76315

Impact Melt Breccia

671 grams

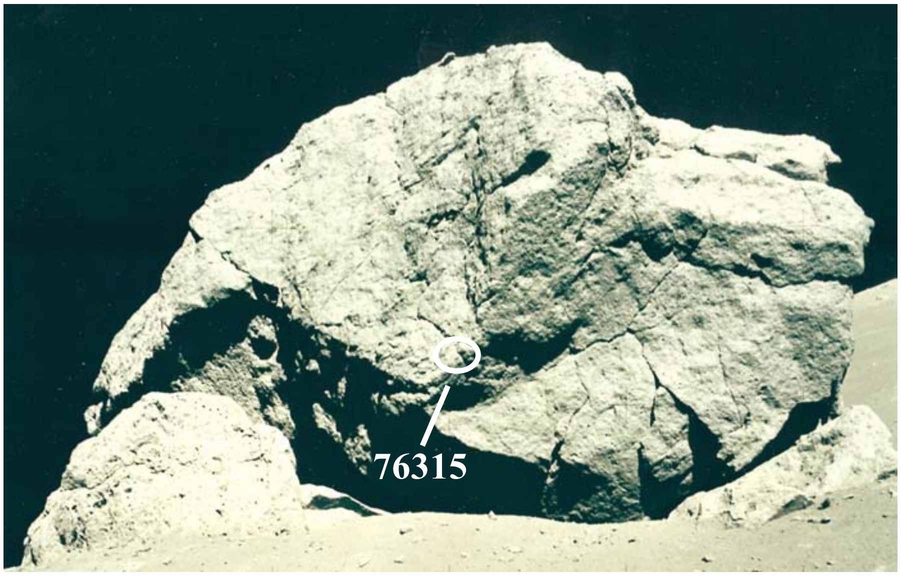


Figure 1: Location of 76315 on station 6 boulder (block 2). AS17-140-21436.

Figure 2: Photo of front, exposed, surface of 76315. The lack of zap pits on the upper left corner, indicate that this corner was facing down on the boulder. Cube is 1 cm. S73-17108.

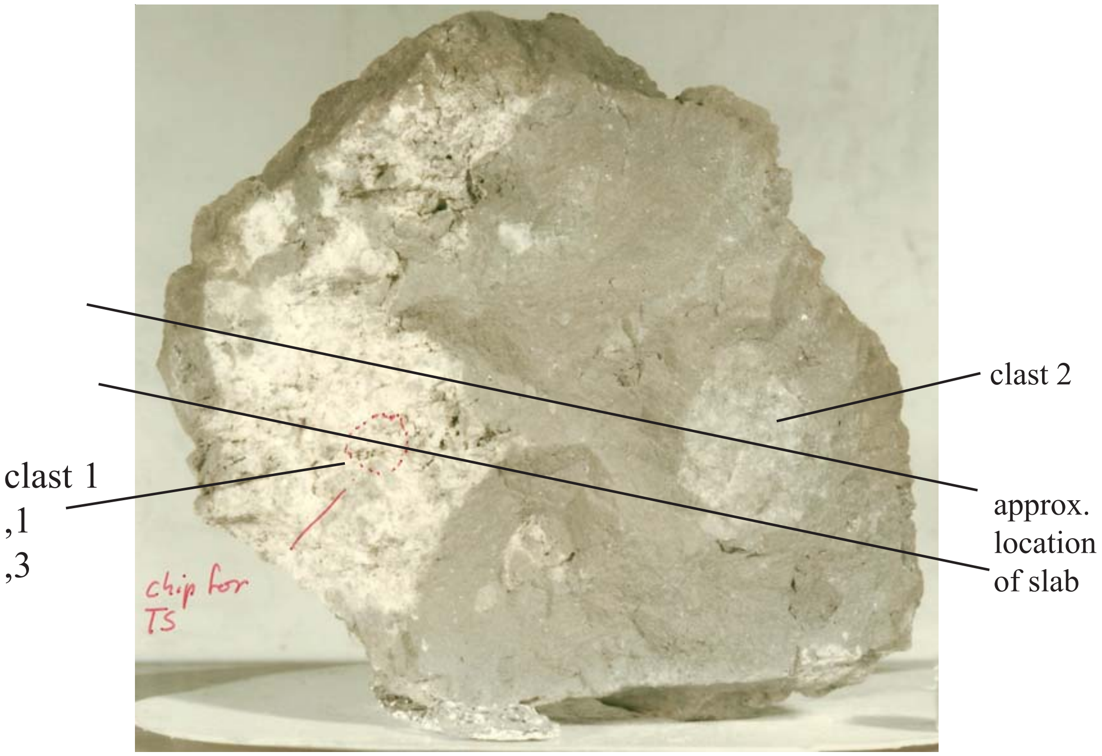


Figure 3: Fresh broken side of 76315, showing thin remnants of large white clast. About 10 cm across. S73-17109.

Figure 3: Photo of top of 76315, showing portion of thin white clast. Cube is 1 cm. S73-17104.

CDR This is the easiest part of the rock in the world to work. Here's a big white clast. There's one on top about a foot and a half across, and here's one – must be 2 feet across – 3 feet, and that's in the blue-grey.

LMP Well, Bob, I think I've done the best I can. I would – I'd say that there're pretty clearly inclusions of the blue-grey in the anortositic gabbro here near the contact.

CC OK. And Gene, your bag is hanging by one hook there. Be careful, if you can – or LMP - -

LMP OK, Bob, by accident – I didn't think I could do it but I got a sample of the inclusion. And it's in bag 539 (76315).

CDR Hey, Jack, that's your bag that's hanging by one hook. Let me get it.

LMP Oh, they're talking to me, huh?

CDR I didn't think they could see me. I'm way up on top.

LMP And it's blue-grey with light colored inclusions in it. But the whole thing seems to be pretty well altered, or metamorphosed – compared to the major rock we sampled – to the other grey rock.

\- - -

LMP OK, Bob, I think that inclusion will give you an example of what this thing – what the anorthositic gabbro did to the blue-grey breccia.

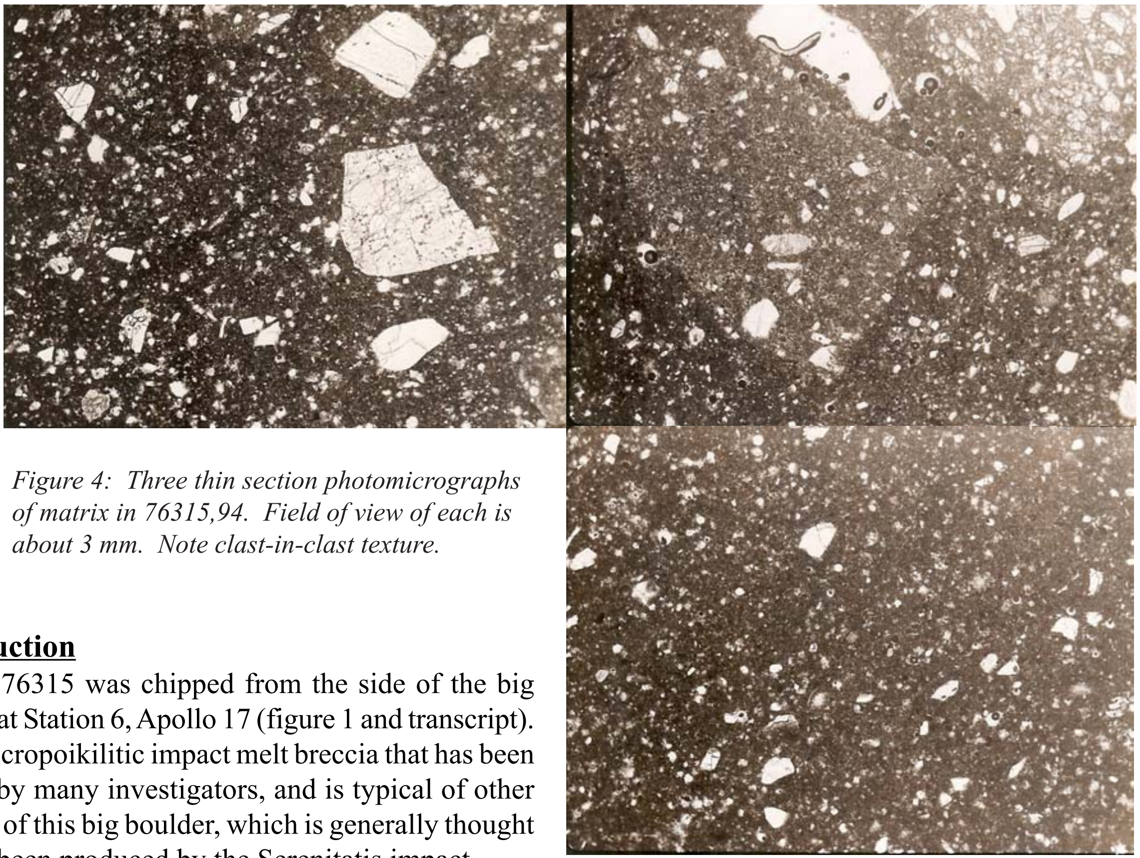


Figure 4: Three thin section photomicrographs of matrix in 76315,94. Field of view of each is about 3 mm. Note clast-in-clast texture.

Introduction

Sample 76315 was chipped from the side of the big boulder at Station 6, Apollo 17 (figure 1 and transcript). It is a micropoikilitic impact melt breccia that has been studied by many investigators, and is typical of other samples of this big boulder, which is generally thought to have been produced by the Serenitatis impact.

The crystallization age of 76315 is 3.9 b.y. with an exposure age of 22 m.y.

Petrography

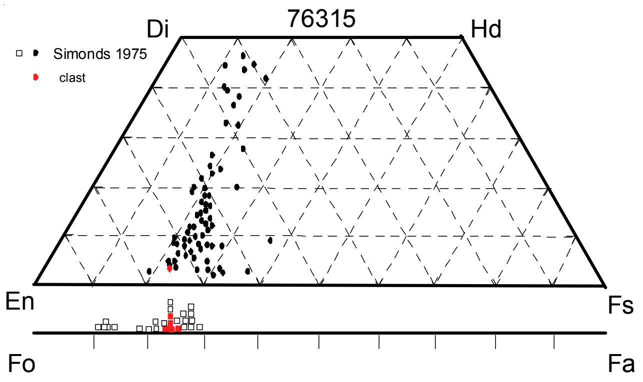
Heiken et al. (1973) mapped the visible features of the Station 6 boulder and identified this blue-gray breccia sample to be from the "transitional zone" (lithology AB). The surface of 76315 was covered with patina (figure 2) such that the underlying lithology could not be discerned except on the freshly broken B1 face (figure 3). The broken surface was composed of dark grey breccia with a large irregular patch of "pink grey" material (clast 1) and a 1 x 2 cm light grey clast (2).

McGee et al. (1977), Phinney (1981) and Meyer (1994) previously made summaries of the studies conducted on 76315. The breccia matrix has finely-divided flow banding which can be seen best in the sawn surface (figure 12a). The distinct foliation is due to variations in matrix color and trains of minute vesicles. The large clasts seen in figures 3 and 4 were found to be very thin and disappointingly small in volume.

The modal mineralogy of the matrix of 76315 is about 50% plagioclase and 40% low-Ca pyroxene with minor amounts of augite, olivine, ilmenite, armalcolite and metallic iron. The grain size of the matrix feldspar is ~10 microns while pyroxene is 25-35 mcirons (figure 4).

Simonds et al. (1974) studied numerous small lithic class in 20 thin sections of 76315, including two poikilitic 70-80% plagioclase fragments, three granulitic 70-80% plagioclase fragments, one crushed feldspar or anorthositic fragment, three intersertal plagioclase-pyroxene-olivine fragments, one crushed olivine or dunite, one poikilitic 50-60% plagioclase, two crushed spinel-olivine fragments, one crushed troctolite fragment and three aphanitic feldspathic fragments. McGee et al. (1979) one basalt clast (1 mm) with acicular plagioclase and subhedral olivine in section 76315,95 and one dunite clast (2 mm) with polygonal olivine and symplectite in 76315,97.

Norman et al. (1993) reported on the chemical composition of mineral clasts in the martix of 76315, with the hope that they could determine the precursor rock type(s), concluding that "troctolites" were the source of the mineral fragments. However, this doesn't explain the relatively high trace element content (figure 9). No mineralogical evidence for "low-K Fra Mauro basalt" could be found.



compiled by C Meyer

Figure 6: Pyroxene and olivine composition of matrix and clast in 76315 (from Simonds 1975).

Significant Clasts

Clast 1: Feldspathic Granulite (,1 ,3 ,22 ,52)

Figure 3 shows a large patch of crumbly "pink-grey" material. This thin brecciated clast is aligned with the direction of foliation in the matrix forming a zone of weakness along which the rock was broken during sampling from the boulder. According to Simonds (1975) this clast is granulitic in texture with ~70% plagioclase (An_{95}), ~15% low-Ca pyroxene ($Wo_{2-3}En_{83}Fs_{12}$) and ~15% olivine (Fo_{82}). Table 1 and figure 8 include an analysis (,52). However, there may be more than one rock type present in this patch.

Clast 2: Anorthositic breccia (,46 ,61 ,62 ,95)

Figure 3 shows a cm-sized light-grey clast, which also turned out to be thin (figure 12a). It has a poikilitic texture with ~70% plagioclase (An_{96}), ~17% low-Ca pyroxene ($Wo_{3-5}En_{78}Fs_{18}$) and ~13% olivine (Fo_{75}). The minerals in this clast were found to be homogeneous in composition. An analysis (,62) showed it to be Al-rich and the Ar plateau (,61) showed that it may be significantly older than the matrix (figure 10). McGee et al. (1979) reported that thin section 76315,95 has a seriate size distribution of subangular plagioclase with less abundant pyroxene and olivien. The largest plagioclase grains have olivine necklaces with 50 micron overgrowths (figure 13).

Clast xyz:

Internal clast exposed by slab cut (see figure 12b).

Mineralogy

Olivine: Olivine in 76315 has a narrow range of composition Fo_{70-76}.

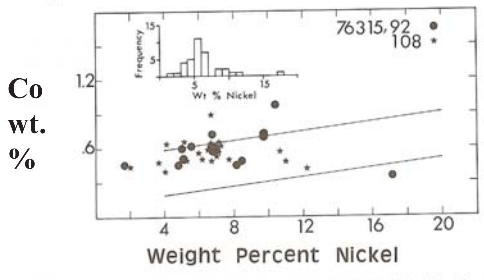


Figure 7: Ni and Co content of metal grains in 76315 (Misra et al. 1976).

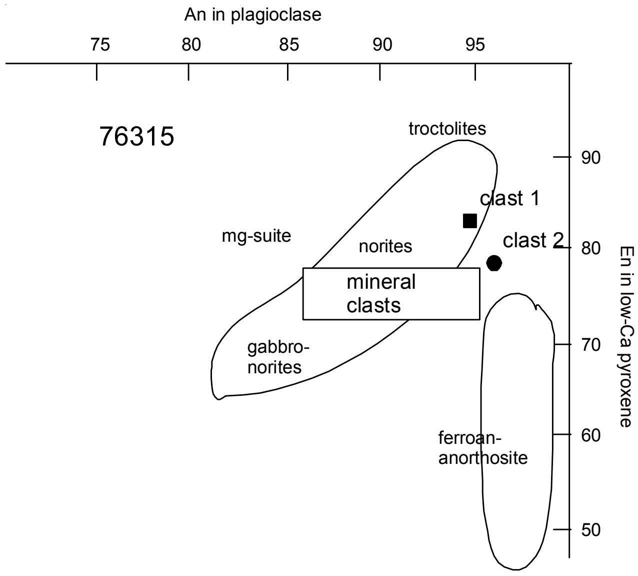


Figure 8: Composition of plagioclase and low-Ca pyroxene in 76315.

Pyroxene: Simonds (1975) determined the composition of pyroxene in matrix and clasts (figure 6). The low-Ca pyroxene is $Wo_4En_{60-73}Fs_{19-26}$ while the high-Ca pyroxene is $Wo_{20-30}En_{44-57}Fs_{12-15}$.

Feldspar: Plagioclase in 76315 is variable (An_{81-97}).

Pink Spinel: Simonds (1975) reports the occurrence of minor amounts of pink spinel in some areas.

Metallic Iron: Misra et al. (1976) determined Ni and Co in iron grains (figure 7).

Chemistry

Hubbard et al. (1974), Rhodes et al. (1974) and Wiesmann and Hubbard (1976) reported numerous analyses of matrix and clasts in 76315 (Table 1 and figure 9). Morgan et al. (1974), Gros et al. (1976) and Norman et al. (2002) have dertermined the siderophile and trace element content of the matrix of 76315. Jovanovic and Reed (1975) and Allen et al. (1975) determined F, Cl, I, Li, U, Ru, Os and Pb.

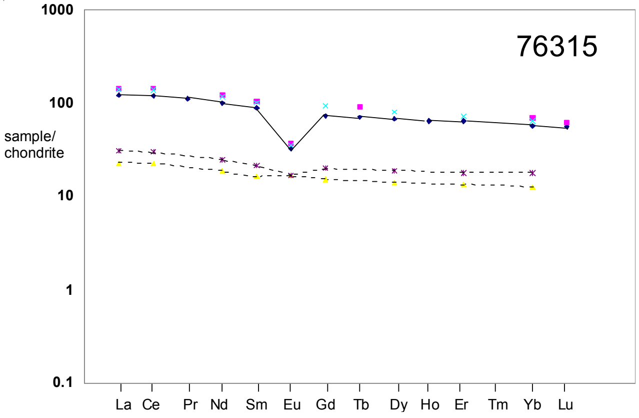


Figure 9: Normalized rare-earth-element diagram for 76315 matrix and clasts.

Radiogenic age dating

Turner and Cadogen (1975) determined the age of the station 6 boulder (figure 10). This has been confirmed by Dalrymple and Ryder (1996) who obtained an age of 3.9 b.y. (figure 11). That's the age of Serenitatis!

Nyquist et al. (1974) found the Rb/Sr systematics of the granulite clast were aligned with other Apollo 17 granulites and gave old model ages. Silver (1974) studied U, Th and Pb isotopes in 76315.

Cosmogenic isotopes and exposure ages

Turner and Cadogen (1975) determined the cosmic ray exposure age of 20, 19 and 17 m.y. by the ^{38}Ar method while Crozaz et al. (1975) determined ^{81}Kr = 22 m.y. (see discussion in Arvidson et al. 1975). Crozaz et al. (1975) also studied cosmic ray tracks in 76315.

Other Studies

Crozaz et al. (1975) and Hohenburg et al. (1980) reported Xe analyses of 76315. Bogard 1974) also analysed rare gas content.

Mayeda et al. (1975) determined the isotopic composition of oxygen in plagioclase and olivine in 76315.

Nagata et al. (1975) reported magnetic data and discussed Ni/Fe phases and Brecher (1976) studied the alignment of magnetization with foliation. Magnetization of this rock was also studied by Stephenson et al. (1974), Pearce et al. (1974) and Gose et al. (1976). Housley et al. (1975) determined the ferromagnetic resonance and Huffman et al. (1975) determined the iron distribution by Mossbauer.

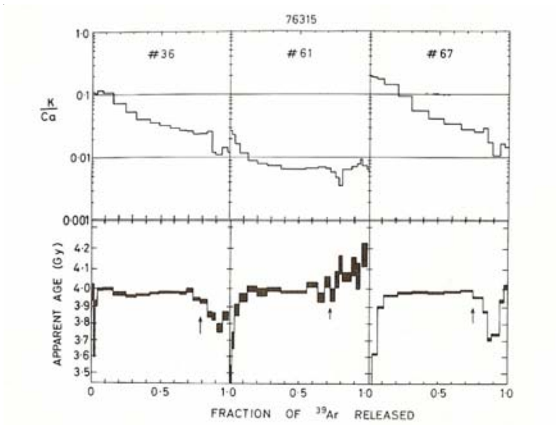


Figure 10: Argon release diagram (Turner and Cadogen 1975). Split ,61 is the white clast.

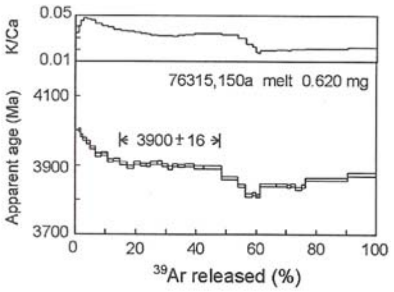


Figure 11: Ar/Ar plateau age diagram for 76315 (from Dalrymple and Ryder 1996).

Summary of Age Data for 76315

	Ar/Ar
Turner and Cadogen 1975	3.98 ± 0.04 b.y.
Dalrymple and Ryder 1996	3.900 ± 0.016

Caution: Beware changes in decay constant.

Adams and Charette (1975) compared the reflectance spectra with other samples (but didn't discuss the effect of patina).

Processing

76315 was studied as part of the Station 6 boulder consortium (Phinney 1981).

A slab was cut through the middle of 76315 (figure 12). There are 22 thin sections.

There were about 22 grams of dirt and chips in the bag with 76315 - which might include additional chips of the white clast (someone needs to look). In addition, chips of the white clast may have fallen off during sawing of the slab (sawing is a rough operation).

Table 1. Chemical composition of 76315.

					,62c		,2	,30M	C3	,35M	,52c					
reference	Norman2002		Dalrymple96		Hubbard74		Wiesmann76						Gnos 76		Morgan74	
weight			melt		Wiesmann76		Rhodes 74									
SiO_2 %	46.6	(b)			Rhodes 74			45.64	46.45	46.21	48.57	(e)				
TiO_2	1.4	(b)			0.36	(e)		1.5	1.43	1.5	0.32	(e)				
Al_2O_3	18.3	(b)			26.37	(e)		17.53	18.8	18.14	17.91	(e)				
FeO	8.02	(b)	8.4	(c)	5.29	(e)		9.53	8.83	8.95	7.66	(e)				
MnO	0.1	(b)			0.07	(e)		0.13	0.13	0.12	0.13	(e)				
MgO	12	(b)			7.46	(e)		12.5	12.34	12.02	13.84	(e)				
CaO	11	(b)			15.12	(e)		10.97	11.3	11.32	10.36	(e)				
Na_2O	0.65	(c)	0.69	(c)	0.47	(e)	0.61	0.7	0.63	0.81	0.47	(e)				
K_2O	0.21	(c)	0.24	(c)	0.097	(d)	0.27	0.27	0.22	0.26	0.15	(d)				
P_2O_5					0.06	(e)		0.3	0.29	0.29	0.12	(e)				
S %					0.04	(e)		0.08	0.07	0.07		(e)				
sum																
Sc ppm	18.2	(a)	16.3	(c)												
V	46	(a)														
Cr	1355	(a)	1317	(c)	770	(d)	1228	1302	1257	1389	813	(d)				
Co	31.2	(a)	16	(c)												
Ni	283	(a)	83	(c)									423	256	260	(f)
Cu	12.1	(a)														
Zn	13.8	(a)											2	3.1	3.4	(f)
Ga	5.1	(a)														
Ge ppb													58	346	354	(f)
As																
Se													71	100	107	(f)
Rb	7.7	(a)			2.336	(d)	5.88	6.56	3.85	5.78	3.73	(d)	2.73	5.91	5.9	(f)
Sr	182	(a)	179	(c)	153.1	(d)	180	175	172	174	115	(d)				
Y	113	(a)														
Zr	493	(a)	330	(c)	95	(d)	477	485	465		105	(d)				
Nb	35.1	(a)														
Mo																
Ru	6.77	(a)														
Rh																
Pd ppb	7.87	(a)											23			
Ag ppb													0.7	0.8	0.9	
Cd ppb													12	5	6	
In ppb													4.6			
Sn ppb																
Sb ppb													0.8	1.5	1.5	(f)
Te ppb													3.4	4	5.1	(f)
Cs ppm	0.12	(a)	0.22	(c)									0.11	0.25	0.25	(f)
Ba	355	(a)	373	(c)	72.8	(d)	359	349	366	337	129	(d)				
La	28.6	(a)	34	(c)	5.41	(d)	30.1	32.9	24.7	31.6	7.33	(d)				
Ce	72.5	(a)	88.3	(c)	13.7	(d)	84.6	84	78.6	82.3	18.4	(d)				
Pr	9.99	(a)														
Nd	45.8	(a)	56	(c)	8.6	(d)	53.5	53.5	50.2	52.7	11.5	(d)				
Sm	13.1	(a)	15.4	(c)	2.42	(d)	15.1	15.1	14.1	14.8	3.2	(d)				
Eu	1.83	(a)	2.09	(c)	0.94	(d)	2	1.97	1.88	1.95	0.971	(d)				
Gd	14.6	(a)			2.99	(d)	18.9	18.5	17.6	18.8	3.93	(d)				
Tb	2.59	(a)	3.3	(c)												
Dy	16.5	(a)			3.39	(d)	19.9	19.7	18.3	19.1	4.59	(d)				
Ho	3.61	(a)														
Er	10.3	(a)			2.14	(d)	11.7	11.5	11	11.4	2.91	(d)				
Tm																
Yb	9.43	(a)	11.3	(c)	2.07	(d)	11	10.6	10	10.4	2.98	(d)				
Lu	1.37	(a)	1.5	(c)	0.3	(d)					0.455	(d)				
Hf	10.1	(a)	12	(c)	5.3	(d)	12.5					(d)				
Ta	1.5	(a)	1.56	(c)												
W ppb	0.86	(a)														
Re ppb	0.36	(a)											1.85	0.507	0.575	(f)
Os ppb													21			(f)
Ir ppb	3.45	(a)											18.6	5.42	5.97	(f)
Pt ppb	7.76	(a)														
Au ppb													6.4	3.2	3.5	(f)
Th ppm	5.87	(a)	5.3	(c)	1.234	(d)	5.2	5.36	5.23	5.69	1.34	(d)				
U ppm	1.54	(a)	1.62	(c)	0.343	(d)	1.52	1.47	1.36	2.52	0.34	(d)	0.355	1.54	1.49	(f)

technique: (a) ICP-MS, (b) fused-bead, e-probe, (c) INAA, (d) IDMS, (e) XRF, (f) RNAA

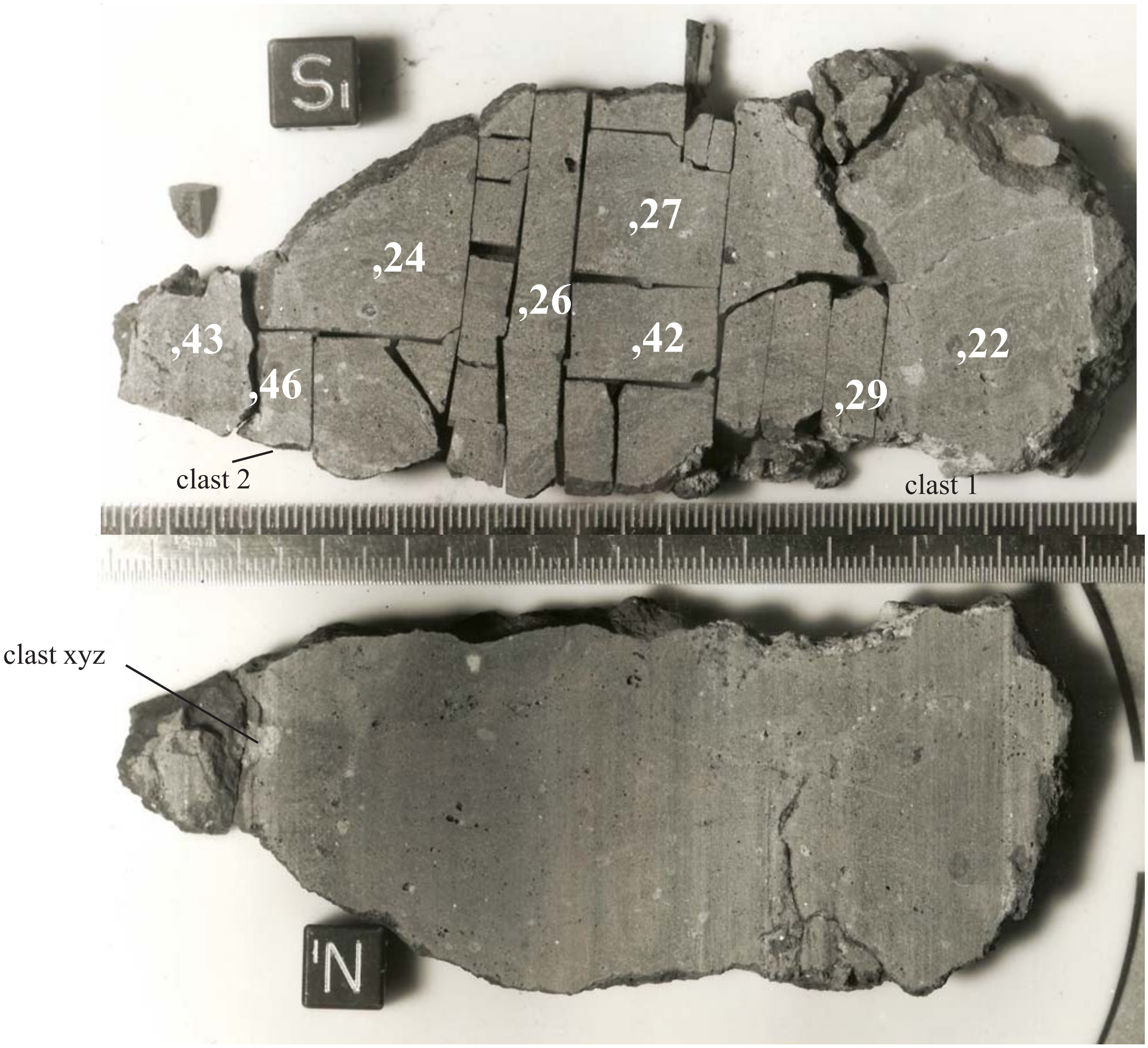
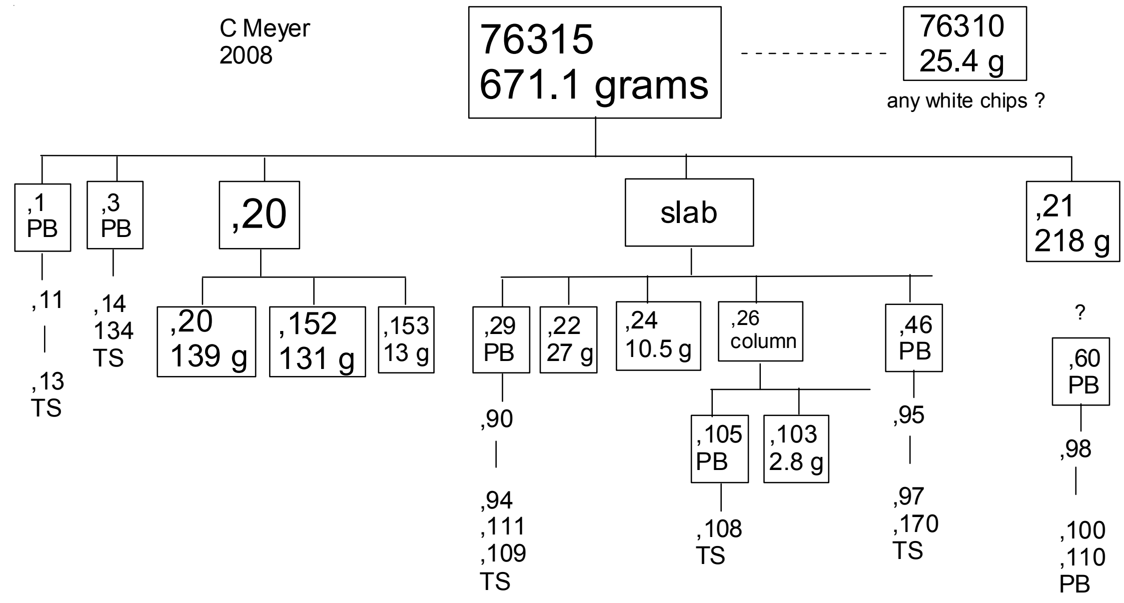


Figure 12a, b: Front and back sides of slab cut through the middle of 76315. Cube is 1 cm. Top is S73-35833; bottom is 34145. Note how thin the "white clast" is.



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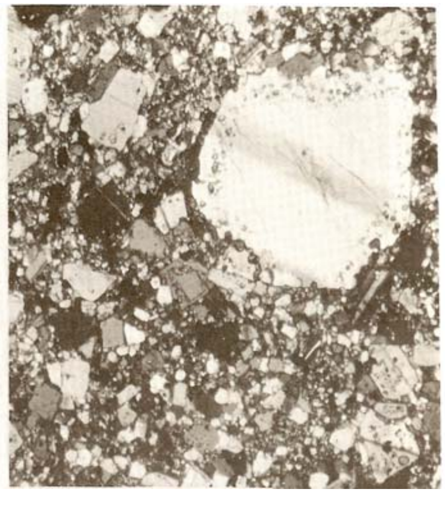

Figure 13: Plagioclase-rich clast with olivine necklace in large plagioclase grain (0.7 mm). 76315,95 (clast 2?). From McGee et al. (1979).