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BRECCIA GUIDEBOOK NO. 6
67435

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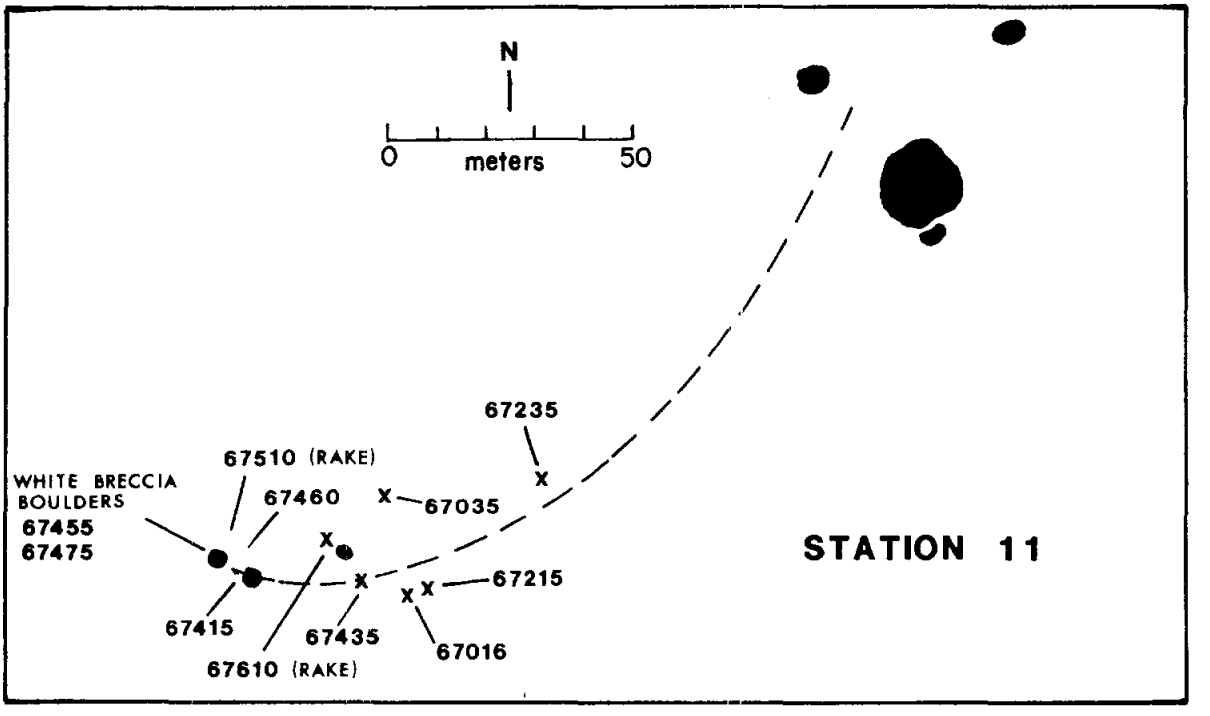
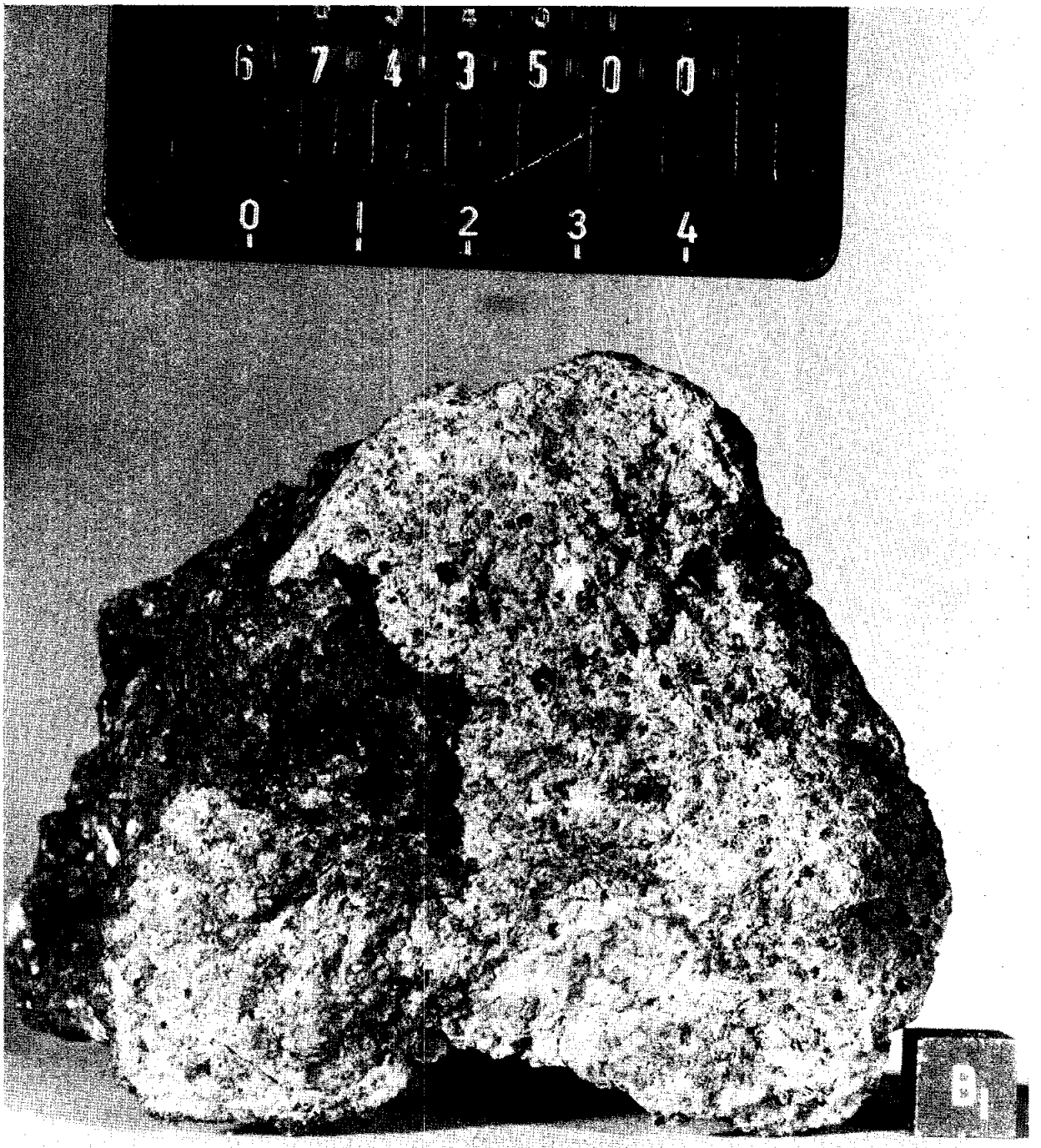


Figure 1

Figure 2. Photograph of 67435 before processing. Note the glass coating covering part of the B surface. The glass coating occurs mostly on the top N-E portion of the breccia.



GENERAL INTRODUCTION TO BRECCIA 67435

Geologic setting

Breccia 67435 was collected on the southeast rim of North Ray Crater at Station 11 (Fig. 1) in a relatively smooth area that slopes up towards boulders of white breccias. The sampling area contains few meter-sized boulders and only one crater (1-2 m across) is visible in photographs (Apollo Lunar Geology Investigation Team, 1972). The sample was perched on the surface and appears to be typical of rocks in the immediate area, although it is among the most angular. The Apollo Lunar Geology Investigation Team (1972) concluded that the rock was ejected from North Ray Crater.

Macroscopic description

Dark gray to black, vesicular glass covers about half of breccia 67435 (Fig. 2). The glass surface has numerous ridges and depressions. Although mostly dark gray to black, some areas are green, especially near vesicles. The differences in color are due to the degree to which the glass has crystallized or devitrified; the darker areas contain the most crystallites. The glass contains numerous white to light-gray, feldspathic clasts. These clasts vary in grain size. Widely scattered zap-pits occur on both the glass coating and exposed portions of the host breccia. The breccia portion of 67435 consists of a fine-grained, light-gray microgranular matrix that contains abundant, subrounded clasts of gray, aphanitic rock and rarer clasts of coarser-grained anorthosite and spinel troctolite. The aphanitic clasts make up more of the rock than does the light matrix. The light matrix and the dark clasts are smeared out, sometimes making it difficult to determine which is matrix and which is clast. In general, however, the light-gray material clearly forms the matrix in which the darker, aphanitic clasts are embedded.

Petrology

The only detailed description of 67435 is given by Warner et al. (1976). Their results form the basis of the following brief account.

Rock 67435 has an overall clastic texture (Fig. 3a) and consists of two major lithologies. One corresponds to the gray, aphanitic clasts visible in hand specimen. These clasts, which Warner et al. (1976) call the "dark-matrix lithology," have a fine-grained poikilitic texture. The gray clasts are separated by zones of lighter-colored material (Fig. 3b). The lighter-colored zones are made of numerous clasts of a more feldspathic lithology. The matrices of the gray clasts contain oikocrysts of olivine (Fa_{72-79}) and low Ca-pyroxene that enclose laths of plagioclase (Fig. 3c). The abundance of olivine as oikocrysts sets the gray clasts in 67435 apart from most but not all Apollo 16 poikilitic rocks, which generally have much more low-Ca pyroxene than olivine. Modal analyses indicate that the gray lithology contains $\sim$ 65% plagioclase, 34% olivine + low-Ca pyroxene and $\sim$ 1% ilmenite (which occurs in widely disseminated grains). Its bulk composition (determined by broad-beam microprobe analysis) plots on the olivine-plagioclase cotectic in the olivine-plagioclase silica pseudo-ternary liquidus diagram (Warner et al., 1976). The gray, poikilitic clasts contain clasts of other lithologies. These include mineral clasts (plagioclase, olivine, and metal), recrystallized ANT clasts, and feldspathic breccia. Most plagioclase clasts are < 200 μm across, but a few are larger, up to 0.5x0.7 mm. Olivine clasts are less abundant than plagioclase clasts and are < 100 μm across. They range in composition from Fo_{74} to Fo_{88}; compositional zoning in the most forsteritic olivines indicates some reaction with the more Fe-rich matrix of the gray lithology. Metal grains contain 0.5 to 1.1 wt.% Co and 4-6 wt.% Ni, typical of impact

melts from the lunar highlands. ANT clasts are typical of granulitic ANT; they have microgranular textures (Fig. 3d) and uniform mineral compositions. The one feldspathic breccia described by Warner et al. (1976) is composed of equant crystals of plagioclase (∿ 88% of the rock) with irregularly-shaped crystals of low-Ca pyroxene and olivine residing between plagioclase grains (Fig. 3e). This lithology may be polymict: olivine ranges in composition from Fo_{58} to Fo_{74}.

The dark clasts are separated by lighter-colored feldspathic material (Fig. 3b). The contacts between the feldspathic lithology and the gray clasts are frequently gradational (Fig. 3f). The feldspathic areas are composed of numerous small (< 1 mm), subrounded clasts that have similar compositions. The clasts contain 80-90% plagioclase that occurs in subequant grains surrounded by micropoikilitic pyroxene or olivine. The feldspathic lithology contains clasts of olivine and low-Ca pyroxene.

Other types of clasts are rare. The most important of these are spinel troctolites (Prinz et al., 1973). Although no trace siderophile-element data are available as yet, petrography and metal compositions strongly suggest that these clasts are pieces of pristine lunar rocks. In hand specimen, spinel troctolites are characterized by the presence of pink spinel, pale-green olivine, and colorless, transparent plagioclase (Fig. 4A). In thin sections, they display a cumulate texture with subhedral spinel and equant, anhedral olivine (Fo_{92}) surrounded poikilitically by plagioclase (An_{97}); spinels contain 85 mol % of the Mg Al_2O_4 component, but also contain ∿ 8 wt.% Cr_2O_3 and ∿ 7 wt.% FeO (Prinz et al., 1973).

Warner et al. (1976) observed a gray clast that was exceptionally large for 67435, ∿ 1.5 cm across. Macroscopically, it is a lighter gray than most

Figure 3. Photomicrographs of 67435 (from Warner et al., 1976).

a) Reflected light view of ,36 showing clastic nature (2 mm across field).

b) Transmitted light view of ,36 showing light-colored lithology separating clasts of dark lithology (2.5 mm. across).

c) Texture of dark lithology (reflected light, sample ,12; 0.2 mm across); laths of plagioclase enclosed by single crystal of olivine.

d) Recrystallized ANT clast within dark lithology (,12; 1 mm across).

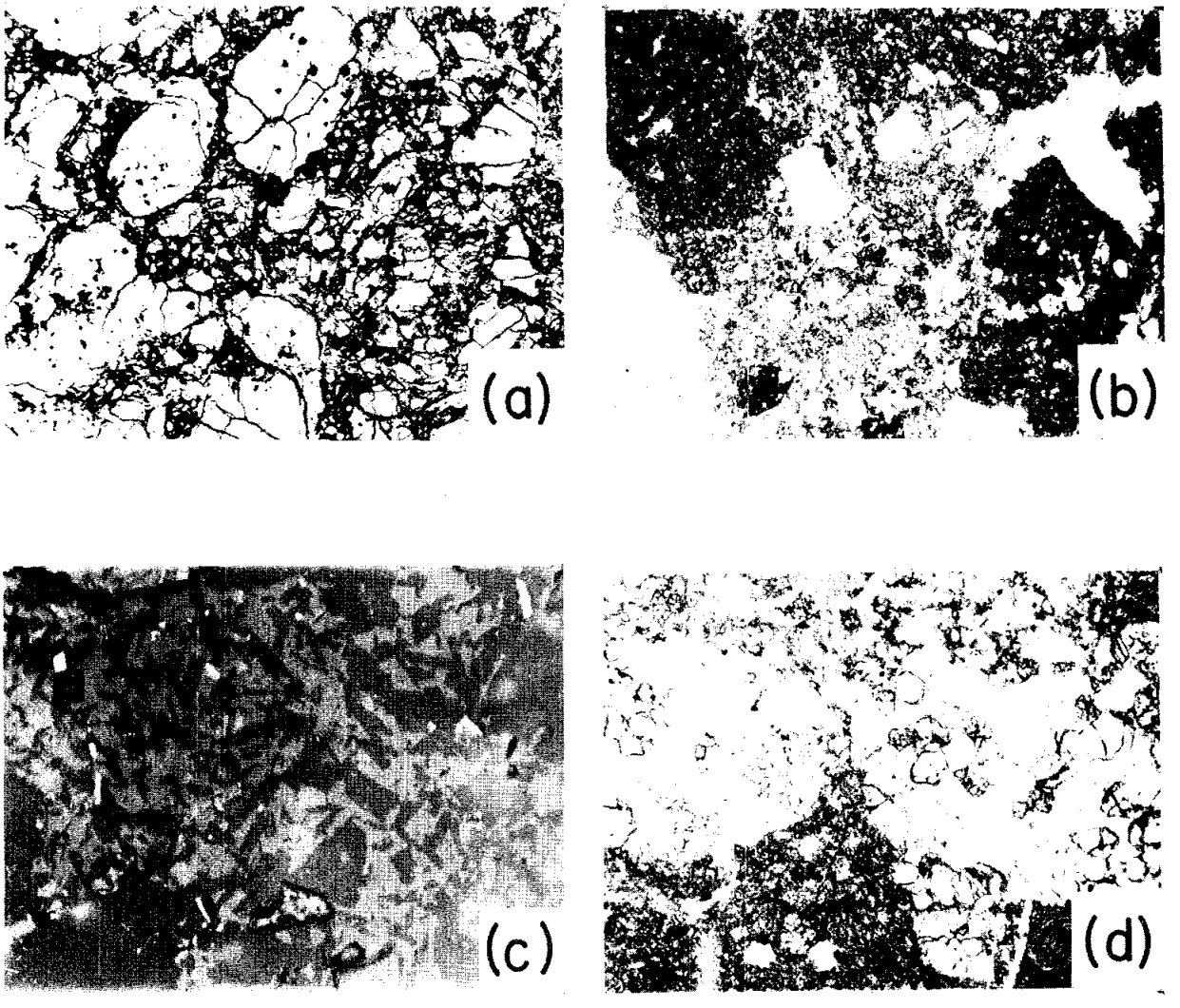
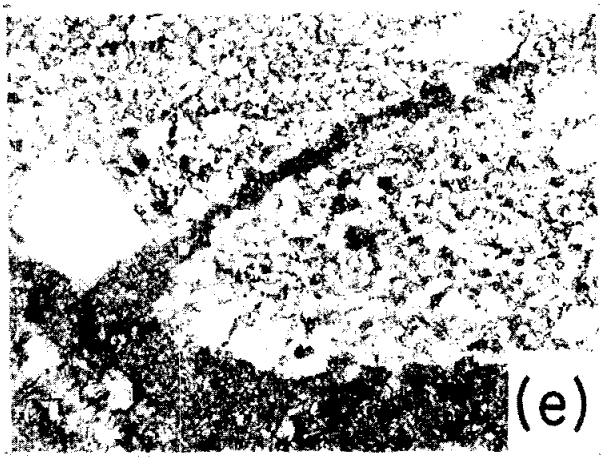


Figure 3 (Continued). Photomicrographs of 67435 (from Warner et al., 1976).

e) Feldspathic breccia clast enclosed in dark lithology (,12; 1 mm across).

f) Transition from dark lithology (left) to light lithology which makes up matrix of 67435 (,36; reflected light; 0.2 mm across).



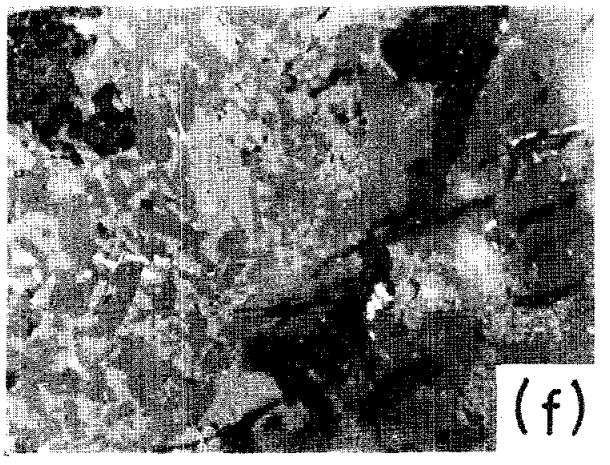


Figure 4. A) Hand specimen of spinel troctolite clast in 67435: clast is about 1 cm across.

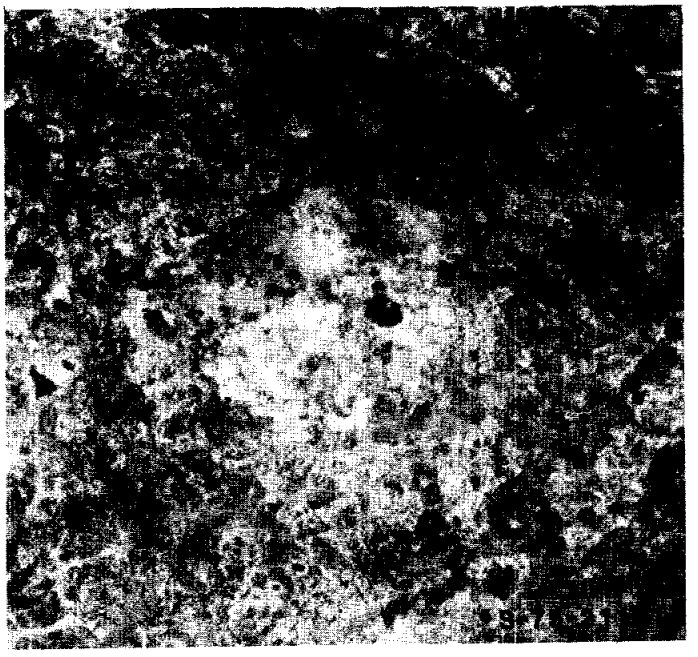
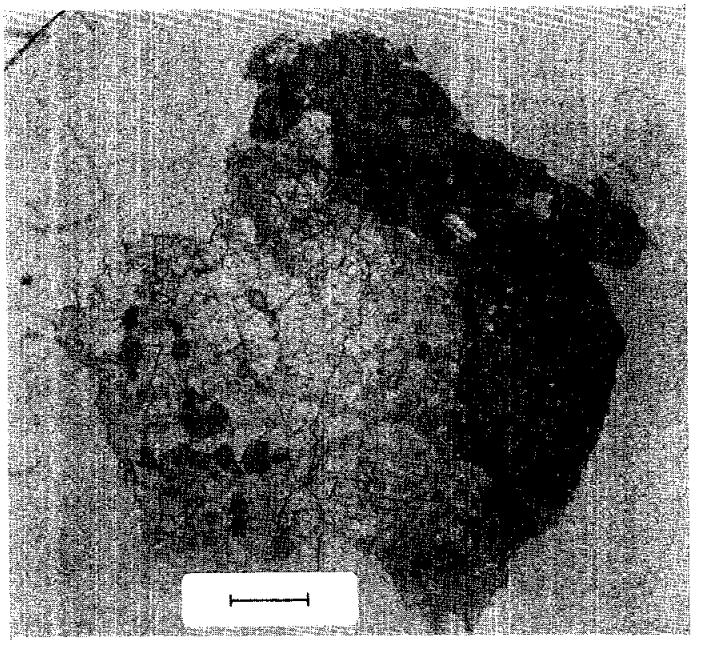


Figure 4. B) Thin section of spinel troctolite (ST1 in 67435,14). Dark band on right is poikilitic melt rock. Dark equant mineral within troctolite is pink spinel. Scale bar is 1 mm.



gray clasts. In thin sections, the clast has a high feldspar content (∿ 88% modal plagioclase) and a recrystallized texture. Plagioclase grains are typically 10-60 μm. The larger grains have a narrow range in composition (An_{95-98}), whereas the smaller ones have more variable compositions, An_{88-98}. Olivine (Fo_{49-63}) is more abundant than low-Ca pyroxene. Ilmenite (MgO of 2.8-4.1 wt.%), metal (∿ 7 wt.% Ni and 1 wt.% Co), and troilite constitute a total of ∿ 0.2% of the clast. Some lithic fragments are present; these include a granulitic ANT clast and two melt rocks.

The glassy coating of breccia 67435 ranges from clear, colorless glass that has a flow-banded structure (caused by linear arrays of submicron-sized spherules of metallic Ni-Fe and possibly troilite) to substantially devitrified (or quench-crystallized). Plagioclase compositions in the devitrified areas have a restricted range in composition, An_{93-95}. No mineral clasts are present in the clear glass, but a few clasts of plagioclase (An_{88-99}) and olivine (Fo_{61-84}) occur in the devitrified areas.

Chemical compositions

Bulk compositions (Table 1) of 67435 indicate that it is feldspathic (∿ 65% normative plagioclase) but has a KREEP REE-pattern (Fig. 5); chondrite-normalized La/Lu is 2.4 compared with 2.2 in KREEP (Warren and Wasson, 1979). This is consistent with nondestructive measurements made on the entire sample of 67435 by Clark and Keith (1973); these authors report that 67435,0 contains 3.6 ppm Th, 1.09 ppm U, and 0.147 ppm K. The glass coating is generally richer in normative plagioclase and lower in REE than the bulk sample. Although one analysis of the glass is very similar in composition to the host breccia (Table 1, column E), Warner et al. (1976) point out that the sample was not pure glass coating but instead contained a significant contribution from gray, aphanitic clasts.

The large recrystallized clast contains more Al_2O_3 (30 wt.%) than the other lithologies analyzed by Warner et al. (1976). It also has lower REE contents, lower chondrite-normalized La/Lu (1.85), and lower contents of siderophile elements (Table 1).

Although variable, contents of siderophile elements are high in 67435, indicating substantial meteorite contamination. Furthermore, there may be two distinct compositions of meteorite components: three of the four samples (glass coating and host breccia) for which Ir and Au data are available have Ir/Au of > 1, whereas the other sample (glass coating) has Ir/Au of 0.2. The fact that the samples of the glass coating are so variable in Ir/Au suggests that the siderophile elements are distributed heterogeneously throughout the glass coating.

Cripe and Moore (1975) measured a total S content of 670 ppm in a sample of gray, aphanitic material and Moore and Lewis (1976) measured total N (72 ppm) and C (44 ppm) contents in a sample of 67435 host.

TABLE 1. CHEMICAL ANALYSES OF LITHOLOGIES IN 67435

wt.%	A	B	C	D	E	F	G	H
SiO_2	47.9	45.2	46.0	37.5	-	45.8	46.0	48.4
TiO_2	0.81	0.66	0.34	0.05	<0.2	0.96	0.92	0.84
Al_2O_3	23.4	25.7	30.1	15.9	20.6	22.3	26.4	26.6
Cr_2O_3	0.14	0.10	0.07	0.49	1.0	0.21	0.23	0.10
FeO	6.9	5.0	3.8	5.8	5.3	7.7	5.4	6.1
MnO	0.08	0.07	0.05	0.16	0.05	0.08	0.06	0.06
MgO	9.3	6.8	3.6	33.7	29.6	10.5	8.2	7.5
CaO	13.5	15.2	17.9	6.2	7.1	13.1	15.2	15.3
Na_2O	0.50	0.52	0.51	0.14	0.14	0.52	0.57	0.57
K_2O	0.16	0.13	0.06	0.04	0.01	0.20	0.23	0.11
P_2O_5	-	0.11	-	0.02	-	-	-	-
ppm								
Sc	11.0	-	7.7	-	1.9	10.7	9.1	8.8
V	30	-	18	-	101	26	60	26
Sr	-	170	-	-	-	-	-	-
Rb	-	4.5	-	-	-	-	-	-
Ba	-	163	-	-	18	-	-	-
La	21.2	-	2.4	-	1.3	23.0	12.2	11.8
Ce	57	35.7	6	-	-	64	37	33
Nd	-	23.8	-	-	-	-	-	-
Sm	9.6	6.61	1.3	-	0.63	9.5	5.7	5.5
Eu	1.40	1.31	1.03	-	0.33	1.52	1.44	1.34
Gd	-	8.14	-	-	-	-	-	-
Tb	1.9	-	0.28	-	0.10	2.2	1.2	1.3
Dy	12	8.85	1.7	-	0.6	13	8	7
Er	-	5.41	-	-	-	-	-	-
Yb	6.7	4.87	0.98	-	0.38	6.7	4.2	3.8
Lu	0.88	0.70	0.13	-	0.05	0.89	0.58	0.52
Zr	279	-	-	-	-	361	103	201
Hf	6.8	-	0.85	-	0.37	7.9	4.1	4.3
Ta	0.88	-	0.12	-	0.04	0.80	0.50	0.62
Th	2.0	-	0.3	-	-	1.8	1.7	1.6
Co	39	-	6	-	57	59	17	41
Ni	620	-	31	-	1230	1080	400	760
Ir	12	-	-	-	-	41	10	24
Au	13	-	-	-	5	32	43	19

Footnotes:

A) 67435,36; host breccia containing dark clasts in light matrix (Warner et al., 1976).
B) 67435,40; host breccia containing dark clasts in light matrix (Lindstrom et al., 1977). Analysis also includes 9.69 ppm Li.
C) 67435,30; light-gray clast (feldspathic recrystallized breccia clast) (Warner et al., 1976).
D) 67435,14; spinel troctolite clast (Prinz et al., 1973).
E) 67435,77; spinel troctolite clast (Ma et al., 1981).
F) 67435,25; dark-green glass coating (Warner et al., 1976).
G) 67435,26; light-green glass coating (Warner et al., 1976).
H) 67435,27; gray glass coating (Warner et al., 1976).

Figure 5. Rare-earth abundances (normalized to chondrites) in 67435 lithologies. Data sources given in Table 1.

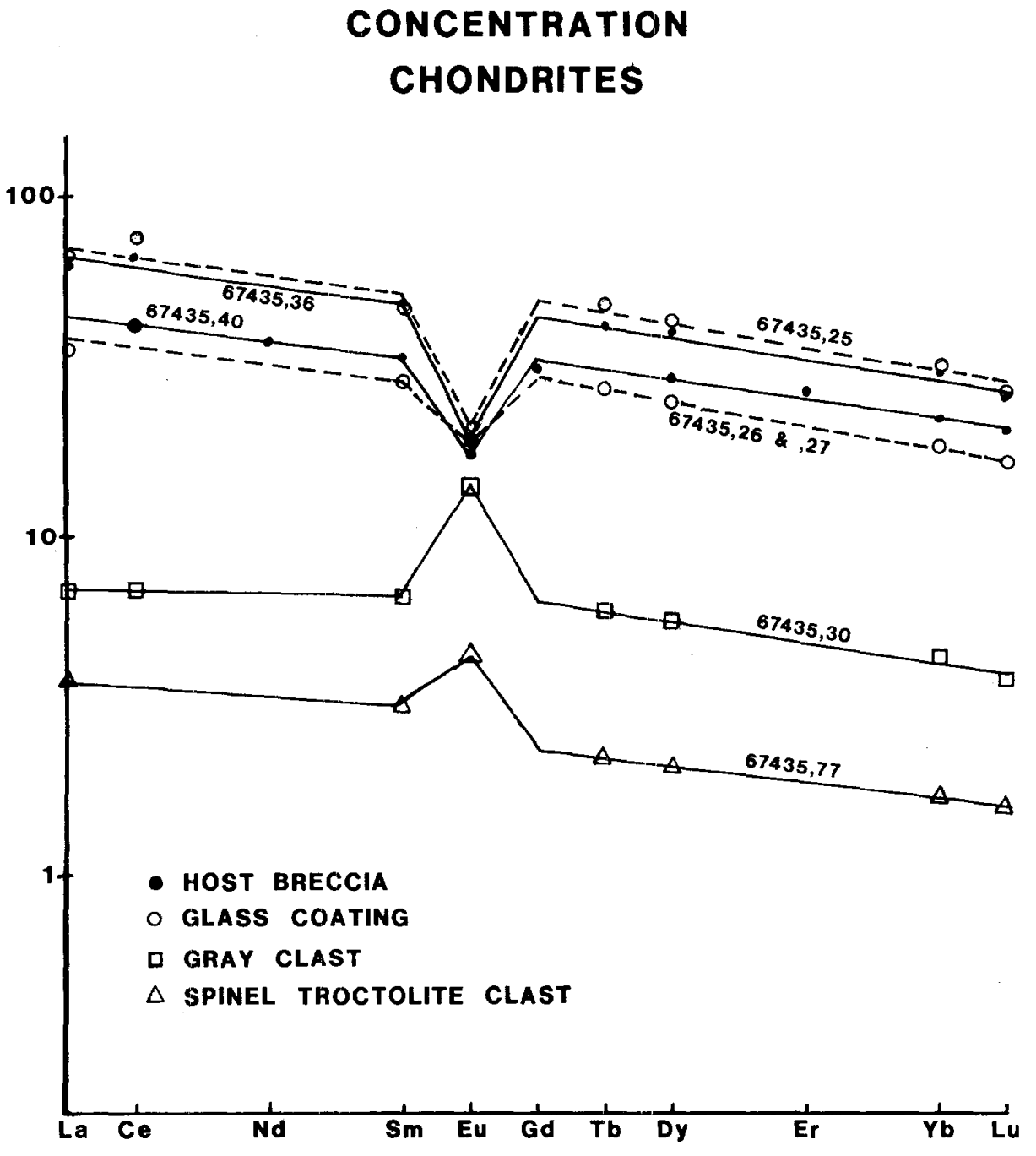


Figure 5

The spinel troctolite stands out because of its high MgO (30 wt.%) contents. Trace element abundances have been reported by Ma et al. (1981). The REE pattern is similar to those of pristine troctolites 76535, 76335, 73146 and 76536, except for a lower Eu content (0.33 ppm vs. 0.73-0.99 ppm) in the other troctolites. The lower Eu content may be due to a lower plagioclase abundance in the sample analyzed. Like other Mg-rich plutonic rocks, the 67435 spinel troctolite has subchondritic Ti/Sm and Sc/Sm ratios.

Oxygen isotopic analyses were made on a sample (67435,22) of the host breccia. Results show $\delta^{18}O=+5.6^{0}/oo$ and $\delta^{17}O=+2.8^{0}/oo$, both relative to SMOW (Warner et al., 1976). Both values are within the range reported for other Apollo 16 breccias.

Age Data

Dominik and Jessberger (1978) studied five samples separated from 67435 (Table 2). Plagioclase clasts yielded good plateaux and ages of ∿ 4.4 Gyr. These old ages suggest that 67435 contains remnants of ancient lunar crustal rocks and that the final assembly of the rock did not involve notably high temperatures. The presence of old material also gives rise to optimism that spinel troctolite clasts can be successfully dated.

Analyses of two dark-gray clasts yielded ages of 3.96 and 4.04 Gyr, but an analysis of the light clast (representing the matrix of 67435) produced no plateau and yielded a rough age estimate of 3.8 Gyr. In all cases, the lowest-temperature fractions have apparent ages of ∿ 1 Gyr. Dominik and Jessberger (1978) note that there are two ways of explaining these data. In one model the rock was assembled in one event ∿ 3.9 Gyr ago, but has since suffered some gas loss; the gas loss is reflected in a gradual rise to a plateau with successively higher-temperature gas extractions. The second model calls for assembly of the breccia much more recently; the ∿ 1 Gyr ages of the low-temperature gas fractions represent an upper limit to the time when the rock was compacted. Existing data do not allow for an unambiguous choice between these two possibilities. It is clear, however, that some components in 67435 formed ∿ 4.4 Gyr ago. Others (the dark-gray clasts) formed ∿ 3.9-4.0 Gyr ago, but possibly in separate events.

Exposure ages of clasts in 67435 (Table 2) cluster around 50 Myr., the age of North Ray Crater. This is consistent with the activities of other radionuclides such as ^{22}Na and ^{26}Al (Clark and Keith, 1973; Yokoyama et al., 1974).

TABLE 2. ^{40}Ar-^{39}Ar AGE DATA ON SAMPLES OF BRECCIA 67435
(Dominik and Jessberger, 1978)

Sample No.	Exposure Age (Myr)	^{40}Ar-^{39}Ar Age (Gyr)
67435,33-E[1]	52.1 ± 2.6	∿3.8 ± 0.1 (no plateau)
67435,33-B[2]	51.2 ± 2.3	3.96 ± 0.01
67435,33-C[2]	46.1 ± 1.9	4.04 ± 0.03
67435,33-A[3]	44.9 ± 2.6	4.43 ± 0.05
67435,33-D[4]	48.1 ± 3.0	4.41 ± 0.04

1) Light-gray matrix of the rock (42.1 mg).

2) Dark-gray clasts with poikilitic textures (42.8 mg, 57.8 mg).

3) Single plagioclase clast (9.3 mg).

4) Several plagioclase clasts (15 mg).

DESCRIPTIONS OF AVAILABLE SAMPLES

67435,4 (1.110 g)

This sample consists of fragments of the glass coating. Two pieces are 5-10 mm in size (Fig. 6); the other two are 1-2 mm across. The two largest pieces are dark, fine-grained to glassy, and contain white clasts. The white clasts appear to be shocked plagioclase. No clear, greenish glass is visible.

67435,5 (11.317 g)

This split consists mostly of two large pieces (Fig. 7). Each contains a patch of the glass coating on one side. The coating is vitreous and translucent with a pale greenish color in some places and dull gray in others. The glass contains some white clasts; most are 1-2 mm across, but one is 6x3 mm.

The rock is light gray with darker clasts. The lighter matrix appears crushed and granulated. The smaller of the two large fragments contain a plagioclase clast about 1x2 mm in size. Both large pieces contain a few metal grains ranging in size from 0.05 to 0.5 mm. Some are euhedral, others appear to be irregular in shape. Although most are clear and shiny, a few are partly to completely covered with red-brown rust.

Some small fragments are also present in split ,5. All of the major lithologies in 67435 are represented among these fragments: pale to dark-green glass and fine-grained, dark-gray material from the glass coating, gray clasts (probably melt rocks) and the light-gray lithology. There are also a few plagioclase crystals and one red-brown transparent grain that has conchoidal fracture (spinel ?). Three of the small fragments have rusty metal on them.

Figure 6. Photograph of sample 67435,4.

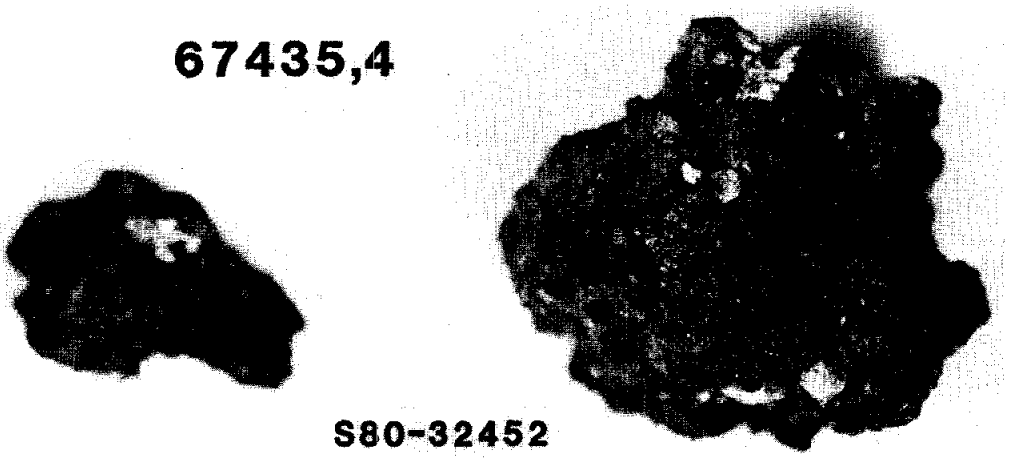
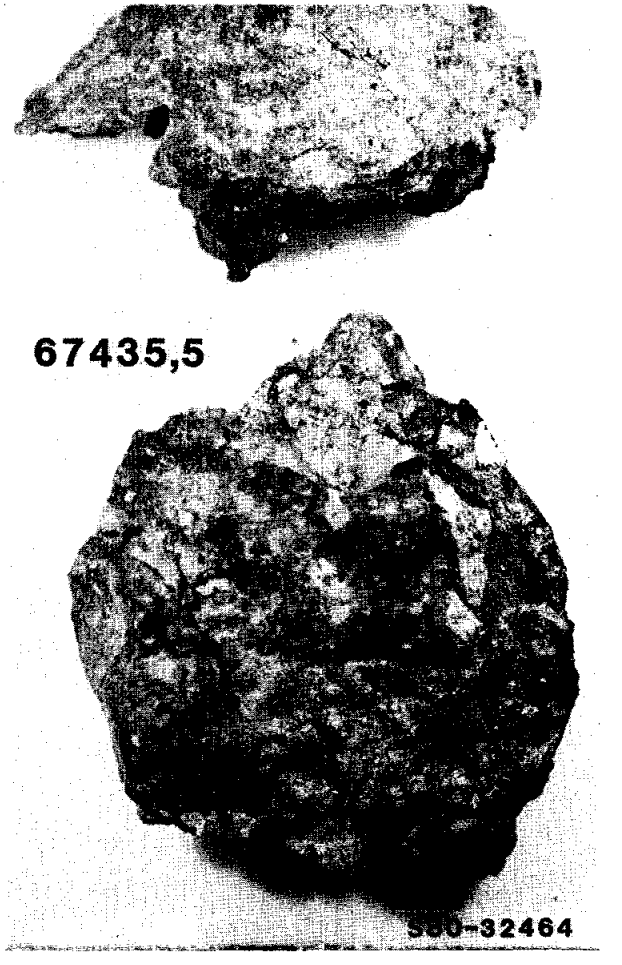


Figure 7. Photograph of sample 67435,5.



67435,6 (4.260 g)

Fragments and light-gray fines (Fig. 8). The largest piece is about 1 cm across. Most are chunks of the glass coating and contain white clasts. One of the larger fragments is a piece of the light-gray lithology that forms the matrix of 67435; this fragment has a small spot of rust. The fines are a mix of light and gray clasts, glass coating, pieces of transparent, greenish glass, and plagioclase fragments.

67435,7 (179.1 g)

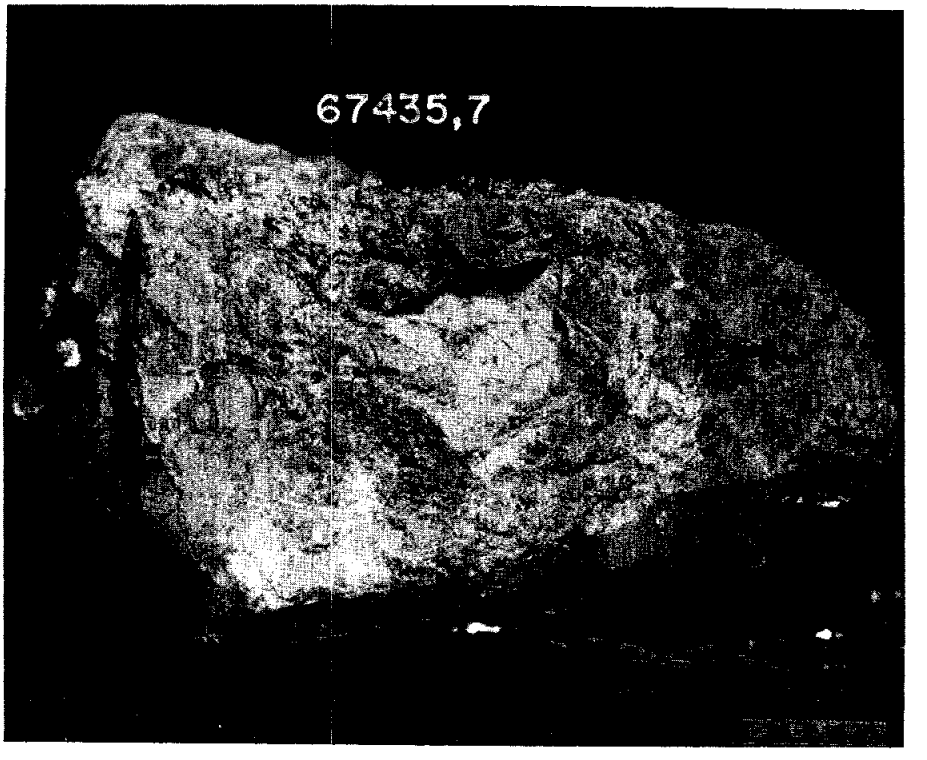
This is the largest specimen of 67435. Except for the sawn surface (Fig. 9), most of the sample is coated with dark gray, vesicular glass. Areas of obvious glass (vitreous), however, are rare; most of the glass coating is probably microcrystalline. The glass coating contains a few whitish to light-gray clasts.

On the sawn surface and on surfaces not coated with dark glass, the rock is generally light gray. Lighter and darker lithologies are visible, but they are intermingled and smeared out. It is difficult to determine which lithology is matrix and which is clast. No coarse-grained clasts are present, although a couple of > 1 mm plagioclase crystals occur. A polycrystalline anorthosite clast (only about 1 mm across) occurs near the rounded surface not coated with glass.

Some smaller fragments are present in the bag with the main mass of ,7. Most of these are typical light-gray and gray lithologies; some mineral fragments and dark glass coating are also present.

Figure 8. Photograph of sample 67435,6.

Figure 9. Photograph of sample 67435,7.



67435,8 (41.34 g)

This sample has both sawn and broken surfaces. It has dark, aphanitic clasts in lighter gray matrix. The dark clasts are readily visible on sawn surfaces (Fig. 10). The lighter matrix is somewhat coarser-grained than the dark clasts, but crystals are still smaller than 0.1 mm. No coarse-grained clasts are present, although one of the spinel troctolite clasts was removed from ,8.

67435,10 (0.480 g)

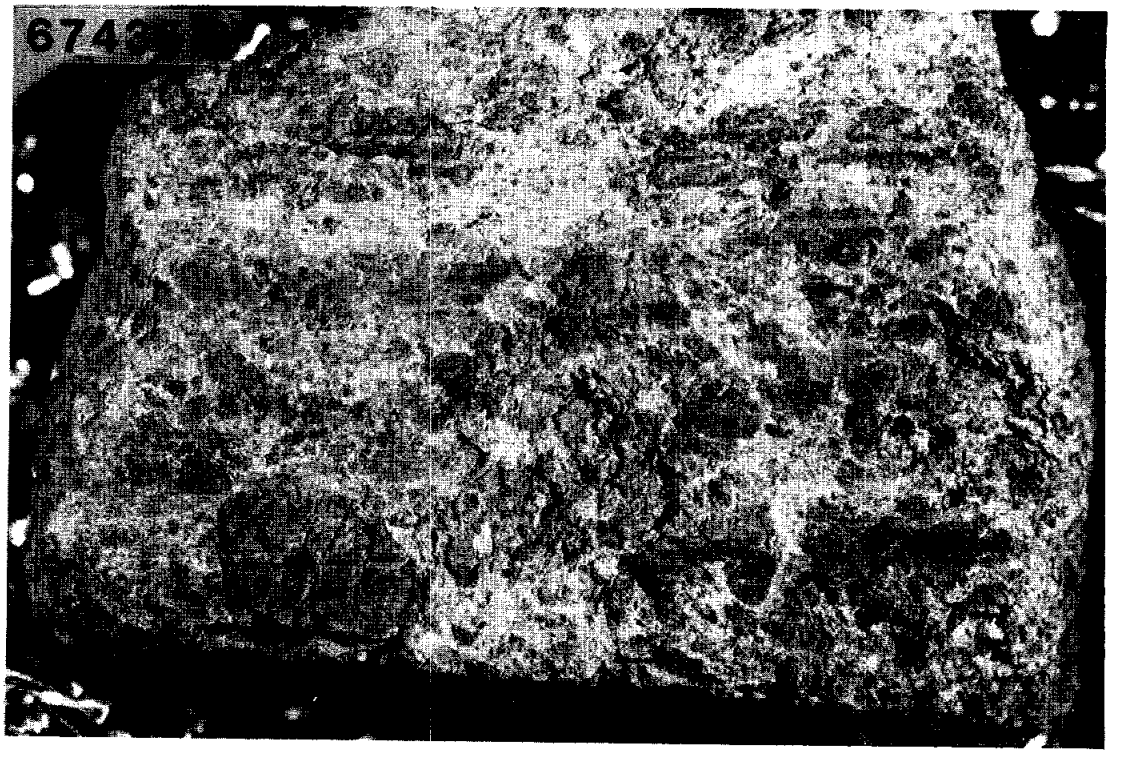
This sample consists of seven fragments, all < 8 mm across (Fig. 11). Most are medium gray in color; a couple are lighter gray. One of the medium gray fragments has a spot of rust on it. Another has a 2-mm long gray, translucent plagioclase crystal.

67435,11 (19.28 g)

This is a triangular piece of a slab (Fig. 12); it has two sawn surfaces and three rough ones. One of the sawn surfaces is marred by saw smears, but the other is clean. Dark clasts are easily visible on the sawn surfaces and they are clearly embedded in a lighter matrix. A few millimeter-sized plagioclase crystals are present, but no coarse-grained rock clasts are.

Some fines are also present in ,11. They are mostly light-gray fragments. One piece is coated on one side with dark gray, glassy material; another is a squarish (1-2 mm) piece of green glass.

Figure 10. Photograph of sample 67435,8.



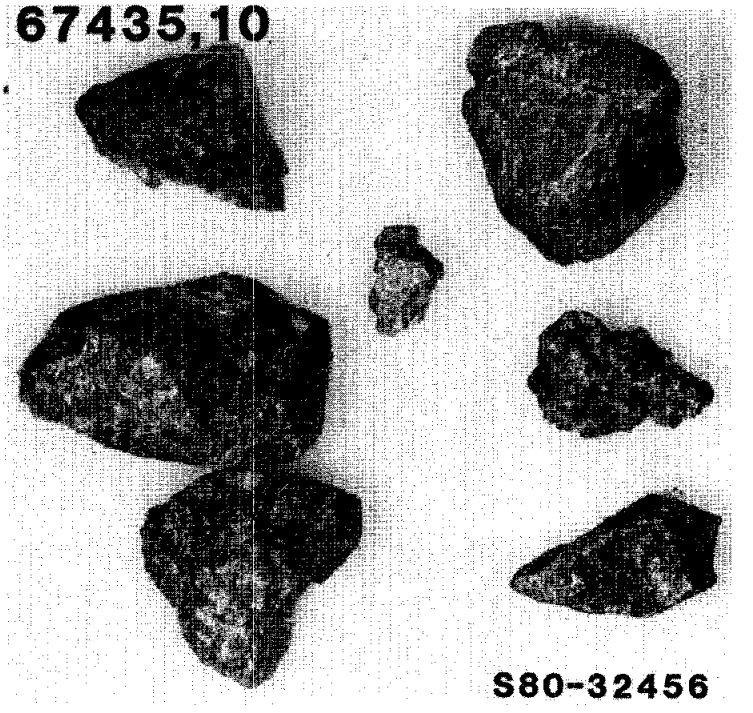


Figure 11. Photograph of sample 67435,10.

Figure 12. Photograph of sample 67435,11.

A.

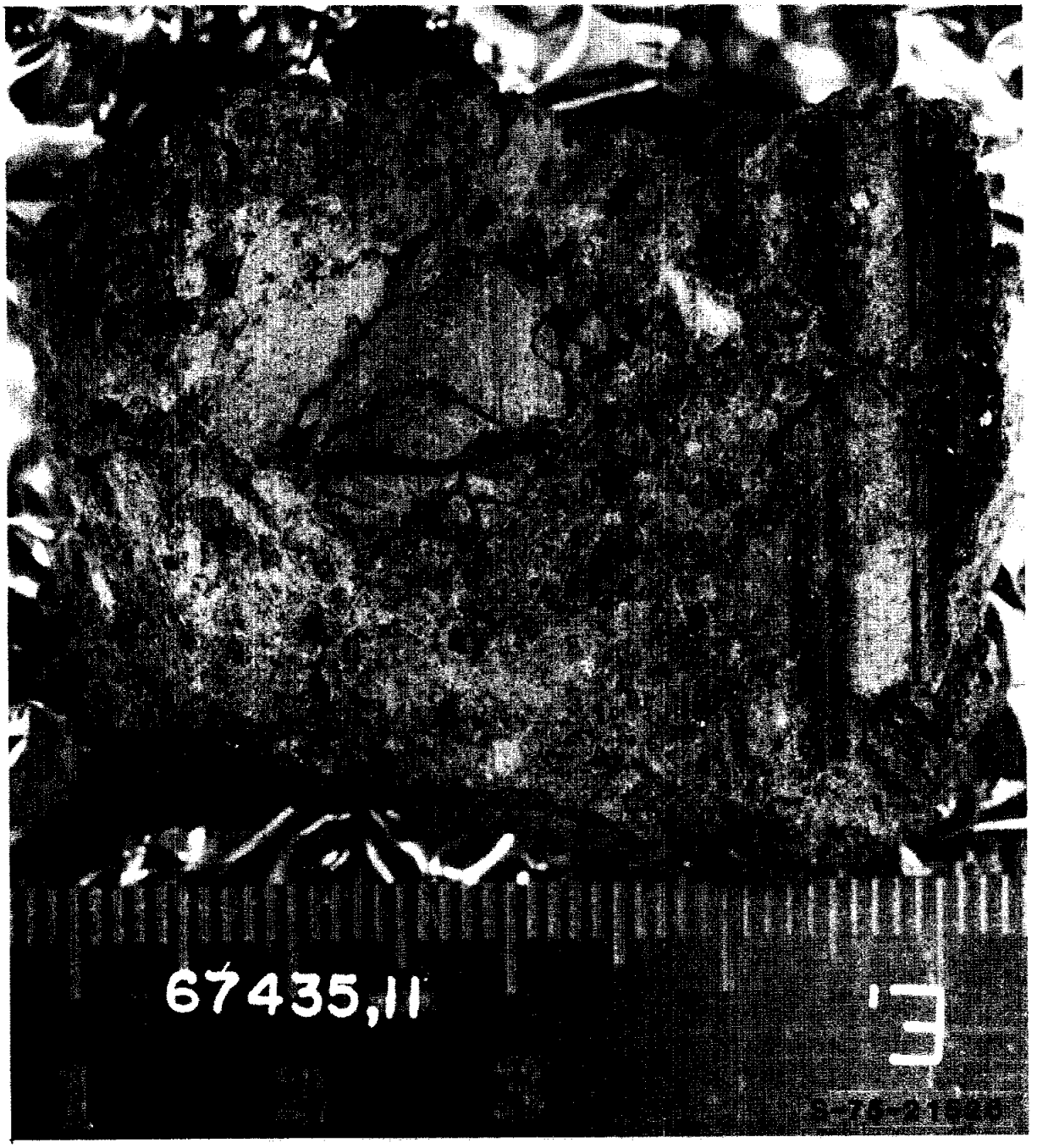
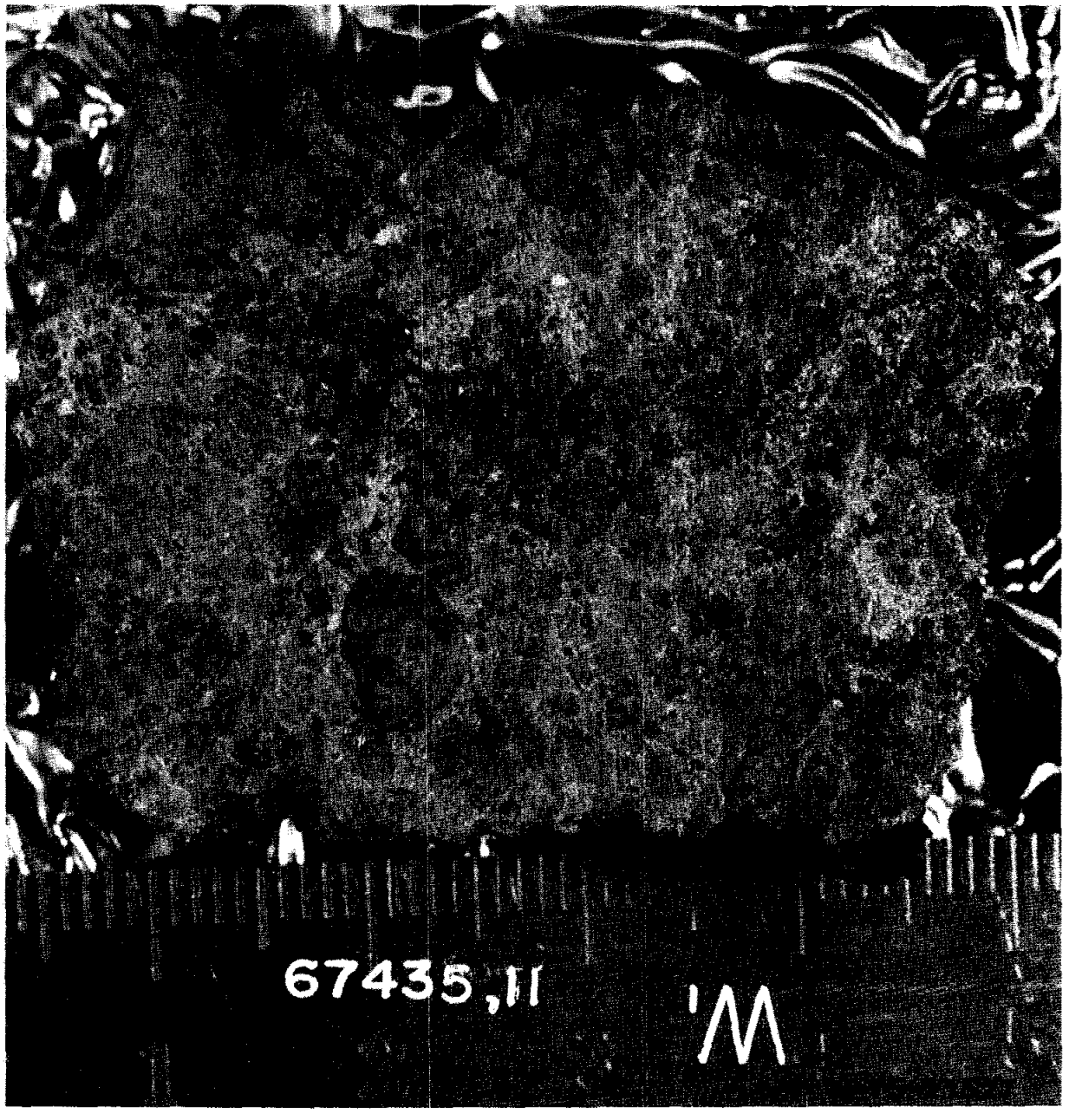


Figure 12. Photograph of sample 67435,11.

B.



67435,23 (0.150 g)

This sample contains fragments of the glass coating (Fig. 13). The largest piece has a white clast in it.

67435,28 (0.180 g)

One fragment (7x3 mm; Fig. 14) makes up sample ,28. It is a medium gray in color, fine-grained, and contains a fine-grained light-colored clast (~ 0.5 mm across). It is probably a sample of the melt-rock lithology.

67435,29 (3.725 g)

This sample consists of four pieces (Fig. 15). The largest and smallest are fragments of the glass coating. The others are light-colored with some small, dark clasts and are typical of the matrix of 67435.

67435,31 (1.480 g)

This sample contains the three major lithologies in 67435: it is a light-colored rock with dark clasts and one surface is glass-coated (Fig. 16A, 16B). The glass coating has a few zap pits on it. A rusty grain occurs on the light-colored portion.

67435,32 (1.950 g)

This is a representative chip of 67435 (Fig. 17). It contains dark clasts in a lighter matrix. Some metal grains have rust on them. No glass coating is present.

67435,34 (0.150 g)

A fragment of typical 67435 material (Fig. 18). It is mostly light-gray matrix, but some darker clasts are visible. A zap pit (3 mm in diameter) occurs on one side.

Figure 13. Photograph of sample 67435,23.

Figure 14. Photograph of sample 67435,28.

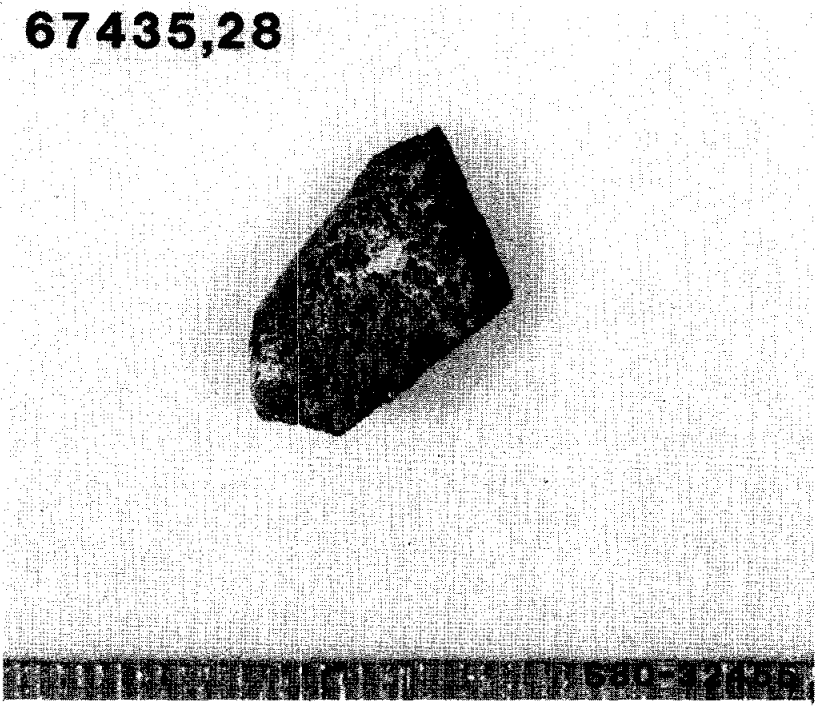


Figure 15. Photograph of sample 67435,29.

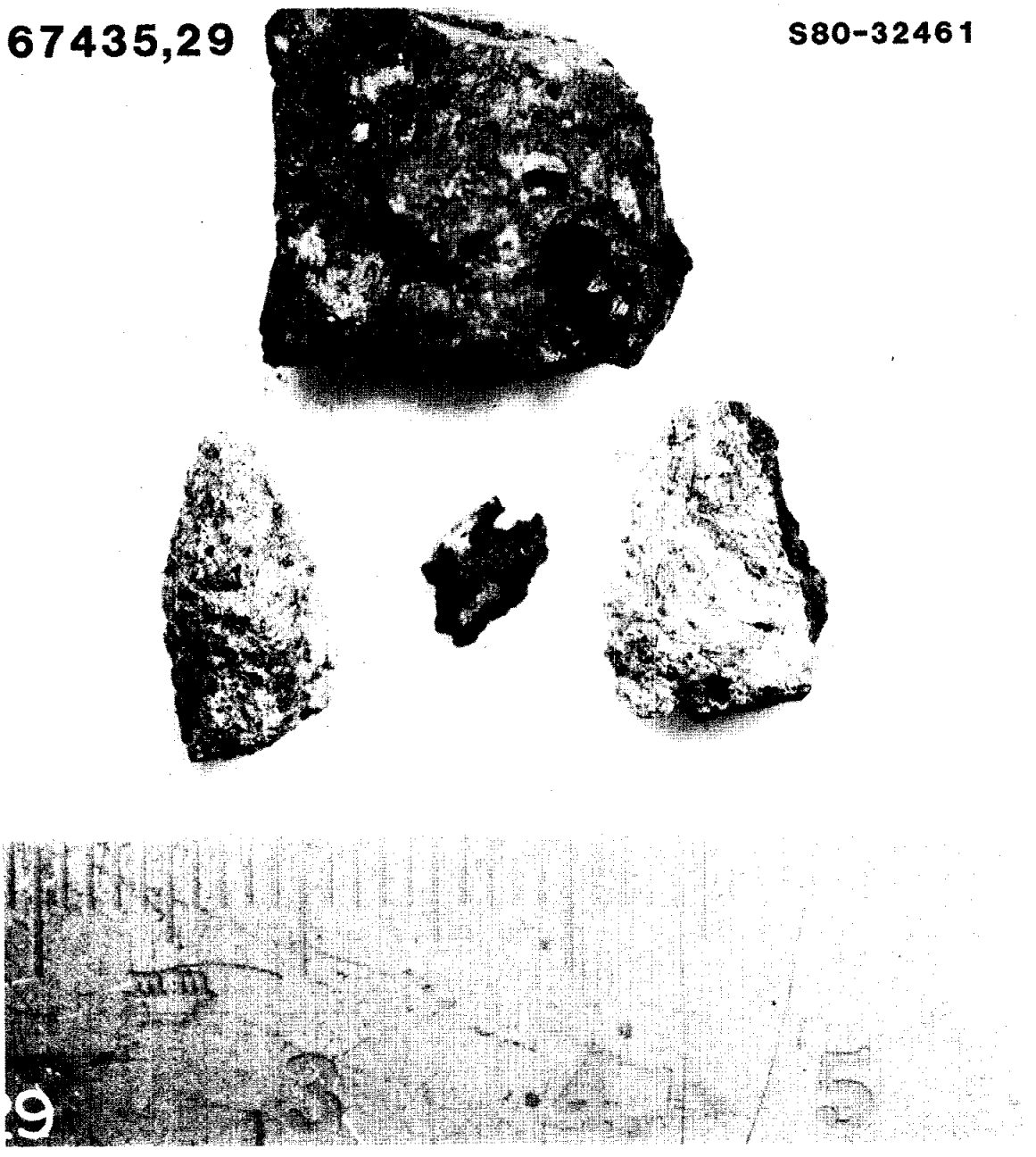
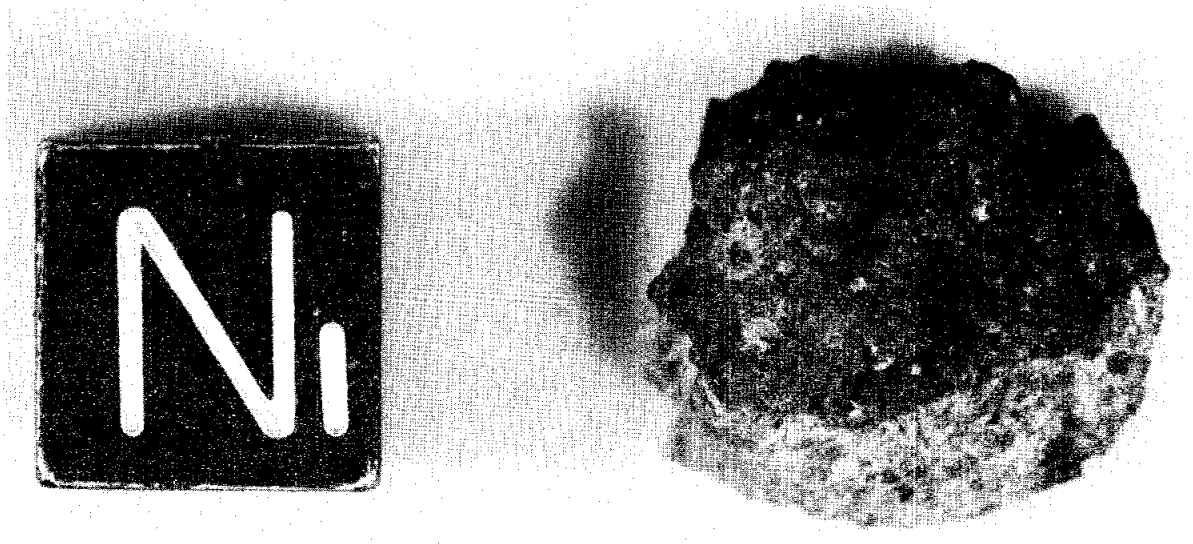


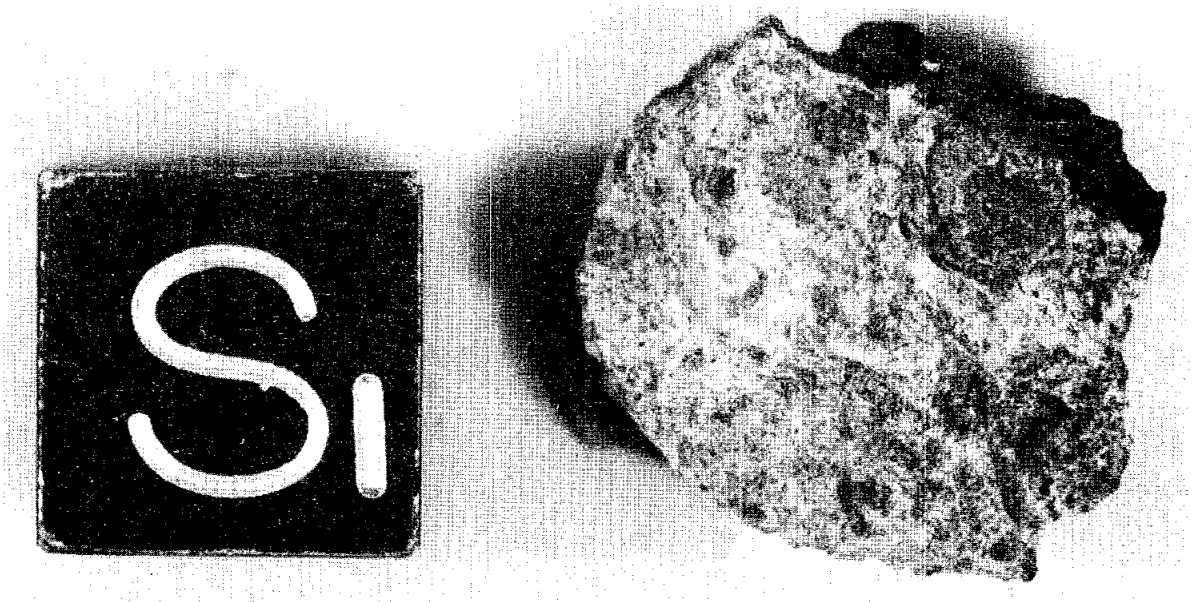
Figure 16. Photograph of sample 67435,31.

A



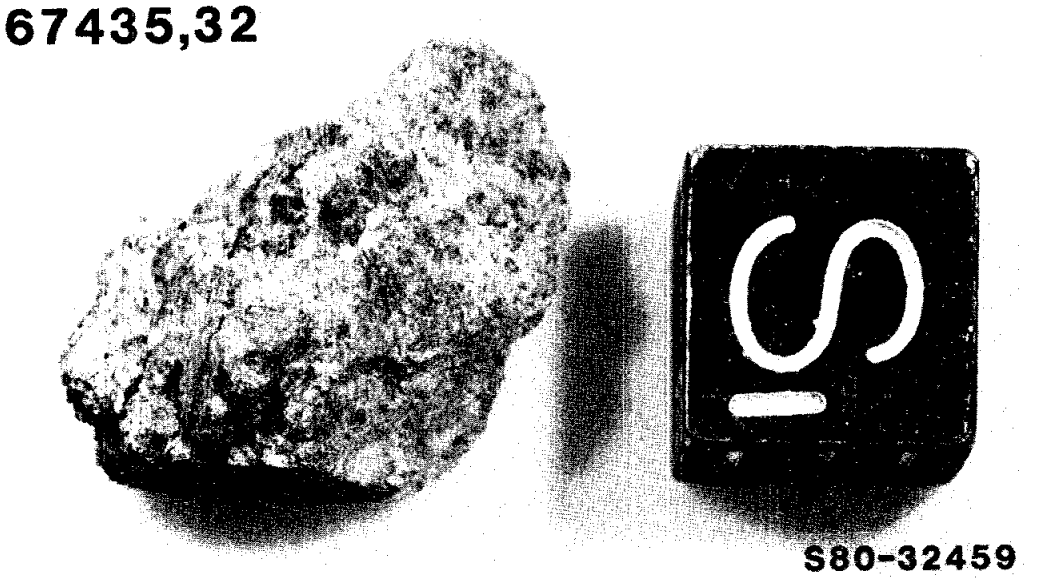
S80-32450

B



S80-32453

Figure 17. Photograph of sample 67435,32.



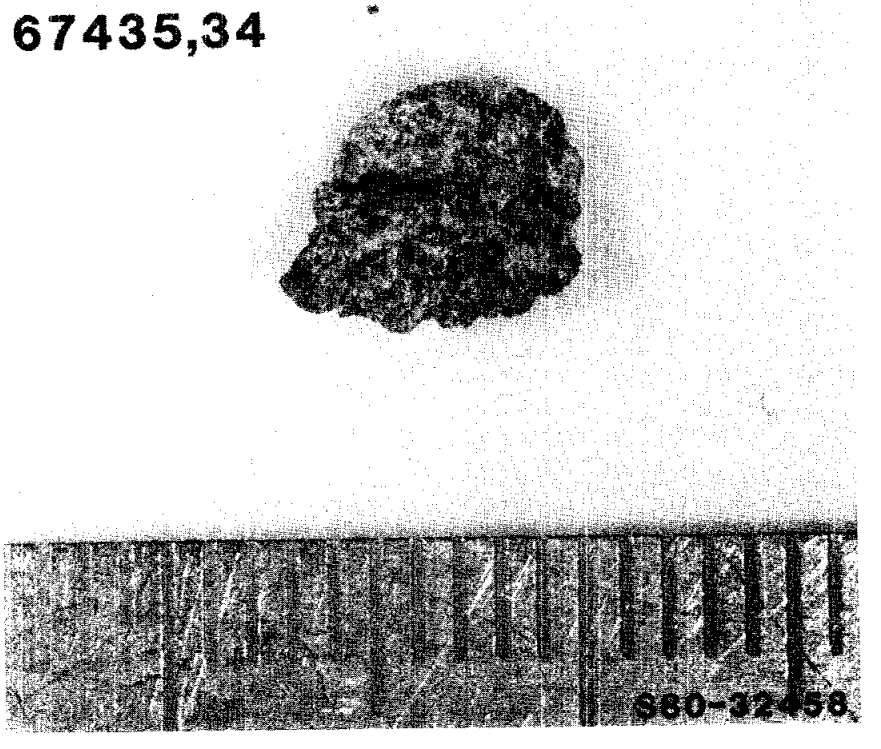


Figure 18. Photograph of sample 67435,34.

67435,37 (2.000 g)

This is a group of fragments composed predominately of the light-colored lithology (Fig. 19). Some dark clasts are present. Fragments range in size from fines (most ∿ 0.5 mm) to ∿ 1 cm. Quite a few metal grains are present, a few of which are rusty.

67435,41 (6.233 g)

This sample was part of a slab, but now most of its surfaces are broken. It is composed of typical light-gray material and darker clasts. Although a few millimeter-sized plagioclase crystals are present, no coarse-grained clasts are visible.

67435,42 (0.790 g)

This sample (Fig. 20) includes four fragments (one ∿ 10 mm, one ∿ 7 mm, two 2-3 mm) and some < 1 mm fines. All are medium-gray, nondescript and fine-grained. They are apparently composed mostly of the darker lithology in 67435 which occurs as clasts in a lighter matrix.

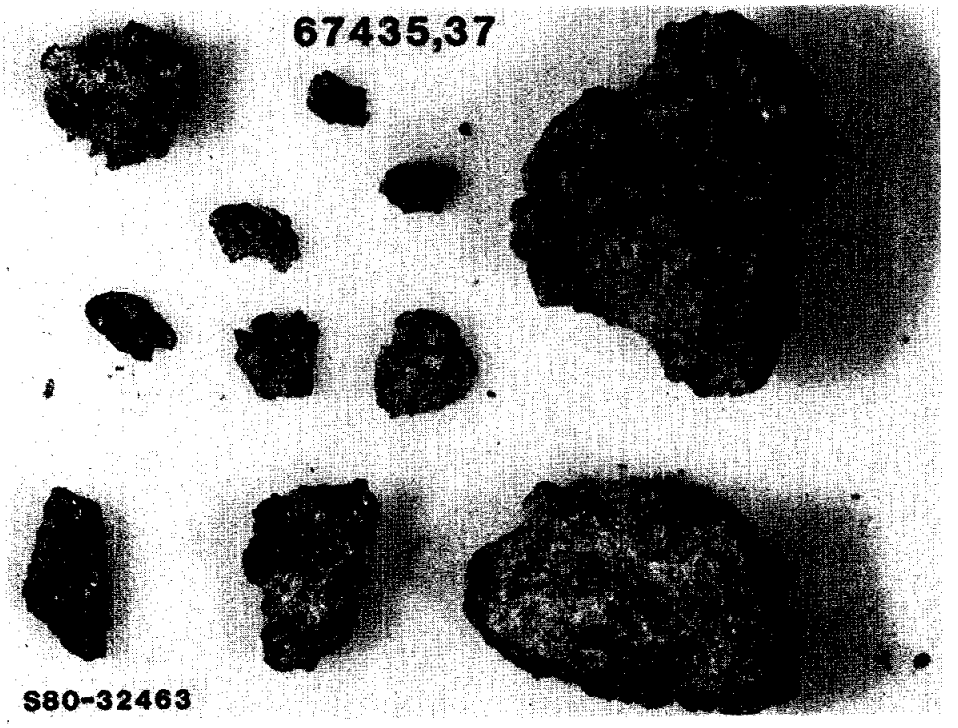
67435,43 (2.370 g)

Small, squarish piece with one sawn surface (Fig. 21). It consists of typical light-gray material containing darker clasts. Some fines are also included in ,43 and are made of the same materials as the large piece. No coarse-grained clasts are visible.

67435,44 (0.510 g)

This sample (Fig. 22) includes pieces of the three major lithologies in 67435: glass coating, light matrix, dark clasts. One of the light-colored fragments has some rust on it. One fragment consists of an isolated metal grain that has a dendritic patch of rust on one surface; the surface opposite the rust seems to be an intergrowth of metal and silicate.

Figure 19. Photograph of sample 67435,37.



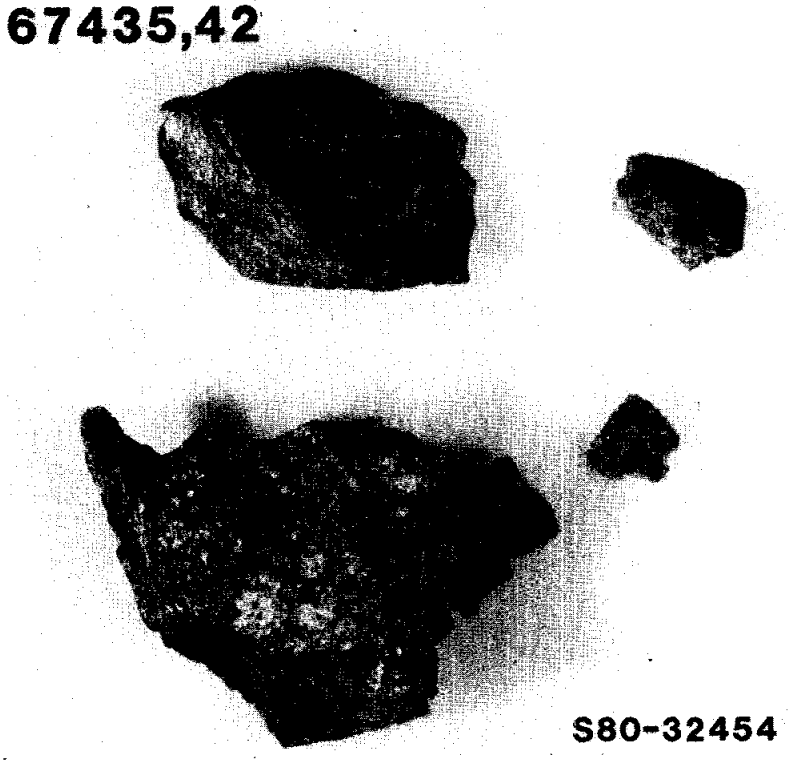
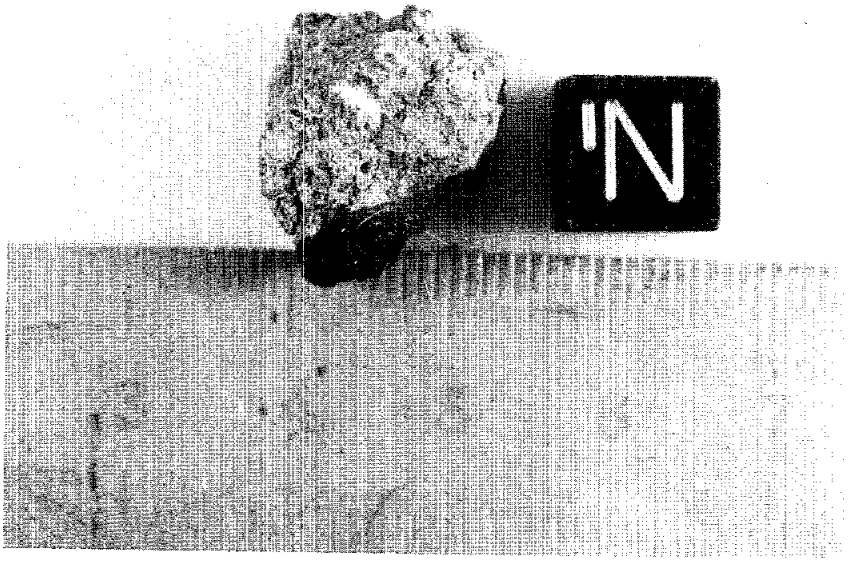


Figure 20. Photograph of sample 67435,42.

Figure 21. Photograph of sample 67435,43.



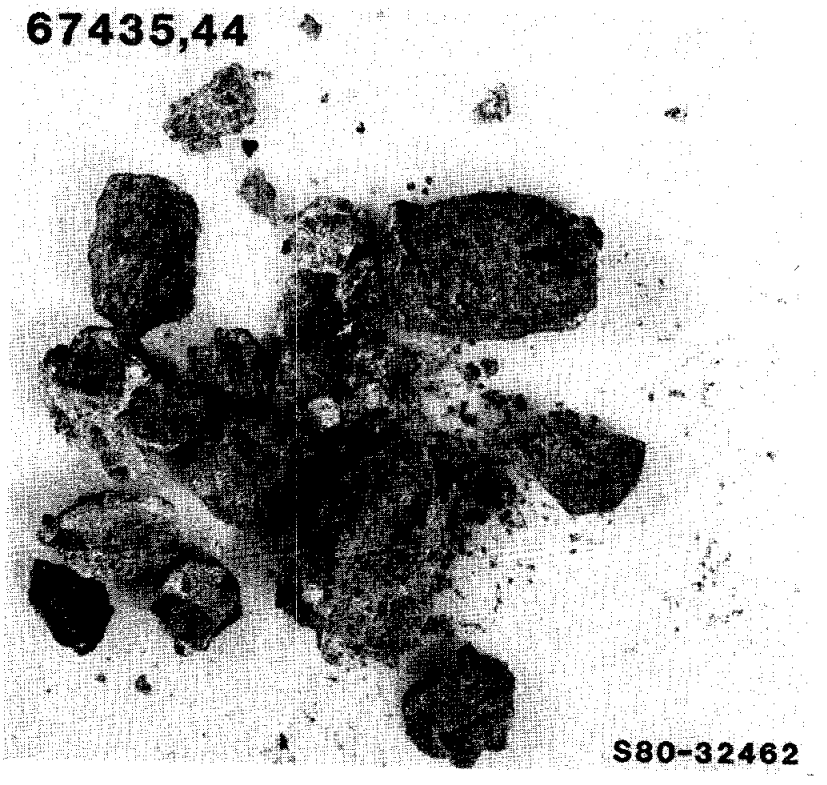


Figure 22. Photograph of sample 67435,44.

67435,47 (11.880 g)

Nondescript gray fines with a few larger lumps of rock. The largest fragment is ∿ 1 cm. Difficult to identify lithologies because of pervasive dust covering.

67435,48 (7.250 g)

This sample (Fig. 23) contains numerous fragments ranging in size from substantially < 1 mm up to ∿ 5 mm. It contains the usual lithologies, including the glass coating. No coarse-grained clasts are present.

67435,75 (14.525 g)

Sample ,75 contains dark clasts in a lighter matrix (Fig. 24). An anorthosite clast is present on one surface close to the sawn surface. This clast is only 1x3 mm in size and is pure white and crystalline; olivine crystals (0.1-0.2 mm) occur at one end of the clast. One of the aphanitic clasts is very white (see Fig. 24) and appears to be granulitic.

67435,76 (7.450 g)

Sample ,76 (Fig. 25) consists of chips and fines generated during the extraction of a spinel troctolite clast. None of the spinel troctolite clast remains in ,76. The fragments are typical light material with darker clasts.

67435,79 (0.656 g)

This sample consists mostly of light material with darker clasts (Fig. 26), but it also contains a thin band of spinel troctolite (ST2; see Ma et al., 1981). Troctolite clast is < 5% of total mass.

Figure 23. Photograph of sample 67435,48.

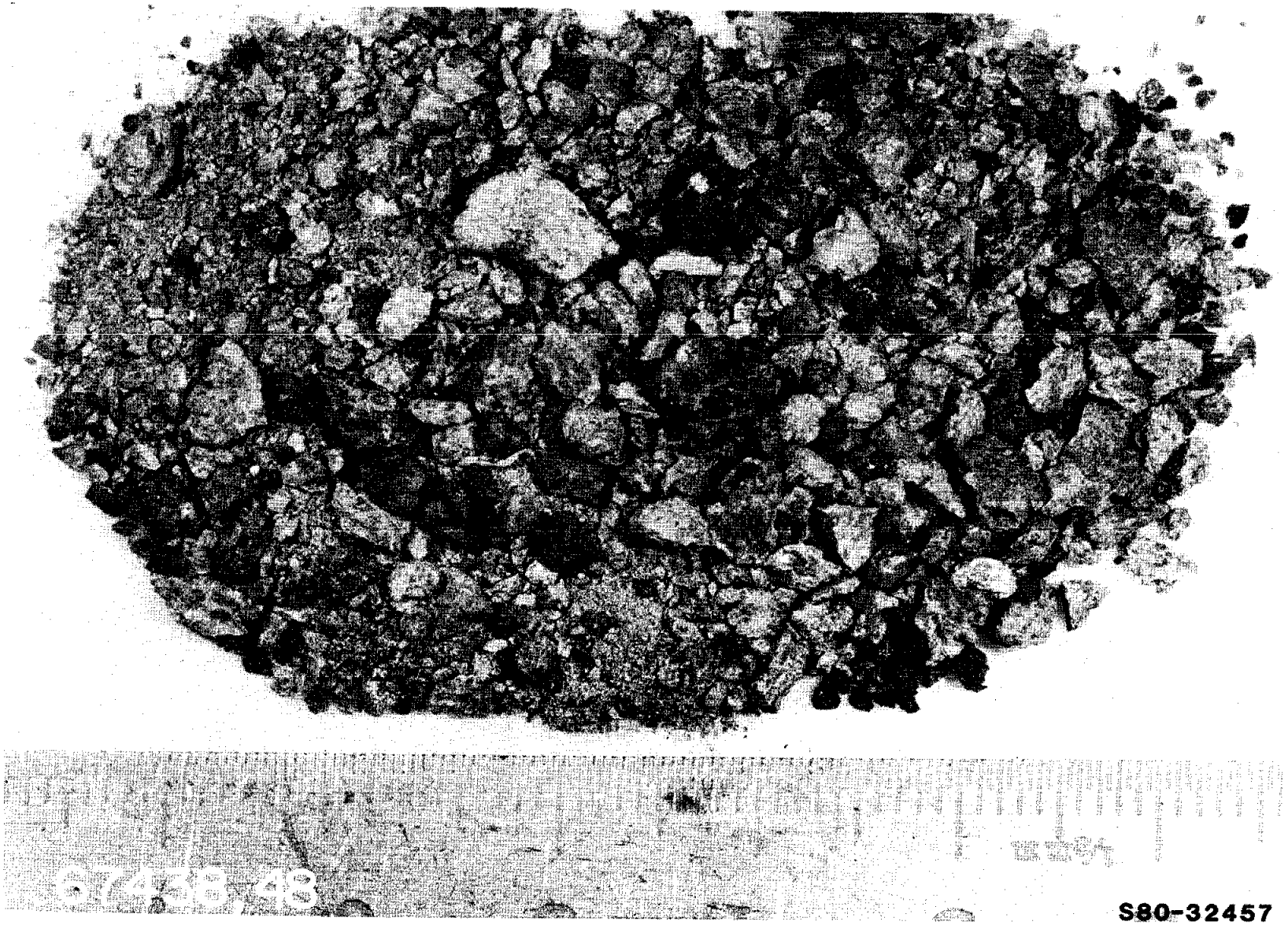


Figure 24. Photograph of sample 67435,75.

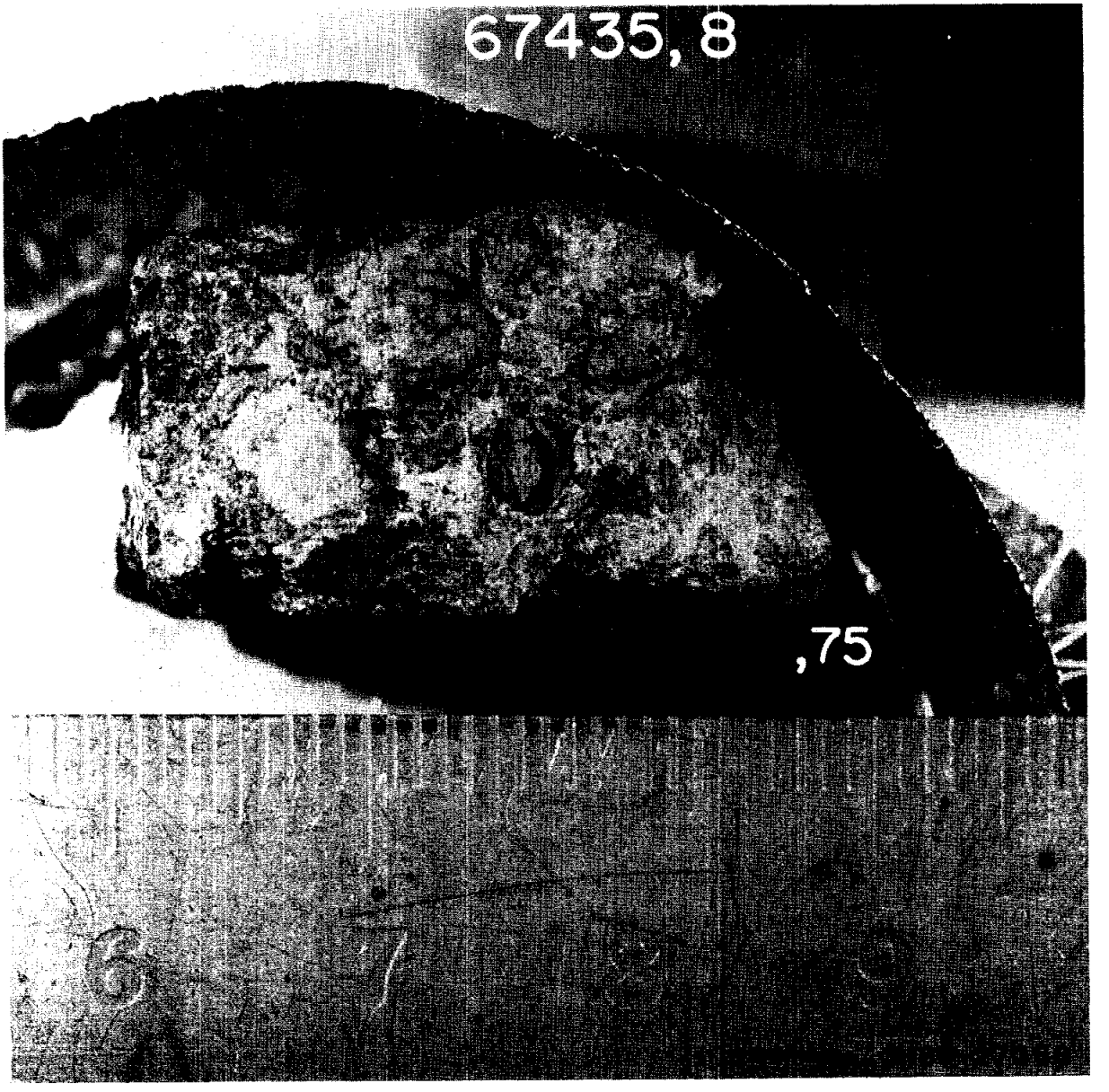
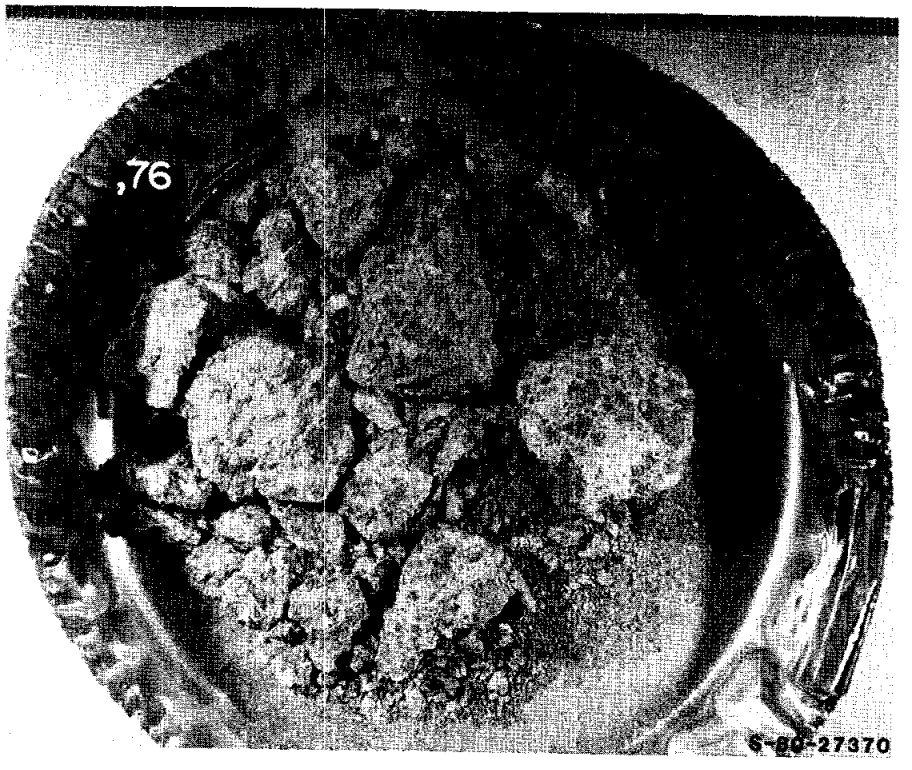


Figure 25. Photograph of sample 67435,76.



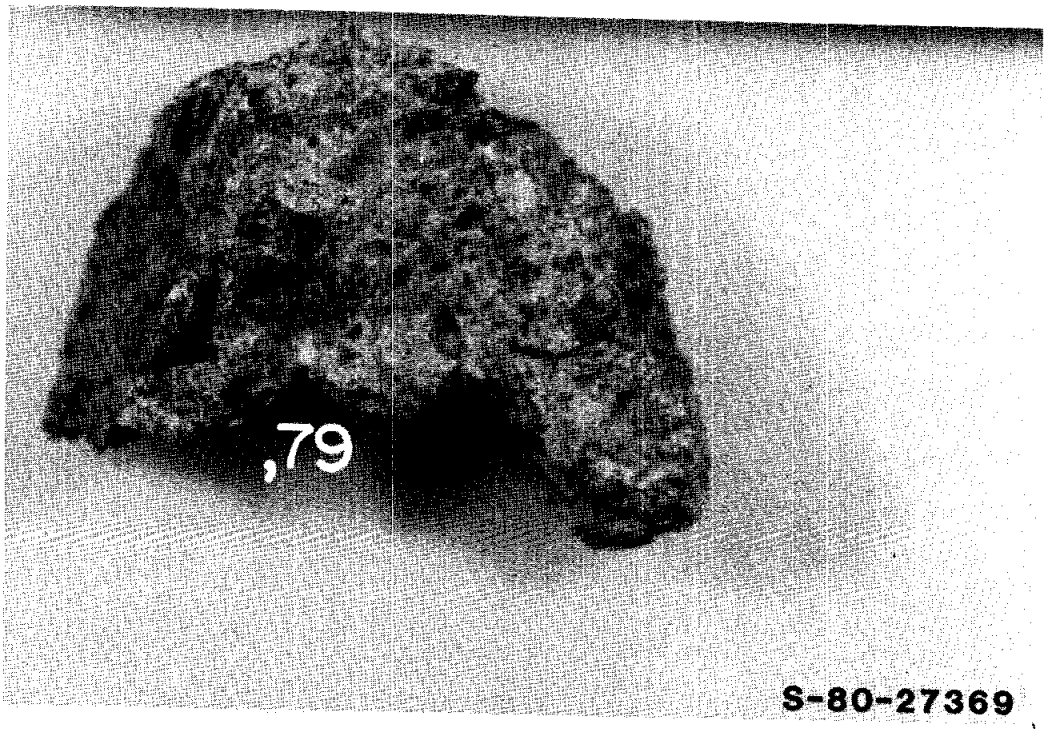


Figure 26. Photograph of sample 67435,79.

67435,80 (0.304 g)

Small fragments consisting of 67435 matrix and spinel troctolite clast ST2. Two pieces are pure clast material. This sample could be used to produce more matrix-free clast material. The spinel troctolite clast makes up < 25% of the total mass of ,80.

67435,82 (0.017 g)

Mineral fragments (plagioclase, olivine and spinel) from spinel troctolite clast (ST2). A small amount (∿ 1%) matrix is probably present, but pure clast material could be easily separated.

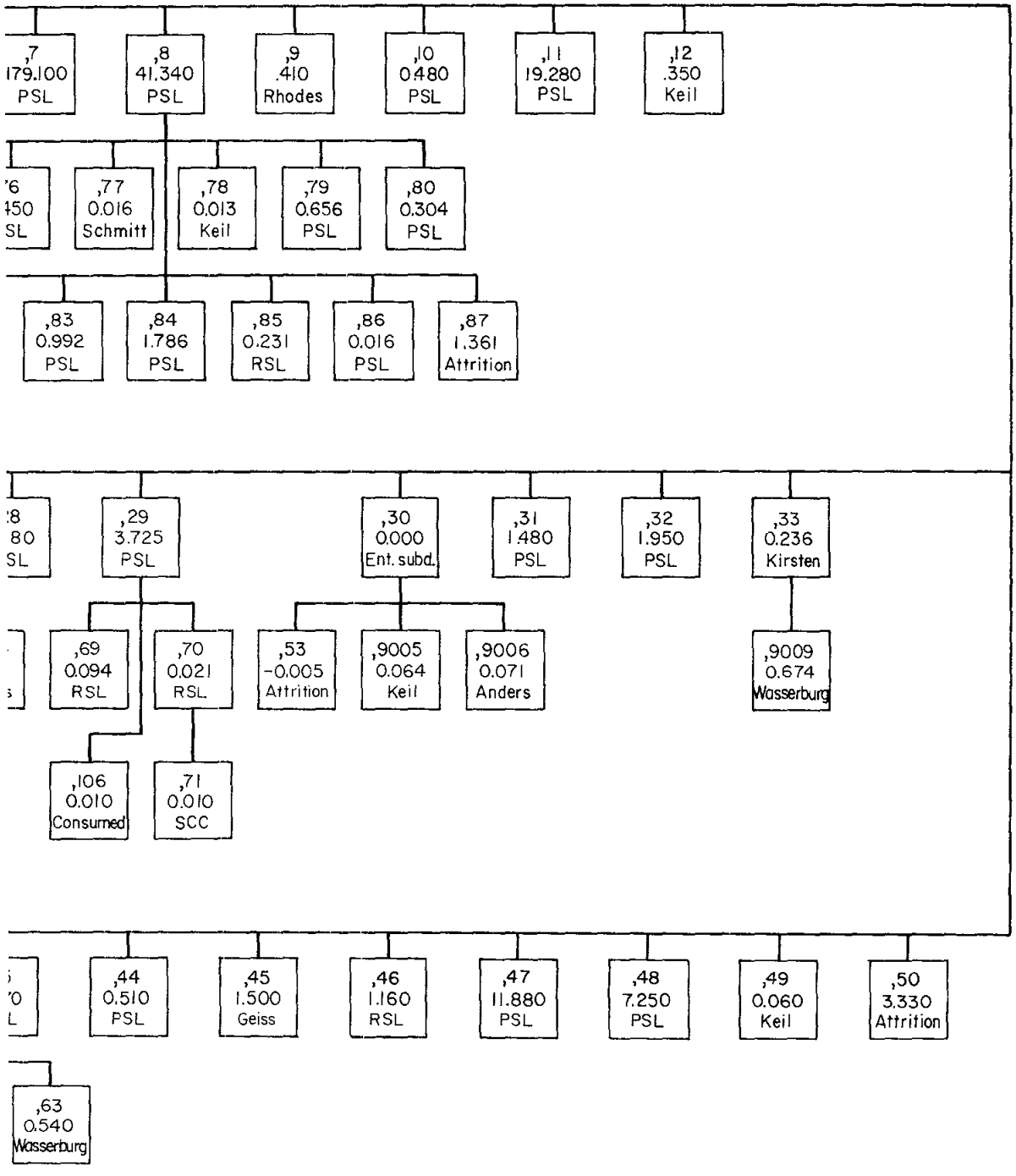
67435,83 (0.992 g)

This sample contains chips and fines found in the sample bag when ,8 was opened to extract spinel troctolite clast, plus sweepings from the band-saw cabinet. Gray, aphanitic and lighter gray fragments are present. No coarse-grained fragments are visible.

67435,84 (1.785 g)

Fines resulting from sawing of ,8 to extract spinel troctolite. No coarse-grained clasts observed.

GENEALOGY


,7
179.100
PSL
,8
41.340
PSL
,9
.410
Rhodes
,10
0480
PSL
,11
19.280
PSL
,12
.350
Keil
,77
0.016
Schmitt
,78
0.013
Keil
,79
0.656
PSL
,80
0.304
PSL
,83
0.992
PSL
,84
1.786
PSL
,85
0.231
RSL
,86
0.016
PSL
,87
1.361
Attrition
,29
3.725
PSL
,30
0.000
Ent. subd.
,31
1.480
PSL
,32
1.950
PSL
,33
0.236
Kirsten
,69
0.094
RSL
,70
0.021
RSL
,53
-0.005
Attrition
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0.064
Keil
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Anders
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Wasserburg
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Consumed
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0.010
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PSL
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Geiss
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1.160
RSL
,47
11.880
PSL
,48
7.250
PSL
,49
0.060
Keil
,50
3.330
Attrition
,63
0.540
Wasserburg

REFERENCES

Apollo Lunar Geology Investigation Team (1972) Documentation and environment of the Apollo 16 samples: A preliminary report. Interagency Report: Astrogeology 51.

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, 2105-2113.

Cripe J.D. and Moore C.B. (1975) Total sulfur contents of Apollo 15, 16, and 17 samples. In Lunar Science VI, 167-168. The Lunar Science Institute, Houston.

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, 407-415.

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, 2137-2151.

Ma M.-S., Schmitt R.A., Taylor G.J., Warner R.D. and Keil K. (1981) Chemical and petrographic study of spinel troctolite in 67435: Implications for the origin of Mg-rich plutonic rocks. In Lunar and Planetary Science XII, 640-642. The Lunar and Planetary Institute, Houston.

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

Prinz M., Dowty E., Keil K. and Bunch T.E. (1973) Spinel troctolite and anorthosite in Apollo 16 samples. Science 179, 74-76.

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. (1976) Consortium investigation of breccia 67435. Proc. Lunar Sci. Conf. 7th, 2379-2402.

Warren P.H. and Wasson J.T. (1979) The origin of KREEP. Rev. Geophys. Space Phys. 17, 73-88.

Yokoyama Y., Reyss J.L., and Guichard F. (1974) ^{22}Na-^{26}Al chronology of lunar surface processes. Proc. Lunar Sci. Conf. 5th, 2231-2247.