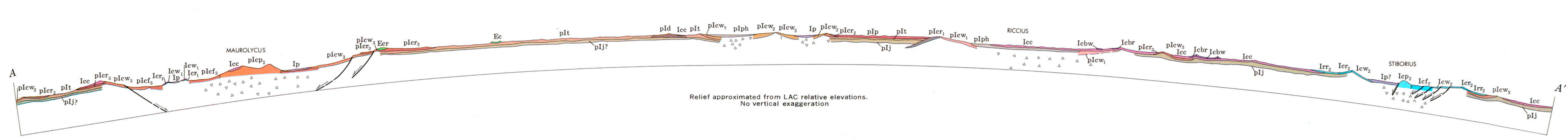
STATUTE MILES
KILOMETERS

Lunar base chart LAC 113, 1st edition, 1966, by the USAF Aeronautical Chart and Information Center, St. Louis, Missouri 63118

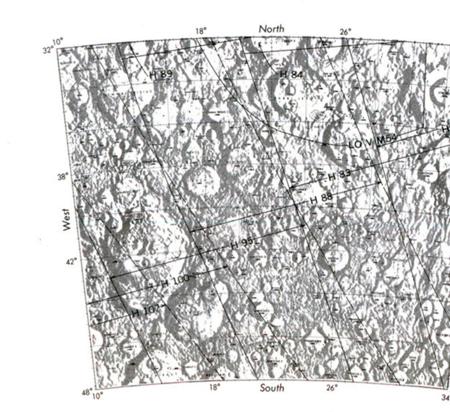
INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1972—G71026

Principal sources of geologic information: Lunar Orbiter IV high-resolution (identification resolution, 100 m) photographs, frames 76, 83, 88, 95, and 100 (see index map); low-illumination and full-Moon photographs from Lick Observatory and full-Moon photograph 5819 from U.S. Naval Observatory, Flagstaff, Arizona. Mapped 1969–1970

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

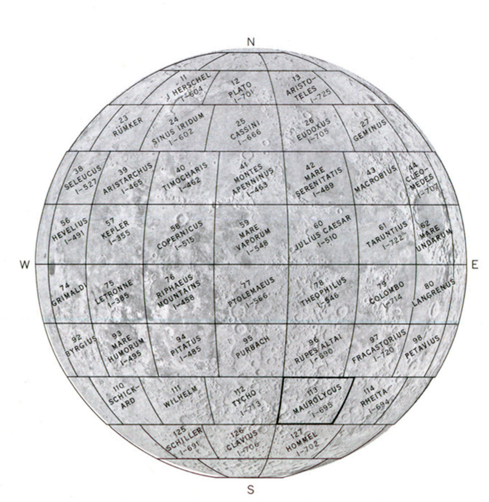


Relief approximated from LAC relative elevations.
No vertical exaggeration



LUNAR ORBITER PHOTOGRAPHIC COVERAGE OF MAUROLYCUS QUADRANGLE

All numbers refer to Lunar Orbiter IV high-resolution frames except LO V M54, Orbiter V medium resolution



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

GEOLOGIC MAP OF THE MAUROLYCUS QUADRANGLE OF THE MOON

By

David H. Scott

1972

EXPLANATION

COPERNICAN SYSTEM

Ccd

Dark-halo crater material

Characteristics
Forms dark halo and rays visible on full-Moon photographs around crater Buch B (8 km diameter). Rays appear to interrupt rays of Tycho

Interpretation
Possibly volcanic; dark material may have deep-seated origin. Apparent superposition of dark rays on Tycho rays and a high infrared thermal anomaly indicate late Copernican age

Light | Dark

Ray material

Characteristics
Light rays occur as diffuse streaks extending across quadrangle and approximately radial to large craters Tycho and Stevinus outside map area. Also form bright halos around smaller Copernican craters. Dark rays surround Buch B and extend locally from Maurolycus A

Interpretation
Light rays comprise fresh rock fragments and secondary impact craters extending outward from Copernican craters. Dark rays may be new volcanic material from explosive maar-type vents or dark colored ejecta. Around Maurolycus A the dark rays may be older than Copernican

Cc | Ccr | Ccw | Ccf

Materials of rayed craters

Characteristics
Craters having most of the following: sharp rim crest, bright halo, high albedo, large local relief, high infrared thermal anomaly, and strong interior shadow contrast at Orbiter IV high photographic resolution
Cc, *crater material, undivided. Craters <3-km rim-crest diameter*
Ccr, *rim material. Forms steep, smooth-appearing, concave-upward surface extending outward from rim crest. Rim crest circular in outline and has marked increase in slope near summit*
Ccw, *wall material. Smooth interior wall of crater. High albedo. (Mapped on previous maps as "bright slope material" and shown as younger than other crater materials)*
Ccf, *floor material. Appears gently domed in craters >10 km; in smaller craters merges with wall material*

Interpretation
Cc, *primary impact craters or impact craters secondary to Tycho and Stevinus*
Ccr, *exterior impact ejecta*
Ccw, *freshly exposed talus and bedrock in crater walls; in Buch B may be volcanic material*
Ccf, *fallback and brecciated bedrock, domed by readjustment to compressive stress following impact*

Csc

Secondary crater material

Characteristics
Small, bright, sharp-rimmed, circular to elongate craters occurring in chains, and clusters whose long axes generally are radial to crater Tycho (43.5° S., 10.5° W.) and, in some places, to crater Stevinus (33° S., 54° E.). Crater frequency decreases eastward across map area

Interpretation
Secondary impact craters formed mostly by fragments ejected from Tycho and a few from Stevinus

ERATOSTHENIAN SYSTEM

Ec | Ecr | Ecw | Ecf | Ecp

Materials of sharp-rimmed rayless craters

Characteristics
All units similar to correspondingly lettered units of Copernican craters above, except halos and walls less bright, wall shadows less arcuate, and rim crests slightly subdued.
Ecp, *crater peak material on part of floor of Maurolycus A*

Interpretation
Same as corresponding units of Copernican craters. Lunar erosional processes have slightly modified craters. Central peak and ridged floor of Maurolycus A may be volcanic

IMBRIAN SYSTEM

Upper Imbrian

Ic_2 | Icr_2 | Irr_2 | Icw_2 | Icf_2 | Icp_2

Materials of slightly subdued craters

Characteristics
Ic_2, *crater material, undivided. Craters generally <5 km whose individual units are too poorly defined to map separately*
Icr_2, *rim material. Rims concave upward; a marked break in slope toward rim crests not present everywhere. Rim crests more crenulated and density of craters <3 km greater than in younger craters of comparable size. Rim flanks relatively free of craters >3 km. Outlines of craters >15 km polygonal but incompletely developed. Grades into:*
Irr_2, *rim material radial. Slightly grooved, outward thinning facies of rim material faintly visible around most of the larger craters*
Icw_2, *wall material. In craters <15 km resembles wall units of younger craters but has less slope and interior shadow contrast. In larger craters forms steep, smooth faces as well as hummocky surfaces*
Icf_2, *floor material. In craters >20 km, appears as undulating, gently ridged surfaces; in smaller craters appears smooth*
Icp_2, *peak material. Prominent rounded to subangular ridges and peaks projecting above floors in craters >15 km. Ridges generally alined in NW-SE and NE-SW parallel to sets of polygonal rim crests*

Interpretation
Ic_2, *mostly craters of primary impact origin. Secondary impact craters of the Orientale basin may be present but have not been recognized*
Icr_2, *thick unsorted ejecta deposits of bedrock and breccia. Rim crest polygonality has developed along major lunar fracture systems*
Irr_2, *thin ejecta layers mostly made up of small-sized fragments*
Icw_2, *talus deposits, slump blocks, terraces, and scarps produced by sliding and faulting of materials after impact*
Icf_2, *fallback and fractured, brecciated bedrock*
Icp_2, *faulted and fractured blocks of bedrock uplifted by readjustment to compressive impact stress and possibly by isostatic forces in larger craters. Similar to floor material but with greater relief toward shock center*

Ip

Material of smooth plains

Characteristics
Forms smooth to lightly pitted level floors embaying walls and rims of craters older than Eratosthenian. Some occurrences have the lowest albedo of any unit in quadrangle but compared with whole Moon, intermediate in albedo. Attains greatest extent in craters of pre-Imbrian age. Occurs locally outside craters. Craters of Eratosthenian and younger age superposed on larger patches. Queried where smoothness doubtful because exposures small or indistinct

Interpretation
Volcanic flows and pyroclastics from vents beneath crater floors and in local areas outside craters. Volume appears related to size and age of confining crater. Intermittent volcanism indicated by variations in small-crater density and overlapping flows on floor of Maurolycus. Small patches of material may be post-Imbrian in age

Lower Imbrian

Id

Dome- and hill-forming material

Characteristics
Small ridges, domes, and elongate hills <30 km in length. Slopes moderate to steep and summits rounded to distinct and sharply crested; no summit craters. Axial trends NW to NNW. Locally transect pre-Imbrian and lower Imbrian crater walls and rims and covered by upper Imbrian crater rim material

Interpretation
Piles of lava and pyroclastic materials extruded from fissures and vents along Imbrium basin-radial and lunar grid fracture systems

Ic_1 | Icr_1 | Icw_1 | Icf_1

Materials of moderately subdued craters

Characteristics
Similar to corresponding upper Imbrian crater units but more subdued and the radial facies is not distinguishable, except for material in northeast associated with Piccolomini, outside map area. Rim crest polygonality more pronounced than in younger craters of comparable size. Interior wall channels in some craters. Most floors covered by smooth plains material; in craters <10 km, walls and floors generally indistinguishable

Interpretation
Similar to corresponding units of younger craters. Extended duration of downslope movement has channeled crater walls. Increased polygonality of rim crests may develop by incremental movements along fracture systems as well as protracted erosion along zones of weakness

Icb | Icbr | Icbw

Materials of bowl-shaped craters

Characteristics
Circular, oval, and irregular outlines. Wall-floor boundaries generally indistinct and craters appear shallower than others of comparable size and rim-crest sharpness. Occur radial to Imbrium basin or arcuately transverse to radial direction. Though more subdued, individual shape and shape of clusters like those of secondary craters around large craters such as Copernicus and Tycho and around parts of the Orientale basin
Icb, *undivided. Rim material poorly defined. Queried where characteristics blurred or gradational with those of flat-floored craters*
Icbr, *rim material. Forms relatively narrow rims on level surfaces. Rim crests similar in sharpness to those of lower Imbrian craters but have less relief*
Icbw, *wall material. Distinguished as separate unit in craters with mapped rims (*Icbr*) or floors (smooth plains material). Walls gently concave upward, without channels*

Interpretation
Most craters formed by secondary impact of Imbrium basin ejecta. Some may be volcanic eruptions along fracture systems radial to Imbrium basin

Icc

Crater cluster material

Characteristics
Overlapping groups and chains of bowl-shaped craters whose indivdual members are <10 km. Distinguished from chain craters by less circularity, relatively shallower depths, restricted age range, and, in places, by preferred orientation along Imbrium basin radials

Interpretation
Same as for bowl-shaped craters

PRE-IMBRIAN

Upper pre-Imbrian

$pIcr_3$ | $pIcw_3$ | $pIcf_3$ | $pIcp_3$

Materials of subdued craters

Characteristics
In places overlain by materials of bowl-shaped craters and crater clusters; partly embayed by pitted plains material but superposed on hummocky terra and Janssen Formation. Superposed craters >5 km common on walls and rims. Outlines vary from polygonal to subcircular; larger craters (Maurolycus, Nicolai, Goodacre) more subcircular
$pIcr_3$, *rim material. Hummocky and moderately raised; rim crests crenulated and generally subdued but appear sharp and distinct in places*
$pIcw_3$, *wall material. Terraces subdued and partly coalesced; interior channels well developed*
$pIcf_3$, *floor material. Hummocky to gently undulating; mostly covered by younger materials*
$pIcp_3$, *peak material. Smooth, rounded; prominent only in Maurolycus*

Interpretation
Same as for correspondingly lettered units in younger craters except that decrease in polygonality of large craters may be due to expansion of rims by slumping beyond zone of intense impact-produced fracturing

pIp

Material of pitted plains

Characteristics
Forms extensive level surfaces pitted by numerous small craters and irregular depressions; outlines of buried and partly buried crater rims are visible. Embays the Janssen Formation, hummocky terra material, and craters as young as late pre-Imbrian in age. In places covered by crater cluster material. Lineaments generally obscure but more conspicuous near margins of unit. Albedo intermediate between hummocky terra and smooth plains materials

Interpretation
Volcanic flows and pyroclastic ejecta. Large lateral extent of unit suggests low viscosity during extrusion similar to some terrestrial basalts and ash-flow tuffs

pIph

Material of hummocky plains

Characteristics
Appears as slightly ridged, hummocky surfaces on crater floors of late pre-Imbrian and older age. Outside craters, occurs only in small area east of Maurolycus

Interpretation
Eroded crater floor material and volcanics whose volume was insufficient to completely bury preexisting topography

Middle pre-Imbrian

pIc

Crater material, undivided

Characteristics
Morphological age criteria blurred through partial burial by regional units, and superposition relations with craters of definitive age cannot be established

Interpretation
Origin uncertain, but presumably mainly produced by impact

$pIcr_2$ | $pIcw_2$ | $pIcf_2$ | $pIcp_2$

Materials of highly subdued craters

Characteristics
Similar to correspondingly lettered units of late pre-Imbrian craters but rims more crenulated and have less relief; terraces rounded and highly dissected by interior channels. Queried where partly buried or superposition relations not definitive

Interpretation
Same as for craters of late pre-Imbrian age. Rejuvenation of crater rims by faulting and slumping has ceased

pIt

Terra material

Characteristics
Highly cratered, hummocky, and lineated material generally lying at higher elevations than plains-forming units and Janssen Formation. Lineations strongly developed in NE, NW, and WNW directions. Rims of middle pre-Imbrian age craters appear to merge into this unit (Buch, Büsching) or are superposed on it (Barocius B). Large linear ridges of Janssen Formation and lower pre-Imbrian irregular-rimmed craters not exposed within unit. Exposures along eastern quadrangle boundary and near Gemma Frisius B show ridges and grooves characteristic of Janssen Formation but on diminished scale

Interpretation
Volcanic materials and pre-Imbrian crater rims reworked by numerous impacts. Forms cover of variable thickness which generally obscures Janssen Formation

pId

Dome- and hill-forming material

Characteristics
Forms hills projecting above pitted plains material, and an elongate hill transecting wall of Zagut and buried by crater cluster material. Queried where occurrences may be remnants of crater rims or part of Janssen Formation

Interpretation
Hills and mounds of volcanic material extruded subsequent to early pre-Imbrian impacts and prior to formation of pitted plains

pIj

Janssen Formation

Characteristics
Exposed along eastern quadrangle boundary continuous with exposures in vicinity of crater Janssen, the type locality (Stuart-Alexander, 1971). Forms undulating, faintly braided, grooved but smooth-appearing surface with numerous ridges and hills radial to Nectaris basin. A grid like texture is formed in places by intersecting NW- and NE-trending lineaments. Some ridges asymmetrical; steeper faces toward west. Small craters abundant but blend with ridged texture of unit. Resembles Fra Mauro Formation (Wilhelms, 1970) in general appearance but more subdued

Interpretation
Blanket of impact ejecta from Nectaris basin. Normal faults have relieved tensional stress along radial directions

Lower pre-Imbrian

$pIcr_1$ | $pIcw_1$ | $pIcp_1$

Materials of completely subdued and lineated craters

Characteristics
Subunits lettered as for younger crater materials. Craters moderate to large size and have low-relief rims and walls pitted by numerous craters. Morphologically similar to craters of middle pre-Imbrian age but terraces and original crater floors no longer visible. Grooves and lineaments on walls of Zagut, and possibly Gemma Frisius B, resemble those of Janssen Formation. Crater morphology is primary basis for age classification and all crater materials which appear older than Nectaris basin are assigned early pre-Imbrian age

Interpretation
Same as craters of late and middle pre-Imbrian age. Morphological features useful in distinguishing impact and volcanic craters become obscure with increasing age. Impact origins are generally assumed for larger craters because of size and random distribution

pIci

Material of craters with irregular rims

Characteristics
Similar in outline and profile to bowl-shaped craters of earliest Imbrian age but highly degraded and indistinct. Clusters intersect rim and wall of early pre-Imbrian crater Zagut outside map area and possibly wall of Gemma Frisius B but are unmapped. Also occur as partly buried rims beneath pitted plains material

Interpretation
Probably secondary impact craters of Nectaris basin. Craters partly buried by plains material may have different origin

lcr | lcw | lcp

Materials of the crater Lockyer G

Characteristics
lcr, *rim material. Similar to rim material of Copernican or Eratosthenian age craters of similar size but possibly less extensive*
lcw, *wall material. Resembles bowl-shaped crater walls but brighter*
lcp, *peak material. Abnormally large and smooth compared with craters of similar size and relative morphological age; resembles inverted bowl*

Interpretation
Possible volcanic construction. Possibly like a terrestrial maar in origin

ch

Chain-crater material

Characteristics
Linear group of three or more adjacent or partly overlapping circular craters. Individual craters small (<5 km) and distinguished from Icc by shape and greater depth-to-width proportions

Interpretation
Volcanic craters developed along fractures

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

(pIc)
Buried contact
Shows topographic limit of buried unit indicated by symbol in parentheses

Fault
Dashed where approximately located. Bar and ball on downthrown side. Offsets a unit or forms scarp against which younger rocks deposited

Lineament
Slight linear depression or ridge; may include chains of small craters only partly visible at Orbiter IV high photographic resolution
Interpretation: *Fracture, fault, or volcanic depression developed along major lunar grid and basin-radial systems. Some may be partly buried and enlarged by collapse*

Ridge of Janssen Formation
Line marks crest
Interpretation: *Ridges and hills formed by ejecta deposits from Nectaris basin*

Concealed crater
Line indicates rim crest. Used without letter symbol instead of dotted contacts where subunits not distinct

Ring depression
Semi-circular trough along lower wall of crater Barocius W
Interpretation: *Graben or rim-wall boundary between concentric craters*

Trough
Line marks axis. dashed where discontinuous
Interpretation: *Graben or depression*

Slump block
Arrow shows direction of landslide movement

Breccia lens
Shown on cross section beneath crater floors
Interpretation: *Fractured bedrock produced by impact*

GENERAL INFORMATION

Although geologic mapping of the Moon has its own techniques and problems, systematic observation and the application of established geological principles have allowed the materials and structures of its surface to be delineated and classified into units (Shoemaker and Hackman, 1962; McCauley, 1967; Wilhelms, 1970). Most of these units are material entities similar to terrestrial rock-stratigraphic units and have been arranged in chronological sequence to form a lunar stratigraphic column. Relative ages are determined by superposition, embayment, and cross cutting relations, and by density of superposed craters and degree of topographic freshness (Wilhelms, 1970). In addition, crater morphologies are believed to be age-dependent, and departures from an original crater form can be used to establish relative age classes (Pohn and Offield, 1970). These classes have been dated relative to the units which define the lunar time-stratigraphic systems (Offield, 1971). The most important information, aside from the valuable data obtained from Apollo material samples, is gathered from Lunar Orbiter high-resolution photographs. These photographs have resolutions superior to the best earth-based telescopic observations, and geologic mapping and interpretation have reached a correspondingly high level of confidence.

GEOLOGIC SETTING

The Maurolycus quadrangle, located in the southeastern highlands, includes densely to moderately cratered terrain with many craters larger than 45 km in rim crest diameter. Several appear to be ancient and may be among the most primitive discernible features on the lunar surface. Major stratigraphic units consist of the Janssen Formation, hummocky terra and pitted plains materials, and extensive clusters of bowl-shaped craters. Two of these units, hummocky terra and pitted plains, are probably volcanic whereas the Janssen Formation and bowl-shaped craters appear to have been formed by ejecta from the multi-ringed Nectaris and Imbrium basins outside the quadrangle.

STRATIGRAPHY

The oldest regional unit, the Janssen Formation (Stuart-Alexander, 1971), is exposed in the eastern part of the quadrangle. It forms hilly, hummocky, and gently undulating terrain with long, linear ridges trending north-northeast, radial to the Nectaris basin. In its general appearance and location relative to a multi-ringed basin, the Janssen Formation resembles the Fra Mauro Formation around the Imbrium basin (Eggleton, 1964, 1965; Wilhelms, 1968, 1970) and a similar but fresher unit around the Orientale basin (McCauley, 1968). As these units are believed to be composed of impact ejecta from their respective basins, the Janssen Formation is believed to be ejecta from the Nectaris basin. However, the textures of the Janssen are more subdued than those of the other units and are therefore less diagnostic of origin; furthermore, an outward gradational decrease in surface slopes and amplitude of radial textures like that of the other units is not apparent in the Janssen. Some of the ridges resemble fault blocks which have been tilted slightly to the east. In places there is a faint grid-like texture consisting of intersecting northwest- and northeast-trending lineaments. The surface appears to be old and is covered with innumerable small craters whose indistinct outlines may give a first impression of low crater density and, therefore, of youth. Irregular-rimmed craters and hills with long axes directed toward the basin center were probably formed during deposition of the Janssen Formation. However, age relations between the Janssen Formation and some pre-Imbrian irregular-rimmed craters and hills are uncertain.

The oldest preserved craters in the quadrangle are moderate to large size (30-90 km) and have low-relief rims and walls that are pitted and scarred by numerous craters. Distinct terraces have disappeared, if ever present, and original crater floors are completely covered by younger deposits. All crater materials in the Maurolycus quadrangle which are probably or possibly older than the Nectaris basin are assigned an early pre-Imbrian age; this dating is not inconsistent with the early middle pre-Imbrian age established for the Nectaris basin (Offield and Pohn, 1970; personal communication). The crater Zagut, and possibly Gemma Frisius B, shows direct evidence of being pre-Nectaris, in that grooves radial to the basin and resembling those of the Janssen Formation occur along its walls and rims. Although proof of a pre-Nectaris age is lacking for Rabbi Levi, Riccius, Gemma Frisius and several other craters, they are provisionally placed in this early pre-Imbrian category by reason of the advanced degradation of their forms comparable to the crater Zagut. In addition, there are vague outlines of several large unnamed craters in the northeastern part of the map area approximately 150 km from the outer ring of the Nectaris basin. The craters are buried and almost obliterated by the Janssen Formation; numerous subsequent impacts have contributed to their degradation. Thus, the durability of craters over what appears to be an extensive period of lunar history that even includes burial by a large ejecta blanket is evident. McCauley (1967) has noticed crater forms beneath the Orientale blanket adjacent to the outer rim of the Orientale basin and partly buried but well-preserved craters about 200 km from the edge of the basin.

The origin of the early pre-Imbrian craters, whether by impact or by volcanism, is not known as features diagnostic of an original form are obliterated. However, the random distribution and large size of the craters, contrasted with known terrestrial volcanoes and calderas, suggest an impact origin.

Craters of middle and younger pre-Imbrian age resemble their older counterparts but individual features are less blurred. Nevertheless, modes of origin are not clearly established by morphology.

Lineated hummocky terra material occurs in the generally more elevated western part of the map. Superposition relations with craters and other units suggest an early to middle pre-Imbrian age for the material. However, there are no distinctive characteristics by which "hummocky terra" can readily be recognized and it probably includes a variety of materials, some of which may be widely separate in age. Subdued ridges and grooves occurring locally within the hummocky terra unit are interpreted as thinly covered parts of the Janssen Formation.

Plains materials of younger pre-Imbrian age are assigned to two units: hummocky plains, mostly occurring on the floors of craters, and pitted plains, a regional unit which fills extensive depressions througout the central and southern parts of the area. As its name implies, the pitted plains unit is level and generally smooth but highly pitted by craters of various sizes. The rims of partly buried craters and the outlines of buried "ghost" craters are visible. Lineaments of the lunar grid system (Strom, 1964) are not visible in pitted plains material except near its thinning margins. Bowl-shaped craters of lowermost Imbrian age are the oldest craters known to be superposed on pitted plains and hummocky plains materials.

The clusters of bowl-shaped craters cut across the pre-Imbrian surfaces in two broad bands, one radial to the Imbrian basin and the other an arcuate belt which loops transversely across this direction. Smaller groups of craters within the large clusters generally preserve the basin-radial alinement and, in this respect, resemble terrestrial volcanic chains developed along structural lineaments (Scott and Trask, 1971 However, individual craters generally exhibit the characteristics of secondary impact craters (Shoemaker, 1962); they are relatively shallow, mostly elongate, and usually without distinct floors and rims. They apparently pre-date all other Imbrian craters and their distinctive morphologies and areal distribution point toward a common origin and narrow age range. It is believed that most of the bowl-shaped craters and their clusters were formed by ejecta which impacted along ballistic trajectories from the Imbrium basin (Wilhelms and McCauley, 1971).

Smooth plains materials of Imbrian age are common on crater floors older than Eratosthenian and also fill small depressions within hummocky terra, pitted plains, and the Janssen Formation. Elsewhere on the Moon, materials similar to smooth plains but occurring in larger patches outside craters, have been named Apennine Bench Formation (Hackman, 1966) and Cayley Formation (Morris and Wilhelms, 1967). Although the crater population suggests a predominantly Imbrian age, variations in small crater density are noticeable throughout the smooth plains unit and it is likely that post-Imbrian materials are locally present.

The character and distribution pattern of rim materials and rays of younger craters are distinguishing criteria for either impact or volcanic origins (Shoemaker, 1962). Unlike terrestrial volcanoes and maars, most large craters of Imbrian and younger age have hummocky rims which grade outward into fine-textured radial grooves and ridges; distinct streaks or rays and secondary craters may be present around the younger craters. Also, large lunar craters do not occur as summit features nor are they alined in chains, and are therefore not analogous to terrestrial calderas and maars. However, some small closely-spaced and overlapping craters having circular, low-relief rims and alined along or parallel to major fracture systems probably are volcanic. Other craters having unusual forms, structures, or dark halos, such as Lockyer G, Barocius G, and Buch B, may also be volcanic. The crater Lockyer G has a smooth, rounded, and abnormally prominent central peak resembling an inverted bowl. Though younger, it is similar to the crater Alpetragius, a possible lunar caldera (Howard and Masursky, 1968).

The youngest appearing craters are among the smallest and include clusters whose shape and orientation suggest they have originated by secondary impacts from the craters Tycho and Stevinus of Copernican age.

STRUCTURE

Regional structural patterns shown by the Moon-wide fracture systems are reflected locally by faults, crater chains, polygonal crater rims, and elongate crater peaks and other hills. On a finer scale they appear as lineaments of narrow ridges and grooves. The relative scarcity of lineaments (at Orbiter IV high resolution) on pitted plains material suggests that little movement has occurred along the fracture systems since late pre-Imbrian time and(or) that the surface material is less cohesive than hummocky terra or the Janssen Formation, which do have lineaments.

Faults and lineaments within the Janssen Formation are mostly radial and subradial to the Nectaris basin. In hummocky terra, two conspicuous sets of lineaments are nearly orthogonal and trend approximately N35°E and N60°W. They cross crater rims and walls but not smooth plains material on crater floors. However, similarly oriented lineaments are visible at the higher resolution of Ranger IX photographs within the Cayley Formation on the floor of Alphonsus (Carr, 1969).

Faults and terraces within craters probably develop soon after impact and continue to grow, producing ever widening and rejuvenated crater rims. This process eventually ends when the accumulation of debris along crater floors and the outward diminution of fracture intensity impede further slippage. This type of crater enlargement is similar to terrestrial landsliding where the fault or slip plane is strongly concave upward and extends only to shallow depths. The crater Barocius G is an interesting exception to the usual structure and may be a caldera where collapse has followed the withdrawal of magma from shallow chambers. The central floor of this crater appears to have subsided quite deeply leaving remnants of smooth plains material perched as terraces along the crater walls.

THERMAL ANOMALIES

Infrared thermal anomalies of the eclipsed Moon (Shorthill and Saari, 1969) are believed to be related to the heat conductivity of surface materials and high values most probably occur where fresh rocks are exposed. In the Maurolycus quadrangle infrared thermal anomalies are associated with eight bright-walled craters ranging in age from Copernican to Eratosthenian and, possibly, to late Imbrian. However, the thermal anomaly coinciding with the late Imbrian crater Riccius E may result from a cluster of Copernican secondary craters on its rim. The greatest intensity is shown by the relatively small, dark-haloed Copernican crater Buch B whose temperature is about 22°K higher than its surroundings. As suggested by its high thermal anomaly, Buch B may be the youngest clearly visible Copernican crater in the region; also, its dark rays appear to be superposed upon the bright rays of the very young crater Tycho. Although high thermal response might also be attributed to a volcanic origin for Buch B, the probability seems to be decreased by the association of an abnormally low thermal anomaly with the crater Lockyer G, also suspected to be volcanic. Thermal anomalies may be useful in crater age classifications where other physical properties are not sufficiently diagnostic. For example, the crater Maurolycus A appears to be late Imbrian from morphological evidence but is assigned an Eratosthenian age because it has a moderate thermal anomaly.

GEOLOGIC HISTORY

An original uncratered lunar surface, if it ever existed, is no longer visible. The earliest deformational history is recorded in the ancient highland terrain by the remnants of large craters and possibly by grid-forming lineaments which may have been active during early stages of tectonic activity.

The Janssen Formation, the oldest regional unit, was deposited as an ejecta blanket by the large impact which produced the Nectaris basin during early to early middle pre-Imbrian time. Older landforms of small to medium size were probably buried by the Janssen Formation but it did not completely obscure large craters. Stresses which developed during the crustal rupture were relieved along fractures and faults radial to the Nectaris basin.

Volcanism on a regional scale extended from middle to late pre-Imbrian time. Extrusions forming hummocky terra were succeeded by pitted plains materials which were more fluid and filled large depressions and crater floors, buried crater rims, and covered a large part of the Janssen Formation.

The Imbrian Period began suddenly and catastrophically with the large impact which formed the Imbrium basin about 1800 km away. In the Maurolycus region, tangible evidence of the impact is in the form of large clusters of craters having physical characteristics and age relations indicative of secondary origins from the Imbrium basin. Active cratering occurred throughout the Imbrian Period but waning volcanism is suggested by a decrease in areal extent of plains deposits which are mostly restricted to crater floors. Elsewhere on the Moon, volcanism was much more extensive in the Imbrian Period, and deposition of mare materials closed the period.

During the Eratosthenian and Copernican Periods no major craters were formed in the Maurolycus quadrangle. The large crater Tycho was produced by an impact about 400 km to the west during Copernican time and secondary chains and clusters formed by the impact are scattered over the region. The apparent decrease in frequency of occurrence of large size craters may be due to a lower flux rate of large meteoroids during the later evolutionary history of the Moon.

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