64435

Revised

Breccia with glass coat

1079 grams

Figure 1: Photo of 64435. Cube is 1 cm. NASA S72-39674. Note the lack of any micrometeorite craters (see flip side, figure 2).

Introduction

64435 has a thick shiny black glass coat on one side (figure 1) and numerous micrometeorite pits on the other (figure 2) as if it had once been an impact bomb that had it glass coat eroded away on the unprotected side. 64435 is an oriented lunar sample that has been studied for cosmic ray induced activity. It contains clasts of plutonic igneous rocks (ferroan anorthosite clan) with "inverted" pigeonite.

Petrography

The majority of 64435 is a fine-grained grey impact melt that has not been described. It is found to be very aluminous in composition (Al_2O_3 = ~31%). Ryder and Norman (1980) noted that the plagioclase microlites in the matrix were often in alignment, as if by flow (figure 3). James and Flohr (1985abs) and James et al. (1989) studied a large (5x2x1 cm) coarse-grained white composite clast (CTA-A-FTA) made up of coarse troctolitic anorthosite and fine troctolitic anorthosite (see below).

Figure 2: Flip side of 64435 (see figure 1). NASA S72-39676. Cube is 1 cm. Note the abundant micrometeorite craters.

Additional data can be found in notes by Brian Mason (unpublished), Kempa and James (1982abs), Lindstrom (1984abs), James (1987abs) and the catalog by Ryder and Norman (1980).

Significant Clasts

Troctolitic Anorthosite ,239: This clast (figures 9 and 10) is coarse grained (1-4 mm) consisting of ~81% plagioclase (An_{97}), 15% olivine ($Fo_{71.5}$), 2-3% orthopyroxene ($Wo_{1.5}En_{74.5}$) and 1% augite ($Wo_{45}En_{45}$) (James et al. 1989). Noteworthy is that the pyroxene in this clast has the texture of "inverted pigeonite" indicating a slow cooling of the igneous body – as in a pluton!

Anorthosite ,210A: Clast (,210A) is about 98% plagioclase (An_{98}), 1% orthopyroxene (Wo_2En_{56}) and 1% augite ($Wo_{44}En_{39}$). Plagioclase is shocked (James et al. 1989).

Fine-grained Troctolitic Anorthosite ,207: James et al. (1989) found that the area surrounding the coarse grained clasts (above) was a fine-grained granulite with the mineralogy of a troctolitic anorthosite. It is composed of about 88% plagioclase ($An_{97.8}$) and 12 % mafic minerals (olivine $Fo_{70.6}$ and pyroxene ($Wo_{1.5}En_{72-75}$ and $Wo_{45}En_{45}$).

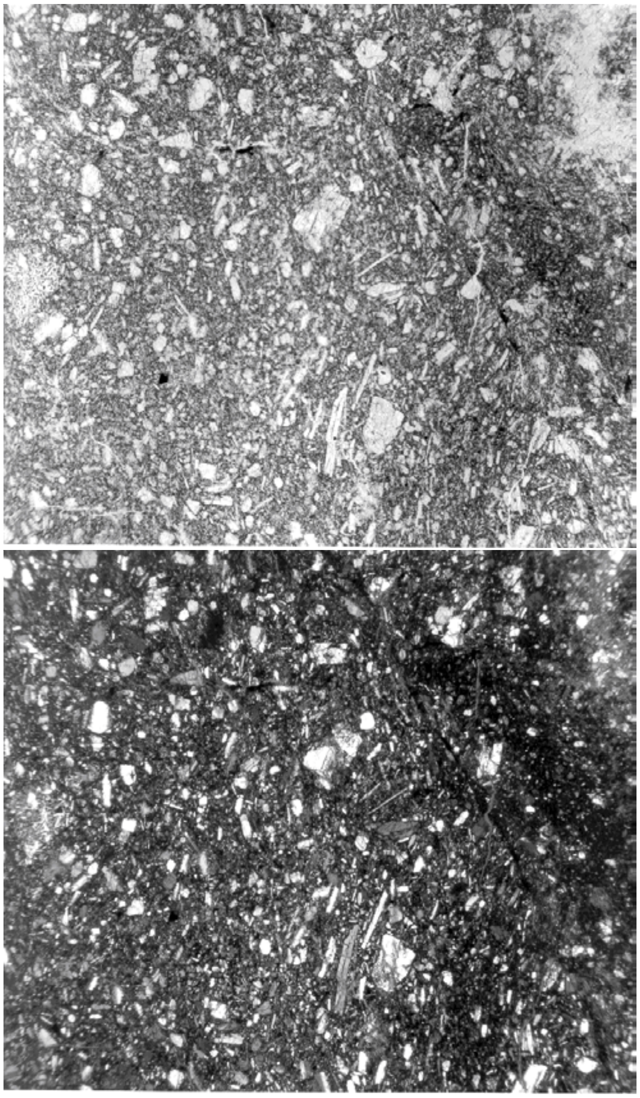


Figure 3: Photomicrographs of thin section 64435,5 (plane polarized and cross polarized) showing microlites of feldspar and mineral clasts in glassy matrix). Field of view about 3 mm. NASA S72-45704 and 45691.

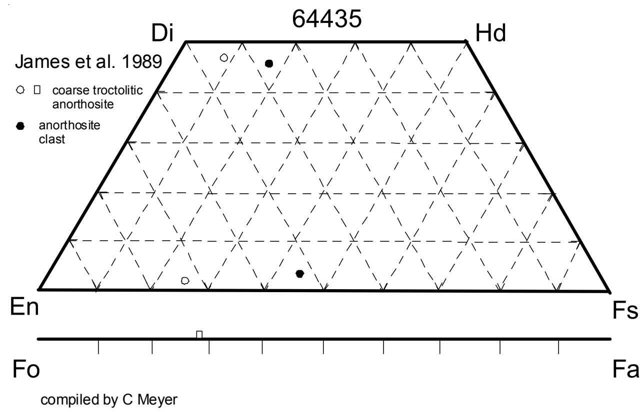


Figure 4: Olivine and pyroxene composition of composite clast in 64435,152 (from James et al. 1989).

Anorthosite: Laul and Schmitt (1974) provide an analysis – may be same as composite clast studied by James et al. (above).

Mineralogy

Olivine: Olivine is very "mafic" (Fo_{72}).

Pyroxene: The composition of pyroxene in the portions of the composite white clast are replotted in figure 4. Noteworthy is the presence of inverted pigeonite (figure 2c in James et al. 1989).

Plagioclase: All of the plagioclase in 64435 is very calcic (An_{96-98}). The plagioclase is highly shocked.

Opaques: James et al. (1989) determined the composition of ilmenite and chromite.

Glass: See et al. (1986) and Morris et al. (1986) included 64435 in their study of "large glass objects".

Metallic Iron: Hewins and Goldstein (1975) reported the Ni and Co in metal grains.

Chemistry

Taylor et al. (1974abs), Laul and Schmitt (1974abs) and Hubbard et al. (1974) determined the chemical composition of the melt rock (figure 6). The anorthosite clast studied by Laul and Schmitt (1974) may be the same as the composite clast studied by James et al. (1989). The composition of the shiny black glass coat (figure 1) has been measured by Morris et al. (1986), See et al. (1986), Laul and Schmitt (1974) and Ebihara et al. (1992).

The average compositions of the three portions of the composite white clast that was carefully studied by James et al. (1989) are summarized in table 1 and figure 6 (see their paper for specific details). The portions of the white clast are all related to ferroan anorthosite (figure 5).

Radiogenic age dating

64435 has not been dated, but Nunes et al. (1974, 1977) and Rosholt (1974) have determined the U, Th and Pb

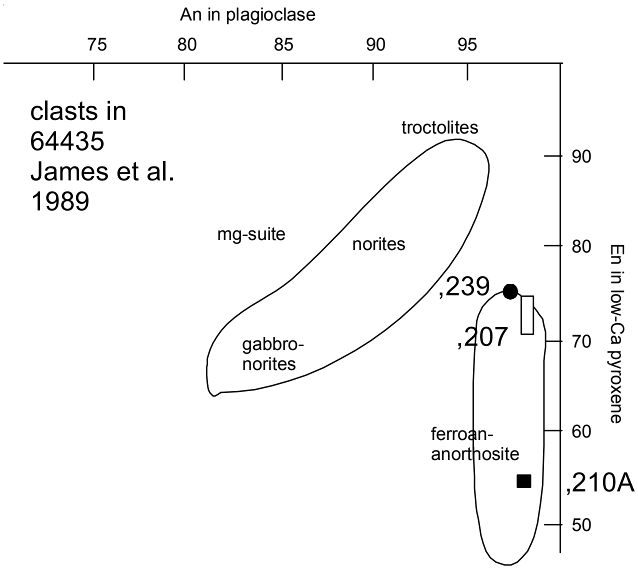


Figure 5: Composition of plagioclase and pyroxene in clasts in 64435,152 (from James et al. 1989).

isotopic composition. Reimold et al. (1985) have studied the Rb-Sr system for a group of "impact melt rocks" from Apollo 16 (figure 7). What is badly needed, is an $^{40}Ar/^{39}Ar$ plateau age for the melt rock portion of this rock! Predictably, the age of the clasts will have been reset.

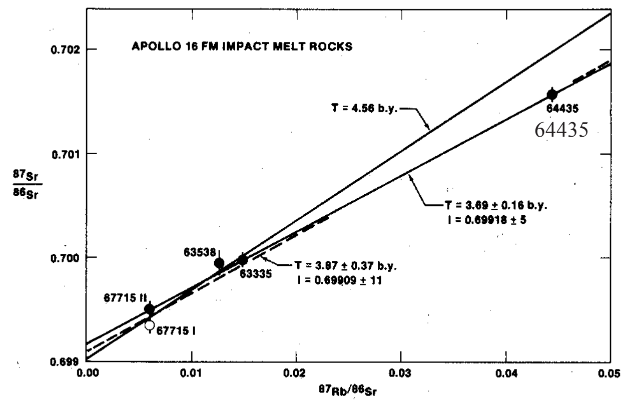


Figure 7: Whole rock Rb/Sr isochron for impact melt rocks Apollo 16 - defining a line with the slope of 3.69 +/- 0.16 m.y. (from Reimold et al. 1984). However, this age is meaningless!

Cosmogenic isotopes and exposure ages

Fruchter et al. (1978) determined the cosmic-ray-induced activity of ^{26}Al and ^{53}Mn for an interior shielded chip and calculated exposure ages 1.3 and 1.7 m.y. Bogard and Gibson (1975) calculated the exposure age as 0.6 and 0.7 m.y. from ^{21}Ne and ^{38}Ar data by Bogard et al. (1973). Bhandari (1977) calculates 0.5 m.y. from ^{26}Al data (Bhandari et al. 1976).

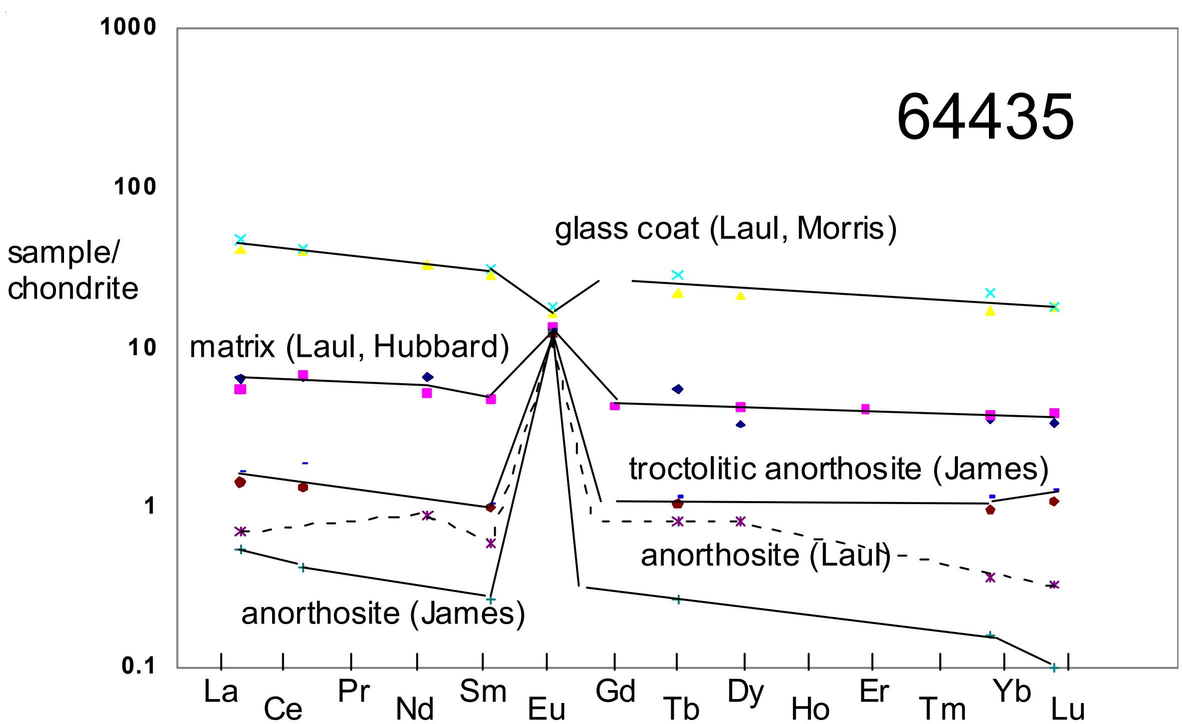


Figure 6: Normalized rare-earth-element diagram for matrix, glass coat and white clasts in 64435.

Table 1. Chemical composition of 64435.

															,239	,210A	,207	
reference	Taylor74		Hubbard74				Laul 74				Morris 86		Ebihara92		James 89			
weight	matrix		matrix		matrix		matrix	glass	anor.		glass		glass		ave	ave	ave	
SiO2 %	44.5	(d)			44.55	(e)					45.41				clast	clast	clast	
TiO2					0.19	(e)	0.2	0.5	0.1	(a)	0.38							
Al2O3	30.8	(d)			30.25	(e)	32.1	24.5	35.5	(a)	24.43				26.5		29.8	(a)
FeO	3.13	(d)			3.42	(e)	3	8	0.61	(a)	6.85				5.17	0.212	3.44	(a)
MnO					0.05	(e)	0.04	0.105	0.011	(a)								
MgO	3.38	(d)			3.83	(e)	3	8			9.4				8.3		4.6	(a)
CaO	17.4	(d)			17.16	(e)	17	13.3	19	(a)	13.5				15.2	19.3	16.8	(a)
Na2O	0.39	(d)					0.34	0.55	0.29	(a)	0.53				0.274	0.299	0.275	(a)
K2O	0.02	(d)	0.026	(b)	0.03	(e)	0.024	0.086	0.025	(a)	0.12				0.02		0.02	(a)
P2O5					0.03	(e)												
S %																		
sum																		
Sc ppm	7	(d)					5.2	6.9	0.9	(a)	7.7	(a)			3.67	0.433	4.3	(a)
V	22	(d)					15	20	4	(a)								
Cr			498	(b)			438	1163	5.7	(a)	1194	(a)			494	12.9	340	(a)
Co	26	(d)					7	100	1.3	(a)	80	(a)			13.5	0.332	7.04	(a)
Ni	56	(d)						1800		(a)	1508	(a)	2220	(c)	35	<3	16	(a)
Cu	4	(d)																
Zn													11.2	(c)				
Ga																		
Ge ppb													1800	(c)				
As																		
Se					**Reimold 84**								1750	(c)				
Rb	0.39	(d)	0.638	(b)	2.24	(b)							2.68	(c)				
Sr					146	(b)									120	160	150	(a)
Y	4.53	(d)																
Zr	17	(d)	11.2	(b)				100		(a)								
Nb	1.38	(d)																
Mo																		
Ru																		
Rh																		
Pd ppb													76.8	(c)				
Ag ppb													12.1	(c)				
Cd ppb													71	(c)				
In ppb													101	(c)				
Sn ppb																		
Sb ppb													5.6	(c)				
Te ppb													68.3	(c)				
Cs ppm	0.02	(d)											108	(c)	0.032	0.045	0.049	(a)
Ba	28	(d)	21.1	(b)			20	90	9	(a)	141	(a)			8	6	9	(a)
La	1.54	(d)	1.32	(b)			1.5	9.6	0.16	(a)	11	(a)			0.336	0.129	0.392	(a)
Ce	3.99	(d)	4.06	(b)			4	24		(a)	25.6	(a)	19.5	(c)	0.81	0.259	1.13	(a)
Pr	0.47	(d)																
Nd	1.95	(d)	2.35	(b)			3	15	0.4	(a)			14.4	(c)				
Sm	0.53	(d)	0.691	(b)			0.7	4.3	0.086	(a)	4.59	(a)			0.146	0.0402	0.157	(a)
Eu	0.68	(d)	0.759	(b)			0.76	0.91	0.69	(a)	1	(a)	2.902	(c)	0.681	0.698	0.716	(a)
Gd	0.72	(d)	0.842	(b)														
Tb	0.13	(d)					0.2	0.8	0.03	(a)	1.07	(a)	0.86	(c)	0.038	0.0099	0.042	(a)
Dy	0.8	(d)	1.03	(b)			0.8	5.1	0.2	(a)								
Ho	0.19	(d)																
Er	0.53	(d)	0.66	(b)														
Tm	0.087	(d)																
Yb	0.53	(d)	0.611	(b)			0.58	2.8	0.06	(a)	3.53	(a)	2.96	(c)	0.158	0.0258	0.189	(a)
Lu	0.082	(d)	0.095	(b)			0.082	0.43	0.008	(a)	0.44	(a)	0.408	(c)	0.028	0.0026	0.032	(a)
Hf	0.52	(d)					0.41	3.2	0.03	(a)	3.27	(a)			0.063	0.0064	0.125	(a)
Ta							0.07	0.35	0.02	(a)	0.45	(a)			0.014	0.004	0.019	(a)
W ppb																		
Re ppb													5.82	(c)				
Os ppb													62.9	(c)				
Ir ppb								50		(a)			57.2	(c)				
Pt ppb																		
Au ppb								30		(a)			21.9	(c)				
Th ppm	0.23	(d)	0.218	(b)			0.25	1.1		(a)	2.84	(a)						
U ppm	0.12	(d)	0.062	(b)			0.1	0.4	0.02	(a)	0.35	(a)	0.372	(c)				

***technique:** (a) INAA, (b) IDMS, (c) RNAA, (d) ssms, (e) XRF*

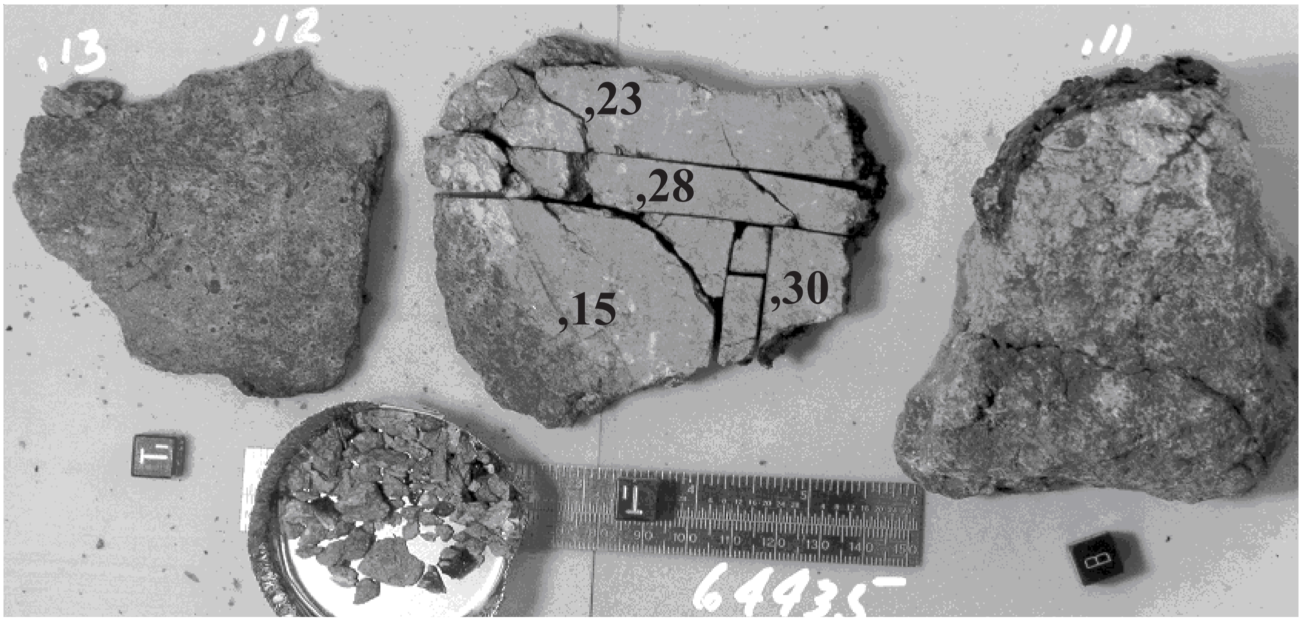


Figure 8: Group photo of first slab 64435. NASA S73-17790. Cubes are 1 cm.

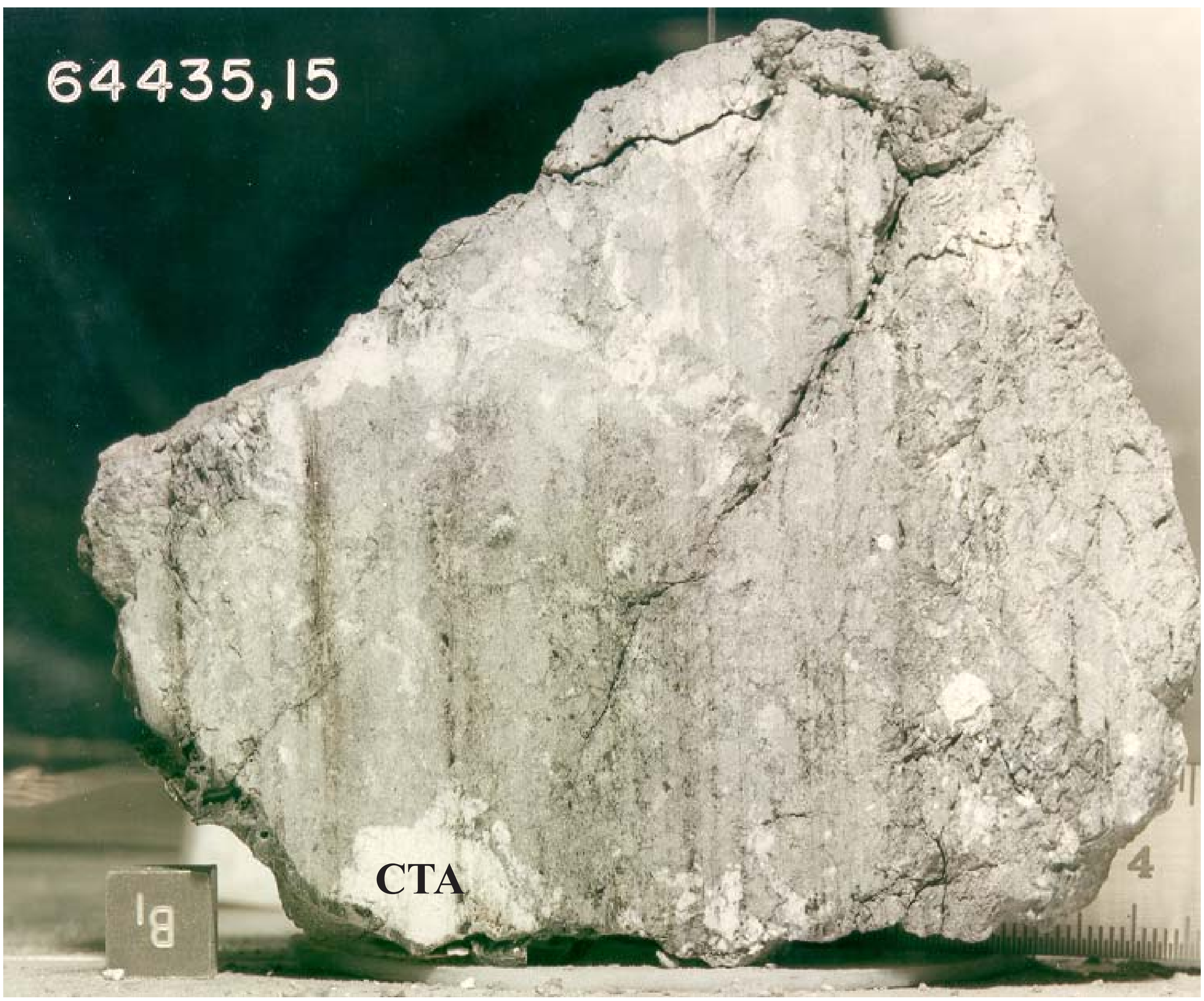


Figure 9: Photo of first slab cut from 64435 showing coarse troctolitic anorthosite ,239 and anorthosite ,210A clasts (near cube). Also see same clasts on opposite face of ,152 (figure 10). Cube is 1 cm.

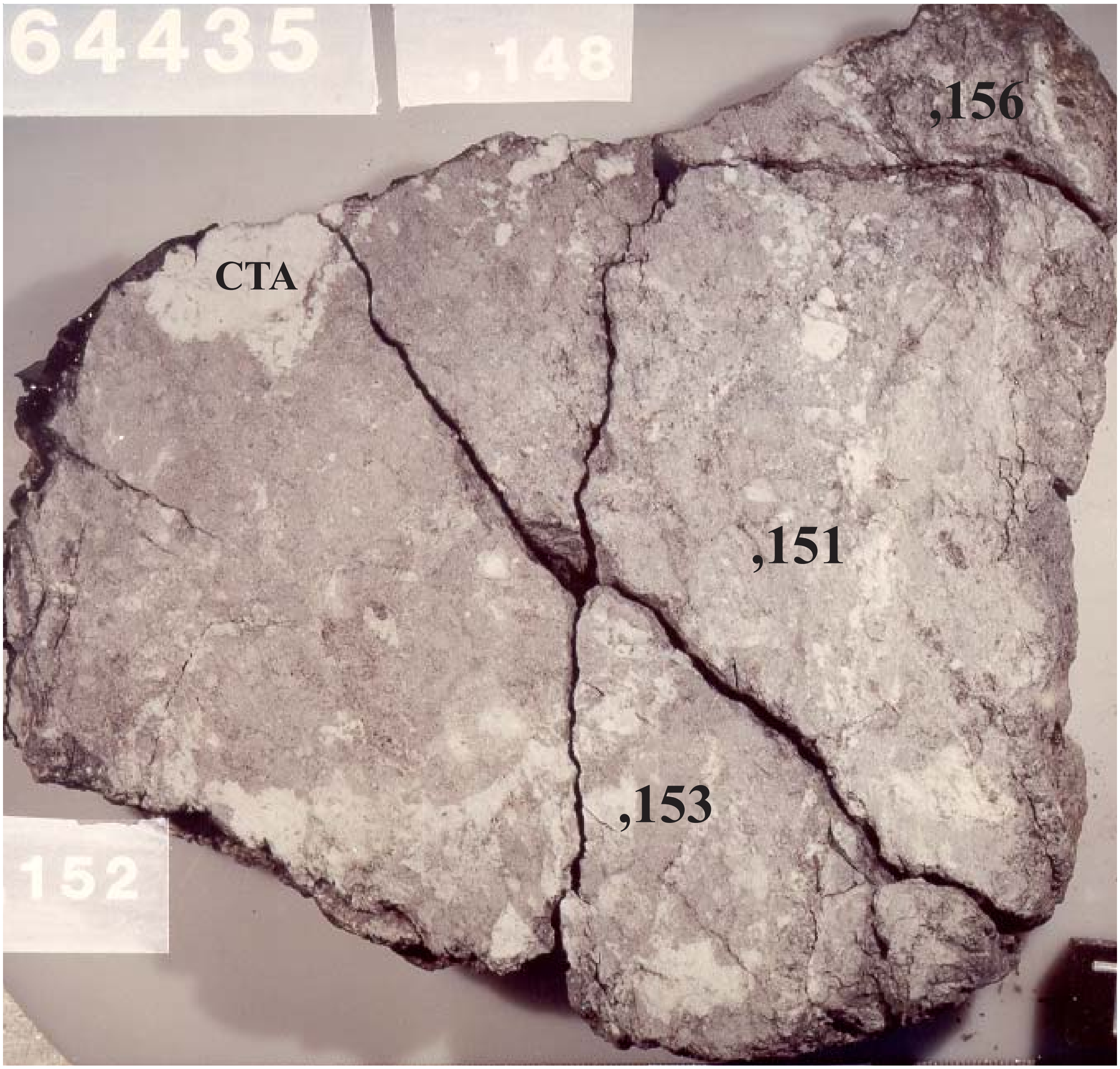


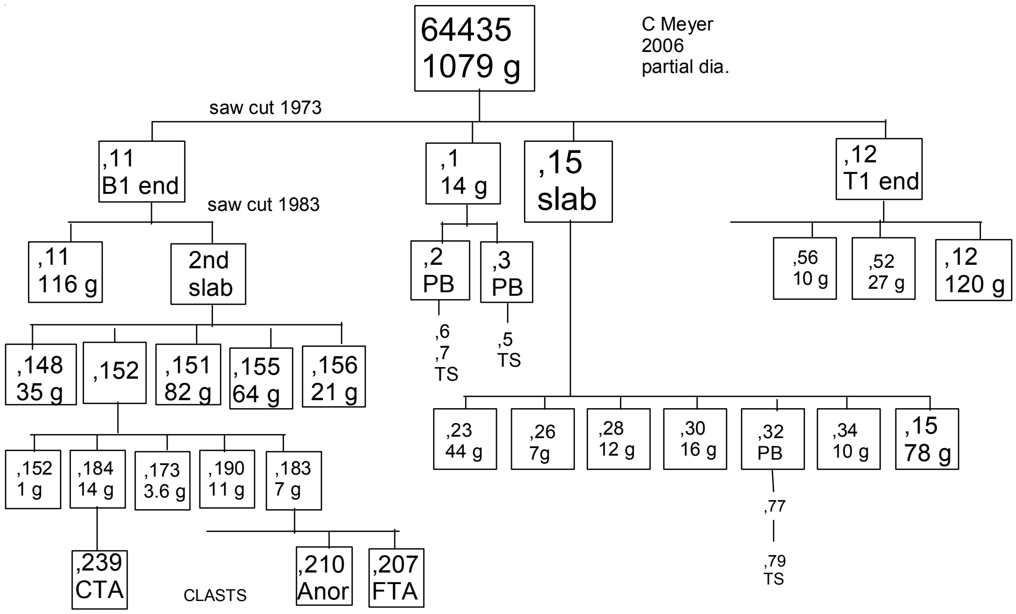
Figure 10: Photo of 2nd slab cut from 64435,11. NASA S83-40347.

Other Studies

Charette and Adams (1977)	spectra
Huffman et al. (1974)	Mossbauer
Huffman and Dunmyre (1975)	Mossbauer
Nagata et al. (1974)	magnetics
Cisowski et al. (1976)	magnetics
Schwerer and Nagata (1976)	magnetics
Gibson and Moore (1975)	gas release
Gibsone and Andrawes (1978)	nitrogen, methane
Bogard et al. (1973)	rare gas content
Bhandari et al. (1976)	tracks, crater counts
Moore et al. (1973)	C
Gripe and Moore (1974)	
Moore and Lewis (1976)	

Processing

Two adjacent slabs have been cut from 64435: one in 1973 and the second in 1983. Portions of the first slab were to be studied by a consortium led by Brian Mason (results published in Ryder and Norman 1980). The second slab included the large white composite clast (,152 CTA-A-FTA) studied in detail by James et al. (1989), but portions of this large clast also outcrop on ,15 and ,11.



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