79215

Feldspathic Granulitic Impactite

553.8 grams

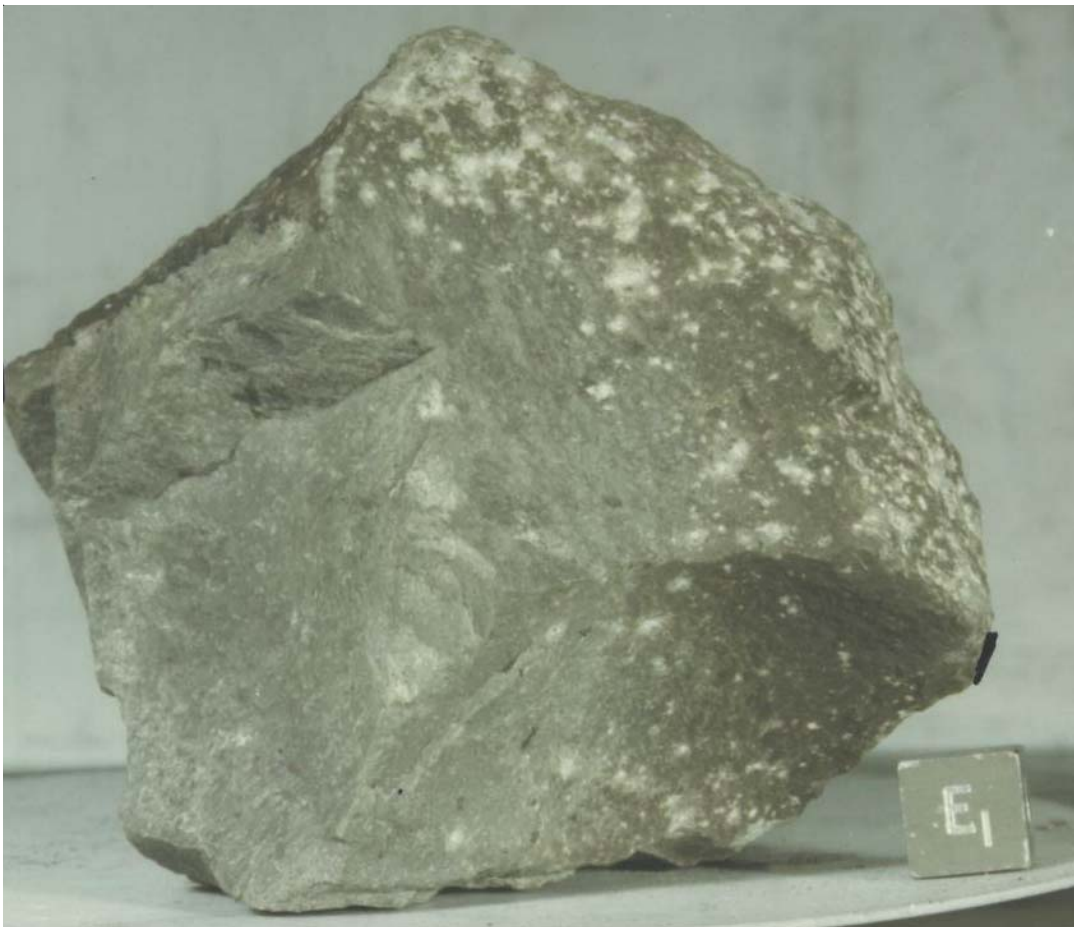


Figure 1: Photo of 79215 showing both freshly broken surface and patina covered exterior. Cube is 1 cm for scale. NASA S73-17184.

Introduction

Sample 79215 was found on the surface near Van Serg Crater (Muehlberger et al. 1974). It's orientation on the surface is known from photographs (see figure 224 in Wolfe et al. 1981) and from the distinct "soil line" around the sample (figure 1). Light-colored rocks in the bottom of Van Serg Crater may be related.

79215 is a holocrystalline, feldspar-rich rock with a granoblastic texture that was formed by a high temperature metamorphic process of unknown origin. The sample is low in KREEP elements, but high in meteoritic siderophiles. It is apparently an annealed aggregate of relict anorthositic and troctolitic cumulates, with an added meteoritic componet. Within 79215 are numerous "oxide complexes" with surrounding reaction corona. The temperature of metamorphism can be calculated from mineral pairs (800 to 950 deg C).

79215 has been dated at ~ 3.9 ± 0.1 b.y., with a long exposure to cosmic rays (170 - 330 m.y.) It is an oriented sample with a thick patina and numerous micrometeorite craters.

Petrography

McGee et al. (1979) and Neal and Taylor (1993) summarized what is known about 79215. This large rock is a coherent granulitic impactite, characterized by a granoblastic matrix of equant plagioclase grains (An_{95}; 0.1 mm) which meet at 120 deg triple junctions with smaller intersertal grains of olivine, pyroxene and opaque minerals (Bickel et al. 1976; McGee et al. 1978)(figure 2).

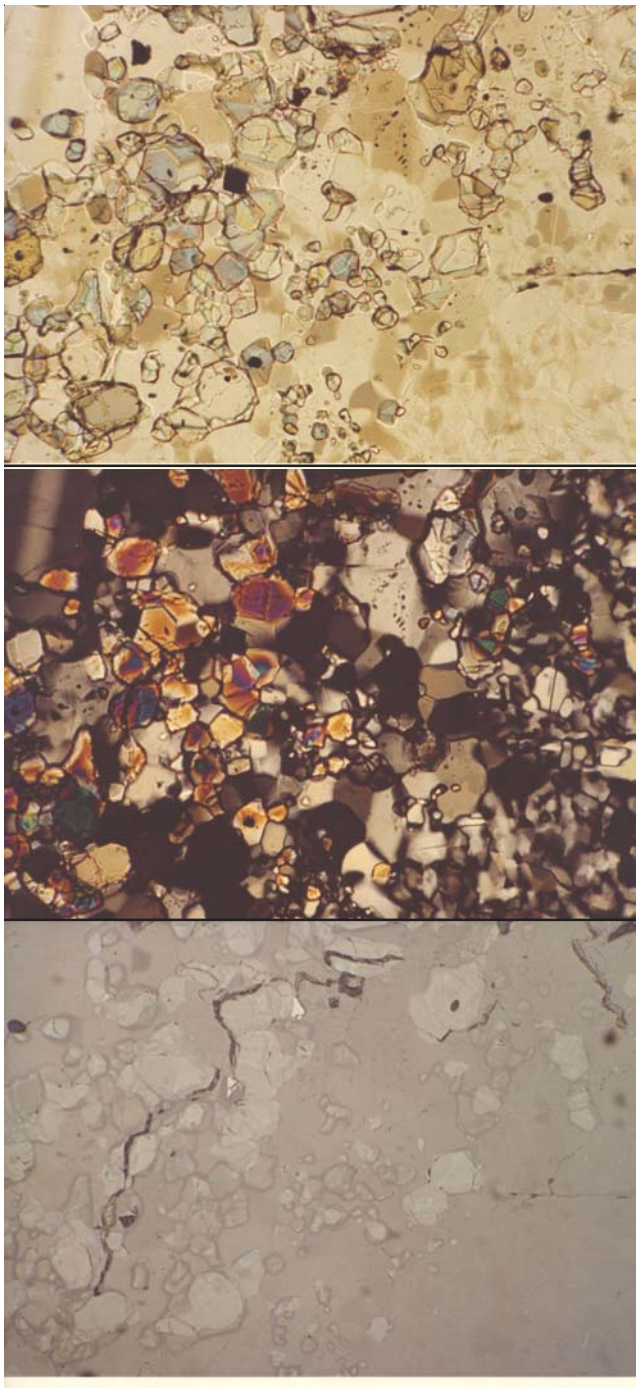


Figure 2: Photomicrographs of thin section 79215,62 (field of view is 0.7 mm). Top is plane-polarized light, middle is crossed-polarized, and bottom is reflected. NASA S79-27264, 27265 and 27263 respectively.

The mineralogic mode was determined for 9 regions in 79215 (see tables). McGee et al. (1978) determined that the rock is about 72% matrix and 28% relict lithic clasts. This variation is also seen in the chemical data of Blanchard et al. (1977). On average the sample is about 80 % plagioclase, 10 % olivine and 8 % pyroxene.

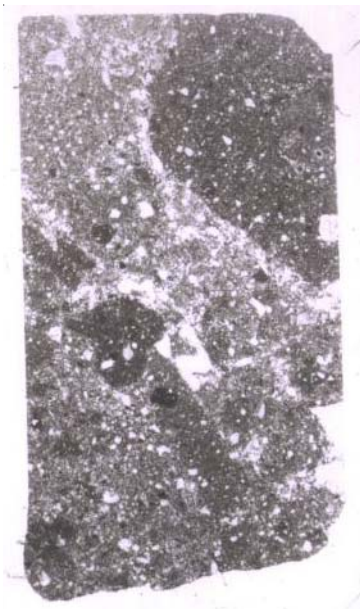


Figure 3: Photo of thin section 79215,73. Scale ~ 1 x 2 cm.

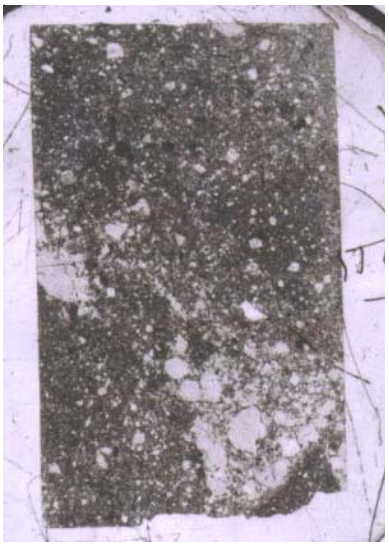


Figure 4: Photo of thin section 79215,55. Scale ~ 1 x 2 cm.

In spite of the variation in mineral mode, the mineral compositions are rather constant (equilibrated?).

McGee et al. (1978) studied numerous reaction corona surronding small "opaque complexes" in the matrix. These complexes consist of core assemblages which may include spinel, ilmenite, armalcolite, troilite, rutile and metallic iron which are surrounded by corona of plagioclase and occasionally olivine. Chomite spinel is the dominant constiuent of the oxide assemblages. The plagioclase in the corona are slightly zoned outward from $An_{96\text{-}90}$.

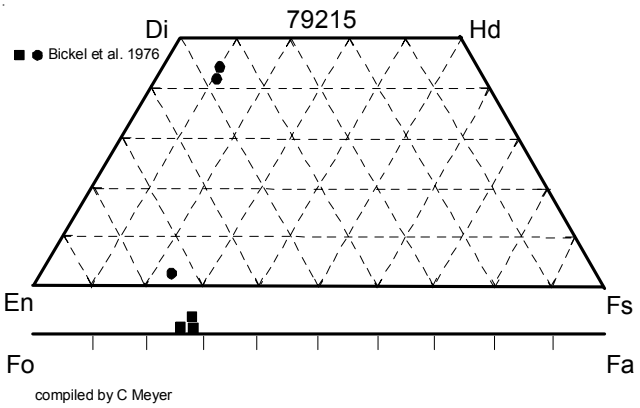


Figure 5: Olivine and pyroxene composition of 79215 as (from Bickel et al. 1976).

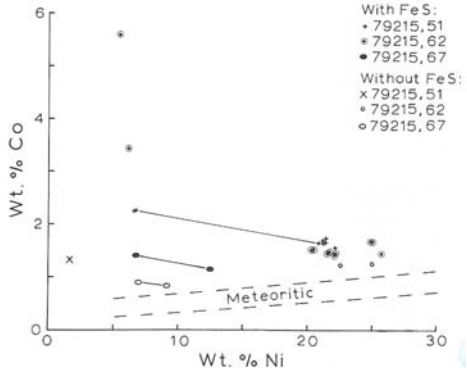


Figure 6: Ni and Co content of metal grains in 79215 (from Bickel et al. 1976).

The temperature of metamorphism can be calculated from the composition of high and low-Ca pyroxene (Cushing et al. 1999) and/or olivine-ilmenite pairs (Anderson and Lindsley 1979). Cushing et al. determined the annealing temperature as 1082 deg C, while Anderson and Lindsley calculate only 660 deg C. McGee et al. (1978) calculated anealling temperatures from 800 to 950 deg C from several mineral pairs.

Mineralogy

Plagioclase: Plagioclase is $An_{92-96.}$ Some large grains have "necklaces" of olivine.

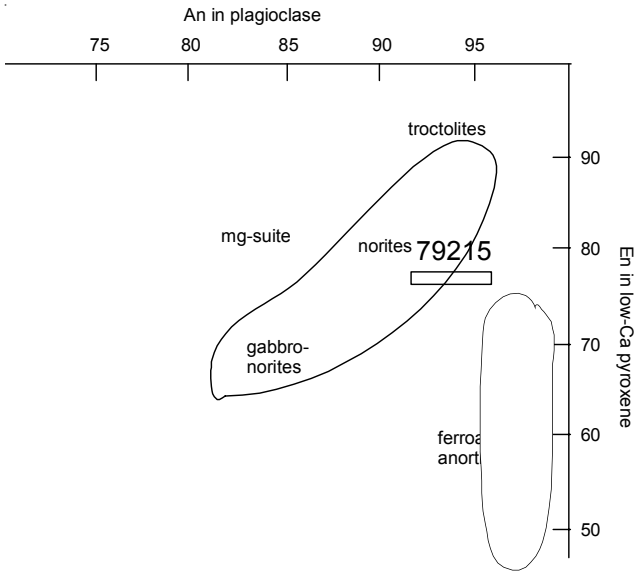


Figure 7: Pyroxene and plagioclase composition of 79215.

Pyroxene: Bickel et al. (1976), McGee et al. (1978), Cushing et al. (1999) and Hudgins et al. (2008) all report pyroxene composition (figure 5).

Olivine: The olivine in 79215 has a range in composition (Fo_{72-86}).

Chromite: Spinel ranges in composition from chromite to ulvospinel (McGee et al. 1978).

Ilmenite: McGee et al. found 6-10% MgO in ilmenite.

Metallic iron: The Ni and Co data for metal in 79215 originally reported by Bickel et al. (1976), were simply repeated by Ryder et al. (1980).

Apatite: Megacrysts of subhedral apatite (up to 1.5 mm) are observed in many of the sections and are believed to have formed during annealing (McGee et al. 1979). Bickel et al. (1976) give a partial analysis.

Armalcolite: McGee et al. determined the chemical composition of armalcolite.

Mineralogical Mode of 79215

	Bickel et al. 1976								
Plagioclase:	89 %	71.3	86.2	80.6	83.4	77.8	83.8	78.2	85.5
High-Ca Pyx.	3.2	0.9	1.7	4.3	5.3	3.4	4.2	3.5	4.1
Low-Ca Pyx.	1.9	0.4	0.1	4.1	3.3	6.3	3.9	9.4	3.3
Olivine	4.5	23.7	10.1	10.5	7.2	10.3	7.1	8.6	6.2
Oxides	0.4	0.4	0.5	0.4	0.4	0.2	0.2	0.2	0.5
Metal and troilite	0.1	.01	0.2	0.1	0.1	0.04	0.05	0.1	0.4
Apatite:	1	3.3	1.2	0.01	0.3	1.9	0.8	0	0

Mineralogical Mode of 79215

	McGee et al. 1978 Matrix	Mineral Clasts	Annorthosite clasts	Troctolite clasts	Whole Rock
	72%	5%	20%	3%	100%
Plagioclase:	78.8	68.3	93.3	42.4	80
Olivine:	13.4	19.3	5.8	30.5	12.7
Orthopyroxene:	5	4.5	0.8	21	4.6
Clinopyroxene:	2.4		0.1	6.1	2
Apatite:		7.8			0.4
Spinel:	0.1				0.1
Ilmenite:	0.1				0.1
Metal:	0.03				0.02
Troilite:	0.07				0.05

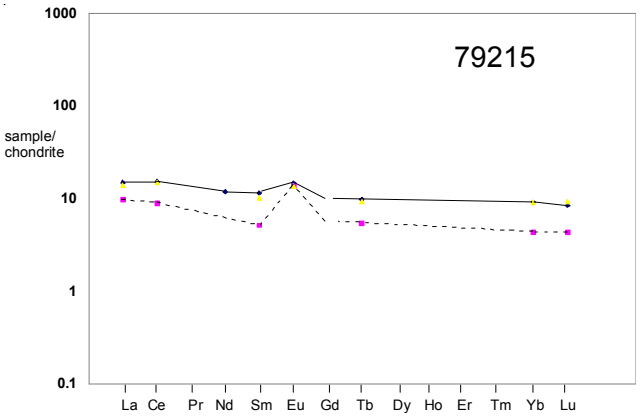


Figure 8: Normalized rare-earth-element diagram for 79215 (data from tables).

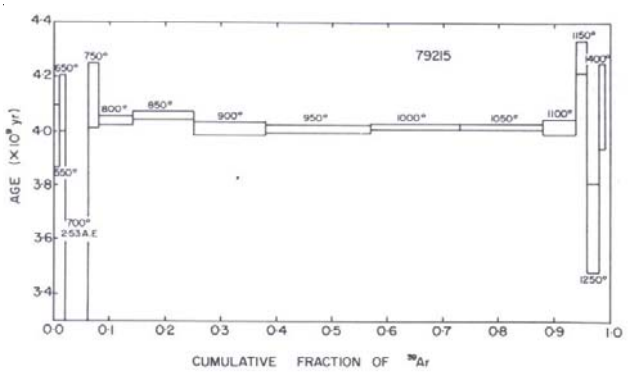


Figure 9: Ar/Ar plateau for 79215 from McGee et al. (1978).

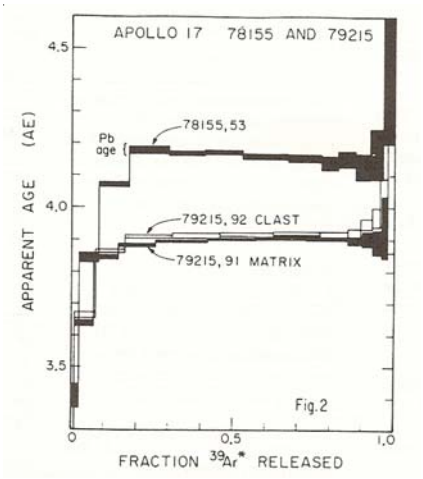


Figure 11: Ar/Ar pleatau diagram for 79215 compared with that of 78155 (Oberli et al. 1979).

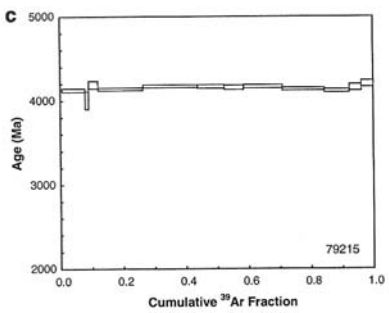


Figure 10: Ar/Ar plateau diagram for 79215 (Hudkins et al. 2008).

Summary of Age Data for 79215

	Ar/Ar
McGee et al 1978	4.03 ± 0.02 b.y.
Oberli et al. 1979	3.91
Hudgins et al. 2008	3.871 ± 0.040

Chemistry

The chemical composition of several pieces of 79215 is given by Blanhard et al. (1977) and Lindstrom and Lindstrom (1986). Fruchter et al. (1975) measured the Th content of the whole sample (550 grams) by radiation counting. Note that the Th for the bulk rock is higher than for the individual splits that were measured. Hudgins et al. (2008) and Higuchi and Morgan (1975) also analysed the sample, finding high siderophiles throughout. The REE pattern is flat and similar to that of other feldspathic granulites (figure 8).

Table 1a. Chemical composition of 79215.

reference	Bickel 76		McGee78		Higuchi and Morgan 1975				Fruchter75		Hudgins 2008				
weight															
SiO2 %	43.8	(c)	43.4	(c)											
TiO2	0.3	(c)	0.13	(c)											
Al2O3	27.7	(c)	28.5	(c)											
FeO	4.6	(c)	4.3	(c)											
MnO	0.06	(c)	0.04	(c)											
MgO	6.3	(c)	6.3	(c)											
CaO	15.9	(c)	15.9	(c)											
Na2O	0.5	(c)	0.38	(c)											
K2O	0.1	(c)	0.09	(c)					0.113	(b)					
P2O5			0.17	(c)											
S %			0.02	(c)											
sum															
Sc ppm											7.7		8	7.8	7.8 (d)
V															
Cr															
Co											16.5		18.6	16.3	15.4 (d)
Ni					221	255	16	(a)			122		125	132	107 (d)
Cu															
Zn					1.6	2.3	6.6	(a)							
Ga															
Ge ppb					39	33	36	(a)							
As															
Se					34	176	424	(a)							
Rb					0.465	0.489	0.187	(a)							
Sr											140		166	139	144 (d)
Y															
Zr											47		38	49	46 (d)
Nb															
Mo															
Ru															
Rh															
Pd ppb															
Ag ppb					0.71	1.16	3.37	(a)							
Cd ppb					1.04	0.98	1.92	(a)							
In ppb															
Sn ppb															
Sb ppb					1.3	2.79	6.36	(a)							
Te ppb					1.9	17	30	(a)							
Cs ppm					0.004	0.005	0.005	(a)							
Ba											89		83	111	135 (d)
La											3.25		3.01	3.15	3.51 (d)
Ce											8		7.1	7.9	9.2 (d)
Pr															
Nd											4.7		4.7	4.2	5.4 (d)
Sm											1.46		1.31	1.34	1.72 (d)
Eu											0.81		0.8	0.82	0.83 (d)
Gd															
Tb											0.31		0.29	0.3	0.36 (d)
Dy															
Ho															
Er															
Tm															
Yb											1.41		1.43	1.39	1.5 (d)
Lu											0.198		0.209	0.197	0.209 (d)
Hf											1.39		1.23	1.26	1.15 (d)
Ta											0.2		0.24	0.12	0.14 (d)
W ppb															
Re ppb					0.5	1.9	2.1	(a)							
Os ppb															
Ir ppb					6.95	21.3	28.8	(a)			6		6	6.6	6.6 (d)
Pt ppb															
Au ppb					1.67	8.27	15.6	(a)			1.1		5	1.9	2.2 (d)
Th ppm									0.88	(b)	1.05		0.64	0.77	1.64 (d)
U ppm					0.043	0.19	0.56	(a)	0.03	(b)	0.39		0.21	0.27	0.72 (d)

technique: (a) RNAA, (b) radiation counting, (c) calculated, (d) INAA

Table 1b. Chemical composition of 79215.

reference	Blanchard77						
weight	Lindstrom 86						
SiO2 %	39.4	43.2	44.8	43.5	44.4	44.8	
TiO2	0.3	0.3	0.3	0.4	0.3	0.5	
Al2O3	10.4	25.8	27.6	26.7	27.9	27.4	
FeO	18.2	4.96	4.15	4.91	3.4	4.86	
MnO	0.17	0.058	0.054	0.063	0.045	0.064	
MgO	24.2	8.51	5.84	7.33	6.18	7.4	
CaO	6.17	15.6	16.3	15.6	16	14.4	
Na2O	0.222	0.616	0.549	0.557	0.616	0.58	(d)
K2O	0.034	0.11	0.107	0.113	0.128	0.119	
P2O5							
S %							
sum							
Sc ppm	7.07	4.6	7.14	7.69	5.53	8.14	(d)
V							
Cr	1628	472	670	787	4555	739	(d)
Co	71.2	17.6	18.8	16.6	7.3	18.9	(d)
Ni	680	152	215	110		126	(d)
Cu							
Zn							
Ga							
Ge ppb							
As							
Se							
Rb							
Sr							
Y							
Zr							
Nb							
Mo							
Ru							
Rh							
Pd ppb							
Ag ppb							
Cd ppb							
In ppb							
Sn ppb							
Sb ppb							
Te ppb							
Cs ppm							
Ba							
La	1.01	2.33	2.5	3.3	2.45	2.65	(d)
Ce	22.4	5.5	6.5	9.1	6.6	6.8	(d)
Pr							
Nd							
Sm	0.481	0.768	1.03	1.53	0.96	1.19	(d)
Eu	0.35	0.77	0.77	0.77	0.94	0.84	(d)
Gd							
Tb	0.12	0.2	0.23	0.34	0.22	0.28	(d)
Dy							
Ho							
Er							
Tm							
Yb	0.78	0.72	1.07	1.5	0.79	1.37	(d)
Lu	0.132	0.106	0.16	0.23	0.108	0.24	(d)
Hf	0.6	0.56	1.34	1.1	0.45	1.2	(d)
Ta				0.14			(d)
W ppb							
Re ppb							
Os ppb							
Ir ppb							
Pt ppb							
Au ppb							
Th ppm	0.46	0.53	0.21	0.37	0.5	0.32	(d)
U ppm							
technique:	*(d) INAA*						

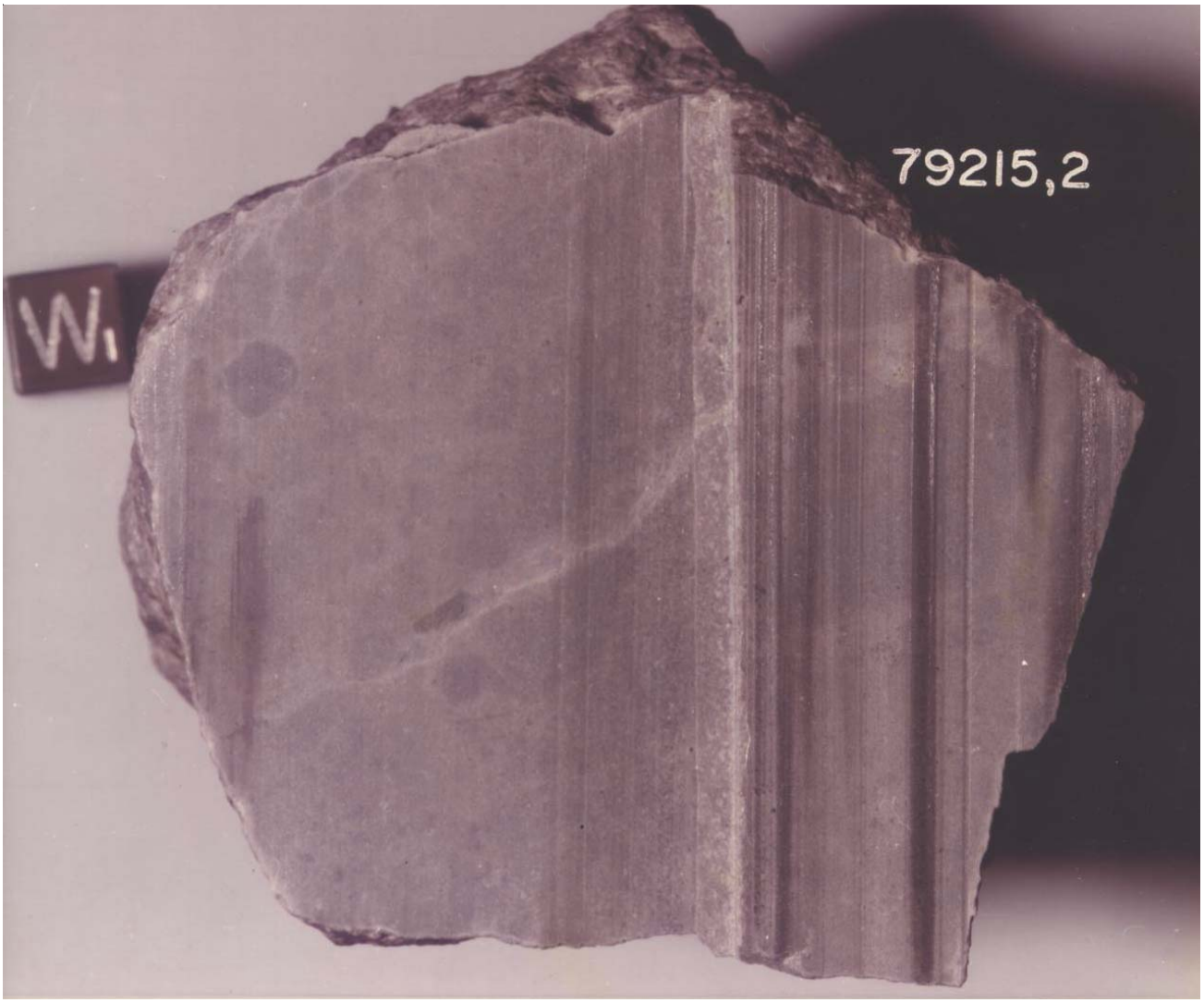


Figure 12: Sawn surface of 79215,2 showing saw marks. Cube is 1 cm. S74-15594.

Radiogenic age dating

Both McGee et al. (1978) and Hudgins et al. (2008) obtained good plateau ages by the stepwise heating technique, but they are not in agreement (figures 9-11). McGee et al. and Hudgins et al. also used the laser probe technique to date spots.

Murthy (1978) reported the initial Sr isotope ratio for plagioclase from 79215. Oberli et al. (1979) reported Pb.

Cosmogenic isotopes and exposure ages

McGee et al. (1978) reported an Ar exposure age of 170 ± 10 m.y., while Hudgins et al. (2008) reported an Ar exposure age of 339 ± 24.2 m.y.

Nautiyal et al. (1981) and Venkatesan et al. (1982) determined cosmogenic He, Ne, Ar and Xe as a function of depth in 79215. Bhandari (1977) studied tracks and measured ^{26}Al a function of depth. These SCR depth profile studies have not been interpreted.

Other Studies

Hohenberg et al. (1980) reported Xe isotopes determined by Morgan (1975). Venkatesan et al. (1982) also reported the isotopic ratio of Xe.

Processing

79215 is an oriented sample with a thick patina and numerous micrometeorite craters. A two-part slab was cut through the rock (figure 13). Half of the slab is thin (~2 mm) and broke into pencil-shaped pieces (,4) and half is thick (~1.5 cm) and subdivided (,5 ,6 ,7 ,9).

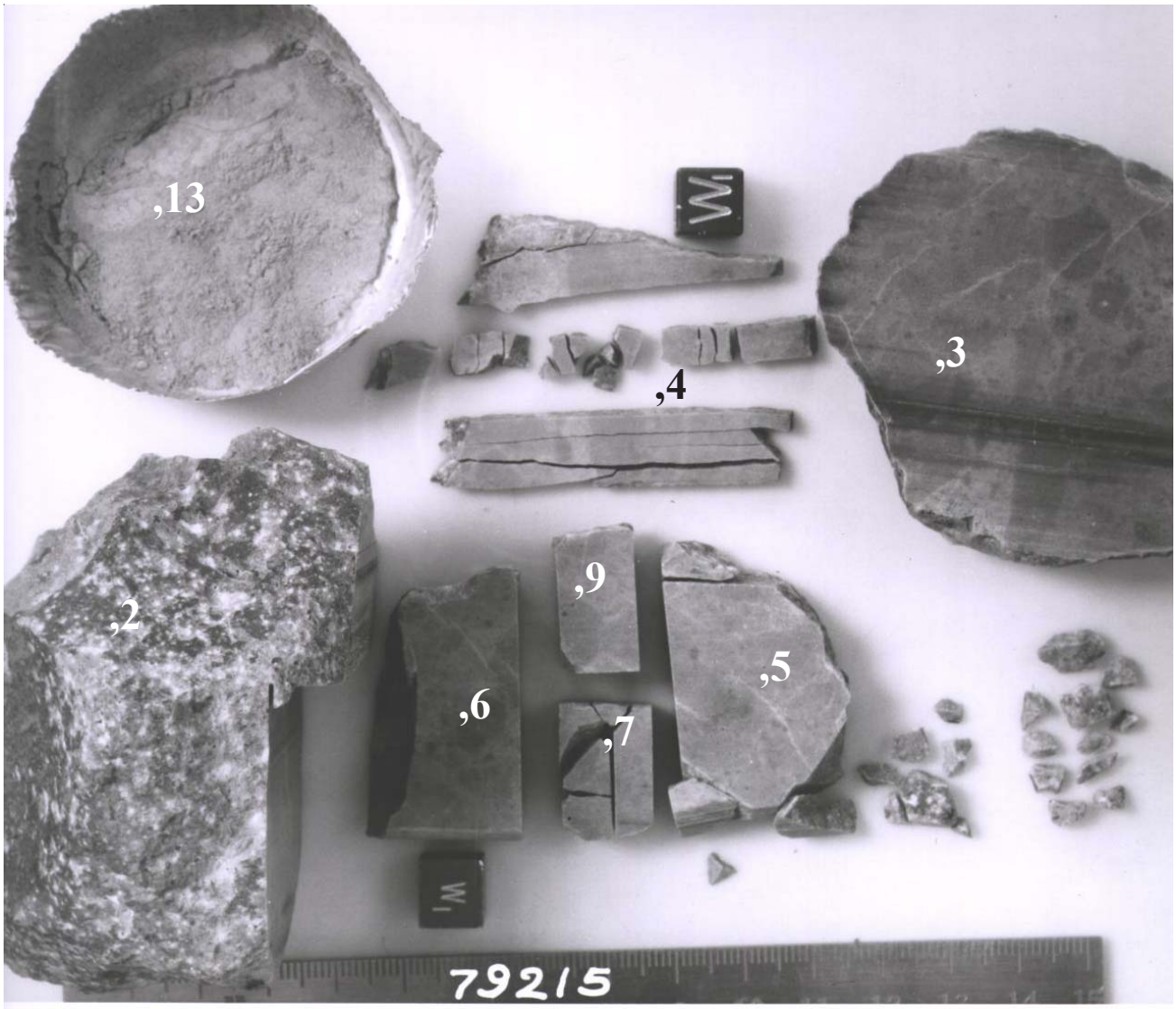
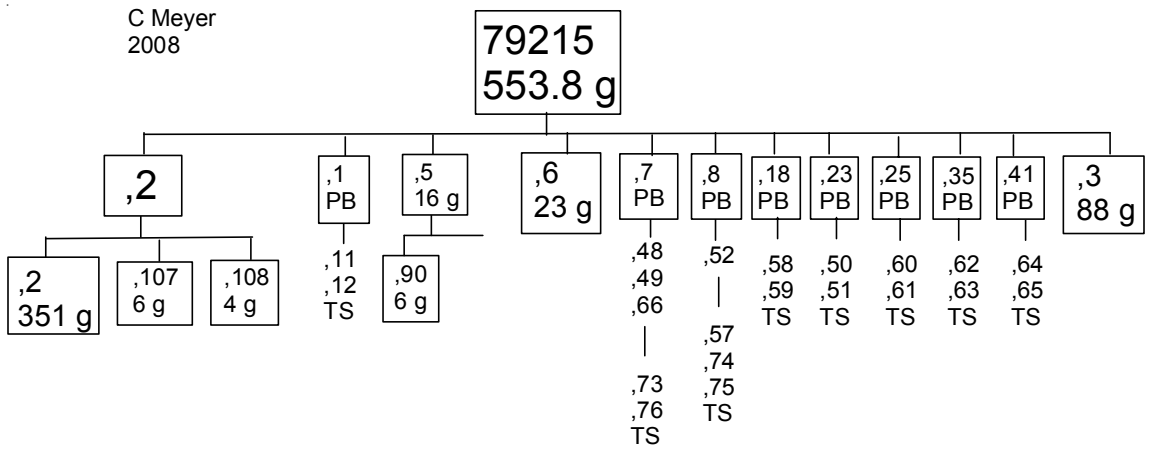


Figure 13: Processing photo of 79215 showing pieces of two-part slab and fine sawdust. NASA S 74-17837. Cubes are 1 cm for scale.



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