67915 GRAY POLYMICT BRECCIA 2559 g

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.

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.

FIGURE 1a. S-75-33755.

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 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.

FIGURE 1b. Samples collected from Outhouse Rock. AS16-116-18653.

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 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.

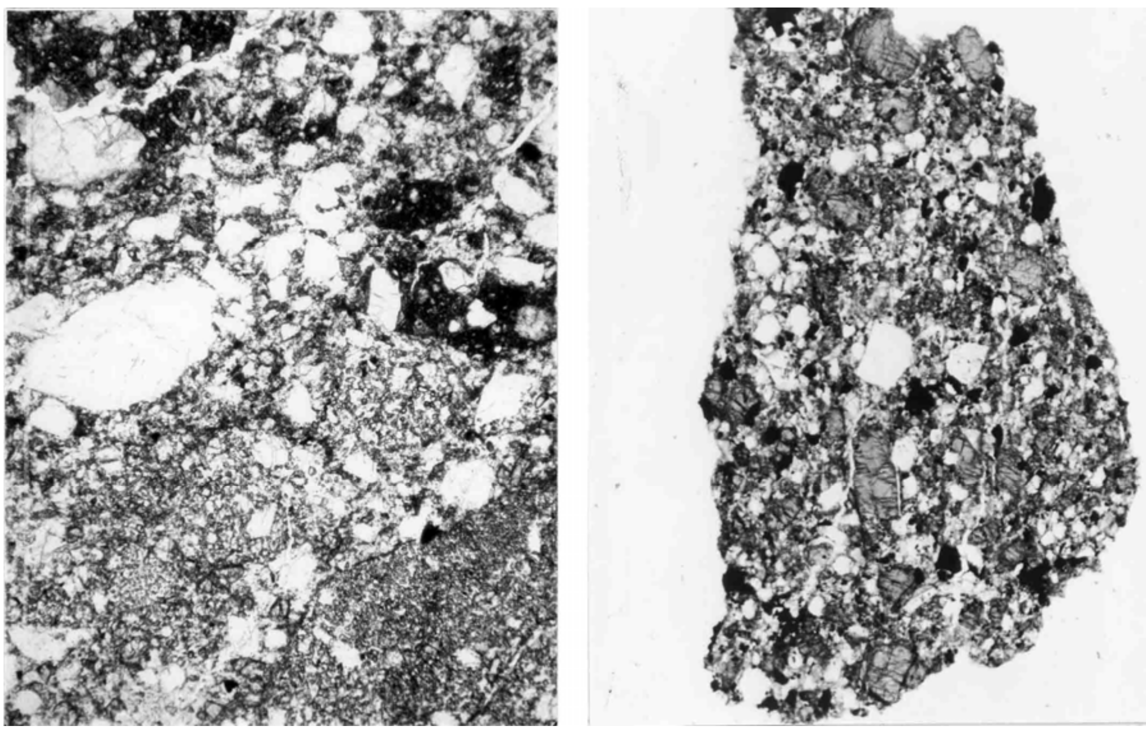


FIGURE 2.
a) 67915,82. Granoblastic clast (lower) and fragmental matrix (upper), ppl. Width 2 mm.
b) 67915,190. Sodic ferrogabbro clast, ppl. Width about 3.5 mm.

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.

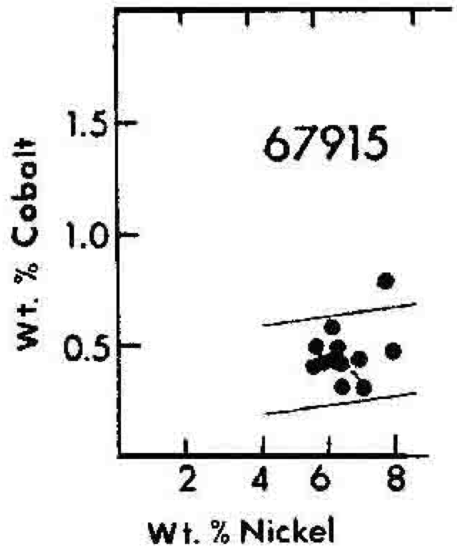


FIGURE 3. Compositions of metals from the matrix, from Misra and Taylor (1975).

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.

<u>CHEMISTRY</u>: 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.

The siderophiles in two breccia subsplits are high and similar (Krahenbuhl 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).

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 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)

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).

TABLE 3. Chemical compositions (wt. %) of clasts in 67915. All analyses by Rose et a1. (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).

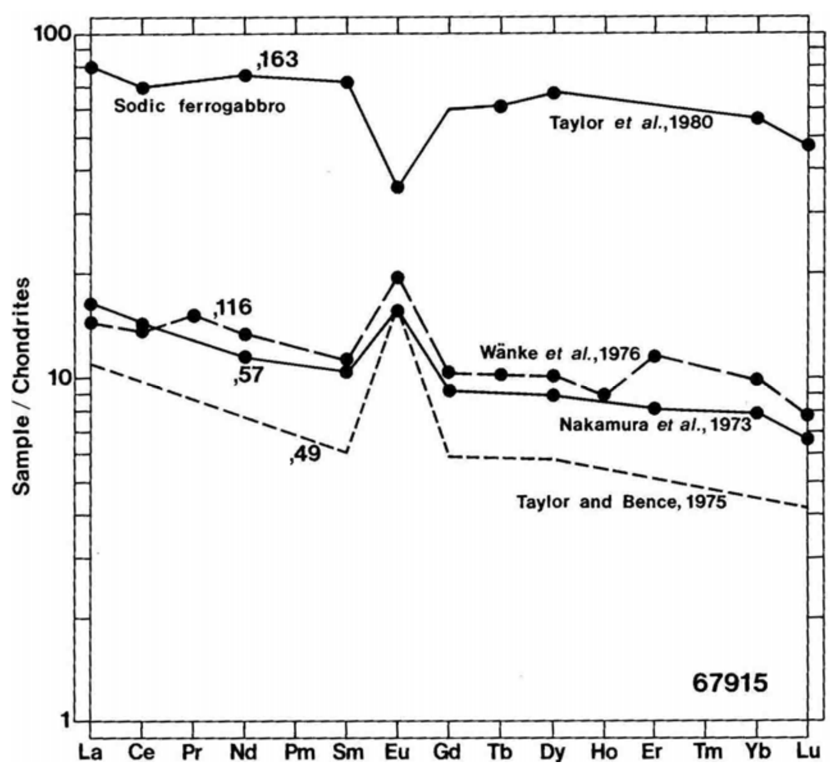


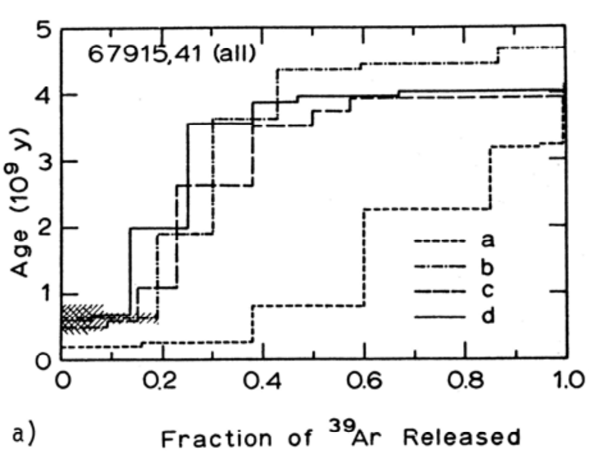
FIGURE 4. Rare earths.

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.

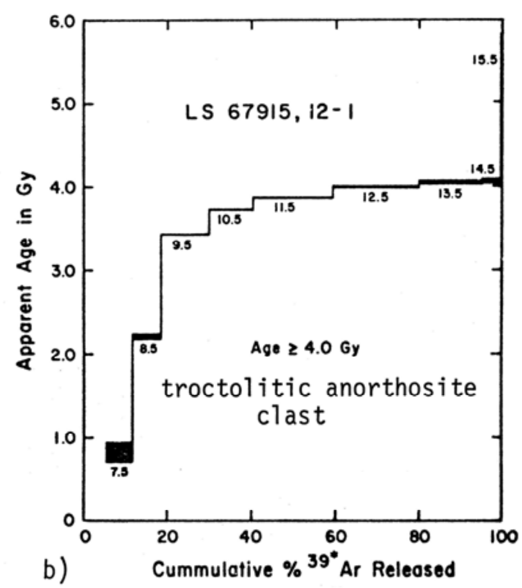
<u>RARE GASES AND EXPOSURE AGES</u>: Several studies concerning rare gas contents and exposure ages have been made. Behrmann et al. (1973) report Ne and Kr isotopic data for releases at 500°C and 1500°C, and total release. The krypton spallation spectrum has no prominent neutron effects. The ^{81}Kr-^{83}Kr exposure age is 50.6 ± 3.8 m.y.; a ^{22}Na-^{22}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 1 mm/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.



Shadowed bars indicate experimental errors.



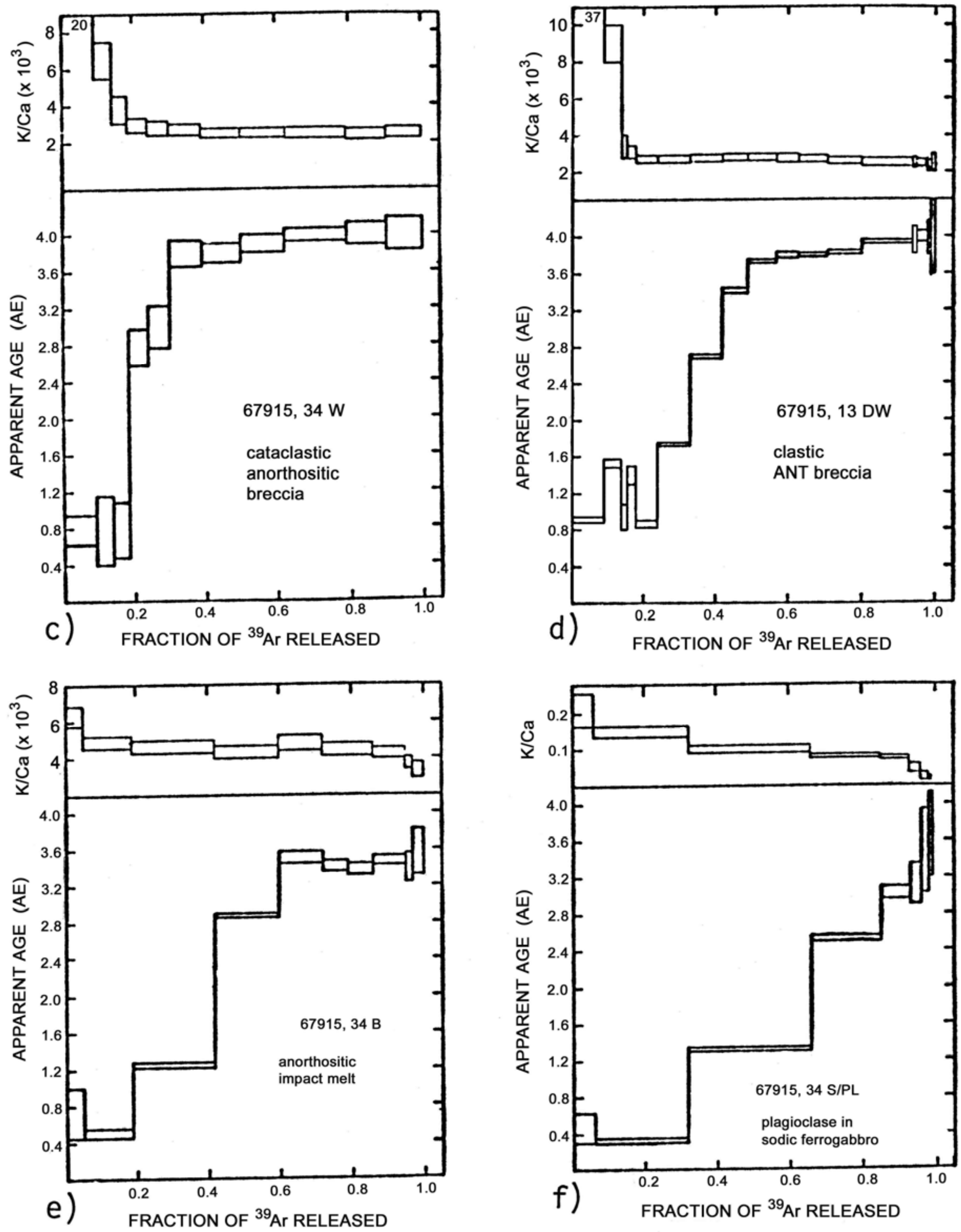


FIGURE 5. Ar releases for various clast and matrix samples, see text for discussion,
a) from Kirsten et al. (1973),
b) from Venkatsan and Alexander (1976),
c)-f) from Marti et al. (1978).

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

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 susceptibilities (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.

<u>PROCESSING AND SUBDIVISIONS</u>: 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.

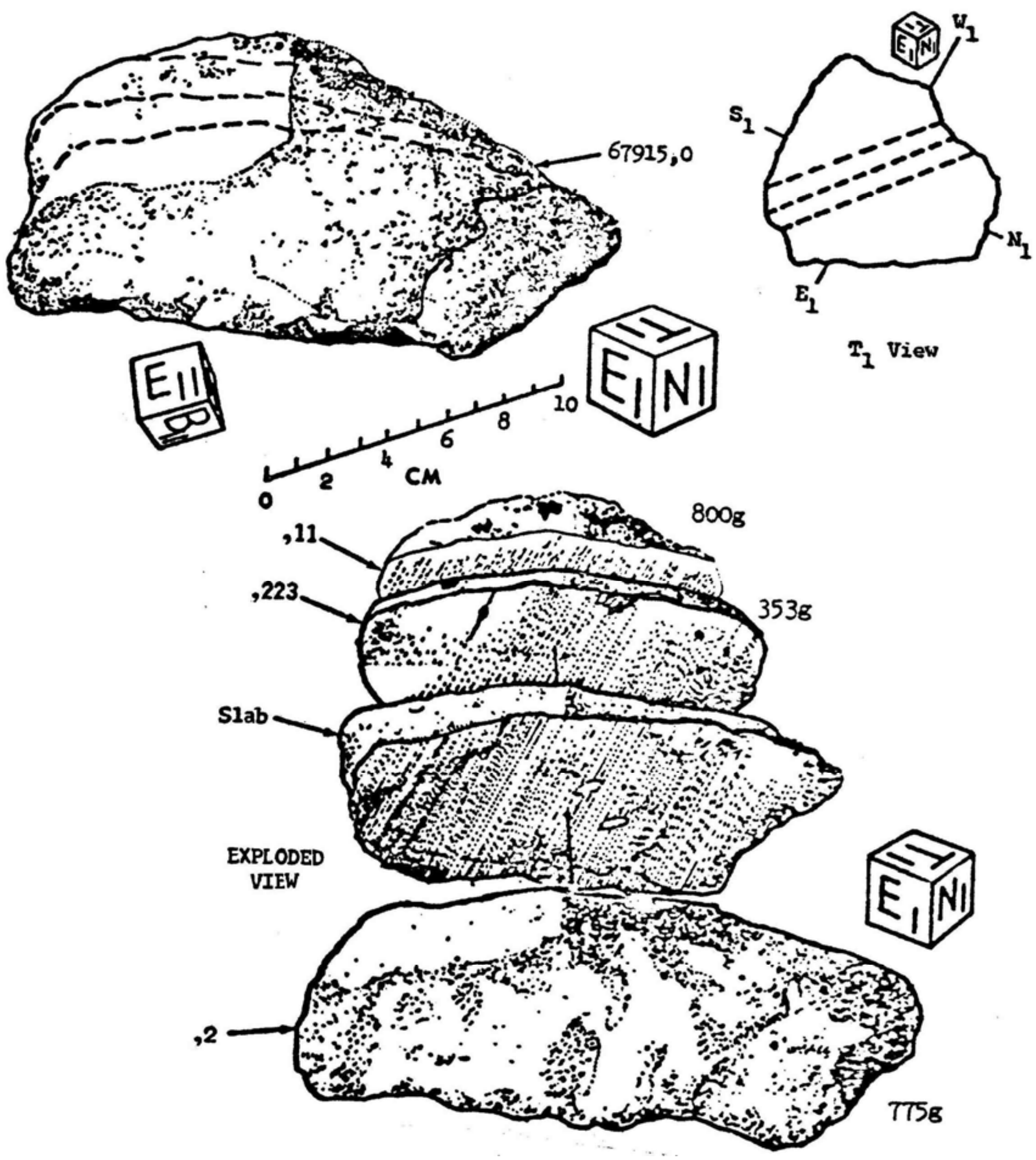


FIGURE 6. Cutting diagram.