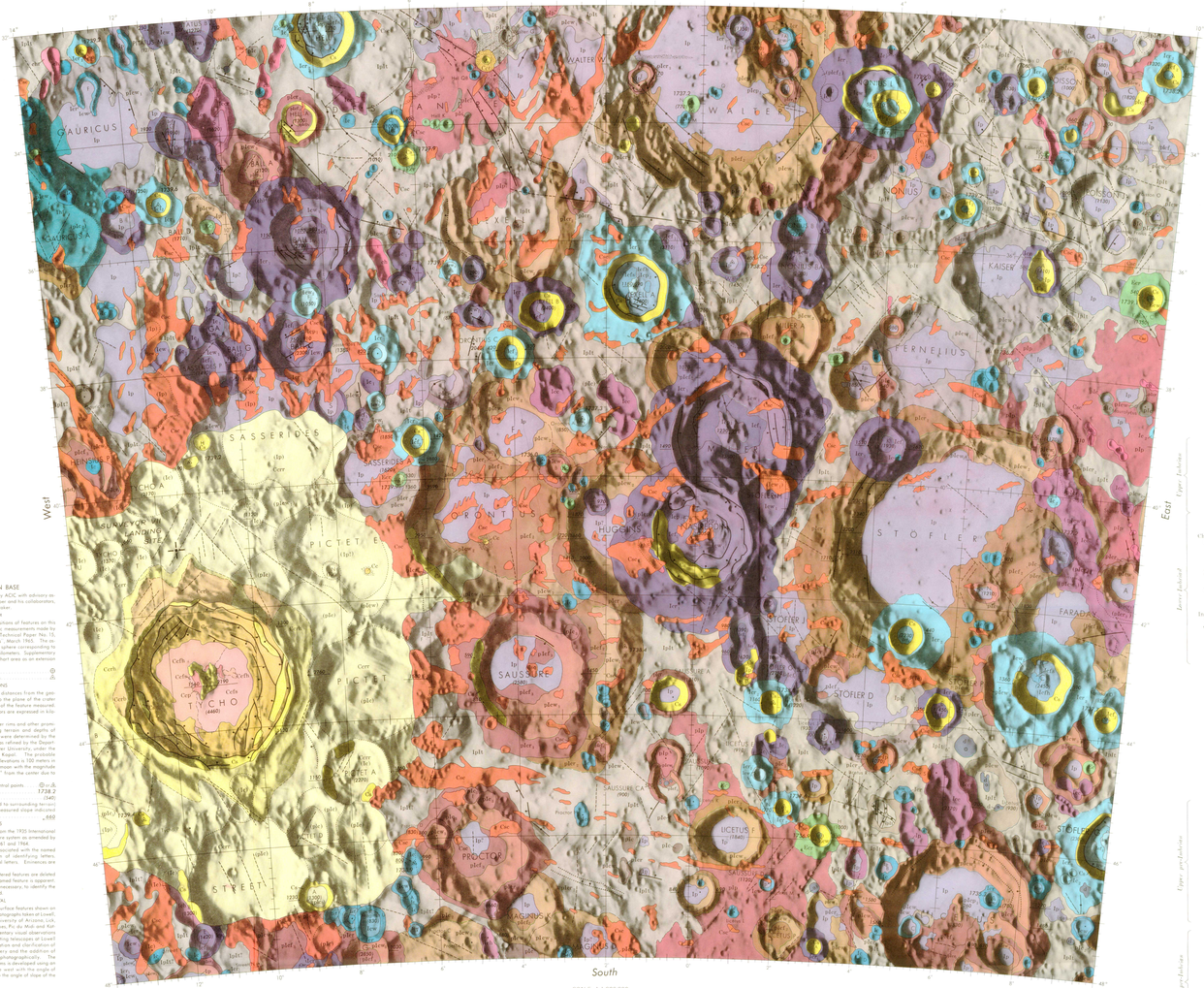
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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

GEOLOGIC ATLAS OF THE MOON
TYCHO QUADRANGLE
I–713 (LAC 112)



SCALE 1:1 000 000
LAMBERT CONFORMAL PROJECTION
STANDARD PARALLELS 21°09' AND 42°40'

Lunar base chart LAC 112, 1st edition, by Aeronautical Chart and Information Center, U.S. Air Force, St. Louis, Missouri, 63118

Principal sources of geologic information: Published and unpublished photographs from the Lick, Pic-du-Midi, Catalina, and Mt. Wilson (Haas-Johnson) 1:1.5 Observatories; Lunar Orbiter photographs IV H100, H107, H112, H119, H124; V M125–128; V H125–128 (Langley Research Center, NASA); near-full-Moon plate 5818 taken at U.S. Naval Observatory, Flagstaff, Arizona.

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

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 a radius of 1738.2 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 geocentrical 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 Astrogeology under the supervision and 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	1738.2
Depths of craters (rim to floor)	(540)

Relative elevations (referenced to surrounding terrain) with direction and extent of measured slope indicated

	+460

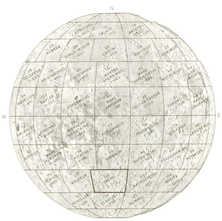
NAMES

Feature names were adopted from the 1935 International Astronomical Union nomenclature system as amended by Commission 16 (A.I.A.U. 1961, 1964, 1967, 1970). Supplementary features are associated with the named feature by means of small capital 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. No.1, Catalina Station University of Arizona, Lick, McDonald, Mount Wilson, Yerkes, Pic du Midi and Kottamia Observatories. Supplementary visual observations with the 20 and 24 inch refracting telescopes at Lowell Observatory provide identification and classification of the various features portrayed. The delineation 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.



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 TYCHO QUADRANGLE OF THE MOON

By
H. A. Pohn
1972

LUNAR ORBITER PHOTOGRAPHIC COVERAGE OF TYCHO QUADRANGLE
LO V H 125–128, Orbiter V high-resolution frames (approx. 8 m identification resolution); LO V M 125–128, Orbiter V medium resolution frames (approx. 60 m); all other numbers refer to Orbiter IV high-resolution frames (approx. 100 m)

EXPLANATION

Cc — Slope material

Characteristics
Material on steep slopes, primarily crater walls, distinctly brighter than Tycho ray material; albedo is 0.06–0.08 (through-out exploration, albedo data from Pohn and Wilhelms, 1970)
Interpretation
Bedrock and blocky talus exposed by impact, faulting, and mass wasting. Generally younger than Tycho ray material

Ccr, Cer — Crater materials

Characteristics
Ccr, crater material, undivided. Material of two bright, steep-sided craters in southcentral part of quadrangle (no small (~1 km size crest diameter) to distinguish subunits. Superposed on Tycho materials
Cer, rim material. Surrounds single crater (Hell QA1) in southcentral part of quadrangle; crater has sharp rim and very bright rays which interrupt Tycho rays
Interpretation
Materials of impact craters younger than Tycho

Rm — Ray material

Characteristics
Streaks and halos having higher albedo than Tycho rays. Occurs around three small (~1 km) Copernican craters and in east-west trending patch on floor of Walter
Interpretation
Fine-grained ejecta of small Copernican impact craters; in Walter, bright slope material and ejecta of secondary impact craters of unknown provenance
NOTE: Ray material from Tycho covers most of quadrangle and has been omitted to clarify map and to show rays of the few small craters younger than Tycho.

Csc — Satellite crater material

Characteristics
Material of small generally sharp-rimmed craters in clusters and strings subradial to crater Tycho. Craters are mostly small simple craters in radial ray crater materials. Most strings extend from atmosphere or bunded pattern splaying outward from Tycho
Interpretation
Material of secondary impact craters produced by ejecta from Tycho. Some patches show abruptly at crater rim crests having Tycho but never on flanks and opposite walls, indicating initial shattering—ejecta impacted surface at angle less than slope of walls

Cefs, Cefh, Cerh, Ceh, Cerr, Cew, Cer — Materials of crater Tycho

Characteristics
Cefs, fluor material, smooth. Few knummocks. Truncated by western frontera knobs of rather rough; barely visible at Orbiter IV resolution (about 30 m) but apparent on Orbiter V photographs (resolution 5 m). Density of craters <1 km diameter less than on rim
Cefh, fluor material, hummocky. Broadly rounded knummocks ½ to 1 km diameter. Numerous fracture bou of craters wide. Density of craters <1 km less than on rim
Cerh, rim material, blocky. Coarse and rather regular knummocks about ½ km diameter adjacent to rim crest
Ceh, rim material, hummocky. Large subdued knummocks 1 to 2 km diameter. Rim crest is discontinuous; subconcentric to rim crest. Heavily faulted in part. Dotted to unit Cerh where that unit present
Cer, rim material, radial. Continuous ejecta having rough or braided texture radial to Tycho. Subdued satellitic craters abundant that are marginal near outer contact; grades outward into fields dominated by satellitic craters; unit Csc
Cew, wall material. Finely hummocky material on terraced wall. Small irregular and locally sharp ridges and rimmed valleys trend down steep slopes
Cep, peak material. Irregular complex complex of ridges and peaks near center of crater

Ec, Ecr, Ecw — Crater materials

Characteristics
Ec, crater materials, undivided. Fresh unerroged craters too small (<5 km rimcrest diameter for subdivision of units
Ecr, rim material. Positive relief outside rim crest; concave upward; hummocky near crest, grading outward into subradial to flat surface
Ecw, wall material. Steep walls in craters; appears finely granular at Orbiter IV resolution but flat floor in Keiser E
Interpretation
Materials of impact craters more degraded than Copernican materials by seismic shaking and micrometeorite bombardment

Ic, Icr, Icw, Icf, Icfh, Icfs, Icp$_h$ — Crater materials

Characteristics
Ic, crater materials, undivided. Rim crests moderately subdued but fresh in appearance. In contact <2 km, similar to Kepler crater. Icw, wall material. Walls terraced but not collected
Icf, fluor material, undivided. Mixture of smooth and hummocky fluor materials
Icfh, fluor material, hummocky. Similar to unit Cefh but more subdued
Icfs, fluor material, smooth. Similar to unit Cefs but without knummocks or hummocks
Icp$_h$, peak material. Similar to unit Cep but more subdued
Interpretation
Materials of impact craters similar in origin to those of younger craters but more highly modified by impact, subsidence, mass-wasting, and seismic shaking

Ice$_1$, Icr$_1$, Icw$_1$, Icf$_1$, Icfh$_1$, Icfs$_1$, Icp$_{h1}$ — Crater materials

Characteristics
Ic$_1$, crater materials, undivided. Rim crests moderately subdued but fresh in appearance. In contact <2 km, similar to Kepler crater. Icw$_1$, wall material. Walls terraced but not collected
Icf$_1$, fluor material, undivided. Mixture of smooth and hummocky fluor materials
Icfh$_1$, fluor material, hummocky. Similar to unit Cefh but more subdued
Icfs$_1$, fluor material, smooth. Similar to unit Cefs but without knummocks or hummocks
Icp$_{h1}$, peak material. Similar to unit Cep but more subdued
Interpretation
Materials of impact craters similar to origin to those of younger craters but more highly modified by impact, subsidence, mass-wasting, and seismic shaking

Ice$_2$, Icr$_2$, Icw$_2$, Icf$_2$, Icfh$_2$, Icfs$_2$, Icp$_{h2}$ — Crater materials

Characteristics
Ic$_2$, crater materials, undivided. Rim crests moderately subdued but fresh in appearance. In contact <2 km, similar to Kepler crater. Icw$_2$, wall material. Similar to unit Ice$_1$ but more subdued; in subdivisions, in subdivisions small craters, less at least one large crater wall
Icf$_2$, fluor material, undivided. Similar to unit Icf$_1$ but considerably subdued and cratered
Icfh$_2$, fluor material. Similar to unit Icfh$_1$
Icp$_{h2}$, peak material. Similar to unit Icp$_{h1}$
Interpretation
Same as for upper Imbrian crater materials but craters more subdued and therefore older

Ipf — Hilly and furrowed material

Characteristics
Material of low, circular to elongate gently rounded hills and subdued furrows; some bounding ridges, in places nearly encompassing crater Ptolemaeus; in Ptolemaeus, subdivided with hilly terra material. Elevation rim material of lower Imbrian crater Sharonov B but other Imbrian craters superposed
Interpretation
Volcanic material of Imbrian age

Ipt — Smooth plains material

Characteristics
Flat cratered surfaces in many crater floors and in broad depressions in crater rims and in subsidiary depressions; elevation ranges from depression to depression. Crater density approximately same as or somewhat higher than on mare materials (not in quadrangle). Queried near crater Tycho where numerous satellite craters obscure characteristics and intercept interval uncertainty of unit
Interpretation
Volcanic materials, possibly ash-flow tuffs—eruptured from many separate vents during Imbrian time and flooded early Imbrian topography of intrusion

Ipltt — Hilly terra material

Characteristics
Forms hilly intercrater terrain. Rolling to irregularly hummocky and pitted at 1–2 km scale; locally rough; rough and highly lineated between craters Nonius and Fernelius. Obscures early pre-Imbrian crater rim materials and grooved wall and floor materials; also present on some small lobes of upper pre-Imbrian rim materials. Queried where patches are surrounded by Tycho ejecta
Interpretation
Probable thin to moderately thick blanket, possibly of ash-flow and ash-fall tuff, deposited on pre-existing terra and crater materials. Lineaments structural or depositional or both. Apparent absence on middle and upper pre-Imbrian crater units possibly due to thinner mantle. Age probably pre-Imbrian but possibly Imbrian in places

plc$_1$, plcr$_1$, plcw$_1$, plcf$_1$, plcp$_1$ — Crater materials

Characteristics
plc$_1$, crater materials undivided. Subunits not mapped because of limited areal extent. Rim crests partly truncated and lower than plcr$_2$
plcr$_1$, rim material. Subdued raised rims; rim crest partly truncated and lower than plcr$_2$
plcw$_1$, wall material. Moderately steep to subdued, hummocky terraced walls; terraces not as well developed as those in small craters of younger materials; terrace width decreased in small craters
plcf$_1$, fluor material. Mostly developed as broad, rather smooth floors; some hilly, ridges and broad hummocks; appears finely granular at Orbiter IV resolution
plcp$_1$, peak material. Moderately cratered. Few sharp ridge crests, in part mesa to steep; moderately subdued peaks in center
Interpretation
Origin similar to corresponding younger crater units but more highly modified by impact, subsidence, mass-wasting, and seismic shaking

plp — Plains material

Characteristics
Mainly in low intercrater areas. Flat to gently rolling surface. Rim materials of craters rectored than hilly terra material; most rim materials not exposed. Rim crests of craters predominant with those units. Pretty craters some pre-Imbrian crater rim materials
Interpretation
Blanket of material thick enough to obscure preexisting topography, probably fluid volcanic materials, most likely ash flow tuffs, in part may be very roguelik developed in place

plc$_2$, plcr$_2$, plcw$_2$, plcf$_2$, plcp$_2$ — Crater materials

Characteristics
plc$_2$, crater materials undivided. Similar to unit plc$_1$ but markedly to completely subdued
plcr$_2$, rim material. Subdued and highly cratered; rim crest mostly rounded; no sharp crests
plcw$_2$, wall material. Subdued, hummocky; terraces subdued and barely discernible; rounded ridges and broad hummocks
plcf$_2$, fluor material. Similar to but more subdued than unit plcf$_1$
plcp$_2$, peak material. Densely cratered; highly subdued peaks in Walter; buried in Wrigley. No sharp crests; slopes gentle
Interpretation
Same as for upper pre-Imbrian crater materials

plcr$_3$, plcw$_3$ — Crater materials

Characteristics
plc$_3$, rim material. Highly reduced to barely discernible rims and ridges; no rim crest discernible; finely cratered
plcw$_3$, wall material. Hummocky; slopes shallow; few terrace segments
Interpretation
Same as for middle and upper pre-Imbrian crater materials

plc, plcr, plcw — Crater materials

Characteristics
plc$_3$, crater materials undivided. Subunits not mapped because of buried or small crater size. Rims markedly to completely subdued
plcr$_3$, rim material. Rim crests subdued and finely crenulated. Rims commonly interrupted by small craters
plcw$_3$, wall material. Similar to units plcw$_1$, plcw$_2$, and plcw$_3$
Interpretation
Same as for other pre-Imbrian crustes but classification within pre-Imbrian uncertain

d — Cratered dome material

Characteristics
Domes with small summit pits. Circular in plan; range from 3 to 16 km diameter, rarely as much as 30 km. Surfaces generally smooth but finely lineated texture in places
Interpretation
Probably volcanic domes

ch, chr — Chain crater materials

Characteristics
ch, crater material. Chains ~30 km long of small rectangular craters. Crater density and degree of subdued rims similar to those of adjacent crater materials
chr, rim material. Low slightly hummocky rims surrounding the chains
Interpretation
Chains of volcanic craters, probably explosion crests; rim material composed of pyroclastic ejecta and possibly some resetting rock. Age not determined

Contact
Solid where well defined; long dashed where approximately located; short-dashed where gradational

Concealed contact
Buried and indicated by symbol to parentheses

Inferred fault or fault scarp
Long dashed where approximately located, dotted where concealed. Line of bow of scarp; bar and ball on apparent downthrown side. Fault either offsets ejecta or is younger against which younger rocks were deposited

Narrow trough
Interpretation: Graben

Lineament
Gentle linear depression or scarp; Interpretation: Fault, buried or exposed; sense of movement undetermined

Buried rim crest

Depression

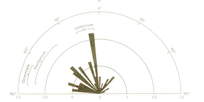


FIGURE 1.—*Azimuth frequency of major faults in the Tycho quadrangle related to the major basins.*

GEOLOGIC SETTING

The Tycho quadrangle is centrally located in the southern half of the Earthside hemisphere of the Moon. The area is characterized by a high density of craters, the largest of which—Stoefler—is about 140 km in diameter. The northern and eastern parts of the quadrangle are dominated by plains (plp, Ipt) and hilly terra (Ipltt) units of regional extent, and the western part by the crater Tycho and its ejecta blanket. Structural features are concentrated mainly in the Imbrian basins to the north and the Orientale and Humorum basins to the southwest are present, although bounding units related to those basins are not recognized.

STRATIGRAPHY

Pre-Imbrian pleistocfloorming material (plp).—Parts of the quadrangle are occupied by densely cratered, relatively bright blanketing plains material of pre-Imbrian age. The unit shares some of the characteristics of hilly terra material (Ipltt) and Imbrian plains (Ipt) units; it is apparently intermediate with respect to these units in terms of age. It is associated only with floodlike, flat-topped, pre-Imbrian plains occupy broad shallow depressions in the northcentral, eastern, and southcentral parts of the quadrangle. The unit lacks the hummocky topography and lineated texture of the hilly terra materials, but has the same albedo. Also, like the Imbrian plains unit, it is apparently of volcanic origin and may have accumulated as a series of highly fluid ash flows—probably from several centers of eruption.

Pre-Imbrian and Imbrian(?) hilly terra material (Ipltt).—Much of the terra in the quadrangle that is not occupied by mapped craters is relatively flat but has a gently hilly, rolling, or finely to irregularly hummocky or faintly lineated surface. Much of this surface texture is believed to be intrinsic to a material stratigraphic unit, mapped as hilly terra material, that fills the intercrater areas. In the east half of the quadrangle this unit covers most of the rim deposits of lower pre-Imbrian craters (unit plcr;) as well as broad expanses having low crater densities. In areas where the finely hummocky topography which best characterizes this unit is absent, rim deposits of pre-Imbrian craters are commonly difficult to identify. They are most preserved and have distinct positive relief. Hilly material is interpreted to be volcanic in origin and may be composed of ash-flow deposits of variable thickness. Inasmuch as topographically distinguishable sources are not present in the area, the volcanic materials may be derived from one of the small craters that are so numerous here (see also Offield, 1971). Part of the unit is probably composed of lunar regolith developed in place.

Imbrian cratering-forming material (Ip).—Mare materials are absent in the quadrangle; however, a plains-forming unit of Imbrian age, similar in some respects to mare material, is present. It occupies the floors of many pre-Imbrian and early Imbrian craters as well as other topographic lows in all parts of the quadrangle, except in the immediate vicinity of the crater Tycho. The unit has about the same density of superposed craters as some mare units mapped elsewhere on the lunar surface but has a slightly higher albedo than typical mare material. On the other hand, it is less densely cratered and slightly darker than the pre-Imbrian plains-forming unit. Its presence in craters of pre-Imbrian age and its lack of association with any basin rim or ejecta blanket is probably was emplaced in early Imbrian time.

Crater materials.—The relative ages of crater materials are determined by a comparison of their morphology within selected size categories (Pohn and Offield, 1970), and their assignment to the lunar time-stratigraphic systems followed Offield (1971).

Rim and floor materials of the crater Tycho.—Tycho is the youngest large crater on the near side of the Moon and is generally recognized to have formed by impact. Because of its youthfulness, the features characteristic of impact-formed craters are well developed. Of particular interest are the materials of the rim and ejecta blanket and the relation of the rim crest to the floor and smaller areas of the crater rim. Their mode of origin is controversial. In describing the geology of the Surveyor VII landing site, Shoemaker and others (1968, p. 26), for example, give three plausible explanations for the origin of flows on the rim of Tycho:

(1) The flows are volcanic and have been produced by extrusion of lava derived from depth, possibly formed or extruded in response to the forces that created the basin.

(2) The flows are relatively cold ejecta flows, which were mobile as fluid because they contained either liquid water or gas at the time of ejection. The ejecta blanket, which is continuous or nearly so around the crater, and possibly some gas) heated by shock and by viscous flow during ejection of the debris from the craters.

STRUCTURE AND MATERIALS OF CRATER CHAINS AND CLUSTERS

An analysis of lineaments from Lunar Orbiter IV photographs (Pohn and Wilhelms, 1970) between 0° and 90° W. and 0° and 90° N. and W. (units: 1 km). On this part of the lunar surface most of these directions is radial to the major lunar basins. On the other hand, an analysis of the major fault directions shows pronounced radiality to the nearby basins, and to the more distant Imbrian basin (fig. 1). In addition, many of the long axes of the crater chains and some clusters (whose materials are mapped as units Ich, Ice, and Icer) are subradial to the Imbrian basin. These subradial chains could be volcanic in origin, but it seems more likely that they are secondary impact craters of the Imbrian basin. Many of the chain craters have pronounced raised rims, and the materials of the rims and ejecta blankets of most craters mapped elsewhere on the Moon. Their detailed morphology is similar to that of the oldest craters on the earliest Imbrian deposits of the Apennine Mountains. Thus, they probably are secondary craters of early Imbrian age.

GEOLOGIC HISTORY

The earliest decipherable events that occurred in the quadrangle were the formation in pre-Imbrian time (presumably by impact) of many of the large craters. Some volcanism also occurred in the late pre-Imbrian, resulting in the deposition of plains and, possibly, hilly terra units. The impact which formed the Imbrian basin (centered about 1,200 miles south of the Tycho quadrangle) is radially oriented Imbrian time-period structures, most of material, some of which apparently formed secondary impact craters and ejecta blanket materials. Some of the hilly terra material (volcanics mentioned during the Imbrian Period, and in early Imbrian time, another plains-forming unit was deposited. A few impact craters were formed during the Imbrian/Eratosthenian Period. Some impact craters were probably formed early in the Copernican Period, but the evidence for dating these craters (ray material) has been largely obscured by the rays from Tycho. Formation of the crater Tycho in late Copernican time is the most recent major event in the area. Deposits formed by the Tycho impact have covered and subdued the topography of the northeastern part of the quadrangle, and abundant secondary craters (Csc) were formed in the eastern part of the quadrangle. Most of the near side and much of the near side of the Moon was mantled with this discontinuous Tycho ray deposits (not mapped).

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