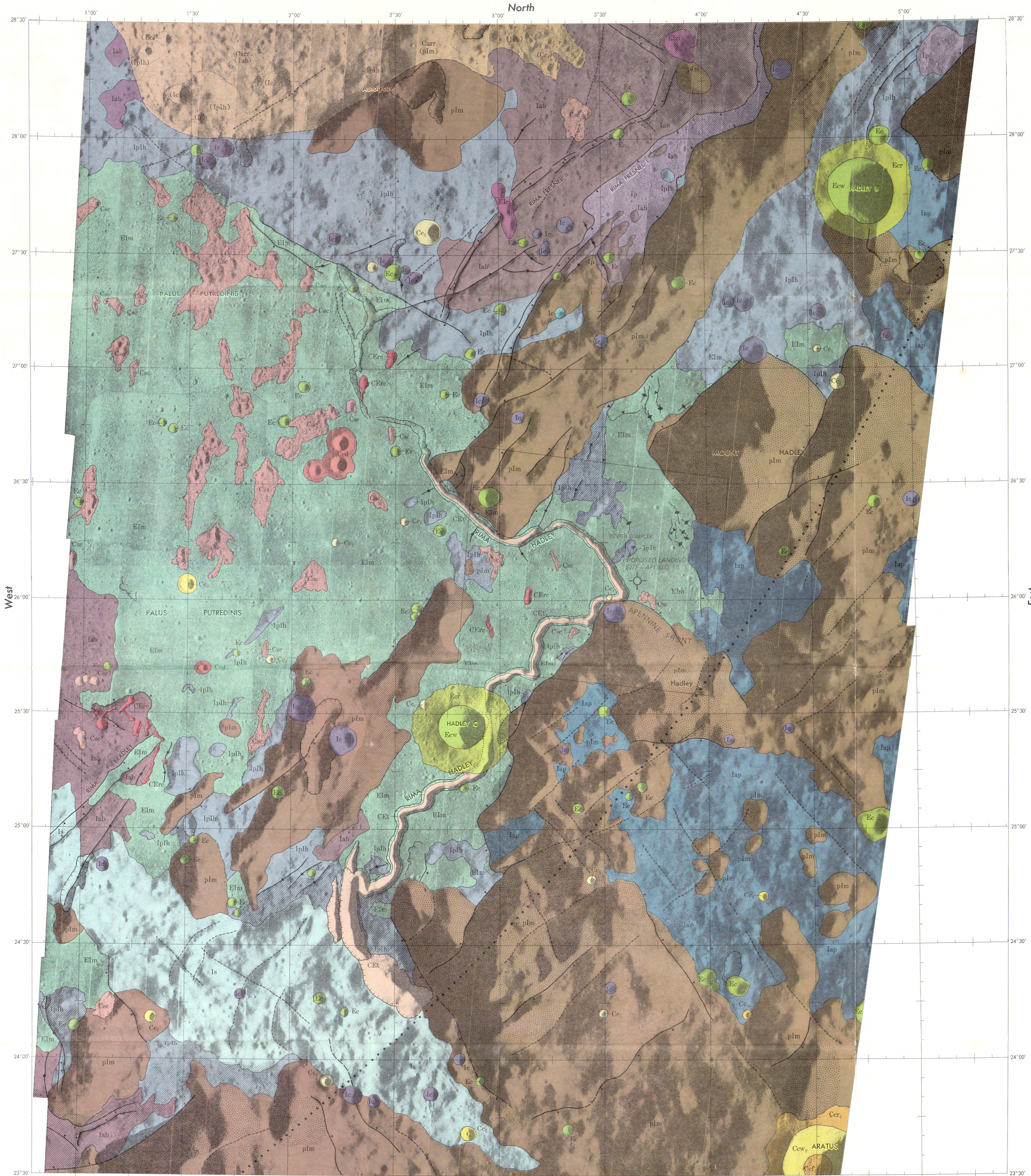
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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



Base map from Rima Hadley, Sheets A and B prepared by U.S. Army Topographic Command under direction of Department of Defense for National Aeronautics and Space Administration, 1st ed. April 1970
Informal names of surface features supplied by NASA, Bellcomm, Inc. and U.S. Geological Survey mission planning personnel.

SCALE 1:250 000
TRANSVERSE MERCATOR PROJECTION

5 0 5 10 15 NAUTICAL MILES
5 0 5 10 15 STATUTE MILES
5 0 5 10 15 KILOMETERS

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1971—G71283

Principal sources of geologic information: Lunar Orbiter moderate resolution photographs V-M104-M107; Lunar Orbiter high resolution photographs IV-H102, V-H104-H107; telescopic photographs L-35 taken at Lick Observatory, Mt. Hamilton, Calif. and full-Moon plate 5818 taken at U.S. Naval Observatory, Flagstaff, Ariz. NASA contract No. T-66353G

GEOLOGIC MAP OF THE APENNINE-HADLEY REGION OF THE MOON
APOLLO 15 PRE-MISSION MAP

By
M. H. Carr and Farouk El-Baz
1971

EXPLANATION

Ray material
[illegible]

Dark mantling material
[illegible]

Is — Slump material
[illegible]

Iplh — Hilly material
[illegible]

CEt — Talus
[illegible]

Elm — Mare basalts
[illegible]

Ip — Pitted plains material
[illegible]

Iab — Apennine Bench Formation
[illegible]

Iap — Apennine material
[illegible]

pIm — Massif materials of Imbrium Basin
[illegible]

Carr

Autolycus rim material, radial
Characteristics
Material that forms the highly cratered surface around Autolycus. Surface consists largely of braided low ridges, mostly less than 1 km across, and shallow depressions. Only the outer radial facies of the Autolycus rim deposits occurs in the map area. Moderate albedo. Material wedges out away from the crater; exact location of contact difficult to define
Interpretation
Base surge deposits and ballistic ejecta derived from Autolycus. Probably finely comminuted basalts and breccias

Ccd

Dark halo crater material
Characteristics
Material in and around fresh-appearing bowl-shaped craters with smooth dark rims that differ from other craters with comparable morphology by their very low rim albedo. Occur on Aristillus/Autolycus rays
Interpretation
Craters younger than unit Csc. *May be young impact craters with dark ejecta or volcanic craters surrounded by halo of pyroclastic debris*

Csc

Secondary crater material
Characteristics
Craters generally elongate N-S and form clusters or linear arrays radial to Autolycus and Aristillus. Many large craters have plumose structure consisting of low ridges and grooves diverging away from Autolycus and Aristillus. Craters commonly shallow with low rims. Albedo moderate
Interpretation
Local materials modified by impact of ejecta from Aristillus and/or Autolycus. Very little exotic material from primary craters. Queried where age or origin uncertain

CErc

Rille crater material
Characteristics
Materials in elongate craters and short linear depressions with connecting craters. Includes several short rilles that cut across or terminate in shallow craters. Elongate craters lack plumose structure normally associated with secondary craters. Albedo same as surroundings
Interpretation
Volcanic crater chains and collapse features

EIci

Irregular crater material
Characteristics
Material of irregular craters that occur at intersection of structural features. 4 km diameter crater at 28°25′N., 3°55′E. appears related to dark mantling material. Crater at 27°45′N., 3°E. forms chain cutting Rima Fresnel II
Interpretation
Volcanic craters

Ccr_2 | Ccw_2 | Ccf_2

Aratus crater materials
Characteristics
Ccr_2, *rim material. Smooth except for faint radial grooves; numerous blocks and small (<100 m) craters close to rim crest. Distinct rays. Moderate to high albedo*
Ccw_2, *wall material. Steeply sloping, blocky. Abuts abruptly against floor. Very high albedo*
Ccf_2, *floor material. Flat except for low elongate ridges. Numerous intersecting fractures*
Interpretation
Young impact crater. High radar reflectivity and enhanced thermal anomaly during eclipse suggest very blocky debris both within crater and on rim

Ecr | Ecw

Hadley B, Hadley C, crater materials
Characteristics
Ecr, *rim material. Near rim crest smooth with very few blocks. Hadley C has low hummocks and ridges farther from rim crest. Frequency of craters same as in surrounding material. Albedo of Hadley B rim same as surroundings. Hadley C has a very faint bright halo*
Ecw, *wall material. Steeply sloping, few blocks, moderate to high albedo*
Interpretation
Fragmental debris associated with primary impact craters

Cc_3

Crater material, undivided
Characteristics
Material of a small crater (<1.5 km diameter) in southeast corner of map; a bright rim but no distinct rays. Rim crest sharply raised. Some blocks on rim. Interior walls steep and bright

Cc_2

Crater material, undivided
Characteristics
Material of craters < 3 km diameter without rays but with rim deposits slightly brighter than surroundings. Slightly subdued rim crests. Interior walls steep and bright

Cc_1

Crater material, undivided
Characteristics
Material of craters < 4 km diameter without rays; rim deposits have same albedo as surroundings. Slightly rounded, raised rim crests. Interiors bowl-shaped

COPERNICAN SYSTEM

Ec

Crater material, undivided
Characteristics
Material of bowl- or pan-shaped craters < 5 km diameter. Craters < 2 km have rims that barely stand above the surrounding terrain. Larger craters have low rims with rounded rim crests. Reflectivity of rim same as surroundings, but crater interiors slightly brighter

ERATOSTHENIAN SYSTEM

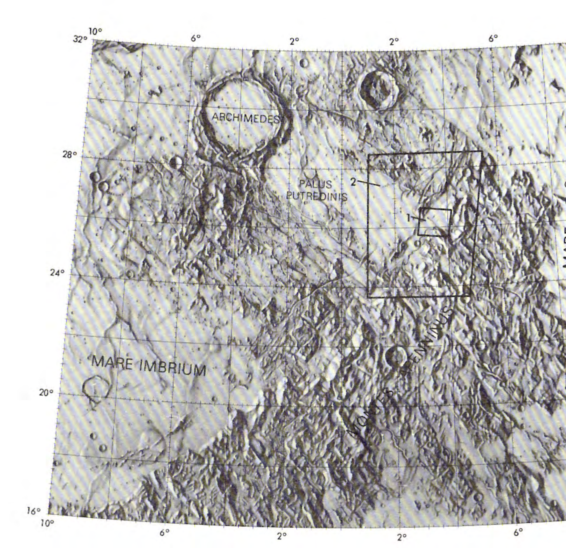
Ic

Crater materials, undivided
Characteristics
Material of shallow bowl- or pan-shaped craters < 4 km diameter. Craters < 2 km barely discernible depressions. Larger craters have very low indistinct rims. Reflectivity of rim same as surroundings, but crater interiors slightly brighter

Interpretation of Crater Materials of Post-Imbrium basin Age
(Cc_3-Ic)
Materials of impact craters ranging from middle Copernican age (Cc_3) *to Imbrian age* (Ic). *Morphologic characteristics indicate a primary impact origin for most of the craters. The older craters were once similar in appearance to the younger craters but have been subdued with time by meteorite and secondary-particle impact erosion and by slumping and downhill creep. The rim deposits of craters consist mainly of poorly sorted crushed rock and some shocked crystalline rock and impact-produced glass. Morphologic characteristics of craters and their materials are both age and size dependent (see fig. 1, in text), and the size range of mappable craters is largely determined by map scale. For these reasons the described characteristics for crater materials having the same relative age may vary between maps having different scales*

IMBRIAN SYSTEM

PRE-IMBRIAN



MONTES APENNINUS QUADRANGLE SHOWING LOCATION OF DETAILED GEOLOGIC MAPS OF THE APOLLO 15 (APENNINE-HADLEY) LANDING AREA

1. Area of 1:50,000 scale map (Howard, 1971)
2. Area of 1:250,000 scale map (Carr and El-Baz, 1971)

(Ic)
Contact
Dashed where approximately located; dotted where buried. Buried units shown in parentheses

Inferred fault
Dashed where location very uncertain, dotted where buried. Bar and ball on downthrown side. Where younger unit deposited against inferred fault scarp, fault mapped by convention as a solid line coincident with the contact between older and younger unit. Faults are mostly inferred from major topographic features

Lineament
Shallow linear grooves except in unit pIm *where symbol may denote steep sided clefts. Probable fault or fracture*

Linear rilles
Double line where wide, single line where narrow. Interpreted as graben

Flow front
Sinuous scarp on the mare surface; arrows indicate direction of flow

Low ridge
Line marks crest. Anticline produced by igneous intrusion

Low scarp
Probably a fault scarp. Barbs point downslope

Rima Hadley
Outer line shows edge of depression. Dashed where approximately located, dotted where buried. Inner line shows extent of bright talus on walls. Surrounding rocks may be exposed as ledges at the top of the rille walls above the talus

Depression

Generalized position of crest of Apennine Scarp, the most prominent of the Imbrium basin rings

Outline of area covered by 1:50 000 scale map of this report

NOTE: Landing site correctly located with respect to topographic features; but because of subsequent revision of lunar control network, mission coordinates for same location are lat 26°04′26″N. and 3°39′14″E.

GEOLOGIC SUMMARY

[illegible]

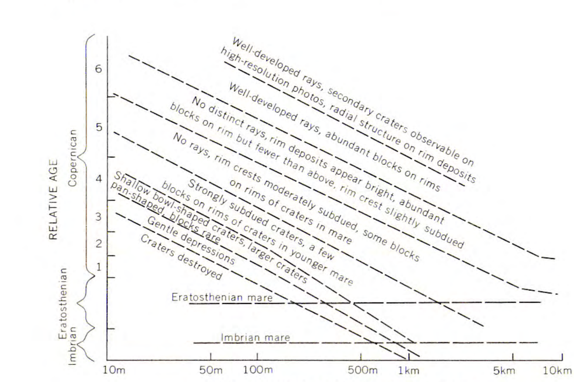


FIGURE 1.—Graphs showing assumed relations among diameters, properties, and ages of craters. Categories are intergradational. Horizontal lines are isochrons indicating variations in crater populations on surfaces of increasing age.

REFERENCES

[illegible]

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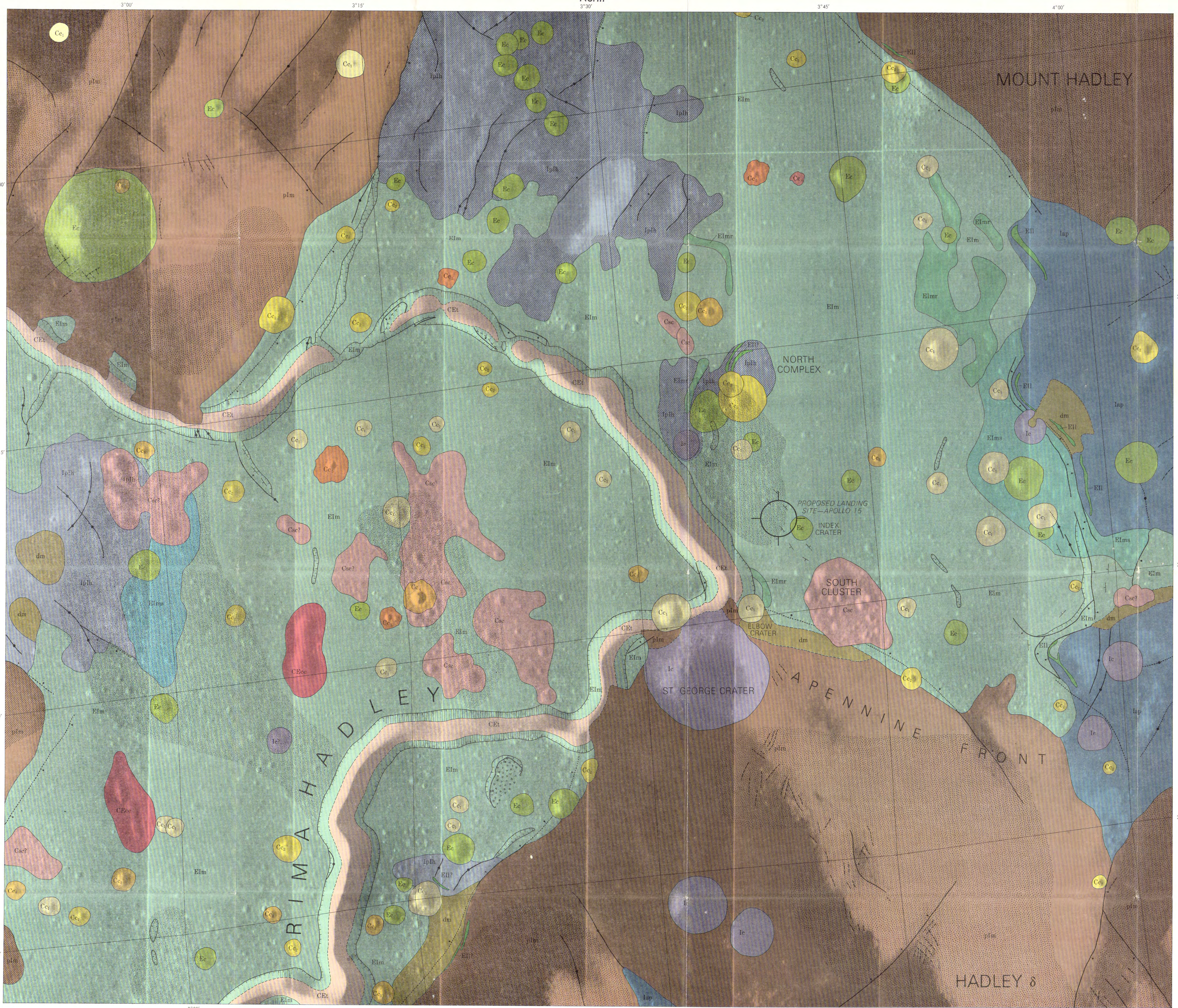
GEOLOGIC ATLAS OF THE MOON
PART OF APENNINE-HADLEY REGION-APOLLO 15
I-723 (SHEET 2 OF 2)

North



West — East

South

Unrectified base enlarged by U.S. Geological Survey from negative supplied by Lunar Orbiter Project Office, Langley Research Center, National Aeronautics and Space Administration.
Selenographic grid plotted by U.S. Geological Survey from U.S. Army Topographic Command, Lunar Photomap Rima Hadley (sheets A and B), scale 1:250,000, 1st ed., April, 1970.
Informal names of surface features supplied by NASA, Bellcomm, Inc. and U.S. Geological Survey mission planning personnel.

APPROXIMATE SCALE 1:50 000

3 NAUTICAL MILES
3 STATUTE MILES
3 KILOMETERS

Principal sources of geologic information: Lunar Orbiter moderate-resolution photographs V-M105, V-M106, and high-resolution photograph V-H106; Full-Moon plate 5818 taken at U.S. Naval Observatory, Flagstaff, Arizona. NASA contract No. T-66353G

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1971—G71283

GEOLOGIC MAP OF PART OF THE APENNINE-HADLEY REGION OF THE MOON
APOLLO 15 PRE-MISSION MAP

By
K. A. Howard
1971

E X P L A N A T I O N

Ray material
Relatively bright patches with no inherent relief; elongate downrange (to south-southeast) from Autolycus or Aristillus, and associated with small craters satellitic to these distant primary craters. Interpreted as a thin spray of ejecta from the primary craters

Csc — Material of satellitic craters
Craters are clustered and generally form elongate herringbone patterns radial to the large craters Autolycus and Aristillus (northwest of map area). Most craters are shallow and have somewhat rounded rim crests; rim crests of 500-m craters are similar to those of Ec *or* Cc_1 *craters; smaller satellitic craters (200 m) are nearly as sharp as* Cc_2 *or* Cc_3 *craters. Interpreted as secondary impact craters; original forms of most craters not as sharp as primary impact craters; dichotomy in apparent age between large and small craters may indicate two populations; older and larger secondaries from Autolycus, younger and smaller from Aristillus. Queried where age or origin uncertain*

Cc_6, Cc_5, Cc_4, Cc_3, Cc_2, Cc_1 — Crater materials
Materials of small round craters (generally 300 to 600 m) Classified in an age sequence, indicated by subscript numbers (Cc_6, *youngest), according to apparent freshness (Trask, 1969, 1970). Classification depends on size, so that for craters assigned the same age the larger craters are sharper.* Cc_6 *craters are very sharp, blocky, and have bright rays;* Cc_5 *craters are very sharp and have rays;* Cc_4 *craters are sharp and bright;* Cc_3 *craters have slightly subdued rim crests;* Cc_2 *craters have moderately subdued rim crests;* Cc_1 *craters are subdued and not bright. Mapping is extended to smaller sizes for younger craters; the smallest craters in all categories are unmapped*

COPERNICAN SYSTEM

dm — Debris of mountains
Forms subdued slopes at the foot of mountains or adjacent to hills; has low crater density and intermediate to low albedo. Some fills in nearby craters. Boundaries diffuse. Interpreted as mass-wasted debris; relative darkness may indicate a scarcity of blocks

CEce — Material of elongate craters
Craters are elongate, coalescing, and have substantial rims—proportionately wider than those of impact craters. Rim crests not sharp, similarly rounded to Ec *or* Cc_1 *craters. Interpreted as probable volcanic vents or fissure cones. Originally may have been deeper than impact craters, so that apparent age may be underestimated*

CEt — Talus deposits
Blocky debris on lower slopes of Rima Hadley; albedo high. Interpreted as talus derived mainly or entirely from cliffs of mare basalt that form rimrock at top of rille

Ec — Crater material
Material of shallow very subdued small craters (300 to 900 m) and of a single 2-km crater that is sharp-rimmed but not bright

ERATOSTHENIAN SYSTEM

Dark mantling material
Dark, covers hills but generally does not subdue their relatively crisp topography; may subdue one 600-m-wide crater, 3 km northwest of targeted landing site, that is a barely discernible circular depression designated "Ic." May cover mare rocks adjacent to hills. Tentatively interpreted as a thin mantle of basaltic material, such as cinders, over pre-mare massif and hilly materials; in low areas next to mare, may be a thin coating of mare basalt

EIm, EImr, EIms — Mare material
EIm, *basalt. Forms dark level plains, slightly darker than typical mare. Pattern indicates outcrops in wall of Rima Hadley; other outcrops are undoubtedly present on upper walls of rille but cannot be recognized because of lighting conditions on the east- and west-facing slopes. Interpreted as a basalt flow or flows; rimrock outcrops in Rima Hadley indicate flow(s) at least 150 m thick*
EImr, *ridge material. Forms winding low ridges in mare; generally flat-topped with steep sides. Tentatively interpreted as squeezeouts or anticlines due to local compression during flowage; may be indirectly related to submare topography*
EIms, *subdued material. Forms uneven rolling plains. Has a lower density of small sharp craters than other mare material* (EIm) *and a slightly higher albedo. Tentatively interpreted as slightly sloping, perhaps tilted, mare basalt. Alternatively may be thin coating of mare basalt over older units such as early mare flow(s), older plains material, or mass-wasted debris from mountains*

EIl — Ledge material
Forms sub-horizontal narrow rounded ledge on mountain slopes, at or slightly above level of mare, but commonly separated from mare by graben. Tentatively interpreted as a thin strand-line ledge of mare basalt. Queried occurrences in unit IpIh *may be fault scarps*

Ic — Crater material
Material of subdued craters ranging from 2½ km down to about 1 km in size

Interpretation of Crater Materials
Craters are mostly of impact origin. Craters are sharp and fresh when first formed but become progressively subdued with age by mass wasting and repeated impact bombardment

IMBRIAN SYSTEM

IpIh — Hilly material
Forms low hilly terrain west (basinward) of main Apennine rim. Cut by numerous sharp scarps and troughs mapped as faults and fractures of Imbrian age. Interpreted, like unit Iap, *mainly as Imbrium-basin ejecta that collected in low areas; subsequently faulted by continued structural adjustments of the basin. May contain subordinate amounts of pre-Imbrian material* (pIm), *especially on or near crests of small hills*

Iap — Apennine material
Forms rolling hills and vales between massifs of main Apennine range. Albedo intermediate. Interpreted mainly as Imbrium-basin ejecta that collected in low areas by later mass wasting; covers a chaotic bedrock of structurally deranged pre-Imbrian blocks

pIm — Massif material
Forms high rugged mountain masses of intermediate to high albedo; pattern shows areas having very high albedo. Interpreted as structurally uplifted blocks of pre-Imbrian rock—including ejecta of the Serenitatis basin—with a relatively thin capping of Imbrium-basin ejecta; bright (patterned) areas more blocky; probably exposed by active creep

PRE-IMBRIAN

Contact
Dashed where inferred

Fault
Dotted where buried. Bar and ball on downthrown side

Trough
Interpreted as overlying a fracture or as a graben. Dotted where buried

Lineament
Narrow (50 to 200 m) linear ridges and troughs on hillsides. Interpreted as patterned ground caused by mass wasting, possibly influenced by fracture patterns; linearity may be enhanced or partly artificial due to low-angle lighting effects

Rim of depression
Interpreted as mostly collapse features; some small elongate depressions may be secondary impact craters

Dip and strike
Gently sloping mare surface; dip may be depositional or caused by tilting

Structurally deranged collapse area

NOTE: Landing site correctly located with respect to topographic features; but because of subsequent revision of lunar control network, mission coordinates for same location are lat 26°04′26″N. and 3°39′14″E.

MONTES APENNINUS QUADRANGLE SHOWING LOCATION OF DETAILED GEOLOGIC MAPS OF THE APOLLO 15 (APENNINE-HADLEY) LANDING AREA

1. Area of 1:50,000 scale map (Howard, 1971)
2. Area of 1:250,000 scale map (Carr and El-Baz, 1971)

GEOLOGIC SUMMARY

The Apollo 15 landing target lies at the base of the Apennine Mountains (Montes Apenninus) in an embayment of Palus Putredinis near the sinuous rille Rima Hadley. The purpose of this map is to portray the geology in the vicinity of the landing site. The regional geologic setting in progressively larger areas has been mapped at the 1:250,000 scale (Carr and El-Baz, 1971), 1:1,000,000 scale (Hackman, 1966), and 1:5,000,000 scale (Wilhelms and McCauley, 1971).

The embayment consists of mare and is bordered by mountains as high as 4 km, such as Mount Hadley and Hadley δ. These mountains form the southeastern part of the most prominent ring of the Imbrium basin and are interpreted as pre-Imbrian rock (unit pIm), block-faulted and uplifted by the Imbrium impact event. Judging from the proximity of the area to the Serenitatis basin, the uppermost parts of these pre-Imbrian rock massifs probably consist partly of Serenitatis ejecta. Underlying materials may consist largely of similar deposits from older basins and craters.

Uplift and faulting of the mountains probably occurred mainly during the short interval between impact and the arrival of ejecta from the Imbrium crater. Comparison with the fresher Orientale basin suggests that some uplift of this rim or ring had already occurred when the ejecta arrived. From the distinctive flow patterns around Orientale, lunar basin ejecta appears to travel radially outward in a ground-hugging flow called a base surge (McCauley, 1968; McCauley and Masursky, 1969). The ejecta probably was deposited only thinly on the high mountains uplifted prior to the time of its arrival; it probably collected to greater thickness, however, in low areas between the massifs. Structural adjustments continued after deposition, as indicated by crisp fault scarps and troughs in hilly material west of the main scarp of the Apennine Mountains. This faulting, accompanied by seismic shaking, would contribute to the shedding of ejecta from the structural highs and their steeply sloping flanks. For these reasons, the Imbrium deposits are believed to be thin on the big massifs (unit pIm), and much thicker on intervening low hilly masses as Apennine material (Iap) and hilly material (IpIh).

All materials exposed on the hillsides have been considerably redistributed by mass wasting. An indication of this is the fact that hillsides have lower crater densities than adjacent younger mare. Rocky areas exposed by active creep may be represented by local bright slopes. Some of the downslope deposits appear to be diffuse aprons, designated as mountain debris (dm). This debris is distinguishable as darker and smoother terrain, gradational with both adjacent hills and lowlands. From exposures elsewhere on the Moon, it is clear that most hill slopes, even those having a sharp boundary at their base, have crept out over adjacent lower terrain; thus, much more mass-wasted debris may be present than indicated. Undoubtedly, mass wasting has thoroughly mixed the Imbrium ejecta with underlying pre-Imbrian rock fragments on all mountain slopes.

Mare basalt (EIm) flooded the embayment to form a dark level surface generally comparable to the Apollo 11 and Apollo 12 sites. A late Imbrian or early Eratosthenian age for this mare is indicated by the size of the oldest superposed craters; the largest highly subdued but not quite obliterated craters are about 300 m across, or lower Eratosthenian (Trask, 1969, 1970). Hence, this basalt appears to be younger than that at the Apollo 11 site and more comparable in age to that at the Apollo 12 site.

Rima Hadley may expose the entire local section of the mare lavas. A semi-continuous ledge or rimrock at the top of the rille wall, uniformly about 150 m thick, may comprise the entire mare sequence. Blocky talus derived mainly from the ledge covers the lower walls of the rille, but subjacent pre-mare rocks could be exposed locally. Presumably the rocks of the lower walls are less resistant giving rise to gentler slopes, more like those of the Apennine Bench Formation exposed nearby (Carr and El-Baz, 1971). Other pre-mare rocks or their debris may be exposed where the rille cuts the edges of massifs (pIm) or where hilly material (IpIh) is mapped close to the rille. The uniform thickness of the basalt ledge suggests that the pre-mare surface was relatively smooth.

Of particular interest during surface operations are visual and photographic observations of the rocks exposed in the upper rille walls to determine whether they constitute one or several superposed flow units.

Despite considerable terrestrial analog work, theoretical analysis, and experimentation, the origin of lunar sinuous rilles is still a controversial subject. For Rima Hadley, a lava channel and collapsed lava tube (Greeley 1971) is perhaps the most likely of many proposed explanations. The sinuosity of the rille suggests an origin by fluid flow. This interpretation is further strengthened by the presence of an elongate crater at the head of the rille, similar to those at the source of many terrestrial lava channels. (See Carr and El-Baz, 1971). Water or other volatiles are unlikely to have been the erosive agent responsible for the rille in view of the extremely dry state of Apollo 11 and 12 basalts. Origins requiring surface fluid transport such as stream flowage (Lingenfelter and others, 1968), erosion by ash flows (Cameron, 1964), or downslope movement of fluidized particulate matter (Schumm and Simons, 1969) are ruled out by interruptions or septa in the rille in the northwest part of the map area that would have acted as dams to block continuous surface transport. The rille widens and narrows abruptly in several places, producing bowl-shaped deeps with intervening shallow bridge-like features at the narrow parts. This pattern is found in numerous partly collapsed terrestrial lava tubes. Together with slump blocks recognized on the walls, and with the rarity of rims or levees along the rille, these interruptions suggest collapse into a subjacent sinuous tube. Elsewhere the rille has a strikingly constant width and cross section, unlike most terrestrial lava tubes, which may indicate that some of the lava channel never roofed over.

Three subsidiary trenches that intersect the rille in the northwest part of the map area, and a fourth just beyond, can be explained by the lava-channel hypothesis as tributary feeders. Like an analogous tributary that feeds at an acute angle into the Mammoth Crater lava tube in northern California, they may have formed by lava that ponded to one side of the main lava stream and crusted over before eventually draining back into the emptying tube and then collapsing. Three of the proposed tributaries, including the one just west of the mapped area, expectedly lead to the rille from adjacent higher terrain; the northeasternmost one may be controlled by a submare fault trough.

Incision by the rille into massif material, and probably into other pre-mare material now buried by talus deposits, indicates substantially more erosion than is accomplished in terrestrial lava tubes, where channel erosion is rare. However, the lower viscosity of mare basalts as compared with terrestrial basalts (Murase and McBirney, 1970), and the large cross section of Rima Hadley compared with terrestrial lava channels, indicate that the Reynolds number for mare lava in the rille would be orders of magnitude higher than that of terrestrial lavas. Thus, the lunar lavas would be in the regime of turbulent flow and could have substantial erosive capabilities. Erosion of the massif material may not have been as great as it appears, however, for the rille has clearly been widened by rockfalls after formation as indicated by a V-shaped profile of talus at the bottom. Where the rille impinges against massifs in the northwest part of the mapped area, the rille is following the only possible escape course for lava out into the main part of Palus Putredinus.

A possible alternative to the lava-tube explanation for the rille is an extension fracture mainly within the mare lava. A purely structural origin such as this is tenable if the "tributary" depressions are fractures rather than channels as perhaps suggested by the approximately orthogonal relation of three of them to the rille and the observation that the fourth is alined along a fault in hills in the northwest of the mapped area. The eastern border of the mare is generally marked by grabens, commonly rimmed by a narrow ledge along the mountainside (unit EIl) that is tentatively explained as a strandline of mare basalt adhering to the mountains. If this is correct, the grabens can be viewed as tensional features within the lava such as might form by contraction due to cooling and degassing. Rima Hadley winds irregularly in an arc of more than 180° around the mare embayment, and this precludes extension faulting by the pulling apart of rigid plates. As A. D. Howard (written commun. 1970) has pointed out in a discussion of lunar analogs of fluvial landscapes, this would tend to close rather than open some segments of the rille. Shrinkage of lava as it cooled and degassed could, however, conceivably open a sinuous gash in the mare lava.

Some of the hills and massifs in the area are unusually dark, with an albedo similar to that of the mare. Topographically these regions appear fresh and are otherwise similar to their brighter equivalents elsewhere. The darkness is therefore interpreted as a thin mantle (overprint on map) of dark material such as basaltic cinders. This dark mantle may cover adjacent mare surfaces as well, but is not recognizable. Cinders could be produced by fountaining at a lava river in Rima Hadley or at some peculiar elongate craters (unit CEce). To cover the highlands from mare sources would require cinder ejection velocities of at least 100 to 150 m/sec, indicating powerful degassing and a greater content of volatiles than indicated for Apollo 11 and 12 basalts. On some very low hills adjacent to mare, the dark mantling material may be a thin skin of mare flow rock—a circumstance that would confirm contraction of the mare after it crusted over.

The lunar surface is randomly pocked by countless small craters of presumed impact origin. These craters exhibit various states of preservation, from very sharp and bright to very subdued. This indicates that craters lose their sharpness with age. An inverse relationship between size and rate of subdual proposed by Trask (1969, 1970) permits the craters in this site to be placed in an age sequence ranging from late Copernican (Cc_6) to early Copernican (Cc_1) and older (Eratosthenian—Ec and Imbrian—Ic). Some Copernican craters (Csc) in the map area are clustered and associated with rays from Autolycus or Aristillus, far to the northwest, indicating the presence of small amounts of ejecta from these distant primary craters.

REFERENCES

Cameron, W. S., 1964, An interpretation of Schröter's Valley and other lunar sinuous rilles: Jour. Geophys. Research, v. 69, no. 12, p. 2423-2430.
Carr, M. H., and El-Baz, Farouk, 1971, Geologic map of the Apennine-Hadley region of the Moon—Apollo 15 pre-mission map: U.S. Geol. Survey Misc. Geol. Inv. Map I-723.
Greeley, Ronald, 1971, Lunar Hadley rille: Considerations of its origin: Science [in press].
Hackman, R. J., 1966, Geologic map of the Montes Apenninus region of the Moon: U.S. Geol. Survey Misc. Geol. Inv. Map I-463.
Lingenfelter, R. E., Peale, S. J., and Schubert, G., 1968, Lunar rivers: Science, v. 171, p. 266-269.
McCauley, J. F., 1968, Geologic results from the lunar precursor probes: Jour. Am. Inst. Aeronautics and Astronautics, v. 6, no. 10, p. 1991-1996.
McCauley, J. F. and Masursky, Harold, 1969, The Orientale basin and associated base surge deposits [abs.]: Geol. Soc. America Spec. Paper 121, p. 528-529.
Murase, Tsutomu, and McBirney, A. R., 1970, Viscosity of lunar lavas: Science, v. 167, no. 3924, p. 1491-1493.
Schumm, S. A. and Simons, D. B., 1969, Lunar rivers or coalesced chain craters?: Science, v. 165, no. 3889, p. 201-202.
Trask, N. J., 1969, Geologic maps of early Apollo landing sites of set C: U.S. Geol. Survey open-file report, 27 p.
_________ 1970, Geologic map of Apollo landing sites 3 and 3R, part of Oppolzer A region, Sinus Medii: U.S. Geol. Survey Misc. Geol. Inv. Map I-621.
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 [in press].