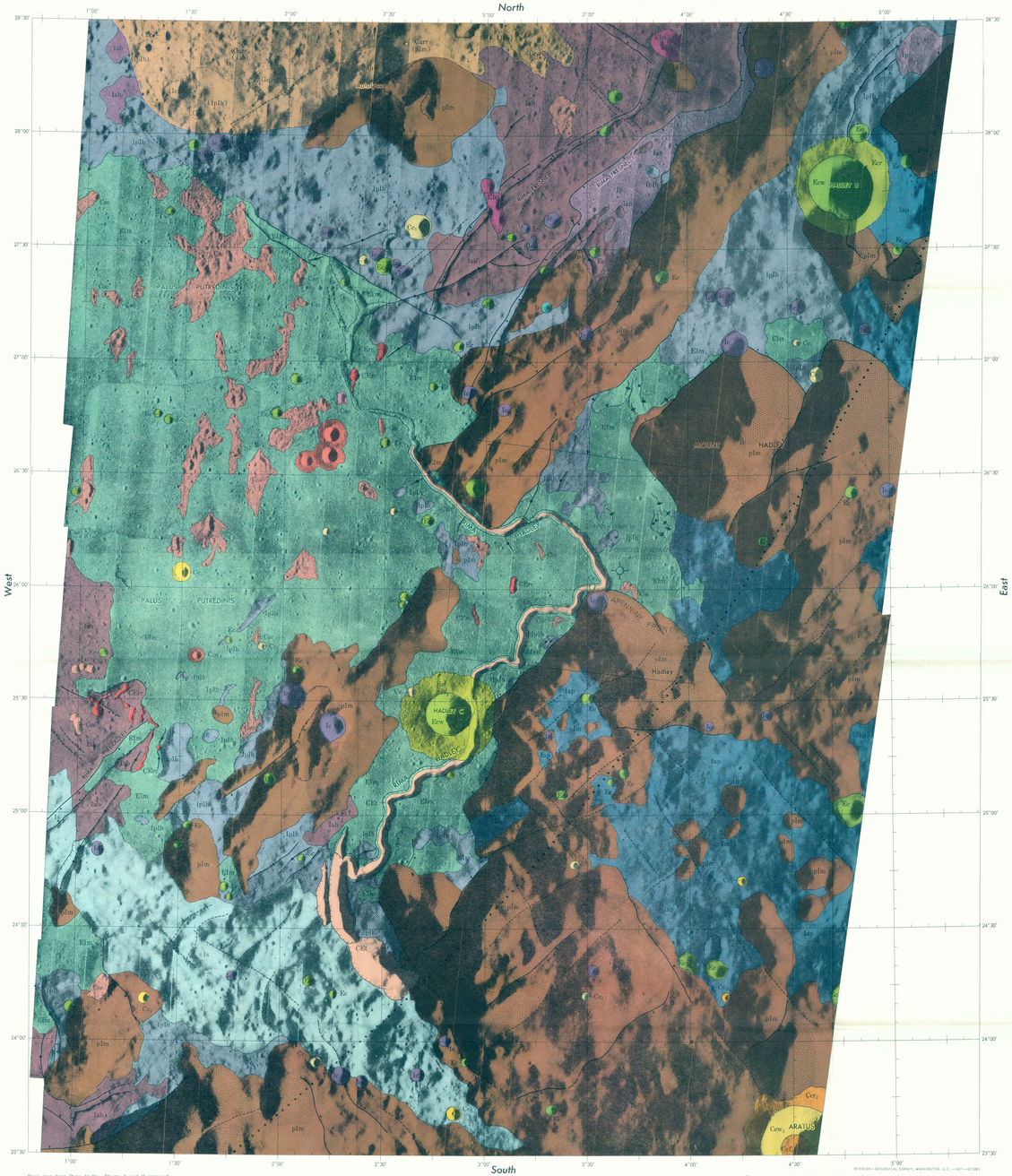
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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

GEOLOGIC ATLAS OF THE MOON
APENNINE-HADLEY REGION—APOLLO 15
I-723 (SHEET 1 OF 2)



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

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

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1971—G73383

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
Characteristics
Bright material with no detectable topographic relief. Occurs mostly as continuous deposits around Autolycus and Aristillus. Commonly associated with clusters of secondary craters (Cec). Discernible only where underlying unit is dark and provides an albedo contrast
Interpretation
Areas with a very high density of small craters cut or resulted at the map scale. Craters formed by ejecta, mainly from Aristillus and Autolycus

Cld — 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 Cuc. May be young impact craters with dark ejecta or volcanic craters surrounded by halo of pyroclastic debris

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 origin: ejecta from the crater; exact location of source not difficult to define
Interpretation
Base surge deposits and ballistic ejecta derived from Autolycus. Probably freshly comminuted basalts and breccias

Cuc — Secondary crater material
Characteristics
Craters generally elongate N-S and form clusters or linear arrays radial to Autolycus and Aristillus. Many large craters have plasmoe 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

Cc$_2$ — Crater material, undivided
Characteristics
Material of craters < 1 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 < 1 km diameter without rays; rim deposits have same albedo as surroundings. Slightly rounded, raised rim crests. Interiors bowl-shaped

Cc — 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

Ce$_2$ — 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 rimmed. Some blocks on rim. Interior walls steep and bright

Ce$_1$ — Crater material, undivided
Characteristics
Material of craters <1 km diameter without rays; rim deposits slightly brighter than surroundings. Rim crests.Interior walls steep and bright

Cec — Talus
Characteristics
Forms steep slopes with high albedo. Occurs only in the Hadley Rille and the depression at its southern end. Tapers out to the north as the rille shallows. Encloses the ledge near the top of the walls
Interpretation
Where rille crosses mare, talus composed largely of basaltic blocks and fragments. At southern end talus includes fragments of the breccias that constitute units plm and Iplh

Cec$_1$ — Aratus crater materials
Characteristics
Cec$_1$, 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
Cec$_2$, wall material. Steeply sloping, blocky. Abuts abruptly against Cec$_1$ and Cec$_3$ materials
Cef$_1$, 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

Cec$_2$ — Aratus crater materials
Characteristics
Cec$_2$, 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
Cec$_3$, wall material. Steeply sloping, blocky. Abuts abruptly against Cec$_1$ and Cef$_2$ materials
Cef$_2$, 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

Cef$_1$ Cew$_1$ Cef$_2$ — Aratus crater materials
Characteristics
Cef$_1$, 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
Cew$_1$, wall material. Steeply sloping, blocky. Abuts abruptly against Cef$_1$ and Cef$_2$ materials
Cef$_2$, 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

Elm — Mare basalts
Characteristics
Forms level cratered plains with low albedo. More heavily cratered in western part of map area where Autolycus and/or Aristillus secondaries common. Non-rim crested areas sparsely cratered and have very low albedo except in northwest corner of map where albedo slightly higher
Interpretation
Basaltic flows similar in composition to those at Apollo 11 and 12 landing sites. Crater frequency, crater shapes, and low albedo suggest an age at least as young as the Apollo 11 basalts (3.2 to 3.5 b.y.) for most of the mare, although some older basalts may occur in the northwest corner of the map

Ecr Eew — 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 further 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
Eew, wall material. Steeply sloping, few blocks, moderate to high albedo
Interpretation
Fragmental debris associated with primary impact craters

Ec — Crater material, undivided
Characteristics
Material of craters <5 km diameter without rays or with only a few rays. Rim crests rounded. Interior walls steep and bright

Ip — Pitted plains material
Characteristics
Most extensive occurrence is level cratered floor of Rima Fresnel I. Forms level cratered plains like unit Im but higher albedo. Resembles unit Iab *but fewer large subdued craters and more small (<100 m) craters. Moderate albedo*
Interpretation
Basaltic flows. Cause of albedo difference between units Ip *and* Im *not known*

Iab — Apennine Bench Formation
Characteristics
Forms level cratered plain in low-lying areas northwest of Apennine Mountains. Surface level with few positive features. Craters, many subdued, number about same as in Elm mare and albedo higher. Rounded shallow craters predominate. Fewer blocky fresh appearing craters than in Elm *mare*
Interpretation
Probably volcanic fines, similar to the mare basalts but older and possibly of different composition. Represents early stage in filling of Imbrium basin

Is — Slump material
Characteristics
Forms tongue cutting across frontal scarp of the Apennine Mountains and the foothills to the northwest. Surface has low arcuate ridges, convex down-slope and faint NW-SE-trending lineaments. Moderate albedo
Interpretation
Part of Apennine Mountains that slumped to the northwest shortly after their formation. Mixture of breccias similar to unit plm

Isp — Apennine material
Characteristics
Forms low but topographically complex areas between outcrops of plm in the Apennine Mountains. Surface characterized by low rounded hills up to 1 km across with smooth areas between. Lacks prominent fracture pattern that characterizes unit plm. *Albedo low to moderate*
Interpretation
Mostly Imbrium breccias similar to those at the Apollo 15 landing site but some pre-Imbrium breccias similar to unit plm *may be present on crests of hills too small to be mapped at this scale. Intervening smooth areas may include material redeposited in post-Imbrium time by mass wasting*

Iplh — Hilly material
Characteristics
Forms terrain with subdued relief (<300 m) and low albedo. Similar to unit Isp, *Asteroidal west lap but lacks distinctive separation into rounded hills and intervening low areas. Consists mostly of ion,indistinct irregular hills. In places NE-SW-trending lineaments, roughly concentric to the Apennines, are common. Albedo low to moderate*
Interpretation
Similar to unit plm *and* Isp. *Mixture of Imbrian and pre-Imbrian breccias*

plm — Massif materials of Imbrium Basin
Characteristics
Forms rugged fractured massifs mainly in the Apennine Mountains. Cut by NE-SW- and NW-SE-trending fractures 1 to 10 km apart. Areas between fractures steeply sloping and relatively free of features in the 0.1 to 1 km size range. Patterned ground over much of the surface. Low frequency of craters less than 1 km across compared with most other units. Moderate to high albedo. Overlap pattern indicates areas of very high albedo
Interpretation
Fine-grained breccias deposited during formation of surrounding pre-Imbrian basins (Nectaris, Vaporum, Asthusus)Originally may have been covered with layer of Imbrian ejecta but slumping and creep has removed it from all but the steepest slopes. Probably debris at base of step outcrops probably scarcers of Imbrian and pre-Imbrian breccias. Overlap pattern indicates bright areas with relatively high rate of surface creep

Ced — Dark mantling material
Characteristics
Distinguished by very low albedo. No observable topographic relief. Slightly subdues underlying terrain. Albedo at edge ceeds approaches that of underlying terrain. Not detectable on mare, similar to Sulpicius Gallus Formation (Carr, 1966)
Interpretation
Origin unknown, Possibly layer of pyroclastic material. Unit thin at ridge crests. Age uncertain because of difficulty of detecting unit in mare areas, but probably spans range Imbrian to Eratosthenian. May represent local surface alteration, and not be a distinct geologic unit

Ic — Crater materials, undivided
Characteristics
Material of shallow bowl- or pan-shaped craters <1 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

Ilc — Irregular crater material
Characteristics
Material of irregular craters that occur at intersection of structural features. 4 km diameter crest at 25°.3°S., 2°.2E. appears related to dark mantling material. Crater at 27°.2°N., 3°E. forms chain cutting Rima Fresnel II
Interpretation
Volcanic craters

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

Inferred fault
Dashed where location very uncertain, dotted where buried. Ball and ball on downthrown side. Where gouge or unit disposition 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 plm *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 ridges
Line marks crest. Antistine produced by igneous intrusion

Low scarp
Probably a fault scarp. Barbs point downslope

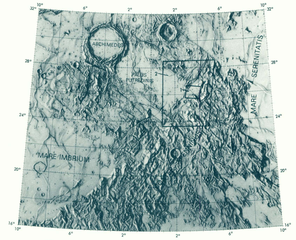
Rima Hadley
Outer line shows edge of depression. Dashed where approximately located, dotted where buried. Inner line shows extent of the rille. Irregularities in rounding rocks may be exposed as ledges at the top of the rille walls above the talus

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.



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

This map shows the regional geologic setting of the landing site for the Apollo 15 mission. The area lies approximately 620 km east of the center of the Imbrian basin, a large basalt-filled multi-ringed structure in the northwest quadrant of the Moon's near side. Several arcuate structures surround the Imbrian basin (Hartmann and Kuiper, 1962). The most prominent of these forms the northwest-facing scarp of the Apennine Mountains that crosses the area from NNE to SSW. This scarp is a major structural boundary separating mostly basin-fill deposits to the northwest from either basin-synchronous or pre-basin deposits to the southeast. Of special interest is Rima Hadley, one of the widest and freshest appearing sinuous rilles on the Moon. It cuts through the mare surface to a maximum depth of about 400 meters and may expose in its walls a substantial section of post-basin basalt. Rimae Fresnel and Rima Bradley are typical linear rilles older than Rima Hadley and do not cut mare materials. This area was previously mapped geologically at the 1:1,000,000-scale by Hackman (1966) from telescopic data.

The earliest recognizable geologic events in the area are the formation of the Imbrian basin and its associated radial and concentric structures and the essentially simultaneous deposition of material excavated from the basin, presumably by impact (Wilhelms and El-Baz, 1971). The Imbrian basin is the youngest of the major geologic basins. A succession of breccias were probably deposited in the area during basin excavation as a result of the formation of the Serenitatis and Vaporum basins and secondary ejecta basin south of the Carpathian Mountains. Formation of each successive basin resulted in reworking of ejecta deposits from previously formed basins such that the local pre-Imbrian rocks are likely to be a complex of impact produced breccias within breccias. The Imbrian basin, the last of these great cratering events in this part of the Moon, was formed before the basalts at the Apollo 11 and 12 landing sites were deposited about 3.6 to 3 billion years ago. The basin is presumed to have been formed by the hypervelocity impact of a large asteroidal-size body. The impact generated an outward moving shock wave which uplifted the pre-existing terrain surrounding the impact point. Subsequently, large parts of this terrain collapsed along basinward-dipping arcuate normal faults to produce the present multiringed structure. The scarp of the Apennine Mountains forms part of the most prominent ring. Although the scarp is part of a nearly circular structure around much of the basin, in detail the arc consists of segmented, generally rectilinear massifs, such as Mount Hadley. Just to the northwest of the Apennine arc and roughly parallel to it, are a series of fault-like that also probably formed by post-basin faulting (Howard, 1971). One of these, the Apennine Front, is the most prominent feature in the area, chiefly terrain extended approximately 350 km northwest to at least the present inner ring of Mare Imbrium (Baldwin, 1963). In addition to the faulting and gravitational collapse along concentric arcs, faulting took place along directions radial to the basin, especially outside the main arc.

While the terrain around the impact point was being uplifted and faulted, material excavated from the basin was being deposited. The mechanism whereby the excavated material was transported and deposited is not clearly understood, nor is the sequence with respect to uplift and faulting. Comparisons with the Orientale basin (McCauley, 1967) and with large volcanic craters (Moore, 1967) and experimental explosion craters (Young, 1963) suggest that much of the deposits surrounding the basin may have been transported as an outward moving, turbulent, near-surface cloud of debris often termed a base surge. As the base surge decelerated, debris was deposited in longitudinal and transverse ridges. Ballistic ejecta was probably laid down more or less contemporaneously. The thickness of these deposits can be roughly estimated from the size of partially filled secondary craters in the Apennine Mountains. Several such craters inside the map area in the Apennine Mountains indicate that the Imbrian ejecta may have been approximately 1 km thick near the crest of the Apennines. Although there is no conclusive evidence, deposition probably took place before the cessation of normal faulting that created the Apennine scarp and similar structures, for the Imbrian ejecta itself appears to be cut by faults that parallel the scarp.

Some slumping probably occurred immediately after the major period of faulting. Slumping is particularly likely in the unconsolidated Imbrian materials inferred to have been deposited or in the pre-Imbrian materials brecciated by impact. Much of the Imbrian ejecta may have been shed from high areas at this time, and slow denudation by surface creep has almost certainly continued until the present. Imbrian materials are therefore thought to be thin or absent on the massif structures along the Apennine front although they may be present in the talus on the slopes. Similarly, Imbrian materials may be thin or absent on local highs between the massifs in the Apennine Mountains. At the map scale, however, no distinct separation can be made between small hills where pre-Imbrian massif material (plm) may be exposed and surrounding smooth areas consisting mostly of Imbrian basin ejecta. For this reason, the materials between the massifs are mapped as undivided hilly material (Iplh) with the understanding that pre-Imbrian material may be present locally. Similarly, massif material (Iplh) northwest of the Apennine Mountains is given a more extended age rating than the adjacent Imbrian plains material. Some time after the formation of the Apennine scarp and before mare filling was complete, a part of the scarp in the southwest corner of the map collapsed and buried some of the nearby fault(s) (Is).

The formation of the basin was followed by a period of partial filling as represented by the Apennine Bench Formation (Iab). The unit forms level plains like the mare basalts but has a higher albedo and is much more highly cratered. This material occurs only to the northwest of the Apennine scarp. It has been interpreted as similar in origin to the mare basalts but older (Hackman, 1966).

Prior to formation of the present mare surface, cratering and faulting disrupted the Apennine Bench Formation and older units. The large crater Archimedes, 200 km northwest of the map area, formed by impact during this time, and numerous Archimedes secondary craters occur in the Apennine Bench Formation but are absent on mare material around this crater. The graben-like linear rilles Rimae Fresnel and Rima Bradley also formed at this time. They occur in the Apennine Bench Formation and older units and are cut by the younger Rima Hadley. The orientation of these features is generally parallel to lines radial to the Imbrian basin, in particular the fault that forms the northwest boundary of Palus Putredinis. This faulting largely determined which parts of the low-lying level terrain in front of the Apennine scarp later remained uncovered by mare basalts. The pitted plains material (Ip) represents a final episode in basin filling before the mare formed.

Deposition of the mare basalts took place toward the end of the Imbrian Period and probably continued into the Eratosthenian. To what extent volcanic filling occurred throughout the Imbrian is not known, but it may have occurred over a wide time span, as suggested by the succession of Apennine Bench, pitted plains and mare materials, all of which post-date the basin but vary in albedo, surface texture and associated structures. Some typical Imbrian mare appears to be present in the northwest part of the map, but low crater frequencies, lack of large subdued craters, and a very low albedo suggest a younger age for most of the mare.

Rima Hadley formed contemporaneously with or later than the mare basalts that it cuts. Several theories have been proposed for the origin of sinuous rilles, but none are very satisfactory. Cameron (1964) suggested that they were eroded by nuées ardentes, clouds of volcanic gases with entrained debris. Several workers have proposed water as the erosive medium, the water being derived either from a primitive hydrosphere (Firsoff, 1963) or by melting of subsurface ice by volcanism or impact (Lingenfelter, R. E., Peale, S. J., and Schubert, G., 1968). Hackman suggested that sinuous rilles formed by venting of closely spaced craters followed by flooding of near-surface materials. Surface lava channels or collapsed lava tubes are other possible explanations. The lack of definitive evidence at Rima Hadley appears to favor a collapsed lava tube of enormous proportions by terrestrial standards. The rille originates at the Apennine scarp in a deep elongate crater. The Apennino-Carpathian arc is a major structure on the Moon and a very likely path along which volcanic material could reach the surface. The coincidence of the head crater with the structure is consistent with the hypothesis that the crater was the source for surrounding mare basalts and that the rille is a lava channel or collapsed lava tube leading away from the crater. According to the lava-tube hypothesis, the constriction of the channel at 3°.9°E., 26°.26°N. indicates a place where the tube did not collapse and the shallow northern part of the rille reflects the decreasing dimensions of the lava tube as the distance from the source crater increases. Alternatively, complete collapse of the lava tube may not have occurred in the north or the channel may have been partially filled by the last of the mare basalts. The rille appears to consist in part of linear segments that parallel structures in the surrounding upland terrain, suggesting control of the lava channeling by subjacent topography.

The surface at several places within the map area is darker than normal for the units exposed there. The darkening has no obvious relation to the local terrain and cuts across all geologic units. Elsewhere (Carr, 1965) this phenomenon has been interpreted as indicating the presence of a thin cover of pyroclastic materials. The lack of volatiles in lunar rocks makes this interpretation questionable, but no alternative explanation has been devised.

Like other areas of the Moon, much of the area around the landing site is covered with craters whose sizes extend downward to the limit of photographic resolution. The craters form a continuum from sharp and fresh appearing to rounded and barely discernible depressions. Craters have been relatively dated and assigned relative age classifications according to their morphology and size on the assumptions that: (1) most craters originate by impact and have similar morphologies when first formed and (2) craters are progressively degraded with time, the smaller craters at a more rapid rate than the larger. The scheme followed (fig. 1) is essentially that devised by Trask (1966). It applies only to craters on a level surface. Rates of degradation seem to be much greater on sloping surfaces; much of the surface of unit plm, for example, is relatively free of small craters. Craters larger than 4 km are dated by criteria described by Pohn and Offield (1970). In addition to the primary craters, the area is liberally covered with secondary impact craters formed by ejecta from Aristillus and Autolycus. Separation of Aristillus and Autolycus secondaries in this area is not practical, but by analogy with other terrain to the northwest of the site, most of the craters here appear to be secondary to Aristillus.

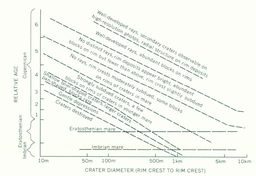


FIGURE 1.—*Graphs showing assumed relations among diameters, properties, and ages of craters. Categories are interpretational. Horizontal lines are isochrons indicating variations in crater populations on surfaces of increasing age.*

COPERNICAN SYSTEM
ERATOSTHENIAN SYSTEM
IMBRIAN SYSTEM
PRE-IMBRIAN

REFERENCES

Baldwin, R. B., 1963, The measure of the Moon: Chicago, Univ. Chicago Press, 488 p.
Cameron, W. S., 1964, An interpretation of Schröters Valley and other lunar rilles: Jour. Geophys. Research, v. 69, p. 2423-2430.
Carr, M. H., 1966, Geologic map of the Mare Serenitatis region of the Moon: U.S. Geol. Survey Misc. Geol. Inv. Map I-483.
Eggleton, R. E., 1963, Thickness of the Apennian Series in the Lansberg region of the Moon, in Astrogeologic studies annual progress report, August 25, 1961 to August 24, 1962, pt. A: U.S. Geol. Survey open-file report, 79-91.
Firsoff, V. A., 1963, Surface of the Moon: London, Hutchinson, 128 p.
Greeley, Ronald, 1971, Lunar Hadley rille: Considerations of its origin: Science [in press].
Hackman, R. J., 1966, The geology of the Montes Apenninus region of the Moon: U.S. Geol. Survey Misc. Inv. Map I-445.
Hartmann, W. K., and Kuiper, G. P., 1962, Concentric structures surrounding lunar basins: Arizona Univ. Lunar and Planetary Lab. Commun., v. 1, no. 12, p. 51-66.
Lingenfelter, R. E., Peale, S. J., and Schubert, G., 1968, Lunar rivers: Science, v. 171, p. 266-268.
McCauley, J. F., 1967, The nature of the lunar surface as determined by systematic geologic mapping, in Runcorn, S. K., ed., Mantles of the Earth and terrestrial planets: New York, Interscience Publishers, p. 431-460, GA 262-676.
Moore, J. G., 1967, Base surge in recent volcanic eruptions: Bull. Volcanologique, v. 30, p. 337-363.
Pohn, H. A., and Offield, T. W., 1970, Lunar crater morphology and relative age determination of lunar geologic units—pt. 1Classification: U.S. Geol. Survey Prof. Paper 700-C, p. C153-C162.
Schumm, S. A., and Simons, D. B., 1969, Lunar rivers or coalesced chain craters: Science, v. 165, no. 3899, p. 201-202.
Trask, N. J., 1970, Geologic maps of early Apollo landing sites of sct C: U.S. Geological Survey, Open file report, 27 p.
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 [in press].
Young, G. A., 1963, The physics of base surge: Silver Spring, Md., U.S. Naval Ordnance Lab.,294 p.

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