66075

revised

Ancient Regolith Breccia

347 grams

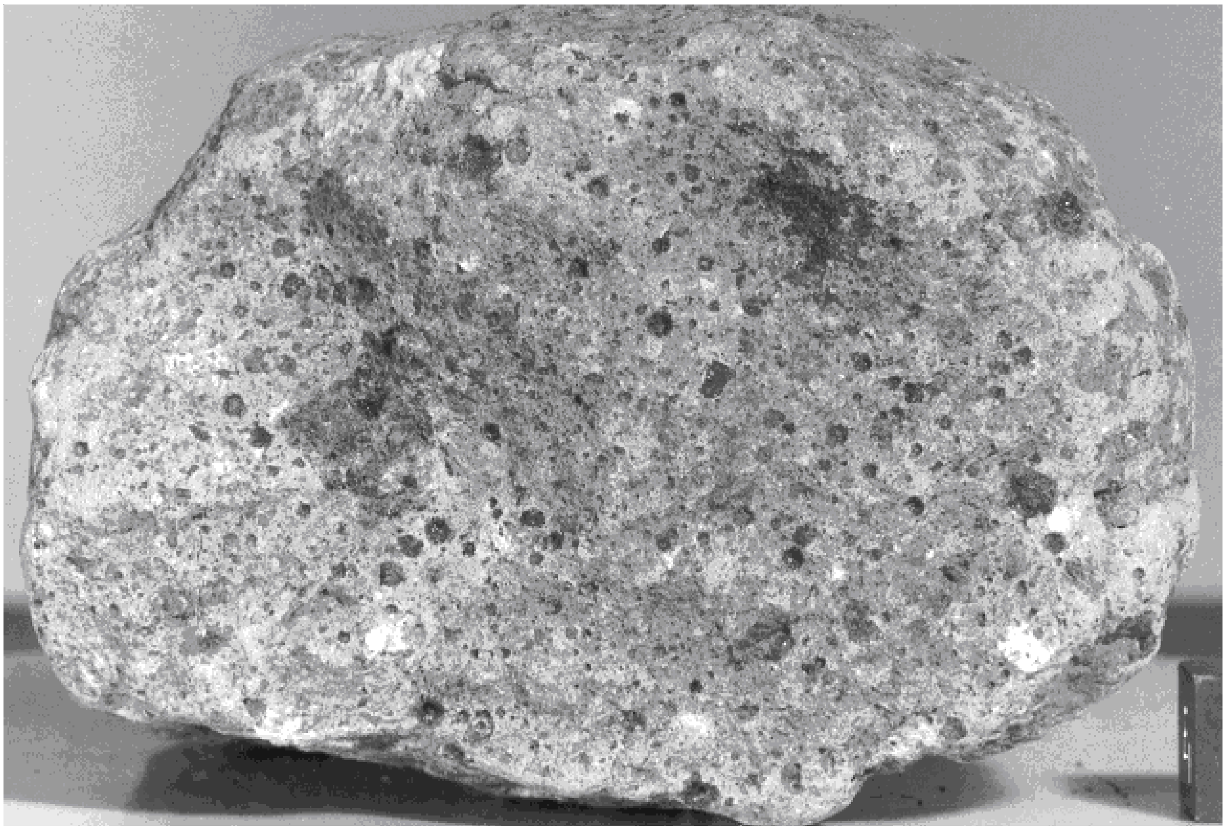

Figure 1: Photo of micrometeorite-cratered surface of 66075. NASA S72-40609. Cube is 1 cm.

Introduction

66075 is one of many coherent, light matrix breccias from Apollo 16 and has about equal amounts of both dark and light aphanitic clasts (figures 4 and 13). It was collected from the rim of a small crater at the base of Stone Mountain and has micrometeorite craters on only one side (figure 1). The matrix contains glass with a wide variety of composition. Fruland (1983), James (1981) and Korotev (1996) list 66075 as a regolith breccia and Korotev suggests that 66075 may be ejecta from North Ray Crater. The clasts have been dated at about 3.8 b.y.

66075 is rather like 66035 from the other side of the same crater.

Petrography

66075 is a highland regolith breccia with light grey friable matrix containing both white and dark clasts (Quick et al. 1978). The matrix is coherent, porous (20%), unsorted and seriate (5 to 200 microns) and made of angular fragments of plagioclase and other minerals along with lithic and glass fragments. Plagioclase and devitrified maskelynite (An_{92-97}) constitute the majority of the matrix, followed in abundance by aphanites and glass.

Quick et al. (1978), McKay et al. (1986) and Simon et al (1988) found 5 – 10 % glass in the matrix. Simon et al. concluded that at least some of the glass was agglutinate, while McKay et al. found the maturity index (I_s/FeO) was low (0.5). However, the rare gas data indicate a trapped solar wind component. According to Wentworth and McKay (1985), McKay et al. (1986), Simon et al. (1988) and Joy et al. (2011), 66075 is an "ancient regolith breccia", because it has a high ratio of ^{40}Ar to ^{36}Ar.

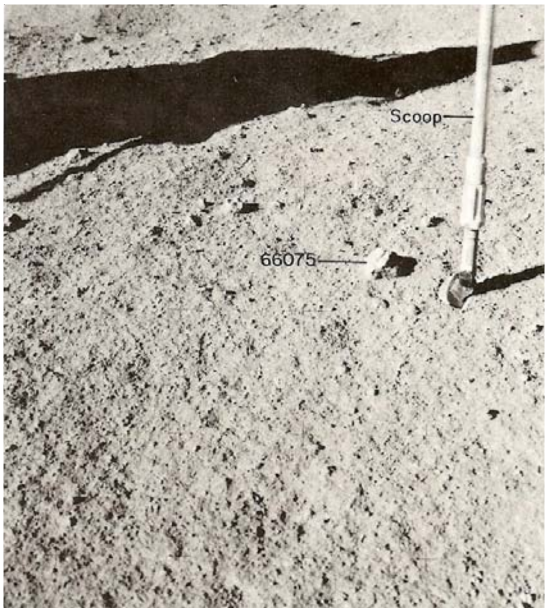

Figure 2: Photo of 66075 perched on surface. AS16-107-17522.

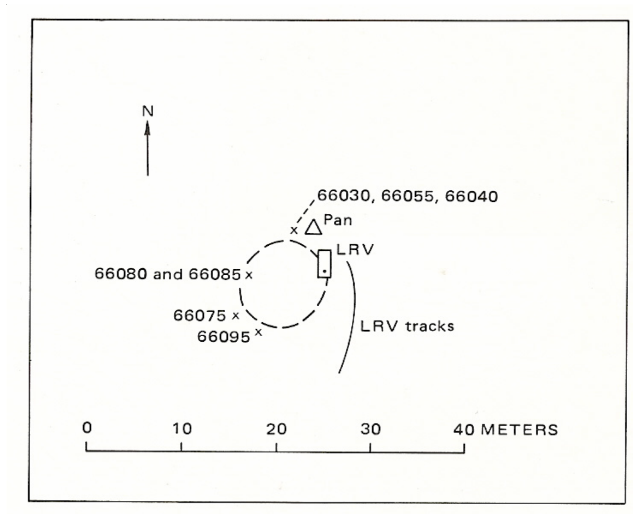

Figure 3: Map of station 6, Apollo 16.

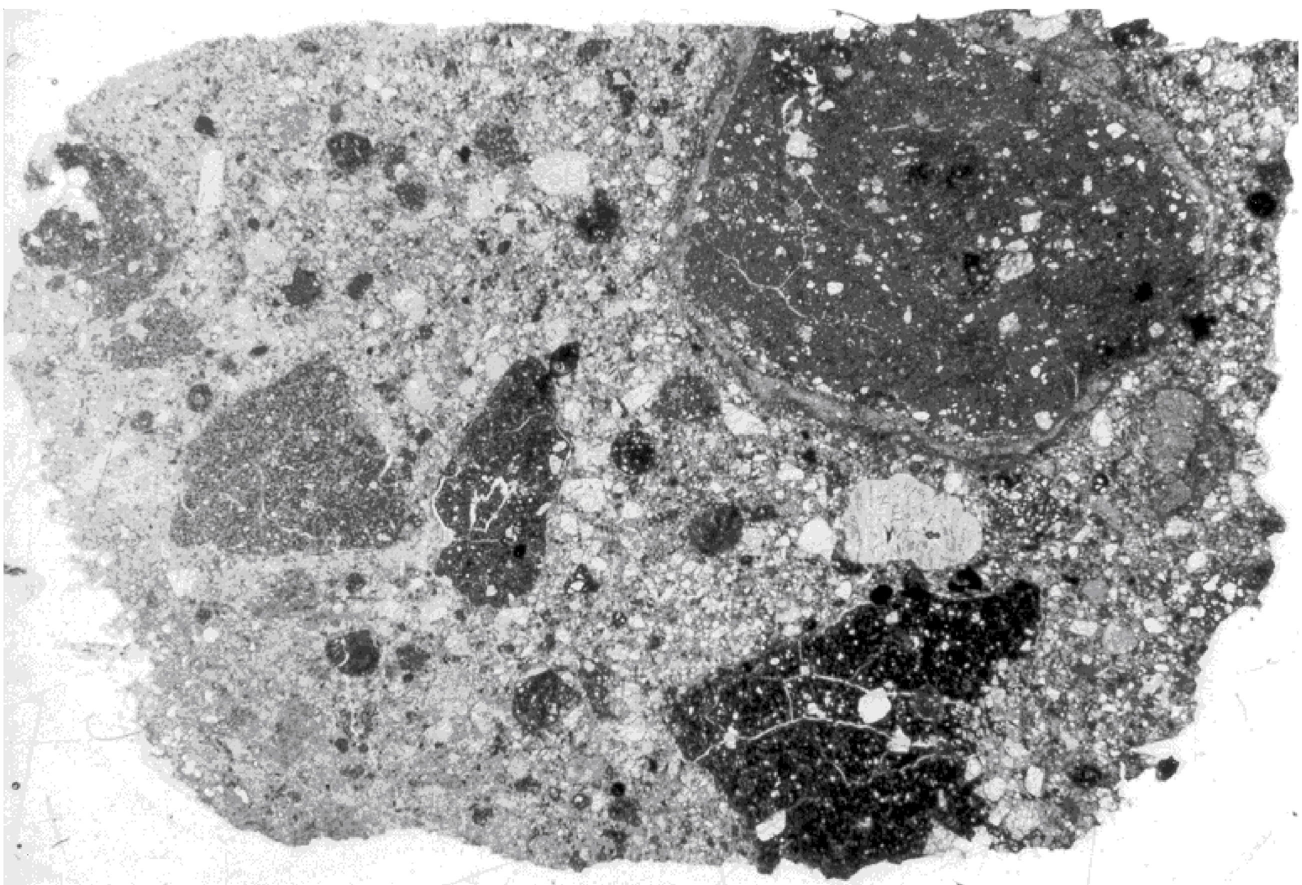

Figure 4: Thin section photomicrograph of 66075,3. Section is about 1.5 cm long. S72-43671.

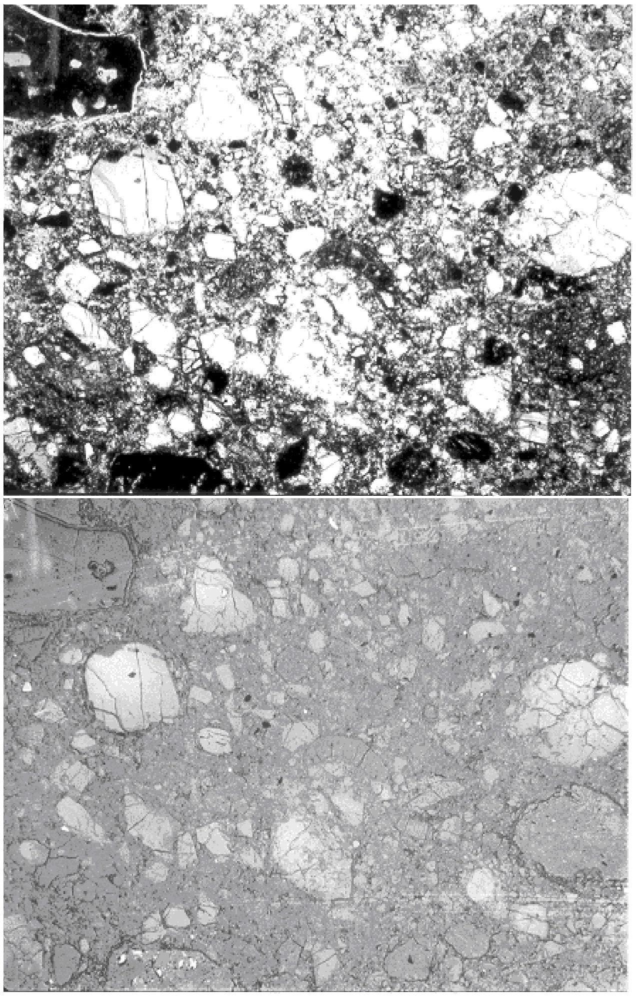

Figure 5: Photomicrgraphs of thin section 66075,63. Top is plane polarized light, bottom is reflected light (with internal reflections). About 3 mm across.

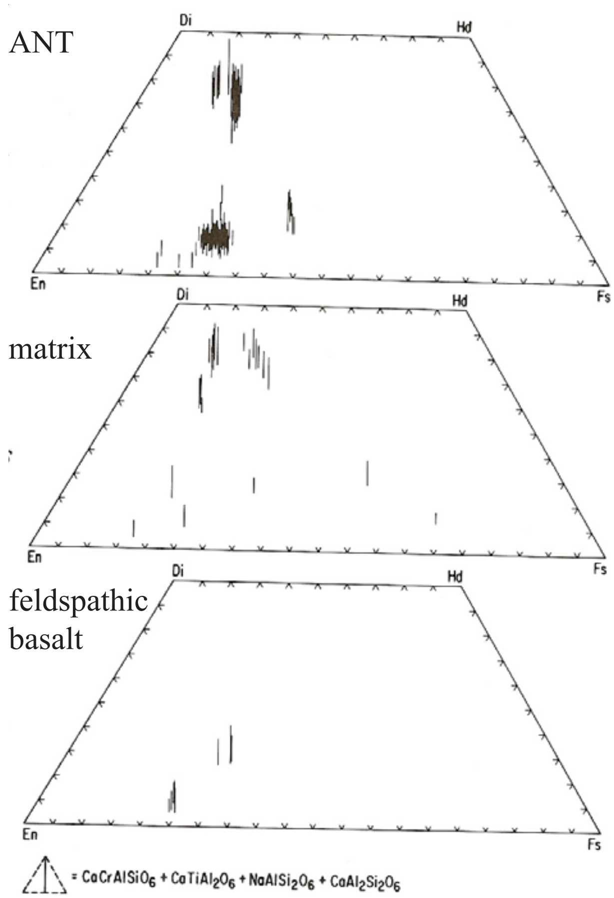

Figure 6: Pyroxene composition in 66075 (Quick et al. 1978).

Mineralogical Mode for 66075

(from Simon et al. 1988)

	20-90 micron	90-1000 micron
Matrix < 20 micron	44.4 %	
Mare basalt	0	0
KREEP basalt	0	1
Feldspathic basalt	0	0
Plutonic rock frag.	0.3	3.7
Granulite	0	0
Poik. rocks	0.2	1.1
Impact melts	0.5	6.7
Regolith brec.	0	1.1
Agglutinate	0.5	4.7
Plagioclase	12.4	9.6
Olivine	2	0.9
Pyroxene	2	1
Opaques	0.2	0
Glass	2.6	4.5

Mineralogical Mode for 66075

(from McKay et al. 1986) ("Optical")

	>500 micron	20-500 micron
Mare basalt	0	0
KREEP basalt	0	0.3
Plutonic rock frag.	10.6	10.4
Other lithic	0	3
Granulitc	0.4	0.3
Poik. Rocks	5.7	1
Subophitic	69.2	69.2
Intergranular	4.6	1.7
Intersertal	0.8	0.7
Vitric breccia	4.2	5
Frag. Breccia		0
Plagioclase	3	57.7
Olivine		6
Pyroxene		4
Opaques		
Glass		10.7
Agglutinate		

Figure 7: Photomicrograph of "basalt" clast in 66075 (from Ryder and Norman 1980).

Significant Clasts

The lithologies which have been identified in 66075 are: anorthosite, gabbroic anorthosite, noritic anorthosite, basalt and troctolite (Quick et al. 1978). The composition of pyroxene in these clasts is presented in figure 6. Olivine ranges from Fo_{65-95}. Plagioclase is An_{90-97}.

Quick et al (1978) found that metal particles were ~4.5 – 5.5 % Ni and 0.05 – 2.0 % Co (meteoritic in origin).

Neither Quick et al. (1978) nor Hunter and Taylor (1981) found "rust" in 66075.

Figure 7 pictures a "basalt" clast – rare at Apollo 16.

Chemistry

Eldridge et al. (1973), Clark and Keith (1973), Wanke et al. (1974), McKay et al.(1986), Wasson et al. (1975), Simon et al. (1988) and Boynton et al. (1975) determined the bulk composition of 66075. Moore and Lewis (1976) reported 28 ppm nitrogen and 54 ppm carbon for 66075 (figure 8). The conclusion is that 66075 has a composition similar to the local soil where it was collected (figure 9).

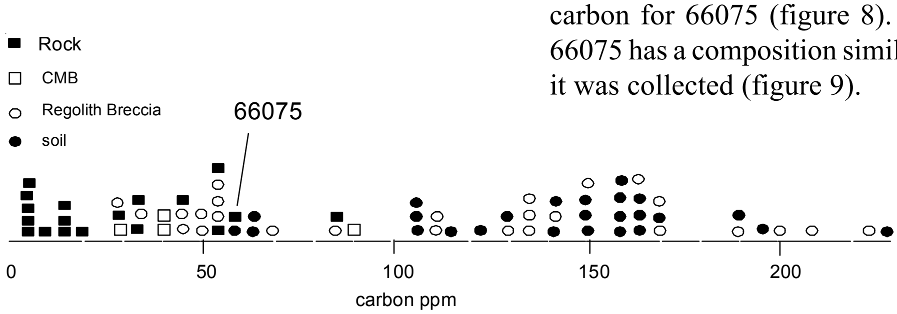

Figure 8: Carbon content of lunar samples (Moore and Lewis 1976).

Table 1. Chemical composition of 66075.

reference	Miller74		Wanke74		Boynton75		Garg76		McKay 86	Korotev96		Wasson75			Simon88	
weight	Clark73						Eldridge73									
SiO2 %	45.6		45.6	(b)												
TiO2	0.8		0.45	(b)	*0.17*	(a)			0.77						0.79	(a)
Al2O3	28		26.6	(b)	*27.2*	(a)			25.7						27.8	(a)
FeO	5		4.7	(b)	5	(a)	4.6	(a)	5.6	4.17	(a)				5.07	(a)
MnO	0.06		0.056	(b)	0.066	(a)									0.068	(a)
MgO	6.6		6.5	(b)	*6.3*	(a)			7.3						7.5	(a)
CaO	15.3		15.7	(b)	16.2	(a)			14.6	15.7	(a)				17.2	(a)
Na2O	0.52		0.49	(b)	0.57	(a)			0.505	0.505	(a)				0.51	(a)
K2O	0.1	(c)	0.09	(b)			0.1	(c)							0.113	(a)
P2O5			0.1	(b)												
S %																
sum																
Sc ppm			6.62	(b)	7.6	(a)	6.62	(a)	8.63	6.14	(a)				7.7	(a)
V									20						29	(a)
Cr			530	(b)	580	(a)	489	(a)	662	498	(a)				635	(a)
Co			25.3	(b)	24	(a)	27.4	(a)	27.6	18.4	(a)				29.9	(a)
Ni			350	(b)					342	225	(a)	195	303	(b)	440	(a)
Cu			4.3	(b)												
Zn			7.6	(b)								5.3	19	(b)		
Ga			5.1	(b)								4.47	4.51	(b)		
Ge ppb			1.7	(b)								1210	2100	(b)		
As			94	(b)												
Se																
Rb			2.01	(b)											3.5	(a)
Sr			200	(b)					187	185	(a)				100	(a)
Y																
Zr							73	(a)	310	127	(a)				200	(a)
Nb																
Mo																
Ru																
Rh																
Pd ppb			17	(b)												
Ag ppb																
Cd ppb												111	151	(b)		
In ppb												58	87	(b)		
Sn ppb																
Sb ppb																
Te ppb																
Cs ppm			0.12	(b)					0.15						0.15	(a)
Ba			106	(b)	90	(a)			186	101	(a)				165	(a)
La			11.8	(b)	9.3	(a)			20.1	8.84	(a)				17	(a)
Ce			28	(b)	28	(a)	26.1	(a)	52	22.4	(a)					(a)
Pr			4.3	(b)											44.3	(a)
Nd									33						27.8	(a)
Sm			5.5	(b)					9.34	4.04	(a)				7.84	(a)
Eu			1.2	(b)	1.45	(a)	1.16	(a)	1.345	1.19	(a)				1.36	(a)
Gd															9.2	(a)
Tb			1	(b)	0.9	(a)	0.97	(a)	1.7	0.81	(a)				1.5	(a)
Dy			6.9	(b)											10.8	(a)
Ho			1.4	(b)											2.2	(a)
Er			4.1	(b)												
Tm																
Yb			3.44	(b)	3.2	(a)			6	2.89	(a)				5.1	(a)
Lu			0.46	(b)	0.51	(a)			0.87	0.396	(a)				0.69	(a)
Hf			3.8	(b)	3.6	(a)	1.5	(a)	7.24	3.01	(a)				5.3	(a)
Ta			0.56	(b)	0.54	(a)			0.84	0.34	(a)				0.67	(a)
W ppb			0.21	(b)												
Re ppb			1	(b)												
Os ppb																
Ir ppb			10	(b)					8.5	5.5	(a)	5.4	6.6	(b)	8.6	(a)
Pt ppb															1.7	(a)
Au ppb			7.8	(b)					5.5	4.1	(a)	3.2	5.1	(b)		
Th ppm	2.05	(c)	1.6	(b)	1.8	(a)	1.86	(c)	3.72	1.37	(a)				2.37	(a)
U ppm	0.55	(c)	0.41	(b)			0.51	(c)	0.8	0.36	(a)				0.72	(a)

technique: (a) INAA, (b) INAA, RNAA, (c) radiation counting

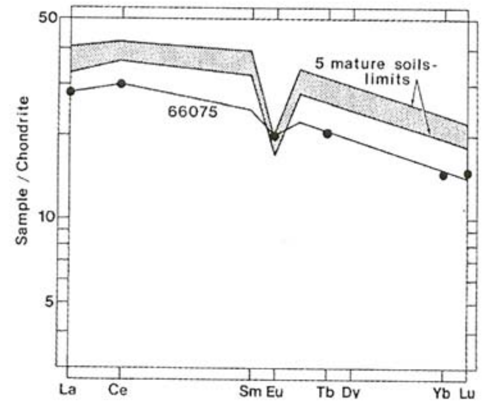

Figure 9: Normalized rare-earth-element diagram for 66075 compared with Apollo 16 soils (data from Boynton et al. 1975)..

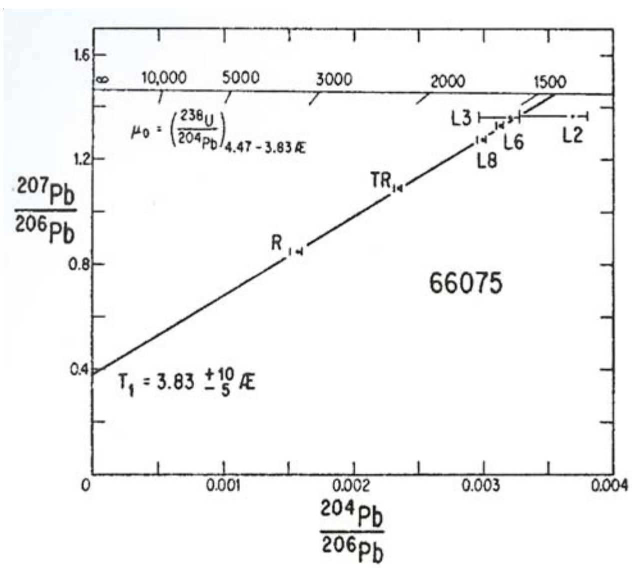

Figure 10: The age of 66075 (Oberli et al. 1979).

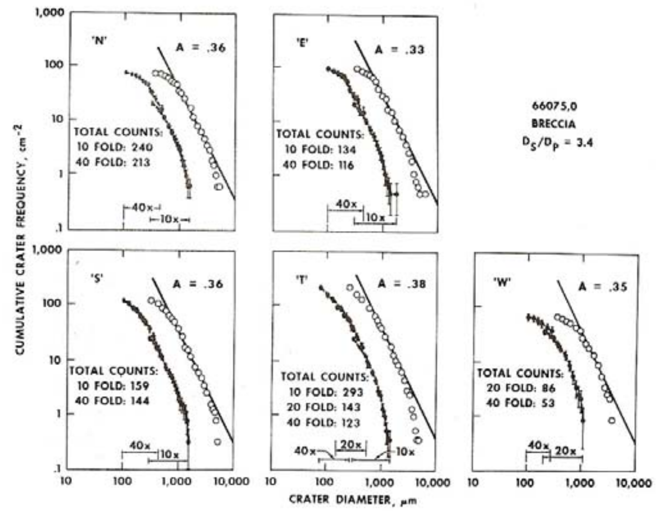

Figure 11: Density of micrometeorite craters on surfaces of 66075 (Neukum et al. 1973).

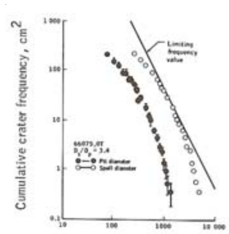

Figure 112: Density of micrometeorite craters on 66075 (Morrison et al. 1973).

Quick et al. (1978) collected data on glass fragments and small clasts within 66075 (table 2) and created a "mixing model" to explain the matrix composition as ~20% high-Ti glass and ~80% ANT. Wanke et al. (1976) and Boynton et al. (1975) also reported results of "mixing models".

Summary of Age Data for 66075

	Ar/Ar	Pb/Pb
Oberli et al. 1979		3.83 b.y
Cohen et al. 2007	3.83	
	3.76	
	4.08	

Radiogenic age dating

Oberli et al. (1979) measured the Pb isotopes in 66075 and determined an age of 3.85+10-5 b.y. (figure 10). Cohen et al. (2006 and 2007) studied the age of small clasts from 66075 by Ar/Ar. Oberli et al. also reported bulk Rb-Sr and Sm-Nd data and calculated model ages.

Table 2. Chemical composition of 66075.

reference	Quick et al. 1978				olivine		
weight	low-Ti glass	high-Ti glass	high-K glass	vitrophyre	aphanite	ANT clasts	
SiO2 %	45.59	49.06	75.38	46.9	45.9	44.3	(a)
TiO2	0.34	1.58	1.1	0.6	0.4	0.15	(a)
Al2O3	27	18	10.9	20	24.7	29.4	(a)
FeO	4.6	7.3	2.8	5.7	4.6	4	(a)
MnO	0.07	0.11	0.08	0.1	0.1	0.06	(a)
MgO	5.8	10.96	0.2	12.4	6.5	4.8	(a)
CaO	15.8	11.3	1.8	12.6	15.5	16.5	(a)
Na2O	0.4	0.62	0.57	0.5	0.5	0.4	(a)
K2O	0.07	0.39	6.19	0.2	0.1	0.01	(a)
P2O5	0.05	0.28	0.1	0.1	0.1		(a)
S %	0.03	0.03	0.04	0.1	0.2		(a)

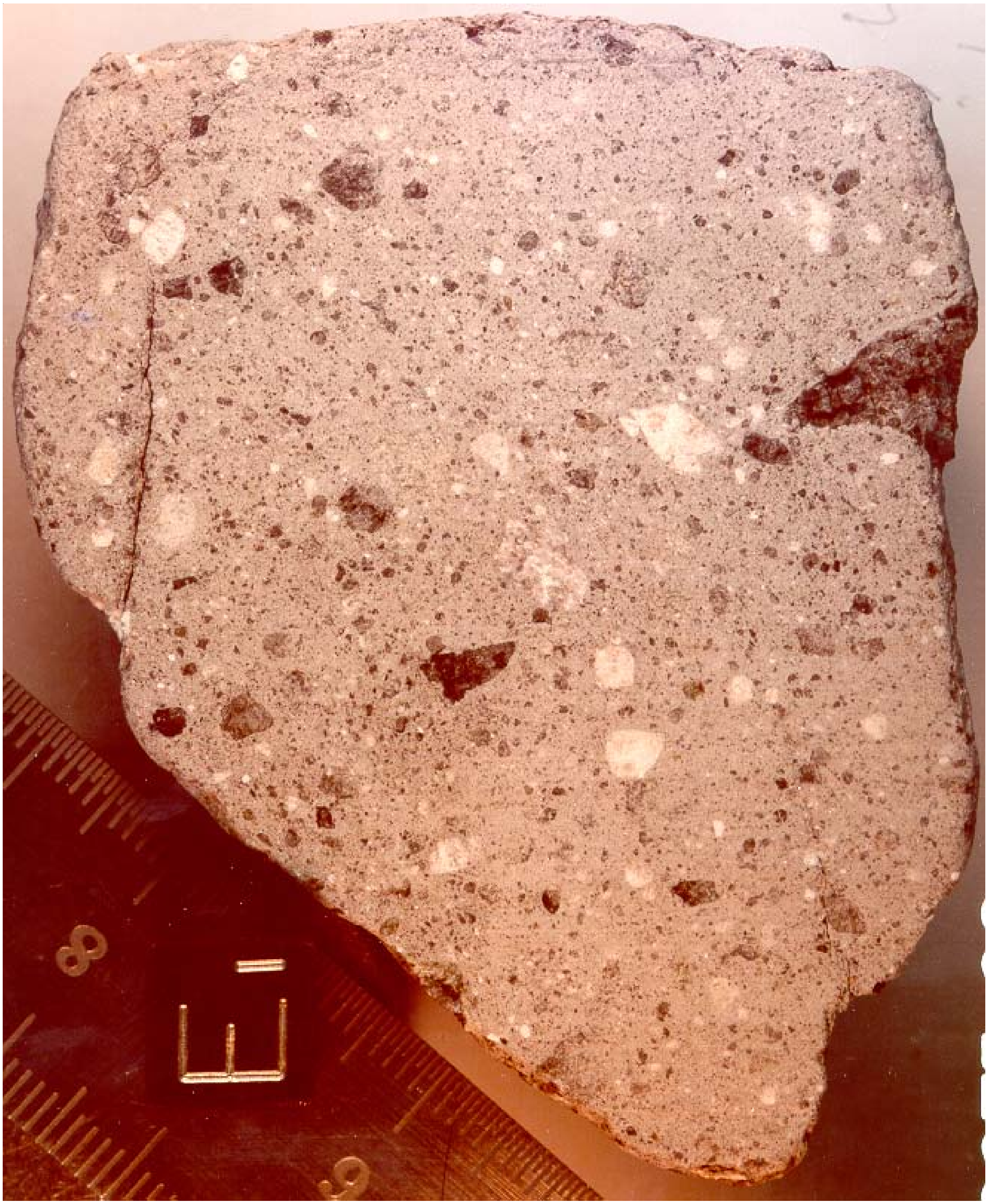

Figure 13: Sawn surface of 66075,26. NASA S78-31377. Cube is 1 cm for scale.

Cosmogenic isotopes and exposure ages

Eldridge et al. (1973) reported the cosmic ray induced activity of ^{26}Al = 130 dpm/kg and ^{22}Na = 49 dpm/kg. Clark and Keith (1973) determined ^{26}Al = 149 dpm/kg, ^{22}Na = 39 dpm/kg, ^{54}Mn = 3 dpm/kg, ^{56}Co = 5 dpm/kg and ^{46}Sc = 1.3 dpm/kg.

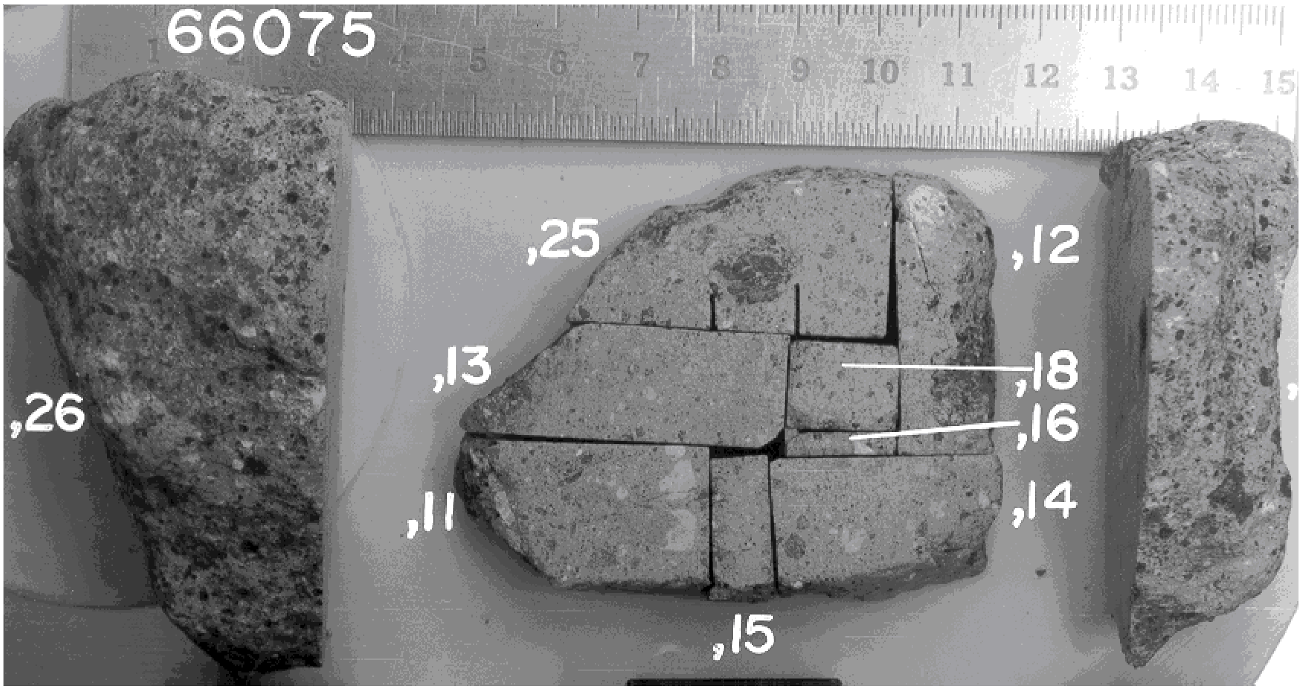

Figure 14: Slab cut from 66095. Scale is in cm.

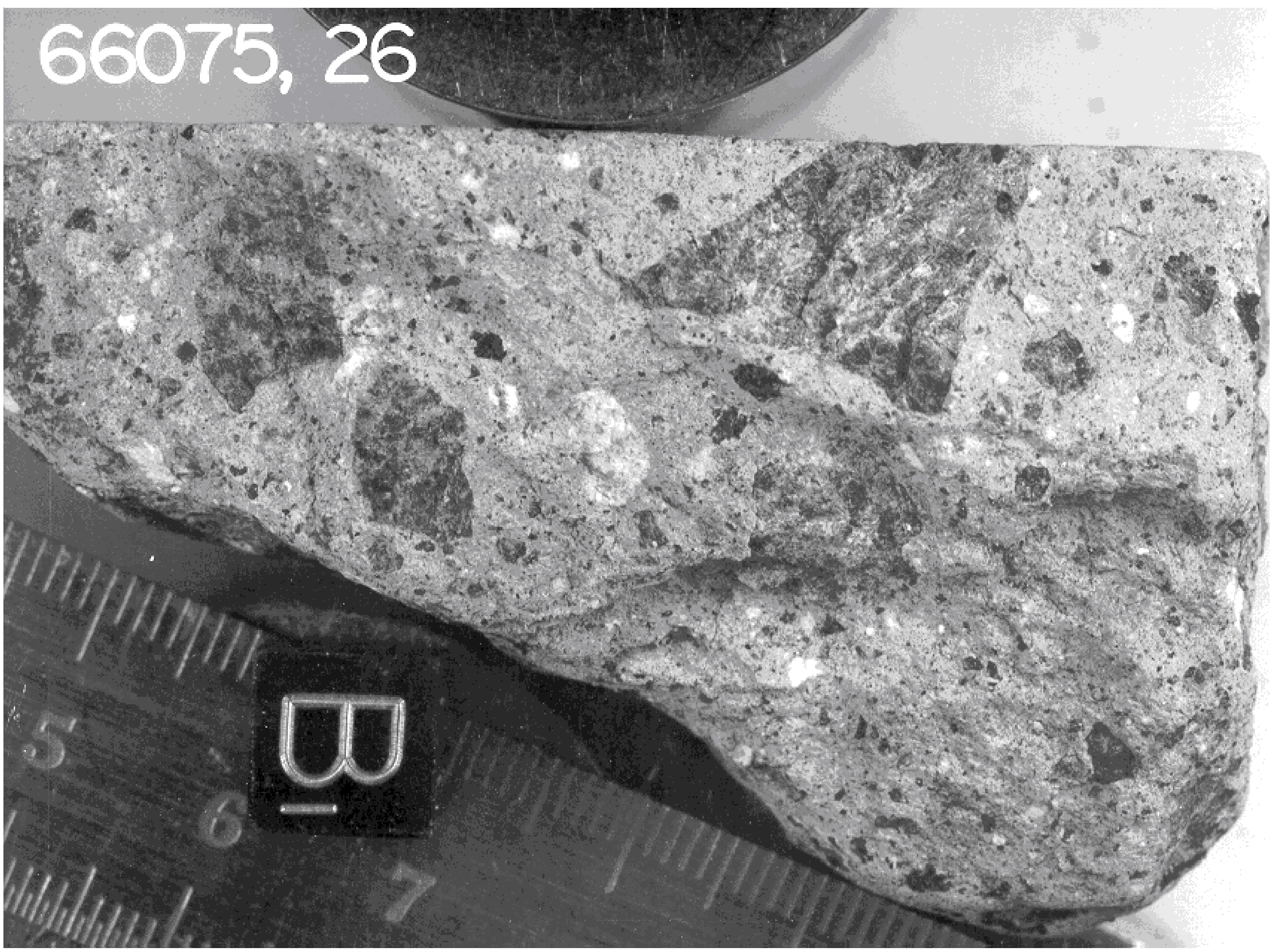

Figure 15: Photo of 66075,26. NASA S78-31382. Cube is 1 cm.

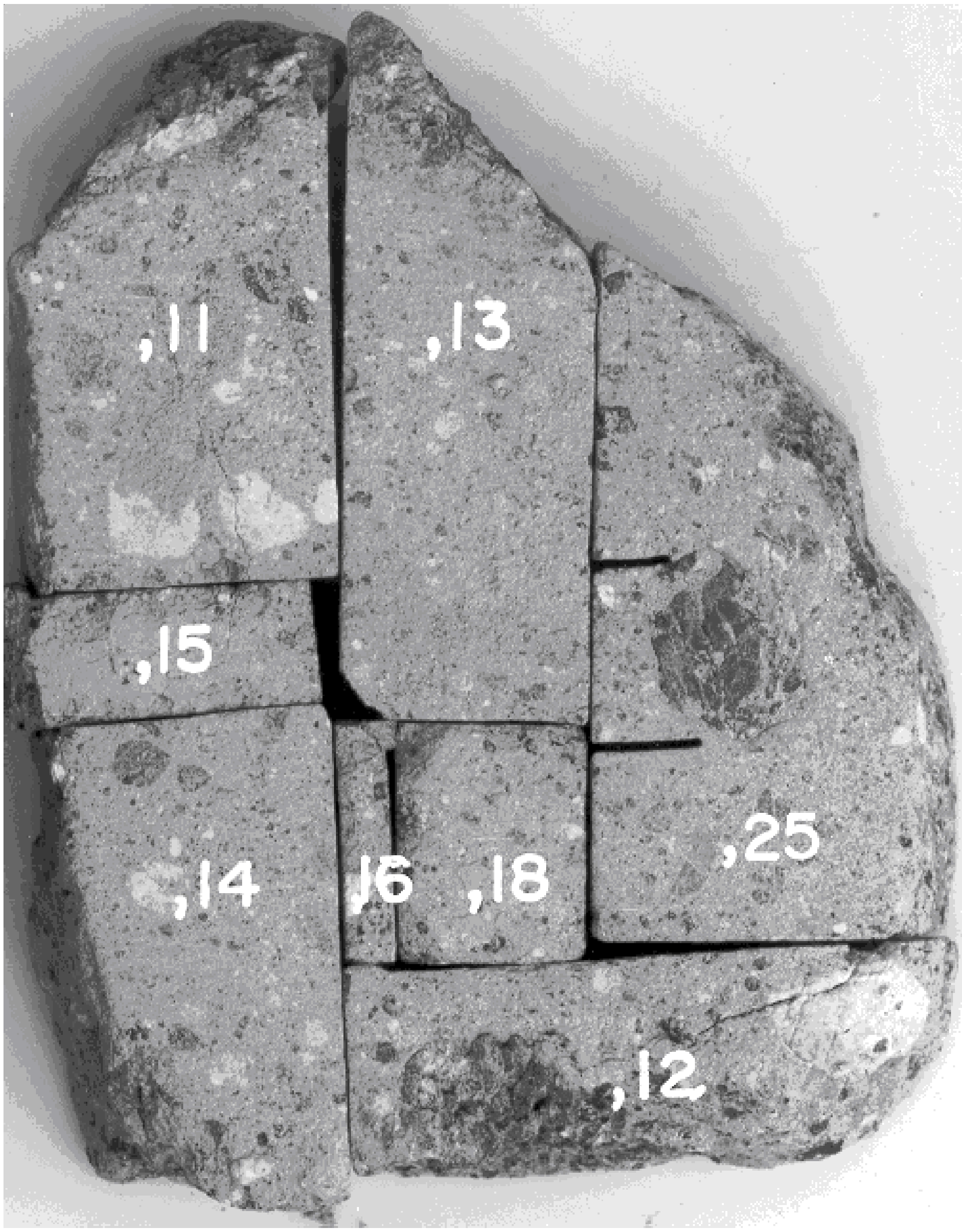

Figure 16: Photo of slab of 66075. NASA S73-28303. Central piece ,18 is 1 cm tall.

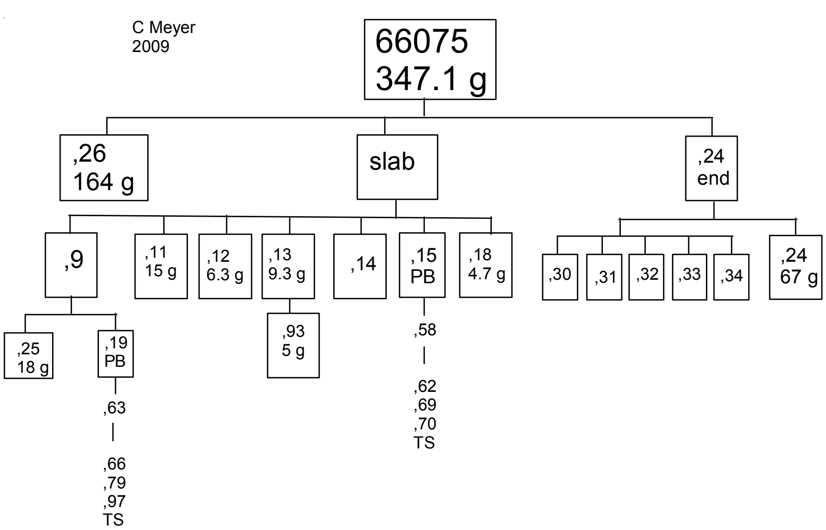

Figure 17: Sawn surface of 66075,26 as mounted for public display. NASA S88-36000.

Other Studies

Neukum et al. (1973) and Morrison et al. (1973) studied the micrometeorite craters (figures 11 and 12).

McKay et al. (1986) and Joy et al. (2012) reported the rare gas content and isotopic ratios.

Processing

A slab was cut through the middle of 66075 (figures 14 and 16). The large end piece (,26) is a public display sample at the Nordlingen-Ries Crater Museum in Germany (figure 17). There are 21 thin sections of 66075 now *(which will increase significantly soon). Would someone who visits the museum please report on whether this rock is "seuvite" or not).*

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