60315

DRAFT

Poikilitic Impact Melt

787 grams

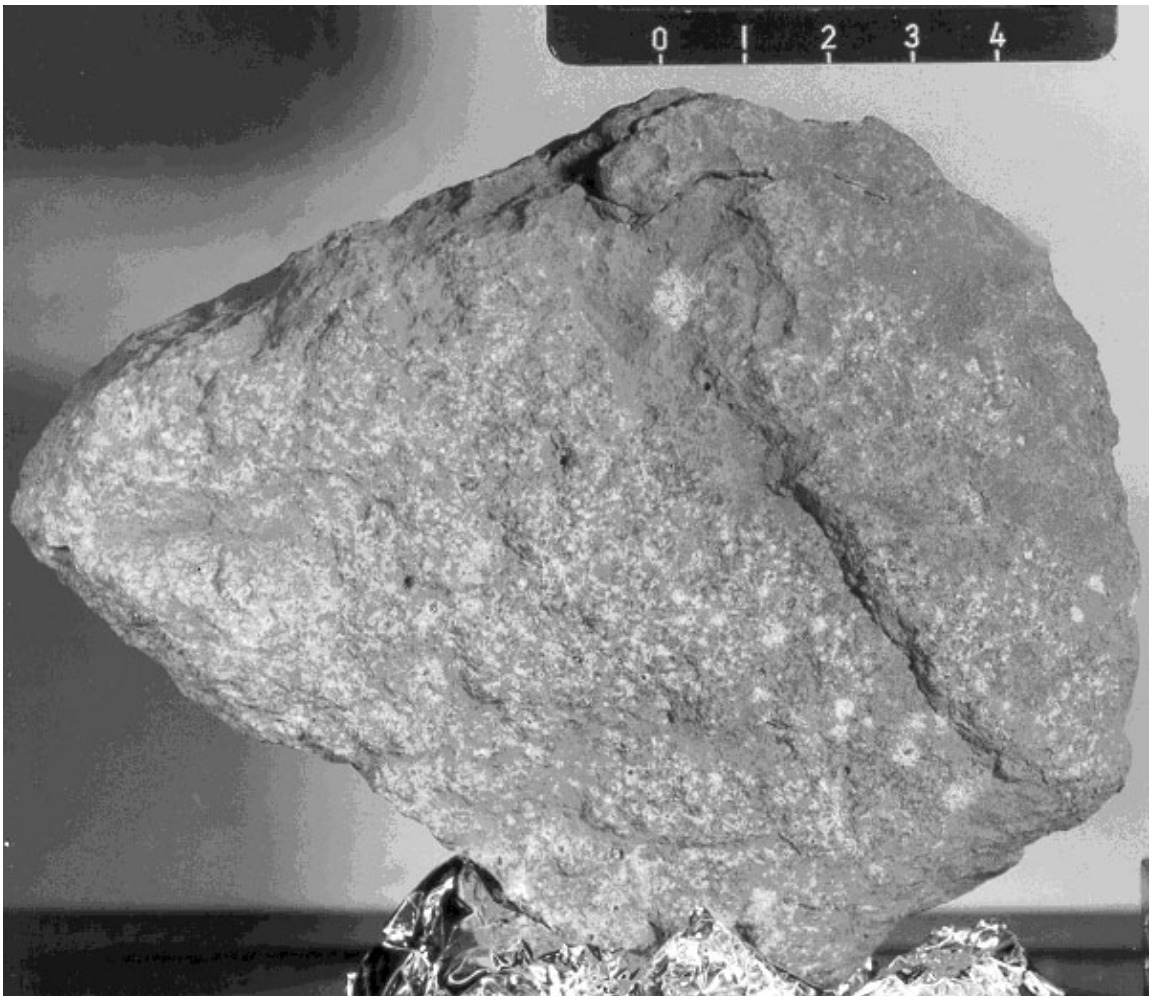


Figure 1: Photo of top surface of 60315. Scale is in cm. Note the many zap pits on this surface. NASA S72-41576.

Introduction

60315 is a flat rock, about 4 cm thick, found loose on the regolith near the LM. The top exposed surface is covered with micrometeorite craters (figure 1). The bottom surface is freshly broken and free of zap pits.

60315 is holocrystalline and dense (almost igneous), but contains significant siderophile content and relict anorthite xenocrysts indicating that it is a recrystallized impact melt. It has a poilkilitic texture where large oikocrysts of pyroxene enclose smaller plagioclase and olivine crystals.

The sample is 3.93 ± 0.01 b.y. old and has been exposed on the surface to cosmic rays for only ~ 4.5 m.y.

Petrography

Bence et al. (1973), Simonds et al. (1973), Hodges and Kushiro (1973) and Walker et al. (1973) each describe the poikilitic texture of 60315 (figure 2). Vaniman and Papike (1981) also provide a mode and mineral compositions for 60315. All note that 60315 is composed of a mesh of relatively large oikocrysts of orthopyroxene (Wo_4En_{80}) which enclose abundant laths and clasts of plagioclase, rare olivine and opaques.

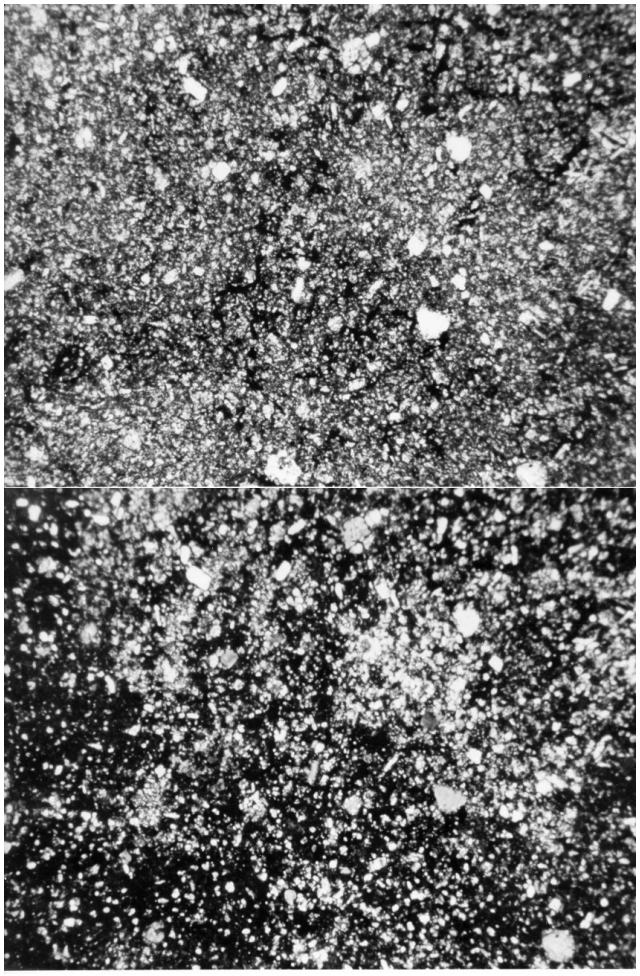


Figure 2: Photomicrographs of thin section of 60315 illustrating poikilitic texture. Field of view is 1.7 mm. Top is plane polarized light; bottom is crossed-polarized. NASA S72-42235 and 42236.

Augite, olivine, ilmenite and armalcolite rim some oikocrysts and/or make up the intersticies between oikocrysts. Rounded vesicles are common.

Bence et al. (1973) also noted some areas with diabasic texture. However, these are all small in size (Hodges and Kushiro).

60315 is similar to 65015, 62235 and 62295 which were originally collectively termed "very high Al_2O_3 (VHA) basalts" by Hubbard et al. (1973a). However, this was refuted by Dowty et al. (1974d). The phase relations of a melt with this composition were worked out by Ford et al. (1974) and Walker et al. (1973), who determined that a liquid with this composition was not on the coetectic. Ridley and Adams (1976) compared the equilibrium temperature for pyroxene and olivine (~1000 deg. C) with that of metal (~600 deg. C).

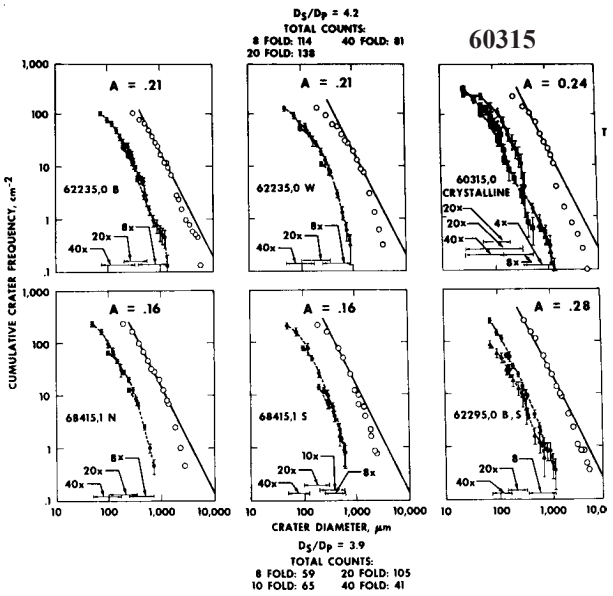


Figure 3: Crater-count size distribution for exposed surfaces on "crystalline" rocks from Apollo 16 including 60315 (by Neukem et al. 1973).

Neukem et al. (1973) and Fectig et al (1974) have studied the size distribution of micrometeorite craters (figure 3).

Mineralogy

Olivine: Olivine is generally small and rounded Fo_{75-71}. Bence et al. (1973) found that olivine found included in augite or orthopyroxene was slightly more mafic (figure 4).

Pyroxene: The largest grains in 60315 are orthopyroxene oikocrysts. Minor augite is enclosed (figure 4).

Plagioclase: Plagioclase clasts (chadocrysts) in 60315 have calcic cores (An_{97-95}) with narrow rims (An_{92}). Interstitial plagioclase ranges down to An_{78}. Meyer (1979) determined the trace element content of plagioclase chadocrysts by ion probe.

Mineralogical Mode for 60315

	Simonds et al. 1973	Vaniman and Papike 1981
Plagioclase	55 %	46.2 %
Augite	4	4.9
Orthopyroxene	34	39
Olivine	6	7.1
Opaque	1	2.1
Metal		0.7

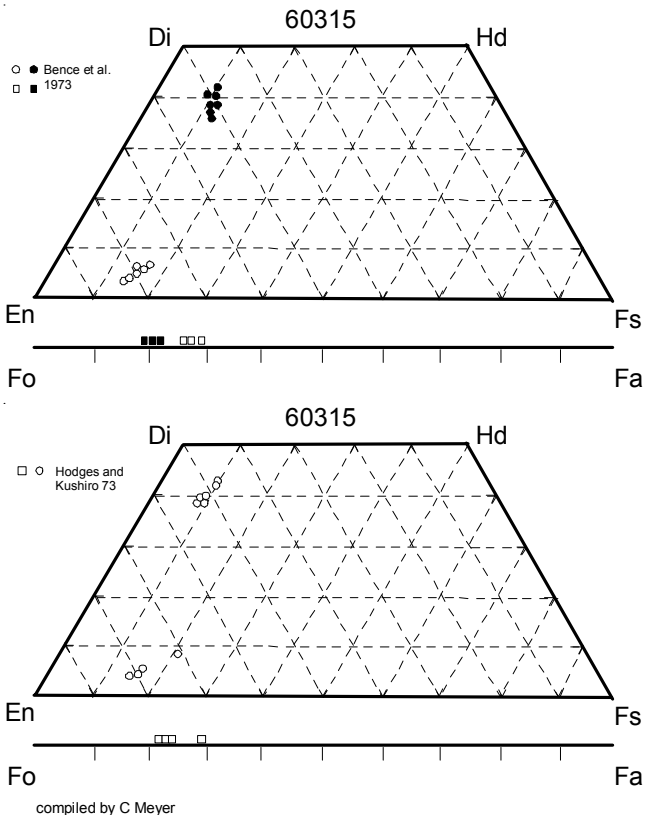


Figure 4: Pyroxene and olivine composition of 60315 (data replotted from Bence et al. and Hodges and Kushiro 1973).

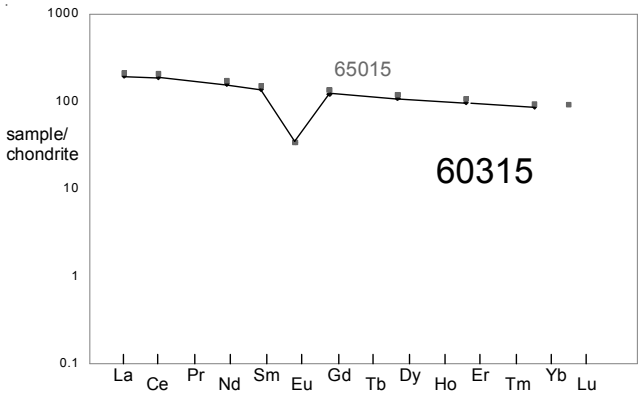


Figure 5: Normalized rare-earth-element composition of 60315 (connected dots) compared with that of 65015 (pink squares). All data by isotope dilution mass spectroscopy (Weismann and Hubbard 1977).

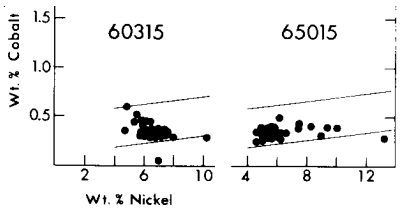


Figure 6: Ni and Co content of metallic iron grains in 60315 compared with 65015 (from Misra and Taylor 1975).

Ilmenite: Ilmenite laths are found in the interstitial areas. Hodges and Kushiro (1973) determined 7-8% MgO in ilmenite.

Metallic iron: Rounded grains of metal (up to 2 mm in dia.) with ~5% Ni are found in interstitial areas (Hodges and Kushiro 1973). Taylor et al. (1973) and Misra and Taylor (1975) determined the composition of metallic iron found in 60315 (Co=0.34%, Ni=6.7%, P=0.26% and S=0.01%)(figure 6). Hunter and Taylor (1981) report "abundant" schreibersite and only minor rust(?).

Chemistry

Rose et al. (1973) and others found high Ni contents in 60315. Ganapathy et al. and others found high Ir and Au.

The composition of 60315 is very similar to that of other Apollo 16 impact melt rocks (e.g. 65015). It has high rare-earth-element content with a KREEP-like pattern (figure 5).

Radiogenic age dating

Kirsten et. al. (1973)(figure 7) and Husain and Schaeffer (1973) (figure 8) determined the age of 60315, which was in agreement with the precise Pb/Pb isochron determined by Nunes et al. (1973) (figure 9).

Cosmogenic isotopes and exposure ages

The relatively young exposure age ^{37}Ar of 4.5 ± 0.1 m.y. for 60315 led Kirsten et al. (1973) to assign this to the age of a 27 meter-sized crater nearby, or possibly, to South Ray Crater (same age). Eldridge et al. (1973) determined the cosmic-ray-inducted activity of ^{26}Al = 92 dpm/kg. and ^{22}Na= 47 dpm/kg.

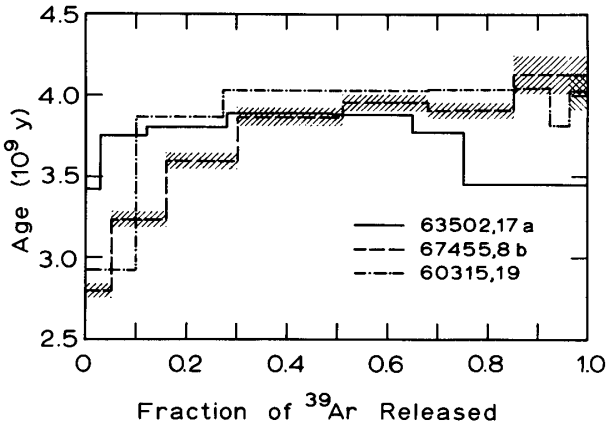


Figure 7: Ar/Ar plateau diagram for 60315 and other samples (from Kirsten et al. 1973).

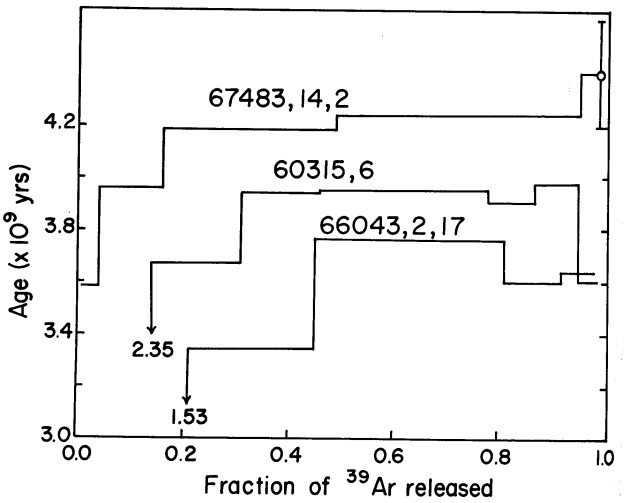


Figure 8: Ar/Ar plateau diagram for 60315 and other samples (from Husain and Schaeffer 1973).

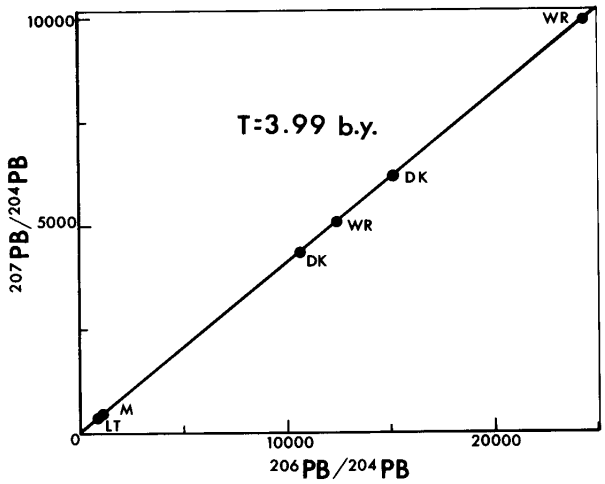


Figure 9: Pb/Pb isochron diagram for 60315 (from Nunes et al. 1973).

Other Studies

Brecher et al. 1973	magnetics
Charette and Adams 1977	spectra
Chung and Westphal 1973	electrical properties
Fechtig et al. 1974	microcraters
Ford et al. 1974	phase diagram
Flory et al. 1973	volatile organics
Hertogen et al. 1977	siderophiles
Hewins and Goldstein 1975	metal
Huffman et al. 1974	Mossbauer
Huffman and Dunmyre 1975	Mossbauer
Mitzutani and Newbigging 1973	seismic wave velocities
Nagata et al. 1973	magnetics
Nagel 1975	microcraters
Nash and Haselton 1975	silica activity
Neukum et al. 1973	microcraters
Nyquist et al. 1973	Sr isotopes
Sato 1976	oxygen fugacity
Scherer and Nagata 1976	magnetics
Tsay and Bauman 1977	electron spin resonance
Ridley and Adams 1976	metal
Reed and Taylor 1974	metal
Walker et al. 1973	phase diagram

Processing

The west end was cut off; followed with a slab which was subdivided (figure 11).

Summary of Age Data for 60315

	Ar/Ar	Pb/Pb
Kirsten et al. 1973	4.03 ± 0.03 b.y.	
Husain and Schaeffer 1973	3.94 ± 0.05	
Schaeffer et al. 1976	3.91 ± 0.02	
Nunes et al. 1973		3.99 ± 0.01
Nunes 1975		3.93

Table 1a. Chemical composition of 60315.

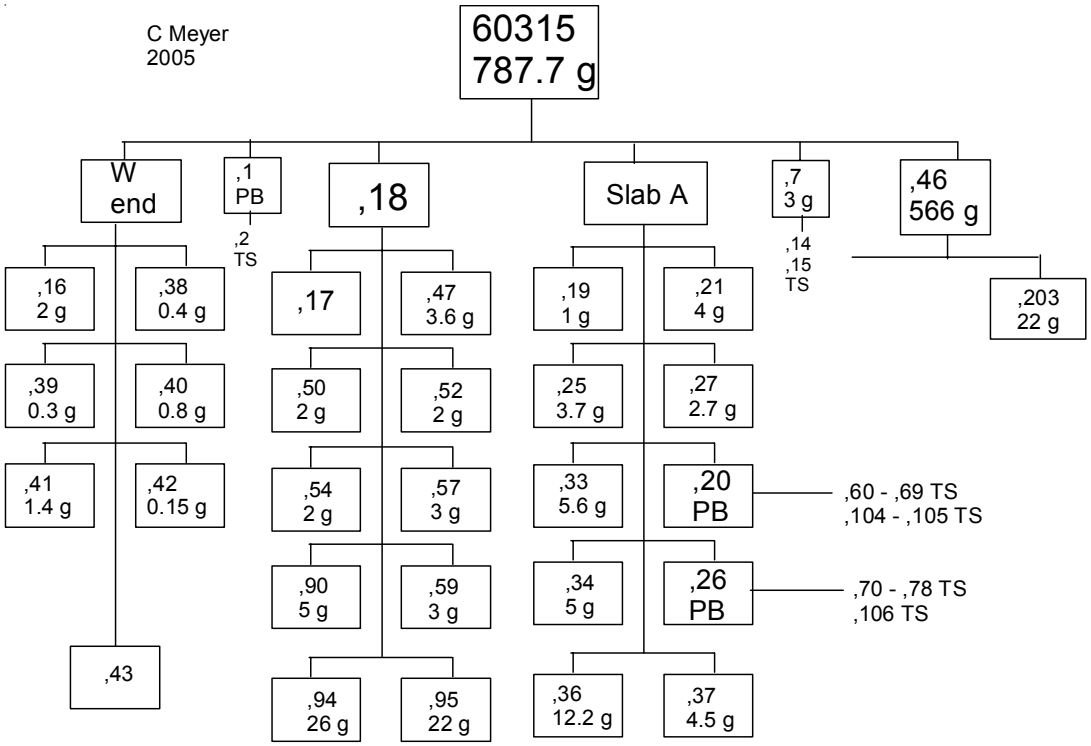
reference	*LSPET 73*		Rose 73		Hubbard 73		Hubbard 73		Morrison 73		Taylor 73		Laul 74		Eldridge 73	
weight													44 mg			
SiO2 %	45.61	(b)	46.75	(a)	46.84	(b)					46.4	(g)				
TiO2	1.27	(b)	1.38	(a)	1.39	(b)	1.26	(c)	1	(d)	1.29	(g)	1.3	(e)		
Al2O3	17.18	(b)	17.1	(a)	17.24	(b)	17.7		16.5		17.6	(g)	17	(e)		
FeO	10.53	(b)	8.64	(a)	8.86	(b)	10.3		9.83		7.98	(g)	10.4	(e)		
MnO	0.12	(b)	0.11	(a)	0.12	(b)			0.11				0.112	(e)		
MgO	13.15	(b)	13.42	(a)	13.81	(b)	13.3	(c)	11.1		13.3	(g)	14	(e)		
CaO	10.41	(b)	10.5	(a)	10.5	(b)	10.1	(c)	10		10.4	(g)	9.4	(e)		
Na2O	0.56	(b)	0.61	(a)	0.51	(b)	0.55		0.62		0.63	(g)	0.76	(e)		
K2O	0.35	(b)	0.49	(a)	0.39	(b)	0.36	(c)	0.37		0.42	(g)	0.42	(e)	0.38	(f)
P2O5	0.45	(b)	0.48	(a)	0.48	(b)			0.57							
S %	0.14	(b)			0.14	(b)			0.105							
sum																
Sc ppm			20	(a)					13.4		9	(g)	14	(e)		
V			47	(a)					31		40	(g)	50	(e)		
Cr	1460	(b)	1642	(a)			1477	(c)	1300		800	(g)	1498	(e)		
Co			48	(a)					89		22	(g)	88	(e)		
Ni	191	(b)	810	(a)					1380		390	(g)	1400	(e)		
Cu			11	(a)					10.8		3.9	(g)				
Zn			12	(a)					8							
Ga			4.6	(a)					4.1							
Ge ppb																
As																
Se																
Rb	9.8	(b)	11	(a)			9.8	(c)	9		7.7	(g)				
Sr	156	(b)	135	(a)			156	(c)	156							
Y	142	(b)	140	(a)					120		131	(g)				
Zr	640	(b)	1370	(a)					840		630	(g)	640	(e)		
Nb	37	(b)	60	(a)					33		39	(g)				
Mo																
Ru																
Rh																
Pd ppb																
Ag ppb																
Cd ppb																
In ppb																
Sn ppb											0.4	(g)				
Sb ppb																
Te ppb																
Cs ppm									0.05		0.4	(g)				
Ba			550	(a)			445	(c)	466		560	(g)	460	(e)		
La			61	(a)			45.5	(c)	37		49	(g)	50	(e)		
Ce							113	(c)	98		123	(g)	120	(e)		
Pr											18	(g)				
Nd							71.3	(c)	47		73.6	(g)	73	(e)		
Sm							20.1	(c)	25		21.1	(g)	21.5	(e)		
Eu							1.89	(c)	1.6		2.18	(g)	1.9	(e)		
Gd							23.8	(c)	16		28	(g)				
Tb									3.7		4.13	(g)	4.4	(e)		
Dy							26.3	(c)	26		26.6	(g)	29	(e)		
Ho									3		6.17	(g)				
Er							15.5	(c)			17.7	(g)				
Tm									1.4		2.7	(g)				
Yb			16	(a)			14	(c)	12		16.3	(g)	15	(e)		
Lu									2.1		2.5	(g)	2.1	(e)		
Hf									13		14.5	(g)	16	(e)		
Ta													2	(e)		
W ppb																
Re ppb																
Os ppb																
Ir ppb													35	(e)		
Pt ppb																
Au ppb													30	(e)		
Th ppm	7.2	(b)							9.2		8.2	(g)	8.1	(e)	8.56	(f)
U ppm							2.05	(c)	2		2.3	(g)	1.7	(e)	2.34	(f)

technique (a) combined XRF, OES, (b) XRF, (c) IDMS, (d) (e) INAA, (f) radiation counting

Table 1b. Chemical composition of 60315.

reference	Wanke 76			Nyquist 73		Nunes 73			Ganapathy 74	
weight	,87	,103								
SiO2 %	46.9	46.6								
TiO2	1.37	1.37								
Al2O3	17.1	17.5								
FeO	8.4	8.6								
MnO	0.11	0.12								
MgO	13.6	13.4								
CaO	10.5	10.7								
Na2O	0.63	0.63								
K2O	0.37	0.38								
P2O5	0.44	0.45								
S %	0.1	0.09								
sum										
Sc ppm	15.7	15.1	(e)							
V										
Cr	1560	1510	(e)							
Co	37.5	35.8	(e)							
Ni	710	690	(e)						798	(e)
Cu		18.6	(e)							
Zn		2.37	(e)						0.3	(e)
Ga		3.85	(e)							
Ge ppb		600	(e)						625	(e)
As		340	(e)							
Se		440	(e)						520	(e)
Rb		9.54	(e)	9.8	(c)				10.8	(e)
Sr	160	159	(e)	156	(c)					
Y	123	131	(e)							
Zr	744	720	(e)							
Nb	27	31	(e)							
Mo										
Ru										
Rh										
Pd ppb										
Ag ppb									0.94	(e)
Cd ppb									5	(e)
In ppb										
Sn ppb										
Sb ppb									11	(e)
Te ppb									4.7	(e)
Cs ppm	0.55	0.58	(e)						0.54	(e)
Ba	475	479	(e)							
La	49.6	49.6	(e)							
Ce	142	136	(e)							
Pr		19.2	(e)							
Nd	87	88	(e)							
Sm	20.8	20.6	(e)							
Eu	1.94	1.95	(e)							
Gd		26	(e)							
Tb	4.6	4.67	(e)							
Dy	26.7	28.5	(e)							
Ho	5.8	6	(e)							
Er		18	(e)							
Tm										
Yb	16	15.8	(e)							
Lu	2.16	2.1	(e)							
Hf	17.1	17.1	(e)							
Ta	2.05	1.96	(e)							
W ppb		488	(e)							
Re ppb		1.3	(e)						1.36	(e)
Os ppb										
Ir ppb	8.5	9.4	(e)						11	(e)
Pt ppb										
Au ppb		16.7	(e)						18.3	(e)
Th ppm	6.82	6.84	(e)			8.164	7.712	(c)		
U ppm	1.82	2.19	(e)			2.221	2.064	(c)	2.28	(e)

technique: (c) IDMS, (e) INAA, RNAA


C Meyer
2005
60315
787.7 g
W end
,1 PB
,2 TS
,18
Slab A
,7 3 g
,14 ,15 TS
,46 566 g
,16 2 g
,38 0.4 g
,17
,47 3.6 g
,19 1 g
,21 4 g
,203 22 g
,39 0.3 g
,40 0.8 g
,50 2 g
,52 2 g
,25 3.7 g
,27 2.7 g
,41 1.4 g
,42 0.15 g
,54 2 g
,57 3 g
,33 5.6 g
,20 PB
,60 - ,69 TS
,104 - ,105 TS
,90 5 g
,59 3 g
,34 5 g
,26 PB
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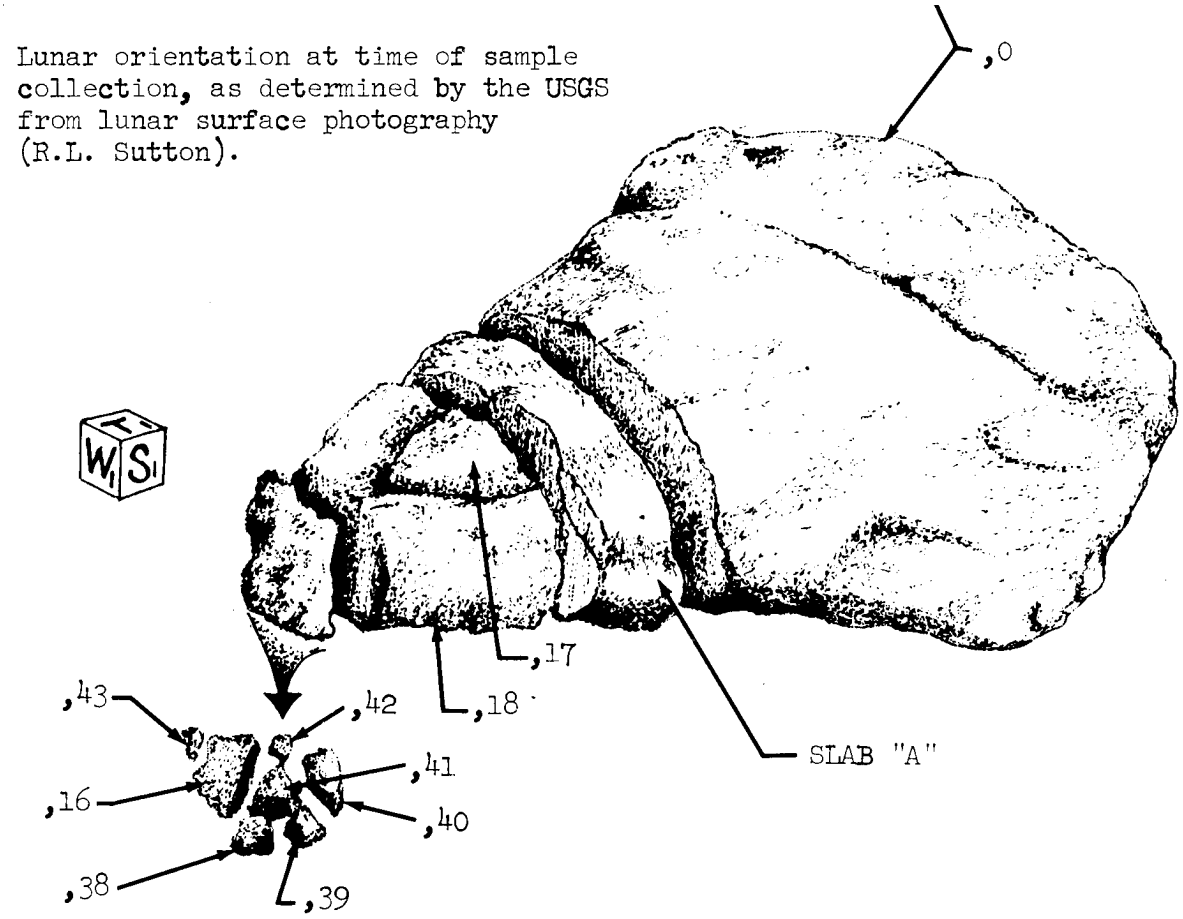
,94 26 g
,95 22 g
,36 12.2 g
,37 4.5 g


Lunar orientation at time of sample collection, as determined by the USGS from lunar surface photography (R.L. Sutton).
,0
W1
S1
,17
,18
SLAB "A"
,43
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,41
,16
,40
,38
,39

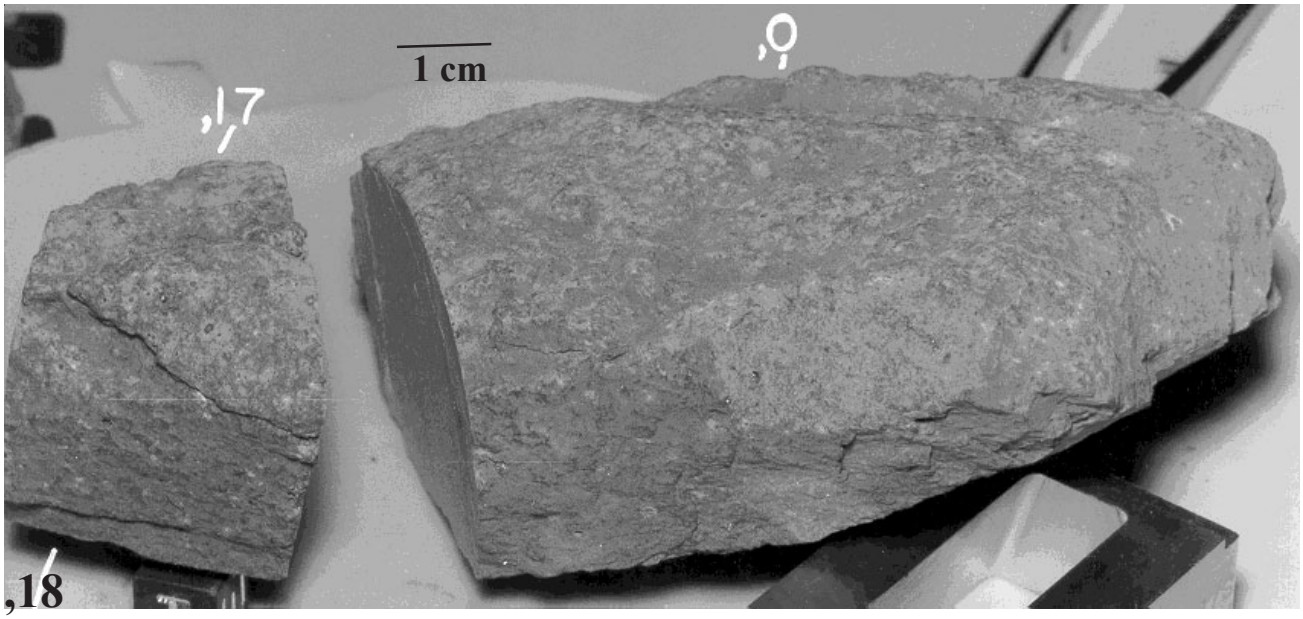

Figure 10: Second sawcut of 60315, before cutting slab. NASA S72-51834.

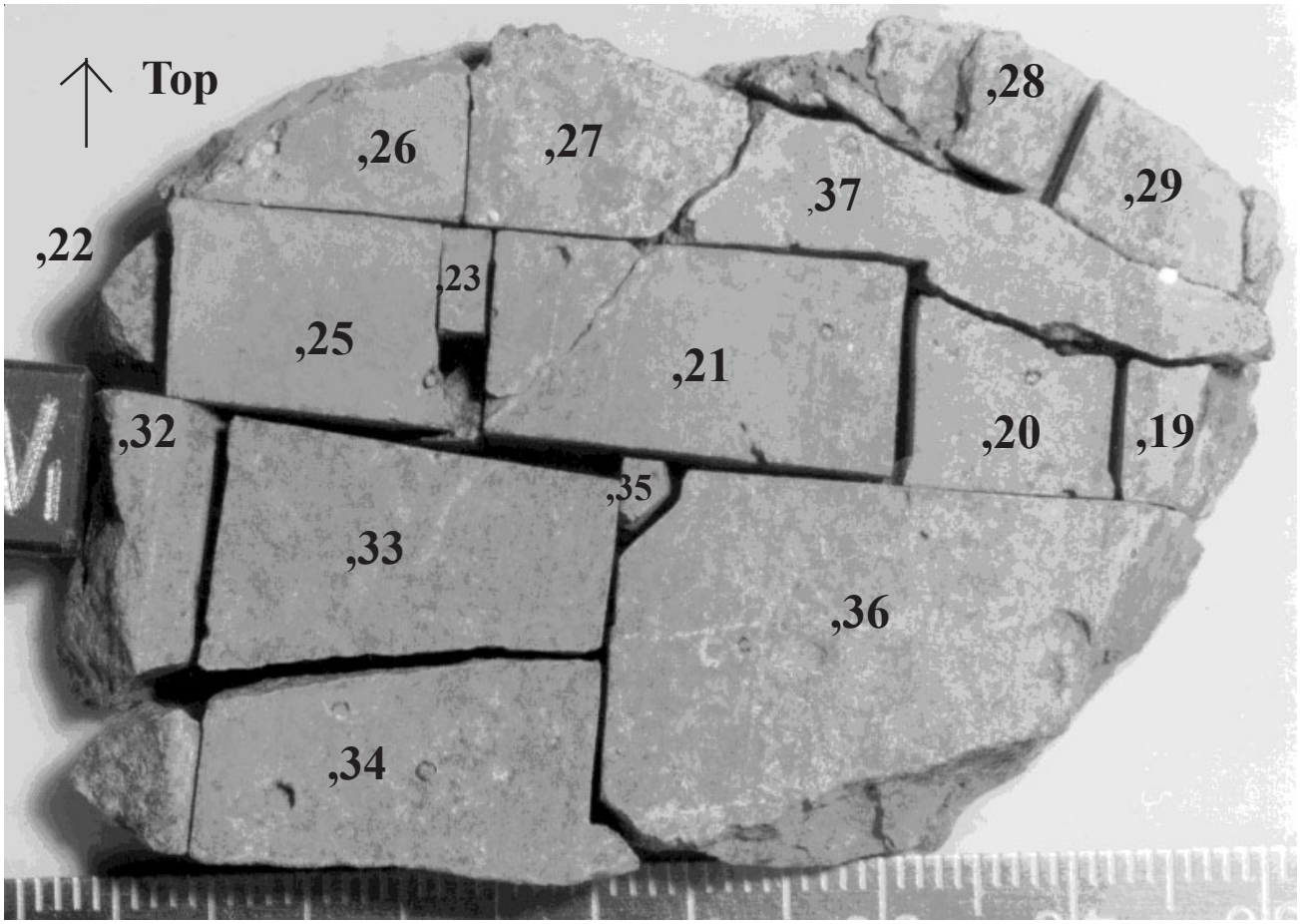

Figure 11: Slab of 60315. NASA S72-51843. Scale in cm and mm. Slab is about 1 cm thick.