67975

Fragmental Breccia

447 grams

Figure 1: Photo of 67975. Cube is 1 cm. NASA S72-43979.

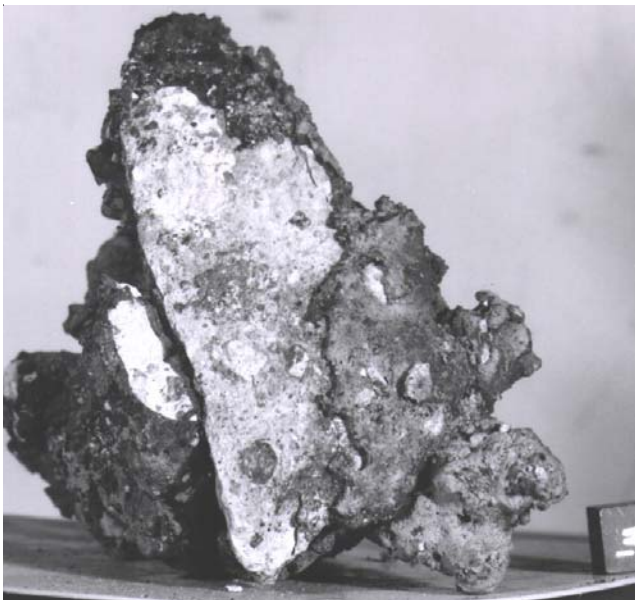


Figure 2: Two large white clasts in 67975. S72-43859. Cube is 1 cm.

Introduction

The feldspathic samples collected from the rim of North Ray Crater contain, as clasts, a variety of rock types. Sample 67975 is a fragmental, polymict breccia from North Ray Crater with numerous lithic clasts cemented together by a dark glass (figures 1, 2 and 9). It is irregular in shape with two main lithologies: a pale grey, feldspar-rich breccia and a frothy, clast-rich glass. Its orientation is unknown, but it contains zap pits on N1 and W1 surfaces. It has been studied by the Lindstrom (1984) and the James Consortium (James et al. 1987).

Sample 67975 was found on the lunar surface near Outhouse Rock, but it was apparently not derived from it. The clast population is diverse and interesting. This rock contains abundant KREEPy, relatively mafic, microprophritic melt breccias and rare pristine alkali gabbronorites, in addition to cataclastic anorthosites

Figure 3: Photomicrograph of thin section of 67975 showing matrix and glass. NASA S72-48139.

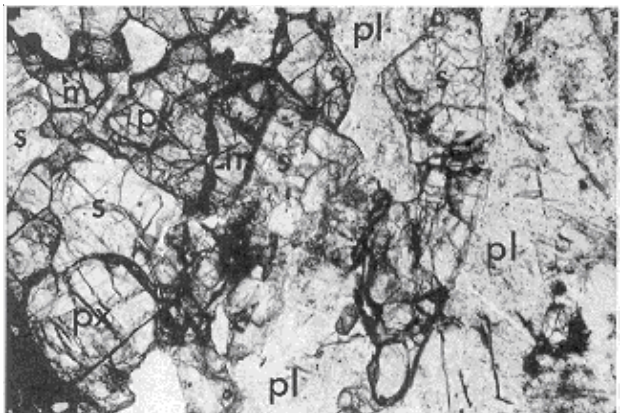


Figure 4: Thin section of 67975,42 alkali gabbronorite. Field of view 1.7 mm. (James et al. 1987).

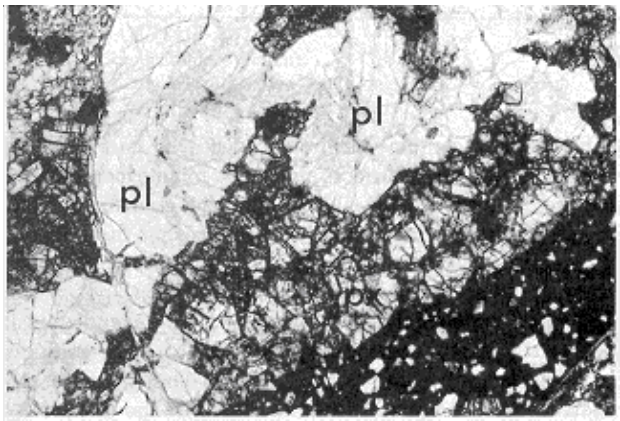


Figure 5: Thin section of 67975,14 alkali gabbronorite. Field of view 2.2 mm (James et al. 1987).

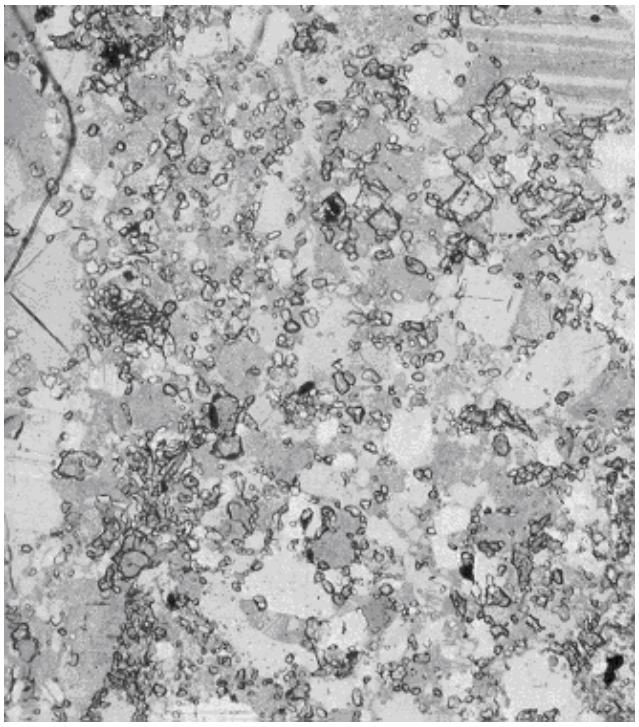


Figure 6: Thin section photo of "granoblastic" fragment 67975,65 (from Ryder and Norman 1980). Scale is 1 mm.

and ganulitic breccias (Lindstrom 1984; McGee 1989). Several of these materials are presumed to be pristine (Warren 1993).

Petrography

Ryder and Norman (1980) give a description of the rock as a whole, while James et al. (1987) and McGee (1987, 1989) reported on the mineralogy of the clast population (mg-norite, ferroan anorthosite and alkali gabbronorite).

The glassy portion of 67975 is made up of thick (5 cm) clean glass (fSee et al. 1986; Morris et al. 1986). Microlites of plagioclase extend from the glass/breccia contact into the glass (Ryder and Norman 1980). The physical nature of the glass has been studied by Uhlmann et al. (1977, 1878).

Hunter and Taylor (1981) note rust in 67975

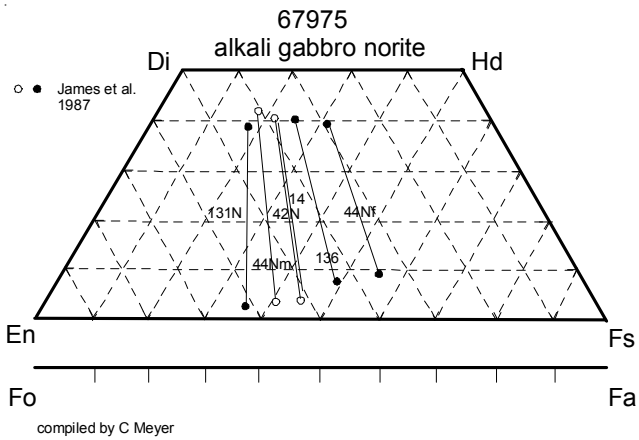


Figure 7: Pyroxene composition diagram for "alkali gabbronorite" clasts in 67975 (from James et al. 1987).

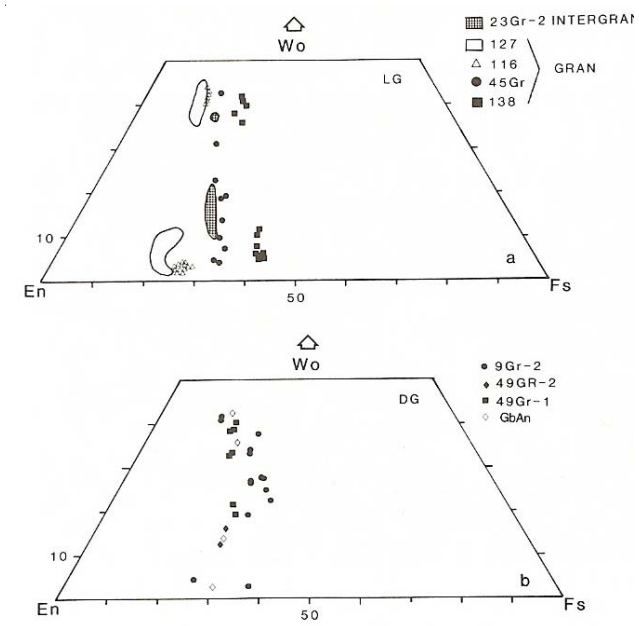


Figure 8: Composition of pyroxenes in granulitic breccia clasts in 67975 (from McGee 1989).

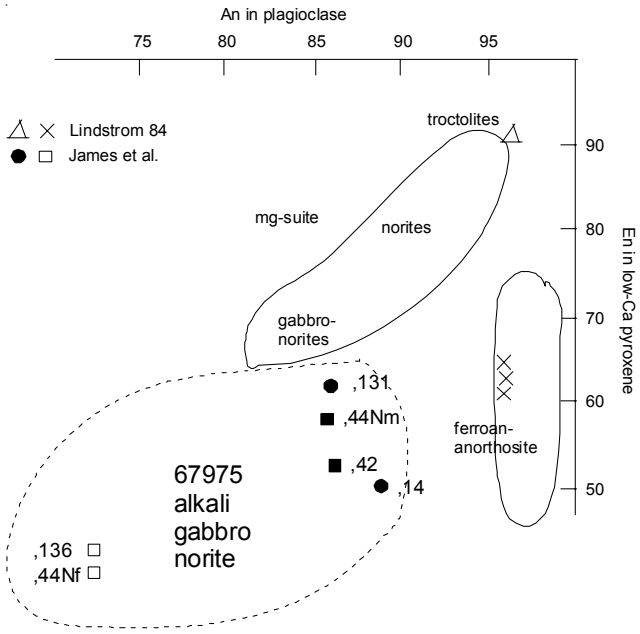


Figure 9: Mineral composition for clasts of "alkali gabbronorite" from 67975 (James et al. 1987).

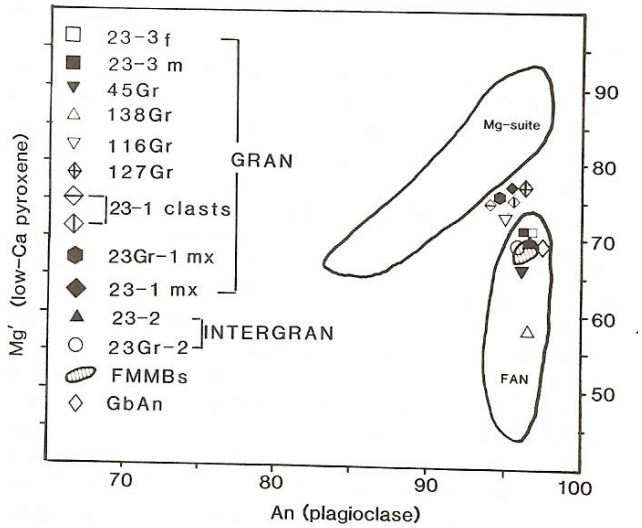


Figure 10: Mineral composition for clasts of "granulite" from 67975 (McGee 1989).

Significant Clasts in 67975

Anorthosite:

Figure 2 shows a large chalky-white clast (splits unknown). Lindstrom (1984) , Wolf et al. (1979) found the anorthosite in 67975 was pristine (table 2).

Spinel troctolite:

Lindstrom (1984) reported two clasts of spinel troctolite (table 2).

Alkali gabbronorite:

Lindstrom et al. (1984) and James et al. (1987) analyzed and described several samples of coarse-grained plagioclase-pyroxene rock with high trace-element content and termed this lithology "alkali gabbronorite" (figures 4 and 5). Analyses indicate it is KREEPy and pristine (figure 11, table 2). One fragment included a large zircon, dated at 4.36 b.y. (see below).

Granulite (various):

McGee (1989) reported on 14 fragments of granulitic breccia with recrystallized granoblastic, poikiloblastic, or honfelsic matrices (figure 5, table 3). They range from ferroan anorthosite to mg-suite anorthosite (figure

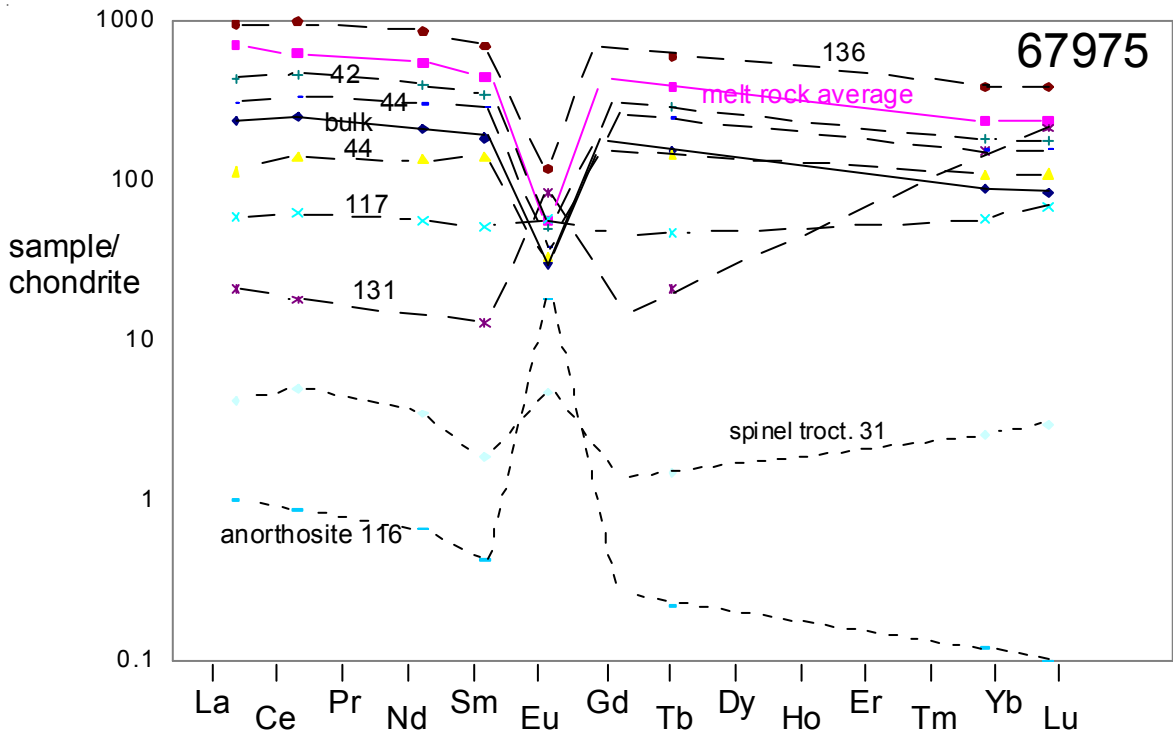


Figure 11: Normalized rare-earth-element diagram for clasts of alkali gabbronorite (long dashes), "bulk rock" (solid line), average of fine-grained "melt rock" (pink) and anorthosite (short dashes) in 67975 (Lindstrom 1984, James et al. 1987).

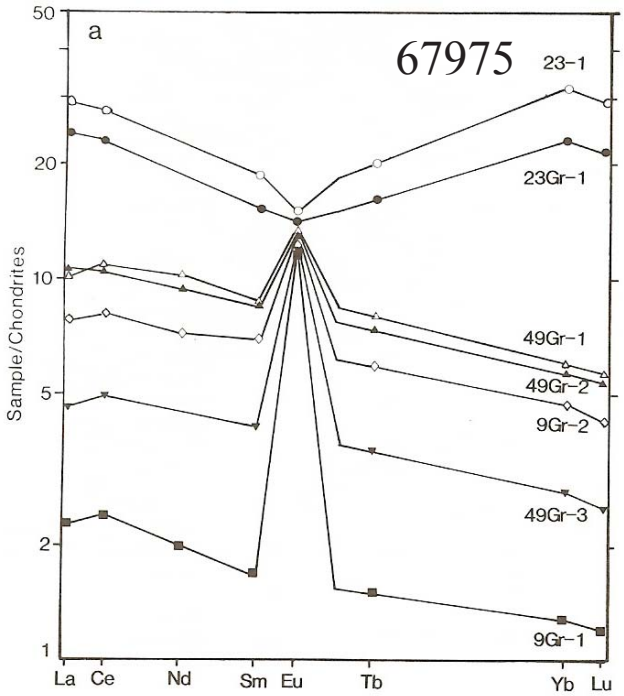


Figure 12: Rare-earth-element pattern for "light green" and "dark gray" granulite clasts in 67975 (McGee 1989).

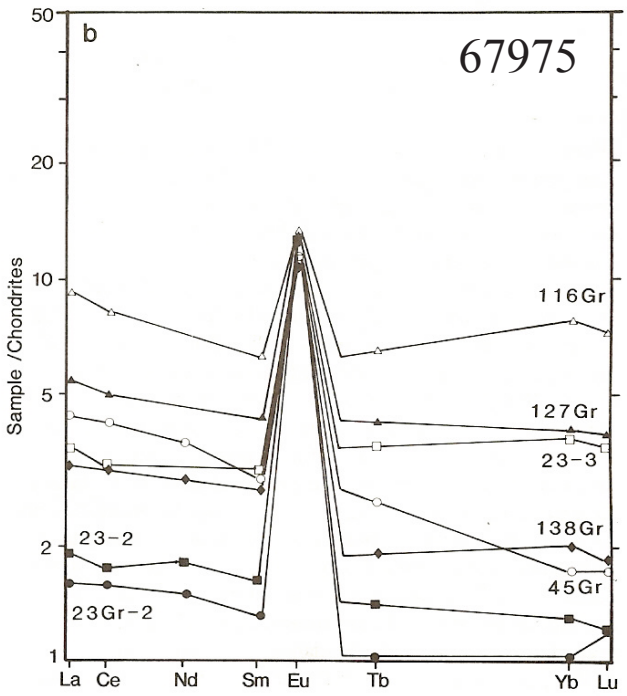


Figure 13: Rare-earth-element pattern for "light gray" granulite clasts in 67975 (McGee 1989).

Table 1. Chemical composition of 67975.

reference	Clark73		Hertogen77		Christian76			Lindstrom84			Uhlmann77		Lindstrom84		Hertogen 77		See 86	
weight	*437 g*		*matrix*		,3	,43		matrix	matrix		glass coat		glass		glass		glass	
SiO2 %					45.33	44.23	(c)				44.7	(e)	ave. 5				45.03	(e)
TiO2					0.49	0.4	(c)				0.7	(e)					0.43	(e)
Al2O3					27.5	29.12	(c)				30.4	(e)					29.43	(e)
FeO					4.27	4.61	(c)	5.09	5.17	(d)	2.5	(e)	3.8	(d)			3.73	(e)
MnO					0.06	0.06	(c)											
MgO					5.58	4.09	(c)				1.2	(e)					4.17	(e)
CaO					15.9	16.7	(c)	17.9	18.2	(d)	18.3	(e)	16.4	(d)			16.36	(e)
Na2O					0.52	0.42	(c)	0.37	0.38	(d)	0.8	(e)	0.525	(d)			0.53	(e)
K2O	0.1	(a)			0.11	0.13	(c)				0.3	(e)	*0.17*	(d)			0.09	(e)
P2O5					0.11	0.2	(c)											
S %																		
sum																		
																	Morris 86	
Sc ppm					6.8	8.7	(c)	10	11	(d)			6.6	(d)			9	(d)
V					10	10	(c)											
Cr								520	573	(d)			477	(d)			780	(d)
Co					5.9	4.6	(c)	8.9	8.7	(d)			12	(d)			13	(d)
Ni			17	(b)	110	22	(c)	20	21	(d)			126	(d)	80	(b)	226	(d)
Cu					3.2	2.4	(c)											
Zn			1.44	(b)	4.1	5.3	(c)								2.44	(b)		
Ga					2.2	2.5	(c)											
Ge ppb			119	(b)											91	(b)		
As																		
Se															63			
Rb			0.47	(b)	1.4	1	(c)	*4*	*8*	(d)			*2.6*	(d)	2.36	(b)		
Sr					150	130	(c)	174	171	(d)			193	(d)				
Y					23	34	(c)											
Zr					76	110	(c)	315	300	(d)			91	(d)				
Nb																		
Mo																		
Ru																		
Rh																		
Pd ppb			0.59	(b)											5	(b)		
Ag ppb			1.34	(b)											1.03	(b)		
Cd ppb			0.74	(b)											1.5	(b)		
In ppb			0.25	(b)											12.5	(b)		
Sn ppb																		
Sb ppb			0.25	(b)											0.33	(b)		
Te ppb			3.8	(b)											12.5	(b)		
Cs ppm			0.03	(b)				0.122	0.111	(d)			0.096	(d)	0.093	(b)		
Ba					67	54	(c)	145	165	(d)			84	(d)			164	(d)
La					11		(c)	43.4	54.9	(d)			7.86	(d)			15	(d)
Ce								117	151	(d)			21.6	(d)			46	(d)
Pr																		
Nd								75	95	(d)			12	(d)				
Sm								21.7	27.4	(d)			3.15	(d)			6.96	(d)
Eu								1.6	1.69	(d)			1.2	(d)			1.3	(d)
Gd																		
Tb								4.41	5.56	(d)			0.7	(d)			1.09	(d)
Dy																		
Ho																		
Er																		
Tm																		
Yb					1.5	2.3	(c)	11.5	14.5	(d)			2.27	(d)			4.71	(d)
Lu								1.64	2.07	(d)			0.35	(d)			0.65	(d)
Hf								8.7	8.15	(d)			2.6	(d)			4.42	(d)
Ta								1	1.25	(d)			0.3	(d)			0.58	(d)
W ppb																		
Re ppb			0.041	(b)											0.361	(b)		
Os ppb			0.67	(b)											5	(b)		
Ir ppb			0.493	(b)											5.14	(b)		
Pt ppb																		
Au ppb			0.046	(b)											1.48	(b)		
Th ppm	1.76	(a)						4.4	5.55	(d)			1.06	(d)			1.87	(d)
U ppm	0.513	(a)	0.032	(b)				0.86	0.84	(d)			0.27	(d)	0.309	(b)	0.5	(d)

technique: (a) rad. counting, (b) RNAA, (c) combined tech., (d) INAA, (e) emp

Table 2. Chemical composition of selected clasts in 67975.

reference	Hertogen77			James 87							Lindstrom 84			See 86
weight	anor	aphan.		44N	117N	131N	136N	42N	44	"melt"	116A	31st		
SiO2 %	Wolf79			alkali gabbronorites						anor.	sp. troct.			44.23
TiO2	,26			4.6	0.64	0.36	2.15	4	7.4	3.16			(b)	0.4
Al2O3				7.19	16.52	28.3	13.9	15.7	8.66	18.8		17.3	(b)	29.12
FeO				17.2	11.8	6.9	13.35	10	17.2	10.2	0.158	15.6	(b)	4.61
MnO				0.26	0.18	0.13	0.19	0.17	0.25	0.15		0.17	(b)	0.06
MgO				12.4	8.3	7.5	8.2	5.1	10.3	6.7		26	(b)	4.09
CaO				15.7	9.1	13.5	9.1	12.8	15.1	13.3	19.8	5	(b)	16.7
Na2O				0.29	0.31	0.925	0.5	0.493	0.308	0.51	0.54	0.09	(b)	0.42
K2O					0.19			0.35					(b)	0.13
P2O5														
S %														
sum														
Sc ppm				53	14	17	27	26	48	23	0.216	4	(b)	
V				88	18	30	21	41	100	36		14	(b)	
Cr				2690	620	645	636	1310	4015	1250	7.2	4750	(b)	
Co				19	11	5.5	10	10.5	17	20	0.23	8	(b)	
Ni	11	44	(a)	<70	<80		<80	<70	<90		<3.5	40	(b)	
Cu														
Zn	4.25	7.49	(a)											
Ga														
Ge ppb	82	135	(a)											
As														
Se	2	134	(a)											
Rb	0.58	2.46	(a)	14	56	20	45	15	15	20	0.25	<10	(b)	
Sr				80	180	260	290	175	80	180	232		(b)	
Y														
Zr				350	150	12700	2100	1300	1270	1340	<9		(b)	
Nb														
Mo														
Ru														
Rh														
Pd ppb	1.2	2.5	(a)											
Ag ppb	1.36	2.08	(a)											
Cd ppb	1.6	4.6	(a)											
In ppb	0.87	0.35	(a)											
Sn ppb														
Sb ppb	0.14	0.71	(a)											
Te ppb	3.5	8.1	(a)											
Cs ppm	0.056	0.133	(a)	0.25	0.76	0.47	1.32	0.37	0.34	0.77	0.007		(b)	
Ba				400	5000	2200	2200	400	480	1090	15		(b)	
La				26.5	14.2	5	225	101.6	72.2	165	0.24	0.99	(b)	
Ce				84	38	11	595	279	202	373	0.53	3	(b)	
Pr														
Nd				62	26		390	181	135	246	0.3	1.6	(b)	
Sm				21	7.65	1.9	103	51	425	66	0.063	0.288	(b)	
Eu				1.88	3.24	4.67	6.62	2.86	2.16	3.16	1	0.27	(b)	
Gd														
Tb				5.25	1.7	0.75	22	10.6	8.93	13.9	0.008	0.053	(b)	
Dy														
Ho														
Er														
Tm														
Yb				17.7	9.37	25	63	29.4	25	38.8	0.02	0.43	(b)	
Lu				2.71	1.67	5.19	9.44	4.34	3.84	5.74	0.002	0.075	(b)	
Hf				11	4.22	330	69.4	36	34.2	39	0.014	0.3	(b)	
Ta				3.53	1.76	0.22	4.95	6.9	7.7	3.67	0.005	0.052	(b)	
W ppb														
Re ppb	0.008	0.163	(a)											
Os ppb	0.069	1.8	(a)											
Ir ppb	0.09	1.66	(a)											
Pt ppb														
Au ppb	0.008	0.98	(a)											
Th ppm				2.55	1.85	2.18	24.7	9.5	7	16.7	0.002		(b)	
U ppm	0.027	2.59	(a)	1.11	0.53	4.2	7.2	2.07	1.9	4.4	<0.02	0.07	(b)	

technique: (a) RNAA, (b) INAA

Table 3: Chemical composition of granulite clasts 67975.
from McGee 1989

	23-1	23gr1	23-2	23-3	23gr2	45gr	116gr	127gr	138gr	9gr1	9gr2	49gr1	49gr2	49gr3
Al2O3	24.6	26.5	33.8	28.6	33.7	33.4	30.7	28.5	33.8	32.4	32.5	30.3	31.2	31.4
FeO	4.26	3.88	1.6	3.54	1.29	2.02	2.41	3.38	2.43	1.8	2.31	2.72	2.56	2.06
MgO	7.8	6.4	2	5	1.1	2.11	2.99	5.1	1.58	2.21	2.67	2.5	2.91	2.21
CaO	14.3	14.7	18.8	17.1	17.7	20.3	15.9	15.1	20.5	18.1	19.6	17.7	19.4	20.1
Na2O	0.43	0.44	0.39	0.34	0.39	0.42	0.45	0.38	0.36	0.37	0.36	0.37	0.37	0.36
K2O	0.49	0.19	0.03	0.02	0.02	0.03		0.08				0.03		0.07
TiO2	0.3			0.2				0.27		0.18	0.16	0.26	0.17	
mg*	76	75	69	72	60	65	69	73	54	69	67	62	67	66

Mineralogical Mode for Alkali Gabbronorite
(from James et al. 1987)

	131N	42N	14	62	86	44Nm	136N	44Nf
Plagioclase	73	51	50	38	15	21	50	63
Low-Ca pyroxene	25	5	46		83	32	33	13
High-Ca pyroxene	tr	11	3	27		37	2	8
Silica		33	0.5	35		tr	3	
Opaque	tr	tr	0.5	tr	2	6	2	tr
K-feldspar	tr	tr				tr	5	16
Phosphate						3	5	tr

10) and have a wide range of trace element content (figures 12 and 13).

Mineralogy

Pyroxene: The pyroxene is alkali gabbronorte is iron-rich (figure 7), while the pyroxene in the ganulitic anorthosites is variable (figure 8).

Plagioclase: James et al. (1987) gives the composition of plagioclase in alkali gabbronorites (An_{84-89}).

Zircon: Meyer et al. (1989) dated a large zircon in 67975,131 at 4339 ± 5 m.y. by ion microprobe U/Pb technique.

Glass: See et al. (1986) and Morris et al. (1986) analyzed the glass that permeates 67975 (table 1).

Chemistry

Lindstrom (1984) found that the composition of the matrix of 67975 was high in trace element content, while Clark and Keith (1973) determined it was less than half as high (Table 1). Analyses by Christian et al. (1976) showed the glass and breccia compositions were similar. Hertogen et al. (1977) found that the glass was high in meteoritic siderophiles (table 1), while Wolf et al. (1979) found the anorthosite(?) was pristine (table 2).

Lindstrom (1984) found the various fragments of alkali ferrogabbro have a wide range of trace element contents, but some are as high as KREEP (figure 10).

Radiogenic age dating

The pristine clasts in 67975 have not been dated. However, Meyer et al. (1989) dated a large zircon in 67975,131 at 4339 ± 5 m.y. by ion microprobe U/Pb technique

Cosmogenic isotopes and exposure ages

Clark and Keith (1973) determined the cosmic-ray-induced activity of ^{26}Al = 68 dpm/kg., ^{22}Na = 23 dpm/kg. and ^{46}Sc = 4 dpm/kg.

Other Studies

Uhlmann et al. (1977, 1978) experimentally found that the relatively low liquidus temperature (120 deg C) and the high viscosity of glass with a composition like that of 67975 make it a good "glass former".

Processing

Humpty-dumpty had a great fall, all the kings men couldn't put Humpty together again.

Figure 914: Bottom of 67975. NASA S72-43982. Cube is 1 cm.

Figure 15: Chips 67975,2 ,4 ,5 ,15. Cube is 1 cm. S75-24541.

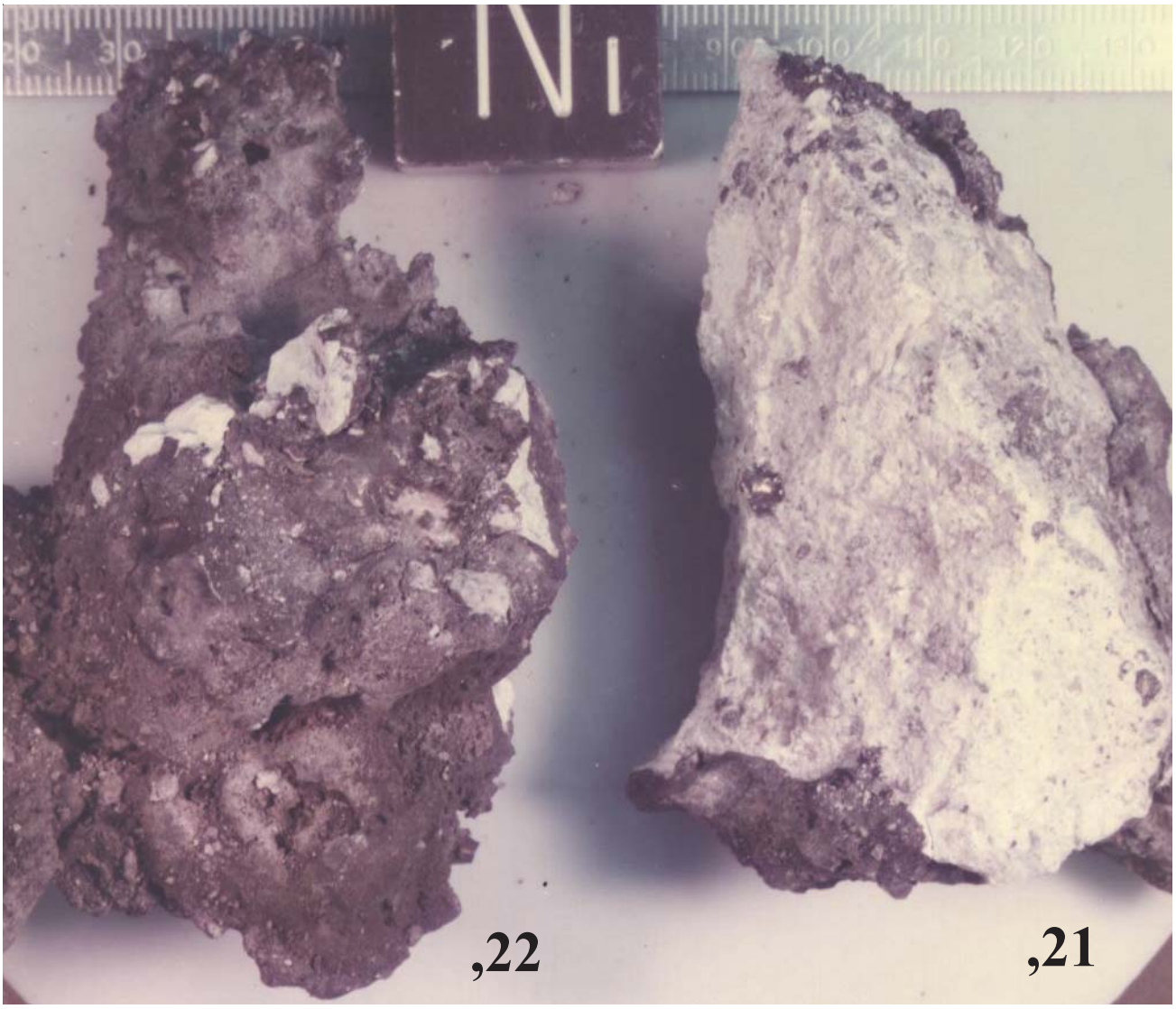
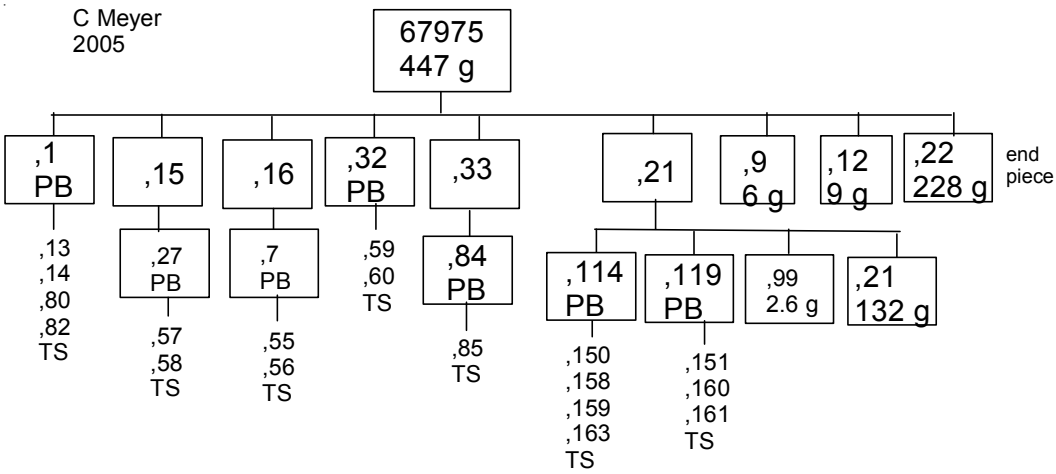


Figure 16: Large pieces of 67975. S75-24528. Cube is 1 inch.



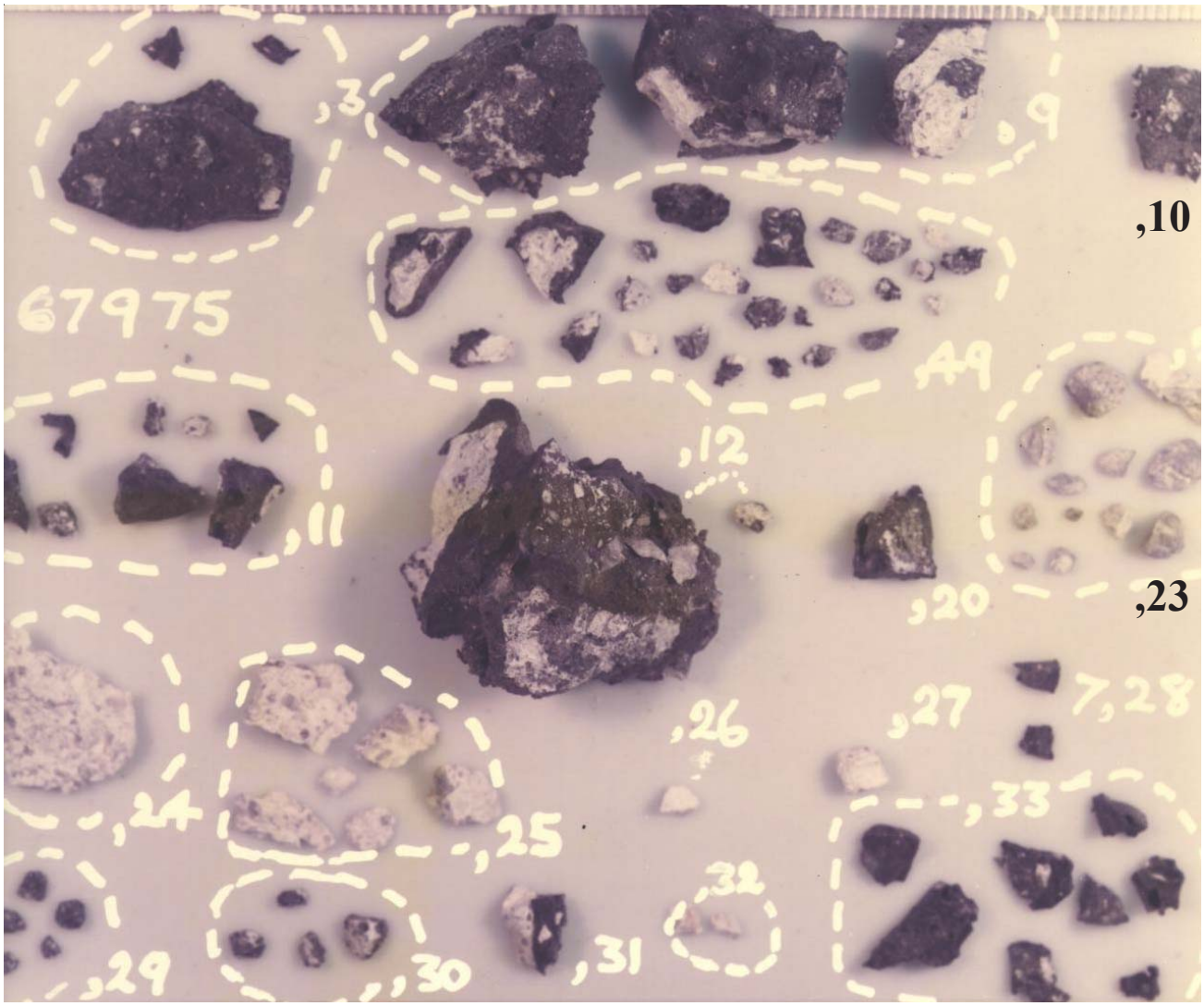


Figure 17: Pieces of 67975. S75-24540. Scale is metric.

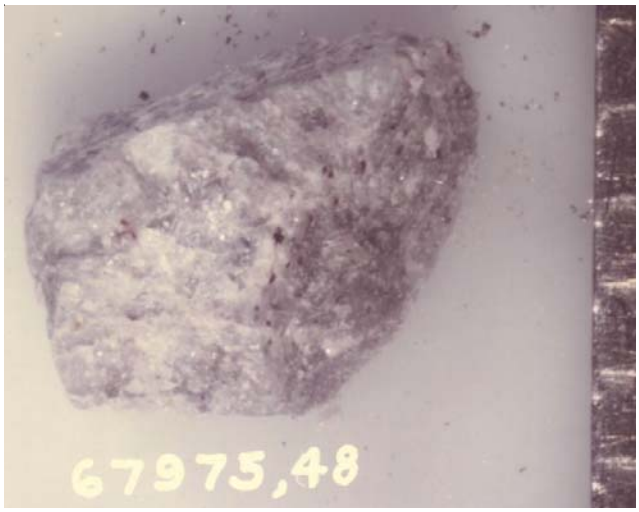


Figure 18: Best piece of 67975. Scale in mm. S75-24529.

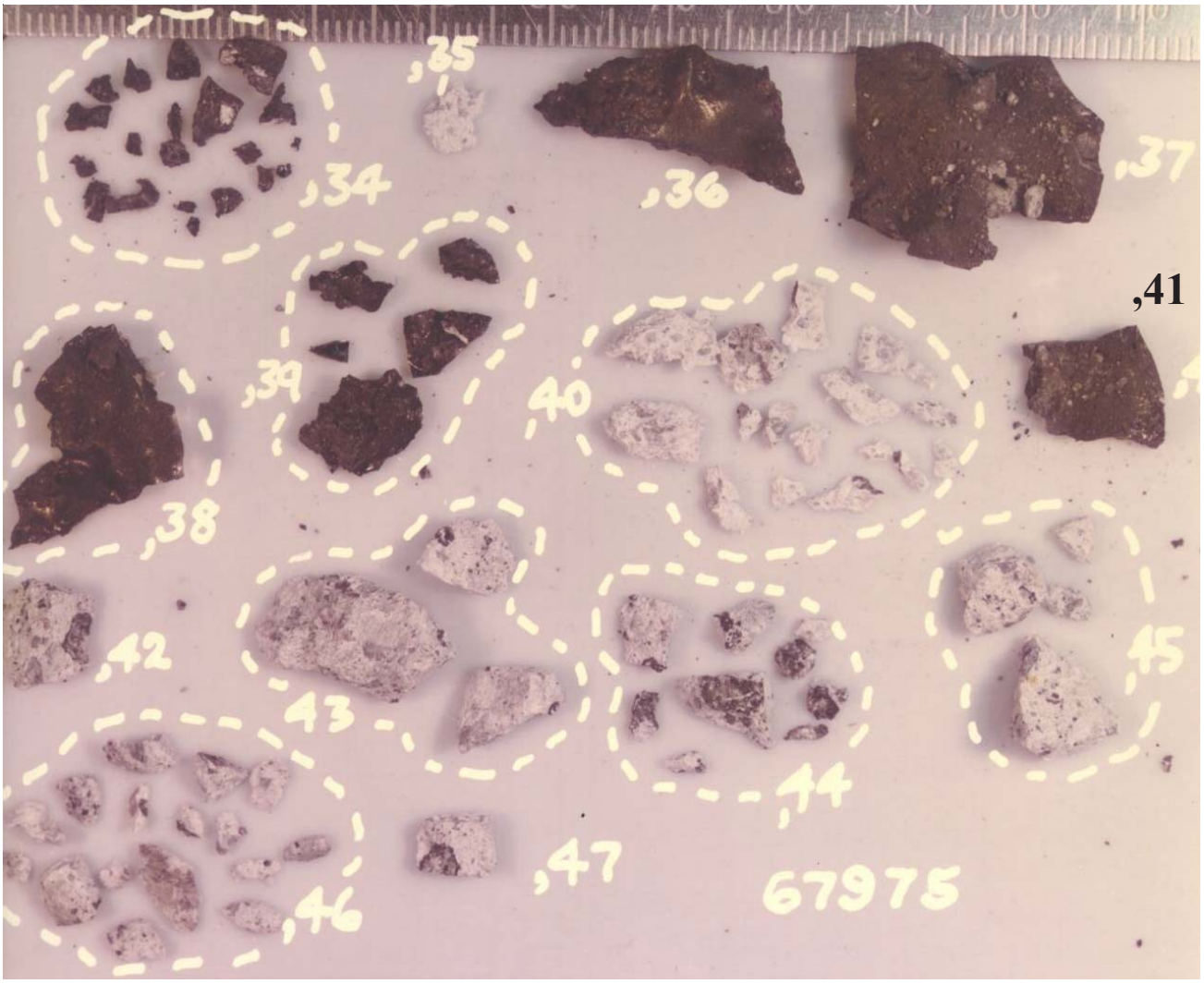


Figure 19: Pieces of 67975. S75-24538. Scale is metric.

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