72235

Aphanitic Impact Melt Breccia
St. 2, 61.9 g

INTRODUCTION

72235 is an aphanitic, clast-rich impact melt interlayered with feldspathic clast material that was sampled as a resistant knob on Boulder 1 (see section on Boulder 1, St. 2, Fig. 2). The knob has a patch of adhering medium light-gray [N6-N7] friable matrix similar to 72275 (Fig. 1). 72235 was given the name "Dying Dog" during processing. The knob is about 4 cm across and angular; its dark gray [N3] and very light gray [N8] materials are tough. The exposed surface is brownish gray with a few zap pits.

The dark and light layers of the knob appear to have been crushed and fluidized; veinlets of dark material intrude white layers, and veinlets of white layers intrude the dark material. The dark material is fine-grained, almost glassy looking, impact melt with numerous clasts. The light material consists of feldspathic granulites, other feldspathic breccias, and other lithic types including plutonic KREEP norite. The aphanitic melt appears to be a low-K Fra Mauro composition, contaminated with meteoritic material. No isotopic or exposure studies have been conducted.

Most of the studies of 72235 were conducted by the Consortium Indomitable (leader J.A. Wood). A slab was cut perpendicular to the layering in the knob for comprehensive petrographic and chemical study (Fig. 2). Detailed maps of the exterior surfaces and the slab based on macroscopic observations, as well as descriptions of the sample allocations, were given in Stoeser *et al.* (in Cl 2, 1974).

PETROGRAPHY

72235 consists of a coherent knob of interlayered dark gray-to-black and white breccias, with a piece of adhering light-gray friable matrix similar to that of 72275 (Marvin, 1975; CI 2, 1974). LSPET (1973) described 72235 as a layered light-gray breccia. Simonds *et al.* (1974) listed it as a fragmental breccia (clast-supported). The most detailed descriptions of the petrography of 72235 are given in Stoeser *et al.* (in Cl 2, 1974) and in Ryder *et al.* (1975). When 72235 broke from Boulder 1, it proved to be a clast of roughly layered gray and white breccias almost wholly enclosed within a gray-black, aphanitic rind. Marvin (1975) described the dark and light layers as appearing to have been crushed and fluidized under confining pressure, with the two phases mutually intrusive. The rind varies

Figure l: Bottom (arbitrary) face of 72235 prior to slabbing. The topmost visible pan was exposed and has patina and zap pits: the remainder is freshly broken. Scale in centimeters. S-73-23589 B.

Figure 2: Cutting of 72235 in 1974. ,13 and,11 are end pieces; 6,',14; and, 15 are matrix pieces that broke away; ,16 is the slab piece. Apart from a thin section from ,6, all further subdivisions and allocations were made from,16. Scale in centimeters. S-74-20429.

in thickness from less than 1 mm to 5 mm.

The adhering light-gray friable breccia contains numerous angular fragments of aphanitic gray material and a few yellowish patches that are possibly pigeonite basalt. In thin sections it varies from very fine-grained and porous to blobby (Figs. 3a and b). It contains a variety of lithic and mineral fragments but no pigeonite basalts occur in the sections.

In the hand specimen the rind looks markedly darker and more vitreous than any of the interior layers. Macroscopically it appeared as an annealed breccia with several percent small angular inclusions. The white layers appeared to be "cataclastic gabbroic anorthosite" with 10 to 20% yellow and brown mafic crystals plus traces of metal and troilite. The white layers include a few dark gray aphanitic clasts and at least two prominent holocrystailine lithic clasts of coarse mafic silicates.

The set of thin sections from the slab revealed that the central clast is composed of a number of different breccias with a complex structural history. Stoeser et al. (in Cl 2, 1974) divided it into 6 domains (Fig. 4).

Domain 1-anorthositic polymict breccia.

Domain 2-Aense dark matrix breccia (impact melt).

Domain 3-white feldspathic granulite breccia.

Domain 4-"core" polymict breccia.

Domain 5-monon-da noritic anorthosite breccia.

Domain 6-dark matrix breccia (impact melt).

Domains 2 and 6 correspond with the rim, and domain 1 lies outside these domains. Domains 3 to 5 are the interior of the knob.

Domain 1: Domain 1 is a feldspathic polymict breccia consisting almost entirely of unshocked mineral fragments of plagioclase and pyroxene, with some fragments of dark melt material and feldspathic granulite. The monomineralic fragments appear to be the crushed remnants of an anorthositic lithology with an average grain size greater than 100 microns and with 10 to 20% mafic silicates. The contact between domains 1 and 2 is sharp.

Domain 2: The rind, domain 2, is the darkest of the melt breccias in 72235, and the least porous. It contains few clasts larger than 0.5 mm, and is poorer in clasts than the other domains (Fig. 3c). A defocused beam analysis indicates its general low-K Fra Mauro composition (Table 1, col. 8) and similarity to other Boulder 1 melts.

Domain 3: Domain 3 is a monomict breccia consisting of fragments of feldspathic granulite in a crushed matrix of itself (Fig. 3d) with a porosity of about 10%. It is similar to other granulites in Boulder 1 except that is appears to contain more ilmenite. Defocused beam analyses indicate that it is chemically similar to domain 5 (Table 2).

Domain 4: The core of 72235 is a complicated polymict breccia consisting of lithic clasts (including melt breccias and feldspathic granulites) and mineral fragments that are crushed and intermixed. The core appears to have been formed in a turbulent environment. Some of the melt breccia clasts are very dark and somewhat vesicular. Defocused beam analyses of such materials show the common low-K Fra Mauro composition (Table 1, cols. 9 and 10), although the core appears to have more titanium.

Domain 5: Domain 5 is a narrow zone (Fig. 4) of monomict breccia containing no polymineralic fragments. The parent consisted of about 75% plagioclase and 25% pyroxene, with small amounts of

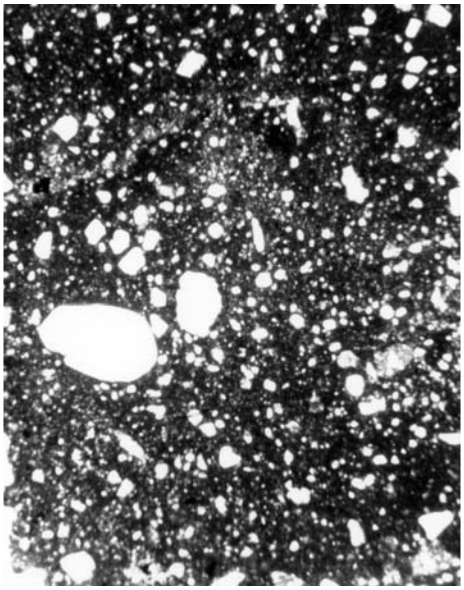

Figure 3: Photomicrographs of 72235; all plane transmitted light, all about 1 mm width of view. a) 72235,9 crushed fragmental fine matrix, dominantly mineral fragments.

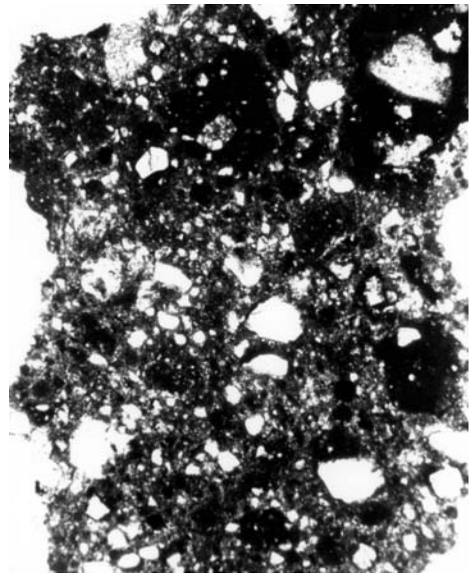

Figure 3b: 72235,86 blobby fragmental matrix showing dark melt blobs and mineral fragments.

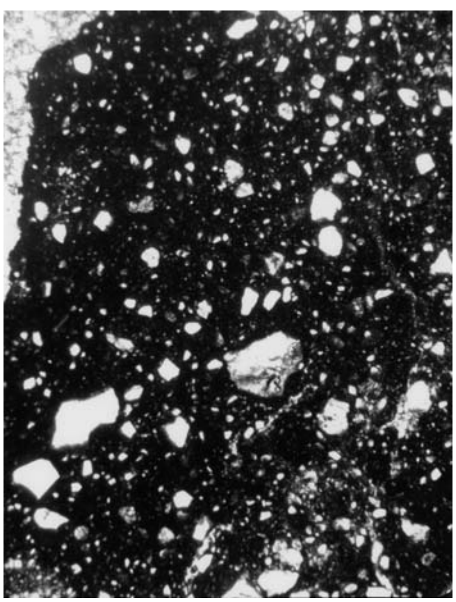

Figure 3c: 72235,59 rind (domain 2) of knobby clast.

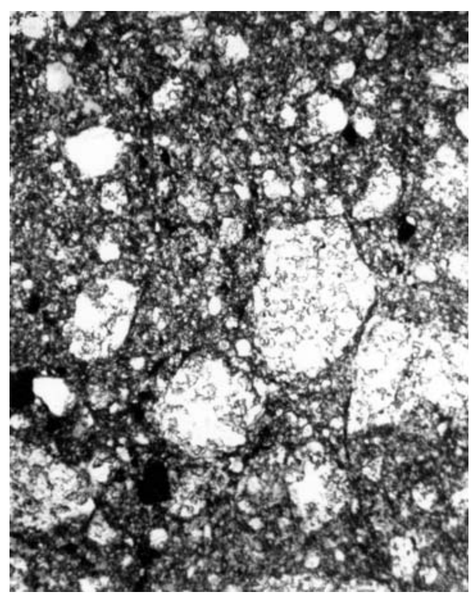

Figure 3d: 72235,61 cataclastic feldspathic granulite (domain 3).

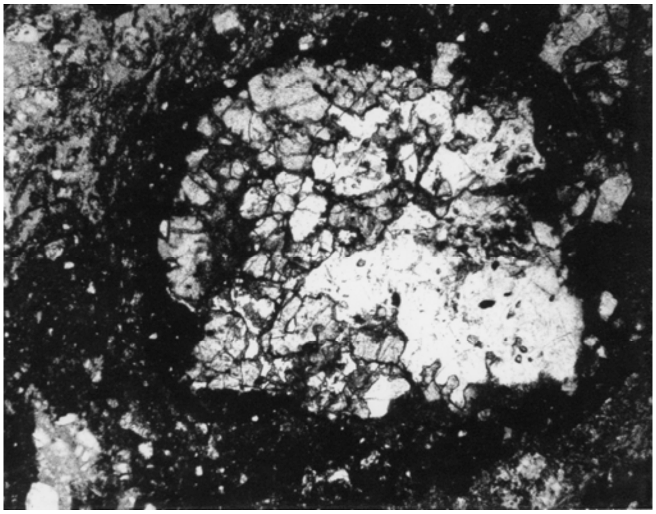

Figure 3e: 72235,52 fragment of KREEP norite.

pink spinel. A defocused beam analysis (Table 2, col. 12) shows that it is very similar to domain 3 feldspathic granulite.

Domain 6: The rind represented by domain 6 is similar to that of domain 2 except that it is a little lighter in color, contains larger clasts, and is slightly more porous.

Stoeser *et al.* (in CI 2, 1974) reported a survey of clast populations in the 72235 melt phases (dark matrix breccias; domains 2, 4, and 6) (Table 3) for clasts larger than 200 microns. Few clasts exceed 1 mm. Compositions of olivines are shown in Fig. 5. The clasts in the melts are dominated by feldspathic materials (varied feldspathic breccias and plagioclase fragments), but there are significant contributions from basaltic (mainly impact melts?) and granitic fragments (see also Spudis and Ryder, 1981). The basaltic fragments include olivine-normative pigeonite-bearing basalts and "troctolitic" fragments bearing pink spinels. Defocused beam analyses of these basaltic fragments are in Table 4. Most of the olivine-normative pigeonite basalts in the boulder are from 72235, and the mineral data given in Fig. 6a are mainly from 72235. The granites were described by Stoeser *et al.* (1975) and Ryder et al. (1975); some mineral data for the granites is given in the catalog section on 72215. They include glassy and holocrystalline varieties.

A distinctive clast in 72235 was a 3 mm fragment of KREEP norite (Fig. 3e) that was yellowish-brown and embedded in feldspathic material. It was recognized macroscopically as distinct, with coarse anhedral brown pyroxene and gray translucent plagioclase (Stoeser *et al.,* in CI 2, 1974). Thin sections show that the KREEP norite consists of equal amounts of plagioclase and pyroxene, with about I% accessory minerals that are mainly ilmenite and troilite, with a trace of phosphate. The silicate grains occur in interlocking domains up to 1 mm diameter. The compositions of silicate minerals are shown in Fig. 6b. The Or component of the plagioclase is uncommonly high.

Stoeser *et al.* (in CI 2, 1974) note that the textural relations of the materials in 72235 are inconsistent with simple plastering on of a rind to anorthositic material in flight. Both lithologies were fluidized and intermixed with rotation. The origin is somewhat complex.

CHEMISTRY

Chemical analyses for matrix and clast samples are given in Tables 5 and 6, with the rare earths diagrammed in Fig. 7. None of the matrix samples in Table 5 are pure impact melt, but are mixtures of melt and white clast material. ,46 and ,48 are the domain 4 polymict breccia from the interior of the clast: ,11 is the entire end-piece consisting of all the domains. The chemistry is consistent with a mixture of melts similar to those in 72215 and 72255 (as suggested by the defocused beam analyses in Table 1) with dominantly feldspathic granulites. The analyzed materials are obviously contaminated with meteoritic siderophiles. The anorthositic breccia (Table 6) is the more pure material of domain 3, feldspathic granulite; it too is obviously contaminated with meteoritic siderophiles. It is far less enriched in incompatible elements than is the bulk rock (Fig. 7).

Higuchi and Morgan (1975) and Morgan *et al.* (1975) placed the meteoritic signature of 72235 in a group 3L with samples from 72215, and distinct from 72235 and 72275. They suggest a heterogeneous impacting body (they assume the siderophiles are derived from a single impacting body).

PROCESSING

72235 was left intact during PET, and was mapped in May, 1973. A chip of dark aphanitic material fell off and was mainly used for thin sections. In 1974 a 1.5 cm thick slab was cut from the center of the large class, after a chunk of the friable matrix broke away. The main cutting is shown in Fig. 2. The slab ,16 was cut into 3 pieces (Fig. 8). ,28 was used for thin sections, and ,29 for other allocations. The remaining piece ,16 was not allocated.

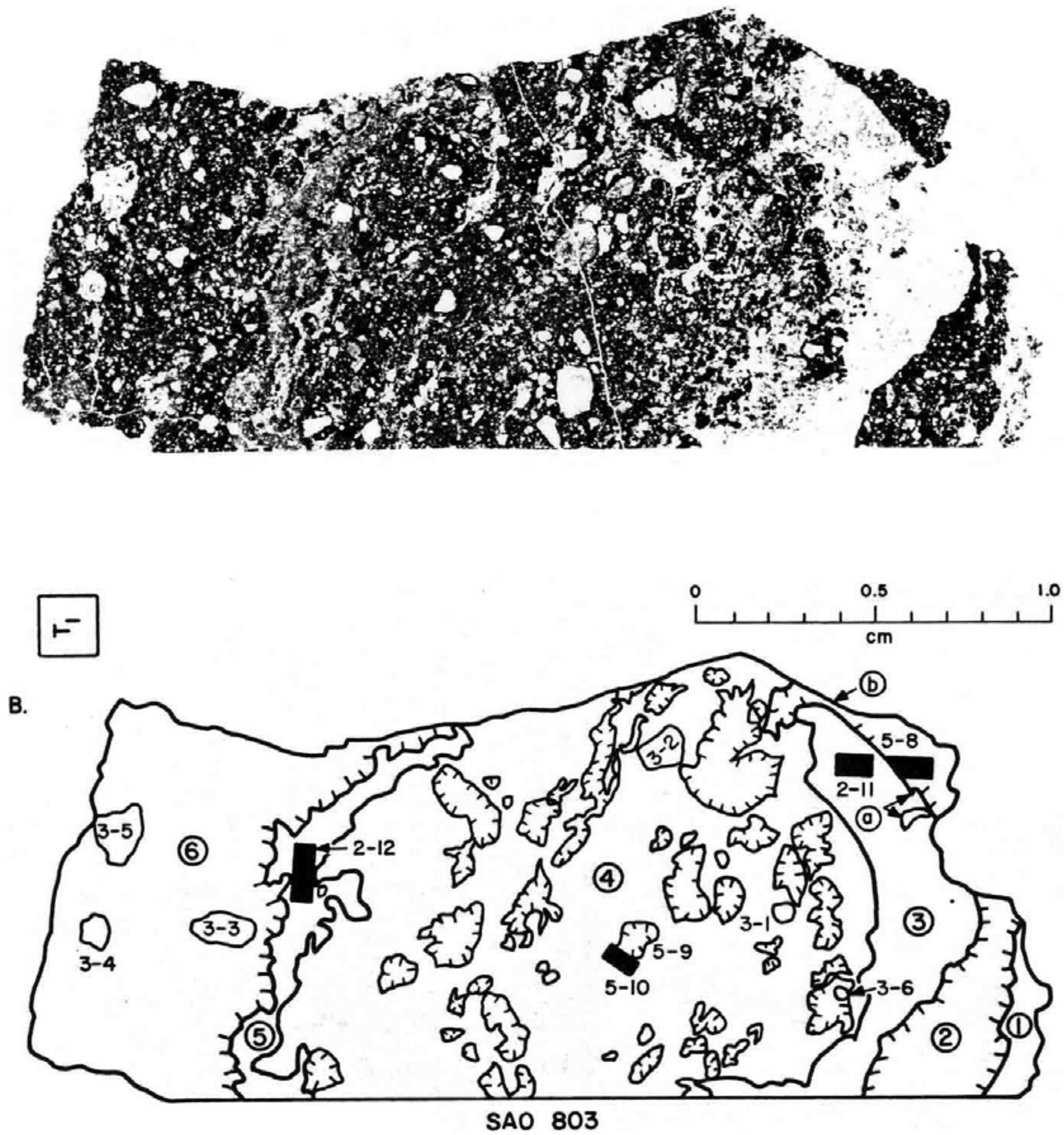

Figure 4: Photograph and sketch map of thin section 72235,59 which is a complete section through the 72235 knob. The circled numbers on the sketch map correspond with the domains. Dark matrix (melt) materials are indicated by barbed lines. From Stoeser et al. (in C12, 1974).

Table 1: Microprobe defocused beam analyses of dark matrix materials in 72235
(from Stoeser et al., in CI 2, 1974).

		8.	9.	10.
		803	803C20	803C20
		matrix dom. 2	vesic. DMB clast	DMB rim
WT. % OXIDES				
SiO_2		45.68	46.71	45.81
TiO_2		0.70	2.05	0.83
Al_2O_3		21.15	20.11	21.52
Cr_2O_3		0.21	0.25	0.28
FeO		8.00	8.44	7.57
MnO		0.11	0.12	0.13
MgO		8.92	8.99	8.33
CaO		12.19	12.13	12.36
Na_2O		0.49	0.68	0.55
K_2O		0.25	0.35	0.20
BaO		0.05	0.02	0.03
P_2O_5		0.23	0.29	0.31
TOTAL		97.98	100.17	97.90
CIPW NORM				
FO		3.6	1.8	1.8
FA		2.4	1.1	1.2
EN		17.6	19.8	18.7
FS		10.7	10.7	11.3
WO		1.8	3.2	1.6
OR		1.5	2.1	1.2
AB		4.3	5.8	4.7
AN		55.9	50.7	56.9
ILM		1.3	3.9	1.6
CHR		0.3	0.4	0.4
QTZ		---	---	---
COR		---	---	---
AP		0.5	0.7	0.7
COMP. NORM MIN.				
OL:	FO	68.3	70.8	68.5
PX:	EN	17.6	64.5	65.3
	FS	29.9	26.6	30.0
	WO	5.7	8.9	4.7
PLAG:	OR	2.4	3.5	1.9
	AB	7.3	10.4	7.9
	AN	90.2	86.1	90.2
atomic Mg/(Mg+Fe		0.666	0.655	0.662
MgO/(MgO+FeO)		0.527	0.516	0.524
No. of analyses		27	18	10

Table 2: Microprobe defocused beam analyses of feldspathic interior materials in 72235
(from Stoeser et al., in Cl 2, 1974).

		11.	12.
		803 dom. 3 gran. ANT breccia	803 dom. 5 crushed gab. anorth.
WT. % OXIDES			
SiO_2		40.43	41.72
TiO_2		0.15	0.18
Al_2O_3		26.98	27.41
Cr_2O_3		0.08	0.09
FeO		3.84	4.00
MnO		0.04	0.06
MgO		5.85	5.02
CaO		14.35	15.06
Na_2O		0.39	0.40
K_2O		0.06	0.09
BaO		n.d.	n.d.
P_2O_5		0.04	0.09
TOTAL		92.23	94.13
CPIW NORM			
FO		8.5	5.8
FA		4.4	3.6
EN		3.6	5.0
FS		1.7	2.8
WO		---	0.6
OR		0.4	0.6
AB		3.6	3.6
AN		77.0	77.3
ILM		0.3	0.4
CHR		0.1	0.1
QTZ		---	---
COR		0.3	---
AP		0.1	0.2
COMP. NORM. MIN.			
OL:	FO	73.7	69.8
PX:	EN	73.7	64.8
	FS	26.3	28.0
	WO	---	7.1
PLAG:	OR	0.5	0.7
	AB	4.7	4.6
	AN	94.9	94.7
atomic Mg/(Mg+Fe		0.731	0.690
MgO/(MgO+FeO)		0.604	0.557
No. of analyses		22	21

Table 3: Clast populations of 72235 dark matrix materials. Percentages by volume in three size categories.
(From Stoeser et al., in Cl 2, 1974).

	0.2-0.5 mm	0.5-1.0 mm	1.0 mm	TOTALS
ANT suite	(46.4)	(8.6)	(0.2)	(55.2)
ANT breccias	(17.5)	(3.1)	-	(20.6)
mafic	0.4	0.2	-	0.6
gabbroic	13.0	2.3	-	15.3
anorthositic	4.1	0.6	-	4.7
Granulitic ANT	(24.8)	(4.3)	-	(29.1)
gabbroic	22.9	4.3	-	27.2
anorthositic	1.9	-	-	1.9
Poikiloblastic ANT	-	-	-	-
Poikilitic ANT	-	-	-	-
Coarse ANT	3.1	0.4	0.2	3.7
Unclassified ANT	1.0	0.8	-	1.8
Ultramafic particles	1.6	-	-	1.6
Basalts	(1.8)	(0.6)	(0.6)	(3.0)
Ol.-norm. pig. bas.	0.4	0.6	0.6	1.6
Pink sp. troct. bas.	0.8	-	-	0.8
Unclassified	0.6	-	-	0.6
Microgranites	4.5	0.8	-	5.3
Civet Cat norite	0.2	-	-	0.2
KREEP norite	-	-	0.2	0.2
Devitrified maskelynite	10.8	1.2	-	12.0
Glassy clasts	2.3	-	-	2.3
Mineral fragments	(19.8)	(0.4)	-	(20.2)
Plagioclase	12.3	0.2	-	12.5
Olivine	1.8	-	-	1.8
Pyroxene	5.7	0.2	-	5.9
TOTAL %	87.4	11.6	1.0	100.0
NO. OF CLASTS	450	58	5	513

Table 4: Microprobe defocused beam analyses of basaltic textured particles in 72235. Cols. 1-S are olivine-normative pigeonite basalts; col. 6 is a pink spinel-bearing troctolitic basalt.
(From Stoeser *et al*., in Cl 2, 1974).

		1.	2.	3.	4.	5.	6.
		803C1 quench basalt	803C4 ol-pheno. basalt	803C7 ol-pheno. basalt	803C9 equigran. basalt	803C10 suboph. basalt	803C5 PSTB
WT. % OXIDES							
SiO_2		48.04	46.92	46.17	45.47	45.37	41.80
TiO_2		0.40	0.84	0.34	0.49	0.23	0.82
Al_2O_3		12.26	11.52	10.99	11.03	14.73	22.89
Cr_2O_3		0.25	1.23	0.28	0.59	0.88	0.05
FeO		15.02	16.51	14.89	16.97	12.75	5.72
MnO		0.25	0.28	0.27	0.27	0.26	0.06
MgO		9.25	13.29	11.91	13.17	10.58	12.91
CaO		12.17	10.26	10.42	10.22	11.45	12.89
Na_2O		0.40	0.11	0.22	0.16	0.13	0.51
K_2O		0.86	0.07	0.20	0.04	0.08	0.16
BaO		0.05	0.07	0.04	0.05	0.03	0.03
P_2O_5		0.02	0.02	n.d.	0.01	0.02	0.11
TOTAL		98.98	101.12	95.75	98.46	96.51	97.96
CIPW NORM							
FO		3.8	6.1	4.7	8.8	3.8	23.0
FA		4.9	5.8	4.7	9.0	3.6	7.3
EN		17.9	24.0	24.3	20.8	21.9	---
FS		21.1	20.6	22.1	19.2	18.9	---
WO		13.2	8.3	10.2	9.1	7.5	1.7
OR		5.2	0.4	1.2	0.2	0.5	1.0
AB		3.4	1.0	1.9	1.3	1.1	4.4
AN		29.4	30.4	29.7	29.7	40.8	60.7
ILM		0.8	1.6	0.7	0.9	0.4	1.6
CHR		0.4	1.8	0.4	0.9	1.3	0.1
QTZ		---	---	---	---	---	---
COR		---	---	---	---	---	0.1
AP		---	---	---	---	---	0.3
COMP. NORM MIN.							
OL:	FO	52.7	60.5	59.0	58.7	60.3	82.1
PX:	EN	39.5	51.2	48.7	48.0	51.2	---
	FS	35.4	33.4	33.7	33.9	33.7	---
	WO	25.1	15.4	17.6	18.1	15.1	---
PLAG:	OR	13.5	1.3	3.8	0.7	1.1	1.4
	AB	9.4	3.2	6.1	4.5	2.9	7.1
	AN	77.1	95.5	90.1	94.7	96.0	91.5
atomic Mg/(Mg+Fe)		0.526	0.589	0.588	0.580	0.596	0.801
MgO/(MgO+FeO)		0.381	0.446	0.444	0.437	0.453	0.693
No. of analyses		16	16	17	17	34	8

Table 5: Chemistry of polymict materials of 72235.

Split	,36	,37
wt %		
SiO_2	44.5	
TiO_2	0.8	
Al_2O_3	25.8	
Cr_2O_3	0.146	
FeO	6.19	
MnO	0.080	
MgO	8.52	
CaO	14.4	
Na_2O	0.42	
K_2O	0.11	
P_2O_5		
ppm		
Sc	9.84	
V		
Co	43.7	
Ni	500	307
Rb		1.41
Sr		
Y		
Zr		
Nb		
Hf	2.2	
Ba		
Th	1.6	
U		0.430
Cs		0.0746
Ta	0.5	
Pb		
La	7.2	
Ce	20	
Pr		
Nd		
Sm	3.66	
Eu	0.92	
Gd		
Tb	0.80	
Dy		
Ho		
Er		
Tm		
Yb	2.9	
Lu	0.41	
Li		
Be		
B		
C		
N		
S		
F		
Cl		
Br		
Cu		0.0434
Zn		1.3
ppb		
Au		4.89
Ir		17.6
I		
At		
Ga		
Ge		210
As		
Se		25
Mo		
Tc		
Ru		
Rh		
Pd		
Ag		0.357
Cd		4.4
In		
Sn		
Sb		0.86
Te		2.7
W		
Re		1.19
Os		
Pt		
Hg		
Tl		0.38
Bi		0.33
	(1)	(2)

References and methods:
(1) Blanchard et al (1975); INAA,AAS also in C.I. (2)
(2) Higuelin ad Moyen (1975); RNAA
Meyer et al (1975)

Table 6: Chemistry of feldspathic granulite (domain 3) interior clast material from 72235.

Split	,46	,11	,40 (black md)	,48
wt %				
SiO_2	44.6			
TiO_2	0.8			
Al_2O_3	23.1			
Cr_2O_3	0.21			
FeO	7.28			
MnO	0.111			
MgO	9.9			
CaO	13.2			
Na_2O	0.514			
K_2O	0.20	0.218		
P_2O_5				
ppm				
Sc	15.4			
V				
Co	24.0			
Ni	190		186	195
Rb			8.57	5.10
Sr				
Y				
Zr				
Nb				
Hf	9.5			
Ba				
Th	4.0	4.67		
U		1.15	1.690	1.350
Cs			0.332	0.220
Ta	1.1			
Pb				
La	22.7			
Ce	58			
Pr				
Nd				
Sm	10.6			
Eu	1.25			
Gd				
Tb	2.4			
Dy				
Ho				
Er				
Tm				
Yb	8.9			
Lu	1.20			
Li				
Be				
B				
C				
N				
S				
F				
Cl				
Br			0.134	0.0361
Cu				
Zn			2.0	1.8
ppb				
Au			2.46	2.77
Ir			7.16	7.51
I				
At				
Ga				
Ge			169	124
As				
Se			67	48
Mo				
Tc				
Ru				
Rh				
Pd				
Ag			5.17	0.448
Cd			7.4	3.1
In				
Sn				
Sb			1.13	0.65
Te			3.5	2.2
W				
Re			0.530	0.524
Os				
Pt				
Hg				
Tl			2.80	0.57
Bi			0.26	0.12
	(1)	(2)	(3)	(3)

References and methods:
(1) Blanchard et al (1975); INAA,AAS - also in Cl(2)
(2) Truchter et al (1975); g. ray
(3) Higuehi ad Moyen (1975); RNAA
Meyer et al (1975)

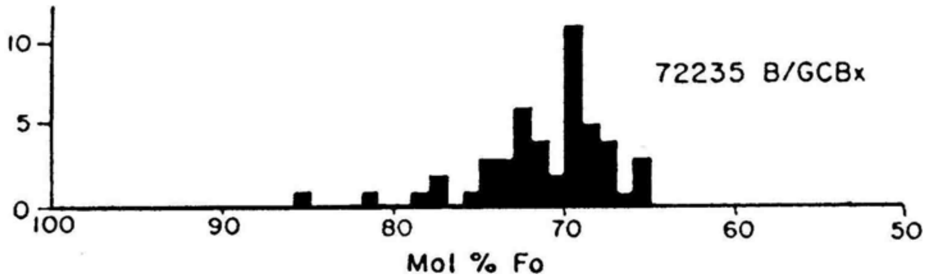

Figure 5: Compositions of olivine in the dark matrix material of 72235. From Ryder et al. (1975).

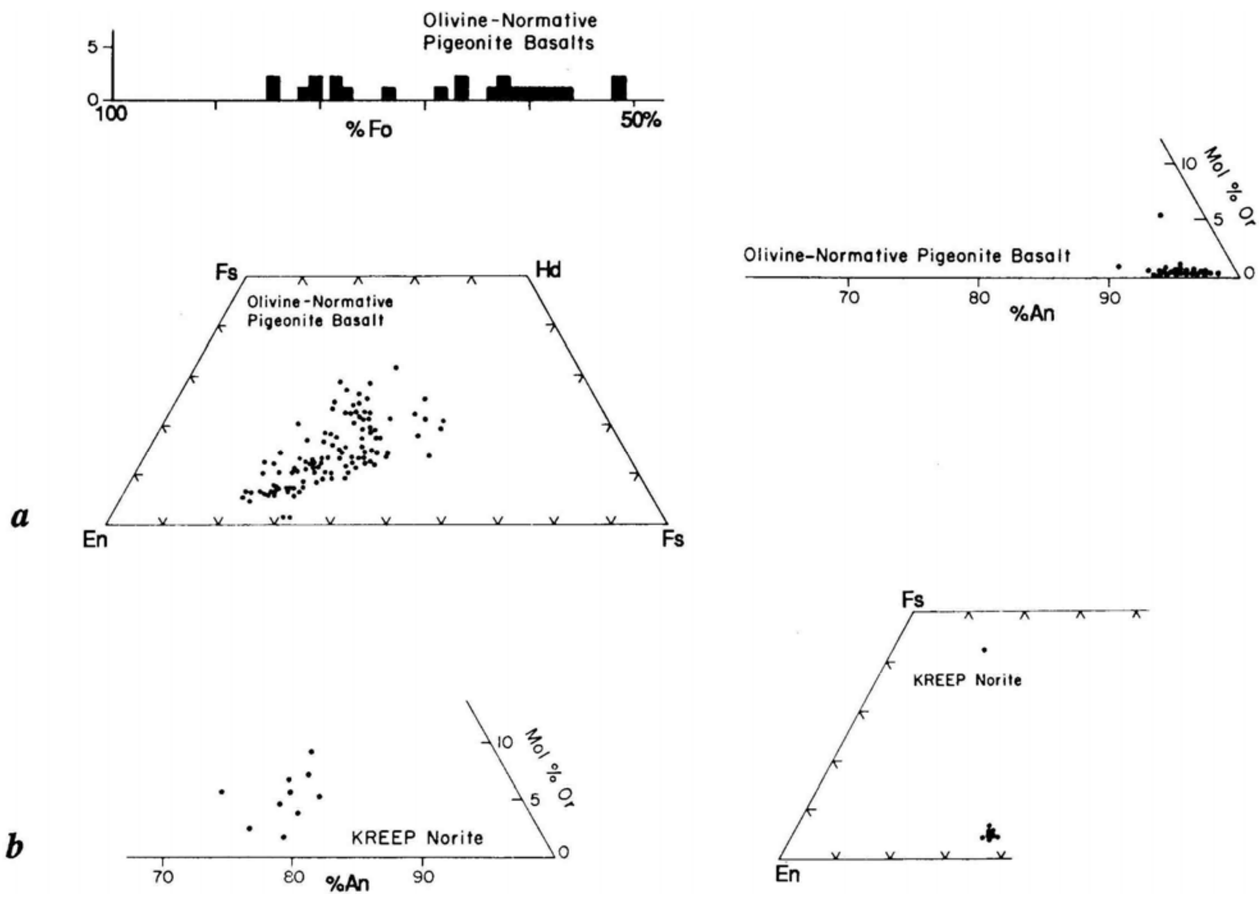

Figure 6: a) Olivine, plagioclase, and pyroxene compositions for olivine-normative pigeonite basalts, mainly from 72235. b) Plagioclase and pyroxene compositions from the KREEP norite clast in 72235. From Ryder et al. (1975).

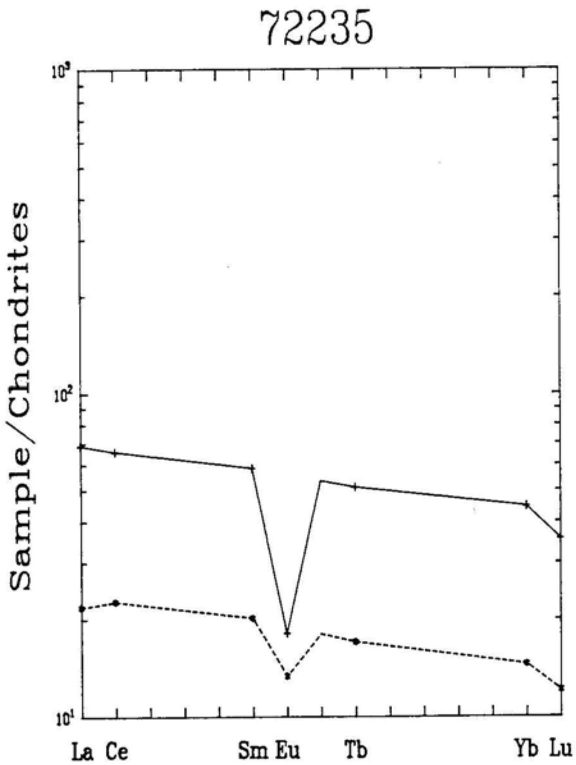

Figure 7. Rare earth elements in polymict breccia (solid line) and feldspathic granulite (dashed line) in 72235. All data from Blanchard et al. (1975).

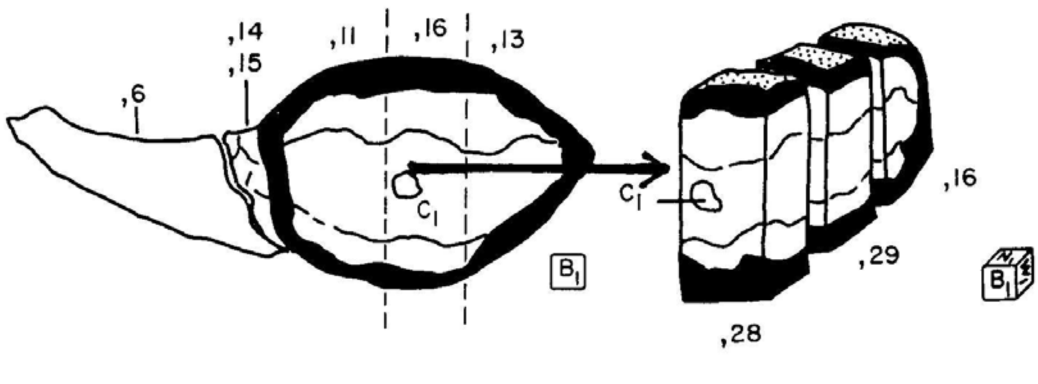

Figure 8: Diagram of cutting of slab and subdivision of slab from 72235 in 1974.