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Preliminary report on the geology and field petrology at the Apollo 15 landing site

by

Apollo Lunar Geology Investigation Team
U.S. Geological Survey

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INTRODUCTION

The Apollo 15 mission was a landmark in the manned geologic exploration of the Moon. The geologic diversity and significance of the site, the extended traverse capability provided by three EVAs and the Lunar Roving Vehicle, the real time television coverage of the terrain and crew activities, and, most of all, the magnificent performance of the astronaut crew contributed to an unprecedentedly successful mission.

PHOTOGEOLOGY OF THE APENNINE-HADLEY AREA

Photogeologic maps of the Apennine-Hadley region (Carr, Howard, and El-Baz, 1971) show the landing area situated near the sinuous Hadley Rille on ray-mantled Eratosthenian mare material in the Palus Putredinis embayment at the base of the Apennine Mountains. Photogeologic map units in this complex area include massif material (pIm), interpreted as structurally uplifted blocks mainly of pre-Imbrian rocks; Apennine material (Iap) and hilly material (IpIh), interpreted as Imbrium basin ejecta locally covering massif material; pre-mare crater material (Ic) consisting of debris from impacts into massif and Apennine material; mare material (EIm, EImr, EIms, and perhaps EIl), which forms the Palus Putredinis plain, low ridges in the plain, and the upper walls of Hadley Rille, and interpreted as basaltic flows; dark mantling material (CEce) that covers low hills near the mare; Eratosthenian and Copernican crater material (Ec, Cc, Csc); talus deposits in the lower part of Hadley Rille (CEt); and a veneer of ray material on mare material over a considerable portion of the area, including the landing site. A detailed local map

(Schaber and Head, 1971) was prepared in conjunction with traverse planning for the three EVAs. EVA I was planned to visit the Rille at Elbow Crater and to sample the Apennine front on the flank of St. George Crater. EVA II was designed to visit the front in the vicinity of Spur to Front Craters and to sample the mare at Arbeit Crater. EVA III was planned to observe the rille near Scarp Crater, to describe and sample the North Complex, and to sample the mare near Ring Crater (see Figure 1).

GEOLOGIC OBJECTIVES OF THE MISSION

The geologic objectives of the Apollo 15 mission were to describe the kinds and proportions of rocks in these various map units, and to collect samples of them; to observe, describe, and collect samples of regolith that was thought to cover most of these units; to look for outcrop, and if found, to describe and sample it; to describe structures in various units, including lineations, layers, beds, faults, etc.; and to observe and describe, where possible, the attitudes of and contacts between the major geologic units. The objectives were optimistic, ambitious, and very largely met due to the outstanding competence and effort of the Apollo 15 crew.

FIELD OBSERVATIONS BY THE CREW

Crew descriptions at the Apennine front revealed that there are no outcrops in the vicinity of the traverses, and only a few on distant slopes. The front is covered by a smooth mantle of breccia and soil. Breccia of more than one kind was observed; some contained coarse dark and light clasts; others were described as microbreccias. The crew noted that the material very much resembled the rocks returned from the Fra Mauro Formation sampled at the Apollo 14 site. Their detailed descriptions are consistent with this comparison. The massif material (pIm) may consist of breccias, or it may be extensively mantled by Apennine material (Iap). The former alternative is supported by the presence of breccia fragments on the flank of St. George Crater (see cross sections, Figure 2), which excavated deep into the massif.

Imbrian crater material (Ic) was observed on the flank of St. George Crater. A large block was described as breccia in contact with very dark fine-grained material, which probably occurs as a large clast in the fragmental rock.

Mare material (EIm) was described and sampled at Elbow Crater (Station 1), at supplementary stop 3 in the mare, at Dune Crater (Station 4), on the rim of Hadley Rille (Stations 9, 9A and possibly 10), and probably at the ALSEP site and at the LM. The material, as expected, was basalt, but, based on the descriptions, is unexpectedly rich in feldspar. Descriptions indicate a range of compositions ranging from rocks with olivine phenocrysts to feldspar phyric types, as well as some aphyric basalts. Most of the samples are vesicular, with a range of vesicle sizes up to 2-3 inches. Several blocks were reported to have pahoehoe-like surfaces. The range of amounts and kinds of phenocrysts, vesicles, and grain sizes suggests that a number of flow units were sampled. Observations in the walls of Hadley Rille confirm the photogeologic interpretation that the mare basalts crop out in nearly horizontal layers in those walls. Units in the western wall range from thin-bedded to massive; more than one flow unit was observed. An outcrop of the uppermost flow unit exposed in the east wall was identified, described, and sampled. Mare subunits EIms and EIl were not visited. Mare subunit EImr was crossed on EVA I, but was not obvious as a distinct unit to the crew.

Crater materials (Ec, Cc, Csc) were described, photographed, and sampled in a number of localities, and, in several places radial samples were collected that permit preliminary stratigraphic sections to be constructed (see Figure 2). Many of the smaller craters contain shock-lithified rock or glass cemented regolith. The larger craters apparently sampled bedrock.

The talus deposits (CEt) in the bottom of Hadley Rille were visually verified and photographed.

Probable ray materials were extensively described, photographed, and sampled at the LM and ALSEP sites. They consist of fine fragmental material with abundant coarser fragments principally of white rock, and possibly including blocks of dark glass.

The contact between massif material and mare material was sharp near Spur Crater, but gradational near Elbow, which may confirm the existence of massif debris (dm) in the latter area. The contact of ray material over mare material proved to be gradational, as expected. Contacts between flow units in the wall of Hadley Rille were observed and photographed, and a gradational contact was found between regolith and underlying bedrock at the Rille lip. A low sinuous ridge or rim parallel and adjacent to the eastern edge of Hadley Rille was observed both in the vicinity of Elbow Crater and near Station 9, confirming the photogeologic interpretation in this area. The uppermost basalt flows on the east side of the Rille appear to dip gently eastward. Horizontal layering in the wall of Crescent Crater was reported. Distant observation toward the base of the Mt. Hadley-Silver Spur area revealed three ledges making up 10-15 percent of the total elevation of the front. In the opinion of the crew, these appeared to be high lava marks of mare flows. Above these features, and extending to the top of Mt. Hadley, a succession of lineations was observed that appeared to be layers dipping 30° NW. If these are truly beds they suggest that this part of the massif is a tilted block. Some horizontal layers or lineations were observed on the SW wall of St. George Crater.

Lineations that may be faults or joints were observed sloping 30° NE in the Apennine front southeast of the landing site and sloping 20° E near Hadley Delta. Strong lineations sloping 20° W were observed in St. George Crater. Columnar jointing was described and photographed in the rocks exposed in Hadley Rille. Lineations striking northwest and north were observed in the mare surface south of the landing site.

TRAVERSE LOCATIONS AND SAMPLE DATA

The Lunar Roving Vehicle permitted the crew to travel a total traverse distance of 27.9 km (approximately 17.5 miles). The odometer distance covered on EVA I was 10.3 km (map distance 8.3 km), on EVA II was 12.5 km (map distance 11.0 km), and on EVA III was 5.1 km (map distance 4.4 km). Figure 1 shows the preliminary locations of these traverses, along with principal physiographic features, and stop locations. It also includes geologic descriptions at the stations, verbal annotations between stations, and sample bag numbers where located as of this date. EVA I proceeded nearly as planned insofar as the geology traverse was concerned but a longer egress time from the LM necessitated the redesignation of Station 3 to a supplemental sample stop in the mare, and some ALSEP tasks were not completed.

EVA II was re-planned and shortened by both life support constraints and by the carry-over of ALSEP site tasks. The traverse was redirected to the vicinity of Spur and Window Craters by reason of crew observation of blocky craters in that general area. Front Crater was no longer a major objective because of the abundance of blocks at Spur Crater. Station 4 became a supplementary sample stop because of time constraints, and tasks planned for Station 8 were performed at the ALSEP site for more efficient use of crew time. EVA III was re-planned due to unfinished ALSEP site tasks and a shortened EVA time from 6 to 4 1/2 hours. Difficulties in recovering and disjointing the high priority deep drill core resulted in additional delay. The re-planned traverse was principally directed at Stations 9 and 10 on the lip of Hadley Rille, and the North Complex was not visited.

Total returned net sample weight is about 171 pounds. EVA I net was 29.8 pounds; EVA II, 77.6 pounds, and EVA III, 63.4 pounds. Table 1 gives a sample summary by EVAs, and includes sample bag numbers, brief sample descriptions, locations where collected, and post-EVA stowage and weight data. Detailed field sample descriptions, cataloged by EVA, bag number, and Ground Elapsed Time (GET) collection time are given in Table 2.

More than 1200 frames of 70 mm and 500 mm film were exposed during the mission. A preliminary catalog of photographs by EVA is given in Tables 3 and 4. The photographs are keyed to GET, magazine number, preliminary frame count number, samples collected, station, and includes comments where appropriate.

Preliminary planimetric station maps of the local geologic relations at Stations 1, 2, 6, 7, 9, 9A and the ALSEP site have been prepared from lunar surface television panoramas (see Figures 3, 4, 5). These maps show sample locations, large observable blocks, crater rims and the position of the Lunar Roving Vehicle during the activities at the station. A geologic cross section of Hadley Rille in the vicinity of Scarp Crater (Figure 6) shows the stratigraphic section described by the crew and observed in the television pans and sample localities.

PRELIMINARY GEOLOGIC EVALUATION OF THE SITE

Mare Material

The mare surface at the Hadley site slopes generally westward from the Mount Hadley area and northward from Mount Hadley Delta. It is gently undulating in detail, and is abundantly cratered. In the area between the LM site and Elbow Crater the craters range in definition from very subdued to very sharp, and several small, sharp ones were reported during the traverse. The mare surface in part of this area is also marked by lineaments trending north and northwest. About 1 km south of the LM is a series of broad, shallow swales that appeared to the crew to trend E-W; they may be old craters. Several very large, angular boulders are visible on the mare across Hadley Rille. Between the LM site and the Apennine front at Spur Crater the mare surface again was reported to be gently undulating, with smooth, rounded features. A crater 30 meters in diameter was described as deep but internally smooth, implying that it had not been excavated to bedrock. This suggests that the regolith is thicker near South Cluster than farther west, where during EVA I a crater 20 to 25 meters in diameter was described as probably reaching bedrock. As traversed in a southerly direction in this area, the plain changed to distinctly smoother ground with few deep craters just before the base of the slope along the Apennine front was reached. This implies that the margin of the mare lies basinward of the base of the slope, and that either craters are initially sharper on the mare, or that they are less readily destroyed. No comparably sharp boundary was noted in the area farther west. A series of large depressions or swales, apparently very subdued craters, was crossed between the LM site and the rim of Hadley Rille to the west. The generally rough surface, likened to "big sand dunes in the desert" with corresponding smoothness of detail, may be characteristic of the mare in this area.

Samples of coarse-grained basalt collected at Elbow Crater almost surely represent mare material. Vesicular mare basalt was described and collected at Station 3. Blocks were described in two areas between the LM site and the Apennine front that appeared to have pahoehoe-like surfaces. Boulders described and sampled at Dune Crater, in South Cluster on the mare surface, consist of markedly vesicular basalts with crystals of feldspar. These rocks do not closely resemble the basalts sampled at Elbow Crater during EVA I, but they probably also represent a part of the mare section. These rocks may correspond to the basalts exposed in the walls of Hadley Rille.

Ray Material

Rocks on the mare surface near the LM have a significant percentage of white fragments and a fair number of glassy fragments. This tends to confirm that the landing site is on a ray, the presence of which is suggested by regional mapping and is shown as such on the data-package maps, and suggests that some of the samples from the vicinity of the LM are not indigenous. Trenching of soil on the surface at the ALSEP site also revealed cohesive fine-grained gray material with small white fragments and

A relatively hard layer rich in black glassy fragments at a depth of about a foot was penetrated by the trench, and this layer is presumed to be the same one that made drilling somewhat difficult at about the same depth. These rocks are quite possibly components of the ray, which may be related to the secondary craters of South Cluster and a linear group of small craters described as extending south up the lower slope of the Apennine front. Alternatively, this material may in part be volcanic. A south-trending line of boulders and blocks also was reported on the interior of Dune Crater.

Hadley Rille

Near Elbow Crater Hadley Rille is markedly sinuous, and it has the expected steeper, ledgy appearing upper slope and more gentle lower slope. Coarse talus is abundant, and at least one apron-like mass may represent slope failure. The bottom of the rille appears to vary considerably in altitude, and does not now represent anything akin to a drainage course. Rather, it is marked as the intersection of talus from the two walls. Exposures on the walls of Hadley Rille in this area suggest multiple layering that is essentially horizontal. Such layering appears mainly in the uppermost parts of the walls, and if it is confirmed as an expression of stratified mare basalts it will indicate the local thickness and sequence of mare lava flows. The general sequence of layers visible on the wall appears to differ, however, from that noted in high-resolution photography of a part of the rille farther south. Vertical joints were described in one outcrop exposed on the rille wall. Broad, low, raised rims are present along the upper margins of the rille in this area, confirming photogeologic observations. Large blocks are locally abundant along these rims. As in the area to the south, a low ridge extends along the easterly rim of Hadley

Rille in the vicinity of Station 9. This topographic expression may be related to the reported gentle outward dips in the rocks below the rim, which may have resulted from arching or structural adjustments. Alternatively, the ridge could be a more restricted deposit of fragmental debris on the mare surface, which might account for the presence of soft soil that was easily cored. A further hypothesis is that the ridge may be a levee. The westerly wall of the rille was exceptionally well described by the crew. One distinct interval of outcrop in the top five percent of the rille wall is characterized by multiple layering. Study of the TV pans of this unit reveal at least 9 layers. Below this is a covered interval, and then a lower line of outcrops in approximately the center of the visible wall which appears to be a more massive unit of somewhat more tan-colored hard rock; it is partly covered with talus and fine-grained debris. Elsewhere the rille wall is studded by blocks as much as 20 to 30 meters in diameter. An accumulation of talus at a level approximately 60 percent of the elevation down the rille wall may indicate a change in slope. An analogous break in slope in the wall of the rille and a concentration of large blocks is observed in high resolution Lunar Orbiter photographs 35-40 km to the southeast of Hadley Base. This level may represent a major change in strata beneath the veneer of talus. The bottom of the rille was not visible from the Lunar Roving Vehicle.

Above the rim at the top of the easterly wall is a bench-like feature that slopes gently to moderately down toward the lip. Near the rim are numerous large blocks and ledges of rock that correspond to the uppermost layers exposed on the opposite side of the rille. The rocks are vesicular basalts with parallel layers of contrasting vesicle size and abundance. Some of the vesicles are 2 to 3 inches across. Most of the basalts contain abundant lath-like phenocrysts of plagioclase, with a maximum reported length of 1 cm. Slight color differences between rocks and variations in size of the plagioclase crystals between samples suggest that more than one lava flow is present. The rocks evidently are similar to basalts collected at Dune Crater during EVA II, and from the mare surface during EVA I.

Massif and Apennine Material

Mountains around the site are characterized by gentle to moderate slopes and rounded outlines. No outcrops were observed on Hadley Delta. Lineaments appear on distant mountain slopes and are well developed on Mt. Hadley. What appeared to be a slump feature was described near St. George Crater, but in general, features suggestive of debris flows or large-scale ground failure were less abundant than anticipated along the southern Apennine front. Blocks are very scarce along the front, suggesting either the presence of a very thick regolith, or that the underlying material, whether it consists of Imbrium ejecta or pre-Imbrian material, is not indurated. Hard rocks apparently were excavated at some 20- to 25-m craters, but elsewhere even pebble-size fragments are scarce. On EVA I breccia was collected at the crest of Elbow Crater that may represent ejected massif material of the Apennine front, which presumably underlies mare deposits at Elbow Crater. Rock at the flank of St. George Crater, excavated into the Apennine massif, is also breccia, and possibly very coarse breccia. Rocks collected from points farther east on the Apennine front on EVA II are dominantly breccias with a variety of clast types and several kinds of internal structures. Features of special note include coarse-grained, plagioclase-rich clasts (anorthositic rocks) and soft, green-gray clasts in breccia at Spur Crater, along with probably layered light and dark breccia at the same crater; a light green (?) band in a boulder of breccia east of Spur Crater (Station 6A); and a glass-veined breccia at the first stop east of Spur Crater (Station 6). Lateral and/or vertical variations in the breccia are indicated, for example, by large clasts described at Spur Crater as contrasted with microbreccia described farther east at Station 6. Rocks on the part of the Apennine front visited during EVA II appear to be more abundant than on the flank of St. George Crater, and they are especially numerous on the rim and interior of Spur Crater. They include one of the larger blocks visited in the uplands, a chunk of breccia two meters long. An arcuate track formed by a small rolling stone also was reported from Spur Crater.

Regolith

Soils range from loose and powdery, particularly on ray material and around crater rims, to fairly cohesive. Some soil seems to have been lithified into clods during formation of small (1-10 m) craters, and it is indurated under some blocks. Soils on the steep slopes of the Apennine front evidently vary from place to place in their cohesiveness, granularity, and stratigraphy. They generally are lighter gray, very fine grained, and moderately cohesive. Some small craters contain clods of glass-cemented soil: samples of this were obtained east of Spur Crater. Regolith developed on mare basalt at the rim of Hadley Rille coarsens to boulder size and drops in elevation toward broken outcrops at the lip of the rille, as if the fine component had been winnowed away. Regolith thickness at the rim of the rille is 5 m. Soil at Station 9 was described as exceptionally soft, the crew leaving boot tracks 4 to 6 inches deep.

White soil, previously described at stations along the Apennine front, was found locally beneath gray soil at Station 9A. Lighter soils below the immediate surface were encountered near the rille edge, around some craters, and in the trench wall at the ALSEP site. The albedo of the maria and mountain front appeared similar on the ground in spite of obvious telescopic differences.

This preliminary summary of the geology of the Apennine Hadley site is constructed from the complementary observations of the photogeologic mapping group, the members of the Apollo Lunar Geology Investigation Team, and the crew working from Hadley base. We have avoided undue speculation on the processes responsible for the described features, and limited our remarks on origin of features to those generally used in normal geologic field practice. A good deal more information on which to base inference and speculation will be available when the samples and photographs have been returned to Earth.

SUMMARY

When the crew of the Falcon departed Hadley Base they had achieved the following notable geologic objectives: (1) Utilizing the new extended stay capability and the remarkable mobility provided by the Rover, they explored the largest area and made the most extensive and thoroughly documented scientific collections in the lunar exploration program to date. (2) More major lunar features were observed, visited, and described than in any previous mission. For the first time the processes of origin of geologic features were extensively considered in real time by the crew. (3) The first extensive observations of lunar outcrops and their stratigraphy were made. Outcrops were described and sampled directly, and documented by close-up photography, long focal-length photography and effective remote television coverage. (4) The most extensive sampling of the lunar regolith to date was achieved, both in terms of number and depth of core samples, and in the number of documented and widely distributed surface samples obtained. (5) The first 360° panoramic view (Standup EVA) prior to surface activities was made for the purpose of visual reconnaissance and high vantage point photography. Collectively, these achievements promise an extraordinary scientific yield from the Apollo 15 mission.

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Table 1. Sample summary

EVA I TOTALS	POST EVA I STOWAGE AND WEIGHTS		
	Item	Weight	Net sample weight lbs.
Contingency sample	SRC 1 (bag 1) including bagged samples and cores	36	14.7 (includes 3.9 core tube material)
6 bags of documented samples includes 1 bag of comprehensive (rake) fragments	SCB 4 (including loose rocks)	15	12.6
4 bags of soil includes 1 bag from from comprehensive sample	Contingency sample	2.7	2.5
2 large rocks		53.7	29.8
1 "selected sample"?			
2 core tubes (double core)			

SAMPLES BY STATION

Station 1 Elbow	Station 2 St. George	Return traverse Station 2 to LM
3 bags of rocks/radial sample, rim 200' East #156 ·friable breccia #157 ·light gray rock with plagioclase, olivine? ·several smaller fragments ·a little soil #158 ·very fine gray, solid rock ·another fragment	3 bags of rocks (1 additional "selected" sample?) #160 ·black basalt from large boulder #161 ·breccia from same boulder #186 ·comprehensive sample fragments ___? ·"selected" sample uphill from large boulder 4 bags of soil #180 ·fillet, downhill side of large boulder #181 ·typical soil away from boulder #182 ·soil from beneath boulder #187 ·comprehensive soil sample 2 core tubes (double) #U03/L04	2 large rocks ·vesicular basalt ·6" x 12" glass, black

Table 1. Sample summary (con't)

EVA II TOTALS

16 bags of documented rock samples
8 bags of soil, clods, or glass welded material
6 large rocks
1 core
2 SESC

POST EVA II STOWAGE AND WEIGHTS

Item	Weight	Net sample weight lbs.
SRC 2 (SCB 5)	40	18.2
SCB 3	30	28.2
SCB 6	33	31.2
	103	77.6

SAMPLES BY STATION

Near LM before traverse
#162 ·glass sphere

Station 6
Apennine front
4 bags of rocks with some soil
#188 ·breccia, white clasts, dark matrix
·another fragment with soil
#190 ·breccia, glass covered
·another breccia frag(?)
#192 ·several rock frags
·breccia
#193 ·breccia with 1 mm white clasts
2 large rocks
·light gray microbreccia
·4" rock with jagged surface
4 bags of soil, clods and glass welded material
#163 ·glass welded material in small crater
#164 ·very fine light gray soil from crater rim
#166 ·bottom of trench
#167 ·near LRV
SESC #1 ·bottom of trench
Core #U07 ·downhill rim of small crater

Station 6a
Apennine front
1 bag of rocks
#168 ·breccia with white clast
·green layer or coating

Station 4
Dune Crater-South cluster
3 bags of rocks with some soil
#203 ·at least 2 rocks with soil
·1 bigger rock
#174 ·another big rock
#204 ·2 frags from boulder
1 large rock
·chipped from crystalline coarsely vesicular boulder

ALSEP site
2 large rocks
·pink rock with plag
·black glassy rock

Station 8
Near ALSEP site
2 bags of soil
#252 ·bottom of trench
#253 ·top of trench
SESC ·bottom of trench

Station 7
Spur Crater-Apennine front
7 bags of rocks including raked fragments
#194 ·breccia "pinnacle"
·caked soil
·glass under rock
·another rock
#195 ·friable green fragment
·soil between broken fragments
#196 ·2 or more crystalline fragments with plagioclase (anorthosite?)
#198 ·4" basalt/white rock with contact
#199 ·glass coated breccia
#171 ·piece of large rock
#172 ·raked fragments
1 large rock
·not described
2 bags of soil, clods, or glass-welded material
#170 ·broken clod
#173 ·soil and glass spherule

Table 1. Sample summary (con't)

EVA III TOTALS

6 bags of documented samples, includes 1 bag of comprehensive (rake) fragments
2 bags of soil, clods, or glass welded material, includes 1 bag from comprehensive sample
2 large rocks; probably more. Approximately ten samples were transferred from LRV seat pan to BSLSS bag
2 core tubes (double drive)
6 core tubes (deep core)
1 SESC (contaminated sample)
Bulk sample (undocumented)

POST EVA III STOWAGE AND WEIGHTS

*Item	Weight	Net sample weight lbs.
BSLSS	25	21.8
SCB 7 (combined with SCB 8)	24	20.4
SCB 2	23	21.2
	72	

SAMPLES BY STATION

ALSEP site

Deep core (6 sections)
- Top section, capped A/C
- Second section, capped D/E
- Third section, capped F/G
- Three bottom sections together, capped H/B

LM site

After return from traverse

SESC # 2 ·contaminated sample at DPS engine bell

Bulk sample
- ·soil and rocks put into BSLSS bag

Station 9

(Scarp crater)

1 bag of rocks with soil and glass
- #255 ·fragment, dust covered, glass sphere, soil

1 bag soil
- #273 ·caked clod

Station 10

Hadley Rille Terrace

Possible large rock sample

Station 9a

Top of Hadley Rille Terrace

5 bags of rocks including 1 bag of raked fragments
- #274 ·fragment with 2 mm vesicles
- #275 ·crystalline rock broken from larger block
- ·a few other fragments
- #278 ·rock fragment with soil
- #281 ·big black vesicular rock
- ·a couple of rounded fragments
- #282 ·fragments from comprehensive (rake) sample

2 large rocks
- ·LMP collected 6" vesicular rock
- ·CDR collected one, as seen on television

1 soil sample
- #283 ·soil from comprehensive sample

2 cores (double drive tubes)
- #U09/L14

Table 2. Sample Descriptions

EVA I

Container number	Site	Number of samples	GET	Sample description and notes
Contingency	LM	Soil, 1 rock	120:04-06	Soil and a 2" rock; soil powdery, soft
156	1	1	122:16	Subangular, friable breccia. Dusty. "Sparklers," no glass.
157	1	2 or more rocks, soil	122:17-18	Subangular, friable rock with olivine and plagioclase (to 1 cm x 1 mm); rock is composed of light gray mm-size grains with 2 mm phenocrysts; other rocks not described
158	1	2 rocks	122:22	Subangular, rough surface, very fine-grained, solid gray rock. Dusty. No pits. 2nd rock has a mm-thick layer of soil caked on bottom
180	2	Soil	122:43	Fillet material, downslope side of 1 m boulder (sample 160)
181	2	Soil	122:45	Typical soil collected away (downslope) from 1 m boulder
(159?)	2	Several rocks?	122:47	"Selected sample" by CDR next to 1 m boulder. Very uncertain; Bag 159 not called.
160	2	1	122:48-50	Dark black, very fine-grained basalt, from uphill corner of boulder. Boulder is angular, very rough-surfaced, partly glass-covered. Glass coating crosses contact which separates breccia (on top) from crystalline rock. Contact divides boulder 1/5-4/5, the larger part being breccia. Parallel to contact is a quite black surface for about 8 inches or so.
161	2	1	122:53	"Dumbell" rock, breccia; lots of glass on it; taken from top of rock (sample 160)
182	2	Soil	122:57	Soil from beneath 1 m boulder
186	2	Several rocks	122:60	Small fragments, comprehensive sample. May have 8 or more fragments

Table 2 (con't)

EVA I (con't)

Container number	Site	Number of samples	GET	Sample description and notes
187	2	Soil	123:04	Soil at comprehensive sample site.
U-03/L-04	2	Double core	123:12	Core from rim of small crater
"Cover" Bag 2 or 4	3	1	123:45	Fairly well-rounded vesicular basalt, vesicles about 3 mm diameter
"Cover" Bag 2 or 4	3	1	126:04	6" x 12" black glass fragment with rough texture

Table 2 (con't)

EVA II

Container number	Site	Number of samples	GET	Sample description and notes
SRC 2	LM	soil	142:44	Organic sample
162	LM	3(?)	142:47	Glass sphere, 1" diameter ("glass aggie"); a couple of other small samples
163	6	scoop several pieces	144:00	Sample scooped from side of small crater with glass in bottom. Welded together, like fragments all glued together.
164	6	scoop several pieces	144:01	Sample scooped from rim of 163 crater; very fine, light gray
188	6	2 + soil	144:04	Fine-grained microbreccia, white clasts in dark matrix; has glass-filled fracture. Second rock the same plus scoop of soil
?	6	1	144:08	Subangular fragment of light gray microbreccia with about 90 percent light gray clasts 1 mm or so in fine grained gray matrix. Bottom is slickensided, glass splatter on one side. One small orange crystal, possibly a piece of olivine
SCB 3	6	1	144:14	Four inch, subangular breccia with a very rough, sharp, jagged, craggy surface.
190	6	2	144:17	Small microbreccia; second sample is microbreccia that is glassy on bottom, has a couple of very small glass pits.
192	6	several	144:21	Small rock fragments, not described
193	6	1	144:23	Microbreccia with 1 mm white clasts and a 3 mm gray clast
166	6	trench soil	144:26-27	Soil from bottom of trench; cohesive, very fine powder, like graphite. No layering.
SESC 1	6	trench soil	144:31-32	Sample from bottom of trench
U07	6	core	144:37-38	Downslope side of 166 crater; soil more granular, kicked up white material
167	6	soil	144:40-41	Soil sample at LRV
168	6a	2	145:18	1 sample gray layer, 1 3"-inch sample of breccia with 1" white clast. Boulder from which these were taken is 3 m long, subangular, very rough, dark breccia with a 1 1/2 - 2' light-gray or green band in it.

EVA II (con't)

Container number	Site	Number of Samples	GET	Sample description and notes
194	7	3 or 4 + soil	145:34-35	Breccia ("pinnacle"); fine-grained, black matrix with mm-size white clasts attached to light gray or medium gray breccia with about 20 percent white clasts; small piece of glass; soil; small rock, not described (bag number uncertain); larger rock, different (not certainly collected). May also have collected more small fragments.
195	7	1 + soil	145:37	Very fine-grained, friable, soft light gray or green rock. Soil scooped between rocks that came from single rock--broke when it hit
196	7	2 or more	145:42	White clast broken from clod; crystalline, close to anorthosite
179	7	1	145:44-45	Scoop sample of broken clod, subround
198	7	1	145:48-49	4" rock. One-half is very dark, black, fine-grained basalt with thin plagioclase laths, mm-size vesicles along a line close to contact. Other half is solid white, fine-grained fragment
199	7	1 or more	145:50-51	Glass-coated breccia; may be in several pieces
171	7	1	145:57	Fragment off large breccia boulder with gray and white clasts
172	7	15+	145:59	Rake sample. Mostly rounded, walnut-size rocks. Full bag.
173	7	1 + soil	146:05-06	Soil at rake site; glass sphere
SCB 3	7	1	146:07-09	Large rock, not described
203	4	soil	146:35	Soil, possibly contains rock or rocks
174	4	1	146:36	Large rock, not described
Loose	4	1	146:37	Corner of large very fine-grained black basalt fragment with vesicles 2-3" across and about 15 percent plagioclase laths. In contact with rock having small vesicles.
204	4	2	146:40	Two pieces from center of rock with 2-3" vesicles.
?	ALSEP	2	147:53	1 pink rock that looks like it has a lot of plagioclase; 1 black glassy rock
SESC 2	8	soil	148:13	Bottom of trench. Trench has small white fragments; 1 black clast. Harder at 12"; more of a black glass fragment. A little lighter at 14-16". White clast in bottom 75 percent in SESC
252	8	soil	148:15	Soil from bottom of trench
253	8	soil	148:17	Soil from top of trench

Table 2 (con't)

EVA III

Container number	Site	Number of samples	GET	Sample description and notes
Bag 2	8	core	164:18	Deep core sample
273	9	1 + broken	165:09	Friable clod from rim of fresh crater. Sample broke when picked up.
255	9	2 + soil	165:12	1 piece of dust-covered glass and soil; possibly collected glass ball
274	9a	1	165:27	Fragment with a great number of vesicles about 2 mm in diameter
275	9a	several	165:42	Light gray to tan crystalline rock with randomly oriented 2 mm plagioclase laths. One glass-filled pit, other pits. Taken from a large block. Others not descb.
278	9a	1 + fines	165:44	Rock fragment and a scoop of fines
281	9a	3	165:48-50	Dark, fine-grained basalt with non-uniformly distributed vesicles on the order of mm across. Plagioclase laths 3 mm x 1/2 mm randomly oriented throughout. Two rounded fragments from surface.
282	9a	Full bag	165:55	Rake sample, includes glass, vesicular basalt, nonvesicular basalt
283	9a	soil	165:58	Soil at rake site
U09/L14	9a	core	166:02	Double core tube sample
Not bagged	9a	1	166:09	Undocumented block of vesicular basalt a little bigger than 6"
Not bagged	9a	1	166:09	Undocumented rock about 6" long, not described
SESC	LM	soil	167:06	Contaminated soil under engine bell
BSLSS	LM	soil + rocks	167:07-09	Bulk sample
?	LM	1	167:07	TV suggests collection of at least one undescribed sample rock
?	9a/8	7		TV coverage of unloading of Rover at close of EVA suggests collection of 7 or s0 undescribed samples, possibly from sites 9 a or 8

Table 3. Preliminary estimate of Apollo 15 lunar surface 70 mm film usage. Comments include both specific and inferred reference to photographic activity. All data are from notes and transcripts recorded in real time.

GET	Mag	Count	By	Cam	Spl	Sta	Comments
SEVA							
106:56	LL	33	CDR	CDR		LM	stereo pan, etc.
106:56	KK*	66	CDR	CDR		LM	stereo pan, etc.
106:58	MM	20	CDR	500		LM	brt, fresh ctr in rim of St. George, Spur, Window, lineaments on Hadley Δ
EVA I							
121:07	LL	33	LMP	LMP			
121:07	NN*	0	CDR	CDR			
121:07	MM	20	CDR	500			
122:14	LL		LMP	LMP		1	pan, E-rim Elbow
122:20	NN*		CDR	CDR	157,158	1	spl, sub-angular frag., scoop, rock
122:41	NN*		CDR	CDR		2	pictures of undisturbed boulder, with fillet
						2	check lens dust
					180	2	fillet material
						2	close-up of contact
						2	after collection of fillet material
					160	2	after chipping uphill core of big rock
						2	material under big rock
122:48					182	2	pictures after sample scooped up
123:10						2	double core
					186	2	close-up of glassy rock with slickensides (chips collected)
					187	2	pictures of comp sample area (?) with foot(?)
123:15	LL		LMP	LMP		2	stereo pan, moving base
						2	gnomon, chart dusty
123:20	MM		CDR	500		2	vertical and horizontal pans showing vertical joints and horizontal layering
123:21	NN*	54	CDR	CDR		2	
	LL	115	LMP	LMP		2	
	MM	51	CDR	500		2	
	NN*	76	CDR	CDR		ALSEP	
	LL	119				ALSEP	
125:51							film jammed, no pictures LMP took all ALSEP photos except HFE

*color

Table 3 (con't)

GET	Mag	Count	By	Cam	Spl	Sta	Comments
EVA II							
142:55							had to wipe dust off of cameras to see settings on first EVA
	LL		LMP	LMP		6	enroute pictures
143:39	LL		LMP	LMP		6	90-100°partial pan
	LL		LMP	LMP		6	full pan
144:12	NN*		CDR	CDR		6	close-up of frag impact (traveled east-west)
	LL		LMP	LMP		6	stereo pan
144:18					190	6	cross-sun of small crater
144:23	NN*		CDR	CDR	192,193	6	close-up of frag
144:28	NN*		CDR	CDR	166	6	trench sample-CDR fell
	LL		LMP	CDR	167	6	soil
144:34	NN*		CDR	CDR		6	SESC (post)
144:40							photos of LRV tracks
	LL	180	LMP	LMP		6a	
144:45	PP	0	LMP	LMP		6a	mag change
	MM	120	CDR	500		6a	Mt. Hadley outcrops near top, with 2 craters, vertical pan through another outcrop plus two craters in Swann Mountain, Hadley Δ with debris at top
144:52	MM	120	CDR	500		6a	4 photos Silver Spur
144:57	NN*	130	CDR	CDR			
145:09	PP		LMP	LMP		6a	pan, high point
145:12	PP		LMP	LMP		6a	block
					168	6a	greenish rock; cross-sun
	NN*		CDR	CDR	195	7	"green rock"
145:28	PP		LMP	LMP		7	pan (from northeast rim?)Spur
						7	block
					170	7	samples on lip on bench in Spur
	NN*		CDR	CDR	198	7	samples dark black fine-grain basalt surface under rock
					199	7	glass coated breccia
	NN*	180	CDR	CDR		7	CDR out of film
	PP		LMP	LMP	171	7	frag from boulder
					172	7	rake sample
					173	7	spherule with soil
						7	layered rock, cross-sun
145:58	KK*	66	CDR	CDR		4	mag change, CDR
	KK*		CDR	CDR		4	very large gray rock with vesicles
146:33	PP	180	LMP	LMP		4	partial pan, out of film, camera jammed
147:19	KK*	89	LMP	CDR			request to do landing site pans, descent engine, SWC
						8	pink rock and black rock

*color

Table 3 (con't)

GET	Mag	Count	By	Cam	Spl	Sta	Comments
					252	8	soil from bottom of trench
						8	penetrometer in trench
						8	drill site, etc.
						8	trench
147:39	KK*					8	pan at drill site
147:41	KK*	180				8	HFE photos
147:41	KK*	180				8	magazine out of film
148:03	OO		CDR	CDR		8	pan
148:32	OO		CDR	CDR		8	drill, trench area
148:58	OO		CDR	CDR		LM	flag, etc. (b/w film)
<u>EVA III</u>							
164:27	TT*		LMP	LMP		8	pan at drill site, photos of trench and Flag LMP requested to take pictures while on LRV
165:06	RR		LMP	LMP		9	try to fix camera--will cycle without film mag but won't advance film
	SS		LMP	CDR		9	pan
165:30	WW	76	CDR	500		9a	horizontal and vertical pans of far wall of rille, ≈20' from pan sta
165:37	SS		LMP	CDR		9a	big rock with horizontal vesicle alignment
165:47						9a	talus 50 percent down far wall
165:51	WW	86	CDR	500		9a	documented sample frag (from boulder?) "just this side of gnomon"
					275	9a	chip from bedrock?
165:55					278	9a	rake area
					281	9a	after sample representative loose frag surface
166:11	WW	120?	CDR	500			
	SS		LMP	CDR		9a	stereo(?) pan
			LMP	CDR		9a	stereo cross-sun? (scoop sample) gnomon vesicles
	SS		CDR	CDR	282	9a	rake samples - down sun
					283		soil sample
	SS		CDR	CDR		9a	core tube (U09, L14)
166:17	SS		LMP	CDR		10	rim (Twin?)
166:20	SS		LMP	CDR		10	pan
166:22	SS		LMP	CDR		10	4 x 5' block w/coarse vesicles
166:24	WW	155	CDR	500			
166:41	SS		LMP	CDR	en route	LM	w/Hadley in background
166:48	SS		LMP	CDR		LM	LRV, SWC
167:00	SS		CDR	CDR		LM	LRV saddle
167:39	SS		CDR	CDR		LM	battery mirror
167:49	SS	?	CDR	CDR		LM	"one last pan"

*color

Table 4. Estimated film usage per EVA

(70 mm only)

EVA	Mag	film type	camera FL	frames	Total for EVA
SEVA	LL	BW	60	33	
SEVA	KK	color	60	66	
SEVA	MM	BW	500	20	
					119
I	NN	color	60	76	
I	LL	BW	60	86	
I	MM	BW	500	31	
					193
II	LL	BW	60	61	
II	PP	BW	60	180	
II	NN	color	60	104	
II	KK	color	60	114	
II	MM	BW	500	129	
					588
III	TT	color	60	8	
III	SS	BW	60	180?	
III	WW	BW	500	155	
III	RR	BW	60	0	
III	OO	BW	60	?	
					343

Total frames	
color, 60 mm FL,	368
BW, 60 mm FL,	540
BW, 500 mm FL,	335

Total frames 1243+

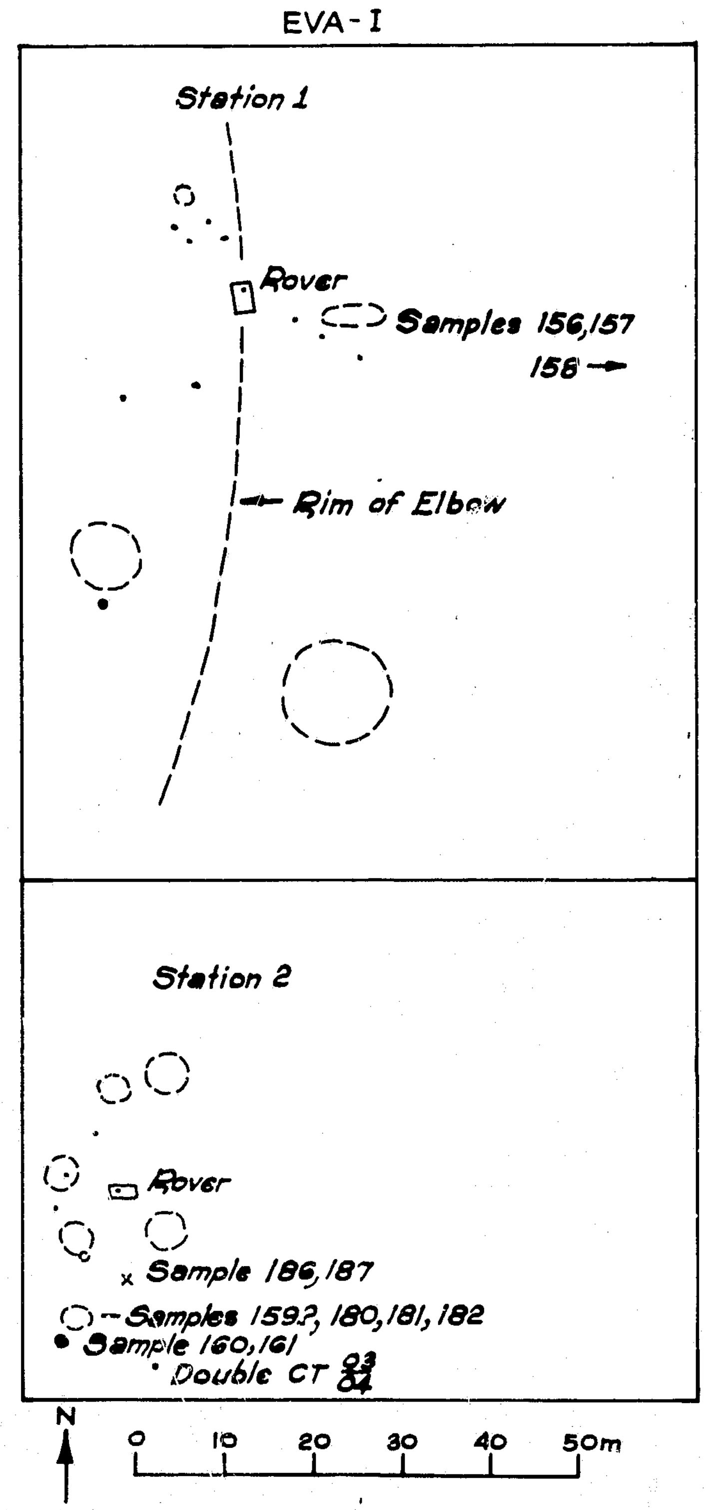


Fig. 3.--EVA I planimetric station maps

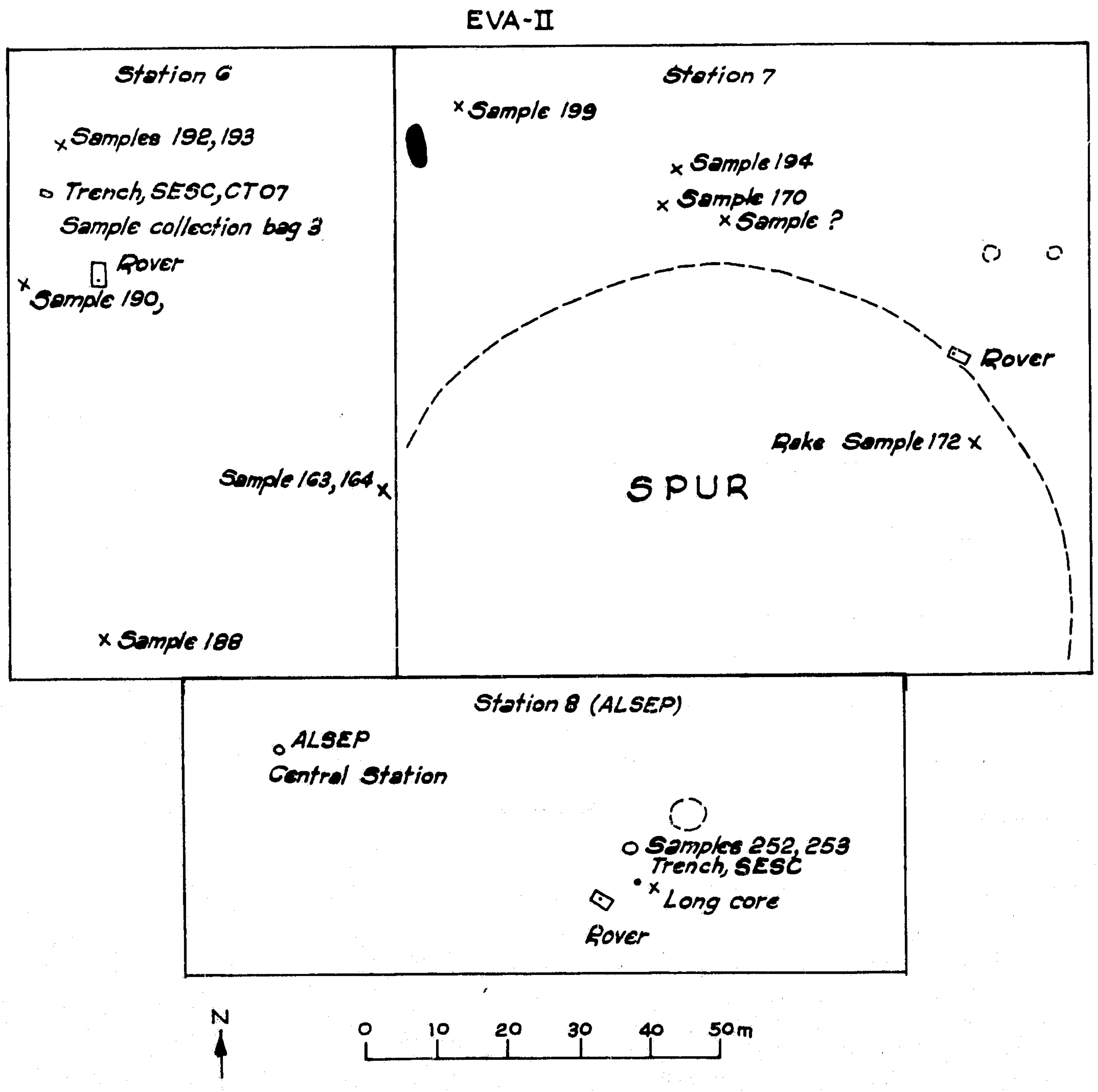


Fig. 4.--EVA II planimetric station maps

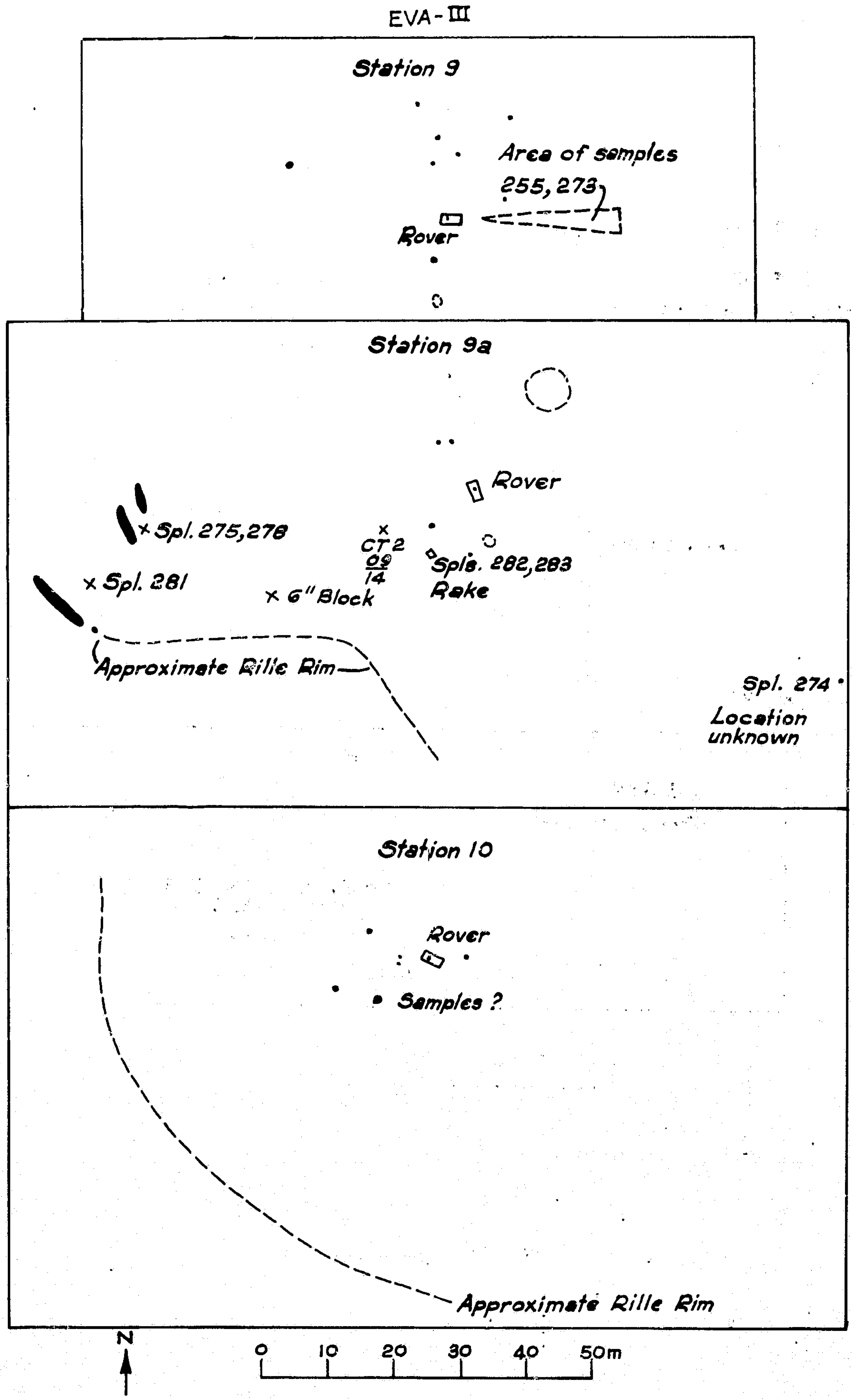


Fig. 5.--EVA III planimetric station maps

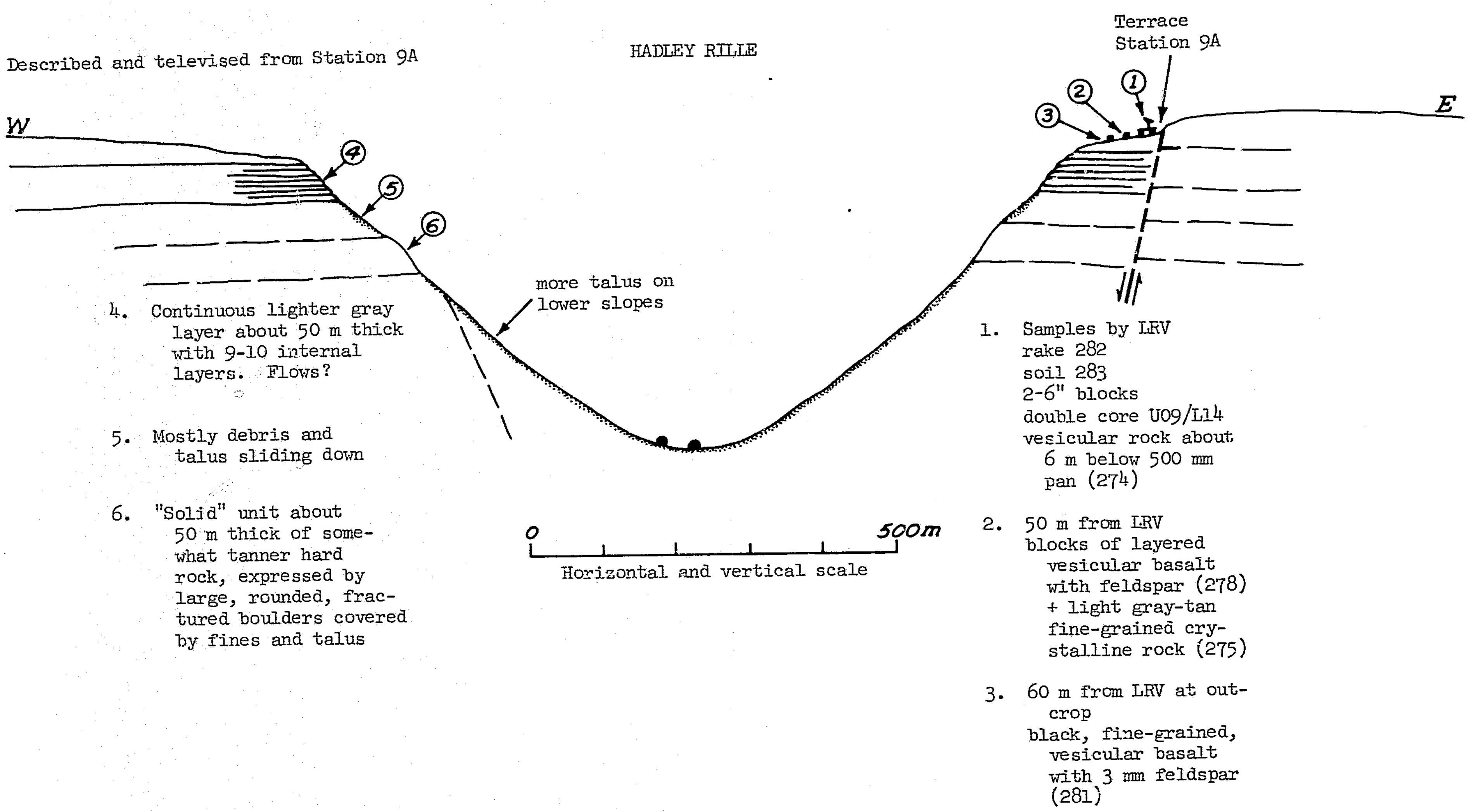


Fig. 6.--Geologic section across Hadley Rille

PRELIMINARY TRAVERSE MAP OF THE APENNINE HADLEY SITE APOLLO 15

by

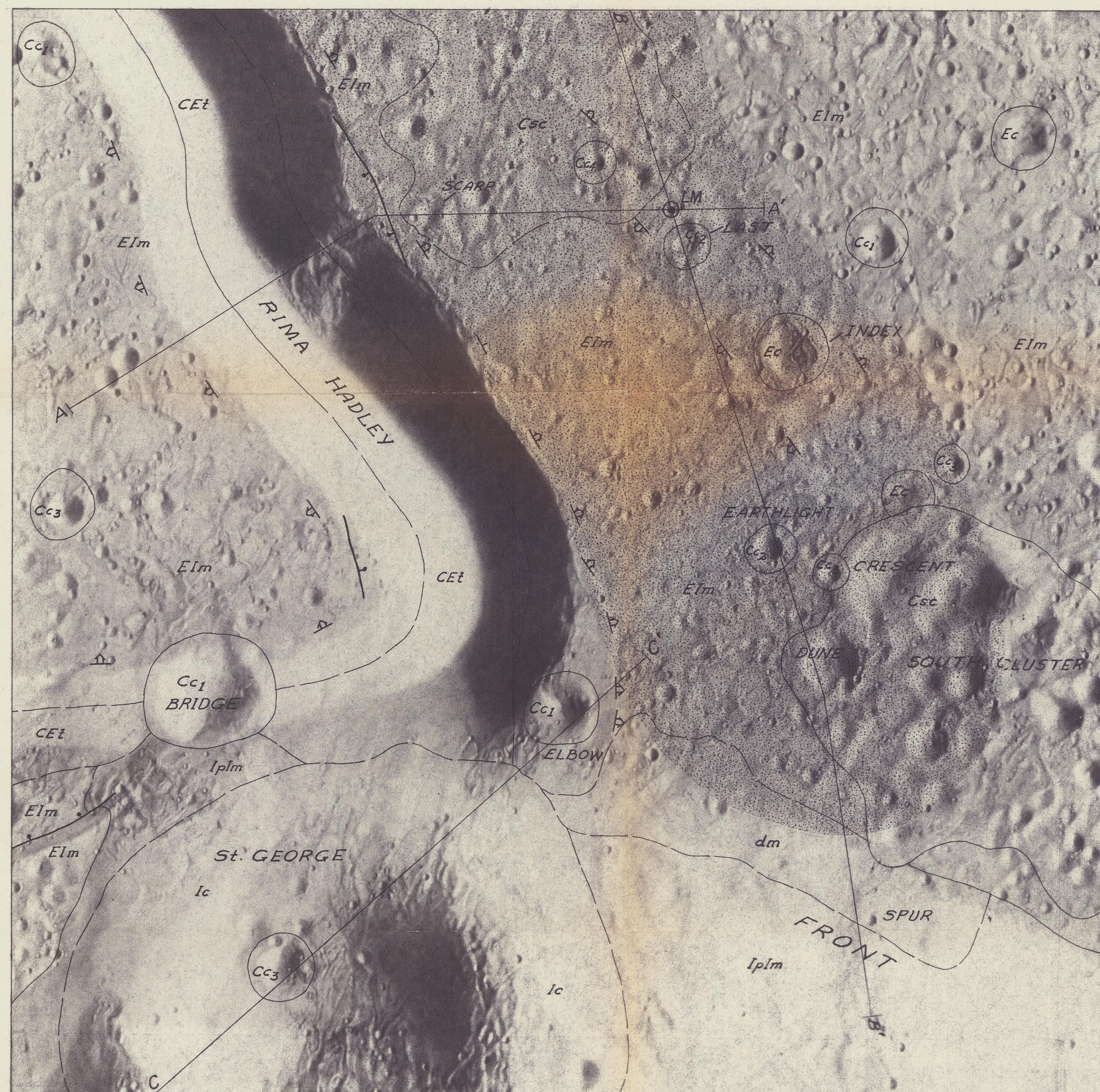
U.S. GEOLOGICAL SURVEY
LUNAR GEOLOGY INVESTIGATION TEAM
AUGUST 5, 1971

Fig.--1. Interagency Report 32

FOLDOUT FRAME 1 FOLDOUT FRAME 2 FOLDOUT FRAME 3 FOLDOUT FRAME 4

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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

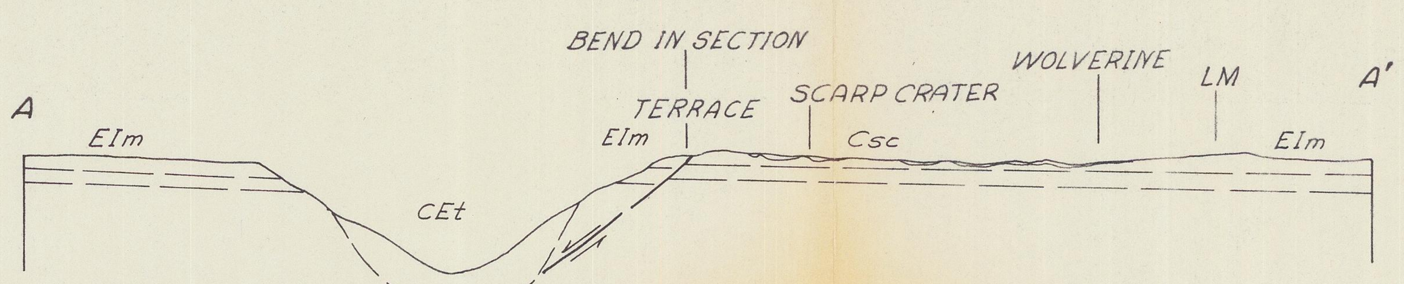


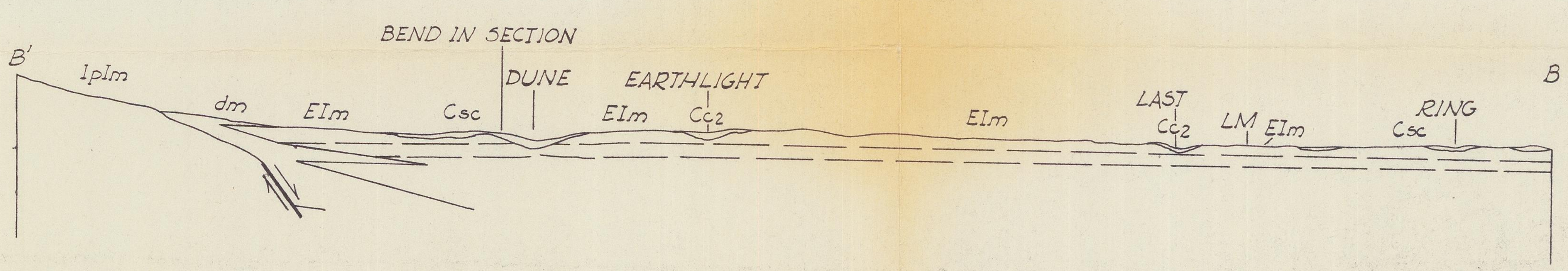
SHADED RELIEF BY PATRICIA M. BRIDGES
SOURCES: L.O. V 105-106

SCALE 1:25,000

PRELIMINARY GEOLOGIC MAP OF THE APPENINE-HADLEY SITE

AUG. 1971





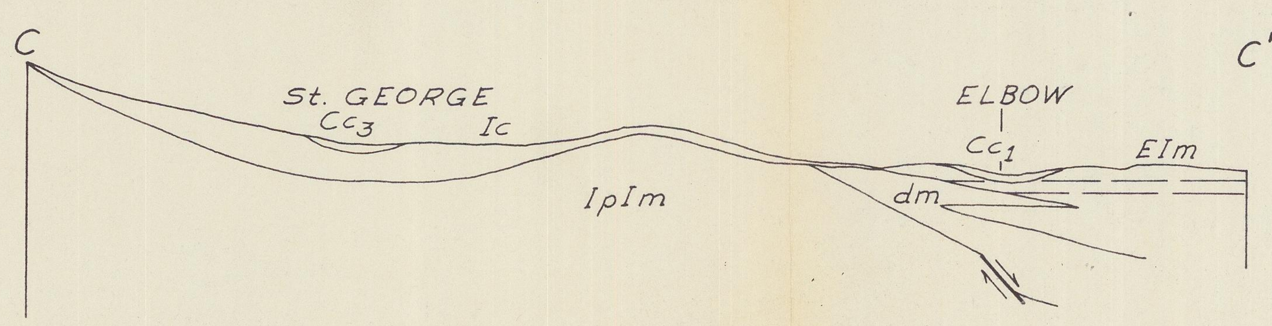


Fig. 2 -- Interagency Report #32

EXPLANATION

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. Craters in north cluster are very subdued gentle depressions; no blocks; secondary origin uncertain

Cc4 / Cc3 / Cc2 / Cc1

Crater material
Debris of circular impact craters, classified in an age sequence according to freshness. 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

COPERNICAN

dm

Debris of massif material
Diffuse darkish apron at base of slope; merges gradually both with massif material and with mare material

CEt

Talus deposits
Blocks as large as 20-30 m. Mainly mare basalt, but also includes massif material (breccia) in the vicinity of St. George crater. Basalt blocks tend to be more tan than fresh cliff exposures

Ec

Crater material
Mainly fine fragmental debris in and around shallow very subdued impact craters

ERATOSTHENIAN

EIm

Mare basalt
Section 150-200 m thick exposed in upper half of Hadley Rille; base not exposed. Upper third is multi-layered plagioclase-phyric and aphyric basalt; commonly vesicular; locally has pahoehoe-like surfaces. Middle third covered by talus in Hadley Rille, but ejecta blocks at Elbow and Dune craters suggest this unit is also plagioclase (±olivine?)-phyric basalt, locally vesicular. Lower third, not sampled, crops out as massive layer slightly more tan than upper third. Mare surface covered by several meters of regolith except near lip of Hadley Rille, where fines of regolith have apparently winnowed away to expose bedrock. Block fields that occur locally elsewhere on mare surface are probably ejecta from fresh craters

Ic

Material of St. George crater
Fragmental debris generally broken down to fines but locally including large blocks. Produced from massif material by the impact that excavated St. George crater

IMBRIAN

IpIm

Massif material
Breccia and microbreccia (locally layered) that have dark and light clasts. Either pre-Imbrian impact breccias or impact breccia from the Imbrium impact, or most likely both, mixed by down-slope mass wasting. Outcrops rare or absent; mantled by regolith with few blocks

IMBRIAN & PRE-IMBRIAN

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

Contact, dashed where position uncertain

Slump fault, ball on downthrown side

Apparent dip and strike

Slope gradient

FOLDOUT FRAME 5 FOLDOUT FRAME 6 FOLDOUT FRAME 7 FOLDOUT FRAME 8