77035

Impact Melt Breccia

5727 grams

Figure 1: Photo of "norite" clast in 77035,23. Round prop is about 3.5 cm. NASA photo # S78-27393.

Introduction

Sample 77035 is an impact melt rock that has partially dissolved the original clasts or welded them into its recrystallized matrix such that they cannot be easily extracted. It has fine-grained flow-banded matrix and contains several clasts including one large, pristine clast of cataclastic norite (figure 1). 77035 has not been dated.

77035 was collected from the regolith at station 7 (figure 2). It was not documented by photographs and was returned with other rocks in the BSLSS (see section on 70050). This bag was exposed to moisture on the floor on the Command Module (Butler 1973).

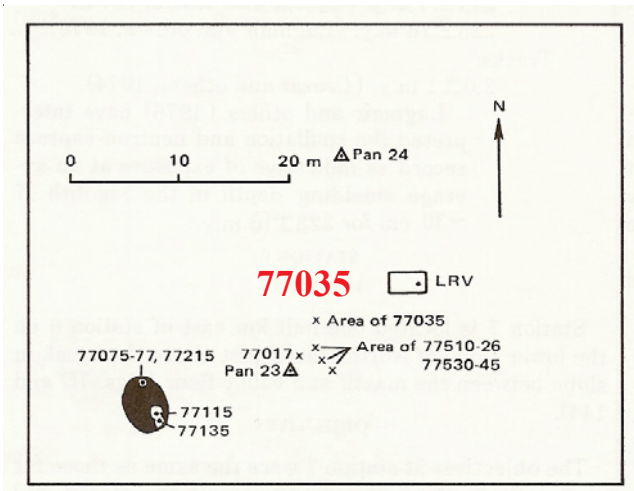


Figure 2: Map of station 7 showing 77035.

Petrography

The main mass of 77035 is a micropoikilitic impact melt breccias (figure 5), apparently similar to the large boulders at stations 6 and 7 (Simonds et al. 1974). However, careful observation of the sawn surface (figure 4) shows that the matrix includes numerous,

Figure 3: PET photo of 77035 showing banded structure and void space. NASA S73-15904. Cube is 1 cm.

small, aphanitic, dark grey clasts, welded together in a "marble cake" pattern. The presence of these aphanitic clasts distinguish this sample from the Apollo 17 boulders.

Significant clasts

Cataclastic Norite: The large white "norite" clast (~100 grams) in 77035 (seen in figure 1) has been studied by Warren and Wasson (1979) and Warren and Kallemyen (1984). Warren (1993) lists this clast as probably "pristine". It is a cataclastic norite with approximately 60% plagioclase An_{93} and 40% orthopyroxene $W_2En_{89}Fs_9$ (figures 7 and 9). However, it is highly shocked with part of the mineralogy converted to diaplectic glass (figure 6). The composition is given in table 1 and figure 10.

Eckert et al. (1991), Neal et al. (1992) and Neal and Taylor (1998) have studied additional lithic clasts extracted from 77035. They analyzed one "dunite", two "norite", and two "anorthosite" clasts. It was difficult to extract them cleanly from the matrix.

Dunite clast ,226 is essentially all olivine (Fo_{80-89}) and has a deep Eu anomaly (figure 11).

Gabbronorite clast , 229 has ~75% plagioclase (An_{85-87}), ~11% orthopyroxene (En_{71-72}), ~11% high-Ca pyroxene ($W_{43}En_{44}Fs_{13}$) and 3% olivine (Fo_{69-73}). It has a positive Eu anomaly and is reported as pristine by Neal and Taylor (1998).

Clast ,206 has 37 ppm Ir and a flat REE pattern (figure 11). It has about 66% plagioclase (An_{93-96}), 12% low-Ca pyroxene ($Wo_4En_{73}Fs_{23}$), 14% high-Ca pyroxene and 7% olivine (Fo_{71-74}).

Bickel and Warner (1978) report a small clast (plutonic fragment?) in thin section 77035,71.

Several dark, fine-grained aphanitic clasts are found in the matrix of 77035 (figure 13). They have not been studied.

Figure 4: Sawn surface of 77035,23. Sample is about 6 inches across. NASA #S89-44217.

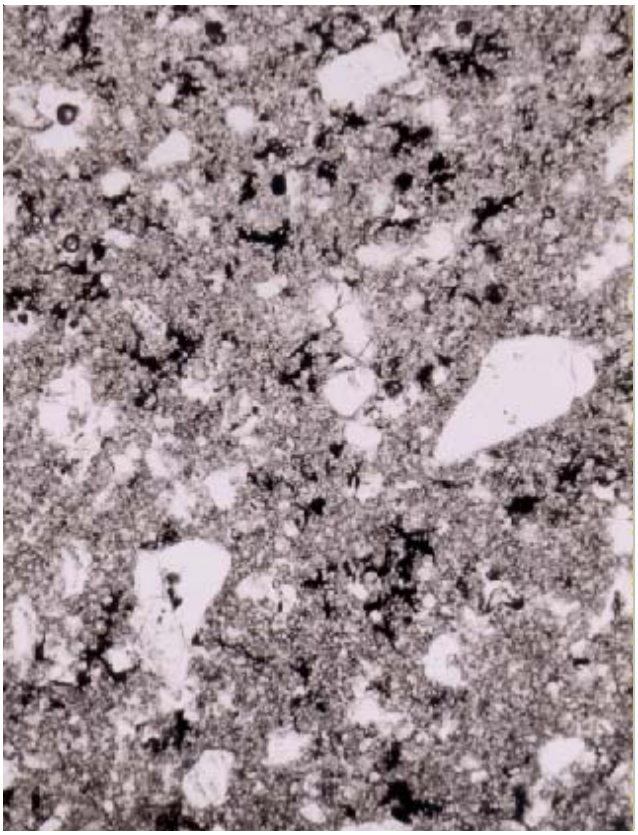


Figure 5: Meyer's photomicrograph of matrix of 77035. Field of view is 3 mm.

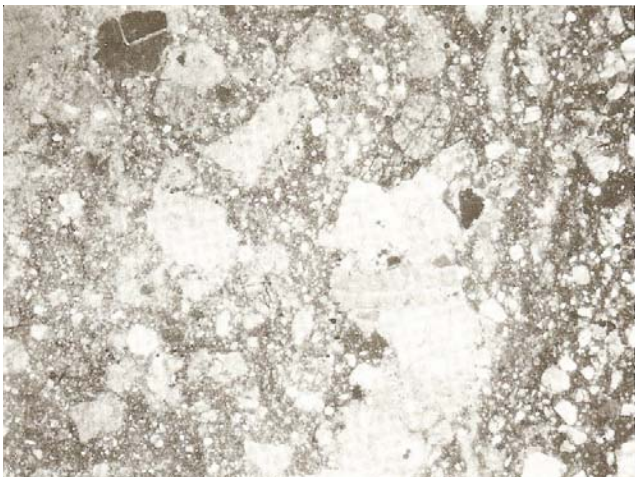


Figure 6: Warren's photo of thin section 77035,69 of the large "norite" clast. Field of view is 1.4 mm.

Mineralogy

Pyroxene: Warren and Wasson (1979), Bersch et al. (1991) and Papike et al. (1994) reported analyses of pyroxene in the cataclastic norite clast from 77035 (figure 7). Neal and Taylor (1998) also determined mineral chemistry of the clasts they studied (figure 8).

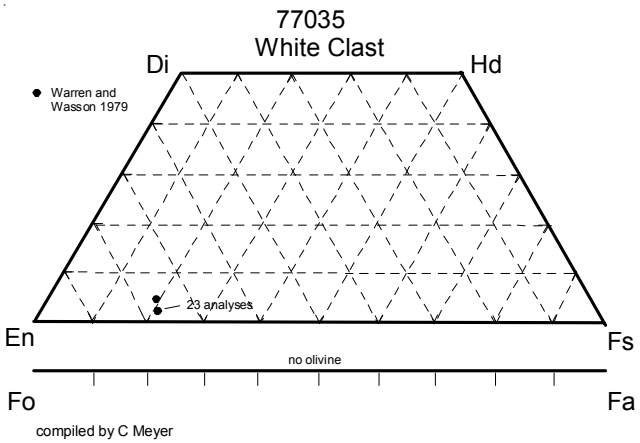


Figure 7: Pyroxene composition for large white "norite" clast in 77035 (from Warren and Wasson 1979).

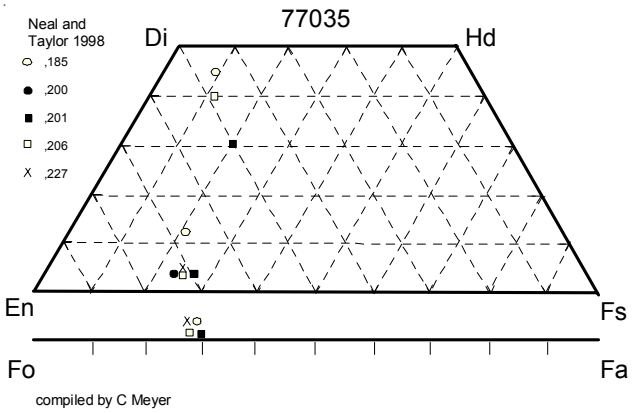


Figure 8: Pyroxene and olivine composition of clasts studied by Neal and Taylor (1998).

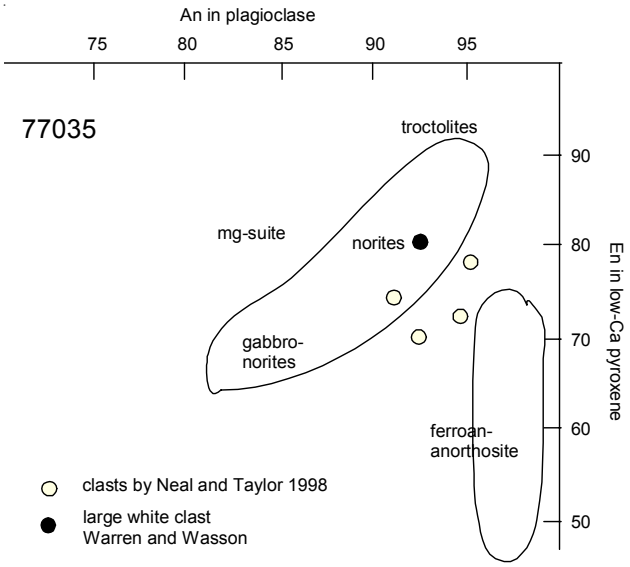


Figure 9: Plagioclase and pyroxene composition for large white clast (norite) and other clasts in 77035. Data from Warren and Wasson 1979, Neal and Taylor 1998.

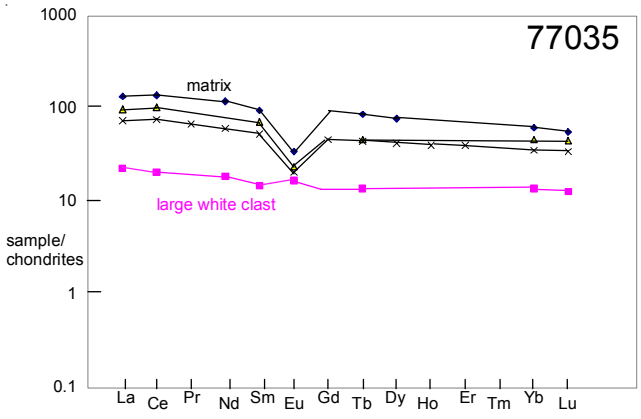


Figure 10: Normalized rare-earth-element composition for matrix and white "notire" clast in 77035 (data for matrix from Wanke 1975, Boynton 1975 and Norman 2002; data for large white clast from Warren and Wasson 1979).

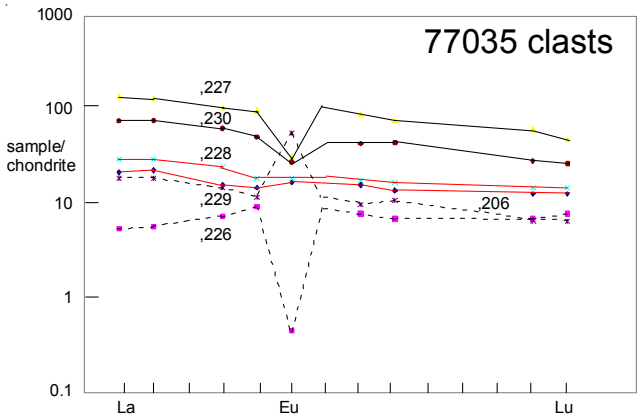


Figure 11: Normalized rare-earth-element composition for selected clasts in 77035 (data of Neal and Taylor 1998).

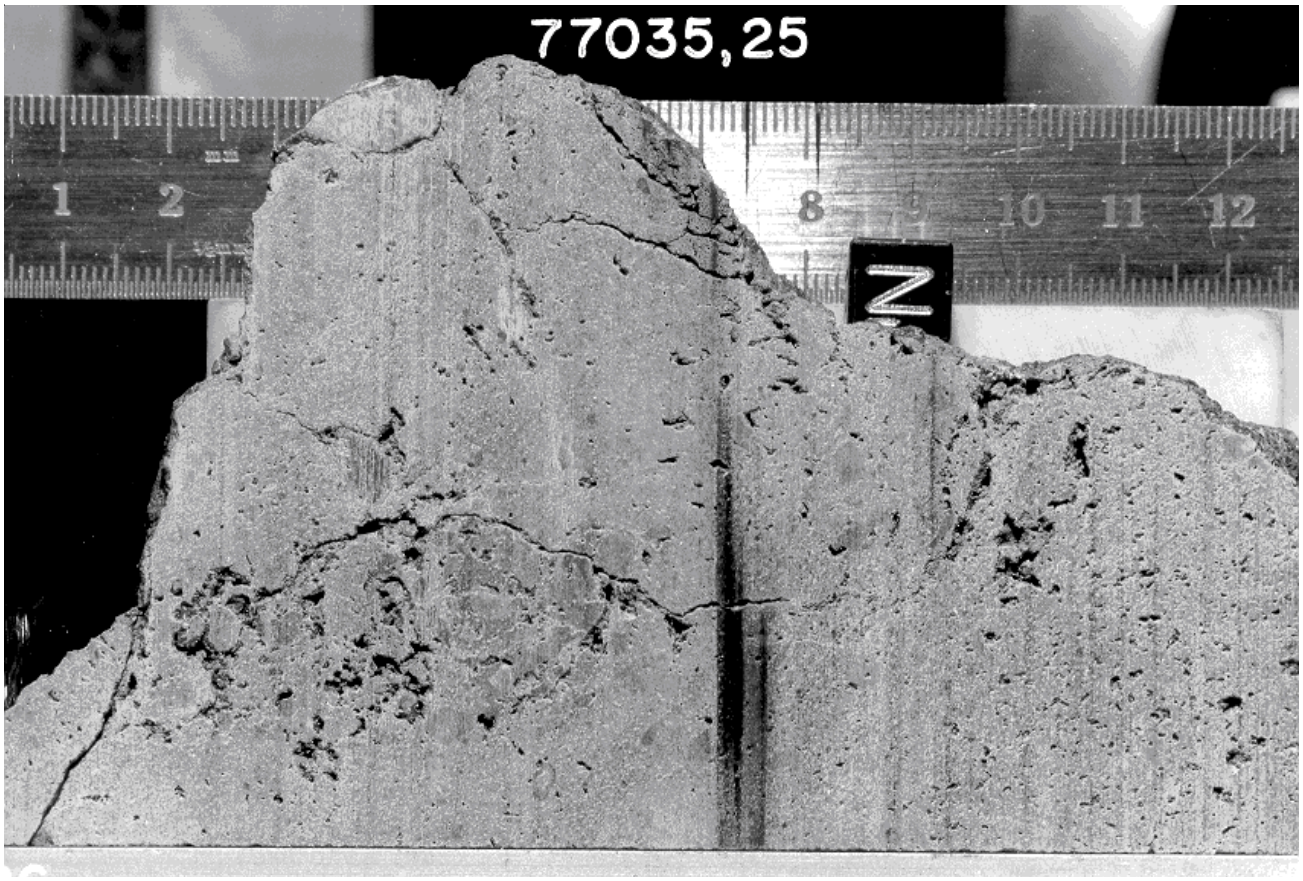
Chemistry

Boynton et al. (1975) and Wanke et al. (1975) analyzed the matrix of 77035 and found it to be similar to the Apollo 17 boulders (figure 10). However, Norman et al. (2002) studied a different piece, which may have included an unrecognized clast (table 1). Wanke et al. (1977) report V analyses and Garg and Ehmann (1977) determined Zr and Hf. The Zr/Hf ratio is high. Hughes and Schmitt (1985) discussed Zr-Hf-Ta fractionation during lunar evolution. Jovanovic and Reed (1974) determined Cl, F, Br and I. Petrowski et al. (1974) reported 12 ppm C and 634 ppm S.

77035 has a distinctly different siderophile content leading Norman et al. (2002) to conclude that there

Table 1. Chemical composition of 77035.

	matrix			matrix		large clast		clast ?								
reference	Boynton 75			Wanke75		Warren 79		Norman02		Neal94						
weight								3 g								
SiO2 %				46.87	(b)			45.3	(d)							
TiO2	1.38	1.38		1.52	(b)	0.2	(c)	0.87	(d)	0.22		1.48	0.21	0.69	0.68	(d)
Al2O3	17.4	18.1		18.1	(b)	19.09	(c)	15.9	(d)	23.9	0.28	17.1	19.7	27.4	32.1	(d)
FeO	6.94	9		8.87	(b)	2.64	(c)	8.12	(d)	5.8	11	8.4	5.8	3.9	2	(d)
MnO	0.12	0.11		0.11	(b)	0.09	(c)	0.11	(d)	0.07	0.12	0.11	0.09	0.05	0.03	(d)
MgO				12.2	(b)	11.95	(c)	18.9	(d)	7.9	49	11.7	11.9	5.9	4.8	(d)
CaO	9.24	11.76		11.23	(b)	11.76	(c)	9.4	(d)	14.6		9.7	12.2	14.2	18.2	(d)
Na2O	0.6	0.62		0.62	(b)	0.44	(c)	0.45	(d)	0.43	0.02	0.65	0.46	1.21	0.55	(d)
K2O				0.26	(b)	0.09	(c)	0.15	(d)	0.08		0.3	0.11	0.18	0.32	(d)
P2O5																
S %																
sum																
Sc ppm	13.6	16.8	(a)	16	(b)	10.9	(c)	13.2	(d)	9.4	5.6	15.7	10.1	3	5	(d)
V								48	(d)							
Cr	1231	1368	(a)	1368	(b)	2190	(c)	1583	(d)	810	510	1170	1950	440	300	(d)
Co	25	32	(a)	32.1	(b)	22	(c)	34.6	(d)	41	62	38	21.4	5.8	4.3	(d)
Ni	281	333	(a)	360	(b)	9.5	(c)	294	(d)	560	110	300	26		35	(d)
Cu								15.1	(d)							
Zn	2.2	2.4	(a)			1.7	(c)	8.6	(d)							
Ga	5.13	5.02	(a)					3.6	(d)							
Ge ppb	444	433	(a)			3.9 ?	(c)									
As																
Se																
Rb								4.4	(d)			12	4		9	(d)
Sr				210	(b)			138	(d)	180		240	160	410	200	(d)
Y								75	(d)							
Zr								315	(d)							
Nb								22.6	(d)							
Mo																
Ru																
Rh																
Pd ppb																
Ag ppb																
Cd ppb																
In ppb																
Sn ppb																
Sb ppb																
Te ppb																
Cs ppm								0.18	(d)			0.34	0.4		0.32	(d)
Ba		360	(a)	370	(b)	96	(c)	200	(d)	110		350	100	130	240	(d)
La	23.4	34	(a)	32.2	(b)	5.5	(c)	17.7	(d)	5.1	1.28	33	7	4.5	18.1	(d)
Ce	63	101	(a)	85	(b)	13	(c)	46.5	(d)	14.1	3.5	81	17.8	11.3	47	(d)
Pr								6.13	(d)							
Nd				55	(b)	8.6	(c)	28.3	(d)	7.5	3.4	48	11.3	6.7	29	(d)
Sm	10.7	15.2	(a)	14.3	(b)	2.19	(c)	8	(d)	2.27	1.38	14.8	2.89	1.81	7.7	(d)
Eu	1.37	1.9	(a)	1.95	(b)	0.93	(c)	1.16	(d)	0.96	0.03	1.78	1.1	3.19	1.58	(d)
Gd								9.2	(d)							
Tb	1.7	3	(a)	3.2	(b)	0.49	(c)	1.63	(d)	0.59	0.3	3.3	0.65	0.38	1.6	(d)
Dy		14	(a)	19.1	(b)			10.4	(d)	3.4	1.8	19	4.1	2.7	11	(d)
Ho								2.28	(d)							
Er								6.53	(d)							
Tm																
Yb	7.6	11.1	(a)	10.2	(b)	2.2	(c)	5.86	(d)	2.12	1.18	10.3	2.5	1.09	4.8	(d)
Lu	1.12	1.5	(a)	1.39	(b)	0.32	(c)	0.85	(d)	0.31	0.2	1.19	0.37	0.16	0.66	(d)
Hf	7.4	10.6	(a)	10.8	(b)	1.9	(c)	6.24	(d)	1.72	0.44	12.8	1.71	0.9	5.2	(d)
Ta		1.8	(a)	1.46	(b)	0.2	(c)	0.92	(d)	0.2	1.7	1.44	0.24	0.19	0.76	(d)
W ppb								0.49	(d)							
Re ppb																
Os ppb																
Ir ppb	5	6.9	(a)	9	(b)	0.05	(c)			37						(d)
Pt ppb																
Au ppb	4.6	5	(a)			0.026	(c)			11	6	9	5	6	15	(d)
Th ppm	3.7	5.5	(a)	4.5	(b)	1.1	(c)	3.55	(d)	0.93	0.33	5.3	1.38	0.47	2.7	(d)
U ppm						0.31	(c)	0.92	(d)	0.2		1.5	0.29		0.8	(d)
technique	*(a) RNAA, (b) INAA, (c) INAA, (d) ICP-MS*															



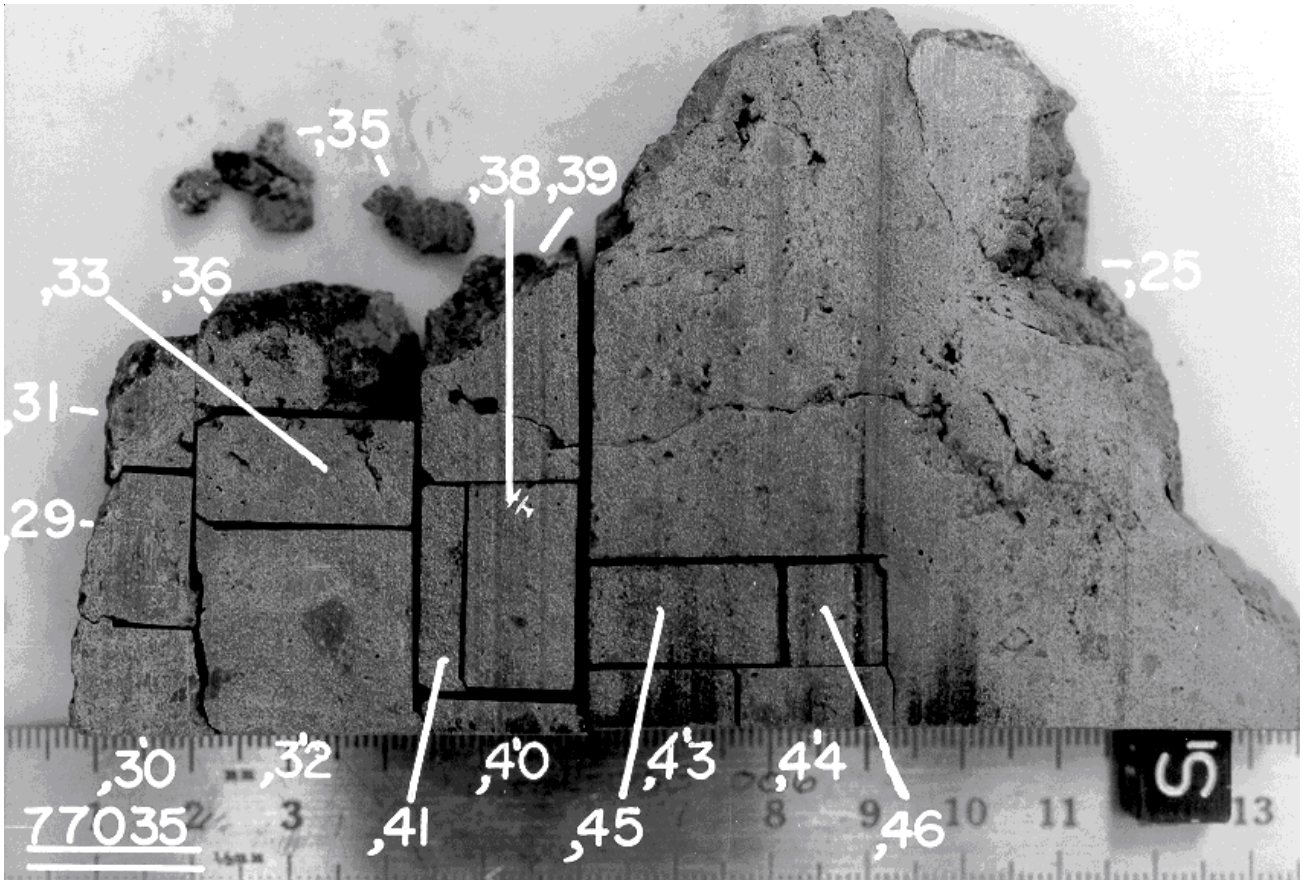


Figure 12 a,b: Two sides of slab ,25 cut from 77035. NASA S74-16783 (below) and NASA S74-15068 (above). Cube is 1 cm.

Figure 13: Sawn surface of 77035,155 showing dark aphanitic clasts in foliated matrix (see also figure 2). NASA S90-28807. Cube is 1 cm.

may have been more than one impact event in the region of Serenitatis.

Radiogenic age dating

None reported.

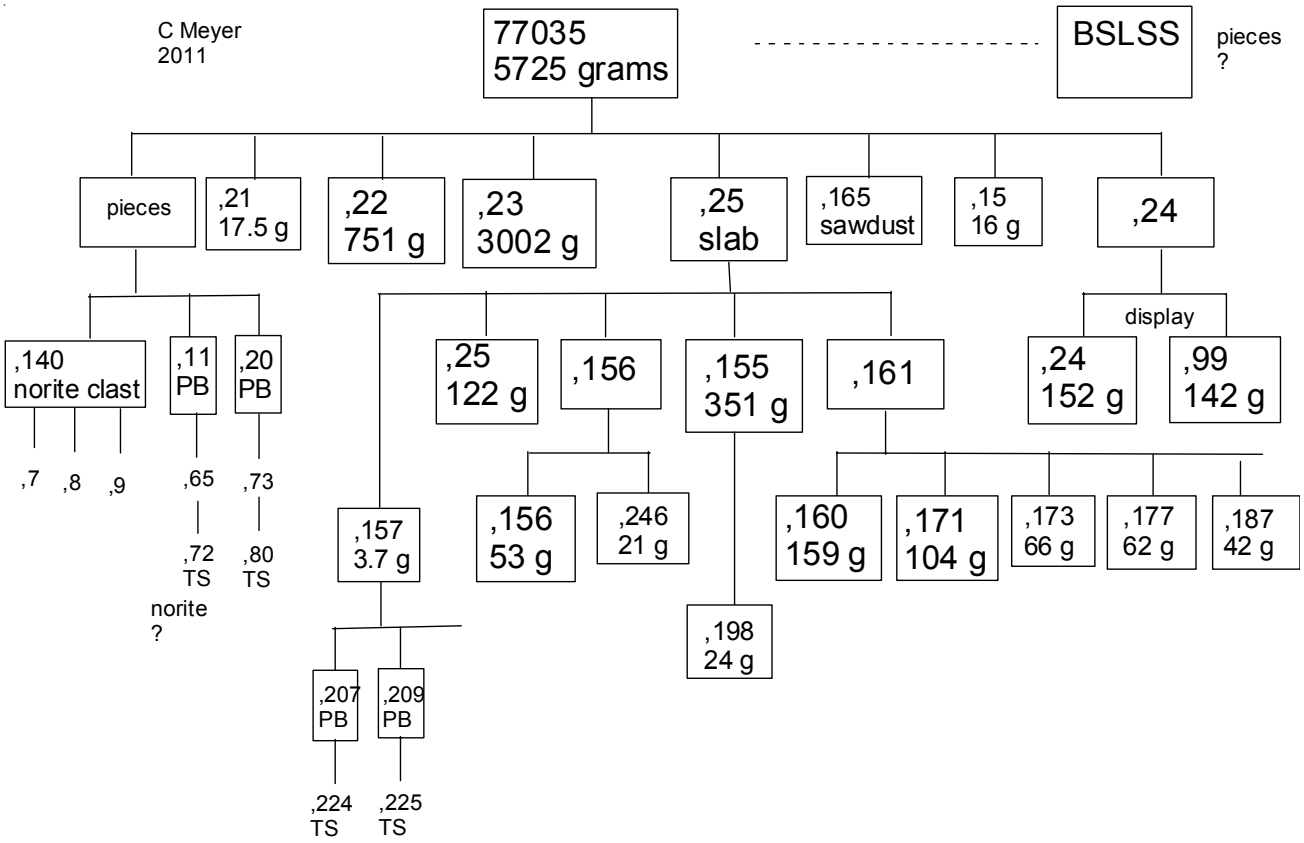
Other Studies

Sugiura et al. (1978) studied the thermal remanent magnetization in 77035. Simmons et al. (1975) studied differential strain and crack closure in 77035. Horai and Winkler (1976) studied the thermal diffusivity.

Processing

A slab was cut through the center of 77035. It proved difficult to sample the small clasts. There are a total of 37 thin sections.

77035 was one of the 4 rocks returned in the BSLSS bag. As such it was broken in pieces and was also exposed to moisture on the floor of the Command Module (see section on 70050). The coarse fines from 70054 may include additional chips (Meyer 1973).



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