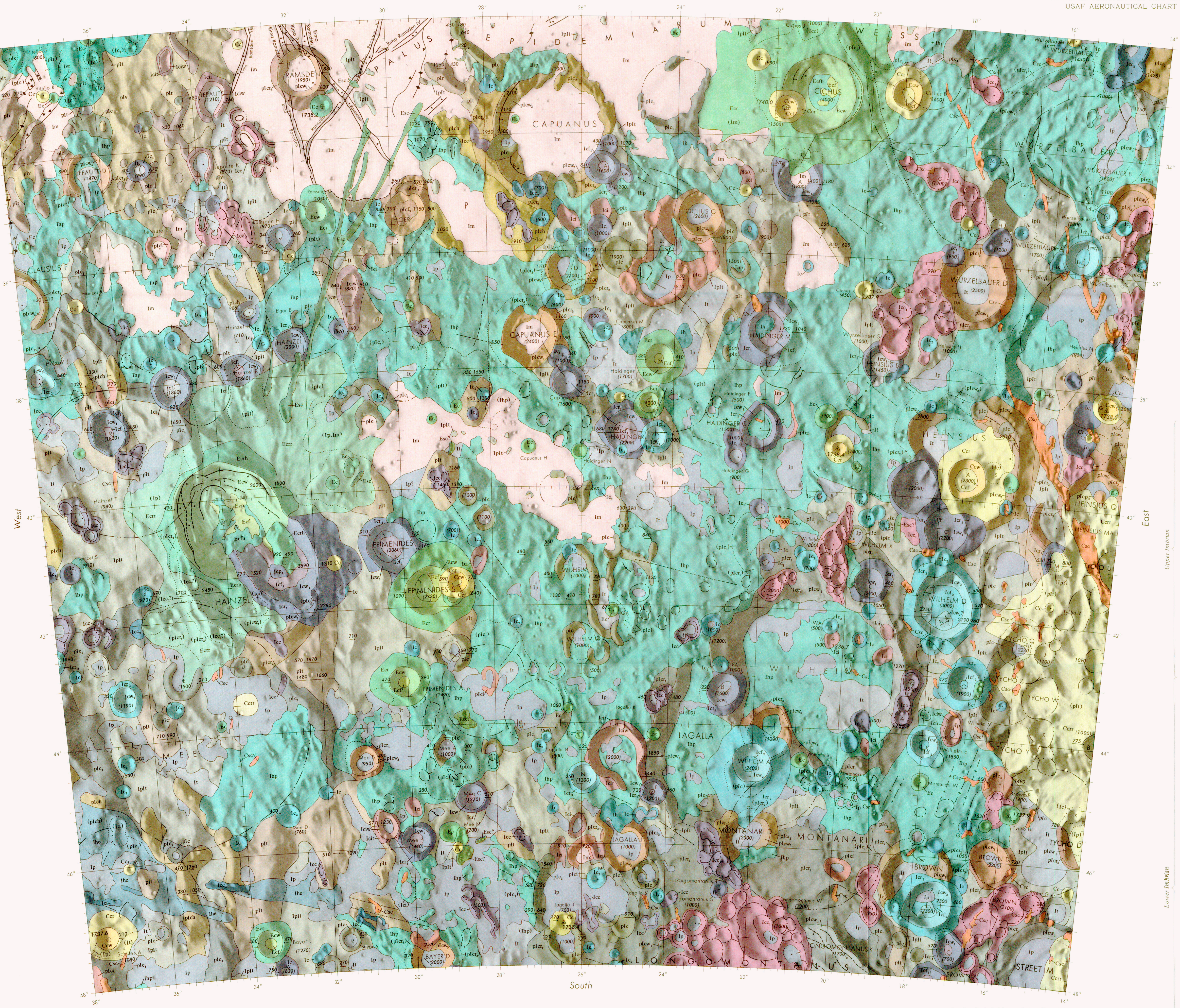
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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

GEOLOGIC ATLAS OF THE MOON
WILHELM QUADRANGLE
I-824 (LAC 111)

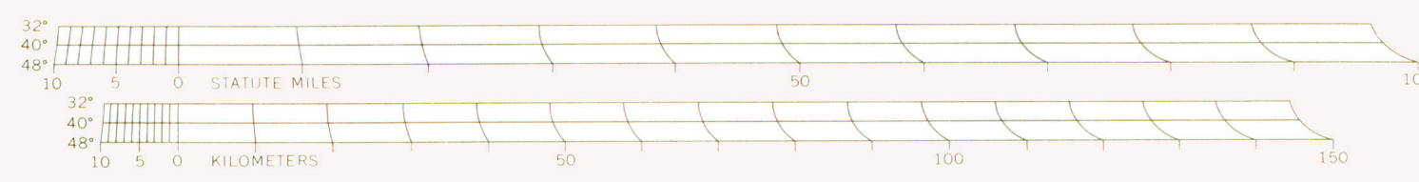


Lunar base chart LAC 111, 1st edition, 1967, by the U.S. Air Force Aeronautical Chart and Information Center, St. Louis, Missouri 63118

Interior—Geological Survey, Reston, Va.—1974

Mapped 1968-71; text and interpretations revised 1972. Principal sources of geologic information: Lunar Orbiter IV and V photographs shown on accompanying index map; Lunar Orbiter IV moderate-resolution photographs 119, 124, 131, 136, 142; telescopic photographs from Consolidated Lunar Atlas (Kuiper and others, 1967). Albedo data from Pohn and Wildey (1970). Infrared data from Saari and Shorthill (1966). Radar data from Thompson (1974).
Prepared 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 21°20′ AND 42°40′



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

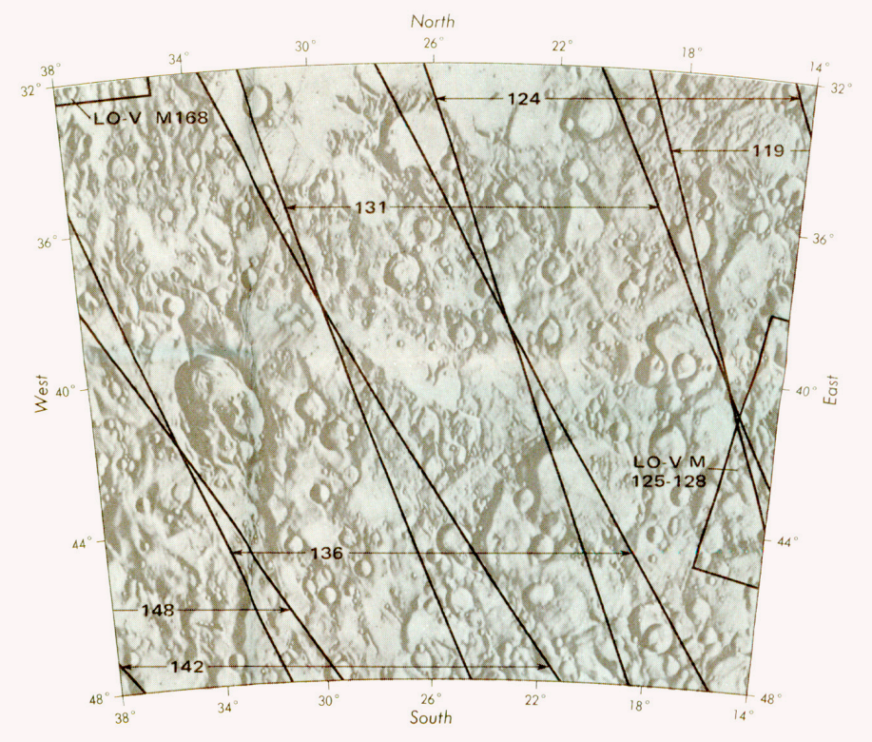
Feature names were adopted from the 1935 International Astronomical Union nomenclature system as amended by Commission 16 of the I.A.U., 1961 and 1964.

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.

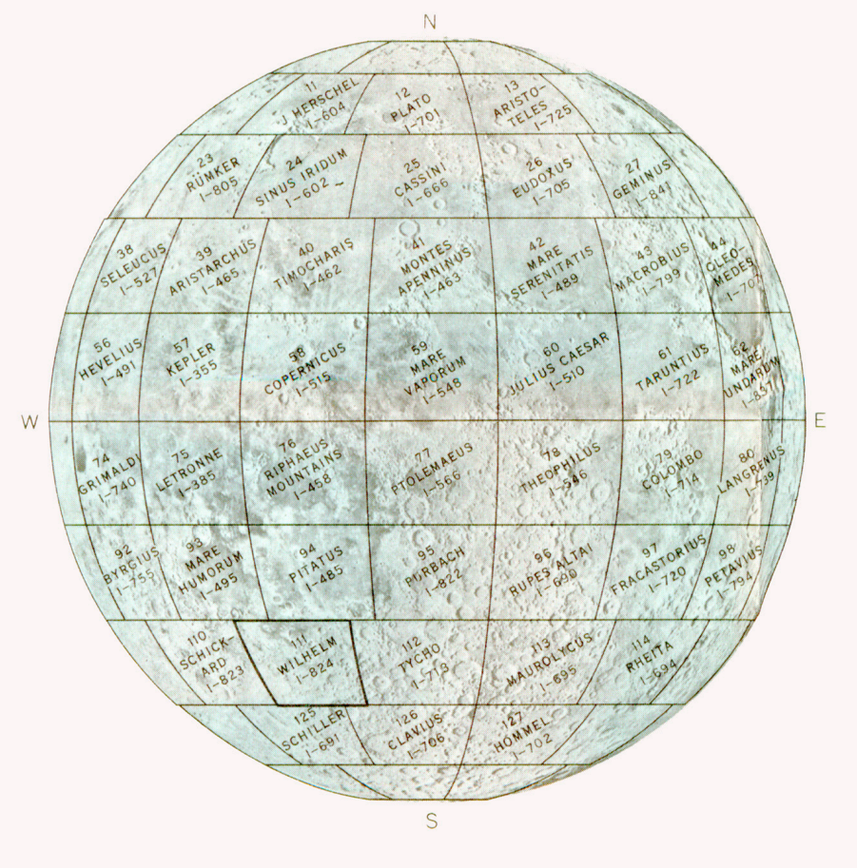
PORTRAYAL

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 Kottamia Observatories and Orbiter IV. 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 ORBITER PHOTOGRAPHIC COVERAGE
OF WILHELM QUADRANGLE

All numbers refer to Orbiter IV high-resolution (approx. 100 m) photographs except LO-V M 125-128 and LO-V M 168, Orbiter V moderate resolution (approx. 35 m)



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 WILHELM QUADRANGLE OF THE MOON

By
R. S. Saunders and Don E. Wilhelms

1974

EXPLANATION

COPERNICAN SYSTEM

Cc | Ccr | Ccrr | Ccw | Ccf

Crater materials

Characteristics
Sharp topographic detail. Craters deep relative to diameter. Bright, and usually surrounded by bright rays or halos. Some >10 km rim crest diameter have high thermal anomalies at eclipse (Thompson and others, 1974)
Cc, *crater materials, undivided. Interiors mostly steeply conical. Bright halos not detected for all craters. In craters >10 km, divided into:*
Ccr, *rim material. Forms concave-upward slope outside rim crest, steep close to crater, gentler farther out (if visible). Mostly smooth at Orbiter IV resolution (approx. 100 m); around large fresh crater Heinsius A, sharply textured subradial ridges and hummocks*
Ccrr, *rim material, radial. Ridges and grooves radial and subradial to crater Tycho, centered east of quadrangle at lat 43° S., long 11° W. Bright ray pattern of 1¼ km crater at lat 43½° S., long 33½° W.*
Ccw, *wall material. On steeply sloping surface inside crater. Very bright. Smooth at Orbiter IV resolution except some fine-scale roughness near top*
Ccf, *floor material. Hills and smooth areas*
Interpretation
Materials of impact craters (see text). Rim material is ejecta; radial textures produced by near-surface movement and coalescence of secondary impacts. Wall material is freshly exposed pre-crater bedrock and talus derived from bedrock and rim. Floor material derived from wall by mass wasting. Sharp detail, high albedo, and thermal anomalies indicate relative youth

Csc

Satellitic-crater material

Characteristics
Chains and clusters of overlapping or coalescing, very sharp-featured, elongate or irregular, bright, small craters (from barely visible to 4 km in greatest dimension). In east part of quadrangle mostly grouped around Tycho; most of remainder radial to Zuchius (southwest of quadrangle, centered at lat 61° S., long 50° W.). Distal ends of Tycho clusters commonly have delicate grooves or herringbone pattern pointing toward Tycho. Most occur along rays
Interpretation
Secondary impact craters of Tycho and probably of Zuchius

ERATOSTHENIAN SYSTEM

Ec | Ecr | Ecrh | Ecrr | Ecw | Ecf | Ecfh | Ecp

Crater materials

Characteristics
Materials of rayless craters without thermal anomalies. Rim crest slightly rounded to sharp. Mostly slightly less sharp topographically than corresponding Copernican units. Superposed on mare material, or on terra and as sharp as the craters on mare
Ec, *crater materials, undivided. Interiors steep, conical, or floored*
Ecr, *rim material, undivided. Texture similar to smooth occurrences of unit Ccr; around Epimenides S, subdued radial ridges and grooves. In Hainzel A divided into:*
Ecrh, *rim material, hummocky. Approximately equidimensional low hills on steep surface near rim crest. Also believed to form lobe in floor of crater Hainzel C*
Ecrr, *rim material, radial. Low ridges and gentle grooves radial and subradial to crater, grading outward from hummocky rim material; gently sloping surface*
Ecw, *wall material. In Hainzel A, multiple sharp-edged terraces; steep inner slopes of upper terraces bright. In Cichus, fewer, smoother terraces; surface apparently convex upward, lower albedo than in Hainzel A. In smaller craters, steep, bright, smooth, nonterraced slopes; in Epimenides S, also forms lobe at base of these steep slopes (shown by slump arrows)*
Ecf, *floor material. In Epimenides S, surface convex upward, hilly. In Hainzel A, undulatory. In Cichus, flat and featureless. In other craters, poorly exposed, apparently flat*
Ecfh, *floor material, hummocky. In Hainzel A, occurs as irregular group of hills 1 to 4 km across like unit Ih. In Cichus, small sharp peaks, rugged central hill 2 by 4 km across, and lower, smooth hummocks*
Ecp, *peak material. Central peak in Hainzel A*
Interpretation
Mostly materials of impact craters. Rim material is ejecta, including blocks thrust outward and upward (hummocky) and finer material ejected along near-surface trajectories (radial). Wall composed of rim material and brecciated bedrock that slumped along crescentic fractures after impact, enlarging crater; where bright, freshly exposed as in Copernican wall material. Hummocky floor material probably slump from walls; sharper hills in Cichus possibly uplifted by shock-induced rebound; in Hainzel A, could be volcanic. Smooth floor material is fine debris from walls, shock-produced melt, or postcrater volcanic fill. Peak material, uplifted in response to complex propagation of shock wave in bedrock materials following impact

Esc

Satellitic-crater material

Characteristics
Mostly long chains, radial to crater Hainzel A, of small, shallow, elongate or irregular craters or rimless pits; herringbone pattern as in unit Csc. Also, isolated variously oriented groups of similar craters. Queried where satellitic association not obvious
Interpretation
Long chains formed by secondary impact of ejecta from Hainzel A; other groups secondary to Hainzel A, Cichus, or some other probably Eratosthenian crater. Queried occurrences could be volcanic

IMBRIAN SYSTEM

Upper Imbrian

Im

Mare material

Characteristics
Darkest unit in quadrangle (albedo approx. 0.096 to 0.108; Pohn and Wildey, 1970) but relatively bright for lunar mare material. Mostly level surfaces; gently undulating where it thinly mantles underlying terrain (shown by dotted contacts and symbols in parentheses). Sparsely cratered. Occupies topographic lows
Interpretation
Basalt flows, highly fluid when emplaced

Ic$_2$ | Icr$_2$ | Icw$_2$ | Icf$_2$

Crater materials

Characteristics
Have general forms of corresponding Copernican and and Eratosthenian units, but more subdued in detail than any crater materials superposed on mare
Ic$_2$, *crater materials, undivided. Interiors moderately deep, conical. Slightly shallower and rim crest slightly more subuded than in unit* Ec
Icr$_2$, *rim material. Smooth or gently hummocky; merges imperceptibly with surroundings*
Icw$_2$, *wall material. Mostly steep, bright, smooth, like wall of small younger craters; also forms several basal hummocky slump lobes. In some craters probably includes flat floors obscured by shadow*
Icf$_2$, *floor material. Surface generally undulatory; some distinct smooth hills and some small moderately sharp hills*
Interpretation
Materials of impact craters. Some small craters (undivided materials) could be secondary to Orientale basin. Rim, wall, and floor materials like younger units but more modified by lunar "erosion"

Ivr

Rim material of crater Vitello

Characteristics
Smooth material, slightly subdues subjacent features around crater Vitello (centered at lat 30½° S., long 37½° W.)
Interpretation
Deposits of volcanic ejecta around Vitello. Vitello may be a caldera or, if impact crater, the volcanic activity may be localized along impact-produced fractures

Ip

Plains material

Characteristics
Surfaces level, smooth. Albedo higher than that of mare material. More craters, and larger subdued craters, than on mare; fewer than on other regional (noncrater) materials except steep slopes. Occupies topographic lows
Interpretation
Origin uncertain; could be volcanic materials, erosional debris, or impact ejecta

Ihe

Hevelius Formation

Characteristics
Mostly smooth in detail; assumes general topography of subjacent terrain, slightly subdues it. Faintly grooved N.77° W. (representative grooves shown by lineament symbols)
Interpretation
Outer ejecta of Orientale basin (lying approx. N65° W. of exposures); interpretation based on similarity to more distinctive occurrences to west

Icc$_2$ ◌

Crater-cluster material

Characteristics
Clusters of craters like those of unit Ic$_2$ or Ic, or chains of shallow coalescing craters approximately radial to Orientale basin
Interpretation
Orientation of some chains, clustering, apparent middle Imbrian age, and position near outer limits of Hevelius Formation suggest origin by secondary impact of ejecta from Orientale basin

Ic

Crater material, undivided

Characteristics
Craters small, moderately subdued, shallow, with conical or floored interiors. Criteria for further subdivision lacking
Interpretation
Origin uncertain, but most are probably impact craters

Ici | Icir | Iciw

Irregular-crater materials

Characteristics
Crater outlines noncircular, either markedly elongate or irregular with reentrants (some possibly composites of circular craters). Similar to many craters of lower Imbrian clusters (Icc$_1$); except in outline, subunits similar to those of many single lower Imbrian craters
Ici, *irregular-crater material, undivided*
Icir, *rim material*
Iciw, *wall material*
Interpretation
Secondary impact craters of Imbrium basin, or volcanic craters

Icc ◌

Crater-cluster material

Characteristics
Diverse groups of circular or irregular craters, individually 3 to 13 km in greatest dimension; morphologically unlike units Icc$_1$ or Icc$_2$. Floor relatively flat
Interpretation
Secondary impact craters of Orientale or Imbrium basins, or volcanic

It

Terra material, undivided

Characteristics
Surfaces undulatory or hilly, texture smooth to moderately rough at 100 m scale. Crater density same as on unit Ip or slightly greater, commonly more 2 to 4 km pits; fewer craters and pits than on hilly and pitted unit
Interpretation
Origin uncertain; may be thin layers of same material as in unit Ip

Lower Imbrian

Ihp

Hilly and pitted material

Characteristics
Aggregates of small (mostly 1 to 5 km), irregular to circular craters or rimless pits, and small (<2 km wide, mostly <4 km long) elongate to irregular, steep to low ridges and hills; many pits furrowlike in crater Wurzelbauer. Crests of pits >4 km diameter shown by dash-dot-dash line; ridges >4 km long shown by dash-cross-dash line. Fewer complete pre-Imbrian craters within unit limits than in adjacent terrain; some scattered domelike probable crater remnants. Best exposures in Wurzelbauer, south of Capuanus P, and at lat 42° S., long 24° W.
Interpretation
Volcanic materials or diverse material pitted by Imbrium or Orientale secondary impacts. Predominantly early Imbrian age determined from superposition relations with lower and upper Imbrian crater materials

Ih

Hilly material

Characteristics
Aggregates of small domelike hills (1 to 3 km; some to 6 km); fairly steep, rounded or peaked; subcircular or irregular plan
Interpretation
Volcanic domes, remnants of fractured bedrock, or crater ejecta

Ic$_1$ | Icr$_1$ | Icw$_1$ | Icf$_1$ | Icp$_1$

Crater materials

Characteristics
Morphologically similar to the most degraded crater materials superposed on basal Imbrian deposits near the Imbrium basin
Ic$_1$, *crater materials, undivided. More pitted, discontinuous, degraded, and shallower than younger units* (Cc, Ec, Ic$_2$)*. Broad, shallow, bowl-shaped floor (where exposed). Low, narrow rim*
Icr$_1$, *rim material. Narrow raised flank bordering rim crest, no evidence of outer radial material as in younger rim materials. Mostly cratered and irregular, texturally similar to surrounding terrain*
Icw$_1$, *wall material. Smooth; slope lower, wider than in most of unit* Icw$_2$*. Material from wall fills some large craters*
Icf$_1$, *floor material. Topographically diverse*
Icp$_1$, *peak material. Low central mound in Hainzel C; subdued analog of unit* Ecp
Interpretation
Origin probably similar to corresponding younger units, less certain because of greater degradation

Icc$_1$ ◌

Crater-cluster material

Characteristics
Large clusters of craters; many craters intersect. Individual craters 2 to 18 km diameter, typically 5 to 10 km; moderately subdued rim crest; mostly shallow concave floor (where exposed), similar to single-occurring lower Imbrian craters (unit Ic$_1$*). Individual rim crests >4 km shown by dash-dot; additional occurrences, shown by dash-dot-dot symbol, probably beneath Tycho rim material (unit* Ccrr*)*
Interpretation
Clustering, apparent early Imbrian age, and position relative to Imbrium basin (Wilhelms and McCauley, 1971; Scott, 1972) suggest origin by secondary impact of ejecta from Imbrium basin

PRE-IMBRIAN OR IMBRIAN SYSTEM

IpIt

Terra material, undivided

Characteristics
Surface non-distinctive, smooth to undulatory or somewhat rugged; shallow 1-2 km pits. Mostly lies at elevations intermediate between units It *and* plt
Interpretation
Intermixture of basin ejecta, crater material, and volcanic material

PRE-IMBRIAN

Upper pre-Imbrian

pIc$_3$ | pIcr$_3$ | pIcw$_3$ | pIcf$_3$ | pIcp$_3$

Crater materials

Characteristics
More degraded than any crater materials on basal Imbrian units, but craters mostly intact
pIc$_3$, *crater materials, undivided. Shallow, bowl-shaped or with distinct floor. Rim raised but indistinct. Following subunits mapped where distinct:*
pIcr$_3$, *rim material. Narrow flank outside rim crest texturally similar to, but distinctly raised above surrounding terrain; considerably pitted, nicked, subdued. Crest elevation variable*
pIcw$_3$, *wall material. Mostly subdued hummocky topography; slope more gentle than younger walls; a few steep "clean"-looking slopes as in Imbrian craters*
pIcf$_3$, *floor material. Subdued hills (where exposed)*
pIcp$_3$, *peak material. Small rounded central mound in Heinsius Q*
Interpretation
Origin probably similar to corresponding younger units, less certain because of greater degradation. Younger than Humorum basin

Middle pre-Imbrian

pIc$_2$ | pIcr$_2$ | pIcw$_2$

Crater materials

Characteristics
Generally similar to corresponding units of upper pre-Imbrian craters but more degraded and pitted, less distinct from surrounding terrain. Similar to materials of several craters outside quadrangle superposed on Humorum basin rim
pIc$_2$, *crater materials, undivided. Part of Capuanus in which rim and wall are indistinguishable*
pIcr$_2$, *rim material*
pIcw$_2$, *wall material*
Interpretation
Origin uncertain. Age relation to Humorum basin not determinable in quadrangle, but probably postbasin by analogy with craters elsewhere. Original crater materials probably buried, except possibly some wall material

pIc

Crater material, undivided

Characteristics
Narrow raised ring without distinct crest; texturally indistinct from surrounding terrain
Interpretation
Origin unknown, but most are probably eroded remnants of impact crater rims

pIci

Irregular-crater material

Characteristics
Similar in topography to unit pIc *and similar in outline to unit* Ici
Interpretation
Probably secondary impact craters of basins, but volcanic origin cannot be excluded

Lower pre-Imbrian

pIv

Vitello Formation

Characteristics
Chaotic, hummocky terrain. Hummocks 1 to 4 km across; gentle, equidimensional or elongate north-south. Surface slopes up to north (toward edge of Mare Humorum). Continuous with type area of Vitello Formation (lat 30°-32° S., long 34°-36° W.; Trask and Titley, 1966). Craters more subdued and older than on basal unit of Imbrian System
Interpretation
Impact ejecta of Humorum basin; possibly buried by younger materials

pIch

Chain-crater material

Characteristics
Chains of incomplete craters forming indistinct troughs approximately radial to Humorum basin
Interpretation
Formed during Humorum event, probably by gouging or secondary impact of basin ejecta along low trajectories; possibly by faulting. Chain-crater designation based on similarity with valleys radial to Orientale and Nectaris basins

pIc$_1$ | pIcr$_1$ | pIcw$_1$

Crater materials

Characteristics
Highly degraded, few distinctive features
pIc$_1$, *crater materials, undivided. Large, low rings texturally similar to surrounding terrain*
pIcr$_1$, *rim material. Outer flank of raised rings that have moderately distinct rim crest. Commonly interrupted*
pIcw$_1$, *wall material. Inner flank of raised rings that have moderately distinct rim crest; steeper than rim material. Subdued, coalesced terraces present in some; many terrace fragments in Longomontanus*
Interpretation
Textural criteria of origin lacking; impact origin inferred by analogy with younger craters. Older than Humorum basin. Original crater materials probably buried, except where wall material exposed by downslope movement. Longomontanus possibly younger than Humorum basin

pIr

Material of rugged terra

Characteristics
Ridges, hills, and plateaus up to 30 km long; steep, high; forms the most rugged features in quadrangle. Generally elongate radial to Humorum basin; less conspicuously, squared off approximately concentric with the basin. Slopes bright to moderately bright at small phase angles; smoother at Orbiter IV resolution than other units except crater walls. Same as material of smooth ridges and hills in adjacent areas (Trask and Titley, 1966; Titley, 1967)
Interpretation
Probably underlain by bedrock uplifted when Humorum basin formed. Steep slopes have shed most of the younger regolith and other materials

pIt

Terra material

Characteristics
Mostly rectangular massifs rising above surrounding terrain. Slopes less steep, smooth, and bright than those of unit pIr*. Nondistinctive surface, either smooth or pitted (like unit* IpIt*)*
Interpretation
Bedrock antedating Nubium and Humorum basins, uplifted during basin formation, covered by basin ejecta and younger materials

(pIc)
Contact
Dotted line marks limit of topographic expression of buried unit indicated in parentheses

Fault
Dashed where inferred and exposed; dotted where inferred and buried. Bar and ball on apparent downthrown side; ball on line indicates narrow graben or arcuate rille. Offsets unit or forms scarp against which younger units deposited

Mare ridge
Line marks crest of sharp mare-type ridge; also occurs in terra (in northwest map corner)

Scarp
Line marks foot of low, broad mare-type ridge; barb points downslope

Lineament
Gentle linear groove or broad trough

– + — + — + –
Narrow terra ridge

Crater rim crest
Line marks crest of exposed individual crater of a cluster or hilly and pitted unit

Obscured crater rim crest
Line marks observed crest of buried crater or inferred connection between segments of partly obliterated crater

Slump mass

Mapping conventions

All conspicuous craters larger than 4 km rim-crest diameter, and all Copernican and Eratosthenian craters larger than 3 km, are mapped. Single craters are either circular (c) or irregular (ci). Single craters larger than 10 km are subdivided into rim, wall, and other units where these are distinct. Indistinct craters are mapped by a dash-dot-dash rim-crest symbol. Grouped craters of similar appearance are mapped as parts of clusters (cc), as parts of clusters having a position satellitic to larger craters (sc), or, where more numerous but less densely packed, as parts of the hilly and pitted unit (hp). Individual craters or pits larger than 4 km in these groups are shown by a dash-dot-dash rimcrest symbol, or where large, high-rimmed, and deep, as separate craters (units c and ci). (As defined here, craters have distinct rims, pits do not.)

Materials of circular craters (designated simply "crater materials" in the explanation) are divided into age categories according to stratigraphic relations (Shoemaker and Hackman, 1962; Wilhelms, 1970; Wilhelms and McCauley, 1971) and morphology (Pohn and Offield, 1970). Where features of crater subunits that are diagnostic of age are lacking or ambiguous, the two Imbrian categories are lumped (Ic) and the three pre-Imbrian categories are lumped (pIc).

GEOLOGIC SETTING AND PHYSIOGRAPHY

The Wilhelm quadrangle lies along a mare – highlands boundary west of the crater Tycho, southeast of Mare Humorum, and southwest of Mare Nubium. The outer scarp of the Orientale basin is 1,200 km to the west-northwest. The quadrangle is characterized by pitted and mantled-appearing terra, which in the north is interrupted by patches of mare and in the south by several large pre-Imbrian craters. Most of the mare material occupies angular massif-bounded depressions which are approximately concentric and radial to the basins that contain Mare Humorum and Mare Nubium. Most of the large craters are either partly subdued (Wilhelm, Lagalla, Mee, Heinsius, Capuanus) or extensively subdued (Wurzelbauer, Montanari), the degree of subdual apparently resulting from a mantle of terra material of varying thickness. Only Longomontanus, though heavily pitted, seems relatively unmantled; it lies on the western margin of a "macro-crater province" of conspicuous large craters that extends southeast and east of the quadrangle (Hackman and Mason, 1961).

STRATIGRAPHY

Photointerpretation and radar, infrared, and photometric data have been used to determine the character, distribution, and stratigraphic relations of geologic units in the quadrangle. The origin of the units is partly inferred from results of lunar surface exploration in other regions. The oldest materials are probably impact breccias emplaced during the formation of large craters and multiringed basins, the mare materials are probably volcanic lavas (basalts), and the younger, larger circular craters are probably mostly of impact origin. The origin of units in the middle part of the sequence is less well understood; they could be formed by volcanism or by deposition of material ejected from the Nubium, Humorum, Imbrium, and Orientale basins. Indirect and tentative evidence of their origin comes from the Apollo 16 site, where units morphologically similar to the light plains and hilly and pitted units were found to consist mostly of impact breccias (AFGIT, 1973; LSPET, 1973). However, the volcanic alternative for these units in the Wilhelm quadrangle cannot be rejected on the basis of available data.

PRE-IMBRIAN BASIN-RELATED UNITS

The mountainous massifs (units pIr and pIt) that are alined concentrically and radially around the Humorum and Nubium basins probably consist of prebasin rock uplifted during or soon after formation of each basin, and mantled to an unknown extent by basin ejecta and postbasin materials. Unit pIr, which forms the steeper and brighter massifs, consists more likely of prebasin rock exposed by mass wasting of the later cover. Unit pIt also occurs as rugged mountains in the southern and western parts of the quadrangle; these massifs are not clearly related to recognizable basin-forming events.

Basin ejecta is recognized mainly in the Vitello Formation, a hummocky and apparently thick blanket that is continuous with the type area to the north along the Humorum basin rim (Trask and Titley, 1966; Titley, 1967). The Vitello is mapped much as originally defined from telescopic observations, although Lunar Orbiter photographs show the type area to be covered by ejecta (possibly volcanic) from the crater Vitello. The terrain around other, younger basins–Orientale, Imbrium, and Nectaris–is covered by ejecta out to about one basin diameter. This analogy, the mantled appearance of much of the terra, and the northward decrease in number and prominence of large craters suggest that Humorum ejecta covers most of the quadrangle. It probably forms much of the nondistinctive mantling unit, pre-Imbrian or Imbrian terra (IpIt), and may also underlie the Imbrian-age pits of the extensive hilly and pitted unit (Ihp).

HILLY AND PITTED MATERIAL

Some of the hilly and pitted material appears to cover crater floors and other features and to be of considerable thickness. Such occurrences may be volcanic deposits and the surface pits intrinsic to the eruptive or depositional processes, as proposed for materials of the Descartes mountains at the Apollo 16 site (Milton, 1968; Wilhelms and McCauley, 1971; Milton and Hodges, 1972). A volcanic origin has also been proposed for some of the materials in the Mare Humorum region mapped as the Vitello Formation by Titley (1967), but which are hilly and pitted and have been dated by their associated craters as significantly younger than the Humorum basin (Offield and Pohn, 1970, p. C166). Alternatively, the pits could be secondary impact craters superposed on other materials including Humorum basin ejecta. The Wilhelm quadrangle lies at a position relative to the Imbrium and Orientale basins where, in other regions, many basin secondary craters have been identified (Wilhelms and McCauley, 1971; Scott, 1972). Large clusters believed to be Imbrium basin secondaries (unit Icc$_1$), and smaller clusters of sharper craters believed to be Orientale secondaries (unit Icc$_2$), are mapped. The majority of the pits of unit Ihp resemble Imbrium secondaries more than the generally sharper Orientale secondaries. If they are members of the Imbrium secondary crater field, many of the underlying craters mapped as early Imbrian must instead be pre-Imbrian.

PLAINS-FORMING MATERIAL

Two units of plains-forming material are mapped, smooth light "terra" plains material (Ip) and dark mare material (Im). Both units occur in depressions but differ not only in albedo but in crater population and the nature of their extent. A third unit, undivided Imbrian terra material (It), forms undulatory surfaces adjacent to and gradational with the light plains. Both mare (Im) and light plains (Ip) materials have small Imbrian-age craters superposed, but the light plains have many more craters of apparently greater age. Light plains cover areas ranging from nearly 3,000 square km down to patches as small as 1 square km, the smallest that can be identified on Orbiter IV photographs. The mean area of mapped occurrences is about 200 square km. Mare material occurs in few patches that are generally of larger extent. Not including Palus Epidemiarum, the largest expanse, mare material covers areas ranging from 5,200 to 90 square km; the mean is 1,300 square km.

The mare material is undoubtedly volcanic (basaltic lava), but the origin of the light units (Ip, It) is in doubt. If the light material is volcanic, its high albedo may result from a distinctively different composition for terra igneous rocks or from some process which causes albedo to increase with time (Saunders, 1970; Stuart-Alexander and Howard, 1970, p. 451). A nonvolcanic alternative is that the light plains could be pooled breccias ejected from distant basins, as the plains at the Apollo 16 site appear to be (AFGIT, 1973; LSPET, 1973). This possibility is, perhaps, supported by the difference in area of occurrence from the known volcanic plains (maria). The terra material (unit It) adjoining the plains may be a thin facies of the same material (volcanic or debris), either synchronous or deposited in the early stages of filling of each depression.

In the southern highlands, differences in albedo and populations of superposed craters (Mutch and Saunders, 1972) between the light plains and adjacent terra materials bear on the origin of the plains. The albedo of the plains material is somewhat lower than that of the terra materials. The light plains have many more small (<10 km) sharp-rimmed craters than do the other regional terra units. However, the total numbers of small (<10 km) craters, including highly subdued craters, are similar or are slightly lower on the plains. These data suggest that plains and adjacent terra materials differ in age or mechanical properties, or in the origin of the superposed small craters. The albedo data suggest a different composition or grain size of surficial materials. The differences between plains and uplands suggest that the plains are not merely pools of extensive blanketing materials such as volcanic ash flows (Mackin, 1969; Cummings, 1972), fluidized impact-basin material deposited in the manner of an ash flow (Pai and others, 1972), or an ejecta blanket. Although such mechanisms might produce the differences in morphology between plains and uplands the distinct plains albedo and a cohesive surface that would preferentially retain sharp craters are properties expected of lava in isolated pools.

MATERIALS OF CIRCULAR IMBRIAN, ERATOSTHENIAN, AND COPERNICAN CRATERS

Several of the larger Eratosthenian and Copernican circular craters display features indicative of impact origin: extensive rough, terraced inner rim materials (McCauley, 1968), radial outer rim materials (out to about one crater diameter), deep floors, fields of satellitic (secondary impact) craters (Shoemaker 1962), and for Tycho on the eastern map margin, long rays (not mapped). Smaller craters displaying some of the same features are also believed to be of impact origin. The interpretation is less certain for other small young craters and all Imbrian craters.

The youngest craters have the highest thermal (Saari and Shorthill, 1966) and radar (Thompson, 1974) anomalies, indicative of fresh rock exposure. Tycho and Heinsius A have large thermal anomalies, as does an extremely sharp crater with a 1¾ km rim-crest diameter and a 12-km bright ray pattern (unit Ccrr) at lat 43½° S., long 33¾° W.

All the above criteria for impact origin are lacking in the crater Vitello, so this crater is probably volcanic or an impact crater greatly modified by volcanism. Its center (north of the quadrangle) has a high thermal anomaly typical of young Copernican craters, yet all photographic evidence indicates that the rim material (unit Ivr) is older than the adjacent mare material, and therefore probably Imbrian in age. This discrepancy suggests post-Imbrian modification of the crater, possibly by isostatic rebound, producing the fresh boulder-strewn cracks which are the apparent source of the anomaly. The rim material is probably volcanic; it is an unusually dark, smooth blanket having little or none of the radial texture that characterize impact blankets of its age and size.

STRUCTURE

The major structures are the raised and depressed belts concentric and radial to the Nubium and Humorum basins (Wilhelms and McCauley, 1971). The one with the greatest relief is the Humorum ring near the northwest map corner. Its jagged basinward scarp is mapped interpretively as a fault (lat 34¾° N., long 29¾° W., to lat 37¼° S., long 38° W.).

Distinct grabens (the Rimae Ramsden) in the mare of Palus Epidemiarum have one trend roughly concentric to the Humorum basin and another that is both radial to the Humorum basin and concentric with the Nubium basin. The emplacement of the mare and therefore the movement on these grabens occurred long after the major basin structures formed. The faulting may have been a result of crustal adjustment to the extrusion of mare material and therefore unrelated to the basin structures, or it may reflect compaction over old basin structures.

In the northwest corner of the quadrangle, part of a system of sharp ridges and scarps several hundred kilometers long and approximately radial to the Humorum basin traverses diverse terra features (Saunders, 1970). These features are typical of lunar maria but are rare in the terrae. The fracturing that produced the ridges–either by faulting of the surface material or by serving as an access route for volcanic extrusions–may have been contemporaneous and cogenetic with the Rimae Ramsden faulting. The ridges have the albedo of the ambient material, either terra or mare, suggesting that they did not extrude new material or at least that new material did not break through the fragmental regolith.

GEOLOGIC HISTORY

The earliest decipherable events in the quadrangle (as on most of the Moon) apparently were impacts that produced large craters and circular multiringed basins. First was the Nubium impact which created several troughs and rises, and probably deposited considerable ejecta. Then were formed large early pre-Imbrian craters and possibly Heinsius and Capuanus. Next, an impact formed the Humorum basin northwest of the quadrangle, constructing new troughs and ridges transverse to those of Nubium, depositing ejecta over much or all of the quadrangle, and gouging basin-radial crater chains onto the old terrain in and beyond the ejecta blanket.

At the beginning of Imbrian time, ejecta from the Imbrium basin far to the north impacted the region. It produced clusters of large craters and possibly many small pits and furrows. Alternatively, the smaller features may have been produced by volcanism following the Imbrium impact. In the middle of the Imbrian Period, the Orientale basin formed west of the quadrangle, resulting in the deposition of some thin ejecta (Hevelius Formation) and the creation of secondary impact craters in the quadrangle. This event was followed by formation of light plains in crater floors and circumbasin troughs, by the formation of impact and volcanic craters, including the possible caldera or hybrid, Vitello, and, at the end of the Imbrian Period, by the eruption of mare materials into depressions.

In the postmare period, which was probably longer than all the preceding time, the only major events were the impacts that formed the Eratosthenian and Copernican craters and the faulting that formed the Rimae Ramsden.

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