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INTERAGENCY REPORT: 36

Preliminary description of Apollo 15 sample environments

by

G. A. Swann, M. H. Hait, G. G. Schaber,
V. L. Freeman, G. E. Ulrich, E. W. Wolfe,
V. S. Reed and R. L. Sutton

September 1971

This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards and nomenclature.

Prepared by the Geological Survey for the National Aeronautics and Space Administration

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Errata and additions
October 1, 1971

Page	
iv	Plate 2; top: Pan 14 should read "northwest"
iv	Plate 2; bottom: Pan 15 should read "northeast"
iv	Plate 3; top: Pan 16 should read "southeast"
vii	Figure 27: Delete "489" insert "498"
vii	Figure 30b: Delete "489" insert "498"
1	Line 3: After word "collected" insert "(558 and [565-587])." The brackets are explained on page 16.
8	Insert "•SWC Solar Wind Composition"
10	Station 4: •Delete "-487" insert ", 486" •Delete "478," insert "476"
10	Station 6: •Add "009" at "Core" •Delete "258" •Add "245" after "240-"
11	Station 7 •Delete "210-" after "Rake" •Add "315-392" after "308"
14-15	Table 2: •Sample 015 is partially oriented •Sample 415 and 445 are oriented •Samples 465, 469, and possibly 467, were broken from the same rock and should be shown as:

465	374.8
467?	1.1
469	1.2

73	Caption: Delete "489", insert "498"
81	Caption: Delete "489", insert "499"
219	100-105: Delete "*"; change page to 54
219	After "435" insert "(431-437)"
219	485-487: Should read "485, 486"

Plate 2, pan 14: Should read "northwest"

Plate 2, pan 15: Should read "northeast"

Plate 3, pan 16: Should read "southeast"

Plate 4, pan 4: Samples 070-076, and 080-088 are shown incorrectly here, but correctly in Figure 12, p. 37.

Plate 1-12: The cardinal directions for each panorama are contained in the photograph numbers. Blanks are directions not covered by a pan.

	North	East	South	West
Pan 1	11361	11366	11372	11382
2	11737	11743	11749	11758
3	11397			11384
4	11401	11406	11411	11415
5	11425	11429	11434	11438
6	11451	11456	11460	11465
7			11584	
8	11475	11479		
9	11485	11490	11495	
10	11509	11513	11518	11522
11	12183	12189	12193	12198
12	12205	12210	12216	12222
13	12242	12247		12238
14	11790	11794	11800	11804
15	11809	11813	11817	11821
16	11837	11834	11828	11822
17	11845	11851	11854	11858
18	12422	12428	12433	12438
19	11881	11054	11059	11064
20	11070	11080	11086	11092
21	11114	11118	11122	11127
22	11170	11175	11179	11184
23	11902	11911	11918	11893
24				11932

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PRELIMINARY DESCRIPTION OF APOLLO 15 SAMPLE ENVIRONMENTS

INTRODUCTION

Approximately 78 kg of lunar rock and soil samples were returned by Apollo 15. The locations are known from which all but two large samples were collected; many of the locations are known to within a meter or less relative to nearby features that can be resolved on the panorama camera photographs. The rather complete documentation of nearly all of the samples allows for relating the samples to the specific and detailed geologic environments from which they were collected. This is especially important in an area as geologically complex as the Hadley-Apennine site (see for example report by Apollo Lunar Geology Investigation Team, 1971).

This preliminary report is intended to provide a background for the Lunar Sample Analysis Planning Team during its considerations for Apollo 15 sample distribution to Principal Investigators, and to provide a detailed geologic context to the Principal Investigators as they analyze the samples.

It was obvious that for this report to fulfill its intended purpose that it would have to be quickly prepared and distributed. Because of the time element, much of the material presented here is not entirely consistent in format, but we feel that early distribution

is more important, or at least more imperative, than a totally consistent manner of presentation. Unfortunately, some errors are bound to show up. For example, Lunar Receiving Laboratory sample number 508 (the prefix 15- is omitted from all LRL numbers in this report) was combined as a part of 505 after Plate 11 was printed for the report (see table 1 for changes in sample numbers at time of writing). Other less excusable errors will also appear, and we hope that our readers will point out these errors to us.

Many of the data contained in the report are being constantly upgraded, for example, the Station locations (fig. 1), the Station maps (figs. 2-5) and locations of features shown in the panoramas (plates 1-12). The upgraded versions will be distributed in later reports.

All of the material presented here was derived from the pre-mission photogeologic maps (Carr and El-Baz, 1971; Howard, 1971; Schaber and Head, 1971; from the lunar surface television video tapes; the air-to-ground transcript and crew debriefings; photographs taken on the lunar surface by the Apollo 15 crew; and information generously supplied by the Lunar Sample Preliminary Examination team from which we categorize the samples into groups consisting

of, broadly, basalts and breccias. The breccias may be considered loosely in terms of two subgroups: "coherent breccias" and "soil breccias." Our concept of "soil breccia" is that they are rocks produced by a one-stage lithification of regolith material. First stage lithification generally appears to be inefficient, so that the rocks commonly are friable. Both unconsolidated soil and "soil breccias" are characterized by an abundance of clastic glass and glass beads, and both commonly contain lithic debris both from the mare and from the front. In contrast, our use of the term "breccias" implies that they are typically much better lithified, i.e. coherent. The "breccias" lack fresh clastic glass and mare-type basalt clasts. These criteria are not mutually exclusive, and, indeed, there appears to be a group of coherent breccias resulting from repeated lithification of soils. Hence, specific assignments remain tentative, and are made only to show, under this breakdown of rock types, how they may relate to the photogeologically mapped units.

Much of the interpretive material in this report is based on data that are, at least at the time of writing, rather incomplete. The interpretations are meant to serve as ideas that may be useful for a more complete synthesis of the data. Many illustrations

are used, partly to help the reader judge for himself what is fact and what is speculation. The more serious reader and critic is urged to go to the actual photographs, refer to all of the photographs that apply to the specific subject (see Sutton et al., 1971; Batson et al., 1971, for photograph and subject matter listings), and to make ample use of the stereoscope.

The scales that appear on most of the photographs or the accompanying sketch maps were derived by fitting a perspective grid to an object of known size. The scales are at best approximate, and apply only to areas of level, uniform slope. Sketch maps accompany the photographs where they aid in description or interpretation; otherwise annotated photographs are used.

Table 1. Summary of combined sample numbers. The present numbers reflect the true affinity of individual fragments as pieces that broke from a specific sample after it was collected. Asterisks indicate pieces that weigh 25 g or more.

Present number		Former numbers
288,0*,1	=	288* and 258
475,0*,1*,2	=	475* and 477* and 478
485,0*,1	=	485* and 487
505,0*,1;506?,508?	=	505* and 506? and 508
515,1*-48	=	515? and 516?

NOTE: 515,1*-48 is the exception and represents two samples that were collected (515 and 516) and broken beyond recognition, with the resulting fragments numbered as shown.

Figure 1. Geologic map of Hadley-Apennine site showing distribution of rock types larger than 20 g (rake samples excluded). (Adapted from Apollo Lunar Geology Field Team report, 1971.)

Explanation

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

Csc

Material of secondary craters
Fragmental debris produced from mare basalt by impact of secondary projectiles from Autolycus or Aristillus.

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.

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.

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

——— — —	Contact, dashed where uncertain
——•———	Slump fault, ball on downthrown side
⊥	Apparent dip and strike
⇧	Slope gradient
•Sta 2	Station location
1br, 2sb, 3bt	Numbers of rock types sampled br, breccia; sb, soil breccia; bt, basalt

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 downslope mass wasting. Outcrops rare or absent; mantled by regolith with few blocks.

IMBRIAN AND PRE-IMBRIAN

x	location of samples
200, 206	LRL sample numbers
▭	LRV, dot shows TV camera
●	large rocks
◯	crater rims or other topographic features
Pan 7 △	panorama stations

Figure 2. Explanation for station maps, Figures 3-5.

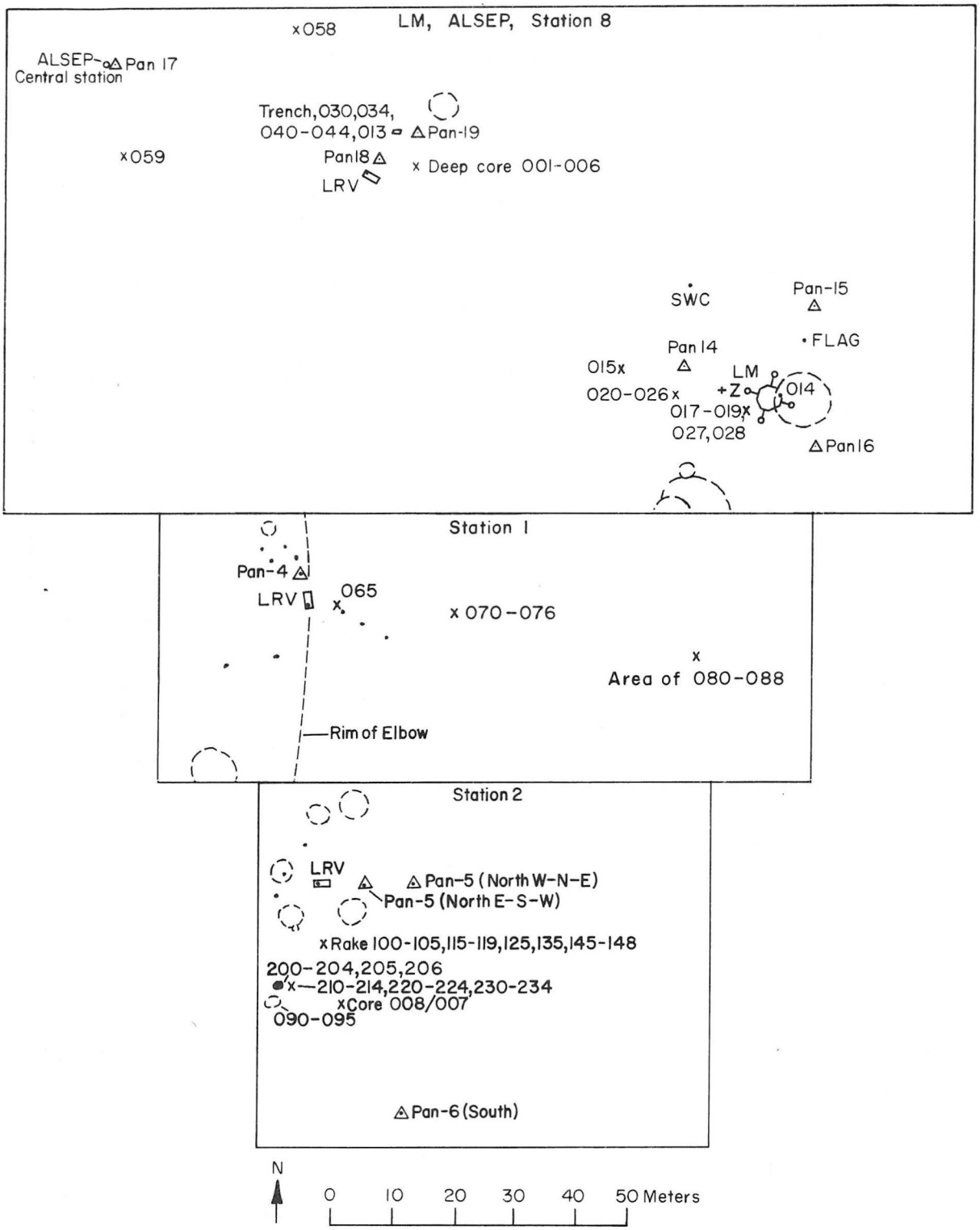

Figure 3. Planimetric station maps for LM area, ALSEP area, Station 8; Station 1; Station 2.

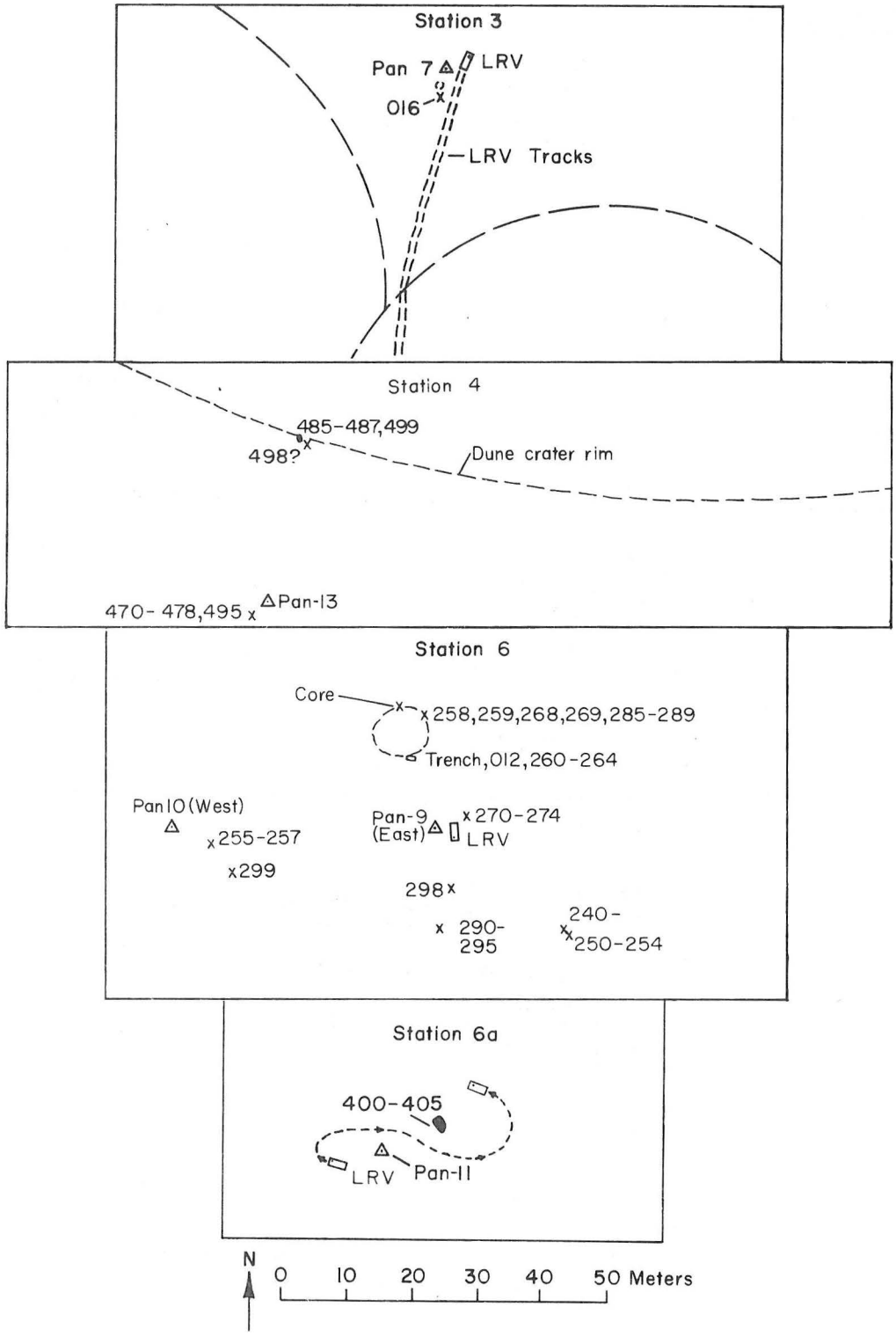

Figure 4. Planimetric station maps for Stations 3, 4, 6, and 6a.

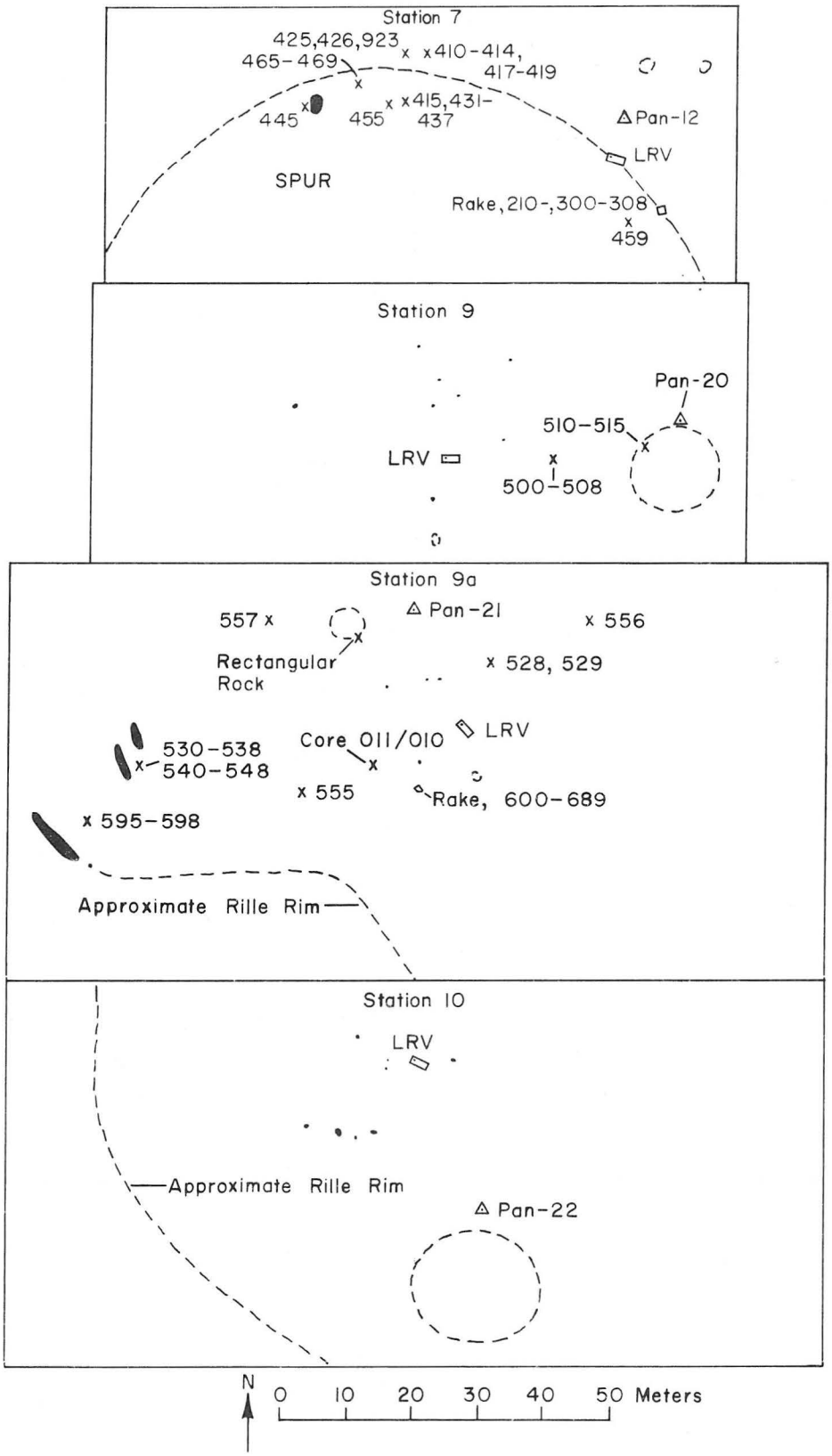

Figure 5. Planimetric station maps for Stations 7, 9, 9a, and 10.

ACKNOWLEDGMENTS

We are grateful to the Lunar Sample Preliminary Examination Team, and especially to Howard G. Wilshire and Leon T. Silver, for supplying us with information on the samples that are being examined in the LRL. We once again acknowledge the underpaid efforts of the Technical Support Unit, Center of Astrogeology, U.S. Geological Survey, in the preparation of the illustrations and the printing of the report.

DISTRIBUTION OF SAMPLE TYPES

The distribution of the rock types represented by the returned samples is shown in Figure 1 and is summarized in Table 2. The samples shown on the map are those that weigh more than 20 g. The soil, rake, and core samples are not included. The purpose of the map is to show the types of rocks collected from within the photogeologically mapped units that may represent materials formed or deposited in the site as mappable units by specific geologic events. Only those rocks that weigh more than 20 g are considered; primarily for this reason the rake samples are excluded (although a few fragments collected with the rake weigh more than 20 g).

The rake samples are statistically representative of materials in a rather restricted, small size range. Shoemaker et al. (1970) have shown that the smaller the fragment, the higher the probability that it has been transported from a source foreign to the site. Thus the smaller fragment population is more representative of the whole moon than the larger fragment population because the smaller fragments have a higher probability of being randomly and continuously transported from distant sources; conversely the smaller fragments that are indigenous to the site have a higher

Table 2. Cross reference of Apollo 15 rock samples, weights, station numbers, general rock types, and status at time of writing of recovering the lunar orientation. See end of table for explanation of symbols and notes.

LRL number	Weight in grams	Station	Breccia	Soil breccia	Basalt	Nature of associated glass, if present	Status of recovering orientation
015	4515	LM	1			coating	
016	923.7	3			1		x
025	77.3	LM		1?			too far away
027	51.0	LM		1			x
028	59.4	LM		1			x
058	2672.5	ALSEP			1		x
059	1149.2	ALSEP	1			coating	x
065	1475.5	1			1		x
075	809.3	1			1		x
076	400.5	1			1		x
085	471.3	1			1		x
086	216.5	1		1			x
095	25.5	2	1			coating	in shadow
[205	337.3	2	1			coating	x
[205,1	1.6						
206	92.0	2	1				
245,1-90	116.58*	6		1		splash	broken
255	240.4	6	1			coating	x
256	201.0	6			1		x
257	22.5	6	1?				not documented
{265	314.2	6		1?			x
266	271.4						
285	264.2	6		1?			x
286	34.6	6		1			too small
287	44.9	6		1			too small
[288,0	62.6	6	1				
288,1	7.6						
289	24.1	6		1			
295	947.3	6		1			broken
298	1731.4	6		1		coating	too fragile
299	1691.7	6		1		coating	too fragile
405	513.1	6a	1				broken
{ 415	269.4	7		1			too fragile
[435,1-17	57.5*						
435,18	49.1						
435,19	9.6						
435,20	58.3						
435,21-32	32.3*						
418	1140.7	7	1				x

Table 2. Continued

LRL number	Weight in grams	Station	Breccia	Soil breccia	Basalt	Nature of associated glass, if present	Status of recovering orientation
425	136.3	7	1			green glass spheres and angular glass	broken
426	223.6	7	1			green glass spheres and glass	broken
445	287.2	7	1				
455,0	885.4	7	1				broken
455,1-23	53.1*						
459	4828.3	7	1?				tentatively
465	374.8	7		1		coating	x
466	119.2	7		1		coating	
475,0	298.2						
475,1	85.2	4			1		x
475,2	23.4						
476	266.3	4			1		x
485,0	102.2						partially
485,1	2.7	4			1		
486	46.8						partially
499	2024.0						x
495	908.9	4			1		x
498	2339.8	4		1		coating	tentative
505,0	1140.3						
505,1	7.1	9		1?			x
506?	22.9						
508?	1.4						
515,1	59.3	9		2?			broken
515,2-48	85.4*						
529	1531.0	9a			1		x
535	404.4	9a			1		x
536	317.2	9a			1		x
545	746.6	9a			1		not located in photos
546	27.8	9a			1		not located in photos
547	20.1	9a			1		
555	9613.7	9a			1		x
556	1538.0	9a			1		x
557	2518.0	9a			1		x
558	1333.3	9→LM		1?			no documentation photos

Table 2. Concluded

LRL number	Weight in grams	Station	Breccia	Soil breccia	Basalt	Nature of associated glass, if present	Status of recovering orientation
[565 - 587]	735.2*	9→LM		1?			No documentation photos
{595	237.6	9a			1		x
{596	224.8						x
597	145.7	9a			1		Not located in photos
598	135.7	9a			1		Not located in photos

? - uncertain identification of rock type

[ ]- one sample that broke

{ }- multiple samples collected from the same rock

* - total weight of a sequence of fragments that weigh less than 20 g each

Note 1. See sample 515, 1-48: This one series of sample numbers represents two separate rocks that were subsequently broken and mixed.

Note 2. Fragments less than 20 g in this table have broken from larger fragments.

Note 3. Status of recovering orientation: An "x" indicates that the fragment has been oriented as it was photographed on the lunar surface. Those without "x" have not been oriented at the time of writing, or could not be oriented for the reasons indicated.

probability of being randomly and continuously transported away from the site, the total effect of which skews the range of sample types in the small fragment population away from the composition of the units formed or deposited in the site by specific geologic events. However, a rake sample, because of its large number of individual fragments, will almost certainly include pieces of the local geologic units. The problem is identifying which fragments are the ones that are representative of the local units, and which are exotic.

Breccias, and soil breccias probably formed from regolith derived from the breccias, are predominant at Stations 2, 6, 6a, and 7 (fig. 1). This was expected because the Apennine front should be mantled by a thick layer of material similar to the Fra Mauro Formation samples returned by Apollo 14. Present contamination of the surface around Stations 6, 6a, and 7 by mare basalts derived from the South Cluster of secondaries (fig. 1) should be slight. Although at the time of formation of the secondary cluster an appreciable amount of mare material was probably strewn over the surface of the lower part of the front near Stations 6, 6a, and 7, the event was long enough ago that this material has since been gardened into and diluted by the fragmental, breccia-derived, debris of the front.

Samples collected at Stations 1 and 4 are predominantly basalts, which were excavated from the mare flows of Palus Putredinis by the impact events that formed Elbow and Dune craters. Appreciable contamination by breccias derived from the nearby Apennine front seems reasonable. All of the larger samples collected from Station 9a at the rim of Hadley Rille are basalt. At this station the regolith is thin over the mare basalts (see Station 9a description, this report).

The samples from Station 9 are from an unusually recent crater that did not penetrate the regolith and are soil breccias.

Some of the samples collected in the LM-ALSEP-Station 8 area are breccias, and may represent Imbrium basin ejecta that was re-excavated from below the mare fill by the Aristillus or Autolycus event, and redeposited in the site as the ray shown on the pre-mission photogeologic maps (Carr and El-Baz, 1971; Howard, 1971; Schaber and Head, 1971). Consideration of cratering mechanics and the locations of Aristillus and Autolycus within the Imbrium basin suggest that some of these samples may have been originally derived from deep within the moon by the Imbrium event. It is also possible that breccias in this area were, at least in part, derived from impact events on the mountain front.

SAMPLE ENVIRONMENTS

The discussions of the sample environments are arranged in order of ascending traverse station numbers, beginning with the LM site. The ALSEP site is described after the LM site. The samples are arranged according to ascending number under each station where they were collected, except where more than one sample is described; in this case they are arranged in the total sequence according to the number of the first sample described. The explanation for the sample environment sketch maps is shown in Figure 6.

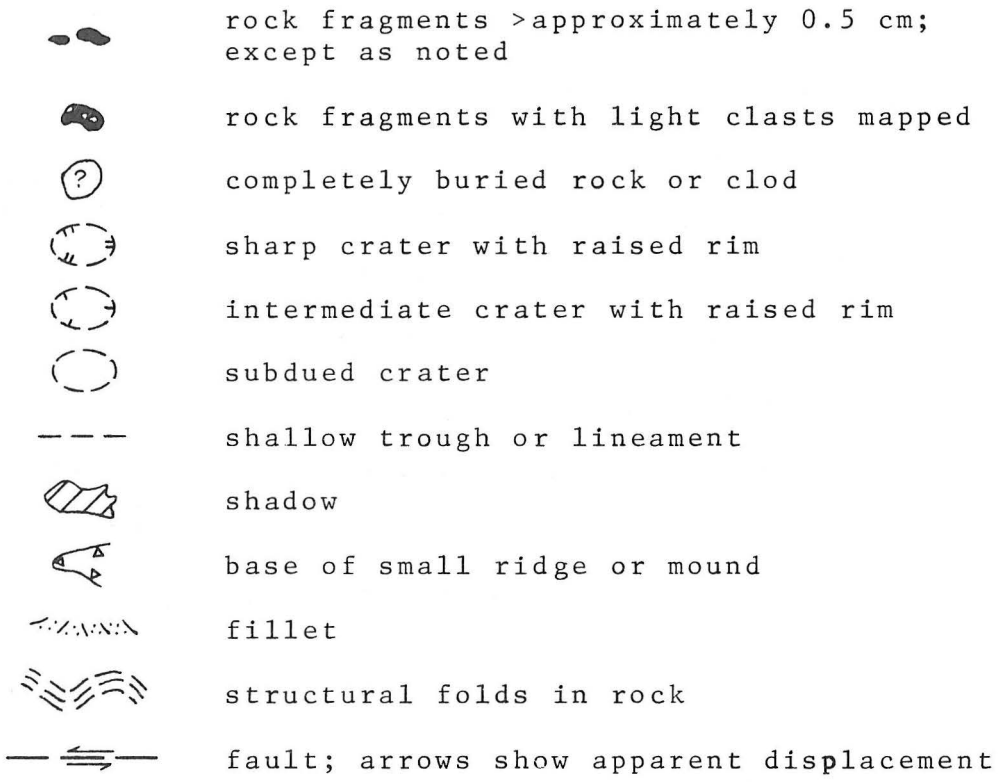

Figure 6. Explanation for sample environment sketch maps.

LM area

The surface material in the vicinity of the landed LM (fig. 1) is fine-grained with less than 2 percent of the surface covered by particles larger than pebble-size. Distinct craters larger than a few meters in diameter are widely separated, and only those less than 25 cm across are closely spaced. Subdued craters in the one-meter size range overlap one another. Small lineaments that appear to be of natural origin are not visible, although streaking from the descent engine exhaust is present. Because the surface is very hummocky in detail, no regional slope is visible from surface photography (plates 1, 2, 3).

Twelve samples were collected from an area approximately 8 x 20 m just west of the LM (fig. 3).

Sample 014.--Contaminated soil sample 014 was collected from an area disturbed by blast from the DPS engine just north of the LM. The documentation photographs show a faint streaking caused by alignment of centimeter-size fragments (probably clods of soil) during descent (fig. 7). Also shown is considerable later disturbance caused by astronaut activities. The surface appears to be that of a slightly cohesive soil layer above which fine loose materials were removed entirely as dust and centimeter-sized particles were moved into the noted alignments.

Sample 014 can be considered representative, except for contamination, of the rim material on the northwest side of the 6-m diameter crater upon which the LM landed.

Sample 020-026 (contingency sample).--Samples 020-026 were collected in the contingency sample approximately 12 m west of the LM +Z footpad (fig. 3).

The site of the contingency sample is visible in photographs taken from the LM window (fig. 8). The surface material is soft and is composed of fine-grained regolith material. Scattered fragments distinctly larger than any in the fines appear to rest on about 2 percent of the surface. One of these fragments is probably sample 025, a 77 g breccia; it is of about average size for the larger fragments in the local area (fig. 8). Subdued craters in the one-meter size range are common near the sample site, which was located on a small flat between two such craters. The photographs that include the site were all taken from too great a range to show details in fillets, albedo, dust coating, and depth of burial (plate 3, pan 3).

The fine-grained material in the contingency sample is seemingly representative of the surface material near the LM. Rock 025 appears in the photographs to be typical of the larger fragments that

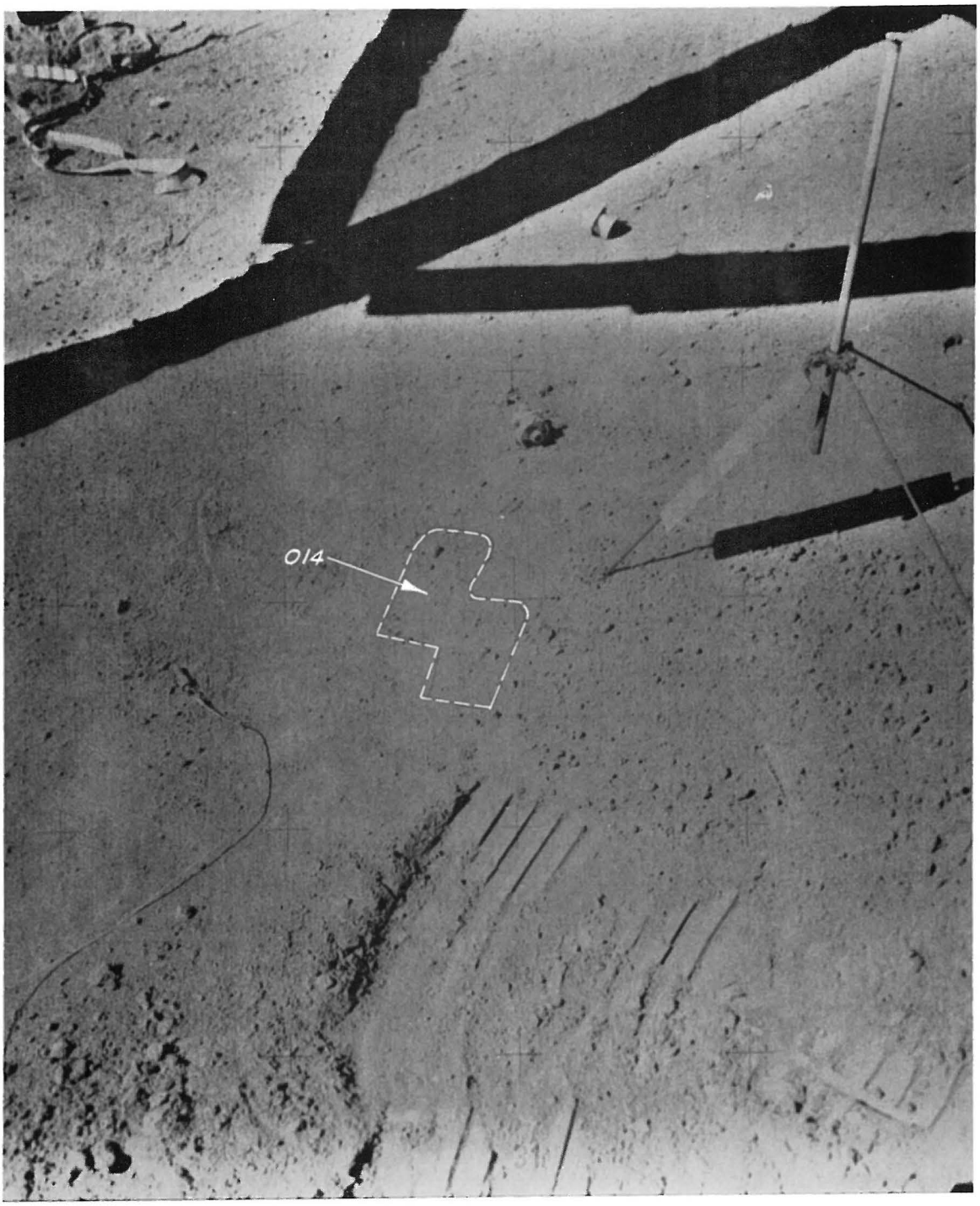

Figure 7. Sample 014, collected adjacent to the LM at at its northeast quadrangle. Note faint streaking from upper right to lower left caused by exhaust. Pre-sampling, cross-sun photograph AS15-88-11884, looking south.

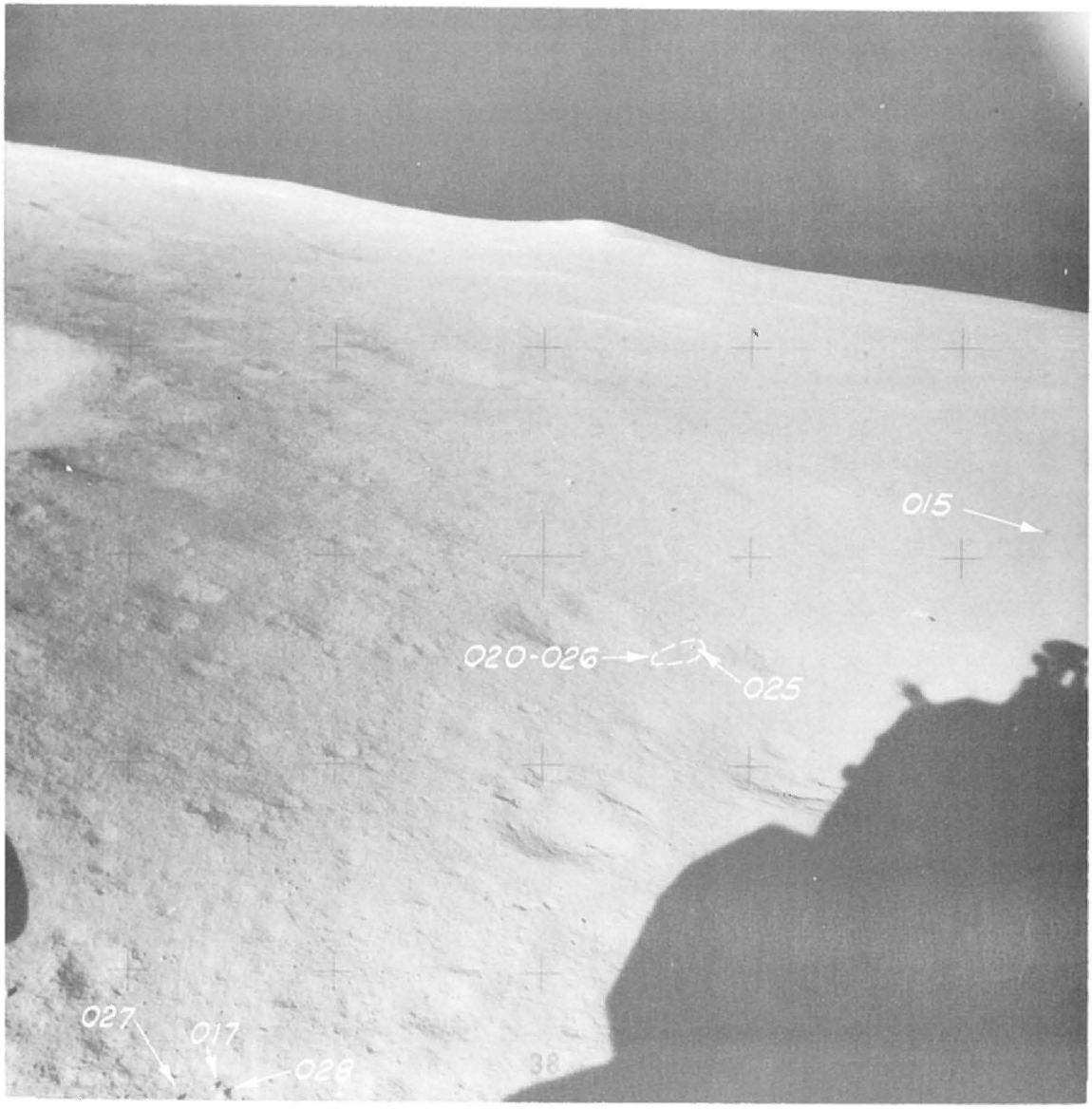

Figure 8. Samples 015, 017, and 020-028, collected adjacent to the LM. Pre-sampling LM window photograph AS15-85-11388, looking west.

rest on the surface. It is not clearly related to any particular nearby crater, nor can it be identified as having been excavated from the soil nearby or projected into its collection site from afar.

Sample 015.--Sample 015 is a large, glass covered breccia which was collected about 20 m west of the LM +Z footpad (fig. 3). The sample was not documented and no details of the local area are available. In general the area is flat and smooth, and no fresh craters and no other fragments of comparable size to sample 015 are visible in the vicinity (plates 1, 2, 3). The sample is distinctly lower in albedo than other cobble-sized fragments visible in photographs taken from the LM (fig. 8).

Astronaut Scott (personal communication) commented that sample 015 was rather unique in appearance as it lay on the lunar surface. As it cannot be related to nearby rocks or craters, it cannot be said to be representative of any particular unit or locality.

Samples 017-019, 027, 028.--Samples 017-019, 027, and 028 were collected from within a subdued 1 m diameter crater located about 4 m south of the LM +Z footpad (fig. 3). Much of the surface was disturbed before the sample area was documented (fig. 9). Samples 018 and 019 have not been identified in the photographs, but the general surface description applies to these samples.

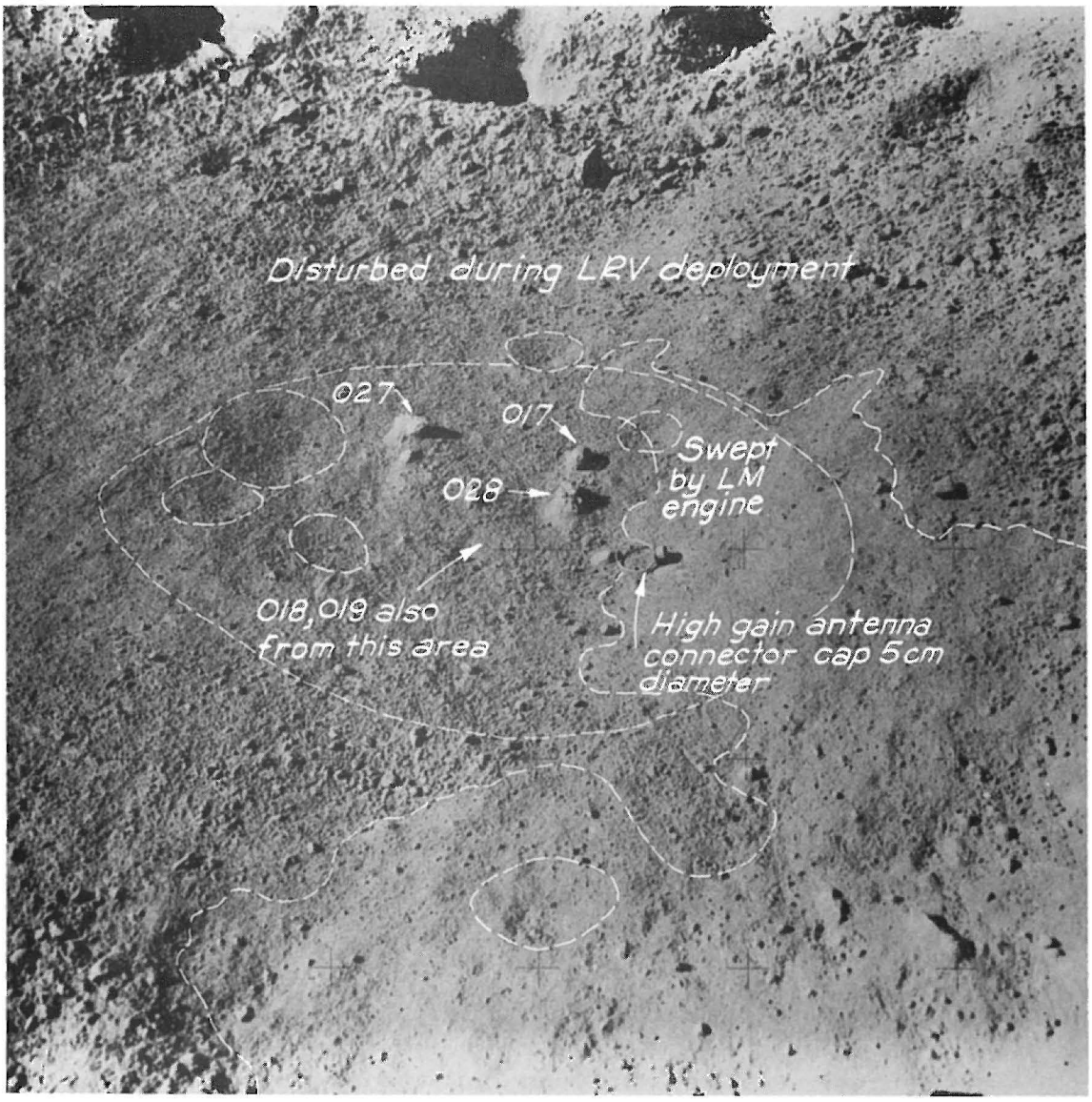

Figure 9. Samples 017-019, 027 and 028, collected west of the LM. Pre-sampling, cross-sun photograph AS15-86-11604, looking south.

The surface material is fine-grained with rare fragments as large as 4 cm across. The samples were in a cluster distinctly apart from other fragments of equal size. The crater containing the collected rocks adjoins two other subdued craters of similar size. Distinct smaller and younger craters are present but scattered. Well developed fillets were banked against the two glassy breccia samples (027, 028) but no fillet is visible against the glass sphere (017). The albedo appears low for 017 and moderate for 027 and 028. The irregularly rough surface texture appears similar in the photographs for all three samples. The obvious difference seen in pre-sampling photographs between sample 017 and the glassy breccia is the rounded shape of 017 and the angular shape of the breccias. The three particles lay on the surface; less than one-fourth of the samples were buried if the fillets are not considered (fig. 9).

The association of the three samples and the other fragments in the cluster with the subdued crater suggests a relationship; however, the crater appears much too old for the cluster to be residuals of that impact. The impacts that formed the small craters within and adjacent to the subdued crater may have excavated the fragments from the local soil. It seems equally likely that at least some of the rocks formed the small craters.

Except for the glass sphere (017) the samples and nearby rocks are similar in size, shape, albedo, and texture. They are also similar, but more "weathered" appearing, to clods of soil kicked up by the astronauts. It seems probable that samples 027 and 028 are representative of the fragments of equal size in the surface material near the LM. Sample 017 is not typical of the area although it possibly could have formed during an impact event in the vicinity; if so, it has been moved at least once since its formation.

ALSEP area

Samples 058 and 059 were collected from the vicinity of the ALSEP (plate 10; fig. 3). The surface in this area is generally flat and smooth, but hummocky in detail. The surface material is fine-grained with cobble-sized fragments covering less than one percent of the area. These larger fragments are widely scattered; that is, no clusters or linear arrangements are noticeable in the available photographs. Large craters in the area are subdued and small fresh craters also appear smooth owing to a lack of clods on their rims.

Sample 058.--Sample 058 was collected about 30 m east northeast of the ALSEP central station site, which is located about 125 m northwest of the LM in an area of smooth hummocky surface on the mare (fig. 3). The surface near sample 058 has a "raindrop" appearance with scattered subdued craters less than 1 m across. The surface material is fine-grained with pebble-sized fragments. Cobble-sized rocks are widely spaced. Lineaments are not visible upon the generally flat surface (plate 10; fig. 10).

Sample 058 is a basalt that in the documentation photographs appears angular, rough surfaced and without visible dust coating. No fillet is seen and the rock projects above the surface suggesting it was less than 1/4 buried. The photographs do not show other cobble-sized

rocks in the vicinity clearly enough for comparison with 058. No small crater can be linked with the sample. The sample probably is a recent arrival at the collection site after being ejected from an unknown locality.

Sample 059.--Sample 059 was collected about 15 m south of the ALSEP central station (fig. 3). Much of the vicinity of sample 059 was disturbed by footprints prior to documentation (fig. 11). The general setting is the same as for sample 058 which is about 35 m to the southwest (plate 10, pan 18). The local area is also similar: a rather smooth hummocky surface of pebbly fine-grained material with rare cobble-sized fragments. The sample, a glass coated breccia, appears very rough and angular, of low albedo, full of dust, and without a definite fillet although it may rest upon a small mound. One corner of the rock overhangs the surface and the general appearance is that the rock rests entirely upon the surface. The features of the rock suggest it is a recent arrival at the site. No impact crater can be linked with the rock. The local setting of the samples gives no clue as to its origin.

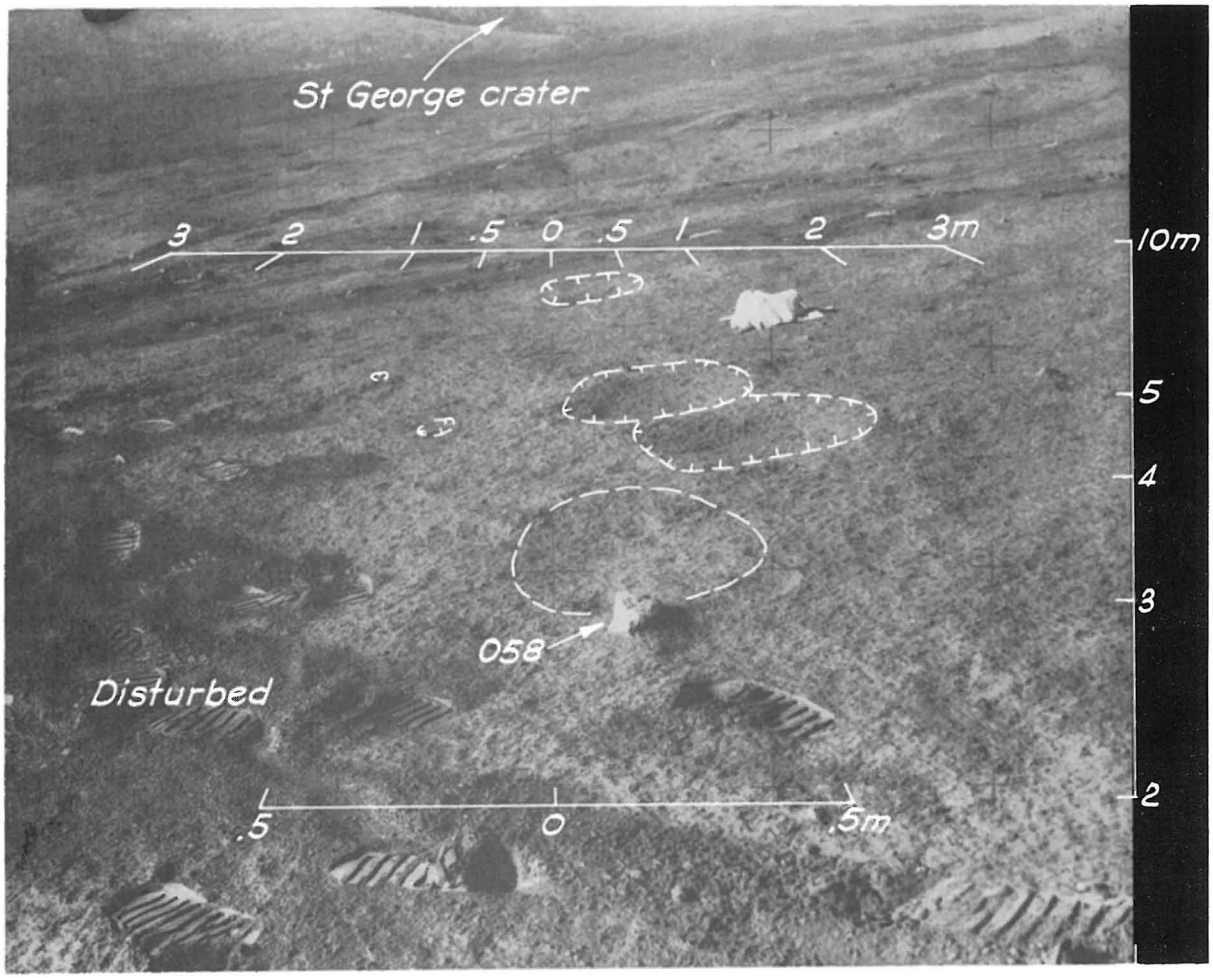

Figure 10. Sample 058, collected near the ALSEP. Pre-sampling, cross-sun photograph AS15-92-12410, looking south.

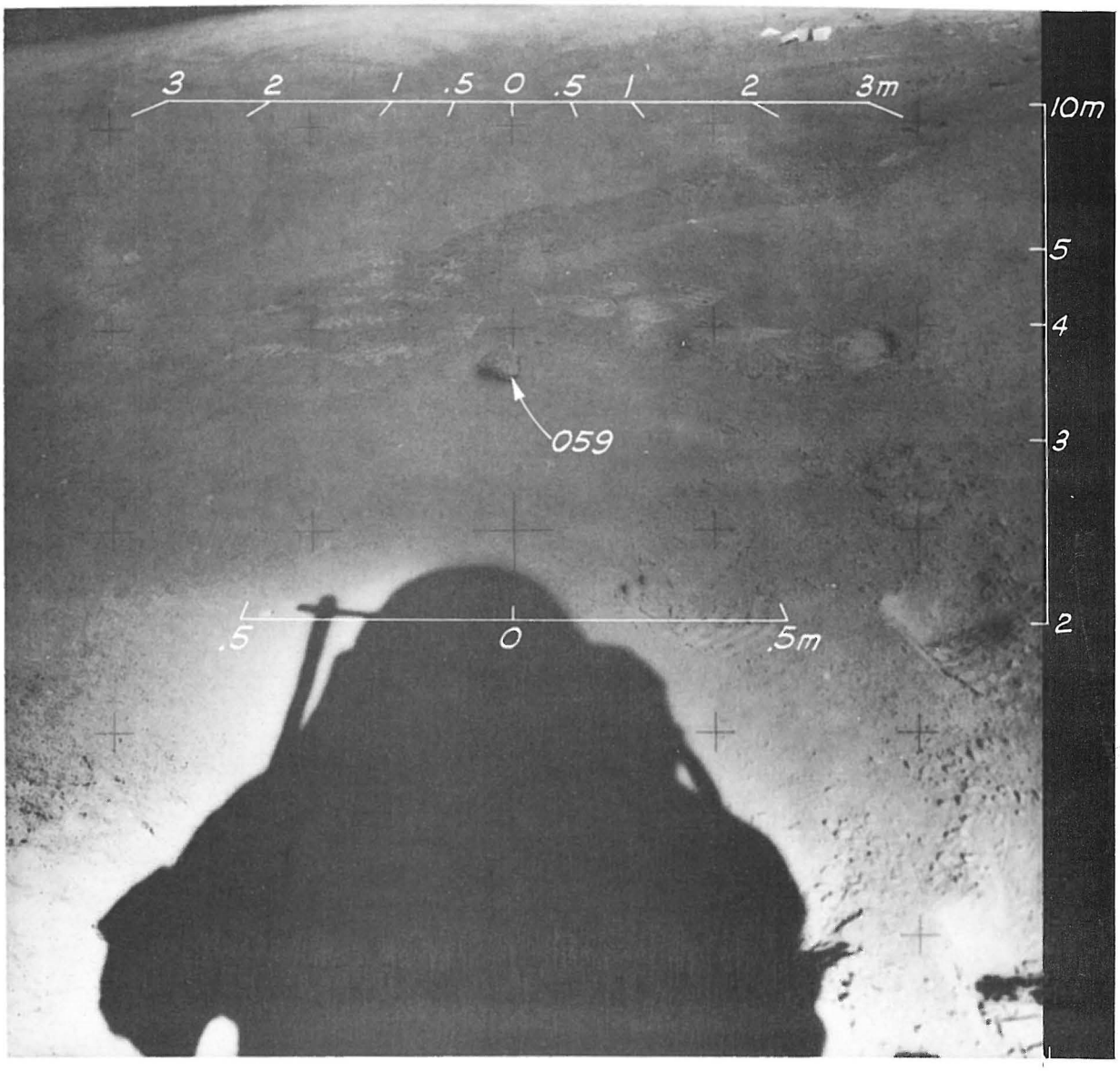

Figure 11. Sample 059, collected near the ALSEP. Pre-sampling, down-sun photograph AS15-92-12413, looking west.

Station 1

Station 1 is located on the east rim of Elbow crater, a crater about 400 m in diameter (fig. 1). The LRV was parked on the crest of the rim and a three-part radial sample was taken along a line extending to the east (plate 4; figs. 3, 12). Sample 065 was collected at a site about 4 m east of the rim crest. Samples 075 and 076 (rocks) and samples 070-074 (soil) were collected at a site about 25 m east of the rim crest. Sample 085 and 086 (with some soil) were collected at a site about 60 m (about 1/6 of a crater diameter) east of the rim crest. All samples from Station 1 are from the area of the ejecta blanket of Elbow crater.

Elbow crater, a relatively old Copernican-age crater (fig. 1), was formed by an impact into the rim of Hadley Rille where the rille bends sharply. North of Elbow crater the mare surface extends from the rille to both east and west, and west of Elbow crater the mare surface extends to the north of the rille. The surface to the south is on the slope of Hadley Delta. Elbow crater is located in the mare about half a kilometer north of the foot of the Hadley Delta slope. The expectation was that the Elbow impact ejected mostly mare basalts, and perhaps some breccia

from overlying regolith and debris from the slope. The preliminary examination of the five returned rocks showed four to be basalt and one to be breccia, which is consistent with what was expected, but the question of whether these samples are representative of the ejecta from Elbow crater is only partly answered.

All of the rocks taken in the radial sample were mostly protruding above the surface of the ejecta blanket. Also all of the rocks are near small craters that are much younger than the ejecta blanket. If the collected rocks were excavated from the blanket by younger impacts and were not thrown far, then they are probably representative of the material ejected from Elbow crater and would give a clue to the stratigraphy in the crater walls. If the samples were excavated from the Elbow crater ejecta by younger impacts and moved a considerable distance, then they could represent the material originally ejected from Elbow crater, but their position within the blanket would bear no relationship to the depth within Elbow crater from which they were derived. A third possibility is that the samples were thrown onto the Elbow crater ejecta blanket by an impact that occurred outside the ejecta blanket and therefore are not representative of the

material excavated from Elbow crater; however, it is improbable that all of the samples were deposited this way.

Sample 065 is photographically similar to many other rocks nearby, and therefore is probably representative of local material in the ejecta blanket; that is, material near the rim of the crater. The rocks collected from farther out on the ejecta blanket are from clumps of rocks all of which seem to have been part of the same young event, or else are too isolated in the photos to compare with the general population. All of the samples from Station 1, although they cannot be said with certainty to represent the material ejected from Elbow crater, probably do so. Preliminary examination of the samples suggests that the rocks are petrographically consistant with an Elbow crater source.

Sample 065.--Sample 065 is from nearest the rim of Elbow crater in the three-part radial sample that extends to the east from the rim (fig. 3). It was taken about 4 m east of the broadly curved crest of the rim and lay about 1 m east of a younger 4 m diameter crater (figs. 12, 13).

The sample was in an area of fine-grained, soft regolith, and no other cobble-sized rocks were closer

than 1 m. Pebble-sized rocks are sparse in the local area. The 4-m crater to the west contains a ring of cobble-sized fragments mostly just within its rim. One flat block, almost 1 m across, lies within the 4-m diameter crater on the west; it shows a faint dark band as does the sample, but unlike the sample it may be mostly buried in the soil (fig. 13). A few subdued craters less than 1/2 m in diameter are near the sample site. There is a suggestion of lineaments crossing the nearly flat area. A small fillet less than 1 cm high is banked against the sample. The small pebbles near the sample and the cobbles farther away appear to have about the same albedo. Dust coatings on the rocks are not evident. The sample was resting on a flat side and less than 1/5 of the rock was below the general surface.

Sample 065 probably is representative of the rock fragments within the near-rim portion of the ejecta blanket of Elbow crater. Its position, more or less resting upon the surface, suggests that it has been moved since the Elbow crater impact. It may well have been ejected from the 4-m crater just to the west, and would therefore be representative of Elbow crater ejecta less than 3 m from the rim of Elbow crater.

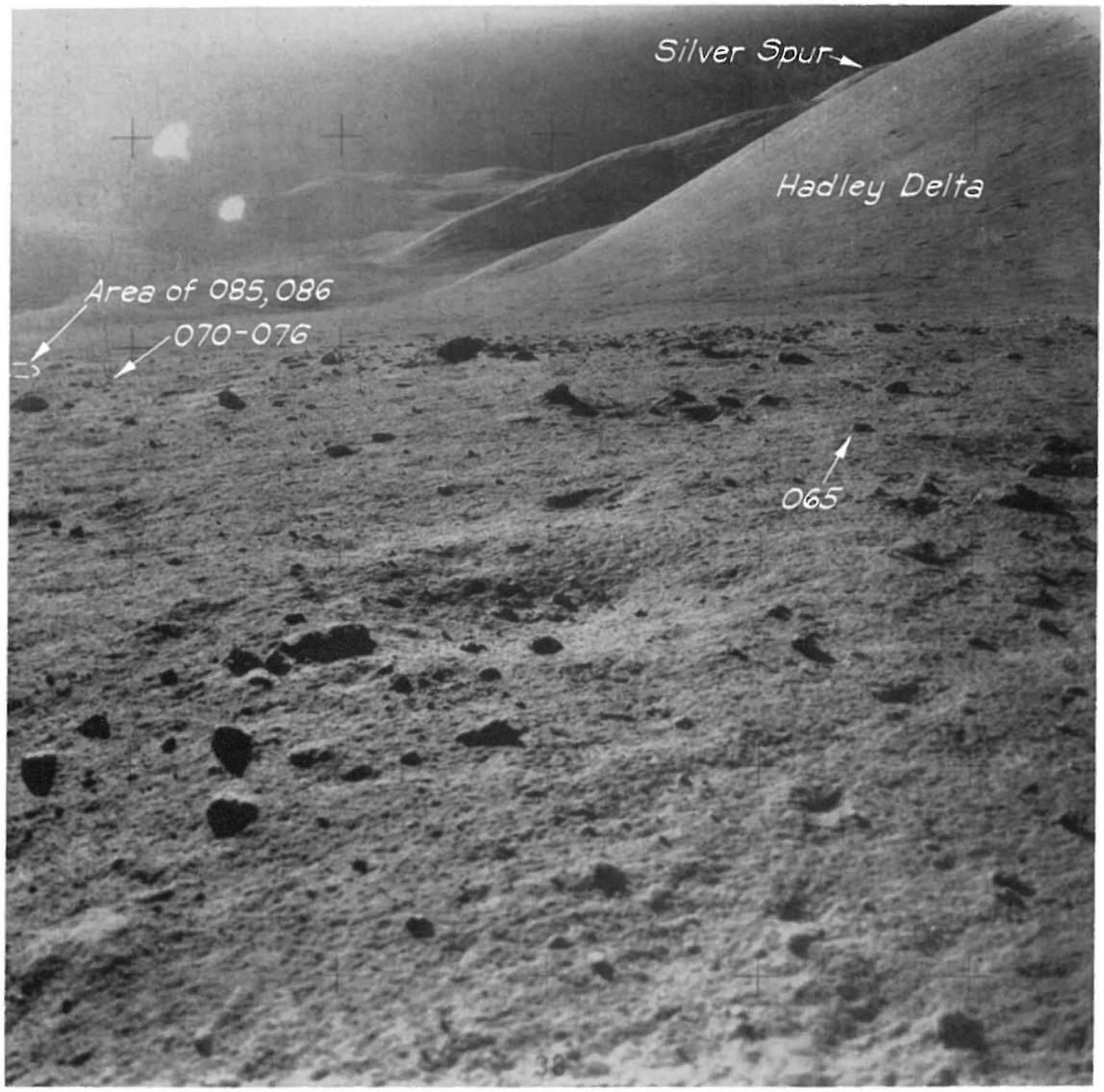

Figure 12. Samples 065, 070-076, 085, and 086, prior to collection at Station 1 near the rim of Elbow crater. Pre-sampling, oblique-to-sun photograph AS15-85-11408, looking east southeast.

Figure 13. Sample 065, collected on east rim of Elbow crater at Station 1. First sample of radial sample. Pre-sampling, cross-sun photograph AS15-86-11531, looking south.

Samples 070-074, 075, 076.--Rock samples 075 and 076, and soil samples 070-074, were taken from a small area about 25 m east of the rim of Elbow crater (plate 4; figs. 3, 12). The samples were taken as the middle part of the three-part radial sample of the ejecta blanket of Elbow crater.

Rock samples 075 and 076 were part of a cluster of rocks located within an area of fine-grained regolith with sparse pebble-sized fragments (figs. 14a, b). The fine-grained material was sampled (070-074) and placed in the same bag. In the local area there are scattered, more or less fresh, small craters, and a group of subdued small craters just east of the cluster of rocks. The area is nearly flat and without obvious lineaments. The rocks in the cluster all appear to have the same albedo and the same rough appearing surface texture. Dust on the fragments is not obvious. Fillets are small to moderate. Some of the rocks in the cluster appear to be mostly buried but others, including the samples, appear to be less than 1/4 buried.

The two samples, 075 and 076, appear to be representative of the cluster of rocks in the local area. The similarities in rounding, filleting, and apparent depth of burial suggest that the rocks of the cluster arrived at the sampling site together. It is postulated

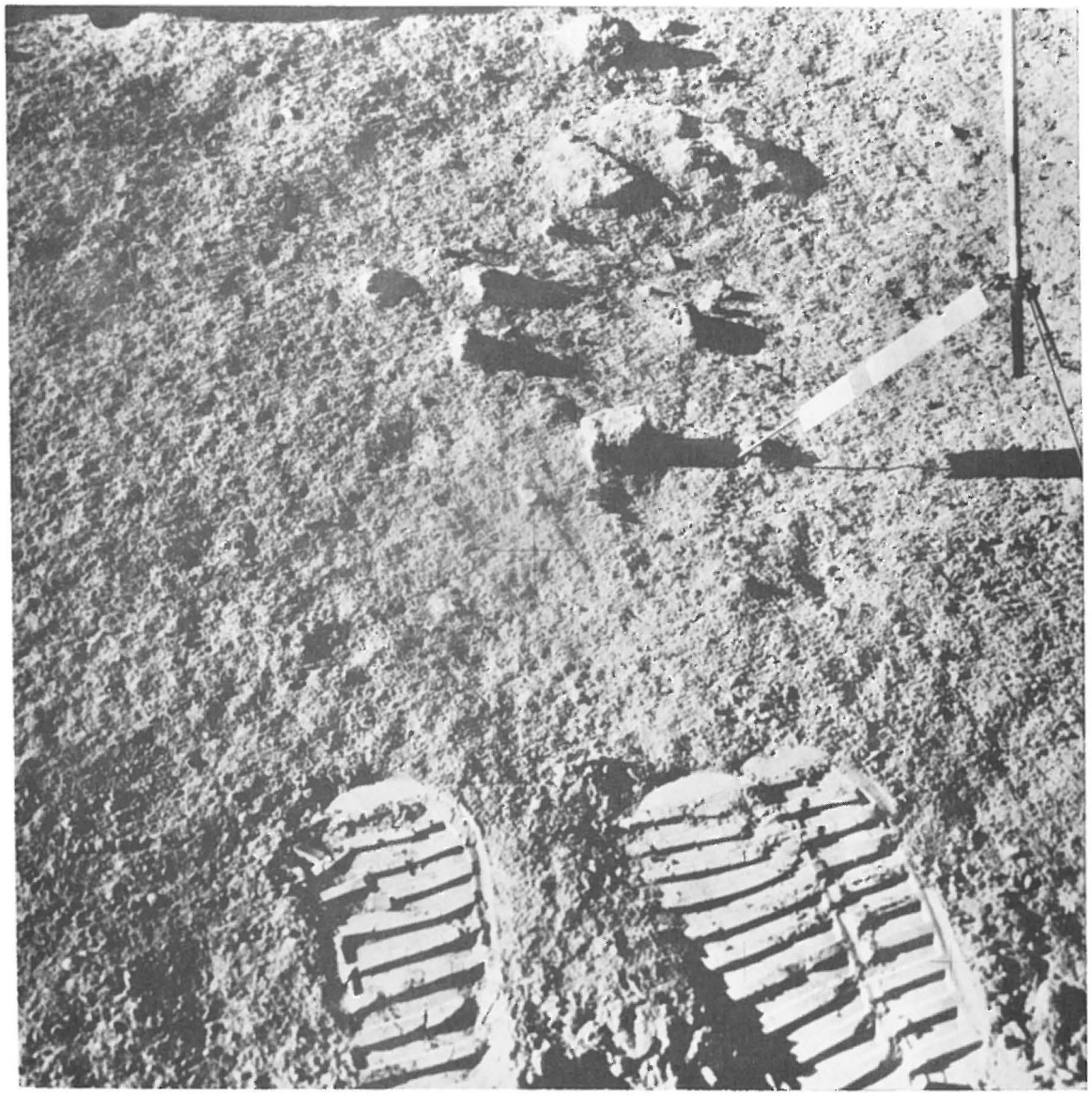

Figure 14a. Samples 070-074, 075, and 076, collected from the east rim of Elbow crater at Station 1. Second sampling point in radial sample. Pre-sampling, oblique-to-sun photograph AS15-86-11534, looking northwest.

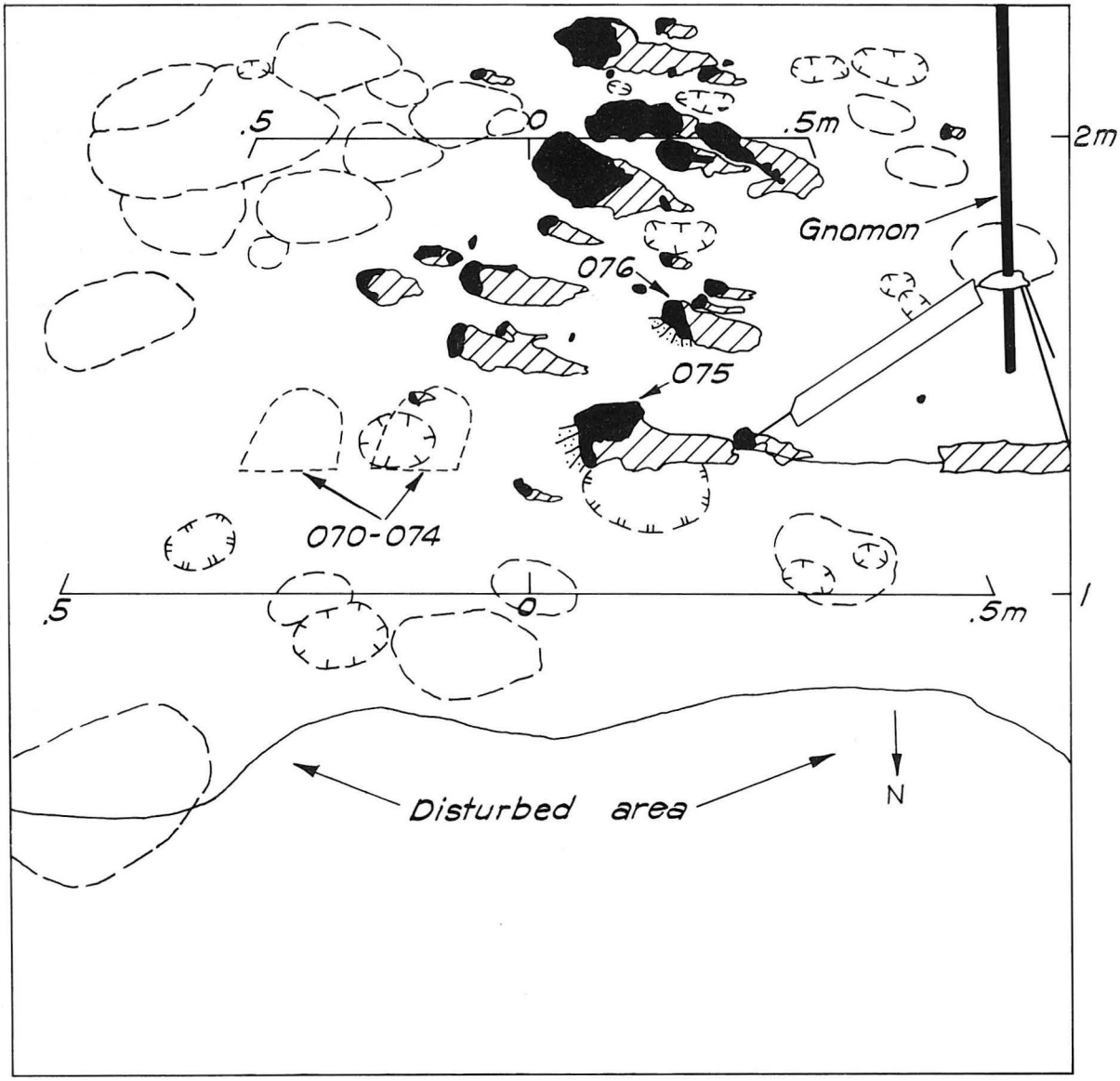

Figure 14b. Sample environment sketch map for samples 070-074, 075, and 076.

that the impact of the cluster of rocks produced the group of subdued crater about 1/2 m to the east of the rocks (figs. 14a, b). If so, the rocks were ejected from some source to the east by a cratering event younger than Elbow crater itself. The younger crater has not been located but probably lies within the ejecta blanket of Elbow crater but considerably farther from the rim than the position of the sampling site. Therefore, it is possible that samples 075 and 076 represent rocks that were originally ejected from Elbow crater to a distance considerably farther than the 25 m to the present sampling site. Components within the soil sample 070-074 may be more representative of the material originally ejected from Elbow crater to a distance of 25 m.

Samples 085, 086.--Samples 085 and 086, and a small amount of soil, were collected about 60 m east of the rim of Elbow crater (plate 4; figs. 3, 12). This collection was the farthest from the rim of the three-part radial sample of the Elbow crater ejecta blanket. In the local area of this sample, the general ejecta blanket surface appears smooth with scattered cobble-sized rocks (figs. 15a, b).

The surface material in the sample area is fine-grained with pebble-sized fragments common. Cobble-sized rocks, such as samples 085 and 086, are distinctly

spaced, about one every 2 m^2. Subdued to fresh small craters are common in the area. Sample 086 lay about 20 cm east-northeast of a moderately fresh, 10 cm diameter crater, and sample 085 lay about 35 cm east-northeast of a moderately fresh, 15 cm diameter crater (figs. 15a, b). The area is generally flat and without lineaments. Small fillets less than a centimeter high are banked against some of the cobble-sized fragments including sample 085. Sample 086 does not have a resolvable fillet. The albedo of all the fragments appears the same. Dust is not visible on the larger fragments, all of which appear to rest upon the general surface. The collected rocks were about 1/4 buried.

The small number of cobble-sized rocks visible in the documentation photographs precludes a definite statement on whether the samples are representative of the area. Sample 085, a basalt, appears more rounded and with a greater fillet development than sample 086, a breccia. At least one other cobble-sized fragment similar in roundness and fillet development to each of the samples appears in the photographs. The rather fresh craters associated with the collected rocks suggest they were recently moved to the collection site from the west-northwest. Probably samples 085 and 086 came from the ejecta blanket of Elbow crater

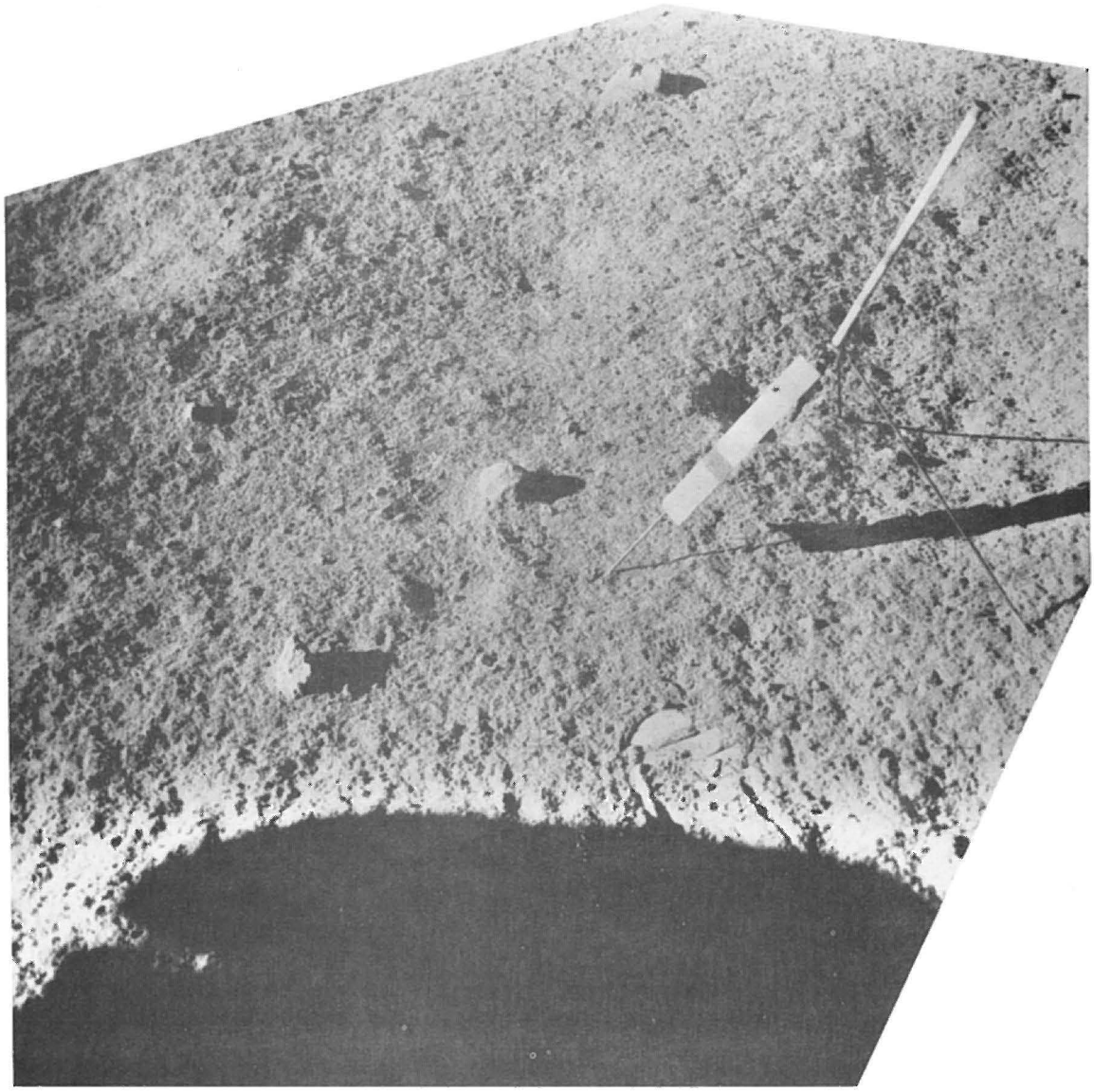

Figure 15a. Samples 085 and 086, collected from the east of the rim of Elbow crater. Third sampling point (farthest out) of radial sample. Pre-sampling, cross-sun photograph AS15-86-11536, looking south.

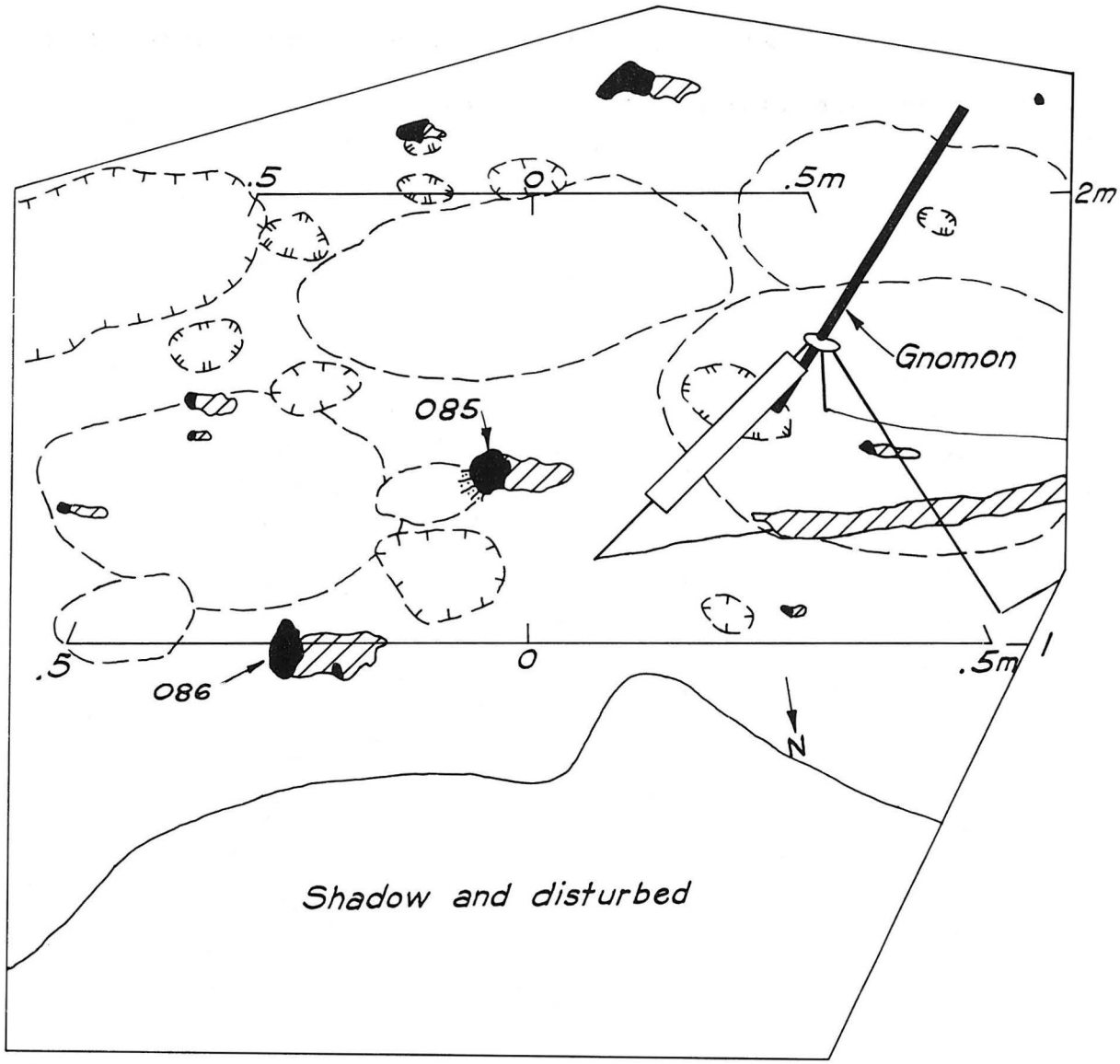

Figure 15b. Sample environment sketch map for samples 085 and 086.

but represent a portion of the blanket less than 60 m from the rim. The soil in the collection bag probably was scooped from beneath sample 085 and therefore may contain some material eroded from 085.

Station 2

Samples collected at Station 2 (plate 5, fig. 1) consist of the following, in order of collection: 210-214, 220-224, 090-093, 095, 200-204, 206, 205, 230-234, 115-148, 100-105, 008/007. The samples were collected from an area of about 12 x 15 m (fig. 3).

Station 2 is located near the base of the Apennine front approximately 600 m north of the northeastern part of the St. George crater rim crest (plate 5, figs. 1, 16). Pre-mission photogeologic maps (Howard, in Carr, Howard, and El-Baz, 1971; Schaber and Head, 1971) interpret the Station 2 area as occurring in the ejecta of St. George crater, which excavated Imbrian or pre-Imbrian impact breccias from the Apennine front before the accumulation of the mare fill was completed. Additional particles derived from impacts elsewhere in both the Apennine Mountains and the Imbrium basin have presumably been mixed with St. George ejecta to form the regolith at Station 2. Elbow crater, on the mare surface about half a kilometer north of Station 2, is a particularly likely source of foreign ejecta.

Lunar surface photographs (e.g., figs. 17, 18) show that the regolith at Station 2 consists of fine grained material with widely scattered fragments a few centimeters in diameter. Except for the two blocks associated with apparent impact craters in Figure 17,

fragments larger than 10 cm are virtually nonexistent. The notably fine grain size, scarcity of blocks, and extremely undulatory character of the surface at the station suggest that the area is one of intensely cratered and gardened regolith. The regolith is apparently somewhat coherent. Numerous small (<5 cm) clods are visible in areas where the surface has been kicked up (fig. 18) or broken by the tongs (fig. 19). Clods are also visible near small, fresh craters (fig. 20).

Two prominent sets of lineaments transecting the face of Hadley Delta and the rim of St. George crater (fig. 16) can be interpreted, similar to those described by Schaber and Swann (1971), as the surface traces of bedrock fractures (or other planar surfaces) propagated through the regolith by repeated small-scale movements. Alternate interpretations that the lineaments are artifacts produced by low angle illumination on an irregular surface or that they represent exposed bedrock structures can be considered. However, in Figure 16, the two sets are visible across a variety of changing surface slopes on Hadley Delta, and in places they seem too continuous and uniform to be artifacts of the lighting. Furthermore, interpretation of the lineaments as exposed bedrock structures would require (1) thinning of the St. George crater ejecta blanket to exposed bedrock, and (2) preservation of pre-existing bedrock structures with minimal

Figure 16. Approximate location of Station 2 as seen from the LM. Exact position of Station 2, near the base of the Apennine front, may be concealed by the local horizon on the most distant visible part of the mare surface. SEVA panorama photograph AS15-85-11375, looking approximately south.

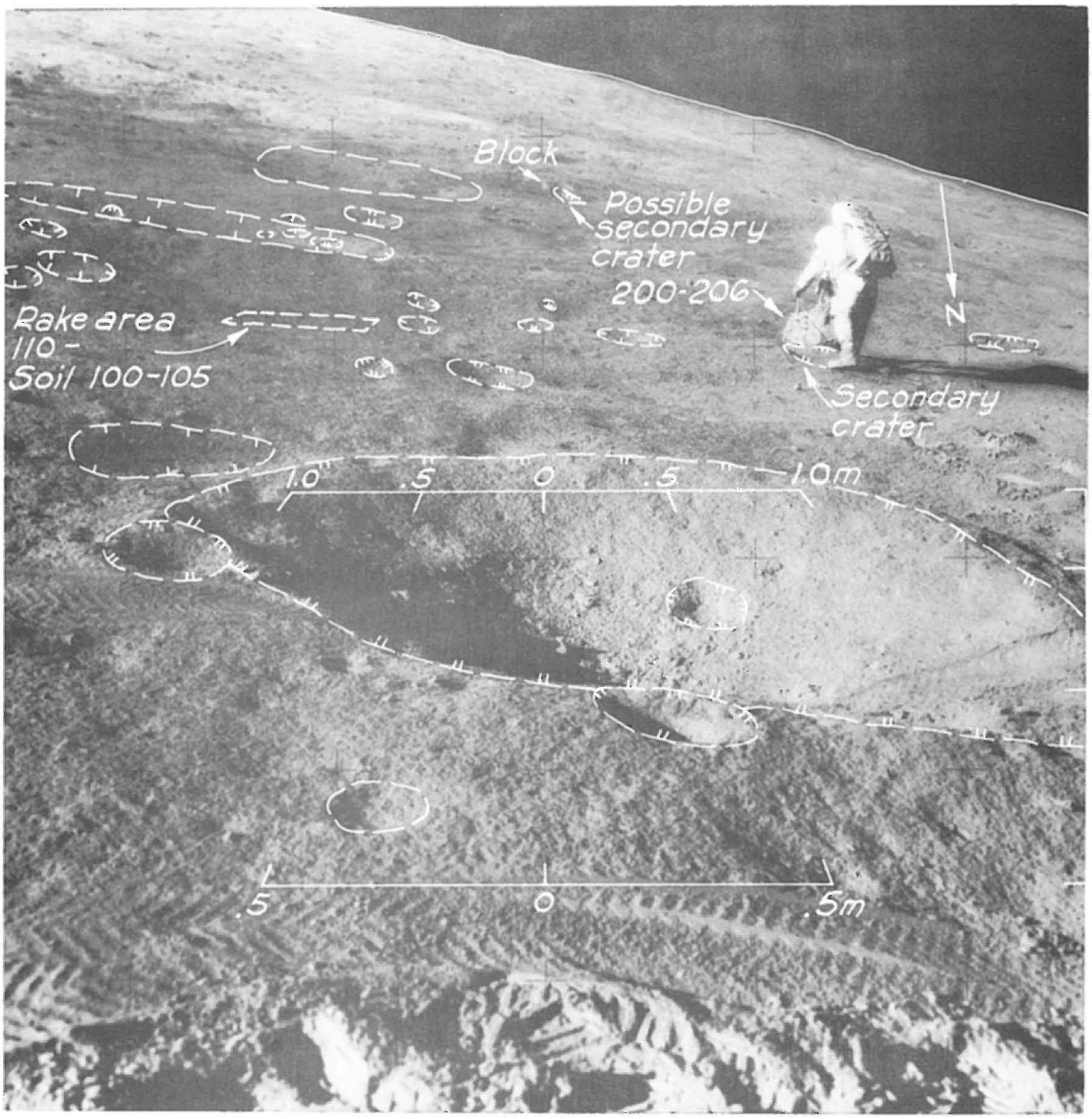

Figure 17. Cratered, undulating surface and fine-grained regolith with widely scattered pebbles and cobbles at Station 2. The large block beside the astronaut, ejected by a distant impact, and soil near the block and beneath it, were sampled. Lunar surface photograph AS15-85-11435, from a panorama at Station 2.

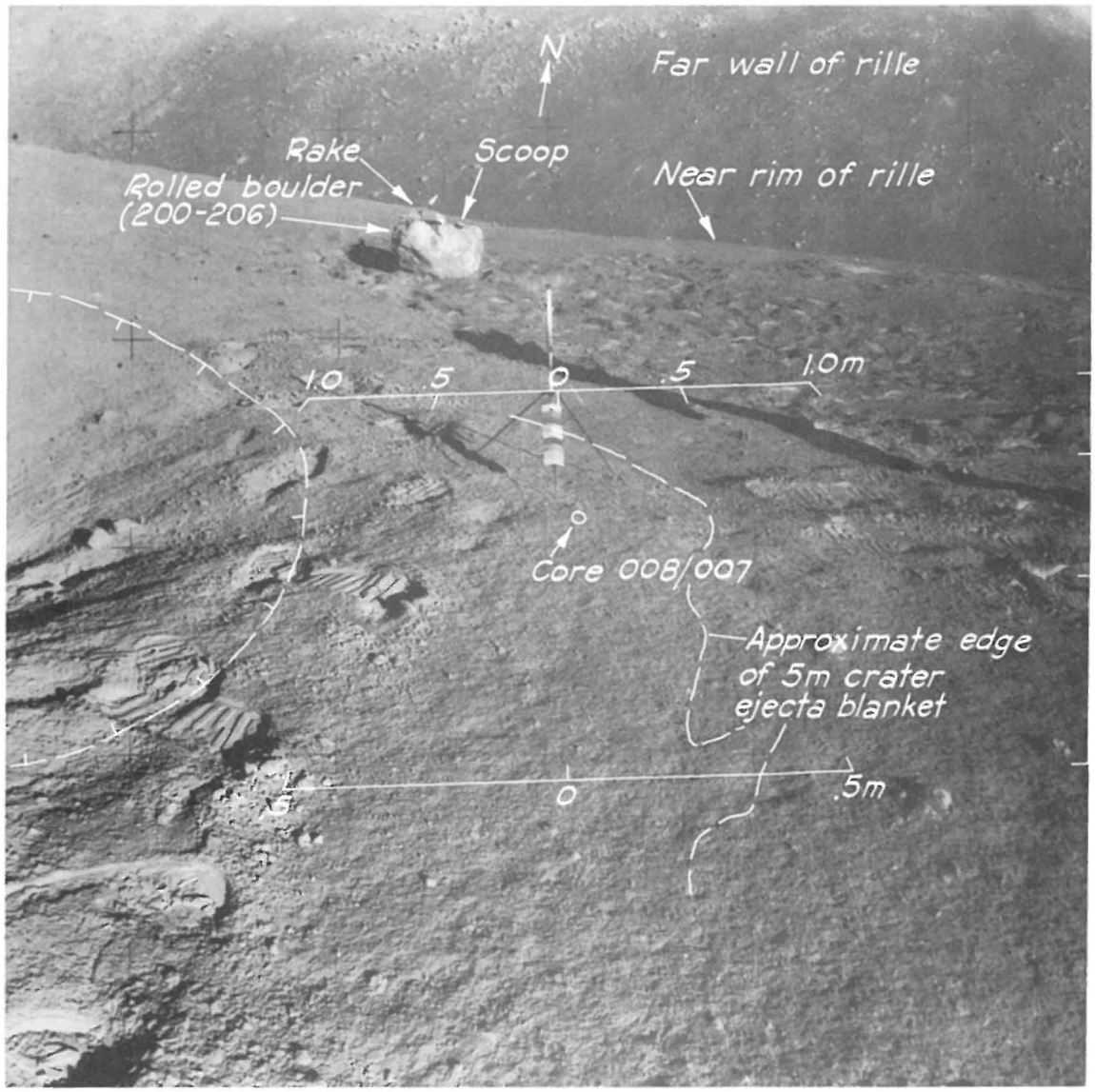

Figure 18. Samples 008 and 007, double core, collected at Station 2. The large boulder has been rolled so that its former base now faces the camera. Pre-sampling, cross-sun photograph AS15-85-11443, looking northwest.

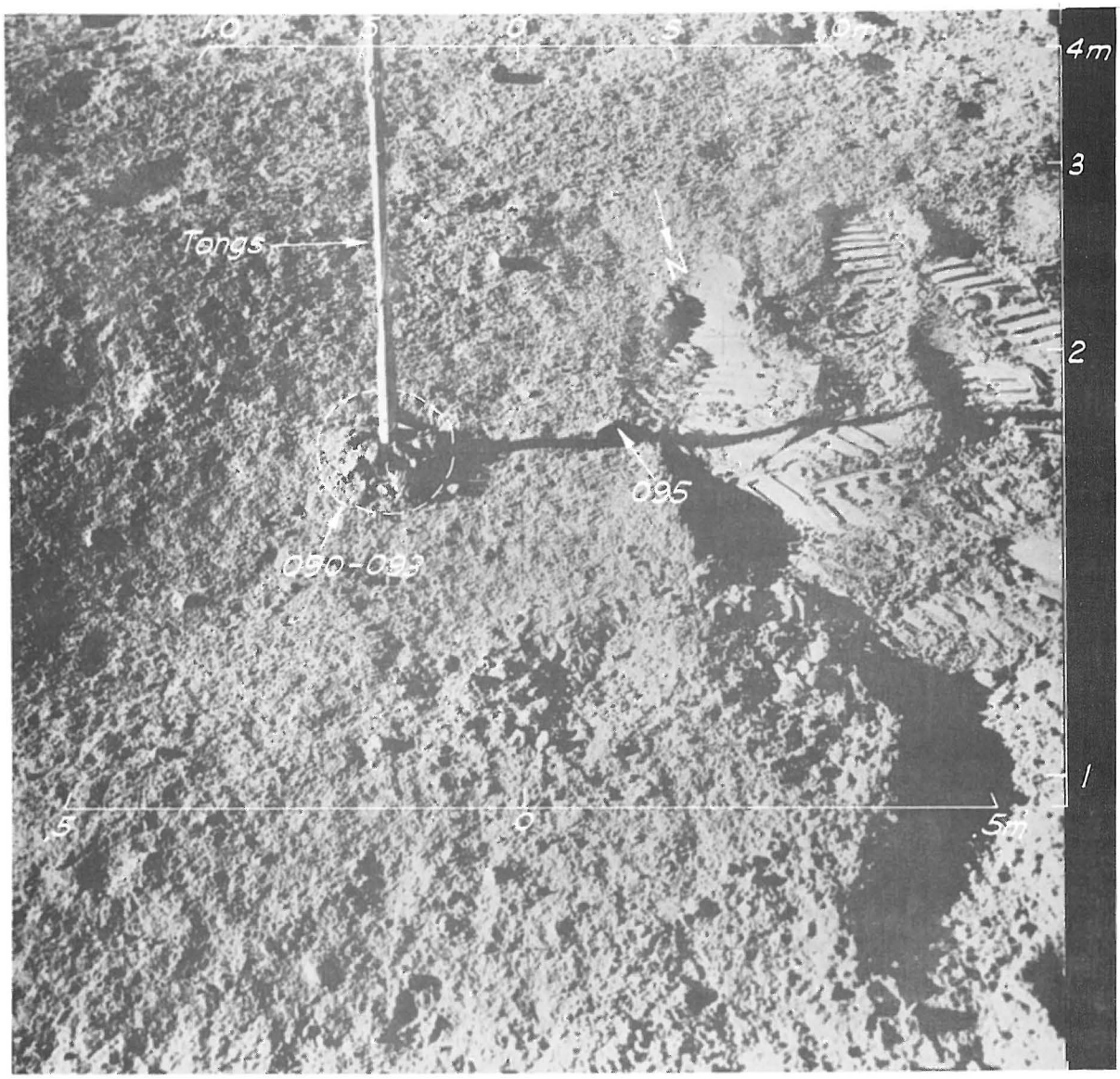

Figure 19. Samples 090-093, and 095, collected from near big rock at Station 2. Pre-sampling, cross-sun photograph AS15-86-11549, looking south.

disruption resulting from the local deformation that should have occurred in the St. Geroge impact. Neither condition seems likely. In addition, the Station 2 photographs, in which the lineaments are not visible, suggest that the flank of St. Geroge is underlain by a thick mature regolith.

Samples 008 and 007.--Samples 008 and 007 (the double core sample) at Station 2 were collected approximately 5 m southeast of the large boulder (figs. 3, 17, 18). The core was driven close to the rim and within the continuous ejecta of a crater about 10 m in diameter, and it may have penetrated the buried contact between the local ejecta blanket and the previously exposed regolith surface.

Figure 18 shows the fine grained character of the regolith at the core site. Except for local concentrations of clods near footprints on the crater rim, coherent fragments larger than a centimeter in diameter are widely scattered, and fragments larger than 10 cm in diameter are almost nonexistent. The fine grain size is typical of the entire Station 2 area. The paucity of blocks and the cratered hummocky character of the local terrain suggest that the core has sampled mature, intensely gardened regolith that can be presumed representative of the whole Station 2 area. Hence the core sample is presumably an intensely gardened mixture of ejecta from

St. George crater and from impacts from elsewhere in the Apennine Mountains and the Imbrium basin.

Samples 090-093 and 095.--Samples 090-093 (soil) and 095 (glass-coated breccia) were collected close to the large boulder at Station 2, where the regolith is notable for its fine texture. Coherent fragments larger than a centimeter in diameter are scattered, and none larger than 10 cm in diameter occur within the immediate sample locality (fig. 19).

The soil (090-093) can be assumed represenative of the mature, well gardened regolith composed of St. George crater ejecta plus whatever exotic components have been admixed since the St. George impact.

The 3 cm, glass-coated, breccia fragment (095) is typical in size and occurrence of fragments scattered on the surface throughout the Station 2 area. It may represent 1) a clast from the impact breccias excavated from St. George crater, 2) a fragment of Apennine front breccia excavated and coated with glass by the St. George event, or 3) a foreign fragment coated with glass and ejected by an impact in some other locality, and deposited at this site after the St. George event.

Sample 100-105.--Sample 100-105 was a bag of soil collected at the rake sample site (figs. 3, 17, 21) 5 m east of the large rock at Station 2.

The mature fine grained regolith with a few scattered fragments up to about 10 cm in diameter (fig. 21) is characteristic of the entire Station 2 area and presumably represents intensely gardened St. George ejecta to which some ejecta from impacts elsewhere in the Apennine Mountains and Imbrium basin have been added.

Sample 115-148.--Sample 115-148 is the rake sample collected 5 m east of the large block at Station 2 (figs. 3, 17, 21).

Figure 21 shows that there are no surface fragments larger than 10 cm in the rake area, and fragments coarser than 1 cm are rare. Astronaut comments made during collection of the rake sample verify the scarcity of coherent fragments large enough (>1 cm) to be returned in the rake. The rake sample fragments are typical in size and distribution of the coarse fraction at the upper surface of the regolith throughout the Station 2 area. The regolith in general can be interpreted as a mature intensely gardened mixture of St. George ejecta plus whatever foreign components have been admixed subsequent to the St. George impact. Hence the geologic significance of the individual pebbles or cobbles is difficult to evaluate. Any one may be either a fragment derived from Apennine front breccias that were excavated by the St. George impact or a fragment derived from rocks redistributed by meteorite impacts at some other locality.

on the lunar surface. It is likely that some foreign fragments at Station 2 are ejecta from the impact that formed Elbow crater about half a kilometer to the north on the mare surface.

Samples 200-206.--Samples 200-206 were broken from the large boulder approximately 1 m across at Station 2 (figs. 3, 17, 20, 22). Samples 200-204 and 206 came from a corner on the south (uphill) side of the rock, and sample 205 came from a corner at the intersection of the top and east faces of the rock.

Several lines of evidence indicate that the boulder is an ejecta fragment from a relatively recent impact of another site that may be northwest of Station 2. The evidence includes the following:

1. The boulder is anomalously large (about 1 m in maximum diameter). Coherent fragments on the surface at Station 2 are scattered in occurrence and generally do not exceed 10 cm in diameter.
2. The boulder surface is relatively free of dust and is fresh in appearance. Much of the surface is covered by bubbly glass that has not been significantly abraded (fig. 23). Rock edges and corners, controlled in part by fracture surface intersections are sharp (fig. 22).
3. The boulder is perched on the south rim of a small, fresh crater that appears to open to

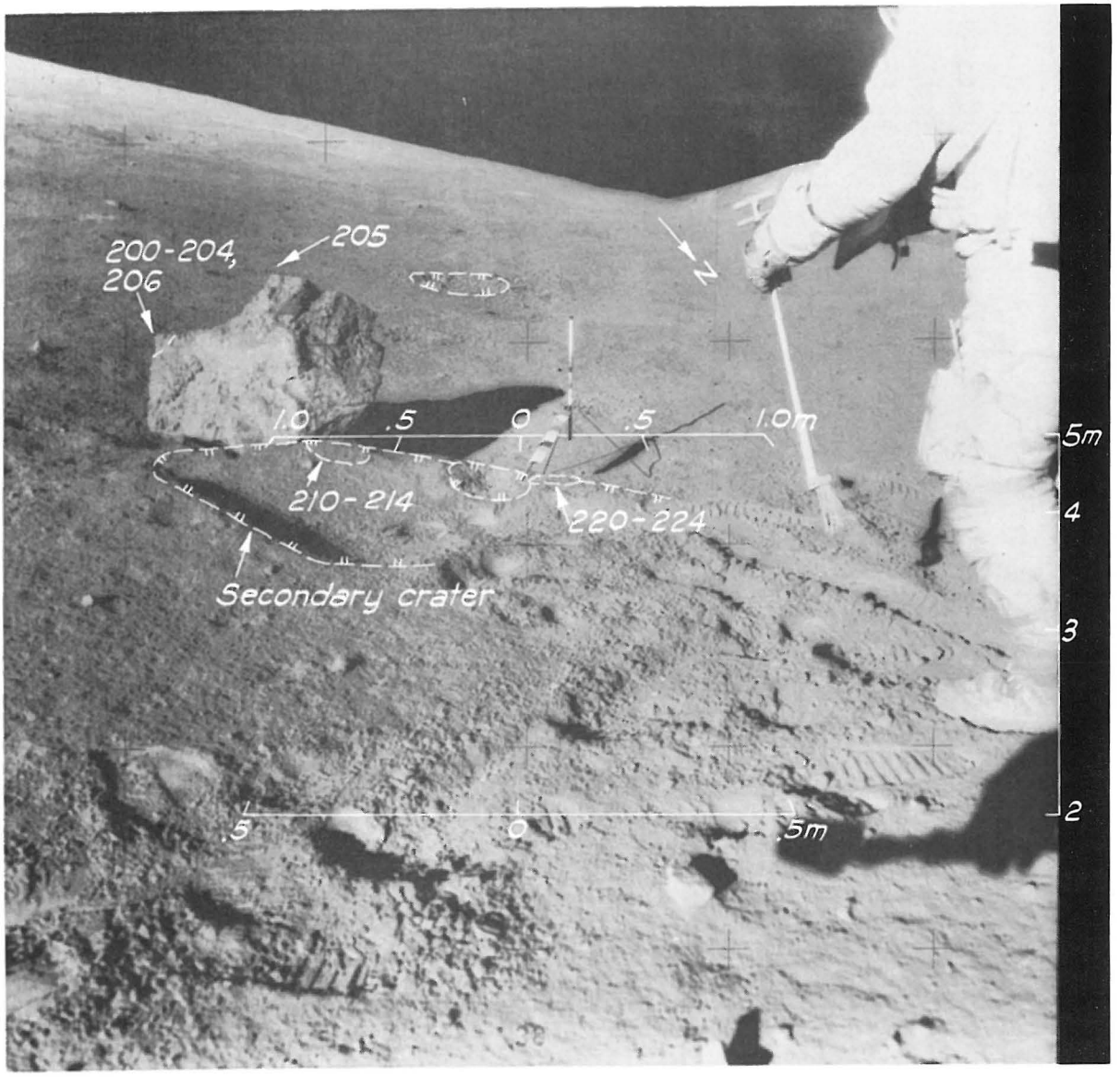

Figure 20. Near-field view of the large rock at Station 2 and its secondary crater showing collection sites for samples 200-204 and 206, 205, 210-214, and 220-224. Sample 230-234 was collected from under boulder after it was rolled to the west. Pre-sampling, oblique-to-sun photograph AS15-85-11440, looking southwest.

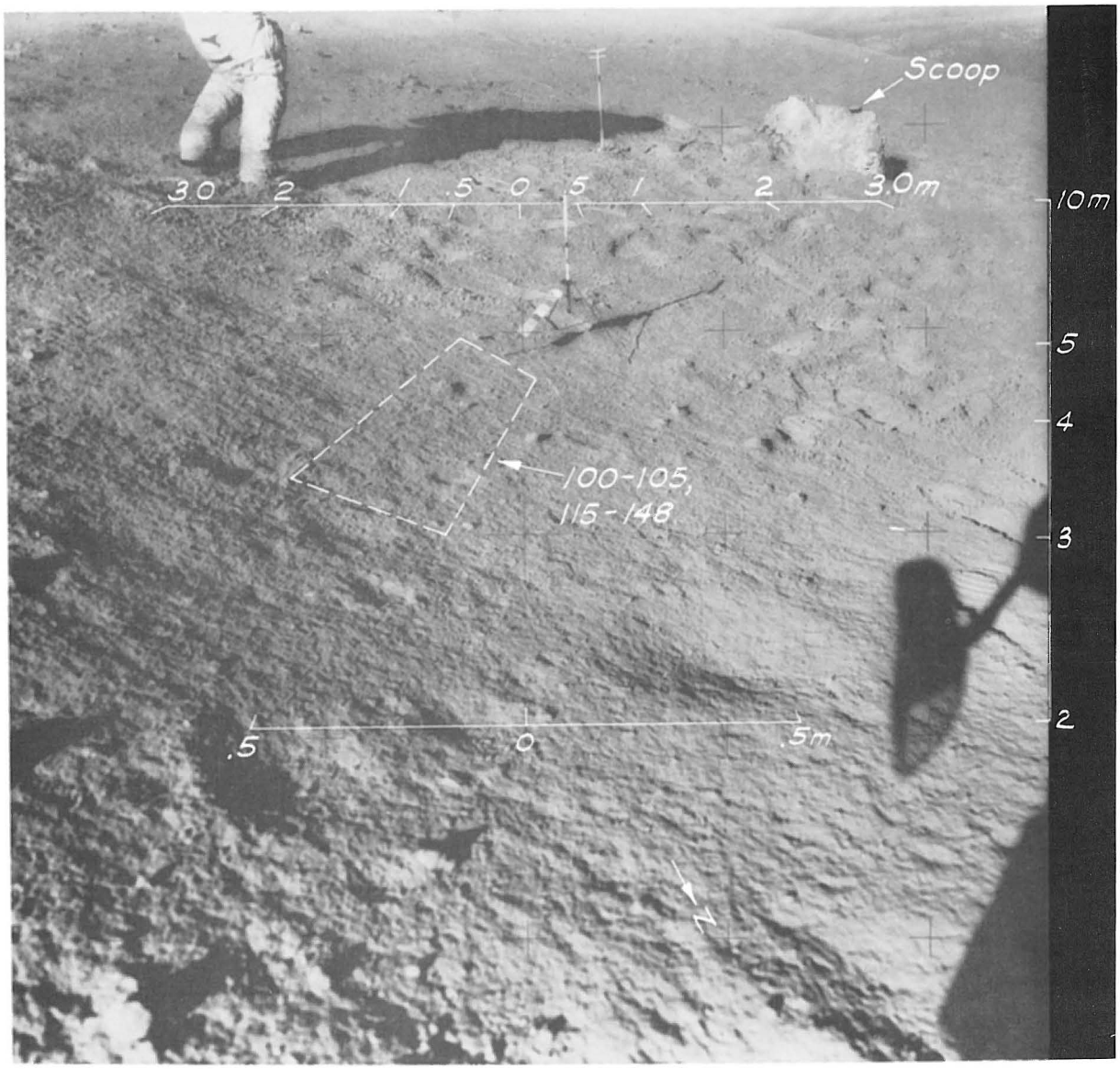

Figure 21. Sample 100-105 (soil) and samples 115-148 (rake), collected as a comprehensive sample at Station 2. The large boulder has been rolled so that its former bottom side now faces the camera. Pre-sampling oblique-to-sun photograph AS15-85-11442, looking southwest.

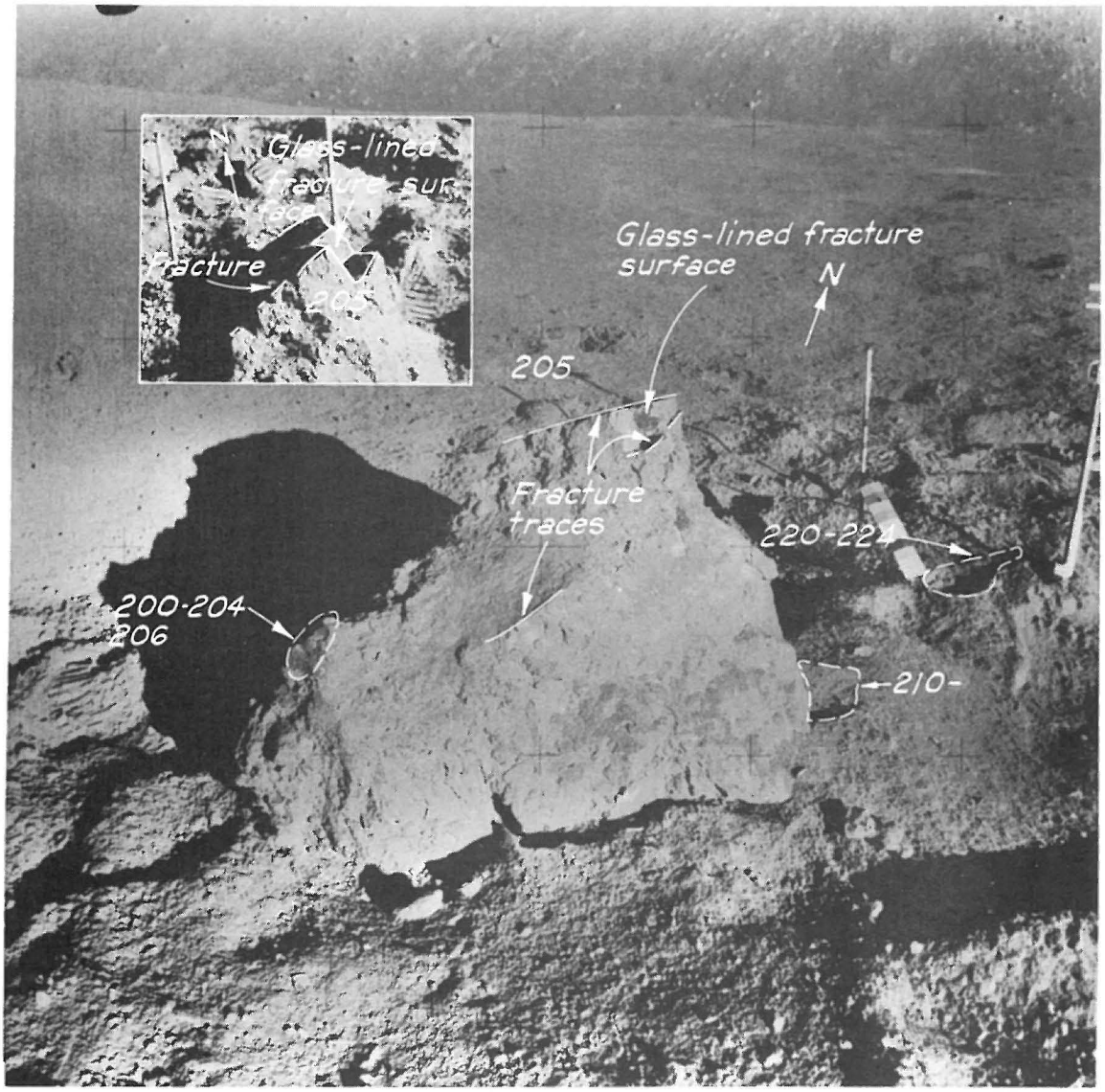

Figure 22. Collection sites for samples 200-204, 206, 205, 210-214, and 220-224. Post-sampling, oblique-to-sun photograph AS15-86-11560, looking northwest. Inset from post-sampling, cross-sun photograph AS15-86-11558, looking north.

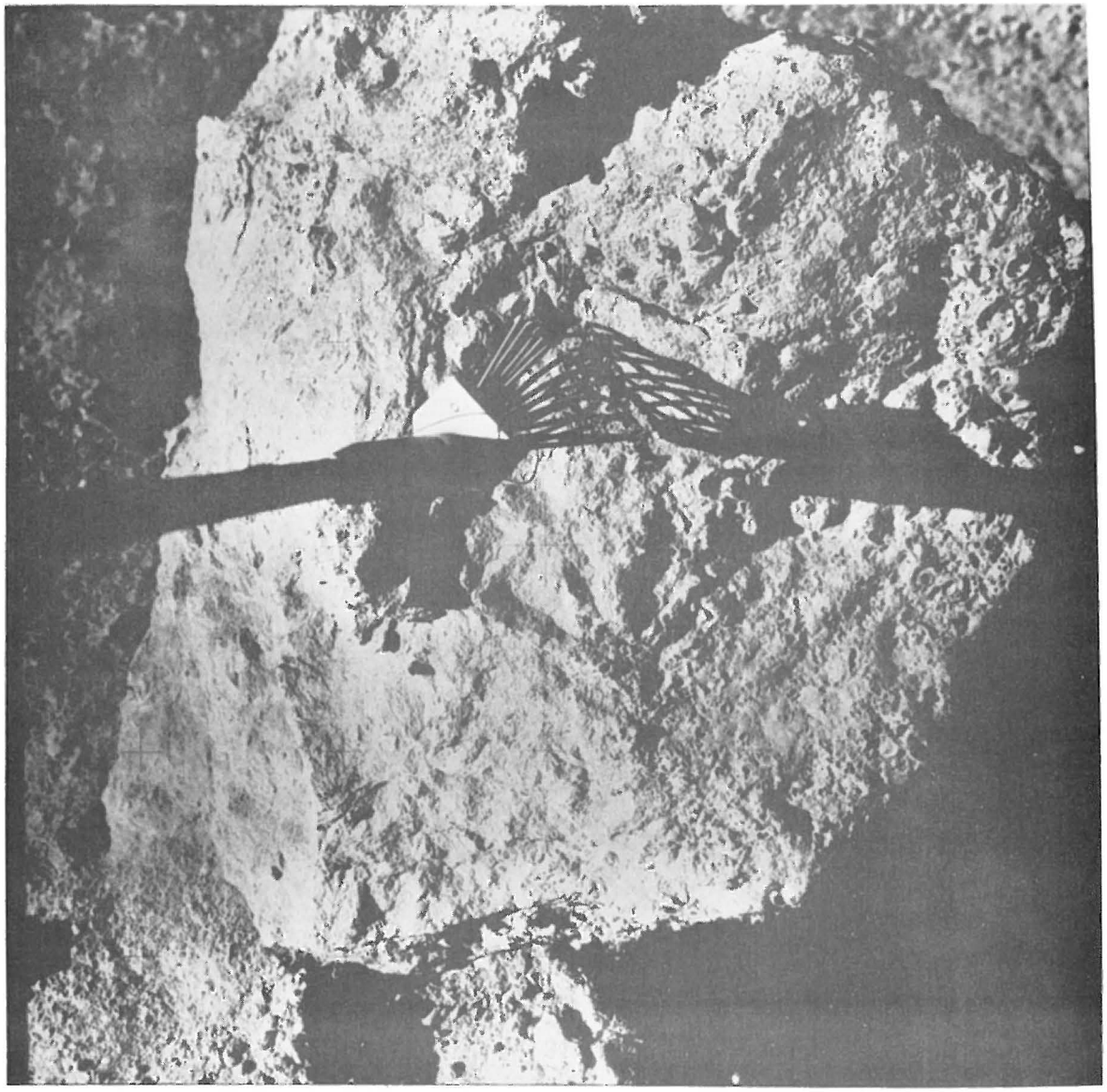

Figure 23. Large block at Station 2 with well preserved coating of bubbly glass. Cross-sun photograph AS15-86-11555, looking south.

the northwest (fig. 20). It looks as if the boulder impacted at a low angle from the north or northwest and rolled uphill onto the rim of its own secondary crater. A similar crater, apparently elongate northwest-southeast, with a large boulder on or near its southeastern rim is visible in the distance in Figure 17. The two craters may be secondary craters produced by two blocks mobilized by a single impact to the northwest.

4. A small fillet occurs where the block rests on the high part of the crater rim (figs. 22, 24) but the underside of the block forms an overhang at its south end. With the boulder removed (fig. 24), the fillet is seen to resemble the slight ridge that might be expected to ring the boulder where it compressed the soft secondary crater rim. Absence of a fillet on the uphill side suggests that the boulder has been in its present position for a relatively short time.

Both samples are breccias. Sample 206 is irregularly shaped and largely glass covered. Sample 205 is an angular block bounded by planar surfaces that are fracture controlled (fig. 22). Glass that intruded a fracture is visible in Figure 22 on a surface exposed by removal of the sample. The bubbly glass coating and the injection

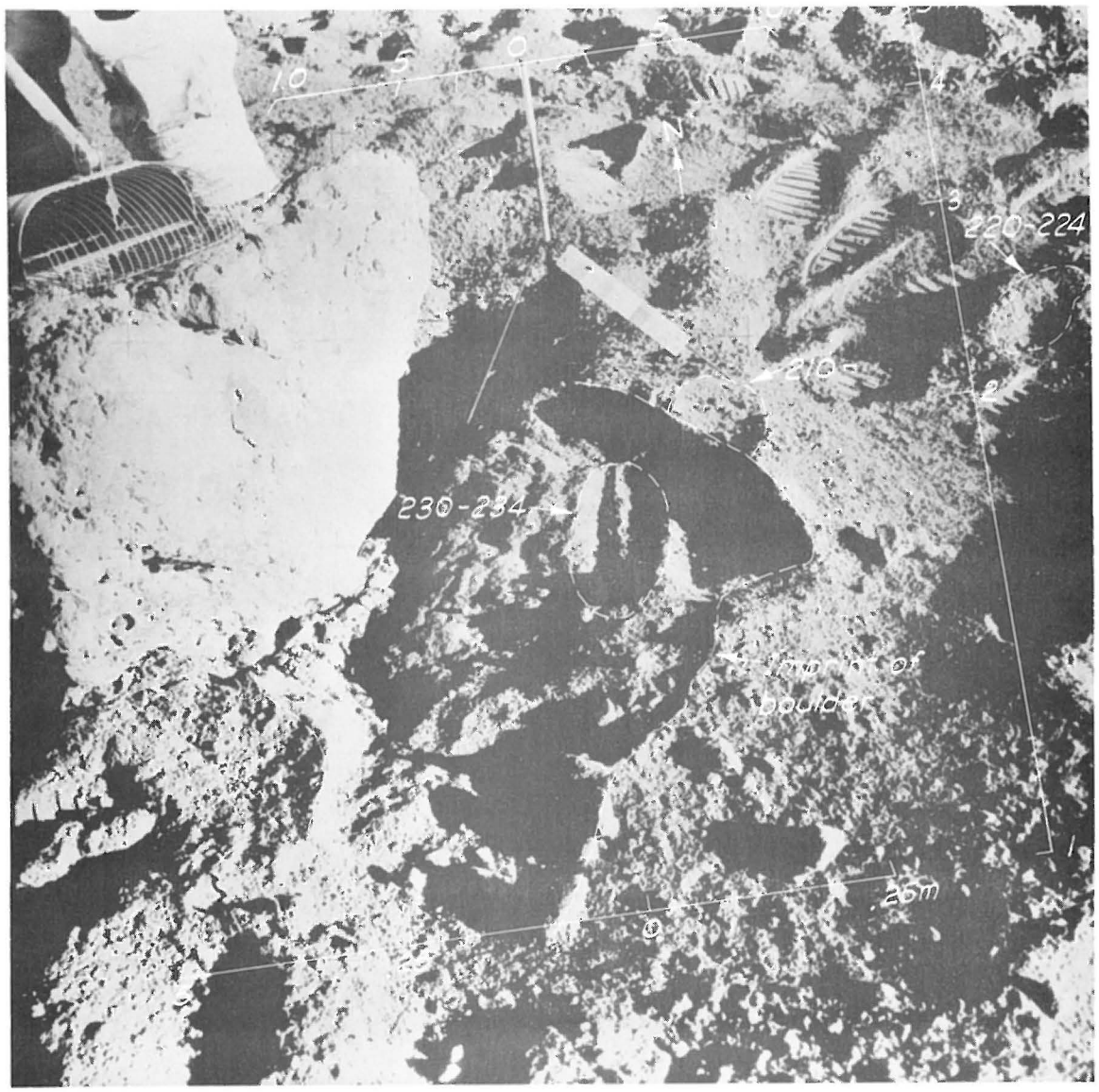

Figure 24. Underside of large rock at Station 2 showing the boulder imprint in the crater rim and the collection site for sample 230-234 in the soil beneath the boulder. Collection sites for samples 210-214 and 220-224 are also indicated. Post-sampling, cross-sun photograph AS15-86-11565, looking north.

of glass into fractures imply that the breccia block was ejected from near the focus of high energy release caused by hypervelocity impact. Good preservation of the glass coating (fig. 23) suggest that little modification of the block has occurred since that impact, and its apparent occurrence on its own secondary crater rim implies that it has moved little since its emplacement at Station 2.

Samples 210-214, 220-224, 230-234.--Samples 210-214, 220-224, and 230-234 are soil samples collected from the rim of the secondary impact crater made by the large rock at Station 2 (figs. 3, 20, 22, 24). Sample 210-214 was collected near the base of the large rock, which lies on the south crater rim. Sample 220-224 was also collected from the crater rim about a meter northwest of the large rock. Subsequently the large boulder was rolled over, and sample 230-234 was collected from the south crater rim where it has underlain the boulder (fig. 24).

All three samples are representative of the fine-grained upper part of the regolith at Station 2. Except for the large boulder itself, the immediate sample area is underlain by sub-centimeter fines with a few scattered consolidated fragments no larger than 10 cm in diameter. The fine grain size and the heavily cratered undulating surface suggest that this is a highly mature regolith.

It is presumed to consist of a thoroughly gardened mixture of St. George crater ejecta plus some ejecta added from elsewhere in the Apennine Mountains and Imbrium basin.

Station 3

Station 3, a mare station, is near the boundary between two subdued craters, each about 125 m in diameter and about 300 m east of Hadley Rille, and about 125 m west southwest of Rhysling crater (plate 6; fig. 1). The surface is undulating on large and small scales because of the intersection of numerous craters. Within the area visible in Plate 6, many 5-25 m diameter subdued craters contribute to surface irregularities. Scattered over the surface are fragments from a few centimeters up to 25 cm across (shown in Figure 25 near where the LRV tracks disappear to the south).

In general, the Station 3 area appears to be a mature surface in which fragments have not been recently excavated from the underlying bedrock.

Sample 016.--Sample 016 was collected from an area with abundant 10 cm to 1 m diameter subdued craters which are characteristic of the nearby lunar surface (fig. 25). In detail, the surface is pitted with craters on the order of a centimeter to several centimeters in diameter. Fragments from less than 1 mm to 10-15 cm across are scattered sparsely over the surface with no noticeable concentrations. Moderately well-developed lineaments around sample 016 trend mainly northwest with a few that trend northeast.

Fillets are not well developed against sample 016 or its vesicular neighbor (figs. 26a, b), and most of the larger fragments in Figure 25 do not appear to have fillets. The apparent depth of burial of the fragments is slight, typically less than 1/4 their exposed height.

Sample 016 was plucked from the rim of a 50 cm diameter crater. Only the northeast bottom corner of the sample was embedded in the regolith, and its south end was suspended above the inner wall of the crater. Astronaut Scott pointed out that the sample was completely dust free when he stopped the LRV to collect it.

Comparing Figures 25 and 26a, b, sample 016 appears to be representative of the general shape, burial, and filleting of the other larger fragments in the photographs. The rounded corners and edges of sample 016 suggest that it has spent considerable time on or near the surface.

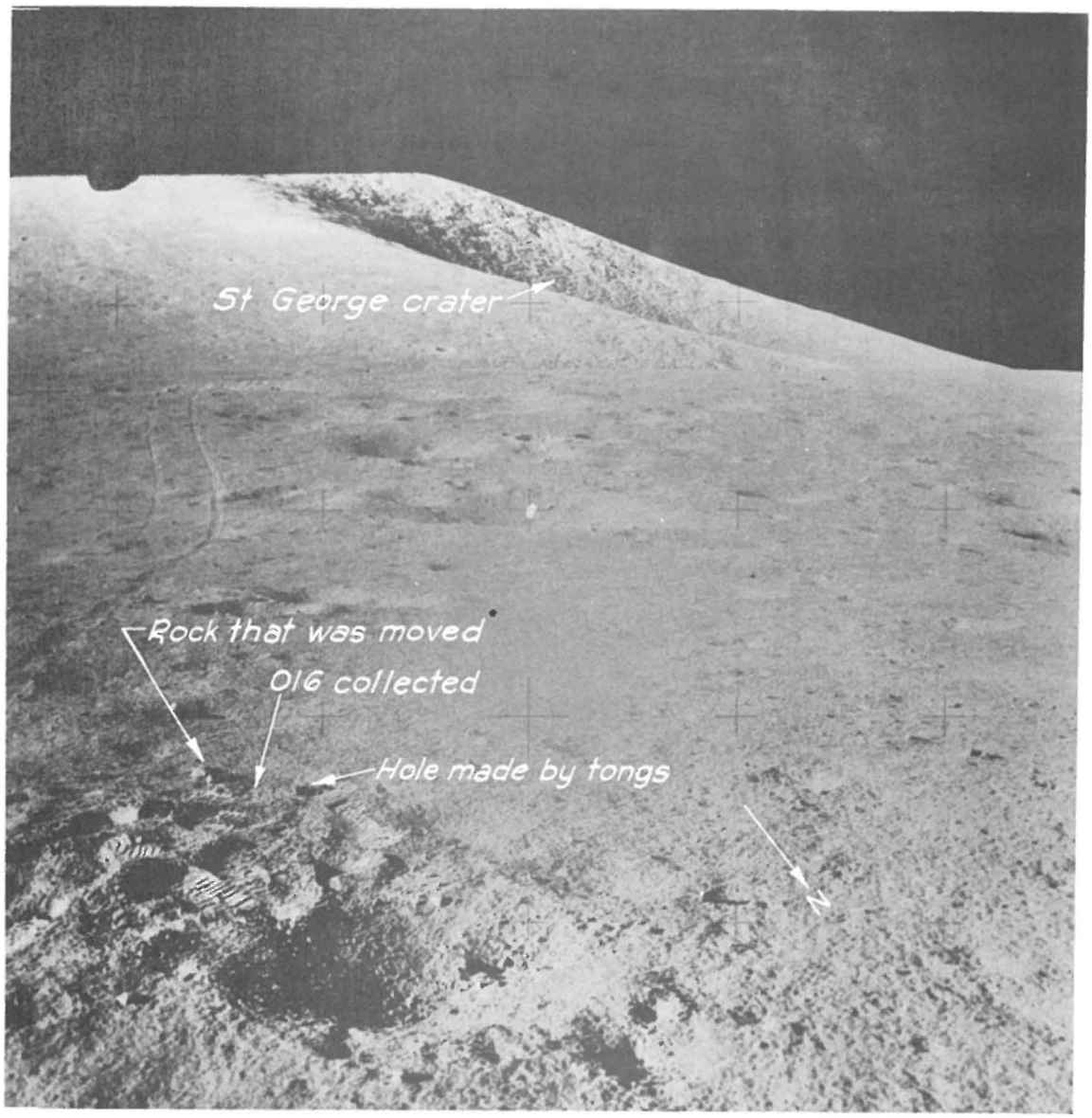

Figure 25. Area from which sample 016 was collected. The LRV tracks are about 2 m apart. Post-sampling, cross-sun photograph AS15-86-11584, looking south.

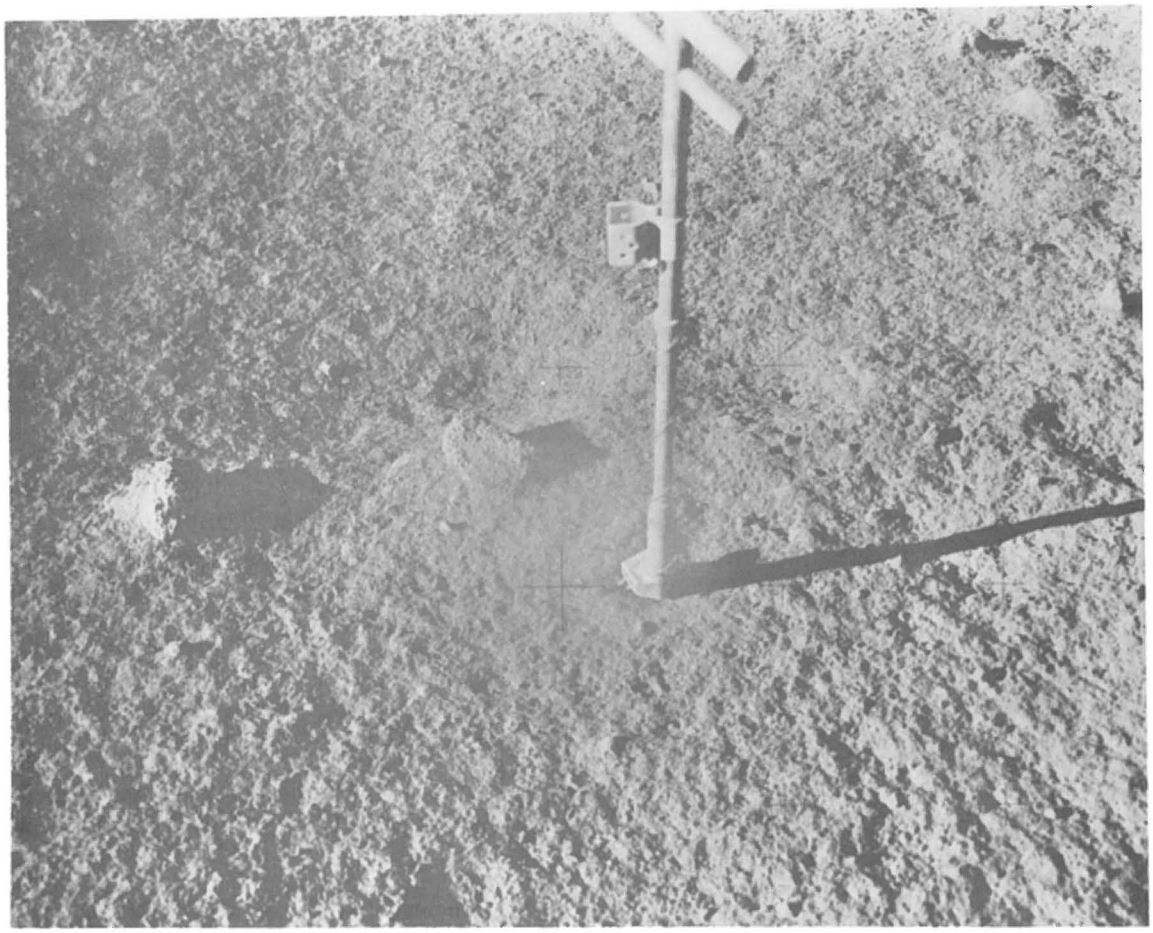

Figure 26a. Sample 016, collected from Station 3. Pre-sampling, cross-sun photograph AS15-86-11579, looking south.

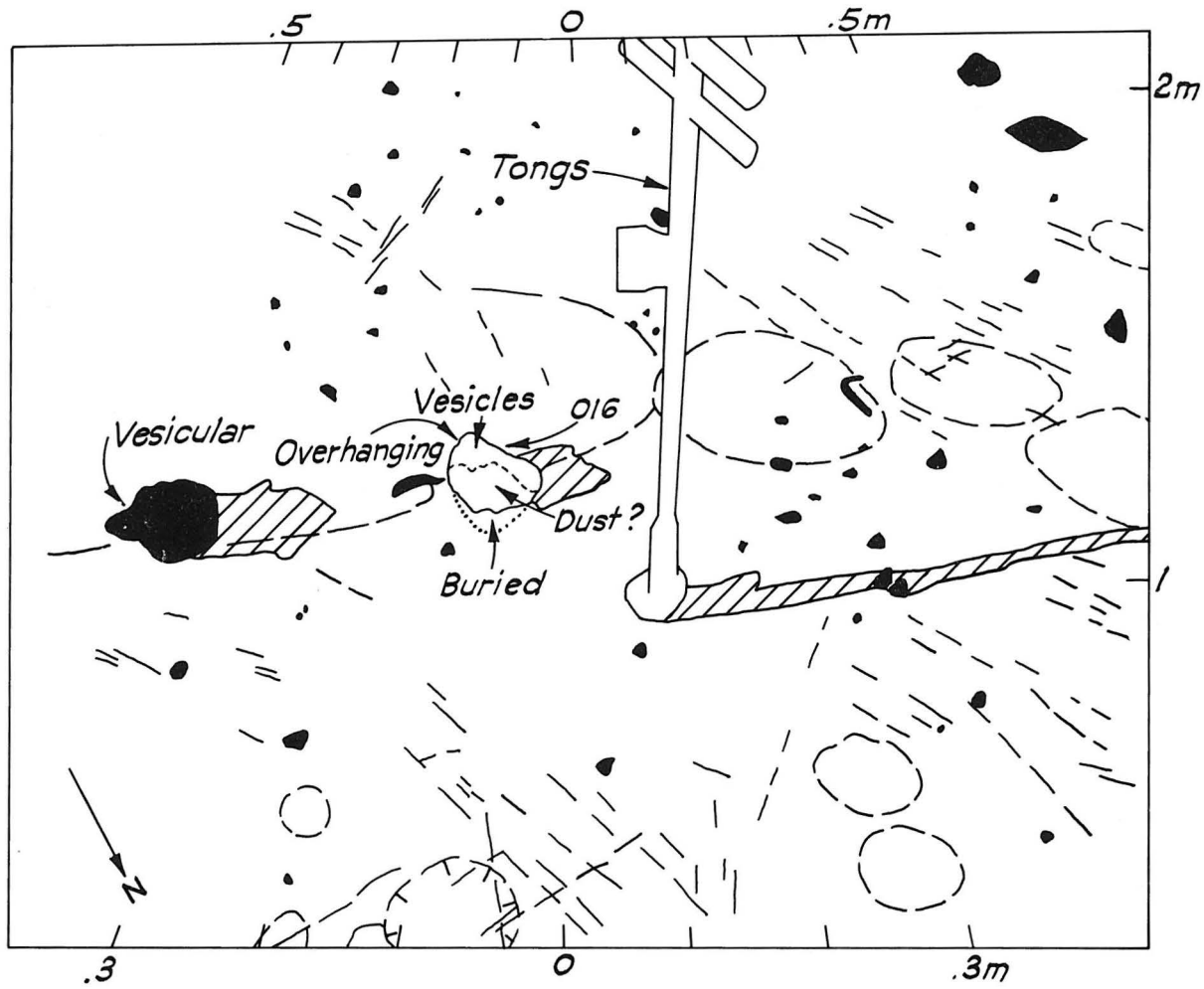

Figure 26b. Sample environment sketch map for sample 016.

Station 4

The basalt samples collected from the southern rim of the 460 m diameter Dune crater (fig. 1) were probably derived from bedded basaltic units from as deep as 90 m below the mare surface. Photographs of the northern wall of Dune crater indicate that the upper 1/3 has a rather uniform exposure of boulders, probably representative of the upper mare flows (plate 9; fig. 27). The smoother lower slopes of the crater wall and floor are covered with fine-grained infilling materials (fig. 27). The "raindrop" texture and relatively low abundance of fragments away from the rim crest of Dune indicate a relatively mature surface and a rather early Copernican age for the South Cluster secondary cratering event.

Most of the specimens collected from the Dune crater site were, as expected, basalts. The basalts, especially the large boulder from which samples 485, 486, and 489 were collected are vesicular (figs. 27, 29, 30). The documentation photographs of the boulder show its textural variations and provide the context from which samples 485, 486, and 499 were collected.

Samples 470-476, and 495.--Samples 470-476 and 495 were collected approximately 28 m south-southeast of the rim crest of Dune crater, the westernmost large

macro-vesicular basalt boulder on the rim of Dune and from or near which samples 485, 486, 498, and 499 were collected.

The immediate surface surrounding the samples has a moderate cover of fragments (figs. 28a, b). Small craters in the near environment are sparse. Lineaments are not visible in the documentation photographs, and the slope in the sample vicinity is negligible. Rock fragments greater than 6 cm across in the sample area are not filleted, and most are rather unique with respect to their lack of burial. The 17 cm rock partly hidden by the gnomon staff in Figure 28 appears to be the only larger fragment that is significantly buried. Nearly all of the rocks appear to be moderately dust covered. The apparent albedo of the samples and associated fragments is low to average and there is no evidence on the photographs of light clast microbreccia in the immediate vicinity.

Sample 495 might be associated with a small, moderately subdued 30 cm diameter secondary crater about 45 cm southwest of its collection site. It may have bounced to its present position from this crater; however, the association of the rock and this crater is only speculative. The 10 cm fragment due south of the sample 495 site also appears to be situated on the rim of a small secondary crater.

Basalt sample 475 is similar to 495 with regard to its size, shape, texture and general lack of filleting or extensive burial. Upon leaving Station 4, Commander Scott said that the samples gathered in this location were dust covered. Sample 476 is rather tabular and not equidimensional like samples 495 and 475. Although there is no visible secondary crater associated with either 475 or 476, their lack of filleting or burial suggests that they may have been recycled onto the surface at least once since the Dune crater event which probably ejected them from a layered basaltic flow material from as deep as 90 m below the present mare surface.

The soil sample (470-474) was taken between samples 475 and 495 as shown in Figure 28 but may contain a small percentage of disturbed (kicked) material due to astronaut activities in the area prior to sampling. The soil was collected from very near the surface probably in the upper 3 to 4 cm.

Samples 485, 486, 498, and 499.--Samples 485, 486, 498, and 499 were all collected either from or near the 2.0 m x 1.0 m x 0.5 macro-vesicular vuggy basalt boulder on the southern rim crest of Dune crater (figs. 4, 27).

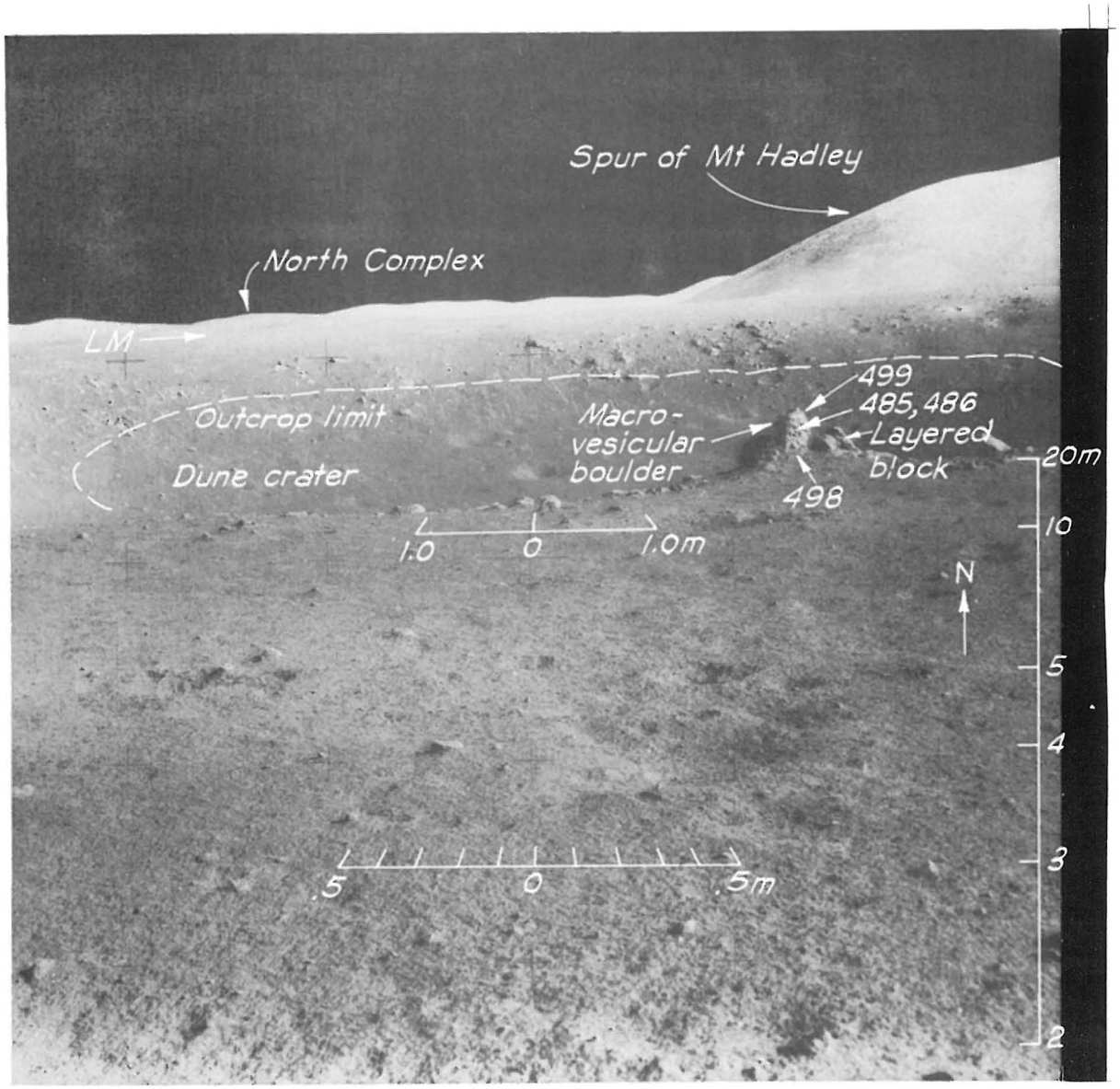

Figure 27. View of the boulders at the south rim of Dune crater showing locations of samples 485, 486, 489, and 499. Pre-sampling photograph AS15-90-12242, looking north.

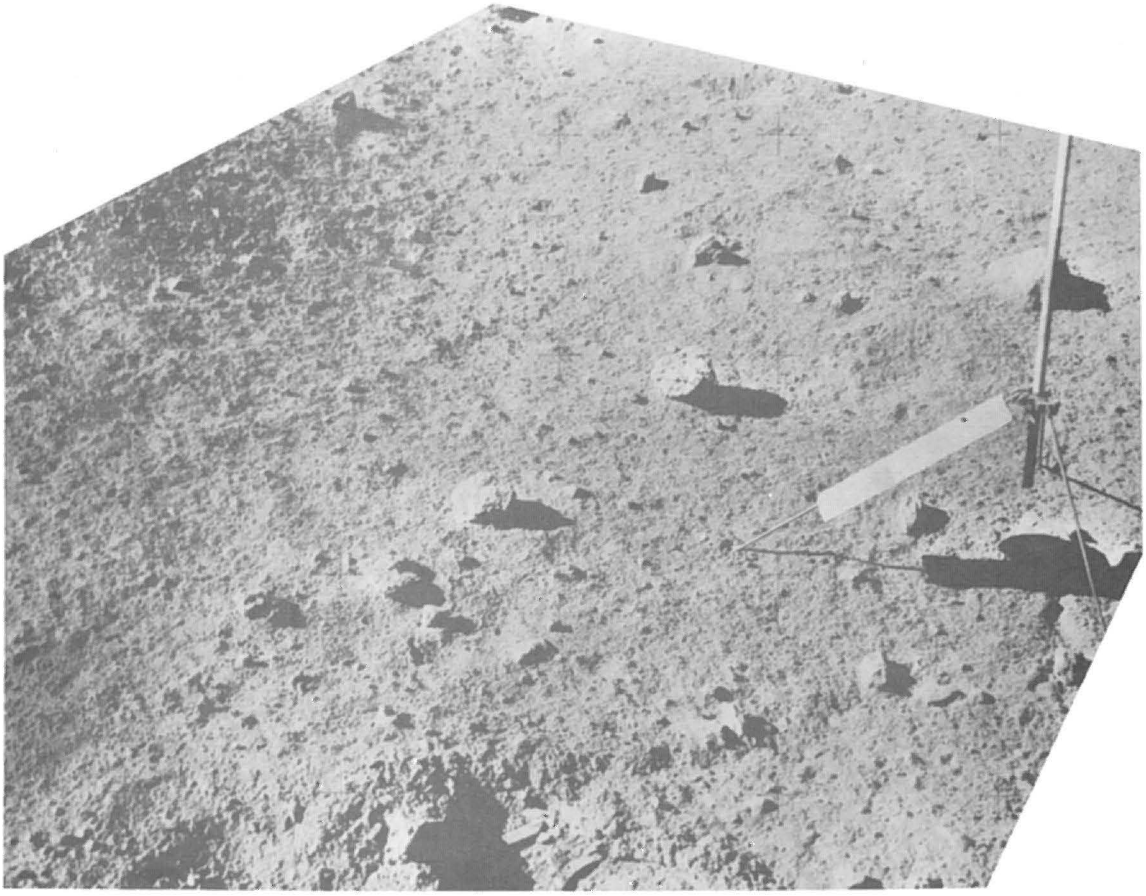

Figure 28a. Samples 470-476, 478, and 479 and vicinity. Pre-sampling photograph AS15-87-11759, looking south.

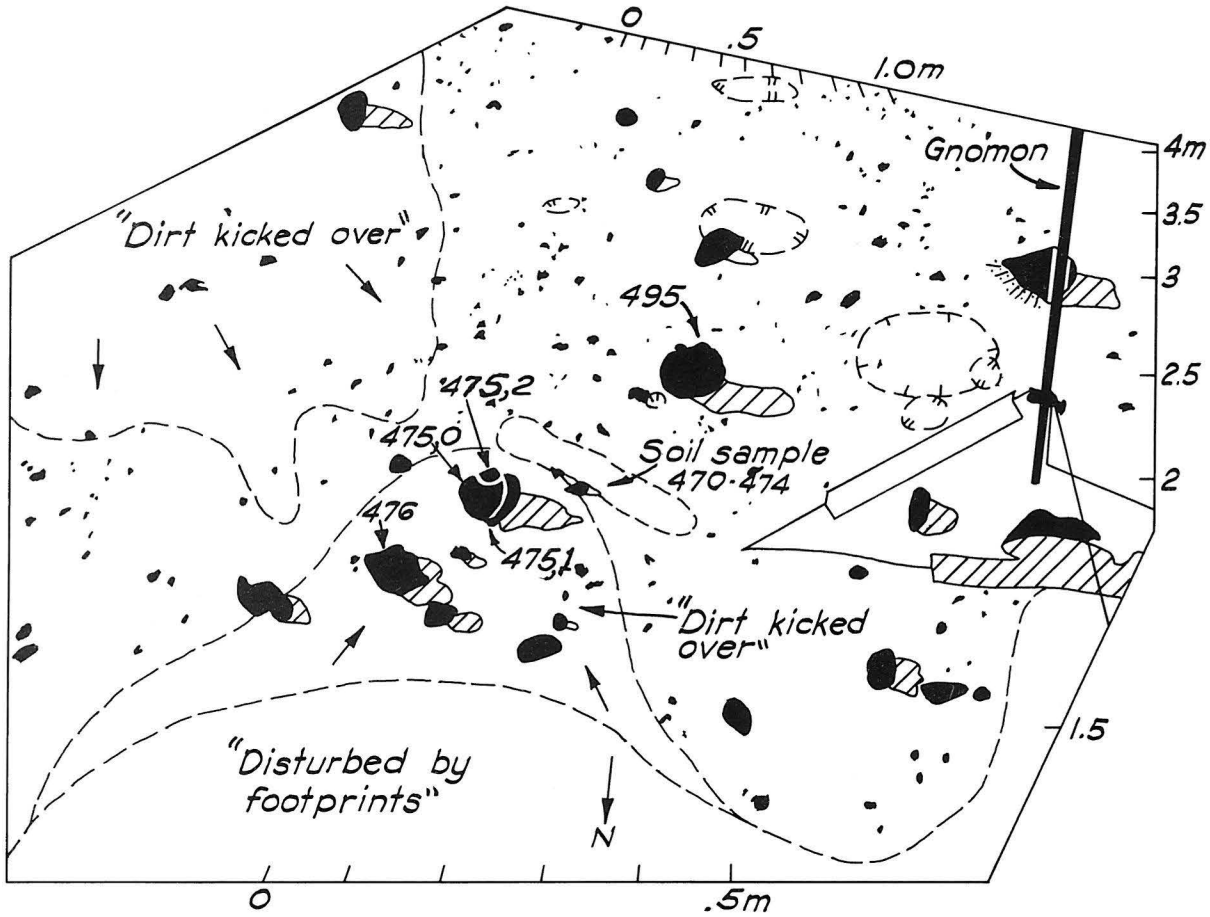

Figure 28b. Sample environment sketch map showing samples 470-476, 478, and 479.

The local surface on the immediate southern side of the basalt block is characterized by a rather well developed fillet formed on the block and a moderate abundance of rock fragments (figs. 29a, b). The rocks on the fillet are well buried and coated with dust. There are only a few fragments smaller than two or so centimeters across visible on the fillet, possibly due to the downslope movement of fines covering them. For possibly the same reason, there are no small craters on the fillet.

Samples 485, 486, and 499 were broken off the large macro-vesicular boulder (figs. 30a, b). Samples 485 and 486 were broken from a large vesicle (compare figs. 29 and 30), and 499 was broken along what appears to be a pre-existing fracture. The context from which the rocks were collected is suggested by Figure 31 that shows the increasing size of vesicles from left to right on the north end of the boulder. For scale, the tongs were included in the photograph. Each tine on the tongs is 3 mm diameter and the width of the tongs where they rest against the rock is 9.8 cm.

The comparison of Figures 29a, 30a, and 31 suggests an overall vesicular zonation of the large boulder. It appears that the finely vesicular zone extends across the area from which samples 485 and 486 were

collected, and the more coarsely vesicular zone extends up through the area from which sample 499 was collected.

Sample 498 (a soil breccia) was collected near the base of the fillet on the large basalt block where it was between 1/3 and 1/2 buried in the fillet (figs. 29a, b). The sample appeared to be moderately covered with dust prior to collection.

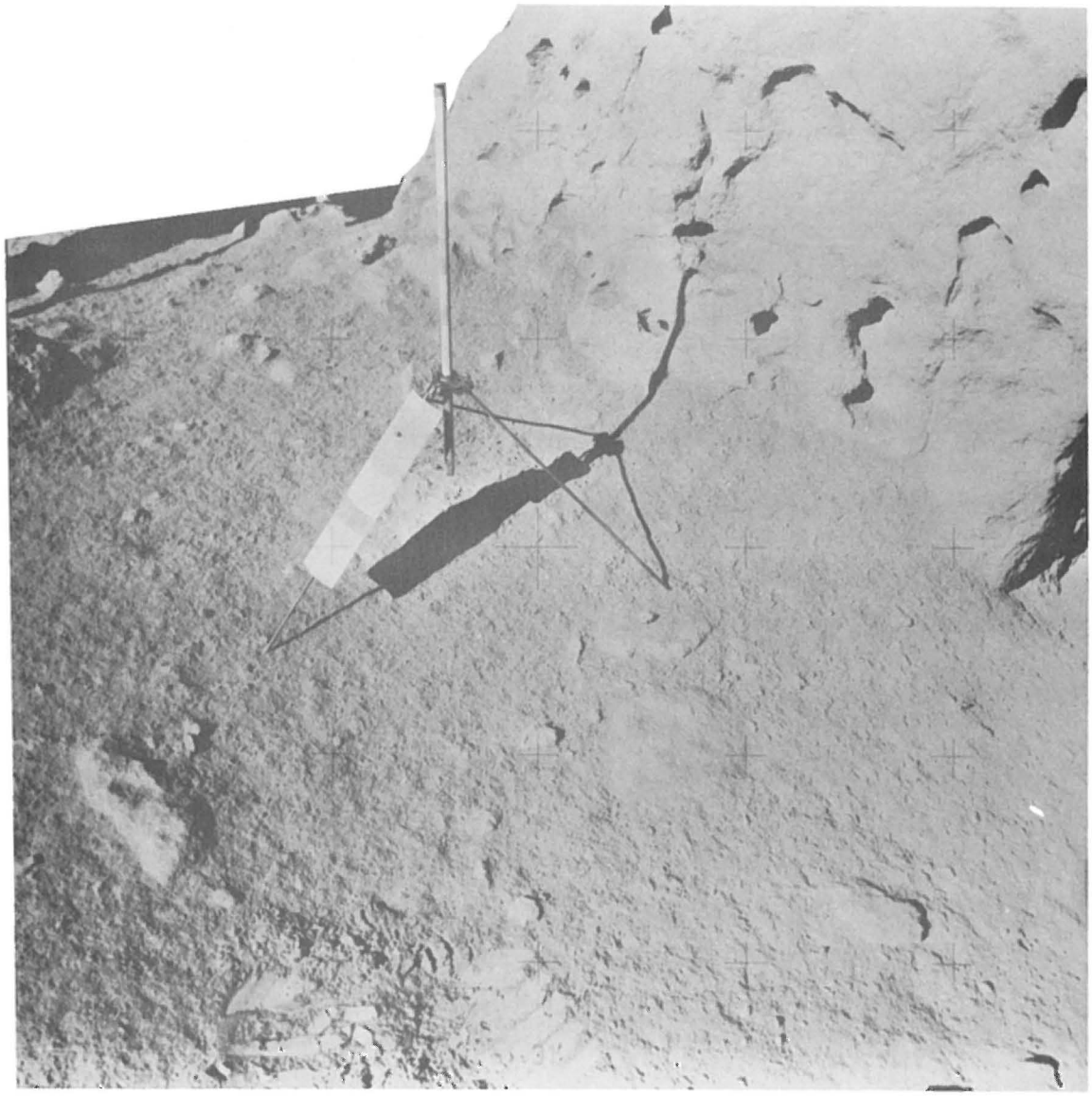

Figure 29a. Samples 485, 486, 498, and vicinity. Pre-sampling oblique-to-sun photograph AS15-87-11765, looking southwest.

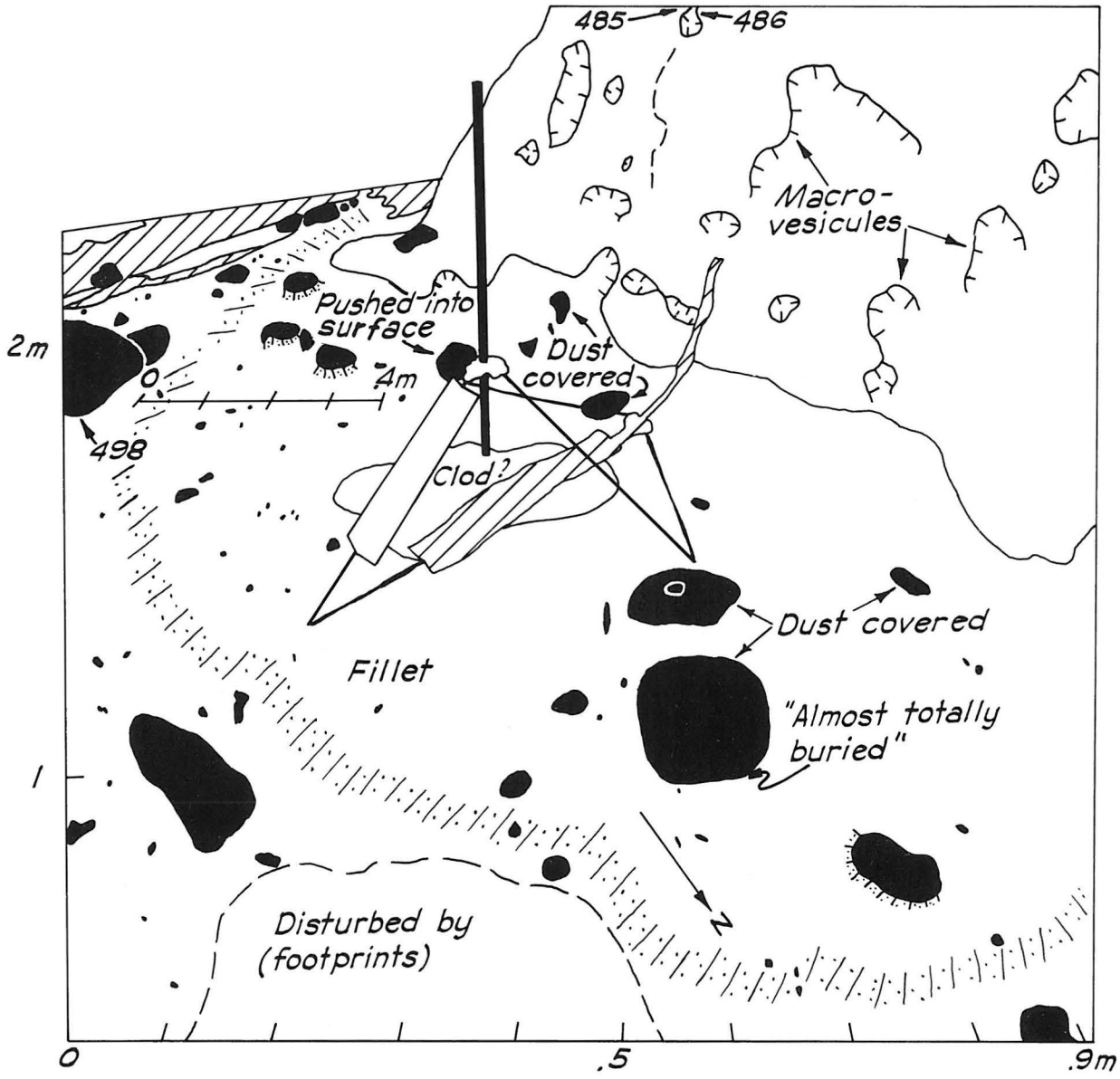

Figure 29b. Sample environment sketch map showing samples 485, 486, and 498.

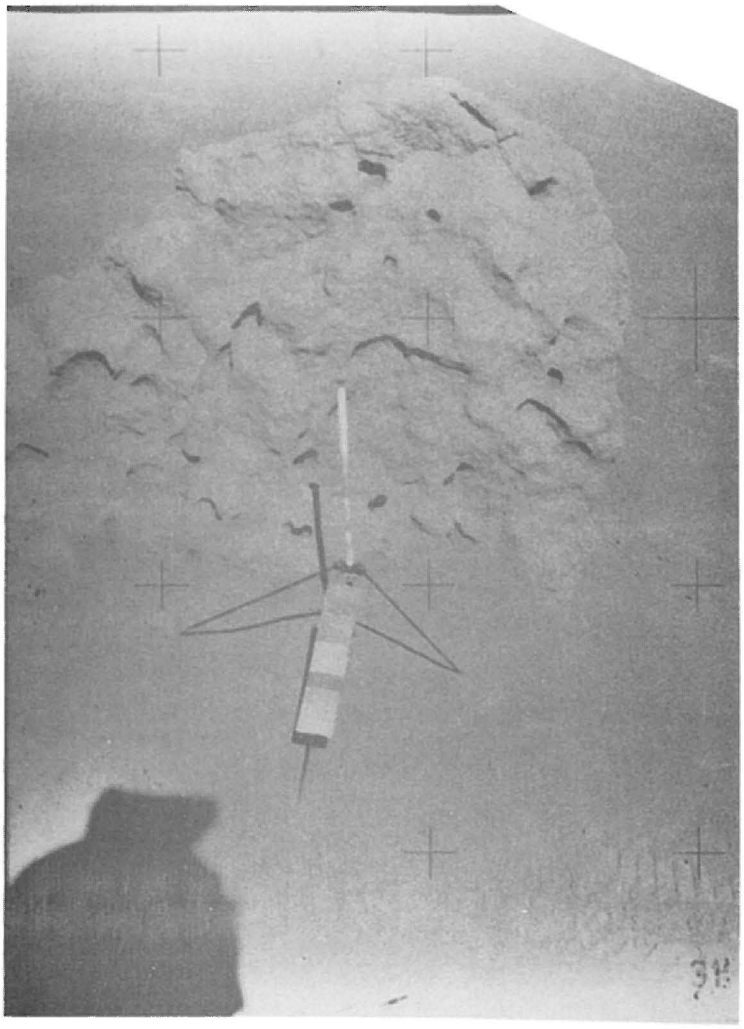

Figure 30a. Samples 485, 486, 499, and vicinity. Pre-sampling, down-sun photograph AS15-87-11768, looking west.

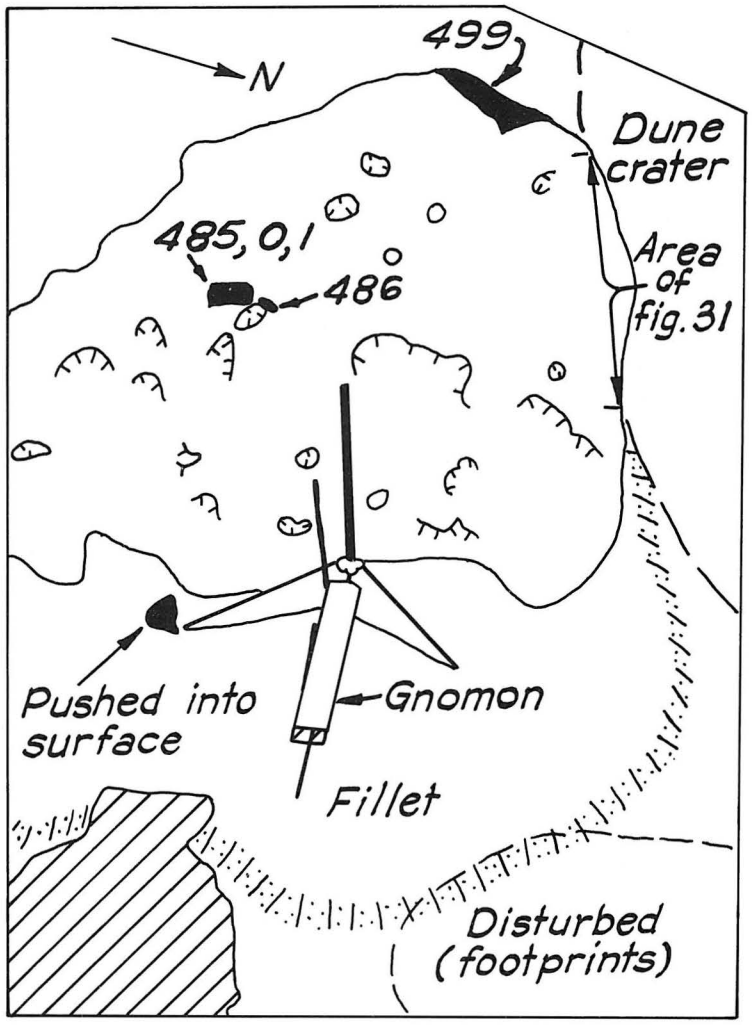

Figure 30b. Sample environment sketch map showing location of samples 485, 486, and 489.

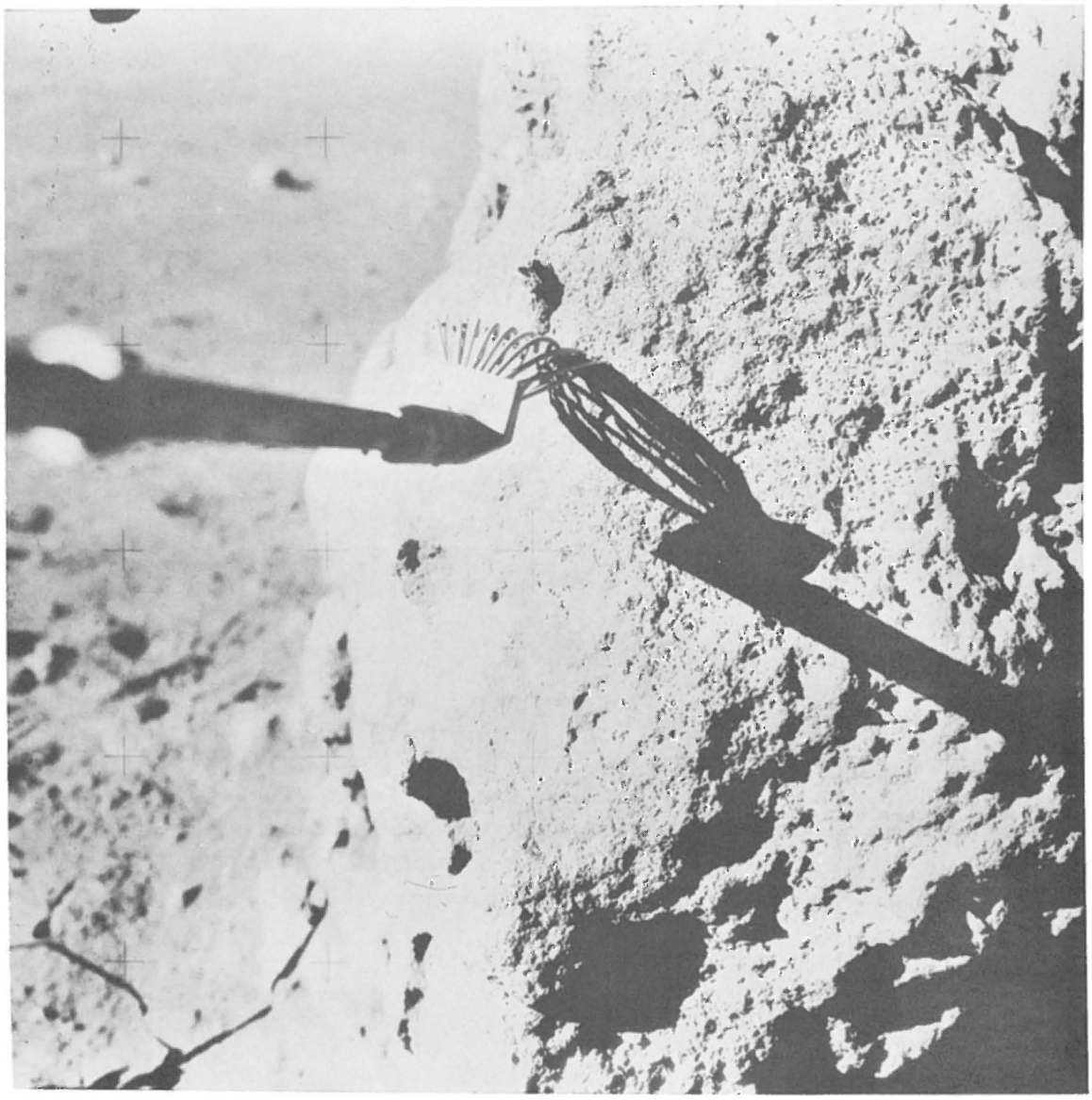

Figure 31. North end of large basalt boulder showing increase in vesicle size from left to right. The largest holes do not seem to be in zones. Sample 499 above the top of the picture. Photograph AS15-87-11773, looking south.

Station 6

Twenty-five samples were collected at Station 6 and represent a total of 5 soil samples, 7 soil breccias, 10 breccias, and one basalt. In addition one SESC and one core tube were collected.

Station 6 is the farthest point east sampled on the Apennine front during the mission (fig. 1). It is located nearly 3 km east of St. George crater and 5 km southeast of the LM, on the north-facing slope of Hadley Delta which varies from 5 to 15+ degrees at this location.

In general the 10 rocks weighing more than 20 g each collected at this station are fine grained breccias, not traceable to local bedrock but probably representative of the larger fragment population on Hadley Delta front. Samples from a depth of about 3 m were collected from a 12-m crater north of the LRV (fig. 32). They are considered to be recycled from underlying regolith as are most of the rocks in this area; originally, however, the majority of material must have come from higher up on the front having moved downslope with time due to cratering and gravity. Some fragments may be exotic to the local geologic unit (fig. 1), in particular sample 256, the one basalt identified from this locality as of the date of this report (see table 2).

A subtle difference in soil characteristics may be expressed in the fine granular appearance and deeper burial of fragments toward the east (fig. 33) as compared with coarser textures (observed as higher concentrations of centimeter-size fragments) and less burial west and north of the LRV (fig. 34). This tentative analysis indicates some variation in distribution of fine and coarse surface materials. Fragments greater than 10 cm are uniformly, although sparsely, distributed in the intercrater areas, with notably higher density around the 12-m diameter crater (fig. 32). The only fresh craters present are less than 1 m in diameter and from these only clods of soil or soil breccia were excavated.

Two types of environments from which samples were collected are defined at Station 6: 1) the 12 m diameter crater rim environment, and 2) the Hadley Delta slope environment. The sample environments are described accordingly in this section.

Sample 009.--Sample 009 is the core which was collected from the north rim of a 12 m diameter crater (fig. 32) that is 10-15 m downslope from the LRV at Station 6 (fig. 4). The rim of this crater is subdued, but distinctly raised about 0.5 m above the surrounding slope. Several 1 m diameter sharp craters are on the rim of the crater.

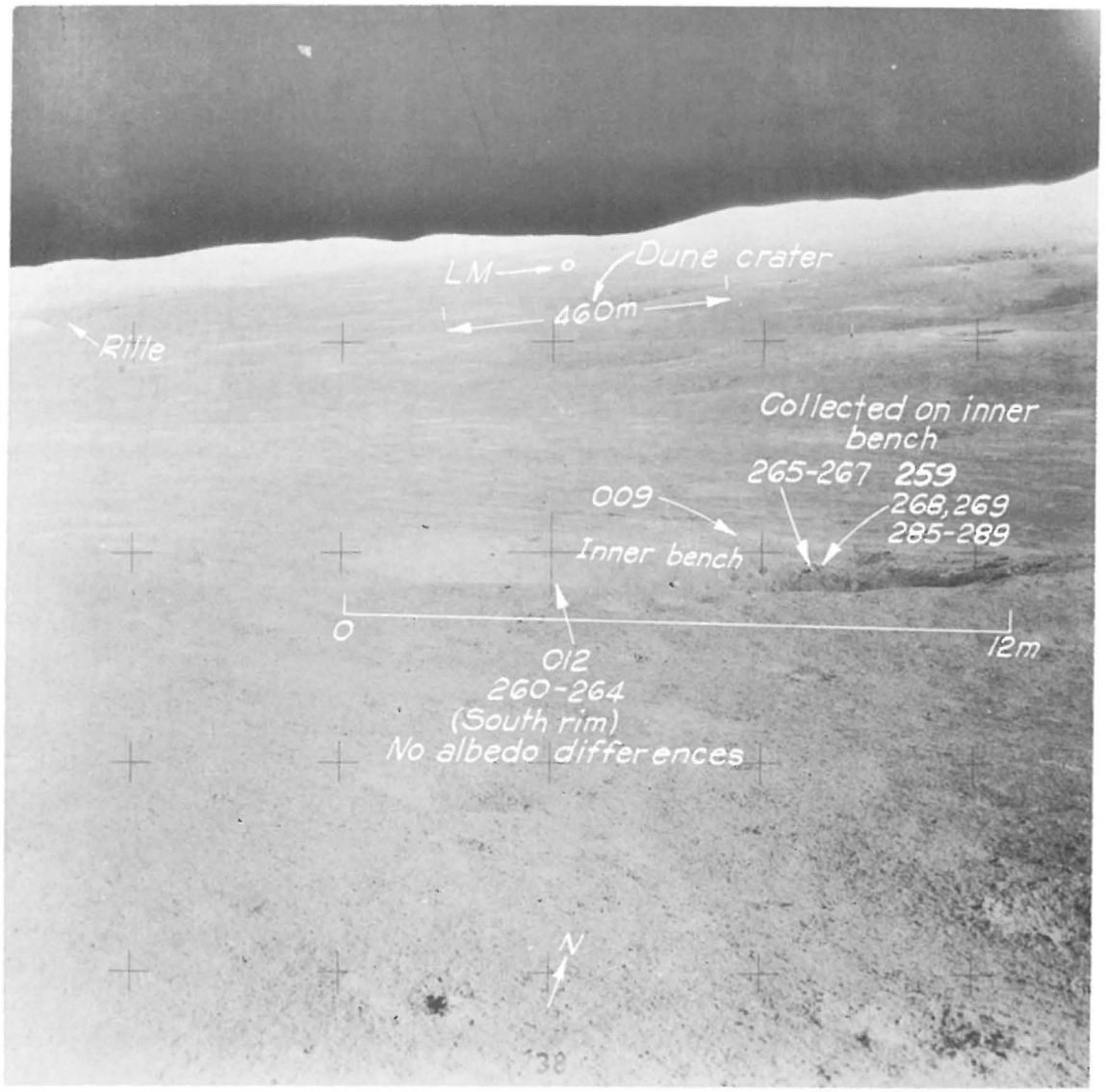

Figure 32. Twelve-meter crater north of LRV at Station 6, showing locations of samples 009, 012, 259, 260-264, 265-269, 285-289. Pre-sampling, panorama 9 photograph AS15-85-11485, looking northwest.

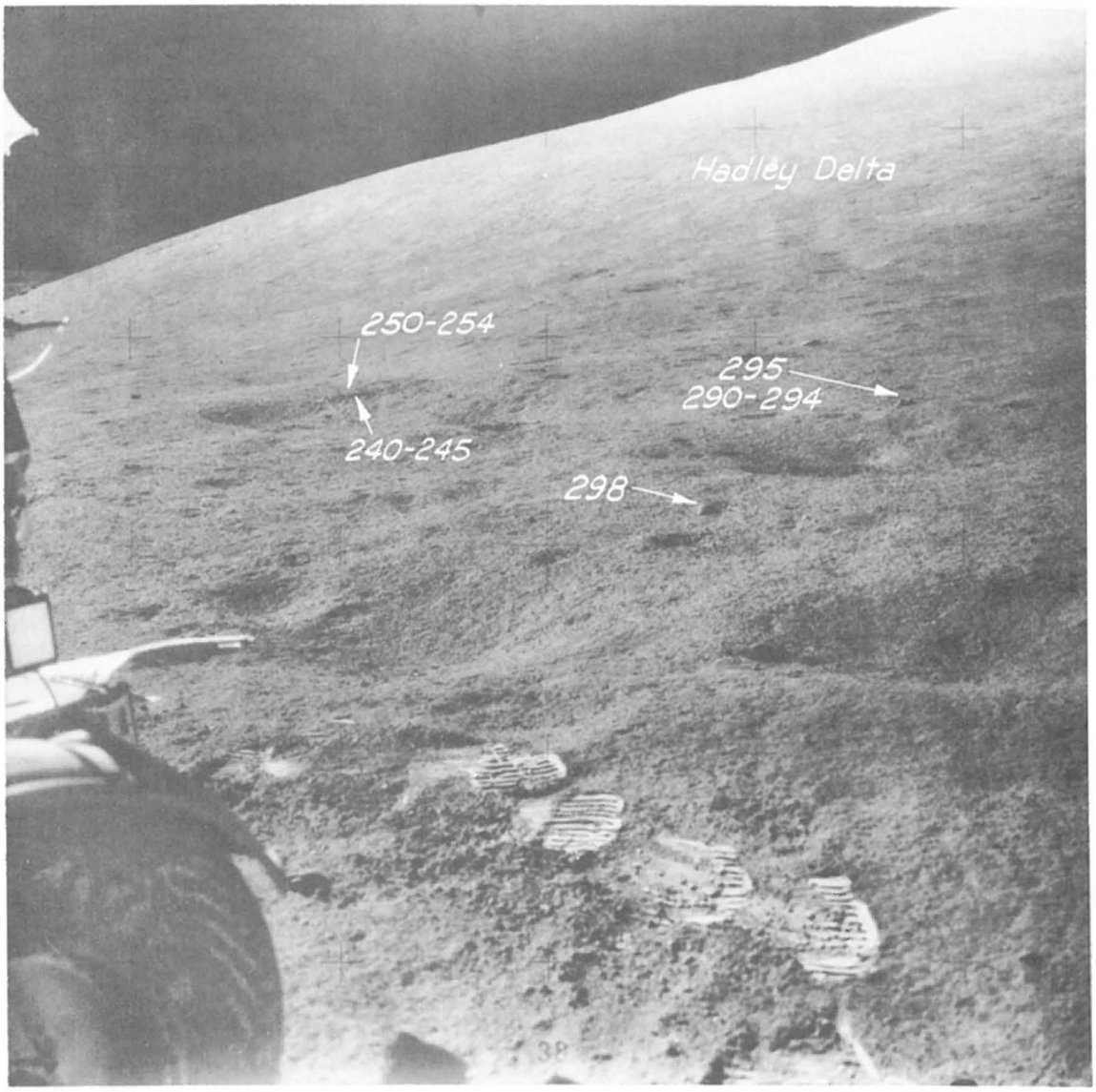

Figure 33. View southeast from LRV showing locations of samples 240-245, 250-254, 290-294, 295, and 298 before sampling. Photograph AS15-85-11495, from panorama 9.

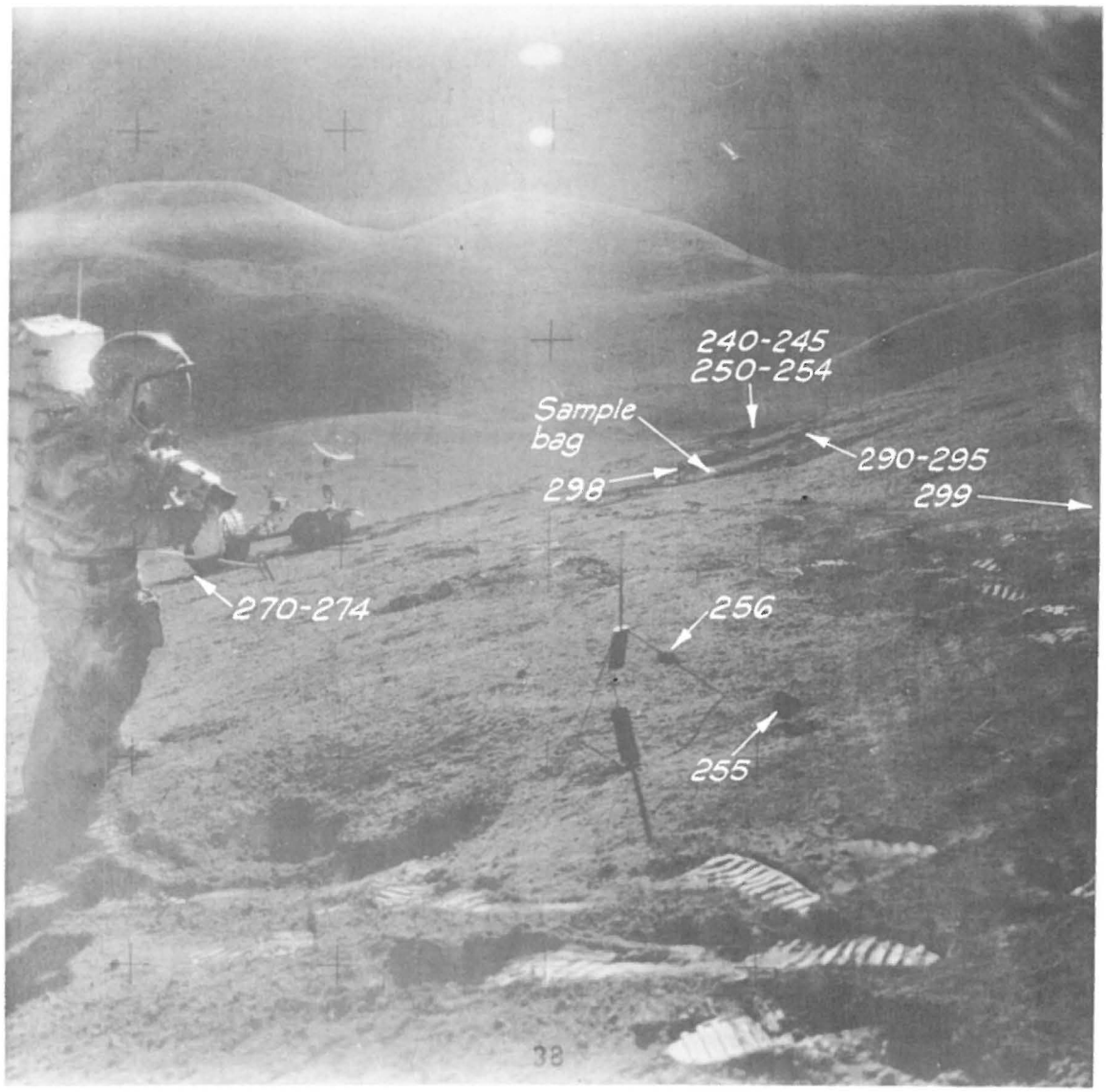

Figure 34. View eastward from panorama 10 showing locations of samples 240-245, 250-254, 290-295, 298 and 299 after collection. Samples 255 and 256 are shown prior to collection; the location of 270-274 is behind the LRV. Photograph AS15-85-11515.

The surface into which the core was driven (fig. 35) is littered with angular fragments on the order of 0.5 to 2 cm and smaller. The astronauts noted that the north rim of this crater was more "granular" than the south rim where they dug the trench. A few 10-20 cm diameter, very subdued craters pock the surface.

Some albedo differences in the fine-grained surface material are present about 1.5 m southeast where samples 265-267 were collected. There, the astronauts' boots kicked up light-toned material. The astronauts returned to this area, after the trenching on the south rim, to collect some of the lighter albedo material in the core.

Samples 259, 265-269, and 285-289.--Samples 259, 265-269, and 285-289 were collected from the crest of an inner bench on the northeast wall of the moderately fresh 12 m diameter crater located approximately 15 m downslope from the parked LRV at Station 6 (approximately 400 m southeast of Spur crater) (figs. 4, 32). The rim of the crater is subdued but raised about 0.5 m above the surrounding surface. Parts of the rim have well developed benches, particularly the north and northeast sides. Several sharp 1 m diameter craters are on the rim of the crater (fig. 36a). Figures 37a,b illustrate the distribution of rock fragments in the

Figure 35. Site of core tube sample 009 on north rim of 12-m diameter crater at Station 6. Pre-sampling cross-sun photograph AS15-86-11648.

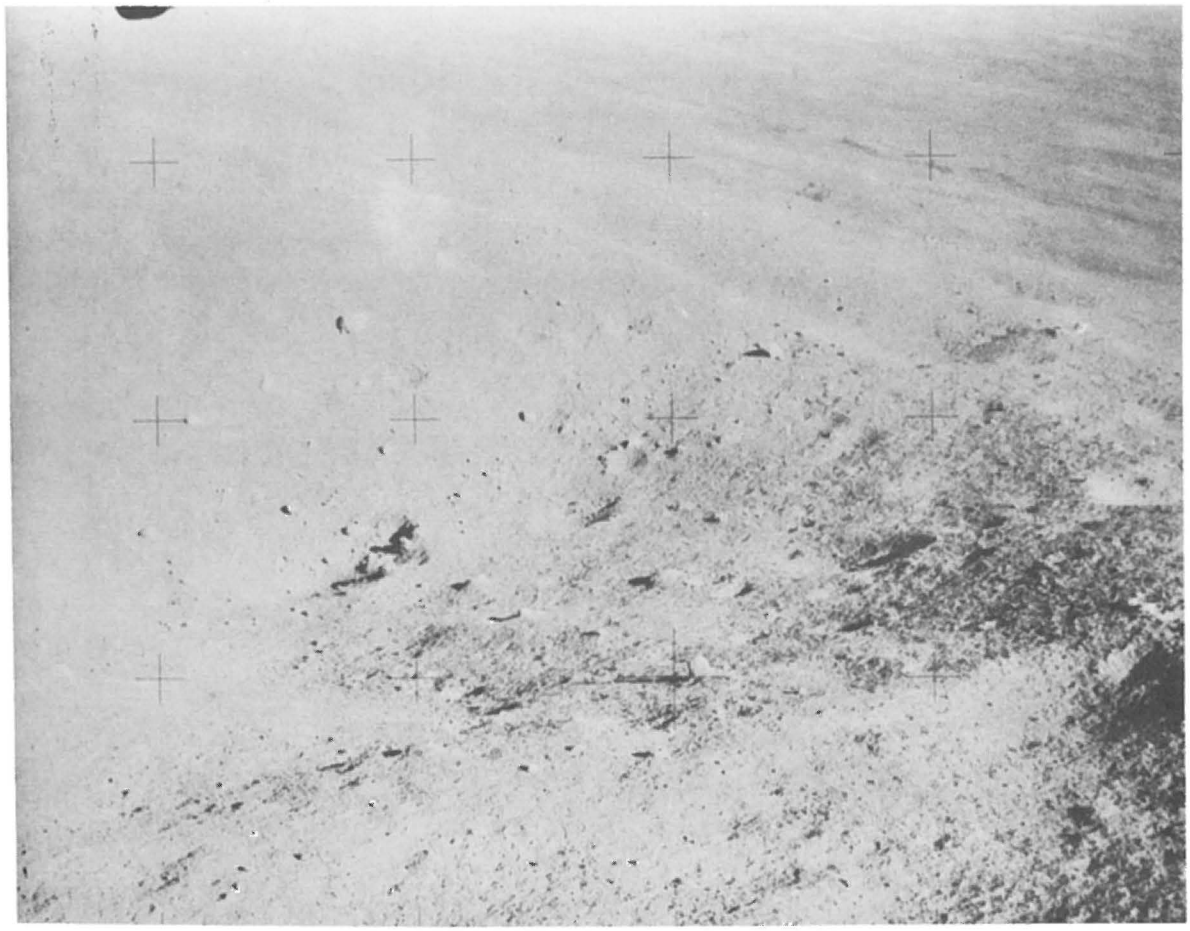

Figure 36a. East end of 12-m diameter crater at Station 6 showing area of samples 259, 265-269, and 285-289. Pre-sampling, cross-sun photograph AS15-86-11634, looking north.

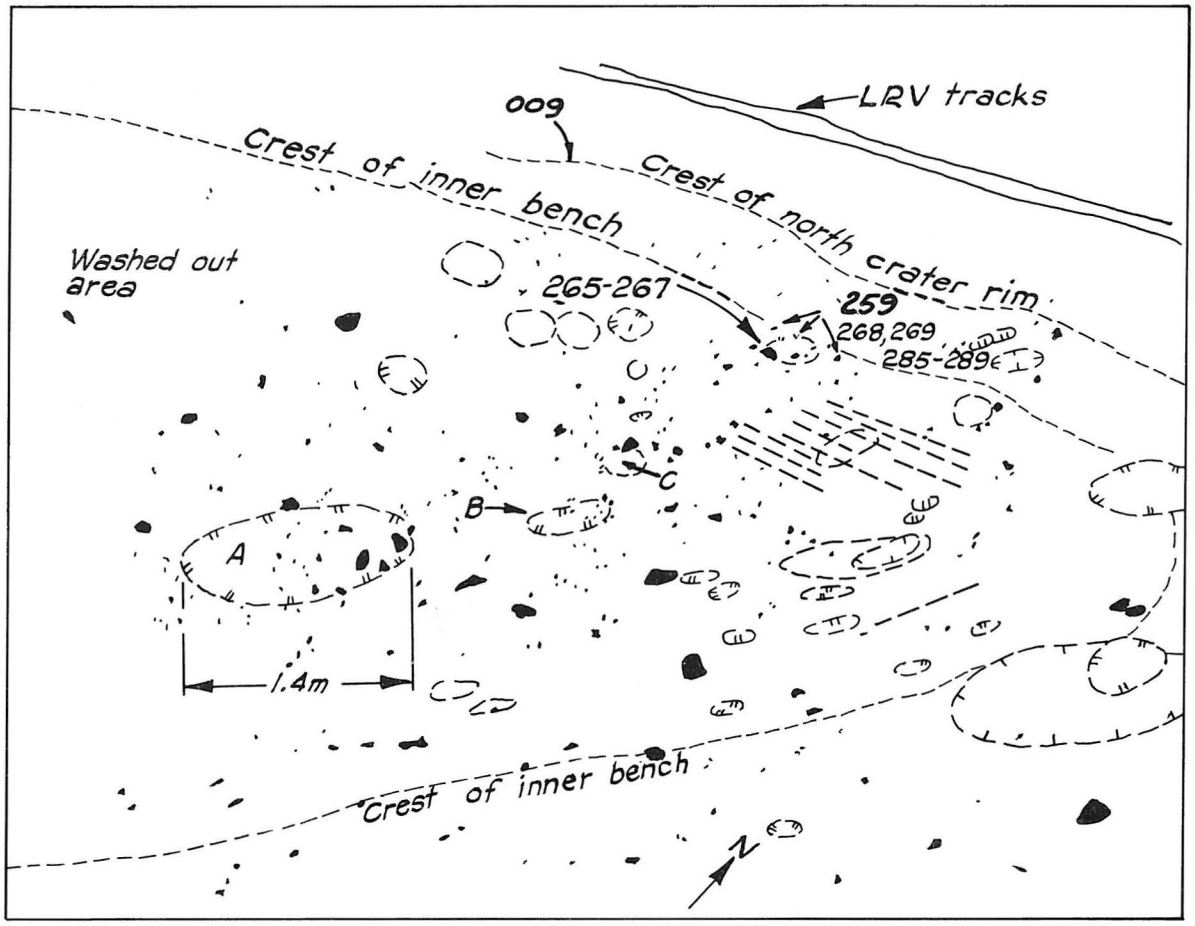

Figure 36b. Sample environment sketch map showing distribution of fragments in the area of samples 259, 265-269, and 285-289.

vicinity of the sampling area and their possible relationships (as ejecta material) to the smaller fresh craters mentioned above. Small, parallel east-trending lineaments are visible on the north wall of the 12 m crater inner bench near the sample area (fig. 36a). The slope in the immediate vicinity of the samples is about 15-20 degrees to the southeast, down toward the floor of the crater. The regional slope, however, is an average of 10 degrees to the north, down the Hadley Delta front toward the South Cluster.

Filleting and burial on the rock fragments in the sampling area is less than would be expected for debris lying in position since ejected from the 12 m crater. Nearly all fragments appear to have been recycled onto the surface by the small, fresh, 1 m diameter range, primary and secondary craters in the near vicinity. Dust cover on many of the rock fragments seems higher than normal; probably the result of ejecta from craters distributed around the immediate area. The north rim of the large crater has a higher-than-average albedo and light colored soil was kicked up during sampling activities.

The largest single rock fragment collected in the sampling area is labeled in Figure 37b as the source of specimens 265-267 (breccias). Commander Scott broke

the large fragment (as it was too large for a sample bag) with a hammer after rolling it toward him. The two largest pieces from the rock after breaking are illustrated in Figure 38a in the positions in which they landed. These two fragments were later collected and are identified as samples 265 and 266. Sample 267 has not been identified in the photographs. The original large breccia was buried up to 1/3 its height and possessed a very slight fillet. Most of the fragment's burial may well have been due to its original impact as a secondary projectile. The "265-267" rock was found resting on the north rim of a small 40 cm diameter secondary crater which was most likely created by the low velocity impact of this sizeable fragment. A very probable source of this rock may have been the 1.4 m diameter crater labeled A in Figures 36a, b and 37a, b. The smaller craters labeled B and C are probably too small to have been the impact source for the "265-267" rock. The abundant small fragments immediately surrounding the larger breccia appear to be pieces of it and were possibly broken from it upon impact. However, some fragments may have spalled from the larger rock after impact. Samples 259, 268, 269, and 286-289 collected from these associated fragments are all breccias like 265-267 and therefore, may be

Figure 37a. Sample 259, 265-269, 285-289 collected on inner bench, inside the north rim of 12-m crater at Station 6. Pre-sampling, cross-sun photograph AS15-86-11635, looking south.

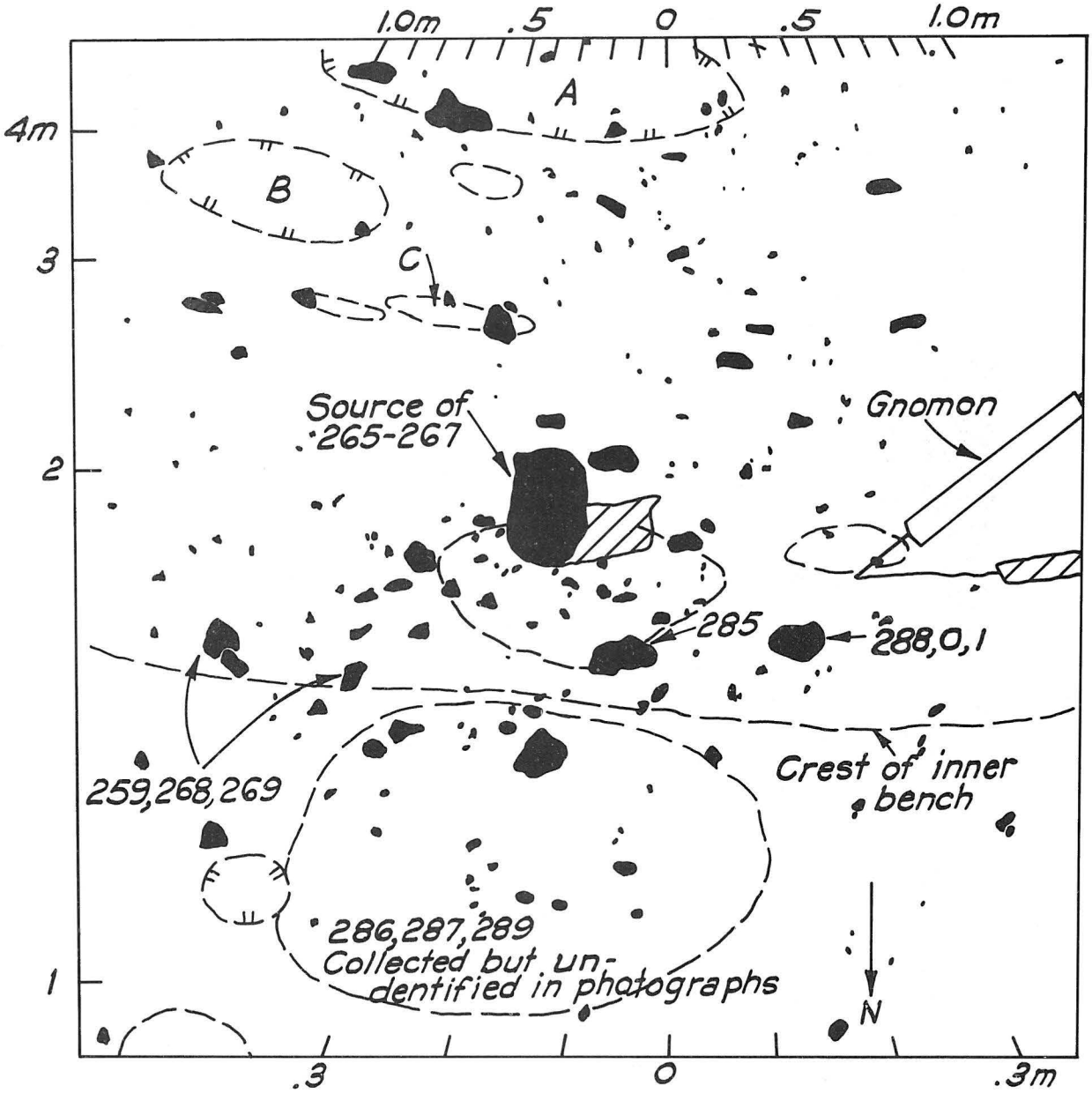

Figure 37b. Sample environment sketch map of vicinity of samples 259, 265-269, 285-289.

Figure 38a. Samples 265-267 and vicnity on inner bench inside north rim of 12-m diameter crater at Station 6. Original position of rock was in shallow crater (20 cm diameter) with pieces surrounding it. Crater "C" also shown on Figures 36a, b and 37a, b. Pre-sampling, cross-sun photograph AS15-86-11638, looking south.

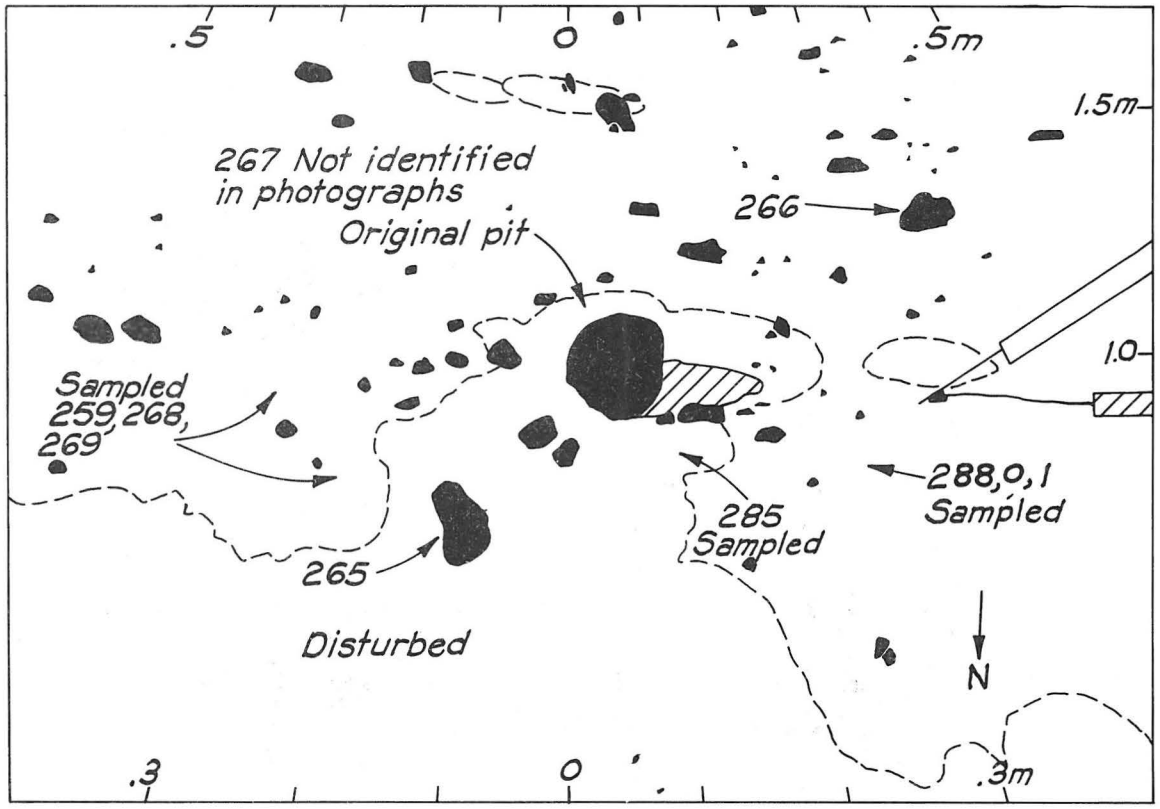

Figure 38b. Sample environment sketch map for vicinity of 265-267.

genetically associated. All fragments from bags 192 and 193 have partial glass coatings, which adds to the possibility of their common origin. The smaller samples were only moderately buried but were covered with a considerable amount of dust that was possibly derived from local ejecta sprays. Commander Scott dusted off one breccia fragment (from bag 192) at the time of sampling for better identification.

In summary, the samples collected at this point may represent material locally recycled to the surface at least once after originally having been ejected from 2-3 m depth by the 12 m diameter benched crater. The material representative of the crater ejecta is apparently breccia which could be interpreted as Imbrian (Fra Mauro) or pre-Imbrian material making up this portion of the Hadley Delta front. The partial glass coating found on nearly all of the collected specimens could have been added at the time of their latest arrival at the surface by either primary or secondary impact.

Samples 012, and 260-264.--Samples 012 and 260-264 were collected from a trench dug into the south rim of a 12 m diameter crater 10-15 m downslope from the LRV at Station 6 (figs. 4, 32).

The surface where the trench was dug (fig. 39a) is littered with fragments ranging from 0.5-2 cm in

size, but distinctly fewer than on the north rim of the same crater (fig. 35). This may have prompted the astronauts' remark that the south rim was softer and the north rim more granular. In the area of the trench, there were no albedo differences reported in the surface or in the subsurface and none are visible in the photographs. At the trench, the fine-grained material resembled the color and texture of cement from the surface to the trench bottom (fig. 39b).

Based on the photographs and astronaut descriptions, the north and south rims of this 12 m diameter crater are significantly different with respect to surface texture and composition of material. These differences should be reflected in the core and trench samples collected.

Samples 240-245, and 250-254.--Samples 240-245 were collected from the floor, and samples 250-254 from the east rim of a 1 m crater approximately 20 m southeast and upslope from the LRV (fig. 33). The crater is marked by a concentration of fragments, primarily clods up to 10 cm in diameter, on an otherwise smooth, finely granular surface (fig. 40). It was described by the crew as a "fresh little crater" and it is superposed on the south wall of a subdued 3 m crater which has no visible ejecta material around it.

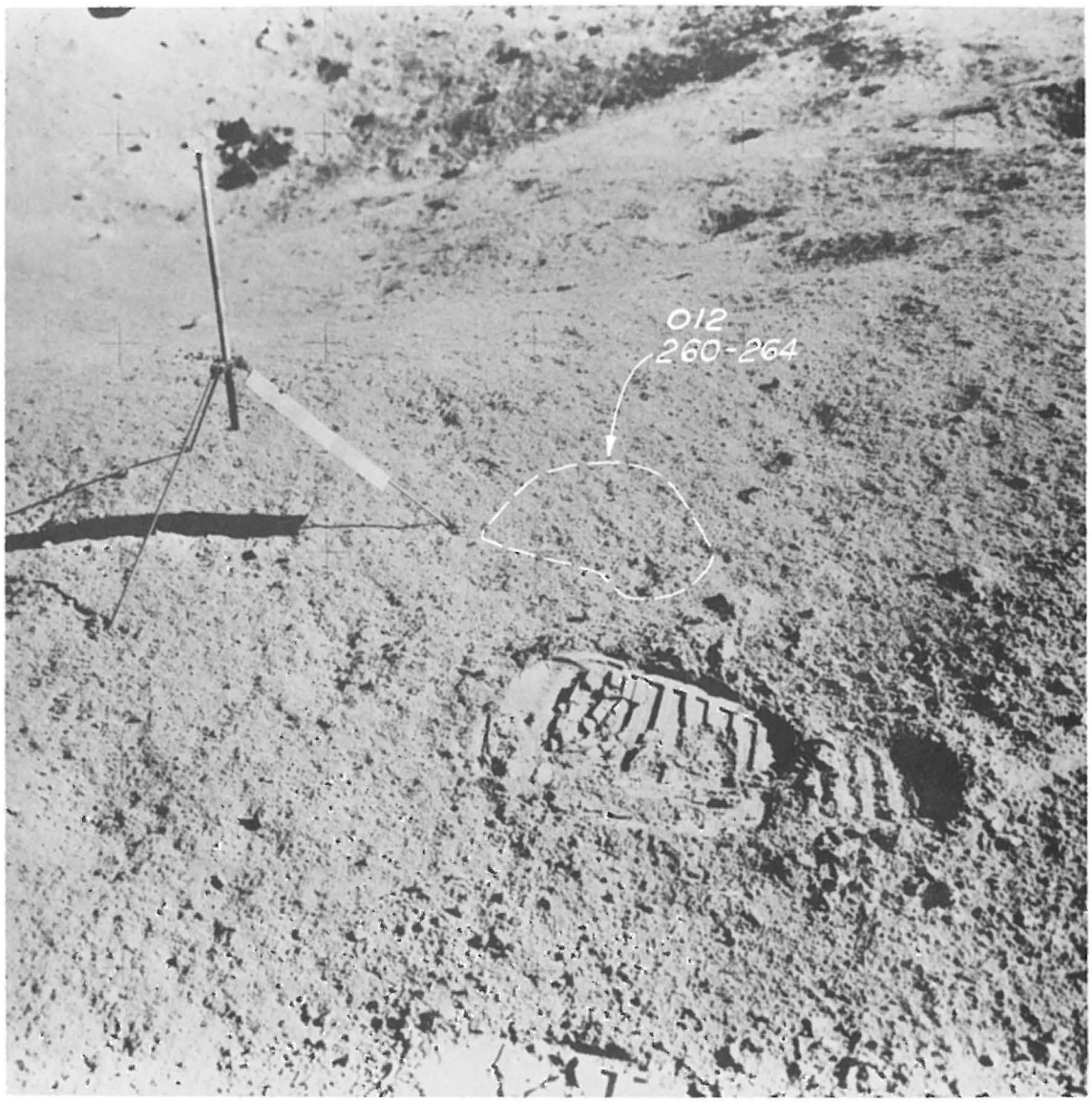

Figure 39a. Site of trench dug on south rim of the 12-m crater. Pre-sampling, cross-sun photograph AS15-86-11641, looking north.

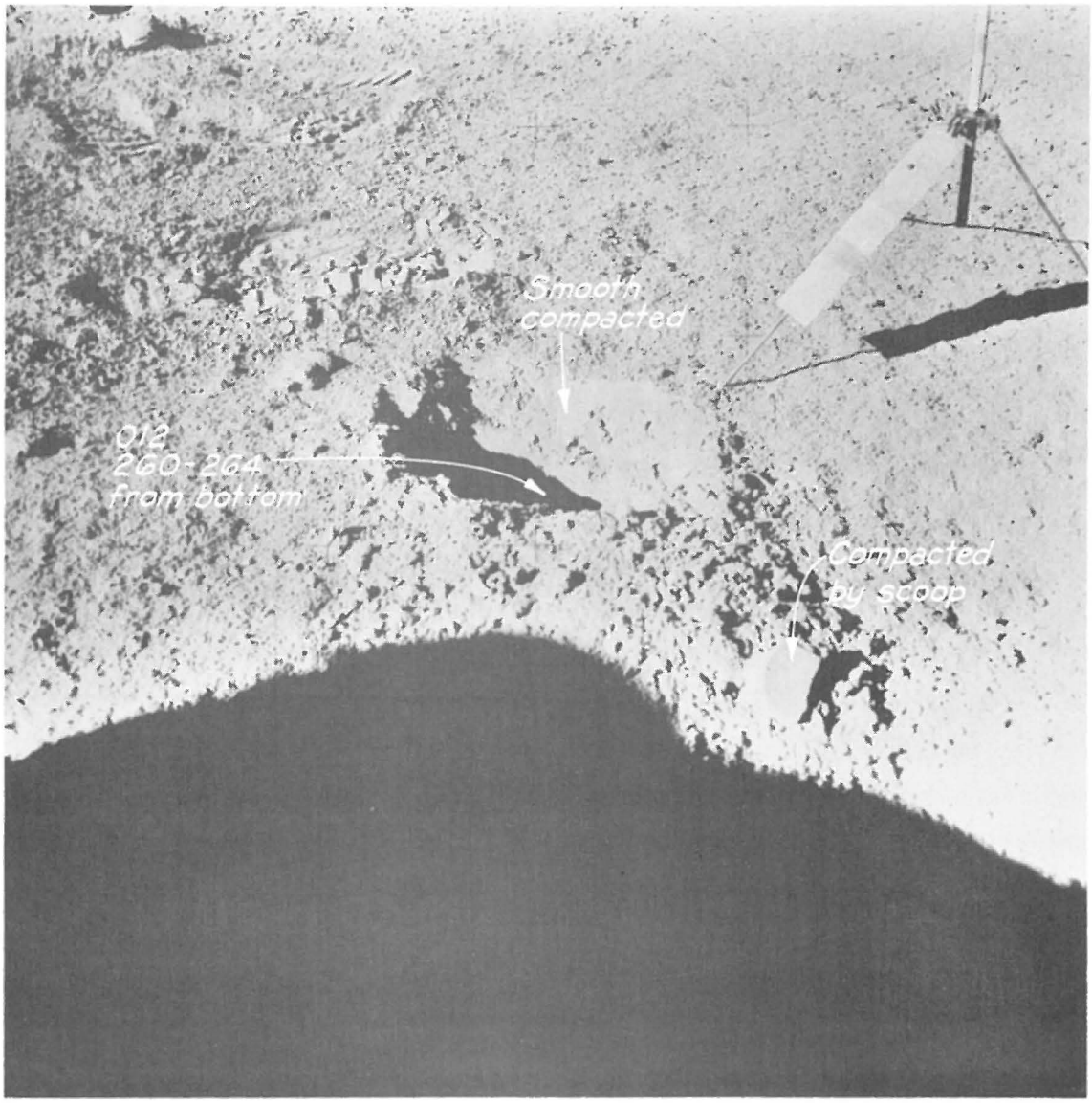

Figure 39b. Post-sampling photograph AS15-86-11643 of trench from which samples 012 (SESC-1) and 260-264 were collected. Looking southwest.

A few isolated rocks in the area are coherent breccias up to 20 cm in diameter with varying degrees of burial (e.g., samples 298 and 299). Approximately six such fragments occur within 20 m of the sample location. The remainder of the surrounding surface is covered by fine material less than a centimeter in size.

The frequency of fresh craters in the area is low. The only one in the immediate vicinity is the one sampled. The remaining craters are subdued with the exception of a few depressions smaller than a meter which have coarsely granular rims and may be relatively young. None of the craters observed appear to penetrate a cohesive substrate.

The general slope in the area of the samples is approximately 10 degrees to the north (the gnomon indicates a local slope of 8 degrees to the northeast). No readily visible lineaments are present. Fillets are notably lacking around the generally angular fragments scattered over the crater rim, wall, and floor, and there is no detectable burial of any clods other than the disturbed fines and smaller clods that were redistributed at the time of crater formation. No apparent variations in albedo occur in the down-sun views.

Samples 240-245 and 250-254 appear to be of similar material in the documentation photographs (AS15-86-11609 through 11615); however, samples 240-245 represent two scoops of the "welded" splash glass, broken soil breccia, and fines from the floor, and 250-254 were described as "very fine light gray" material from the east crater rim. Therefore the two samples may reflect the composition of a glass-coated projectile from outside the area with local soil, and freshly cratered soil from about 20 cm depth in the immediate locality, respectively.

Samples 255-257.--Three rocks were collected in a single bag from this location, 30 m west of the LRV and approximately 25 m southwest and upslope from the 12 m diameter crater (plate 7; fig. 4).

The only basalt collected at Station 6 is sample 256, (table 2) and was presumably the first of the three rocks collected. It has a more friable or granular surface texture and a lower profile on the surface, due perhaps to minor filleting, than rock 255, a breccia, which was collected less than a meter away (fig. 41) and was described by the crew as a micro-breccia with "glass all over the bottom" and "a couple of very small glass-filled pits." The third rock in the bag is a breccia (257) that has not yet been

located but may represent "other soil" referred to by the crew at the time of collection, or may have broken off one of the other two samples. Comparison of the shape, texture, and composition of sample 257 with these rocks should establish its relationship to them.

The general surface texture around samples 255-257 is coarsely granular with 10-15 percent of the undisturbed area covered by centimeter-size clods. Several craters 10-30 cm in diameter with slightly raised rims but no pronounced ejecta occur in the vicinity. No distinctive lineaments are apparent although a very subtle pattern trending north-south occurs near the gnomon (fig. 41). The area slopes approximately 10 degrees to the north; the gnomon in Figure 34 and in the down-sun view (AS15-86-11631) indicates a local slope 13 to 18 degrees north. Two 3-4 cm fragments near the gnomon appear partly buried (10-15 percent) and slightly filleted on the uphill side. These are candidates for identification as sample 257. No albedo differences in the rocks or soil are visible down-sun.

Samples 255-257 are not obviously related to prominent nearby craters. Sample 255 may have bounced out of the small crater just to the west (fig. 41) and it shows the least burial of the few local rocks

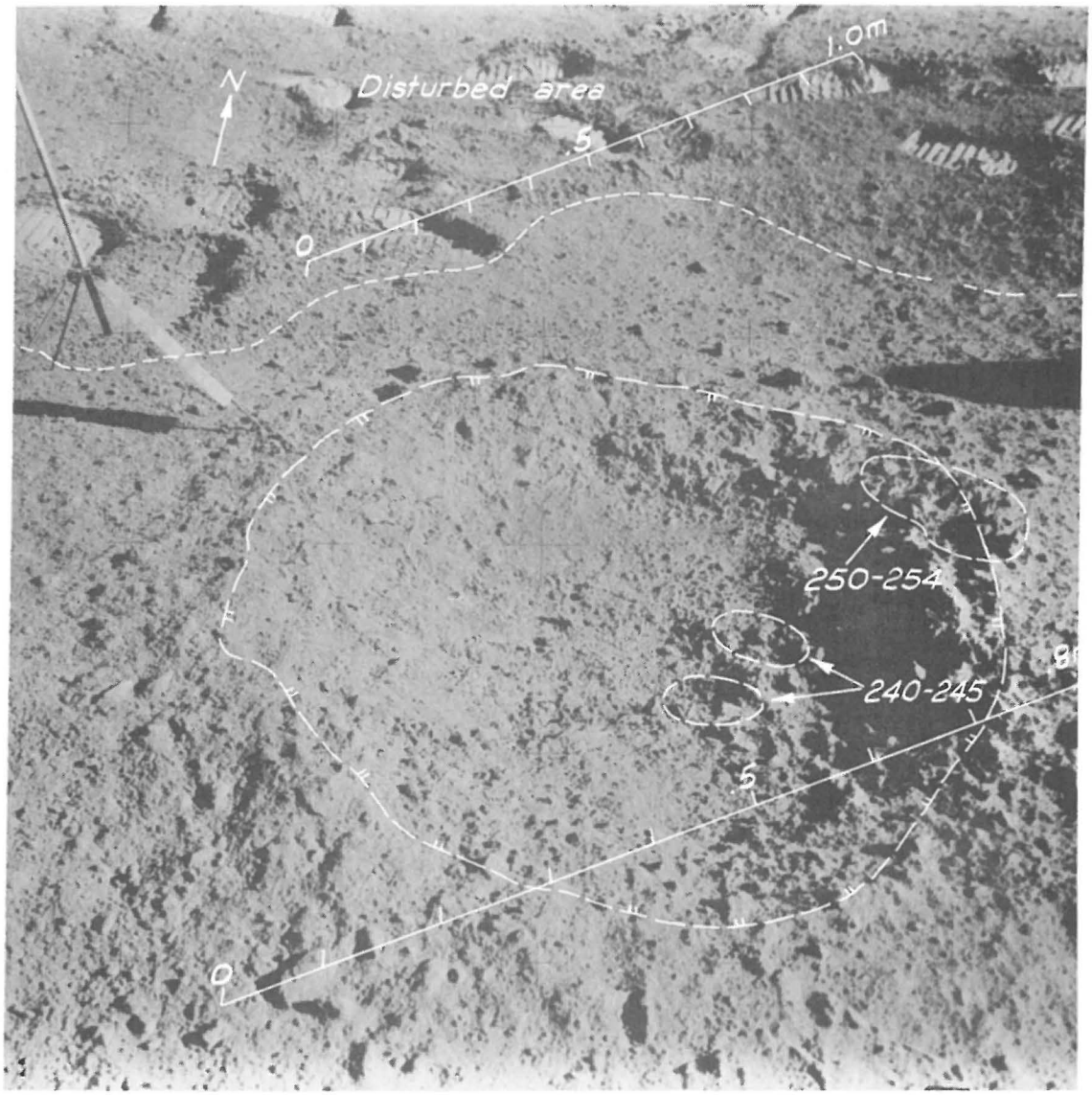

Figure 40. "Fresh little crater" at Station 6 from which samples 240-245 and 250-254 were collected. Pre-sampling, cross-sun photograph AS15-86-11610.

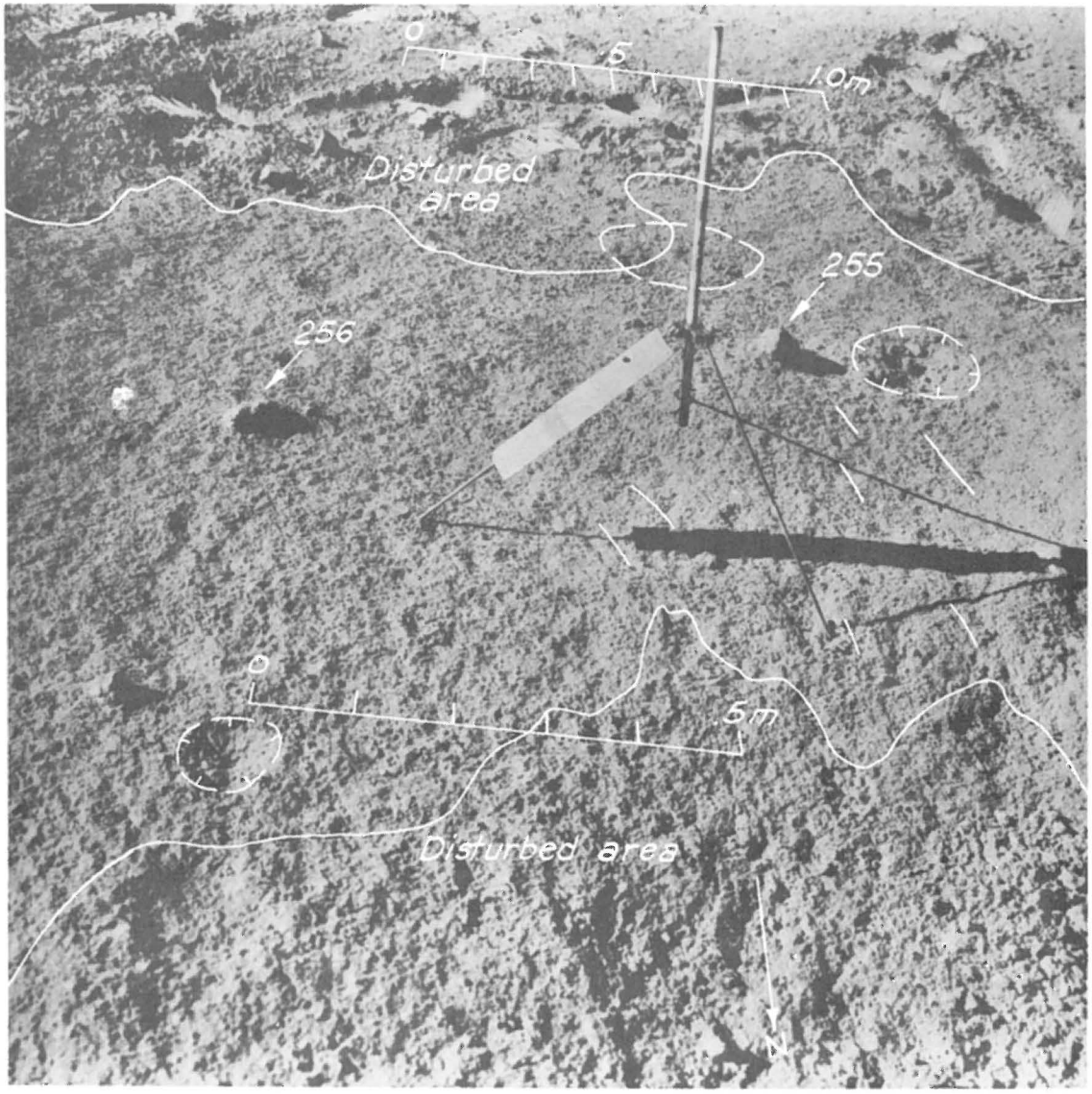

Figure 41. Samples 255 and 256 shown prior to sampling at Station 6. Sample 257 was collected here, but it has not yet been identified in the photographs. Cross-sun photograph AS15-86-11630.

observed. Sample 256 thus may have preceded 255 in arriving at the site, but neither rock can be traced to a nearby source.

Samples 270-274.--Samples 270-274 were a large soil sample collected from the compressed wheel track behind the LRV which was parked on a slope of 10-15 degrees toward the north (plate 7; figs. 4, 34).

The adjacent undisturbed soil surface (fig. 42) appears typical of the coarsely granular texture to the west and north at Station 6 (west and north). The immediate vicinity is 5-7 percent covered by centimeter-size clods, and is lacking in fresh craters or coherent looking rock fragments.

Prior to reaching the LRV, the crew commented on how the chevrons of the wheels compacted the soil, but inferred that their bootprints were much deeper than the wheel tracks. They documented this comparison with several photographs (AS15-86-11652 through 11655) which also illustrate the characteristic appearance of the undisturbed soil in the area. Sample 270-274 is probably representative of these surface materials and is large enough to be a good statistical sample as well.

Samples 290-295.--Samples 290-295 were collected upslope 10 to 15 m south of the LRV (plate 7; fig. 4).

Sample 295 is the single, large angular rock shown in Figure 33, described by the crew as a fine-grained breccia, with white clasts in a dark matrix, and as having a glass-filled fracture. The rock is distinctive in the area due to its large size (about 15 cm long), angularity, and the presence of a fillet developed on the uphill side (figs. 43a, b). Additional material collected includes soil from the immediate area and possibly a fragment from "right next to" 295 which may have disintegrated in transit into additional fines. This is also indicated by the large 4-10 mm fraction of the fines (10.2 g for sample 254). Post-sampling photographs of the locality were not taken; therefore the precise relation of soil to sample is not known. It may have come partly from the fillet lying against the rock but should be representative of the local soil in any case.

The general surface characteristics around the sample are similar to those in the eastern area of Station 6. The soil is finely granular with centimeter-size fragments or clods comprising only one or two percent of the area. The crater population is low; one small fresh crater lies approximately 2 m north of the sample, excavating clods from about 15 cm depth and possibly contributing some of the sparse centimeter-size fragments to the sampled area (figs. 43a, b).

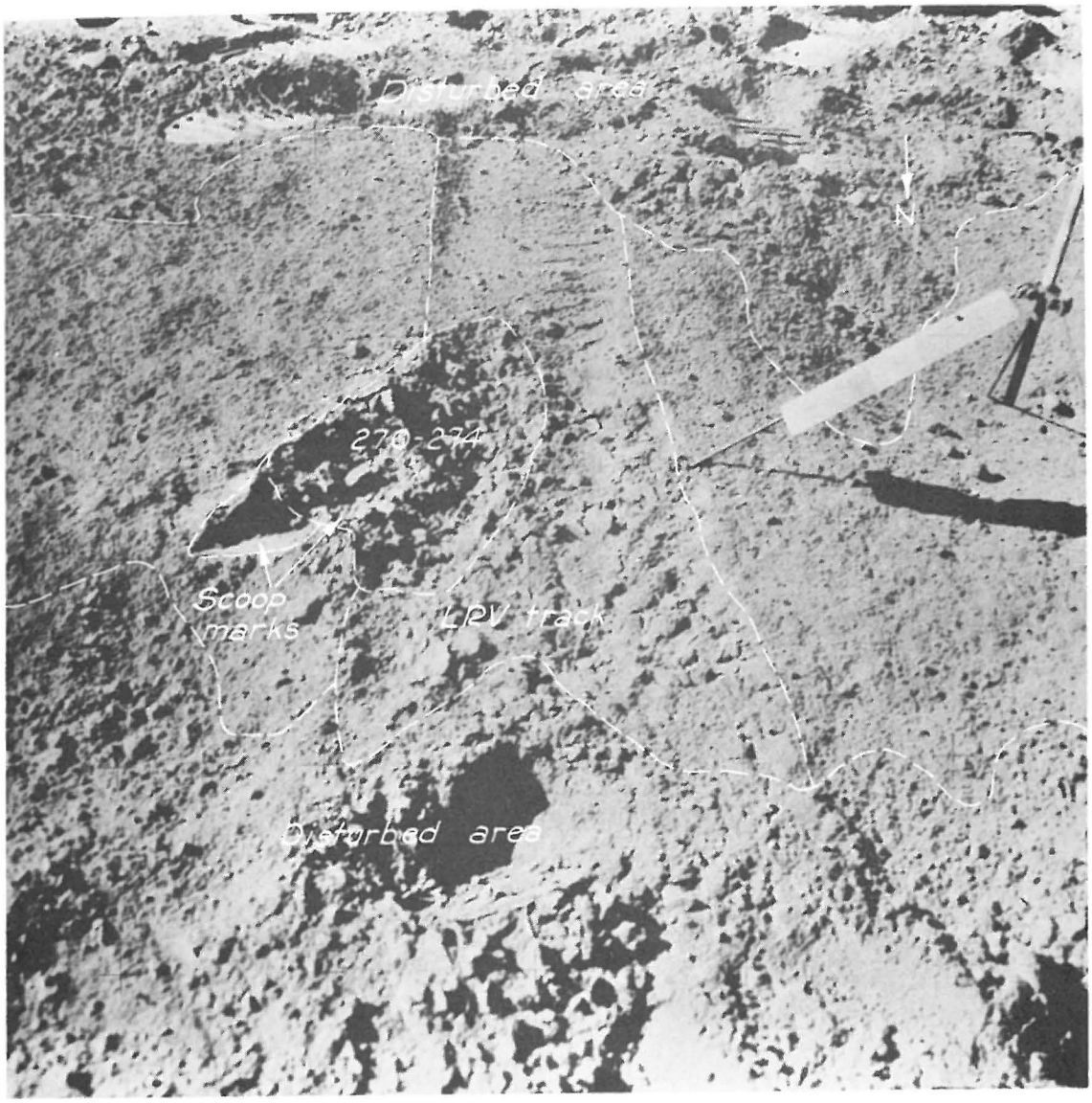

Figure 42. Location of soil samples 270-274 from the LRV track. Post-sampling, cross-sun photograph AS15-86-11657.

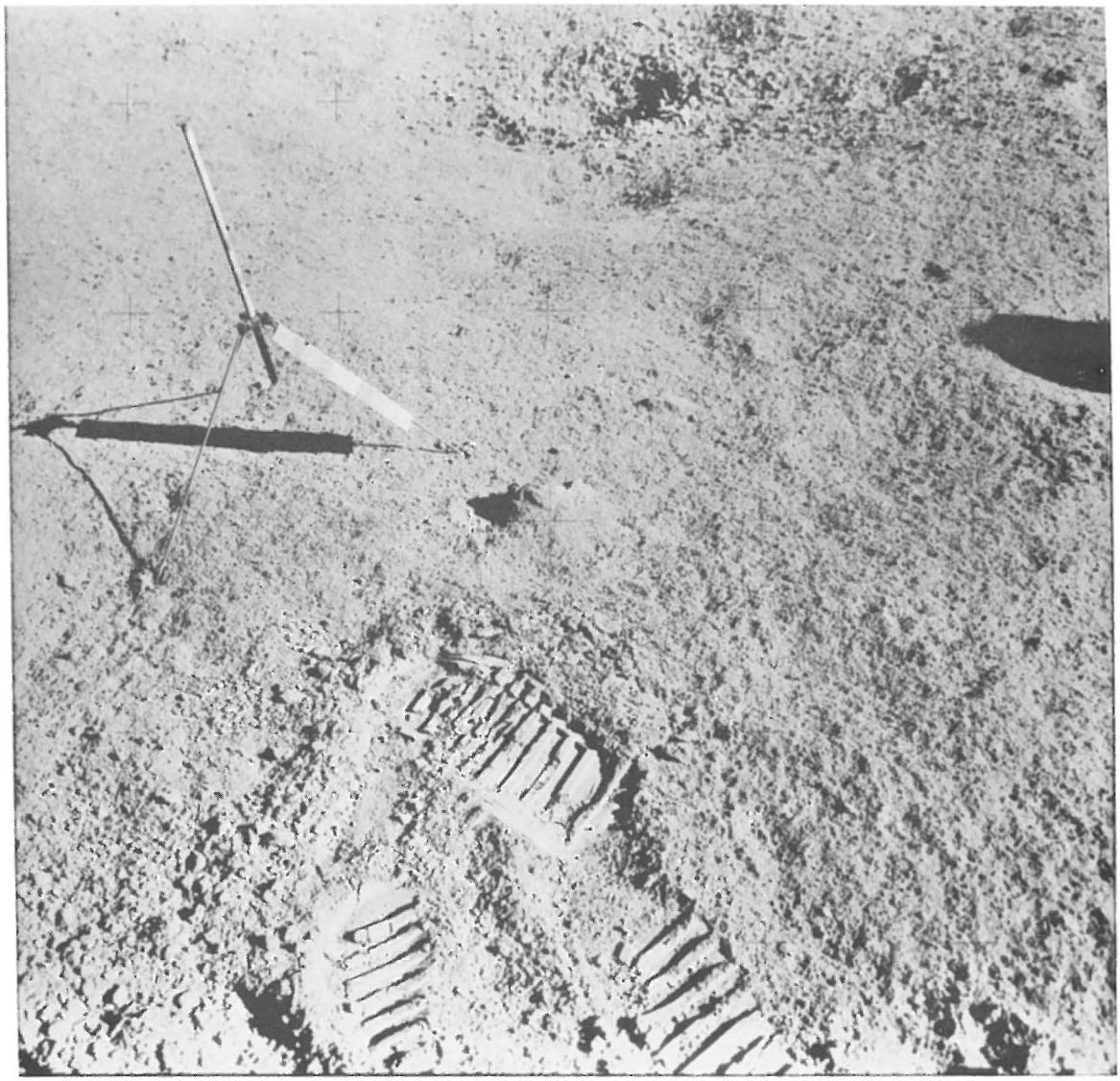

Figure 43a. Samples 290-294 and 295 collected at Station 6. The location of the soil (290-294) is inferred to be from around the rock (295). Pre-sampling, cross-sun photograph AS15-86-11617, looking north.

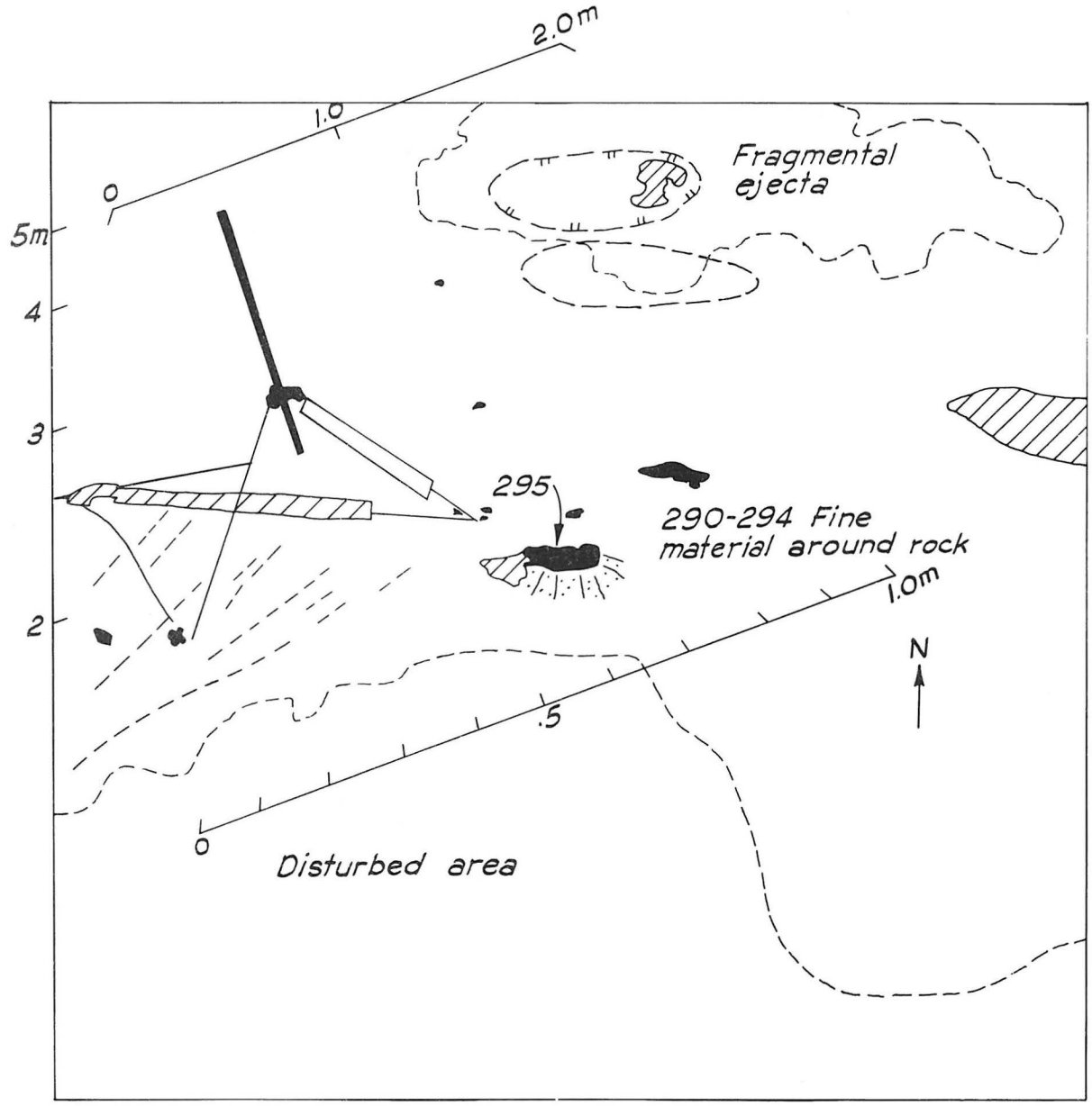

Figure 43b. Sample environment sketch map for samples 290-294.

A few subtle lineaments having a northeast trend occur near the gnomon. The local slope is approximately five degrees to the north. The down-sun view (AS15-85-11501) suggests that the albedo of the soil is the same or very slightly lower than that of sample 295. The crew described the fragments at this location as being "all covered with dust." The only other rock in the area larger than 10 cm across is a rounded and partially buried rock just to the northeast of sample 295 (figs. 43a, b).

Samples 290-294 therefore may be typical of the local soil, and sample 295 is probably fairly representative of the small population of rocks larger than 10 cm in the area of Station 6.

Sample 298.--Sample 298 is a fractured soil breccia nearly 20 cm long and half as wide, collected about 10 m south and upslope from the LRV. It was too large to go into a sample bag and was described by the crew as a light gray, subangular microbreccia having slickensides and glass splatter on one side.

The rock was partially buried in granular soil. The general surface is 5 to 7 percent covered by centimeter-size clods (fig. 44). A small fillet occurs on the south and possibly on other sides of the rock but the uphill side is on the west and is obscured

in shadow. Other fragments greater than 10 cm in diameter are sparse in the area, and those collected are all breccias. Two small fresh craters several meters north of the sample have excavated centimeter-size clods locally and may be the source of the similar clods near the sample. An unexplained linear pattern formed by these clods follows a curved path east of the sample trending northeast and bending left toward the northwest as sketched in Figure 44. These lineaments may reflect the combined effects of surface transport from a recent crater (not likely those in fig. 44) and of local slope, which here is approximately ten degrees toward the east or northeast.

Sample 298 has a slightly higher apparent albedo than the surrounding soil (AS15-85-11503) and was 1/4 to 1/3 buried prior to collection. Penetrating fractures can be seen on both the east and west sides of the rock parallel to its length as seen in Figures 33 and 44. It apparently broke after collection along one of these fractures into two large fragments. No dust coating was noted on this sample although the crew mentioned at the preceding sample site (295) about 5 m away that all of the rocks were "covered with dust."

Sample 298 has no obvious relation to nearby craters or other features. Its source is unknown;

however, the slickensides and glass coating suggest that it may have passed through several stages of shock metamorphism. Its texture, shape, and partial burial indicate that it is typical of other large rocks collected at Station 6.

Sample 299.--Sample 299 was collected approximately 25 m west southwest of the LRV (plate 7; fig. 4). It attracted the crew's interest because it appeared to have struck the surface "about a foot" east of where it was collected. The rock is a breccia and is almost equant, being 11-12 cm across in three dimensions; it was too large for a bag and was described as having "a very rough surface" and as being "really covered" presumably with soil or dust. In Figure 45 it appears perched on the surface with no evidence of burial or filleting.

Closeup stereo photos of the inferred impact site (see area in fig. 45) do not show a depression from the impact; however, a light area which is anomalously bright in the down-sun view (AS15-85-11505) occurs at the impact spot mentioned by the crew and may represent the last bounce of a slowly moving object.

The general surface at the sample site is coarsely granular with 10-15 percent centimeter-size clods distributed uniformly around the area. The crew

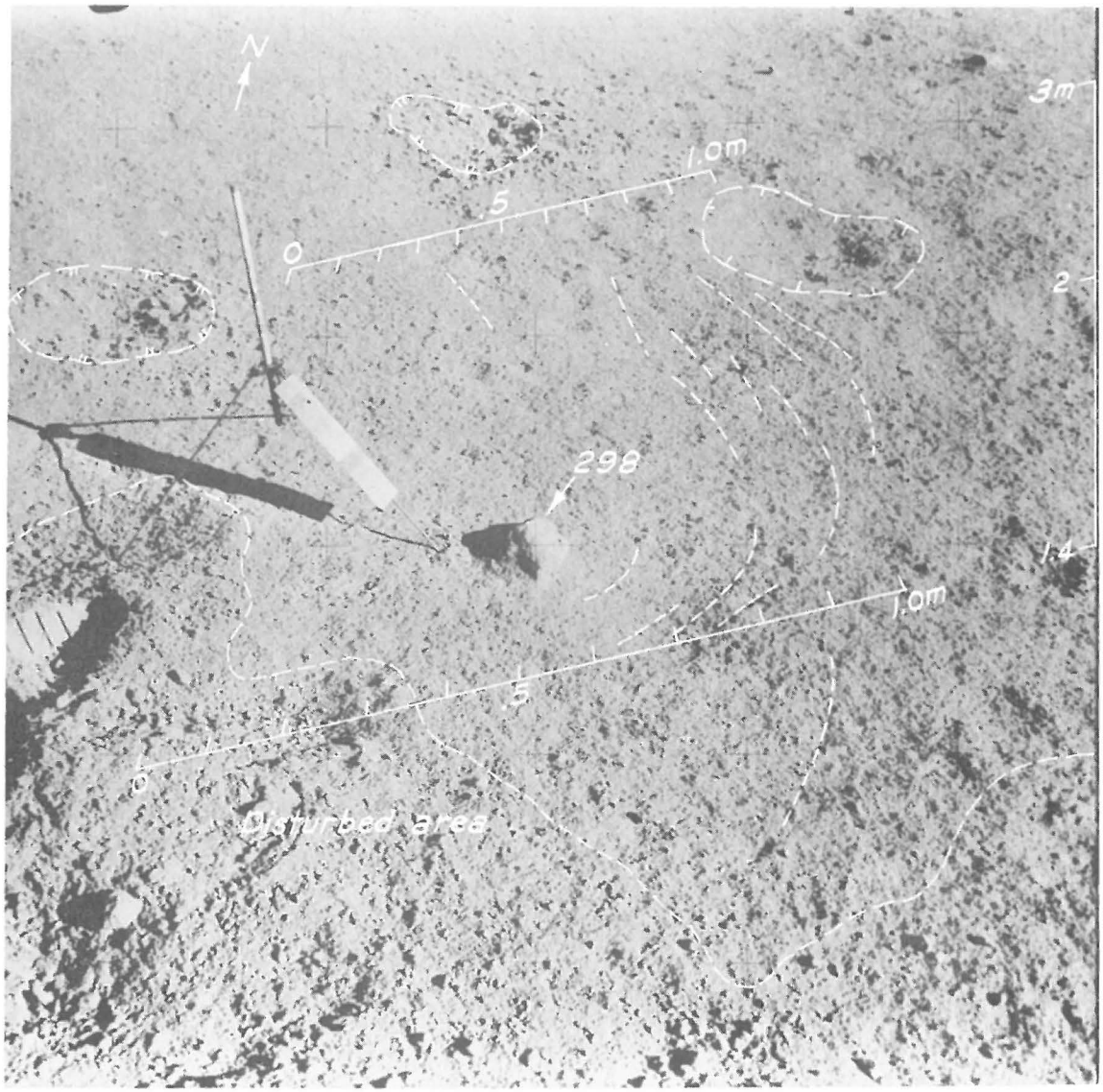

Figure 44. Sample 298 about 10 m upslope from LRV. The largest rock, a breccia, collected at Station 6. Pre-sampling, cross-sun photograph AS15-86-11622.

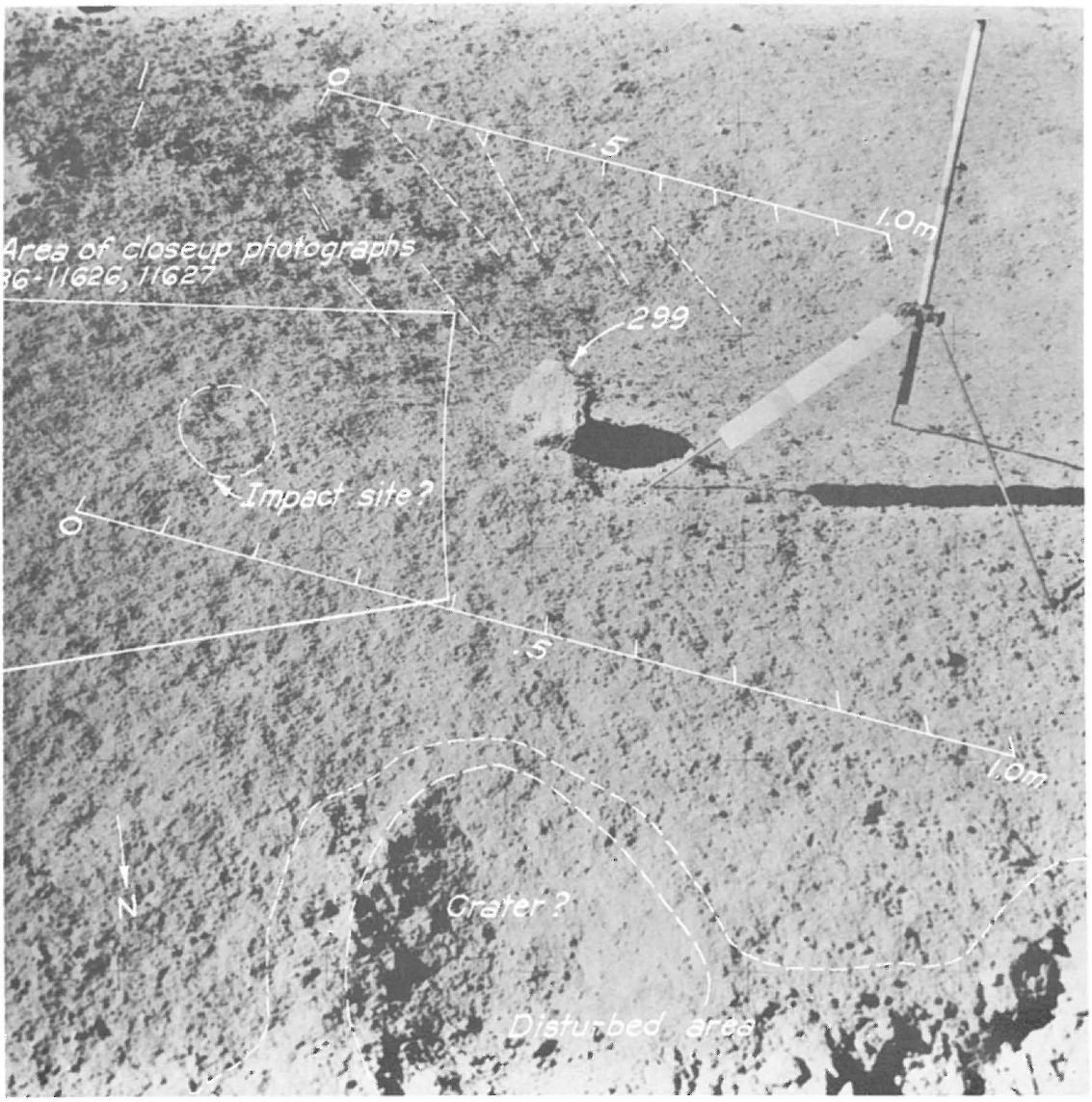

Figure 45. Sample 299 at Station 6 about 25 m west southwest of LRV. The second largest rock, a breccia, collected in this area. Pre-sampling, cross-sun photograph AS15-86-11624.

mentioned sinking into the surface two or three inches. The crater population (greater than 10 cm diameter) is low in the immediate vicinity with none being obviously related to the sample. The slope of the area averages 5 to 10 degrees toward the north. Five lineaments on the south side of the sample trend north, or parallel to the area slope.

Although atypical of the immediate vicinity in size and appearance, sample 299 is probably representative of the larger than 10-cm fragments around Station 6. It has some irregular patches of high albedo in the down-sun photograph indicative of light clast composition and it seems to be relatively coherent. It probably arrived at its last location more recently than rock 298 collected about 20 m to the east.

Station 6a

The highest location visited on the Apennine front was selected by the crew as an intermediate stop at a distinctive isolated boulder enroute to Spur crater (Station 7). The station is approximately 130 m above the mare and 250 m south-southwest of Spur crater (plate 8). The boulder was sighted as a distinctive landmark and sampling target from Station 6, and upon reaching it, the crew described it as a "big breccia" and as "the first green rock" they had seen.

Samples 400-405.--Samples 400-404 (soil) and 405 (green breccia) were collected from the singular, rounded, 3-m long boulder, and from an apparent fillet developed high on the south side of the boulder (fig. 46). The astronaut crew recalled later that the undisturbed surface of the boulder was the same gray as the soil but was underlain by green friable material.

Relatively few fragments occur in the vicinity of the rock. Most are angular and lie on the fillet, but sparse fragments are found with random distribution in all directions. A small blocky crater, from which presumably indurated soil was excavated, lies downslope to the northeast. There is no local crater associated with the boulder, and local smaller craters are generally obscured by the hummocky slopes of the area.

Visible lineaments are close-spaced grooves in the near-field trending approximately northwest-southeast; they are several millimeters in width, several meters in length, and are roughly parallel to much larger linear hummocks.

The slope is to the north, probably the steepest one traversed during the mission (estimated at approximately 15 degrees). The fillet occurs upslope from the boulder, but its high position on the boulder and the presence of larger fragments indicate it is derived at least partly from the rock against which it lies.

The down-sun view (fig. 47) illustrates the relative albedo differences between white irregular clasts in the light matrix and the darker clast-poor surface which may represent the light green layer described by the crew and the green glass-rich surficial coating on rock 405 described by the Preliminary Examination Team. Similar clasts are visible in fragments photographed on the slope northwest of the boulder. Dust coatings are probably indigenous because the boulder is weakly coherent and fractured and appears to be disintegrating to granular fines in place.

The samples are probably representative of the boulder (405) and its disintegration products (400-404) which may typify the composition of its fillet. The

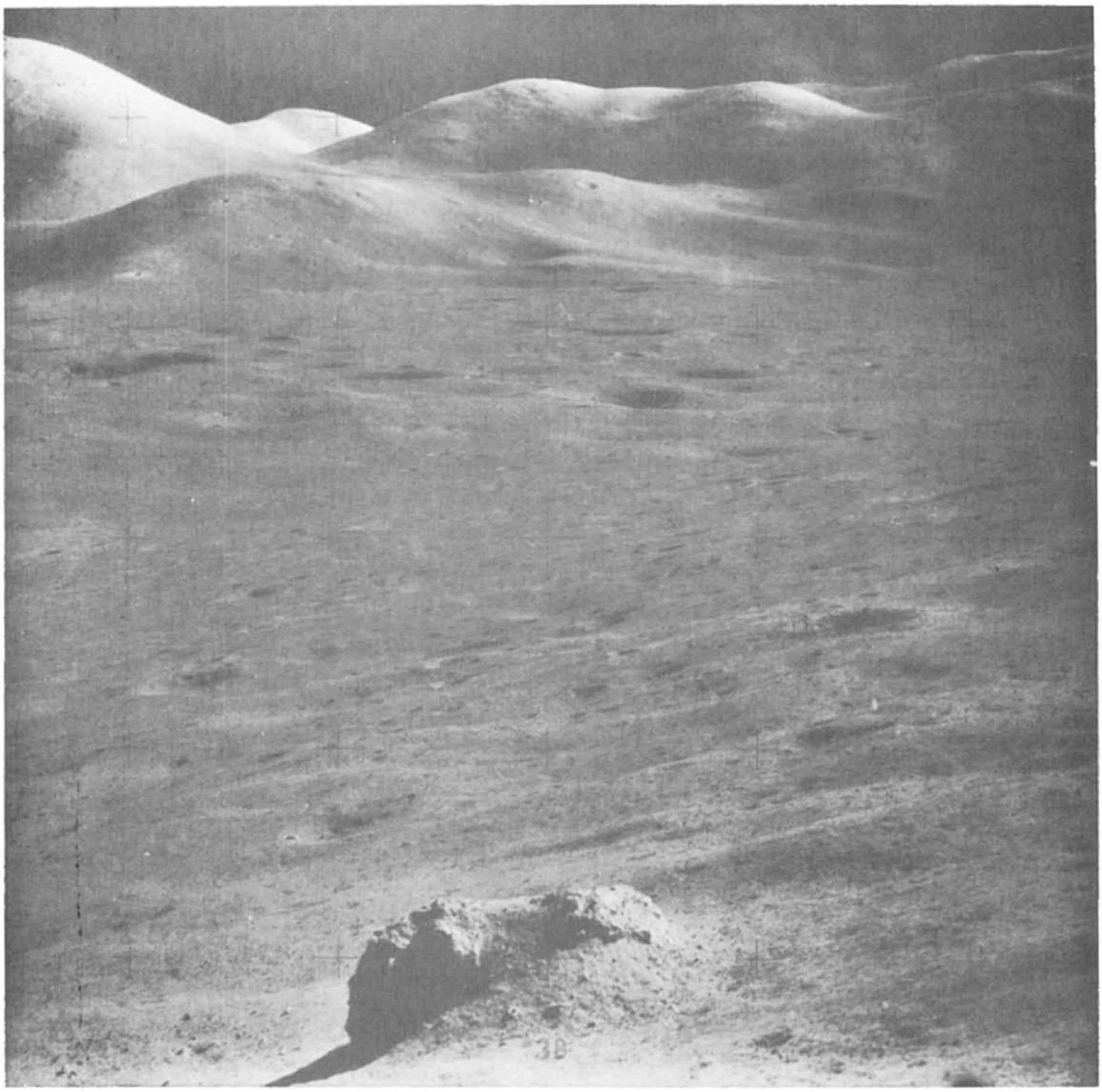

Figure 46a. View from Station 6a looking northeast across 3-m filleted boulder. Highest vantage point reached during all EVA's. Photograph AS15-90-12188.

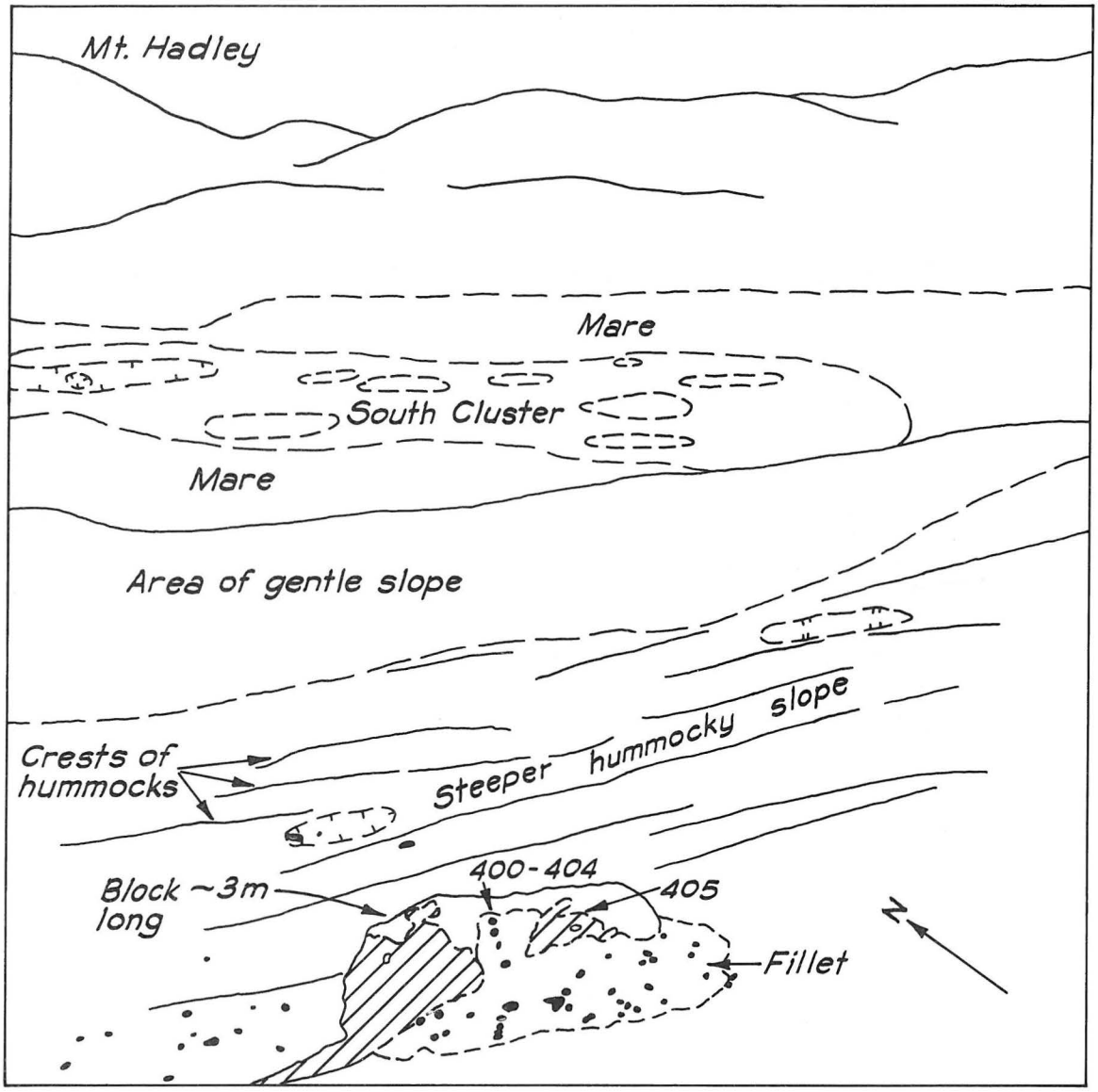

Figure 46b. Sketch map showing locations of samples 400-404 and 405 collected from filleted boulder.

Figure 47a. Close-up view of 3-m breccia boulder at Station 6a showing albedo variations in clasts and matrix. Scale is not shown due to steep slope. Down-sun, pre-sampling photograph AS15-90-12199.

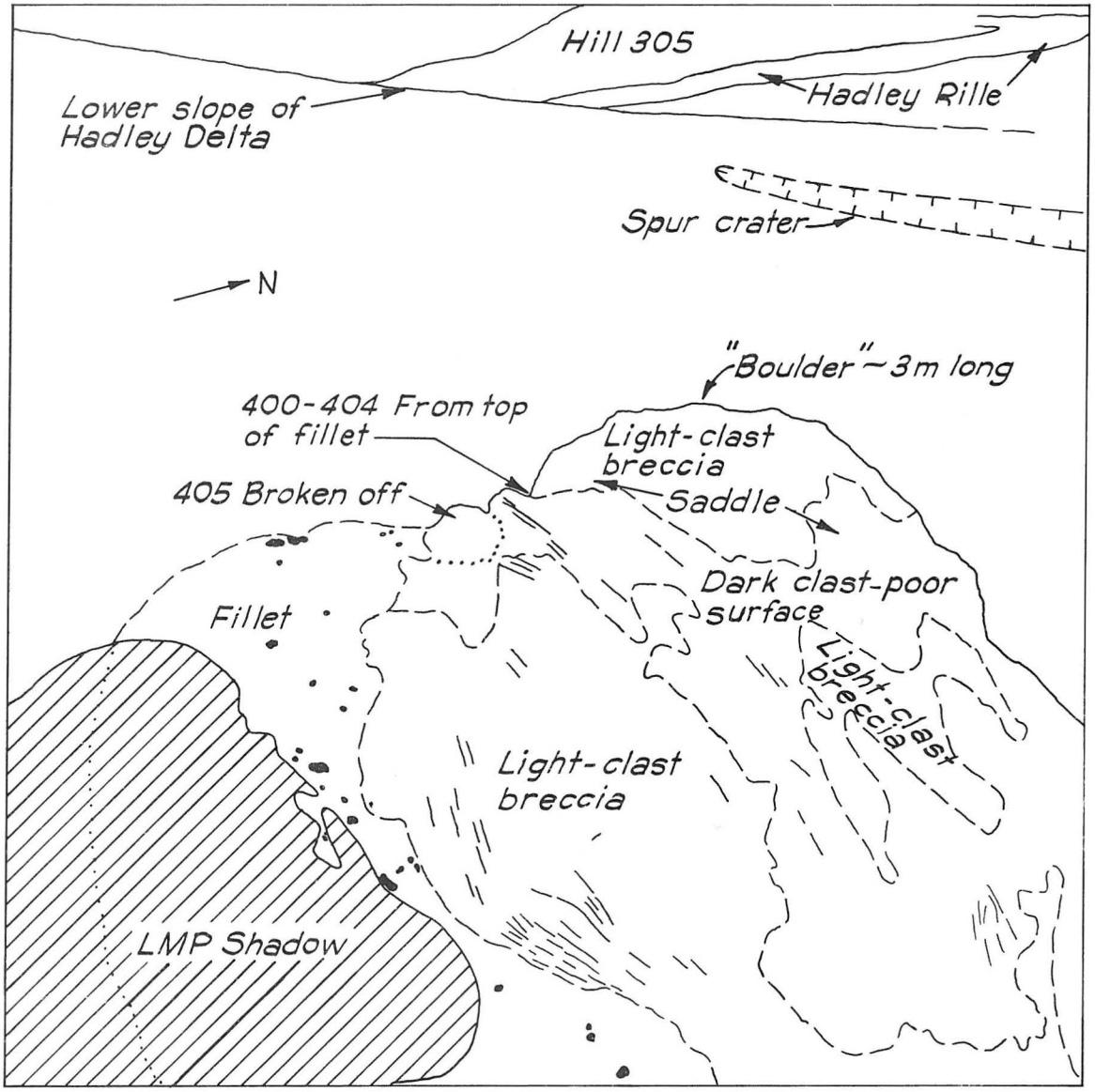

Figure 47b. Sketch map of surface textures on boulder showing locations of samples 400-404 and 405 from east end of boulder.

fillet samples alternatively may represent soil debris concentrated by downslope movement. Except for its larger size (1 x 3 m exposed) and greater depth of burial, the boulder is similar to the few white clast-bearing fragments on the surrounding surface. The large boulder at Spur crater (Station 7) has a similar surface texture but contains larger clasts and has no apparent fillet.

The source of the boulder and samples 400-405 is uncertain. There is no nearby crater from which it could have been ejected. Its rounded friable appearance indicates it is undergoing disintegration rather than being exhumed. The nearest fresh crater from which it might have come is 800 m directly south and upslope from the boulder.

Station 7

Station 7 is located at the rim of the 100 m diameter Spur crater on the lower slope of Hadley Delta, about 60 m above the level of the LM (fig. 1). Nine bags of material and one "football size rock" were collected from an area of about 780 m^2 on the crater's northern rim (plate 8; fig. 5), and represent four general textural rock types that include: 1) aggregates of splash glass and light clast breccia (samples 465, 466); 2) light clast breccias (306, 445, 455); 3) friable, greenish, fine grained breccias (425, 426); and 4) a partially shocked, partially crystalline plagioclase-rich clast (415) in a friable soil breccia matrix (430). Light clast breccias are abundant in the sampled area and may be the dominant rock type. Aggregates of splash glass and light clast breccias were seen by the crew in several areas around Spur crater rim during sampling activities. The green breccias were first observed at Station 6a at the 3 m breccia block approximately 320 m south-southeast (upslope) and about 70 m vertically above Station 7 (fig. 1). The green breccias may be rather abundant in this particular portion of the Hadley Delta front, but the general distribution of the green breccias along the massif face is undertain. The "light reflecting"

crystals of plagioclase characterizing sample 415 were thought by the crew to have been relatively rare. The majority of the other light clast material at the station area was described by the crew to have the same general sugary appearance as the Apollo 14 "White rocks" material.

It is probable that the diverse rock material sampled at Station 7 represents the major components of the Spur crater ejecta from a maximum of 20 m depth in the Hadley Delta front. Most or all of the sampled materials, including sample 415, have undergone at least two and possibly more episodes of intense shock including pre-Imbrian (pre-Imbrium basin ejecta deposits), Imbrian (Imbrium event) and Copernican (Spur crater event).

Samples 410-414, and 417-419.--Samples 410-414 (soil) and 417-419 (breccias) were collected from the summit of the subdued rim crest of Spur crater and about 18 m northeast of the 1.5 m breccia block on the north-northwest rim of Spur crater (plate 8; fig. 5). The local surface in the sample vicinity is moderately well populated with rock fragments (figs. 48a, b, 49) up to several tens of centimeters across. The sample area is characterized, however, by the abundance of less than 1 cm size fragments. Small craters less

than 1 m are generally common and range from very fresh to moderately subdued. Lineaments are not present. Because the sample locality is just on the summit of the Spur crater rim crest, the local surface slope is essentially zero. The regional slope, however, is approximately 10 degrees down to the north toward the mare.

Most of the rock fragments greater than 10 cm across have moderate-to-well developed fillets (possibly due to the nearly level surface in the near sample environment). The immediate sample locality is of much lower albedo than that of the sample 415 environment, although there are a few scattered high albedo rock fragments or breccia "clasts" in the area (see photograph AS15-90-12223). Most of the fragments greater than about 6 cm across appear to have a significant dust cover although it is difficult to discern much, in this regard, from the surface photographs. A large percentage of the greater than 6 cm size fragments are buried to about 1/4 to 1/2 their height.

As can be seen in Figures 48a, b, sample 418 is clearly associated with several other greater than 10 cm rocks, and three moderately fresh to moderately subdued craters. The largest crater (0.3 to 0.4 m diameter) due south of the sample is subdued and may

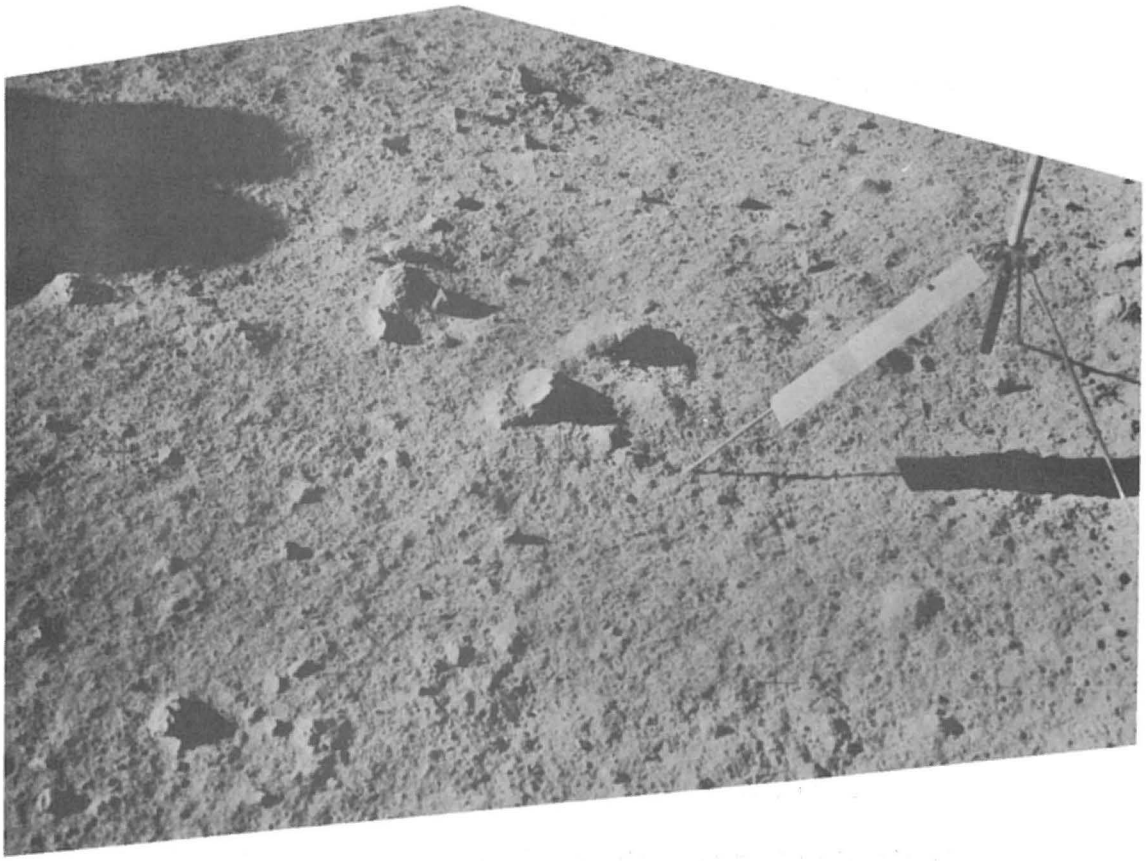

Figure 48a. Sample 418, and vicinity of samples 410-414, 417, and 419. Pre-sampling, cross-sun photograph AS15-86-11662, looking south.

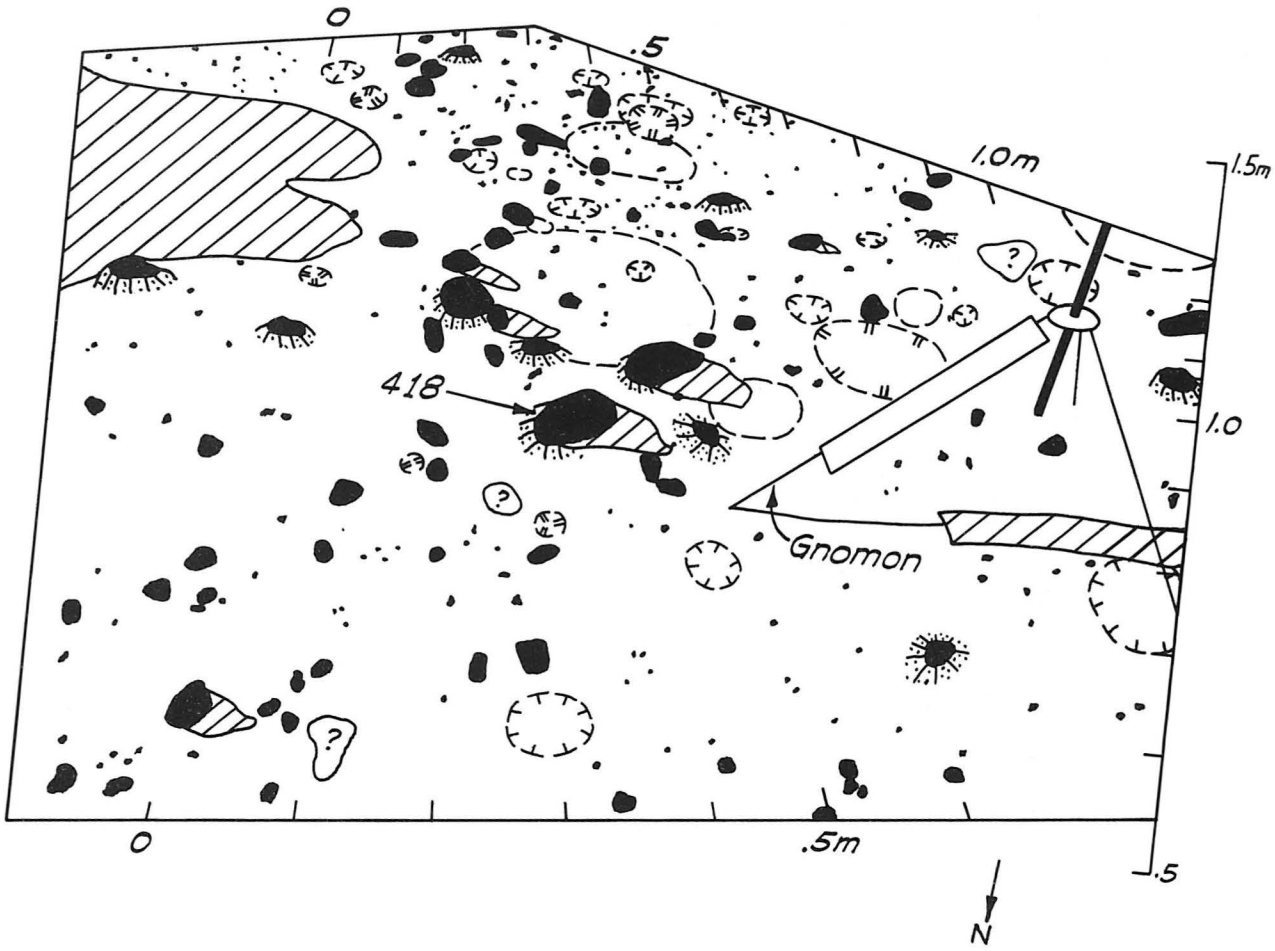

Figure 48b. Sample environment sketch map of the vicinity of sample 418.

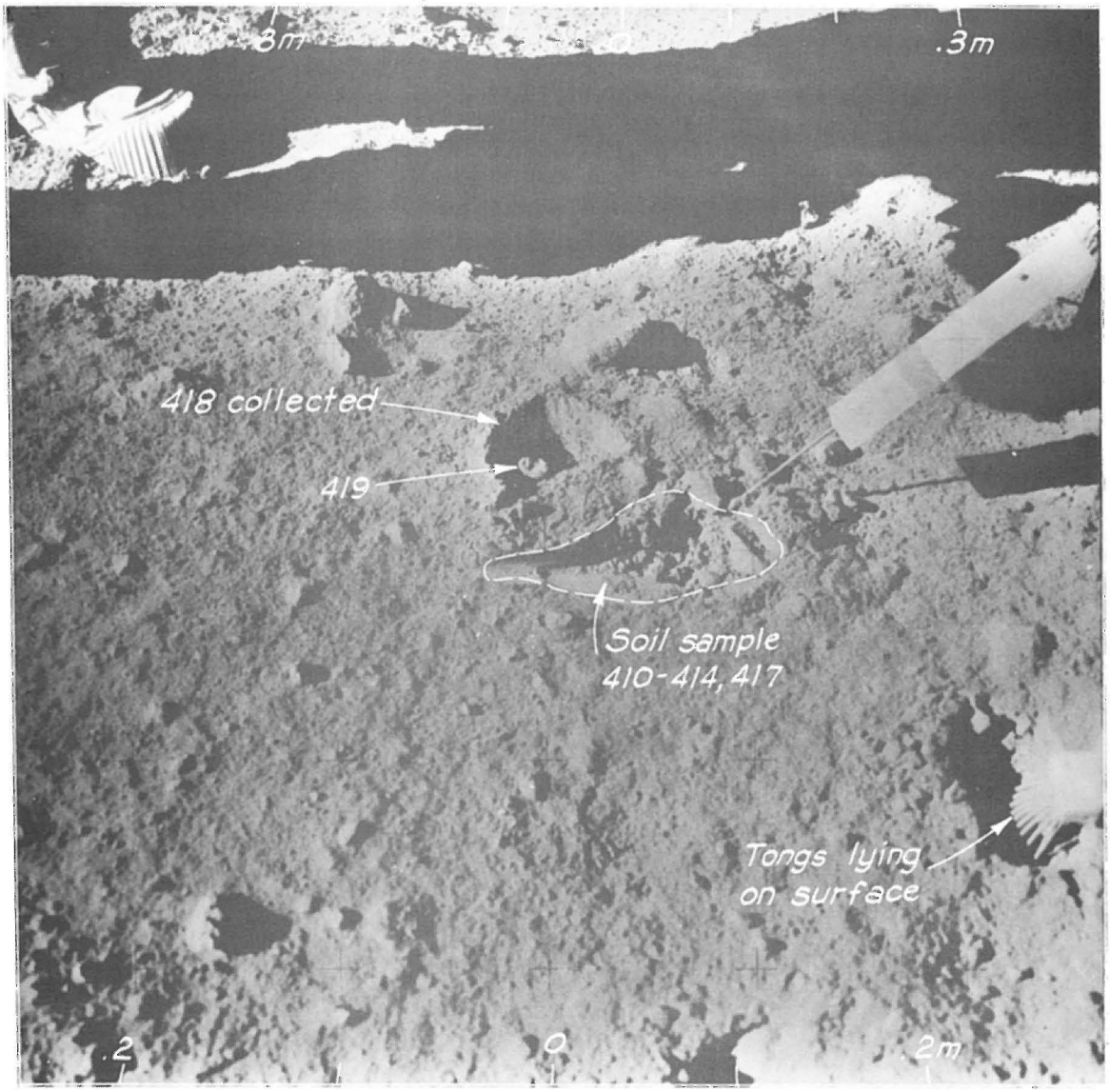

Figure 49. Areas from which samples 410-414, 417, and 418 were collected; sample 419 prior to collecting. Cross-sun photograph AS15-86-11664, looking south.

possibly be a secondary crater formed by one or more of the three larger rocks (including sample 418). The filleting and degree of burial of all three rocks indicate their having been in this position for some time, but it is likely that they all have been recycled to the surface at least once, perhaps by the small crater mentioned above. Sample 419 is a small glass coated breccia fragment that was found by the crew in the hole left by removal of sample 418. The soil sample taken just north of the site of 418 probably was the source of the small (1.3 g) breccia sample 417.

As stated above, all breccias sampled appear to have been recycled to the surface (at least once) by small cratering events but, however, very likely represent Spur crater ejecta derived from a depth down to 20 m. High albedo soil was kicked up adjacent to this sampling site indicating a possible abundance of light clast breccia in the immediate vicinity. The astronaut crew also mentioned that the soil here "caked" on the surface (upper layer) (this phenomenon was responsible for their decision to take the soil sample). Soil was also apparently caked on top of the 418 breccia sample when collected.

Samples 415 and 435.--Sample 415 (anorthosite) was collected at Station 7 about 10 m east of the 1.5 m breccia block on the north-northwest rim of Spur crater

(figs. 5, 50a, b). The sample location was 3 m east of sample 455, the "black and white breccia" (plate 8).

The fragment population in the immediate sample vicinity is moderate to high, as is the abundance of small (less than 1 m) fresh to subdued craters. Lineations are sparse and none are well developed. The sample rests on a gentle slope of several degrees to the south toward the bottom of Spur crater. The local slope, however, is to the north approximately 10 degrees down the Hadley Delta front. Filleting on rock fragments in the immediate vicinity of the sample is moderate, and none of the rocks larger than 6 cm across are entirely free from fillets (figs. 50a, b).

Study of NASA photographs AS15-90-12227 and 12228 from the wide-angle panorama taken about 33 m east of the sample site (fig. 5) indicates that the area surrounding sample 415 is generally of higher albedo than most of the Spur crater northern rim; however, isolated patches of light material in the soil occur in other parts of the Spur crater sampling area. Dust coating on fragments in the vicinity of sample 415 appears to be greater than that at the nearby sampling site of sample 445, which is adjacent to the large breccia boulder described later. The depth of burial of most fragments greater than 6 cm across is between 1/4 and 1/2 of the rock heights.

The size and shape of sample 415 is not unique on the northern rim of Spur crater but the material (sample 435, shock lithified soil breccia or extremely weathered breccia) from which it was plucked is one of the largest "fragments" (approximately 17 cm across) in the immediate vicinity. The texture and albedo of sample 415 was described by the crew as unique to the area, probably by virtue of the abundance of reflecting plagioclase surfaces. There are, however, a great number of rock fragments with similar appearing albedos scattered around the north rim of Spur crater in the sample area as seen in the down-sun photographs (figs. 51a, b) (this was also verified by the astronaut crew). These fragments, including sample 455, may also be of similar origin and composition as sample 415, but apparently sustained more shock and do not have the crystalline plagioclase that 415 contains. This may be the only major difference between 415 and the other light clast fragments observed in the immediate vicinity of Spur crater.

The east side of sample 435, from which sample 415 was plucked as viewed in photograph AS15-90-12227 (fig. 51a) does not appear to contain any observable high albedo clasts other than sample 415. Sample 435 is filleted (likely due primarily to disintegration of

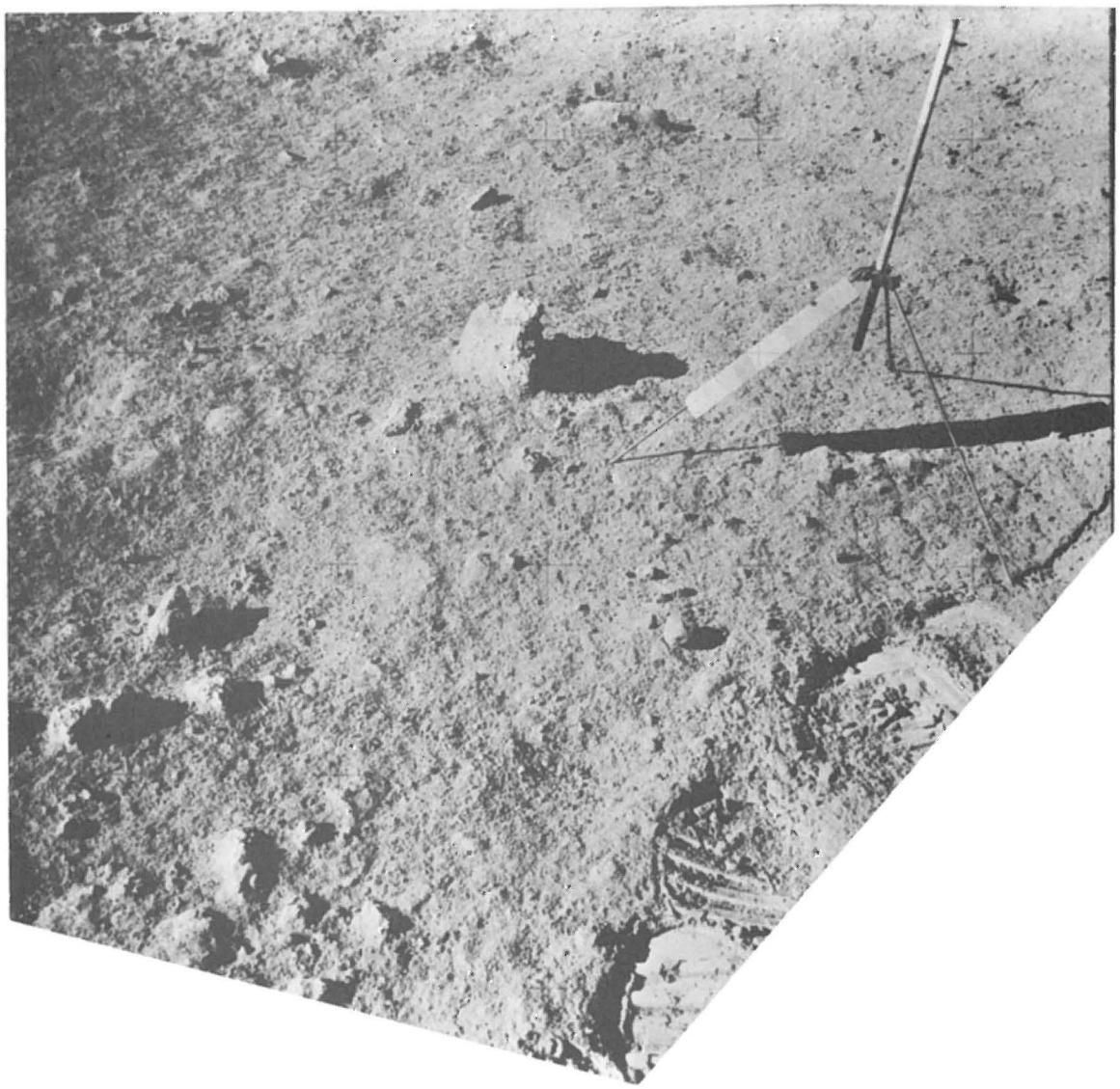

Figure 50a. Samples 415 and 435. Pre-sampling, cross-sun photograph AS15-86-11670, looking south.

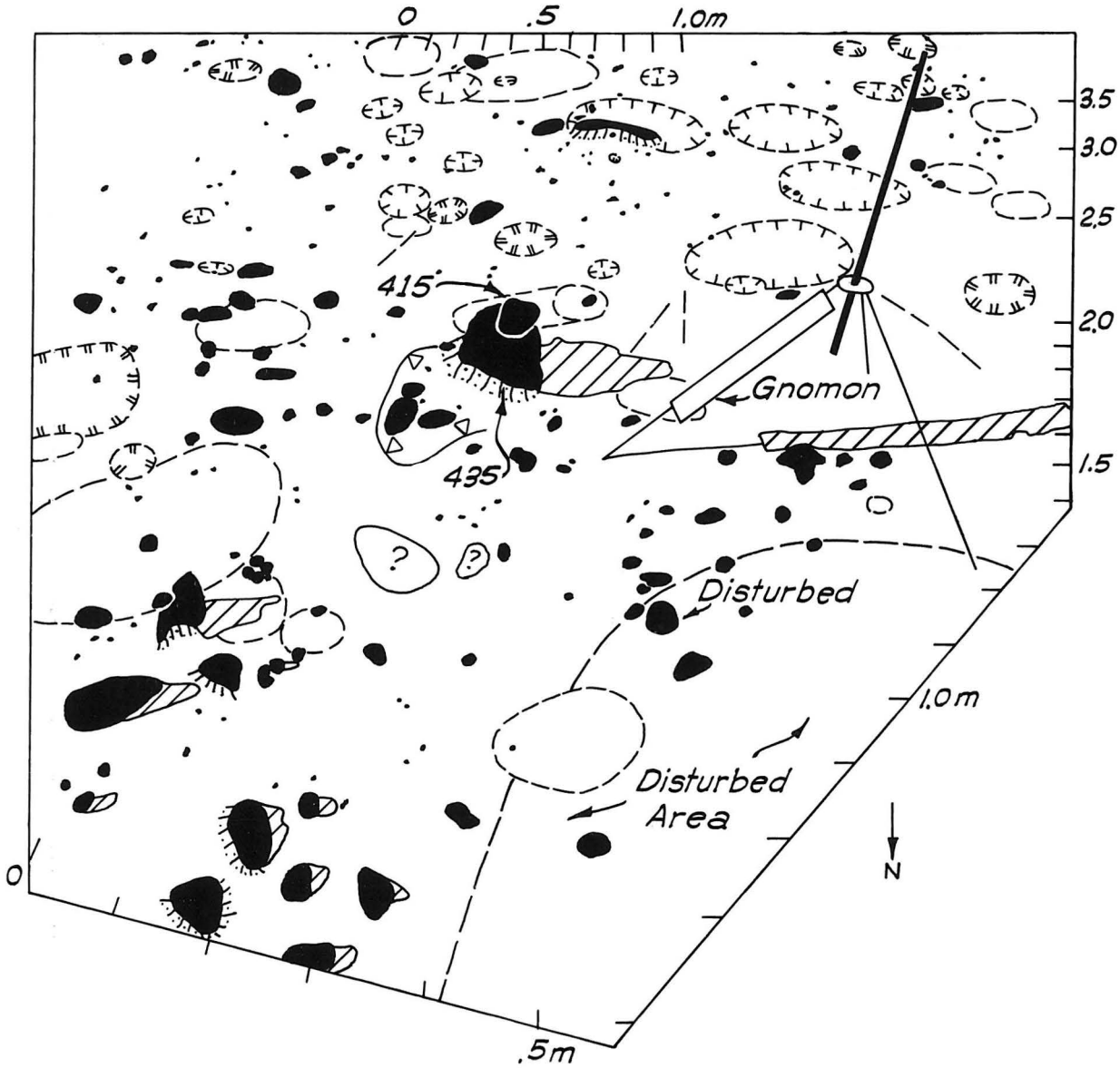

Figure 50b. Sample environment sketch map of vicinity of samples 415 and 435.

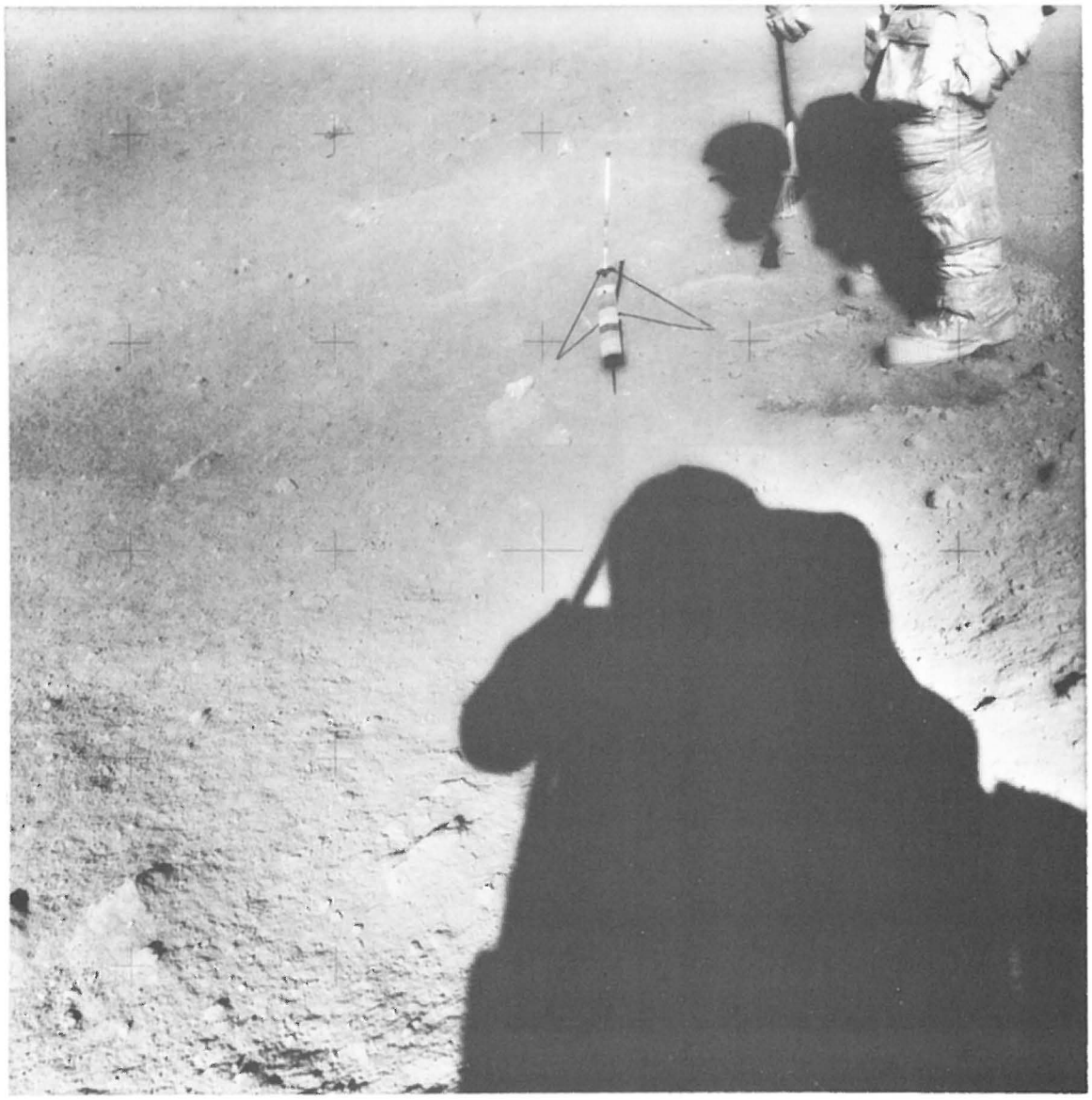

Figure 51a. Samples 415 and 435. Pre-sampling, down-sun photograph AS15-90-12227, looking west.

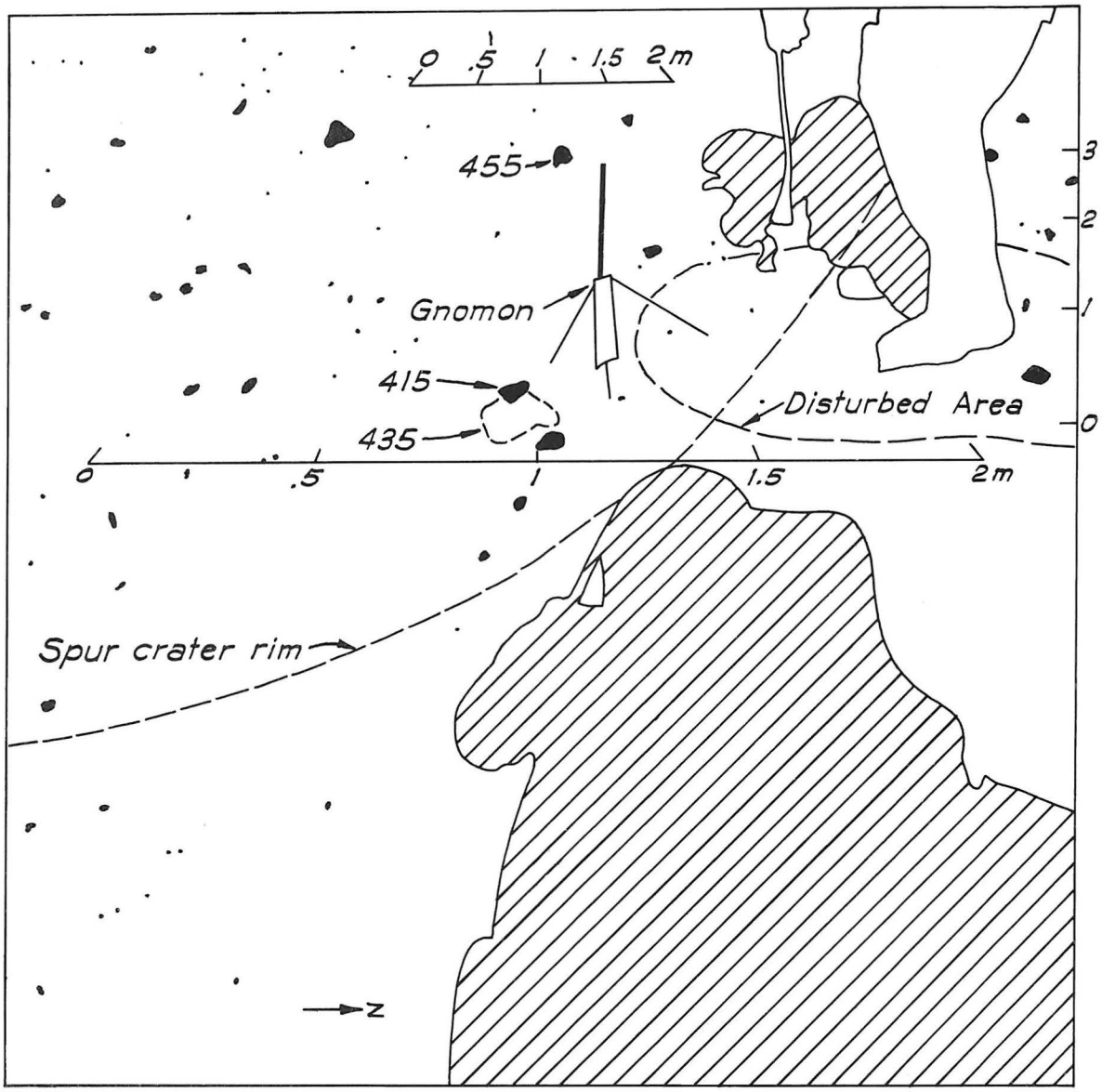

Figure 51b. Sample environment sketch map of vicinity of samples 415 and 435. Map shows distribution of only the light clasts.

the poorly indurated breccia) and may be buried as much as 1/4 of its height. All evidence indicates that sample 415 and the associated sample 435 have been in this position for a long period of time. There is no closely associated secondary crater from which the breccia may have been thrown.

In summary, sample 415 is a very high albedo, plagioclase-rich clast, plucked from the lunar top of a much lower albedo, poorly consolidated breccia (of presently unknown genesis) on the northern rim crest of Spur crater. The sample was described by the crew as exotic to the local area by virtue of its shiny, high-albedo plagioclase content and its "come and sample me" situation on top of sample 435. Sample 415 was described by Commander Scott as being easily lifted off with the tongs and therefore poorly attached to sample 435 (possibly weathered loose). Astronaut Scott confirmed (personal communication) that it was his opinion that the anorthosite was a part of sample 435.

It is difficult to say for sure from what depth the samples were derived but the abundance and distribution of similar light clast breccia in the vicinity indicates its original source in this area to be Spur crater ejecta from a depth of as much as 20 m. It may

however, have been recycled to the surface by at least one post-Spur cratering event. Sample 415 has undergone at least two fragmentation events (one prior to its incorporation into the breccia (435) and one which produced the breccia containing 415), and at least one of relithification (which produced the breccia). This suggests a rather complex history, probably associated with cratering, which decreases the probability that 415 is indigenous to the bedrock in the immediate vicinity of Spur crater.

The appearance of sample 415 as a "weathered out" clast from a friable breccia matrix makes the genetic association of the anorthosite clast with the matrix also rather uncertain. The clast may have been incorporated into a soil breccia by lithification of the regolith by the Spur crater event or an event that post-dated the Spur crater event (but in the local environment), or may have been earlier incorporated in a poorly indurated tectonic breccia thrown out of Spur crater and weathered to its present state since that time. A detailed comparison of sample 435 matrix with other more coherent breccia samples should clarify this uncertainty regarding its origin.

Samples 425, 426, and 923.--Samples 425, 426, and 923 were collected on the crest of the north rim of

Spur crater approximately 15 m northeast of the 1.5 m breccia block on the crater's north-northwest rim (fig. 5). The collection area is about 8 m north of the site of the anorthosite sample 415. The rock samples are part of a small cluster of fragments which are up to 25 cm or more across (figs. 52a, b). Craters in the near sample environment are sparse with only two subdued 35 cm diameter craters in the mapped area. A very small (7 to 8 cm diameter) secondary crater, with an associated rock fragment in its bottom, is present in the near vicinity (figs. 52a, b) but none are clearly related to the rock cluster sampled.

Lineaments are not present in the immediate sample area. The slope in the sample environment is gently to the south 1 to 2 degrees toward the bottom of the crater but the regional surface slopes about 10 degrees to the north down the Hadley Delta front. Fillets are not well developed on the rocks in the sample fragment cluster but nearly all of the fragments (except the two samples) are partially buried.

The general albedo of the rocks in the sample cluster appears to be typical of other fragments in the area. Abundant light clasts are visible (figs. 52a, b). Dust coating on the samples is low to average; but moderate to high on the rest of the fragments forming the sample cluster.

Samples 425 and 426 were collected by the crew because they appeared to have a green tint similar to other materials they had seen elsewhere on the Hadley Delta traverse (Station 6a). They mentioned that the samples appeared to be part of a cluster of rocks that all seemed to be "roughly the same." Astronaut Scott suggested that possibly all the fragments in the cluster were part of a "big frag, but it broke when it hit." This is favored by the general abundance of light clast breccia in the cluster but is not supported by the green glass content of the samples or their general lack of burial in a cluster of well buried fragments. As mentioned above, the dust cover on the samples also appears to be less than that of the other fragments. The albedo of the samples appears to be average in the documentation photographs but as mentioned above, many of the rocks in the cluster have mappable light clasts. Samples 425 and 426 are of similar size and shape to the rest of the fragments in the sample cluster but their apparent lack of extensive burial and dust cover makes them appear rather unique in the near sample environment, and may have been emplaced later than the remainder of the partially buried cluster fragments. The samples are, however, probably part of the Spur crater ejecta from a depth of perhaps 20 m beneath the

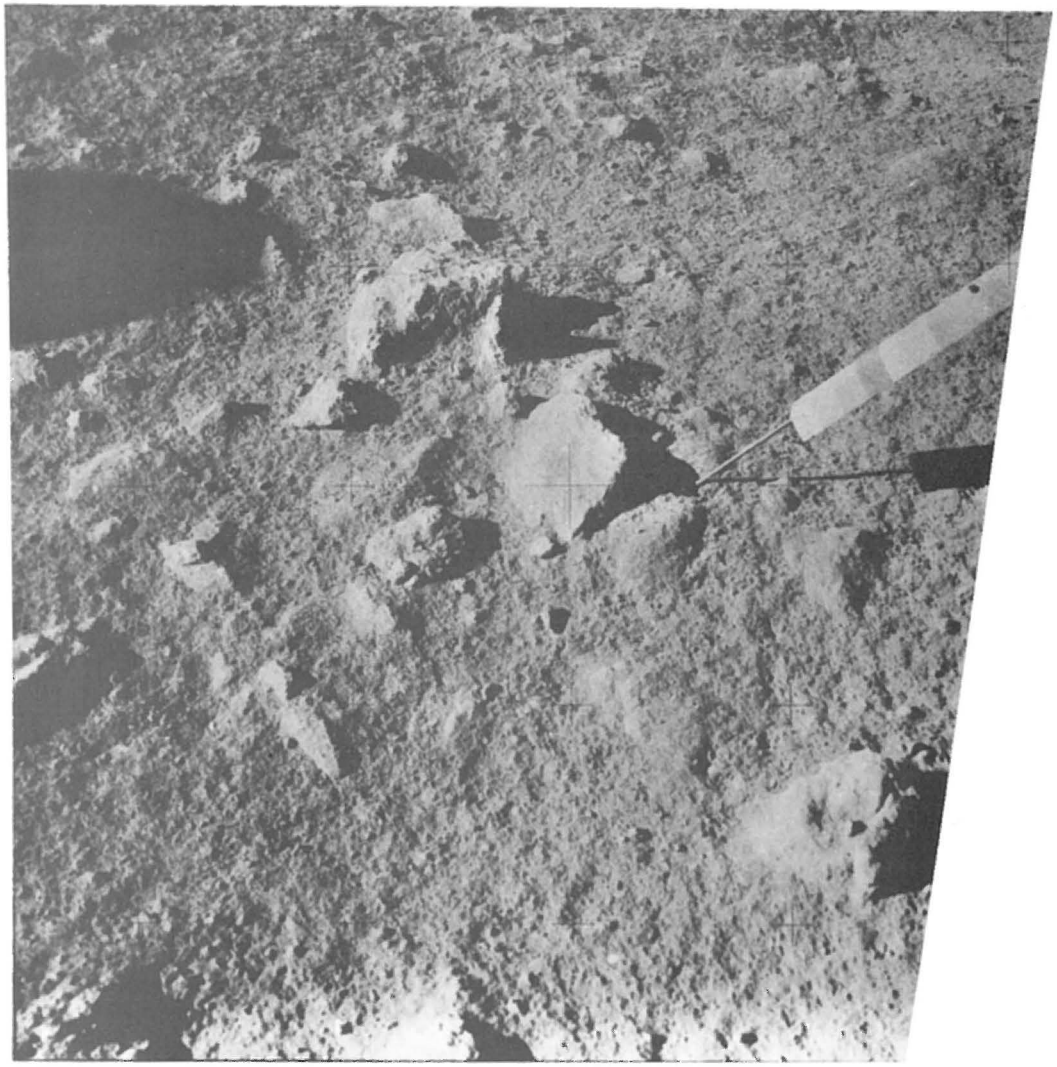

Figure 52a. Samples 425, 426, and 923. Pre-sampling, cross-sun photograph AS15-86-11666, looking south.

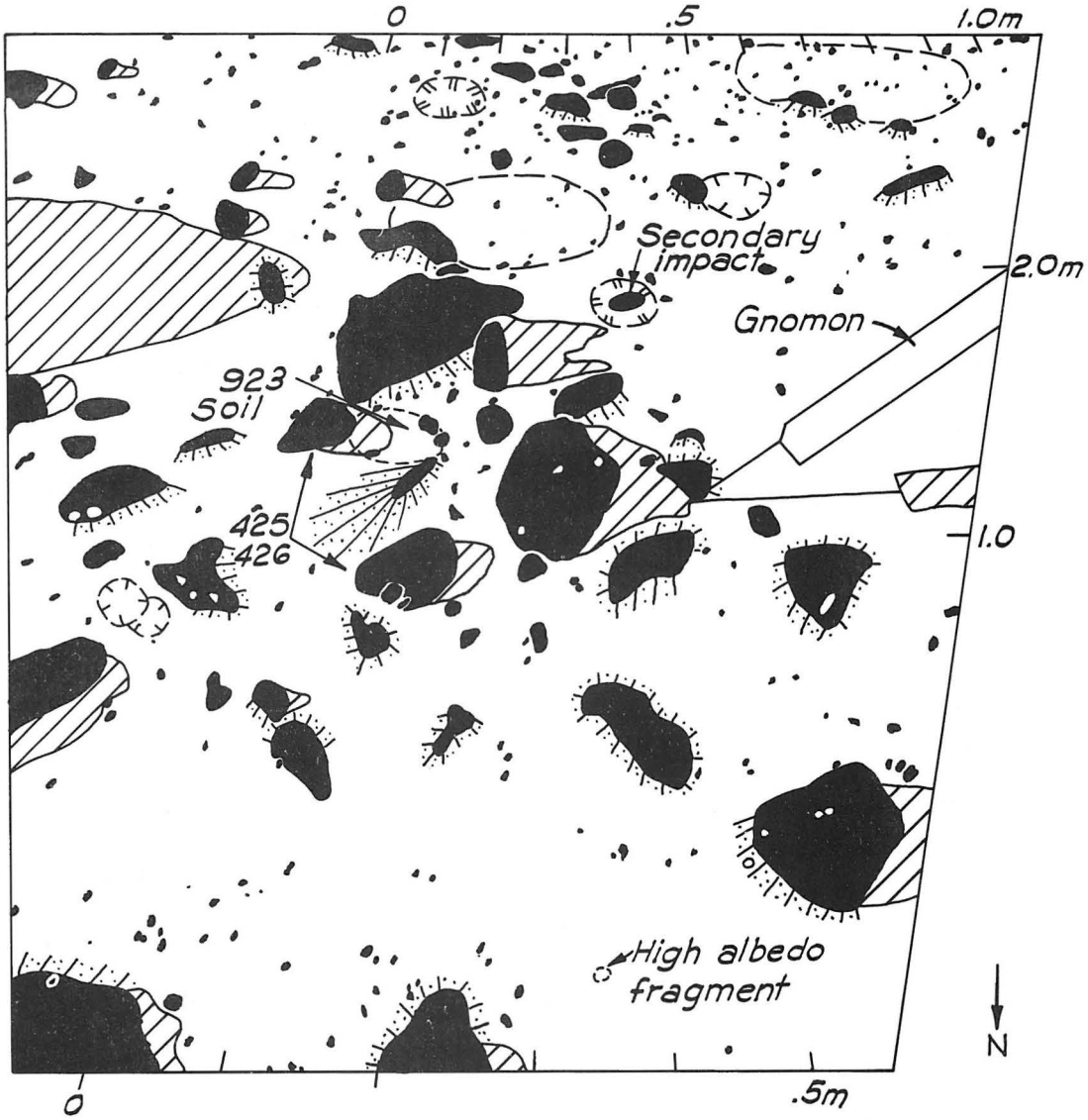

Figure 52b. Sample environment sketch map of vicinity of samples 425, 426, and 923.

Hadley Delta front at this point. The samples are unique, however, by virtue of their soft, green coating and general friable nature.

Breccia block (not directly sampled).--The largest rock fragment on the Spur crater rim is a 1.5 x 0.6 m, light-clast breccia block resting on the crater's north-northwest rim crest (plate 8; fig. 5). This block has many interesting features and although not directly sampled, Commander Scott picked up a smaller rock fragment (445) next to it and described the sample as likely the same material as the large breccia and probably having come from it.

Light clasts are abundant within, and on the surface surrounding, the breccia block (figs. 53a, b). The breccia block also has well developed joints or fractures, and significant structural folds, indicative of a complex history of intense shock and deformation (figs. 54a, b). This particular breccia block probably represents a larger version of most of the smaller breccia samples collected at Station 7, and, due to its size, shows shock history information and general textural details over a much larger area than will be found on the returned samples.

The block is broken in several places along what appear to be fracture faces forming a system of shears

parallel to the long dimension of the block (figs. 54a, b). There is a second, equally well developed fracture system that is perpendicular to the one mentioned above. Three or four additional minor sets are also present.

Well developed folds are present on the boulder. The folds are visibly enhanced on the block by what appears to be a differential weathering or erosion of the individual fold "layers" and the interface between them (figs. 54a, b). The fold axis appears to be parallel to the fracture faces mapped on the block and is oriented parallel to the long dimension of the breccia block.

Some areas on the base of the breccia block appear to have a vesicular texture and may be a glassy outer covering on the rock resulting from its latest shock event, probably the Spur crater impact. The astronaut crew did not mention any glass coating on the block but said that it looked very much like the Apollo 14 rocks (near Cone crater) but was "perhaps a little darker gray."

The breccia block is resting on the crater rim with no fillet buildup and with minimal burial. The southern end of the block is actually off the surface as the crater wall slopes toward the bottom of the crater (fig. 53a). The situation of the block on the

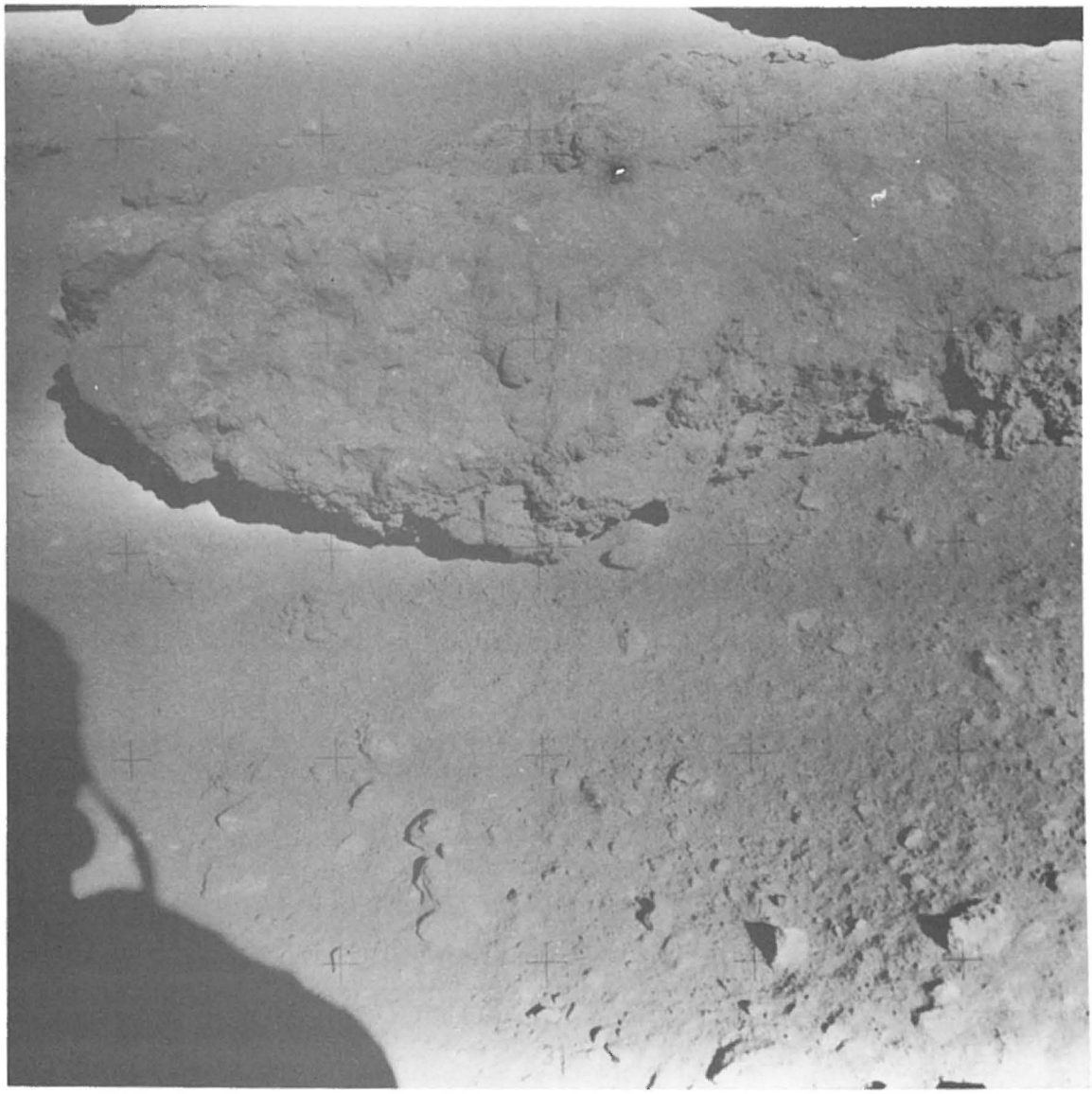

Figure 53a. Breccia block 1.5 m across, on the north northwest rim of Spur crater. Down-sun photograph AS15-86-11689.

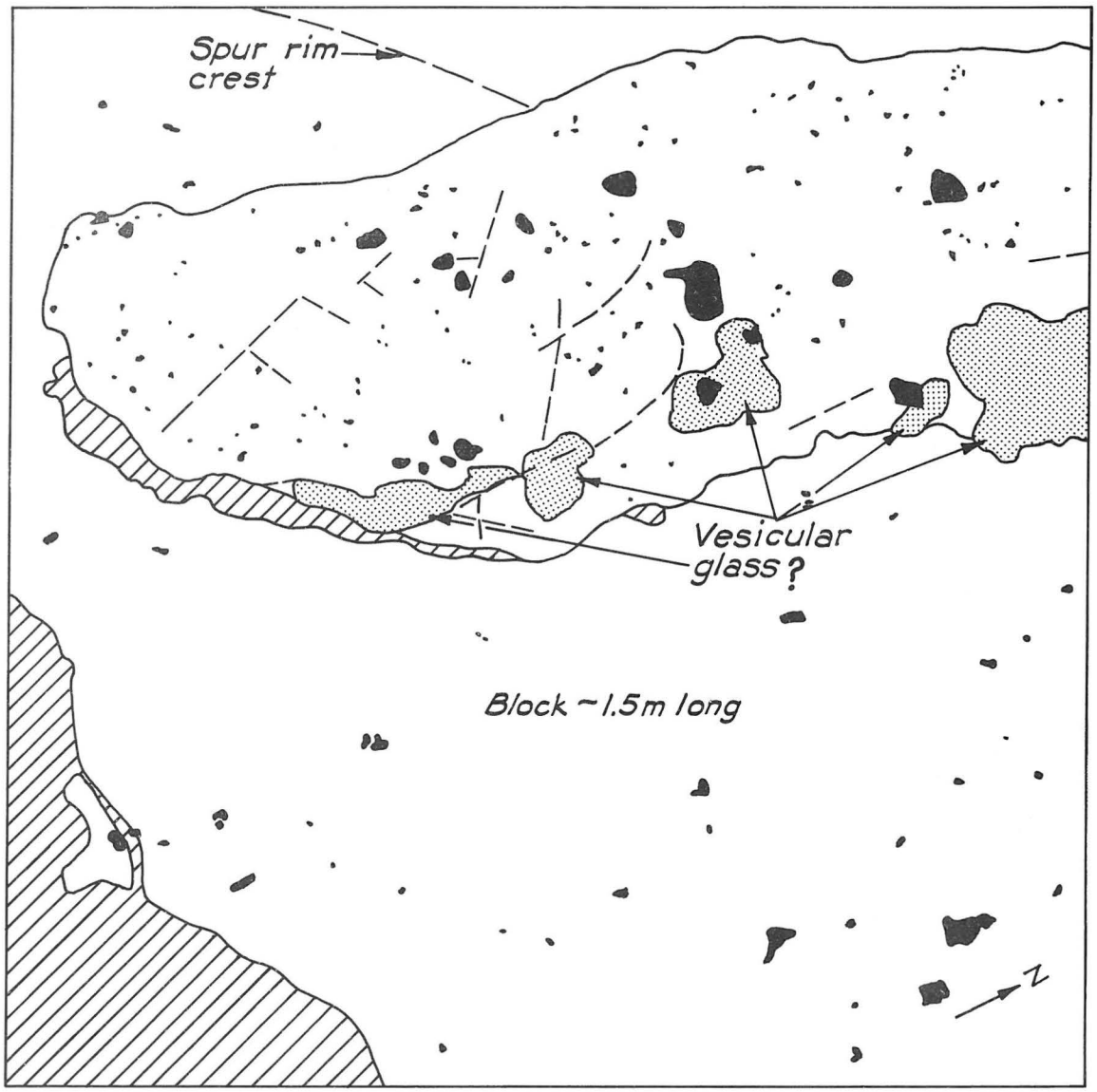

Figure 53b. Sketch map of surface of breccia block, showing light clasts in and around block, and fractures and glass coatings on block.

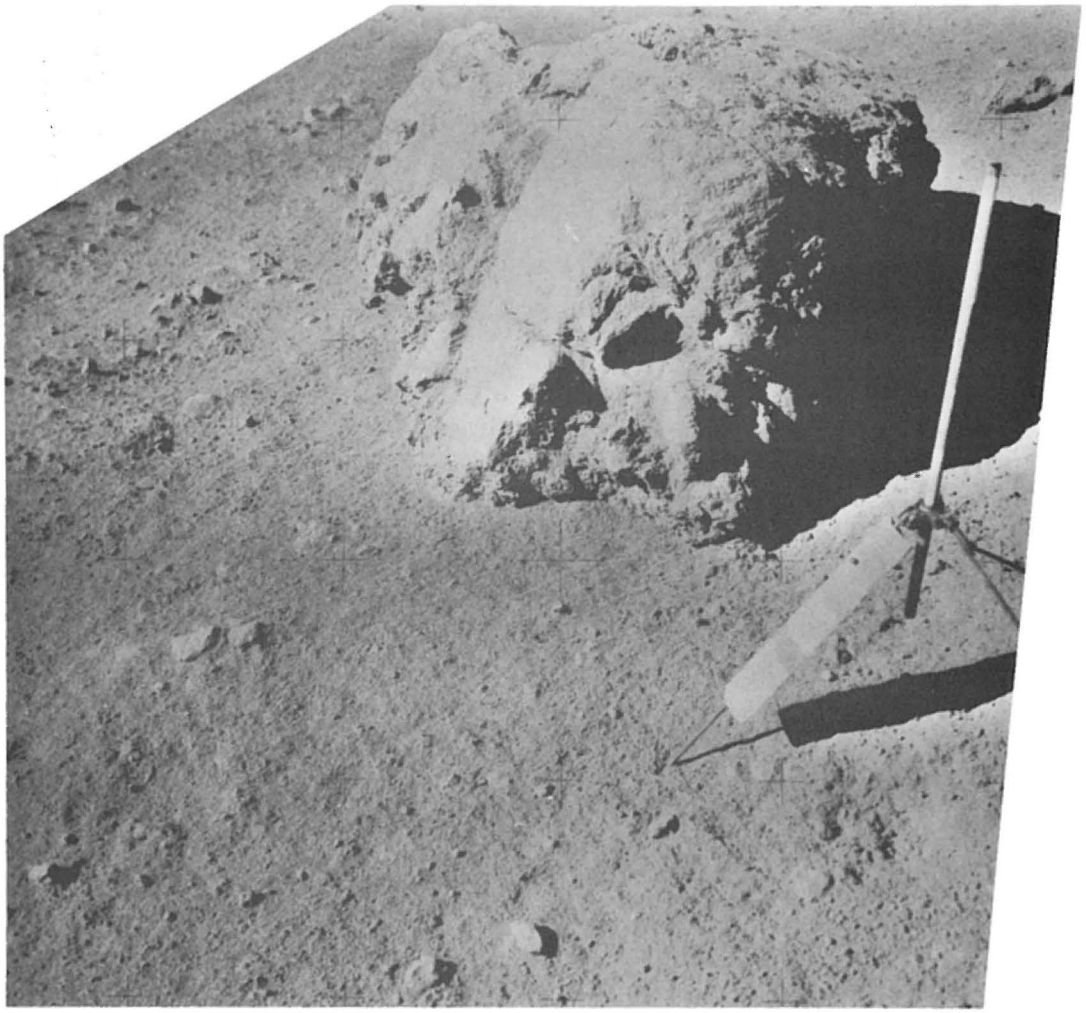

Figure 54a. Breccia block on the north northwest rim of Spur crater. Note fold structures near center of north face of block. Cross-sun photograph AS15-86-11682, looking south.

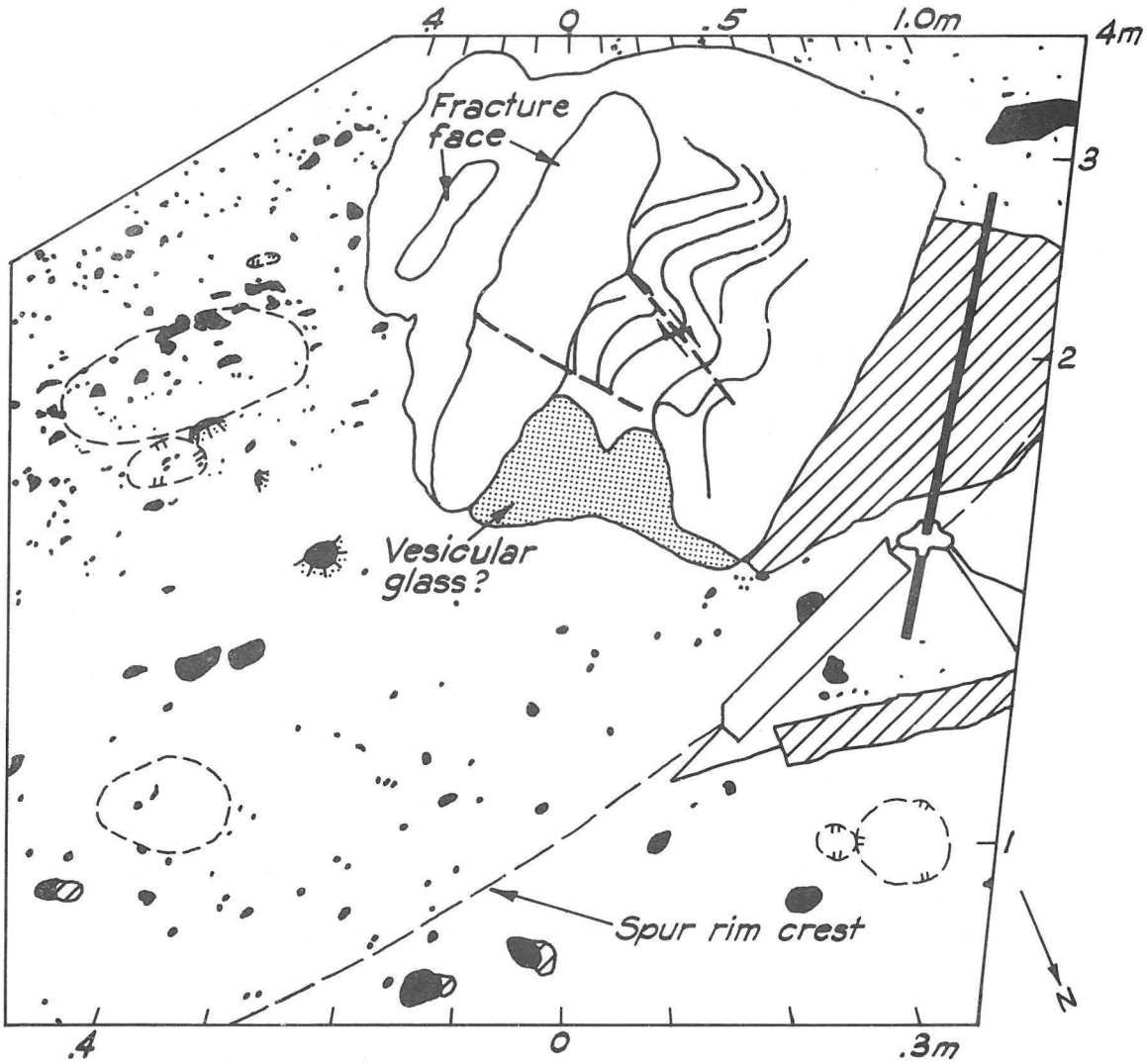

Figure 54b. Sketch map of breccia block on north northwest rim of Spur crater. Traces of fold planes on surface shown near center of block.

top of the inner crater wall slope to the south permits most surface fines to migrate toward the center of the crater and inhibits buildup around the block itself. It is unlikely that the block has moved from its present position since being evcavated by the Spur crater event. The condition of the Spur crater boulder illustrates the extreme deformation that perhaps all of the light clast breccias sampled have undergone.

Sample 445.--Sample 445 was located approximately 0.6 m west-southwest of the 1.5 m breccia block on the north-northwest rim crest of Spur crater (plate 8; fig. 5). The local surface is notably free of large (greater than 6 cm) buried rocks with most of the rocks on the surface having little or no filleting (fig. 55a, b). Many of the smaller rocks are perched on small topographic highs indicating the possibility that many of these smaller rocks may be recently derived from the breccia boulder by spalling. Most rock fragments surrounding sample 445 are less than 1 cm across with very few larger than 2 to 3 cm across. The local surface slopes moderately to the south-southeast toward the floor of Spur crater.

The regional surface slope in the vicinity of Spur crater is downward to the north about 10 degrees.

Lineaments are not present in the vicinity of sample 445. There are a few scattered subdued craters

(less than 0.3 m) near sample 445 but none are close enough to the sample to be associated with it as a secondary crater. The sample does not appear to be clearly representative of those in the immediate environment of the 1.5 m breccia block, especially in shape and texture, but it does resemble them in regard to the general lack of fillet buildup. Astronaut Scott picked up the sample as a likely fragment off the large breccia block and mentioned that it was the same rock type and was fairly "clean."

Most larger (greater than 3 to 4 cm) rocks in the sample environment are rough textured and irregular in shape, unlike sample 445 which is equidimensional and relatively smooth, but with angular corners. Chances of the sample being derived from the large breccia block is good but not definite for the above cited reasons.

The sample and the breccia block are probably represenative of local bedrock or mountain debris characteristic of the Hadley Delta front at the 60 m elevation (above the plains) where it was sampled. The position of the large breccia block (and possibly the sample 445) on the rim crest of Spur crater indicates that this material may have been derived from the maximum sample depth (about 20 m) from within the crater.

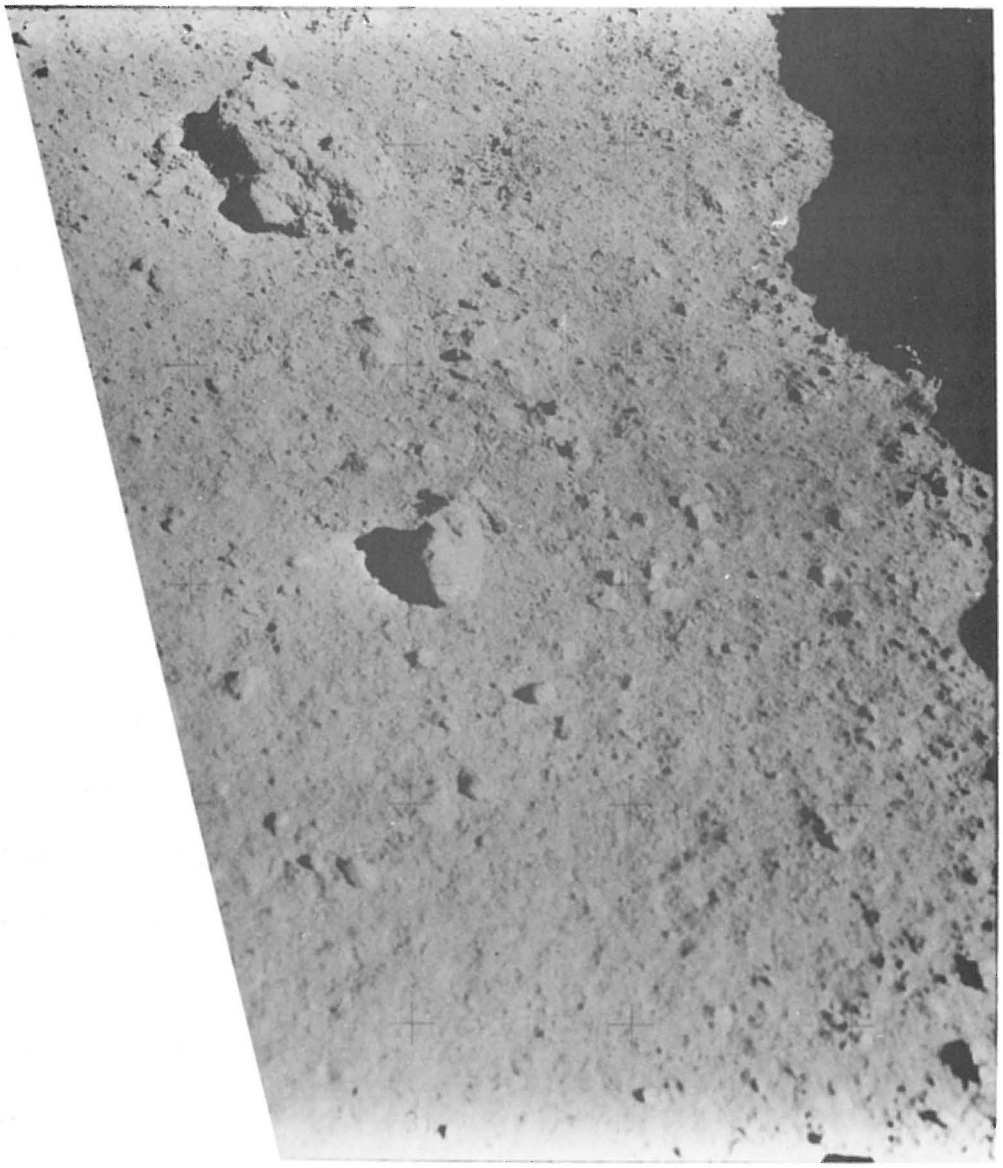

Figure 55a. Sample 445. Pre-sampling, cross-sun photograph AS15-86-11691, looking north.

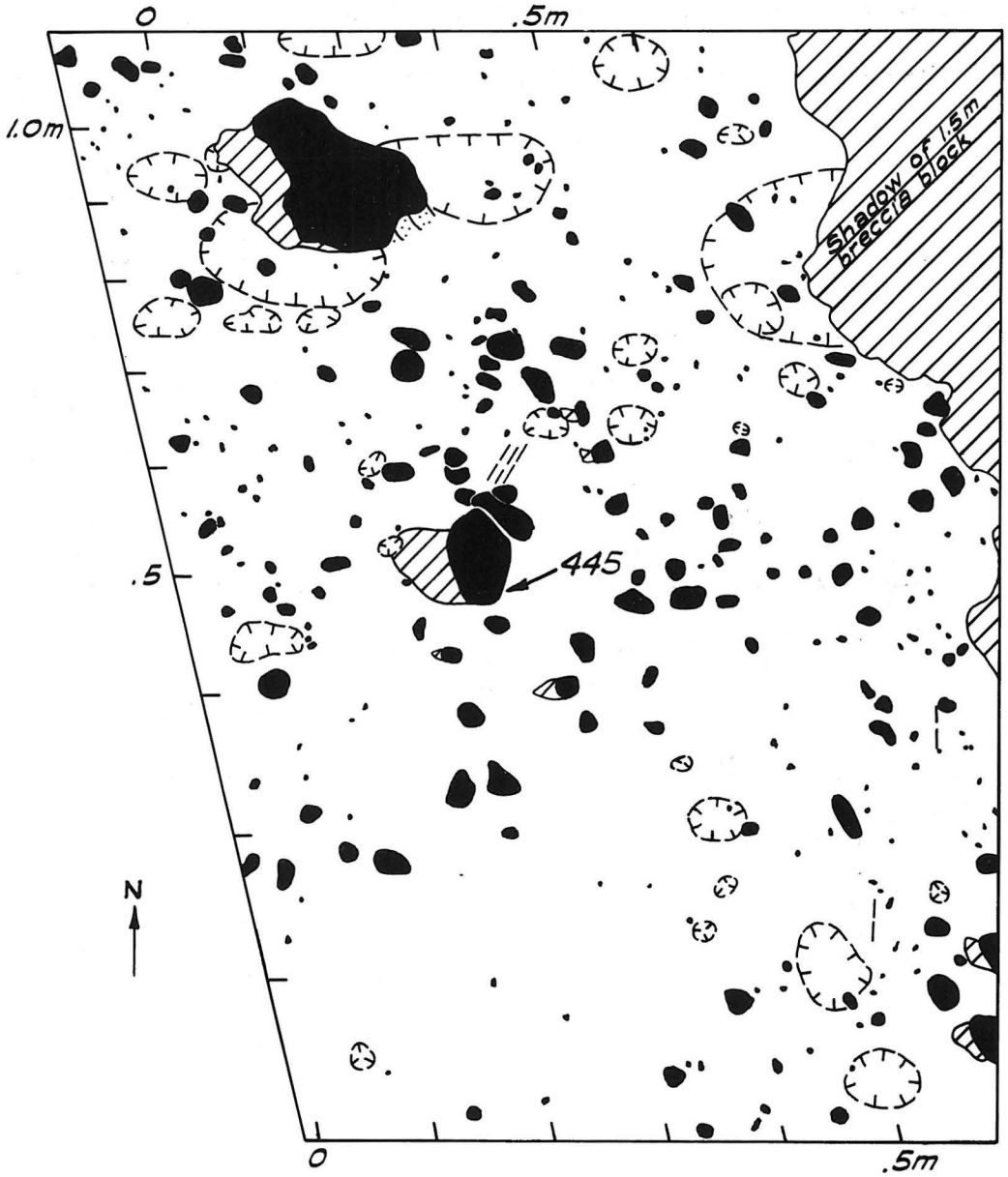

Figure 55b. Sample environment sketch map of sample 445 and vicinity.

Sample 455.--Sample 455 was collected approximately 10 m east of the 1.5 m breccia block and 3 m west of the anorthosite sample (415) on the north rim of Spur crater on the Hadley Delta front (plate 8; fig. 5).

The surface in the immediate vicinity is not characterized by the cluster or grouping of rock debris that was typical of several other sample sites at Station 7. There are fewer rocks of all sizes, and sample 455, about 10 cm across, is the largest fragment visible in pre-sample photographs (figs. 56, 57a). There are no sharp, fresh primary or secondary craters of any significant size in the sample environment. The surface in the sample vicinity slopes to the south several degrees toward the floor of Spur crater. Regional surface slopes in the area, however, are to the north about 10 degrees down the Hadley Delta front.

Filleting on the rocks at the sample site is low-to-average, and some larger rocks, including sample 455, rest on small topographic highs above the immediate surface level. Albedo of the local rocks and associated soil can be best observed on the down-sun photograph (fig. 56). The undisturbed surface next to the sample site appears to have an albedo typical of the area, but an area disturbed by the astronauts' boots immediately to the north contains higher albedo material,

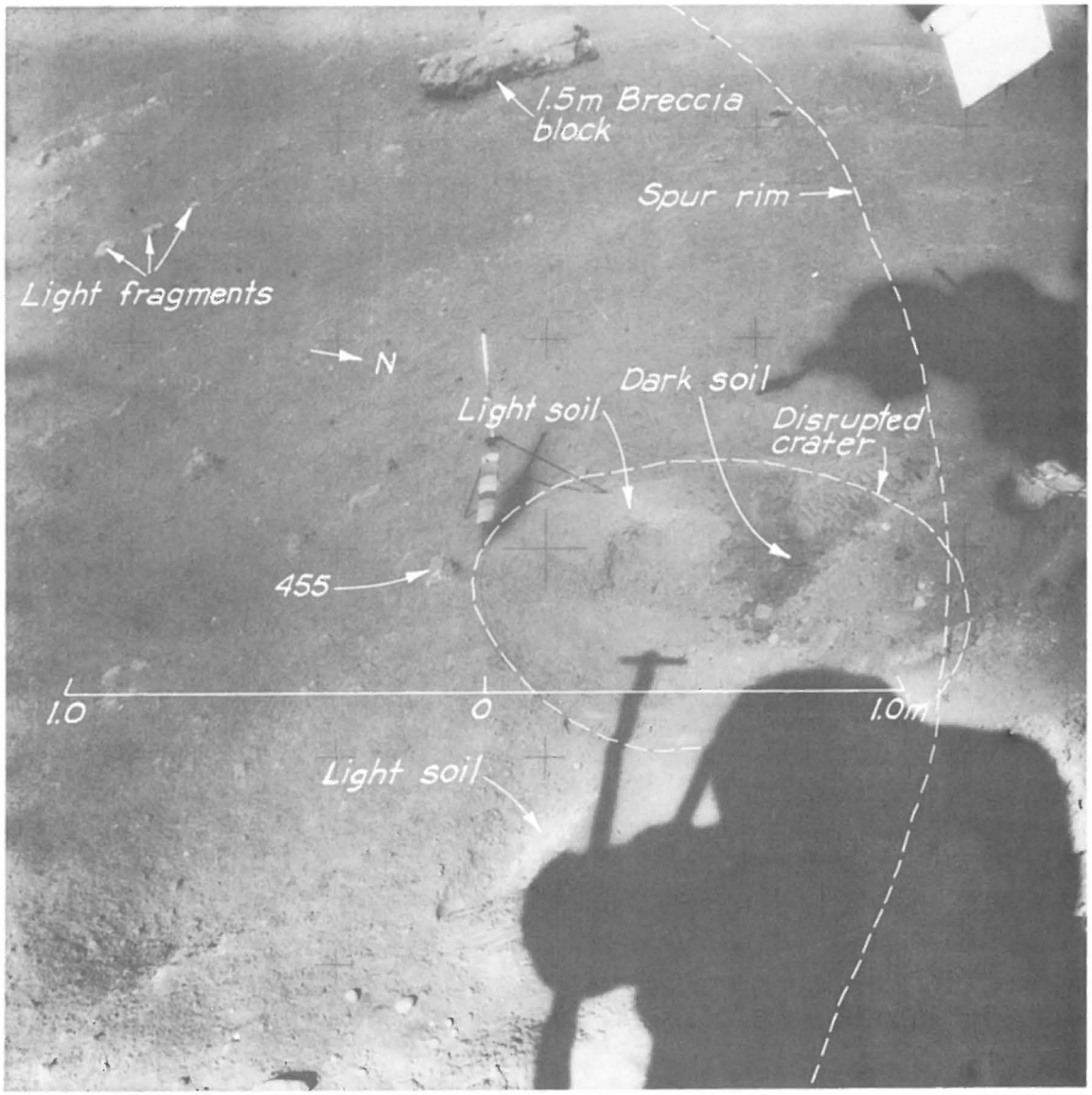

Figure 56. Sample 455 and vicinity. Pre-sampling, down-sun photograph AS15-90-12229, looking west.

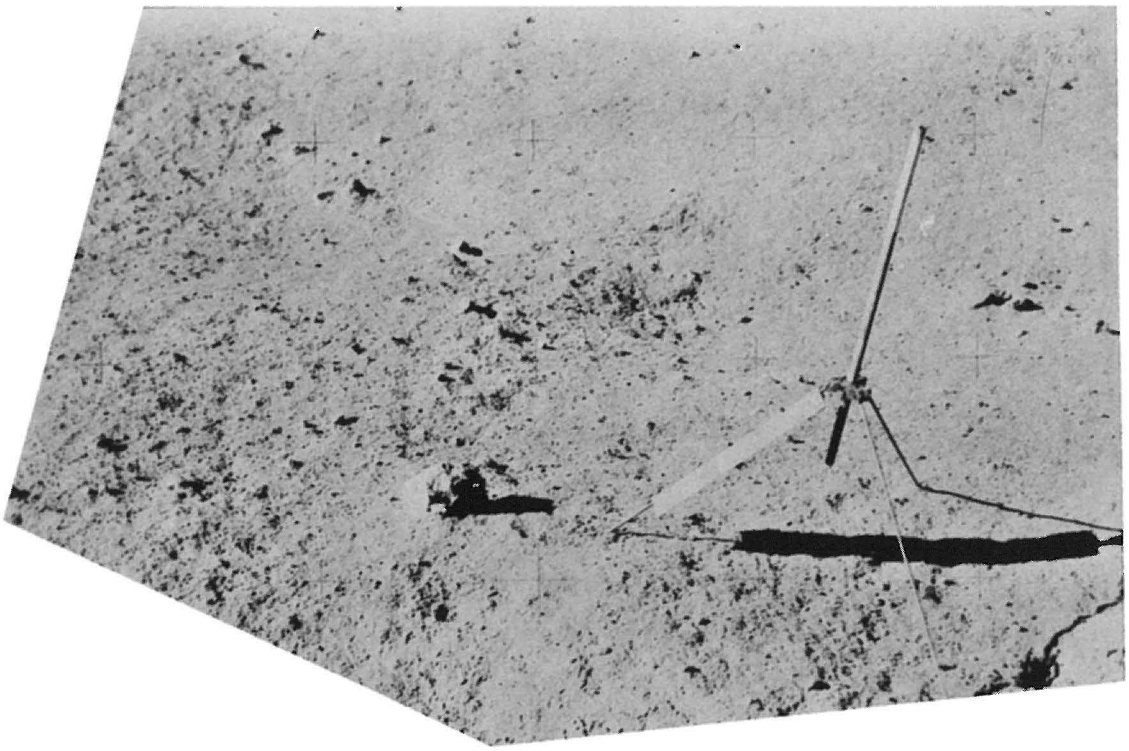

Figure 57a. Sample 455. Pre-sampling, cross-sun photograph AS15-86-11675, looking south.

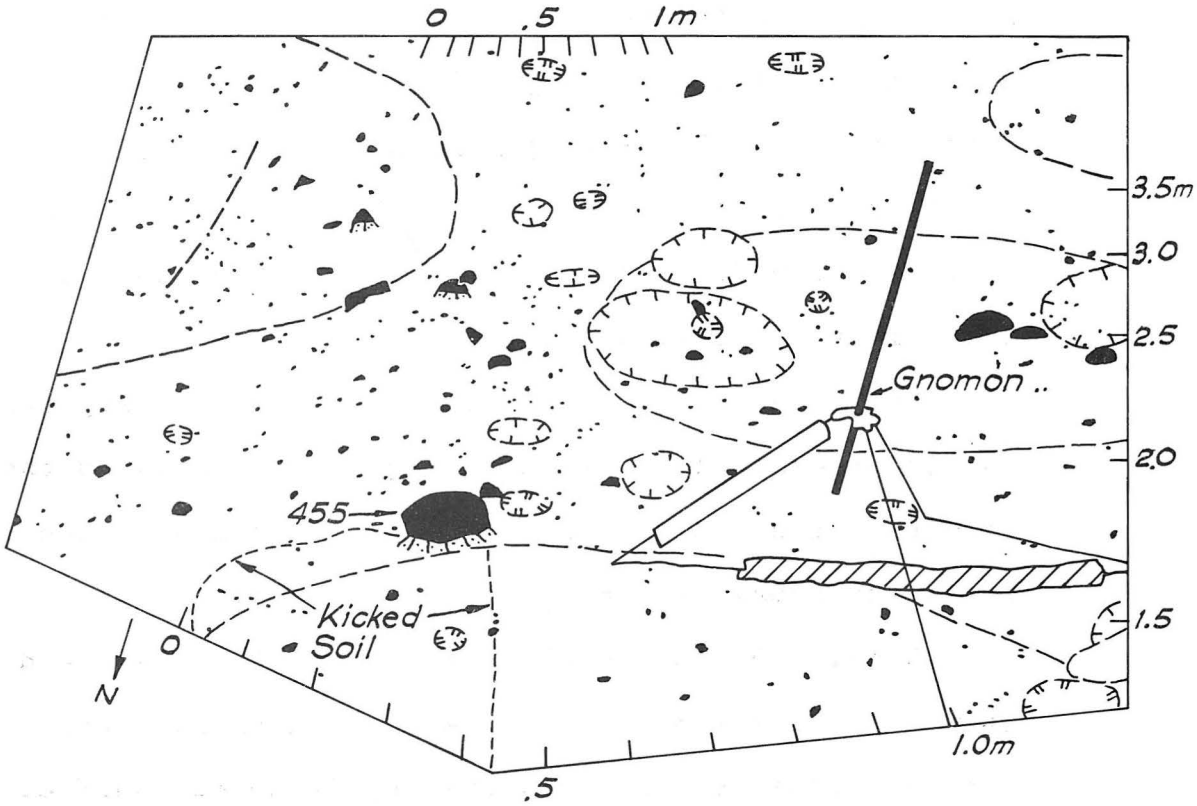

Figure 57b. Sample environment sketch map of sample 455 and vicinity.

perhaps indicating the presence of abundant light clast breccia material in the general vicinity underlying the upper few millimeters of surface soil (fig. 56). Figures 51a, b illustrate the presence of a number of rock fragments in the area of samples 415 and 455 with high albedo clasts or large phenocrysts. This local area appears to be heavily populated with such light clast breccias, all of which may be related to a single ejecta stream from Spur crater from perhaps the same depth in the Hadley Delta surface.

Dust covering on the local rocks surrounding sample 455 is probably lower than average, especially on the perched rocks. Burial is lower than average in the immediate sample vicinity.

Sample 455 is closely associated with a subdued, shallow crater (about 1 m diameter) which may have been responsible for re-excavating it to the surface. The sample is sitting on the southern rim crest of this crater and may have been re-excavated from possibly 0.2 m to 0.3 depth. The local slopes associated with sample 455 are gently to the south on its south side and gently to the north (into the small 1 m crater) on the sample's north side. The fact that the sample is resting exactly on the rim crest of the small recent crater where fines should be preferentially moved into

the crater by small impacts may account for its lack of burial.

The sample is perhaps slightly larger than other rocks in its immediate vicinity but is certainly not unusual in respect to the local area encompassing the area between samples 415, 455, and the 1.5 m breccia block.

The texture and structure of sample 455 is not particularly unique but the down-sun photograph (fig. 56) does reveal the presence of larger-than-average high albedo clasts on its lunar northeast side.

The sample is obviously one fragment of many in the general area of 100 m^2 that are characterized by the presence of high albedo clasts associated with high albedo soils exposed by cratering on the surface or below the upper few millimeters of the present surface. All of these fragments are probably excavated from about 20 m depth below the original Spur crater surface and possibly represent either layered deposits or debris from pre-Imbrian or Imbrium (Fra Mauro) ejecta deposits making up the Hadley Delta front.

Sample 459.--Sample 459 was collected on the northeast inner wall of Spur crater (above the steepest part of the wall slope) approximately 6 m southeast of the rim crest and 50 m east-southeast of the 1.5 m

block on the crater's north-northeast rim (plate 8; fig. 5). The rock fragments in the immediate vicinity of the sample form a group or "cluster" and range in size up to about 1.0 x 0.5 m (figs. 58a, b). The rake sample area is 3 m northeast of the 459 site. Two main types of rocks are distinquishable by their shape and texture in the immediate sampling area. The first, characteristic of the sample 459 rock as well as the large 1.0 x 0.5 m block adjacent to it, has at least three or four directions of jointing or parting giving the rocks a distinct rectangular, "platy" appearance. These jointed rocks are all semi-rounded, at least on their exposed surfaces. The only diverse rock visible in the photographs is a 20 to 30 cm long, very rough, possibly vesicular fragment lying just to the east of the large block (figs. 58a, b). This rough rock may be an exotic thrown up to this position by a local impact in the mare plains to the north, or, more likely, is a splash-glass coated breccia similar to samples 465 and 466. Such glass coated breccias are apparently rather common the Spur crater rim.

The crater population in the near sample environment is unusually low with a definite lack of small fresh craters. This is probably due to the location

of the sample area over the inner wall of Spur with downslope movement quickly destroying craters in this size range.

A few well developed lineaments are present in the near field of photograph AS15-90-12235 (figs. 58a, b). The presence of even these few lineaments is considered unusually high at the Apollo 15 site when compared to all other sample documentation areas studied and may be related to fracturing under the regolith at the rim crest of Spur crater. Fillets are poorly developed on almost all rocks in the sample area. Most of the fragments are buried from 1/3 to 1/2 their height. There is no post-sample photograph to verify the exact burial depth.

The albedo of the rocks and soil surrounding the group of rocks appears average to slightly below average for the Spur crater rim sample sites. There is no light clast material visible and where the soil has been disturbed during sampling activities, there is no higher than average albedo soil.

Sample 459 was taken from the "center 1/3" of a 30 x 30 cm rock that had two well developed parallel fractures running through it. Astronaut Scott mentioned it looked like "layering in it." The sample was broken loose along these fractures.

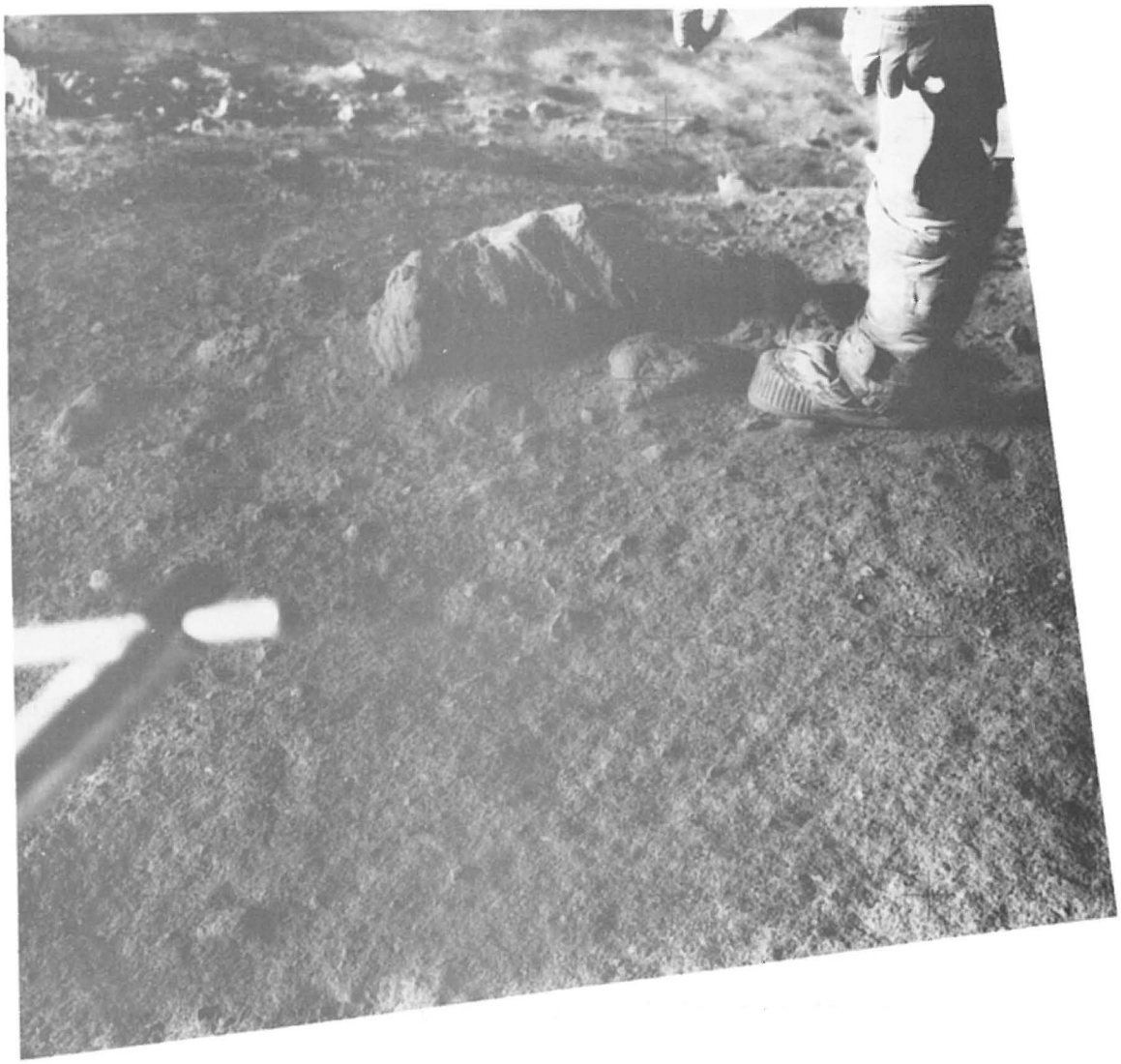

Figure 58a. Sample 459. Pre-sampling, cross-sun photograph AS15-90-12235, looking south

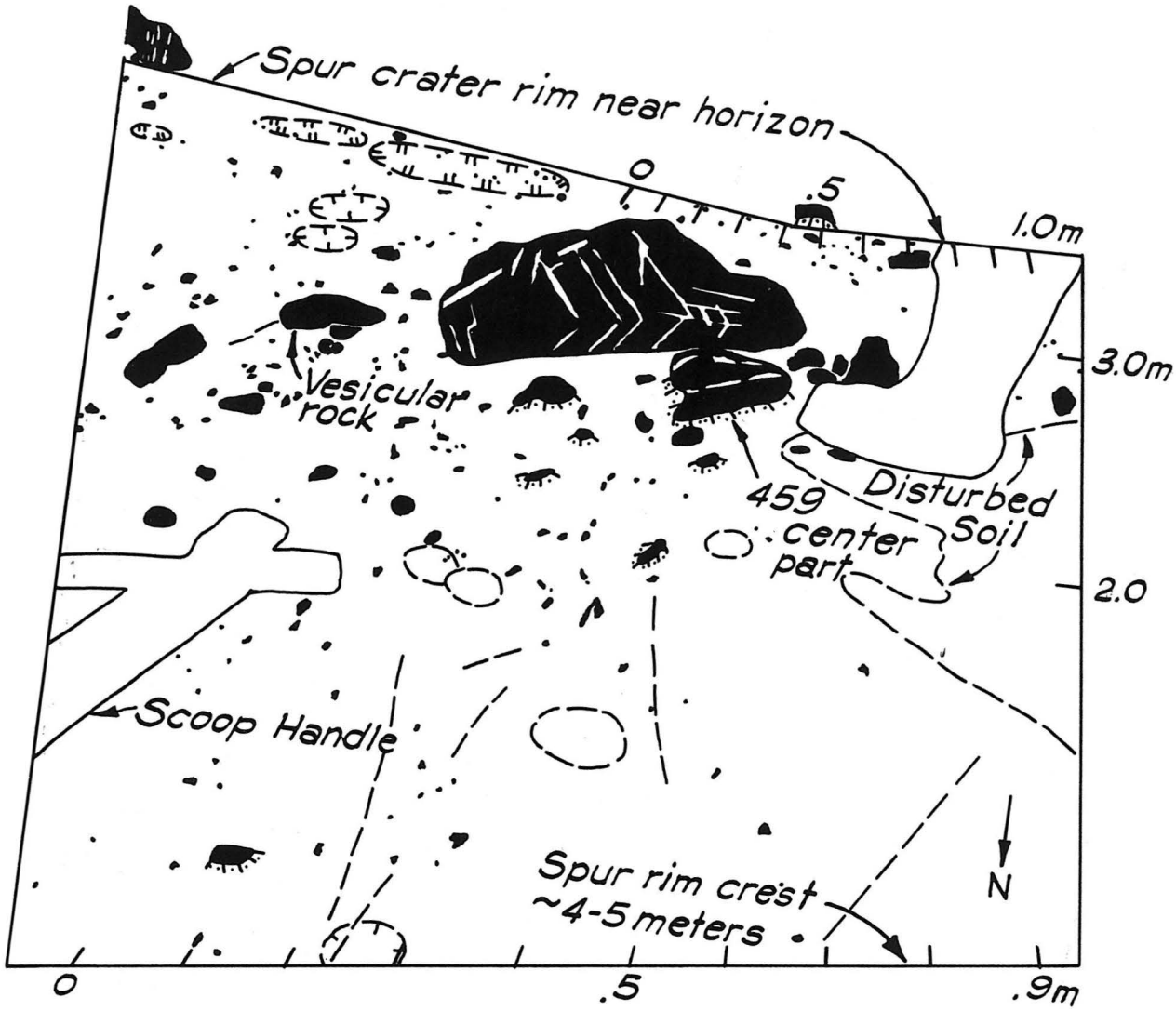

Figure 58b. Sample environment sketch map of sample 459 and vicinity.

Both the sampled rock and the large fractured block immediately adjacent (southeast) are buried from 1/3 to 1/2 their height and have apparently been in these relative positions for quite some time (probably since the formation of Spur crater). Dust cover on the sampled block appears minimal.

The jointed or fractured sample block as well as the larger block adjacent to it are probably the same material and have undergone similar histories. They probably represent highly fractured Apennine mountain material that has been excavated by the Spur crater event from a depth approaching 20 m and have not been moved significantly or buried since that time.

Samples 465 and 466.--Samples 465 and 466 were taken about 3 m east-northeast of the 1.5 m breccia block on the north-northwest rim crest of Spur crater (plate 8; fig. 5). The sample location is just over the summit of Spur crater rim crest on a surface sloping several degrees to the south-southeast toward the crater floor. However, the regional surface slope is approximately 10 degrees north, down the Hadley Delta front.

The surface in the immediate vicinity of the samples is rather blocky with fragment sizes up to 10 to 12 cm (figs. 59a, b). The rock types are unusually

diverse for such a limited area and include: 1) equidimensional-subangular fragments; 2) rough macro-vesicular-appearing fragments, and 3) foliated ropey-to-rough fragments. The largest fragments in the near sample environment are grouped into a 1 m^2 area as illustrated in Figure 59b. The small group of rocks characterizing the area appear in the down-sun photograph (AS15-90-12230) to contain rather abundant high albedo clasts. A disturbed area about 0.8 m to the north (over the Spur crater rim summit) of the sample site contains abundant high albedo soil, also visible in photograph AS15-90-12230. This lighter subsoil may indicate a concentration of lighter clast breccias in the immediate vicinity.

Small craters (less than 1 m diameter) are in low-to-average abundance. Lineaments are sparse but two rather distinct linear troughs are present in a small crater (about 12 cm diameter) approximately 20 cm east of the sample site (fig. 59a, b).

All of the larger rock fragments have moderately well developed fillets and appear to be about equally buried to 1/4 to 1/3 their height. Dust cover on the rocks is difficult to evaluate from the photographs available.

The samples are clearly related to Spur crater (resting on its north-northwest rim crest) but are not

Figure 59a. Samples 465 and 466. Pre-sampling, cross-sun photograph AS15-86-11678, looking south.

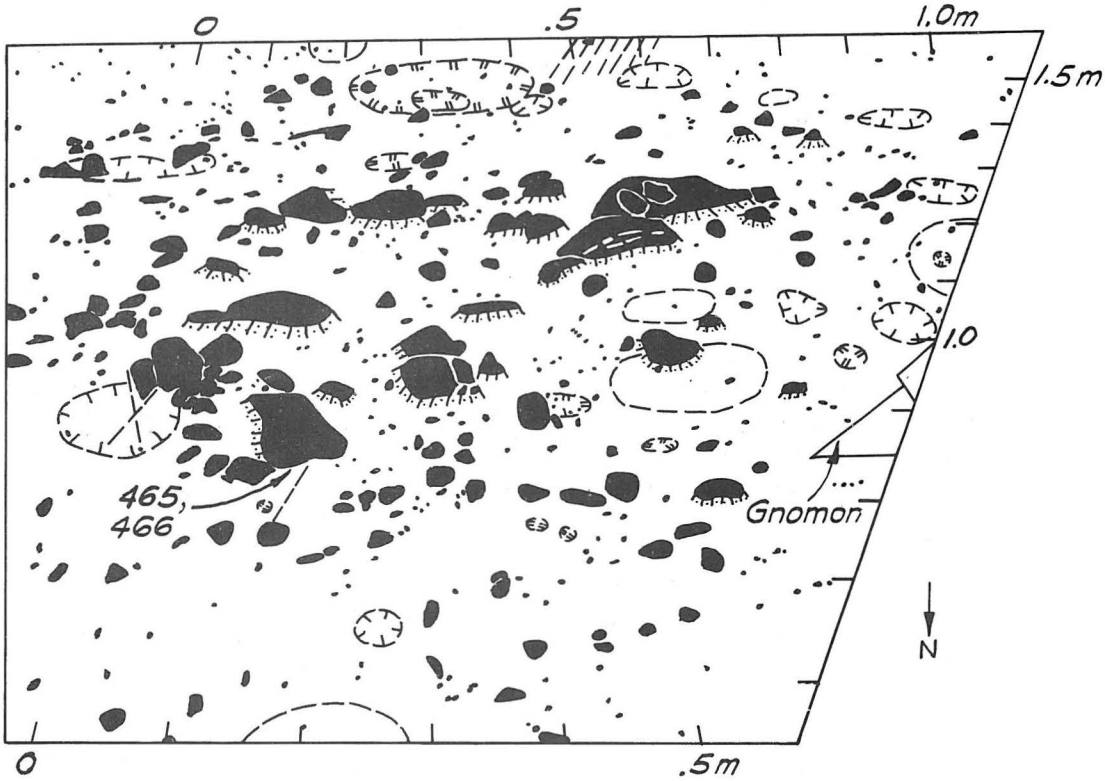

Figure 59b. Sample environment map of samples 465 and 466, and vicinity.

likely associated genetically to the small 12 cm crater (the one with the lineaments) 20 cm east of it. Samples 465 and 466 should probably be considered as representative of the rocks in the immediate vicinity, or perhaps, the entire Spur crater rim. Astronaut Scott said the splash-glass-breccia agglomerates were seen in other areas around Spur crater rim during the traverse. The fragment sampled, however, was perhaps larger and therefore more obvious than the rest. The sample is an aggregate of splash glass and light clast microbreccia with macrovesicles. This type of rock is distinct in the standard documentation photos and appears very rough and irregular due to abundant shadows.

The light clast breccia portions of the samples are probably representative of material from the bottom of Spur crater that were fractured and simultaneously injected with impact glass during the Spur crater event; thus the condition of the samples may be indicative of the pre-Imbrian and Imbrian events as well as the much more recent Copernican age Spur impact.

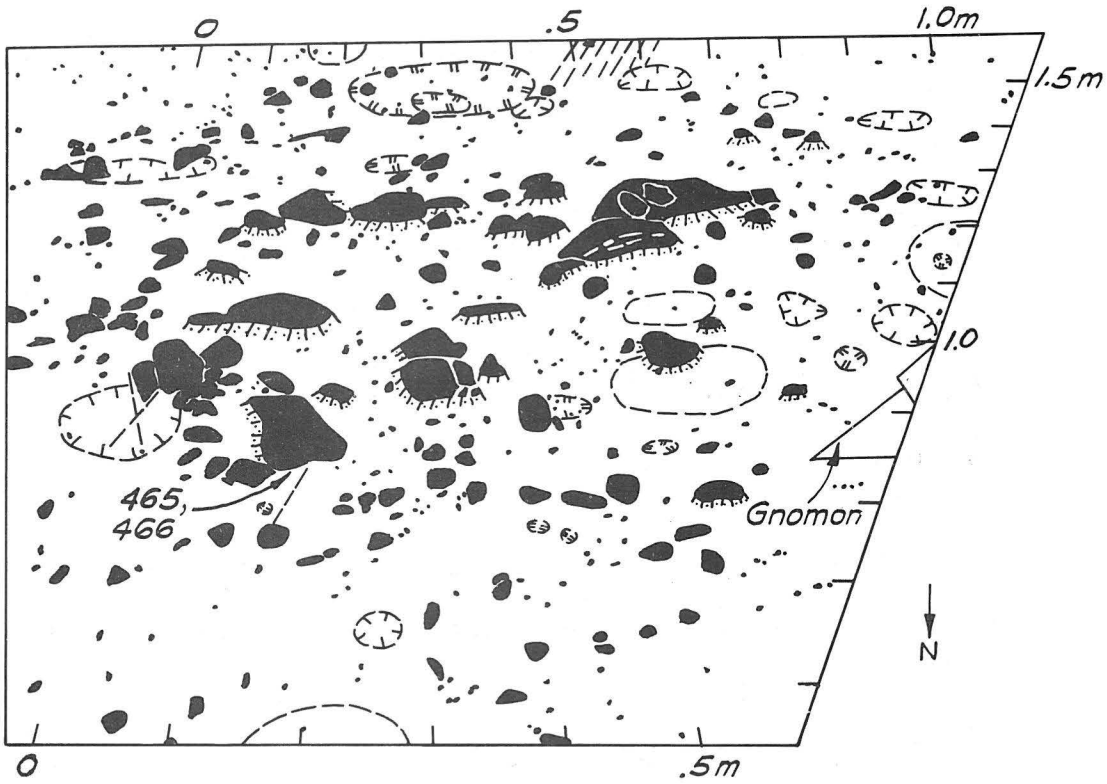

Figure 59b. Sample environment map of samples 465 and 466, and vicinity.

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Samples 305-308 and 315-392.--Samples 305-308 are soil samples, and 315-392 are fragments collected with the rake, for the comprehensive sample at Station 7. The samples were collected on the northeast rim of Spur crater (figs. 1, 5).

The area raked was slightly disturbed in the eastern part by footprints prior to raking (fig. 59c), but this should not degrade the quality of the sample. As previously described, small fragments are moderately abundant on and near the rim crest of Spur crater. Most of the fragments collected are breccias and soil breccias, which is consistent with the interpretation that most of the material in the vicinity is breccia that was originally derived from the event that formed the Imbrium basin, some of which has been recycled by later, local cratering events such as the Spur crater event.

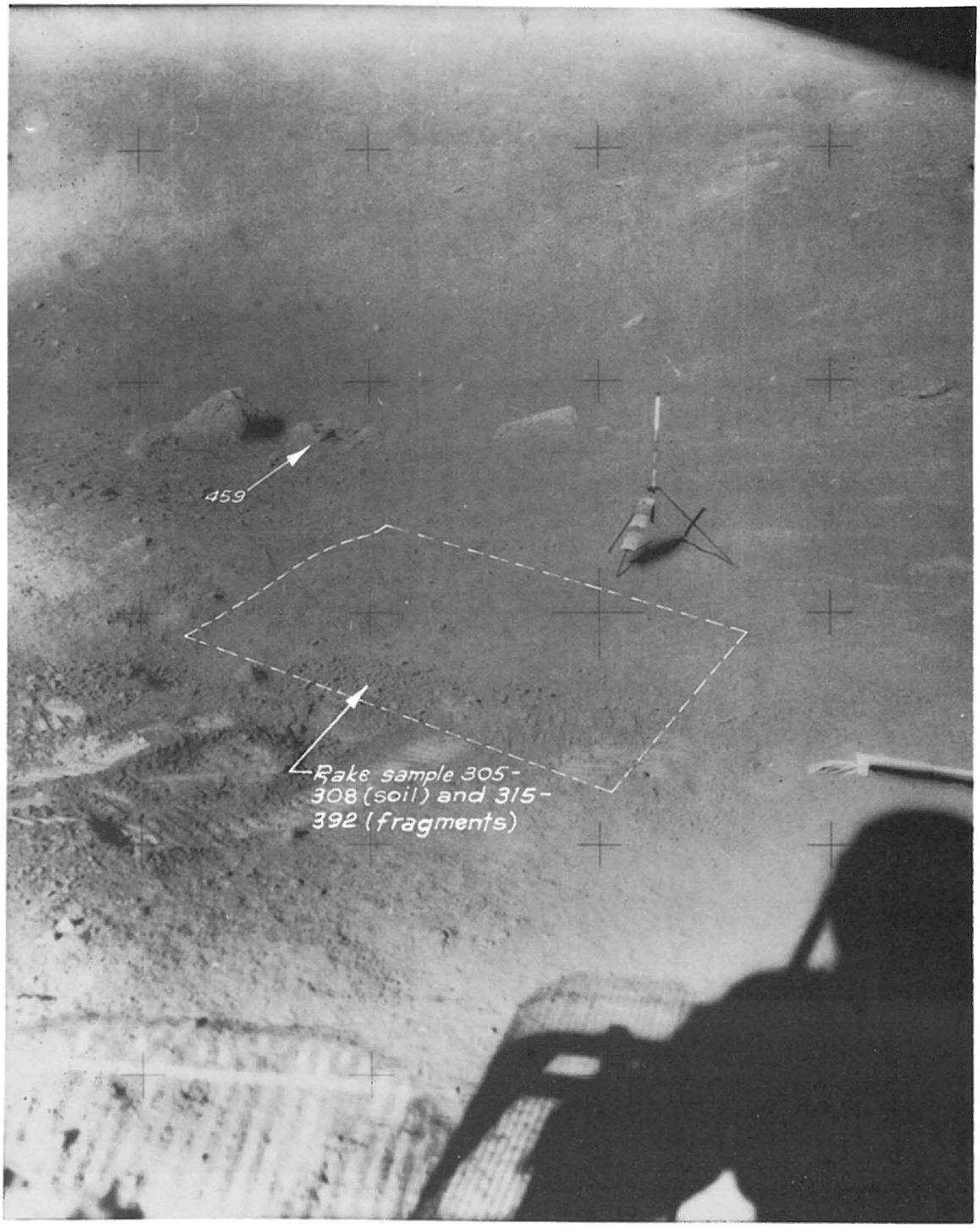

Figure 59c. Vicinity of samples 305-308 and 315-392 collected with the rake at Station 7. Pre-sampling, down-sun photograph AS15-90-12232, looking west.

Station 8

Station 8 is located between the LM landing site, and the ALSEP site, about 50 m from the ALSEP central station (figs. 1, 3). The surface at Station 8 is similar to that described at the LM and ALSEP sites (plate 10). Samples from the "deep trench," and the "deep drill," were collected at Station 8 (fig. 3).

Samples 013, 030-034, and 040-044.--At Station 8, Astronaut Irwin dug the deep trench from which the following samples were taken: Sample 013 (the SESC) and samples 030-034 from the bottom of the trench; and samples 040-044 from the top of the trench (figs. 3, 60, 61). The trench area is similar to the area near the ALSEP; a smooth, hummocky surface of fine-grained material with rare, cobble-sized fragments not visibly related to any particular crater. One small fresh crater occurs a few meters north of the trench, but is too distant to add a signficant layer of ejecta to the trench area.

The trench wall was described by the astronauts as uniform, with perhaps a slight color darkening in the middle part, above a hard layer the top of which was at a depth of about 14 inches. This layer was not penetrated by the trench but may well be the same hard layer cut by the drill, that appeared

during drilling to be about six thick. The top of the hard layer was described as flat and easy to clean off.

Samples 001-006.--Samples 001-006 are from the deep core which was taken at Station 8 about 5 m southeast of the trench (fig. 3). The local surface is described with the trench samples (see also plate 10).

It can be reasonably assumed that the greatest number of layers in the drill core were derived from craters not much farther from the site than the extent of their continuous ejecta blankets or about one crater diameter away. The greatest number of layers would then represent ejecta from craters smaller than the crater size that has saturated the surface. At the drill site, therefore, the largest number of layers are probably of material derived from less than 500 m away. Because the saturation-size craters also determine the depth of the generalized base of the regolith, a layer from a larger crater should contain material derived directly from bedrock.

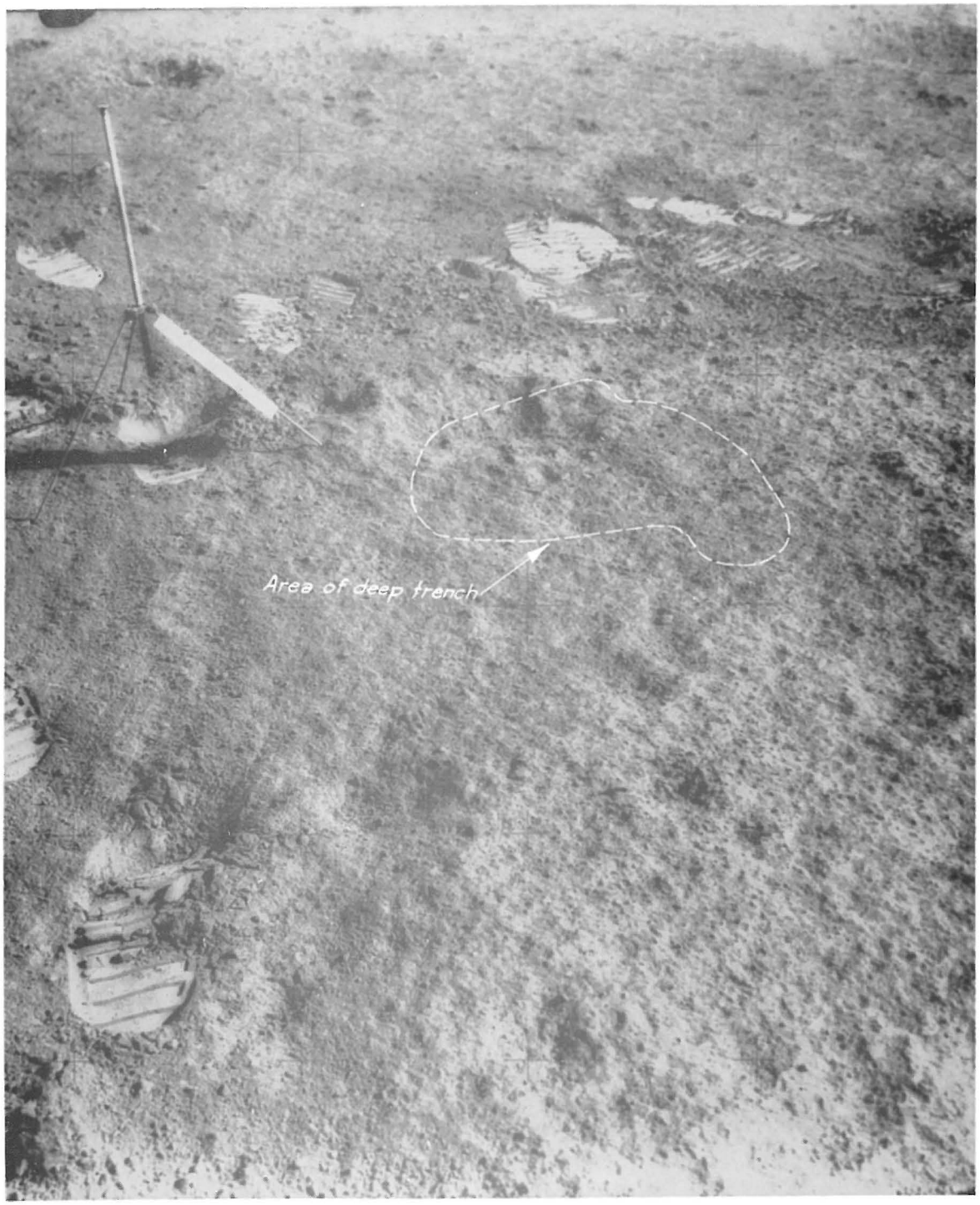

Figure 60. Approximate area of deep trench, from which samples 013, 030-034, and 040-044 were taken. Pre-sampling, cross-sun photograph AS15-92-12417, looking north.

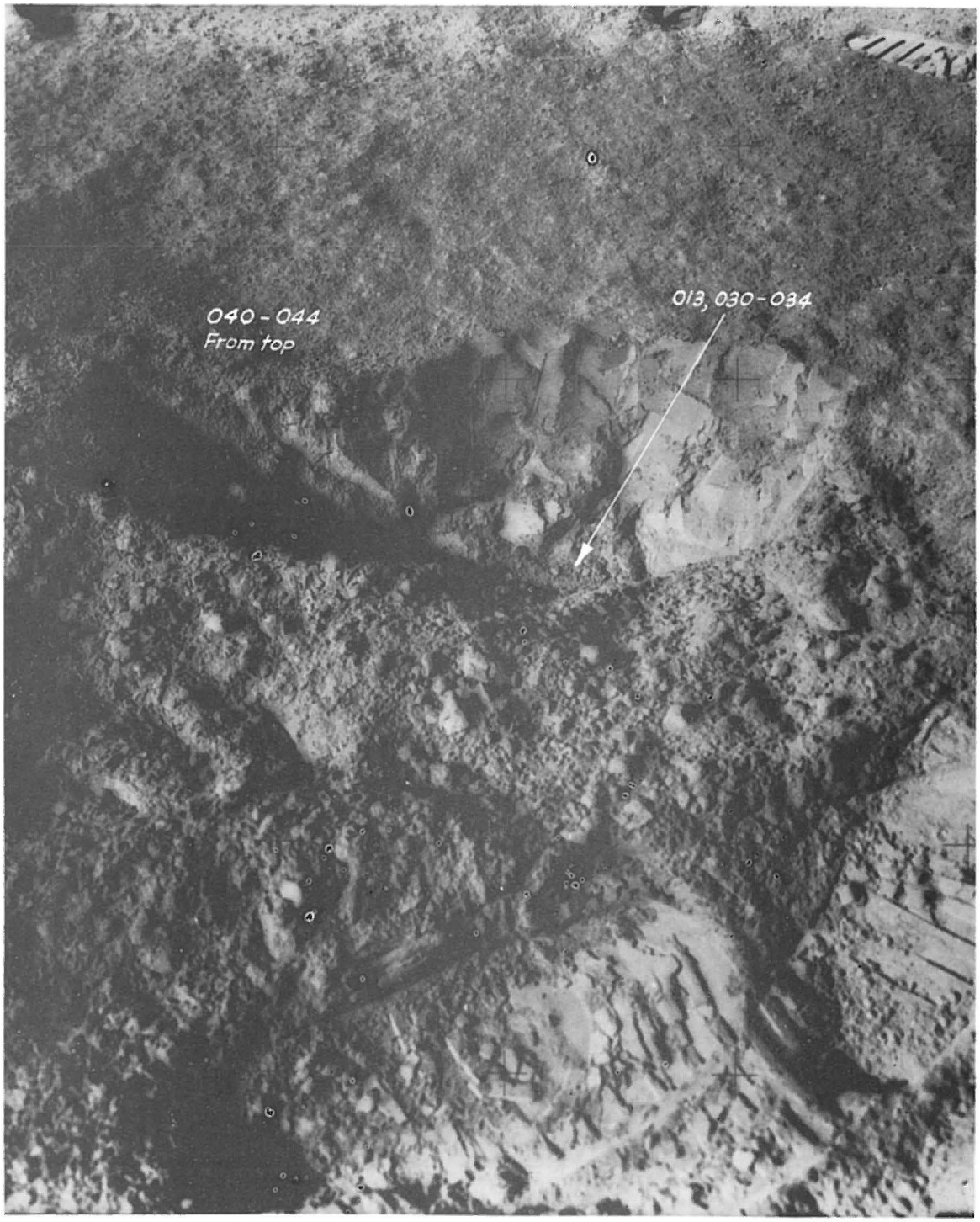

Figure 61. Deep trench, from which samples 013, 030-034, and 040-044 were taken. Cross-sun photograph AS15-92-12439, looking south.

Station 9

Samples 500-507 and 510-515 were collected at Station 9 (fig. 1) from the ejecta blanket of a 15 m diameter, fresh, cloddy crater (fig. 5), about 350 m east of Hadley Rille. The samples were soft clods that broke apart, and possibly some soil, and the total parts were assigned the above numbers (plate 11; since plate 11 was printed for this report, sample 508 was reassigned as a small part of 505). Sample 508 is a very small fragment that broke off 505. Sample 506 is a glass-coated breccia that probably also broke from 505.

The surface material near the rim of the crater was reported by the astronaut crew to be noticeably soft. The crew also reported that the fragments all seemed to be clods, with a considerable amount of associated glass.

Very fresh, blocky or cloddy craters several meters in diameter but not large enough to penetrate to bedrock are visible in several of the Apollo 11 and 14 photographs, but were not visited by the Apollo 11 or 14 crews. Similar craters 10 to 30 cm in diameter with small clods are common in photographs from all surface missions. It is apparent that impacts into the regolith produce abundant clods of regolith

material, which, because of their softness, rapidly erode into loose fines, even before the rim of the crater becomes significantly eroded (for example Sharp crater, Apollo 12).

The ejecta blanket of this crater probably represents the freshest surface of any significant extent that has been sampled by the Apollo missions. This exposure, however, is probably not the first exposure to the lunar surface of many of the particles in the samples.

Because the crater does not penetrate what appears to be true bedrock, the regolith is greater than 3 m thick at Station 9, as opposed to the very thin regolith at Station 9a as discussed in the next section.

From the panorama photographs (plate 11) it appears that the fragments associated with this crater at Station 9 are of two basic types: 1) rounded or subrounded, easily eroded fragments, some of which contain smaller fragments and which are definitely breccias, and some of which are layered; 2) angular fragments with vesicular or froathy coatings of glass, or possibly entirely glass, that appear darker. Some fragments are of type 1 with a partial glass coating, and suggest a transition from type 1 to type 2.

The crater itself is about 3 m deep with a distinct bench about 1 m or slightly more above the crater

floor (fig. 62). Below the bench the crater walls and floor are covered by a jumble of blocks, with no visible fine-grained matrix. All of the fragments appear very angular with abundant vesicles. These fragments are considered to be type 2 material (glass or glass-coated). Above the bench the crater is also very blocky but with some fine-grained matrix. The blocks are of both type 1 and type 2 material. On the west side of the crater there is an outcrop that is layered, dipping outward, that is considered type 1 material. The crater is interpreted as resulting from impact into a soft layered soil-breccia deposit (type 1 material) at least 3 m thick. The impact is thought to have converted the breccia to glass (type 2 material) in the lower part of the crater. Most of the rim material is of type 1 material, the unmelted breccia, with some fall-back of the fused or partly fused breccia.

It is also remotely possible that the bench in the crater is correlative with the top of the hard layer at the ALSEP site and at Station 8 which was encounted with the drill and in digging the large trench. Astronaut Irwin commented on the increase in glass while digging the trench prior to reaching the hard surface through which he could not dig.

Samples 505-508.--Samples 505 and 507 (with 506 and 508 which probably broke off 505) were collected about half way out from the rim of the 15 m crater on its ejecta blanket that is about 25 m across (plate 11; fig. 5). The surface is saturated with "raindrop depressions" and fragments less than 1 cm in diameter; cobble-size fragments and craters are sparse (figs. 63a, b). The samples are probably part of the ejecta blanket and not related to smaller features in the field of view. Sample 505 was less than half buried, other nearby fragments are mostly buried to slightly buried and only a few have fillets. The nearby fragments are rounded to subangular (fig. 63a). Albedo differences on local fragments are not apparent; however, considering the crater and its ejecta blanket as a whole, there are two types of fragments present: 1) fragments of easily eroded material, and 2) darker (glassy?), hard fragments. The local slope is gentle.

Sample 505 is among the largest 2 percent of fragments on the ejecta blanket at this distance from the rim. It is also more angular than most and is less buried than most. It was apparently free from dust and without a fillet. The sample probably is part of the ejecta blanket but may have been one of the last fragments to come to rest. The small crater

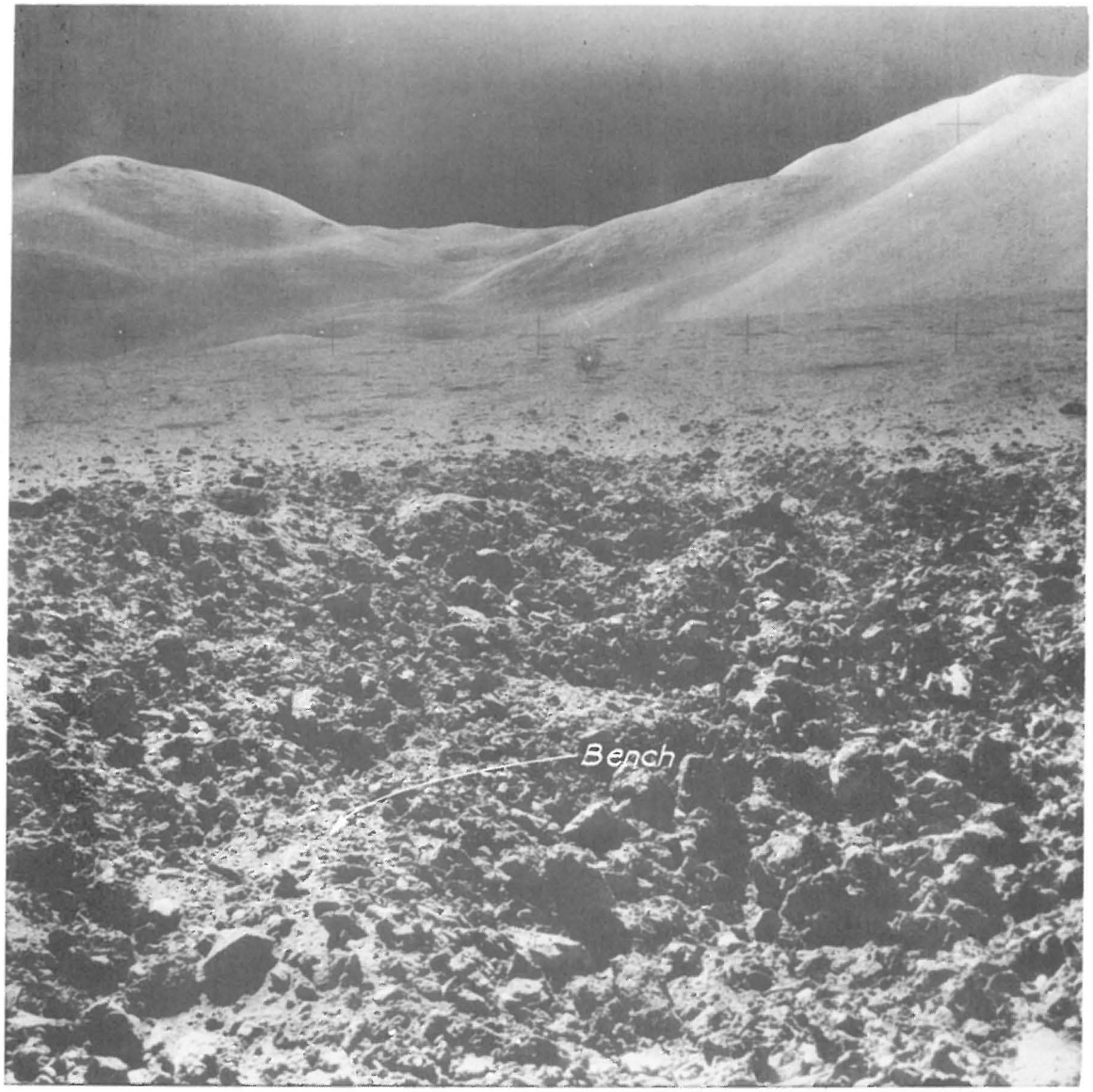

Figure 62. Sharp, cloddy crater with bench, at Station 9. Photograph AS15-82-11082

Figure 63a. Sample 505,506, and 508, and vicinity of unidentified sample 507. Pre-sampling, cross-sun photograph AS15-82-11105.

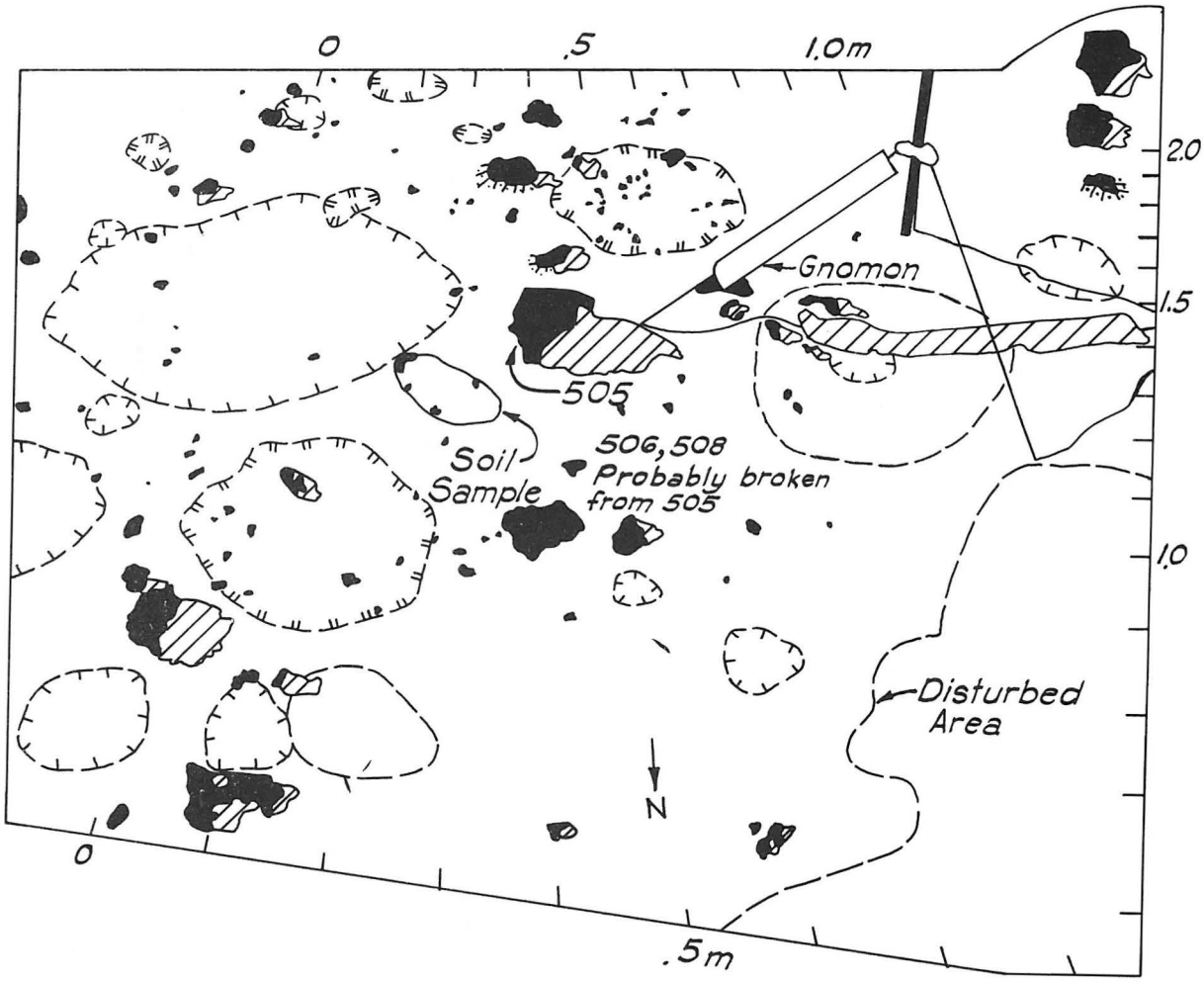

Figure 63b. Sample environment sketch map of samples 505, 506, and 508 and vicinity.

just up-sun from the sample (figs. 63a, b) may have been made by the sample. The interpretation is that the sample had a high trajectory and thus may have been derived from rather deep within the crater. The composition of the sample supports the interpretation as it is both faintly layered and glassy. This sample seems to represent the layered material, but partly fused by the process that formed the hard dark material in the bottom of the crater. It is possible that the sample represents material from the lower part of the easily eroded layered unit that has been partly fused.

Sample 507 is a hollow dark glass and may be representative of the hard dark material that occurs abundantly in the center of the crater, but in lesser amount in the ejecta blanket. To the Apollo 15 crew it appeared as a glassy ball and distinct from most nearby fragments which are typical of the layered and easily eroded material.

Samples 510-515.--Samples 510-515 were collected from the northwest rim crest of the 15 m diameter, cloddy crater at Station 9 (fig. 5). The two clods shown in Plate 11 and Figures 64a, b were collected, but disintegrated to form the parts that are numbered 510-516.

Fragments are abundant on the rim crest and on the walls of the crater. On the rim, where these samples were collected, most of the fragments are easily eroded breccias (type 1 material) mixed with about 10 percent of hard glassy (type 2) material.

Closely spaced but poorly developed north trending lineaments are visible. The local slope is a few degrees southeast into the crater. Fillets are common on the easily eroded type 1 fragments; however, the fillets are small and merge with the fine-grained matrix of the ejecta and were not mapped (figs. 64a, b). Most of the type 2 fragments and some type 1 fragments appear to be perched on the ejecta blanket; however, most of the type 1 fragments appear partly buried. Only those fragments that are mostly buried appear dusty on top. Some of the dust may be derived by erosion of the fragment itself; however, more may have been deposited along with the partly buried fragments.

The samples are both representative of the type 1 material on the rim except that they appear less easily eroded and rest upon the surface rather than being partly buried. They probably are both pieces of the layered breccia that have been slightly fused and so are transitional to type 2 material. They are definitely

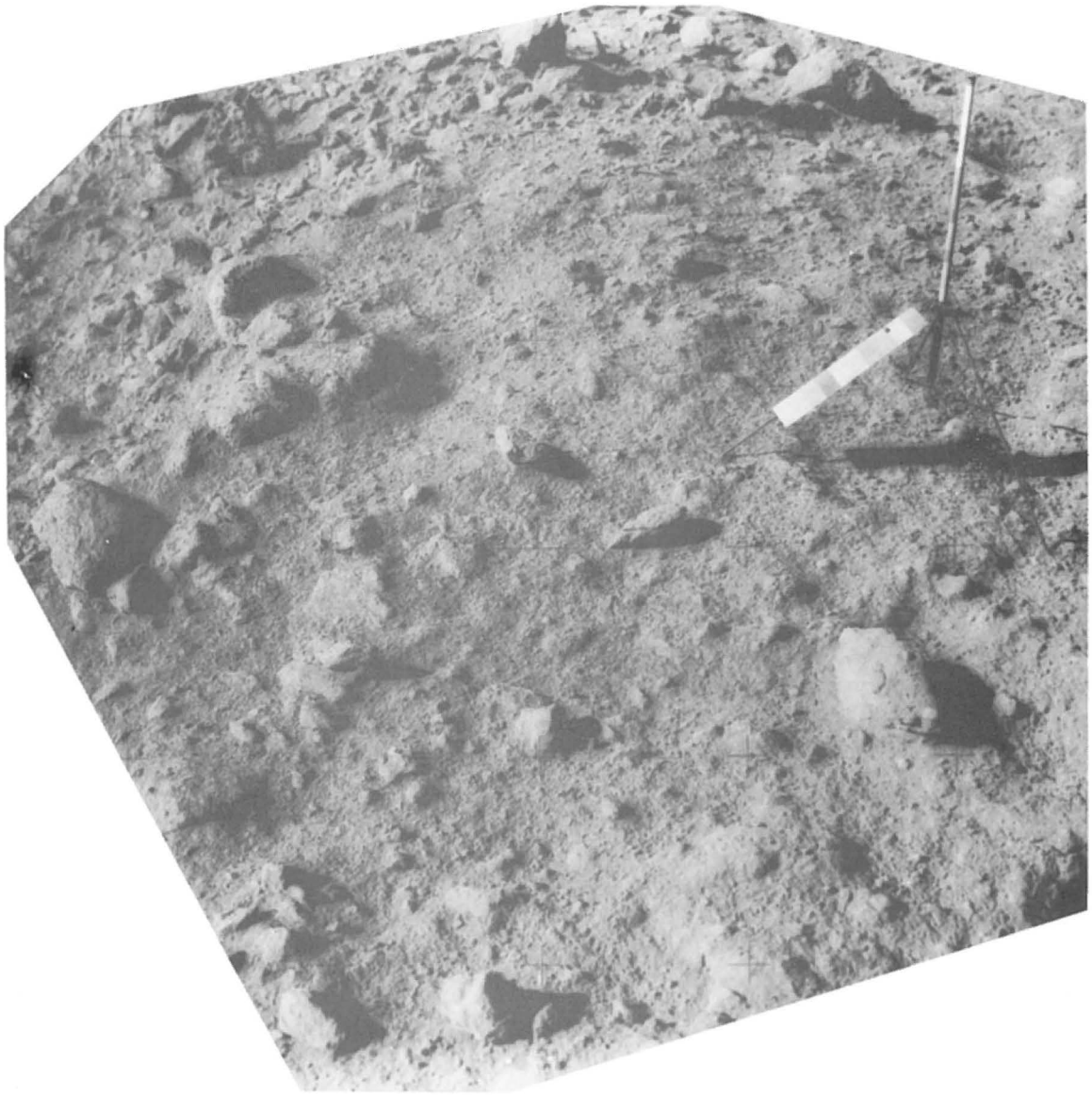

Figure 64a. Clods that were collected and broke in transit to form samples 510-515. Pre-sampling, cross-sun photograph AS15-82-11098, looking south.

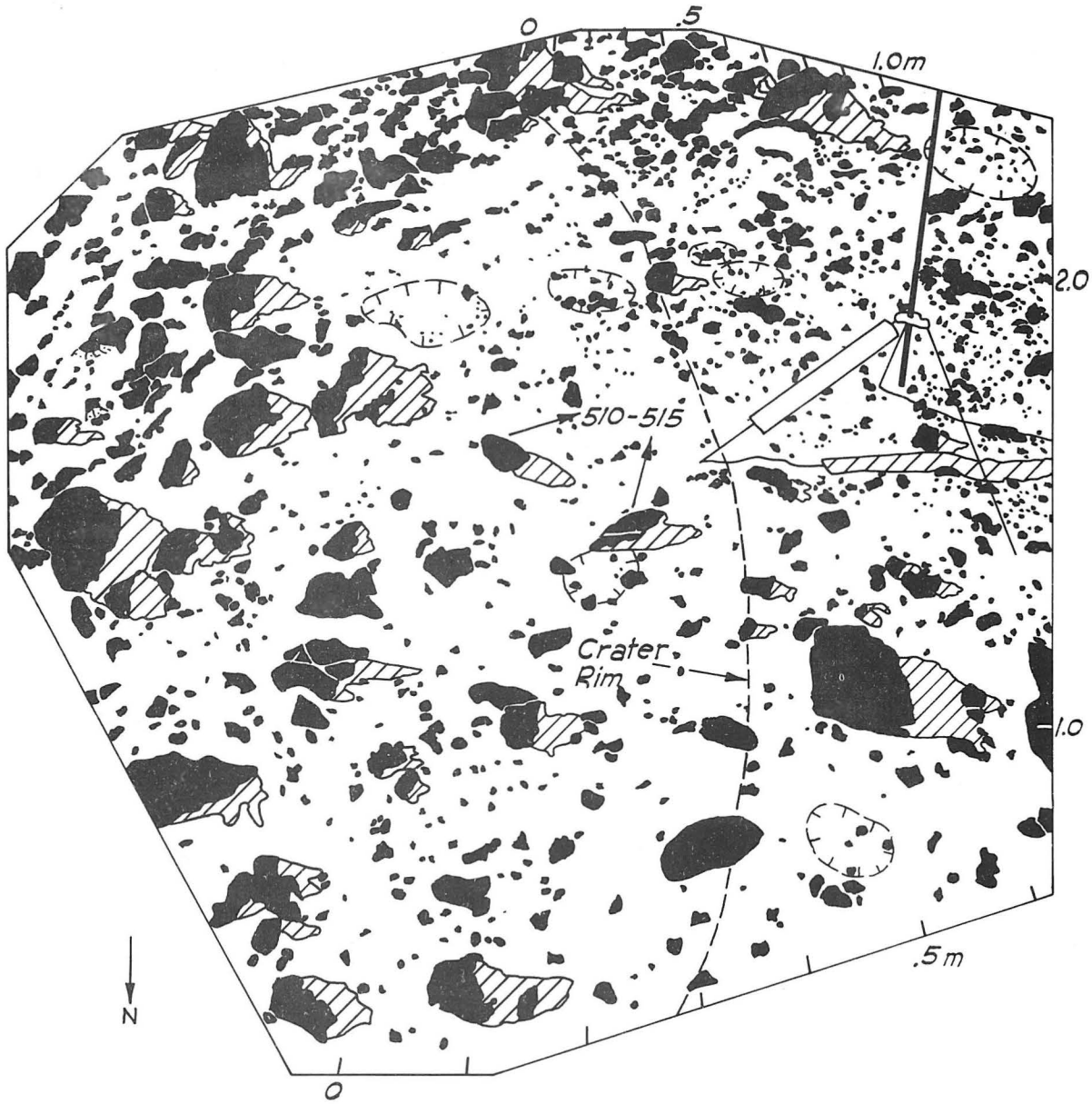

Figure 64b. Sample environment sketch map of samples 510-515 and vicinity.

more rounded and lighter in color than typical type 2 material and lack the abundant vesicles. They rest upon the ejecta blanket and probably fell back upon the rim after most of the blanket was deposited. They lacked fillets and appear dust free. They likely originated from a depth just less than the depth of the bench in the crater.

Station 9a

Station 9a is near the rim of Hadley Rille (plate 12; fig. 1). The area sampled is approximately 40 x 70 m, and extends to the rille rim (fig. 5). Eight documented or partly documented rock samples were collected at Station 9a. The documentation of these eight rocks is sufficient to locate them accurately, and to ascertain their original lunar orientation after the photography of the returned samples in the LRL is completed. Stereo pairs of samples 556, 535, 536, 595, and 596 were taken before the samples were collected; only monoscopic photographs were taken of samples 529, 555, and 557.

The surface generally slopes toward the rille rim from Station 9a. Small craters are difficult to see in the photographs because of the undulating nature of the surface and because of occultation of much of the surface by large boulders. The only visible fresh crater in the vicinity of Station 9a that is larger than 2 m in diameter is the 3 m crater where samples 535 and 536 were collected. The undulating character is probably largely due to old subdued craters. Small surface lineaments are essentially absent. Many of the rock fragments have well developed fillets banked against their sides, and in general the more rounded

fragments have the best developed fillets (plate 12). Rock fragments with well developed fillets whose tops do not protrude far above the ground are commonly dust covered. The astronaut crew mentioned two spots where light albedo material was kicked up from just beneath the surface. This material was not specifically sampled.

Small fragments and clods ranging from the limit of resolution of the photographs up to 2 cm across are abundant in the vicinity of sample 555. Fragments in this size range were mapped in detail on the photograph taken of this sample because the camera was pointed steeply at the surface and provides a close-up view of the immediate vicinity of the sample. Comparison of this photograph with the somewhat more distant views of the other samples suggests that the fragment and clod distribution is probably representative of the area around Station 9a.

Rock fragments are more abundant within about 300 m of the rille rim than they are on the mare surface to the east. Most of the fragments at a distance of 200-300 m are a few centimeters across. The size of the fragments increases markedly toward the rille, and near the rille rim there are numerous boulders and bedrock protruberances from 1 to 3 m across (plate 12).

The regolith thins in the vicinity of the rille, and within about 25 m of the rim the regolith is essentially absent. The thinning is due to impacts which occur near the rim that distribute material in all directions, including into the rille. The narrow zone of thin regolith along the rille, however, receives material only from the east because of the presence of the rille to the west (fig. 65). The net result is that the fine grained material is preferentially moved toward and into the rille; therefore, as the rille rim recedes by erosion, so will the zone of thin regolith recede.

The abundance of rocks in the 200-300 m wide zone along the rille is related to the nearness of outcrop to the surface in the vicinity of the rim. All craters greater than a half meter or so in diameter in the narrow zone along the rim penetrate into rock and therefore the ejecta consists primarily of rock fragments. Out in the areas of normal regolith thickness, only those craters greater than about 25 m in diameter penetrate the regolith, and even then most of the ejecta is fine grained material from craters up to 100 or so meters in diameter. Therefore the blocky nature of the 300 m zone along the rille is due to the nearby source of rocks in the area of thin or absent regolith along the rille rim.

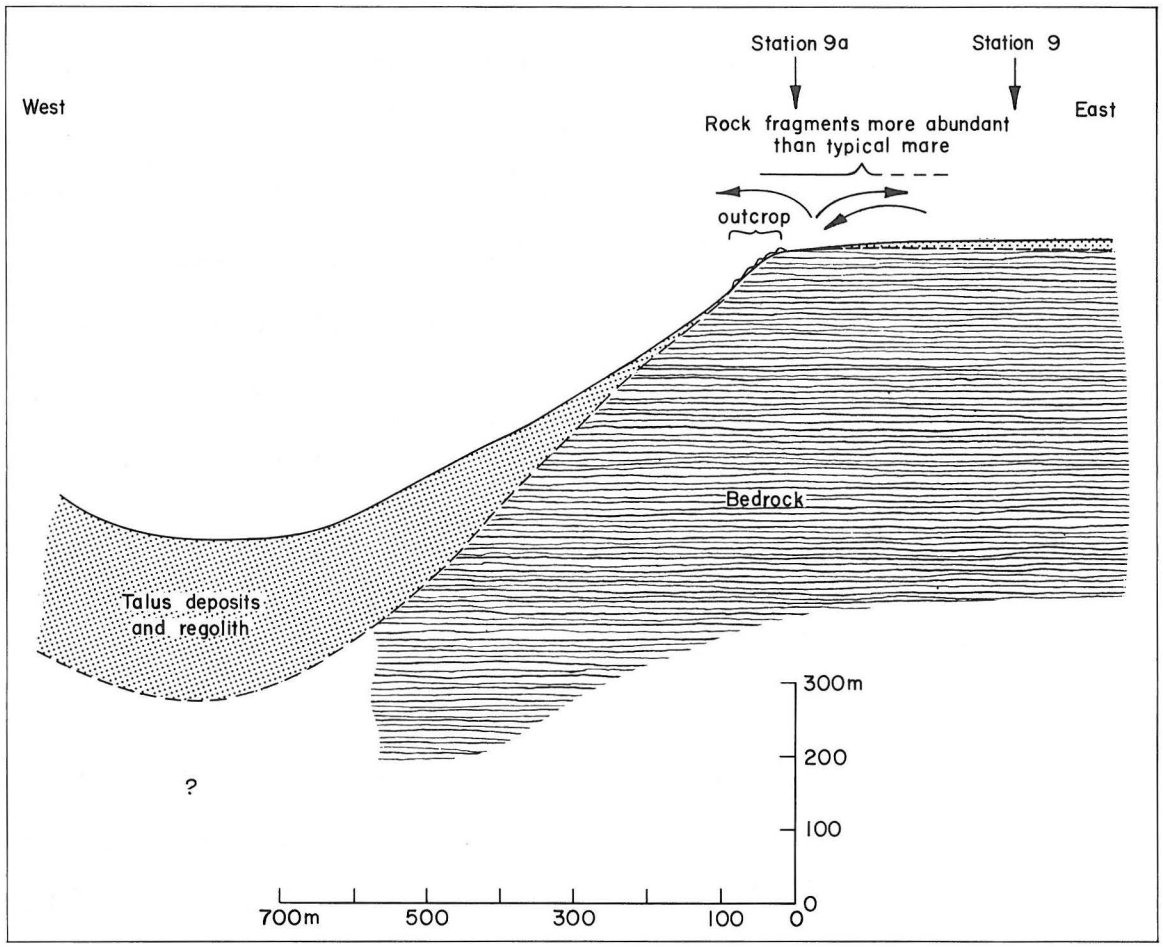

Figure 65. Schematic section of east rim and wall of Hadley Rille. Curved arrows above rille rim indicate trajectory directions of impact-derived ejecta.

Because of the nearby source for fragments from the rille rim it is concluded that most of the samples collected are probably representative of the local bedrock in the vicinity of Station 9a. Samples 535, 536, 595, and 596 are almost certainly representative of bedrock at the spots where they were collected. Samples 535 and 536 were collected from the ejecta from the fresh crater that penetrates the thin regolith cover; samples 595 and 596 were collected from a large rock in the group of rocks exposed along the rille rim, and were identified by the astronaut crew as samples of bedrock from the rim. Samples 529 and 556, because they are perched on the surface, do not appear to have been in place for a long period of time, and samples 555 and 557 appear to have been in place for somewhat longer periods.

Samples 010 and 011.--Samples 010 and 011 are from the double core collected at Station 9a. Sample 011 is the upper part of the core and 010 is the lower part. The sample site is approximately 20 m north of the rim of Hadley Rille (figs. 1, 5).

The surface in the vicinity of the core is generally level with no fresh crater apparent in the immediate vicinity of the sample site. Fragments up to 20 cm or so across are common in the area, and

boulders greater than 1 m across are sparsely scattered in the general area. Small subdued craters ranging from raindrop size depressions up to 20 cm across are fairly common. Small fillets are banked against many of the resolvable rock fragments in the sample vicinity (fig. 66).

The surface in the vicinity of the core appears to have been undisturbed by footprints or LRV tracks after the core was inserted into the ground. Therefore the uppermost part of the core, except for the disturbance caused by driving the core and subsequent handling, should be representative of the undisturbed lunar surface.

The lack of nearby fresh craters and the moderately well developed fillets banked against the rock fragments suggest that the surface is fairly mature and was not significantly disturbed by recent cratering.

Sample 529 and including 528.--Sample 529 was collected at Station 9a approximately 60 m northeast of the rim of Hadley Rille (figs. 1, 5). Sample 528 was also collected at this site. The general surface description applies to sample 528, but it has not been identified on the photographs.

The surface is fairly level in the vicinity of the sample site, but approximately 6 m west of the

sample site the ground slopes gently toward the rim of Hadley Rille (fig. 67a). Sample 529 was collected from an area where rock fragments are fairly abundant from 20 cm down to the limit of resolution of the photograph. Fragments are more abundant in this area than at the LM landing site, but less abundant than near the rille rim. No fresh craters are in the immediate vicinity of the sample; a few subdued craters a few centimeters to a half-meter in diameter are present. "Raindrop" size depressions are abundant. No lineaments are visible in the photographs (figs. 67a, b).

Fillets are well developed on all of the rock fragments in the near vicinity of sample 529. A fillet approximately 3 cm high was banked against sample 529. Dust coatings are common on many of the fragments in the area; no dust coating is visible, however, on sample 529 (fig. 67a).

All of the rock fragments in the vicinity of the sample are well rounded. Sample 539 is more spherical than most of the other nearby fragments, but it is rounded by approximately the same amount.

Sample 529 appears in the photographs to be representative of the other fragments in the vicinity. The very subdued craters, the gently undulating surface, and the abundant "raindrop" size depressions and the

rounding and filleting of the rock fragments, suggests that this is a relatively mature or old surface. Therefore, the probability is fairly high that some of the fragments, including the sample, may have been derived from a distant source. However, the increase in the number of fragments as the rille rim is approached, where the regolith is relatively thin, suggests that most of the fragments were derived from the vicinity of the rille rim.

Samples 535 and 536 (and including 530-534, 537-538, 540-548).--Samples 535 and 536 were collected at Station 9a approximately 20 m east of the rim of Hadley Rille, from the north rim of a moderately fresh, blocky, 3 m diameter crater (figs. 5, 68, 69). The two samples were chipped from a 0.75 m diameter boulder. In addition, rock and soil samples 530-534, 537-538, and 540-548 were collected. The general surface description applies to these samples, but they have not been identified on the photographs.

The ground slopes gently from the sample site toward the rim of Hadley Rille. Rock fragments on the surface become increasingly abundant as the rille rim is approached. Boulders up to a meter in diameter are abundant on the rim of the 3 m diameter crater, and are moderately abundant in the general vicinity.

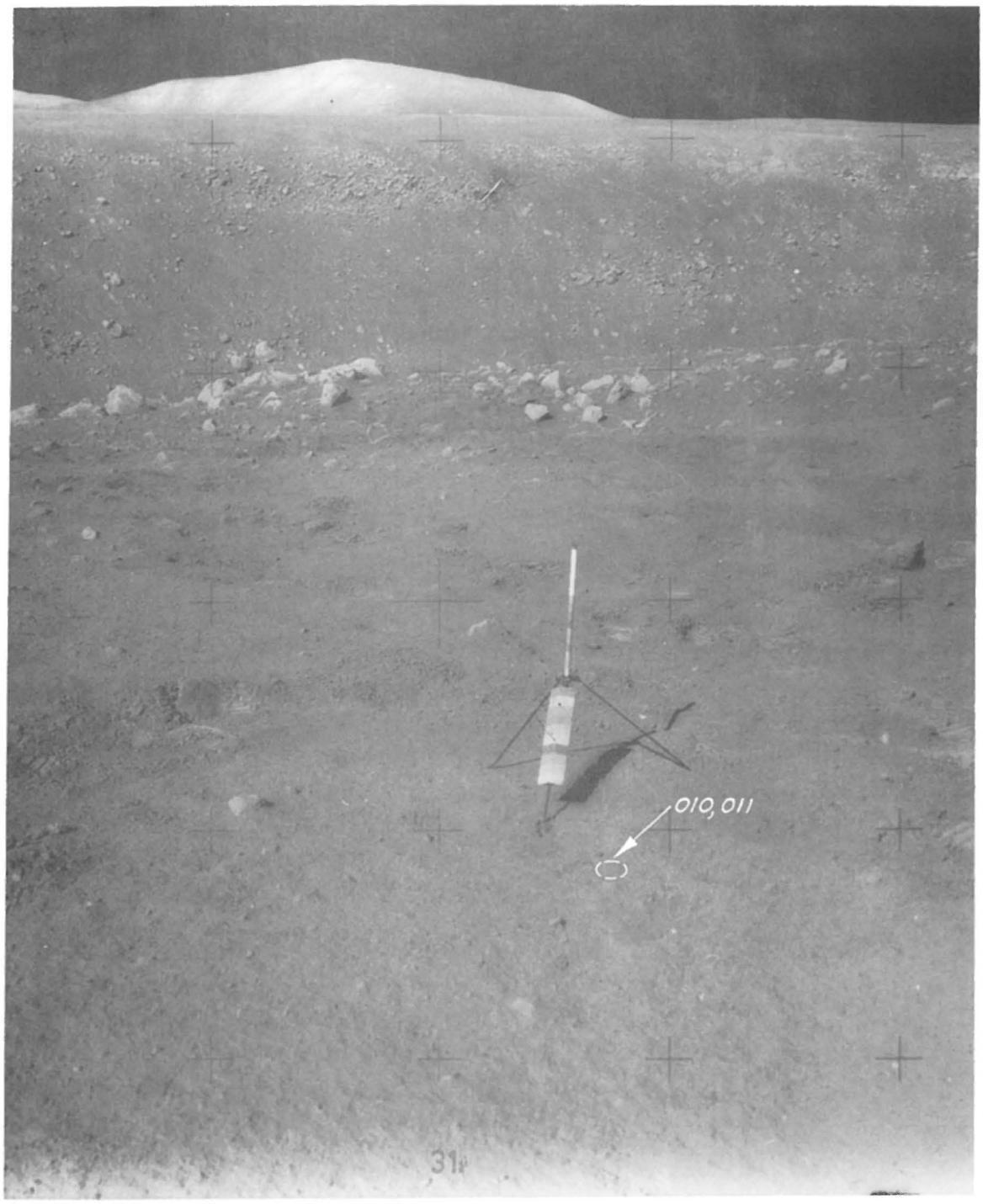

Figure 66. Vicinity of samples 010 and 011 (double core). Pre-sampling, oblique-to-sun photograph AS15-82-11159, looking southwest.

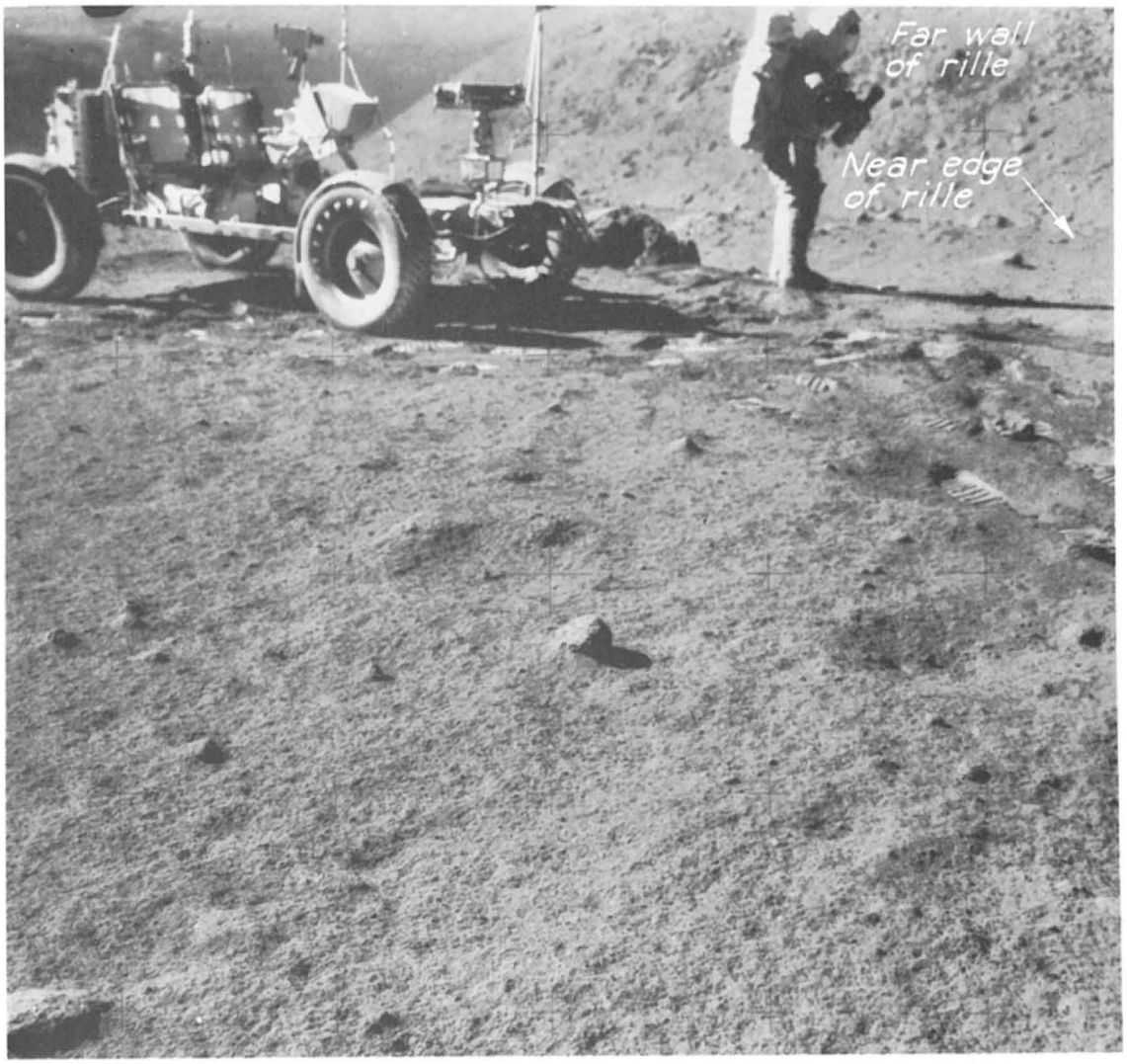

Figure 67a. Sample 529 and vicinity. Pre-sampling, oblique-to-sun photograph AS15-82-11129, looking southeast.

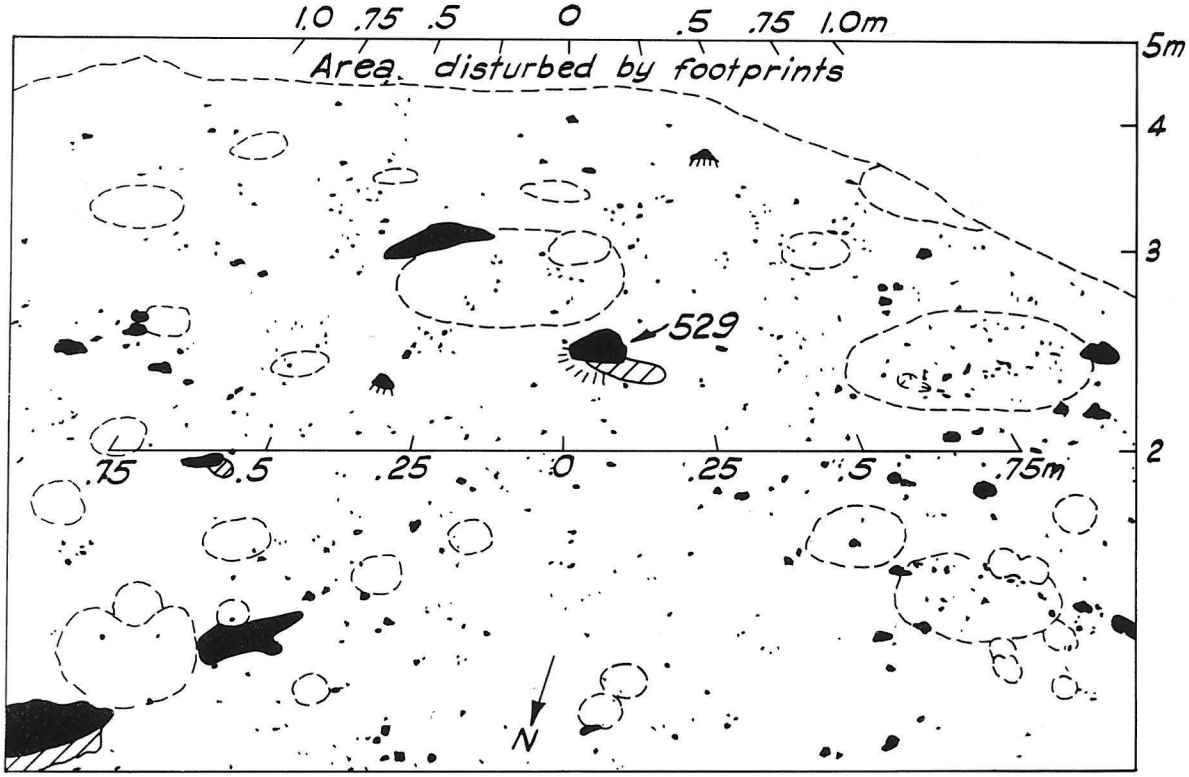

Figure 67b. Sketch map of vicinity of sample 529. Rock fragments and clods approximately 2 cm across are shown.

Smaller fragments are also abundant down to the limit of resolution of the photographs. No other fresh craters are visible on the photographs in the immediate vicinity of the sample site. A linear trough approximately 5 cm deep, 10 cm wide, and 1 m long that trends approximately west is adjacent to the sampled rock (fig. 68). No other linear features are apparent.

Fillets are generally poorly developed or absent in the sample site. Except where rocks appear to have been covered by dust kicked by the astronauts, the rocks appear to be free from dust coatings.

The rock from which samples 535 and 536 were chipped appears to be representative of the other rocks in the area. Most of the rocks are subangular with a few planar faces that may be joint surfaces that were present in the bedrock from which the rocks were derived. Most of the rocks were probably derived from within the 3 m diameter crater. The angularity of the rocks, the lack of fillet development, and the blocky nature of the crater rim suggest that the crater was formed rather recently. This apparently young ejecta surface has probably not had many fragments from foreign surfaces deposited upon it. This, plus the locally thin regolith, suggests that the rocks are probably representative of bedrock excavated by the cratering event,

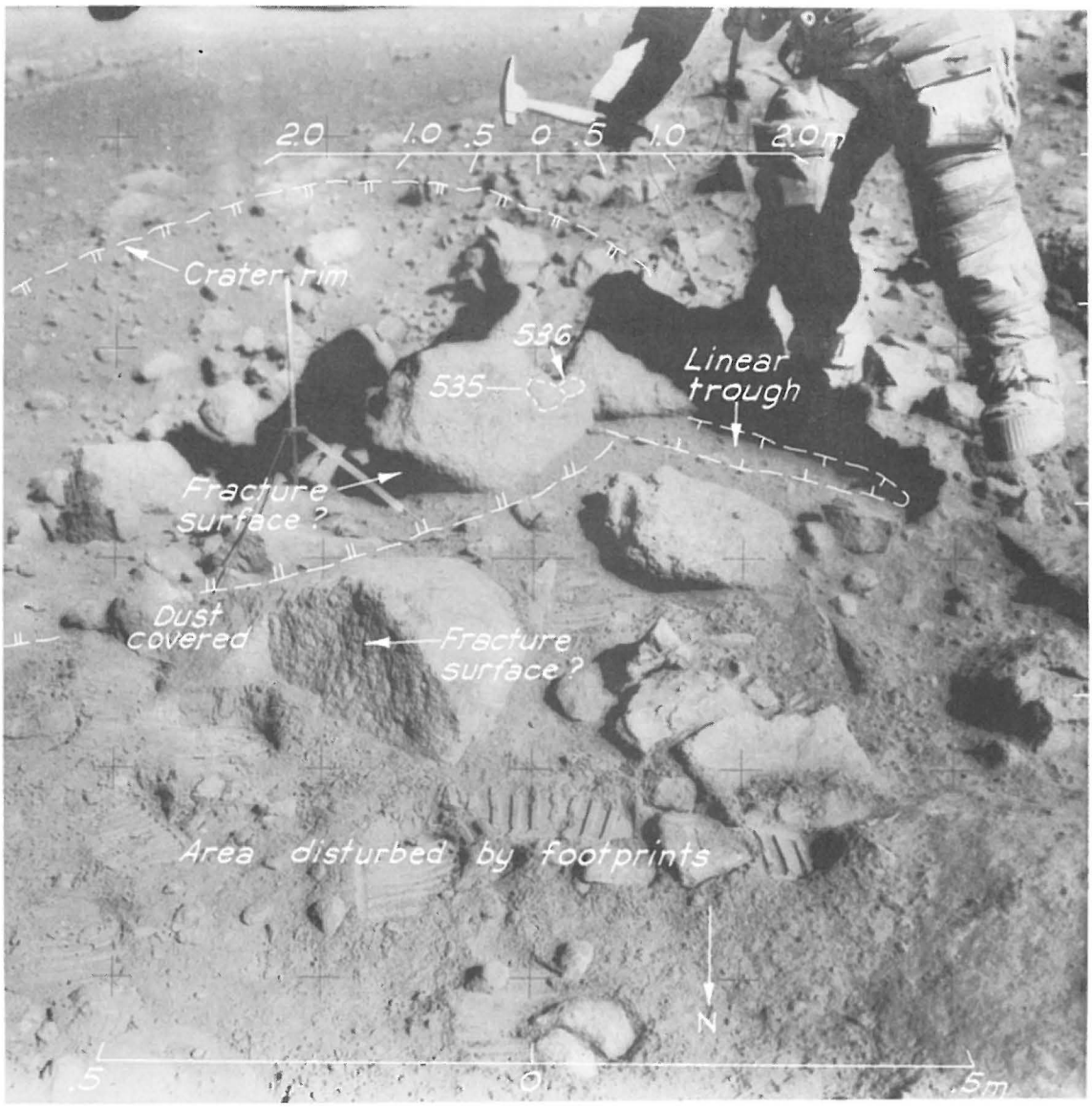

Figure 68. Samples 535 and 536 and vicinity. Pre-sampling, cross-sun photograph AS15-82-11140, looking south.

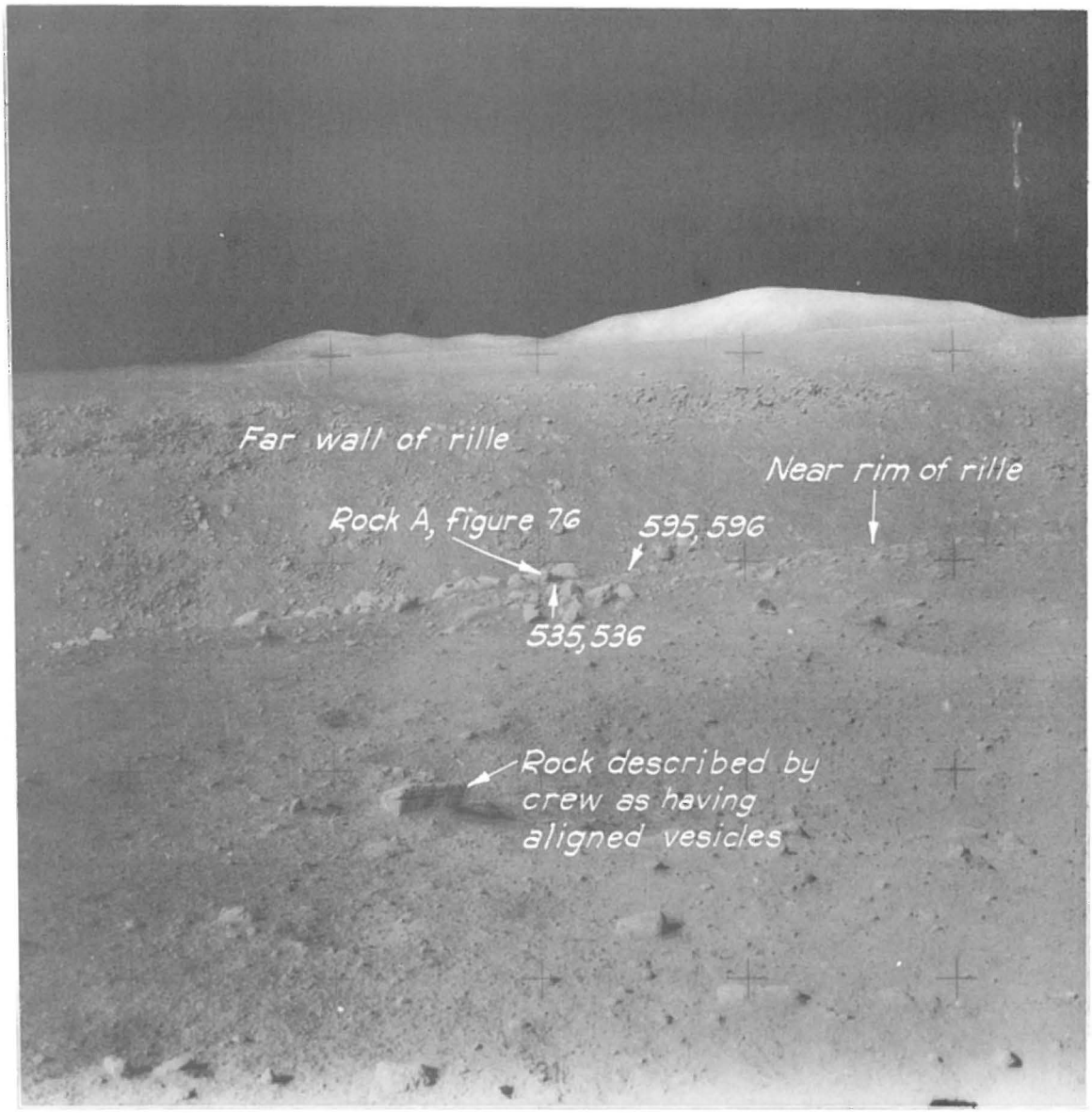

Figure 69. Rocks from which samples 535 and 536, and 595 and 596, were chipped. Rock A is the same as that shown as rock A in Figure 76. Photograph AS15-82-11126, looking southwest.

and therefore samples 535 and 536 are probably from bedrock in this vicinity.

Sample 555.--Sample 555 was collected at Station 9a approximately 12 m north of the rim of Hadley Rille (figs. 1, 5). It is the largest sample ever returned from the lunar surface. The sample was collected from the rim of a very subdued depression; too subdued to identify with certainty as a crater (plate 12).

The ground slopes gently from the sample site toward the rim of Hadley Rille. Rock fragments are more abundant in the area of the sample site than in the LM landing site, but less abundant than near the rille rim. The fragments range in size from 35 cm across down to the limit of resolution of the photographs. Small fragments or clumps of fines less than a centimeter in diameter are abundant (figs. 70a, b). No fresh craters are in the immediate vicinity of the sample; a few subdued craters a few centimeters in diameter are present. "Raindrop" size depressions are abundant. A few poorly developed lineaments several centimeters long are present.

Fillets appear to be fairly well developed on all of the rock fragments in the near vicinity of sample 555. However, the steep inclination of the camera axis and the lack of stereo coverage makes it impossible

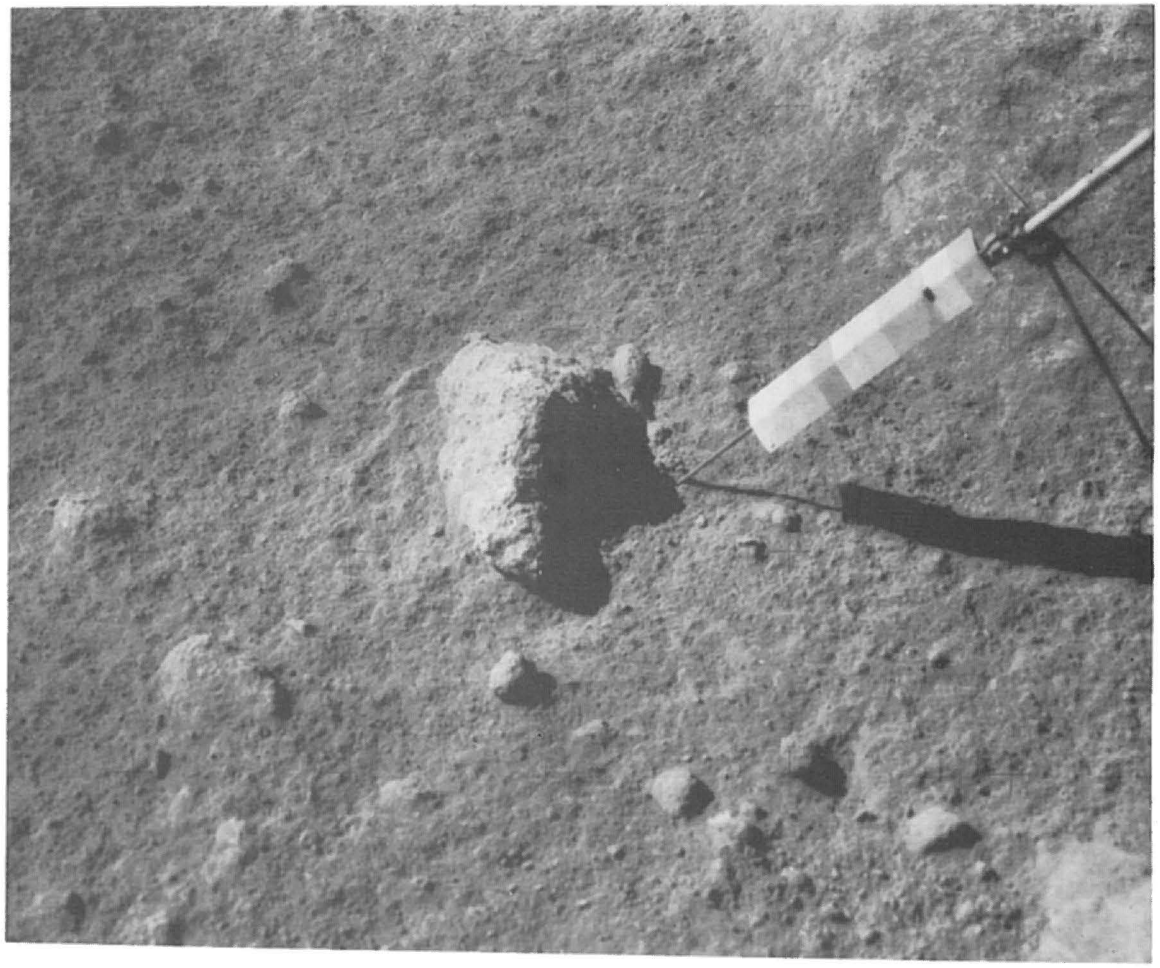

Figure 70a. Sample 555 and vicinity. Pre-sampling, cross-sun photograph AS15-82-11164, looking south.

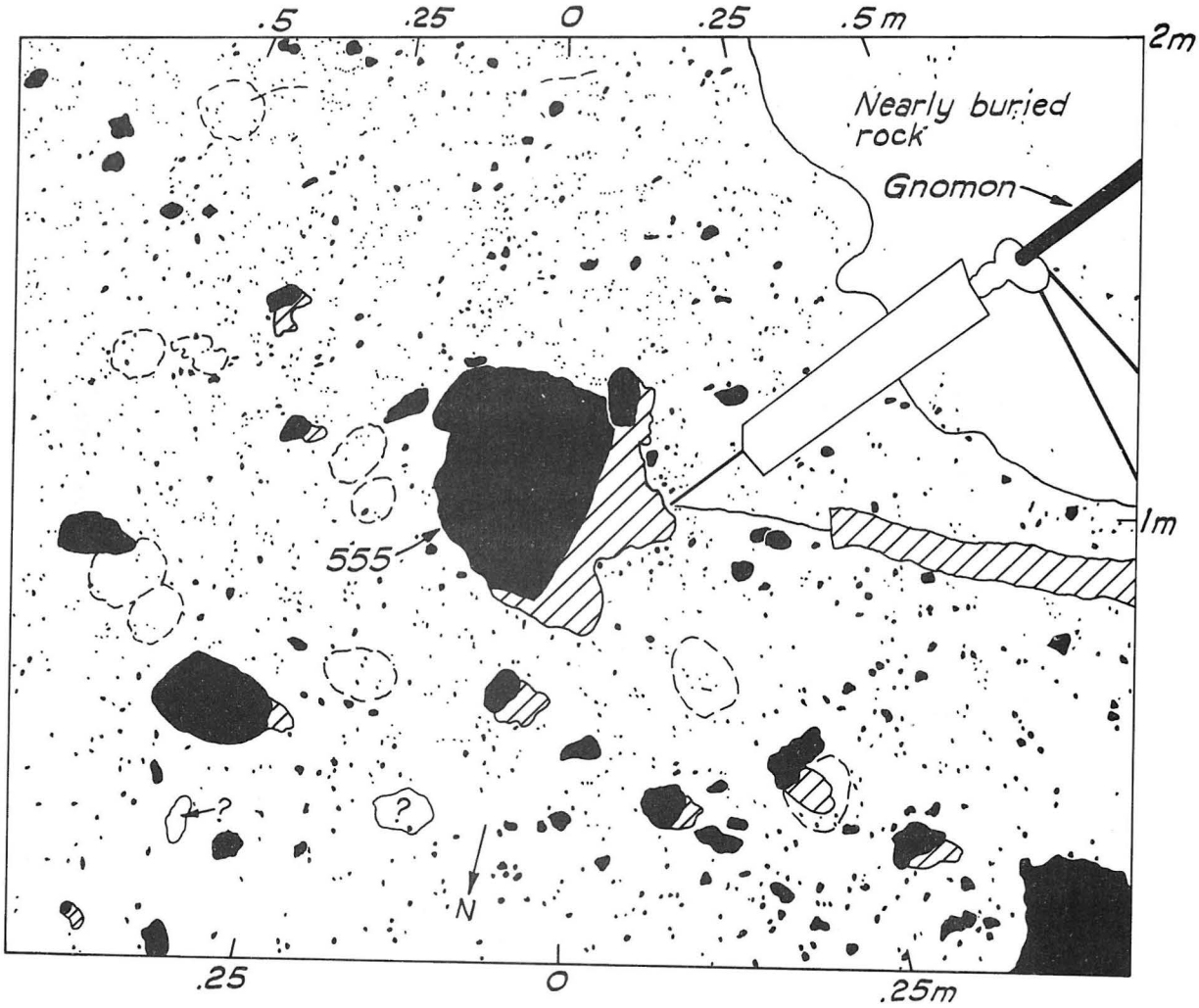

Figure 70b. Sketch map of vicinity of sample 555. Rock fragments and clods approximately 1 cm across are shown.

to specifically define the extent and height of the fillets. Dust coatings appear to be present on all of the fragments in the photograph except for sample 555 (fig. 70a). This is probably because the sample is larger and extends farther above the surface than the other fragments in the vicinity.

A large, very subdued dust coated and nearly buried rock appears present in the southwest corner of the photograph (figs. 70a, b). A few very small rock fragments are perched on the surface of the buried rock, but are much less abundant than on the normal surface of fine-grained material (figs. 70a, b). Zap pits are common on the surface of this partially buried rock.

All of the rock fragments in the vicinity of the sample are well rounded. The surface texture of most of the fragments is somewhat rough, probably from zap pits.

Sample 555 appears in the photographs to be representative of the other fragments in the immediate vicinity except that it is much larger than any except the buried rock. Fragments as large and larger than 555 are common in the general area, however (plate 12). The very subdued craters, the gently undulating surface, and the abundant "raindrop" depressions and the rounding

and filleting of the rock fragments, suggests that this is a relatively mature or old surface. Therefore, the probability is fairly high that some of the fragments including the sample may have been derived from a source other than the immediate sample area. However, the increase in the number of fragments as the rille rim is approached where the regolith is relatively thin suggests that most of the fragments in the area were derived from the vicinity of the rille rim.

Sample 556.--Sample 556 was collected at Station 9a approximately 60 m northeast of the rim of Hadley Rille. Rock fragments up to 20 cm across are fairly common in the sample site, and small fragments or clumps of fines less than a centimeter across are abundant. One small fresh crater approximately 20 cm in diameter occurs about 1 m east of the sample. This crater is surrounded by ejected clumps of fines but is probably not related to the sample. No other fresh craters are present in the vicinity of the sample. "Raindrop" size depressions are abundant. No lineaments are apparent in the photographs (figs. 71, 72).

Fillets up to 3 cm high are fairly well developed on all of the rock fragments in the near vicinity of sample 556. Dust coatings appear to be present on all of the fragments in the photograph except for sample 556. This is probably because the sample extends

farther above the surface than the other fragments in the vicinity. Sample 556 does not appear to be quite as deeply buried as the other fragments in the area.

All of the rock fragments in the vicinity of the sample are well rounded including sample 556, but the sample is more spherical than the other fragments.

The surface appears to be relatively old and mature. The rounded character of the rocks, the well developed fillets and apparent burial, and the dust coatings suggest that most of the rocks have been in their present position for a relatively long period of time. The lack of burial of sample 556 suggests it has not been in its present position quite as long as the typical fragments in the area. There is no reason, however, to suspect that the sample was derived from a distant source.

Sample 557.--Sample 557 was collected at Station 9a approximately 40 m north of the rim of Hadley Rille (figs. 1, 5). The surface in the vicinity of the sample is generally smooth but slopes gently toward the rille. Rock fragments greater than 2 cm across are generally sparse within a few meters of the sample. Several subdued craters less than a half meter in diameter are present in the vicinity of the sample. One

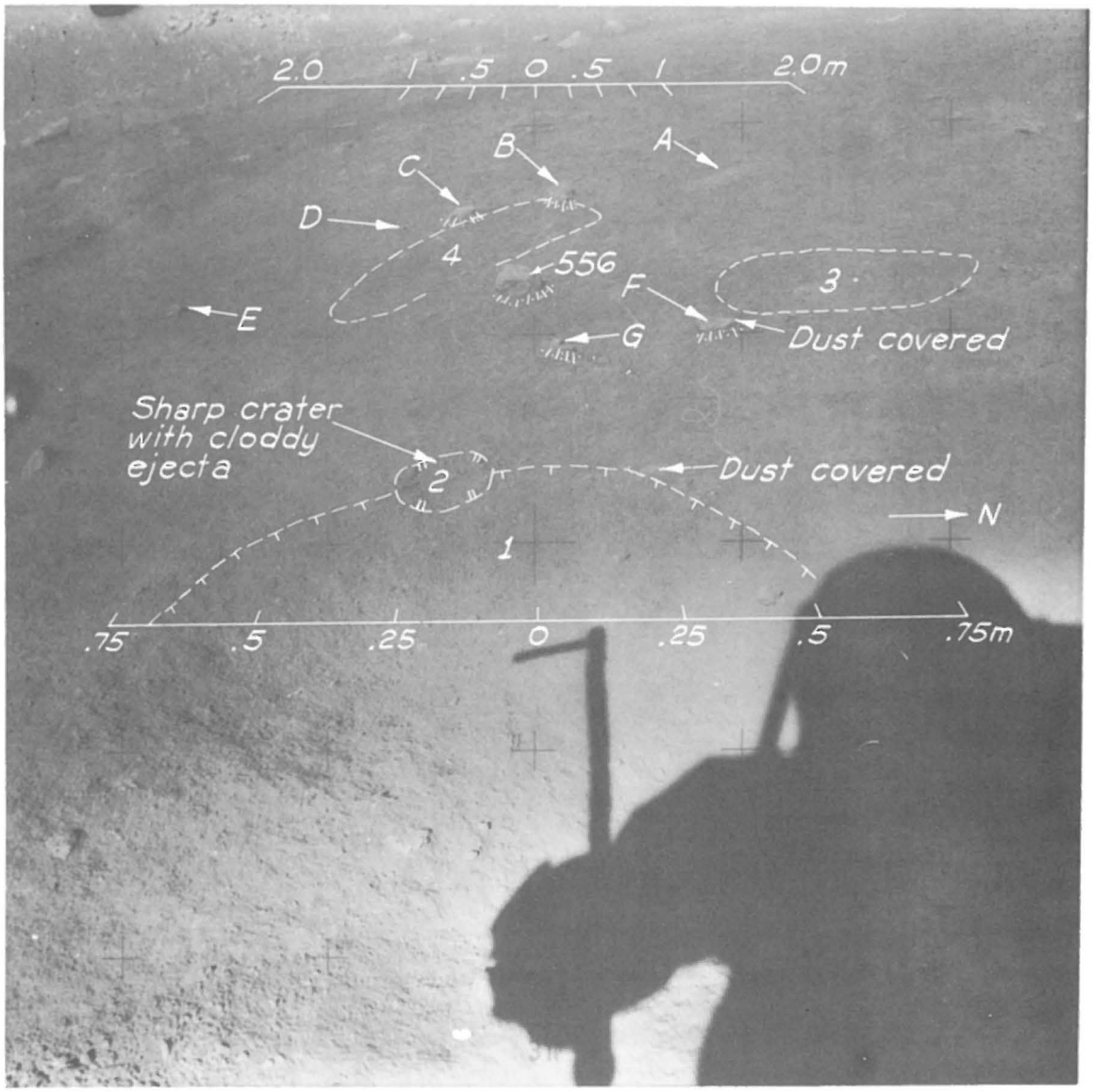

Figure 71. Sample 556 and vicinity. Lettered rock fragments and numbered craters are for cross-reference with those in Figure 72. Pre-sampling, down-sun photograph AS15-82-11133, looking west.

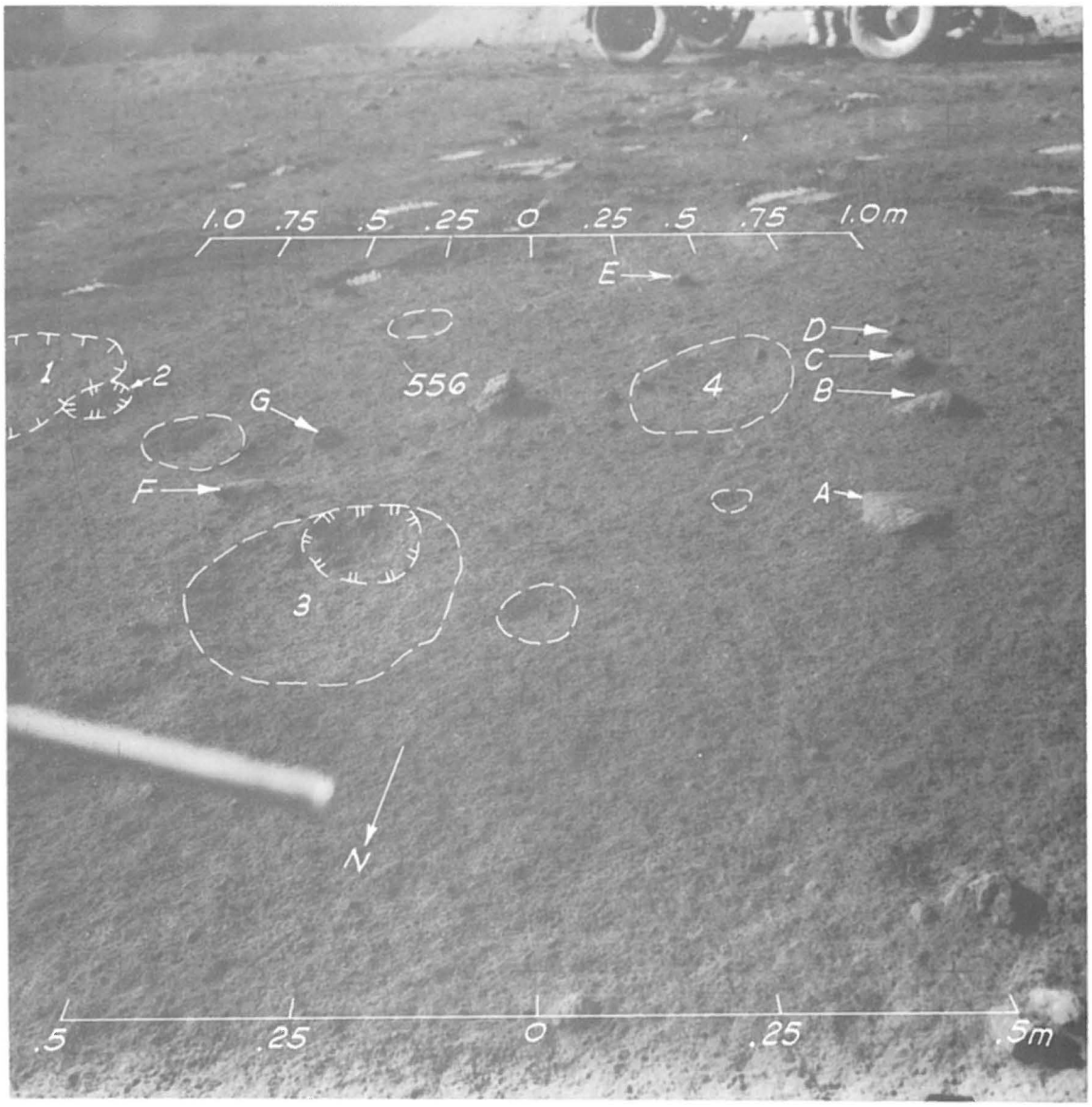

Figure 72. Sample 556 and vicinity. Lettered rock fragments and numbered craters are for cross-reference with those in Figure 71. Pre-sampling, oblique-to-sun photograph AS15-82-11135, looking southeast.

crater approximately 0.25 m in diameter with cloddy ejecta is about 0.5 m to the southwest of the sample. The freshness of this crater suggests that it is not related to the sample. No small lineaments are present (fig. 73).

Sample 557 is well rounded and has a well developed fillet as does the 3 cm diameter fragment just south of the sample. The 5 cm diameter fragment in the lower right hand corner of Figure 73 is angular and does not have a well developed fillet. This supports the contention that well developed fillets are generally associated with the well rounded rocks.

Sample 557 is the largest rock fragment in the immediate vicinity; because of its size, it is difficult to compare it with other nearby rock fragments. It is similar in appearance to other well rounded and filleted rocks around Station 9a and probably had the best developed fillet of any of the documented samples collected at this station.

Samples 595 and 596 (and including 597-598).-- Samples 595 and 596 were collected at Station 9a, approximately 8 m east of the rim of Hadley Rille. These two samples were chipped from the surface of a large rock (figs. 74, 75) identified by the astronaut crew as bedrock exposed along the rim of Hadley Rille.

The rock from which the samples were chipped is one of hundreds of such rocks exposed along both sides of the rille. In addition, samples 597-598 were collected. The general surface description applies to these samples, but they have not been identified on the photographs.

The ground slopes gently from the sample site toward the rim of Hadley Rille. Rock fragments on the surface become increasingly abundant as the rille rim is approached; large boulders or exposures of bedrock up to several meters in diameter are abundant along the rille rim (fig. 76). The rock from which 595 and 596 were chipped is one of these large exposures (figs. 69, 76). Smaller fragments are also abundant from small boulder size down to the limit of resolution of the photographs.

No fresh craters larger than a meter or so in diameter are apparent in the vicinity of the sample site. The undulating character of the topography, however, suggests that it is in part due to old subdued craters. Occultation of much of the surface by the large rock exposures in the photographs makes it difficult to identify craters that might be present. Smaller craters are not numerous; this may be in part due to local undulations in the topography and the

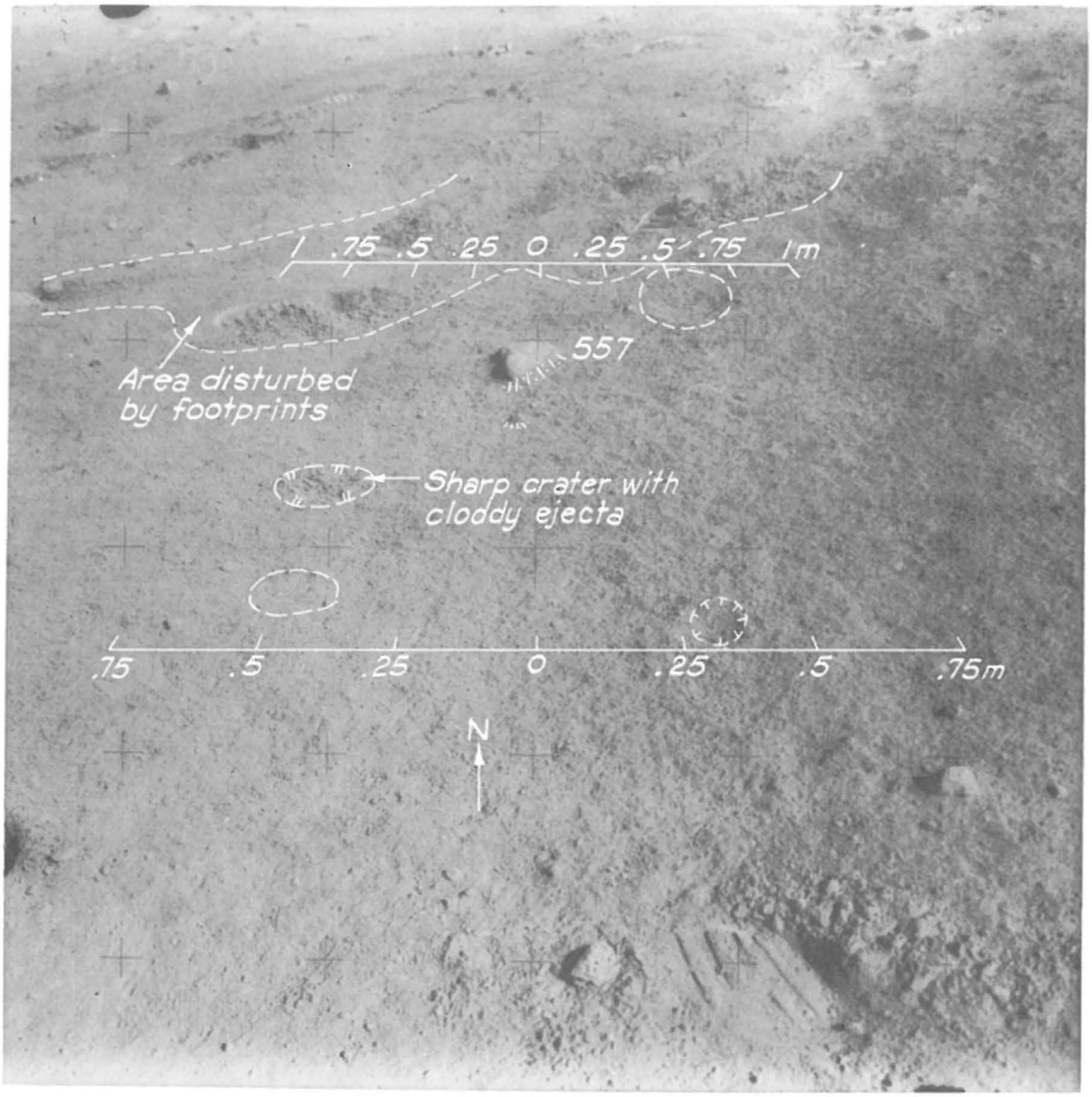

Figure 73. Sample 557 and vicinity. Pre-sampling, cross-sun photograph AS15-82-11137, looking north.

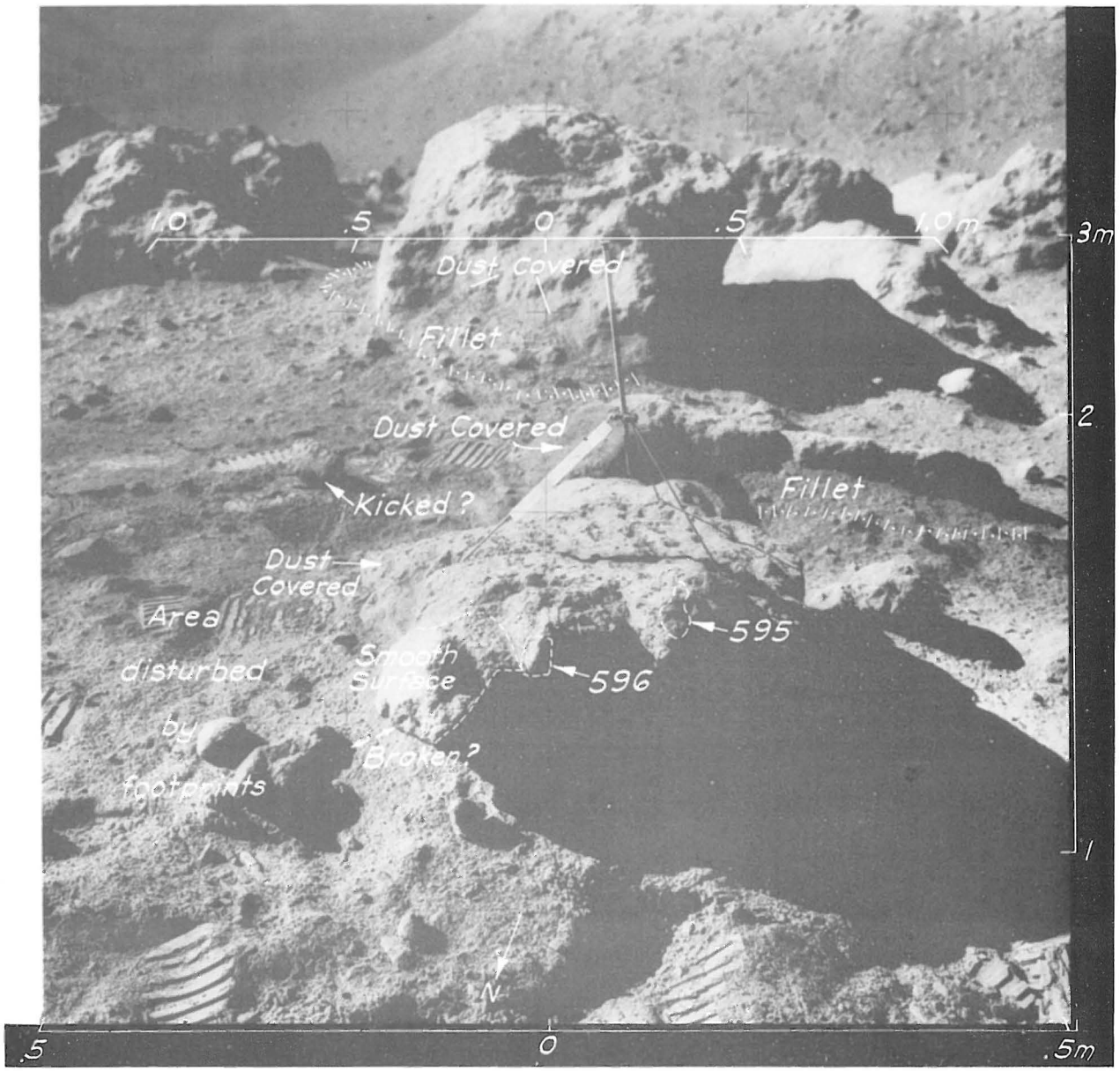

Figure 74. Rock from which samples 595 and 596 were chipped and vicinity. Pre-sampling, oblique-to-sun photograph AS15-82-11143, looking southeast.

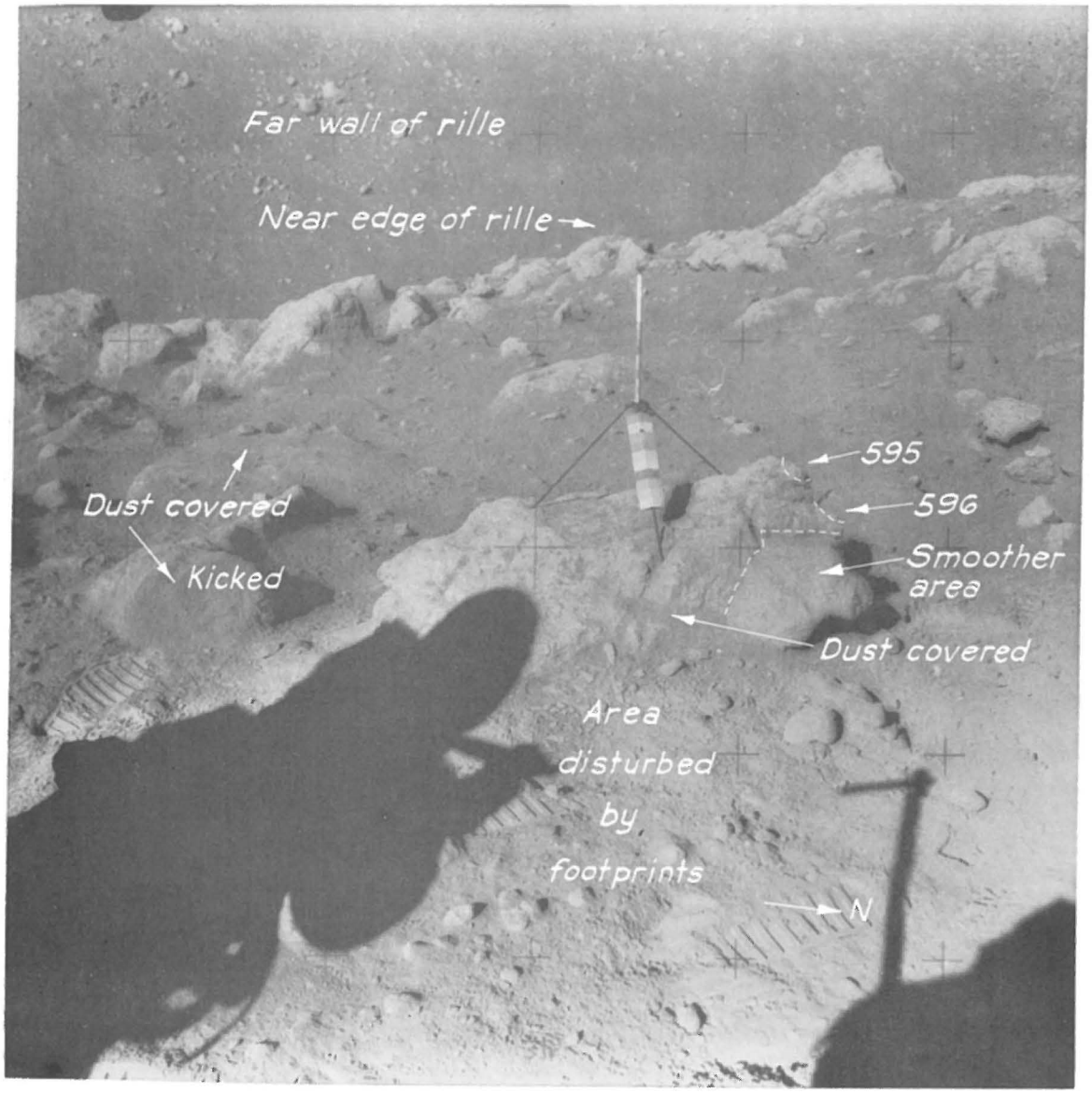

Figure 75. Rock from which samples 595 and 596 were chipped and vicinity. Pre-sampling, down-sun photograph AS15-82-11142, looking west.

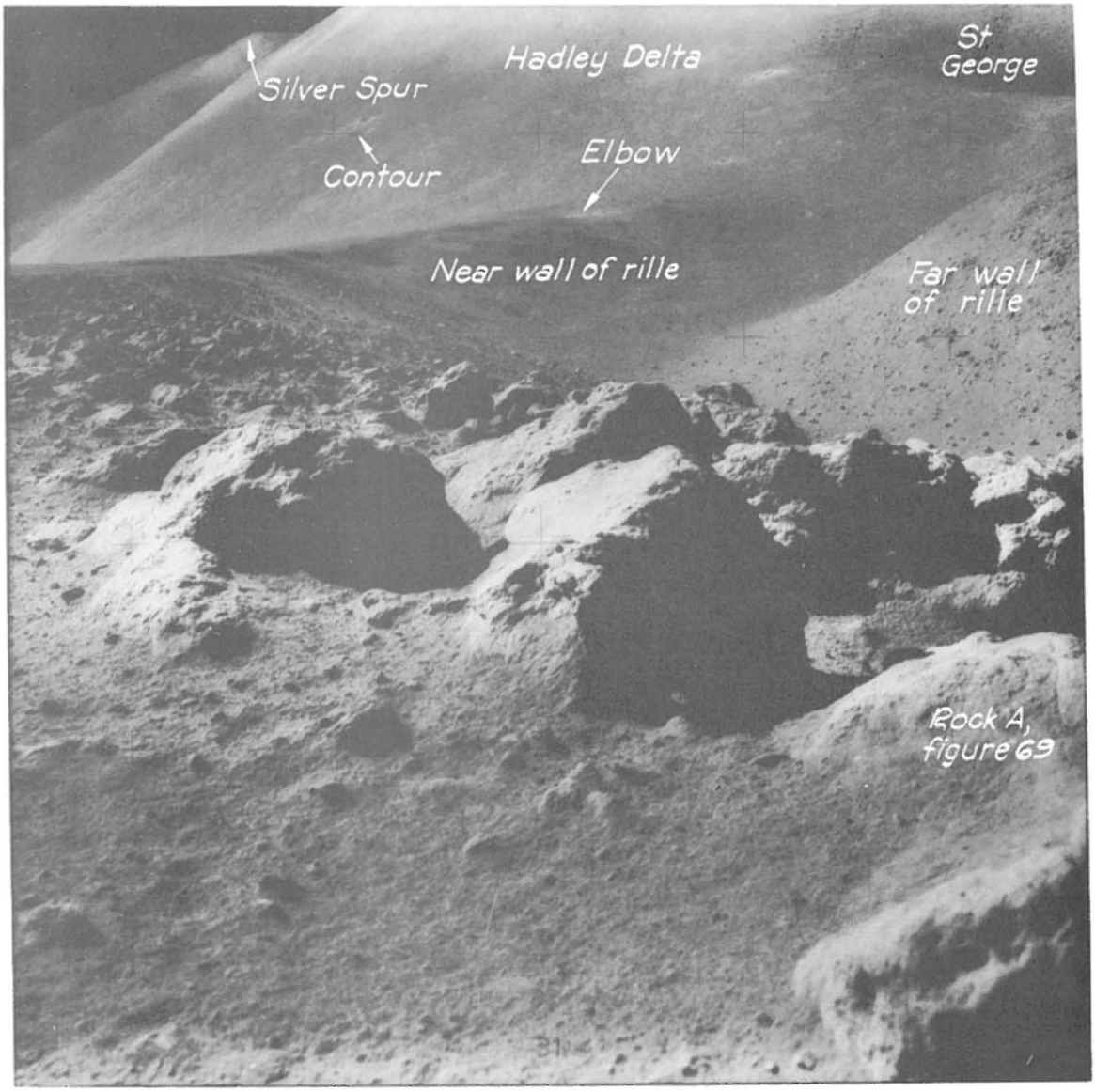

Figure 76. Outcrops and boulders derived from outcrops along rim of Hadley Rille, looking southeast. Rock A is the same as that shown as rock A in Figure 69. Photograph AS15-82-11147.

occultation from the large rock exposures. Lineaments are not visible in the sample site.

Most of the rock fragments have well developed fillets banked against their visible sides, except under overhanging parts of the rocks. Fillets up to 10 cm high are common on the large exposed rocks. Many of the fragments are partially coated with dust; especially those whose tops are near the surface and those that have gentle slopes low on their sides. Some of the smaller fragments however, appear to "hold up" small topographic highs that comprise fine-grained materials.

The rock from which samples 595 and 596 were chipped appears to be similar to other large rocks exposed in the area. It is approximately a half-meter high and 2 meters across and is somewhat more tabular than many of the rocks in the same size range. It is well rounded with a hackly, pitted surface, and appears to have throughgoing planar structures. It is similar in these respects to the other large rocks in the area.

The down-sun photograph of the boulder (fig. 75), and to some extent the cross-sun photographs (fig. 74), suggest that the northeast protuberance of the rock has a slightly smoother surface. Sample 596 was collected from along the contact between this smooth portion and the rougher portion of the rock, from the

rough side of the contact. Generally the surface texture, gray tone, size, and rounding of the sampled rock is similar to the others in the field of view of the photograph.

The rock sampled appears to be one of a family of large boulders or bedrock protuberances exposed all along the upper rim of the rille. These rocks are probably in place or very nearly in place and therefore the two samples almost certainly represent samples from the upper bedrock surface exposed along the rille edge.

Samples 600-689.--Samples 600-689 were collected with the rake at Station 9a approximately 20 m northeast of the rim of Hadley Rille (figs. 1, 5).

The surface in the vicinity of the sample is smooth and level and locally free of rock fragments greater than 5 cm across (fig. 77). The general vicinity is littered with fragments commonly up to 20 cm across and a few sparse scattered boulders greater than a meter across (fig. 77).

Several moderately subdued to subdued craters up to 2 or so meters in diameter are present in the general vicinity, but the sampled area is sufficiently far from craters greater than a meter in diameter to be in their continuous ejecta (fig. 75). The surface is relatively level and was undisturbed by footprints or wheel tracks prior to the raking.

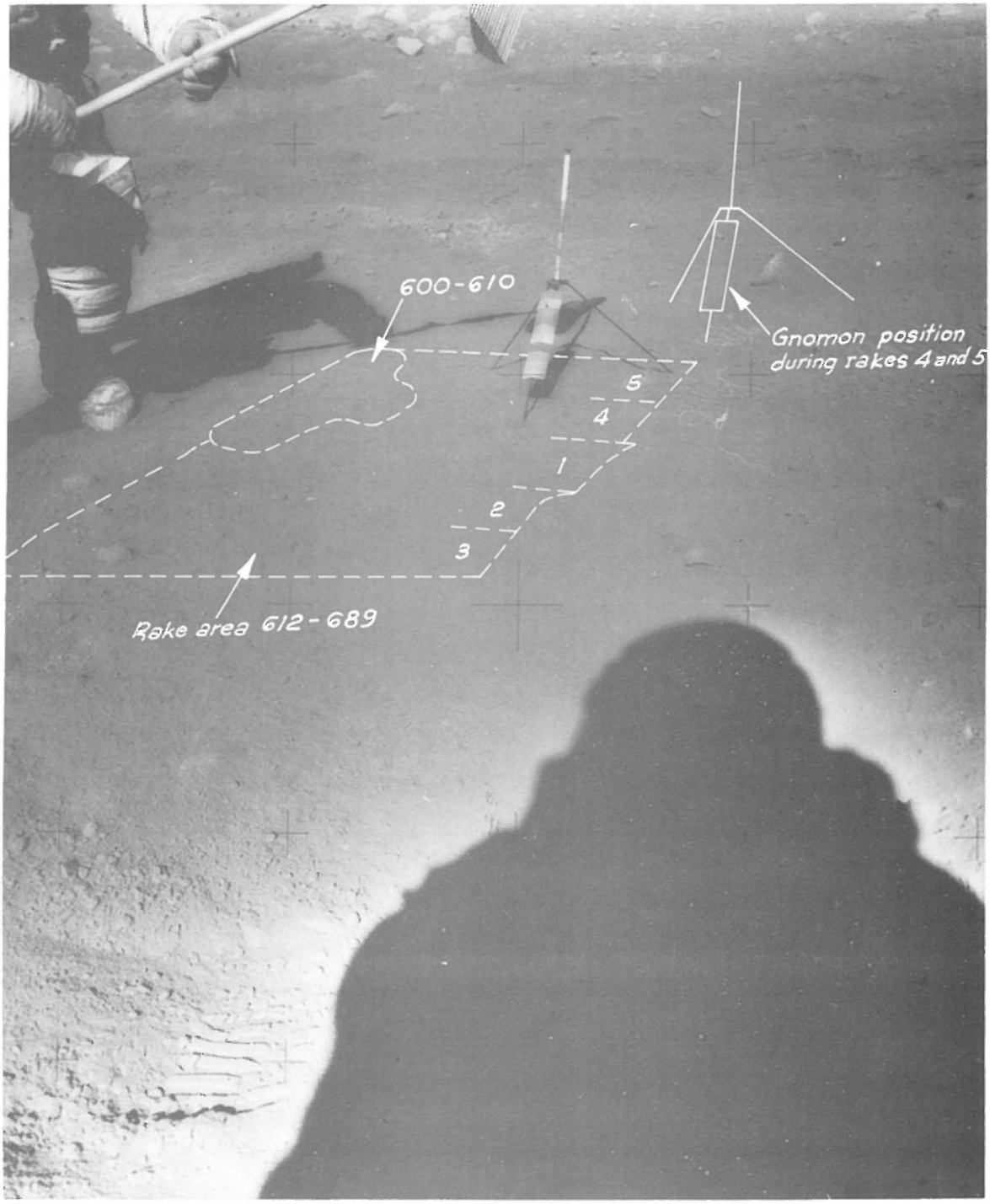

Figure 77. Samples 600-610 and samples 612-689 collected with rake at Station 9a near Hadley Rille. Pre-sampling, down-sun photograph AS15-82-11153, looking west.

A few subdued craters ranging from raindrop size depressions to 20 cm across are present in the raked area. Many of the resolvable rock fragments have small fillets banked against their sides. The absence of fresh craters in the immediate vicinity of the sample site and the fillets banked against many of the rocks suggests that this is a relatively mature surface that has not been significantly disturbed by recent impacts.

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*Samples not mentioned in the text, but the area from which the samples were collected is covered by the environment description on the page listed.

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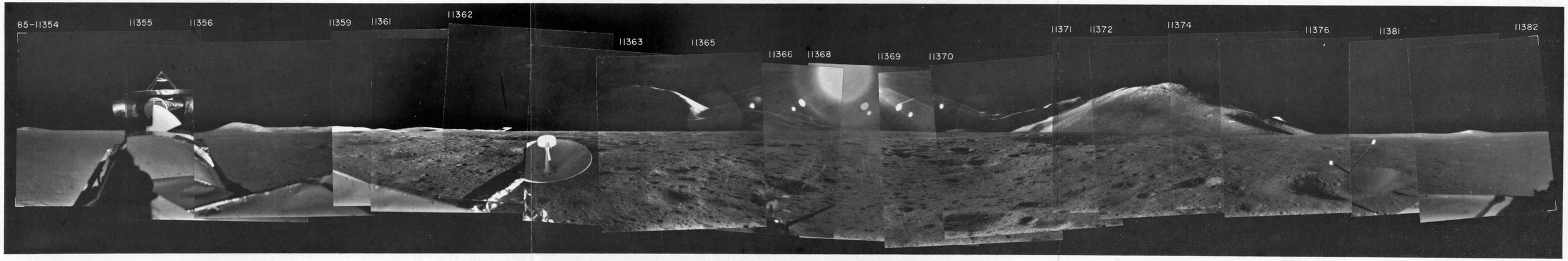
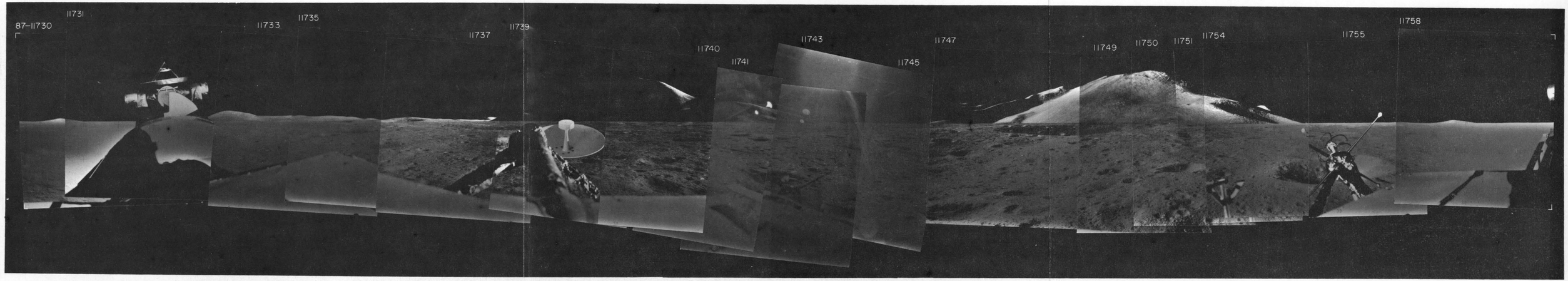
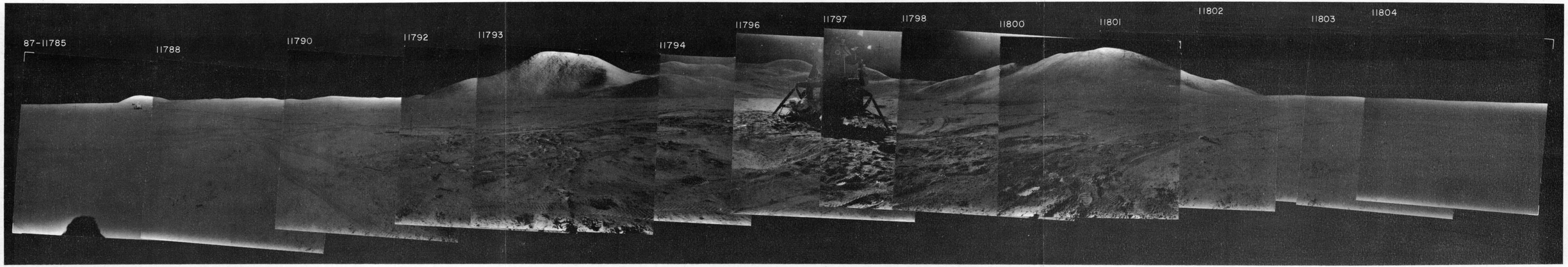
259	88	6	595-598	207	9a
260-264	98	6	600-689	214	9a
265-269	88	6	923	139	7



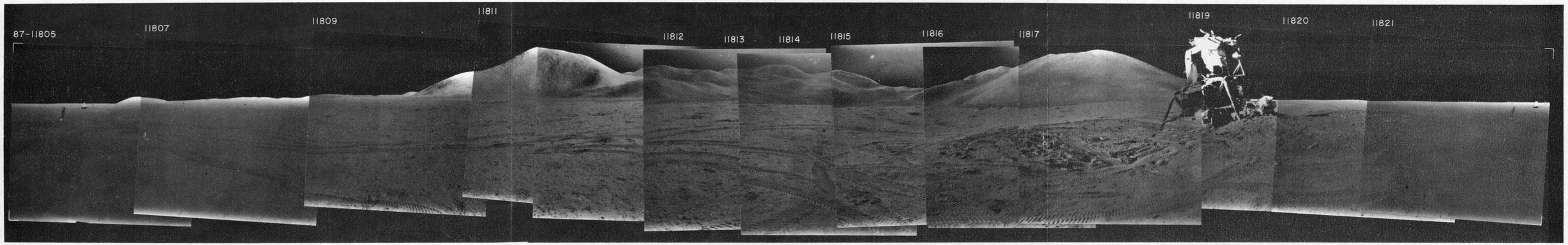
Pan 1, SEVA; upper of vertical stereo



Pan 2, SEVA; lower of vertical stereo

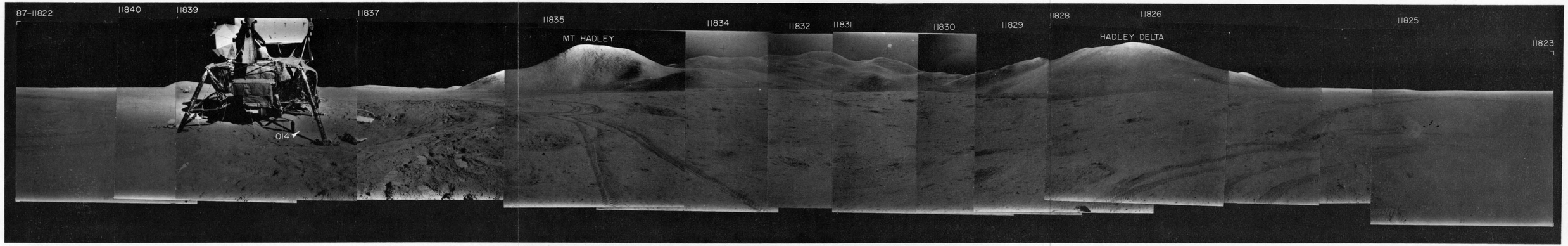


Pan 14, north of LM

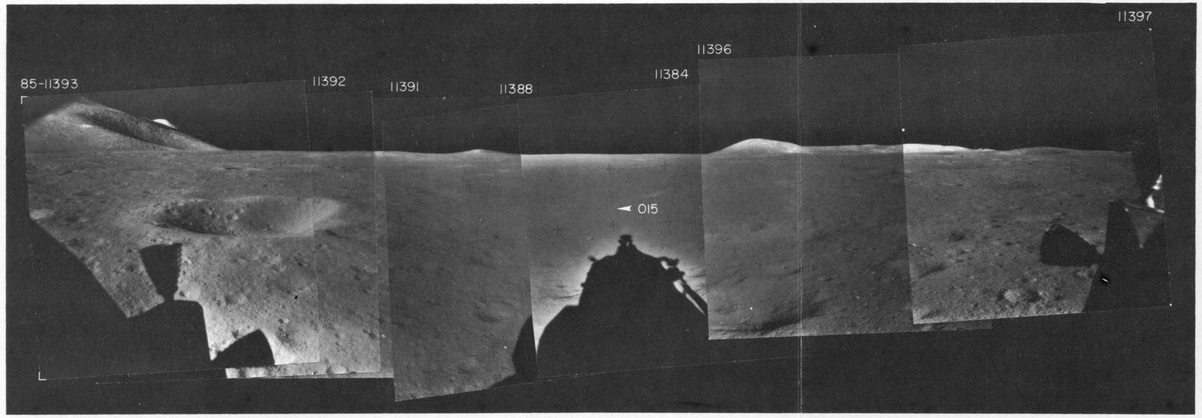


Pan 15, southeast of LM

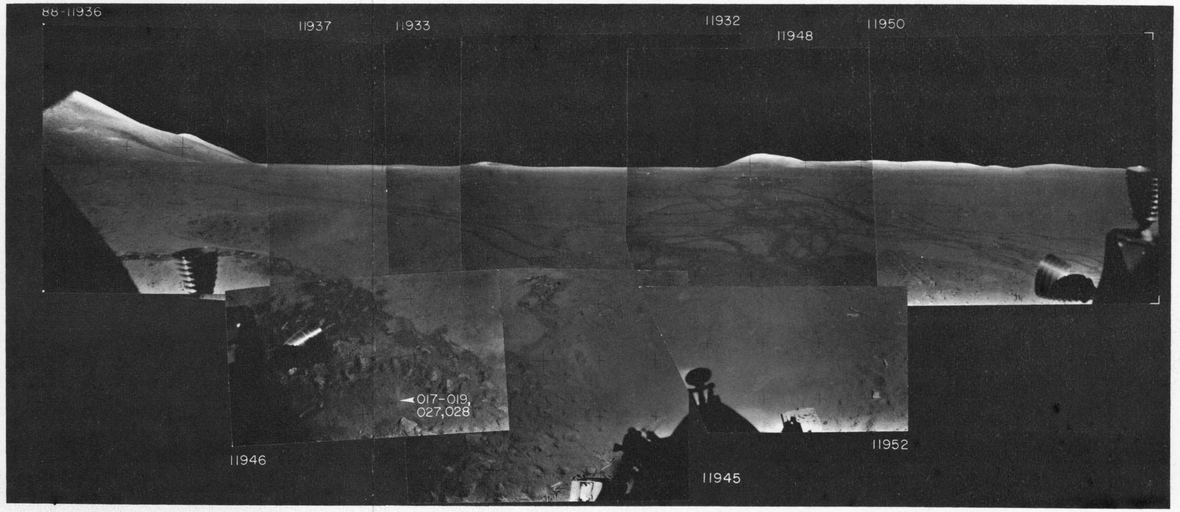
Plate 2



Pan 16, west of LM

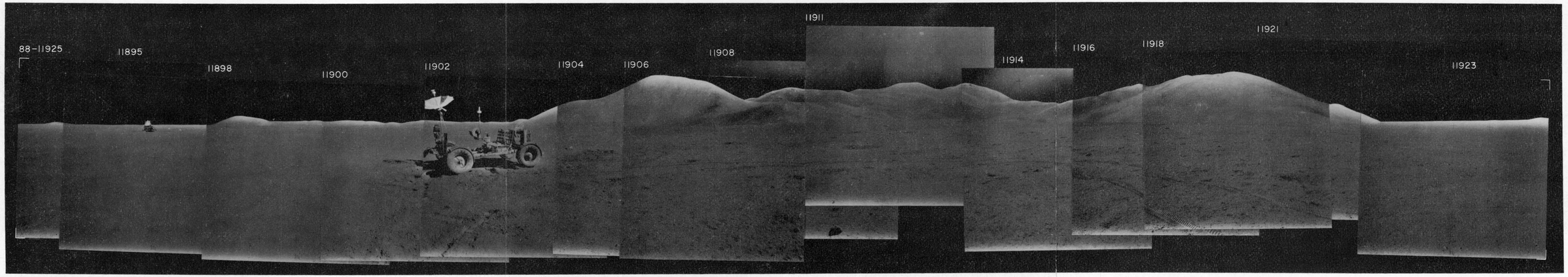


Pan 3, LM window, pre-EVA I

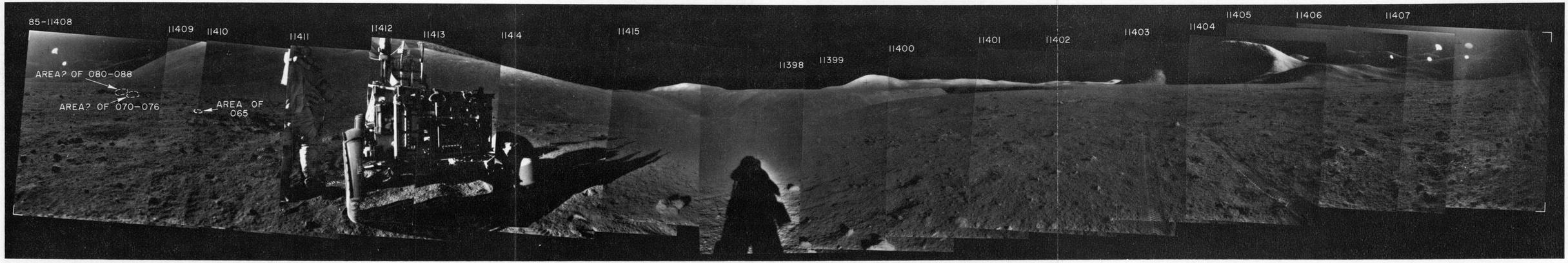


Pan 24, LM window, post-EVA III

Plate 3



Pan 23, 300 feet east of LM



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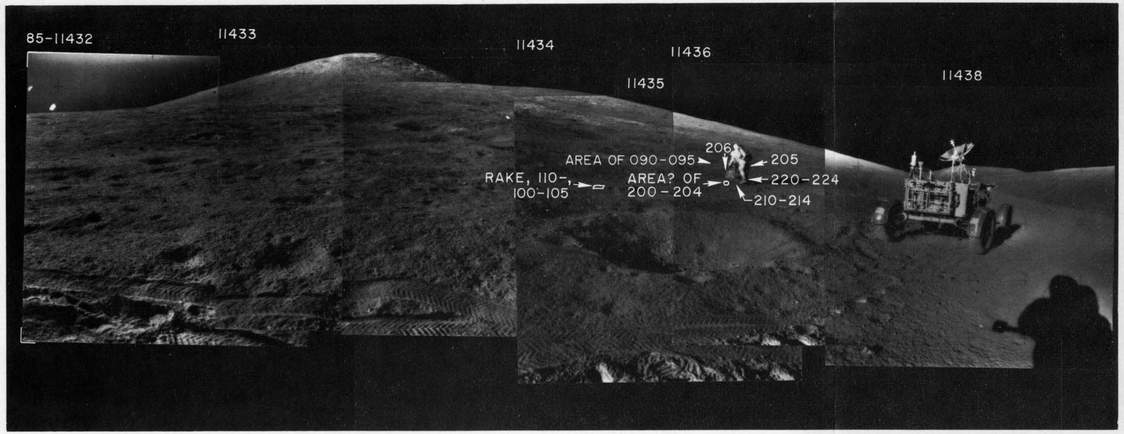
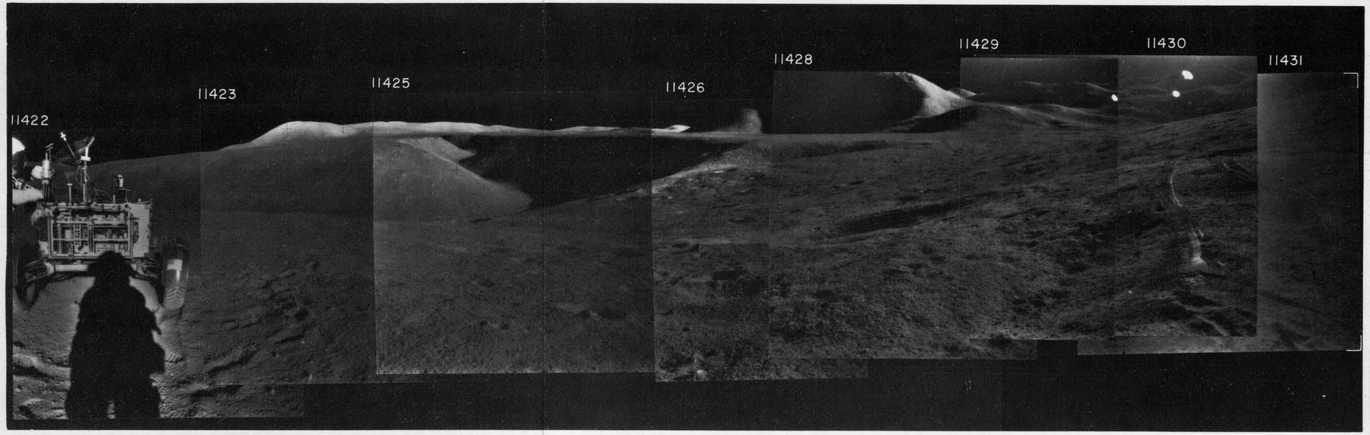
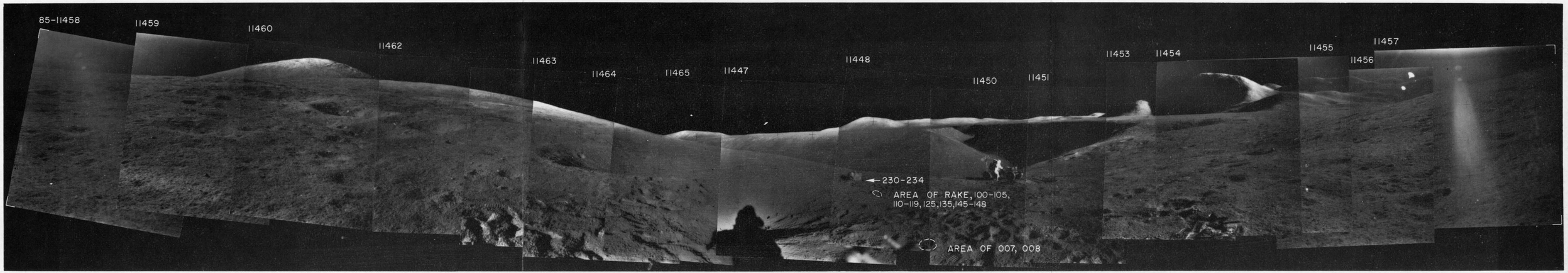


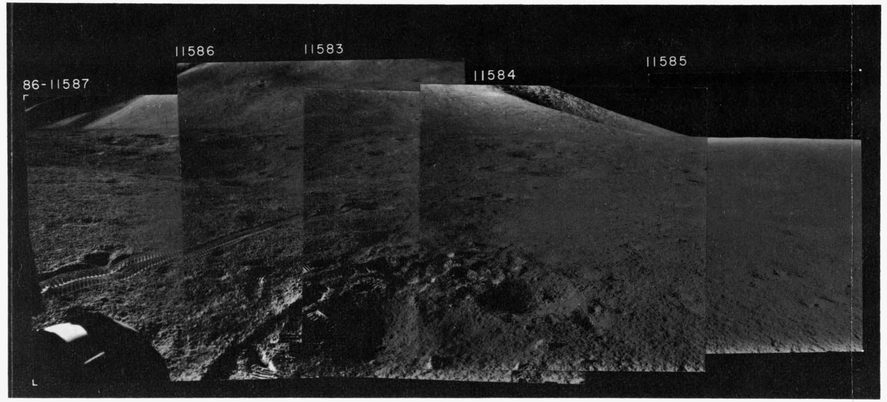
Pan 5, north (east), Station 2



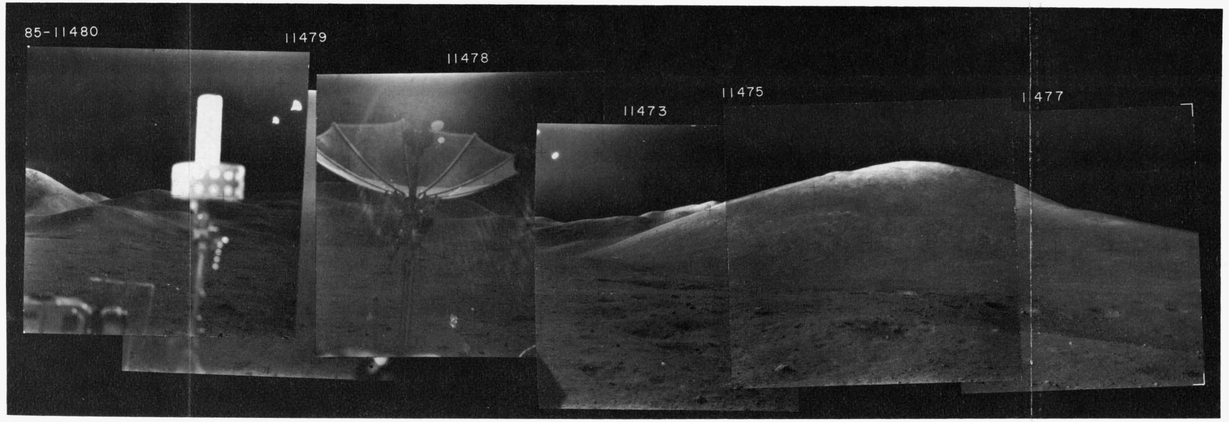
Pan 5, north (west), Station 2



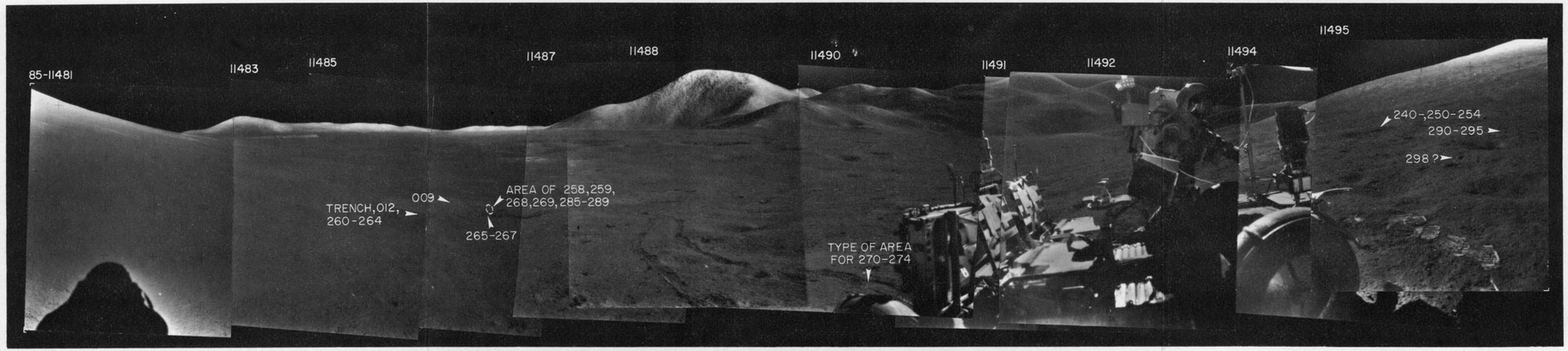
Pan 6, south, Station 2



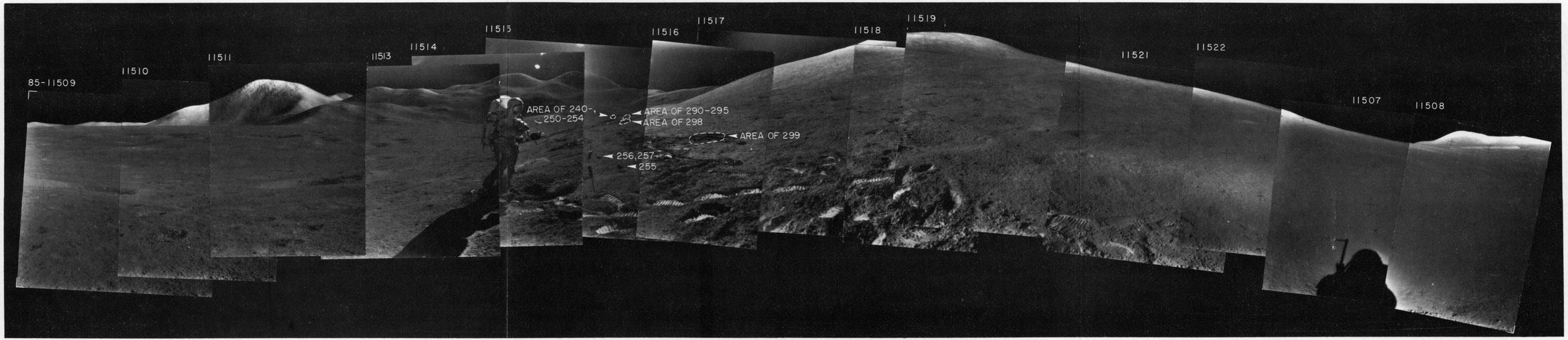
Pan 7, Station 3



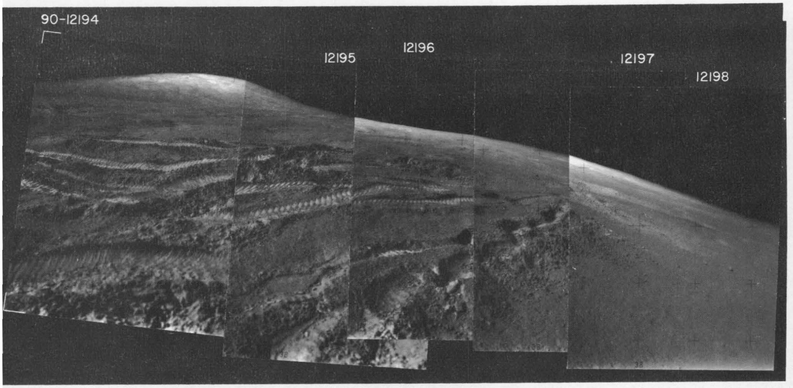
Pan 8, between LM and Station 6, from LRV

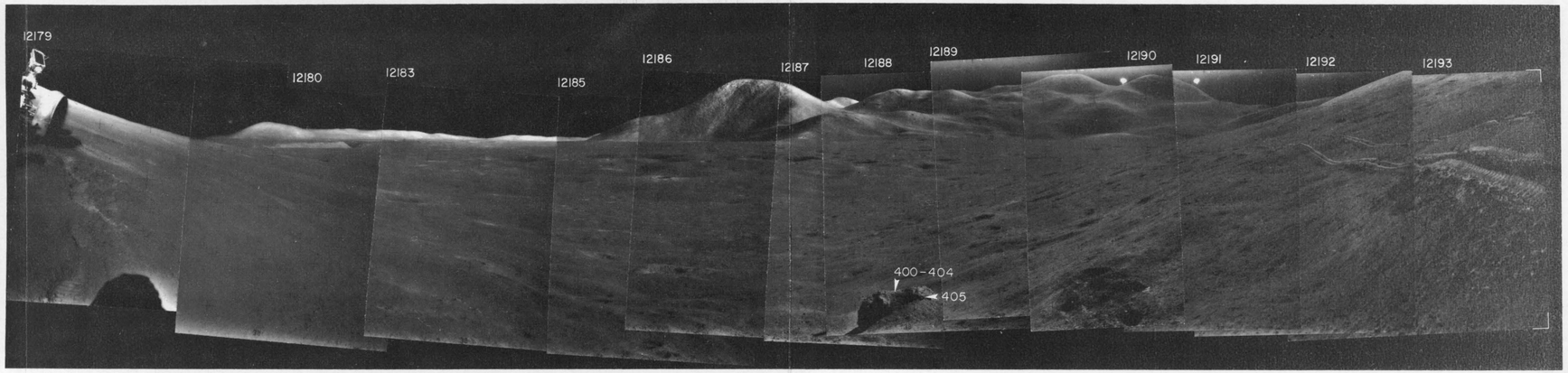


Pan 9, east, Station 6

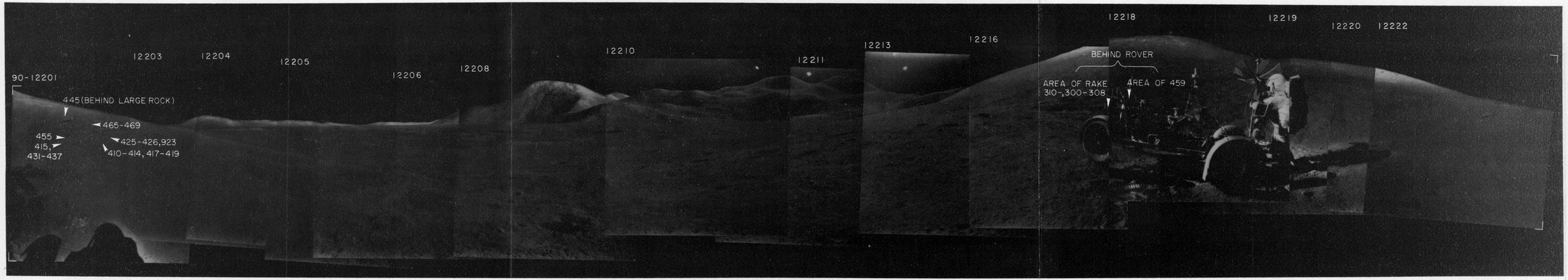


Pan 10, west, Station 6

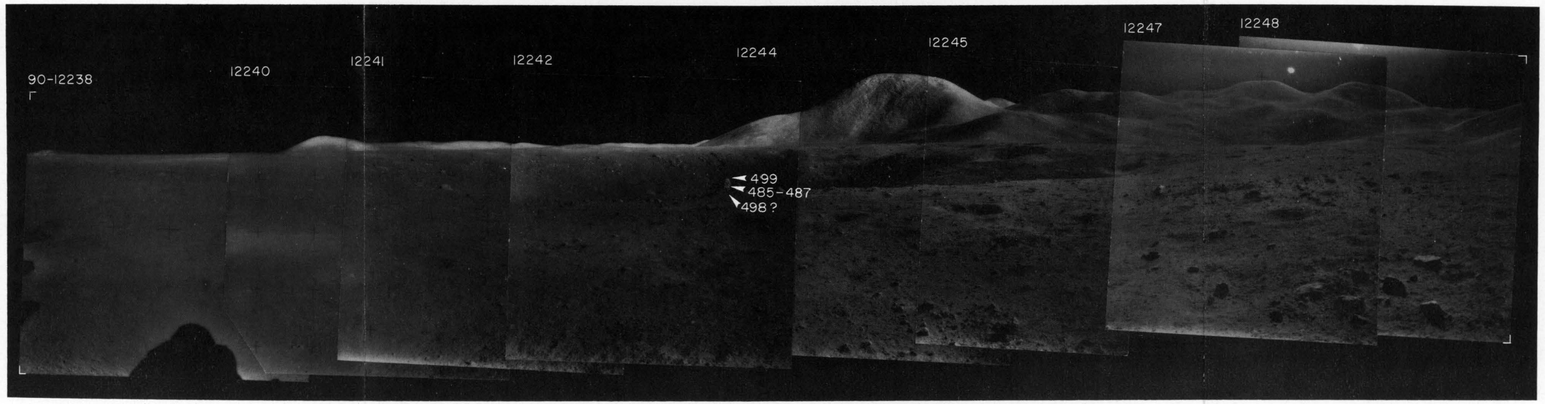




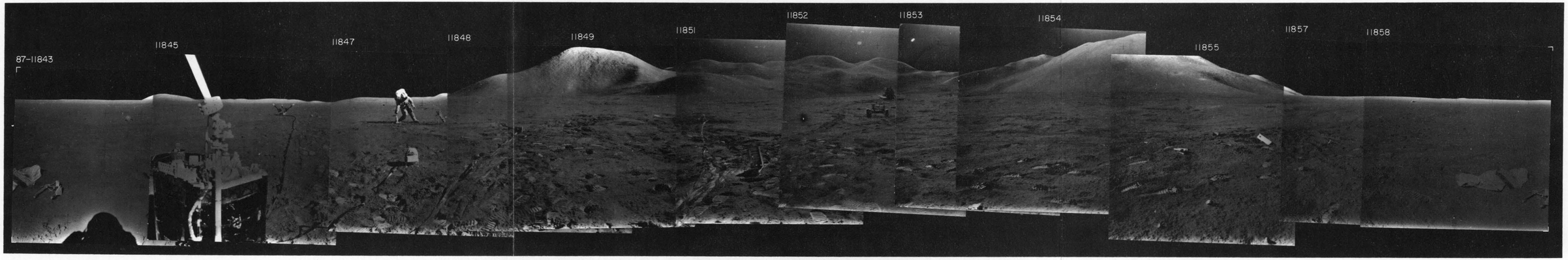
Pan 11, Station 6a



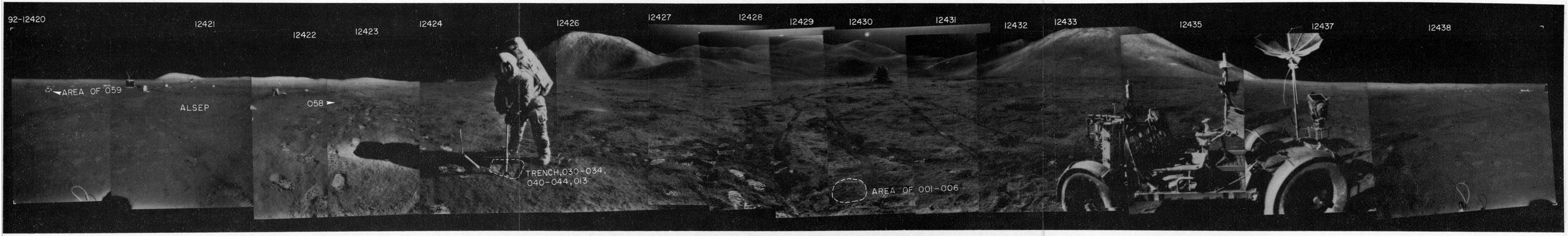
Pan 12, Station 7



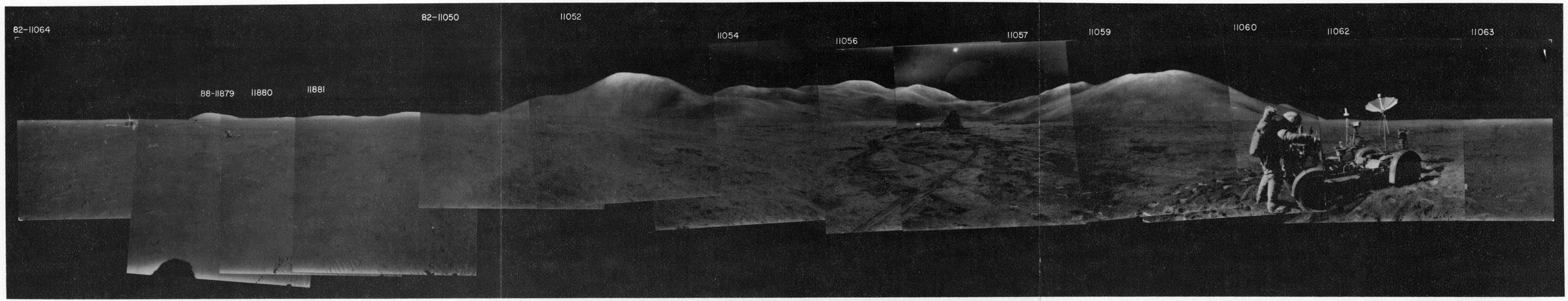
Pan 13, Station 4



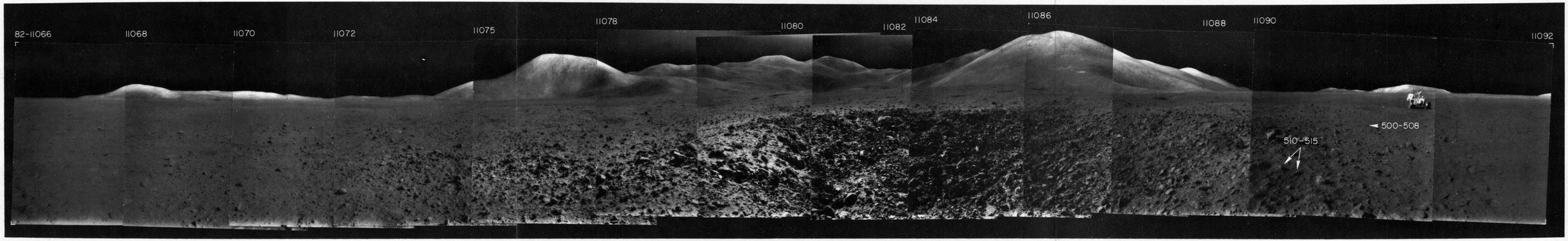
Pan 17, ALSEP site



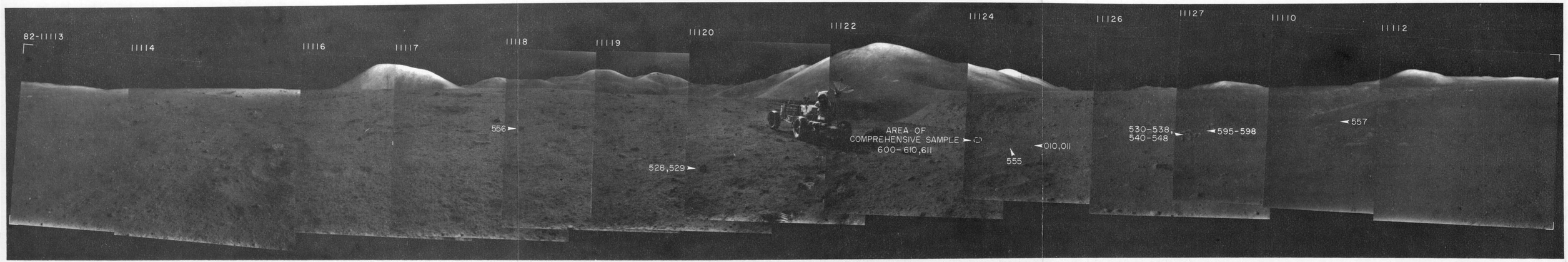
Pan 18, Station 8, end of EVA II



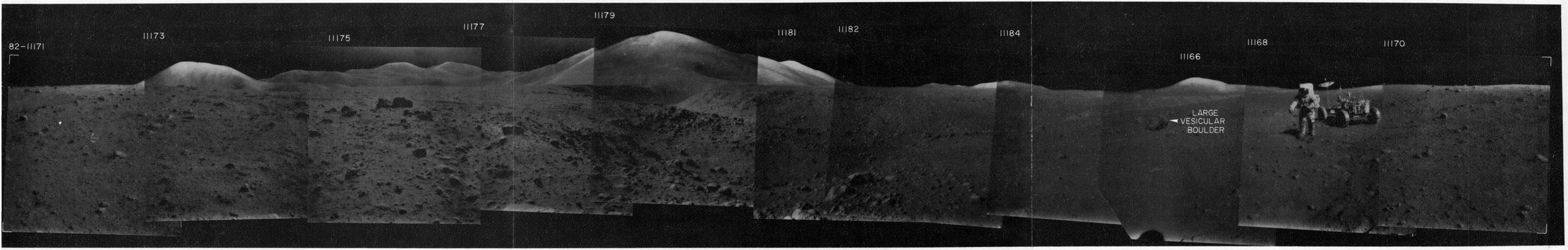
Pan 19, Station 8, beginning of EVA III



Pan 20, Station 9



Pan 21, Station 9a



Pan 22, Station 10