67955

Noritic Anorthosite

163 grams

revised

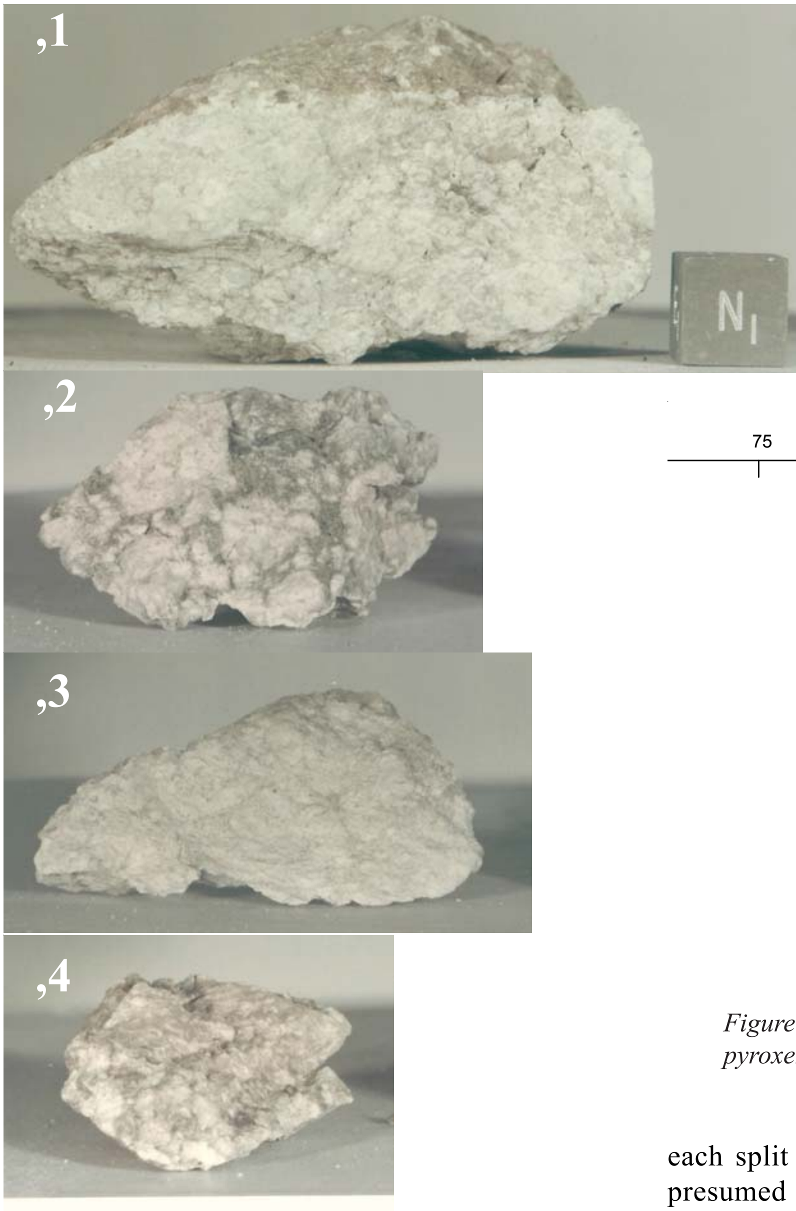


Figure 1: Four pieces of 67955. a) ,1. Cube is 1 cm. S72-45682; b) ,2. S72-37720; c) ,3. S72-37521; d) ,4. S72-37527. Not all to same scale.

Mineralogical Mode for 67955

	Hollister 1973
Plagioclase:	78.5%
Pyroxene:	14.5%
Olivine:	6%
Opaques	1%
Metal	

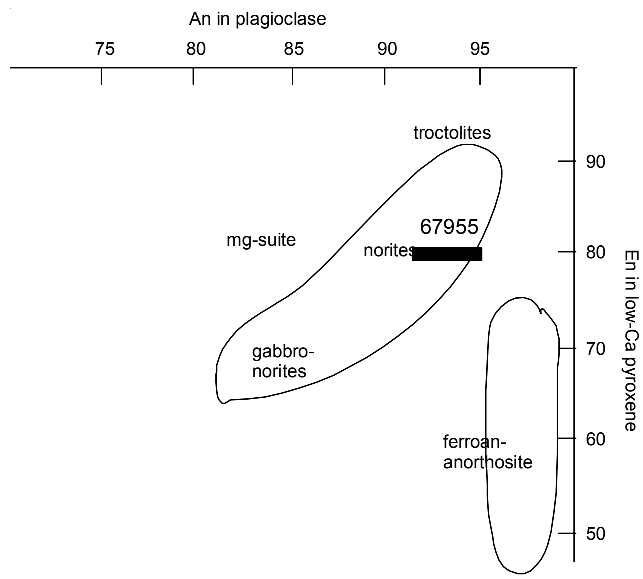


Figure 2: Chemical composition of plagioclase and pyroxene in 67955 (from Hollister 1973).

Introduction

67955 was chipped from a large white clast in Outhouse Rock (figure 3). It was returned as several pieces and is friable (figure 1). The exterior surface has a thin brown patina with micrometeorite pits. It is brecciated and has thin black glass veins, but the mineralogy indicates it is a fragment of plutonic rock. However, each split analysed has high Ni, Ir and Au and is presumed to have formed by crystallization of an impact melt sheet.

67955 has been dated at 4.2 b.y. with exposure to cosmic rays for ~ 50 m.y. (age of North Ray Crater).

Petrography

Hollister (1973), Ashwal (1975) and Nord et al. (1975) describe the white clast in 67955 as a brecciated noritic anorthosite made up of various clasts of coarse-grained noritic anorthosite (up to 1.5 cm) which grade to a matrix of finely comminuted mineral grains (figure 4). All mineral grains in the clasts and the matrix have

Figure 3: Photo of large spall zone around impact on 0uthouse rock showing approximate location of 67955 and 67956. Note black glass splatter in photo. NASA AS16-106-17345. see also figures 17 and 79a in Ulrich et al. 1981

CDR Look at that shatter cone right there, Charlie. I'll be darned. It is, I'm sure.
LMP Put your tongs up there and I'll get a closeup.
LPM OK, heres's a chunk of it. The black rock looks - - some of it is glass coated, Tony, and man, that is a shatter cone.
CDR Charlie, let's get a piece of it.
LMP OK, here you go. I got a piece. Give me a bag. On the next one how about stepping back and as I point to it, I'll pull off another piece and we'll put a couple of pieces in here.
CDR OK.
LMP That's going in bag 389. OK, let's take a picture of that. So you'll know where it came from. It's badly shattered, Tony, so I don't know whether it's going to stay together or not.
CDR Get it, Charlie, I'll get the picture. That's right near the shatter cone.
LPM OK 5 samples in 389 Tony.

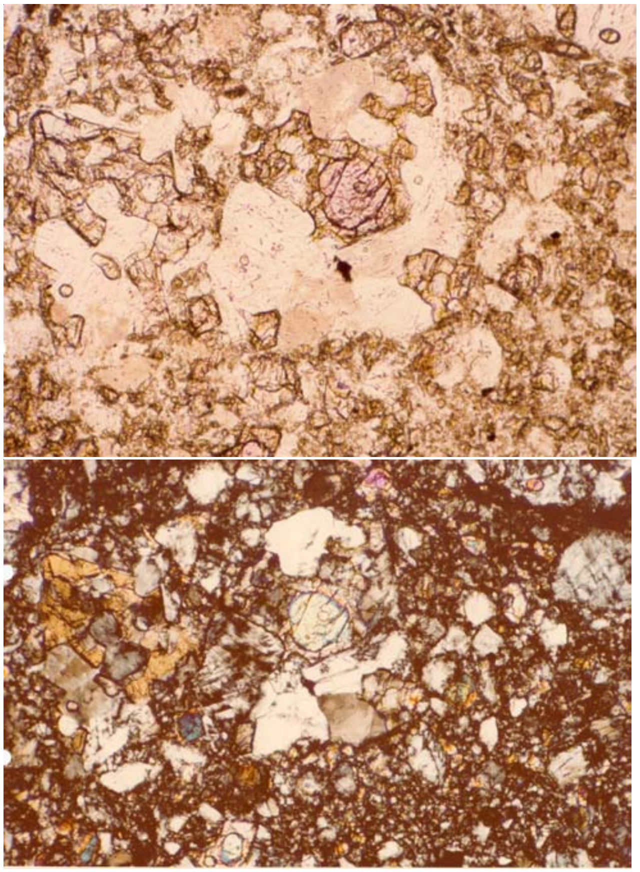


Figure 4: Photomicrographs of thin section 67955,55. Field of view is 1.4 mm. Top is plane-polarized light S79-27768; bottom is with crossed-nicols S79-27769. Note the pyroxene reaction rim on the olivine.

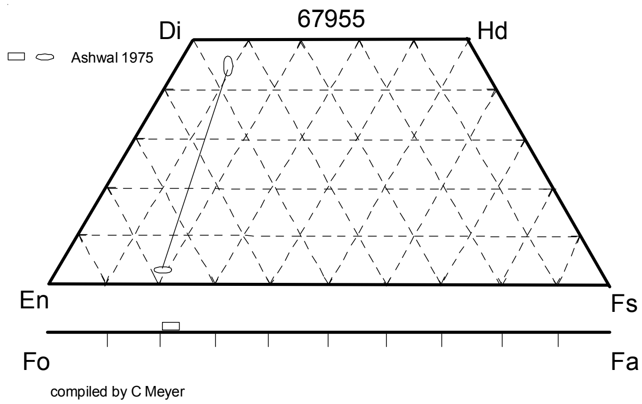


Figure 5: Composition of mafic minerals in 67955 (from Hollister 1973, Ashwal 1975).

Figure 6: Thin section photo of fine-grained radiating oxide-anorthite complex in 67955 (Nord et al. 1975).

uniform composition, such that the matrix was formed by brecciation of the parent rock. The typical mineral assembledge in the clasts consists of a large single poikilitic pyroxene enclosing discrete grains of olivine and plagioclase. The surrounding pyroxene oikocryst is either Ca-rich or Ca- poor, but not exsolved (Hollister 1973). Cushing et al. (1999) calculate an equilibrium temperature of mafic minerals as 1112 deg C.

Petrographic descriptions of the recrystallized, brecciated texture of 67955 include terms like "poikiloblastic" (Ryder and Norman 1980), "granulitic impactite" (Warenr et al. 1977), and "hornfels" (Nord et al. 1975). Nord et al. (1975) concluded that 67955 was "not lithified by the North Ray Crater event" and Norman et al. (2007) concluded that 67955 formed from an impact melt with a significant component of meteoritic siderophiles (Ni, Ir and Au).

Dramatic clusters of intregrown, radiating opaque and anorthite (figure 6) and large blobs of metallic iron are found in 67955. Hunter and Taylor (1981) report abundant "rust" and moderate schreibersite. Roedder and Weiblen (1977) studied the glass veins, finding them to be formed from the rock they cut.

Mineralogy

Olivine: Olivine occurs as rounded grains, sometime surronded by pyroxene (figure 4).

Pyroxene: Hollister (1973) and Ashwal (1975) reported the pyroxene composition, with extemely low Ca in orthopyroxene and high Ca in augite indicating a high temperature of equilibrium (figure 5).

Plagioclase: Hollister (1973) reported the plagioclase in 67955 was $An_{92} – An_{95}$.

Ilmenite: Ashwal (1975) found the ilmenite was Mg rich.

Metal: Misra and Taylor (1975) found 10 % Ni, but no P in metal in 67955. Ashwal (1975) found metal

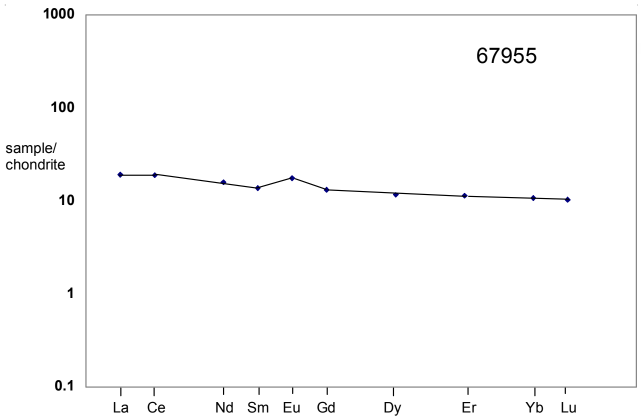


Figure 7: Normalized rare-earth-element diagram for 67955 (Hubbard et al. 1974).

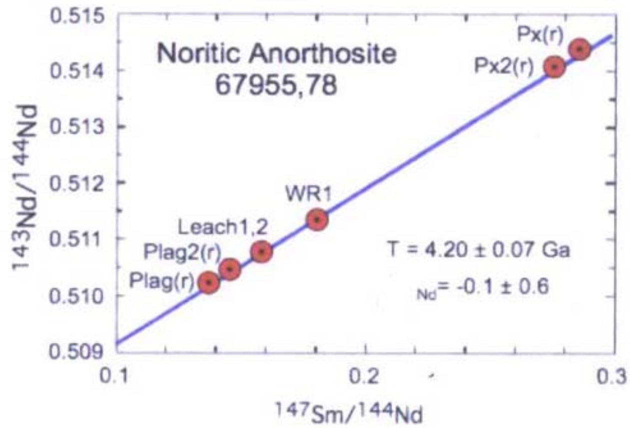


Figure 8: Sm/Nd isochromn diagram for 67955 (Norman et al. 2007).

grains with ~6 % Ni, coexisting with metal grains of ~26 % Ni!

Chemistry

Hubbard et al. (1974), Lindstrom and Salpus (1981), Lindstrom and Lindstrom (1986), Boynton et al. (1976), Wasson et al. (1977) and Palme et al. (1978) determined the chemical composition of 67955 (table 1, figure 7). These splits were consistent with the values determined on the bulk samples by radiation counting. The relatively high Mg/Fe ratio of 67955 distinguishes it from ferroan anorthosites (figure 2). Ganapathy et al. (1974), Boynton et al. (1976) and Palme et al. (1978) found high Ir, Re, and Au and the sample is apprently not “pristine”.

Radiogenic age dating

Norman et al. (2007) reported a crystallisation age of 4.20 ± 0.07 b.y. determined a Sm/Nd internal mineral isochron (figure 8). They also reported disturbed Rb/Sr and Ar/Ar ages. Nyquist et al. (1974) reported Sr isotopes, while Oberli et al. (1979) reported U/Th/Pb.

Cosmogenic isotopes and exposure ages

Rancitelli et al. (1973) determined the cosmic-ray-induced activity of ^{22}Na = 37 dpm/kg. and ^{26}Al = 125 dpm/kg.

Drozd et al. (1974, 1977) found the exposure age of 67955 was ~ 50 m.y. – the age of North Ray Crater.

Processing

This sample has been chipped, not sawn, in order to obtain clean splits for analysis (figures 9 - 11).

Summary of Age Data for 67955

	Sm/Nd
Norman et al. 2007	4.20 ± 0.07 b.y.

Table 1. Chemical composition of 67955.

reference	LSPET73		Ganapa74		Hubbard74		Lindstrom81		Boynton76		Wasson77		Lindstrom86			Palme78		Rancettelli73	
weight					Wiesmann75						,35		74a	74b		43		118 g	
SiO2 %	45.01	(a)																	
TiO2	0.27	(a)					0.29	(d)	0.34	(d)	0.32	(d)	0.3		(d)	0.28	(e)		
Al2O3	27.68	(a)					27	(d)	26.1	(d)	28.5	(d)	26.6		(d)	27	(e)		
FeO	3.84	(a)					4.28	(d)	4.37	(d)	4.46	(d)	4.5	4.55	(d)	4.14	(e)		
MnO	0.05	(a)					0.06	(d)	0.07	(d)	0.054	(d)				0.059	(e)		
MgO	7.69	(a)					8.9	(d)	6.8	(d)	8.3	(d)	7.4		(d)	8.12	(e)		
CaO	15.54	(a)					15.1	(d)	15.4	(d)	15	(d)	14.9	14.8	(d)	15.1	(e)		
Na2O	0.4	(a)			0.36		0.447	(d)	0.52	(d)	0.81	(d)	0.44	0.45	(d)	0.45	(e)		
K2O	0.05	(a)			0.053	(c)			0.055	(d)	0.064	(d)				0.041	(e)	0.099	(f)
P2O5	0.03	(a)														0.078	(e)		
S %	0.01	(a)																	
sum																			
Sc ppm							6.5	(d)	7.4	(d)	7.1	(d)	6.26	6.03	(d)	7.24	(e)		
V									26	(d)	25	(d)							
Cr	750	(a)			659	(c)	877	(d)	870	(d)	870	(d)	675	692	(d)	833	(e)		
Co							26	(d)	15	(d)	19.6	(d)	28.9	27.3	(d)	18.2	(e)		
Ni	108	(a)	231	(b)			220	(d)	185	(b)	170	(b)	346	328	(d)	170	(e)		
Cu																1.28	(e)		
Zn			6.7	(b)					5	(b)	7	(b)				8.16	(e)		
Ga									4	(b)	4.2	(b)				3.52	(e)		
Ge ppb			59	(b)					113	(b)	140	(b)							
As																21	(e)		
Se			26	(b)															
Rb	0.6	(a)	1.2	(b)	0.884	(c)										0.93	(e)		
Sr	170	(a)			169.1	(c)	195	(d)					205	198	(d)	168	(e)		
Y	16	(a)														17	(e)		
Zr	59	(a)			124	(c)							50		(d)	66	(e)		
Nb	4	(a)														6	(e)		
Mo																			
Ru									16	(b)	12	(b)							
Rh																			
Pd ppb																			
Ag ppb			1.2	(b)															
Cd ppb			4.3	(b)					3.5	(b)	3.5	(b)							
In ppb									0.79	(b)	0.79	(b)							
Sn ppb																			
Sb ppb			0.23	(b)															
Te ppb			9.7	(b)															
Cs ppm			0.064	(b)									0.075	0.078	(d)	0.07	(e)		
Ba					61.9	(c)	72	(d)	60	(d)	78	(d)	66	65	(d)	73.4	(e)		
La					4.45	(c)	4.72	(d)	5	(d)	5.3	(d)	3.82	3.97	(d)	5.02	(e)		
Ce					11.3	(c)	12.7	(d)	12	(d)	13	(d)	9.8	10	(d)	13.3	(e)		
Pr													5.9	6.1	(d)	1.72	(e)		
Nd					7.09	(c)					8	(d)				7.7	(e)		
Sm					2.02	(c)	2.12	(d)	2.2	(d)	2.1	(d)	1.79	1.83	(d)	2.08	(e)		
Eu					0.973	(c)	0.98	(d)	1.05	(d)	1.06	(d)	1.114	1.133	(d)	0.98	(e)		
Gd					2.57	(c)										2.7	(e)		
Tb							0.51	(d)	0.45	(d)	0.51	(d)	0.41	0.39	(d)	0.5	(e)		
Dy					2.81	(c)					2.6	(d)				3.33	(e)		
Ho																0.73	(e)		
Er					1.79	(c)										2.1	(e)		
Tm																0.3	(e)		
Yb					1.74	(c)	1.9	(d)	2.02	(d)	2	(d)	1.57	1.58	(d)	2.08	(e)		
Lu					0.25	(c)	0.28	(d)	0.28	(d)	0.28	(d)	0.24	0.237	(d)	0.27	(e)		
Hf					3.1	(c)	1.8	(d)	1.7	(d)	1.6	(d)	1.59	1.48	(d)	1.79	(e)		
Ta							0.3	(d)	0.21	(d)	0.24	(d)	0.28	0.26	(d)	0.25	(e)		
W ppb																120	(e)		
Re ppb			0.572	(b)															
Os ppb																			
Ir ppb			5.56	(b)					7.2	(b)	8	(b)	11	10	(d)	6.8	(e)		
Pt ppb																			
Au ppb			1.6	(b)					2	(b)	2.2	(b)				2	(e)		
Th ppm	1.9	(a)			1.03	(c)	1.12	(d)	0.97	(d)	1.08	(d)	0.92	0.91	(d)	0.84	(e)	0.98	(f)
U ppm			0.36	(b)	0.38	(c)	0.34	(d)	0.32	(d)	0.33	(d)	0.22	0.23	(d)	0.26	(e)	0.29	(f)

technique: (a) XRF, (b) RNAA, (c) IDMS, (d) INAA, (e) mixed, (f) radiation counting

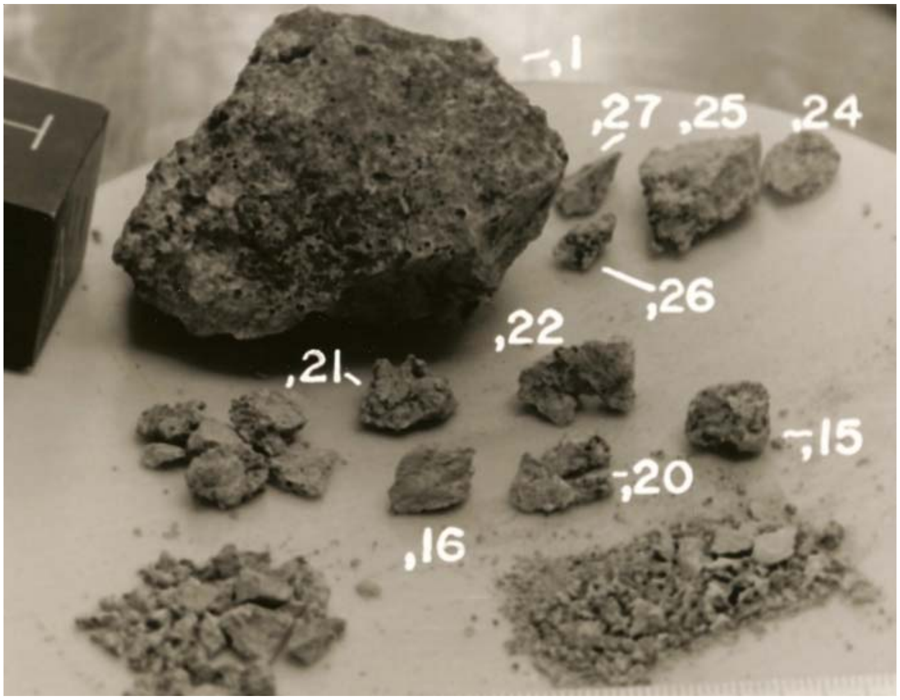


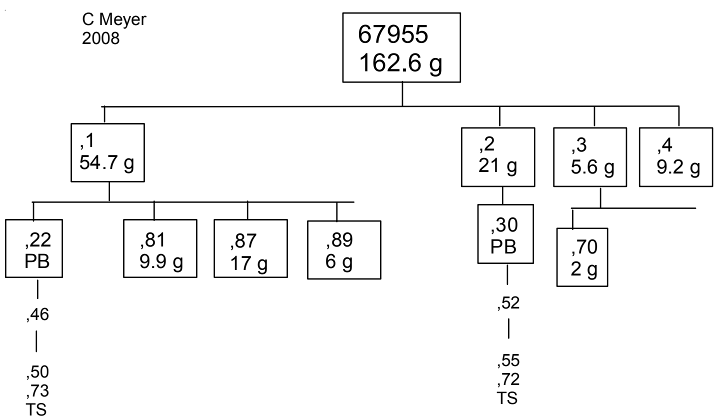
Figure 9: Initial processing of 67955,1 Cube is 1 inch. S73-22428.

Figure 10: Photo of 67955,1 prior to second round of sampling. Cube is 1 inch. S92-33078.

,77

,78

Figure 11: Processing photo for sampling 67955,1 in 1992. Cube is 1 cm. S92-32811.



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