Reports

Geologic Setting of the Apollo 15 Samples

Abstract. *The samples and photographs returned from the Apollo 15 site show that Hadley Delta is largely underlain by breccias whose clasts are mainly fragments of coarse-grained feldspathic rocks and nonmare-type basalt. Conspicuous sets of lineaments, visible in surface and orbital photographs of Mount Hadley and Hadley Delta, may represent systematic layering or fracture sets. The mare surface, with regolith about 5 meters thick, is underlain by two major basalt types, at least one of which has extensive lateral continuity and is exposed in the upper wall of Hadley Rille. Gradual erosional recession of the edges and filing of the interior of the rille by talus have contributed to the present cross sectional profile.*

The Apollo 15 lunar module (LM) landed at latitude 26°26′00″N and longitude 03°39′20″E on the mare surface of Palus Putredinis on the eastern edge of the Imbrium basin. The site is between the Apennine Mountain front and Hadley Rille. The three major geologic objectives of the mission, in order of decreasing priority, were description and sampling of (i) the Apennine front, (ii) Hadley Rille, and (iii) the mare.

Both the Apollo 15 and Apollo 14 missions investigated features related to the huge multiringed Imbrium basin. Much of the regional geology as described here was derived from premission photogeologic mapping from Lunar Orbiter photographs of the Imbrium basin and related features (*1*, *2*). The landing site of Apollo 15 is on a dark mare plain (part of Palus Putredinis, or the Marsh of Decay) near the sinuous Hadley Rille and the frontal scarp of the Apennine Mountains. This scarp is the main boundary of the Imbrium basin, which is centered approximately 650 km to the northwest (Fig. 1). The largest mountains of the Apennines are a chain of discontinuous rectilinear massifs 2 to 5 km high that are interpreted as fault blocks uplifted and segmented at the time of the Imbrium impact. Between the massifs and beyond them outside the basin are hilly areas that merge southeastward with a terrain interpreted as a blanket of ejecta from the Imbrium basin. The ejecta blanket, known as the Fra Mauro formation, was sampled by the Apollo 14 astronauts. The hills appear to be jostled blocks mantled and subdued by the Imbrium ejecta. The large massifs, however, are not similarly subdued and so may be composed mainly of pre-Imbrium rock, perhaps thinly veneered by Imbrium ejecta. The area is near the old Serenitatis basin, which suggests that at least part of the pre-Imbrium material in the massifs is ejecta from Serenitatis.

The mare material of Palus Putredinis fills the lowlands at the base of the Apennines and creates a dark plain. The regional relations to the west show that several events occurred between the formation of the Imbrium basin and the emplacement of the mare material. These included deposition of the premare plains-forming material and the cratering event that formed the crater Archimedes (*1*). The morphologies of the craters on the mare surface at the landing site indicate that the age of the surface is late Imbrian or early Eratosthenian.

Some of the hills and mountains in the area are dark like the mare and may be coated by a thin mantle of dark material. The region contains numerous diffuse light-colored rays and satellitic clusters of secondary impact craters from the large Copernican craters Autolycus and Aristillus to the north (Fig. 1).

Hadley Rille (Fig. 2) follows a sinuous course through the mare, and locally it abuts premare massifs. It is one of the freshest sinuous rilles, and rock outcrops are common along the upper walls. The rille is over 100 km long, 1500 m wide, and 400 m deep.

The regional relations indicate that the mare rocks may rest on faulted pre-Imbrium rocks, breccia from the Imbrium impact, and light plains-forming units such as the Apennine Bench formation (*2*). Whether the rille penetrates the premare material is unknown.

The LM landed near the crest of a very gentle ridge that trends northwest between the South Cluster and the North Complex (Figs. 2 and 3). The ridge is slightly brighter than the surrounding areas, which suggests that it may represent a broad diffuse ray from one of the large craters, Aristillus or Autolycus. Another gentle ridge in the mare near Elbow crater is apparently truncated by Hadley Rille.

The mare surface is covered with regolith approximately 5 m thick. The surface contains numerous subdued craters 100 to 400 m in diameter, and many smaller ones, some of which are fresh. A prominent concentration of the larger craters, known as the South Cluster, is one of many clusters in Palus Putredinis that form a pattern pointing to a source in Aristillus or Autolycus. A less distinctive cluster of more subdued craters lies immediately northwest of the landing site.

Two major Apennine massifs, Mount Hadley to the northeast and Hadley Delta just south of the landing site (Fig. 2), tower over the Hadley plain to heights of 4.5 and 3.5 km, respectively. The face of Mount Hadley is steep and high in albedo. The northern face of Hadley Delta, called the "front" during the Apollo 15 mission, rises abruptly above the younger mare surface, except near Elbow Crater where the contact is gradational, apparently because of the accumulation of debris from the slopes. As elsewhere on the moon, the steep slopes of the massifs are sparsely cratered because the craters are destroyed by the downslope movement of debris. A prominent exception is St. George, a subdued crater 2.5 km in diameter, that predates the mare (Fig. 3).

The Apollo 15 crew visited Hadley Rille at a place where the rille changes from a predominantly northeastward to a predominantly northwestward course (Fig. 2). Southwest of the landing site, the rille winds northeastward from its head, which is an elongated cleftlike depression, across the floor of a mare-filled graben valley. To the northwest a series of shallow septa interrupt the rille and divide it into a chain of coalescing elongate bowls indicative of collapse (*2, 3*). Beyond these the rille widens again and reaches the main part of Palus Putredinis through a mare-filled gap in the mountains.

Optical properties of surface materials. The abundant Apollo 15 photographs provide documentation and a detailed local geologic context for the returned samples. In addition, the combination of panoramic and surface photographs have been used in a study of the optical properties of a large area of the Hadley-Apennine site. The sources of the photometric data were a black and white, master positive film from the panoramic camera in the Command Module and a 70-mm film taken with the wide-angle Hasselblad cameras on the surface. The surface photographs were controlled with a photometric chart that was deployed on the lunar surface and with film sensitometry data. The panoramic photograph was scanned with a microdensitometer. After computer processing, the actual albedo values derived from the 70-mm surface photographs were used to convert the scanning data from the panoramic photograph to albedo values. After corrections were made for slope and scanning noise, an albedo map was prepared (Fig. 4).

The map shows an albedo range of 9 to 19 percent for the mare area and 15 to 23 percent for the Apennine front. Between the front and the mare the zone of intermediate albedo contains mixed debris from both areas. The rille wall is brighter than typical mare material because it is largely covered by blocky rock talus. The mare surface is darker toward the east. This may indicate areal variations in the underlying volcanic rocks of the mare or the presence of ray material in the western areas.

Apennine front. The slopes of Mount Hadley and Hadley Delta rise steeply above the local mare surface. The scarcity of blocks on both massifs indicates a thick regolith. The lower slopes of Hadley Delta were visited at stations 2, 6, 6a, and 7 (Fig. 3), and rock samples collected there indicate that the bedrock beneath the regolith consists of breccias.

Well-developed systems of lineaments suggestive of fractures or compositional layers or both, were observed and photographed on Mount Hadley and Hadley Delta by the astronauts. Surface photographs taken with the wide-angle (see cover photograph) and telephoto Hasselblad cameras show the lineaments clearly and orbital photographs taken with the high-resolution panoramic camera generally show the same lineament sets.

Previous orbital and surface photographs of the lunar surface have shown that all the lineaments tend to be arrayed in preferred directions—predominantly northwest, north, and northeast. This "lunar grid" has usually been seen only under the restricted conditions of low sun and lighting from either the east or the west. Hence, some of the lineaments may be artifacts produced by the low-angle illumination of randomly irregular surfaces. Experiments with small-scale models show that oblique illumination of such surfaces produces systematic sets of lineaments that resemble some of those recorded at the Hadley site (*4*). The lineaments in the models form conjugate sets bisected at acute angles by the illumination line.

Because the Apennine front lineaments have great interpretive significance if they are the surface traces of compositional layers or of regional fracture sets, an attempt has been made to learn whether some of them may be lighting artifacts. Statistical analyses of the trends were made by measuring the orientations of approximately 1500 lineaments in six separate areas on orbital panoramic photographs taken at different sun angles.

Two prominent sets of lineaments, trending north and northeast, characterize most of the mountain slopes. These directions are approximately

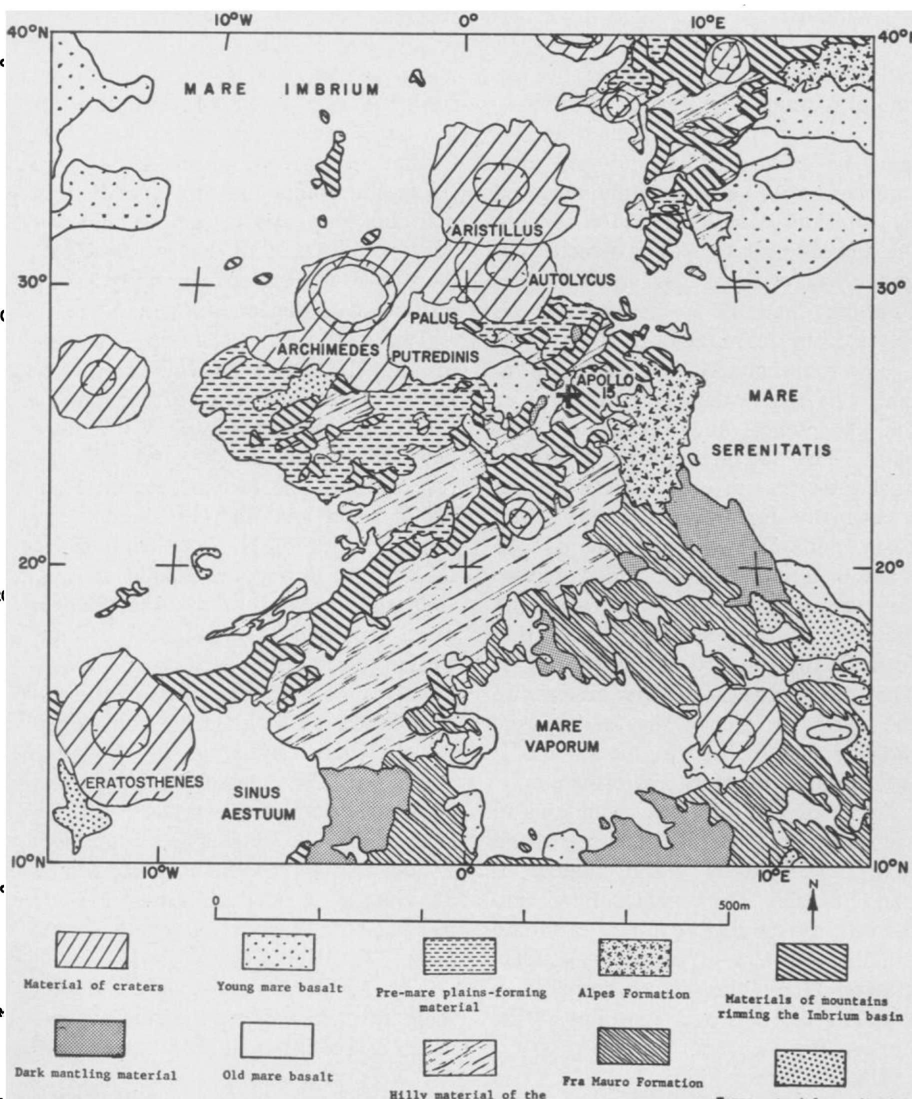

Fig. 1. Regional geologic map of the Apennine Mountains area. [Modified from Wilhelms and McCauley (*6*)]

symmetrical about the sun azimuth. The data so far are insufficient to distinguish whether the lineaments are lighting artifacts or steeply dipping geologic structures expressed in the regolith. At Silver Spur (Fig. 2), however, prominent linear ribs trend northeast and northwest (instead of north) and may be directly related to geologic structures.

Hadley Rille. In Hadley Rille (Fig. 2), the strata exposed in cross section offer a new perspective in lunar geology. The rille was described and photographed by the astronaut crew from four locations (stations 1, 2, 9a, and 10; Fig. 3). In addition, it was photographed from the Apollo 15 Command Module, which flew over many times.

Subtle raised rims are locally present along the rille. Such a rim can be seen on the topographic map (Fig. 3) between Elbow Crater and station 9a, and a less prominent rim is present on the southwestern side of the rille.

Southwest of the rille the mare surface is 30 to 40 m lower than on the northeastern side (Fig. 3). Both the higher mare surface and the higher rim occur on the outside of a bend in the rille. Just west of St. George Crater, an outlier of mare isolated on the eastern side of the rille, inside a bend, is at least as low as mare on the other side. This suggests that the differences in mare elevations across the rille may be systematically related to the bends in the rille, as if they might be related to the momentum of a fluid flowing in the rille. In addition, for each curve of the rille the radius of the outside wall is greater than that of the inside wall. This geometry cannot result from simple fracturing because the two sides do not fit together.

The materials in the rille include the regolith on the mare surface, bedrock exposures in the upper walls, and talus deposits that vary in grain size from fine soil to blocks greater than 10 m across. The inward slopes of the walls average between 25 and 30 degrees. Near the edge of the rille west of the landing point, the regolith surface slopes gradually down to a sharp lip about 5 m below the level of the local mare surface. Discontinuous outcrops form a scarp that extends 35 to 60 m downward from the lip (Fig. 5). Still lower, blocky talus extends about 300 m to the bottom of the rille. However, where the rille cuts against the Apennine front near St. George Crater, fine-grained debris similar to that on the rest of the surface of the massif is exposed. Apparently mare rock, which forms the rock ledges and the blocks derived from them, is locally absent at the rille edge along the massif.

The uppermost rock unit exposed along most of the rille appears to be mare basalt. Mare rocks in the traverse area consist of vuggy to vesicular porphyritic basalts, which were sampled at the top of the outcrop in the rille at station 9a and also at the rims of Elbow and Dune craters. Because these craters have excavated to depths of 50 to 100 m, this basalt may extend down that far. Most or all of the fragments in the regolith above the lip of the rille at station 9a are mare basalt; outcrops of basalt, such as that sampled at station 9a, are the obvious source of most of the talus blocks in the rille walls.

In one area of well-exposed rocks on the far (southwestern) rille wall, the lowest unit exposed (30 m below the mare surface) is prominently layered and has an albedo of 17 percent (Fig. 5, unit *A*). About 12 layers occur within its exposed thickness of approximately 8 m, and several of the more massive of these layers, 1 to 3 m thick, contain internal layering or parallel banding that is less well defined. Within this unit fractures are predominantly vertical or near-vertical, cut distinctly across the massive layers, and commonly continue from one massive layer across an adjacent thinner layer into the next massive layer.

Above the prominently layered outcrop is a covered interval 8 m thick (Fig. 5, unit *B*). It may be soft fragmental material, but it is probably not an old regolith because the exposed top of the underlying outcrop is relatively even.

Above the covered interval are prominent massive outcrops, 15 to 20

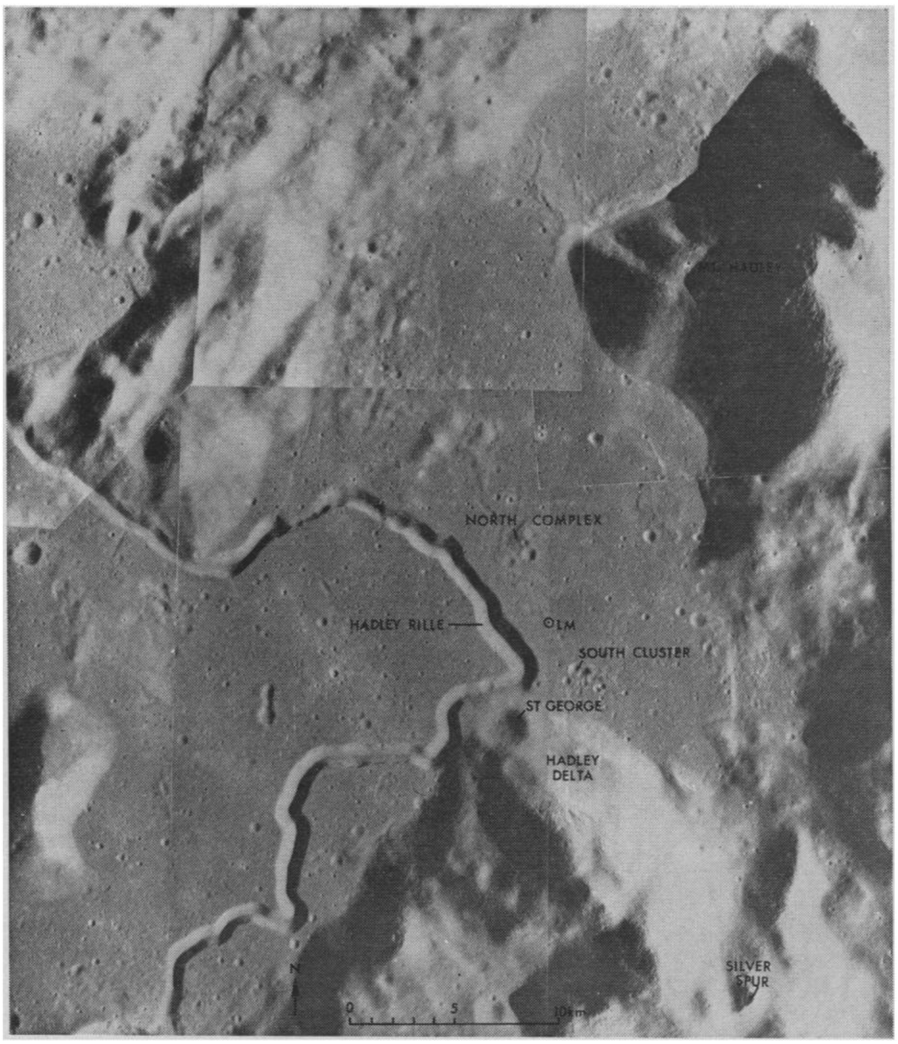

Fig. 2. Landmarks around the Apollo 15 landing site (uncontrolled mosaic from Apollo 15 panoramic camera photographs).

EXPLANATION

COPERNICAN SYSTEM

Cc6 | Cc5 | Cc4 | Cc3 | Cc2 | Cc1

CRATER MATERIAL
Debris of circular impact craters, classified in an age sequence according to freshness.
Cc6 craters very sharp, very blocky, bright halo;
Cc5 craters sharp, blocky; have bright halos;
Cc4 craters sharp and somewhat blocky;
Cc3 craters slightly subdued;
Cc2 craters moderately subdued;
Cc1 craters subdued, lack large blocks.
Rocks are derived from formations penetrated by crater

Csc

MATERIAL OF SECONDARY CRATERS
Fragmental debris produced from mare basalt by impact of secondary projectiles from Autolycus or Aristillus. Craters in south cluster are subdued and bowl-shaped; ejecta is blocky.

RAY

Very diffuse slightly bright area radial to Aristillus and Autolycus; boundaries gradational. May include a thin deposit of dominantly light-colored clasts, and possibly dark glass fragments

CEt

TALUS DEPOSITS
Blocky debris with some fines. Blocks as large as 20 m. Derived from ledgy outcrops of mare basalt. Basalt blocks tend to be more tan than fresh cliff exposures

CEd

DEBRIS OF MASSIF MATERIAL
Mainly fines; blocks rare. Fills floor of rille, rounding the bottom

ERATOSTHENIAN SYSTEM

Ec

CRATER MATERIAL
Mainly fine fragmental debris in and around shallow very subdued impact craters

EIm

MARE BASALT
Vesicular and vuggy basalt; locally has pahoehoe-like surfaces. Thickness unknown but locally exposed as thick as 60 m in Hadley Rille. Outcrops locally layered: some massive outcrops 20 m thick. Moderately to sparsely jointed. Albedo of outcrops 15-20 percent; variable. Mare surface covered by several meters of regolith except near bedrock exposures at lip of Hadley Rille

IMBRIAN SYSTEM

Ic

MATERIAL OF ST. GEORGE CRATER
Fragmental debris generally broken down to fines but locally including blocks. Produced from massif material by the impact that excavated St. George crater

PRE-IMBRIAN OR IMBRIAN SYSTEM

IpIm

MASSIF MATERIAL
Breccia and microbreccia that have dark and light clasts. Either pre-Imbrian impact breccias or impact breccia from the Imbrium impact, or both, mixed by down-slope mass wasting. Thick regolith with few blocks

Contact, dashed where position uncertain

Slump fault, ball on downthrown side. Dashed where uncertain

Slope gradient

Gentle scarp, barb points downhill

Lineament

Traverse, solid where LRV tracks visible on panoramic camera photographs, dashed where inferred

$\circ^{5}$
Station location

m thick, of light-toned rock (albedo 21 percent) (Fig. 5, unit *C*). These outcrops locally contain discontinuous thin internal layers or partings about 35 cm thick. A conspicuous series of closely spaced (0.5- to 2-m) joints dips 45 degrees or more to the northwest. The joints diminish in abundance in the upper 4 to 6 m of the outcrops, where nearly vertical joints dominate. In another exposure, the interval of massive outcrops (unit *C*) includes two subunits and is at least 50 m thick. This massive unit provides most of the outcrops as well as a high proportion of the talus blocks in the rille.

An upper unit is tentatively identified from small intermittent exposures (Fig. 5, unit *D*). Only 2 to 3 m are exposed below the regolith. The outcrop surfaces are characteristically dark and hackly, and layering is irregular.

The attitude of all the layering visible in the rille walls is horizontal or nearly so. Slabs south of station 9a, however, slope gently away from the rille, which suggests that the strata dip outward a few degrees. This outward dip may be related to the raised rim of the rille.

The top of the rille wall above the outcrops presents a cross section of the lunar regolith. The vertical distance between the outcrops and the nearby mare surface indicates that the regolith

Fig. 3. Geologic map of the Apollo 15 landing site; traverse routes and sampling and photographic stations are shown.

is normally about 5 m thick and has an irregular base. The topographic surface slopes gently downward from the crest of the rim to the sharp lip of the rille, and the regolith thins and becomes coarser. Within about 25 m of the sharp lip, regolith is essentially absent, and numerous boulders and bedrock protuberances 1 to 3 m across are exposed. Presumably, impacts near the rille distribute ejecta in all directions; the narrow zone of thin regolith along the rille, however, receives material only from the east because impacts that occur to the west within the rille do not eject material up to the rim. There is a net loss of material to the rille, and, as the rille edge recedes by erosion, the zone of thin regolith also recedes.

The maximum size of the talus blocks is an estimate of the minimum thickness of the source layers along the rille wall. Several of these blocks in the bottom of the rille are more than 10 m across. Unbroken blocks of basalt this large are uncommon on the earth. Apparently the lunar basalt flows are thick and remarkably unjointed compared to many terrestrial counterparts.

The thickness of the talus deposits is not known, nor is the distance through which the lip of the rille has receded.

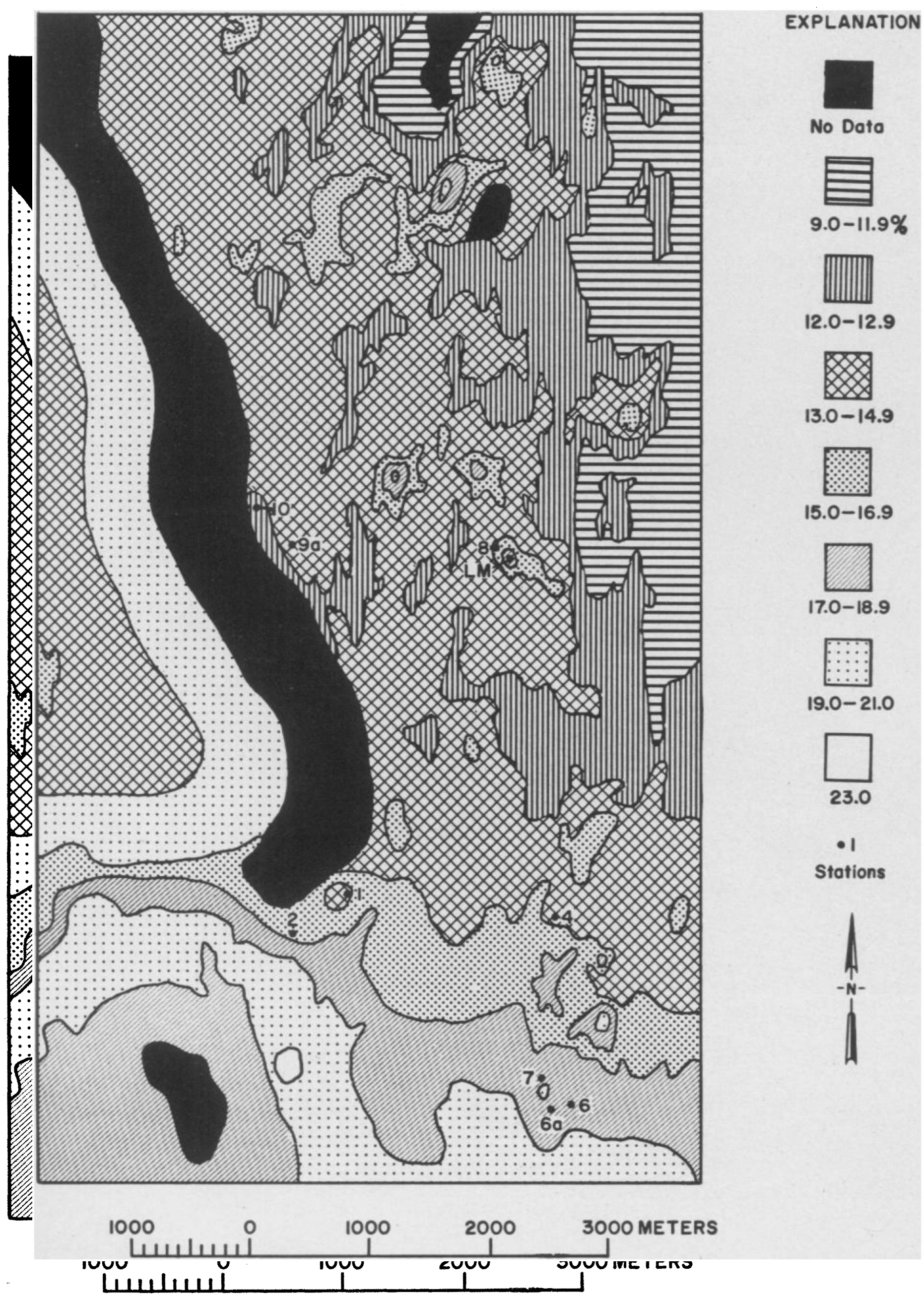

Fig. 4. Albedo map of the Apollo 15 landing site. The stations shown are those from which photographs taken on the lunar surface were used to derive actual albedo values.

The present cross-sectional profile apparently has resulted in part from the recession of the upper walls by mass wasting and the filling of the lower part by the development of talus slopes that impinge on each other from opposite rille walls.

Mare surface. The surface of the mare in the area visited by the Apollo 15 crew is generally a plain that slopes slightly to the northwest. To the astronauts it appeared as a hummocky or rolling surface with subtle ridges and gentle valleys. The surface texture appeared smooth with scattered rocks occupying less than 5 percent of the total area. Widely separated, locally rough areas occur where recent impacts have left sharp crater rims and small boulder fields. The visible ridges and valleys are largely the forms of greatly subdued, large craters, and the smoothness is caused by the destruction of blocks by erosion from small impacts. The large but indistinct ray shown on pre-mission maps (*1, 2*) as crossing the mare surface was not visible to the astronauts as either a topographic or a compositional feature, but they did note patches of lighter-colored material that may represent remnants of rays that have been largely mixed with the mare regolith.

Panoramic camera photographs of the site taken from orbit after the LM descent show that the area disturbed during descent has a high albedo. Presumably, darker surface material was removed, and more compacted underlying material with a lighter color was exposed. The high-albedo area extends in the southeastern quadrant to about 160 m from the LM. A ray extends about 125 m to the north and other rays extend about 100 m to the northwest and southwest.

The LM landed near the center of a low, linear, northwest-trending ridge several meters high and 600 m wide. This low ridge, which was identified on the pre-mission geologic maps (*5*), extends from the North Complex area to Crescent Crater of the South Cluster but may be unrelated to either in origin.

The contact between the mare and the front of Hadley Delta is marked by a change of slope and a band of soft material with fewer large craters than are typical of the mare. The soft material of the band is probably a thickened regolith that includes debris derived from the slope by both cratering processes and downslope creep.

This material may be slowly extending out over the mare.

Approximately 78 kg of Apollo 15 rock and soil samples were returned. The precise locations, many accurate to within a meter or less relative to features identifiable in the panoramic camera photographs (Fig. 6), of all but two large samples are known.

Relative ages of surfaces. The data obtained during the mission permit an evaluation of the relative ages of local surfaces that were photographed and sampled. The sequence was established by (i) crater morphology; (ii) the size, shape, and abundance of the rock fragments; and (iii) their relation to distinct local and regional geologic and morphologic units. Surfaces on the nearly horizontal mare tend to be modified at different rates than those on the Apennine front because of downslope movement of debris on the front. Similarly, the mare surface near the rille (for example, at station 9a, Fig. 3) cannot be directly compared with surface areas that are beyond the influence of the nearby rille edge.

The sequence in Table 1 is tentative. Relative assignments are probably correct to within one position. At each site, only surfaces free from small fresh craters are considered because recent impact features create relations that require special consideration.

At stations 2, 6, and 9, several fresh small crater rims and ejecta blankets were sampled and documented, which enables us to compare older and younger surfaces on similar materials. Generally, the mean exposure ages of the materials on and underlying the surface are expected to increase with increasing surface age. However, local or special circumstances related to such processes as mass wasting on the slopes and thinning of the regolith at the rille edge may modify this relationship.

Table 1. Relative ages of surfaces photographed and sampled during the Apollo 15 mission. The acronym ALSEP stands for Apollo Lunar Surface Experiments Package.

	Mare	Front
Youngest	Station 9	
	Station 9a (Rille margin)	
		Station 7 (Spur)
	Station 4 (Dune)	
	Station 1 (Elbow)	
	LM site	
	ALSEP-station 8	
	Station 3	
		Station 6
Oldest		Station 2 (St. George)

Mare basalts. Two main basalt types, each with textural variants, are recognized in the mare basalts: (i) type A basalts rich in yellow-green to brown pyroxene, commonly in long prisms, and (ii) type B, olivine-phyric basalt. Type A basalt, with a groundmass ranging from glassy to coarsely crystalline, is the dominant variety and occurs at each of the three main mare sites (stations 1, 4, and 9a). Type B basalt, with a small range in groundmass grain size, occurs mainly at station 9a.

The mare material from three widely spaced areas provided data on lateral variations among the mare basalts. Vertical variations to depths as great as 90 m were examined with samples from two crater sites (stations 1 and 4). The prevalence of type A basalt at the three main collecting sites suggests that it has significant lateral continuity. The samples collected from two large craters on the mare are also of this type. Samples from the rim of Dune Crater, possibly from as deep as 90 m, are porphyritic basalts with an aphanitic groundmass, in contrast to the medium- or coarse-grained rocks from the flank of Dune Crater and from Elbow Crater. The textural difference is sufficiently great to suggest that more than one flow unit of pyroxene-rich basalt was sampled. The variations in granularity of the pyroxene-rich basalts from the radial samples at Elbow Crater may represent either intraflow variations or multiple flow units. Type B basalt was collected from a slightly higher elevation than the pyroxene-rich basalts from the outcrop at the edge of Hadley Rille. Type B basalt is abundant in the rake sample at station 9a but was not found at Elbow or Dune craters. It may represent a local olivine basalt flow stratigraphically above the pyroxene-rich basalt in the vicinity of station 9a.

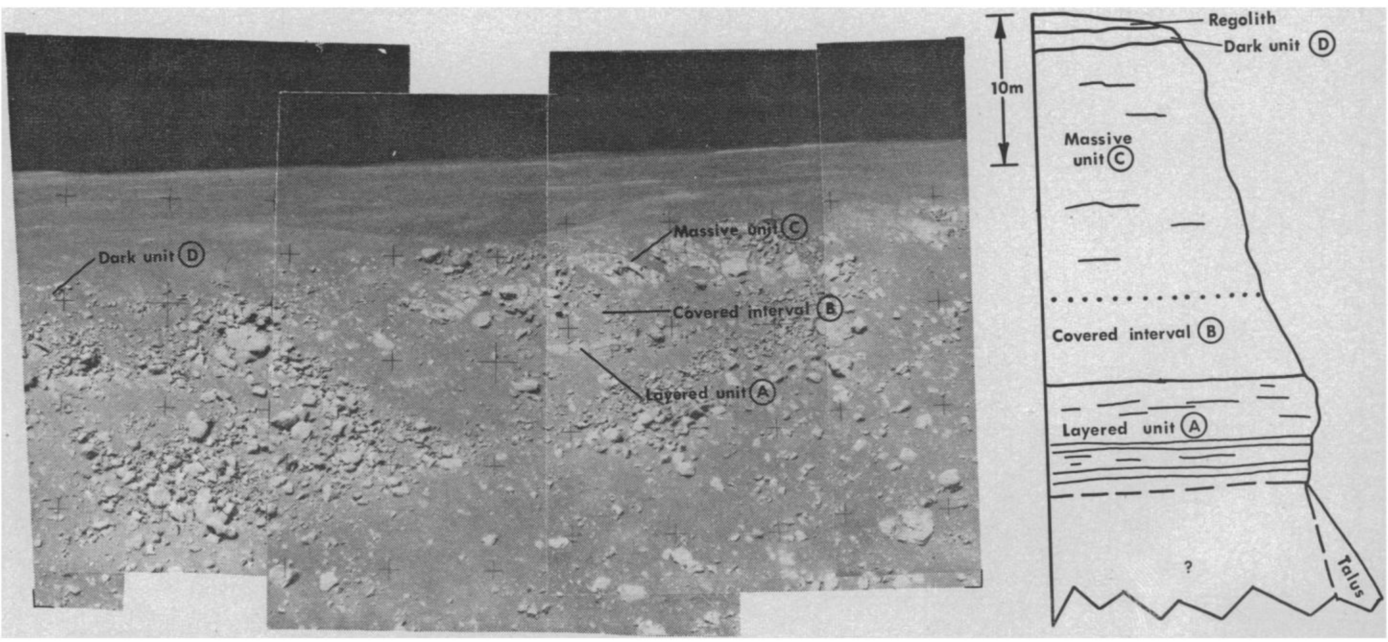

Fig. 5. Partial panorama of the far wall of Hadley Rille, photographed with a camera of 500-mm focal length from station 9. On the right is an idealized section of the upper portion of the rille wall.

Apennine front samples. Three main types of breccias were collected from stations 2, 6, 6a, and 7 on the Apennine front: (i) type A, generally friable breccias containing fragments of glass, basalt, and debris derived from coarse-grained feldspathic rocks; some of the breccias also contain fragments of basalts like those collected from the mare sites; (ii) type B, generally coherent breccias with medium- to dark-gray, vitreous matrices; these breccias contain abundant debris derived from coarse-grained feldspathic rocks and varying proportions of clasts of non-mare type basalt and they are commonly partly coated by glass; and (iii) type C, coherent breccias with dark gray aphanitic matrices in intrusive relation with clasts composed dominantly of granulated feldspathic rocks.

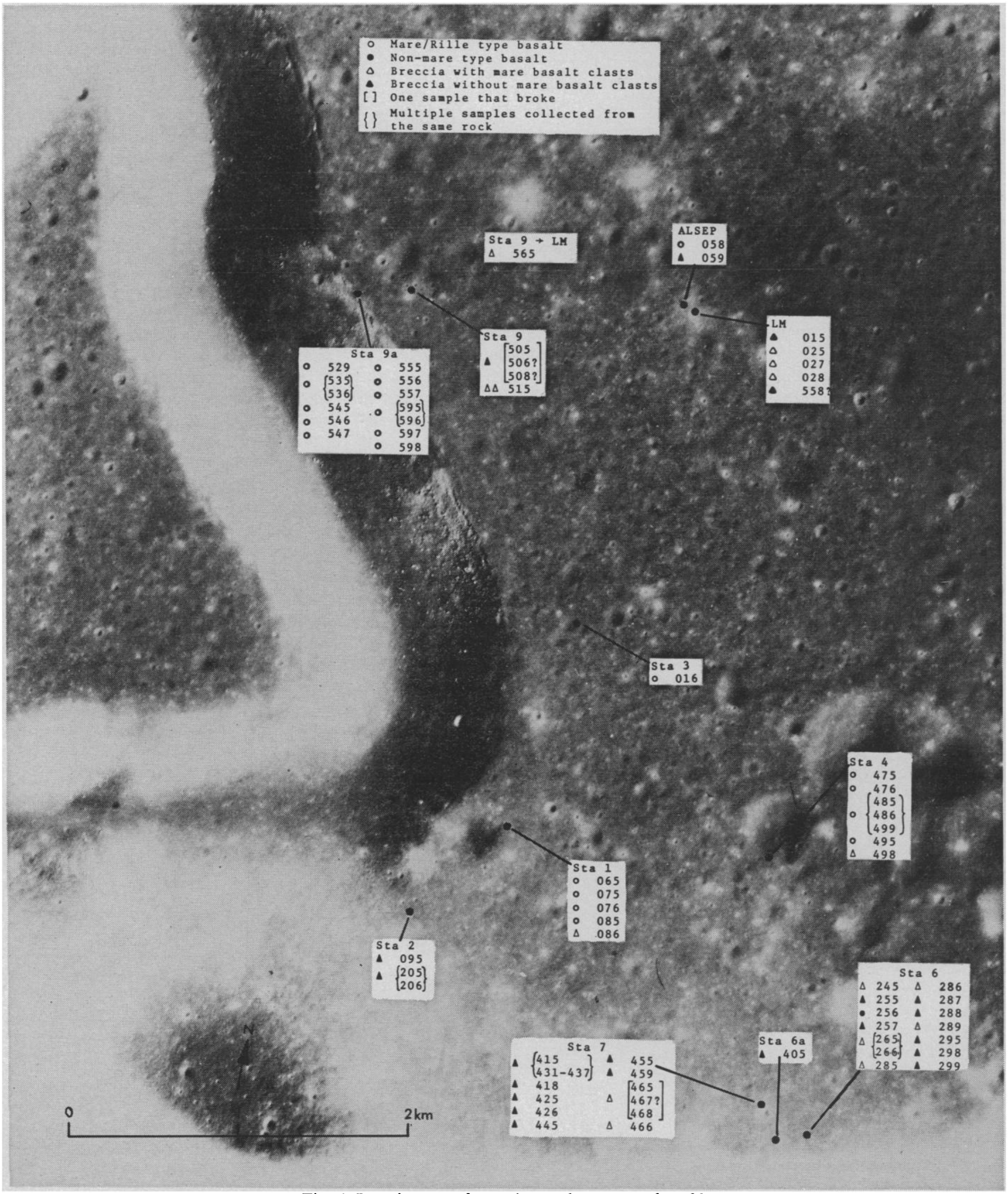

Fig. 6. Location map for rock samples greater than 20 g.

Type A breccia is considered to be weakly lithified regolith that locally contains scattered clasts of mare basalt thrown up on the Apennine front, mostly from South Cluster. Type B breccia is the most common type collected on the Apennine front and is also common at the LM site and in samples from the mare surface at station 9. Because these breccias are the dominant rock type collected from the front and do not contain mare-like basalt clasts, they are presumed to represent premare material of the front. Type C breccias, of which there are only three documented samples, are also considered to represent Apennine front material, differing from type B mainly in the proportion of coarse-grained feldspathic clasts and in the intrusive relation of matrix and clasts in type C. Accordingly, rocks underlying the Apennine front are thought to be breccias whose clasts are mainly coarse-grained feldspathic rocks and nonmare-type basalts in varying proportions.

The distribution of rock types (Fig. 6) reveals an unexpected abundance of nonmare-type rocks on the mare surface, especially around the LM site and station 9. The best samples of mare basalts were obtained from two craters (Elbow and Dune) that penetrated through the regolith on the mare and from the rille edge, where the regolith is very thin or absent. Much of the mare surface, where sampled, is covered by a ray that contributed an unknown quantity of foreign material to the surface. Furthermore, the area is bounded on two sides by high mountains composed at least partly of breccias; the downslope movement of material and lateral transport both tend to contaminate the mare surface. The North Complex, on a third side of the area, may also contribute breccias to the mare surface (*2*). These features, combined with the general lack of large craters on the mare surface, tend to enhance the contamination of the surface by foreign debris.

A distinctive feature of the breccias collected from the Apennine front is the lack of the multiple brecciation that is so well displayed in the Apollo 14 samples. This strongly suggests that the Apollo 15 crew sampled a level of the lunar crust that is lower and thus less reworked than that sampled during the Apollo 14 mission.

APOLLO LUNAR GEOLOGY INVESTIGATION TEAM*

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7. Work done under NASA contract T-65253-G. Published by permission of the director, U.S. Geological Survey.
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Chemistry, Geochronology, and Petrogenesis of Lunar Sample 15555

Abstract. *Lunar sample 15555 is a mare type basalt generally similar in chemical composition to the Apollo 12 basalts. Sample 15555 is older than any Apollo 12 basalt but younger than the Apollo 14 basalts analyzed thus far.*

Data are given for rock 15555, the largest sample yet returned from the moon, collected at the edge of Hadley Rille during the third period of extravehicular activity on the Apollo 15 mission. Sample 15555 is thought to be a fragment of very locally derived bedrock (*1*). It is an equigranular basalt containing olivine, plagioclase, and pyroxene in the size range from 0.3 to 1 mm (*1*). We received a 0.56-g chip of sample 15555 for major element analysis. Since 0.3 g was sufficient for that purpose, we decided to use the remainder for microprobe analyses of minerals and for an isotopic age-determination by the Rb-Sr method (*2*).

The results of a chemical analysis of the major elements of sample 15555 are given in Table 1. Data were obtained by x-ray spectrometry (except for Na), as for earlier lunar samples (*2*). Sample 15555 was thus seen to be a mare type basalt, generally similar in composition to Apollo 12 basalts. Its content of ($MgO + FeO$) and all other single components and its content of normative olivine resemble those of sample 12020. However, the MgO/FeO ratio of sample 15555 is lower than that of the Apollo 12 basalts, with 100 Mg/(Mg + Fe) equal to 44.3 for sample 15555 as compared with 53.5 for sample 12020. All Apollo 12 samples containing normative olivine have appreciably higher Mg/Fe ratios than sample 15555; those with low Mg/Fe ratios (for example, samples 12038 and 12052) have lower contents of total ($MgO + FeO$) and normative quartz and higher contents of alkalies. These results independently suggest crystal fractionation (*3*). Such is not the case for sample 15555.

After the sample was washed and screened, we separated 0.12 g in the 75- to 150-μm size range into the mineral concentrates shown in Table 2 by hand-picking various density fractions. Every mineral sample is a different concentrate; so, except for the total rock, there was no expectation of close agreement in the Rb and Sr concentrations between the A and B samples. The "ilmenites" both contain of the order of 50 percent ilmenite, both as free grains and as composites with pyroxene. The chemical processing and mass spectometry tech-

Table 1. Chemical analysis of rock 15555.

Component	Percentage (by weight)
SiO_2	43.82
TiO_2	2.63
Al_2O_3	7.45
FeO	24.58
MnO	0.32
MgO	10.96
CaO	9.22
Na_2O	0.24
K_2O	0.04
P_2O_5	0.07
S	0.06
Cr_2O_3	0.59
Total	99.98
$O \equiv S$	0.03
Total	99.95