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BRECCIA GUIDEBOOK NO. 3

67915

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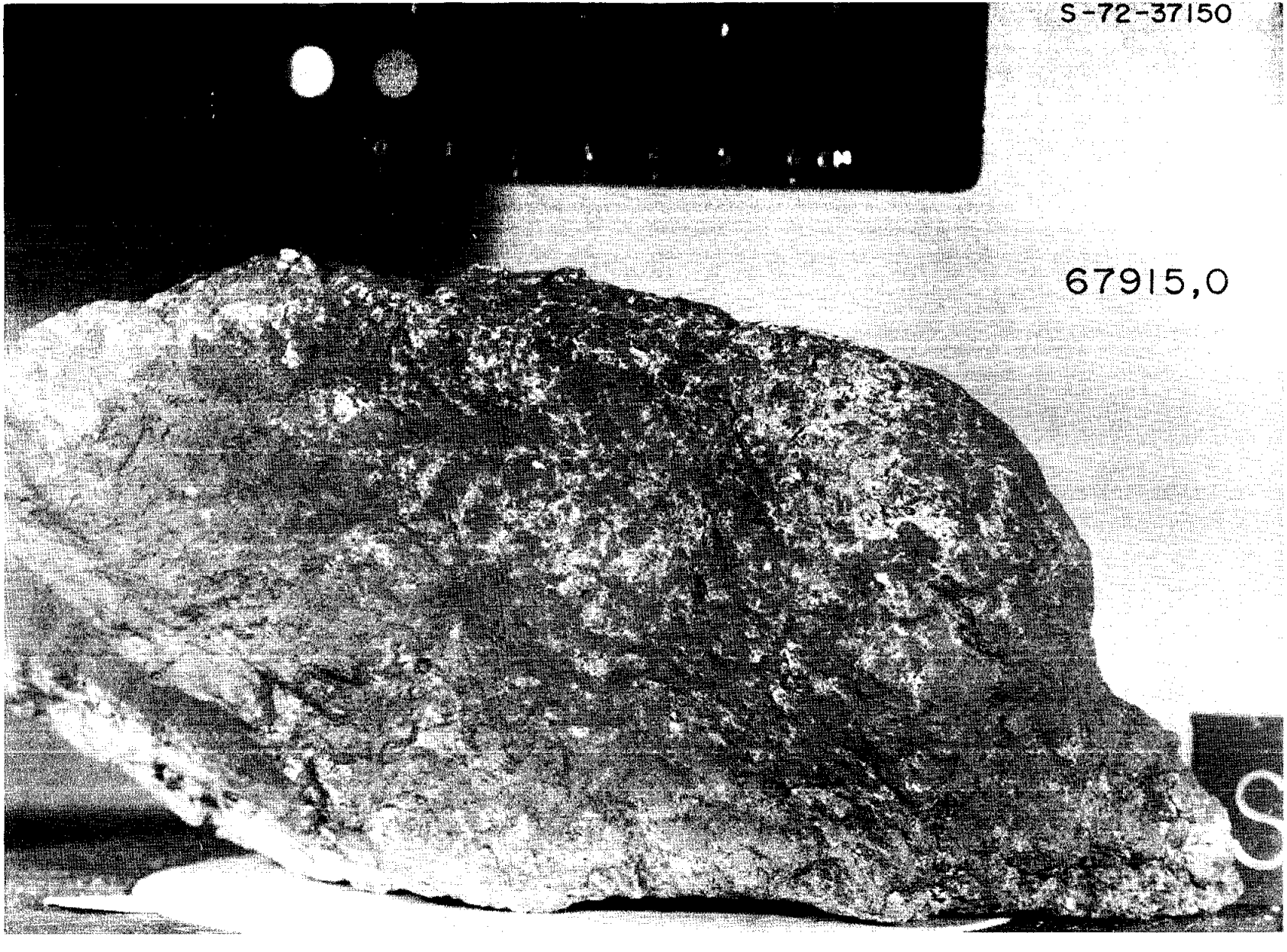


Figure 2.

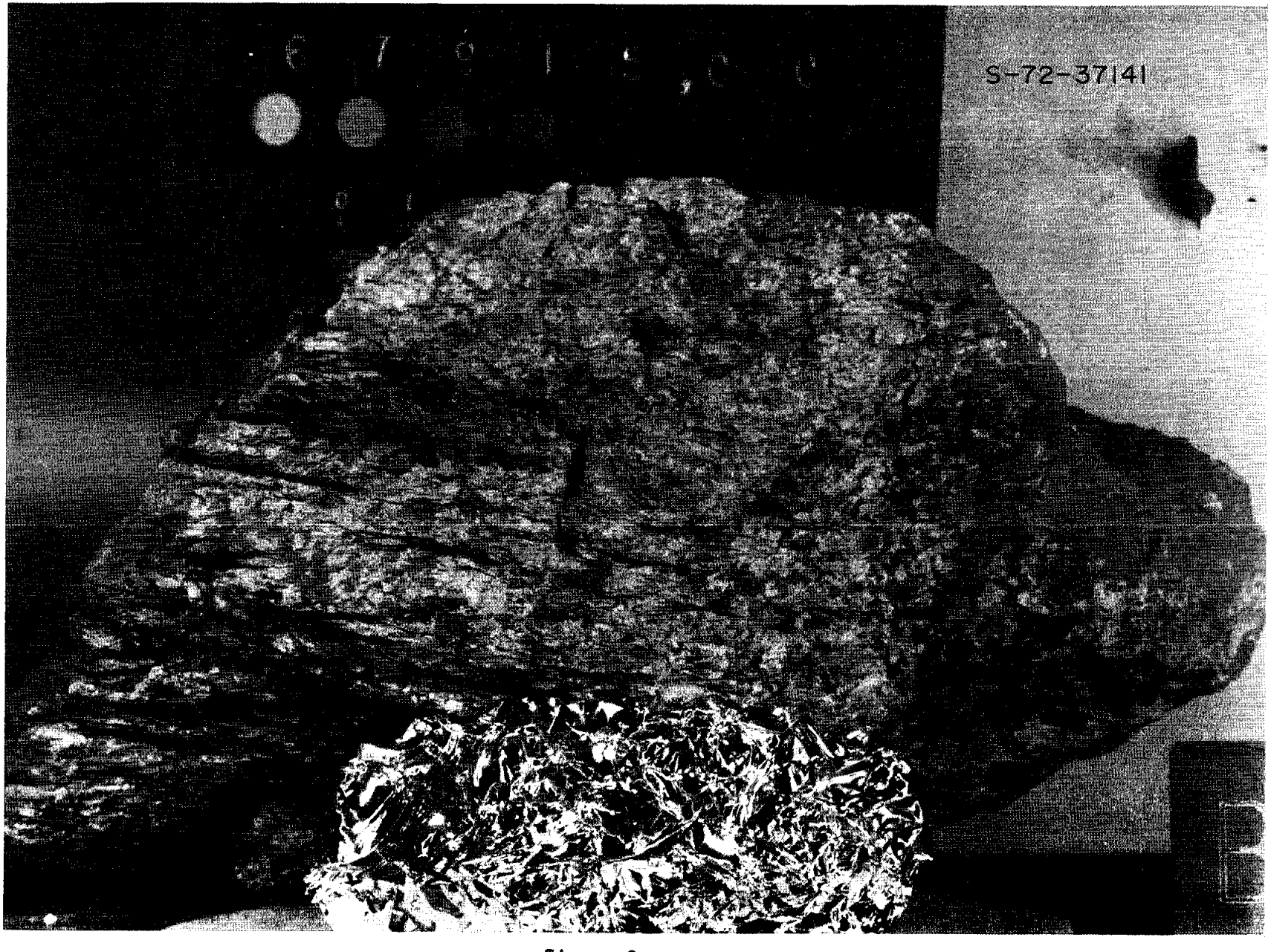


Figure 3.

GENERAL INTRODUCTION TO BRECCIA 67915

Breccia 67915 was chipped off a two-meter boulder near the rim of North Ray Crater (Fig. 1). The boulder, called South Boulder or Outhouse Rock, appears to have broken off a much larger boulder adjacent to it, House Rock. According to the Apollo Lunar Geology Investigation Team (1972), 67915 appears typical of both South Boulder and House Rock, and could represent the deepest ejecta from North Ray Crater.

The rock has been described by Weiblen and Roedder (1973) and by Roedder and Weiblen (1974). It weighed 2.6 kg and was rounded on all surfaces except B, where it had been broken from the boulder (Figs. 2,3). Numerous glass veins (< 5 mm thick) cut the rock in all directions. The rock is composed of two main lithologies (Fig. 4) both of which are polymict breccias. One is white or very light gray and composed of rounded clasts of fine-grained anorthositic breccias (Fig. 5). For short, we call the "white breccia" lithology "WB". The clasts in WB range in size from < 1 mm to ∿ 1 cm and are randomly arranged like a pile of pebbles. Some coarser plagioclase crystal fragments (up to ∿ 1 mm in size) occur between the larger (but fine-grained) white clasts. The other main lithology has a gray color and is clearly polymict (Fig. 6). We call it the "gray breccia" lithology, or "GB" for short. It is composed of a diverse collection of clasts that range in size from < 1 mm to ∿ 3 cm. Some clasts are rounded, others are angular. Most of the clasts in GB are gray, but others are white like those in WB and some are dark gray. Other lithologies, such as sodic ferrogabbro and troctolitic anorthosite, also occur as clasts within the gray breccia. These lithologies, as well as the white, gray, and dark-gray clasts, are described in the next section.

The boundary between the large white-breccia (WB) clasts and the gray breccia (GB) is generally quite distinct. In some places, however, the border is smeared out with white material mixed into the gray matrix; in one case, it appears that one of the white clasts within the white breccia was dislodged and incorporated into the dark lithology. Although two pieces of white breccia occur at opposite ends of the rock, field observations indicate that they are clasts within the gray breccia.

Chemical analyses (Table 1) indicate that both breccia lithologies are similar in composition, containing 80-85% normative plagioclase. Abundances of K, REE, and P are low, indicating that KREEP rocks are a minor component of 67915. (Except for sodic ferrogabbros, no clasts of KREEPy rocks have been observed in thin sections of the breccia.) The REE pattern (Fig. 7) displays a monotonic decrease in normalized abundances from La to Lu and a positive Eu-anomaly.

Siderophile elements (Table 1) are high in both the white and gray breccias, indicating meteoritic contamination. Although elemental ratios of the key trace siderophiles are the same in each lithology, the white breccia contains slightly lower absolute abundances. Ir, for example, is 3.6 ppb (6.9×10^{-3} times Cl abundance) in the white breccia and 7.3 ppb (1.4×10^{-2} times Cl) in the gray breccia. The In/Au and Re/Au ratios in 67915 are higher than in other Apollo 16 breccias, suggesting a distinct meteoritic source for the siderophile

elements (Krähenbühl et al., 1973).

The glass veins that crisscross the rock have an average composition that is similar to that of the bulk rock (Table 1), although individual analyses of glass veins are quite variable. For an interesting and detailed discussion of glassy veins in meteoritic and lunar samples, including 67915, see Roedder and Weiblen (1977).

The glass veins in 67915 were almost certainly produced by shock and because they cut all lithologies in the rock, the shock event that made them must have been one of the most recent events that affected the rock. This event might have been the excavation of North Ray Crater. If so, this recent heating could have affected the chronology of all the clasts in the rock.

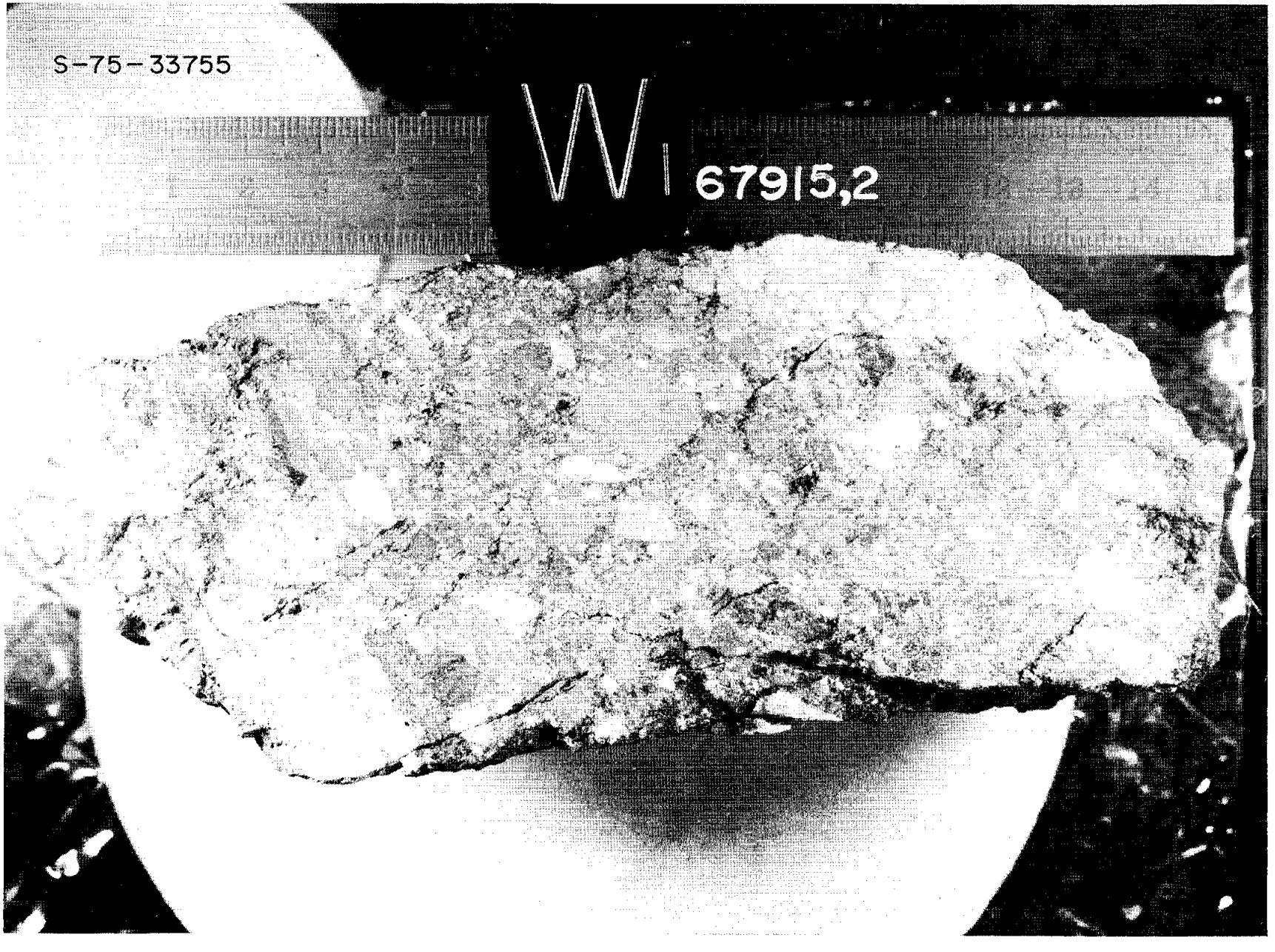


Figure 4.

Table 1. Bulk Chemical Analyses of 67915

Wt. %	A	B	C	D	E	F	G	H
SiO_2	44.8	45.1	43.2	43.7	45.1	45.7		
TiO_2	0.30	0.35		0.05	0.58	0.25		
Al_2O_3	28.9	30.0	28.4	29.4	29.3	30.5		
Cr_2O_3				0.05	0.06	0.03		
FeO	3.5	3.6	4.1	3.0	2.9	2.7		
MnO	0.05	0.05	0.05	0.05	0.06	0.06		
MgO	5.7	4.2	3.6	6.0	3.8	2.9		
CaO	16.0	16.8		16.6	17.0	17.5		
Na_2O	0.39	0.46	0.59	0.45	0.63	0.39		
K_2O	0.06	0.07		0.06	0.09	0.06		
P_2O_5	0.08	0.07		0.04	0.04	0.03		
ppm								
Sc				343	8.2			
Sr	187	194			177			
Rb	0.95	1.1			0.79		0.8	1.1
Zr	71.8	56.8			49			
Ba	64	62		59.7	65			
La				5.40	4.75			
Ce				12.4	12.2			
Nd				6.87	7.9			
Sm				1.92	2.02			
Eu				1.06	1.32			
Gd				2.27	2.55			
Tb					0.48			
Dy				2.55	2.9			
Er				1.63	2.2			
Yb				1.57	1.92			
Lu				0.22	0.26			
Ni	75.4	52.1			57		160	95
ppb								
Ir							7.33	3.57
Re							0.67	0.346
Au					0.79		1.90	1.06

A) ,53L, light breccia (Duncan et al., 1973).

B) ,53G, gray breccia (Duncan et al., 1973).

C) ,56, gray breccia (Janghorbani et al., 1973).

D) ,57, gray breccia (Nakamura et al., 1973).

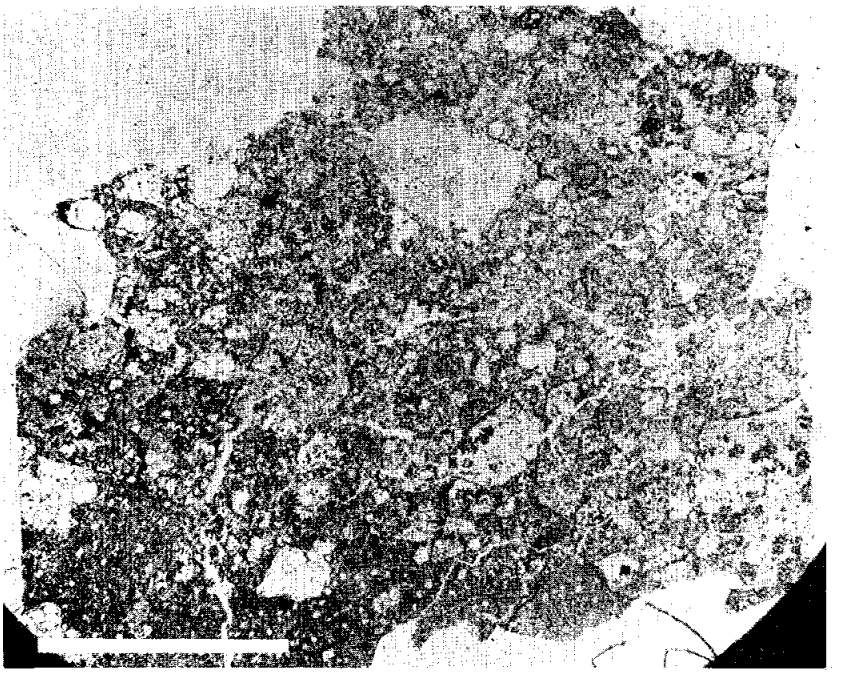
E) ,116, petrography unknown (Wanke et al., 1976).

F) Glassy veins, average of 15 analyses (Roedder and Weiblen, 1977).

G) ,63a, > 50% gray clasts (Krähenbühl et al., 1973).

H) ,63b, > 80% white clasts (Krähenbühl et al., 1973).

Figure 5.



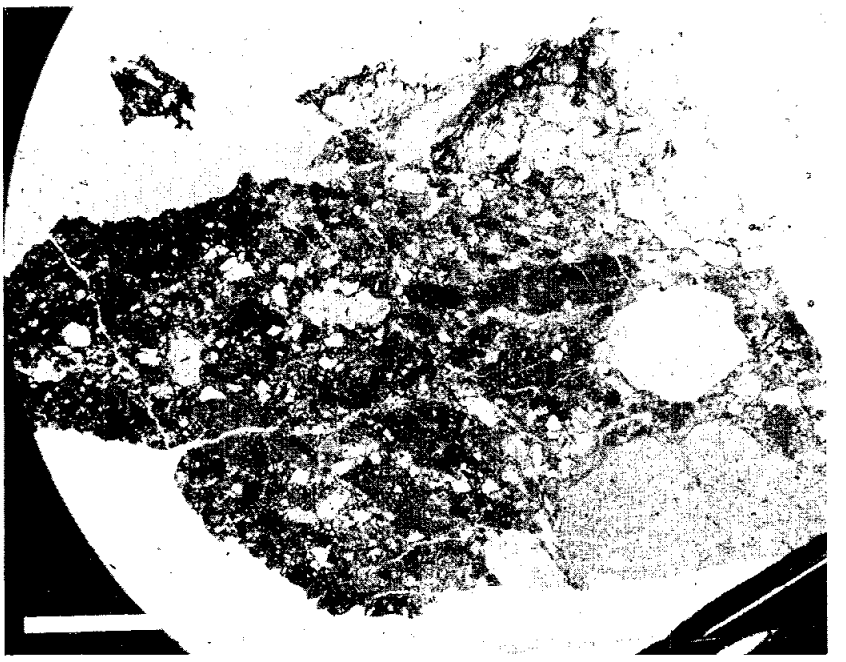


Figure 6.

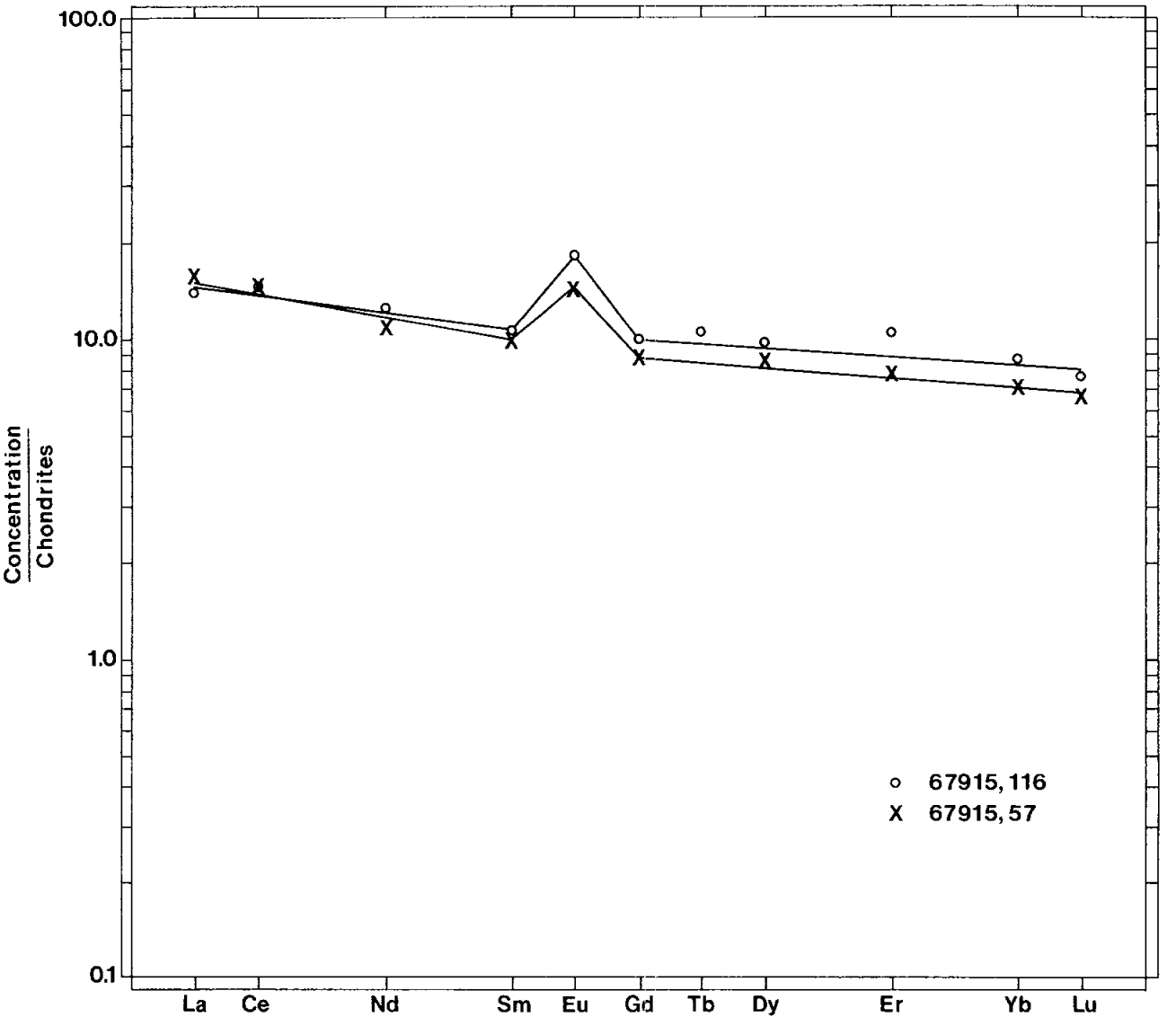

100.0
10.0
1.0
0.1
Concentration / Chondrites
La
Ce
Nd
Sm
Eu
Gd
Tb
Dy
Er
Yb
Lu
o 67915,116
X 67915,57

Figure 7.

TYPES OF CLASTS IN 67915

Breccia 67915 contains a wide assortment of clast types: anorthosites, noritic and troctolitic anorthosites, troctolites, peridotites, and ferrogabbro. Within some of these groups, textural subdivisions exist; for example, some appear to be coarse-grained igneous rocks, possibly pristine, whereas others are clearly metamorphosed breccias or are melt rocks. Brief descriptions of the main types of clasts follow, with emphasis given to those that might be pristine lunar rocks. All petrologic information is from Roedder and Weiblen (1974), Marti et al. (1978), or unpublished data obtained by the 67915 consortium (headed by K. Marti).

Probably Not Pristine Clasts

Three types of clasts constitute over 90% of 67915. These are described below, classified by their macroscopic color.

White clasts

The clasts that compose most of the white breccia (WB) are white macroscopically. They are rounded to oblong in shape, usually friable, and range in size from < 1 mm to ~ 1 cm. Although pale-green mafics are visible in some clasts, most are a uniform white color. Study of thin sections indicates that most white clasts are anorthositic and have hornfelsic (microgranular) textures. Plagioclase crystals are up to 0.1 mm across, but are usually smaller. The abundance of mafic silicates varies from clast to clast, as do the grain sizes. The white clasts in the gray breccia (GB) are also predominantly hornfelsic, anorthositic breccias, but a small percentage are richer in mafics, containing up to 40% olivine and pyroxene; macroscopically, however, they all look alike. A few white clasts are feldspathic melt rocks with subophitic textures. Chemical analyses of white clasts (Rose et al, 1975) are similar to that of the bulk white breccia (Table 2).

Gray clasts

Most of the clasts in the gray breccia (GB) are gray macroscopically. They vary from rounded to angular in shape, are coherent, and range in size from < 1 mm to ~ 2 cm. They are polymict breccias, containing white clasts (plagioclase clasts and fine-grained, white, friable clasts that look macroscopically like the white clasts described above) and also dark-gray clasts like those described below. The white and dark-gray clasts are set in a gray, fine-grained matrix. This matrix displays an igneous texture in thin sections, indicating that the gray clasts are melt rocks. Some contain feldspar and other light-colored clasts that are aligned, suggesting flow and affirming a melt origin. A chemical analysis (Table 2) of a gray clast was done by Rose et al. (1975).

Dark-gray clasts

The gray breccia (GB) also contains rounded, coherent clasts that have a darker gray color than most of the clasts. These dark-gray clasts range in size from ~ 1 to ~ 3 mm and are very fine-grained breccias. They occur both as isolated clasts within the gray breccia and as clasts within gray clasts. They are far

less abundant than either white or gray clasts. Thin section study suggests that the dark-gray clasts are very fine-grained melt rocks.

Possibly Pristine Rock Types

A minority of the clasts in 67915 might represent pristine lunar rocks. These are described here, classified by their mineralogy.

Troctolitic anorthosites

Troctolitic anorthosites occur in two main textural varieties (not including microgranular types described under "white clasts" above). One type, although usually severely shocked, appears to have a cumulate texture (Fig. 8A), with large plagioclase (originally probably > 1 mm) and intercumular olivine. A chemical analysis (Table 2) by Rose et al. (1975) is not greatly different from that of the bulk rock, however. Olivine compositions in two separate clasts are the same, Fo_{55}. Plagioclase is low in Na (An_{98} in one clast, An_{93-96} in the other.) This lithology is relatively easy to spot macroscopically, consisting of white plagioclase surrounded by pale green to yellowish olivine.

The other troctolitic lithology has more of a granular, but not obviously metamorphic, texture (Fig. 8B). Equidimensional plagioclase grains are up to 0.6 mm across and olivine is up to 0.4 mm. In the one sample for which data are available (Marti consortium), olivine is homogeneous and has a composition of Fo_{75}. Plagioclase has a composition of An_{95}.

Sodic ferrogabbros

Weiblen and Roedder (1973) discovered this unique lithology in 67915. It is characterized by the presence of sodic plagioclase ($An_{69}Ab_{28}Or_3$ to $An_{54}Ab_{37}Or_9$), iron-rich pyroxene, ilmenite ($\sim$ 5% of the rock), with minor amounts of silica and K-feldspar. The pyroxene appears to have crystallized with two distinct compositions: a ferropigeonite with $\sim En_{34}Fs_{52}Wo_{14}$ and a ferroaugite with $\sim En_{31}Fs_{35}Wo_{34}$. Each phase has exsolved somewhat, although the exsolution lamellae are usually too small to analyze. Sodic ferrogabbro clasts are usually cataclastic (Fig. 8C), so it is difficult to determine the original texture. However, because some clasts approach 1 mm in size and because the quartz and K-feldspar grains do not form a fine-grained intergrowth, one might infer that the original texture was fairly coarse-grained. Macroscopically, the sodic ferrogabbros are identified by the presence of brown pyroxenes and a fairly high abundance of ilmenite.

Peridotites and pyroxenites

Roedder and Weiblen (1974) described one and possibly two ultramafic rocks in 67915. One was rather rich in opaques and its pyroxene contained coarse (up to 10 μm thick) exsolution lamellae (Fig. 8D). The size of the lamellae and the large difference in composition between the host and the lamellae ($En_{63}Wo_4Fs_{33}$ vs $En_{41}Wo_{42}Fs_{17}$) suggest a long subsolidus annealing history. This suggests that some clasts in 67915 could come from deep within the moon's crust.

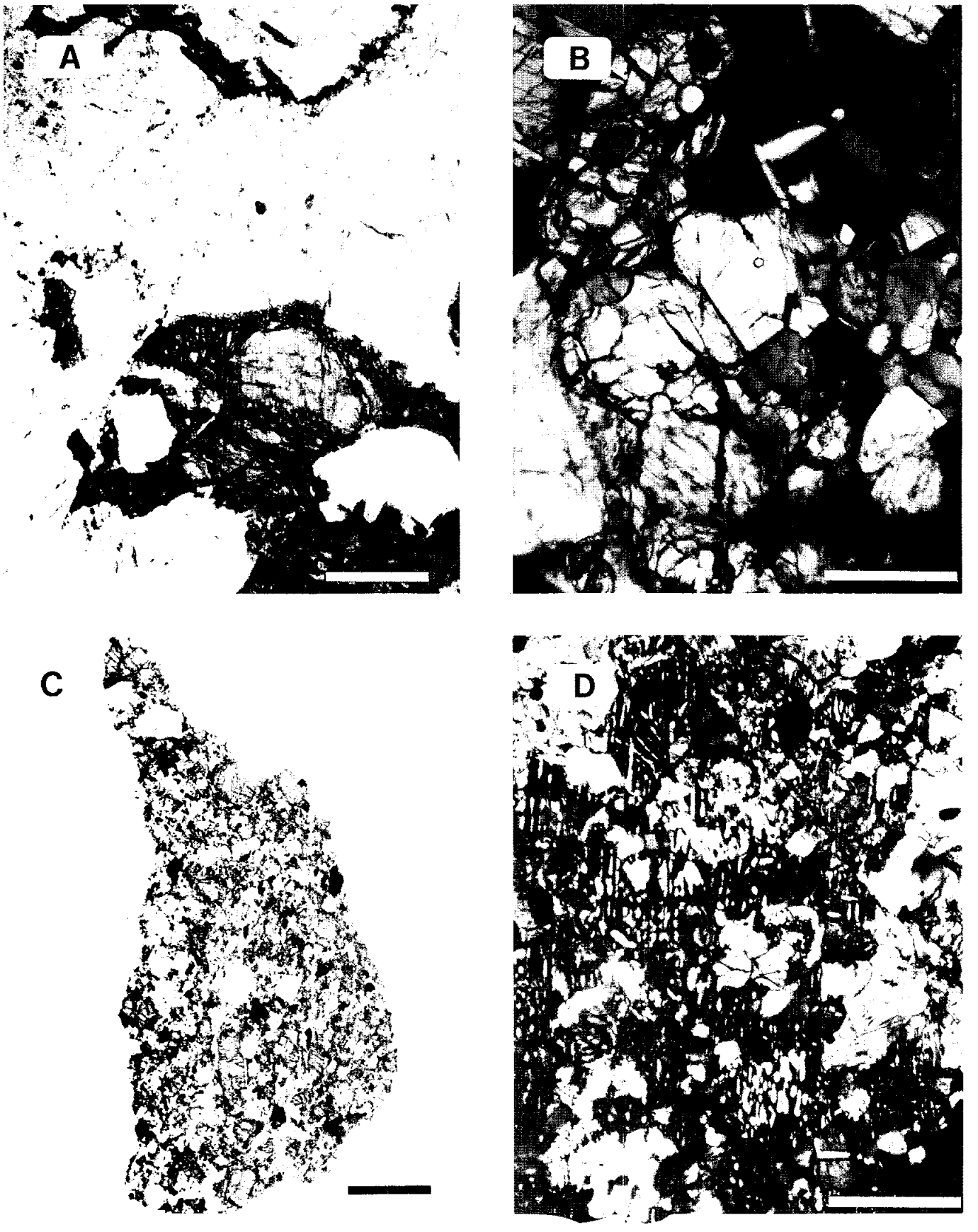


Figure 8.

Table 2. 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).

AGE DATA

The only age data available so far for 67915 derive from two studies of clasts (Kirsten et al., 1973; Marti et al., 1978), although the Marti consortium will produce additional data, including Nd-Sm analyses. Age data are summarized in Table 3. Three points are obvious from a glance at these data. First, there are no well-defined ages older than ∿ 4.0 b.y. Second, most samples show significant gas loss. This is consistent with the shocked nature of much of 67915 and may be due in part to excavation from the bottom of North Ray Crater. Third, some clasts do give good plateau ages, around 3.9-4.0 b.y. This indicates that younger shock events have not totally disturbed the chronology of the clasts in 67915. There is, therefore, some hope of identifying clasts with ages older than 4.0 b.y., assuming such clasts are present in the rock.

DESCRIPTIONS OF AVAILABLE SAMPLES

67915,223 (353.200 g)

E Sawn Surface 67915,223

The two main breccia lithologies stand out vividly on this surface (Fig. 9). Each is composed of numerous clasts. Possibly pristine or otherwise interesting clasts are noted on the map in Fig. 9 and described below.

Clast 1 Sodic ferrogabbro

Size:	4 x 5 mm
Shape:	Round
Color:	Brownish
Coherence:	Coherent
Mineralogy:	Plagioclase and brown pyroxene, with a smaller amount of shiny, black ilmenite.
Texture:	Plagioclase and pyroxene occur as larger crystals (up to ∿ 0.4 mm) in a finer-grained, apparently crushed matrix. The clast has a sharp boundary with the matrix of the rock.

Clast 2 Troctolite (?)

Size:	3 x 8 mm
Shape:	Elongated, but not angular
Color:	Light gray
Coherence:	Coherent

Mineralogy: Plagioclase (most of it shiny and gray, some chalky white) ∿ 60%, greenish mineral (probably olivine) ∿ 35-40%, and a few percent of an opaque.

Texture: The rock is crushed, but mm-sized areas of plagioclase and the green mineral remain.

Remarks: This clast is actually a clast within a gray breccia. Although it is coherent, it would be difficult to separate from the gray matrix. The boundary with the gray breccia is indistinct.

Clast 3 Troctolitic anorthosite

Size: 2 x 5 mm

Shape: Oval

Color: Whitish

Coherence: Friable

Mineralogy: ∿ 20% pale-greenish mineral (olivine?) and ∿ 80% white plagioclase, with 2-3% opaques.

Texture: Cataclastic; original crystals were ∿ 1 mm or larger in size, but cataclasis hides the original texture.

Clast 4 Anorthosite (?)

Size: 7 x 6 mm

Shape: Equant with rounded corners

Color: White

Coherence: Moderately coherent

Mineralogy: ∿ 10% greenish mafics and ∿ 90% plagioclase.

Texture: This is basically a white clast (w), but it is coarser grained than most. Crystals are up to 0.25 mm across. It appears to have a granular texture.

Remarks: Boundaries with surrounding gray breccia clast are indistinct.

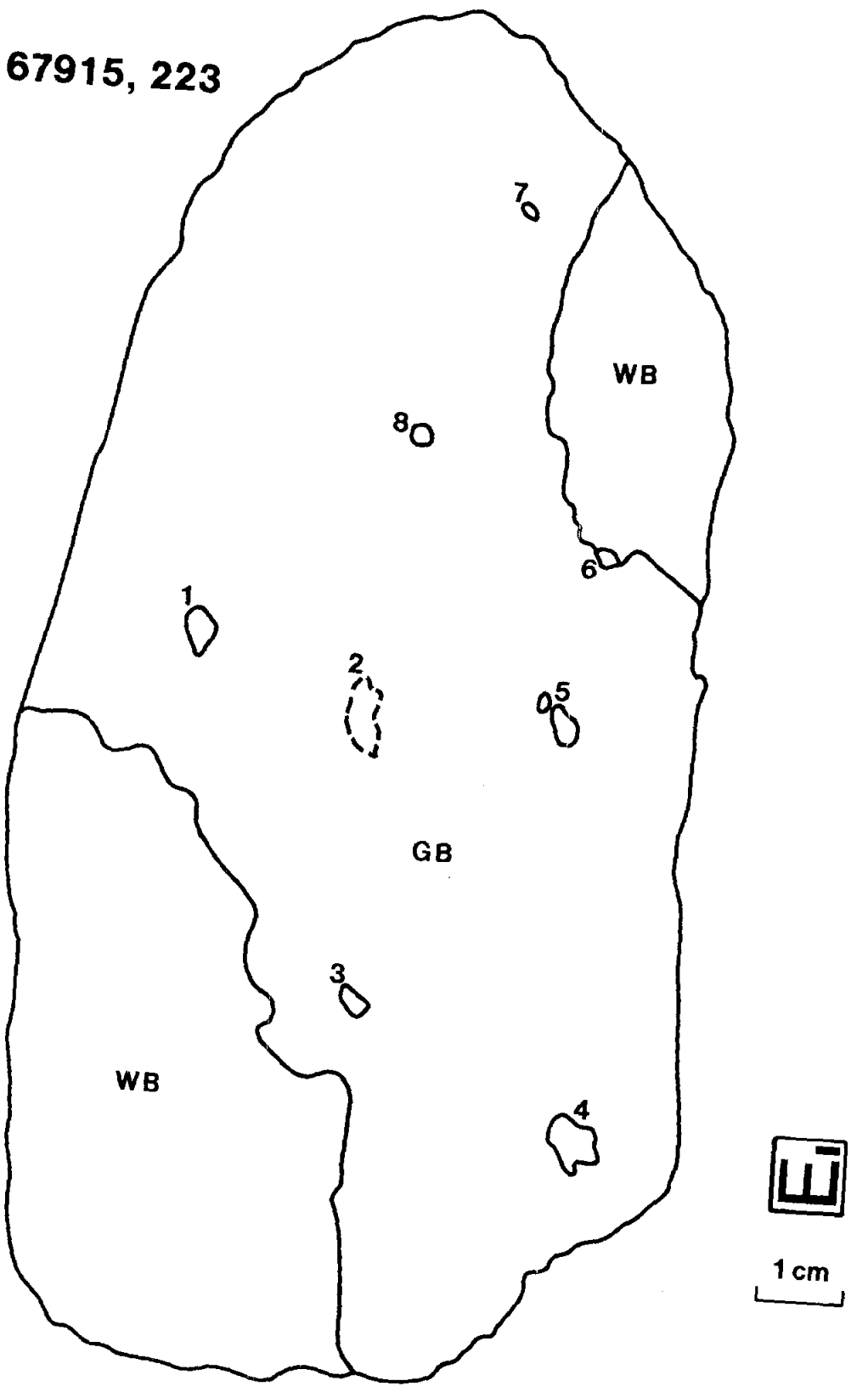


Figure 9.

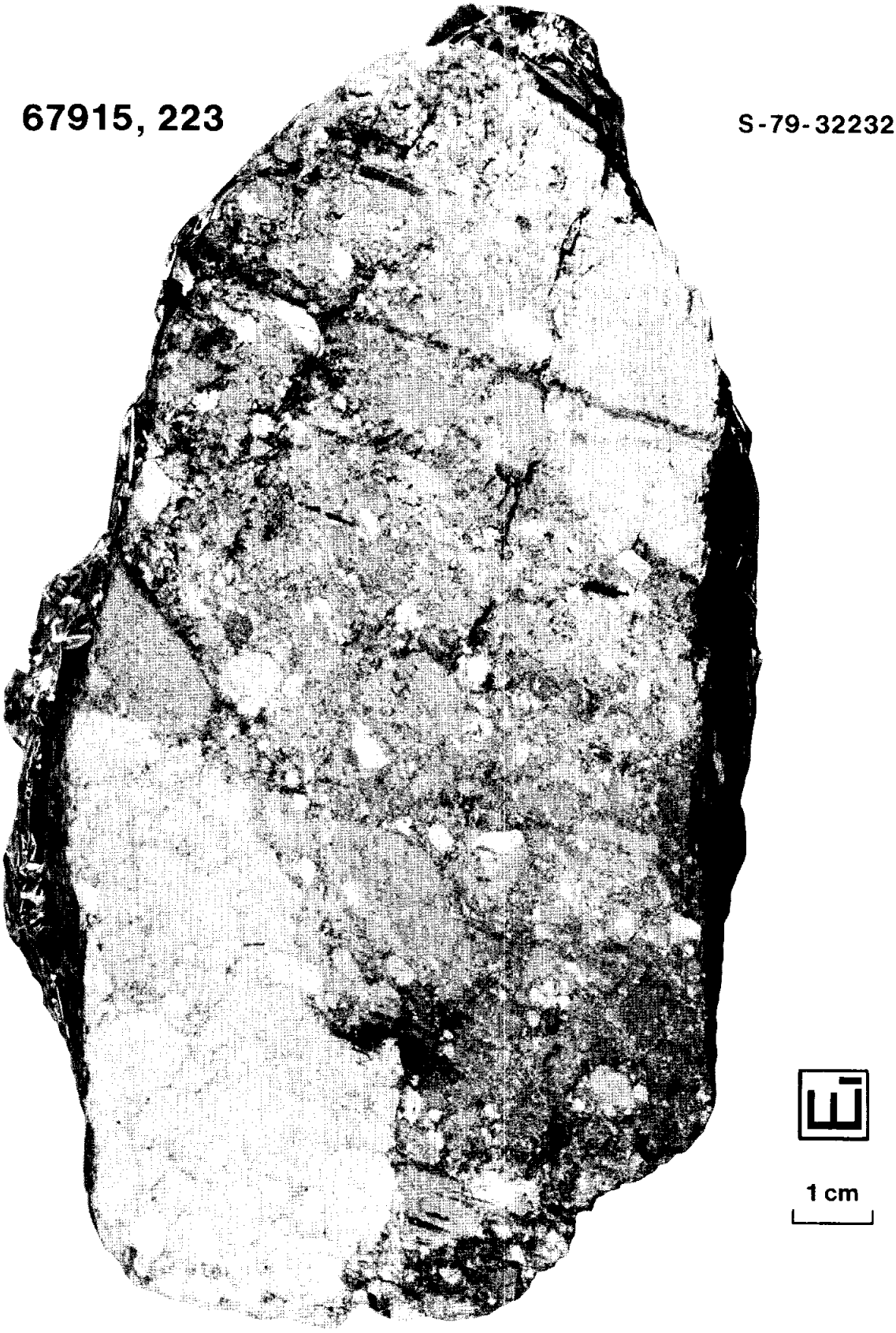


Figure 9.

Clast 5 Sodic ferrogabbro

Size:	2 x 2 mm; 4 x 3 mm
Shape:	Two pieces, both rounded. They appear to be connected by a smeared-out zone, so were probably one clast originally.
Color:	Brownish
Coherence:	Friable because of fractures
Mineralogy:	White plagioclase and brown pyroxene, with a few percent opaques.
Texture:	The larger fragment is banded, with zones of white plagioclase, brown pyroxene, and black ilmenite. It could have some of the gray matrix of the rock mixed in, too. It appears that a single clast was crushed during assembly of the rock.
Remarks:	Not a good candidate for matrix-free clast.

Clast 6 Troctolitic

Size:	2 x 3 mm
Shape:	Subangular
Color:	Whitish
Coherence:	Friable
Mineralogy:	Plagioclase with 15-20% greenish mineral (olivine?).
Texture:	The white matrix surrounds a band of greenish mineral.
Remarks:	This clast occurs at the border of one of the large white breccias (WB), and except for the band of green mineral, is not different in appearance from the typical white breccia clasts.

Clast 7 Sodic ferrogabbro

Size:	2 x 2 mm
Shape:	Round
Color:	Brownish
Coherence:	Coherent

Mineralogy: Plagioclase, brown pyroxene, ilmenite

Texture: Finer-grained than most of the ferrogabbro clasts; crystals are no more than ∿ 0.3 mm across. The fragment has a sharp boundary with the rock matrix.

Clast 8 Troctolitic anorthosite

Size: 2.5 x 2 mm

Shape: Rounded to subangular

Color: Whitish

Coherence: Friable

Mineralogy: Plagioclase (some white, some gray and shiny) with ∿ 20% greenish mineral (olivine?)

Texture: Crystals up to 0.5 mm across. The texture could be cumulate, but the small size of the clast and some cataclasis makes this uncertain.

W Sawn Surface 67915,223

None of the clasts described on the E face of ,223 (above) extend to this face of slab (which is ∿ 1.7 cm thick). The larger of the two white-breccia clasts is bigger on this face than it is on the E face. The other white-breccia clast is about the same size on both faces.

A 0.5-1 mm wide vein black glass cuts across the smaller of the two white-breccia clasts. The same vein appears on 67915,11 E (the butt end of the rock), but not on the E side of slab ,223. Smaller, grayish veins are also visible, especially in the white-breccia clasts. (They may be equally abundant in the gray-breccia, but do not show up as well.) A glass vein could be sampled on the B edge (see Fig. 10). Sufficient material could be obtained for age and chemical data; more glass apparently from the same vein, is available on 67915,11.

Two interesting clasts are present:

Clast 1 Sodic ferrogabbro

Size: 4 x 4 mm

Shape: Equant

Color: Brownish

Coherence: Moderately coherent

Mineralogy: Plagioclase, brown pyroxene, and ilmenite

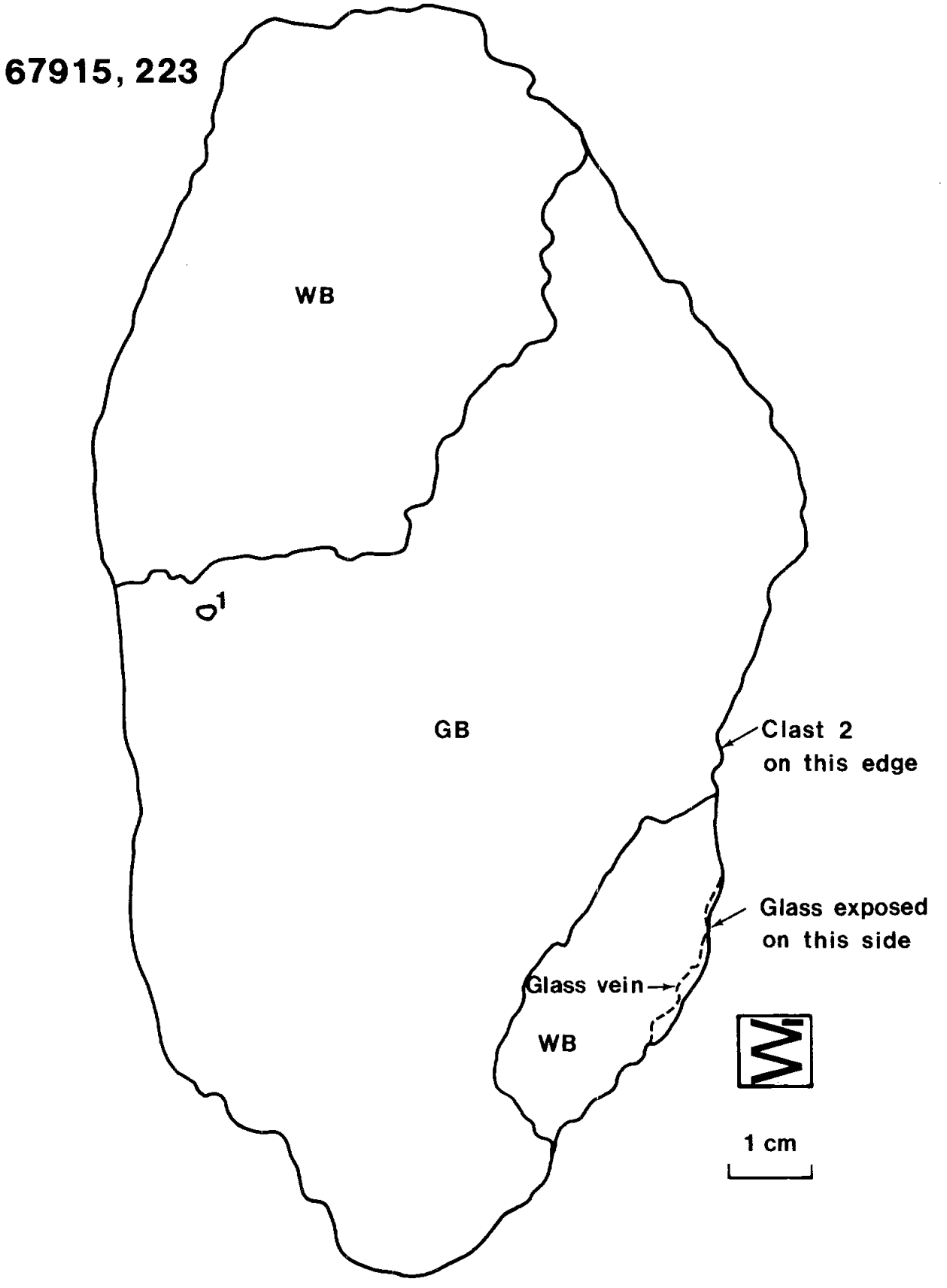

67915, 223
WB
o1
GB
Clast 2
on this edge
Glass exposed
on this side
Glass vein
WB
1 cm

Figure 10.

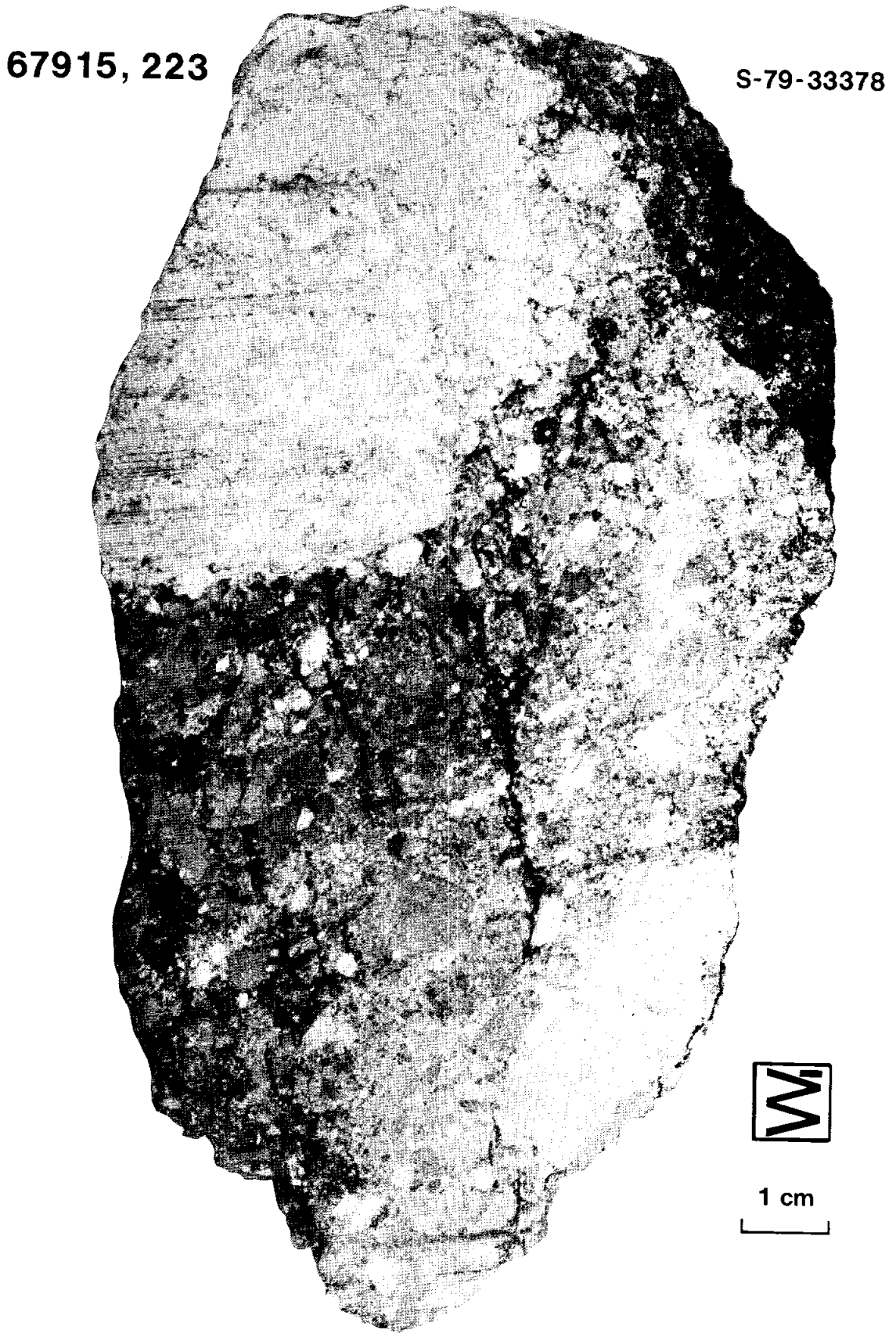


Figure 10

Texture: Plagioclase is equant. The texture looks granular.

Clast 2 Troctolitic anorthosite (?)

Size: 5 mm

Shape: Round

Color: Whitish

Coherence: Coherent

Mineralogy: ∿ 75% plagioclase (white) and ∿ 25% of a greenish mineral, probably olivine.

Texture: Appears to have a fairly coarse-grained, granular texture. Green mineral occurs in grains up to 0.5 mm across.

Remarks: The clast occurs on the B edge, in an area free of patina. The clast does not intersect either the E or W faces of slab ,223.

67915,11 (800.0 g)

E Sawn Surface

This surface is marred by numerous smears from the saw blade used to cut slab ,223 (Fig. 11). These marks make identification of clasts difficult. Although the boundary between the smaller of the two white-breccia clasts and the gray breccia is obscured by the smears, it does not seem to be as sharp as it is on the other surfaces.

A vein of black glass cuts across the smaller white-breccia clast (Fig. 11), near the sample's edge. This vein is 0.5 mm across and is the same one visible on 67915,223 W. It also extends to the side (B) of the sample, where one can see that it is a planar body that cuts through the rock. It would be easy to sample the glass without removing any significant amount of the white-breccia.

67915,23 (72.380 g)

E Sawn Surface

This is a piece from the first slab cut from 67915. Although light-colored clasts are evident (Fig. 12), it was cut entirely from the gray-breccia portion of the rock (i.e., the rock's matrix). Clasts other than common white and gray clasts include the following (see Fig. 12):

Clast 1 Troctolitic anorthosite

Size:	3 x 5 mm
Shape:	Rounded
Color:	Whitish
Coherence:	Moderately coherent
Mineralogy:	White plagioclase with 15-20% pale-green olivine.
Texture:	Granular, with olivines up to 0.5 mm. The olivine might poikilitically enclose the plagioclase.
Remarks:	Although moderately coherent, the rock is strongly cemented to the matrix.

Clast 2 Anorthosite

Size:	15 x 20 mm
Shape:	Rounded but elongated
Color:	White
Coherence:	Friable
Mineralogy:	More than 90% plagioclase with a few grains of greenish-yellow mafic silicate.
Texture:	Mostly fine-grained and non-descript, but it has a coarser-grained area in which plagioclase crystals are up to 1 mm across and the mafic mineral is 0.5 to 0.75 mm across.
Remarks:	A typical white clast except for the coarse-grained area.

Clast 3 Sodic ferrogabbro?

Size:	1 x 4 mm
Shape:	Long, thin and angular
Color:	Dark gray to black
Coherence:	Moderate
Mineralogy:	Some ilmenite present and probably some brown pyroxene.
Texture:	Fine-grained. Probably a sodic ferrogabbro.

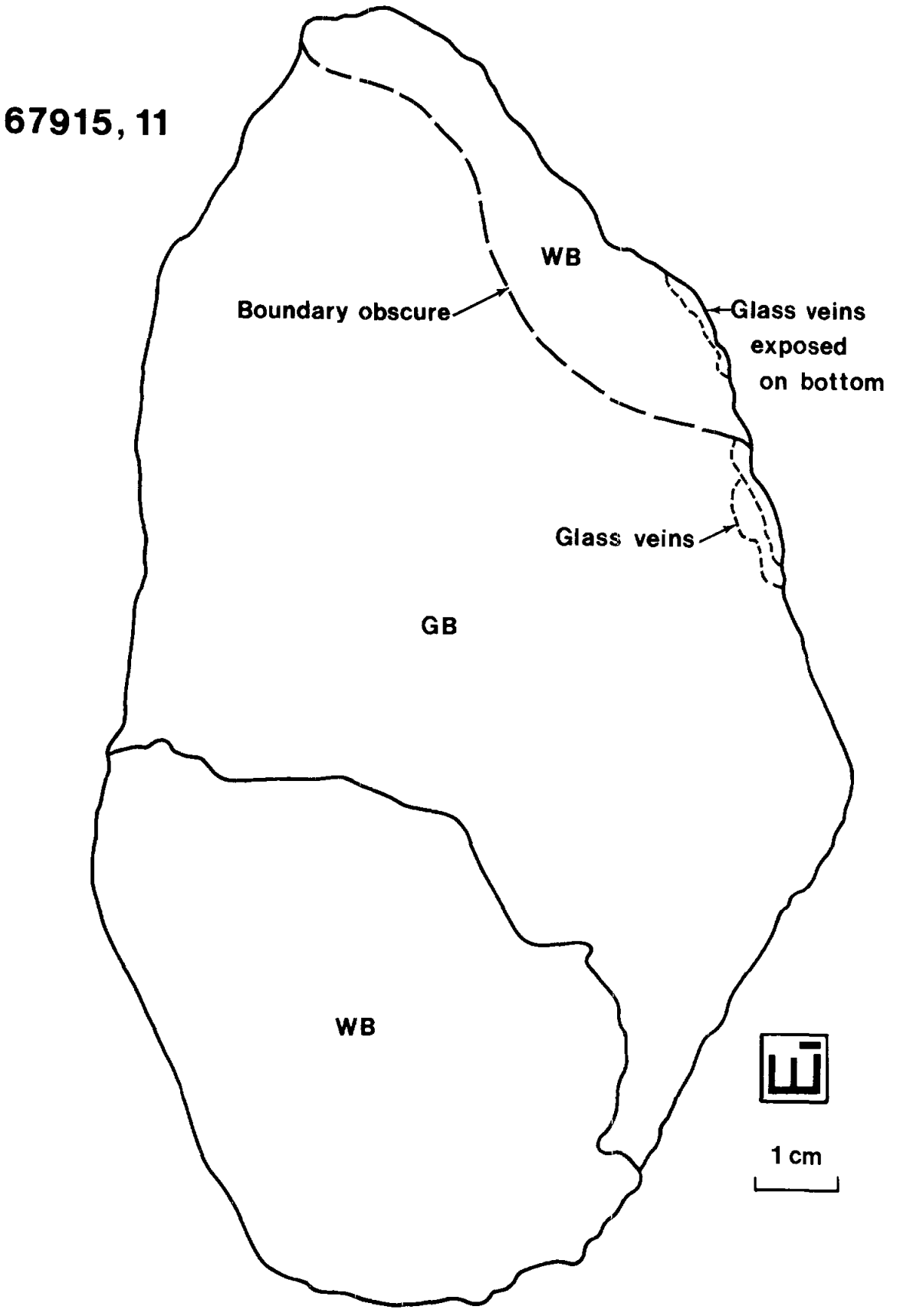

67915, 11
WB
Boundary obscure
Glass veins
exposed
on bottom
Glass veins
GB
WB
1 cm

Figure 11.

Figure 11.

67915, 23

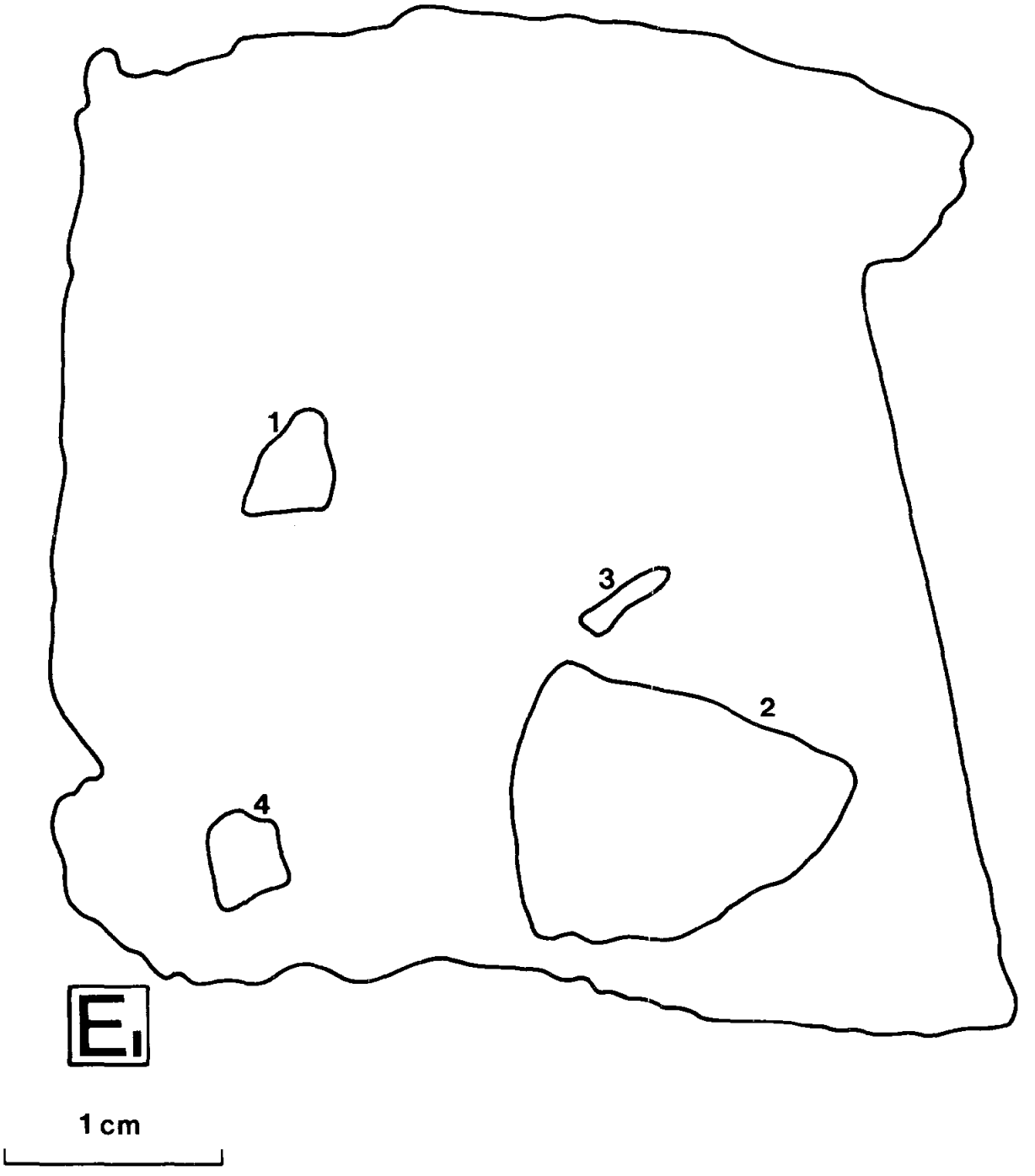


Figure 12.

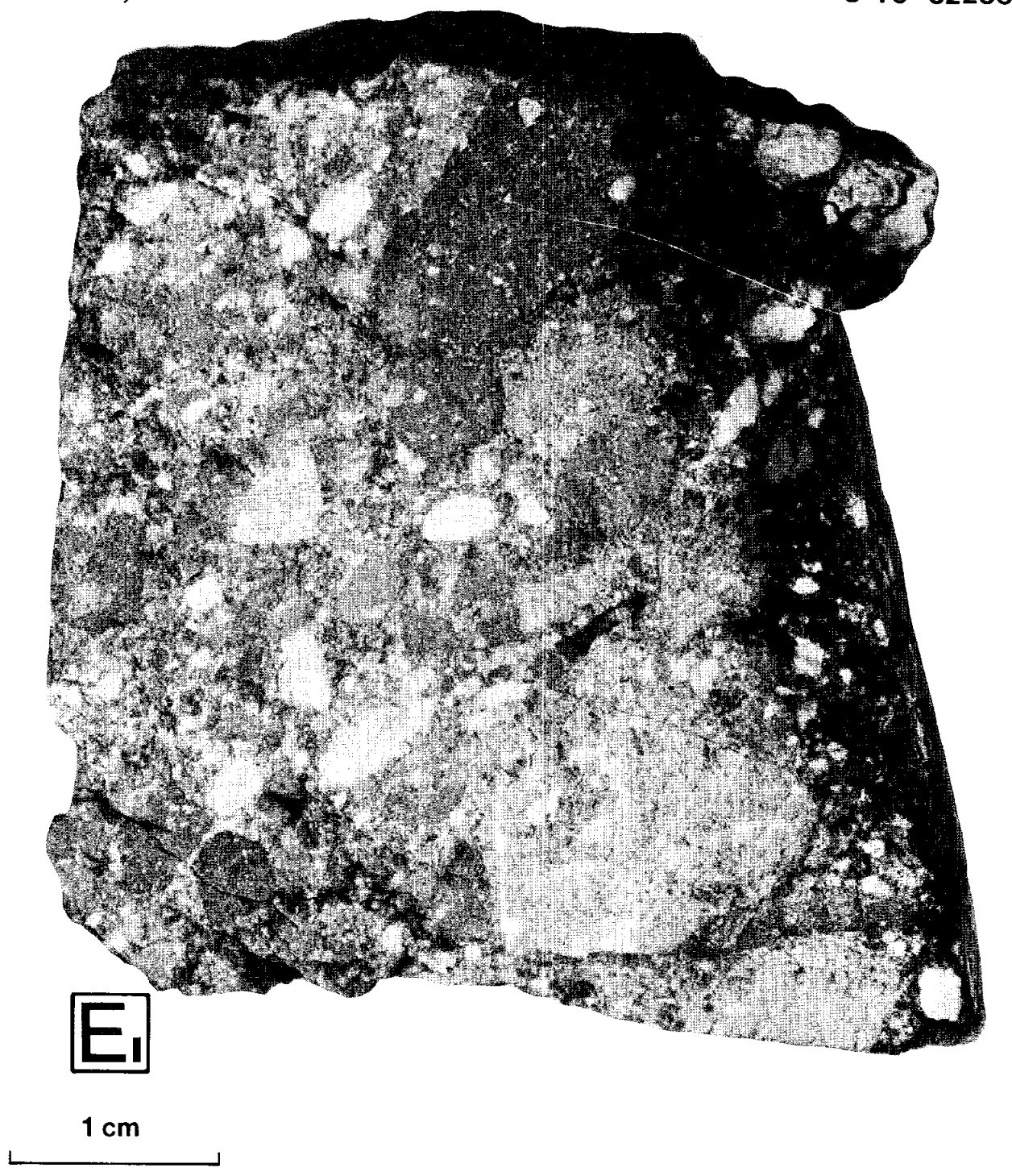


Figure 12.

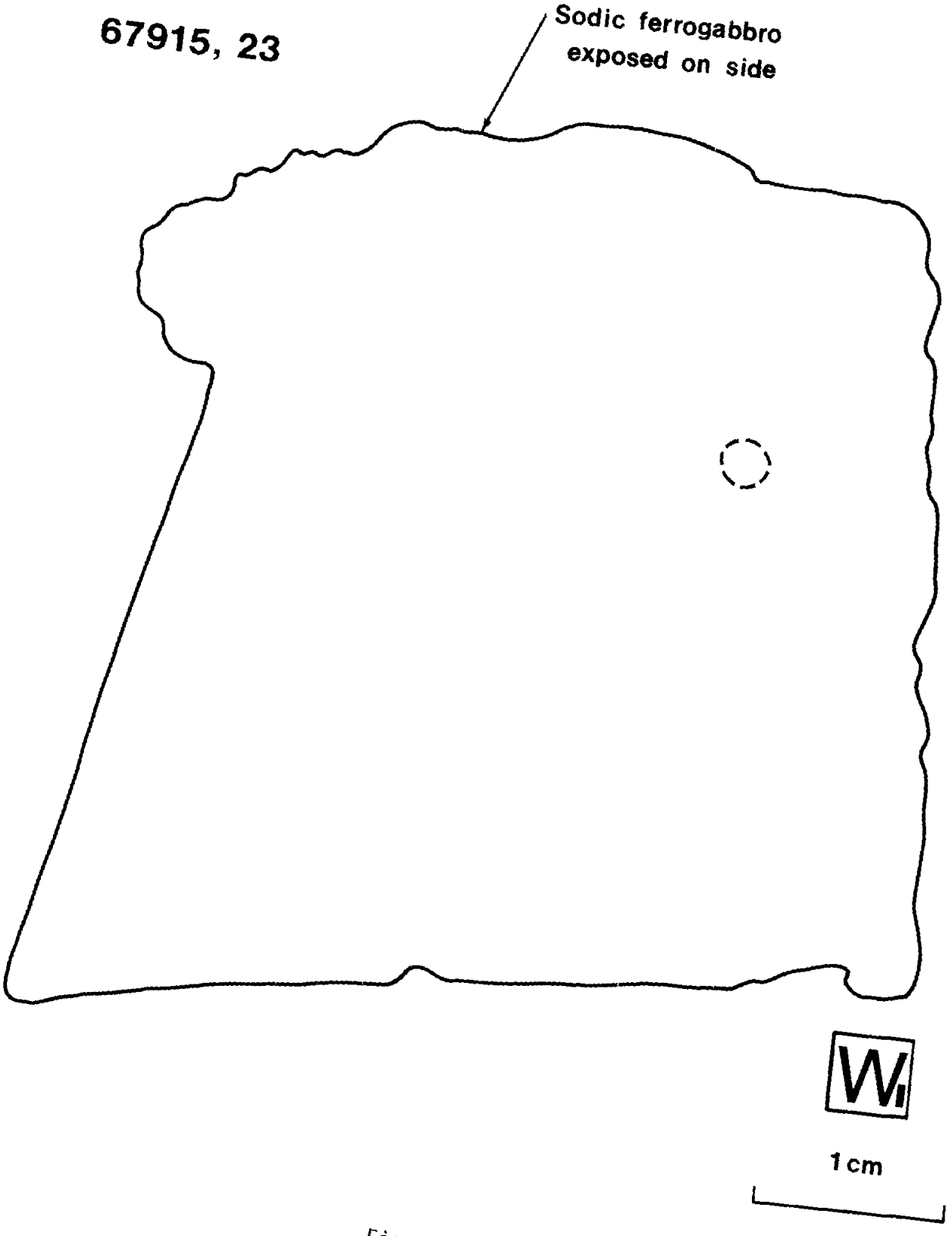


Figure 13.

67915, 23

S-79-36624

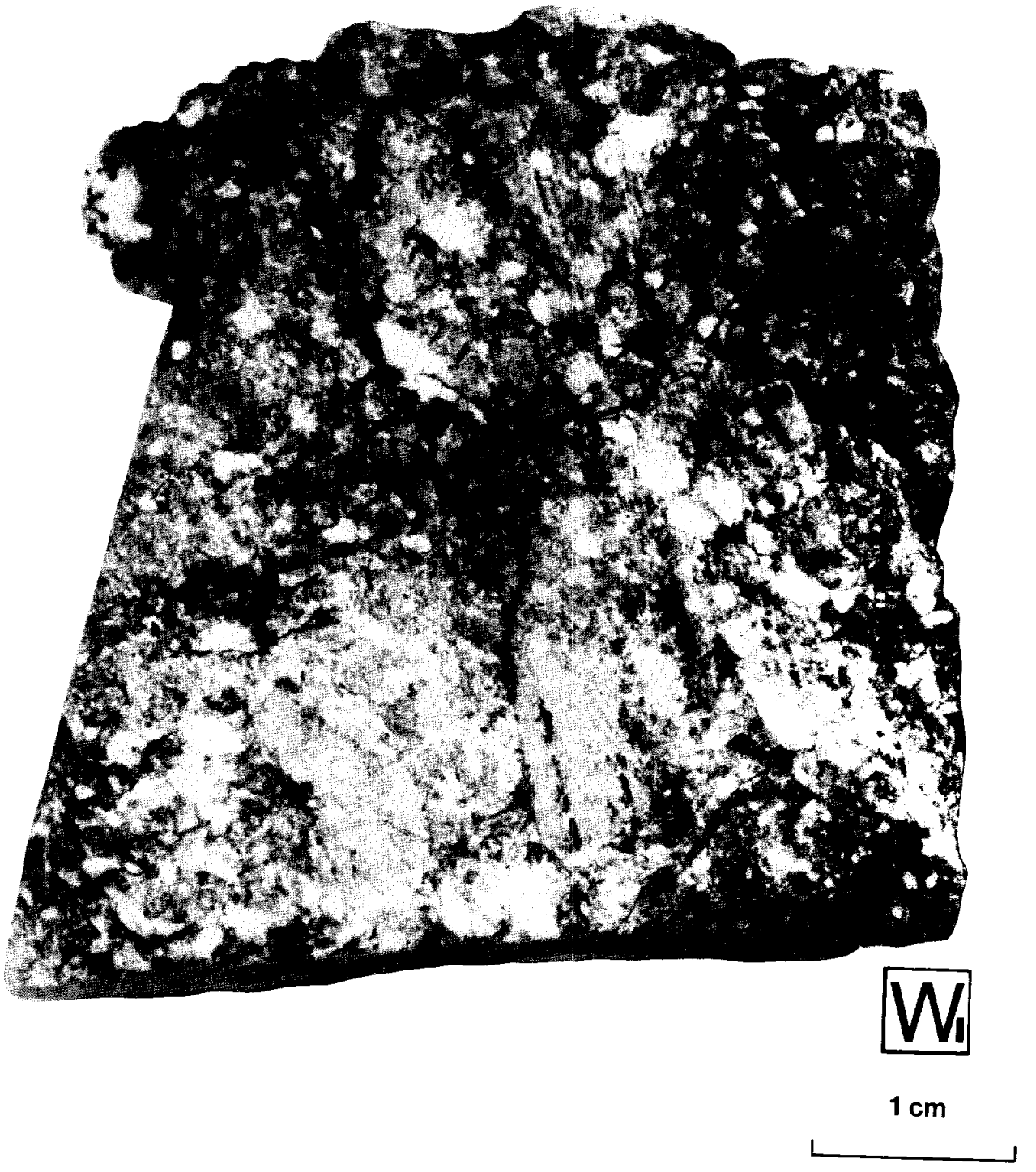


Figure 13.

Clast 4 Sodic ferrogabbro with gray breccia

Size:	3 x 4 mm
Shape:	Rounded and equant
Color:	Gray
Coherence:	Coherent
Mineralogy:	Contains brown pyroxene and ilmenite, but most is too fine-grained to identify minerals.
Texture:	Fine-grained with coarser grains of pyroxene and ilmenite.
Remarks:	Probably a gray breccia clast that contains a crushed sodic ferrogabbro. Not a good sample for pure ferrogabbro material.

W Sawn Surface 67915,23

Typical gray breccia (Fig. 13). The surface was badly plucked during sawing. A clast of sodic ferrogabbro occurs below the sawn surface. Its location is outlined in Fig. 13.

There is also a 3 x 5 mm sodic ferrogabbro on the side of slab ,23, nearer to the W than E face (Fig. 13). The clast has large, brown pyroxene grains (one is ∿ 1 mm across) and crushed, white plagioclase. Ilmenite is also present and occurs in crystals about 0.5 mm across. The clast is fairly friable.

67915,9 (94.910 g)

Sawn Surfaces

This sample contains areas of both white (WB) and gray (GB) breccias (Fig. 14). The gray areas contain isolated crystals of olivine and plagioclase up to a millimeter across, but no clasts of possible pristine rocks were observed on the sawn surfaces. A relatively coarse-grained clast, however, is present on the side of the specimen, where it is broken. The clast is quite friable, 4 x 6 mm in size, and contains olivine crystals (∿ 15% of the rock) up to ∿ 1 mm across in a plagioclase matrix.

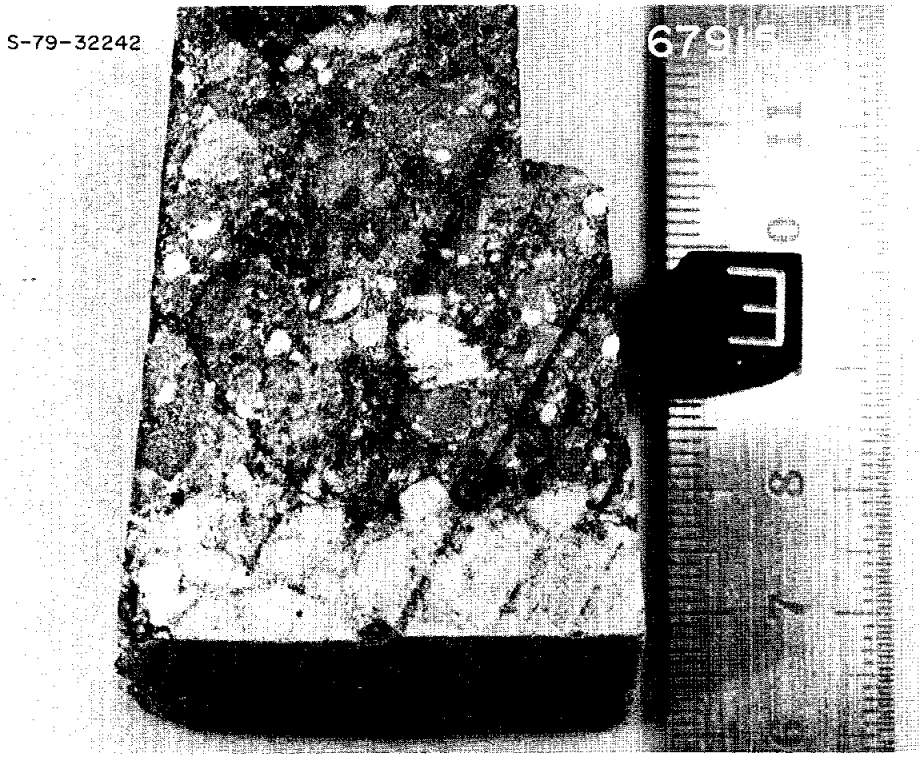
67915,5 (20.470 g)

This sample is rectangular in shape with four sawn surfaces and two broken surfaces (Fig. 15). It represents typical gray breccia, containing mostly gray clasts. White clasts are also present; most of these are typical fine-grained white clasts, except for one 5-mm clast on the N side. This clast is different from most white clasts in 67915 in being coarse grained enough to see that olivine is present. The texture, however, appears granular with no indication of a remnant coarse-grained igneous texture.

Table 3. Summary of ^{39}Ar-^{40}Ar age data on clasts from 67915

Clast No.	Petrography	Age (b.y.)	Ref.	Comments
67915,41a	Light-gray breccia	-	1	Continuous increase in apparent age with fraction of ^{39}Ar released
67915,41b	White, aphanitic	-	1	Semi-plateau with age > 4.2 b.y., but 1500° fraction has apparent age of 4.65 b.y.
67915,41c	White to light-gray coarser-grained than clast b	3.91±.05	1	Good plateau for last 40% of ^{39}Ar released
67915,41d	Friable matrix of breccia	3.99±.05	1	Good plateau for just 60% of ^{39}Ar released last
67915,34W	Large plag. crystals in a much finer-grained matrix (white clast)	4.01±.1	2	Plateau for last 40% of ^{39}Ar released
67915,13DW	Slightly recrystallized ANT breccia (white clast)	~4.0	2	Continuous increase in apparent age with fraction of ^{39}Ar released; final 50% has age > 3.7 b.y.
67915,34B	Fine-grained, plag.-rich melt rock	~3.5	2	Poorly-defined plateau that comprises 40% of the ^{39}Ar and has a slight dip in it.
67915,34S	Sodic ferrogabbro	>3.2	2	Plag. separate; continuous increase in apparent age with fraction of ^{39}Ar released. No plateau.

1) Kirsten et al. (1973)
2) Marti et al. (1978)



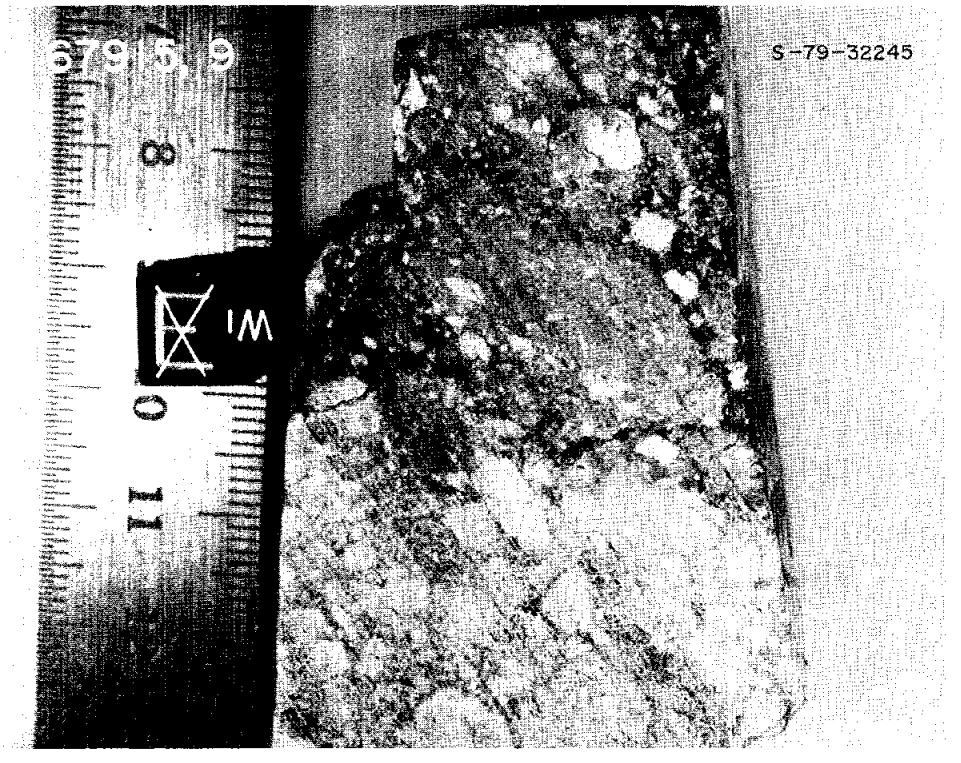
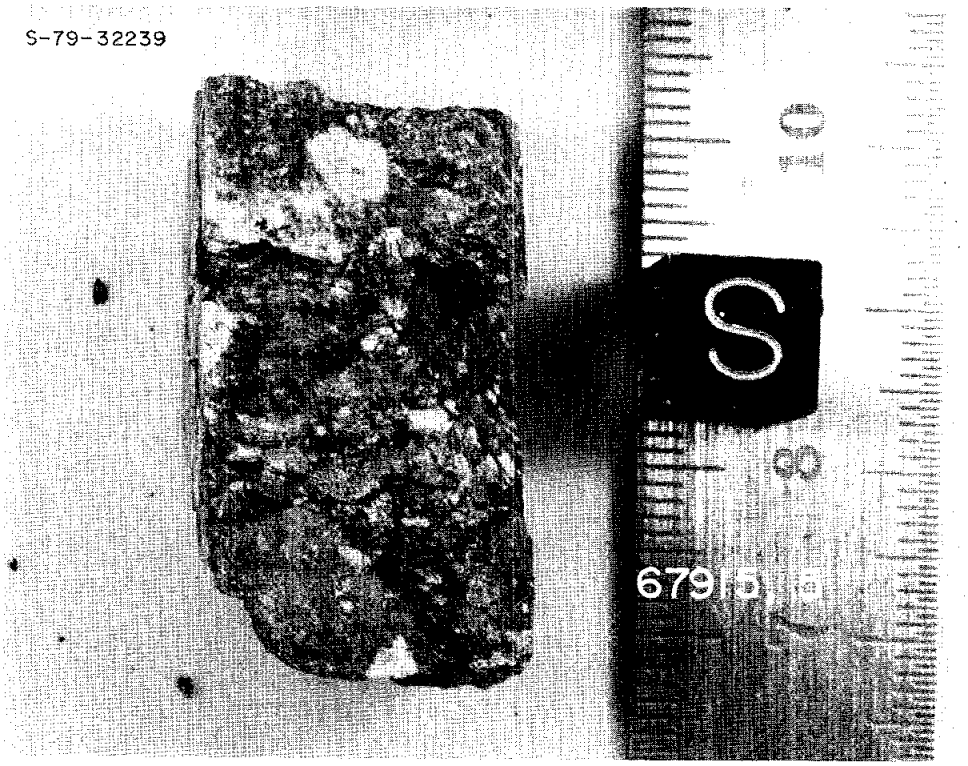


Figure 14.



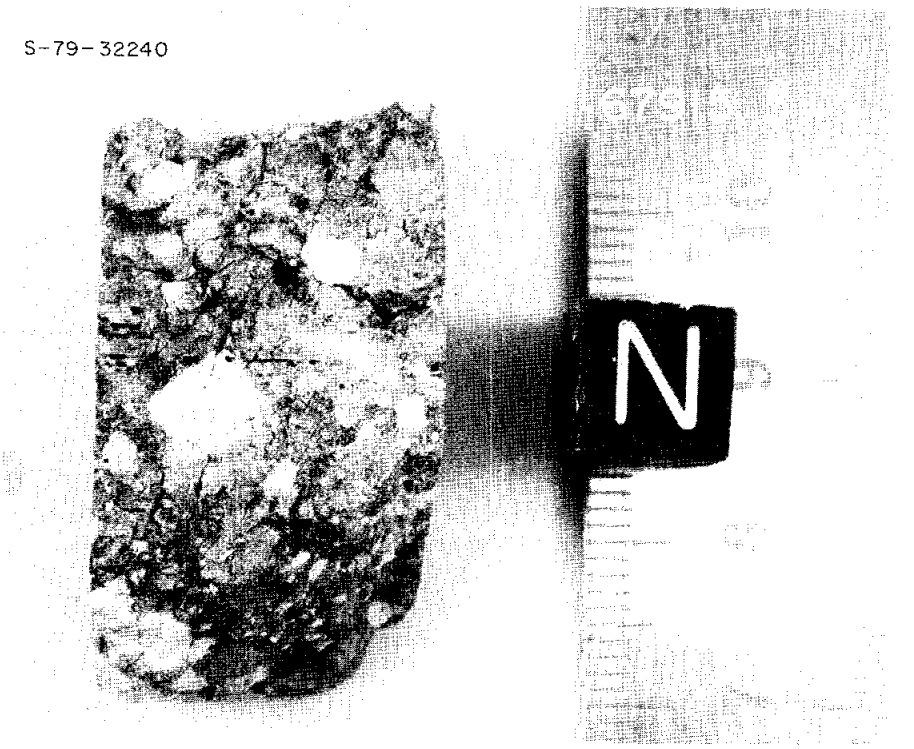


Figure 15.

67915,21 (21.100 g)

This is a sample of one of the two white-breccia clasts in 67915 (Fig. 16). Two surfaces (parts of E and B) are patina-covered outer surfaces of the rock.

67915,210 (0.710 g)

This is a > 1 cm fragment that was separated from 67915,25 (unsieved fines produced when the first slab cut from 67915 was subdivided). It is clearly a piece of one of the white breccia (WB) clasts, containing several individual white clasts (Fig. 17). The sample has been cut into a thin section (67915,221) and the potted butt could be used to make more thin sections.

67915,211 (9.29g)

This is a group of white and gray breccias in the 4-10 mm size range that were sieved from 67915,25 (Fig. 17). They appear typical of these lithologies in 67915. Gray clasts are more abundant than white.

67915,212 (0.39g)

This is a group of three particles (Fig. 17) separated from 67915,211. They are not typical white or gray clasts. One is a mixture of gray and white lithologies. The gray is typical gray breccia, but the white is a troctolitic anorthosite, consisting of ∿ 20% greenish or yellowish mineral (probably olivine) and 80% plagioclase. Crystals are ∿ 1 mm across. The clast is quite friable and it would be difficult to remove it undamaged from the gray portion. The whole fragment measures 9 x 7 x 2 mm; less than half of the volume is the white clast.

The second fragment is white with some greenish-yellow grains. The grain size is ∿ 1 mm. There appears to be a foliation, which is probably caused by admixed gray breccia. The fragment is ∿ 4 x 8 x 3 mm in size.

The third clast is probably from one of the large white breccia (WB) clasts in the rock, but it consists largely of the coarser-grained plagioclase that occurs between the pebble-shaped, fine-grained white clasts.

67915,213 (0.07g)

This is a 4 x 7 x 1.5 mm fragment of sodic ferrogabbro (Fig. 17). The sample is somewhat friable and appears granulated. Brown pyroxene crystals are up to 0.5 mm across; ilmenite is up to 0.2 mm. The fragment is totally free of matrix. It has been allocated to the Marti consortium.

67915,214 (9.80g)

A group of about 100 fragments in the 2-4 mm size range (Fig. 17). They are typical gray and white clasts.

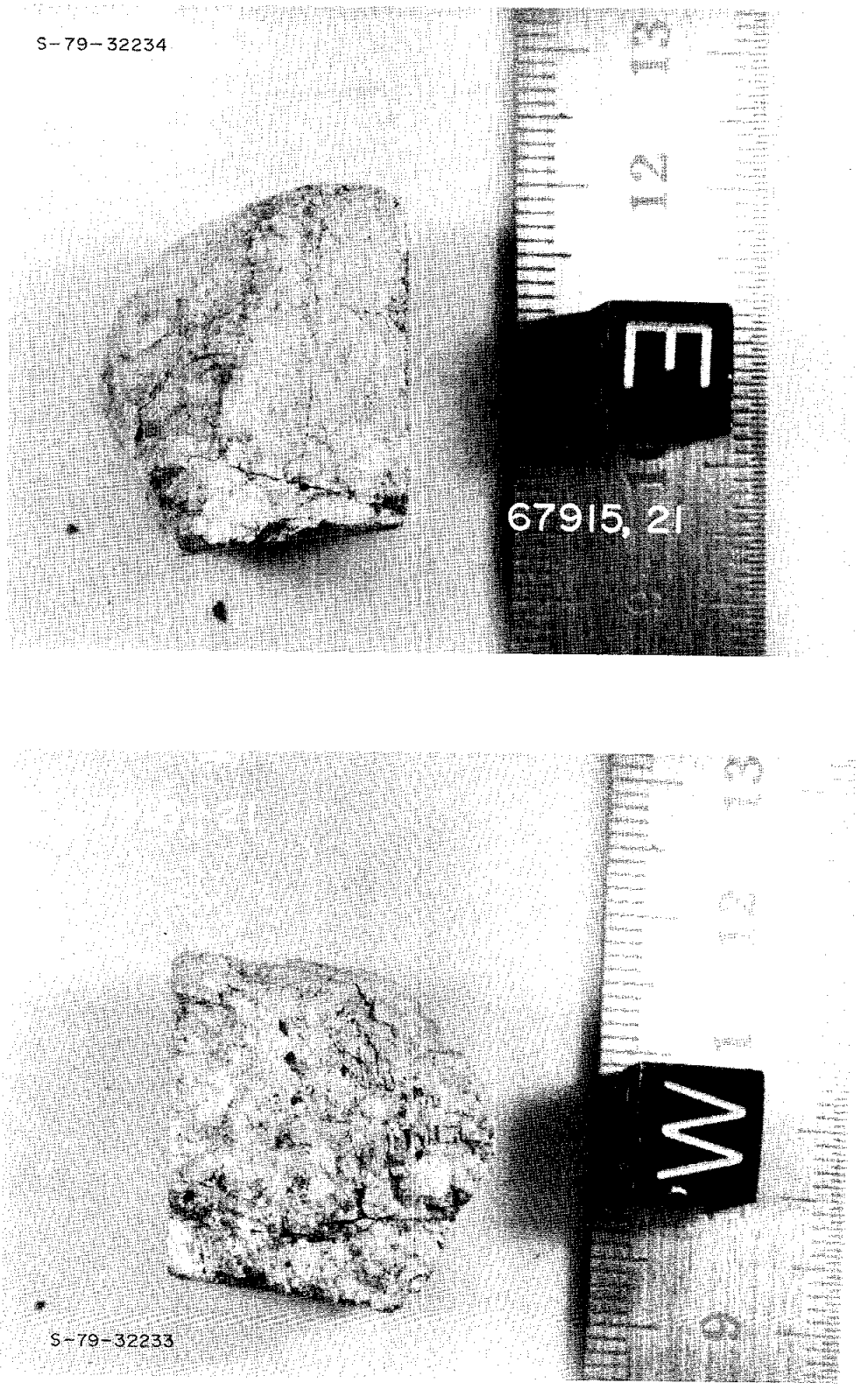


Figure 16.

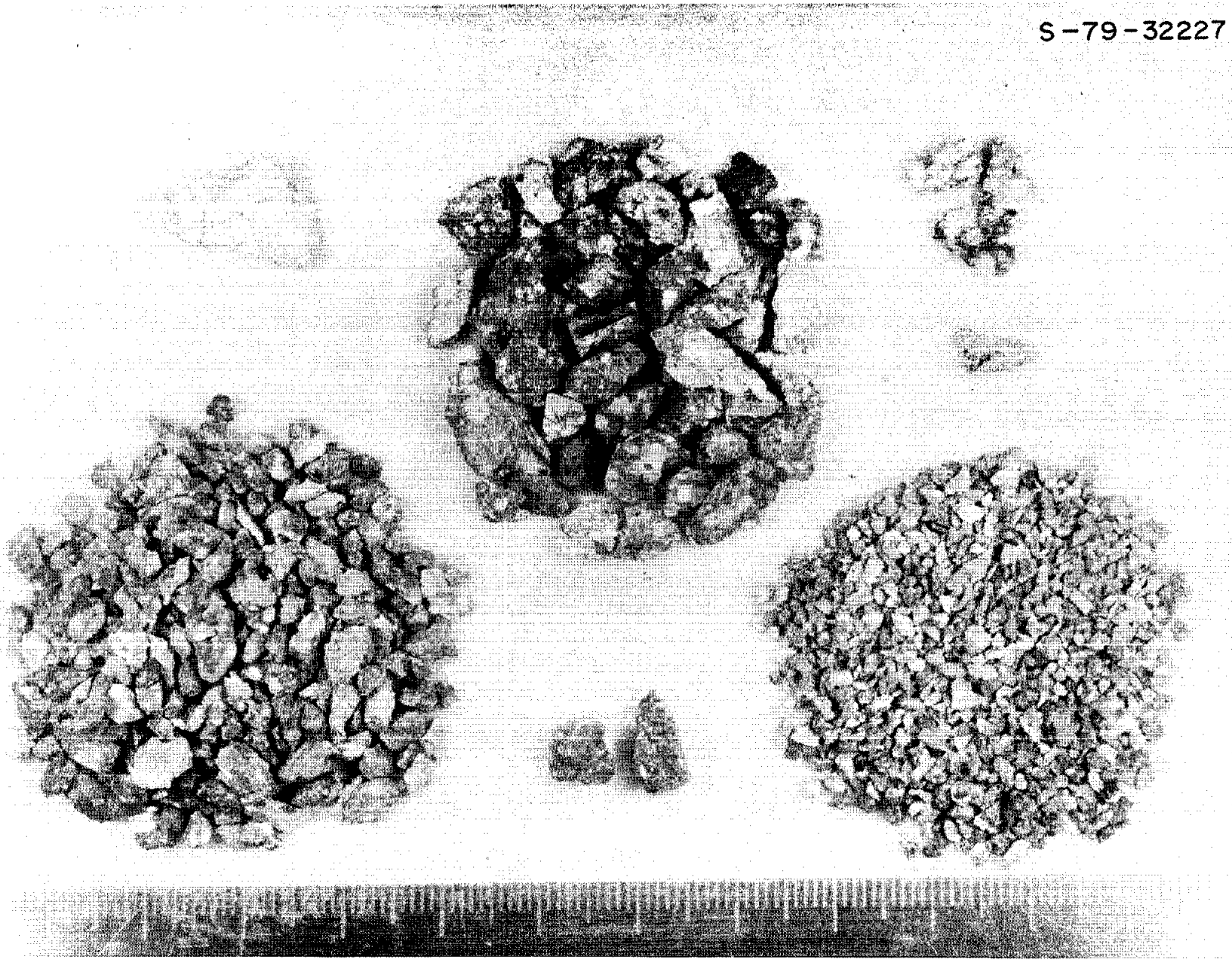


Figure 17.

67915,215 (9.46g)

A group of > 100 fragments in the 1-2 mm size range (Fig. 17). These are gray and white clasts.

67915,216 (.560g)

These are two gray breccias separated from ,212, the 4-10 mm fraction of ,25. They appeared to be typical gray breccias and so were cut into a thin section (67915,222) to aid in the general description of 67915.

67915,217 (31.4g)

These are < 1 mm gray fines.

67915,224 (1.01g)

This is a group of five fragments that fell off 67915,11 during the sawing that created slab ,223. (The group originally consisted of nine fragments, but four were removed for the Marti consortium: see ,234 below). The fragments fell off the T side of the slab (Figs. 10,18). All five are typical gray clasts.

67915,225 (0.48g)

This is a group of 11 fragments that fell off the larger of the two white breccia (WB) clasts (Figs. 10,18). They are typical fine-grained, white clasts.

67915,226 (0.69g)

Group of five particles that fell off the smaller of the two white breccia (WB) clasts (Figs. 10,18). All are white and fine-grained.

67915,227 (13.0g)

This sample is the bandsaw fines produced during the sawing of ,11 (Fig. 18).

67915,228 (2.13g)

This sample, consisting mostly of gray clasts but with some white ones, too, also fell off during slabbing, but sample documentation does not indicate explicitly where they came from (Fig. 18). However, one fragment is coated with dark glass identical in appearance to that on slab ,223 and on ,11 (see descriptions above). Sample ,228, therefore, probably came from the outside of 67915 near the smaller white breccia clast. The glass could be a useful sample.

67915,228 also contains a 2 x 2 x 2 mm clast of troctolitic anorthosite. It has greenish olivine interstitial to white plagioclase and looks much like the clast in ,234.

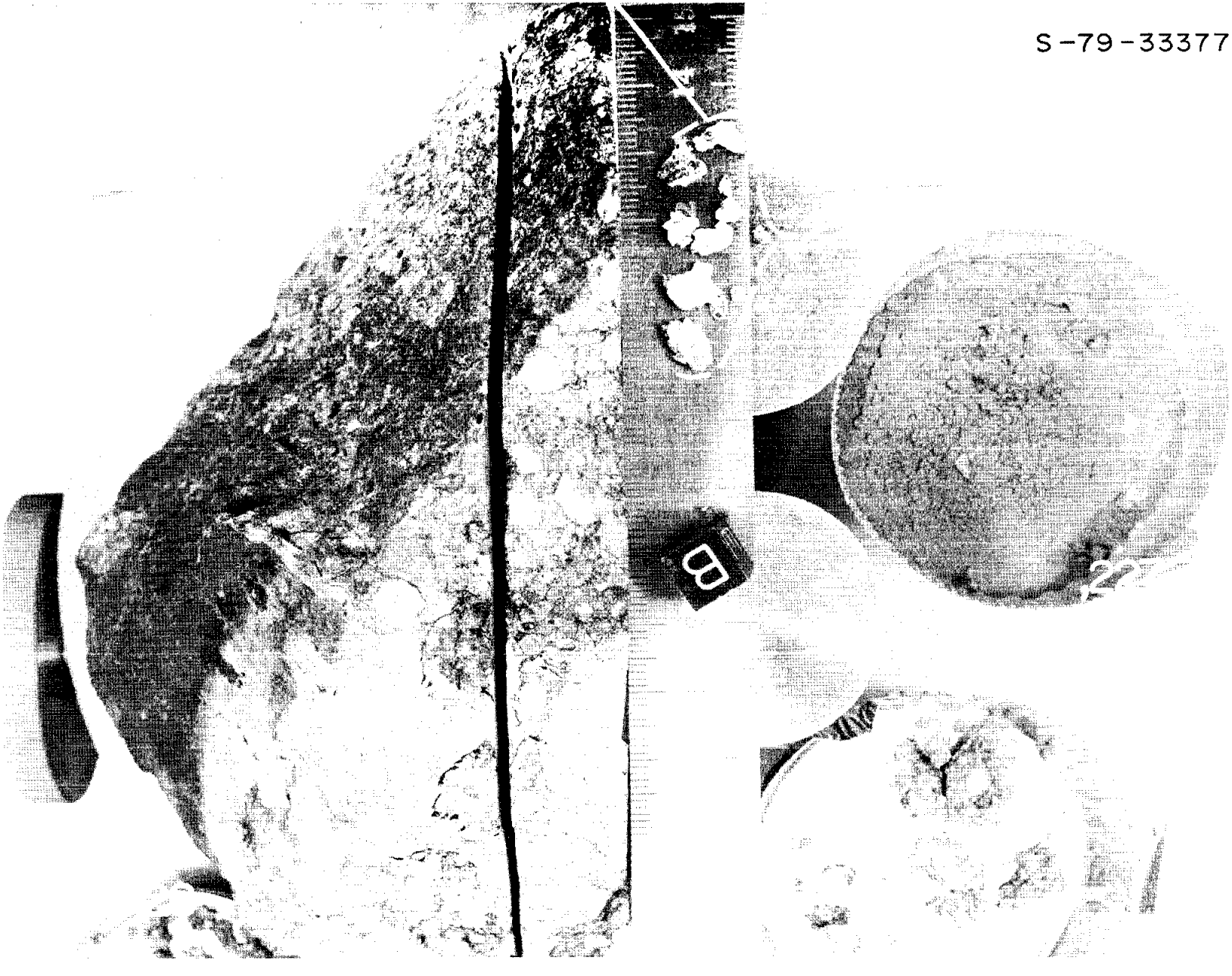


Figure 18.

67915,234 (3.31g)

This sample consists of four fragments picked from a group (,224) of fragments that fell off an area of 67915,11 when it was sawed. They fell off the T side of the slab (,223) created by the cut. All four fragments are typical fine-grained gray breccias, but each contains pieces of troctolitic anorthosite. It seems likely that the pieces of troctolitic anorthosite are from one clast because the fragments in ,224 fell off one place on the slab. The clast consists of plagioclase (white, crushed, but crystals larger than 0.25 mm are present) with narrow zones of olivine (greenish). This is a common (but not abundant) lithology in 67915. In thin sections, similar clasts appear to consist of cumulate plagioclase with intercumulus olivine (see Fig. 8A). Although sample ,234 weighs 3.3 grams, the clast of troctolitic anorthosite weighs less, about 0.5 to 1.0 grams. No pieces of the clast remain on slab ,223 or on sample ,11. The clast has been allocated to the Marti consortium.

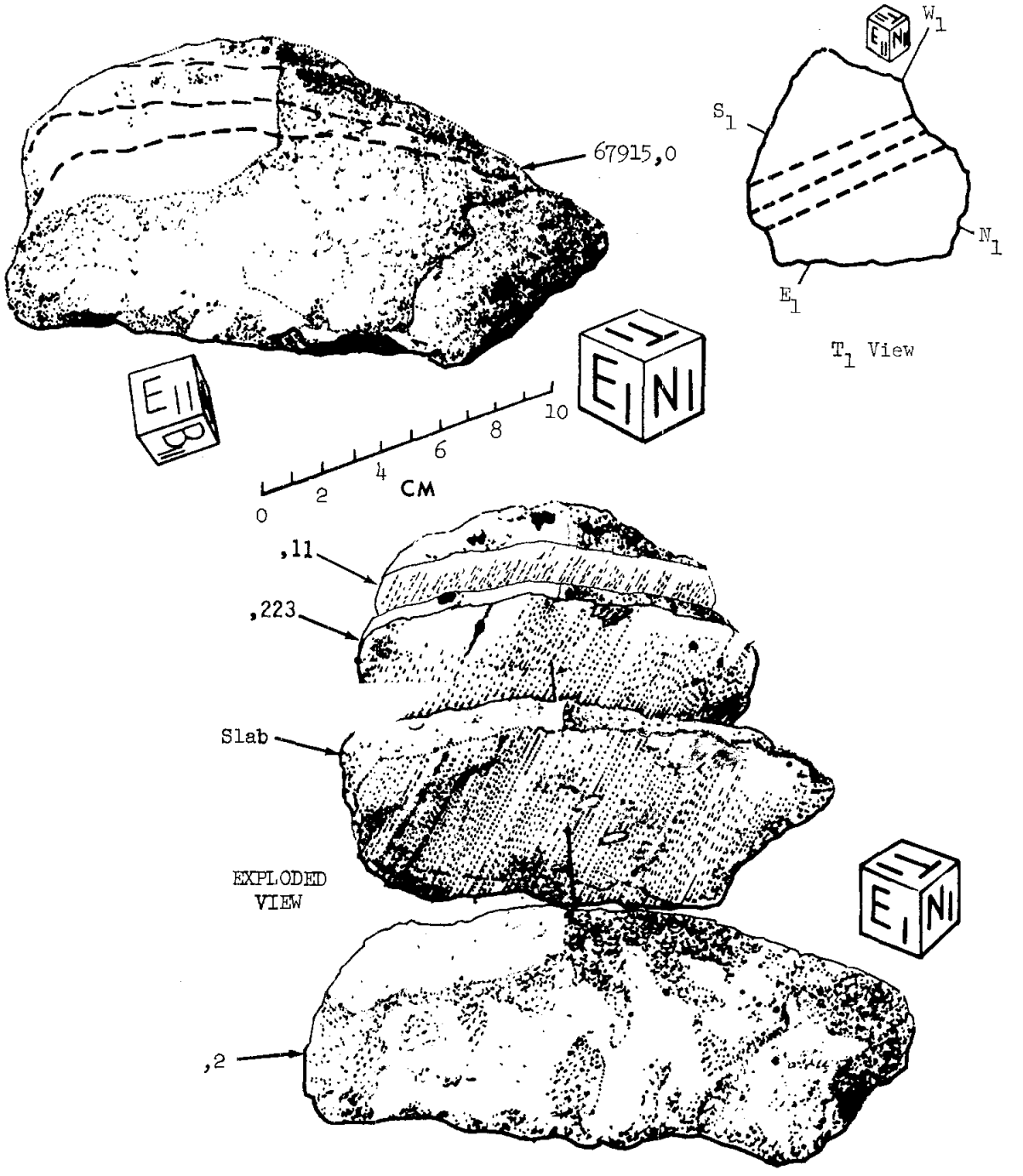

67915,0
W1
S1
N1
E1
T1 View
E11
E1 N1
0
2
4
6
8
10
CM
,11
,223
Slab
EXPLODED
VIEW
E1 N1
,2

Figure 19

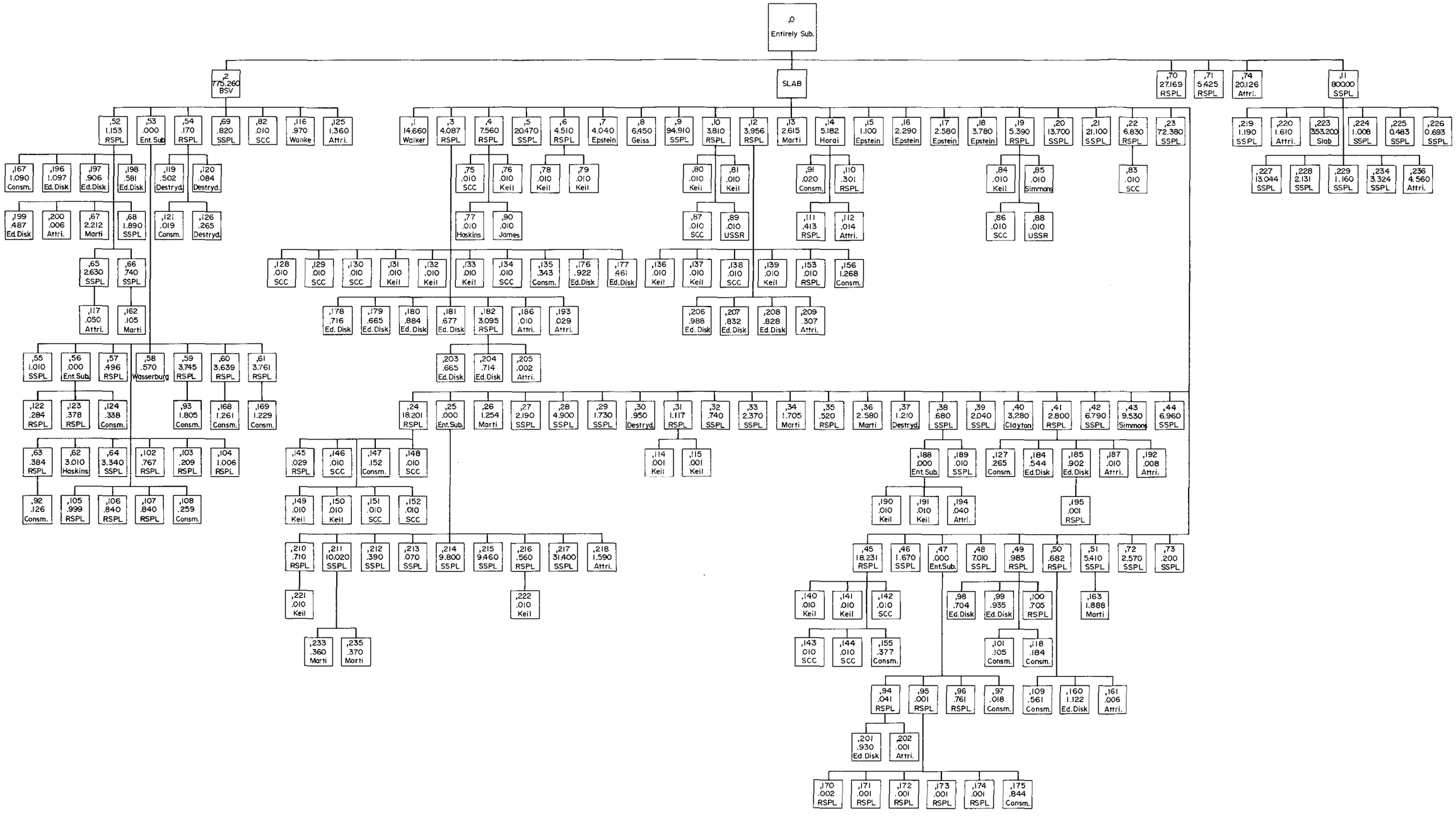

,0 Entirely Sub.
SLAB
,2 775.260 BSV
,70 27.169 RSPL
,71 5.425 RSPL
,74 20.126 Attri.
,11 800.00 SSPL
,52 1.153 RSPL
,53 .000 Ent.Sub
,54 .170 RSPL
,69 .820 SSPL
,82 .010 SCC
,116 .970 Wanke
,125 1.360 Attri.
,1 14.660 Walker
,3 4.087 RSPL
,4 7.560 RSPL
,5 20.470 SSPL
,6 4.510 RSPL
,7 4.040 Epstein
,8 6.450 Geiss
,9 94.910 SSPL
,10 3.810 RSPL
,12 3.956 RSPL
,13 2.615 Marti
,14 5.182 Horai
,15 1.100 Epstein
,16 2.290 Epstein
,17 2.580 Epstein
,18 3.780 Epstein
,19 5.390 RSPL
,20 13.700 SSPL
,21 21.100 SSPL
,22 6.830 RSPL
,23 72.380 SSPL
,219 1.190 SSPL
,220 1.610 Attri.
,223 353.200 Slab
,224 1.008 SSPL
,225 0.483 SSPL
,226 0.693 SSPL
,227 13.044 SSPL
,228 2.131 SSPL
,229 1.160 SSPL
,234 3.324 SSPL
,236 4.560 Attri.
,167 1.090 Consm.
,196 1.097 Ed. Disk
,197 .906 Ed.Disk
,198 .581 Ed.Disk
,119 .502 Destryd.
,120 .084 Destryd.
,199 .487 Ed.Disk
,200 .006 Attri.
,67 2.212 Marti
,68 1.890 SSPL
,121 .019 Consm.
,126 .265 Destryd.
,65 2.630 SSPL
,66 .740 SSPL
,117 .050 Attri.
,162 .105 Marti
,75 .010 SCC
,76 .010 Keil
,78 .010 Keil
,79 .010 Keil
,77 .010 Hoskins
,90 .010 James
,80 .010 Keil
,81 .010 Keil
,87 .010 SCC
,89 .010 USSR
,91 .020 Consm.
,110 .301 RSPL
,111 .413 RSPL
,112 .014 Attri.
,84 .010 Keil
,85 .010 Simmons
,86 .010 SCC
,88 .010 USSR
,83 .010 SCC
,128 .010 SCC
,129 .010 SCC
,130 .010 SCC
,131 .010 Keil
,132 .010 Keil
,133 .010 Keil
,134 .010 SCC
,135 .343 Consm.
,176 .922 Ed.Disk
,177 .461 Ed.Disk
,136 .010 Keil
,137 .010 Keil
,138 .010 SCC
,139 .010 Keil
,153 .010 RSPL
,156 1.268 Consm.
,178 .716 Ed. Disk
,179 .665 Ed. Disk
,180 .884 Ed. Disk
,181 .677 Ed. Disk
,182 3.095 RSPL
,186 .010 Attri.
,193 .029 Attri.
,206 .988 Ed. Disk
,207 .832 Ed.Disk
,208 .828 Ed.Disk
,209 .307 Attri.
,203 .665 Ed.Disk
,204 .714 Ed.Disk
,205 .002 Attri.
,55 1.010 SSPL
,56 .000 Ent.Sub.
,57 .496 RSPL
,58 .570 Wasserburg
,59 3.745 RSPL
,60 3.639 RSPL
,61 3.761 RSPL
,122 .284 RSPL
,123 .378 RSPL
,124 .338 Consm.
,93 1.805 Consm.
,168 1.261 Consm.
,169 1.229 Consm.
,63 .384 RSPL
,62 3.010 Haskins
,64 3.340 SSPL
,102 .767 RSPL
,103 .209 RSPL
,104 1.006 RSPL
,92 .126 Consm.
,105 .999 RSPL
,106 .840 RSPL
,107 .840 RSPL
,108 .259 Consm.
,24 18.201 RSPL
,25 .000 Ent.Sub.
,26 1.254 Marti
,27 2.190 SSPL
,28 4.900 SSPL
,29 1.730 SSPL
,30 .950 Destryd.
,31 1.117 RSPL
,32 .740 SSPL
,33 2.370 SSPL
,34 1.705 Marti
,35 .520 RSPL
,36 2.580 Marti
,37 1.210 Destryd.
,38 .680 SSPL
,39 2.040 SSPL
,40 3.280 Clayton
,41 2.800 RSPL
,42 6.790 SSPL
,43 9.530 Simmons
,44 6.960 SSPL
,114 .001 Keil
,115 .001 Keil
,145 .029 RSPL
,146 .010 SCC
,147 .152 Consm.
,148 .010 SCC
,149 .010 Keil
,150 .010 Keil
,151 .010 SCC
,152 .010 SCC
,210 .710 RSPL
,211 10.020 SSPL
,212 .390 SSPL
,213 .070 SSPL
,214 9.800 SSPL
,215 9.460 SSPL
,216 .560 RSPL
,217 31.400 SSPL
,218 1.590 Attri.
,221 .010 Keil
,222 .010 Keil
,233 .360 Marti
,235 .370 Marti
,188 .000 Ent.Sub.
,189 .010 SSPL
,127 .265 Consm.
,184 .544 Ed.Disk
,185 .902 Ed.Disk
,187 .010 Attri.
,192 .008 Attri.
,190 .010 Keil
,191 .010 Keil
,194 .040 Attri.
,195 .001 RSPL
,45 18.231 RSPL
,46 1.670 SSPL
,47 .000 Ent.Sub.
,48 7.010 SSPL
,49 .985 RSPL
,50 .682 RSPL
,51 5.410 SSPL
,72 2.570 SSPL
,73 .200 SSPL
,140 .010 Keil
,141 .010 Keil
,142 .010 SCC
,98 .704 Ed. Disk
,99 .935 Ed. Disk
,100 .705 RSPL
,163 1.888 Marti
,143 .010 SCC
,144 .010 SCC
,155 .377 Consm.
,101 .105 Consm.
,118 .184 Consm.
,94 .041 RSPL
,95 .001 RSPL
,96 .761 RSPL
,97 .018 Consm.
,109 .561 Consm.
,160 1.122 Ed.Disk
,161 .006 Attri.
,201 .930 Ed.Disk
,202 .001 Attri.
,170 .002 RSPL
,171 .001 RSPL
,172 .001 RSPL
,173 .001 RSPL
,174 .001 RSPL
,175 .844 Consm.

Figure 20.

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E. Roedder separated clasts from 67915. Data were reported in Roedder and Weiblen (1973) and Rose et al. (1975). When the thin sections Roedder had made were returned to RSPL, they were renumbered. The table below cross-references Roedder's numbers with the new ones.

NASA Number	Original Roedder Number
128	3-1a
129	3-1B
130	3-2a
131	3-2c
132	3-3
133	3-4
134	3-2b
136	12-1b
137	12-1c
138	12-1l
139	12-1i
140	45-1
141	45-3a
142	45-3b
143	45-1b
144	45-1e
146	24-A
148	24-3
149	24-1c
150	24-1d
151	24-3
152	24-4