(34)

National Aeronautics and
Space Administration

CURATORIAL BRANCH

Lyndon B. Johnson Space Center
Houston, Texas 77058

Publication 57
JSC-17393

June 1981

GUIDEBOOK FOR LUNAR BRECCIA 67016 #5

Marc D. Norman

and

Gabriel G. Garcia

Lunar Curatorial Laboratory
Northrop Services, Inc.
P.O. Box 34416
Houston, Texas 77034

GUIDEBOOK FOR LUNAR BRECCIA 67016

Marc D. Norman

and

Gabriel G. Garcia

Lunar Curatorial Laboratory

Northrop Services, Inc.

P.O. Box 34416

Houston, Texas 77034

TABLE OF CONTENTS

INTRODUCTION: This catalog is one of a series of breccia guidebooks published under the auspices of the Lunar Curatorial Branch of Johnson Space Center, Houston. It is intended to assemble in a convenient manner descriptions and processing history of all splits of a single lunar breccia, 67016. A brief literature summary is included also. Hopefully this guidebook will aid principal investigators in making sample requests and will facilitate processing these requests.

67016 is one of the light-colored fragmental breccias that are the predominant rock type on the rim of North Ray Crater. It was collected as an isolated sample, perched on the lunar surface just outside the southern rim crest of North Ray, near the Lunar Roving Vehicle (Figs. 1,2). The literature has most often referred to these rocks as "light matrix breccias" (e.g. Warner et al., 1973; Ulrich, 1973; Hodges et al., 1973; Taylor et al., 1973; Delano et al., 1973) or "light matrix-dark clast (B_2) breccias" (Wilshire et al., 1973). Recent attempts to standardize the nomenclature of lunar highlands rocks (Stöffler et al., 1979, 1980) assign the term "feldspathic fragmental breccias" to these rocks, and this terminology will be used here.

In 1972, 67016 was unpacked from the Buddy Secondary Life Support System (BSLSS) bag in several pieces. Although collected as a single specimen (Fig. 2), it was stored

beneath 61016 during the return to Earth and apparently disaggregated along pre-existing fractures. Reconstruction efforts in the Lunar Receiving Laboratory succeeded in mating eight of the pieces which were subsequently numbered ,1-,8 (,0 was considered to be completely subdivided). Fragments which could not be fit into the reconstruction were numbered ,9-,36 and ,38. Small chips and fines were assembled as ,37 (Figs. 3,4). There is no doubt that the fragments with undocumented locations on the rock are pieces of 67016 as this was the only rock in the BSLSS bag. To fill the initial round of allocations splits ,46-,94 were taken from ,2. Most of the currently existing splits are daughters of ,2, but splits have also been made from ,1 ,3 ,4 ,9 ,10 and ,11 (see Flowchart).

PETROGRAPHIC CHARACTERISTICS: Like the other feldspathic fragmental breccias, 67016 is characterized by abundant dark, fine-grained, melt breccia clasts, and lesser amounts of plutonic and granulitic lithic clasts in a porous matrix of crushed plagioclase and rare pyroxene, olivine, ilmenite, spinel, and Fe-metal. Rare lithic clasts include subophitic and poikilitic impact melt, ilmenite- and silica-bearing melt breccia, KREEP basalt, and "granitic" intergrowths of silica and K-feldspar. Regolith-derived components such as agglutinates or glass spherules are absent from this rock. The matrix of 67016 is more coherent than that of most of the other feldspathic fragmental breccias, though an

extensive network of fractures allow the rock to be broken easily into smaller pieces. The coherence of this rock allow the splits to be dusted easily and processed with little attrition. Further petrographic information on 67016, including electron microprobe analyses, is given by Norman (1981). Nord et al. (1975) report an electron petrographic study of North Ray breccias that includes 67016.

CHEMISTRY: 67016 is compositionally similar to other feldspathic fragmental breccias, being characterized by high alumina and relatively low levels of incompatible and siderophile elements (Tables 1,2). Solar wind components such as C, N, and other light gases are present in very small amounts, implying very little, if any, surface exposure of the breccia components prior to their assembly. The low levels of light gases, together with the absence of regolith-derived components such as agglutinates and glass spheres, and the low levels of meteoritic siderophiles all suggest that 67016 is not lithified lunar regolith.

AGE DATA: Ar isotopic data (Turner and Cadogan, 1975) constrain the age of 67016 to be 3.88 - 4.00 b.y. The total K-Ar age of 3.88 b.y. fixes the lower limit (Turner and Cadogan, 1975) and a 3.95 ± 0.05 b.y. Ar^{40}-Ar^{39} plateau age of a dark clast fixes the upper limit since the rock cannot be older than any clasts within it. A coarse plagioclase separate yielded an Ar^{40}-Ar^{39} plateau age of 3.95 ± 0.07

b.y., and a sample of "white powdery matrix" gave a complex release pattern with no plateau (Turner and Cadogan, 1975).

EXPOSURE HISTORY: Exposure ages of 40 - 50 m.y. were calculated from the Ar data summarized above (Turner and Cadogan, 1975), consistent with the excavation of 67016 by North Ray Crater. Particle tracks yields significantly younger exposure ages: 1.0 m.y. and 1.2 m.y. for two surface chips and a subdecimeter age of 15 m.y. for an interior chip (Bhandari et al., 1973). These particle track data and the occurrence of zap pits on all exterior surfaces of the rock suggest a complex exposure history (Bhandari et al., 1973). Cosmogenic radionuclide abundances indicate that 67016 is unsaturated in ^{26}Al (Eldridge et al., 1975).

PHYSICAL PROPERTIES: 67016 contains one component of magnetization that is fairly stable against AF-demagnetization (Pearce et al., 1973). The ferromagnetic resonance (FMR) intensity of this rock is dissimilar to that of typical lunar fines (Housley et al., 1976).

TABLE 1. Summary chemistry of 67016 lithologies
Oxides in wt%, others in ppm except as noted.

	Bulk Rock	Granulitic Clast	Melt Breccia Clasts*
SiO_2	44.5		44.8
TiO_2	0.34		0.31
Al_2O_3	29.6		30.6
Cr_2O_3	0.07		
FeO	3.7		3.3
MnO	0.05		
MgO	4.1		2.8
CaO	16.4		17.6
Na_2O	0.52		0.50
K_2O	0.05		0.05
Sr	174		
Rb	1.0	0.66	0.34
U ppb	200	216	92
Ba	64		
La	3.4		
Ce	9.4		
Sm	1.81		
Eu	0.96		
Tb	0.34		
Yb	1.4		
Lu	0.23		
Sc	7.7		
Zn	6	5.59	0.75
Cu	2		
Ni	80	182	14
Co	10		
Ir ppb	2.3-10	2.90	1.14
Au ppb	0.5-4.5	1.01	0.08
C	35		
N	20		
S	175		

*Oxides are the average of three clasts analyzed by defocussed electron beam (DBA), trace elements from a separate clast. See Table 2 for references.

TABLE 2. Chemical studies of 67016 (all bulk rock or matrix except as noted.

REFERENCE	SPLIT ANALYZED	ELEMENTS ANALYZED
Duncan et al. (1973)	,47	majors and traces
Brunfelt et al. (1973)	,86	majors and traces
S.R. Taylor et al. (1974)	,63	majors and traces
Lindstrom and Salpas (1981)	,9	majors and traces
Janghorbani et al. (1973)	,78	majors
Wanke et al. (1976)	,173	majors,traces, siderophiles
Wanke et al. (1977)	,173	V
Garg and Ehmann (1976)	,78	Zr,Hf,Fe,Co,Sc,Cr, REEs,Th
Hertogen et al. (1977)	,167,170,172*	meteoritic siderophiles and volatiles
Jovanovic and Reed (1973)	,64	halogens,Li,U,Te,P_2O_5
Eldridge et al. (1975)	,2	K,U,Th
Moore et al. (1973)	,90	C
Cripe and Moore (1974)	,90	S
Moore and Lewis (1976)	,90	C,N
Gibson and Andrawes (1978)	,88	N by crushing
Flory et al. (1973)	,81,91	Organogenic gases
Gibson and Moore (1975)	,88	Volatile gases
Gibson and Chang (1974)	,88	Volatile gases, carbon and oxygen isotopes
Norman (1981)	melt breccia clasts	majors by DBA

(*melt breccia clast, granulitic clast, and bulk rock respectively).

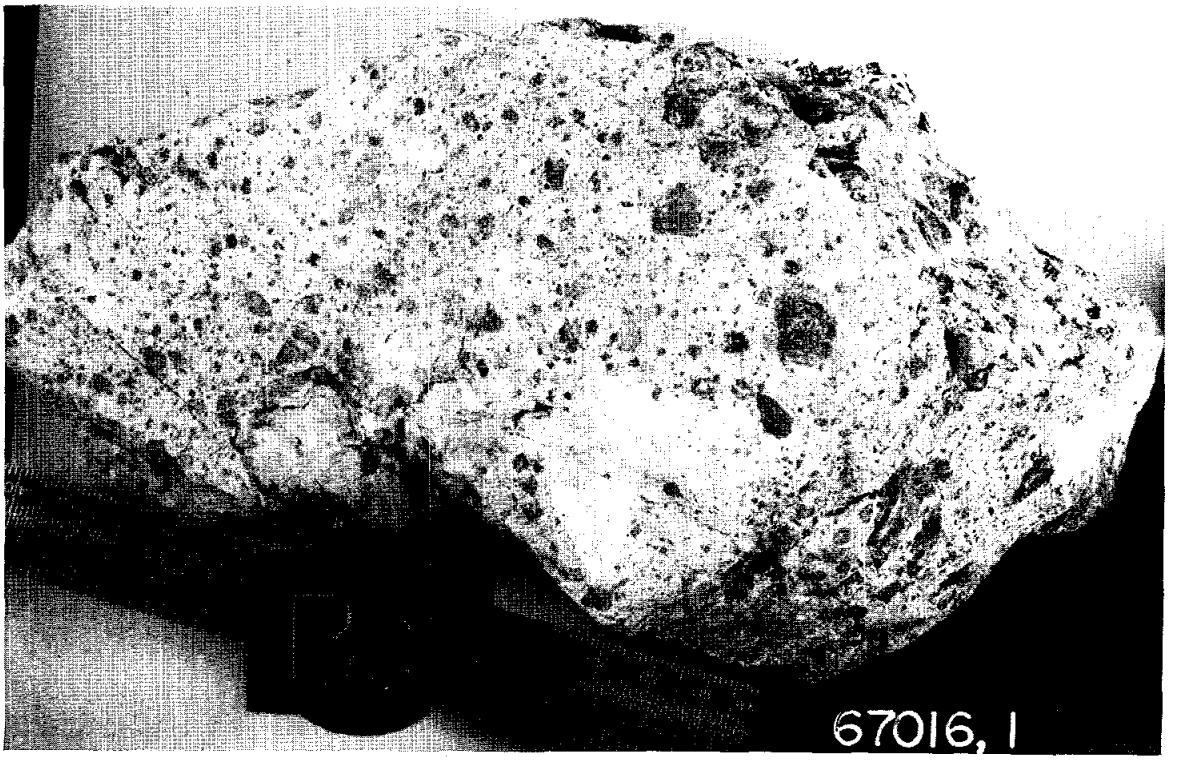
67016,1 2499.260 g

This is the largest extant piece of 67016. It is cut along its margins by several penetrating fractures. The range of clast types exposed on this piece is much less than the total range sampled by all of the splits.

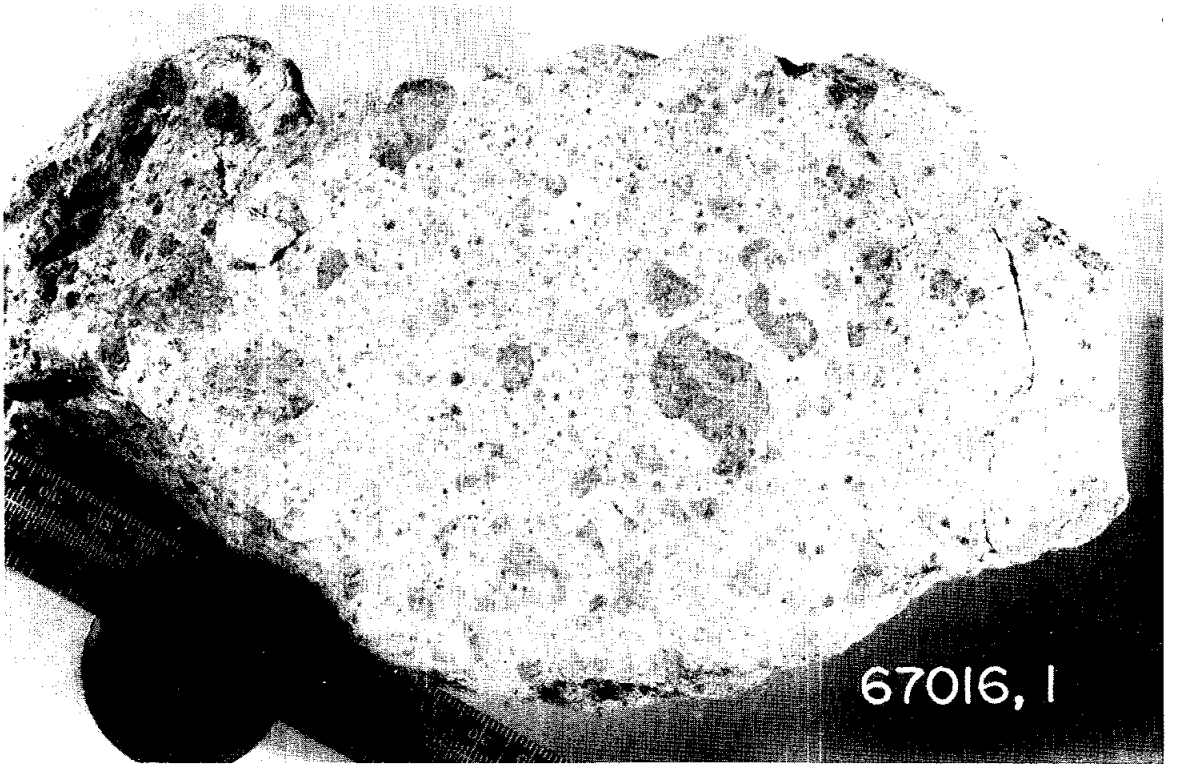
Dark clasts are about twice as abundant as light-colored clasts and tend to be larger. These dark clasts correspond to the melt breccia clasts described by Norman (1981) and Nord et al. (1975). They range in shape from angular to rounded. Most have a vitreous or resinous luster; small ones are more glassy and large ones are more granular. All are aphanitic with abundant white clasts. Rarely, dark material is extensively marbled with white, anorthositic stringers giving the clast as a whole a light gray appearance. Unlike the dark clasts observed in 67015 (Marvin, 1980), vesicles are rare in these clasts in 67016.

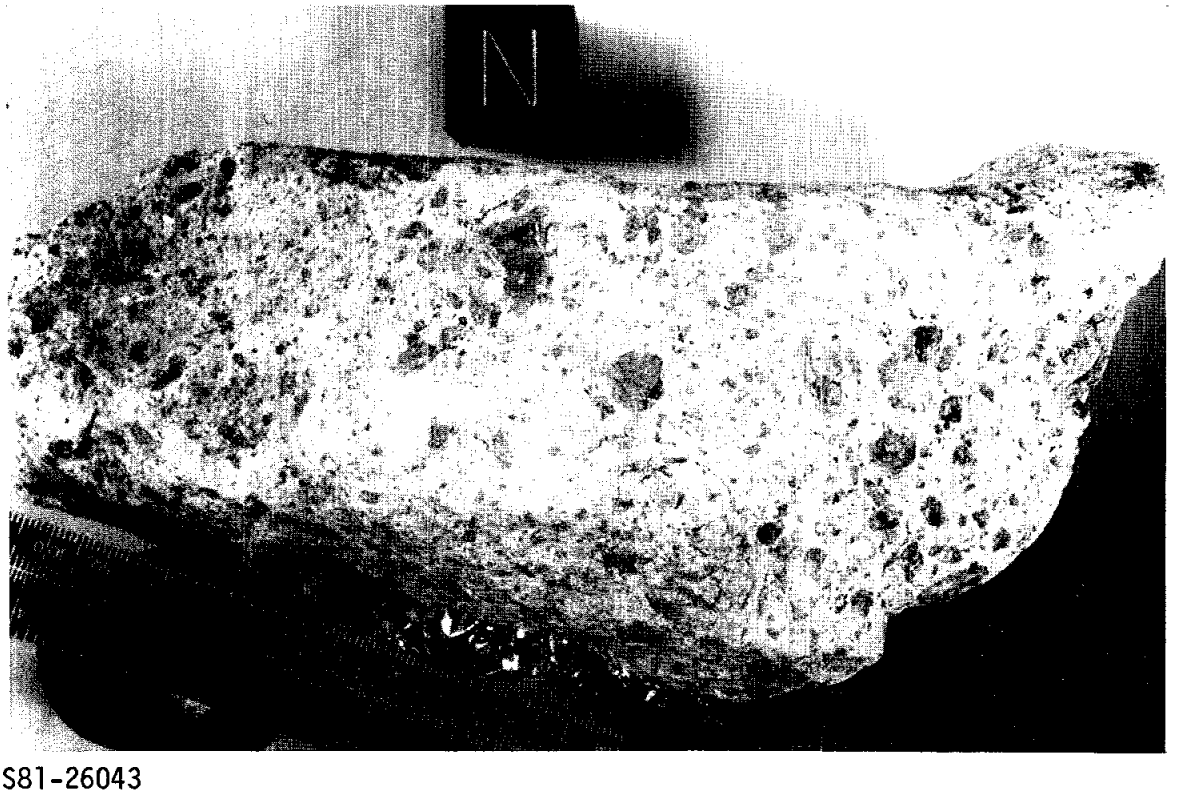
White clasts on this split are dominated by chalky white anorthositic material containing uncommon brown or pale yellow mafic minerals. The 1 cm angular white clast exposed on the B surface is granular with approximately 30% tan mafic silicates. A few small (<5 mm) pale green clasts with granular textures are scattered over the surfaces of this split.

Zap pits and patina occur on four surfaces indicating exposure at the lunar surface.



S81-26051





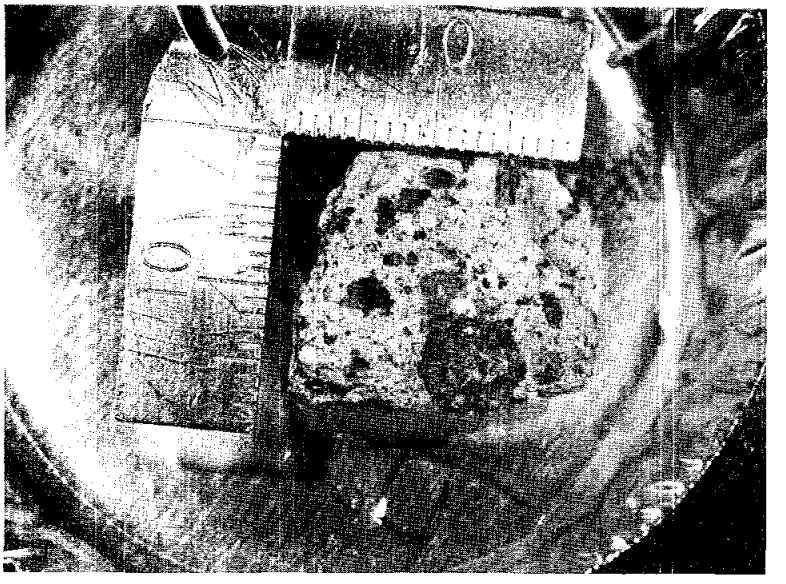
S81-26043

67016,6 40.520 g

This bulk rock split comprises one 4 cm piece and two smaller pieces which can all be fit together. One light-colored clast with 40-50% pale yellow mafic minerals is present on each of the three pieces. The estimated total weight of this clast is 5-6 g. A dark material with a bronze tint appears to be invading this clast and may be a sample of the troilite-rich intergrowth observed on some of the plutonic lithic clasts in thin section (Norman, 1981). Several 2-3 mm granular clasts with a green tint are on the largest piece. Three exterior surfaces are present.

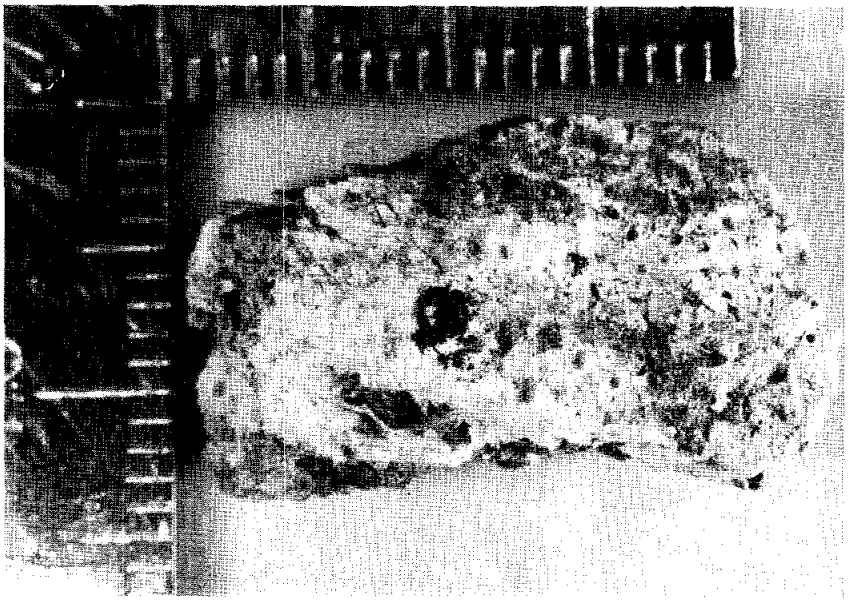
67016,7 6.910 g

A bulk rock chip containing a typical assemblage of clast types. Dark clasts range from very black and vitreous to light gray to black and white mottled with stringers of plagioclase. A chalky white clast with yellow mafic minerals and a clot of opaques is on one corner of the split and could be easily sampled. One poorly preserved zap pit on one edge of this chip is the only sign of exterior surface.



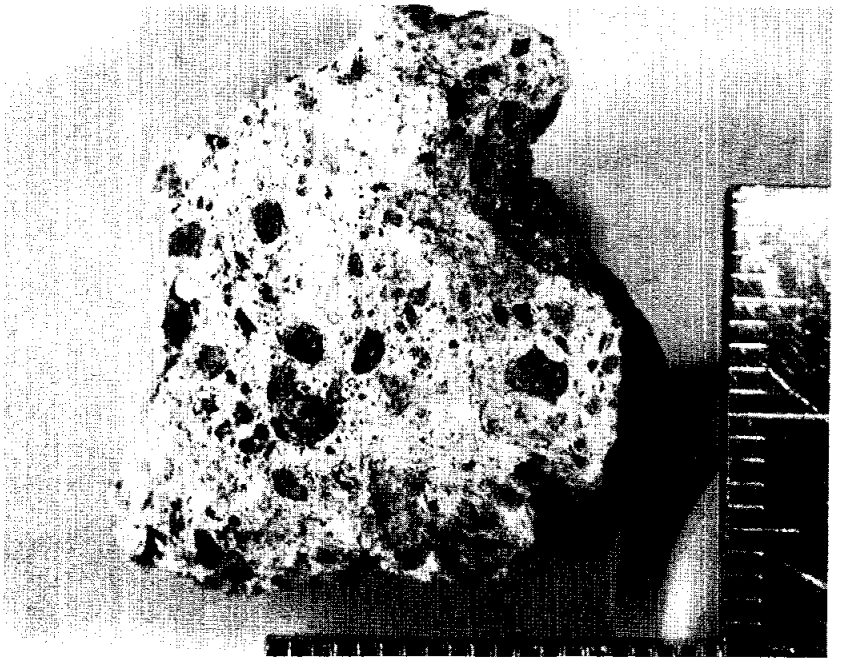
67016,8 1.860 g

Probably a bulk rock chip, but much whiter than typical bulk rock. 1 mm crystals of clear plagioclase are embedded in a matrix of more chalky material. Dark clasts are rare. One exterior surface is present. Some of the interior surfaces have slickensides.



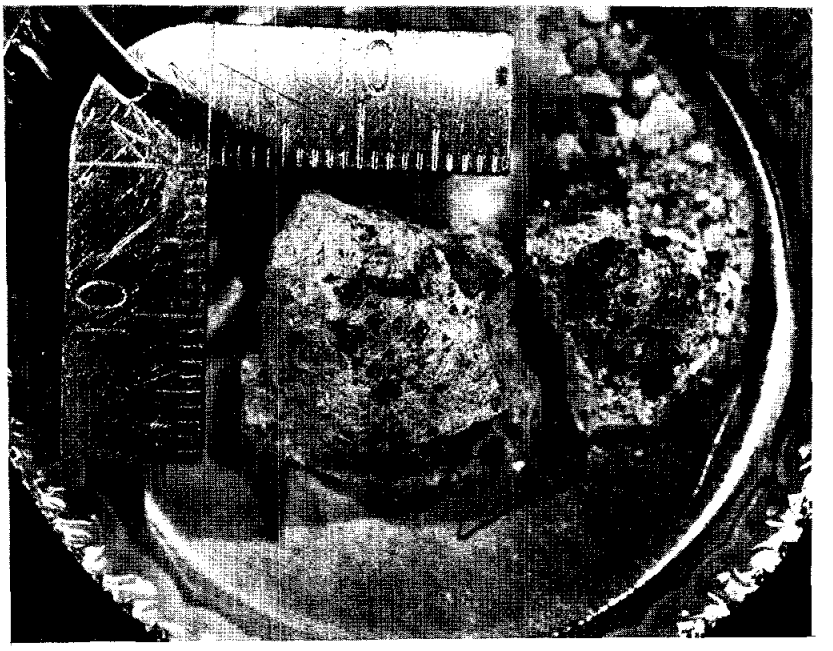
67016,10 13.750 g

A bulk rock chip with a typical assemblage of clasts. One exterior surface is present.



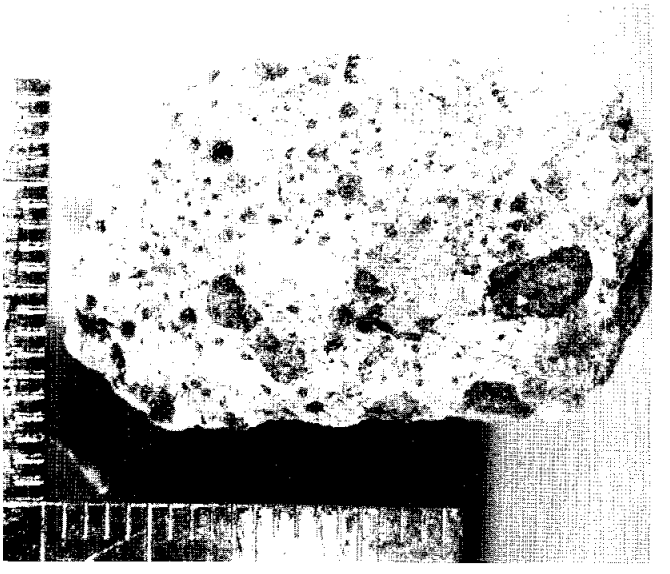
67016,11 8.410 g

Two bulk rock chips and a small amount of fines. Some rust is associated with metal grains in the matrix. One exterior surface is present with a heavy patina and many zap pits.



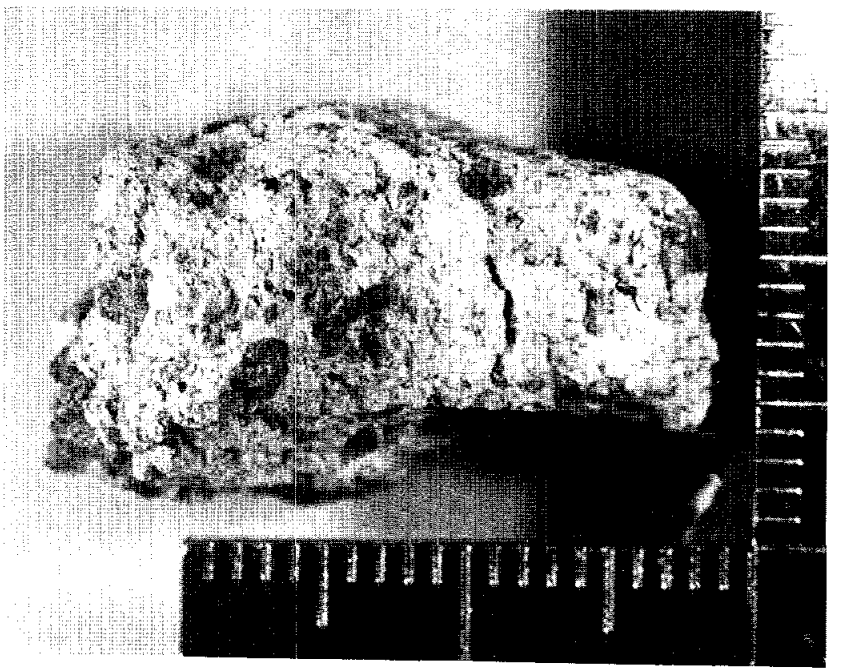
67016,12 8.410 g

This is a split of bulk rock that contains two large white clasts with abundant mafic silicates. The larger of these clasts accounts for about 1/3 of the volume of the entire split. Mafic silicates in this clast are light tan and are heterogeneously distributed, accounting for 25-30% of the clast as a whole, but ranging up to 50% in places. The second clast is much smaller (approximately 3 mm long) and has more of a crushed appearance than the clast described above. Mafic minerals in this clast are pale yellow, and account for about 30% of the clast. One surface of this split has zap pits and patina.



67016,13 4.680 g

This split of bulk rock contains two coarse-grained white clasts, each with approximately 10% yellow mafic silicates and a small amount of opaques. A small patch of exterior surface with a few zap pits is present. Many small fractures make this split more friable than most of the bulk rock chips.

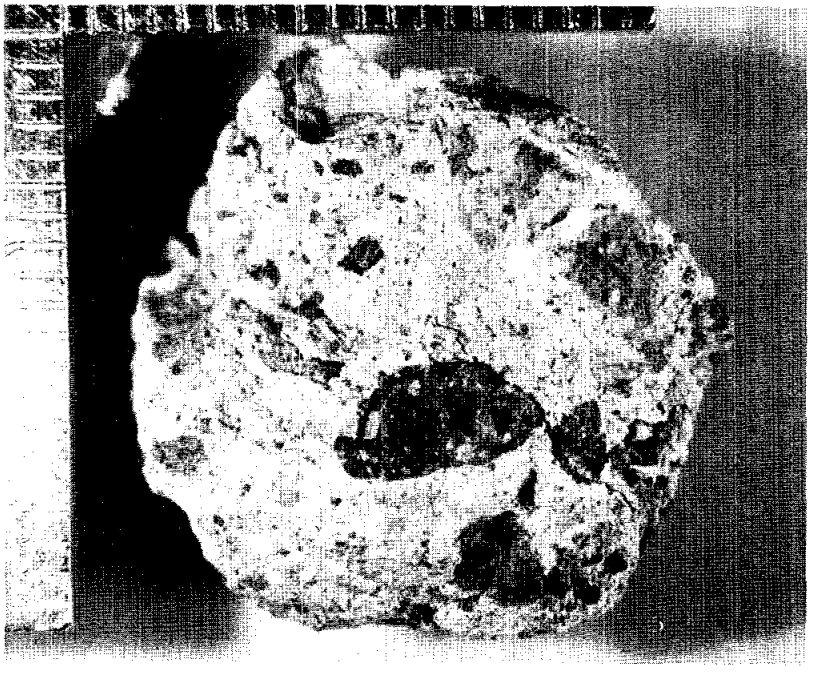


67016,14 3.160 g

Bulk rock chip. A 1 mm grain of brown pyroxene showing good cleavage is exposed on one of the interior surfaces. One of the broad surfaces has a heavy patina and many zap pits.

67016,15 4.970 g

Bulk rock chip. Several granular clasts with a pale green color are present. Dark clasts are vitreous to finely crystalline. One surface has patina and zap pits.

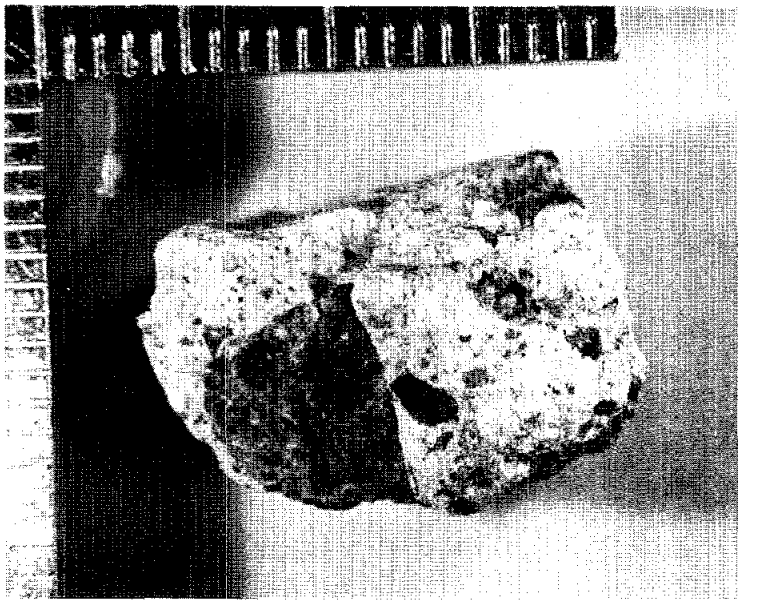


67016,16 3.840 g

Bulk rock chip. Clasts include one 5 mm white clast with approximately 50% pale yellow mafic minerals and a large, elongate opaque grain, and one 3 mm pale gray breccia clast which is slightly darker in color than the bulk rock matrix and has sharp contacts with the bulk rock. Several 0.5-1 mm fragments of dark brown pyroxene occur within the pale gray breccia clast. The white clast could be easily sampled but the breccia clast is embedded in the matrix and would be difficult to remove. A small area of this split is exterior surface.

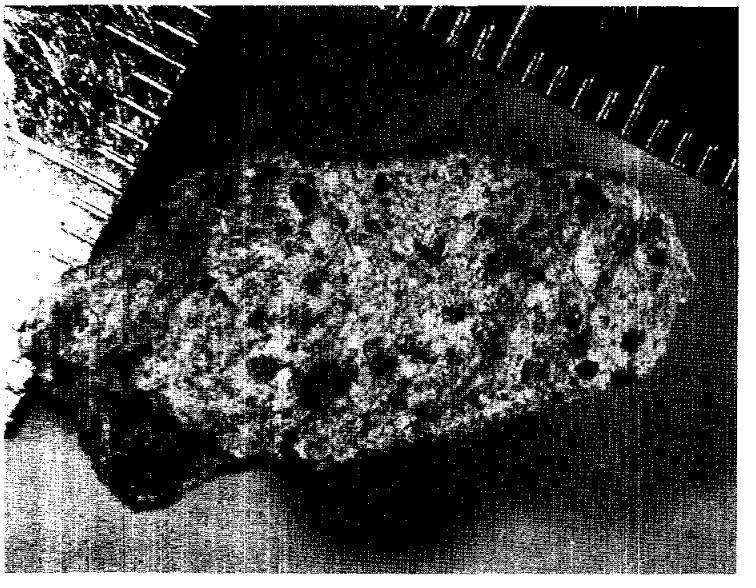
67016,17 3.080 g

Bulk rock chip. One exterior surface is present.



67016,18 2.580 g

Bulk rock chip. Zap pits and patina occur on one surface.



67016,19 2.810 g

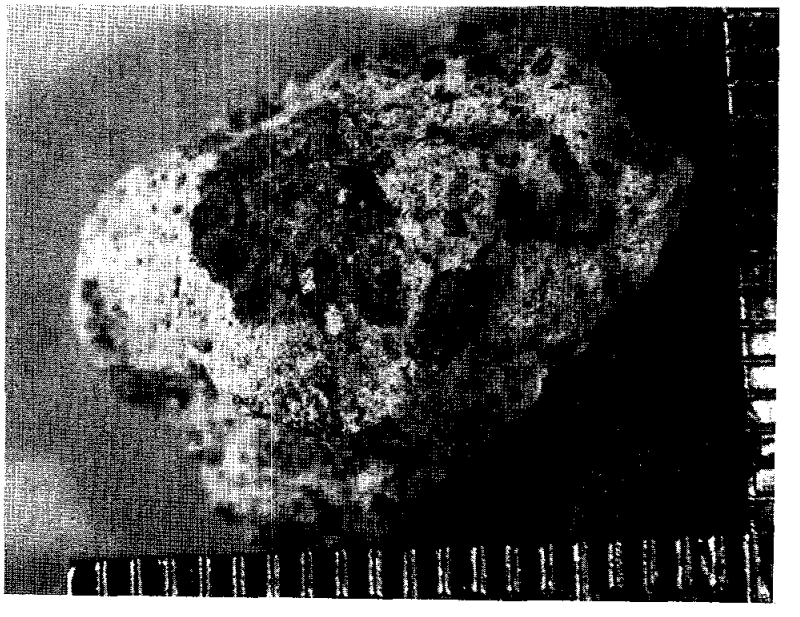
Half of this split is typical pale gray breccia with several dark and light colored clasts, and half is considerably whiter with few dark clasts. A 1 cm white clast with approximately 25% dark brown mafic minerals is estimated to weigh approximately 0.8 g. Zap pits and patina indicate one exterior surface.

67016,20 3.160 g

Bulk rock chip. One surface has zap pits and patina.

67016,21 3.250 g

Bulk rock chip. One 7 mm pale green clast with a granular texture is present. One surface has patina and zap pits.

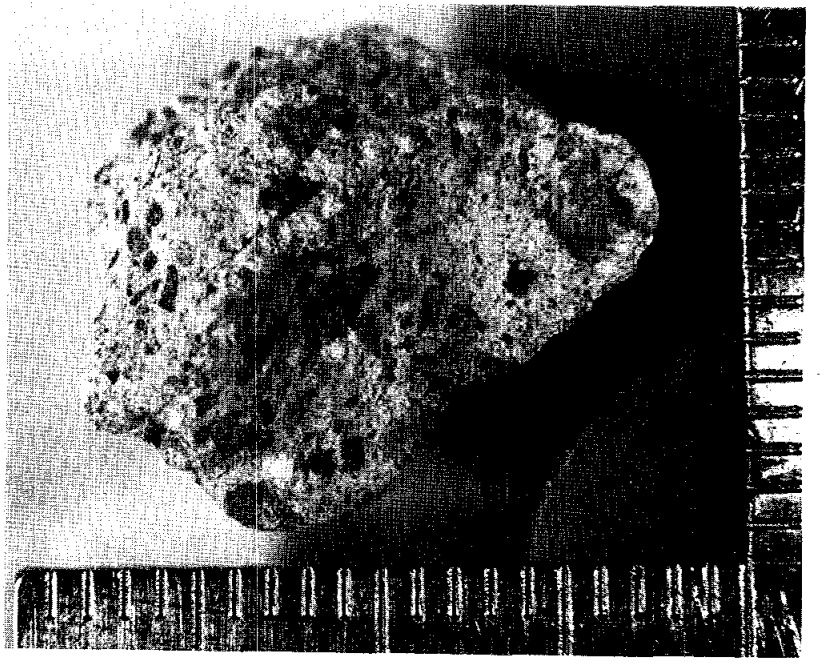


67016,22 2.480 g

Bulk rock chip. One end of this split is a white cataclastic clast with a few scattered pale green mafic minerals. A different 5 mm chalky white clast has a single pale yellow mafic grain with well preserved grain boundaries showing an apparent cumulate texture. One surface of this split has zap pits and patina.

67016,23 1.670 g

Bulk rock chip. A few zap pits occur along one edge but most of this split is interior breccia.



67016,24 2.550 g

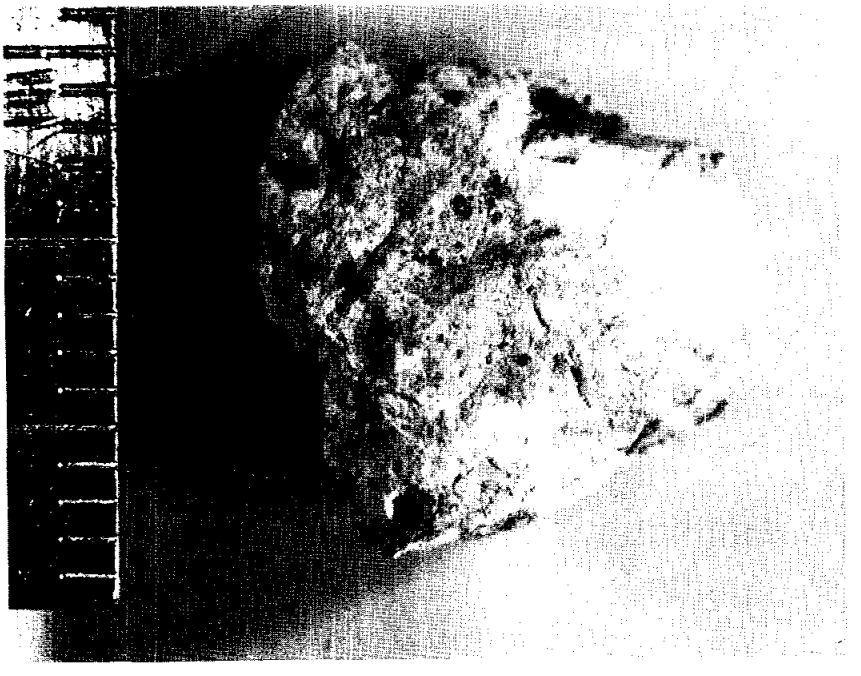
Bulk rock chip. About 1/3 of this split is a white cataclastic clast with 1-2% tan mafic minerals and <1% small dark flecks. Two exterior surfaces are present.

67016,25 1.970 g

Bulk rock chip. All surfaces are of interior breccia.

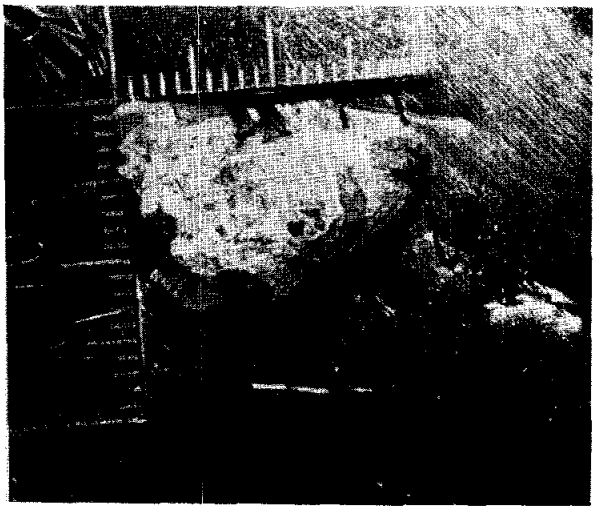
67016,26 1.510 g

A bulk rock chip containing a 1 cm chalky white clast with no visible mafic minerals. One exterior surface is present.



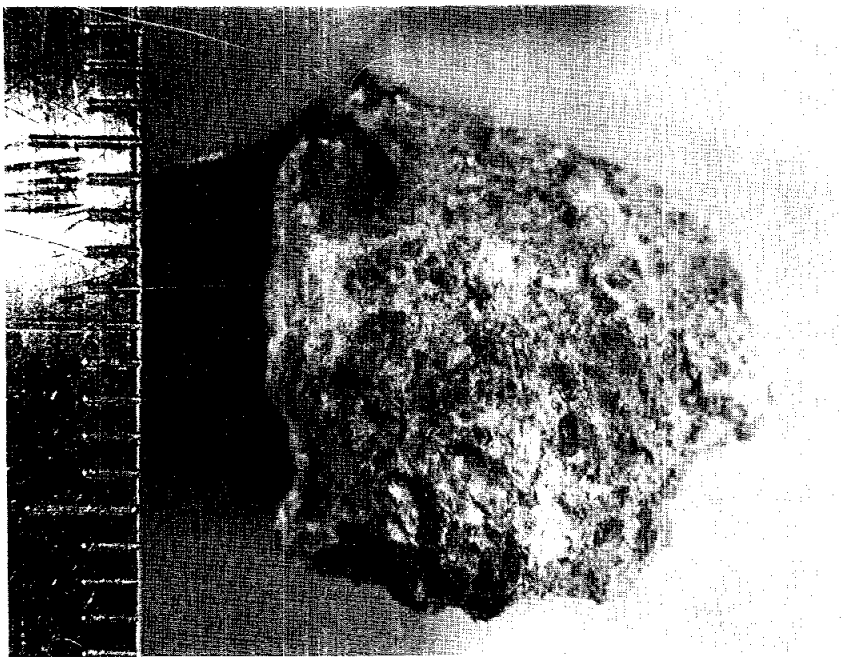
67016,27 1.530 g

This split consists of a 1.5 cm chip of bulk rock and several smaller pieces of bulk rock and dark clast material. Exterior surfaces are present on most of the fragments.



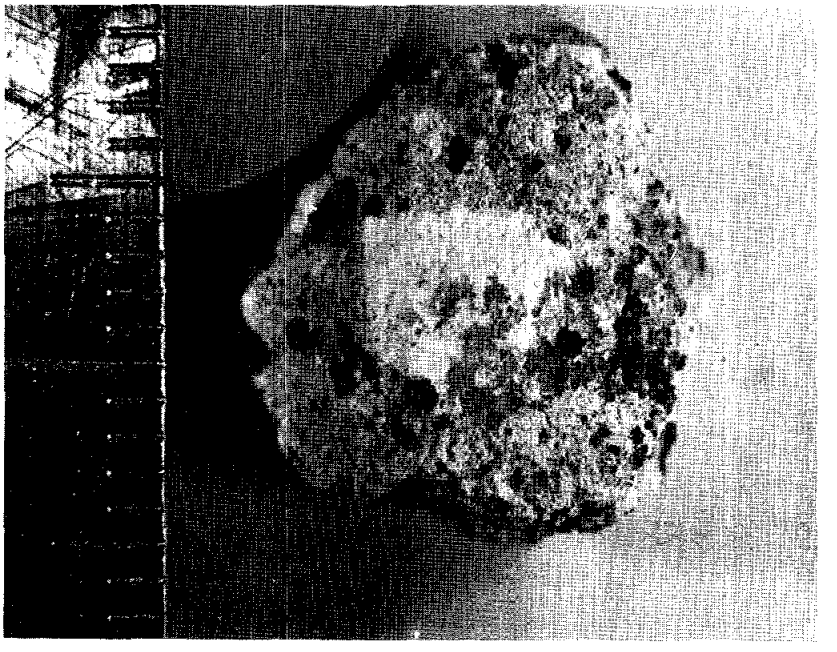
67016,28 2.200 g

A very fractured and sheared bulk rock chip. All surfaces are of interior breccia.



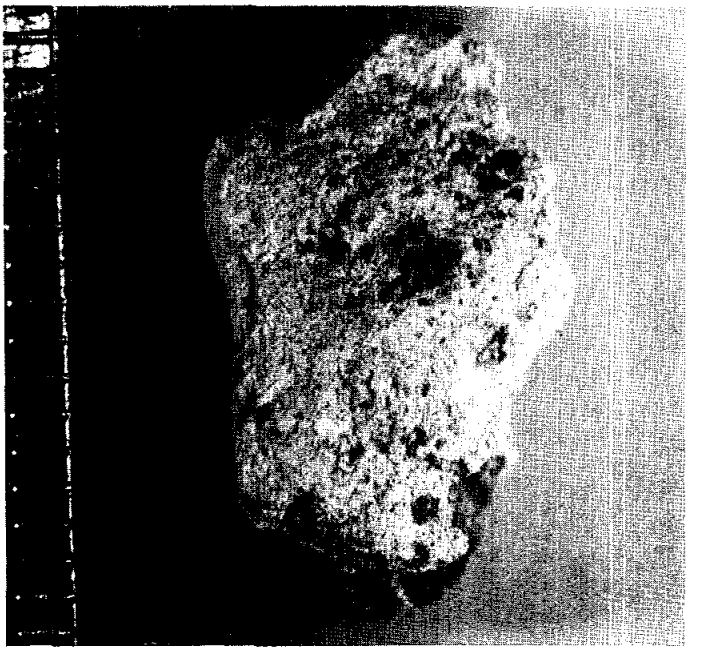
67016,29 2.200 g

Bulk rock chip. Two 1 cm chalky white clasts are present, one with no visible mafic minerals, the other with approximately 15% pale brown mafics and irregularly distributed opaques. Several discrete grains of dark brown pyroxene are scattered through the split. One exterior surface is present.



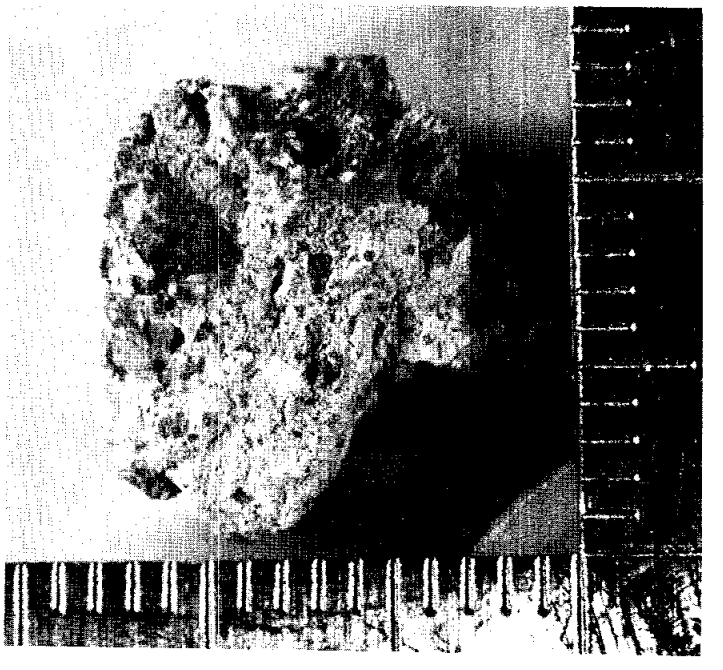
67016,30 1.520 g

A very white piece of bulk rock. Dark clasts are rare. A 1 cm granular clast with a pale green color and a 1 cm white chalky clast are present. Some rust is associated with metal grains in the matrix. One surface has patina and zap pits.



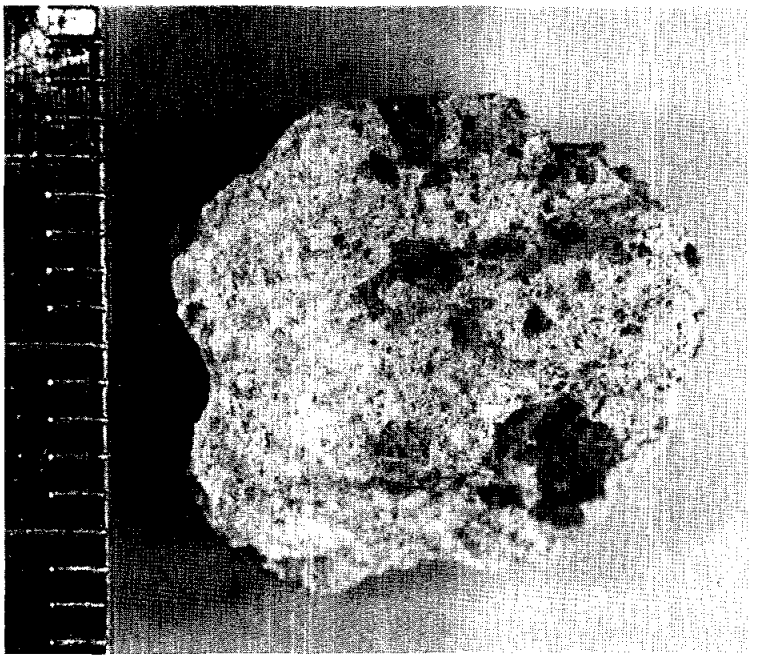
67016,31 1.350 g

A bulk rock chip with one exterior surface.



67016,32 1.510 g

This split is a bulk rock chip containing a 1.5 cm white clast with approximately 20% pale yellow mafic silicates, approximately 1% scattered opaques, and several tiny grains of rusty metal. This clast is on an edge of the split and could be easily sampled. One exterior surface is present.

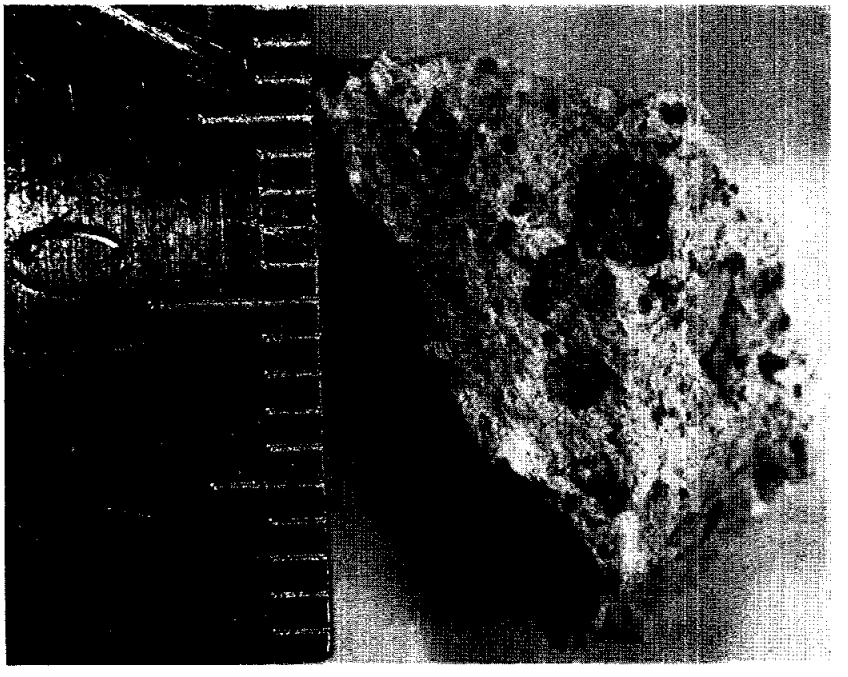


67016,33 1.720 g

A bulk rock chip with two exterior surfaces.

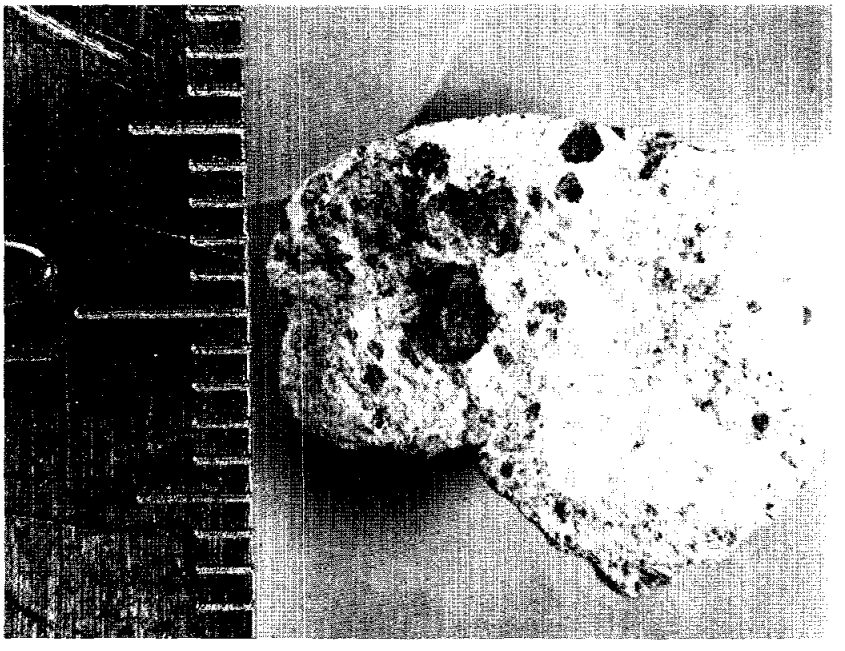
67016,34 1.520 g

Bulk rock chip. One surface has patina but no zap pits; other surfaces are of interior breccia.



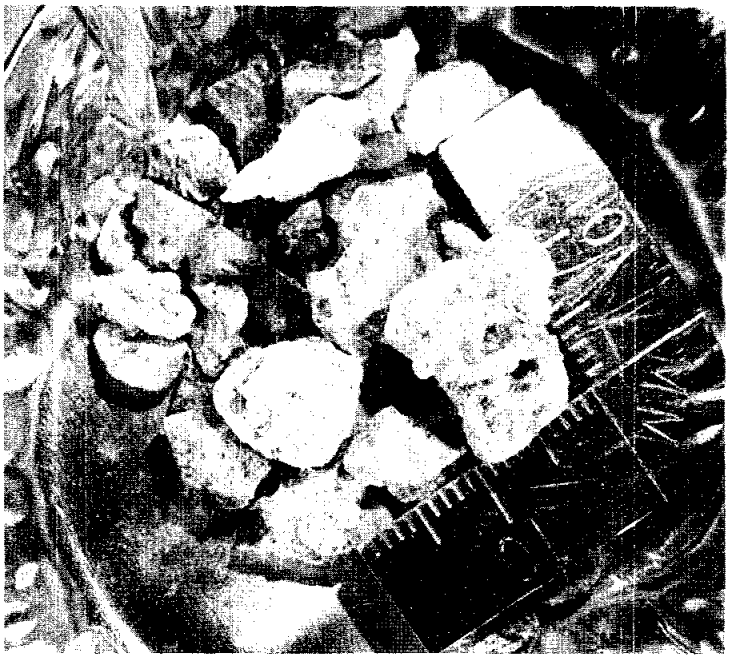
67016,35 1.730 g

A bulk rock chip with one exterior surface.



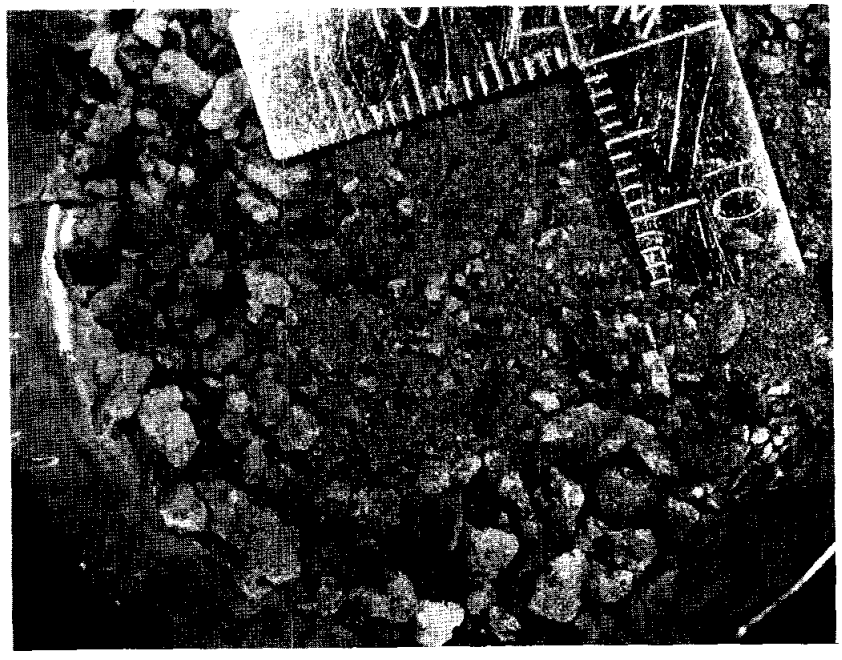
67016,36 6.000 g

A mixture of bulk rock chips and separated dark clasts. There are no separated white clasts in this split. Some of the bulk rock chips have exterior surfaces while others are entirely of interior breccia.



67016,37 9.660 g

This split is a dusty collection of mixed chips and fines. Dark clasts are easily recognized and separated. Some separated white clasts are present but are difficult to distinguish from small bulk rock chips due to the pervasive dust coating.

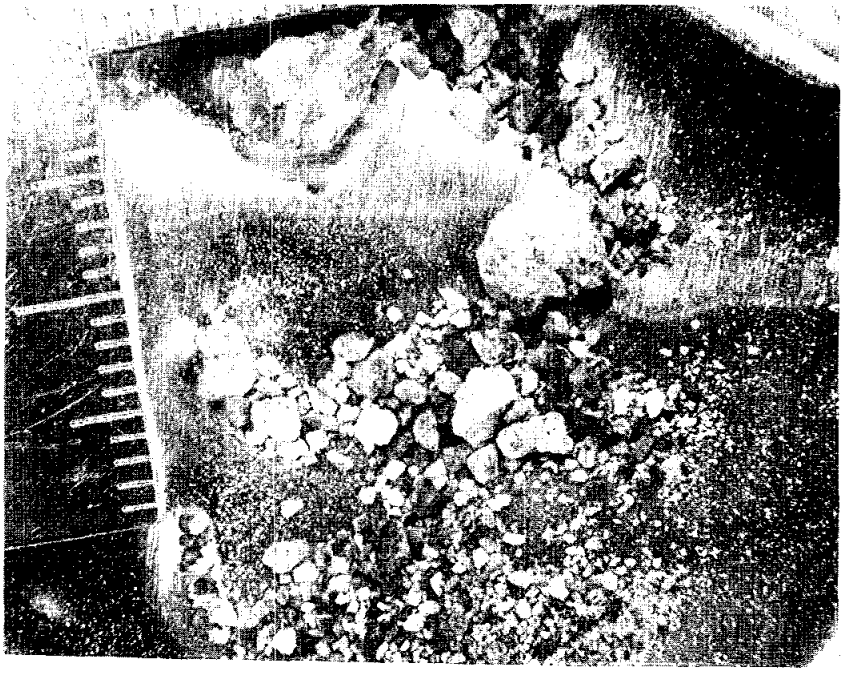


67016,38 1.150 g

Most of this chip is a white breccia that is probably bulk rock. All surfaces are of interior breccia.

67016,39 0.550 g

Small chips and fines. Many small pieces of dark clast material and a few chips of white clast material with pale yellow mafic minerals could be separated from this split. The largest chips in this split are of bulk rock.



67016,46 2.980 g

Bulk rock chip. An area of very white breccia is in sharp contact with the light gray bulk rock matrix. A few 1 mm white clasts with dark brown pyroxenes, and a 2 mm granular clast with a green tint protrude from the rock and could be easily sampled.

67016,48 3.120 g

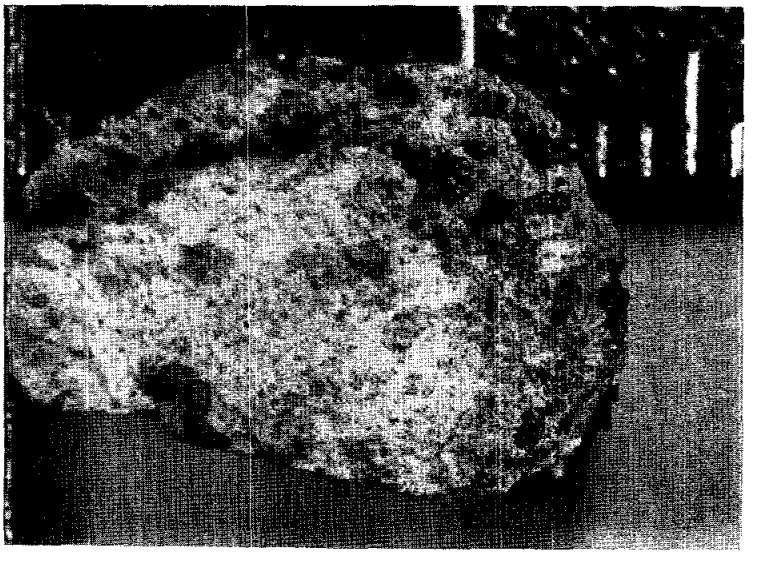
This split is virtually all dark clast material. Traces of bulk rock matrix and white clasts adhere to some of the chips.

67016,49 2.990 g

This split consists of small chips, mostly of dark clast material, but also some bulk rock pieces.

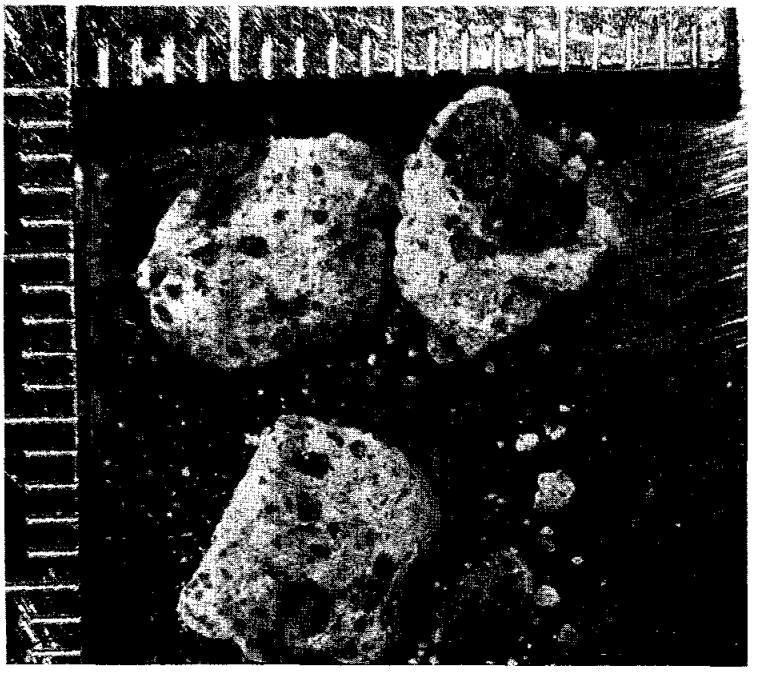
67016,50 0.640 g

This split consists of a 1.5 cm clast of white breccia with a rind of light gray matrix. Several 0.5-1 mm fragments of clear to milky plagioclase and a few dark clasts are embedded within the white breccia. The matrix of the white breccia is chalky with no visible mafic minerals. All surfaces of this split are of interior breccia.



67016,53 0.500 g

Three 1 cm chips of bulk rock and a small amount of fines compose this split. Each of the 1 cm chips has at least one exterior surface.



67016,54 0.370 g

This split consists of three separated chips of white clast material with approximately 30% pale yellow mafic minerals. Each of the chips is speckled with veins and patches of a black material, either opaques or glass. No exterior surfaces are present on any of the chips.

67016,55 0.570 g

Small bulk rock chips and some fines. The two largest chips have exterior surfaces.

67016,56 0.730 g

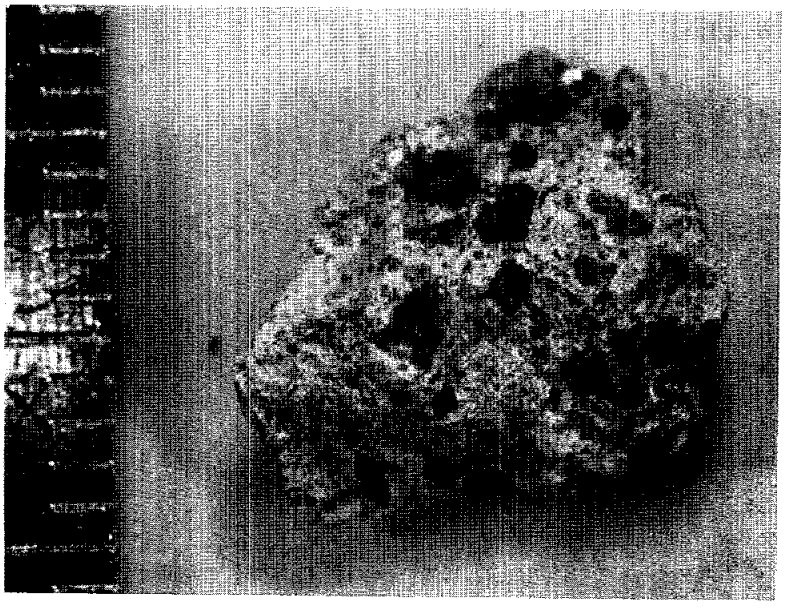
This split consists of assorted bulk rock chips plus a small amount of separated dark clast material and some fines. Most of the larger bulk rock chips have exterior surfaces.

o/016,58 0.790 g

Assorted bulk rock chips, separated dark clast material, and fines compose this split. Several of the bulk rock chips have exterior surfaces.

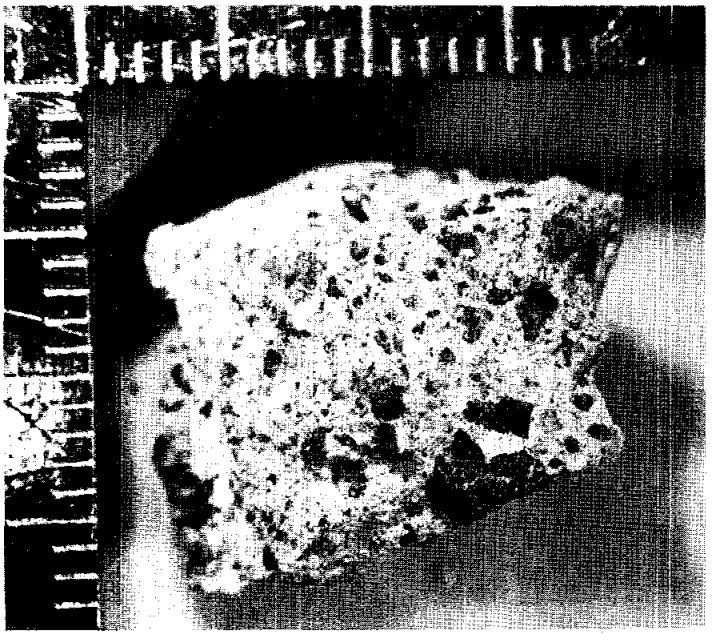
67016,67 0.540 g

A bulk rock chip with one exterior surface.



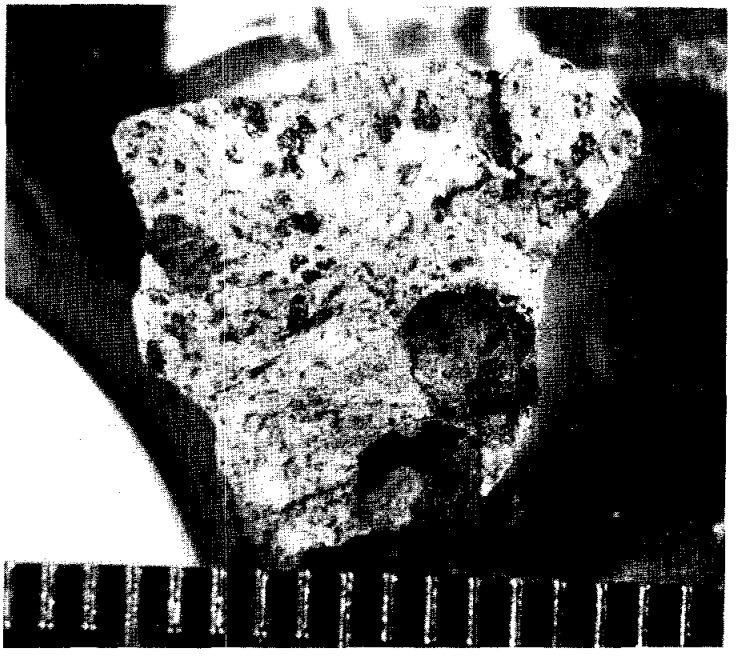
67016,68 3.420 g

Bulk rock chip. Clasts include a 0.5 cm white fragment with about 20% pale yellow mafic minerals and streaks of opaques or black glass, a 0.5 cm white, finely crystalline clast with no visible mafic minerals or opaques, and a 2 mm fragment of brown pyroxene with good cleavage. Two exterior surfaces are present.



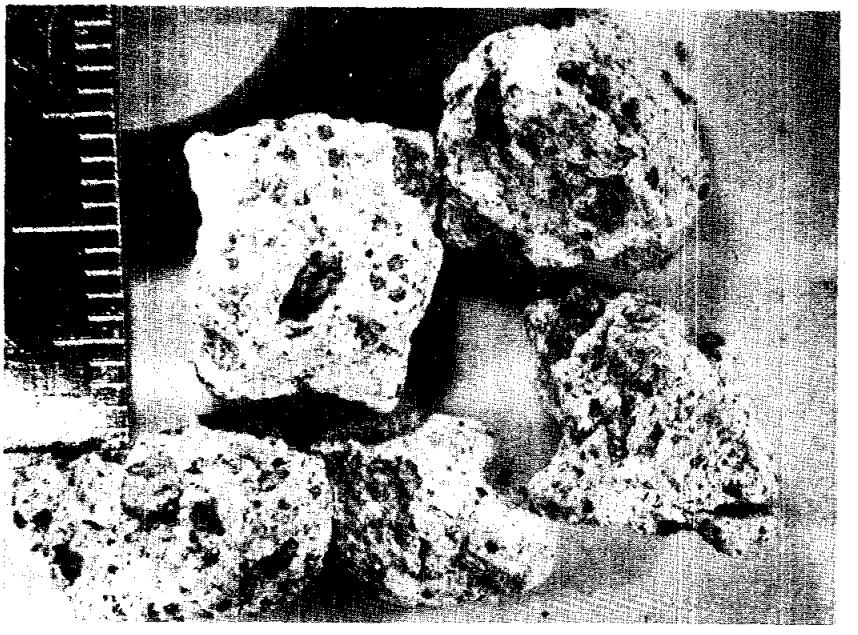
67016,70 0.990 g

Bulk rock chip. Two 0.5 cm white clasts with pale yellow mafic minerals and streaks of opaques or glass are situated on the edges of this split where sampling would be facilitated. One of the clasts accounts for about 1/3 of the total split and is estimated to weigh about 0.3 g. This split is entirely of interior breccia.



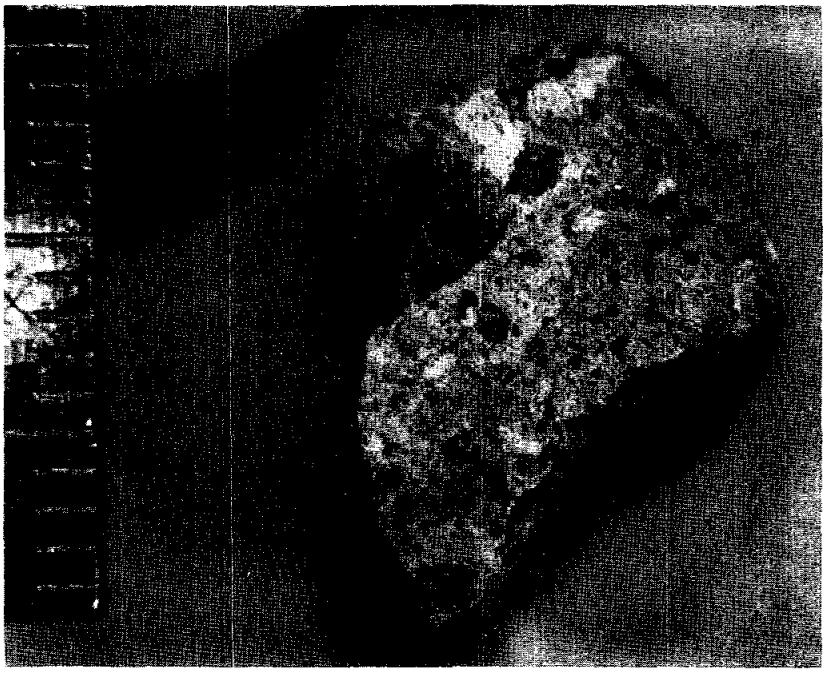
67016,74 5.750 g

Five bulk rock chips. One of the chips has one exterior surface; the others appear to have all interior surfaces.



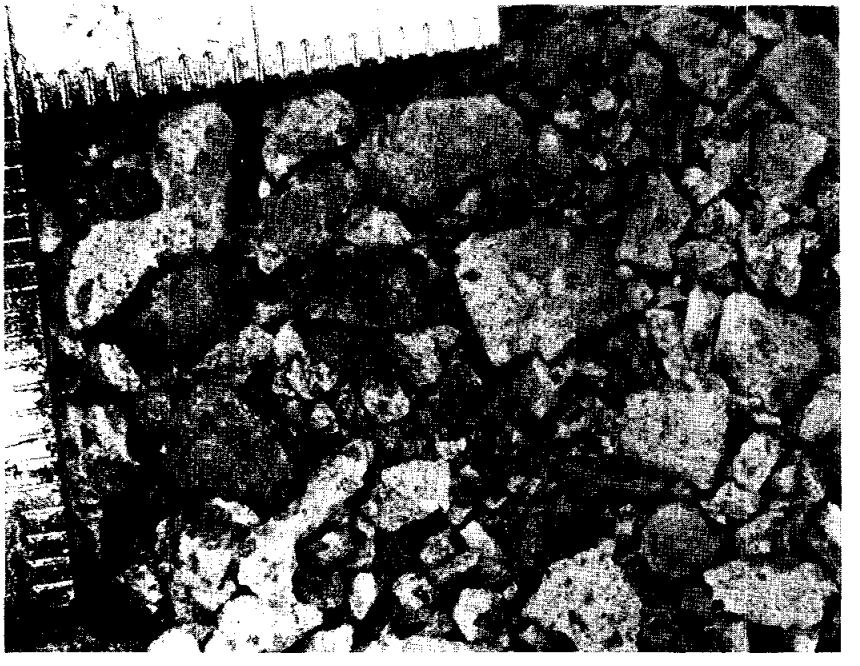
67016,85 1.150 g

Bulk rock chip with all interior surfaces.



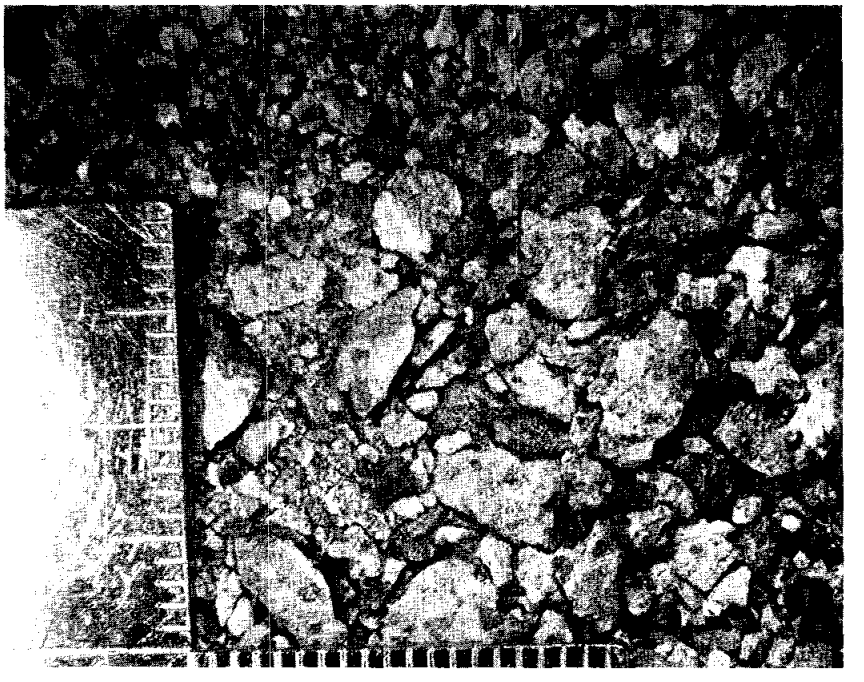
67016,92 11.610 g

This split consists of mixed small chips and fines. Separated dark clast material is abundant and several small pieces of pale green, granular clasts could also be picked out.



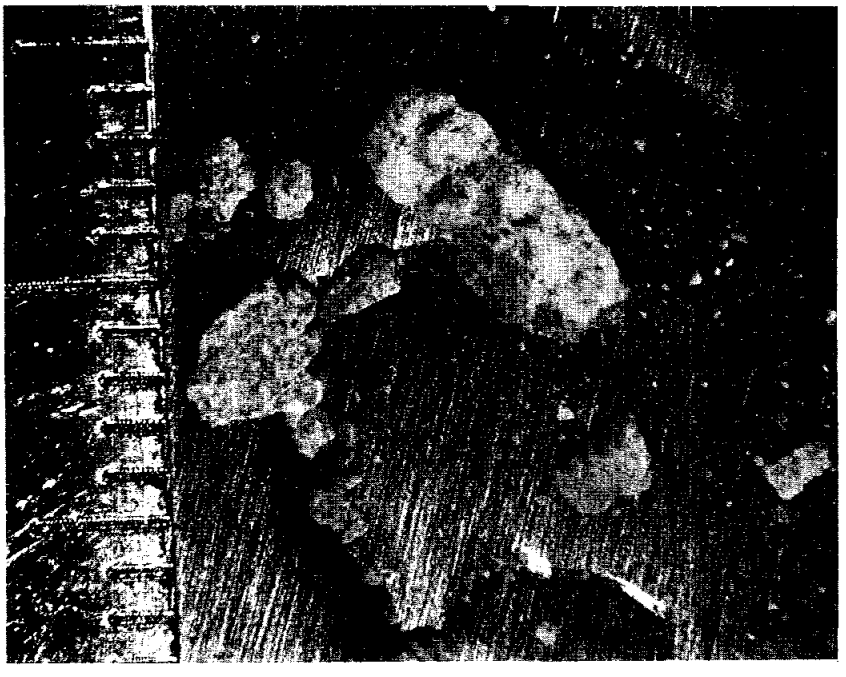
67016,93 5.770 g

Mixed chips and fines.



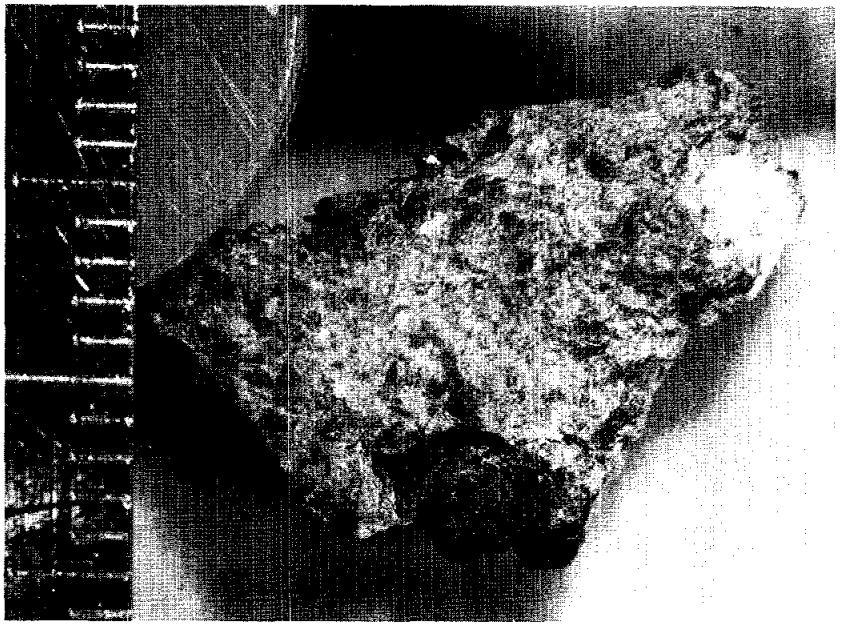
67016,95 0.050 g

This is a nearly pure split of white clast material with 20-30% pale yellow mafic minerals. A small amount of bulk rock matrix forms a rind on the largest chip of this split.



67016,96 1.260 g

This split appears to be a single fragment of dark clast material which has been sheared on one side. One side of the split is dark and vitreous and grades to the sheared surface which is lighter in color but still vitreous. No exterior surfaces are present.

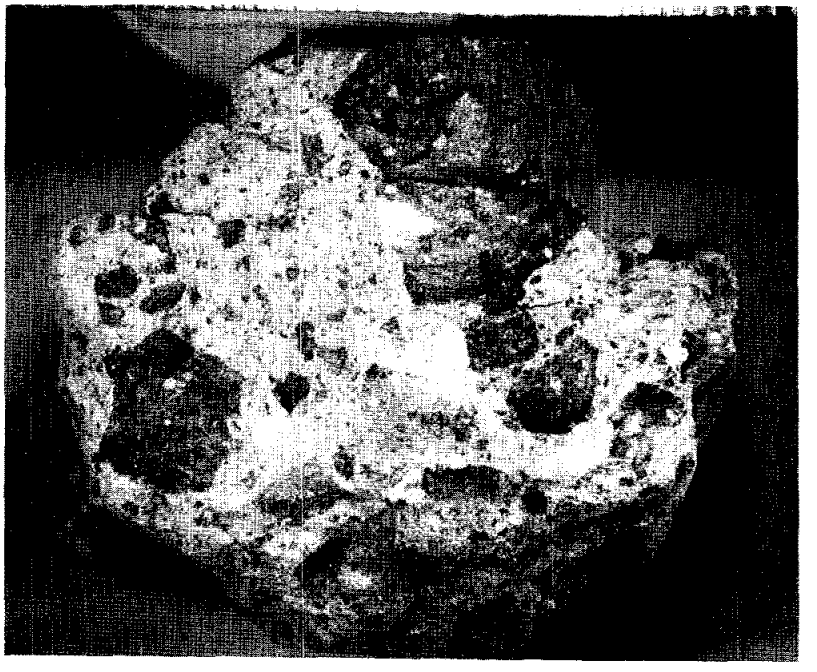


67016,98 5.320 g

Bulk rock chip. Several 1 mm crystals of a bright green mineral are scattered through the matrix.

67016,99 21.130 g

Bulk rock chip. A 1 cm chalky white clast with <1% visible mafic minerals is enclosed by a rind of dark melt breccia. This same white clast is also present on an interior face of split ,102. One face of ,99 is an exterior surface.



67016,101 1.050 g

This split is a collection of assorted chips and fines produced during the splitting of ,3 into ,98-,102.

67016,102 53.580 g

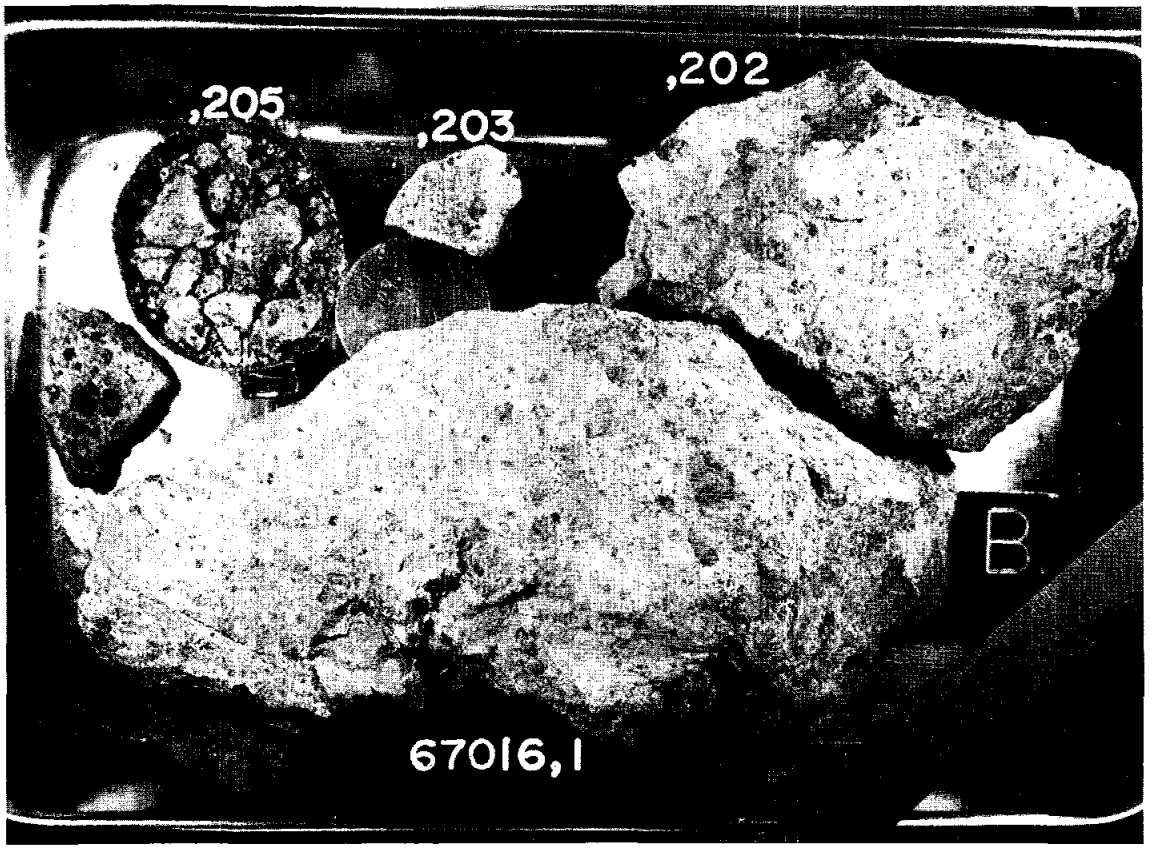
This split of bulk rock contains the same 1 cm white clast as ,99, and a diverse assemblage of other clasts. Two of the faces show evidence for exposure at the lunar surface.

67016,176 0.040 g

This split is tray sweepings produced during the removal of ,167-,174 and ,177 from ,10.

67016,202 669.700 g

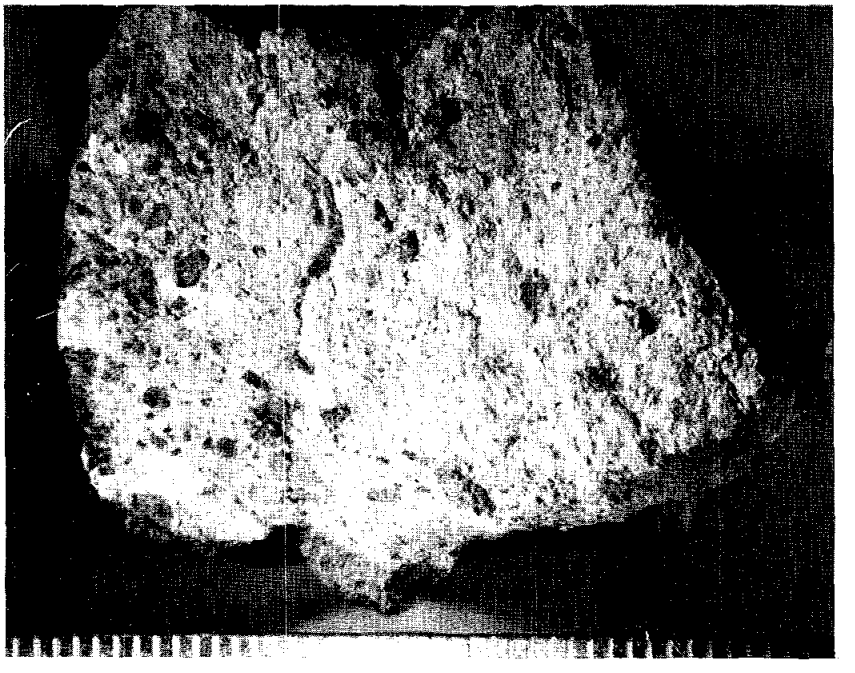
This large piece of bulk rock is stored at the Brooks Remote Storage Vault and is unavailable for inspection or allocation at this time.



S75-31798

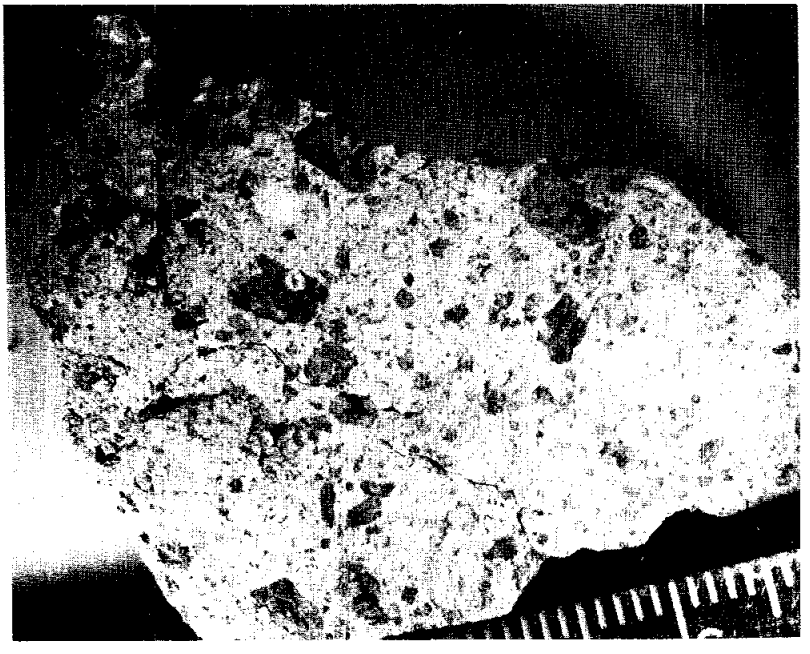
67016,203 28.360 g

Bulk rock chip. One exterior surface with a heavy patina is present.



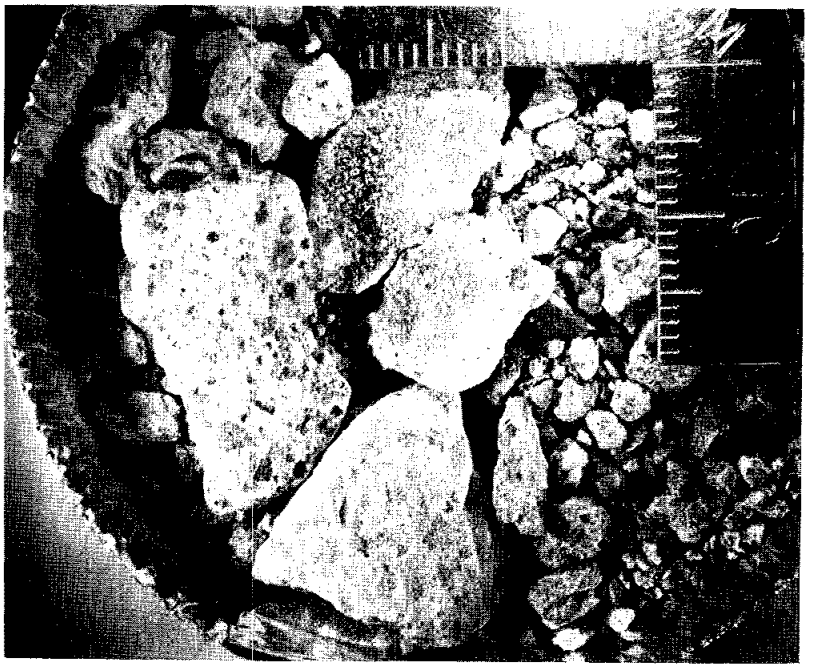
67016,204 23.630 g

Bulk rock chip. A 0.5 cm white clast with pale yellow mafic minerals is present on one edge and could be easily sampled. A 0.3 cm granular clast with a pale green color is present on one of the interior surfaces. Three faces of this split are exterior surfaces.



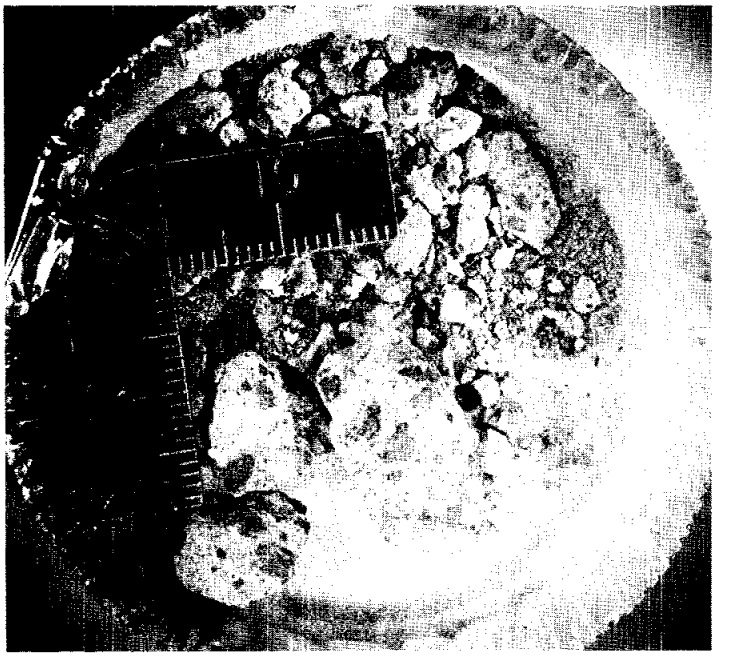
67016,205 29.190 g

This is a split of mixed chips and fines with a considerable amount of very fine dust. Most of the large pieces are of bulk rock, many of which have exterior surfaces.



67016,261 7.838 g

This is a split of mixed chips and fines produced to bring split ,9 down to the desired weight for allocation.



Appendix 1. Thin Sections

All sections are of bulk rock chips except as noted.
JSC = Lunar Sample curator's library

Section No.	Parent	Location
,105	,51	JSC
,106	,51	Adams
,107	,51	JSC
,108	,61	James
,109	,61	James
,110	,71	James
,111	,71	JSC
,112	,76	JSC
,113	,76	Strangway
,114	,77	James
,115	,77	JSC
,116	,71	Meyer
,117	,61	JSC
,140	,83	JSC (P.I.-made, subophitic impact melt clast)
,141	,83	JSC (P.I.-made, unpolished, dark clast)
,187	,71	James
,188	,71	James
,189	,169	JSC (dark clast)
,190	,169	JSC (dark clast)
,191	,171	JSC (light clast)
,192	,171	JSC (light clast)
,237	,162	JSC (P.I.-made, dark clast)
,240	,162	JSC (P.I.-made)

Appendix 2. Allocations Outstanding

All samples are bulk rock chips except as noted.
TS = thin section

Sample No.	Parent	Weight (g)	P.I.
,4	,0	93.49	Public Affairs Office (PAO)
,9	,0	20.00	Haskin
,41	,89	0.68	PAO
,42	,89	0.80	PAO
,43	,89	0.55	PAO
,52	,2	1.68	Reed, G. W.
,57	,2	2.15	Reed, G. W.
,59	,2	0.49	Lal
,60	,2	1.76	Housley
,62	,2	5.28	Strangway
,64	,2	2.08	Reed, G. W.
,65	,2	0.62	Lal
,69	,2	0.22	Lal
,75	,2	1.04	Strangway
,88	,2	2.99	Gibson
,97	,1	0.58	Turner (dark clast)
,100	,3	0.55	Turner
,106	,51	0.01	Adams (TS)
,108	,61	0.01	James (TS)
,109	,61	0.01	James (TS)
,110	,71	0.01	James (TS)
,113	,76	0.01	Strangway (TS)
,114	,77	0.01	James (TS)
,116	,71	0.01	Meyer (TS)
,168	,10	0.01	Rhodes (dark clast)
,173	,10	0.93	Wanke
,174	,10	1.49	Rhodes
,175	,11	0.46	Rhodes
,187	,71	0.01	James (TS)
,188	,71	0.01	James (TS)
,220	,126	1.05	PAO
,222	,126	0.88	PAO
,225	,84	1.08	PAO
,226	,84	0.50	PAO
,227	,73	1.01	PAO
,228	,73	0.51	PAO
,229	,73	0.89	PAO
,230	,73	0.91	PAO
,259	,11	1.38	Des Marais
,9002	,88	1.03	Gibson

Appendix 3. Samples consumed or destroyed

Sample No.	Parent	Weight (g)	Consumed by
,123	,81	0.021	Oro
,127	,91	0.015	Oro
,129	,66	0.021	Friedman
,131	,87	1.600	Friedman
,132	,84	0.007	Adams
,133	,80	3.460	Wiik
,134	,82	1.136	Wiik
,137	,47	0.122	Ahrens
,138	,63	0.285	Taylor, S. R.
,142	,83	0.111	Andersen
,143	,73	0.026	Heier
,166	,86	0.474	Heier
,196	,90	0.285	Destroyed, JSC
,197	,90	0.078	Destroyed, JSC
,198	,90	0.001	Destroyed, JSC
,201	,78	0.342	Ehmann
,215	,90	0.223	Destroyed, JSC
,216	,90	0.213	Destroyed, JSC
,217	,90	0.199	Destroyed, JSC
,218	,89	0.007	Kirsten
,233	,167	0.025	Anders
,234	,170	0.032	Anders
,235	,172	0.054	Anders
,241	,162	0.656	Lally

Appendix 4. Returned samples (single chip unless otherwise indicated).

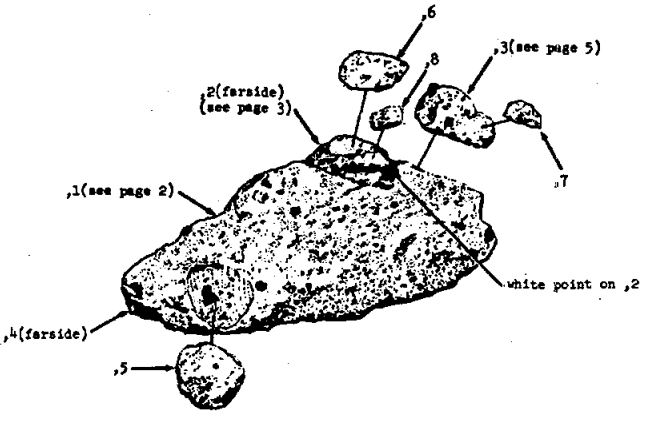
Split	Current Mass (g)	Returned by	State of Degradation
,46	2.980	Silver	unopened
,47	2.898	Ahrens	<0.074 mm, exposed to air, irradiated by X-rays
,48	3.120	Silver	unopened
,49	2.990	Silver	unopened
,50	0.640	Silver	unopened
,63	2.175	S.R. Taylor	<0.1 mm fines, exposed to air
,73	2.709	Heier	chips and fines, exposed to air
,74	2.070	Fitton	4 chips, unopened
,80	0.060	Wiik	powder, exposed to air
,82	0.114	Wiik	powder, exposed to air
,83	0.448	Andersen	chips and fines, exposed to air, oxygen, admixed with epoxy
,84	0.094	Adams	fines, exposed to air, trace element degraded
,85	1.150	Silver	unopened
,89	0.986	Kirsten	chips and fines, organically degraded, exposed to air
,90	0.001	Moore	fines
,94	2.082	JSC	freon fines
,95	0.050	Silver	unopened
,96	1.260	Silver	unopened
,98	5.320	Silver	unopened
,99	21.130	Silver	unopened
,101	1.050	Silver	unopened
,119	0.210	Oro	crushed, exposed to air, heated to 1100oC in vacuum, organically degraded
,120	0.043	Oro	crushed, admixed with terrestrial dust, exposed to air
,121	1.006	Oro	crushed, exposed to air
,122	0.536	Oro	chips and fines, exposed to air
,124	0.230	Oro	crushed, exposed to air, heated to 1100oC in vaccum, organically degraded
,125	0.605	Oro	fines, exposed to air
,126	0.675	Oro	chips and fines, exposed

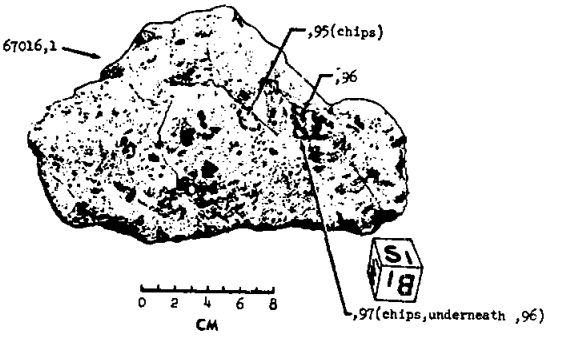
Split	Current Mass (g)	Returned by	State of Degradation
			to air
,128	4.989	Friedman	chips, exposed to air, heated to 1100oC in oxygen
,130	3.400	Friedman	chips, melted by heating to 1300oC in vacuum, then heated to 1100oC in oxygen
,135	1.011	Ahrens	XRF pellet
,136	0.839	Ahrens	three fused discs
,139	0.021	Keith	exposed to air, organically degraded
,140	0.001	Andersen	P.I.-made probe mount
,141	0.500	Andersen	P.I.-made unpolished mounted butt
,144	0.041	Heier	crushed, irradiated with neutrons, washed in ethanol, heated to 100oC in air
,145	0.052	Heier	crushed, irradiated with neutrons, washed in ethanol, heated to 100oC in air
,146	0.007	Heier	crushed, irradiated with neutrons, washed in ethanol, heated to 100oC in air
,147	0.010	Heier	crushed, irradiated with neutrons, washed in ethanol, heated to 100oC in air
,148	0.058	Heier	crushed, irradiated with neutrons, washed in ethanol, heated to 100oC in air
,149	0.063	Heier	crushed, irradiated with neutrons, washed in ethanol, heated to 100oC in air
,150	0.009	Heier	plagioclase concentrate, irradiated with neutrons, washed with ethanol, heated to 100oC in air
,151	0.013	Heier	plagioclase concentrate, irradiated with neutrons, washed with ethanol, heated to 100oC in air
,152	0.010	Heier	crushed, irradiated with neutrons, washed in ethanol, heated to 100oC in air
,153	0.010	Heier	crushed dark fragments, irradiated with neutrons, washed with ethanol, heated to 100oC in air
,154	0.102	Heier	plagioclase concentrate,

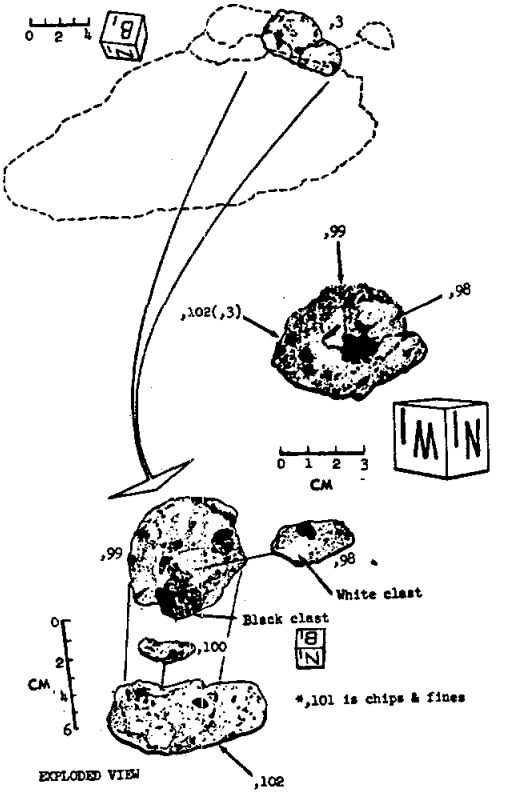
Split	Current Mass (g)	Returned by	State of Degradation
			irradiated with neutrons, washed with ethanol, heated to 100oC in air
,155	0.102	Heier	plagioclase concentrate, irradiated with neutrons, washed with ethanol, heated to 100oC in air
,156	0.068	Heier	crushed, irradiated with neutrons, washed in ethanol, heated to 100oC in air
,157	0.074	Heier	crushed, irradiated with neutrons, washed in ethanol, heated to 100oC in air
,158	1.780	Heier	<0.15 mm magnetic separate, washed with ethanol, heated to 75oC in air
,159	0.575	Heier	<0.6 mm grind, washed with ethanol, heated to 75oC in air
,160	0.009	Heier	separate of dark fragments, washed in ethanol, heated to 75oC in air
,161	0.046	Heier	plagioclase concentrate, washed in ethanol, heated to 75oC in air
,162	0.487	Lally	chips and fines, exposed to air
,164	0.117	Heier	crushed, exposed to air, washed in ethanol
,165	0.300	Heier	XRF pellet
,167	0.015	Anders	exposed to air
,170	0.018	Anders	crushed, exposed to air
,172	0.076	Anders	crushed, exposed to air
,194	1.707	Warren	unopened
,199	0.479	Ehmann	two chips and fines, exposed to air
,200	0.339	Ehmann	fines, exposed to air, irradiated with neutrons
,219	0.557	Bhandari	chips and fines, exposed to air, washed in ethanol
,221	0.508	PAO	exposed to air, organically degraded
,223	0.750	PAO	exposed to air, organically degraded
,236	0.001	Lally	potted butt
,237	0.001	Lally	P.I.-made thin section, dark clast

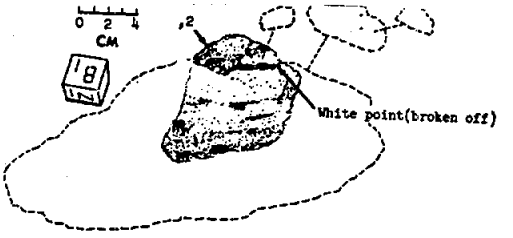
Split	Current Mass (g)	Returned by	State of Degradation
,238	0.001	Lally	dark clast, TEM foil, exposed to air
,239	0.001	Lally	TEM foil, exposed to air
,240	0.001	Lally	P.I.-made thin section, bulk rock
,242	0.024	PAO	exposed to air, organically degraded
,243	0.027	PAO	exposed to air, organically degraded
,9003	1.100	Bhandari	potted butt

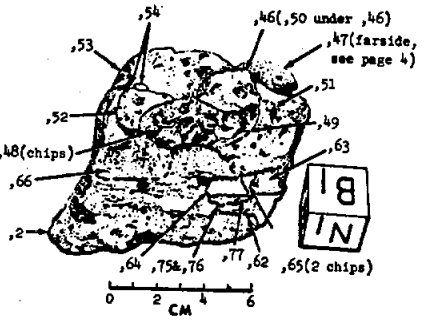
Appendix 5. Drawings of the locations of splits taken from 67016 prior to Feb., 1973, and a flowchart of all splits created prior to June, 1981.

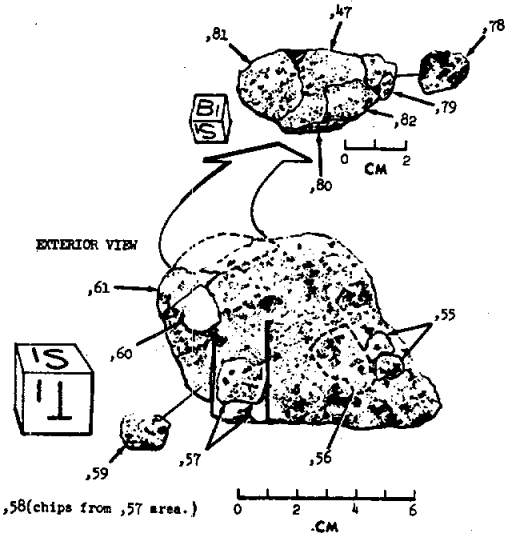


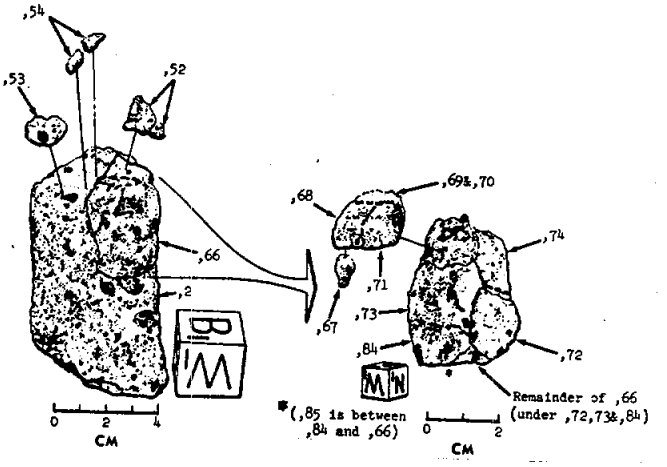


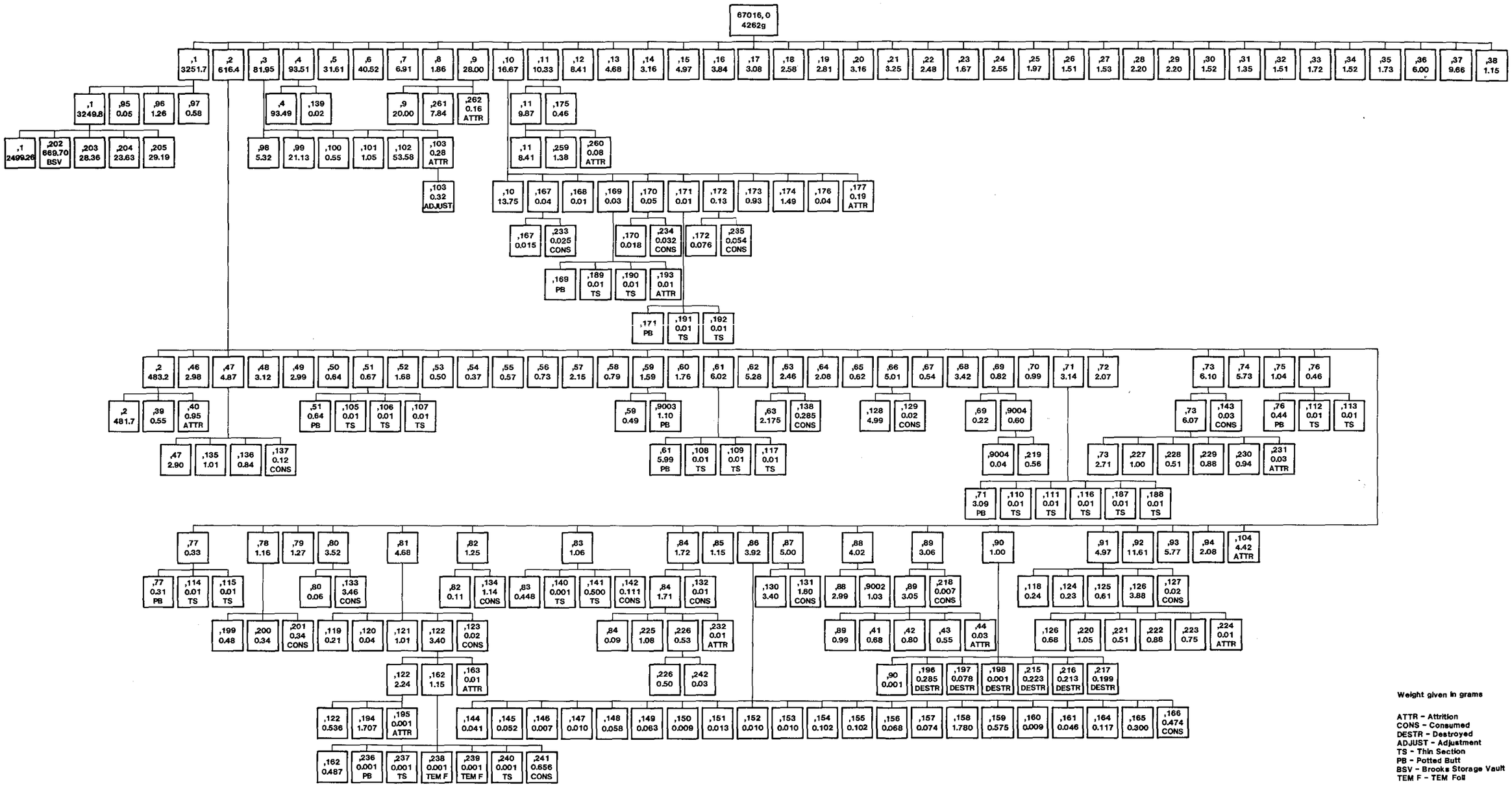



0 2 4
CM
,2
White point(broken off)


,54
,46(,50 under ,46)
,47(farside, see page 4)
,53
,51
,52
,49
,48(chips)
,63
,66
,2
,64
,75&,76
,77
,62
,65(2 chips)
0 2 4 6
CM


,47
,81
,78
,79
,82
,80
0 CM 2
EXTERIOR VIEW
,61
,55
,60
,57
,56
,59
,58(chips from ,57 area.)
0 2 4 6
CM


,54
,53
,52
,66
,2
0 2 4
CM
,68
,69&,70
,74
,71
,73
,67
,84
,72
Remainder of ,66 (under ,72,73&,84)
*(,85 is between ,84 and ,66)
0 2
CM



Weight given in grams

ATTR - Attrition
CONS - Consumed
DESTR - Destroyed
ADJUST - Adjustment
TS - Thin Section
PB - Potted Butt
BSV - Brooks Storage Vault
TEM F - TEM Foil

REFERENCES

Bhandari N., Goswami J., and Lal D. (1973) Surface irradiation and evolution of the lunar regolith. Proc. Lunar Sci. Conf. 4th, p. 2275-2290.

Brunfelt A.O., Heier K.S., Nilssen B., Sundvoll B., and Steinnes E. (1973) Geochemistry of Apollo 15 and 16 materials. Proc. Lunar Sci. Conf. 4th, p. 1209-1218.

Cripe J.D. and Moore C.B. (1974) Total sulfur contents of Apollo 15 and Apollo 16 lunar samples. In. Lunar Science V, p. 523-525. The Lunar Science Institute, Houston.

Delano J.W., Bence A.E., Papike J.J., and Cameron K.L. (1973) Petrology of the 2-4 mm soil fraction from the Descartes region of the moon and stratigraphic implications. Proc. Lunar Sci. Conf. 4th, p. 537-551.

Duncan A.R., Erlank A.J., Willis J.P., and Ahrens L.H. (1973) Composition and inter-relationships of some Apollo 16 samples. Proc. Lunar Sci. Conf. 4th, p. 1097-1113.

Eldridge J.S., O'Kelley G.D., and Northcutt K.J. (1975) Primordial and cosmogenic radionuclides in Descartes and Taurus-Littrow materials: extension of studies by nondestructive γ-ray spectrometry. Proc. Lunar Sci. Conf. 6th, p. 1407-1418.

Flory D.A., Oro J., Wikstrom S.A., Beaman D.A., and Lovett A. (1973) Organogenic compounds in Apollo 16 lunar samples. Proc. Lunar Sci. Conf. 4th, p. 2229-2240.

Garg A.N. and Ehmann W.N. (1976) Zr-Hf fractionation in chemically defined lunar rock groups. Proc. Lunar Sci. Conf. 7th, p. 3397-3410.

Gibson E.K., Jr. and Chang S. (1974) Abundance and isotopic composition of carbon in lunar rock 67016: suggestions of a carbonate-like phase. In Lunar Science V, p. 264-266. The Lunar Science Institute, Houston.

Gibson E.K., Jr. and Moore G.W. (1975) Breccias and crystalline rocks from Apollo 16 which contain carbonate-like phases. In Lunar Science VI, p. 287-289. The Lunar Science Institute, Houston.

Gibson E.K., Jr. and Andrawes F.F. (1978) Nature of the gases released from lunar rocks and soils upon crushing. Proc. Lunar Planet. Sci. Conf. 9th, p. 2433-2450.

Hertogen J., Janssens M.-J., Takahashi H., Palme H., and Anders E. (1977) Lunar basins and craters: Evidence for systematic compositional changes of bombarding population. Proc. Lunar Sci. Conf. 8th, p. 17-45.

Hodges C.A., Muehlberger W.R., and Ulrich G.E. (1973) Geologic setting of Apollo 16. Proc. Lunar Sci. Conf. 4th, p. 1-25.

Housley R.M., Cirlin E.H., Goldberg I.B., and Crowe H. (1976) Ferromagnetic resonance studies of lunar core stratigraphy. Proc. Lunar Sci. Conf. 7th, p. 13-26.

Janghorbani M., Miller M.D., Ma M.-S., Chyi L.L., and Ehmann W.D. (1973) Oxygen and other elemental abundance data for Apollo 14, 15, 16, and 17 samples. Proc. Lunar Sci. Conf. 4th, p. 1115-1126.

Jovanovic S. and Reed G.W., Jr. (1973) Volatile trace elements and the characterization of the Cayley Formation and the primative lunar crust. Proc. Lunar Sci. Conf. 4th, p. 1313-1324.

Lindstrom M.M. and Salpas P.A. (1981) Geochemical studies of rocks from North Ray Crater, Apollo 16. Proc. Lunar Planet. Sci. Conf. 12th, in press.

Marvin U.B. (1980) Breccia guidebook no. 4, 67015. JSC publication 16671, 69 pp.

Moore C.B. and Lewis C.F. (1976) Total nitrogen contents of Apollo 15, 16 and 17 lunar rocks and breccias. In Lunar Science VII, p. 571-573. The Lunar Science Institute, Houston.

Moore C.B., Lewis C.F., and Gibson E.K., Jr. (1973) Total carbon contents of Apollo 15 and 16 lunar samples. Proc. Lunar Sci. Conf. 4th, p. 1613-1623.

Nord G.L., Christie J.M., Heuer A.H., and Lally J.S. (1975) North Ray Crater breccias: an electron petrographic study. Proc. Lunar Sci. Conf. 6th, p. 779-797.

Norman M.D. (1981) Petrology of suevitic lunar breccia 67016. Proc. Lunar Planet. Sci. Conf. 12th, in press.

Pearce G.W., Gose W.A., and Strangway D.W. (1973) Magnetic studies of Apollo 15 and 16 lunar samples. Proc. Lunar Sci. Conf. 4th, p. 3045-3076.

Stoffler D., Knoll H.-D., and Maerz U. (1979) Terrestrial and lunar impact breccias and the classification of lunar highlands rocks. Proc. Lunar Planet. Sci. Conf. 10th, p. 639-675.

Stoffler D., Knoll H.-D., Marvin U.B., Simonds C.H., and Warren P.H. (1980) Recommended classification and nomenclature of lunar highlands rocks-a committee report. Proc. Conf. Lunar Highlands Crust (Papike J.J. and Merrill R.B., eds.), p. 51-70.

Taylor G.J., Drake M.J., Hallam M.E., Marvin U.B., and Wood J.A. (1973) Apollo 16 stratigraphy: the ANT hills, the Cayley Plains, and a pre-Imbrian regolith. Proc. Lunar Sci. Conf. 4th, p. 553-568.

Taylor S.R., Gorton M.P., Muir P., Nance W., Rudowski R., and Ware N. (1974) Lunar highland composition. In Lunar Science V, p. 789-791. The Lunar Science Institute, Houston.

Turner G. and Cadogan P.H. (1975) The history of lunar bombardment inferred from ^{40}Ar-^{39}Ar dating of highland rocks. Proc. Lunar Sci. Conf. 6th, p. 1509-1538.

Ulrich G.E. (1973) A geologic model for North Ray Crater and stratigraphic implications for the Descartes region. Proc. Lunar Sci. Conf. 4th, p. 27-39.

Wanke H., Palme H., Kruse H., Baddenhausen H., Cendales M., Dreibus G., Hofmeister H., Jagoutz E., Palme C., Spettel B., and Thacker R. (1976) Chemistry of lunar highlands rocks: a refined evaluation of the composition of the primary matter. Proc. Lunar Sci. Conf. 7th, p. 3479-3499.

Wanke H., Baddenhausen H., Blum K., Cendales M., Driebus G., Hofmeister H., Kruse H., Jagoutz E., Palme C., Spettel B., Thacker R., and Vilcsek E. (1977) On the chemistry of lunar samples and achondrites. Primary matter in the lunar highlands: a reevaluation. Proc. Lunar Sci. Conf. 8th, p. 2191-2213.

Warner J.L., Simonds C.H., and Phinney W.C. (1973) Apollo 16 rocks: Classification and petrogenetic model. Proc. Lunar Sci. Conf. 4th, p. 481-504.

Wilshire H.G., Stuart-Alexander D.G., and Jackson E.D. (1973) Apollo 16 rocks: Petrology and classification. J. Geophys. Res. 78, 2379-2392.