79215

Metabreccia
553.8g, 9 x 8 x 7.5 cm

INTRODUCTION

79215 was described as a medium light gray, blocky (angular on fresh fractures, rounded on exposed surfaces) metabreccia, containing no fractures and with a microbrecciated fabric (Apollo 17 Lunar Sample Information Catalog, 1973). The original sample contained a truly fresh fracture on B, no cavities, but many zap pits on N, W, and T, with a few on E, S, and B (Fig. 1 a,b). The soil line was very distinct on 79215,0 and there was a thin veneer of dark glass in the rim of an arcuate fracture on T.

PETROGRAPHY AND MINERAL CHEMISTRY

The petrography of thin section 79215, 11 was reported by the Apollo 17 Lunar Sample Information Catalog (1973). It is a recrystallized anorthositic gabbro or troctolite (Fig. 2). A few poikilitic orthopyroxenes with small inclusions of euhedral to subhedral plagioclase occur interstitially in the groundmass. The recrystallized groundmass forms 85% of the rock and is composed of: 73% polyhedral plagioclase (0.3-0.8 mm); 26% euhedral olivine (0.1 mm); < 1% anhedral pyroxene (up to 1.3 mm); and < 1% globular to irregular opaques (0.05 mm). Plagioclase is predominantly in the form of polyhedra in a close-packed array. Small olivines outline the polyhedra and occur as inclusions in the plagioclase (Fig. 2). The sparse, tiny opaques are mainly metallic iron, but also traces of ilmenite

Figure 1: Hand specimen photograph of 79215,0.

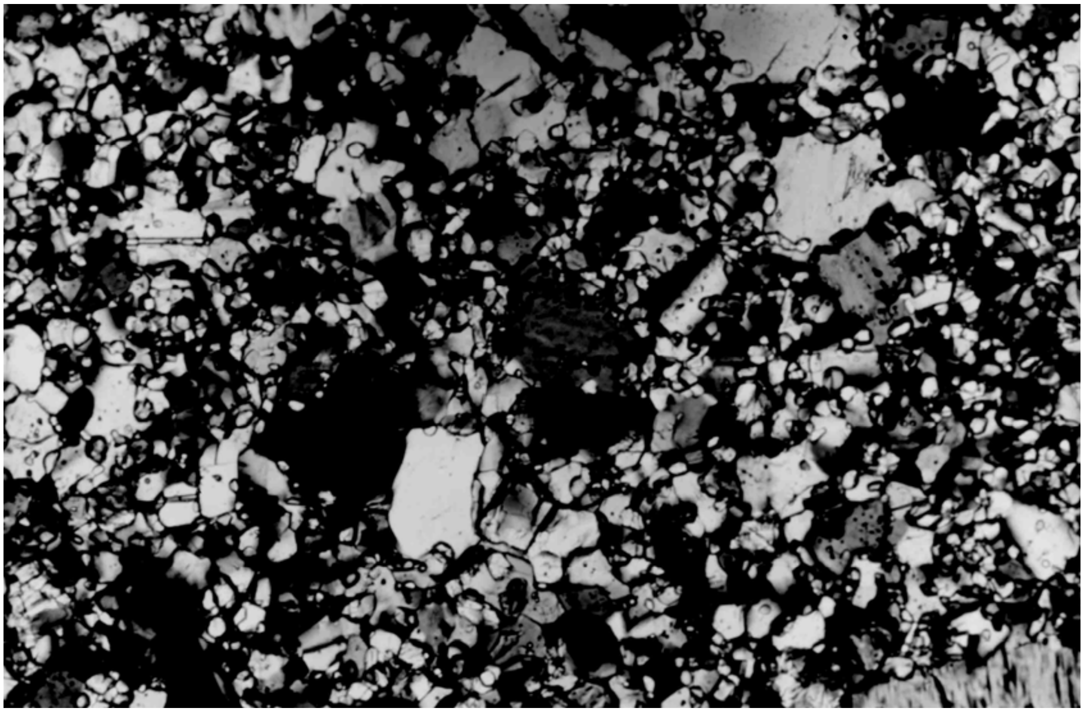

Figure 2: Photomicrograph of 79215. Field of view is 0.825 mm.

and troilite. Relict clasts make up the remaining 15% of 79215,11. These are anhedral mineral clasts of plagioclase (80%), pyroxene (15%, and olivine (5%). Plagioclase occurs sporadically throughout the groundmass as unshocked, twinned crystals. In some cases, these have been recrystallized to exhibit polyhedra free of olivine inclusions. A few large pyroxene grains, and 1 or 2 olivine grains also occur as relicts.

79215,11 contains three generations of plagioclase: relict clasts; 2) polyhedra; and inclusions in pyroxene. Two generations of pyroxene are present: 1) relict clasts; and interstitial grains. Two generations of olivine are present: 1) relict clasts; and 2) euhedral grains, One area is characterized by a concentration of opaques (ilmenite and magnesio-ilmenite) rimmed by a fan-shaped array of elongate plagioclase polyhedra. The opaques in 79215,11 were described by Brett in the Apollo 17 Lunar Sample Information Catalog (1973). The opaques are: < 0.5% armalcolite (up to 0.5 mm); < 0.3% ilmenite (< 0.03 mm); < 0.2% FeNi metal (< 0.02 mm); < 0.2% troilite (< 0.02 mm); and a trace of rutile (< 0.01 mm). The opaques occur in two textural types: 1) as polygons, blebs, and laths (in the case of ilmenite), which apparently are products of recrystallization; and 2) as ragged, round mineral clasts, which is exemplified by a 50011 grain of armalcolite rimmed by ilmenite. Armalcolite contains tiny laths of rutile or possibly ilmenite. Some grains contain ilmenite-armalcolite with subhedral boundaries.

Simonds et al. (1974) classified 79215 as a granulitic breccia, with a matrix feldspar grain size between 25-100u and a matrix mafic grain size between 10-30u, rarely reaching 100u. Stoffler et al. (1979) classified 79215 as a granoblastic, metamorphic matrix breccia. Bickel et al. (1976) devoted an entire paper to the petrography and mineral chemistry of 79215. This paper gives detailed descriptions of the petrography, modal mineralogy and mineral compositions (Fig. 3 a-d) of this sample. McGee et al. (1978) also gave a detailed report of the mineral chemistry and petrography of 79215, as well as the whole-rock chemistry.

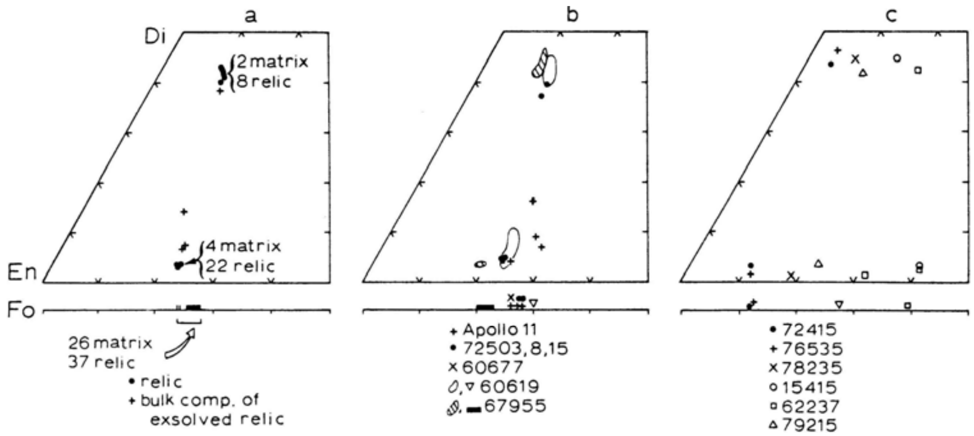

Figure 3a: Compositions of mafic silicates in some proposed primitive lunar samples. (a) 79215: The shaded pyroxene compositions include multiple analyses as indicated. (b) Lunar samples with textures similar to those of 79215. (c) Large plutonic and Apollonian metamorphosed plutonic rocks: dunite 72415 (Dymek et al. 1975), troctolite 76535 (Cooley et al., 1974), norite 78235 (Dymek et at., 1975), anorthosite 15415 (James, 1972), and troctolitic anorthosite 62237 (Dymek et al., 1975). 62237 contains two distinct low-Ca pyroxenes; the one richer is Fs is exsolved from pigeonite.

Haggerty et at. (1975) also reported the mineral chemistry of 79215, although he quoted only one analysis for each phase. Ryder et al. (1980) analyzed the FeNi metal in 79215 and found it to lie just above the meteorite field defined by Goldstein and Yakowitz (1971), similar to the results of Bickel et al. (1976) and McGee et al. (1978). Hansen et al. (1980) analyzed olivine in 79215,62 for minor and trace elements. These authors reported the concentrations of TiO_2 (350 ppm), Cr_2O_3 (430 ppm), P_2O_5 (70 ppm), MnO (2580 ppm), and CaO (710 ppm) in an olivine of Fa27 and containing 24.6 wt% FeO. Smith et al. (1980) reported the range of olivine minor element concentrations,

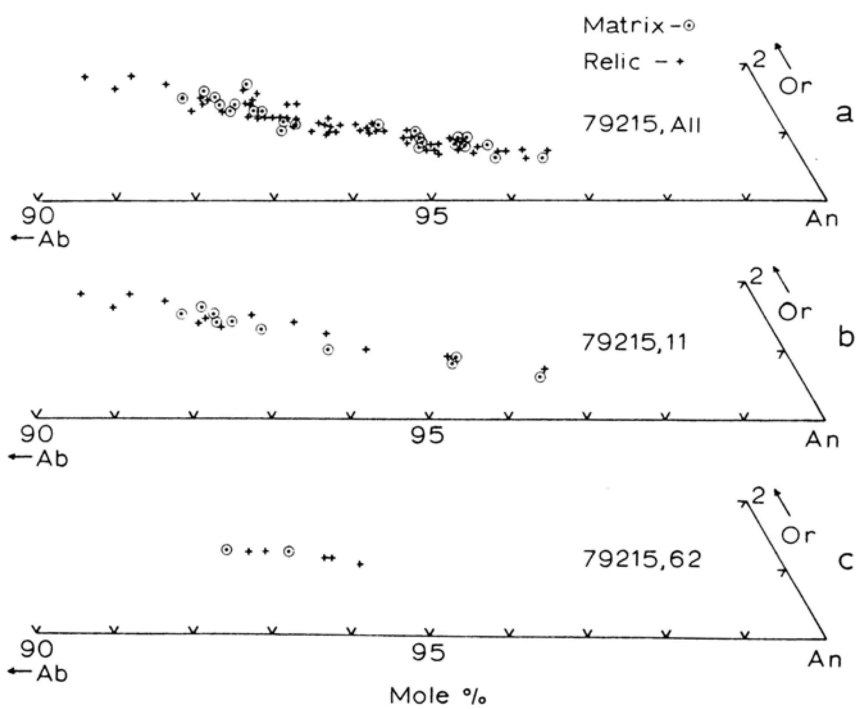

Figure 3b: Compositions of anorthite from 79215. (a) Anorthite from. 79215,11 ,51 60,62 ,65 ,67. (b) The entire compositional range of a is found in section, 79215,11. (c) 79215,62 has very limited ranges of lagioclase compositions. Taken from Bickel et al. (1976).

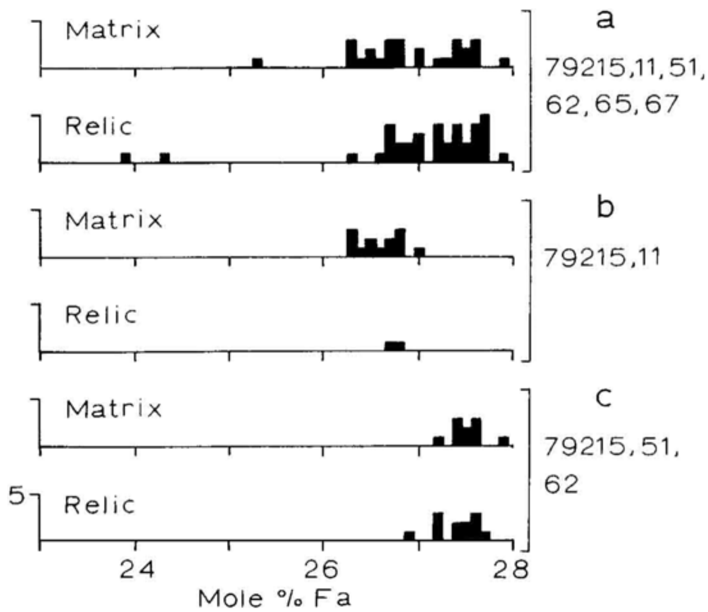

Figure 3c: Compositions of olivine from 79215. The analyses of (a) with Fa <25 are from the ilmenite -rich relict (lithic clast?) in 79215,67 and are associated with abundant ilmenite and Cr-spinel. The analysis with Fa=25.3 is from the matric of 79215,67, about 60 ym from a 125 pm grain of Fe-Ni-Co metal. B and e illustrate that there are slight regional variations of the olivine compositions. Relict olivines have the same compositions as olivines in the associated matrix. Taken from Bickel et al. (1976).

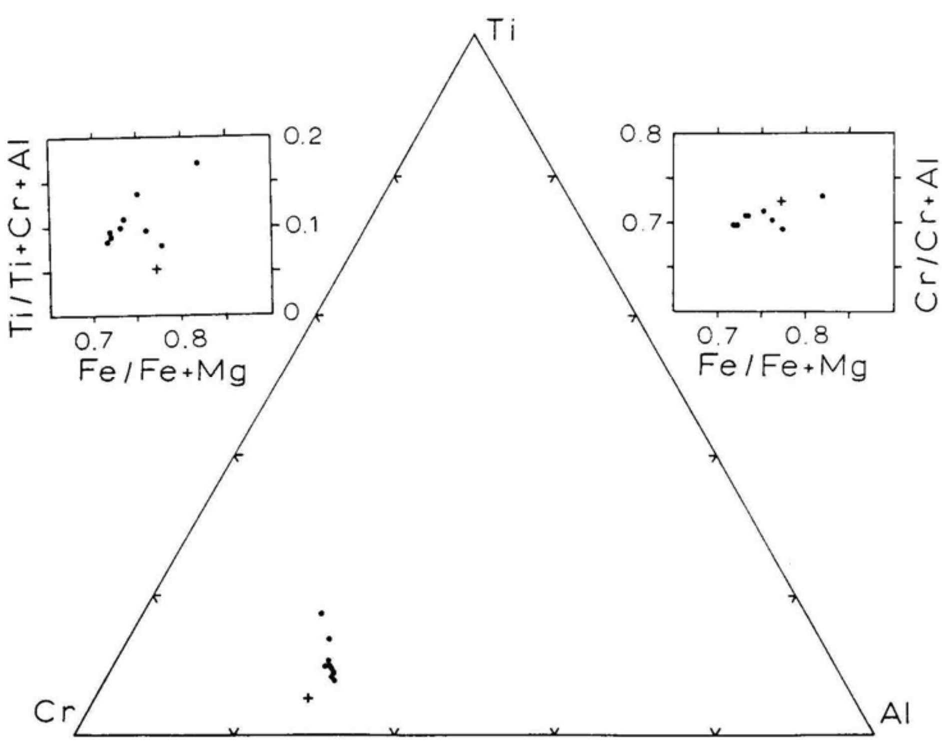

Figure 3d: Compositions of Cr-spinels represented in three projections (atomic proportions). Cr-spinel from the ilmenite-rich fragment (lithic clast?) is distinguished with a"+". The compositional trend indicated by the remaining analyses does not maintain a constant ratio Crl(C·- + Al) and therefore cannot be a function only of progressive reduction of ulvospinel. Taken from Bickel et al. (1976).

the averages of which are in H ansen et al. (1980). Steele et al. (1980) reported the minor element concentration in plagioclase from 79215. The reported concentrations are: Li = 11 ppm; Na = 6.1 mol%; Mg = 465 ppm; K = 1580 ppm; Ti = 260 ppm; Sr = 220 ppm; and Ba = 290 ppm.

WHOLE-ROCK CHEMISTRY

The most complete whole-rock study of 79215 was by Blanchard et al. (1977) who reported six major and trace element analyses of 79215 (Table 1). The modal reconstruction of McGee et al. (1978) compares well with the major element analyses of Blanchard et al. (1977) (Table 1); the MG# of McGee et al. (1978) is 72.3 and the range of MG#'s reported by Blanchard et al. (1977)is 70-76.

One sample reported by Blanchard et al. (1977) (21,1) is considerably more mafic than the other five (FeO = 18.2 and MgO = 24.2). Higuchi and Morgan (1975) analyzed three sample of 79215 for siderophile elements (Table 1).

The REE abundances for 79215 reported by Blanchard et al. (1977) have been normalized to chondrites and are presented in Fig. 4. The LREE range from 2.5 to 11 x chondrites, whereas the HREE range from 3-7 x chondrites. All profiles are LREE-enriched with a positive Eu anomaly [$(Eu/Eu^*)_N$ = 1.5-2.81. Four samples exhibit enrichment of the HREE over the middle REE (Fig, 4), probably due to increased pyroxene contents in the whole-rock sample.

RADIOGENIC ISOTOPES

Murthy (1978) reported Rb-Sr analysis of plagioclase from 79215 (Table 2) in a study of the initial lunar 87Sr/86Sr ratio_ Oberli et al. (1979) reported the U-Th-Pb isotopic concentrations (in picomoles) of 79215,91 (Table 2). McGee et al. (1978) analyzed 79215 for the Ar isotopes using thermal release and laser methods (Table 3). The Ar work of McGee et al. (1978) yielded an age of ~3.9-4.0 Ga for 79215.

EXPOSURE AGES AND COSMOGENIC RADIONUCLIDES

The exposure age of 79215 has been determined using ^{26}A1 activity, Ne, and Ar isotopes. Bhandari et al. (1976) and

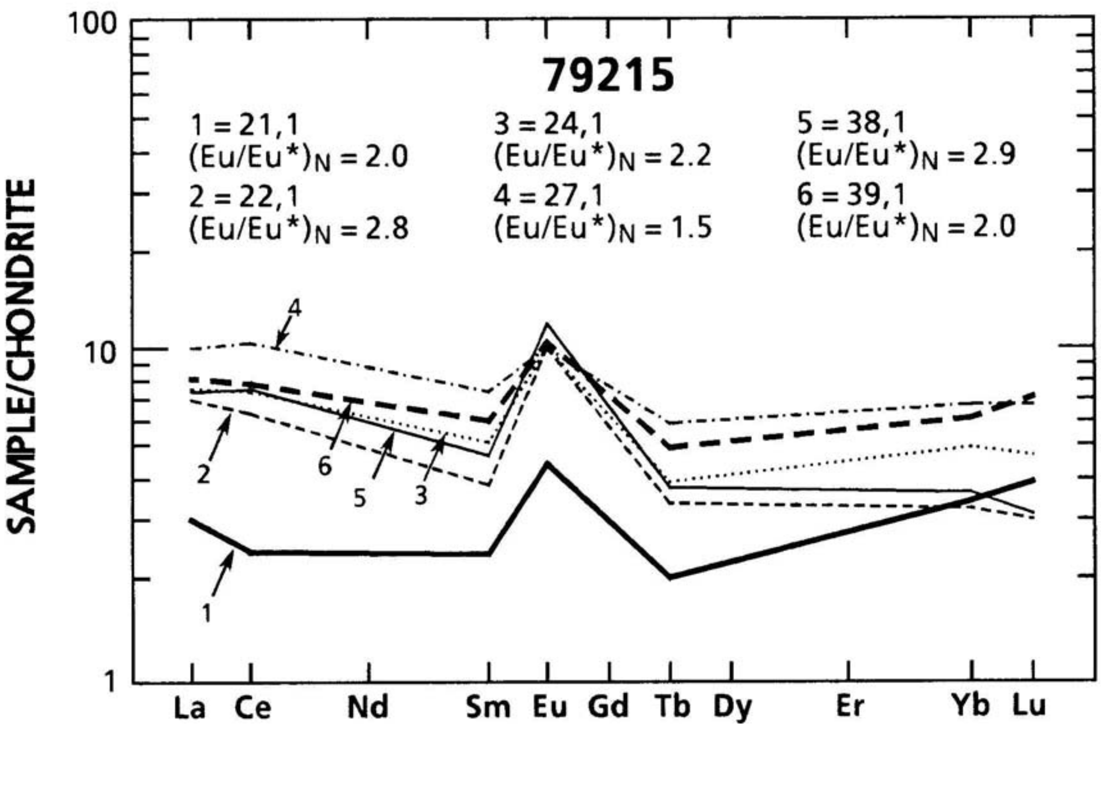

Figure 4: Chondrite -normalized rare earth element profiles of 79215, from Blanchard et al. (1977).

Bhandari (1977) reported a ^{26}A1 exposure age between 2.3 and 3.7 Ma. Venkatesan et al. (1982) reported a Ne exposure age of 3.7 Ma. However, McGee et al. (1978) reported an Ar exposure age of 170 ± 10 Ma.

Bhandari et al. (1976) analyzed 79215 for 26A1 at a variety of depths. These authors reported ^{26}A1 concentrations of 735 ± 110 dpm kg-^{1} between 0-0.1 g cm-^{2}, & 430 ± 55 dpm kg-^{1} between a depth of 1.5-1.6 g cm-^{2}. Nautiyal et al. (1978) reported the Ar and Ne isotopic ratios and cosmogenic abundances in 79215 (Table 4), and Venkatesan et al. (1982) reported the Xe isotopic ratios (Table 4).

EXPERIMENTAL STUDIES

79215 was used to test an olivine-ilmenite thermometer developed by Anderson and Lindsley (1979). If the calibration is correct, then 79215 equilibrated at a temperature of 660°C, for an olivine composition of $_{Fa13A}$ and an ilmenite composition of ^{11}62.5•

PROCESSING

The original sample 79215,0 has been entirely subdivided, as has sub-sample ,1. The largest remaining sub-samples are: ,2 (~330g);,3 (~80g); and,6 (~23g). Twenty six thin sections have been made: 79215,11; ,50-,65; ,67-,74; and,76.

Table 1: Whole-rock compositions of 79215.

Sample Method Reference	 Mod. 1	21,1 N 2	22,1 N 2	24,1 N 2	27,1 N 2	38,1 N 2	39,1 N 2	,0 G-Ray 3	,26 R 4	,28 R 4	,34 R 4	 5
SiO_2 (wt%)	43.4	39.4	43.2	44.8	43.5	44.4	44.8					43.8
TiO_2	0.13	0.3	0.3	0.3	0.4	0.3	0.5					0.3
Al_2O_3	28.5	10.4	25.8	27.6	26.7	27.9	27.4					27.7
Cr_2O_3	0.07	0.238	0.069	0.098	0.115	0.541	0.108					0.2
FeO	4.3	18.2	4.96	4.15	4.91	3.40	4.86					4.6
MnO	0.04	0.170	0.058	0.054	0.063	0.045	0.064					0.06
MgO	6.3	24.2	8.51	5.84	7.33	6.18	7.40					6.3
CaO	15.9	6.17	15.6	16.3	15.6	16.0	14.4					15.9
Na_2O	0.38	0.222	0.616	0.549	0.557	0.616	0.580					0.5
K_2O	0.09	0.034	0.110	0.107	0.113	0.128	0.119	0.113				0.1
P_2O_5	0.17											0.4
S	0.02											
Nb (ppm)												
Zr												
Hf		0.6	0.56	1.34	1.1	0.45	1.2					
Ta					0.14							
U								0.03	0.043	0.19	0.56	
Th		0.46	0.53	0.21	0.37	0.50	0.32	0.88				
W												
Y												
Sr												
Rb									0.465	0.489	0.187	
Li												
Ba												
Cs									0.037	0.048	0.048	
Be												
Zn									1.6	2.3	6.6	
Pb												
Cu												
Ni		680	152	215	110		126		221	225	16	
Cr												
Co		71.2	17.6	18.8	16.6	7.3	18.9					
V												
Sc		7.07	4.60	7.14	7.69	5.53	8.14					
La		1.01	2.33	2.5	3.3	2.45	2.65					
Ce		2.2	5.5	6.5	9.1	6.6	6.8					
Nd												
Sm		0.481	0.768	1.03	1.53	0.96	1.19					
Eu		0.35	0.77	0.77	0.77	0.94	0.84					
Gd												
Tb		0.12	0.20	0.23	0.34	0.22	0.28					

Table 1: (Concluded).

Sample Method Reference	Mod. 1	21,1 N 2	22,1 N 2	24,1 N 2	27,1 N 2	38,1 N 2	39,1 N 2	,0 G-Ray 3	,26 R 4	,28 R 4	,34 R 4	 5
Dy												
Er												
Yb		0.78	0.72	1.07	1.5	0.79	1.37					
Lu		0.132	0.106	0.16	0.23	0.108	0.24					
Ga												
F												
Cl												
C												
N												
H												
He												
Tl (ppb)									0.084	0.41	0.48	
Ge									39	33	36	
Re									0.495	1.90	2.10	
Ir									6.95	21.3	28.8	
Au									1.67	8.27	15.0	
Cd									1.04	0.98	1.98	
Sb									1.30	2.79	6.36	
Bi									0.30	0.16	0.30	
Se									34	176	424	
Ag									0.71	1.16	3.37	
Te									1.7	17.0	30.1	
Br									4.8	6.9	79.7	

X = XRF; N = INAA: R = RNAA; G-Ray = Gamma Ray Spectrometry; Mod. = Modal Reconstruction

References: 1 = McGee et al. (1978); 2 = Blanchard et al. (1977); 3 = Fruchter et al. (1975); 4 = Higudi and Morgan (1975); 5 = Bickel et al. (1976).

Table 2: Radiogenic isotope ratios from 79215.

Reference Sample no.	1 79215	2 79215,91
$^{87}Sr/^{86}Sr_{Meas}$	0.69936 ± 7	
$^{87}Sr/^{86}Sr_{Init.}$	0.69889 ± 7	
E_{BABI}	-1.3 ± 1.0	
Wt (mg)		90.3
$^{208}Pb^*$(Picomoles)		146.06
$^{207}Pb^*$(Picomoles)		117.63
$^{206}Pb^*$(Picomoles)		209.20
$^{204}Pb^*$(Picomoles)		0.1413
Alpha[a]		1358
$^{204}Pb^@$(Picomoles)		0.0129
$^{238}U^*$(Picomoles)		214.1
$^{232}Th^*$(Picomoles)		559.0

* = Corrected for blank; a = Corrected for spike cross contamination only.

References: 1 = Murthy (1978); 2 = Oberli et al. (1979).

Table 3: Isotopic Ar results for ^{39}Ar-^{40}Ar thermal release study from 79215 (McGee et al., 1978).

Temp. °C	$^{36}Ar/^{38}Ar^{a}$	$^{38}Ar/^{37}Ar$	$^{39}Ar/^{37}Ar$	$^{40}Ar^{*}/^{39}Ar^{*b}$	$^{39}Ar \times 10^{-8}$Exp. ccSTP/g	Age (Ma)	Age (Ga)
79215,45:6927 (14.5 mg)							
500	0.369±44	0.01454±15	0.0148±12	179.8±12	0.27±12		5.450±3.1
550	0.323±58	0.01660±33	0.0123±8.8	76.5±8.6	0.20±8.5		3.975±3.0
600	0.730±50	0.00642±34	0.0106±10	110.6±9.0	0.32±8.9	133±40	4.598±2.7
650	1.114±50	0.00525±18	0.0151±7.9	82.3±7.6	0.78±7.5	100±27	4.096±2.5
700	0.592±21	0.00570±6.6	0.395±2.8	29.9±1.9	3.47±1.8		2.533±1.0
750	0.725±13	0.00761±2.5	0.0142±4.3	87.1±4.2	2.16±4.1	158±6.6	4.192±1.4
800	0.586±7.3	0.00745±2.8	0.0158±1.2	79.6±1.2	4.92±1.2		4.041±0.4
850	0.653±4.2	0.00761±3.8	0.157±1.3	80.4±1.1	8.92±1.1	160±7.0	4.057±0.4
900	0.630±8.8	0.00825±3.6	0.0165±1.9	77.9±1.8	10.99±1.8	174±7.0	4.005±0.6
950	0.633±5.4	0.00809±3.7	0.0160±1.7	78.3±1.0	16.59±1.0	171±6.9	4.014±0.3
1000	0.643±3.2	0.00790±1.7	0.0156±1.4	78.4±0.8	13.68±0.8	166±5.9	4.017±0.3
1050	0.613±3.5	0.00842±2.0	0.0158±0.8	78.7±0.8	12.46±0.8		4.023±0.3
1100	0.615±13	0.00827±12	0.0157±3.1	78.8±2.0	5.04±2.0		4.023±0.7
1150	0.676±6.2	0.00901±5.0	0.131±5.3	91.8±4.3	2.02±4.3	189±7.9	4.280±1.4
1250	0.489±14	0.01095±11	0.0140±12	62.7±12	1.94±11		3.649±4.5
1400	1.040±28	0.00741±28	0.0030±10	82.7±11	0.90±10	143±35	4.105±3.8
1750	4.763±120	0.0197±72	0.0100±23	188.5±23	0.62±23	5±990	5.534±5.9

a = All errors are relative errors in percent; b = ^{40}Ar from the decay of ^{40}K only.

Laser released Ar isotopes from various minerals of breccia 79215 in 10^{-12} cm^3 STP@.

Phase	^{40}Ar	$^{39}Ar^{*}$	$^{38}Ar^{*}$	^{37}Ar	$^{36}Ar^{*}$	$^{40}Ar_K/^{39}Ar_K$	Age (Ga)
Matrix[a]	30.0±1.3[b]	0.32±0.03	1.54±1.54[c]	8.94±8.94	3.70±3.70[c]	90.2±11.7	4.19±0.17
Plagioclase	74.9±2.5	1.02±0.08	1.53±1.53	27.9±7.8	1.11±1.11	73.2±6.4	3.86±0.12
Matrix	198.2±2.4	2.71±0.12	1.51±1.51	37.6±8.0	4.07±4.07	72.5±3.5	3.84±0.07
Plagioclase	113.0±3.5	1.36±0.08	2.68±2.68	22.8±22.8	4.81±4.81	81.9±5.8	4.04±0.10
Olivine	53.6±1.6	0.79±0.05	1.15±1.15	22.8±22.8	4.62±4.62	65.4±6.4	3.68±0.13
Matrix	156.2±5.6	2.02±0.11	2.29±2.29	30.8±9.5	3.70±3.70	76.6±5.1	3.93±0.09
Plagioclase	170.2±9.4	2.21±0.14	1.13±1.13	64.0±7.1	1.10±1.10	76.9±6.4	3.94±0.11
Olivine	66.4±3.3	0.88±0.08	3.07±3.07	15.1±15.1	4.07±4.07	73.6±7.7	3.87±0.14

@ = The exact amount of material melted by the laser pulses cannot be determined. The data can (within a factor of approximately 5) also be understood in units of 10^{-9} cm^3 STP/g.

* = Corrected for neutron-induced contributions; a = All analyses are on an unheated sample; b = All errors are actual amounts; c = ^{38}Ar and ^{36}Ar are below detectability. Values are those of the blank.

Table 4: Cosmogenic radionuclide abundances in 79215 (Nautiyal et at., 1981).

Sample (mm)	Depth Temp. (°C)	$^{20}Ne/^{22}Ne$	$^{21}Ne/^{22}Ne$	^{22}Ne (10^{-8} ccSTP/g)	$^{38}Ar/^{36}Ar$	$^{40}Ar/^{36}Ar$	^{36}Ar (10^{-8} ccSTP/g)
0-1.5	600	11.44	0.064	33.89	0.683	72.98	32.71
	1600	4.40	0.629	22.78	0.439	31.04	84.56
	TOTAL	8.62	0.291	56.67	0.507	42.74	117.27
2-5	TOTAL MELT	2.25	7.80	21.51	1.243	143.47	43.58
5-8	TOTAL MELT	0.83	0.891	18.08	1.488	143.61	28.15

Xe data from Venkatesan et al. (1982)

$^{126}Xe/^{132}Xe = 0.2183$

$^{129}Xe/^{132}Xe = 0.1336$

$^{134}Xe/^{132}Xe = 0.2851$