DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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 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 due to foreshortening.

Lengths of Radius Vectors to control points ⊕ or △	1736.7
Depths of craters (rim to floor)	(400)
Relative elevations (referenced to surrounding terrain) with direction and extent of measured slope indicated	410

NAMES

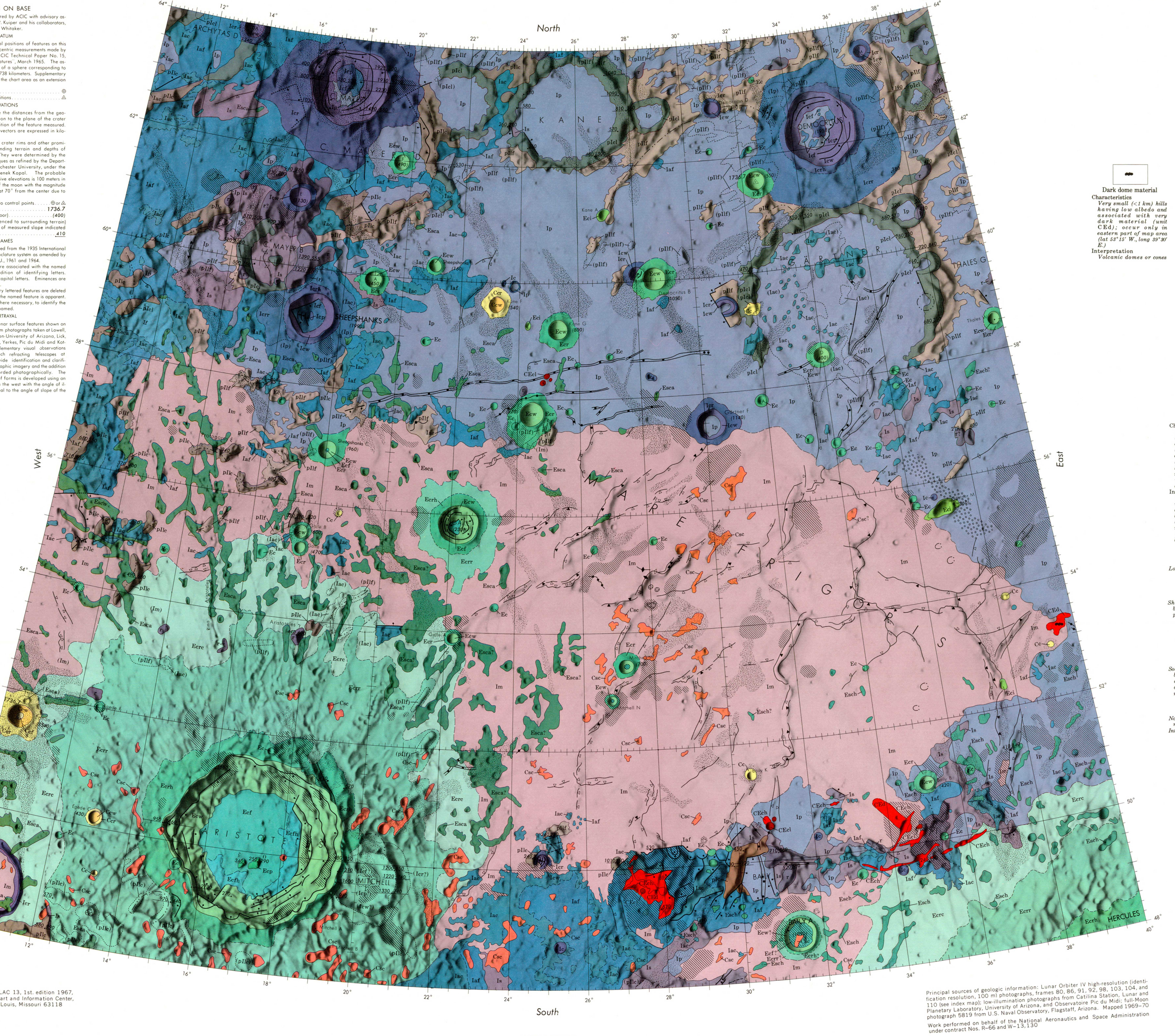
Feature names were adopted from the 1935 International Astronomical Union nomenclature system as amended by Commission 16 of the I.A.U., 1961 and 1964.

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.

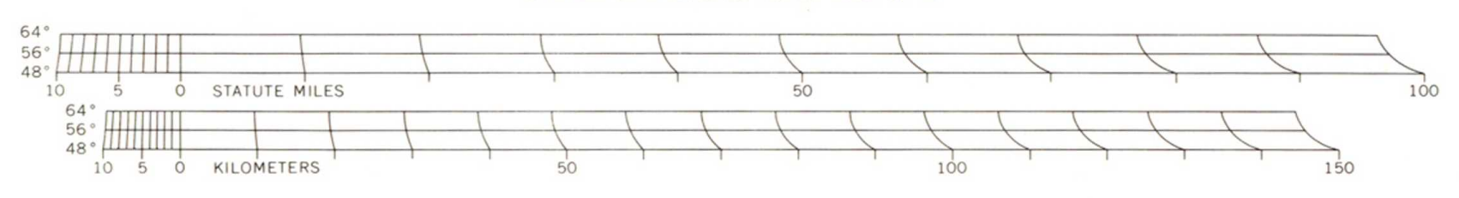


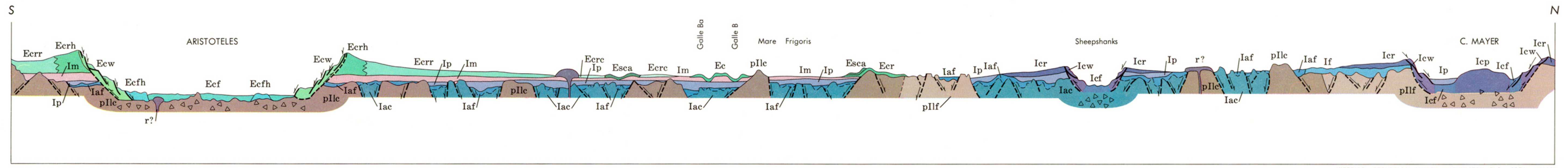
Lunar base chart LAC 13, 1st edition 1967, by Aeronautical Chart and Information Center, U.S. Air Force, St. Louis, Missouri 63118

Principal sources of geologic information: Lunar Orbiter IV high-resolution (identification resolution, 100 m) photographs, frames 80, 86, 91, 92, 98, 103, 104, and 110 (see index map); low-illumination photographs from Catilina Station, Lunar and Planetary Laboratory, University of Arizona, and Observatoire Pic du Midi; full-Moon photograph 5819 from U.S. Naval Observatory, Flagstaff, Arizona. Mapped 1969–70

Work performed on behalf of the National Aeronautics and Space Administration under contract Nos. R–66 and W–13,130

SCALE 1:1 000 000
LAMBERT CONFORMAL PROJECTION
STANDARD PARALLELS 53°20' AND 47°40'





Diagrammatic cross section. Large vertical exaggeration

GEOLOGIC MAP OF THE ARISTOTELES QUADRANGLE OF THE MOON

By
Baerbel Koesters Lucchitta
1972

PREPARED IN COOPERATION WITH THE
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION AND THE
USAF AERONAUTICAL CHART AND INFORMATION CENTER

EXPLANATION

COPERNICAN SYSTEM

Cc Ccr Ccw Ccf

Materials of rayed or bright-haloed craters

Characteristics
Cc, rim, wall, and floor materials, undivided. Craters <5 km rim crest diameter; high albedo, sharp rims. In larger craters divided as follows:
Ccr, rim material. Rim crest sharply raised, circular to slightly polygonal, locally crenulated. Irregular, faint radial ribbing toward outer margin
Ccw, wall material. Steep, smooth, very bright
Ccf, floor material. Small ridged area in crater Egede A; albedo low
Interpretation
Young craters. Impact origin suggested by relatively high depth-to-width ratio, sharpness and height of rim, and bright extensive rays. Some small craters possibly of volcanic origin

▨

Ray material

Characteristics
Bright, diffuse streaks extending across map area mainly in southeasterly and southwesterly directions. Bright halos and streaks around sharp-rimmed craters. No visible topographic expression
Interpretation
Very thin blanket of fine ejecta from Copernican impact craters, and bright slope material in associated secondary impact craters. Sources of large streaks (outside quadrangle) are large craters Anaxagoras (lat 74° N., long 10° W.) and Thales (lat 62° N., long 50° E.). Rays obliterated by erosion around older craters

Csc

Satellitic crater material

Characteristics
Rim and wall material of irregular, bowl-shaped craters, mostly in clusters or chains; in places have sharply raised rims. Occur on Aristoteles rim materials and on mare northeast of Aristoteles; long axes mostly radial to Eudoxus, south of quadrangle (lat 44° N., long 16° E.). Small irregular clusters near Baily A have long axes trending southwest toward Bürg, outside quadrangle, (lat 45° N., long 28° E.)
Interpretation
Orientation of long axes indicate secondary impact origin from Copernican craters Eudoxus and Bürg. Queried where could be Eratosthenian secondary impact craters

ERATOSTHENIAN SYSTEM

Eci

Irregular-crater material

Characteristics
Crater material, undivided. Irregular or elliptical outline. Raised, moderately subdued rim; steep or gentle walls. Superposed on Imbrian mare and plains materials. Includes conspicuous (about 10 km long) crater Gärtner M (lat 55° 30' N., long 37° E.)
Interpretation
Origin unknown. Maybe secondary impact or volcanic craters. Age assigned on basis of superposition and moderately degraded topography

Ec Ecr Ecrh Ecrr Ecrc Ecw Ecf Ecfh Ecp

Materials of sharp-rimmed craters

Characteristics
Ec, rim wall, and floor materials, undivided. Craters <5 km. Fairly high albedo; moderately sharp rims; interior less deep, more rounded, and shadow more diffuse than in Cc. In larger craters divided as follows:
Ecr, rim material, undivided. Craters <15 km. Rim raised, fairly sharp-crested, locally somewhat crenulated. Outer rim smooth, or has faint radial ribbing. In larger craters divided as follows:
Ecrh, rim material, hummocky. On Aristoteles, rugged hummocks or blocks; terraces at different elevations separated by scarps; some smooth surfaces in troughs; albedo variable, irregular; transition to radial unit marked in places by sharp break in slope. On Hercules, relief more subdued, hummocks or blocks rounded; albedo higher than mare material, lower than plains material. On Galle and Baily A, steep, raised rim having fairly smooth, subdued hummocks
Ecrr, rim material, radial. On Aristoteles, hummocky, smooth, undulatory ridges, 2 to 5 km wide; radial ridging and herringbone pattern pronounced toward outer part; transitional into cratered unit near beginning of satellitic crater chains; albedo slightly higher than mare, variable radially. On Galle, similar but less extensive. On Hercules, broad low hills dominant on inner part; radial ridging on periphery more subdued than on Aristoteles; albedo varies in intermediate range. On Baily A very subdued, low albedo
Ecrc, rim material, cratered. Generally abundant satellitic craters; on Aristoteles vague radial ridging locally, otherwise fairly smooth between craters; albedo like that of mare; outer boundary indistinct. On Hercules, texture like that of plains, with slightly higher albedo
Ecw, wall material. In craters <15 km high, smooth, bright. In Galle A, Mitchell M and N, bowl shaped; diffuse shadow. In larger craters, rugged, hummocky; some smooth, level surfaces; part nearest rim crest smooth and steep. Albedo variable; highest on high steep part. In Aristoteles, numerous scarps, some continuous to ½ crater circumference. Thermal enhancement at smooth steep northwest wall (Shorthill and Saari, 1966). In Galle, steep coalesced scarps separating donut-shaped ridges. In Baily A smooth
Ecf, floor material. In Aristoteles, smooth, mottled texture similar to plains but albedo slightly higher; surface slightly coarser textured, and somewhat less cratered; very gently rolling; has isolated small hills. In Galle, hummocky, albedo slightly higher than mare material. In Sheepshanks C, Mitchell M and N, small, dark. In Baily A, similar to mare material but not as smooth
Ecfh, floor material, hummocky. Angular and round to elongate hills and blocks of various sizes in random orientations. Albedo intermediate to high
Ecp, peak material. Domes with triangular facets, moderately sharp ridge crests, and smooth sides. Albedo high
Interpretation
Impact origin suggested for large craters by their size, morphology of ejecta blanket, pattern and large distance of secondary craters from crater center. Morphology of smaller craters suggests origin similar to that of small Copernican craters; however, absence of rays and greater topographic subdual indicate older age. Bowl-shaped craters Galle A, Mitchell M and N could be volcanic. Eratosthenian age for Aristoteles, Hercules, and Galle based on superposition of secondary craters on mare and very faint rays. Late Eratosthenian age indicated for Aristoteles by fresh appearance of units, early Eratosthenian age for Hercules by more subdued appearance. Subdued and dark units in Baily A are queried, indicating possible volcanic origin or Imbrian age
Ecr, ejecta material
Ecrh, fractured and brecciated rock, locally overlain by finer material. Probably combination of uplifted blocks, thrust slices, overturned flaps from crater interior, and large ejecta blocks
Ecrr, ejecta blanket deposited partly as turbulent density flow and partly along ballistic trajectories
Ecrc, very thin ejecta blanket and large fragments that formed secondary impact craters
Ecw, fault scarps and slump masses. Possibly includes volcanic material. Thermal anomaly in Aristoteles probably results from fresh rock exposed along young fault scarp
Ecf, volcanic material, fallback, and mass wasted material. In Aristoteles similarity to plains material suggests fluid, probably endogenetic origin. Small hills possibly protrusions of bedrock or volcanic cones
Ecfh, slumped wall material
Ecp, terrestrial impact crater analogs suggests brecciated bedrock uplifted immediately after impact. Alternatively, volcanic structures fed through conduits near brecciated crater center

Esca

Satellitic crater material, Aristoteles

Characteristics
Morphologically similar to unit Csc. Herringbone pattern commonly diverges from Aristoteles; axes of bilateral symmetry directed towards Aristoteles. Albedo generally higher than that of mare
Interpretation
Circumferential distribution and radial orientation with respect to Aristoteles and general crater asymmetry suggest formation by secondary impact of ejecta from Aristoteles. Queried where could be Copernican secondary craters

Esch

Satellitic crater material, Hercules

Characteristics
Similar to unit Esca, but rims lower and less well defined; fewer large clusters. Albedo slightly higher than plains material. Superposed on mare and Imbrian plains material. Clusters radial and peripheral to Hercules (lat 47° N., long 39° E.), southeast of map area
Interpretation
Position and orientation suggest origin as secondary impact craters of Hercules. Queried where source uncertain

IMBRIAN SYSTEM

Im

Mare material

Characteristics
Smooth, level, low density of small craters, and low albedo. Prominent ridges, irregular scarps, and some linear rilles disrupt surface. Embays Imbrian plains unit and Alpes Formation
Interpretation
Large areal extent, smooth appearance, and embayment and superposition relations suggest origin mostly as lava flows; deposited mostly but possibly not entirely within Imbrian Period

Ic Icr Icrh Icrr Icw Icf Icp

Materials of moderately subdued craters

Characteristics
Ic, rim, wall, and floor materials, undivided. Craters <5 km. Moderate albedo, subdued, narrow rim; less deep than Ec. *In larger craters divided as follows:*
Icr, rim material, undivided. Occurs around craters <20 km and large craters C. Mayer and Egede, where rim facies not distinguishable. Subdued, locally pitted with small craters; outer part smooth, barely visible, flooded by mare on Egede; rim crest faintly raised, circular to polygonal. In other large craters subdivided as follows:
Icrh, rim material, hummocky. Polygonal outline, topography of flank and crest subdued, locally cratered
Icrr, rim material, radial. Smooth, faint radial ribs; underlying topography visible; outer edge indistinct
Icw, wall material. Generally smooth, moderately steep and bright. Large craters have pronounced scarps continuous to about ½ crater circumference
Icf, floor material. Mapped in craters >20 km. In Democritus, smooth, some low broad hills. In Sheepshanks, subdued, faint scarps. In C. Mayer, ridged, rough
Icp, peak material. In Democritus, smooth domes. In Sheepshanks, small composite, elongate (north-south trending) hills. In C. Mayer, large, bulbous
Interpretation
Morphologies of crater units suggest impact origin. Subdued appearance compared with younger craters attributed to longer duration of mass wasting and erosion by impact. Queried, buried units in crater Mitchell could be Eratosthenian in age

Ip

Plains material

Characteristics
Flat, smooth, finely mottled texture; heavily cratered (mostly <1 km diameter). Commonly topographically low; covers some Imbrian and pre-Imbrian crater floors. In north and northeast overlies low pre-Imbrian linear ridges. Albedo intermediate. Embayed by mare material. In southeast could be mare material densely cratered by secondary impacts from Hercules
Interpretation
Volcanic flows or tuffs. Older than Imbrian mare material and younger than some Imbrian craters. General similarity in appearance to mare suggests similar composition, but exposed longer to erosion

Is

Smooth hilly material

Characteristics
Texture slightly coarser than that of Imbrian plains material and finer than fine member of Alpes Formation. Distinguished from plains unit by rolling and undulatory surface extending to higher elevations than plains. In places forms low broad swells, crudely alined radial to Imbrium basin. Locally embayed by Imbrian plains material. Albedo similar to that of plains
Interpretation
May be smooth facies of Alpes or Fra Mauro Formations or thin mantle of plains material on basement

Iac Iaf

Alpes Formation

Characteristics
Iac, *Coarse material. Irregular hilly terrain having disordered appearance similar to hummoky and blocky rim facies around some impact craters. Hills circular and elongate. Large hills have faceted or grooved sides, angular peaks, and some sharp-crested ridges. Small hills and hills in north and northeast map area have smooth, rounded tops. Local elongation of hills in northeasterly direction. Fine and smooth material between hills. In places covered by Imbrian plains unit and embayed by mare material. Albedo intermediate to high, mottled. Intergradational with:*
Iaf, *fine material. Rough, irregular, finely hummocky surface texture and small (<1 km) angular peaks. Some hills alined in northeasterly direction. Occurs largely between areas of coarse material of formation. Albedo similar to that of plains unit*
Interpretation
Mostly produced by Imbrium basin impact (see text). Coarse member is considered largely brecciated bedrock; fine member mostly Imbrium ejecta

If

Fra Mauro Formation

Characteristics
Sinuous, subparallel, locally knobby ridges, with mostly rounded crests. Ridges trend approximately radial to Imbrium basin in area west of crater Sheepshanks. Northeast of Sheepshanks consists of thick, ropy, northeast-trending ridges. Albedo intermediate, irregular
Interpretation
Position on periphery of Imbrium basin and depositional appearance indicate material may be ejecta from Imbrium basin

PRE-IMBRIAN

pIc

Material of crater Baily

Characteristics
Rim flank subdued; rim crest sharp. Steep scarps on western and northern wall; southern and eastern walls not visible
Interpretation
Origin impact or volcanic. Eastern and southern rims believed obliterated by faulting and volcanism. Age assigned on basis of degraded morphology

pIlc pIlf

Lineated material

Characteristics
pIlc, *coarsely lineated material. High mountainous areas and sharp-crested ridges. Ridges and peaks locally rounded. Ridge crests and valleys alined in northeasterly direction. Embayed by mare and plains units. Albedo intermediate to high. Queried where covered by Aristoteles ejecta blanket and lineation not discernible*
pIlf, *finely lineated material. Plateaus and ridges having pervasive northeasterly lineation of parallel ridges and rows of hills. Ridge and hill tops commonly smooth and round, only locally sharp-crested or peaked. Generally peripheral to Imbrium basin but at greater distance from basin than* pIlc; *mostly lower elevations. Contact with plains unit sharp to indistinct. Albedo intermediate*
Interpretation
Ancient bedrock consisting in part of crater rims highly modified by fractures and faults. (Where discernible, rim crest outlined by special line symbol). Northeast lunar grid lineation (Strom, 1964) enhanced by radial fractures and faults following Imbrium impact. Coarseness of lineation directly dependent on distance from Imbrium basin. Locally rounded by subduing cover, possibly Imbrium ejecta or plains material. Some ridges may be later volcanic material

pIcl

Lineated crater materials

Characteristics
Generally low lineated crater rims and walls; locally resemble coarsely and finely lineated pre-Imbrian ridges. In crater C. Mayer B, subdued; lineation indicated by a few sharp-crested ridges
Interpretation
Ancient faulted and eroded crater rims, presumably of impact origin. Lineations produced by Imbrium impact, as in coarsely and finely lineated materials. Crater C. Mayer B possibly thinly covered by ejecta from Imbrium basin or volcanic material

●

Dark dome material

Characteristics
Very small (<1 km) hills having low albedo and associated with very dark material (unit CEd*); occur only in eastern part of map area (lat 53°15' W., long 39°30' E.)*
Interpretation
Volcanic domes or cones

▨

Dark mantling material

Characteristics
Lower albedo than surrounding areas but higher than dark material (unit CEd*). Generally shows underlying topography. Forms circular, elongate, or sinuous patches on mare material and crater rims and walls. Extends across mare scarps and associated in places with faint sinuous depressions. Darkens some satellitic craters from crater Hercules in southeast corner of quadrangle*
Interpretation
Thin volcanic material; in places, may be rayless areas. Near craters, probably extrusions through fractured bedrock and may be much later than crater-forming event

CEd

Dark material

Characteristics
Very low albedo; smooth, velvetlike surfaces; associated with low-rimmed craters, crater chains, dark domes, and rilles. Obliterates underlying topography
Interpretation
Late lava flows or tuffs; thick cover in smooth, low areas. Generally young age indicated by association with sharply expressed crater chains, low-rimmed craters and rilles

CEch

Chain crater material

Characteristics
Deep and shallow rimless craters forming elongate troughs having scalloped, steep, locally bright walls with sharp edges. Associated with very dark material, rilles, grabens. Mainly trend in northeasterly and east-northeasterly directions
Interpretation
Association with very dark material, rilles, and grabens suggests volcanic origin along structurally controlled fissures. Larger craters may be calderas resulting from subsurface withdrawal of material. Sharp topography suggests young age

CEcl

Low-rimmed crater material

Characteristics
Crater materials, undivided. Small (<5 km) craters with low rims or no rims. Generally steep walls, flat floor. Associated with dark material, rilles, crater chains, or grabens. Sharp topographic expression
Interpretation
Volcanic origin suggested by association with volcanic and tectonic features. Age assigned on basis of fresh appearance

⁘

Densely cratered material

Characteristics
In vicinity of Gärtner M, high density of small craters
Interpretation
Probably secondary impact craters; source unknown. Proximity to large, elongate, irregular crater Gärtner M suggests possible endogenetic origin

r

Rugged hill material

Characteristics
Cones and domes having round to elliptical outlines and variable albedo. Locally alined in northeasterly direction but in places transect regional lineation patterns. Larger and higher than hills of immediate surroundings. Bulbous mountains south of crater C. Mayer. Dark irregular smooth hills south of Baily B. On crater rims, high ridges having bulbous sides and smooth, subdued rolling surface. Unit occurs in terrain of various ages
Interpretation
Volcanic constructional origin suggested by shape, isolated occurrence, and association with rilles and dark mantling material. Development of bulbous masses on craters facilitated by intense bedrock brecciation upon impact. Age indeterminate, as superposition relations not conclusive. Queried where could be faulted pre-Imbrian bedrock

Contact
Long dashed where approximately located; short dashed where gradational

(pIlf)
Buried contact
Shows limit of topographically expressed part of buried unit, which is indicated by symbol in parenthesis

Transitional contact
Shown only in cross section

Fault
Solid line at base of prominent scarp; dotted where buried. Bar and ball on downthrown side. On cross section, dashed where inferred. Indicates offset unit or scarp against which younger rocks deposited

Lineament
Narrow linear depression, or broad swale. Not mapped within units described as lineated
Interpretation: Fault, joint, or fracture

Scarp
Solid barb where high, open barb where low. Line at base of scarp; barb points downslope. Scarp continuous or sequence of overlapping small segments. Mostly on mare and plains
Interpretation: Flow front, fault scarp, or boundary of shallow intrusive along fissures. Where curved may be buried crater rim

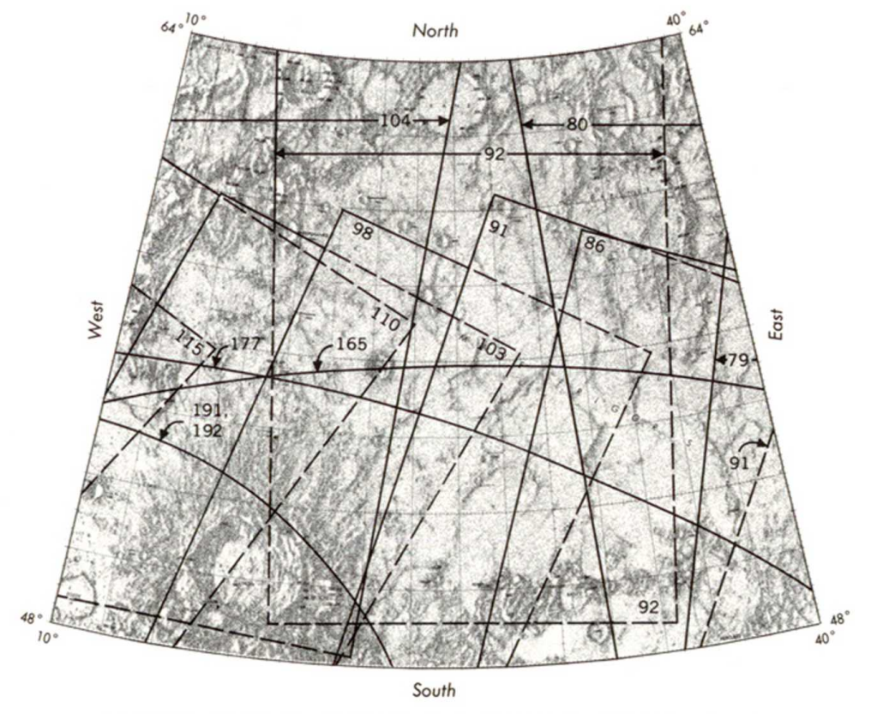
Rille
Sinuous or straight linear depression; some have shallow crater at one end. Line marks edge; single line where narrow
Interpretation: Where straight, graben. Where sinuous, may be lava-flow channel or collapsed lava tube

Mare and plains ridge
Solid diamond where high, open diamond where low
Interpretation: Intrusive doming, or extrusion of viscous material. Locally may be buried ridge or ridge bounded by fault scarps

Depression
Generally very indistinct; gently sloping walls merge with floor
Interpretation: Sag formed by subsurface withdrawal of material or topographic low not completely filled by mare material

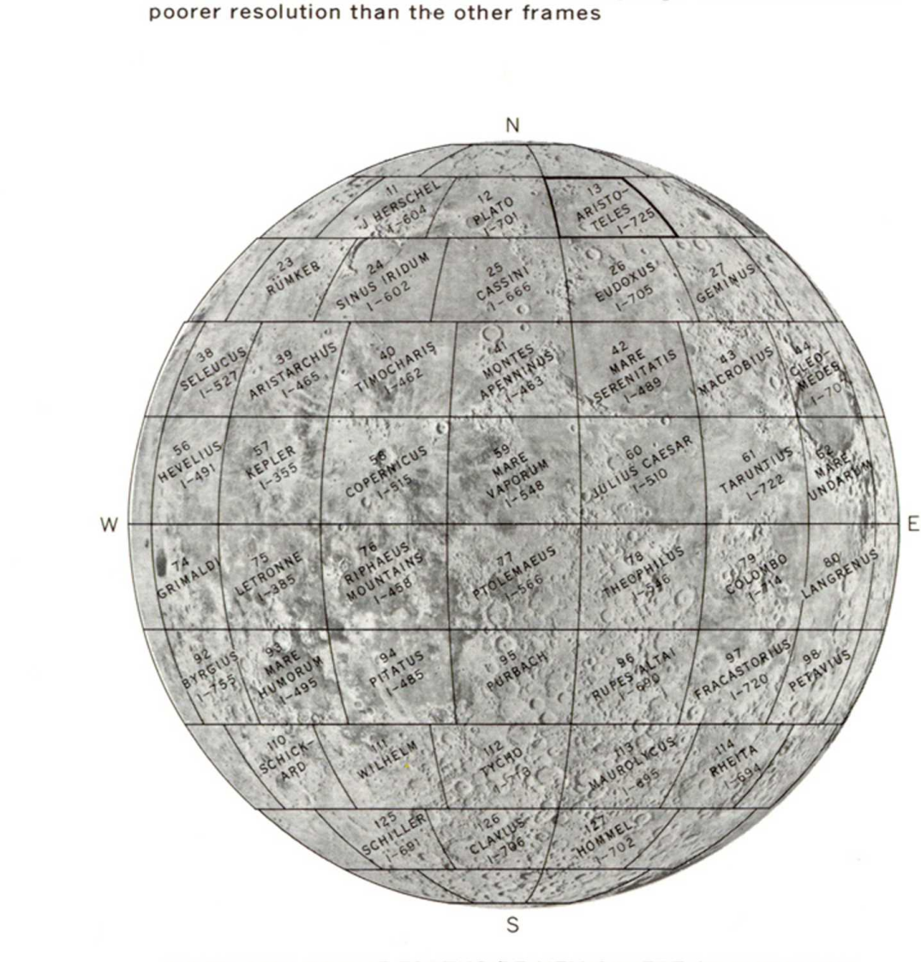
Concealed crater or crater remnant
Symbol outlines rim crest of buried crater, or approximate rim crest remnant of ancient crater

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



LUNAR ORBITER IV HIGH-RESOLUTION COVERAGE OF ARISTOTELES QUADRANGLE

Frames 165, 177, 191, and 192 cover area north of lines indicated; they were taken obliquely from relatively high altitude and have poorer resolution than the other frames



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 ATLAS OF THE MOON
ARISTOTELES QUADRANGLE
I–725 (LAC–13)

GEOLOGIC SUMMARY

INTRODUCTION

Materials of the lunar surface are divided into mappable units and relatively dated on the basis of morphology, albedo (reflectivity under full-Moon illumination), and superposition and crosscutting relations. Time-stratigraphic classification of units follows the work by Shoemaker (1962), Shoemaker and Hackman (1962), McCauley (1967), and Wilhelms (1970).

PHYSIOGRAPHIC AND GEOLOGIC SETTING

The Aristoteles quadrangle, located on the northeastern periphery of the Imbrium basin on the near side of the Moon, consists of four physiographic provinces: a northern mountainous belt, chiefly of lineated crater rims and other lineated terrain; a middle-northern belt covered by light-colored plains material; a middle belt covered by mare material of Mare Frigoris; and a southern belt composed of mountainous material of diverse characteristics.

The crater Aristoteles and its ejecta blanket dominate the southwestern part of the quadrangle, and ejecta from the crater Hercules (outside the quadrangle) covers a small part of the southeastern corner. Other prominent craters are Democritus, C. Mayer, Gärtner, and Kane. Two probable centers of tectonism and volcanism are present in the southern mountainous belt.

STRATIGRAPHY

Geologic units of the Aristoteles quadrangle are divided into three major groups: (1) mountain units, mostly produced or modified when the Imbrium basin was formed and chiefly represented in the northern physiographic belt; (2) plains and mantling units, which cover or embay the mountain units and extend throughout the middle-northern and middle belt; and (3) crater units.

Mountain units.—Mountain units include coarsely (pIlc) and finely (pIlf) lineated terrain, coarse (Iac) and fine (Iaf) members of the Alpes Formation, the Fra Mauro Formation (If), and rugged hills (r). The pre-Imbrian units consist of ancient rocks that were deformed when the Imbrium basin was formed, whereas the Imbrian units consist of rocks that were emplaced and deformed at the time of this event; the rugged hills are rocks of uncertain origin and age. The Imbrium basin was probably formed by impact (Gilbert, 1893; Baldwin, 1963; Hartmann and Kuiper, 1962; Wilhelms and McCauley, 1971).

Most of the lineated terrain, which is similar to lineated terrain around the basin in other areas (Howard and Masursky, 1968; Hartmann, 1963; Wilhelms and McCauley, 1971), is believed to consist of segments of old crater rims faulted at the time of the Imbrium impact (see section on structure). Some of these crater rims are shown by a special line symbol, and the most distinct ones are mapped as a geologic unit, lineated crater material (pIcl). The coarsely lineated terrain is generally at a higher elevation and occurs closer to the Imbrium basin than the finely lineated terrain. All the lineated units locally have a subdued topography that may indicate a thin covering blanket of Imbrium basin ejecta, and some of the lineation could be depositional texture intrinsic to this blanket.

The Alpes Formation forms irregular, hilly terrain and is thought to consist of a mixture of brecciated pre-Imbrian bedrock, large and small fragments of Imbrium basin ejecta, and volcanic domes. This composition is suggested by the following observations:

(1) Some pre-Imbrian bedrock appears to be preserved within Alpes terrain because (a) some alined Alpes-type hills merge into ridges similar to the pre-Imbrian lineated ridges; (b) pre-Imbrian lineated ridges are locally transected by linear grooves in directions not radial to the Imbrium basin, creating Alpes-type hills; and (c) pre-Imbrian faulted crater remnants occur throughout Alpes terrain, indicating that pre-Imbrian rock lies near the surface.

(2) The origin of the Alpes Formation as massive Imbrium basin ejecta is suggested by (a) its resemblance to the similar but better preserved material of the Orientale basin, which is considered by McCauley (1968) to be slumped ejecta deposits, and (b) the aspect of the fine member of the Alpes Formation, which appears to partly cover peaks composed of the coarse member.

(3) Many small hills mapped as Alpes Formation resemble larger probably volcanic domes (mapped as unit r).

On the basis of these considerations, an attempt has been made to subdivide the Alpes Formation into two separate members. The coarse member is thought to consist largely of brecciated bedrock, whereas the fine member is considered to be mostly Imbrium basin ejecta and material mass-wasted off Alpes peaks.

The Fra Mauro Formation, as defined by Eggleton (1964) and Wilhelms (1970, p. F25), is not recognized with certainty in large parts of the quadrangle, although it commonly occurs in other areas that border the Imbrium basin (Eggleton, 1965; Wilhelms, 1968; Ulrich, 1969). In the Aristoteles quadrangle, only two small areas appear to have the characteristic hummocky and swirly texture of this formation, which is believed to consist of Imbrium basin ejecta. As noted above, some lineations on the pre-Imbrian highlands could result from blanketing by a thin layer of Imbrium ejecta.

Rugged hills, some of probable volcanic origin, occur throughout the map area and are distinguished from hills of the Alpes Formation by larger size, bulbous or irregular-rounded shapes, or very low albedo. Some hills are crudely alined along the pervasive northeasterly lineation that marks the pre-Imbrian mountain units; others are transverse to this direction. Locally, the hills truncate faults and modify crater shapes; these relations suggest that the hills were constructed by volcanism after formation of the faults and craters. Where relative ages cannot be established, occurrences of this unit could be pre-Imbrian bedrock.

Plains and mantling units.—These include smooth, hilly material (Is), light-colored plains material (Ip), mare material (Im), moderately dark, probably thin material (ruled overlay pattern), and very dark material which subdues underlying topography (CEd).

Imbrian hilly material is smooth and gently rolling and locally is embayed by Imbrian plains material. In the south-central part of the quadrangle, hilly material forms broad, low parallel swells similar to those mapped by Wilhelms (1968) as the smooth member of the Fra Mauro Formation. Here the unit may be either a moderately thick blanket of smooth Fra Mauro or Alpes on pre-Imbrian lineated ridges, or a mantling deposit of volcanic material like that of the plains but thinner.

Imbrian plains material is extensive throughout the area. In places it embays steep landforms and overlies small hills and linear ridges. Its generally level surface suggests an origin similar to that of mare lava flows, and the higher density of small craters indicates an older age. However, the apparent draping of some plains material over low topographic irregularities suggests that tuffs may form a sizable fraction of the unit, and the higher crater density may reflect an internal process such as gas venting rather than a longer period of impact erosion.

Mare material of Mare Frigoris surrounds some Imbrian and pre-Imbrian craters and embays the plains material. It is believed to be lava on the basis of flat surfaces, abrupt terminations, and general similarity to maria where samples have been collected by Apollo missions and analyzed. Rilles, scarps, and ridges in the mare may be genetically related to the emplacement of lava, and may represent faults, collapse features, extrusions from linear vents, lava channels, or flow fronts. The mare material is relatively thin, as evidenced by many islands of older rock and by some ridges that have the outlines of crater rims.

Dark mantling material occurs on several types of terrain. In the eastern part of the map area, it gives a low marelike albedo to the Imbrian plains material without noticeably affecting the underlying highly cratered topography. Parts of the rim material and satellitic crater field of Hercules and Aristoteles are similarly darkened without being obliterated. The albedo of Mare Frigoris is variable, owing largely to a pattern of light rays and interspersed patches of dark material, which in places could be produced by a thin mantle on the rays. The dark areas are locally less cratered than other mare and probably represent late eruptions of mare material. Locally such dark patches occur on and around craters, suggesting a volcanic origin for the craters. Because much of the dark mantling material rests upon late Imbrian or Eratosthenian units, it is regarded as Eratosthenian or Copernican in age.

Other materials (CEd) are noticeably darker than the mantling unit and form deposits of detectable thickness usually near low-rimmed craters, crater chains, dark domes, and rilles. The dark materials must be of volcanic origin.

Crater units.—Most of the craters of Imbrian and younger age in the quadrangle are considered to be of impact origin because of their morphological similarity to terrestrial impact craters and the crater Copernicus (Shoemaker, 1962). The morphology of pre-Imbrian craters has been largely destroyed by later impacts and fractures produced by the Imbrium impact; their origins are therefore unknown but presumably are mostly impact.

A few irregular-shaped craters (unit Eci) also are of unknown origin. Among these, Gärtner M is conspicuous.

Secondary impact craters produced by ejecta from Aristoteles are spread over more than a quarter of the quadrangle and are superposed on mountains, plains, and mare materials. Aristoteles looks fresh and is similar to the crater Copernicus (Shoemaker, 1962; Shoemaker and Hackman, 1962) but lacks well-defined rays and is therefore considered of late Eratosthenian age. It shows a pronounced thermal anomaly, which suggests fresh rock exposure (Shorthill and Saari, 1966). This anomaly may be related to a large and fresh-looking slump scar on the northwest crater wall. Several dark patches on the walls and rims that locally have the shape of flows emanating from a point source are considered to be evidence for volcanic activity.

Secondary craters of the large crater Eudoxus south of Aristoteles (outside the quadrangle) overlie and postdate the Aristoteles ejecta blanket. They cannot easily be distinguished morphologically from those of Aristoteles, and their respective origins, where superposition relations are not clear, are determined largely by the orientation and position of chainlike clusters.

Several craters of probable volcanic origin are present within the Aristoteles quadrangle. Low-rimmed craters (unit CEcl) and a large (10 km by 4 km) crater chain (unit CEch), possibly a caldera complex, are conspicuous near lat 50° N., long 28° E. The area south of crater Baily B has prominent and deep rimless fissures with craterlike widenings. The fissures may be composed of a series of volcanic craters; alternatively, they may be tension gaps; if they are, the craterlike morphology resulted from wall collapse along curved slump blocks. The fresh appearance of these features suggests a relatively young age.

STRUCTURE

The most prominent structures in the quadrangle are the long fine and coarse grooves in the ridges trending northeast radial to the Imbrium basin. The origin of radial grooves has been discussed by several authors (Gilbert, 1893; Urey, 1952, p. 40; Baldwin, 1963, p. 323-331; Hartmann, 1963). Some investigators suggest that missile gouging by Imbrium basin ejecta produced the grooves, whereas others suggest radial fracturing and faulting. A structural origin for the northeast-trending grooves in the map area is proposed here for the following reasons:

(1) Northeast lunar grid lineaments (Fielder, 1963; Strom, 1964) are well developed where they coincide with Imbrium basin radial lineaments (in the northern part of the quadrangle), but where they do not (in the southern part), they are much less pronounced.

(2) Outlines of very old craters are highly modified and have rectangular shapes; many rim segments coincide with Imbrium basin radial directions.

(3) Massive bulbous mountains north of the map area are in crude radial alinement to the Imbrium basin and somehow must be controlled by radial fractures; they may be volcanic materials extruded along fissures.

(4) The dominant northeasterly trend of mare ridges and scarps suggests structural control.

Structures that trend approximately east-west, probably unrelated to the Imbrium basin, are present in the extensive graben system north of Galle C and Gärtner F, in a few mare ridges, and in fault scarps, crater chains, and rilles of the southern terra. And eastern Mare Frigoris, partly shown on the map, occupies an east-west-trending trough peripheral to the ancient Serenitatis basin to the south, and possibly is related genetically to that basin.

North-south-trending structures—mare ridges and faults—are present but not abundant.

In the southern part of the quadrangle, the region around the crater Baily is considered to have been tectonically active. In addition to the distinctive young volcanic deposits and craters (CEd, CEch) discussed above, older craters are highly faulted and partly covered by bulbous, rugged hill material. Terra material, against which mare material appears to be deposited, is unusually high and may be uplifted by faults.

GEOLOGIC HISTORY

The pre-Imbrian history of the region is characterized by cratering so intense as to saturate the surface. Probably most of the craters were formed by impact; some may have been formed during the early accretion of the Moon. Upon formation of the Serenitatis basin, a peripheral trough may have developed at the present location of eastern Mare Frigoris. Fractures and faults of the lunar grid system probably started to develop at an early stage in lunar history and may be responsible for the modification of old crater rims into rectangular shapes in pre-Imbrian time.

The Imbrium impact resulted in the ejection of large blocks and fine debris and in extensive brecciation of bedrock areas around the basin rim. Faults and fractures developed predominantly in a direction radial to the basin. The fractures activated lines of weakness previously established by the lunar grid system and probably contributed to the alteration of crater outlines to rectangular forms.

During the Imbrian Period vast quantities of volcanic material mantled highlands and flooded lowlands. Craters presumably formed by impact throughout this period and over the entire area, but only those in the north are well exposed; those presumably once present in the south have been buried by late Imbrian mare materials. In the Eratosthenian and Copernican Periods, the progressively younger craters Hercules, Aristoteles, and Eudoxus were formed by impact in or near the southern part of the quadrangle. Minor volcanic activity associated with older craters or with chain craters and rilles took place during this time and continued after the major impacts.

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