10057

Ilmenite Basalt (high K)

919 grams

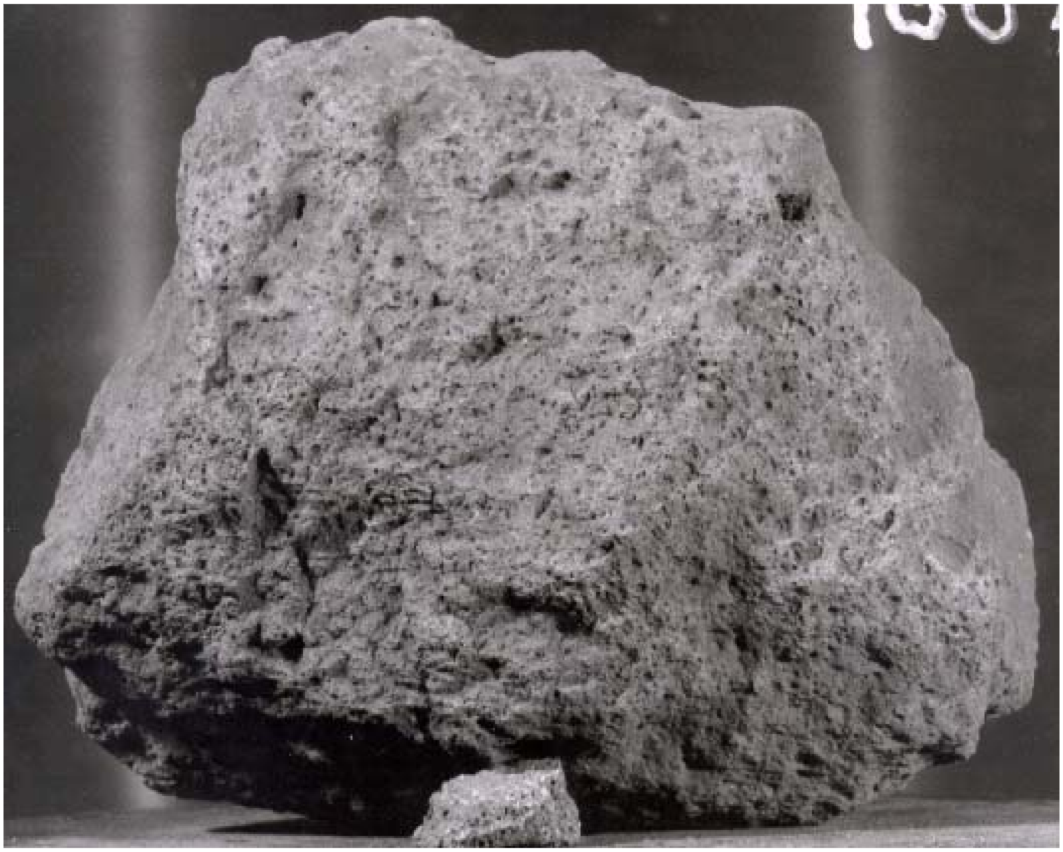


Figure 1: Photo of whole rock 10057,0 during preliminary examination. NASA photo # S69-46287. Sample is about 11 cm across.

Introduction

All of the Apollo 11 basalts have high TiO_2 and low SiO_2 contents. Apollo 11 did not sample a very wide area and it appears that only 2 lava flows may have been sampled, distinguished by higher K, and slightly higher REE, contents in one flow compared with the other. There is also a correlation with cosmic ray exposure age.

10057 belongs to the group of samples known as "high K, Apollo 11 basalts". Although they range in texture, they are remarkable similar in composition and are probably from the same basalt flow (Beaty and Albee 1978). The range of texture is attributed to differences in cooling rate. 10057 is fine-grained and cooled rather quickly (Grove and Beaty 1980). The crystallization age is about 3.6 b.y. and the cosmic ray exposure age is about 54 m.y.

Petrography

Lunar basalt 10057 is composed of intergrown subhedral to anhedral plagioclase, euhedral to subhedral ilmenite, subhederal pyroxene and a residual fine-grained mesostasis composed of plagioclase, cristobalite and potassic glass. 10057 has a high abundance (~10%) of vesicles (figure 1). LSPET (1969) termed this group of vesicular, fine-grained rock "type A basalts". James and Wright (1972) termed these rocks "intersertal ilmenite basalts". Schmitt et al. (1970) termed 10057 as a "fine-grained, vesicular to vuggy, granular basalt." Grove and Beaty (1980) term them "antiophitic".

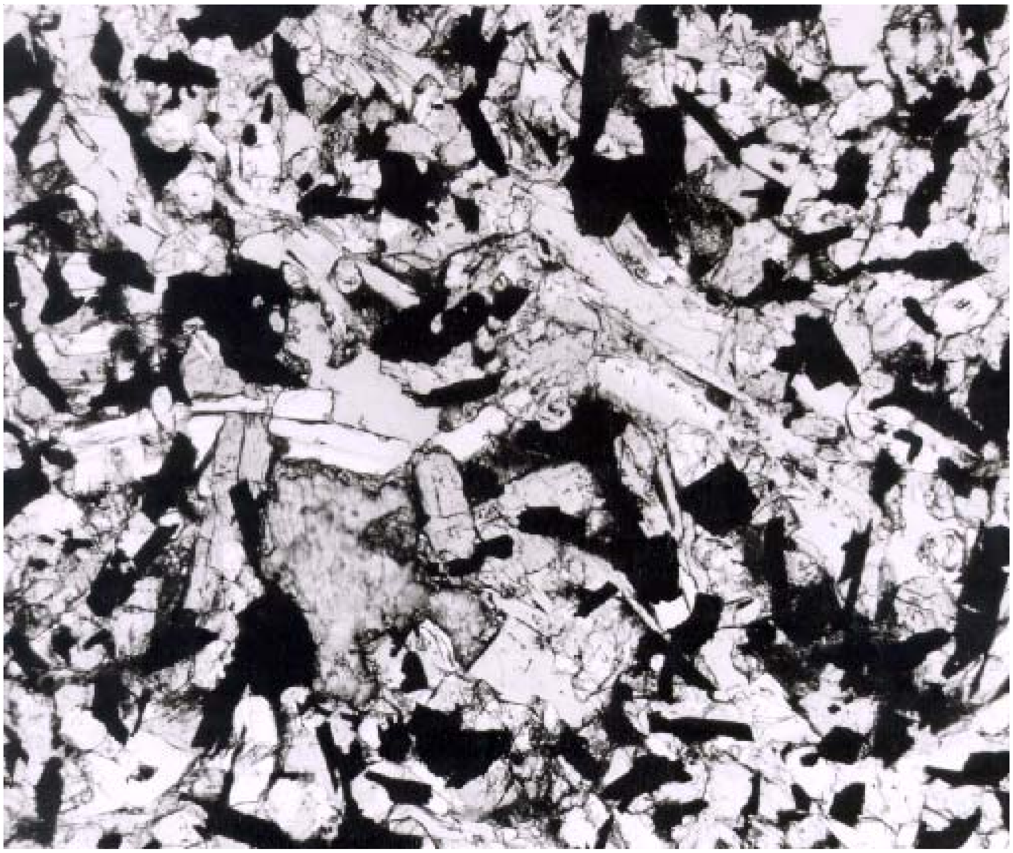


Figure 2: Photomicrograph of thin section of 10057 (plane polarized light). NASA #76-26315.

Mineralogy

Pyroxene: Pyroxenes in 10057 are chemically zoned in major and minor elements (Lovering and Ware 1970, Essene et al. 1970 and Beaty and Albee 1978) (figure 3). Large grains have pigeonite cores with augite rims trending towards iron rich, but without the extreme iron enrichment of other lunar basalts. Essene et al. (1970) studied the variation of Ti and Al as a function of Mg/Fe in pyroxene in 10057.

Plagioclase: The plagioclase in 10057 ranges in composition from An_{74} to An_{81} (Reid et al. 1970, Beaty and Albee 1978). Steward et al. (1970) obtain An_{75} from cell size measurements.

Opaques: Ilmenite in 10057 is about the same size (40 microns) as pyroxene or plagioclase (Lovering and Ware 1970).

Chemistry

Lunar basalt 10057 was widely distributed and analyzed by numerous persons (tables 1, 2). Figures 4

Mineralogical Mode for 10057

	Haggerty et al. 1970	Beaty and Albee 1978
Olivine		<0.04
Pyroxene	50.9 vol. %	50.8
Plagioclase	19.2	24
Opaques	15.7	15.5
Cristobalite		1.05
Troilite		0.42
Phosphate		0.21
Mesostasis	3.3	8.04
Metal		0.04
Vesicles	11	
Armalcolite		absent

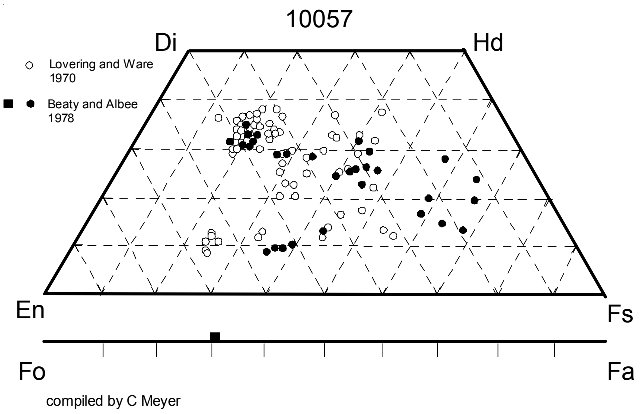


Figure 3: Olivine and pyroxene composition diagram for 10057 (data replotted from Lovering and Ware 1970 and Beaty and Albee 1977).

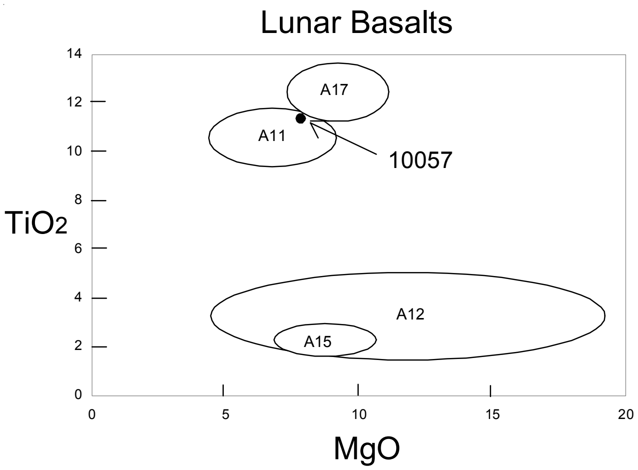


Figure 4: Composition of lunar basalts showing position for 10057 (data from table 1).

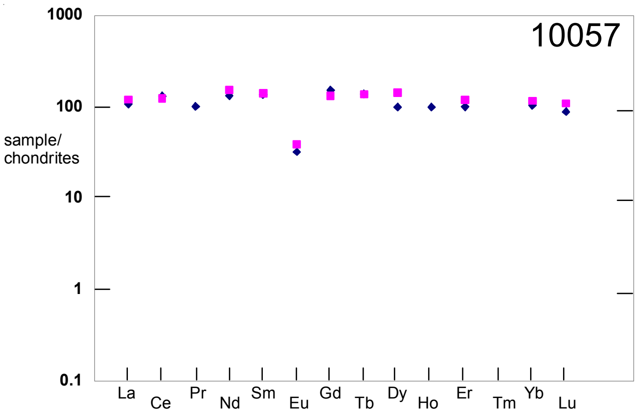


Figure 5: Normalized rare-earth-element diagram for high-K basalt 10057 (data from Wanke et al. 1970 and Haskin et al. 1970 only).

and 5 show that 10057 is a typical high-K, high-Ti Apollo 11 basalt.

Radiogenic age dating

Papanastassiou et al. (1970) dated 10057 as 3.63 ± 0.02 b.y. by the Rb-Sr internal isochron method. Davis et al. (1971) and Tatsumoto (1970) found that they could not date 10057 by the ^{39}Ar/^{40}Ar or U/Pb methods.

Cosmogenic isotopes and exposure ages

O'Kelley et al. (1970) determined the cosmic ray induced activity of ^{22}Na (41 dpm/kg), ^{26}Al (75 dpm/kg), ^{46}Sc (10 dpm/kg), ^{54}Mn (32 dpm/kg) and ^{56}Co (31 dpm/kg). Perkins et al. (1970) found ^{22}Na (43 dpm/kg), ^{26}Al (84 dpm/kg), ^{46}Sc (11 dpm/kg), ^{54}Mn (41 dpm/kg) and ^{56}Co (19 dpm/kg). Wrigley and Quaide (1970) measured significant ^{22}Na (49 dpm/kg) and ^{26}Al (75 dpm/kg) in 10057 due to recent cosmic ray events.

The cosmic ray exposure ages for 10057 were reviewed by Hintenberger et al. (1971) and Srinivasan (1974). Hohenberg et al. (1970) determined 34 ± 5 m.y. by ^{83}Kr, Marti (1970) and Marti and Lugmair (1971) determined 47 ± 2 m.y. by ^{83}Kr, Bochsler et al. (1971) reported 52.5 m.y. Hintenberger et al. (1971) and Guggisberg et al. (1979) determined 58 m.y. and 52 m.y. by ^{38}Ar. Arvidson et al. (1975) reported a ^{81}Kr exposure age of 52.5 m.y. (determined by Schwaller 1971). Eugster et al. (1984) determined 54.2 m.y. Srinivasan (1974) used the Xe data from Marti et al. (1970) and Hohenberg et al. (1970) to calculate 34 and 54 m.y. respectively.

Other Studies

The rare gas contents and isotopic ratios of 10057 were reported by Hohenberg et al. (1970), Hintenberger et al. (1971), Bogard et al. (1971) and Eugster et al. (1984).

Oxygen isotope ratios were reported for whole rock and mineral separates of 10057 by O'Neil and Adams (1970) and Taylor and Epstein (1970).

Summary of Age Data for 10057

	Rb-Sr	Ar-Ar	K-Ar
Papanastassiou et al. 1970	3.63 ± 0.02 b.y.		

Caution: Age not corrected for "new" Rb decay constant.

Table 1a. Chemical composition of 10057.

reference	Engel 70		Wanke 70		Wasson 70		Wrigley 70		Ganapathy 70		Anders 71		Morrison 70		Perkins 70		O'Kelly 70	
weight	Engel 71																	
SiO2 %	39.79	(a)	40.43										46	(d)				
TiO2	11.44	(a)	10.84	(b)									7.56	(b)				
Al2O3	10.84	(a)	7.56	(b)									10.84	(b)				
FeO	19.35	(a)	18.01	(b)									20.2	(b)				
MnO	0.2	(a)	0.23	(b)									0.22	(b)				
MgO	7.65	(a)	6.96	(b)									6.13	(b)				
CaO	10.08	(a)	11.75	(b)									14.13	(b)				
Na2O	0.54	(a)	0.4	(b)									0.47	(b)				
K2O	0.32	(a)	0.24	(b)									0.26	(b)	0.28	(e)	0.31	(e)
P2O5	0.17	(a)											0.09	(c)				
S %																		
sum																		
Sc ppm	100	(f)	87	(b)									84	(b)				
V	66	(f)											40	(b)				
Cr	2400	(f)	2160	(b)									2100	(b)				
Co	21	(f)	25.4	(b)					27.2	(b)	30	(b)	24	(b)				
Ni	7	(f)	<10	(b)									40	(b)				
Cu	11	(f)	4.3	(b)					3.52	(b)			5.5	(b)				
Zn									1.7	(b)	1.75	(b)	2.9	(b)				
Ga			5.2	(b)	4.9	(b)							4.7					
Ge ppb					< 70	(b)												
As																		
Se											0.181	(b)						
Rb			5.2	(b)					3.68	(b)			4.8	(b)				
Sr	130	(f)	100	(b)									130	(b)				
Y	180	(f)											210	(c)				
Zr	400	(f)							560	(b)			360	(b)				
Nb													42	(c)				
Mo													0.4	(b)				
Ru																		
Rh																		
Pd ppb			10	(b)					7.3	(b)								
Ag ppb									0.69	(b)								
Cd ppb									3.15	(b)	3.5	(b)						
In ppb			2.7	(b)	3				3.2	(b)								
Sn ppb																		
Sb ppb																		
Te ppb									8	(b)								
Cs ppm			0.2	(b)					0.159	(b)			0.2	(b)				
Ba	130	(f)	208	(b)									280	(b)				
La			25	(b)									31	(b)				
Ce			79	(b)									83	(b)				
Pr			9	(b)									22	(c)				
Nd			60	(b)									66	(b)				
Sm			20	(b)									24	(b)				
Eu			1.8	(b)									2.1	(b)				
Gd			30	(b)									26	(b)				
Tb			5	(b)									5.6	(b)				
Dy			24	(b)									42	(c)				
Ho			5.5	(b)									8	(b)				
Er			16	(b)									32	(c)				
Tm													2.3	(b)				
Yb	16	(f)	16.8	(b)									26	(b)				
Lu			2.15	(b)									2.2	(b)				
Hf			16.9	(b)									15	(b)				
Ta			2	(b)									1.2	(b)				
W ppb			430	(b)									0.42	(b)				
Re ppb																		
Os ppb																		
Ir ppb					0.1				0.023	(b)	0.009	(b)						
Pt ppb																		
Au ppb			1.6		< 0.3				0.017	(b)	0.013	(b)						
Th ppm			3.94	(b)			3.27	(e)					4.5	(b)	3.6	(e)	3.3	(e)
U ppm			0.8	(b)			0.97	(e)					0.56	(b)	0.95	(e)	0.79	(e)

technique (a) wet chem. (b) INAA, RNAA, (c) SSMS, (d) AA, (e) radiation counting, (f) emission spec.

Table 1b. Chemical composition of 10057.

reference	Smales71	Turekian70	Kharkar71		Annell 70		Tatsumoto70 Haskin 70 Baedecker70		LSPET 70		Duncan76		Neal2001	
weight														
SiO2 %	41.4								*36*	(c)	40.67	(g)		
TiO2	10.9	*8.2*	12.18	(b)					*12.5*	(c)	11.35	(g)		
Al2O3	8.1								*11*	(c)	7.99	(g)		
FeO	19.1		18.65	(b)					*20*	(c)	19.4	(g)		
MnO	0.23	*0.25*	0.23	(b)	0.28	(c)			*0.49*	(c)	0.233	(g)		
MgO	7.4								*9.5*	(c)	7.65	(g)		
CaO	10.4		9.37	(b)					*10*	(c)	10.75	(g)		
Na2O	0.54	*0.55*	0.55	(b)					*0.54*	(c)	0.57	(g)		
K2O	0.33	*0.43*							*0.18*	(c)	0.287	(g)		
P2O5											0.197	(g)		
S %											0.26	(g)		
sum														
Sc ppm	86		90	(b)	99	(c)			*110*	(c)			77.2	(h)
V					65	(c)			*50*	(c)	47	(g)	45.5	(h)
Cr	2250		2290	(b)	2790	(c)			*6500*	(c)	2374	(g)	2063	(h)
Co			26	(b)	30	(c)			*22*	(c)	25	(g)	26.8	(h)
Ni					6.1	(c)			*25*	(c)	<2	(g)	5.91	(h)
Cu					5.7	(c)							60.5	(h)
Zn													75.6	(h)
Ga					5	(c)	4.9	(b)					4.19	(h)
Ge ppb							<0.2	(b)						
As														
Se		*0.12*												
Rb					4.7	(c)			*6*	(c)	6.5	(g)	5.27	(h)
Sr					140	(c)			*230*	(c)	166	(g)	144	(h)
Y					165	(c)			*310*	(c)	170	(g)	176	(h)
Zr					635	(c)					517	(g)	523	(h)
Nb					29	(c)					28.7	(g)	26.7	(h)
Mo		*0.1*											0.07	(h)
Ru														
Rh														
Pd ppb														
Ag ppb		*52*												
Cd ppb														
In ppb														
Sn ppb														
Sb ppb													20	(h)
Te ppb														
Cs ppm													0.36	(h)
Ba					440	(c)			*180*	(c)	319	(g)	261	(h)
La		*25*	23	(b)	26	(c)	28.2	(b)					23.4	(h)
Ce			69.6	(b)			75	(b)					83.3	(h)
Pr													11.1	(h)
Nd							69	(b)					59.4	(h)
Sm		*17*	14.3	(b)			20.8	(b)					20.1	(h)
Eu		*2.5*	2.4	(b)			2.18	(b)					1.95	(h)
Gd							26	(b)					26.4	(h)
Tb							5	(b)					4.53	(h)
Dy		*37*	29.9	(b)			34.7	(b)					29.3	(h)
Ho													6.5	(h)
Er							19	(b)					17.8	(h)
Tm													2.43	(h)
Yb			13.2	(b)			18.8	(b)	*6*	(c)			17	(h)
Lu			2.48	(b)			2.66	(b)					2.26	(h)
Hf			18.1	(b)									13.6	(h)
Ta			1.7	(b)									1.76	(h)
W ppb													520	(h)
Re ppb														
Os ppb														
Ir ppb														
Pt ppb														
Au ppb		*6.4*												
Th ppm							3.415	(a)					2.77	(h)
U ppm		*0.47*					0.865	(a)					0.76	(h)

technique (a) IDMS, (b) INAA, (c) emission spec., (g) XRF, (h) ICP-MS

Table 2. Light and/or volatile elements for 10057

	Engel 70	Wanke 70	Annell 70	Morrison 70	Ganapathy 70
Li ppm	14	14	17	8	
Be			3.3	2.5	
B		0.8		4	
C					
S					
F ppm				70	
Cl		12		50	
Br ppb				100	25.2
I					
Pb ppm					
Hg ppb					
Tl ppb					1.09
Bi ppb					0.27

Figure 6: Space Window at US National Cathedral in Washington DC with piece of 10057 located in center of rose window.

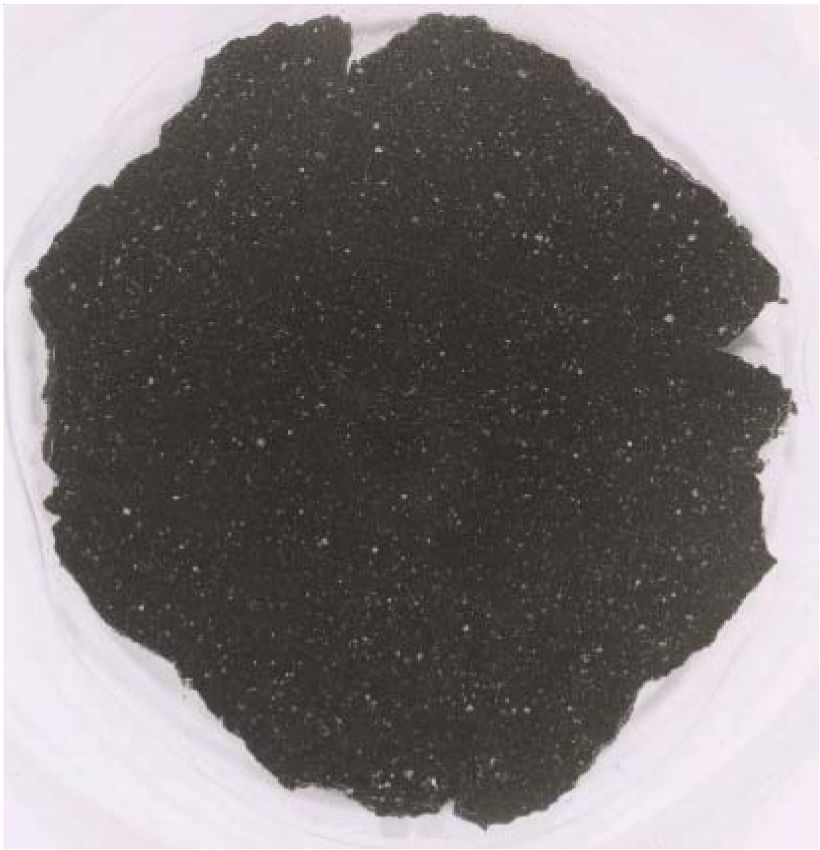


Figure 7: Photo of thin slice of 10057 located in Space Window.

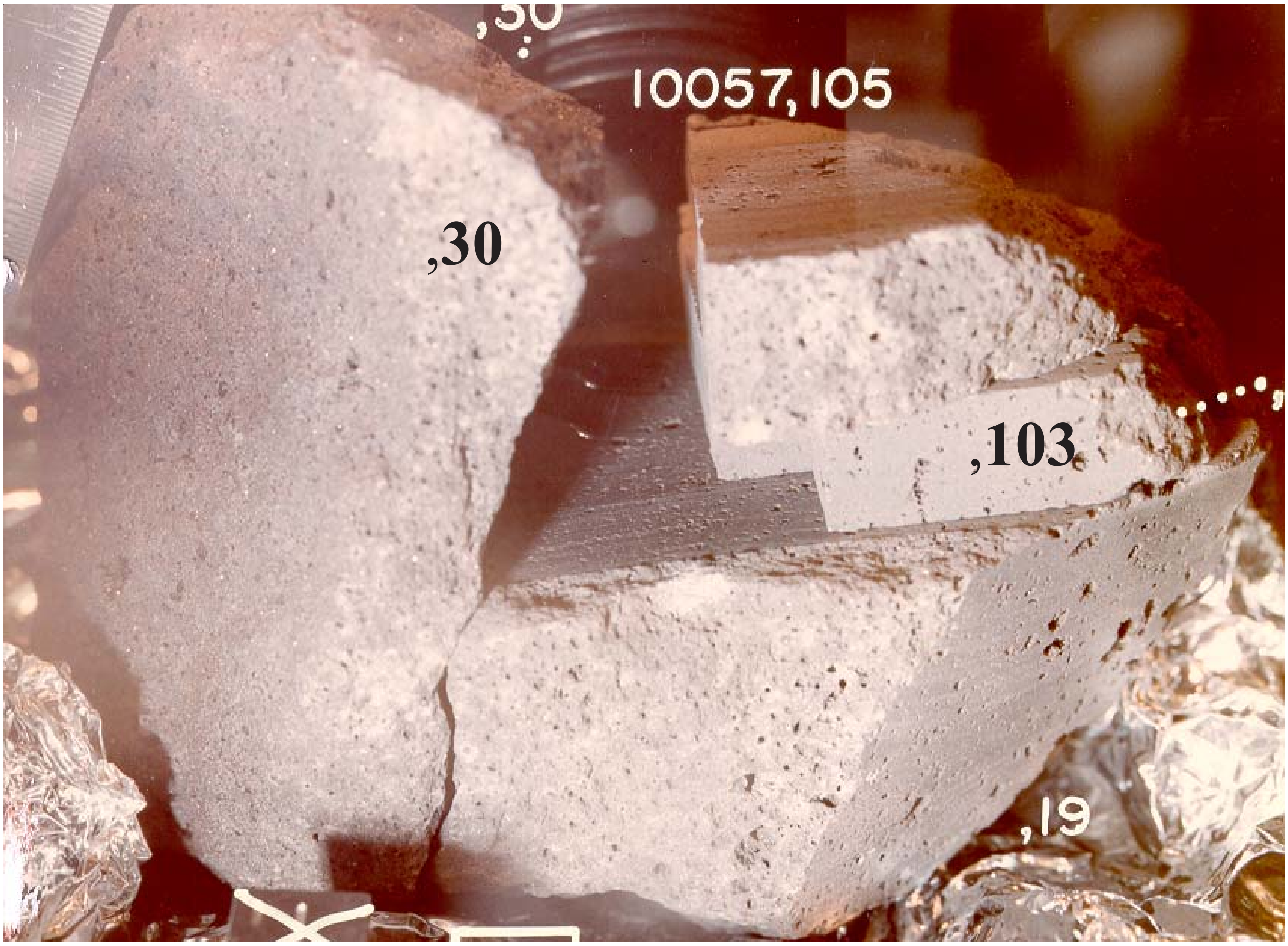


Figure 8: Photo of 10057 after sawing into chunks. NASA S75-33923. Cube is 1 cm.

Housley et al. (1970) determined the Mössbauer spectra.

Processing

Apollo 11 samples were originally described and cataloged in 1969 and "recataloged" by Kramer et al. (1977). There are 12 thin sections.

A piece of 10057 (large area thin section) is in the center of the Space Window of the National Cathedral (figures 6 and 7). In 1976 the sample was sawn at various odd angles into several chunks (figures 8 and 9).

Table 2	U ppm	Th ppm	K ppm	Rb ppm	Sr ppm	Nd ppm	Sm ppm	technique
Perkins 1970	0.95	3.6	2300					rad. Cout.
O'Kelley 1970	0.79	3.3	2550					rad. Cout.
Haskin 1970						69	20.8	

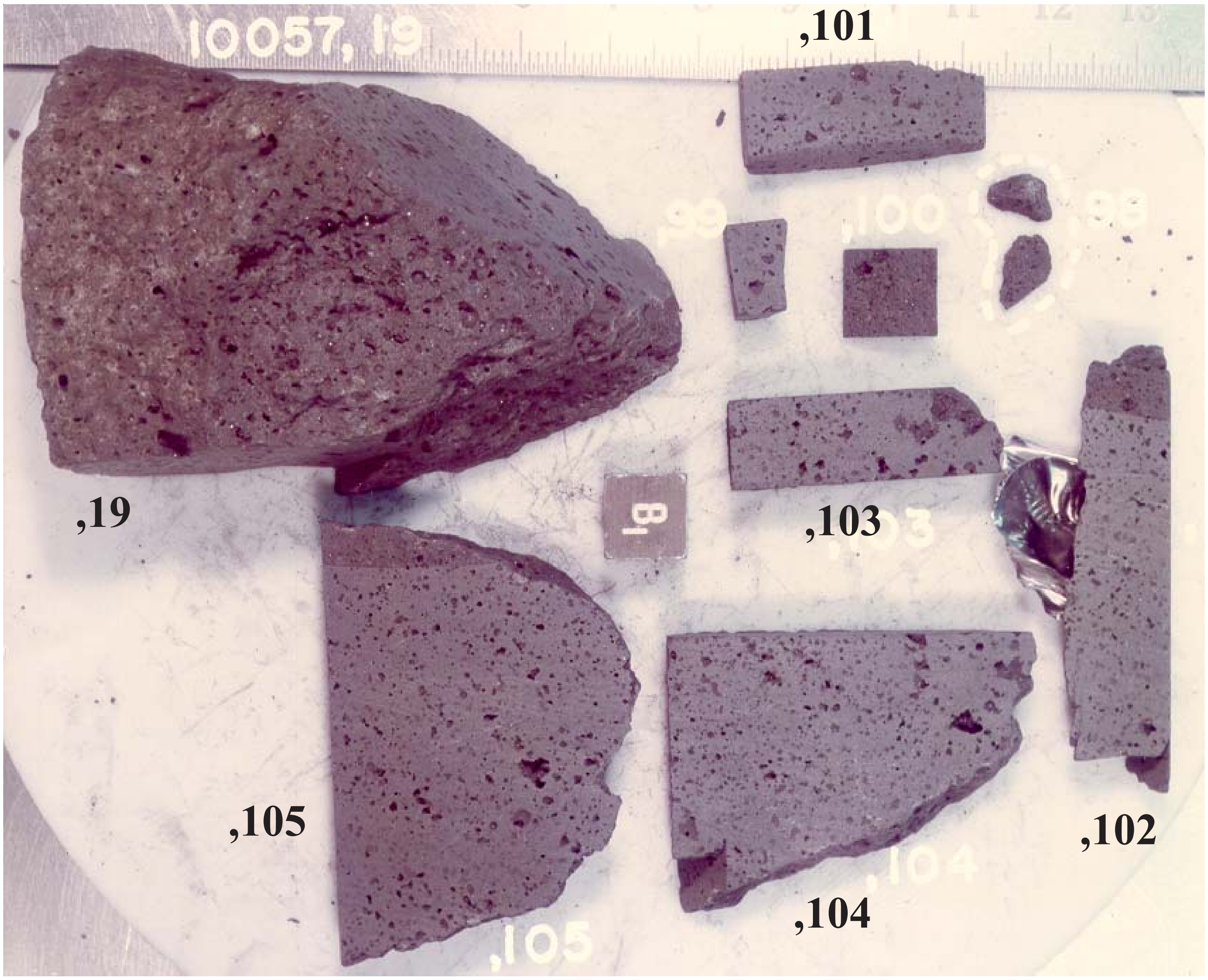
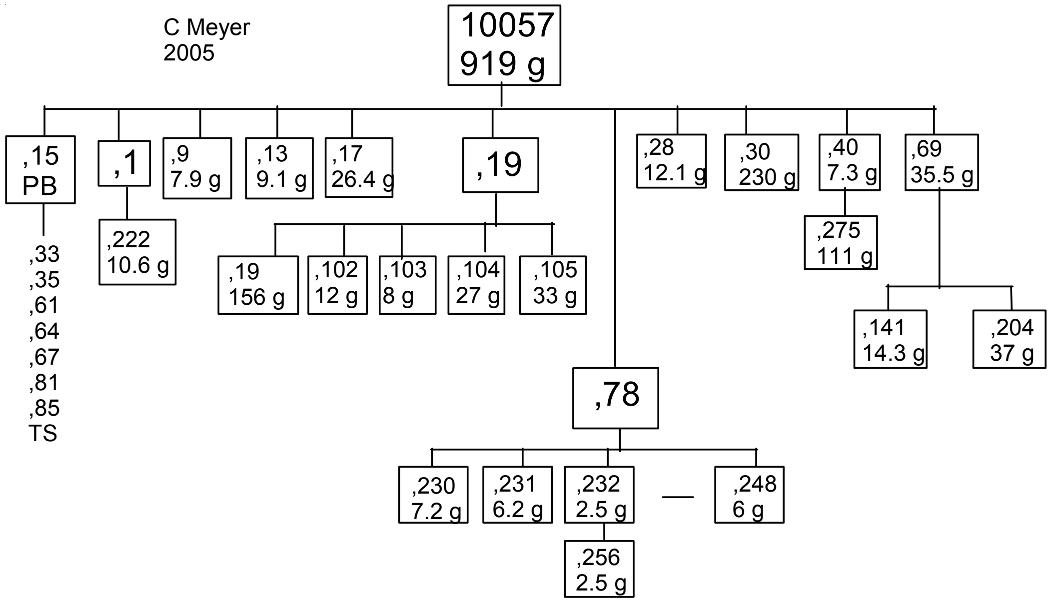


Figure 9: Group photo of pieces of 10057. NASA S75-20522. Cube is 1 cm.



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