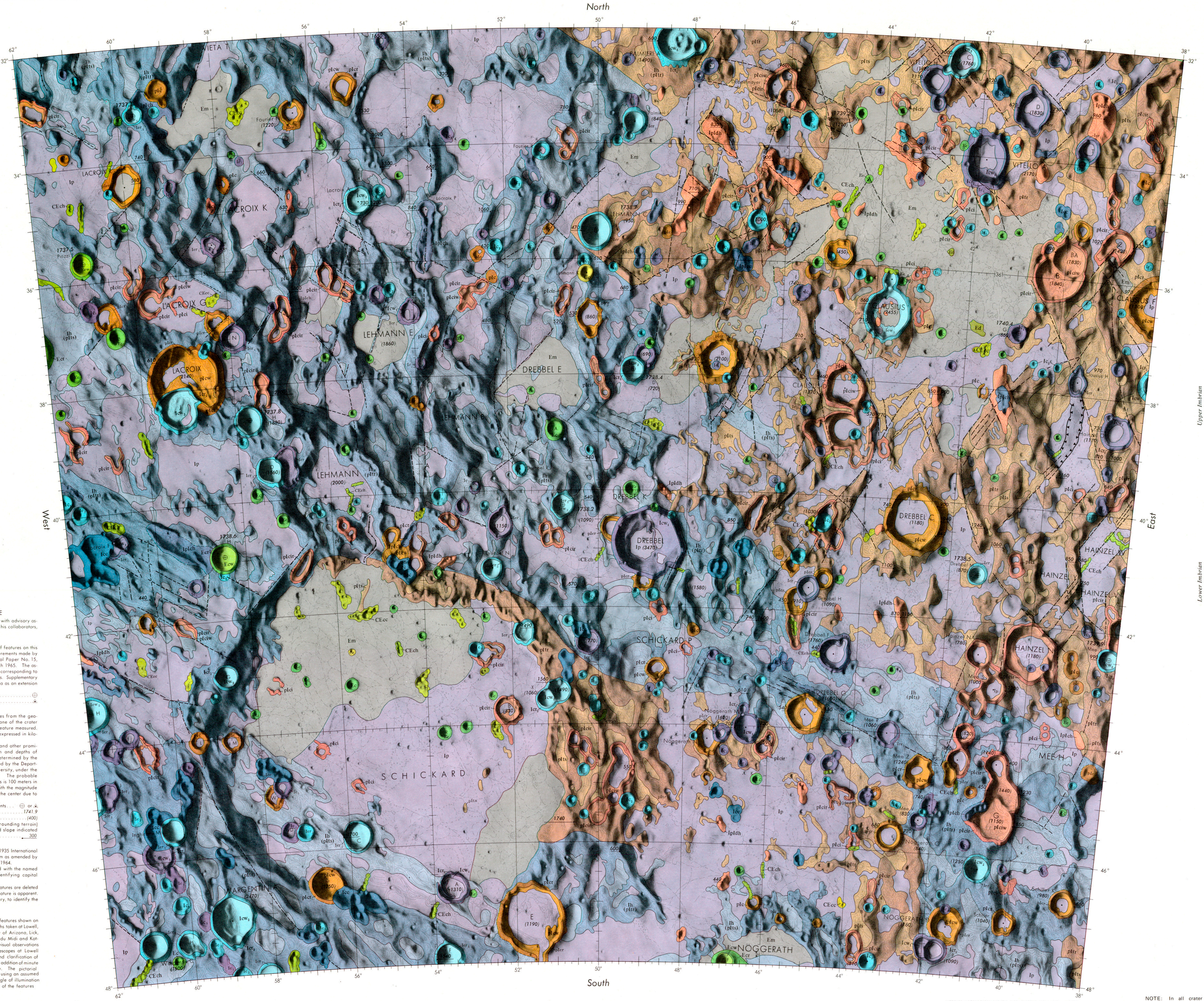
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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

GEOLOGIC ATLAS OF THE MOON
SCHICKARD QUADRANGLE
I–823 (LAC 110)



NOTES ON BASE

The base chart was prepared by ACIC with advisory assistance from Dr. Gerard P. Kuiper and his collaborators, D. W. G. Arthur and E. A. Whitaker.

DATUM

The horizontal and vertical positions of features on this chart are based on selenocentric measurements made by ACIC and published in ACIC Technical Paper No. 15, "Coordinates of Lunar Features", March 1965. The assumed lunar figure is that of a sphere corresponding to the mean lunar radius of 1738 kilometers. Supplementary positions are developed in the chart area as an extension of the primary control.

Primary Control Positions . . . . ⊕
Supplementary Control Positions . . . . ▲

ELEVATIONS

Radius vector lengths are the distances from the geometrical center of the moon to the plane of the crater rim or the designated position of the feature measured. The lengths of the radius vectors are expressed in kilometers.

The relative elevations of crater rims and other prominences above the surrounding terrain and depths of craters are in meters. They were determined by the shadow measuring techniques as refined by the Department of Astronomy, Manchester University, under the direction of professor Zdenek Kopal. The probable error of the localized relative elevations is 100 meters in the vicinity of the center of the moon with the magnitude increasing to 300 meters at 70° from the center due to foreshortening.

Lengths of Radius Vectors to control points . . . ⊕ or ▲ 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 capital letters.

Names of the supplementary lettered features are deleted when the association with the named feature is apparent. A black dot is included, where necessary, to identify the exact feature or features named.

PORTRAYAL

The configuration of the lunar surface features shown on this chart is interpreted from photographs taken at Lowell, U.S. Navy, Catalina Station-University of Arizona, Lick, McDonald, Mount Wilson, Yerkes, Pic du Midi and Kottomia Observatories. Supplementary visual observations with the 20 and 24 inch refracting telescopes at Lowell Observatory provide identification and clarification of indistinct photographic imagery and the addition of minute details not recorded photographically. The pictorial portrayal of relief forms is developed using an assumed light source from the west with the angle of illumination maintained equal to the angle of slope of the features portrayed.

Lunar base chart LAC 110, 1st edition, 1967, by the U.S. Air Force Aeronautical Chart and Information Center, St. Louis, Missouri 63118, with added secondary topographic relief patterns compiled by author from Lunar Orbiter IV photographs

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

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1974—G73192

Mapped 1971-72. Principal sources of geologic information: Published photographs from the Lick, Mt. Wilson, and Yerkes Observatories; full moon plate 5818 taken at U.S. Naval Observatory, Flagstaff, Arizona; Lunar Orbiter IV high-resolution photographs shown on photo index map.

Prepared on behalf of the National Aeronautics and Space Administration under contract No. W-13, 130

GEOLOGIC MAP OF THE SCHICKARD QUADRANGLE OF THE MOON

By
Thor N. V. Karlstrom
1974

EXPLANATION

MAIN CRATER SEQUENCE

Cc

Materials of sharp-rimmed craters with rays

Two known occurrences: lat 43¾° S., long 55¾° W.; lat 36¼° S., long 50¼° W.

Interpretation: *Presumably of primary impact origin*

Ec | Ecr | Ecw

Materials of sharp-rimmed craters without rays

Characteristics

Craters up to 20 km rim-crest diameter. Superposed on mare, plains, and terra, and locally on larger more modified craters; distribution possibly random, but craters commonly occur along lineaments, at lineament intersections, and in line with crater chains, domes, and smooth-crested terra peninsulas projecting into the plains unit. Craters >10 km subdivided into rim and wall materials

Interpretation

Most likely of impact origin but possibly volcanic

Upper Imbrian

Ic_2 | Icr_2 | Icw_2

Materials of craters with moderately sharp rim crests

Characteristics

Craters moderately sharp-rimmed, nearly circular. Up to 25 km rim-crest diameter. Steep smooth to ridgy interior walls. Floors generally inconspicuous or absent, but some larger craters have broad floors of mare or plains materials or both. Craters occur mostly in terra units. Subdued ridgy patterns within some larger craters apparently extensions of similar exterior patterns. Some craters doughnut shaped, with a subordinate ring surrounding the floor. Unlike older craters, rims not conspicuously serrated by small grooves or troughs parallel to lunar grid directions

Interpretation

Most likely of impact origin but possibly volcanic, especially the doughnut-shaped craters

Lower Imbrian

Ic_1 | Icr_1 | Icw_1

Materials of craters with subdued rims

Characteristics

Rims subdued and irregular; more superposed younger craters, more irregularly textured walls and floors, and more floors covered by mare and plains materials than in younger craters. Generally restricted to terra units, or occur on larger craters with more modified and serrated rims. Craters of late Imbrian and younger age are superposed

Interpretation

Same as for younger craters

pIc | pIcr | pIcw

Materials of craters with considerably subdued rims

Characteristics

More polygonal shape and more irregular rim textures than younger craters. Up to 35 km diameter. Occur on terra units and on more irregularly shaped craters and crater groups

Interpretation

Craters of late pre-Imbrian age. Highly subdued morphology precludes determination of origin

pIci | pIcir | pIciw

Materials of irregularly shaped craters and crater groups

Characteristics

Subdued, generally narrow-or bulbous-rimmed, irregularly shaped craters and crater groups. In terra, plains, and on summits of some irregularly shaped domes. Craters seemingly a distinctive class within gradational continuum between more regular, less modified craters, and more subdued shallow crater-like forms mapped as part of the ground textural patterns; somewhat arbitrary separation from the latter based on greater size and relief (mainly relief of rims); separated from other mapped craters on one or more of the following criteria: more distinctive elongation (2:1 or more), more irregular rims, presence of smooth-crested, narrow, or bulbous rim segments locally traceable continuously into sinuous smooth-crested terra ridges, absence or subdual of common septa in crater groups having no apparent age or superposition differences, and local continuity of subordinate ridge patterns from outside into interiors with minor deflections at rims, but no apparent offsets. Most craters at all elevations have plains floors, including small elongated crestline craters on highest terra summits. Superposed craters range in age from pre-Imbrian to Copernican. Pronounced preferred directions of linear elements coincide with NW, NNW, N, and NNE lunar grid directions (fig. 1, E)

Interpretation

Irregular shapes and relations to primary and secondary terra ridges suggest either caldera subsidence along broad crests of extrusive ridges and domes, or highly modified and partly buried groups of primary and secondary impact craters. Preferred directions of angular elements suggest control by pre-existing, or contemporaneously developing fracture sets, similar to structural controls of polygonal shapes of terrestrial calderas, explosion craters, and impact craters. Evidence favors development as calderas, and fracture-controlled extruded rim forms, during active phases of volcanism. Morphology and superposition relations suggest early pre-Imbrian age; some irregularly shaped craters may be younger

NOTE: In all crater units r refers to rim material, w to wall material

CRATER GROUPS

CEcc

Material of sharp-rimmed crater clusters

Characteristics

Conspicuous clusters (non-linear arrays) of three or more similar, relatively sharp rimmed craters. On terra, plains, and mare units

Interpretation

Secondary impact or volcanic origin. Sharpness of rims and superposition on mare material suggest Eratosthenian and Copernican ages

CEch

Material of sharp-rimmed crater chains

Characteristics

Linear and curvilinear arrays of three or more overlapping or tangential, sharp-rimmed craters of comparable size and morphology. Chain lengths 5-20 km; crater diameters 1-5 km. In places, craters alined along inferred lunar grid fracture sets (fig. 1, D) or terra ridge crestlines. Occur on terra, plains, and mare surfaces, and locally on rims of pre-Eratosthenian craters

Interpretation

Alinement and distribution patterns suggest secondary impact and volcanic origins. Chains alined parallel to inferred fractures and along ridge crests are most likely volcanic. Sharpness of crater rims and local superposition on mare suggest Eratosthenian and Copernican age

Icc

Material of moderately sharp to subdued-rimmed crater clusters

Characteristics

Conspicuous clusters of two or more relatively subdued craters of similar morphology. Cluster shapes range from irregular to looped and sizes from 25-30 km longest dimensions. Craters commonly coalescent, 2 to 5 km rim diameter, most with shallow bowl-shaped interiors without distinct floors separated by straight to curvilinear common rims or septa; some are floored with plains materials. Clusters locally superposed on early Imbrian craters and on northwest trending textural patterns of Hevelius Formation. Oldest superposed craters are of late Imbrian age

Interpretation

Secondary impact or volcanic craters of Imbrian age; a few may be older. Cluster form and apparent superposition on Hevelius texture consistent with interpretation that some may be secondary impact craters formed late in deposition of Orientale basin ejecta blanket (Wilhelms and McCauley, 1971). However, similarity of many clusters to honeycomb forms of some terrestrial volcanic calderas suggests endogenetic origin

IpIcc

Material of subdued crater clusters

Characteristics

Clusters of two or more subdued-rimmed craters of comparable morphology. Superposed on terra units

Interpretation

Grouping and distribution pattern indicate either a secondary impact or volcanic origin. Morphologic subdual and restriction to terra units suggest Imbrian or older age

IpIch

Material of subdued crater chains

Characteristics

Linear and curvilinear arrays of 3 or more overlapping or tangential, subdued-rimmed craters. Chain lengths from 6 to 25 km. Occur within terra and plains units; locally on pre-Imbrian crater rims but Eratosthenian craters superposed along or transverse to rim crests; some on summits of domes (unit IpIdh*). Orientation of chains variable, many parallel to the inferred NW, N and NE lunar grid directions (fig. 1, C)*

Interpretation

Secondary impact or volcanic craters. Subdued morphology of crater rims and superposition relations suggest pre-Imbrian or Imbrian age. Chains alined with northwest-trending texture of Hevelius Formation possibly secondary impact craters of Orientale basin. Conversely, the preferred alinements with all the lunar grid directions, as elsewhere on Moon (Strom, 1964), suggests volcanic origin of most chains here

DOMES

Ed

Material of low domes or cones

Characteristics

Dark, bulbous, low domes or cones with gentle slopes and convex upward profiles. In mare material in northeast quadrant of map area

Interpretation

Dark color and morphology suggest volcanic intrusions or extrusions developed during emplacement and solidification of mare materials

IpIdh

Materials of high domes or cones

Characteristics

Materials of steep domes commonly with summit or flank craters or furrows. Some are curved in plan (circular, elliptical, arcuate) with smooth, convex upward profiles; others rectilinear with angular outlines and profiles. On terra and plains units. Large, irregular, seemingly fracture bounded domes in north have coalescent, topographically subdued crater pits

Interpretation

Either volcanic constructional forms in part alined with major fracture sets, or fault- and fracture-controlled hills of terra material. Morphology suggests pre-Imbrian and Imbrian age

HEVELIUS FORMATION

Ih (pItr) | Ih (pIts)

Hevelius Formation

Characteristics

*Predominance of sinuous to straight ridges and troughs alined parallel to northwest lunar grid direction, and radial to Orientale basin which is about 1200 km northwest of crater Schickard. Pronounced NW-trending textures locally best developed where superimposed over rough terra (*pItr*) and subdued terra (*pIts*); only locally and subtly expressed in plains unit* Ip*; inconspicuous or absent in mare unit* Em*. Comparably trending fine grooves locally present on early Imbrian and older crater rims but inconspicuous or absent on late Imbrian and younger crater rims. Formation boundary separates broad areas with discontinuous but predominant NW textures from those with more pronounced transverse textures and is approximate*

Interpretation

Alinement radial to Orientale basin and apparent superposition relations with dated craters compatible with interpretation of lineated ridge and groove pattern as constructional surface features of distal part of depositional blanket ejected from Orientale basin in middle Imbrian time (Wilhelms and McCauley, 1971). Slight or undetectable morphologic differences of early Imbrian and older craters within and outside of mapped formation, and extensiveness of ridge trends transverse to formation lineaments suggest that ejecta blanket is generally thin and discontinuous throughout quadrangle. Conversely, as indicated by coincidence of both pre-Hevelius and post-Hevelius preferred lineament trends with lunar grid fracture sets (figs. 1, A; 1, B), some or all of NW-trending lineaments possibly structurally controlled, and not ejecta-blanket features

MARE, PLAINS, AND TERRA

Em

Mare material

Characteristics

Smooth, level surfaces and low albedo. Occurs as irregularly shaped patches within plains material and in floors of deeper craters. Smoother than plains material but includes low mare ridge complexes, smooth-rimmed dark craters (not mapped), and domes. Contacts with plains and terra units locally gradational but generally sharp, straight to curvilinear with numerous reentrants. Superposed craters, clusters, and chains Eratosthenian and Copernican in age. Material flooring craters as young as late Imbrian in age. Unit includes a structurally complex area in northeast sector of quadrangle having somewhat greater dome and crater populations than elsewhere in quadrangle

Interpretation

Probably relatively thin cover of young lava flows and pyroclastic material over thicker accumulations of Imbrian plains material. Shape and contact relations suggest extrusion both within fracture-bounded crustal blocks that subsided during extrusion, and within pre-existing low areas of plains unit and in deeper craters. Low albedo and contact and superposition relations wtih plains material and craters suggest emplacement between late Imbrian and late Eratosthenian time. The greater crater population in the northeast sector may reflect pitted Imbrian plains material only thinly covered by mare material. Conversely, these craters may be part of dark unit, largely volcanic in origin, and Eratosthenian in age

Ip

Plains material

Characteristics

Relatively level; intermediate but locally variable albedo. Predominantly in low-lying areas, topographic lows of terra and bottoms of large late Imbrian and older craters, but also in numerous small craters on high terra summits. Commonly occurs at several elevations in an area. Smooth, undulating surfaces generally with a complex pattern of intersecting, straight to curvilinear low ridges continuous in places with ridge patterns in adjoining terra. In other areas contacts appear sharp and discordant

Interpretation

Planar surfaces and smooth textures, distribution in topographic lows, discordant to gradational contacts, and association with smooth-crested, sinuous ridges, suggest emplacement of both fluid and fragmental materials from subcrustal sources, thus probably lava and pyroclastics from many separate vents. Some small patches in rugged terra possibly fine grained ejecta material or fragmental material eroded from adjoining steep slopes. Variable albedo and amount of fill relative to crater age suggest several episodes of emplacement possibly as early as pre-Imbrian, seemingly concentrated in middle Imbrian time, extending locally into late Imbrian time, but with general termination before emplacement of the Eratosthenian mare

pItr | pIts

Terra materials

Characteristics

Upland materials beyond mapped boundaries of Hevelius Formation:

pItr, *rough terra. Includes rugged areas with steep-sided, broadcrested, sinuous ridges characterized by a complex of secondary ridges and depressions: local relief 300 m to 1500 m within unit*

pIts, *subdued terra. Less rugged than unit* pItr *and includes: (1) broad irregular floors of upland depressions with ridgy topography, and (2) benches, peninsulas, and islands of intermediate relief and secondary ridge patterns comparable to those associated with bordering plains and mare units. Elliptical to rectilinear transecting secondary ridge patterns generally traceable continuously between rugged and subdued units*

Inside boundary of Hevelius Formation, units morphologically similar for most part; symbolized by Ih (pItr) *and* Ih (pIts).

Interpretation

Ancient crustal rocks broken and jumbled during formation of basins and craters and mantled by crater ejecta and lunar erosional products. Mantling materials probably thickest on gentler slopes and in depressions: may be discontinuous in areas of more rugged relief where ancient rocks possibly exposed locally. For alternate interpretations of terra genesis and rock types see text

COPERNICAN SYSTEM

ERATOSTHENIAN SYSTEM

IMBRIAN SYSTEM

PRE-IMBRIAN

———

Approximate contact

– – – – – –

Outer rim boundary of early Imbrian
and older craters which may be
partially mantled by Hevelius Formation

— — — — —

Major fracture system

Inferred from most pronounced topographic lineaments

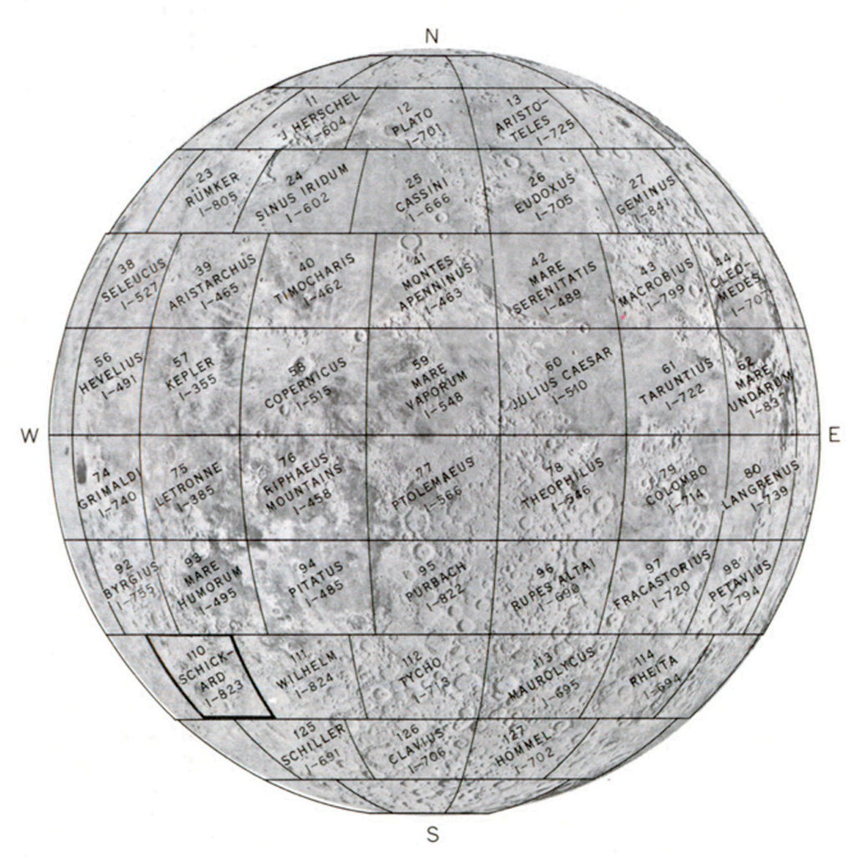
Rilles

Plains ridges

Secondary topographic lineaments

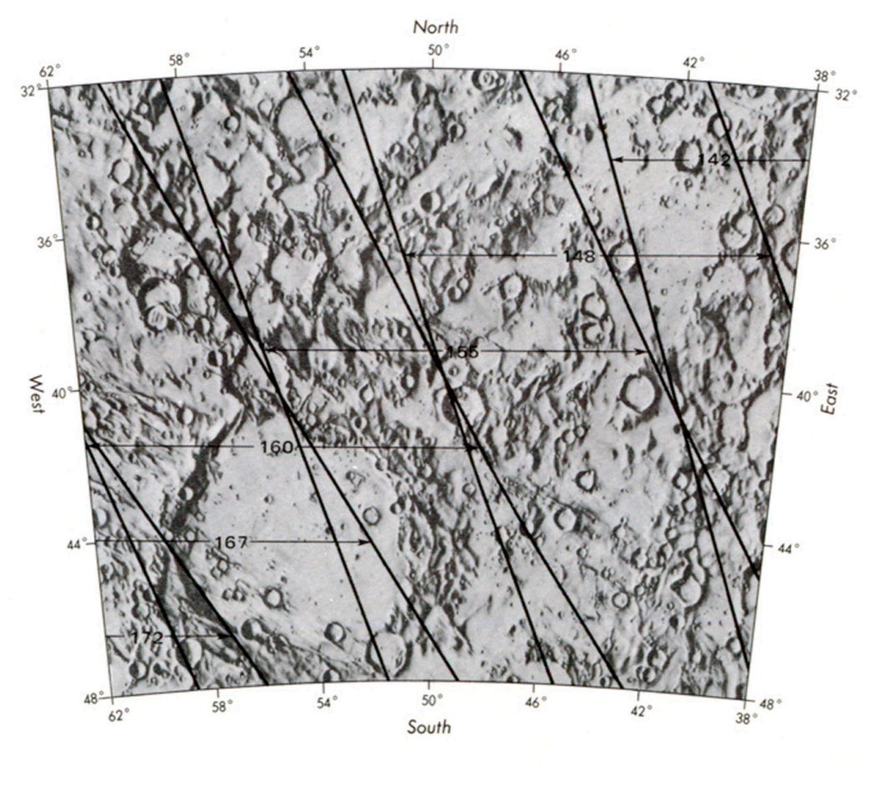
Crests of subdued smooth ridges in plains and mare. Small circles and dots represent small young craters at the limits of resolution

Crests of intersecting elliptical to linear secondary ridge systems and associated depressions in terra



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 SCHICKARD QUADRANGLE

GEOLOGIC SUMMARY

LOCATION AND GEOLOGIC SETTING

The Schickard quadrangle lies in the southwest quadrant of the near side of the moon between Mare Humorum to the northeast, the Orientale multi-ring basin to the northwest, and the crater Tycho to the east. A northward-trending arcuate chain of large craters occurs along the south and west margins of the quadrangle and includes the 180-km-wide crater Schickard, the most conspicuous feature in the quadrangle. The region is part of the southern highlands lunar province and is characterized by rugged and complex topography, 40 percent of which is uplands rising as much as 1600 meters above irregular patches of smooth plains and mare.

METHODS OF MAPPING

Because of inherent uncertainties in photogeologic interpretation of lunar features (Karlstrom, 1968, p. 135), an attempt was made in the Schickard quadrangle to map the secondary topographic elements that comprise the subtle textural patterns of ground surfaces. These patterns, graphically shown as part of the map base, provide the basis for some additional geologic inferences, and illustrate the degree of concordance or discordance along the inferred geologic boundaries. Nonetheless, these additional morphologic criteria, when combined with gross topographic form, also fail to provide unequivocal genetic and sequential inferences about landform development. Therefore, in the absence of more diagnostic ground data, the concept of multiple working hypotheses is emphasized in interpreting the geology of the quadrangle.

The conventional map units of the Geological Survey (see especially Wilhelms and McCauley, 1971) have been applied, where pertinent, in the Schickard quadrangle. Crater dating is based on the morphologic criteria defined by Pohn and Offield (1970). Their age classification of lunar craters assumes impact origin, approximately similar original crater form, and uniform rates of modification with time by impact bombardment and weathering. As a relative age classification, it remains useful when based on the broader assumption of uniform initial morphology exclusive of genetic considerations; but it may be modified when morphologic distinctions between craters of different origin become better known.

The graphic portrayal of the secondary topographic elements is unique to this map. It reveals a complex, sinuous, intertwining ridge pattern, which encloses elliptical to rectilinear shallow depressions that in part appear to be controlled by curvilinear to straight fractures trending mostly in the dominant lunar grid directions (fig. 1; Strom, 1964). The resulting surface textures may represent surface depositional features, buried structures or surfaces reflected through thin mantling deposits, or combinations of these constructional and structural elements. Mapping of this pattern may lead to new interpretations of lunar geology. For example, the fact that the inter-crater cellular surface-textural pattern persists right up to crater rim crests suggests that it primarily reflects structures or buried constructional surfaces rather than the morphologic characteristics of the uppermost surficial layers, the crater ejecta. For this reason, in the absence of textural evidence for an extensive ejecta blanket around most craters in the quadrangle, outer crater rim boundaries are conservatively drawn at the most conspicuous topographic break between crater rim crest and surrounding terrain; this is closer to the crest than on most lunar maps. Since these boundaries are primarily topographic, not stratigraphic, their geometric relations to contacts of surrounding materials do not necessarily reflect actual superposition relations.

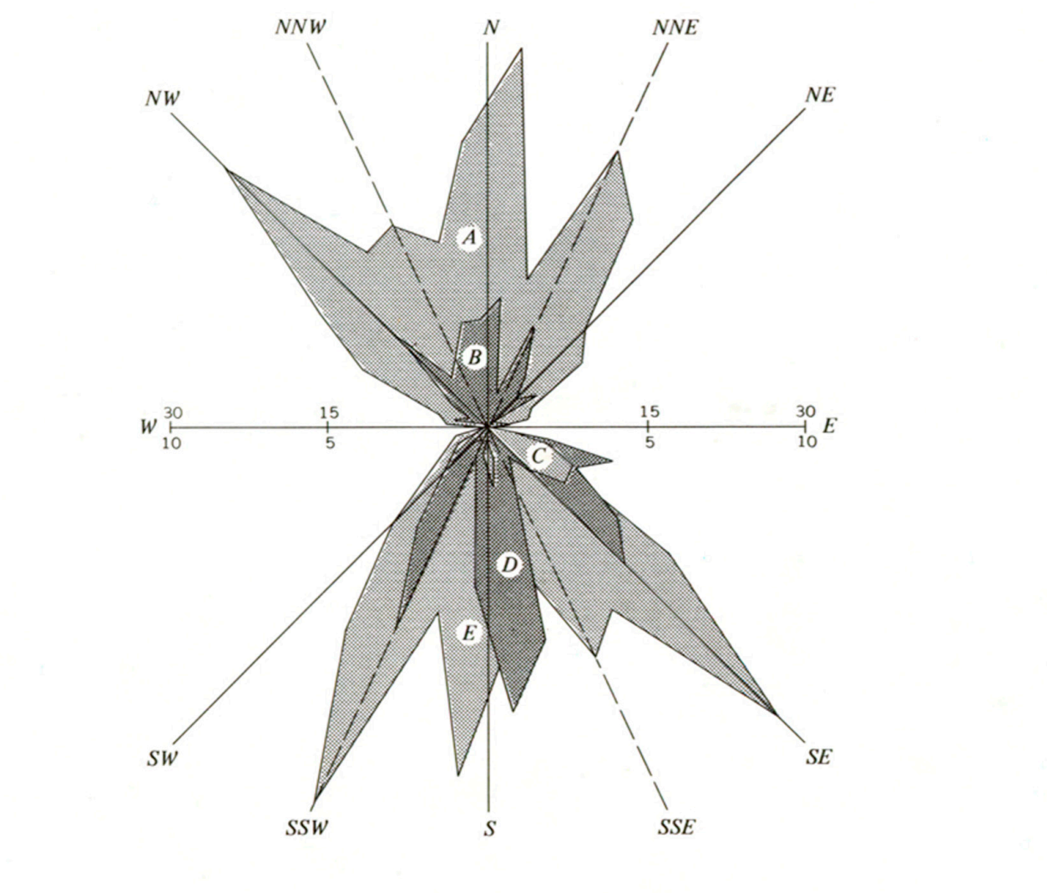


FIGURE 1.--*Azimuth frequency diagrams of large, dated lineament features (crater chains and polygonal crater rims) in relation to inferred lunar grid fracture sets: A. Pre-Hevelius lineaments* (Ic_1, pIc, pIci, IpIch)*, n=203; B. Post-Hevelius lineaments* (Ic_2, Icc, CEch)*, n=99; C.* IpIch *crater chain trends; n=18; D.* CEch *crater chain trends, n=43; E.* pIci *irregularly shaped crater and crater group trends and polygonal rims, n=91. Solid and dashed radial lines: dominant, nonradial lunar grid fracture sets inferred from lineament studies of undated polygonal crater rims and crater chains in two large areas on near side of moon (Strom, 1964); NW-SE and NE-SW sets attributed to primary shear directions, NNW-SSE and NNE-SSW sets to secondary shear directions, and N-S set to tensional direction resulting from fundamental stress field generated in a rotating planetary body. Note that the common E-W lineament gap is also reflected by all age intervals within Schickard quadrangle, but that the NE-SW direction, prominent elsewhere, is either weakly developed or missing, suggesting a local structural anomaly that seemingly persisted since the beginning of recorded events. Number of azimuth readings centered in nonoverlapping 10° intervals.*

In a significant departure from other maps, highly modified large crater forms morphologically datable to early and middle pre-Imbrian age are mapped as part of the undivided rugged terra units of the quadrangle. This convention serves to emphasize the dominant topographic continuity of the complex system of sinuous and intersecting compound ridges surrounding the larger irregularly shaped basins floored by plains and mare materials. Considering age, size, and probable rock compositional differences, the terra ridge systems are similar in important aspects of outline, and in relations of secondary to primary ridges, to those of larger mare ridge complexes mapped elsewhere on the Moon. For example, there are striking similarities between the ridge and plains distribution around Schickard crater and the concentric and transecting ridge patterns of the large Lamont ring structure (lat 6°N., long 24°E.) in Mare Tranquillitatis. These morphologic similarities suggest a common genesis as intrusions or extrusions localized along fracture sets resulting from magmatic updoming or inherited from previous craters. In the absence of proof of an impact origin for the degraded crater Schickard and associated basin forms, an alternate working hypothesis, herein referred to as the tectono-volcanic hypothesis, is considered for their genesis and for that of other terra ridges.

TECTONO-VOLCANIC HYPOTHESIS

Under this hypothesis, the terra ridges originally developed as fracture-controlled volcanic intrusive-extrusive welts that enclosed small as well as large depressions produced by differential subsidence of thin crustal plates during an early molten phase of the Moon. This early volcanic constructional surface was then modified by later volcanism, tectonic adjustment, and impact cratering. Associated plains material could have been emplaced penecontemporaneously with, as well as later than, the ridges. Such a time sequence is suggested by the mare ridge analog, by gradational as well as discordant plains contacts, and by evidence suggesting multiple episodes of volcanism.

According to the tectono-volcanic hypothesis: (1) the abundant irregularly shaped craters and crater groups in the region (along with an unspecified number of more circular craters) may be mainly volcanic calderas and explosion craters rather than impact craters; (2) the pervading cellular surface patterns may primarily represent relatively thinly mantled, brecciated, and fractured constructional volcanic surfaces rather than secondary patterns developed on thickening regolith by prolonged impacting and accompanying tectonic adjustments, and; (3) the NW-SE trending ridges and structures in whole or in part, may be volcanic ridges and structures controlled by repeated reactivation along a fundamental lunar grid fracture set, rather than solely the surface configuration of a thin radial ejecta blanket (in this sector only conincidentally parallel to a preexisting fracture set) thrown out from the Orientale basin.

The tectono-volcanic hypothesis, supported by morphologic similarities between mare and terra ridges, must also explain the differences in size (mainly in relief) between these two classes of lunar features. According to the hypothesis, the larger size of the terra ridge complexes reflects the more viscous initial phases of a cooling, fractionating Moon, whereas the basin-restricted, more subdued mare ridges reflect later, less vigorous phases of more deeply derived, more basic, and thus more fluid magma sources. The available Surveyor and Apollo data are seemingly consistent with the inference of more acidic compositions for terra rock types.

IMPLICATIONS OF APOLLO GROUND DATA ON IMPACT CRATER MODELS, THE TECTONO-VOLCANIC WORKING HYPOTHESIS, AND TERRA GENESIS

Radiometric analysis of igneous lunar rocks from Apollo 11 and 12 sites located in the maria and assigned to the Imbrian and Eratosthenian or Imbrian Systems respectively (Grolier, 1970; Pohn, 1972), provides dates respectively of 3.65±0.06 x 10^9 years and 3.3±0.1 x 10^9 years (Wasserburg and Papanastassiou, 1970). Analysis of igneous rocks from the Apollo 14 mission (Wasserburg and others, 1971) suggests a maximum age of 3.9± x 10^9 years for the type Fra Mauro Formation of earliest Imbrian age. If these analyzed rocks are representative of comparably crater dated units in the Schickard region, as is probable, then nearly all the inferred volcanic and impact events took place very early in lunar history. Moreover, if the fine surface texture has a tectono-volcanic origin as suggested here, a surprisingly small amount of topographic modification by surface processes (presumably primarily solar radiation and impact bombardment) has taken place since the first billion years. Other features that have been attributed to long extensive mass wastage of lunar slopes may also prove instead to be primary depositional features (Karlstrom, 1968, p. 135).

The ground data obtained by the Apollo 11 through 15 missions are now generally accepted as favoring the exponential-decay flux-rate impact model over the uniform flux-rate impact model. The latter model, as presently radiometrically calibrated, predicts pre-Imbrian events and lunar origins much older than the solar system itself. No such difficulties seemingly accrue to the exponential-decay impact model nor to the proposed tectono-volcanic model, wherein the most ancient terra rocks could be either about the same age or only slightly older than the oldest plains materials.

Thus, two alternative working hypotheses are seemingly favored for the genesis of the ancient terra rocks and the associated crater-like landforms in the quadrangle: (1) The terra includes ancient crustal rocks of unspecified origin that have been modified into present sinuous ridges primarily composed of ejecta, and resulting from a long history of random impact cratering with an exponential decay in flux rate with time. Subsequent volcanic episodes, which may or may not have been triggered by major impact events, produced the mare and plains materials that locally bury maturely cratered surfaces. (2) The terra is underlain by intrusive-extrusive igneous rocks emplaced along fractures, in part controlled by the lunar-grid stress field and developed within a thin cooling crust of an early molten phase of a primordial rotating moon. Impact played a subordinate role in shaping the landforms. Modification of this early volcanic surface by a complex history of repeated volcanic episodes, accompanying tectonic adjustments, and impact cratering has produced the present cratered and fractured terra, plains, and mare topography of the quadrangle.

Demonstration of the primacy of one or the other of these hypotheses ultimately will depend on more direct determinations of subsurface stratigraphy, structure, and rock types within the quadrangle. Nonetheless, the tectono-volcanic hypothesis seemingly provides the simplest and most direct explanation for the range of primary and secondary landforms mapped, and is therefore currently favored by the author of this map.

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