65015

DRAFT

Poikilitic Impact Melt Breccia

1802 grams

Figure 1: Photo of 65015 showing rounded exposed surface with numerous zap pits and angular portion without zap pits protected by burial in soil. NASA photo # S72-43936. Cube and scale are 1 cm.

Introduction

Sample 65015 was collected from the lower slope of Stone Mountain. It was about half buried in the soil, as judged by the obvious "soil line", below which there are no micrometeorite pits (figure 1-3). It is a very coherent, dense rock with little void space.

The research on 65015 is well summarized by Ryder and Norman (1980).

Petrography

65015 is a feldspathic impact melt characterized by a well developed poikilitic texture in which oikocrysts of pyroxene enclose abundant clasts and chadocrysts (figures 5-7). Most, but not all, of the chadocrysts are plagioclase. Albee et al. (1973) also report numerous relict lithic fragments as clasts in 65015.

Large interlocking oikocrysts of pyroxene (up to 0.6 mm) dominate the texture (figures 6-7). Boundaries between the oikocrysts are characterized by lath-shaped plagioclase intergrown with granular olivine and accessory ilmenite, Fe-Ni metal, troilite, phosphates and K-feldspar. The ilmenite (0.2 mm) occurs in chains and is itself poikilitic. Abundant plagioclase grains (up to 1.5 mm), occurring as chadocrysts throughout the rock, are found to be very calcic (An_{93-95}). Papanastassiou and Wasserburg (1973) and Meyer et al. (1974) found that the large plagioclase grains were not in equilibrium with the trace element content of the bulk sample.

The rock has a high content of trace elements and meteoritic siderophiles (Ni, Ir, Au). Wasson et al. (1975) found that the ratios of siderophile elements in metal grains separated from the rock were different from those in the bulk rock.

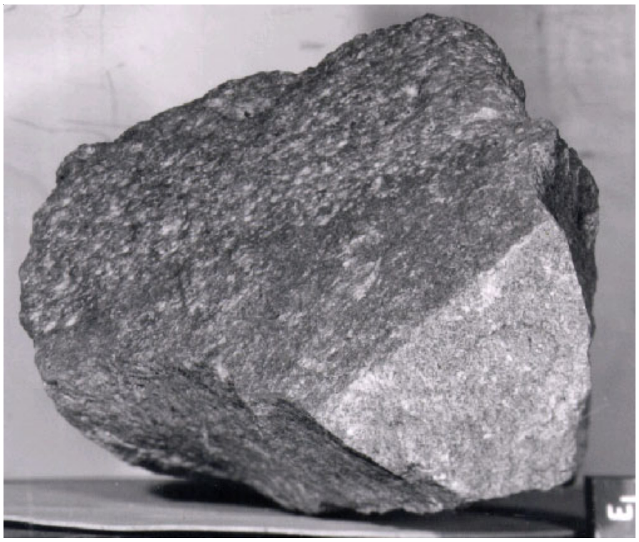


Figure 2: End view of 65015 showing angular surface that was buried in the soil. NASA # S72-43935

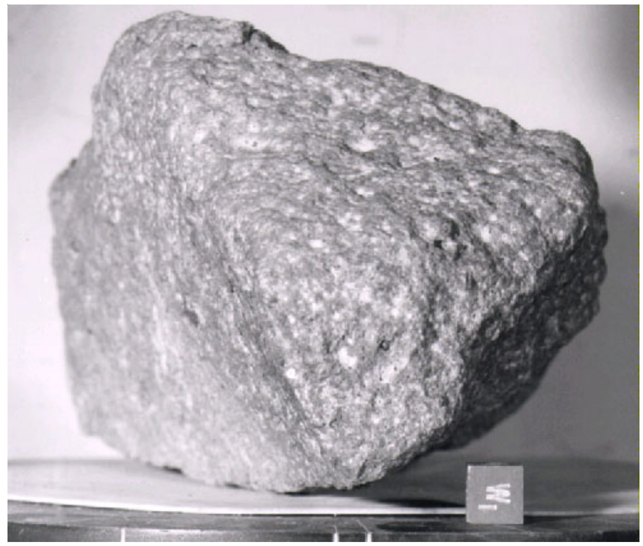


Figure 3: End view of 65015 illustrating rounding caused by micrometeorite bombardment. NASA # S72-43939

Mineralogical Mode

	Albee et al. 1973	Simonds et al. 1973
Plagioclase	57.1 vol. %	61
Low-Ca pyroxene	28.9	29
High-Ca pyroxene	6.4	6
Olivine	1.1	1
Opaques	1.7	3
Mesostasis	3.6	
Whitlockite	0.7	

The distinctive poikilitic texture of this rock, the inclusion of relict lithic and mineral clasts and the high meteoritic siderophile content are also common features of the Apollo 17, Boulder 6 samples as well as the melt sheets found in large terrestrial craters. Simonds et al. (1976) modeled the formation of these rocks as a mix of impact melt and cold clastic material.

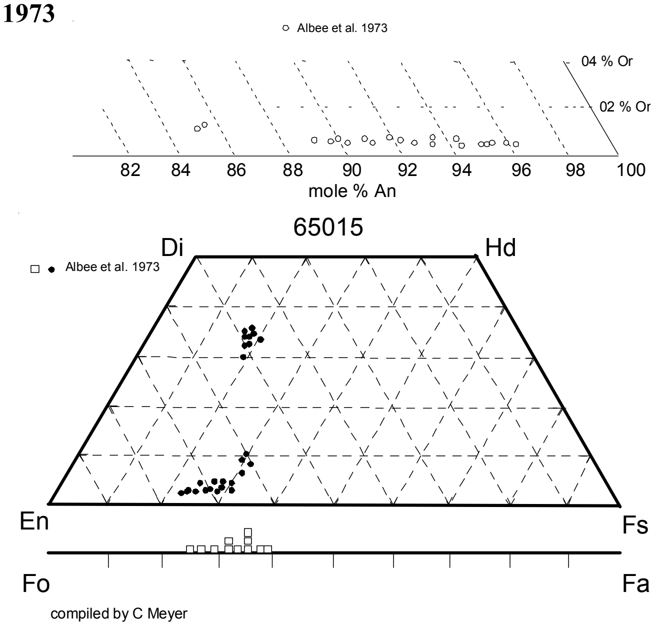


Figure 4: Plagioclase, pyroxene and olivine composition for 65015 (data replotted from Albee et al. 1973).

Mineralogy

Olivine: Relict, partially reacted, olivine grains (Fo_{65-74}) are reported by Albee et al. (1973)

Pyroxene: Albee et al. (1973) determined the chemical composition of pyroxene in 65015 (figure 4). The low-Ca pyroxene occurs as large oikocrysts and is generally homogenous. The high-Ca pyroxene is found in the intergranular regions and in clasts and is somewhat variable in composition.

Plagioclase: Abundant plagioclase grains (up to 1.5 mm) occur as chadocrysts throughout the rock and are found to be very calcic (An_{93-95}). Laths of plagioclase (An_{85-90}) are found in the mesostasis between the oikocrysts (figure 4). Albee et al. (1973) found that the trace FeO content of the plagioclase in the clasts was lower than for the plagioclase in the groundmass. Meyer et al. (1974) found that the trace element (Li, Ba etc) content of the plagioclase phenocrysts was well below the level expected for plagioclase in equilibrium with the bulk rock content. Papanastassiou and

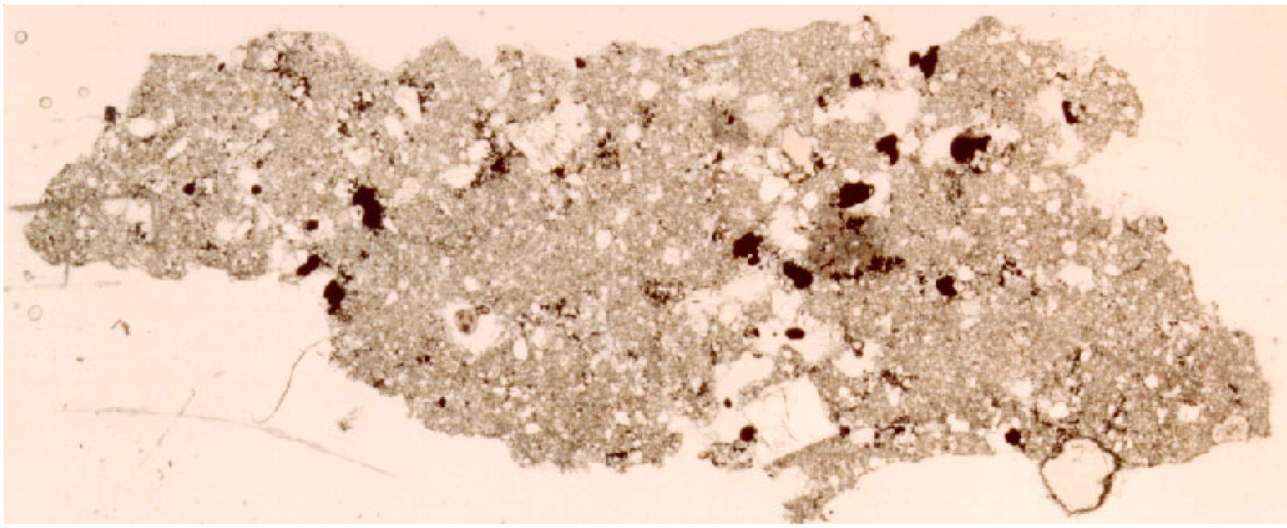


Figure 5: Thin section of 65015. Field of view about 1 inch.

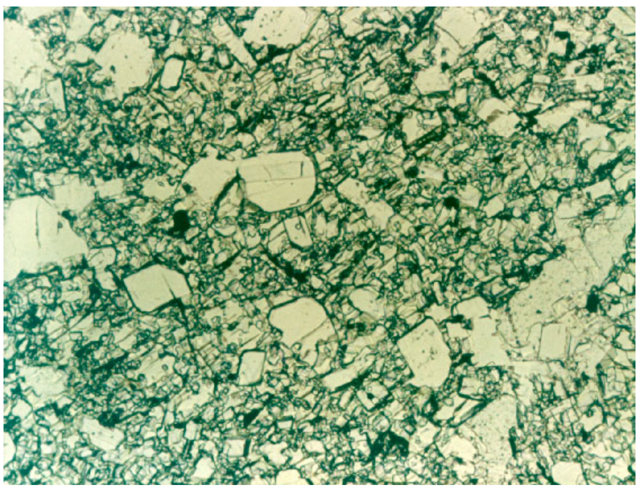


Figure 6: Closeup photomicrograph of thin section of 65015 in plain polarized light. Field of view is about 5 mm.

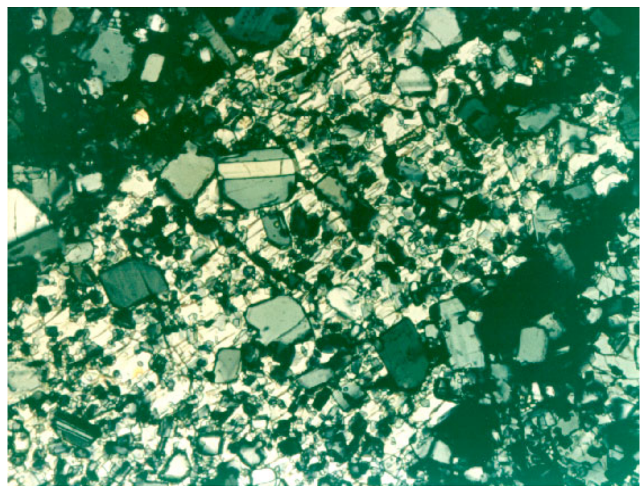


Figure 7: Same area as figure 6, but with crossed polarizers, illustrating large oikocryst of low-Ca pyroxene enclosing numerous chadocrysts of plagioclase.

Wasserburg (1972) also showed that the plagioclase was not in isotopic equilibrium (figure 10).

Ilmenite: Ilmenite occurs as irregular poikilitic grains intergrown with other minor phases in the mesostasis (figure 8). It rarely has exsolution of rutile, baddeleyite and Cr-rich spinel (Albee et al. 1973).

Metal: El Goresy et al. (1973), Albee et al. (1973) and Misra and Taylor (1975) analyzed the Fe-metal grains (including one large ball, 400 microns) and found they were generally homogeneous 5-6% Ni, 0.2-0.3% Co, 0.12% P and 0.01 % S. Taylor et al. (1976) found that this composition did not change during annealing experiments.

Whitlockite: Long needles (40 microns) of whitlockite are the only phosphate (Albee et al. 1973).

Chemistry

Hubbard et al. (1973), Haskin et al. (1973), Wanke et al. (1977) and others have analyzed 65015 (table 1). The rare earth elements are in high abundance and similar to KREEP (figure 9). The meteoritic siderophiles are relatively high (Ir > 10 ppb) indicating that this is not a pristine rock, but rather an impact melt (Krahenbuhl et al. 1973, Wanke et al. 1977) contaminated with a significant meteoritic component.

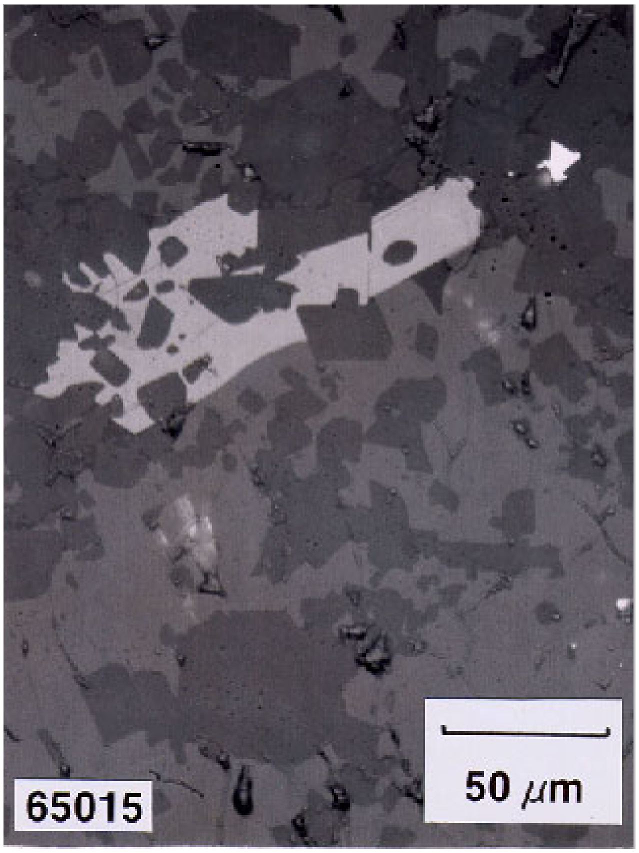


Figure 8: Ilmenite and metal grains in 65015. Reflected light photo of polished thin section.

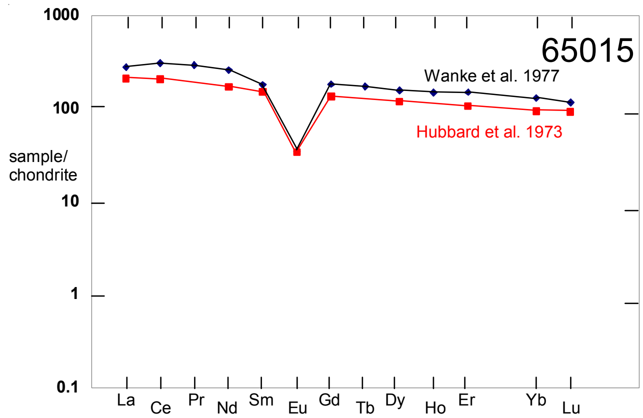


Figure 9: Normalized rare-earth-element diagram for 65015 (data from table 1).

Radiogenic age dating

Because of the included old component, it has proven difficult to accurately date 65015. Papanastassiou and Wasserburg (1972) found that the plagioclase separates were not on the isochron defined by quintessence and whole rock (figure 10). But these and various other investigators (figure 11) have concluded that 65015 was last melted or "metamorphosed" at about 3.9 b.y. (see table).

Lugmair and Carlson (1978) determined a "model age" of 4.32 ± 0.12 b.y. by Sm-Nd. Nunes et al. (1973) found that U/Pb ages were concordant at 3.99 b.y. and that initial Pb was extremely low. Schaeffer et al. (1978, 1979) studied laser extraction of Ar.

Cosmogenic isotopes and exposure ages

Kirsten et al. (1973) reported a cosmic ray exposure age of 365 ± 20 m.y. for 65015 by the ^{38}Ar method. Jessberger et al. (1974) found it to be about 490 m.y. Bhandari et al. (1973) determined the "suntan" age as 1.2 m.y. by track studies.

Other Studies

Sato (1976) measured the in-situ oxygen fugacity as a function of temperature.

The magnetic properties were studied by Brecher (1977) and Stephenson et al. (1977); electrical properties were determined by Olhoeft et al. (1973) and Alvarez (1977); thermal expansion by Todd et al. (1973); electron spin resonance by Tsay and Live (1974) and ultraviolet reflectance spectra by Hapke et al. (1978).

Processing

In 1972 a small slab was cut from this rock (figure 12). Allocations were also made from the small butt end.

List of Photo #s 65015

S72-39208-39213	Color
S72-43925-43940	B & W (in focus)
S72-47353-47376	slab parts
S76-23580	1st cut
S76-23578	2nd cut

Table 1a. Chemical composition of 65015.

reference	Hubbard 73		Hubbard 73		Duncan 73		Haskin 73		Krahenbuhl 73		Boynton 75	Wasson 77	Wanke 77	Garg 76
weight														
SiO2 %	47.18	(a)			46.99	(a)	47.6	(b)					46.77	
TiO2	1.04	(a)	1.1	(d)	1.26	(a)	1.23	(b)			1.2	1.22	1.27	
Al2O3	19.98	(a)	23.2	(c)	19.68	(a)	19.5	(b)			20.03	20.6	19.33	
FeO	7.91	(a)	8.71	(b)	8.59	(a)	8.52	(b)			7.98	8.33	8.81	
MnO	0.12	(a)			0.112	(a)	0.11				0.13	0.11	0.11	
MgO	10.34	(a)	9.5	(b)	9.31	(a)	9.66	(b)				8.34	9.61	
CaO	12.03	(a)	12	(b)	11.9	(a)	12.3	(b)			12.73	11.75	11.98	
Na2O	0.44	(a)	0.59	(b)	0.55	(a)	0.57				0.63	0.52	0.57	
K2O	0.32	(a)	0.34	(d)	0.36	(a)	0.35	(b)					0.36	
P2O5	0.4	(a)			0.409	(a)							0.39	
S %	0.13	(a)			0.079	(a)							0.139	
sum	99.89				99.24								99.339	
Sc ppm							14.9	(e)			17	16.1	17.1	
V												40	36.7	
Cr			2350	(d)			1280	(e)			1270	1320	1300	
Co							27.1	(e)				49	42.6	
Ni					185	(a)	400	(e)	580	(f)	30		730	
Cu					1.8	(a)							5.06	
Zn									0.48	(f)			1.46	
Ga							4.25	(e)					3.81	
Ge ppb									380	(f)			600	
As													0.17	
Se									0.245	(f)			0.29	
Rb			9.09	(d)	9.55	(a)	9.2	(e)	7.8	(f)			10.2	
Sr			164	(d)	157	(a)							146	
Y					179	(a)							174	
Zr					909	(a)						920	940	933
Nb					55.2	(a)								
Mo														
Ru														
Rh														
Pd ppb														
Ag ppb									1.5	(f)				
Cd ppb									9.25	(f)				
In ppb														
Sn ppb														
Sb ppb									4.34	(f)				
Te ppb									3.25	(f)				
Cs ppm							0.42	(e)	0.405	(f)			0.423	
Ba			492	(d)	609						460	560	570	
La			49.5	(d)			60	(e)			47	55.6	65.5	
Ce			125	(d)			153	(e)			180	132	185	
Pr							98	(e)					26	
Nd			78	(d)								80	118	
Sm			22.2	(d)			26.5	(e)			35	24.8	26.7	
Eu			1.91	(d)			2.12	(e)			2.28	2.1	1.97	
Gd			26.6	(d)			33	(e)					36	
Tb							5.2	(e)			5.4	5.2	6.28	
Dy			28.8	(d)			38	(e)				33	38.1	
Ho							7.4	(e)					8.3	
Er			16.8	(d)			22	(e)					23.8	
Tm														
Yb			15.3	(d)			19.1	(e)			20.8	17.1	21.1	
Lu			2.24	(d)			2.6	(e)			2.87	2.44	2.84	
Hf							19.3	(e)			22	19.2	21.6	20.6
Ta											2.4	2.1	2.46	
W ppb													883	
Re ppb									1.16	(f)			1.8	
Os ppb														
Ir ppb									11.6	(f)			17	
Pt ppb										(f)				
Au ppb									10.2	(f)			10.9	
Th ppm											10.7	9.4	8.92	
U ppm			3.42	(d)					3.42	(f)		2.6	2.22	

technique (a) XRF, (b) AA, (c) colorimetry, (d) IDMS, (e) INAA, (f) RNAA

Table 1b. Chemical composition of 65015.

reference	Lugmair 78	Nyquist 73	Nunes 73		Ehmann 74		Miller 74		Taylor 73		LSPET 73	
weight												
SiO2 %									47.1	(g)		
TiO2									1.16	(g)		
Al2O3									20.7	(g)		
FeO							8.1	(e)	7.37	(g)		
MnO												
MgO									9.58	(g)		
CaO									11.9	(g)		
Na2O									0.52	(g)		
K2O									0.47	(g)	0.48	(h)
P2O5												
S %												
sum												
Sc ppm							14.4	(e)	9.5	(g)		
V									44	(g)		
Cr							1230	(e)	1400	(g)		
Co							30	(e)	25	(g)		
Ni									260	(g)		
Cu									6.5	(g)		
Zn												
Ga												
Ge ppb												
As												
Se												
Rb		9.09		(d)					8.3	(g)		
Sr		163.8		(d)								
Y									182	(g)		
Zr					920	1010		(e)	960	(g)		
Nb									58	(g)		
Mo												
Ru												
Rh												
Pd ppb												
Ag ppb												
Cd ppb												
In ppb												
Sn ppb									400	(g)		
Sb ppb												
Te ppb												
Cs ppm									0.35	(g)		
Ba									540	(g)		
La							56	(e)	58	(g)		
Ce									145	(g)		
Pr									21	(g)		
Nd	101			(d)					81	(g)		
Sm	28			(d)					24.5	(g)		
Eu							2	(e)	2	(g)		
Gd									32	(g)		
Tb									4.86	(g)		
Dy									30.5	(g)		
Ho									7.44	(g)		
Er									21	(g)		
Tm									3.1	(g)		
Yb									19	(g)		
Lu									2.9	(g)		
Hf					19.8	21.4		(e)	19	(g)		
Ta												
W ppb												
Re ppb												
Os ppb												
Ir ppb												
Pt ppb												
Au ppb												
Th ppm			10.32	(d)					10.4	(g)	10	(h)
U ppm			2.58	(d)					2.34	(g)	3	(h)

***technique** (a) XRF, (b) AA, (c) colorimetry, (d) IDMS, (e) INAA, (f) RNAA, (g) SSMS, (h) radiation counting*

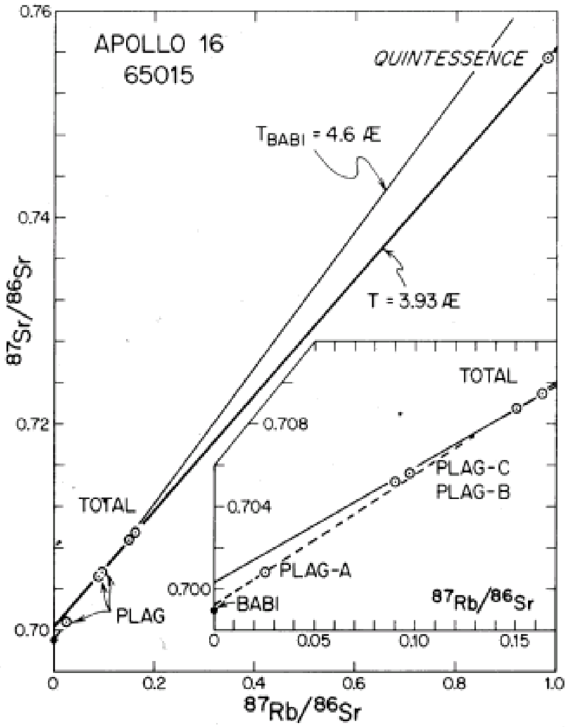


Figure 10: Rb-Sr isochron diagram for 65015 (from Papanastassiou et al. 1972).

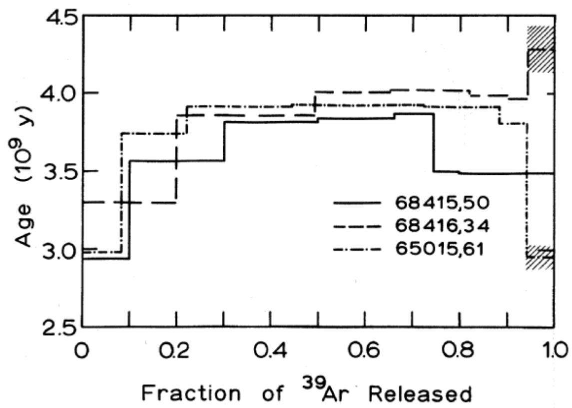
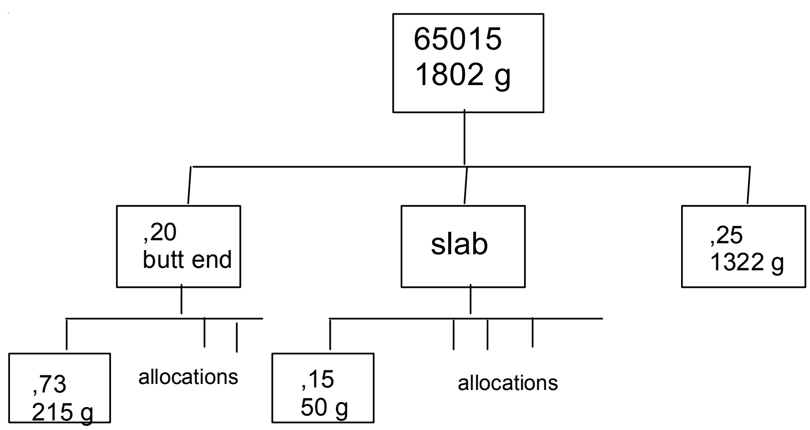


Figure 11: Ar relase pattern for 65015 (figure from Kirsten et al. 1973).



Summary of Age Data for 65015

	Ar-Ar	Rb/Sr	Sm/Nd	Pb/Pb
Papanastassiou and Wasserburg 1972		3.93 ± 0.02 b.y.		
Kirsten et al. 1973	3.92 ± 0.04			
Jessberger et al. 1974	~3.98			
Nunes et al. 1973				3.99

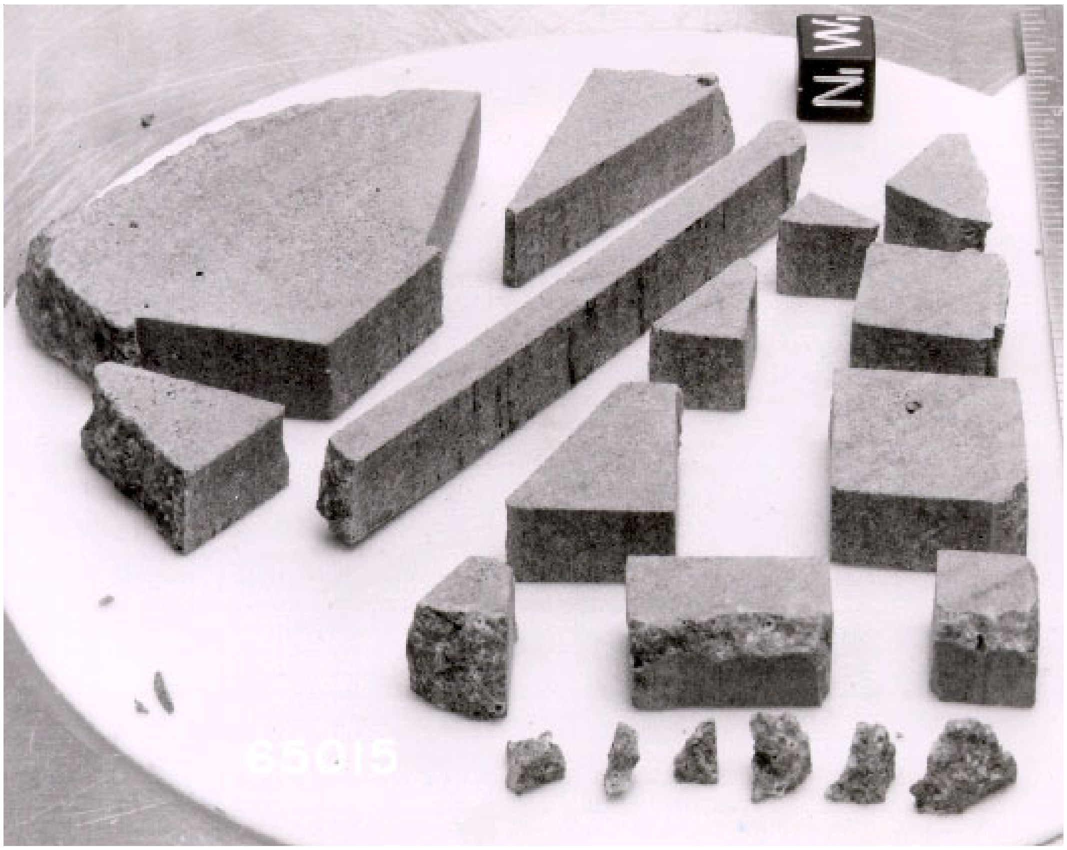


Figure 12: Group photo of pieces cut from slab of 65015. The cube is 1 cm. NASA photo # S72-47359.