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
FRACASTORIUS QUADRANGLE
I-720 (LAC-97)

GEOLOGIC MAP OF THE FRACASTORIUS QUADRANGLE OF THE MOON

By
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1972

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

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 assumed lunar figure is that of a sphere corresponding to the mean lunar radius of 1738 kilometers. Elevations are referred to a spherical datum 2.6 kilometers below the mean radius to minimize minus elevation values.

CONTROL

The horizontal and vertical positions of features on this chart are based primarily on the positions of 150 lunar points established by the Aeronautical Chart and Information Center, St. Louis, Missouri, from a network of 273 points established by ACIC, Aeronautical Chart and Information Center, St. Louis, Missouri, from a network of 273 points established by ACIC, extensions in localized areas. Additional horizontal positions have been selected from the Consolidated Catalog of Selenographic Positions by D. W. G. Arthur and others (Publication 1256, U.S. Naval Observatory, 1963). The probable error of the control is evaluated at 1000 meters.

NAMES

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

Supplementary features are associated with the named feature 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 named feature or lettered feature.

PORTRAYAL

The configuration of the lunar surface features shown on the base chart is based on photographs taken at Lick, McDonald, Mt. Wilson, Yerkes, Stony Ridge, Kwiatek, and Pic du Midi Observatories. Supplementary visual observations with the 20 and 24 inch refracting telescopes of the Naval Observatory provided information on the nature of relationships and the sharpening and rendering 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.

North

West

East

South

MARE NECTARIS

FRACASTORIUS

PICCOLOMINI

BONNENBERGER

COLOMBO

SANTBECH

BIOT B

RICHENBACH

ALEXANDER

BRUNO

WERNER

Lunar base chart LAC 97, 1st edition, 1965, by the USAF Aeronautical Chart and Information Center, St. Louis, Missouri 63118

SCALE 1:1 000 000
LAMBERT CONFORMAL PROJECTION
STANDARD PARALLELS 27.30° AND 40.90°

Principal sources of geologic information: Lunar Orbiter IV photographs (shown on index map); high-resolution telescopic photographs, Lick Observatory, mostly generously loaned by Dr. Gerard P. Kuiper; and 24", 61", and 82" reflectors, U.S. Naval Observatory, Flagstaff, Arizona; low-resolution photographs, 61-inch reflector, Catalina Observatory, University of Arizona.

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.

LUNAR ORBITER IV HIGH-RESOLUTION COVERAGE OF FRACASTORIUS QUADRANGLE

EXPLANATION

Ray material

Characteristics
Streaks of pitchy material with albedo higher than surrounding terrain. No detectable topographic expression.
Interpretation
Ejecta from Copernicus impact craters that churned up surface material

Dark mantling material — Dm

Characteristics
Low-albedo material that covers portions of plains and other terra and subdues most craters. High turbidance of subdued small irregular craters.
Interpretation
Volcanic material from local sources such as the irregular craters, possibly thin lava flows or ash of different composition than light mantling material

Mare material — Ems

Characteristics
Level, generally featureless plains of low albedo, large area in Mare Nectaris has sharp sinuous ridge. Very few superposed craters, fills in low areas
Interpretation
Basaltic lava flows. Some may grade into Imbrian mare

Light mantling material

Characteristics
Subdued craters and rugged and hilly terra, subduing normally sharp features such as crater rim crests and filling in rough terrain. Albedo indistinguishable from surrounding terrain. In south central part of quadrangle
Interpretation
Probably volcanic ash

Material of craters with convex floors — Ipf, Icfr, Icfw, Ipff

Characteristics
Craters with convex floors having mesa-escarpment contacts with walls, some with irregular cracks or rilles; rim crests distinct to quite sharp; albedo intermediate
Ipf, material, undivided
Icfr, wall material. Smooth, steep slope, uneven depth; albedo slightly higher than rest of crater
Ipff, floor material. Level, commonly ridged to small craters, crosscutting irregular rilles and small depressions in Ruthenheyer C
Interpretation
Probably volcanic craters; some may be impact craters flooded with lavas

Mare material — Im

Characteristics
Similar to Erathosthenian mare except slightly higher albedo and generally more superposed craters
Interpretation
Basaltic lava flows. Abundant superposed craters record considerable duration of Lower Erathostenian mare. Locally overgrade into Erathostenian mare

Terra mound material — Itm

Characteristics
Hummocky material forming knobby and pitted mounds of some craters in northeastern part of quadrangle, forms low, basin-like areas in terra. Albedo intermediate and locally high where material exposed on crater walls.
Interpretation
Volcanic material, possibly fields of cinder cones

Irregular-crater material — Ici

Characteristics
Irregular craters. Large, relatively shallow crater near Fracastorius K, subdued-appearing but superposed on lower part of crater wall. Crater interior with smaller crater (crop circle) on floor. Colombo E is deepest with uneven floor and small central cone of smallcrater interior
Interpretation
Crater-cone Fracastorius K probably volcano with lava flooding and only have volcanic floor

Plains-forming material — Ip

Characteristics
Terra-level plains, sparsely to moderately cratered; albedo intermediate, similar to adjacent terra. Fills irregular low-lying areas in central third of quadrangle and flanks many prominent and rarely isolated mountain masses in terra. Lies as much as 1 km topographically lower than more hilly terra. Superposed craters have more subdued rampart-ejecta ejecta blankets
Interpretation
Ignimbrite, lava, debris, or mixture of these. Much may be ejecta from craters that have since been buried by younger ejecta blankets

Crater material

Characteristics
Craters with sharp rims in comparable-sized upper Imbrian craters, most craters a little shallower with more rim ridges and knobs in rim crest. Plains-forming material on wall and floor. Albedo intermediate; many slightly brighter on upper walls of larger craters.
Ipc, undivided. Some shallow, bowl-shaped; others deeper with distinct floors
Icr, rim material. Narrow and quite rounded ramparts; Fracastorius where it grades outward into radial pattern
Icrs, smooth rim material. Relatively smooth on ejecta blanket
Icrw, wall material. Relatively smooth except for crenulations and well-developed terracing in Fracastorius; Colombo E has irregular wall
Icf, floor material. Horizontal or shelf-like craters; level with smooth mounds in Piccolomini
Icps, ejecta material. Large, segmented mound in Piccolomini, gullied ridge in Beichenbach A, small, low mound in Beichenbach C
Interpretation
Most craters probably of impact origin. The small bowl-shaped craters resemble those of younger Imbrian craters and therefore may be isolated Imbrian-basin secondary craters. Rim and ejecta material in far upper Imbrian craters, mound material probably more fluid part of ejecta blanket; wall material more cohesive and slump, less bedrock than in younger craters; floor mostly disrupted material

Crater cluster material — Icc

Characteristics
Clusters of overlapping craters, either mostly 10–15 km wide and moderately subdued or 5 km or less and subdued, craters shallow without distinct floor and broad in slope. Elongation and overlap direction of most clusters approximately radial to Imbrian basin; in Fracastorius quadrangle, clusters are in northeast part of quadrangle and in small central cluster in southwest part of quadrangle observed by new mantling material
Interpretation
Most craters believed secondary impact craters of Imbrian basin because of consistent radial alignment. Similar to abundant Imbrian secondary crater clusters in Macrobius quadrangle (Scott, 1971)

Crater material

Characteristics
Crater features moderately subdued in largest craters, very subdued in small ones. Albedo intermediate, locally high on walls
plcr, crater material, undivided. Mainly shallow craters
plcrw, wall material. Terraces in all larger craters except Saldanha E; commonly subdued. Crenulated radially in a few craters
plcrf, floor material. Level to convex with subdued hummocks in most. Contact with wall material indistinct
plcrs, small craters
Interpretation
Most are probably impact craters. Units interpreted as for lower Imbrian craters

Crater material

Characteristics
Crater features very subdued, rim crests rounded, irregular, and broken. Albedo intermediate and indistinguishable from surrounding terra
plfc, crater material, undivided. Shallow, poorly defined; rim crests generally indistinct
plfcr, rim material. Rim crests commonly destroyed by mantling and subdued small craters. Abundant superposed smaller craters
plfcw, wall material. Terraces indistinct and incomplete
plfcf, floor material. Low mounds in Fracastorius central peak in Beichenbach
Interpretation
Probably impact craters, although diagnostic features such as shape and type of floor mostly obliterated. Units interpreted as for lower Imbrian craters

Hilly and rugged mountainous terra material — plhh, plhr

Characteristics
Gently rolling to rugged terrain, uneven on a fine scale, steepest slopes lead to low Mare Nectaris, and in south and eastern part of quadrangle, the most mountainous terra; numerous small basin-facing scarps form a concentric belt around Mare Nectaris
plhh, hilly relatively subdued sculpted-grading into
plhr, rugged mountains
Interpretation
Remnants of three concentric mountain rings and intermountain ejecta of Nectaris basin. Considerably subdued and mantled by younger deposits. Analogous to mountain rings and ejecta of Orientale basin (McCauley, 1967). Gentler ruggedness and concentric belt of small scarps on outer two ring segments typical of degraded circular basins (Stuart-Alexander and Howard, 1970)
plsr, mostly up-faulted, pre-Nectaris bedrock, partly mantled with Nectaris ejecta and younger deposits
plhh, most is Nectaris ejecta; some probably subdued mountain rings; some inside inner ring may be basin floor material

Janssen Formation — pJj

Characteristics
Present along southern border and continuous with strongly lineated terra in Janssen quadrangle to south. Weakly lineated radial to Nectaris basin
Interpretation
Nectaris basin ejecta blanket (Stuart-Alexander, 1971)

Crater cluster material — Icc

Characteristics
Elongate clusters of overlapping 5–5 km craters and gouges in Mare Nectaris and clusters of smaller craters and chains in quadrangle. Some smaller craters very sharp and not necessarily overlapping. Most clusters in Mare Nectaris radial to Imbrigenus; those in northeast radial to Langrenus
Interpretation
Secondary craters of secondary impact craters radial to the primary crater. Other clusters, such as in crater Fracastorius, may be secondaries of Tycho, source of a few clusters uncertain

Crater material

Characteristics
Moderately elongate clusters of overlapping craters; crater size varies from cluster to cluster; largest craters 10 km in diameter. Craters shallow, subdued interior bowl in shape
Interpretation
Probably secondary impact craters. Small (1–2 km) craters in long cluster north of, and radial to, Nectaris are secondaries; sources of other clusters uncertain

Crater material

Characteristics
Crater features range from sharp to moderately subdued with decreasing crater size. Albedo usually intermediate except on upper part of walls of most craters. >30 km in diameter
Ipc, crater material, undivided. Moderately shallow craters, most lacking floors. Craters with distinct rims
Ipcr, rim material. Appears smooth except for radially lineated area on south side of Mouge. Irregularly cellar about ½ crater diameter, crest around Biot A and ten largest craters, Mouge and Nonidez; there it is ½ to ¾ crater diameter
Ipcw, wall material. Generally smooth except for terraces in Nonidez; less steep than in younger craters
Ipcf, floor material. Flat to slightly crater; generally more extensive than in craters of equivalent younger craters. Smooth in most, raised with elongate low mounds in Nonidez, subdued and smooth, flat pebble in Nonidez; large hummocks in Mouge
Ipcs, ejecta material. Large light-colored mound in Nonidez
Interpretation
Probably of impact origin. Rim, wall, and floor interpreted as for Copernican craters. Raised floor in Ruthenheyer C may be lava. Peak material structurally complex but much uplifted during crater-forming process

Crater material

Characteristics
Craters less sharp than in comparable-sized upper Imbrian craters, most craters a little shallower with more rim ridges and knobs in rim crest. Plains-forming material on many floors. Albedo intermediate; many slightly brighter on upper walls of larger craters.
Iplc, undivided. Some shallow, bowl-shaped; others deeper with distinct floors
Iplcr, rim material. Narrow and quite rounded ramparts; Fracastorius where it grades outward into radial pattern
Iplcrs, smooth rim material. Relatively smooth on ejecta blanket
Iplcw, wall material. Relatively smooth except for crenulations and well-developed terracing in Fracastorius; Colombo E has irregular wall
Iplcf, floor material. Horizontal or shelf-like craters; level with smooth mounds in Piccolomini
Iplcps, ejecta material. Large, segmented mound in Piccolomini, gullied ridge in Beichenbach A, small, low mound in Beichenbach C
Interpretation
Most craters probably of impact origin. The small bowl-shaped craters resemble those of younger Imbrian craters and therefore may be isolated Imbrian-basin secondary craters. Rim and ejecta material in far upper Imbrian craters, mound material probably more fluid part of ejecta blanket; wall material more cohesive and slump, less bedrock than in younger craters; floor mostly disrupted material

Crater material

Characteristics
Crater features moderately subdued in largest craters, very subdued in small ones. Albedo intermediate, locally high on walls
Iplcr, crater material, undivided. Mainly shallow craters
Iplcrw, wall material. Terraces in all larger craters except Saldanha E; commonly subdued. Crenulated radially in a few craters
Iplcrf, floor material. Level to convex with subdued hummocks in most. Contact with wall material indistinct
Iplcrs, small craters
Interpretation
Most are probably impact craters. Units interpreted as for lower Imbrian craters

Crater material

Characteristics
Crater features very subdued, rim crests rounded, irregular, and broken. Albedo intermediate and indistinguishable from surrounding terra
Iplfc, crater material, undivided. Shallow, poorly defined; rim crests generally indistinct
Iplfcr, rim material. Rim crests commonly destroyed by mantling and subdued small craters. Abundant superposed smaller craters
Iplfcw, wall material. Terraces indistinct and incomplete
Iplfcf, floor material. Low mounds in Fracastorius central peak in Beichenbach
Interpretation
Probably impact craters, although diagnostic features such as shape and type of floor mostly obliterated. Units interpreted as for lower Imbrian craters

Hilly and rugged mountainous terra material — Iplhh, Iplhr

Characteristics
Gently rolling to rugged terrain, uneven on a fine scale, steepest slopes lead to low Mare Nectaris, and in south and eastern part of quadrangle, the most mountainous terra; numerous small basin-facing scarps form a concentric belt around Mare Nectaris
Iplhh, hilly relatively subdued sculpted-grading into
Iplhr, rugged mountains
Interpretation
Remnants of three concentric mountain rings and intermountain ejecta of Nectaris basin. Considerably subdued and mantled by younger deposits. Analogous to mountain rings and ejecta of Orientale basin (McCauley, 1967). Gentler ruggedness and concentric belt of small scarps on outer two segments typical of degraded circular basins (Stuart-Alexander and Howard, 1970)
Iplsr, mostly up-faulted, pre-Nectaris bedrock, partly mantled with Nectaris ejecta and younger deposits
Iplhh, most is Nectaris ejecta; some probably subdued mountain rings; some inside inner ring may be basin floor material

Contact
Dashed where approximately located or gradational; tail-maker restriction boundaries are gradational and some are time-wavy approximate. Queried where photography poor. Dotted where concealed; buried and indicated by symbol in parentheses

Inferred fault
Dashed where approximately located; dotted where buried. Ball on line indicates narrow graben; bar and ball on opposite downthrown side. Offset in wall or furrow wavy against which younger rocks are deposited

Lineament
Linear feature, chiefly shallow groove
Interpretation
Zone of weakness; may be joint, fracture, or fault with scrap of movement obliterated. Locally grades into graben

Mare ridge crest
Barbs point down slope

Ridge crest
Linear ridges, mostly symmetrical

Slope
Dream at base of steep slope; barb points down slope

Covered crater rim crest

Narrow circular ridge in mare
Interpretation
May be covered crater rim crest or may be structure related to mare material

Approximate location of Nectaris basin mountain chain
Interpretation
Approximate location of crest of inward facing scarp of the three circular mountain chains of Nectaris basin

Slump
Arrows point in direction of down-slope movement

INTRODUCTION

Lunar geology is mapped on the basis of the principles of stratigraphic sequence. Superposition relations are determined and crater morphologies compared. The sequence of events established in the Fracastorius quadrangle is correlated with the sequence of the established lunar time-stratigraphic system. (Shoemaker, 1962; Shoemaker and Hackman, 1962; McCauley, 1967; and Wilhelms, 1970). The age of a crater is determined from several lines of evidence, but particularly from the morphologic criteria discussed by Pike and Offield (1970), who studied crater morphologies on Lunar Orbiter photographs and correlated crater shapes with the ages of the lunar surfaces established by Apollo 11 (Pike and Offield, 1970; Offield, 1971). Particularly pertinent to the understanding of geologic processes in the Mare Nectaris area, where this quadrangle is situated, are the features and sequence of formation of large, multi-ringed basins (McCauley, 1968, Stuart-Alexander and Howard, 1970).

In general, only craters more than 5 km in diameter are mapped, and only those larger than 10 km are subdivided. However, very subdued craters in the 5–10 km range are not mapped because they are made if the units are less than 1 or 2 km wide.

An earlier study of this quadrangle was made by Elston (1961). His work delineated some of the basic plains and crater units used here.

GEOLOGIC SUMMARY

The multi-ringed Nectaris basin (Hartmann and Kuiper, 1962) dominates the Fracastorius quadrangle. The basin is 860 km across as measured from the outermost ring and lies athwart four quadrangles. Fracastorius, the southeasters quadrangle, straddles the three rings of the basin (fig. 1). In this quadrangle most of the interior mare and terra and ejecta units were formed by the Nectaris impact. Subsequent to the formation of many craters, the basin was modified by Imbrian-age processes and locally by prelatelar multi-ring structures related to the Fecunditatis basin centered northeast of the quadrangle. Other geologic features in the area include diverse mantling deposits and both primary impact craters and secondary impact craters produced by ejecta from distant impacts.

Interpretation of the deposits and structures of this quadrangle is based partly on studies of similar features in other areas of the moon and partly on the results of the detailed study of large circular basins (Stuart-Alexander and Howard, 1970). The Orientale basin has three well-developed mountain rings with steep, inward-facing scarps, scalloped on a coarse scale. Rugged terrain at the top of the scarps slopes gently outward, grading into small pimply hills and finally passing under plains or mare material at the foot of the next scarp. A thick blanket inferred to be ejecta surrounds the outer mountain ring. The low inner basin is partly flooded with mare material younger that the basin.

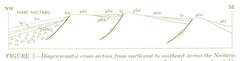

FIGURE 1.—*Diagrammatic cross section from northwest to southeast across the Nectaris basin structure; all craters have been omitted for clarity. Triangles represent probable impact breccia of Nectaris basin*

The Nectaris basin is older, and although now highly subdued and modified largely by superposed impact craters, it appears to have originally been similar to the Orientale basin. Its three mountain rings are 140 km apart, on the average. The rings are discontinuous and are not as obvious as they are in the Mare Atlas quadrangle to the west, where the prominent inward-facing Altai scarp marks the outermost ring. A jagged line of mountains continues from the Altai scarp arcuately across the Fracastorius quadrangle, roughly paralleled by remnants of the two inner rings. The low areas or inter-ring troughs, filled by plains or mare, are 70 km wide between the first and second rings and 140 km between the second and third. The inner basin is retained by the main fill, and even though the large crater Fracastorius interrupts the basin, the mare has flooded the crater to a line approximately coincident with the foot of the innermost mountain ring.

The mountain rings in the Fracastorius quadrangle are composed of a rugged terra unit that is similar to the terra in the Orientale basin rings (McCauley, 1967). The Nectaris mountain grade into a hilly terra unit, analogous in position to the pimply hills of Orientale, and interpreted to be predominantly ejecta from the Nectaris impact subsequently degraded by erosion or covered by younger material. In the Imbrian basin, pimply material of the Alpes Formation occurs in corresponding positions and has been interpreted in a like manner (Page, 1970). The youngest terra unit, mapped as plains-forming material, is interpreted to be ignimbrite, lava, debris, or a mixture of these (see glossary heading). On the outer flank it is dominated by upthrown blocks and ejecta of pre-Nectaris bedrock.