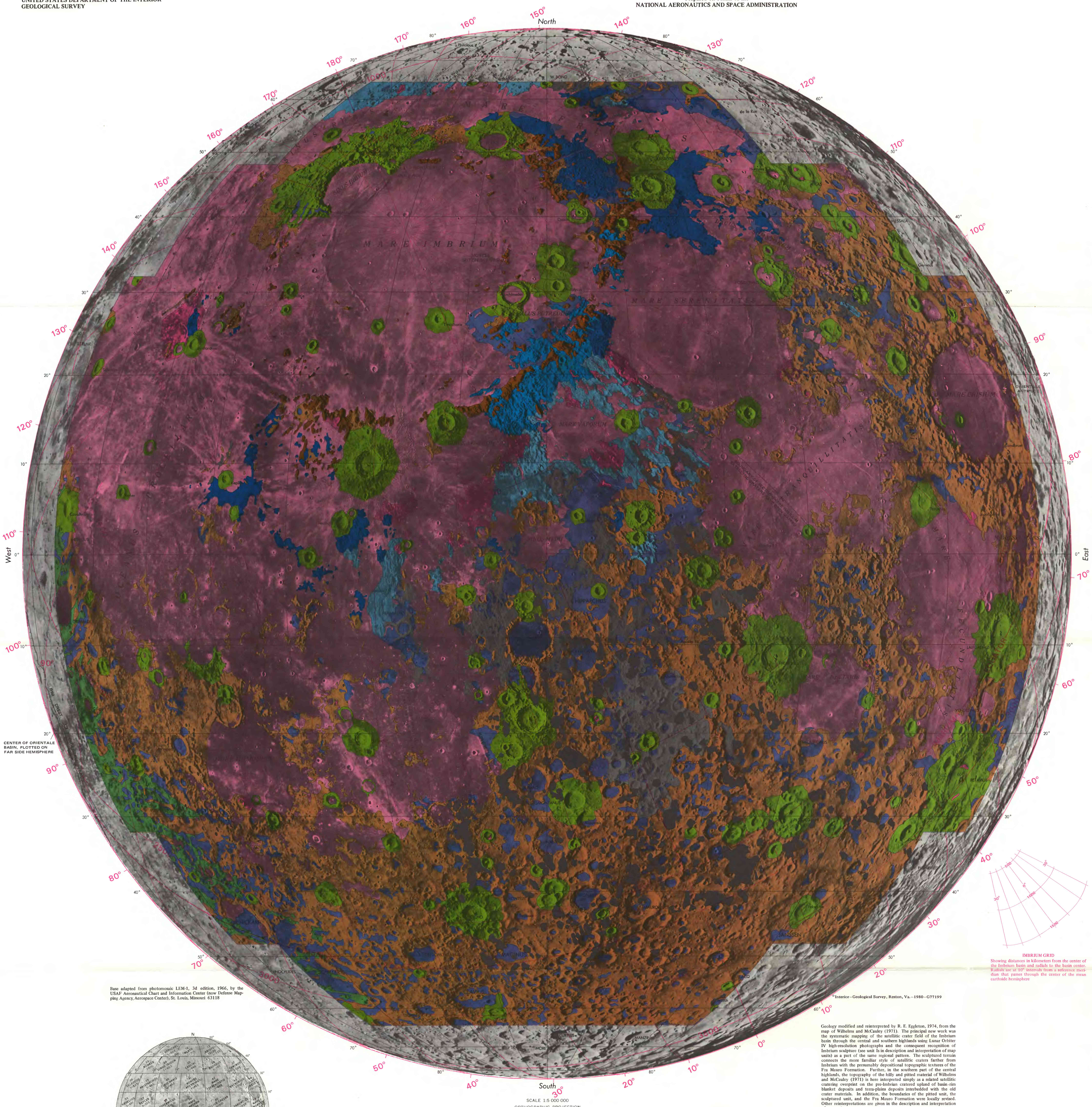
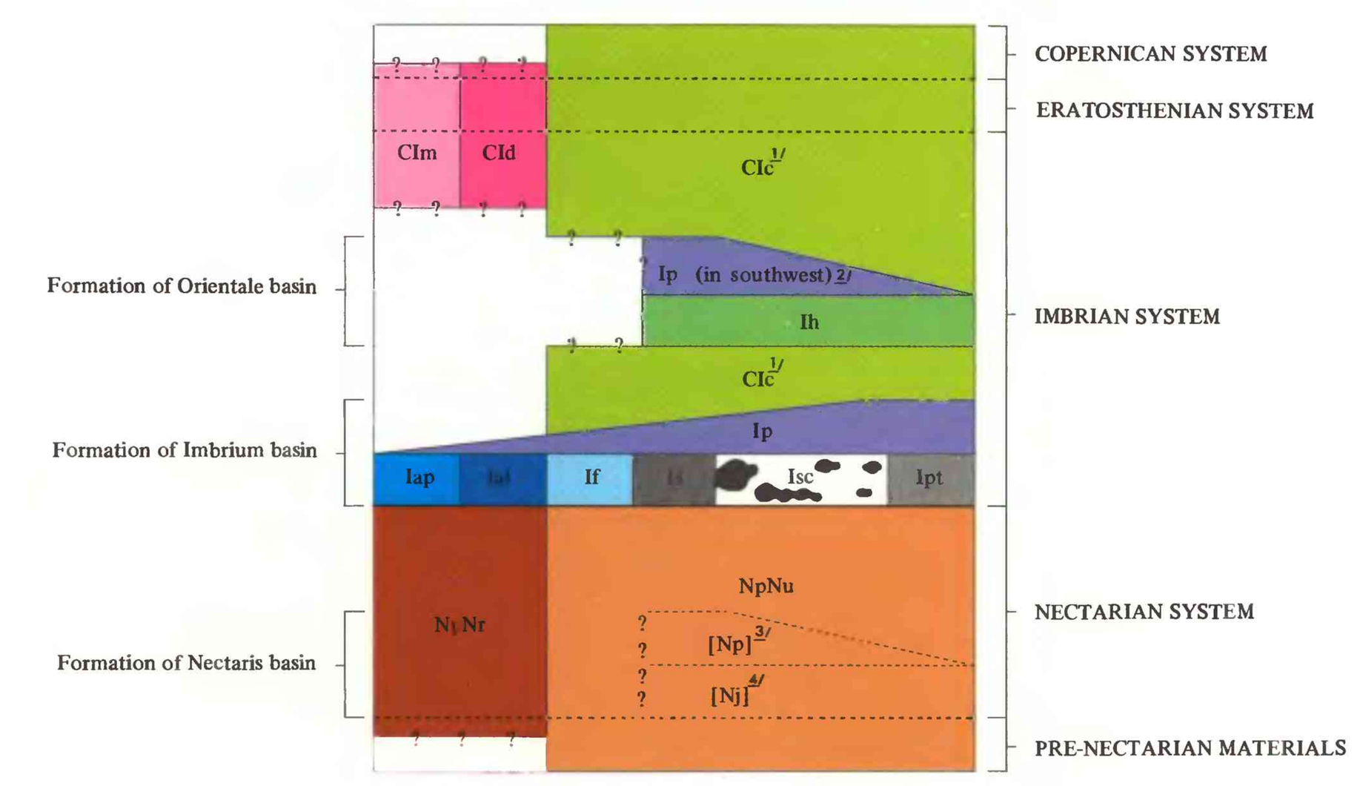
Prepared on behalf of the
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION



CORRELATION OF MAP UNITS



System boundary, dotted where not mapped

Unit boundary, dotted where not mapped

Symbols for unmapped units enclosed in brackets

DESCRIPTION AND INTERPRETATION OF MAP UNITS

CIm MARE MATERIAL (Copernican to Imbrian)—Forms dark, generally flat and level plains divisible into areas having different, relatively low crater densities and different crater-erosion states, albedoes, and colors. *Interpretation:* Predominantly mare-basalt flows of varied composition with intercalated regolith zones at most flow tops and possibly some basaltic pyroclastic layers of similar composition; total accumulations, typically of a few hundred meters to several kilometers, are indicated by the degree to which craters with predictable morphologies are flooded

CId DARK-MANTLE MATERIAL (Copernican to Imbrian)—Mostly forms smooth, gently undulating to flat surfaces having low crater densities; probably includes the darkest lunar materials, locally somewhat lighter. *Interpretation:* Volcanic ash blankets of varied composition and (or) physical state; probably related to mare basalt; the manner of apparent mantling suggests thicknesses of a few meters to a few tens of meters

CIc CRATER MATERIALS (Copernican to Imbrian)—Includes rim, wall, floor, and central-peak materials of craters younger than the Imbrium event. Unit includes bright, younger steep-slope deposits inside craters. Shown only for deposits more than 50 km across.

Crater-rim materials generally form a narrow, sharp-crested raised collar around the crater, grading outward into fairly low-lying hummocky to subradially ridgy aprons about a crater diameter wide. Crater-wall materials form very irregular hummocky surfaces in the lower parts of the crater walls. (Upper parts of crater walls are apparently occupied by slump scarps and terraces.) Crater-floor materials include an upper unit of pool-like deposits that have crackled surfaces when uneroded. These pool-like deposits are nested in depressions within a lower crater-floor deposit whose surface is rough and hilly in detail but gently undulating on a larger scale. Central-peak materials form clusters of hills and mountainous peaks with steep slopes.

Albedo highly varied; albedoes of Copernican materials generally high to very high, locally intermediate to low; albedoes of Eratosthenian and Imbrian crater materials mostly high intermediate to low intermediate, locally low; density of craters superposed on rim materials generally increases with age. Subunits are discrete deposits of crater materials associated with separate craters, mostly as mapped by Wilhelms and McCauley (1971). *Interpretation:* Deposits of impact-cratering origin. Rim, wall, hilly floor, and central-peak materials are mostly rubble and (or) breccias derived from target materials by ejection, slump, fallback (?), and target rebound, respectively; smooth-floor materials are probably thin accumulations having glassy to mostly finely crystalline "igneous" textures, derived from essentially whole-rock shock melts and having various amounts of admixed target fragments

Ip TERRA-PLAINS MATERIAL (middle and lower Imbrian)—Includes Cayley Formation in the uplands in the central part of map and, between Archimedes (30° N., 4° W.) and Montes Apenninus, the Apennine Bench Formation. Terra-plains material forms generally smooth but locally undulating pool-like plains of mid- to high-intermediate albedo in most preexisting depressions. More cratered than maria, less cratered than Fra Mauro Formation. *Interpretation:* Probably mostly formed as a sequence of layers of polymict, highly feldspathic rubble and (or) breccia, each layer deposited from a fluidized cloud of basin-associated ejecta; probably predominantly secondary-impact ejecta derived from basin-associated secondary-impact sites. Unit may include, and might be dominated by, layers of materials deposited from a series of large, expanding, dusty, and probably gas-fluidized clouds, one centered over each basin and associated with the event that formed it. Concentration of large patches in center of map lying peripheral to the Fra Mauro Formation (unit If) is apparently genetically related to the Imbrium multiringed basin; concentration of numerous patches in southwestern part of map is apparently related to the Orientale multiringed basin. Mantling of preexisting craters in pools suggests thicknesses of as much as a few hundred meters for individual layers in large pools measuring several tens of kilometers across

(Note: The remaining terra materials described below have the same general lithologic character as the terra-plains material described above.)

Ih HEVELIUS FORMATION (middle Imbrian)—Surface characterized by closely spaced, narrow ridges and troughs alined radially or subradially to center of Orientale multiringed basin on western edge of map; ridges typically as much as 3 to 5 km long at west edge of mapped area; roughness of unit decreases away from edge of basin and is gradational into stringers and disconnected patches of faintly lineated materials that become indistinguishable from underlying terra units as distance from basin increases. Albedo midintermediate; more cratered than maria; less cratered than Fra Mauro Formation. Morphologic details appear little eroded at Lunar Orbiter IV scale. *Interpretation:* Impact ejecta from Orientale basin that probably contains admixtures of secondary ejecta in the basal part and perhaps throughout the entire thickness of the unit in areas farthest from the basin; mantling and filling of preexisting craters indicates thicknesses ranging from zero to several hundred meters in the mapped area

Iap MATERIAL OF MONTES APENNINUS (lowermost Imbrian)—Forms surface consisting of closely spaced, moderately rugged hills and short ridges oriented generally concentric to Imbrium multiringed basin and an intervening network of valleys with smooth to undulating floors. Hills and ridges typically 1 to 4 km wide and commonly as much as 5 to 10 km long; albedo mottled intermediate to high with abrupt variations. *Interpretation:* Fault- and fracture-bounded blocks of Imbrium-basin impact ejecta and underlying country rock of the Imbrium craters. By analogy with Hevelius Formation, thickness of ejecta probably reaches a few kilometers; depth of faulting and fracturing may originally have reached more than 100 km; the mass may be reindurated below about 25 km below surface, or, because of much nearby mare-basalt magmatism, at even shallower depths. Crater densities probably greatly modified by rapid erosion on steep slopes of hills and ridges

Ial ALPES FORMATION (lowermost Imbrian)—Typically forms rugged, closely spaced, subequidimensional hills, locally with intervening valley floors that are grossly flat but gently undulating owing to the presence of very subdued small hills 1 or 2 km in diameter; albedo mottled intermediate to high with abrupt variations. *Interpretation:* Similar to material of Montes Apenninus but more thoroughly broken up; unit grossly flattened by fragmental flow as the mass slumped into freshly excavated Imbrium basin and possibly other depressions. Crater densities probably considerably modified by rapid erosion on steep slopes of hills

If FRA MAURO FORMATION (lowermost Imbrian)—Forms blanket mantling older terrain features, such as craters, on flanks of Imbrium multiringed basin; surface characterized (a) by subdued, closely spaced, slightly sinuous ridges generally 1 to 4 km wide, 5 to 15 km long, and as much as a few hundred meters high, trending generally subradial to Imbrium basin or (b) commonly in peripheral areas farthest from basin, by irregular, closely spaced subdued hills 1/2 to 2 km in diameter; albedo mid- to low-intermediate; moderately cratered and eroded. *Interpretation:* Mainly the continuous blanket of impact ejecta associated with Imbrium basin; includes a few patchy deposits with similar surface morphology farther from basin; dominantly primary ejecta close to Carpatus-Apenninus-southern Caucasus arc but probably includes some secondary ejecta there in basal zone; in peripheral hilly parts, the formation may consist mostly of secondary ejecta throughout its thickness and may contain only subordinate primary ejecta there; by analogy with the better preserved Hevelius Formation, probably reaches thicknesses of a few kilometers near the Carpatus-Apenninus-southern Caucasus arc, grading to a few meters or tens of meters at the mapped distal edge

Is MATERIALS OF SCULPTURED TERRAIN (lowermost Imbrian)—Crater-rim and crater-interior materials associated with numerous chains of subequidimensional satellitic craters. Individual craters are commonly merged and form troughs subradial to Imbrium basin and typically 5 to 10 km wide, at places fairly smooth-sided, but commonly including short arcs of subcircular crater walls. Rim deposits are inconspicuous and form narrow ridges where best developed; commonly crowded between closely spaced troughs. Where they overlap adjacent troughs, the rim deposits become indistinguishable from normal crater-interior deposits. No extensive rim deposits with characteristic topographic textures such as are associated with the satellitic craters of the Orientale basin are recognized. Albedo of unit intermediate to high, correlated with slope. Emplacement of materials may have been less continuous than shown, but unit probably covers more than half of area mapped as Is. *Interpretation:* Craters formed by secondary impact of materials ejected from Imbrium basin. Deposits resulting from this cratering are ejecta and fallback dominantly of local derivation with minor primary Imbrium ejecta. Much of the secondary ejecta probably forms, or becomes incorporated into, a fluidized cloud and is swept away into depressions to form deposits of terra-plains materials. Crater densities probably considerably modified by rapid erosion on steeply sloping walls of troughs

Isc MATERIALS OF SATELLITIC CRATERS (lowermost Imbrian)—Crater-rim and crater-interior materials of main field of satellitic craters of Imbrium multiringed basin. Craters typically 10 to 15 km in diameter; locally, mainly in areas closest to basin, as much as 25 km in diameter; arranged in clusters and radial chains commonly with few individuals and with a limited size range in a group. Craters in a cluster or chain typically merge or overlap. Rim crests typically fairly sharp and, even on isolated craters, commonly have minor elliptical or irregular deviations from circularity. Width of crater rims is typically no more than 1/4 to 1/6 of a crater diameter; zero where craters merge. Rim deposits do not have distinctive surface textures normally seen on younger individual craters. Crater interiors in simpler groups typically fairly smooth and steep walled but somewhat less so than in isolated main-sequence craters of same age. Craters larger than 15 km in diameter commonly are very irregular, and all are more filled than main-sequence craters of the same age. Albedo of unit intermediate to high, correlated with slope. Unit mapped only between 25° W. and 35° E. of the Imbrium-grid coordinate system. Satellitic craters covered by ejecta from younger craters (unit CIc) are mapped, where discernible, to show field as completely as possible. *Interpretation:* Same as for materials of sculptured terrain (unit Is): materials of secondary-impact craters of the Imbrium-basin crater. Materials filling the larger craters of the array probably were deposited from the large amounts of basin-associated ejecta in transit during secondary cratering. One effect presumably was the deposition of considerable masses of material in the secondary-impact craters immediately following, or even during, their formation. Another effect may have been to stifle ejection from the secondaries. Crater densities probably considerably modified by rapid erosion on steep crater walls

Ipt MATERIALS OF PITTED TERRAIN (lowermost Imbrian)—Crater-interior and crater-rim deposits of innumerable, densely overlapping, small craters typically 1/2 to 3 km in diameter. Most craters are randomly scattered but locally some are grouped in clusters or chains having irregular arrangement. Relief of crater interiors and rims generally moderately to heavily subdued. Albedo mottled intermediate to high with gradual variations. *Interpretation:* Similar to materials of satellitic crater (unit Isc). Smaller secondary-impact craters characteristic of the pitted terrain probably were formed by locally fine grained primary ejecta. Alternatively, the small crater size may indicate origin as tertiary impact craters. Deposits may typically range in thickness from several meters to a few tens of meters. Unit is absent west of about 4° W. in the Imbrium-grid coordinate system, possibly reflecting the presence of an upland-mantling equivalent of terra-plains material associated with the Orientale basin. (This great circle is very nearly an Orientale-centered equator.)

NpNr RUGGED MATERIAL (Nectarian and pre-Nectarian?)—Rugged blocks, most commonly 10 to 30 km across and as much as a few kilometers high, generally with rectilinear outline; unit forms highest and most rugged parts of arcuate mountain ranges and rings of isolated mountains in and around the Imbrium basin; slopes steep, smooth, and bright at Lunar Orbiter IV scale; flatter mountain tops have intermediate albedo. Contacts of unit with adjacent lower terrain may be gradational or, where slopes are high and deeply mantled with talus, may be sharply overlapping in detail. *Interpretation:* Fault blocks and large fragments of pre-basin rocks. Crater densities probably greatly modified by rapid erosion on steep mountainous slopes

NpNu UNDIVIDED MATERIALS (Nectarian and pre-Nectarian)—Primarily heavily to very heavily cratered and eroded crater- and basin-associated deposits of pre-Imbrian age. Albedo mainly high intermediate, high on some slopes. For simplicity, unit includes some areas mapped by Wilhelms and McCauley (1971) as mantling terra materials of Imbrian age, particularly in areas close to and within the Imbrium basin (unit It and part of unit IpIt); terra domes of Imbrian or younger age (units CEd, Id); and hilly units of Imbrian and younger age (units CEhf, Ih, Ihf, part of Ihp). *Interpretation:* The target materials of the Imbrium event

REFERENCES

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Stuart-Alexander, D. E., and Wilhelms, D. E., 1975, The Nectarian System, a new lunar time-stratigraphic unit: U.S. Geol. Survey Jour. Research, v. 3, no. 1, p. 53-58.

Wilhelms, D. E., and McCauley, J. F., 1971, Geologic map of the near side of the Moon: U.S. Geol. Survey Misc. Geol. Inv. Map I-703, scale 1:5,000,000.

1/ Essentially one continuous sequence. The interruption (if any exists) by the Orientale event is negligible in terms of duration

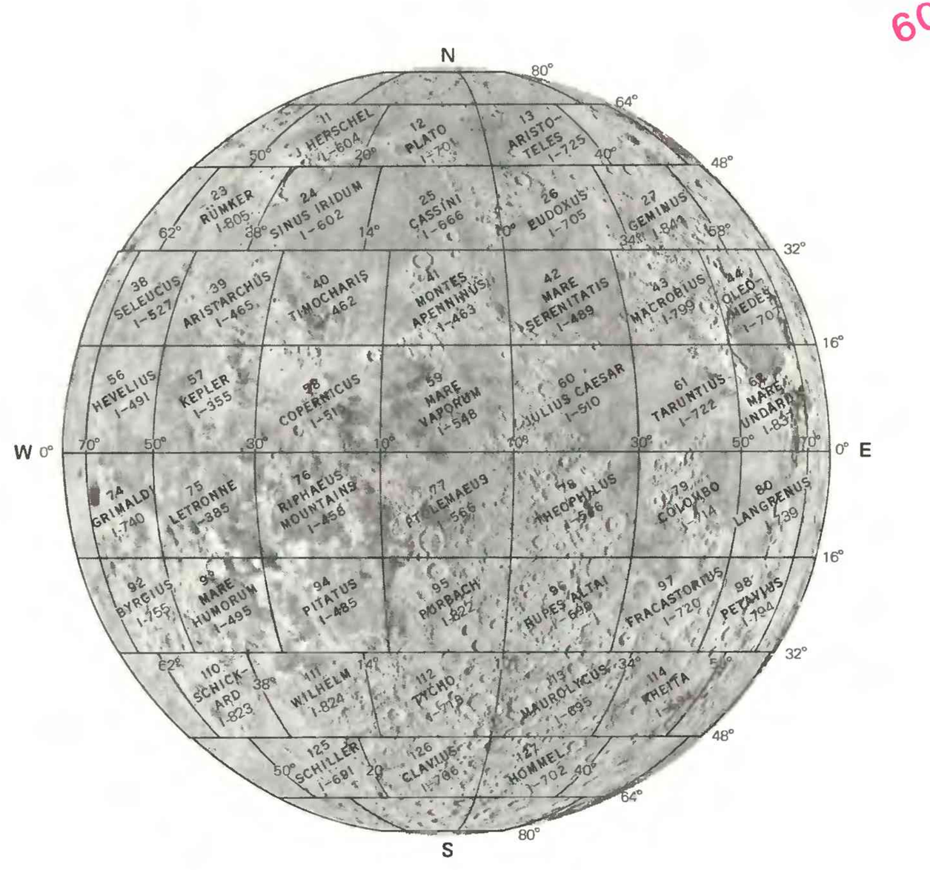
2/ Especially the concentration along the southwestern edge of the map. The older component of Ip may underlie many of the patches there

3/ Terra-plains materials of Nectarian age (see Stuart-Alexander and Wilhelms, 1975). Equals terra-plains materials of pre-Imbrian age mapped by Wilhelms and McCauley (1971) from 35° to 59° S. and 1° W. to 32° E.

4/ Janssen Formation, named by Stuart-Alexander (1971) and mapped in the area of this map by Wilhelms and McCauley (1971)

IMBRIUM GRID
Showing distances in kilometers from the center of the Imbrium basin and radials to the basin center. Radials are at 10° intervals from a reference meridian that passes through the center of the mean earthside hemisphere

Base adapted from photomosaic LEM-1, 3d edition, 1966, by the USAF Aeronautical Chart and Information Center (now Defense Mapping Agency, Aerospace Center), St. Louis, Missouri 63118



INDEX OF 1:1,000,000-SCALE MAPPING OF THE MEAN EARTHSIDE HEMISPHERE OF THE MOON
Number above quadrangle name refers to the LAC series shaded-relief topographic map (for example, LAC 11 in the upper left) published by the USAF Aeronautical Chart and Information Center. (See address in the note above.) The identifier below the name is that of the geologic map published by the U.S. Geological Survey (for example Map I-602 by Schaber, 1969).

☆Interior—Geological Survey, Reston, Va.—1980—G77199

Geology modified and reinterpreted by R. E. Eggleton, 1974, from the map of Wilhelms and McCauley (1971). The principal new work was the systematic mapping of the satellitic crater field of the Imbrium basin through the central and southern highlands using Lunar Orbiter IV high-resolution photographs and the consequent recognition of Imbrium sculpture (see unit Is in description and interpretation of map units) as a part of the same regional pattern. The sculptured terrain connects the more familiar style of satellitic craters farther from Imbrium with the presumably depositional topographic textures of the Fra Mauro Formation. Further, in the southern part of the central highlands, the topography of the hilly and pitted material of Wilhelms and McCauley (1971) is here interpreted simply as a related satellitic cratering overprint on the pre-Imbrian cratered upland of basin-rim blanket deposits and terra-plains deposits interbedded with the old crater materials. In addition, the boundaries of the pitted unit, the sculptured unit, and the Fra Mauro Formation were locally revised. Other reinterpretations are given in the description and interpretation of map units.

The grid of great circles and small circles radial and concentric to the Imbrium basin was derived at a scale of 1:10,000,000 by Eggleton in 1962 (unpublished). The grid has been photographically enlarged to 1:5,000,000 and slightly refined. The basin center for the grid was taken as 37.83° N., 20.00° W. The prime meridian of the grid was arbitrarily selected to pass through the adopted center of the basin and the center of the mean earthside hemisphere. The center was located on the bisector of the angle subtended by the inner ring at the center of the earthside hemisphere, midway between the points of intersection of the bisector and the inner ring. This is the center of the innermost mountain ring, the Montes Recti-Montes Spitzbergensis ring. A more accurate location of the center was subsequently derived by Hartmann and Kuiper (1962) by fitting circles to ring structures on rectified photographs. This was the basis of the center plotted by Schaber (1969) at 37.13° N., 18.80° W.

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MAP OF THE IMPACT GEOLOGY OF THE IMBRIUM BASIN OF THE MOON