78155

Feldspathic Granulitic Impactite
401.1 g, largest piece 6.5 x 4.5 x 3.0 cm

INTRODUCTION

Sample 78155 is a friable white cataclasite that was found in a small "pit crater" (1 meter) in the wall of a 15-meter crater at Station 8. The sample itself may have been the projectile that made the small "pit crater." It appears to be exotic to the site because other pieces of it were not found in the nearby rake sample. The transcript shows that the astronauts originally collected "one big and several small in bag 567" and recognized that it was very friable. The big piece apparently broke up along the arduous way to Houston (Fig. 1)!

Sample 78155 is important because its clast population reveals the nature of rocks that resided at or near the lunar surface before 4.2 Ky. (Bickel, 1977, and Warner et al., 1977).

PETROGRAPHY

Bickel (1977) describes 78155 as a holocrystalline, weakly coherent polymict breccia that has been thermally metamorphosed at a high temperature (1100 °C). Warner et al. (1977) group it with other rocks from the early lunar crust as "feldspathic granulitic impactites. " Lindstrom and Lindstrom (1986) have also discussed the polymict nature of 78155.

Table 1, from Bickel (1977), shows the complexity of 78155 based on his study of a number of thin sections. Roughly 65% of the rock is granoblastic matrix with another 20% "crushed material." The mineralogical mode of the matrix is -~75% plagioclase (An_{95}), and ~25% mafic silicates (mostly pigeonite $Wo_{14}En_{62}Fs_{18}$) with trace olivine (Fo_{60-65}), augite, and opaques. Figs. 2 and 3 illustrate the granoblastic matrix next to a polygonal anorthosite clast.

Figure 1: Photograph of 78155. The largest sample is about 66 cm. S73-15408.

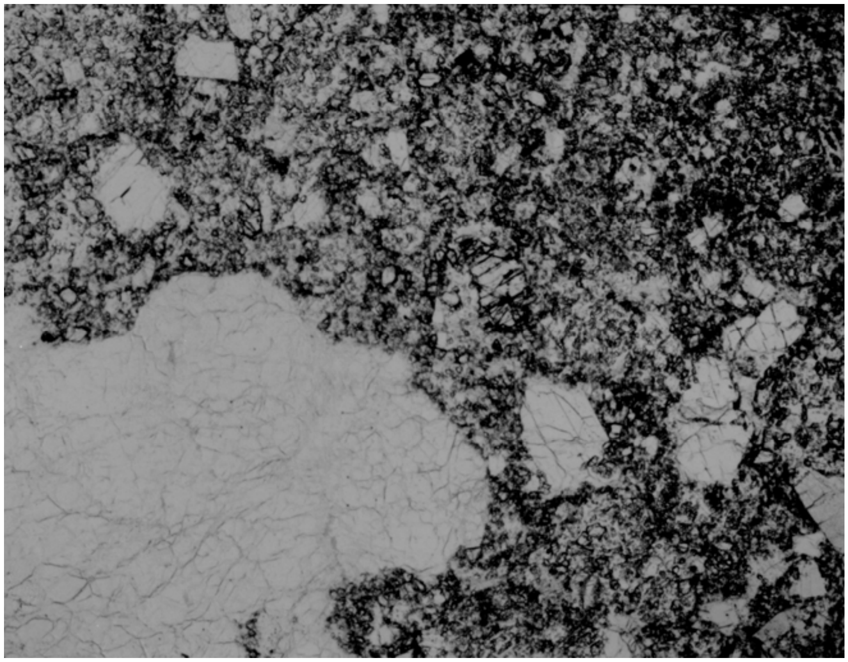

Figure 2: Photomicrograph of thin section 78155,48. Field on view is 3 x 4 mm.

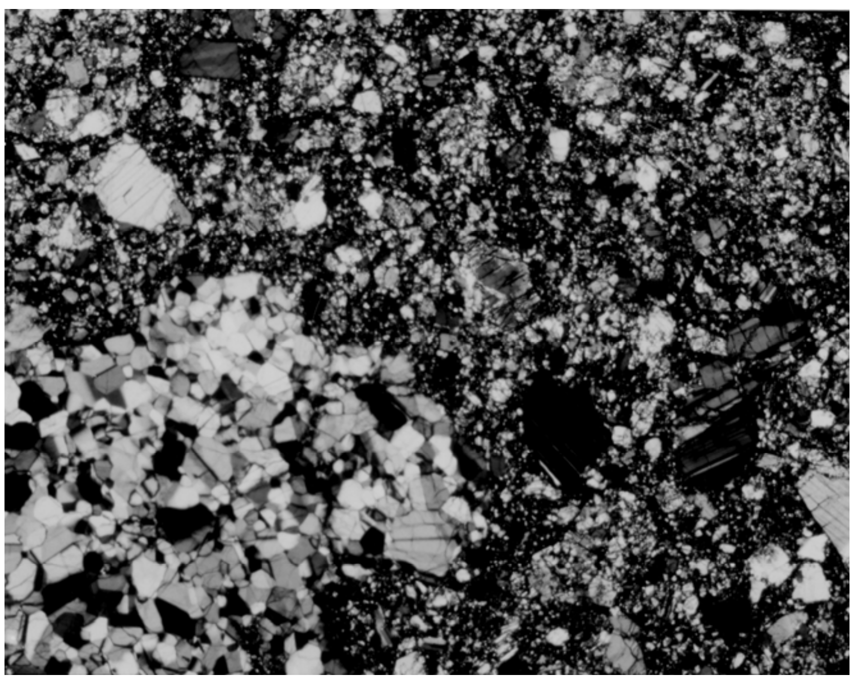

Figure 3: Same area of thin section as Fig. 2, but with partially crossed polarizers showing the granoblastic texture of the matrix and the polygonal texture of the plagioclase clast

A variety of lithic clasts from the highlands are described by Bickel (1977). Most of the lithic clasts have mineral compositions like those of the matrix (relatively Fe-rich pyroxene), but a few clasts have more Mg-rich pyroxene (Fig. 4). Type I clasts are fine-grained anorthosites with a felty texture in which the interstices between tabular plagioclase are occupied by crystals of pigeonite and olivine. Type II lithic clasts in 78155 are coarse grained and display a range in composition (40-80% plagioclase; the major mafic mineral is olivine in some, low-Ca pyroxene in others, and augite in one) and texture (subophitic, poikiloblastic, and granoblastic).

Evidence of temperatures in excess of 1100 °C during the metamorphism of breccia 78155 are inferred from coexisting uninverted pigeonite and low-Ca augite (Bickel, 1977) and equilibrated olivine and ilmenite (Anderson and Lindsley, 1979).

MINERAL CHEMISTRY

Mineral compositions are given in Bickel (1977). The average plagioclase composition in 78155 is $Or_{0.8}Ab_{4.7}An_{94.5}$, with a narrow range from An_{91} to An_{97} (Fig. 5). Average pyroxene is $Wo_{10}En_{61}Fs_{29}$ (Fig. 4). Note that pyroxene with less than Wo5 is exceedingly rare in this piece of the early lunar crust (although it is common in impact melt breccias from the 3.9 b.y. event). Olivine also has a limited range of composition (Fo_{62-65}). Engelhardt (1979) has studied the ilmenite in 78155.

Hewins and Goldstein (1975) studied the provenance of iron metal in 78155 (Fig. 6). They found that the Ni and Co contents were inter-mediate between those of the coarse-grained lunar anorthosites and anorthositic "remelts." Again, there is a rather narrow range in metal composition.

WHOLE-ROCK CHEMISTRY

Laul and Schmitt (1973), Hubbard et al. (1974), Wanke et al. (1976), and Lindstrom and Lindstrom (1986) have analyzed 78155 (Table 2 and Fig. 7). Moore et al. (1974) and Gibson and Moore (1974) reported sulfur abundance and Brett (1976) discussed reduction by sulfur loss.

Morgan et al. (1974) have deter-mined the trace siderophile and volatile elements (Table 3). Morgan et al., Wanke et al., and Lindstrom and Lindstrom have all found high Ir (3, 4, and 8 ppb, respectively), indi - cating that this rock is not pristine. This is consistent with the relatively high Ni content of the metal.

SIGNIFICANT CLASTS

So far, clast studies have been limited to small clasts in thin sections.

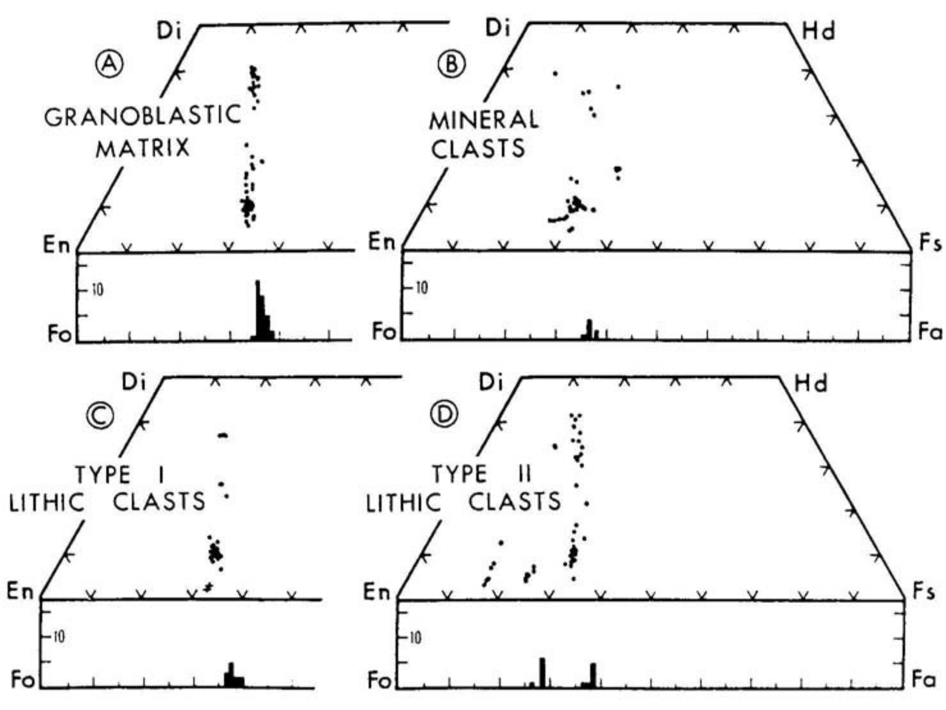

Figure 4: Pyroxene compositions in matrix and in clasts in 78155. From Bickel (1977).

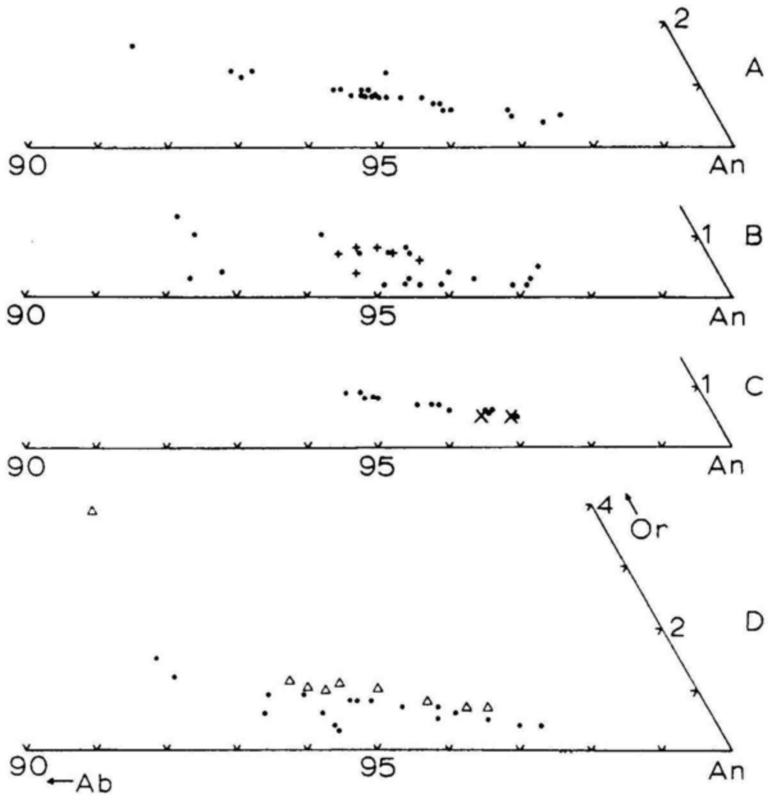

Figure 5: Plagioclase composition in 78155. A is plagioclase in the matrix, B is small plagioclase clasts, C is Type 1 lithic clasts, and D is Type 11 lithic clasts. From Bickel (1977).

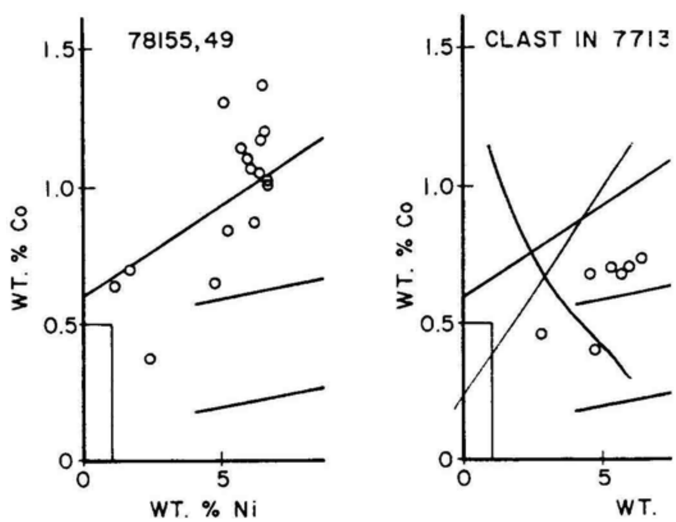

Figure 6: Composition of metal grains in 78155. From Hewins and Goldstein (1975).

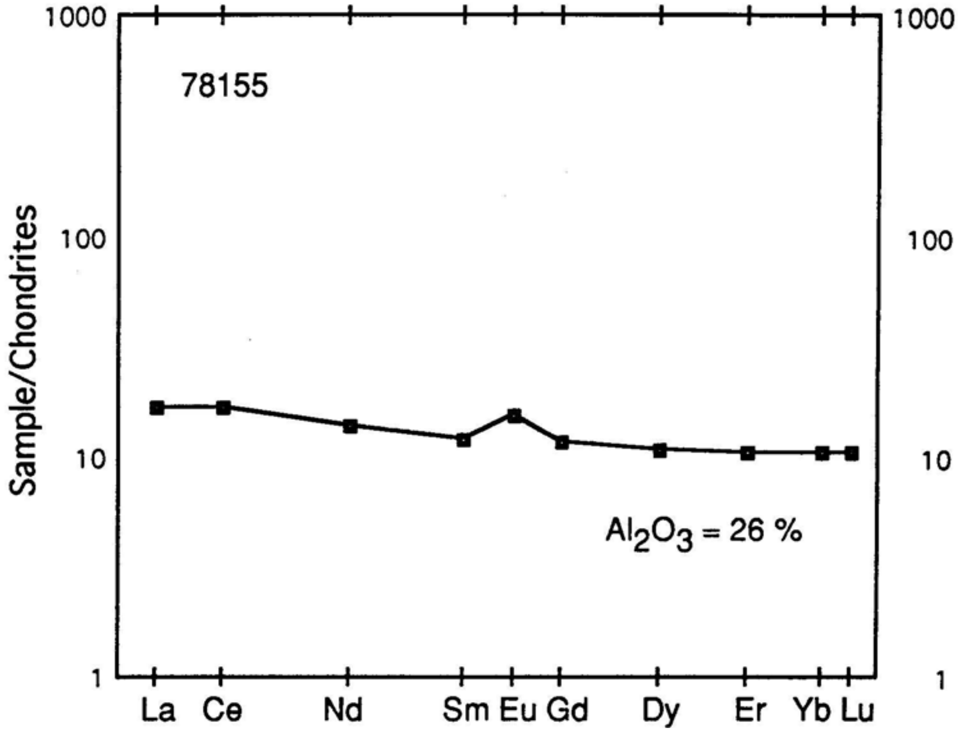

Figure 7: Normalized rare earth element diagram for 78155. Data from Hubbard et al. (1974).

COMETS?

Sill et al. (1974) studied the carbon content of 78155 with the hope of finding evidence of a cometary contribution to breccia 78155. They found that 78155 was the most volatile-rich of all samples studied. The CO_2, CO, and CH_4 content represented 267 ppm carbon. Hydrocarbons (exclusive of CH_4) were present in approximately 60 ppm quantity; the most abundant ion was m/e = 43. This sample also outgassed hydrogen cyanide (~5 ppm) and hydrogen sulfide (~6 ppm).

RADIOGENIC ISOTOPES

Turner and Cadogan (1975a) determined a ^{39}Ar-^{40}Ar plateau age of 4.22 ± 0.04 b.y., identical to its total Ar age (Fig. 8). Oberli et al. (1979) confirmed this Ar age with a plateau of their own at 4.17 ± 0.03 b.y. (Fig. 9). Using acid-leaching experiments, Oberli et al. were also able to obtain a ^{207}Pb/^{206}Pb age of 4.17 ± 0.02 b.y. (Fig. 10). Nunes et al. (1974 and 1975) also studied the U-Pb systematics of 78155 (Table 4), but there were too many different Pb components and Pb loss events to obtain a unique U/Pb age. However, there is evidence from these studies that the early Moon had a high U/Pb l atio.

Nyquist et al. (1974) (Table 5), Murthy and Coscio (1977), and Murthy (1978) have determined the Rb/Sr ratio and Sr isotopes in 78155. These studies did not yield Rb/Sr ages, but they did set limits on the initial Sr isotopic ratio for the Moon.

COSMOGENIC RADIOISOTOPES AND EXPOSURE AGES

Drozd et al. (1977) have determined an exposure age of 22 m.y. for 78155 using the ^{81}Kr-Kr method, and Turner and Cadogan (1975) determined an exposure age of 30 m.y. by the Ar exposure age technique.

MAGNETIC STUDIES

Nagata et al. (1974 and 1975) reported the intensity of saturation magnetization for 78155. Hargraves and Dorety (1975) have also attempted to study the remanent magnetism of 78155.

SURFACE STUDIES

Adams and Charette (1975) have determined the reflectance spectra of 78155 (Fig. 11). Note the deep pyroxene absorption band at 0.91 pm. This absorption band appears deeper than for rocks with high contents of pyroxene!

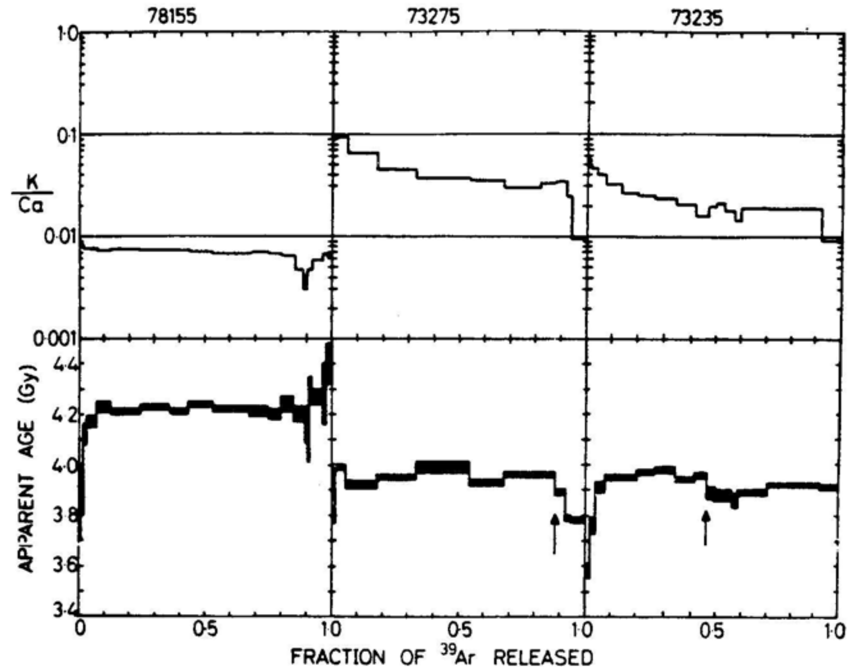

Figure 8: $^{39}Ar\_^{40}Ar$ plateau age of 78155 (4.22 + 0.04 b.y.). Note the, flat pattern for all temperatures. From Turner and Cadogan (1975a).

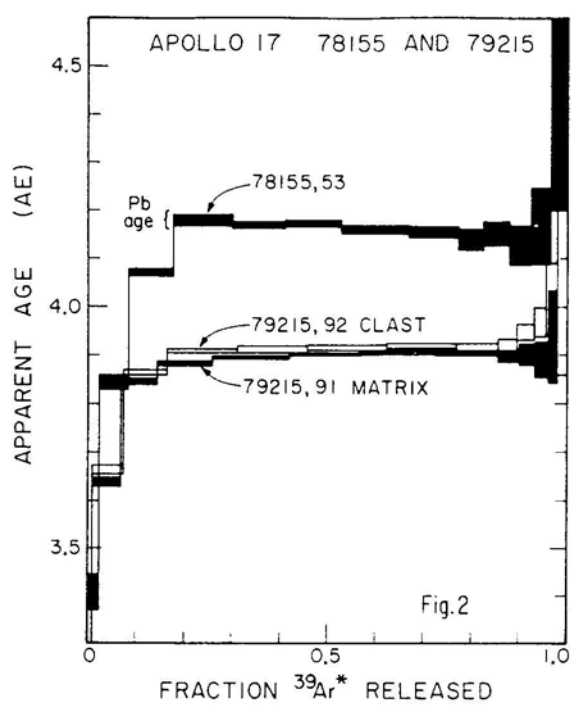

Figure 9: ^{39}Ar-^{40}Ar plateau age of 78155 (4.17 ±0.03 b.y.). Note the agreement with Turner and Cadogan.From Oberli et al. (1975[1]).

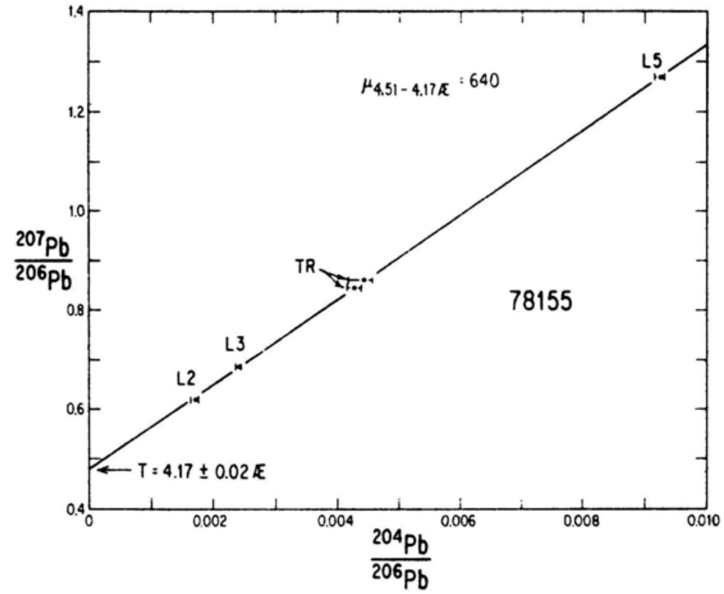

Figure 10: ^{207}Pb/^{2O6}Pb diagram for 78155. Note the age of 4.17 0.02. From Oberli et al. (1979).

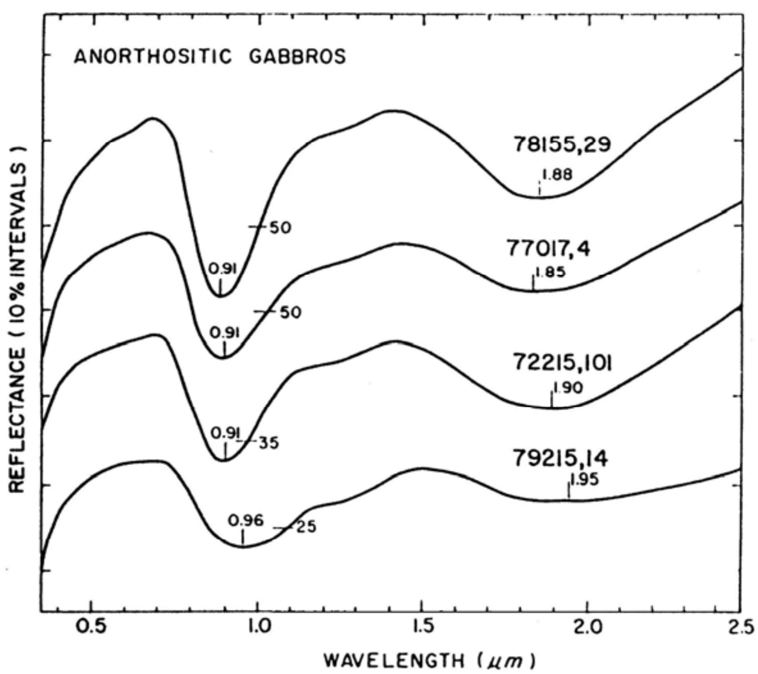

Figure 11: Reflectance spectra of 78155. From Adams and Charette (1975).

Table 1: Lithology of 78155.
From Bickel (1977).

Lithology	Approximate % of rock*	Maximum size of fragment or clast (mm)#	Grain size (µm)
Granoblastic matrix	65	4.6 x 3.0	Anorthite: 20-100, mafic silicates: 2-40, oxides: 0.5-75
Mineral clasts			
Anorthite	10	3 x 2	–
Pyroxene†	3	0.8 x 0.6	–
Olivine	< 1	0.6 x 0.2	–
Polymineralic lithic clasts			
Fine-grained, felty textured anorthosite (Type I)	1-2	2.8 x 1.0	Finer grained: Anorthite: 8 x 40 to 16 x 80; mafic silicates: 8 x 12 Coarser grained: Anorthite: 20 x 160 to 30 x 200; mafic silicates: 15 x 25, wedge shaped up to 60 µm long
Annealed Type I	1-2	1.2 x 0.8	Same as Type I, but with greater range in sizes of mafic silicates
Medium and coarse grained (Type II)	< 1	1.5 x 1.0	See Table 3
Crushed material	20	0.1	Angular fragments ≤ 100 µm across

*Mode based on visual estimates and limited point counting.
#All the constituents are seriate in size.
†Pigeonite is much more abundant than augite.

Table 2: Chemical composition of 78155.
a) LSPET; b) Wiesmann and Hubbard (1975); c) Hubbard et al. (1974); d) Laul and Schmitt (1973); e) Wanke et al. (1976); f) Lindstrom and Lindstrom (1986)

Split Technique	,2 (a, b, c) XRF, IDMS	,57 (d) INAA	,127 (e) INAA	,137 (f) INAA
SiO_2 (wt%)	45.57	–	45.35	–
TiO_2	0.27	0.22	0.29	0.32
Al_2O_3	25.94	26.2	25.34	26.0
Cr_2O_3	0.14	0.12	0.14	0.14
FeO	5.82	5.3	5.63	5.62
MnO	0.10	0.076	0.085	–
MgO	6.33	6.2	6.42	6.2
CaO	15.18	15.2	15.19	15.2
Na_2O	0.33	0.39	0.38	0.39
K_2O	0.08	0.07	0.073	–
P_2O_5	0.04	–		
S	0.04	–		
Nb (ppm)	4.8		2	
Zr	59	–	54	48
Hf		1.4	1.49	1.42
Ta		0.23	0.25	0.22
U	0.28	0.4	0.24	0.25
Th	1.01	0.9	0.84	0.86
W			0.104	
Y	16		16	
Sr	147		141	165
Rb	2.061		2.01	–
Li	5.2		4.8	
Ba	58.8	50	63.6	61
Cs			0.11	0.103
Zn	4		4.13	
Cu			4.52	
Ni	53	90	80	100
Co		14	14.3	15.8
Sc		11	13.3	12.9
La	4.02	4.3	4.28	3.98
Ce	10.2	12	11.3	9.9
Nd	6.29	8	7.3	5.7
Sm	1.81	1.9	1.69	1.74
Eu	0.874	0.9	0.862	0.835
Gd	2.32		2.3	

Table 2: (Concluded).

Split Technique	,2 (a, b, c) XRF, IDMS	,57 (d) INAA	,127 (e) INAA	,137 (f) INAA
Tb		0.35	0.39	0.41
Dy	2.64	2.3	2.63	
Er	1.69		1.90	
Yb	1.73	1.7	1.83	1.57
Lu	0.259	0.23	0.271	0.244
Ga			2.91	
F			15	
Cl			6.9	
Re (ppb)			0.24	
Ir		–	3.9	8
Au		–	0.68	

Table 3: Trace element data for 78155.
a) Morgan et al. (1974); b) Wanke et al. (1976)

	Sample 78155,30 (a)	Sample 78155,127 (b)
Ir (ppb)	3.32	3.9
Os (ppb)		
Re (ppb)	0.278	0.24
Au (ppb)	0.66	0.68
Ni (ppm)	68	80
Sb (ppb)	20.4	
Ge (ppb)	27	
Se (ppb)	49	60
Te (ppb)	3.2	
Ag (ppb)	1	
Br (ppb)	65	68
Bi (ppb)	0.29	
Zn (ppm)	2.3	4.13
Cd (ppb)	63	
Tl (ppb)	5.9	
Rb (ppm)	1.76	2.01
Cs (ppb)	84	110
U (ppb)	250	240

Table 4: U-Th-Pb composition of 78155.
From Nunes et al. (1974).

Split	78155
wt (mg)	112.1
U (ppm)	0.2683
Th (ppm)	0.9352
Pb (ppm)	0.8513
$^{232}Th/^{238}U$	3.60
$^{238}U/^{204}Pb$	165

Table 5: Rb-Sr composition of 78155.
Data from Nyquist et al. (1974).

Sample	78155,2
wt (mg)	51.6
Rb (ppm)	2.06
Sr (ppm)	146.7
$^{87}Rb/^{86}Sr$	0.0406 ± 4
$^{87}Sr/^{86}Sr$	0.70164 ± 6
T_B	4.37 ± 0.14
T_L	4.48 ± 0.14

B = Model age assuming I = 0.69910 (BABI + JSC bias)
L = Model age assuming I = 0.69903 (Apollo 16 anorthosites for T = 4.6 b.y.)