67475

Impact Melt Breccia

175 grams

Figure 1: Location of 67475 on white boulder 67455. AS16-106-17337.

Figure 2: Photo of 67475. Cube is 1 cm. S72-43363

Introduction

67475 was sampled as a large dark clast on the top of the White Boulder on the rim of North Ray Crater, Apollo 16 (figures 1 and 9). It is similar to other smaller clasts in 67455 from the matrix of the boulder. 67475 contains unusual clasts, some with abundant melt, some with abundant Fe-rich olivine and ferro-augite. There are zap pits on the outer surfaces.

Figure 3: Photo of 67475. Cube is 1 cm. S72-43359

Figure 4: Photomicrograph of thin section 67475,82. Scale bar is 1 mm. From Minkin et al. 1977.

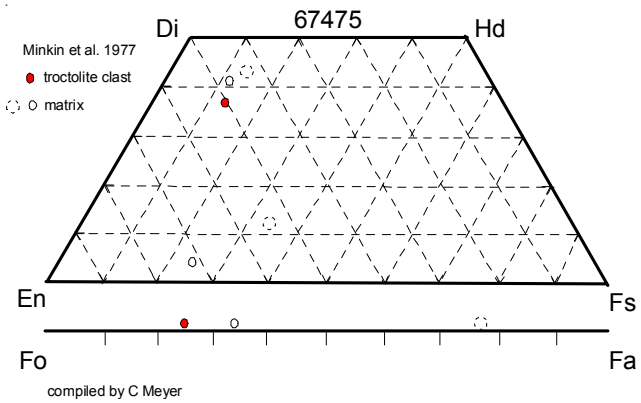


Figure 5: Composition of some mafic minerals in 67475 as gleaned from Minkin et al. (1977).

Petrography

67475 is a tough purplish-grey, glassy breccia (figures 4 and 6). Minkin et al. (1974) describe the matrix as *"a fragment-laden melt containing two major clast types – a dark clast rich in metallic iron and a light clast with a high percentage of olivine"*. Minkin et al. (1974) present a table of mineral and clast types.

Minkin et al. (1974) and Stoffler et al. (1985) find that 67475 contains "unusual" clasts. Clasts of devitrified glass are present. Other clasts are rich in metallic iron. One clast type has Fe-rich olivine in abundance. Pyroxene chemistry is also unusual, with some ferro-augite reported (figure 5).

Chemistry

Lindstrom et al. (1977) showed that 67475 was highly aluminous and had a positive Eu anomaly (figure 7). There is relatively high meteoritic siderophile content. Stoffler et al. (1985) noted several clasts in 67475 had high K, P contents (table 2). The "analysis" by

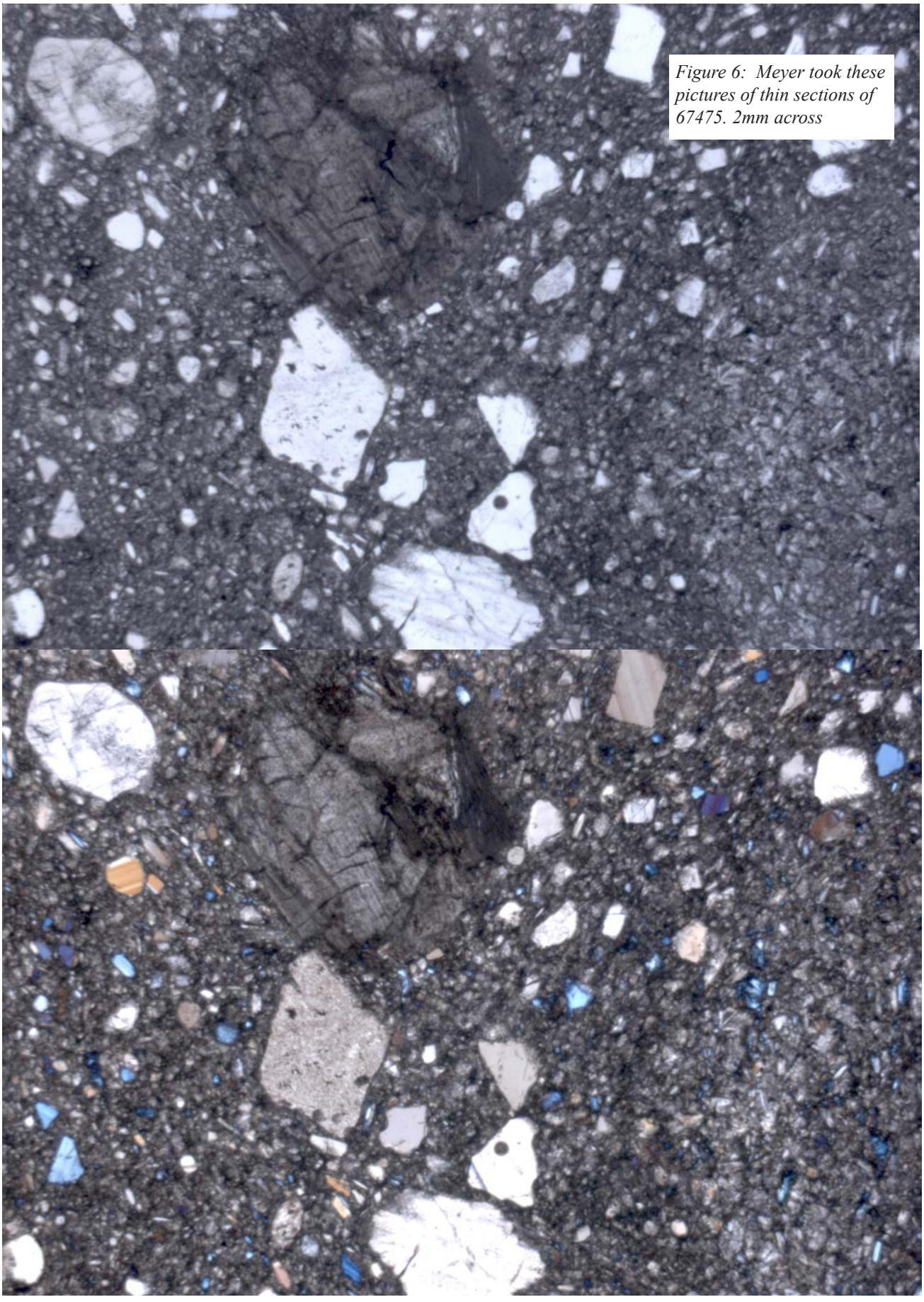


Figure 6: Meyer took these pictures of thin sections of 67475. 2mm across

(b) Fragment population (> 40 μm) of thin section 67475,82 (903 counts)

Fragment type	Fragment-laden melt	Metal- and silica-rich breccia clast	Light-colored olivine-bearing breccia clast
Gabbroic-troctolitic anorthosite	4.5	0.4	15.3
Cataclastic anorthosite w/mafic minerals	0.3	—	—
Cataclastic anorthosite	4.2	—	0.5
Anorthosite w/polygonal texture	1.0	—	1.6
Crushed anorthite stringers	0.5	—	—
Plagioclase	71.7	51.5	44.2
Olivine	2.9	—	13.7
Clinopyroxene	5.3	16.5	8.4
Orthopyroxene	1.0	—	5.8
Silica	2.0	11.8	1.1
Feldspar w/silica lamellae	1.4	6.3	—
NiFe	0.04	—	0.5
Fe-metal	0.9	7.2	—
Ilmenite	2.1	3.4	4.2
Troilite	0.4	—	4.7
P-rich grains	0.3	2.5	—
Glass: devitrified	1.5	0.4	—
Total	100.04	100.0	100.0

McKinley et al. (1984) appears to be an average of earlier work. Borchardt et al. (1986) used 67475 as an end-member in their mixing model calculations.

Moore and Lewis (1976) and Cripe and Moore (1975) reported C = 11 ppm and N = 135 ppm.

Radiogenic age dating

None

Cosmogenic isotopes and exposure ages

Clark and Keith (1973) determined the cosmic-ray-induced activity of ^{23}Na = 38 dpm/kg, ^{26}Al = 126 dpm/kg and ^{54}Mn = 2 dpm/kg.

Processing

A slab was cut through the middle of 67475 (figure 8). There are 21 thin sections.

References for 67475

Borchardt R., Stoffler D., Spettel B., Palme H., Wanke H., Wacker K. and Jessberger E.K. (1986) Composition, structure and age of the Apollo 16 subregolith basement as deduced from the chemistry of post-Imbrium melt bombs. *Proc. 17th Lunar Planet. Sci. Conf.* in J. Geophys. Res. **90**, E43-E54.

Butler P. (1972a) Lunar Sample Information Catalog Apollo 16. Lunar Receiving Laboratory. MSC 03210 Curator's Catalog. pp. 370.

Clark R.S. and Keith J.E. (1973) Determination of natural and cosmic ray induced radionuclides in Apollo 16 lunar samples. *Proc. 4th Lunar Sci. Conf.* 2105-2113.

Cripe J.D. and Moore C.B. (1974) Total sulfur contents of Apollo 15 and 16 lunar samples (abs). *Lunar Sci.* **V**, 523-525. Lunar Planetary Institute, Houston.

Garg A.N. and Ehmann W.N. (1976a) Zr-Hf fractionation in chemically defined lunar rock groups. *Proc. 7th Lunar Sci. Conf.* 3397-3410.

Hertogen J., Janssens M.-J., Takahashi H., Palme H. and Anders E. (1977) Lunar basins and craters: Evidence for systematic compositional changes of bombarding population. *Proc. 8th Lunar Sci. Conf.* 17-45.

Hunter R.H. and Taylor L.A. (1981) Rust and schreibersite in Apollo 16 highland rocks: Manifestations of volatile-element mobility. *Proc. 12th Lunar Planet. Sci. Conf.* 253-259.

Lindstrom M.M., Nava D.F., Linstrom D.J., Winzer S.R., Lum R.K.L., Schuhmann P.J., Schumann S. and Philpotts J.A. (1977) Geochemical studies of the White Breccia Boulders at North Ray Crater, Descartes region of the lunar highlands. *Proc. 8th Lunar Sci. Conf.* 2137-2151.

Lindstrom M.M. and Salpus P.A. (1981) Geochemical studies of rocks from North Ray Crater Apollo 16. *Proc. 12th Lunar Planet. Sci. Conf.* 305-322.

Lindstrom M.M. and Salpus P.A. (1982) Geochemical studies of feldspathic fragmental breccias and the nature of

Table 1. Chemical composition of 67475.

reference	Lindstrom77		Hertogen77			Miller74		Clark73		McKinley84	
weight			,4	,106							
SiO2 %	44.4	(a)				44.5	(a)			44.5	(e)
TiO2	0.36	(a)				<0.83	(a)			0.4	(e)
Al2O3	30.87	(a)				30.2	(a)			30.5	(e)
FeO	2.91	(a)				3.2	(a)			3.1	(e)
MnO	0.04	(a)				0.046	(a)			0.04	(e)
MgO	2.57	(a)				3.31	(a)			3	(e)
CaO	17.21	(a)				18.3	(a)			17.8	(e)
Na2O	0.6	(a)				0.62	(a)			0.6	(e)
K2O	0.04	(b)						0.054	(d)	0.06	(e)
P2O5		(a)									
S %											
sum											
Sc ppm											
V											
Cr											
Co											
Ni			87	39	(c)						
Cu											
Zn			1.61	1.14	(c)						
Ga											
Ge ppb			18	12	(c)						
As											
Se			25	19	(c)						
Rb	0.672	(b)	0.89	0.66	(c)						
Sr	216	(b)									
Y											
Zr											
Nb											
Mo											
Ru											
Rh											
Pd ppb			4.5	1.2	(c)						
Ag ppb			0.61	1.46	(c)						
Cd ppb			1.13	2.03	(c)						
In ppb			0.53	0.57	(c)						
Sn ppb											
Sb ppb			0.15		(c)						
Te ppb			0.6	1.7	(c)						
Cs ppm			0.052	0.032	(c)						
Ba	48.5	(b)									
La											
Ce	6.66	(b)									
Pr											
Nd	4.22	(b)									
Sm	1.21	(b)									
Eu	1.28	(b)									
Gd	1.43										
Tb											
Dy	1.68	(b)									
Ho											
Er	1.06	(b)									
Tm											
Yb	1.01	(b)									
Lu	0.14	(b)									
Hf											
Ta											
W ppb											
Re ppb			0.604	0.156	(c)						
Os ppb			7.64	1.57	(c)						
Ir ppb			7	1.68	(c)						
Pt ppb											
Au ppb			1.27	0.382	(c)						
Th ppm								0.67	(d)		
U ppm			0.155	0.109	(c)			0.19	(d)		

technique: (a) mixed, (b) IDMS, (c) RNAA, (d) rad. count. (e) mysterious

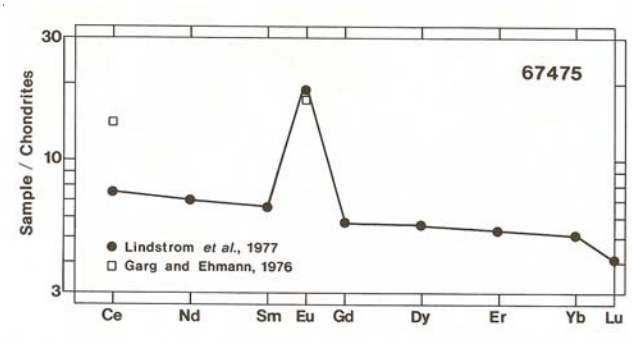


Figure 7: Normalized rare-earth-element diagram for 67475.

North Ray Crater Ejecta. *Proc. 13th Lunar Planet. Sci. Conf.* A671-A683. JGR

LSPET (1973b) The Apollo 16 lunar samples: Petrographic and chemical description. *Science* **179**, 23-34.

LSPET (1972c) Preliminary examination of lunar samples. *In* Apollo 16 Preliminary Science Report. NASA SP-315, 7-1—7-58.

McKinley J.P., Taylor G.J., Keil K., Ma M.-S. and Schmitt R.A. (1984) Apollo 16: Impact sheets, contrasting nature of the Cayley Plains and Descartes Mountains, and geologic history. *Proc. 14th Lunar Planet. Sci. Conf.* in J. Geophys. Res. **89**, B513-B524.

Miller M.D., Pacer R.A., Ma M.-S., Hawke B.R., Lookhart G.L. and Ehmann W.D. (1974) Compositional studies of the lunar regolith at the Apollo 17 site. *Proc. 5th Lunar Sci. Conf.* 1079-1086.

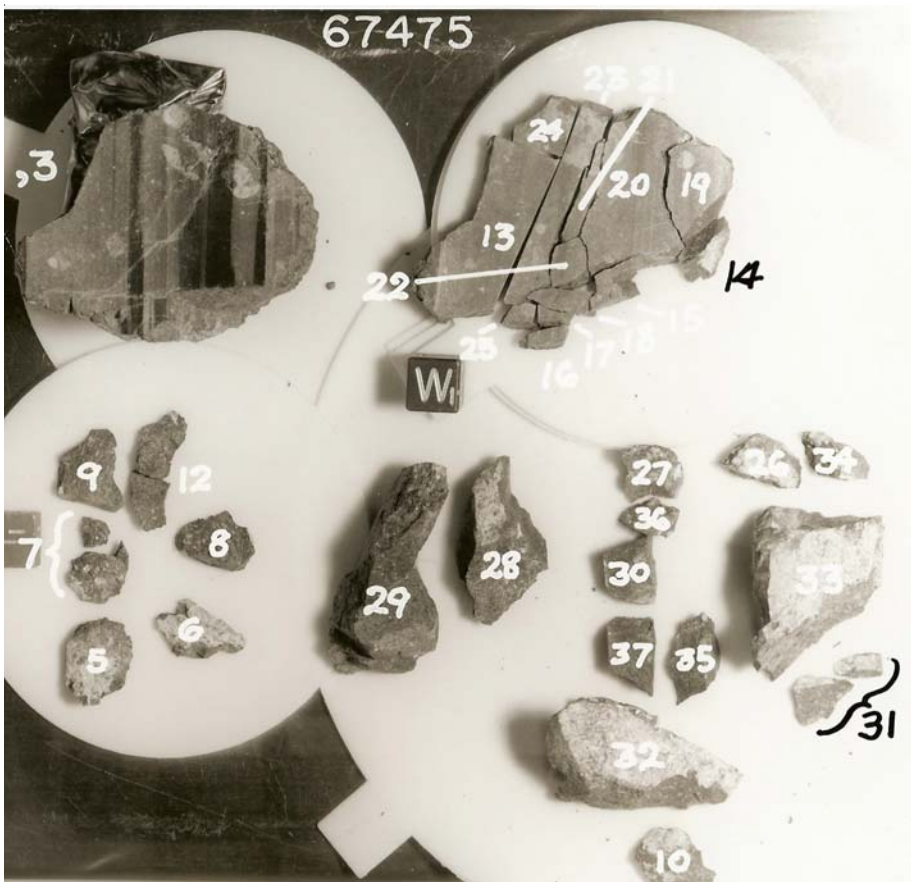
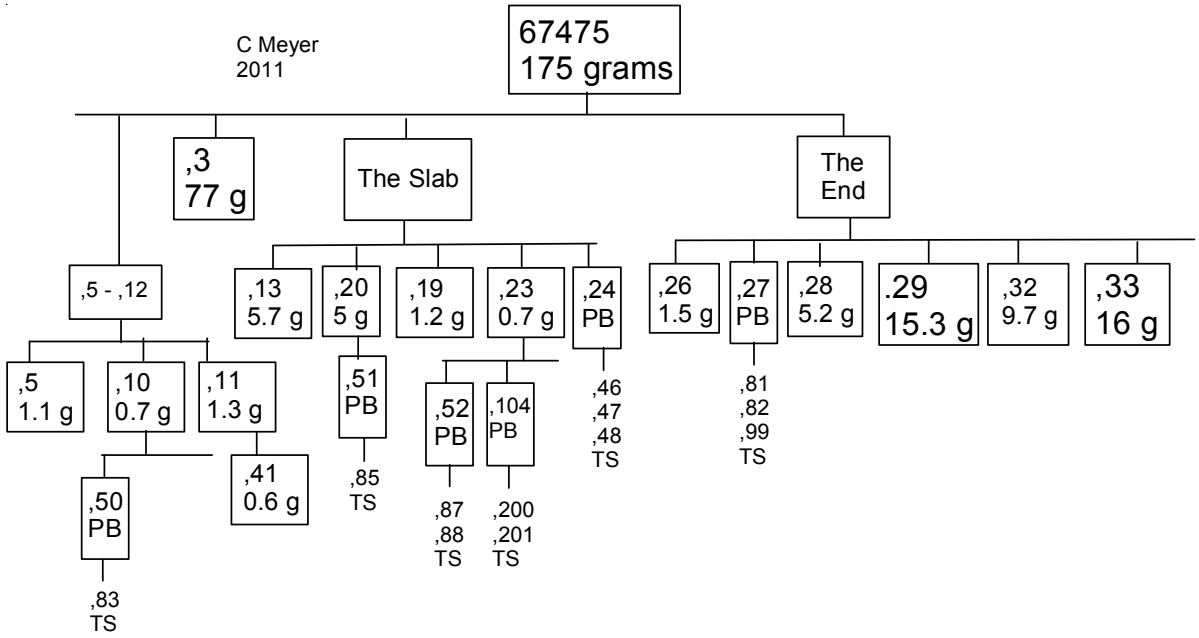


Figure 8: Processing of 67475. Cube is 1 cm. S73-30709



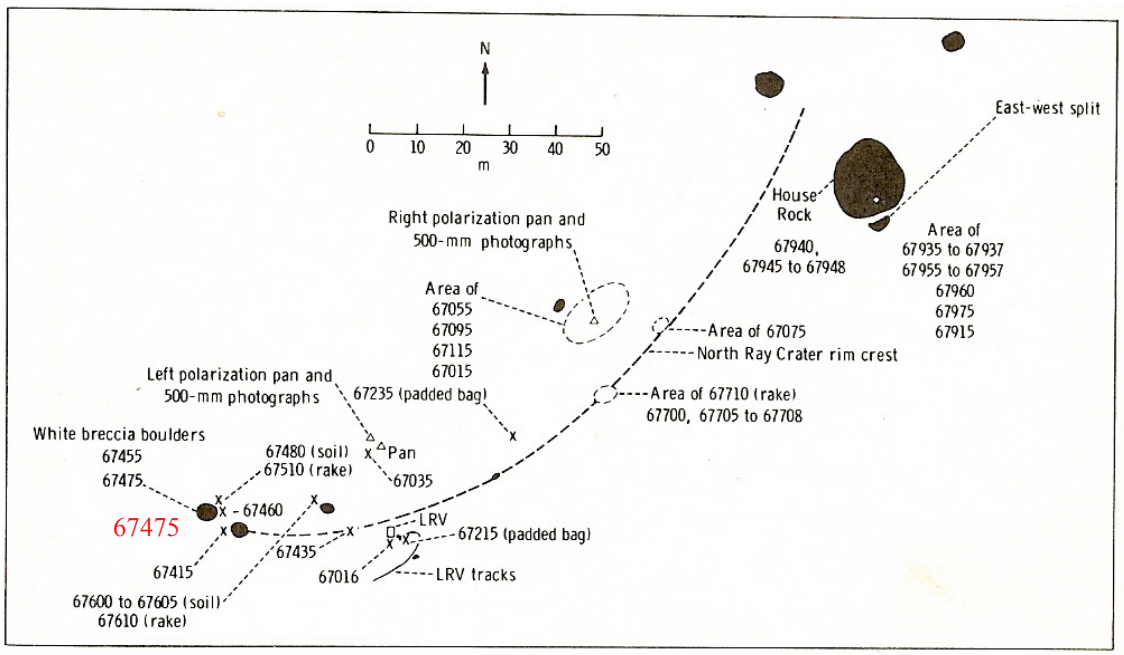


Figure 9: Location, location, location.

Table 2. Chemical composition of 67475

reference	Stoffler85				unusual		
weight	,46	,48	,90	,46	,48	,90	
SiO2 %	46.2	44.4	44.8	46.9	52.1	52.8	(a)
TiO2	0.32	0.37	0.29	1.06	2.14	0.67	(a)
Al2O3	29.9	30.6	32.1	24.8	16.5	25.1	(a)
FeO	3	3.2	2.65	8.2	13.6	5.3	(a)
MnO	0.03	0.02	0.02	0.11	0.15	0.08	(a)
MgO	2.77	2.97	2.04	2.99	2.1	1.37	(a)
CaO	17.3	17.8	17.3	14.9	11	11.9	(a)
Na2O	0.38	0.56	0.67	0.49	1.04	1.76	(a)
K2O	0.07	0.06	0.07	0.15	0.59	0.6	(a)
P2O5	0.05	0.06	0.05	0.4	0.83	0.43	(a)
S %							
sum							

(a) broad beam elec. Probe analysis

Minkin J.A., Thompson C.L. and Chao E.C.T. (1977) Apollo 16 white boulder consortium samples 67455 and 67475: Petrologic investigations. *Proc. 8th Lunar Sci. Conf.* 1967-1986.

Moore C.B. and Lewis C.F. (1975) Total nitrogen contents of Apollo 15, 16 and 17 lunar fines samples. *Lunar Sci.* **VI**, 569-571.

Moore C.B. and Lewis C.F. (1976) Total nitrogen contents of Apollo 15, 16 and 17 lunar rocks and breccias (abs). *Lunar Sci.* **VII**, 571-573. Lunar Planetary Institute, Houston.

Ryder G. and Norman M.D. (1980) Catalog of Apollo 16 rocks (3 vol.). Curator's Office pub. #52, JSC #16904

Stöffler D., Ostertag R., Reimold W.U., Borchardt R., Malley J. and Rehfeldt A. (1981) Distribution and provenance of lunar highland rock types at North Ray Crater, Apollo 16. *Proc. 12th Lunar Planet. Sci. Conf.* 185-207.

Stöffler D., Bischoff A., Borchardt R., Burghele A., Deutsch A., Jessberger E.K., Ostertag R., Palme H., Spettel B., Reimold W.U., Wacker K. and Wanke H. (1985) Composition and evolution of the lunar crust in the Descartes highlands. *Proc. 15th Lunar Planet. Sci. Conf.* in J. Geophys. Res. **90**, C449-C506.

Sutton R.L. (1981) Documentation of Apollo 16 samples. In Geology of the Apollo 16 area, central lunar highlands. (Ulrich et al.) U.S.G.S. Prof. Paper 1048.