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
CLAVIUS QUADRANGLE
I-706 (LAC-126)

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 △ 1738.7
Depths of craters (rim to floor) . . . . (1670)
Relative elevations (referenced to surrounding terrain) with direction and extent of measured slope indicated 800

NAMES

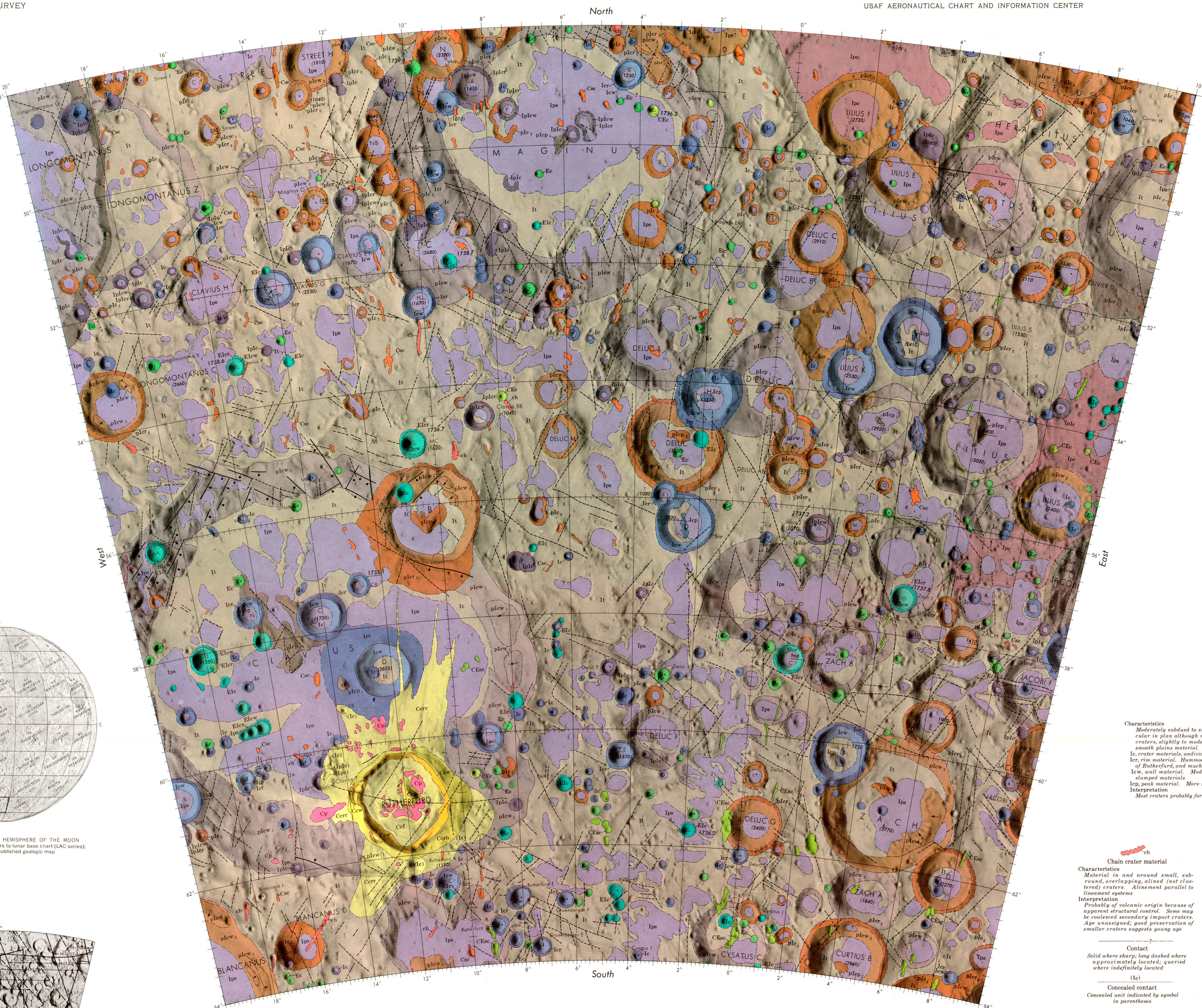
Feature names were adopted from the 1935 International Astronomical Union nomenclature system as amended by Commission 16 of the I.A.U., 1961 and 1964.

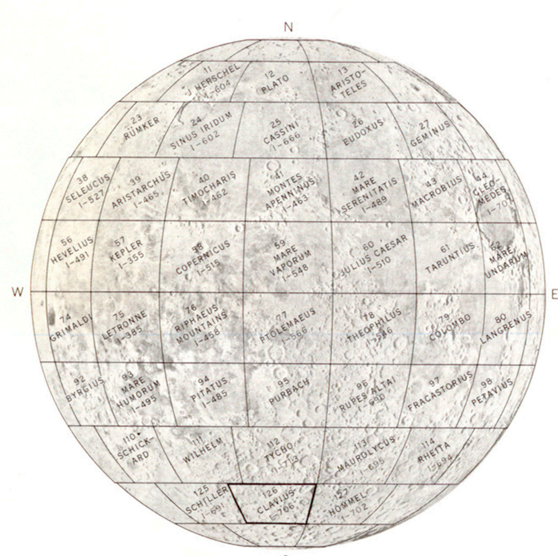
Supplementary features are associated with the named features through the addition of identifying letters. Craters are identified by capital letters. Eminences are identified by Greek letters.

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.

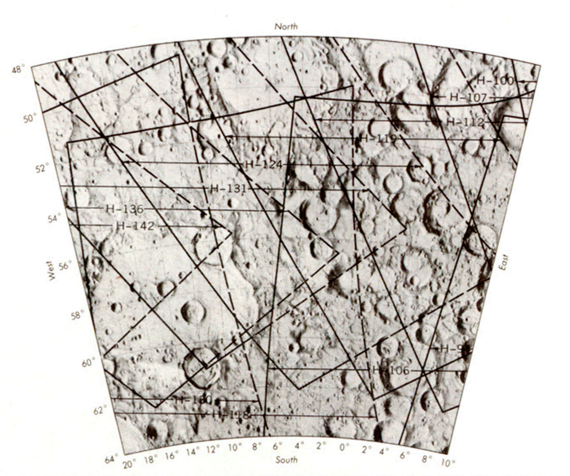
PORTRAYAL

"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."





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 CLAVIUS QUADRANGLE

Lunar base chart LAC 126, 1st edition, 1967, by U.S. Air Force Aeronautical Chart and Information Center, St. Louis, Missouri 63118

SCALE 1:1 000 000
LAMBERT CONFORMAL CONIC PROJECTION

10 5 0 50 100 STATUTE MILES
10 5 0 50 100 150 KILOMETERS

Principle sources of geologic information: Unpublished Lunar Orbiter IV high-resolution photographs (identification resolution, approx. 100 m), NASA, Langley Research Center (see index map); published and unpublished photographs by G. H. Herbig, Lick Observatory; rectified photographic lunar atlas by Whitaker and others (1963); visual telescopic observations by author at U.S. Geological Survey Observatory, Flagstaff, Ariz., 1966–1967. Mapped 1966–1970

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

GEOLOGIC MAP OF THE CLAVIUS QUADRANGLE OF THE MOON

By

David Cummings

1972

EXPLANATION

COPERNICAN SYSTEM

Cp

Plains material, very smooth

Characteristics
Dark, very smooth mare-like material; appears uncratered on Lunar Orbiter IV photographs. Occurs only in and around crater Rutherfurd. Embays Rutherfurd ejecta and apparently interrupts Tycho ray material (unmapped). Patches >2 km mapped
Interpretation
Probably volcanic extrusions younger than Rutherfurd and Tycho

Csc

Satellitic crater material of Tycho

Characteristics
Material of small (generally <3 km), distinct, sharply defined craters; circular, elongate, or irregular in outline. Occur singly or in clusters. Clusters and elongate craters generally alined radially to crater Tycho (north of quadrangle). Only conspicuous occurrences mapped
Interpretation
Radial orientation suggests origin by secondary impact of Tycho ejecta; probably contains material excavated from Tycho

Ccrh | Ccrr | Ccw | Ccf | Ccp

Materials of crater Rutherfurd

Characteristics
Materials of sharp-rimmed crater approx. 48 km in diameter at rim crest
Ccrh, *rim material, hummocky. Forms raised hummocky rim immediately surrounding crater. Hummocks decrease in size outward from rim crest. Grades peripherally into:*
Ccrr, *rim material, radial. Ridges and grooves radial to crater. North of crater includes radial chains of satellitic craters*
Ccw, *wall material. Forms steep slope immediately inside rim crest and terraced and slumped materials below*
Ccf, *floor material. Generally hummocky, rough texture*
Ccp, *peak material. Generally hummocky, sharp, steep hills on crater floor.*
Interpretation
Irregular distribution of rim material, hummocky and radial textures of rim deposits, and satellitic (secondary) craters indicate impact origin. Hummocky rim material probably overturned flap of bedrock and relatively large blocks of fragmented and brecciated bedrock ejecta; radial material, relatively small blocks of ejected bedrock, some excavating secondary craters. Wall material possibly brecciated bedrock; terraces formed by slumping of crater wall indicate widening of crater. Floor material, fallback, slump material from wall, or shocked bedrock (very high-temperature, very high-pressure metamorphism) resulting from impact. Peak material, possibly brecciated bedrock uplifted by decompression or gravitative rebound; highly metamorphosed by shock. Alternatively, all materials could be volcanic; rim material, cinders and bombs; radial rim material, cinders; floor material may include lava; peak material, domed volcanics

ERATOSTHENIAN OR COPERNICAN SYSTEM

CEc

Crater materials

Characteristics
Materials of fresh craters having sharp rim crests. No rays visible. Craters generally <5 km; circular in outline and conical in profile. Small size precludes subdivisions into rim, wall, and floor units
Interpretation
Mainly impact crater materials; some possibly volcanic

CEsc

Satellitic crater material of Moretus

Characteristics
Generally slightly subdued rim crests; craters similar to but less distinct than unit Csc. *Clusters and elongate craters generally alined radially to crater Moretus south of quadrangle. Only conspicuous occurrences mapped*
Interpretation
Formed by secondary impact of Moretus ejecta; may contain material excavated from Moretus

ERATOSTHENIAN SYSTEM

Ec

Crater materials

Characteristics
Typically very slightly subdued rim crests; otherwise similar to unit CEc
Interpretation
Mainly impact crater materials; some possibly volcanic

IMBRIAN OR ERATOSTHENIAN SYSTEM

EIc | EIcr | EIcw

Crater materials

Characteristics
Slightly subdued to moderately subdued rim crests. Small craters (<5 km) generally circular in outline and conical in profile; partly polygonal rim crests in some craters. Larger craters have slightly polygonal rim crests. Satellitic craters not observed
EIc, *crater materials, undivided*
EIcr, *rim material, hummocky and smooth; more cratered and subdued than rim materials of Rutherfurd*
EIcw, *wall material. Steep interior slope, slightly more cratered and subdued than unit* Ccw
Interpretation
Impact crater materials; some may be volcanic. Small polygonal craters are probably older

IMBRIAN SYSTEM

Ic | Icr | Icw | Icp

Crater materials

Characteristics
Moderately subdued to subrounded rim crests. Small craters (<5 km), generally circular in plan although more polygonal than younger craters of same size. In larger craters, slightly to moderately polygonal rim crests. Many craters partly filled by smooth plains material. Satellitic craters not observed
Ic, *crater materials, undivided*
Icr, *rim material. Hummocky and smooth; more cratered and subdued than rim materials of Rutherfurd, and much less extensive even in largest craters*
Icw, *wall material. Moderately steep interior slope; in places includes terraced and slumped materials*
Icp, *peak material. More subdued than unit* Ccp
Interpretation
Most craters probably formed by impact; modified by slumping and filling

It

Terra material, hilly

Characteristics
Moderately dark; subdued, hilly surface. Abundant in intercrater areas and also present on some crater floors of Imbrian and older age
Interpretation
May be relatively thin deposits of ash-flow or ash-fall tuffs partly burying or mantling older terrain of unknown origin

Ips

Plains material, smooth

Characteristics
Generally dark, flat, smooth; moderate density of craters; in places undulatory. Covers some intercrater areas, and floors and flanks of many Imbrian and older craters. Patches >2 km are mapped
Interpretation
Probably extensive deposits of ash-flow and ash-fall tuff; possibly some basalt flows. Deposits relatively thick, completely burying subjacent topography

Ipc

Plains material, cratered

Characteristics
Generally dark, moderately cratered; covers some intercrater areas and older crater floors in east and northeast parts of quadrangle. More densely cratered than smooth plains material and craters generally larger; 1 km craters common; some are indistinct. Patches >3 km are mapped
Interpretation
Probably ash-flow and ash-fall tuff. Higher density of small craters compared with smooth plains may be due to greater age. Deposits relatively thick, completely burying underlying terrain

PRE-IMBRIAN OR IMBRIAN

IpIc | IpIcr | IpIcw

Crater materials

Characteristics
Subrounded to rounded rim crests that are moderately to distinctly polygonal. Craters partly filled with a plains unit, Ips *or* Ipc
IpIc, *crater materials, undivided*
IpIcr, *rim material. Subdued material in narrow belt outside rim crest*
IpIcw, *wall material. Moderately steep slope between crater rim crest and floor*
Interpretation
Origin probably same as for younger crater materials

PRE-IMBRIAN

Upper Pre-Imbrian

pIc_2 | $pIcr_2$ | $pIcw_2$ | $pIcp_2$

Crater materials

Characteristics
Rounded rim crests and heavily cratered rim flanks. Smaller craters lack elevated rim crests, and walls merge with surrounding terrain. Polygonal outlines. Craters partly filled with a plains unit
pIc_2, *crater materials, undivided*
$pIcr_2$, *rim material. Subdued hummocky material in narrow belt outside rim crest*
$pIcw_2$, *wall material. Forms slope between crater rim crest and floor. Surface more cratered and subdued than younger crater walls. In places includes terraced and slumped materials*
$pIcp_2$, *peak material. Subdued hills on crater floor*
Interpretation
Most craters probably formed by impact but crater morphologies highly altered by slumping, superposed cratering, and filling

Lower Pre-Imbrian

$pIcr_1$ | $pIcw_1$ | $pIcp_1$

Crater materials

Characteristics
Remnants of very subdued craters. Most craters lack elevated rim crests and outer rim material. Craters partly filled with plains unit
$pIcr_1$, *rim material. Very subdued, highly cratered, hummocky material outside crater*
$pIcw_1$, *wall material. Moderately sloping walls, highly cratered and subdued. Terraced in Clavius*
$pIcp_1$, *peak material. Subdued hills on crater floor*
Interpretation
Probably similar in origin to younger pre-Imbrian craters

ch

Chain crater material

Characteristics
Material in and around small, subround, overlapping, alined (not clustered) craters. Alinement parallel to lineament systems
Interpretation
Probably of volcanic origin because of apparent structural control. Some may be coalesced secondary impact craters. Age unassigned; good preservation of smaller craters suggests young age

———— — —?— — —
Contact
Solid where sharp; long dashed where approximately located; queried where indefinitely located

(Ic)
Concealed contact
Concealed unit indicated by symbol in parentheses

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

Lineament
Gentle linear scarp or depression. Interpretation: Fault or surface expression of buried fault or graben

Slump block
Arrow indicates direction of movement

INTRODUCTION

The Clavius quadrangle is in the southern lunar highlands about 500 km south of Mare Nubium and 150 km south of the large young crater Tycho. This part of the Moon is characterized by densely cratered topography and the absence of mare material. Geologic units in the quadrangle cannot be directly correlated with those in the vicinity of Mare Imbrium, 2500 km to the north, which define most of the lunar time-stratigraphic systems (Shoemaker and Hackman, 1962; Wilhelms, 1970). However, the relative ages of rock units, including crater materials, have been determined by established geologic methods, such as superposition and cross-cutting relations. In addition, crater materials have been positioned within the lunar time stratigraphic framework (Offield, 1971) by estimates, based on morphology, of their state of erosion (Pohn and Offield, 1970).

REGIONAL STRATIGRAPHIC UNITS

Major stratigraphic units not directly related to craters are Imbrian in age. They consist of hilly terra (It), smooth plains (Ips), and cratered plains (Ipc) materials. Hilly terra material covers most intercrater areas and is present on the walls and floors of some Imbrian and pre-Imbrian craters. It is smoother and less cratered westward across the quadrangle, as if it were a blanketing material which either thickens or overlies less rugged terrain westward. In places, boundaries between the hilly terra and the plains materials are indistinct and the units may be intergradational. Smooth plains material, like the hilly terra material, is present throughout the quadrangle but mostly occurs on the floors of Imbrian and older craters. It has flat, level surfaces and a moderate density of small craters. Cratered plains material is present in the eastern and northeastern parts of the map area. In addition to having a higher density of small craters, it is also overlapped, in places, by smooth plains material and thus is older. Young plains material of Copernican age is restricted to the vicinity of the crater Rutherfurd. It is probably the youngest unit in the map area as it apparently partly covers ray material from Tycho.

The wide distribution, considerable lateral uniformity, and mantling characteristics of hilly terra and plains materials suggest an origin similar to that of terrestrial ash-flow tuffs (Smith, 1960; Ross and Smith, 1961). Many ash flows spread in a fluid-like manner over wide areas. They tend to accumulate in depressions, where they level out to a flat surface and obscure underlying topographic irregularities (Ross and Smith, 1961, p. 23). They may, however, form an irregular surface if they thickly mantle an irregular surface, then differentially compact in an amount proportional to their local thickness, so that the underlying topography is expressed in subdued form (Smith, 1960, p. 158 and plate 20D). Both the plains and the hilly terra of the Clavius quadrangle could thus be formed by ash-flow tuffs. An early series of ash-flow sheets may have formed the cratered plains and adjacent hilly terra, and a second series may have formed the smooth plains and most of the remaining hilly terra.

CRATER MATERIALS

Most of the craters in the quadrangle have the morphologic characteristics of impact craters (Shoemaker, 1962). Some of the oldest craters are very large and have rim crest diameters of 100-200 km. They have been highly modified and partly destroyed by subsequent impact, and slumping and faulting have increased their diameters and filling by younger materials has decreased their depth. In contrast to the older craters, the relatively young crater Rutherfurd has a sharp rim crest, well defined subunits in rim materials, numerous satellitic craters, and a high thermal anomaly (Shorthill and Saari, 1969). These characteristics indicate that Rutherfurd is Copernican in age, although rays are not visible and presumably are obscured by those from the younger crater Tycho. Ray material from Tycho covers most of the quadrangle and thus is not mapped.

STRUCTURE

Lineaments are abundant throughout the quadrangle, and faults are conspicuous on the walls of Clavius. The lineaments are probable fractures and joints of tectonic origin; others may be faults, but because displacement cannot be determined they are classified and mapped as lineaments. Figure 1 shows the percent frequency of approximately 640 lineaments plotted against azimuth in 10-degree increments. The maxima closely coincide in azimuth, but less closely in frequency, with the Moon-wide lunar grid system recognized by Strom (1964). Age relations of lineaments or lineament sets generally are not consistent, and the lineaments probably formed intermittently without uniform temporal order.

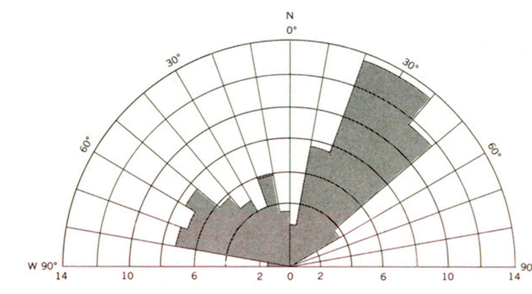


FIGURE 1—*Strike orientations of 643 lineaments plotted against their frequency*

GEOLOGIC HISTORY

The earliest recognizable events in the Clavius region are recorded by abundant large pre-Imbrian impact craters on the old highland surface. The old craters and intercrater areas were subsequently partly filled and covered by regional materials of Imbrian age, possibly ash-flow tuffs, and by ejecta from impact craters which continued to be formed into the Copernican Period. Volcanic activity appears to have decreased during Eratosthenian and Copernican times because only small patches of plains material that young occur in the quadrangle.

REFERENCES

Offield, T. W., 1971, Geologic map of the Schiller quadrangle of the Moon: U.S. Geol. Survey Misc. Geol. Inv. Map I-691.
Pohn, H. A., and Offield, T. A., 1970, Lunar crater morphology and relative-age determination of lunar geologic units—Part 1. Classification: U.S. Geol. Survey Prof. Paper 700-C, p. C153-C162.
Ross, C. S., and Smith, R. L., 1961, Ash-flow tuffs: their origin, geologic relations, and identification: U.S. Geol. Survey Prof. Paper 366, 79 p.
Shoemaker, E. M., 1962, Interpretation of lunar craters, *in* Kopal, Zdeněk, ed., Physics and astronomy of the Moon: New York, Academic Press, p. 283-359.
Shoemaker, E. M., and Hackman, R. J., 1962, Stratigraphic basis for a lunar time scale, *in* Kopal, Zdeněk, and Mikhailov, Z. K., eds., The Moon—Internatl. Astron. Union Symposium 14, Leningrad, 1960: London, Academic Press, p. 289-300.
Shorthill, R. W., and Saari, J. M., 1969, Infrared observation on the eclipsed Moon: Seattle, Boeing Sci. Research Lab., Doc. D1-82-0778, 73 p.
Smith, R. L., 1960, Zones and zonal variations in welded ash flows: U.S. Geol. Survey Prof. Paper 354-F, p. 149-159.
Strom, R. G., 1964, Analysis of lunar lineaments, I: Tectonic map of the Moon: Arizona Univ. Lunar and Planetary Lab. Commun., v. 2, no. 39, p. 205-221.
Whitaker, E. A., Kuiper, G. P., Hartman, W. K., and Spradley, L. H., eds., 1963, Rectified lunar atlas—supp. 2 to the Photographic Lunar Atlas: Tucson, Univ. Arizona Press
Wilhelms, D. E., 1970, Summary of lunar stratigraphy—telescopic observations: U.S. Geol. Survey Prof. Paper 599-F, p. F1-F47.