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CATALOG OF PRISTINE NON-MARE MATERIALS
PART 1. NON-ANORTHOSITES
REVISED

GRAHAM RYDER AND MARC NORMAN
(NORTHROP SERVICES, INC.)

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NOTE: This is a reprinted version of the original edition, with the correction of the errors of commission and omission which have been brought to our attention. There has been no attempt to update the contents of this catalog.

INTRODUCTION

This volume is Part 1 of a catalog of known pristine non-mare (highlands) materials and is devoted to non-anorthosites. As such it includes information on pristine samples which contain less than about 90 volume % plagioclase or less than about 32 weight % Al_2O_3, depending on what information is available. Part 2 will deal with pristine anorthosite samples. The purpose is to encourage investigation of those samples by providing descriptive and processing information about them.

By pristine we mean lunar materials which were created by igneous events within the Moon and subsequently have retained their bulk chemistry without contamination by other lunar or non-lunar materials, and in general this is the same definition used by Warren and Wasson (1977), 1978). A pristine sample may have a plutonic, extrusive, metamorphic or brecciated texture; it is the chemistry and not necessarily the texture which is pristine. Pristine does not necessarily mean primitive or primordial. Pristine samples described in this volume include large whole-rocks, clasts in breccias, and rake and fines samples.

In establishing whether or not a sample is pristine we have relied heavily, but not exclusively, on the siderophile data of the Anders group at Chicago and the Wasson group at Los Angeles. In some cases such data is not available and we have relied on petrographic/chemical criteria such as outlined by Irving (1975) and Warren and Wasson (1977). As noted above, the purpose of this volume is to encourage investigation of this fundamentally significant group of samples, which contains critical information on the nature, origin, and evolution of the lunar crust. We have attempted to cover all non-mare samples known or strongly believed to be pristine, other than a few small fragments which were discovered only in thin sections. For each sample we give:

(i) Evidence for its pristinity, using criteria referred to above.

(ii) A description including tables and figures of what is known about the pristine sample. To accomplish this for pristine clasts it has been necessary to make extensive use of the processing data packs and other information kept at the Lunar Curatorial Facility to establish what allocations of the clast were made. This is important because frequently an investigator has received and studied a pristine sample but has no way of knowing with the information supplied to him/her that it was found by another investigator to be pristine.

For all clast samples, and for several whole-rocks we also give:

(iii) A table and selected photographs showing the splits of the pristine sample. (For most whole-rock pristine samples we have omitted this table as superfluous, but we have included the table if it is fairly short - a subjective choice). The table provides locations, masses and brief descriptions of the splits which contain the pristine material. For samples in RSPL the state of degradation is also contained in the description, except for potted butts, which have been through normal thin-sectioning procedures and contaminants. Parentheses around daughter number splits indicate that the daughter is not direct but a daughter of the split number preceding the parentheses. The word chip does not necessarily mean that split was chipped or pried off, merely that it is a single small piece.

This compendium is meant to enable an investigator to judge for him/herself that, or if, a sample satisfies his/her own criteria for pristinity, whether what is already known about a sample makes it interesting to him/her, whether there are data gaps the investigator would like to fill, and whether (and which) samples suitable for the study are available.

The information contained in the descriptions and the split tables is as correct as possible at the time of writing. If this volume fulfills its function, then more allocations will be made, and more information will be forthcoming. Therefore this volume has a planned obsolescence.

Abbreviations and/or possibly unfamiliar terms used in this volume include the following:

BSV	Brooks Storage Vault - Comparatively inaccessible samples, San Antonio, Tx.
B01	Building 1, JSC - Interim storage vault, samples accessible with difficulty
B16	Building 16, JSC "
B45	Building 45, JSC "
SSPL	Sample Storage and Processing Laboratory, Lunar Curatorial Facility, JSC
RSPL	Returned Sample Processing Laboratory, Lunar Curatorial Facility, JSC
SCC	Sample Control Center, Lunar Curatorial Facility, JSC
TSL	Thin Section Laboratory, Lunar Curatorial Facility, JSC
TS	Thin section
PM	Probe mount
P.I.	Principal Investigator
Ent. subd.	Entirely subdivided
Generic listing:	A computer listing compiled at the Lunar Curatorial Facility providing splits, masses, precise locations and brief physical descriptions of lunar samples.

In anticipation of a revised edition or a supplement, we solicit communications regarding errors of omission and comission, unpublished data, processing information, and suggestions for improvement. Input from investigators could greatly improve the volume.

ACKNOWLEDGEMENTS

Paul Warren, Lee Silver, Doug Blanchard, Henry Wiesmann, and Karen Motylewski provided us with unpublished scientific and documentation information and/or photomicrographs.

Sue Goudie typed most of the manuscript, aided by Alene Simmons, Polly McCamey, and Jean Leecraft. Sherry Feicht did the necessary drafting on the photographs.

Roy Brown oriented us on the microprobe fast enough for us to obtain some preliminary data included in this volume, and Chuck Meyer provided helpful advice and suggestions.

TABLE OF CONTENTS AND AVAILABLE MASSES

TABLE OF CONTENTS AND AVAILABLE MASSES (cont.)

*Not including material with P.I. which may not have been consumed and could be transferred (see specific tables), but including clean returned material in RSPL.

15265,13 ,6 Norite/Troctolite (?) ?gm

Evidence for pristinity: Ganapathy *et al*. (1973) analyzed a fragment of a clast from 15265 and found it to be meteorite-free (Table 1).

Description: 15265,13 was a piece of a soil breccia which was sent to Burlingame for splitting and subsequent allocation to P.I.'s. We do not have documentation on what was allocated to Anders (as 15265,13 ,6) for siderophile and volatile analyses, nor on what else may have been allocated from the same clast. 15265,13 ,6 was described as a "breccia norite?" by Ganapathy *et al*. (1973) but its contents of Ni and Rb (Table 1) are more suggestive of a troctolite.

,13 was not completely subdivided by Burlingame and most of it was returned to the Lunar Curatorial Facility. The main piece has 4 somewhat large clasts exposed, three of which are the same lithology, possibly plutonic; the largest of these is suspected as being the parent of 15265,13 ,6 (letter from J. T. Wasson to the Lunar Sample Curator). However, due to the present uncertainty concerning the source of 15265,13 ,6, we will not pursue documentation here.

Table 1

Ir	0.023	Rb	0.84
Re	0.0065	Cs	36
Au	0.091	U	1030
Ni	55		

All data in ppb, except Ni, Rb ppm.

15382 KREEP Basalt 3.2 gm

Evidence for pristinity: Dowty *et al.* (1976) and Gros *et al.* (1976b) found splits to be free of meteoritic contamination.

Description: 15382 is a fine-grained KREEP basalt taken from the Station 7 rake sample at Spur Crater. A petrographic study was made by Dowty *et al.* (1976), and further details are given in Dowty *et al.* (1973), Hlava *et al.* (1973), and Nehru *et al.* (1973, 1974). 15382 is mineralogically and texturally similar to other KREEP basalts from the Apollo 15 landing site (Figure 1). Modal data are given in Table 1. Plagioclase laths are 0.2-0.8 mm long and zoned from An_{85} cores to $<An_{80}$ rims; a single grain was reported with a core of An_{95} (Dowty *et al.*, 1976). Pyroxenes are zoned from orthopyroxene cores to pigeonite rims as shown in Figure 2. Large patches of mesostasis contain high-SiO_2 glass, cristobalite, ilmenite, tranquillityite, armalcolite, baddeleyite, whitlockite, apatite, and ulvöspinel. Olivine is absent from this rock (Dowty *et al.*, 1976).

Bulk chemistry and REE data mainly from Hubbard *et al.* (1973) are presented in Table 1. Additional chemical data appears in Church *et al.* (1972).

Age dates by the Ar-Ar method cluster around 3.90 b.y. (Stettler *et al.*, 1973, Turner *et al.*, 1973). A Rb-Sr model age is 4.30 b.y. (Nyquist *et al.*, 1973).
Papanastassiou and Wasserburg (1976) provide a Rb-Sr isochron age of 3.90 ± 0.02 b.y with an initial $^{87}Sr/^{86}Sr$ of 0.70024 ± 12.

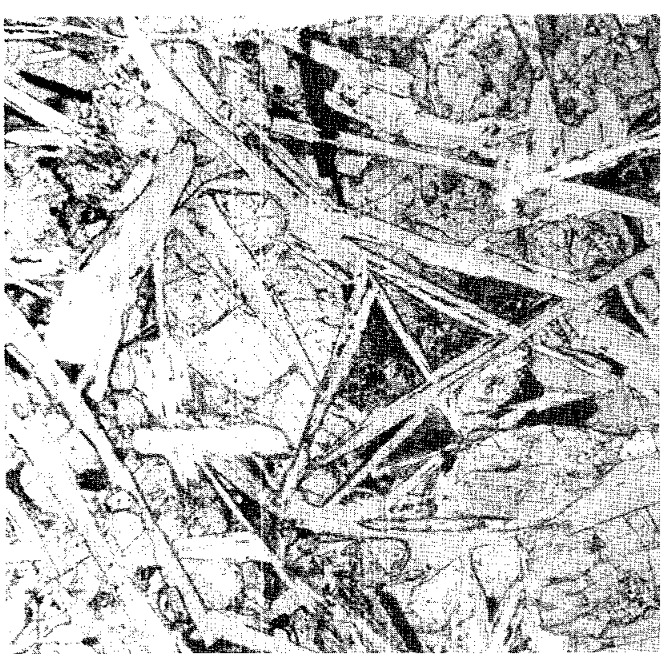


Figure 1. Transmitted light photomicrograph of 15382,6. Width of view ~1 mm.

Table I

	1) Microprobe (Defocussed beam)	2) portion of ,9 (12 mg)	3) ,14	4)
SiO_2	52.4	--		
TiO_2	1.78	2.17	2.2	
Al_2O_3	17.8	14.9	16.4	
Cr_2O_3	0.21	--	0.31	
FeO	8.6	9.2	10.0	
MnO	0.10	--	0.143	
MgO	7.1	7.4	9.8	
CaO	9.9	7.1	10.4	
Na_2O	0.96	0.85	0.81	
K_2O	0.57	0.63	0.53	0.59
P_2O_5	0.55	--		
Rb		16.1		
Sr		195		
Ba		793		
La		79.5	68.1	
Ce		212	218	
Nd		127		
Sm		35.2	29.7	
Eu		2.77	2.72	
Gd		42.9		
Dy		45.7	40	
Er		28.1		
Yb		24.0	19.2	
Lu		3.43	2.70	
U		3.72		3.1
Th		--		10.5

Other references:

Lugmair et al.((1976); Sm-Nd

Lugmair and Carlson (1978); Sm-Nd

Tera and Wasserburg (1976); U-Pb

Papanastassiou et al. (1977); U-Pb

Oxides in wt%, all others in ppm.
Col. 2 from Hubbard et al. (1973) and Church et al. (1972)
Col. 3 from Murali et al. (1977)
Col. 4 from Schonfeld et.al. (1977)

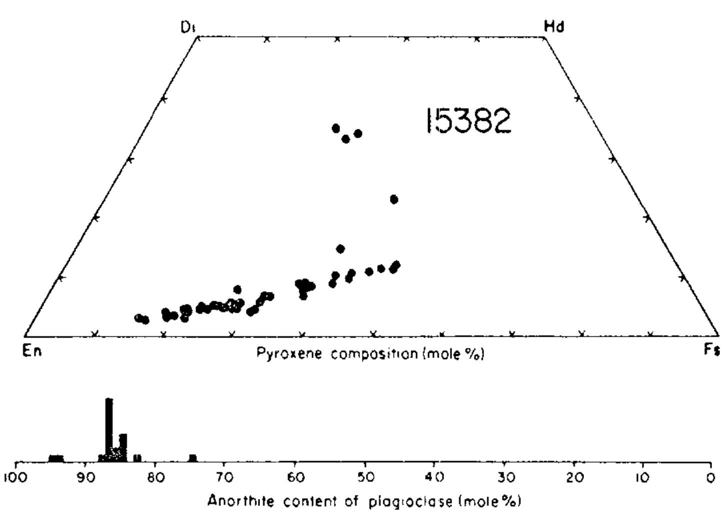


Figure 2. Pyroxene and plagioclase compositions in 15382. (From Dowty et al., 1976).

Table 2

Split	Parent	Location	Mass	Description and daughters
,0	,0	Ent. Subdivided	0.000	--
,1	,0	SSPL	0.270	3 chips. ,9 ,10
,2	,0	Ent. Subdivided	0.000	(P.I.) Potted butt. ,3 ,6 ,7 ,8 ,17
,3	,2	Attrition	0.401	--
,6	,2	SCC	0.010	TS
,7	,2	SCC	0.010	PM
,8	,2	RSPL	0.019	Chip, returned from TSL. Air
,9	,1	Consumed, Gast	0.012	-- ,9001
,10	,1	Consumed, Turner	0.028	--
,11	,0	Attrition	0.186	--
,12	,0	SSPL	0.680	Chips and fines
,13	,0	SSPL	0.810	Chip
,14	,0	Wasserburg	0.420	Chip. ,9002 ,9003 ,9004 ,9005
,15	,0	RSPL	0.001	Fines, returned by Anders. Air, glassine paper. ,18
,16	,0	Attrition	0.060	
,17	,2	Engelhardt	0.010	TS
,18	,15	Consumed, Anders	0.039	--
,19	,9003	Consumed, Schmitt	0.001	--
,20	,9005	Consumed, Haines	0.004	--
,21	,9005	RSPL	0.018	6 P.I. Mounts, returned by Haines. Air, crushed, sieved, acetone, polish. Neutron irradiated, etc.
,9001	,9	Geiss	0.014	Chip?
,9002	,14	Marti	0.050	Chip?
,9003	,14	RSPL	0.084	Fines (?), returned by Schmitt. Air, neutron irradiated. ,19
,9004	,14	(Reserved, SCC)	0.000	--
,9005	,14	RSPL	0.003	Fines, returned by Haines. Air, sieved, hand-picked, pure acetone. ,20 ,21

15386 KREEP Basalt 7.5 gm

Evidence for pristinity: A split analyzed by Warren and Wasson (1978) and Warren et al. (1978b) was free of meteoritic contamination.

Description: Like most fine-grained KREEP basalts this sample has an intersertal to subophitic texture (Figure 1) with ∿35% plagioclase, ∿50% interstitial pyroxene, ∿10% cristobalite, and 3% miscellaneous phases such as ilmenite, phosphate, and troilite. No olivine is present (Steele et al., 1972). Pyroxenes show a wide range in composition (Figure 2) and plagioclase is fairly sodic (An_{70-85}, Figure 3) relative to other lunar basalts (Steele et al., 1972). Bulk chemical data are given in Table 1. Incompatible elements show a typical KREEPy distribution (Figure 4).

A Rb/Sr internal isochron (Figure 5) yields an age of 3.94 ± 0.01 b.y. with an initial $^{87}Sr/^{86}Sr$ = 0.70038. Model ages of 4.25 and 4.28 b.y. are obtained when $^{87}Sr/^{86}Sr$ is assumed to be 0.69910 and 0.69903 respectively (Nyquist et al., 1975).

Figure 1. Transmitted light photomicrograph of 15386,8. Width of view ∿ 2 mm.

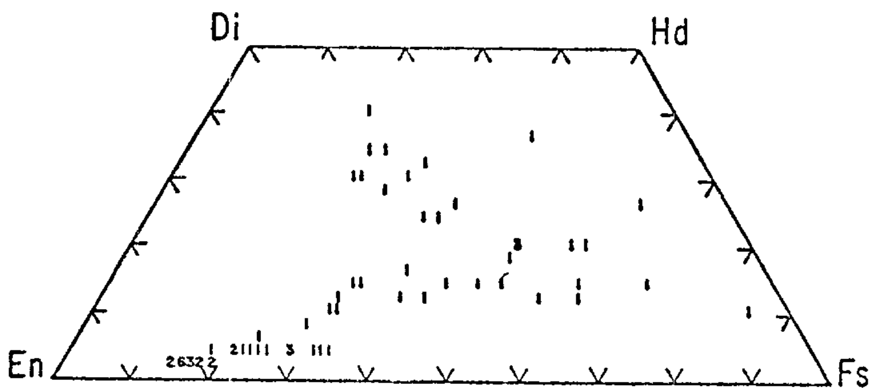


Figure 2. Compositions of pyroxenes in 15386. (From Steele *et al.*, 1972)

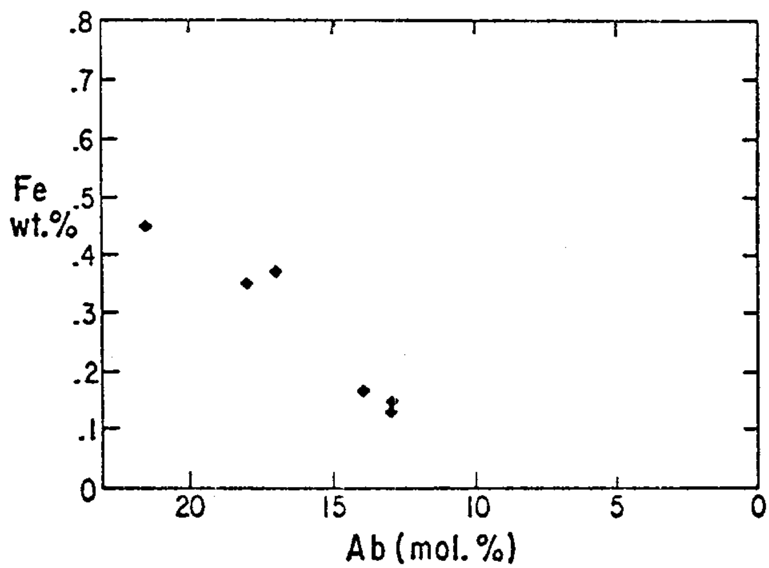


Figure 3. Compositions of plagioclases in 15386. (From Steele *et al.*, 1972)

Table 1

	1)	2)
SiO_2	50.83	--
TiO_2	2.23	1.94
Al_2O_3	14.77	15.31
FeO	10.55	10.19
MnO	0.16	0.15
MgO	8.17	10.46
CaO	9.71	9.52
Na_2O	0.73	0.81
K_2O	0.67	0.50
P_2O_5	0.70	--
Cr_2O_3	--	0.35
Li	27.2	
Rb	18.5	14
Sr	187	--
La	83.5	58
Ce	211	147
Nd	131	80
Sm	37.5	25.5
Eu	2.72	2.4
Gd	45.4	--
Dy	46.3	32
Er	27.3	--
Yb	24.4	18.2
Co	--	23
Ni	--	12.5

Oxides in wt %, all others ppm.
Col. 1 oxides from Rhodes and Hubbard (1973)
Col. 1 elements from Hubbard et al. (1974)
Col. 2 from Warren et al. (1978b)

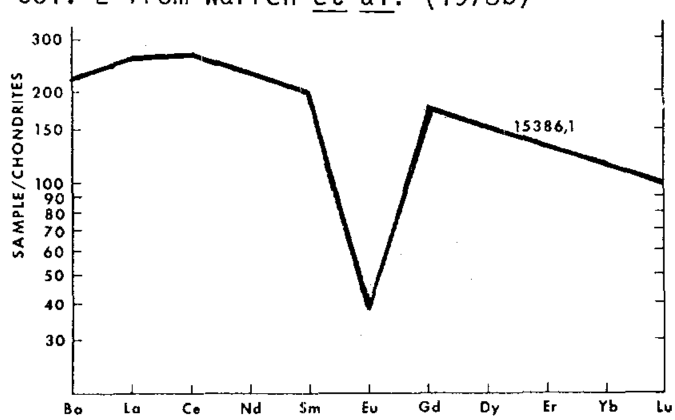


Figure 4. Incompatible elements in 15386. (From Meyer, 1977)

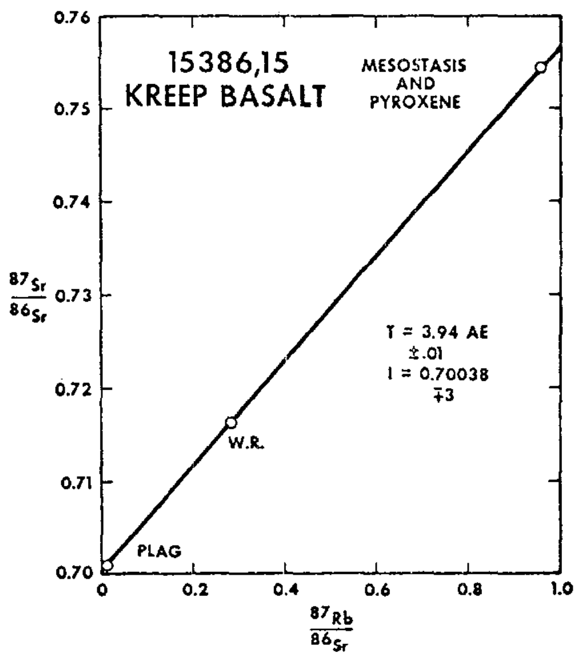


Figure 5. Rb-Sr internal isochron for 15386. (From Nyquist et al., 1975)

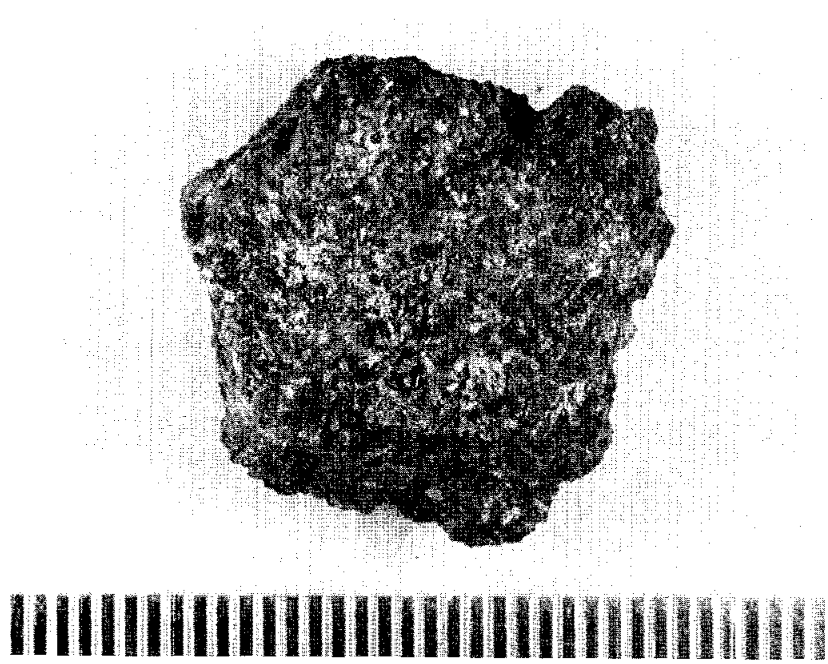


Figure 6. Sample 15386,0. (Photo S-76-24072)

15405 Quartz Monzodiorite (QMD) Clasts ~2-3 gm

Note: There appear to be three exposed clasts of QMD (Lithology 05B of the Imbrium Consortium) as identified by their distinct macroscopic appearance. For convenience, these will informally be termed here Clast A (pieces picked from ,8), Clast B (exposed by cutting of the slab ,95) and Clast C (embedded in ,6).

Evidence for pristinity: Gros et al. (1976a,b) analyzed a split of Clast A and found it to be free of meteoritic contamination. The distinct petrology supports its pristinity (Ryder, 1976).

Description: Macroscopically the QMDs are black and white speckled material (Marvin,1976b) with approximately equivalent amounts of light and dark crystals; the grain-size is ~1.5-2 mm (Figure 1). The QMD clasts occur in a competent fine-grained KREEP impact melt; other clasts are virtually all KREEP basalts or small "granitic" fragments mineralogically similar to QMD.

Clast A: Petrographic studies (Ryder,1976, Ryder and Bower,1976, 1977b, Taylor,1976) show that Clast A consists of a silica mineral potash feldspar, plagioclase, pyroxene, zircon, whitlockite, ilmenite, and Fe-metal. A mode by Taylor (1976) gives 15% Si, 11% Kspar, 35% pl, 36% px and 3% others. Pyroxene is unzoned but exsolved and iron-rich (Figure 2) and the plagioclase is sodic (An_{80-50}). An estimate of the bulk composition of Clast A was made from the mode and mineral analyses by Taylor (1976) and is reproduced in Table 1.

The trace element data of Gros et al. (1976a,b), apart from demonstrating the pristinity of the clast, show that among meteorite-free samples it is highest in Rb (39.00 ppm), Cs (1190 ppb) and U (11500 ppb). Given typical K/U ratios, the U content suggests K_2O of ~2 to 2.5%, in agreement with the estimated composition of Taylor (1976).

LIL data are given by Nyquist et al. (1977a,b) and are reproduced in Table 2 and Figure 3. The data show that the REE abundances are among the highest reported for lunar samples. A quantitative evaluation of the data supports the suggestion of Ryder (1976) that QMD is a differentiate of KREEP basalt liquid; alternatively, partial melting of a KREEP basalt source is possible. An unpublished analysis (Shih et al., in preparation) is also listed in Table 2. The data is very similar to that of Nyquist et al. (1977a,b) and indicates the general reliability of the calculated bulk composition of Taylor (1976).

Rb-Sr isotopic data is presented by Nyquist et al. (1976, 1977a,b). The Rb-Sr system is severely disturbed (Figure 4). The high model age of 5.4 b.y. for K-spar and silica separates is conclusive evidence of

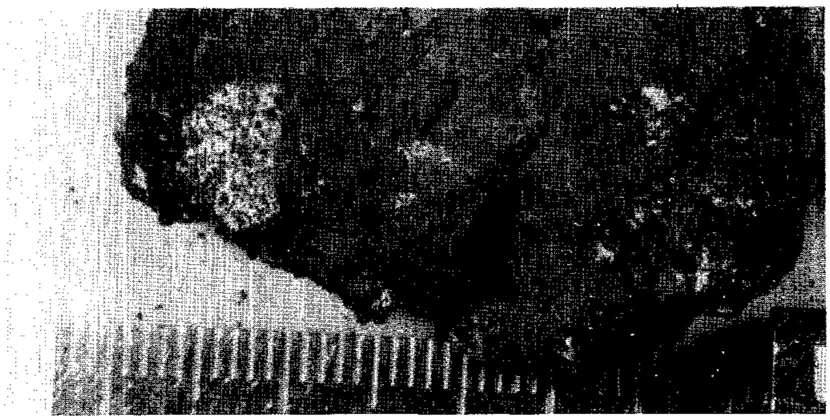


Figure 1a. QMD clast C in 15405,6. Scale in mm.

Figure 1b. QMD clast A in 15405,56. Crossed polarizers.

Rb loss. With various assumptions a model age of 4.2 - 4.4 b.y. has been calculated, but the data does not preclude a younger age (Nyquist et al., 1977a,b).

U-Th-Pb systematics demonstrate that 15405 as a whole has had a complex history, with at least two U-Pb distrubances in the interval 0.6-1.5 b.y. (Tatsumoto and Unruh, 1976a,b). With an assumption that the U-Pb system of QMD was closed during all but one of the "recent" disturbances, the data indicate that QMD formed at 4.0 ± 0.1 b.y. (Figure 5). The whole rock data (for WR_1 which has a mass ∿30 x WR_2) shows a U content of 17.4 ppm, equivalent to a K_2O content of ∿3%.

Argon analyses (Bernatowicz et al., 1977a,b) fail to give a well-defined ^{40}Ar-^{39}Ar plateau age (Figure 6). The data was interpreted to suggest a real thermal event at ∿1.25 b.y. that degassed K-spar but not necessarily other minerals. The data indicate that QMD has ∿2.8% K_2O. A fission track study of a whitlockite grain suggests an age of 0.5-1.5 b.y. (Podosek and Walker, 1976).

In summary, the geochronological data indicate thermal events on the order of 1 b.y. ago which distrubed the systems making evaluation of the true formation age of QMD subject to substantial assumptions.

Oxygen isotope analyses (Clayton, 1977) give a $\delta\, ^{18}O$ (SMOW) of 5.68 o/oo, in no way exceptional for lunar rocks. There is apparently very little effect on the oxygen isotopic composition resulting from igneous differentiation of lunar materials.

Clast B: Ryder and Bower (1977b) confirmed that Clast B had the mineralogy of a QMD, using reflected light petrographic and microprobe studies.

Clast C: No allocations of Clast C have been made.

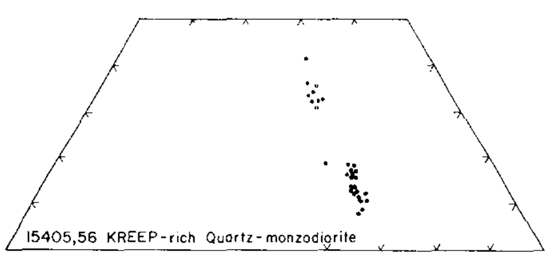


Figure 2. Compositions of pyroxenes in QMD clast A. (From Ryder, 1976)

Table 1

Estimated bulk composition of QMD, (wt. %)

SiO_2	57.4
TiO_2	1.1
Al_2O_3	13.2
FeO	11.2
MgO	3.4
CaO	9.0
Na_2O	1.0
K_2O	1.9
P_2O_5	0.4
ZrO_2	0.4

From Taylor (1976)

Table 2

	1) Portion of ,85 (17 mg)	2) Portion of ,85
FeO		15.1
Na_2O		0.87
K_2O	1.7	1.8
Rb	40.6	
Sr	154	
Ba	1,490	
Li	40.9	
Sc		30.7
Cr		1220
Co		7.8
Zn		60
Cs		1.1
Hf		51
Ta		13
Th		43
La	224	210
Ce	555	560
Nd	328	
Sm	92.0	93
Eu	2.69	2.52
Gd	110	
Tb		19.7
Dy	116	
Er	71.7	
Yb	60.9	65
Lu	8.06	9.0

Oxides in wt. %, others in ppm.
Col. 1 from Nyquist *et al.* (1977a, b)
Col. 2 from Shih *et al.* (in preparation)

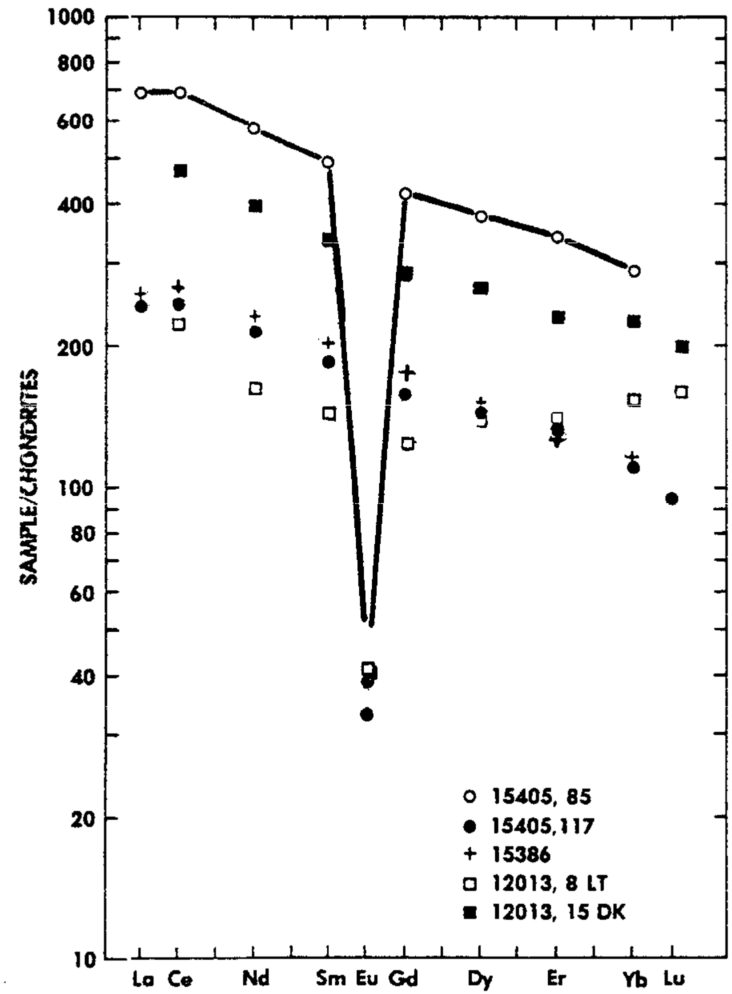


Figure 3. Concentrations of REE's in 15405 and other selected lunar samples. (From Nyquist *et al.*,1977a,b).

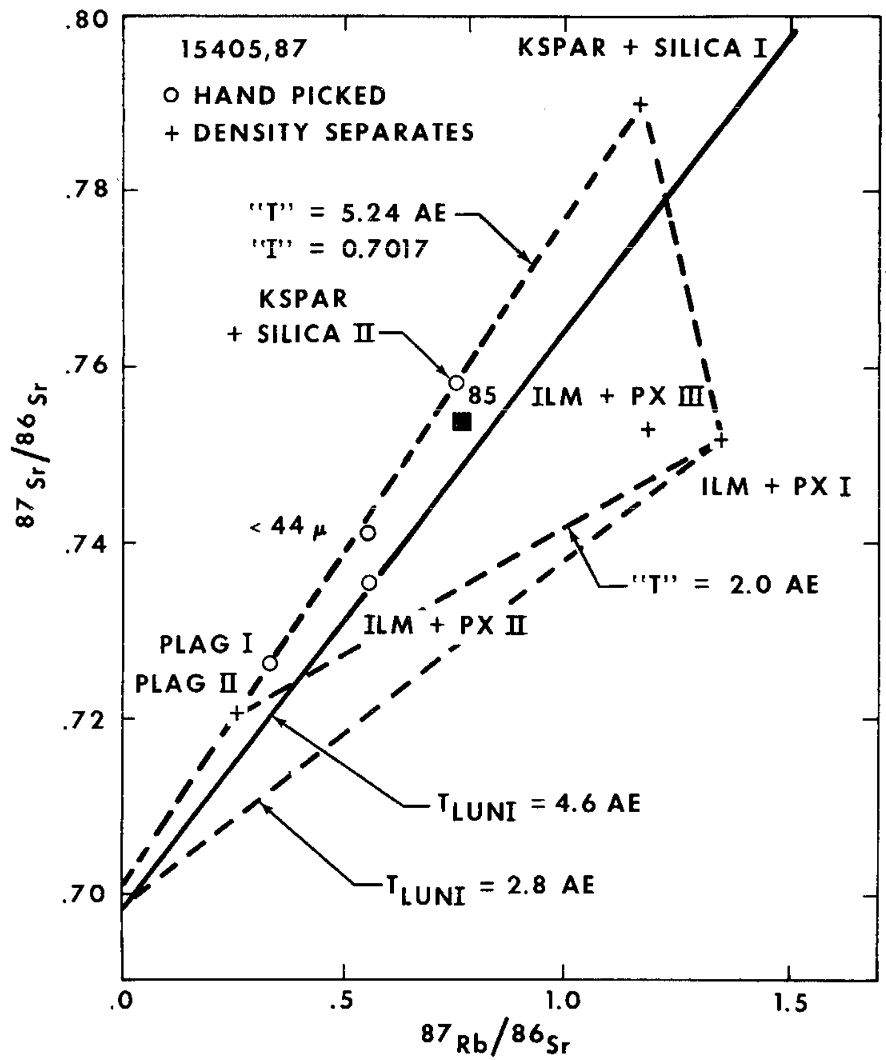


Figure 4. Rb-Sr data for "whole rock" QMD within field of mineral separates. (From Nyquist *et al.*, 1977a,b).

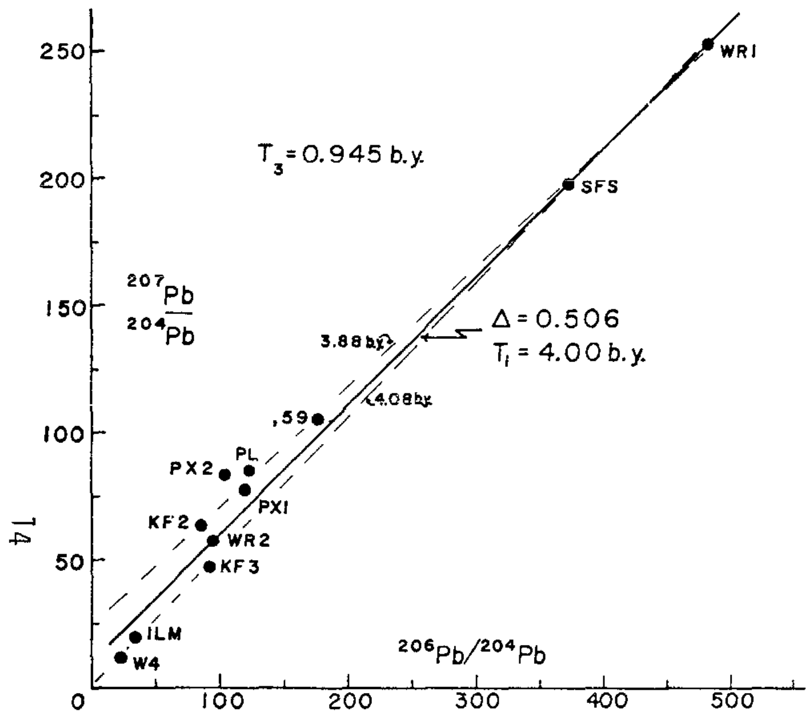


Figure 5. $^{207}Pb/^{204}Pb$ vs. $^{206}Pb/^{204}Pb$ diagram of 15405,88 (QMD) and ,59 (matrix) data. (From Tatsumoto and Unruh, 1976b, which see for explanation).

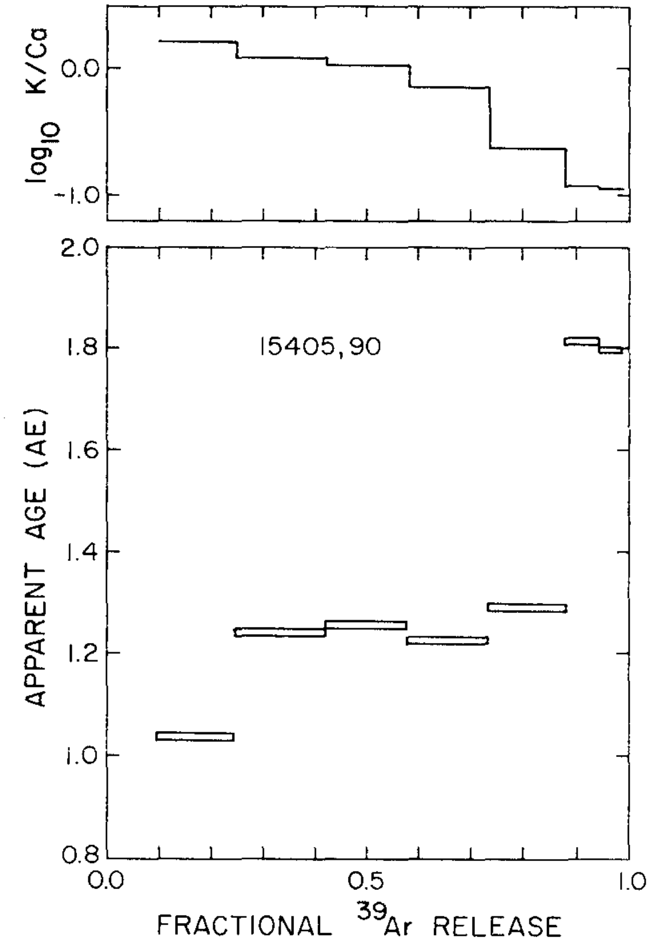


Figure 6. ^{40}Ar-^{39}Ar plateau data for QMD. (From Bernatowicz *et al.*, 1977a,b).

Table 3

Split	Parent	Location	Mass	Description* and daughters containing QMD
,6	,0	SSPL	20.920	C. Mainly matrix
,8	,0	SSPL	2.360	A. (all extracted) 1cm-1mm fines; ,51 ,52 (,56 ,57) ,65 (,85-,90 ,103) ,122 (,130) ,123
,51	,8	Walker, R.M.	0.020	A. Chip; PI TS was cut
,52	,8	Ent. Subdivided	0.000	A. Chip; was potted butt. ,56 ,57
,56	,52	Wood	0.01	A. TS
,57	,52	Wood	0.01	A. TS
,65	,8	Ent. Subdivided	0.000	A. Chips; ,85-,90 (,103 ,9006)
,85	,65	Nyquist	0.027	A. Chip; ,9006
,86	,65	RSPL	0.026	A. Chip; Returned by Anders. Air, glassine paper; ,103
,87	,65	Nyquist	0.11	A. Chip; (partly consumed)
,88	,65	Consumed, Tatsumoto	0.040	A. Chip
,89	,65	Tatsumoto	0.03	A. Chip
,90	,65	Walker, R.M.	0.33	A. 5 Chips, largest includes matrix
,91	,0	BSV	117.090	B. E_1 butt end. Mainly matrix.
,95	,0	Ent. Subdivided	0.000	B. Was slab piece; ,106-,110 ,114-,116 (,148) ,119 ,138 (,145)
,103	,86	Consumed, Anders	0.064	A.
,106	,95	RSPL	0.100	B. Chip, mainly matrix. Returned by Wood, unopened.
,107	,95	RSPL	0.330	B. Chips and fines, mainly matrix. Returned by Wood, unopened.
,108	,95	RSPL	0.040	B. Chip, mainly matrix. Returned by Wood, unopened.
,109	,95	RSPL	1.730	B. Chip, mainly matrix. Returned by Wood. Clean air, stainless steel.
,110	,95	SSPL	0.390	B. Includes matrix.
,114	,95	RSPL	0.040	B. Mainly matrix. Returned by Wood, unopened.
,115	,95	Reed	0.025	B. Chip, some matrix; ,148
,116	,95	Wood	0.630	B. Chip, mainly matrix.
,119	,95	RSPL	0.350	B. Fines & chips, mainly matrix. Returned by Wood. Clean air.
,122	,8	SSPL	0.040	A. Many chips, fairly pure; ,130

*Initial letter refers to specific clast

15405

Split	Parent	Location	Mass	Description* and daughters containing QMD
,123	,8	SSPL	0.490	A. Chips, includes matrix.
,130	,122	Clayton	0.010	A. Chips, partly consumed.
,138	,95	RSPL	2.890	B. Potted butt, mainly matrix; ,145
,145	,138	Wood	0.01	B. TS, includes matrix.
,148	,115	Takeda	0.015	B. Chip, includes matrix.
,9006	,85	Consumed, Haskins	0.033	A.

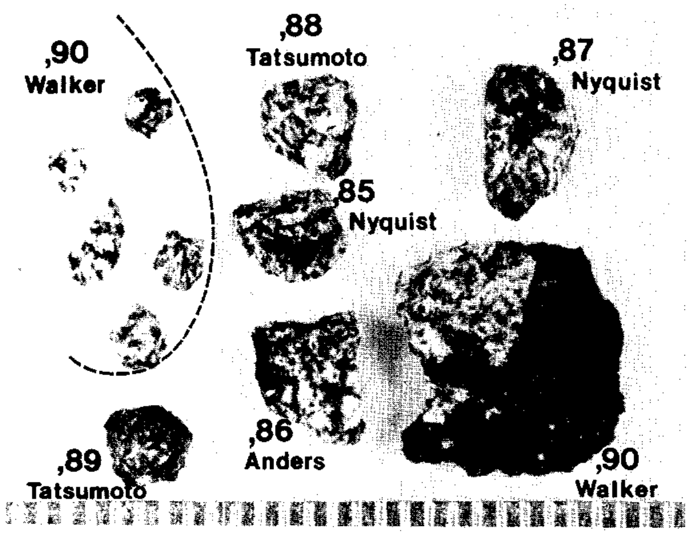


Figure 7. Original splits of clast A

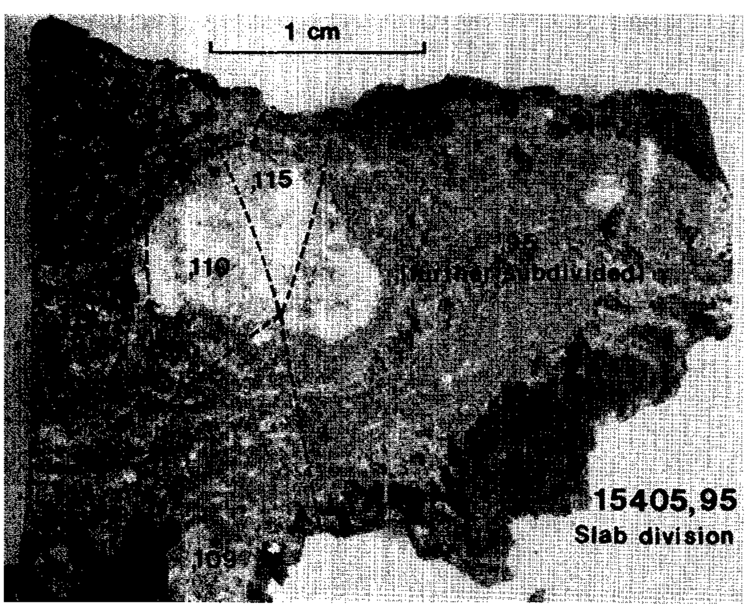


Figure 8. Initial splits of slab containing clast B

15437 Troctolitic Anorthosite 1.06 gm

Evidence for pristinity: Warren and Wasson (1978) analyzed a fragment and found it to be free of meteoritic contamination and low in incompatibles (Table 1).

Description: 15437 is a small fragment from 4 - 10 mm fines sample 15434 from which it was removed and renumbered (see Phinney et al.,1972). The data of Warren and Wasson (1978) (Table 1) show a troctolitic anorthosite (∿82% plagioclase, ∿11% olivine). Inspection of ,4 and ,7 in the library revealed a breccia of low-porosity which appears to be monomict. Clasts of plagioclase and mafics (mainly olivine?) are set in a fine-grained matrix of the same (Figure 1). The finer grained matrix has a rather granulated texture, but is not texturally homogenized overall as is "granulitic ANT". Most grains are less than 1 mm.

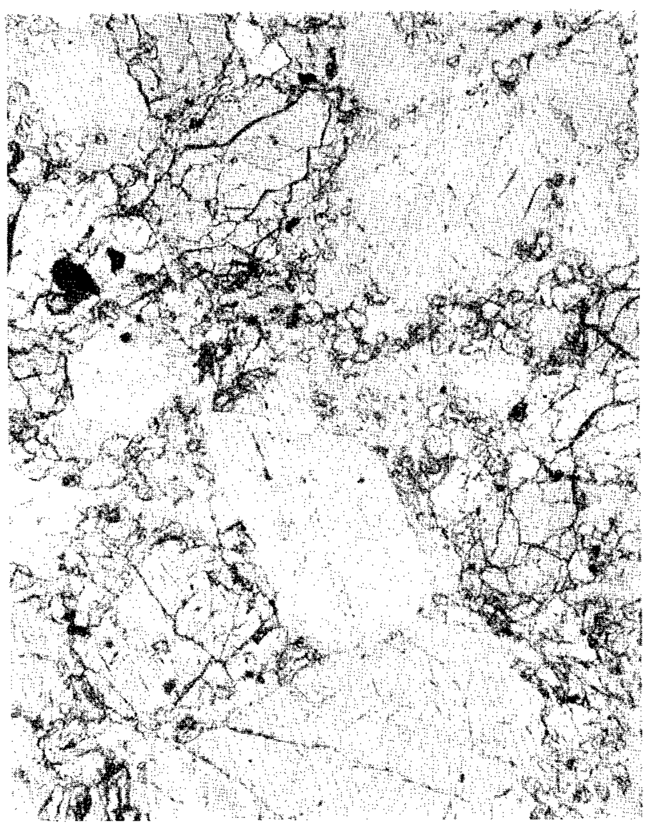


Figure 1. Transmitted light photomicrograph of 15437,4. Width of view ∿1 mm.

Table 1

,3 (0.090 gm)

SiO_2	43.4	Ba	26.
Al_2O_3	29.5	La	0.40
FeO	4.3	Ce	1.50
MgO	4.9	Sm	0.194
CaO	16.9	Eu	0.60
Na_2O	0.23	Yb	0.13
K_2O	0.007	Lu	0.022
Cr	280.		
Mn	456.	Re ppb	0.016
Sc	3.0	Au ppb	0.024
Co	12.		
Ni	10.7		
Zn	1.68		
Ga	2.6		
Ge ppb	33.4		
Cd	1.1		
In	0.35		

Oxides in wt %, others in ppm except as noted.

From Warren and Wasson (1978)

Table 2

Split	Parent	Location	Mass	Description and daughters
,0	,0	SSPL	.800	
,1	,0	RSPL	.110	Potted butt; ,4 ,5 ,7
,2	,0	Attrition	-0.030	----
,3	,0	Wasson	0.090	4 white chips
,4	,1	SCC	0.010	TS, broken
,5	,1	Wasson	0.010	PM
,7	,1	SCC	0.010	PM

15445 Clasts

Sample 15445 contains several white clasts in a fine-grained black matrix. Several of the white clasts are pristine (or probably so) and are described in the following pages. Other clasts, incompletely studied or unstudied, may also be pristine.

Specific clasts in 15445 have been labelled A, B, C....etc., (not to be confused with Type A, B of Ridley et al., 1973). Use of these designations has not been entirely consistent, and some clasts have not previously received letter designations. To clarify the subsequent sections on specific pristine clasts, the following photographs label clasts as used in this catalog. They conform with past designations as much as possible.

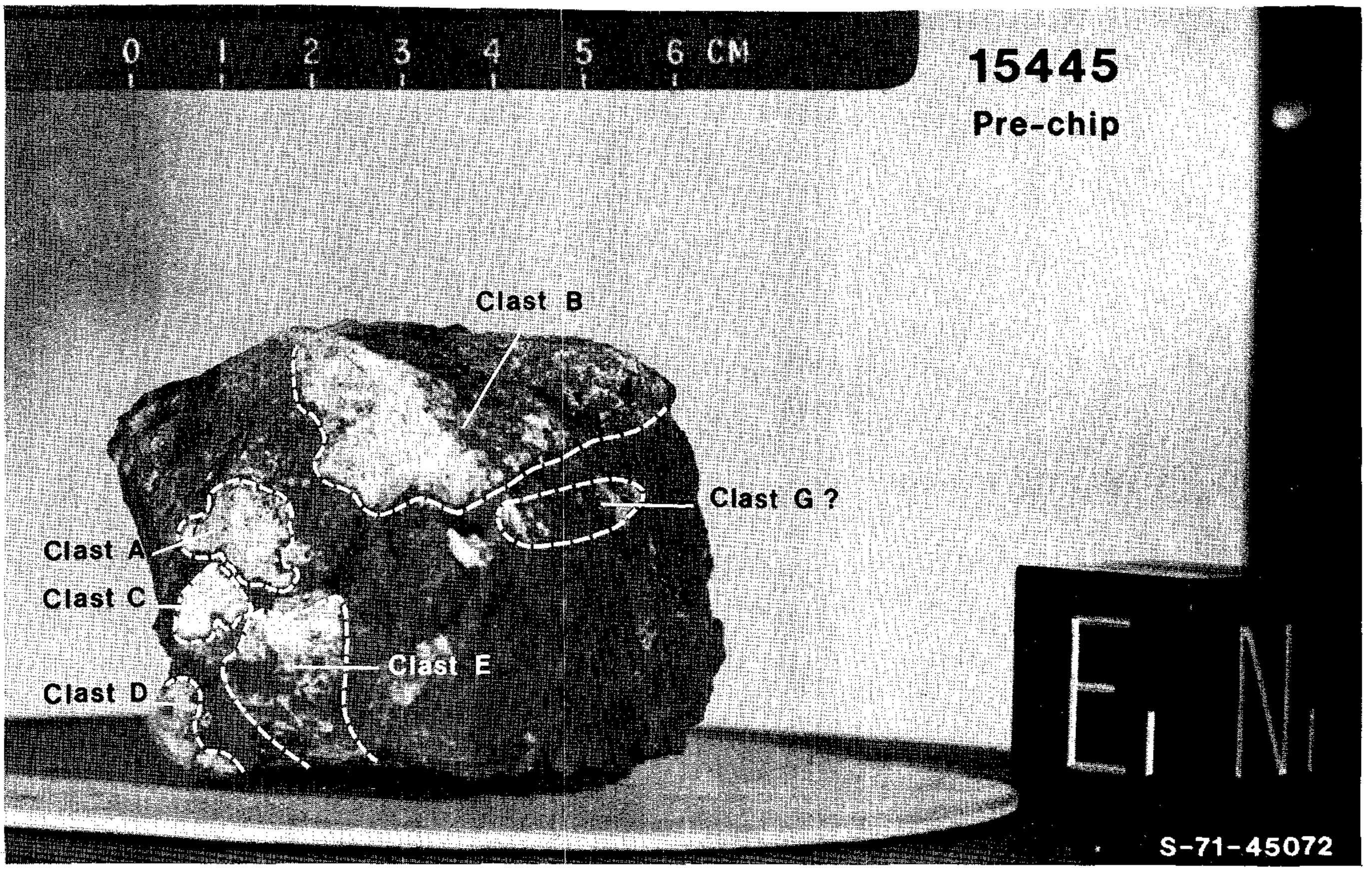


Figure 1.

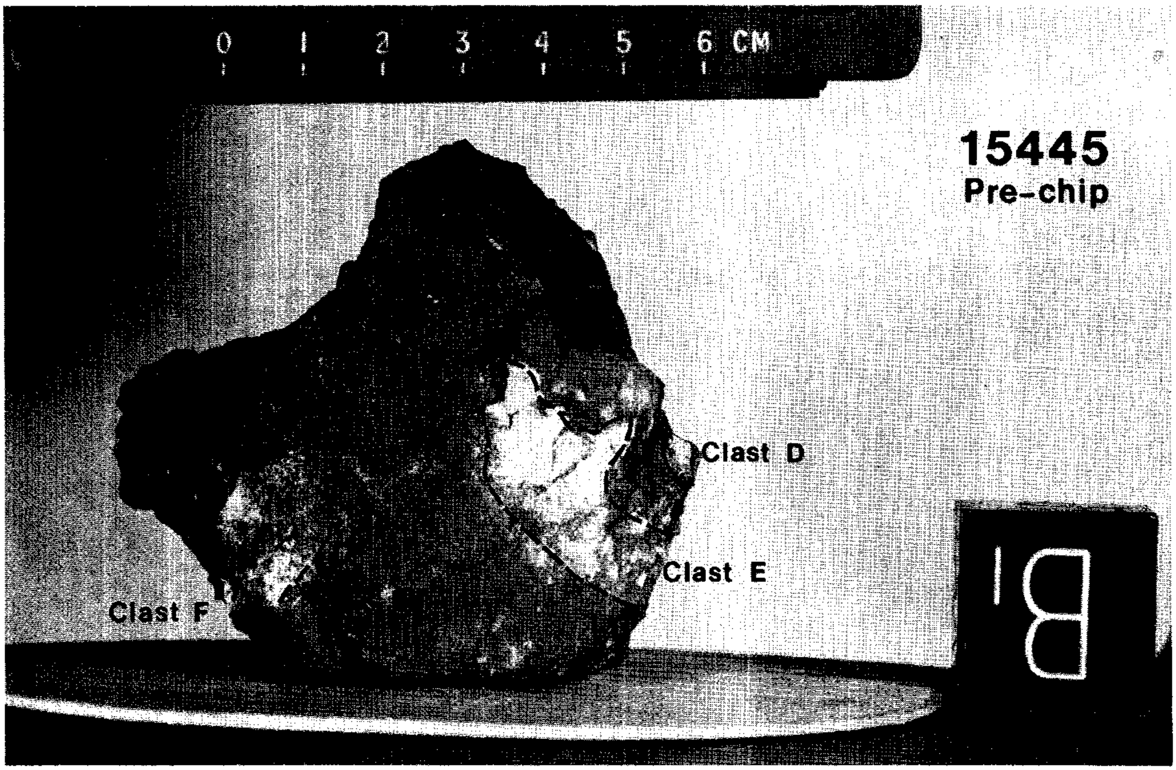


Figure 2

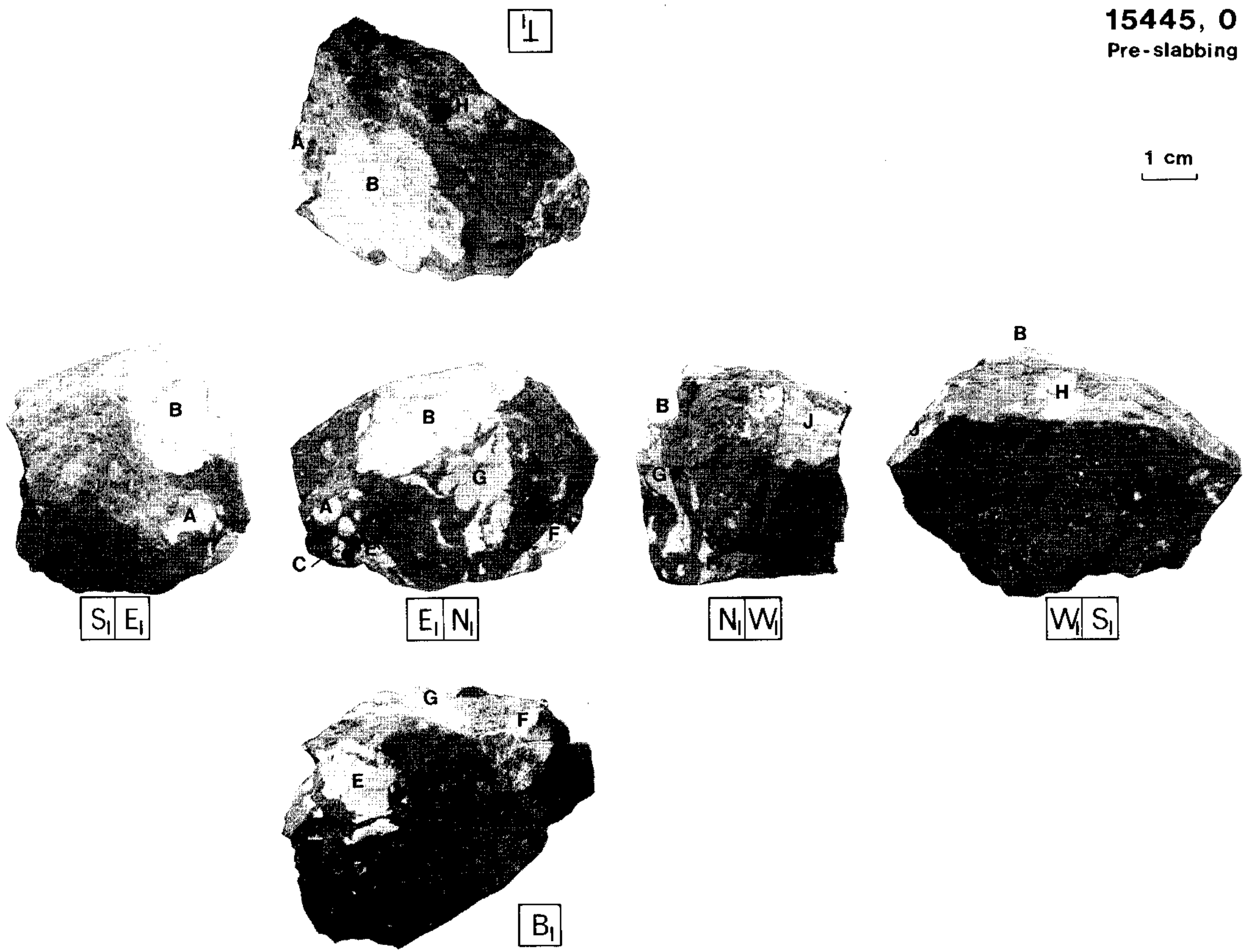


Figure 3

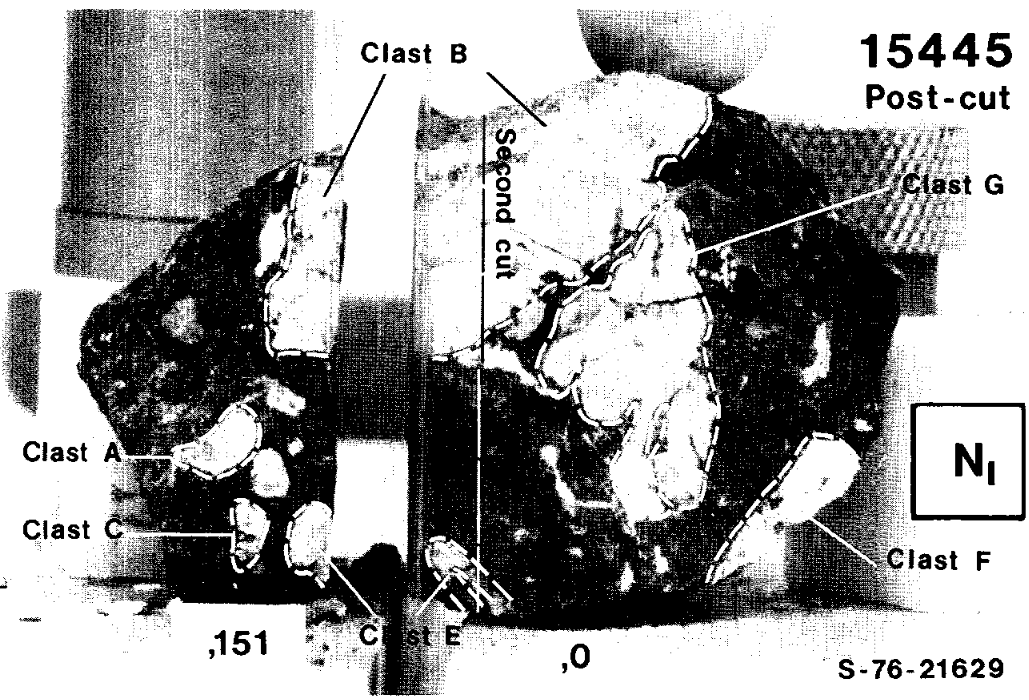

15445
Post-cut
Clast B
Second cut
Clast G
Clast A
Clast C
Clast E
Clast F
,151
,0
S-76-21629
N

Figure 4

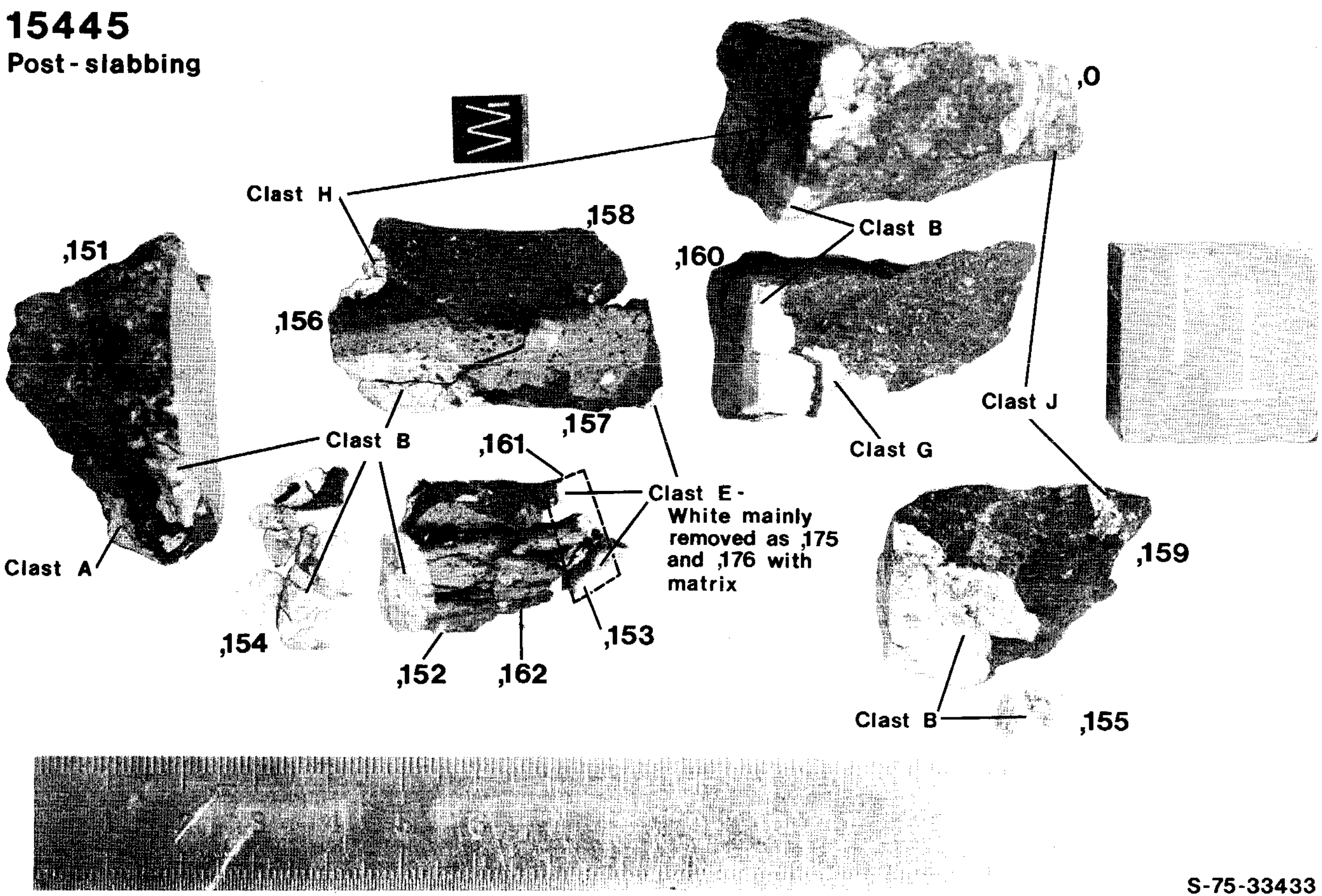

15445
Post-slabbing
,0
Clast H
,158
Clast B
,151
,160
,156
Clast J
,157
Clast B
Clast G
,161
Clast E -
White mainly
removed as ,175
and ,176 with
matrix
,159
Clast A
,154
,153
,152
,162
Clast B
,155
S-75-33433

Figure 5

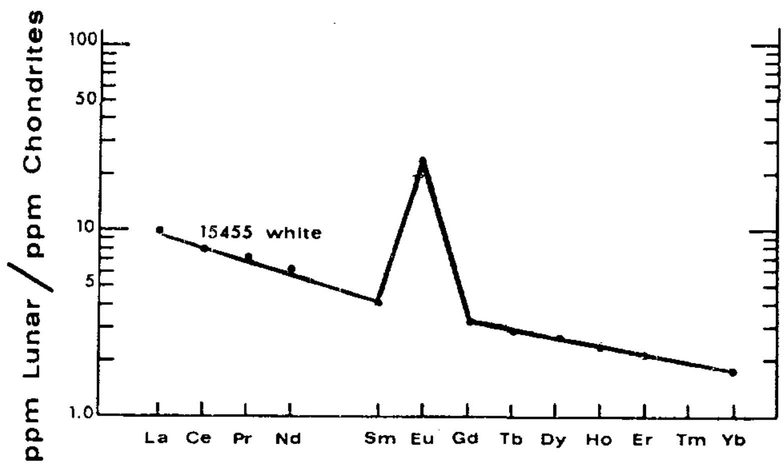


Figure 3. REE data from white clast, probably anorthositic norite, in 15455. (From Taylor *et al.*, 1973)

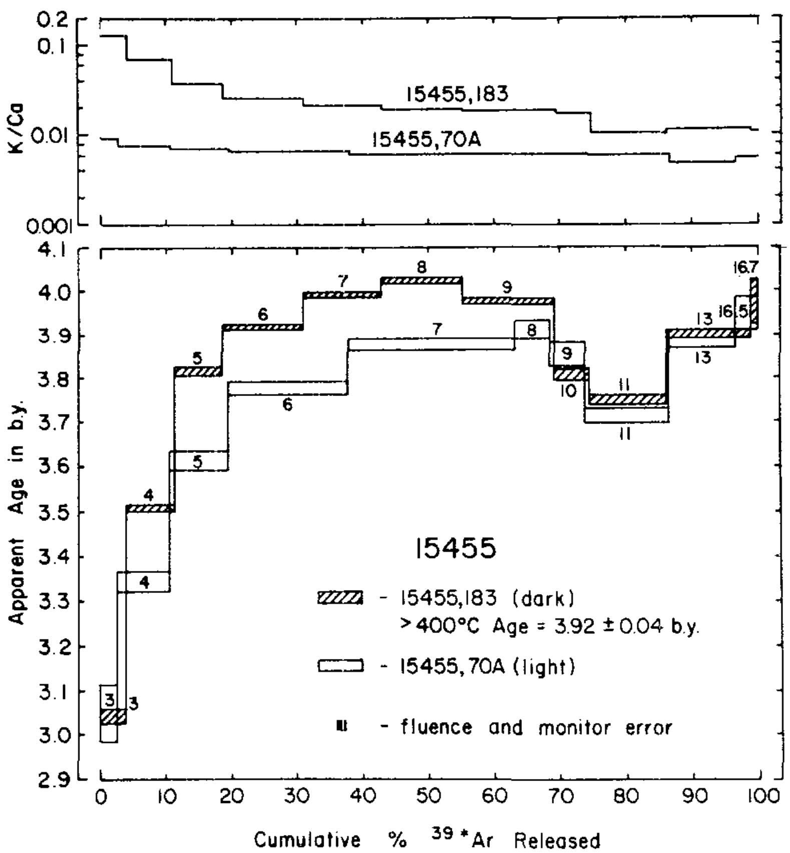


Figure 4. ^{40}Ar-^{39}Ar plateau data for anorthositic norite in 15455. (From Alexander and Kahl, 1974)

15445 Clast A Spinel Troctolite $\sim$1.5 gm

Evidence for pristinity: Thin section and grain mount observations show that Clast A, although brecciated, has homogeneous mineral phases consisting of very magnesian olivines and pyroxenes, chromian pleonastes, and plagioclase (Anderson, 1973; Ridley et al., 1973; Ryder and Bower, 1977a,b). Relict zones indicate a coarse pre-brecciation grain size of more than 2 mm suggestive of a cumulate (Ryder and Bower, 1977a,b, Ridley et al., 1973). Steele and Smith (1975) found extremely low Ca contents in the olivines, indicative of a deep-seated igneous origin. Oxygen isotopes are consistent with an igneous origin (Clayton et al., 1973). The low levels of light REEs and the unusual REE pattern (Ridley et al., 1973) if real indicate a pristine lithology. (A similar clast of spinel troctolite in 15445 analyzed by Gros et al., 1976a,b may be free of meteoritic siderophiles if allowance is made for matrix contamination).

Description: 15445 Clast A (Lithology 45E of the Imbrium Consortium, and represents Type B of Ridley et al., 1973) is a friable brecciated clast (Figure 1). Mineral data is given in Table 1 (compiled by Ryder and Bower, 1977a,b); noteworthy are the very magnesian mafics and the chromian pleonaste.

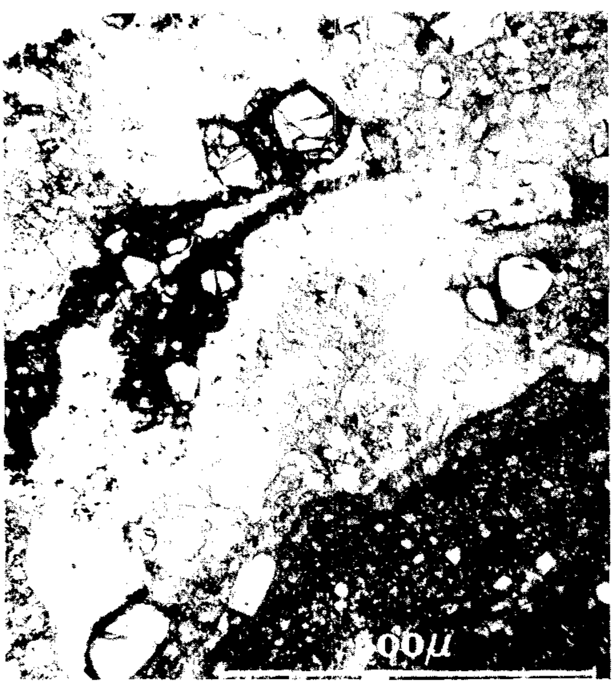


Figure 1. Transmitted light photomicrograph of clast A in 15445,92. Bottom right corner is matrix.

The mode is in doubt and the clast seems heterogeneous on a 5 mm scale or more, presumably a reflection of a cumulate nature with a coarse grain size. Anderson (1973) referred to Clast A as a peridotite (plag ∿5%) whereas Ryder and Bower (1977a,b) observed 30-40% plagioclase (i.e. spinel troctolite). Ryder and Bower (1977a,b) did not find pyroxene in 4 thin sections of Clast A, whereas Anderson (1973) implies ∿20% pyroxene.

Ridley et al. (1973) and Wiesmann and Hubbard (1975) report partial analyses of Clast A (Table 2, Figure 2) and found it to be ultrabasic. The small sample sizes as compared to the grain-sizes of the clast cast doubt on how representative the analyses might be. The analysis of Ridley et al. (1973) has an unusual REE pattern, unique among lunar samples, which they attribute to the possible former presence of garnets. However, a second, smaller split shows a more normal pattern (Figure 2).

Whole rock Rb-Sr data for 15445,9, including model ages of 4.2 ± 1.6 b.y. and 4.4 ± 1.6 b.y. are given in Nyquist et al. (1973).

Mineral	Proportion	Composition
Olivine	(a) present (b) >40% (c) ~50%	(a) Fo_{91-88} (b) Fo_{91} (c) Fo_{90-92} (d) Fo_{92}
Plagioclase	(a) minor (b) 5% (c) 30–40%	(a) An_{98} (b) An_{90-95}(?) (c) An_{89-95}
Pyroxene	(a) present (b) <40% (c) not found	(a) En_{92}, Al_2O_3 2–3% (b) En_{91}, Al_2O_3 5%
Pleonaste	(a) present (b) 15% (c) 10–20%	(a) 13% Cr_2O_3, 9.5% FeO (b) 14% Cr_2O_3, 9.4% FeO (c) 10.2–15.3% Cr_2O_3, 8.0–12.6% FeO
Others	(b) traces (c) traces	(b) rutile(?), armalcolite (c) unidentified opaques

Table 1. Summary of Clast A mineral data. (a) Ridley et al. (1973), (b) Anderson (1973), (c) Ryder and Bower (1977), (d) Steele and Smith (1975).

Table 2

	1) ,71 (55.7 mg)	2) ,9 (5 mg)
TiO_2	0.588	0.154
Al_2O_3	7.2	
MgO	31.1	36.7
CaO	1.9	4.76
Na_2O	0.10	
K		122
Rb		0.80
Sr		42.6
Ba	25	23.6
U		0.151
Zr		35
Hf		1
La	1.84	
Ce	3.2	
Nd	2.89	3.35
Sm	1.05	1.02
Eu	0.196	0.275
Gd	2.09	
Dy	4.88	1.65
Er	4.04	1.12
Yb	3.89	
Lu	0.573	
Sr^{87}/Sr^{86}		0.70238±44

Oxides in wt. %, others in ppm.
Col. 1 from Ridley et al. (1973)
and Wiesmann and Hubbard (1975)
Col. 2 from Wiesmann and Hubbard (1975)

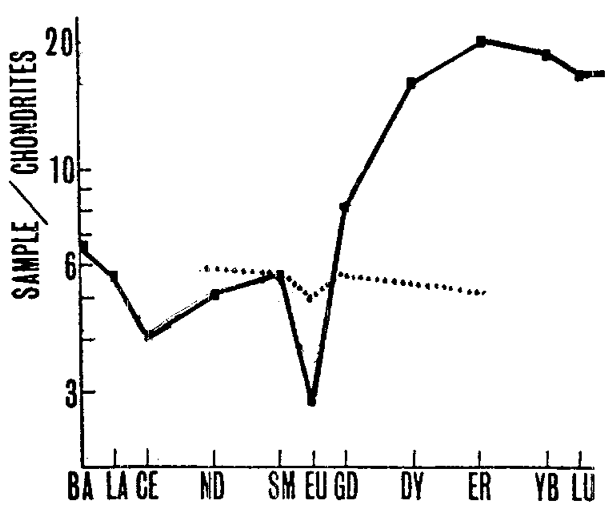


Figure 2. Incompatible element data for Clast A. Solid line from Ridley et al. (1973), dotted line from Wiesmann and Hubbard (1975).

Table 3

Split	Parent	Location	Mass	Description and daughters containing Clast A
,7	,0	RSPL	0.220	Potted butt, includes matrix: ,60 ,92
,8	,0	Geiss	0.100	Crumbs
,9	,0	Consumed, Gast	0.005	Crumbs: ,94 ,9001 (,89 ,90)
,10	,0	Clayton	0.050	Crumbs
,11	,0	Price	0.050	Crumbs
,40	,0	SSPL	4.100	Matrix plus other clast, possibly a trace of Clast A. Daughters do not include Clast A.
,60	,7	Smith	0.010	TS, includes matrix
,70	,0	Geiss	0.066	Fines
,71	,0	Consumed, Gast	0.055	Fines
,76	,0	SSPL	1.620	Chip, mainly matrix
,77	,0	SSPL	1.220	Chip, includes matrix and Clast B
,78	,0	RSPL	1.880	Potted butt chip, was mainly matrix and Clast B: ,132-,136 ,149
,89	,9001	RSPL	0.001	P.I. Grain Mount, returned by Brett
,90	,9001	RSPL	0.003	Clasts, returned by Brett. Air
,92	,7	Dence	0.010	TS, includes matrix
,94	,9	Consumed	0.051	Gast ?
,132	,78	Reid	0.010	TS
,133	,78	Dence	0.010	TS
,134	,78	Dence	0.010	TS includes matrix and Clast B
,135	,78	Wood	0.010	TS
,136	,78	Reid	0.010	TS
,149	,78	Walker, R.M.	0.030	TS - Thick Section
,151	,0	BSV	44.510	End piece after slabbing. Remains of Clast A (~8 x 5mm) are in this piece.
,9001	,9	Ent. Subdivided	0.000	Crumbs: ,89 ,90

15445 Clast B Norite ~10 gm plus

Evidence for pristinity: Gros et al. (1976a,b) analyzed a split (,107) and found it to be free of meteoritic contamination, despite the brecciation of the clast.

Description: 15445 Clast B (Lithology 45D of the Imbrium Consortium, represents type A of Ridley et al. (1973)) is a brecciated norite (Figure 1) containing 60-65% plagioclase, 35-40% low-Ca pyroxene, and minor silica and opaques (Ridley et al., 1973, Ryder and Bower, 1977a,b). Plagioclases are An_{94-96}. Pyroxene compositions from Ryder and Bower (1977a,b) are reproduced in Figure 2; similar compositions were reported by Ridley et al. (1973). Relict zones and textures suggest an original grain size greater than 1 mm. The mineralogy is similar to that of the norite boulder 78235/55 and the clast in 15455 except that these latter norites contain a greater variety of minor phases.

Chemical analyses are reproduced in Table 1 and REE data are plotted in Figure 3. The data from the different sources are in good agreement and are consistent with a plagioclase content of 60-65%. The positive Eu anomaly suggests plagioclase accumulation; constraints on the parent magma are discussed in Ridley et al. (1973) and Ryder and Bower (1977a,b). Additional trace element data is given in Gros et al. (1976a,b).

U-Th-Pb isotopes were analyzed in split ,106 (Tatsumoto and Unruh, 1976a). Mafics, plagioclase, and whole rock concentrations showed a large amount of non-radiogenic Pb, which may have been due to contamination.

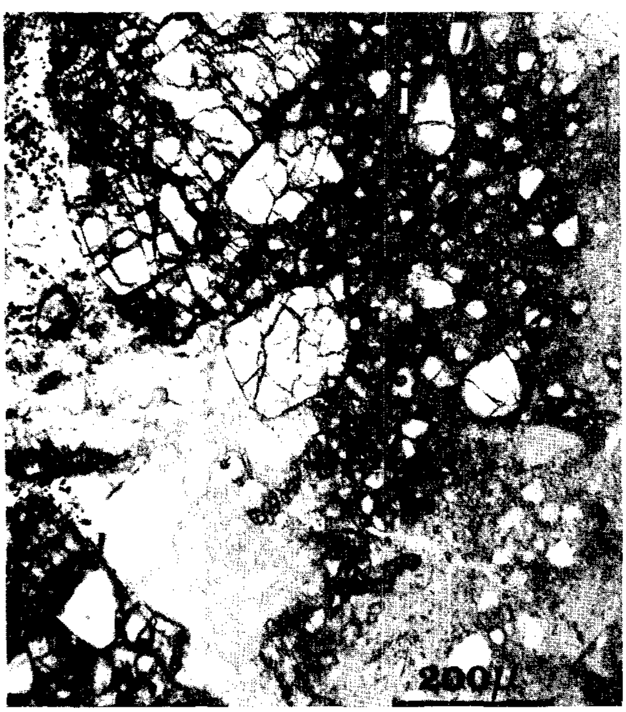


Figure 1. Transmitted light photomicrograph of 15445,134.

Oxygen isotopic data (Clayton et al.,1973) are typical for lunar samples; there is no evidence for isotopic exchange, following igneous crystallization, over distancies of 1 cm or more.

Whole rock Rb-Sr data for 15445,17, including model ages of 4.64 ± 0.15 b.y. (TBABI) and 4.85 ± 0.15 b.y. (TLUNI) are given in Nyquist et al. (1973).

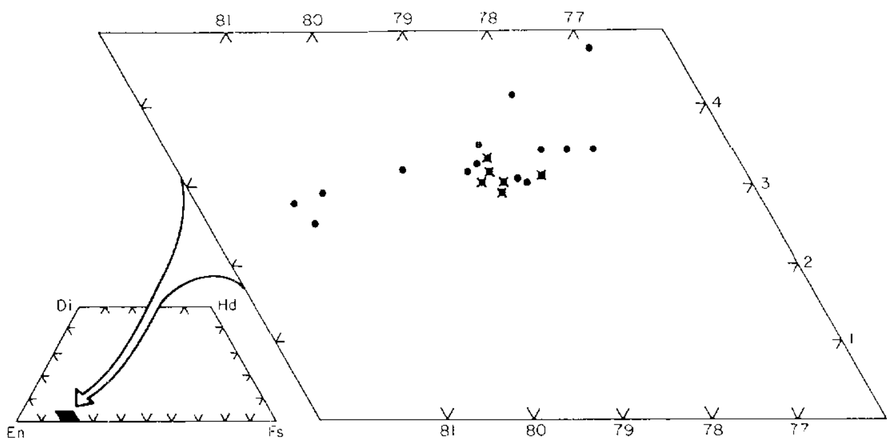


Figure 2. Compositions of pyroxene in 15445 norite. (From Ryder and Bower, 1977)

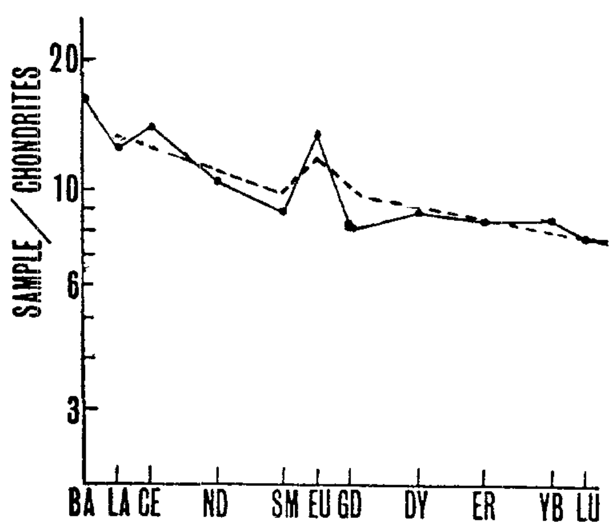


Figure 3. Incompatible trace element data for 15445 norite. Solid line from Ridley et al. (1973), dashed line from Blanchard et al. (1977).

Table 1

	Portion of ,17 (51.0 mg)		Portion of ,104
	1)	2)	3)
SiO_2	48.7		47.7
TiO_2	0.15	0.14	0.27
Al_2O_3	23.76	20.80	23.0
(Cr)		(1561)	(1710)
Cr_2O_3			0.25
FeO	3.88	3.8	3.9
MnO	0.08		
MgO	9.94	9.7	10.2
CaO	13.26	12.6	12.8
Na_2O		0.33	0.32
(K)		(582)	
K_2O			0.066
P_2O_5	0.03		
Rb		1.43	
Sr		130	
Ba		61.9	
S	0.00		
Sc			7.1
Co			10.3
Ni			n.d.
Zr	115		
Hf	4.1		1.36
Ta			0.13
U	0.54		
Th			0.82
La	4.02		4.02
Ce	11.1		10.8
Nd	5.91		
Sm	1.65		1.81
Eu	0.929		0.87
Gd	2.05		
Tb			0.46
Dy	2.69		
Er	1.72		
Yb	1.78		1.72
Lu	0.268		0.28
Sr^{87}/Sr^{86}	0.70122±5		

Cols. 1, 2 from Ridley *et al.* (1973), Hubbard *et al.* (1973, 1974), Wiesmann and Hubbard (1975).
Col. 3 from Blanchard *et al.* (1977 and unpublished)
Oxides in wt. %, others in ppm.
n.d. = not detected.

Table 2

Split	Parent	Location	Mass	Description and daughters containing Clast B
,0	,0	SSPL	61.670	Mainly matrix. Also contains Clasts G, I, (H?) and others?
,4	,0	SSPL	3.02	Contains matrix.
,12	,0	RSPL	0.030	Chips, includes black veinlet. Returned by Griscom. Air, alum. can.
,13	,0	Nyquist	0.110	Chip
,14	,0	Clayton	0.060	Chip
,15	,0	Price	0.120	Chip
,16	,0	RSPL	0.487	Chips and fines. Returned by Appleman. Air, alum. can; ,91
,17	,0	Nyquist	2.030	Chips
,18	,0	RSPL	0.040	Potted butt, polished; ,61
,19	,0	RSPL	0.100	Potted butt, polished; ,62
,20	,0	RSPL	0.110	Potted butt, polished; ,63
,21	,0	RSPL	0.120	Potted butt, polished; ,64
,22	,0	RSPL	1.800	Chip. Returned by O'Hara, unopened.
,38	,0	Walker, R.M.	2.000	Chips and fines, includes matrix and Clast G.
,39	,0	Pillinger	1.300	3 chips, may be or include Clast B. Includes matrix and probably Clast G.
,42	,0	SSPL	8.70	Includes matrix and other white clasts.
,61	,18	RSPL	0.010	TS, broken
,62	,19	Reid	0.010	TS
,63	,20	SCC	0.010	TS
,64	,21	SCC	0.010	TS
,75	,0	SSPL	8.839	Potted butt, mainly matrix and Clast G, but may include Clast B. Daughters do not include Clast B.
,77	,0	SSPL	1.220	Chip, includes matrix and Clast A.
,78	,0	RSPL	1.880	Potted butt, includes matrix and Clast A; ,132-,136 ,149
,79	,0	SSPL	0.310	Contains matrix.
,80	,0	SSPL	0.088	Includes minor matrix; ,104-,110 (,141 ,142) ,174. Was chip, now fines.

Split	Parent	Location	Mass	Description and daughters containing Clast B
,91	,16	Consumed, Appleman	0.024	
,104	,80	Nyquist	0.107	Chips
,105	,80	Walker, R.M.	0.016	Chips
,106	,80	Tatsumoto	0.053	Small chips and fines
,107	,80	Consumed, Anders	0.029	Small chips and fines
,108	,80	Walker, R.M.	0.052	Chips
,109	,80	Ent. Subdivided	0.000	(Chips, made into potted butt); ,141 ,142
,110	,80	Walker, R.M.	0.023	Chips
,132	,78	Reid	0.010	TS
,133	,78	Dence	0.010	TS
,134	,78	Dence	0.010	TS contains matrix and Clast A
,135	,78	Wood	0.010	TS
,136	,78	Reid	0.010	TS
,141	,109	Wasson	0.006	PM
,142	,109	Dence	0.006	TS
,149	,78	Walker, R.M.	0.030	TS, thick section
,151	,0	BSV	44.510	E_1 end piece. Mainly matrix, contains Clast B as well as other clasts.
,152	,0	SSPL	4.21	Contains matrix. Slab piece.
,154	,0	SSPL	1.46	Chips, contain minor matrix, from slabbing.
,155	,0	SSPL	0.590	Chip
,156	,0	SSPL	2.270	Contains matrix (daughters do not include Clast B).
,157	,0	SSPL	4.470	Contains matrix.
,159	,0	SSPL	24.010	Part of W_1 end piece. Mainly matrix. Also contains Clast I and others (?)
,160	,0	SSPL	34.790	Part of W_1 end piece. Contains matrix, Clast F and Clast G.
,161	,0	SSPL	1.010	Contains a trace of Clast B? Mainly matrix and Clast E (daughters do not include Clast B).
,163	,0	SSPL	8.790	Chips and fines, includes matrix. White probably includes Clast B.
,174	,80	Wasson	.200	Chips

15445 Clast E Complex of Norite/Troctolite/Glass

~3 gm (?)

Evidence for pristinity: Warren and Wasson (1978) analyzed a split; Au and Ir contents indicate that the clast is free of meteoritic contamination (Table 1).

Description: Clast E (Lithology 45B of the Imbrium Consortium) is texturally and mineralogically complex (Figure 1). Macroscopically it is white and gray, lacking pink spinels and green mafics (Marvin, 1976a). 4 thin sections indicate the complexity and variety of the clast:

> ,65 is a brecciated plagioclase-rich troctolite with veins of brown glass and devitrified glass.
> ,139 is anorthosite, with rare mafics, opaques, and Fe-metal.
> ,220 (which also contains matrix) is a plagioclase-rich norite (phases unanalyzed) with a brown glass vein which partially surrounds the clast. Part of the glass surrounding the clast is mixed with matrix, part occurs as shards in the matrix.
> ,221 is complex, containing brown glass veins, a vein-like mass of ilmenite/ulvöspinel, a brecciated noritic portion and a brecciated troctolitic portion. The phases in the norite are identical to those in Clast B, while the troctolite contains olivine with the same Mg/Fe i.e. Fo_{80-82}. The brown glass is troctolite.

Further petrographic information is given in Ryder and Bower (1977a,b).

Chemical analyses were made by Blanchard et al. (1977 and unpublished) and Warren and Wasson (1978) (Table 1). Agreement is poor (Table 1, Figure 2) perhaps not surprising given the small sample masses and the complex nature of the clast. The Mg/Fe ratios of the analyses are in agreement with those of the analyzed mineral phases in ,221.

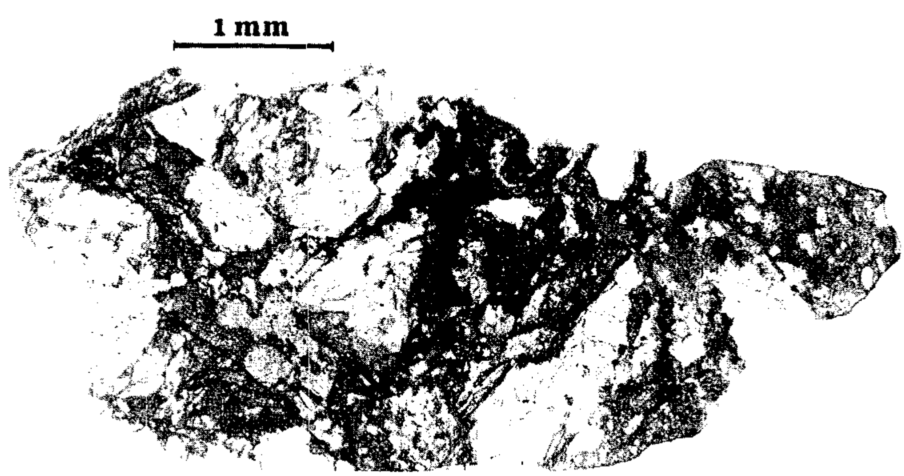


Figure 1. Transmitted light photomicrograph of 15445,221.
To left is troctolite and glass, to right is norite and glass.

Table 1

	1) Portion of ,113 (22 mg)	2) Portion of ,175 (29 mg)		1)	2)
SiO_2	43.4	45.58	Cd		< 9
TiO_2	0.01	0.07	In		<150
Al_2O_3	33	30.43	Re ppb		0.70
FeO	0.55	2.32	Ir ppb		0.14
MgO	1.56	4.70	Au ppb		< 0.035
CaO	17.3	16.38	Hf	0.60	
Na_2O	0.31	0.36	Ta	0.19	0.12
K_2O	0.045		Th	0.94	0.68
Cr_2O_3	0.033	0.13	U		0.18
Sc	1.90	4.3	La	1.15	3.3
Mn		292.	Ce	3.1	8.6
Co	2.64	10.1	Sm	0.61	1.28
Ni	70	<90	Eu	0.77	1.14
Zn		0.81	Tb	0.15	0.35
Ga		4.80	Yb	0.49	1.3
Ge ppb		3820	Lu	0.069	0.17

Oxides in wt. %, others in ppm except as noted.
Col. 1 from Blanchard *et al.* (1977 and unpublished).
Col. 2 from Warren and Wasson (1978).

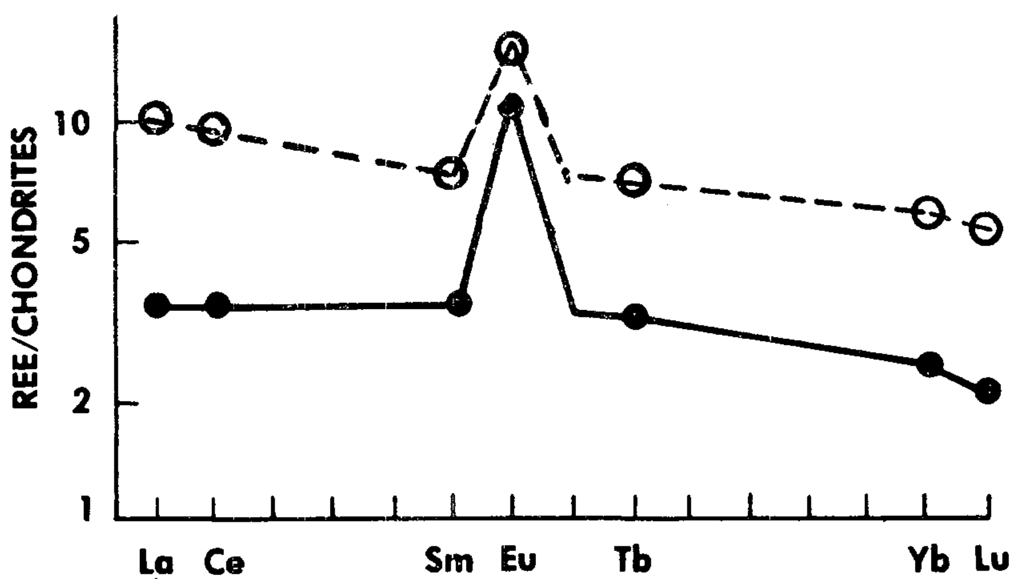


Figure 2. REE data for 15445 clast E. Solid line from Blanchard *et al.* (1977), dashed line from Warren and Wasson (1978).

Warren and Wasson (1978) note the Clast E might be the first case of a meteorite-free polymict rock; an alternative possibility is that the troctolite and norite lithologies were part of adjacent bands as a layered complex. The origin of the brown glass, which is chemically distinct from the 15445 matrix, is unclear. Presumably it is not included in the chemical analyses, which were made on picked white chips.

Table 2

Split	Parent	Location	Mass	Description and daughters containing Clast E
,2	,0	SSPL	2.76	Contains also matrix and Clast D
,3	,0	SSPL	1.58	Contains matrix
,33	,0	RSPL	0.05	Chips, returned by Brett, unopened
,34	,0	SSPL	1.100	Chip
,35	,0	RSPL	0.05	Potted butt; ,65
,36	,0	SSPL	0.07	Chip
,37	,0	SSPL	0.060	Chip; ,173 (,221)
,40	,0	SSPL	4.10	Mainly matrix. Also contains Clast C and possible trace of Clast A; ,171 (,220)
,41	,0	SSPL	7.80	Mainly matrix, also contains other clasts
,42	,0	SSPL	8.70	Mainly matrix and Clasts B, G.
,65	,35	RSPL	0.010	TS, broken
,112	,0	SSPL	0.086	Small chips and fines; ,113-,117; ,169
,113	,112	Nyquist	0.102	Fines
,114	,112	Walker, R.M.	0.023	Fines
,115	,112	Walker, R.M.	0.012	Fines
,116	,112	Walker, R.M.	0.026	Fines
,117	,112	Ent. Subd.	0.000	Small chips ,139
,139	,117	Wasson	0.010	PM
,151	,0	BSV	44.510	E_1 end piece. Mainly matrix. Also contains Clasts A, B, C and others.
,153	,0	SSPL	0.27	Virtually all Clast E removed; ,175
,161	,0	SSPL	1.010	Virtually all Clast E removed; ,176
,162	,0	SSPL	0.170	Mainly matrix

,169	,112	Anders	0.055	Small white chips
,171	,40	RSPL	0.080	Potted butt, mainly matrix; ,220
,173	,37	RSPL	0.030	Potted butt, 99% pure; ,221
,175	,153	Wasson	0.07	= 0.11 Combined chips; includes matrix
,176	,161	Combined with ,175	0.04	
,220	,171	Wood	0.010	TS
,221	,173	Dence	0.010	TS

15445 Clast G Spinel Troctolite 4-5 gm (?)

Evidence for pristinity: Gros et al. (1976a, b) analyzed split ,166, a portion of ,102. Although Ir (.34 ppb) and Au (.319 ppb) are slightly enriched compared to meteorite-free levels, Gros et al. (1976a) believe this could be accounted for by contamination with ∿ 5% matrix - however this interpretation is not referred to by Gros et al. (1976b). Ni is very high (920 ppm), perhaps spuriously (Gros et al., 1976a, b).

Note: In Table 2 (below) 3 splits are listed as "possible Clast F". It is not possible to be certain from data pack information, but it is most likely that these splits are actually of Clast G. They were listed in original Imbrium Consortium documents as Lithology 45C (i.e. Clast F), but so were other splits (e.g. ,99 and thin sections ,143 and ,144) which are definitely Clast G. Both Clast F and Clast G are spinel-bearing and presumably represent the same lunar lithology, so the distinction may not be critical.

Description: Macroscopically Clast G (part of Lithology 45C of the Imbrium Consortium) is a spinel-bearing white clast. The spinel is heterogeneously distributed such that some portions seem devoid of spinel. The two thin sections show plag-olivine-spinel material crushed and mixed with matrix. No analyses have been made but the clast appears to be similar to the other spinel troctolites in 15445, e.g. Clast A.

A chemical analysis of a portion of ,103 was made by Blanchard et al. (1977 and unpublished) and is reproduced in Table 1 and Figure 1. (As outlined above, this split is believed to be Clast G not Clast F as indicated in Imbrium Consortium documents.) The analysis is not substantially different from split ,9 of Clast A (Wiesmann and Hubbard, 1975) but different from split ,71 of Clast A (Wiesmann and Hubbard, 1975, Ridley et al., 1973). The high Ni content is similar to that of Gros et al. (1976a,b).

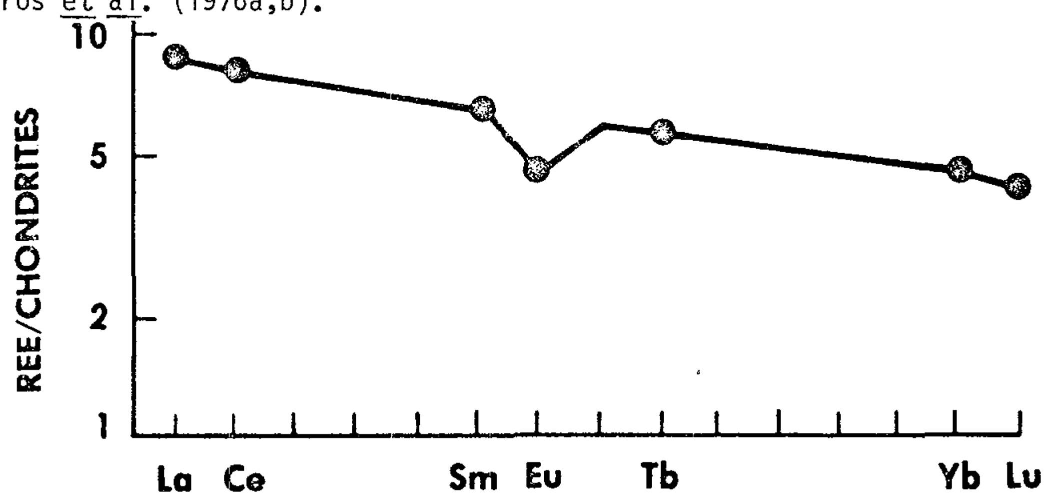


Figure 1. REE data for 15445 clast G. (From Blanchard et al., 1977)

Table 1

Portion of ,103

SiO_2	37.5	Ni	820
TiO_2	0.25	Hf	0.74
Al_2O_3	14.7	Ta	n.d.
FeO	6.4	Th	0.27
MgO	33	La	2.86
CaO	4.8	Ce	n.d.
Na_2O	0.140	Sm	1.19
K_2O	0.022	Eu	0.31
Cr_2O_3	1.01	Tb	0.26
Sc	3.43	Yb	0.90
Co	50.4	Lu	0.136

Oxides in wt. %, others in ppm.
From Blanchard et al. (1977 and unpublished).
n.d. = not detected

Table 2

Split	Parent	Location	Mass	Descriptions and daughters containing Clast G
,39	,0	Pillinger	1.300	3 chips, probably G; some matrix, Clast B may be present
,42	,0	SSPL	8.70	Includes matrix and Clast B, minor Clast E
,74	,0	SSPL	7.549	Includes matrix and Clast F; ,96 (?) ,98 (?) ,103 (?)
,75	,0	SSPL	8.839	Includes matrix (and possibly Clast B); ,99-,102; (,166)
,96	,74	Tatsumoto	0.052	Chip (possibly Clast F)
,98	,74	Walker, R.M.	0.021	Chips (possibly Clast F)
,99	,75	Walker, R.M.	0.020	Chip, includes minor matrix
,100	,75	Reed	0.021	Chip, includes minor matrix
,101	,75	Ent. Subdivided	0.000	Was potted butt; ,143 ,144
,102	,75	RSPL	0.019	Returned chips and fines by Anders. Crushed (trace element degraded), air, physically separated pink-white
,103	,74	Nyquist	0.102	Chips, (possibly Clast F)
,143	,101	Dence	0.010	TS; mainly matrix
,144	,101	Wood	0.010	TS; mainly matrix
,160	,0	SSPL	34.790	Part of W end piece. Mainly matrix and includes Clasts B, F (?)
,166	,102	Consumed, Anders	0.041	Chips

15455 Anorthositic Norite Clast ~200 gm

Evidence for pristinity: Ganapathy et al. (1973) found a split to be free of meteoritic contamination (Table 1).

Description: The norite is the largest single clast in 15455. The norite is brecciated (Figure 1) and is penetrated by matrix veins. Macroscopically the pyroxenes are pale green. Estimates from a slab and from thin sections suggest 25-40% pyroxene, the remainder being mainly plagioclase.

A preliminary petrographic study was made by Ryder and Bower (1977a,b). Distinct cumulate textures exist and the original grain size was on the order of 5mm. Pyroxene and plagioclase data are given in Figure 2; similar data are provided by Reid et al. (1977). A wide variety of minor phases is present (Ryder and Bower, 1977a,b). Hewins and Goldstein (1975) analyzed Fe-metal in the norite (referred to as "anorthositic facies"), found it to contain up to 9% Co, and suggested that a Ni/Co correlation indicated igneous fractionation.

Taylor (1973) and Taylor et al. (1972, 1973) analyzed a fragment believed to be from the norite (a loose chip in the returned sample bag). This analysis is given here in Table 1 and Figure 3. Note that a CIPW norm of the analysis contains 20% olivine and only 7% pyroxene, whereas observation of thin sections shows that the clast lacks olivine. Because the analyzed material was hand-picked separates it may be unrepresentative (S.R. Taylor, pers. comm.). Alternatively the fragment was not from the norite clast. Additional trace element data from Reed and Jovanovic (1972) and Jovanovic and Reed (1977) are given in Table 1. These authors also provide data on halogens.

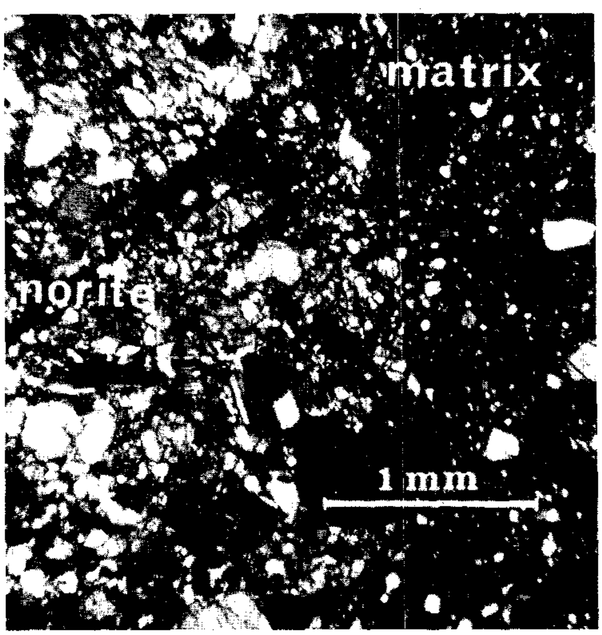


Figure 1. Transmitted light photomicrograph of norite and matrix in 15455,28.

Table 1

	1) portion of ,20 (,203)		1)
SiO_2	44.4	La	3.0
TiO_2	< 0.07	Ce	6.7
Al_2O_3	26.2	Pr	0.95
FeO	4.2	Nd	3.73
MgO	10.9	Sm	0.88
CaO	14.3	Eu	1.67
Na_2O	0.36	Gd	0.95
K_2O	< 0.06	Tb	0.14
Cr_2O_3	0.064	Dy	0.84
		Ho	0.17
Ba	42.0	Er	0.46
Pb	1.0	Tm	0.06
Th	0.23	Yb	0.36
U	0.05	Lu	0.06
Zr	11.0	Y	4.8
Hf	0.17		
Nb	0.95		2) Portion of ,70A (,89)
Cr	440		
V	16.0	Ir ppb	≤ 0.002
Ni	12.0	Re ppb	0.0023
Co	10.0	Au ppb	0.009
Cu	1.3	U	0.0195
Ga	2.6		
			3) portion of ,3
		U	0.073
		Li	8.4
		Te ppb	124
		P_2O_5	0.05%

Oxides in wt %, all others in ppm except as noted.
Col. 1 from Taylor (1973) and Taylor et al. (1972, 1973)
Col. 2 from Ganapathy et al. (1973)
Col. 3 from Reed and Jovanovic (1972) and Jovanovic and Reed (1977)

Epstein and Taylor (1972) made an oxygen isotope analysis of a split of the norite (not numbered in their paper but described as plagioclase plus pale-green pyroxene). Their $\delta\ O^{18}$ (o/oo) of +5.83 is a typical value for lunar rocks.

A ^{40}Ar-^{39}Ar age was attempted by Alexander and Kahl (1974). No plateau was reached (Figure 4), but a minimum age of 3.82 ± 0.04 was suggested; this age is younger than the suggested age of the matrix and is due to ^{40}Ar loss. The Ca content calculated is much lower than that of Taylor et al. (1972, 1973) corresponding to a plagioclase content of only $\sim$55%. No other geochronological studies have been published.

Other references:

Christie et al. (1973); Electron petrography
Heuer et al. (1972); Electron petrography
Modzeleski et al. (1972); Carbon
Moore et al. (1973); Carbon

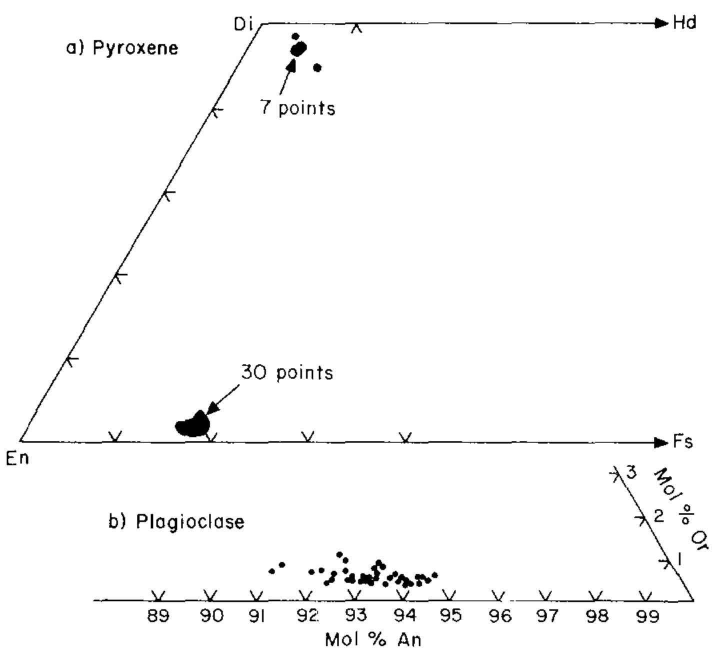


Figure 2. Compositions of pyroxenes and plagioclases in the 15455 norite. (From Ryder and Bower, 1977a).

Table 2

Split	Parent	Location	Mass	Description and daughters containing norite
,1	,0	SSPL	14.100	Includes matrix
,2	,0	SSPL	10.300	Includes matrix
,3	,0	Reed	4.500	Includes matrix and a separate white clast
,4	,0	SSPL	5.800	Chip
,6	,0	SSPL	1.700	Chip
,8	,0	SSPL	1.700	Mainly matrix
,9	,0	SSPL	1.400	Chip
,10	,0	RSPL	2.380	Potted butt, includes black veins. ,25-,36
,11*	,0	SSPL	0.200	Includes matrix
,12*	,0	Housley	0.830	Includes matrix
,13*	,0	Ent. Subdivided	0.000	Was chip, included matrix. ,96 ,97 ,98 ,99 ,100 ,220
,14*	,0	Ent. Subdivided	0.000	Was mainly matrix. ,204 ,205
,15*	,0	SSPL	1.100	Includes black veins, patina
,16*	,0	Maurette	0.123	Includes patina. ,91
,17*	,0	Maurette	0.166	Chip. ,92
,18*	,0	SSPL	0.500	Includes black veins
,19*	,0	SSPL	0.300	Includes black veins
,20*	,0	Ent. Subdivided	0.000	Included black veins. ,202 ,203
,21*	,0	SSPL	0.300	Includes black veins
,22*	,0	SSPL	0.300	Includes veins and patina (?)
,23	,0	SSPL	1.700	Fines and chips, residue includes matrix, other clasts
,24	,0	SSPL	1.400	Residues, includes matrix, other clasts

*Samples were unlocated but their white portions are almost certainly from the large norite clast.

Split	Parent	Location	Mass	Description and daughters containing norite
,25	,10	Reid	0.010	PM, includes black vein
,26	,10	Dence	0.010	PM, includes black vein
,27	,10	SCC	0.010	TS, includes black vein
,28	,10	Dence	0.010	PM, includes black vein
,29	,10	SCC	0.010	TS, includes black vein
,30	,10	SCC	0.010	TS, includes black vein
,31	,10	Reid	0.010	PM, includes black vein
,32	,10	SCC	0.010	TS, includes black vein
,33	,10	SCC	0.010	TS, includes black vein
,34	,10	Haggerty	0.010	PM, includes black vein
,35	,10	Reid	0.010	PM, includes black vein
,36	,10	SCC	0.011	PM, includes black vein
,37	,0	B16	498.000	End piece, mainly matrix. Includes other clasts. ,165
,38	,0	RSPL	85.263	Slab piece, mainly matrix. Includes other clasts. Returned by Silver. Air, stainless steel tools. ,70 (,89 ,103Q ,104 ,170 ,171 ,172 ,173 ,174 ,175 ,176 ,177 ,178 ,189 ,190 ,191 ,195 ,196 ,223 ,9001 ,9003 ,9007Q ,9008Q ,9011) ,71 ,72 ,73 ,84 ,102Q ,9006 ,9013Q ,9014Q
,39	,0	SSPL	3.970	Chip, includes some matrix. ,59 (,94) ,61 (,101) ,63 (,198 -,200) ,65 (,206 -,208) ,67 (,201)
,40	,0	SSPL	1.090	Chip, includes some matrix
,41	,0	Ent. Subdivided	0.000	Was large piece, including matrix. ,43 -,47
,42	,0	SSPL	5.390	Fines and chips, include matrix
,43	,41	SSPL	1.320	Chip
,44	,41	SSPL	0.640	Chip
,45	,41	SSPL	3.240	Chip, includes matrix
,46	,41	BSV	85.260	Large piece, includes matrix
,47	,41	SSPL	2.700	Chips, include matrix

Split	Parent	Location	Mass	Description and daughters containing norite
,55	,38	RSPL	4.125	Chip, mainly matrix. Probably includes norite. Never allocated.
,56	,0	RSPL	5.130	Chips and fines, matrix, probably include norite
,57	,0	RSPL	4.530	Chips and fines, matrix, probably include norite
,58	,0	RSPL	6.800	Dust, includes matrix
,59	,39	RSPL	1.512	Chips and fines, returned by Biemann. Possibly opened by P.I.
,61	,39	RSPL	0.459	Chips and fines, returned by Burlingame. Air. ,101
,63	,39	RSPL	0.244	Chip, with black veins, returned by Moore. Air. ,198 ,199 ,200
,65	,39	RSPL	0.837	Chips, with some black material, returned by Nagy. Air. ,206 ,207 ,208
,67	,39	RSPL	0.305	Chips, with some black material, returned by Schopf. Air, electron irradiated (SEM)
,70	,38	RSPL	4.081	Chips, includes matrix, returned by Silver. Air, chipped with stainless steel. ,103Q ,104 (,223) ,170 ,171 ,172 (,175 ,177) ,173 (,176 ,178) ,174 (,189 ,190 ,195 ,196) ,9001 ,9003 (,89) ,9007Q ,9008Q ,9011 (,221)
,71	,38	SSPL	2.280	Chip, includes matrix
,72	,38	SSPL	16.100	Chips and fines, mainly matrix, probably includes norite
,74 -,84	,38	RSPL	Σ 1.82	Small pieces, matrix and white, include norite?/matrix contacts. Never allocated
,89	,9003	Consumed, Anders	0.087	--
,91	,16	RSPL	0.307	Chip, returned by Maurette. Air, stainless steel.
,92	,17	RSPL	0.444	Chips, returned by Maurette. Air, stainless steel.
,96	,13	RSPL	0.001	TEM foil, matrix and/or norite, returned by Lally.

Split	Parent	Location	Mass	Description and daughters containing norite
,97	,13	RSPL	0.001	TEM foil, matrix and/or norite, returned by Lally
,98	,13	RSPL	0.001	Potted butt, includes matrix, returned by Lally
,99	,13	RSPL	0.001	Fines, matrix?, returned by Lally. Air, polystyrene
,100	,13	RSPL	0.002	2 TS, include matrix, returned by Lally
,101	,61	Consumed, Burlingame	0.081	--
,102[Q]	,38	Consumed, Silver	0.550	?
,103[Q]	,70	Consumed, Silver	0.452	?
,104	,70	RSPL	0.111	Potted butt. ,223
,165	,37	RSPL	0.034	Fines, mainly matrix, probably include norite. Never allocated.
,170	,70	RSPL	3.482	Chip, includes some matrix, returned by Silver. Air, stainless steel, Saran wrap.
,171	,70	RSPL	0.440	Chip, includes some matrix, returned by Silver. Air, stainless steel, Saran wrap.
,172	,70	RSPL	0.071	Potted butt. ,175 ,177
,173	,70	RSPL	0.036	Potted butt. ,176 ,178
,174	,70	RSPL	5.200	Chip, includes some matrix, returned by Silver. Air, stainless steel, Saran wrap. ,189 (,195 ,196) ,190
,175	,172	SCC	0.010	TS, broken
,176	,173	SCC	0.010	TS, broken
,177	,172	SCC	0.010	TS
,178	,173	SCC	0.010	TS
,189	,174	RSPL	1.460	Potted butt. ,195 ,196
,190	,174	RSPL	0.040	Fines, include matrix?
,195	,189	Stöffler	0.030	TS
,196	,190	SCC	0.030	TS
,198	,63	Destroyed (Moore)	0.066	--

Split	Parent	Location	Mass	Description and daughters containing norite
,199	,63	Destroyed (Moore)	0.214	--
,200	,63	Consumed, Moore	0.026	--
,201	,67	Consumed, Schopf	0.015	Included matrix??
,202	,20	RSPL	0.651	Residue fines, returned by Taylor, S.R. Air, crushed, sieved, hand-picked, physically separated (depleted in white material).
,203	,20	Consumed, Taylor,S.R.	0.209	--
,206	,65	RSPL	0.035	Ground-up chips, returned by Nagy. Air.
,207	,65	RSPL	0.047	Fines, returned by Nagy. Air, crushed, vacuum, fused at 1000°C.
,208	,65	Consumed, Nagy	0.071	Norite and/or matrix
,220	,13	Consumed, Lally	0.874	Norite and/or matrix
,221	,9011	Consumed, Nava	0.104	Includes matrix?
,223	,104	Wasson	0.010	PM
,9001	,70	Reynolds	0.426	Includes matrix?
,9003	,70	RSPL	0.032	Fines, returned by Anders. Air, hand-picked.
,9006	,38	RSPL	0.044	Chips and fines, returned by Anders. Air, hand-picked.
,9007[Q]	,70	Marti	.405	Probably norite?
,9008[Q]	,70	Marti	.419	Probably norite?
,9011	,70	RSPL	0.301	White powder, returned by Nava.
,9013[Q]	,38	Epstein	0.129	?
,9014[Q]	,38	Epstein	0.080	?

Q: Questionable. Sample may be norite, matrix, or other clast; inadequate data in Lunar Curatorial Facility.

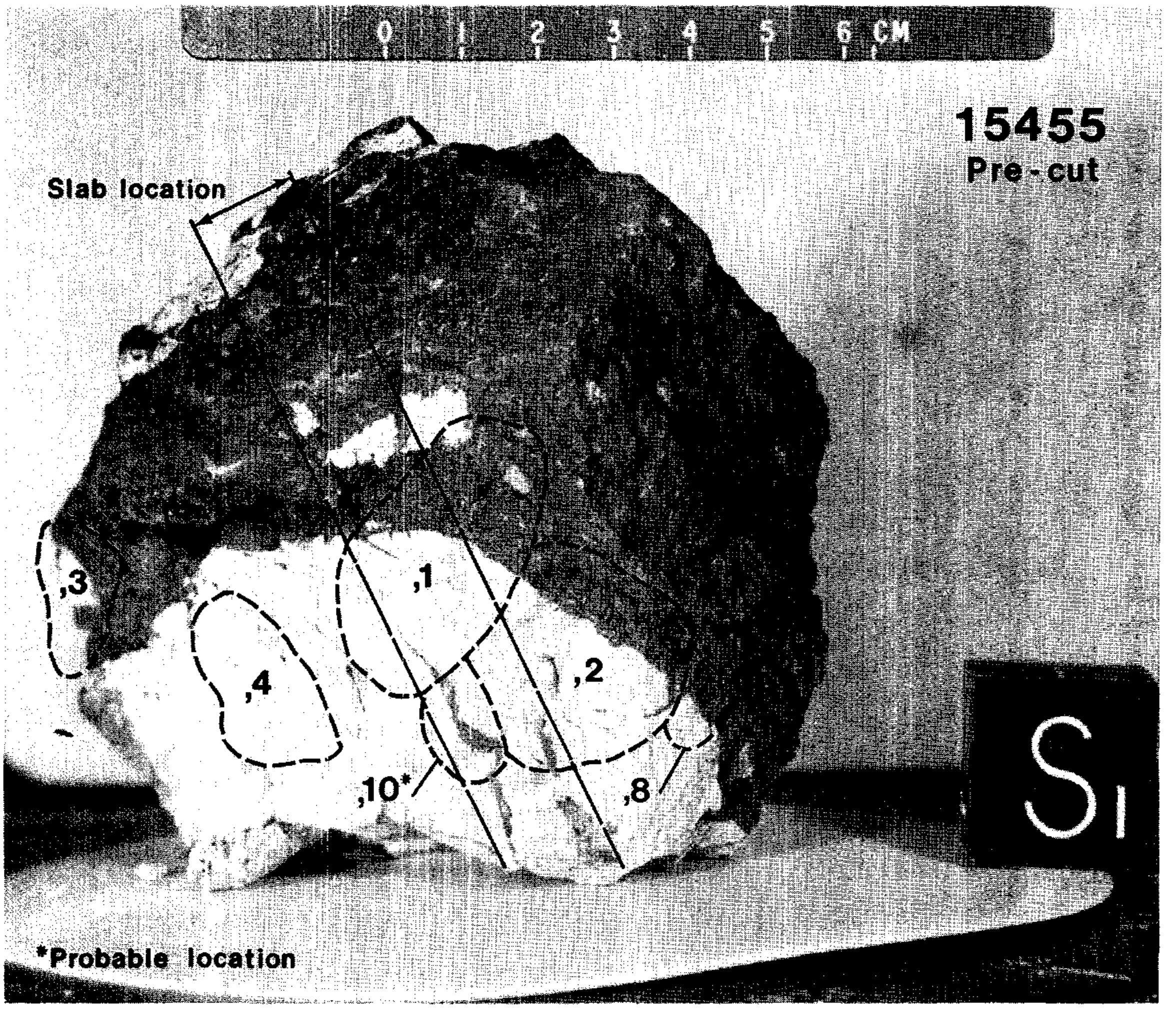

0 1 2 3 4 5 6 CM
15455
Pre-cut
Slab location
,3
,1
,4
,2
,10*
,8
*Probable location
S1

Figure 5

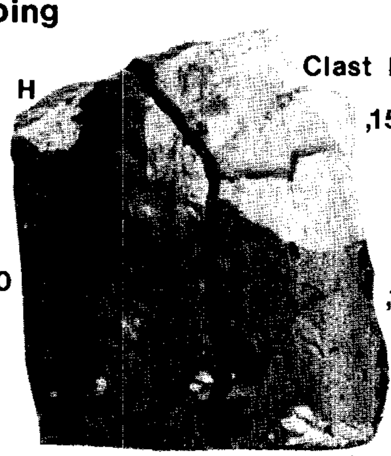


Figure 6


Post-slabbing
,37
,38
,55
,51
Anorthosite
norite
,45
,44
,43
,39
,40
,53
,46
S-71-60227

Figure 7


15455
Post-chipping of slab
S-71-60917
,171
,172
,173
,174
Anorthositic norite
,85
,87
,179
,38
Troctolitic anorthosite
,185
Approximate location of ,106 ,107

Figure 8

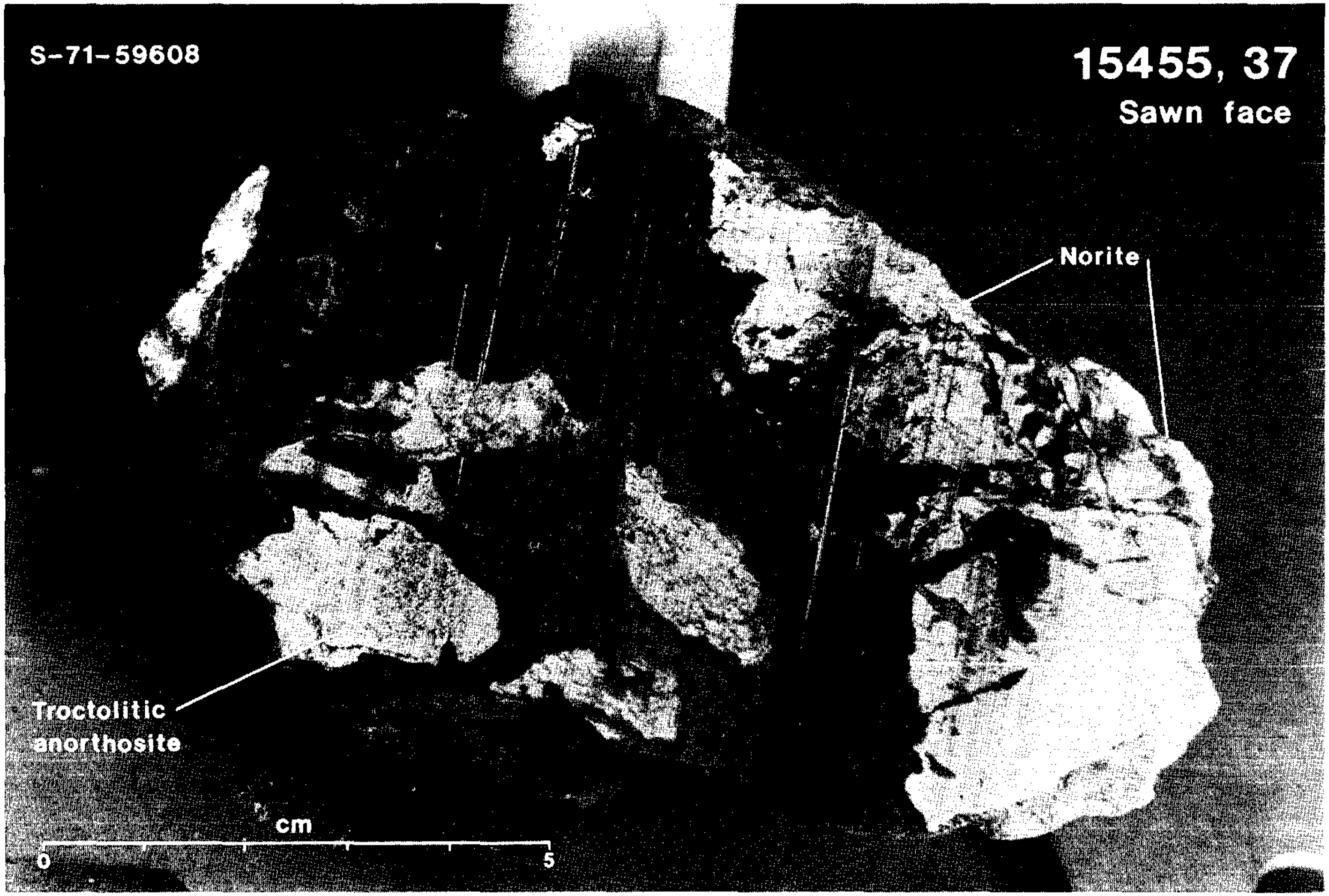

S-71-59608
15455, 37
Sawn face
Norite
Troctolitic
anorthosite
cm
0
5

Figure 9

15455 Troctolitic Anorthosite ~3 gm

Evidence for pristinity: Ganapathy et al. (1973) analyzed a split and found it to be free of meteoritic contamination (Table 1).

Description: The troctolitic anorthosite is an egg-shaped white clast; binocular inspection reveals pale yellow mafics. Preliminary petrography of thin section ,224 by Paul Warren (pers. comm.) shows a brecciated clast with 80-90% plagioclase. Phases are homogeneous with plagioclase $\sim An_{95}$, olivine $\sim Fo_{83}$ and rather less abundant orthopyroxene $\sim En_{85}$. Our own examination of thin section ,169 shows a brecciated clast containing relict fragments with a "granulitic ANT" texture (Figure 1) consisting of about 75% plagioclase, the remainder mainly olivine with minor opaques. Our analyses of olivines and pyroxenes confirm Warren's data.

No other studies have been made.

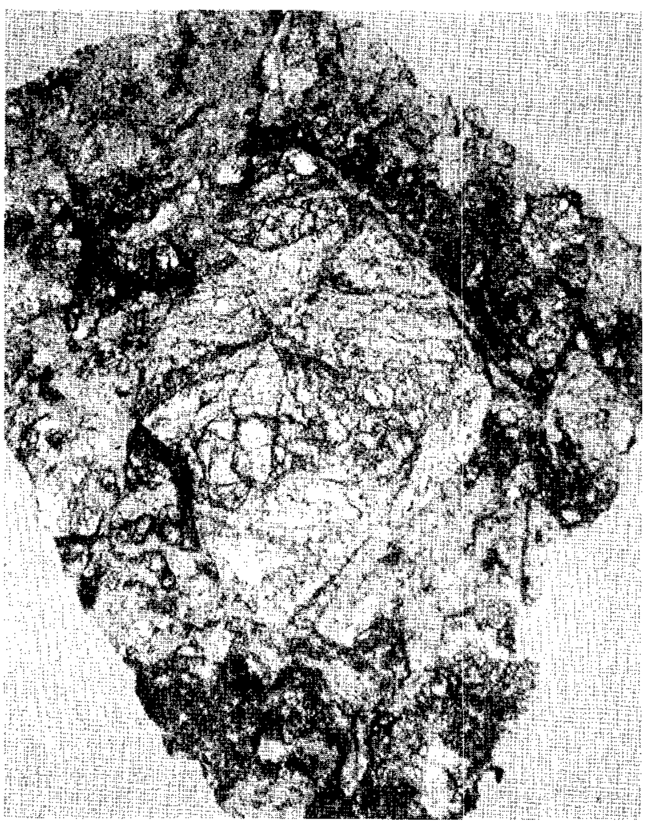


Figure 1. Transmitted light photomicrograph of 15455,169. Width of view ~2 mm.

Table 1

	,192*
Ir	0.024
Re	0.0058
Au	0.042
Rb	0.54
Cs	54
U	170

Data in ppb except Rb, ppm.
*Listed by Ganapathy et al. (1973) (and other Anders group publications) as ,179, from which it derives by way of ,9004.

Table 2

Split	Parent	Location	Mass	Description and daughters containing troctolite
,37	,0	B16	498.00	Mainly matrix, contains norite and other clasts
,38	,0	RSPL	85.263	Mainly matrix and norite, contains other clasts, returned by Silver. Air, stainless steel tools. ,88 (,169 ,215) ,179 (,106 ,107 ,192 ,224 ,9004) ,180 ,183 (,185 ,187 ,188)
,88	,38	RSPL	0.011	Potted butt. ,169 ,215
,106	,179	Wasson	0.085	Chip
,107	,179	RSPL	0.052	Potted butt. ,224
,169	,88	SCC	0.010	TS
,179	,38	RSPL	14.437	Includes matrix and another clast, returned by Silver. Air, stainless steel tools. ,106 ,107 (,224) ,9004 (,192)
,180	,38	RSPL	4.902	Includes matrix, returned by Silver. Air, stainless steel tools
,183	,38	RSPL	0.866	No longer includes troctolite
,185	,183	RSPL	2.540	Includes matrix and another clast, both with patina, returned by Silver. Air, stainless steel tools.
,187	,183	RSPL	0.889	Mainly matrix, returned by Silver. Air, stainless steel tools.
,188	,183	RSPL	0.225	White chips, fines, powder, returned by Silver. Air, crushed in boron carbide mortar
,183	,38	RSPL	0.866	No longer includes troctolite. ,185 ,187 ,188 ,9002Q ,9010Q
,192	,9004	Consumed, Anders	0.086	--
,215	,88	RSPL	0.001	Residue
,224	,107	Wasson	0.010	PM
,9002Q	,183	Reynolds	0.398	?

Split	Parent	Location	Mass	Description and daughters containing troctolite
,9004	,179	RSPL	0.018	Fines, returned by Anders. Air, hand-picked.
,9010[Q]	,183	Marti	0.396	?

Q: Questionable. Sample may be troctolite or matrix, or other clast; inadequate data in Lunar Curatorial Facility

For split photographs of the 15455 troctolitic anorthosite, see section on 15455 anorthositic norite

61224,6 Norite 0.340 gm

Evidence for pristinity: 61224,6, though shock-melted along grain boundaries, has a cumulate texture (Figure 1) and a coarse grain-size (Marvin, 1976c,d), indicating that it is pristine. The restricted phase compositions and the sodic plagioclase support this interpretation.

Description: 61224,6 consisted of 3 particles among the coarse fines from a trench at Plum Crater. These particles were distinct macroscopically and consist of 40% plagioclase and 60% pyroxene (Marvin, 1972). A petrographic study was made by Marvin (1976c,d). Plagioclase is sodic (Ab_{80-84}); pyroxene is pigeonite ($En_{68}Wo_5$) with exsolved augite ($En_{46}Wo_{40}$). Minute amounts of troilite and metal occur within some pyroxenes and shock melting in situ has rimmed every pyroxene grain with a selvage of glass and crystallites. MnO contents of the pyroxenes show that the norite is lunar, not meteoritic.

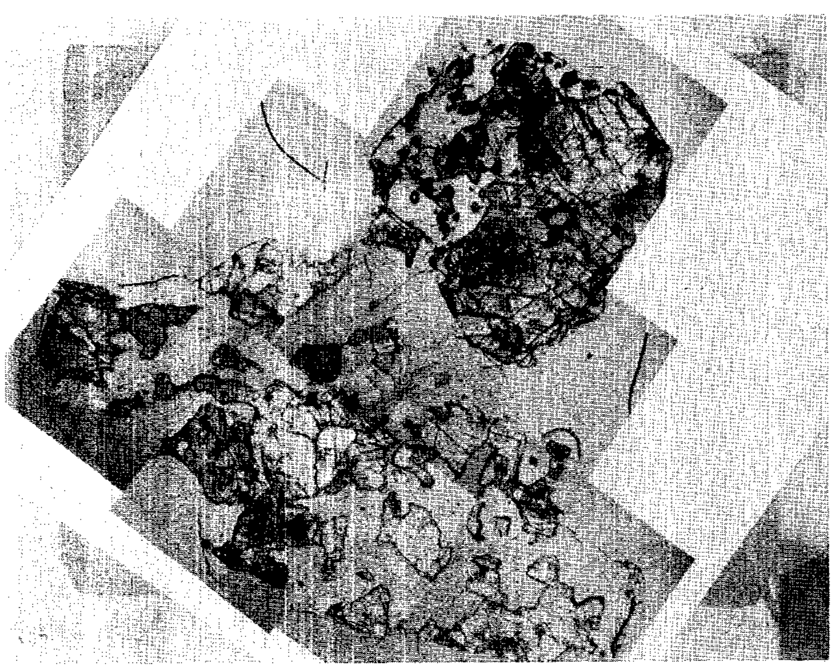


Figure 1. Transmitted light photomicrograph of 61224,10. Width of view ∿4 mm. (Photo courtesy K. Motylewski)

Table 1

Split	Parent	Location	Mass	Description and daughters
,6	--	SSPL	0.150	Chips
,9	,6	RSPL	0.080	Potted butt; ,10
,10	,9	Wood	0.010	TS
,11	,6	SSPL	0.030	numerous very small fragments
,12	,6	SSPL	0.010	5 small chips
,13	,6	SSPL	0.010	6 small chips
,14	,6	SSPL	0.010	numerous very small fragments
,15	,6	Attrition	0.040	---

Two more thin sections can probably be cut from ,9.

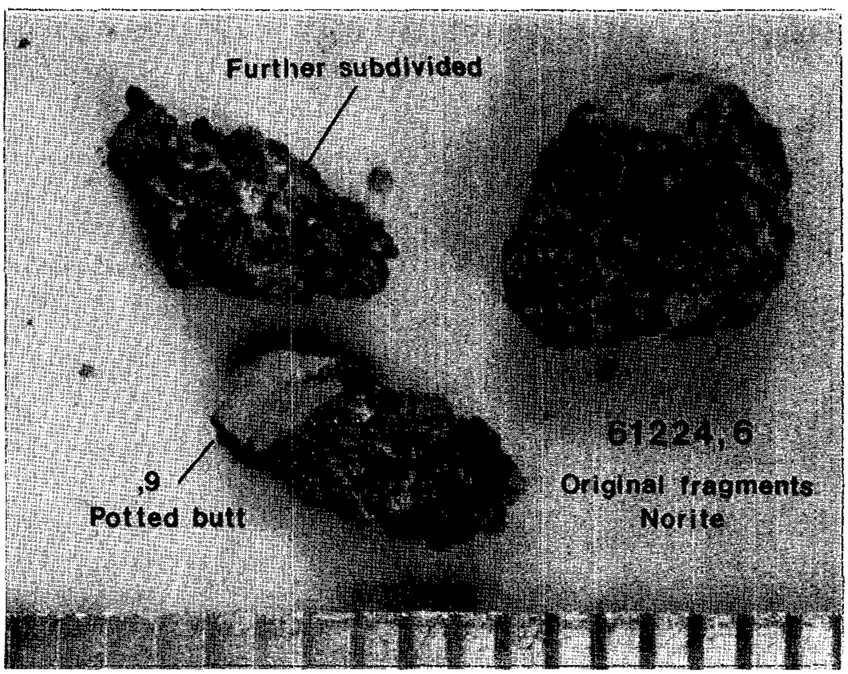


Figure 2. Original 3 fragments of 61224,6.

62236 Noritic Anorthosite (?) 57.27 gm

Evidence for pristinity: Analyses by Warren and Wasson (1978) show this rock to have low levels of siderophile and incompatible elements (Table 1) and tight mineral compositional ranges. Clark and Keith (1973) obtained similar results for the incompatible elements Th and U.

Description: Macroscopically 62236 is a very light gray, coherent to slightly friable, monomict anorthositic breccia. Thin sections show a monomict breccia (Figure 1) with about 15% mafics.

Warren and Wasson (1978) noted that its phase compositions are identical to those of 62237 (which was from the same location) and the incompatible elements are very similar. However, the norms are somewhat different; 62236 has 83% plag, 7% opx, 5% olivine and 5% cpx (cf. 85% plag, 13% ol in 62237). Plag is An_{96-98}, olivine is Fo_{60}, opx is $En_{64}\ Wo_{2-3}$, cpx is $En_{40}\ Wo_{44}$. Texturally 62236 appears to be more severely shocked than 62237. Macroscopic observations (Apollo 16 Sample Information Catalog) indicate that the mafics are not evenly distributed. Quite possibly 62236 and 62237 are essentially the same lithology. The mafic content is high for pristine Apollo 16 rocks.

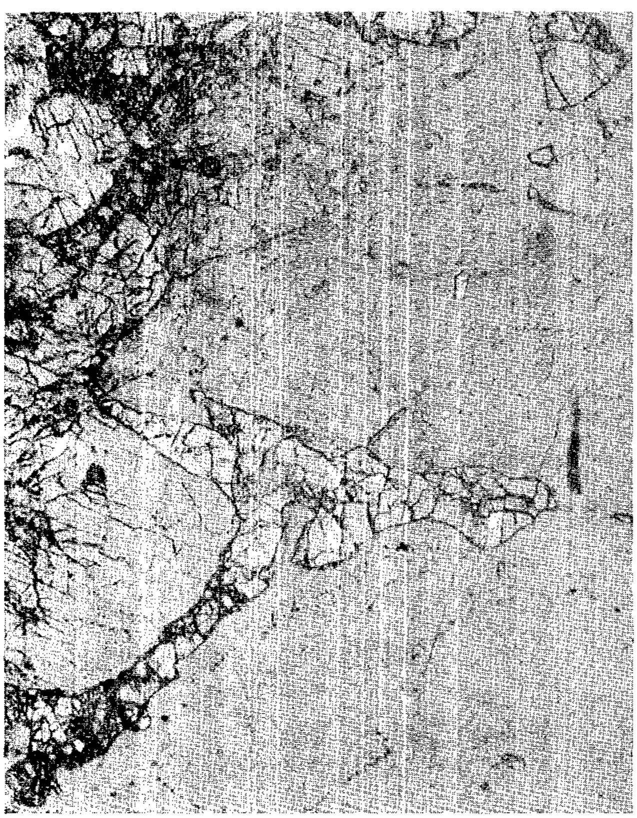


Figure 1. Transmitted light photomicrograph of 62236,6. Width of view ~1 mm.

Table 1

SiO_2	43.3	Ga	3.0
Al_2O_3	29.7	Ge ppb	16.3
FeO	4.0	Cd	0.75
MgO	3.8	In	1.3
CaO	17.4	Re ppb	0.013
Na_2O	0.213	Au ppb	0.0076
K_2O	0.015	Th	0.040
Sc	5.3	La	0.18
Cr	510	Ce	0.68
Mn	460	Sm	0.092
Co	9.0	Eu	0.59
Ni	3.5	Yb	0.13
Zn	2.0	Lu	0.021

Oxides in wt. %, others in ppm except as noted.
From Warren and Wasson (1978)

Table 2

Split	Parent	Location	Mass	Description and daughters
,0	,0	B01	51.860	Anorthositic breccia
,1	,0	RSPL	1.562	Potted butt; ,5 ,6 ,7
,2	,0	SSPL	0.946	Doc chip
,3	,0	SSPL	0.190	Chip + fines
,4	,0	Attrition	0.281	---
,5	,1	Wasson	0.010	TS
,6	,1	SCC	0.010	TS
,7	,1	Wasson	0.010	PM
,9	,0	Wasson	0.480	5 chips, interior
,10	,0	SSPL	1.690	Chips + fines
,11	,0	Attrition	0.240	---

62237 Troctolitic Anorthosite 62.35 gm

Evidence for pristinity: Warren *et al.* (1978a) and Warren and Wasson (1978) made analyses of a split and found low siderophile and incompatible levels (Table 1). Petrographic data (Dymek *et al.*, 1975, Warren and Wasson, 1978) support a pristine origin.

Description: 62237 is a light gray, moderately friable brecciated cumulate. Thin section analyses by Dymek *et al.* (1975) and Warren and Wasson (1978), indicate that it is a coarse grained monomict brecciated igneous cumulate (Figure 1). Plagioclase and olivine are the dominant mineral phases; small amounts of pyroxene are also present. All of the phases are coarse grained (up to 4 mm) and homogeneous. Very low Ca contents in the olivines and coarse exsolution lamellae are indicative of a deep seated, plutonic origin (Dymek *et al.*, 1975). Mineral data are given in Figure 2. Minor phases include Cr-spinel, ilmenite, and troilite (Dymek *et al.*, 1975).

A bulk composition was estimated from the mode and mineral analyses by Dymek *et al.* (1975) and analyses were made by Warren and Wasson (1978); these are given in Table 1. The low concentration of REE's and the unusual REE pattern (Figure 3) together with the low levels of the incompatible elements Th, U, and K (Clark and Keith, 1973) argue convincingly that 62237 is a pristine lithology. The initial $^{87}Sr/^{86}Sr$ ratio (∿0.699) is also consistent with the crystallization of 62237 early in lunar history (Dymek *et al.*, 1975).

Figure 1. Transmitted light photomicrograph of 62237,23. Width of view ∿2 mm.

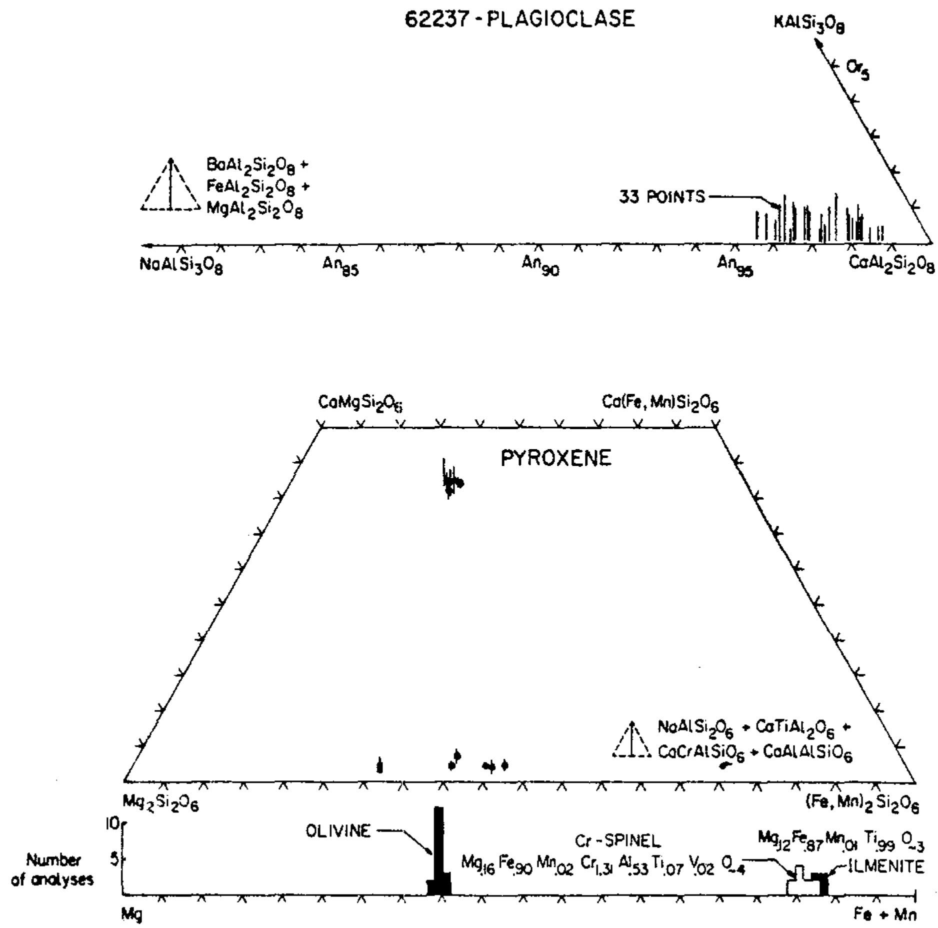


Figure 2. Compositions of plagioclases (top) and mafics (bottom) in 62237. (From Dymek et al., 1975).

<u>Table 1</u>

	1)	2)	3)		1)	2)
	,6					
SiO_2			41.9	Ge ppb	3.4	3.2
Al_2O_3	32.1	30.2	28.2	Cd	4.1	3.6
FeO	4.4	5.2	7.4	In	1.2	<1.0
MgO	3.7	4.7	6.3	Ir ppb	0.015	0.13
CaO	17.5	16.4	15.7	Au ppb	0.146	0.017
Na_2O	.223	0.196	0.20	La	0.21	0.17
K_2O	.13		0.01	Ce	0.44	
Sc	3.45	5.3		Nd	0.28	
Cr	330	510		Sm	0.074	0.076
Mn	420	540		Eu	0.65	0.58
Co	10.8	11.4		Tb	0.018	
Ni	5.8	<18		Yb	0.084	0.12
Zn	1.88	1.34		Lu	0.012	0.017
Ga		2.82				

Oxides in wt. %, others in ppm except as noted.
Col. 1 from Warren and Wasson (1978), Warren *et al*. (1978)
Col. 2 from Warren and Wasson (1978)
Col. 3 from Dymek *et al*. (1975)

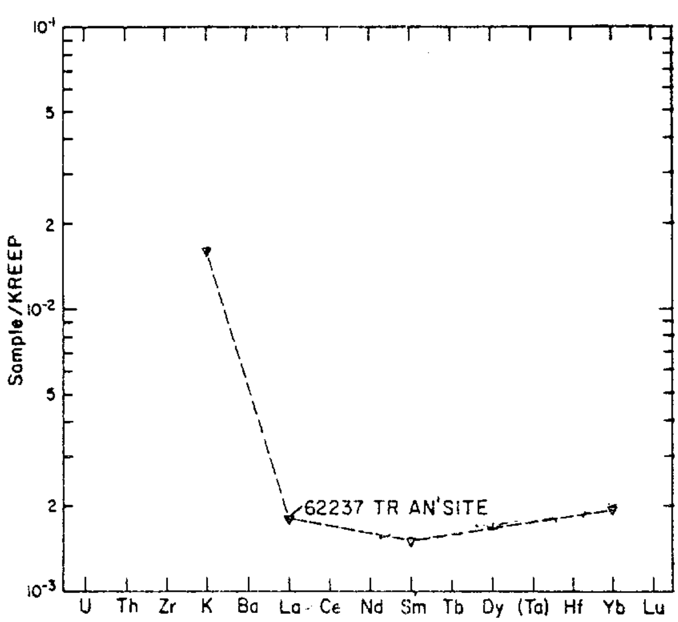


Figure 3. Incompatible element data for 62237. Note normalization is to KREEP, not chondrites. (From Warren and Wasson, 1977)

Table 2

Split	Parent	Location	Mass	Description
,0	,0	B01	42.340	
,1	,0	BSV	8.929	Chip
,2	,0	Schmitt	0.569	Chip
,3	,0	Nyquist	0.458	Chip
,4	,0	RSPL	1.608	Potted butt. ,8 -,10 ,22 ,23
,5	,0	Wasserburg	0.891	Chip
,6	,0	Consumed, Wasson	0.500	---
,7	,0	Attrition	0.560	---
,8	,4	Wasson	0.010	PM
,9	,4	Meyer	0.010	TS
,10	,4	Wasserburg	0.010	TS
,11	,0	Keil	0.260	7 small chips
,12	,0	Schaeffer	0.440	4 interior chips
,13	,0	SSPL	2.500	exterior chip
,14	,0	SSPL	0.940	3 interior chips
,15	,0	Wasserburg	0.690	interior chip
,16	,0	Walker, R.M.	0.950	1 interior & 1 exterior chip
,17	,0	SSPL	0.300	small chips and fines
,18	,0	Attrition	0.150	---
,19	,6	SSPL	0.215	small chips
,22	,4	Sato	0.010	PM
,23	,4	SSPL	0.010	PM

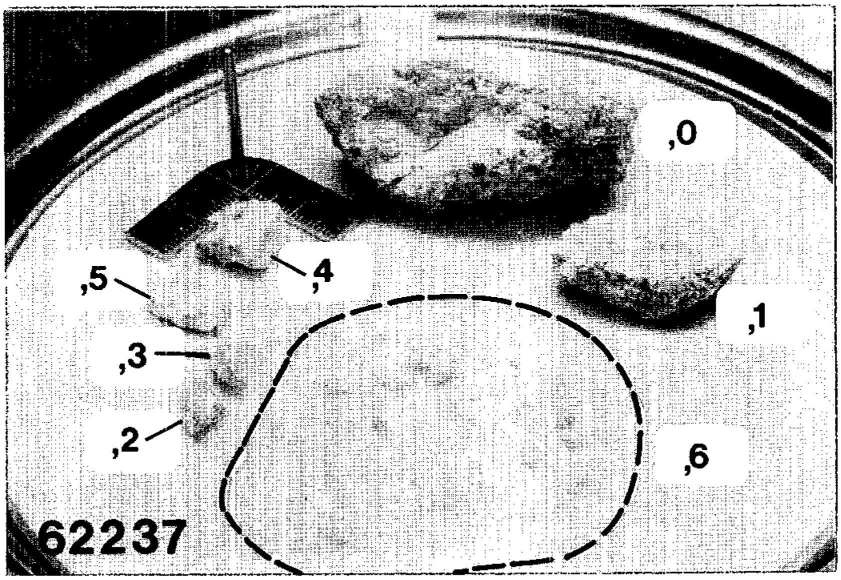


Figure 4. Splits of 62237

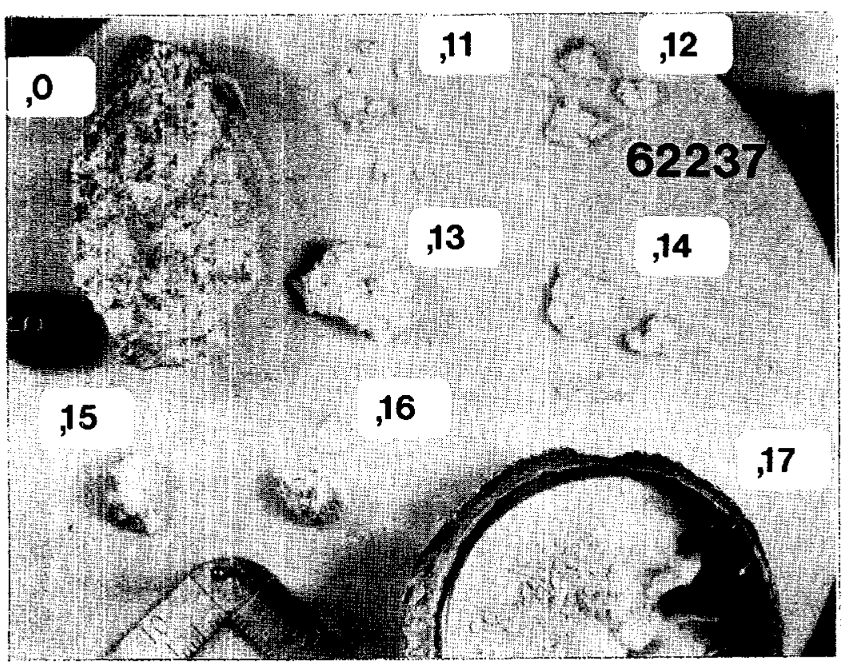


Figure 5. Splits of 62237

67035 Gabbro/Norite (?) Clast 2.31 gm

Evidence for pristinity: Hertogen et al. (1977) analyzed a small fragment and found it to be free of meteoritic contamination.

Description: The clast was a 1.5 x 1.5 cm coherent dark clast or piece which was split to reveal a marble pattern of ~50% dark and 50% light "swirled together". One end was made into a potted butt. These show a cataclasized anorthosite, almost all white material, with a thin rind of adhering matrix (Figure 1). The thin sections do not have the marbling, however a 2-3 mm pyroxene occupies the center of each section. Our own preliminary analyses indicate that the pyroxene is mainly augite ($\sim En_{40}Wo_{30-40}$) with exsolved low - Ca pyroxene ($\sim En_{60-65}Wo_3$). The plagioclase grain size is about 5 mm and, despite the cataclasis, some original grain boundaries are preserved.

The only published work is that of Hertogen et al. (1977) which shows Rb of 0.57 ppm which is high for an anorthosite, though low for a norite of the plutonic variety (Civet Cat, 15445 norite, etc.). Nickel at 9.4 ppb is consistent with a high mafic content. The clast seems to be unique in the Apollo 16 collection.

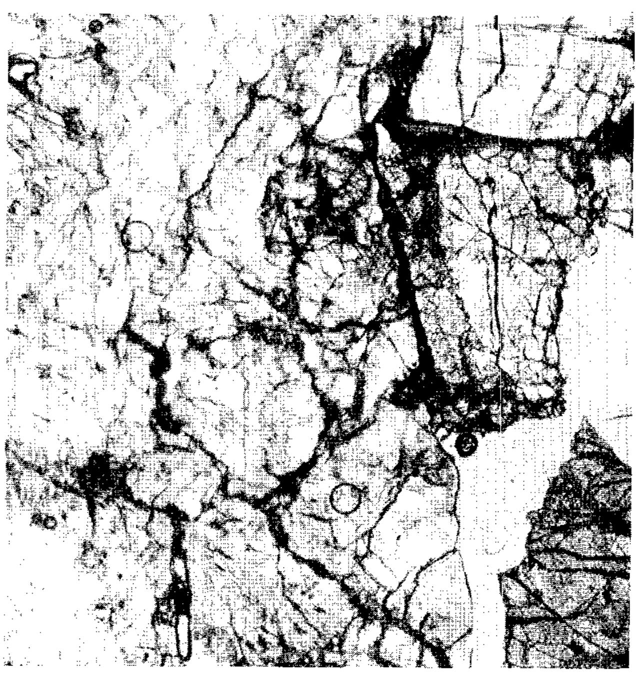


Figure 1. Transmitted light photomicrograph of 67035,7. Width of view ~2 mm.

Table 1

Split	Parent	Location	Mass	Description and daughters
,6	,33	SCC	0.010	TS
,7	,33	SCC	0.010	TS
,8	,33	SCC	0.010	TS
,9	,33	SCC	0.010	TS
,26	,18	RSPL	0.174	Returned fines from Anders. Crushed (trace element degraded), air; ,64
,33	,18	RSPL	0.040	Potted butt; ,6-,9
,36	,18	SSPL	1.28	Black + White Chip
,37	,18	Nyquist	0.230	Black + White Chip
,38	,18	SSPL	0.060	Black + White Chips
,64	,26	Consumed, Anders	0.086	

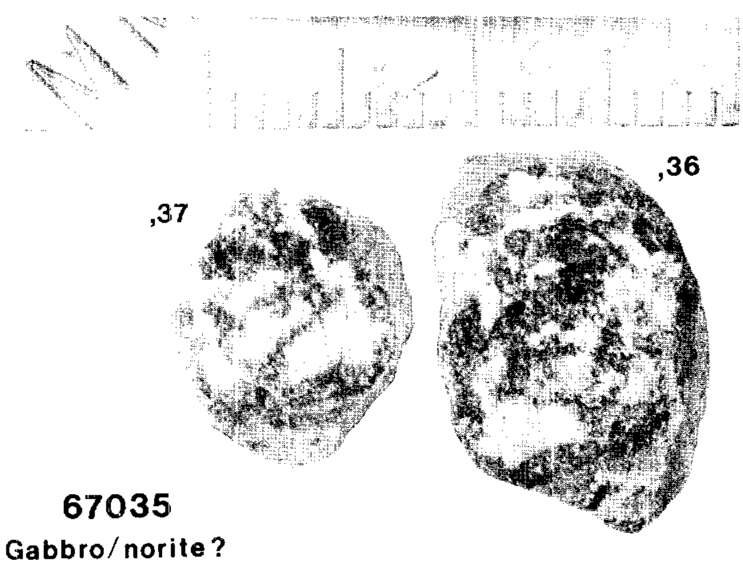


Figure 2. Two splits of the 67035 gabbro-norite. Smallest division on scale bar is mm.

67435 Spinel Troctolites (PST) ~2 gm?

Evidence for pristinity: The distinct texture, grain sizes up to 3 mm and the ultrabasic composition strongly suggest that PST is a pristine cumulate (Prinz et al.,1973).

Description: Two fragments of PST, from distinct locations in 67435, were found. One occurs in thin sections, the other remains in the rock.

Prinz et al. (1973) reported on the petrology and mineralogy of the sample in thin section ,14. (A small portion also occurs in ,17 but no data has yet been published for it.) PST has a distinct cumulate texture (Figure 1) and consists of olivine (Fo_{92}) and pleonaste poikilitically enclosed by plagioclase (An_{97}). Minor amounts of troilite and metal occur, but pyroxene is apparently absent. Spinel totals about 5%, olivine 70% and plagioclase 25%. The fragment has been mildly shocked.

A bulk composition calculated from the mode and mineral compositions by Prinz et al. (1973) demonstrates that the clast is ultrabasic, and is reproduced here as Table 1.

The other fragment remains in ,8. Spinel composes about 5% of the clast and plagioclase and olivine are about equally abundant. One spinel grain is ~1 mm in diameter (R. Warner et al.,1976).

Figure 1. Transmitted light photomicrograph of 67435,14. Width of view ~2 mm.

Table 1

SiO_2	37.5
TiO_2	0.05
Al_2O_3	15.9
Cr_2O_3	0.49
FeO	5.8
MnO	0.16
MgO	33.7
CaO	6.2
Na_2O	0.14
K_2O	0.04
P_2O_5	0.02

From Prinz et al. (1973)

Table 2

Split	Parent	Location	Mass	Description and daughters containing spinel troctolites
,2	,0	RSPL	0.270	Potted butt, probably no longer contains PST. ,14 ,17
,8	,0	BSV	68.770	Butt end. Contains 8x8mm clast of PST
,14	,2	Meyer	0.010	TS, includes matrix
,17	,2	Keil	0.010	TS, mainly glass and matrix

67667 Peridotite (?) 7.89 gm

Evidence for pristinity: Macroscopic observations (Apollo 16 Lunar Sample Information Catalog) and thin section examinations (Steele and Smith 1973, Warren and Wasson 1978) show that 67667 is an unusually mafic (∿80% mafics) monomict breccia. It has homogeneous phase compositions and its pre-cataclasis grain size appears to have been at least 2 mm. Such features suggest pristinity. Furthermore, metal grains with low Ni/Co suggest, though not conclusively, their non-meteoritic origin (Warren and Wasson,1978).

Description: 67667 is a rake fragment from near the white breccia boulders on the southern rim of North Ray Crater.

Despite its brecciation (Figure 1) Warren and Wasson (1978) reported mineral compositions which are homogeneous: An_{90-92}, Fo_{70-72}, $En_{74-77}Wo_{4-5}$, and $En_{52-55}Wo_{34-37}$. Ilmenite contains 4-5% MgO. There are also traces of Cr-spinel, troilite, and metal. Steele and Smith (1973) reported very similar phase compositions (Figure 2) and noted that Fe in plagioclase (∿0.1%) is consistent with a non-mare origin. Warren and Wasson (1978) reported a mode of ∿50% olivine, ∿20% plagioclase, ∿2% ilmenite and ∿30% pyroxene with clino-and orthopyroxene about equally abundant. Steele and Smith (1973) reported a mode of ∿50% pyroxene, ∿20% olivine, and ∿30% plagioclase.

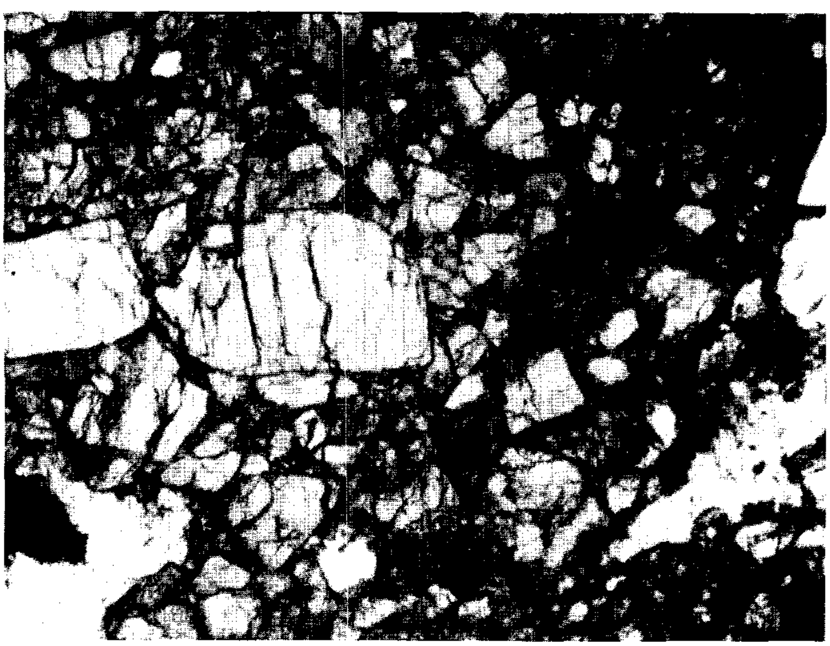


Figure 1. Transmitted light photomicrograph of 67667,6. Width of view ∿1.5 mm. (Photo courtesy of P. Warren).

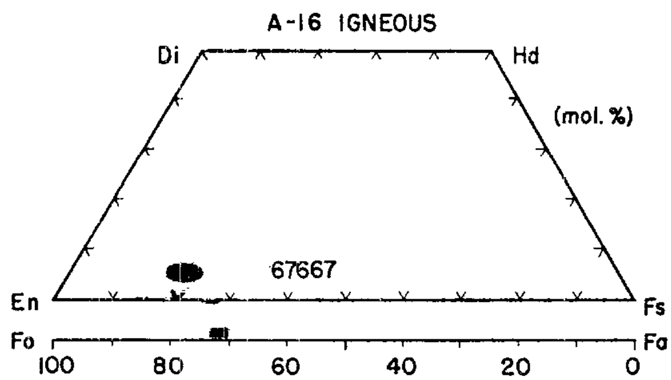


Figure 2. Compositions of olivines and low- Ca pyroxenes in 67667. (From Steele and Smith, 1973)

Table 1

Split	Parent	Location	Mass	Description and daughters
,0	,0	SSPL	5.220	
,1	,0	Smith	0.110	3 chips
,2	,0	RSPL	0.790	Potted butt; ,6
,3	,0	Wasson	0.190	Chip
,4	,0	SSPL	1.490	Chips and fines
,5	,0	Attrition	0.080	---
,6	,2	Wasson	0.010	PM

Only one thin section was cut from ,2 but enough remains for about 3 more sections.

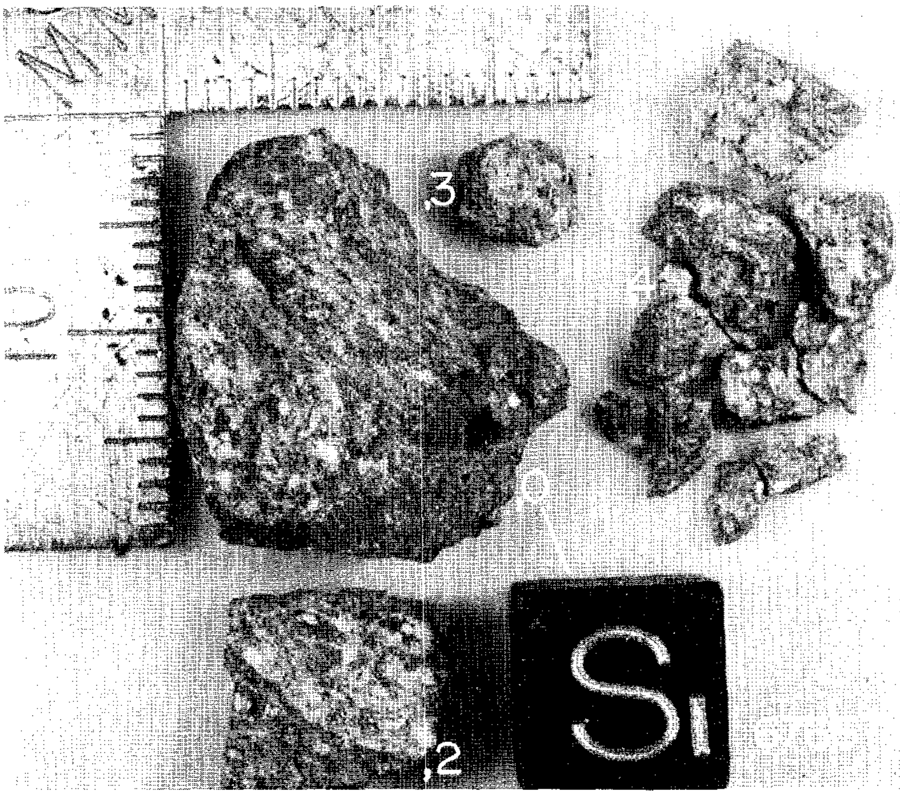


Figure 3. Splits of 67667,0, excluding ,1. (Photo S-78-27395)

72255 Norite Clast (Civet Cat) ~10 gm (?)

Evidence for pristinity: Morgan et al. (1974a,b, 1975) found the norite to be free of meteoritic contamination (Table 1).

Description: The norite is a small clast in the competent breccia matrix of 72255 (Marvin,1975). The petrography has been described by Stoeser et al. (1974a,b,c) and Ryder et al. (1975). The clast is shocked (Figure 1), containing kinked pyroxenes. It contains about 60% orthopyroxene and 40% plagioclase (See Figure 2 for compositions) with less than 1% total augite (exsolved), cristobalite, ilmenite, chromite, troilite, metal, baddeleyite, zircon, Zr-armalcolite, and niobian rutile (?). Takeda et al. (1976) in single crystal studies observed weak reflections of secondary pigeonite in the orthopyroxene as well as the augite.

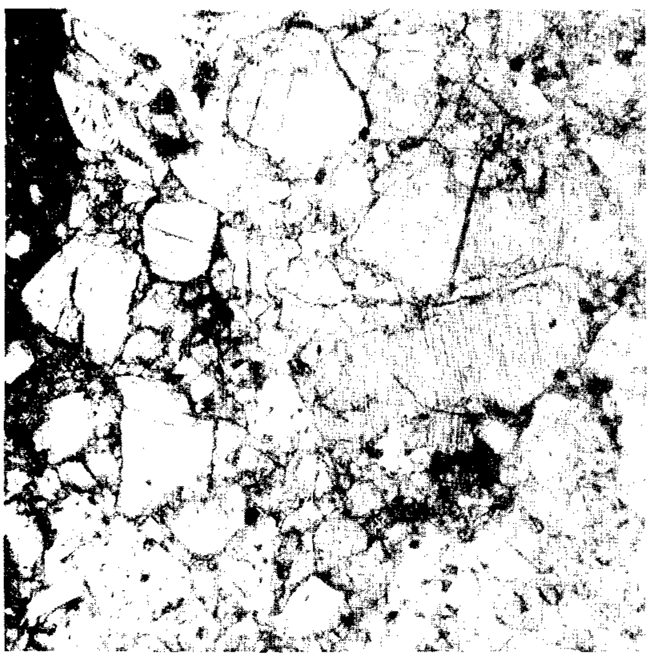


Figure 1. Transmitted light photomicrograph of 72255,104. Width of view ~2 mm.

Major and trace elements were determined by Haskin et al. (1974b) and Blanchard et al. (1974, 1975a) and are reproduced in Table 1 and Figure 3. The REE abundances (Figure 3) suggest an evolved parent liquid, though the pattern is fractionated cf. KREEP.

Rb-Sr studies were reported and discussed by Compston et al. (1974, 1975) and Gray et al. (1974). The norite has a minimum age of 4.17 ± 0.05 b.y. (Figure 4) but could be rather older.

U-Th-Pb systematics were reported by Nunes and Tatsumoto (1974a,b, 1975) and Nunes et al. (1974b). Excess Pb was probably introduced into the Civet Cat from the matrix 3.9 to 4.0 b.y. ago. Two U-Th-Pb analyses are too uncertain to yield an accurate age determination.

Argon analyses (Leich et al.,1974, 1975) yield a ^{40}Ar-^{39}Ar plateau age of 3.99 ± 0.03 b.y. (Figure 5) which is presumed to be the age of the matrix forming event which disturbed the clast. Other rare gas analyses were made by these authors.

Other references:
Banerjee and Swits (1975)

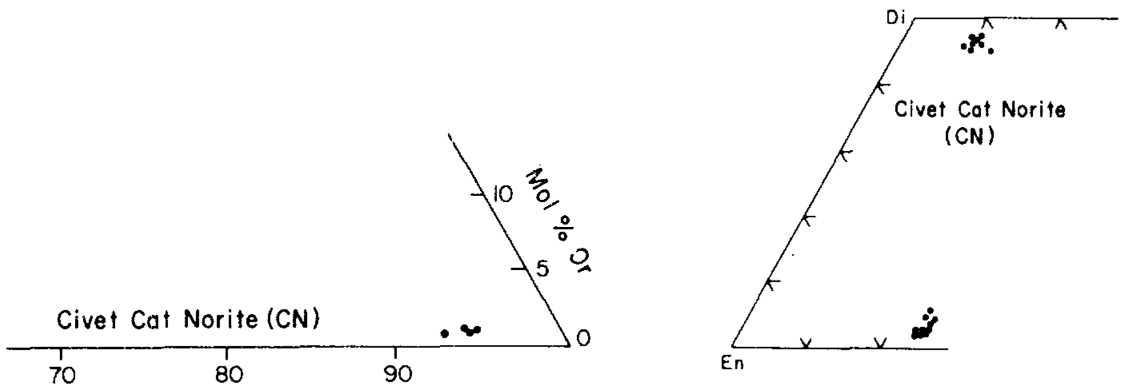


Figure 2. Compositions of plagioclase (left) and pyroxene (right) in Civet Cat norite. (From Ryder et al., 1975).

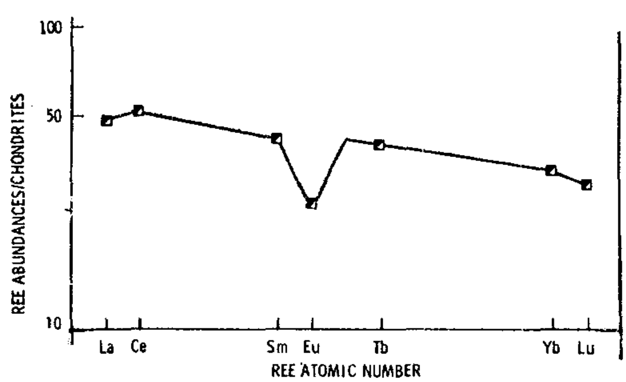


Figure 3. REE abundances in the Civet Cat norite. (From Blanchard et al., 1975a)

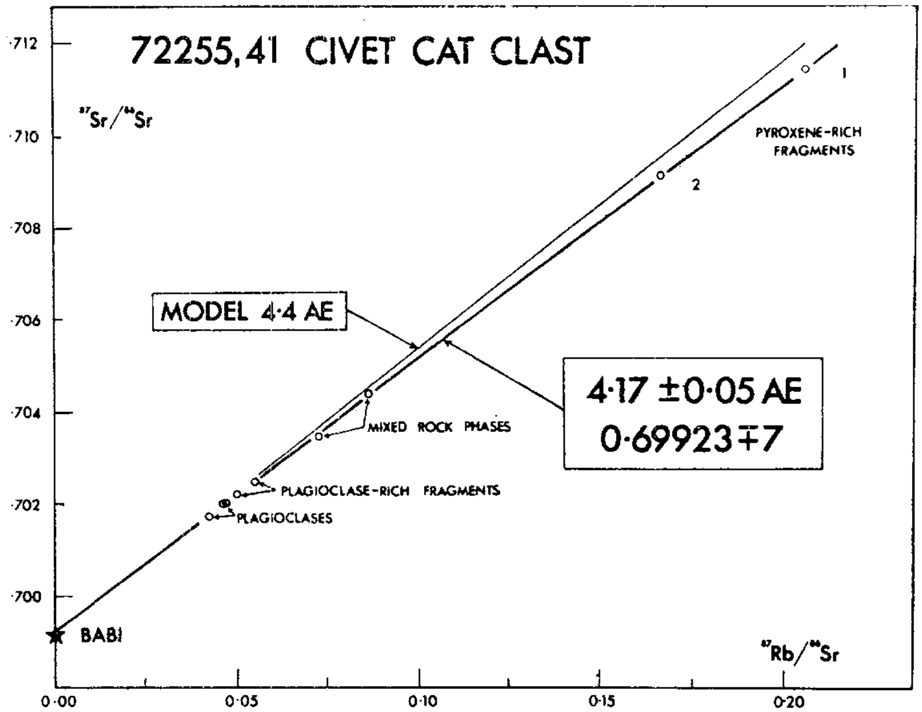


Figure 4. Rb-Sr isochron for the Civet Cat norite. (From Compston et al., 1975)

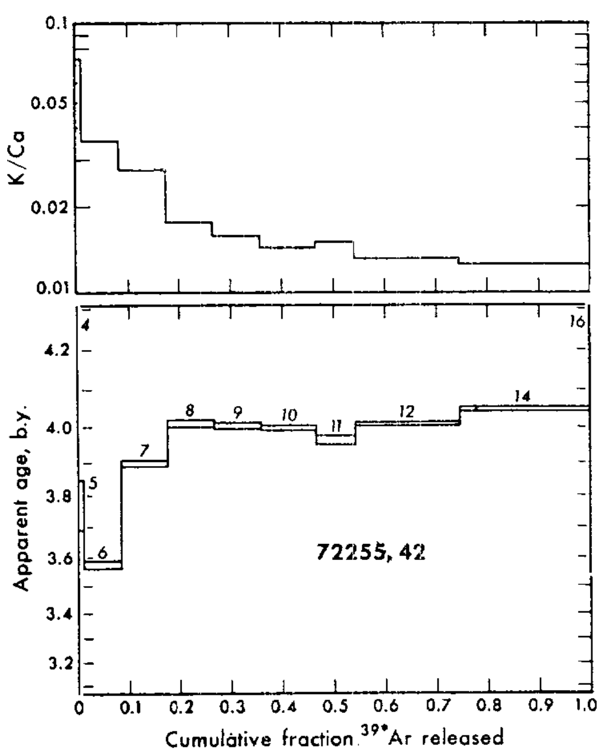


Figure 5. ^{40}Ar-^{39}Ar plateau age for the Civet Cat norite. (From Leich et al., 1975)

Table 1

	1) Portion of ,42 (212 mg)		1)
SiO_2	52	La	16
TiO_2	0.3	Ce	46
Al_2O_3	15.5	Sm	7.6
FeO	7.4	Eu	1.75
MnO	0.122	Tb	1.9
MgO	15.9	Yb	6.6
CaO	9.1	Lu	1.01
Na_2O	0.33		
K_2O	0.08		
Cr_2O_3	0.16		
Sc	13.2		
Co	29		
Hf	5.5		

	2) ,9001, a portion of ,42 (27 mg)
Ir ppb	0.0040
Re ppb	0.0068
Au ppb	0.008
Ni	4
Rb	1.27
Cs	58
U	240

Oxides in wt %, others in ppm except as noted.
Col. 1 from Blanchard *et al.* (1975a)
Col. 2 from Morgan *et al.* (1975)

Table 2

Split	Parent	Location	Mass	Description and daughters containing norite clast
,23	,0	SSPL	287.30	Mainly matrix
,29	,10	SSPL	3.320	Slab, Matrix, may contain norite
,30	,10	Price	0.6	Includes matrix
,35	,10	SSPL	1.05	Chip
,36	,10	Banerjee	3.49	Includes matrix
,37	,10	SSPL	1.470	Chips, some may be norite
,40	,10*	SSPL	0.86	2 black chips, one white; ,202 ,203
,41	,10*	RSPL	0.404	Fines, returned by Compston. Residues of handpicking. Crushed, clean air. ,116
,42	,10*	Consumed, Haskin	0.212	Chip; ,9001 ,9005
,43	,10*	Banerjee	0.14	Chip
,48	,10*	RSPL	0.42	Potted butt; ,123-,126
,49	,10*	Consumed, Tatsumoto	0.26	Chip
,51	,10**	SSPL	0.98	Chips, include matrix
,75	,10	RSPL	4.860	Potted butt; ,100-,105
,100	,75	SCC	0.010	TS
,101	,75	Wood	0.010	TS
,102	,75	SCC	0.010	TS 2 orthogonal sets
,103	,75	Wood	0.010	TS
,104	,75	SCC	0.010	TS
,105	,75	Wood	0.010	TS
,108	,75	SCC	0.010	TS
,116	,41	Consumed, Compston	0.556	---
,123	,48	Wood	0.010	PM
,124	,48	Wood	0.010	PM
,125	,48	Wood	0.010	PM
,126	,48	Wood	0.010	PM

*although listed as from ,10, more directly these splits came from ,35 (part of ,10).
**although listed as from ,10, more directly this split came from ,76 (part of ,10).

Split	Parent	Location	Mass	Description and daughters containing norite clast
,137	,202	RSPL	0.001	Pyroxene crystals returned by Takeda. Hand-picked, x-rayed, acetone, air, admixed organic solids.
,138	,202	RSPL	0.001	
,139	,202	RSPL	0.001	
,140	,202	RSPL	0.001	Fines on slides, returned by Takeda. Handpicked, x-rayed, electron irradiated, acetone, air, araldite, heated to 80°C.
,141	,202	RSPL	0.001	
,142	,202	RSPL	0.001	
,143	,202	RSPL	0.001	
,144	,202	RSPL	0.015	Fragments and fines, returned by Takeda. Air.
,145	,202	RSPL	0.002	Fines, returned by Takeda. Air.
,146	,202	Attrition	-0.007	---
,202	,40	RSPL	0.033	Chips and fines, returned by Takeda. Air, acetone.
,203	,40	Attrition	0.060	---
,9001	,42	Consumed, Anders	0.06	
,9005	,42	Consumed, Reynolds	0.210	
,9007	,9005	Consumed, Hubbard	0.015	

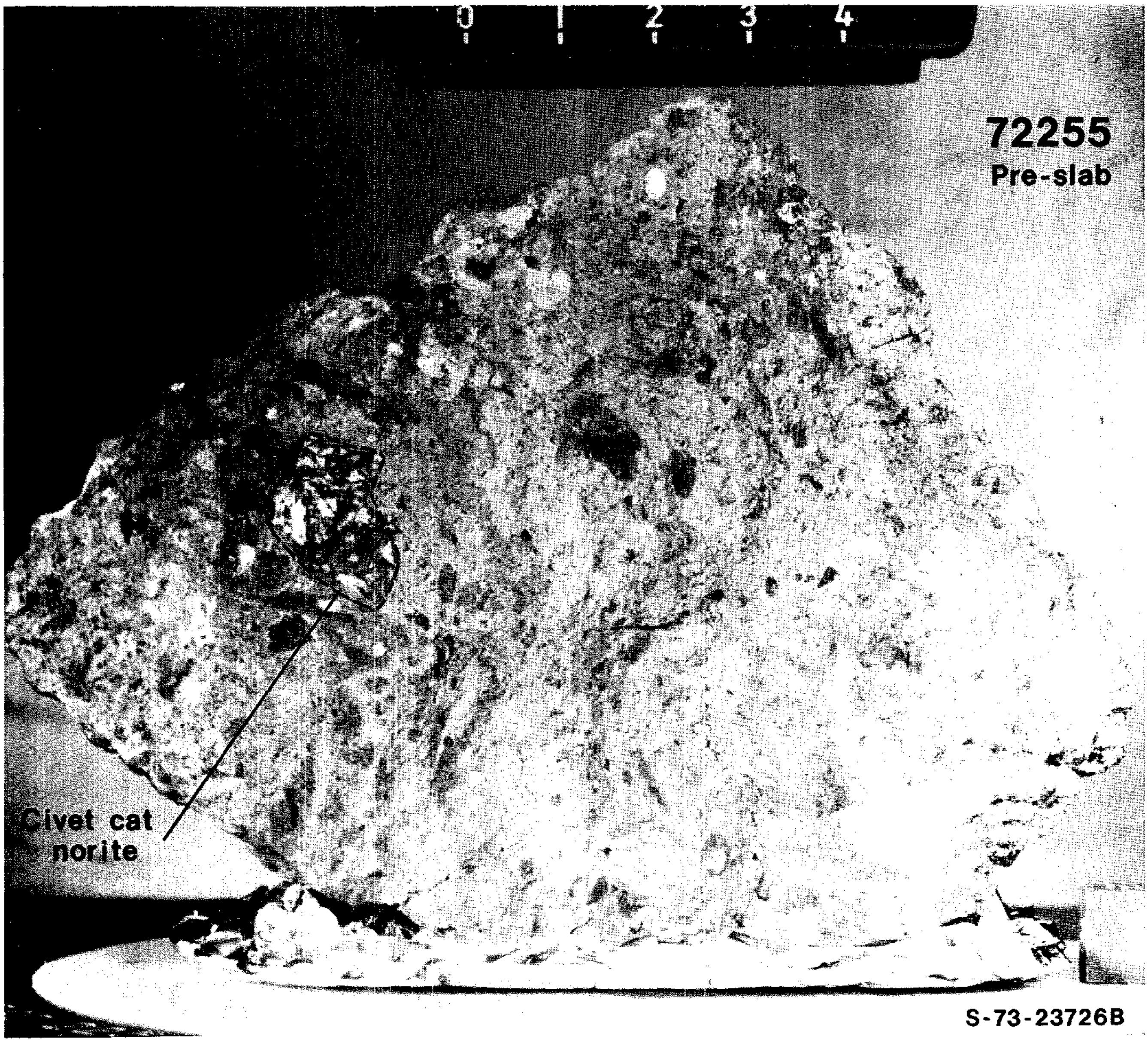


Figure 6. Civet Cat norite in 72255 as originally received.

72275 KREEPy Basalt Clasts ∿5 gm?

Evidence for pristinity: Morgan et al. (1974a,b, 1975) analyzed one clast of pigeonite basalt (#5, split ,91) and found it to be free of meteoritic contamination.

Description: Pigeonite basalt occurs in the Boulder 1, Station 2 breccia 72275 as individual clasts and as areas of nearly monomict breccia. It typically has a subophitic to intersertal texture (Figure 1) with plagioclase laths up to 1 mm long surrounded by interstitial pyroxene or mesostasis (Stoeser et al., 1974a,b,c, Ryder et al., 1975, 1977, Marvin 1974, 1975). Pyroxene and plagioclase are approximately subequal in abundance with mesostasis accounting for 10-30% of the sample. Minor phases include silica-rich glass, chromite, native Fe, ilmenite, whitlockite (?), troilite, K-Ba feldspar, and zircon. Pyroxenes have Mg-pigeonite cores zoned to ferroaugite rims; plagioclase is zoned from $An_{94}Or_1$ to $An_{76}Or_8$ (Figure 2). Olivine is very rare and has a composition $\sim Fo_{69}$ (Stoeser et al., 1974a,b,c, Ryder et al., 1975, 1977).

The pigeonite basalt clasts in 72275 appear to be chemically transitional between Apollo 15 KREEP and high-Al mare basalts (Ryder et al., 1977). Chemical data are given in Table 1. Several defocused beam electron microprobe analyses can also be found in Ryder et al. (1975, 1977). Figure 3 shows the pigeonite basalt to have KREEP-like REE abundances except for being slightly more depleted in the heavy REE's (Blanchard et al., 1974, 1975a,b, Haskin et al., 1974b). This basalt is unusual in having an extremely high Ge content for a meteorite-free igneous rock (Morgan et al., 1975).

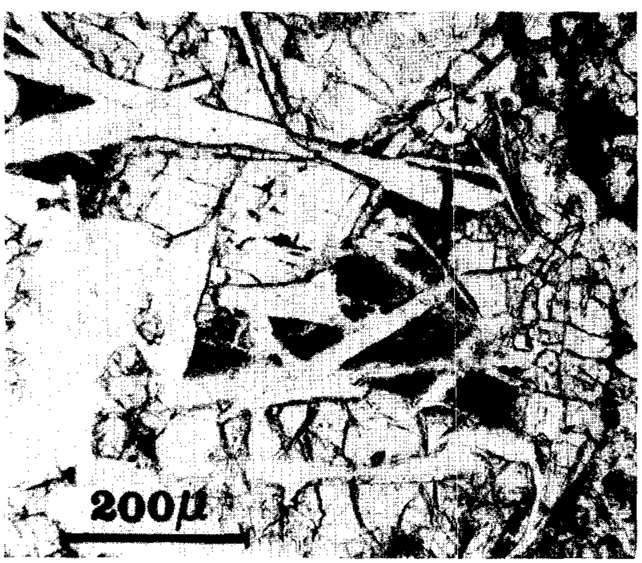


Figure 1. Transmitted light photomicrograph of KREEPy basalt clast in 72275,128.

Ages of 4.01 and 4.05 b.y. have been determined by Rb-Sr (Figure 4, Gray et al., 1974, Compston et al., 1975) and U-Pb (Nunes and Tatsumoto, 1975) respectively. Initial $^{87}Sr/^{86}Sr$ was determined to be o.69957±14 (Gray et al., 1974, Compston et al., 1975).

Several small basalt clasts were identified in 72275, and much basalt is intimately mixed into the matrix (Marvin, 1974). Table 2 concentrates mainly on the two clasts which were prominent after cutting the slab i.e. clasts #4 and #5.

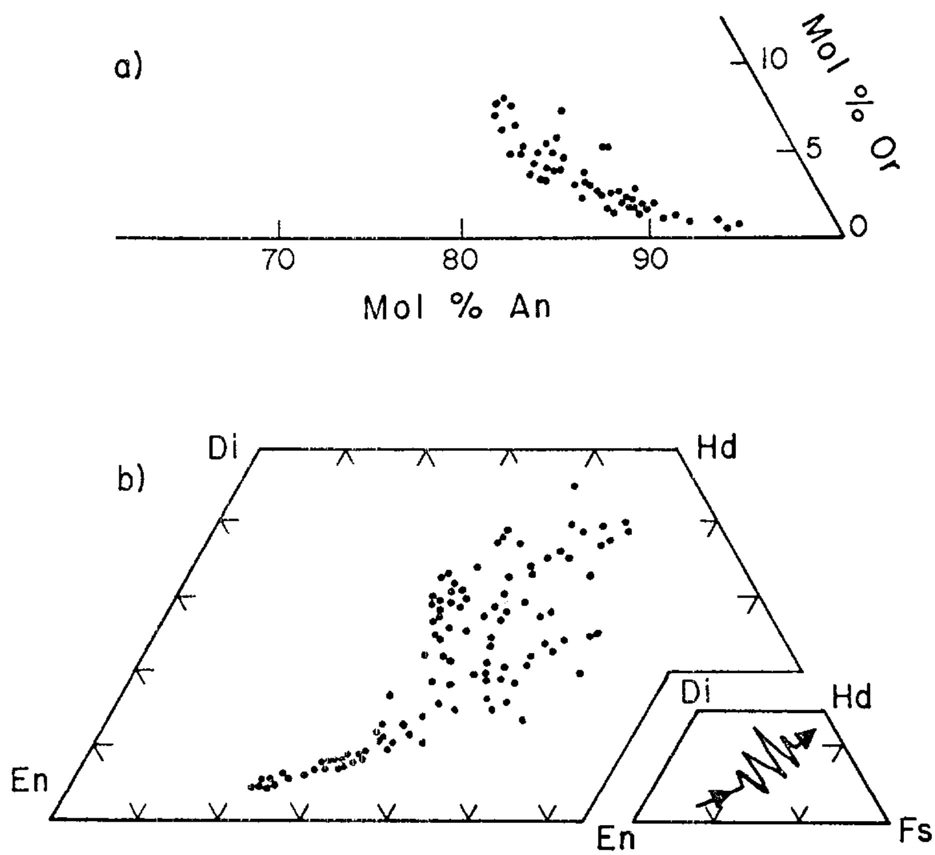


Figure 2. Compositions of plagioclases (a) and pyroxenes (b) in KREEPy basalt. Inset is generalized zoning trend. (From Ryder et al., 1977).

Table 1

SiO_2	48
TiO_2	1.4
Al_2O_3	13.5
FeO	15
MnO	0.156
MgO	10.0
CaO	10.5
Na_2O	0.29
K_2O	0.25
Cr_2O_3	0.46
La	48
Ce	131
Sm	23
Eu	1.58
Tb	4.5
Yb	11.9
Lu	1.75
Co	37
Sc	61
Hf	18

Oxides in wt %, all others ppm.
From Blanchard *et al*. (1974, 1975a,b)

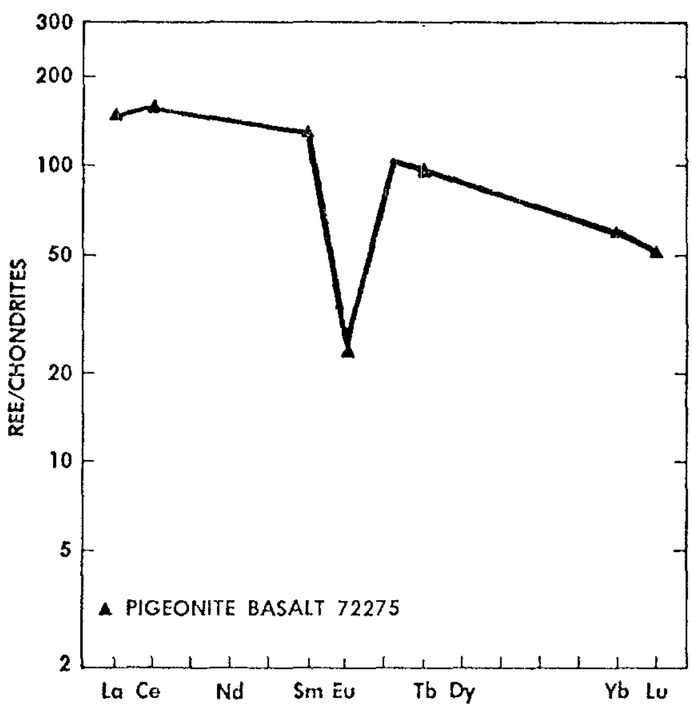


Figure 3. REE data for KREEPy basalt. (From Blanchard *et al*., 1974, 1975a,b).

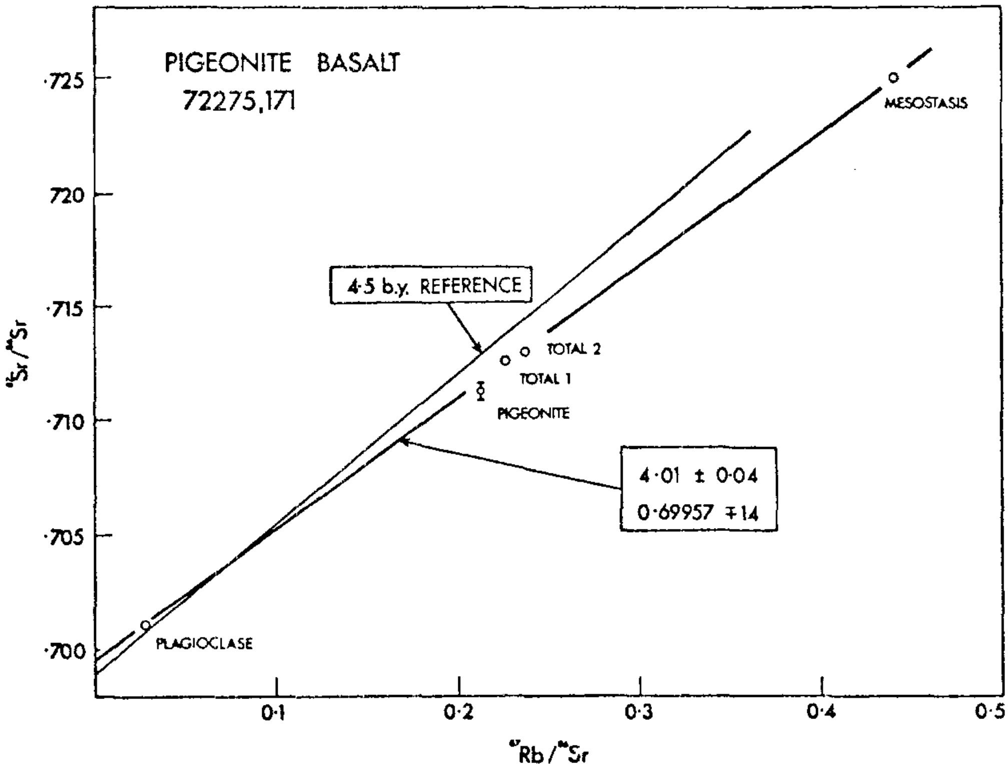


Figure 4. Rb-Sr internal isochron for KREEPy basalt. (From Gray *et al.*, 1974, Compston *et al.*, 1975)

Table 2

Split	Parent	Location	Mass	Description and daughters containing basalt
,27	,0	BSV	298.420	W end piece, contains basalt clasts, probably including Clast #4
,36	,0	SSPL	1.130	Mainly matrix; includes 3 mm basalt clast
,51	,42	SSPL	5.07	Mainly matrix, part of Clast #5
,56	,42	Banerjee	3.830	Mainly matrix, part of Clast #4
,57	,42	Blanchard	2.048	Mainly matrix, small part of Clast #4
,91	,42	Consumed, Haskin	0.133	Clast #5. ,181 ,9006 (,222) ,9011 (,9016)
,93	,42	RSPL	0.540	Potted butt, Clast #5. ,147-,149
,102	,0	SSPL	2093.6	E end piece. Probably contains both Clasts #4 and #5
,120	,170	Consumed, Tatsumoto	0.134	Clast #4
,147	,93	Wood	0.010	TS, Clast #5
,148	,93	SCC	0.010	TS, Clast #5
,149	,93	James	0.010	TS, Clast #5
,163	,185	SSPL	0.460	Chip, Clast #4. ,170 ,171 (,228-,232) ,172-,174 (,179)
,165	,185	SSPL	1.150	Matrix, probably contains small piece of Clast #4
,170	,163	RSPL	0.096	Chip and fines of Clast #4, returned by Tatsumoto. Air, partly crushed. ,120
,171	,163	Ent. Subdivided	0.260	Clast #4. ,228-,232
,172	,163	SSPL	0.110	Chip, Clast #4
,173	,163	SSPL	0.190	Chips, Clast #4
,174	,163	Ent. Subdivided	0.020	Was potted butt, Clast #4. ,179
,179	,174	Wood	0.010	TS, Clast #4
,181	,91	Consumed, Wood	0.405	? Clast #5
,185	,42	SSPL	14.140	Mostly matrix, may have pieces of Clast #4 remaining

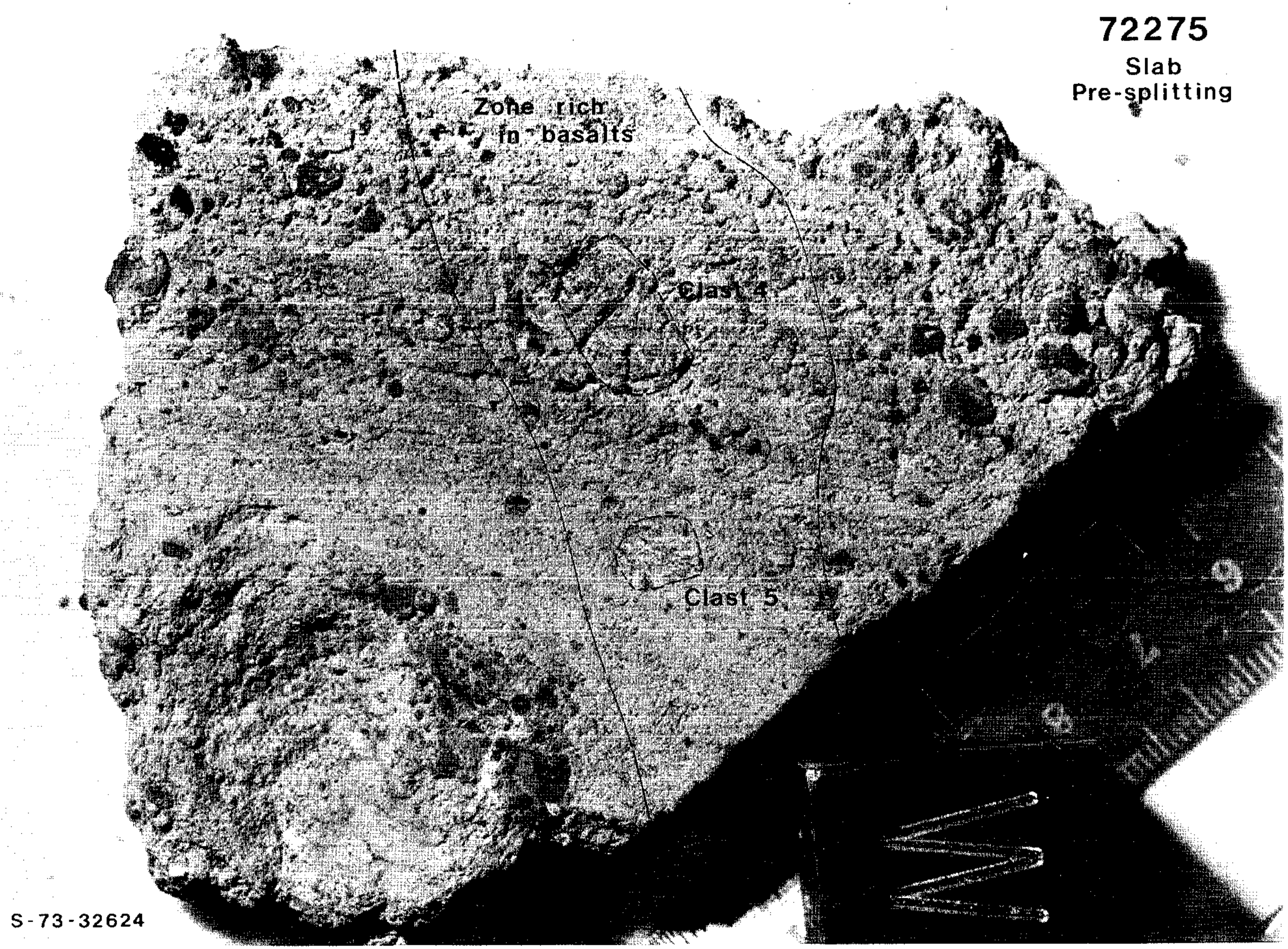


Figure 5. W side of the 72275 slab, showing basalt clasts.

Split	Parent	Location	Mass	Description and daughters containing basalt
,222	,9006	Consumed, Anders	0.046	
,228	,171	RSPL	0.034	Fines, returned by Compston. Air, crushed
,229	,171	RSPL	0.099	Chip, returned by Compston. Air
,230	,171	RSPL	0.033	Fines, returned by Compston. Air, residue after handpicking
,231	,171	RSPL	0.001	PM, Clast #4
,232	,171	Consumed, Compston	0.093	
,9006	,91	RSPL	0.021	Fines, returned by Anders. Air, glassine paper ,222
,9011	,91	Consumed, Reynolds	0.177	,9016
,9016	,9011	Consumed, Hubbard	0.013	

Parent numbers given are not always those given in the generic listings but more accurately reflect the immediate parent.

72275,185
Chipping

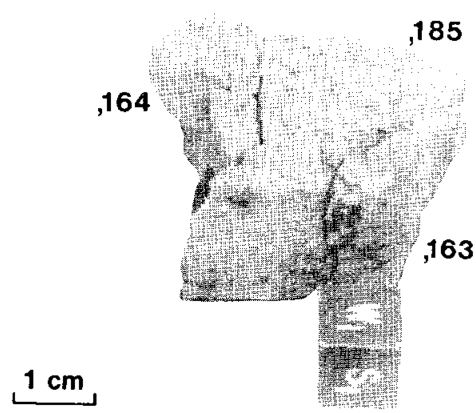


Figure 6.

Apollo 17, Station 2, Boulder 3 Dunite Clast Samples

Boulder 3 at Station 2 contained a 10 cm friable clast which was sampled as 72415, 72416, 72417, and 72418. The clast is a pale colored breccia with pale-green olivine clasts and sparse feldspathic clasts in a moderately coherent matrix of the same constituents.

72415 Dunite 32.34 gm

Evidence for pristinity: Siderophile abundances show a split of 72415 to be free of meteoritic contamination (Higuchi and Morgan, 1975).

Description: Petrographic studies of 72415 reveal it to be an olivine cataclasite formed predominantly by simple crushing (Albee *et al.*, 1974, Dymek *et al.*, 1975) (Figure 1). Large (10 mm) clasts of slightly deformed single crystals (Fo_{86-89}) sit in a granulated olivine matrix. The matrix is identical in composition to the clasts. Olivine makes up 93% of the rock, plagioclase (Ab_{92}) 4%, pyroxene (Wo_3En_{84} and $Wo_{42}En_{50}$) 3%, with minor amounts of spinel, Fe-Ni metal, troilite, whitlockite, and armalcolite. Symplectic intergrowths exist along grain boundaries and as inclusions in olivine and plagioclase (Bell *et al.*, 1975, Albee *et al.*, 1974, Dymek *et al.*, 1975). Chemical data is given in Table 1.

Other references:

Keith *et al.* (1974); Radionuclides by γ-rays
Yokoyama *et al.* (1974); ^{22}Na-^{26}Al
Gibson and Moore (1974; Sulfur
Snee and Ahrens (1975); Shock-induced features
Pearce *et al.* (1974); Magnetic properties
Richter *et al.* (1976); Microcracks

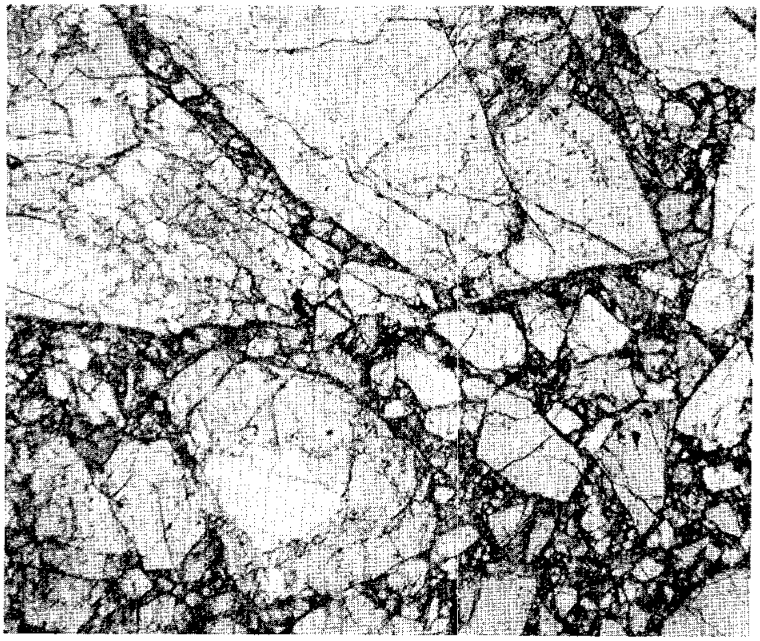


Figure 1. Transmitted light photomicrograph of 72415,25. Width of view ∿2 mm.

Table 1

	1)	2)	3)
SiO_2	40.6	40.70	39.93
TiO_2	0.0	0.03	0.03
Al_2O_3	1.2	1.25	1.53
Cr_2O_3	0.1	0.19	0.34
FeO	11.4	11.82	11.34
MnO	0.1	0.13	0.13
MgO	45.5	45.24	43.61
CaO	1.2	1.04	1.14
Na_2O	0.0	0.02	<0.02
K_2O	0.0	0.00	0.00

Oxides in wt. %.
Col. 1 from Albee *et al.* (1974), calculated from mode
Col. 2 from Dymek *et al.* (1975), calculated from mode (72415 and 72417)
Col. 3 from LSPET (1973), (analysis Rhodes, Rodgers, Bansal)

72416 Dunite 11.53 gm

Evidence for pristinity: 72416 is from the same clast in Boulder 3, Station 2 from which meteorite free sample 72415 was taken.

Description: Macroscopically 72416 is similar to 72415, 72417 and 72418. It has never been allocated and is stored in B45.

72417 Dunite 11.32 gm

Evidence for pristinity: Because this is from the same clast in Boulder 3, Station 2 as 72415 and has the same petrography, it is presumed to be pristine. A split analyzed by Higuchi and Morgan (1975) had high levels of siderophiles, which may not be due to meteoritic contamination.

Description: 72417 is similar to 72415, and is included in a petrographic study of the latter by Dymek et al. (1975). Symplectites were studied by Bell et al. (1975).

Chemical studies of 72417 show it, and the entire dunite, to be somewhat heterogeneous. Data are given in Table 1. Laul and Schmitt (1975) found normative plagioclase to vary from 1-11% and large ion lithophiles to vary over 1 order of magnitude (Figure 1) for 9 samples (from different locations) of $\sim$100 mg. The siderophile data of Higuchi and Morgan (1975) also stress differences between splits of the dunite, and Papanastassiou and Wasserburg (1975) report highly variable Rb/Sr among chips from the same sub-sample.

An age of 4.55 $\pm$ 0.10 b.y. was determined by the Rb/Sr method (Albee et al., 1974, Papanastassiou and Wasserburg, 1975) with an initial $^{87}Sr/^{86}Sr$ of 0.69900 (Figure 2).

72417 was sent to Wasserburg, by whom allocations were made to other P.I.'s. The remainder of the sample ($\sim$8 gm) remains with Wasserburg except for some samples returned to Houston.

Other references:
Jovanovic and Reed (1974); Labile and nonlabile elements

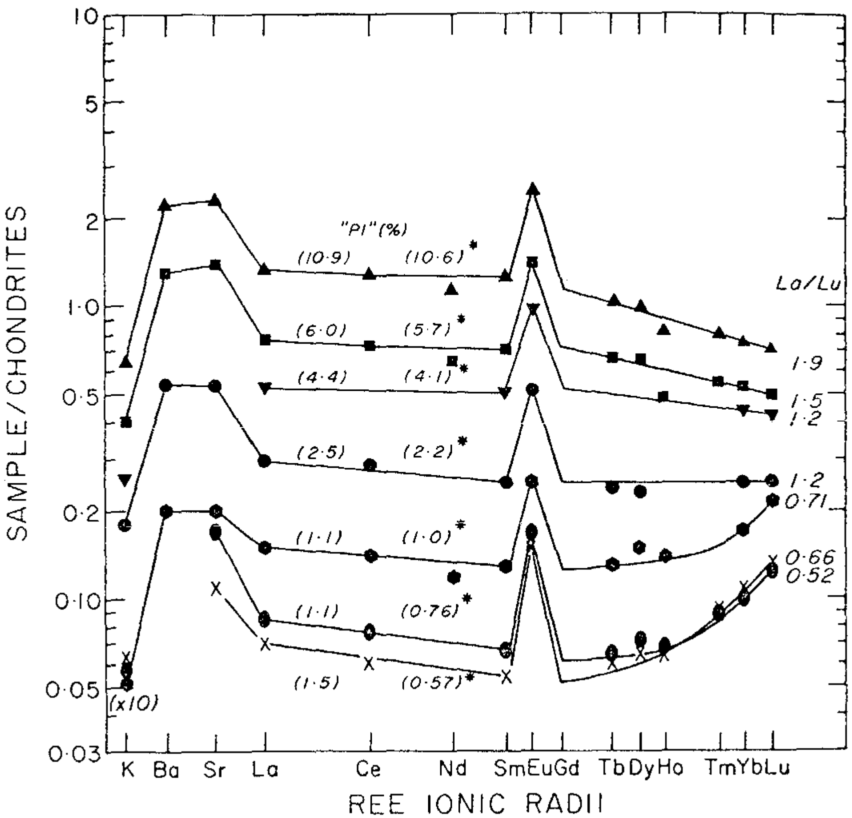


Figure 1. Incompatible element data for nine 72417 fragments. "Pl" is calculated plagioclase abundance. (From Laul and Schmitt, 1975)

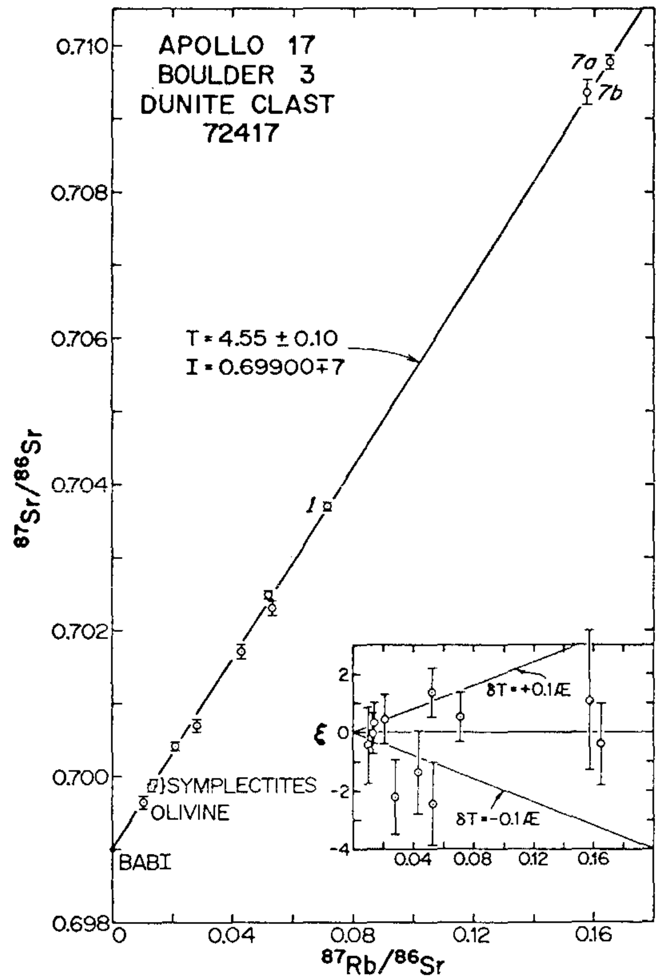


Figure 2. Rb-Sr isochron and evolution diagram. (From Papanastassiou and Wasserburg, 1975)

72417

Table 1

Al_2O_3	1.3	Sr	8.2
Cr_2O_3	0.34	La	0.15
FeO	11.9	Ce	0.37
MnO	0.11	Sm	0.080
MgO	45.4	Eu	0.061
CaO	1.1	Tb	0.017
Na_2O	0.02	Dy	0.11
K_2O	0.00	Ho	0.023
Sc	4.3	Yb	0.074
V	50.	Lu	0.012
Co	55.	Hf	0.010
Ba	4.1	Ni	160.

Oxides in wt. %, all other data in ppm.
From Laul and Schmitt (1975), mass weighted mean.

72418 Dunite 3.55 gm

Evidence for pristinity: 72418 is from the same clast in Boulder 3, Station 2 from which meteorite-free sample 72415 was taken.

Description: Macroscopically 72418 is similar to 72415, 72416, and 72417. It has never been allocated and is stored in SSPL.

76255 Norite Clast ∿300 gm

Evidence for pristinity: Gros et al. (1976b) analyzed a chip and found it to be free of meteoritic contamination (Table 1). (Note that the piece referred to as troctolite by the Anders group is in fact the norite).

Description: 76255 was taken to sample matrix and a large (0.5-1m) inclusion in the Station 6 boulders; most of the sample, representing the inclusion, is the norite, which is cataclastic (Figure 1). The norite has been described by J. Warner et al. (1976). It has been pervasively crushed and is permeated to some extent by rods and septa of matrix material, however the analysis of Gros et al. (1976b) indicates that clean separations are possible.

The norite consists mainly of plagioclase (An_{87-88}), pigeonite with coarse exsolved augite lamellae, and augite with exsolved pigeonite lamellae. Mineral data are given in Figure 2; the compositions of the phases are similar to those in the gabbro. Ilmenite, troilite and metal are also present. The nature of the pyroxene exsolution has been studied by J. Warner et al. (1976) and Takeda and Miyamoto (1977), the latter using single crystal x-ray diffraction as well as microprobe studies. The latter confirm the compositional data of J. Warner et al. (1976), conclude that the low-Ca pyroxene is inverted pigeonite, and suggest that exsolution developed at a depth of a few kilometers in the lunar crust.

A bulk composition, calculated from the mode by J. Warner et al. (1976) is given in Table 1, and suggests the overall similarity of the 76255 norite to other lunar plutonic norites such as 72255 Civet Cat, 72215, and so on. This is supported by the incompatible trace element data of Gros et al. (1976b).

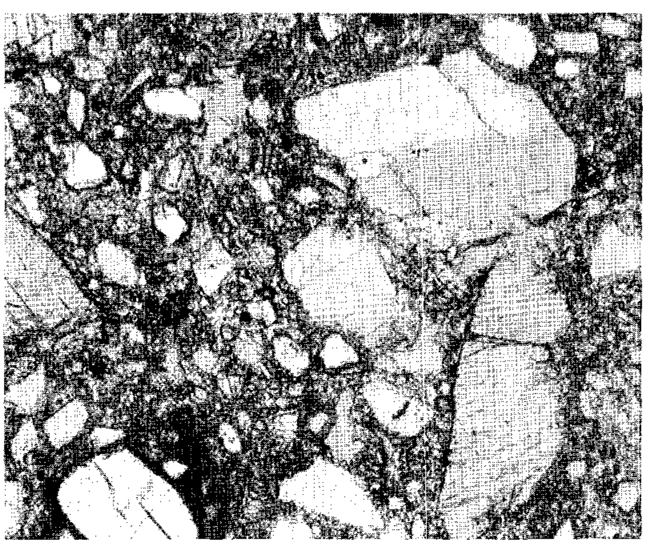


Figure 1. Transmitted light photomicrograph of 76255,74. Width of view is ∿1 mm.

Table 1

	1)	2) ,82, a portion of ,56	
SiO_2	49		
TiO_2	0.5	Ir ppb	0.042
Al_2O_3	16	Os ppb	0.035
Cr_2O_3	0.2	Re ppb	0.028
FeO	9.8	Au ppb	0.178
MgO	11	Ni	31
CaO	12		
Na_2O	0.6	Rb	12.8
K_2O	0.1	Cs ppb	842
		U	0.445

Oxides in wt %, others in ppm except as noted.
Col. 1 from J. Warner et al. (1976)
Col. 2 from Gros et al. (1976b)

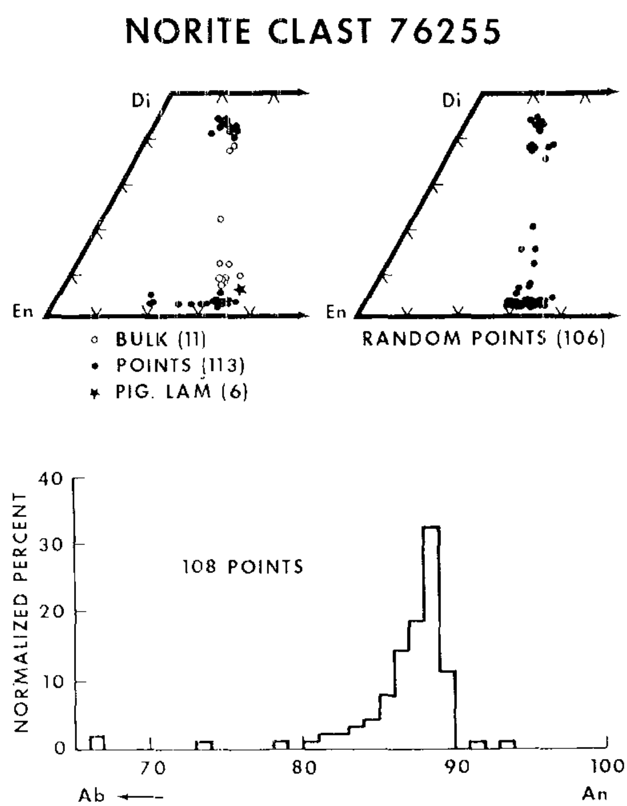


Figure 2. Compositions of pyroxene and plagioclase in the 76255 norite (from J. Warner et al., 1976)

Table 2

Split	Parent*	Location	Mass	Description and daughters containing norite
,1	,0	SSPL	13.150	Piece split off W end
,2	,0	SSPL	0.180	Undocumented chip, may be norite
,3	,0	SSPL	1.450	Chip
,5	,0	RSPL	0.060	Potted butt. ,12
,6	,0	RSPL	0.050	Potted butt. ,14
,8	,0	Walker, R.M.	0.090	Chip
,9	,0	Consumed, Bogard	0.080	Undocumented chip, probably norite
,12	,5	SCC	0.010	TS
,14	,6	SCC	0.010	TS
,20	,0	SSPL	238.600	End piece, includes other lithologies. ,59 (,60)
,21	,0	SSPL	4.580	4 chips
,22	,0	BSV	38.630	End piece, mainly norite
,24	,0	SSPL	1.580	Chip. ,55 ,56 (,82)
,25	,0	Hörz	0.030	Mainly zap pit
,26	,0	SSPL	23.390	Slab remnant. ,29 (,57 ,58 ,62 ,68-,70 ,74-,76) ,31 ,33-,38 (,39-,43)
,29	,26	RSPL	6.660	Potted butt, includes zone mixed with melt matrix. ,57 ,58 ,62 (,74-,76) ,68 ,69 ,70
,31	,26	SSPL	3.930	Slab piece
,33	,26	SSPL	0.050	Slab piece
,34	,26	SSPL	0.140	Slab piece
,35	,26	Walker, R.M.	0.950	Slab piece. ,41 ,42
,36	,26	Gibson	1.190	Slab piece. ,39 ,40
,37	,26	SSPL	1.620	Slab piece, includes zone mixed with melt matrix
,38	,26	Rhodes	1.530	Slab chips, coarse mafic zone. ,43
,39	,36	Bogard	0.100	Chip
,40	,36	SSPL	0.470	Chips and fines

Split	Parent	Location	Mass	Description and daughters containing norite
,41	,35	SSPL	0.960	Chips
,42	,35	Turner	0.120	4 chips
,43	,38	SSPL	0.900	Chips, coarse mafic zone
,55	,24	Rhodes	1.620	Chip
,56	,24	RSPL	0.082	Chips and fines, returned by Anders. Air, glassine paper. ,82
,57	,29	RSPL	0.025	Fines, returned by Anders. Mainly troctolite. Includes some matrix. Air, physically separated, crushed (trace element degraded), hand-picked.
,58	,29	Wasson	0.110	Chip, mainly troctolite
,59	,20	SSPL	5.730	Chips, patina on surface. ,60
,60	,59	SSPL	3.020	Chips
,61	,26(?)	Takeda	0.010	Pyroxene grains
,62	,29	RSPL	5.440	Potted butt, includes troctolite. ,74-,76
,63	,0	SSPL	3.430	Band saw chips. Includes other lithologies
,64	,0	SSPL	5.190	Band saw chips and fines. Includes other lithologies
,65	,0	SSPL	9.960	Band saw power, mixed lithologies
,67	,0	RSPL	2.100	Freon fines, includes norite
,68	,29	Phinney	0.010	TS
,69	,29	Stöffler	0.010	TS
,70	,29	SCC	0.010	TS
,74	,62	SCC	0.010	TS, includes troctolite
,75	,62	Phinney	0.010	TS, includes troctolite
,76	,62	SCC	0.010	TS, includes troctolite
,82	,56	Consumed, Anders	0.068	---

*Many of the parents given here are not the same as in the generic listings; those given here are from data pack information and accurately denote the <u>direct</u> parent of the split.

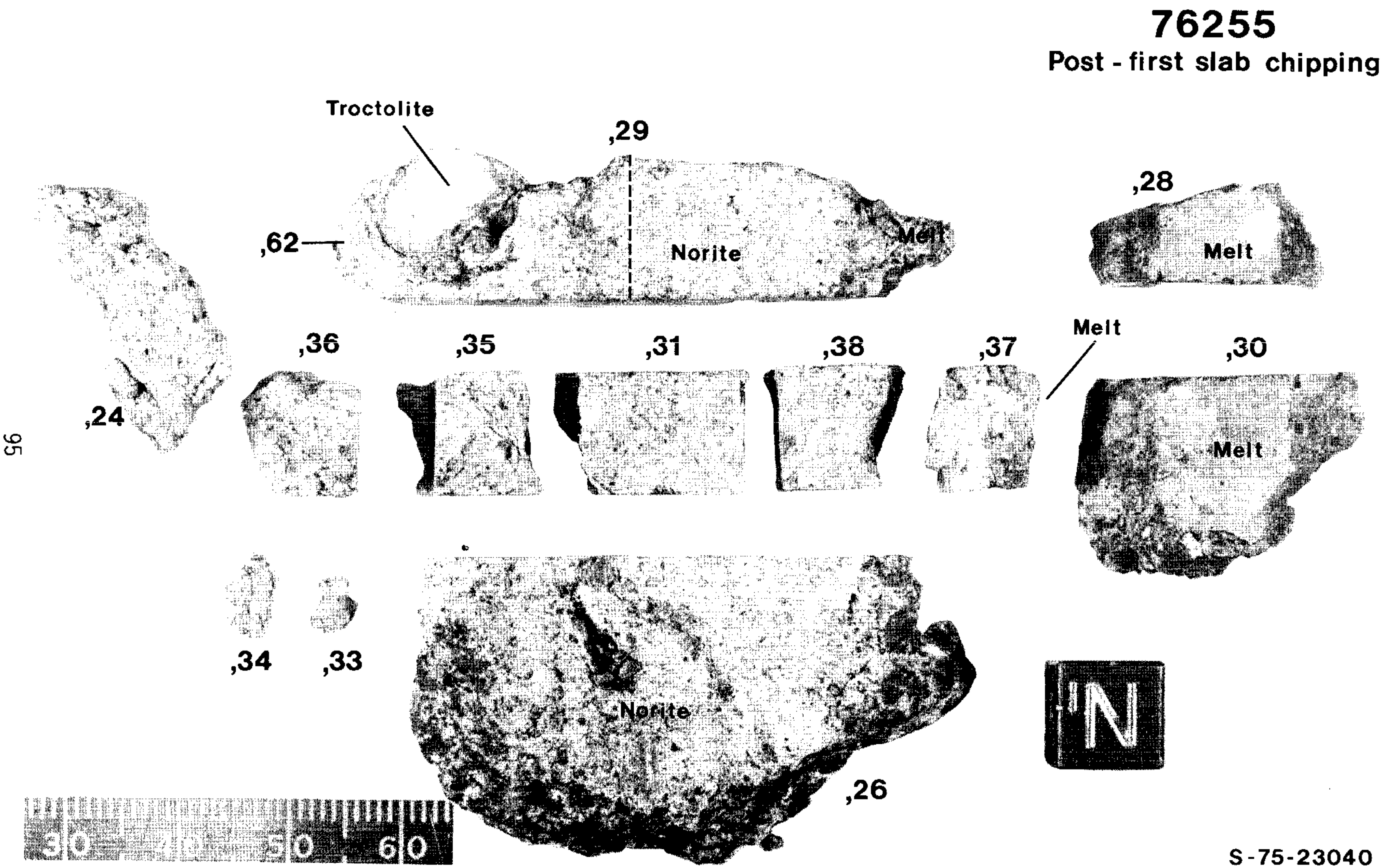


Figure 3. Initial splitting of the 76255 slab. Further subdivision was made.

76255 Troctolite ~2 gm (??)

Evidence for pristinity: Gros et al. (1976b) analyzed a chip and found it to be free of meteoritic contamination. (Note that the piece referred to as troctolite by the Anders group is in fact norite, and the piece they refer to as gabbro is in fact the troctolite).

Description: The troctolite clast occurs in the slab cut from 76255 and had dimensions of 8 x 12 mm (reported in J. Warner et al. 1976 in error as 0.8 x 1.2 mm). Confusion has arisen because in the data pack this clast is quoted as Unit 5 whereas in J. Warner et al. (1976) the clast is Unit 4.

J. Warner et al. (1976) show that the troctolite consists of ~77% "flame-textured" plagioclase (~An_{96}) and ~23% olivine (~Fo_{90}). Troilite, Fe-metal, and one pyroxene grain (En_{90}) were observed. The clast is brecciated (Figure 1). Warren and Wasson (1978) analyzed a crushed fragment (P.I.-P.I. transfer from Haskin) but found it to be contaminated with siderophiles. Major element data agree reasonably with the J. Warner et al. (1977) estimated composition (Table 1). Unfortunately, virtually the entire clast from the slab was made into a potted butt. Photographs indicate that a 2 mm white patch in a clast mold in butt end piece ,22 may be the troctolite.

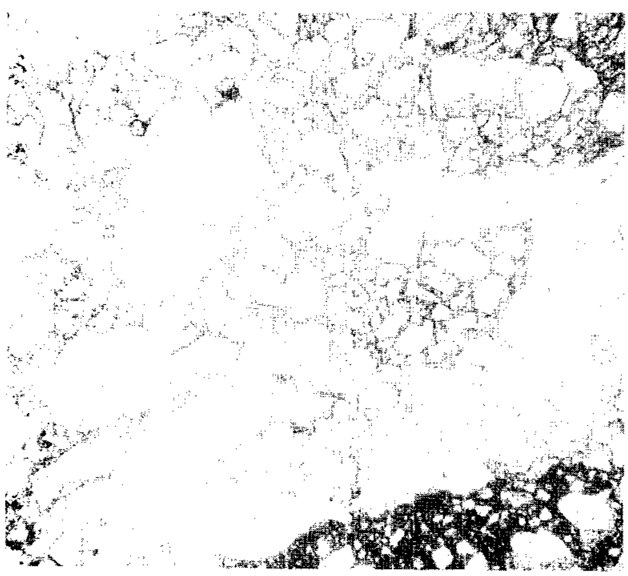


Figure 1. Transmitted light photomicrograph of 76255,75 troctolite. Width of view ~3 mm.

Table 1

	1)	2) Portion of ,58	3)		2)	3)
SiO_2	43	44.1		Zr	150	
Al_2O_3	26	26.1		Cd	6.4	0.006
FeO	3.1	4.3		In	< 5	0.010
MgO	13	10.2		Ba	240	
CaO	14	15.0		Hf	3.0	
Na_2O	0.3	0.47		Ta	0.27	
K_2O	0.05	--		Ir ppb	0.63	0.019
				Re ppb		0.0068
				Au ppb	10.8	0.0093
Sc		4.7		Th	1.30	
Ti %		0.16		U	0.38	0.019
Cr		461				
Mn		367		La	16.1	
Co		19.4		Ce	38	
Ni		<70	≤15	Nd	24	
Zn		53.2	2.3	Sm	5.4	
Ga		4.81		Eu	1.77	
Ge ppb		22.0	2.2	Tb	0.94	
Rb			3.68	Yb	3.4	
Cs			0.175	Lu	0.46	

Oxides in wt %, others in ppm except as noted.
Col. 1 from J. Warner et al. (1976), calculated from mode.
Col. 2 from Warren and Wasson (1978)
Col. 3 from Gros et al. (1976b)

Table 2

Split	Parent	Location	Mass	Description and daughters containing troctolite
,22	,0	BSV	38.630	Mainly norite, may contain troctolite
,57	,0	RSPL	0.025	Chips and fines, returned by Anders. Probably includes norite. Air, physically separated, crushed (trace element degraded), hand-picked. ,81
,58	,0	Wasson	0.110	Chip, crushed (transferred from Haskin). (analyzed)
,62	,0	RSPL	5.44	Potted butt, includes norite. ,74 ,75 ,76
,74	,62	SCC	0.010	TS, includes norite
,75	,62	Phinney	0.010	TS, includes norite
,76	,62	SCC	0.010	TS, includes norite
,81	,57	Consumed, Anders	0.005	Chip

76255 Gabbro Clast ~ 0.5 gm.

Evidence for pristinity: The coarse unbrecciated cumulate texture (Figure 1) and the gabbroic composition strongly suggest a pristine rock. (The "gabbro" in 76255 found to be meteorite-free by Gros et al., 1976b, is in fact troctolite; the gabbro was not sampled for chemistry).

Description: The gabbro was a small clast described by J. Warner et al. (1976)* The gabbro was described during cutting as the only one of its kind observed, and was removed entirely as ,50.

The gabbro consists of plagioclase (An_{89-75}), augite ($En_{48}Wo_{36}$) with exsolved thin lamellae of low-Ca pyroxene, and interstitial pigeonite ($En_{61}Wo_{10}$) with exsolved thick augite lamellae (Figures 1 and 2). Troilite, metal, and Mg-ilmenites are also present. The phase compositions are similar to those of the 76255 norite. J. Warner et al. (1976) interpret the petrography to indicate that the gabbro was not

Figure 1. Transmitted light photomicrograph of 76255,72 gabbro. Width of view ~2 mm.

*The gabbro is not from the location indicated in Figure 1 of J. Warner et al. (1976). In fact it did not occur in the slab at all but in a portion of the parent which fell off during the cutting of the slab. The clast figured as Unit 5 on Figure 1 of J. Warner et al. (1976) is a shocked troctolite (?).

extensively annealed, and clearly has highland, not mare, affinities. Pyroxenes from the gabbro were probably included in a study of 76255 by Takeda and Miyamoto (1977), but no specific information is given therein.

A bulk composition calculated from the mode by J. Warner et al. (1976) is given in Table 1.

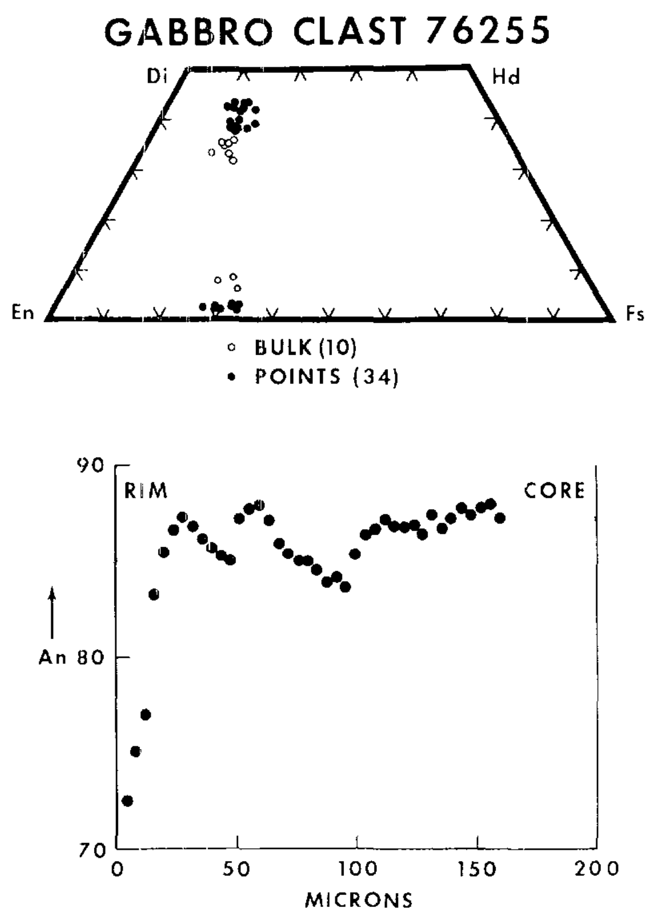


Figure 2. Compositions of pyroxenes (top) and plagioclase (bottom) in 76255 gabbro. (From J. Warner et al., 1976)

Table 1

SiO_2	49
TiO_2	0.8
Al_2O_3	13
Cr_2O_3	0.4
FeO	7.1
MgO	11
CaO	17
Na_2O	0.5
K_2O	0.06

Oxides in wt %.
From J. Warner _et al._ (1976), calculated from mode.

Table 2

Split	Parent	Location	Mass	Description and daughters containing gabbro
,50	,0*	RSPL	1.410	Potted butt, probably still includes gabbro. ,71 -,73 ,83
,71	,50	SCC	0.010	TS
,72	,50	Phinney	0.010	TS
,73	,50	Engelhardt	0.010	TS
,83	,50	Takeda	0.010	TS unpolished

*Although listed in generic list as coming from ,0 ,50 more directly came from ,27.

76335 Troctolitic Anorthosite 352.9 gm

Evidence for pristinity: Warren and Wasson (1978) and Warren *et al.* (1978a) analyzed a fragment and found it to be free of meteoritic contamination and to have low incompatible element concentrations. (Table 1).

Description: Sample 76335 was a fragile sample picked up near the Station 6 Boulders and described by Schmitt as "looks like a crushed anorthosite". The DB residues 76330 (418.6 gm) must be from the same rock. Warren and Wasson (1977, 1978) and Warren *et al.* (1978a) made a chemical and petrographic study of 76335. The rock is brecciated (Figure 1), but shows a vestigial cumulate texture. Intact plagioclase grains (An_{96}) are up to 4 mm across and original olivine grains (Fo_{87}) were at least 2 mm. The analysis of Warren and Wasson (1978) is reproduced in Table 1. The norm of their analysis is 79% plagioclase, 21% olivine; the mode of the thin section is 88% plagioclase, 12% olivine. The original catalog description estimated 92% plagioclase, 8% olivine. Inspection of 2 other thin sections in SCC (cut from the same chip as Wasson's thin section) confirmed the essentially bimineralic plagioclase (∿85-90%) - olivine nature of this chip.

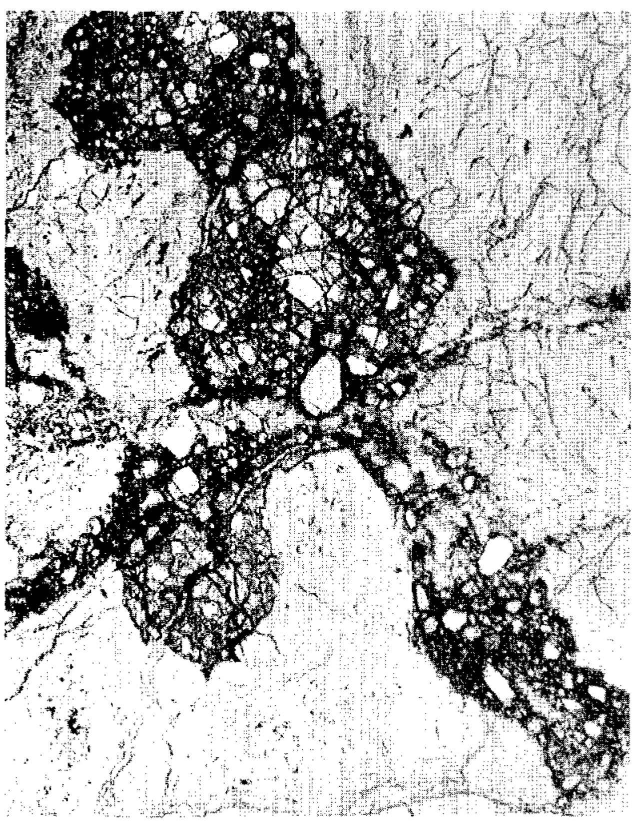


Figure 1. Transmitted light photomicrograph of 76335,28. Width of view ∿2 mm.

Table 1

	,38				
SiO_2		43.4	Ge ppb	10.2	1.1
TiO_2		0.07	Cd	5.2	8.7
Al_2O_3	31.2	27.6	In	0.078	<1.1
FeO	2.26	3.0	Hf	0.40	0.45
MgO	9.0	10.3	Ir ppb	0.013	0.13
CaO	16.8	15.0	Au ppb	0.089	0.013
Na_2O	0.323	.308	Th		0.16
K_2O	0.03		U		0.10
			Ba	56	46
Sc	1.33	1.72			
Cr	356	408	La	2.47	2.12
Mn	202	286	Ce	6.7	5.3
Co	13.1	15.6	Sm	0.80	0.70
Ni	20.4	<20	Eu	1.03	0.91
Zn	3.1	0.38	Tb	0.12	0.13
Ga	3.5	3.15	Yb	0.56	0.56
			Lu	0.073	0.082

Oxides in wt. %, others in ppm except as noted.
From Warren and Wasson (1978).

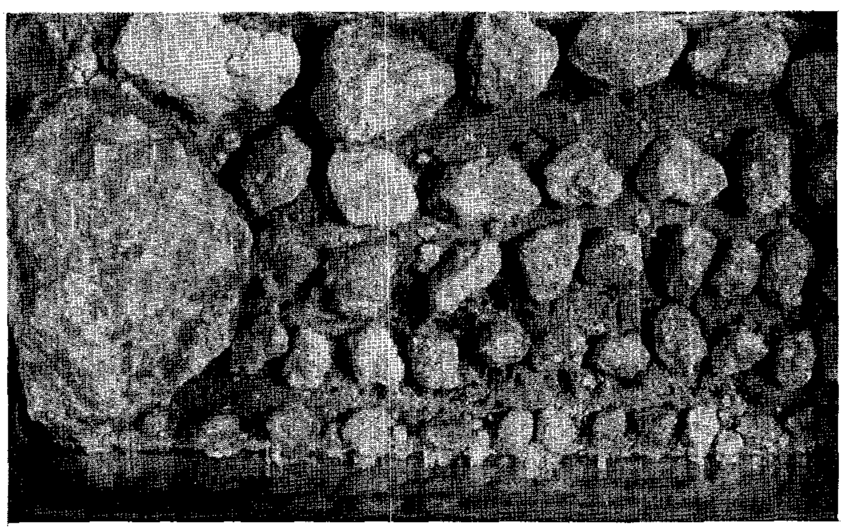


Figure 2. 76335 as originally returned.

Table 2

Split	Parent	Location	Mass	Description & daughters
,0	,0	Entirely Subdivided	0.000	352.9 gm cataclasite
,1	,0	SSPL	7.600	7 frags; ,2 ,5
,2	,1	RSPL	1.390	Potted butt; ,27-,29
,3	,0	SSPL	0.470	Loose chip
,4	,0	SSPL	0.800	Loose chip
,5	,1	Attrition	0.170	---
,27	,2	SCC	0.010	PM
,28	,2	SCC	0.010	TS
,29	,2	Wasson	0.010	PM
,30	,0	SSPL	206.720	Chip
,31	,0	SSPL	19.030	Chip
,32	,0	SSPL	5.260	Chip
,33	,0	SSPL	4.050	Chip
,34	,0	BSV	9.950	2 chips
,35	,0	BSV	39.350	44 fragments
,36	,0	SSPL	27.140	35 fragments; ,38 ,39
,37	,0	SSPL	30.090	Small chips + fines
,38	,36	Wasson	.500	7 chips
,39	,36	Attrition	.350	---

76535 Troctolite 155 gm

Evidence for pristinity: Morgan et al. (1974a)found 76535 to be meteorite-free with respect to siderophiles and very low in U, alkalis, and volatiles. Similar incompatible data are reported by Keith et al. (1974).

Description: 76535 is a coarse grained troctolitic granulite with chemistry and texture (Figure 1) indicative of a cumulate origin, apparently at a considerable depth (10-30 km) in the lunar crust (Gooley et al., 1974, Haskin et al., 1974a, Dymek et al., 1975). It is one of the few genuine nonmare igneous rocks, having suffered virtually no brecciation or recrystallization due to impact processes (Gooley et al., 1974). Large plagioclase (aggregates up to 1 cm) and olivine (up to 0.8 cm) grains are quite homogeneous internally and from grain to grain (Haskin et al. 1974a). Modally it consists of 58% plagioclase (An_{95}), 37% olivine (Fo_{88}), and 4% bronzite (En_{86}) (Haskin et. al., 1974a, Brown et al., 1974). Plagioclase often contains small oriented inclusions which Nord (1976) found to be various pryoxenes and rare Fe-Ni metal particles.

Polygonal mosaic assemblages of bronzite, diopside, Mg-Al chromite, troilite, and various other exotic phases such as whitlockite, apatite, baddeleyite, and K-feldspar are present. No Ti-rich phase was found (Gooley et al., 1974). Symplectites were studied by Bell et al. (1975), Gooley et al. (1974), and Dymek et al. (1975). A chemical analysis was made by Haskin et al.(1974a) and Rhodes et al.(1974), reproduced here as Table 1; the REEs are plotted in Figure 2. The chemistry supports a cumulate origin with 8-16% trapped liquid and some metamorphic re-equilibration (Haskin et al., 1974a).

Isotope systematics appear to have been disturbed yielding inconsistent age data. Pb may have been mobilized during a major impact (Tera and Wasserburg, 1974) and the plagioclase may contain a significant component of trapped Ar (Bogard et al., 1974). The Rb-Sr technique yields an age of 4.61 + 0.07 b.y. (Figure 4, Papanastassiou and Wasserburg, 1976) compared to model ages of ∿4.55 b.y. by Pb-Pb and U-Pb (Tera and Wasserburg, 1974) and ∿4.26 b.y. by Sm-Nd (Figure 5, Lugmair et al., 1976), Pb-Pb (Hinthorne et al., 1975, and K-Ar (Bogard et al., 1974, Husain and Schaeffer, 1975, Huneke and Wasserburg, 1975). In addition to the model ages, Tera et al. (1974) report that 76535 was equilibrated possibly as late as 4.0 b.y. based on U-Pb. These ages are summarized in Table 2, adapted from Papanastassiou and Wasserburg (1976). Initial $^{87}Sr/^{86}Sr$ based on a corrected K-Ar age is 0.69913+6 (Bogard et al., 1974).

Other references:

Crozaz et al. (1974); exposure ages
Jovanovic and Reed (1974); halogens, Li, Hg, U, Ru, Os
Keith et al. (1974); radionuclides ^{26}Al, ^{22}Na, ^{54}Mn, ^{56}Co, ^{46}Sc, ^{48}V
Lugmair et al. (1976); Xenon systematics
Smyth (1975); crystalline cation ordering
Garg and Ehmann (1976); Zr-Hf fractionation

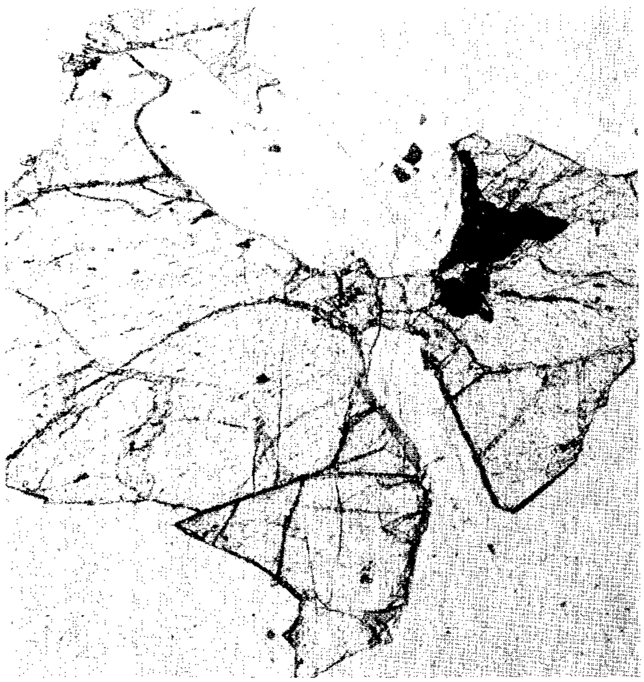


Figure 1. Transmitted light photomicrograph of 76535,55. Width of view ~3 mm.

Table 1

SiO_2	42.9	Li	3.0	La	1.51
TiO_2	0.05	Rb	0.24	Ce	3.8
Al_2O_3	20.7	Sr	114	Nd	2.3
FeO	4.99	Ba	33	Sm	0.61
MnO	0.07	U	0.056	Eu	0.73
MgO	19.1	Zr	23.6	Gd	0.73
CaO	11.4	Hf	0.52	Dy	0.80
Na_2O	0.2			Er	0.53
K_2O	0.03			Yb	0.56
Cr_2O_3	0.11			Lu	0.079
P_2O_5	0.03				

Oxides in wt. %, others in ppm.
From Haskin et al. (1974a) Rhodes et al. (1974).

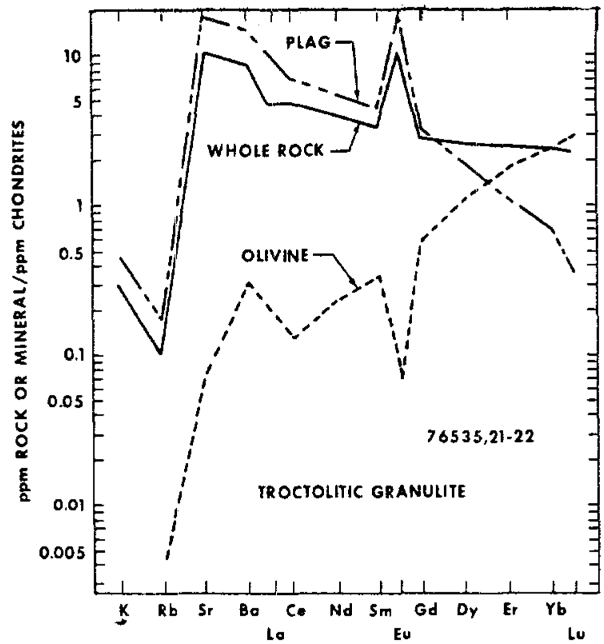


Figure 2. Incompatible trace element data for whole rock and separates of 76535. (From Haskin et al., 1974a)

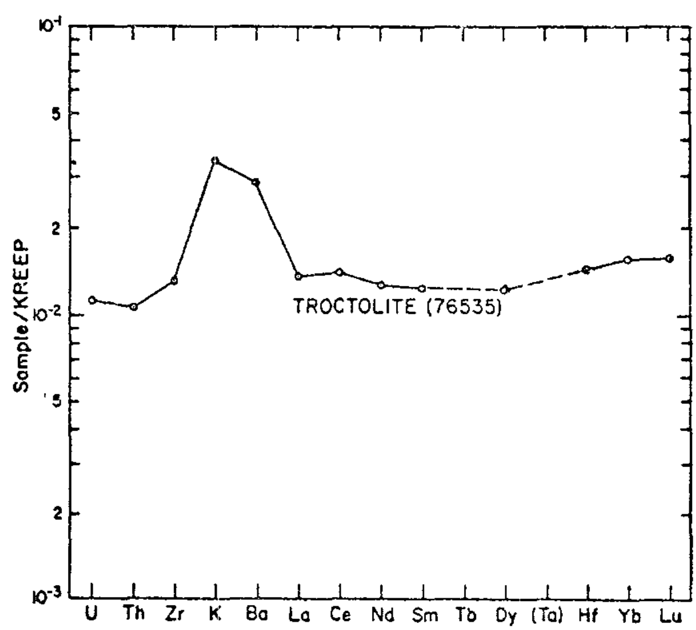


Figure 3. Incompatible element concentrations for 76535, normalized to KREEP. (From Warren and Wasson, 1977)

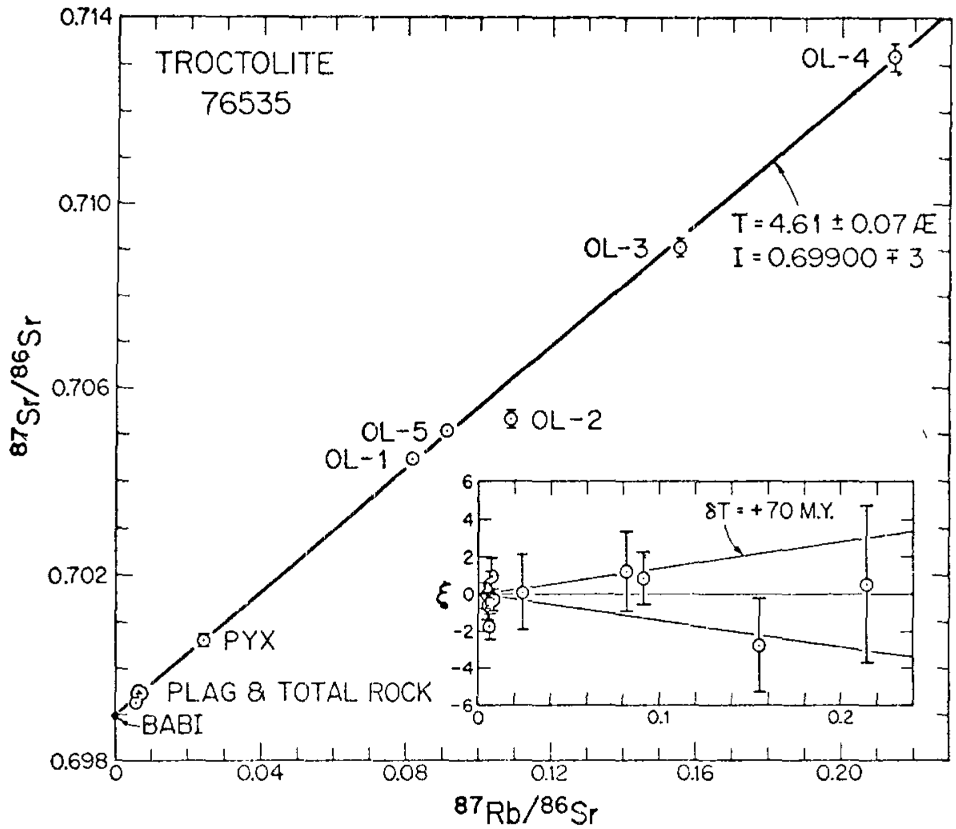


Figure 4. Rb-Sr isochron and evolution diagram for 76535. (From Papanastassiou and Wasserburg, 1976)

Table 2. Ages of 76535 (AE)

Rb-Sr	4.61 ± 0.07	(Papanastassiou and Wasserburg, 1976)
Sm-Nd	4.26 ± 0.06	(Lugmair et al., 1976)
U-Pb	∿4.0	(Tera and Wasserburg, 1974)
	∿4.55	(Tera et al., 1974)
Pb-Pb	4.27	(Hinthorne et al., 1975)
	∿4.55	(Tera et al., 1974)
K-Ar	4.26 ± 0.02	(Husain and Schaeffer, 1975)
	4.34 ± 0.08	(Bogard et al., 1974)
	4.23 ± 0.04	(Huneke and Wasserburg, 1975)
	<4.08	(Huneke and Wasserburg, 1975)

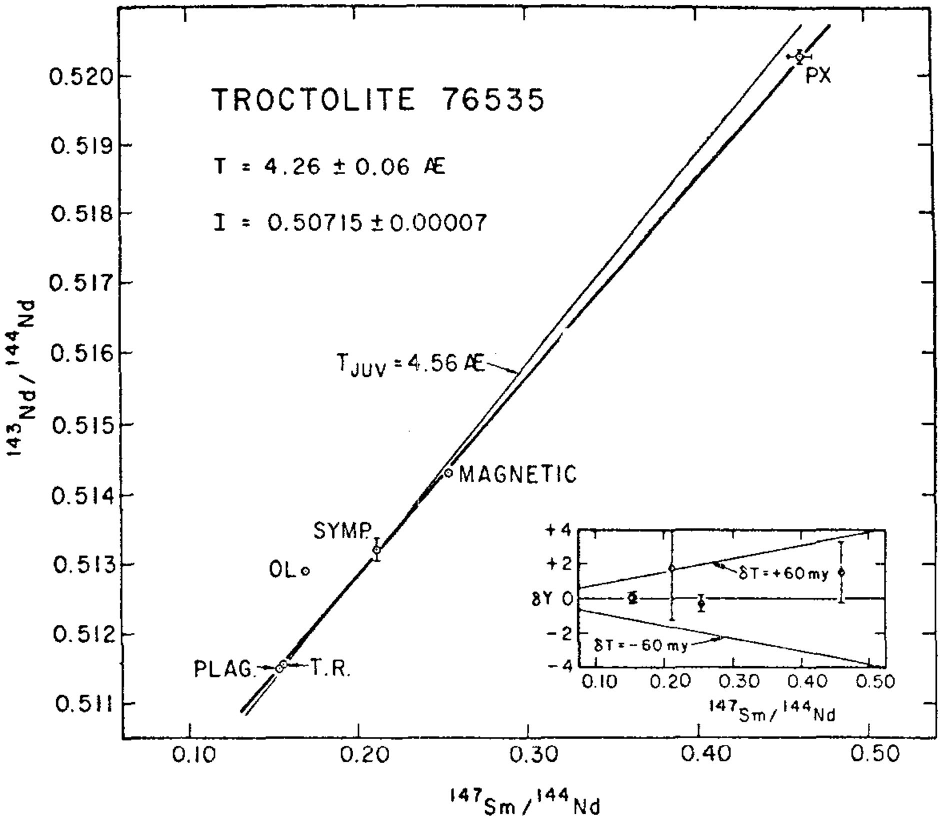


Figure 5. Sm-Nd isochron and evolution diagram for 76535. (From Lugmair et al., 1976)

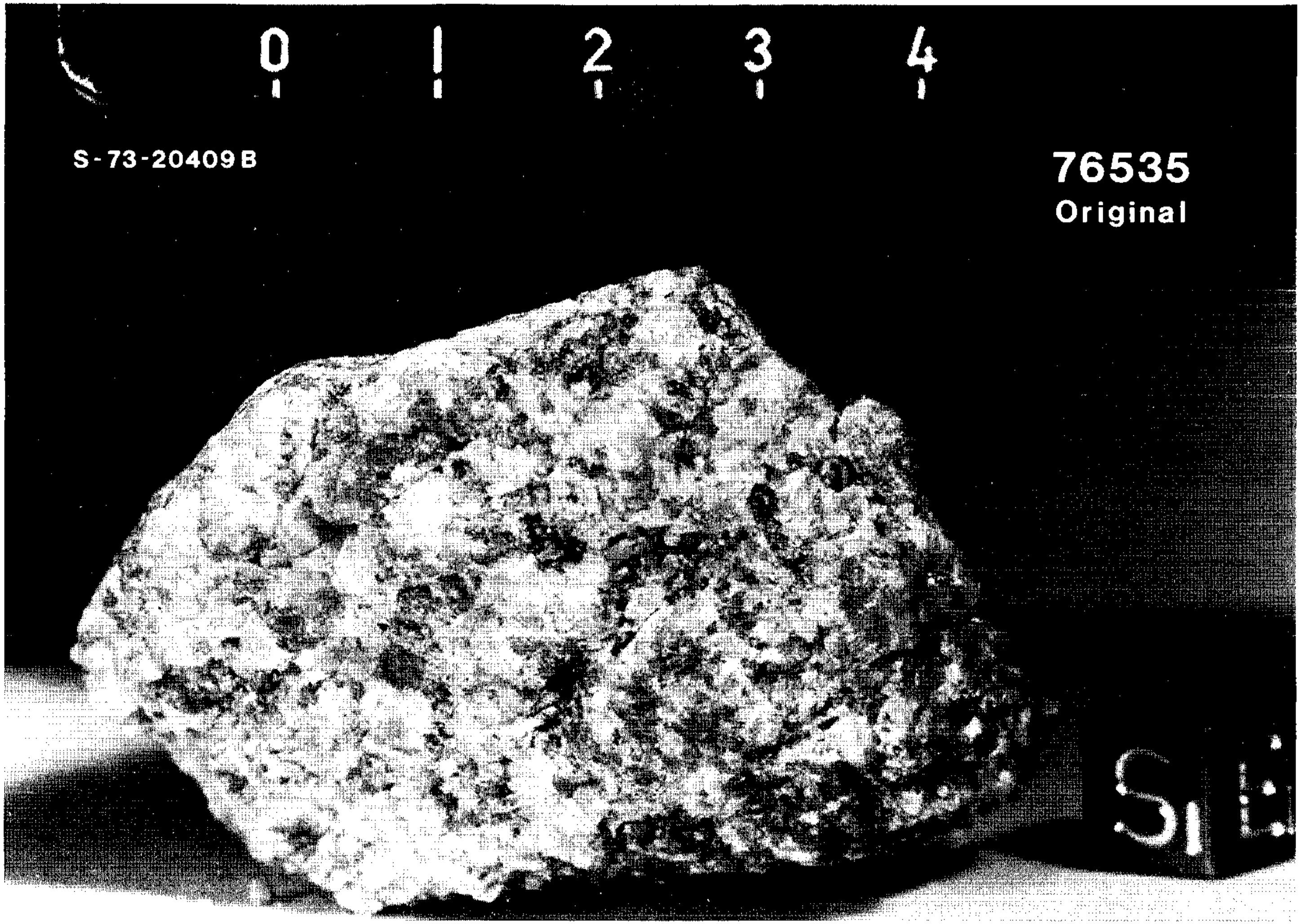


Figure 6.

76536 Troctolite 10.26 gm

Evidence for pristinity: The Ni content of 32 ppm (Blanchard, unpublished) (Table 1) is not high for a pristine troctolite and is lower than 76535 and dunite 72415. 76535 and 76536, from the same rake sample, were described together in the Apollo 17 Lunar Sample Information Catalog and clearly were presumed to be the same lithology. However, the REE abundance pattern for 76536 (Blanchard, unpublished) (Table 1) is 10x higher than 76535 and is roughly flat compared to KREEP, perhaps indicating contamination. Clearly the evidence for pristinity is conflicting.

Description: Macroscopically 76536 is similar to 76535 but is finer grained and granulated. Thin sections ,14 and ,15 show a severely brecciated, fairly porous troctolite (Figure 1) with conspicuous olivine rather less abundant than plagioclase. The largest grains are ∿1 mm. Fragments of symplectites visually identical to those in 76535 are present. Our preliminary mineral analyses show olivines are Fo_{83} and pyroxenes Wo_2En_{84}. This may indicate that 76536 is distinct from 76535.

A partial analysis by Blanchard (unpublished) is reproduced in Table 1. The analysis indicates elemental abundances similar to 76535 with the exception of the REEs.

Figure 1. Transmitted light photomicrograph of 76536,14. Width of view ∿2 mm.

Table 1

	,9		
FeO	5.07	La	11.0
Na_2O	0.249	Ce	31.9
		Sm	6.03
Co	25.6	Eu	0.745
Sc	2.42	Tb	1.13
Hf	1.04	Yb	2.67
Cr	1000	Lu	0.341
Ni	32		
Zn	12		
Ta	0.13		
Th	4.2		

Oxides in wt %, others in ppm.
From Blanchard (unpublished)

Table 2

Split	Parent	Location	Mass	Description and daughters
,0	,0	Ent. Subdivided	0.000	--
,1	,0	SSPL	6.500	Piece. ,8 -,11
,2	,0	SSPL	0.890	Chip
,3	,0	SSPL	0.605	Chip
,4	,0	SSPL	0.380	Chip and fines. ,16 ,18
,5	,0	SSPL	0.440	Chip
,6	,0	SSPL	0.369	Chip
,7	,0	SSPL	0.364	Chip
,8	,1	SSPL	0.090	Chip
,9	,1	Blanchard	0.080	Chip
,10	,1	RSPL	0.200	Potted butt. ,14 ,15
,11	,1	Attrition	0.085	--
,14	,10	SCC	0.010	TS
,15	,10	SCC	0.010	TS
,16	,4	Wasson	0.190	Chip
,17	,0	Reserve, TSL	0.000	--
,18	,4	Attrition	0.047	--

Apollo 17 Station 7 Boulder Norite Clast Samples

The Station 7 boulder contained a conspicuous 1.5x0.5 m white inclusion, which was cut by small dikes of matrix material. The white inclusion was friable and was sampled with the dikes as 77075, 77076, with very little dike material as 77077 and almost pure as 77215; the latter sample was extremely friable and broke up in transport from the Moon.

In general the norite contains about 55% plagioclase and about 45% greenish yellow pyroxene.

77075 Norite Clast ∿30 gm

Evidence for pristinity: Warren and Wasson (1978) analyzed the norite and found it to be free of meteoritic contamination (Table 1).

Description: 77075 norite is a brecciated white portion adhering to black aphanitic vein material. It is the same norite clast in the Station 7 boulder which is also represented by the white portions of 77076, 77077, and 77215.

Like the other fragments of the norite, that in 77075 is brecciated (Figure 1). Mineral analyses reported by Warren and Wasson (1978) (An_{90-92}, En_{65-70}, Wo_{4-5}, combined with data from 77077) are similar to the same phases in 77215.

A bulk analysis by Warren and Wasson (1978) reproduced here as Table 1 is similar to analyses of 77075 and 77215.

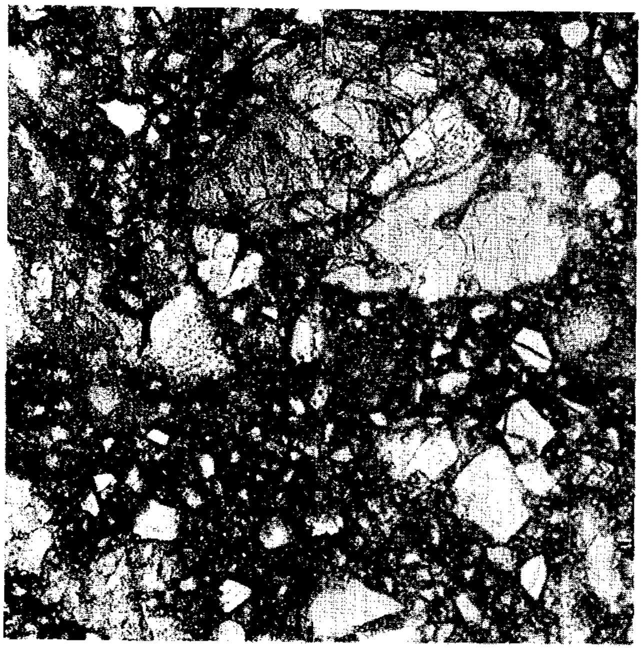


Figure 1. Transmitted light photomicrograph of 77075,12. Width of view ∿1 mm.

Table 1

	Split ,27				
SiO_2	51.2	50.9	Cd	5.4	5.4
Al_2O_3	15.0	14.0	In	<9	0.24
FeO	10.7	10.2	Hf	3.5	3.5
MgO	13.0	13.8	Ta	0.34	0.40
CaO	8.8	8.8	Re ppb	0.022	<0.0030
Na_2O	0.382	0.358	Ir ppb	0.25	
K_2O	0.18	0.16	Au ppb	0.026	0.088
Sc	16.6	16.5	Th	1.57	1.8
Ti %	0.20	0.21	U	0.5	0.58
Cr	2650	2810	Ba	160	158
Mn	1320	1370			
Co	33.0	25.9	La	7.2	8.3
Ni	6.1	<1.1	Ce	22	24
Zn	3.25	3.31	Nd	8.5	15
Ga	4.03	4.1	Sm	3.0	3.9
Ge ppb	10.9	16.8	Eu	0.98	1.01
Zr	210	170	Tb	0.74	0.92
			Yb	3.9	4.4
			Lu	0.59	0.68

Oxides in wt. %, others in ppm except as noted.
From Warren and Wasson (1978)

Table 2

Split	Parent	Location	Mass	Description and daughters containing norite
,1	,0	RSPL	0.720	Potted butt, 20% norite; ,2 ,11 ,12
,2	,1	Wasson	0.010	PM
,11	,1	Bence	0.010	TS; includes black aphanitic
,12	,1	SCC	0.010	TS; includes black aphanitic
,13	,0	SSPL	64.500	Mainly black aphanitic
,14	,0	SSPL	41.230	Mainly black aphanitic
,15	,0	SSPL	53.770	Mainly black aphanitic
,23	,0	SSPL	1.030	Includes black aphanitic
,24	,0	SSPL	1.160	Chips and fines, mainly black aphanitic; ,27
,27	,24	Wasson	0.500	Chip
,28	,16	SSPL	1.190	4 chips, includes black aphanitic

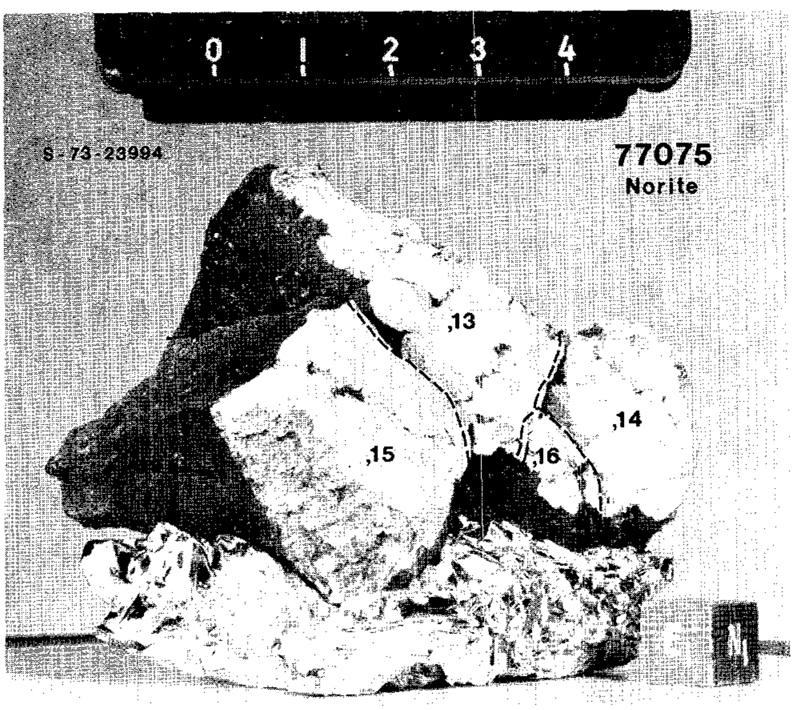


Figure 2. Primary subdivision of 77075 norite and matrix.

77076 Norite Clast ~3 gm

Evidence for pristinity: The 77076 norite is the same norite clast as 77075, 77076, and 77215, which have been analyzed (Warren and Wasson, 1978, Higuchi and Morgan, 1975) and found to be free of meteorite contamination. Macroscopically the 77076 norite is similar to these others. It has not been allocated or even split and is stored in B01.

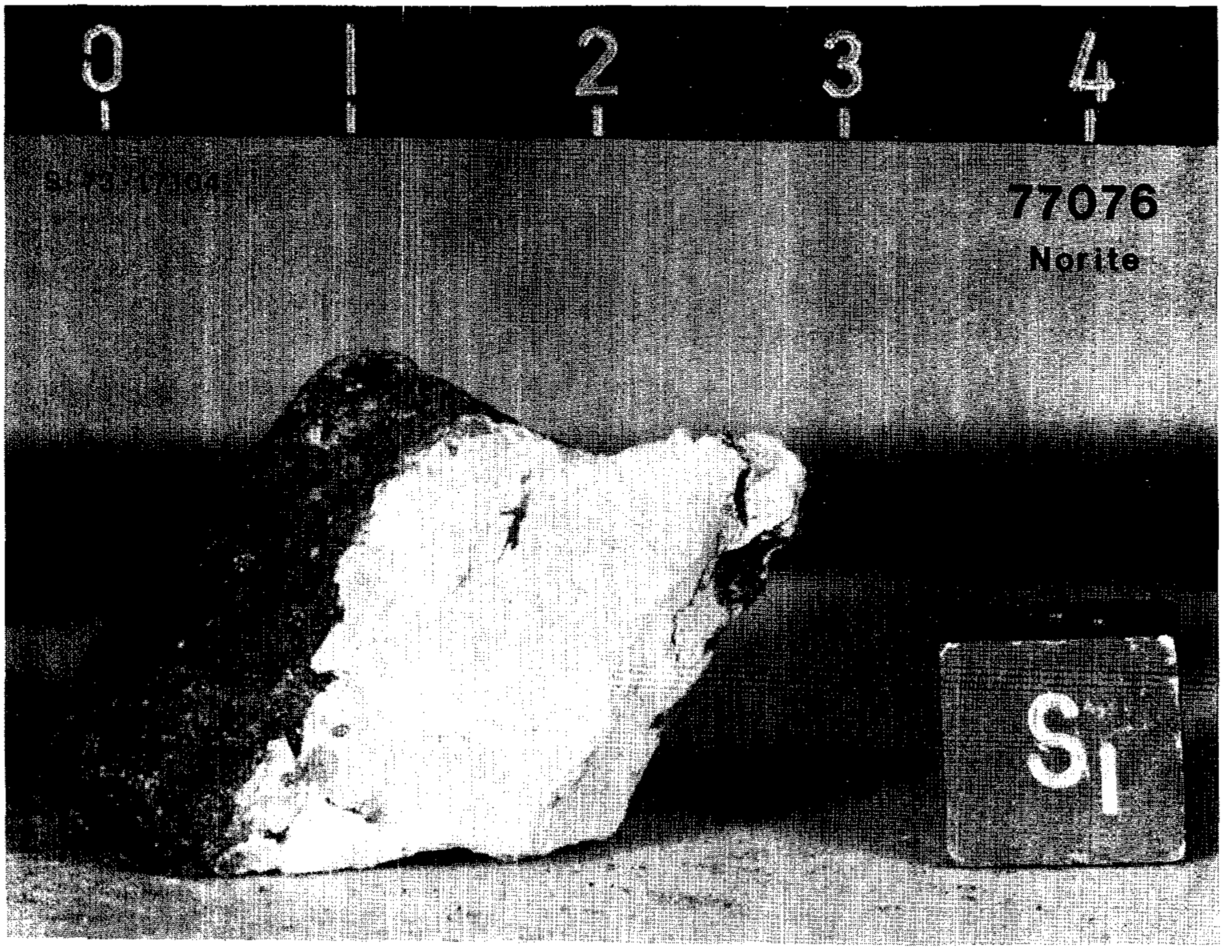


Figure 1. Sample 77076 as received.

77077 Norite 5.450 gm

Evidence for pristinity: Warren and Wasson (1978) analyzed a fragment and found no meteoritic contamination (Table 1).

Description: Except for some black aphanitic veins, 77077 is entirely norite. It is the same norite clast in the Station 7, Apollo 17 boulder which is also represented by the white portions 77075, 77076, and 77215.

77077 is brecciated (Figure 1). Warren and Wasson report plagioclase of An_{90-92} and orthopyroxene of En_{65-70} Wo_{4-5}, combining data for 77075 with 77077. These compositions are similar to those reported by Chao et al. (1976) for 77215.

A bulk analysis reported by Warren and Wasson (1978) reproduced here as Table 1 is similar to analyses of 77075 and 77215.

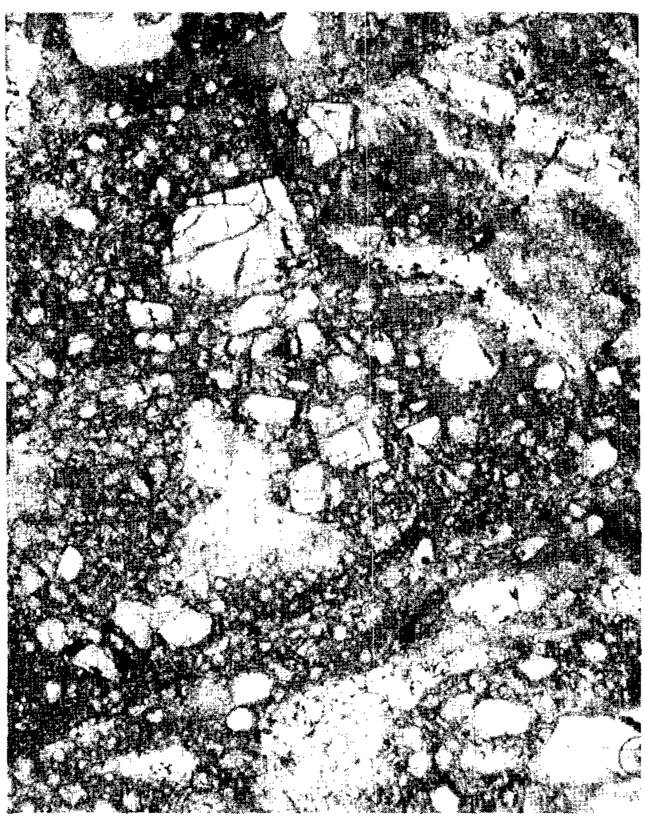


Figure 1. Transmitted light photomicrograph of 77077, 6. Width of view ∿1 mm.

Table 1

Split ,1

SiO_2	50.9	Cd	4.3
Al_2O_3	16.2	In	0.37
FeO	8.8	Hf	3.4
MgO	10.6	Ta	0.38
CaO	9.9	Re ppb	0.0027
Na_2O	0.439	Au ppb	0.056
K_2O	0.22		
		Th	2.0
Sc	13.8	U	0.59
Ti%	0.18	Ba	220.
Cr	2210.		
Mn	1130.	La	9.9
Co	25.2	Ce	25.
Ni	<1.7	Nd	16.
Zn	2.84	Sm	4.28
Ga	5.0	Eu	1.12
Ge ppb	18.7	Tb	1.0
Zr	150.	Yb	4.5
		Lu	0.67

Oxides in wt %, others in ppm except as noted.
From Warren and Wasson (1978).

Table 2

Split	Parent	Location	Mass	Description and daughters
,0	,0	B45	4.940	---
,1	,0	Wasson	0.200	4 chips
,2	,0	Entirely Subdivided	0.000	Was potted butt; ,4-,8
,3	,0	Attrition	0.080	---
,4	,2	SCC	0.010	TS
,5	,2	Wasson	0.01	TS
,6	,2	SCC	0.01	TS
,7	,2	SCC	0.01	TS
,8	,2	SCC	0.01	TS
,9	,2	Attrition	0.180	---

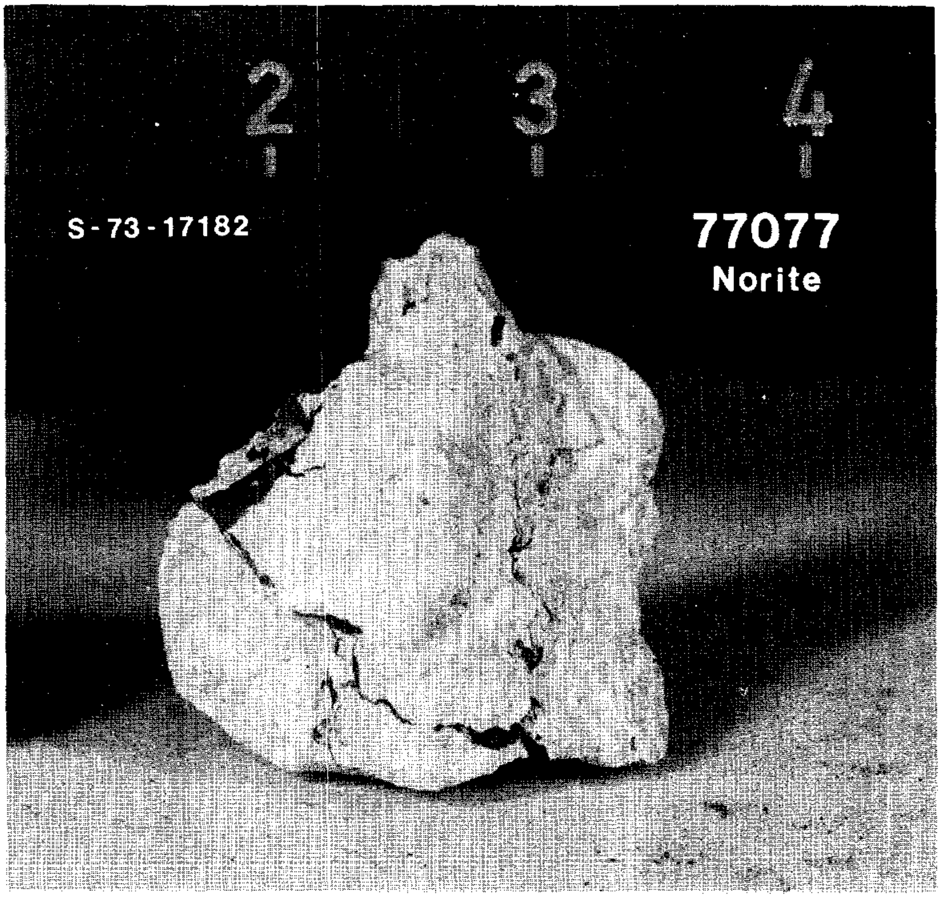


Figure 2. Sample 77077 as originally received.

77215 Norite ~800 gm

Evidence for pristinity: Higuchi and Morgan (1975) report 77215 to be free of meteoritic siderophiles. In addition age dates tend to cluster ~4.4 b.y. (Nakamura et al., 1976, Nunes et al., 1974a).

Description: Norite 77215 was taken from the Station 7 boulder and is the same norite as the white portions of 77075, 77076, and 77077. It is a friable, granulated, off-white breccia and is cut by dark gray-black veinlets. Fragments are predominantly mineral and lithic fragments of plagioclase and orthopyroxene although rare fragment-laden glass and olivine are also present (Chao et al., 1974). Winzer et al. (1977) thought the texture somewhat suggestive of a cumulate origin but the highly fractured nature of the clasts preclude a firm conclusion.

A petrographic study was made by Chao et al. (1974, 1976). The norite is highly brecciated (Figure 1). Plagioclase averages An_{90} and makes up ~54% of the rock. Orthopyroxene has a composition $Wo_{3-5}En_{65-68}$ (Figure 2) and makes up ~41% of the rock. Orthopyroxene is untwinned, ungrooved, and shows well developed exsolution augite (Chao et al., 1976, Huebner et al., 1975).

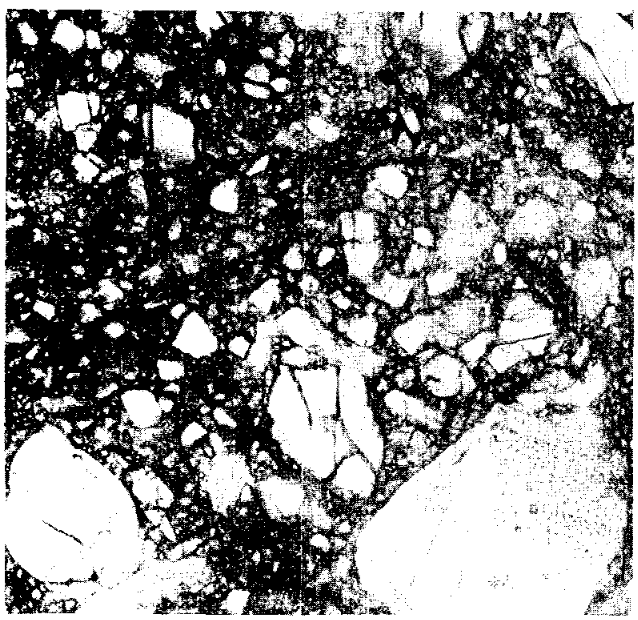


Figure 1. Transmitted light photomicrograph of 77215,14. Width of view ~1 mm.

A bulk chemical analysis of the norite was reported by Winzer et al. (1974) and Philpotts et al. (1974) and is reproduced here as Table 1 and Figure 3.

Age dates by various techniques tend to cluster ~4.4 b.y. Nakamura et al. (1976) report Rb-Sr (Figure 4) and Sm-Nd ages of 4.42±0.04 b.y. and 4.37±0.07 b.y. respectively. Nunes et al. (1974a) determined a Pb-Pb age of 4.49 b.y. The Ar-Ar age of 4.04 b.y. (Stettler et al., 1974) is significantly younger. Initial $^{87}Sr/^{86}Sr$ was determined to be 0.69889±0.00014 (Nakamura et al., 1976).

The norite has been substantially split and widely allocated.

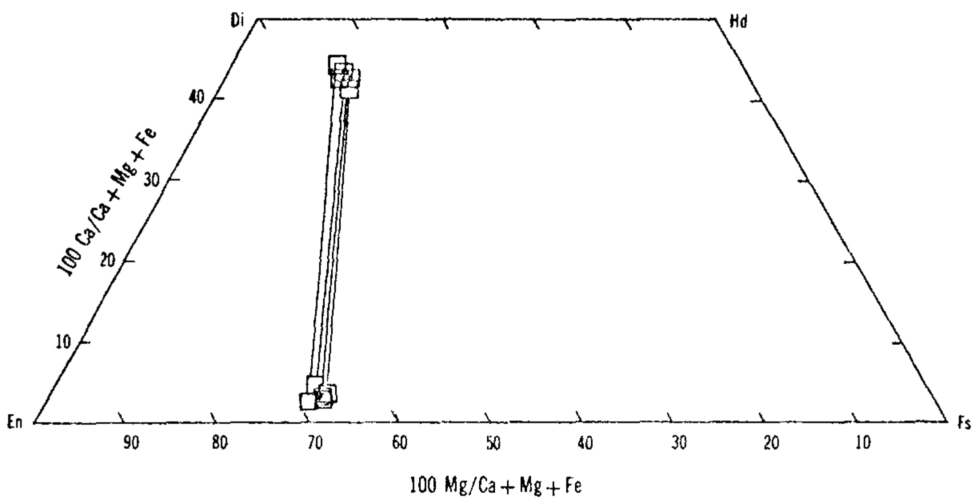


Figure 2. Compositions of coexisting orthopyroxene (host) - augite (exsolved) pairs in the 77215 norite. (From Huebner et al., 1975)

Table 1

SiO_2	51.3	Li	12.3
TiO_2	0.32	Rb	3.54
Al_2O_3	15.06	Sr	105.
FeO	10.07	Ba	166.
MnO	0.16	Zr	171.
MgO	12.56		
CaO	8.96	Ce	27.2
Na_2O	0.43	Nd	16.8
K_2O	0.14	Sm	4.68
Cr_2O_3	0.32	Eu	1.08
P_2O_5	0.11	Gd	6.64
	99.43	Dy	7.08
		Er	4.51
		Yb	4.98
		Lu	0.766

Oxides in wt %, others in ppm.
From Winzer et al., (1974)

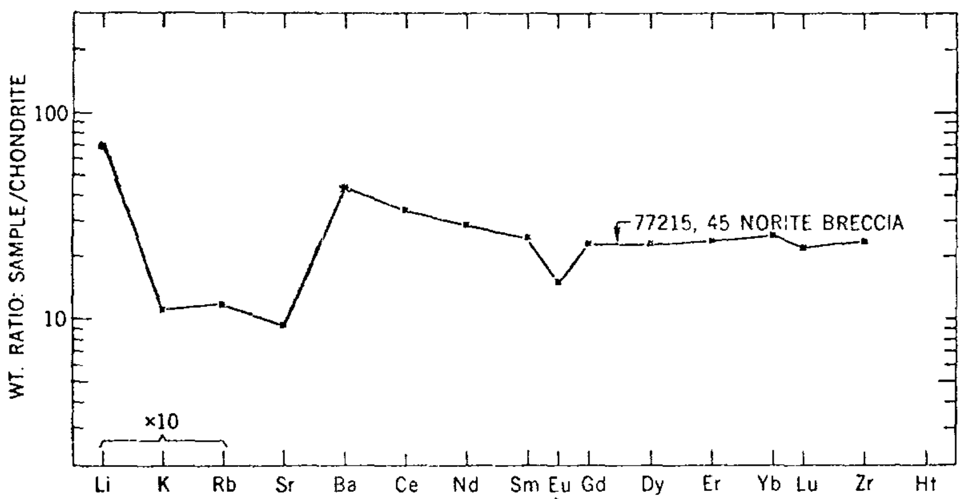


Figure 3. Incompatible trace element data for the 77215 norite. (From Philpotts et al., 1974)

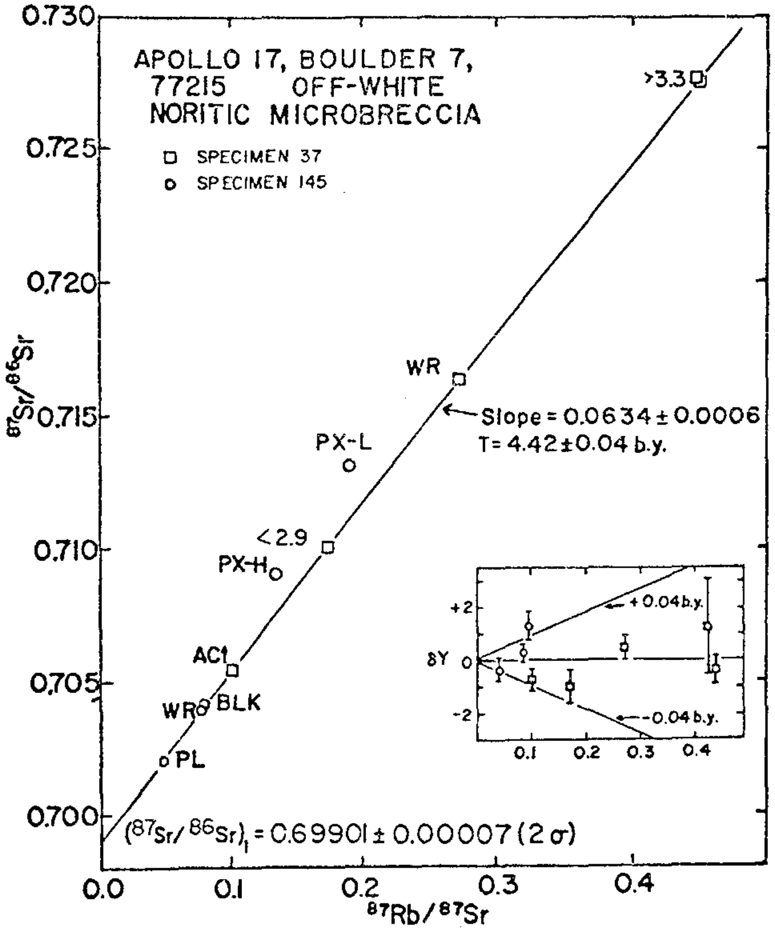


Figure 4. Rb-Sr isochron and evolution diagram for the 77215 norite. (From Nakamura *et al.*, 1976)

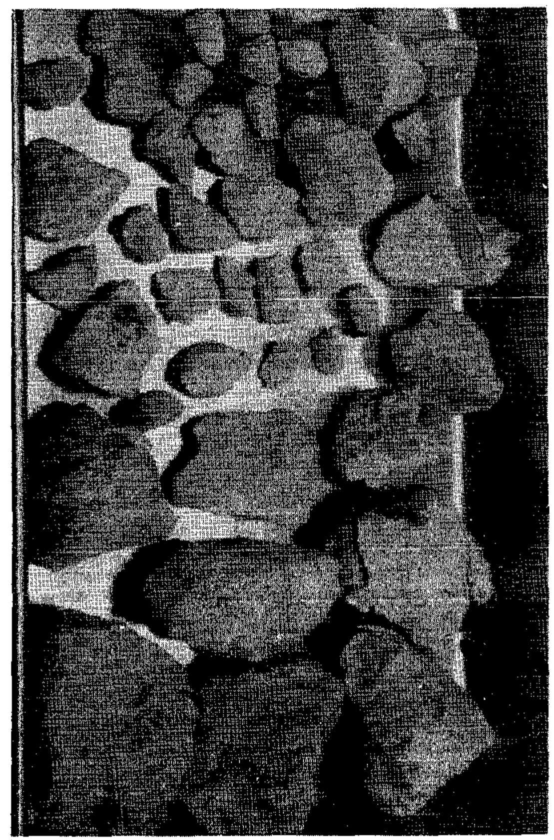


Figure 5. Sample 77215 as received from the Moon.

77115 Troctolite Clast ~0.6 gm (?)

Evidence for pristinity: The small clast has an unusual, mafic composition with a unique incompatible element pattern and high phosphorous (Winzer et al., 1974) and is thus unlikely to be a mixed rock. Winzer et al. (1974) note that it has a coarse grain size, and Stettler et al. (1975) report ^{40}Ar-^{39}Ar ages of 4.23 and 4.10 b.y. for plagioclase and olivine respectively, supporting a pristine origin.

Description: Macroscopically the clast consists of plagioclase and greenish-yellow olivine (?) several millimeters in diameter (Chao et al., 1974). The two thin sections show only the plagioclase, with dimensions greater than 2 mm (apart from matrix of 77115). No analyses are reported.

The unusual chemistry (Winzer et al., 1974) includes high REE abundances (100-300x chondrites, Table 1, Figure 1) but the pattern is enriched in light REEs compared to KREEP. The Niggli norm has ~60% olivine, ~40% plagioclase, and ~1% apatite. The Mg/Fe suggests olivine of ~Fo_{86-88}. The Ca contents of plagioclases (14%, Stettler et al., 1975) corresponds to An_{97-98}.

Apart from the "old" ages noted above, which are high-temperature release plateaus, Stettler et al. (1975) report an intermediate temperature release age of 3.96 b.y., equivalent to the age of the matrix.

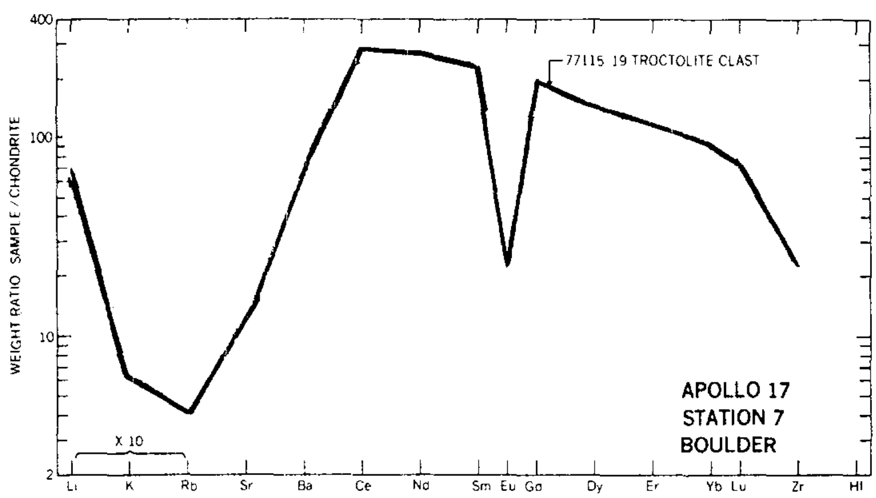


Figure 1. Incompatible trace element data for 77115 troctolite. (From Winzer et al., 1974)

Table 1

	Portion of ,19 (20.35 mg)		
SiO_2	41.8	Rb	1.24
TiO_2	0.17	Sr	134
Cr_2O_3	0.04	Ba	243
Al_2O_3	16.78	Zr	160
FeO	6.08		
MnO	0.06	Ce	226
MgO	23.54	Nd	155
CaO	10.24	Sm	42.2
Na_2O	0.31	Eu	1.68
K_2O	0.08	Gd	50.8
P_2O_5	0.53	Dy	44.2
		Er	21.6
Li	12.1	Yb	17.2
K	643	Lu	2.51

Oxides in wt %, others in ppm.
From Winzer _et al_. (1974)

Table 2

Split	Parent	Location	Mass	Description and daughters containing the troctolite
,17	,0	Ent. Subdivided	0.000	Was potted butt, mainly matrix. ,48 ,49
,19	,0	RSPL	0.494	Chip, only a trace of clast remains, returned by Nava. Air. ,71 ,74 ,75 ,77 ,84.
,48	,17	SCC	0.010	TS, includes matrix
,49	,17	SCC	0.010	TS, includes matrix
,71	,19	RSPL	0.074	4 separate vials returned by Nava. One vial is 0.0089 gm clast and chilled matrix. Air, crushed, hand-picked, saw contamination, aluminum can.
,74	,19	Anders	0.200	Chips, includes some matrix
,75	,19	Geiss	0.220	Chip, includes some matrix
,77	,19	Consumed, Nava	0.324	Includes matrix. Lithologies analyzed separately
,84	,19	RSPL	0.242	4 separate vials returned by Nava. One vial is 0.0005 gm v. fine troctolite. Air, physically separated, crushed, hand-picked

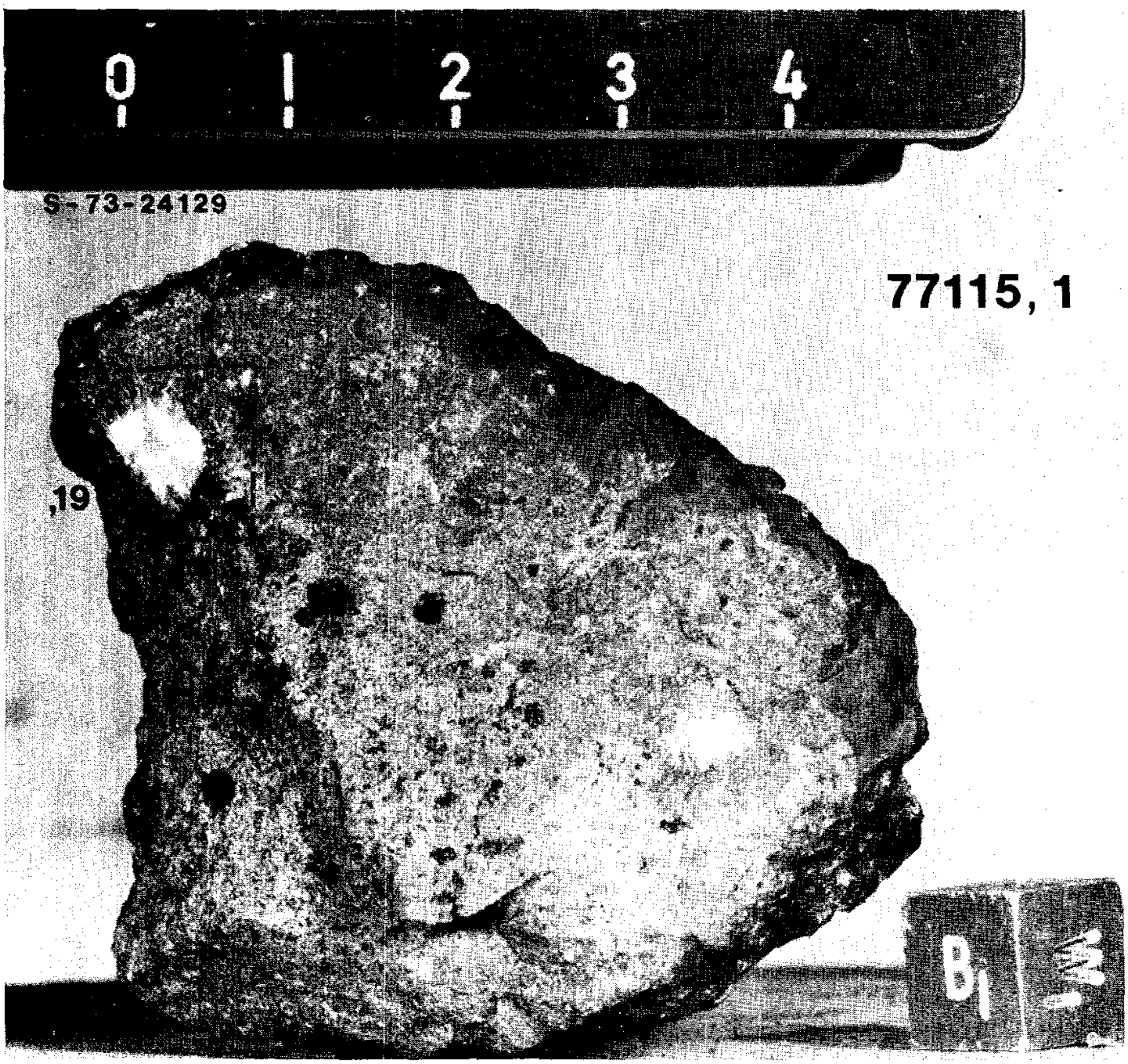
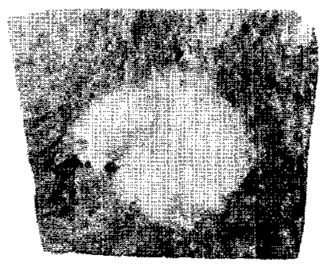


Figure 2. 77115,1, showing location of the troctolite clast in ,19. ,17 has already been removed.

77115, 19 Pre-chip



77115, 19 Post-chip

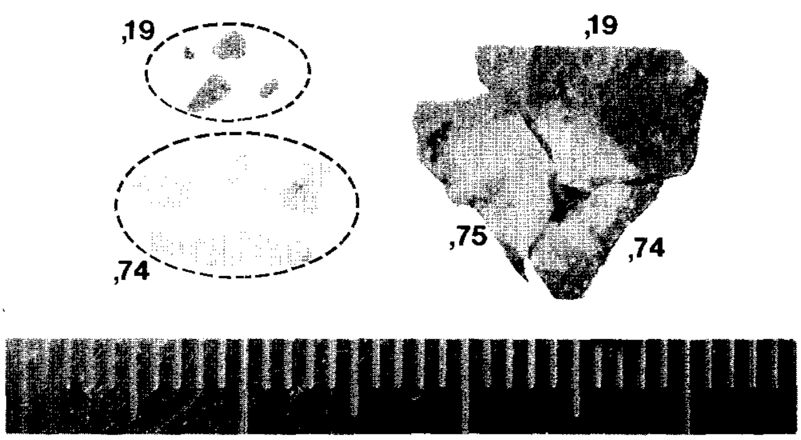


Figure 3. Initial splitting of ,19.

Apollo 17, Station 8 Boulder (Norite) Samples

A 30 x 55 x 55 cm boulder was sampled at Station 8 near the foot of the Sculptured Hills. Samples 78235, 78236, 78237, 78238 and 78255 were taken from it; 78235 and 78237 were found to fit together and so were combined as 78235. The samples and the boulder are all of essentially the same norite lithology. The boulder is glass-coated and even in lunar examination was obviously shattered.

The boulder is coarse-grained ($\sim$ 0.5 - 1.0 cm) with about 50% orthopyroxene and 50% plagioclase. The plagioclase is blue-gray, the pyroxene a yellow-tan. Distinct structural features such as foliations and fracture planes, as well as branching glass veins, are conspicuous features of the boulder and the samples taken from it (Jackson *et al.*, 1975).

No radiometric age has yet been established.

Figure 1. Location of samples from the Station 8 boulder.

78235 Norite 199.0 gm

Evidence for pristinity: Higuchi and Morgan (1975) analyzed a split and found it to be free of meteoritic contamination.

Description: Petrographic descriptions of the shocked sample (Figure 1) were given by Jackson et al. (1975), Dymek et al. (1975), McCallum and Mathez (1975), Winzer et al. (1975), Sclar and Bauer (1975) and Steele (1975). Plagioclase and pyroxene are approximately equal in abundance; phase compositions are given in Figure 2. Minor phases include silica, clinopyroxene, chromite, whitlockite, apatite, rutile, zircon, baddeleyite, metal, and troilite. Shock studies were made by Sclar and Bauer (1975, 1976).

A bulk chemical analysis by Winzer et al. (1975) is reproduced here as Table 1 and Figure 3. Mayeda et al. (1975) report typical lunar $\delta^{18}O$ (o/oo) values of 5.67 (plagioclase) and 5.41 (pyroxene).

Other references:

Simmons et al. (1975); microcracks.
Irving et al. (1974); norites in soils.
Keith et al. (1974); radionuclides by γ-rays.
Yokoyama et al. (1974); exposure ages.
Drozd et al. (1977); exposure ages.
Hewins and Goldstein (1975); metal compositions.
Sclar and Bauer (1976); subsolidus reduction.

Figure 1. Transmitted light photomicrograph of 78235,36. Width of field ~1 mm.

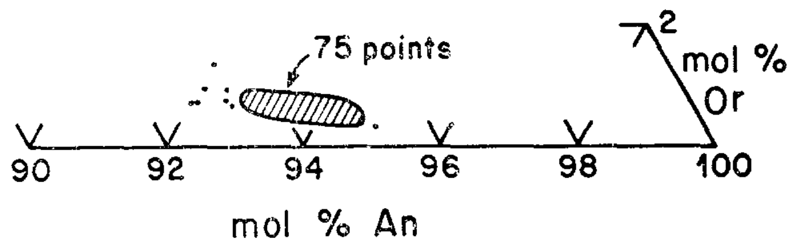


Figure 2a. Compositions of plagioclases in 78235 norite, including data from 78238. (From McCallum and Mathez, 1975)

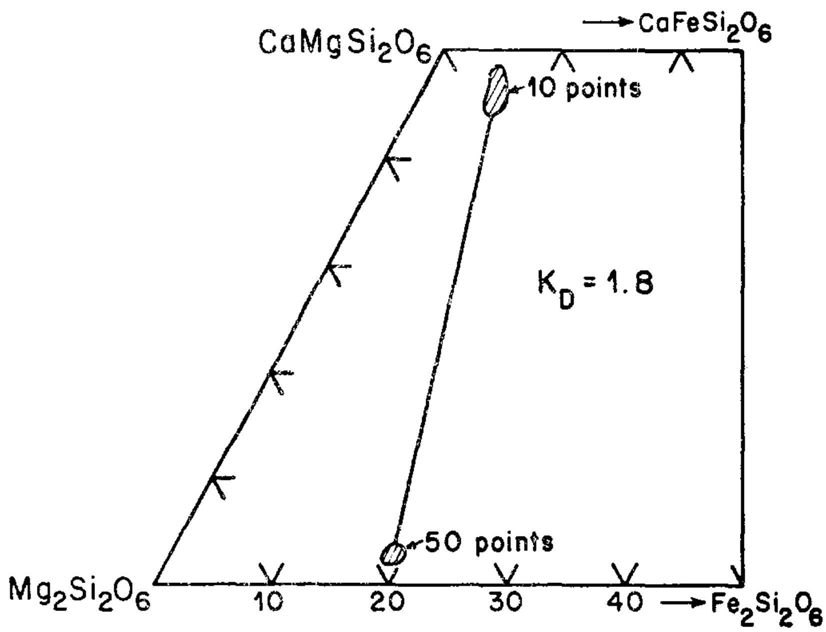


Figure 2b. Compositions of pyroxenes in 78235 norite, including data from 78238. (From McCallum and Mathez, 1975)

Table 1

	1)	2)
SiO_2	49.8	49.5
TiO_2	0.08	0.16
Al_2O_3	18.4	20.87
Cr_2O_3	0.31	0.23
FeO	6.02	5.05
MnO	0.10	0.08
MgO	14.5	11.76
CaO	10.5	11.71
Na_2O	0.30	0.35
K_2O	0.05	0.06
P_2O_5	--	0.04
Ce		9.16
Nd		5.40
Sm		1.49
Eu		1.03
Dy		2.26
Er		1.47
Yb		1.64
Lu		0.24

Oxides in wt %, all others ppm.
Col. 1 from Dymek *et al.* (1975)
Col. 2 from Winzer *et al.* (1975)

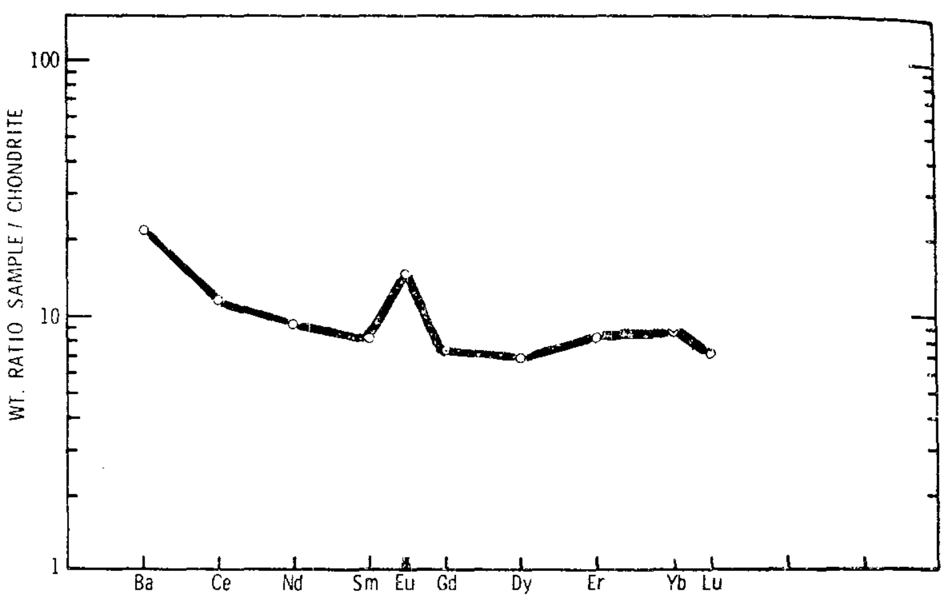


Figure 3. Incompatible elements in 78235 norite. (From Winzer *et al.*, 1975).

78236 Norite 93.06 gm

Evidence for pristinity: This is a portion of the same homogeneous boulder of a single lithology which was found to be meteorite-free in 78235 (Higuchi and Morgan, 1975) and 78255 (Warren and Wasson, 1978).

Description: Macroscopically the sample is similar to other samples of the boulder (Jackson *et al.*, 1975). No allocations have been made and it is stored in SSPL.

78238 Norite 57.58 gm

Evidence for pristinity: This is a portion of the same homogeneous boulder of a single lithology which was found to be meteorite-free in 78235 (Higuchi and Morgan, 1975) and 78255 (Warren and Wasson, 1978).

Description: Petrographic descriptions were given by Jackson *et al.* (1975) and McCallum and Mathez (1975). The sample is mineralogically similar to 78235. Metal data presented by Hewins and Goldstein (1975) virtually coincide with that given for 78235/8 by McCallum and Mathez (1975).

No other studies have been published.

Table 1

Split	Parent	Location	Mass	Description and daughters
,0	,0	SSPL	56.580	
,1	,0	RSPL	0.970	Potted butt. ,7 -,9
,7	,1	SCC	0.010	TS
,8	,1	SCC	0.010	TS
,9	,1	Goldstein	0.010	TS

78255 Norite 48.3 gm

Evidence for pristinity: Apart from its being part of the same boulder of single lithic type represented by meteorite-free sample 78235, Warren and Wasson (1978) found 78255 to be very low in meteoritic siderophiles, although 2x higher than their usual "meteorite-free" level.

Description: 78255 was taken from the end of the boulder opposite from the location of 78235, 78236 and 78238. Macroscopically it appears to have a slightly higher proportion of plagioclase than these latter samples. The thin sections are mainly glass and/or contain "fluidized" plagioclase and are too small to be useful in establishing a mode.

A bulk analysis by Warren and Wasson (1978) is given in Table 1 and Figure 1. This analysis (normatively ∿ 77% plagioclase) may be subject to sampling problems.

Other references:
Keith *et al.* (1974); radionuclides by γ-rays.

Table 1

SiO_2	47.29
TiO_2	< 0.01
Al_2O_3	27.41
Cr_2O_3	0.14
FeO	2.64
MnO	0.05
MgO	5.98
CaO	15.62
Na_2O	0.45
K_2O	0.08
La	3.3
Ce	7.8
Nd	5.0
Sm	1.20
Eu	1.21
Tb	0.23
Yb	0.98

Oxides in wt %, all others in ppm.
From Warren and Wasson (1978)

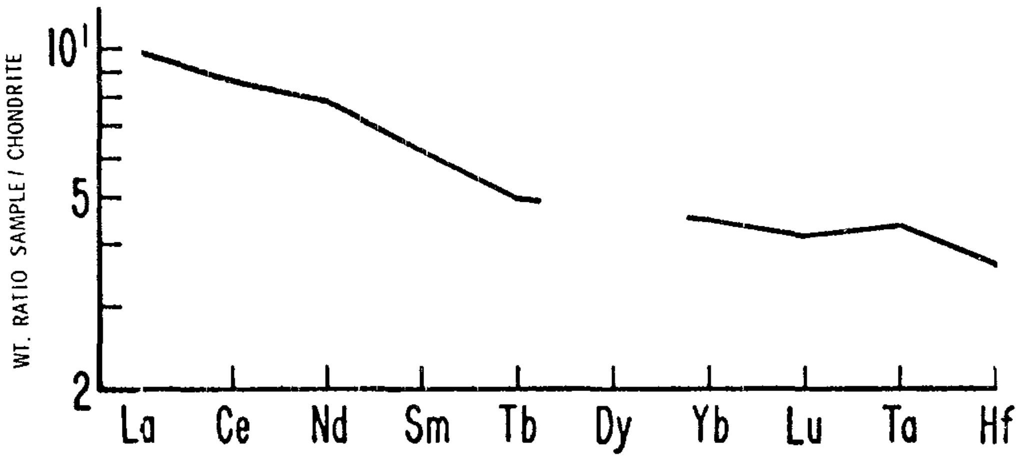


Figure 1. REE data for 78255. (From Warren and Wasson, 1978)

Table 2

Split	Parent	Location	Mass	Description and daughters
,0	,0	Ent. Subdivided	0.000	
,1	,0	BSV	31.010	,3
,2	,0	B45	11.570	,4 ,5 ,6 ,11
,3	,1	B01	0.190	
,4	,2	Wasson	0.520	Chip
,5	,2	RSPL	0.200	Potted butt. ,7 ,8 ,9
,6	,2	SSPL	4.480	Chips and fines, include glass
,7	,5	SCC	0.010	TS
,8	,5	Wasson	0.010	TS
,9	,5	SCC	0.010	TS
,10	,0	Reserve TSL	0.000	--
,11	,2	Attrition	0.310	--

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