NASA

National Aeronautics and
Space Administration

Curatorial Branch

Lyndon B. Johnson Space Center
Houston, Texas 77058

Publication 52

September 1980

JSC 16904

CATALOG OF APOLLO 16 ROCKS

Part 3. 67015 - 69965

Graham Ryder and Marc D. Norman

(Lunar Curatorial Laboratory, Northrop Services, Inc.)

CATALOG OF APOLLO 16 ROCKS

GRAHAM RYDER AND MARC D. NORMAN
(Northrop Services, Inc.)

September, 1980

TABLE OF CONTENTS

INTRODUCTION: 67015 is a friable breccia with a light-colored matrix and light and dark colored clasts (Fig. 1). The light colored clasts include plagioclases, feldspathic granulitic impactites, and anorthositic breccias; the dark-colored clasts include aphantic, glassy, and fine-grained basaltic impact melts.

The sample was collected from the southeast rim of North Ray Crater. It was approximately half-buried. It is subangular and fractured, and lacks zap pits, probably because its surface is fragile.

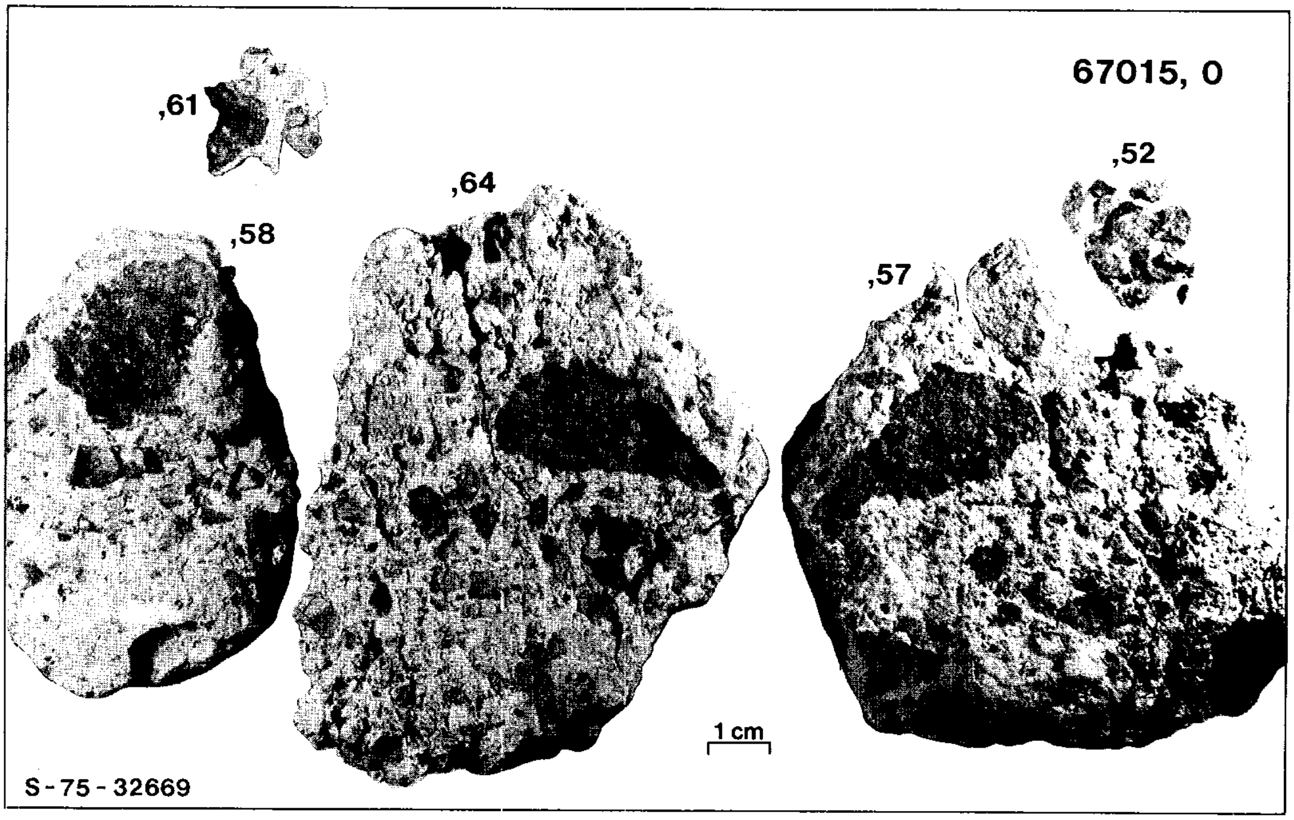
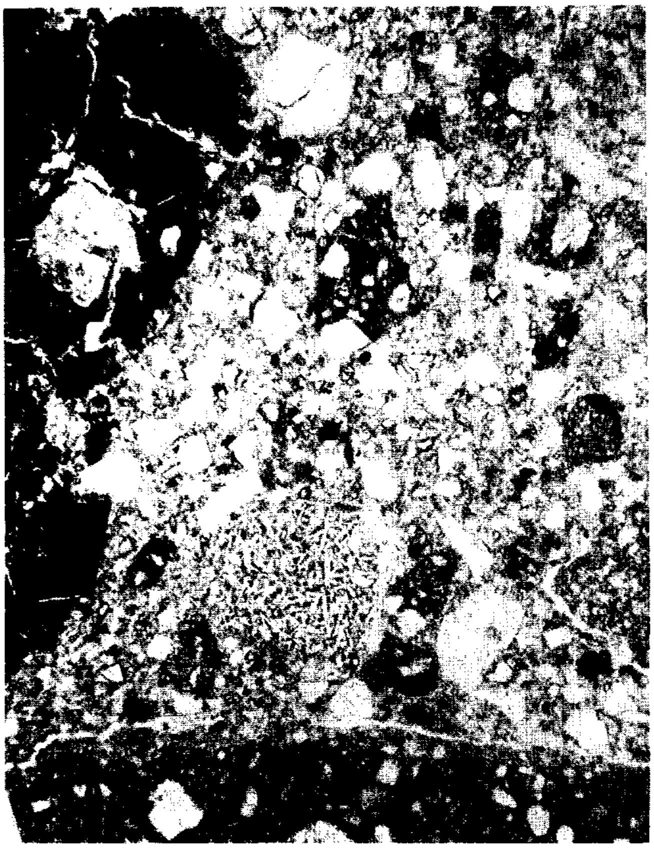


Figure 1.

PETROLOGY: Brief petrographic descriptions are presented by Juan et al. (1974) and McGee et al. (1979). The latter also provide some microprobe data. A guidebook by Marvin (1980) reports macroscopic observations of several subsamples.

The sample is inhomogeneous on the centimeter scale. It is porous, fragmental, and polymict (Fig. 2). McGee et al. (1979) report a mode for thin section ,74: 55% matrix (fragments <39 μm), 13% mineral clasts (mainly plagioclase), 5% fragmental breccias, 17% crystalline breccias, and 10% granulitic/metamorphic fragments. Ilmenite, spinel and orange glass are present. Most of the dark clasts are aphanitic or glassy to fine-grained basaltic impact melts (Fig. 2). Compositions of pyroxene and olivine fragments (McGee et al., 1979) are shown in Figure 3.

a



b

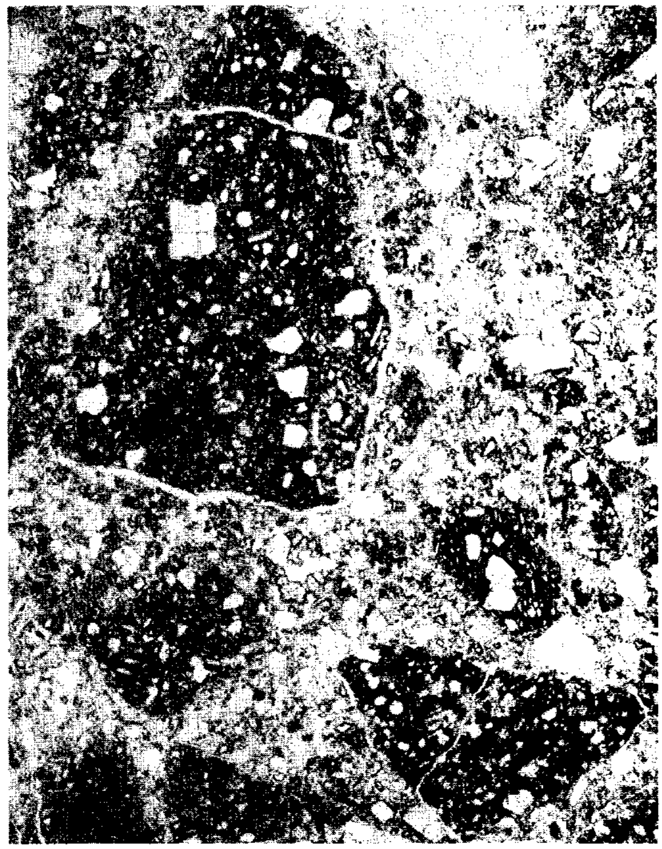


Figure 2. a) 67015,88, general view, ppl. width 2mm.
b) 67015,9, dark clasts and fragmental matrix, ppl. width 2mm.

CHEMISTRY: Chemical studies of both matrix and dark clasts are listed in Table 1 and a summary chemistry of the matrix in Table 2. The rare earth element data of Wänke et al. (1975) on the matrix are plotted in Figure 4.

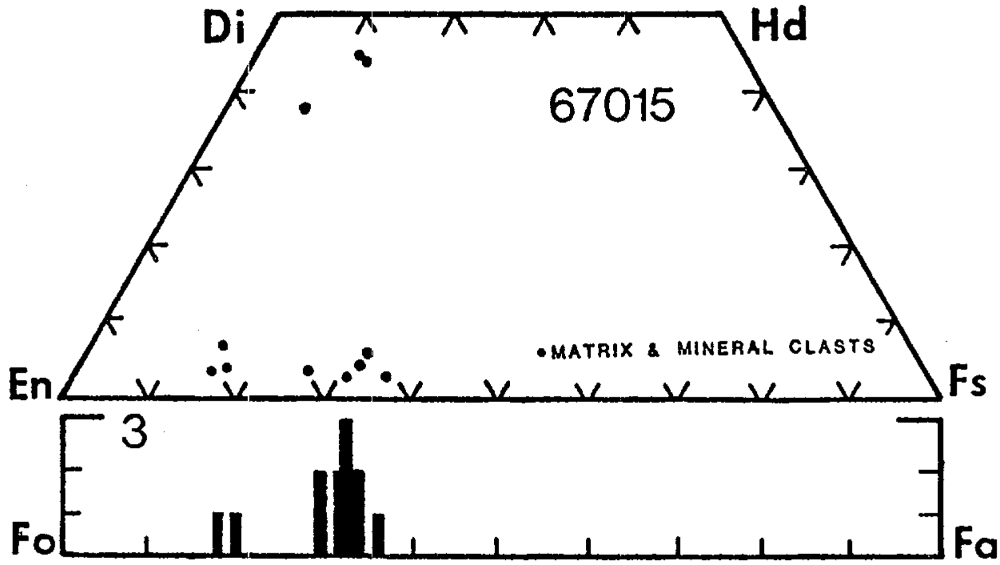


Figure 3. Olivine and pyroxene compositions, from McGee et al. (1979).

The matrix is very aluminous and although contaminated with meteoritic siderophiles, the level of contamination is quite low. The composition is distinct from that of local soils in its higher alumina and lower rare-earth and volatile elements. The rare-earth pattern has a distinct positive europium anomaly (Fig. 4). The matrix meteoritic signature is classified by Hertogen et al. (1977) as a hybrid lying between groups 5H and 5L. Because it lies on a mixing line between the group of other alkali-poor breccias (Group 7) and that of a separated dark clast (Group 1H), Hertogen et al. (1977) suggest that their matrix sample contained a small amount of dark clast material.

The partial analyses of dark clasts by Nunes et al. (1973), Rosholt (1974), and Hertogen et al. (1977) are similar to each other in U contents but the data pack evidence suggest that the analyses are of distinct clasts. The incompatible element abundances are ~5x those of the matrix and are similar to those of basaltic impact melts which have 23-25% Al_2O_3, and which petrographically appear to be the dominant dark clast type in 67015. The meteoritic signature (Group 1H) is similar to many other KREEP-rich crystalline Apollo 16 rocks (Hertogen et al., 1977).

TABLE 1. Chemical references for 67015

Reference	Split #	Description	Elements analyzed
Wänke *et al.* (1975)	,106	matrix	Majors, REEs, other trace (∿50 els.)
Wänke *et al.* (1977)	,106	matrix	V
Hertogen *et al.* (1977)	,104 m	matrix	Meteoritic siderophiles and volatiles
"	,104 c	dark clast	"
Modzeleski *et al.* (1973)	,33	matrix	C
Kerridge *et al.* (1975b)	,31	matrix	C,S Compounds
"	,39	matrix	"
Marti *et al.* (1973)	,14	matrix	K
Nunes *et al.* (1973)	,12	matrix	U, Th, Pb
"	,11	dark clast	"
Rosholt (1974)	,12*	matrix	U, Th
"	,11*	dark clast	"

*Same solutions as Nunes *et al.* (1973).

TABLE 2. Summary chemistry of 67015 matrix

SiO_2	46.0
TiO_2	0.48
Al_2O_3	29.5
Cr_2O_3	0.06
FeO	3.6
MnO	0.05
MgO	3.9
CaO	15.4
Na_2O	0.52
K_2O	0.08
P_2O_5	
Sr	195
La	4.9
Lu	0.24
Rb	∿1
Sc	7.5
Ni	39-110
Co	∿10
Ir ppb	1.8
Au ppb	0.6-1.0
C	∿20
N	
S	140-220
Zn	3-10
Cu	1.5

Oxides in wt%; others in ppm except as noted.

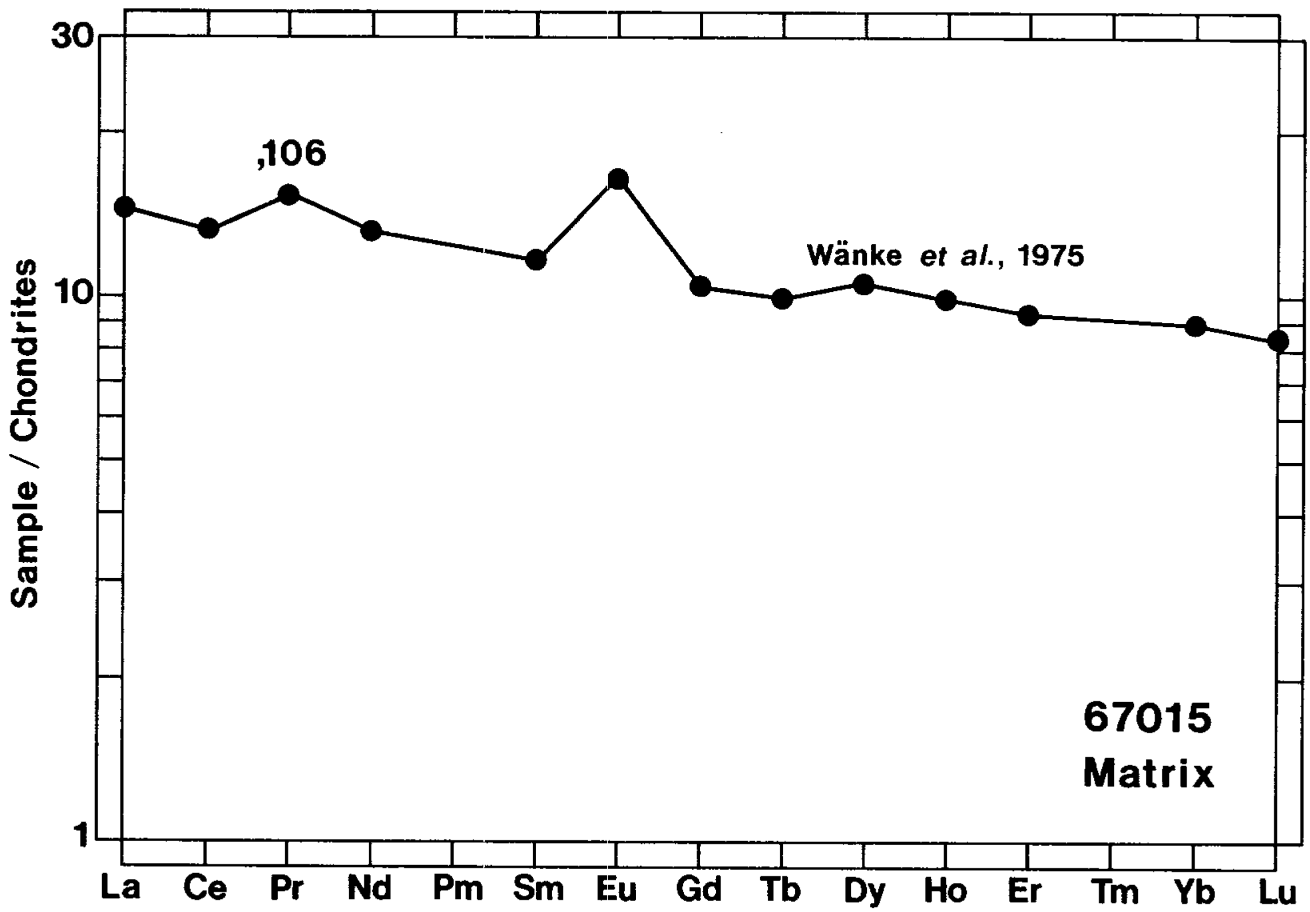


Figure 4. Rare earths.

STABLE ISOTOPES: Clayton et al. (1973) found δO^{18} (SMOW) values of +5.64 $^{o}/oo$ (matrix), +5.73 $^{o}/oo$ (plagioclase) and +5.64 $^{o}/oo$ (dark clast) in splits of ,32. The values are typical of lunar rocks.

Kerridge et al. (1975b) report C and S isotopic analyses for matrix splits ,31 and ,39 (Table 3). These values contrast with the strongly positive values of typical Apollo 16 soils.

TABLE 3. C and S isotopic data for 67015 (Kerridge et al., 1975b)

	$\delta^{13}C$	$\delta^{34}S$
67015,31	-19.3	-0.02
67015,39	-17.9	-2.2

GEOCHRONOLOGY AND RADIOGENIC ISOTOPES: Nunes et al. (1973) report U, Th, and Pb isotopic data for both matrix and dark clast materials. The lead in the dark clast is very radiogenic ($^{206}Pb/^{204}Pb \sim 1000$), but the matrix only moderately so ($^{206}Pb/^{204}Pb \sim 300$). The matrix plots well above concordia but the dark clast plots only slightly above it, and both lie within error of a 4.47-3.99 b.y. discordia line (Fig. 5). The precision of the data of Nunes et al. (1973) was questioned by Tera and Wasserburg (1974).

Rosholt (1974) analyzed samples of the solutions used by Nunes et al. (1973) for Th isotopic abundances.

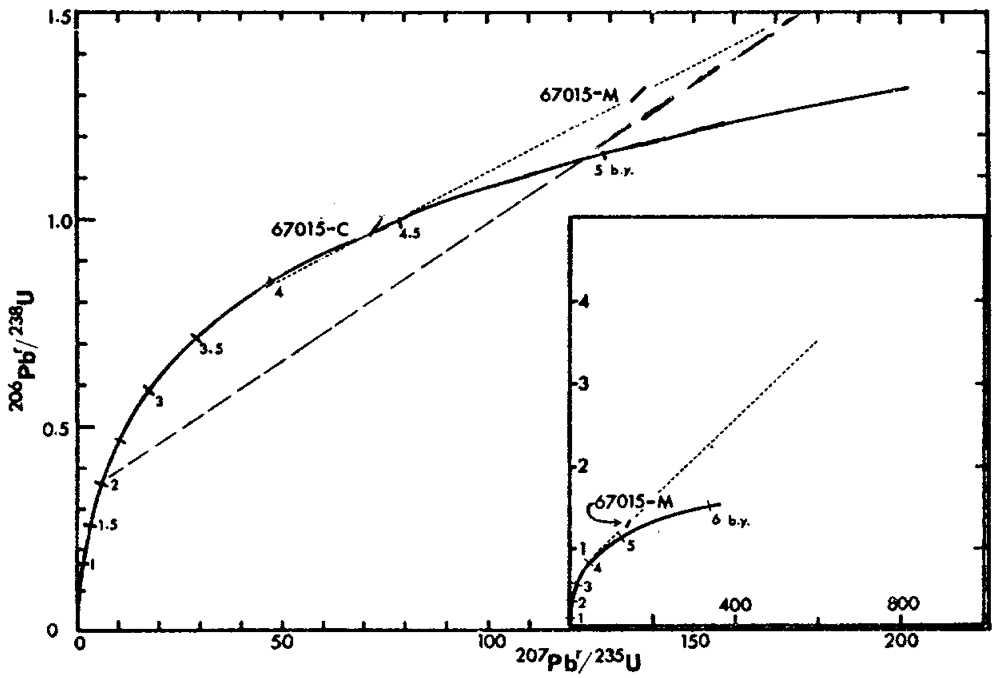


Figure 5. Concordia diagram, from Nunes et al. (1973).

RARE GASES, EXPOSURE AGES AND TRACKS: Marti et al. (1973) report Kr isotopic data for interior chip ,14. They calculate an exposure age of 51.1±5 m.y. which is similar to that of most other North Ray Crater samples. Lightner and Marti (1974b) report Xe isotopic data for the same chip.

Hohenberg et al. (1978) report Kr, Ar, and Xe isotopic data (also for ,14) and compare the observed with the predicted rates of production of cosmogenic noble gases.

MacDougall et al. (1973) did not find solar flare-produced particle tracks in either olivine or plagioclase grains in the matrix, and suggest that particle tracks have faded during heating events.

Hörz et al. (1975) quote a subdecimeter age (i.e. length of residence at less than 10 cm. burial) of 15 m.y. from Lal (pers. comm.) derived from particle track data. However, Hörz et al. (1975) list the sample mass appropriate for 67016, and according to curator records, Lal received a sample of 67016 but not 67015. This track age therefore probably has no relevance to 67015.

PHYSICAL PROPERTIES: Brecher (1977) reports that initial magnetic measurements were made on a 12 g bulk rock sample (,42) but the data are not reported. The sample was unreliable for a study of the influence of rock fabric as it affects magnetic characteristics.

Tsay and Baumann (1975) measured the ferromagnetic resonance of chip ,30. The results indicate that the metallic iron annealed to multidomain phases at temperatures of 800°-1000°C. ,30 contains a large portion of dark clast material, thus the data probably pertains to basaltic and glassy impact melts rather than bulk matrix.

PROCESSING AND SUBDIVISIONS: 67015 has been sawn in half and substantially subdivided as described by Marvin (1980). The initial subdivision was the removal of several small chips for various allocations (Fig. 6). In 1975, ,0 was sawn; the friability of the matrix caused pieces to break off. One end piece is ,57 (342 g) (Fig. 7). The other end piece (,0) split into 2 main pieces numbered ,64 (340.5 g) ,58 (109.14 g) and a small piece ,61 (2.24 g) (Figs. 7 and 8). ,64 is in remote storage. ,58 has been entirely subdivided leaving ,161 (32.7 g) and ,162 (31.0 g) as the larger of its derivatives.

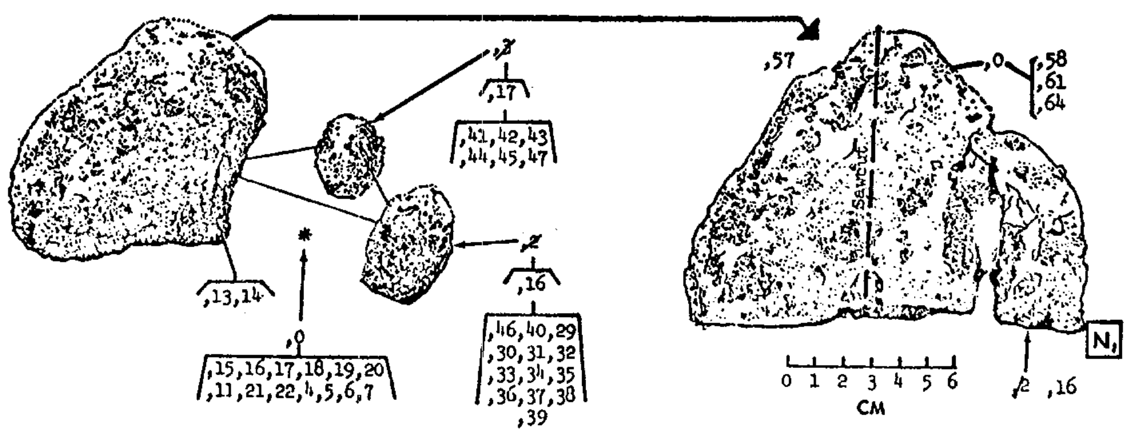


Figure 6. Major subdivisions of 67015.

INTRODUCTION: 67016 is a friable, light gray breccia with abundant light and dark clasts (Fig. 1). It was collected just outside the southeast rim of North Ray Crater; lunar orientation is known. Zap pits are present on all sides, with preserved exterior surfaces indicating a rather complex exposure history.

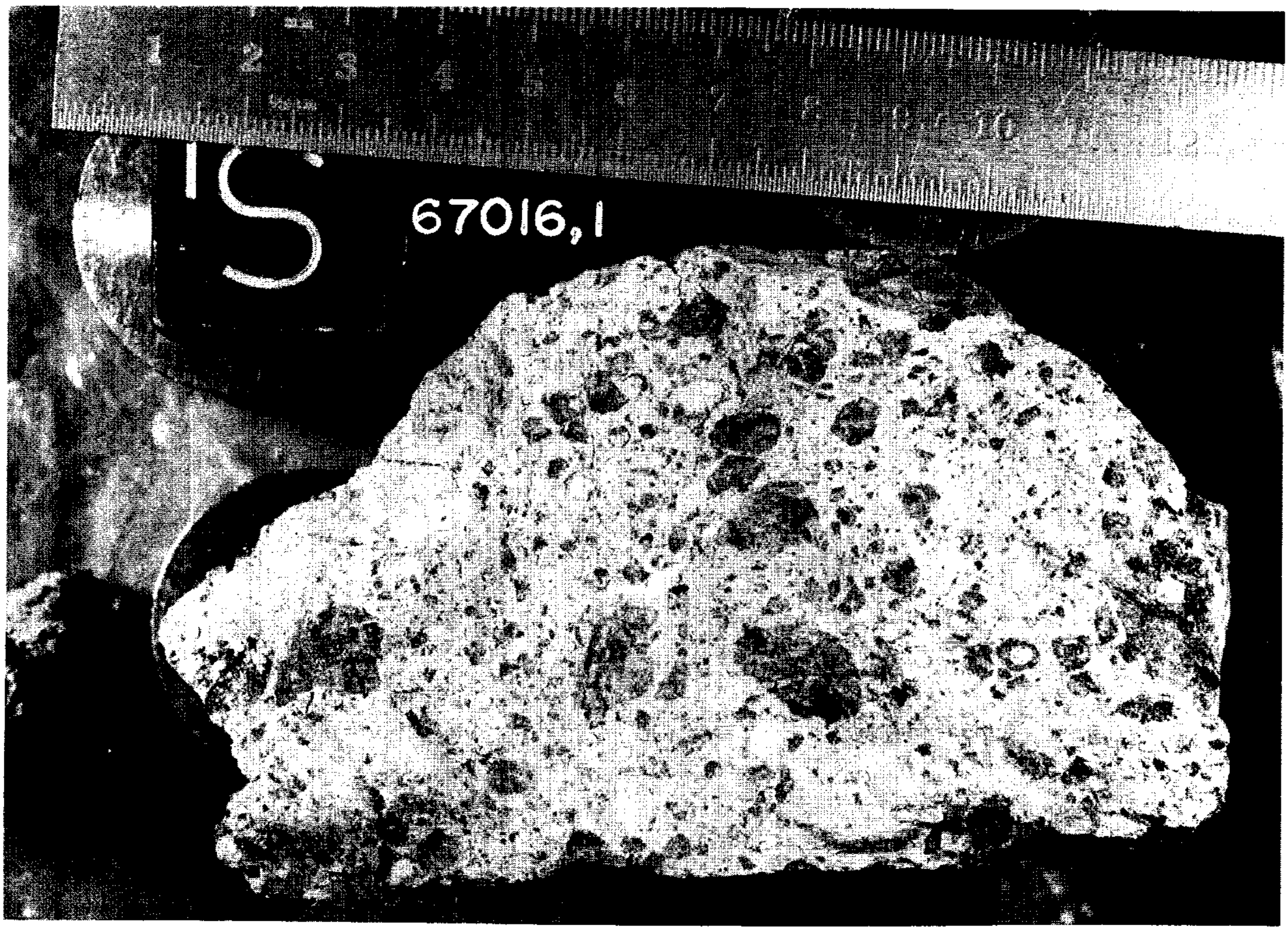


Figure 1. S-75-32783, smallest scale subdivision 0.5mm.

a b

c d

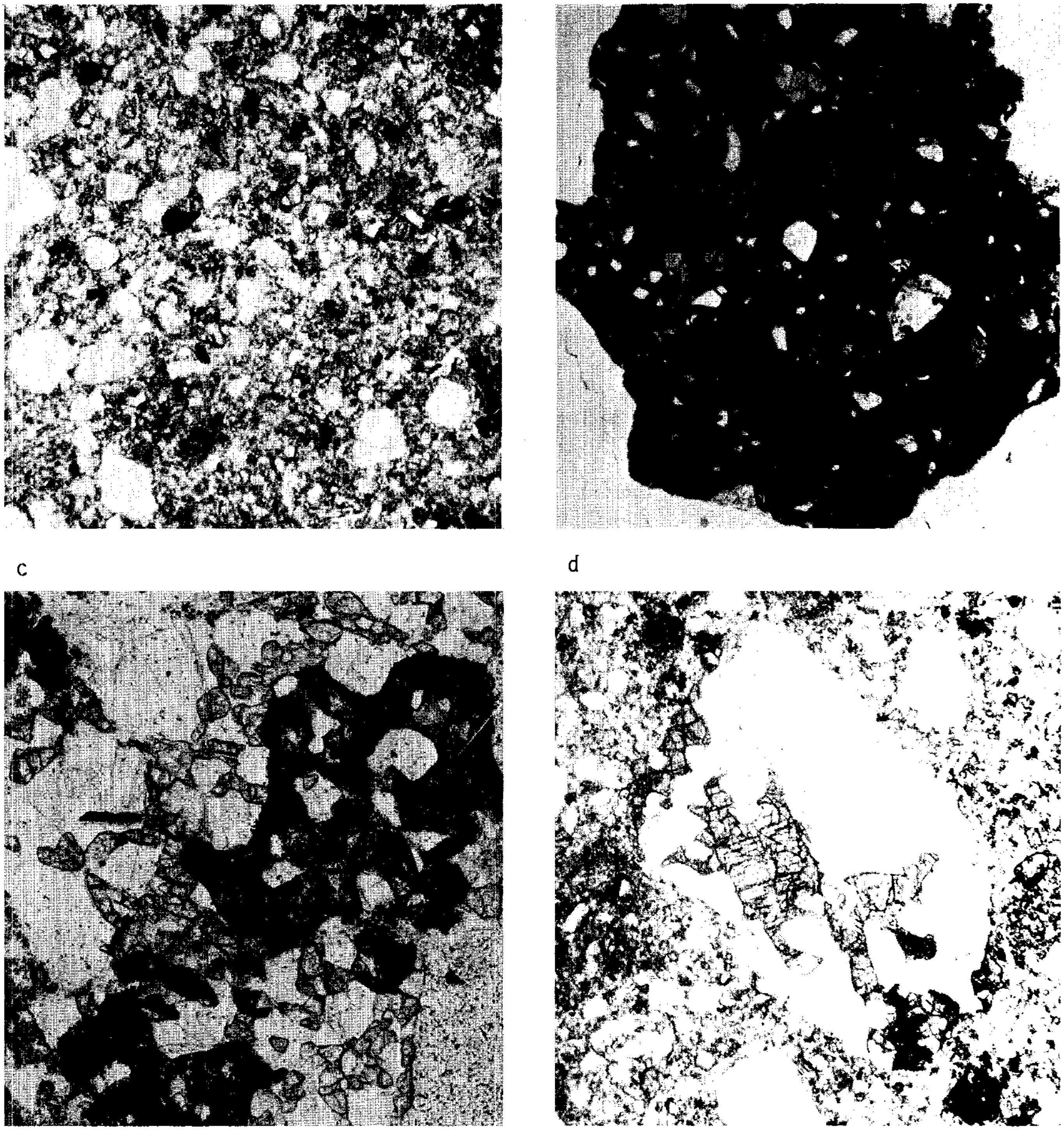


Figure 2. a) 67016,111, matrix, ppl. width 2mm.
b) 67016,189, dark clast, analyzed by Hertogen et al. (1977), ppl. width 2mm.
c) 67016,111, granoblastic clast with troilite-rich intergrowths replacing mafic minerals, ppl. width 1mm.
d) 67016,104, possible cumulate clast, ppl. width 2mm.

PETROLOGY: 67016 is a polymict breccia dominated by two types of lithologies; granoblastic lithic fragments and clast-rich, dark, aphanitic melt breccia fragments. Minor basaltic, "granitic" and cumulate-textured clasts, as well as abundant mineral clasts are also present. The matrix is fragmental but bonded by a small amount of glass.

The matrix of 67016 is mostly fine-grained plagioclase with minor pyroxene, olivine, ilmenite, metal and spinel. Nord et al. (1975) note the presence of several small (< 0.1 mm) clasts of silica-potassium feldspar intergrowths. All of these "granitic" clasts have thin reaction rims of pyroxene. Nord et al. determined that the matrix is bonded by a small amount of glass at grain contacts and conclude that this rock could have been lithified by the North Ray event.

The dark aphanitic melt clasts are packed with angular fragments, most of which are plagioclase grains (Fig. 2). In an electron microscopy study, Nord et al. (1975) found that the dark matrix was completely crystalline with blocky to anhedral plagioclase and interstitial pyroxene in a microsubophitic texture. The grain size of this dark matrix is on the order of a few microns.

Granoblastic lithologies include noritic, troctolitic and possibly gabbroic anorthosites. Mafic minerals are generally small (< 0.1 mm), rounded grains interstitial to larger, anhedral plagioclases (Fig. 2). Occasionally gradations to a coarser, more cumulate-appearing texture can be found. A fine-grained intergrowth rich in troilite (Fig. 2) appears to be replacing the mafic minerals in several granoblastic clasts.

Other clasts retain what may be a cumulate texture. These fragments show irregular mafic minerals interstitial to granoblastic plagioclase (Fig. 2). These clasts have generally not been affected by cataclasis.

A single 8 mm fragment of cataclastic anorthosite was found with rare pyroxene(?) as intra-crystalline rods and stringers and interstitial grains. Plagioclase up to 4 mm long is preserved in a relict granoblastic texture.

CHEMISTRY: Several chemical analyses on 67016 are available; references are given in Table 1.

67016 is one of a number of highly aluminous ($Al_2O_3 \sim 30\%$) polymict breccias from the North Ray Crater area that are characterized by low levels of incompatibles and a relatively high Fe/Mg (Table 2, Fig. 3). Overall 67016 is compositionally very similar to the North Ray soils. The low total C,N and other light gases indicate no substantial solar wind component in the rock (Fig. 4). Nitrogen was the only gas detected by Gibson and Andrawes (1978) upon crushing to 25 tons. Gibson and Chang (1974) note that the low temperature evolution of CO_2 may indicate the presence of a "carbonate-like phase" in 67016.

The only chemical analyses of clasts are provided by Hertogen et al. (1977) who report meteoritic siderophiles and volatiles for a typical dark matrix breccia clast (Fig. 2), and a very fine-grained granoblastic clast. Both of these lithologies were found to be very low in both siderophiles and incompatibles (Table 2).

TABLE 1. 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
Janghorbani *et al.* (1973)	,78	majors
Wänke *et al.* (1976)	,173	majors, traces, siderophiles
Wänke *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

(*aphanitic melt clast, granoblastic clast and bulk rock respectively).

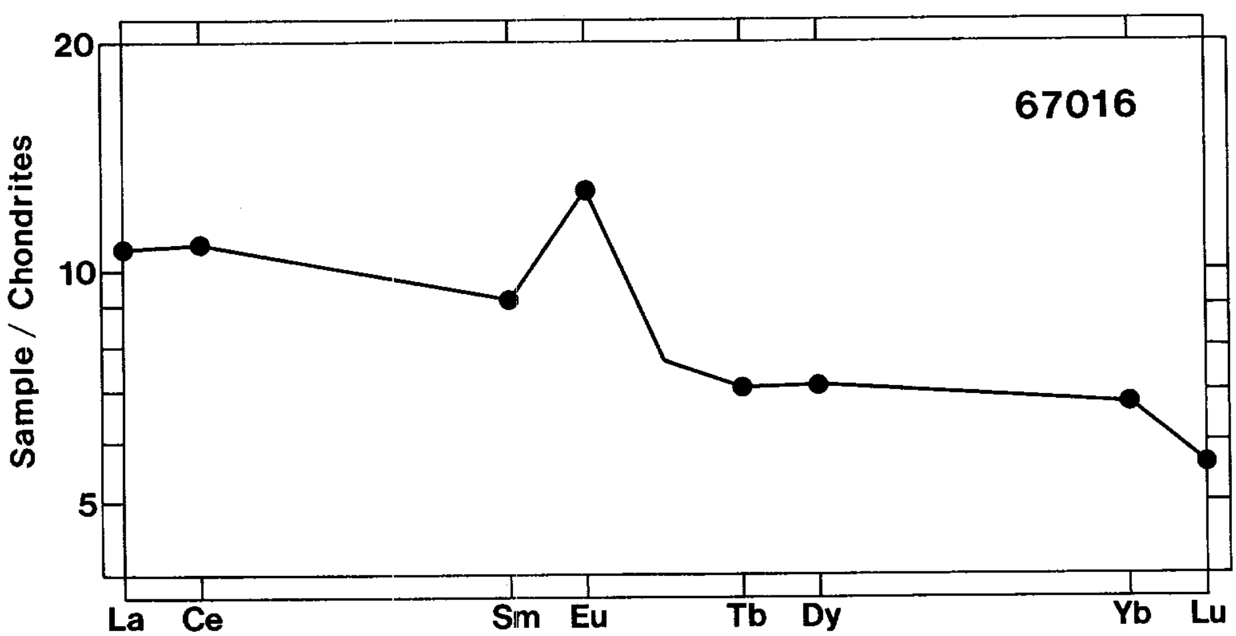
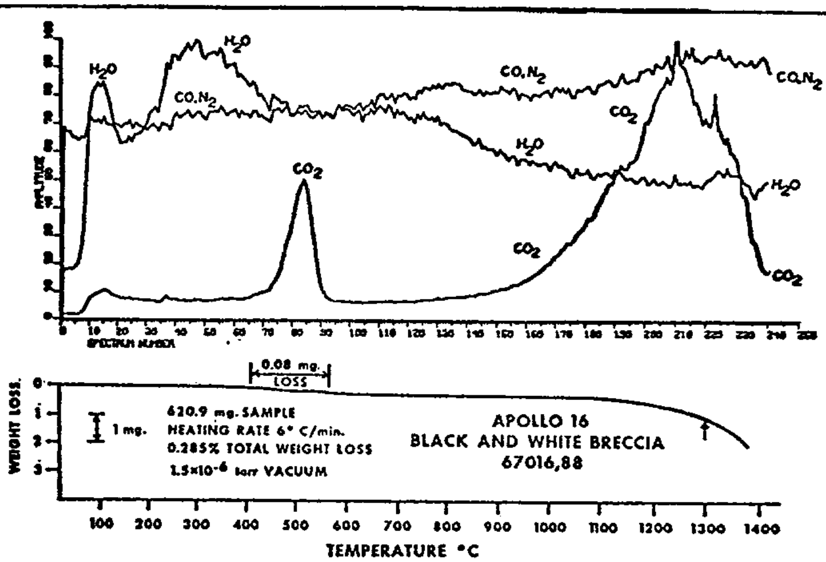


Figure 3. Rare earths, from Wanke *et al.* (1976).

TABLE 2. Summary chemistry of 67016 lithologies

	Bulk Rock	Granoblastic clast	Dark aphanitic melt clast
SiO_2	44.5		
TiO_2	0.34		
Al_2O_3	29.6		
Cr_2O_3	0.07		
FeO	3.7		
MnO	0.051		
MgO	4.1		
CaO	16.4		
Na_2O	0.52		
K_2O	0.05		
P_2O_5	0.03		
Sr	174		
La	3.8		
Lu	0.23		
Rb	1.0	0.66	0.34
Sc	7.7		
Ni	80	182	14
Co	10		
Ir ppb	2.3-10	2.90	1.14
Au ppb	0.5-4.8	1.01	0.08
C	35		
N	20		
S	∿175		
Zn	∿6	5.59	0.75
Cu	∿2		

Oxides in wt%; others in ppm except as noted.



Gas release pattern for light-matrix breccia 67016,88. Note the carbon dioxide evolution between 450-550°C.

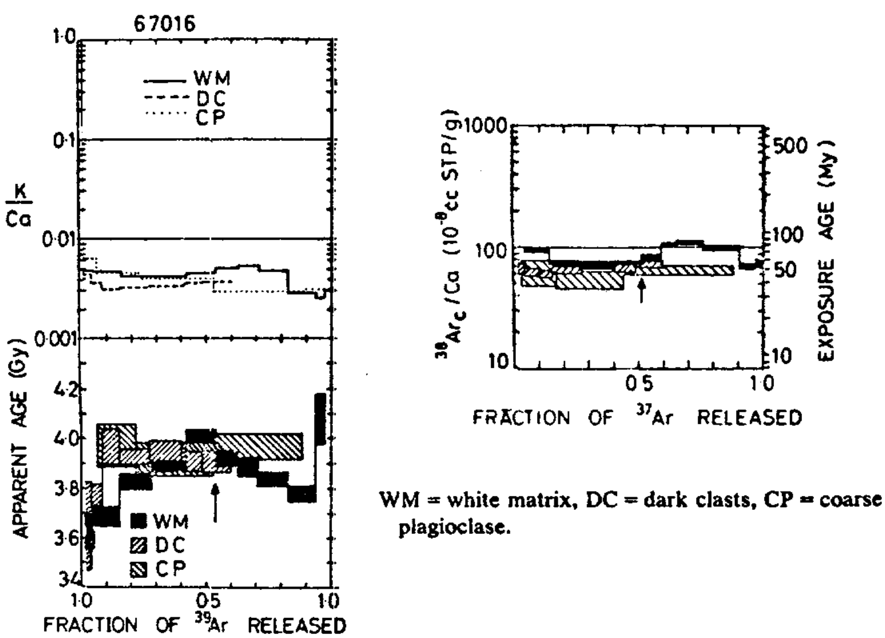
Figure 4. Gas releases, from Gibson and Chang (1974).

STABLE ISOTOPES: Gibson and Chang (1974) report the $\delta^{13}C$ and $\delta^{18}O$ of CO_2 from 67016 in an attempt to characterize a possible "carbonate-like phase" (Table 3). These isotopic data are outside the ranges of meteoritic carbonates and terrestrial atmospheric contamination.

TABLE 3. Isotopic composition of CO_2 in 67016,88 (Gibson and Chang, 1974)

Extraction method	$\delta^{13}C$	$\delta^{18}O$
Acid hydrolysis	-32.83	-16.57
Vacuum pyrolysis		
150-550°C	-12.53	-33.41
550-1200°C	-14.08	-31.03

RADIOGENIC ISOTOPES/GEOCHRONOLOGY: Ar isotopic data are given by Turner and Cadogan (1975). The release patterns are shown as Figure 5. A sample of "white" powdery matrix" yielded a complex release pattern with no plateau. The total Ar age of 3.88 b.y. places a lower limit on the age of 67016 (Turner and Cadogan 1975). A dark clast yielded a good plateau age of 3.95 ± 0.05 b.y. Since the rock must be younger than any clasts within it, the age of this clast is an upper limit to the age of 67016. Thus 67016 is constrained to be 3.88-4.00 b.y. old. A coarse plagioclase separate also yielded a plateau age of 3.95 ± 0.07 b.y.



WM = white matrix, DC = dark clasts, CP = coarse plagioclase.

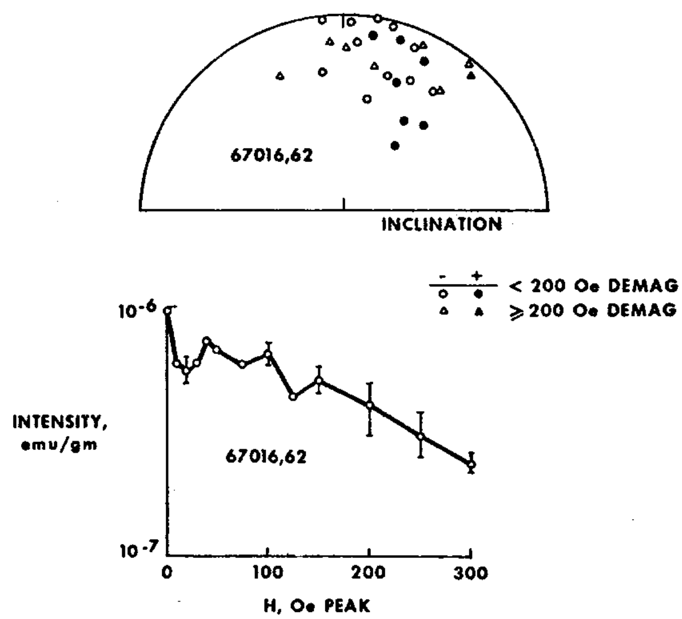
Figure 5. Ar releases, from Turner and Cadogan (1975).

RARE GASES/EXPOSURE AGES: Turner and Cadogan (1975) provide Ar isotopic data on a split of matrix, a dark clast and a coarse plagioclase separate. All three splits yield Ar exposure ages of 40-50 m.y.

Bhandari et al. (1973) give surface exposure ages of 1 m.y. and 1.2 m.y. for two surface chips and a subdecimeter age of 15 m.y. from an interior chip, based on particle tracks. From the track gradient on opposite faces of the rock Bhandari et al. (1973) also conclude that 67016 has been exposed in at least two orientations on the Moon. (Hörz et al., 1975, quote a subdecimeter age of 15 m.y. by Lal, pers. comm., for a rock listed as 67015. The data are actually for 67016 and are the same as that given by Bhandari et al., 1973).

Cosmogenic radionuclide abundance data indicate that 67016 is unsaturated in ^{26}Al (Eldridge et al., 1973).

PHYSICAL PROPERTIES: Pearce et al. (1973) find that 67016 contains one component of magnetization which is fairly stable against AF demagnetization (Fig. 6). This rock does not possess the FMR intensity characteristic of lunar fines (Housley et al., 1976).



AF demagnetization of 67016,62. No systematic changes in direction were observed above 200 Oe.

Figure 6. From Pearce et al. (1973).

PROCESSING AND SUBDIVISIONS: 67016 has been extensively split and widely allocated. Due to its friable nature 67016 was never sawn but was chipped into several smaller pieces in 1972 (Fig. 7). Most of the allocations were taken from ,2 with a few from ,3 and ,10.

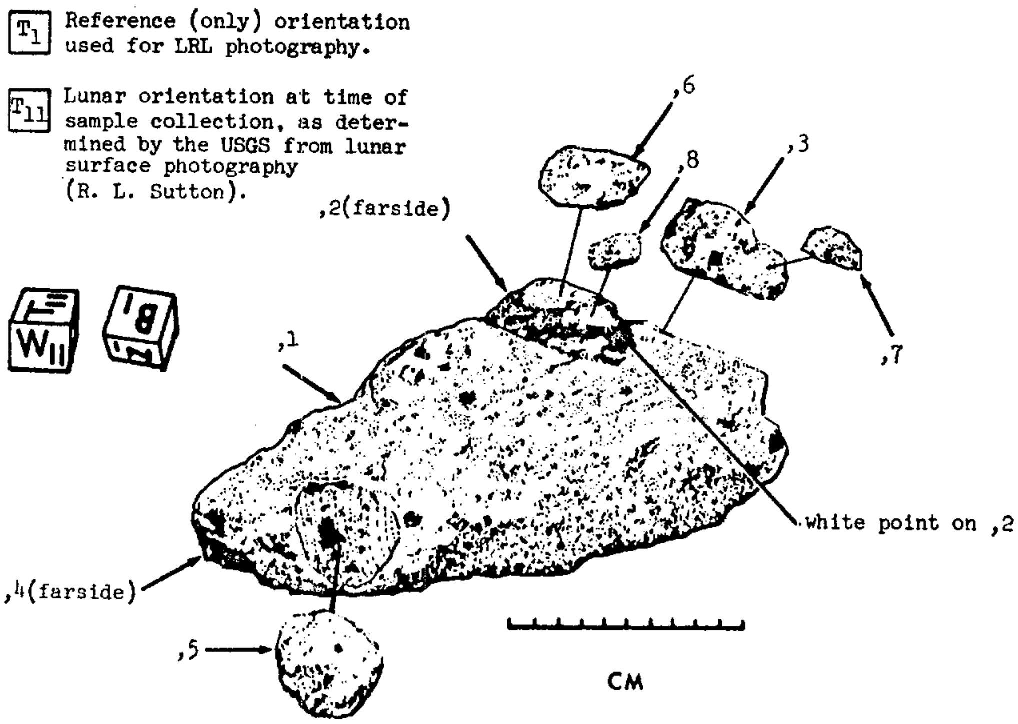


Figure 7. Major subdivisions of 67016.

INTRODUCTION: 67025 is a homogeneous, gray, coherent, basaltic impact melt with a partial glass coating (Fig. 1). It was returned in the same sample bag as 67016 and was probably from the same location, near the lunar roving vehicle (LRV) and about 50 m east of the White Breccia boulders. Its orientation is unknown. Many zap pits occur on one surface.

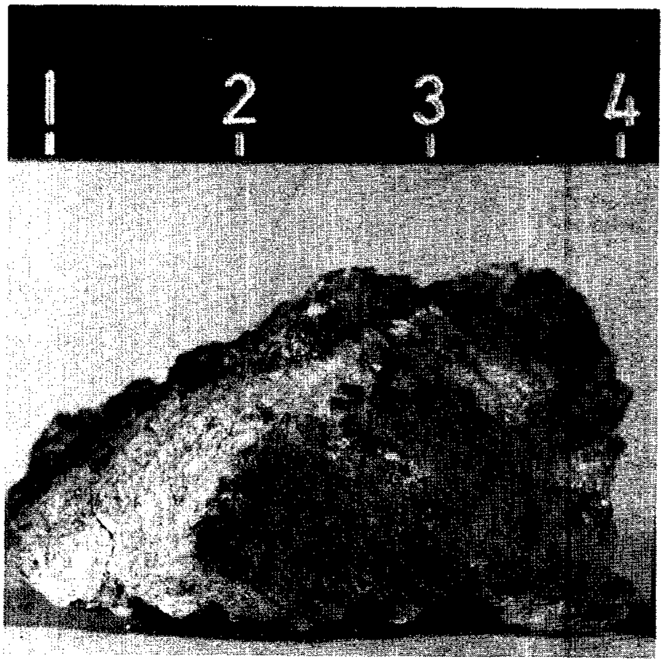


Figure 1. S-72-40525, cm scale.

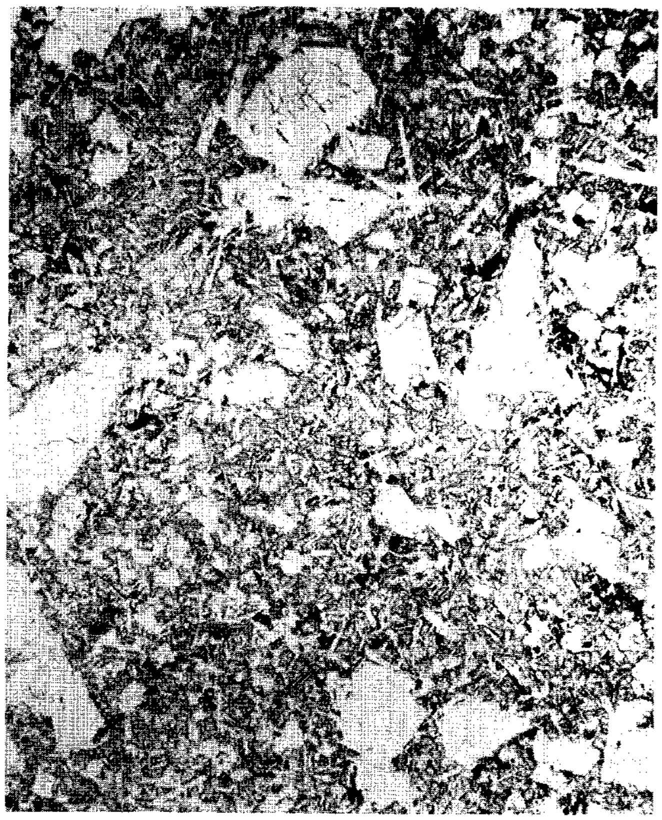


Figure 2. 67025,13, general view, ppl. width 2mm.

PETROLOGY: 67025 is a fine-grained ophitic impact melt (Fig. 2) with well-developed plagioclase laths (~60% of the sample) ophitically enclosed by pyroxene(?). Fe-metal, troilite, ilmenite, and interstitial glassy areas are present. The plagioclase laths are 50-100 μm and the mafic mineral is generally 100 μm across. Plagioclase clasts are up to 500 μm across. Most of the clasts and some of the basaltic melt is shocked to glass. A small patch of brown glass coat is present in thin section ,13. The contact is not sharp but the glass penetrates the basalt; the glass is largely devitrified.

PROCESSING AND SUBDIVISIONS: A single chip ,1, mainly of homogeneous gray material but with a patch of the glass coat, was made into thin sections ,13 and ,14.

INTRODUCTION: 67035 is a very friable, light matrix breccia that was found to be in several pieces when returned from the Moon (Fig. 1). Relatively coherent, dark and light clasts are abundant with the dark clasts rather more common. Two clasts from this rock, a gabbro/norite and a cataclastic ferroan anorthosite, are chemically pristine.

This rock was a grab sample taken from just inside the southeast rim of North Ray Crater; its lunar orientation is unknown. Due to its friability, no original surface of the rock is recognizable.

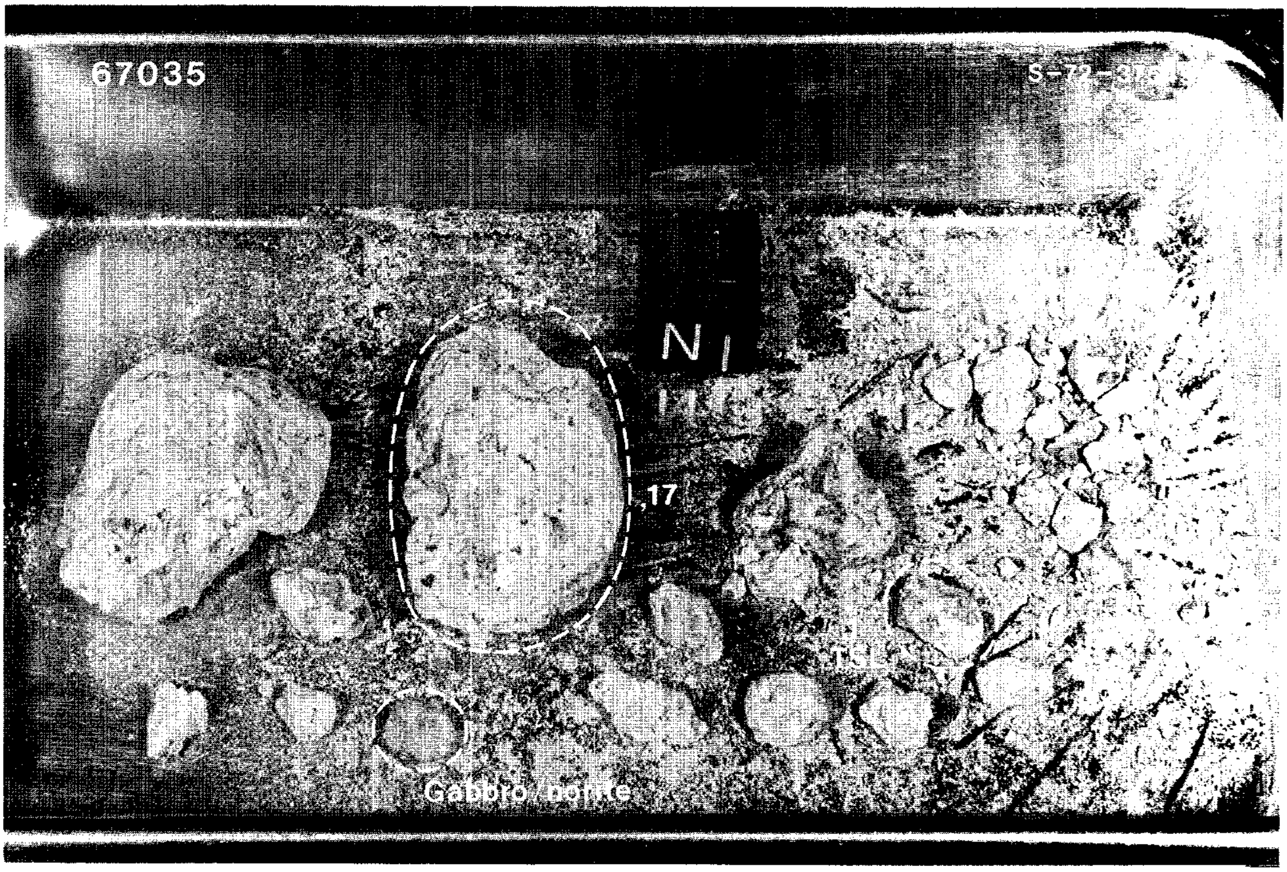
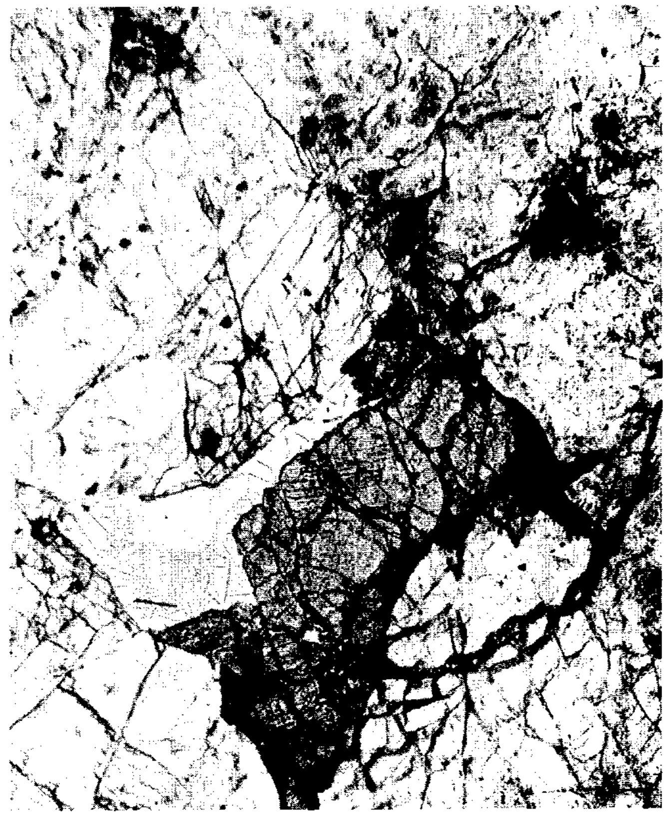


Figure 1. Cube is 1cm.

a

b



c

Figure 2. a) 67035,13, aphanitic breccia clasts,and fragmental matrix, ppl. width 2mm.
b) 67035,8, pristine gabbro/ norite clast, ppl. width 2mm.
c) 67035,10, pristine anorthosite clast, xpl. width 2mm.

PETROLOGY: 67035 is a fragmental, porous breccia which is predominantly made up of angular plagioclase grains (Fig. 2). Olivine, pyroxene, spinel, metal, troilite, opaque oxides, lithic fragments and some glass fragments are present. Some of the metal in the matrix and in some lithic clasts is rusty. The lithic clast population is varied, including dominant dark aphanitic melt breccias, and granoblastic and poikiloblastic impactites. At least two clasts--a gabbro/norite and an anorthosite--are chemically pristine.

The pristine gabbro/norite clast was completely extracted from the rock and, when split, revealed a marbled pattern of intergrown feldspar and pyroxene (Fig. 3). A thin selvage of glassy breccia coats the entire clast. Thin sections from this clast show a severely shocked and cataclastic anorthosite with ∿10% pyroxene; the marbling is not present. Grain size of the plagioclase is ∿5 mm and despite the cataclasis some original grain boundaries are preserved. Most of the pyroxenes have been crushed and many have been plucked from the slides. A 2-3 mm pyroxene grain occupies the center of each section (Fig. 2). Our analyses indicate the pyroxene to be mainly augite (∿$Wo_{30-40}En_{40}$) with an exsolved low-Ca phase (∿$Wo_{3}En_{60-65}$). This is somewhat more ferroan than the pyroxenes in most other pristine norites but is similar to those in pristine anorthosites.

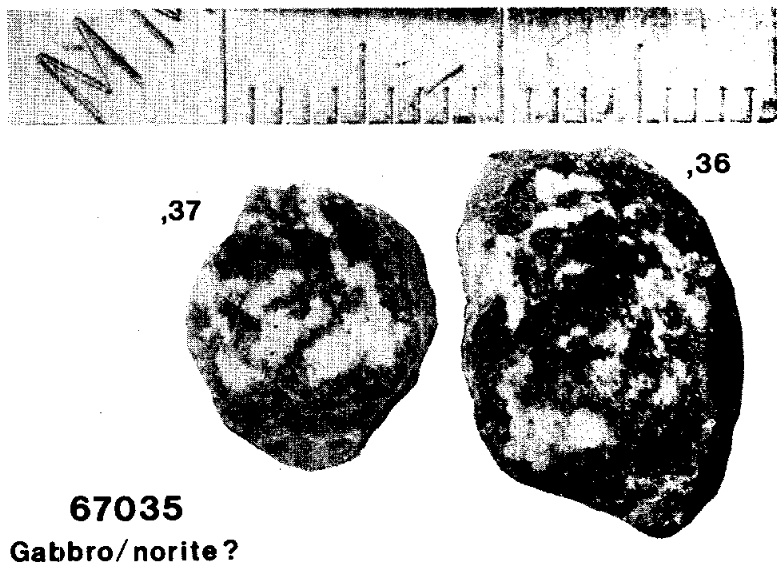


Figure 3. Pristine gabbro/norite clast, mm scale.

The pristine cataclastic anorthosite clast was also completely extracted from the rock (Fig. 4). A relict cumulate texture with interstitial pyroxene has been retained despite cataclasis (Fig. 2). The original grain size was >2 mm. Our analyses indicate that the mafic phase is a low-Ca pyroxene averaging ∿En_{60} (Fig. 5), not unusual for a pristine anorthosite.

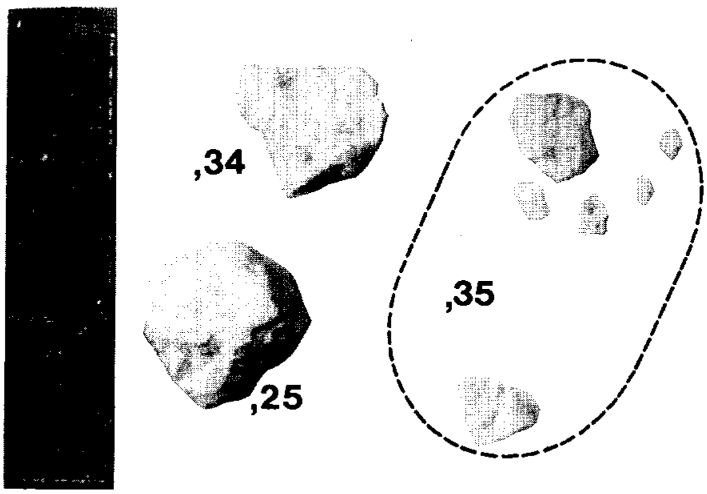


Figure 4. Pristine anorthosite clast, mm scale.

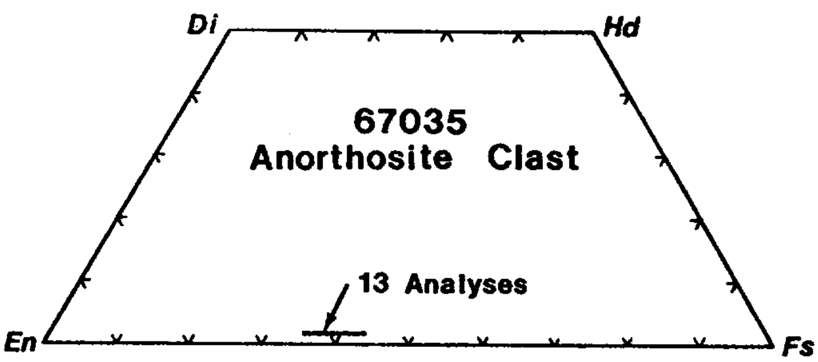


Figure 5. Pyroxene compositions of pristine anorthosite clast, from Ryder and Norman (unpublished).

CHEMISTRY: Major and trace element analyses of the bulk rock are given by Laul and Schmitt (1973) and Wasson et al. (1977). Hertogen et al. (1977) report siderophile, volatile and other trace element data on the bulk rock, the gabbro/norite clast and the pristine anorthosite clast. Nyquist (unpublished; in Ryder and Norman, 1978) provides major and trace element data for the pristine anorthosite clast. Clark and Keith (1973) give natural and cosmogenic radionuclide abundances for the large fragment ,17.

The bulk rock is highly aluminous and fairly low in siderophile and rare earth elements (Table 1, Fig. 6). These are common characteristics of many of the rocks considered to be North Ray ejecta. Laul and Schmitt (1973) note that their analysis of 67031,14 (actually a portion of 67035) is virtually identical to that of 60017, also North Ray ejecta. The rare earths in 67035 are significantly fractionated relative to KREEP (Wasson et al., 1977). The siderophiles in the bulk rock were tentatively assigned to meteoritic group 2 by Hertogen et al. (1977). This group dominates the Serenitatis ejecta at Apollo 17 but may also be a mixture of other groups (Hertogen et al., 1977).

TABLE 1. Summary chemistry of 67035 lithologies

	Bulk rock	Cataclastic anorthosite clast	Gabbro/norite clast
SiO_2			
TiO_2	0.31	0.032	
Al_2O_3	29.8		
Cr_2O_3	0.059	0.017	
FeO	3.4		
MnO	0.05		
MgO	3.7	1.05	
CaO	16.5		
Na_2O	0.510		
K_2O	0.051	0.023	
P_2O_5			
Sr		164	
La	2.5	0.22	
Lu	0.15		
Rb	1.12	0.77	0.57
Sc	6.2		
Ni	∿48	3.4	9.4
Co	∿8		
Ir ppb	1.54	0.045	0.0043
Au ppb	0.842	0.031	0.012
C			
N			
S			
Zn	2.78	1.09	0.51
Cu			

Oxides in wt%; others in ppm except as noted.

The gabbro/norite clast has very low levels of siderophiles confirming its pristine nature. Uranium (0.63 ppb) and Rb are also quite low compared to other pristine norites (Table 1).

The pristine cataclastic anorthosite clast is also low in siderophiles though Rb and U (6.2 ppb) are rather high for an anorthosite. The REE abundances of this clast are typical of pristine anorthosites (Table 1).

RADIOGENIC ISOTOPES/GEOCHRONOLOGY: Schaeffer and Schaeffer (1977) report an Ar-Ar plateau age of 3.95±0.05 b.y. and a total K-Ar age of 3.89±0.01 b.y. for the bulk rock.

Nyquist (unpublished; in Ryder and Norman, 1978) measured an $^{87}Sr/^{86}Sr$ ratio of 0.69976±8 on the pristine cataclastic anorthosite clast.

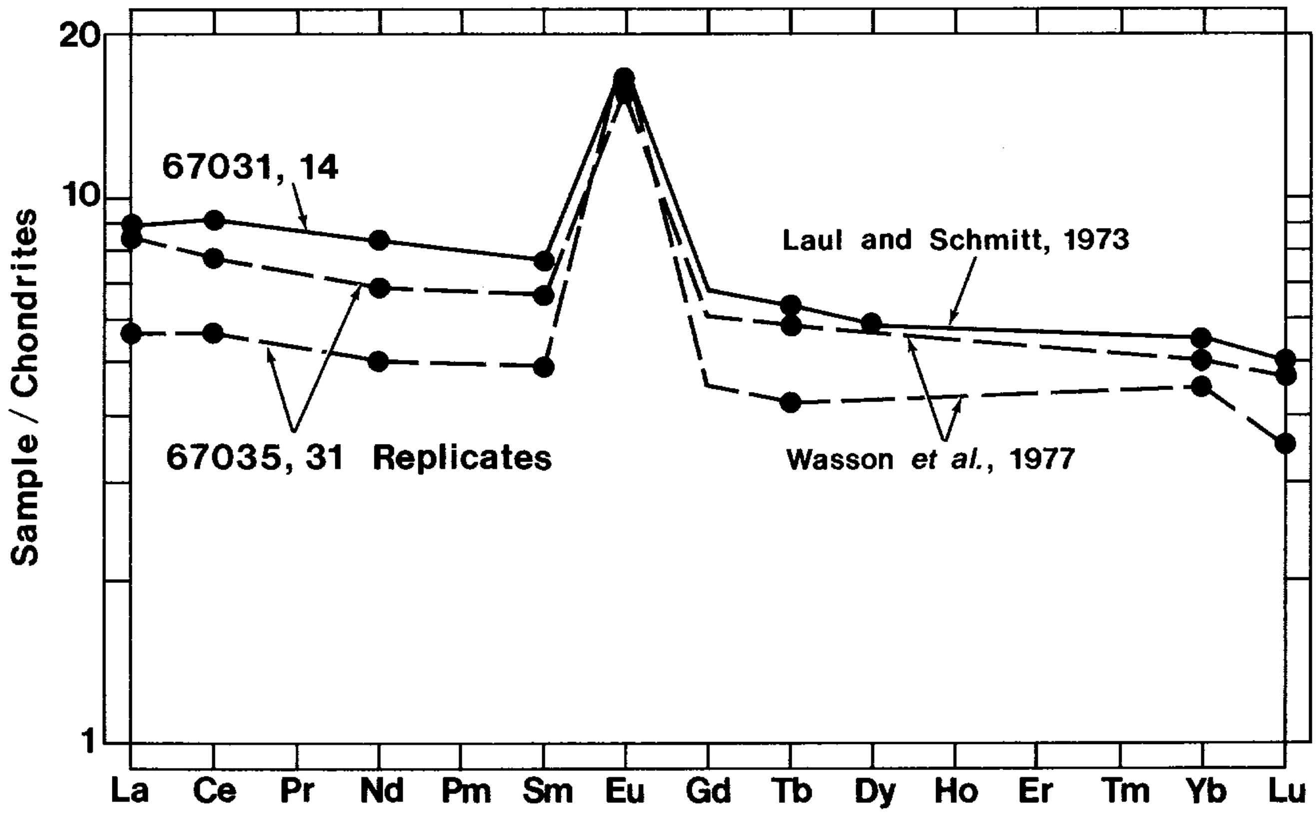


Figure 6. Rare earths of bulk rock.

RARE GASES/EXPOSURE AGE: Schaeffer and Schaeffer (1977) report Ar isotopic data and an average Ar exposure age of 35 m.y., consistent with the generally accepted age of North Ray Crater. Clark and Keith (1973) provide cosmogenic radionuclide data.

PROCESSING AND SUBDIVISIONS: In 1972, Documented Bag 382 was opened and found to contain two large (>50 g) pieces of friable rock, a number of >1 cm fragments, and abundant smaller chips and fines. The large pieces and about a dozen >1 cm fragments were given the generic 67035,0. The <1 cm fraction was sieved and numbered 67034 (4-10 mm), 67033 (2-4 mm), 67032 (1-2 mm) and 67031 (<1 mm).

67035,0 was subsequently entirely subdivided as ,1; ,17; and ,18 (Fig. 1). ,1 was made into thin sections. ,18 was further split to produce ,20 and ,24-,60 (Fig. 7). ,17 is preserved at JSC as an 87.1 g piece.

Laul and Schmitt's (1973) analysis was of a 0.25 g split of the <1 mm fraction (67031,14).

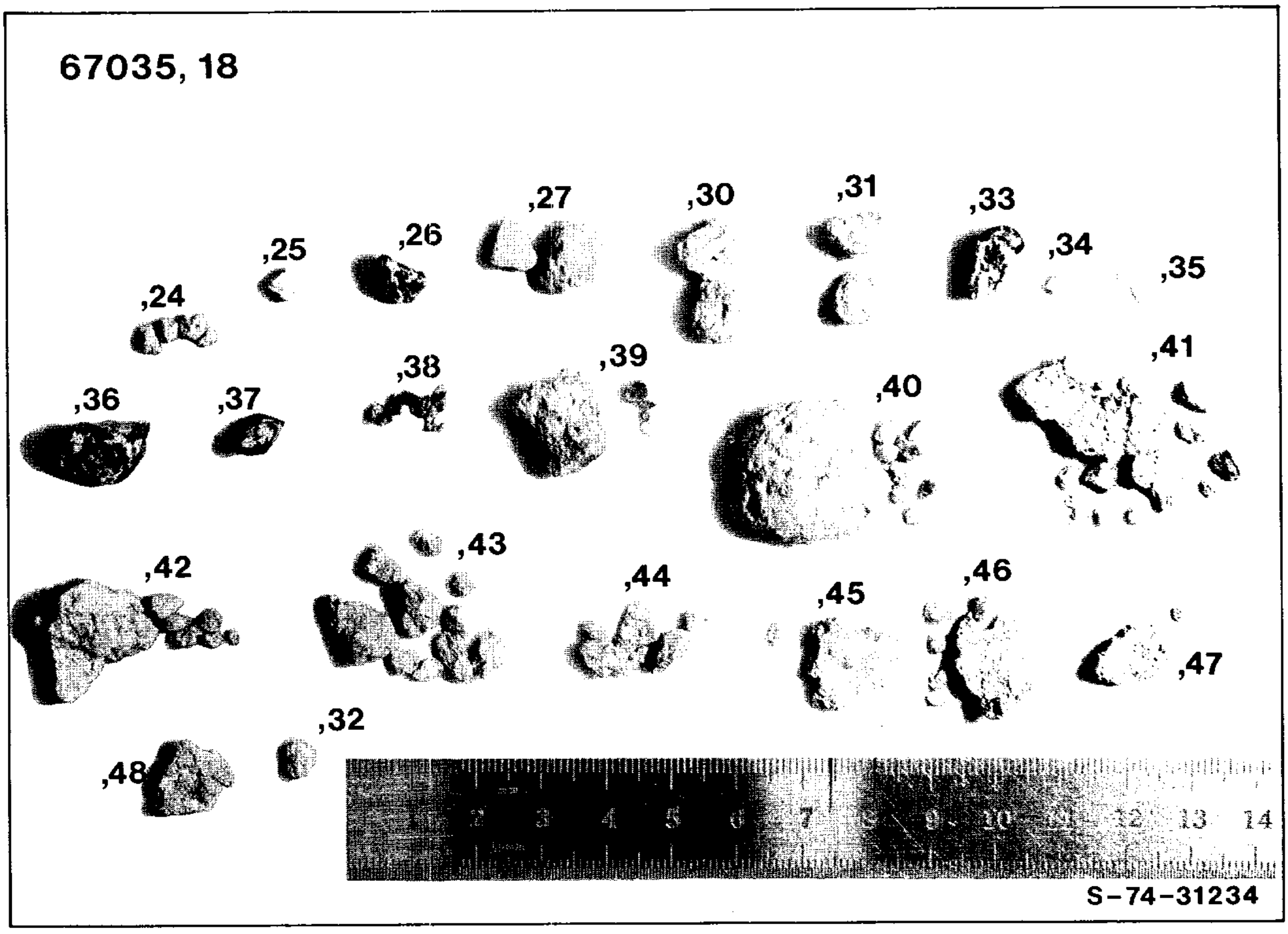


Figure 7. Major subdivisions of 67035,18.

INTRODUCTION: 67055 is a friable polymict breccia with a light colored, feldspathic matrix and some large dark clasts (Fig. 1). The dark clasts are aphanitic impact melts. The light matrix also contains light-colored clasts including feldspathic granulitic impactites.

67055 was collected on the rim of North Ray Crater, approximately 100 meters from House Rock. The sample is blocky and subrounded. It was perched, without a fillet and its orientation is known. Zap pits occur on at least the north face.

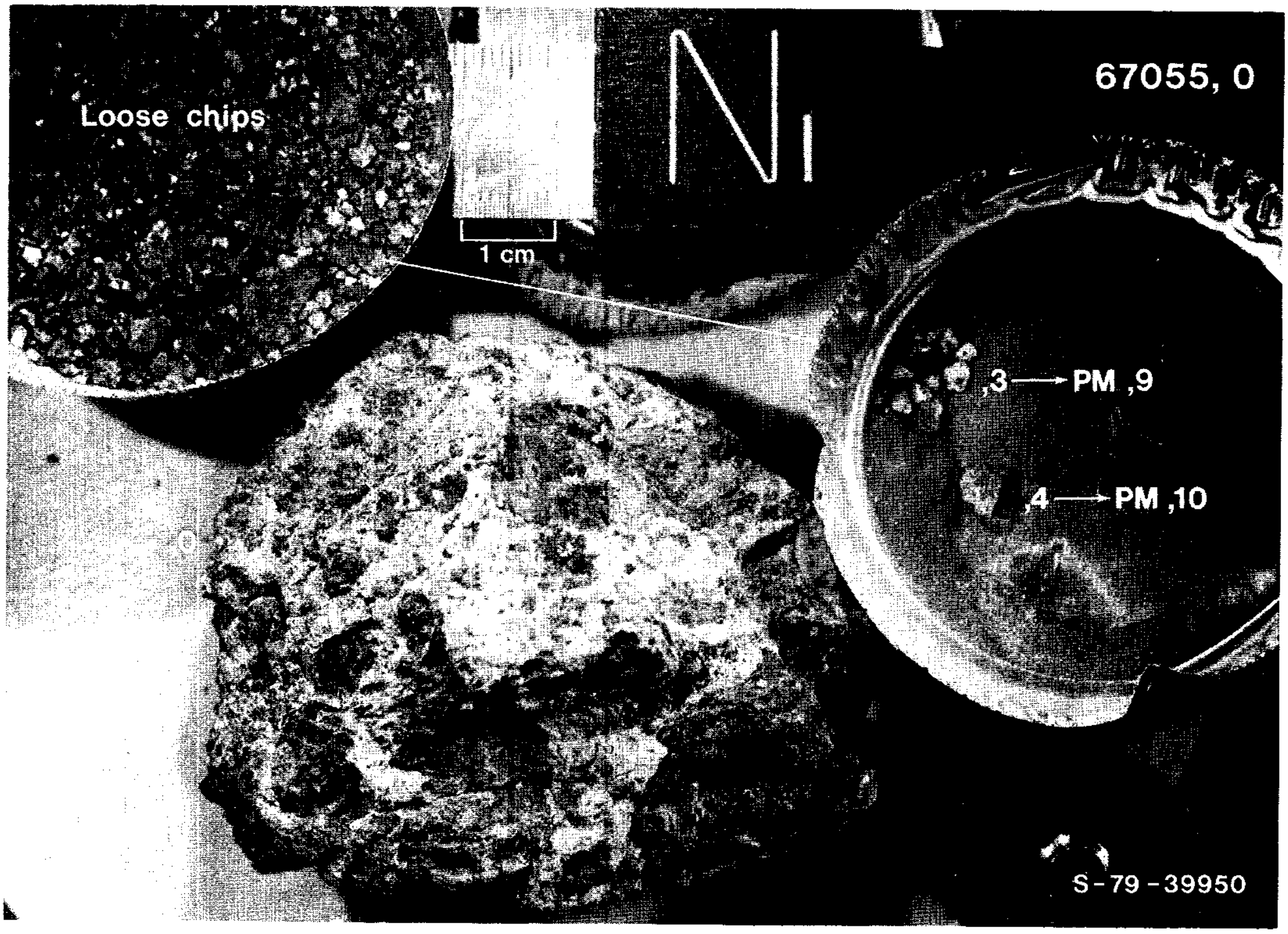


Figure 1.

PETROLOGY: No allocations have been made but thin sections were cut for this study. Small chips (TS ,9) show that the breccia consists of a porous, fragmental, feldspathic matrix containing a variety of clasts, which are dominated by dark, aphanitic impact melts (Fig. 2). The matrix is ~80% plagioclase with few individual plagioclase grains bigger than 200 µm; most larger fragments are lithic clasts. Olivine, pyroxene, ilmenite, troilite, and scarce pink spinels are also present. The aphanitic melts are much more mafic (60% plagioclase?) and contain Fe-metal. Clasts of plagioclase are common in these melts. Other clasts include feldspathic granulites, coarser basaltic impact melts, and glassy breccias.

A thin section of a single aphanitic clast (,10) is of a coherent melt containing rounded clasts of plagioclase with very rare mafic and small lithic clasts (Fig. 2). The melt contains more mafic material than the clast population, but plagioclases range down to very small sizes and the ratio of plagioclase:mafics in the melt is indeterminable.

a b

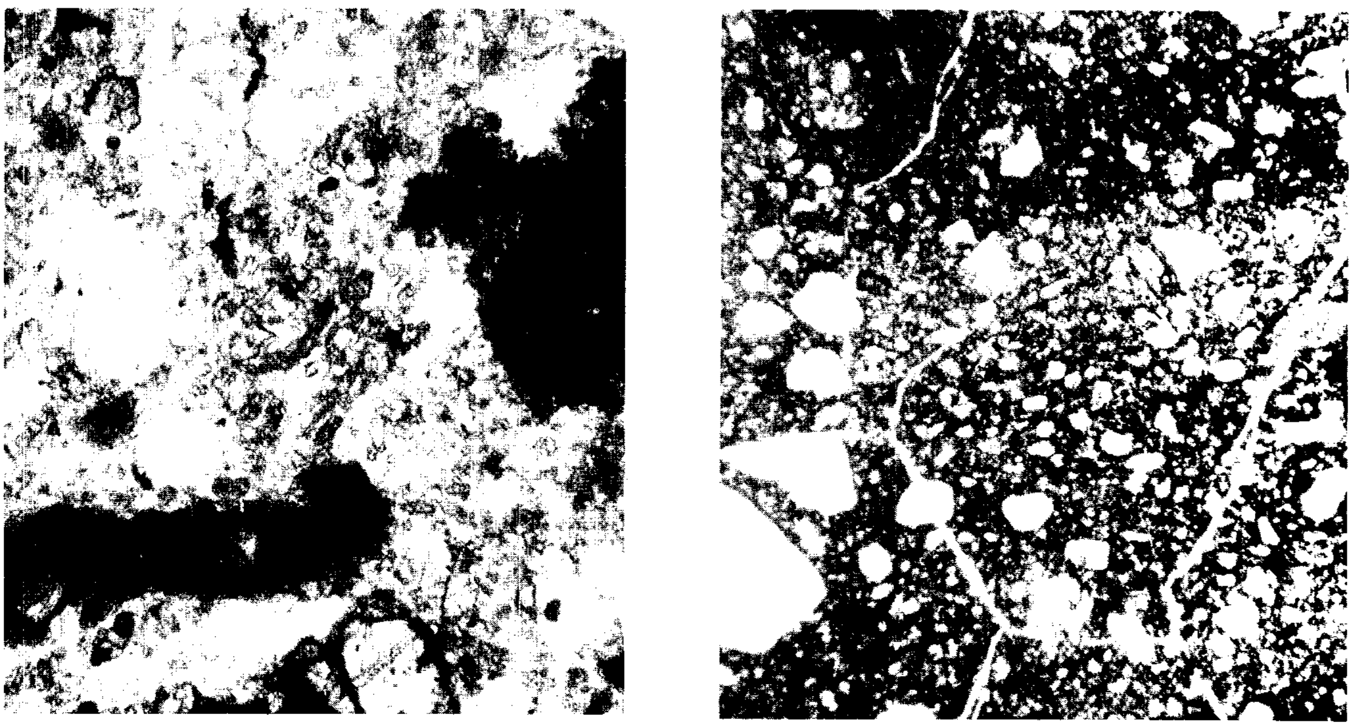


Figure 2. a) 67055,9, general view, ppl. width 1mm.
b) 67055,10, aphanitic breccia, ppl. width 2mm.

CHEMISTRY: Clark and Keith (1973) and Eldridge et al. (1973) provide whole rock K (K_2O = 0.19%), U (0.99 ppm) and Th (3.6 ppm) abundances. These values are extremely high for North Ray Crater samples.

EXPOSURE AGES: Yokoyama et al. (1974) conclude that the cosmogenic nuclide data of Clark and Keith (1973) and Eldridge et al. (1973) show that 67055 is saturated with ^{26}Al. Thus 67055 has been exposed for at least a few million years.

PROCESSING AND SUBDIVISIONS: 67055 was not subdivided until 1979 when loose chips (,3 and ,4) were taken for thin sections (Fig. 1).

INTRODUCTION: 67075 is an anorthosite breccia which is so friable it has broken into many small fragments and powders (Fig. 1). Mafic grains are not uniformly distributed, but tend to be concentrated in clots or "veins". Overall the plagioclase content is more than 95%. The sample is contaminated, at least in part, with a small amount of meteoritic material. The variations in mafic mineral compositions suggest that the rock is polymict, but is derived from a genetically-related suite of anorthositic rocks.

The sample was collected from the southeast rim of North Ray Crater and was originally two white, subrounded fragments. They were perched and unburied. Because of the breakage into many small pieces, lunar orientation information has been lost, and zap pits are absent.

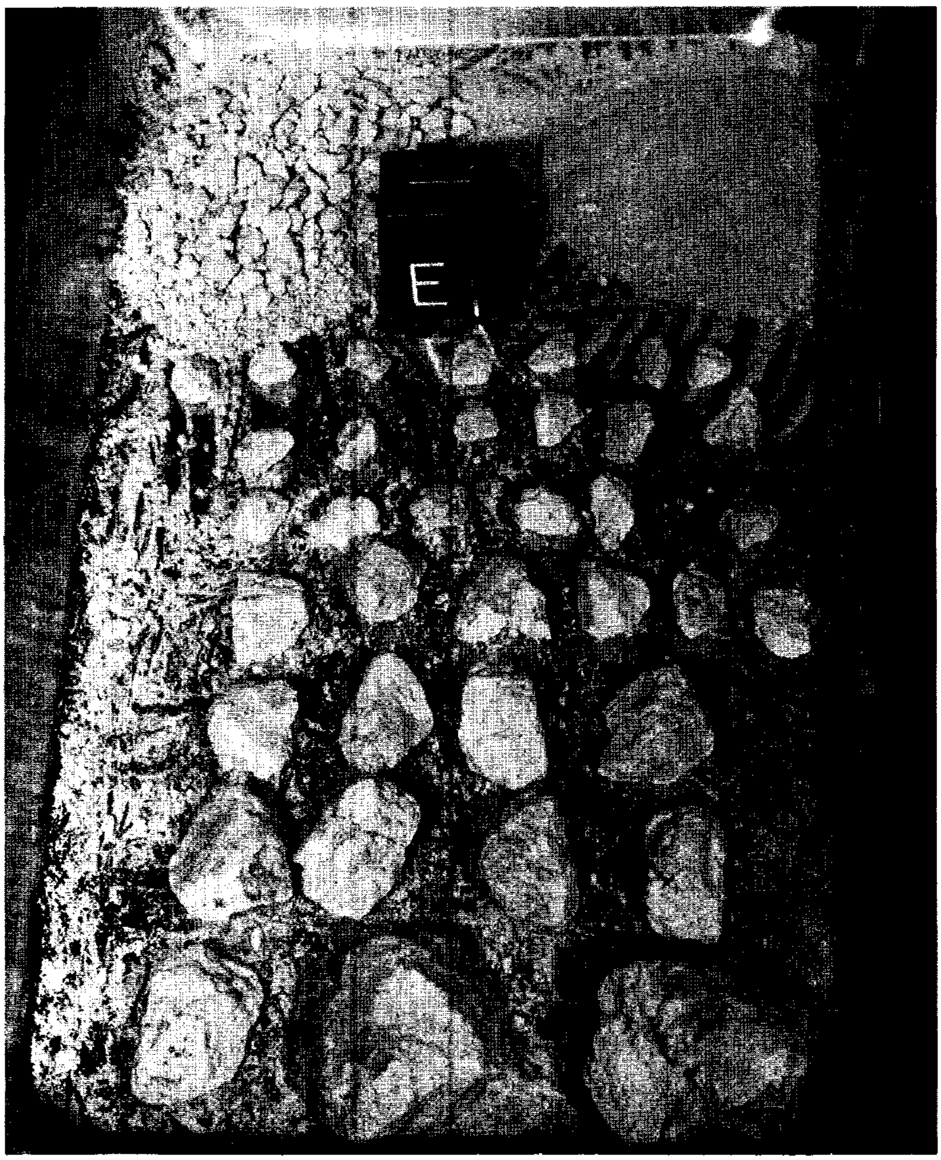


Figure 1. S-72-37539, cube is 1cm.

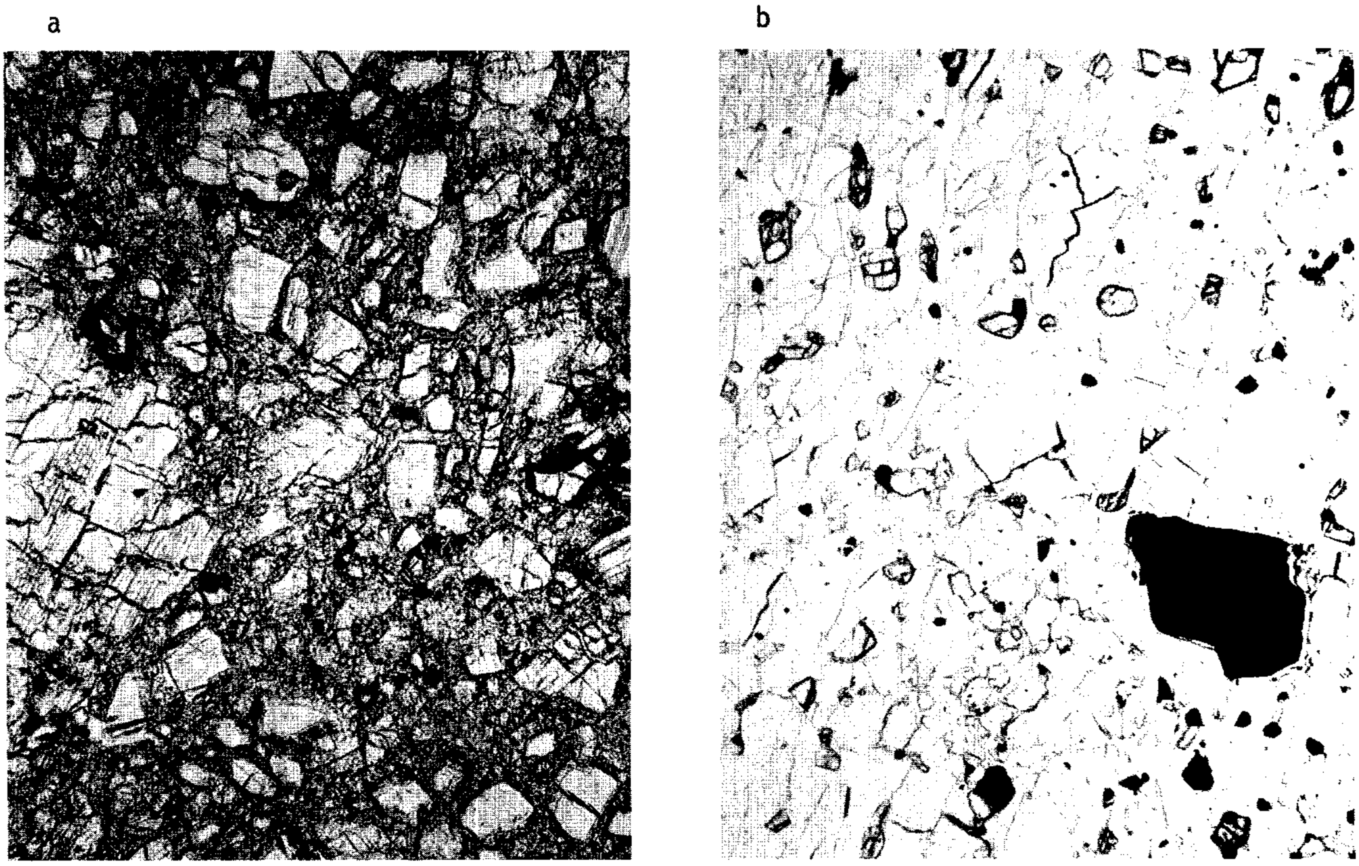


Figure 2. a) 67075,42, brecciated area, ppl. width 2mm.
b) 67075,3, granoblastic area, ppl. width 1mm.

PETROLOGY: A comprehensive petrographic description, including microprobe and x-ray precession data, is given by McCallum et al. (1975), and less detailed accounts by Peckett and Brown (1973), Brown et al. (1973), Steele and Smith (1973), Smith and Steele (1974), Nord et al. (1973; includes high voltage electron microscopy studies) and Dixon and Papike (1975). Specific studies are El Goresy et al. (1973a) on opaque phases, Meyer et al. (1974) and Meyer (1979) on ion probe analyses of trace elements in plagioclase, Steele and Smith (1975) on minor elements in olivines, Hansen et al. (1979a) on minor elements in plagioclases, Okamura et al. (1976) on spinel exsolution from pyroxenes and Ghose et al. (1975) on cation ordering studies of olivines and pyroxenes. Hewins and Goldstein (1975b) use published data to calculate a pyroxene exsolution equilibration temperature.

67075 is a brecciated anorthosite (Fig. 2). It contains plagioclase, olivine, low-Ca pyroxene, high-Ca pyroxene, and traces of Cr-spinel, ilmenite, Fe-Ni metal, and troilite (McCallum et al., 1975). Smith and Steele (1974) also observed silica. The mafic grains are not evenly distributed but occur in zones or veins which may represent crushed, originally coarse, mafic crystals. Plagioclases occur as single fragments up to 2 mm long, in micro-anorthosite (polygonally-textured) clasts and as shocked, vitrified grains. They have restricted compositions of An_{93-98} (Steele and Smith, 1973; McCallum et al., 1975); Brown et al. (1973) report An_{92-96}. Meyer et al. (1974) and Meyer (1979) found low trace elements in plagioclases (Table 1), similar to whole-rock values.

TABLE 1. Minor elements in plagioclase

	Na_2O %	Li ppm	Mg ppm	Ti ppm	Sr ppm	Ba ppm
Meyer et al.(1974)	0.43	1.6	210	63	154	10
Meyer (1979)		3.2	300			16

Hansen et al.(1979a) report that minor element microprobe analyses for several plagioclase types show no significant differences between grains, which average 2.8 mol % Ab, 0.029% MgO, 0.069% FeO, and 0.016% K_2O.

Olivines are isolated, small, and unzoned. Reported compositions range from Fo_{40} to Fo_{60} (McCallum et al., 1975; Brown et al., 1973; Steele and Smith 1973, 1975). McCallum et al. (1975) report a bimodal compositional distribution (Fig. 3). Steele and Smith (1975) report minor element compositions for olivines.

Figure 3 also shows pyroxene compositions. High-Ca pyroxene and low-Ca pyroxene (both pigeonite and orthopyroxene) are roughly equal in volume and occur in anhedral grains up to 800 µm in diameter. Large grains show distinct exsolution lamellae 20-30 µm wide, but pyroxenes in the polygonal clasts do not show exsolution. X-ray precession photographs show that most low-Ca pyroxenes are inverted or partially inverted pigeonites with well developed exsolution. Ghose et al. (1975) conclude from cation-ordering studies that slow cooling followed crystallization--a cation equilibration temperature from K_D in orthopyroxene is 650°C. Hewins and Goldstein (1975b) calculated a (Wood-Banno) pyroxene equilibration temperature of ∿880°C.

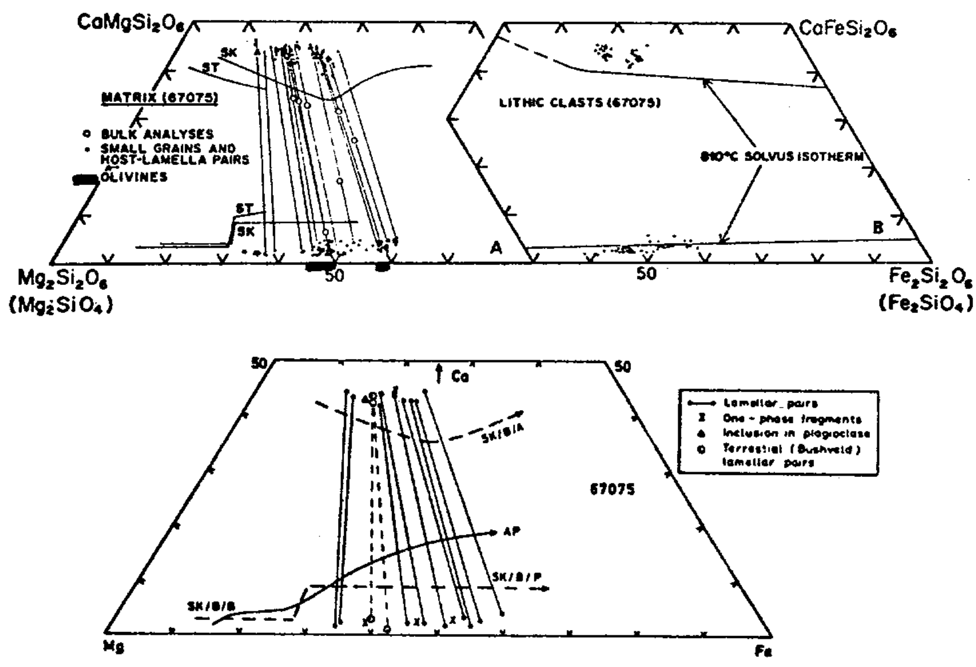


Figure 3. Compositions of pyroxenes and olivines in 67075, from Brown et al. (1973). SK= Skaergaard trend, B= Bushveldt trend, A= augite, P= pigeonite, AP= trend for lunar pigeonites.

El Goresy et al. (1973a) report compositions for spinels (Fig. 4). There are two occurrences of Ti-chromite: one primary, the other (associated with sulfide and exclusively exsolved from pyroxene) El Goresy et al. (1973a) interpret as reduced from Cr-Al-ulvöspinel. This interpretation was criticized by McCallum et al. (1975). Okamura et al. (1976) report the compositions of, and x-ray data for, spinel lamellae exsolved from augites.

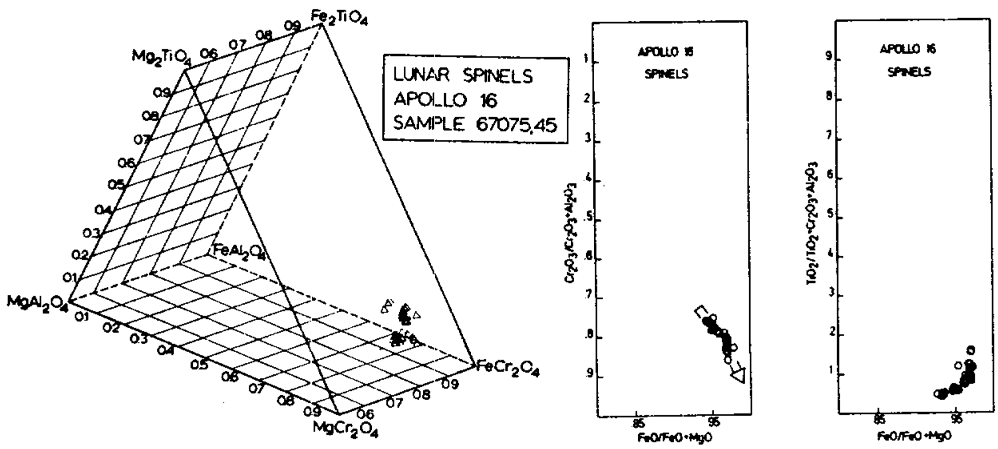


Figure 4. From El Goresy et al. (1973a).

Nord et al. (1975) show that 67075 lithified under conditions which did not appreciably alter the internal structure of clasts. Unlike other Apollo 16 breccias (except possibly 67016) considered by Nord et al. (1975), 67075 could have been lithified by the North Ray Crater event itself.

Peckett and Brown (1973), Brown et al. (1973) and McCallum et al. (1975) all suggest that 67075 was assembled from genetically-related fragments of a layered plutonic anorthosite complex. This interpretation can explain the pyroxene exsolutions and the range of compositions of mafic minerals.

CHEMISTRY: Chemical studies are listed in Table 2 and a summary chemistry in Table 3. Rare-earth elements are shown in Figure 5. The compositions vary in mafic content, a reflection of the heterogeneous distribution of mafic phases in 67075. It is clearly a ferroan anorthosite. The sample is slightly contaminated with meteoritic siderophiles and Hertogen et al. (1977) classify the signature as Group 7.

GEOCHRONOLOGY AND RADIOGENIC ISOTOPES: Whole-rock Rb-Sr isotopic data are presented by Nyquist et al. (1974, 1976) (Table 4).

Nyquist et al. (1976) also report Rb-Sr isotopic data for mineral separates and report an internal isochron age of 3.66±0.63 b.y. (Fig. 6). The data scatter and the pyroxene datum Px1 is omitted from the age calculation--this pyroxene may have been altered by leaching in heavy liquids.

TABLE 3

Summary chemistry of 67075

SiO_2	45
TiO_2	0.05-0.10
Al_2O_3	31-34
Cr_2O_3	0.02-0.08
FeO	1-4
MnO	0.02-0.06
MgO	0.5 - 3
CaO	17 - 20
Na_2O	0.3
K_2O	0.02
P_2O_5	0.02
Sr	∿150
La	0.35
Lu	0.04
Rb	0.6
Sc	< 8
Ni	< 4
Co	< 7
Ir ppb	0.3
Au ppb	<0.7
C	5
N	
S	100
Zn	0-15
Cu	13

Oxides in wt.%; others in ppm except as noted.

TABLE 2. Chemical studies of 67075, whole-rock

Reference	Split #	Elements analyzed
LSPET (1973)	,4	majors, Rb, Y, Zr, Cr
Haskin et al. (1973)	,17	majors, REEs, other trace (∿ 30 els.)
Hubbard et al. (1974)	,53,55	REEs,other trace
Wänke et al. (1975)	,11	majors, REEs, siderophiles, other trace (∿ 40 els.)
Wänke et al. (1977)	,11	V
Scoon (1974)	,22	majors
Hertogen et al.(1977)	,9	meteoritic siderophiles and volatiles
Moore et al.(1973)	,7	C
Jovanovic and Reed (1976a)	,10	Ru, Os
Jovanovic and Reed (1976b)	,10	F, Cl, Br, U, P_2O_5
Nyquist et al. (1974)	,53	Rb, Sr
Nyquist et al. (1976)	,17	Rb, Sr
Silver (1973)	,5	U, Th, Pb
Oberli et al. (1979)	,34	U, Th, Pb
Marti et al. (1973)	,8	K

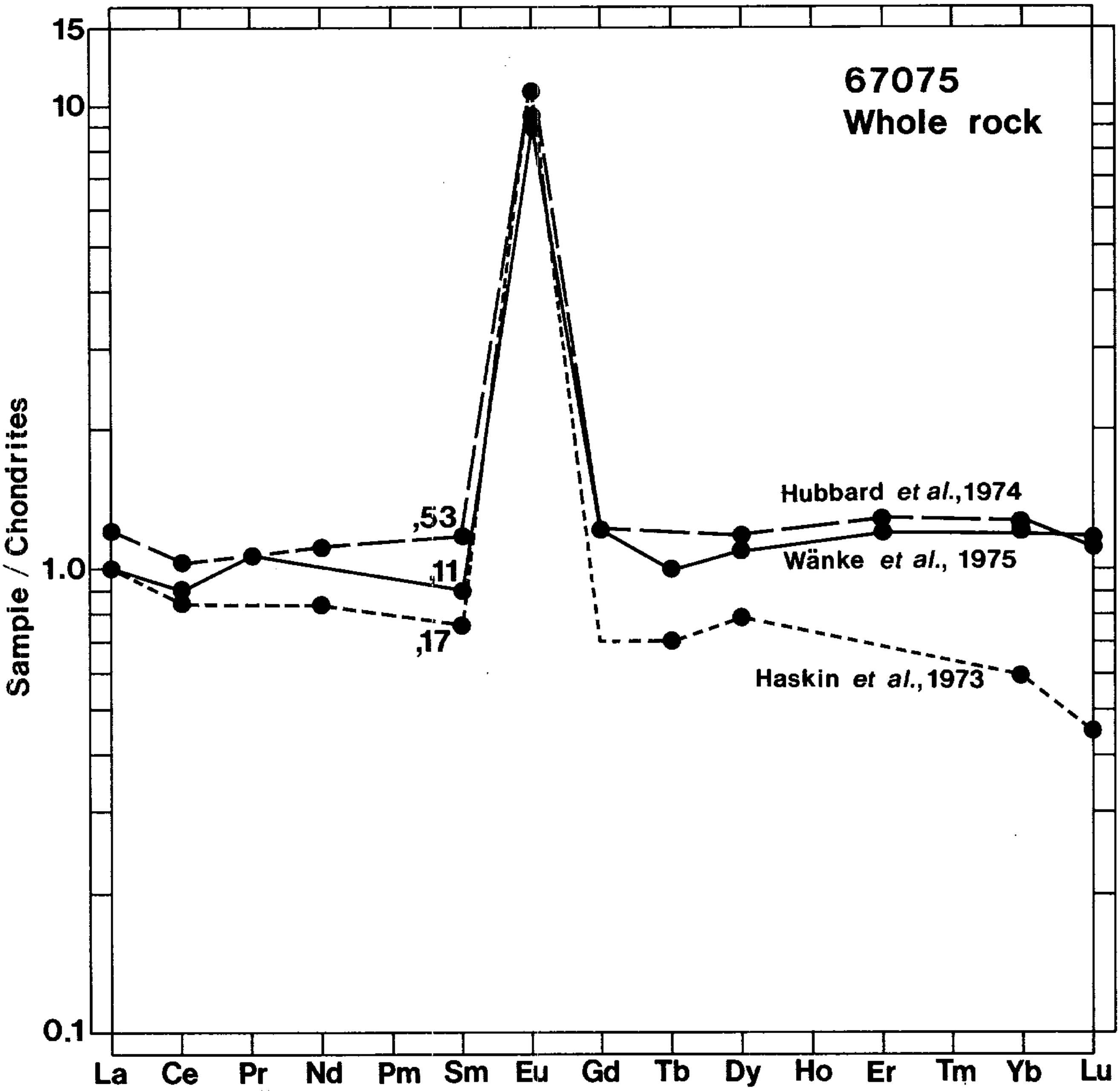


Figure 5. Rare earths.

TABLE 4

	Split	Rb_{ppm}	Sr_{ppm}	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	T_{BABI} (b.y.)	T_{LUNI} (b.y.)
Nyquist et al. (1974)	,53	0.593	145.0	0.0118±3	0.69984±7	4.38±.52	4.78±.52
Nyquist et al. (1976)	,17	0.499	158.0	0.0092±2	0.69958±3	3.66±.31	4.18±.31

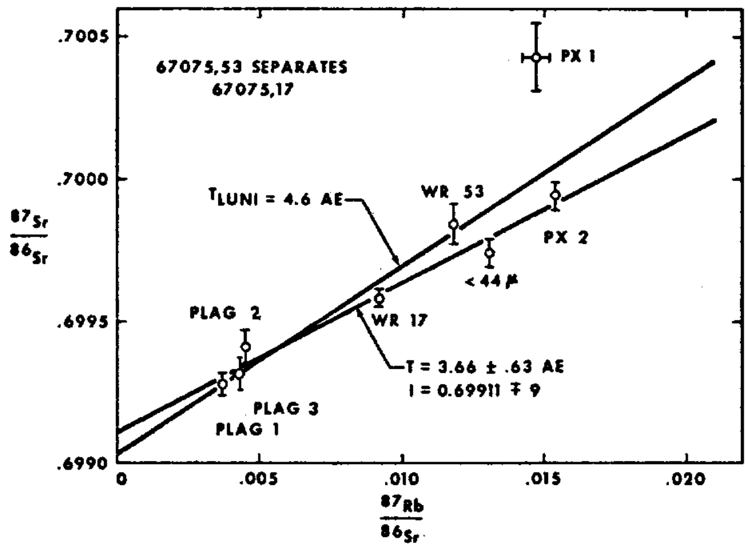


Figure 6. Rb-Sr isotopic data, from Nyquist et al. (1976).

Turner et al. (1973) report Ar isotopic data, which have simple systematics. The release diagram is shown as Figure 7. The 900-1250°C release gives an age of 4.04±0.05 b.y. Huneke et al. (1977) report whole rock and plagioclase Ar isotopic data. The age spectra are anomalous (Fig. 8) and different to that of Turner et al. (1973). The ages increase, then decrease, then increase again with temperature. The plagioclase clast is less disturbed than the whole-rock; the >850°C release gives a K-Ar age of 3.95±0.1 b.y. No ages are significantly older than 4.0 b.y.

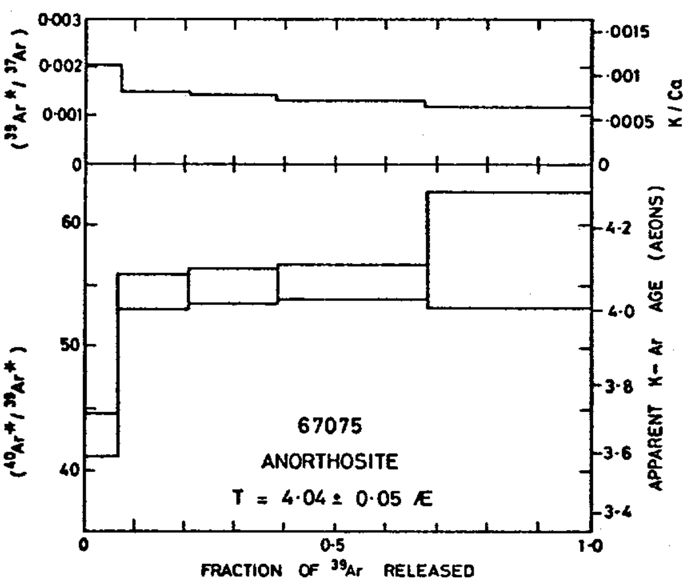


Figure 7. Ar releases, from Turner et al. (1973).

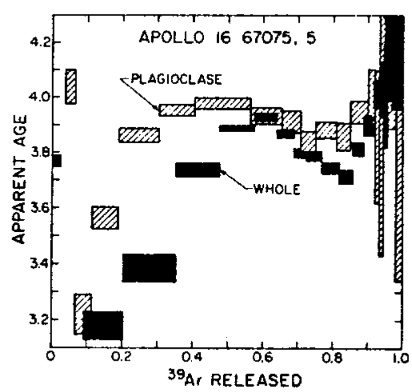
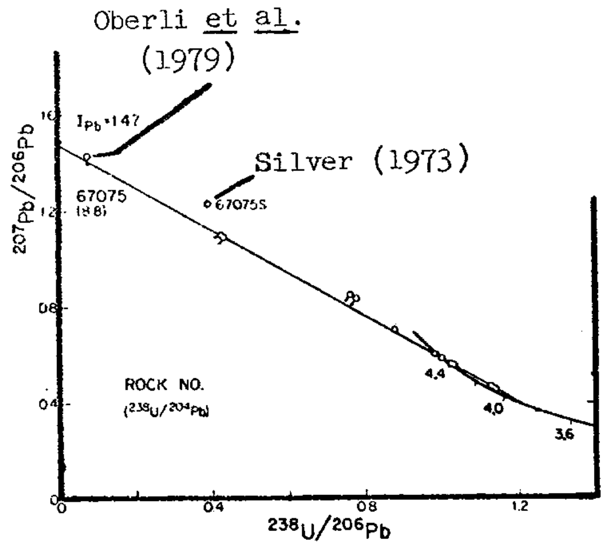


Figure 8. Ar releases, from Huneke et al. (1977).

U-Th-Pb isotopic data are given by Silver (1973) and Oberli et al. (1979). Silver's (1973) results show the lead to be moderately radiogenic but unsupported by the observed U and Th abundances. The lead may contain one of the oldest lunar components identified. Oberli et al. (1979) made new determinations, showing Silver's (1973) data to be in error. The new data appear to be compatible with the "cataclysm array" (i.e. other rocks with ~4.0 b.y. ages) (Fig. 9) and thus compatible with a primary age of 4.47 b.y.

Figure 9. U-Pb isotopic data.



RARE GAS AND EXPOSURE AGES: Turner et al. (1973) report Ar isotopic data and calculate an exposure age of 46 m.y. Marti et al. (1973) report Kr isotopic data for an interior chip and calculate an exposure age of 48.5±5.5 m.y. Hohenberg et al. (1978) compare observed (published data) with predicted cosmogenic Ar, Kr, and Xe abundances, and list exposure ages of 50.2 m.y. and 49 m.y.

Lightner and Marti (1974a) report Xe isotopic data and report that the sample contains little trapped Xe. Drozd et al. (1977) note that $(^{131}Xe/^{126}Xe)_{SPALL}$ = 3.35, among the lowest observed among the samples they studied.

PHYSICAL PROPERTIES: Weeks et al. (1973) report electron paramagnetic resonance studies of plagioclases, with reference to Ti^{3+} and Fe^{3+} abundances. Both Ti^{3+} and Fe^{3+} are low, even compared to most other Apollo 16 samples.

PROCESSING AND SUBDIVISIONS: 67075 is so friable that it broke into many small pieces and powder during transportation to Earth (Fig. 1). Thus no sawcuts or extensive chipping were necessary.

INTRODUCTION: 67095 is a coherent, coarse-grained basaltic impact melt with a thick coat of frothy, clast-laden glass (Fig. 1). The large "norite" clasts referred to in the original Apollo 16 Sample Information Catalog (1972) are actually portions of the basalt showing through the glass coat.

This rock was collected within the southeast rim of North Ray Crater; lunar orientation is unknown. Zap pits are absent from all surfaces.

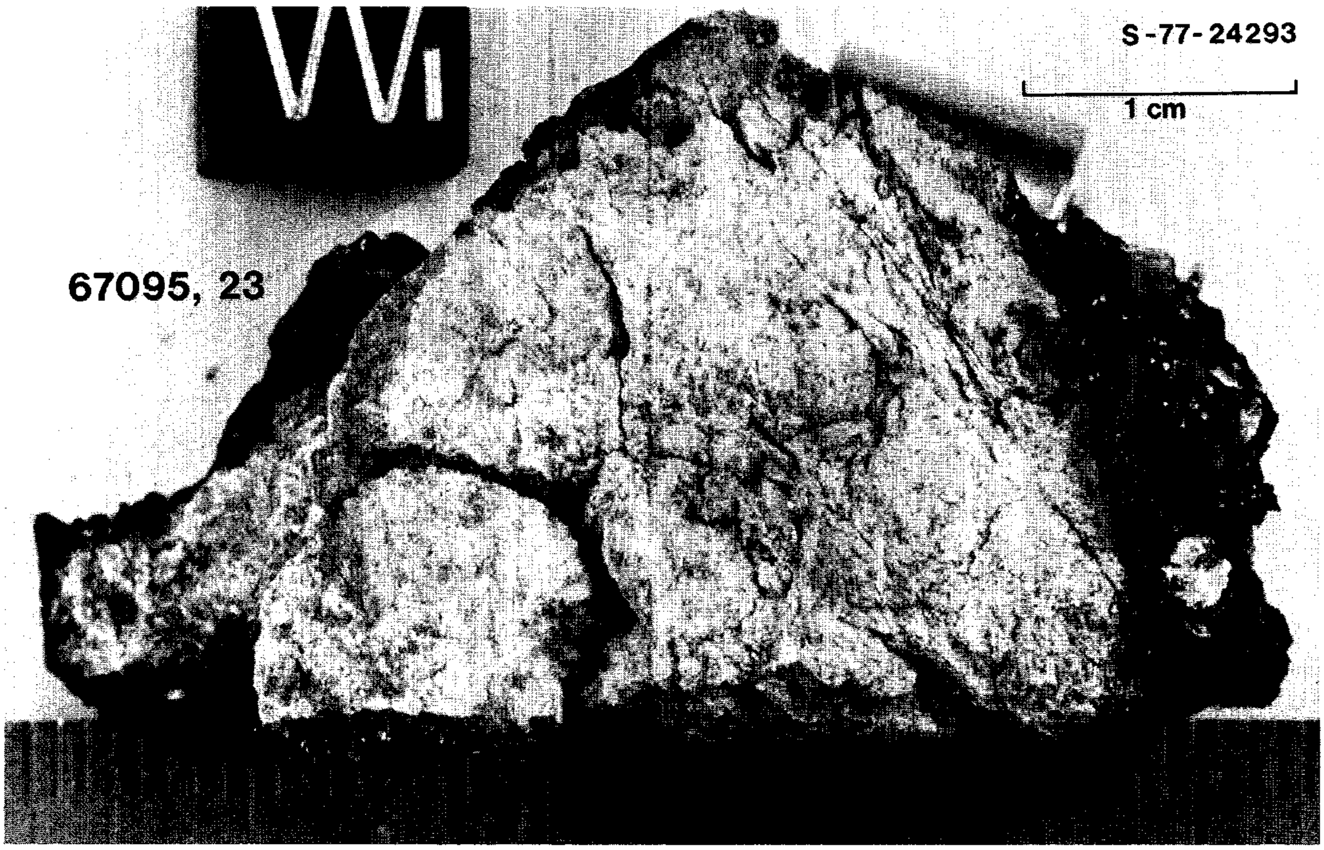


Figure 1.

PETROLOGY: This coarse-grained, basaltic impact melt rock is characterized by equant to lathy plagioclase (up to 1.5 mm long) ophitically enclosed by large (up to 10 mm) single crystals of olivine and pyroxene (Fig. 2). The plagioclase is normally zoned from An_{90-95}; olivine is Fo_{78-83}, clinopyroxene $Wo_{40}En_{47}$, and pigeonite $Wo_{14}En_{59}$ (Warren and Wasson, 1978). The mesostasis consists of dark brown glass, metal, troilite, ilmenite and other opaque oxides. The grain size is locally variable with clots of much finer-grained basalt scattered through the rock. Xenocrysts are rare, and are mostly a b c

Figure 2. a) 67095,45, general view, olivine crystal at extinction, xpl. width 2mm.
b) 67095,35, zone of internal shearing, ppl. width 1mm.
c) 67095,36, contact of basalt and glass coat, ppl. width 1mm.

plagioclase or plagioclase aggregates. A few very fine-grained, recrystallized breccia clasts (1-2 mm) are recognized by Warren and Wasson (1978). Zones of internal shearing have disrupted the original texture in places (Fig. 2), causing minor brecciation and recrystallization.

The dark glass coat is clear in thin section, with schlieren indicating flow parallel to the basalt/glass contact (Fig. 2). Partial crystallization of the coat to a fine-grained groundmass has occurred around local nuclei. Some melting of the host rock near the contact is apparent (Fig. 2).

CHEMISTRY: Major and trace element analyses of the bulk rock are reported by Laul et al. (1974), Palme et al. (1978) and Warren and Wasson (1978). Hertogen et al. (1977) give meteoritic siderophile and volatile element abundances for the glass coat and for the bulk rock. Rancitelli et al. (1973a,b), provide whole rock abundances of natural and cosmogenic radionuclides.

67095 is compositionally distinct from the local soils, being considerably less aluminous and with higher levels of REEs (Table 1, Fig. 3). Palme et al. (1978) note that the Na content of 67095 is somewhat high for a typical basaltic impact melt, and that the K/La ratio (K/La = 95) is also high compared to the average highlands (K/La ∿70). Both the basalt and the glass coat contain meteoritic contamination (Table 1). Hertogen et al. (1977) assign the basalt to ancient meteoritic group 1L which they interpret to represent Imbrium ejecta. The glass coat is probably a young hybrid with siderophiles unrelated to a particular ancient meteoritic group (Hertogen et al., 1977).

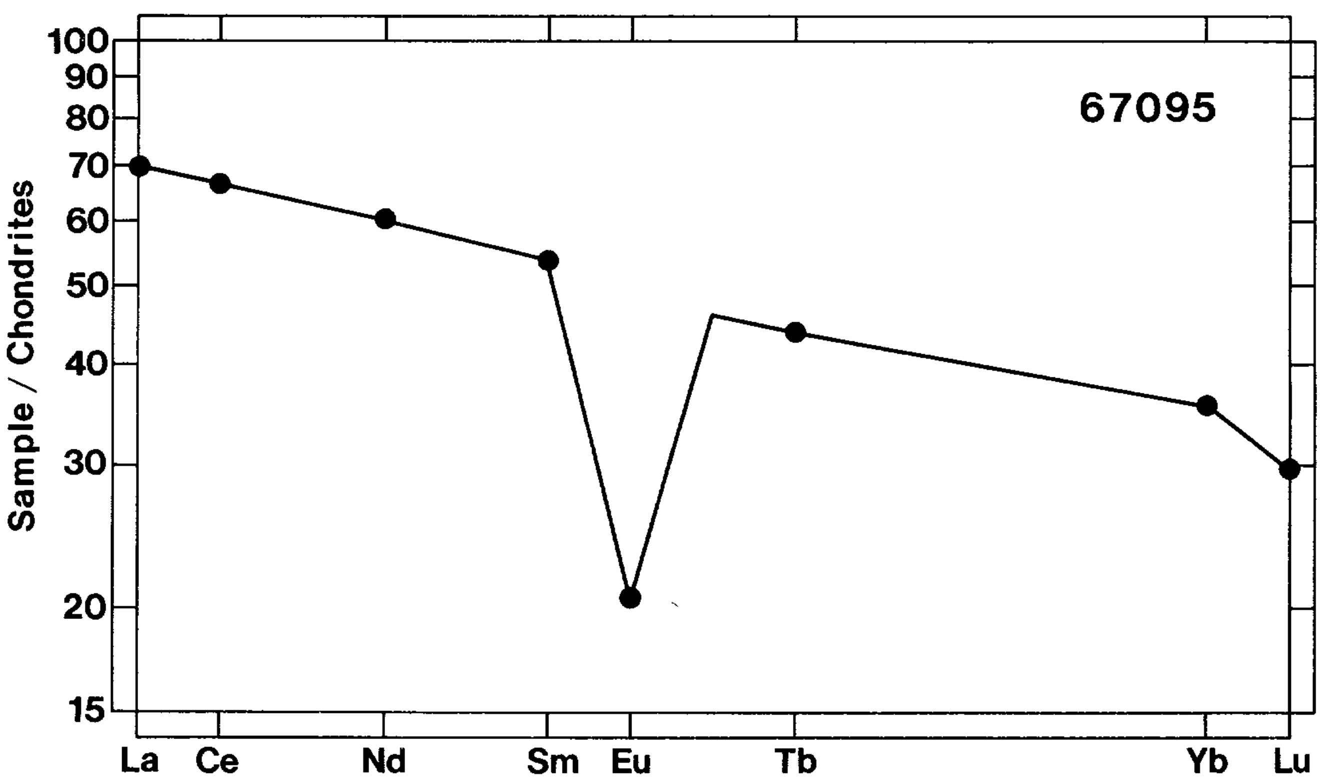


Figure 3. Rare earths, average of published analyses.

TABLE 1. Summary chemistry of 67095 lithologies

	Basalt	Glass coat
SiO_2	47.3	
TiO_2	0.71	
Al_2O_3	22.2	
Cr_2O_3	0.14	
FeO	5.6	
MnO	0.08	
MgO	11.0	
CaO	12.8	
Na_2O	0.609	
K_2O	0.268	
P_2O_5		
Sr	180	
La	23	
Lu	1.0	
Rb	7.94	6.42
Sc	9.6	
Ni	125	129
Co	11	
Ir ppb	3.37	5.81
Au ppb	3.34	2.02
C		
N		
S		
Zn	4.7	2.27
Cu		

Oxides in wt%; others in ppm except as noted.

RARE GASES/EXPOSURE AGES: Cosmogenic radionuclide data are given by Rancitelli et al. (1973b) and Fruchter et al. (1978). These data indicate that 67095 is undersaturated in ^{26}Al activity (Rancitelli et al., 1973b; Yokoyama et al., 1974).

A ^{26}Al exposure age of >2.5 m.y. and a ^{53}Mn age of >12 m.y. were calculated by Fruchter et al. (1978), who also conclude that 67095 had a simple exposure history.

Kr isotopic data yield an exposure age of 50.2±1.8 m.y., consistent with the excavation of 67095 by the North Ray Crater event (Drozd et al., 1974). Xe isotopic data are provided by Hohenberg et al. (1978).

PROCESSING AND SUBDIVISIONS: In 1973, 67095 was slabbed and the slab subdivided (Fig. 4). Allocations have been made from all portions of the rock. Many splits remain at JSC, the largest being the W end piece ,1 (183.6 g).

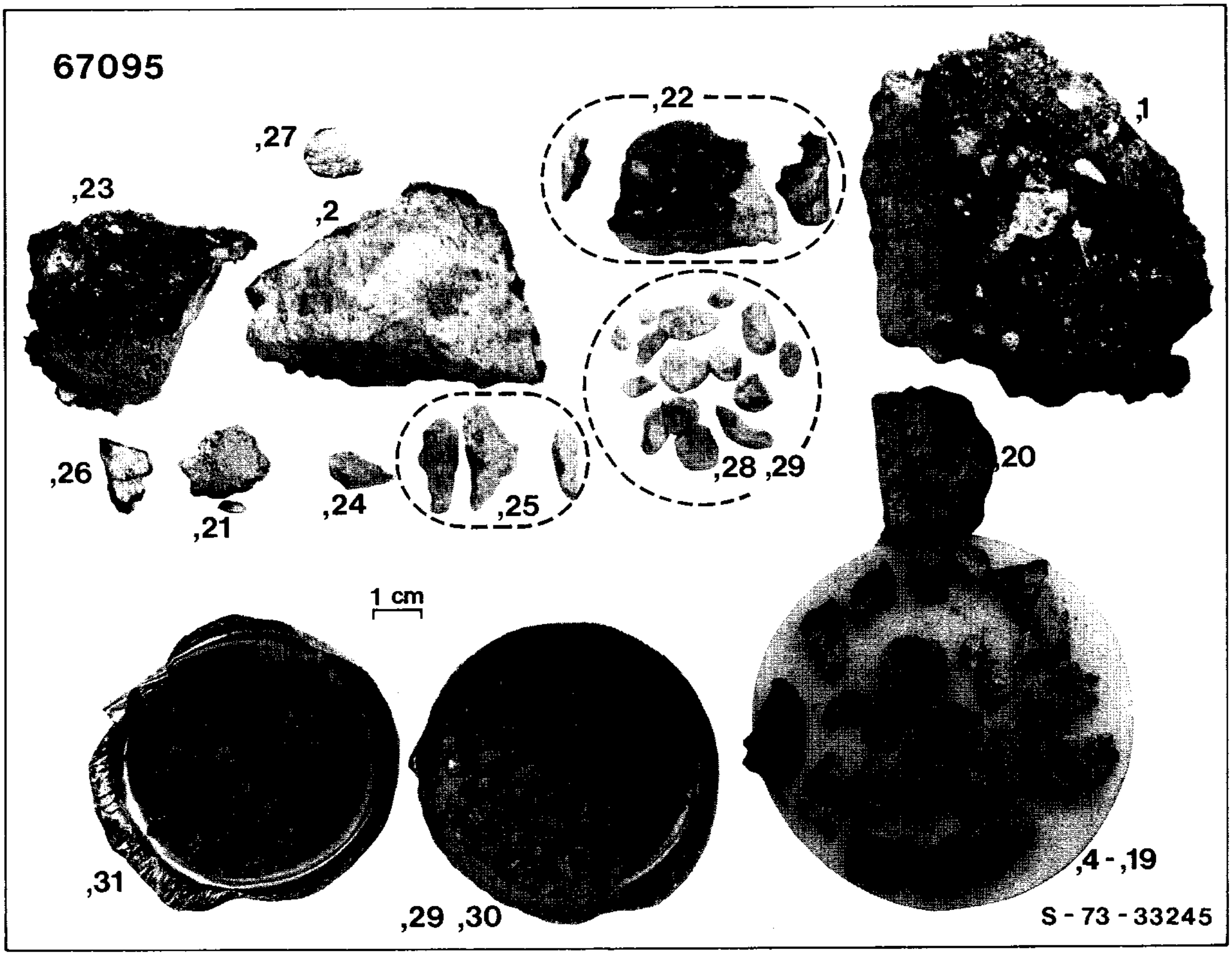


Figure 4. Major subdivisions of 67095.

INTRODUCTION: 67115 is a friable, light gray matrix breccia partially coated by dark glass (Fig. 1). Macroscopically the rock has a shattered appearance, being cut by many penetrating fractures and veined by dark glass.

This sample was collected within the southeast rim of North Ray Crater; lunar orientation is unknown. Many zap pits are present on the S surface of the rock, with few to none on other surfaces.

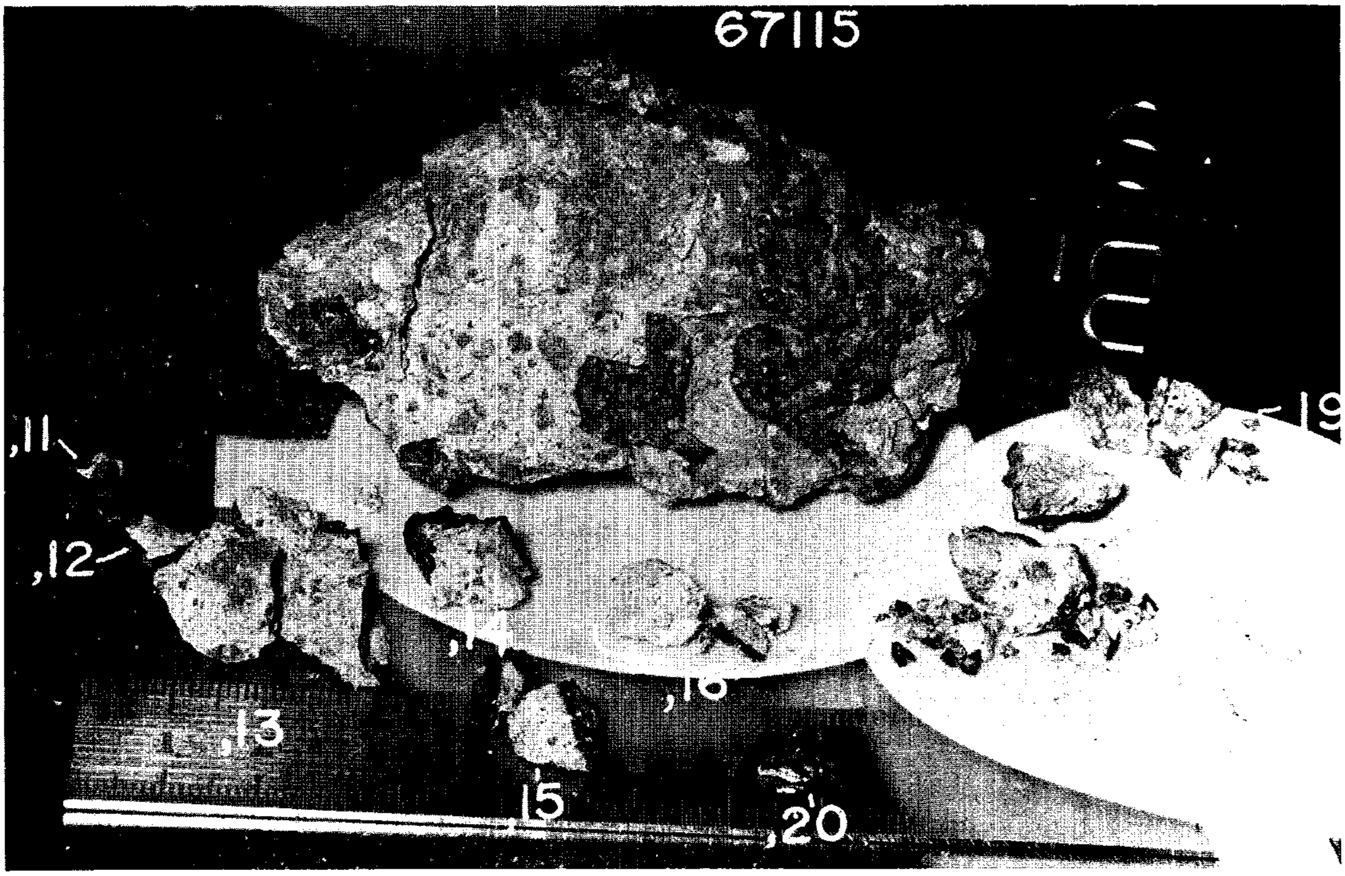


Figure 1. S-72-53517, smallest scale subdivision 0.5mm.

PETROLOGY: A restricted population of clast types characterizes this fragmental matrix breccia (Fig. 2). Mineral fragments of plagioclase are by far the most abundant constituent. Granoblastic anorthosites with variable percentages of mafic minerals, and clast-rich, dark melt matrix breccias are virtually the only lithic types in the rock (Fig. 2), though both are present in abundance. Fragments of olivine, pyroxene, spinel, metal and schreibersite are minor components.

Incipient recrystallization appears to have affected the finest portion of the matrix. Abundant tiny, rounded grains of olivine(?) fill interstices and occasionally rim larger, more angular grains (Fig. 2).

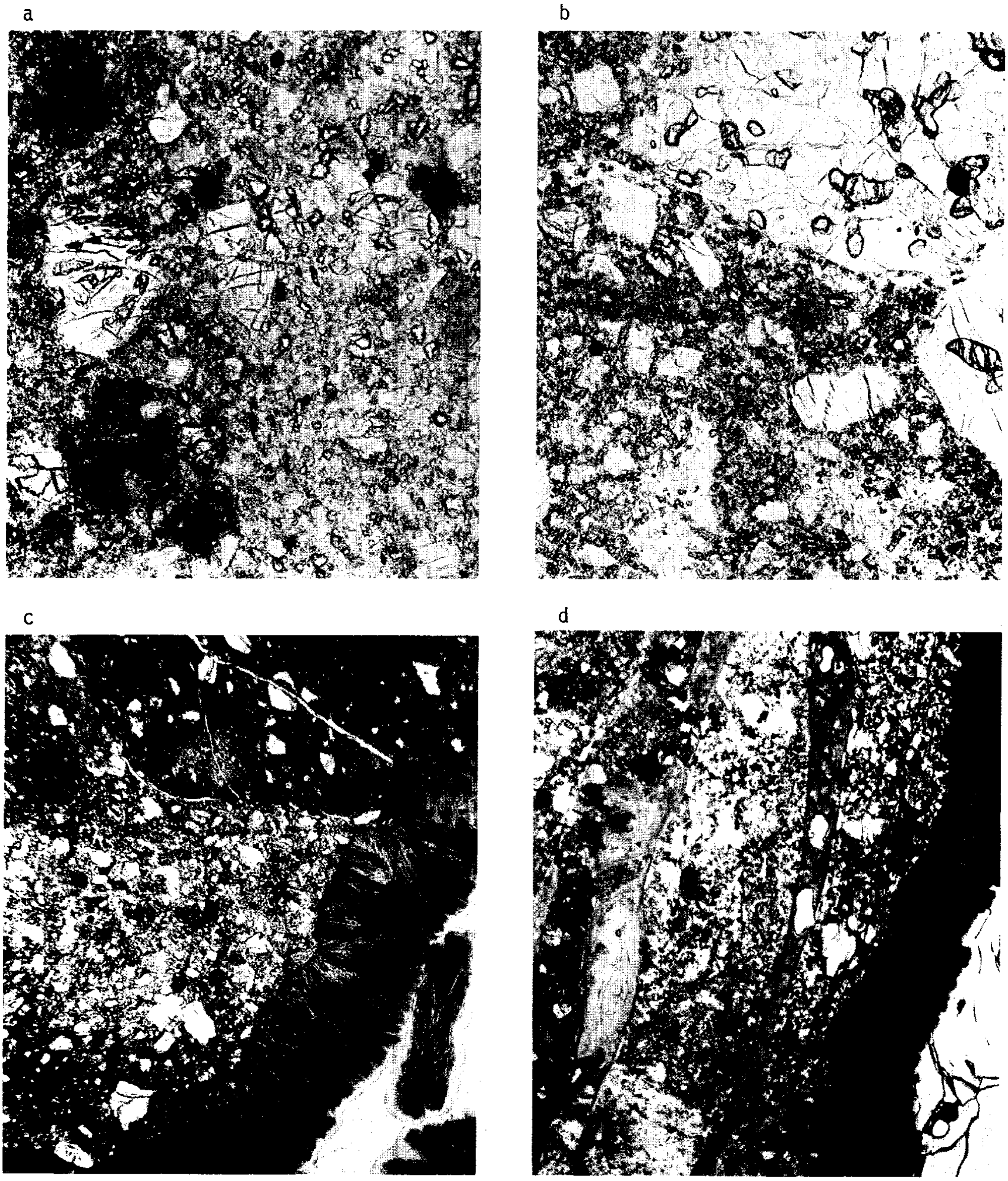


Figure 2. a) 67115,31, matrix, ppl. width 0.5mm.
b) 67115,30, matrix and granoblastic clast, ppl. width 1mm.
c) 67115,30, matrix, dark clast, and glass coat, ppl. width 2mm.
d) 67115,49, glass veins near contact of breccia and glass coat, ppl. width 2mm.

The glass coat is irregularly distributed over the surface of the rock. Schaal et al. (1979) tabulate various physical parameters of the glass coat, such as vesicularity. A zone of fine-grained quench crystals occurs at the breccia/glass contact (Fig. 2).

CHEMISTRY: Major and trace element abundances for the bulk rock are given by Rose et al. (1973). Major and trace element analyses of "black" and "white" portions of the rock reported by S.R. Taylor et al. (1973) bracket the bulk analysis of Rose et al. (1973). (The rock is erroneously referred to as 61175 in the text of S.R. Taylor et al. (1973) but is correctly labeled in all tables). Clark and Keith (1973) and Eldridge et al. (1975) provide natural and cosmogenic radionuclide data and Jovanovic and Reed (1976a,b) report halogens and other trace element data for the bulk rock. Major and trace element analyses of the glass coat and a plagioclase separate are given by S.R. Taylor et al. (1973). Meteoritic siderophile and volatile abundances for two "gray" clasts, a glass vein and the bulk matrix are given by Hertogen et al. (1977). Schaal (unpublished) determined major elements in the glass coat by electron microprobe.

67115 is compositionally similar to several other Apollo 16, Station 11 and 13 light matrix breccias in being very aluminous (~30% Al_2O_3) and low in lithophile and siderophile elements (Table 1, Fig. 3). All of the samples analyzed by Hertogen et al. (1977) are contaminated with meteoritic siderophiles but the low levels of these elements renders assignments to specific meteoritic groups somewhat tenuous. The "light gray clast" is nearly pristine (Table 1). Photographs of this split show a single, nearly white clast but no thin sections or other chemical data are available.

The glass samples are poorer in Al_2O_3 and richer in lithophiles and siderophiles than the bulk rock, and are close to the composition of North Ray soils.

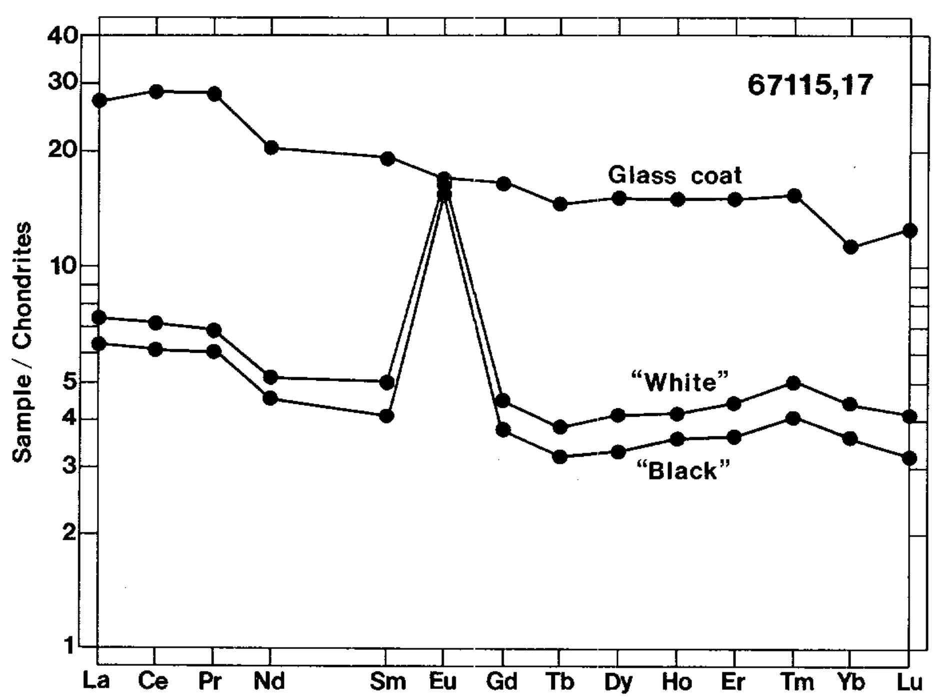


Figure 3. Rare earths, from S.R. Taylor et al. (1973).

TABLE 1. Summary chemistry of 67115 lithologies

	Bulk rock	Glass coat and vein	Light gray clast	Medium gray clast
SiO_2	44.6	44.5		
TiO_2	0.2	0.65		
Al_2O_3	31.0	27.9		
Cr_2O_3	0.06	0.10		
FeO	2.5	4.8		
MnO	0.04			
MgO	3.1	4.9		
CaO	17.7	15.8		
Na_2O	0.5	0.45		
K_2O	0.08	0.12		
P_2O_5	0.02	0.06		
Sr	180			
La	2.2	9.0		
Lu	0.12	0.43		
Rb	~1	1.5	0.36	0.45
Sc	2			
Ni	50	164	28	45
Co	5			
Ir ppb	1.59	7.17	0.44	2.69
Au ppb	0.16	3.27	0.39	0.5
C				
N				
S				
Zn	~4	2.54	4.85	4.13
Cu	2			

Oxides in wt%; others in ppm except as noted.

EXPOSURE AGES: Clark and Keith (1973) and Eldridge et al. (1975) provide cosmogenic radionuclide data as determined by gamma-ray spectroscopy. 67115 is apparently unsaturated in ^{26}Al activity.

MICROCRATERS: Morphological parameters of microcraters in the 0.2-100 µm diameter range are reported by Brownlee et al. (1973), from scanning electron microscopy (SEM) studies (Fig. 4).

PROCESSING AND SUBDIVISIONS: 67115 has never been sawn but was extensively subdivided by chipping in 1972. Allocations have been made from all areas of the rock. ,16 and ,17 (Fig. 1) were allocated for chemistry to Rose and S.R. Taylor, respectively. ,25-,28 (Fig. 5) were analyzed by Hertogen et al. (1977). The largest single piece remaining is ,9 (161.6 g).

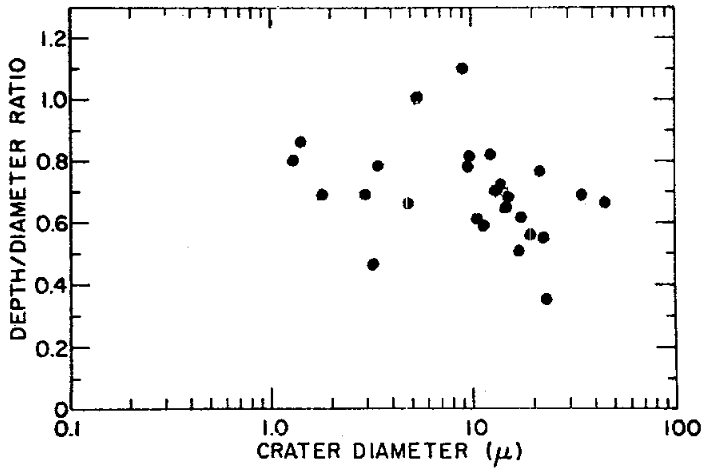


Figure 4. Microcraters, from Brownlee et al. (1973).

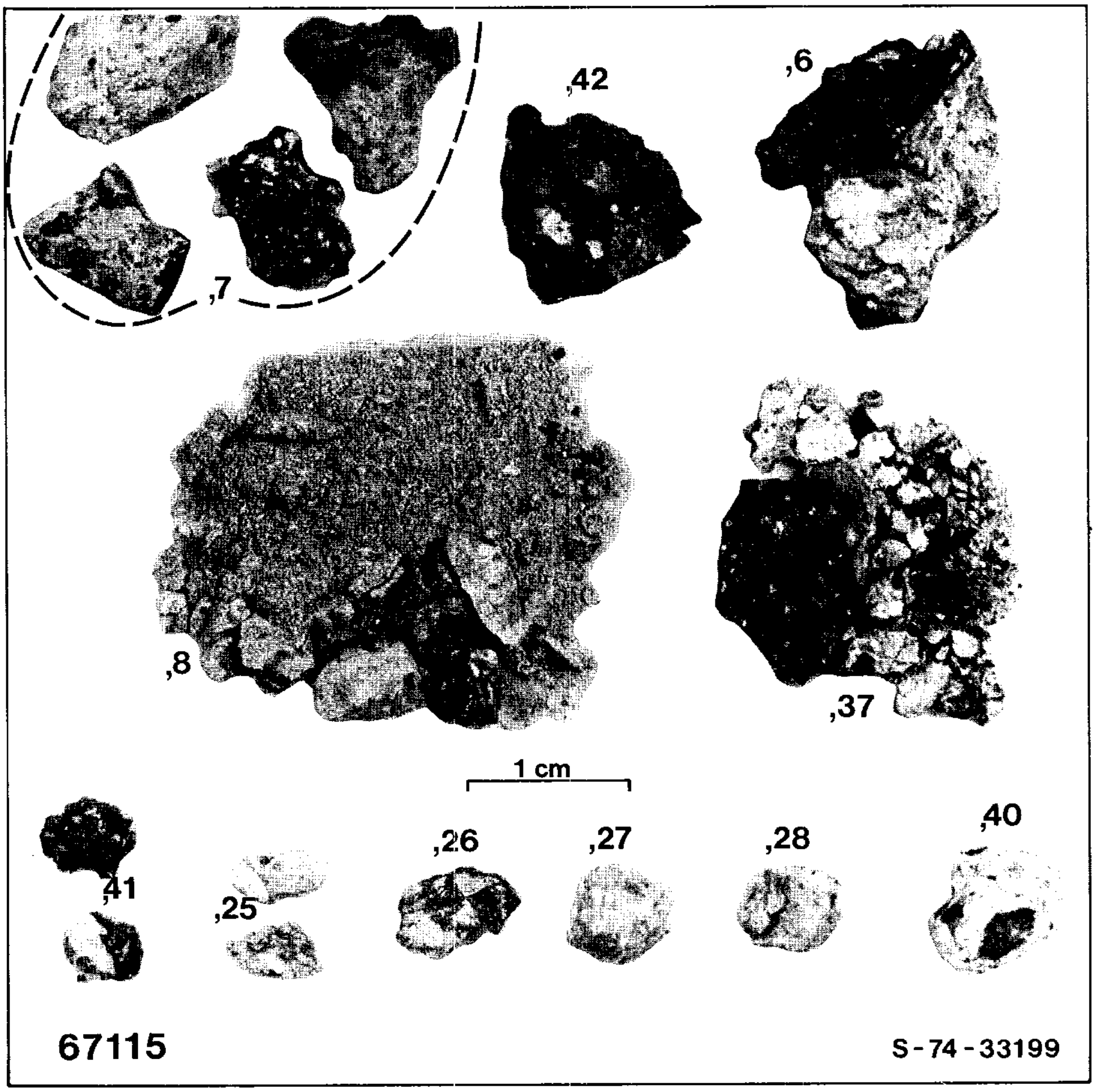


Figure 5.

INTRODUCTION: 67215 is a moderately friable, light gray, fine-grained, and fairly uniform fragmental breccia (Fig. 1). The sample may be monomict with most material derived from granoblastic, anorthositic granulite, but a few dark aphanitic clasts are present.

67215 was collected on the south rim of North Ray crater. It was collected as a special sample for the study of rock surfaces; hence, to avoid abrasion and other degradation, it was packed in a padded bag. However, apparently because it is a breccia, and not the tough crystalline rock planned premission as a padded bag sample, it has not been requested for surface studies and has only recently been inspected. The sample has zap pits on all surfaces except new fractures.

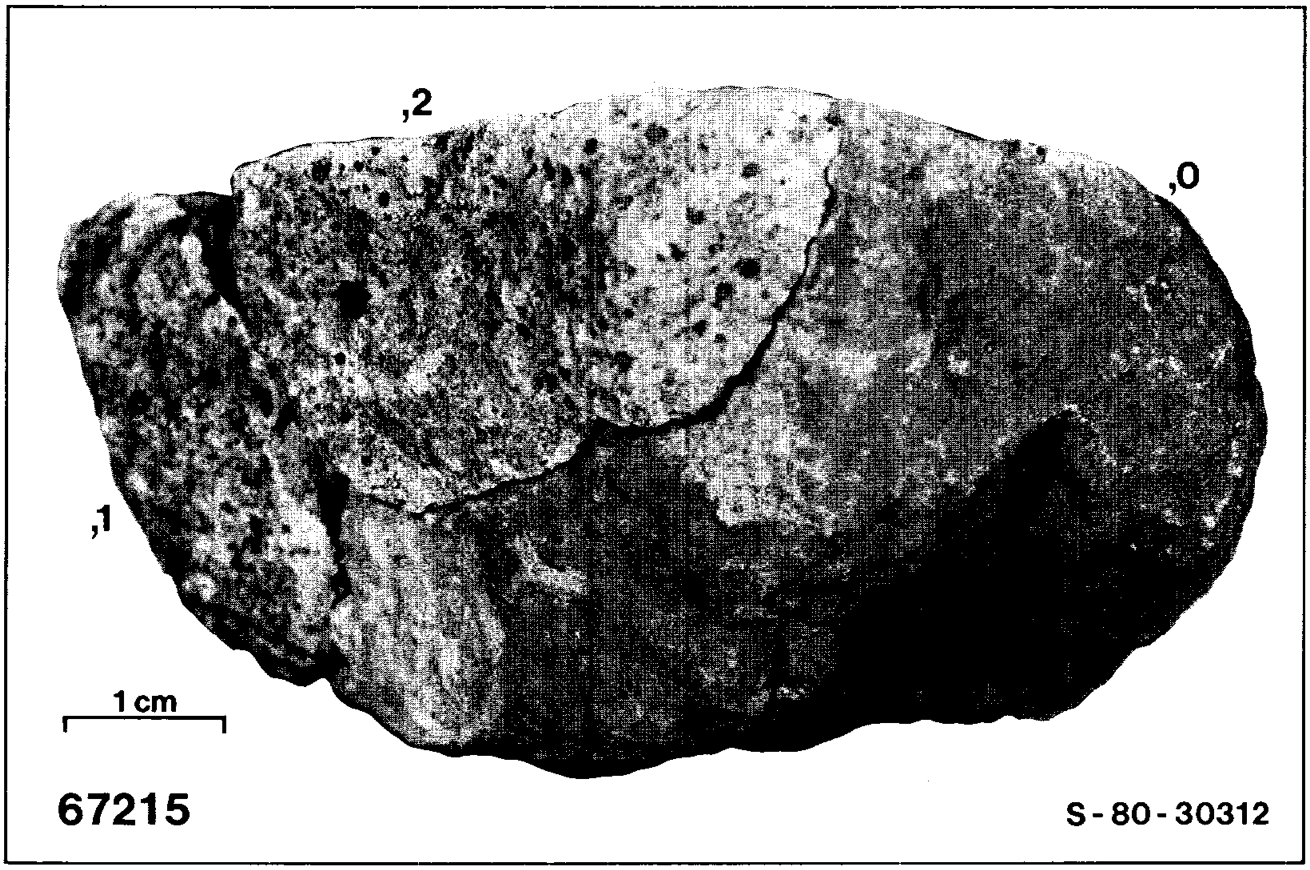


Figure 1.

PETROLOGY: A macroscopic description has been made by G. J. Taylor (unpublished Data Pack information). The sample is light gray and fine-grained. The most abundant clast type consists of plagioclase, brown pyroxene(?), and yellow olivine(?), with granular textures. The matrix (arbitrarily defined) consists of crushed debris of the same mineral. In thin section the fragments are granoblastic or cumulate-textured, and anorthositic (Fig. 2). The fragments vary in the size and abundance of pyroxene, which shows exsolution, and they contain troilite, Fe-metal, ilmenite, and traces of silica. The matrix consists of crushed, angular mineral fragments.

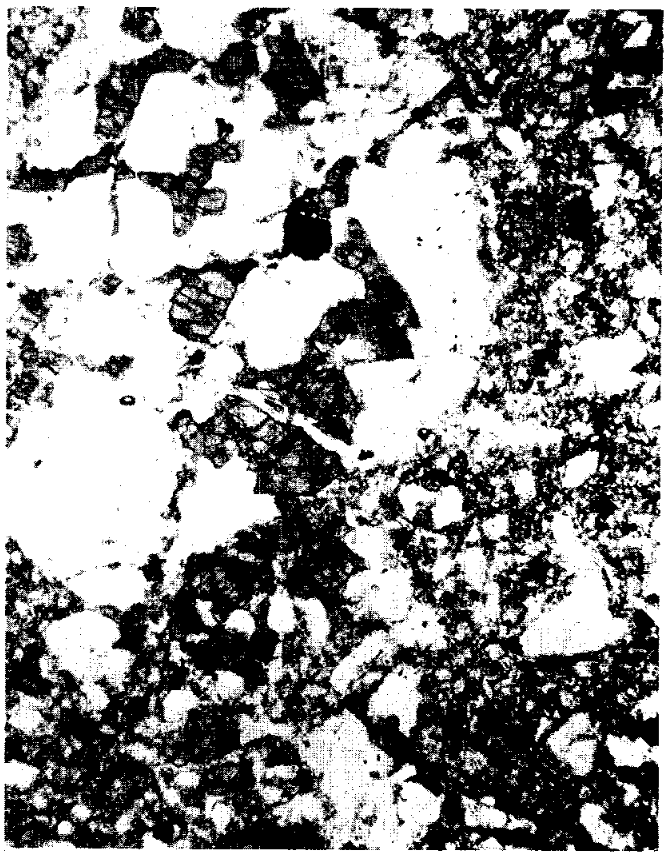


Figure 2. 67215,6, general view, ppl. width 2mm.

PROCESSING AND SUBDIVISIONS: 67215 has only recently been inspected and was found to have broken into one large piece, two smaller pieces, and several small fragments (Figs. 1,3). ,3 was allocated for thin sections.

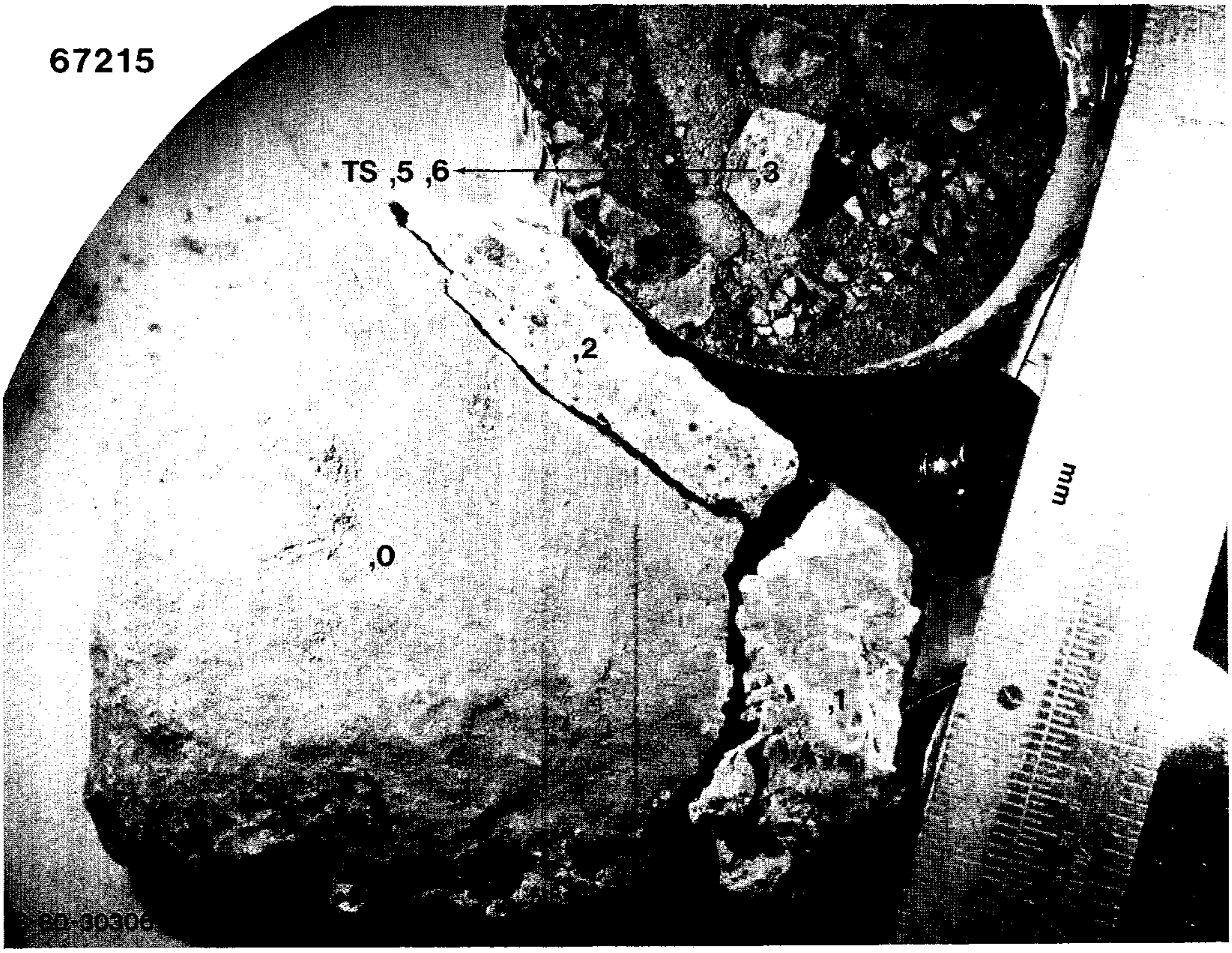


Figure 3. Subdivisions of 67215.

INTRODUCTION: 67235 is a fine-grained, crystalline sample (Fig. 1) which is a poikilitic impact melt. It is pervasively fractured, allowing the rock to fall apart, but individual pieces are coherent.

67235 was collected on the south rim of North Ray crater. It was collected as a special sample for the study of rock surfaces; hence, to avoid abrasion and degradation, it was packed in a padded bag. However, it has not been requested for surface studies and has only recently been inspected; it is obvious that the surfaces have not been preserved but have flaked off (G. J. Taylor, unpublished Data Pack information). The sample has only rare zap pits.

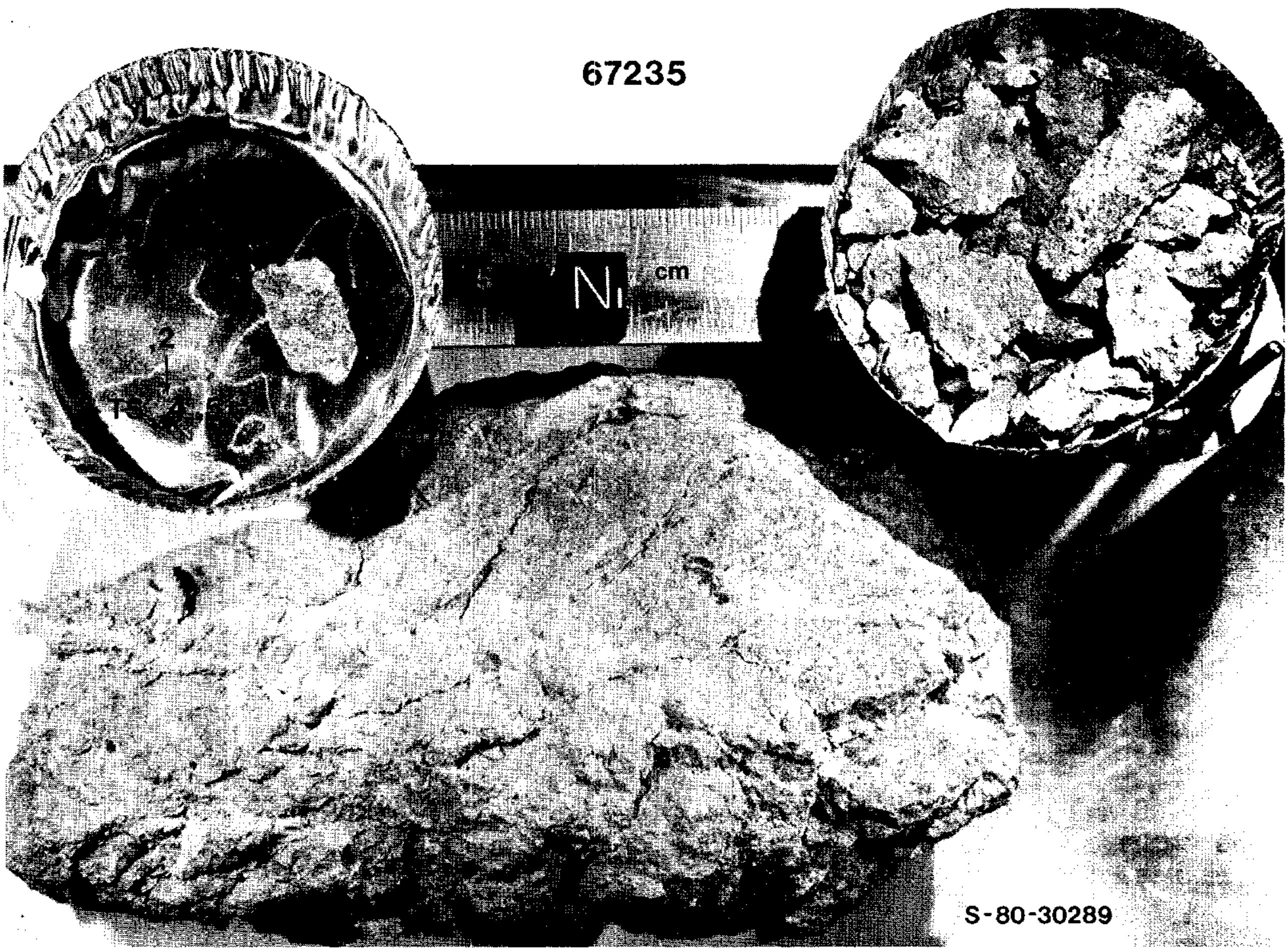


Figure 1.

PETROLOGY: A macroscopic description has been made by G. J. Taylor (unpublished Data Pack information). The sample is fine-grained (<0.2 mm?) and uniform, but with some whitish clasts. Metal grains are conspicuous.

Thin sections show that the sample is a poikilitic impact melt (Fig. 2), with oikocrysts less than 500 μm across. Most of the enclosed plagioclase chadacrysts are less than 30 μm long, and the interoikocryst areas are glassy and opaque-mineral rich. Fe-metal and troilite are present. Most of the clasts are plagioclase, and thin section ,5 contains one granoblastic impactite (~80% plagioclase).

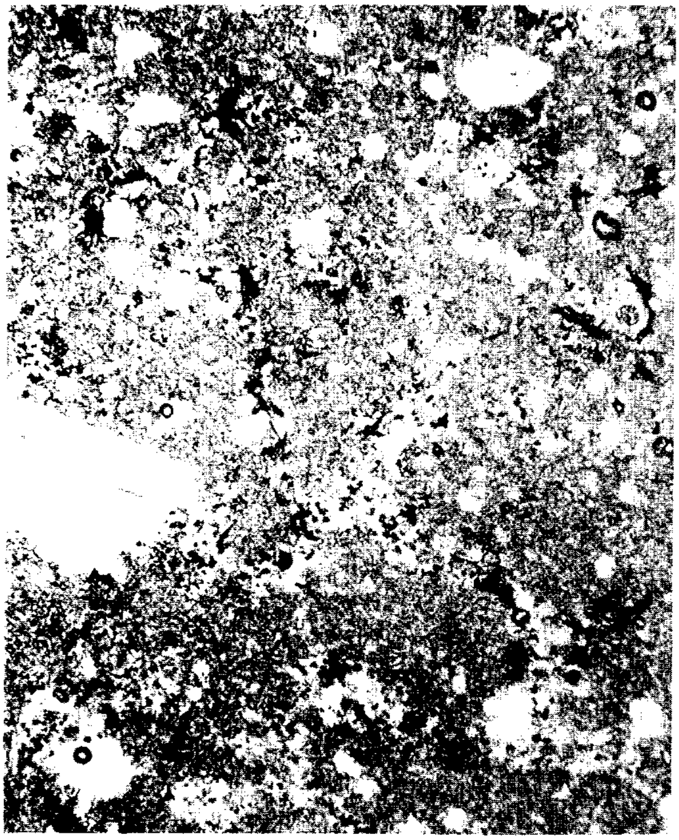


Figure 2. 67235,5, general view, ppl. width 2mm.

PROCESSING AND SUBDIVISIONS: 67235 has only recently been inspected and was found to have shed many small chips (Fig. 1). One of these ,2 was allocated for thin sections.

INTRODUCTION: 67415 is an extremely friable, cataclastic noritic anorthosite that was removed from its documented bag in many pieces (Fig.1). It appears to be nearly monomict, but is not chemically pristine.

This sample was collected from the south rim of North Ray Crater, near the large, White Breccia boulders that yielded 67455, and 67475. The lunar orientation of 67415 could not be determined. Due to its friable nature, no lunar exterior surfaces could be recognized.

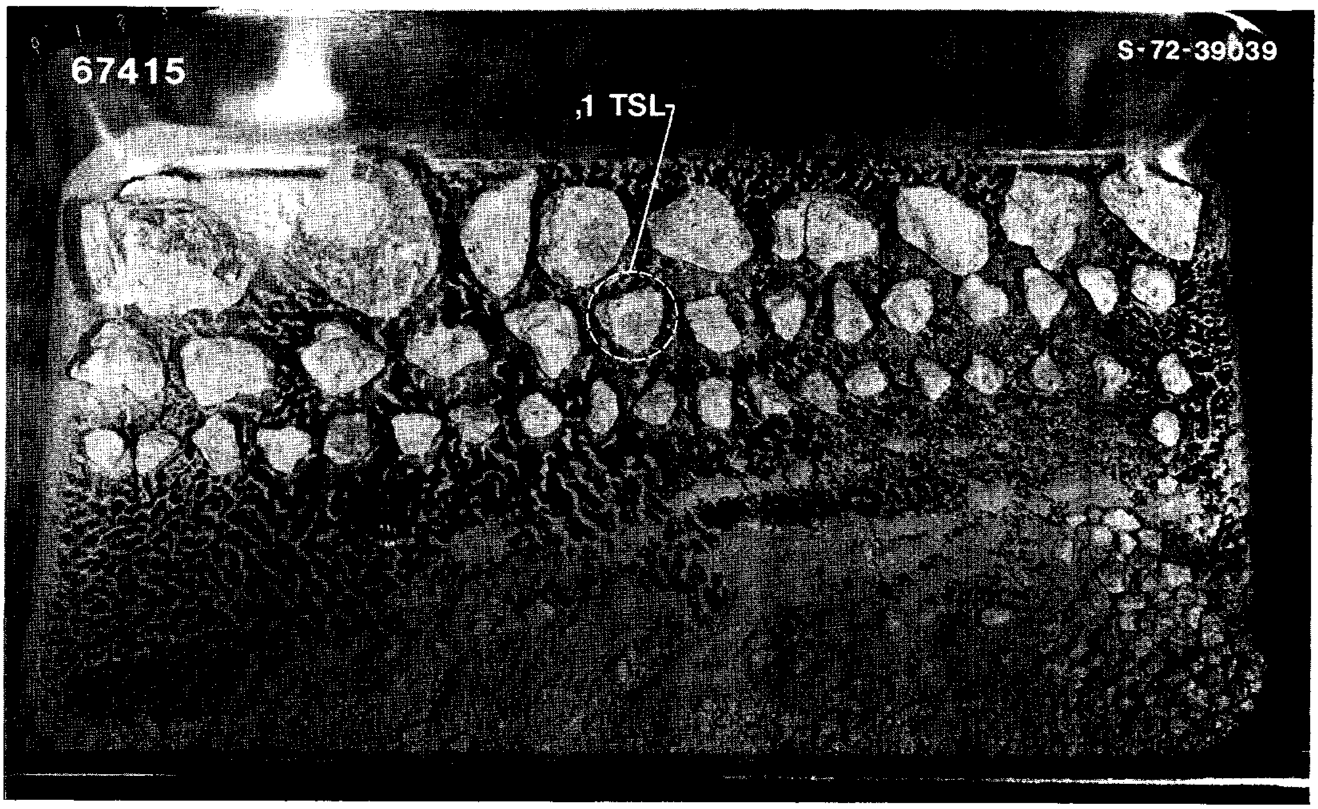


Figure 1. cm scale.

PETROLOGY: 67415 is a clastic rock apparently formed by simple crushing of a granoblastic noritic anorthosite. It is composed predominantly of angular grains of plagioclase with lesser amounts of mafic minerals (mostly orthopyroxene), granoblastic lithic fragments, minor metal (some rusty), troilite, ilmenite and very rare symplectites. Pre-cataclasis texture of the rock is preserved only in small (up to 3 mm) lithic fragments (Fig.2).

Figure 2. 67415,14, general view, ppl. width 2mm.

Minor elements in plagioclase as determined by ion probe are given by Meyer (1979) (Table 1).

TABLE 1. Minor elements in plagioclase (ppm)(Meyer, 1979)

	Li	Mg	Ti	Sr	Ba
a.	6	650			100
b.	6	637	203	300	103

CHEMISTRY: Major and trace element analyses are given by Wänke et al. (1976, 1977) and Lindstrom et al. (1977). Hertogen et al. (1977) report meteoritic siderophile and volatile abundances. Cripe and Moore (1975) and Moore and Lewis (1975) provide total C, N and S data.

67415 is compositionally distinct from the local mature soils, being less aluminous and somewhat more magnesian (Table 2). The rare-earth element abundances for this rock are fairly low (Fig. 3), about a factor of 3 less than in the soils. 67415 is not chemically pristine: siderophiles indicate a significant meteoritic component (Table 2). The low total C and S indicate the lack of a significant solar wind component in this breccia. Although 67415 was collected near the White Breccia boulders, it is not similar to the known sample of light matrix from these boulders, 67455 (Lindstrom *et al.*, 1977).

TABLE 2. Summary chemistry of 67415

SiO_2	45.2	Sr	168
TiO_2	0.38	La	5.0
Al_2O_3	25.4	Lu	0.27
Cr_2O_3	0.10	Rb	0.8
FeO	4.9	Sc	8.3
MnO	0.07	Ni	90
MgO	7.9	Co	12
CaO	14.9	Ir ppb	3.0
Na_2O	0.53	Au ppb	1.0
K_2O	0.05	C	13
P_2O_5	0.03	N	99
		S	<17
		Zn	5.8
		Cu	

Oxides in wt%; others in ppm except as noted.

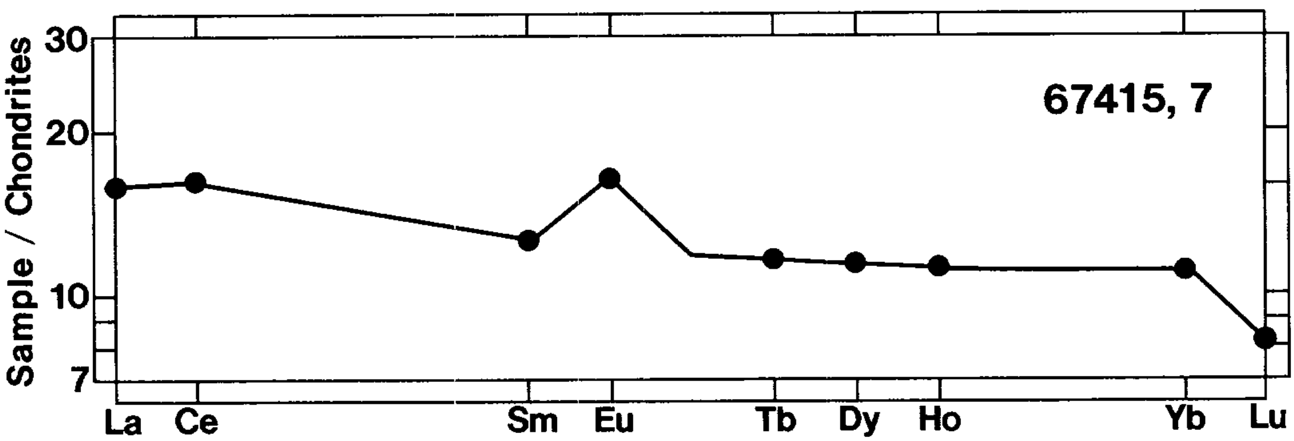


Figure 3. Rare earths, from Wänke *et al.* (1976).

PROCESSING AND SUBDIVISIONS: Although 67415 was collected as a single piece, it broke up during transport and was removed from its documented bag as ~40 fragments > 1 g, the largest (,8) being ~3 cm across. Initial allocations in 1972 were filled largely by individual fragments. In 1974 several of the individual fragments were assigned split numbers and the largest fragment (,8) extensively subdivided for allocations. ,18 contains a 7x4 mm dark, coherent clast of unknown affinity.

INTRODUCTION: 67435 is a coherent, medium gray breccia (Fig. 1) consisting of poikilitic impact melt clasts in a more feldspathic, more porous matrix; these two lithologies are in roughly equivalent proportions. A distinctive clast is the cumulate-textured, probably pristine, spinel-troctolite (Prinz et al., 1973). About half the surface of the breccia is coated with hackly, glassy, vesicular material, largely devitrified or crystallized.

67435 was collected from the southeast rim of North Ray Crater and was perched. The sample is subrounded and elongated with some penetrative fractures. Its orientation is known and a few zap pits occur on four sides, with none on the other two.

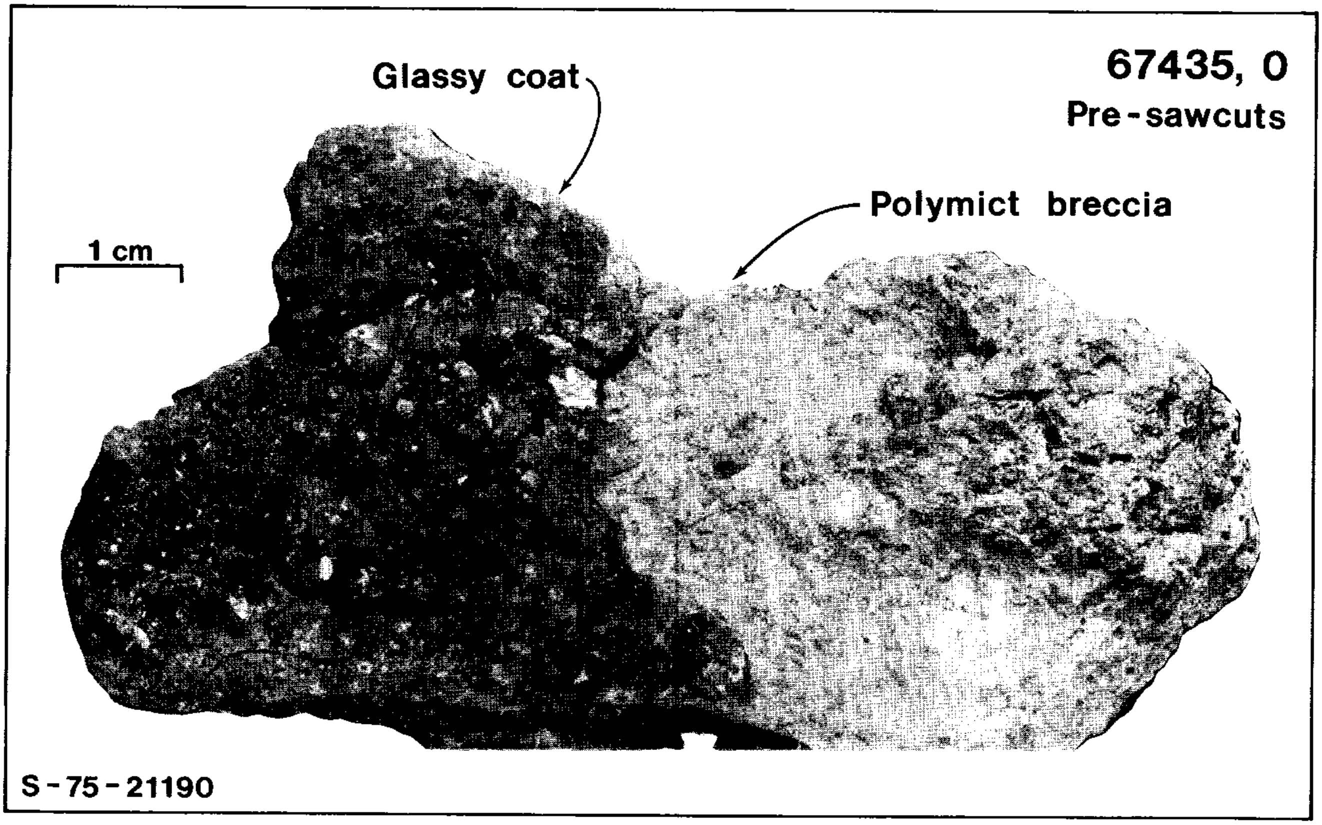
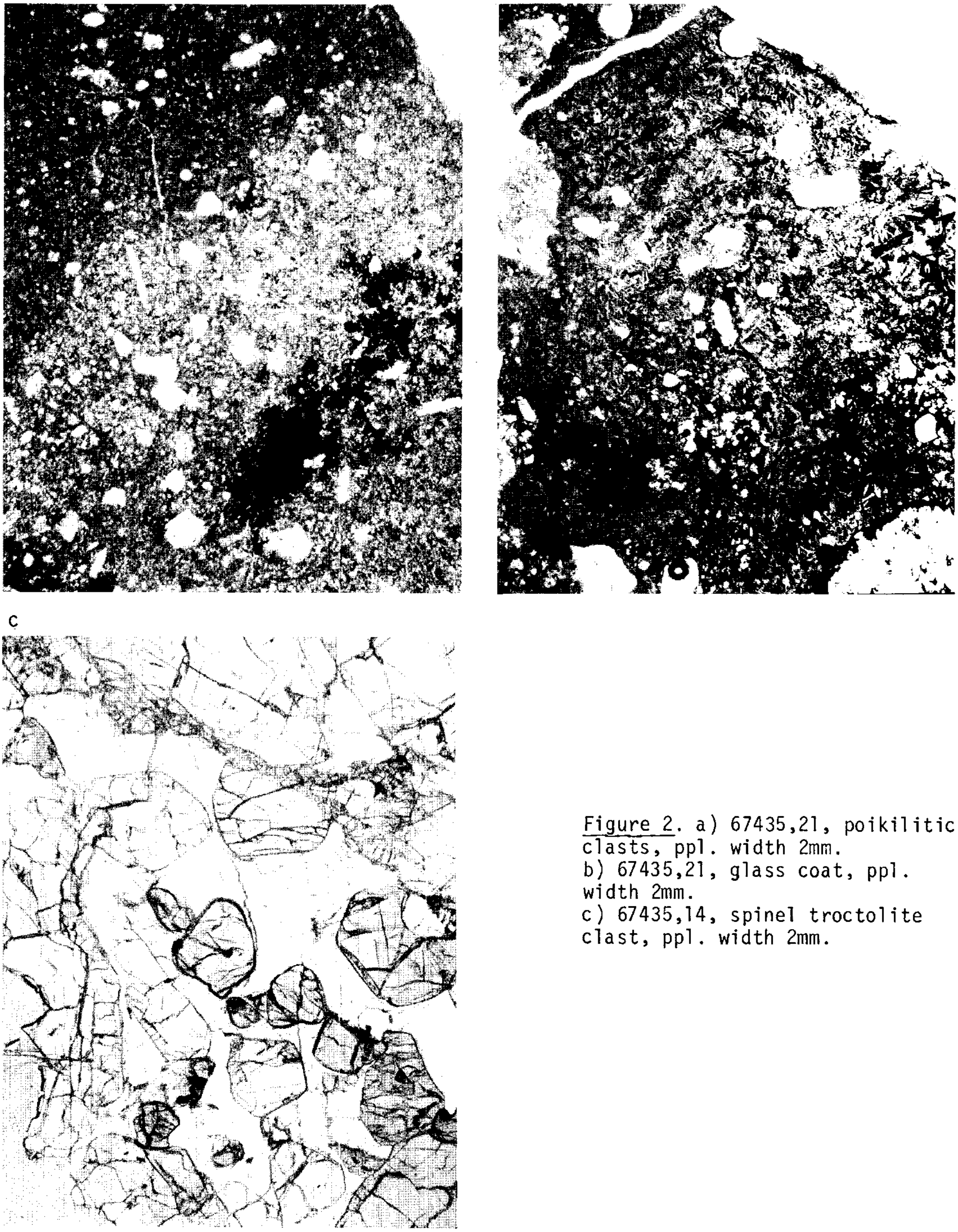


Figure 1.

PETROLOGY: A comprehensive petrographic description, with microprobe data, is provided by R. Warner et al. (1976a). Prinz et al. (1973) describe the spinel troctolite clast, with microprobe analyses, in detail, and the attached breccia briefly. Mehta and Goldstein (1980) report analyses of metal in the glass coat. Longhi et al. (1976) and Huebner et al. (1976) use the data of Prinz et al. (1973) for the spinel troctolite in element partitioning studies.

a b



c

Figure 2. a) 67435,21, poikilitic clasts, ppl. width 2mm.
b) 67435,21, glass coat, ppl. width 2mm.
c) 67435,14, spinel troctolite clast, ppl. width 2mm.

R. Warner et al. (1976a) describe 67435 as consisting of a light-colored, sugary matrix enclosing numerous gray aphanitic clasts (poikilitic impact melts) and several white feldspathic clasts. About half of the surface is covered with an irregular glassy coat.

The matrix surrounding the aphanitic clasts is more feldspathic, porous, and contains clasts (usually <1 mm) with 80-90% plagioclase. Most of these clasts are characterized by small plagioclase grains surrounded by an extremely fine-grained, micropoikilitic intergrowth of mafic phases and plagioclase. In places this matrix grades into the poikilitic clasts.

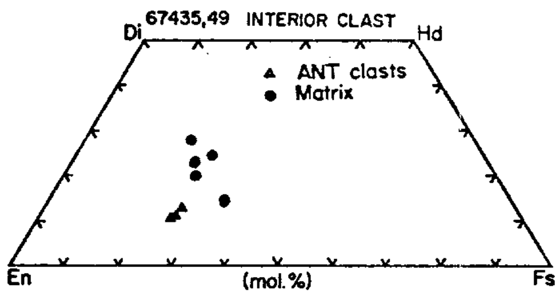
The aphanitic clasts have poikilitic textures (Fig. 2) similar to, but generally finer-grained than, typical Apollo 16 poikilitic impact melts. The oikocrysts are 200-400 μm x 100-150 μm and include both olivine and low-Ca pyroxene. Mineral compositions are shown in Figures 3-5. These clasts contain ~65% plagioclase. They contain xenocrysts of plagioclase, olivine and metal, and a few lithic fragments. These latter include fragments with a granular texture; their mineral compositions are shown in Figures 3-5 as "host breccia, ANT clasts".

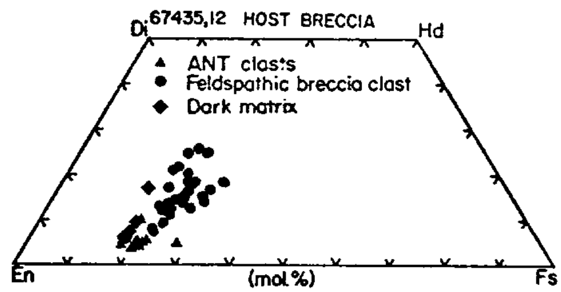
One 1.5 cm interior clast of lighter-colored material is described by R. Warner et al. (1976a). This is a feldspathic (~88% plagioclase) breccia. Mineral compositions are given in Figures 3-5. Plagioclase occurs as subequant grains 10-60 μm across with some larger fragments. Mafic minerals are concentrated between and around the plagioclase as irregular granules or as oikocrysts. The olivines are quite iron-rich (~Fo_{50-60}).

The clast of spinel troctolite (PST) described by Prinz et al. (1973) has a cumulate texture (Fig. 2) and is probably a pristine lithology. Poikilitic plagioclases (2 to 3 mm) enclose olivines (0.2-1.1 mm) and pink spinel (pleonaste) grains (0.1-0.7 mm). No pyroxene is present and the only other phases observed are Fe-Ni metal and troilite. The mode of the clast in thin section (,14) is 69% olivine, 26% plagioclase, 5% spinel, others trace. Prinz et al. (1973) report microprobe data for all phases. Olivines cluster at $Fo_{91.9-92.4}$, and plagioclases at $An_{96.6-97.4}$. The clast was completely used up in making two thin sections; a second spinel troctolite clast has been identified and extracted as mineral grains.

Prinz et al. (1973) report that the spinel troctolite clast is enclosed in a dense, annealed microbreccia for which microprobe analyses are given. A defocussed-beam analysis suggests that the microbreccia has ~24% Al_2O_3. The mineral compositions, particularly olivine, are quite varied.

The glass coat is mainly "devitrified" or has a rapidly cooled, quench texture. Some clear glass, frequently flow-banded, is present, and some clasts of plagioclase (An_{88-99}) and olivine (Fo_{61-84}) occur in the "devitrified" areas (R. Warner et al., 1976a). The boundary between clear and "devitrified" glasses is very sharp. Metal grains larger than 5 μm in the glassy coat appear to be quite restricted in composition with 5-7% Ni and ~0.5% Co (Mehta and Goldstein 1980) (Figure 6). The smaller grains (1 μm - 1000 Å) have ~ 14% Ni, with a few grains devoid of Ni - these compositions differ from the particles larger than 5 μm. Both large and small metal particles appear to be single-phase.





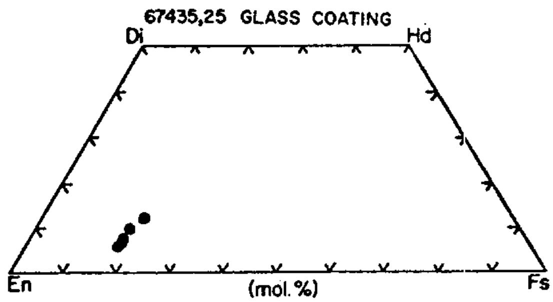
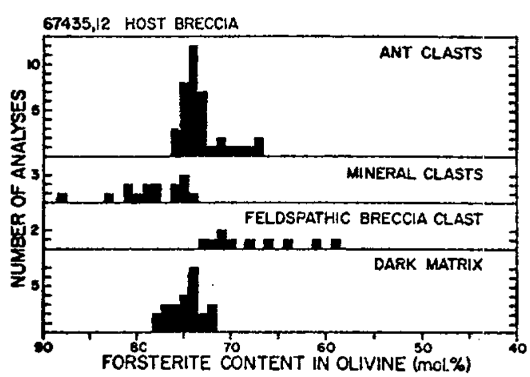
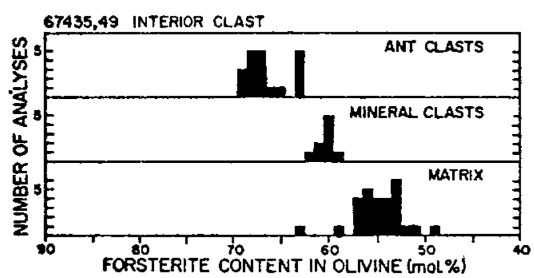


Figure 3. Pyroxene compositions, from R. Warner et al. (1976a).





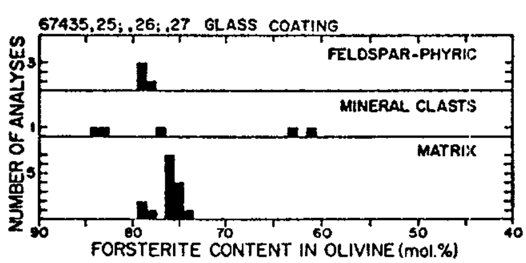


Figure 4. Olivine compositions, from R. Warner et al. (1976a).

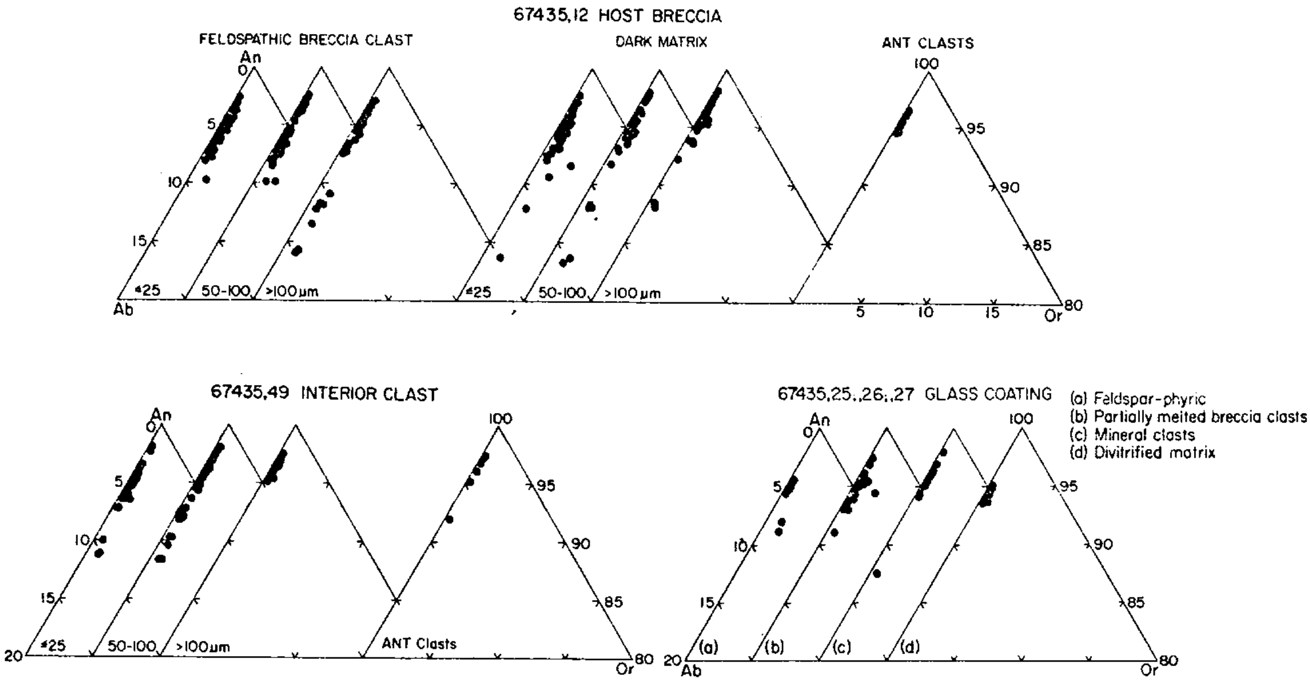


Figure 5. Plagioclase compositions, from R. Warner et al. (1976a).

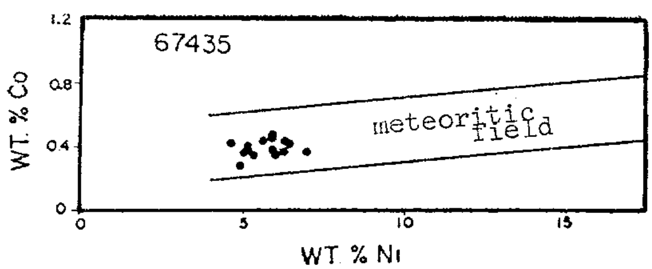


Figure 6. Compositions of metal in the glass coat, from Mehta and Goldstein (1980).

CHEMISTRY: Chemical studies are listed in Table 1, and summary chemistries of the matrix or bulk rock, the glass coat, the large feldspathic breccia clast, and the poikilitic clasts are given in Table 2. Rare-earth element plots are shown in Figures 7 and 8. The glass coat and the host breccia have roughly similar compositions, but the coat is nearly identical to typical Apollo 16 soils (not those from Station 11). The interior feldspathic breccia clast is very similar to the Station 11 feldspathic samples, including low siderophile abundances. All samples are contaminated with meteoritic material; one of the glass samples has a much higher Au/Ir ratio then the other samples and R. Warner et al.(1976a) suggest that there are two distinct meteoritic components.

TABLE 1. Chemical studies of 67435

Reference	Split #	Description	Elements analyzed
R. Warner *et al.* (1976a)	,36	matrix	majors, trace, rare earths, siderophiles.
"	,25,26,27	glass coat	"
"	,30	white interior clast	"
Lindstrom *et al.* (1977)	,40	matrix	majors, trace, rare earths.
Wänke *et al.* (1976)	,39	matrix	majors, trace, rare earths (∿ 50 els.)
Clark and Keith (1978)	,0	bulk rock	K, U, Th
Moore and Lewis (1977)	,18	matrix	C, N
Cripe and Moore (1975)	,18	matrix	S
Dominik and Jessberger (1978)	,33E	matrix	K, Ca
"	,33B,33C	dark clasts	"

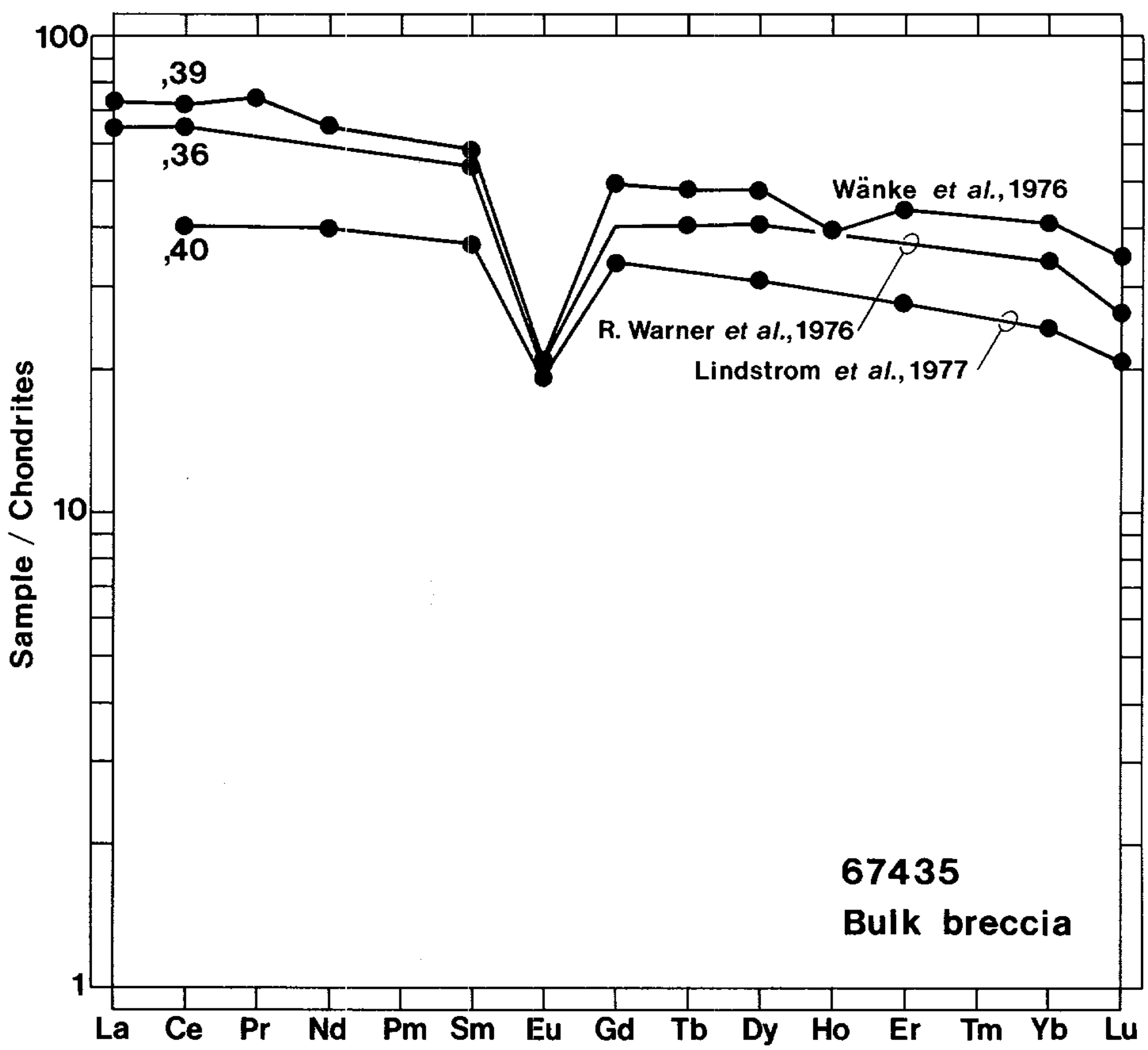


Figure 7. Rare earths for the bulk breccia.

STABLE ISOTOPES: R. Warner et al.(1976a) report oxygen isotopic data performed by the Clayton group on a bulk breccia sample (,22). The $\delta\ ^{18}O$ (SMOW) of +5.6% and $\delta\ ^{17}O$ (SMOW) of + 2.8% are typical lunar values.

GEOCHRONOLOGY AND RADIOGENIC ISOTOPES: Dominik and Jessberger (1978) and Jessberger et al. (1977) report Ar isotopic data for gray matrix, dark clasts, and plagioclase separates of 67435. The release diagrams are shown as Figure 9 and the data summarized in Table 3. The clasts and matrix were not isotopically equilibrated in the last heating or assembly event. The two plagioclase samples both have good plateaux at 4.42 b.y., the dark clasts at ∿4.0 b.y. The matrix age spectrum is not well-defined. The data allow either that the breccia formed in a mild event of ∿ 1 b.y. from older, varied components, or that it was assembled at ∿ 3.9 b.y. and has suffered post-aggregation gas loss. The major resetting for most constituents was ∿ 3.9 b.y.

RARE GASES AND EXPOSURE AGES: Dominik and Jessberger (1978) and Jessberger et al. (1977) report Ar isotopic analyses and calculate exposure ages ranging from 44.9 to 52.1 m.y.(Table 3). These are similar to the exposure ages of most other Station 11 rocks, suggesting that 67435 was ejected in the North Ray Crater event.

Clark and Keith (1973) reported cosmogenic nuclide data and Yokoyama et al.(1974) interpret the data as showing saturation with ^{26}Al. Thus the exposure is more than a few million years.

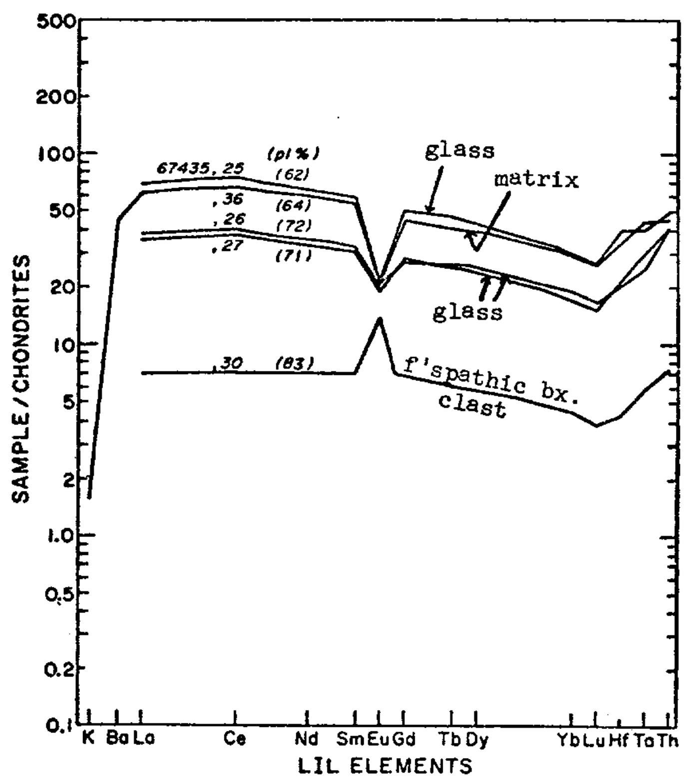


Figure 8. Rare earths for various subsamples, from R. Warner et al. (1980). Pl%= normative plagioclase content.

TABLE 2. Summary chemistry of lithic types in 67435

	[1]Matrix	[2]Glass Coat	[3]White interior clast	[4]poikilitic clasts
SiO_2	~46	~47	46.0	46
TiO_2	0.83	0.9	0.34	1.0
Al_2O_3	23	26.5	30.1	21.3
Cr_2O_3	0.15	0.1-0.2	0.067	
FeO	6.9	~5.5	3.8	6.4
MgO	9.3	~ 8	3.6	11.2
CaO	13.4	15.2	17.9	13
Na_2O	0.5	0.57	0.51	0.55
K_2O	0.15	0.1-0.2	0.056	0.25
P_2O_5	0.19			
Sr	176			
La	23	12	2.4	
Lu	1	0.5	0.13	
Rb	4			
Sc	11	9	7.7	
Ni	700		31	
Co	40	~ 20	6	
Ir ppb	12-23	10-24		
Au ppb	14	19-43		
C	44			
N	72			
S	700-1100			
Zn	8			
Cu	5			

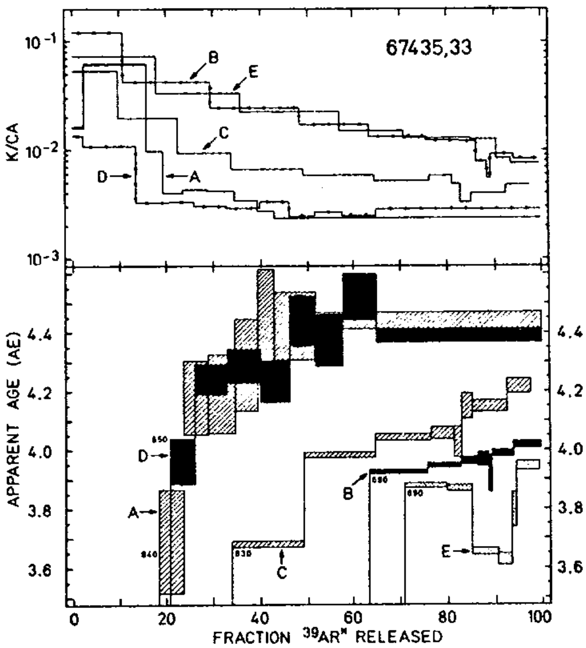
Oxides in wt.%; others in ppm except as noted.

[1]from analyses of R. Warner et al. (1976a) and Wänke et al. (1976); analysis by Lindstrom et al. (1977) is more feldspathic.

[2]from analyses of ,26 and ,27 and omitting ,25 of R. Warner et al. (1976a).

[3]R. Warner et al. (1976a).

[4]R. Warner et al. (1976a) - from defocussed beam analyses.



Apparent ^{40}Ar-^{39}Ar ages and K/Ca ratios vs. fractional ^{39}Ar release for samples of breccia 67435. Only ages in the range 3.5–4.6 AE are shown. Numbers give the temperature of that fraction which is the first to fall in that age range. A, D = plagioclase clasts; B, C = dark breccia clasts; E = light grey matrix.

Figure 9. Ar releases, from Dominik and Jessberger (1978).

TABLE 3. ^{40}Ar-^{39}Ar summary (Dominik and Jessberger, 1978)

Subsample	Ca (%)	K (ppm)	K/Ar age (b.y.)	^{40}Ar-^{39}Ar age (b.y.), plateau range (°C, ^{39}Ar), $^{40}Ar_R$ loss	Exposure age (m.y.)
,33 E matrix	6.5	1190	2.78±0.05	3.82±0.09 (no plateau) 690-1110°, 70-99%,49% loss	52.1±2.6
,33 B dark clast	8.8	1520	3.08±0.05	3.955±0.013 690-1090°, 63-99%,42% loss	51.2±2.3
,33 C dark clast	6.6	445	3.59±0.05	4.044±0.029 690-1130°, 49-98%,25% loss	46.1±1.9
,33 A plagioclase clast	8.5	270	4.11±0.06	4.427±0.050 920-1200°,34-100%,14% loss	44.9±2.6
,33 D plagioclase clast	9.6	3300	4.08±0.05	4.407±0.035 960-1170°,46-99%,18% loss	48.1±3.0

PROCESSING AND SUBDIVISIONS: Following some early subdivisions by chipping, a 1 cm slab was cut through 67435. This slab was positioned to avoid a clast of spinel troctolite (later extracted) and to some extent avoid the glass coating. The location of the main subdivisions produced (the rock broke during sawing) and maps of them are shown in Figure 10. The face of ,7 is shown in Figure 11. ,7 (179 g) ,8 (69 g) and ,11 (19 g) remain nearly intact; many smaller pieces were produced during sawing.

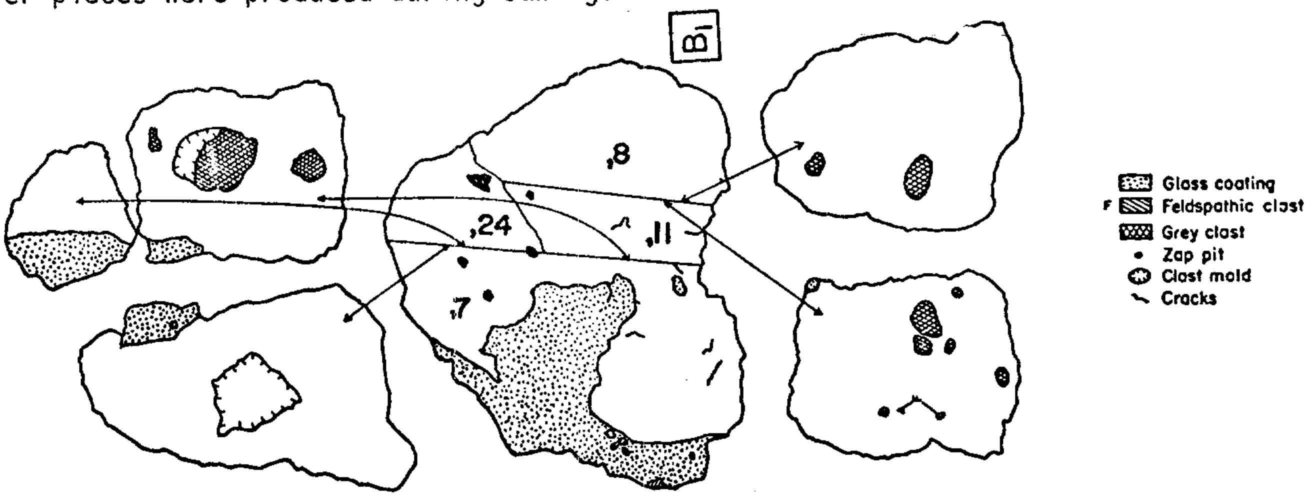


Figure 10. Major subdivisions of 67435, from R. Warner *et al*. (1976a).

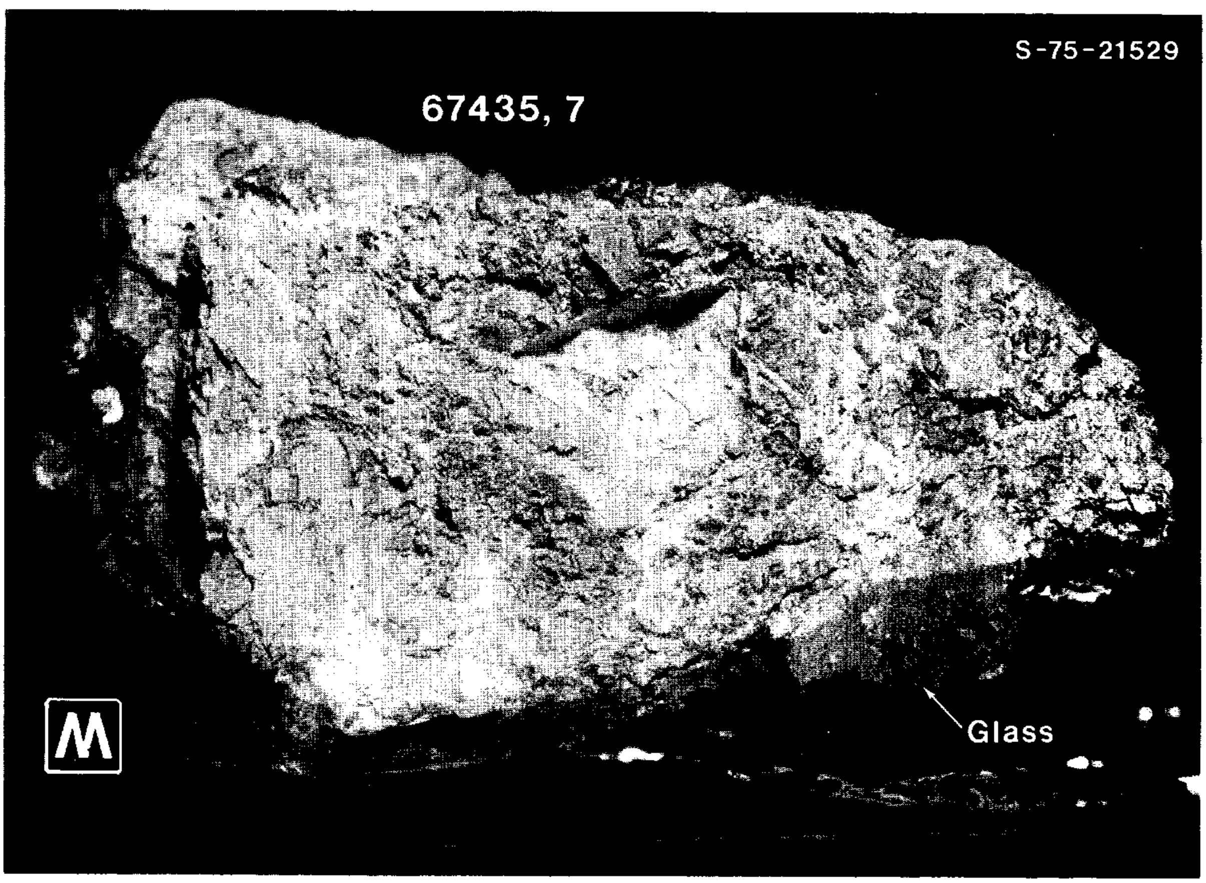


Figure 11. Sawn face.

INTRODUCTION: 67455 is a very friable, feldspathic breccia that contains a variety of clast types, including pristine anorthosites. This rock was chipped from a large white boulder on the south rim of North Ray Crater together with 67475. Due to its friability it broke into several pieces during transport from the Moon (Fig. 1). Exact lunar orientation is unknown, but some exterior surfaces were recognized during the original processing by their discoloration and a few remaining zap pits. Much of the post-1974 work referenced here is the work of a consortium headed by Chao.

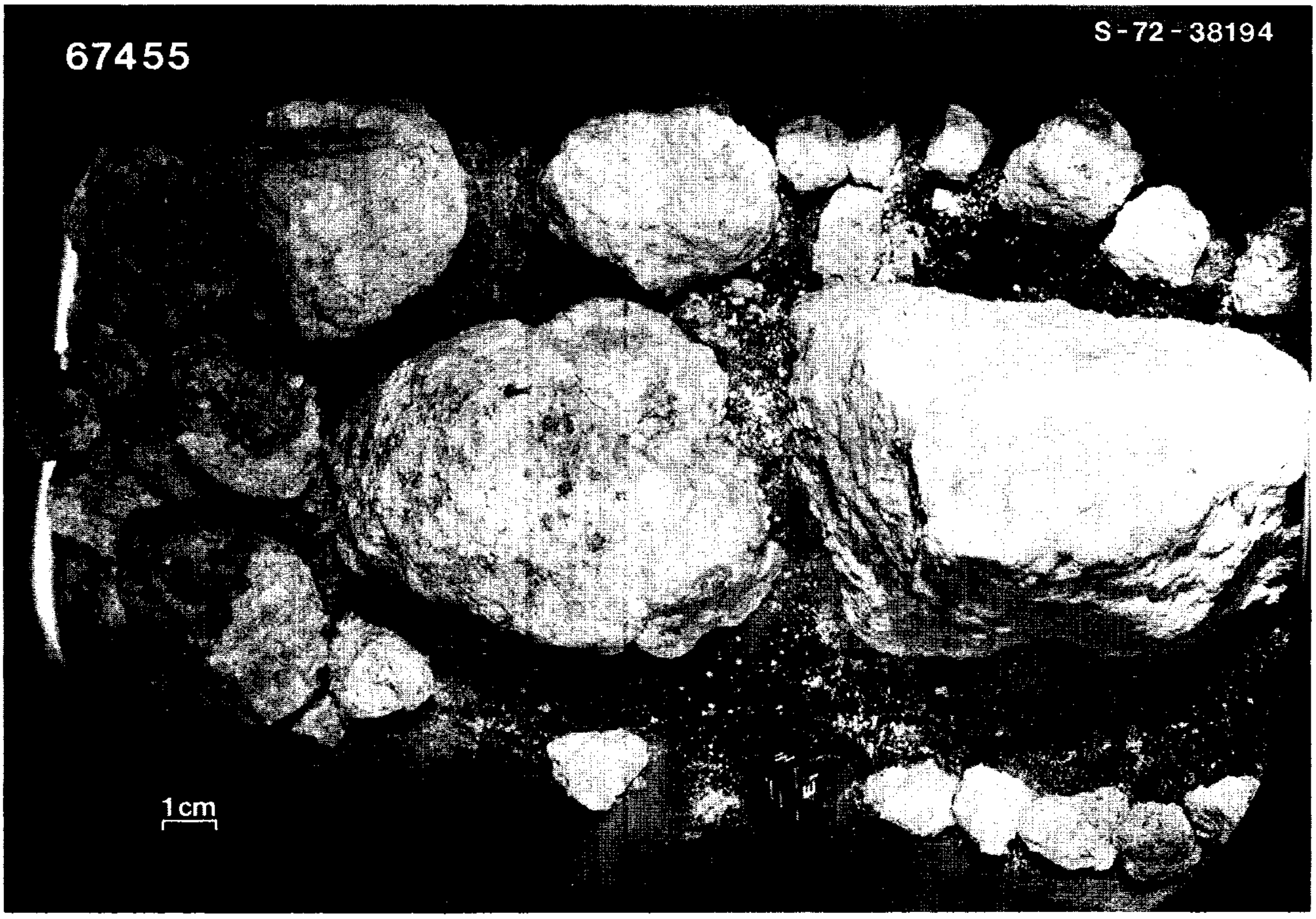


Figure 1.

PETROLOGY: An extensive petrographic description is given by Minkin et al.(1977) and their terminology will be used here to avoid confusion. Several different clast types occur in a very friable groundmass of predominantly crushed and compacted plagioclase grains (Fig.2). Monomineralic plagioclase dominates the clast population,with lesser amounts of olivine, pyroxene, metal, troilite, ilmenite,and lithic fragments. Metal grains in the groundmass tend to be rusty,

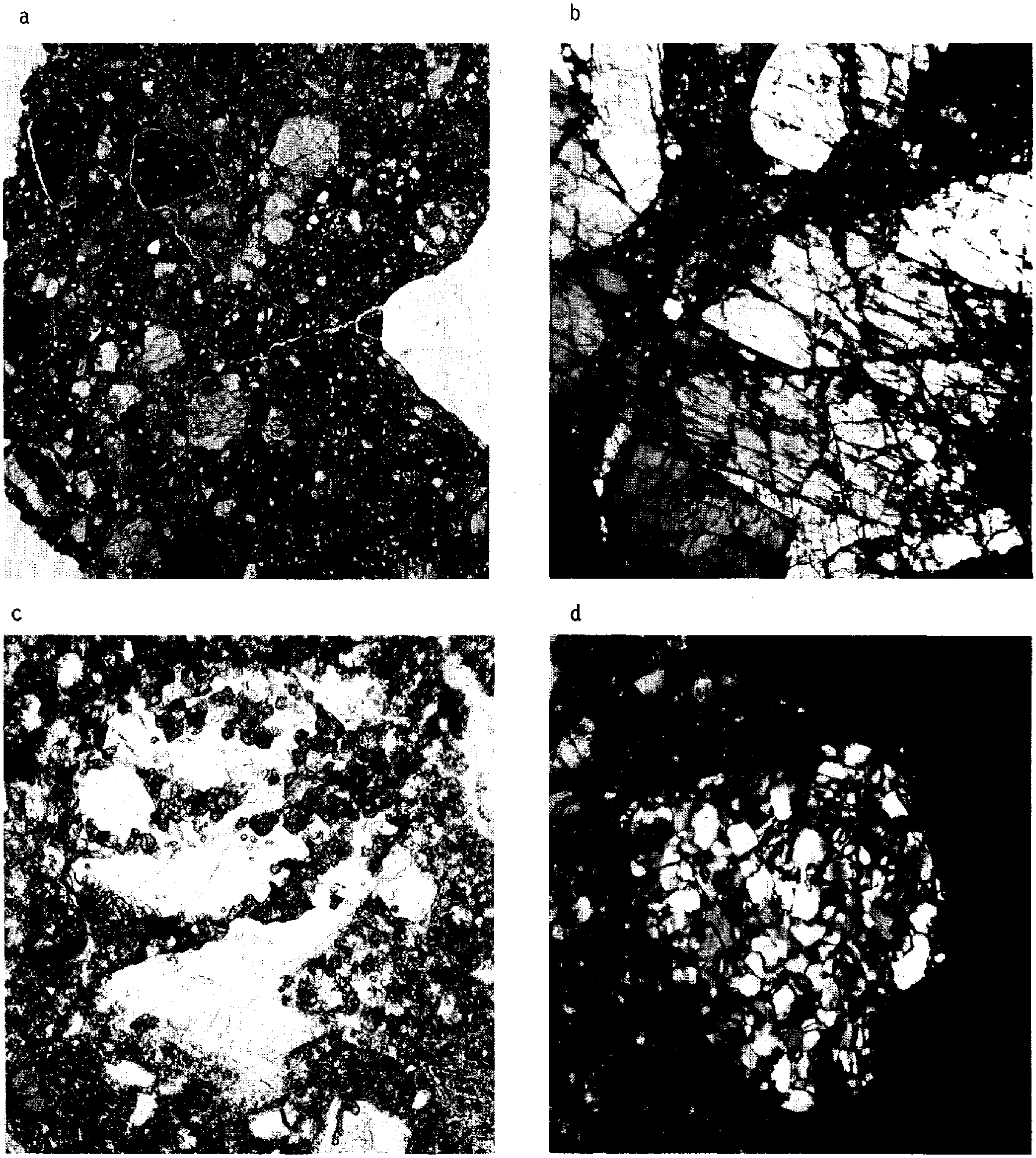


Figure 2. a) 67455,49, whole thin section, ppl. width about 10mm.
b) 67455,109, shocked anorthosite clast, xpl. width 2mm.
c) 67455,48, gabbroic anorthosite clast, ppl. width 1mm.
d) 67455,43, feldspathic microbreccia clast, xpl. width 1mm.

with compositions outside of the "meteoritic" field (Fig.3) (L.A. Taylor et al., 1973b). El Goresy et al. (1973a) report one occurrence of sphalerite and "goethite" as a reaction rim around troilite. Lithic clasts include cataclastic anorthosites, gabbroic anorthosites, annealed feldspathic microbreccia and various glassy clasts. Modal abundances are summarized in Table 1 (reproduced from Minkin et al., 1977).

Figure 3. Metal compositions, from L. A. Taylor et al. (1973b).

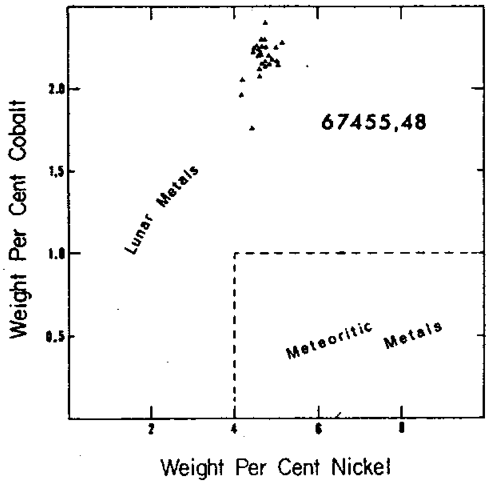


TABLE 1. From Minkin et al. (1977).

Fragment population (> 40 μm) of 67455

Fragment type	67455,50 (1554 counts)	67455,57 (825 counts)
Gabbroic anorthosite	7.9	9.1
Feldspathic microbreccia	2.7	6.8
Cataclastic anorthosite with olivine	0.7	3.4
Cataclastic anorthosite with pyroxene	5.0	3.4
Cataclastic anorthosite	8.3	4.4
Plagioclase	51.0	46.2
Olivine	3.7	6.2
Pyroxene	8.2	3.2
Glass:		
devitrified and brown with schlieren	0.5	0.9
annealed	0.8	0
coated grains	1.4	5.1
Fragment-laden melt:		
with plagioclase laths	3.4	2.5
without plagioclase laths	4.2	6.5
Opaque	2.2	2.3
Total	100.0	100.0

Weakly shocked, cataclastic anorthosite clasts often retain a cumulate texture (Fig.2) with either olivine or pyroxene as interstitial phases. Not all cataclastic anorthosite clasts have interstitial mafics, but all contain elongate inclusions (generally < 5 μm) of olivine within the plagioclase crystals (Minkin et al., 1977). Mineral compositions in these clasts are typical of ferroan anorthosites (plagioclase An_{96-98}; olivine Fo_{49-54};orthopyroxene Wo_2En_{40}, pigeonite $Wo_{5-7}En_{40-43}$; augite $Wo_{40-45}En_{35-30}$). Minor phases include interstitial ilmenite and troilite. Three cataclastic anorthosites were physically separated from the rock (,30, 31 and ,32), and found to be chemically pristine (see Ryder and Norman, 1978, for further descriptions and documentation of these particular clasts).

Gabbroic anorthosite clasts are largely recrystallized, though to varying degrees. Textures range from coarse granoblastic (Fig.2)to very fine-grained "hornfelsic". Pyroxene and olivine tend to occur in roughly equal amounts with interstitial ilmenite and metal. Mineral compositions are: plagioclase An_{92-97}, olivine Fo_{46-65}, pigeonite $Wo_{7-18}En_{54-48}$, augite $Wo_{20-40}En_{50-40}$ and orthopyroxene $Wo_{2-3}En_{63-56}$ (Minkin et al., 1977).

The feldspathic microbreccias of Minkin et al. (1977) consist entirely of many small (< 30 μm), anhedral plagioclase grains in a recrystallized mosaic (Fig.2). These fragments could also be called "granoblastic anorthosite" or "recrystallized plagioclase".

Two types of melt-glass clasts are recognized by Minkin et al. (1977): fragment-laden, glassy matrix breccia and xenocryst-free glasses. The glassy matrix breccia clasts tend to be very coherent, with abundant mineral and lithic fragments cemented by a small amount of interstitial melt. The interstitial melt is most often a dark brown glass, but in places shows a very faint poikilitic texture. Abundant xenocrysts and laths of plagioclase (An_{87-97} and An_{94-97}, respectively) and some olivine (Fo_{46-70}), orthopyroxene ($Wo_{2-3}En_{58-77}$), augite ($Wo_{31-43}En_{41-38}$) and lithic fragments are all found within the glassy matrix clasts. Xenocryst-free glasses, most of which possess schlieren, are uncommon. Some are strained as indicated by their wavy extinction, while others show evidence of annealing or devitrification. The lack of glass spherules in the rock indicates that no significant regolith component is present (Minkin et al., 1977).

CHEMISTRY: Lindstrom et al. (1977) and Hertogen et al. (1977) provide major element, lithophile, siderophile and volatile element data on a suite of separated clast and matrix samples. Reed et al. (1977) and Jovanovic and Reed (1978) provide data on volatile metals, halogens,and other trace elements for some of these same samples. Other major and trace element analyses of the bulk rock are given by Rose et al. (1973), Wänke et al. (1973,1977), Fruchter et al. (1974) and Müller (1975). (The analysis listed as 67455,13 in Fruchter et al., 1974, is actually of 68115,78). Bulk C, N and S data are reported by Moore et al. (1973), Cripe and Moore (1974) and Moore and Lewis (1976). Wrigley (1973) provides natural and cosmogenic radionuclide abundances. Defocused beam microprobe analyses of several clast types are given by Minkin et al. (1977).

All of the bulk analyses show 67455 to be a highly aluminous breccia with relatively low levels of both lithophiles and siderophiles and a somewhat high Fe/Mg (Table 2, Figs. 4,5,6,7). The very low C and N abundances (Table 2) indicate a negligible solar wind component in the bulk breccia.

The major and lithophile element compositions of the clast population can be accounted for by mixing a relatively ferromagnesian, REE-rich component with an aluminous, REE-poor component (Figs. 4,5,6) (Lindstrom et al., 1977). These two end-members are represented petrographically by the glassy matrix breccia or some of the recrystallized breccia clasts, and the cataclastic ferroan anorthosite clasts, some of which are pristine. The bulk matrix is, however, somewhat enriched in REEs relative to those two components (Figs. 6,7) and a third component seems to be required. To match the petrographically observed abundances of clasts, which require ~70-80% anorthositic material (Table 1), Lindstrom et al. (1977) postulate a "gabbroic anorthosite" component with 28-30% Al_2O_3 and REEs ~10 X chondrites as this cryptic third end-member.

All of the clasts and matrix samples analyzed by Hertogen et al. (1977) have low abundances of meteoritic siderophiles (Table 2). Three of the cataclastic anorthosite clasts have low enough levels of these elements to be classified as chemically pristine. Only meteoritic groups 5H and 7, groups common in rocks from North Ray Crater, are recognized in the 67455 samples (Hertogen et al., 1977).

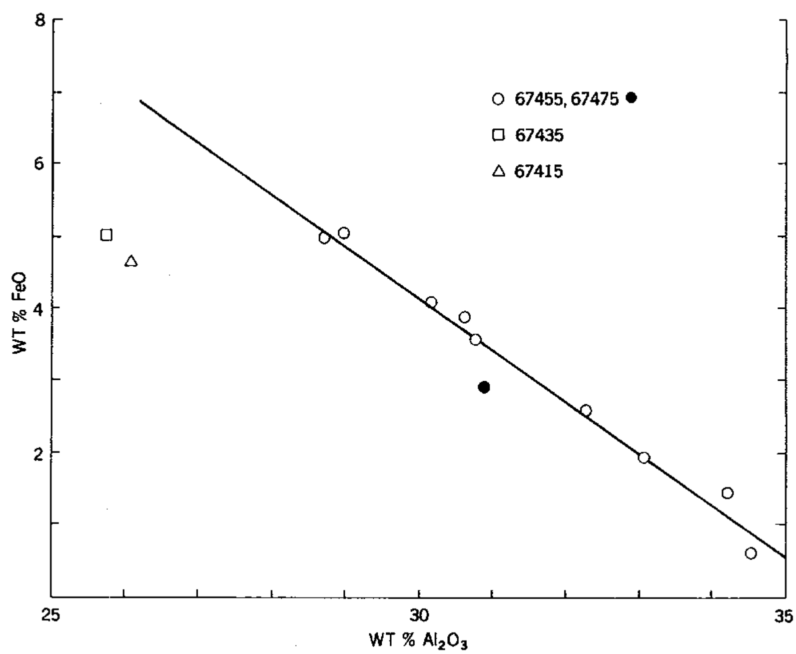


Figure 4. Variation of FeO with Al_2O_3 for clast and matrix samples of 67455, and bulk samples of 67415, 67435, and 67475; from Lindstrom et al. (1977). The lines in Figures 4 and 5 represent linear regressions on the 67455 and 67475 data.

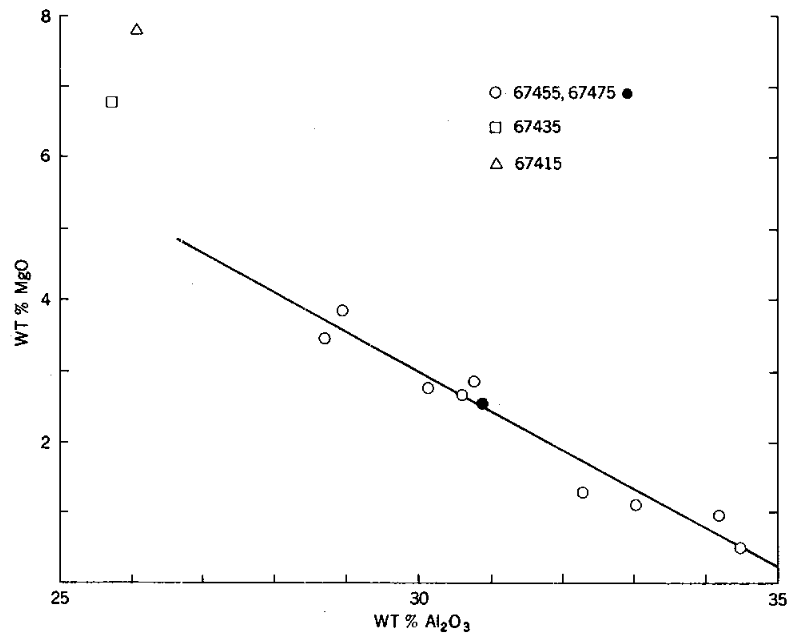
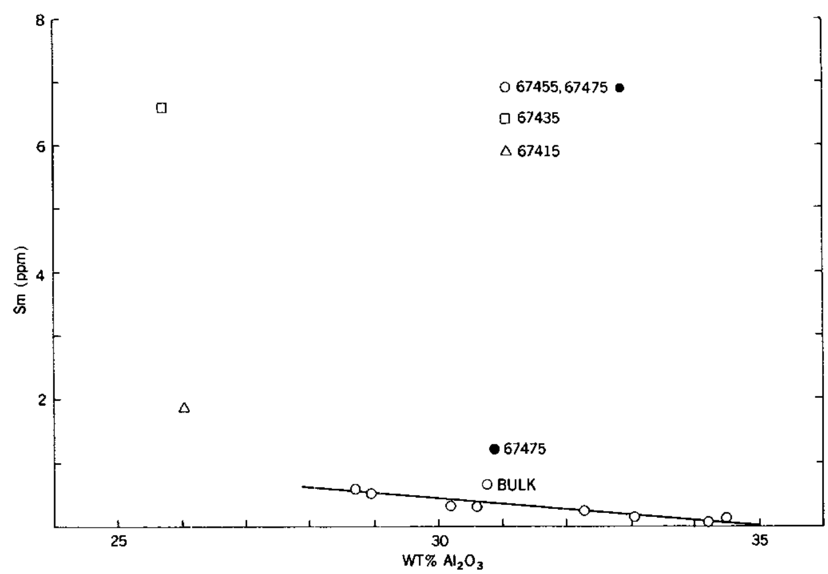


Figure 5. Variation of MgO with Al_2O_3 for clast and matrix samples of 67455, and bulk samples of 67415, 67435, and 67475; from Lindstrom et al. (1977).



Variation of Sm with Al_2O_3 content for samples from the White Breccia Boulders. The line is a linear regression for 67455 clast data.

Figure 6. From Lindstrom et al. (1977).

TABLE 2. Summary chemistry of 67455 lithologies

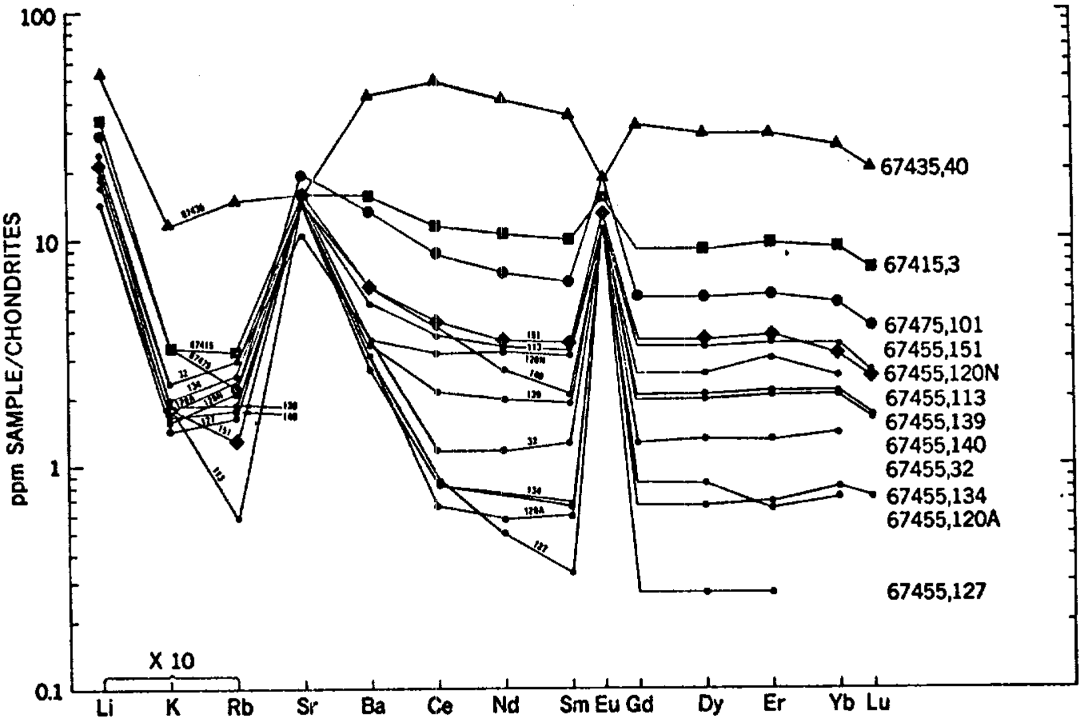
	Bulk rock	Cataclastic anorthosite clasts, pristine	Glassy matrix breccia clasts
SiO_2	44.8	44.7	44.4
TiO_2	0.25	<0.1	0.23
Al_2O_3	31.1	33.2	28.7
Cr_2O_3	0.07	<0.01	0.05
FeO	4.0	2.0	5.0
MnO	0.05	0.018	0.07
MgO	3.0	1.1	3.5
CaO	17.8	18.4	17.0
Na_2O	0.37	0.39	0.47
K_2O	0.024	0.023	0.023
P_2O_5	0.02	~0.02	0.02
Sr	150	145	152
La	1.1	~0.3	~1
Lu	0.09	~0.025	0.089
Rb	0.6	0.7	0.17
Sc	7.7		
Ni	26	<7	7.9
Co	8		
Ir ppb	1.08	0.003	1.23
Au ppb	0.355	0.008	0.12
C	8		
N	10		
S	<20		
Zn	7.5	~3	4.13
Cu	1.9		

Oxides in wt%; others in ppm except as noted.

RADIOGENIC ISOTOPES/GEOCHRONOLOGY: Schaeffer and Schaeffer (1977) report Ar isotopic data for the bulk rock. A gas release plateau could not be obtained. ^{40}Ar has apparently been lost through diffusive processes and the >1200°C fractions show evidence for excess ^{38}Ar.

Kirsten et al. (1973) give Ar data for two clasts, one dark and one light, separated by them from a bulk sample. The dark clast failed to yield a plateau while the light clast gave a plateau age of 3.91±0.12 b.y.

Assuming that the total K-Ar age gives a lower limit to the age of the rock (e.g.Turner and Cadogan, 1975) and that the rock is younger than the clasts it contains, 67455 is thus bracketed to be between 3.80-4.03 b.y. old.



Lithophile trace element abundances for samples from the White Breccia Boulders. The light REE analyses for 67455,140 and 67455,127 are not reliable because of large blank and spike corrections on very small anorthositic samples.

Figure 7. Rare earths for clast and matrix samples, from Lindstrom et al. (1977).

RARE GASES/EXPOSURE AGES/TRACKS: Published exposure ages are given in Table 3. These ages place the age of North Ray Crater at ~40-50 m.y. Kr and Xe isotopic data are reported by Drozd et al. (1974), Drozd (1974), and Bernatowicz et al. (1978) (Figs. 8,9). The unusual low temperature release peak of Xe (Fig. 10) is ascribed to lightly bound, surficial gas by Bernatowicz et al. (1978). Drozd (1974) and Bernatowicz et al. (1978) disagree on whether or not excess fission Xe is present in 67455. The latter authors suggest the possibility of a variation in the trapped gas component.

TABLE 3. Exposure ages of 67455

Method	Age (m.y.)	Reference
^{81}Kr-Kr	50.2±1.8	Drozd et al.(1974)
^{21}Ne	17.3±4.1	"
^{38}Ar	38.0±13	"
^{38}Ar (dark clast)	31±2	Kirsten et al.(1973)
^{38}Ar (light clast)	33±2	"
^{38}Ar	35	Schaeffer and Schaeffer (1977)
Cosmic ray tracks	~30	Storzer et al.(1973)

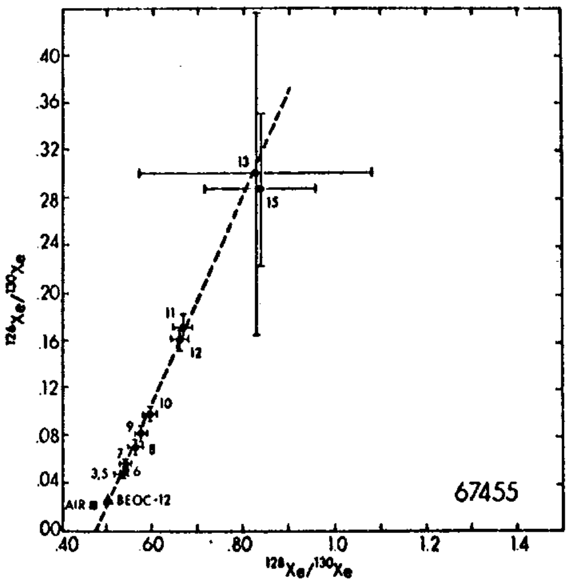


Figure 8.

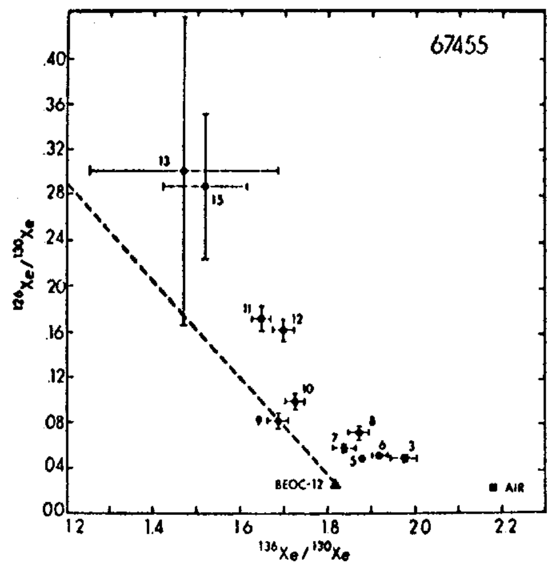


Figure 9.

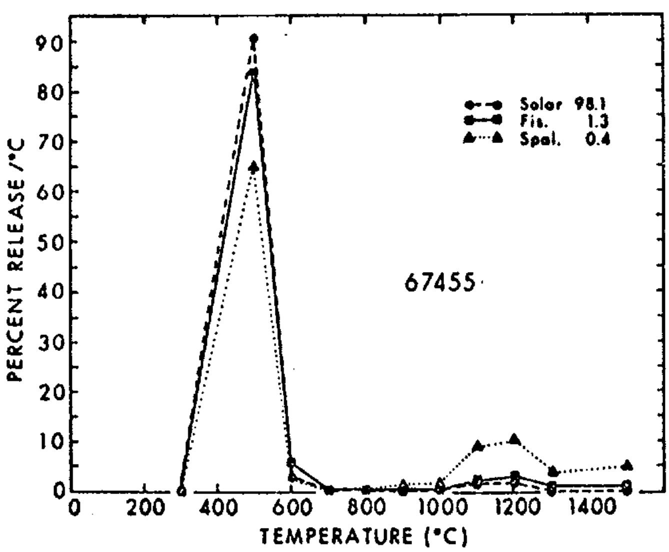


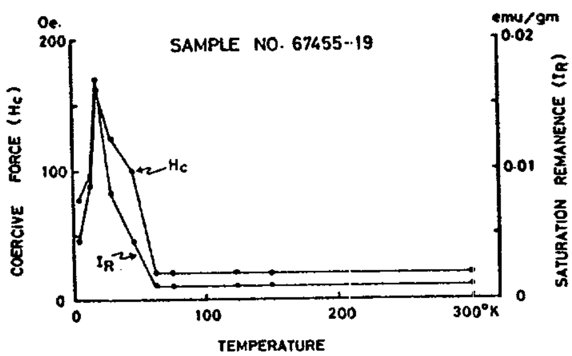
Figure 10. Xe isotopic data. Figures 8,9,10 from Bernatowicz et al. (1978).

Pepin <u>et al</u>. (1974) note that total ^{21}Ne and ^{38}Ar ages are usually significantly lower than the ^{81}Kr-Kr ages, and calculate the shielding depth within the rock necessary to account for these lower ages. For three North Ray Crater rocks, these depths range from ∿ 3-6 g/cm^2. The data are consistent with the ejection of the 67455 boulder from a well-shielded location with no significant pre-surface irradiation history to its present location in a single event (Drozd <u>et al</u>. 1974; Pepin <u>et al</u>., 1974).

^{26}Al and ^{22}Na are given by Wrigley (1973). 67455 is probably not saturated in ^{26}Al activity (Yokoyama <u>et al</u>., 1974).

Cosmic ray tracks in 67455 feldspars indicate a trace of ancient solar flare irradiation prior to breccia formation (Storzer <u>et al</u>., 1973).

<u>PHYSICAL PROPERTIES</u>: Basic magnetic and natural remanent magnetization characteristics of a bulk rock split are given by Nagata <u>et al</u>. (1973,1975). 67455 is an example of a rock whose dependence of coercive force (Hc) and saturation remanence (I_R) on temperature is characterized by an asymmetrical distribution around a low temperature spike (Fig.11). Such a peak may represent the blocking temperature of a population of fine metallic grains (Nagata <u>et al</u>., 1973).



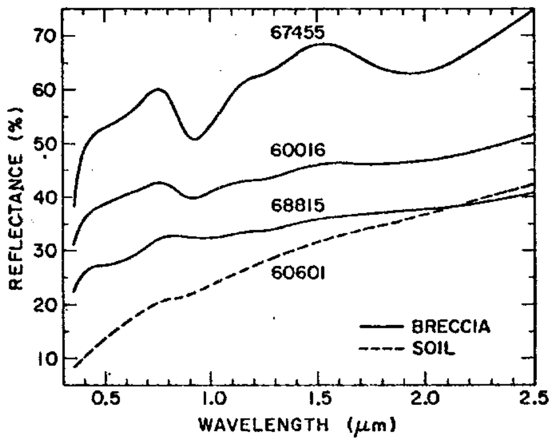
Example of Group III of the dependence of H_c and I_R on temperature; there is a sharp increase in H_c and I_R at a critical temperature (T^*) and the largest value of H_c at the low temperature is reasonably close to $\frac{1}{2}H_{RC}$.

<u>Figure 11</u>. Magnetic parameters, from Nagata <u>et al</u>. (1973).

Schwerer <u>et al</u>. (1973) and Huffman <u>et al</u>. (1974) tabulate the distribution of Fe among the mineral phases and the Fe^0/Fe^{2+} ratio of 67455 as determined by Mossbauer and magnetic techniques. Very little Fe-metal (∿ 0.02 wt%, 2.5% Ni) is present in this rock (see also Nagata <u>et al</u>., 1973).

IR and UV spectral reflectance and other polarimetric property measurements are given by Adams and McCord (1973), Dollfus and Geake (1975), Hua <u>et al</u>.(1976) and Zellner <u>et al</u>. (1977) (Figs. 12,13).

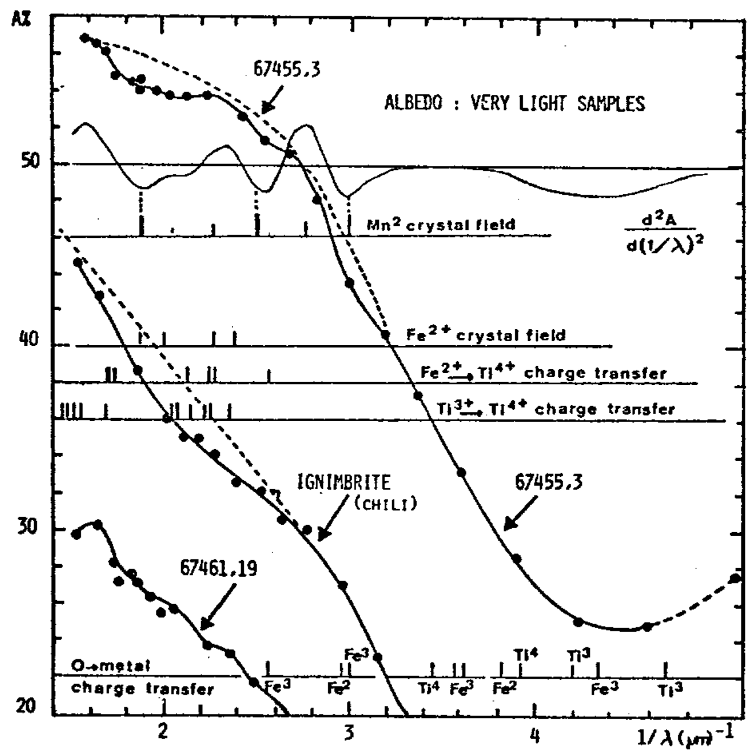
Weeks (1973b) reports electron paramagnetic resonance (EPR) spectral data. Huffman and Dunmyre (1975) studied superparamagnetic Fe^{2+} spin clusters in olivine. 78% of the Fe^{2+} in 67455 olivines are contained within such clusters.



Spectral reflectance of three Apollo 16 breccias (crushed to < 250 μm) compared with a mature soil. Sample 67455 is a friable white breccia from North Ray Crater. Samples 60016 and 68815 are dark breccias.

Figure 12. Spectral reflectance curves, from Adams and McCord (1973).

Figure 13. Spectral reflectance curves, from Hua et al. (1976).



Spectral diffuse reflectance curves for very light samples. Second-derivative curve for lunar sample 67455,3 enhancing the absorption features.

PROCESSING AND SUBDIVISIONS: 67455 was removed from its documented bag in several pieces. In 1972, during the original round of allocations, individual fragments and chips from one of the larger pieces were assigned split numbers (Fig. 14). In 1974, under the direction of Chao, the powder residue was passed through a 2 mm sieve to recover clasts and fragments. Chao then classified these >2 mm fragments (total wt. 47.1 g) macroscopically into 6 groups and assigned each group a split number (,35 - ,40). Individual fragments representative of each group were selected by Chao for allocation to members of his consortium.

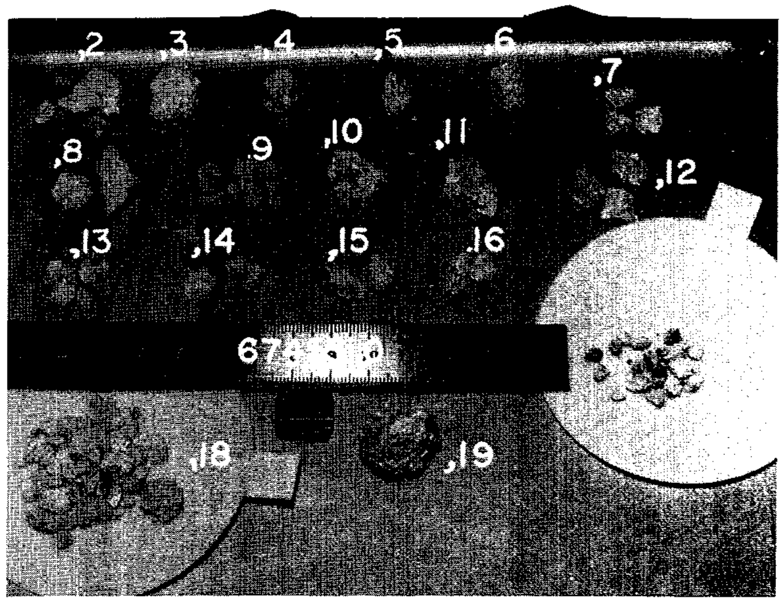


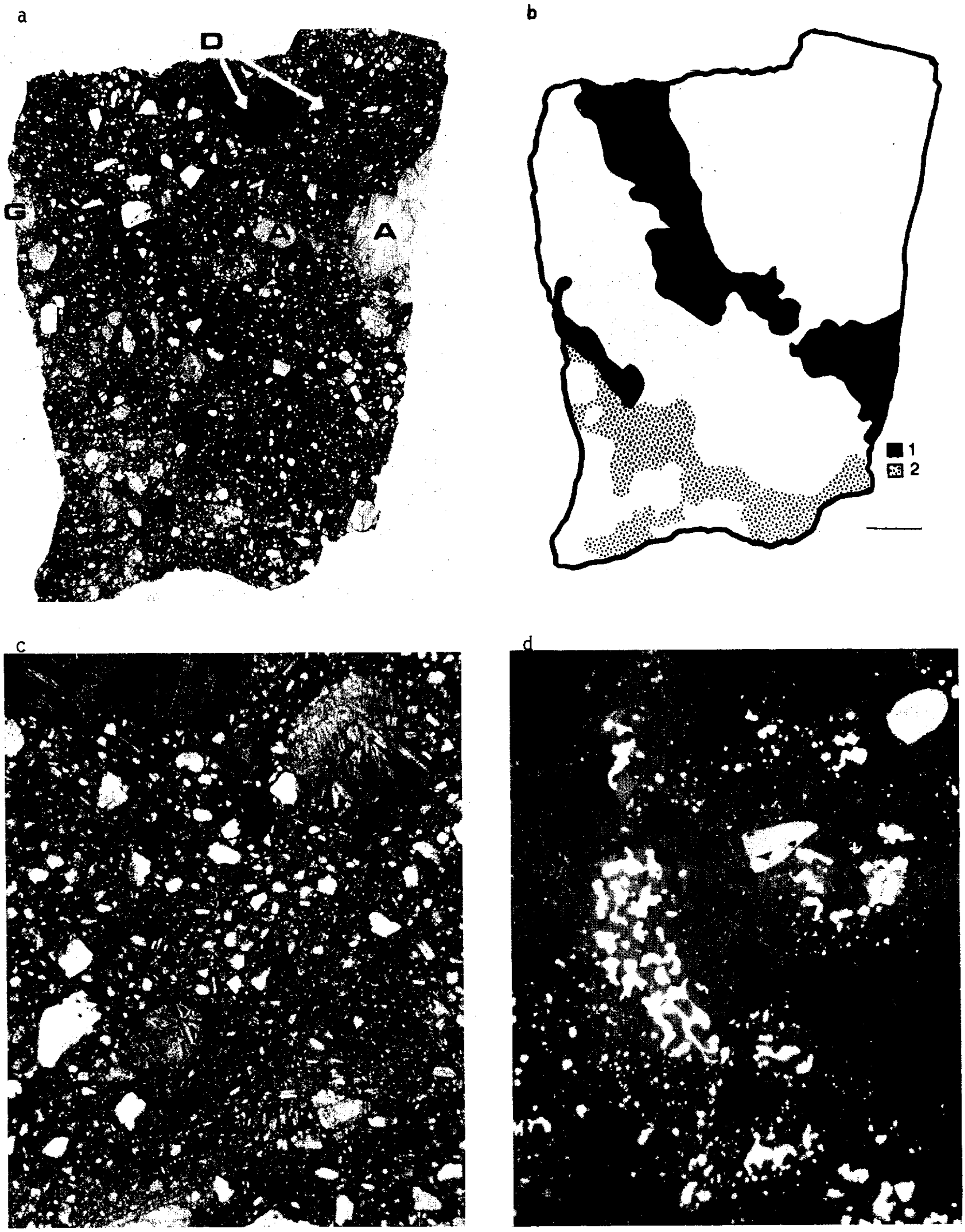
Figure 14. S-72-51830, smallest scale subdivision 0.5mm.

INTRODUCTION: 67475 is a tough, purplish-gray, glassy breccia (Fig.1) that was collected to sample a large, dark clast within the white boulders on the south rim of North Ray Crater. It is from the same boulder which yielded 67455.

Lunar orientation is unknown due to a lack of surface photographs. Zap pits occur on the T and S surfaces only; the other surfaces were either buried in the boulder or are freshly broken. This rock was studied as part of the Chao consortium.

Figure 1.

Figure 2. 67475,82 a) whole thin section, ppl. width about 8mm. Labeled clasts are: A= cataclastic anorthosites, D= devitrified glass, and G= recrystallized olivine bearing gabbroic anorthosites; from Minkin et al. (1977). b) map of thin section ,82 outlining the major lithic types. 1= metal- and silica-rich breccia, 2= light colored, olivine-rich breccia; the remainder of the section is fragment-laden, glassy breccia. Scale bar is 1mm; from Minkin et al. (1977). c) glassy matrix breccia, ppl. width 2mm. d) metal- and silica-rich breccia, rfl. width 0.5mm.


a
D
G
A
A
b
1
2
c
d

PETROLOGY: Minkin et al. (1977) give a petrographic description and most of the following is taken from that work. 67475 is a glassy, clast-rich breccia composed of three distinct lithologies: a fragment-laden, glassy matrix breccia; a dark, metal- and silica-rich breccia; and a light colored, olivine bearing breccia (Fig. 2). Contacts between all lithologies are sharp.

The fragment-laden, glassy matrix breccia (Fig.2) accounts for the majority of the rock. It is very similar to the much smaller glassy matrix breccia clasts in 67455. Plagioclase xenocrysts (An_{87-98}) dominate the fragment population within this lithology. Lesser amounts of olivine (Fo_{56-66}), orthopyroxene (Wo_{3-4} En_{71-64}), augite (Wo_{42} En_{41-47}), silica, troilite, Fe-metal (4% Ni, 0.2% Co) and devitrified glass are also present. Lithic clasts include cataclastic and polygonal anorthosites and granoblastic to poikilitic gabbroic anorthosites composed of plagioclase (An_{93-96}), augite oikocrysts ($Wo_{34-38}En_{52-50}$), interstitial olivine (Fo_{74-77}) and ilmenite.

The metal-and silica-rich breccia (Fig. 2) accounts for ∿ 12% of thin section ,82 and contains a mineral assemblage appropriate for a highly differentiated residuum. Large grains of silica (up to 400 μm long) coexist with ferroaugite ($Wo_{32-42}En_{22-15}$), apatite, whitlockite and ilmenite. Potash feldspars ($Or_{82-84}An_{16-13}$) are often intergrown with lamellae of silica and plagioclase ($An_{53-63}Or_{8-5}$). Olivine (Fo_{22-24}) is rare. Metal occurs as discrete grains and in myrmekitic intergrowths with silica. The "matrix" of this lithology consists of very fine-grained pyroxene ($Wo_{4-3}En_{45-34}$) and tiny blebs of metal.

The light colored, olivine-rich breccia (∿8% of thin section ,82) contains clasts of plagioclase (An_{92-96}, rarely $An_{60}Or_5$), orthopyroxene ($Wo_{35-42}En_{18-10}$), olivine (Fo_{63-68}), ilmenite, silica and abundant, finely dispersed troilite. Fragments of granoblastic gabbroic anorthosite similar to those in the glassy matrix breccia are also abundant here, along with a few granoblastic (polygonal) anorthosites.

CHEMISTRY: Some compositional variation among different splits of this rock is apparent from the published data. From data pack photos we have identified all allocations for chemistry as nearly homogeneous, dark fragments but the relative abundances of either the glassy or the metal/silica-rich lithologies are unknown.

Major and trace element analyses are provided by Lindstrom et al. (1977), Miller et al. (1974) and Garg and Ehmann (1976) (Table 1; Fig. 3). Hertogen et al. (1977) give meteoritic siderophile and volatile abundances for two splits. Both splits have similar amounts of volatiles and similar interelement ratios, but the absolute abundances of siderophiles vary by a factor of four (Table 2). Cripe and Moore (1975) and Moore and Lewis (1976) report total C, N and S abundances. Natural and cosmogenic radionuclides for the whole rock were determined by Clark and Keith (1973) using gamma ray spectroscopy.

67475 is a very aluminous breccia with a relatively high Fe/Mg (Table 1, see also Figs. 4 and 5 of 67455). In terms of major elements, 67475 is very similar to the bulk rock from which it was taken (represented by 67455) but rare earths in 67475 are considerably enriched over those in 67455. Although petrographically similar to the glassy matrix breccia clasts of 67455, 67475 is somewhat more aluminous and considerably richer in REEs than these clasts (Lindstrom et al., 1977). Also notable is the high S abundance of 67475 (Table 1).

TABLE 1. Summary chemistry of 67475

SiO_2	44.5	Sr	216
TiO_2	~0.4	La	
Al_2O_3	30.5	Lu	0.140
Cr_2O_3	0.04	Rb	0.74
FeO	3.1	Sc	5.92
MnO	0.04	Ni	~60
MgO	3.0	Co	7.8
CaO	17.8	Ir ppb	1.68-7.01
Na_2O	0.60	Au ppb	0.382-1.27
K_2O	0.05	C	11
P_2O_5	<0.02	N	135
		S	995
		Zn	1.4
		Cu	

Oxides in wt%; others in ppm except as noted.

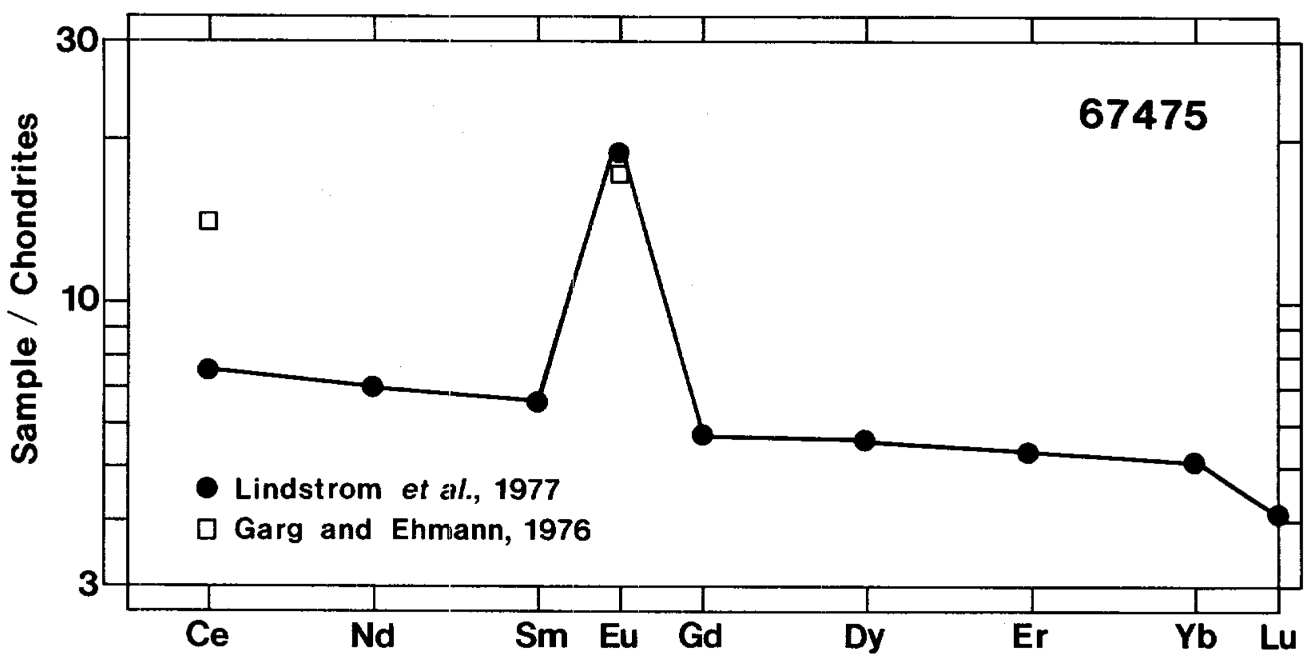


Figure 3. Rare earths.

EXPOSURE AGES: Cosmogenic radionuclide abundances are provided by Clark and Keith (1973). From these data, Yokoyama et al. (1974) conclude that 67475 is probably saturated in ^{26}Al activity. This contrasts with 67455 which Yokoyama et al. (1974) believe to be unsaturated.

PROCESSING AND SUBDIVISIONS: In 1973 this rock was slabbed. During sawing the slab broke along natural fractures as did several exterior chips from the butt ends (Fig. 4). In 1974, under Chao's direction, several more pieces were chipped for allocations from both the slab and the smaller end pieces. The largest single piece remaining is ,3 (76.56 g).

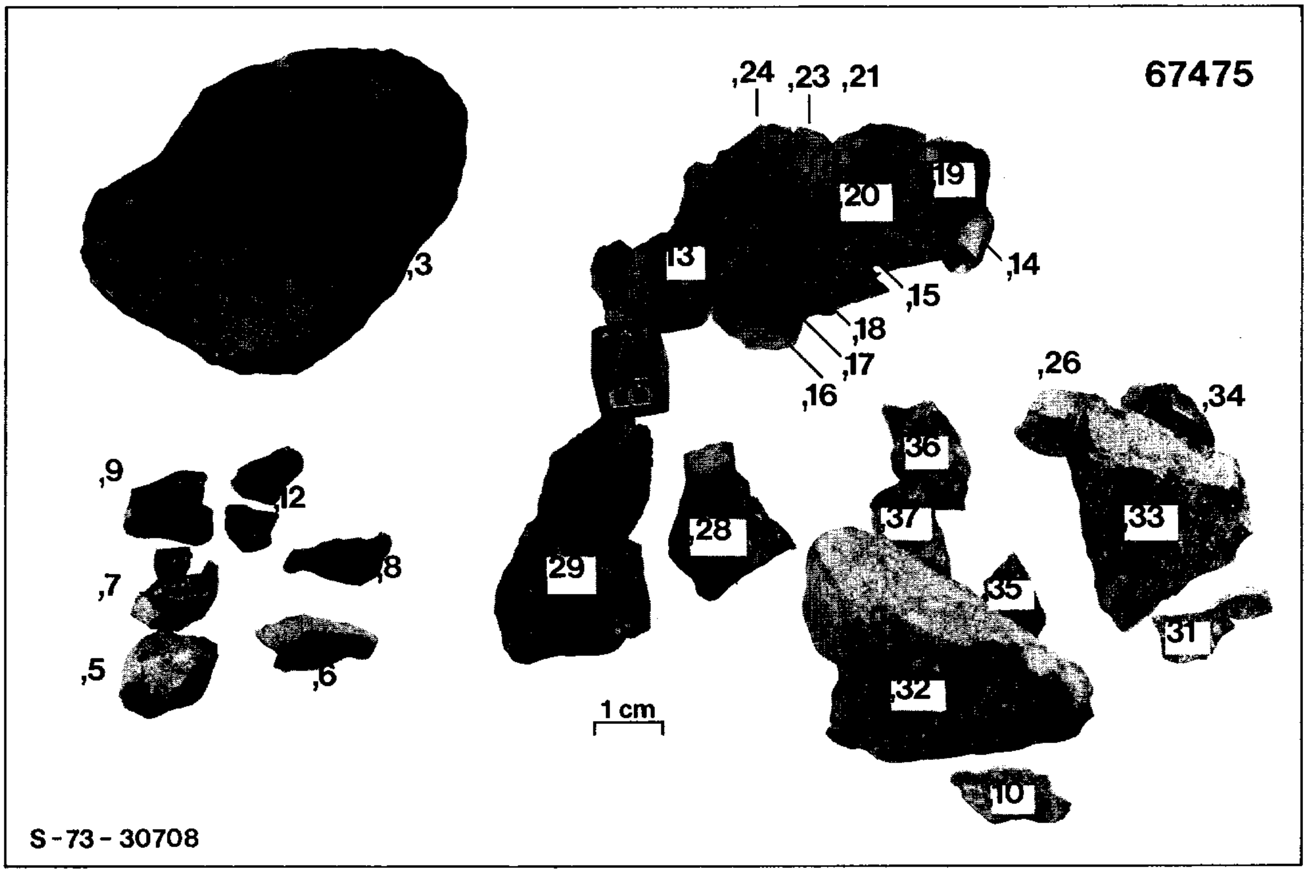


Figure 4. Major subdivisions of 67475.

67485 FINE-GRAINED IMPACT MELT (?) 6.55 g

INTRODUCTION: 67485 is an angular, medium gray, coherent and aphanitic rock (Fig. 1). It has scarce vugs and a few areas consist of powdery white material. It was taken from a regolith sample collected by the White Breccia boulders and lacks zap pits.

a

b

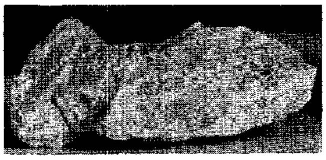


Figure 1. a) S-72-41421
b) S-72-41422.
Sample is about 3 cm long

INTRODUCTION: 67486 is medium dark gray vesicular glass of irregular shape (Fig. 1). It is devitrified around vesicles and contains a powdery, white lithic inclusion. It was taken from a regolith sample collected by the White Breccia boulders and lacks zap pits.

a

b

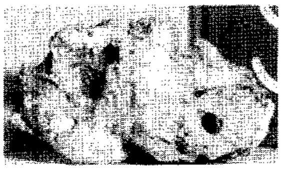


Figure 1. a) S-72-41421
b) S-72-41422.
Sample is about 2.5 cm long

67487 FINE-GRAINED IMPACT MELT (?) 2.65 g

INTRODUCTION: 67487 is a medium dark gray, coherent and aphanitic rock (Fig. 1). It has scarce vugs. It was taken from a regolith sample collected by the White Breccia boulders and lacks zap pits.

a

b

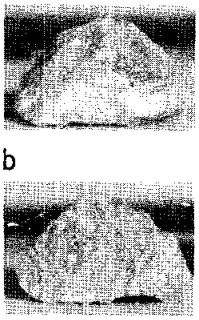


Figure 1. a) S-72-41421
b) S-72-41422.
Sample is almost 2 cm long

67488 FINE-GRAINED IMPACT MELT (?) 2.25 g

INTRODUCTION: 67488 is an olive gray, coherent and aphanitic rock (Fig. 1). It lacks cavities and has some white patches. It was taken from a regolith sample collected by the White Breccia boulders and has zap pits on one side.

a

b

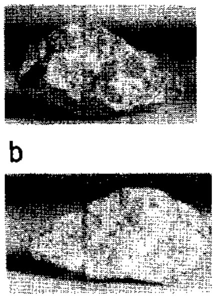


Figure 1. a) S-72-41421
b) S-72-41422.
Sample is about 1.5 cm long

67489 BASALTIC IMPACT MELT(?) 2.06 g

INTRODUCTION: 67489 is a dark gray, coherent and aphanitic rock (Fig. 1). It contains a few vugs, some scarce, pale yellow mineral grains, and plagioclases up to 300 μm. It is possibly a basaltic impact melt. It was taken from a regolith sample collected by the White Breccia boulders and has some zap pits.

a

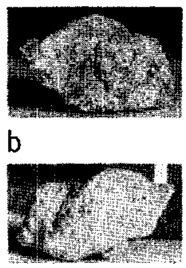


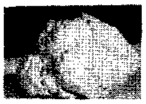
Figure 1. a) S-72-41421
b) S-72-41422.

Sample is almost 1.5 cm long

67495 FINE-GRAINED IMPACT MELT (?) 1.34 g

INTRODUCTION: 67495 is possibly a gray aphanite clast in a gray breccia matrix, but the original data pack description notes that the sample is too dust covered for real identification. It was taken from a regolith sample collected by the White Breccia boulders.

a



b

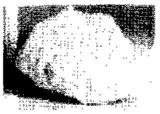


Figure 1. a) S-72-41421
b) S-72-41422.
Sample is about 1 cm long.

INTRODUCTION: 67515 is a polymict, friable, and fine-grained breccia (Fig. 1). It contains abundant cataclastic anorthosite,and smaller amounts of aphanitic and glassy impact melts and feldspathic granulitic impactite. It is a rake sample collected near the White Breccia boulders. It is rounded; a few zap pits occur on one surface.

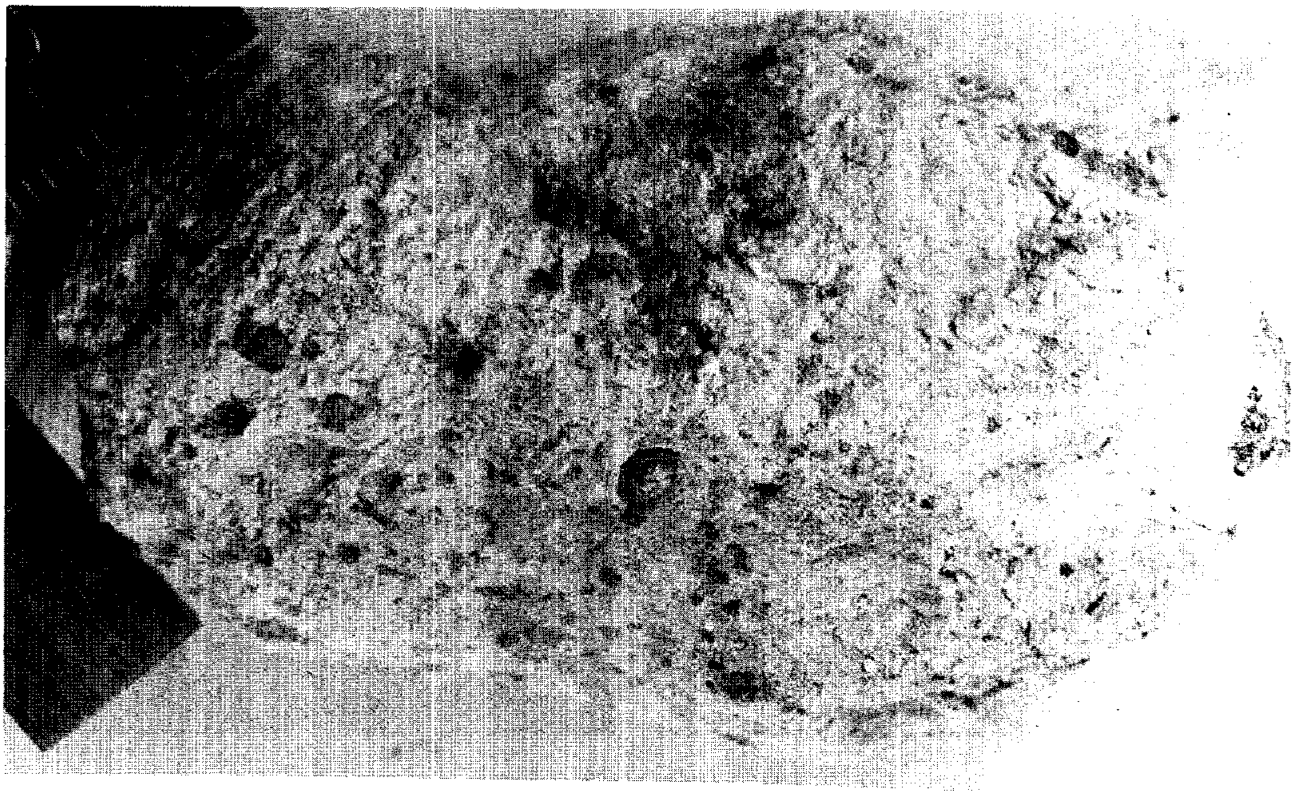


Figure 1. S-72-51238, mm scale.

PETROLOGY: Thin sections of loose fragments are mainly cataclastic anorthosites, aphanitic and glassy impact melts, and a single fragment of feldspathic granulitic impactite.

The anorthosites appear to be pure and monomict. The textures differ from fragment to fragment, but all contain shocked and fractured plagioclases (Fig. 2). Mafic minerals are rare. Exsolution or shock lamellae are present in several of the mafic minerals, which appear to be mainly low-Ca pyroxenes. The aphanitic and glassy impact melts are all brown or nearly opaque, containing plagioclase and tiny ($\leqslant$10 μm) mafic grains. Plagioclase clasts ($\sim$100 μm diameter) are common. The feldspathic granulitic impactite consists of 65-70% plagioclase as stubby, ~150 μm grains with ~50 μm mafic grains (Fig. 2). Most of the latter are low-Ca pyroxene, but both olivine and high-Ca pyroxene are present, as well as ilmenite, sulfide, Fe-metal, and chromite(?). Some of the plagioclase grains have mafic mineral "necklaces".

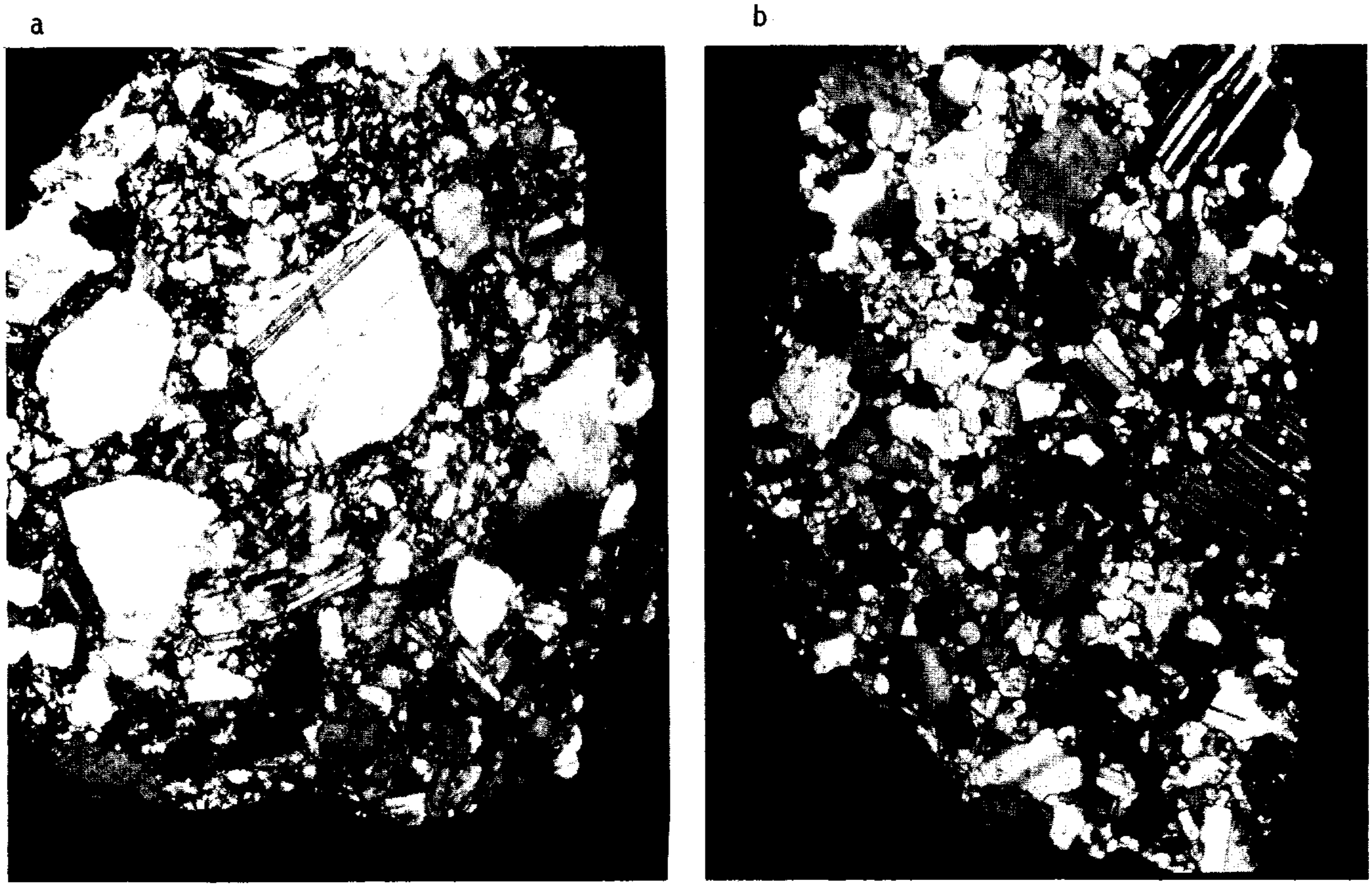


Figure 2. 67515,1 a) cataclastic anorthosite fragment, xpl. width 2mm.
b) feldspathic granulite fragment, xpl. width 2mm.

PROCESSING AND SUBDIVISIONS: Several small loose chips were taken for a potted butt, resulting in thin sections ,1 and ,4.

INTRODUCTION: 67516 is a white, coherent breccia containing darker clasts (Fig. 1). It is fine-grained with few clasts larger than 1 mm. It is a rake sample collected near the White Breccia boulders, and lacks zap pits.

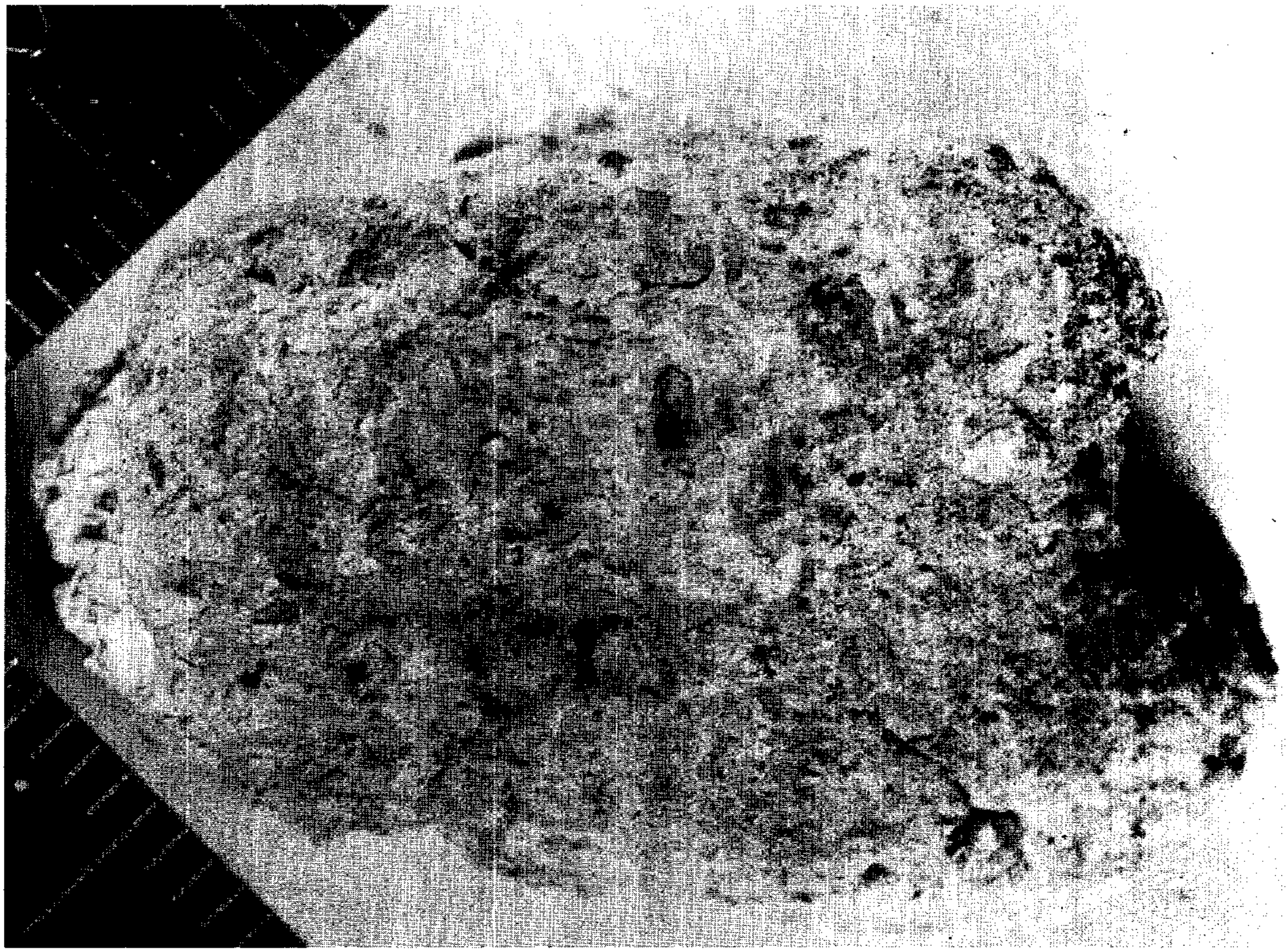


Figure 1. S-72-51052, mm scale.

INTRODUCTION: 67517 is an extremely friable and very pale-colored breccia containing some small dark clasts (Fig.1). It has broken into several pieces. It is a rake sample collected near the White Breccia boulders, and its surface is too friable to have retained zap pits.

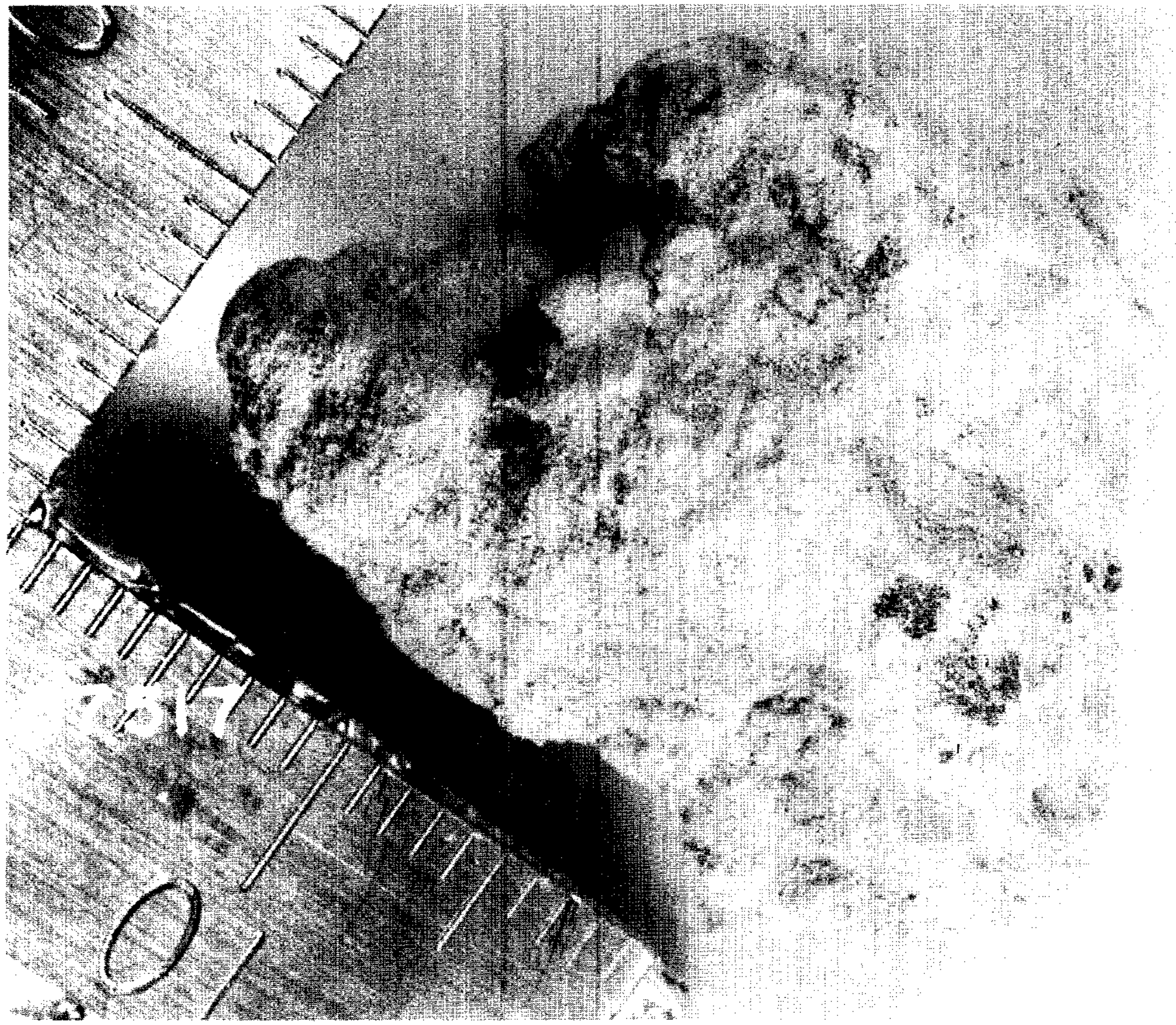


Figure 1. S-72-51281, mm scale.

67518 FRAGMENTAL BRECCIA OR CATACLASTIC ANORTHOSITE 3.74 g

INTRODUCTION: 67518 is a white, moderately friable breccia which is fine-grained and homogeneous (Fig.1). It lacks obvious clasts but has ∿ 1% dark specks, possibly ferromagnesian minerals. It is possibly a pure, cataclastic anorthosite. It is a rake sample collected near the White Breccia boulders, and its friable surface lacks zap pits.

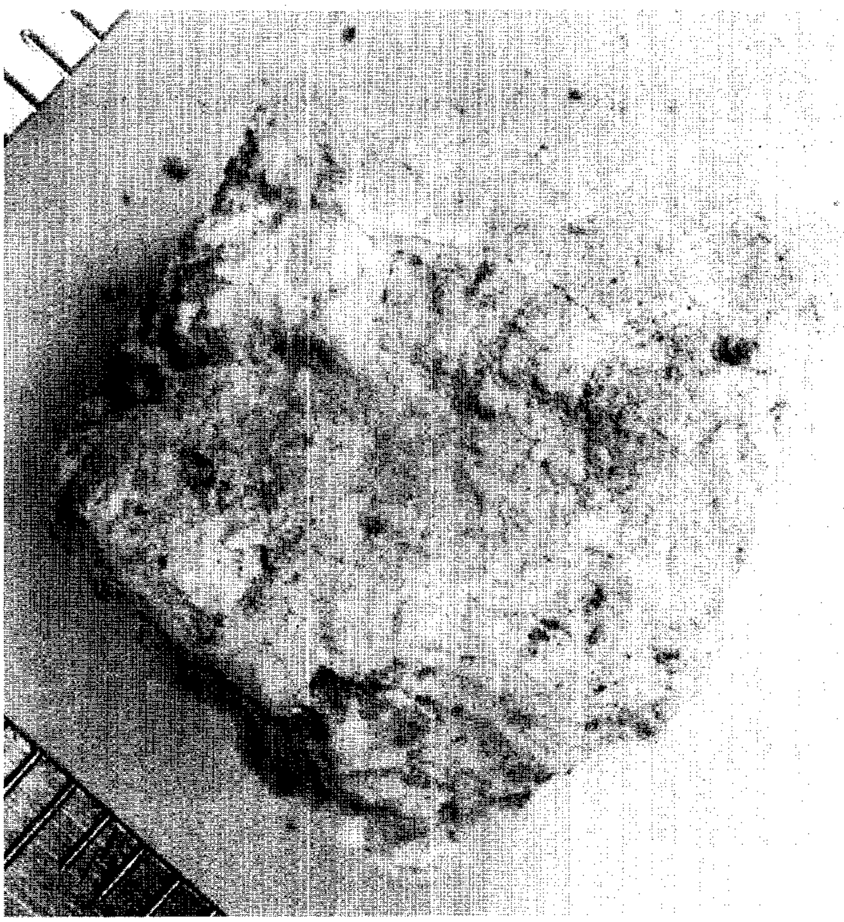


Figure 1. S-72-49577, mm scale.

67519 FRAGMENTAL POLYMICT BRECCIA 2.04 g

INTRODUCTION: 67519 (Fig. 1) is a moderately coherent but porous, polymict breccia, with only sparse fragments of glass and mafic minerals. It is a rake sample collected near the White Breccia boulders. It is free of zap pits.

PETROLOGY: A thin section (,1) is of a porous breccia consisting of more than 95% plagioclase. It is fine-grained, with most fragments less than 50 µm and a few larger plagioclases (Fig. 2). Traces of mafic minerals, ilmenite, and Fe-metal are present. Brown glass fragments occur in zones and appear to be mafic in composition.

PROCESSING AND SUBDIVISIONS: Some small chips were made into a potted butt for thin section ,1.

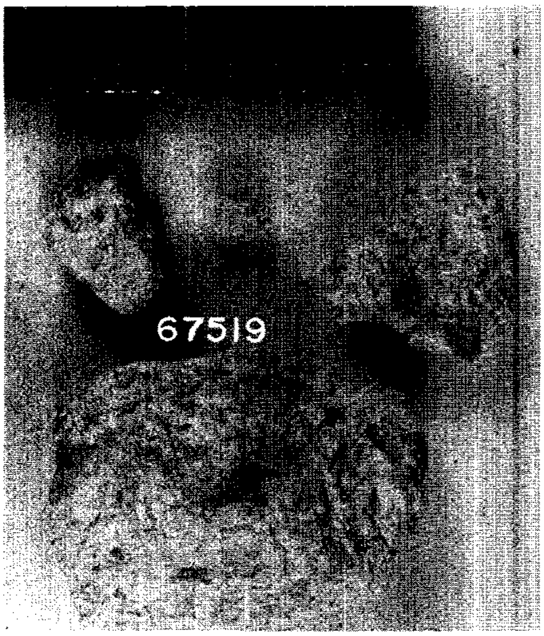


Figure 1. S-72-51047, mm scale.

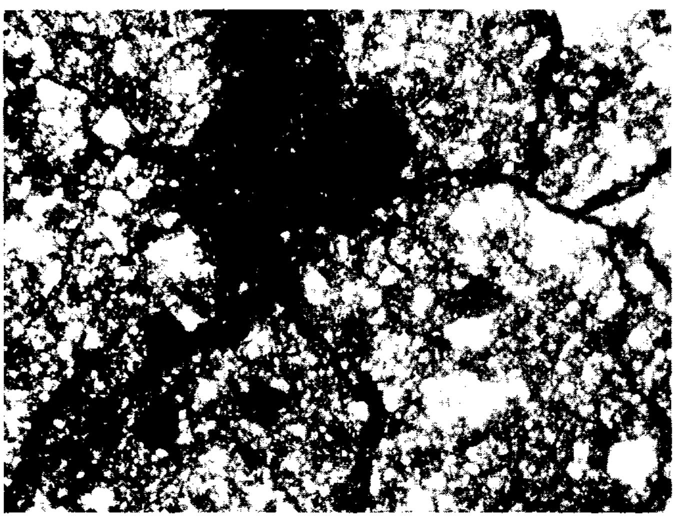


Figure 2. 67519,1, general view, dark clot is glass, xpl. width 2mm.

67525 CATACLASTIC ANORTHOSITE(?) 2.52 g

INTRODUCTION: 67525 is a coherent, fine-grained breccia which appears to be entirely plagioclase (Fig.1). It is very light-colored and appears to be heavily shocked. It is a rake sample collected near the White Breccia boulders and has a few zap pits.

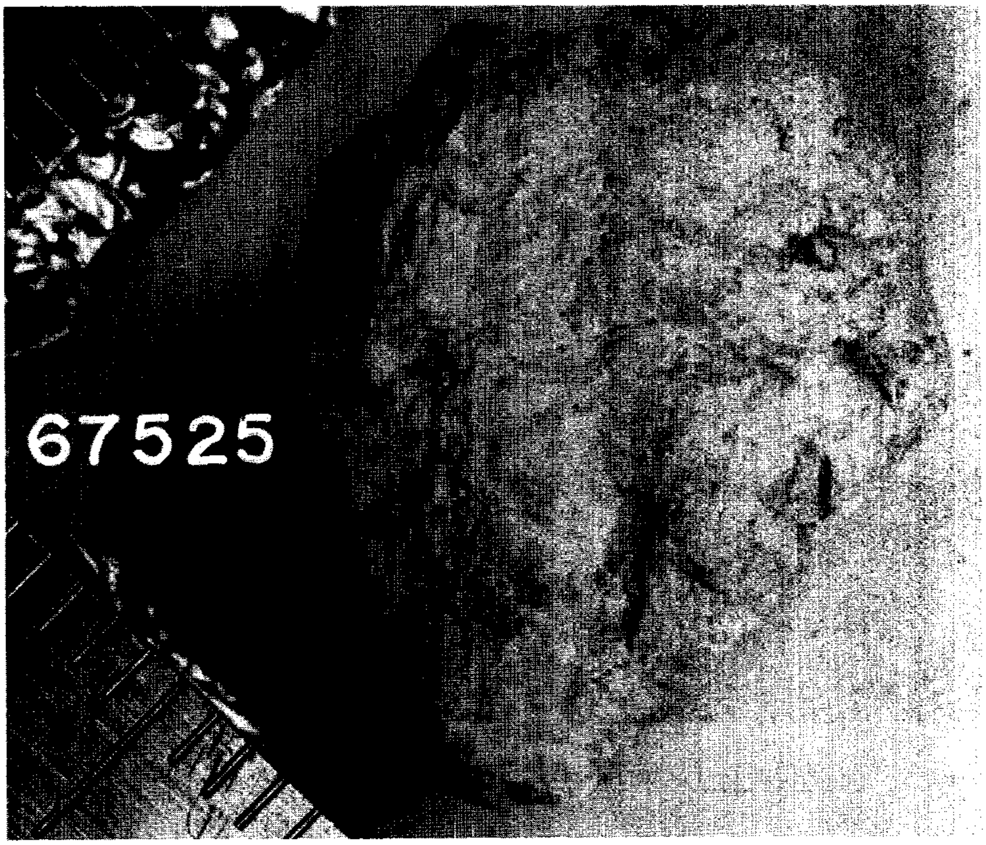


Figure 1. S-72- 49549, mm scale.

INTRODUCTION: 67526 is a pale gray to white friable breccia containing a few gray clasts (Fig.1). The clasts are coherent. It is a rake sample collected near the White Breccia boulders and its friable powdery surface lacks zap pits.

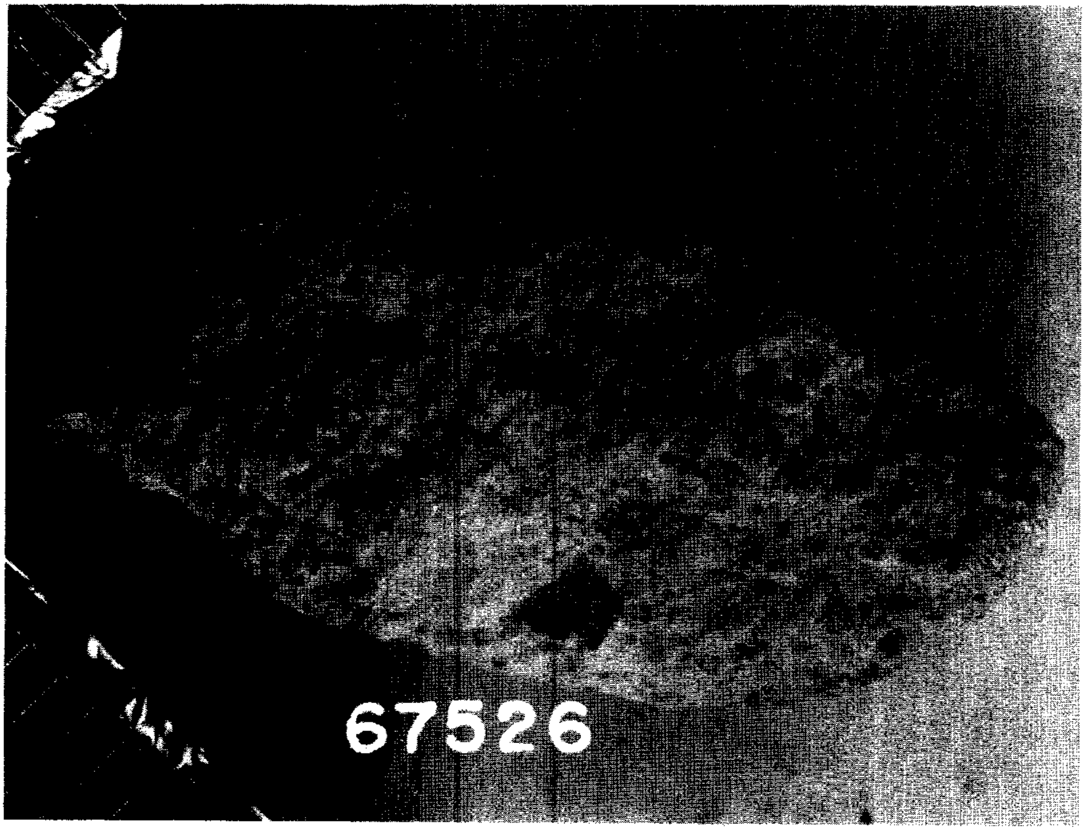


Figure 1. S-72-51252, mm scale.

INTRODUCTION: 67527 is a friable, fine-grained, polymict breccia (Fig. 1) with about 80% plagioclase, and cataclastic anorthosite clasts. It is a rake sample collected near the White Breccia boulders. It is rounded with few zap pits.

PETROLOGY: 67527 consists of coherent cataclastic anorthosite clasts in a porous matrix which is mainly angular fragments of plagioclase (~80%) and mafic minerals (Fig. 2). Ilmenite is also present. Most matrix grains are less than 50 μm in diameter. The cataclastic anorthosite (Fig. 2) which is half of thin section (,1) is finely ground up in places, but is non-porous due to sintering.

PROCESSING AND SUBDIVISIONS: Small chips were removed to make the potted butt from which thin section ,1 was cut.

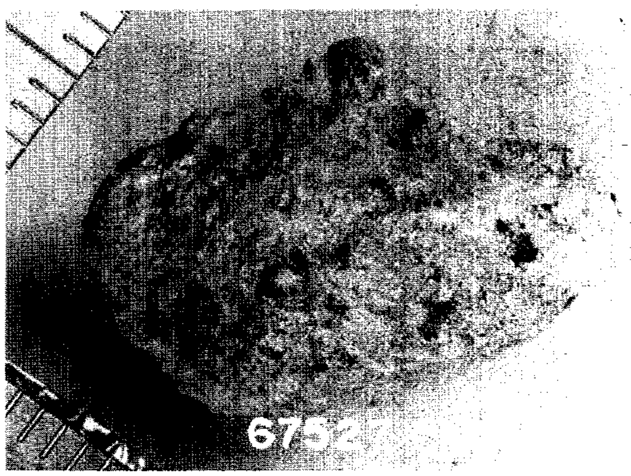


Figure 1. S-72- 51280, mm scale.

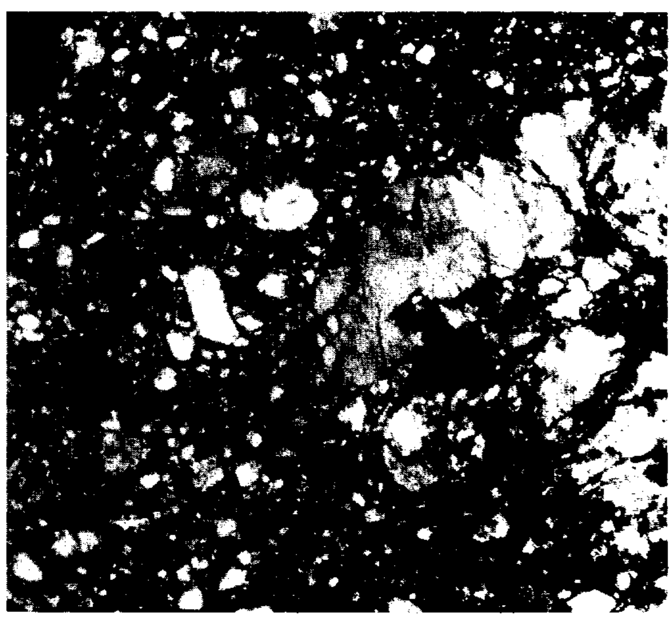


Figure 2. 67527,1, fragmental matrix and cataclastic anorthosite clast, xpl. width 2mm.

INTRODUCTION: 67528 is a friable pale-colored breccia with a few dark clasts (Fig. 1). It is porous and contains a variety of lithic clasts. It is a rake sample collected near the White Breccia boulders. It is subrounded and free of zap pits.

PETROLOGY: 67528 consists of porous, clastic polymict breccias (Fig. 2) if the thin sections are representative, as they appear to be (Fig. 1). Steele and Smith (1973) refer to it as a fine-grained breccia with 50% matrix.

The matrix contains ∿75% plagioclase, ∿25% mafic minerals, and some ilmenite, in grains mainly less than 200 μm in diameter. Lithic clasts, nearly all less than 500 μm diameter, are mainly brown glassy or aphanitic melt breccias and granulitic impactites.

PROCESSING AND SUBDIVISIONS: Chipping for thin section allocations resulted in substantial disaggregation as shown in Figure 1.

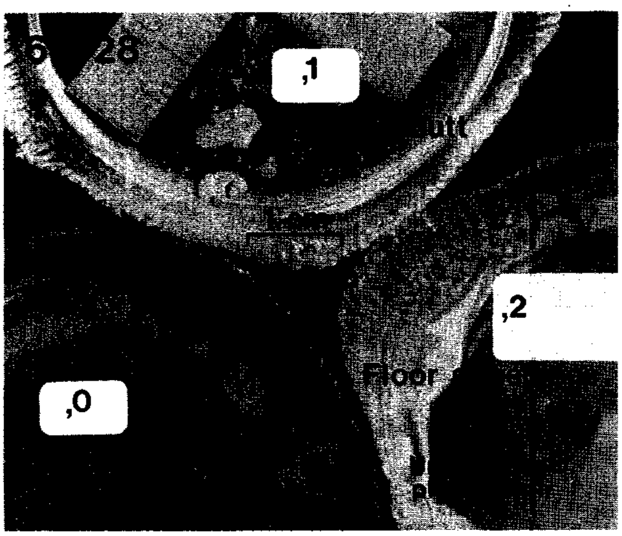


Figure 1.

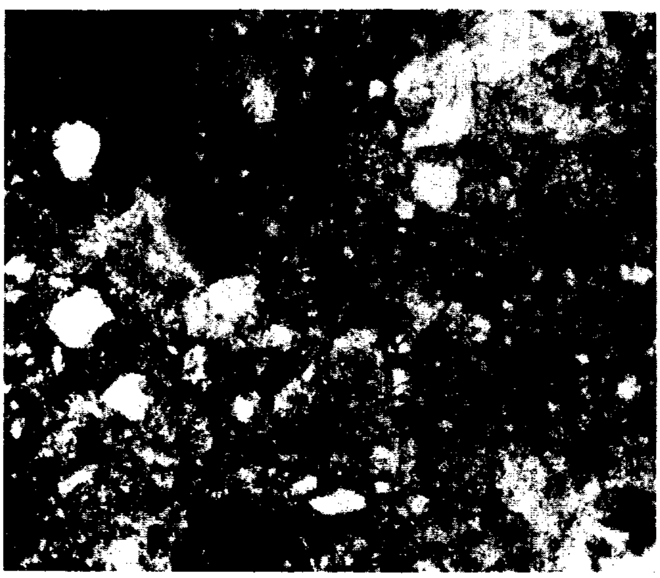


Figure 2. 67528,1, general view, ppl. width 2mm.

67529 CATACLASTIC ANORTHOSITE 1.13 g

INTRODUCTION: 67529 is a white, monomict, cataclastic anorthosite which is fairly coherent (Fig. 1). It is a rake sample from near the White Breccia boulders. It is subangular and lacks zap pits.

PETROLOGY: 67529 consists of a monomict, cataclastic anorthosite (Fig. 2) with only rare mafic grains, probably low-Ca pyroxenes. Opaque minerals are extremely rare. The texture is variable, ranging from very finely ground shear zones to shocked and fractured regions (Fig. 2). Most of the finely ground regions are porous, whereas the remainder is not porous.

PROCESSING AND SUBDIVISIONS: Small fragments from which thin section ,1 was made were chipped from the sample.

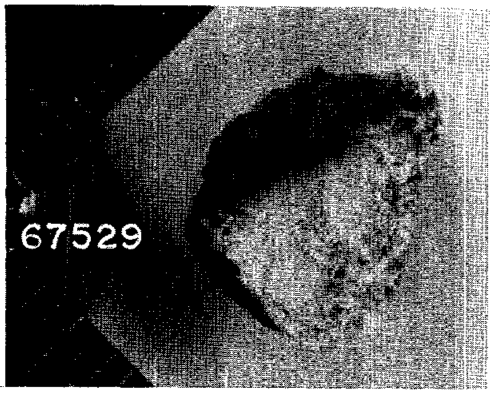


Figure 1. S-72-51043, mm scale.

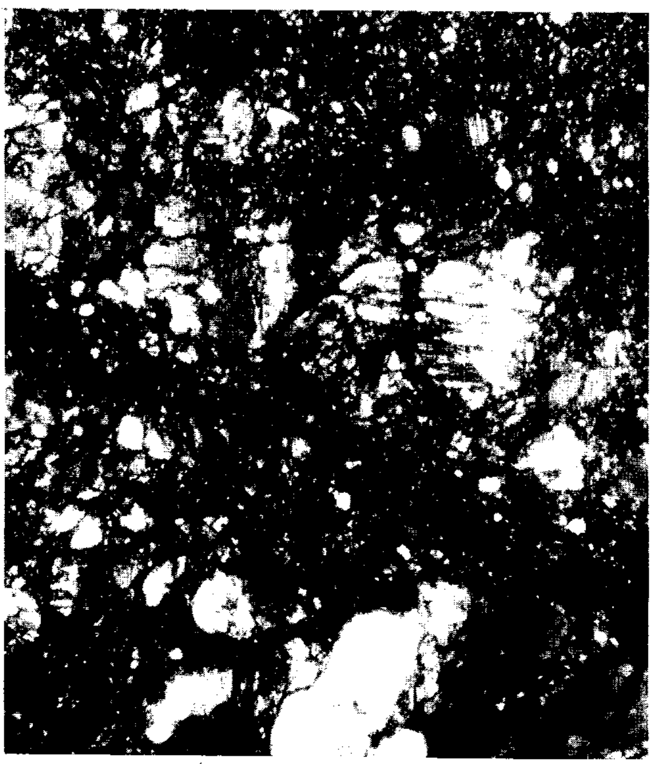


Figure 2. 67529,1, general view, xpl. width 2mm.

67535 FRAGMENTAL BRECCIA OR CATACLASTIC ANORTHOSITE 0.99 g

INTRODUCTION: 67535 is a white to light-gray, fairly friable and fine-grained breccia (Fig.1). Only a few small gray clasts (?) are present and the sample may be nearly pure plagioclase. It is a rake sample collected near the White Breccia boulders and lacks zap pits.

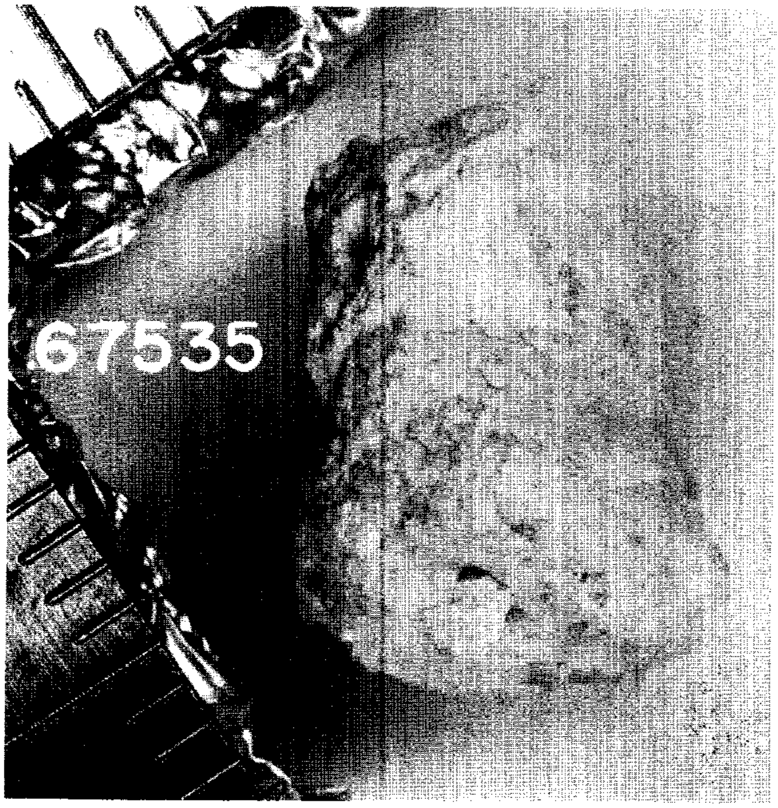


Figure 1. S-72-51273, mm scale.

INTRODUCTION: 67536 is a white, fine-grained, homogeneous and friable breccia (Fig.1). It appears to be pure plagioclase and might be a cataclastic anorthosite. It is a rake sample collected near the White Breccia boulders and its powdery surface lacks zap pits.

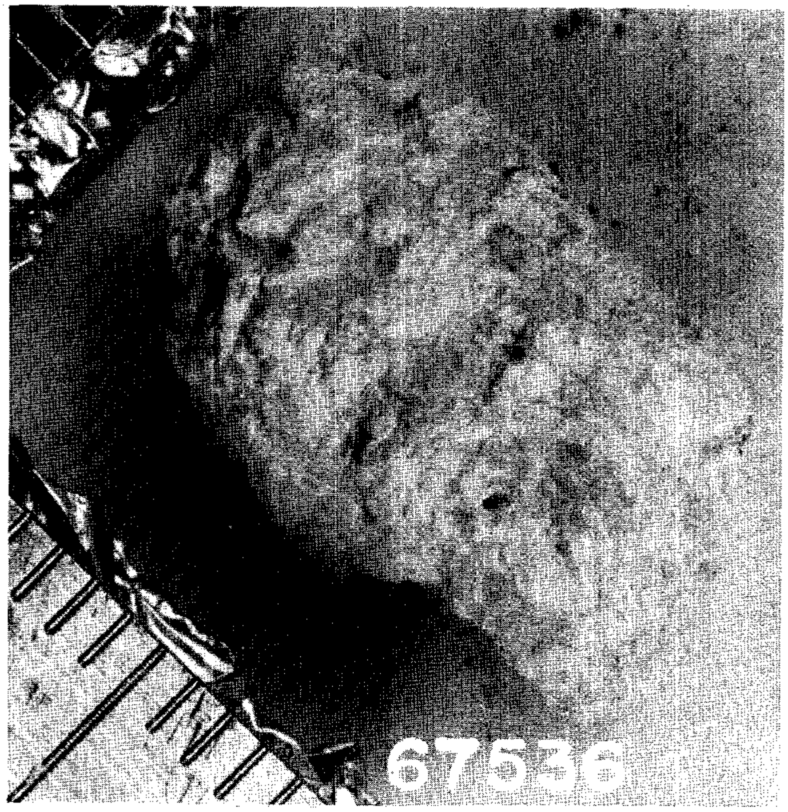


Figure 1. S-72-49548, mm scale.

INTRODUCTION: 67537 is a monomict, white, cataclastic anorthosite (Fig. 1). It is a rake sample collected near the White Breccia boulders. It is homogeneous, moderately friable, and lacks zap pits.

PETROLOGY: The sample consists of large plagioclase clasts in a finer-grained plagioclase matrix (Fig. 2) which contains few mafic mineral grains (<5%). All the large plagioclase clasts are strained or have offset fractures and twins. The mafic phases are localized as if crushed from original larger grains.

PROCESSING AND SUBDIVISIONS: Chipping to produce material for thin section ,1 produced some small chips and fines.

Figure 1. S-72-49573, mm scale.

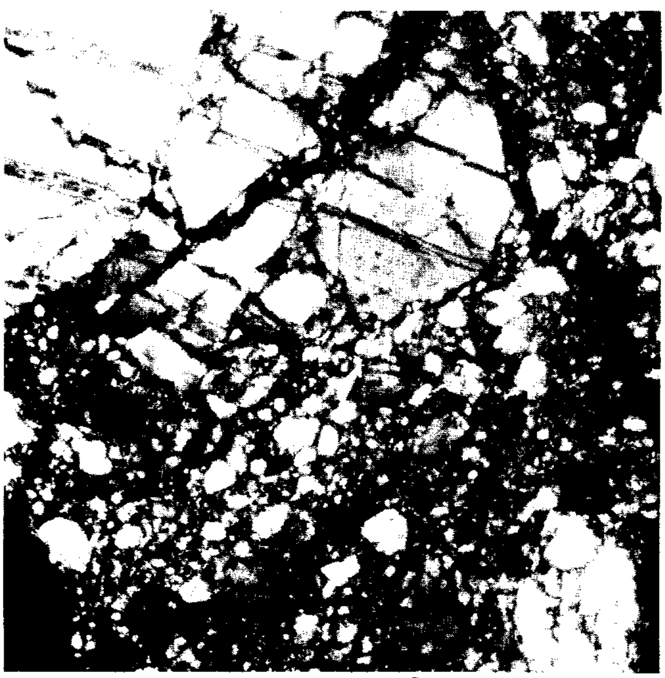


Figure 2. 67537,1, general view, xpl. width 2mm.

INTRODUCTION: 67538 is a friable breccia consisting of gray and white clasts in a pale colored, fine-grained matrix (Fig. 1). It is a rake sample collected near the White Breccia boulders and lacks zap pits.

Figure 1. S-72-51245, mm scale.

INTRODUCTION: 67539 consists of dark clastic material enclosed in a fairly coherent, mainly white matrix (Fig. 1). It is a rake sample collected near the White Breccia boulders and lacks zap pits.

Figure 1. S-72-49554, mm scale.

INTRODUCTION: 67545 is a friable, light-gray breccia with about 10% gray clasts (Fig. 1). The matrix is fine-grained. It is a rake sample collected near the White Breccia boulders and lacks zap pits.

Figure 1. S-72-51057, mm scale.

67546 FRAGMENTAL POLYMICT BRECCIA 1.50 g

INTRODUCTION: 67546 is a pale-gray to white, friable breccia containing many small gray clasts (Fig. 1). Its matrix is fine-grained and powdery. It is a rake sample collected near the White Breccia boulders and lacks zap pits.

Figure 1. S-72-51284, mm scale.

67547 FRAGMENTAL POLYMICT BRECCIA 0.83 g

INTRODUCTION: 67547 is a moderately porous, polymict breccia (Fig. 1), with a feldspathic matrix enclosing fragments of aphanitic breccias and granulitic impactites. It is a rake sample collected near the White Breccia boulders. It is fairly coherent and angular, and lacks zap pits.

PETROLOGY: The matrix of 67547 consists of plagioclase (∿ 80%) of which most fragments are less than 100 µm in diameter (Fig.2). Lithic clasts are mainly brown aphanitic breccias with a few larger granulitic impactite fragments (Fig.2) which contain about 30% mafic minerals and are fine-grained (mafics < 50µm, plagioclase 50-200 µm).

PROCESSING AND SUBDIVISIONS: Fragments were chipped off to obtain material for thin section ,1.

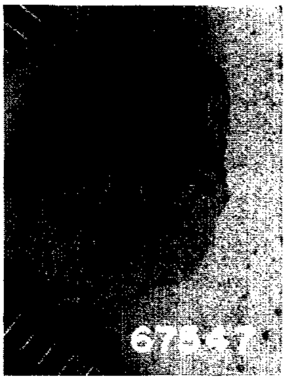


Figure 1. S-72-49544, mm scale.

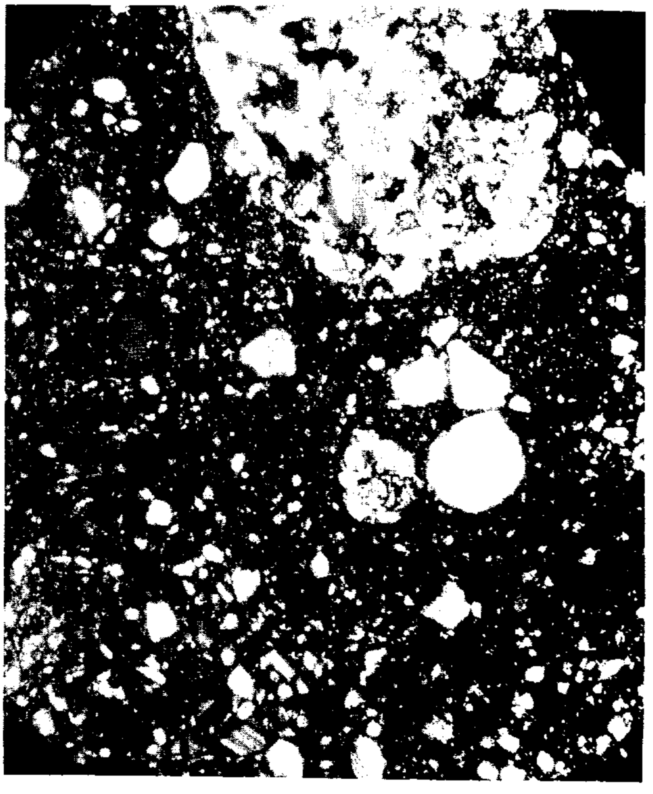


Figure 2. 67547,1, general view, xpl. width 2mm.

INTRODUCTION: 67548 is a porous, polymict, glassy breccia containing shocked plagioclase clasts and lithic clasts (Fig. 1). It is a rake sample collected near the White Breccia boulders. It is light gray, homogeneous, ovoid, and lacks zap pits.

PETROLOGY: Steele and Smith (1973) tabulate 67548 as a plagioclase-rich breccia with ∿40% matrix (defined as less than 5 μm). The breccia (Fig. 2) is polymict, glassy, and in thin section, brown. It contains shocked plagioclase and, locally, lithic clasts consisting of plagioclase-pyroxene-troilite-chromite assemblages in which the troilite is conspicuous. Aphanitic brown clasts are also common.

PROCESSING AND SUBDIVISIONS: Chips were removed, some of which were made into thin section ,1.

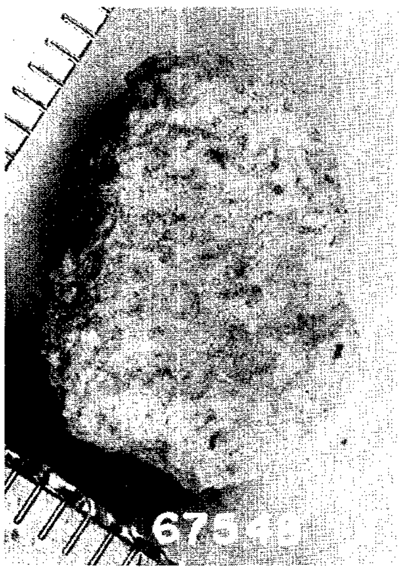


Figure 1. S-72-51282, mm scale.

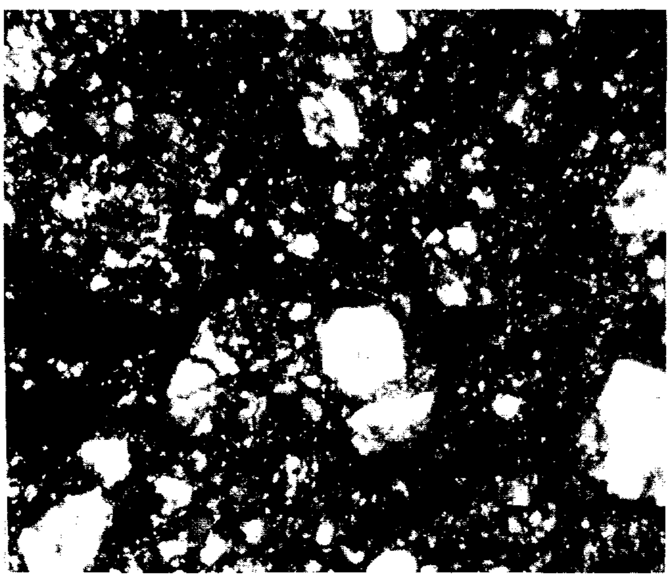


Figure 2. 67548,1, general view, xpl. width 2mm.

INTRODUCTION: 67549 is a porous, friable, light matrix breccia with both light and dark clasts (Fig. 1). It is fairly fine-grained with few clasts bigger than 5 mm. It is a rake sample collected near the White Breccia boulders. No zap pits are present.

PETROLOGY: A thin section (,5) cut for this study is a porous, fragmental breccia in which most grains are small (less than 200 μm) and angular (Fig. 2). It is polymict, containing a few lithic clasts including anorthositic breccia and very fine-grained brown melts. The matrix contains ~35% low-Ca pyroxene, conspicuous in being complexly exsolved and probably from a single source or single crushed clast. Some of these pyroxenes are almost 1 mm in diameter. Neither plagioclase nor pyroxene matrix fragments are heavily shocked.

PROCESSING AND SUBDIVISIONS: Some small chips were removed and from two of these thin section ,5 was made.

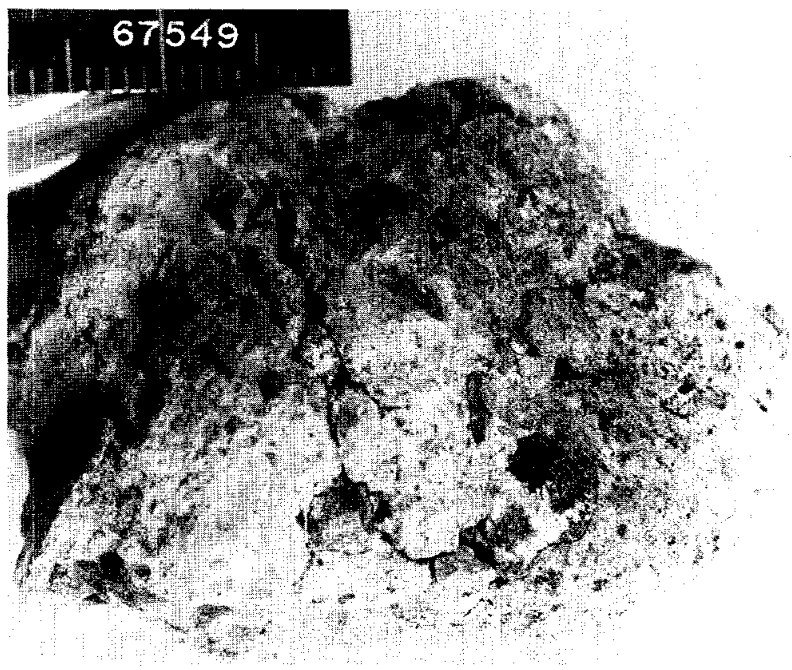


Figure 1. S-72-51274, mm scale.

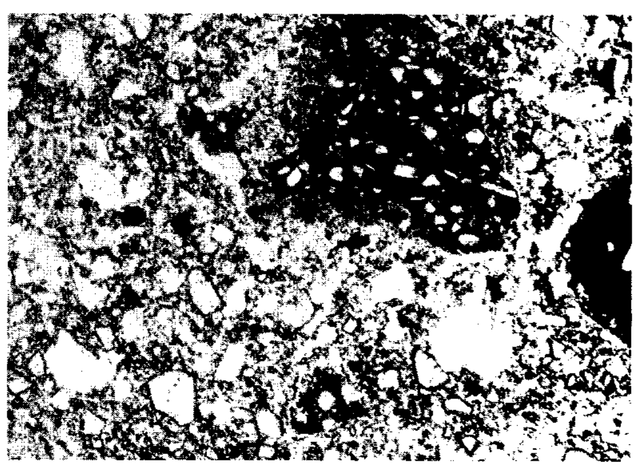


Figure 2. 67549,5, general view, ppl. width 2mm.

INTRODUCTION: 67555 consists of two pieces of coherent, glassy and aphanitic breccia with a diverse clast population (Fig. 1). It is a rake sample collected near the White Breccia boulders. The fragments are angular and neither has zap pits.

PETROLOGY: The darkest portion of the sample is homogeneous, pale-brown (in thin section), fragment-laden, aphanitic melt breccia (Fig. 2) whose clast population is mainly small plagioclases. The more heterogeneous portion has a brown, glassy, partially devitrified matrix (Fig. 2) containing clasts among which glassy fragments and plagioclases are common. Basaltic impact melts and one clast containing ~40% low-Ca pyroxene with a cumulate(?) texture are also present.

PROCESSING AND SUBDIVISIONS: Thin section ,1 was made from small chips removed from the sample.

Figure 1. S-72-51247, mm scale.

a b

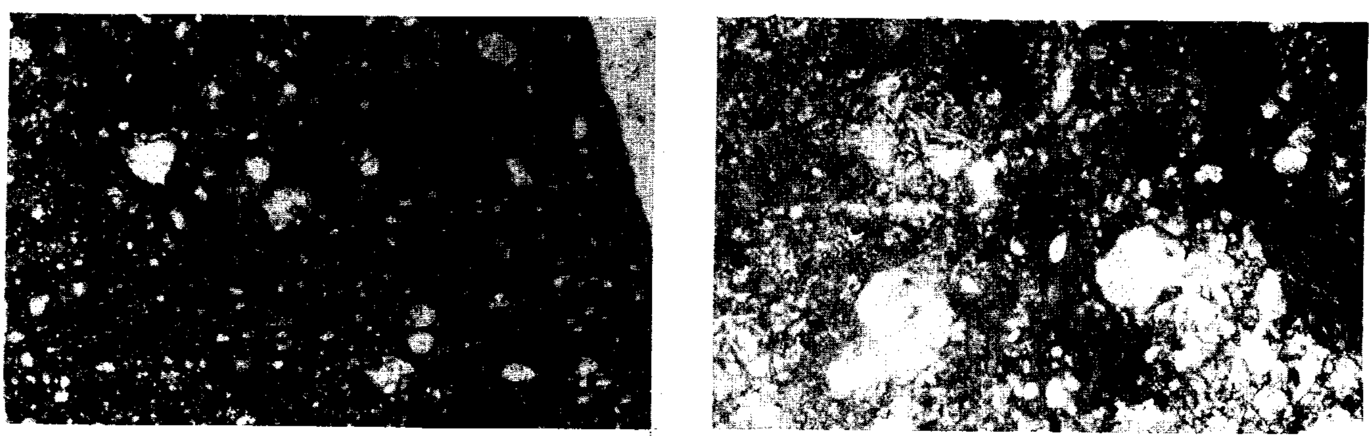


Figure 2. 67555,1 a) aphanitic breccia, ppl. width 2mm.
b) heterogeneous glassy breccia, ppl. width 2mm.

INTRODUCTION: 67556 is a pale-colored, moderately friable basaltic impact melt, broken up and deformed by intrusive glass veins (Fig. 1). It is a rake sample collected near the White Breccia boulders. Zap pits occur on one face.

PETROLOGY: 67556 consists of fragments of basaltic impact melt separated by glass veins. The texture of the basaltic fragments is different from fragment to fragment, but all have ~25% pyroxene subophitically or ophitically enclosing ~70% plagioclase laths (Fig. 2). Some contain distinct, shocked plagioclase clasts and a few mafic clasts are also present. The melt also crystallized armalcolite (and ilmenite?) and Fe-metal.

The glass veins (Fig. 2) are cross-cutting, brown, and change width along their path, in places tapering out. They contain fragments of mineral clasts, and much Fe-metal as disseminated specks.

PROCESSING AND SUBDIVISIONS: Several small fragments were chipped off, and some of them used to make thin section ,1.

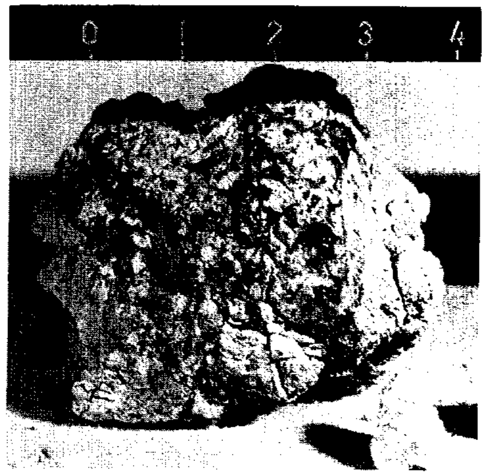


Figure 1. S-72-43435, cm scale.

a b

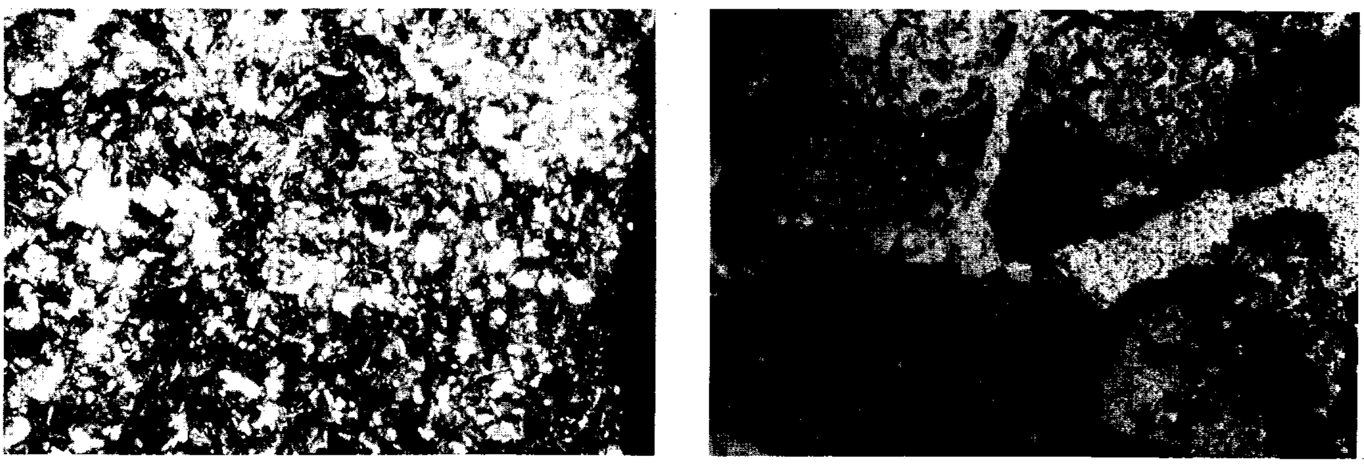


Figure 2, 67556,1 a) basalt, xpl. width 2mm.
b) glass veins, ppl. width 2mm.

INTRODUCTION: 67557 is a coherent, dark, polymict breccia (Fig. 1) with a glassy matrix. Its clast population includes agglutinitic material and it is probably lithified soil. It is a rake sample collected near the White Breccia boulders. It is subrounded and has a few zap pits on one face.

PETROLOGY: 67557 has an opaque, fine-grained, glassy matrix and is clearly polymict (Fig. 2). Its clasts include plagioclases, mafic minerals, glasses, agglutinitic (opaque, vesicular) glasses and lithic fragments. The latter include feldspathic granulites, poikilitic melts, and other breccias.

PROCESSING AND SUBDIVISIONS: A few small chips were taken from 67557 and a few of them used to make thin section ,1.

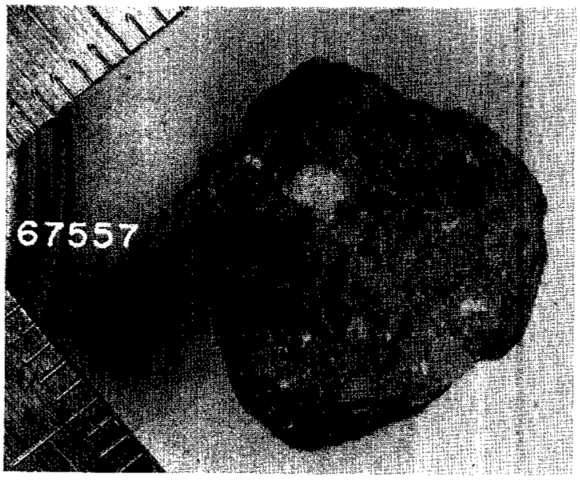


Figure 1. S-72-51270, mm scale.

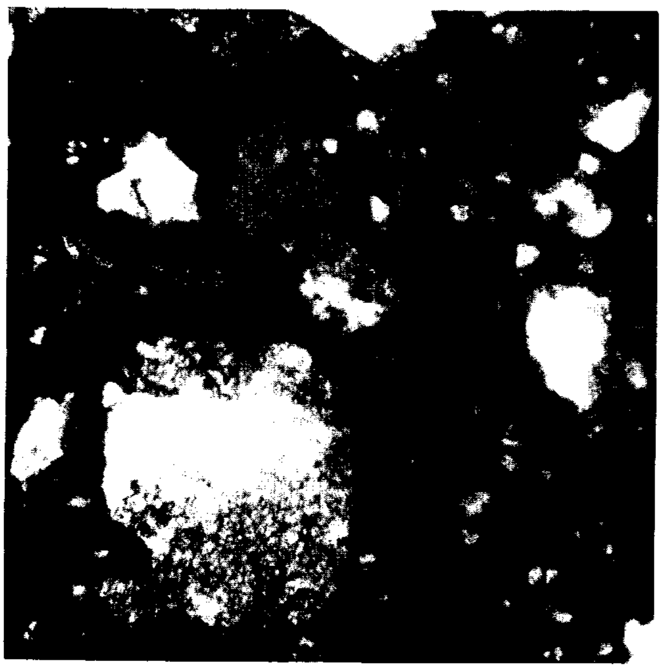


Figure 2. 67557,1, general view, ppl. width 2mm.

67558 FRAGMENTAL(?) POLYMICT BRECCIA 2.56 g

INTRODUCTION: 67558 is a light gray, moderately friable breccia with light and dark clasts (Fig. 1). The clasts include both aphanitic and crystalline rock fragments. It is a rake sample collected near the White Breccia boulders and has a few zap pits on all surfaces.

Figure 1. S-72-51279, mm scale.

INTRODUCTION: 67559 is a subophitic, plagioclase-rich impact melt, similar to 68415. The sample is gray and homogeneous (Fig. 1).

It is a rake sample collected near the White Breccia boulders. It is angular, coherent, and free of zap pits.

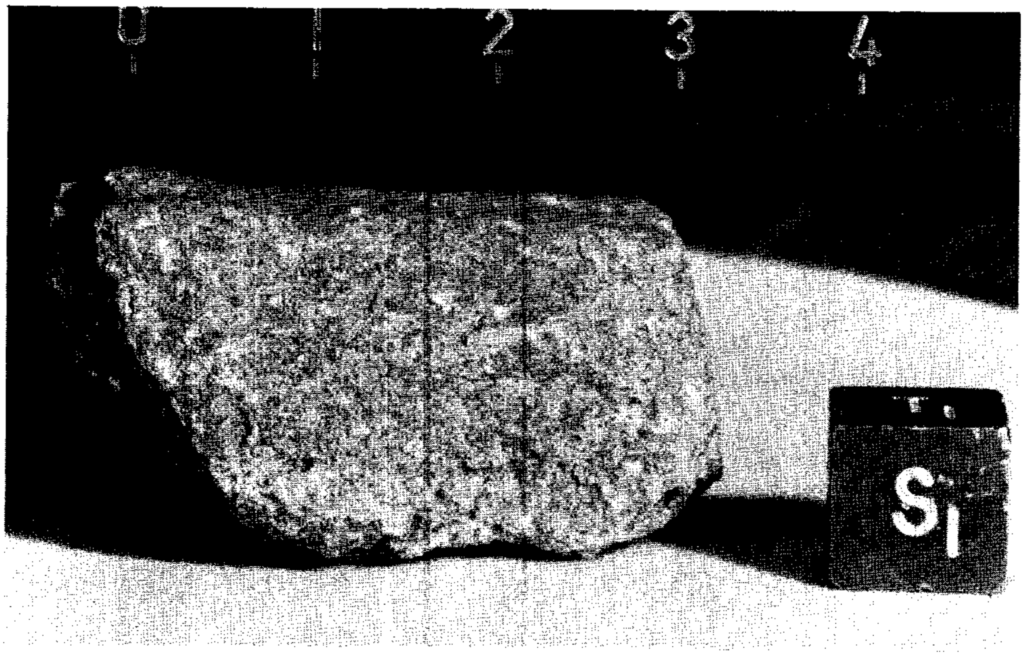


Figure 1. S-72-43448, cm scale.

PETROLOGY: 67559 is briefly described by Steele and Smith (1973) and Vaniman and Papike (1981). It is a coarse-grained, subophitic basalt (Fig. 2). Plagioclase laths are up to 1 mm x 200-300 µm, but most are much smaller; mafic minerals are interstitial. A mode by Vaniman and Papike (1981) has 74.7% plagioclase, 20.1% pyroxene, 2.1% olivine, and 2.1% ilmenite, metal, troilite, and mesostasis. Pyroxene and olivine compositions are given in Figure 3. Plagioclases range from An_{90-98} and have less than 0.2% Fe (Steele and Smith, 1973).

CHEMISTRY: A major element analysis is given by Nava (1974), and Wasson et al. (1977) provide major, rare earth, siderophile and other trace element data. Tera et al. (1974) provide K, Rb, Sr, U, Th, and Pb abundances. The chemistry is summarized in Table 1 and Figure 4. It is a meteorite-contaminated melt, very similar in all respects to 68415 and 68416. It lacks a significant Eu anomaly, a feature noted by Nava (1974; quotes unpublished data of Philpotts).

Figure 2. 67559,1, general view, xpl. width 2mm.

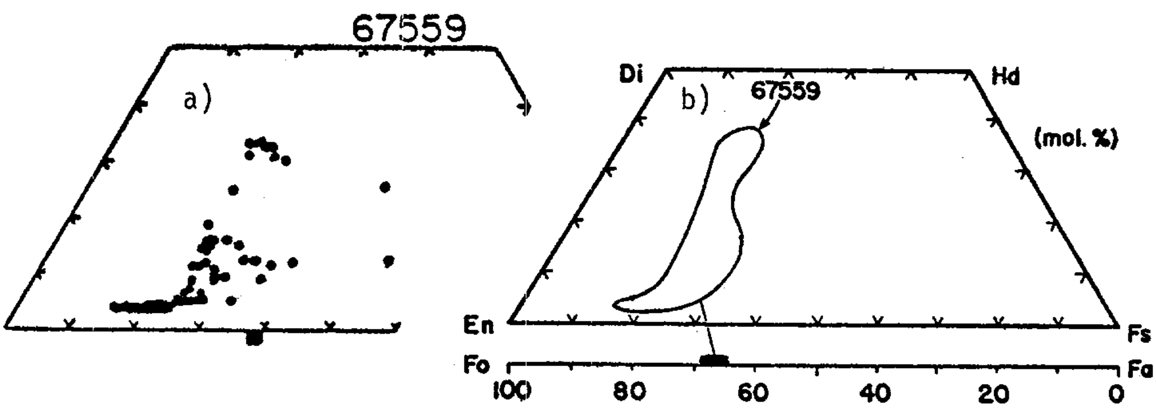


Figure 3. Pyroxene and olivine compositions.
a) from Vaniman and Papike (1981)
b) from Steele and Smith (1973).

TABLE 1. Summary chemistry of 67559

SiO_2	45	Sr	179
TiO_2	0.26-0.47	La	7.2
Al_2O_3	~28.5	Lu	0.34
Cr_2O_3	0.09	Rb	2
FeO	4.3	Sc	8.8
MnO	0.06	Ni	257
MgO	~4	Co	20.6
CaO	16.5	Ir ppb	11
Na_2O	0.5	Au ppb	5.0
K_2O	0.08	C	
P_2O_5	0.11	N	
		S	
		Zn	≤5.6
		Cu	

Oxides in wt%, others in ppm except as noted.

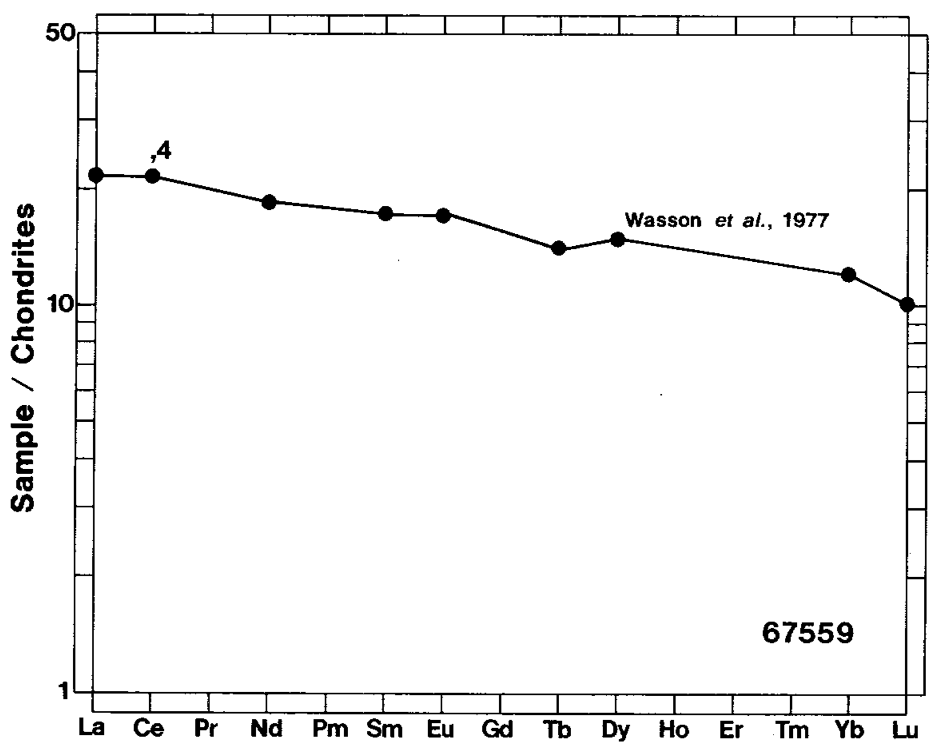


Figure 4. Rare earths.

RADIOGENIC ISOTOPES: Tera et al. (1974) report Rb-Sr and U-Th-Pb isotopic data. $^{87}Rb/^{86}Sr$ = 0.03128, $^{87}Sr/^{86}Sr$ = 0.70087 ± 6 and T_{BABI} = 4.22 ± 0.13 b.y., all very similar to corresponding data for 68415 and 68416. The lead isotopic results are also very similar to those from 68415, giving a concordant age at 4.42 b.y. The data do not specify the crystallization age.

PROCESSING AND SUBDIVISIONS: Several small chips were removed and thin section ,1 was made from a different chip than were thin sections ,9 and ,10.

INTRODUCTION: 67565 (Fig. 1) is a homogeneous, gray, coherent impact melt with a poikilitic texture. It is a rake sample collected near the White Breccia boulders. A few zap pits are present.

PETROLOGY: 67565 is fine-grained poikilitic impact melt with oikocrysts of mafic minerals (~200 µm) enclosing plagioclase chadacrysts (<30 µm) (Fig. 2). The interoikocryst areas contain chains of ilmenite and armalcolite. Sulfides, Fe-metal, and vesicles are present. Most of the clast population is plagioclase, but a few plagioclase-rich lithic fragments are also present.

PROCESSING AND SUBDIVISIONS: Several small chips were taken, and thin section ,1 made from one of them. Allocations were made for chemical and rare gas studies, but no results have been published.

Figure 1. S-72-51269, mm scale.

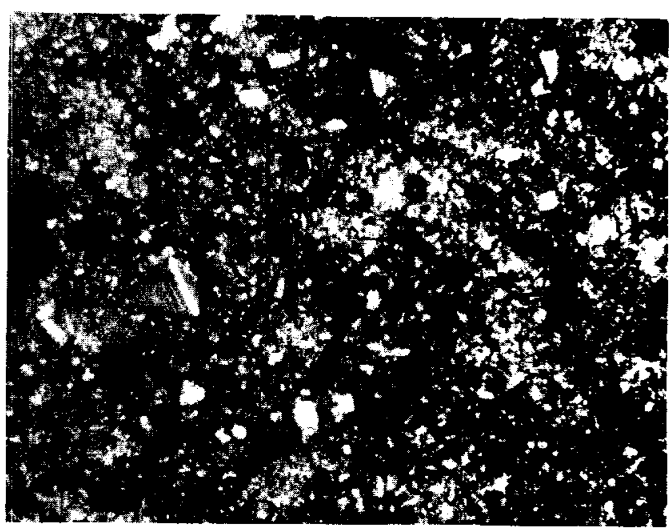


Figure 2. 67565,1, general view, xpl. width 2mm.

INTRODUCTION: 67566 is a coherent, polymict breccia (Fig. 1) with a granoblastic groundmass enclosing mineral and lithic clasts. Its texture and mode are variable but in general the sample is more obviously polymict and feldspathic than most granulitic impactites.

67566 is a rake sample collected near the White Breccia boulders. It is angular and lacks zap pits.

Figure 1. S-72-51249, mm scale.

PETROLOGY: Two thin sections (,1 and ,2) are similar except that ,2 is more mafic and more clast-rich. ,1 contains about 85% plagioclase, including shocked clasts, and has a fine-grained granoblastic matrix (Fig. 2). ,2 has about 65% plagioclase and about half of its larger clasts are olivine or olivine-plagioclase. Many of the clasts are angular (Fig. 2) but as in ,1, the fine-grained groundmass is granoblastic.

PROCESSING AND SUBDIVISIONS: Two chips were removed for making thin sections.

a b

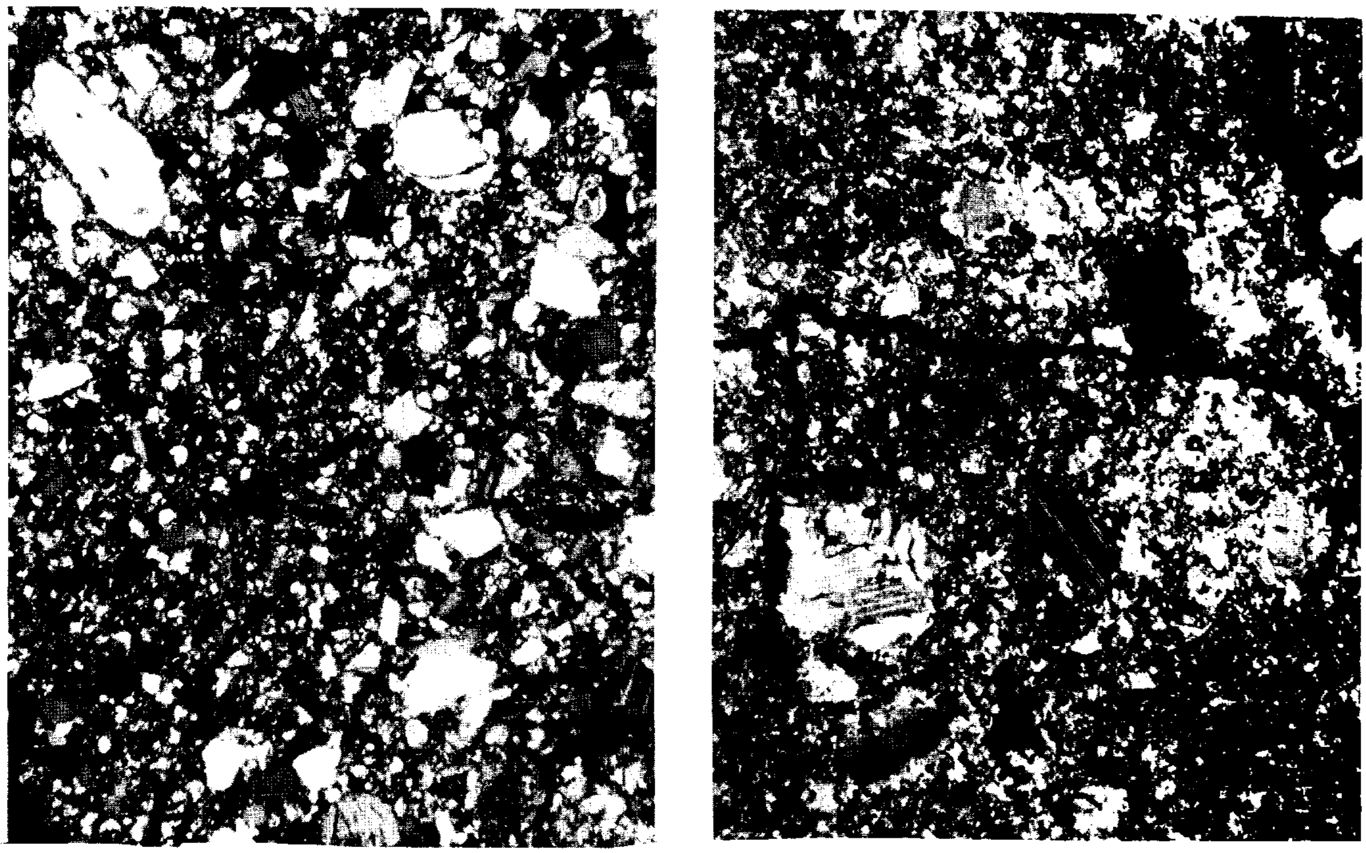


Figure 2. a) 67566,2, general view, xpl. width 2mm
b) 67566,1, general view, xpl. width 2mm.

INTRODUCTION: 67567 is a coherent, black, vesicular glass with smooth surfaces in places, containing white clasts and partly coated with dust (Fig.1). It is a rake sample collected near the White Breccia boulders and lacks zap pits.

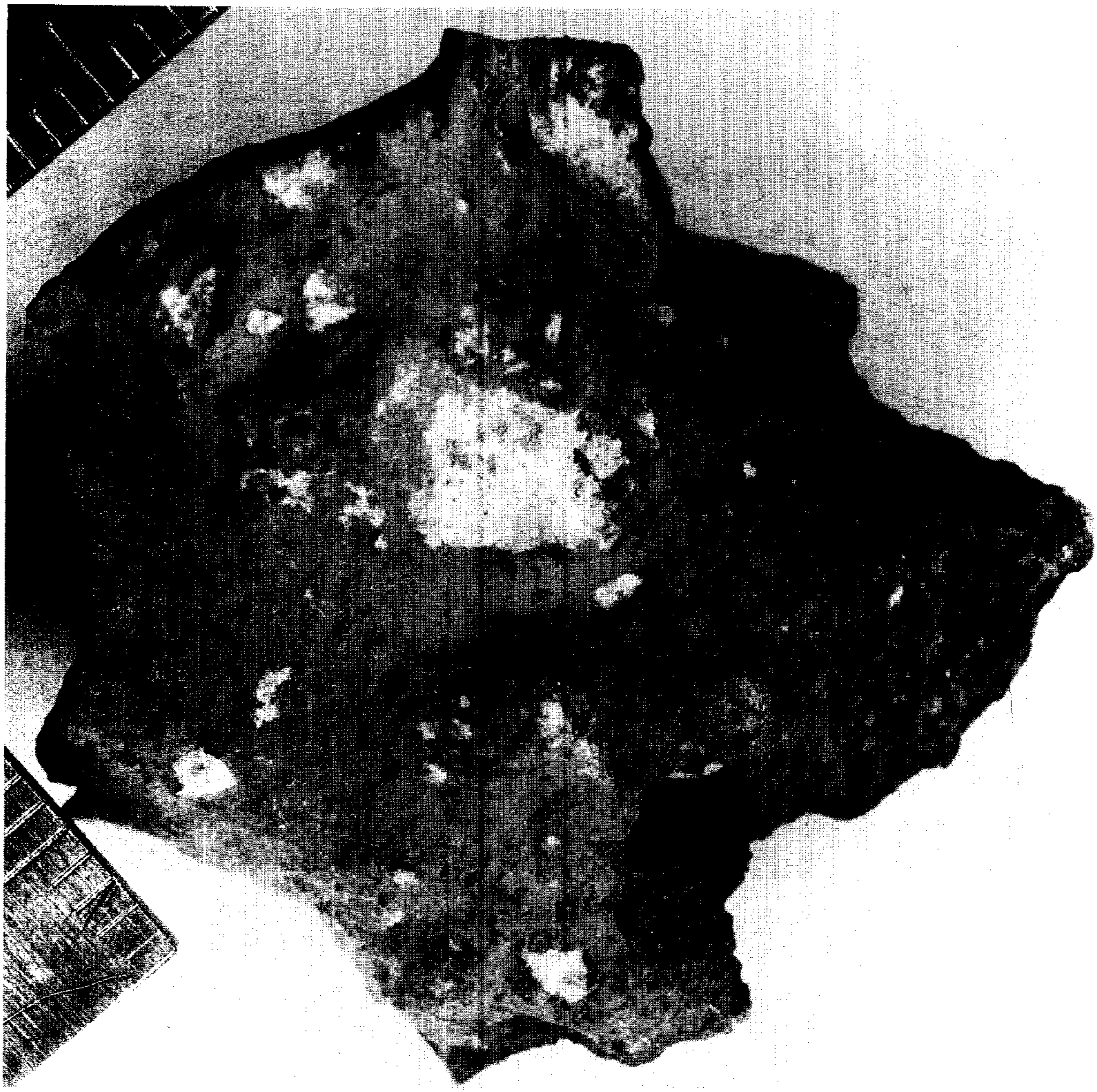


Figure 1. S-72-51261, mm scale.

INTRODUCTION: 67568 is a coherent, cindery,vesicular glass containing clasts (Fig. 1). It is a rake sample collected near the White Breccia boulders. Zap pits may be present.

PETROLOGY: 67568 consists largely of a devitrified vesicular glass (Fig. 2). In places where it is not devitrified the glass is clear and colorless; where devitrified it is brown and contains plagioclase spherulites and needles. It also contains Fe-metal and troilite blebs. Enclosed clasts are not numerous and are mainly plagioclase, with some lithic fragments. The latter are mainly basaltic impact melts.

PROCESSING AND SUBDIVISIONS: Several small chips were removed, some of which were used to make thin section ,1.

Figure 1. S-72-51055, mm scale.

Figure 2. 67568,1, general view, ppl. width 2mm.

INTRODUCTION: 67569 is a coherent, black, vesicular glass with smooth surfaces (Fig. 1). It contains a few light-colored clasts (Fig. 1). It is a rake sample collected near the White Breccia boulders and lacks zap pits.

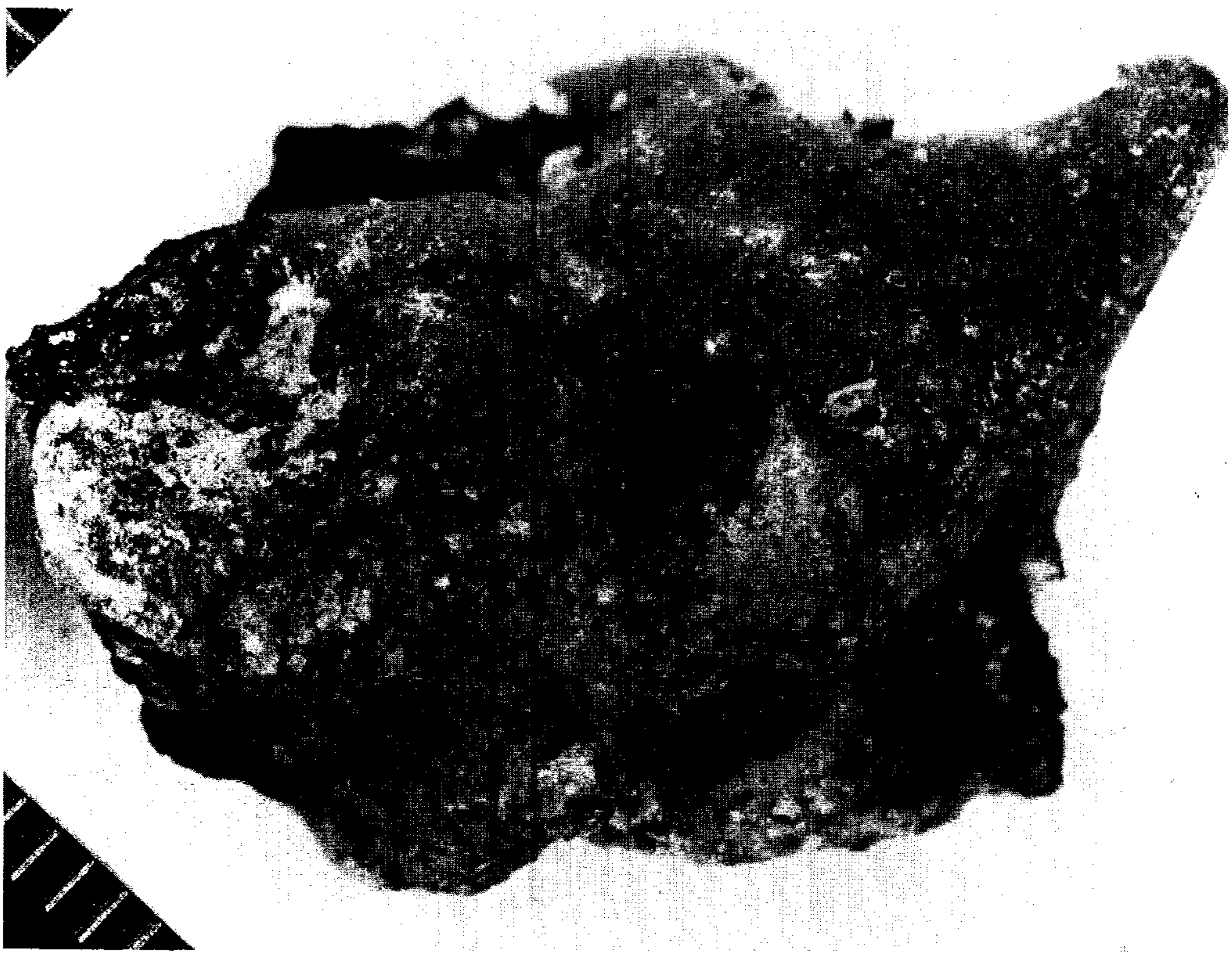


Figure 1. S-72-51050, mm scale.

67575 VESICULAR GLASSY(?) BRECCIA — 4.47 g

INTRODUCTION: 67575 is a coherent, heterogeneous, dark breccia (Fig. 1) with vesicles and is probably mainly glass. It contains several small, white clasts. It is a rake sample collected near the White Breccia boulders and lacks zap pits.

Figure 1. S-72-49543, mm scale.

67576 CINDERY POLYMICT BRECCIA OR REGOLITH BRECCIA 3.98 g

INTRODUCTION: 67576 is a dark gray or black, moderately friable, glassy to powdery breccia (Fig. 1) which may be a lithified soil. It is a rake sample collected near the White Breccia boulders and lacks zap pits.

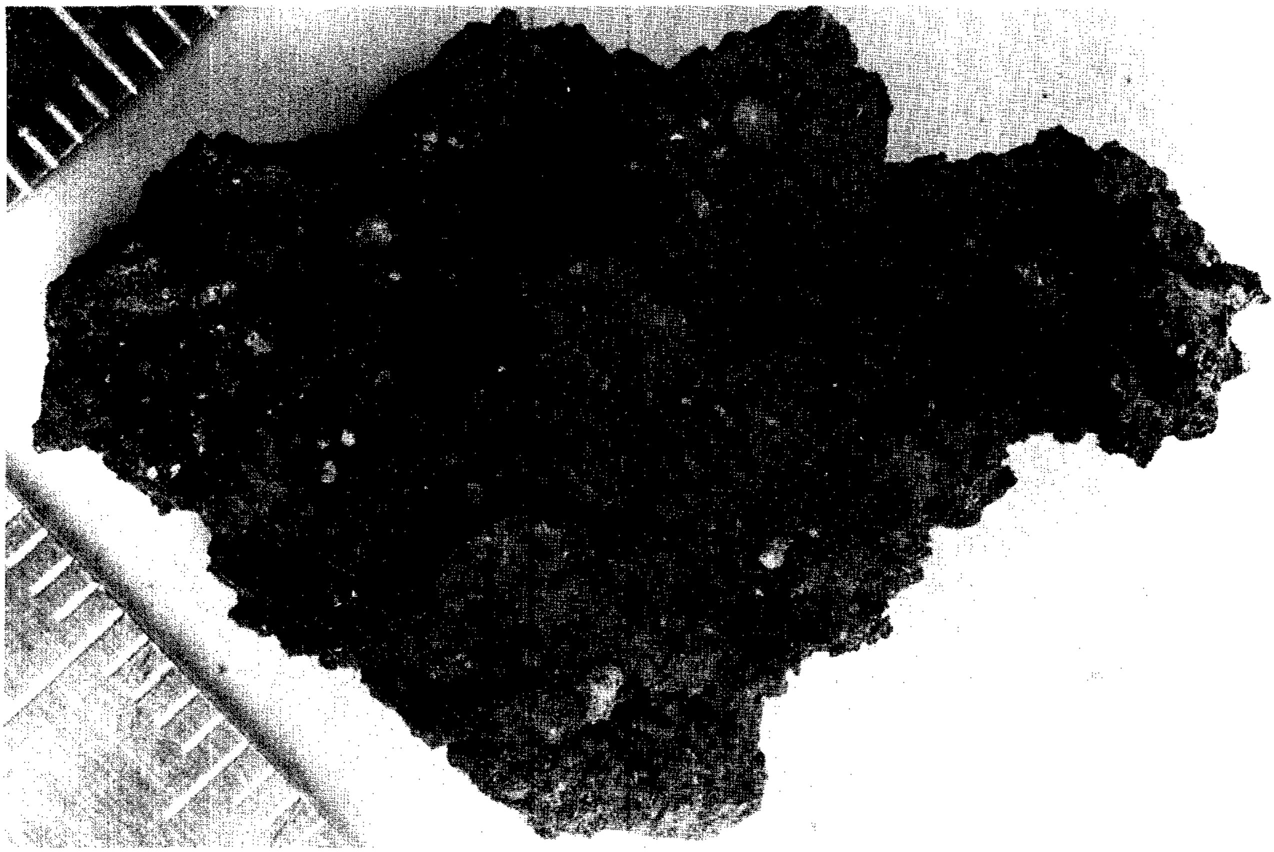


Figure 1. S-72-51263, mm scale.

67605 FRAGMENTAL POLYMICT BRECCIA 44.5 g

INTRODUCTION: 67605 is a moderately friable, polymict breccia with a pale-colored matrix (Fig. 1). It was collected about 30 m east of the White Breccia boulders; its orientation is unknown because it was not identified in surface photographs. It has zap pits on all surfaces.

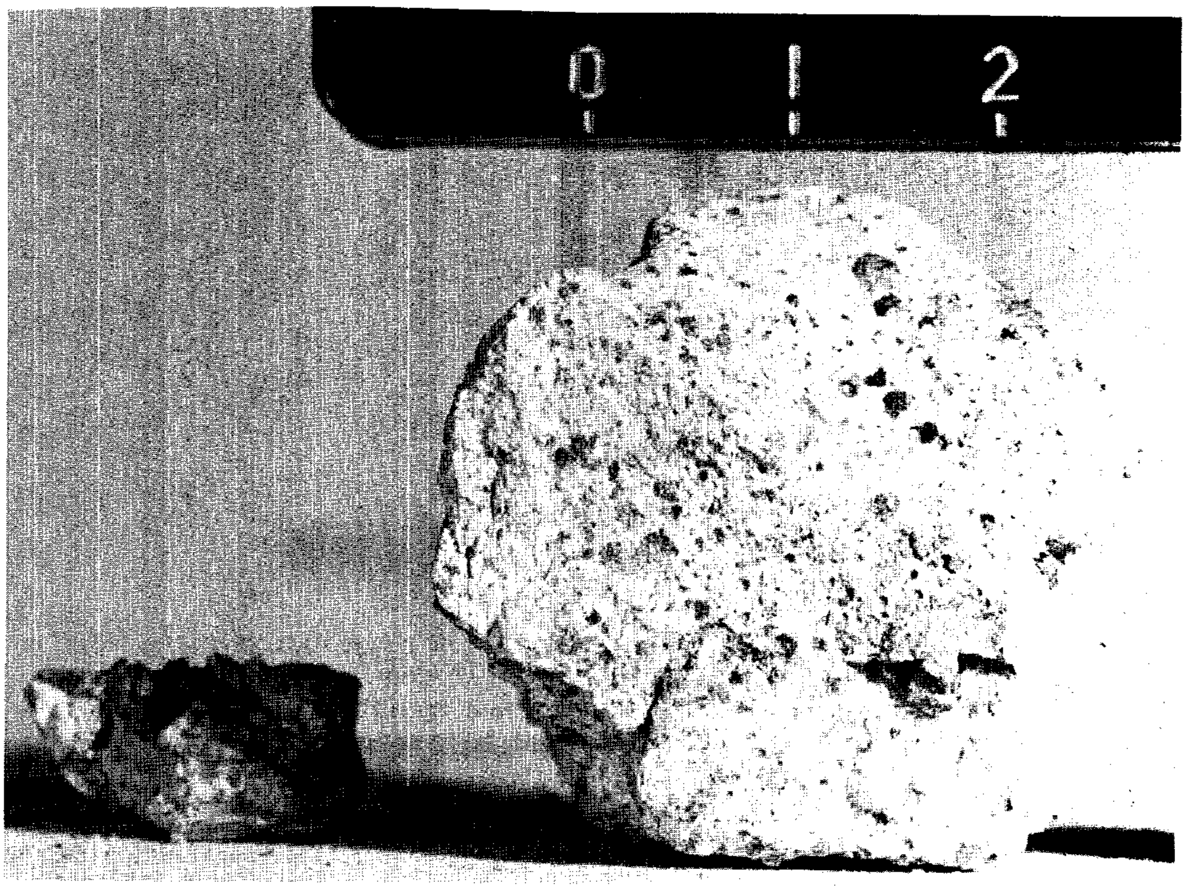


Figure 1. S-72-41580, cm scale.

PETROLOGY: 67605 is a fragmental breccia with many plagioclase and plagioclase-rich breccia clasts, as well as opaque (brown) aphanitic impact melt debris which gives some areas of the thin sections a dark aspect (Fig. 2). One small clast in thin section ,6 is a mafic basalt (~60% pyroxene) with a significant silica phase and some ilmenite. The pyroxene is brown, probably ferroaguite, and olivine is absent.

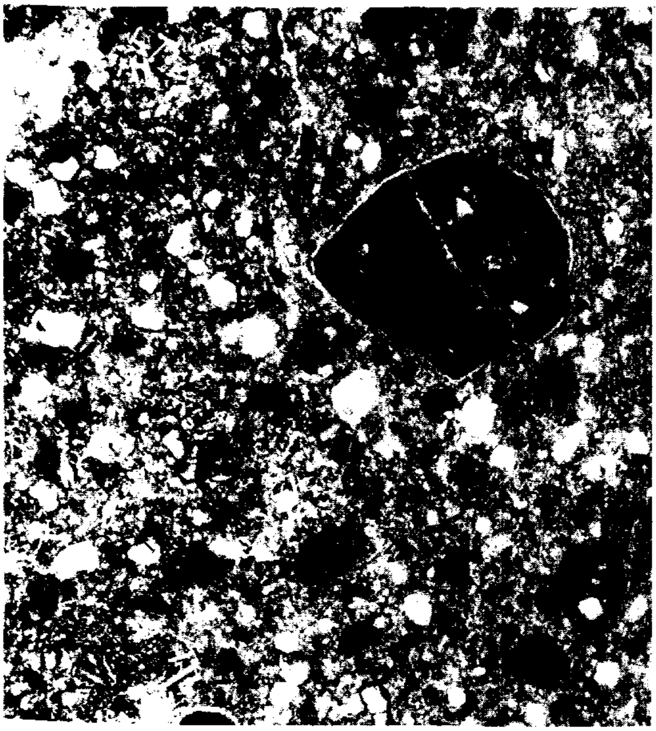


Figure 2. 67605,6, general view, ppl. width 2mm.

CHEMISTRY: A major and trace element analysis of a typical chip (,2) is presented by Warren and Wasson (1978) and summarized in Table 1 and Figure 3. The sample is aluminous, with low levels of incompatible elements, and is clearly contaminated with meteoritic debris.

TABLE 1. Summary chemistry of 67605 (Warren and Wasson, 1978)

		Sr	
SiO_2	47	La	2.1
TiO_2	0.19	Lu	0.12
Al_2O_3	30.0	Rb	
Cr_2O_3	0.06	Sc	∿4.8
FeO	2.6	Ni	95
MnO	0.04	Co	7.4
MgO	4.0	Ir ppb	3.6
CaO	16.8	Au ppb	<0.6
Na_2O	0.49	C	
K_2O	0.05	N	
P_2O_5		S	
		Zn	11
		Cu	

Oxides in wt%; others in ppm except as noted.

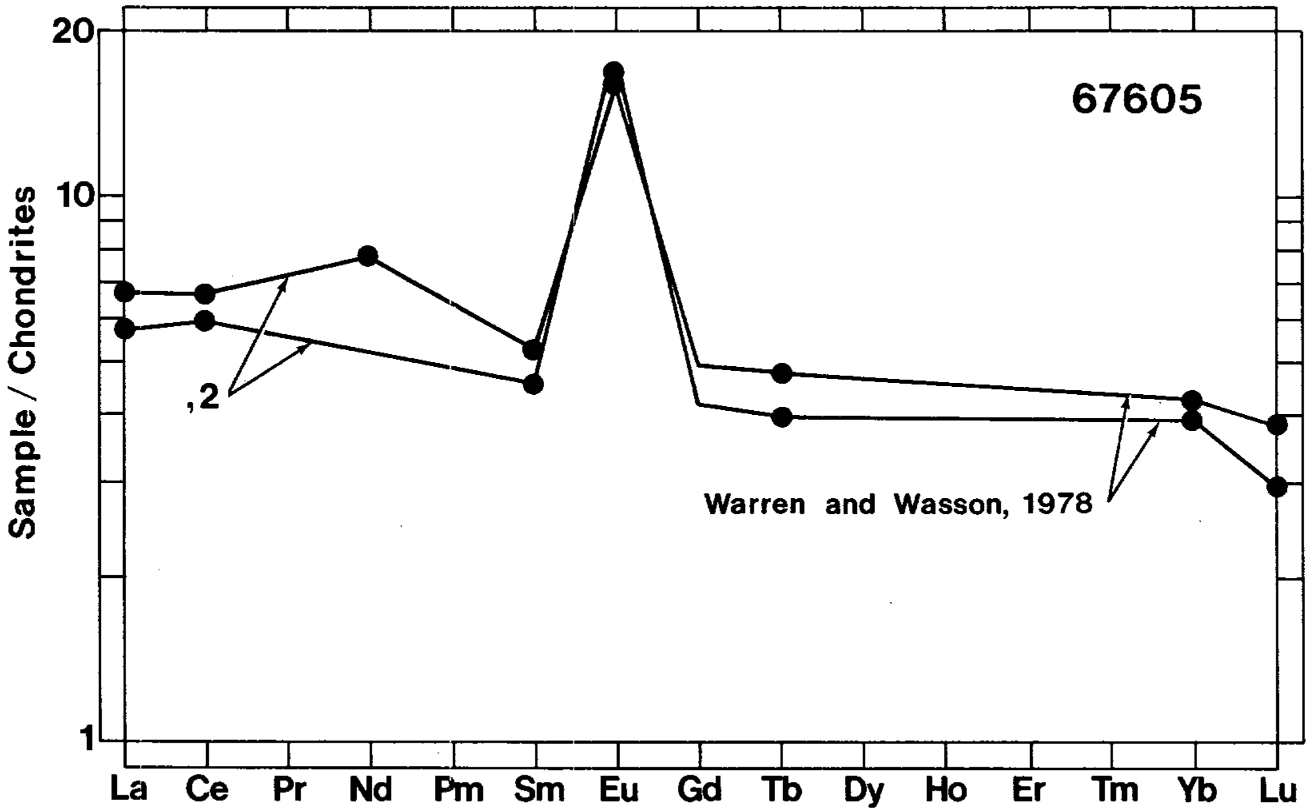


Figure 3. Rare earths.

PROCESSING AND SUBDIVISIONS: Several small chips have been removed, all typical in appearance. ,1 was allocated for Ar-Ar studies, ,2 for chemistry, and ,3 was made into thin sections ,5 and ,6.

INTRODUCTION: 67615 is coherent and consists mainly of small plagioclase clasts bonded with a fine-grained melt (Fig. 1). It is a rake sample collected 30 m east of the White Breccia boulders and has zap pits on all but one face.

PETROLOGY: Steele and Smith (1973) refer to 67615 as a breccia with a trace of poikilitic matrix. It is homogeneous, polymict, and fine-grained, consisting mainly of plagioclase clasts bonded with a micropoikilitic or microsubophitic melt. The total plagioclase content is more than 80%. Most of the clasts are unshocked or only lightly shocked. Lithic clasts or patches are mainly basaltic impact melts and glassy breccias. Steele and Smith (1973) note that pyroxene is absent; the rock consists of plagioclase (An_{92-97}; Fe 0-0.45%) and olivine (Fo_{52-64}); it is not clear whether micropoikilitic melt phases are included in these analyses.

PROCESSING AND SUBDIVISIONS: Chips were removed both for a thin section (,4) and for chemical analysis; the latter has not been published.

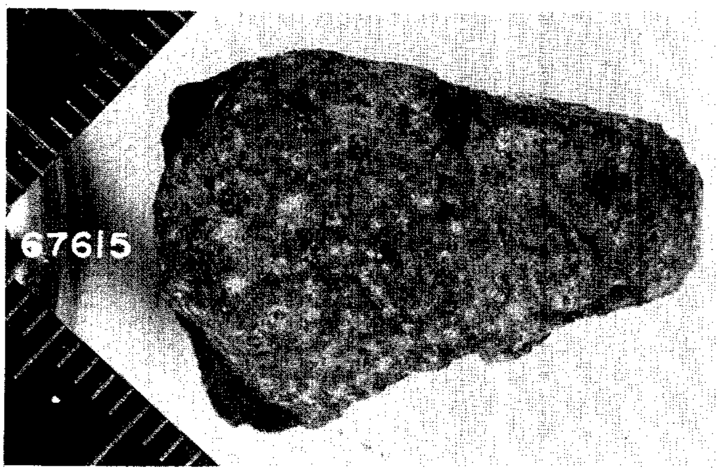


Figure 1. S-72-51058, mm scale.

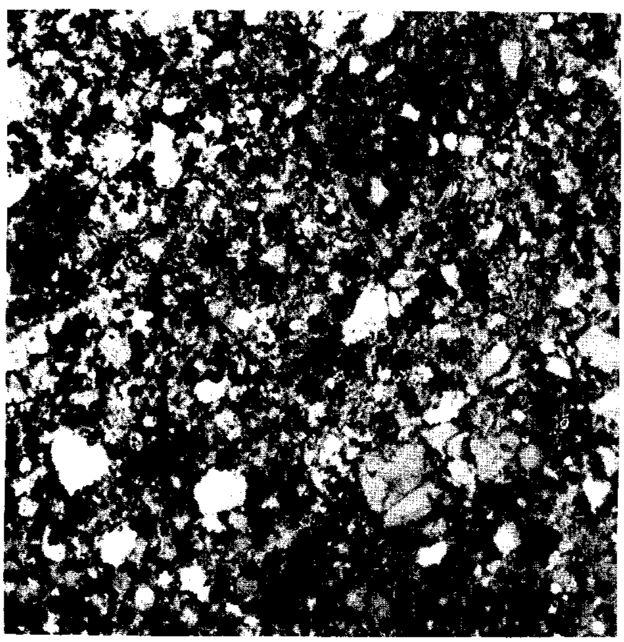


Figure 2. 67615,4, general view, ppl. width 2mm.

INTRODUCTION: 67616 is a gray, coherent breccia (Fig. 1) made up of tiny plagioclase clasts bonded by ~10-15% fine-grained mortar which is probably melt but could be metamorphic. It is a rake sample collected 30 m east of the White Breccia boulders. Many zap pits are present on all surfaces.

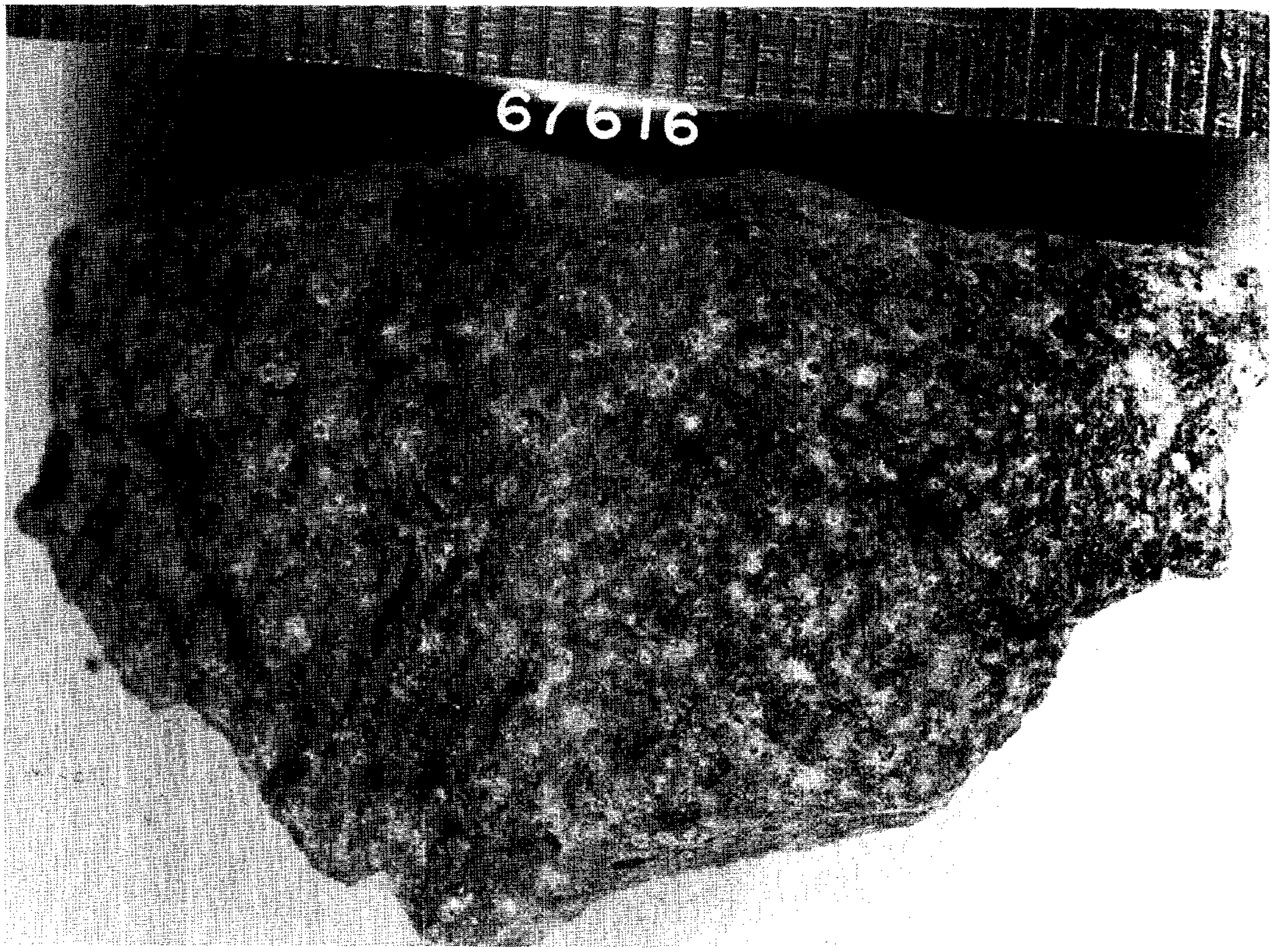


Figure 1. S-72-49574, mm scale.

PETROLOGY: 67616 is a coherent, very plagioclase-rich breccia (Fig. 2). Abundant fragments of plagioclase, mainly in the 10-30 μm size range, are held together by a mortar of more mafic crystalline material. Large clasts (up to ~400 μm) are mainly unstrained, unshocked plagioclases. The total plagioclase content is more than 90%.

The fine-grained (~3-5 μm) mortar composes 10-15% of the rock and is more mafic than the bulk rock, with about equal proportions of plagioclase and mafic minerals. Its texture is equivocal as to melt or metamorphic origin, but the presence of plagioclase laths suggests that a melt origin is more likely.

There is a fine-scale banding in the breccia, occurring in fans covering areas of 1 mm^2 (Fig. 2). The bands are ~20-30 μm wide. The dark bands appear to be concentrations of pyroxene, the light concentrations of plagioclase. The features suggest spherulitic crystallization of a melt.

PROCESSING AND SUBDIVISIONS: Small chips were removed, and from some of them thin section ,2 was made.

Figure 2. 67616,2, general view, ppl. width 2mm.

INTRODUCTION: 67617 is a coherent breccia consisting of abundant plagioclase clasts bonded with ~50% fine-grained mortar of probable melt origin (Fig. 1). It is a rake sample collected 30 m east of the White Breccia boulders. Many zap pits are present on one surface.

PETROLOGY: Steele and Smith (1973) refer to 67617 (Fig. 2) as a "breccia; mostly plagioclase" with 50% matrix (material less than 5 µm). The matrix is more mafic than the clast population, which includes lithic clasts, mainly plagioclase-rich breccias. Steele and Smith (1973) analyzed pyroxenes and olivines (Fig. 3) and plagioclases (An_{90-97}).

PROCESSING AND SUBDIVISIONS: Several small pieces were chipped off, some of which were used to make thin section ,1.

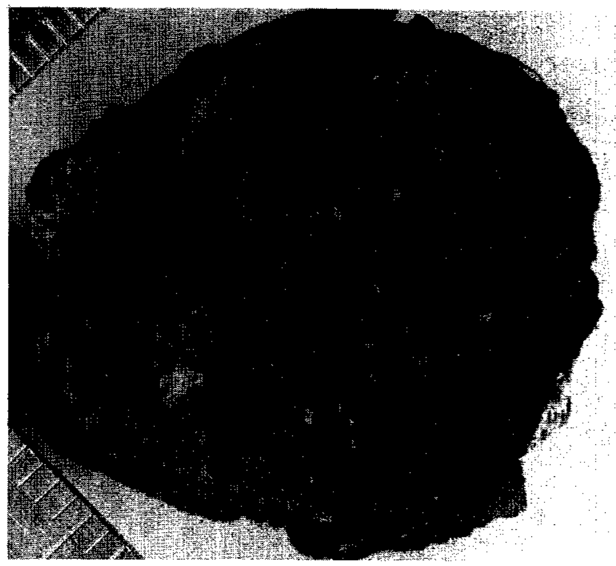


Figure 1. S-72-51243, mm scale.

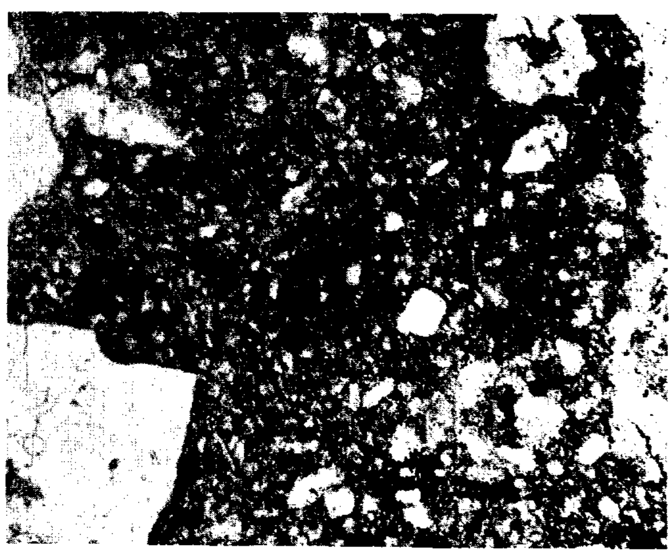


Figure 2. 67617,1, general view, ppl. width 2mm.

67618 CRYSTALLINE BRECCIA, PARTLY GLASS-COATED 11.17 g

INTRODUCTION: 67618 is a dark gray, coherent, fine-grained breccia (Fig. 1), possibly a basaltic or poikilitic impact melt, but no thin sections exist. A glass coat covers part of the surface. It is a rake sample collected 30 m east of the White Breccia boulders. Zap pits are abundant.

CHEMISTRY: Schaeffer and Schaeffer (1977) report K (K_2O = 0.22%) and Ca (CaO = 11.8%) abundances. These values suggest an Al_2O_3 content of about 22%, consistent with its being a poikilitic or basaltic impact melt.

RADIOGENIC ISOTOPES: Schaeffer and Schaeffer (1977) report Ar isotopic analyses. No Ar release plateaus were obtained. The "ages" rose from 1.35 b.y. for the 600°C release to 3.68 b.y. for the 900°C release, then fell to 3.01 b.y. for the 1250°C release. A total K-Ar age of 2.59 ± 0.01 b.y. has no real significance.

RARE GASES AND EXPOSURE AGES: Schaeffer and Schaeffer (1977) report Ar isotopic analyses and calculate exposure ages ranging from 34 to 77 m.y., averaging 50 m.y.

PROCESSING AND SUBDIVISIONS: Small chips were removed and allocated for rare gas and chemical studies; the results of the latter have not been published.

Figure 1. S-72-51262, mm scale.

INTRODUCTION: 67619 consists of fine-grained, clast-rich, homogeneous breccia (Fig. 1) with a melt matrix containing aligned plagioclase laths. It is a rake sample collected 30 m east of the White Breccia boulders, is subangular, and free of zap pits. It is coated with white powder.

PETROLOGY: 67619 is a polymict breccia consisting of mineral and lithic clasts embedded in a matrix in which aligned plagioclase laths are conspicuous (Fig. 2). It is dark in thin section because of abundant glassy and cryptocrystalline material interstitial to the plagioclase laths. The alignment indicates that the matrix was created in a single event and is not a regolith breccia. Most of the plagioclase laths are 10-30 μm long. Most clasts are plagioclase, and only about 10% of the rock is composed of grains larger than about 100 μm. Lithic clasts include a granulitic impactite and a (meta)basalt.

PROCESSING AND SUBDIVISIONS: Two chips were removed from one end to make thin section ,1. Another chip was also broken off the opposite end, but was not separately numbered.

Figure 1. S-72-51046, mm scale.

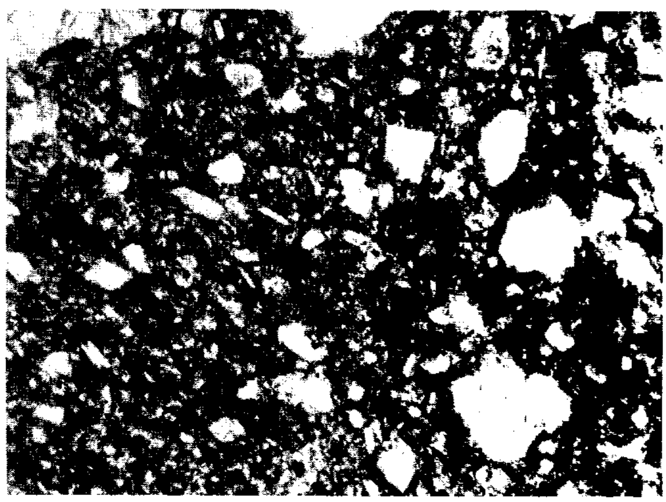


Figure 2. 67619,1, general view, ppl. width 2mm.

INTRODUCTION: 67625 is a dark, coherent, polymict breccia (Fig. 1) which is fairly homogeneous. It has a fine-grained matrix which is probably an impact melt. It is a rake sample collected 30 m east of the White Breccia boulders. It is subrounded to angular and lacks zap pits.

PETROLOGY: 67625 is a brown polymict breccia, consisting of numerous small plagioclase grains bonded by a fine-grained, more mafic mortar which composes about 40% of the sample. The plagioclase clasts are mainly 20-30 μm in diameter but range up to ∿500 μm. Lithic clasts include cataclastic anorthosite, granulitic impactite, plagioclase-rich breccias, and devitrified brown glasses. The mortar has a grain size of 2-5 μm, and contains some Fe-metal/troilite assemblages.

PROCESSING AND SUBDIVISIONS: Two chips were removed to make thin sections ,1 and ,2.

Figure 1. S-72-49563, mm scale.

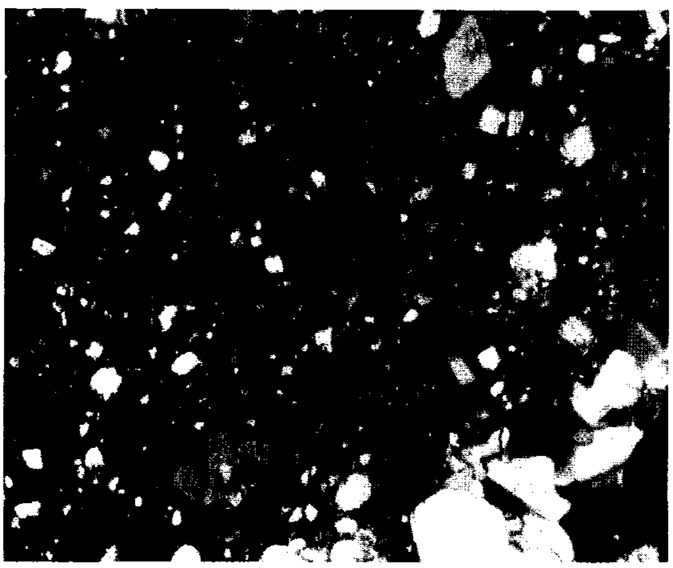


Figure 2. 67625,1, general view, xpl. width 2mm.

INTRODUCTION: 67626 is a coherent, dark-colored, cindery-looking polymict breccia (Fig.1). It is a rake sample collected 30 m east of the White Breccia boulders and has some zap pits.

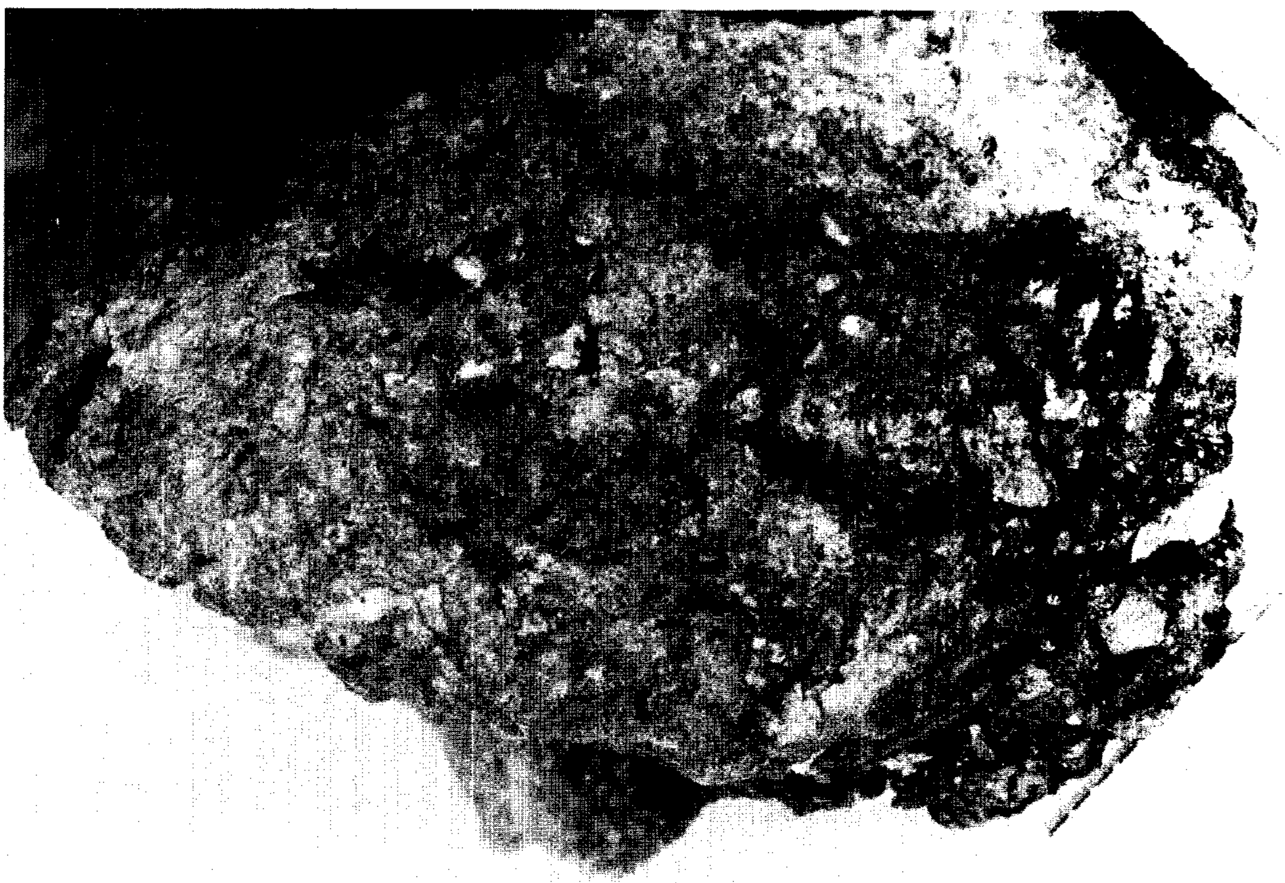


Figure 1. S-72-51267, mm scale.

INTRODUCTION: 67627 is a dark gray, vesicular melt or devitrified glass (Fig. 1). It is not homogeneous--one area is much smoother than the rest (,2 in Fig. 1). It is a rake sample collected 30 m east of the White Breccia boulders. It is angular, coherent, and has a few zap pits.

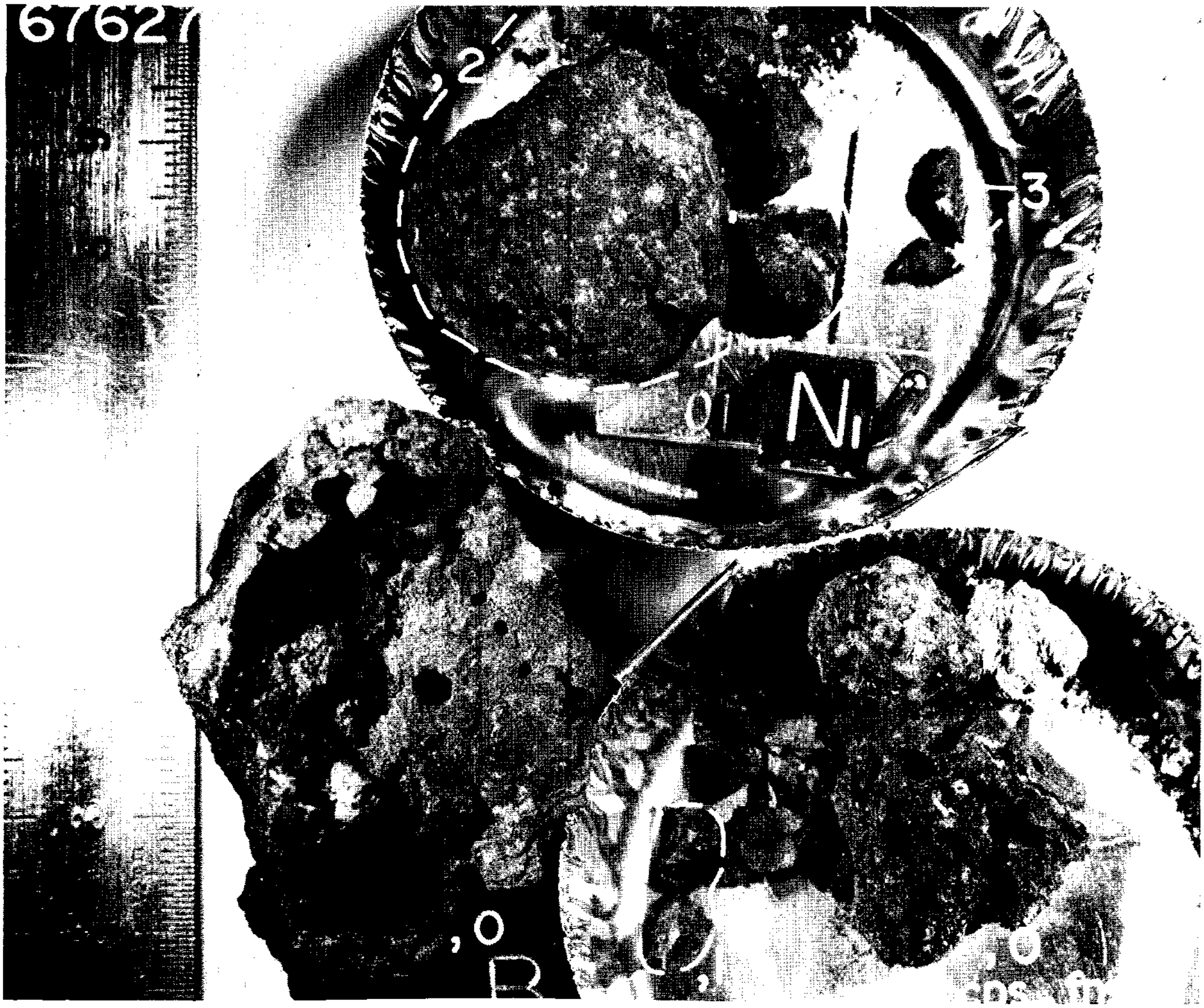


Figure 1. S-80-28174, cube is 1cm.

PETROLOGY: Thin sections made for this study of both the rougher area (from ,1 in Fig. 1) and the smoother area (,3 in Fig. 1) are of vesicular, partly crystalline, brown glassy materials (Fig. 2). They contain acicular plagioclases (from crystallization or devitrification) and clastic materials. (,2 was separated, in fact, because it was believed to be a crystalline clast.)

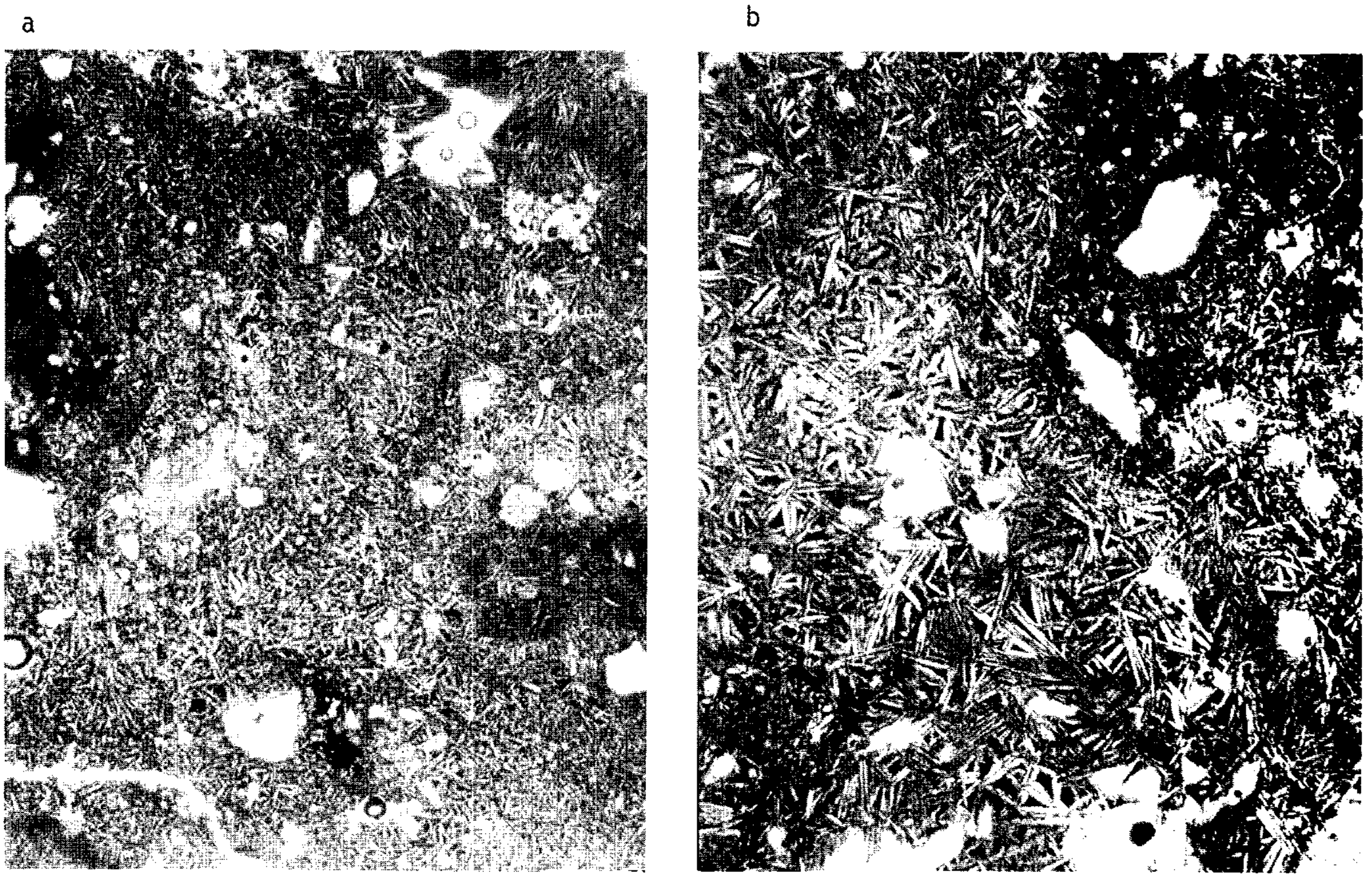


Figure 2. a) 67627,5, general view, ppl. width 2mm
b) 67627,6, general view, ppl. width 2mm.

PROCESSING AND SUBDIVISIONS: The sample was chipped into pieces as shown in Figure 1. Thin section ,5 was made from chips ,1, and thin section ,6 from chips ,3. The latter were taken to represent the smooth, less vesicular "clast" ,2.

INTRODUCTION: 67629 is a glass containing small white fragments (Fig. 1). It is a rake sample collected 30 m east of the White Breccia boulders and lacks zap pits.

CHEMISTRY: Haskin et al. (1973) report major and trace element abundances for 67629, summarized in Table 1 and Figure 2. It is a meteorite-contaminated melt similar but not identical to typical Apollo 16 soils and rather less aluminous than Station 11 soils.

PROCESSING AND SUBDIVISONS: 67629 is the smallest of 4 fragments originally numbered together as 67629. The other three have been renumbered 67695, 67696, and 67697. Chips were taken from the small fragment for chemical and radiogenic isotope studies.

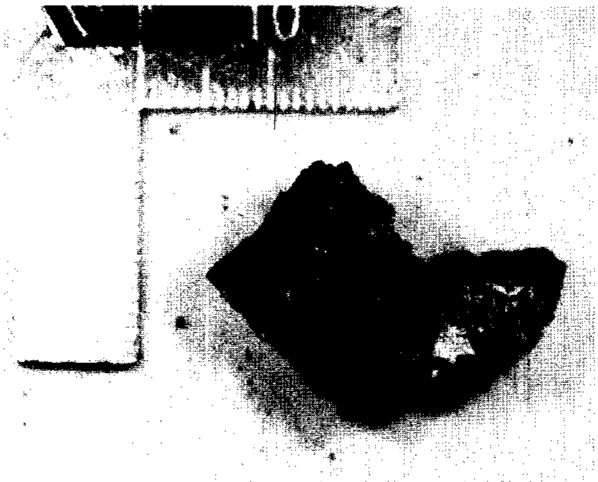


Figure 1. mm scale.

TABLE 1. Summary chemistry of 67629

(Haskin et al., 1973)

SiO_2	46.3	Sr	
TiO_2	0.85	La	11.7
Al_2O_3	24.0	Lu	0.55
Cr_2O_3	0.11	Rb	3.1
FeO	5.3	Sc	9.4
MnO	0.067	Ni	350
MgO	5.9	Co	23.8
CaO	15.2	Ir ppb	
Na_2O	0.62	Au ppb	
K_2O	0.137	C	
P_2O_5		N	
		S	
		Zn	11.0
		Cu	

Oxides in wt%; others in ppm except as noted.

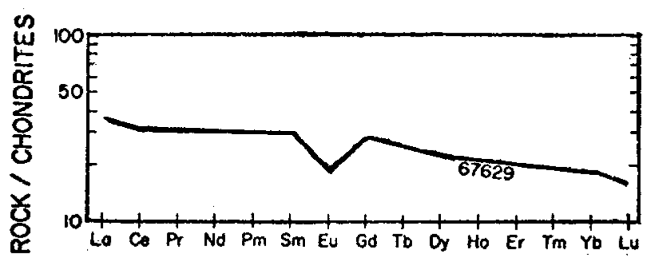


Figure 2. Rare earths, from Haskin et al. (1973).

INTRODUCTION: 67635 is a coherent, fine-grained, cataclastic ferroan anorthosite (Fig. 1) which is chemically pristine. It is a rake sample collected 30 m east of the White Breccia boulders and has some zap pits.

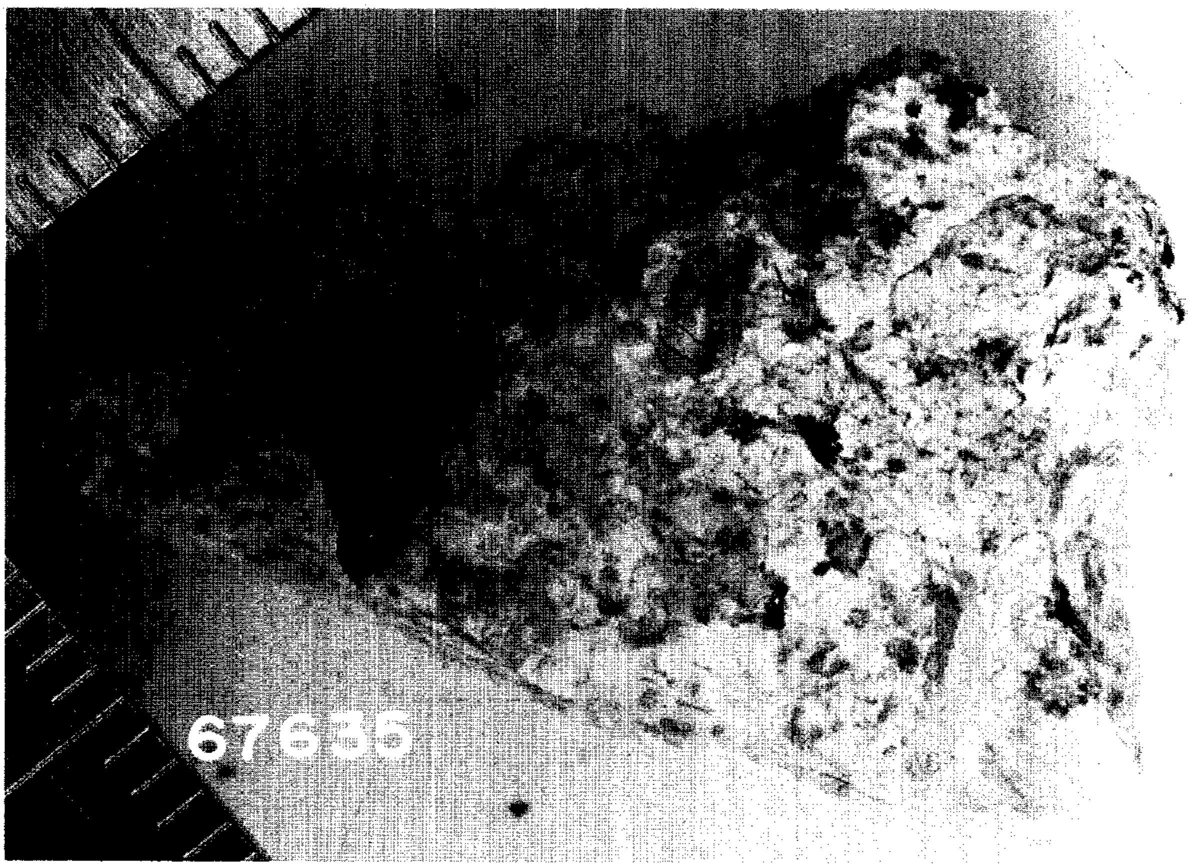


Figure 1. S-72-49561, mm scale.

PETROLOGY: Steele and Smith (1973) refer to 67635 as "plagioclase (100%) breccia; heavily shocked". A brief petrographic description with microprobe analyses is given by Warren and Wasson (1980). Hansen et al. (1979b and unpublished) also report microprobe analyses.

67635 is a monomict, cataclastic anorthosite (Fig. 2) with ∿99% plagioclase, mafic mineral grains less than 50 μm in diameter, and traces of ilmenite. Mineral compositions from Warren and Wasson (1980) are shown in Figure 3; pyroxene and plagioclase analyses by Hansen et al. (1979b and unpublished) are very similar. The latter also report minor element data for plagioclases: K_2O 0.028%, FeO 0.078%, MgO 0.049%, (average of 12 points; little variation). Warren and Wasson (1980) note that the plagioclases are up to 3 mm in diameter.

Figure 2. 67635,2, general view, xpl. width 2mm.

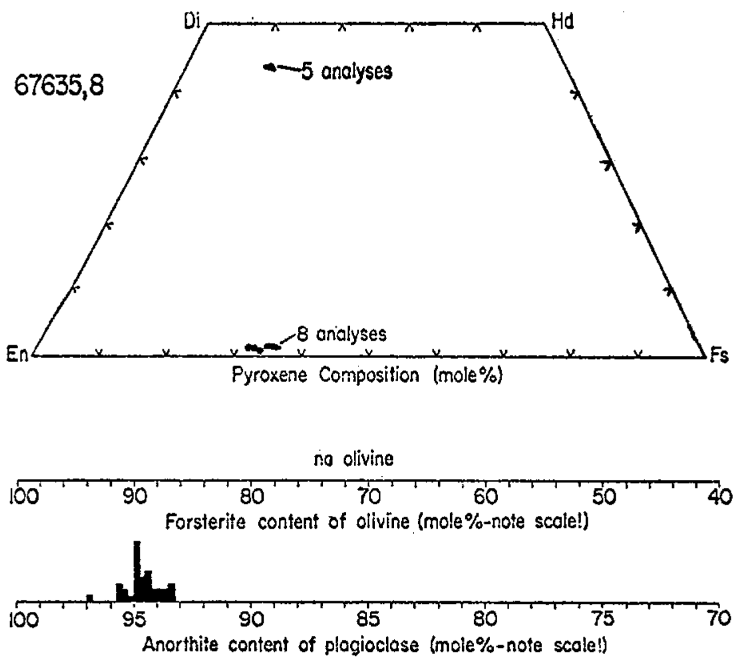


Figure 3. Mineral compositions, from Warren and Wasson (1980).

CHEMISTRY: A major and trace element chemical analysis is reported by Warren and Wasson (1980) (Table 1, Fig. 4). The anorthosite is ferroan, and uncontaminated by either KREEP or meteoritic material.

PROCESSING AND SUBDIVISIONS: Small chips were removed for making thin sections ,2 and ,8 (same potted butt) and the chemistry allocation.

TABLE 1. Summary chemistry of 67635 anorthosite (Warren and Wasson, 1980)

SiO_2	44.9	Sr	
TiO_2	<0.13	La	0.33
Al_2O_3	34.8	Lu	0.0047
Cr_2O_3	0.002	Rb	
FeO	0.26	Sc	0.34
MnO	0.006	Ni	1.2
MgO	0.17	Co	1.5
CaO	18.9	Ir ppb	0.027
Na_2O	0.56	Au ppb	0.024
K_2O	0.018	C	
P_2O_5		N	
		S	
		Zn	
		Cu	

Oxides in wt%; others in ppm except as noted.

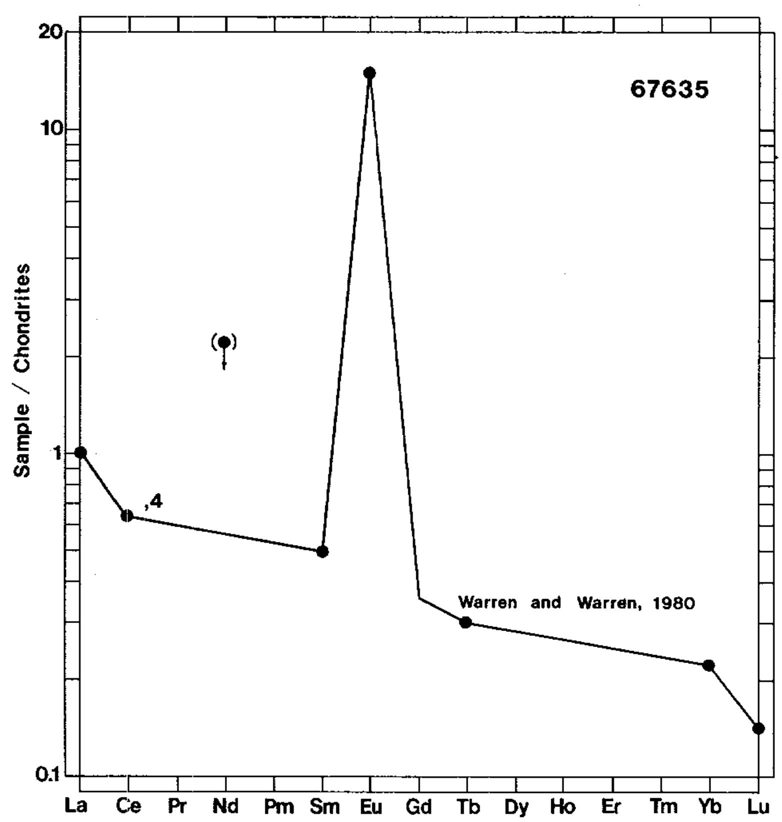


Figure 4. Rare earths.

INTRODUCTION: 67636 is a coherent, cataclastic, pristine ferroan anorthosite (Fig. 1). It is a rake sample collected 30 m east of the White Breccia boulders, and has many zap pits.

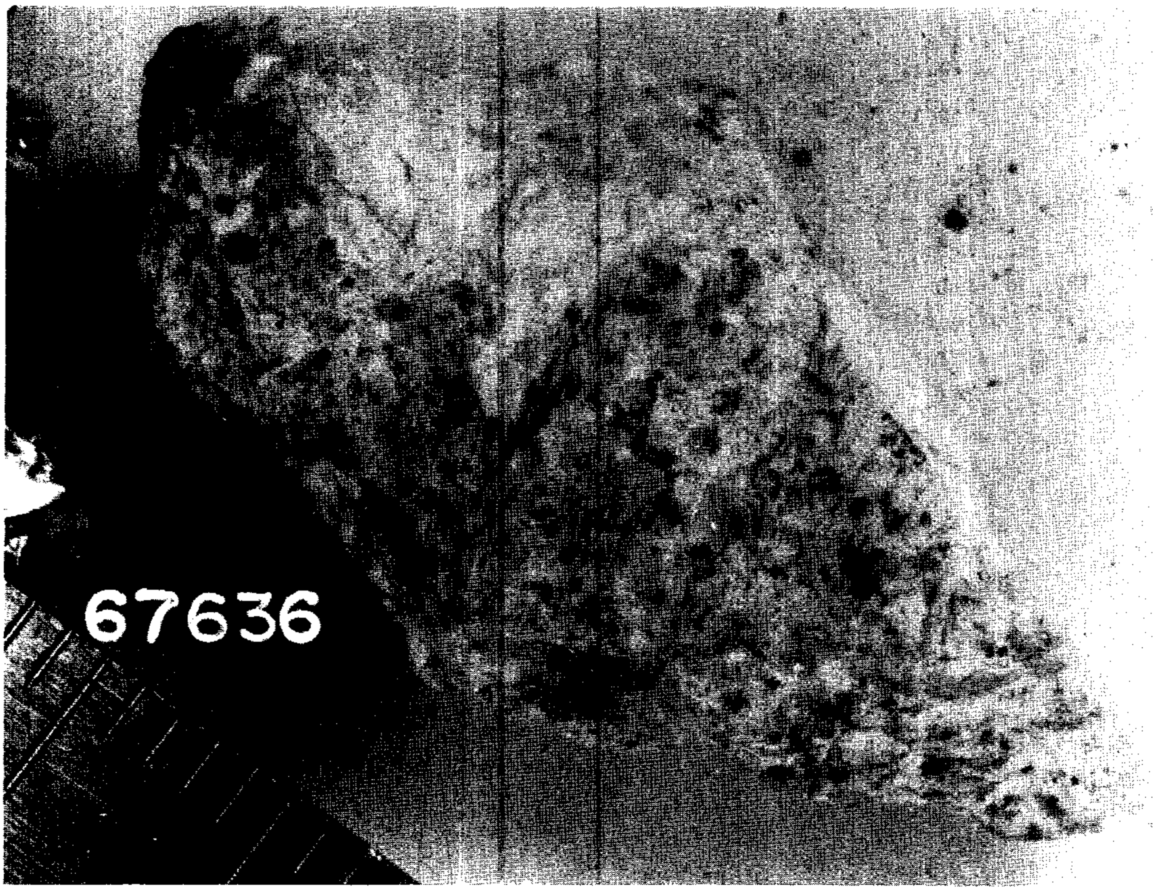


Figure 1. S-72-49551, mm scale.

PETROLOGY: A brief description with microprobe analyses is given by Warren and Wasson (1980). The sample is cataclastic (Fig. 2) with relict plagioclases up to 2 mm in diameter and only minor mafic minerals. Mineral compositions are shown in Figure 3 and show that the sample is a ferroan anorthosite. Ilmenite is present but extremely rare.

CHEMISTRY: A major and trace element analysis is given by Warren and Wasson (1980) (Table 1, Fig. 4). The sample is a ferroan anorthosite, uncontaminated with meteoritic material.

PROCESSING AND SUBDIVISIONS: Chips were taken to make thin sections ,1 and ,7 (same potted butt) and for the chemistry allocation.

Figure 2. 67636,1, general view, xpl. width 2mm.

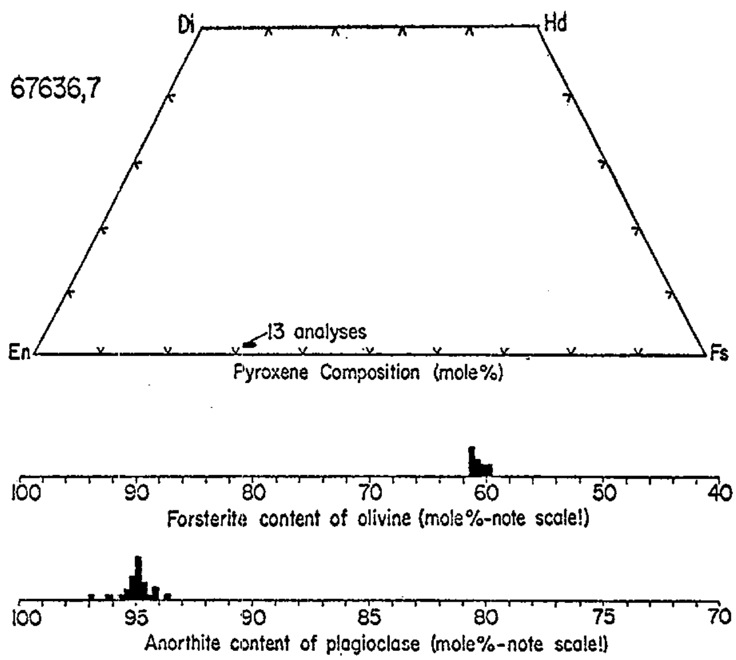


Figure 3. Mineral compositions, from Warren and Wasson (1980).

TABLE 1. Summary chemistry of 67636

(Warren and Wasson, 1980)

SiO_2	44.5	Sr	
TiO_2	<0.15	La	0.40
Al_2O_3	32.9	Lu	0.0061
Cr_2O_3	0.009	Rb	
FeO	1.9	Sc	1.00
MnO	0.029	Ni	3.6
MgO	1.8	Co	5.0
CaO	17.6	Ir ppb	0.17
Na_2O	0.517	Au ppb	0.022
K_2O	0.017	C	
P_2O_5		N	
		S	
		Zn	
		Cu	

Oxides in wt%; others in ppm except as noted.

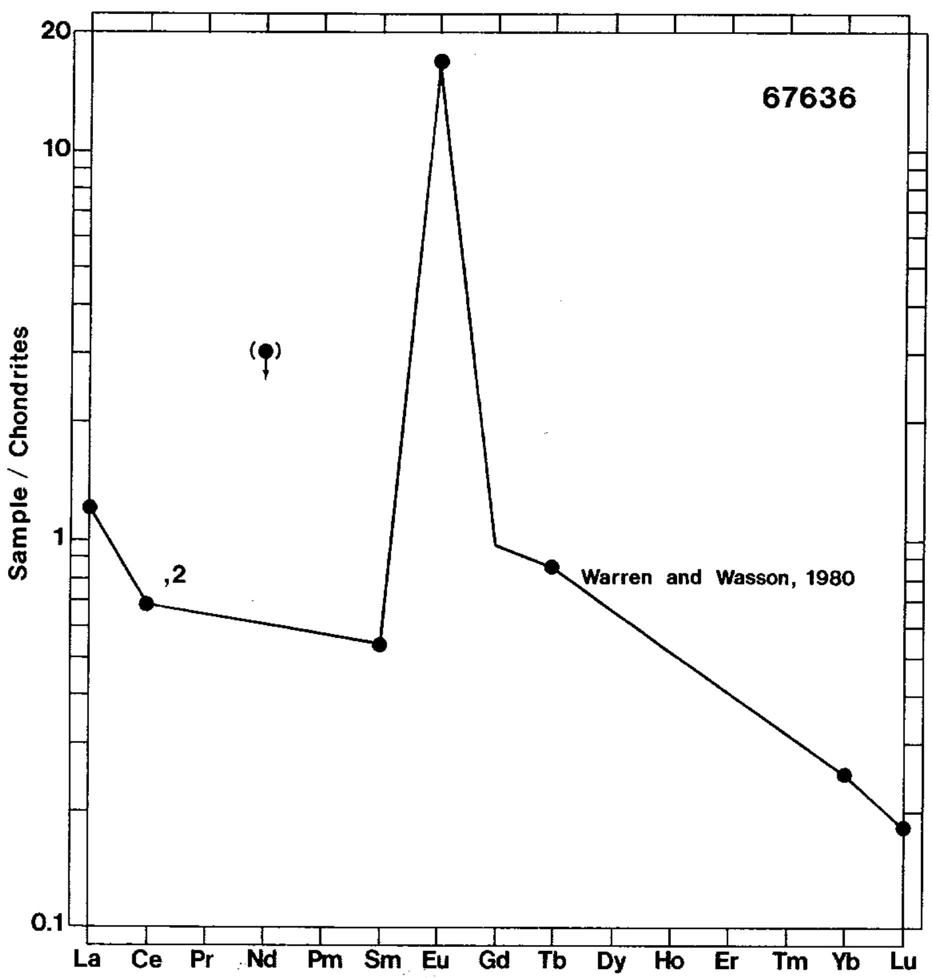


Figure 4. Rare earths.

INTRODUCTION: 67637 is a coherent, cataclastic, pristine ferroan anorthosite (Fig. 1). It is a rake sample collected 30 m east of the White Breccia boulders and has many zap pits.

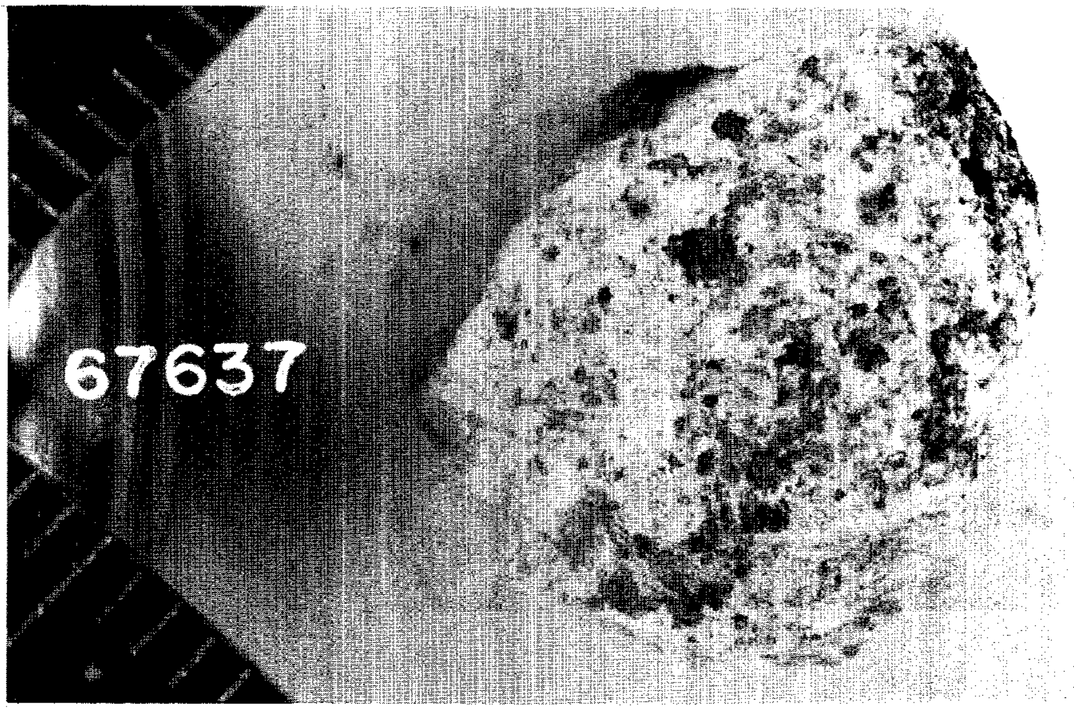


Figure 1. S-72-51053, mm scale.

PETROLOGY: Steele and Smith (1973) refer to 67637 as a "plagioclase (95%) breccia; minor olivine and pyroxene; heavily shocked". Microprobe analyses are reported by Warren and Wasson (1980) and Hansen *et al*. (1979a,b).

The sample is fairly porous and consists of angular fragments of plagioclase, up to 1.5 mm in diameter (Fig. 2). Mafic mineral grains are up to 300 μm; most have high birefringence and are olivines. Microprobe data (Fig. 3) demonstrate the ferroan character. Analyses by Hansen *et al*. (1979a,b) are similar to those of Warren and Wasson (1980) except that the former show a clearer distinction between low-Ca and high-Ca pyroxenes.

CHEMISTRY: Warren and Wasson (1980) report major and trace element data, summarized in Table 1 and Figure 4. The sample is a ferroan anorthosite, uncontaminated with meteoritic material.

PROCESSING AND SUBDIVISIONS: A chip was removed, from which thin sections ,1 and ,7 were made. A second chip was allocated for chemical analysis.

Figure 2. 67637,1, general view, xpl. width 2mm.

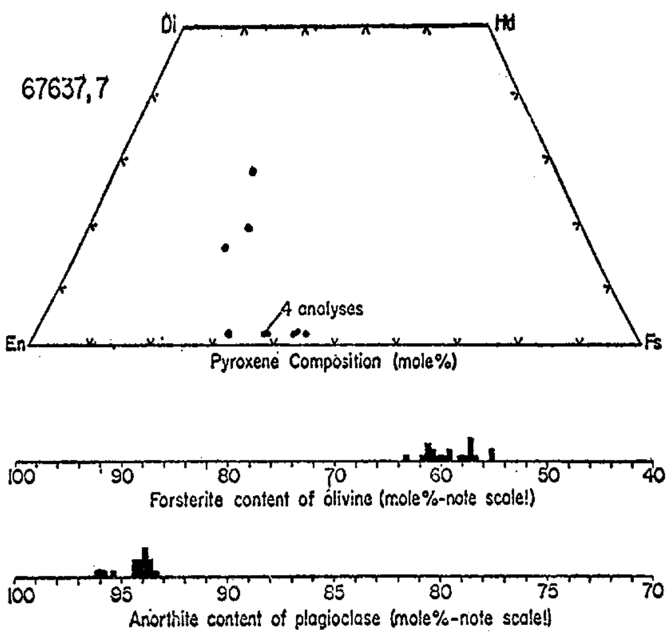


Figure 3. Mineral compositions, from Warren and Wasson (1980).

TABLE 1. Summary chemistry of 67637
(Warren and Wasson, 1980)

SiO_2	44.3	Sr	
TiO_2	0.038	La	0.40
Al_2O_3	34.4	Lu	0.0134
Cr_2O_3	0.005	Rb	
FeO	0.70	Sc	0.96
MnO	0.011	Ni	1.6
MgO	0.56	Co	3.8
CaO	18.8	Ir ppb	1.2
Na_2O	0.595	Au ppb	0.02
K_2O	0.019	C	
P_2O_5		N	
		S	
		Zn	
		Cu	

Oxides in wt%; others in ppm except as noted.

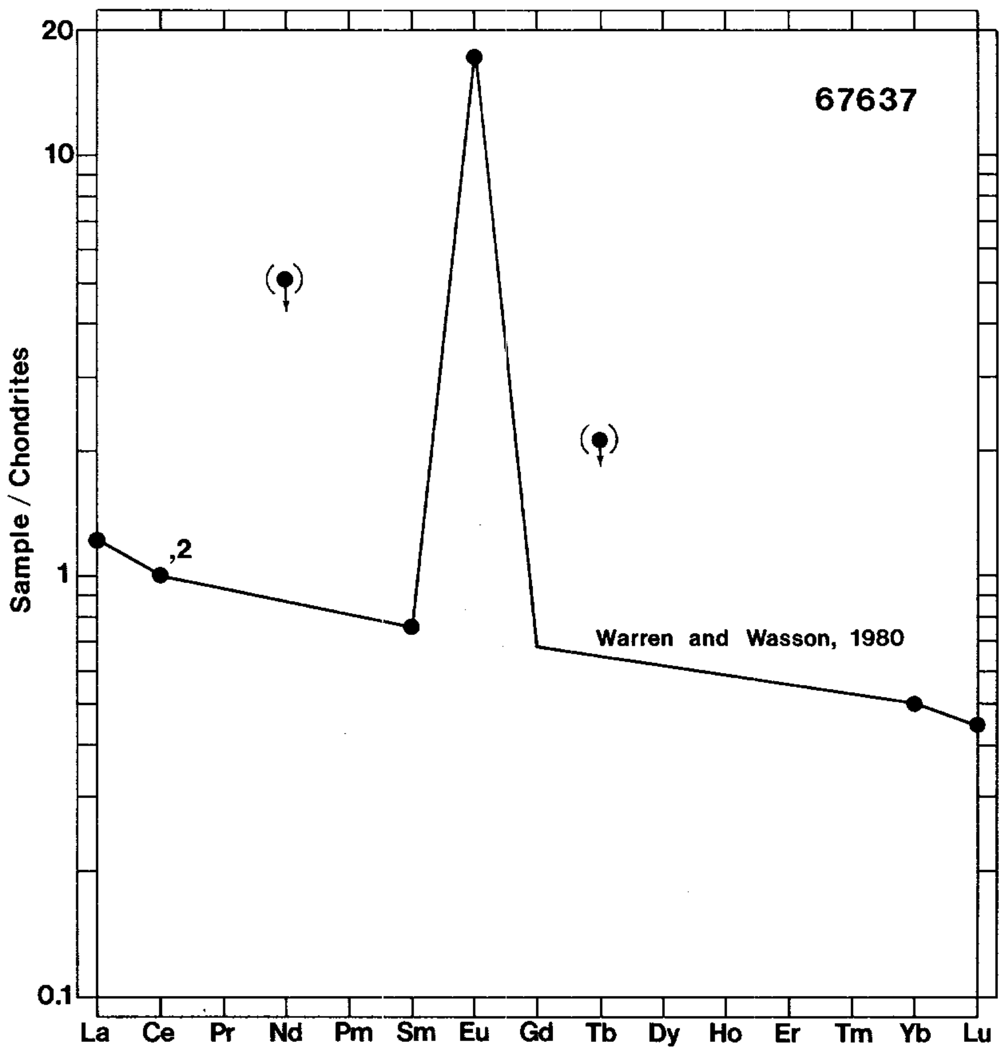


Figure 4. Rare earths.

67638 FRAGMENTAL/GLASSY POLYMICT BRECCIA 7.23 g

INTRODUCTION: 67638 is a light gray polymict breccia which is coherent and fractured (Fig. 1). Its matrix varies from fragmental to glassy. The sample is a rake sample collected 30 m east of the White Breccia boulders and has many zap pits.

PETROLOGY: 67638 consists of polymict, coherent dark breccia, which is fairly heterogeneous (Fig. 2). The general matrix is very fine-grained and fragmental in most areas. Only about 10% of the matrix is in fragments larger than 100 μm. The clast population is more coherent that the matrix and is mainly plagioclase; lithic fragments are dominated by aphanitic impact melts but also include granulitic impactites. Brown and glassy or crypto-crystalline material intrudes the matrix in places (Fig. 2).

PROCESSING AND SUBDIVISIONS: Two small chips were removed to make thin section ,1.

Figure 1. S-72-51244, mm scale.

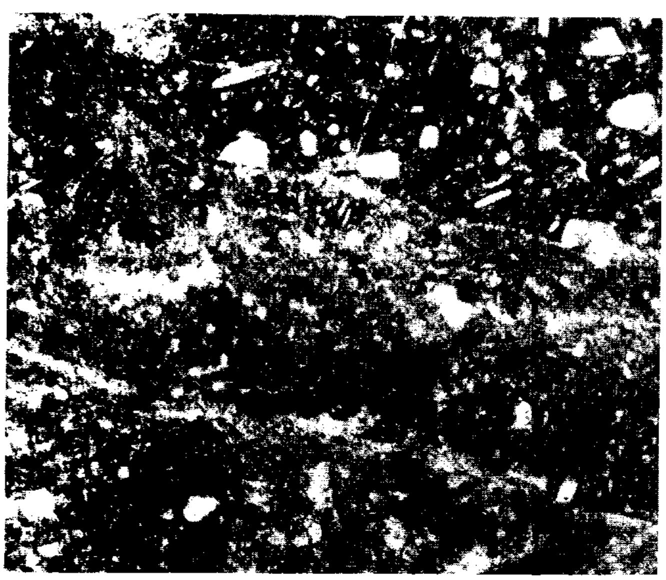


Figure 2. 67638,1, gemeral view, ppl. width 2mm.

67639 CRYSTALLINE(?) POLYMICT BRECCIA 7.34 g

INTRODUCTION: 67639 is a coherent, light gray breccia with some dark clasts (Fig. 1). The matrix is fine-grained and homogeneous. It is a rake sample collected 30 m east of the White Breccia boulders and has zap pits.

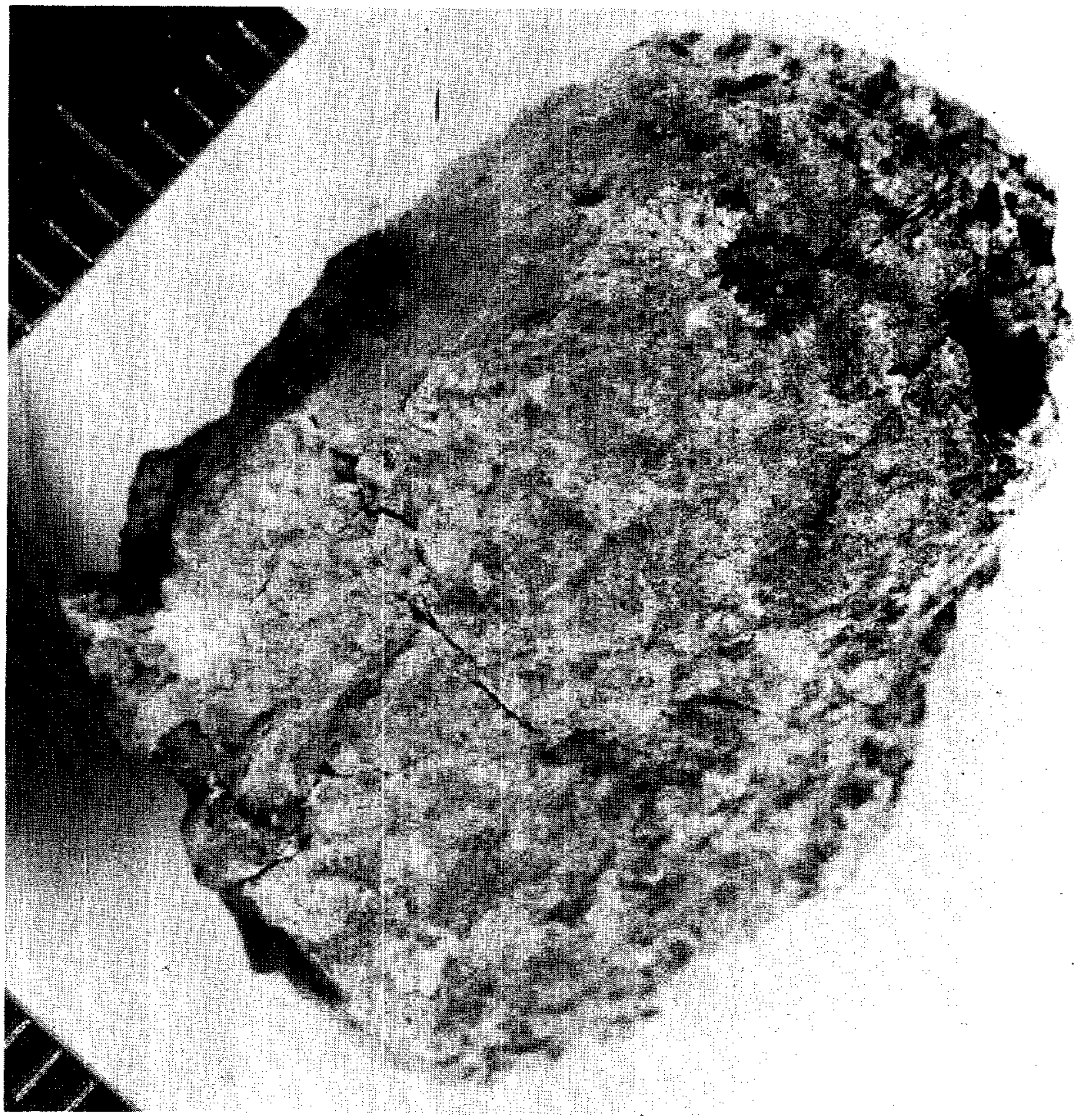


Figure 1. S-72-51045, mm scale.

67645 FRAGMENTAL POLYMICT BRECCIA 0.84 g

INTRODUCTION: 67645 is a pale gray, extremely friable breccia with a few dark gray clasts (Fig. 1). It is a rake sample collected 30 m east of the White Breccia boulders and lacks zap pits.

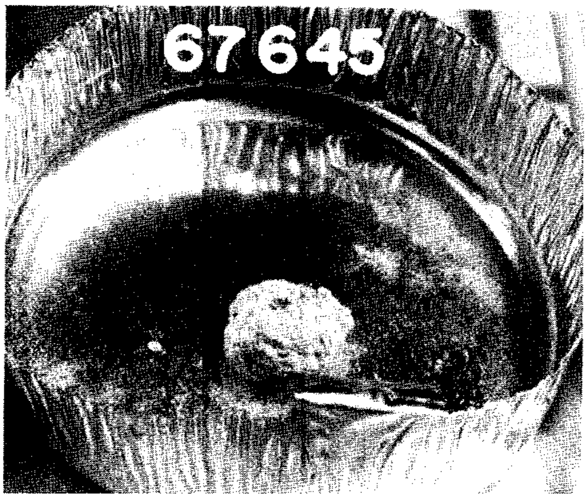


Figure 1. S-72-43730, cup is 5cm in diameter.

67646 FRAGMENTAL POLYMICT BRECCIA 3.94 g

INTRODUCTION: 67646 is a white, friable, and powdery breccia containing dark clasts (Fig. 1). It is a rake sample collected 30 m east of the White Breccia boulders and its friable surface lacks zap pits.

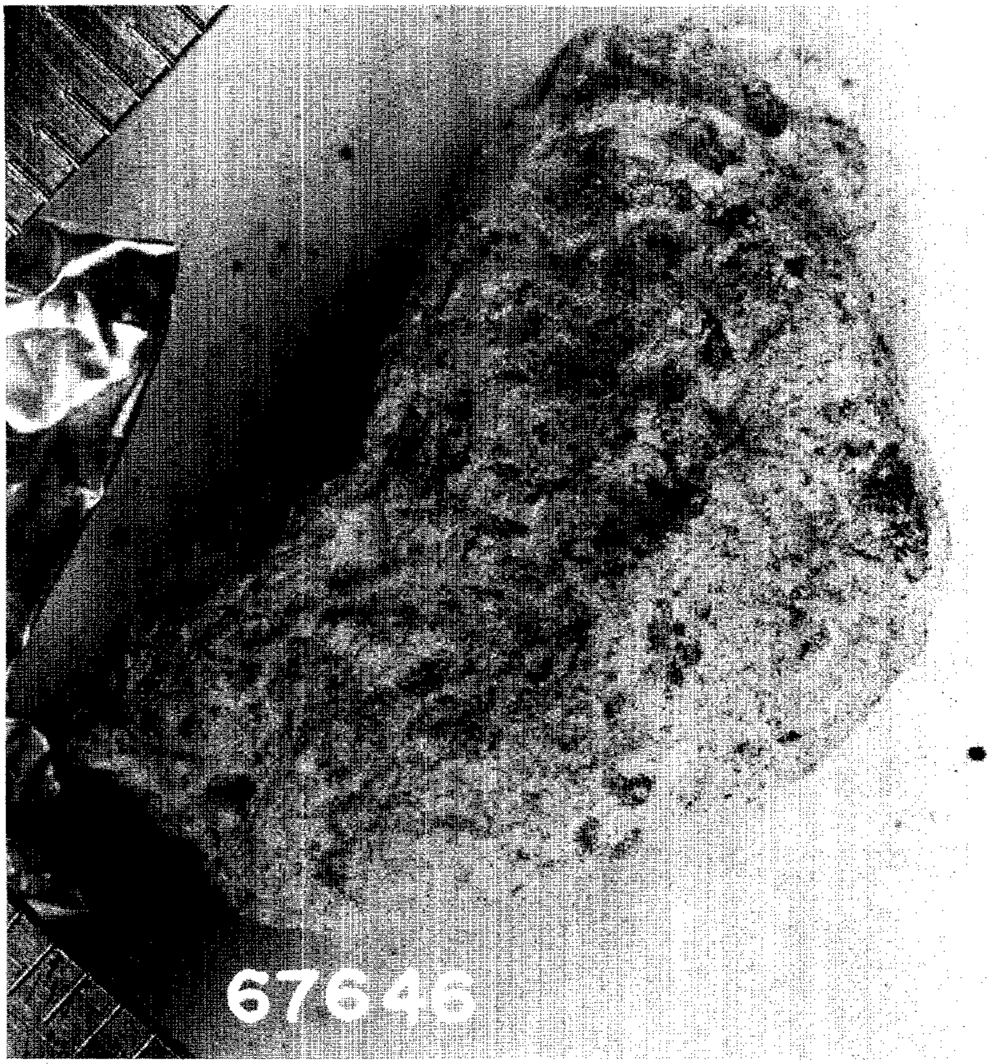


Figure 1. S-72-49564, mm scale.

INTRODUCTION: 67647 is a pale colored, coherent, glassy breccia, which is probably a lithified soil (Fig. 1). It is a rake sample collected 30 m east of the White Breccia boulders, and has numerous zap pits.

PETROLOGY: A thin section cut for this study shows that 67647 is a fine-grained, brown, glassy, porous breccia (Fig. 2). Its clast population consists mainly of brown aphanitic impact melts and glassy breccias, as well as abundant shocked minerals. Its characteristics are those of regolith material.

PROCESSING AND SUBDIVISIONS: A chip (,1) was removed from one end (Fig. 1) to make thin section ,2.

Figure 1. S-80-27469, mm scale.

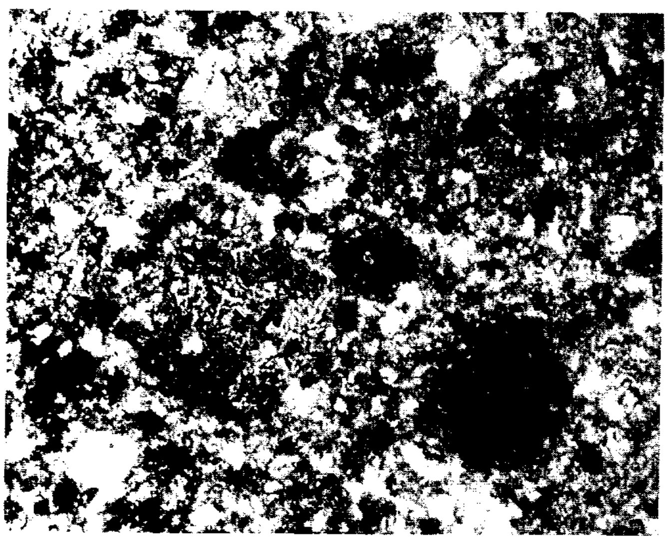


Figure 2. 67647,2, general view, ppl. width 2mm.

INTRODUCTION: 67648 is a coherent, polymict breccia with a pale colored matrix (Fig.1). The matrix is extremely fine-grained (∿ 60% of the rock is grains less than 5 μm). It is a rake sample collected 30 m east of the White Breccia boulders, and has a high density of zap pits on half its surface.

PETROLOGY: Steele and Smith (1973) refer to 67648 as a dark "lithified soil breccia". It is heterogeneous, dark, and polymict, and most material is extremely fine-grained (Fig.2). The lithic clasts and the matrix have similar textures and in transmitted light the distinction of some of the lithic clasts from the matrix is difficult. While most of the matrix is finely divided or even glassy, the vesicular glasses which are characteristic of regolith are absent. Some very tiny clasts are clear glass.

PROCESSING AND SUBDIVISIONS: A chip was removed, and thin section ,1 made from it.

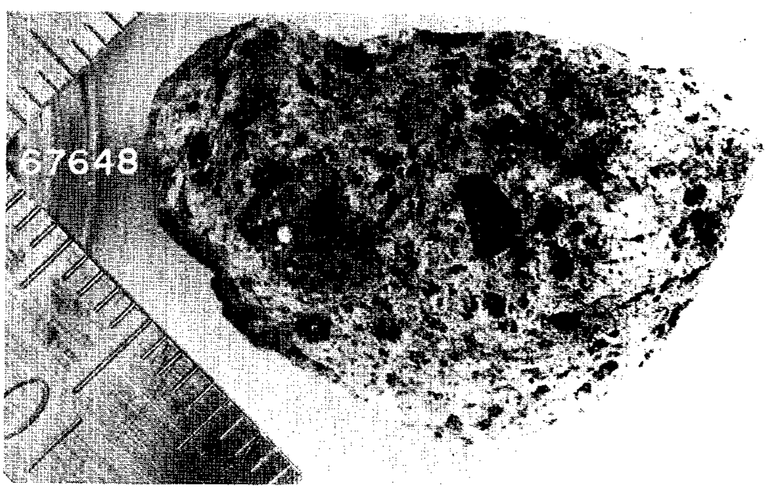


Figure 1. S-72-51268, mm scale.

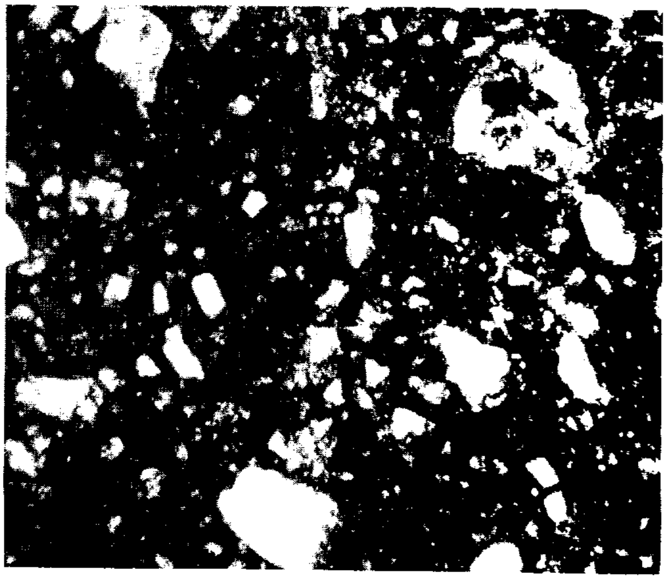


Figure 2. 67648,1, general view, ppl. width 2mm.

INTRODUCTION: 67649 is a pale colored, friable breccia containing dark angular clasts (Fig. 1). It is a rake sample collected 30 m east of the White Breccia boulders and its friable surface lacks zap pits.

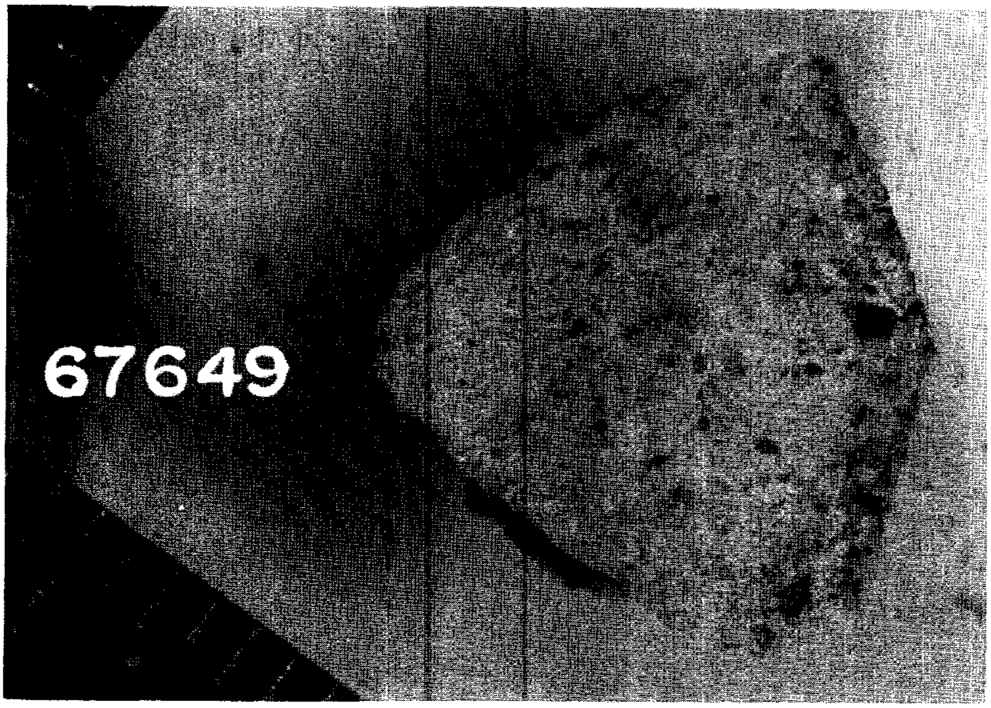


Figure 1. S-72-51051, mm scale.

INTRODUCTION: 67655 is a pale colored, polymict breccia (Fig.1) which is coherent and fairly heterogeneous. An unusual feature is that almost all of the plagioclase is "flame-textured". It is a rake sample collected 30 m east of the White Breccia boulders and lacks zap pits.

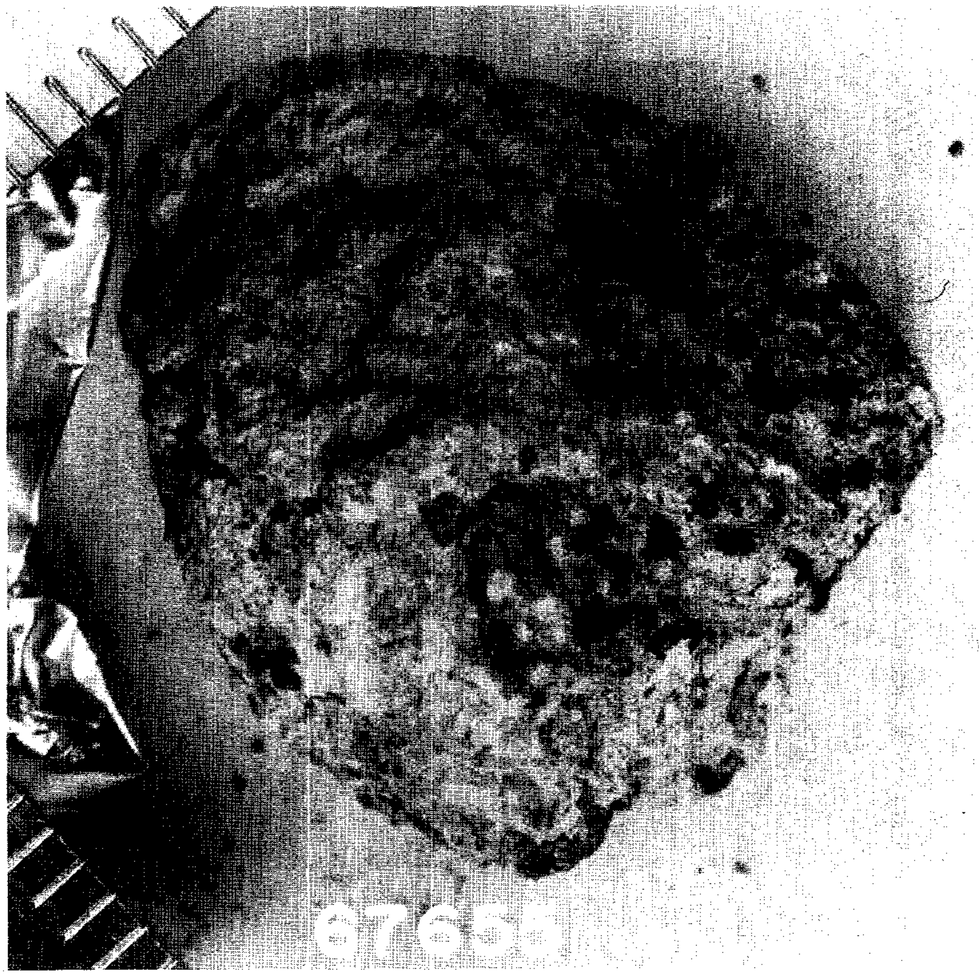


Figure 1. S-72-49579, mm scale.

PETROLOGY: Steele and Smith (1973) refer to 67655 as a "recrystallized breccia" with 30% matrix (defined as material less than 5 μm diameter). It is a fairly heterogeneous, polymict breccia (Fig.2) in which large clasts are more coherent than the fine-grained matrix. The latter is slightly porous. Lithic clasts larger than 300 μm compose ∿ 25% of the rock, and include basaltic impact melts, aphanitic materials, and plagioclase-rich feldspathic granulites. The matrix contains many plagioclase and mafic clasts in the 20-100 μm range, but the interstitial material is of equivocal nature.

An unusual feature is that nearly all of the plagioclase, as single fragments or in lithic clasts, is "flame-textured", and that which is not, is shocked (Fig.2). This suggests a post-assembly shock event causing maskelynitization followed by devitrification.

PROCESSING AND SUBDIVISIONS: Thin section ,1 was made from one of a few small chips removed.

a

b

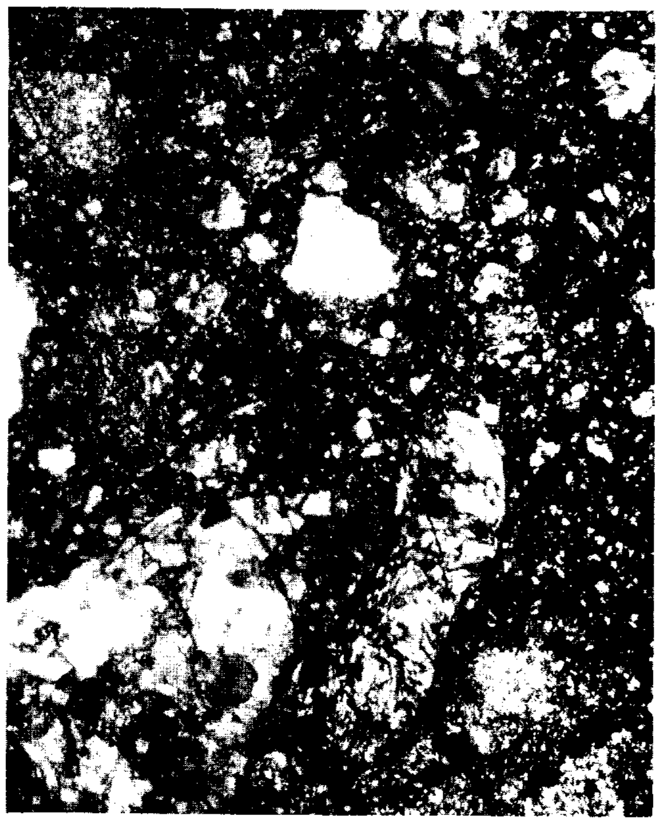


Figure 2. 67655,1, general view, width 2mm
a) ppl. b) xpl.

INTRODUCTION: 67656 is a light gray, friable breccia containing dark clasts. It is a rake sample collected 30 m east of the White Breccia boulders and its powdery surface lacks zap pits.

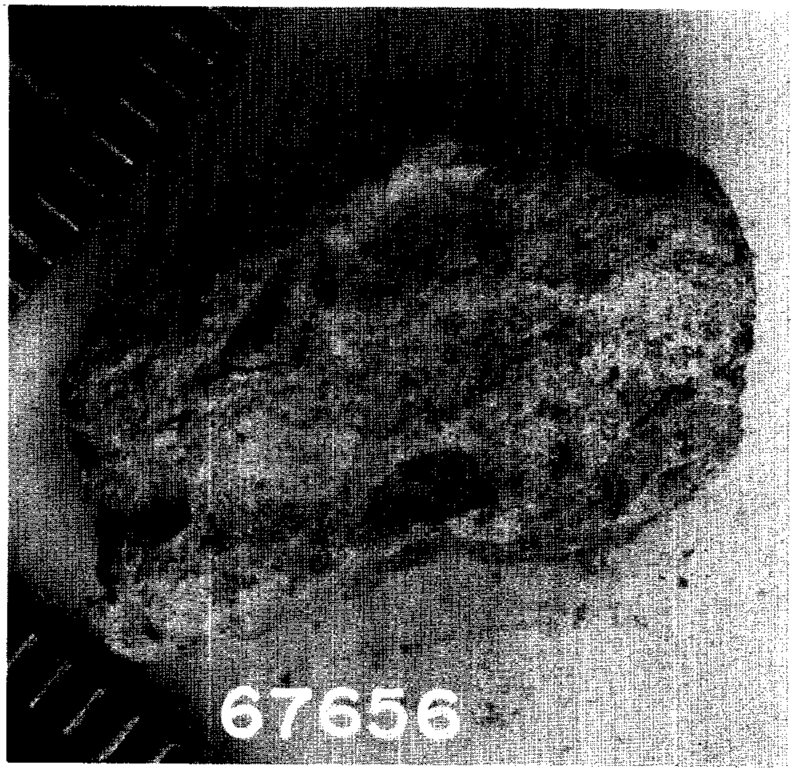


Figure 1. S-72-49571, mm scale.

INTRODUCTION: 67657 is a pale gray friable breccia containing gray clasts (Fig. 1). It is a rake sample collected 30 m east of the White Breccia boulders and its powdery surface lacks zap pits.

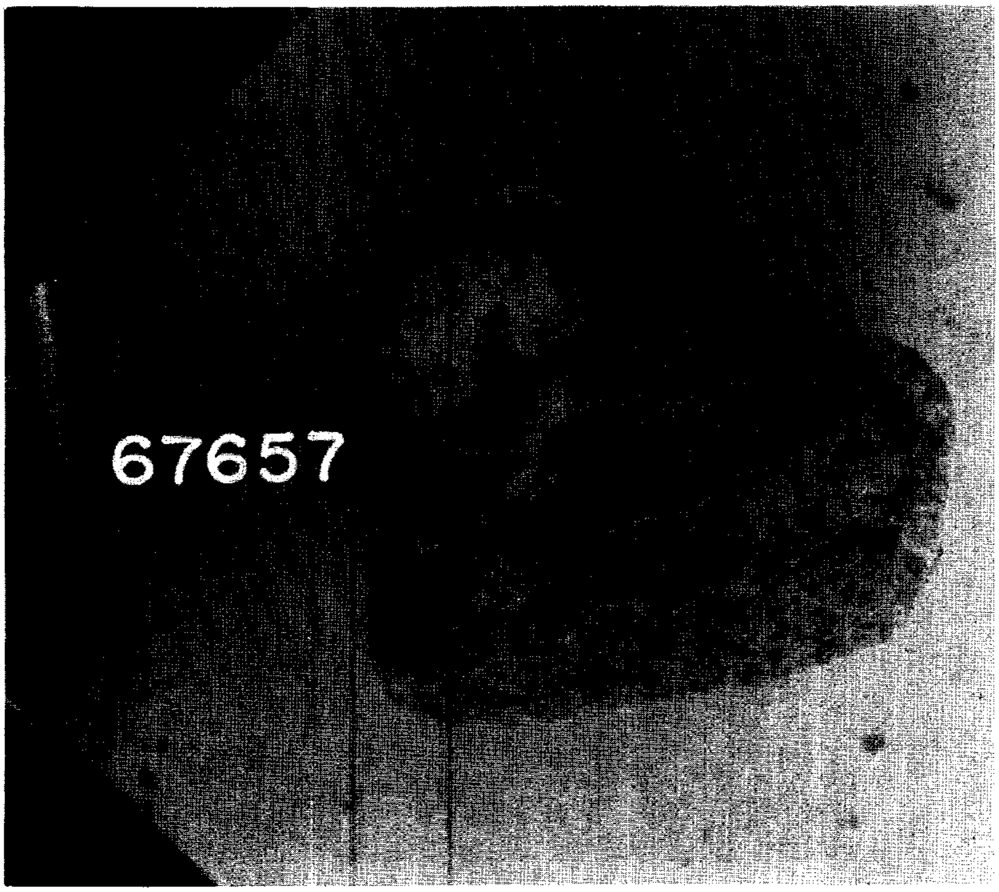


Figure 1. S-72-51254, mm scale.

INTRODUCTION: 67658 is a white to pale gray friable breccia containing some darker gray clasts (Fig. 1). It is a rake sample collected 30 m east of the White Breccia boulders and its friable surface lacks zap pits.

Figure 1. S-72-51060, mm scale.

67659 CRYSTALLINE OR FRAGMENTAL(?) POLYMICT BRECCIA 1.62 g

INTRODUCTION: 67659 is a white to pale gray, fairly coherent, polymict breccia, containing some small gray clasts (Fig. 1). The matrix is fine-grained. It is a rake sample collected 30 m east of the White Breccia boulders and lacks zap pits.

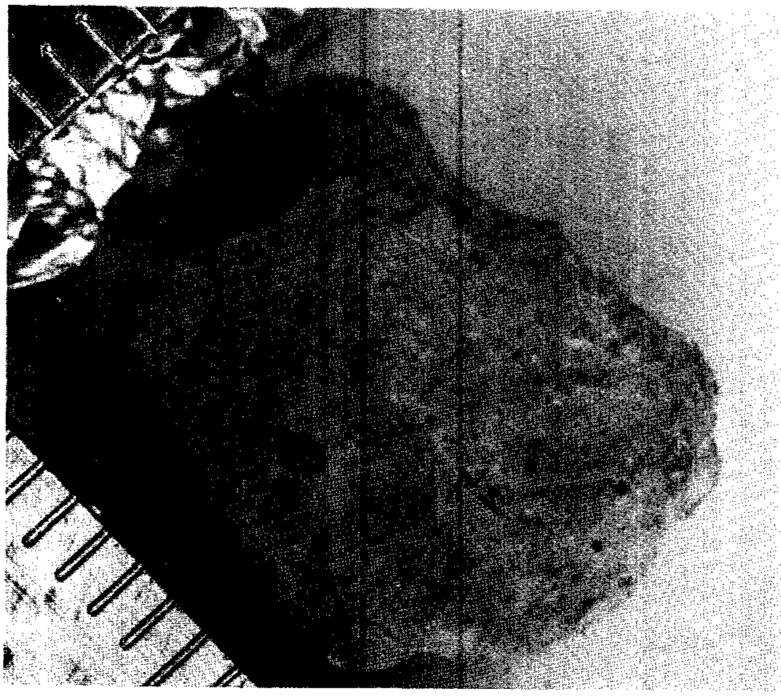


Figure 1. S-72-51246, mm scale.

INTRODUCTION: 67665 is a light gray, extremely friable, polymict breccia containing a few dark clasts (Fig. 1). It is a rake sample collected 30 m east of the White Breccia boulders.

Figure 1. S-72-49542, mm scale.

67666 GLASSY POLYMICT BRECCIA 5.47 g

INTRODUCTION: 67666 is a coherent, polymict, glassy breccia (Fig. 1). It is fine-grained and heterogeneous. It is a rake sample collected 30 m east of the White Breccia boulders and has many zap pits.

PETROLOGY: 67666 has a fine-grained, glassy matrix which is patchy and variable and contains small clasts which are themselves mainly aphanitic or glassy breccias (Fig. 2). Opaque minerals are not common but traces of ilmenite and some Fe-metal grains are present.

PROCESSING AND SUBDIVISIONS: Three small chips were used to make thin section ,1.

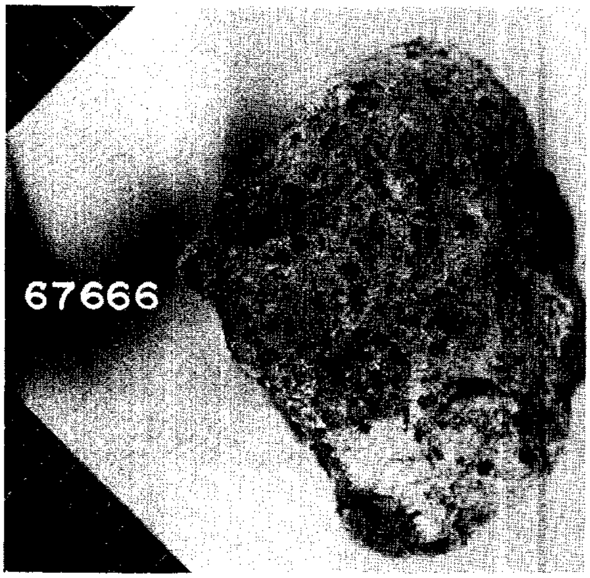


Figure 1. S-72-51059, mm scale.

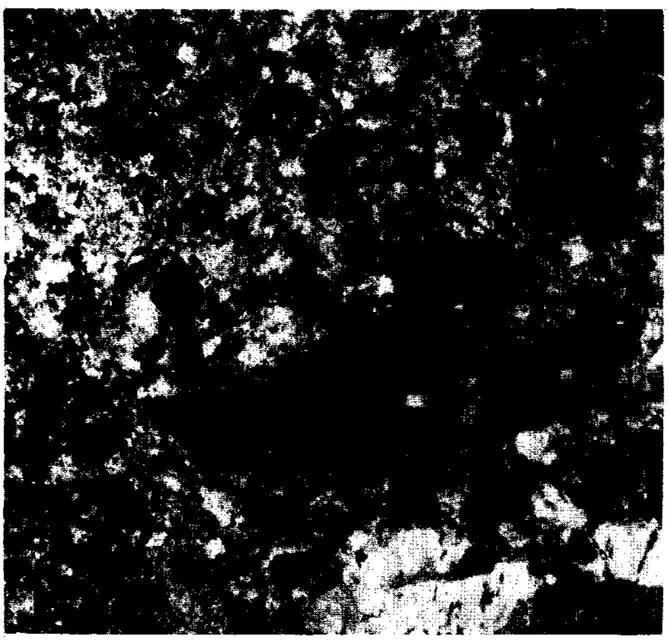


Figure 2. 67666,1, general view, ppl. width 2mm.

INTRODUCTION: 67667 is a monomict breccia (Fig. 1) with ~70 to 80% mafic minerals, and uncontaminated with meteoritic material. Few grains are larger than 100 μm. It is a rake sample collected 30 m east of the White Breccia boulders and has many zap pits.

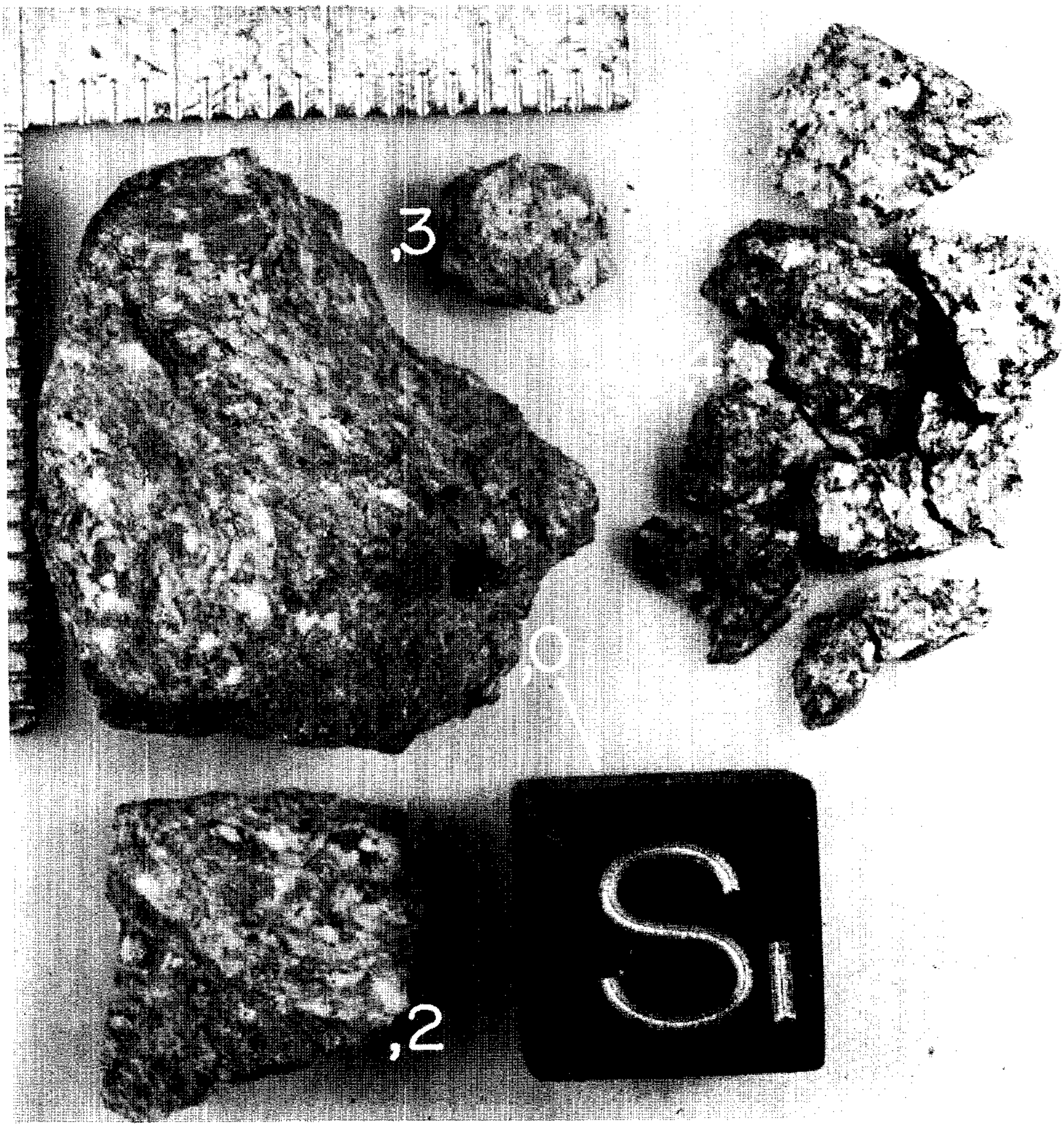


Figure 1. S-78-27395, mm scale.

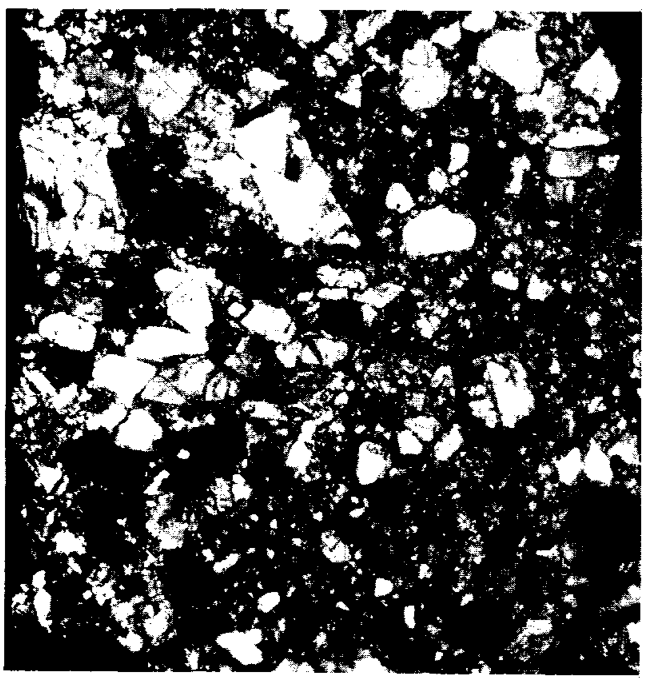
PETROLOGY: Petrographic descriptions and microprobe analyses are given by Steele and Smith (1973), Warren and Wasson (1978, 1979) and Hansen et al. (1979b, and unpublished). It is an extremely mafic rock (Table 1), though modally heterogeneous; Steele (1979, pers. comm.) notes that a microprobe search of thin section ,1 failed to find high-Ca pyroxene, whereas Warren and Wasson (1978) find ∿15% high-Ca pyroxene in thin section ,6. Warren and Wasson (1978) note that in the Streckeisen (1973) classification their sample of 67667 would be termed a "mela-olivine gabbro norite", but choose to emphasize its unique character among lunar samples by referring to it as a "feldspathic lherzolite".

TABLE 1. Modal analyses of 67667

,1 Steele and Smith (1973)		,6 Warren and Wasson (1978)	
Plagioclase	30%	Plagioclase	20%
Olivine	20%	Olivine	50%
Low-Ca pyroxene	50%	Low-Ca pyroxene	∿15%
		High-Ca pyroxene	15%
		Ilmenite	2%
		Cr, spinel, troilite, Fe-metal	Tr

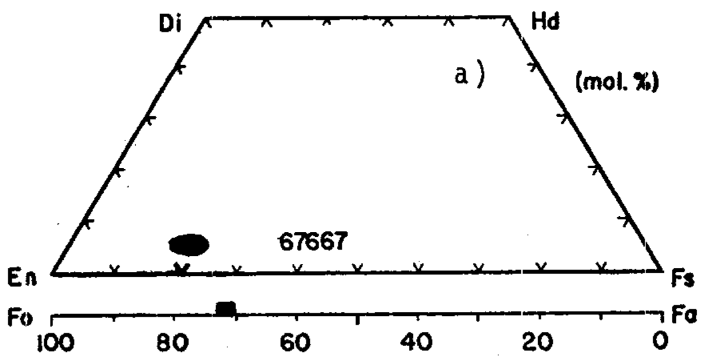
67667 is brecciated (Fig. 2) with few grains larger than 100 µm or less than ∿5 µm. It is not porous and portions may have been melted. A few areas appear themselves to be clasts (Fig. 2). The plagioclase is commonly shocked or badly strained, and mafic minerals fractured. Silicate mineral compositions are shown in Figure 3 and appear to be restricted. Metal grains (Fig. 4) are outside of the "meteoritic" range.

a



b

Figure 2. 67667,1, general view, width 2mm. a) xpl. b) ppl.



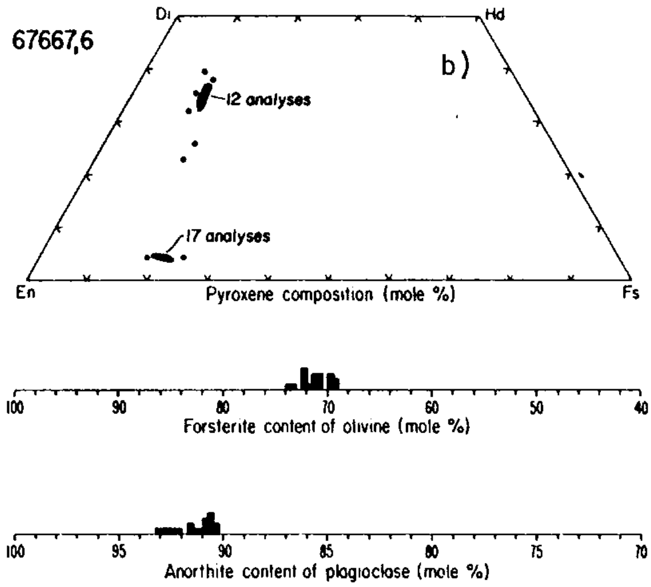


Figure 3. Mineral compositions
a) from Steele and Smith (1973)
b) from Warren and Wasson (1979).

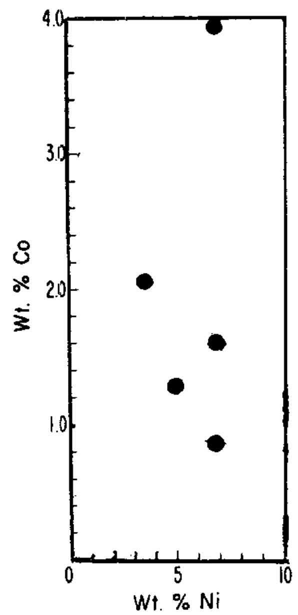


Figure 4. Metal compositions, from Warren and Wasson (1979).

CHEMISTRY: A major and trace element analysis is given by Warren and Wasson (1979) and is summarized in Table 2 and Figure 5. The low siderophile abundances demonstrate that it is uncontaminated with meteoritic material. The norm of the analysis is in rough agreement with Warren and Wasson's (1979) mode but has only ∿5% high-Ca pyroxene. The REE pattern of 67667 is unusual among lunar samples in being flat and lacking a Eu anomaly.

TABLE 2. Summary chemistry of 67667
(Warren and Wasson, 1979)

SiO_2	42.4	Sr	
TiO_2	1.04	La	3.6
Al_2O_3	7.6	Lu	0.32
Cr_2O_3	0.38	Rb	
FeO	17.2	Sc	24.4
MnO	0.20	Ni	4.4
MgO	26.4	Co	26
CaO	5.3	Ir ppb	0.013
Na_2O	0.158	Au ppb	0.029
K_2O	0.023	C	
P_2O_5		N	
		S	
		Zn	
		Cu	

Oxides in wt%; others in ppm except as noted.

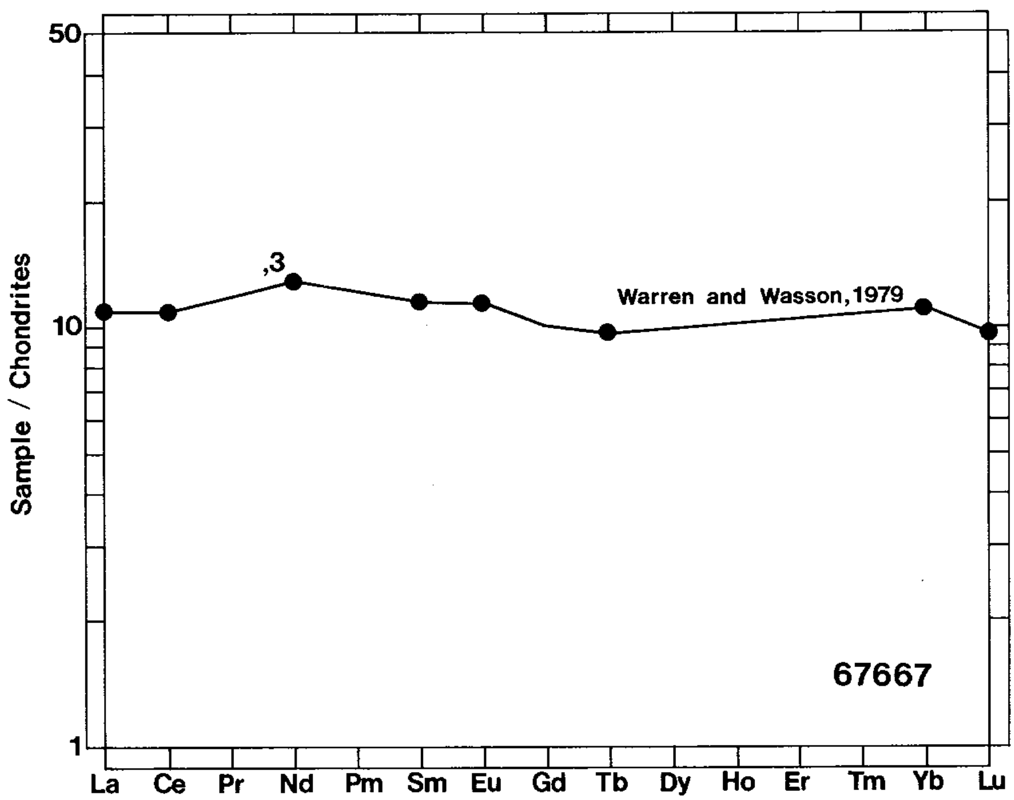


Figure 5. Rare earths.

PROCESSING AND SUBDIVISIONS: A chip was removed to make thin section ,1. The main subsequent subdivisions are shown in Figure 1. ,3 was allocated for chemistry, ,4 for radiogenic isotope studies, and ,2 for a potted butt for thin sections. A small chip from ,0 was allocated for further chemical analyses (meteoritic siderophiles and volatiles).

67668 POIKILITIC IMPACT MELT 3.58 g

INTRODUCTION: 67668 is a light gray, coherent, fine-grained poikilitic impact melt (Fig. 1). It is a rake sample collected 30 m east of the White Breccia boulders and is free of zap pits.

PETROLOGY: Steele and Smith (1973) refer to 67668 as a "recrystallized breccia; poikilitic pyroxene matrix". It consists of oikocrysts ∿200-500 μm in diameter enclosing plagioclase laths rarely larger than 30 μm (Fig. 2). Interoikocryst areas contain armalcolite, Fe-metal and troilite with minor glass. Clasts of plagioclase, usually 100-200 μm and rarely bigger, are present.

PROCESSING AND SUBDIVISIONS: Several small chips were taken to make thin section ,1.

Figure 1. S-72-49541, mm scale.

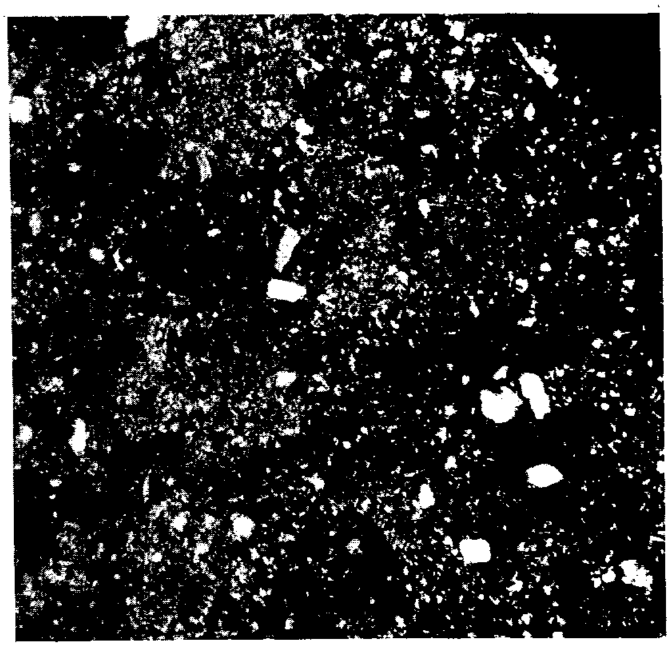


Figure 2. 67668,1 general view, xpl. width 2mm.

INTRODUCTION: 67669 is a fairly friable,polymict,and heterogeneous breccia (Fig. 1) containing aphanitic melt and cataclastic anorthosite clasts. It is a rake sample collected 30 m east of the White Breccia boulders and has irregularly distributed zap pits.

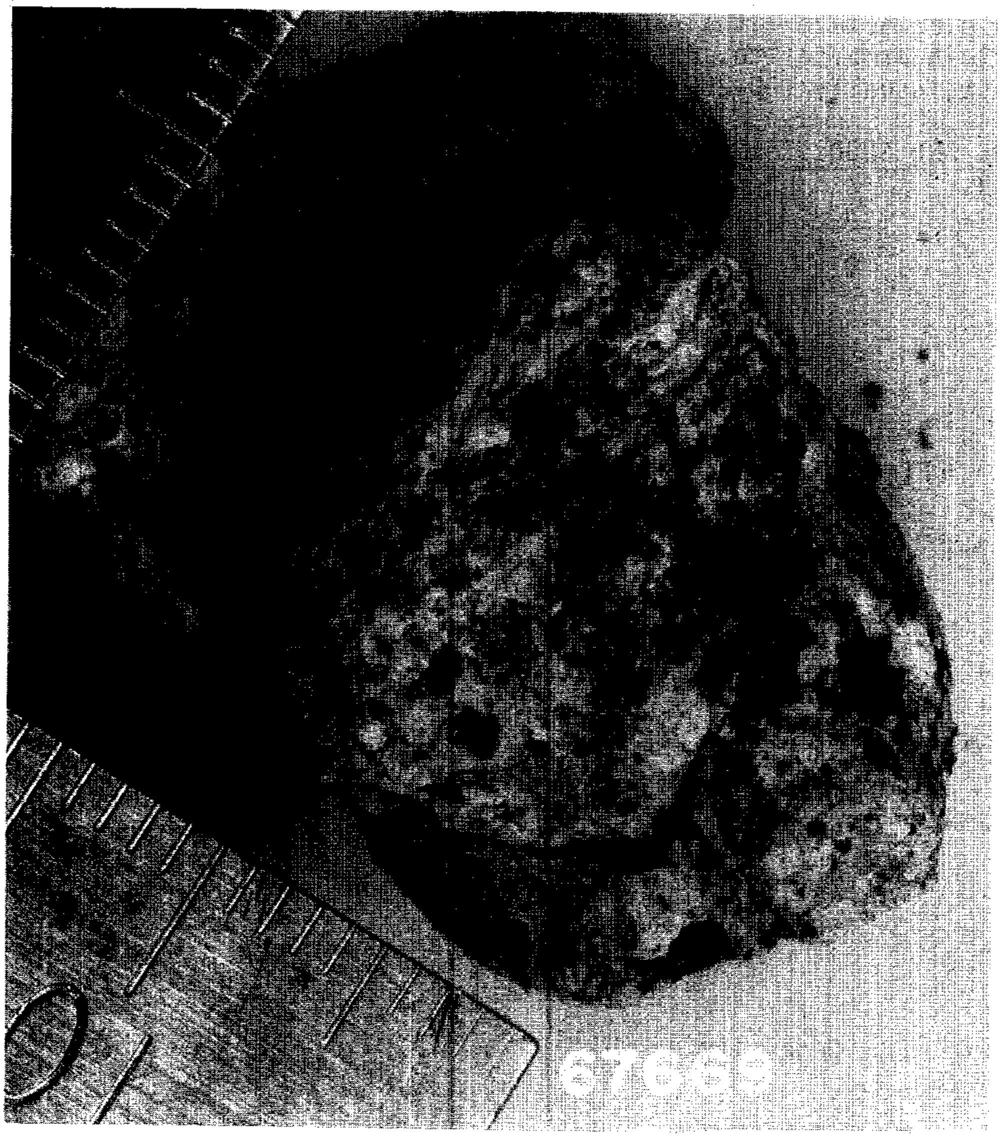
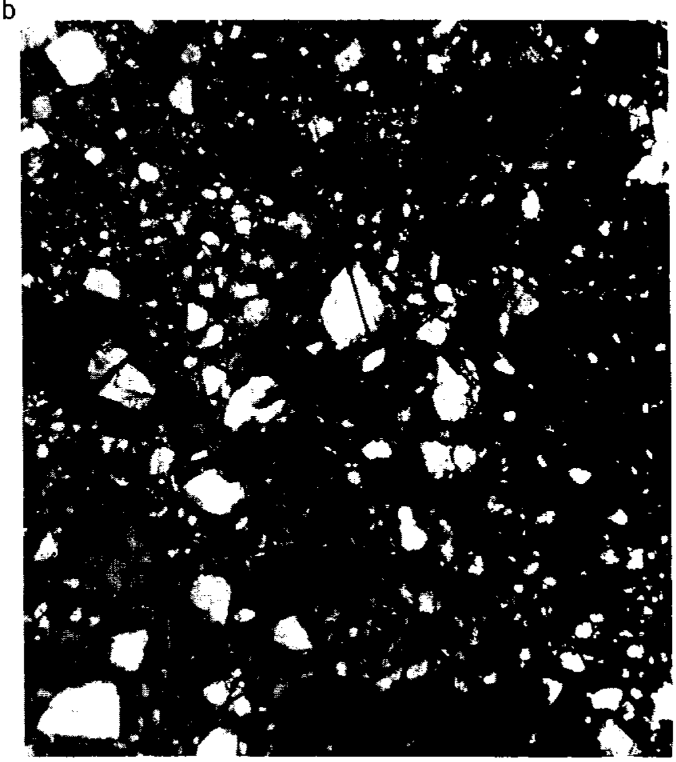


Figure 1. S-72-49580, mm scale.

PETROLOGY: 67669 consists of a polymict breccia which contains a variety of lithic clasts (Fig. 2). Prominent are aphanitic and glassy fragments, as well as cataclastic anorthosites. The former are dark, coherent and contain oriented feldspars. The latter are almost purely plagioclase with minor mafics, are crushed and sintered, and have most grains smaller than 200 µm. Some granulitic impactite material is present.

a

b



c

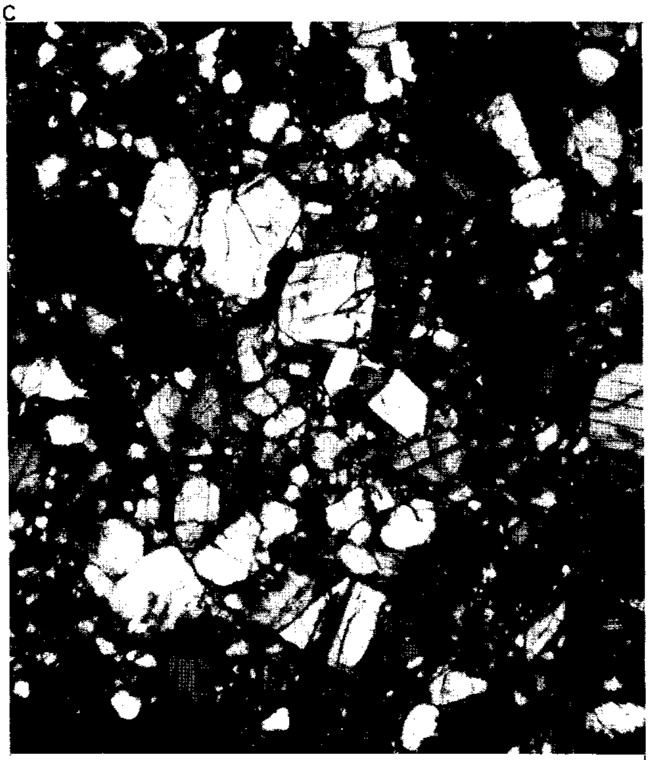


Figure 2. 67669,1 a) dark clasts and fragmental matrix, ppl. width 2mm.
b) dark clasts and fragmental matrix, xpl. width 2mm.
c) cataclastic anorthosite clast and fragmental matrix, xpl. width 2mm.

PROCESSING AND SUBDIVISIONS: Several small chips were removed, one of which was used to make thin section ,1.

INTRODUCTION: 67675 is a dark gray, irregularly shaped (twisted), coherent piece of glass (Fig. 1). It is covered by fine powder but no crystalline material is apparent in the glass. It is a rake sample collected 30 m east of the White Breccia boulders and lacks zap pits.

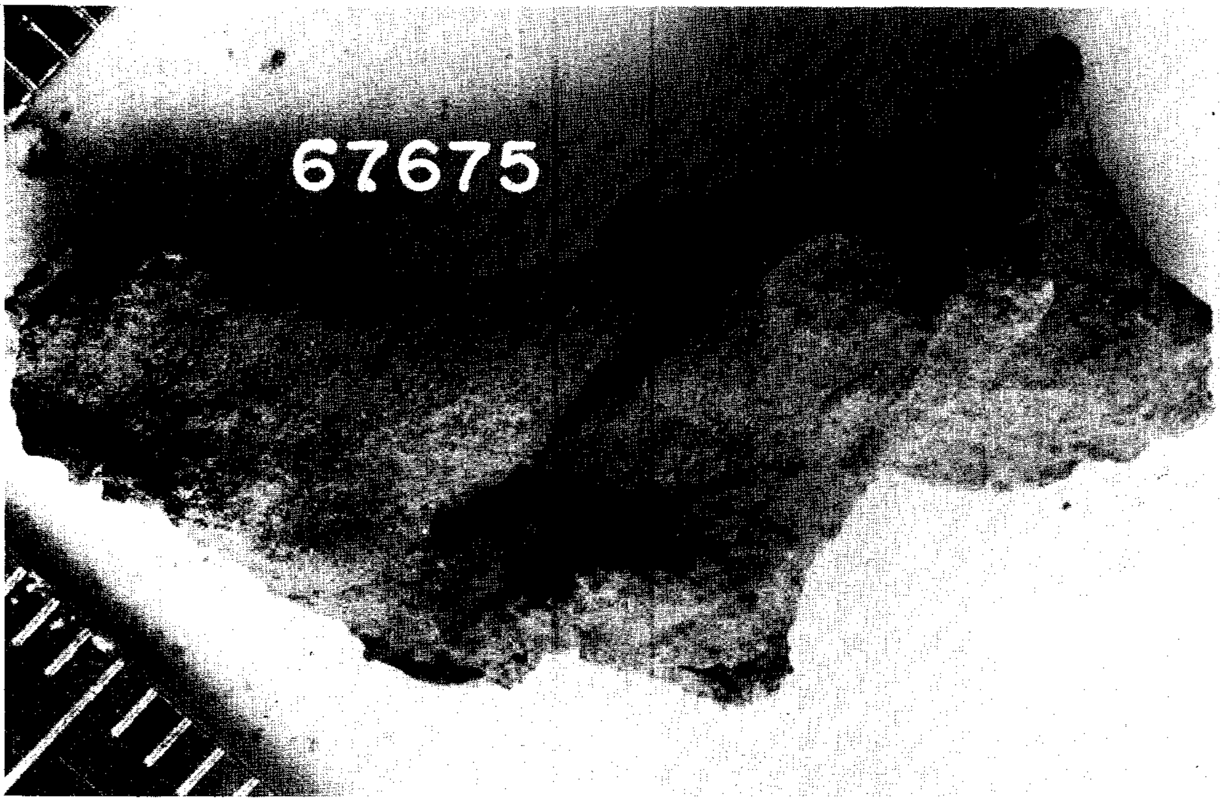


Figure 1. S-72-49559, mm scale.

INTRODUCTION: 67676 is a coherent, dark gray, vesicular, and variolitic impact melt (Fig. 1) with acicular plagioclase. It is a rake sample collected 30 m east of the White Breccia boulders and lacks zap pits.

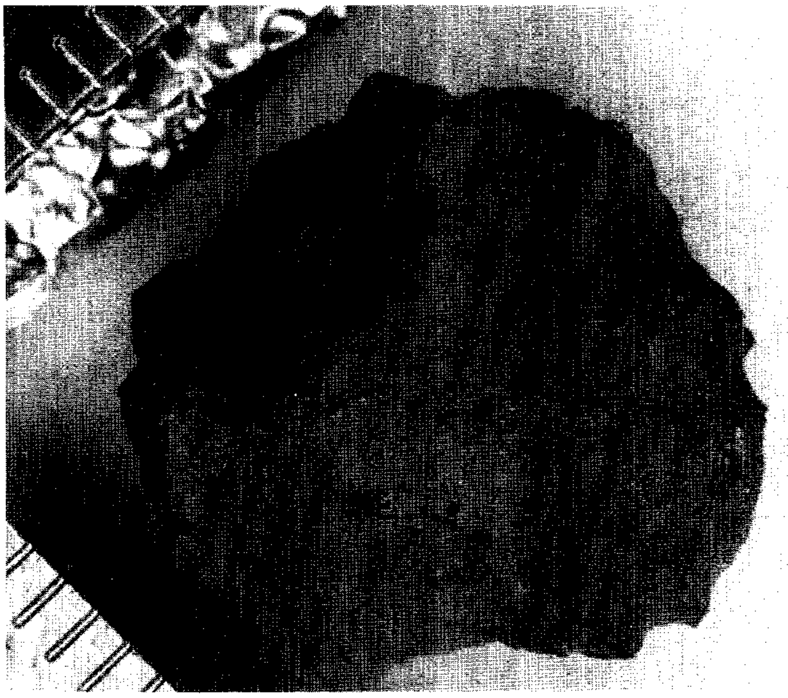


Figure 1. S-72-51250, mm scale.

PETROLOGY: Most of 67676 is a variolitic impact melt (Fig. 2) which is virtually pure plagioclase. Needles of plagioclase up to 300 μm long, but mostly 50 to 150 μm long, are separated by interstitial aluminous glass(?). A few plagioclase and lithic clasts are present.

The rim of the rock appears to be the original rim of the cooling unit: towards the outside the plagioclase is finer-grained, and at the outer edge in places there is a zone of glass. A thin coating of very fine-grained fragmental material forms the outermost rim, 100 μm at its widest. A similar sequence is observed towards vesicles. In the vesicle rim exposed in the thin sections a fine grained, melt-matrix, clast-rich breccia is present (Fig. 2).

a b

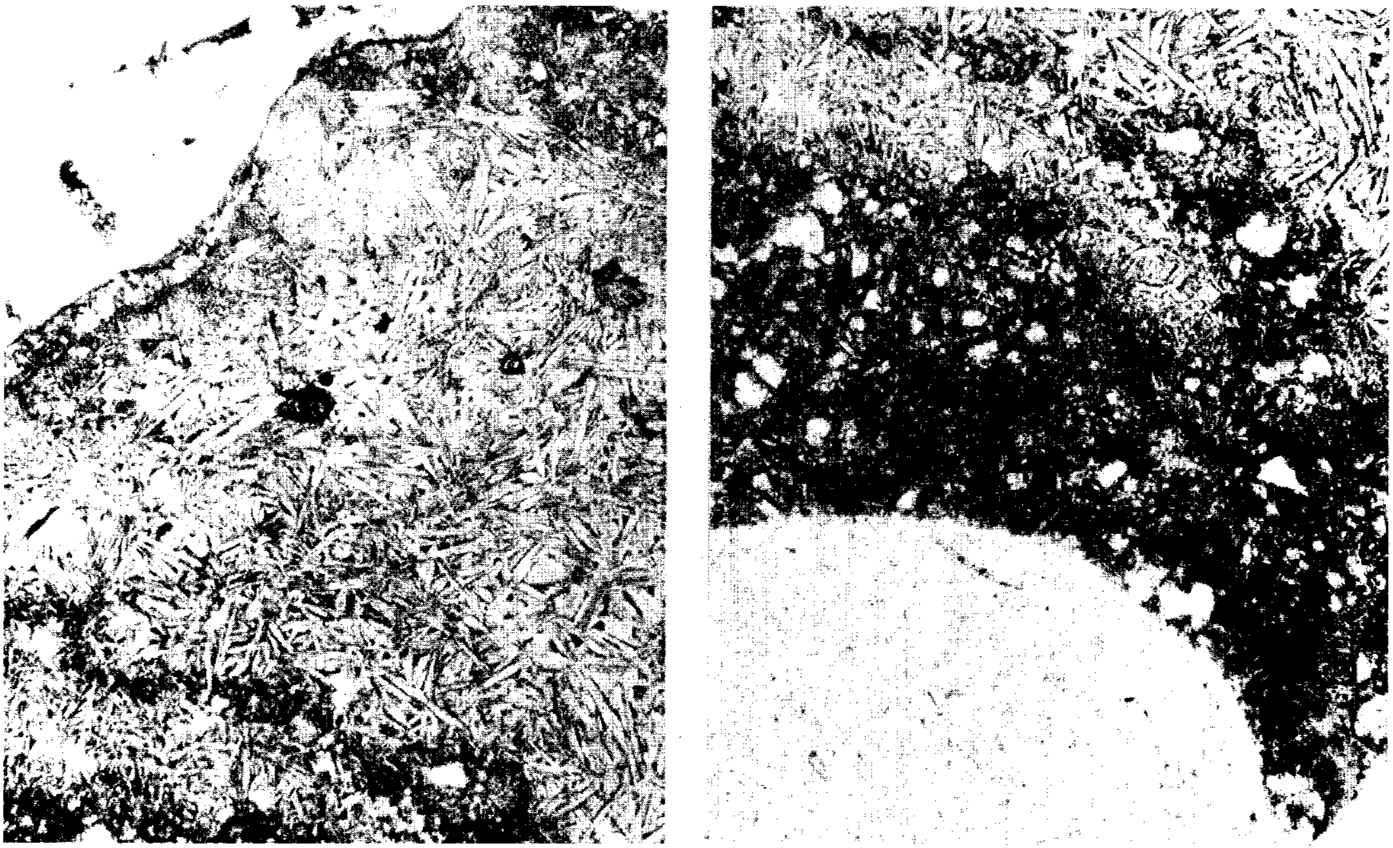


Figure 2. 67676,1 a) variolitic melt, ppl. width 2mm
b) vesicle rim, ppl. width 2mm.

PROCESSING AND SUBDIVISIONS: Small chips were chipped to make the potted butt from which thin sections ,1 and ,3 were made.

INTRODUCTION: 67685 is a dark cindery, vesicular glass containing fragments (Fig. 1). It is coherent and irregularly shaped. It is a rake sample collected 30 m east of the White Breccia boulders and lacks zap pits. It was originally the largest of four fragments of similar appearance which were numbered together as 67628 and now renumbered 67685-67688.

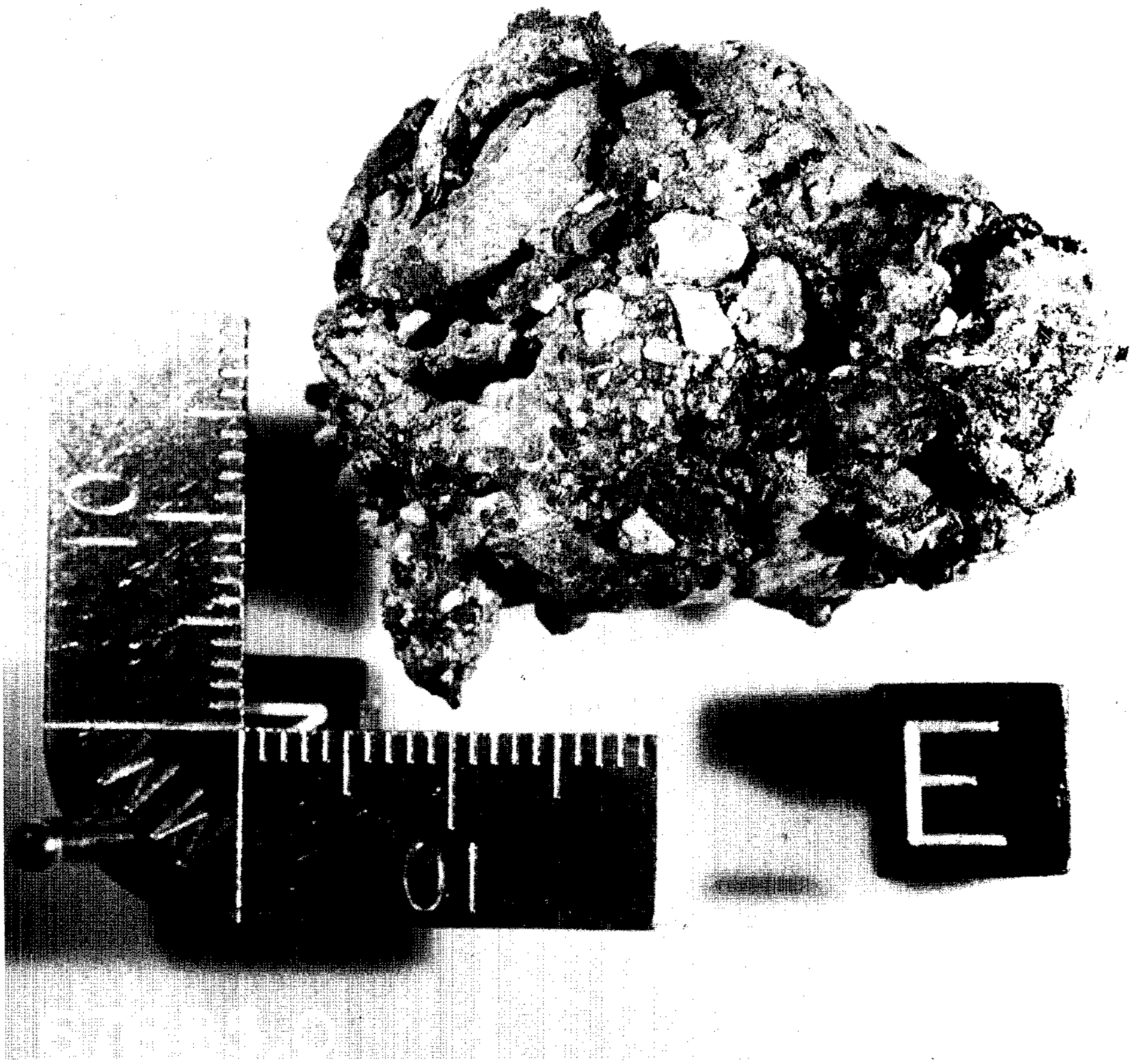


Figure 1. S-80-28630, mm scale.

INTRODUCTION: 67686 is a dark, cindery, vesicular glass containing fragments (Fig. 1). It is coherent and irregularly shaped. It is a rake sample collected 30 m east of the White Breccia boulders and lacks zap pits. It was originally the second largest of four fragments of similar appearance which were numbered together as 67628, and now renumbered 67685-67688.

Figure 1. S-80-28629, mm scale.

INTRODUCTION: 67687 is a dark, cindery, vesicular glass containing fragments (Fig. 1). It is coherent and irregularly shaped. It is a rake sample collected 30 m east of the White Breccia boulders and lacks zap pits. It was originally the third largest of four fragments of similar appearance which were numbered together as 67628, and now renumbered 67685-67688.

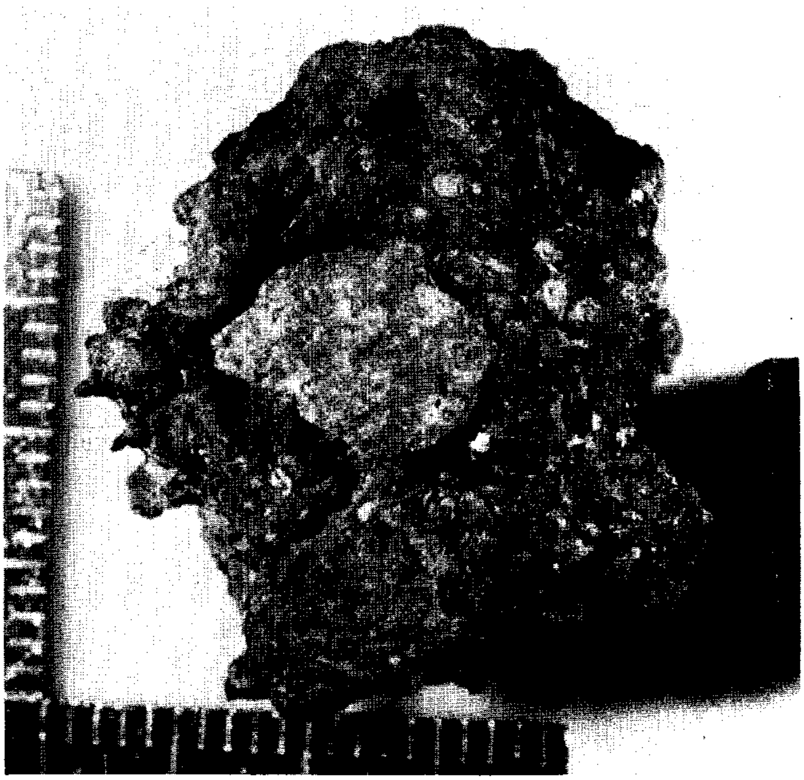


Figure 1. S-80-28631, mm scale.

INTRODUCTION: 67688 is a vesicular, coherent glass containing clasts (Fig. 1). It is a rake sample collected 30 m east of the White Breccia boulders and lacks zap pits. Originally it was the smallest of four fragments numbered together as 67628.

PETROLOGY: A thin section cut for this study is of a vesicular glass containing lithic and mineral fragments. Part of the glass is clear, but mainly it is devitrified giving plagioclase colonnades (Fig. 2). Lithic clasts include granulitic impactites and plagioclase-rich breccias. One clast is rimmed with tiny Fe-metal blebs.

PROCESSING AND SUBDIVISIONS: Originally 67688 was the smallest of four fragments of similar appearance which were grouped together as 67628. During this cataloguing they were renumbered separately (67685-67688). A chip (,1) of 67688 was taken for a thin section (Fig. 1).

Figure 1. S-80-28628, mm scale.

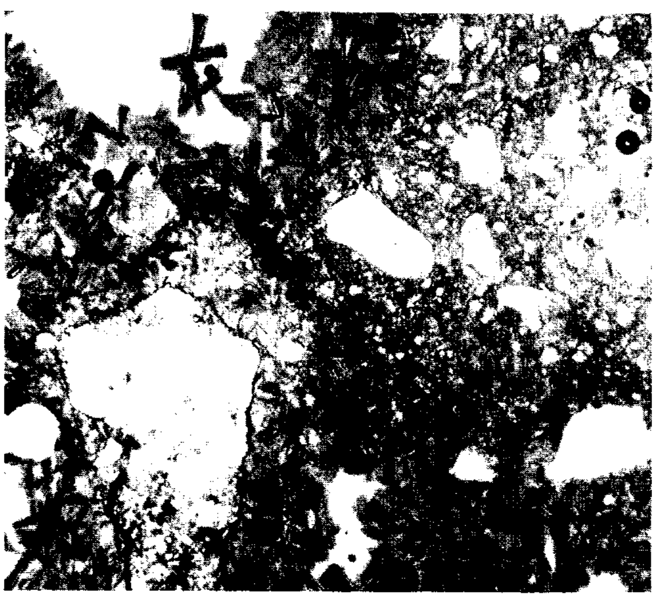


Figure 2. 67688,2, general view, ppl. width 2mm.

INTRODUCTION: 67695 is a coherent, black, vesicular, glassy impact melt with a smooth exterior surface and broken on other sides (Fig. 1). The glass encloses white clasts, and in part may be crystallized. It is a rake sample collected 30 m east of the White Breccia boulders and appears to lack zap pits.

PROCESSING AND SUBDIVISIONS: 67695 was originally the largest of four fragments numbered together as 67629, now renumbered 67629, 67695, 67696 and 67697.

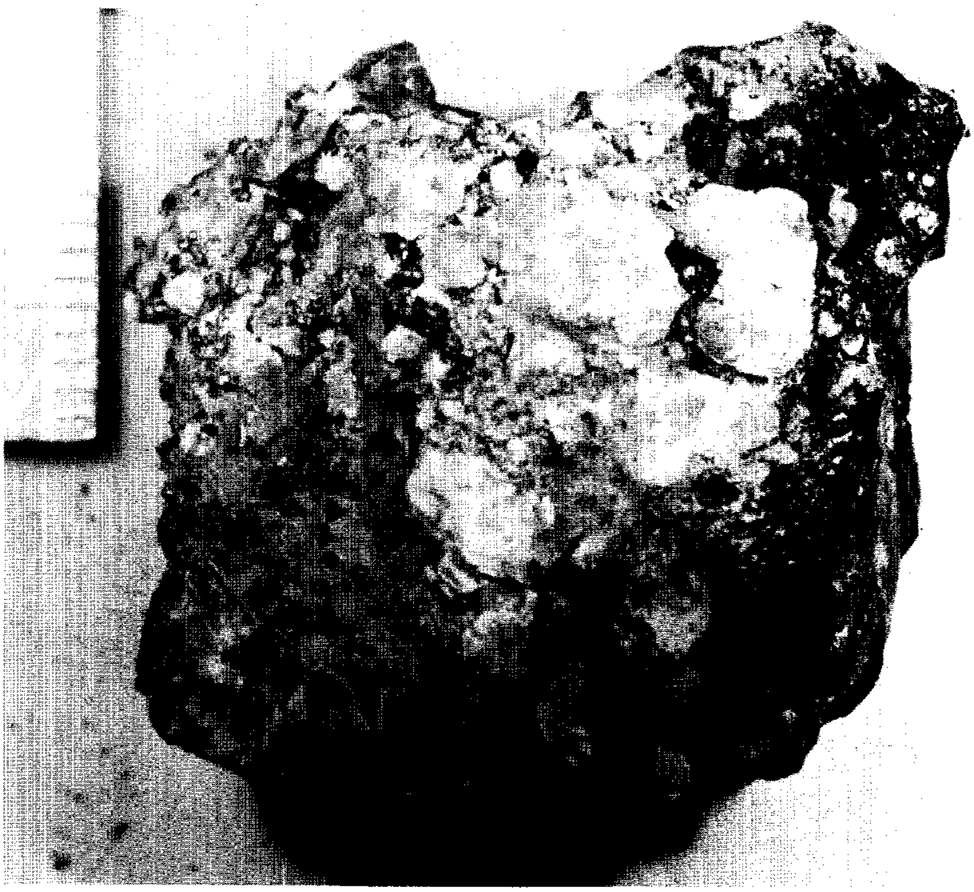


Figure 1. S-80-30292, mm scale.

INTRODUCTION: 67696 is a coherent, black, vesicular glass with a smooth exterior surface and broken elsewhere (Fig.1). The glass encloses white clasts (or coated a white rock) and is at least partly crystallized into plagioclase laths. The vesicles include some more than a centimeter across. It is a rake sample collected 30 m east of the White Breccia boulders and appears to lack zap pits.

PROCESSING AND SUBDIVISIONS: 67696 was originally the second largest of four fragments numbered together as 67629, now renumbered 67629, 67695, 67696, and 67697.

Figure 1. S-80-30291, mm scale.

INTRODUCTION: 67697 is a coherent, glassy, vesicular breccia containing a few small white clasts (Fig.1). It is a rake sample collected 30 m east of the White Breccia boulders and appears to lack zap pits.

PROCESSING AND SUBDIVISIONS: 67697 was originally the third largest of four fragments numbered together as 67629, and now renumbered 67629, 67695, 67696, and 67697.

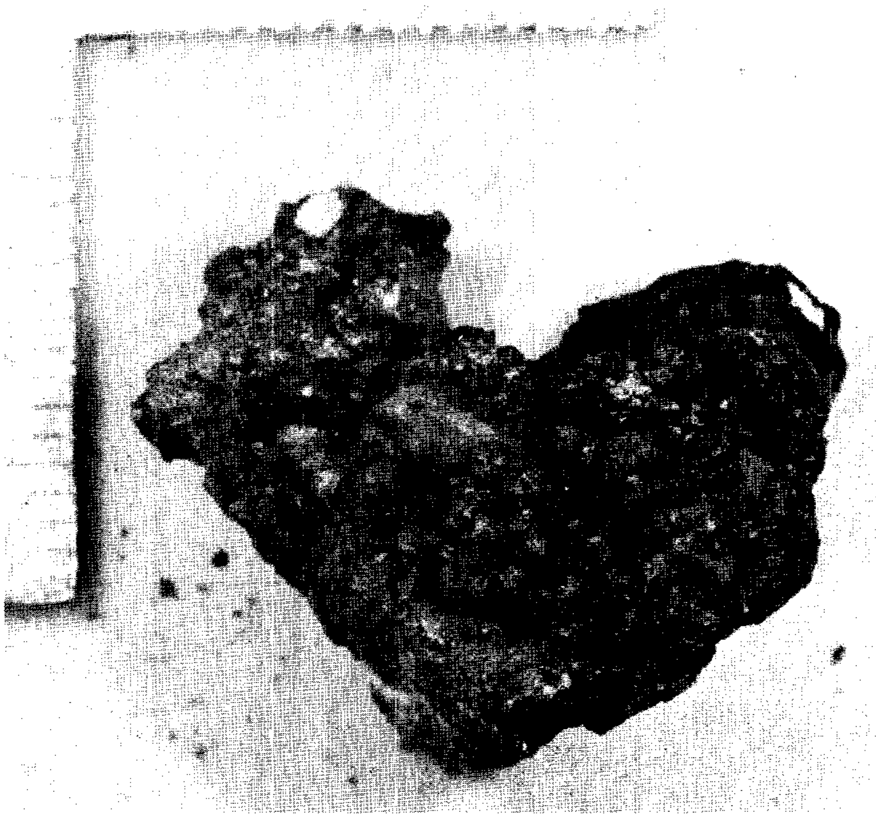


Figure 1. S-80-30293, mm scale.

INTRODUCTION: 67705 is a cindery, crumbly, dark glassy breccia with white clasts (Fig. 1). It was taken from the regolith sample collected halfway between the White Breccia boulders and House Rock.

PETROLOGY: 67705 is a brown, vesicular, devitrified glass with spherulitic and "bow-tie" structures (Fig. 2). In contains lithic and mineral clasts; the former are mainly plagioclase breccias but include a subophitic impact melt fragment which has shock glass, sometimes yellow, at its grain boundaries.

PROCESSING AND SUBDIVISIONS: A single chip ,1 was taken (Fig. 1) to make thin sections ,5 ,6 and ,7. It was a representative chip with a large white clast.

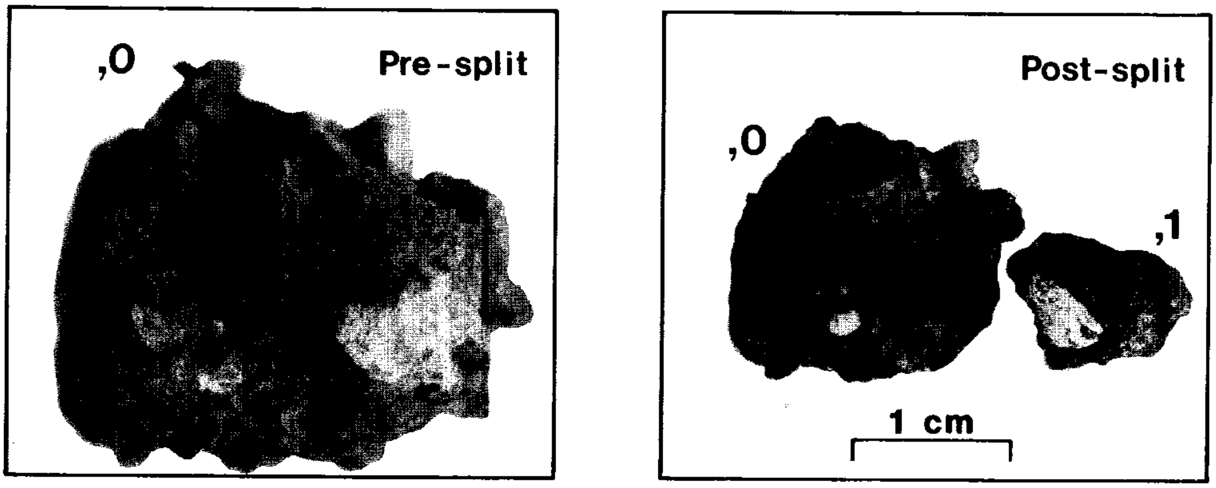


Figure 1.

Figure 2. 67705,5, general view, ppl. width 2mm.

67706 FRAGMENTAL POLYMICT BRECCIA 1.52 g

INTRODUCTION: 67706 is a very friable white or pale gray breccia (Fig. 1). It was taken from a regolith sample collected halfway between the White Breccia boulders and House Rock.

Figure 1. S-72-37797, cup is 5cm in diameter.

INTRODUCTION: 67707 is a pale-colored, friable, polymict breccia (Fig. 1). It was taken from the regolith sample collected halfway between the White Breccia boulders and House Rock.

PETROLOGY: 67707 has a porous, feldspathic, and fragmental matrix (Fig.2). It is polymict, with a clast population dominated by angular plagioclase fragments but including aphanitic brown impact melts, granulitic impactites, and feldspathic breccias.

PROCESSING AND SUBDIVISIONS: Small, representative breccia chips (,1, Fig. 1) were taken to make thin sections ,13 and ,14.

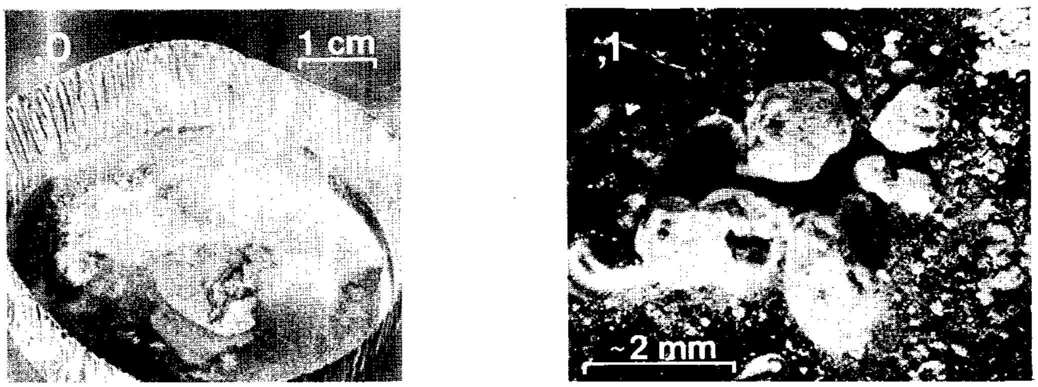


Figure 1. S-72-37798.

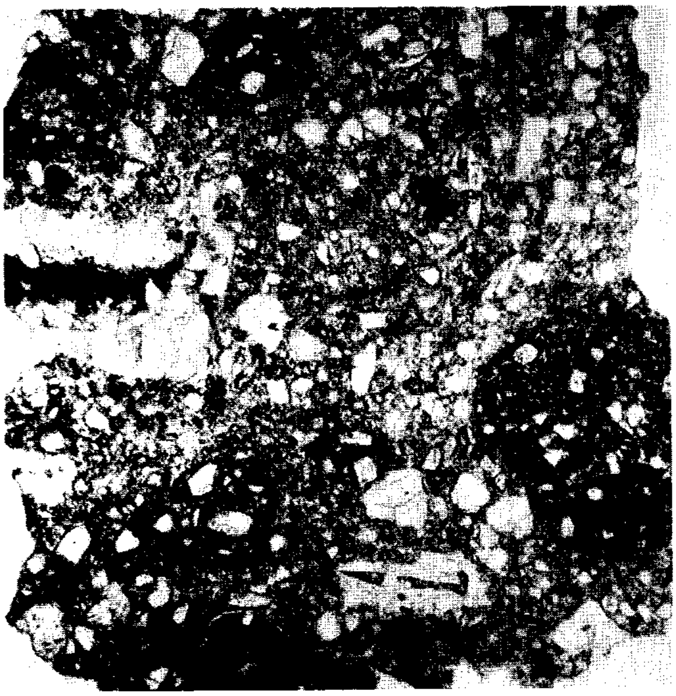


Figure 2. 67707,13, representative chip, ppl. width 2mm.

INTRODUCTION: 67708 is a friable white or pale gray breccia with a glass coat (Fig. 1). It was taken from a regolith sample collected halfway between the White Breccia boulders and House Rock.

Figure 1. S-72-37798, cup is 5cm in diameter.

67715 FINE-GRAINED IMPACT MELT 9.44 g

INTRODUCTION: 67715 is dark, coherent, fine-grained impact melt with abundant clasts (Fig. 1). Macroscopically it is homogeneous. It is a rake sample collected halfway between the White Breccia boulders and House Rock. It lacks zap pits but has a small amount of white coating.

PETROLOGY: 67715 consists of a microscopically heterogeneous, brown polymict breccia (Fig. 2). The matrix is fine-grained and even glassy, but contains plagioclase laths in places. Most of the lithic clasts are aphanitic impact melts which are difficult to distinguish from the matrix. Cataclastic anorthosite and fine-grained, plagioclase-rich breccia are also present as clasts. Most mineral fragments are angular, undeformed plagioclase.

PROCESSING AND SUBDIVISIONS: Only chips for thin section ,1 have been removed.

Figure 1. S-72-51251, mm scale.

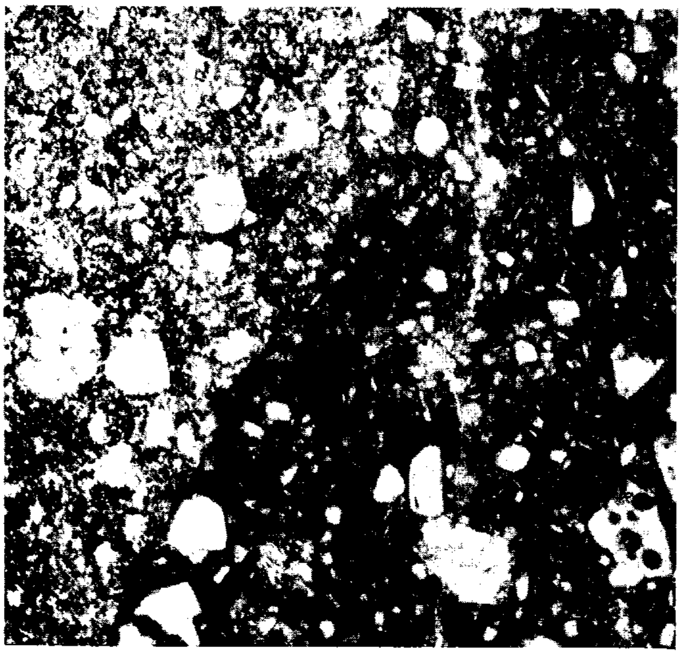


Figure 2. 67715,1, general view, ppl. width 2mm.

INTRODUCTION: 67716 is a polymict breccia (Fig.1) with a fine-grained impact melt matrix. It is coherent, irregularly shaped, and is partly covered with white material. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and has zap pits on one corner.

PETROLOGY: 67716 has a fine-grained matrix containing patches of oriented plagioclase laths (Fig.2) which are generally about 50 μm long. The amount of mafic material in the melt is very small. Much of the fine-grained material is clastic, particularly plagioclase, and embedded in the melt. About 5-10% of the thin section (,1) consists of angular to rounded clasts of plagioclase larger than 100 μm in diameter. One pink spinel grain (∿100 μm) is present.

PROCESSING AND SUBDIVISIONS: A single chip was removed to make thin section ,1.

Figure 1. S-72-49547, mm scale.

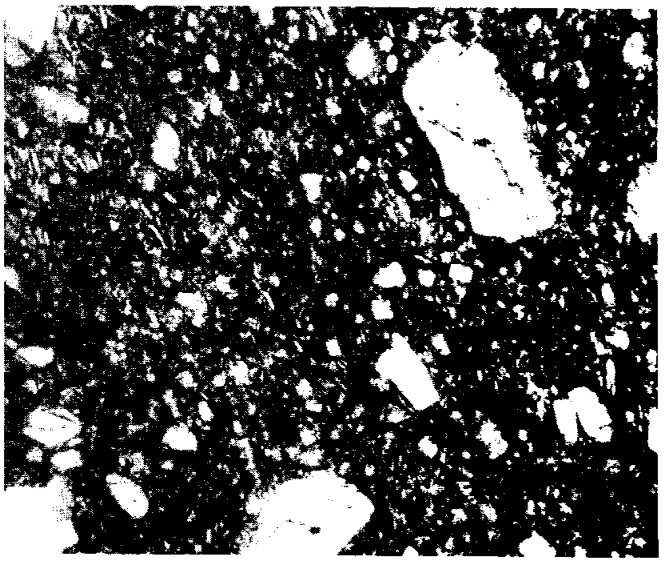


Figure 2. 67716,1, general view, ppl. width 2mm.

INTRODUCTION: 67717 is a coherent, dark, polymict breccia with a white coating up to 0.5 mm thick over three-quarters of the surface (Fig.1). It has a glassy to cryptocrystalline matrix. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and lacks zap pits.

PETROLOGY: 67717 is a heterogeneous, brown, polymict breccia with distinct textural zones (Fig.2). Steele and Smith (1973) note that "some areas appear melted in place". The matrix is glassy to cryptocrystalline, and the fine-grained material consists of roughly equal proportions of clasts (plagioclase > mafics) and finely divided mortar. Most clasts larger than 200 µm, of which there are few, are plagioclase, but some are basaltic impact melts.

PROCESSING AND SUBDIVISIONS: A single chip was taken to make thin section ,1.

Figure 1. S-72-49540, mm scale.

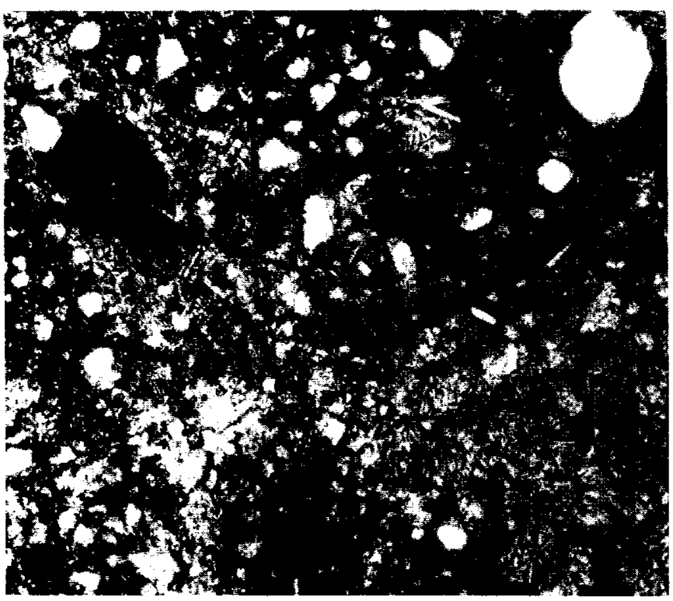


Figure 2. 67717,1, general view, ppl. width 2mm.

INTRODUCTION: 67718 consists of a core of coherent, dark, fine-grained breccia with a thick rind of a pale-colored, polymict breccia (Fig.1). The dark breccia is an impact melt. It is a rake sample collected halfway between the White Breccia boulders and House Rock and has a few zap pits.

PETROLOGY: The pale-gray material does not occur in the thin section (,1). The dark breccia is a heterogeneous, polymict, brown and fine-grained impact melt (Fig.2). Clasts are seriate down to extremely small sizes (few microns) and are bonded by about 35% cryptocrystalline mortar; only about 10% of the breccia consists of grains larger than 100 μm. Most clasts are plagioclase, and among the small clasts, mafic minerals are extremely rare .

PROCESSING AND SUBDIVISIONS: Small chips were taken to make thin section ,1.

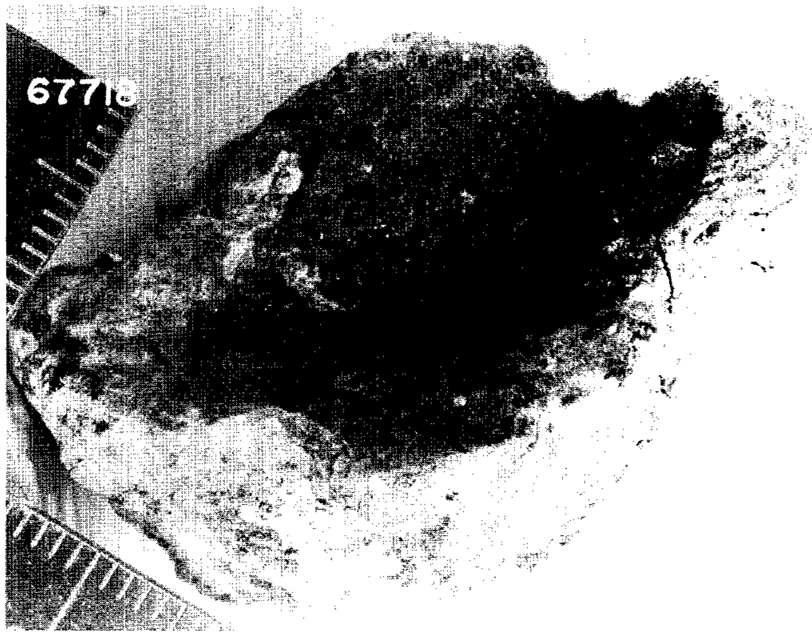


Figure 1. S-72-51242, mm scale.

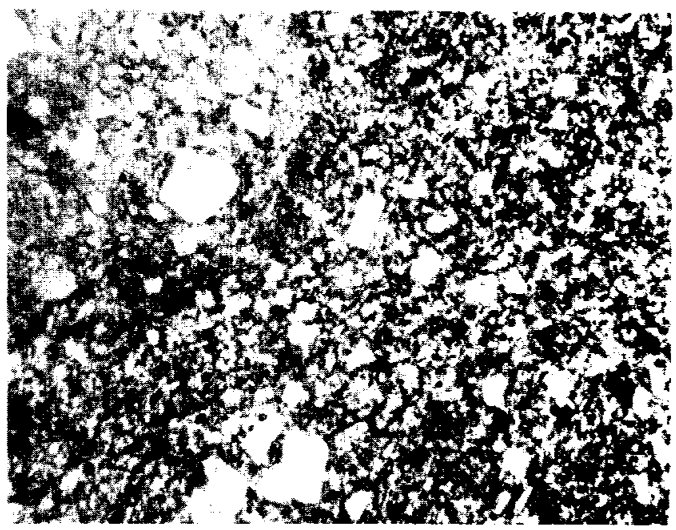


Figure 2. 67718,1, general view, ppl. width 2mm.

INTRODUCTION: 67719 is a coherent, subrounded, homogeneous and fine-grained breccia which is partly coated with white powder (Fig. 1). It is an impact melt. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and lacks zap pits.

PETROLOGY: 67719 consists of about 15% rounded plagioclase clasts embedded in a pale-brown matrix of plagioclase laths and fine clastic material (Fig. 2). Plagioclase laths, mainly about 50 μm long, are oriented generally in the same direction. The melt has little mafic material and mafic clasts are extremely rare: about 95% of the rock is plagioclase. Troilite and Fe-metal are present. The plagioclase clasts are unshocked and many have thin (10 μm) overgrowth rims.

PROCESSING AND SUBDIVISIONS: A single chip was removed for thin section ,1.

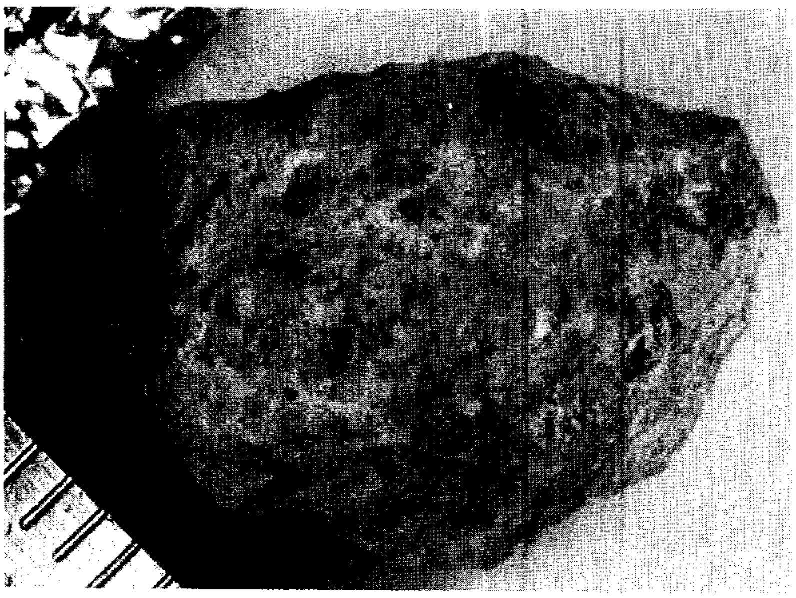


Figure 1. S-72-51248, mm scale.

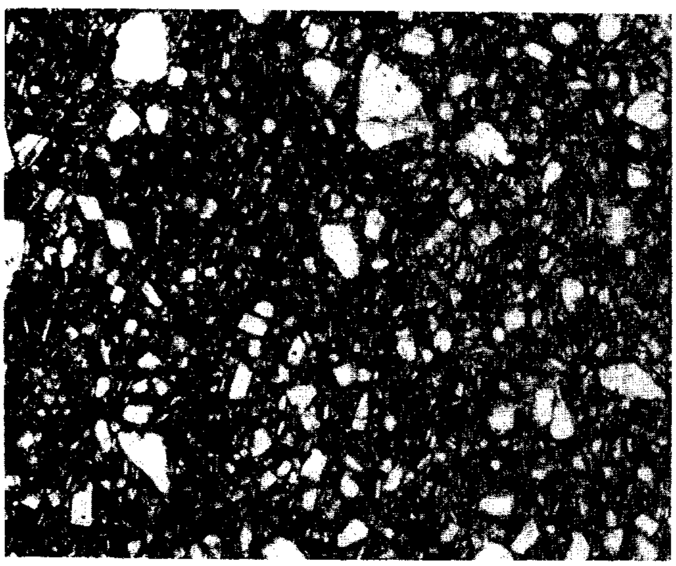


Figure 2. 67719,1, general view, ppl. width 2mm.

INTRODUCTION: 67725 is a coherent, light gray breccia containing pale-colored clasts (Fig. 1). The matrix is fine-grained and the sample is partly coated with glass. It is a rake sample collected halfway between the White Breccia boulders and House Rock and has zap pits on all but one (broken) surface.

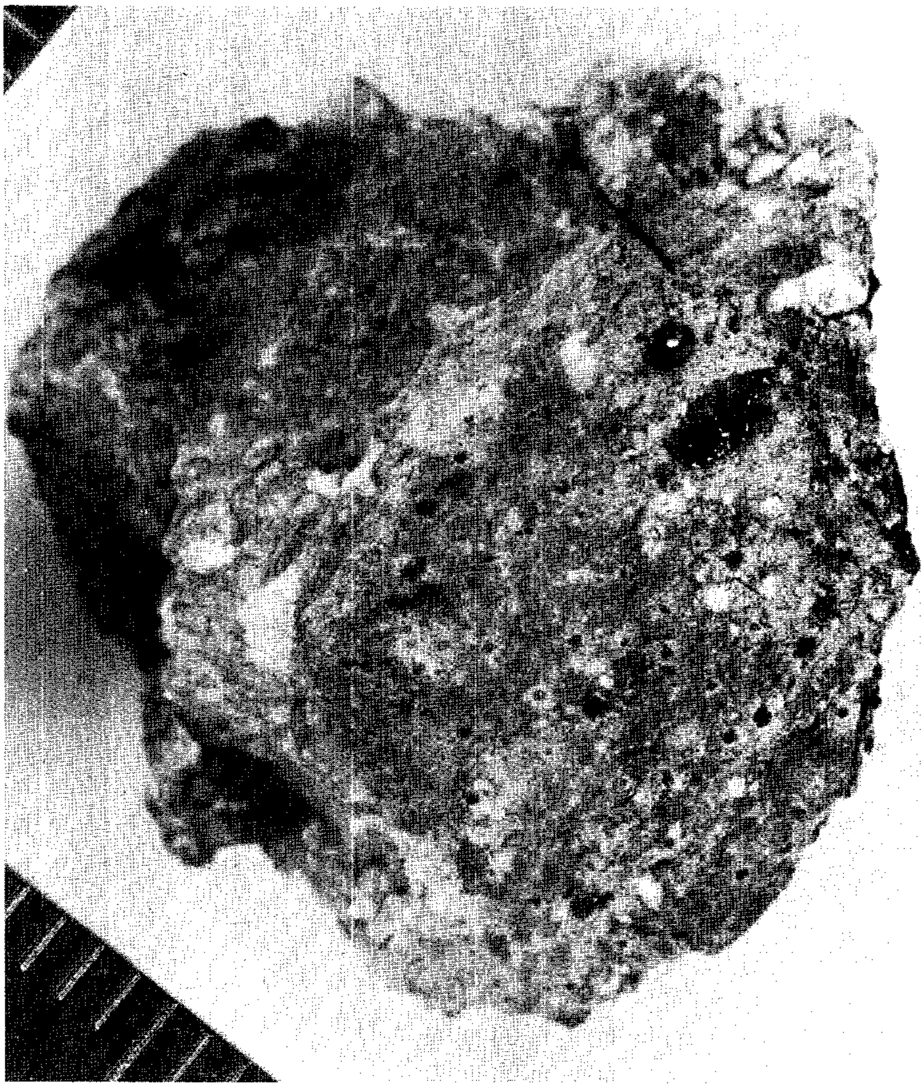


Figure 1. S-72-51054, mm scale.

INTRODUCTION: 67726 is a coherent, fine-grained, light gray breccia containing white clasts (Fig. 1). It is a rake sample collected halfway between the White Breccia boulders and House Rock, and has several zap pits.

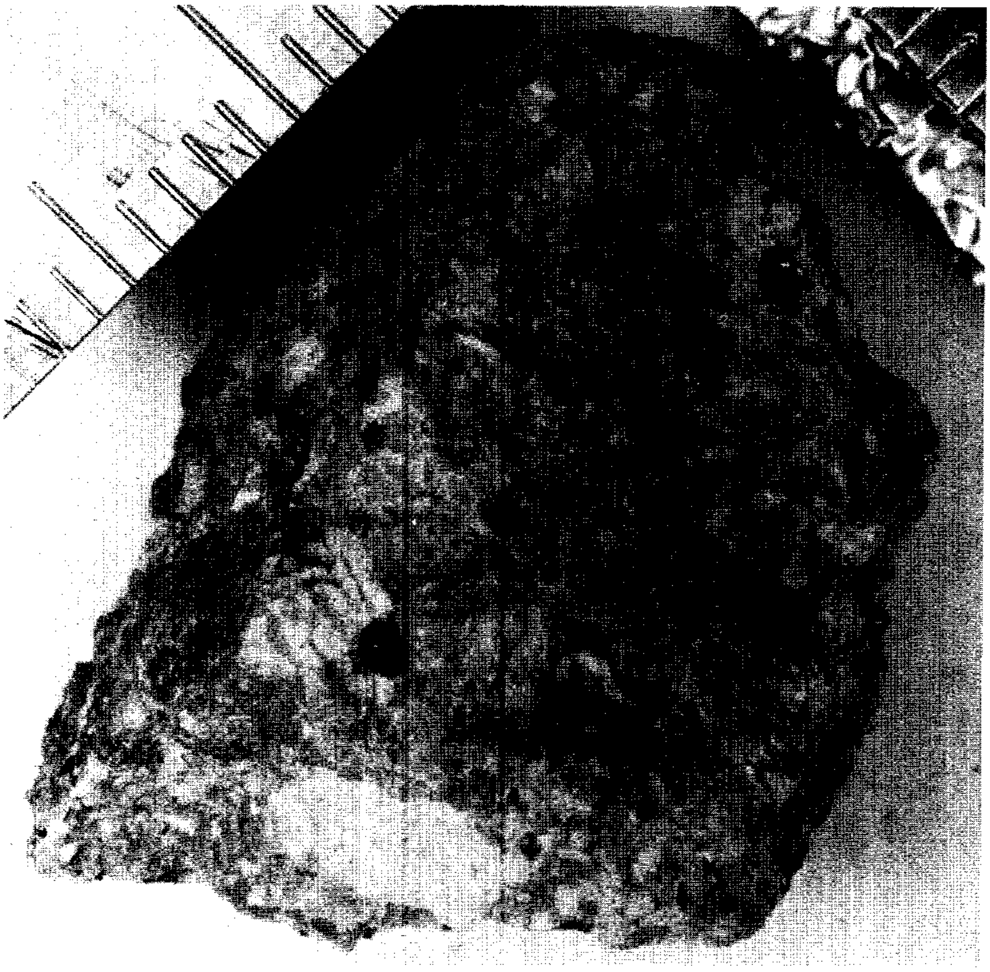


Figure 1. S-72-51278, mm scale.

INTRODUCTION: 67727 is a dark gray, coherent, fine-grained breccia containing white clasts (Fig. 1). The matrix contains a few vesicles. It is a rake sample collected halfway between the White Breccia boulders and House Rock and has a few zap pits.

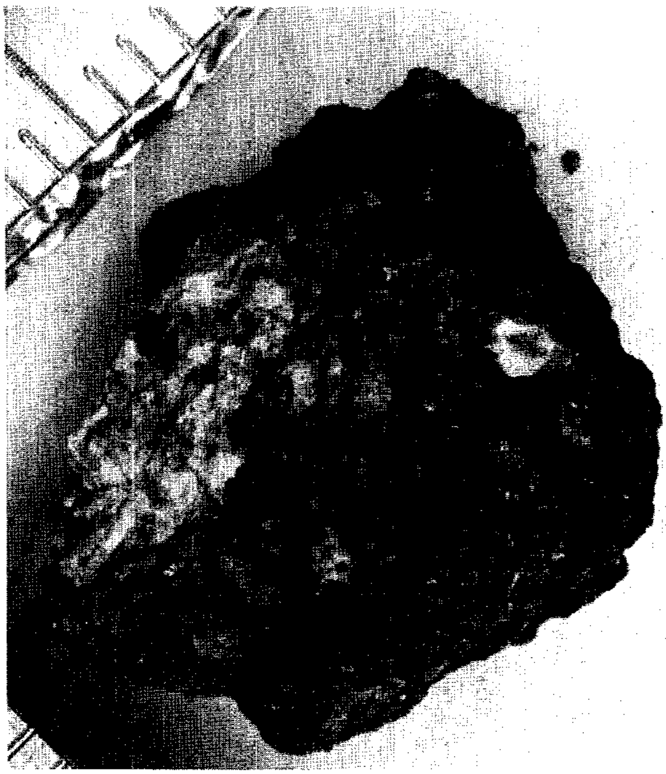


Figure 1. S-72-49565, mm scale.

INTRODUCTION: 67728 is a coherent, vesicular, fine-grained breccia containing a few white clasts. The matrix appears to be glass in part. It is a rake sample collected halfway between the White Breccia boulders and House Rock.

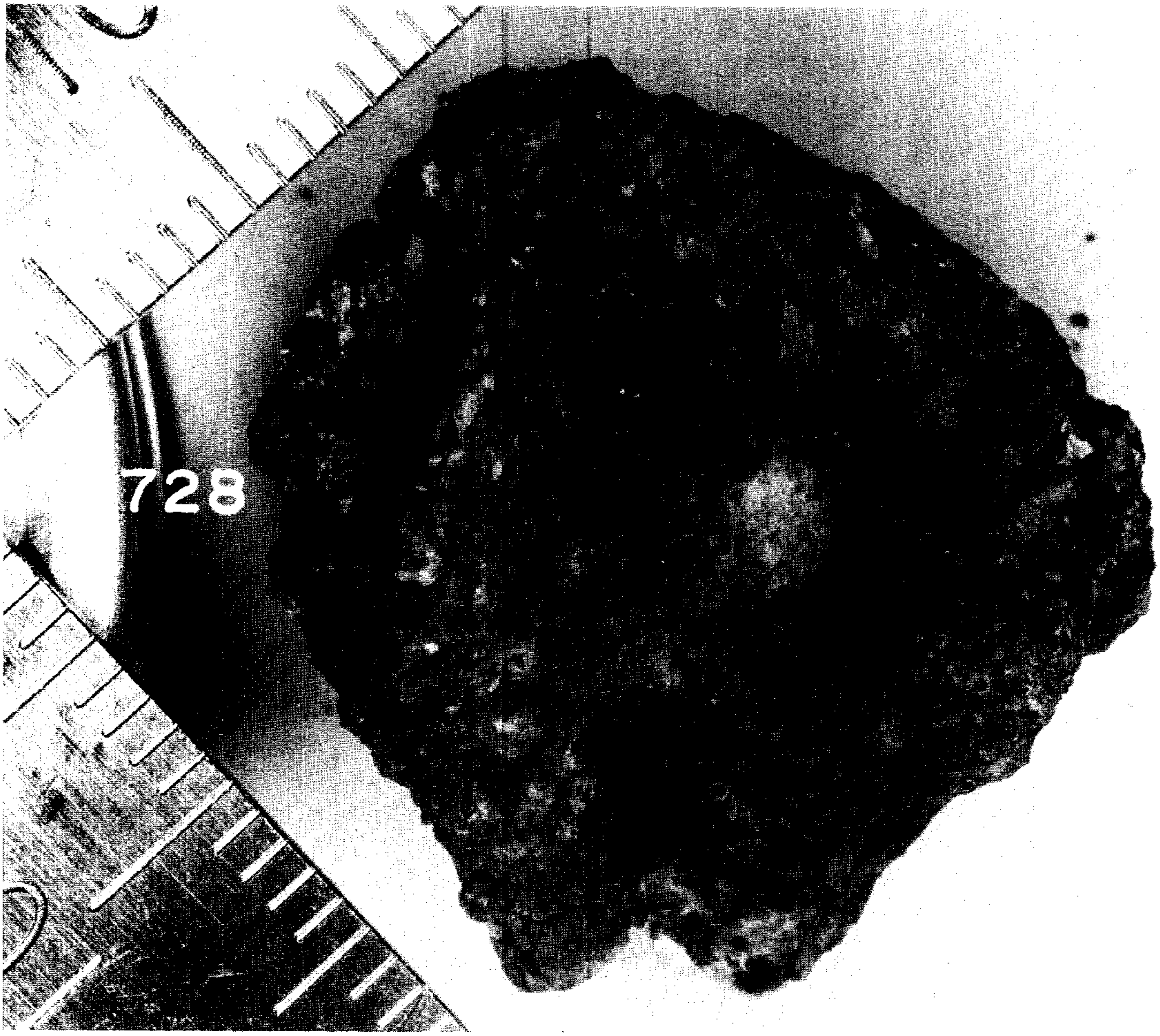


Figure 1. S-72-49545, mm scale.

INTRODUCTION: 67729 is a dark gray, irregular, coherent and vesicular glass (Fig.1) largely devitrified or partly crystalline. It contains a few prominent clasts (Figs. 1,3,4) which are basaltic impact melts. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and has many zap pits on one side.

Figure 1. S-80-28171, smallest scale subdivision 0.5mm.

PETROLOGY: 67729 is mainly a vesicular, brown, glassy material - no clear glass is present, all having devitrified or partly crystallized into acicular plagioclases (Fig.2). In places the glass is flow-banded and vein-like and contains clasts of breccia and impact melts towards which the glass is chilled.

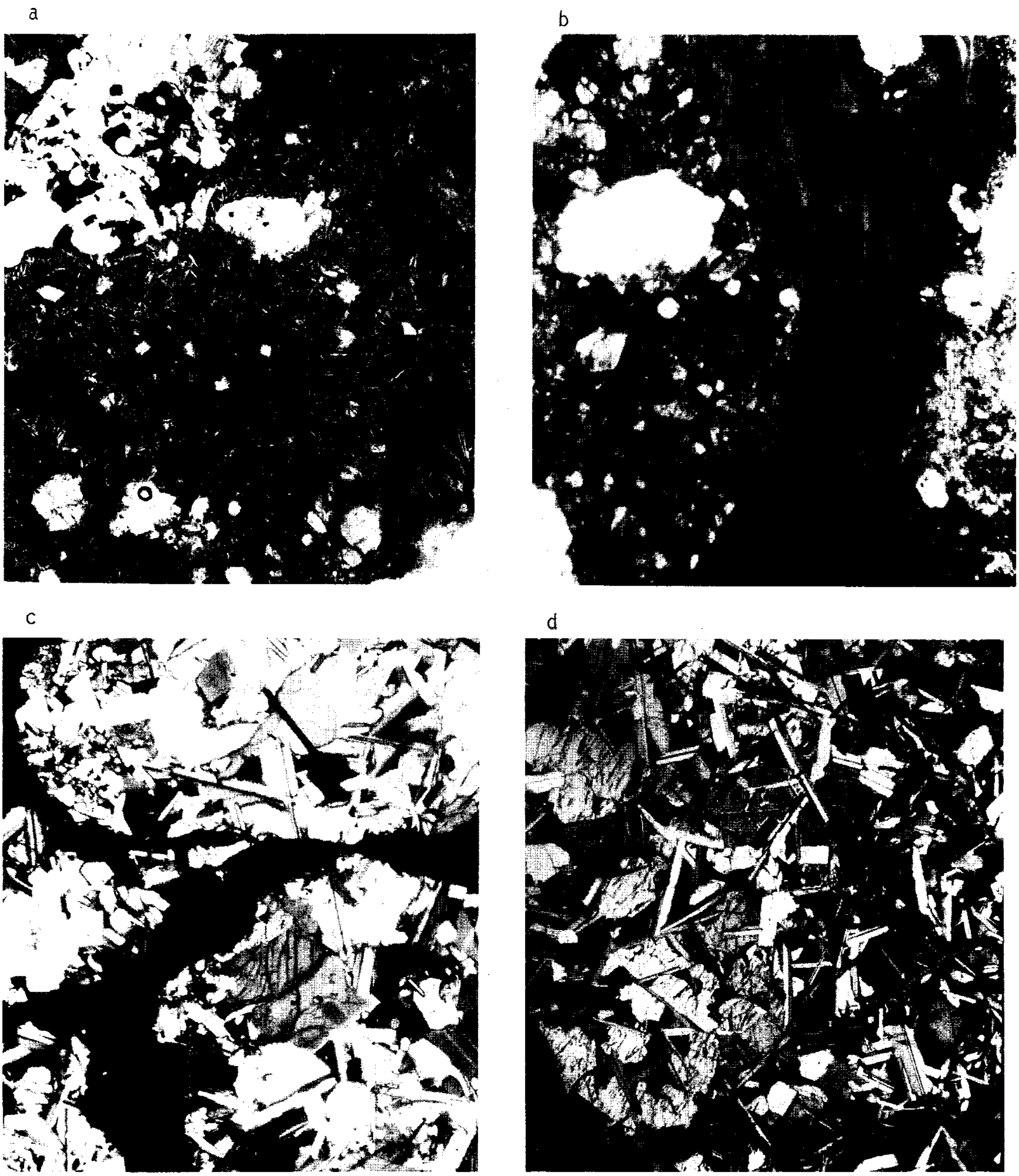


Figure 2. a) 67729,16, melt matrix, ppl. width 2mm.
b) 67729,1, melt matrix, ppl. width 2mm.
c) 67729,14, white clast, xpl. width 2mm.
d) 67729,15, gray-green clast, xpl. width 2mm.

Three prominent clasts larger than a centimeter are basaltic impact melts. The large white clast (,4) macroscopically contains ∿ 30% yellow mafic minerals. In thin section it has lathy plagioclase as well as many anhedral plagioclases, most less than 500 μm, and mafic minerals less than 1 mm. Overall its texture is subophitic to granular (Fig.2) and it contains interstitial Fe-metal, troilite, phosphate, cryptocrystalline material and glass. The large green-gray clast (,9) is an ophitic basalt with a well-developed plagioclase network enclosed by olivines up to 3 mm in diameter (Fig.2). Interstitial brown glass is conspicuous. The third clast (,6) has not been sectioned but is macroscopically similar to ,9.

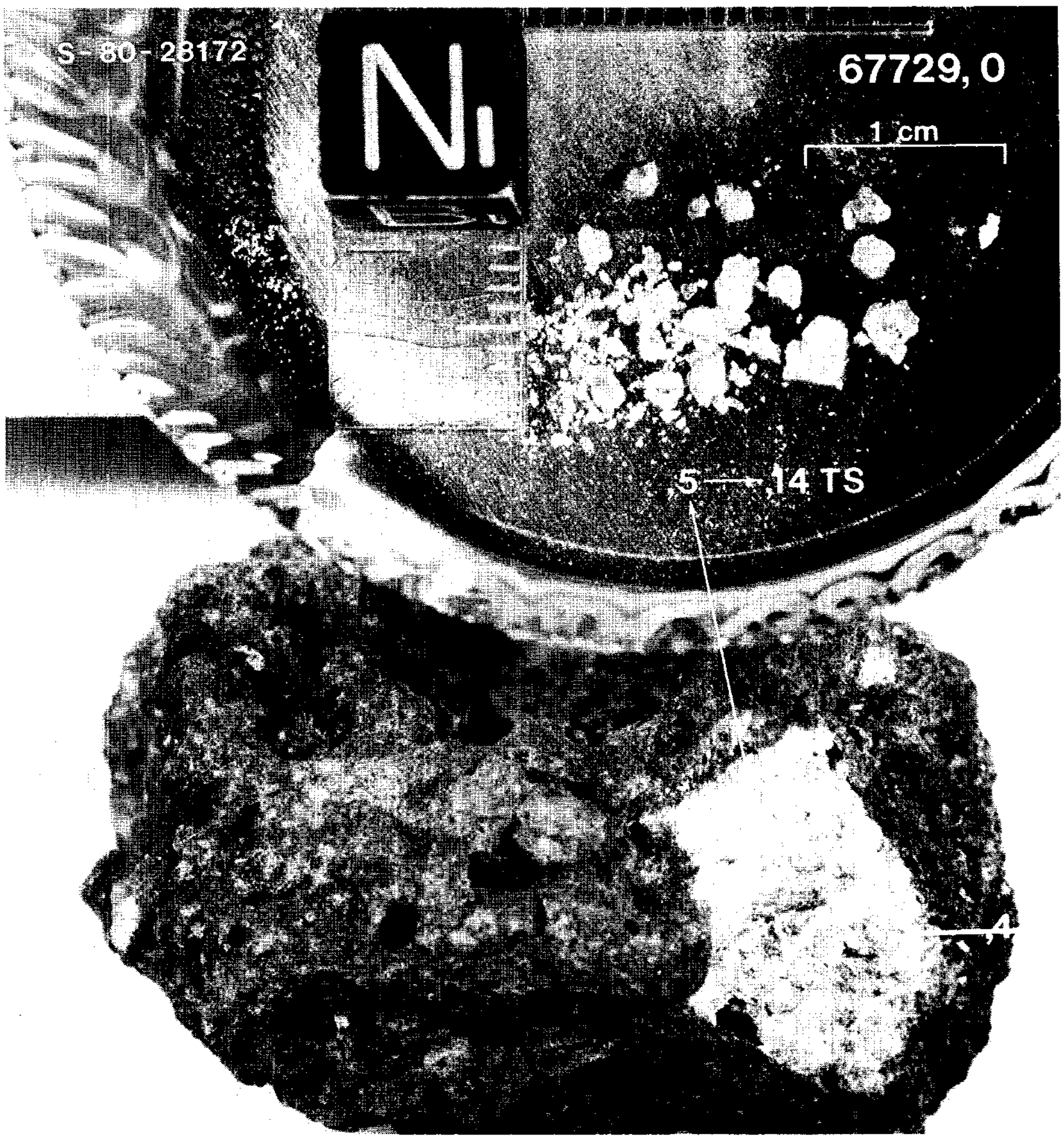


Figure 3.

PROCESSING AND SUBDIVISIONS: Initially, small chips of matrix glass were taken to make thin section ,1. For the present study, further chips of matrix glass and clasts were taken for the sections, as shown in Figures 3 and 4.

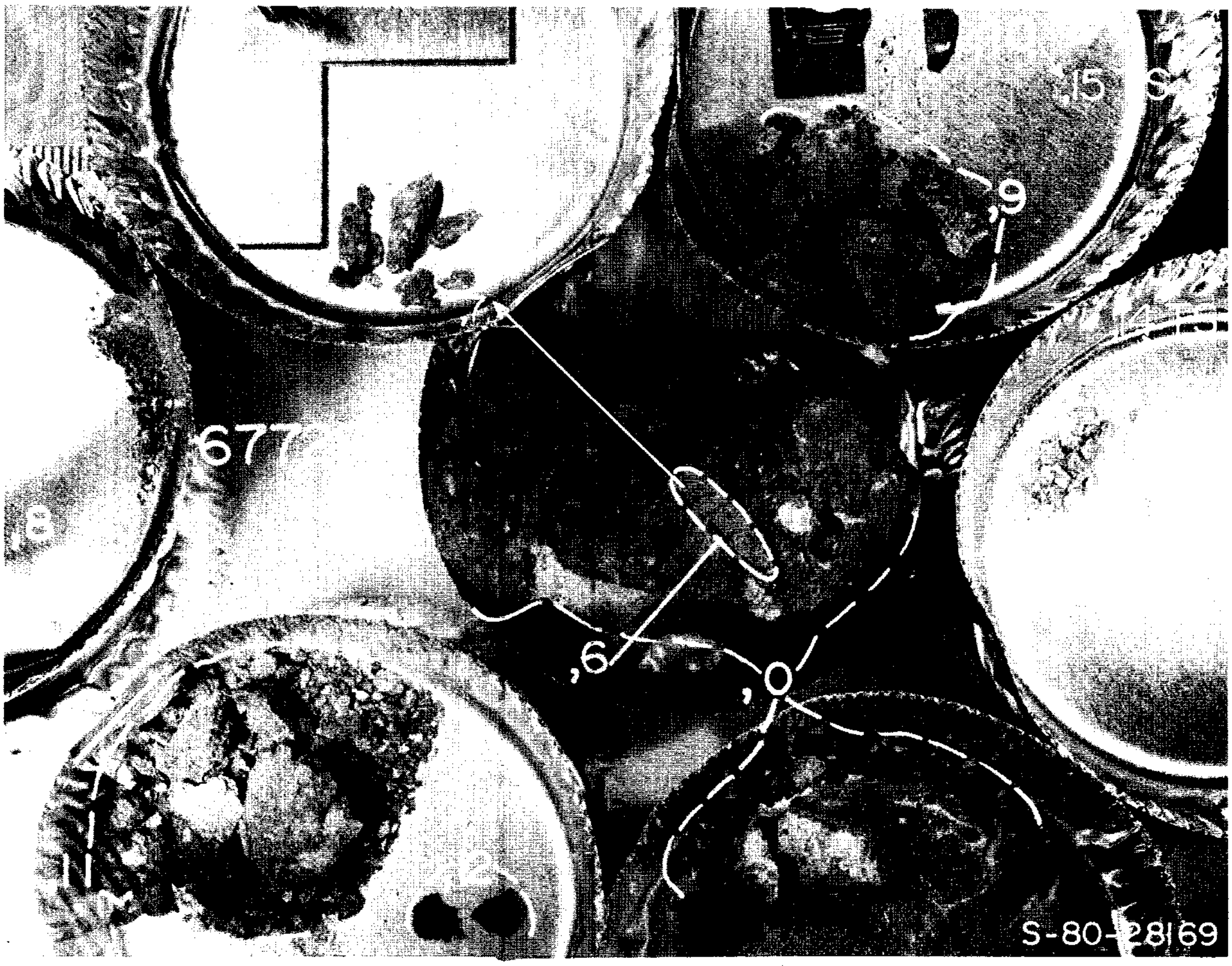


Figure 4. mm scale.

67735 GLASSY IMPACT MELT BRECCIA 13.30 g

INTRODUCTION: 67735 is a coherent, fine-grained breccia (Fig.1) with a brown glassy or cryptocrystalline matrix. It has a coating of varied character. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and lacks zap pits.

PETROLOGY: Steele and Smith (1973) refer to 67735 as a "soil breccia; some layering present". 67735 has a brown-glassy or cryptocrystalline matrix enclosing fragments of plagioclase which are rounded on the corners (Fig.2). Some roughly defined banding is caused by color and grain-size differences, but the breccia matrix probably resulted from a single impact in that it is not patchily bound like an agglomeration such as regolith. The clasts are not shocked. Some crushed lithic fragments, including aphanitic breccias and crushed granulites (or other coarse feldspathic rocks), are present.

PROCESSING AND SUBDIVISIONS: A chip from one end was divided into two pieces to make thin sections ,13 and ,14 (potted butt ,1)and ,15(a second potted butt).

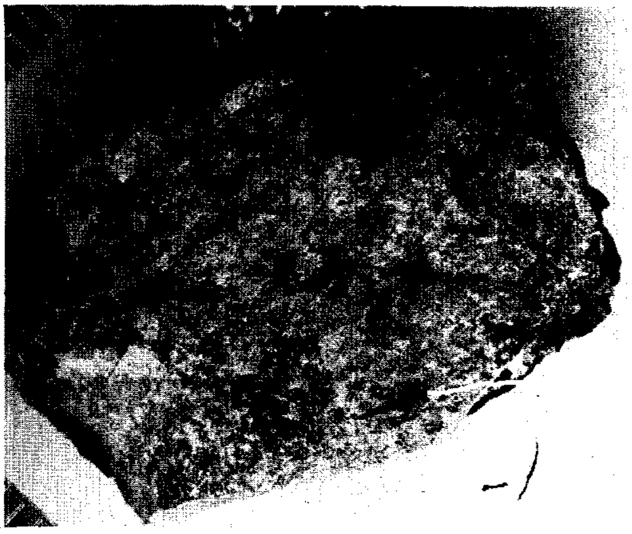


Figure 1. S-72-51258, mm scale.

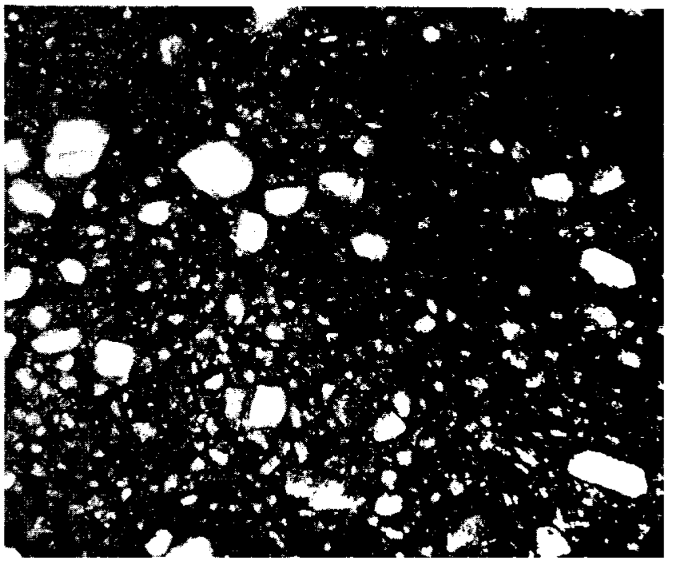


Figure 2. 67735,15, general view, ppl. width 2mm.

INTRODUCTION: 67736 is a dark gray, coherent, and fine-grained breccia (Fig. 1), similar in appearance to known poikilitic and fine-grained subophitic impact melts. It contains a few vesicles and some white plagioclase clasts. It consists of about 50% plagioclase, 45% gray mineral (pyroxene?) and 5% yellow mineral (olivine?). Conspicuous is a clast of spinel troctolite containing roughly equal amounts of yellow olivine and white plagioclase, with a few burgundy-colored spinels (Fig. 1). The grain sizes of this clast are up to 1 mm.

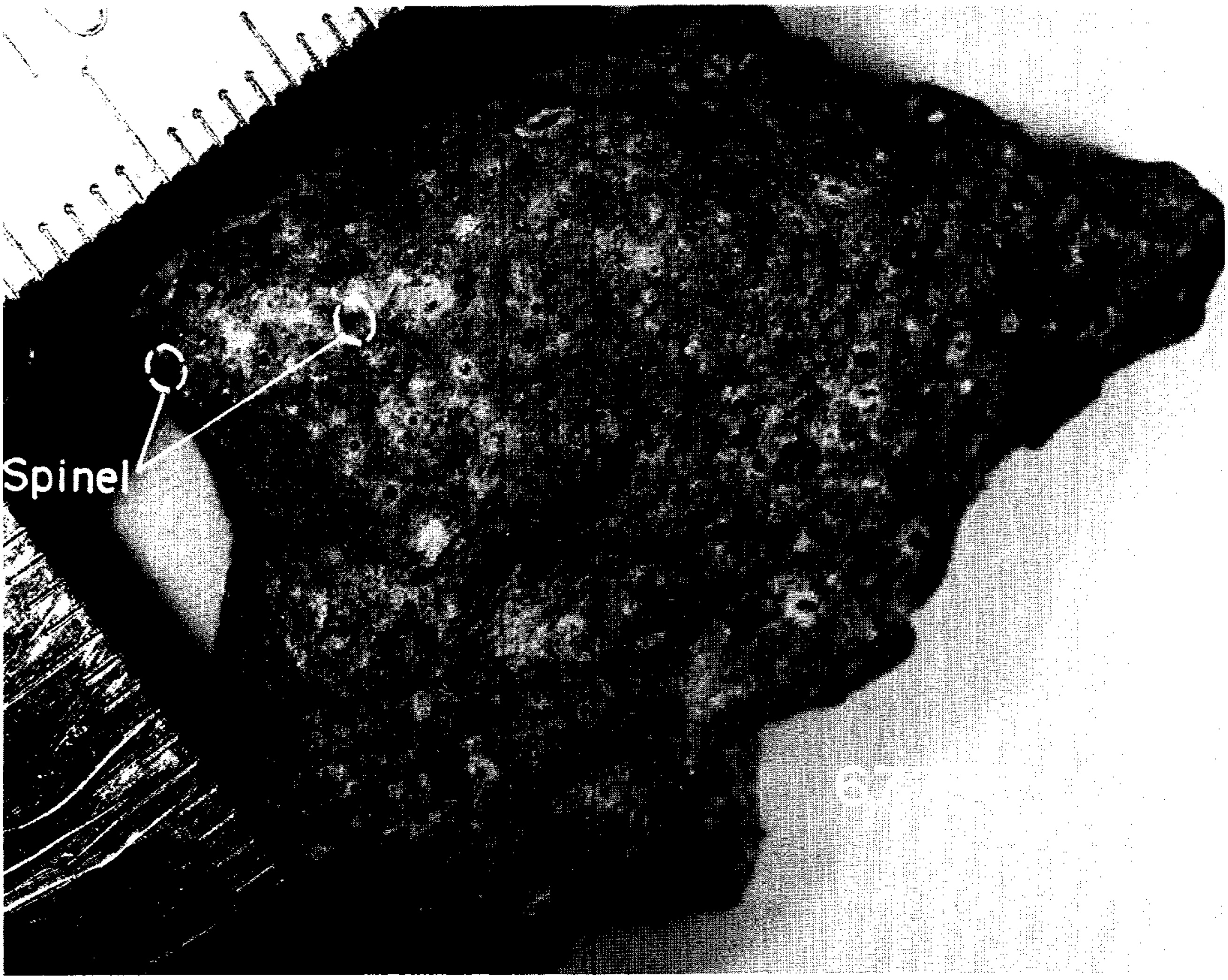


Figure 1. S-80-28529, mm scale.

INTRODUCTION: 67737 is a coherent, dark, fine-grained rock (Fig. 1), probably an impact melt. Clasts are inconspicuous but a white coating patchily covers the surface. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and lacks zap pits.

Figure 1. S-72-49557, mm scale.

INTRODUCTION: 67738 is a coherent,dark,fine-grained impact melt which is macroscopically homogeneous (Fig.1). Part of the surface is coated with pale-colored powder. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and lacks zap pits.

PETROLOGY: 67738 is a pale-brown polymict breccia (Fig.2). It has a seriate size distribution of clasts and about 20-30% of the rock is a fine-grained mortar which is probably of melt origin. Very little mafic material is present and opaque minerals and Fe-metal grains are almost absent.

PROCESSING AND SUBDIVISIONS: Several small chips were removed to make thin section ,1.

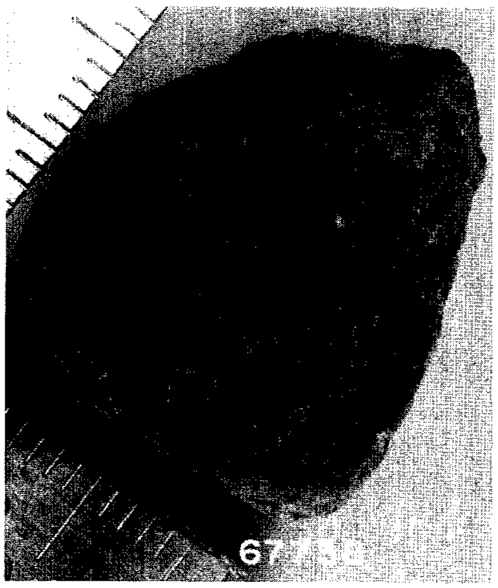


Figure 1. S-72-51283, mm scale.

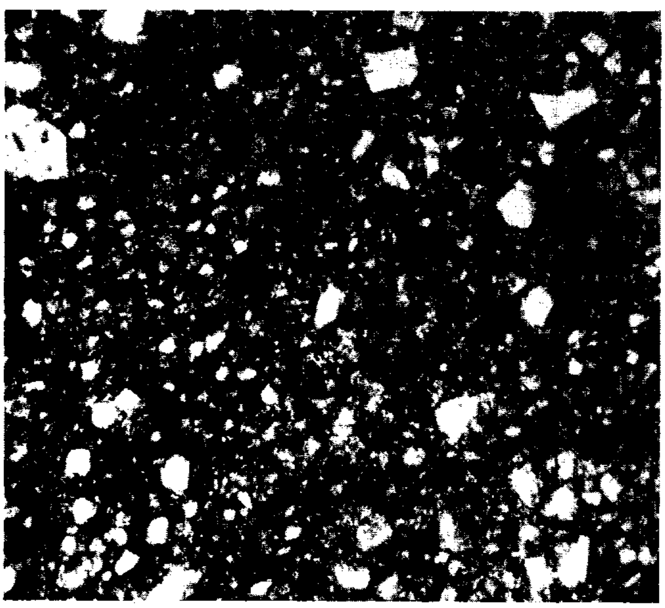


Figure 2. 67738,1 general view, ppl. width 2mm.

INTRODUCTION: 67739 is a coherent, light-colored polymict breccia (Fig.1) with a fine-grained, probably impact melt, matrix. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and lacks zap pits.

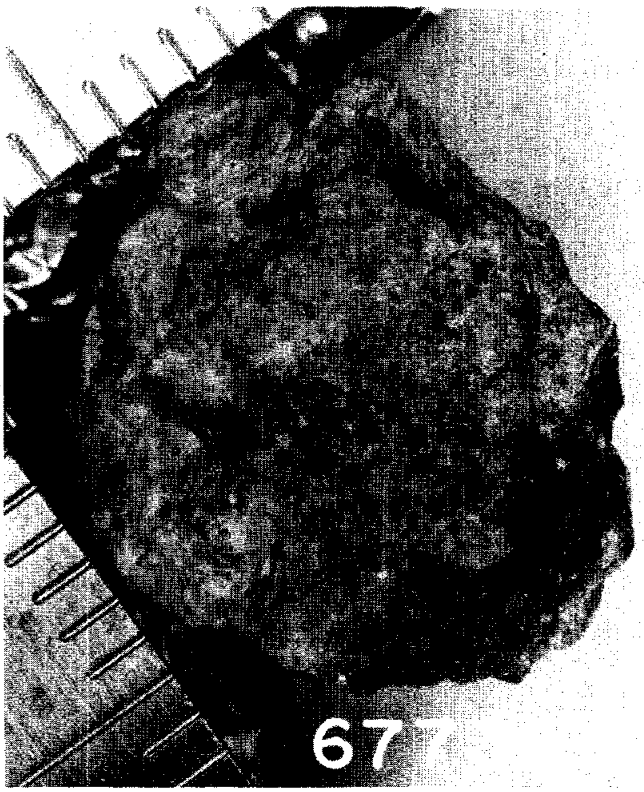


Figure 1. S-72-51272, mm scale.

PETROLOGY: Steele and Smith (1973) refer to 67739 as "breccia; numerous plagioclase-olivine clasts" with about 60% matrix (defined as material less than 5 µm in diameter). They report microprobe data for pyroxenes, olivines and plagioclases.

67739 is a homogeneous, pale brown polymict breccia (Fig.2). About 10% of the rock is clasts larger than 200 µm, the rest is seriate down to extremely fine. The fine-grained mortar, which is at least 30% of the rock, is probably impact melt or devitrified glass, and binds plagioclase grains (20 µm and smaller). Mafic grains and opaque minerals are extremely rare. The pyroxene analyses shown in Figure 3 are for matrix fragments.

Conspicuous are a few granoblastic and poikiloblastic impactite fragments which have about twice as much plagioclase as mafic minerals (Fig. 2). The mafic minerals are less than 100 μm except for one poikiloblastic mineral which is about 300 μm across. Plagioclases are 100-200 μm, and a few have mafic mineral "necklaces". Steele and Smith (1973) report that the mafic mineral in these fragments is olivine (Fo_{68}); however, the poikiloblast has lamellae in it which are apparently exsolved, and it could be augite.

Plagioclase mineral clasts are unshocked or lightly shocked and subangular. Microprobe analyses of plagioclase are reported by Steele and Smith (1973); they range from An_{98}-An_{90} (Fe 0.2% or less) but which plagioclases were analyzed is not reported.

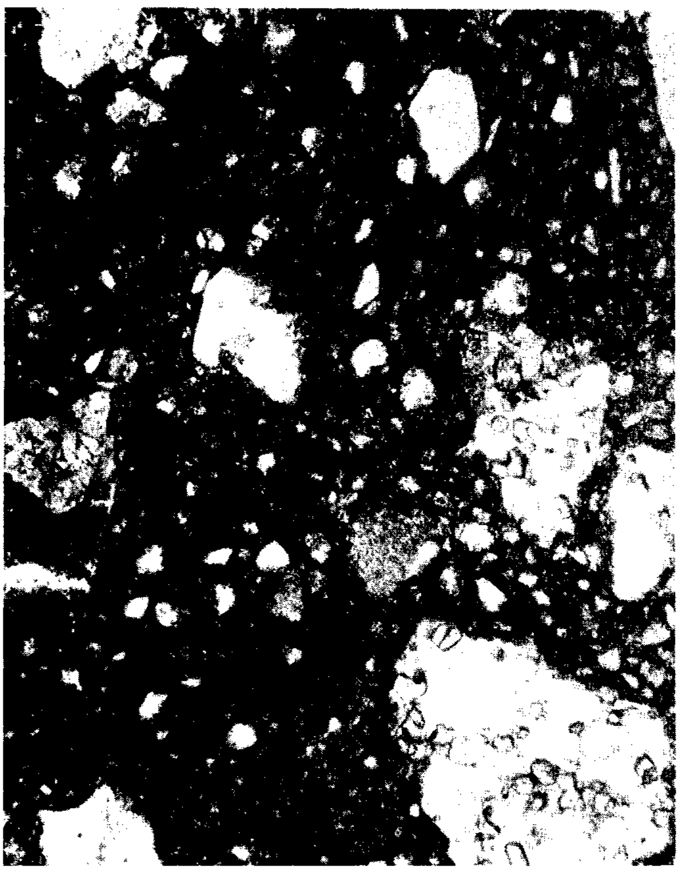


Figure 2. 67739,1 general view, ppl. width 2mm.

PROCESSING AND SUBDIVISIONS: A single chip was taken to make thin section ,1.

67745 FINE-GRAINED OR GLASSY IMPACT MELT 3.53 g

INTRODUCTION: 67745 is a coherent, fine-grained breccia (Fig.1) whose matrix appears to be glassy or fine-grained impact melt. It is a rake sample collected halfway between the White Breccia boulders and House Rock. It lacks zap pits.

PETROLOGY: 67745 is a homogeneous, fine-grained polymict breccia (Fig.2). Its matrix consists of tiny plagioclase clasts bound by an extremely fine-grained mortar of glass or melt; some plagioclase laths are present. Most clasts are plagioclase with a few larger than 200 μm, usually unshocked. There are very few mafic clasts. One 100 μm-diameter feldspathic granulite clast is present in thin section ,1. In some cases, the clast boundaries are indistinct or ragged.

PROCESSING AND SUBDIVISIONS: A single chip was taken to make thin section ,1.

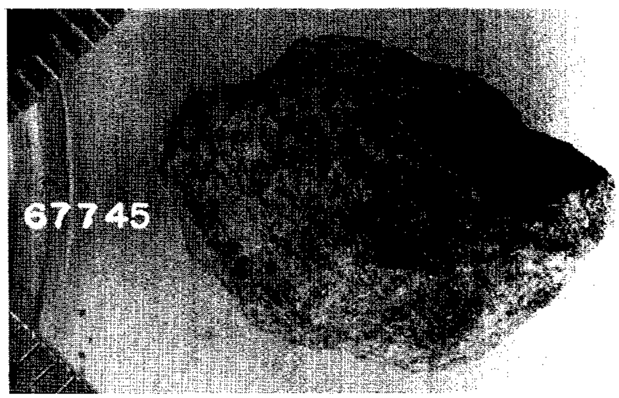


Figure 1. S-72-51256, mm scale.

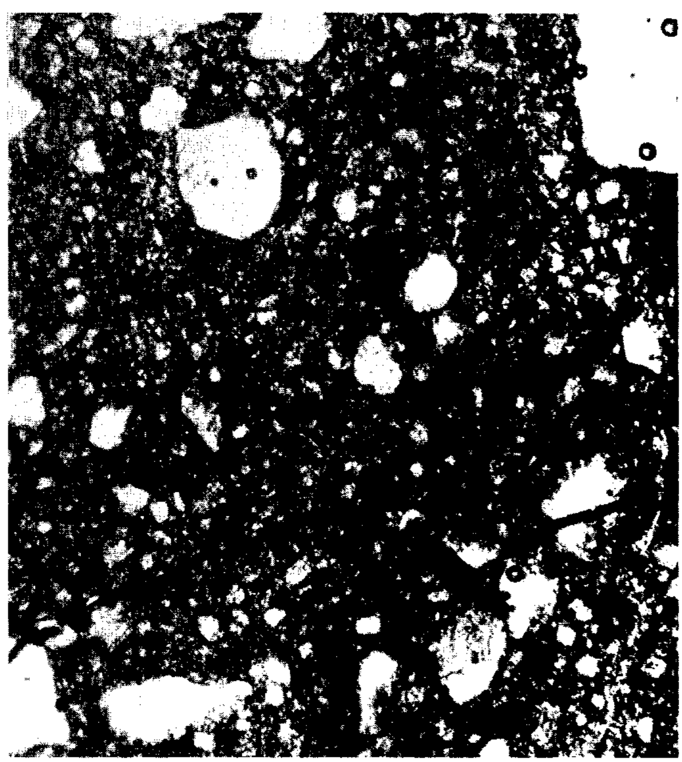


Figure 2. 67745,1, general view, ppl. width 2mm.

INTRODUCTION: 67746 (Fig. 1) is a light gray, homogeneous, poikiloblastic noritic anorthosite. It has white powder on most of its surface. It is a rake sample collected halfway between the White Breccia boulders and House Rock and lacks zap pits.

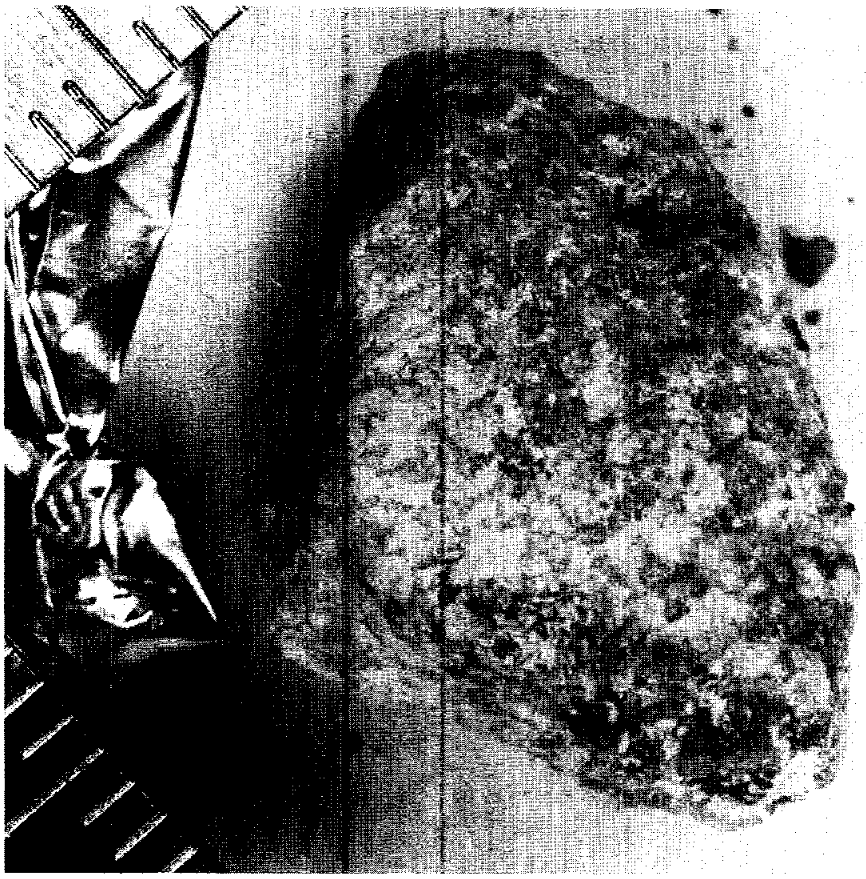


Figure 1. S-72-49567, mm scale.

PETROLOGY: 67746 has a coarse poikiloblastic (or poikilitic?) texture. Some pyroxene poikiloblasts are at least 1.5 mm in diameter and enclose rounded plagioclase grains less than 100 μm in diameter (Fig. 2). In between poikiloblasts, plagioclases form a granoblastic texture with grain sizes up to 1 mm but mainly 100-300 μm; many of the larger grains are strained. Other minerals present include olivine, ilmenite, Fe-metal, sulfide, and other opaque phases. Plagioclase occupies about 80% of the sample.

Microprobe analyses by Hansen et al. (1979a,b, and unpublished) have pyroxenes En_{75-74} Wo_{3-4}, olivine Fo_{75}, plagioclases An_{94}, ilmenite 6-7% MgO, and Fe-metal ~ 7% Ni.

PROCESSING AND SUBDIVISIONS: Several representative small chips were taken to make thin section ,1.

Figure 2. 67746,1, general view, xpl. width 2mm.

INTRODUCTION: 67747 is a homogeneous, medium gray impact melt (Fig. 1) with an ophitic texture. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and has a few zap pits on one side.

PETROLOGY: Steele and Smith (1973) refer to 67747 as "feldspathic basalt; 10% poikilitic olivine" and provide microprobe data. It contains about 80% plagioclase in laths up to about 750 µm long, ophitically enclosed in olivine (Fig. 2). One olivine grain is optically continuous over nearly the entire thin section (,1) which is 5x3 mm. Optically zoned pyroxene is interstitial to plagioclase laths and adjacent to mesostasis areas. The latter contain brown glass, ilmenite, Fe-metal, sulfide, and various other minor phases. The plagioclases are zoned from ∿ An_{95-75} (Fig. 4 of Steele and Smith, 1973). Analyses of mafic minerals are shown in Figure 3.

PROCESSING AND SUBDIVISIONS: A single chip was taken to make thin section ,1.

Figure 1. S-72-49576, mm scale.

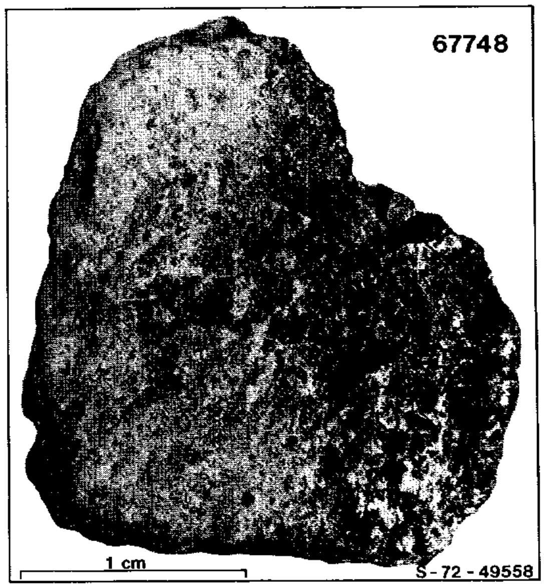
Figure 2. 67747,1 general view, xpl. width 2mm.

INTRODUCTION: 67748 is a coherent, dark,homogeneous breccia (Fig.1) which is fine-grained and apparently bonded by melt. A white powder partially coats the surface. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and lacks zap pits.

PETROLOGY: 67748 is a fine-grained, homogeneous, and plagioclase-rich breccia (Fig.2). The matrix is fine-grained but plagioclase laths, up to 100 μm long and very roughly aligned, demonstrate the presence of melt. Virtually all clasts are slightly rounded and unshocked plagioclases; nearly all these are less than 200 μm in diameter. Mafic phases are rare (∿ 5%?).

PROCESSING AND SUBDIVISIONS: A few small chips were used to make thin section ,1.

Figure 1.



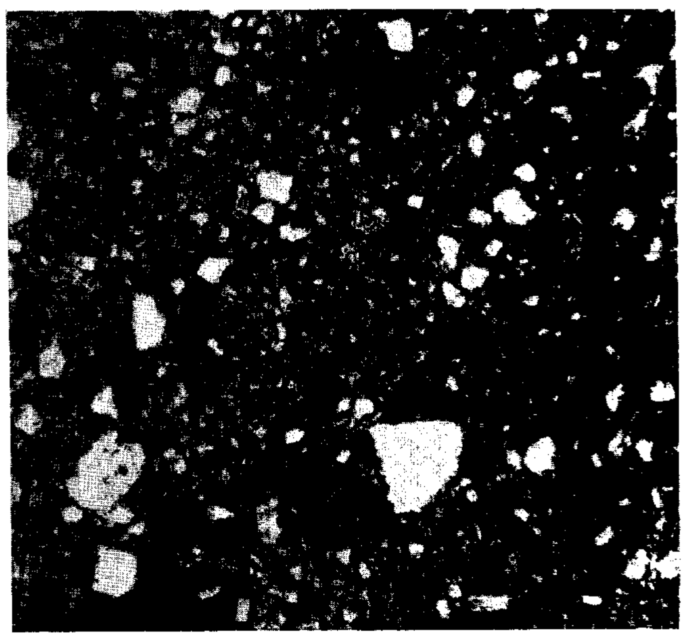


Figure 2. 67748,1, general view, ppl. width 2mm.

INTRODUCTION: 67749 is a pale-colored, heterogeneous, moderately friable breccia (Fig.1). It contains a distinct clast of basaltic-textured iron-rich KREEP. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and has many zap pits on most of its surface.

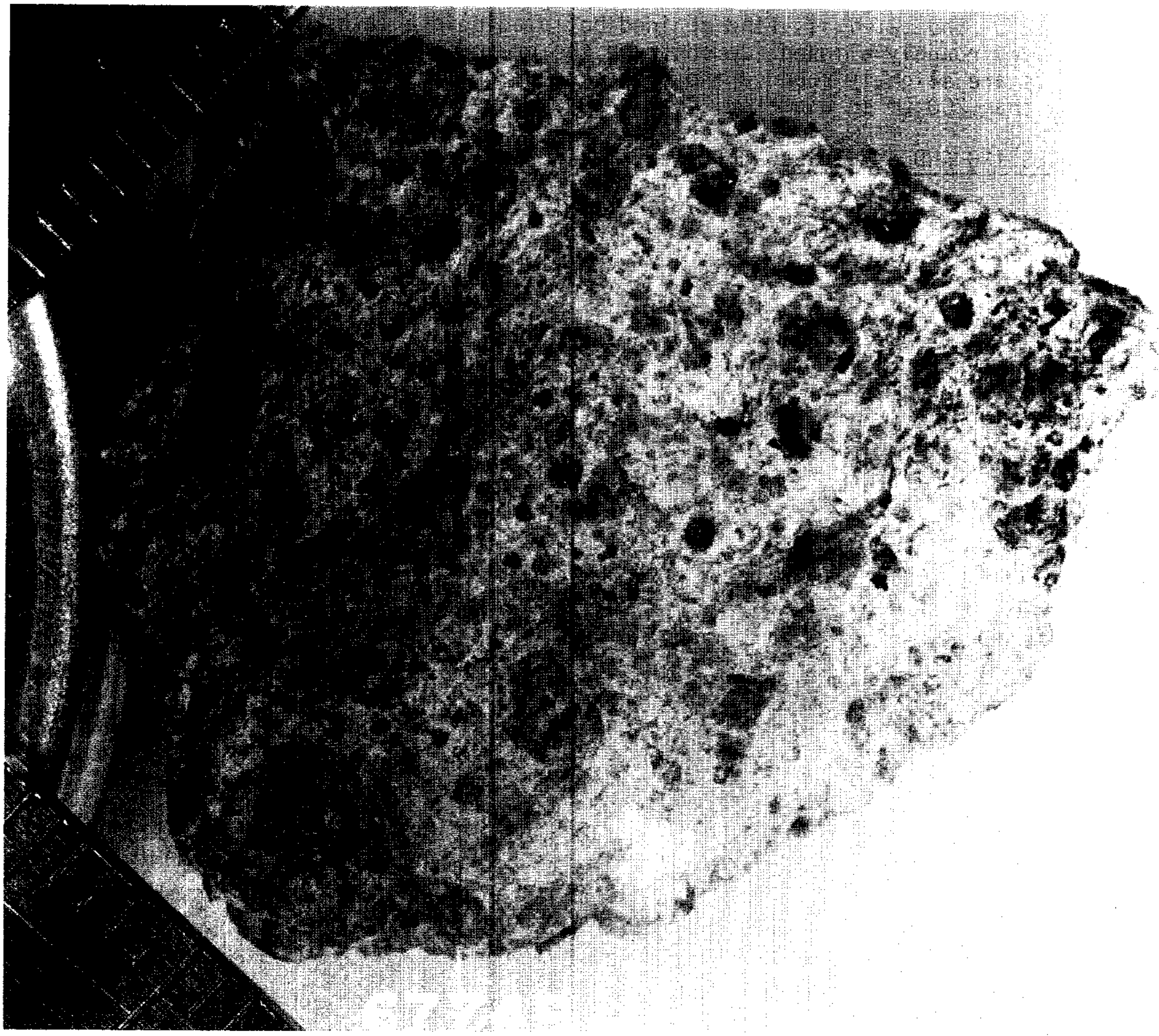


Figure 1. S-72-49570, mm scale.

PETROLOGY: Steele and Smith (1973) refer to 67749 as a "partly recrystallized breccia; one large KREEP-basalt clast" with ∿ 30% matrix (defined as material less than 5 μm in diameter).

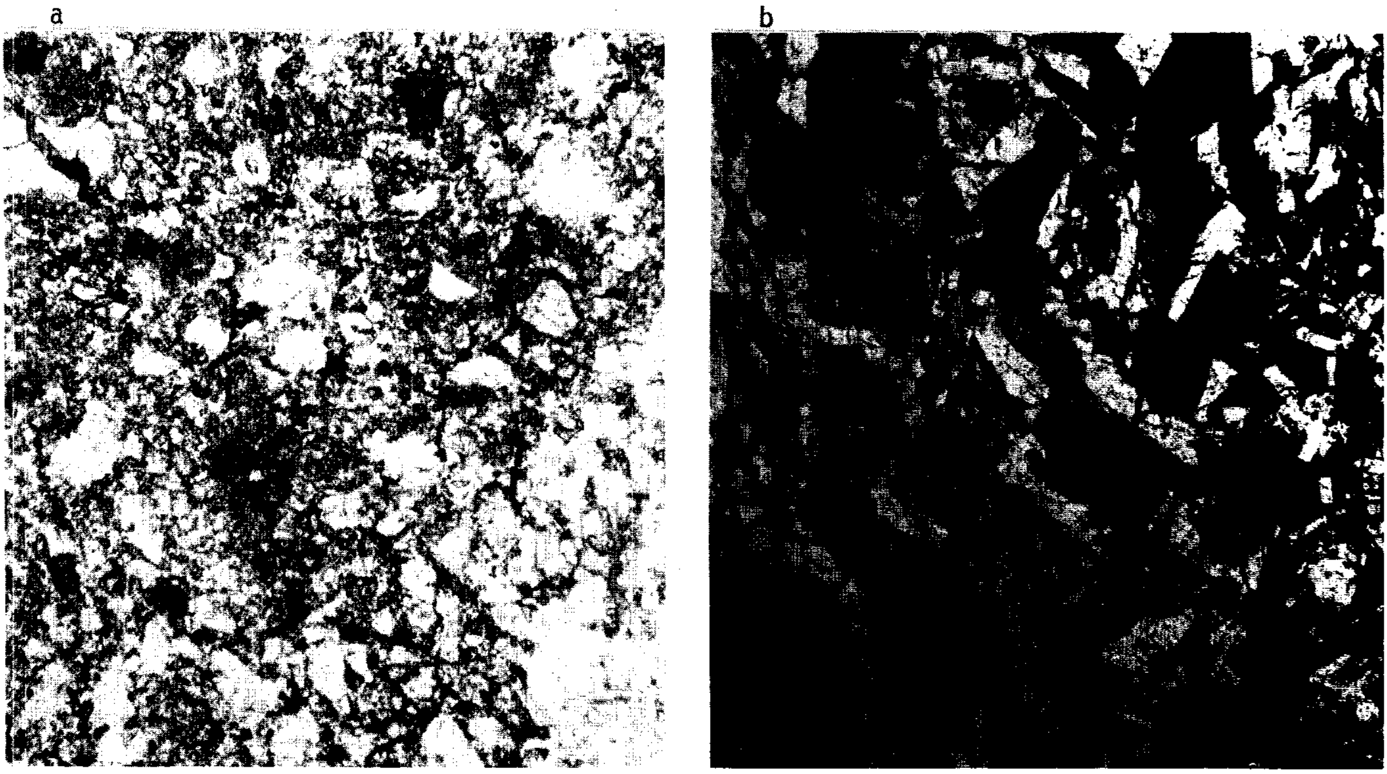
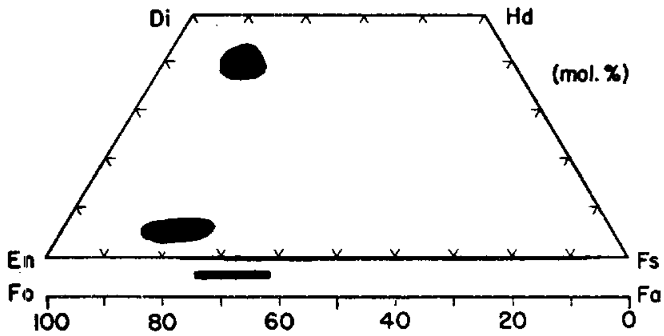


Figure 2. 67749,1 a) matrix, ppl. width 2mm
b) KREEP basalt clast, ppl. width 2mm.

The breccia is heterogeneous and polymict with several large lithic clasts. The matrix texture is sub-equigranular, tending towards granoblastic. There is little material finer than a few microns and the texture is suggestive of minor recrystallization of a fragmental breccia (Fig.2). Mafic minerals compose about 10% of the matrix. Analyses are shown in Figure 3. Matrix plagioclase ranges from An_{98-93} with less than 0.1% Fe (Fig. 4 of Steele and Smith, 1973). Lithic clasts larger than 500 μm include cataclastic anorthosite (or shocked plagioclase), a basaltic impact melt, and a KREEP basalt clast.

Figure 3. Pyroxene and olivine compositions of matrix, from Steele and Smith (1973).



The KREEP basalt clast (Fig.2) contains 35-40% plagioclase, 35-40% pyroxene, ∿ 5% ilmenite, and ∿ 20% mesostasis (glass and accessory phases). Plagioclase occurs in laths ∿ 50x200 µm, and pyroxene as interstitial grains ∿ 300 µm in diameter. The plagioclase ranges from An_{70-65} (Steele and Smith, 1973) and the pyroxenes are iron-rich (Fig.4) The clast shows brittle fracture displacement and many pyroxenes have shock lamellae. The uniform, clast-free texture and the Fe-rich mafic minerals and sodic plagioclases suggest that this clast is a fragment of volcanic KREEP, not an impact melt.

PROCESSING AND SUBDIVISIONS: Small chips were taken to make thin section ,1.

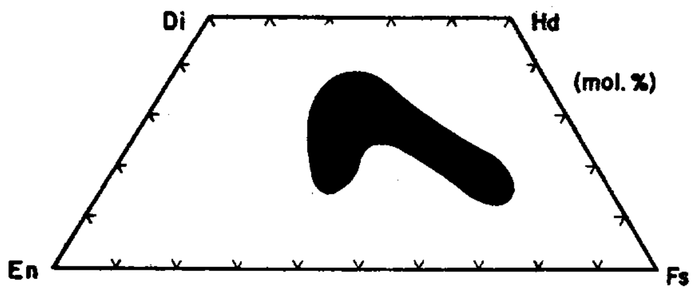


Figure 4. Pyroxene compositions of KREEP basalt clast, from Steele and Smith (1973).

INTRODUCTION: 67755 is a fairly coherent,pale-colored,polymict breccia with white patches (Fig.1). Its matrix is fine-grained and is apparently impact melt. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and lacks zap pits.

PETROLOGY: Steele and Smith (1973) refer to 67755 as a "fine-grained; plagioclase rich" breccia with 50% matrix (defined as material less than 5 μm diameter). It is pale-brown and contains only scattered clasts greater than 200 μm diameter; the remainder is seriate down to submicroscopic (Fig. 2). Most of the fine-grained material is plagioclase bonded by a glassy or cryptocrystalline mortar with scattered sulfide and metal flecks. The clasts are almost all plagioclase, most unshocked but some heavily shocked. The boundaries of some of these clasts are ragged and indistinct.

PROCESSING AND SUBDIVISIONS: A single chip was removed to make thin section ,1.

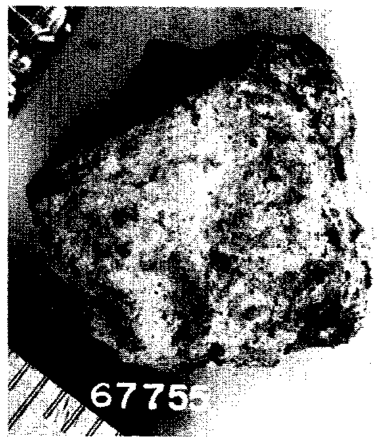


Figure 1. S-72-49556, mm scale.

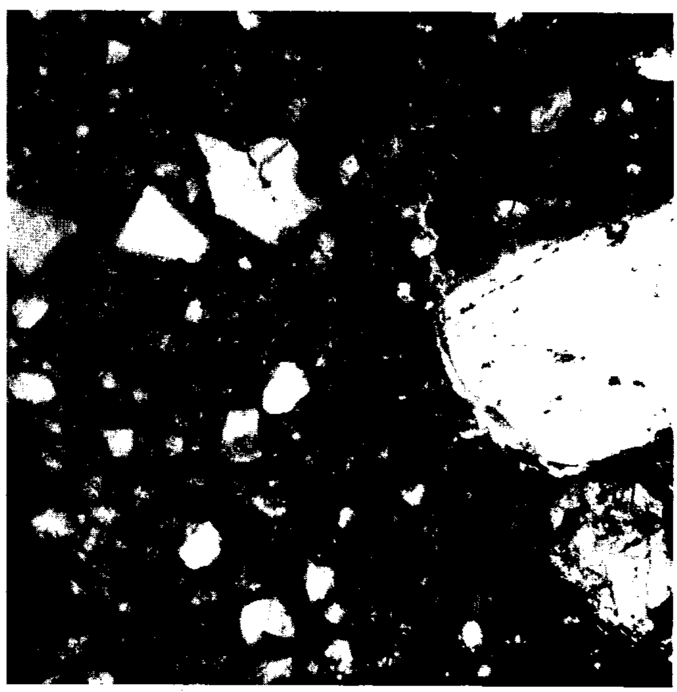


Figure 2. 67755,1, general view, ppl. width 2mm.

INTRODUCTION: 67756 is a pale-colored, coherent, polymict breccia (Fig. 1) with a crystalline matrix of equivocal origin; restricted mineral compostions suggest possible recrystallization. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and lacks zap pits.

Figure 1. S-72-51276, mm scale.

PETROLOGY: Steele and Smith (1973) refer to 67756 as a "recrystallized breccia" with 10% matrix (defined as material less than 5 μm diameter) and provide microprobe data.

The breccia is plagioclase-rich and polymict, and quite heterogeneous in the thin section (,1) (Fig.2). Clasts larger than 200 μm occupy about 20% of the area, and include angular plagioclases and mafic minerals, mostly unshocked and unstrained. Lithic clasts are mainly light gray and aphanitic with equigranular textures; one is a poikiloblastic impactite.

Figure 2. 67756,1, general view, ppl. width 2mm.

The matrix is coherent and crystalline and contains about 10% mafic minerals. The lack of fine-grained material may be due to recrystallization, a feature also suggested by the restricted mineral compositions: plagioclase An_{98-95} (Fig. 4 of Steele and Smith, 1973) and moderately iron-rich mafic minerals (Fig. 3).

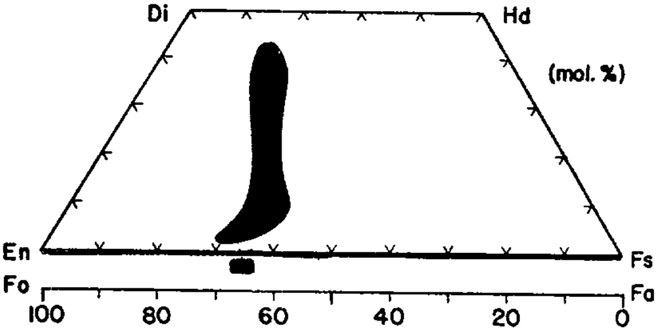


Figure 3. Pyroxene and olivine compositions, from Steele and Smith (1973).

PROCESSING AND SUBDIVISIONS: A single chip was taken to make thin section ,1.

INTRODUCTION: 67757 is a dark gray, coherent, fine-grained impact melt (Fig. 1) with a texture that varies from subophitic to poikilitic. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and has a few zap pits on one side.

Figure 1. S-72-49568, mm scale.

PETROLOGY: 67757 is an impact melt with fine-grained subophitic and poikilitic textures (Fig. 2). The poikilitic areas have a greater proportion of mafic material than the subophitic areas. Overall the rock has about 60% plagioclase. Some oikocrysts (mafic minerals) are ~ 200 μm across, but where the textures grade into subophitic the oikocrysts are much smaller. Plagioclase laths are rarely longer than 30 μm. Scattered ilmenite also forms stubby laths 10-15 μm long. The clasts are mainly shocked plagioclase, but one clast of basaltic impact melt and one mafic vitrophyre are present in the thin sections (,1 ,2).

The rock is somewhat sheared and broken up, with the intrusion of red-brown to black glass veins (Fig.2).

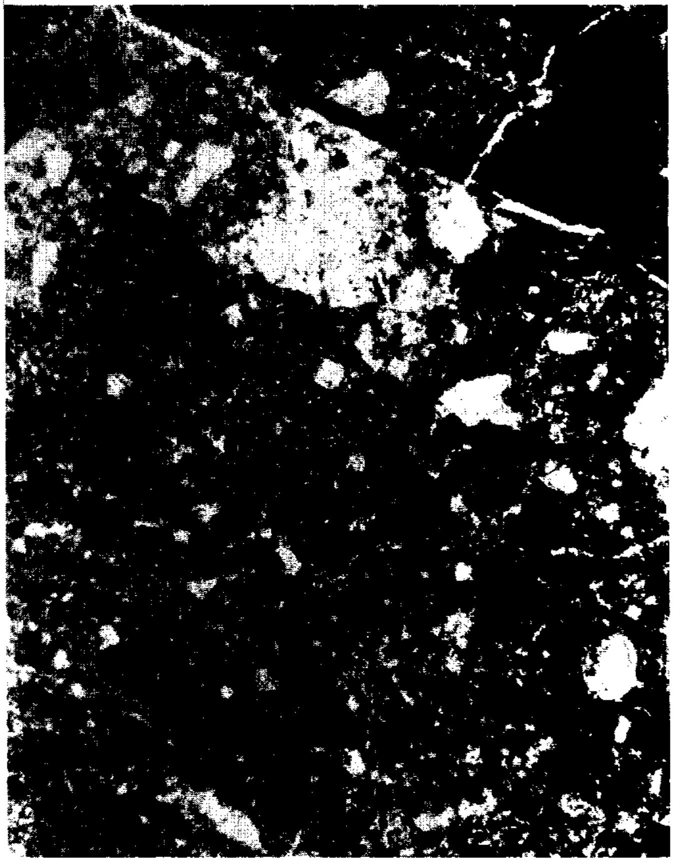


Figure 2. 67757,1 general view, ppl. width 2mm.

PROCESSING AND SUBDIVISIONS: Two thin sections ,1 and ,2 were cut from a single chip.

INTRODUCTION: 67758 is a coherent, gray breccia with a few white clasts and with a powdery coat (Fig. 1). It is a rake sample collected halfway between the White Breccia boulders and House Rock and lacks zap pits.

Figure 1. S-72-49560, mm scale.

INTRODUCTION: 67759 is a heterogeneous gray and white breccia (Fig.1) which is moderately friable. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and has many zap pits.

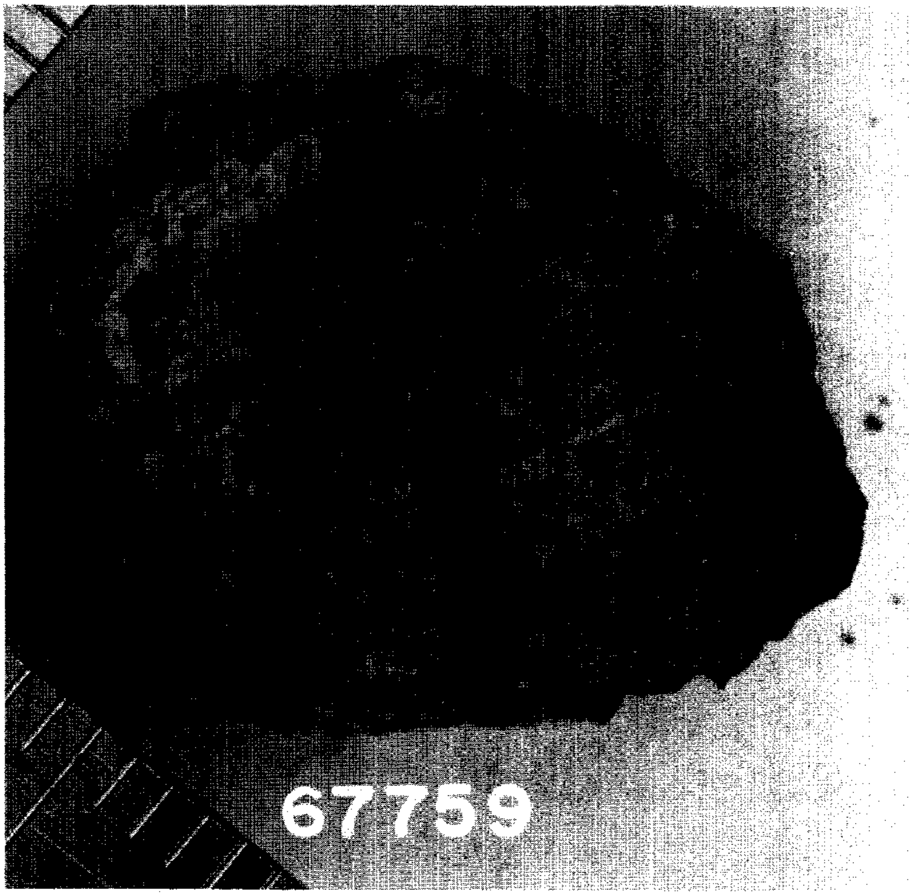


Figure 1. S-72-49566, mm scale.

67765 FINE-GRAINED IMPACT MELT(?) 1.73 g

INTRODUCTION: 67765 is a coherent, dark gray, crystalline breccia which is homogeneous but with a white rind over part of its surface (Fig.1). The matrix has no obvious clasts. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and lacks zap pits.

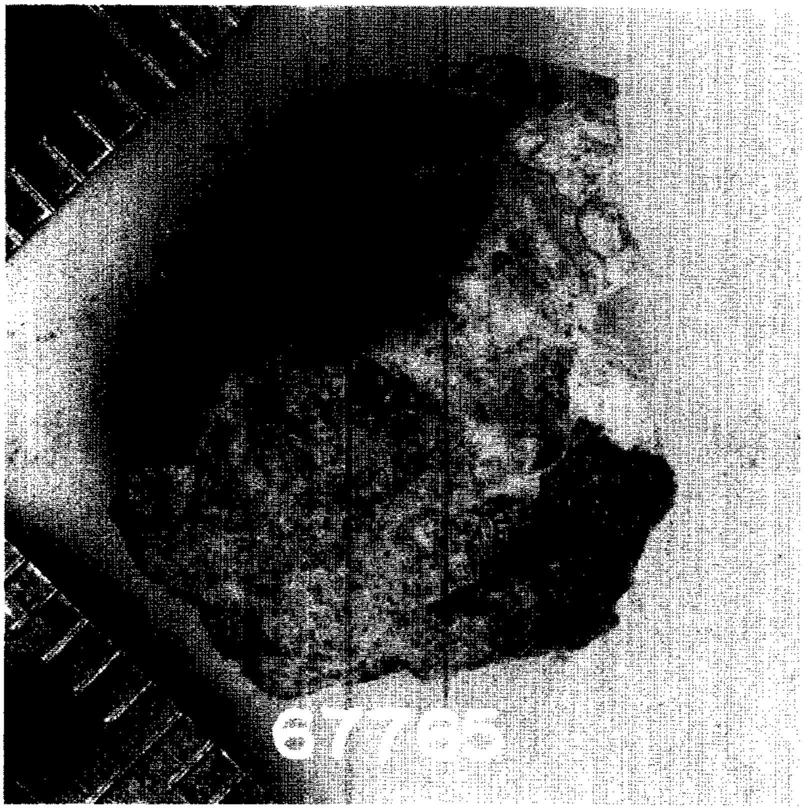


Figure 1. S-72-49575, mm scale.

67766 CRYSTALLINE POLYMICT(?) BRECCIA 5.47 g

INTRODUCTION: 67766 is a coherent, plagioclase-rich breccia (Fig. 1) with a granular, fine-grained matrix which might be recrystallized. The matrix might be the ground-up equivalent of its enclosed lithic clasts. It is a rake sample collected halfway between the White Breccia boulders and House Rock and has zap pits on all faces.

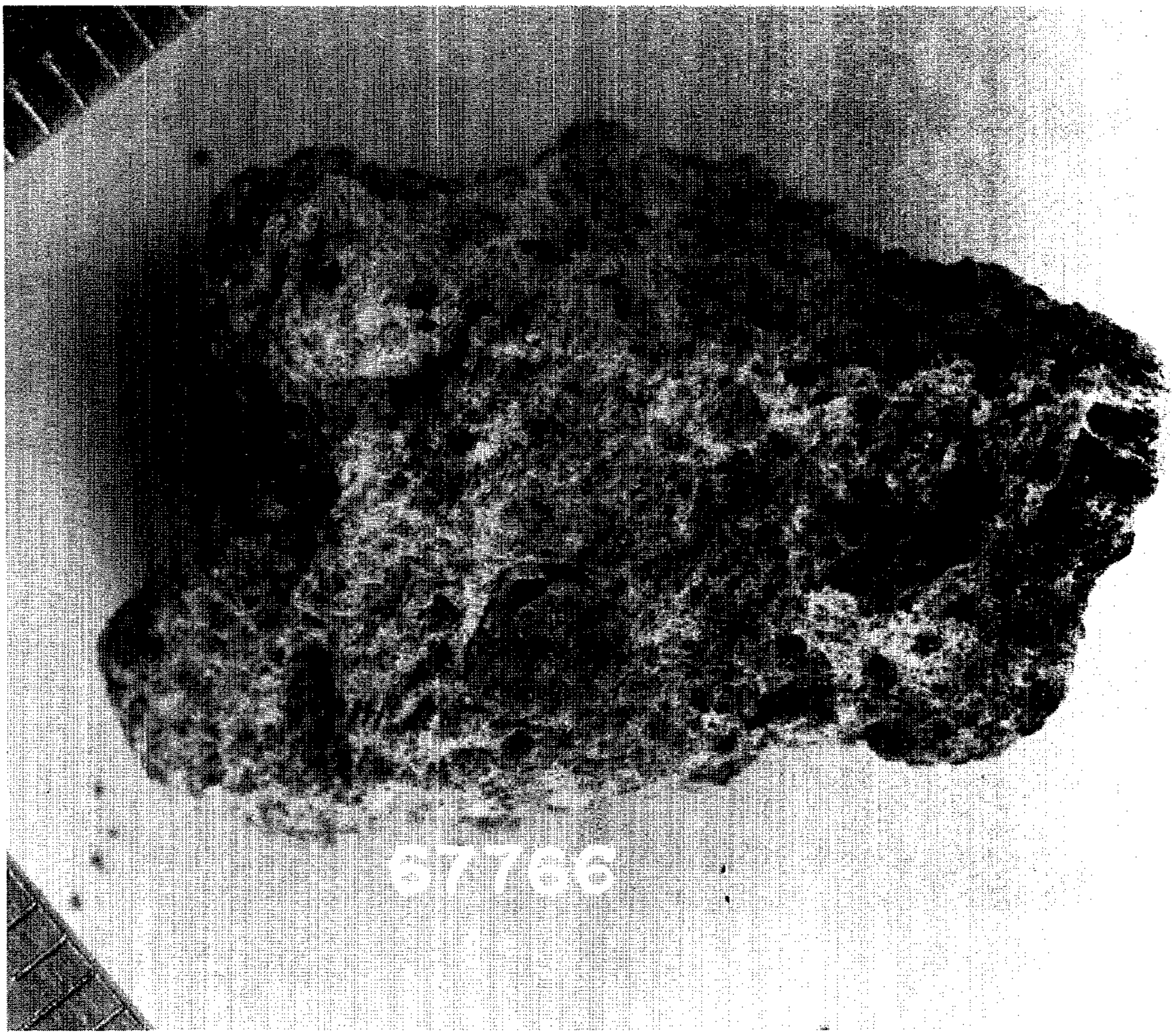


Figure 1. S-72-51257, mm scale.

PETROLOGY: Steele and Smith (1973) refer to 67766 as a "recrystallized breccia" with 10% matrix (defined as material less than 5 μm) and report microprobe data.

The breccia is sheared, containing large clasts in a fine-grained matrix (Figs. 1 and 2). The texture of the matrix is granular, hence possibly recrystallized. It contains ∿ 80% plagioclase. The largest clast in the thin section (,1) contains ∿ 90% plagioclase, the remainder is olivine and ilmenite; the smaller clasts are similar except that one 7 mm clast is almost entirely a single plagioclase grain. Steele and Smith (1973) note that the absence of pyroxene suggests that 67766 is monomict. Plagioclases are An_{97-94} with varied Fe contents (Fig. 4 of Steele and Smith, 1973) and the olivines (Fig. 3) are iron-rich like those in ferroan anorthosites.

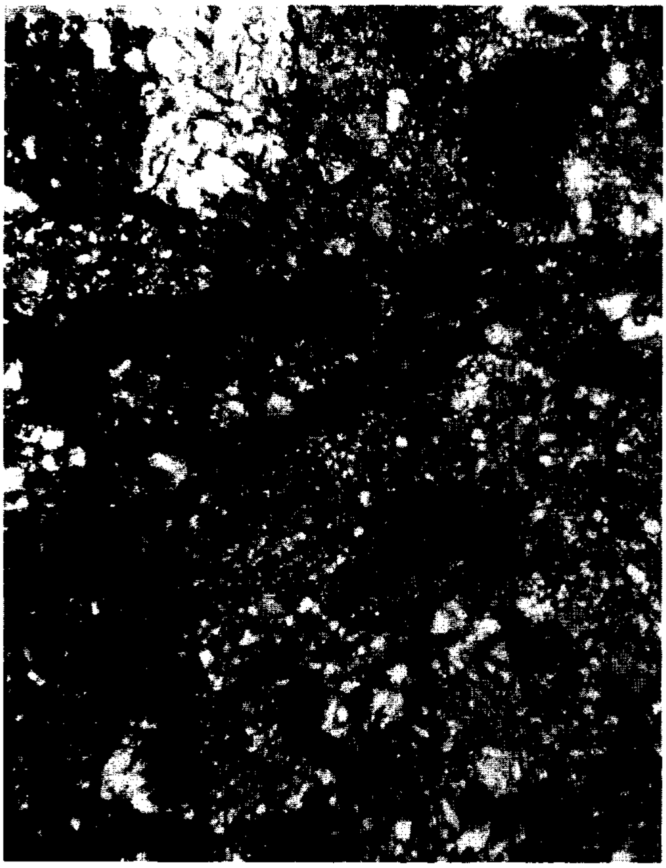


Figure 2. 67766,1, general view, xpl. width 2mm.

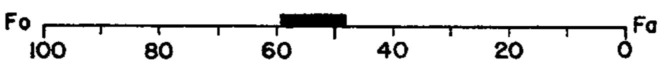


Figure 3. Olivine compositions, from Steele and Smith (1973).

PROCESSING AND SUBDIVISIONS: Of two small chips removed, one was made into thin section ,1.

INTRODUCTION: 67767 is a white, homogeneous, friable breccia (Fig. 1) which is fine-grained and lacks obvious clasts. A few yellow to gray mineral grains are present. The fragment might be a pure,friable cataclastic anorthosite. It is a rake sample collected halfway between the White Breccia boulders and House Rock.

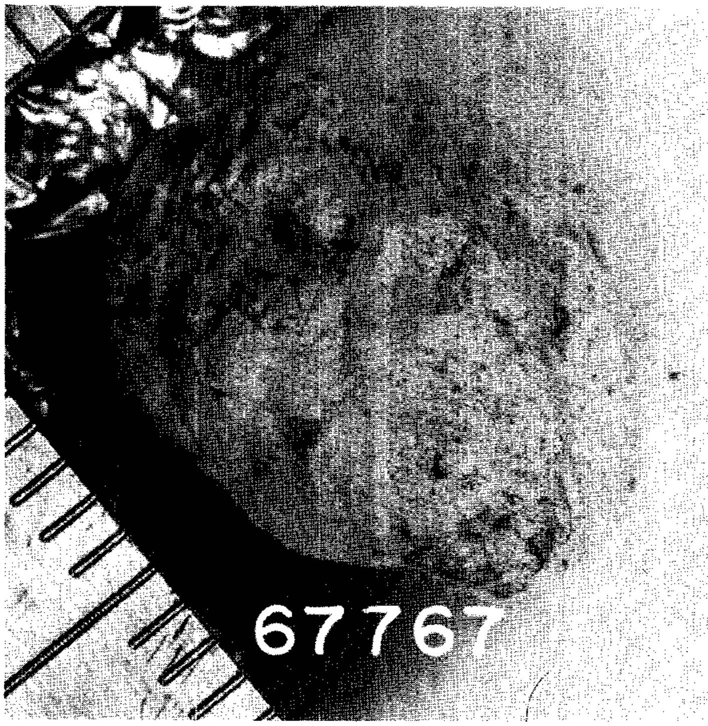


Figure 1. S-72-51275, mm scale.

INTRODUCTION: 67768 is a white, powdery, friable breccia with a few gray inclusions (Fig.1). It is a rake sample collected halfway between the White Breccia boulders and House Rock, and its powdery surface lacks zap pits.

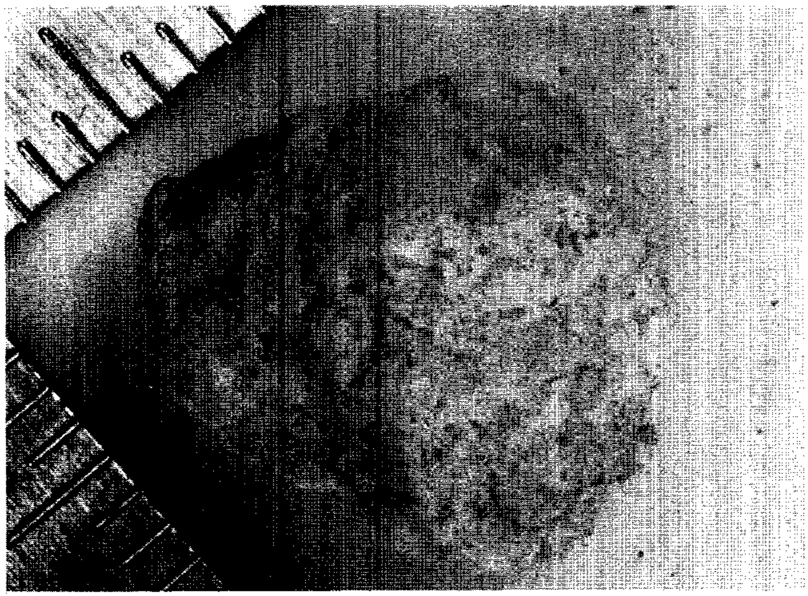


Figure 1. S-72-49550, mm scale.

INTRODUCTION: 67769 is a homogeneous, coherent and fine-grained poikilitic impact melt (Fig. 1). It is a rake sample collected halfway between the White Breccia boulders and House Rock and has zap pits.

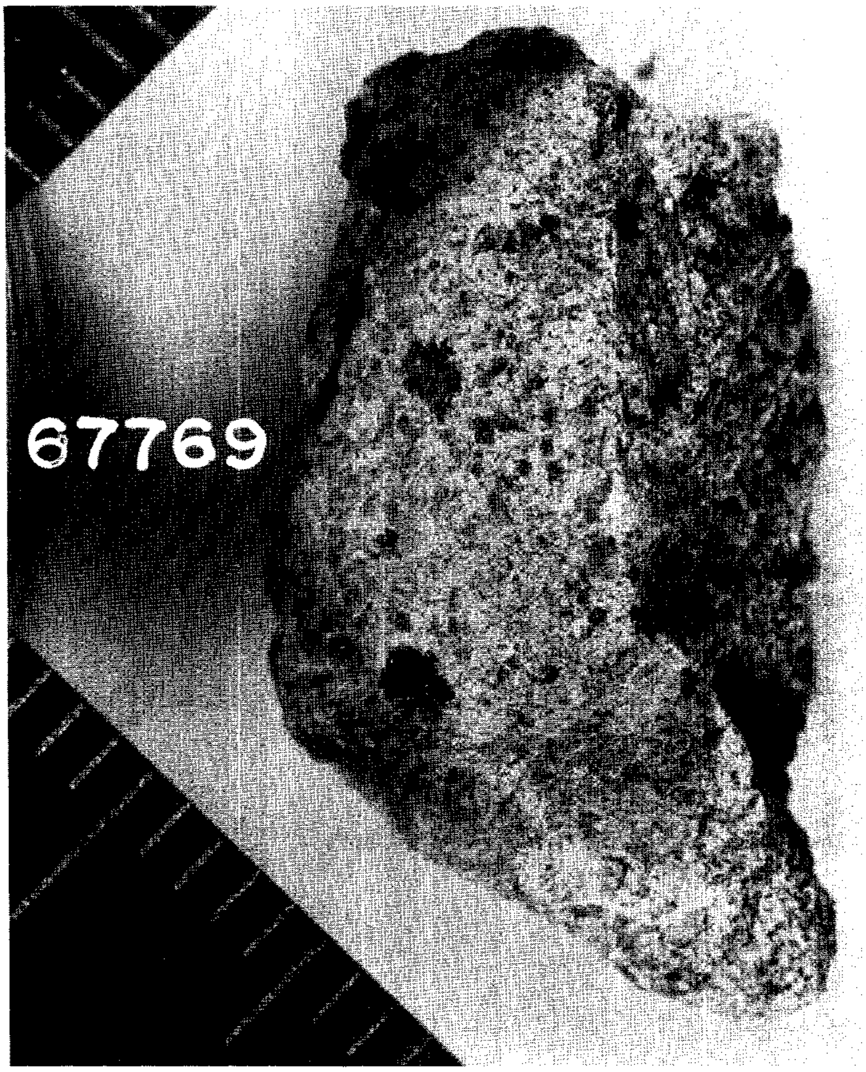


Figure 1. S-72-51044, mm scale.

PETROLOGY: Steele and Smith (1973) refer to 67769 as a "breccia with poikilitic pyroxene as matrix", and report microprobe data. It is fine-grained, homogeneous and contains few clasts (Fig. 2). The pyroxene forms indistinct oikocrysts up to 100 μm in diameter which enclose 20-40 μm long plagioclases. The pyroxenes have a narrow range of compositions (Fig. 3), while plagioclases range from An_{95-85} with a wide range Fe, up to 0.8 wt% (Steele and Smith, 1973). Armalcolite(?) is present and Fe-metal blebs usually ~50 μm in diameter are common. Glass is extremely rare. Most clasts, almost all less than 150 μm in diameter, are plagioclase; a single lithic clast in thin section ,1 is 1 mm across, and is a feldspathic breccia.

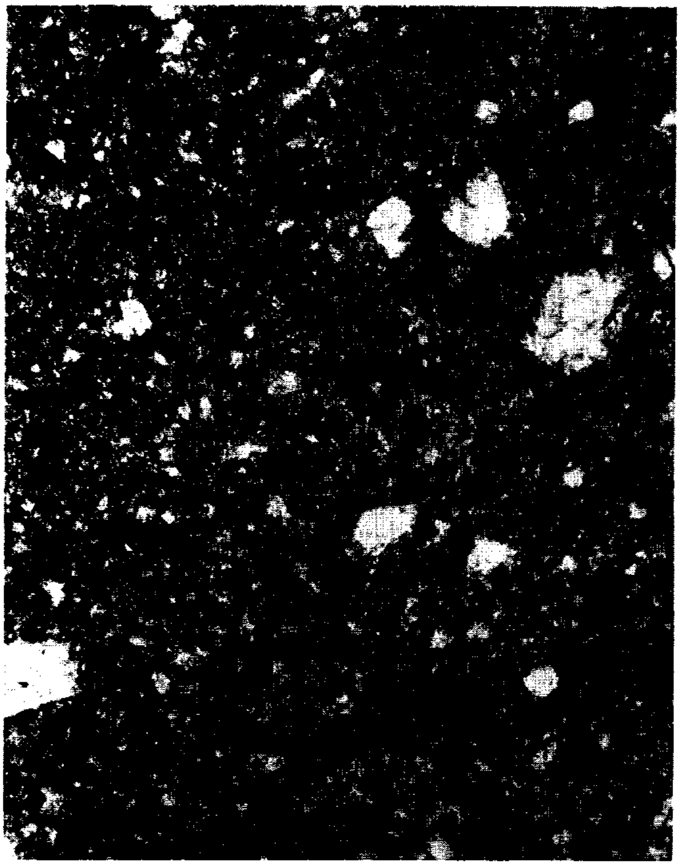


Figure 2. 67769,1, general view, ppl. width 2mm.

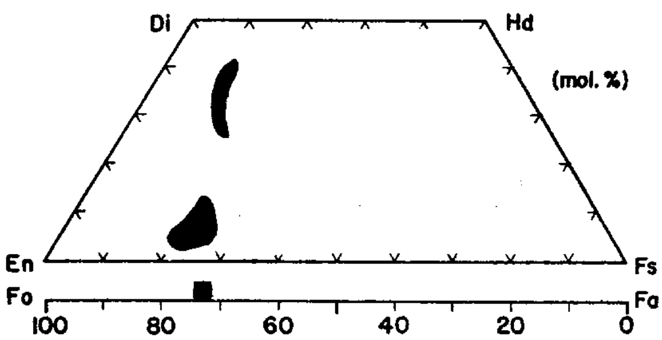


Figure 3. Pyroxene and olivine compositions, from Steele and Smith (1973).

PROCESSING AND SUBDIVISIONS: A single chip was split into three smaller pieces, one of which was used to make thin section ,1.

INTRODUCTION: 67775 is a homogeneous, crystalline breccia (Fig. 1) with a fine-grained impact melt matrix. It is a rake sample collected halfway between the White Breccia boulders and House Rock. It has many zap pits on all faces.

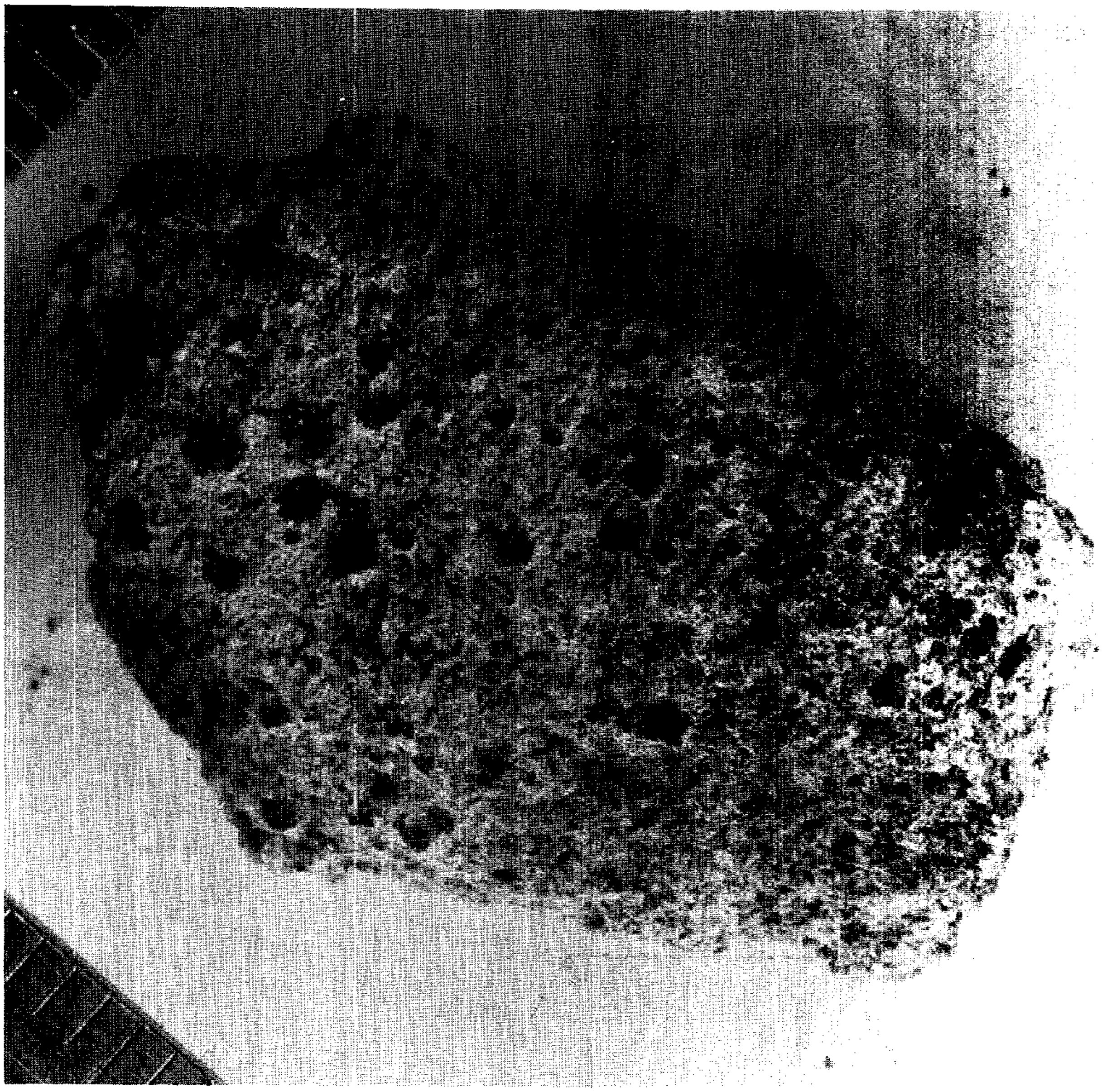


Figure 1. S-72-51259, mm scale.

PETROLOGY: Steele and Smith (1973) refer to 67775 as a "recrystallized breccia" with 20% matrix (defined as material less than 5 μm), and provide microprobe data. It contains clasts of plagioclase, mafic minerals, and lithic materials, including feldspathic granulite and a fine-grained basaltic impact melt. The matrix contains about 60% plagioclase as laths, and pyroxene which is equigranular and tending towards poikilitic. The grain size is 10-40 μm. The analyzed plagioclases have a narrow range from An_{96-94} with little Fe (Fig. 4 of Steele and Smith, 1973) and pyroxenes are also fairly restricted in composition (Fig. 3). Armalcolite, ilmenite, and Fe-metal are common.

Figure 2. 67775,1, general view, ppl. width 2mm.

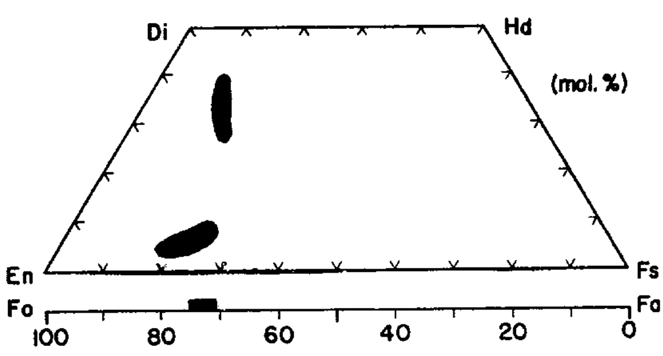


Figure 3. Pyroxene and olivine compositions, from Steele and Smith (1973).

PROCESSING AND SUBDIVISIONS: Several small chips were taken to make thin section ,1.

INTRODUCTION: 67776 is a white, homogeneous, and friable breccia (Fig.1) with some rare, small, dark clasts. It is a rake sample collected halfway between the White Breccia boulders and House Rock, and its dusty surface lacks zap pits.

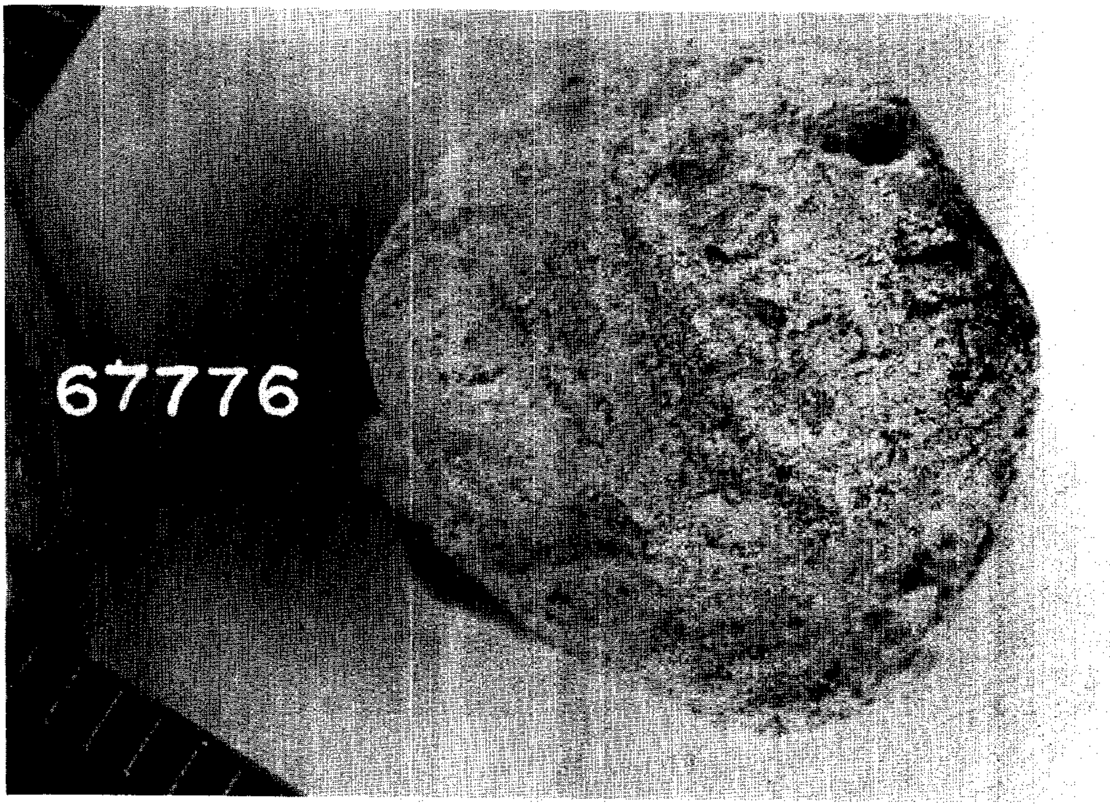


Figure 1. S-72-51056, mm scale.

INTRODUCTION: 67915 is a heterogeneous polymict breccia with two main lithologies(Fig. 1a), both polymict breccias. One is white (or light gray), the other darker gray. Most other clasts are also polymict breccias but sodic ferrogabbro and (possibly) troctolitic anorthosite clasts are monomict. Glass veins are prominent.

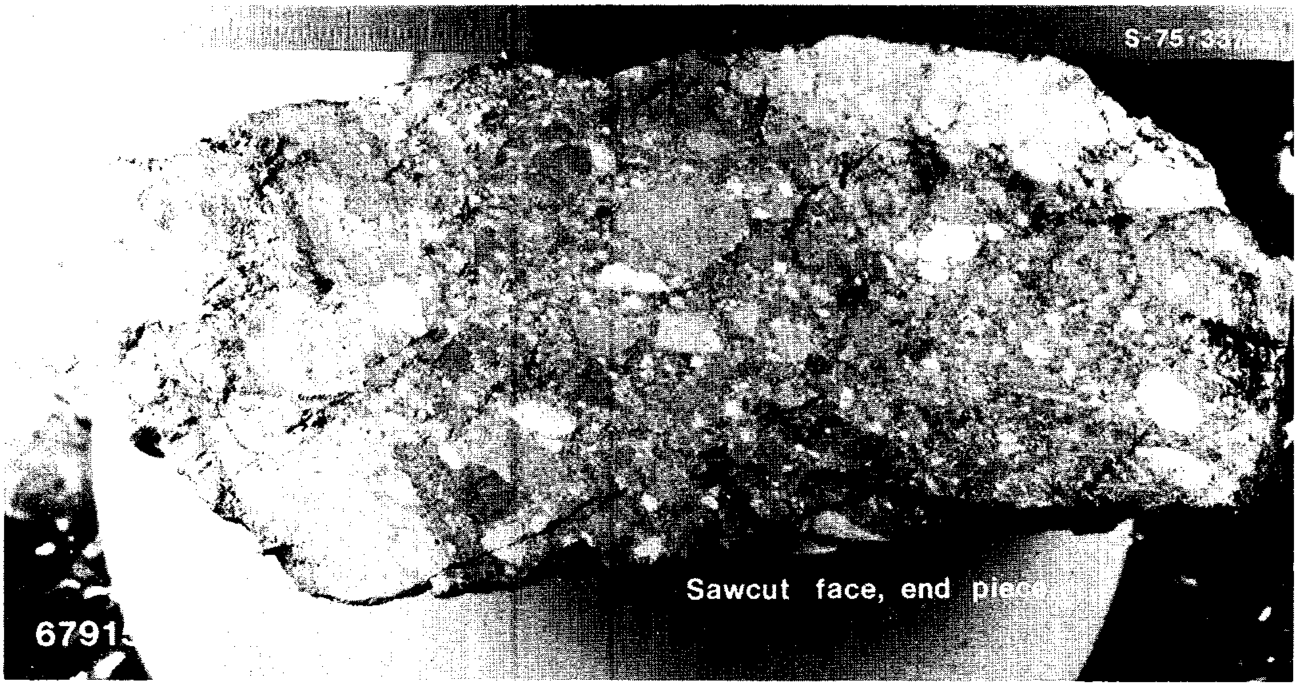


Figure 1a.

67915 was collected, with 67935-7 and 67955-7, from Outhouse Rock (Fig. 1b). The sample is coherent, and is blocky and subangular. Its orientation is known and many zap pits occur on its exposed surface.

Much of the work on 67915 has been coordinated through two consortia, an early one organized by Roedder and a later one organized by Marti.

PETROLOGY: Weiblen and Roedder (1973) and Roedder and Weiblen (1974) provide a comprehensive description of 67915. The former paper emphasizes the characteristics of shock glass veins and sodic ferrogabbro clasts. Nord et al. (1975) describe deformation, based on high-voltage transmission electron microscopy (HVEM) techniques, Misra and Taylor (1975) provide metal compositional data, Roedder and Weiblen (1977a) discuss in detail the glass veins in 67915 (and

Figure 1b. Samples collected from Outhouse Rock.

some other rocks) providing microprobe data, and Weiblen et al. (1980) provide minor element data on plagioclases in 67915. G. J. Taylor et al. (1979) and Marti et al. (1978) provide petrographic descriptions of various clasts, and Ganapathy et al. (1974) describe a thin section. The sodic ferrogabbro clast is described additionally in G. J. Taylor et al. (1980a,b). Taylor and Mosie (1979) summarize data on 67915 and provide macroscopic descriptions of many subsamples of the rock.

Most of the gray clasts are fine-grained impact melts with a variety of textures and shock-features, whereas most of the white clasts are microgranular and similar to feldspathic granulitic impactites (Fig. 2). Weiblen and Roedder (1973) studied 5 different areas of clasts and found them all to be polymict breccias. Despite the variety of textures their compositions are quite similar. More clasts were described and analyzed in greater detail by Roedder and Weiblen (1974) who conclude that 95% of the rock consists of breccia clasts ranging in composition from "gabbroic" (noritic) to troctolitic anorthosite, set in a matrix of similar materials. Most are microbreccias, and most have plagioclase

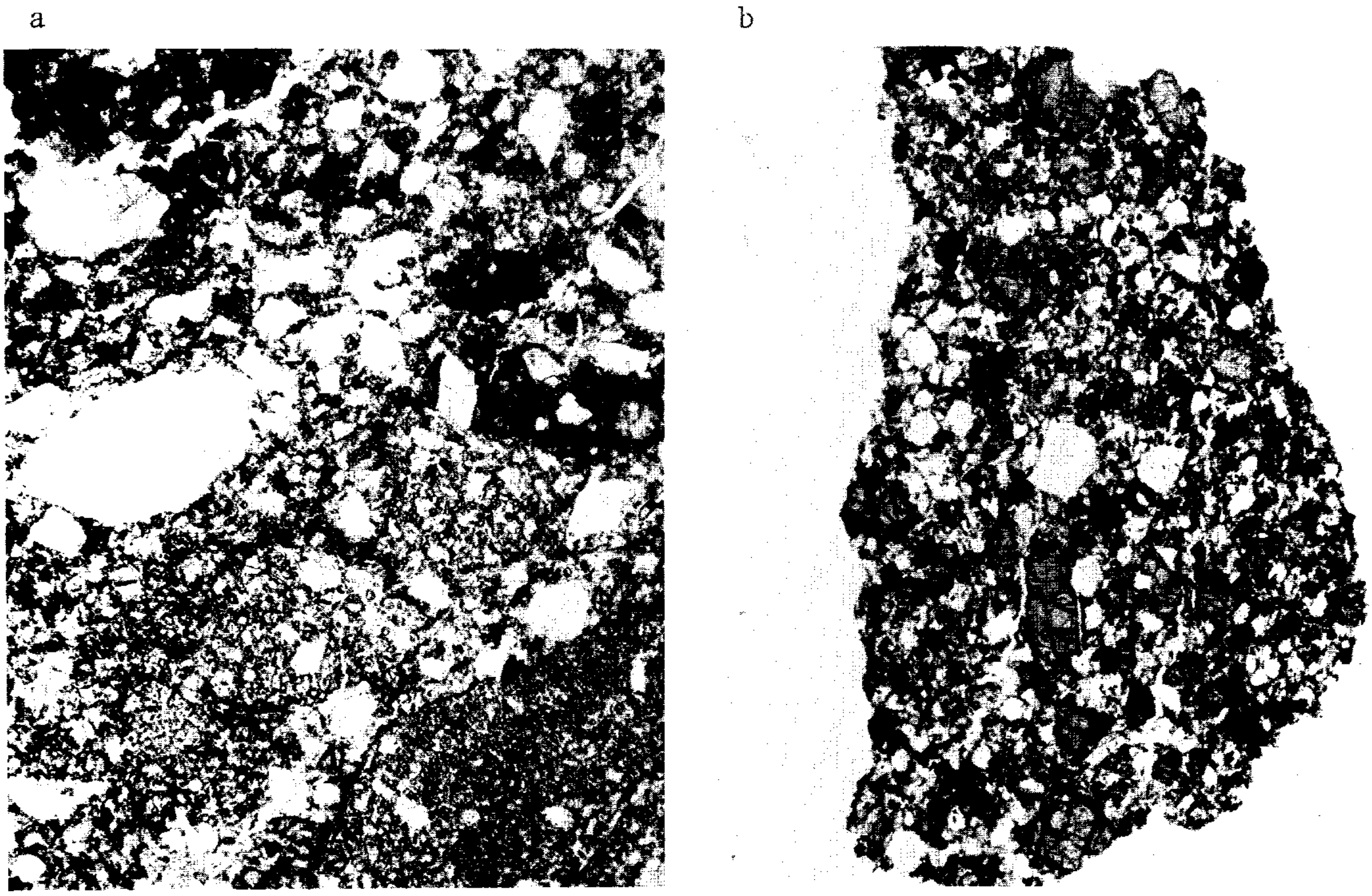
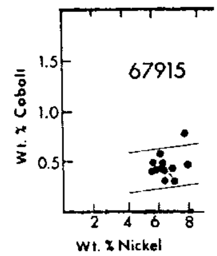


Figure 2. a) 67915,82, granoblastic clast (lower) and fragmental matrix (upper), ppl. width 2mm. b) 67915,190, sodic ferrogabbro clast, ppl. width about 3.5mm.

with An ~93-95 and mafic minerals with molar Mg/Mg+Fe ~70-85. Among the troctolitic breccias a granoblastic texture is most common. One has a cumulus-like texture and has plagioclase An_{93-95} and olivine Fo_{53-56}, and may be a relative of pristine ferroan anorthosites. Several clasts are more distinctive, for instance ferro-peridotite (Fo_{62}, An_{87} and Fo_{65}, An_{90-95}) and sodic ferrogabbro. Several clasts are basaltic melts ("criss-cross texture"; Roedder and Weiblen 1974); although most are aluminous impact melts, one observed by Roedder and Weiblen (1974) had the petrographic characteristics of a mare basalt. Poikilitic impact melt breccia (like 65015 etc.) clasts have not been observed in 67915.

Nord et al. (1975) state that the matrix of 67915 shows no evidence of recrystallization although many clasts are shocked. All areas have abundant thetomorphic glass according to the HVEM study. This glass is not readily visible optically but the lithification of the rock is largely due to it. Misra and Taylor (1975) made 20 analyses of 12 metal grains which have a fairly restricted compositional range (Fig. 3) and average 6.43% Ni and 0.46% Co. P is extremely low in the grains compared with most other metals in polymict rocks.

Figure 3. Compositions of metals from the matrix, from Misra and Taylor (1975).



The sodic ferrogabbro clasts were discovered by Weiblen and Roedder (1973). They are characterized in particular by sodic (and potassic) plagioclases ($An_{69}Or_3$ to $An_{54}Or_9$), iron-rich exsolved pyroxenes, and ilmenite (~5% of the rock) (Weiblen and Roedder 1973; Roedder and Weiblen 1974; G. J. Taylor et al. 1979, 1980a,b). The distinctive chemistry indicates that it is a pristine lunar lithology despite the fact that its original texture has been destroyed by cataclasis (Fig. 2). Weiblen et al. (1980) deduce from their analysis of minor elements in plagioclase that a) pyroxene and plagioclase equilibrated at ~1333°C,b) the liquid from which sodic ferrogabbro crystallized had 2.4 wt% TiO_2,and c) the sodic ferrogabbro clasts did not equilibrate at all with the 67915 matrix. G. J. Taylor et al. (1980b) conclude from petrographic and chemical studies that fractional crystallization, not liquid immiscibility, was responsible for the composition of the sodic ferrogabbro.

Weiblen and Roedder (1973) and Roedder and Weiblen (1977a) describe the glass veins in 67915. The veins are similar, but not identical, in composition (~30.5% Al_2O_3) to the bulk rock. They have features suggesting the injection of extremely hot material (rather than in situ glass-formation) possibly at several thousand degrees of superheat, but the physical nature of the process is debatable.

CHEMISTRY: Several analyses of matrix (~ bulk rock) and individual clasts have been made (Table 1). These are summarized in Tables 2 and 3. Rare earth abundances for matrix and for the sodic ferrogabbro are shown in Figure 4; other partial analyses of matrix by Haskin et al. (1973) and Garg and Ehmann (1976) are roughly similar to those illustrated with the exception of the very high Lu value of the latter. Most of the references listed in Table 1 have little specific discussion of the chemistry of 67915.

All matrix and polymict breccia clasts are aluminous and have little variation in composition, despite the heterogeneous appearance of the breccia (Fig. 1). They all have higher Al_2O_3 than typical Apollo 16 soils and have positive Eu anomalies (Fig. 4). Only the sodic ferrogabbro lithology appears to be significantly different. The light clast analyzed by Moore et al. (1973), Cripe and Moore (1974) and Moore and Lewis (1976) is low in volatiles (C,N, and S) but has not been analyzed for other elements.

TABLE 2. Summary Chemistry of 67915 matrix and sodic ferrogabbro

	1	2	3
SiO_2	44.4	(57.3)	56.7
TiO_2	0.43	6.0	4.7
Al_2O_3	29.2	8.4	11.1
Cr_2O_3	0.06	0.03	0.03
FeO	3.4	13.6	12.8
MnO	0.05	0.20	0.2
MgO	4.7	3.8	3.0
CaO	16.6	8.9	8.9
Na_2O	0.50	1.35	1.1
K_2O	0.07	0.46	0.6
P_2O_5	0.05		0.1
Sr	185		
La	5.0	26.7	
Lu	0.26	1.58	
Rb	0.9		
Sc	7.0	34	
Ni	88		
Co	11	6.6	
Ir ppb	7.3		
Au ppb	1.9		
C			
N			
S	<600		
Zn	6.5		
Cu	∿5		

1) Matrix

2) Sodic ferrogabbro: 67915,163 by INAA. Taylor *et al*.(1980b)

3) Sodic ferrogabbro: best estimate Taylor *et al*.(1980b)

TABLE 1. Chemical work on 67915

Reference	Split	Description	Elements analyzed
Duncan *et al*.(1973)	,53 L	lighter matrix	Majors, some trace
"	,53 D	darker matrix	"
Janghorbani *et al*.(1973)	,56	matrix	Majors
Nakamura *et al*. (1973)	,57	matrix	Majors, rare earth
Taylor and Bence (1975)	,49	matrix	Rare earths
Wänke *et al*. (1976)	,116	matrix	Majors,minors, traces (∿ 50 elements)
Haskin *et al*. (1973)	,52	matrix	Sm, Eu (approximate)
Garg and Ehmann (1976)	,56	matrix	Zr,Hf,Fe,Cr,Sc,Co,Eu,Lu
Rancitelli *et al*. (1973b)	,11	bulk rock	K,U,Th
Krähenbühl *et al*. (1973)	,63 a	50% dk.mx.	meteoritic siderophiles and volatiles
"	,63 b	80% wh.cl.	"
Ganapathy *et al*. (1975)	,63 a,b		Corrects Ir value of Krähenbühl *et al*.(1973)
Rose *et al*. (1975)	,3(-4)	gray bx.clast	Majors
"	,12(-1)	troctolitic clast	"
"	,45(-1)	gray bx.clast	"
"	,45(-3)	wh.bx.clast	"
Moore *et al*.(1973)	,54	lt. clast	C
Cripe and Moore (1974)	,54	lt. clast	S
Moore and Lewis (1976)	,54	lt. clast	N
Taylor *et al*. (1980b)	,163	Sodic ferro-gabbro	Majors,REEs, some other trace

Table 3. Chemical compositions (wt. %) of clasts in 67915. All analyses by Rose et al. (1975)

	A	B	C	D
SiO_2	43.9	44.4	44.4	43.4
TiO_2	0.26	0.26	0.29	0.15
Al_2O_3	32.2	27.2	31.4	29.2
Cr_2O_3	0.02	0.05	0.02	0.02
FeO	2.7	3.0	3.6	6.0
MnO	0.02	0.05	0.03	0.05
MgO	2.3	9.0	2.6	4.8
CaO	17.9	15.0	17.6	15.9
Na_2O	0.57	0.38	0.44	0.38
K_2O	0.06	0.07	0.04	0.04
P_2O_5	0.02	0.04	0.03	0.02
Total	99.95	100.05	100.45	99.96

A) ,3-4; weakly recrystallized ANT (white clast).

B) ,45-3; fine grained, hornfelsic troctolitic anorthosite breccia (white clasts).

C) ,45-1; gray clast

D) ,12-1; troctolitic anorthosite with cumulate texture (Fig. 8A).

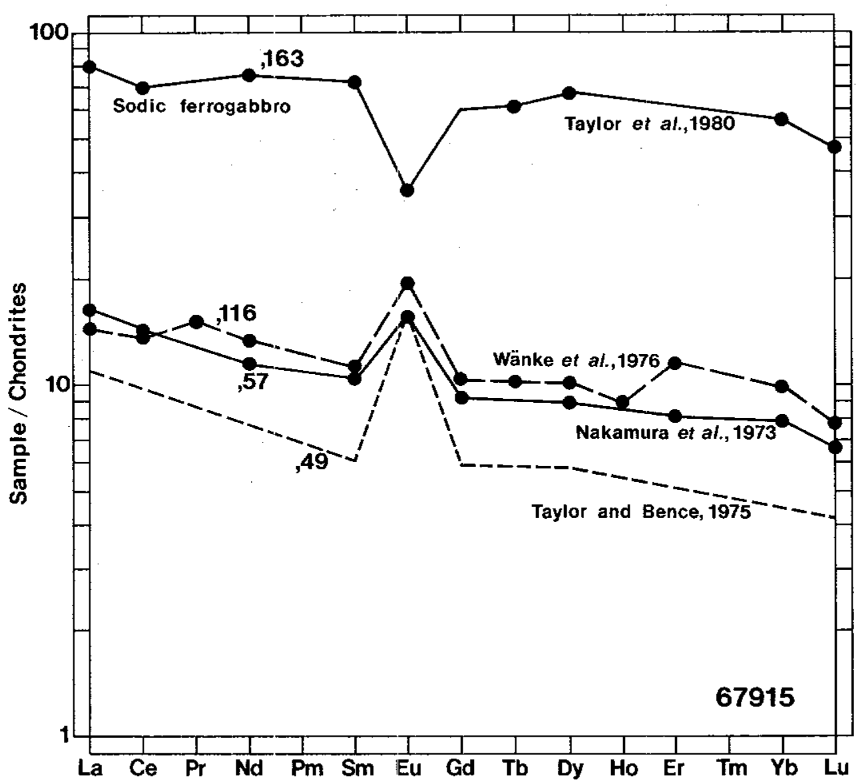


Figure 4. Rare earths.

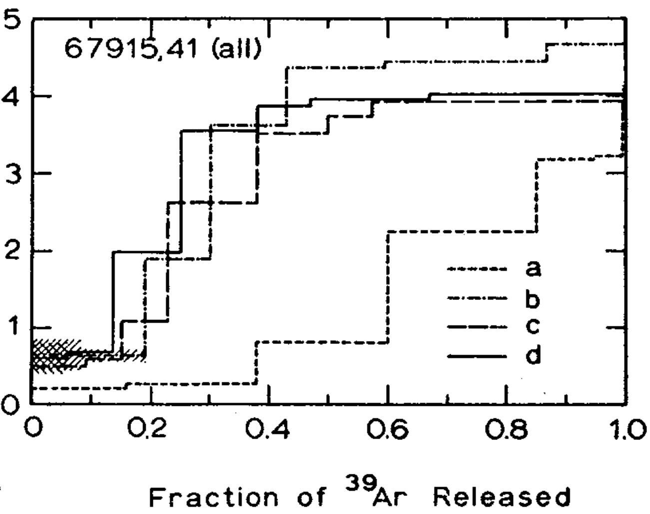
The siderophiles in two breccia subsplits are high and similar (Krähenbühl et al., 1973; Ganapathy et al., 1974). They were placed in meteoritic Class A (a small group) by Ganapathy et al. (1973), revised to Group 5 by Ganapathy et al. (1974) and to Group 5H by Hertogen et al. (1977). A Nectaris origin for the group was suggested by Krahenbuhl et al. (1973) and either Crisium or Nectaris by Hertogen et al. (1977)

GEOCHRONOLOGY: ^{40}Ar-^{39}Ar isotopic data are presented for several clasts by Kirsten et al. (1973), Venkatesan and Alexander (1976), and Marti et al. (1978).

Kirsten et al. (1973) analyzed four distinct lithologies (Fig. 5a and Table 4), two of which give reasonable plateau ages of 3.91 and 3.99 b.y. The 4.3 b.y. plateau "age" may be either a true old age or be the result of implanted argon (note that this lithology is apparently a feldspathic granulitic impactite, some others of which have also given old ages).

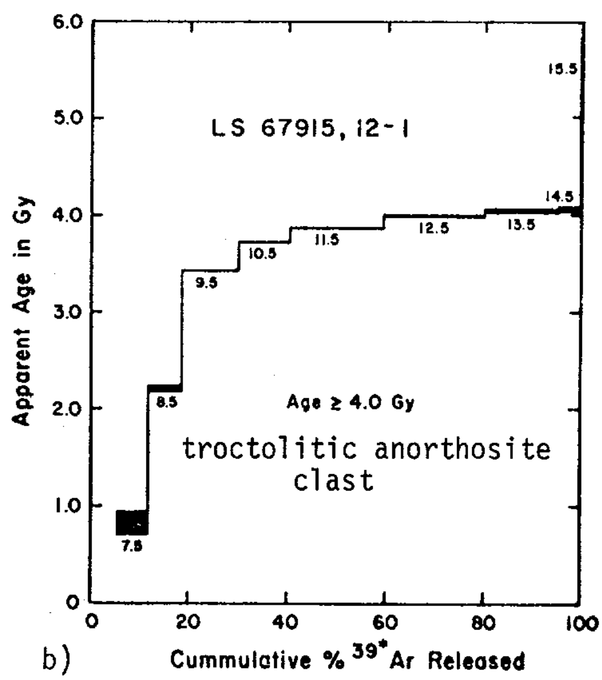
Venkatesan and Alexander (1976) provide an argon release diagram (Fig. 5b) for the troctolitic anorthosite ("cumulus") described by Roedder and Weiblen (1977a). The plateau age is 4.03±0.04 b.y. and the release pattern essentially identical to the matrix sample (,41d) analyzed by Kirsten et al. (1973).

Marti et al. (1978) report ^{39}Ar-^{40}Ar release data for several described clasts and matrix (Figs. 5c,d,e,f). The patterns show substantial diffusion losses. Clast W defines the best apparent age of 4.00 b.y., and a lower age limit of 3.98 b.y. is assigned to clast DW. It appears unlikely, despite diffusion loss, that clast B could be older than 3.6 b.y. The plagioclase separate from the sodic ferrogabbro shows an exceedingly large diffusion loss, and only a lower age limit of 3.2 b.y. can be assigned.



a)

Shadowed bars indicate experimental errors.



b)

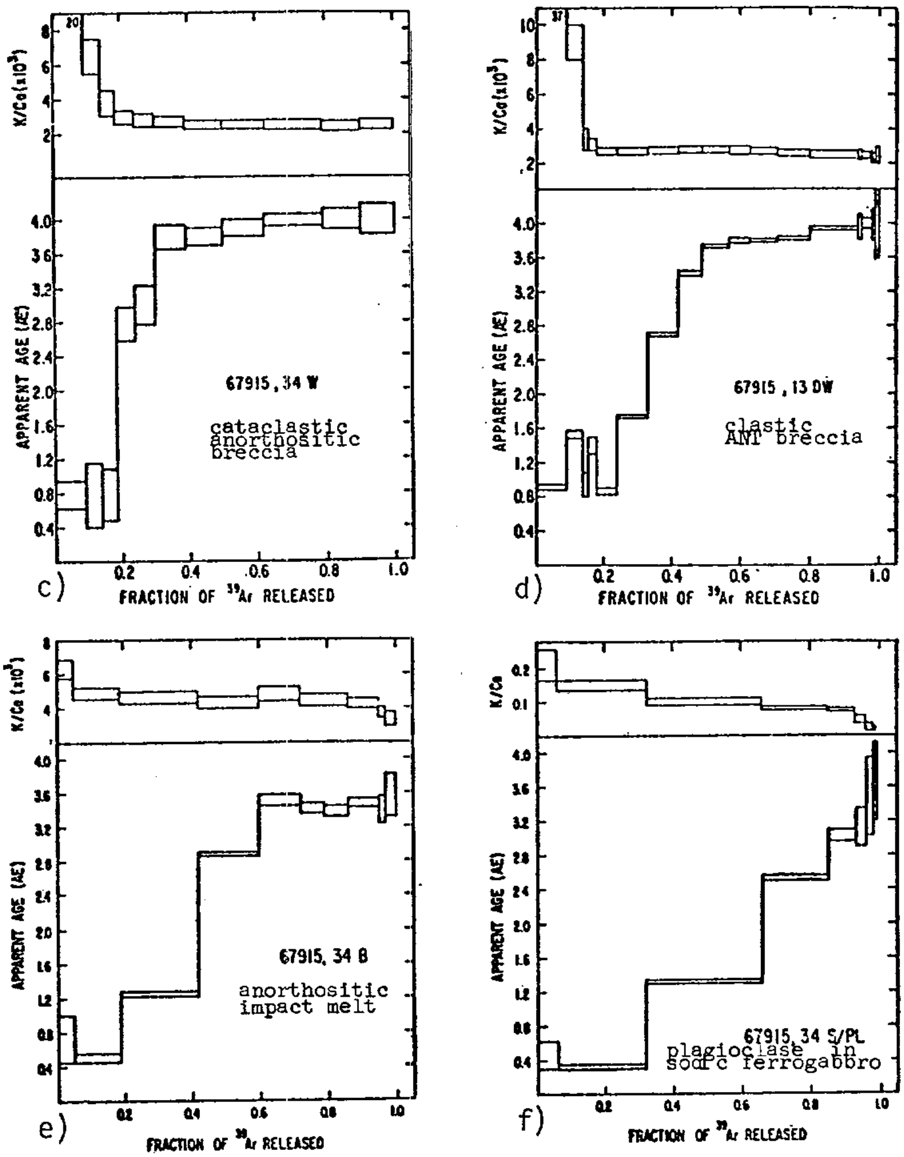


Figure 5. Ar releases for various clast and matrix samples, see text for discussion. a) from Kirsten et al. (1973), b) from Venkatsan and Alexander (1976), c)-f) from Marti et al. (1978).

TABLE 4. Summary of ^{39}Ar-^{40}Ar results from Kirsten et al. (1973).

Sample	Description	Total Ar age (b.y.)	Plateau age (b.y.)
67915,41a	Lt.gy.polymict	1.67 ± 0.08	—
67915,41b	v. lt.gy.,fine-grain	3.80 ± 0.08	(4.3 ± 0.1)
67915,41c	v. lt.gy., coarser	3.26 ± 0.08	3.91 ± 0.05
67915,41d	matrix	3.53 ± 0.08	3.99 ± 0.05

RARE GASES AND EXPOSURE AGES: Several studies concerning rare gas contents and exposure ages have been made. Behrmann et al. (1973) report Ne and Kr isotopic data for releases at 500°C and 1500°C, and total release. The krypton spallation spectrum has no prominent neutron effects. The ^{81}Kr-^{83}Kr exposure age is 50.6±3.8 m.y.; a ^{22}Na-^{21}Ne exposure age of 45.3±9.5 m.y. is also calculated. Track production rates at the deepest point in a sampled column of 67915 give a lower exposure age of 29±4 m.y.

Drozd et al. (1974) report Kr isotopic data (1500°C release) and Kr spallation spectra for 67915. Although this is the same analytical group as Behrmann et al. (1973) the data appear to be distinct. An ^{81}Kr-^{83}Kr exposure age is 50.6±1.5 m.y. and ^{21}Ne and ^{38}Ar exposure ages of 21.0±4.9 and 16.0±10.0 m.y., respectively, are also reported. The ∿50 m.y. age is assigned to North Ray Crater. Crozaz et al. (1974), discussing the Drozd et al. (1974) and Behrmann et al. (1973) results state that 67915 has a single-stage exposure history and that a 1mm/m.y. erosion rate can give agreement between the rare-gas and the Kr ages.

Marti et al. (1973) report Kr isotopic data from three samples at different depths (Table 5) which are not significantly different from each other or from the exposure age given by Drozd et al. (1974) or Kirsten et al. (1973). They assign this age to North Ray Crater.

TABLE 5. Summary of ^{81}Kr-^{83}Kr exposure ages from Marti et al. (1973)

Split	Depth	Exposure age (m.y.)
,13	60 mm	49.7 ± 3.5
,34	30 mm	48.6 ± 4.0
,36	10 mm	46.4 ± 3.7

Xenon isotopic data are provided by Lightner and Marti (1974b) and Marti et al. (1978) for the same splits analyzed for Kr by Marti et al. (1973). These two sets of Xe isotopic data appear to be separate analyses. The data are consistent with a single-stage, near-surface irradiation history. Eugster et al. (1977) quote (Xe^{131}/Xe^{126})cosmogenic ratios of 2.6, 2.7, and 2.9 for ,34 ,36 and ,13 respectively, from Marti (pers. comm.).

Rancitelli et al. (1973a) report ^{22}Na and ^{26}Al count data for ,11, a large piece of 67915. Yokoyama et al. (1974) in discussing such data note that the sample was shielded from solar flares; thus ^{22}Al saturation exposure results are indeterminate. In another solar flare study, Fireman et al. (1973) report tritium data for an exterior chip (,37) and an interior chip (,30).

PHYSICAL PROPERTIES: Collinson et al. (1973) and Runcorn et al. (1974) report magnetic results for ,47 and ,49 both polymict breccia chips. The chip ,47 had an anomalous intensity variation during alternating field demagnetization which was not of repeatable direction in the same demagnetizing field. The initial intensity was 3.2×10^{-6} emu g^{-1}. ,49 had a similar initial intensity, but became too weak to measure in demagnetizing fields above 30 Oe.

The difference is probably a result of different amounts of iron. The initial suceptibilities (Runcorn et al., 1974) were 59.0×10^{-6} (,47) and 19.2×10^{-6} (,49) emu g^{-1} Oe^{-1}. A second split of ,49 had a saturation IRM of 8.6×10^{-3} emu g^{-1}, which reduced to 1.9×10^{-3} in a 5000 Oe demagnetizing field. This suggests the presence or iron grains capable of retaining a hard remanent magnetization. The magnetization history of 67915 is obscure.

Tsay and Baumann (1975) infer an annealing temperature for ,110 (polymict breccia) of 700-900°C from ferromagnetic resonance spectral features.

PROCESSING AND SUBDIVISIONS: The rock has been substantially subdivided and many of the splits are illustrated in Taylor and Mosie (1979), together with a generic chart.

A lengthwise slab was cut (1972) for the Roedder Consortium study and a second slab (,223) was cut (1979) during the Marti consortium study as shown in Figure 6. The first slab was extensively dissected, the second has not yet been split. Several splits have also been made from the large end-piece ,2.

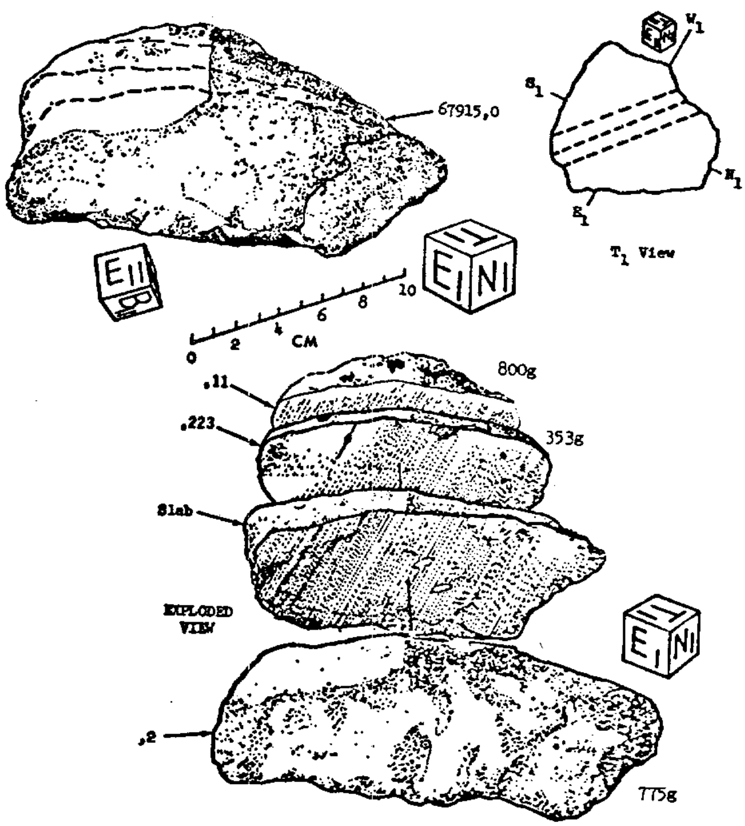


Figure 6. Cutting diagram.

INTRODUCTION: 67935 is a moderately coherent, light gray, basaltic impact melt that is cut by many penetrating fractures and glass veinlets (Fig. 1).

This sample was collected, along with 67936 and 67937, from within the spall zone of a shatter cone on Outhouse Rock (see 67915, Fig. 1). Its precise lunar orientation is unknown, but many zap pits are present on the B surface. In contrast, zap pits are absent from all other surfaces, which are fresh fracture faces.

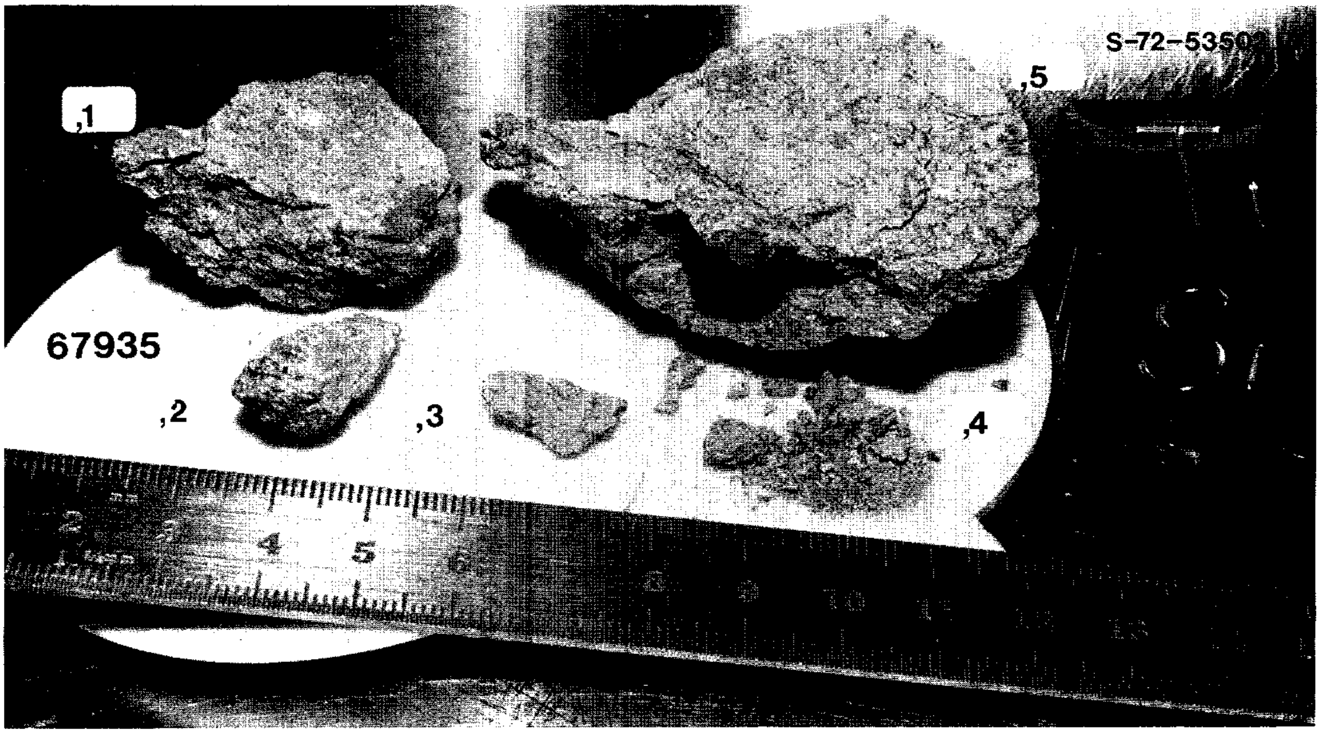


Figure 1.

PETROLOGY: 67935 is a fine-grained impact melt of somewhat varied grain size and texture. The coarser-grained areas tend to be basaltic with a subophitic texture (Fig. 2). Many of the plagioclase laths are hollow and a flow-alignment is apparent in some areas. Ilmenite and glassy mesostasis are minor, interstitial components. In finer-grained (down to a few microns) areas the rock takes on a vaguely poikilitic texture with oikocrysts generally a few tenths of a mm across. Fe-metal/troilite intergrowths are randomly distributed through the rock, locally in association with a small amount of phosphide and/or ilmenite(?). Clasts of plagioclase and anorthosite, showing varied degrees of shock and recrystallization, make up ~10% of the rock.

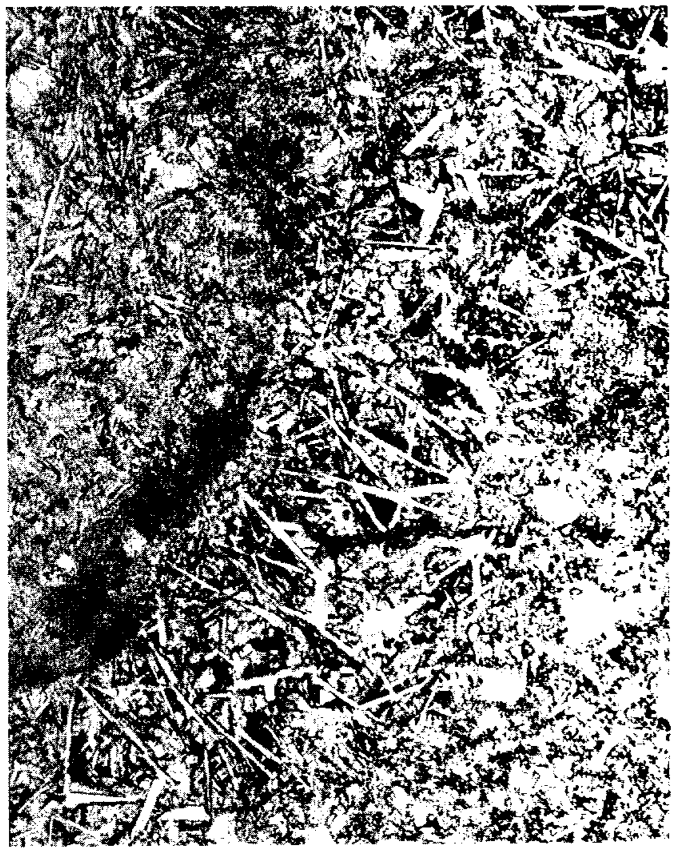


Figure 2. 67935,25, basaltic melt, ppl. width 1mm.

CHEMISTRY: Hertogen et al. (1977) report meteoritic siderophile and volatile abundances and Clark and Keith (1973) present natural and cosmogenic radionuclide abundances. On the basis of these limited data, 67935 appears to be unique among rocks from the North Ray Crater area. It has high Rb and K_2O contents (Table 1). Ge (633 ppm, Hertogen et al., 1977) is also quite high, although volatile/involatile ratios, e.g. Tl/Cs, are not particularly high (compare to diagrams in Krähenbühl et al., 1973). Siderophile elements are also present at very high levels (Table 1) and are classified as meteoritic group 1H (a group largely restricted to Apollo 16) by Hertogen et al. (1977).

TABLE 1. Summary chemistry of 67935

K_2O	wt%	0.196
Rb	ppm	6.07
Ni	ppm	659
Ir	ppb	12.9
Au	ppb	12.3
Zn	ppm	3.98

RARE GAS/EXPOSURE AGE: Clark and Keith (1973) and Fruchter *et al.* (1978) provide cosmogenic radionuclide abundances. These authors and Yokoyama *et al.* (1974) agree that 67935 is unsaturated in absolute amounts of ^{26}Al but Fruchter *et al.* (1978) contend that the sample can be considered essentially saturated if its partially shielded position on the lunar surface is taken into account. From a comparison of ^{53}Mn and ^{26}Al activity, Fruchter *et al.* (1978) conclude that the shatter cone from which 67935 was taken formed $\sim$2 m.y. ago, possibly during the South Ray Crater event.

PROCESSING AND SUBDIVISIONS: In 1972, 67935 was split into five subsamples (,1-,5; Fig. 1). All allocations have been filled from ,1 and ,5. The rock separates easily along fractures and splits have always been made by prying. The largest single piece remaining is ,5 (70.22 g) at JSC.

INTRODUCTION: 67936 consists mainly of a medium-gray, fine-grained, subophitic impact melt with thick glass veins and a few white clasts (Fig. 1). It is coherent and slabby. It was chipped from Outhouse Rock (see 67915, Fig. 1) to sample a shatter cone, as were 67935 and 67937. Its orientation is unknown and zap pits are absent.

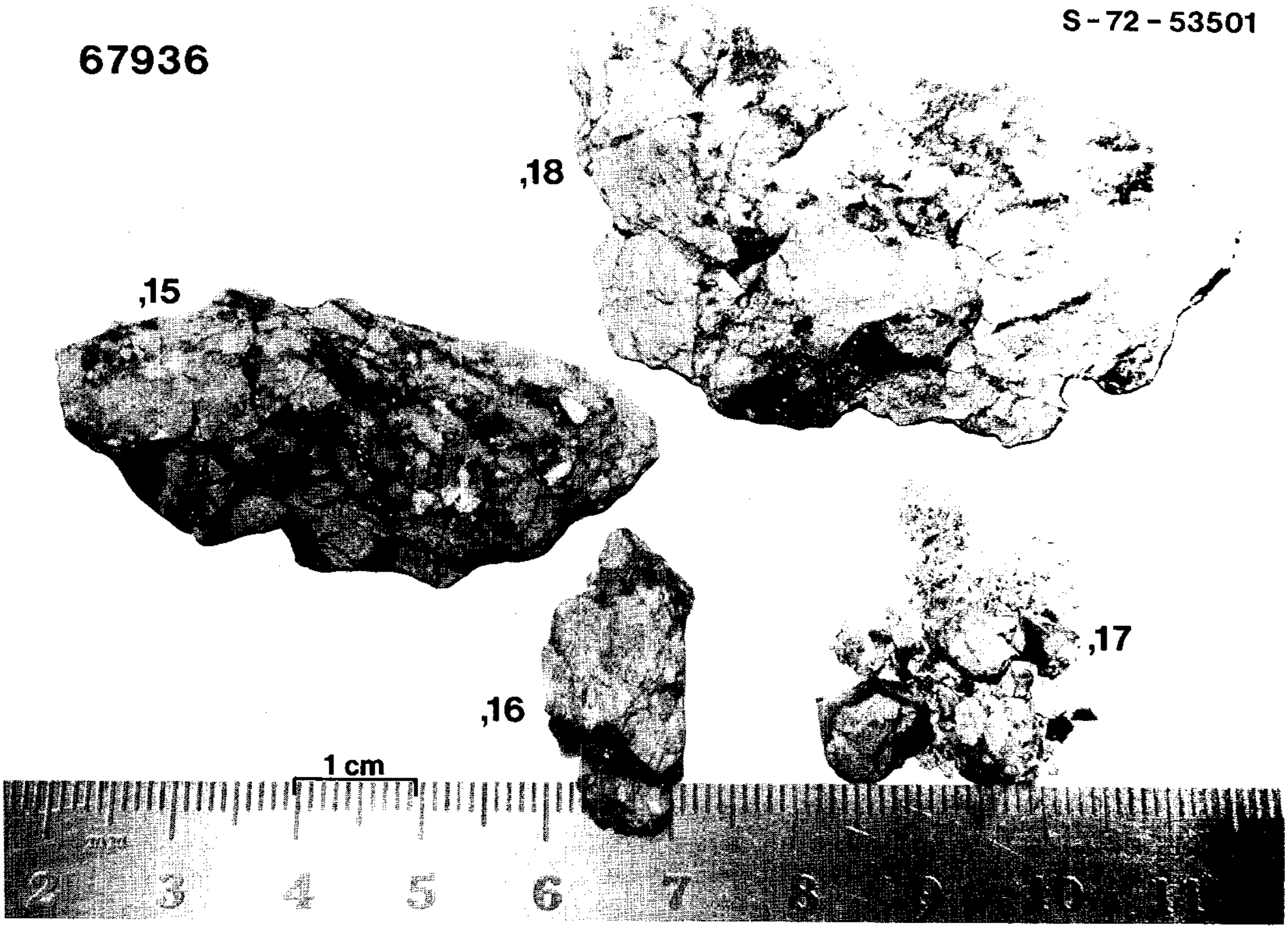


Figure 1.

PETROLOGY: Roedder and Weiblen (1977a) describe, analyze, and discuss the origin of the glass veins, and also report a defocussed beam analysis and some mineral chemical data purportedly from the host rock.

67936 is mainly a basaltic impact melt with a fine-grained subophitic to intergranular texture (Fig. 2). Plagioclase laths less than 100 μm long have

Figure 2. 67936,20, basaltic melt, glass vein in upper right corner, ppl. width 0.5mm.

interstitial mafic and opaque minerals. Minor residual glass (or silica or K-feldspar?) is present. In places there are clasts of plagioclase-rich breccia which have a fine-grained mortar of melt but are mainly clastic plagioclase. A defocussed beam analysis of "breccia matrix" by Roedder and Weiblen (1977a) is reproduced in Table 1. However, our inspection of the material analyzed shows that it was in fact a plagioclase-rich breccia clast, not the general basaltic matrix of 67936. The analyses of olivine (Fo_{80}) and plagioclase (An_{94}) reported for the matrix by Roedder and Weiblen (1977a) also apply to the breccia clast, not the basalt.

The glass veins (discussed in detail by Roedder and Weiblen, 1977a) are anastomosing masses of banded gray glass (Fig. 2). The glass contains abundant metal spheres and a few mineral clasts. The mineral clasts include plagioclase, olivine (Fo_{77}),chromite, and pleonaste spinel. The larger metal spheres ($\sim$7 μm) contain $\sim$7% Ni, 5% S and are composite; the smaller spheres (<0.1 μm) have $\sim$3% Ni and lack sulfur (Roedder and Weiblen, 1977a). An average analysis of the clear glass is given in Table 1. Roedder and Weiblen (1977a) note that the Al_2O_3 content is much lower than the host breccia, but in fact the value of 25.13% is in accord with the mode of the basaltic impact melt which has $\sim$70% plagioclase; hence the glass could be a shock melt of the basaltic impact melt.

TABLE 1. Microprobe analyses of glass veins and breccia clast in 67936 (from Roedder and Weiblen, 1977a)

Wt%	*Glass	Breccia clast
SiO_2	46.1	46.4
TiO_2	0.20	<0.05
Al_2O_3	25.1	31.5
Cr_2O_3	-	<0.05
FeO	5.74	2.77
MnO	0.02	<0.05
MgO	7.08	2.11
CaO	15.28	16.7
Na_2O	0.21	0.39
K_2O	0.03	<0.05
P_2O_5	<0.05	<0.05

* Average of 4 clear glass areas.

CHEMISTRY: Clark and Keith (1973) report K (K_2O 0.193%), U (0.91 ppm) and Th (3.12 ppm) abundances for ,18, a large piece of the bulk rock.

RARE GASES AND EXPOSURE AGES: Roedder and Weiblen (1977a) report rare gas data (by C. Alexander) for both glass veins and matrix. The veins have less Kr, He, and Xe than the matrix, and both veins and matrix have 2-3 orders of magnitude less rare gases than typical regolith. The $^{40}Ar/^{36}Ar$ ratio of 220 (soils are $\sim$1.0) shows that virtually all the Ar is radiogenic. These data all show that there is no solar wind gas in the glass veins.

Yokoyama et al. (1974) note that the cosmogenic radionuclide data of Clark and Keith (1973) indicate that 67936 is unsaturated in ^{26}Al.

PROCESSING AND SUBDIVISIONS: 67936 has been substantially subdivided. The main pieces are shown in Figure 1. An undocumented chip (,1) was made into thin sections ,2; ,13; ,14; ,22; ,23 and ,24 and two small chips of matrix and glass were made into thin sections ,20 (from ,3) and ,21 (from ,4).

INTRODUCTION: 67937 is a medium gray, fine-grained impact melt cut by glass veins (Fig. 1). It is coherent and slabby. Sharp variations in grain size are apparent macroscopically. It was chipped from Outhouse Rock (see 67915, Fig.1) to sample a shatter cone, as were 67935 and 67937. Its orientation is not precisely known but a few zap pits on one surface indicate the exterior.

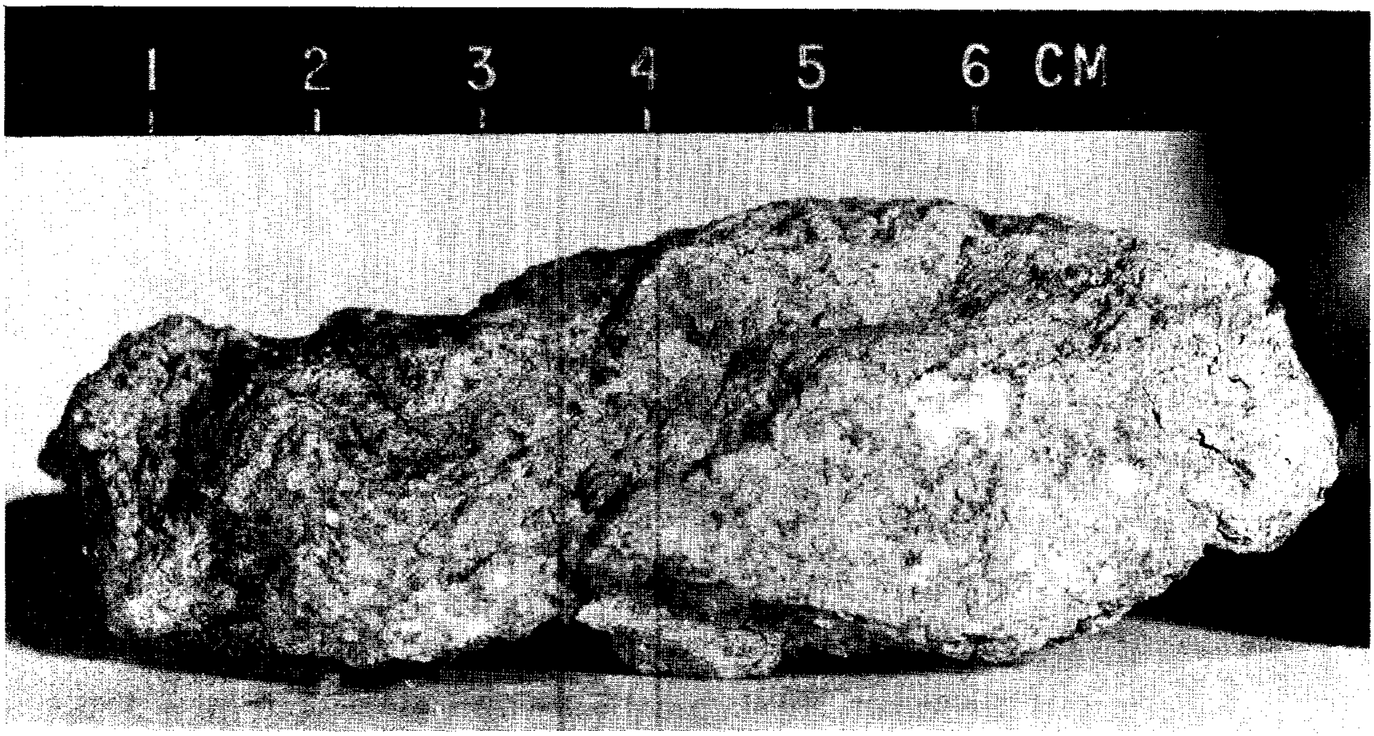


Figure 1. S-72-37771.

PETROLOGY: 67937 is a fine-grained, subophitic to ophitic impact melt with plagioclase laths up to 300 μm long embedded or partly embedded in mafic minerals 300 μm across (Fig. 2). A small amount of mesostasis glass and opaque minerals fills angular interstices. Fe-metal is present. A large clast (4 mm) in thin section ,13 is a crushed anorthosite. Other clasts are mainly plagioclase, but a pink spinel grain is present.

CHEMISTRY: Eldridge et al. (1973) report K (K_2O 0.19%), U (0.91 ppm) and Th (3.12 ppm) abundances for the whole rock.

EXPOSURE: Eldridge et al. (1973) report ^{22}Na and ^{26}Al data for the whole rock. The values indicate that the sample is unsaturated with ^{26}Al activity (Yokoyama et al., 1974).

Figure 2. 67937,13, basaltic melt, ppl. width 2mm.

PROCESSING AND SUBDIVISIONS: A small chip was used up to make thin sections ,4 and ,13-,16. Most of the remainder of the rock occurs as two large pieces which make up ,0 (55.98 g).

67945 FINE-GRAINED BASALTIC IMPACT MELT 4.37 g

INTRODUCTION: 67945 is a light gray, fine-grained impact melt (Fig. 1) with a subophitic to poikilitic texture and a small piece of adhering glass coat(?) and veins. It was collected from the regolith at the east-west split of House and Outhouse Rocks (see 67915, Fig. 1). Its orientation is unknown and it lacks zap pits.

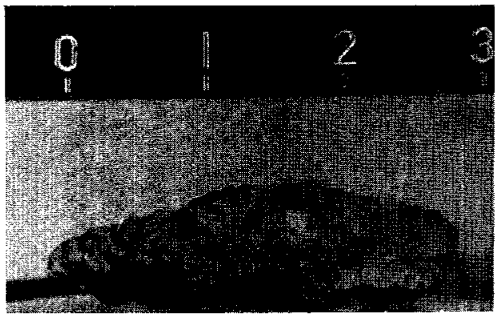


FIGURE 1. S-72-38977. Scale in cm.

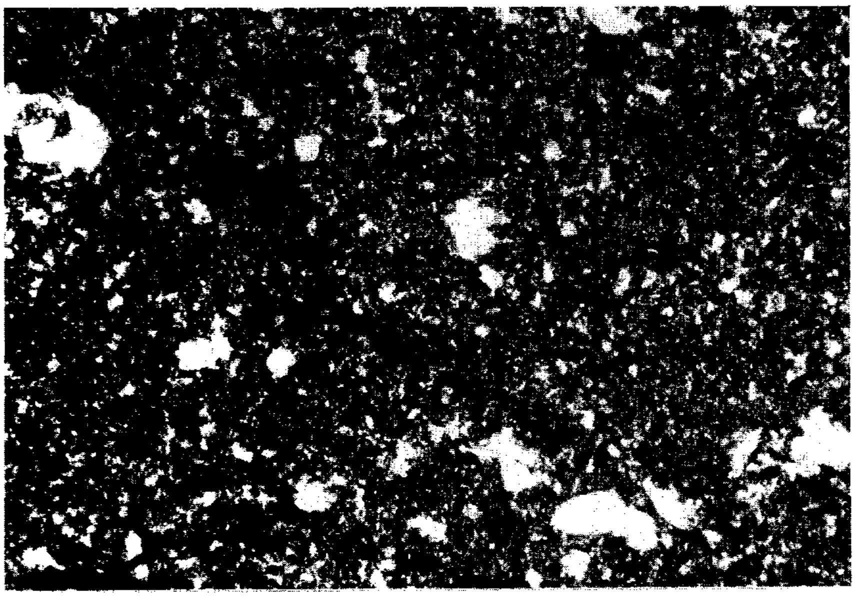


FIGURE 2. 67945,14. ppl. width 3mm.

PETROLOGY: 67945 is an impact melt with a micropoikilitic to microsubophitic texture (Fig.2). Plagioclase laths are mainly $\sim$ 30 μm long with pyroxenes partly enclosing them. Some interstitial glass, laths of ilmenite, and Fe-metal are present. A few plagioclase clasts (less than 200 μm) and a 400 μm diameter pink spinel clast are present.

PROCESSING AND SUBDIVISIONS: A single chip (,1), typical except that it lacks glass, was taken to make thin sections ,13-,15.

67946 VARIOLITIC IMPACT MELT OR DEVITRIFIED GLASS 3.20 g

INTRODUCTION: 67946 is a coherent, medium dark gray, impact melt (Fig.1) which is vesicular and either devitrified or crystallized into variolites. It was collected from the regolith at the east-west split of House and Outhouse Rocks (see 67915, Fig.1). Its orientation is unknown and it has a few zap pits on one face.

PETROLOGY: Spherulitic or variolitic structures are visible macroscopically. In thin sections they can be seen as bundles up to 1 mm across (Fig.2), embedded in a glassy or devitrified groundmass. The variolites are intergrown plagioclase and subordinate mafic minerals. One lithic clast in ,13 and ,14 is a pure plagioclase breccia. The vesicles are perfectly spherical.

PROCESSING AND SUBDIVISIONS: ,2, a located chip, was made into thin sections ,13 and ,14. Most of 67946 exists as ,0 (2.46 g), but a documented chip ,1 (0,66 g) also exists.

FIGURE 1. S-72-38977. Sample is about 2.5 cm long.

FIGURE 2. 67946,14. ppl. width 3mm.

PROCESSING AND SUBDIVISIONS: ,2 was made into thin sections ,13 and ,14. Most of 67946 exists as ,0 (2.46 g), but a documented chip ,1 (0.66 g) also exists.

67947 BASALTIC IMPACT MELT(?) 2.43 g

INTRODUCTION: 67947 is a light gray, slabby, coherent fragment (Fig.1) which may have glass veins. The bulk matrix has distinguishable gray and white (plagioclase?) and brownish gray (mafic?) minerals and may be a basältic impact melt. A small amount of fine-grained white material is embedded in the melt. It was collected from the regolith at the east-west split of House and Outhouse Rocks (see 67915, Fig.1). Its orientation is unknown and it lacks zap pits.

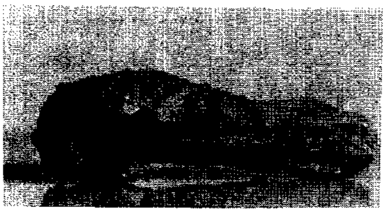


FIGURE 1. S-72-38977. Sample is about 2.5 cm long.

INTRODUCTION: 67948 is a yellowish-gray, angular, coherent, basaltic impact melt lacking obvious clasts (Fig.1). It was collected from the regolith at the east-west split of House and Outhouse Rocks (see 67915, Fig.1). Its orientation is unknown and it lacks zaps pits.

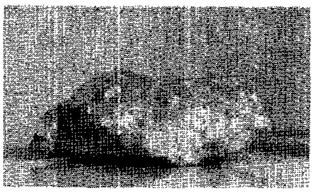


FIGURE 1. S-72-38977. Sample is about 1.5 cm across.

FIGURE 2. 67948,14. ppl. width 2mm.

PETROLOGY: 67948 has a fairly heterogeneous ophitic to subophitic texture (Fig.2). There are abundant anhedral plagioclases, some of which are optically zoned around an unzoned core. Most of the plagioclase occurs as laths 300 to 600 μm long, embedded or partly embedded in mafic minerals ∿ 500 μm across. Many pyroxenes are optically zoned and some are twinned. A brown glassy mesostasis with ilmenite laths and cristobalite is present.

PROCESSING AND SUBDIVISIONS: 2 chips (,1) from one end were made into thin sections ,13-,15.

INTRODUCTION: 67955 is a gray, noritic anorthosite which has experienced extensive subsolidus annealing and equilibration, followed by mild brecciation. The sample breaks apart easily along the many fractures but individual pieces are coherent. Several glass veins cut the rock (Fig. 1).

67955 was collected to sample a large white clast in Outhouse Rock on the east rim of North Ray Crater (see 67915, Fig. 1). The lunar orientation is unknown. Many zap pits are present on original surfaces but are poorly preserved due to the friability of the rock.

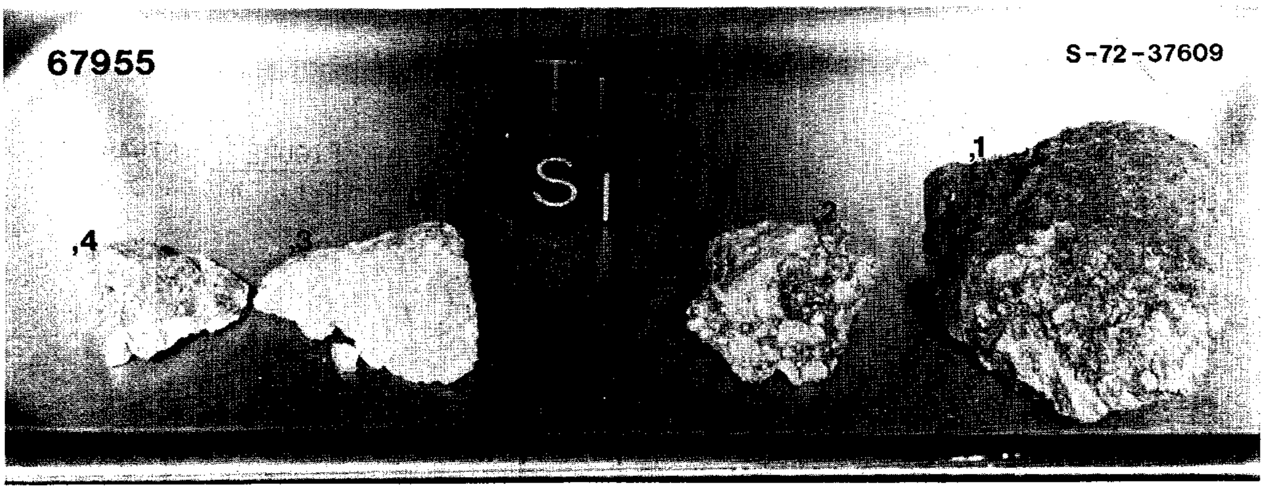
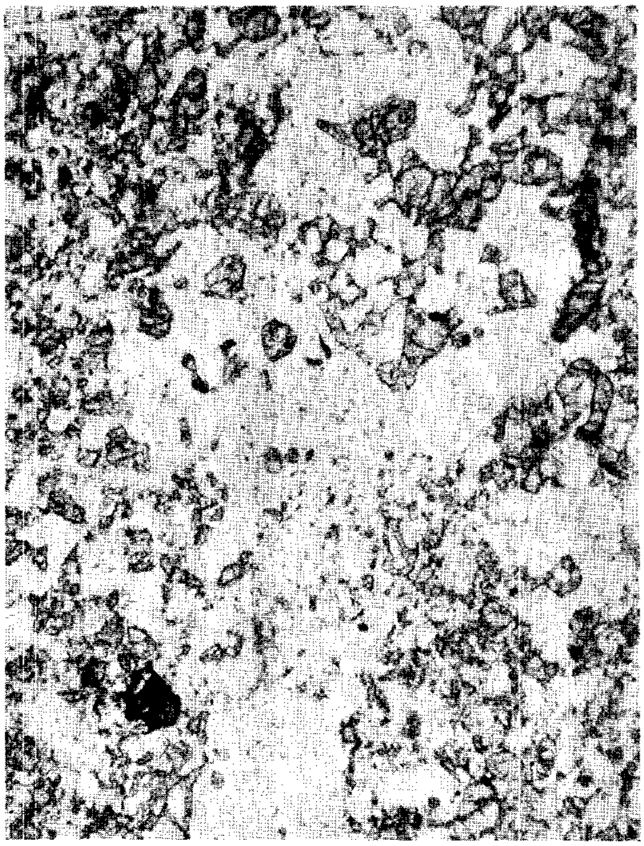


Figure 1. cube is 1cm.

PETROLOGY: 67955 is a coarse-grained, poikiloblastic rock that has been extensively annealed and subsequently brecciated. Warner et al. (1977) classify it as a "feldspathic granulitic impactite". Petrographic descriptions are given by Hollister (1973), Ashwal (1975) and Nord et al. (1975). Texturally 67955 is dominated by coarse-grained clasts of noritic anorthosite (up to 1.5 cm) that grade to a matrix of finely comminuted mineral grains (Fig. 2). These lithic clasts typically show large (some >1 mm) pyroxene poikiloblasts surrounding subhedral to anhedral plagioclase and olivine. Brown glass veins penetrate the matrix but do not cut larger clasts. Roedder and Weiblen (1977a) discuss these glass veins in detail.

A mode given by Hollister (1973) is 78.5% plagioclase, 14.5% pyroxene (low-Ca > high-Ca), 6% olivine and 1% opaques. Minerals in both the lithic clasts and in the matrix are compositionally identical and very homogeneous (Fig. 3). Together with the seriate texture this suggests that the last brecciation event involved simple crushing of the precursor without the introduction of significant foreign material.

a



b

c

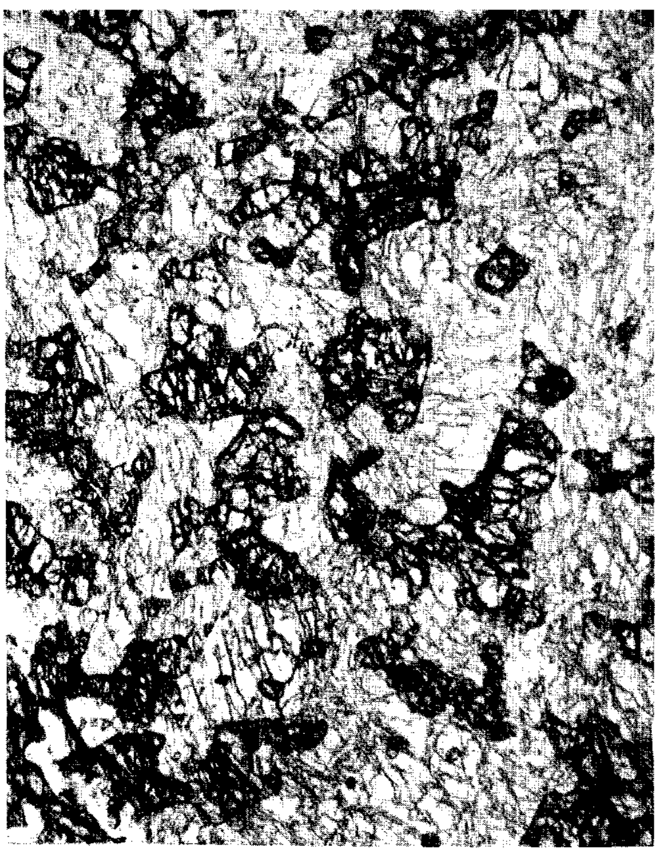


Figure 2. a) 67955,6, granoblastic clast in fragmental matrix, ppl. width 2mm.
b) same view as a) but xpl.
c) 67955,47, coarse-grained area, ppl. width 2mm.

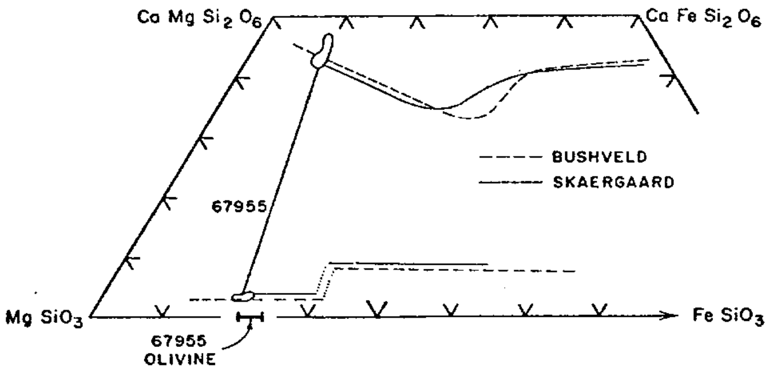


Figure 3. Pyroxene and olivine compositions, from Ashwal (1975).

Plagioclase is An_{92-97} (Fig. 4). Ashwal (1975) notes a weak but perceptible normal zoning (up to 2 mol % An). Shock effects in plagioclase range from fracturing and twinning through complete vitrification. The large oikocrysts are chiefly low-Ca pyroxene with high-Ca pyroxene restricted to interoikocryst regions. Neither of the pyroxenes in 67955 appear to be exsolved, but a small amount of optically invisible exsolution may account for some of the compositional variation in the high-Ca pyroxenes (Ashwal, 1975). Within the lithic clasts, olivine occurs either as rounded, interstitial grains or as inclusions within plagioclase and pyroxene. In some places, olivine inclusions are concentrated near the rims of larger plagioclase grains producing a "necklace" structure. Minor elements in olivine are very low (CaO 0.06%, Cr_2O_3 0.04%, TiO_2 0.04%) (Hollister, 1973). Trace phases in the lithic clasts include coexisting low-Ni and high-Ni metal (Fig. 5), ilmenite, troilite, phosphate, spinel and rare radiating oxide-anorthite complexes. Hollister (1973) reports a single large (0.5 mm) olivine clast, weakly zoned from Fo_{78-81}. This grain has no apparent counterpart in any of the lithic fragments.

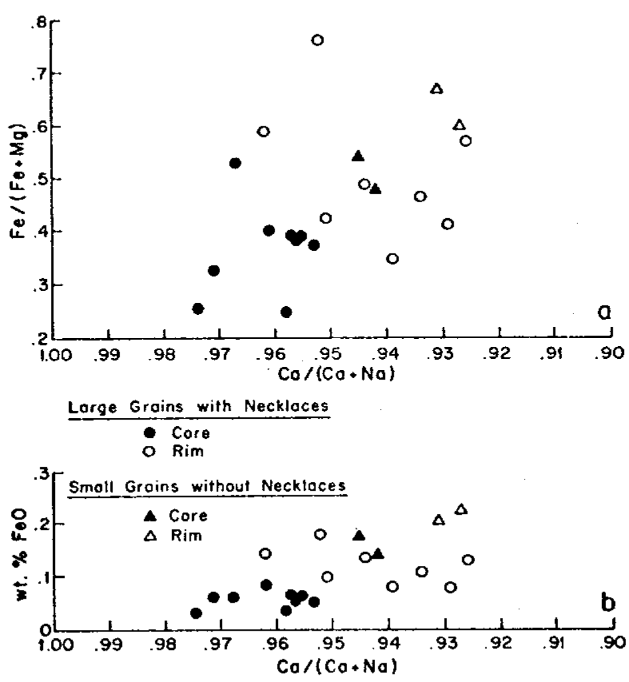
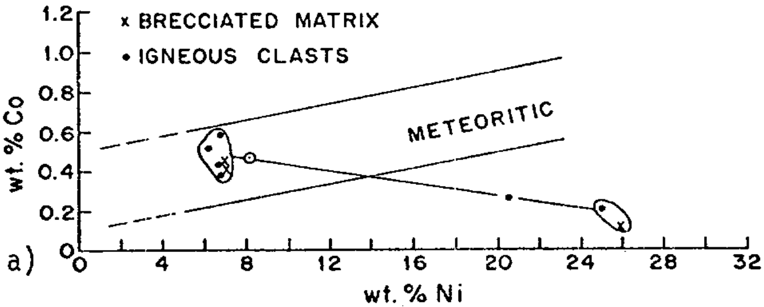


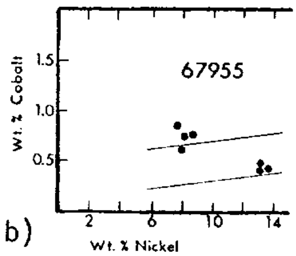
Figure 4. Plagioclase compositions, from Ashwal (1975).

Temperatures of equilibration of 1000-1100° C have been calculated from the composition of the mafic silicates in 67955 (Ridley and Adams, 1976; Hollister, 1973). Considering such high temperatures it is likely that some silicate melt was involved in the petrogenesis of this rock (Hollister, 1973). In an electron petrographic study Nord et al. (1975) conclude that 67955 was not lithified by the North Ray Crater event.



a)

Compositions of coexisting low- and high-Ni metallic phases from 67955 showing chemical similarity between grains in the anorthositic norite clasts and the granulated matrix. The circle indicates estimated pre-unmixing composition assuming 5 vol.% of high-Ni phase.



b)

Figure 5. Metal compositions. a) from Ashwal (1975), b) from Misra and Taylor (1975). See also Hollister (1973).

CHEMISTRY: Major and trace element analyses of the bulk rock are reported by Hubbard et al. (1974), Boynton et al. (1976), Wasson et al. (1977), Palme et al. (1978) and LSPET (1973). Meteoritic siderophile and volatile abundances are given by Ganapathy et al. (1974). Rancitelli et al. (1973a,b) provide natural and cosmogenic radionuclide abundances. Roedder and Weiblen (1977a) give electron microprobe analyses of the glass veins.

The analyses show that 67955 is a very homogeneous rock with ∿27% Al_2O_3 and rare earths ∿15 times chondrites (Table 1, Fig. 6). Siderophile element abundances indicate that there is significant meteoritic contamination. Hertogen et al. (1977) assign the meteoritic signature to Group 5H, common among North Ray Crater rocks. The glass veins are distinctly more aluminous and less magnesian than the bulk rock (Table 1), and therefore must represent injected foreign material rather than mobilized bulk rock.

RADIOGENIC ISOTOPES AND GEOCHRONOLOGY: Nyquist et al. (1974) give whole rock Rb-Sr isotopic data and calculate model ages of 4.70±0.46 b.y. (T_{BABI}) and 5.01±0.46 b.y. (T_{LUNI}) (Table 2).

U-Th-Pb isotopic data are reported by Oberli et al. (1979). 67955 contains excess U relative to its Pb content and plots slightly above the 3.9-4.45 b.y. "cataclysm" line.

TABLE 1. Summary chemistry of 67955 lithologies

	Bulk Rock	Glass Veins
SiO_2	45.2	46.3
TiO_2	0.30	0.21
Al_2O_3	27.3	29.8
Cr_2O_3	0.12	<0.05
FeO	4.2	3.0
MnO	0.06	<0.05
MgO	7.7	4.9
CaO	15.3	15.5
Na_2O	0.45	0.23
K_2O	0.060	0.06
P_2O_5	0.05	<0.05
Sr	170	
La	4.9	
Lu	0.27	
Rb	0.9	
Sc	7.2	
Ni	173	
Co	17	
Ir ppb	6.9	
Au ppb	2.0	
C		
N		
S	100	
Zn	6.6	
Cu	1.28	

Oxides in wt%; others in ppm except as noted.

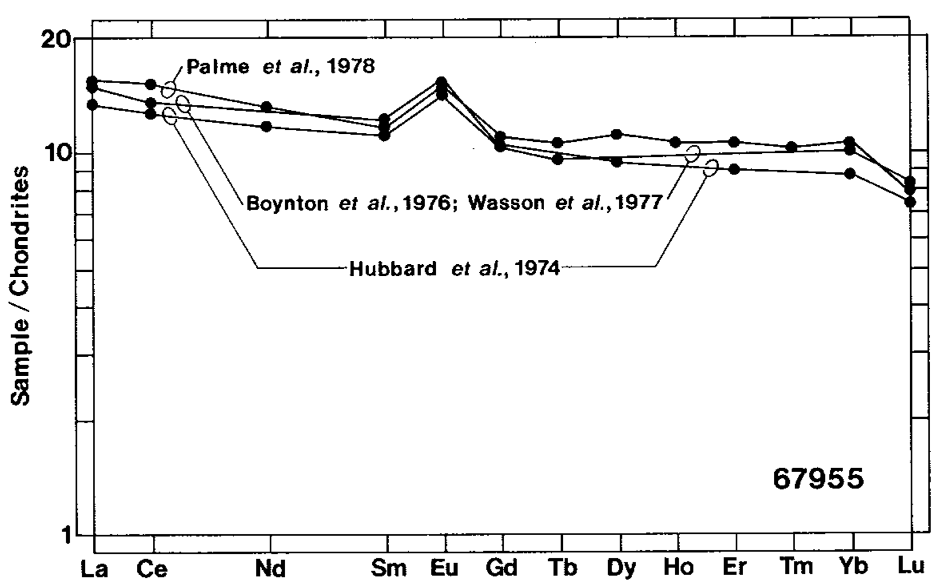


Figure 6.
Rare earths.

TABLE 2. Rb-Sr data for 67955,56 (Nyquist et al., 1974)

Rb ppm	Sr ppm	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	T_{BABI} (b.y.)	T_{LUNI} (b.y.)
0.885	169.1	0.0151±3	0.70012±8	4.70±.46	5.01±.46

RARE GASES/EXPOSURE AGES: Drozd et al. (1974) give Kr isotopic data and calculate ^{81}Kr-Kr, ^{21}Ne and ^{38}Ar exposure ages of 50.1±1.6, 17.9±4.2 and 32.0±12 m.y., respectively. Pepin et al. (1974) note that ^{21}Ne and ^{38}Ar ages tend to be systematically lower than ^{81}Kr ages, and calculate a shielding depth of 4.8 g/cm^2 for which all ages are concordant at ~50 m.y. These data are consistent with the excavation of Outhouse Rock from a well-shielded area to its present location in a single event.

^{22}Na and ^{26}Al data are given by Rancitelli et al. (1973a). From these data Yokoyama et al. (1974) conclude that 67955 is probably saturated in ^{26}Al activity.

PROCESSING AND SUBDIVISIONS: In 1972, 67955 was removed from its Documented Bag as four pieces, which were numbered ,1-,4 (Fig. 1). Allocations were filled mostly from chips from the largest piece (,1). The sample has never been sawn. ,1 is the largest single piece remaining (103.07g).

INTRODUCTION: 67956 is a coherent, gray, basaltic impact melt lacking obvious clasts and containing irregular vugs (Fig. 1). It was collected from Outhouse Rock, adjacent to 67955 and 67957 (see 67915, Fig. 1). Its orientation is unknown, but it has a few zap pits on one surface indicating the exposed side.

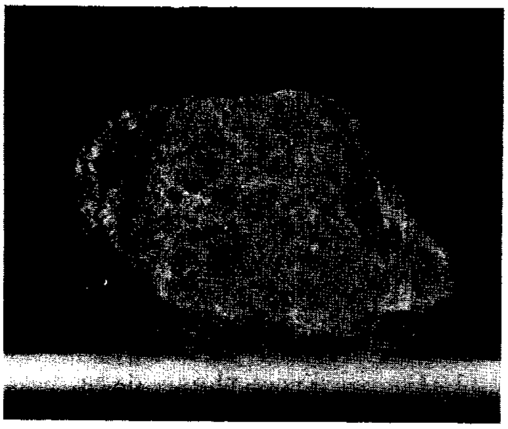


FIGURE 1. S-72-37547. Width of sample about 1.5 cm.

PETROLOGY: 67956 is homogeneous, with a subophitic melt texture. Most plagioclase laths are ∿ 500 μm long with a maximum around 1 mm; some anhedral plagioclases are also ∿ 1 mm in diameter. Mafic minerals partly enclose the plagioclase laths, and interstices are filled with a glassy mesostasis.

PROCESSING AND SUBDIVISIONS: A chip (,1) was made into thin sections ,1 ,13 and ,14. Interior chips were allocated for meteoritic siderophile and volatile element analyses. ,0 remains as 5 chips, one considerably larger than the others, totalling 3.20 g.

INTRODUCTION: 67957 is a grayish olive to dark gray coherent rock which contains a few vesicles or cavities (Fig. 1). The matrix is complex, brown, and possibly largely plagioclase-rich devitrified glass. It was collected from Outhouse Rock adjacent to 67955 and 67956 (see 67915, Fig. 1). Its orientation is unknown but many zap pits on one side indicate the exposed surface.

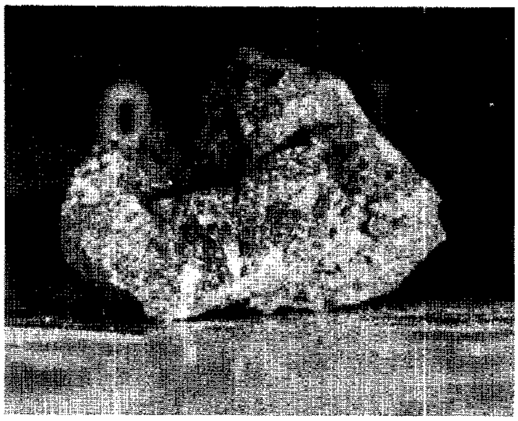


FIGURE 1. S-72 37793. Sample is about 1 cm wide.

FIGURE 2. 67957,5. ppl. width 3mm.

PETROLOGY: 67957 is a brown, glassy or microcrystalline, heterogeneous breccia (Fig.2) containing a few brown, ragged, "microcrystalline" plagioclase clasts which may be devitrified maskelynite. A few mafic and shocked plagioclase clasts are also present.

PROCESSING AND SUBDIVISIONS: A representative chip (,1) was made into thin section ,5 - ,7.

INTRODUCTION: 67975 is an irregularly shaped rock which has roughly equal amounts of a pale gray, fragmental, friable breccia and a coating of frothy, clast-rich glass (Fig. 1). It was picked off the regolith near Outhouse Rock, on the east rim of North Ray Crater. Its orientation is unknown. Zap pits are present on the N and W surfaces of the breccia.

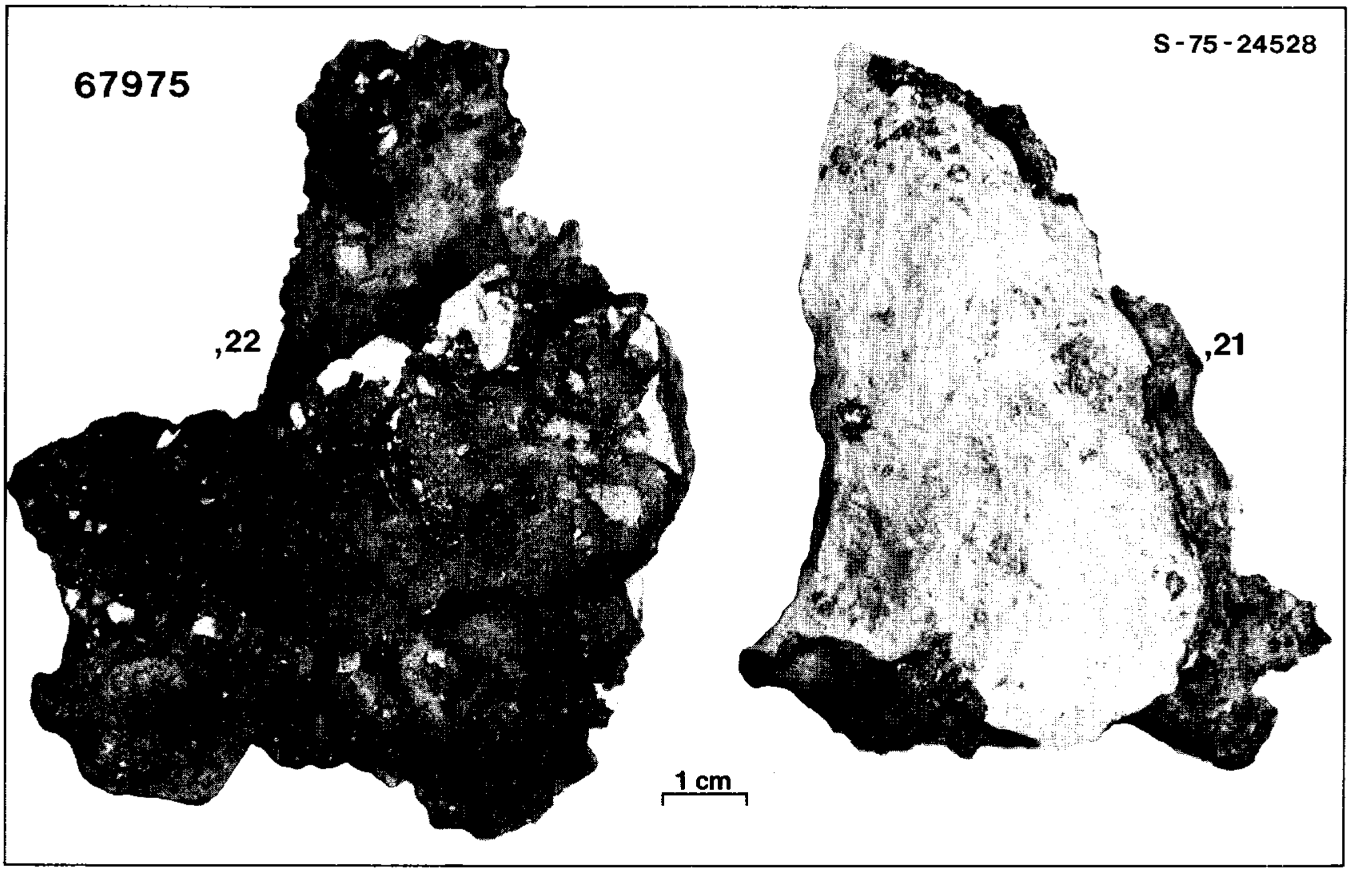


Figure 1.

PETROLOGY: Two lithologies make up 67975 in approximately equal proportions: a fragmental, pale gray breccia, and a glassy coating. Plagioclase mineral fragments dominate the breccia (Fig. 2) with subordinate amounts of mafic minerals, Fe-metal (some rusty) and troilite, and rare ilmenite and spinel. Lithic clasts (Fig. 2) are not common and include basaltic impact melt, granoblastic troctolitic anorthosite, and cataclastic anorthosite, at least one clast of which is pristine. A few dark, irregular, metal-rich glass veins penetrate the breccia.

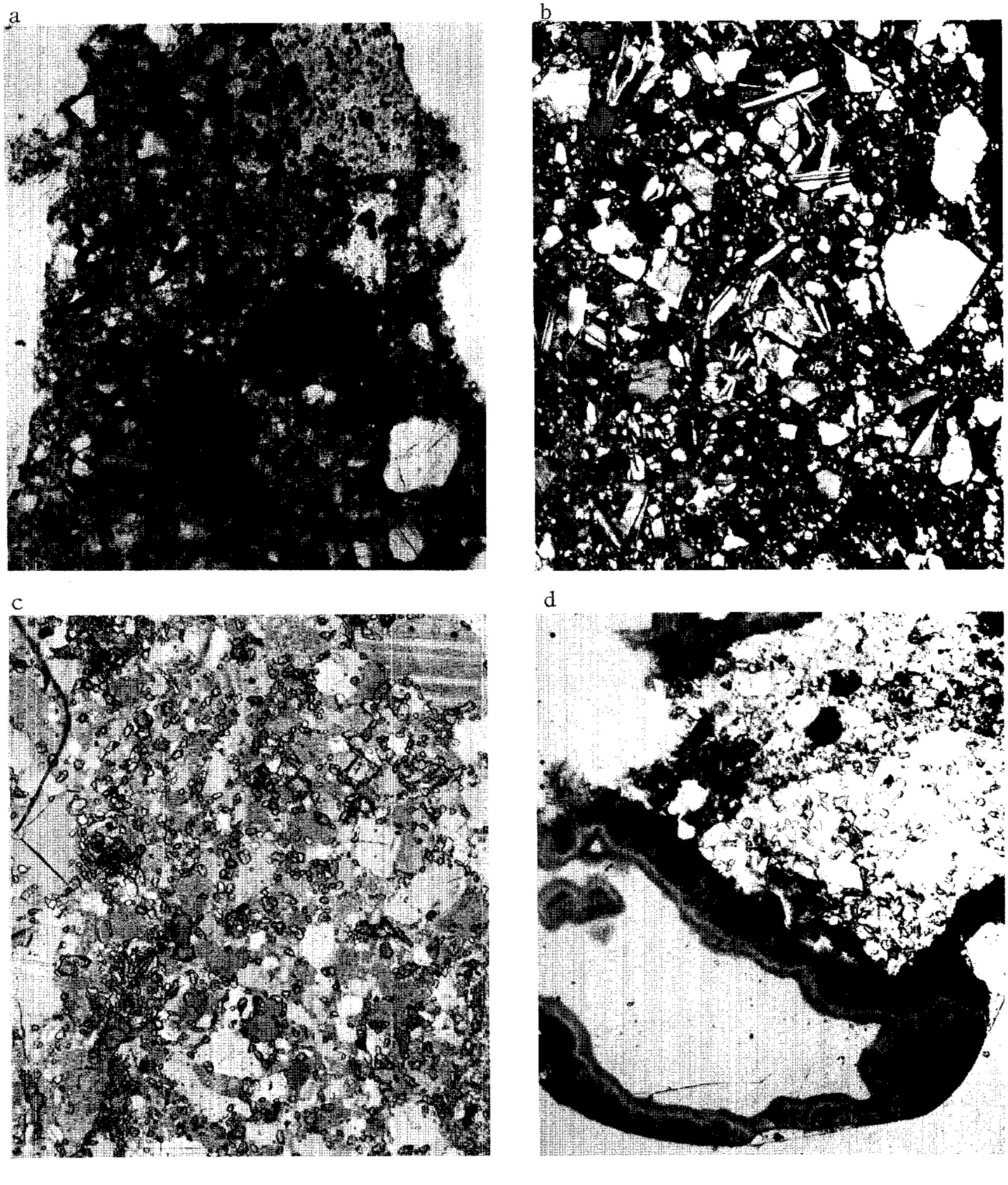


Figure 2. a) 67975,81, fragmental breccia, ppl. width 2mm
b) 67975,62, fragmental breccia, basalt clasts, xpl. width 1mm
c) 67975,65, granoblastic clast, partly xpl. width 1mm.
d) 67975,55, granoblastic clast in glass coat, ppl. width 2mm.

The glass coating (up to ~5 cm thick in places) is generally clean glass with a few mineral and lithic clasts (Fig. 2). Very fine-grained "quench" crystals of plagioclase commonly radiate from the glass/breccia contact and from the exterior surface of the coat.

CHEMISTRY: Major and trace element analyses of representative chips of glass coat and fragmental breccia are given by Christian et al. (1976) (splits ,3 and ,43 respectively). Hertogen et al. (1977) report meteoritic siderophile and volatile element abundances for the glass coat, the fragmental breccia, a pristine cataclastic anorthosite clast, and a dark, aphanitic clast. Total N and C abundances of the glass and the breccia are provided by Moore and Lewis (1976). Clark and Keith (1973) measured natural and cosmogenic radionuclide abundances in the whole rock. Uhlmann et al. (1977) report an average microprobe major element analysis of the glass coat.

TABLE 1. Summary chemistry of 67975 lithologies

	Fragmental, gray breccia	Glass coat	Anorthosite Clast	Aphanitic Clast
SiO_2	44.23	45.33		
TiO_2	0.40	0.49		
Al_2O_3	29.12	27.50		
Cr_2O_3	0.05	0.08		
FeO	4.61	4.27		
MnO	0.06	0.06		
MgO	4.09	5.58		
CaO	16.70	15.90		
Na_2O	0.42	0.52		
K_2O	0.13	0.11		
P_2O_5	0.20	0.11		
Sr	130	150		
La	<10	11		
Lu				
Rb	0.5-1	~1.8	0.58	2.46
Sc	8.7	6.8		
Ni	20	95	≤11	44
Co	4.6	6		
Ir ppb	0.493	5.14	0.091	1.66
Au ppb	0.046	1.48	0.0084	0.98
C	51	31		
N	42	54		
S				
Zn	1.44	2.44	4.25	7.49
Cu				

Oxides in wt%; others in ppm except as noted.

A summary chemistry for each analyzed lithology is given in Table 1. The major element data for the glass coat are those by Christian et al. (1976). The microprobe analysis of the glass coat by Uhlmann et al. (1977) is significantly more aluminous (30.4% Al_2O_3), possibly indicating some heterogeneity in the glass. Significant compositional differences between the glass coat and the fragmental breccia are apparent, especially for Al_2O_3 and Fe/Mg. Except for the pristine anorthosite clast, all samples are contaminated with meteoritic material.

PHYSICAL PROPERTIES: Uhlmann et al. (1977,1978) experimentally and theoretically studied various aspects of the glass forming process for a composition matching their microprobe analysis of the 67975 glass coat (Figs. 3,4,5). The relatively low liquidus temperature (1210°C) and the high viscosity of this composition make it a good glass-former. Uhlmann et al. (1977) estimate the cooling rate of the 67975 glass coat to have been 0.06°C/min and conclude that it did not form as an isolated body but as part of a larger cooling unit.

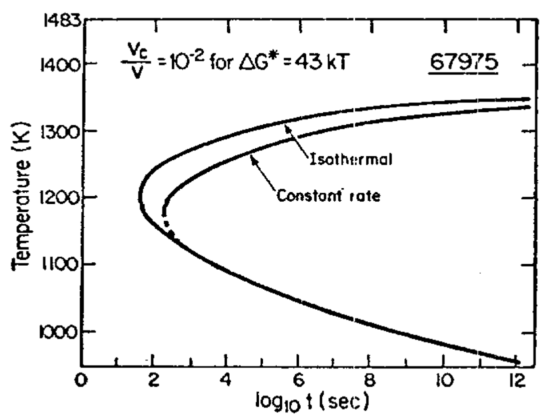


Figure 3. From Uhlmann et al. (1978).

Time-temperature-transformation (TTT) and continuous cooling (CT) curves for matrix composition of lunar breccia 67975. Nucleation barrier = 43 kT at ΔT_r = 0.2.

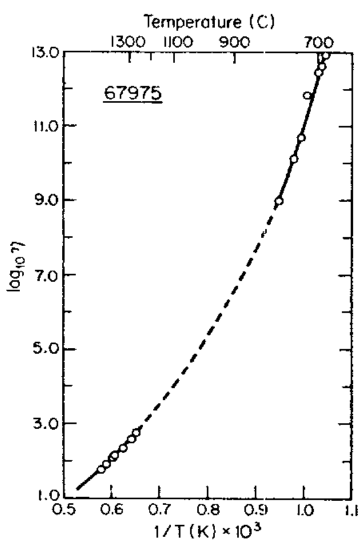
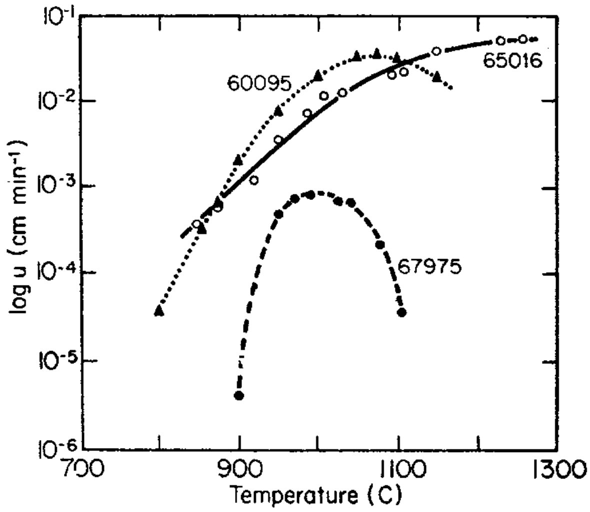


Figure 4. From Uhlmann et al. (1977).

Viscosity versus temperature relation for lunar composition 67975.



Crystal growth rate versus temperature relations for lunar compositions 67975, 60095, and 65016.

Figure 5. From Uhlmann et al. (1977).

PROCESSING AND SUBDIVISIONS: In 1972 a few chips of glass coat were pried off for allocations. In 1975 the rock was extensively subdivided by chipping and prying. The sample has never been sawn. During the 1975 processing the rock was broken into two large pieces (Fig. 1) representing the bulk of the fragmental breccia (,21) and a large portion of the glass coat (,22). ,21 (172.55 g) is stored at the Brooks Remote Vault. ,22 (227.59 g) remains at JSC.

68035 POLYMICT BRECCIA WITH CATACLASTIC ANORTHOSITE, PARTLY GLASS-COATED — 21.0 g

INTRODUCTION: 68035 is a coherent polymict breccia, consisting of aphanitic gray impact melt and cataclastic anorthosite in a plagioclase-rich matrix (Fig. 1). Glass both coats one side and intrudes the breccia (Figs. 1, 2); its color ranges from blues to turquoises to yellow browns.

68035 was collected on the north rim of a 10-15 m crater. Its orientation is known, and zap pits occur on most sides.

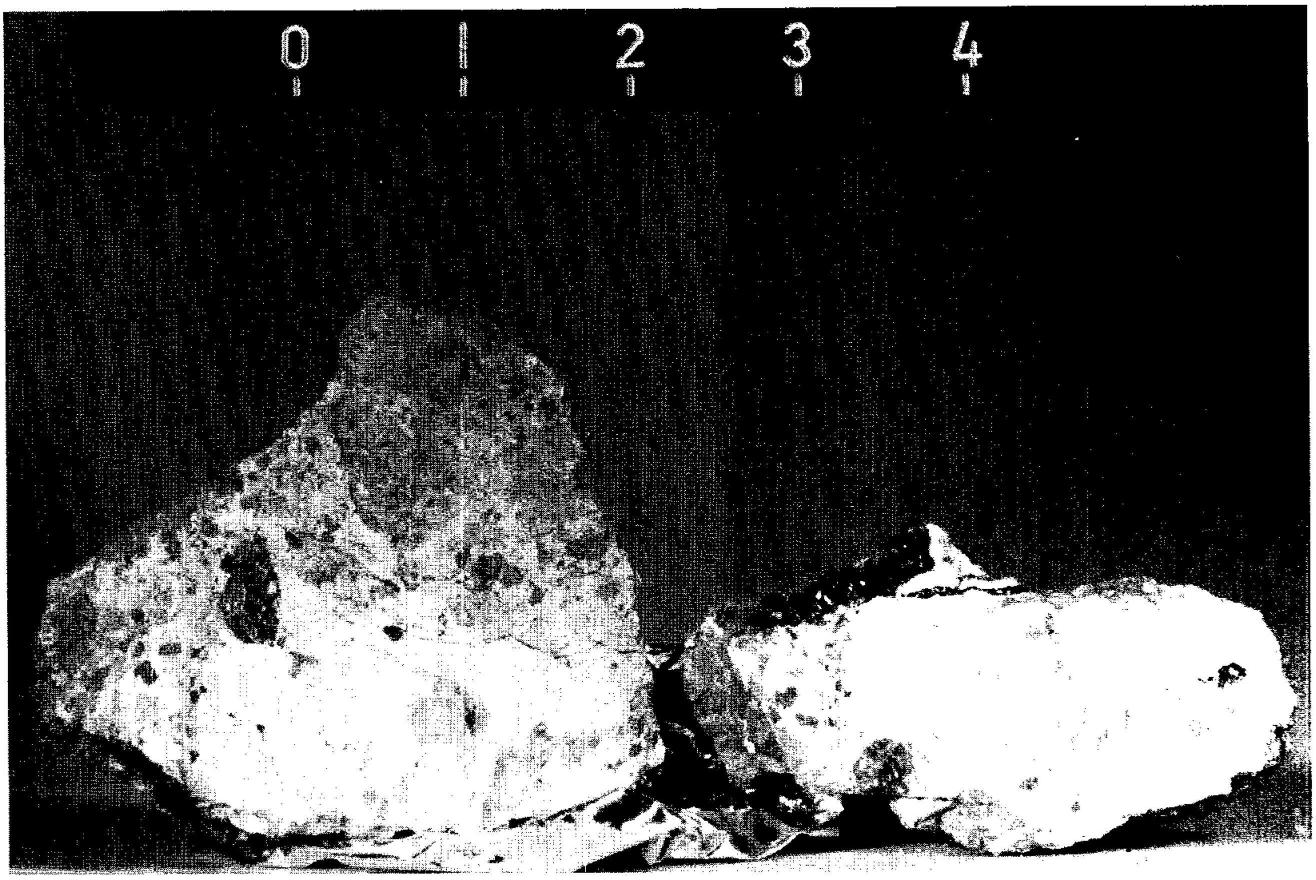


FIGURE 1. S-72-40518.
Scale in cm.

PETROLOGY: Two unlocated chips, one white and one gray, were thin sectioned. The white fragment is a cataclastic anorthosite (Fig. 3) consisting mainly of deformed plagioclase grains, with continuous relics up to 3 mm across preserved. The anorthosite contains a few percent of mafic minerals, at least most of which are pyroxene, and some are exsolved. The mafic minerals range up to 500 μm long. The gray chip is a coherent fine-grained, plagioclase-rich impact melt (Fig. 3) containing mineral and lithic (aphanitic melt) fragments. Its matrix is micropoikilitic in places, and its plagioclase clasts are ragged.

FIGURE 2. S-72-40516. Scale in cm.

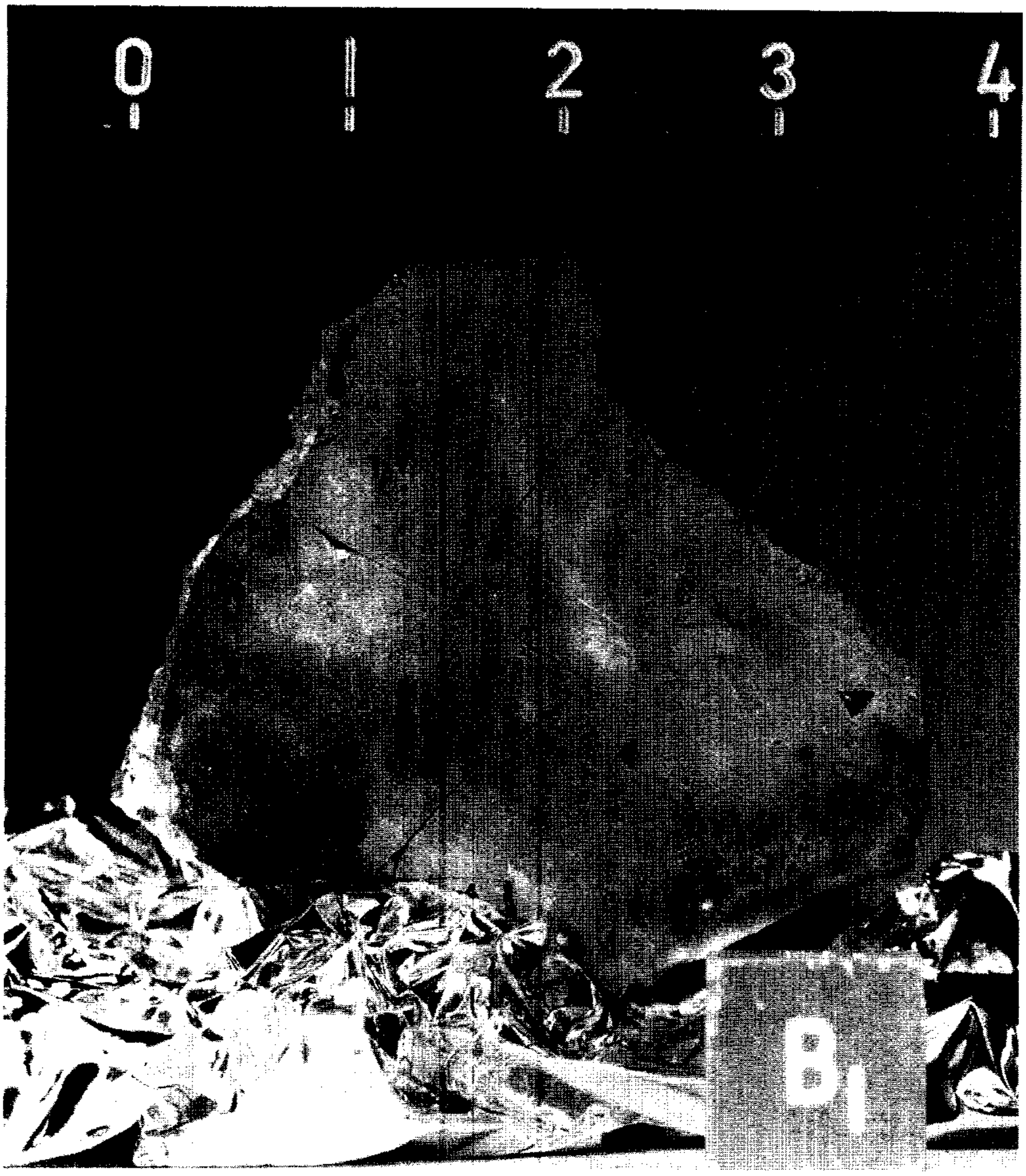


FIGURE 3. 68035,6. a) anorthosite, xpl. width 2mm. b) breccia matrix, ppl. width 2mm.

CHEMISTRY: Rancitelli et al. (1973b) provide whole rock K (K_2O 0.073%), U (0.23 ppm) and Th (0.91 ppm) abundances, measured by γ-ray spectroscopy.

EXPOSURE AGE: Rancitelli et al. (1973a) provide cosmogenic radionuclide data, measured by γ-ray spectroscopy. Yokoyama et al. (1974) tabulate the sample as undecided in terms of saturation or non-saturation in ^{26}Al activity.

PROCESSING AND SUBDIVISIONS: 68035 remains essentially intact as ,0. Small chips and fines have been numbered ,1 (0.020 g). 2 small unlocated chips (,2) were potted together to make thin sections ,6 and ,7.

INTRODUCTION: 68115 is a heterogeneous polymict breccia (Fig. 1) which is heavily shocked. The event forming the breccia melted material, apparently mainly ferroan anorthosite, which then flowed between clasts. These latter are mainly aphanitic and basaltic impact melts. The glass is flow-banded, vesicular, and contains relict white material (Fig. 1).

The sample was the only sample chipped from the 1 m boulder on the southeast rim of a 10-15 m crater. The location and the exposure ages suggest that the boulder is South Ray ejecta. 68115 is medium to medium dark gray, subangular, and tough. Its orientation is known and zap pits occur on all surfaces except that freshly exposed by its break from the boulder.

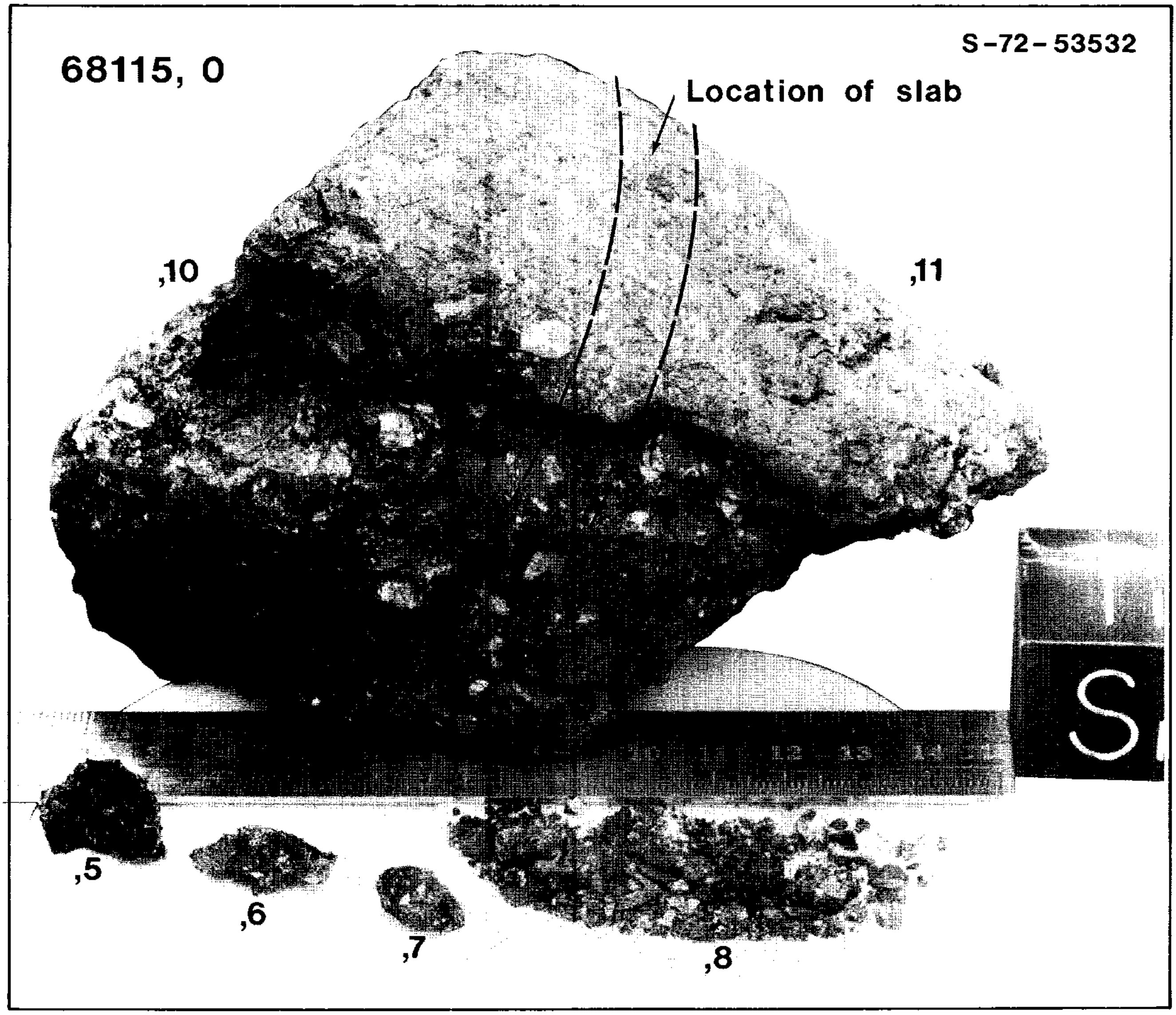


FIGURE 1.

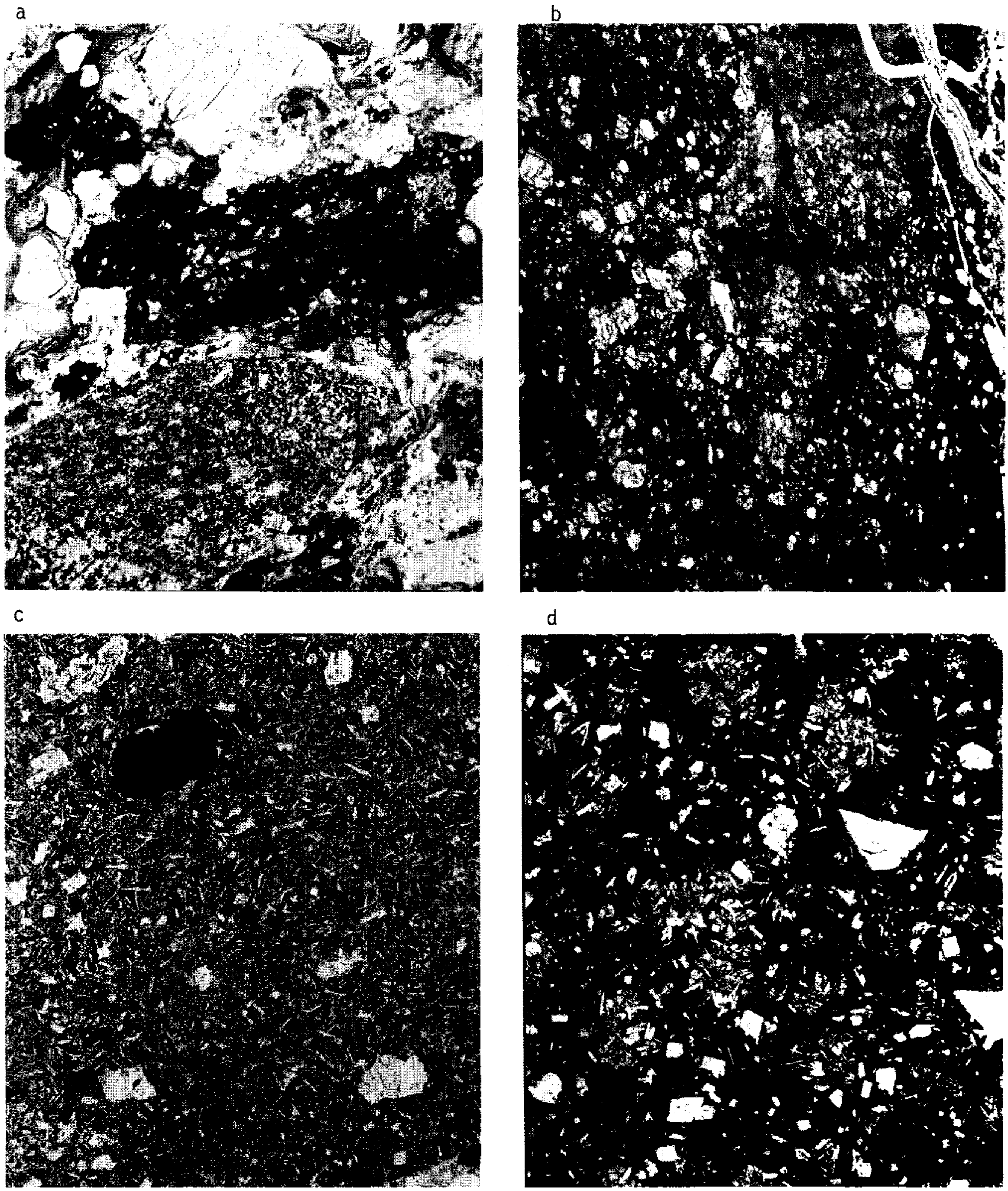


FIGURE 2. a) 68115,3. general glassy breccia, ppl. width 2mm.
b) 68115,3. general glassy breccia, ppl. width 2mm.
c) 68115,3. basaltic melt clast, ppl. width 2mm.
d) 68115,98. glassy basaltic impact melt clast, ppl. width 2mm.

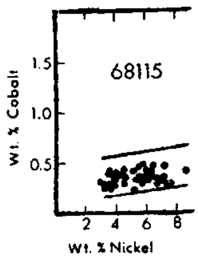


FIGURE 3. Metals; from Misra and Taylor (1975).

PETROLOGY: Grieve et al. (1974) give a petrographic description, with microprobe analyses, of glasses and impact melt fragments. Misra and Taylor (1975) give a brief petrographic description in their study of metal and schreibersite grains. L.A. Taylor et al. (1976), describing heating experiments on 68115, provide an analysis of glass.

68115 is a heterogeneous breccia (Fig. 2) which is welded together by flow-banded glass. The glass varies from colorless to brown, is extremely vesicular, and is aluminous (analyses in Table 1). Plagioclase relicts, shocked and partly isotropized, merge into the glass, commonly with indistinct boundaries; "cumulate" textures occur rarely where mafics are present. The aluminous nature of the glass and the size of the plagioclase relicts (up to two millimeters) suggest a ferroan anorthosite precursor. Most of the clasts, apart from plagioclase, are aphanitic or fine-grained basaltic impact melts (Fig. 2); some are over 1 cm in diameter. They are varied in texture. The melts contain varied amounts of clastic material, mainly plagioclases, but some lithic clasts. These melts contain 21-26% Al_2O_3 (Grieve et al., 1974).

Metal grains analyzed by Misra and Taylor (1975) have features suggestive of crystallization from melts. Their compositions show some spread in Ni values (Fig. 3) with an average of 5.4% Ni and 0.4% Co. Schreibersite is also present; metal-schreibersite tie-lines do not match experimentally determined tie-lines in the Fe-Ni-P system. Fe-metal/troilite intergrowths are common. Kerridge et al. (1975b) report three values of total Fe^0 in 68115: 0.39, 1.07 and 1.62 wt%.

CHEMISTRY: S.R. Taylor et al. (1974) and Fruchter et al. (1974; analysis erroneously tabulated as 67455,13) analyzed some major and trace elements (including rare earths); Rancitelli et al. (1973b) provide U, Th, and K abundance data; and Ganapathy et al. (1974) provide meteoritic siderophile and volatile element abundances. Drozd et al. (1974) list a U abundance and Kerridge et al. (1975b) provide C and S abundances as well as analyses for carbon compounds. All these analyses are of bulk rock or matrix, and the differences between the analyses (Table 1) demonstrate the heterogeneity of the rock although the two rare earth patterns (Fig. 4) are similar. Remarkable is the difference between the siderophile and alkali contents measured by S.R. Taylor et al. (1974) and Ganapathy et al. (1974) on two chips which were similar in appearance; the analysis of Ganapathy et al. (1974) corresponds to a meteorite-free, pristine lithology (Hertogen et al., 1977).

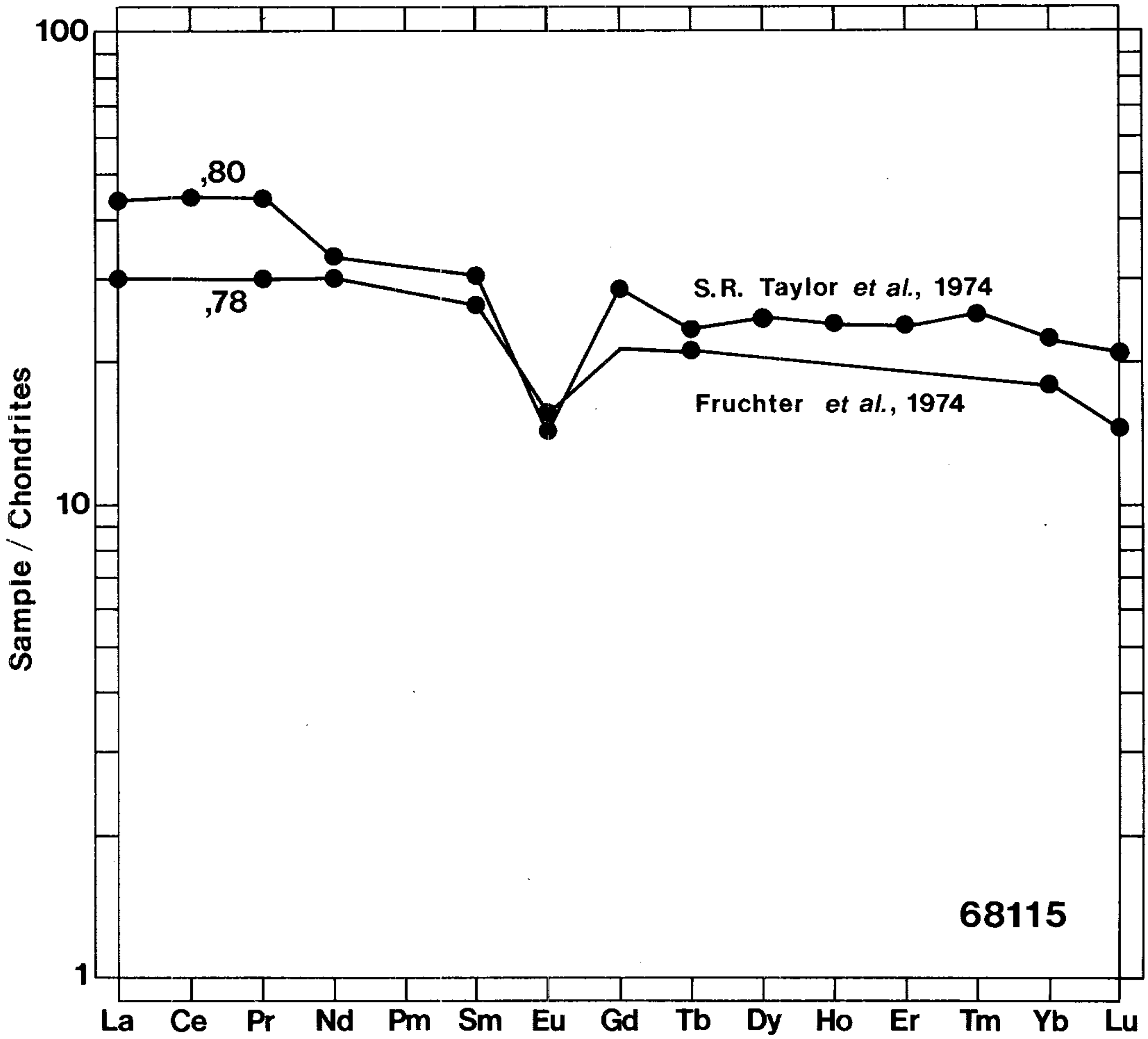


FIGURE 4. Rare earths.

TABLE 1. Chemical Analyses of chips of 68115

	A	B	C	D	E	F
SiO_2	44.8				44.2	44.5
TiO_2	0.34				0.10	0.22
Al_2O_3	27.6	31.6			34.4	29.4
Cr_2O_3	0.10	0.09			0.01	0.06
FeO	5.10	3.2			1.18	3.3
MnO					0.04	0.00
MgO	5.79				0.86	3.6
CaO	15.4				18.7	17.5
Na_2O	0.47	0.45			0.47	0.68
K_2O	0.06				0.06	0.12
P_2O_5						
Sr						
La	14.3	9.8				
Lu	0.7	0.5				
Rb	2.6			0.043		
Sc	9	5.2				
Ni	2000			≤ 7		
Co	105	19.4				
Ir ppb				0.04		
Au ppb				0.005		
C			13-112			
N						
S			600-800			
Zn						
Cu	17					

Oxides in wt%; others in ppm except as noted.

A) ,80 S.R. Taylor et al. (1974)
B) ,78 Fruchter et al. (1974)(erroneously listed as 67455,13)
C) ,67 Kerridge et al. (1975b)
D) ,77 Ganapathy et al. (1974)
E) L.A. Taylor et al. (1976)-microprobe data: glass
F) Grieve et al. (1974)-microprobe data: average glass matrix and injection vein

STABLE ISOTOPES: Kerridge et al. (1975b) report a $\delta^{13}C$ value of -25.8 and a $\delta^{34}S$ value of +1.9, which contrast with values for local regolith of +11 and +9 respectively.

RARE GASES AND EXPOSURE AGES: Drozd et al. (1974) report Kr isotopic and spallation spectra and give a spallation ^{81}Kr-Kr age of 2.08±0.14 m.y. ^{21}Ne and ^{38}Ar ages of 1.75±0.41 and 1.63±0.67 m.y. respectively are tabulated. Bogard and Gibson (1975) report ^{21}Ne ages of 2.2 and 2.1 m.y. and ^{38}Ar ages of 1.3 and 0.9 m.y. Rancitelli et al. (1973a) report ^{22}Na and ^{26}Al data but because the sample was shielded from solar flares the information is not relevant to exposure (Yokoyama et al., 1974).

Bogard and Gibson (1975) report Kr and Xe isotopic abundances for different temperature releases. The data are unusual in that the concentrations released were higher than expected and were associated with the release of chemically active species including hydrocarbons. H_2O and CO_2 were also released and suggest terrestrial contamination. It is probable that the high Kr and Xe releases can be explained as strongly adsorbed atmospheric gases introduced, with other species, at an unknown time.

PROCESSING AND SUBDIVISIONS: Following removal of a few chips, a slab was cut from 68115 in 1973 leaving two large end-pieces ,10 (760 g) and ,11 (252 g) (Figs. 1,5). The slab and ,11 have been extensively subdivided (Fig. 5) but ,10 remains intact.

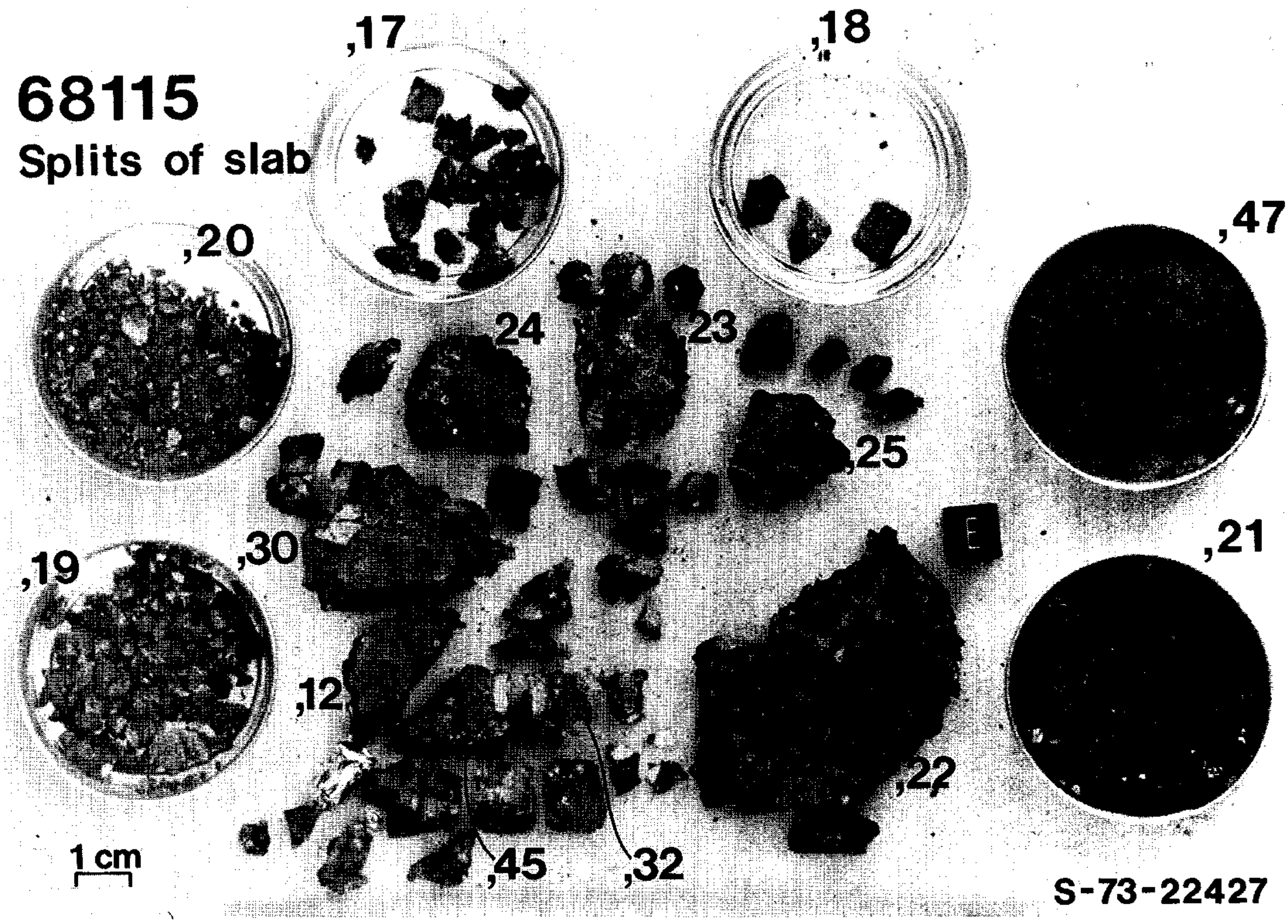


FIGURE 5.

INTRODUCTION: 68415 is a fairly homogeneous basaltic impact melt but with a patchy distribution of light and dark colors suggestive of resorbed clasts (Fig. 1). It contains 75-80% plagioclase in an interlocking network, is contaminated with meteoritic siderophiles, and has a precise Rb-Sr age of 3.84±0.01 b.y. (Papanastassiou and Wasserburg, 1972a). The Rb-Sr isotopic data strongly suggest that 68415 was totally molten at 3.84 b.y., leaving no relics.

Both 68415 and 68416 were chipped from the top of a 0.5 m angular boulder (Fig. 2) on the outside rim of a 5 m crater. The samples were taken ~20 cm apart. 68415 is greenish-gray, coherent and has many zap pits on its lunar exposed, rounded face.

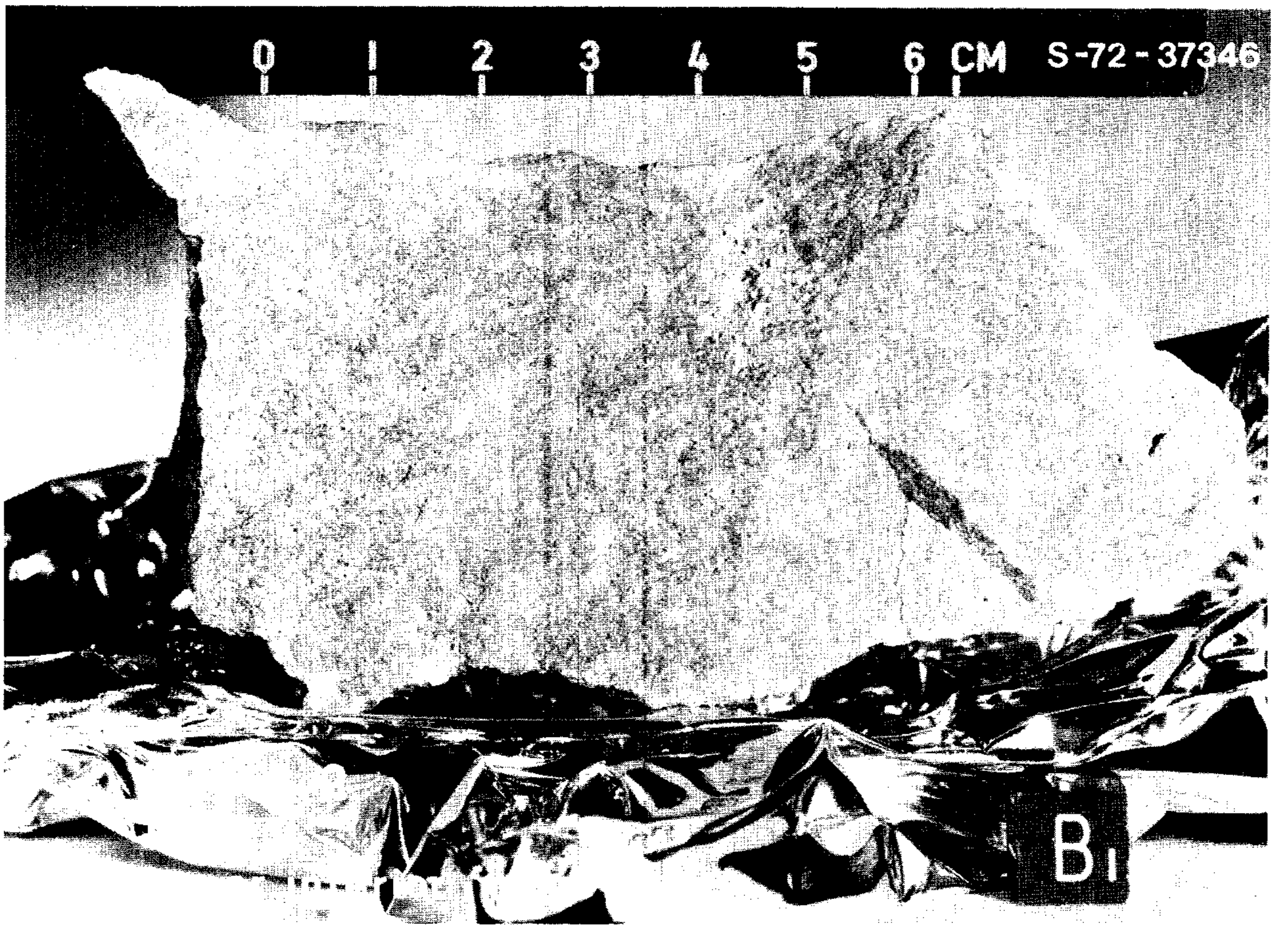


FIGURE 1a.

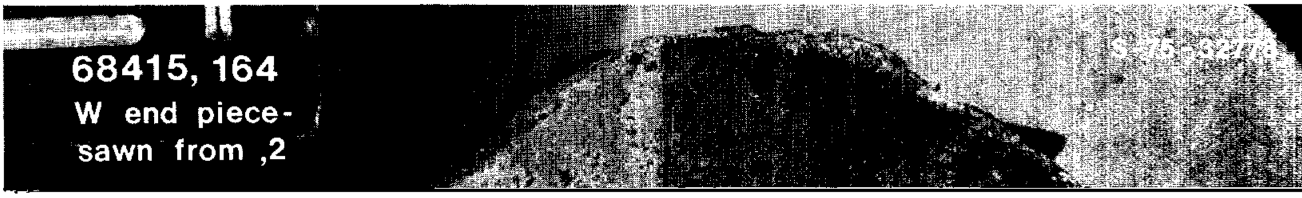

68415, 164
W end piece-
sawn from ,2

FIGURE 3. a) 68415,133. xpl. width 2mm. b) 68415,141. xpl. width 2mm.

PETROLOGY: Petrographic descriptions with microprobe analyses are given by Gancarz et al. (1972), Helz and Appleman (1973), Walker et al. (1973) and Vaniman and Papike (1981). A brief description is given by McGee et al. (1979). Nord et al. (1973) report high voltage electron microscope (HVEM) studies of mineral phases, and Takeda (1973) gives some microprobe and x-ray data for pyroxenes. Studies of opaque phases, particularly Fe-metal and schreibersite, are reported by L.A. Taylor et al. (1973a), Misra and Taylor (1975), and Pearce et al. (1976). Meyer et al. (1974) report trace element abundances in plagioclases, from ion probe analyses. Studies on crack porosity (Simmons et al., 1974), olivine-augite equilibration temperature (Ridley and Adams, 1976) and ilmenite paragenesis (Englehardt, 1978, 1979) have been reported. Jagodzinski and Korekawa (1973) studied diffuse x-ray scattering of plagioclases, mainly to understand radiation defects. Hewins and Goldstein (1975a) modelled the metal compositions reported by L.A. Taylor et al. (1973a) using fractional crystallization schemes.

TABLE 1. Ion microprobe data for trace elements in 68415,131 (from Meyer et al., 1974) (wt% and ppm)

	# analyses	Na_2O	Li	Mg	K	Ti	Sr	Ba
Large grains	27	0.29	1.5	790	110	75	177	11
Small grains	3	0.22	1.0	490	55	83	180	17
Grain A	4	0.31	1.8	570	100	68	192	13
Grain B	6	0.27	1.5	680	71	62	188	11

68415 has an ophitic-subophitic texture with a few phenocrysts (Fig. 3); although some authors have referred to the texture as intersertal, there is so little glass (<1%) that the term is inappropriate. According to Helz and Appleman (1973) the grain size is seriate, with rare phenocrysts. The dominant texture is of interlocking plagioclase laths with interstitial mafic minerals, but grades to phenocryst-like plagioclase, sometimes in radial clusters, and fine-grained patches which are possibly cognate inclusions (Gancarz et al., 1972). Neither Walker et al. (1973) nor Helz and Appleman (1973) observed obvious xenocrystic plagioclase and suggest that there is little accumulated plagioclase; in contrast Gancarz et al. (1972) suggest that the sample contains 5 to 25% accumulated plagioclase. While Helz and Appleman (1973) and Walker et al. (1973) suggest that an impact melt origin is most likely, Gancarz et al. (1972) leave open the possibility of a partial melt of a source even more aluminous than 68415 itself.

Groundmass plagioclases are mainly An_{98-92}, but rims range to An_{71} (Fig. 4). The phenocrysts and large grains have cores with the same compositions as the groundmass and the large grains frequently show a reversal of zoning at their outer edges (Gancarz et al., 1972; Helz and Appleman, 1973; Walker et al., 1973). Nord et al. (1973) detail antiphase domains in plagioclase. Meyer et al. (1974) show that plagioclases do not differ significantly in their trace element contents (Table 1), thus there is no evidence that any of the plagioclases they analyzed are relict. The interiors of grains are chemically homogeneous. Pyroxenes show two main compositional clusters, of which low-Ca varieties are dominant (Fig. 5). Orthopyroxene is not present. Pyroxenes are zoned, but not in any systematic fashion, although the most iron-rich grains occur only in mesostasis regions. Exsolution is not apparent with the petrographic microscope, but Nord et al. (1973) observed 1000 Å-wide augite lamellae in pigeonite, using HVEM techniques, and Takeda (1973) also found x-ray evidence for augite exsolution. The small, interstitial olivine crystals have restricted compositions with the total reported range of Fo_{67-73}. Ridley and Adams (1976) calculated an olivine-augite equilibration temperature of 998°C.

The mode by Gancarz et al. (1972) has 82% plagioclase, 8% pigeonite, 4% augite, 3% olivine, 2% mesostasis (∿1% ilmenite, chromite, ulvöspinel, troilite, Fe-metal, cristobalite,and glass). Other modes are fairly similar, differing mainly in the plagioclase and olivine contents. Other phases observed include armalcolite (Helz and Appleman, 1973), schreibersite (Misra and Taylor, 1975 and others), and phosphates and Y-Zr phases (Anderson and Hinthorne, 1973).

Metal grains have compositions spanning a wide range (Fig. 6) (Gancarz et al., 1972; L.A. Taylor et al., 1973a; Misra and Taylor, 1975; Pearce et al., 1976), and appears to have formed throughout the crystallization sequence, occurring in large plagioclases through to mesostasis areas. Schreibersite is fairly common in metal-schreibersite-troilite particles (less than 20 µm in diameter) enclosed in plagioclase; the compositions of coexisting metal and troilite suggest an equilibration temperature of ∿650°C (Misra and Taylor, 1975). Residual, mesostasis glasses contain 64-85% SiO_2 and 0.2-5.0% K_2O (Gancarz et al., 1972). Anderson and Hinthorne (1973) report ion-probe analyses of rare earth elements in a Y-Zr phase and phosphates, as well as Th/U ratios.

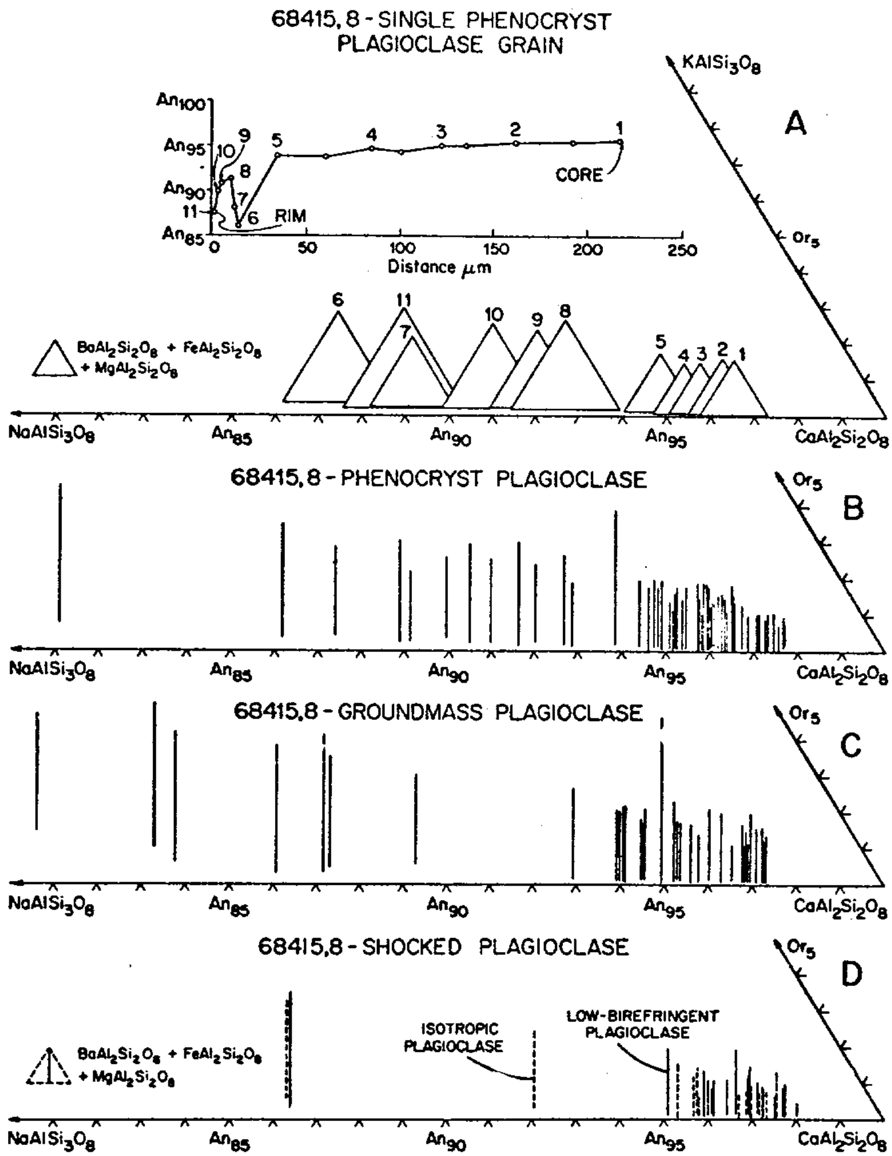


FIGURE 4. Plagioclase compositions; from Gancarz <u>et al</u>.(1972).

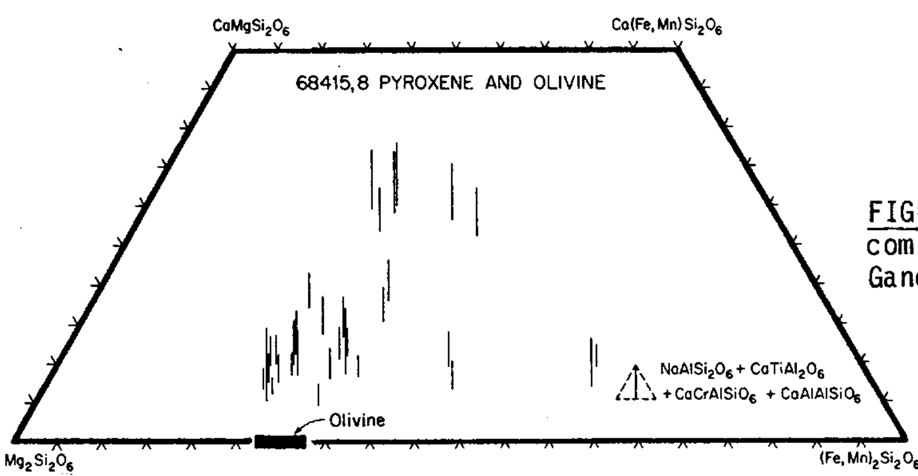


FIGURE 5. Mafic mineral compositions; from Gancarz <u>et al</u>. (1972).

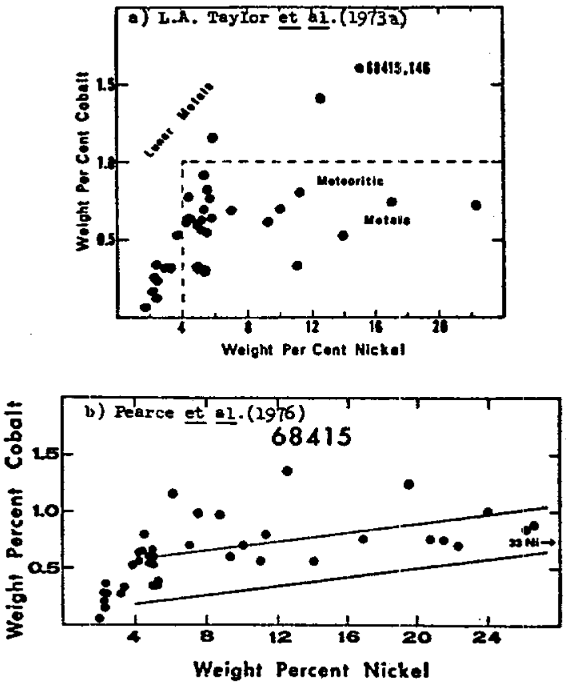


FIGURE 6. Metals.

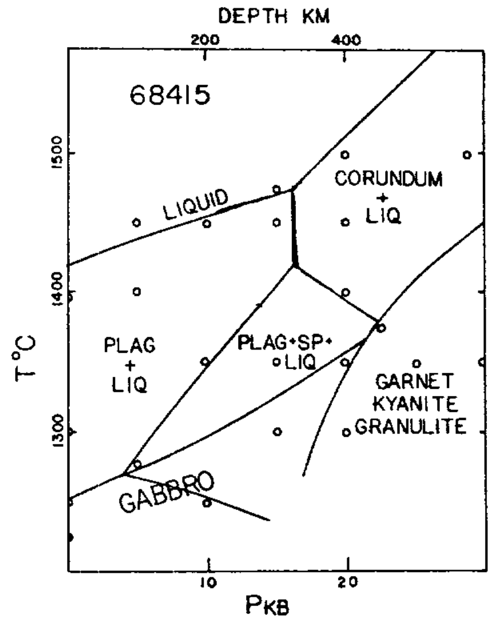


FIGURE 7. Experimental results; from Walker et al.(1973).

EXPERIMENTAL PETROLOGY: Results of phase equilibria studies are reported by Walker et al. (1973), Ford et al. (1974), and Muan et al. (1974).

Walker et al. (1973) conducted crystallization experiments on a 68415 composition at several pressures (Fig. 7). The composition is not related to any low pressure saturation curves. If the composition was a result of partial melting, the experiments suggest that the source would have consisted of anorthite+spinel+corundum at 18 kb. Such a lunar interior is unlikely, and Walker et al. (1973) prefer to interpret 68415 as a total impact melt. Ford et al. (1974) conducted atmospheric pressure experiments; plagioclase is the liquidus phase followed by spinel, which is not, however, stable below the solidus. They state that high water pressure suppresses plagioclase and that a water pressure over 5 kb would cause olivine to be the liquidus phase, and suggest that 68415 could have been produced by partial melting under high water pressure in the lunar interior. Muan et al. (1974) briefly report on low-pressure equilibrium experiments on 68415. The sequence of crystallization with decreasing pressure is plagioclase, spinel, olivine. Olivine, pyroxene and plagioclase coexist with liquid at some unspecified temperature between 1080 and 1150°C.

CHEMISTRY: A list of references to chemical work is given in Table 2, a summary chemical composition in Table 3, and rare-earth element abundances in Figure 8.

Few of the references contain much specific discussion. The rock is both more aluminous and poorer in incompatible elements, transition metals, and volatile elements than local soils. Philpotts et al. (1973) remark on the homogeneity of the sample at the 0.1 g level; the REE abundances shown in Figure 8 for ,79 is for two near-identical compositions. The level of siderophiles (Krähenbühl et al., 1973; Wasson et al., 1975) demonstrates significant meteoritic contamination. The meteoritic signature was classed DN by Ganapathy et al. (1973), Group 2 by Gros et al. (1976), and eventually considered (unreliably) Group 1H and possibly hybridized by Hertogen et al. (1977).

TABLE 2. Chemical work on 68415

Reference	Split #	Elements Analyzed
Rose et al. (1973)	,85	Majors, some trace
LSPET (1973)	,6	Majors, some trace
Bansal et al. (1972) Hubbard et al. (1974)	,10	Majors, REEs, other trace
Philpotts et al. (1973)	,79	*REEs, other incompatibles
Nava (1974)	,79	Majors
Jovànovic and Reed (1973)	,107	Halogens, Li, U
Krähenbühl et al. (1973)	,67	Meteoritic siderophiles and volatiles
Jovanovic and Reed (1976a)	,26	Ru, Os
Wasson et al. (1975)	,68	**Meteoritic siderophiles and volatiles
Jovanovic and Reed (1977)	,26	Hg
Reed et al. (1977)	,26	Tl and Zn (volatilized)
Papanastassiou and Wasserburg (1972a)	,10	Rb, Sr, K, Ba
Nyquist et al. (1973)	,10	Rb, Sr
Nunes et al. (1973)	,63	U, Th, Pb
Tera et al. (1973, 1974)	,10	U, Th, Pb
Stettler et al. (1973)	,49	K, Ca
Huneke et al. (1973)	,10	K, Ca
Kirsten et al. (1973)	,50	K, Ca
Rancitelli et al. (1973b)	,1	K, U, Th
Drozd et al. (1974)	?	U

*includes pyroxene and plagioclase as well as two whole-rock replicates

**three replicates

TABLE 3. Summary chemistry of 68415

SiO_2	45.5	Sr	180
TiO_2	0.31	La	6.8
Al_2O_3	28.6	Lu	0.3
Cr_2O_3	0.1	Rb	1.7
FeO	4.1	Sc	8.2
MnO	0.05	Ni	∿135
MgO	4.4	Co	11
CaO	16.3	Ir ppb	∿5
Na_2O	0.48	Au ppb	2.65
K_2O	0.07	C	
P_2O_5	0.07	N	
		S	400
		Zn	1.5
		Cu	12

Oxides in wt%; others in ppm except as noted.

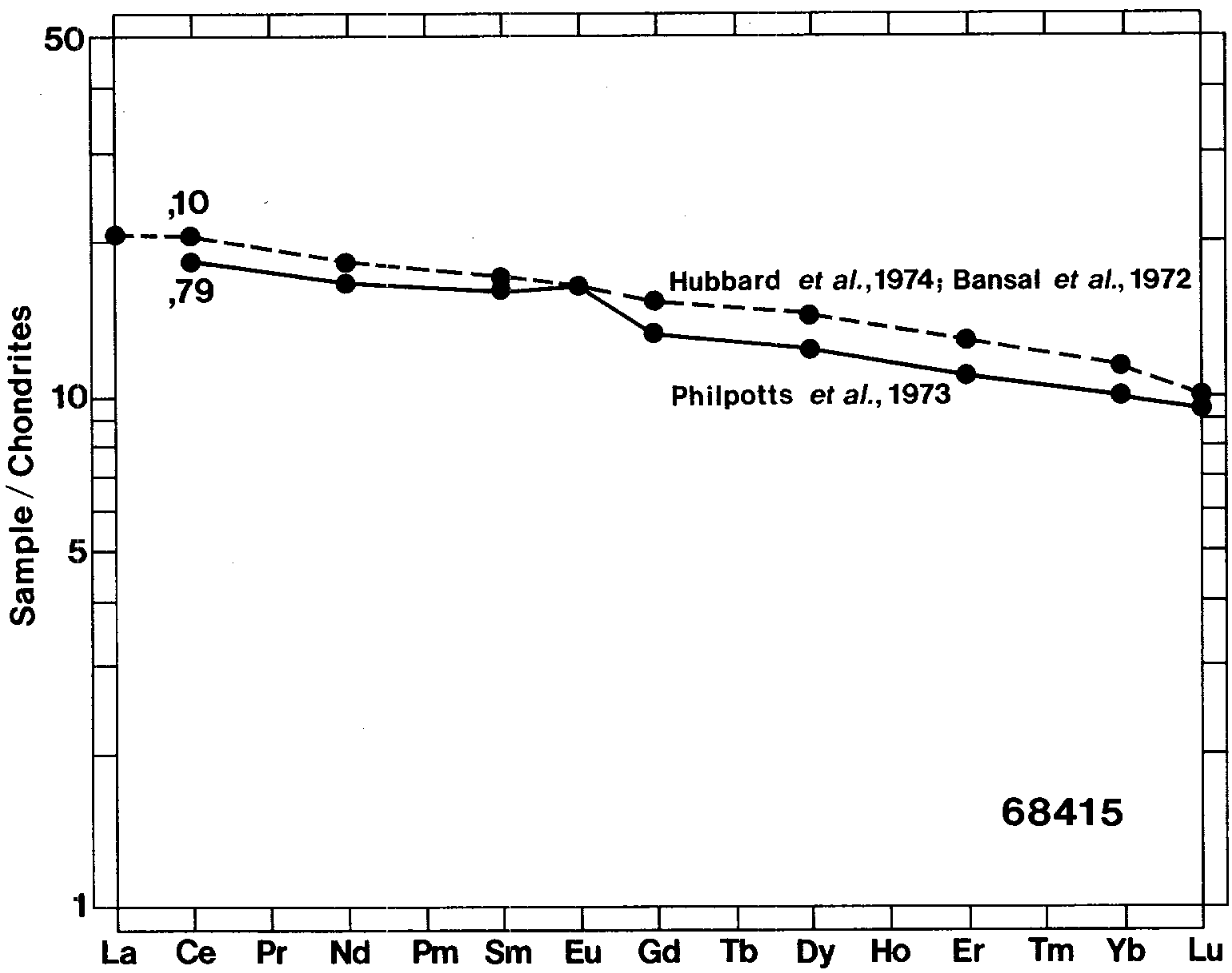
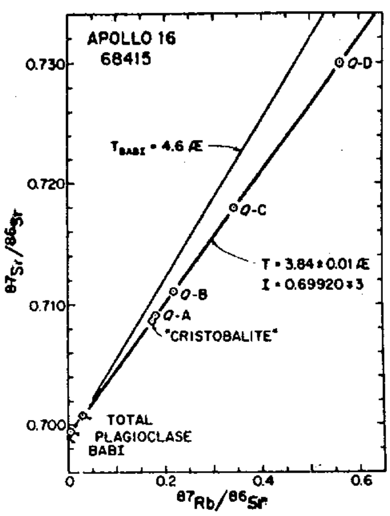


FIGURE 8. Rare earths.

STABLE ISOTOPES: Clayton et al. (1973) analyzed ,75 for oxygen isotopes. Typical lunar values for δO^{18} $^{0}/_{00}$ for plagioclase (+5.69) and olivine (+4.91) indicate equilibration at about 1100°C. Taylor and Epstein (1973) found that ,74 whole rock had δSi^{30} $^{0}/_{00}$ of +6.08±0.06 (two determinations) which, when adjusted for interlaboratory bias, is similar to the Clayton et al (1973) plagioclase value. The whole rock δSi^{30} of -0.05±0.02 (two determinations) is also fairly typical for lunar samples (Taylor and Epstein, 1973).

GEOCHRONOLOGY: Papanastassiou and Wasserburg (1972a) report a Rb-Sr internal isochron for interior chips (without saw cuts) from ,10 (Fig. 9). A precise age of 3.84±0.01 b.y. with initial $^{87}Sr/^{86}Sr$ of 0.69920±3 was obtained. Mineral separations were made using both heavy liquids and a Frantz separator; the whole-rock chip was not contaminated. The initial $^{87}Sr/^{86}Sr$ is quite primitive. The T_{BABI} model age of 4.3±0.2 b.y. calculated by Papanastassiou and Wasserburg (1972a) is similar to that calculated from whole-rock data for a second split of ,10 analyzed by Nyquist et al. (1973), 4.44±0.20 b.y.



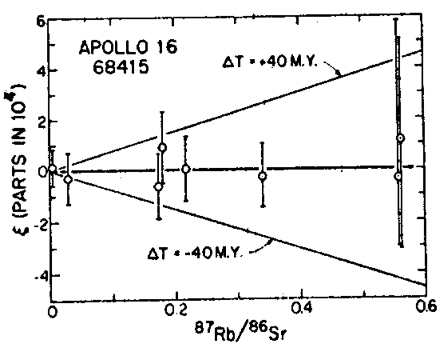


FIGURE 9. Rb-Sr data; from Papanastassiou and Wasserburg (1972a).

^{40}Ar-^{39}Ar data are presented by Stettler et al. (1973), Huneke et al. (1973) and Kirsten et al. (1973) and their release diagrams are shown in Figure 10. The derived ages are summarized in Table 4. These ages are consistent with the internal Rb-Sr isochron age except for that of the plagioclase separate (Huneke et al., 1973). This plagioclase separate is unusual in that its apparent age is greater than that of the whole rock, the reverse of the results usually obtained from lunar rocks. This feature is not understood (Huneke et al., 1973).

TABLE 4. Summary of ^{49}Ar-^{39}Ar ages (b.y.)

Stettler et al. (1973)	Whole rock	: 3.70±0.10 (plateau), 3.80±0.04 (intermediate release)
Huneke et al. (1973)	Whole rock	: 3.85±0.04 (intermediate release)
	Plagioclase	: 4.09 (intermediate release), 4.51 (final release)
Kirsten et al. (1973)	Whole rock	: 3.85±0.06 (plateau)

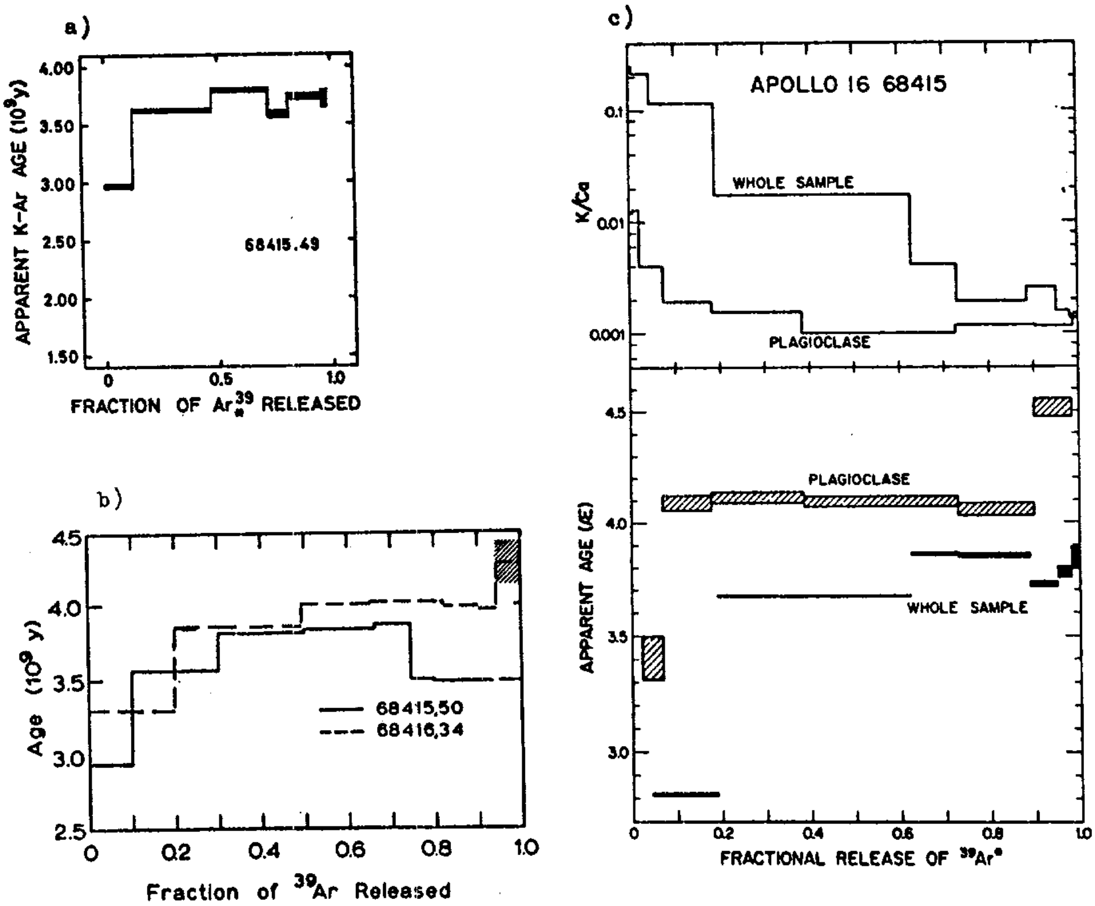


FIGURE 10. Ar release; from a) Kirsten et al. (1973). b) Stettler et al. (1973). c) Huneke et al. (1973).

Nunes et al. (1973) report whole rock U, Th, and Pb isotopic data. These fall on concordia at 4.47 b.y. and, by definition, also on a 3.99 to 4.47 b.y. discordia line. These data cannot by themselves specify the crystallization age. Tera et al. (1973) report U, Th, and Pb isotopic data for bulk rock and mineral separates. The large difference in $^{207}Pb/^{206}Pb$ between the bulk rock and the plagioclase separate shows that there is initial radiogenic Pb in the rock. Thus the essentially concordant whole rock U-Th-Pb ages of 4.47 b.y. do not correspond to the crystallization age but reflect the possibility that the rock was an early lunar differentiate, not significantly altered isotopically during its melting at $\sim$3.9 b.y. An isochron through the plagioclase and whole rock data intersect concordia at 3.94±0.05 and 4.47±0.02 b.y. (Fig. 11, where the isochron drawn is for combined 65015 and 68415 data). In Tera et al. (1974) the same data are presented but with more discussion. The whole rock concordant age is revised down to 4.42 b.y. because of the use of different U decay constants, but the main conclusions are the same as those of Tera et al. (1973).

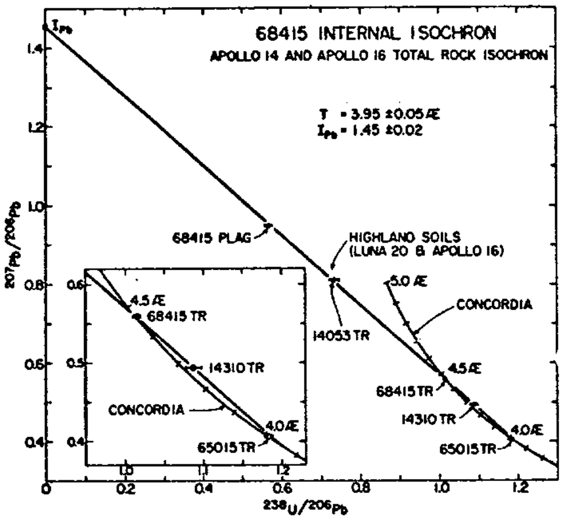


FIGURE 11. U-Pb isochron; from Tera et al. (1973).

Anderson and Hinthorne report Pb^{207}/Pb^{206} ages of 3.96±0.18 b.y. for a phosphate and 3.96±0.28 b.y. for a Zr-phase in 68415. The isotopic data were acquired with the ion probe.

RARE GASES AND EXPOSURE AGES: Ar isotopic data are reported by Stettler et al. (1973), Huneke et al. (1973) and Kirsten et al. (1973), with calculated ^{38}Ar exposure ages of 90 m.y., 105±15 m.y., and 88±4 m.y. respectively for whole rock data. Huneke et al. (1973) also calculated an exposure age of 95±15 m.y. for a plagioclase separate. Drozd et al. (1974) report Kr isotopic and spallation spectra for whole rock,and calculate an ^{81}Kr-Kr exposure age of 92.5±5.9 m.y., as well as ^{21}Ne (32.5±7.8 m.y.) and ^{38}Ar (113.0±42.0 m.y.) ages. Because the cosmic ray track ages (below) are of the order of a few million years, Drozd et al. (1974) conclude that the rare gas data indicate a pre-surface exposure for 68415.

Behrmann et al. (1973),from single point cosmic ray track studies,conclude that 68415 resided at the surface for ∿4 m.y. (this data quoted by Crozaz et al., 1974,as Yuhas, unpublished). The cosmogenic radionuclide data of Rancitelli et al. (1973a) shows that ^{26}Al is saturated (Yokoyama et al., 1974) demonstrating a surface exposure of at least a few million years. Morrison et al. (1973) suggest a surface exposure age of ∿2 m.y. from microcrater abundances.

MICROCRATERS: Morrison et al. (1973) and Neukum et al. (1973) present frequency v. diameter data for microcraters (Fig. 12). While the crater population is probably in production, the data are not definitive. Morrison et al. (1973) and Neukum et al. (1973) also tabulate data on the diameter of the spall zone/diameter of the pit (Ds/Dp) for both N and S surfaces. Hörz et al. (1974) note the considerable overlap of microcraters, hence calculated production rates are minima. (Hörz et al., 1974 erroneously state that the cosmic ray track and ^{81}Kr-Kr exposure ages are concordant).

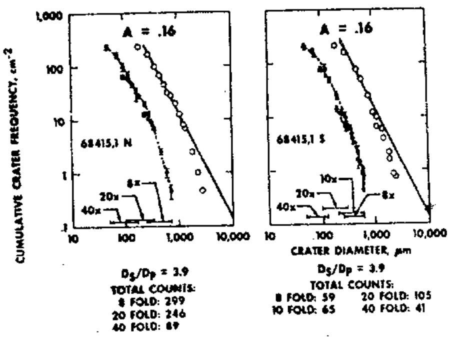


FIGURE 12. Microcraters; from Neukum et al.(1973).

PHYSICAL PROPERTIES: Nagata et al. (1973) and Pearce et al. (1973) tabulate basic magnetic properties for bulk rock samples. The results are not in agreement,showing the rock to be magnetically inhomogeneous compared with other lunar crystalline rocks such as mare basalts. Nagata et al. (1973) illustrate the thermal hysteresis of the thermomagnetic curve and demonstrate its inversion into four components (Fig. 13). The cooling curve (of thermomagnetic curve) is more complicated than for other Apollo 16 rocks, having at least three transition points (395°C, 682°C, 781°C) and the heating curve also appears to have at least two transition points (700°C, 781°C). Nagata et al. (1973) tabulate coercive force v. temperature, coercive force, saturation remanent magnetization, saturation magentization (at 4.2°K and 300°K), and the natural remanent magnetization (NRM) and its stability against alternating field demagnetization. Nagata et al. (1975) discuss some of these data.

Pearce et al. (1973) illustrate the demagnetization of two chips (Fig. 14) which are quite different. ,41 is stable whereas ,17 has a pronounced soft component whose direction is different from that of the stable direction, which is the same in both chips. They note that the results are more appropriate for a recrystallized breccia than for an igneous rock. Pearce et al. (1976) report partial thermoremanent magnetization (PTRM) and NRM for these same two chips ,41 and ,17 as part of a study of the complexities involved in determining lunar paleointensities; the results are shown on several diagrams in their paper. There appears to be no textural control on the magnetic features and the NRM is of thermal origin. ,41 has no stable NRM after alternating field demagnetization

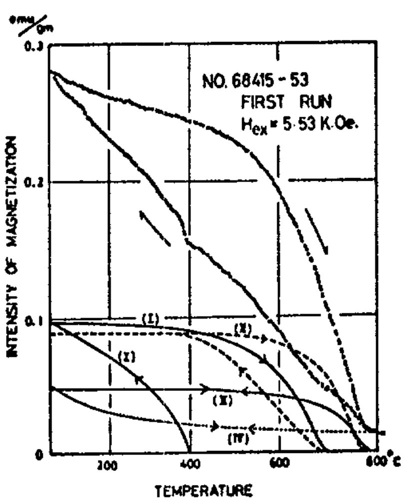


FIGURE 13. Thermal hysteresis; from Nagata et al. (1973).

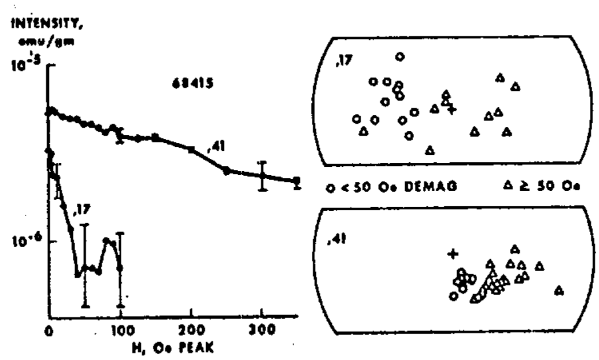


FIGURE 14. Demagnetization; from Pearce et al. (1973).

to 400 Oe, and the data are not of use for paleointensity determinations. In contrast ,17 gives an ancient field value of ~5000γ, which is substantially lower than the value given for 68416 (from the same boulder) by Stephenson et al. (1974). Pearce and Simonds (1974) tabulate iron valencies and iron metal contents deduced from magnetic measurements.

Brecher (1977) found the NRM of chip ,54 to be rather weak but unusually stable in both intensity and direction. The NRM directions lie close to and between two prominent petrographic planes, contrary to the conclusions of Pearce et al. (1976) for chips ,41 and ,17.

Mossbauer spectral analyses for 68415 both "as-received" and annealed at ≥800°C in a He-H_2 atmosphere are reported by Schwerer et al. (1973). The "as received" conditions suggest an absence of metallic iron. Huffman et al. (1974) report the same data and note the difference of metal content as compared to magnetic results, a difference they attribute to sample inhomogeneity.

Electrical conductivity measurements are reported by Schwerer et al. (1974). The trend of conductivity v. temperature has an unusual break at low temperatures (Fig. 15) which is reproducible but not well understood.

Todd et al. (1973) measured several physical properties, including elastic wave velocities, density, and crack porosity for ,54 (Table 5), as well as thermal expansion coefficients. They also plot the ratio of the wave velocities at atmospheric pressure and at 10 kb against the crack porosity. Maxwell (1978) used Todd et al.'s (1973) data to calculate Lamé elastic constants. Wang et al. (1973) report the same velocity data as Todd et al. (1973).

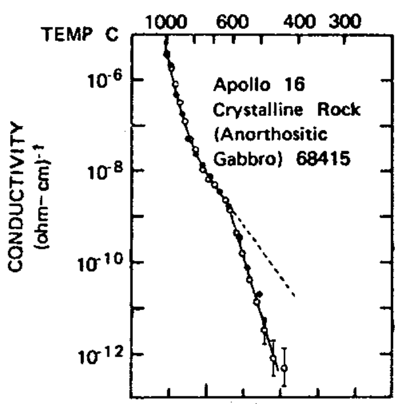


FIGURE 15. Electrical conductivity v. Temperature; from Schwerer et al. (1974).

TABLE 5. Physical properties of 68415,54 (Todd et al., 1973)

				Confining Pressure (bars)										
	Density (g/cc)	Crack Porosity	Elastic Property*	1	100	250	500	750	1000	1500	2000	3000	4000	5000
A direction	2.78	0.83	P	4.70	5.02	5.29	5.63	5.89	6.09	6.37	6.54	6.76	6.85	6.94
			S	2.59	2.69	2.80	2.94	3.05	3.13	3.26	3.35	3.43	3.47	3.54
			β	22.0	15.2	11.1	7.7	5.8	4.7	3.8	3.4	2.7	2.6	2.5
B direction			P	4.95	5.25	5.57	5.92	6.11	6.27	6.49	6.64	6.80	6.92	7.04
			S	2.48	2.60	2.73	2.88	3.00	3.09	3.23	3.31	3.41	3.46	3.54

* P = compressional velocity (km/sec), S = shear velocity (km/sec), β = static compressibility (Mb^{-1}). A and B are mutually perpendicular.

PROCESSING AND SUBDIVISIONS: 68415 was received as two pieces labelled ,1 (202g) and ,2 (169g) both of which were subsequently totally subdivided with several saw cuts (Fig. 16). The largest pieces now remaining are ,30 (113g) ,163 (85g) and ,164 (78g). All other pieces are less than 7 g.

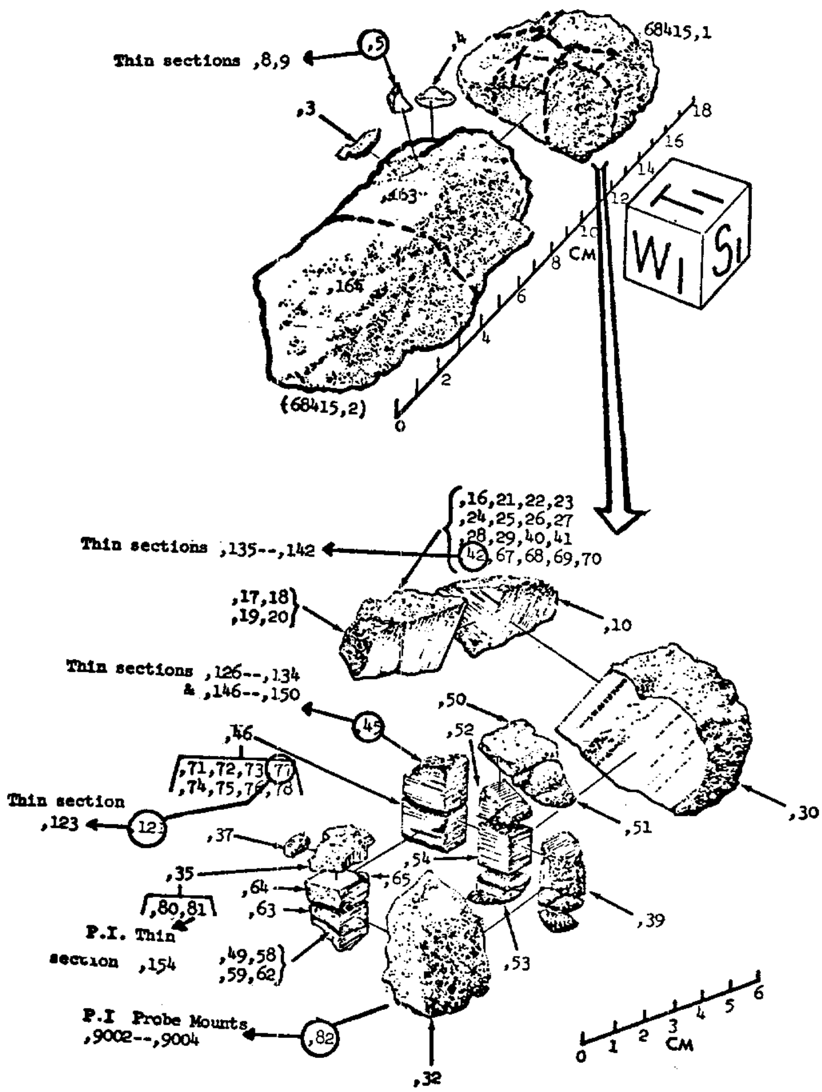


FIGURE 16. Cutting diagram.

INTRODUCTION: 68416 is a subophitic-ophitic impact melt which is fairly homogeneous but contains a few large plagioclase xenocrysts (Fig. 1). It is similar in chemistry and petrography to, but slightly coarser-grained than, 68415, which was taken from the same boulder (see 68415, Fig. 2). Its Rb-Sr isotopics agree well with those of 68415 but an Ar-Ar age of 4.00±0.05 b.y. (Kirsten et al., 1973) is older.

68416 was sampled a few centimeters from 68415 and its orientation is known. It is pale gray and tough like 68415. Zap pits are present on its rounded, lunar exposed face.

PETROLOGY: Petrographic descriptions with microprobe data are given by Brown et al. (1973), Hodges and Kushiro (1973), and Vaniman and Papike (1981). Juan et al. (1973) give a petrographic description with compositions of mineral phases deduced from the optical characteristics. Misra and Taylor (1975) report analyses of metal grains, and Englehardt (1978,1979) briefly notes the ilmenite paragenesis. Nash and Haselton (1975) used the data of Hodges and Kushiro (1973) to calculate the silica activity as a function of temperature.

68416 has a subophitic-ophitic texture (Fig. 2) which is slightly coarser-grained than 68415. Brown et al. (1973) note a weak preferred orientation of plagioclase laths and the presence of phenocrysts, and Juan et al. (1973) report anhedral-subhedral megacrysts which have wavy extinction, but note an absence of any preferred orientation. Published modes have 73-79% plagioclase, 16-20% pyroxene, and 2-4.5% olivine. Other reported phases include ilmenite, ulvöspinel, troilite, cristobalite, Fe-metal, and mesostasis glass. Misra and Taylor (1975) note that schreibersite is present but is less common than in 68415.

Plagioclase phenocrysts and laths are mainly An_{95-98} with microlaths much more sodic (Fig. 3) (Hodges and Kushiro, 1973; Brown et al., 1973; and Vaniman and Papike, 1981). Pyroxene and olivine compositions are shown in Figure 4. Brown et al. (1973), Hodges and Kushiro (1973), and Vaniman and Papike (1981) all report similar compositions, and these papers and that of Juan et al. (1973) report the presence of rare orthopyroxene in contrast to 68415 for which no orthopyroxene has been reported. Brown et al. (1973) report that augite is more common than low-Ca pyroxene, also in contrast to 68415, but this feature is not apparent in the data of Hodges and Kushiro (1973) (Fig. 4) or Vaniman and Papike (1981). Metals contain 4-16% Ni (Fig. 5) (Misra and Taylor, 1975; Brown et al., 1973; and Hodges and Kushiro, 1973).

EXPERIMENTAL PETROLOGY: Melting experiments at 5 kb pressure on 68416,21, a homogeneous powder, show phase relationships very similar to those of 68415. Plagioclase is the high temperature (>1400°C) liquidus phase, followed by spinel (1300-1250°C), then olivine (1250-1225°C) (Hodges and Kushiro, 1973). The results are consistent with a plagioclase cumulate origin of 68416 or impact melting of a plagioclase cumulate. The silica activities in excess of 1, calculated by Nash and Haselton (1975) from the data of Hodges and Kushiro (1973), support the textural evidence that 68416 is a rapidly quenched, not an equilibrium, assemblage.

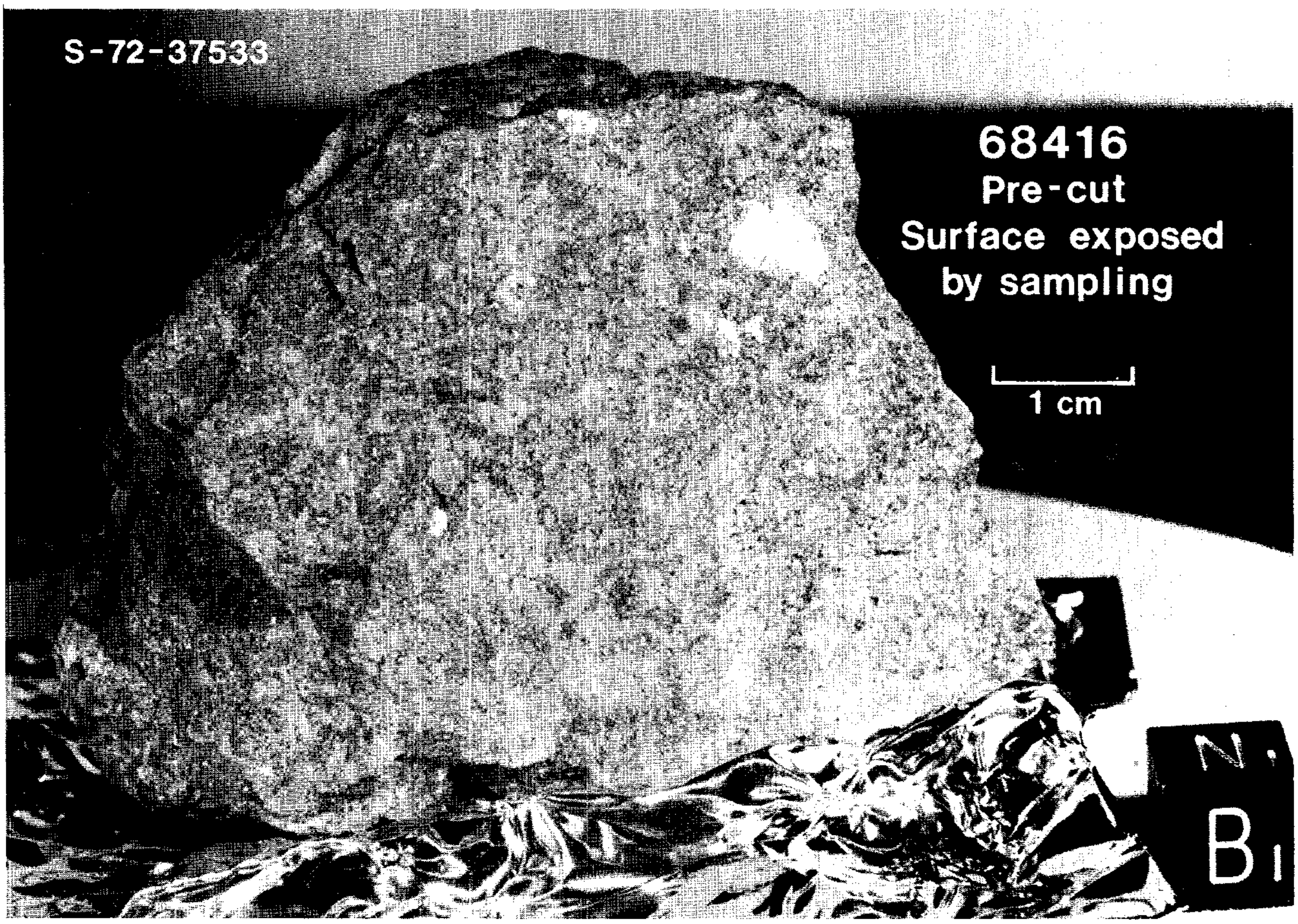


FIGURE 1.

a

b

FIGURE 2. a)68416,6. xpl. width 2mm. b)68416,70. xpl. width 2mm.

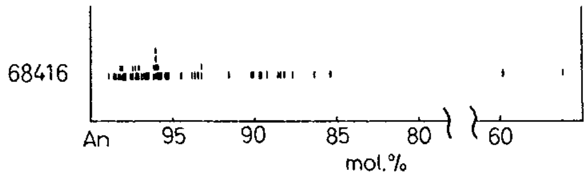


FIGURE 3. Plagioclase compositions; from Hodges and Kushiro (1973).

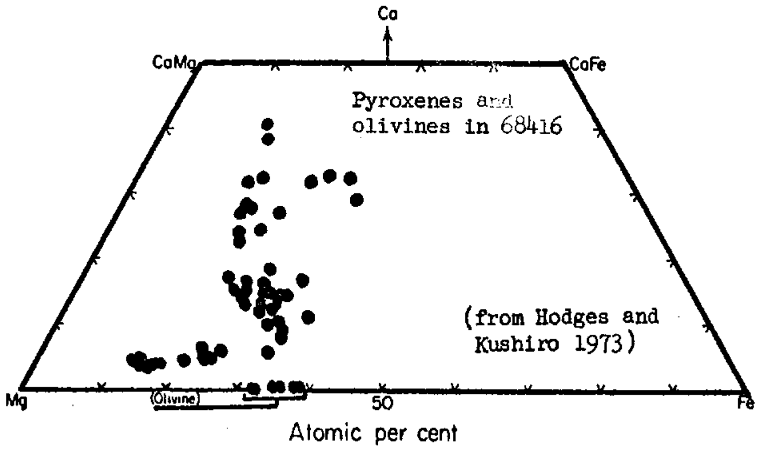


FIGURE 4. Mafic mineral compositions; from Hodges and Kushiro (1973).

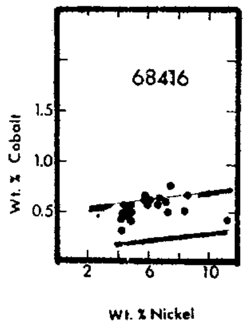


FIGURE 5. Metals; from Misra and Taylor (1975).

CHEMISTRY: Major and some trace element analyses are reported by Juan et al. (1973), Rose et al. (1973) and Hubbard et al. (1973,1974). Partial analyses are reported by Rancitelli et al. (1973b; K,U,Th), Moore et al. (1973; C), Kirsten et al. (1973; Ca,K) and Compston et al. (1977; Rb,Sr). The data are summarized in Table 1 and Figure 6, and are very similar to those for 68415. The composition is more aluminous and lower in rare-earth, transition metal, and volatile elements than are local soils.

GEOCHRONOLOGY: Rb-Sr isotopic data for plagioclase and "quintessence" separates reported by Papanastassiou and Wasserburg (1975) agree well with the isochron drawn for 68415 (Fig. 7). This shows an age of 3.84±0.01 b.y. with initial $^{87}Sr/^{86}Sr$ of 0.69920±3. Compston et al. (1977) obtained an internal Rb-Sr isochron age of 3.79±0.03 b.y. (Fig. 8) in good agreement with the data of Papanastassiou and Wasserburg (1975). The initial $^{87}Sr/^{86}Sr$ ratio of 0.69940 is also in good agreement after adjusting for interlaboratory bias.

The ^{40}Ar-^{39}Ar plateau age of 4.0±0.05 b.y. (Kirsten et al., 1973) (Fig. 9) is distinctly higher than the Rb-Sr age for 68416 (and 68415) and the Ar-Ar whole-rock age for 68415. Kirsten et al. (1973) attempt to explain the age difference by interpreting 68416 as a xenolith in 68415; however, this "explanation" does not account for the identical Rb-Sr results nor for the near-identical petrographic and chemical nature of 68415 and 68416.

TABLE 1

Summary chemistry of 68416

SiO_2	45.3	Sr	∿160
TiO_2	0.31	La	7.2
Al_2O_3	28.5	Lu	
Cr_2O_3	0.11	Rb	1.8
FeO	4.3	Sc	9.2
MnO	0.06	Ni	∿180
MgO	4.6	Co	10-40
CaO	16.2	Ir ppb	
Na_2O	0.43	Au ppb	
K_2O	0.07	C	5
P_2O_5	0.08	N	
		S	500
		Zn	30
		Cu	∿10

Oxides in wt%; others in ppm except as noted.

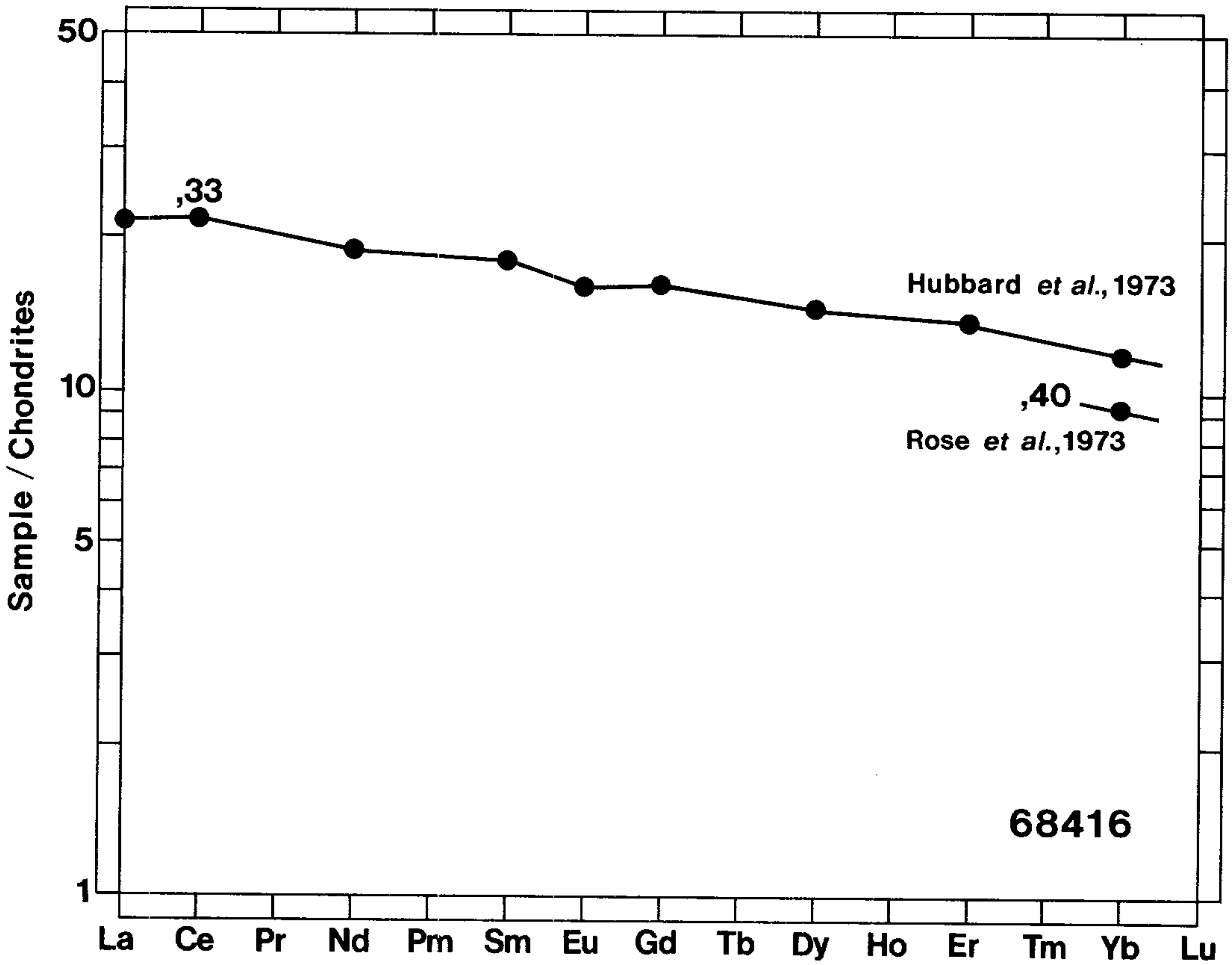


FIGURE 6. Rare earths.

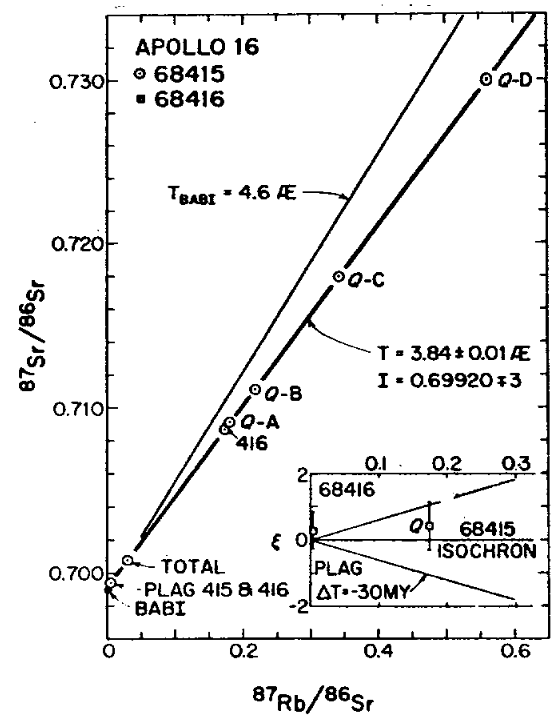


FIGURE 7. Rb-Sr data; from Papanastassiou and Wasserburg (1975).

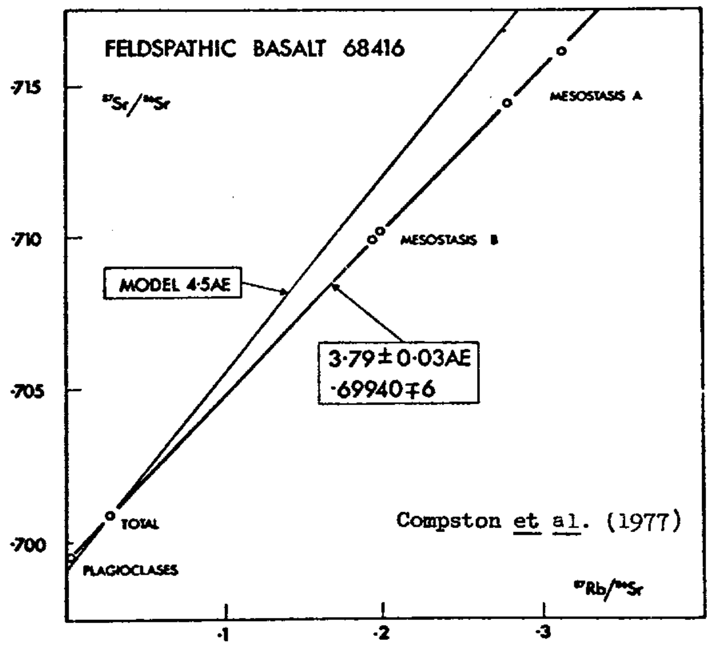


FIGURE 8. Rb-Sr data; from Compston et al.(1977).

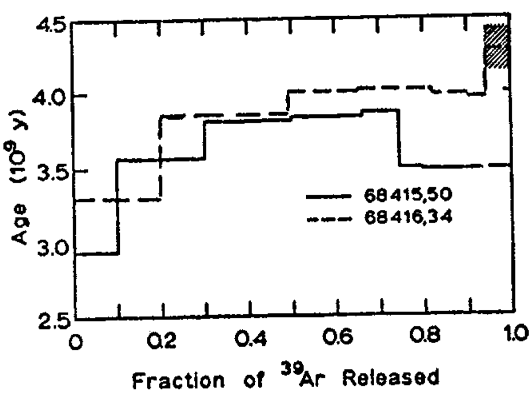


FIGURE 9. Ar release; from Kirsten et al. (1973).

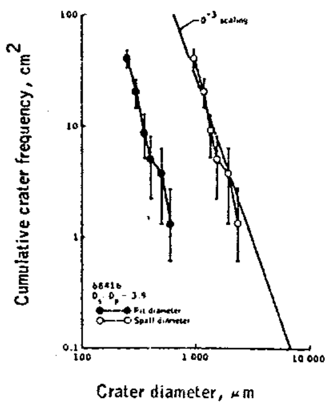


FIGURE 10. Microcraters; from Morrison et al.(1973).

RARE GAS AND EXPOSURE AGES: The only rare gas data are the Ar isotopic data reported by Kirsten et al. (1973) from which they calculated an exposure age of 39±4 m.y. (identical to their 87±5 m.y. age for 68415).

Yokoyama et al. (1974) note that the cosmogenic nuclide data of Rancitelli et al. (1973a) show that 68416 is saturated with ^{26}Al, thus the exposure age is at least a few million years.

MICROCRATERS: Morrison et al. (1973) report microcrater frequency v. diameter data (Fig. 10) without specific discussion.

PHYSICAL PROPERTIES: Collinson et al. (1973) report that ,23 has an initial natural remanent magnetization (NRM) of 2.0×10^{-6} emu•g^{-1}. There appears to be a hard NRM nearly opposed in direction to the soft one. Stephenson et al. (1974) report alternating field (AF) demagnetization results for the same chip ,23 (Figs. 11,12). The hard component corresponds to a paleofield of 1.2 Oe--the interpretation is colored by the Kirsten et al. (1973) interpretation of 68415 as a xenolith, i.e. two heating events occurring with sample movement in between them at 3.84-4.0 b.y. can explain a relatively hard secondary component. (In reality, because 68416 is almost certainly not a xenolith, the explanation must be more complex). Brecher (1977) notes that the directional data presented by Stephenson et al. (1974) lie on a small circle of constant inclination, demonstrating some kind of planar control.

Abu-Eid et al. (1973) include 68416 in a list of samples studied by Mossbauer and electron absorption spectroscopy in which 1) rims of pyroxenes contain Ti^{+3}, 2) olivines and pigeonite cores contain Cr^{3+}, and 3) olivines and pyroxenes contain no Fe^{3+} and probably no Cr^{2+}. The spectral measurements indicate that the olivines are "magnesian varieties". Weeks (1973a) reports electron paramagnetic resonance data pertaining to the presence of Fe^{3+} in plagioclases.

Tsay and Live (1976) and Tsay and Bauman (1977) also report the presence of Fe^{3+} in plagioclase using data derived from electron spin resonance spectra. The Fe^{3+}/Fe^0 of 68416 (and other plagioclase-rich rocks) is higher than soils. Some of the Fe^{3+} may be terrestrial but some may also be indigenous.

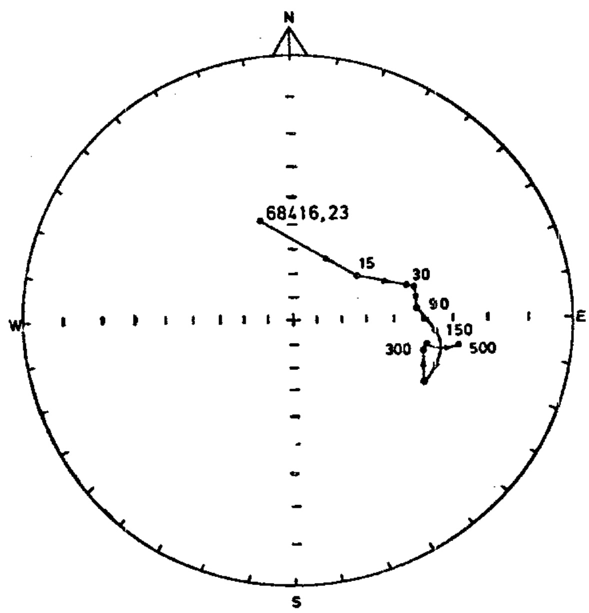


FIGURE 11. Demagnetization; from Stephenson et al.(1974).

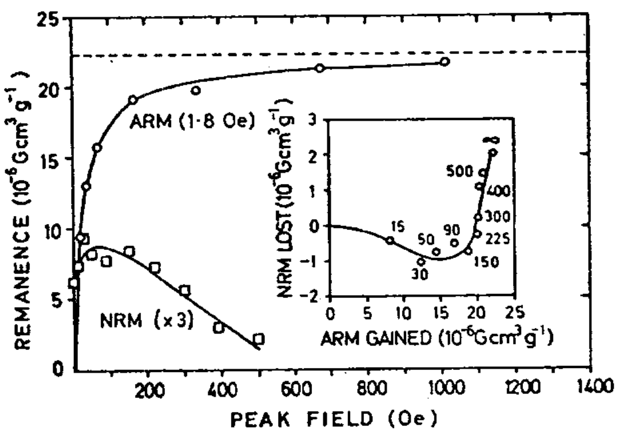


FIGURE 12. Demagnetization; from Stephenson et al.(1974).

PROCESSING AND SUBDIVISIONS: 68416 was sawn into the two halves ,8 (102 g) and ,9 (71 g). ,8 is intact and in remote storage. ,9 has been entirely subdivided (Fig. 13). The largest pieces remaining are ,10 (8.9 g) and ,27 (15 g); no other splits are over 5 g.

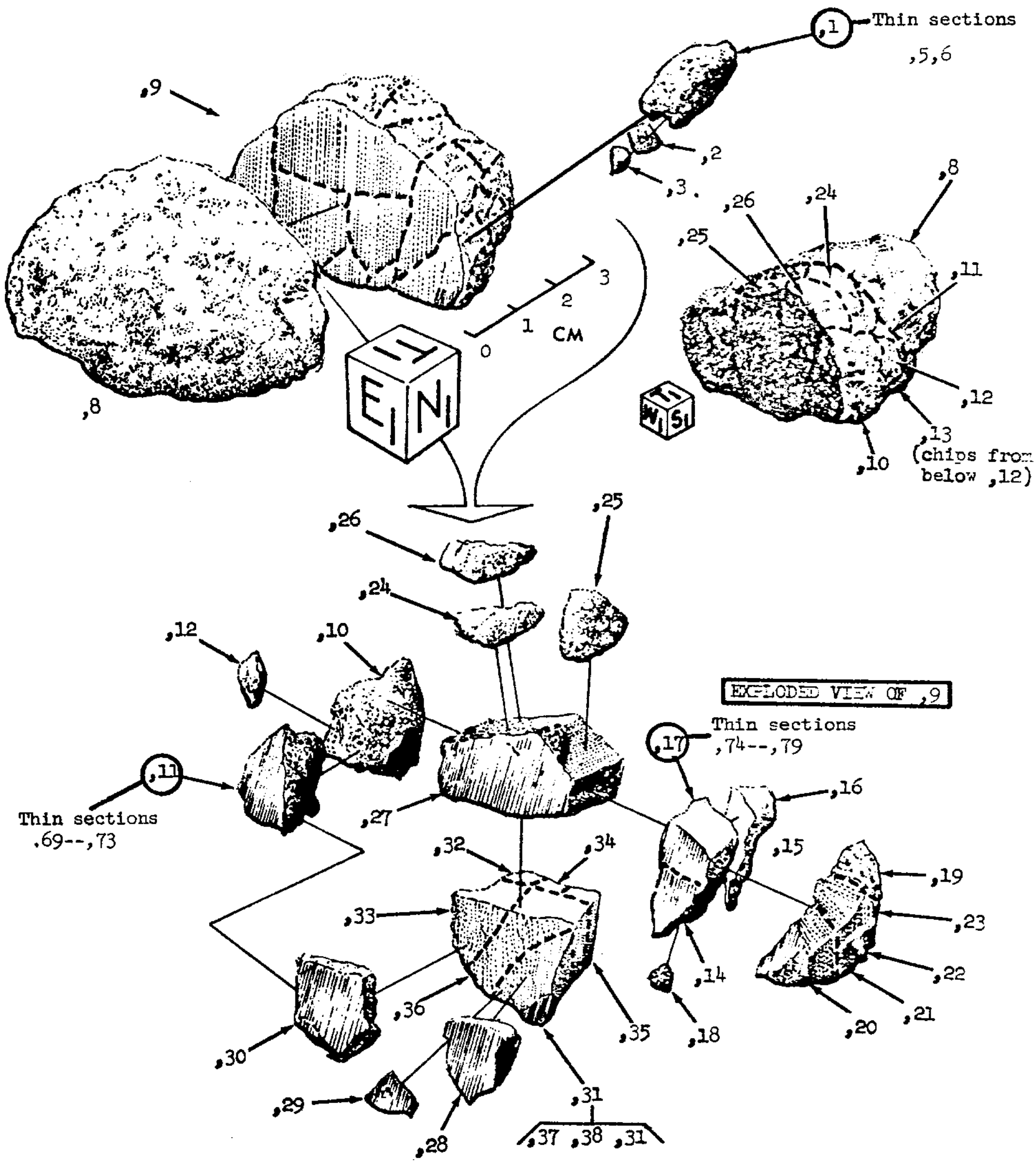


FIGURE 13. Cutting diagram.

INTRODUCTION: 68505 is a coherent, dark gray, poikilitic impact melt (Fig. 1). Vugs are common. This rock was taken from a soil sample in the vicinity of a visible ray from South Ray crater. A few zap pits are present on one surface.

PETROLOGY: 68505 is a fine-grained, poikilitic impact melt (Fig. 2). Clasts of plagioclase and more rarely, mafic silicates are present. Blebs of Fe-metal (some rusty) with associated troilite occur as clasts and in interstices with laths of ilmenite. Oikocrysts are generally <0.2 mm.

PROCESSING AND SUBDIVISIONS: In 1973 a chip (,1) was removed for thin sections.

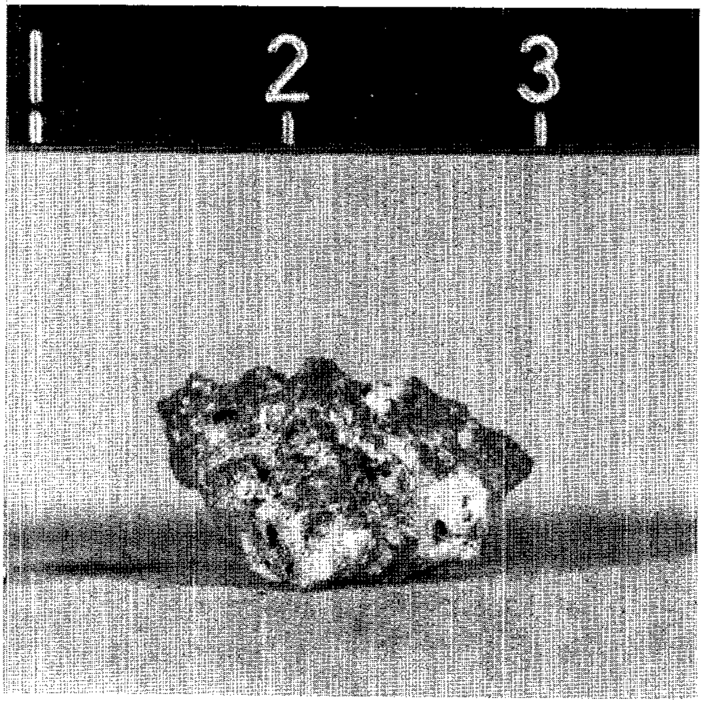


FIGURE 1. Scale in cm. S-72-40520.

FIGURE 2. 68505,7. ppl. width 0.5 mm.

INTRODUCTION: 68515 consists of white, anorthositic breccia which locally is mixed with angular aphanitic to basaltic impact melt fragments (Fig.1). Part of the sample is coated with glass (Fig.2). 68515 is a rake sample and fairly tough. Zap pits are most prominent on the anorthositic breccia area, but a few are present on the glass-coated surface.

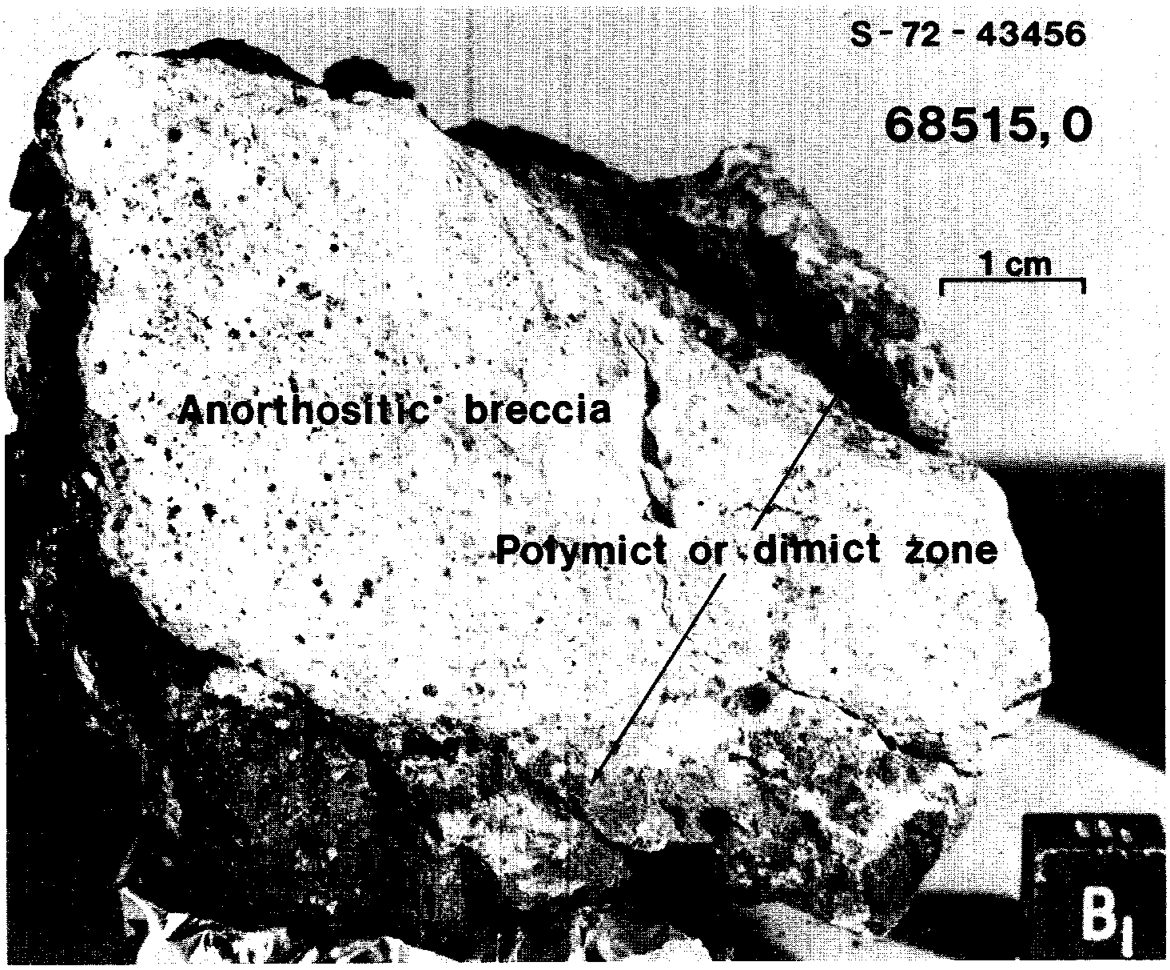


FIGURE 1.

PETROLOGY: Steele and Smith (1973) refer to 68515 as a complex, black and white breccia with some devitrified glass; they do not provide probe data. Their thin section (,1) consists of a cataclastic anorthosite with few mafic minerals but containing angular aphanatic and glassy impact melt fragments which have plagioclase laths (Fig.3). One edge of the section is a clear or gray glass, devitrified adjacent to the breccia and probably the glass coat. Thin sections of glass coat (,13), polymict material (,14) and white material (,15) were cut from undocumented chips for the present study.

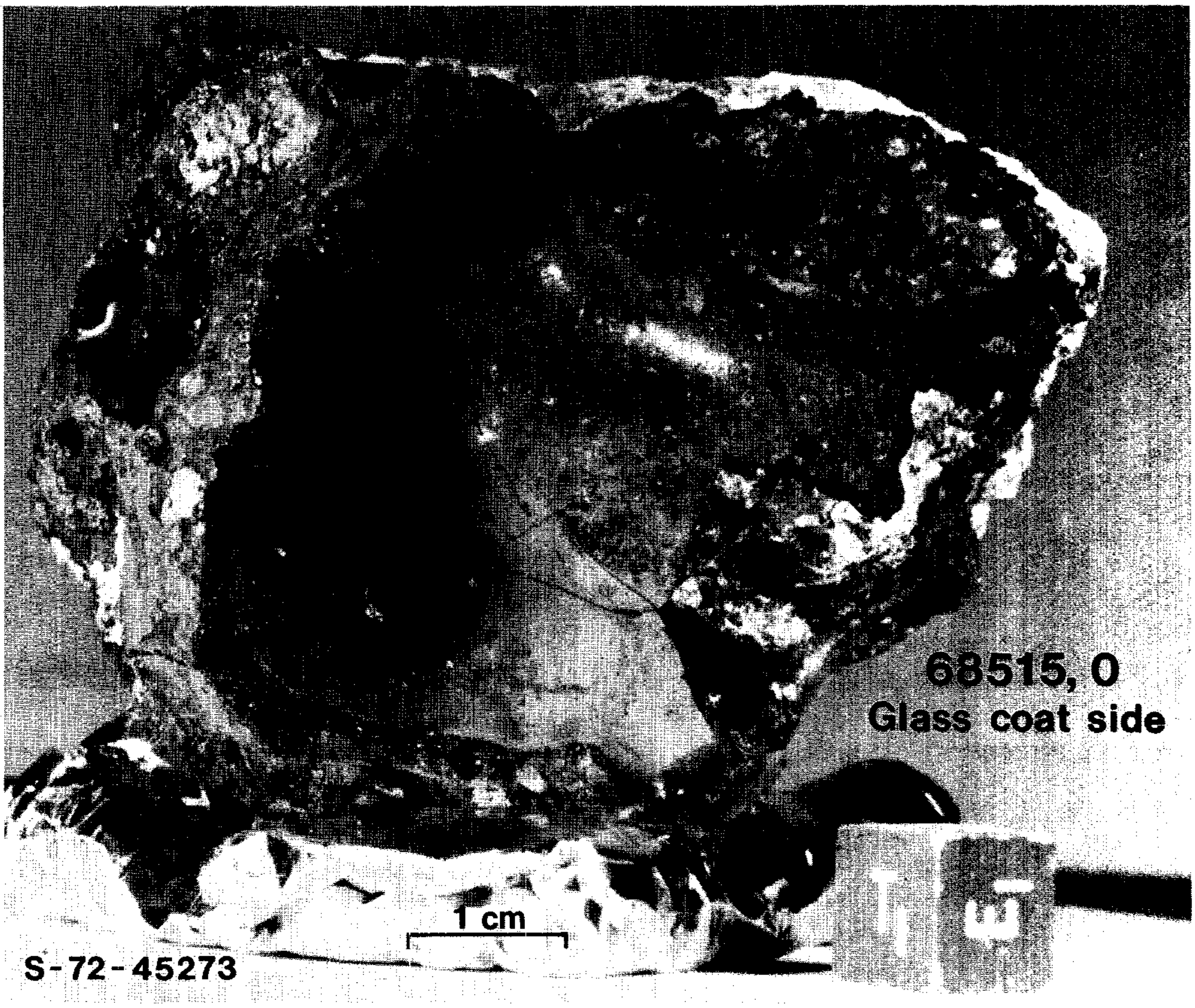
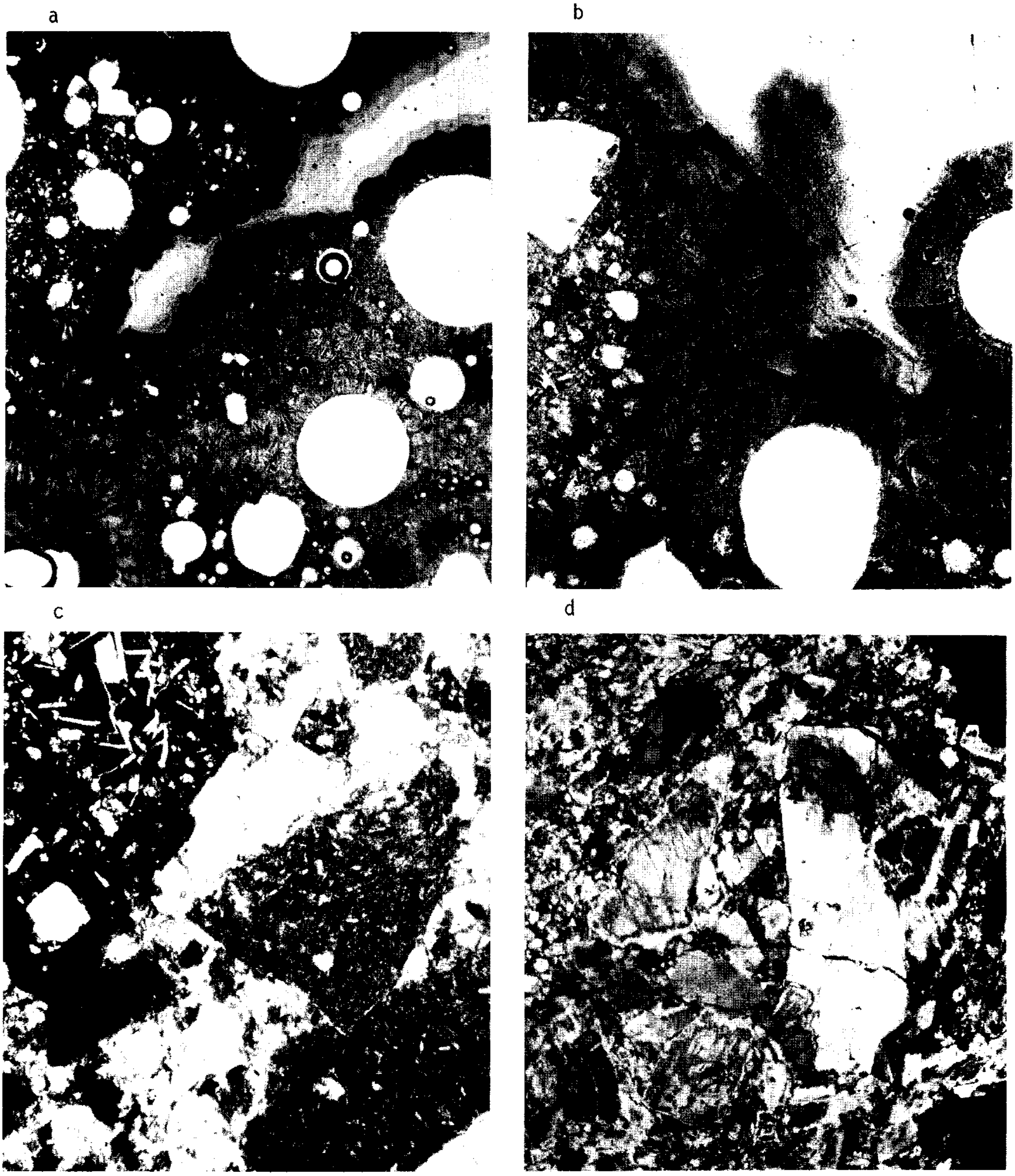


FIGURE 2.

The glass coat (,13) is vesicular and largely devitrified (Fig.3); undevitrified patches show flow banding. A few lithic clasts, including basaltic and poikilitic impact melt fragments, are present. The polymict area consists of cataclastic anorthosite and a variety of brown glassy and basaltic fragments (Fig.3). The white chips are all similar cataclastic anorthosites (Fig.3) with minor mafic minerals which appear to be orthopyroxene.

The macroscopic and thin section studies indicate that 68515 may be similar to other Apollo 16 "black-and-white" rocks- a fairly pure light phase with fragments of dark material of fairly restricted lithology were mobilized together, with the dark material acting more coherently. In the case of 68515, a glass coat was splashed on later.

PROCESSING AND SUBDIVISIONS: 68515 has not been sawn or substantially subdivided, though several small fragments of undocumented location have been produced during handling. From some of these the thin sections have been made.



<u>FIGURE 3.</u> a) 68515,13. glass coat, ppl. width 2mm.
b) 68515,13. glass coat and breccia clast (left); clear glass at top, ppl. width 1mm.
c) 68515,1. polymict or dilithologic breccia, ppl. width 2mm.
d) 68515,15. anorthosite clast, xpl. width 2mm.

INTRODUCTION: 68516 consists of a dark vesicular glass containing large clasts of fine-grained or glassy impact melts (Fig. 1). The vesicular glass consists at least in part of maskelynite grains which have cores of relict shocked plagioclase. The sample is coherent and irregularly shaped. It is a rake sample and lacks zap pits.

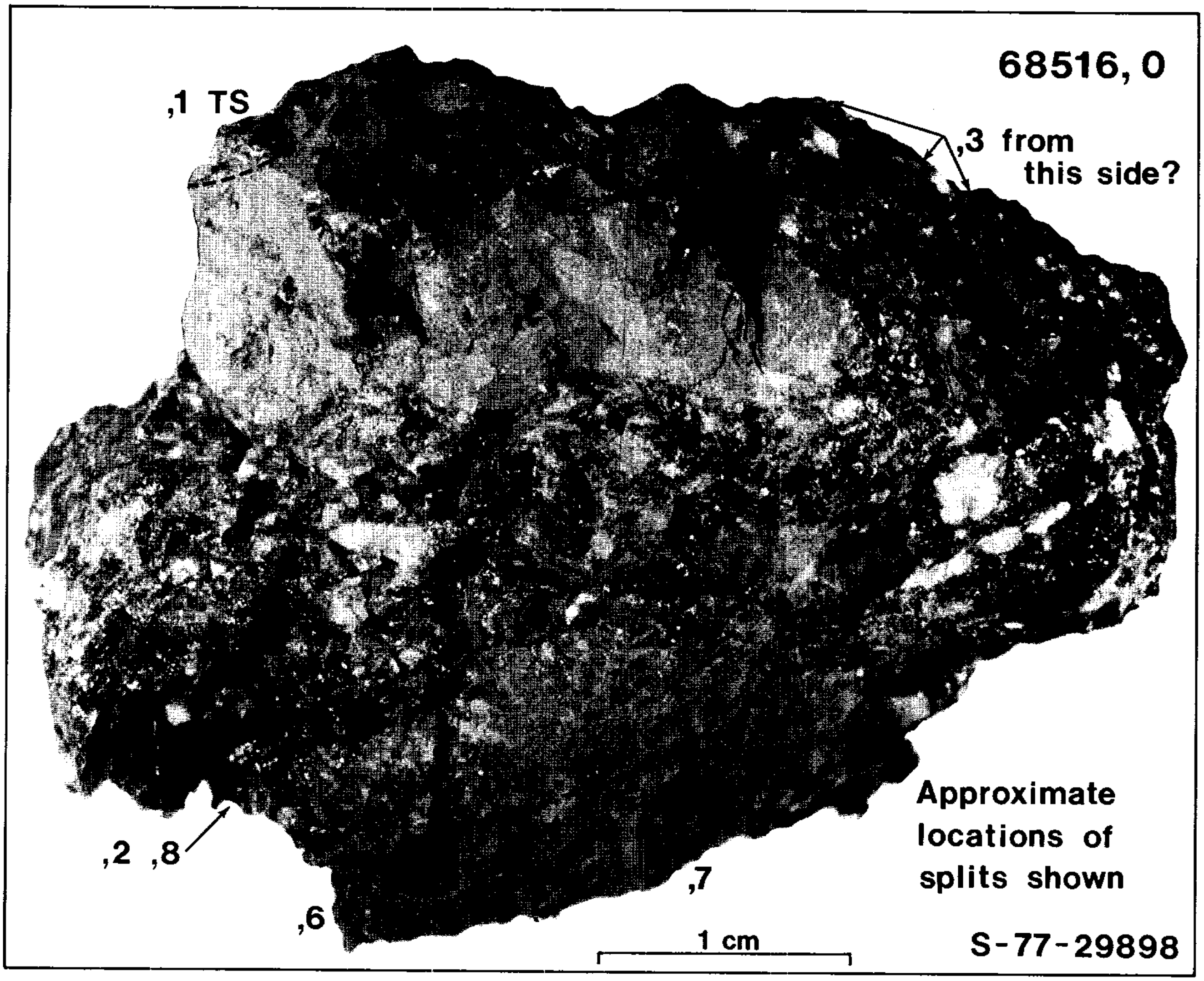


FIGURE 1.

PETROLOGY: A single thin section covers a clast/glass boundary (Figs. 1,2). The clast is an impact melt with ~60% plagioclase crystallites set in ~40% opaque, brown glass. The glass is a heavily shocked material containing maskelynite grains, the larger ones having shocked plagioclase cores. Both the maskelynite and the cores have shock lamellae. These grains are set in a fine-grained material consisting of both maskelynite and cryptocrystalline material; the bulk glassy lithology is extremely plagioclase-rich. A few small basaltic clasts occur in this zone.

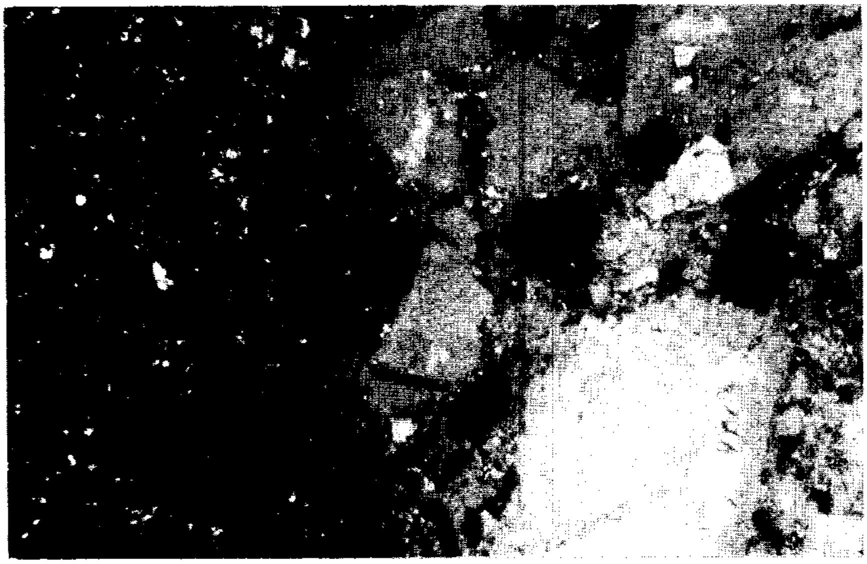


FIGURE 2. 68516,1. basaltic melt (left) and shocked plagioclase (right), ppl. width 3mm.

TABLE 1. Summary Chemistry of clasts from 68516

	mixed clasts and glass (Laul and Schmitt, 1973)	gray clast (Palme et al.,1978)
SiO_2		45.8
TiO_2	0.35	
Al_2O_3	28.1	22.6
Cr_2O_3	0.09	
FeO	4.8	8.2
MnO	0.06	
MgO	7	10.5
CaO	15.9	13.0
Na_2O	0.43	0.49
K_2O	0.08	0.17
P_2O_5		0.31
Sr		165
La	8.2	26.7
Lu	0.36	1.16
Rb		5.23
Sc	6.8	11.1
Ni	520	1385
Co	34	83.2
Ir ppb	10	35.0
Au ppb	11	32
C		
N		
S		1000
Zn		4.05
Cu		7.2

Oxides in wt%; others in ppm except as noted.

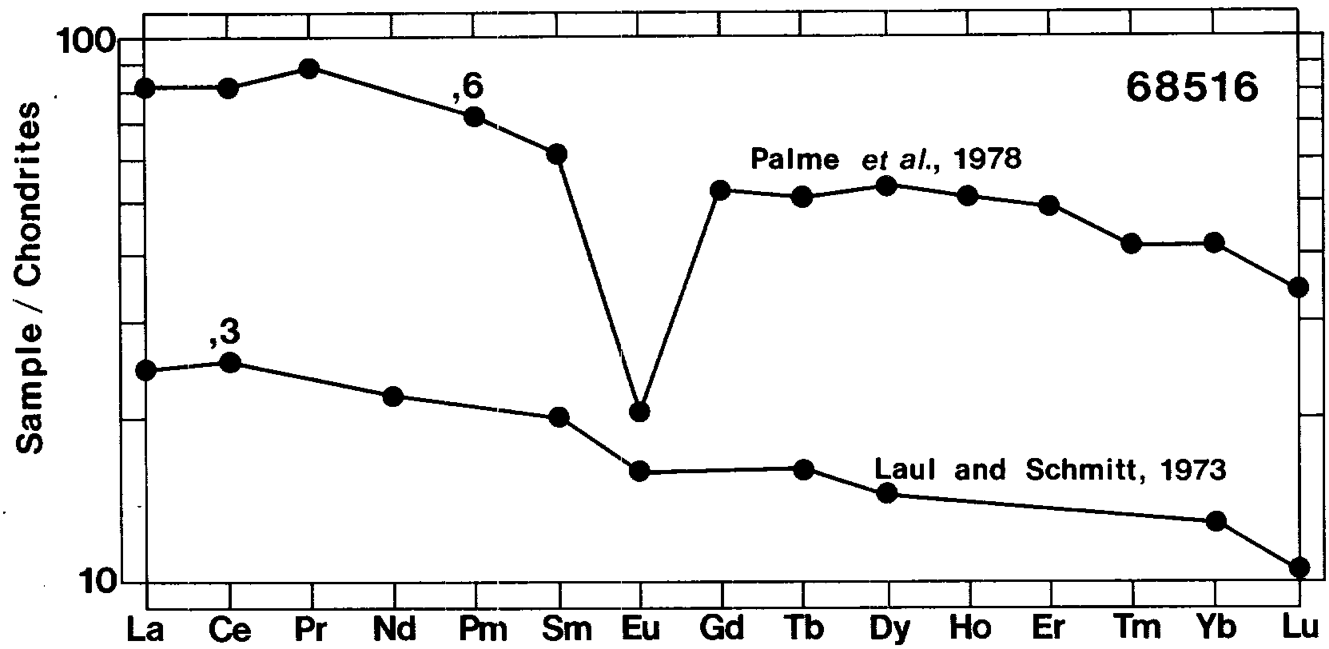


FIGURE 3. Rare earths.

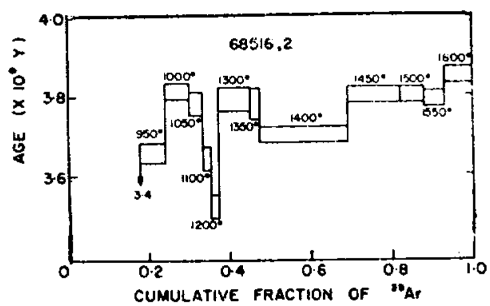


FIGURE 4. Ar release; from Schaeffer and Schaeffer (1977).

CHEMISTRY: Laul and Schmitt (1973) report major and trace element abundances for some undocumented chips (,3) which include glass but are mainly gray clast material. Palme et al. (1978) report major and trace element analyses for a gray clast (,6). These are summarized in Table 1 and Figure 3. Schaeffer and Schaeffer (1977) report K and Ca abundances for mixed glass and clast chips. The analyses suggest that the gray clasts are fine-grained impact melts (contaminated with meteoritic material) and the glass is much more aluminous (and probably also contaminated with meteoritic material).

RADIOGENIC ISOTOPES: Schaeffer and Schaeffer (1977) report argon isotopic data for 68516,2, which is mainly shocked glass. The extractions (with two exceptions) between 1300°C and 1600°C give a plateau age of 3.80 ± 0.05 b.y. (Fig. 4).

RARE GAS AND EXPOSURE AGE: Schaeffer and Schaeffer (1977) report argon isotopic data for 68516,2, which is mainly shocked glass. An Ar cosmic ray exposure age of 50 m.y. is a minimum exposure age as the sample contains excess ^{38}Ar, probably from chlorine irradiation.

PROCESSING AND SUBDIVISIONS: The approximate locations of the main splits are shown in Figure 1.

INTRODUCTION: 68517 consists of a moderately coherent, gray, polymict breccia enclosed in a shiny, vesicular, greenish glass (Fig. 1). It is a rake sample and lacks zap pits.

PETROLOGY: Steele and Smith (1973) refer to 68517 as a "vitrified soil breccia". The core of 68517 is a plagioclase-rich breccia (Fig. 2), with lithic clasts including poikilitic impact melts. It is wrapped by a vesicular, clear to partly-devitrifed glass; during this coating the enclosed breccia seems to have flowed, and the breccia-glass contact is indistinct. A few stringers of gray glass cut the breccia; the relationship of this glass to the coating glass is unknown.

PROCESSING AND SUBDIVISIONS: A single chip was removed to make thin section ,1.

FIGURE 1. Smallest scale division in mm. S-72-51260.

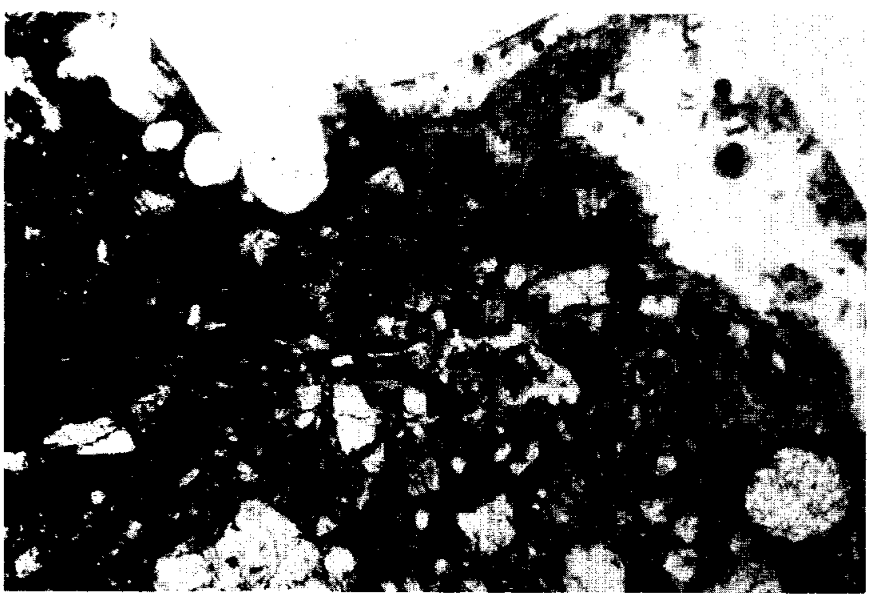


FIGURE 2. 68517,1. ppl. width 3mm.

INTRODUCTION: 68518 is a coherent, black, vesicular glass with a smooth exterior surface on one side (Fig.1). It contains clasts of plagioclase-rich breccia and may be coating a gray polymict breccia. It is a rake sample. Zap pits are present on all surfaces.

FIGURE 1a. Smallest scale division in mm. S-72-51240.

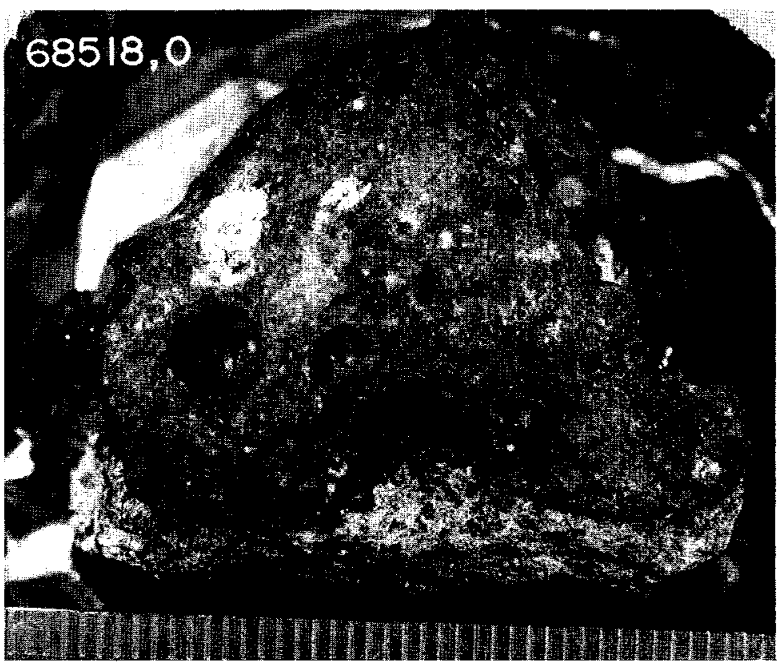


FIGURE 1b. Scale division in mm. S-80-24740.

INTRODUCTION: 68519 is a coherent, fine-grained, intergranular to poikilitic impact melt which has a partial glass coat (Fig. 1). It is subangular and dark gray. It is a rake sample and has many zap pits.

PETROLOGY: 68519 is a clast-rich impact melt (Fig. 2). The matrix consists of about 75% plagioclase laths, less than 150 μm, with interstitial mafic minerals which in places poikilitically enclose the plagioclases. Opaque phases are small and not well-developed and include armalcolite(?), Fe-metal, and troilite. The angular clasts (Fig. 2) are all strained plagioclases and comprise 10-15% of the total rock.

PROCESSING AND SUBDIVISIONS: A few small pieces have been chipped off. ,1, consisting of many chips which are mainly basalt, was allocated for geochronological (Ar-Ar) studies. A single chip was used to make thin section ,2 and lacks the glass coat.

FIGURE 1. Smallest scale division in mm. S-72-49569.

FIGURE 2. 68519,2. ppl. width 2mm.

INTRODUCTION: 68525 is a fine-grained, poikilitic impact melt. It is dark gray, angular, and vesicular (Fig. 1). It is a rake sample and has many zap pits on one surface; the other side is broken.

PETROLOGY: Steele and Smith (1973) refer to 68525 as a "plagioclase-rich breccia; matrix of poikilitic pyroxene". It is homogeneous with stubby, ∿30 μm plagioclase chadacrysts enclosed in 200-300 μm mafic oikocrysts (Fig. 2). Many of the oikocrysts are composite--olivine or clinopyroxene with low-Ca pyroxene. Interoikocryst areas consist of ilmenite (or armalcolite), phosphates, Fe-metal, and glass. No lithic clasts are present in thin section ,1 but about 20% of the area consists of plagioclase fragments (Fig. 2). One other fragment is a pink spinel.

PROCESSING AND SUBDIVISIONS: A single representative chip was made into thin section ,1.

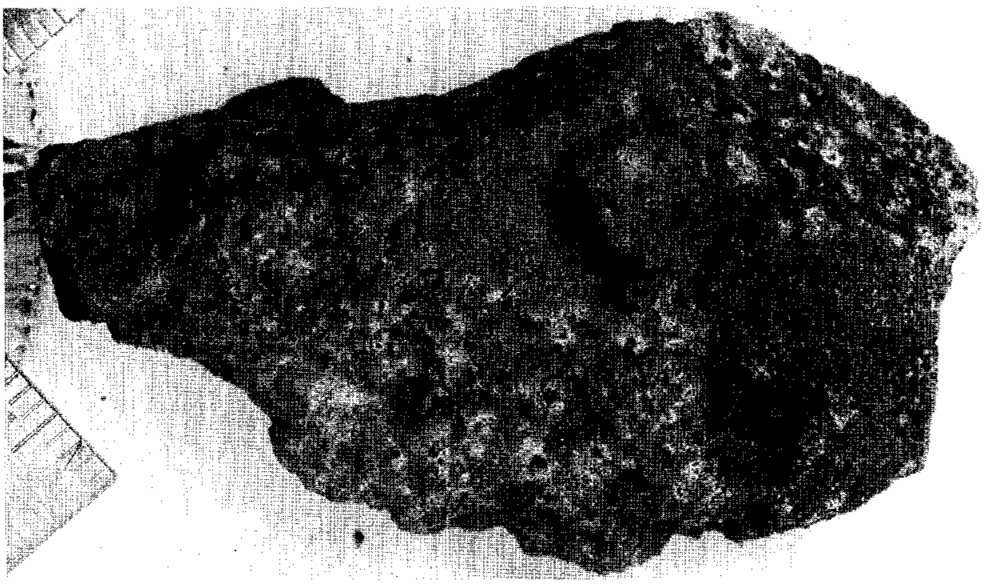


FIGURE 1. Smallest scale division in mm. S-72-51255.

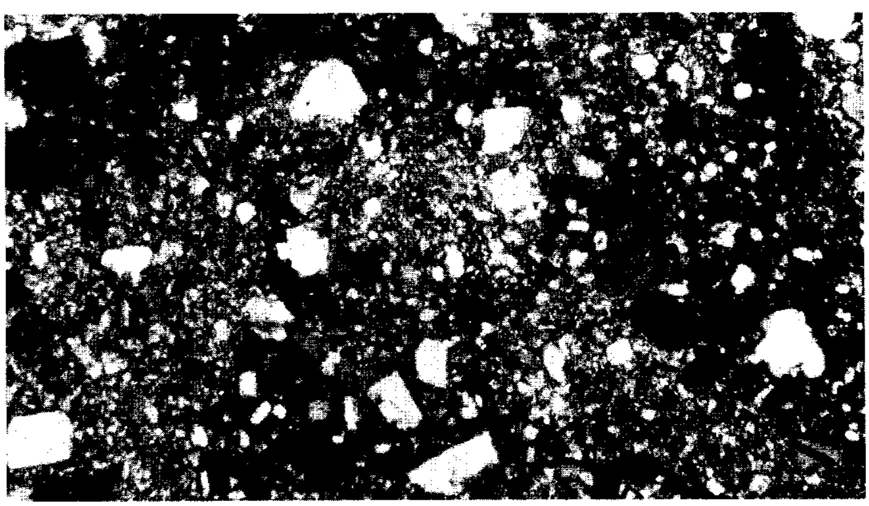


FIGURE 2, 68525,1. xpl. width 3mm.

68526 CLAST-RICH, FINE-GRAINED, POIKILITIC IMPACT MELT 7.21 g

INTRODUCTION: 68526 is a coherent, clast-rich impact melt with a poikilitic-textured matrix. It is gray and angular (Fig. 1). It is a rake sample and has a few zap pits.

PETROLOGY: 68526 consists of abundant plagioclase clasts up to 1.5 mm across in a crystalline, poikilitic matrix (Fig. 2). Chadacrysts of plagioclase are about 20 μm long, mafic oikocrysts are 200-400 μm in diameter. In interoikocryst areas plagioclase laths are up to 100 μm in length. Opaque phases are not common and are generally at the edge of oikocrysts. Plagioclase clasts larger than 100 μm account for ∿30% of the rock.

PROCESSING AND SUBDIVISIONS: A single representative chip was taken to make thin section ,1.

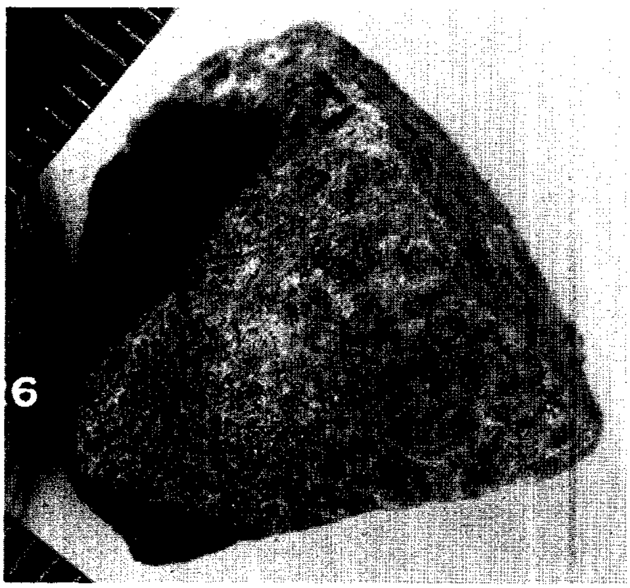


FIGURE 1. Smallest scale division in mm. S-72-51048.

FIGURE 2. 68526,1. xpl. width 3mm.

68527 CRYSTALLINE POLYMICT BRECCIA (POIKILITIC IMPACT MELT?) 3.03 g

INTRODUCTION: 68527 is a light gray, coherent breccia (Fig.1) consisting of plagioclase fragments in a fine-grained crystalline groundmass of equivocal origin. It is a rake sample and has few zap pits.

PETROLOGY: Steele and Smith (1973) refer to 68527 as a "plagioclase-rich breccia; matrix of poikilitic pyroxene". It is homogeneous and consists of a plagioclase-rich breccia with abundant clasts; probably $\sim$ 30% is grains of plagioclase larger than 100 μm. These are unshocked to badly shocked, including devitrified glasses. One lithic clast is a brecciated troctolite(?). The matrix is fine-grained and tends to have poikilitic pyroxenes $\sim$ 150 μm across enclosing tiny plagioclases. Its origin is probably an impact melt but recrystallization cannot be excluded.

PROCESSING AND SUBDIVISIONS: Small representative chips were taken to make thin section ,1.

FIGURE 1. Smallest scale division in mm. S-72-53536.

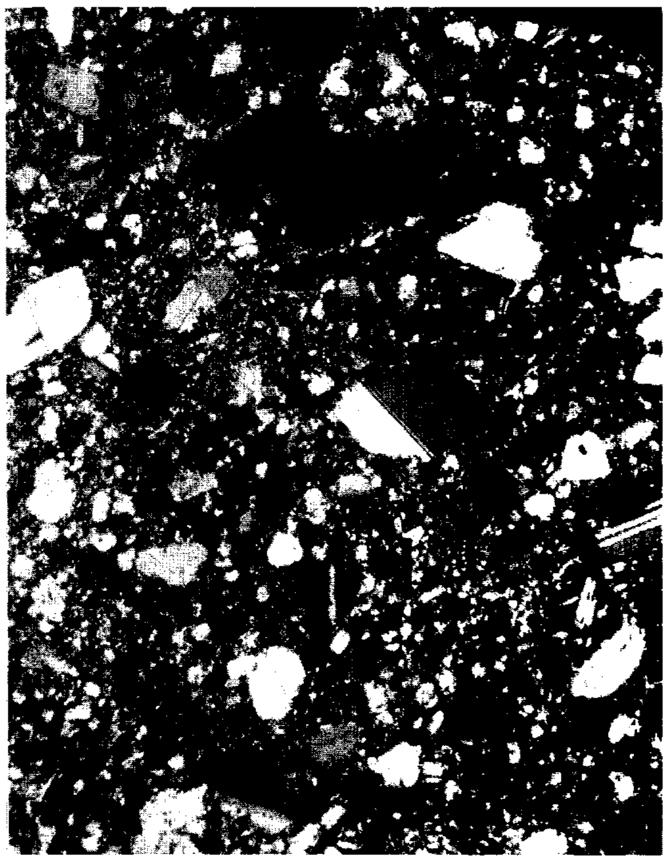


FIGURE 2. 68527,1. xpl. width 2mm.

INTRODUCTION: 68528 consists of a gray and white,coherent,polymict breccia which is coated and intruded by a vesicular black glass (Fig.1). It is a rake sample and lacks zap pits.

PETROLOGY: Thin sections of the gray and white breccia do not exist. The vesicular glass is brownish, and devitrified into "bow-tie" arrangements and rare spherulites (Fig.2). There is a gradation in size of the devitrification products over the thin section. The bow-ties are thinly banded plagioclase-mafic mineral intergrowths, some of which are nucleated on plagioclase fragments.

PROCESSING AND SUBDIVISIONS: A single chip of mainly black glass, with some adhering white material, was taken to make thin section ,1; however the white material is not represented in the thin section.

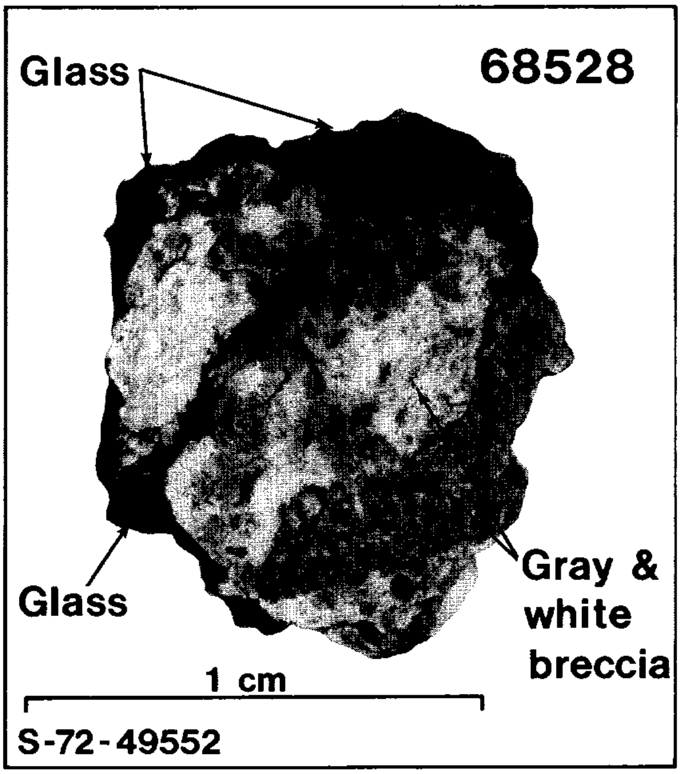


FIGURE 1.

FIGURE 2. 68528,1. glass coat, ppl. width 2mm.

INTRODUCTION: 68529 is a coherent, cindery, dark glass with some vesicles, and containing a few white clasts (Fig. 1). It is a rake sample and has a few zap pits on one corner.

PETROLOGY: 68529 consists mainly of brown, opaque glass which is patchy and irregular and contains some Fe-metal. Thin section ,1 is atypical in containing one of the conspicuous white clasts, which is a shocked and sheared plagioclase or cataclastic anorthosite.

PROCESSING AND SUBDIVISIONS: Some small chips, atypically containing a white clast as well as dark glass, were taken to make thin section ,1.

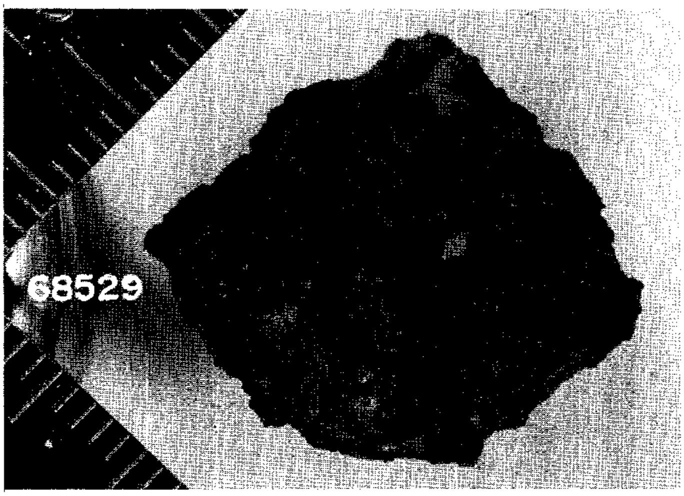


FIGURE 1. Smallest scale division in mm. S-72-51049.

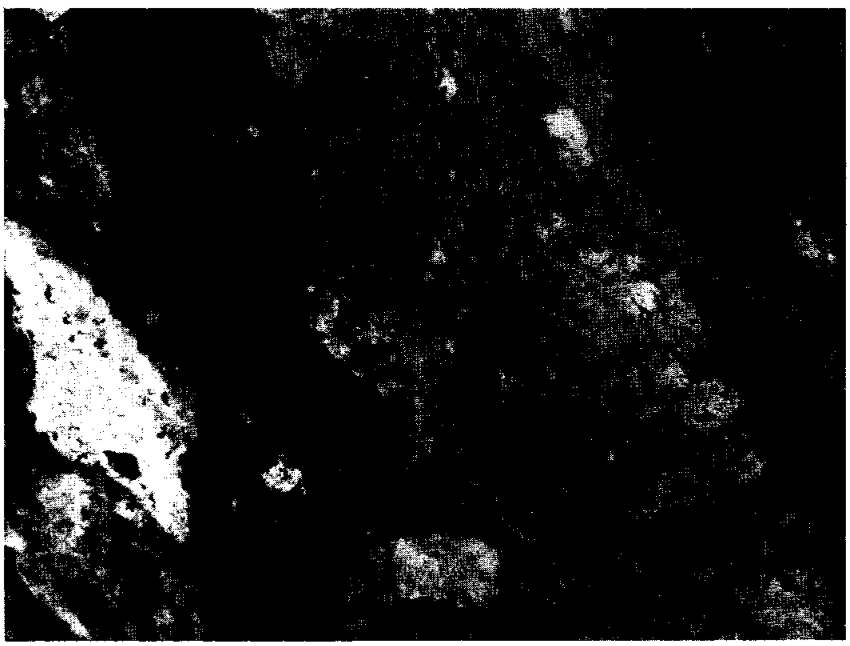


FIGURE 2. 68529,1. glass (left) and shocked plagioclase (right), partly xpl. width 3mm.

INTRODUCTION: 68535 consists of about equal proportions of gray, fine-grained impact melt(?) clasts and black glass matrix. A few small plagioclase clasts are also present (Fig. 1). The glass contains small vesicles and is coherent. 68535 is a rake sample and lacks zap pits.

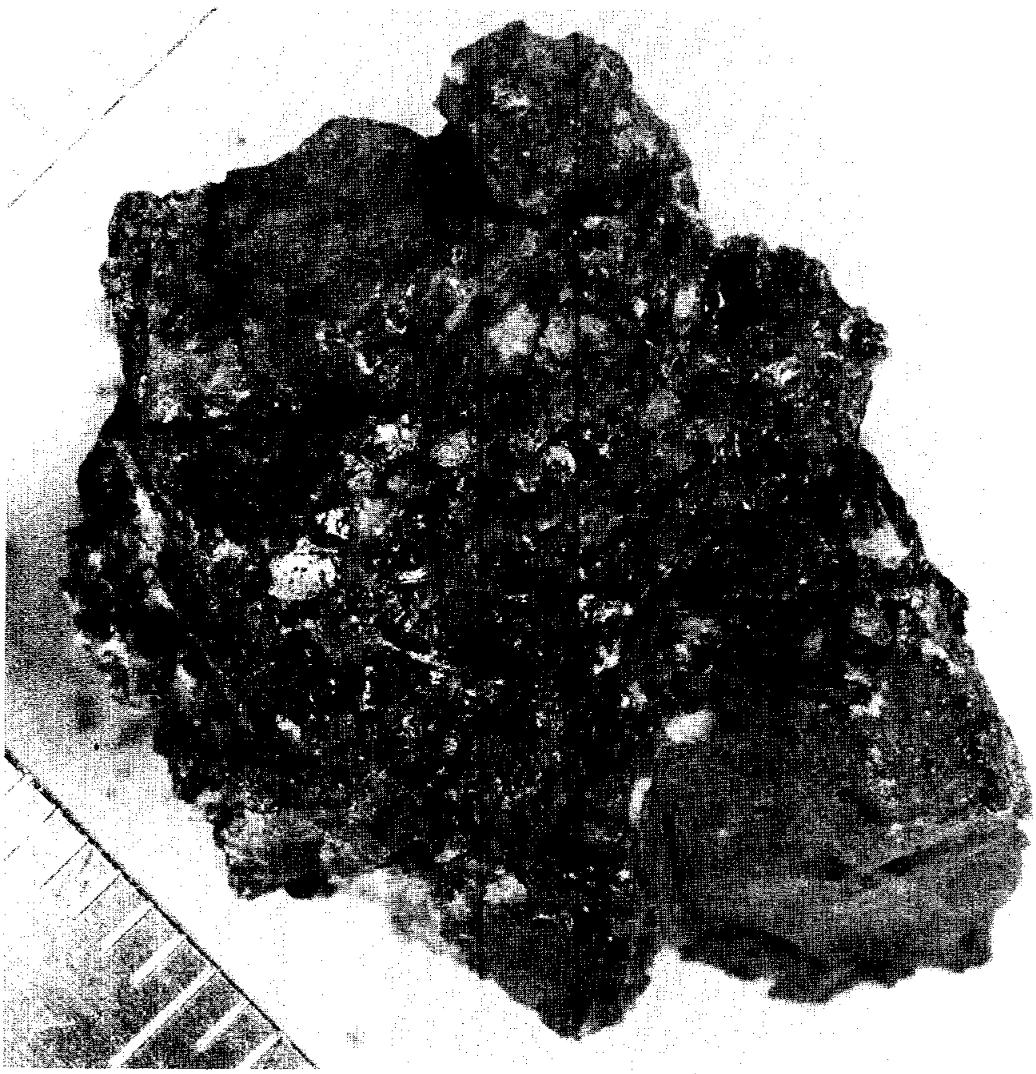


FIGURE 1. Smallest scale division in mm. S-72-49572.

INTRODUCTION: 68536 consists of fine-grained, light gray, basaltic impact melt intruded by dark vesicular glass (Fig. 1). It is a rake sample and lacks zap pits.

PETROLOGY: Steele and Smith (1973) refer to 68536 as "partially devitrified glass". It consists of fine-grained, brown, basaltic impact intruded by clear glass (Fig. 2). The impact melt has plagioclase laths 20-30 μm long (∿65%), similarly-sized intergranular mafic minerals (∿25%), and interstitial glass (∿10%). Fe-metal and other tiny opaque phases are present, as well as a few shocked plagioclase clasts. The glass is clear to brown, partly flow-banded, and carries maskelynite fragments, opaque aphanitic lithic materials, and other debris.

PROCESSING AND SUBDIVISIONS: A single fragment was taken to make thin section ,1.

FIGURE 1. Smallest scale division in mm. S-72-51253.

a b

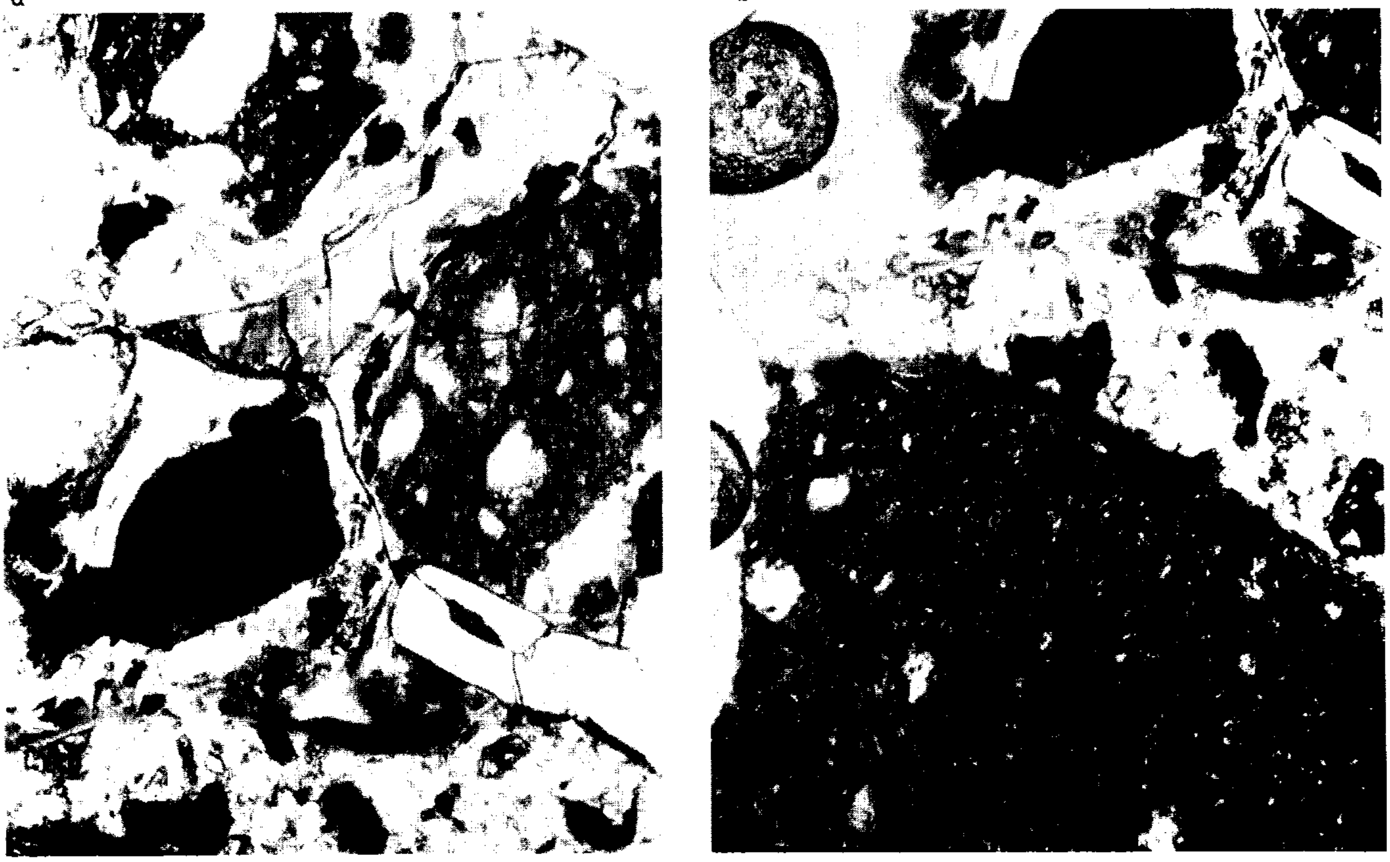


FIGURE 2.a b) 68536,1. general views, ppl. widths 2mm.

INTRODUCTION: 68537 is a polymict breccia consisting of fine-grained, gray impact melt(?) clasts and glass (Fig. 1). The glass may be a coat on the impact melt and contains white fragments. It is a rake sample and lacks zap pits.

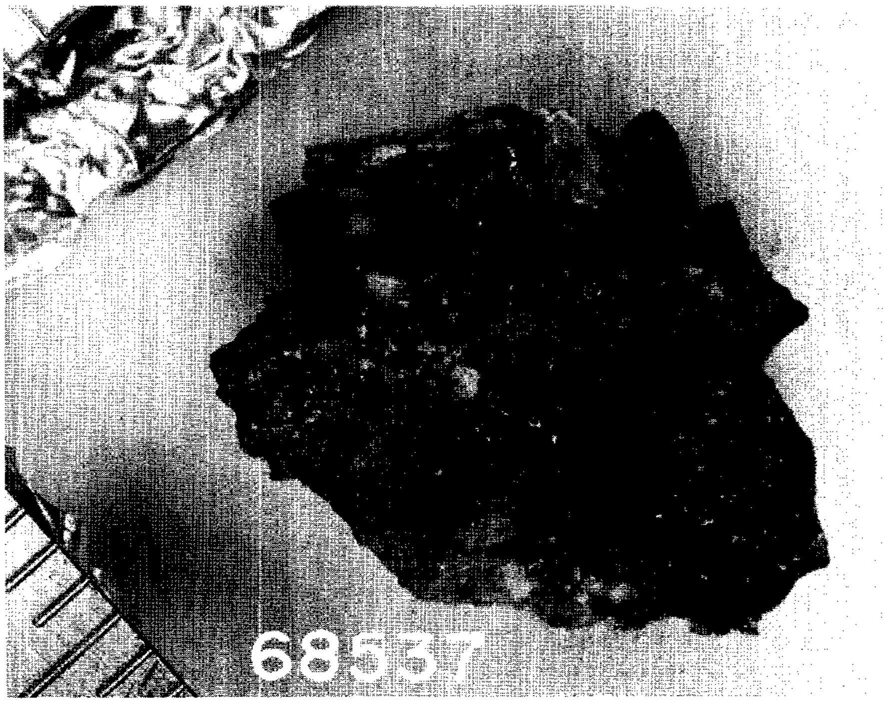


FIGURE 1. Smallest scale division in mm.
S-72-51277.

INTRODUCTION: 68815 is a polymict breccia (Fig. 1) consisting of a variety of clasts in a flow-banded, heterogeneous, and partly devitrified glass. The glass is extremely vesicular locally. Most clasts are small (1-2 mm) but two pale colored lithic clasts (fine-grained granoblastic/poikiloblastic, and feldspathic) are prominent (Fig. 2).

The medium dark-gray sample was chipped from a 1 m boulder which was macroscopically similar to most other rocks in the area. The boulder lay east of the LRV. The sample is coherent and fairly angular where broken, but subrounded on its exposed lunar surface, on which zap pits are common.

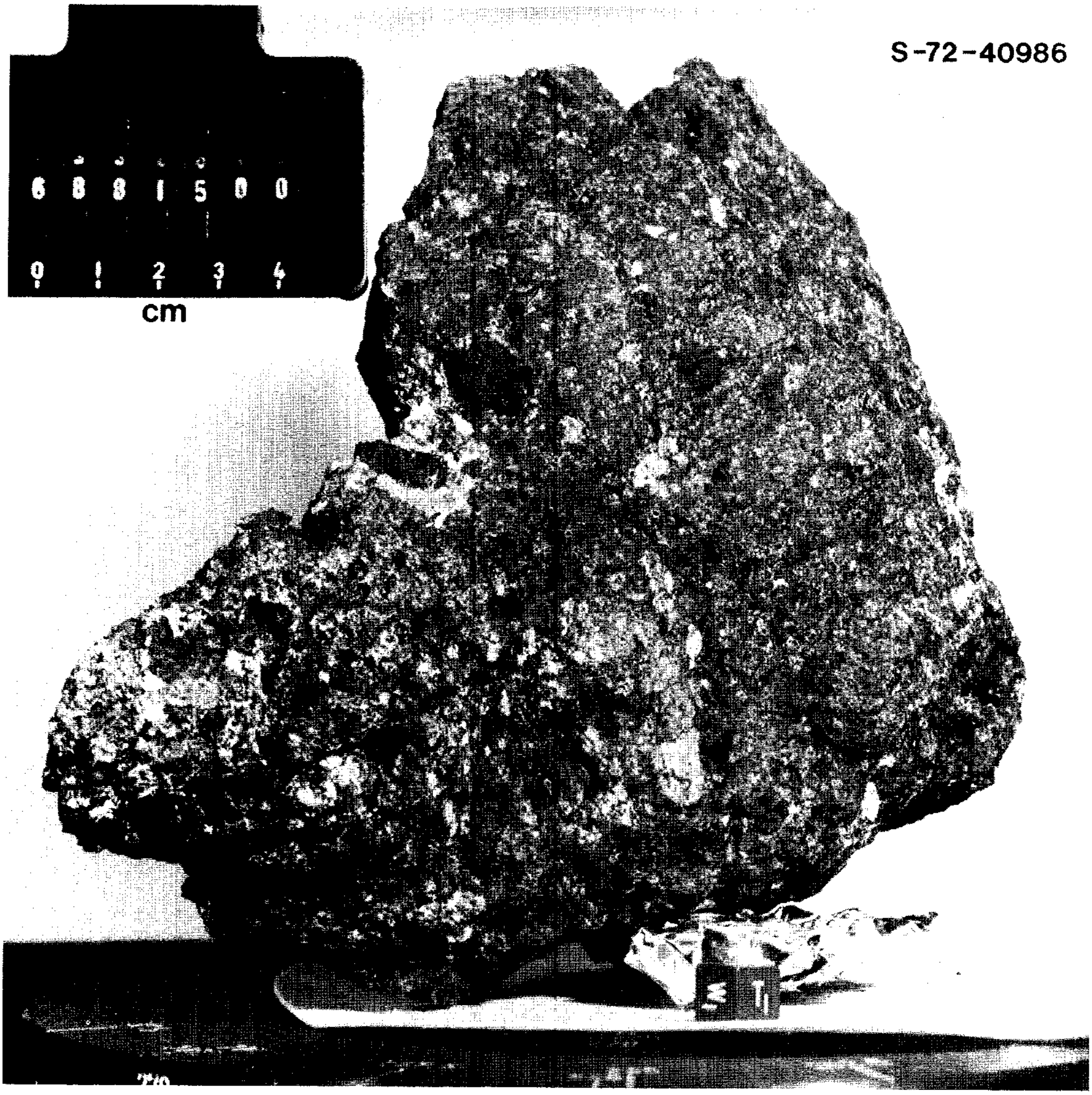


FIGURE 1.

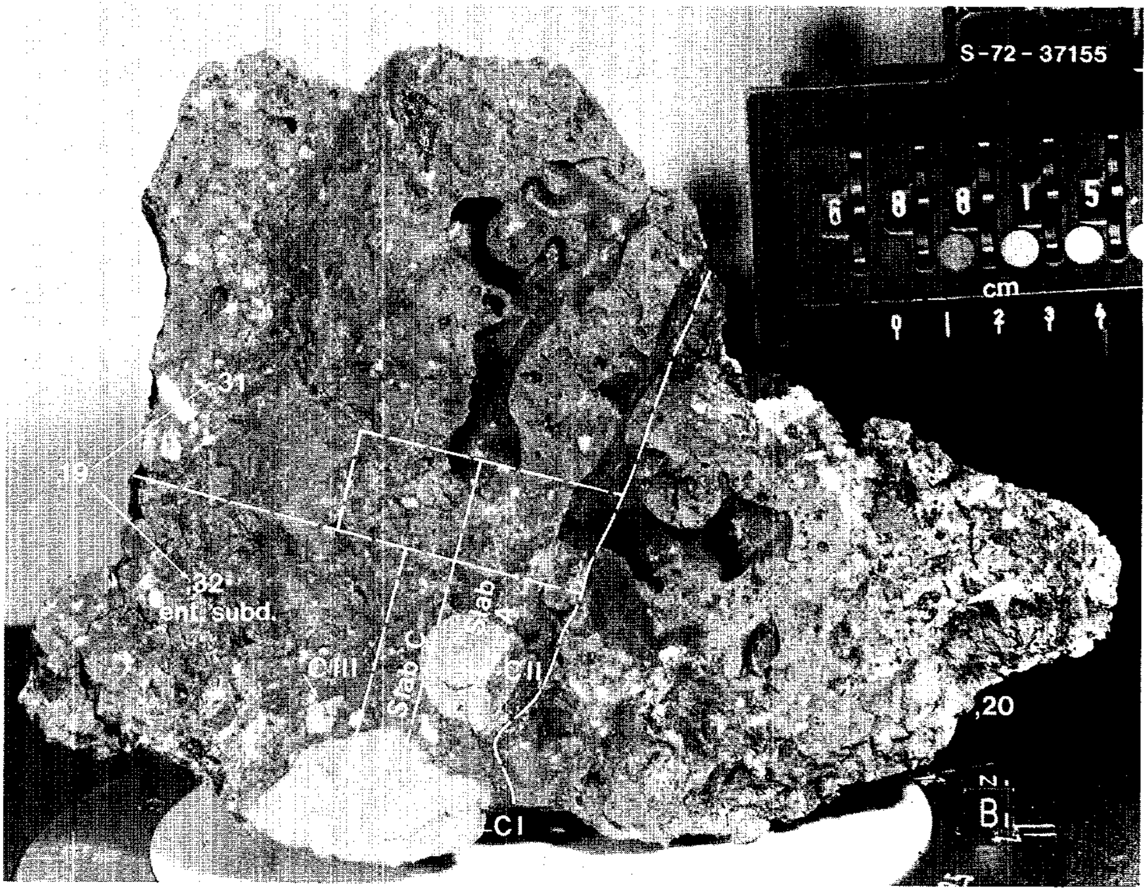
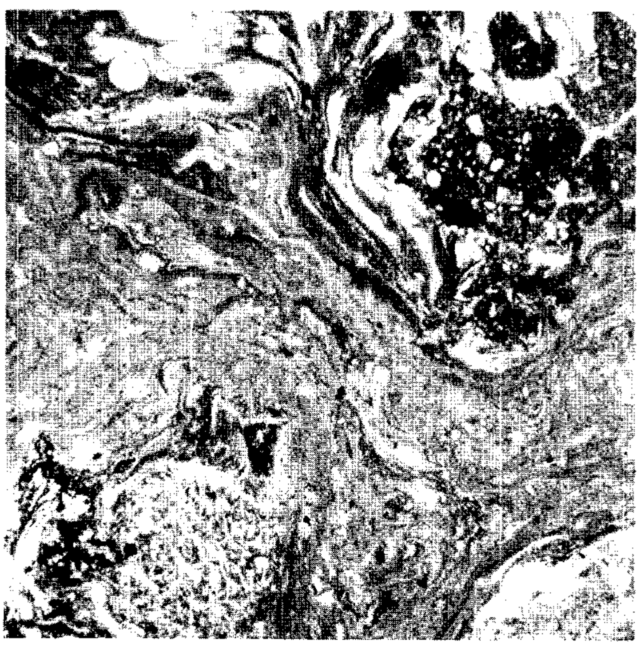


FIGURE 2.



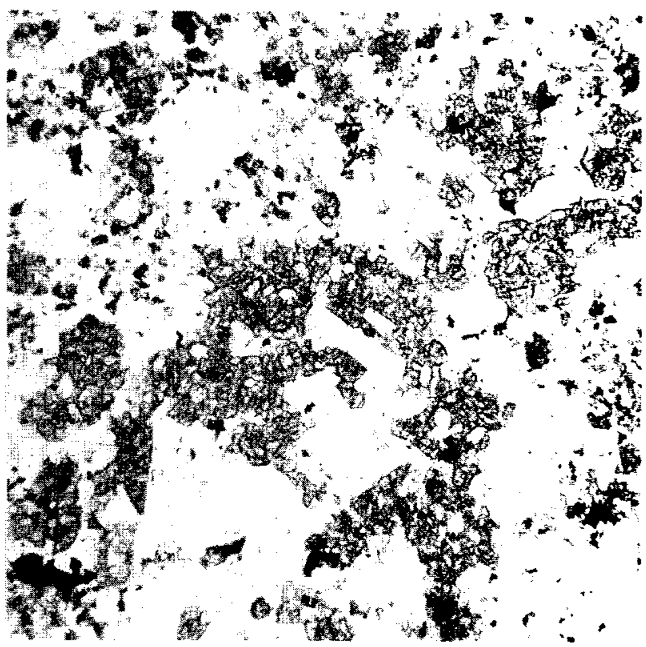


FIGURE 3. a) 68815,18. general glassy breccia, ppl. width 2mm.
b) 68815,150. Clast II, ppl. width 1mm.

PETROLOGY: An overall petrographic description is given by Brown et al. (1973) and descriptions of the two prominent light-colored clasts (I and II, Fig. 2) are given by Dixon and Papike (1978). Analyses of metal grains are given by Misra and Taylor (1975).

Much of 68815 consists of lobes of glass (Fig.3) ranging from colorless to brown/yellow in color and frequently banded, such that Brown et al. (1973) described it as a "fluidized lithic breccia". The colorless glasses are anorthositic whereas the brown/yellow glasses have 26-30% Al_2O_3. The clasts are prominently fine-grained, brown impact melts, most of which have 22-23% Al_2O_3 (Brown et al., 1973). Most such clasts have sharp, frequently angular boundaries and some are several centimeters in diameter. Some clasts are aphanitic brown breccias, others are plagioclase vitrophyres. Rare mineral fragments analyzed by Brown et al. (1973) include olivine (up to Fo_{91}), magnesian orthopyroxene (up to En_{81}), magnesian ilmenite and pleonaste spinel. Schreibersite was observed in a troctolitic clast.

Metal grains in the glasses have an average 6.3% Ni and 0.4% Co (Misra and Taylor, 1975). They occur particularly as spherical inclusions, up to 20 μm across, which are particularly concentrated in the dark bands of flow-banded glass. Metal/troilite intergrowths are common.

Clast I contains 60% plagioclase and 40% mafics, and a small amount of Fe-metal, Cr-spinel, and ilmenite. In general it has a fine-grained granoblastic or hornfelsic texture, but several poikiloblastic areas are present. In these, orthopyroxene (100-200 μm) encloses chadacrysts of plagioclase, olivine, and augite. Clast II is less mafic (30%) but has a similar mineralogy to Clast I. Its texture is mainly poikiloblastic (Fig.3). Dixon and Papike (1978) provide mineral analyses showing that the groundmass plagioclases in these clasts range from $An_{96.5-89.5}$ and the chadacrysts are An_{97-91}. The chadacrysts contain more FeO and are deemed to be, on average, more sodic. Most pyroxenes are in the En_{65-75} range (Fig. 4) and olivines vary from $\sim Fo_{69}$ in groundmass to Fo_{73} chadacrysts.

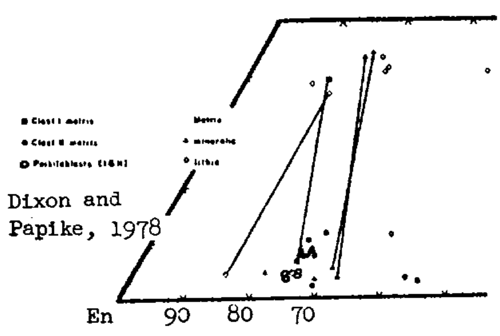


FIGURE 4. Pyroxenes in Clasts I and II. from Dixon and Papike (1978).

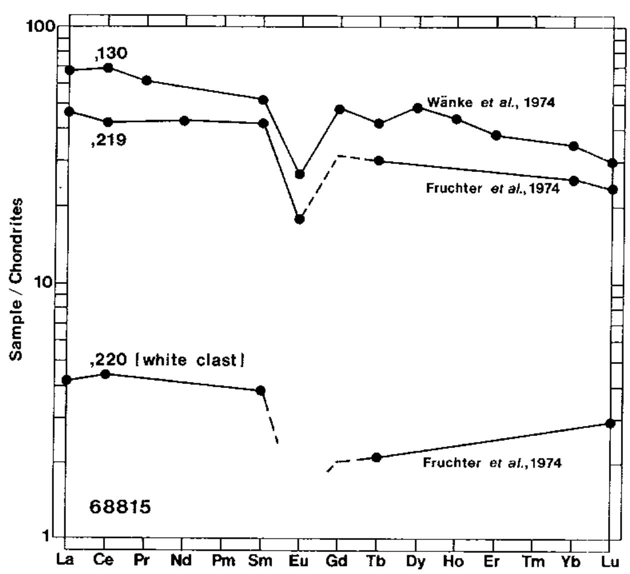


FIGURE 5. Rare earths.

CHEMISTRY: Chemical analyses are listed in Table 1 and a summary of the chemical composition of the bulk rock is given in Table 2. Additional information on Ca and K is provided in the Ar-Ar work on matrix and clasts (refs. below). Chemical analyses of clasts I and II have not been made.

Despite the heterogeneous nature of individual glasses as derived by microprobe analyses, four analyses for bulk rock Al are remarkably similar (Al_2O_3 26.8-27.6%) and the REE abundances of two splits not remarkably dissimilar (Fig. 5). The volatile elements are much lower in abundnace than in local soils although the major element and rare-earth element composition is fairly similar to such soils. The bulk rock is greatly enriched in meteoritic siderophile elements (Krähenbühl et al., 1973). The meteoritic signature was placed marginally in Group LN (possibly Imbrium) by Ganapathy et al. (1973) and revised to IH, though labelled an unreliable assignment, by Hertogen et al. (1977).

TABLE 1. Chemical work on 68815

Reference	Split #	Description	Elements Analyzed
Krähenbühl et al. (1973)	,124	bulk rock	meteoritic siderophiles and volatiles
LSPET (1973)	,9	bulk rock	majors, some trace
Clark and Keith (1973)	,2	bulk rock	K, U, Th
Jovanovic and Reed (1973)	,107	bulk rock	F, Cl, Br, I, Li, U
Wänke et al. (1974)	,130	bulk rock	major, minors, trace (∿50 elements)
Fruchter et al. (1974)	,220*	bulk rock	Al, Fe, REEs, other trace
Fruchter et al. (1974)	,219**	white clast	Al, Fe, REEs, other trace
Rees and Thode (1974)	,101	bulk rock	S
Jovanovic and Reed (1976a)	,107	bulk rock	Ru and Os
Jovanovic and Reed (1977)	,107	bulk rock	Hg
Reed et al. (1977)	,107	bulk rock	^{204}Pb, Tl, Zn
Wänke et al. (1977)	,130	bulk rock	V
Becker et al. (1976)	,66	bulk rock	N
Graf et al. (1973)	?	bulk rock ?	U
Goel et al. (1975)	?		N
Moore and Lewis (1976)	,129		N, C
Modzeleski et al. (1973)	,122; ,123	bulk rock	C and C compounds
Moore et al. (1973)	,7; ,129	bulk rock	C
Cripe and Moore (1974)	,129	bulk rock	S
Scoon (1974)	,120	bulk rock	majors
Leich et al. (1973)	,27	bulk rock	H, F with depth
Padawer et al. (1974)	,25	bulk rock	H with depth
Kohl et al. (1978)	,234	bulk rock	Al, Fe, Mn
Drozd et al. (1974)	?	bulk rock	U

*tabulated erroneously as ,61
**tabulated erroneously as ,W

TABLE 2. Summary chemistry of 68815 bulk rock

SiO_2	46	Sr	170
TiO_2	0.49	La	15–22
Al_2O_3	27	Lu	0.9
Cr_2O_3	0.10	Rb	2–9
FeO	5.0	Sc	7.2
MnO	0.06	Ni	~300
MgO	5.9	Co	~40
CaO	15.4	Ir ppb	11
Na_2O	0.48	Au ppb	8–15
K_2O	~0.15–0.20	C	6–17
P_2O_5	0.18	N	2–53
		S	550
		Zn	2.45
		Cu	7.8

Oxides in wt%; others in ppm except as noted.

STABLE ISOTOPES: Clayton *et al.* (1973) report a whole rock δO^{18} value of +5.72 for ,121. This is a typical lunar value.

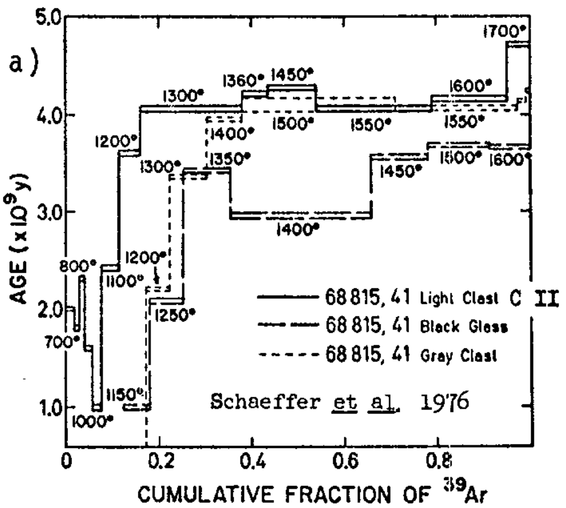
Rees and Thode (1974) report a whole rock δS^{34} value of +0.4 for ,101, without discussion. This value is similar to other lunar breccias and much lower than the regolith values of +8 to +10.

Becker *et al.* (1976) report a δN^{15}_{air} value of +10.4±1.5. Technical problems caused the sample to be exposed to air, and if any of the N analyses was atmospheric, then the indigenous lunar δN^{15}_{air} value is even higher.

GEOCHRONOLOGY: Schaeffer *et al.* (1976) and Schaeffer and Schaeffer (1977) report ^{40}Ar-^{39}Ar data for glassy matrix and clasts in 68815. The results are summarized in Table 3 and release diagrams are given in Figure 6. In general good plateaus were not attained. The glassy matrix appears to be older than 3.76 b.y., clast II (,41A) has a plateau age of 4.12 b.y., and clast I (,60B) yields an age ~4.07 b.y. Even the 4.12 b.y. age appears to be unreliable because the plateau is considerably disturbed. Schaeffer *et al.* (1976) and Schaeffer and Schaeffer (1977) detail the complexities associated with the interpretation of each analysis.

TABLE 3. Summary of ^{40}Ar-^{39}Ar Results from 68815

Sample	Description	Plateau Age (b.y.)	K-Ar Age (b.y.)	Reference
,41A	Lt. clast CII	4.120±0.040	4.01±.01	Schaeffer et al. (1976)
,41B	Gy. clast	4.020±0.024	3.66±.04	Schaeffer et al. (1976)
,41C	Glass	3.630±0.054	3.05±.01	Schaeffer et al. (1976)
,60A	Glass	3.692±0.037	3.30±.01	Schaeffer et al. (1976)
,60B	Clast I	4.073±0.027	3.76±.01	Schaeffer et al. (1976)
,141B	Glass		2.681±0.003	Schaeffer & Schaeffer (1977)
,133B	Glass		3.015±0.003	Schaeffer & Schaeffer (1977)
,133C	Wh. clast	3.811±0.012	3.686±0.007	Schaeffer & Schaeffer (1977)
,67D	Wh. clast		3.54±0.02	Schaeffer & Schaeffer (1977)



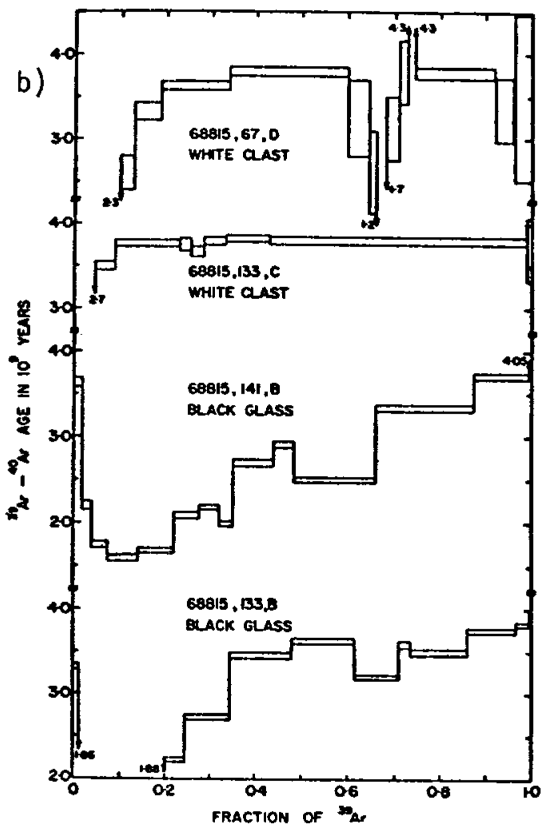


FIGURE 6. Ar release. a)from Schaeffer et al. (1976). b) from Schaeffer and Schaeffer (1977).

RARE GASES AND EXPOSURE AGES: Rare gas isotopic data is presented by Behrmann et al. (1973), Drozd et al. (1974), Schaeffer et al. (1976), and Schaeffer and Schaeffer (1977). Behrmann et al. (1973) report Ne, Kr (including spallation spectra data, and conclude that 68815 contains a small concentration of solar rare gases as compared with soils. ^{81}Kr-^{83}Kr and ^{81}Kr-^{78}Kr exposure ages are both 2.0±0.2 m.y. A ^{22}Na-^{21}Ne age, calculated directly, is 1.5±0.4 m.y. (when normalized to 67195 = 50.6 m.y., age is 1.7±0.4 m.y.). The absence of prominent neutron effects implies that prior to ejection 68815 must have been buried deeper than 7 m. Drozd et al. (1974) report Kr isotopic data (including spallation spectra) and calculate a ^{81}Kr-Kr age of 2.04±0.09 m.y. (^{21}Ne age, 1.21±0.29 m.y. and ^{38}Ar, 2.18±.98 m.y.). Pepin et al. (1974) used the Drozd et al. (1974) data to calculate cosmic ray exposure ages using effective production rates v. depth expressions, and find that their derived ^{21}Ne age (1.97±0.32) and ^{38}Ar, 1.98±0.26) are in agreement with the Kr ages. They also find that an irradiation history of ~70 m.y. at ~6.5 m depth, followed by a 2 m.y. residence at the surface is consistent with spallation Ne and Ar concentrations.

Schaeffer et al. (1976) tabulate Ar exposure ages, but note in the text that such ages are actually invalid because of the production of ^{38}Ar from Cl during irradiation. The calculated ages of 34 to 201 m.y. are indeed totally out of agreement with those derived by other methods. Schaeffer and Schaeffer (1977), to overcome this problem, measured argon isotopes on 5 unirradiated samples. One sample requires a large correction for trapped ^{38}Ar; the other four give exposure ages ranging from 1.51 to 2.43 m.y. (average 1.83±0.24 m.y.) in agreement with other published exposure ages.

Yaniv et al. (1980) report that their ^{81}Kr-Kr data confirm a 2 m.y. exposure age for 68815 but do not tabulate data. They also discuss observed increases in ^{3}He and ^{81}Kr in the surface of 68815 due to solar cosmic ray effects. Hohenberg et al. (1978) calculate the cosmogenic contribution to ^{21}Ne, ^{38}Ar, ^{83}Kr and ^{126}Xe in ,113, but do not specify the data sources.

Cosmogenic radionuclide data are presented by Clark and Keith (1973), Fruchter et al. (1977,1978) and Kohl et al. (1978). Fruchter et al. (1977) measure ^{53}Mn at 2 cm depth and derive a ^{53}Mn age of 1.9 m.y. The ^{26}Al data suggest 85% saturation, in agreement with this age. The data indicate that no substantial exposure at a depth less than 60 cm occurred prior to the 2 m.y. excavation. In Fruchter et al. (1978) the same data are presented but ages of 2.1±0.3 m.y. (^{26}Al) and 1.7±0.2 m.y. (^{53}Mn) are tabulated. Data for ^{53}Mn and ^{26}Al in 14 samples from the upper 1.5 cm of 68815 reported by Kohl et al. (1978) are fairly constant, agree with other data, and are consistent with a 2 m.y. exposure age. Activity v. depth for three different faces shows that surface activity is nearly independent of inclination.

Yuhas and Walker (1973; quoted in Crozaz et al., 1974) derived a track density/depth exposure age of 2.0 m.y., and Dust and Crozaz (1977) found track density/depth data to be consistent with the 2 m.y. age.

MICROCRATERS, TRACKS, AND SURFACES: Behrmann et al. (1973) counted 30 to 50 pits larger than 30 μm diameter on a 0.5 cm^2 surface area of 68815.

Walker and Yuhas (1973) used 68815 to derive an "empirical track production energy spectrum" with a track profile. 3 samples from depths of 0-5 mm (,74), 2.8±0.3 cm (,109) and 5.5±0.3 cm (,113) were used and only tracks >2 μm in length were measured. The average for these was 4.9 μm and the largest was 9 μm. Yuhas and Walker (1973) and Dust and Crozaz (1977) also studied track density profiles; the solar flare track profile is typical. Graf et al. (1978) used a track method to determine the U concentration of the sample.

Chemical studies of surface and near-surface regions for light elements were reported by Leich et al. (1973,1974), Padawer et al. (1974), and Stauber et al. (1973). Goldberg et al. (1976) studied F on vesicle surfaces. Leich et al. (1973,1974) studied H and F to 2000 Å depth from the surface for a chip exposed on the lunar surface. A peak of 700 ppm H near the surface falls to 150 ppm in the interior. F also shows a surface peak. In Leich et al. (1973), the results are interpreted as indigenous H in the interior and terrestrial contamination on the exterior, but Leich et al. (1974) apparently reinterpret the surface H to be from the solar wind. Padawer et al. (1974) got similar results (∿400 ppm H at surface, to less than 50 ppm at 10,000 Å depth) for a chip of interior material, not exposed at the lunar surface. This strongly suggests that such H peaks are from terrestrial contamination, not from the solar wind. Stauber et al. (1973), using nuclear microprobe analysis on a clast embedded in the lunar exterior surface of the rock, also found a H peak (∿150 ppm) near the surface.

Goldberg et al. (1976) found a distinct F peak on vesicle walls, but intervesicular areas also showed F peaks (the samples were processed without exposure to Teflon) making equivocal the interpretation of the vesicle F peaks as lunar volatile deposits.

PHYSICAL PROPERTIES: Nagata et al. (1973) tabulate the basic magnetic properties of ,70, a bulk rock chip, tabulate the coercive force, the saturation remanent magnetization, and saturation magnetization at 4.2°K, 300°K, and tabulate the natural remanent magnetization and its stability against alternating field demagnetization. An acquisition experiment on the piezoremanent magnetization indicated the ambient magnetic field to be about 200 γ. Cisowski et al. (1974) plot Fe^0 v. $Fe^0 + Fe^{2+}$; Fe^{2+} (∿4.5%) is from published paramagnetic susceptibility measurements and Fe^0 (∿0.06%) is from the value of saturation magnetization. Schwerer and Nagata (1976) tabulate magnetic data relevant to the characterization of superparamagnetic-ferromagnetic components, without discussion.

Mossbauer spectroscopic data are presented by Schwerer et al. (1973), Huffman et al. (1974) and Huffman and Dunmyre (1975) (all same group). The data show that the ratio of olivine:pyroxene is about 2:1. 7% of the total iron present is Fe^0 (Schwerer et al., 1973). Huffman et al. (1974) reproduce the data of Schwerer et al. (1973) but from magnetic analysis also deduce that Fe^0 total = 0.62 wt% and Fe^{2+} total = 6.28 wt%. Approximately 2% of the total Fe is in an unidentified phase (possibly chromite) which is not ordered at room temperature. Huffman and Dunmyre (1975) note that no Fe occurs in superparamagnetic clusters in olivine in 68815.

Katsube and Collett (1973a,b) report electrical data: real relative permittivity, parallel resistivity, and dissipation factor (Fig. 7). Schwerer et al. (1974) measured electrical conductivity as a function of temperature (Fig. 8) and tabulate conductivity parameters.

Charette and Adams (1977) illustrate spectral reflectance v. wavelength for powders made from 68815. Only weak pyroxene and plagioclase bands are present.

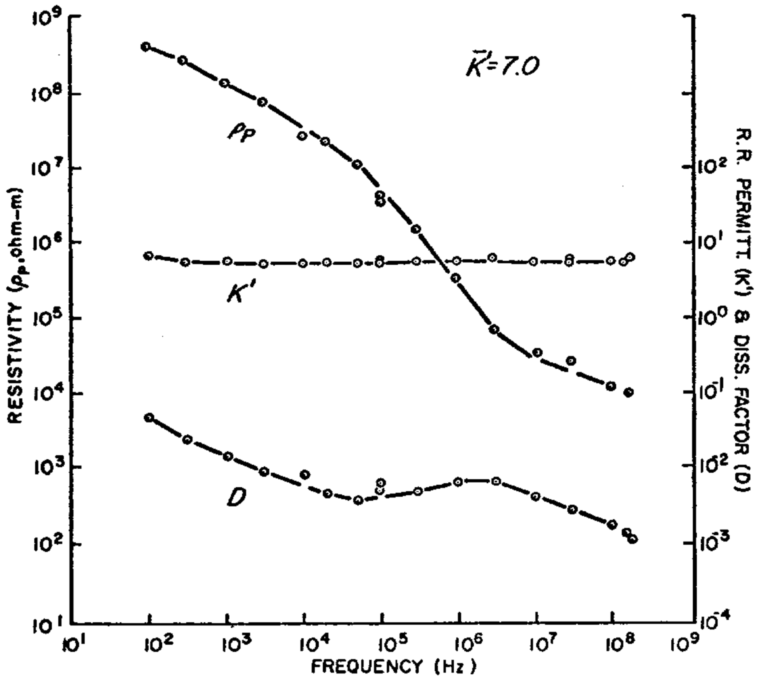


FIGURE 7. Electrical data; from Katsube and Collett (1973a).

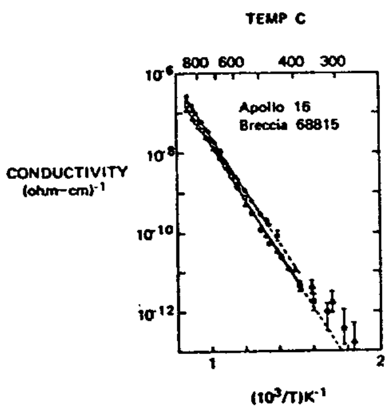


FIGURE 8. Electrical data; Schwerer et al.(1974).

PROCESSING AND SUBDIVISIONS: 68815 has been substantially subdivided. A fracture split the sample into two main pieces, one of which (,20, 545 g) remains intact. The other (,19, originally 1235 g) has been totally subdivided with extensive chipping and sawing (Figs. 2, 9, 10) to produce slabs and columns. Considerably more subdivisions occur than are apparent in the illustrations. Thin sections occur for clast I and II and for several matrix areas.

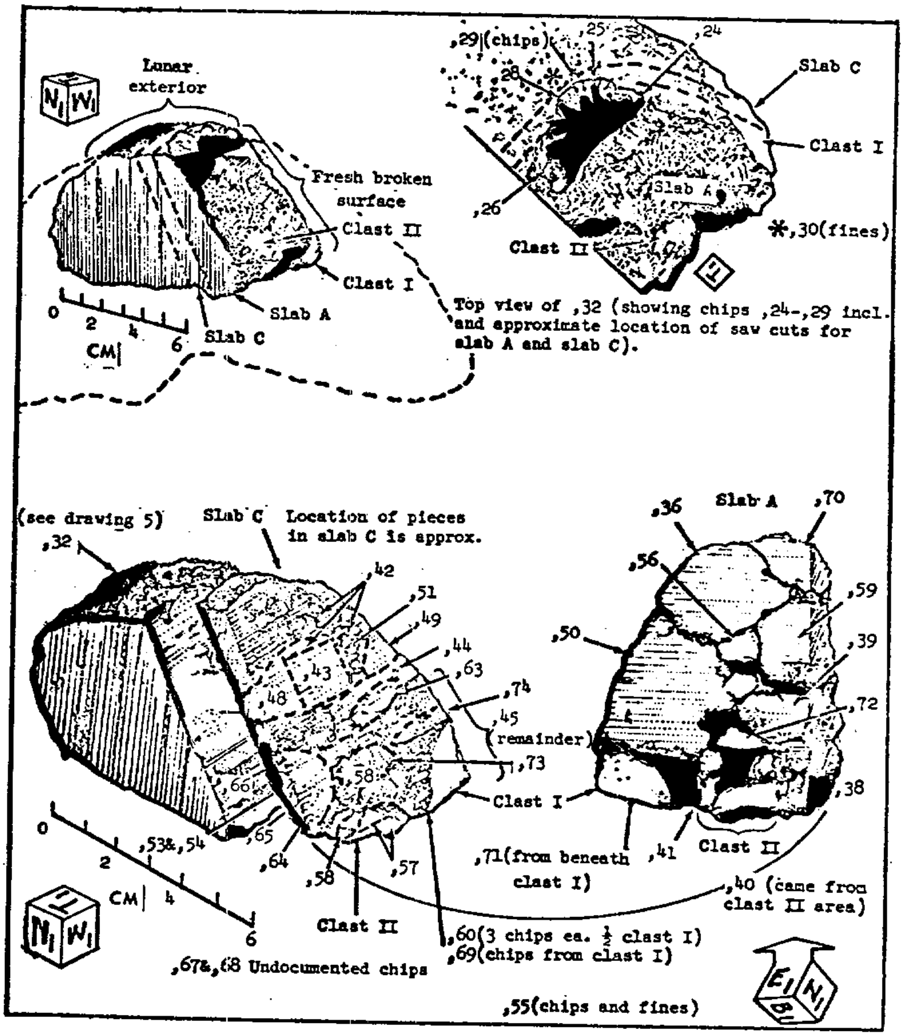


FIGURE 9. Cutting diagram.

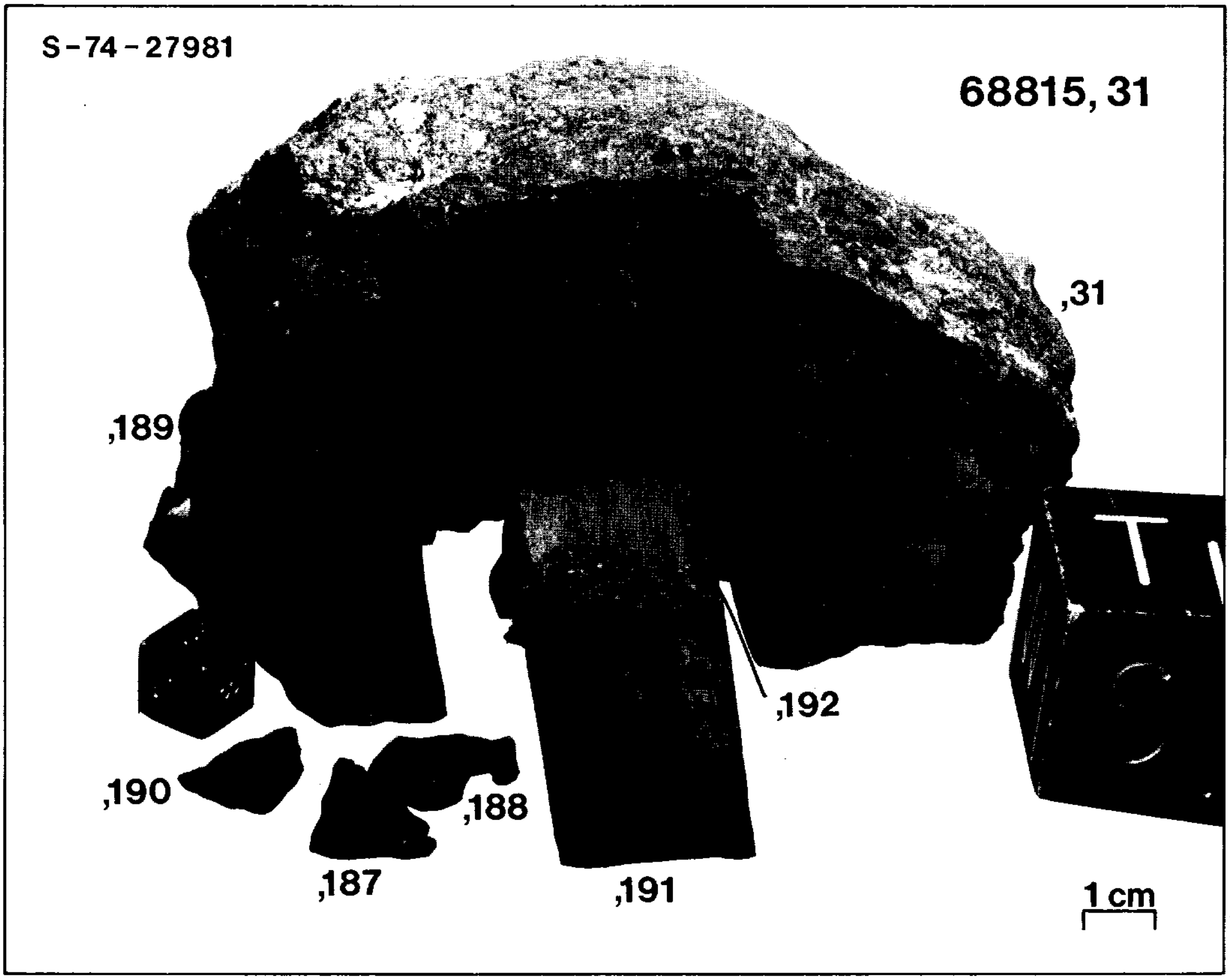


FIGURE 10.

INTRODUCTION: 68825 is a dark, coherent, irregularly shaped fragment of glassy impact melt (Fig. 1). At least one side apparently preserves a smooth exterior surface of a once-molten mass. The other side is coated by a thick layer of adhering soil. 68825 was taken from a soil collected adjacent to the boulder which yielded 68815.

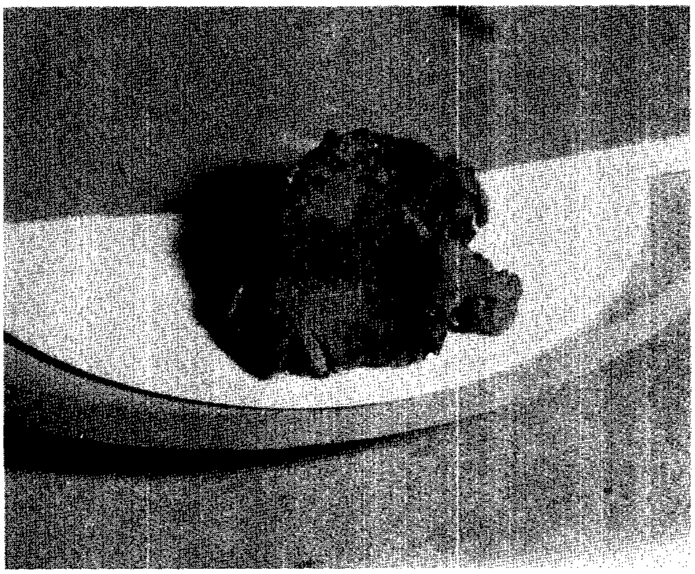


FIGURE 1. Sample is about 3 cm. across.

INTRODUCTION: 68845 is a coherent, medium gray, crystalline rock, probably an impact melt, with several small (<1 mm) white clasts (Fig. 1). It was taken from a soil sample.

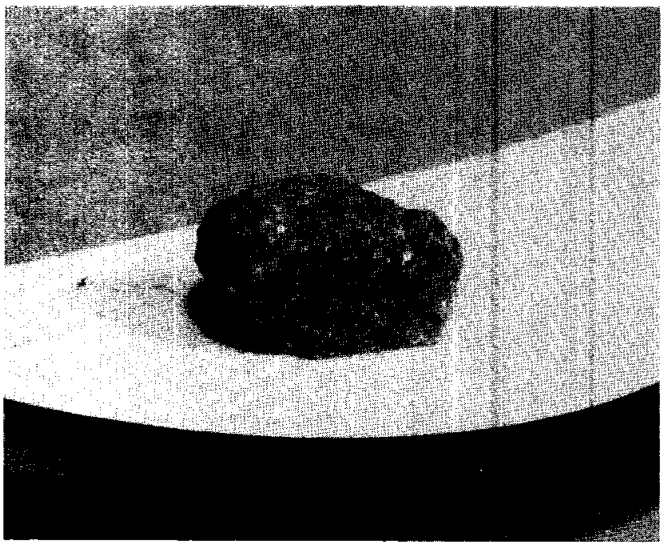


FIGURE 1. Sample is about 2.5 cm. across.

68846 FINE-GRAINED IMPACT MELT 2.28 g

INTRODUCTION: 68846 is a coherent, medium gray, crystalline rock, probably an impact melt, with several small (<1 mm) white clasts. It was taken from a soil sample.

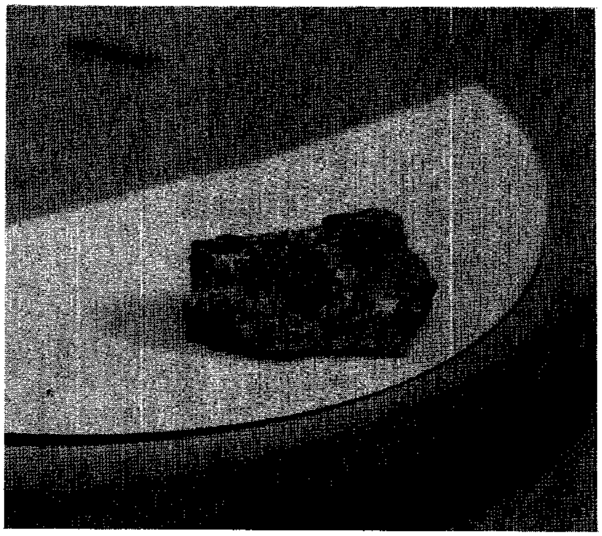


FIGURE 1. Sample is about 1.5 cm across.

68847 FINE-GRAINED OR GLASSY IMPACT MELT(?) 2.85 g

INTRODUCTION: 68847 is coherent, medium dark gray, and contains small white clasts (Fig. 1). The presence of vesicles suggests that it is an impact melt, and it is either fine-grained or glassy. It was taken from a regolith sample collected a few meters north of a small boulder (from which 68815 was taken) and about 40 m east of the two small craters at the station. Zap pits are present on some surfaces.

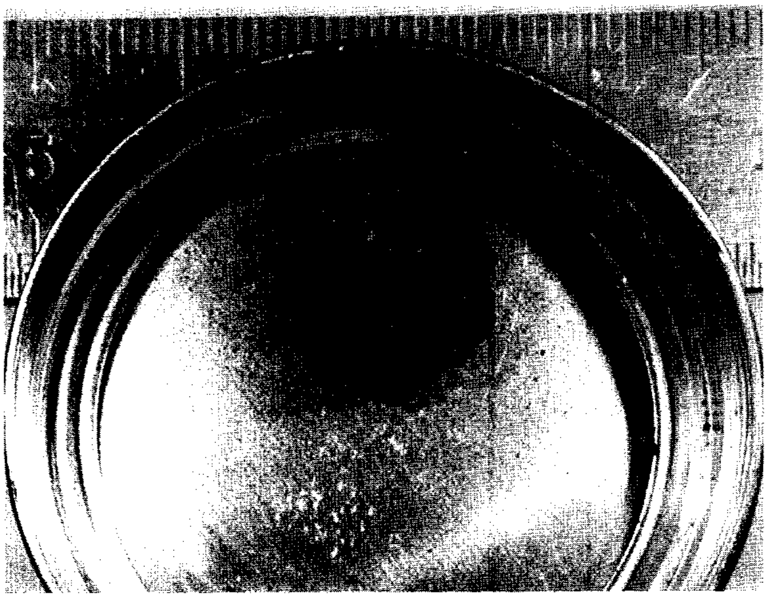


FIGURE 1. Smallest upper scale divisions in mm.

INTRODUCTION: 68848 is a coherent, medium dark gray fragment (Fig. 1). It contains plagioclase laths (not particularly elongated) about 500 μm to 1 mm long, and is vesicular. Some metal is apparent, but the sample contains no obvious clasts. A vesicular, black glass coat is attached to one side.

68848 was taken from a regolith sample collected a few meters north of a small boulder (from which 68815 was taken) and about 40 m east of the two small craters at the station. The dusty surface appears to lack zap pits.

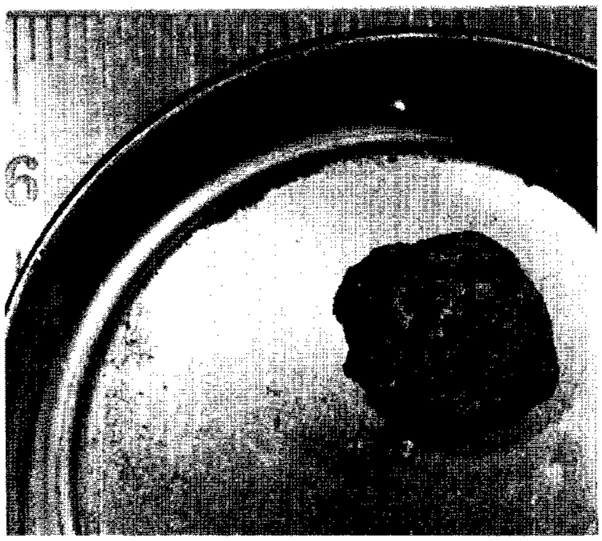


FIGURE 1. Smallest scale divisions in mm.

INTRODUCTION: 69935 is a coherent, dark gray, glassy breccia. Complex relations among a variety of lithologies mark this rock (Fig. 1).

At Station 9, two samples were taken from a dark boulder ~60 cm in diameter. 69935 was removed from the very top of the boulder and 69955 was chipped from the bottom side after the boulder was overturned by the Apollo 16 crew (Fig. 2). Lunar orientation of 69935 is not precisely known due to its small size. Many zap pits are present on the T surface; the B surface is a fracture face.

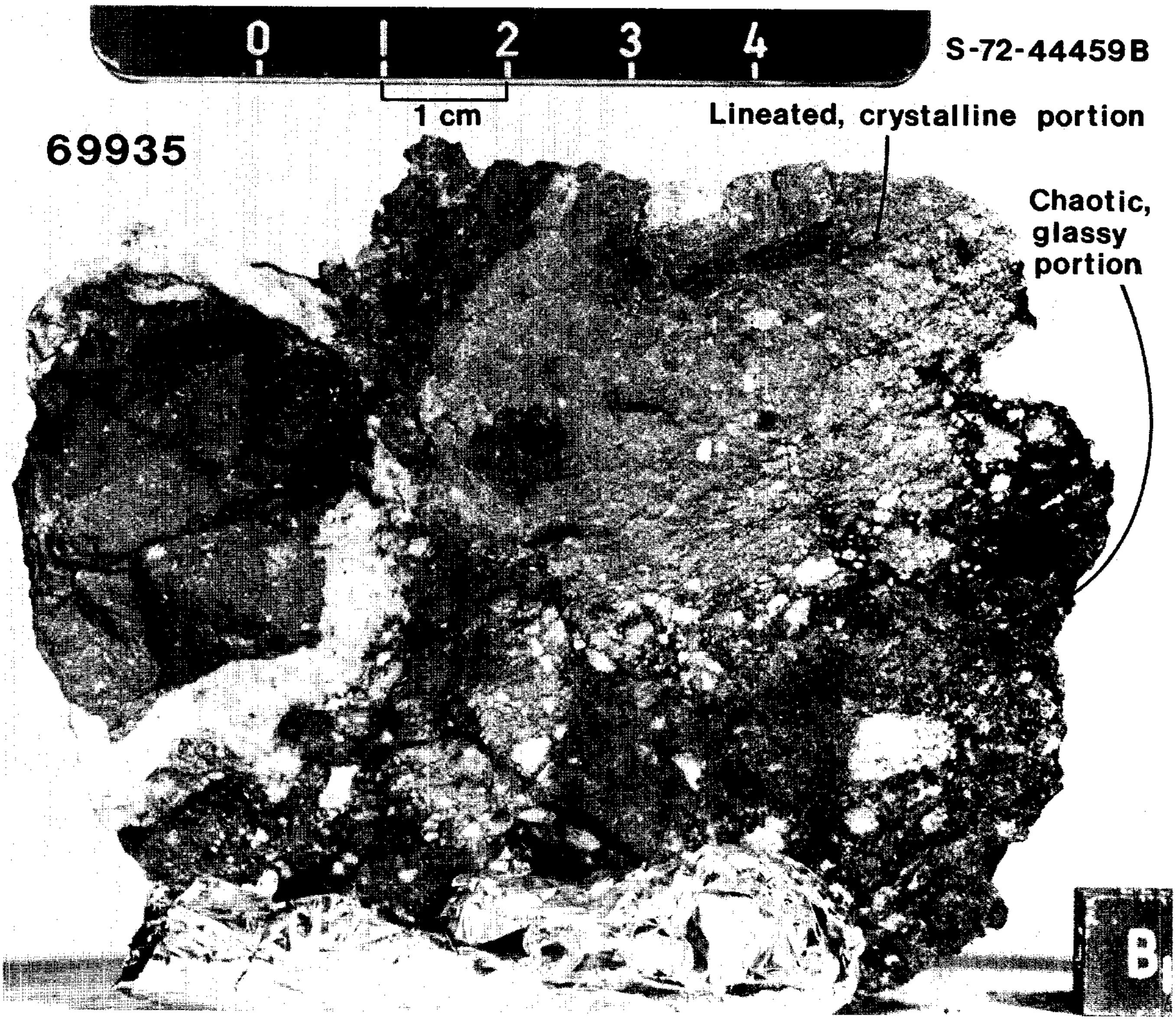


FIGURE 1.

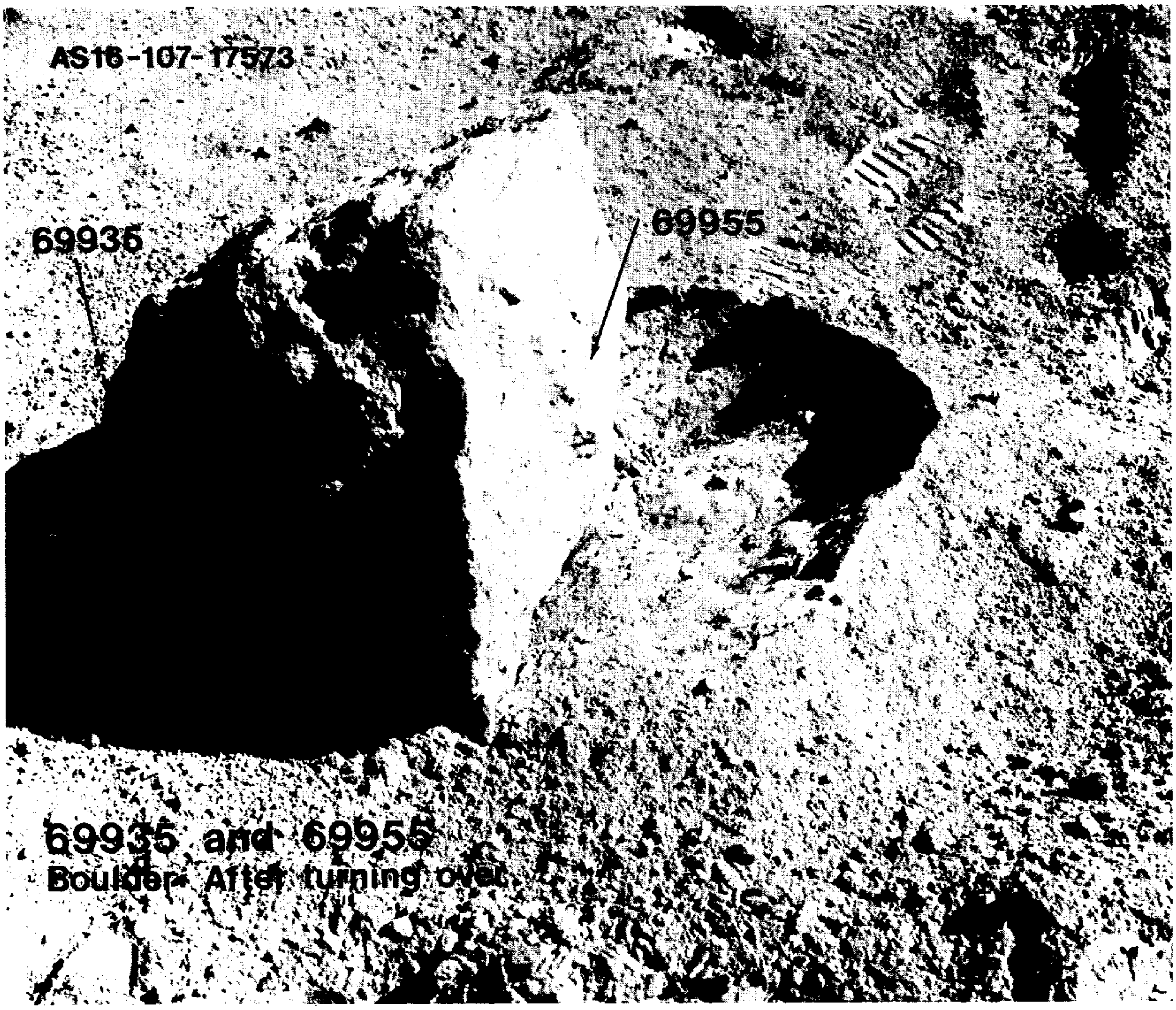


FIGURE 2.

PETROLOGY: 69935 is a clast-rich, dark gray breccia that is texturally inhomogeneous. Most of the rock is chaotic, glassy, and non-porous, with a diverse clast population (Fig. 3). Vesicles are apparent macroscopically (Fig. 1). This lithology probably represents the matrix of the boulder. Clasts of basaltic impact melt, glassy matrix breccia, lightly shocked plagioclase, rusty metal and glass beads and fragments are abundant. One large (8 mm) clast of cataclastic anorthosite is also present in one thin section (Fig. 3). Several brown glass veins cut this portion of the rock (Fig. 3).

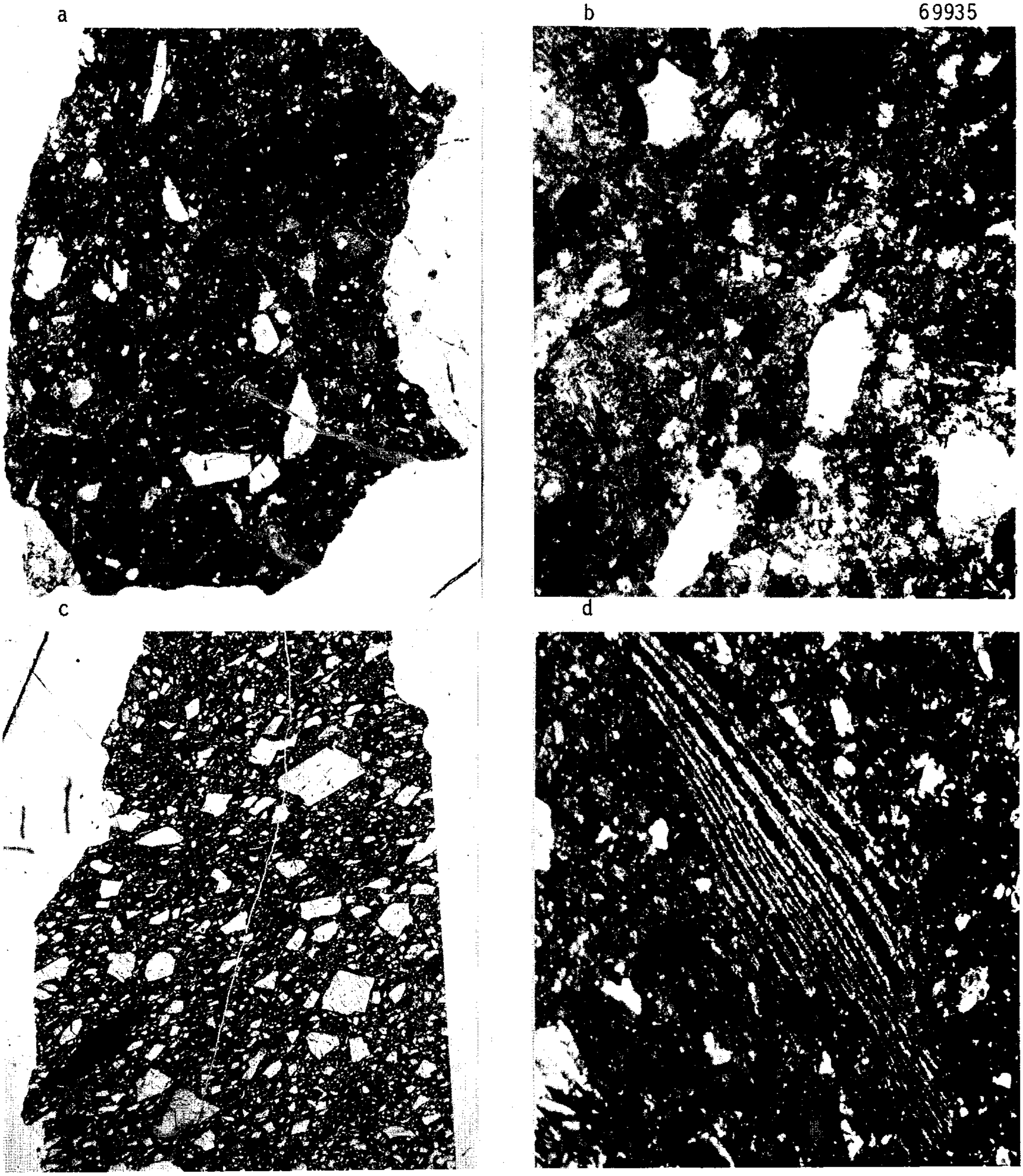


FIGURE 3. a) 69935,65. dark, glassy breccia, anorthosite clast to right, ppl. width about 1 cm.
b) 69935,64. dark, glassy breccia, ppl. width 2 mm.
c) 69935,60. fine-grained melt region, ppl. width about 1 cm.
d) 69935,60. barred olivine clast in basaltic melt portion, xpl. width 2 mm.

The light gray area of the rock (Fig. 1) has a lineated clast population in a fine-grained, probably melt, matrix (Fig. 3). This lithology is probably a large clast in the rock. Most of the lineated grains are angular fragments of heavily shocked plagioclase with rounded corners. Many of these grains are maskelynite. Mafic mineral clasts are very rare. Fe-metal, troilite and schreibersite are common; metal compositions are given in Figure 4 (Misra and Taylor, 1975). Rock fragments are virtually absent except for a few cataclastic anorthosites. One barred olivine fragment with interfingering feldspathic glass is also present (Fig. 3). The matrix of this lithology is non-porous and crystalline with blocky plagioclase grains surrounded by mafic minerals.

No thin sections of the large, white, anorthositic area (Fig. 1) have been made.

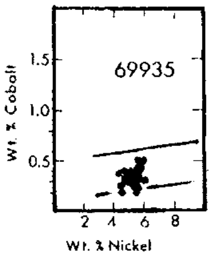


FIGURE 4. Metals in light gray area; from Misra and Taylor (1975).

EXPERIMENTAL PETROLOGY: L.A. Taylor et al. (1976) observed significant changes in metal composition following periods of subsolidus annealing (Fig. 5).

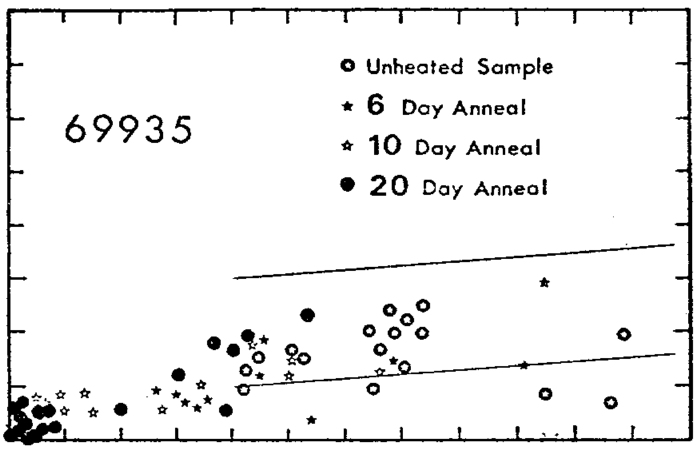


FIGURE 5; from L.A. Taylor et al. (1976).

CHEMISTRY: Major and trace element analyses of clast-rich fragments from the glassy portion of the rock are provided by Rose et al. (1973) and Laul and Schmitt (1973). Meteoritic siderophile and volatile elements from similar fragments are given by Ganapathy et al. (1974). Rancitelli et al. (1973a,b) report whole rock natural and cosmogenic radionuclide abundances.

The analyzed splits of 69935 are very aluminous (Table 1) and resemble some Station 11 rocks in this respect. Unlike most of these rocks, however, 69935 contains levels of REEs similar to the local mature soils (Table 1, Fig. 6). Siderophiles are also enriched in 69935 indicating a significant meteoritic component. Hertogen et al. (1977) assign the siderophiles in 69935 to meteoritic group 1H, a group largely restricted to Apollo 16.

TABLE 1.

Summary chemistry of 69935

SiO_2	44.7	Sr	125
TiO_2	0.29	La	11.2
Al_2O_3	30.0	Lu	0.52
Cr_2O_3	0.06	Rb	3.9
FeO	3.2	Sc	5.6
MnO	0.04	Ni	408
MgO	3.3	Co	19
CaO	17.6	Ir ppb	12.7
Na_2O	0.42	Au ppb	11.9
K_2O	0.08	C	
P_2O_5	0.15	N	
		S	
		Zn	0.88
		Cu	3.6

Oxides in wt%; others in ppm except as noted.

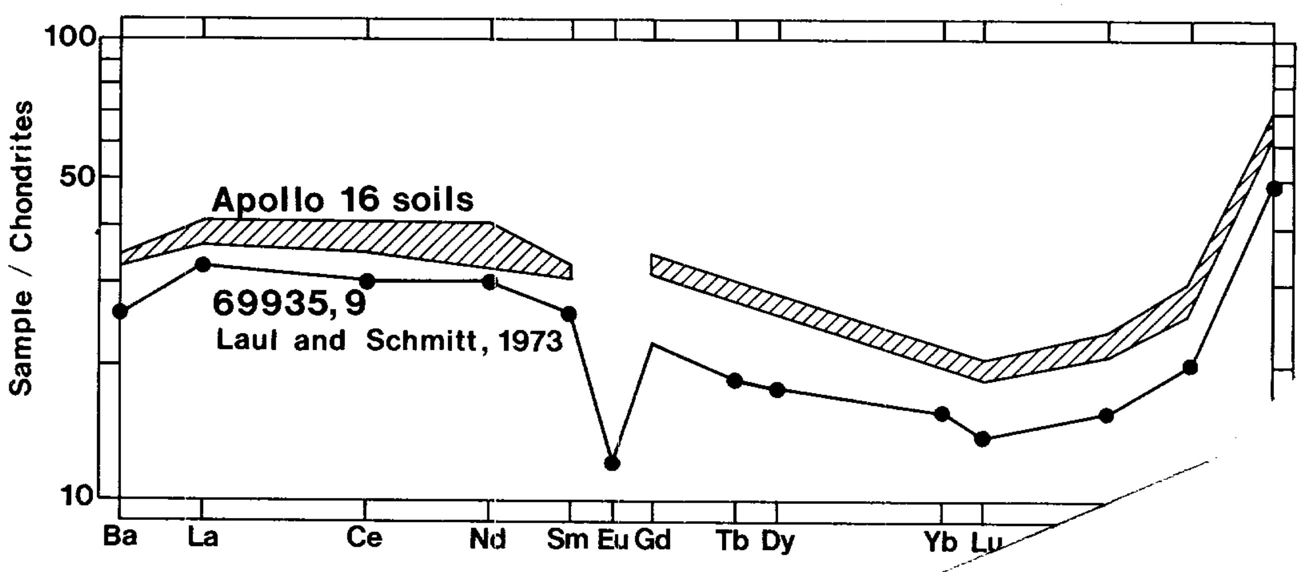


FIGURE 6. Rare earths.

RARE GASES/EXPOSURE AGES: Surface exposure ages by a variety of methods are consistently ∿2 m.y. (Table 2), indicating that the 69935/55 boulder was excavated by the South Ray Crater event.

From a "soft" component in the Kr spallation spectrum, Behrmann et al. (1973) and Drozd et al. (1974) conclude that the 69935/55 boulder must have experienced significant near-surface exposure prior to its emplacement in its present configuration. Behrmann et al. (1973) infer that the boulder was buried ∿ 1-5 m below the surface prior to excavation. Drozd et al. (1974) note significant differences between the apparent exposure ages of 69935 and 69955 and conclude that the boulder must have been inverted relative to its present position during its subsurface residence (see 69955).

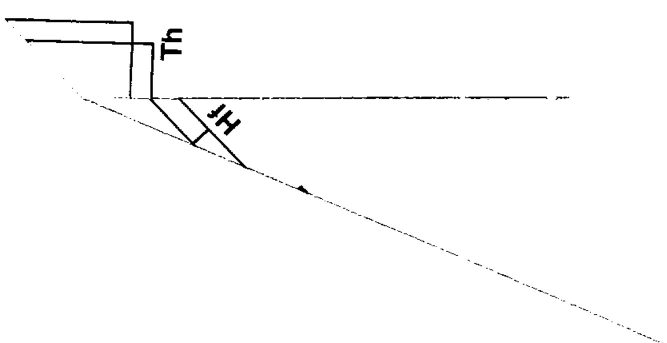
TABLE 2.

Surface exposure ages of 69935

Method	Age (m.y.)	Reference
^{81}Kr- ^{83}Kr	3.3±0.3	Behrmann et al. (1973)
^{81}Kr- ^{78}Kr	1.9±0.2	"
^{22}Na-^{21}Ne (direct)	2.0±0.3	"
^{22}Na-^{21}Ne (normalized)	2.2±0.3	"
^{81}Kr-^{78}Kr	1.99±0.16	Drozd et al. (1974)
^{21}Ne	1.40±0.33	"
^{38}Ar	4.0±1.7	"
Cosmic ray tracks	2.3	Yuhas (unpublished, referenced in Crozaz et al., 1974)

Whole rock ^{22}Na and ^{26}Al data are given by Rancitelli et al. (1973a). From these data Yokoyama et al. (1974) conclude that 69935 is saturated in ^{26}Al activity.

^{26}Al data and a cosmic ray track profile (Fig. 7) are provided by Bhandari (1977). Calculated exposure ages from these data (0.4±0.3 m.y. and 0.5 m.y., respectively)
? m.y. exposure ages discussed above. Bhandari
ographs show a large crack in the 69935/55
a face of 69935 exposed along this crack.
in a fragmentation event ∿ 0.5 m.y. ago.



ic ray track profile;
77).

MICROCRATERS: Size-frequency distribution data (Fig. 8) are given by Morrison et al. (1973), Neukum et al. (1973) and Fechtig et al. (1974). Nagel et al. (1975) report diameter/depth ratios (Fig. 9). An exposure age of 2.8 m.y. based on an empirically calibrated constant flux is calculated by Morrison et al. (1973).

FIGURE 8. Microcraters; from Morrison et al.(1973).

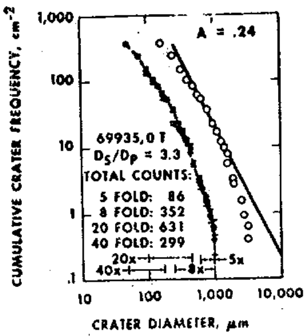
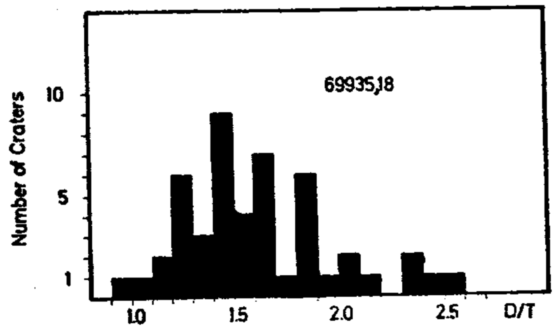


FIGURE 9. Microcraters; from Nagel et al.(1975).



PROCESSING AND SUBDIVISIONS: In 1972, 69935 was slabbed and several other pieces removed by sawing and chipping. Thin sections that sample the lineated and the glassy lithologies were made from ,19 (sections ,59-,63) and ,25 (sections ,64-,67), respectively (Fig. 10). Many chips remain in stock at JSC; the largest single piece is ,1 (66.12 g) which contains all major lithologies in the rock. ,3 (15.55 g, split from ,2 in Fig. 10) is stored at the Brooks Remote Storage Vault and is largely the lineated lithology.

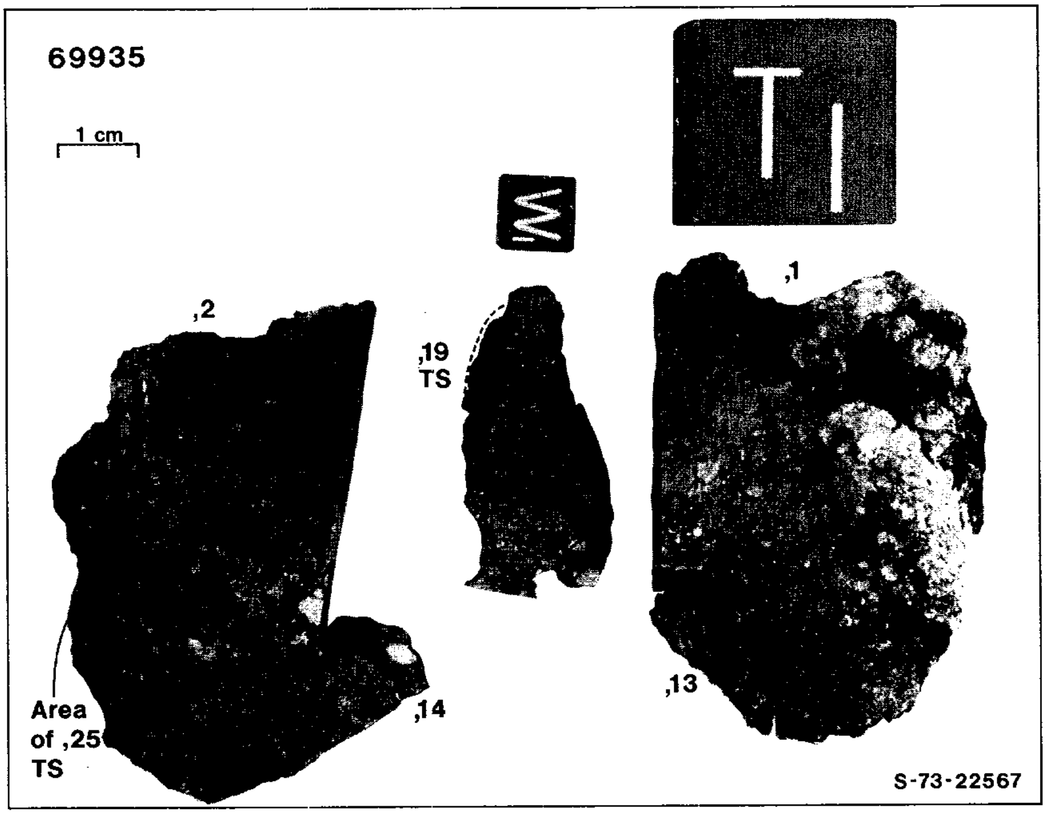


FIGURE 10.

INTRODUCTION: 69945 is a coherent, medium gray, poikilitic impact melt (Fig. 1). This rock was taken from a soil sample from near the 69935/55 boulder. A few zap pits and a small amount of splash glass are present on the S surface. A patch of white material (adhering soil?) coats a portion of the W surface.

PETROLOGY: 69945 is a fine-grained, poikilitic impact melt (Fig. 2). Plagioclase clasts are common; one clast of basaltic impact melt was also observed. Oikocrysts are generally <0.2 mm and tend to be necklaced by ilmenite laths. Subophitic patches in interoikocryst regions are scattered throughout the rock.

PROCESSING AND SUBDIVISIONS: In 1973, 69945 was sawn and the W end piece subdivided for allocations.

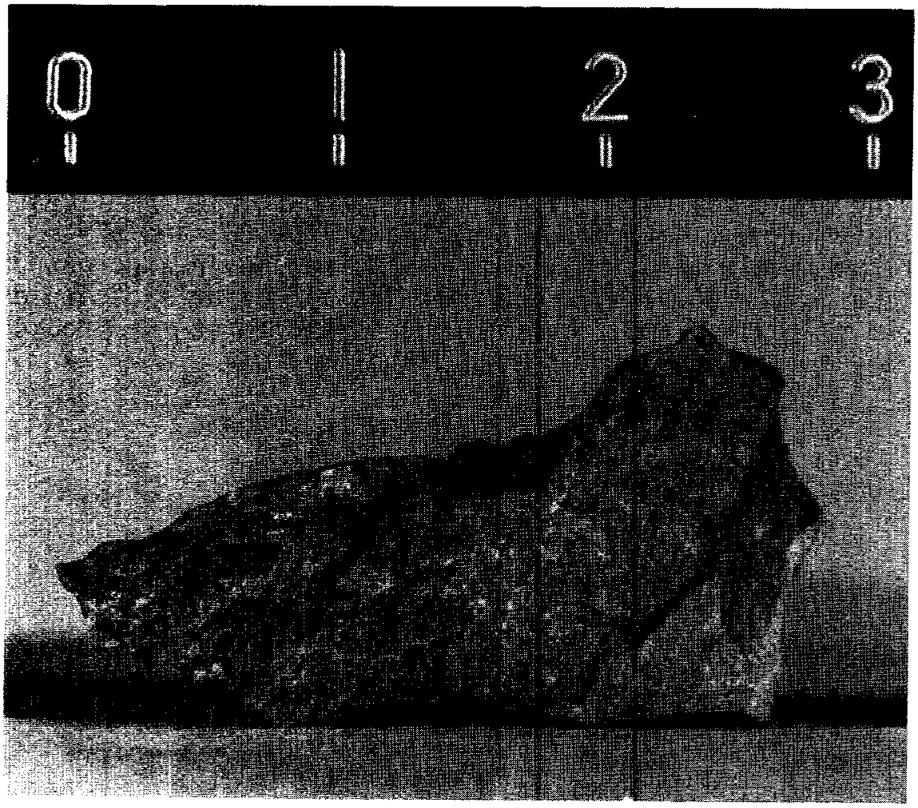


FIGURE 1. Scale in cm. S-72-40137.

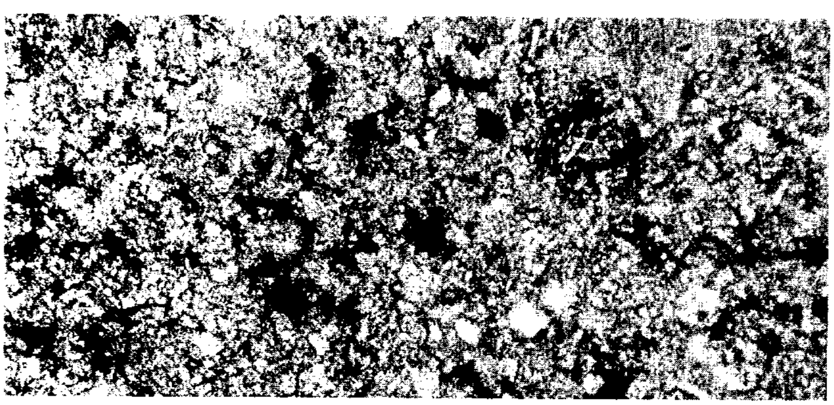


FIGURE 2. 69945,11. general view, ppl. width 1.5mm.

INTRODUCTION: 69955 is a cataclastic anorthosite that has been heavily shocked (Fig. 1). Much of the plagioclase is translucent and appears glassy. At least a portion of the rock is probably chemically pristine.

69955 was collected from the bottom side of the same boulder that yielded 69935 (see 69935, Fig. 2) on the lower slope of Stone Mountain. Its lunar orientation is unknown, and zap pits are absent from all surfaces.

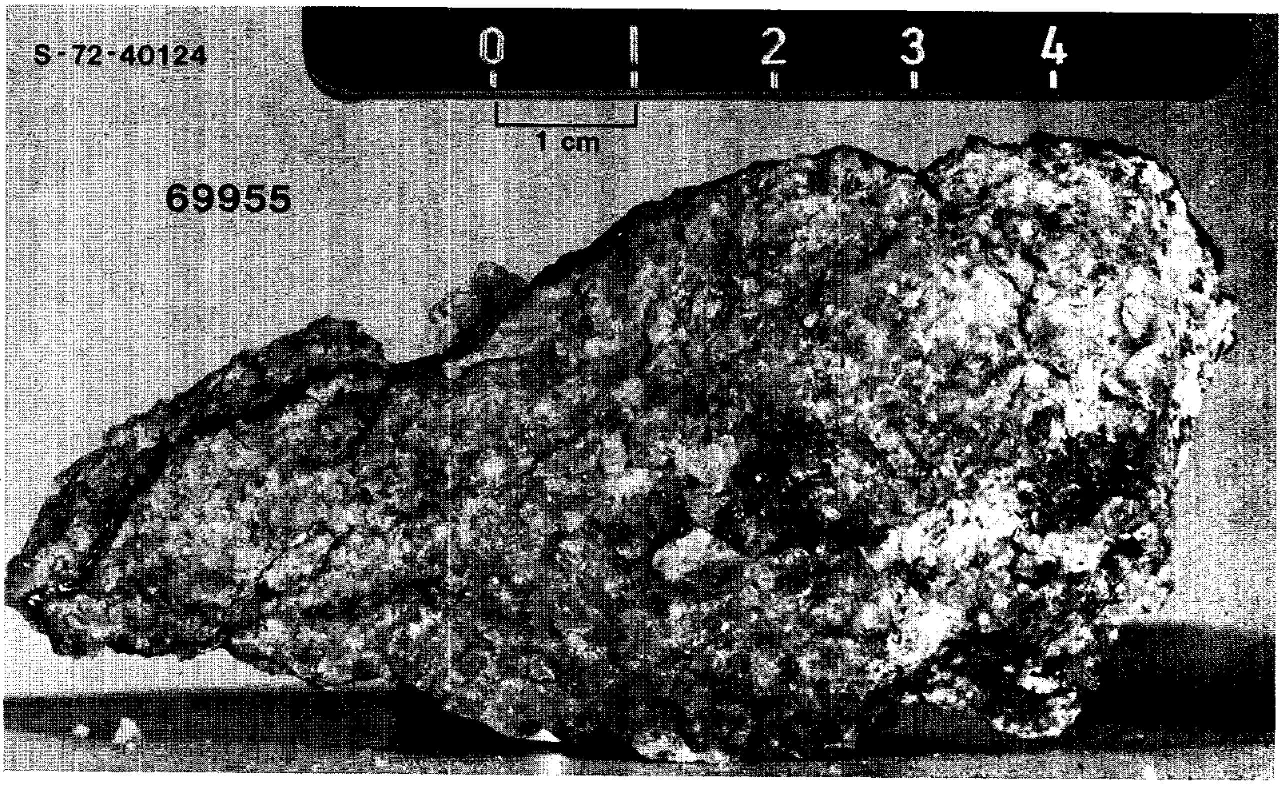


FIGURE 1.

PETROLOGY: 69955 is a nearly monomict, cataclastic anorthosite veined by a small amount of dark, vesicular glass (Fig. 2). The anorthosite has been extensively recrystallized and some maskelynite is present. Mafic minerals are rare and occur as interstitial grains and as inclusions within plagioclase. The plagioclases are up to ∿5 mm across. Meyer (1979) reports ion probe analyses of minor elements in plagioclase (Table 1), and Misra and Taylor (1975) provide compositional data for metal grains in a dark glass vein (Fig. 3).

a b

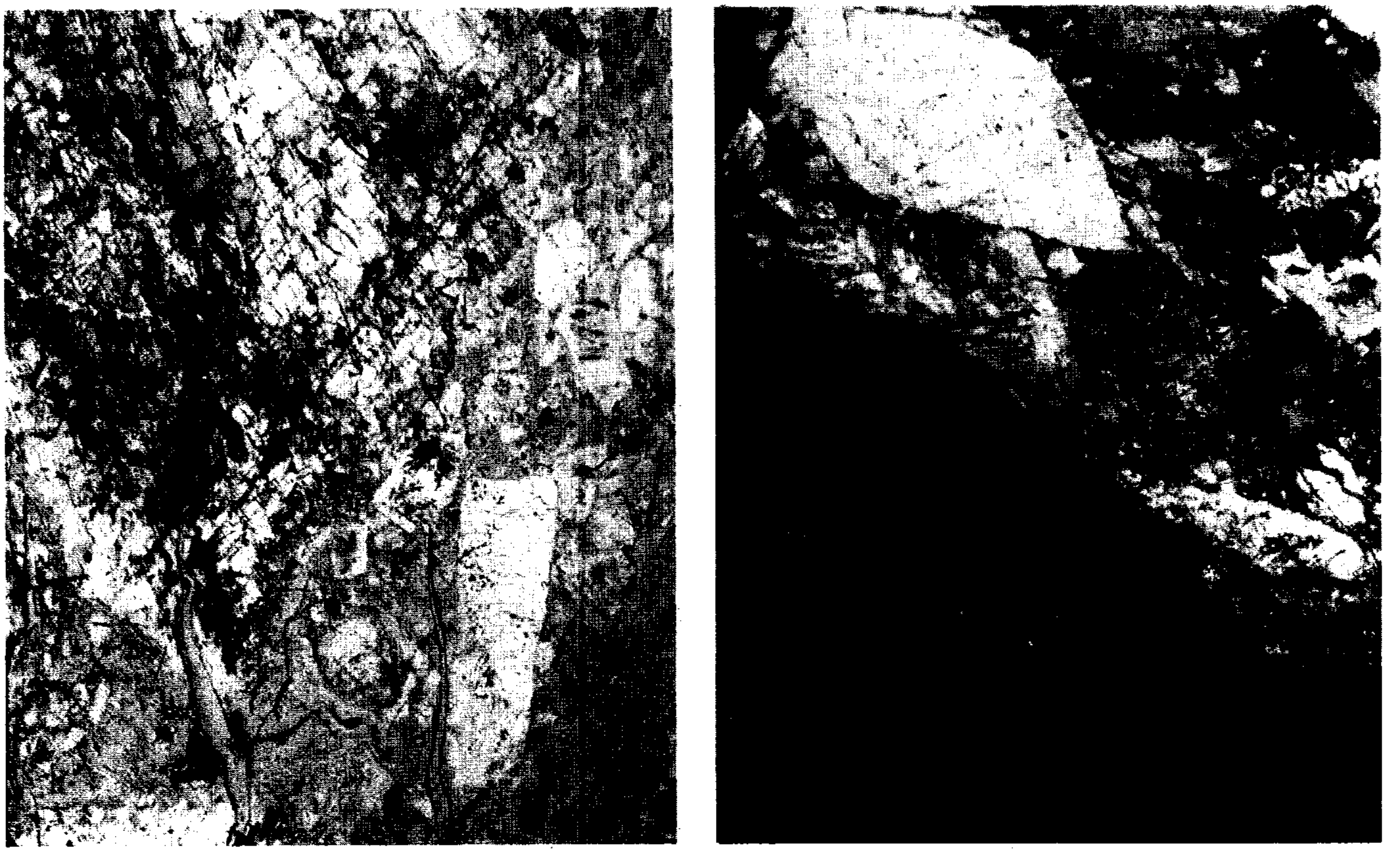


FIGURE 2. a) 69955,27. cataclastic anorthosite, partly xpl. width 2mm.
b) 69955,28. cataclastic anorthosite and glass coat, partly xpl. width 2mm.

TABLE 1.

Minor elements in 69955 plagioclase (ppm)

	Li	Mg	Ti	Sr	Ba
a)	1.0	750			12
b)	1.7	781	200	275	14

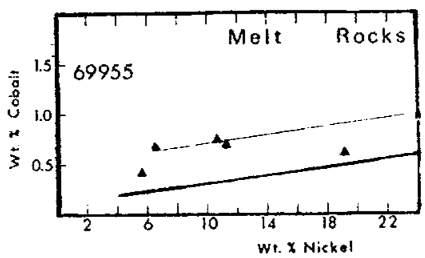


FIGURE 3. Metals; from Misra and Taylor (1975).

CHEMISTRY: Major and trace element analyses of the anorthosite are provided by Rose et al. (1973) and Laul and Schmitt (1973). Krähenbühl et al. (1973) give meteoritic siderophile and volatile element abundances, and Rancitelli et al. (1973a,b) report whole rock abundances of natural and cosmogenic radionuclides.

The bulk analyses (Table 2) indicate that 69955 is a ferroan anorthosite with low levels of incompatible elements (Fig. 4). Some portions of the rock are probably meteorite-free as indicated by the low Co and REE contents of one split (Laul and Schmitt, 1973). The entire anorthosite is not chemically pristine, however, as data by Rose et al. (1973) and Krähenbühl et al. (1973) show a detectable amount of meteoritic siderophiles. Hertogen et al. (1977) assign the siderophiles in 69955 to meteoritic group 1L which they interpret to represent Imbrium ejecta.

TABLE 2. Summary chemistry of 69955

SiO_2	44.1	Sr	135
TiO_2	0.01	La	0.27
Al_2O_3	35.3	Lu	0.01
Cr_2O_3	0.005	Rb	0.4
FeO	0.42	Sc	0.8
MnO	0.01	Ni	9.8-43
MgO	0.23	Co	0.8
CaO	19.1	Ir ppb	0.289
Na_2O	0.41	Au ppb	0.307
K_2O	~0.01	C	
P_2O_5	0.01	N	
		S	
		Zn	0.37
		Cu	1.1

Oxides in wt%; others in ppm expect as noted.

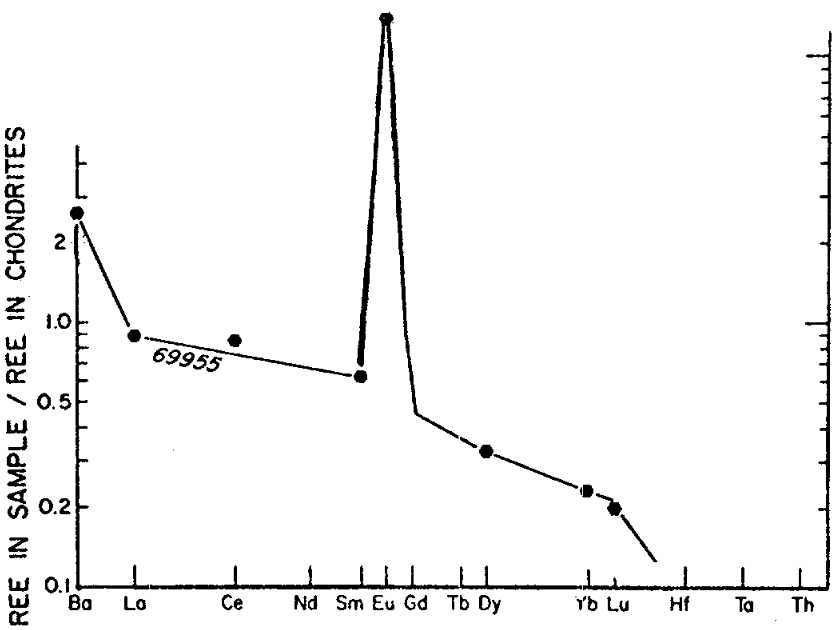


FIGURE 4. Rare earths; from Laul and Schmitt (1973).

RARE GASES/EXPOSURE AGES: Drozd et al. (1974) report Kr isotopic data and exposure ages of 4.23±0.21 m.y. (^{81}Kr-Kr) and 2.13±0.51 m.y. (^{21}Ne). These authors note that although both 69935 and 69955 came from the same boulder, their Kr exposure ages vary by a factor of 2. This is taken as further evidence for the complex exposure history of the boulder (see 69935). From the apparent differences in shielding between 69935 and 69955, Drozd et al. (1974) conclude that the 69935/55 boulder was buried in the lunar regolith for ∿1-6 m.y. until it was excavated and inverted by the South Ray Crater event (Fig. 5), where it has remained in its present configuration since.

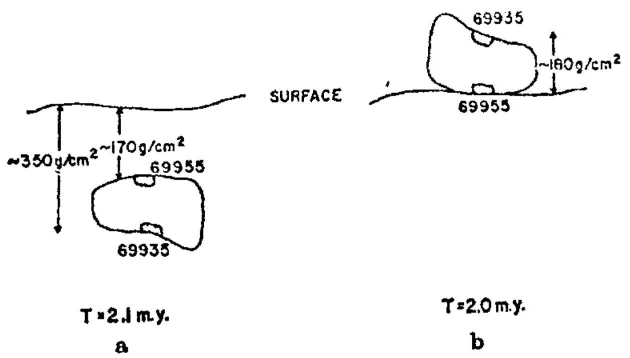


FIGURE 5. Schematic exposure history; from Drozd et al. (1974).

Pepin et al. (1974) discuss the results of Drozd et al. (1974) and calculate a subsurface residence time of 2.1 m.y. using an empirically derived spallation Ne production rate profile.

^{22}Na and ^{26}Al data are given for the whole rock by Rancitelli et al. (1973a). From these data Yokoyama et al. (1974) conclude that 69955 is saturated in ^{26}Al activity. Fruchter et al. (1978) provide ^{26}Al and ^{53}Mn data for a surface chip. These data also indicate saturation in ^{26}Al and yield exposure ages of >3 m.y. (^{26}Al) and 5±1 m.y. (^{53}Mn).

TRACKS: Yuhas (pers. comm., quoted in Drozd et al., 1974) finds no solar flare tracks in 69955, indicating that it has received no direct exposure to the sun since its latest excavation.

PROCESSING AND SUBDIVISIONS: In 1973, 69955 was extensively subdivided by chipping (Fig. 6). Thin sections were cut from ,9. The largest single piece remaining is ,17 (46.40 g) at JSC.

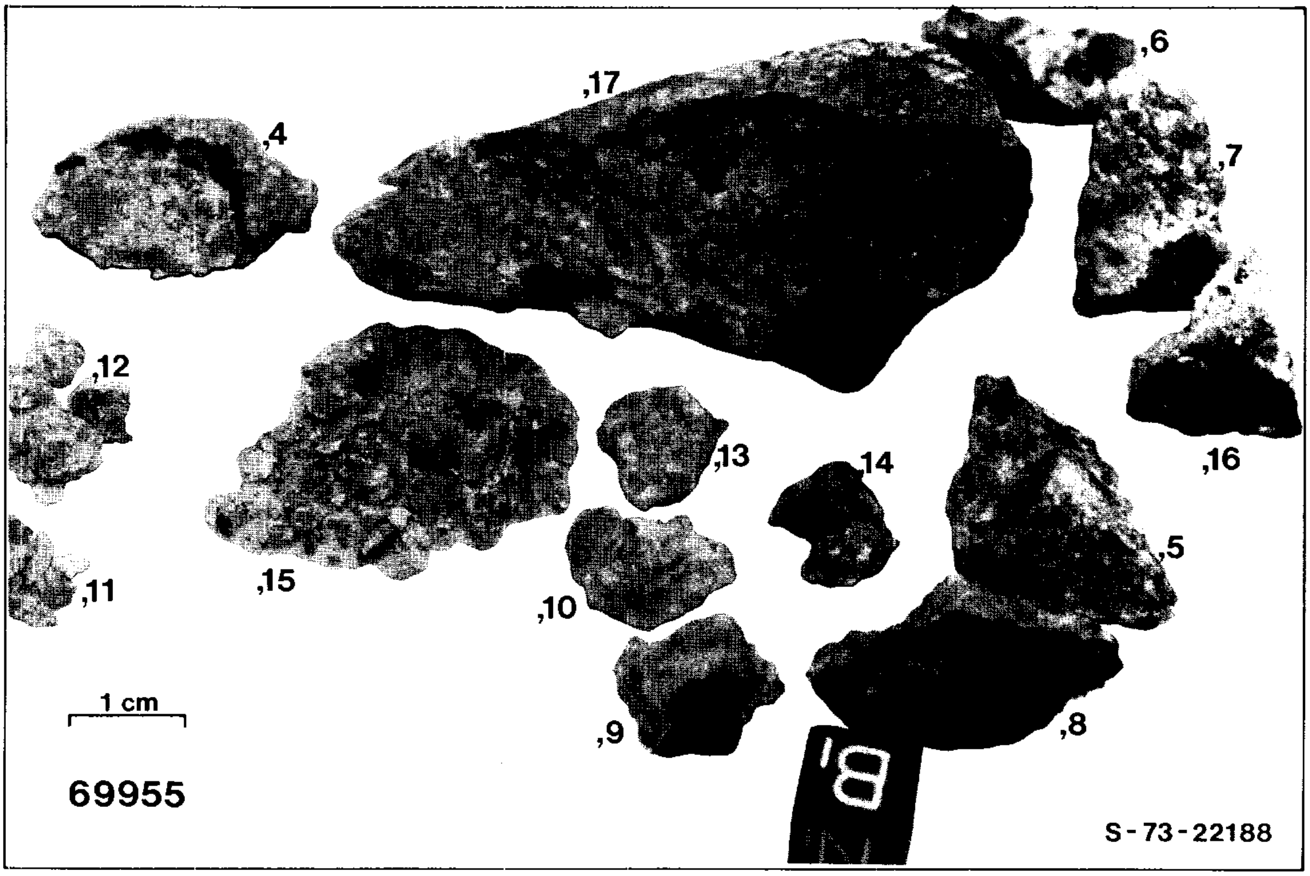


FIGURE 6.

69965 FRAGMENTAL POLYMICT BRECCIA, GLASS VEINED, PARTLY GLASS-COATED 1.12 g

INTRODUCTION: 69965 is a friable, medium gray, clastic breccia veined and partially coated by dark glass (Fig. 1). It was separated from the soil sample taken from beneath the 69935/55 boulder. Zap pits are absent.

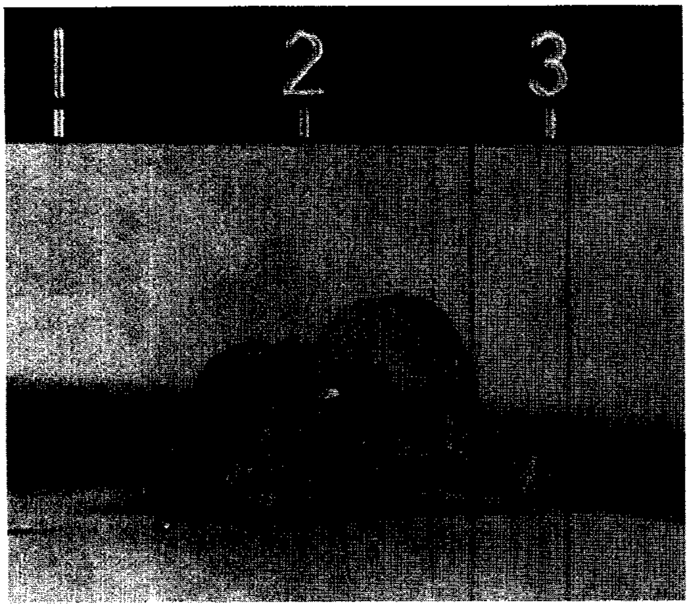


FIGURE 1. Scale in cm. S-72-40521.

REFERENCES

Abu-Eid R.M., Vaughan D.J., Witner M., Burns R.G. and Morawski A. (1973) Spectral data bearing on the oxidation states of Fe, Ti and Cr in Apollo 15 and Apollo 16 samples. In Lunar Science IV, p. 1-3. The Lunar Science Institute, Houston.

Adams J.B. and McCord T.B. (1973) Vitrification darkening in the lunar highlands and identification of Descartes material at the Apollo 16 site. Proc. Lunar Sci. Conf. 4th, p. 163-177.

Agrell S.O., Agrell J.E., Arnold A.R. and Long J.V.P. (1973) Some observations on rock 62295. In Lunar Science IV, p. 15-17. The Lunar Science Institute, Houston.

Albee A.L., Gancarz A.J. and Chodos A.A. (1973) Metamorphism of Apollo 16 and 17 and Luna 20 metaclastic rocks at about 3.95 AE: Samples 61156, 64423,14-2, 65015, 67483,15-2, 76055, 22006, and 22007. Proc. Lunar Sci. Conf. 4th, p. 569-595.

Alexander E.C., Jr. and Kahl S.B. (1974) ^{40}Ar-^{39}Ar studies of lunar breccias. Proc. Lunar Sci. Conf. 5th, p. 1353-1373.

Allen R.O., Jr., Jovanovic S. and Reed G.W., Jr. (1974) A study of ^{204}Pb partition in lunar samples using terrestrial and meteoritic analogs. Proc. Lunar Sci. Conf. 5th, p. 1617-1623.

Allen R.O., Jr., Jovanovic S. and Reed G.W., Jr. (1975) Agglutinates: role in element and isotope chemistry and inferences regarding volatile-rich rock 66095 and glass 74220. Proc. Lunar Sci. Conf. 6th, p. 2271-2279.

Alvarez R. (1977) Photoconductive effects on lunar and terrestrial fines. Proc. Lunar Sci. Conf. 8th, p. 1277-1290.

Andersen C.A. and Hinthorne J.R. (1973) ^{207}Pb-^{206}Pb ages and REE abundances in returned lunar material by ion microprobe mass analysis. In Lunar Science IV, p. 37-39. The Lunar Science Institute, Houston.

Apollo 16 Lunar Sample Information Catalog (1972) NASA publication MSC03210, Manned Spacecraft Center, Houston. 372 pp.

Ashwal L.D. (1975) Petrologic evidence for a plutonic igneous origin of anorthositic clasts in 67955 and 77017. Proc. Lunar Sci. Conf. 6th, p. 221-230.

Baedecker P.A., Chou C.-L., Sundberg L.L. and Wasson J.T. (1974a) Volatile and siderophilic trace elements in the soils and rocks of Taurus-Littrow. Proc. Lunar Sci. Conf. 5th, p. 1625-1643.

Baedecker P.A., Chou C.-L., Grudewicz E.B., Sundberg L.L. and Wasson J.T. (1974b) Extralunar materials in lunar soils and rocks. In Lunar Science V, p. 28-30. The Lunar Science Institute, Houston.

Bansal B.M., Church S.E., Gast P.W., Hubbard N.J., Rhodes J.M. and Wiesmann H. (1972) The chemical composition of soil from the Apollo 16 and Luna 20 sites. Earth Planet. Sci. Lett. 17, p. 29-35.

Barnes I.L., Garner E.L., Gramlich J.W., Machlan L.A., Moody J.R., Moore L.J., Murphy T.J. and Shields W.R. (1973) Isotopic abundance ratios and concentrations of selected elements in some Apollo 15 and Apollo 16 samples. Proc. Lunar Sci. Conf. 4th, p. 1197-1207.

Becker R.H., Clayton R.N. and Mayeda T.K. (1976) Characterization of lunar nitrogen components. Proc. Lunar Sci. Conf. 7th, p. 441-458.

Behrmann C., Crozaz G., Drozd R., Hohenberg C., Ralston C., Walker R. and Yuhas D. (1973) Cosmic-ray exposure history of North Ray and South Ray material. Proc. Lunar Sci. Conf. 4th, p. 1957-1974.

Bell P.M. and Mao H.K. (1973) An analytical study of iron in plagioclase from Apollo 16 soils 64501, 64502, 64802, rock 66095, and Apollo 15 rock 15475. In Lunar Science IV, p. 57-59. The Lunar Science Institute, Houston.

Bell P.M. and Mao H.K. (1975) Cataclastic plutonites: possible keys to the evolutionary history of the early moon. In Lunar Science VI, p. 34-35. The Lunar Science Institute, Houston.

Bence A.E., Papike J.J., Sueno S. and Delano J.W. (1973) Pyroxene poikilo-blastic rocks from the lunar highlands. Proc. Lunar Sci. Conf. 4th, p. 597-611.

Bernatowicz T.J., Hohenberg C.M., Hudson B., Kennedy B.M. and Podesek F.A. (1978) Excess fission xenon at Apollo 16. Proc. Lunar Planet. Sci. Conf. 9th, p. 1571-1597.

Bhandari N. (1977) Solar flare exposure ages of lunar rocks and boulders based on ^{26}Al. Proc. Lunar Sci. Conf. 8th, p. 3607-3615.

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

Bhandari N., Bhattacharya S.K. and Padia J.T. (1975) The surface radioactivity of lunar rocks: implications to solar activity in the past. Proc. Lunar Sci. Conf. 6th, p. 1913-1925.

Bhandari N., Bhattacharya S.K. and Padia J.T. (1976) Solar proton fluxes during the last million years. Proc. Lunar Sci. Conf. 7th, p. 513-523.

Bhattacharya S.K. and Bhandari N. (1975) Effects of exposure conditions on cosmic-ray records in lunar rocks. Proc. Lunar Sci. Conf. 6th, p. 1901-1912.

Bickel C.E. and Warner J.L. (1978) Survey of lunar plutonic and granulitic lithic fragments. Proc. Lunar Planet. Sci. Conf. 9th, p. 629-652.

Blanford G.E., Fruland R.M., McKay D.S. and Morrison D.A. (1974) Lunar surface phenomena: Solar flare track gradients, microcraters and accretionary particles. Proc. Lunar Sci. Conf. 5th, p. 2501-2526.

Blanford G.E., Fruland R.M. and Morrison D.A. (1975) Long-term differential energy spectrum for solar-flare iron-group particles. Proc. Lunar Sci. Conf. 6th, p. 3557-3576.

Bogard D.D., Nyquist L.E., Hirsch W.C. and Moore D.R. (1973) Trapped solar and cosmogenic noble gas abundances in Apollo 15 and 16 deep drill samples. Earth Planet. Sci. Lett. 21, p. 52-69.

Bogard D.D. and Gibson E.K., Jr. (1975) Volatile gases in breccia 68115. In Lunar Science VI, p. 63-65. The Lunar Science Institute, Houston.

Boynton W.V., Baedecker P.A., Chou C.-L., Robinson K.L. and Wasson J.T. (1975) Mixing and transport of lunar surface materials: Evidence obtained by the determination of lithophile, siderophile, and volatile elements. Proc. Lunar Sci. Conf. 6th, p. 2241-2259.

Boynton W.V., Chou C.-L., Robinson K.L., Warren P.H. and Wasson J.T. (1976) Lithophiles, siderophiles, and volatiles in Apollo 16 soils and rocks. Proc. Lunar Sci. Conf. 7th, p. 727-742.

Brecher A. (1975) Textural remanence: a new model of lunar rock magnetism. In Lunar Science VI, p. 83-85. The Lunar Science Institute, Houston.

Brecher A. (1977) Interrelationships between magnetization directions, magnetic fabric and oriented petrographic features in lunar rocks. Proc. Lunar Sci. Conf. 8th, p. 703-723.

Brecher A., Vaughan D.J., Burns R.G. and Morash K.R. (1973) Magnetic and mossbaur studies of Apollo 16 rock chips 60315,51 and 62295,27. Proc. Lunar Sci. Conf. 4th, p. 2991-3001.

Brown G.M., Peckett A., Phillips R. and Emeleus C.H. (1973) Mineral-chemical variations in the Apollo 16 magnesio-feldspathic highland rocks. Proc. Lunar Sci. Conf. 4th, p. 505-518.

Brownlee D.E., Hörz F., Vedder J.F., Gault D.E. and Hartung J.B. (1973) Some physical properties of micrometeoroids. Proc. Lunar Sci. Conf. 4th, p. 3197-3212.

Brownlee D.E., Hörz F., Hartung J.B. and Gault D.E. (1975) Density, chemistry, and size distribution of interplanetary dust. Proc. Lunar Sci. Conf. 6th, p. 3409-3416.

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.

Cadenhead D.A. and Brown M.G. (1976) The surface and composition of 60017,43. Proc. Lunar Sci. Conf. 7th, p. 927-936.

Carey W.C. and McDonnell J.A.M. (1976) Lunar surface sputter erosion: a Monte Carlo approach to microcrater erosion and sputter redeposition. Proc. Lunar Sci. Conf. 7th, p. 913-926.

Charette M.P. and Adams J.B. (1977) Spectral reflectance of lunar highland rocks. In Lunar Science VIII, p. 172-174. The Lunar Science Institute, Houston.

Chou C.-L. and Pearce G.W. (1976) Relationship between nickel and metallic iron contents of Apollo 16 and 17 soils. Proc. Lunar Sci. Conf. 7th, p. 779-789.

Christian R.P., Berman S., Dwornik E.J., Rose H.J., Jr., and Schnepfe M.M. (1976) Composition of some Apollo 14, 15, and 16 lunar breccias and two Apollo 15 fines. In Lunar Science VII, p. 138-140. The Lunar Science Institute, Houston.

Chung D.H. (1973) Elastic wave velocities in anorthosite and anorthositic gabbros from Apollo 15 and 16 landing sites. Proc. Lunar Sci. Conf. 4th, p. 2591-2600.

Chung D.H. and Westphal W.B. (1973) Dielectric spectra of Apollo 15 and 16 lunar solid samples. Proc. Lunar Sci. Conf. 4th, p. 3077-3091.

Cirlin E.H. and Housley R.M. (1980) Lunar metamorphism and its effects on the distribution of volatiles. Proc. Lunar Planet. Sci. Conf. 11th, in press.

Cisowski C.S., Dunn J.R., Fuller M., Rose M.F. and Wasilewski P.J. (1974) Impact processes and lunar magnetism. Proc. Lunar Sci. Conf. 5th, p. 2841-2858.

Cisowski S.M., Fuller M.D., Wu Y.-M., Rose M.F. and Wasilewski P.J. (1975) Magnetic effects of shock and their implications for magnetism of lunar samples. Proc. Lunar Sci. Conf. 6th, p. 3123-3141.

Cisowski S.M., Dunn J.R., Fuller M., Wu Y.-M., Rose M.F. and Wasilewski P.J. (1976) Magnetic effects of shock and their implications for lunar magnetism (II). Proc. Lunar Sci. Conf. 7th, p. 3299-3320.

Cisowski S.M., Hale C. and Fuller M. (1977) On the intensity of ancient lunar fields. Proc. Lunar Sci. Conf. 8th, p. 725-750.

Clark R.S. and Keith J.E. (1973) Determination of natural and cosmic ray induced radionuclides in Apollo 16 lunar samples. Proc. Lunar Sci. Conf. 4th, p. 2105-2113.

Clayton R.N., Hurd J.M. and Mayeda T.K. (1973) Oxygen isotopic compositions of Apollo 15, 16, and 17 samples, and their bearing on lunar origin and petrogenesis. Proc. Lunar Sci. Conf. 4th, p. 1535-1542.

Clayton R.N. and Mayeda T.K. (1975) Genetic relations between the moon and meteorites. Proc. Lunar Sci. Conf. 6th, p. 1761-1769.

Collinson D.W., Stephenson A. and Runcorn S.K. (1973) Magnetic properties of Apollo 15 and 16 rocks. Proc. Lunar Sci. Conf. 4th, p. 2963-2976.

Compston W., Foster J.J. and Gray C.M. (1977) Rb-Sr systematics in clasts and aphanites from consortium breccia 73215. Proc. Lunar Sci. Conf. 8th, p. 2525-2549.

Crawford M.L. and Hollister L.S. (1974) KREEP basalt: a possible partial melt from the lunar interior. Proc. Lunar Sci. Conf. 5th, p. 399-419.

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.

Cripe J.D. and Moore C.B. (1975) Total sulfur contents of Apollo 15, 16, and 17 samples. In Lunar Science VI, p. 167-168. The Lunar Science Institute, Houston.

Crozaz G., Drozd R., Hohenberg C., Morgan C., Ralston C., Walker R. and Yuhas D. (1974) Lunar surface dynamics: Some general conclusions and new results from Apollo 16 and 17. Proc. Lunar Sci. Conf. 5th, p. 2475-2499.

Delano J.W. (1975) Petrology of the Apollo 16 mare component: Mare Nectaris. Proc. Lunar Sci. Conf. 6th, p. 15-47.

Delano J.W. (1977) Experimental melting relations of 63545, 76015, and 76055. Proc. Lunar Sci. Conf. 8th, p. 2097-2123.

Des Marais D.J. (1978) Carbon, nitrogen and sulfur in Apollo 15, 16, and 17 rocks. Proc. Lunar Planet. Sci. Conf. 9th, p. 2451-2467.

Dixon J.R. and Papike J.J. (1975) Petrology of anorthosites from the Descartes Region of the moon: Apollo 16. Proc. Lunar Sci. Conf. 6th, p. 263-291.

Dixon J.R. and Papike J.J. (1978) Petrologic history of Apollo 16 breccia 68815. In Lunar and Planetary Science IX, p. 253-255. The Lunar and Planetary Institute, Houston.

Dollfus A. and Geake J.E. (1975) Polarimetric properties of the lunar surface and its interpretation: Part 7-Other solar system objects. Proc. Lunar Sci. Conf. 6th, p. 2749-2768.

Dominik B. and Jessberger E.K. (1978) Early lunar differentiation: 4.42-AE-old plagioclase clasts in Apollo 16 breccia 67435. Earth Planet. Sci. Lett. 38, p. 407-415.

Dowty E., Prinz M. and Keil K. (1974a) Ferroan anorthosite: A widespread and distinctive lunar rock type. Earth Planet. Sci. Lett. 24, p. 15-25.

Dowty E., Keil K. and Prinz M. (1974b) Igneous rocks from Apollo 16 rake samples. Proc. Lunar Sci. Conf. 5th, p. 431-445.

Dowty E., Green J.A., Hlava P.F., Keil K., Moore R.B., Nehru C.E., Prinz M. and Warner R.D. (1976) Electron microprobe analyses of minerals from Apollo 16 rake samples. Special publication no. 14, UNM Institute of Meteoritics, 141 pp.

Drake J.C. (1974) Mineralogy and chemistry of 61016,215. In Lunar Science V, p. 177-179. The Lunar Science Institute, Houston.

Drozd R.J. (1974) Krypton and xenon in lunar and terrestrial samples. Ph.D. dissertation, Washington University, St. Louis, Missouri.

Drozd R.J., Hohenberg C.M., Morgan C.J. and Ralston C.E. (1974) Cosmic-ray exposure at the Apollo 16 and other lunar sites: lunar surface dynamics. Geochim. Cosmochim. Acta 38, p. 1625-1642.

Drozd R.J., Hohenberg C.M., Morgan C.J., Podosek F.A. and Wroge M.L. (1977) Cosmic-ray exposure history at Taurus-Littrow. Proc. Lunar Sci. Conf. 8th, p. 3027-3043.

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.

Dust S. and Crozaz G. (1977) 68815 revisited. Proc. Lunar Sci. Conf. 8th, p. 2315-2319.

Dyal P., Parkin C.W., Colburn D.S. and Schubert G. (1972) Lunar surface magnetometer experiment. In Apollo 16 Preliminary Science Report, NASA publication SP-315, p. 11-1 - 11-13.

Dymek R.F., Albee A.L. and Chodos A.A. (1975) Comparative petrology of lunar cumulate rocks of possible primary origin: dunite 72415, troctolite 76535, norite 78235, and anorthosite 62237. Proc. Lunar Sci. Conf. 6th, p. 301-341.

Eberhardt P., Eugster O., Geiss J., Graf H., Grögler N., Mörgeli M. and Stettler A. (1975) Kr^{81}-Kr exposure ages of some Apollo 14, Apollo 16 and Apollo 17 rocks. In Lunar Science VI, p. 233-235. The Lunar Science Institute, Houston.

Ehmann W.D. and Chyi L.L. (1974) Abundances of the group IVB elements, Ti, Zr and Hf and implications of their ratios in lunar materials. Proc. Lunar Sci. Conf. 5th, p. 1015-1024.

Ehmann W.D., Chyi L.L., Garg A.N., Hawke B.R., Ma M.-S., Miller M.D., James W.D., Jr. and Pacer R.A. (1975) Chemical studies of the lunar regolith with emphasis on zirconium and hafnium. Proc. Lunar Sci. Conf. 6th, p. 1351-1361.

El Goresy A., Ramdohr P. and Medenbach O. (1973a) Lunar samples from Descartes site: opaque mineralogy and geochemistry. Proc. Lunar Sci. Conf. 4th, p. 733-750.

El Goresy A., Ramdohr P., Pavicevic M., Medenback O., Miller O. and Genter W. (1973b) Zinc, lead, chlorine and FeO(OH)-bearing assemblages in the Apollo 16 sample 66095: origin by impact of a comet or a carbonaceous chondrite? Earth Planet. Sci. Lett. 18, p. 411-419.

Eldridge J.S., O'Kelley G.D. and Northcutt K.J. (1973) Radionuclide concentrations in Apollo 16 lunar samples determined by nondestructive gamma-ray spectrometry. Proc. Lunar Sci. Conf. 4th, p. 2115-2122.

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.

v.Engelhardt W. (1978) Textural characterization of impact melt rocks. In Lunar and Planetary Science IX, p. 288-290. The Lunar and Planetary Institute, Houston.

v.Englehardt W. (1979) Crystallization behavior of ilmenite in lunar rocks of endogenic and impact origin. In Lunar and Planetary Science X, p. 355-357. The Lunar and Planetary Institute, Houston.

Epstein S. and Taylor H.P., Jr. (1974) D/H and $^{18}O/^{16}O$ ratios of H_2O in the "rusty" breccia 66095 and the origin of "lunar water." Proc. Lunar Sci. Conf. 5th, p. 1839-1854.

Eugster O., Eberhardt P., Geiss J., Grögler N., Jungck M. and Mörgeli M. (1975) Solar wind and other trapped gases in lunar material. In Lunar Science VI, p. 257-259. The Lunar Science Institute, Houston.

Eugster O., Eberhardt P., Geiss J., Grögler N., Jungck M. and Mörgeli M. (1977) The cosmic-ray exposure history of Shorty Crater samples; the age of Shorty Crater. Proc. Lunar Sci. Conf. 8th, p. 3059-3082.

Fechtig H., Hartung J.B., Nagel K. and Neukum G. (1974) Lunar microcrater studies, derived meteoroid fluxes and comparison with satellite-borne experiments. Proc. Lunar Sci. Conf. 5th, p. 2463-2474.

Filleux C., Tombrello T.A. and Burnett D.S. (1977) Direct measurement of surface carbon concentrations. Proc. Lunar Sci. Conf. 8th, p. 3755-3772.

Filleux C., Spear R.H., Tombrello T.A. and Burnett D.S. (1978) Direct measurement of surface carbon concentrations for lunar soil breccias. Proc. Lunar Planet. Sci. Conf. 9th, p. 1599-1617.

Fireman E.L., D'Amico J. and De Felice J. (1973) Radioactivities vs. depth in Apollo 16 and 17 soil. Proc. Lunar Sci. Conf. 4th, p. 2131-2143.

Flavill R.P., Allison R.J. and McDonnell J.A.M. (1978) Primary, secondary and tertiary microcrater populations on lunar rocks: Effects of hyper-velocity impact microejecta on primary populations. Proc. Lunar Planet. Sci. Conf. 9th, p. 2539-2556.

Fleischer R.L. and Hart H.R. (1974) Particle track record of Apollo 16 rocks from Plum crater. J. Geophys. Res. 79, p. 766-769.

Floran R.J., Phinney W.C., Blanchard D.P., Warner J.L., Simonds C.H., Brown R.W., Brannon J.C. and Korotev R.L. (1976) A comparison between the geochemistry and petrology of Apollo 16-Terrestrial impact melt analogs. In Lunar Science VII, p. 263-265. The Lunar Science Institute, Houston.

Flory D.A., Oró 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.

Ford C.E., Biggar G.M., O'Hara M.J., Humphries D.J. and Spencer P.N. (1974) Origin of the lunar highlands. In Lunar Science V, p. 239-241. The Lunar Science Institute, Houston.

Friedman I., Hardcastle K. and Gleason J.D. (1974) Water and carbon in rusty lunar rock 66095. Science 185, p. 346-349.

Fruchter J.S., Kridelbaugh S.J., Robyn M.A. and Goles G.G. (1974) Breccia 66055 and related clastic materials from the Descartes region, Apollo 16. Proc. Lunar Sci. Conf. 5th, p. 1035-1046.

Fruchter J.S., Rancitelli L.A., Laul J.C. and Perkins R.W. (1977) Lunar regolith dynamics based on analysis of the cosmogenic radionuclides ^{22}Na, ^{26}Al, and ^{53}Mn. Proc. Lunar Sci. Conf. 8th, p. 3595-3605.

Fruchter J.S., Rancitelli L.A., Evans J.C. and Perkins R.W. (1978) Lunar surface processes and cosmic ray histories over the past several million years. Proc. Lunar Planet. Sci. Conf. 9th, p. 2019-2032.

Ganapathy R., Morgan J.W., Krähenbühl U. and Anders E. (1973) Ancient meteoritic components in lunar highlands rocks: Clues from trace elements in Apollo 15 and 16 samples. Proc. Lunar Sci. Conf. 4th, p. 1239-1261.

Ganapathy R., Morgan J.W., Higuchi H. and Anders E. (1974) Meteoritic and volatile elements in Apollo 16 rocks and in separated phases from 14306. Proc. Lunar Sci. Conf. 5th, p. 1659-1683.

Gancarz A.J., Albee A.L. and Chodos A.A. (1972) Comparative petrology of Apollo 16 sample 68415 and Apollo 14 samples 14276 and 14310. Earth Planet. Sci. Lett. 16, p. 307-330.

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.

Garrison J.R., Jr. and Taylor L.A. (1979a) Petrology of lunar rock 66095: implications for the genesis of highland basalt and the stratigraphy of the Apollo 16 landing site. In Papers Presented to the Conference on the Lunar Highlands Crust, p. 18-20. The Lunar and Planetary Institute, Houston.

Garrison J.R., Jr. and Taylor L.A. (1979b) Breccia guidebook #2, 66095, "Rusty Rock". Lunar Curatorial Branch, Johnson Space Center, Houston. 27 pp.

Garrison J.R., Jr. and Taylor L.A. (1980) Genesis of highland basalt breccias: a view from 66095. Proc. of the Conference on the Lunar Highlands Crust, p. 395-417.

Ghose S., Wan C. and McCallum I.S. (1975) Late thermal history of lunar anorthosite 67075: evidence from cation order in olivine and orthopyroxene. In Lunar Science VI, p. 282-283. The Lunar Science Institute, Houston.

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.

Goel P.S., Shukla P.N., Kothari B.K. and Garg A.N. (1975) Total nitrogen in lunar soils, breccias, and rocks. Geochim. Cosmochim. Acta 39, p. 1347-1352.

Gold T., Bilson E. and Baron R.L. (1974) Observation of iron-rich coating on lunar grains and a relation to low albedo. Proc. Lunar Sci. Conf. 5th, p. 2413-2422.

Gold T., Bilson E. and Baron R.L. (1975) Auger analysis of the lunar soil: Study of processes which change the surface chemistry and albedo. Proc. Lunar Sci. Conf. 6th, p. 3285-3303.

Gold T., Bilson E. and Baron R.L. (1976a) The surface chemical composition of lunar samples and its significance for optical properties. Proc. Lunar Sci. Conf. 7th, p. 901-911.

Gold T., Bilson E. and Baron R.L. (1976b) Electrical properties of Apollo 17 rock and soil samples and a summary of the electrical properties of lunar material at 450 MHz frequency. Proc. Lunar Sci. Conf. 7th, p. 2593-2603.

Goldberg R.H., Weller R.A., Tombrello T.A. and Burnett D.S. (1976) Surface concentrations of F, H, and C. In Lunar Science VII, p. 307-309. The Lunar Science Institute, Houston.

Gooley R.C., Brett R. and Warner J.L. (1973) Crystallization history of metal particles in Apollo 16 rake samples. Proc. Lunar Sci. Conf. 4th, p. 799-810.

Gopalan K. and Rao M.N. (1976) Solar cosmic ray effects in heavy noble gases of lunar soils and breccias. In Lunar Science VII, p. 316-318. The Lunar Science Institute, Houston.

Graf H., Shirck J., Sun S. and Walker R. (1973) Fission track astrology of three Apollo 14 gas-rich breccias. Proc. Lunar Sci. Conf. 4th, p. 2145-2155.

Grieve R.A.F. and Plant A.G. (1973) Partial melting on the lunar surface, as observed in glass coated Apollo 16 samples. Proc. Lunar Sci. Conf. 4th, p. 667-679.

Grieve R.A.F., Plant A.G. and Dence M.R. (1974) Lunar impact melts and terrestrial analogs: their characteristics, formation and implications for lunar crustal evolution. Proc. Lunar Sci. Conf. 5th, p. 261-273.

Haggerty S.E. (1973) Armalcolite and genetically associated opaque minerals in the lunar samples. Proc. Lunar Sci. Conf. 4th, p. 777-797.

Hansen E.C., Steele I.M. and Smith J.V. (1979a) Lunar highland rocks: Element partitioning among minerals I: Electron microprobe analyses of Na, Mg, K and Fe in plagioclase; Mg partitioning with orthopyroxene. Proc. Lunar Planet. Sci. Conf. 10th, p. 627-638.

Hansen E.C., Steele I.M. and Smith J.V. (1979b) Minor elements in plagioclase from lunar highland rocks: new data, especially for granulitic impactites. In Papers Presented to the Conference on the Lunar Highlands Crust, p. 39-41. The Lunar and Planetary Institute, Houston.

Hapke B.W., Partlow W.D., Wagner J.K. and Cohen A.J. (1978) Reflectance measurements of lunar materials in the vacuum ultraviolet. Proc. Lunar Planet. Sci. Conf. 9th, p. 2935-2947.

Hargraves R.B. and Dorety N.F. (1975) Remanent magnetism in two Apollo 16 and two Apollo 17 rock samples. In Lunar Science VI, p. 331-333. Lunar Science Institute, Houston.

Hartung J.B., Breig J.J. and Comstock G.M. (1977) Microcrater studies on 60015 do not support time variation of meteoroid flux. In Lunar Science VIII, p. 406-408. The Lunar Science Institute, Houston.

Hartung J.B., Nagel K. and El Goresy A. (1978) Chemical composition variations in microcrater pit glasses from lunar anorthosite, 65315. Proc. Lunar Planet. Sci. Conf. 9th, p. 2495-2506.

Haselton J.D. and Nash W.P. (1975a) Ilmenite-orthopyroxene intergrowths from the moon and the Skaergaard intrusion. Earth Planet. Sci. Lett. 26, p. 287-291.

Haselton J.D. and Nash W.P. (1975b) Observations on titanium in lunar oxides and silicates. In Lunar Science VI, p. 343-345. The Lunar Science Institute, Houston.

Haskin L.A., Helmke P.A., Blanchard D.P., Jacobs J.W. and Telunder K. (1973) Major and trace element abundances in samples from the lunar highlands. Proc. Lunar Sci. Conf. 4th, p. 1275-1296.

Helz R.T. and Appleman D.E. (1973) Mineralogy, petrology, and crystallization history of Apollo 16 rock 68415. Proc. Lunar Sci. Conf. 4th, p. 643-659.

Herminghaus C.H. and Berckhemer H. (1974) Shock induced ultra-sound absorption in lunar anorthosite. Proc. Lunar Sci. Conf. 5th, p. 2939-2943.

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.

Herzberg C.T. (1979) Identification of pristine lunar highlands rocks: Criteria based on mineral chemistry and stability. In Lunar and Planetary Science X, p. 537-539. The Lunar and Planetary Institute, Houston.

Hewins R.H. and Goldstein J.I. (1975a) The provenance of metal in anorthositic rocks. Proc. Lunar Sci. Conf. 6th, p. 343-362.

Hewins R.H. and Goldstein J.I. (1975b) Comparison of silicate and metal geothermometers for lunar rocks. In Lunar Science VI, p. 356-357. The Lunar Science Institute, Houston.

Heymann D. and Hübner W. (1974) Origin of inert gases in "rusty rock" 66095. Earth Planet. Sci. Lett. 22, p. 423-426.

Hinthorne J.R. and Andersen C.A. (1974) Uranium-lead and lead-lead ratios in lunar samples 66095 and 12013 by ion microprobe mass analysis. In Lunar Science V, p. 337-339. The Lunar Science Institute, Houston.

Hodges F.N. and Kushiro I. (1973) Petrology of Apollo 16 lunar highland rocks. Proc. Lunar Sci. Conf. 4th, p. 1033-1048.

Hohenberg C.M., Marti K., Podosek F.A., Reedy R.C. and Shirck J.R. (1978) Comparisons between observed and predicted cosmogenic noble gases in lunar samples. Proc. Lunar Planet. Sci. Conf. 9th, p. 2311-2344.

Hollister L.S. (1973) Sample 67955: a description and a problem. Proc. Lunar Sci. Conf. 4th, p. 633-641.

Hopper R.W., Onorato P. and Uhlmann D.R. (1974) Thermal histories and crystal distributions in partly devitrified lunar glasses cooled by radiation. Proc. Lunar Sci. Conf. 5th, p. 2257-2273.

Horn P., Jessberger E.K., Kirsten T. and Richter H. (1975) ^{39}Ar-^{40}Ar dating of lunar rocks: effects of grain size and neutron irradiation. Proc. Lunar Sci. Conf. 6th, p. 1563-1591.

Hörz F., Schneider E. and Hill R.E. (1974) Micrometeroid abrasion of lunar rocks: a Monte Carlo simulation. Proc. Lunar Sci. Conf. 5th, p. 2397-2412.

Hörz F., Gibbons R.V., Gault D.E., Hartung J.B. and Brownlee D.E. (1975) Some correlation of rock exposure ages and regolith dynamics. Proc. Lunar Sci. Conf. 6th, p. 3495-3508.

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.

Hua C.T., Dollfus A. and Mandeville J.-C. (1976) Ultraviolet diffuse reflectance spectroscopy for lunar, meteoritic, and terrestrial samples. Proc. Lunar Sci. Conf. 7th, p. 2605-2622.

Hubbard N.J., Rhodes J.M., Gast P.W., Bansal B.M., Shih C.-Y., Wiesmann H. and Nyquist L.E. (1973) Lunar rock types: the role of plagioclase in non-mare and highland rock types. Proc. Lunar Sci. Conf. 4th, p. 1297-1312.

Hubbard N.J., Rhodes J.M., Wiesmann H., Shih C.-Y. and Bansal B.M. (1974) The chemical definition and interpretation of rock types returned from the non-mare regions of the moon. Proc. Lunar Sci. Conf. 5th, p. 1227-1246.

Huebner J.S., Lipin B.R. and Wiggins L.B. (1976) Partitioning of chromium between silicate crystals and melts. Proc. Lunar Sci. Conf. 7th, p. 1195-1220.

Huffman G.P. and Dunmyre G.R. (1975) Superparamagnetic clusters of Fe^{2+} spins in lunar olivine: dissolution by high-temperature annealing. Proc. Lunar Sci. Conf. 6th, p. 757-772.

Huffman G.P., Schwerer F.C. and Fisher R.M. (1974) Iron distributions and metallic-ferrous ratios for Apollo lunar samples: Mossbauer and magnetic analysis. Proc. Lunar Sci. Conf. 5th, p. 2779-2794.

Hughes T.C., Keays R.R. and Lovering J.F. (1973) Siderophile and volatile trace elements in Apollo 14, 15 and 16 rocks and fines: evidence for extralunar component and Tl-, Au-, and Ag-enriched rocks in the ancient lunar crust. In Lunar Science IV, p. 400-402. The Lunar Science Institute, Houston.

Huneke J.C. and Smith S.P. (1976) The realities of recoil: ^{39}Ar recoil out of small grains and anomalous age patterns in ^{39}Ar-^{40}Ar dating. Proc. Lunar Sci. Conf. 7th, p. 1987-2008.

Huneke J.C., Jessberger E.K., Podosek F.A. and Wasserburg G.J. (1973) ^{40}Ar-^{39}Ar measurements in Apollo 16 and 17 samples and the chronology of metamorphic and volcanic activity in the Taurus-Littrow region. Proc. Lunar Sci. Conf. 4th, p. 1725-1756.

Huneke J.C., DiBrozolo F.R. and Wasserburg G.J. (1977) ^{40}Ar-^{39}Ar measurements on lunar highlands rocks with primitive $^{87}Sr/^{86}Sr$. In Lunar Science VIII, p. 481-483. The Lunar Science Institute, Houston.

Husain L. and Schaeffer O.A. (1973) ^{40}Ar-^{39}Ar crystallization ages and ^{38}Ar-^{37}Ar ray exposure ages of samples from the vicinity of the Apollo 16 landing site. In Lunar Science IV, p. 406-408. The Lunar Science Institute, Houston.

Ishii T., Miyamoto M. and Takeda H. (1976) Pyroxene geothermometry and crystallization-, subsolidus equilibration temperatures of lunar and achondritic pyroxenes. In Lunar Science VII, p. 408-410. The Lunar Science Institute, Houston.

Jagodzinski H. and Korekawa M. (1973) Diffuse x-ray scattering by lunar materials. Proc. Lunar Sci. Conf. 4th, p. 933-951.

James O.B., Brecher A., Blanchard D.P., Jacobs J.W., Brannon J.C., Korotev R.L., Haskin L.A., Higuchi H., Morgan J.W., Anders E., Silver L.T., Marti K., Braddy D., Hutcheon I.D., Kirsten T., Kerridge J.F., Kaplan I.R., Pillinger C.T. and Gardiner L.R. (1975) Consortium studies of matrix of light gray breccia 73215. Proc. Lunar Sci. Conf. 6th, p. 547-577.

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.

Jeanloz R. and Ahrens T.J. (1978) The equation of state of a lunar anorthosite: 60025. Proc. Lunar Planet. Sci. Conf. 9th, p. 2789-2803.

Jeanloz R. and Ahrens T.J. (1979) Equation of state of lunar anorthosite and anorthite, criteria for impact melting and vaporization. In Lunar and Planetary Science X, p. 622-624. The Lunar and Planetary Institute, Houston.

Jessberger E.K., Huneke J.C., Podosek F.A. and Wasserburg G.J. (1974) High resolution argon analysis of neutron-irradiated Apollo 16 rocks and separated minerals. Proc. Lunar Sci. Conf. 5th, p. 1419-1449.

Jessberger E.K., Dominik B., Kirsten T. and Staudacher T. (1977) New ^{40}Ar-^{39}Ar ages of Apollo 16 breccias and 4.42 AE old anorthosites. In Lunar Science VIII, p. 511-513. The Lunar Science Institute, Houston.

Johan Z. and Christophe M. (1974) Origin of pyroxene and silica exsolutions in anorthite from 60016,95 polished thin section. In Lunar Science V, p. 385-387. The Lunar Science Institute, Houston.

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.

Jovanovic S. and Reed G.W., Jr. (1976a) Chemical fractionation of Ru and Os in the moon. Proc. Lunar Sci. Conf. 7th, p. 3437-3446.

Jovanovic S. and Reed G.W., Jr. (1976b) Convection cells in the early lunar magma ocean: trace element evidence. Proc. Lunar Sci. Conf. 7th, p. 3447-3459.

Jovanovic S. and Reed G.W., Jr. (1977) Trace element geochemistry and the early lunar differentiation. Proc. Lunar Sci. Conf. 8th, p. 623-632.

Jovanovic S. and Reed G.W., Jr. (1978) Trace element evidence for a laterally inhomogeneous moon. Proc. Lunar Planet. Sci. Conf. 9th, p. 59-80.

Juan V.C., Chen J.C., Huang C.K., Chen P.Y. and Wang Lee C.M. (1973) Petrology and chemistry of Apollo 16 gabbroic anorthosite 68416. In Lunar Science IV, p. 421-423. The Lunar Science Institute, Houston.

Juan V.C., Chen J.C., Huang C.K., Chen P.Y. and Lee C.M.W. (1974) Petrology and chemistry of some Apollo 16 lunar samples. In Lunar Science V, p. 394-396. The Lunar Science Institute, Houston.

Katsube T.J. and Collett L.S. (1973a) Electrical characteristics of Apollo 16 lunar samples. Proc. Lunar Sci. Conf. 4th, p. 3101-3110.

Katsube T.J. and Collett L.S. (1973b) Electrical characteristics of rocks and their application to planetary and terrestrial EM-sounding. Proc. Lunar Sci. Conf. 4th, p. 3111-3131.

Keil K., Dowty E., Prinz M. and Bunch T.E. (1972) Description, classification, and inventory of 151 Apollo 16 rake samples from the LM area and station 5. Manned Spacecraft Center, Houston.

Keith J.E. and Clark R.S. (1974) The saturated activity of ^{26}Al in lunar samples as a function of chemical composition and the exposure ages of some lunar samples. In Lunar Science V, p. 405-407. The Lunar Science Institute, Houston.

Keith J.E., Clark R.S. and Bennett L.J. (1975) The saturated activities of ^{22}Na, ^{54}Mn, and ^{56}Co and the depth of sampling of soils. Proc. Lunar Sci. Conf. 6th, p. 1879-1890.

Kerridge J.F., Kaplan I.R. and Petrowski C. (1975a) Evidence for meteoritic sulfur in the lunar regolith. Proc. Lunar Sci. Conf. 6th, p. 2151-2162.

Kerridge J.F., Kaplan I.R., Petrowski C. and Chang S. (1975b) Light element geochemistry of the Apollo 16 site. Geochim. Cosmochim. Acta 39, p. 137-162.

Kirsten T., Horn P. and Kiko J. (1973) ^{39}Ar-^{40}Ar dating and rare gas analysis of Apollo 16 rocks and soils. Proc. Lunar Sci. Conf. 4th, p. 1757-1784.

Klein L.C. and Uhlmann D.R. (1976) The kinetics of lunar glass formation, revisited. Proc. Lunar Sci. Conf. 7th, p. 1113-1121.

Kohl C.P., Russ G.P., III, Arnold J.R., Nishiizumi K., Imamura M. and Honda M. (1977) ^{53}Mn in lunar cores: evidence for the time scale of surface gardening. In Lunar Science VIII, p. 552-554. The Lunar Science Institute, Houston.

Kohl C.P., Murrell M.T., Russ G.P., III and Arnold J.R. (1978) Evidence for the constancy of the solar cosmic flux over the past ten million years: ^{53}Mn and ^{26}Al measurements. Proc. Lunar Planet. Sci. Conf. 9th, p. 2299-2310.

Krähenbühl U., Ganapathy R., Morgan J.W. and Anders E. (1973) Volatile elements in Apollo 16 samples: implications for highland volcanism and accretion history of the moon. Proc. Lunar Sci. Conf. 4th, p. 1325-1348.

Kridelbaugh S.J., McKay G.A. and Weill D.F. (1973) Breccias from the lunar highlands: preliminary petrographic report on Apollo 16 samples 60017 and 63335. Science 179, p. 71-74.

Lambert G., Le Roulley J.C. and Bristeau P. (1975) Evidence of gaseous radon-222 between fines grains within lunar regolith. Proc. Lunar Sci. Conf. 6th, p. 1803-1809.

Laul J.C. and Schmitt R.A. (1973) Chemical composition of Apollo 15, 16, and 17 samples. Proc. Lunar Sci. Conf. 4th, p. 1349-1367.

Laul J.C., Hill D.W. and Schmitt R.A. (1974) Chemical studies of Apollo 16 and 17 samples. Proc. Lunar Sci. Conf. 5th, p. 1047-1066.

Leich D.A. and Niemeyer S. (1975) Trapped xenon in lunar anorthositic breccia 60015. Proc. Lunar Sci. Conf. 6th, p. 1953-1965.

Leich D.A., Tombrello T.A. and Burnett D.S. (1973) The depth distribution of hydrogen and fluorine in lunar samples. Proc. Lunar Sci. Conf. 4th, p. 1597-1612.

Leich D.A., Goldberg R.H., Burnett D.S. and Tombrello T.A. (1974) Hydrogen and fluorine in the surfaces of lunar samples. Proc. Lunar Sci. Conf. 5th, p. 1869-1884.

Lightner B.D. and Marti K. (1974a) Lunar trapped xenon. Proc. Lunar Sci. Conf. 5th, p. 2023-2031.

Lightner B.D. and Marti K. (1974b) Lunar trapped xenon. In Lunar Science V, p. 447-449. The Lunar Science Institute, Houston.

Lindstrom M.M., Nava D.F., Lindstrom D.J., Winzer S.R., Lum R.K.L., Schuhmann P.J., Schuhmann S. and Philpotts J.A. (1977) Geochemical studies of the white breccia boulders at North Ray Crater, Descartes region of the lunar highlands. Proc. Lunar Sci. Conf. 8th, p. 2137-2151.

Longhi J., Walker D. and Hays J.F. (1976) Fe and Mg in plagioclase. Proc. Lunar Sci. Conf. 7th, p. 1281-1300.

Lovering J.F. and Wark D.A. (1974) Rare earth element fractionation in phases crystallizing from lunar late-stage magmatic liquids. In Lunar Science V, p. 463-465. The Lunar Science Institute, Houston.

LSPET (1973) The Apollo 16 lunar samples: petrographic and chemical description. Science 179, p. 23-34.

Lugmair G.W. and Carlson R.W. (1978) The Sm-Nd history of KREEP. Proc. Lunar Planet. Sci. Conf. 9th, p. 689-704.

Macdougall D., Rajan R.S., Hutcheon I.D. and Price P.B. (1973) Irradiation history and accretionary processes in lunar and meteoritic breccias. Proc. Lunar Sci. Conf. 4th, p. 2319-2336.

Mandeville J.-C. (1976) Microcraters on lunar rocks. Proc. Lunar Sci. Conf. 7th, p. 1031-1038.

Mandeville J.-C. and Dollfus A. (1977) Optical properties of lunar and terrestrial rock samples submitted to micrometeoroid bombardment. In Lunar Science VIII, p. 616-618. The Lunar Science Institute, Houston.

Mao H.K. and Bell P.M. (1976) Lunar metallic phase: compositional variation in response to disequilibrium in regolith melting processes. Proc. Lunar Sci. Conf. 7th, p. 857-862.

Mark R.K., Lee-Hu C.-N. and Wetherill G.W. (1974) Rb-Sr age of lunar igneous rocks 62295 and 14310. Geochim. Cosmochim. Acta 38, p. 1643-1648.

Marti K., Lightner B.D. and Osborn T.W. (1973) Krypton and xenon in some lunar samples and the age of North Ray Crater. Proc. Lunar Sci. Conf. 4th, p. 2037-2048.

Marti K., Eberhardt P., Grögler N., Keil K., Lugmair G., Stettler A., Taylor G.J. and Warner R.D. (1978) Search for pieces of the ancient lunar crust: a study of clasts in rock 67915. In Lunar and Planetary Science IX, p. 696-698. Lunar and Planetary Institute, Houston.

Marvin U.B. (1980) Breccia guidebook no. 4, 67015. JSC publication no. 16671, Lunar Curatorial Branch publication no. 51, Johnson Space Center, Houston. 69 pp.

Maxwell T.A. (1978) Origin of multi-ring basin ridge systems: an upper limit to the elastic deformation based on a finite-element model. Proc. Lunar Planet. Sci. Conf. 9th, p. 3541-3559.

McCallum I.S., Okamura F.P. and Ghose S. (1975) Mineralogy and petrology of sample 67075 and the origin of lunar anorthosites. Earth Planet. Sci. Lett. 26, p. 36-53.

McDonnell J.A.M., Flavill R.P. and Carey W.C. (1976) The micrometeoroid impact crater comminution distribution and accretionary populations on lunar rocks: experimental measurements. Proc. Lunar Sci. Conf. 7th, p. 1055-1072.

McDonnell J.A.M. (1977) Accretionary particle studies on Apollo 12054,58: In situ lunar surface microparticle flux rate and solar wind sputter rate defined. Proc. Lunar Sci. Conf. 8th, p. 3835-3857.

McGee P.E., Simonds C.H., Warner J.L. and Phinney W.C. (1979) Introduction to the Apollo collections: Part II, Lunar breccias. Johnson Space Center, Houston. 203 pp.

McKay G., Kridelbaugh S. and Weill D. (1973a) A preliminary report on the petrology of microbreccia 66055. In Lunar Science IV, p. 487-489. The Lunar Science Institute, Houston.

McKay G.A., Kridelbaugh S.J. and Weill D.F. (1973b) The occurrence and origin of schreibersite-kamacite intergrowths in microbreccia 66055. Proc. Lunar Sci. Conf. 4th, p. 811-818.

McKay G.A., Wiesmann H., Nyquist L.E., Wooden J.L. and Bansal B.M. (1978) Petrology, chemistry, and chronology of 14078: chemical constraints on the origin of KREEP. Proc. Lunar Planet. Sci. Conf. 9th, p. 661-687.

Mehta S. and Goldstein J.I. (1980) Metallic particles in the glassy constituents of three lunar highland samples 65315, 67435 and 78235. Proc. Lunar Planet. Sci. Conf. 11th, in press.

Meyer C., Jr., Anderson D.H. and Bradley J.G. (1974) Ion microprobe mass analysis of plagioclase from "non-mare" lunar samples. Proc. Lunar Sci. Conf. 5th, p. 685-706.

Meyer C., Jr. (1979) Trace elements in plagioclase from the lunar highlands. In Papers Presented to the Conference on the Lunar Highlands Crust, p. 111-113. The Lunar and Planetary Institute, Houston.

Meyer H.O.A. and McCallister R.H. (1973) Mineralogy and petrology of Apollo 16: rock 60215,13. Proc. Lunar Sci. Conf. 4th, p. 661-665.

Meyer R.W., Garrison J.R., Jr. and Taylor L.A. (1979) Rusty rock consortium-VAPOR: petrographic framework for clasts of 66095. In Papers Presented to the Conference on the Lunar Highlands Crust, p. 114-116. The Lunar and Planetary Institute, Houston.

Miller M.D., Pacer R.A., Ma M.-S., Hawke B.R., Lookhart G.L. and Ehmann W.D. (1974) Compositional studies of the lunar regolith at the Apollo 17 site. Proc. Lunar Sci. Conf. 5th, p. 1079-1086.

Minkin J.A., Thompson C.L. and Chao E.C.T. (1977) Apollo 16 white boulders consortium samples 67455 and 67475: petrologic investigation. Proc. Lunar Sci. Conf. 8th, p. 1967-1986.

Misra K.C. and Taylor L.A. (1975) Characteristics of metal particles in Apollo 16 rocks. Proc. Lunar Sci. Conf. 6th, p. 615-639.

Mizutani H. and Newbigging D.F. (1973) Elastic wave velocities of Apollo 14, 15 and 16 rocks. Proc. Lunar Sci. Conf. 4th, p. 2601-2609.

Mizutani H. and Osako M. (1974) Elastic wave velocities and thermal diffusivities of Apollo 17 rocks and their geophysical implications. Proc. Lunar Sci. Conf. 5th, p. 2891-2901.

Modzeleski J.E., Modzeleski V.E., Nagy B., Nagy L.A., Sill G.T., Hamilton P.B., McEwan W.S. and Urey H.C. (1973) Types of carbon compounds examined in Apollo 16 lunar samples by vacuum pyrolysis-mass spectrometry and by photoelectron spectroscopy. In Lunar Science IV, p. 531-533. The Lunar Science Institute, Houston.

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.

Morrison D.A., McKay D.S. and Fruland R.M. (1973) Microcraters on Apollo 15 and 16 rocks. Proc. Lunar Sci. Conf. 4th, p. 3235-3253.

Morrison G.H., Nadkarni R.A., Jaworski J., Botto R.I. and Roth J.R. (1973) Elemental abundances of Apollo 16 samples. Proc. Lunar Sci. Conf. 4th, p. 1399-1405.

Muan A., Löfall T. and Ma C.-B. (1974) Liquid-solid equilibria in lunar rocks from Apollo 15, 16 and 17 and phase relations in parts of the system $CaMgSi_2O_6$-$CaFeSi_2O_6$-Fe_2SiO_4-$CaAl_2Si_2O_8$. In Lunar Science V, p. 529-530. The Lunar Science Institute, Houston.

Müller O. (1975) Lithophile trace and major elements in Apollo 16 and 17 lunar samples. Proc. Lunar Sci. Conf. 6th, p. 1303-1311.

Murali A.V., Ma M.-S. and Schmitt R.A. (1976) Mare basalt 60639, another eastern lunar basalt. In Lunar Science VII, p. 583-584. The Lunar Science Institute, Houston.

Murali A.V., Ma M.-S., Laul J.C. and Schmitt R.A. (1977) Chemical composition of breccias, feldspathic basalt and anorthosites from Apollo 15 (15308, 15359, 15382 and 15362), Apollo 16 (60618 and 65785), Apollo 17 (72435, 72536, 72559, 72735, 72738, 78526 and 78527) and Luna 20 (22012 and 22013). In Lunar Science VIII, p. 700-702. The Lunar Science Institute, Houston.

Murthy V.R. (1978) Considerations of lunar initial strontium ratio. In Lunar and Planetary Science IX, p. 778-781. The Lunar and Planetary Institute, Houston.

Murthy V.R. and Coscio M.R. (1977) Rb-Sr isotopic systematics and initial Sr considerations for some lunar samples. In Lunar Science VIII, p. 706-708. The Lunar Science Institute, Houston.

Nagata T., Fisher R.M., Schwerer F.C., Fuller M.D. and Dunn J.R. (1973) Magnetic properties and natural magnetization of Apollo 15 and 16 lunar materials. Proc. Lunar Sci. Conf. 4th, p. 3019-3043.

Nagata T., Sugiura N., Fisher R.M., Schwerer F.C., Fuller M.D. and Dunn J.R. (1974) Magnetic properties of Apollo 11-17 lunar materials with special reference to effects of meteorite impact. Proc. Lunar Sci. Conf. 5th, p. 2827-2839.

Nagata T., Fisher R.M., Schwerer F.C., Fuller M.D. and Dunn J.R. (1975) Effects of meteorite impact on magnetic properties of Apollo lunar materials. Proc. Lunar Sci. Conf. 6th, p. 3111-3122.

Nagel K., Neukum G., Eichhorn G., Fechtig H., Muller O. and Schneider E. (1975) Dependencies of microcrater formation on impact parameters. Proc. Lunar Sci. Conf. 6th, p. 3417-3432.

Nagel K., Neukum G., Dohnanyi J.S., Fechtig H. and Gentner W. (1976) Density and chemistry of interplanetary dust particles, derived from measurements of lunar microcraters. Proc. Lunar Sci. Conf. 7th, p. 1021-1029.

Nakamura N., Masuda A., Tanaka T. and Kurasawa H. (1973) Chemical compositions and rare-earth features of four Apollo 16 samples. Proc. Lunar Sci. Conf. 4th, p. 1407-1414.

Nash W.P. and Haselton J.D. (1975) Silica activity in lunar lavas. Proc. Lunar Sci. Conf. 6th, p. 119-130.

Nava D.F. (1974) Chemical compositions of some soils and rock types from the Apollo 15, 16, and 17 lunar sites. Proc. Lunar Sci. Conf. 5th, p. 1087-1096.

Neukum G., Hörz F., Morrison D.A. and Hartung J.B. (1973) Crater populations on lunar rocks. Proc. Lunar Sci. Conf. 4th, p. 3255-3276.

Niemeyer S. and Leich D.A. (1976) Atmospheric rare gases in lunar rock 60015. Proc. Lunar Sci. Conf. 7th, p. 587-597.

Nord G.L., Jr., Lally J.S., Heuer A.H., Christie J.M., Radcliff S.V., Griggs D.T. and Fisher R.M. (1973) Petrologic study of igneous and metaigneous rocks from Apollo 15 and 16 using high voltage transmission electron microscopy. Proc. Lunar Sci. Conf. 4th, p. 953-970.

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.

Nunes P.D. (1975) Pb loss from Apollo 17 glassy samples and Apollo 16 revisited. Proc. Lunar Sci. Conf. 6th, p. 1491-1499.

Nunes P.D. and Tatsumoto M. (1973) Excess lead in "Rusty Rock" 66095 and implications for an early lunar differentiation. Science 182, p. 916-920.

Nunes P.D., Tatsumoto M., Knight R.J., Unruh D.M. and Doe B.R. (1973) U-Th-Pb systematics of some Apollo 16 lunar samples. Proc. Lunar Sci. Conf. 4th, p. 1797-1822.

Nunes P.D., Knight R.J., Unruh D.M. and Tatsumoto M. (1974) The primitive nature of the lunar crust and the problem of initial Pb isotopic compositions of lunar rocks: a Rb-Sr and U-Th-Pb study of Apollo 16 samples. In Lunar Science V, p. 559-561. The Lunar Science Institute, Houston.

Nunes P.D., Unruh D.M. and Tatsumoto M. (1977) U-Th-Pb systematics of Apollo 16 samples 60018, 60025, and 64435; and the continuing problem of terrestrial Pb contamination of lunar samples. In Lunar Sample Studies, NASA SP-418, p. 61-69.

Nyquist L.E. (1977) Lunar Rb-Sr chronology. Phys. Chem. Earth 10, p. 103-142.

Nyquist L.E., Hubbard N.J., Gast P.W., Bansal B.M., Wiesmann H. and Jahn B. (1973) Rb-Sr systematics for chemically defined Apollo 15 and 16 materials. Proc. Lunar Sci. Conf. 4th, p. 1823-1846.

Nyquist L.E., Bansal B.M., Wiesmann H. and Jahn B.-M. (1974) Taurus-Littrow chronology: some constraints on early lunar crustal development. Proc. Lunar Sci. Conf. 5th, p. 1515-1539.

Nyquist L.E., Bansal B.M. and Wiesmann H. (1975) Rb-Sr ages and initial $^{87}Sr/^{86}Sr$ for Apollo 17 basalts and KREEP basalt 15386. Proc. Lunar Sci. Conf. 6th, p. 1445-1465.

Nyquist L.E., Bansal B.M. and Wiesmann H. (1976) Sr isotopic constraints on the petrogenesis of Apollo 17 mare basalts. Proc. Lunar Sci. Conf. 7th, p. 1507-1528.

Nyquist L.E., Shih C.-Y., Wooden J.L., Bansal B.M. and Wiesmann H. (1979) The Sr and Nd isotopic record of Apollo 12 basalts: implications for lunar geochemical evolution. Proc. Lunar Planet. Sci. Conf. 10th, p. 77-114.

Oberli F., McCulloch M.T., Tera F., Papanastassiou D.A. and Wasserburg G.J. (1978) Early lunar differentiation constraints from U-Th-Pb, Sm-Nd and Rb-Sr model ages. In Lunar and Planetary Science IX, p. 832-834. The Lunar and Planetary Institute, Houston.

Oberli F., Huneke J.C. and Wasserburg G.J. (1979) U-Pb and K-Ar systematics of cataclysm and precataclysm lunar impactites. In Lunar and Planetary Science X, p. 940-942. The Lunar and Planetary Institute, Houston.

Okamura F.P., McCallum I.S., Stroh J.M. and Ghose S. (1976) Pyroxene-spinel intergrowths in lunar and terrestrial pyroxenes. Proc. Lunar Sci. Conf. 7th, p. 1889-1899.

Olhoeft G.R., Strangway D.W. and Frisillo A.L. (1973) Lunar sample electrical properties. Proc. Lunar Sci. Conf. 4th, p. 3133-3149.

Padawer G.M., Kamykowski E.A., Stauber M.C., D'Agostino M.D. and Brant W. (1974) Concentration-versus-depth profiles of hydrogen, carbon, and fluorine in lunar rock surfaces. Proc. Lunar Sci. Conf. 5th, p. 1919-1934.

Palme H., Baddenhausen H., Blum K., Cendales M., Dreibus G., Hofmeister H., Kruse H., Palme C., Spettel B., Vilcsek E. and Wänke H. (1978) New data on lunar samples and achondrites and a comparison of the least fractionated samples from the earth, the moon and the eucrite parent body. Proc. Lunar Planet. Sci. Conf. 9th, p. 25-57.

Papanastassiou D.A. and Wasserburg G.J. (1972a) The Rb-Sr age of a crystalline rock from Apollo 16. Earth Planet. Sci. Lett. 16, p. 289-298.

Papanastassiou D.A. and Wasserburg G.J. (1972b) Rb-Sr systematics of Luna 20 and Apollo 16 samples. Earth Planet. Sci. Lett. 17, p. 52-63.

Papanastassiou D.A. and Wasserburg G.J. (1975) A Rb-Sr study of Apollo 17 Boulder 3: dunite clast, microclasts, and matrix. In Lunar Science VI, p. 631-633. The Lunar Science Institute, Houston.

Papanastassiou D.A. and Wasserburg G.J. (1976) Early lunar differentiates and lunar initial $^{87}Sr/^{86}Sr$. In Lunar Science VII, p. 665-667. The Lunar Science Institute, Houston.

Pearce G.W. and Simonds C.H. (1974) Magnetic properties of Apollo 16 samples and implications for their mode of formation. J. Geophys. Res. 79, p. 2953-2959.

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.

Pearce G.W., Hoye G.S., Strangway D.W., Walker B.M. and Taylor L.A. (1976) Some complexities in the determination of lunar paleointensities. Proc. Lunar Sci. Conf. 7th, p. 3271-3297.

Peckett A. and Brown G.M. (1973) Plutonic or metamorphic equilibration in Apollo 16 lunar pyroxenes. Nature 242, p. 252-255.

Pepin R.O., Brasford J.R., Dragon J.C., Coscio M.R., Jr. and Murthy V.R. (1974) Rare gases and trace elements in Apollo 15 drill core fines: depositional chronologies and K-Ar ages, and production rates of spallation-produced ^{3}He, ^{21}Ne, and ^{38}Ar versus depth. Proc. Lunar Sci. Conf. 5th, p. 2149-2184.

Pepin R.O. and Phinney D. (1979) Fisson and fractionation in lunar xenon and the composition of solar wind xenon. In Lunar and Planetary Science X, p. 972-974. The Lunar and Planetary Institute, Houston.

Philpotts J.A., Schuhmann S., Kouns C.W., Lum R.K.L., Bickel A.L. and Schnetzler C.C. (1973) Apollo 16 returned samples: lithophile trace-element abundances. Proc. Lunar Sci. Conf. 4th, p. 1427-1436.

Phinney D., Kahl S.B. and Reynolds J.H. (1975) ^{40}Ar-^{39}Ar dating of Apollo 16 and 17 rocks. Proc. Lunar Sci. Conf. 6th, p. 1593-1608.

Phinney W. and Lofgren G. (1973) Description, classification, and inventory of Apollo 16 rake samples from stations 1, 4, and 13. Johnson Space Center, Houston. 69 pp.

Phinney W.C., McKay D.S., Simonds C.H. and Warner J.L. (1976) Lithification of vitric-and clastic-matrix breccias: SEM petrography. Proc. Lunar Sci. Conf. 7th, p. 2469-2492.

Powell B.N., Dungan M.A. and Weiblen P.W. (1975) Apollo 16 feldspathic melt rocks: clues to the magmatic history of the lunar crust. Proc. Lunar Sci. Conf. 6th, p. 415-433.

Prinz M., Dowty E., Keil K. and Bunch T.E. (1973) Spinel troctolite and anorthosite in Apollo 16 samples. Science 179, p. 74-76.

Quick J.E., Brock B.S. and Albee A.L. (1978) Petrology of Apollo 16 breccia 66075. Proc. Lunar Planet. Sci. Conf. 9th, p. 921-939.

Rancitelli L.A., Perkins R.W., Felix W.D. and Wogman N.A. (1973a) Lunar surface and solar process analyses from cosmogenic radionuclide measurements at the Apollo 16 site. In Lunar Science IV, p. 609-611. The Lunar Science Institute, Houston.

Rancitelli L.A., Perkins R.W., Felix W.D. and Wogman N.A. (1973b) Primordial radionuclides in soils and rocks from the Apollo 16 site. In Lunar Science IV, p. 615-617. The Lunar Science Institute, Houston.

Rao M.N., Venkatesan T.R., Goswami J.N. and Nautiyal C.M. (1979) Solar cosmic ray produced neon and argon isotopes and particle tracks in Apollo 16 soils and rocks and their solar flare exposure ages. In Lunar and Planetary Science X, p. 1004-1006. The Lunar and Planetary Institute, Houston.

Reed G.W., Jr., Allen R.O., Jr., and Jovanovic S. (1977) Volatile metal deposits on lunar soils-relation to volcanism. Proc. Lunar Sci. Conf. 8th, p. 3917-3930.

Reed S.J.B. and Taylor S.R. (1974) Meteoritical metal in Apollo 16 samples. Meteoritics 9, p. 23-34.

Rees C.E. and Thode H.G. (1974) Sulfur concentrations and isotope ratios in Apollo 16 and 17 samples. Proc. Lunar Sci. Conf. 5th, p. 1963-1973.

Ridley I.W. and Adams M.-L. (1976) Petrologic studies of poikiloblastic textured rocks. In Lunar Science VII, p. 739-740. The Lunar Science Institute, Houston.

Roedder E. and Weiblen P.W. (1974) Petrology of clasts in lunar breccia 67915. Proc. Lunar Sci. Conf. 5th, p. 303-318.

Roedder E. and Weiblen P. (1977a) Shocked glass veins in some lunar and meteoritic samples--their nature and possible origin. Proc. Lunar Sci. Conf. 8th, p. 2593-2615.

Roedder E. and Weiblen P.W. (1977b) Barred olivine "chondrules" in lunar spinel troctolite 62295. Proc. Lunar Sci. Conf. 8th, p. 2641-2654.

Rose H.J., Jr., Cuttitta F., Berman S., Carron M.K., Christian R.P., Dwornik E.J., Greenland L.P. and Ligon D.T., Jr. (1973) Compositional data for twenty-two Apollo 16 samples. Proc. Lunar Sci. Conf. 4th, p. 1149-1158.

Rose H.J., Jr., Baedecker P.A., Berman S., Christian R.P., Dwornik E.J., Finkelman R.B. and Schnepfe M.M. (1975) Chemical composition of rocks and soils returned by the Apollo 15, 16, and 17 missions. Proc. Lunar Sci. Conf. 6th, p. 1363-1373.

Rosholt J.N. (1974) Isotopic composition of thorium in lunar samples. In Lunar Science V, p. 648-650. The Lunar Science Institute, Houston.

Runcorn S.K., Collinson D.W. and Stephenson A. (1974) Magnetic properties of Apollo 16 and 17 rocks. In Lunar Science V, p. 653-654. The Lunar Science Institute, Houston.

Ryder G. and Norman M. (1978) Catalog of pristine non-mare materials, part II. Anorthosites. JSC publication 14603, Lunar Curatorial Facility, Johnson Space Center, Houston. 86 pp.

Sato M. (1976) Oxygen fugacity values of some Apollo 16 and 17 rocks. In Lunar Science VII, p. 758-760. The Lunar Science Institute, Houston.

Schaal R.B., Hörz F. and Gibbons R.V. (1976) Shock metamorphic effects in lunar microcraters. Proc. Lunar Sci. Conf. 7th, p. 1039-1054.

Schaal R.B., Fryer K.H. and Hörz F. (1979) Petrography and composition of large lunar glass objects. In Papers Presented to the Conference on the Lunar Highlands Crust, p. 135-137. The Lunar and Planetary Institute, Houston.

Schaeffer G.A. and Schaeffer O.A. (1977) ^{39}Ar-^{40}Ar ages of lunar rocks. Proc. Lunar Sci. Conf. 8th, p. 2253-2300.

Schaeffer J. (1974) An electron microprobe analysis of Apollo 16 breccia 60255,78. B.A. Thesis, Princeton University. 86 pp.

Schaeffer J. and Hollister L.S. (1975) The petrology of two coarse-grained clasts in breccia sample 60255. In Lunar Science VI, p. 705-706. The Lunar Science Institute, Houston.

Schaeffer O.A. and Husain L. (1974) Chronology of lunar basin formation. Proc. Lunar Sci. Conf. 6th, p. 1541-1555.

Schaeffer O.A., Husain L. and Schaeffer G.A. (1976) Ages of highlands rocks: the chronology of lunar basin formation revisited. Proc. Lunar Sci. Conf. 7th, p. 2067-2092.

Schaeffer O.A., Bence A.E. and Eichhorn G. (1978) Ancient clasts in a 4.0 G.y. breccia: laser ^{39}Ar-^{40}Ar analysis of 65015. In Lunar and Planetary Science IX, p. 1004-1006. The Lunar and Planetary Institute, Houston.

Schaeffer O.A., Bence A.E. and Eichhorn G. (1979) Are there ancient clasts in lunar highland rocks? In Papers Presented to the Conference on the Lunar Highlands Crust, p. 138-140. The Lunar and Planetary Institute, Houston.

Schonfeld E. (1976) Chronology of the early lunar crust. Proc. Lunar Sci. Conf. 7th, p. 2093-2105.

Schwerer F.C., Huffman G.P., Fisher R.M. and Nagata T. (1973) Electrical conductivity of lunar surface rocks at elevated temperatures. Proc. Lunar Sci. Conf. 4th, p. 3151-3166.

Schwerer F.C., Huffman G.P., Fisher R.M. and Nagata T. (1974) Electrical conductivity of lunar surface rocks: laboratory measurements and implications for lunar interior temperatures. Proc. Lunar Sci. Conf. 5th, p. 2673-2687.

Schwerer F.C. and Nagata T. (1976) Ferromagnetic-superparamagnetic granulometry of lunar surface materials. Proc. Lunar Sci. Conf. 7th, p. 759-778.

Sclar C.B., Bauer J.F., Pickart S.J. and Alperin H.A. (1973) Shock effects in experimentally shocked terrestrial ilmenite, lunar ilmenite of rock fragments in 1-10 mm fines (10085,19), and lunar rock 60015,127. Proc. Lunar Sci. Conf. 4th, p. 841-859.

Sclar C.B. and Bauer J.F. (1974) Shock-induced melting in anorthositic rock 60015 and a fragment of anorthositic breccia from the "picking pot" (70052). Proc. Lunar Sci. Conf. 5th, p. 319-336.

Scoon J.H. (1974) Chemical analysis of lunar samples from the Apollo 16 and 17 collections. In Lunar Science V, p. 690-692. The Lunar Science Institute, Houston.

Silver L.T. (1973) Uranium-thorium-lead isotopic characteristics in some regolithic materials from the Descartes region. In Lunar Science IV, p. 672-674. The Lunar Science Institute, Houston.

Simonds C.H., Warner J.L. and Phinney W.C. (1973) Petrology of Apollo 16 poikilitic rocks. Proc. Lunar Sci. Conf. 4th, p. 613-632.

Simonds C.H., Warner J.L., Phinney W.C. and McGee P.E. (1976) Thermal model for impact breccia lithification: Manicouagan and the moon. Proc. Lunar Sci. Conf. 7th, p. 2509-2528.

Simmons G., Siegfried R., Richter D. and Schotz J. (1974) Estimating peak shock pressures for lunar rocks. In Lunar Science V, p. 709-711. The Lunar Science Institute, Houston.

Simmons G., Siegfried R. and Richter D. (1975) Characteristics of micro-cracks in lunar samples. Proc. Lunar Sci. Conf. 6th, p. 3227-3254.

Smith J.V. and Steele I.M. (1974) Intergrowths in lunar and terrestrial anorthosites with implications for lunar differentiates. Am. Mineralogist 59, p. 673-680.

Sondergeld C.H., Granryd L.A. and Spetzler H.A. (1979) Compressional velocity measurements for a highly fractured lunar anorthosite. In Lunar and Planetary Science X, p. 1143-1145. The Lunar and Planetary Institute, Houston.

Stauber M.C., Padawer G.M., Brandt W., D'Agostino M.D., Kamykowski E. and Young D.A. (1973) Nuclear microprobe analysis of solar proton implantation profiles in lunar rock profiles. Proc. Lunar Sci. Conf. 4th, p. 2189-2201.

Steele I.M. and Smith J.V. (1973) Mineralogy and petrology of some Apollo 16 rocks and fines: general petrologic model of the moon. Proc. Lunar Sci. Conf. 4th, p. 519-536.

Steele I.M. and Smith J.V. (1975) Minor elements in olivine as a petrologic indicator. Proc. Lunar Sci. Conf. 6th, p. 451-467.

Stephenson A. and Collinson D.W. (1974) Lunar magnetic field paleointensities determined by an anhysteretic remanent magnetization method. Earth Planet. Sci. Lett. 23, p. 220-228.

Stephenson A., Collinson D.W. and Runcorn S.K. (1974) Lunar magnetic field palaeointensity determinations on Apollo 11, 16, and 17 rocks. Proc. Lunar Sci. Conf. 5th, p. 2859-2871.

Stephenson A., Runcorn S.K. and Collinson D.W. (1975) On changes in the intensity of the ancient lunar magnetic field. Proc. Lunar Sci. Conf. 6th, p. 3049-3062.

Stephenson A., Runcorn S.K. and Collinson D.W. (1977) Paleointensity estimates from lunar samples 10017 and 10020. Proc. Lunar Sci. Conf. 8th, p. 679-687.

Stettler A., Eberhardt P., Geiss J., Grögler N. and Maurer P. (1973) Ar^{39}-Ar^{40} ages and Ar^{37}-Ar^{38} exposure ages of lunar rocks. Proc. Lunar Sci. Conf. 4th, p. 1865-1888.

Stettler A., Eberhardt P., Geiss J., Grögler N. and Maurer P. (1974) Sequence of terra rock formation and basaltic lava flows on the moon. In Lunar Science V, p. 738-740. The Lunar Science Institute, Houston.

Stöffler D., Schulien S. and Ostertag R. (1975) Rock 61016: multiphase shock and crystallization history of a polymict troctolitic-anorthositic breccia. Proc. Lunar Sci. Conf. 6th, p. 673-692.

Storzer D., Poupeau G. and Krätschmer W. (1973) Track-exposure and formation ages of some lunar samples. Proc. Lunar Sci. Conf. 4th, p. 2363-2377.

Streckeisen A.L. (1973) Plutonic rocks: classification and nomenclature recommended by the IUGS Subcommission on the Systematics of Igneous Rocks. Geotimes 18, p. 26-30.

Sugiura N., Strangway D.W. and Pearce G.W. (1978) Heating experiments and paleointensity determinations. Proc. Lunar Planet. Sci. Conf. 9th, p. 3151-3163.

Takeda H. (1973) Inverted pigeonites from a clast of rock 15459 and basaltic achondrites. Proc. Lunar Sci. Conf. 4th, p. 875-885.

Takeda H., Miyamoto M., Ishii T. and Reid A.M. (1976) Characterization of crust formation on a parent body of achondrites and the moon by pyroxene crystallography and chemistry. Proc. Lunar Sci. Conf. 7th, p. 3535-3548.

Takeda H., Miyamoto M. and Ishii T. (1979) Pyroxenes in early crustal cumulates found in achondrites and lunar highlands rocks. Proc. Lunar Planet. Sci. Conf. 10th, p. 1095-1107.

Taylor G.J. and Mosie A.B. (1979) Breccia guidebook no. 3, 67915. JSC publication no. 16242, Curatorial Branch publication no. 50, Johnson Space Center, Houston. 43 pp.

Taylor G.J., Warner R., Keil K., Geiss J., Martî K., Roedder E., Schmitt R.A. and Weiblen P. (1979) The 67915 consortium: searching for pieces of the ancient lunar crust. In Papers Presented to the Conference on the Lunar Highlands Crust, p. 169-171. The Lunar and Planetary Institute, Houston.

Taylor G.J., Warner R.D., Keil K., Ma M.-S. and Schmitt R.A. (1980b) Silicate liquid immiscibility, evolved lunar rocks and the formation of KREEP. Proc. of the Conference on the Lunar Highlands Crust (Pergamon Press), p. 339-352.

Taylor G.J. Wentworth S., Warner R.D., Keil K., Ma M.-S. and Schmitt R.A. (1980a) Major-element compositional variations of KREEP. In Lunar and Planetary Science XI, p. 1131-1133. The Lunar and Planetary Institute, Houston.

Taylor H.P., Jr. and Epstein S. (1973) O^{18}/O^{16} and Si^{30}/Si^{28} studies of some Apollo 15, 16, and 17 samples. Proc. Lunar Sci. Conf. 4th, p. 1657-1679.

Taylor L.A., McCallister R.H. and Sardi O. (1973a) Cooling histories of lunar rocks based on opaque mineral geothermometers. Proc. Lunar Sci. Conf. 4th, p. 819-828.

Taylor L.A., Mao H.K. and Bell P.M. (1973b) "Rust" in the Apollo 16 rocks. Proc. Lunar Sci. Conf. 4th, p. 829-839.

Taylor L.A., Mao H.K. and Bell P.M. (1974a) β-FeOOH, akaganeite, in lunar rocks. Proc. Lunar Sci. Conf. 5th, p. 743-748.

Taylor L.A., Mao H.K. and Bell P.M. (1974b) Identification of the hydrated iron oxide mineral akaganeite in Apollo 16 lunar rocks. Geology 1, p. 429-432.

Taylor L.A., Misra K.C. and Walker B.M. (1976) Subsolidus reequilibration, grain growth, and compositional changes of native FeNi metal in lunar rocks. Proc. Lunar Sci. Conf. 7th, p. 837-857.

Taylor S.R. and Bence A.E. (1975) Evolution of the lunar crust. Proc. Lunar Sci. Conf. 6th, p. 1121-1141.

Taylor S.R., Gorton M.P., Muir P., Nance W.B., Rudowski R. and Ware N. (1973) Composition of the Descartes region, lunar highlands. Geochim. Cosmochim. Acta 37, p. 2665-2683.

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.

Tera F. and Wasserburg G.J. (1972) U-Th-Pb systematics in lunar highland samples from the Luna 20 and Apollo 16 missions. Earth Planet. Sci. Lett. 17, p. 36-51.

Tera F. and Wasserburg G.J. (1974) U-Th-Pb systematics on lunar rocks and inferences about lunar evolution and the age of the moon. Proc. Lunar Sci. Conf. 5th, p. 1571-1599.

Tera F., Papanastassiou D. and Wasserburg G.J. (1973) A lunar cataclysm at ∿3.95 AE and the structure of the lunar crust. In Lunar Science IV, p. 723-725. The Lunar Science Institute, Houston.

Tera F., Papanastassiou D.A. and Wasserburg G.J. (1974) Isotopic evidence for a terminal lunar cataclysm. Earth Planet. Sci. Lett. 22, p. 1-21.

Todd T., Richter D.A., Simmons G. and Wang H. (1973) Unique characterization of lunar samples by physical properties. Proc. Lunar Sci. Conf. 4th, p. 2639-2662.

Tsay F.-D. and Bauman A.J. (1975) Ferromagnetic resonance as a geothermometer for probing the thermal history of lunar samples. In Lunar Science VI, p. 821-823. The Lunar Science Institute, Houston.

Tsay F.D. and Bauman A.J. (1977) Implications of the occurrence of Fe^{3+} and Fe° in lunar samples. In Lunar Science VIII, p. 943-945. The Lunar Science Institute, Houston.

Tsay F.-D. and Live D.H. (1974) Ferromagnetic resonance studies of thermal effects on lunar metallic Fe phases. Proc. Lunar Sci. Conf. 5th, p. 2737-2746.

Tsay F.D. and Live D.H. (1976) Detection of paramagnetic Fe^{3+} and radiation damage centers in lunar soils. In Lunar Science VII, p. 870-872. 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.

Turner G., Cadogan P.H. and Yonge C.J. (1973) Argon selenochronology. Proc. Lunar Sci. Conf. 4th, p. 1889-1914.

Uhlmann D.R., Klein L., Kritchevsky G. and Hopper R.W. (1974) The formation of lunar glasses. Proc. Lunar Sci. Conf. 5th, p. 2317-2331.

Uhlmann D.R., Klein L.C. and Handwerker C.A. (1977) Crystallization kinetics, viscous flow, and thermal history of lunar breccia 67975. Proc. Lunar Sci. Conf. 8th, p. 2067-2078.

Uhlmann D.R., Handwerker C.A., Onorato P.I.K., Salomaa R. and Goncz D. (1978) The formation kinetics of lunar glasses. Proc. Lunar Planet. Sci. Conf. 9th, p. 1527-1536.

Ulrich D.R. and Weber J. (1973) Correlation of the thermal history of lunar and synthetic glass by DTA and x-ray techniques. In Lunar Science IV, p. 743-744. The Lunar Science Institute, Houston.

Vaniman D.T. and Papike J.J. (1981) The lunar highland melt rock suite. In Basaltic Volcanism (Pergamon Press), in press.

Venkatesan T.R. and Alexander E.C. (1976) $^{40}Ar-^{39}Ar$ study of a clast 12-1 from 67915. In Lunar Science VII, p. 894. The Lunar Science Institute, Houston.

Walker D., Longhi J., Grove T.L., Stolper E. and Hays J.F. (1973) Experimental petrology and origin of rocks from the Descartes Highlands. Proc. Lunar Sci. Conf. 4th, p. 1013-1032.

Walker R. and Yuhas D. (1973) Cosmic ray track production rates in lunar materials. Proc. Lunar Sci. Conf. 4th, p. 2379-2389.

Wang H., Todd T., Richter D. and Simmons G. (1973) Elastic properties of plagioclase aggregates and seismic velocities in the moon. Proc. Lunar Sci. Conf. 4th, p. 2663-2671.

Wänke H., Baddenhausen H., Driebus G., Jagoutz E., Kruse H., Palme H., Spettel B. and Teschke F. (1973) Multielement analyses of Apollo 15, 16, and 17 samples and the bulk composition of the moon. Proc. Lunar Sci. Conf. 4th, p. 1461-1481.

Wänke H., Palme H., Baddenhausen H., Dreibus G., Jagoutz E., Kruse H., Spettel B., Teschke F. and Thacker R. (1974) Chemistry of Apollo 16 and 17 samples: bulk composition, late stage accumulation and early differentiation of the moon. Proc. Lunar Sci. Conf. 5th, p. 1307-1335.

Wänke H., Palme H., Baddenhausen H., Dreibus G., Jagoutz E., Kruse H., Palme C., Spettel B., Teschke F. and Thacker R. (1975) New data on the chemistry of lunar samples: primary matter in the lunar highlands and the bulk composition of the moon. Proc. Lunar Sci. Conf. 6th, p. 1313-1340.

Wänke 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.

Wänke 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.

Warner J.L., Phinney W.C., Bickel C.E. and Simonds C.H. (1977) Feldspathic granulitic impactites and pre-final bombardment lunar evolution. Proc. Lunar Sci. Conf. 8th, p. 2051-2066.

Warner R.D., Planner H.N., Keil K., Murali A.V., Ma M.-S., Schmitt R.A., Ehmann W.D., James W.D., Jr., Clayton R.N. and Mayeda T.K. (1976a) Consortium investigation of breccia 67435. Proc. Lunar Sci. Conf. 7th, p. 2379-2402.

Warner R.D., Dowty E., Prinz M., Conrad G.H., Nehru C.E. and Keil K. (1976b) Catalog of Apollo 16 rake samples from the LM area and Station 5. Special publication no. 13, UNM Institute of Meteoritics, 87 pp.

Warner R.D., Taylor G.J. and Keil K. (1980) Petrology of 60035: evolution of a polymict ANT breccia. Proc. of the Conference on the Lunar Highlands Crust (Pergamon Press), p. 377-394.

Warren N. and Trice R. (1975) Correlation of elastic moduli systematics with texture in lunar materials. Proc. Lunar Sci. Conf. 6th, p. 3255-3268.

Warren N., Trice R., Soga N. and Anderson O.L. (1973) Rock physics properties of some lunar samples. Proc. Lunar Sci. Conf. 4th, p. 2611-2629.

Warren P.H. (1979) The quest for pristine nonmare rocks: a new crop of toisons d' or. In Lunar and Planetary Science X, p. 1301-1303. The Lunar and Planetary Institute, Houston.

Warren P.H. and Wasson J.T. (1977) Pristine nonmare rocks and the nature of the lunar crust. Proc. Lunar Sci. Conf. 8th, p. 2215-2235.

Warren P.H. and Wasson J.T. (1978) Compositional-petrographic investigation of pristine nonmare rocks. Proc. Lunar Planet. Sci. Conf. 9th, p. 185-217.

Warren P.H. and Wasson J.T. (1979) The compositional-petrographic search for pristine nonmare rocks: third foray. Proc. Lunar Planet. Sci. Conf. 10th, p. 583-610.

Warren P.H. and Wasson J.T. (1980) Further foraging for pristine non-mare rocks: Correlations between geochemistry and longitude. Proc. Lunar Planet. Sci. Conf. 11th, in press.

Wasson J.T., Chou C.-L., Robinson K.L. and Baedecker P.A. (1975) Siderophiles and volatiles in Apollo 16 rocks and soils. Geochim. Cosmochim. Acta 39, p. 1475-1485.

Wasson J.T., Warren P.H., Kallemeyn G.W., McEwing C.E., Mittlefehldt D.W. and Boynton W.V. (1977) SCCRV, a major component of highland rocks. Proc. Lunar Sci. Conf. 8th, p. 2237-2252.

Weber H.W. and Schultz L. (1978) Rare gases in matrix and clast samples of 60016. In Lunar and Planetary Science IX, p. 1234-1236. The Lunar and Planetary Institute, Houston.

Weeks R.A. (1973a) Paramagnetic states of Apollo 16 plagioclases: Fe^{3+}, Ti^{3+}, radiation effects. In Lunar Science IV, p. 775. The Lunar Science Institute, Houston.

Weeks R.A. (1973b) Ferromagnetic phases of lunar fines and breccias: electron magnetic resonance spectra of Apollo 16 samples. Proc. Lunar Sci. Conf. 4th, p. 2763-2781.

Weiblen P.W. and Roedder E. (1973) Petrology of melt inclusions in Apollo samples 15598 and 62295, and the clasts in 67915 and several lunar soils. Proc. Lunar Sci. Conf. 4th, p. 681-703.

Weiblen P.W., Day W.C., and Miller J.D. (1980) Significance of major and minor element variations in plagioclase in highlands breccia 67915. In Lunar and Planetary Science XI, p. 1228-1230. The Lunar and Planetary Institute, Houston.

Wiesmann H. and Hubbard N.J. (1975) A compilation of the lunar sample data generated by the Gast, Nyquist, and Hubbard lunar sample P.I.-ships. Manned Spacecraft Center, Houston. 50 pp.

Wilshire H.G. and Moore H.J. (1974) Glass-coated lunar rock fragments. J. Geol. 82, p. 403-417.

Winzer S.R., Nava D.F., Meyerhoff M., Lindstrom D.J., Lum R.K.L., Lindstrom M.M., Schuhmann P., Schuhmann S. and Philpotts J.A. (1977) The petrology and geochemistry of impact melts, granulites, and hornfelses from consortium breccia 61175. Proc. Lunar Sci. Conf. 8th, p. 1943-1966.

Wrigley R.C. (1973) Radionuclides at Descartes in the central highlands. Proc. Lunar Sci. Conf. 4th, p. 2203-2208.

Yaniv A., Marti K., and Reedy R.C. (1980) The solar cosmic-ray flux during the last two million years. In Lunar and Planetary Science XI, p. 1291-1293. The Lunar and Planetary Institute, Houston.

Yokoyama Y., Reyss J.L. and Guichard F. (1974) ^{22}Na-^{26}Al chronology of lunar surface processes. Proc. Lunar Sci. Conf. 5th, p. 2231-2247.

Yuhas D. and Walker R. (1973) Long term behavior of VH cosmic rays as observed in lunar rocks. In 13th International Cosmic Ray Conference Papers, p. 1116-1121. University of Denver.

Zellner B., Leake M., Lebertre T., Duseaux M. and Dollfus A. (1977) The asteroid albedo scale. I. Laboratory polarimetry of meteorites. Proc. Lunar Sci. Conf. 8th, p. 1091-1110.