66035 – 211.4 grams
66036 – 4.4 grams
66037 – 3.7 grams
Ancient Regolith Breccia

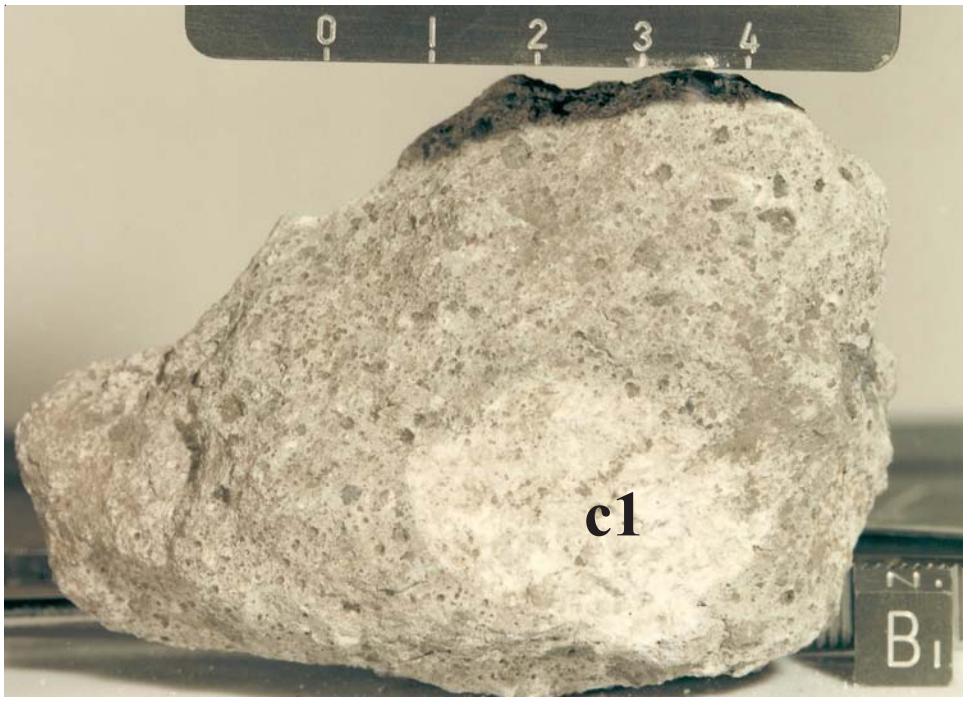


Figure 1: Photo of 66035 showing large cataclastic anorthosite clast (c1). Cube and scale are in cm. S72-39662.

Figure 2: Photo of 66035. Cube is 1 cm. S72-39665.

Figure 3: Photo of 66036. Cube is 1 cm. S72-40389

Figure 4: Photo of 66037. Scale in cm. S72-40392

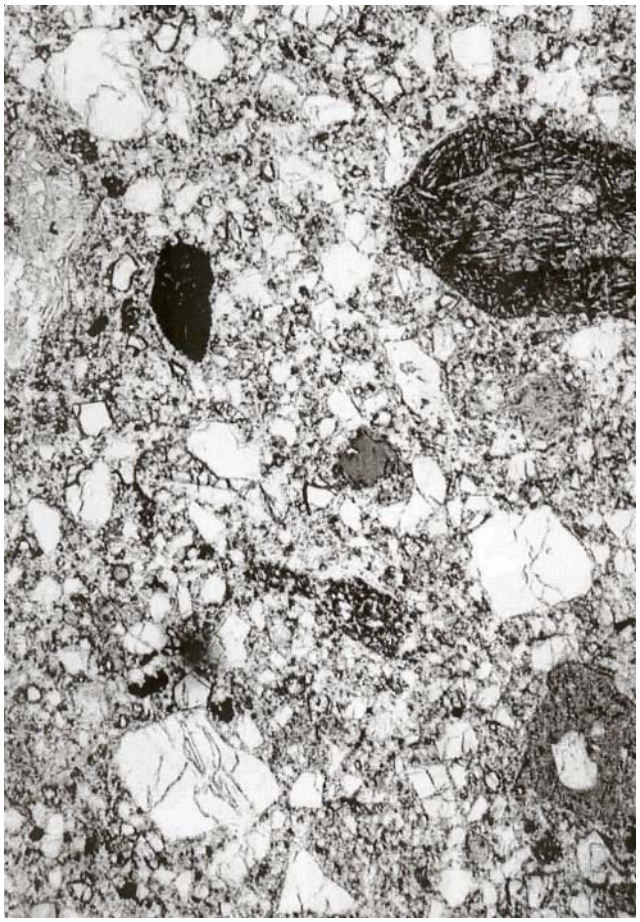


Figure 5: Photomicrograph of thin section of 66036 from Ryder and Norman 1980. Field of view 2 mm.

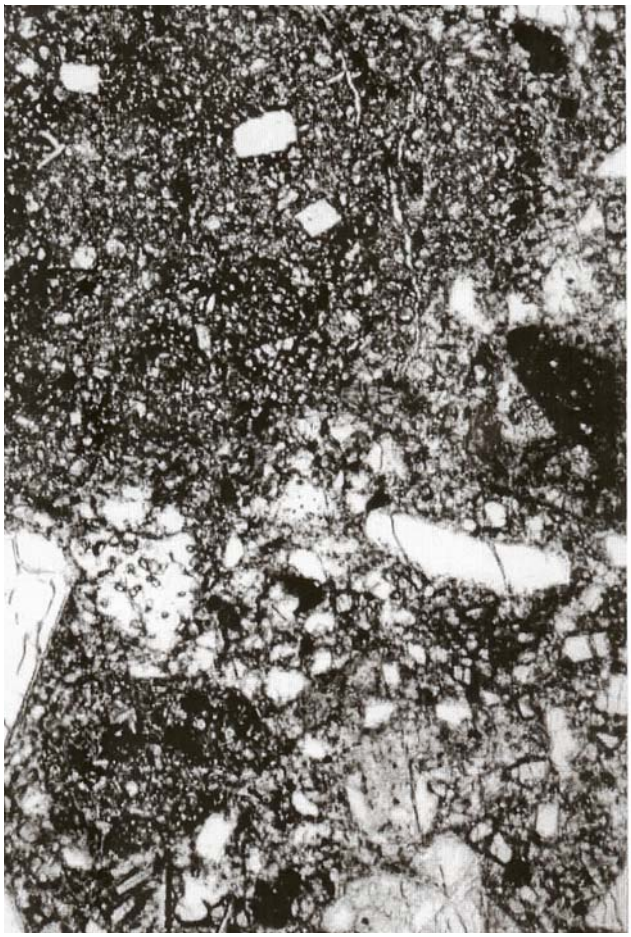


Figure 6: Photomicrograph of thin section 66037 from Ryder and Norman 1980. Field of view 2 mm.

Introduction

66035 – 66037 are from the base of Stone Mountain, Apollo 16. They were collected together with 66030 near the rim of a 10 m crater, and near 66055 (figures 7 - 9). These samples are regolith breccias, but they have excess ^{40}Ar and have been termed "ancient regolith breccia".

66035 has zap pits on all surfaces (figures 1, 2, 15 and 16), so it must have "rolled or jumped" on the regolith.

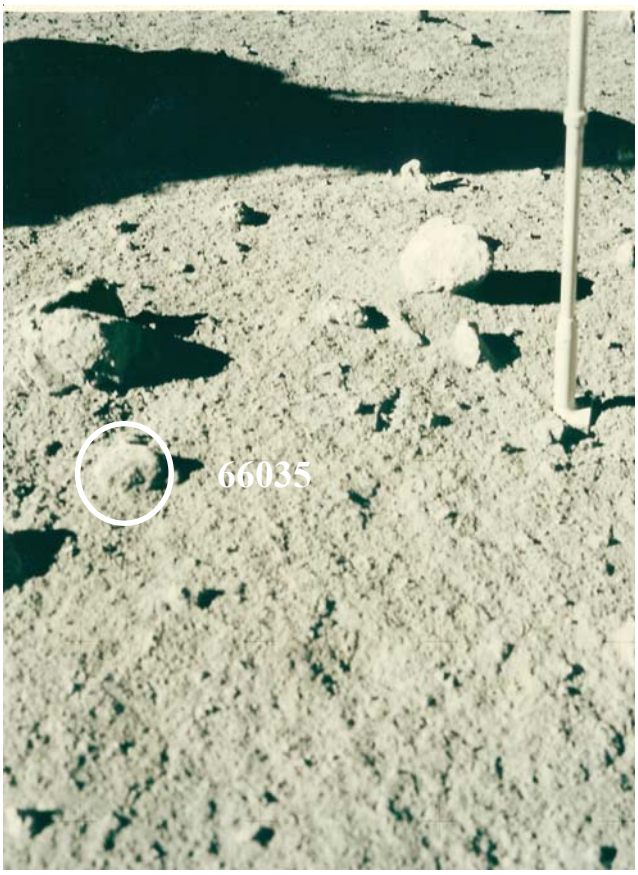


Figure 7: Surface photo of 66035. AS16-107-17513.

Petrography

Grieve et al. (1974) recognized a suite of impact melt products in the matrix of 66035, ranging from glasses to crystalline poikilitic and subophitic rocks (figure 14).

James (1981) and Fruland (1983) identified 66035 as a regolith breccia. Consequently, McKay et al (1986), Simon et al. (1988) and Joy et al. (2011) included 66035 and 66036 in their study of regolith breccias. The maturity index (I_s/FeO) is low, but the rare gas content is high.

Quick et al. (1978) describe 66075, which is presumably a companion rock to 66035.

Significant clasts

c1 Large Cataclastic Anorthosite ,12 ,13TS

This is the large (3.5 cm) clast seen in figure 1. However, it was only "skin deep" and there is not a lot of mass. It is ~95% plagioclase (An_{94-95}), 5% pyroxene ($Wo_{2-6}En_{66-68}Fs$), but it is not pristine. According to Warren and Wasson (1978) it has a "granulitic" texture, but Ryder and Norman (1980) termed it "granoblastic noritic anorthosite". The REE are shown in figure17 and the pyroxene composition is shown in figure 12.

c2 Coarse-grained Norite ,18 ,22TS

This clast was seen by PET who described the abundant pyroxene as honey-brown. It is ~58% plagioclase (An_{97}), pyroxene (En_{57}) (figure 13) and plots within the field of "ferroan anorthosite". However, it also has significant Ir and Au (contamination?)(table).

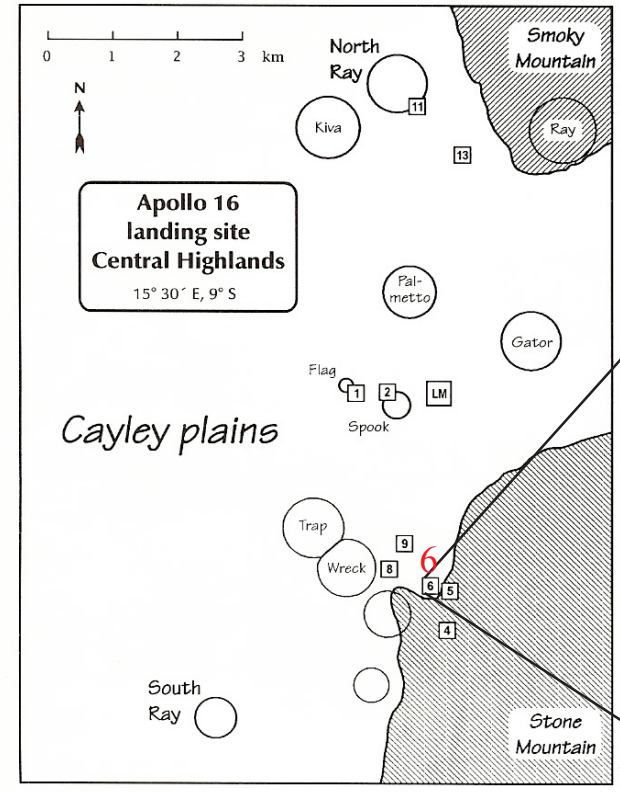


Figure 8: Map of Apollo 16 site with station 6.

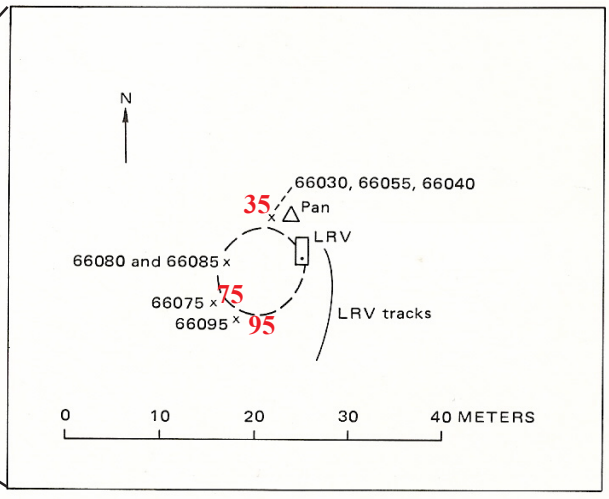


Figure 9: Map of station 6 with 66035, 66075 and 66095.

Figure 10: Photo of thin section of 66035,5. S72-43566. About 1 cm across.

Porous Olivine: Fo_{97} with 1.2% Ca_2SiO_4 of meteoritic origin (Warren and Wasson 1979, Joy et al. 2012).

Granitic Glass: Grieve et al. (1974) reported several clasts of granitic glass (table 3) – significant, because the same thing is found in 66055.

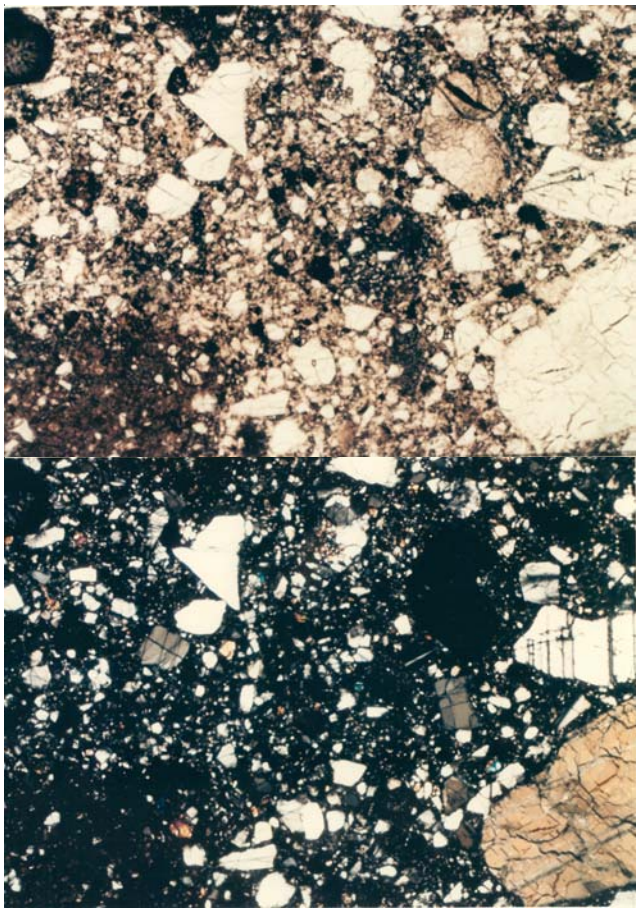


Figure 11: Photomicrographs of thin section of matrix of 66035 showing abundant glass: a) top is plane polarized light S72-42258, b) bottom is crossed-polarized light S72-42259. Scale is about 2 mm across.

Summary of Age Data for 66035

	Ar/Ar
Cohen et al. 2007	3956 +/-579 m.y.

Mineralogical Mode for 66035
(from McKay et al. 1986) ("Optical")

	>500 micron	20-500 micron
Mare basalt	0	0
KREEP basalt	1.2	3.2
Plutonic rock frag.	94	8.1
Other lithic	0	7.5
Granulitc	0	0
Poik. Rocks	1.8	8.8
Subophitic	0.9	7.5
Intergranular	0	3
Intersertal	0	0.3
Vitric breccia	0	1
Frag. Breccia	0	0
Plagioclase	0	41.4
Olivine	0	8.5
Pyroxene	0	2.7
Opaques	0	0
Glass	0.9	13.9
Agglutinate	0	1.1

Mineralogical Mode for 66035
(from Simon et al. 1988)

	20-90 micron	90-1000 micron
Matrix < 20 micron	34.9 %	
Mare basalt	0	0
KREEP basalt	0	0
Feldspathic basalt	0	0
Plutonic rock frag.	0	0.4 %
Granulite	0	0.2
Poik. rocks	0.2	4.7
Impact melts	0.7	6
Regolith brec.	0	1
Agglutinate	0.3	1.6
Plagioclase	14.6	17.3
Olivine	1.3	0.1
Pyroxene	1.7	0.3
Opaques	0.1	0
Glass	2.2	4

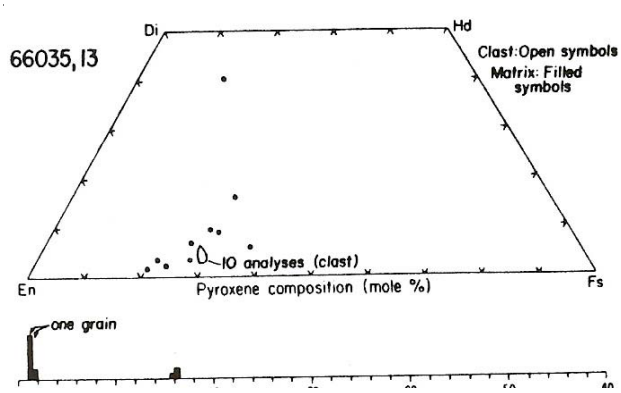


Figure 12: Pyroxene composition of c1 (Warren and Wasson 1979).

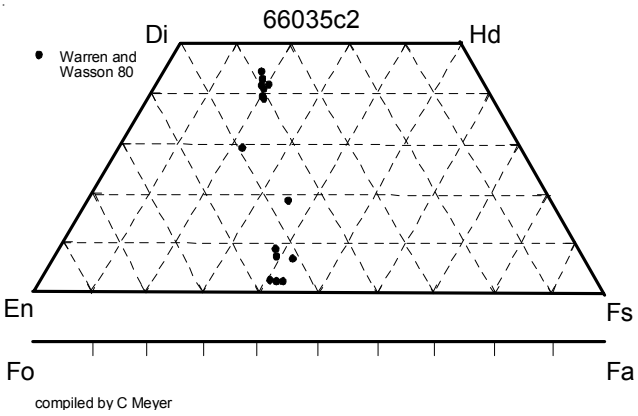


Figure 13: Pyroxene composition.of c2 (Warren and Wasson 1980).

Chemistry

The composition of the matrix of 66035 has been reported by Korotev (1990), McKay et al. (1986) and Simon et al. (1988). Eldridge et al. (1973) obtained a measure of K, U and Th, for the bulk rock, in agreement with the data for the matrix. Warren and Wasson reported data for the clasts.

Radiogenic age dating

Cohen et al. (2007) dated a clast by Ar/Ar (with poor precision).

Cosmogenic isotopes and exposure ages

Eldridge et al. (1973) reported the cosmic ray induced activity of ^{26}Al = 136 dpm/kg and ^{22}Na = 42 dpm/kg.

Other Studies

The rare gas content and isotopic ratios are given in McKay et al. (1986) and Joy et al. (2011).

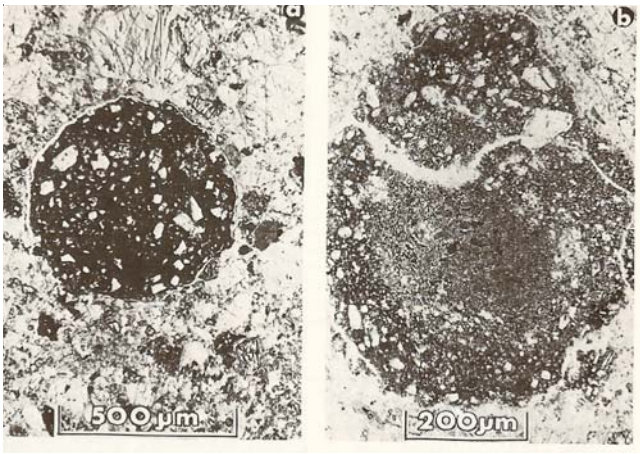


Figure 14: Photo of clasts in 66035 (from Grieve et al. 1974).

Processing

66035, 66036 and 66037 were returned in a bag with soil 66030 – see section on 66031.

66035 had not been sawn (as of 2009). The clasts were sampled by chipping. There are 17 thin sections of 66035, 2 each of 66036 and 66037.

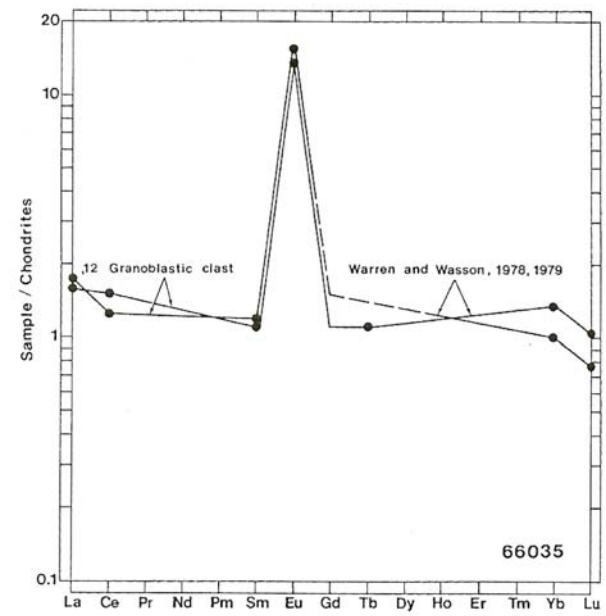


FIGURE 4. Rare earths.

Figure 17: Compsosition of clast "c1".

Figure 15: Photo of 66035 showing clasts. Cube is 1 cm. S72-39664.

Figure 16: Photo of 66035 showing clast. Cube is 1 cm. S72-39663.

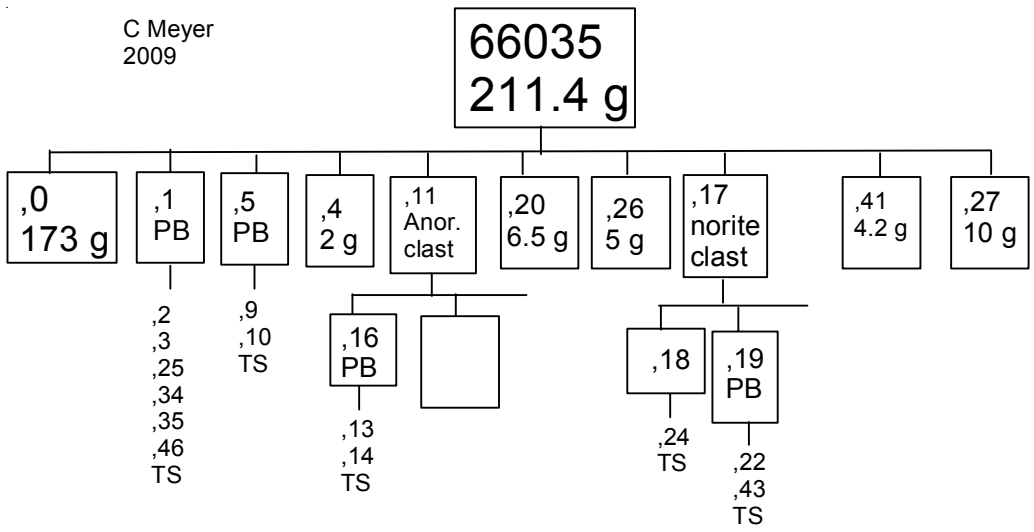
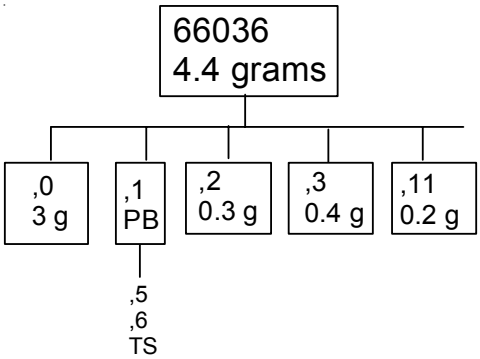


Table 1. Chemical composition of 66035.

reference	McKay86	Korotev96	Simon88		Warren80	Warren 79		Warren 78		Eldridge73	
weight					clast c2	clast c1		,12 clast			
SiO2 %					47.1	44.3	44.3	44.3	(a)		
TiO2	0.43		0.66	(a)	0.27	0.84	0.67				
Al2O3	28.5		30	(a)	19.6	29.8	31	29.8	(a)		
FeO	4.85	4.69	4.15	(a)	10.9	3.21	2.83	3.22	(a)		
MnO			0.053	(a)	0.16	0.04	0.033	0.04	(a)		
MgO	5.25		4.6	(a)	8.8	4.64	3.81	4.64	(a)		
CaO	16	15.6	15.2	(a)	12.6	16.8	17.2	16.8	(a)		
Na2O	0.442	0.474	0.5	(a)	0.22	0.41	0.43	0.41	(a)		
K2O			0.096	(a)	0.02	0.016	0.01	0.016	(a)	0.092	(b)
P2O5											
S %											
sum											
Sc ppm	9.26	7.25	6.5	(a)	23.1	2.3	3.1	2.32	(a)		
V	20		14	(a)							
Cr	700	673	501	(a)	1400	250	240	25.2	(a)		
Co	18.6	25	25.7	(a)	19.5	7.8	7.1	7.8	(a)		
Ni	214	354	370	(a)	52	20.4	6	20.4	(a)		
Cu											
Zn					3.2	1.03	0.82	1.03	(a)		
Ga						4.1	4.5	4.1	(a)		
Ge ppb					195	72	48	72.4	(a)		
As											
Se											
Rb			1.6	(a)							
Sr	187	183	110	(a)							
Y											
Zr	150	214	140	(a)	220						
Nb											
Mo											
Ru											
Rh											
Pd ppb											
Ag ppb											
Cd ppb						19	21	19	(a)		
In ppb						4.3	1.3	4.3	(a)		
Sn ppb											
Sb ppb											
Te ppb											
Cs ppm	0.1		0.14	(a)							
Ba	101	150	120	(a)	113	21	17	21	(a)		
La	9.08	15.6	11.3	(a)	1.88	0.58	0.54	0.58	(a)		
Ce	24.5	40.1	29.5	(a)	4.6	1.1	1.3	1.1	(a)		
Pr											
Nd	14		18.5	(a)	6						
Sm	4.23	6.93	5.09	(a)	0.89	0.22	0.2	0.22	(a)		
Eu	1.095	1.23	1.24	(a)	0.68	1.09	0.95	1.09	(a)		
Gd			6.3	(a)							
Tb	0.81	1.41	1.04	(a)	0.24		0.054		(a)		
Dy			7.6	(a)							
Ho			1.4	(a)							
Er											
Tm											
Yb	2.97	4.92	3.5	(a)	1.11	0.2	0.27	0.2	(a)		
Lu	0.424	0.669	0.47	(a)	0.18	0.026	0.036	0.026	(a)		
Hf	3.26	5.27	3.6	(a)	0.53		0.15				
Ta	0.39	0.57	0.41	(a)	0.14						
W ppb											
Re ppb					0.099	0.06	0.11	0.06	(a)		
Os ppb											
Ir ppb	4.4	8.3	5.5	(a)	1.04	0.3	0.9	0.3	(a)		
Pt ppb											
Au ppb	4.5	7.8	1.4	(a)	0.8	0.132	0.14	0.132	(a)		
Th ppm	1.77	2.5	1.52	(a)	0.17					1.87	(b)
U ppm	0.38	0.67	0.51	(a)	0.6					0.49	(b)
technique:	*(a) INAA, (b) radiation counting*										



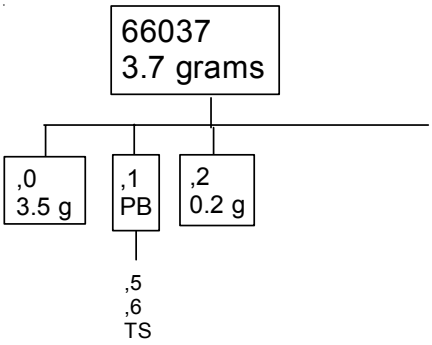


Table 2: Glass compositions in 66035.

	Grieve et al.1974													Shearer 1990		
	1	2	3	4	5	6	10	11	12	13	14	15	16	Wentworth 1988		
SiO2	71.25	56.69	63.94	57.68	44.89	43.38	49.77	43.55	44.94	44.1	44.17	47.48	47.31	48.5	48.9	(a)
TiO2	0.58	1.18	2.83	0.98	0.01	0.03	1.13	2.99	2.62	1.74	2.49	0.92	1.27	0.7	1.56	(a)
Al2O3	12.35	6.76	11.52	17.05	35.62	33.36	20.84	22.43	17.87	14.77	14.77	22.74	19.79	23.46	18.8	(a)
FeO	5.67	30.23	10.4	7.77	0.14	0.88	2.28	4.04	6.27	5.07	7.77	6.73	8.42	2.1	0.52	(a)
MnO	0.11	0.4	0.14	0.11	0.01	0.02	0.27	0.04	0.1	0.05	0.11	0.1	0.11	0.9	0.17	(a)
MgO	0	0.57	1.73	4.12	0	1.33	8.44	12.96	16.05	17.4	20.65	7.79	9.22	10.44	10.58	(a)
CaO	1.99	1.44	5.81	8.4	18.74	18.71	12.54	13.2	10.52	11.34	8.29	13.66	12.03	14.83	16.72	(a)
Na2O	2.43	0.05	0.11	1.12	0.28	0.77	1.2	0.05	0	0.06	1.26	0.16	0.67	0.24	1.26	(a)
K2O	5.39	2.65	4.49	2.25	0.01	0.01	2.14	0.07	0	0.01	0.27	0	0.35	0.05	0.5	(a)
P2O5														0.01	0	(a)
Zr														256	768	(b)
Ba														128	986	(b)
La														16	68	(b)

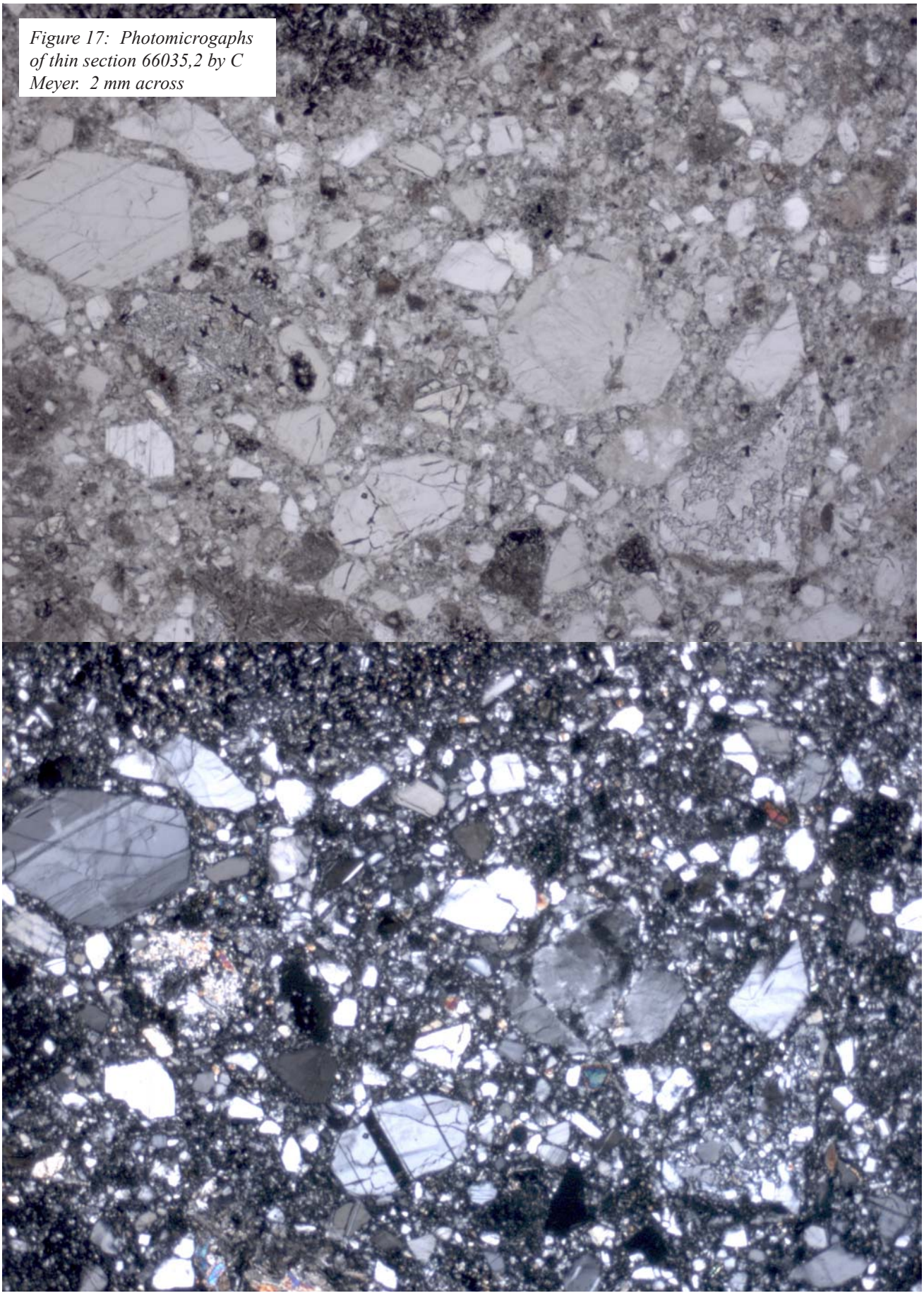


Figure 17: Photomicrogaphs of thin section 66035,2 by C Meyer. 2 mm across

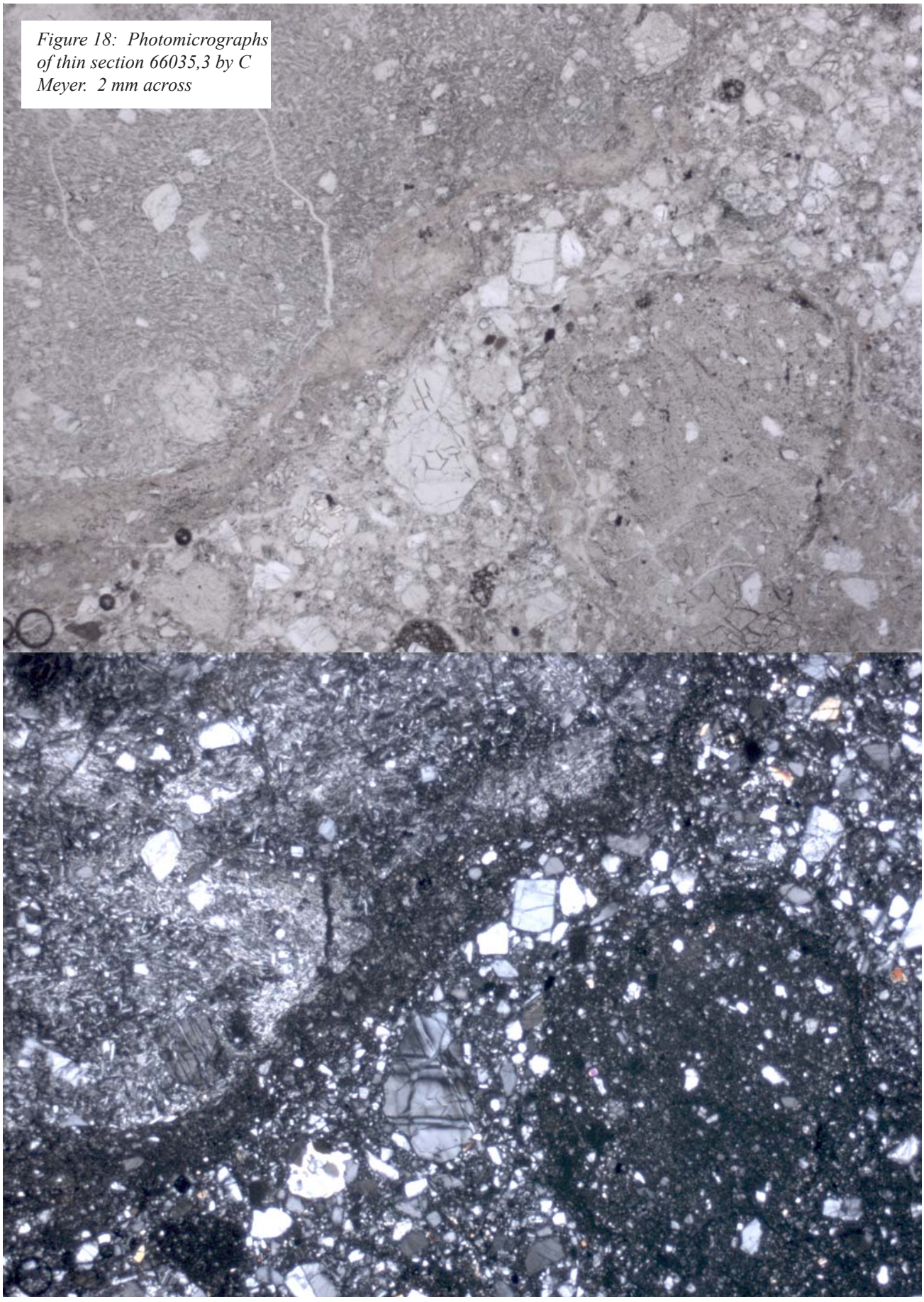


Figure 18: Photomicrographs of thin section 66035,3 by C Meyer. 2 mm across

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