PREPARED IN COOPERATION WITH THE
MANNED SPACECRAFT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

GEOLOGIC SUMMARY

The Apollo 16 mission has been designed to obtain photographic, petrologic, and on-site experimental data from the central highlands of the Moon's near side, a major geologic province thus far unexplored during manned lunar excursions. The projected landing site, about 60 km north of the large crater Descartes, is on an intermontane plain, bounded on the east by the moderately rugged Descartes Mountains (informal mission name). The target point is centered approximately between two conspicuous bright-rayed craters, about 10.5 km apart, each of which is immediately adjacent to a relatively steep front of the Descartes Mountains. A variety of morphologic features and rock types, including two major lithologic units and bright ray materials from the two young craters, should be accessible to the Apollo 16 crew.

The regional geology is shown on the accompanying 1:250,000 scale map, and the area is included on the Theophilus quadrangle map at 1:1,000,000 scale (Milton, 1968).

The Cayley Formation, defined by Morris and Wilhelms (1967), is representative of the extensive light terra plains materials (Wilhelms, and McCauley, 1971), which cover approximately 7 percent (Wilhelms, oral commun., 1971) of the lunar near side. These materials commonly occupy the floors of large old craters and form conspicuous intermontane plains.

The albedo of the Cayley Formation is significantly higher than that of mare materials, suggesting, perhaps, a silica and (or) alumina content somewhat higher than that of the basaltic maria. Viscosity, however, must have been relatively low during emplacement, in order for the broad, nearly level surfaces to have formed. Impact ejecta and, possibly, pyroclastics may be interlayered with volcanic flow units.

Elsewhere, the Cayley Formation is older than most mare materials, according to analyses of crater size-frequency distributions (Gault, 1970; Greeley and Gault, 1970), crater shapes (Soderblom and Lebofsky), and embayment relations (Wilhelms and McCauley, 1971); superposed Imbrian craters, and the absence of Imbrian sculpture and pre-Imbrian craters, establish its Imbrian age (Wilhelms, 1970). Crater size-frequency distributions on the Cayley surface in the Descartes area, as compared with those at the landing sites of Apollo 11, 12, and 14, indicate that the formation here is slightly younger than the Fra Mauro Formation (Apollo 14), but older than the mare surfaces on which Apollo 11 and 12 landed (R. Greeley, written commun., 1971).

The Descartes Mountains are composed of four units whose morphologies are suggestive of volcanic landforms. Most distinctive is the hilly unit with rounded "haystack" hills and arcuate ridges, separated by curved troughs and escarpments; the surface of the unit slopes gently down to the north, grading into the less distinct subdued unit. A relatively sharp topographic break separates the hilly materials from the Cayley plains near South Ray crater, but farther to the southwest the contact is more subdued and thus less accurately located.

The furrowed unit in the northeast quadrant of the map area slopes southward gradually to an almost indistinguishable contact with both the subdued unit and the Cayley Formation; it is adjacent to the domical unit, a broadly convex feature with a gradual southward slope but distinct western escarpment. Overlap relations seem to vary between the furrowed and domical materials, and the two units may be largely contemporaneous.

The materials of the Descartes Mountains may represent a series of relatively viscous extrusions, perhaps contemporaneous and partly interfingering with the more fluid Cayley Formation. Stratigraphic relations are ambiguous, probably as a result of mass wasting and regolith formation at contacts.

Comparisons of crater densities suggest that the surface materials of the furrowed and domical units are approximately equivalent in age to the Cayley surface; the hilly unit, with apparent slopes no steeper than those of the furrowed and domical units, is conspicuously smooth and uncratered, and may therefore be the youngest extrusive phase.

Two conspicuous bright-rayed craters puncture the Cayley plains north and south of the landing point. Layered strata are exposed in both, and an examination of North Ray crater is planned by the mission crew. This crater, situated on a locally high part of the plains, may actually have penetrated the Descartes materials in addition to the Cayley Formation; in the cross section, the projected slope of the Descartes domical unit is shown intersecting the crater wall.

Superposition of rays from South Ray crater on those from North Ray indicates the sequence of formation, but both are relatively young Copernican craters. A still younger crater, Baby Ray, is superposed on the rays from South Ray, so that three Copernican impact events can be assigned relative ages.

Other craters throughout the map area have been assigned ages according to the relative brightness of rays and halos and apparent freshness of morphology with respect to size (Trask, 1969, 1970; Pohn and Offield, 1970). An impact origin is assumed for those craters so dated.

Convex floors or central mounds occur in seven Eratosthenian craters, ranging from about 500 to 1000 m in diameter; the smaller craters are possibly as young as earliest Copernican. Quaide and Oberbeck (1968), on the basis of experimental work, suggested that such features in much smaller craters indicated the approximate depth to a resistant substrate beneath the lunar regolith. Resistant strata may lie at various intervals within the discontinuous flow units of the Cayley Formation, so that the formation of convex floors here may depend on the depth of the crater relative to the local depth to a resistant layer.

Imbrian craters appear to form a gradational series from relatively conspicuous craters with rounded rims and broad bowl-shaped interiors to highly subdued craters apparently lacking raised rims. Only the most conspicuous are mapped as Imbrian crater materials; the rimless depressions are indicated by a dashed rim crest symbol. Some of these may be of endogenetic origin, but at the scale of available photographs, no evidence of such origin was recognized.

Chains and clusters of craters with a general northwest orientation are conspicuous in the map area. Discrete crater rim crests are recognized in some of these groups, but in others the craters coalesce or overlap. Raised rims surround some of the clusters and chains. The northwest alignment suggests two possible origins: as secondary impact craters of Theophilus, or as structurally controlled endogenetic craters. The crater groups are about three crater diameters (300 km) from Theophilus, approximately the same distance as the distal ends of chains more obviously related to Theophilus on its north side. Secondary origin is suggested by the overlapping or coalescent character of the chains, as well as by the regional context of their occurrence. The northwest alignment of the chains is, however, parallel to the prominent Abulfeda structural lineament to the south, and therefore an endogenetic hypothesis also is plausible. The group northwest of North Ray crater may be divided into a random cluster on the east end and a linear trough on the west; these two parts of the group may not necessarily have the same origin, but there is no sharp morphologic break between them.

Superficially, the clusters appear as subdued as Eratosthenian or Imbrian craters. Secondary craters, however, have low, rounded rims even when fresh, and if these are secondary, their relative prominence suggests that they are probably much younger than Imbrian and can be assigned the early Copernican age of Theophilus suggested by Milton (1968). If the craters are of volcanic collapse origin, their initial morphologies, and thus their degradational histories and ages, cannot be determined.

The spacecraft landing site, about midway between North and South Ray craters, offers an excellent opportunity to sample materials of the lunar highlands which probably are of volcanic origin. The Cayley plains are assumed to be representative of a widespread low-viscosity unit, older than the previously sampled maria, and the Descartes mountains may be volcanic materials quite different from the maria. Radiometric dates and compositions of samples obtained from these units will help to fill a significant gap in our current knowledge of the history and composition of the Moon. In addition, three separate Copernican ages are represented by three craters whose materials are superposed; if these can be sampled and radiation ages determined, the first sequential absolute dates of Copernican stratigraphic units will have been obtained.

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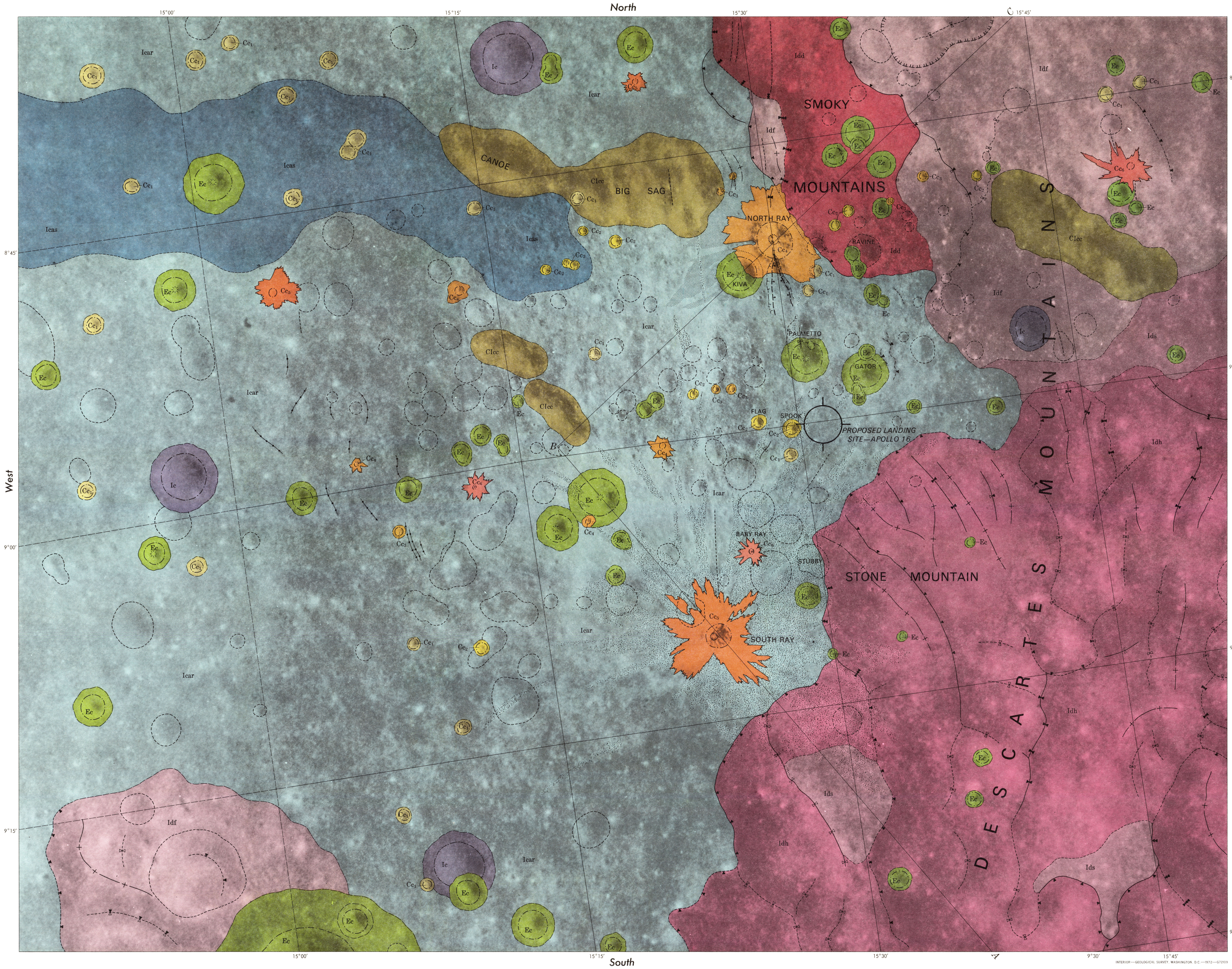


Unrectified photomosaic base made by U.S. Geological Survey, Center of Astrogeology from Apollo 14 photographs 9785 (80 mm) and 9520, 9530, 9605 (500 mm) supplied by Manned Spacecraft Center, National Aeronautics and Space Administration. High-resolution (500 mm) photographs cover central part of mosaic.
Selenographic grid plotted (solid lines) and extended (dashed lines) by U.S. Geological Survey, Center of Astrogeology from U.S. Army Topographic Command, Lunar Photomap Descartes, scale 1:100,000 1st ed., September 1971.
Informal names of surface features supplied by Apollo 16 crew and U. S. Geological Survey mission planning personnel.
Relative elevations along profile estimated from preliminary topographic map of the Descartes area, scale 1:25,000, prepared by the U. S. Army Topographic Command, October, 1971.

APPROXIMATE SCALE 1:50 000

1 ½ 0 1 2 3 NAUTICAL MILES
1 ½ 0 1 2 3 STATUTE MILES
1 .5 0 1 2 3 KILOMETERS

Principal sources of geologic information: Entire area covered by Lunar Orbiter IV photograph frame 89 H3 (scale approximately 1:600,000), Apollo 12 photograph 7428 (scale approximately 1:1,000,000), and Apollo 14 80 mm lens photograph 9785 (scale approximately 1:350,000). Central area of map, including landing site, covered by high resolution (20 m) Apollo 14 500 mm lens photographs 9508-34, 9546-74, 9589-9615. Mapped detail greater in central area of map. NASA contract No. T-66353G

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1972—G72109

EXPLANATION

Ray materials
Characteristics
Diffuse streaks and halos around craters, relatively high to very high albedo with no obvious relief at photographic scale; highest albedo around topographically sharpest craters, mapped only around North Ray (Cc_4) and South Ray (Cc_5) craters; rays and halos around smaller craters included in crater material units
Interpretation
Ejecta from young impact craters

Cc_6 Cc_5 Cc_4 Cc_3 Cc_2 Cc_1

Crater materials
Characteristics
Materials of circular craters having relatively sharp rim crests. Numbered sequence based on apparent freshness of crater morphologies and associated rays (Trask, 1969, 1970) and on superposition relations of crater rays; high-numbered craters characterized by sharpest rim crests, bright rays and rim material, and numerous blocks; low-numbered craters shallower and with only faint halos, if any. Classification depends also on size, with small craters more subdued than large craters of same age. Contact around large craters placed at break in slope at outer limit of continuous rim material; extent of ray pattern included around small craters
Interpretation
Impact craters, as inferred from rays, raised rim crests, and blocky floors around large bright craters; relative age sequence from oldest (Cc_1) to youngest (Cc_6) inferred from state of degradation with respect to size (Trask, 1969, 1970); gradual fading of rays and degradation of rim crests assumed to occur with time

COPERNICAN SYSTEM

Clcc

Material of crater chains and clusters
Characteristics
Material of tangential or coalescing craters grouped in elongate clusters or chains; raised rims apparent around some groups; rim crests rounded and indistinct; chains oriented northwest; morphologically similar to crater chains clearly related to Theophilus elsewhere
Interpretation
Probably secondary craters formed by ejecta from Theophilus, as suggested by alinement approximately radial to Theophilus, complex or overlapping configuration, and similarity in freshness (and therefore age) to continuous secondary chains north of Theophilus; alternatively, volcanic craters of Eratosthenian or Imbrian age, alined along northwest structural trends

Ec

Crater material
Characteristics
Material of circular craters having distinct rim crests with no observable bright halo or rays; rim crests sharp to rounded, depending on size, with small craters generally more subdued than large; convex floors common in craters 500 m or more in diameter
Interpretation
Impact craters; convexity of some crater floors possibly attributable to presence of resistant substrate

ERATOSTHENIAN SYSTEM

Ic

Crater material
Characteristics
Material of circular craters with slightly raised, rounded rim crests, and broad bowl-shaped interiors; shallower than younger craters of same diameter
Interpretation
Probably impact craters, but diagnostic criteria obliterated by subsequent meteorite bombardment and mass wasting; age uncertain if endogenetic

Idh / Idf | Idd | Ids

Materials of the Descartes Mountains
Characteristics
Mountainous and hilly materials on east side of map area, having predominantly rugged relief and intermediate albedo (locally high south of map area); subdivided according to topographic characteristics as follows:
Idh, *hilly unit. Clustered "haystack" hills and rounded ridges interspersed with deep curving troughs; contact with Cayley Formation drawn at base of slope; surface conspicuously smooth and relatively uncratered at resolution of photographs (approximately 20 m)*
Idf, *furrowed unit. Sloping surfaces and rounded ridges interrupted by elongate, somewhat twisting furrows; characteristic deep furrows most conspicuous outside map area; contact with Cayley Formation indistinct, but drawn at apparent base of slope*
Idd, *domical unit. Similar to furrowed material but forming discrete dome or broad convex surface*
Ids, *subdued unit. Relatively smooth material with little or no intrinsic relief; best delineated on regional map (Milton, accompanying map)*
Interpretation
Volcanic materials, probably highly viscous at time of emplacement. Furrows possibly structurally controlled. Age relations between units of Descartes materials and between Descartes materials and Cayley Formation unclear; stratigraphic relations at contacts probably obscured by regolith and mass wasting along escarpments; as inferred from superposed crater densities, furrowed and domical units possibly same age as Cayley Formation and hilly unit probably youngest of all, but appearance possibly deceptive because of slopes in Descartes materials. Subdued unit possibly derived by surface degradation

Icas / Icar

Cayley Formation
Characteristics
Materials of plains having level appearance on Lunar Orbiter IV photographs (approx. 100 m resolution); undulating to slightly hummocky surface at high resolution (20 m); intermediate albedo, higher than that of mare material; widespread throughout lunar highlands, with crater size-frequency distributions commonly higher than on maria (Gault, 1970; Greeley and Gault, 1970); subdivided within map area according to surface texture as follows:
Icas, *smooth member. Nearly level surface*
Icar, *rolling member. Surface characterized by superposed series of craters gradational from shallow, subdued, apparently rimless depressions (about 400 to 1000 m in diameter) to well-defined craters with rounded rim crests as large as 1300 m across; where subdued depressions numerous, as indicated by dashed rim-crest symbol, plains essentially equivalent to cratered unit* (Icac) *of regional map (Milton, accompanying map)*
Interpretation
Probably interfingering volcanic materials of initially low viscosity; stratification indicated by apparent layering in fresh superposed craters; superposed shallow depressions and large degraded craters probably Imbrian (Trask, 1969, 1970). Formation older than mare basalts, as suggested by higher Imbrian crater density; composition different from that of maria possibly indicated by higher albedo; age with respect to Descartes materials unclear but probably contemporaneous in part

IMBRIAN SYSTEM

Contact
Long dashed where approximate; short dashed where gradational between members of formation; dotted where buried; queried where doubtful

Gentle Moderate Steep Asymmetric
Trough
Line along axis of conspicuous furrow or trough; dashed where indistinct

Lip of rimless depression or subdued rim crest of relatively shallow crater
Less distinct than colored crater units; several large depressions covered by rays from South Ray crater. Origins probably diverse; primary impact craters of earliest post-Cayley age, secondary impact craters of later age, and/or endogenetic craters of indeterminate age

Probable fault
Bar and ball on downthrown side

Approximate crest of scarp

Lineament
Line along axis of narrow, shallow furrow

Chain of very small craters (diagrammatic)
Secondary impact or internal origin

Blocky floor of crater

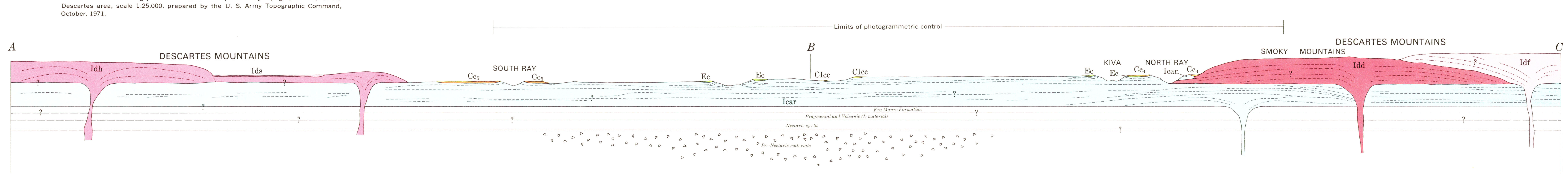
Gentle Moderate Steep
Slope
Line at base of slope; barbs point downslope; coincident with contact in places; dashed where break in slope indistinct

Axis of rounded ridge

Convex floor of crater

Prominent crater rim crest

Conspicuous large depression
Possibly coalescent impact craters or collapse features



HYPOTHETICAL SECTION
No vertical exaggeration
NOTE: Nectaris basin ejecta, fragmental and volcanic (?) materials, and Fra Mauro Formation (Imbrium basin ejecta) inferred from regional relations (Milton, accompanying map; Wilhelms and McCauley, 1971); surficial material of crater walls not shown; bedrock probably exposed in most craters, as schematically indicated

THEOPHILUS QUADRANGLE SHOWING LOCATION OF DETAILED GEOLOGIC MAPS OF THE APOLLO 16 (DESCARTES) LANDING AREA AND GENERALIZED GEOLOGIC PROVINCES
1. Area of 1:250,000 scale map (Milton, 1972)
2. Area of 1:50,000 scale map (Hodges, 1972)

GEOLOGIC MAP OF PART OF THE DESCARTES REGION OF THE MOON
APOLLO 16 PRE-MISSION MAP

By
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1972