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

GEOLOGY OF THE MOON
MONTES APENNINUS REGION
I-463 (LAC-41)

NOTES ON BASE

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

CONTROL

The position of features on this chart was determined through the use of selenographic control established primarily from the measures of J. Franz and S. A. Saunder, as compiled by D. W. G. Arthur and E. A. Whitaker in the Orthographic Atlas of the Moon, edited by Dr. G. P. Kuiper, 1960.

VERTICAL DATUM

Vertical datum is based on an assumed spherical figure of the moon and a lunar radius of 1738 kilometers. The datum plane was subsequently adjusted to 2.6 kilometers below the surface described by the 1738 kilometer radius to minimize the extent of lunar surface of minus elevation value. Gradients of major surface undulations were established by interpolating Schrotka-Rechtenstamm computations of J. Franz's measurements of 150 moon craters. The probable error of comparative elevation values is evaluated at 1000 meters. Vertical datum, as established, is considered interim and will be refined as soon as a more accurate figure of the moon is determined

ELEVATIONS

All elevations are shown in meters. The relative heights of crater rims and other prominences above the maria and depths of craters were determined by the shadow measuring technique as refined by the Department of Astronomy, Manchester University, under the direction of Professor Zdenek Kopal. Relative heights, thus established, have been referenced to the assumed vertical datum and have been integrated with the gradients of the surface undulations. The probable error of the localized relative heights is 100 meters. Inherent with measuring technique used, relative height determinations in the E-W direction are in general more accurate than in the N-S direction

Elevations (referenced to datum).....1100
Depth of crater (rim to floor).....1900
Relative Elevations (referenced to surrounding terrain).....1828
Direction and extent of slope measured.....

CONTOURS

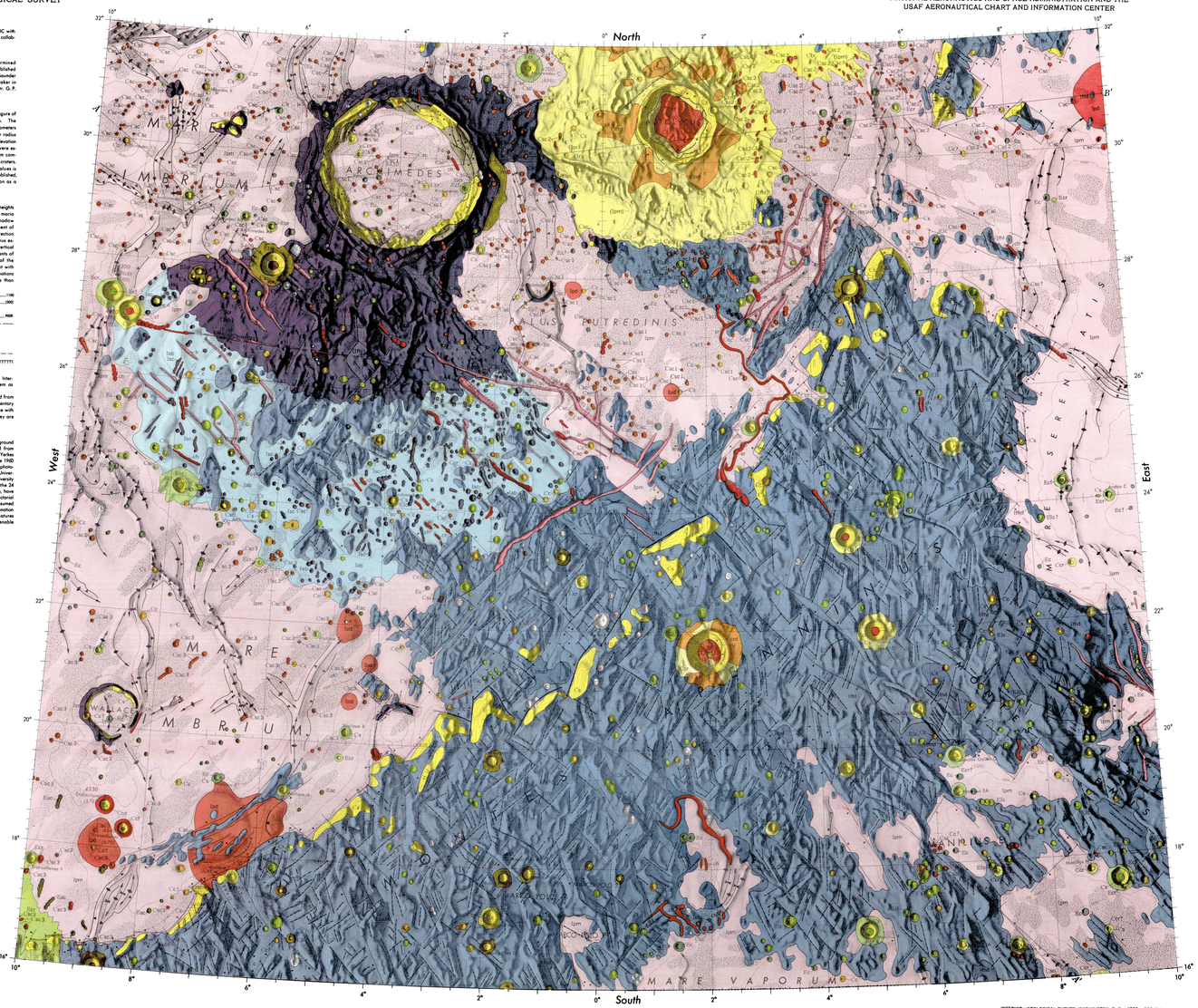
All contours are approximate
Contour interval is 300 meters
Approximate contour
Depression contour

NAMES

The feature names were adopted from the 1935 International Astronomical Union nomenclature system as amended by Commission 16 of the I. A. U.
Craters designated by capital letters were selected from the I.A.U. list of Named Lunar Formations. Supplementary lettered formations have been added in accordance with the criterion suggested by Blagg and Muller. They are designated by lower case letters

RELIEF PORTRAYAL

The configuration of the relief features and background coloration shown on this chart were interpreted from photographs taken at Lick, McDonald, Mt. Wilson, Yerkes and Pic du Midi Observatories, and published in the 1960 Edition of the USAF Lunar Atlas, and unpublished photographs from the Lunar and Planetary Laboratory, University of Arizona, and Department of Astronomy, University of Manchester. Visual observations made with the 24 inch Lowell refracting telescope, Flagstaff, Arizona, have also been used to add and clarify details. The pictorial portrayal of relief forms was 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. Cast shadows were eliminated to enable complete interpretation of relief forms.



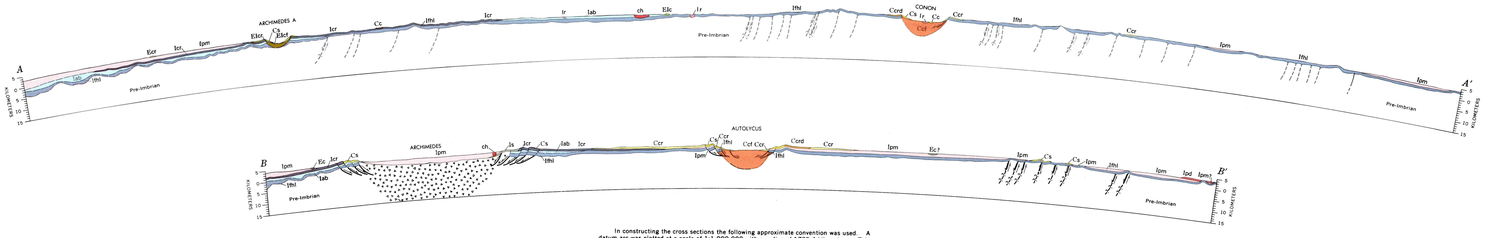
Lunar base chart LAC 41, 1st edition, 1963, by the Aeronautical Chart and Information Center, United States Air Force, St. Louis, Missouri 63118

LAMBERT CONFORMAL PROJECTION
SCALE 1:1 000 000
STANDARD PARALLELS 21°20' AND 42°40'

STATUTE MILES
KILOMETERS

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C.—1970—665438

Sources of geologic information: Published and unpublished photos from the Lick, McDonald, Mount Wilson, Pic Du Midi, and Yerkes Observatories. Visual telescopic observations by R. J. Hackman made at the Leander McCormick Observatory, University of Virginia, 1961, 1962, and 1963



In constructing the cross sections the following approximate convention was used. A datum arc was plotted at a scale of 1:1,000,000 with a radius of 1735.4 kilometers. This arc represents the datum from which elevations on the map are measured. The chord of the arc is equal to the length of the line of section on the map. Topographic and geologic data points along the line of section are projected perpendicular to the chord onto the concentric arc which is at the appropriate level in the cross section

GEOLOGIC MAP OF THE MONTES APENNINUS REGION OF THE MOON

By
R.J. Hackman

1966

USGS science for a changing world

EXPLANATION

Each system or series corresponds to a period or epoch whose salient events are listed on the table below:

PERIOD	EPOCH	EVENTS
Copernican		Formation of ray craters
Eratosthenian		Formation of craters of which rays are no longer visible
Imbrian	*Archimedian*	Extensive deposition of mare material of the Procellarum Group
	Apenninian	Formation of post-Apenninian craters older than at least part of the Procellarum Group
		Events related to the formation of the Mare Imbrium basin
pre-Imbrian time		Not yet formally divided

Material exposed on the surface of the Moon is heterogeneous. The albedo and other physical characteristics that have been determined with the use of optical and radio telescopes vary from one part of the Moon to another, and the variations are partially correlated with differences in topography. Discontinuities in the areal variation permit the surface material to be divided into map units, each exhibiting a limited range of photometric properties associated with a limited range of topographic characteristics. Each map unit is further characterized by a distinctive pattern of distribution, and the patterns of certain units are in places superimposed on the patterns of other units. From the relations of superposition it is possible to determine the sequence in which the units were formed.

For the purpose of geologic mapping a classification has been adopted in which map units are grouped according to sequence or relative age. The major divisions of this classification are called systems (Shoemaker, 1962; Shoemaker and Hackman, 1962) and subdivisions of the systems are called series. The systems and series are arranged below in the order of relative age, the youngest at the top and oldest at the bottom.

The boundaries or contacts and photometric and topographic characteristics of the map units have been determined by a combination of direct telescopic observation and examination of photographs. Albedo is described for full moon illumination. The photometric properties observed are those only of the material exposed at the surface. The distribution of certain units that are concealed or partly concealed by superimposed material has been inferred entirely from topographic characteristics.

Certain elements of the lunar topography suggest the presence of a variety of structural features in the Moon's crust. These are indicated on the map with special symbols.

Each map unit and each type of probable structure has been given a descriptive name. A genetic interpretation follows the description of each unit and probable structure. These interpretations are based partly on analogy with terrestrial features and partly on analysis of the detailed interrelations of the features on the Moon, and are necessarily speculative. Discrimination and mapping of the units and determination of their sequences, however, are independent of the genetic interpretation placed on them.

The geologic mapping has been carried out to the precision obtainable with existing telescopic technique. As more detailed information is acquired through lunar exploration, further refinement of the chronologic sequence of map units will be possible, and greater precision in the discrimination and location of geologic units and structures is to be expected.

A question mark after the crater label (Ec?) implies that the stratigraphic designation is questionable.

REFERENCES CITED

Shoemaker, E. M., 1962, Interpretation of lunar craters, in Kopal, Zdenek, ed., Physics and Astronomy of the Moon: London, Academic Press, p. 283–359.

Shoemaker, E. M., and Hackman, R. J., 1962, Stratigraphic basis for a lunar time scale, in Kopal, Zdenek, and Mikhailov, Z. K., eds., The Moon—Symposium of the International Astronomical Union: London, Academic Press, p. 289–300.

COPERNICAN SYSTEM

Cs — Slope material
Telescopic characteristics: *Very high albedo. Occurs on or at the base of steep slopes*
Interpretation: *Freshly exposed bedrock and freshly preserved, partially sorted talus material. Formed by sliding and slumping. Process of formation may still be continuing*

Crd — Dark halo crater material
Telescopic characteristics: *Very low albedo. Smooth topography. Readily distinguishable only when superimposed on ray material*
Interpretation: *Either dark ejecta from an impact crater or volcanic ejecta*

Cr — Ray material
Telescopic characteristics: *Generally high albedo but grades laterally into that of the surrounding material. Local contrast in reflectivity commonly large; lateral variations locally abrupt; characterized by bright patches and streaks. Ray material is superimposed on parts of all other units except dark halo material. Except for satellite craters, topography controlled by underlying units*
Interpretation: *Probably a thin layer of fragmented rock, ejected from both primary and satellite craters. A large number of satellite craters lie on the unit. The concentration of satellite craters on the unit is probably even more pronounced for craters smaller than those presently observable*

Ec — Crater material, undifferentiated
Telescopic characteristics: *Low to moderate albedo. Craters too small to permit identification of individual crater units*
Interpretation: *Brecciated bedrock, talus material and poorly sorted ejecta*

Ecr — Crater rim material
Telescopic characteristics: *Albedo low to moderate. Local variations in albedo small. Topography around large craters hummocky near the rim crest with low hummocks and subradial ridges and depressions around the flanks. Topography opposes smooth around small craters*
Interpretation: *Ejecta from an impact crater. Poorly sorted crushed and brecciated debris, largest blocks near the rim crest, finer grained debris away from the rim crest*

Ecf — Crater floor material
Telescopic characteristics: *Albedo low to moderate. Little local contrast in albedo. Topography generally smooth and flat*
Interpretation: *Exposed, brecciated bedrock, slumped wall material and possibly some ejecta that has fallen back into the crater*

Esc — Satellite craters
Telescopic characteristics: *Shallow craters with low, rounded rims, and irregular indistinct outlines. Commonly elongated radial to primary crater. Many occur in chains or clusters and merge with one another*
Interpretation: *Secondary impact craters, i.e., craters formed by impact of fragments ejected from large primary craters*

Esc — Crater material, undifferentiated
Telescopic characteristics: *Low to moderate albedo. Craters too small to permit identification of individual crater units*
Interpretation: *Brecciated bedrock, talus material and poorly sorted ejecta*

Eler — Crater rim material
Telescopic characteristics: *Low to moderate albedo. Moderate local contrast in albedo. Topography hummocky at the rim crest but generally not distinguishable from the subdued topography away from the rim crest*
Interpretation: *Ejecta from an impact crater. Poorly sorted crushed and brecciated debris, largest blocks near the rim crest*

Elcf — Crater floor material
Telescopic characteristics: *Low to moderate albedo. Smooth topography*
Interpretation: *Probably slumped wall material and brecciated bedrock. Possibly some ejecta that has fallen back into the crater*

ERATOSTHENIAN SYSTEM

Archimedian Series — *Procellarum Group*

Ipd — Dome material
Telescopic characteristics: *Low albedo. Forms low smooth domes up to 15 kilometers across and about 300 meters high*
Interpretation: *Probably chiefly volcanic flows. May include volcanic ash*

Ipm — Mare material
Telescopic characteristics: *Low albedo, small lateral variation. Forms extensive surfaces that are smooth and level except for low rounded irregular ridges and scarps*
Interpretation: *Volcanic materials. Flows and ash beds. Probably fragmental and nonvesicular at the surface*

Icr — Crater rim material
Telescopic characteristics: *Low to moderate albedo, moderate local contrast. Topography hummocky near the rim crest. Low hummocks and subradial ridges and depressions away from the rim crest. Low flanks generally covered with mare material*
Interpretation: *Ejecta from impact craters. Poorly sorted crushed and brecciated debris; largest blocks near the rim crest, fine debris away from the rim crest*

Is — Slope material
Telescopic characteristics: *Low to moderate albedo. Occurs on the inner wall of craters*
Interpretation: *Stable talus formed by slumping and sliding on steep slopes. Probably includes both partially sorted fragmental material and large slump-blocks*

Isc — Satellite craters
Telescopic characteristics: *Shallow craters with low rounded rims and irregular indistinct outlines. Many occur in clusters or chains and merge with one another. Occur to the south of Archimedes*
Interpretation: *Secondary craters formed by impact of ejecta from Archimedes*

Apenninian Series

Iab — Apennine Bench Formation*
Telescopic characteristics: *Moderate albedo, little lateral variation in albedo. Smooth rolling topography with many small craters. Type area: 21°-25° N, 1°-4° W. (Apennine Bench is an informal geographic name)*
Interpretation: *Volcanic materials. Flows and ash beds. Similar to Ipm but older and more cratered. Probably fragmental and non-cohesive at the surface*

*New name

Ihr / Ihd — Pra Mauro Formation
Telescopic characteristics: *Ihd has generally moderate albedo. Uhd has very low albedo. Topography of both generally rough, but this probably reflects roughness of subjacent topography. (Areas where unit is very thin and pre-Imbrian material may be locally exposed are shown with ruled pattern)*
Interpretation: *Chiefly crushed rocks and large blocks ejected from the Imbrium Basin. Forms a layer ranging from a few meters to 1000 meters in thickness. Layer is probably heterogeneous in composition*

IMBRIAN SYSTEM

Csc 3 / Csc 2 / Csc 1 — Satellite craters
Telescopic characteristics*: *Shallow craters with low rims, irregular outlines, commonly elongated radial to primary crater. Many occur in chains or clusters and merge with one another. Especially common on ray material*
Interpretation: *Secondary impact craters, i.e., craters formed by impact of fragments ejected from large primary craters. Csc 1 denotes a crater secondary to Aristillus, Csc 2 denotes a crater secondary to Autolycus and Csc 3 denotes a crater secondary to Copernicus*

ch — Crater chain material
Telescopic characteristics: *Low to moderate albedo. Occurs in linear chains of craters*
Interpretation: *Probably volcanic materials associated with craters aligned along a structural lineament. May also include some chains of satellite craters*

Sr — Sinuous rille material
Telescopic characteristics: *Low to moderate albedo. Occurs within narrow sinuous depressions*
Interpretation: *Volcanic ash, lava flows and possibly talus material. Probably Eratosthenian and Copernican in age*

lr — Linear rille material
Telescopic characteristics: *Low to moderate albedo. Materials occurring in linear rilles. Includes materials associated with craters in and on the rilles. Where rille is heavily cratered, distinction between linear rille material and crater chain material is ambiguous*
Interpretation: *Probably includes talus materials associated with fault scarps bounding the rilles, volcanic materials, especially where rille is heavily cratered, and down-faulted country rock*

Cx — Crater material
Undifferentiated as to age and type

Irregular depression
Undifferentiated as to age and type

Contact
Dashed where approximately located

(lab) / (ipe)
Concealed contact
Symbols in parentheses refer to concealed units

Major fault
Dotted where concealed. Bar and ball on downthrown side

Fault
Dotted where concealed. Bar and ball on downthrown side

Lineament
Probable fault or fracture. Inferred from linear topography

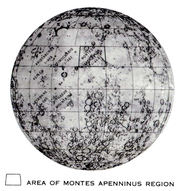
Mare ridge
Showing crest line. Tapered end indicated by arrowhead. Dashed where probable. (Probably underlain by anticline; possibly the site of a volcanic extrusion)

Mare trough
Showing trough line. Tapered end indicated by arrowhead. (Probably underlain by syncline)

Rounded mare scarp
Shows trace of foot of scarp. Only prominent scarps denoted. Dashed where probable; dotted where concealed. (Probably a flow front or monocline)

Brecciated rock

INDEX MAP OF THE SUBTERRESTRIAL HEMISPHERE OF THE MOON



AREA OF MONTES APENNINUS REGION