DRAFT

73235

Aphanitic Impact Melt Breccia

878.3 grams

Figure 1: Lunar sample 73235 showing zap pits.. Cube is 1 cm. NASA photo # S73-19958.

Introduction

Rock 73235 is a blue-grey breccia sample collected on the rim of a 10 meter crater at Station 3 within the light-mantle, "landslide material" off of the South Massif. The material in 73235 is generally interpreted as Serenitatis ejecta (Wolfe et al. 1981), although Spudis and Ryder (1980) suggest that the aphanitic melt rocks from Apollo 17 may have a different origin (unspecified).

73235 has numerous micrometeorite craters (zap pits) on almost all sides and must have rolled over during gardening of the lunar regolith (figure 1).

Lunar breccia 73235 has a fine-grained "aphanitic" matrix and is trace-element-enriched, with a bulk composition similar to that of 73215 and 73217. Wilshire (in Wolfe et al. 1981) and Ryder (1993) suggests that 73235 is generally similar to 73215. However, it is more dense and coherent than 73215.

It has been dated at ~3.98 b.y. and has had 110 m.y. exposure to cosmic rays.

Petrography

The catalog by Ryder (1993) provides a complete and thorough review of everything learned from the analysis of 73235 up to that time. Ryder describes this breccia sample with a dense, aphanitic melt groundmass with seriate clast distribution. The groundmass consists mainly of plagioclase, pyroxene, opaque minerals and rare pleonaste spinel. Lithic clasts include granoblastic feldspathic impactities with a variety of grain sizes,

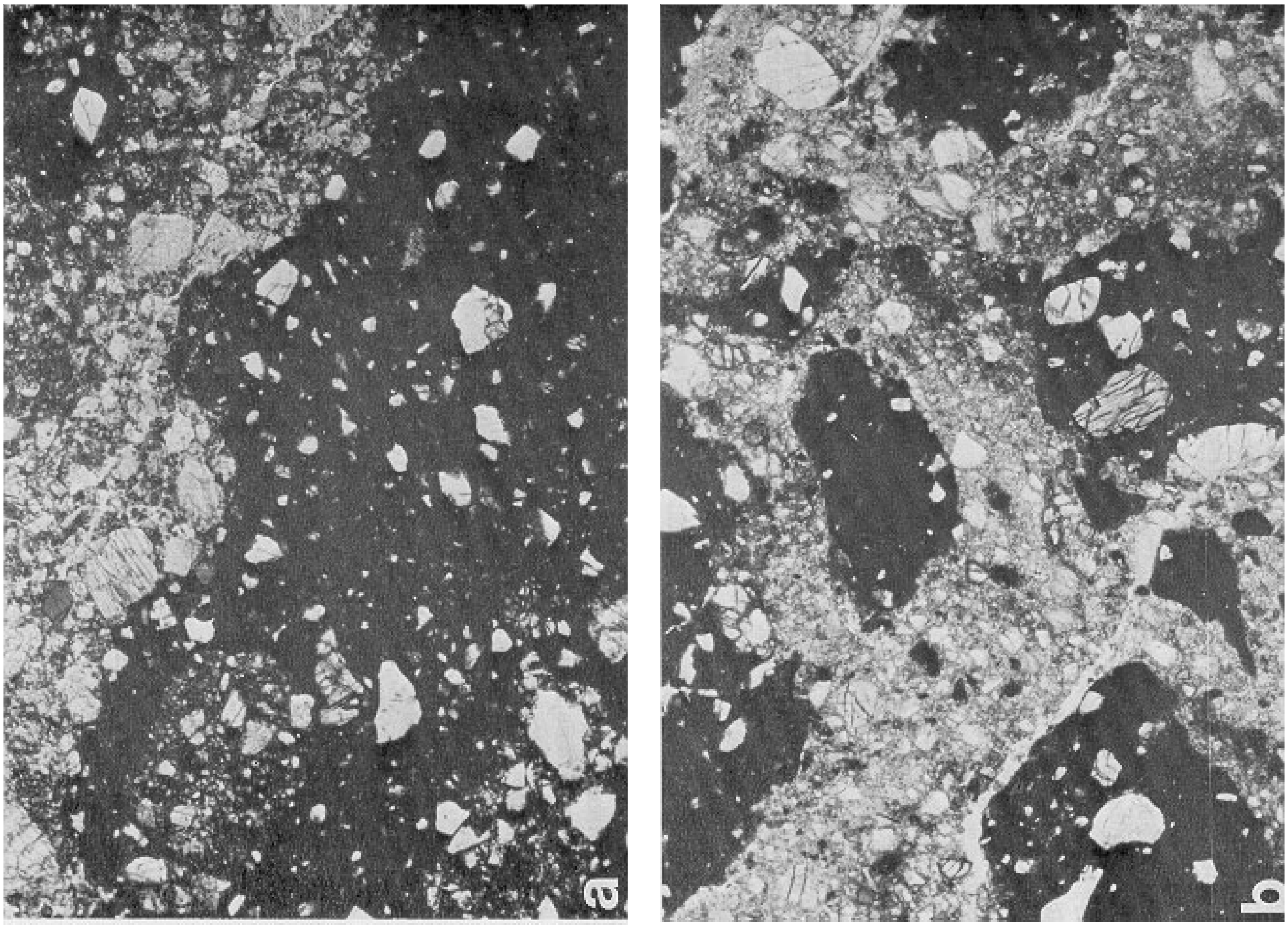

Figure 2: Thin section photomicrographs of matrix of 73235 (from Dence et al. 1974). Photos are 1 mm across.

shocked anorthosites, and cataclasized troctolites and norites. Many lithic clasts are strung out as schlieren within the dense matrix.

Brown et al. (1974) described 73235 as a polygenetic microbreccia with calcic plagioclase (An_{94}), zoned olivine (Fo_{87-81}) and bronzite. They noted patches of potassic rhyolite and purple Cr-pleonastes. Hodges and Kushiro (1974) describe 73235 as being a fine-grained, dark brown, slightly metamorphosed breccia with numerous minerals and lithic clasts. They noted that olivine clasts in the matrix are more Mg-rich than olivine in the lithic clasts (figure 4).

Dence et al. (1976) observed that 73235 consisted of two lithologies, a coherent clast-rich dark matrix breccia interlayered with lighter more porous clastic breccia, with the former predominate. The light clastic material has irregular, locally sheared boundaries (figure 2). They noted that the clast population includes "noritic microbreccias, granoblastic or crushed anorthositic and troctolitic fragments".

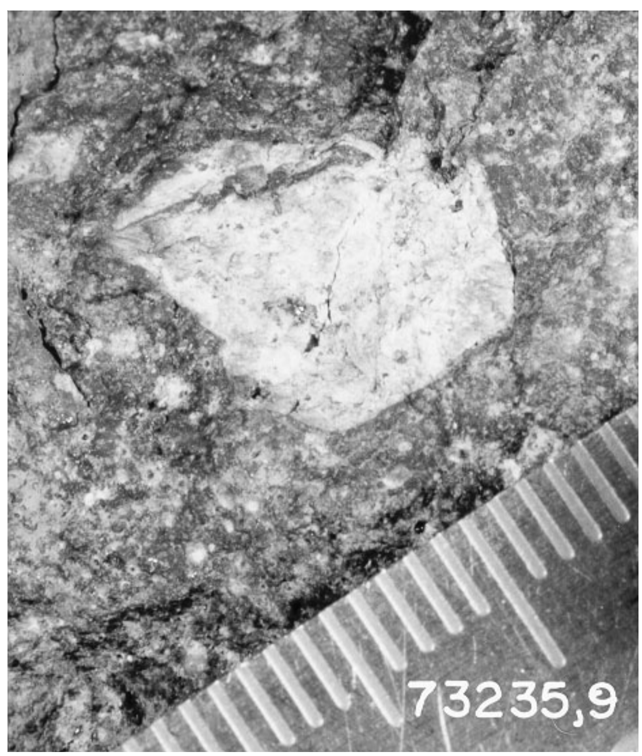

Figure 3: White clast in 73235,9. Scale is in mm. NASA S78-25431. Note micrometeorite craters.

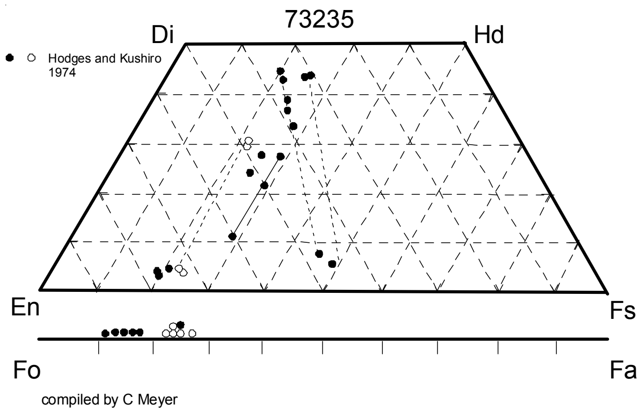

Figure 4: Pyroxene and olivine composition of mineral grains and clasts in 73235 (adapted from Hodges and Kushiro 1974).

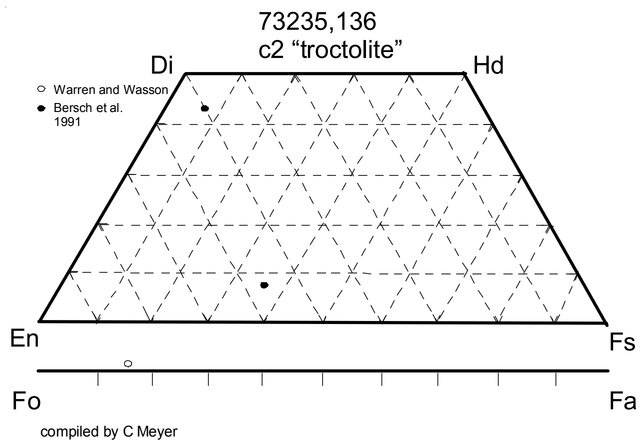

Figure 5: Pyroxene and olivine in troctolite clast c2 (from Warren and Wasson 1981).

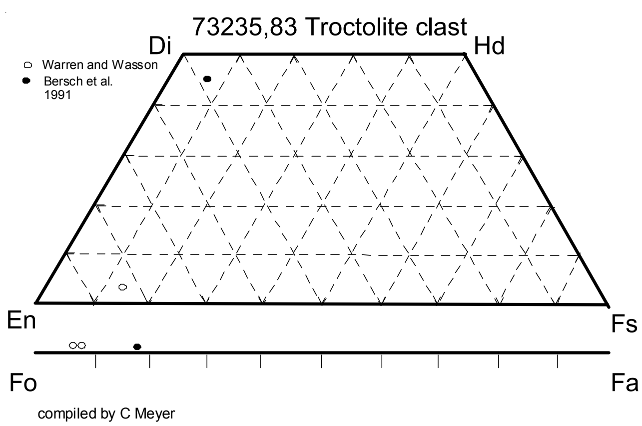

Figure 6: Pyroxene and olivine composition of troctolite clast c1 (from Warren and Wasson 1981).

Significant Clasts

Troctolite clast (C1): TS,83

Bersch et al. (1991) and Warren and Wasson (1979) apparently studied the same pristine troctolite clast (,49?) as Taylor et al. (1974). It is composed of 60%

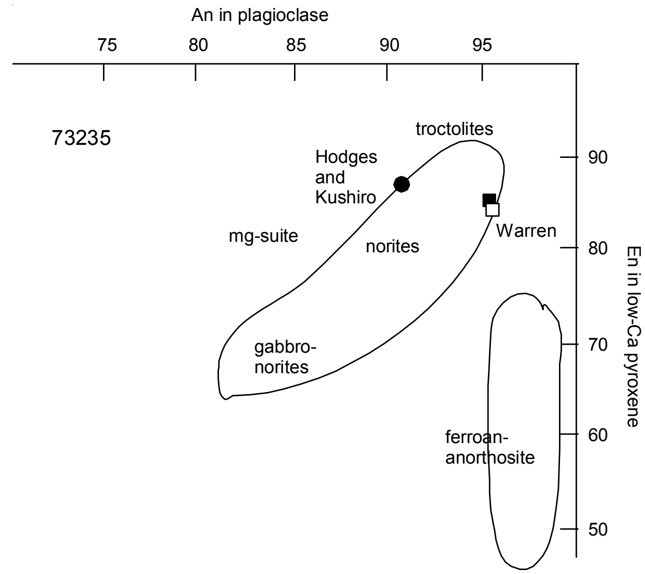

Figure 7: Composition of minerals in clasts in 73235 (from Hodges and Kushiro 1974 and Warren and Wasson 1979).

plagioclase (An_{95}), 30% olivine (Fo_{80-90}) and ~10% low-Ca pyroxene ($Wo_4En_{83}Fs_{13}$). Bersch et al. also reported high-Ca pyroxene (figure 6). The composition is repeated in table 1c and the REE pattern is shown in figure 8.

Troctolite clast (C2): TS,136

Warren and Wasson (1979) also analyzed a second troctolite clast (table 1b). Bersch et al. (1991) analyzed the pyroxene (Fe-rich?)(figure 5).

Pomegranate clast: ,82

Smith et al. (1984) and Pidgeon et al. (2005, 2006) have described a unique zircon-bearing clast in thin section 73235,82 (figures 9, 10 ,11). The surrounding plagioclase is An_{80-85}.

Pink Spinel Troctolite:

One small clast of fine-grained spinel troctolite was observed to consist of plagioclase (An_{90-88}), olivine (Fo_{86-87}) and pink spinel (chr_4her_{96})(Hodges and Kishiro 1994).

“White” Clast:

Taylor et al. (1974) reported the composition of a “white” clast (table 1, figure 7), but gave no description. It may be the same clast as C1 (above).

Mineralogy

Pyroxene: Hodges and Kushiro (1974) and Bersch et al. (1991) have analyzed pyroxene (figures 4, 5, 6).

Zircon: Numerous zircons are found in 73235, including the unusual patch called “Pomegranate” (Smith et al. 1984, Pidgeon et al. 2005, 2006)

Metallic iron: Watson et al. (1974) studied the metallic iron in 73235. Hewins and Goldstein (1975) studied Ni,Fe grains in the clasts.

Chemistry

Taylor et al. (1974), Wanke et al. (1974), Philpotts et al. (1974), Duncan et al. (1974), Rhodes et al. (1974) Hubbard et al. (1974), Brunfelt et al. (1974) and others all determined the composition of this breccia (in remarkable agreement, table 1).

Jovanovic and Reed (1974) also determined halogens, Hg, Li and other elements in dark matrix, exterior and a white clast. Reese and Thode (1974), Moore et al. (1974) and Moore and Lewis (1976) determined nitrogen (54 ppm), carbon (30 ppm) and sulfur (~400 ppm).

Morgan et al. (1976) and Hertogen et al. (1977) found the meteoritic siderophiles matched Serenitatis ejecta, but the sample is enriched in Br, Zn and Cd. Jovanovic and Reed (1974) determined Cl , P, Ru, Os and U.

Radiogenic age dating

Phinney et al. (1975) and Turner and Cadogen (1975) determined 39Ar/40Ar ages of 3.98 b.y. and 3.96 b.y. respectively (figures 12, 13). Oberli et al. (1978) determined the U-Th-Pb system (figure 14) and reported data for Rb-Sr and Sm-Nd for the bulk sample. Nyquist et al. (1973) included 73235 in their whole rock Rb/Sr isochron.

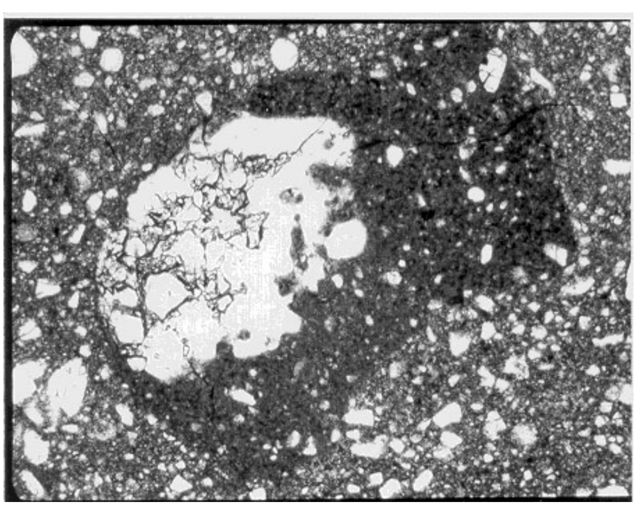

Figure 9: Zircon-plagioclase-containing clast in 73235,82. Note breccia-in-breccia texture. Field of view is 2 mm.

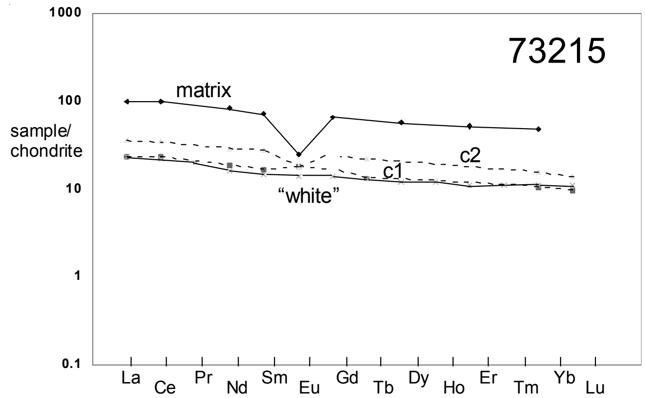

Figure 8: Normalized rare-earth-element diagram for 73235 and its white clasts (data for matrix from Hubbard et al. 1974, "white" Taylor et al. 1974 and c1, c2 from Warren and Wasson 1979).

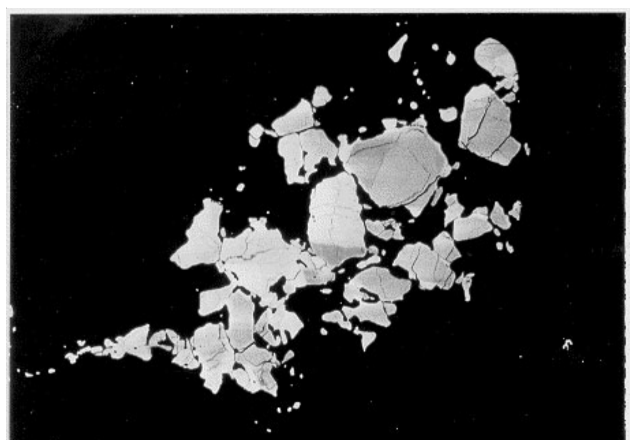

Figure 10: Complex patch of zircon fragments (resembling cross-section thru seeds in a pomegranate) in 73235,82. About 1 mm across.

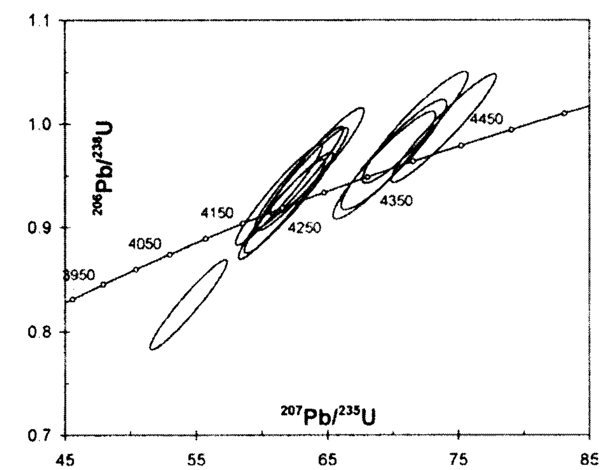

Figure 11: Ion microprobe U-Pb age data for complex zircon (called Pomegranate) in clast from 73235,82 (from Pidgeon et al. 2005, 2006). Note the evidence for an overgrowth or second generation.

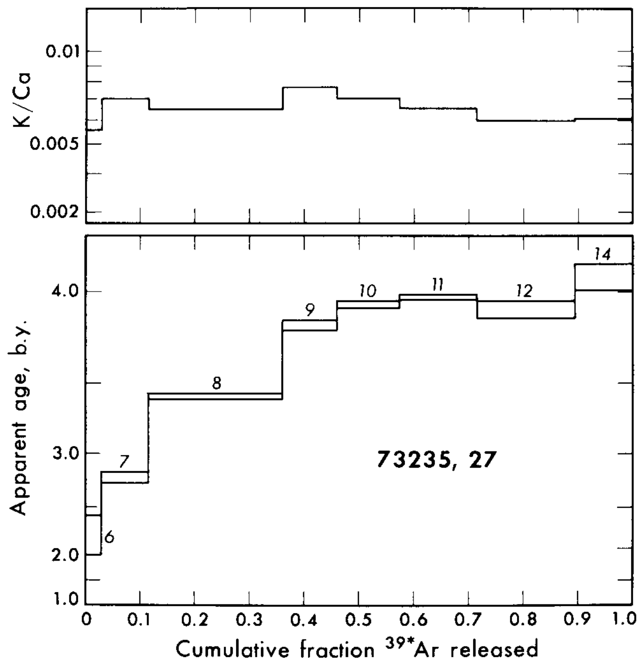

Figure 12: Ar release pattern for 73235 (from Phinney et al. 1975).

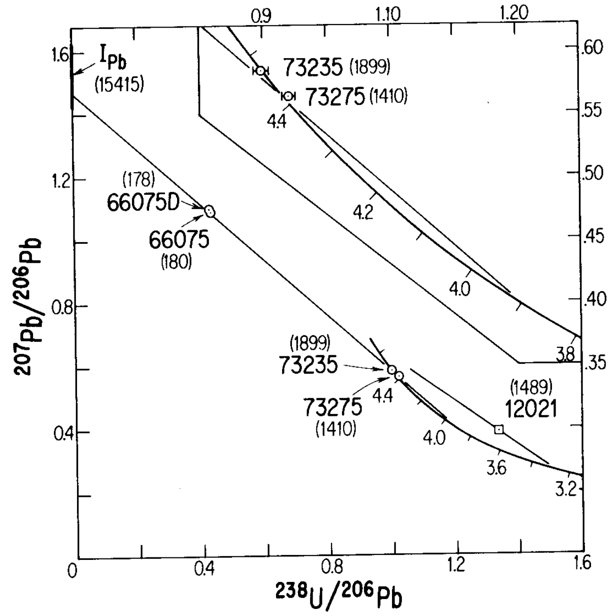

Figure 14: U/Pb concordia diagram for Apollo 17 rocks including 73235 (from Oberli et al. 1978).

Summary of Age Data for 73235

	Ar/Ar	U/Pb
Phinney et al. 1975	3.98 ± 0.04 b.y.	
Turner and Cadogen 1975	3.96 ± 0.04	
Pidgeon et al. 2005		4.2 with 4.1 (zircon)

Note: These are based on the old decay constants.

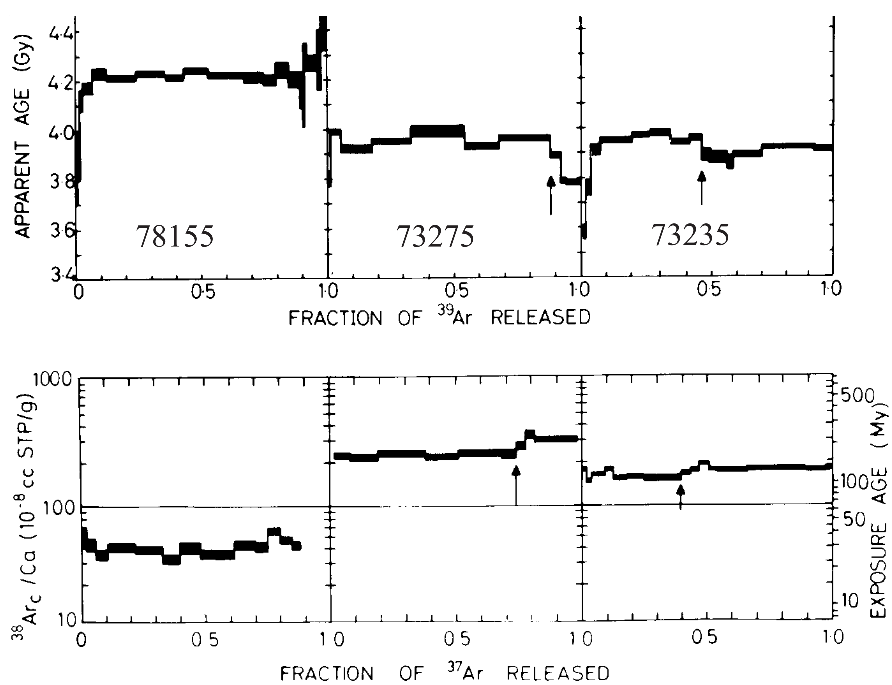

Figure 13: Ar release pattern for 73235, 73275 and 78155 (from Turner and Cadogen 1975).

Table 1a. Chemical composition of 73235 (bulk?).

												clast						
reference	Wanke 74		Philpotts 74		Weismann75		Duncan74		Masuda74		Taylor 74			Rhodes74		Hubbard74		Brunfelt74
weight			95 mg								black	white						
SiO2 %	46.64						45.96	(c)			46.4	44.2	(e)	46.2	(c)			
TiO2	0.65						0.6	(c)			0.63		(e)	0.67	(c)			0.75
Al2O3	20.5						22.57	(c)			21.2	23.1	(e)	21.28	(c)			22.2
FeO	7.38						6.68	(c)			7.33	5.06	(e)	7.32	(c)			6.6
MnO	0.1						0.091	(c)						0.11	(c)			0.09
MgO	11.54						9.61	(c)			10.7	14	(e)	11.05	(c)			10.6
CaO	11.89						13.18	(c)			12.5	12.7	(e)	12.55	(c)			12.9
Na2O	0.456						0.44	(c)			0.47	0.3	(e)	0.48	(c)	0.51		0.47
K2O	0.2		0.2	(b)	0.21	(b)	0.2	(c)			0.18	0.06	(e)	0.2	(c)	0.21	(b)	0.17
P2O5	0.186						0.192	(c)						0.2	(c)			
S %							0.027	(c)						0.04	(c)			
sum																		
Sc ppm	13.4	(a)									17	5	(d)					12.1
V							40	(c)			58	33	(d)					51
Cr	1360				1331	(b)	1341	(c)			1500	600	(d)			1331	(b)	
Co	26.3	(a)					22	(c)			33	17	(d)					23.7
Ni	205	(a)					118	(c)			250	28	(d)					150
Cu	3.8	(a)					2	(c)			3	1	(d)					4.3
Zn							2	(c)										3
Ga	4	(a)																3.4
Ge ppb	360	(a)																
As																		
Se																		
Rb			5.26	(b)	5.128	(b)	5.6	(c)			3.1		(d)			5.13	(b)	4.1
Sr	150	(a)	141	(b)	147	(b)	145	(c)								146.9	(b)	137
Y	69	(a)					62.3	(c)			85	18	(d)					
Zr	343	(a)	366	(b)	341	(b)	315	(c)			350	85	(d)			341	(b)	
Nb	20.4	(a)					19.7	(c)			21.5	5.2	(d)					
Mo																		
Ru																		
Rh																		
Pd ppb	11	(a)																
Ag ppb																		
Cd ppb																		
In ppb																		
Sn ppb																		
Sb ppb																		
Te ppb																		
Cs ppm	0.17	(a)									0.15		(d)					0.17
Ba	260	(a)	288	(b)	263	(b)	252	(c)	260	(b)	315	100	(d)			263	(b)	238
La	24.5	(a)			23.3	(b)			22.8	(b)	24	5.31	(d)			23.3	(b)	19.7
Ce	58.5	(a)	58.4	(b)	60.6	(b)			60.4	(b)	61	13.3	(d)			60.6	(b)	51.5
Pr	8.4	(a)									7.92	1.76	(d)					
Nd			37.3	(b)	37	(b)			36.7	(b)	33.5	7.33	(d)			37	(b)	
Sm	9.4	(a)	10.4	(b)	10.4	(b)			10.4	(b)	8.95	2.17	(d)			10.4	(b)	9.43
Eu	1.25	(a)	1.35	(b)	1.36	(b)			1.42	(b)	1.2	0.79	(d)			1.37	(b)	1.43
Gd	12.5	(a)	12.6	(b)	12.9	(b)			12.6	(b)	12.1	2.73	(d)			12.8	(b)	
Tb	2.2	(a)									1.88	0.48	(d)					1.58
Dy	14.3	(a)	13.7	(b)	13.8	(b)			13.7	(b)	11.9	2.97	(d)			13.8	(b)	11.9
Ho	3.3	(a)									2.85	0.67	(d)					
Er	7.8	(a)	8.27	(b)	8.22	(b)			8.28	(b)	8.15	1.85	(d)			8.2	(b)	
Tm											1.2	0.28	(d)					
Yb	7.9	(a)	7.69	(b)	7.68	(b)			7.74	(b)	7.47	1.72	(d)			7.7	(b)	5.9
Lu	1.08	(a)	1.17	(b)	0.76	(b)			1.07	(b)	1.2	0.27	(d)					0.98
Hf	7.85	(a)									6.5	1.53	(d)					7.7
Ta	0.94	(a)																0.87
W ppb	0.58	(a)																0.26
Re ppb																		
Os ppb																		
Ir ppb																		
Pt ppb																		
Au ppb	3.2	(a)																
Th ppm	3.75	(a)			4.19	(b)					4.3	1	(d)			4.19	(b)	
U ppm	1.05	(a)			1.14	(b)					1.1	0.27	(d)			1.14	(b)	

technique: (a) INAA, (b) IDMS, (c) XRF, (d) SSMS, (e) e. probe

Table 1b. Chemical composition of 73235 (matrix).

	,45						
reference	Morgan74		Oberli78	Jovanovic74		Dence76	
weight	83 mg			,48	exterior	ave.	
SiO2 %						46.69	(c)
TiO2						0.82	(c)
Al2O3						20.7	(c)
FeO						7.73	(c)
MnO						0.09	(c)
MgO						10.5	(c)
CaO						12.18	(c)
Na2O						0.57	(c)
K2O						0.27	(c)
P2O5							
S %							
sum							
Sc ppm							
V							
Cr						1710	(c)
Co							
Ni	144	(b)					
Cu							
Zn	9.4	(b)					
Ga							
Ge ppb	230	(b)					
As							
Se	53	(b)					
Rb	4.7	(b)					
Sr							
Y							
Zr							
Nb							
Mo							
Ru				7.6	5.3		
Rh							
Pd ppb							
Ag ppb	1	(b)					
Cd ppb	27	(b)					
In ppb							
Sn ppb							
Sb ppb	1.14	(b)					
Te ppb	4.3	(b)					
Cs ppm	0.198	(b)					
Ba							
La							
Ce							
Pr							
Nd							
Sm							
Eu							
Gd							
Tb							
Dy							
Ho							
Er							
Tm							
Yb							
Lu							
Hf							
Ta							
W ppb							
Re ppb	0.385	(b)					
Os ppb				12	14		
Ir ppb	3.71	(b)					
Pt ppb							
Au ppb	2.31	(b)					
Th ppm							
U ppm	1.06	(b)		0.61	0.42		

technique: (a) INAA, (b) RNAA, (c) broad beam e. probe

Table 1c. Chemical composition of 73235 (clasts).

	troctolite					basalt?		basalt?	anorthosite	
reference	Warren 79		Warren84			Ehmann74		Miller74	Miller74	Jovanovic74
weight	,127	,135	,127	,135		Garg76				
SiO2 %	44.3	42.6			(a)			47.7		
TiO2		3.34			(a)					
Al2O3	24.94	21.92			(a)			20.8		
FeO	4.5	6.17			(a)			7.8	0.6	
MnO	0.05	0.07			(a)			0.1		
MgO	12.43	17.74			(a)			12.8		
CaO	13.7	11.05			(a)			11		
Na2O	0.27	0.38			(a)			0.47		
K2O	0.057	0.077			(a)					
P2O5										
S %										
sum										
Sc ppm	3.9	6.4			(a)			13.2	0.8	
V										
Cr	710	1080			(a)			1350	41	
Co	19.8	33			(a)			27	7	
Ni	94	206			(a)					
Cu										
Zn	0.94	5			(a)					
Ga			3.5	3.1	(a)					
Ge ppb	10.4	92			(a)					
As										
Se										
Rb										
Sr			200	210	(a)					
Y										
Zr						365				
Nb										
Mo										
Ru										
Rh										
Pd ppb										
Ag ppb										
Cd ppb	73	29			(a)					
In ppb	4.3	4.7			(a)					
Sn ppb										
Sb ppb										
Te ppb										
Cs ppm										
Ba	110	130			(a)					
La	5.4	8.4			(a)					
Ce	14	21			(a)					
Pr										
Nd	8.4	13			(a)					
Sm	2.43	4.1			(a)					
Eu	1	1			(a)					
Gd										
Tb	0.48	0.8			(a)					
Dy										
Ho										
Er										
Tm										
Yb	1.7	2.5			(a)					
Lu	0.23	0.34			(a)					
Hf	1.6	2.1			(a)	8.03	(a)			
Ta	0.23	0.26			(a)					
W ppb										
Re ppb	0.029	0.41			(a)					
Os ppb										
Ir ppb	0.38	5.51			(a)					
Pt ppb										
Au ppb	0.14	1.37			(a)					
Th ppm	0.98	1.6			(a)					
U ppm		0.34			(a)					0.48

technique: (a) INAA, (b) RNAA

Cosmogenic isotopes and exposure ages

The ^{38}Ar exposure age of 73235 has been determined to be 110 m.y. or 195 ± 20 m.y. (Turner and Cadogen 1975, Phinney et al. 1975, respectively). However, the age of the "landslide" is generally thought to be determined as 53 ± 3 m.y. from ^{81}Kr dating of 72275 (Liech et al. 1975, Arvidson et al. 1975) or 95 ± 5 m.y. from 72535 (Arvidson et al. 1976). That would indicate that 73215 and 73235 may have had a previous exposure on the South Massif. Indeed, Wolfe et al. (1981) discuss the age of the "light mantle" material and conclude that it may include regolith material off of the South Massif derived by both landslide and ballistic trajectory from Tycho secondaries, an event they place about 100 m.y. ago.

Other Studies

Mitzutani and Osako (1974) determined the elastic wave velocity and Watson et al. (1974) determined the magnetic properties.

Processing

A slab was cut through the middle of 73235 (terrible saw marks)(figures 14 – 17). There are 34 thin sections.

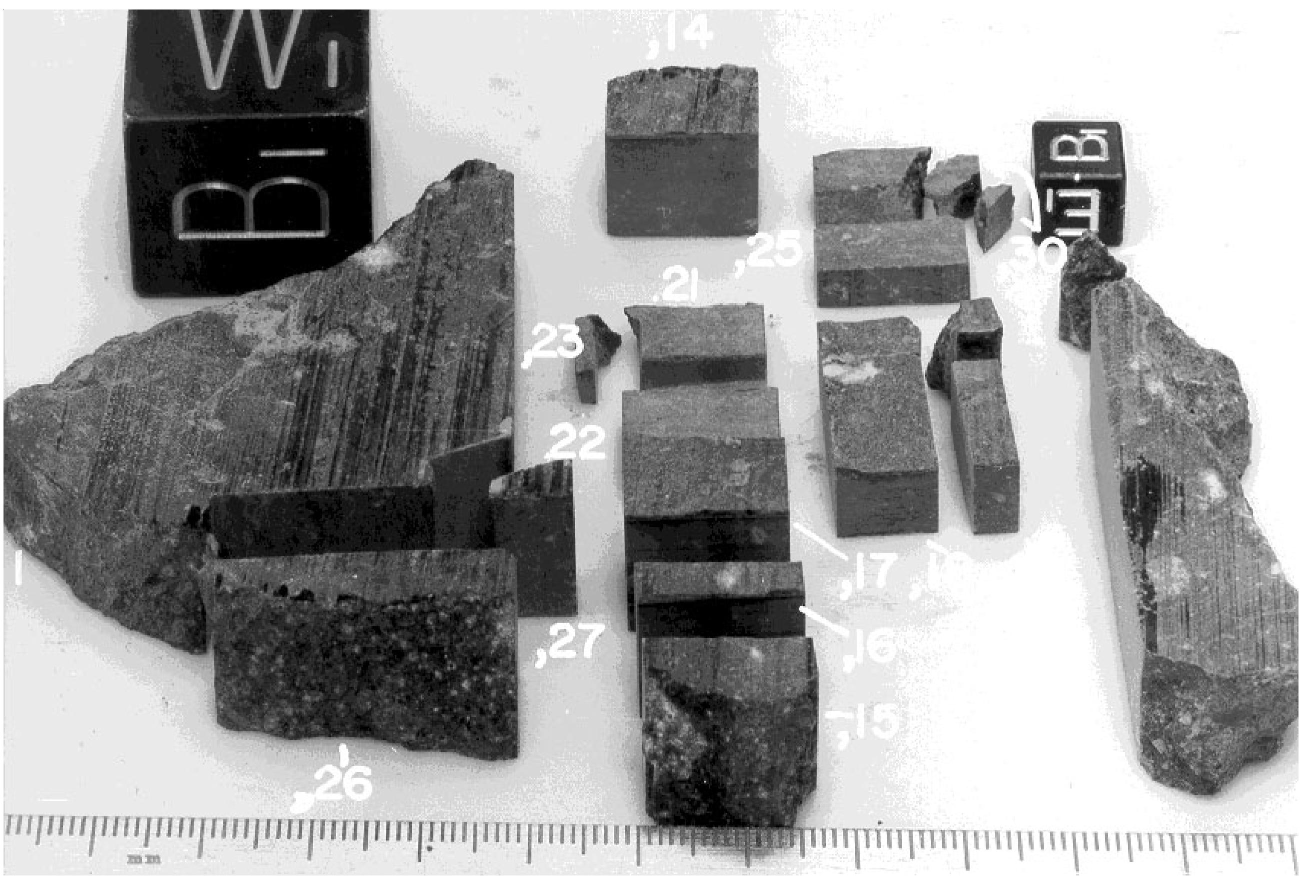

Figure 14: Exploded parts diagram of slab of 73235. NASA S73-28685. Scale in cm.

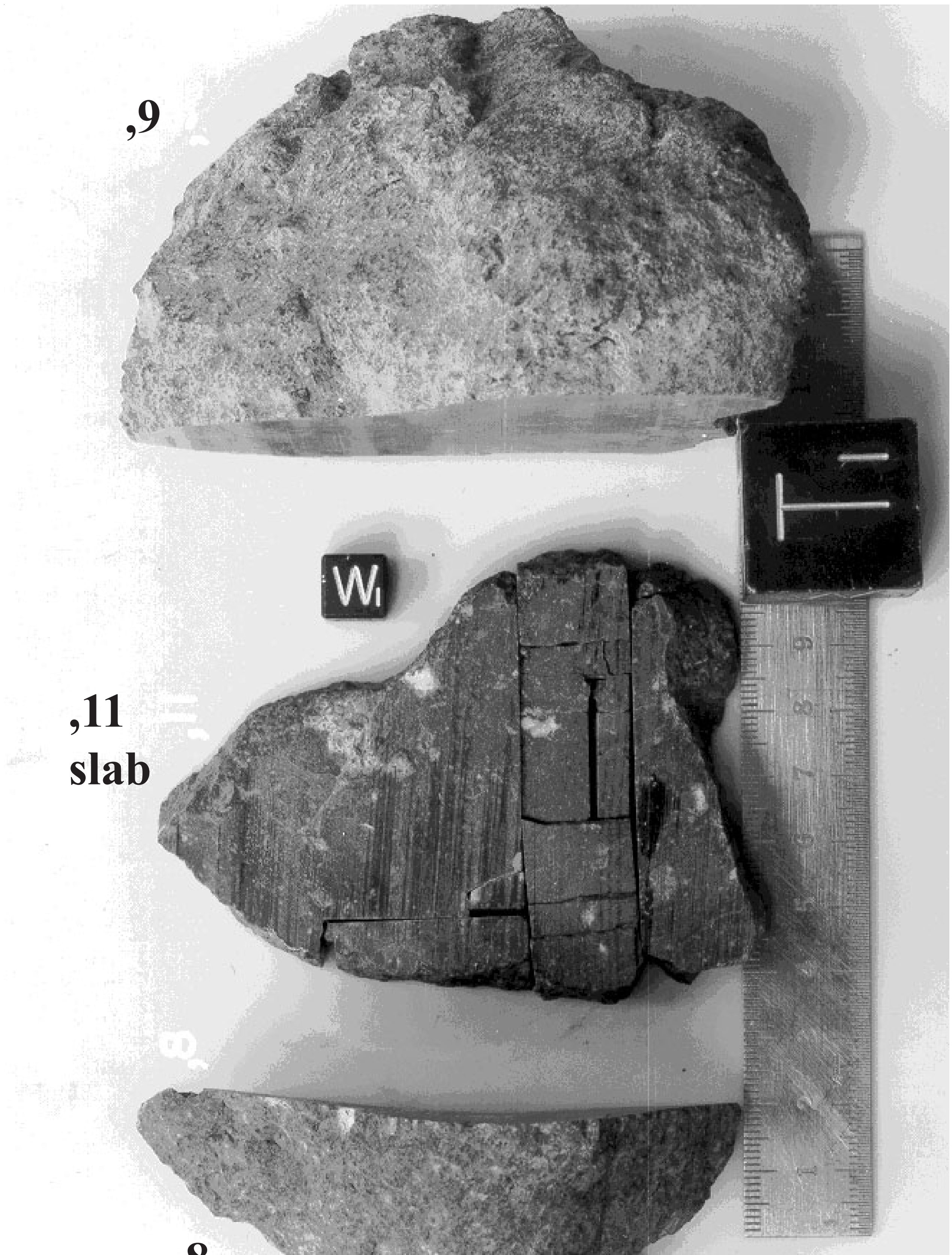

Figure 15: Cutting diagram for 73235 showing slab. NASA S73-28684. Small cube is 1 cm; large is 1 inch

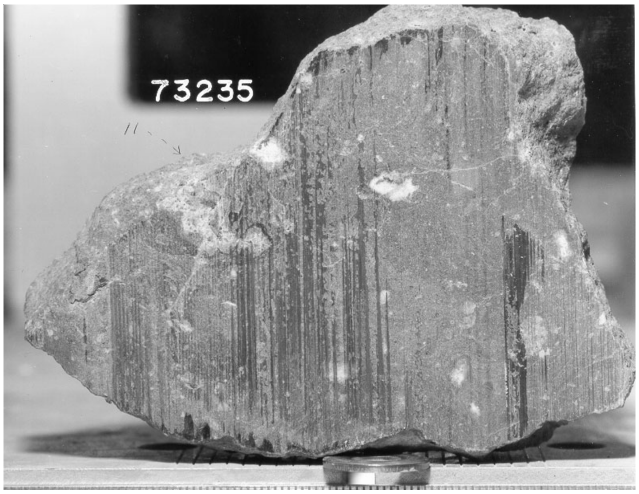

Figure 16: Slab 73235,11 showing saw marks. Scale in mm. NASA S73-27284.

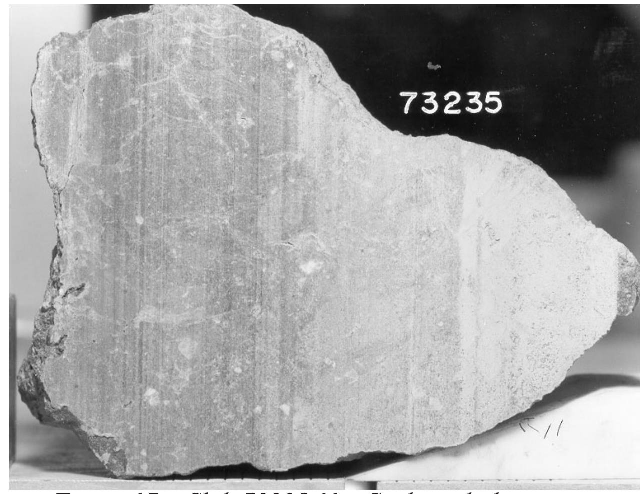

Figure 17: Slab 73235,11. Scale includes mm marks. NASA S73-27283.