72255

DRAFT

Aphanitic Impact Melt Breccia

461.2 grams

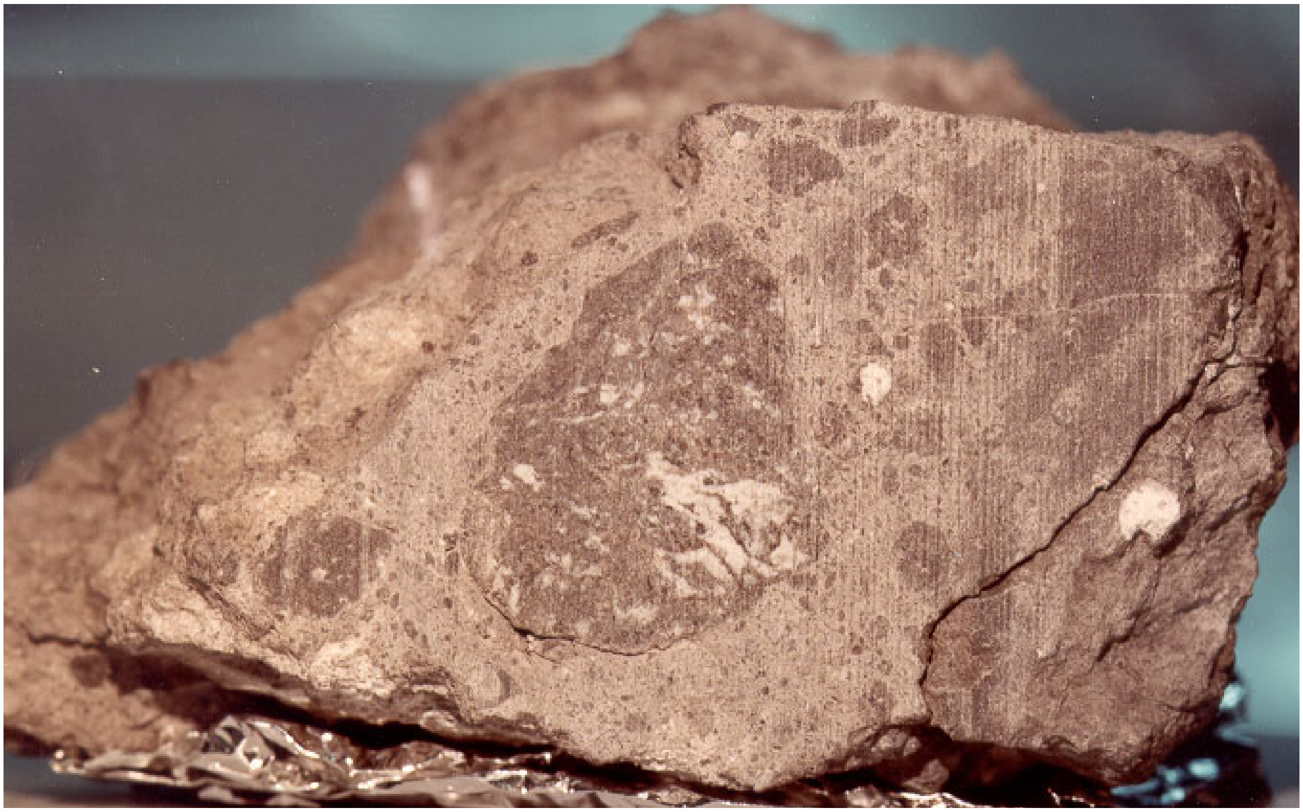


Figure 1: Sawn surface of 72255,23 after first slab removed.. NASA S84-37180. Large clast is "Civet Cat Norite" 2 x 1.5 cm. (see also figure 17b)

Introduction

Lunar sample 72255 was collected from the side of a layered boulder #1 at station 2 located on the bottom slope of the South Massif and within the landslide material at Apollo 17 Taurus-Littrow (Schmitt 1973, Wolfe et al. 1981). Samples 72215, 72235 and 72275 are from other layers in this boulder and soils 72220, 72240 and 72260 are from the fillet surrounding the boulder (figure 1, section 72215). The boulder had a prominent layering with clasts weathering out as knobs. 72255 was one of these knobs and was from a distinctly different layer than 72275 (which is otherwise vaguely similar).

Sample 72255 is a clast-rich breccia with a layered aphanitic matrix (figure 1). The age of the matrix of this rock is ~ 3.8 b.y. It contains a large relic norite clast (Civet Cat) with an age of ~4.08 b.y., and also contains various small clasts of silica-rich, "granitic" material. It also contains numerous zircons ~ 4.2 b.y. (Nemchin et al. 2008).

The cosmic ray exposure age of 72255 has been determined to be about 44 Ma.

Clast Population 72255

(from Stoeser et al. 1974)

Granulitic ANT breccias	31.3%
Granulitic polygonal anorthosite	6.3
Crushed anorthosite	5.2
Devitrified glass	13.8
Ultra mafic particles	1.5
Basaltic troctolite	2.2
Other basaltic particles	1.9
Granitic clasts	2.6
Civet Cat Norite	0.7
Plagioclase grains	19.3
Mafic grains	14.5
Opaque	0.7

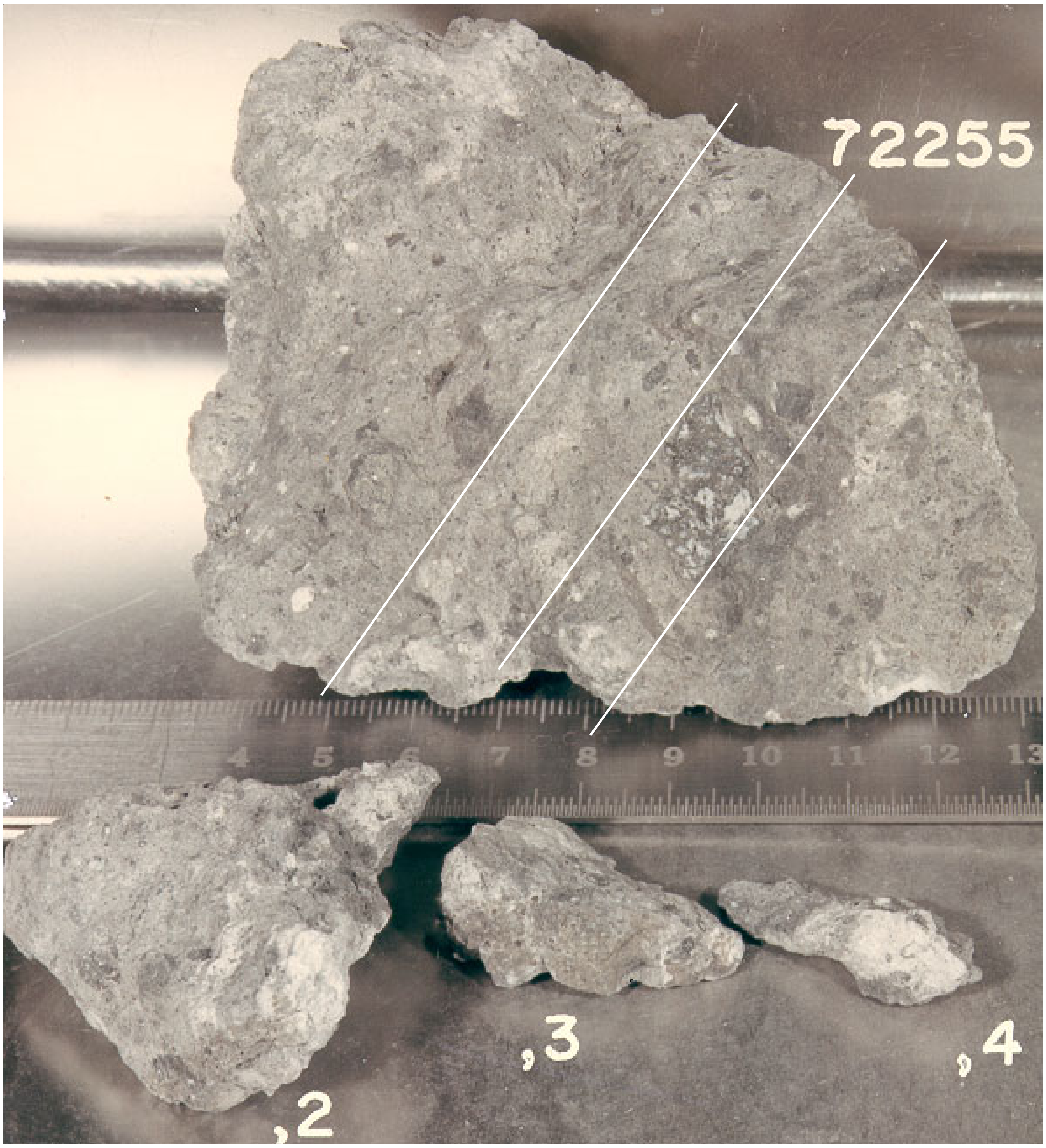


Figure 2: Photo of 72255 and pieces. NASA S73-21975. Scale is in cm. Outcrop of "Civet Cat Norite" is visible. White lines are approximate trace of saw cuts for slabs.

Wolfe et al. (1981) and others interpret this boulder to be part of the Serenitatis ejecta blanket, originally located high up on the South Massif. However, based on subtle, but reproducible, differences in the ratios of trace amounts of meteoritic siderophile elements, Morgan et al. (1975) conclude that the samples of *"this boulder cannot represent ordinary Serenitatis ejecta",* and may instead *"represent Serenitatis material excavated from the fringes of the crater during late stages of the Serenitatis impact, but only slightly shocked and hence uncontaminated by the Serenitatis projectile*".

Petrography

Graham Ryder (1993) carefully summarized what is known about this rock. It was originally studied in consortium mode by a large group of scientists led by John Wood called "Consortium Indomitable" (Marvin et al. 1975) – of which Graham was an original member.

Knoll and Stoffler (1979) described 72255 as having a dark, fine-grained, equigranular crystalline matrix that contains some areas of lighter, coarser-grained matrix. Stoeser et al. (1974) reported that the sample was about 60% matrix and gave a lithologic mode for the clast

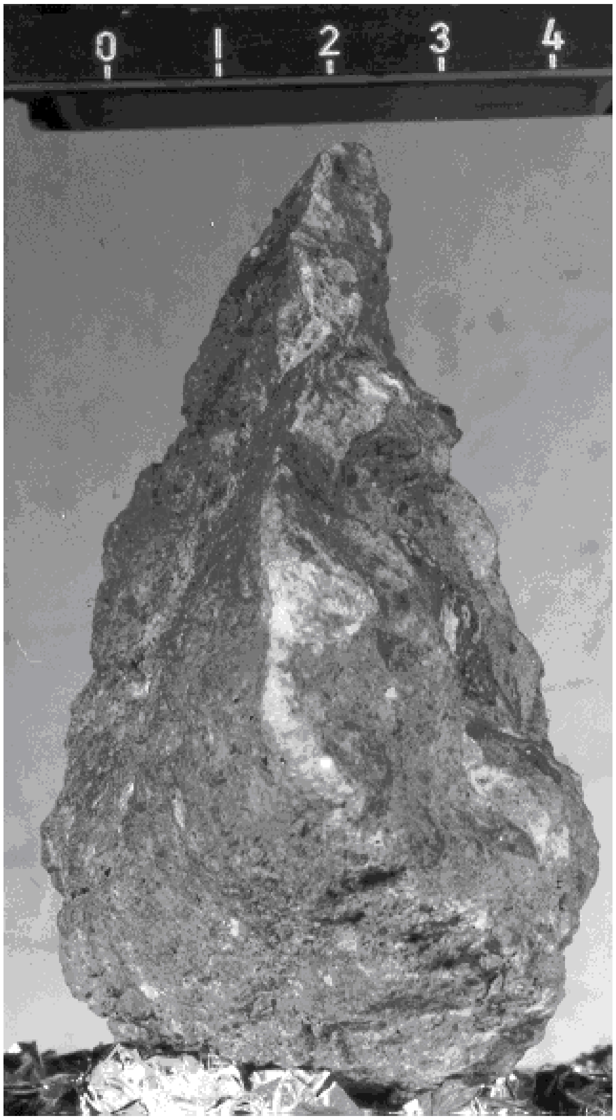


Figure 3: Edge view of 72255. Note that one side is freshly broken; the other is rounded with zap pits and patina. Scale in cm. NASA S73-23729.

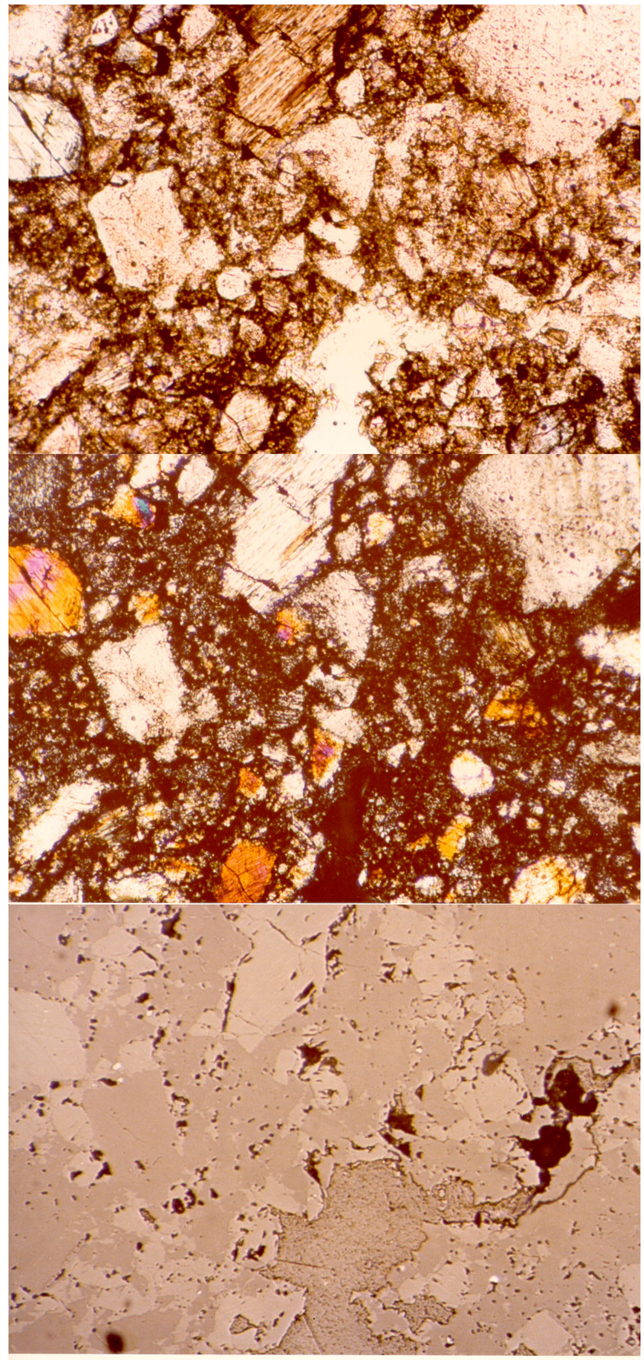


Figure 4: Photomicrographs of thin section 72255,108. Top is with plane-polarized, middle is crossed-polarized and bottom is reflected light. NASA S79-27771, 27772, 27770. Field of view is 1.3 mm.

population. Simonds et al. (1974), Spudis and Ryder (1981), Ryder (1993) and others conclude that 72255 is an aphanitic impact-melt breccia.

Significant Clasts

Civet Cat Norite clast (~ 10 grams)

This 2 cm sized clast (figures 1 and 2) is a pristine shocked, norite with about 40% plagioclase and 60% orthopyroxene with minor augite lamellae (Stoeser et al. 1975, Ryder and Norman 1979). It has a cataclastic texture with light and dark streaks. Some of the plagioclase in the light streaks is maskelynite, and the pyroxene has "kink-bands". Ryder et al. (1975), Stoeser et al. (1975) and Bersch et al. (1993) analyzed the minerals and found that they were homogeneous (figures 7 and 8). The rare-earth-element pattern is given in figure 9. It was dated by Ar/Ar at 3.99 b.y. (figure 11) and Rb/Sr at 4.08 b.y. (figure 14). Based on low siderophile element content (Morgan et al. 1975), Warren (1993) declared it "pristine" (lacking meteoritic siderophiles). James (1982) and James and Flohr (1983) grouped the Civet Cat Norite with the

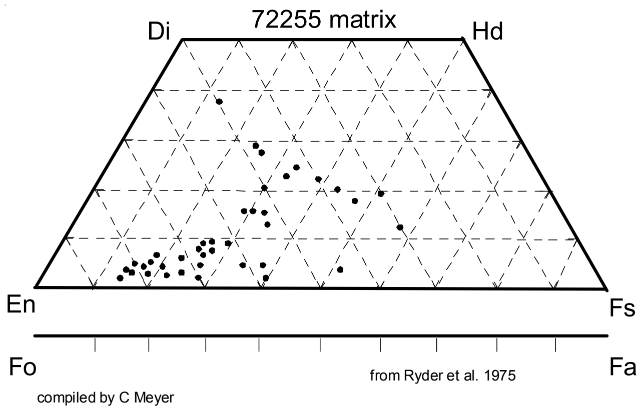


Figure 5: Chemical composition of pyroxene grains in the matrix of 72255 (from Ryder et al. 1975 and Stoeser et al. 1975).

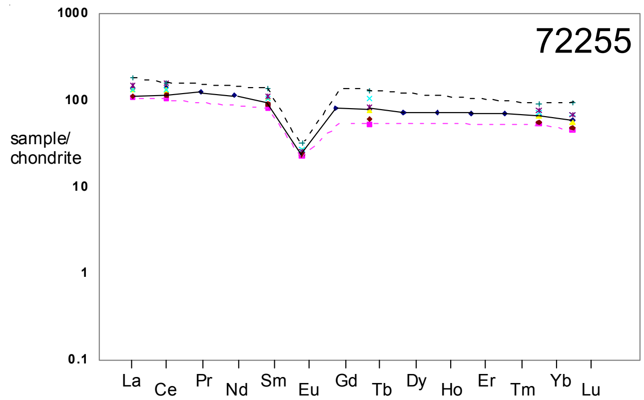


Figure 6: Normalized rare-earth-element diagram for matrix of 72255. Soild line is data from Palme et al. 1978; data in brackets is from Blanchard et al. 1975 - see table 1.

Mg-norites on the basis of both chemistry and mineralogy.

Granite clasts

As is typical of the matrix of 72215, the matrix of 72255 also has abundant small (~25 micron to 2 mm) patches of "granitic" material with different textures. Typically it is intergrown silica with Ba-rich K-spar and some plagioclase. Often it contains ternary feldspar.

Poikilitic Impact Melt clast

Ryder (1992) reported a fragment of poikilitic impact melt within 72255 that was distinct in texture from the matrix. This clast (,287) is reported to be about 7 mm in size, have mm sized oikocrysts of pigeonite (En_{82-70}) and "rather more high-Ca clinopyroxene" than the common Apollo 17 poikilitic boulders. Both plagioclase chadocrysts and pyroxene oikocrysts are said to be chemically zoned. It was uncovered during the cutting of the second slab and has been dated by Dalrymple and Ryder (1996). However, complete description is not available.

Chemistry

The chemical composition of the matrix of 72255 was determined by Keith et al. (1974), Fruchter et al. (1975), Palme et al. (1978), Blanchard et al. (1975) and others (tables 1 and 2). It is high in Al_2O_3 (~20%) and the trace element pattern is that of KREEP (figure 6).

The composition of the clasts that have been extracted is given in Table 3 and figure 9.

Morgan et al. (1975) and Higuchi and Morgan (1975) found that the trace meteoritic siderophile elements (Ir, Re and Au) have different ratios for samples form this boulder, as compared with other boulders at Apollo 17 and elsewhere. They concluded that boulder 1, station 2 was Serenitatis ejecta, *albeit strange*.

Radiogenic age dating

Leich et al. (1975) determined an age of 4.01 ± 0.03 b.y. for the matrix (,52) and an age of 3.99 ± 0.03 b.y. for the Civet Cat norite clast (,42) (figures 12 and 11). On the other hand, Compston et al. (1975) also dated the Civet Cat norite clast by internal Rb/Sr isochron technique (figure 14) and obtained an age of ~ 4.08 b.y. (corrected to modern decay constant for Rb). However, they noted a hint of "*disturbance*". Schaeffer et al. (1982) found a wide variety of ages by Ar-Ar laser probe analysis of small spots (mostly plagioclase). Dalrymple and Ryder (1996) determined a number of Ar/Ar plateaus on different lithologies (figures 13 and 15), but generally found the same result as Leich et al. (1975). They interpret their age for the youngest material as the age of the Serenitatis Impact (3.84 b.y.).

Nunes et al. (1974) collected U-Pb data, but it is difficult to interpret. Hutcheon et al. (1974) determined an age of a whitlockite grain (81 ppm U) of ~3.9 b.y. by the fission track method!

Cosmogenic isotopes and exposure ages

The cosmic-ray induced activity for 72255 was determined by Keith et al. (1974) as ^{22}Na = 61 dpm/kg., ^{26}Al = 78 dpm/kg., ^{46}Sc = 6 dpm/kg., ^{54}Mn = 41 dpm/kg., and ^{56}Co = 35 dpm/kg.

Leich et al. (1975) determined an exposure age of 44.1 ± 3.3 m.y. from ^{81}Kr data and 41 m.y. from ^{38}Ar data.

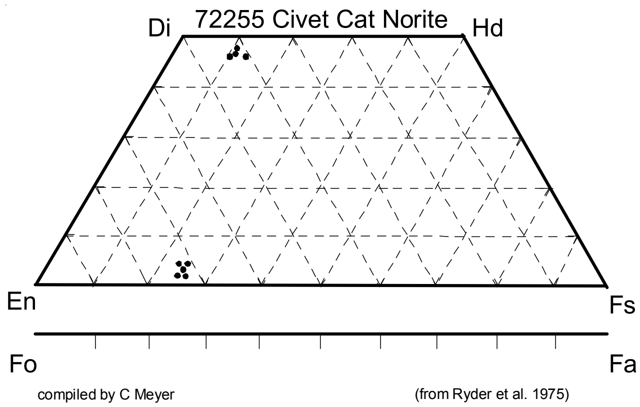


Figure 7: Chemical composition of pyroxene grains in the clast called "Civet Cat Norite" (from Ryder et al. 1975 and Stoeser et al. 1975).

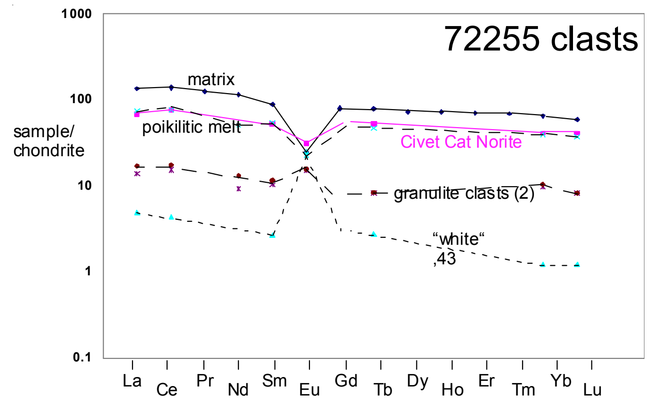


Figure 9: Normalized rare-earth-element diagram for clasts in 72255. Soild line is data for matrix from Palme et al. 1978; data in brackets is from Blanchard et al. 1975 and Dalrymple and Ryder 1996 - see table 3.

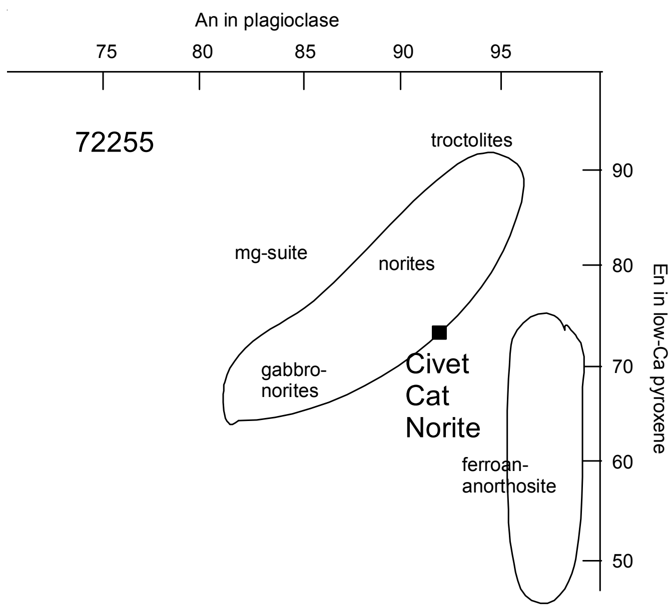


Figure 8: Mineral compositon diagram of pristine lunar plutonic rock fragments including Civet Cat Norite clast from 72255 (Ryder et al 1975).

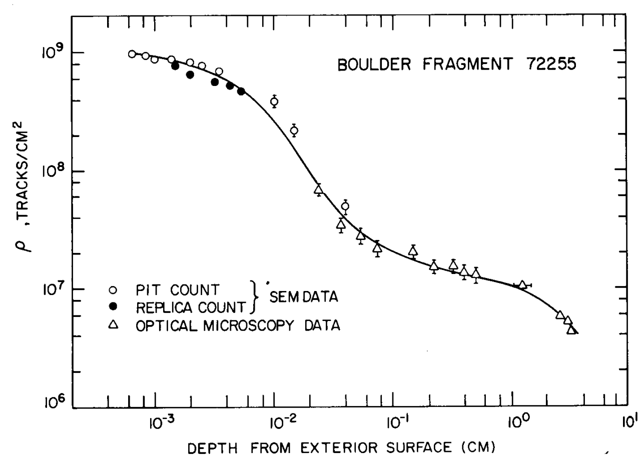


Figure 10: Density of cosmic ray tracks beneath surface of 72255 (Goswami and Hutcheon 1975).

This is less than the exposure age of samples form the top of the boulder (e.g. 72275), probably because of shielding effects. Arvidson et al. (1976) speculate that this might be the age of Tycho!

Other Studies

Rare gas data for 72255 can be found in Leich et al. (1975). There does not seem to be a significant solar wind component, so there is little or no ancient regolith admixed into this boulder.

Adams and Charette (1975) determined the spectra of 72255. Banerjee et al. (1974) and Banerjee and Swits (1975) studied the magnetization including paleointensity and direction. Macdougall et al. (1974), Hutcheon et al. (1974), Goswami and Hutcheon (1975) and Goswami et al. (1976) have studied cosmic-ray induced nuclear particle track densities, complicated by shock alteration and erosion and spallation (figure 10).

Processing

The original subdivision of the first slab was well documented by Consortium Indomitable (Vol. 1, Appendix A). There is additional material from the Civet Cat Norite clast available in the second slab (,226), but the CCN clast did not continue through the second slab (Mosie 1985). There are 31 thin sections of 72255.

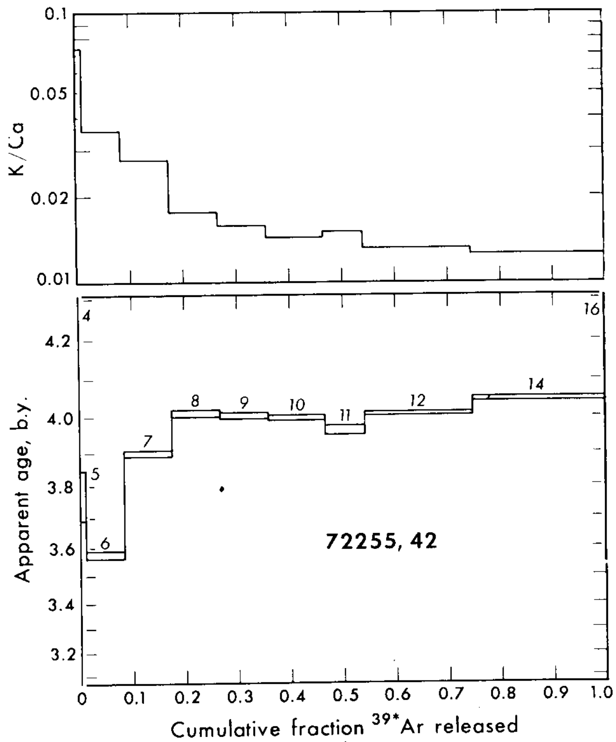


Figure 11: Ar/Ar plateau diagram for Civet Cat Norite clast in 72255. The intermediate temperatue plateau corresponds to an age of 3.99 +/- 0.03 Ga. Leich et al. 1975.

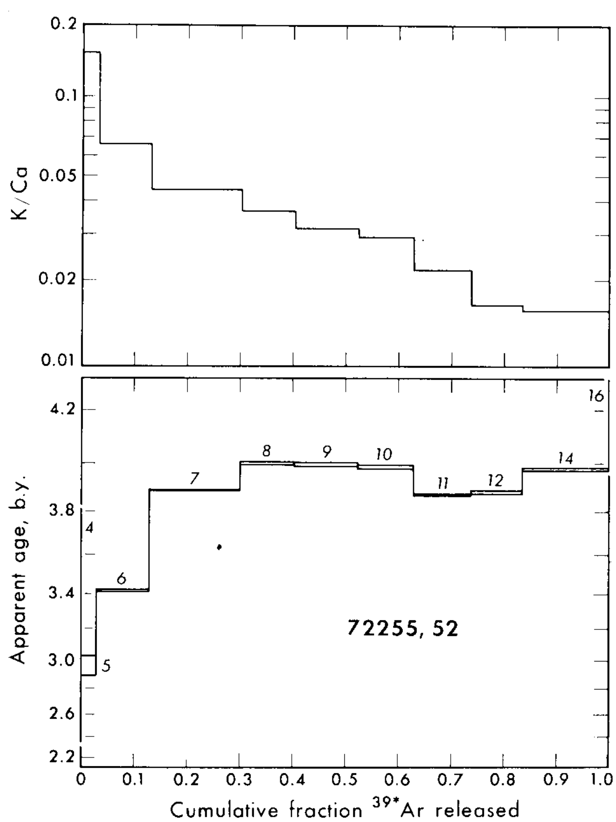


Figure 12: Ar/Ar plateau diagram for matrix of 72255. Age 4.01 =/- 0.03 Ga. Leich et al. 1975.

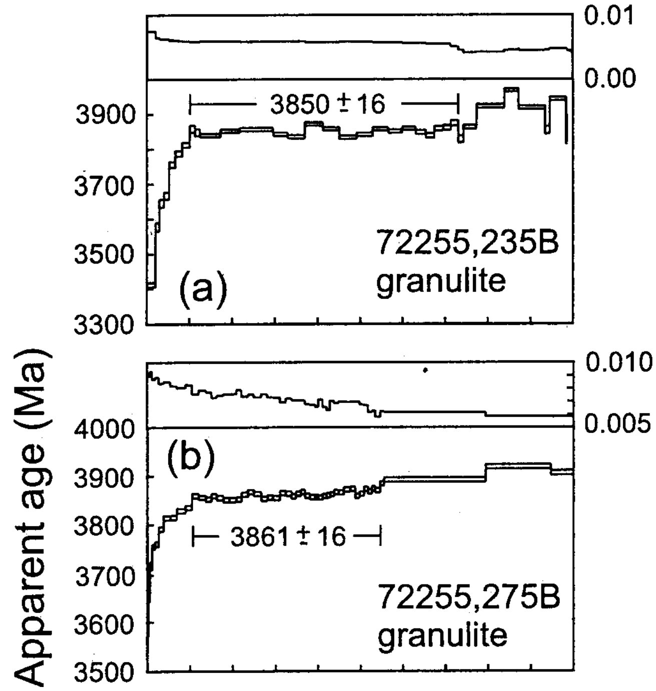


Figure 13: Ar/Ar release plateaus for granulite clasts in 72255 (Dalrymple and Ryder 1996).

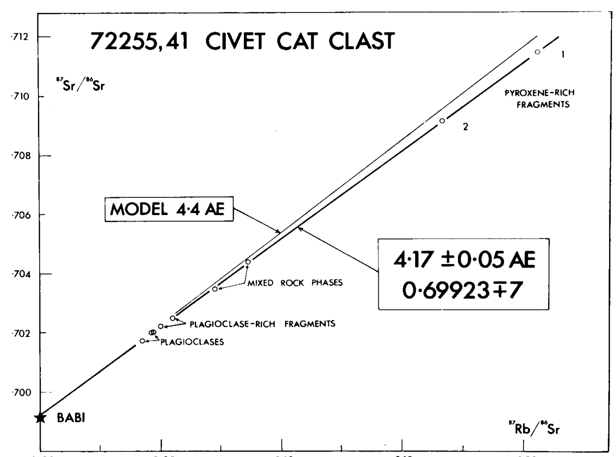


Figure 14: Rb/Sr isochron age of Civet Cat norite clast from 72255. The age recalculated with "new" decay constant for Rb is 4.08 +/- 0.05 Ga.(Compston et al. 1975).

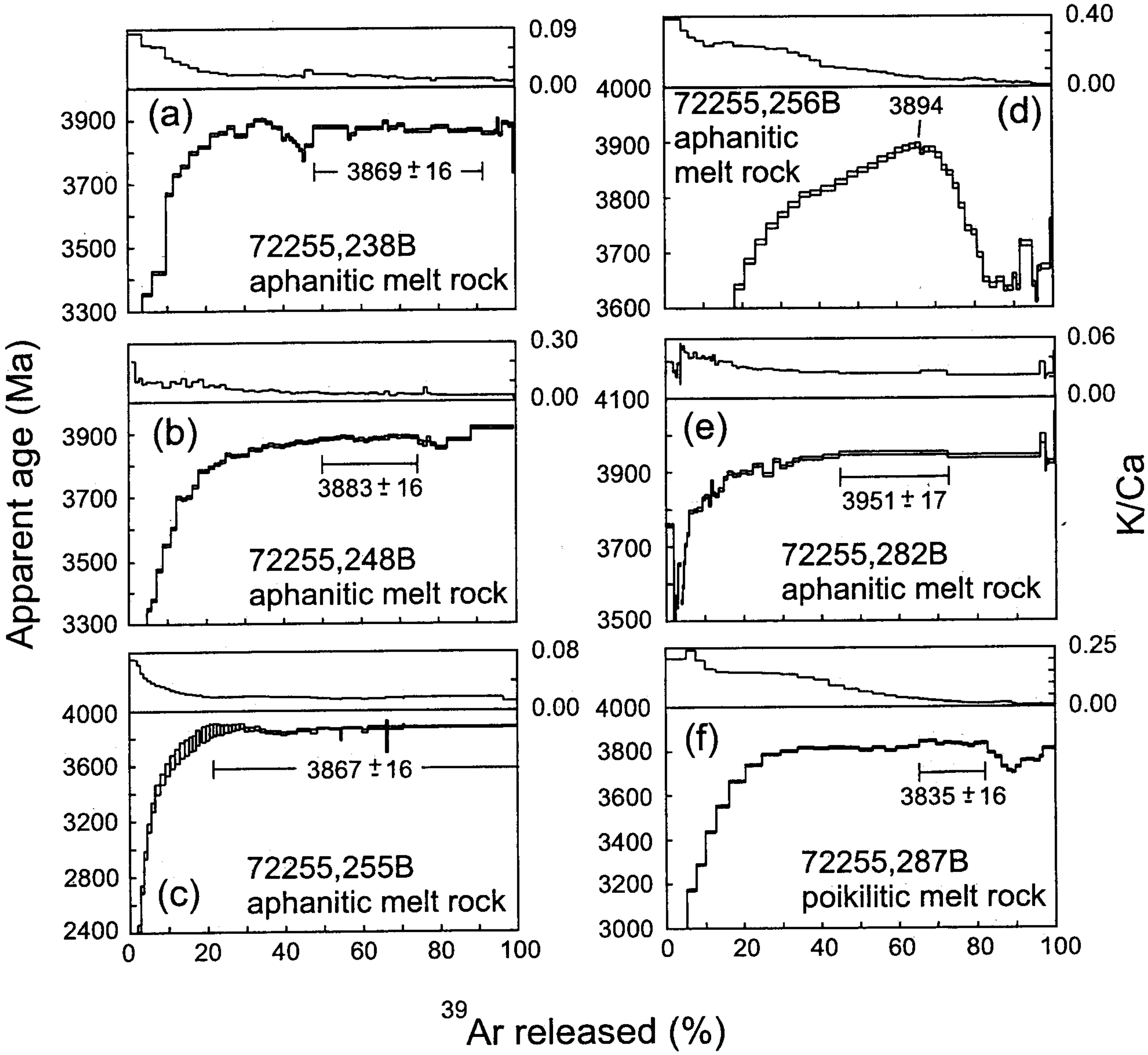


Figure 15: Ar/Ar release pateaus for different lithologies in 72255 (from Dalrymple and Ryder 1996).

Summary of Age Data for 72255

	Ar/Ar	Rb/Sr	tracks	
Leich et al. 1975	3.99 ± 0.03 b.y.			Civet Cat clast
	4.01 ± 0.03			matrix
Compston et al. 1975		4.08 ± 0.05		Civet Cat clast
		4.4 ?		ANT clasts
Schaeffer et al. 1982	laser probe			
Dalrymple and	3.862 ± 0.008			ave. 2 aphanitic “blobs”
Ryder 1996	3.883 – 3.894			2 aphanitic “blobs”
	3.835 ± 0.016			poikilitic melt clast
Hutcheon et al. 1974			3.9	whitlockite
Nemchin et al. 2007			4.2	U/Pb zircons

Table 1. Chemical composition of 72255 (matrix).

reference	Stoeser74		Morgan74	Higuchi75		Palme78		Blanchard75							
weight	matrix		,52	,83		,44		,73	,79	,52	,52	,64	,69	,69	
SiO2 %	45.1	(a)				46.72	(d)	44.8	45	49	45	45.1	44.7	46	(f)
TiO2	0.6	(a)				0.76	(d)	0.9	0.9	1.4	0.75	0.8	0.8	0.7	(f)
Al2O3	20	(a)				20.8	(d)	19.4	20.7	14.5	20.4	21.9	20.5	19.8	(f)
FeO	7.7	(a)				8.1	(d)	9.05	8.31	14	8.55	7.42	9.5	9.8	(e)
MnO	0.1	(a)				0.12	(d)	0.13	0.13	0.16	0.13	0.12	0.11	0.11	(f)
MgO	9.1	(a)				9.9	(d)	10.5	11.3	9.7	11.3	10.7	10.5	10.4	(f)
CaO	12.7	(a)				12.6	(d)	11.5	12	10.7	12	12.4	12.3	12.3	(f)
Na2O	0.5	(a)				0.48	(d)	0.49	0.58	0.32	0.56	0.5	0.4	0.38	(e)
K2O	0.2	(a)				0.2	(d)	0.39	0.21	0.27	0.23	0.27	0.28	0.25	(e)
P2O5	0.2	(a)				0.25	(d)								
S %						0.0375	(d)								
sum															
Sc ppm						18.8	(e)	15.5	18.2	19.8	18.3	17.3		19.5	(e)
V															
Cr															
Co						24.5	(e)	2530	28.9	28	25.6	26.6		21	(e)
Ni			227	222	(c)	150	(e)	7700	260		150	180			(e)
Cu						3	(e)								
Zn			2.8	2.2	(c)	2.43	(e)								
Ga						3.66	(e)								
Ge ppb			174		(c)	<100	(c)								
As						0.086	(c)								
Se			77	67	(c)										
Rb			5.8	6.85	(c)	4.98	(e)								
Sr						151	(e)								
Y						100	(e)								
Zr						400	(e)								
Nb						28									
Mo															
Ru															
Rh															
Pd ppb						<10	(c)								
Ag ppb			0.57	3.03	(c)										
Cd ppb			8.1	6.8	(c)	<50	(c)								
In ppb															
Sn ppb															
Sb ppb			0.77	1.74	(c)										
Te ppb			4.7	3.3	(c)										
Cs ppm			0.24	0.287	(c)	0.18	(e)								
Ba						328	(e)								
La						31.7	(e)	25	31	31	35	26		43	(e)
Ce						83.3	(e)	62	79	80	94	69		95	(e)
Pr						11.1	(e)								
Nd						51	(e)								
Sm						12.86	(e)	11.7	15.7	15.5	16.5	13.2		20	(e)
Eu						1.39	(e)	1.26	1.45	1.49	1.44	1.32		1.76	(e)
Gd						15.6	(e)								
Tb						2.83	(e)	1.9	2.8	3.8	3	2.2		4.7	(e)
Dy						17.7	(e)								
Ho						4	(e)								
Er						11.1	(e)								
Tm						1.68	(e)								
Yb						10.5	(e)	8.55	10.5	11.6	12.3	9.04		14.8	(e)
Lu						1.42	(e)	1.1	1.34	1.69	1.66	1.15		2.25	(e)
Hf						10.5	(e)	9.1	11.2	9.8	10.4	9.9		13.1	(e)
Ta						1.27	(e)		1.5		1.6	1			(e)
W ppb						630	(c)								
Re ppb			0.498	0.503	(c)	0.3	(c)								
Os ppb															
Ir ppb			5.28	7.01	(c)										
Pt ppb															
Au ppb			2	2.95	(c)	2.6	(c)								
Th ppm						4.31	(e)	6.6	5.4		5.8	4.3			(e)
U ppm			1.79		(c)	1.41	(e)								

technique: (a) broad-beam, e-porbe, (b) fused-bead, e.probe, (c) RNAA, (d) XRF, (e) INAA, (f) AA

Table 2. Chemical composition of 72255 (matrix).

reference	Fruchter75	Keith74		Morgan75		Jovanovic75		Compston75			and others		
weight		402 g		,83									
SiO2 %													
TiO2													
Al2O3													
FeO													
MnO													
MgO													
CaO													
Na2O													
K2O	0.22	0.22	(a)										
P2O5						0.25	(b)						
S %													
sum													
Sc ppm													
V													
Cr													
Co													
Ni				222	(b)								
Cu													
Zn				2.2	(b)								
Ga													
Ge ppb													
As													
Se				67	(b)								
Rb				6.68	(b)			15	14.6	9.8	5.7	5.8	(c)
Sr								145	142	141	137	141	(c)
Y												Leich75	
Zr												376	(c)
Nb													
Mo													
Ru						>20	(b)						
Rh													
Pd ppb													
Ag ppb				3.03	(b)								
Cd ppb				6.8	(b)								
In ppb													
Sn ppb													
Sb ppb				1.74	(b)								
Te ppb				3.3	(b)								
Cs ppm				0.287	(b)							Liech75	
Ba												324	(c)
La													
Ce													
Pr													
Nd													
Sm													
Eu													
Gd													
Tb													
Dy													
Ho													
Er													
Tm													
Yb													
Lu													
Hf													
Ta													
W ppb													
Re ppb				0.503	(b)								
Os ppb						17	(b)						
Ir ppb				7	(b)								
Pt ppb													
Au ppb				2.95	(b)			Nunes et al. 1974				Leich75	
Th ppm	4.8	4.4	(a)					4.22	5.72	6.36			(c)
U ppm	1.28	1.2	(a)	1.82	(b)	1	(b)	1.145	1.536	1.663		1.42	(c)

technique: (a) radiation counting, (b) RNAA, (c) IDMS

Table 3. Chemical composition of 72255 (clasts).

						Morgan74								
reference	Dalrymple96					Wolf79		Blanchard75		Leich75		Blanchard75		
weight	aphanite	poik.	granulite	granulite		Civit Cat		Civit Cat		Civit Cat		while,45	black rim,45	
SiO2 %	46.1	45.1	44.3		(b)	norite		52	(d)			43	46	(d)
TiO2	0.8	1.4	0.2		(b)			0.3	(d)			0.7	1.2	(d)
Al2O3	20	22.3	29		(b)			15.5	(d)			35.8	19.7	(d)
FeO	8.4	6.8	4.5	4.5	(a)			7.4	(a)			0.13	9.05	(a)
MnO	0.12	0.1	0.05		(b)			0.12	(d)			0.003	0.136	(d)
MgO	10.3	9.4	7.7		(b)			15.9	(d)			1.43	11.3	(d)
CaO	11.8	12.4	15.2		(b)			9.1	(d)	13	(a)	18.9	11.5	(d)
Na2O	0.47	0.42	0.36	0.39	(a)			0.33	(a)			0.63	0.54	(a)
K2O	0.23	0.22	0.02	0.03	(a)			0.08	(d)	0.17	(a)	0.12	0.28	(d)
P2O5														
S %														
sum														
Sc ppm	19	14.2	5.8	6.4	(a)			13.2	(a)			0.45	20.1	(a)
V														
Cr	1837	1378	714	777	(a)			1095	(a)					
Co	29	16	22	22	(a)			29	(a)			0.33	24.9	(a)
Ni	181	92	274	243	(a)	4	(c)						140	(a)
Cu														
Zn						4.5	(c)							
Ga														
Ge ppb						61	(c)							
As														
Se						280	(c)							
Rb	8	12			(a)	1.27	(c)							
Sr	151	151	144	172	(a)					139				
Y														
Zr	469	215	59	100	(a)					132				
Nb														
Mo														
Ru														
Rh														
Pd ppb														
Ag ppb						0.76	(c)							
Cd ppb						5.8	(c)							
In ppb														
Sn ppb														
Sb ppb														
Te ppb						14	(c)							
Cs ppm	0.31	0.35	0.04		(a)	0.058	(c)							
Ba	362	221	61	68	(a)					172				
La	33.3	17.3	3.3	4	(a)			16	(a)			1.15	40.1	(a)
Ce	89.9	46.4	9.2	10.5	(a)			46	(a)			2.68	102	(a)
Pr														
Nd	51.8	22.6	4.2	5.9	(a)									
Sm	15.1	8	1.5	1.7	(a)			7.6	(a)			0.4	18.8	(a)
Eu	1.44	1.27	0.85	0.88	(a)			1.75	(a)			1.39	1.53	(a)
Gd														
Tb	3.1	1.7	0.3	0.3	(a)			1.9	(a)			0.1	4.3	(a)
Dy														
Ho														
Er														
Tm														
Yb	10.7	6.5	1.6	1.7	(a)			6.6	(a)			0.2	14.2	(a)
Lu	1.5	0.9	0.2	0.2	(a)			1.01	(a)			0.03	1.88	(a)
Hf	11.5	6.6	1.7	1.4	(a)			5.5	(a)				14.2	(a)
Ta	1.22	0.92	0.22	0.23	(a)								1.4	(a)
W ppb														
Re ppb						0.007	(c)							
Os ppb														
Ir ppb	4.9	3.2	11.2	12.1	(a)	0.004	(c)							
Pt ppb														
Au ppb	5.9	4.3	5.9	4.4	(a)	0.008	(c)							
Th ppm	6	3.5	1.3	1.5	(a)								6.6	(a)
U ppm	1.89	0.92	1.27	0.33	(a)	0.24	(c)			0.45	(a)			

technique: (a) INAA, (b) fused-bead elec. Probe, (c) RNAA, (d) AA

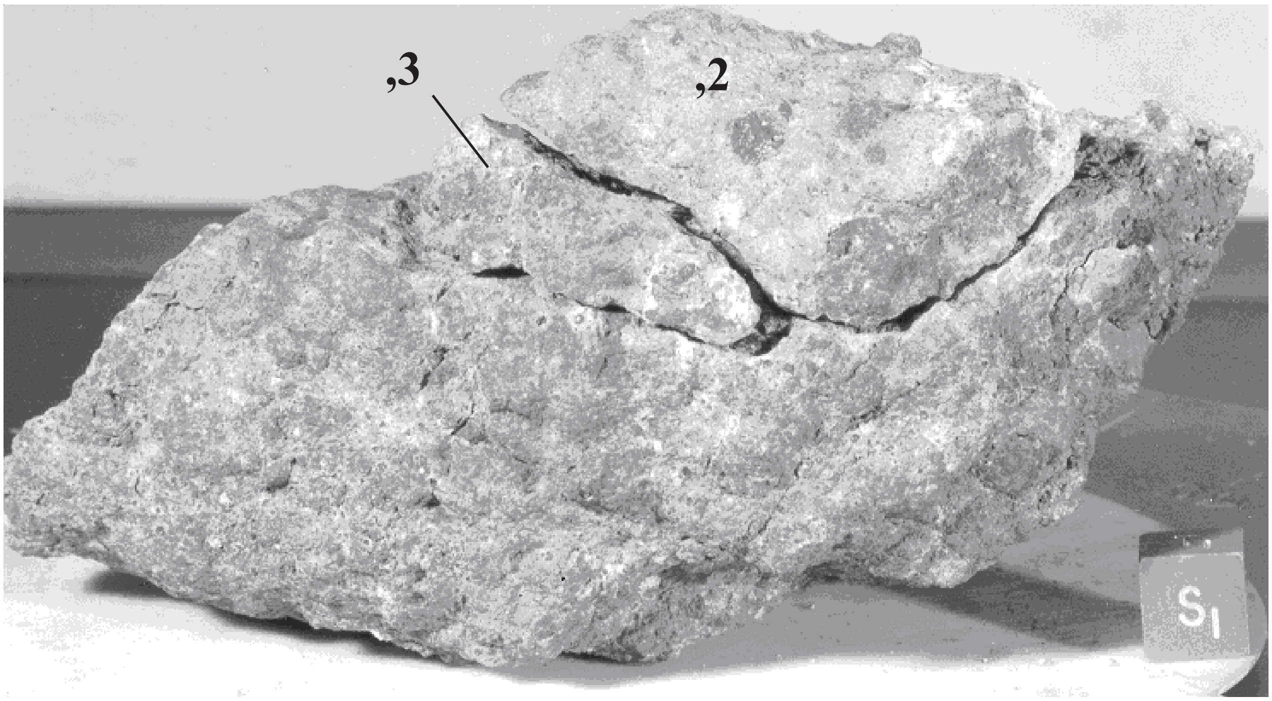
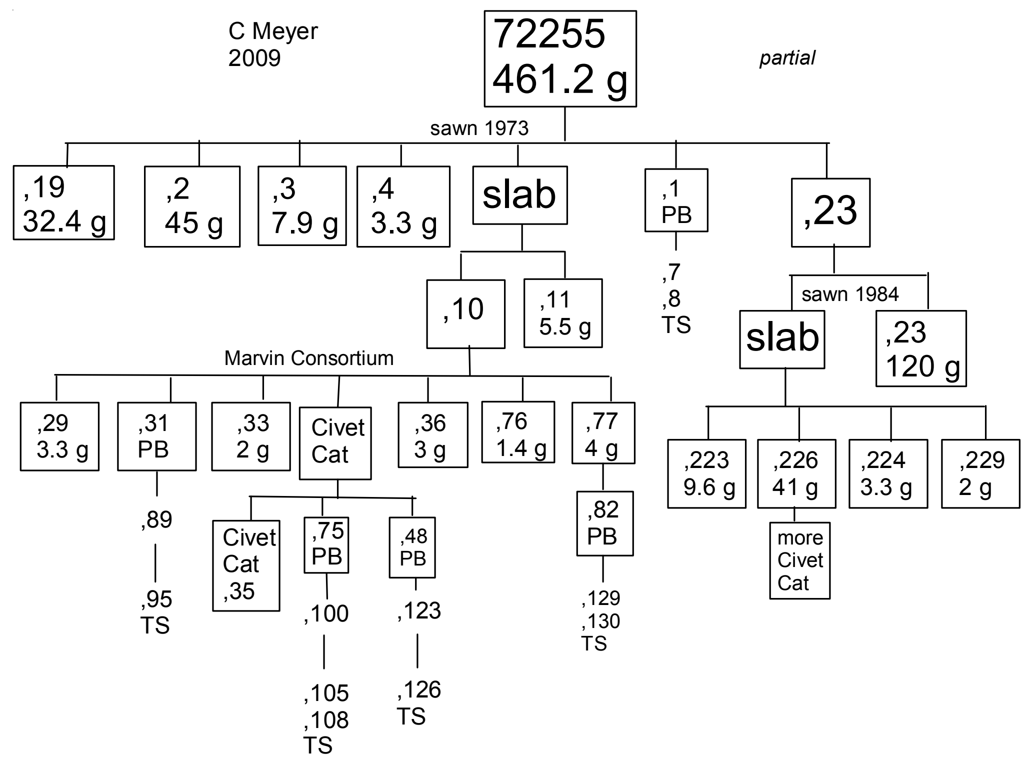
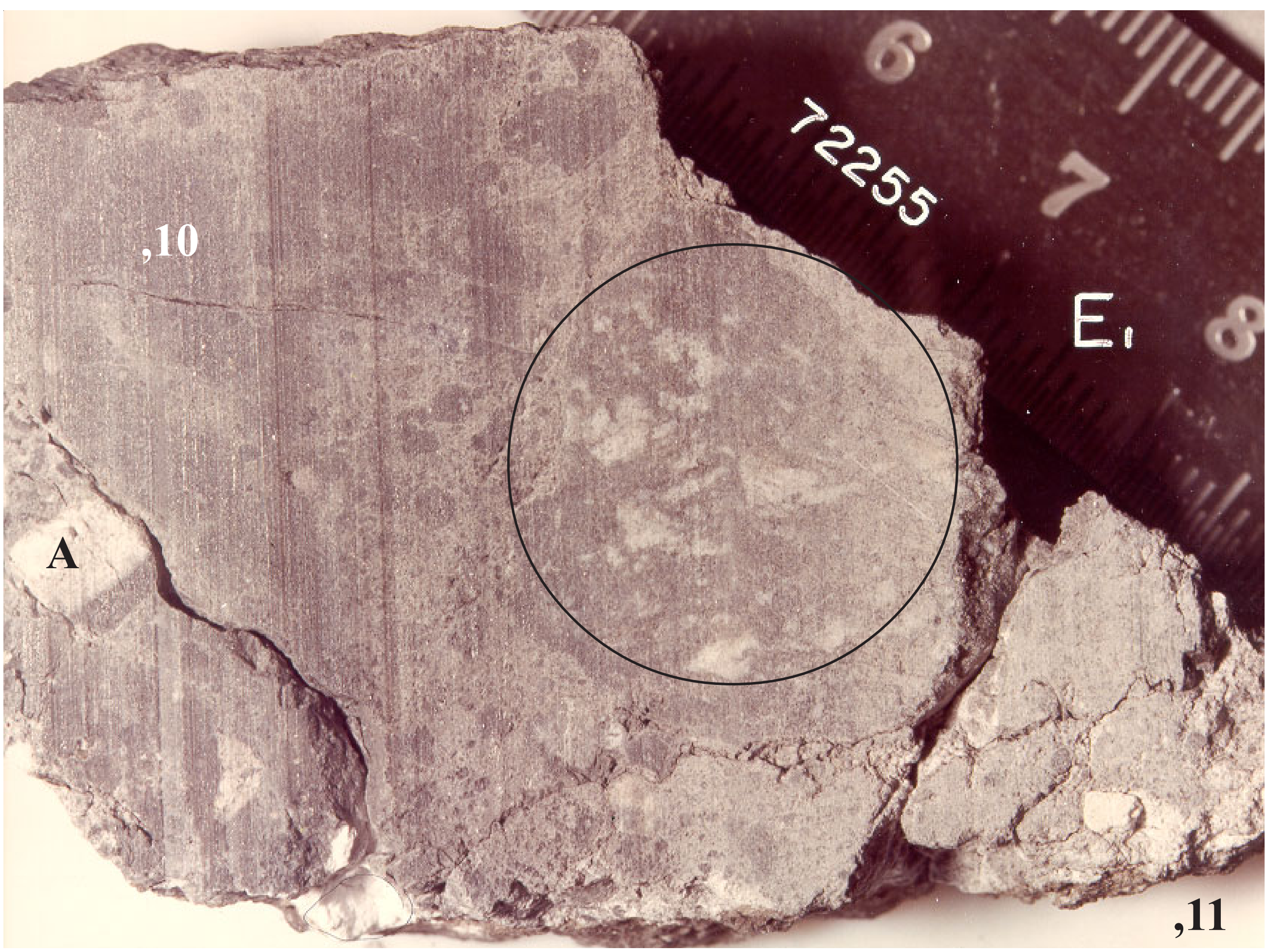


Figure 16: Exterior surface of 72255 showing pitina with micrometeorite craters. Note position of numbered pieces. Cube is 1 cm. NASA S73-16005.





Figures 17 a and b: Two views of both sides of first slab (,10) cut thru 72255. NASA S73-32647 left; S73-32648 above. Scale is in cm. Circle above approximately outlines "Civet Cat" norite clast.

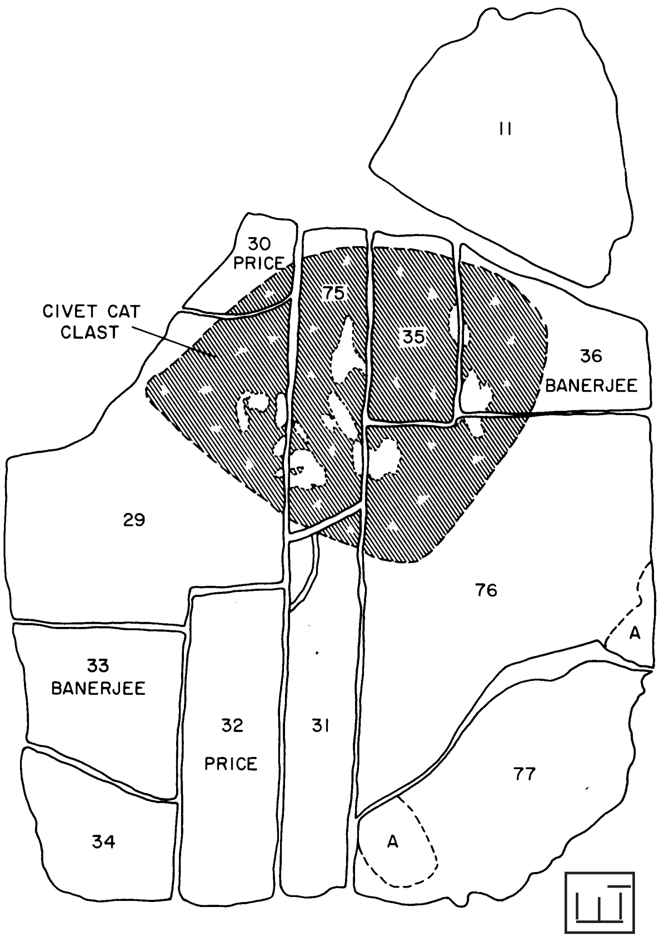
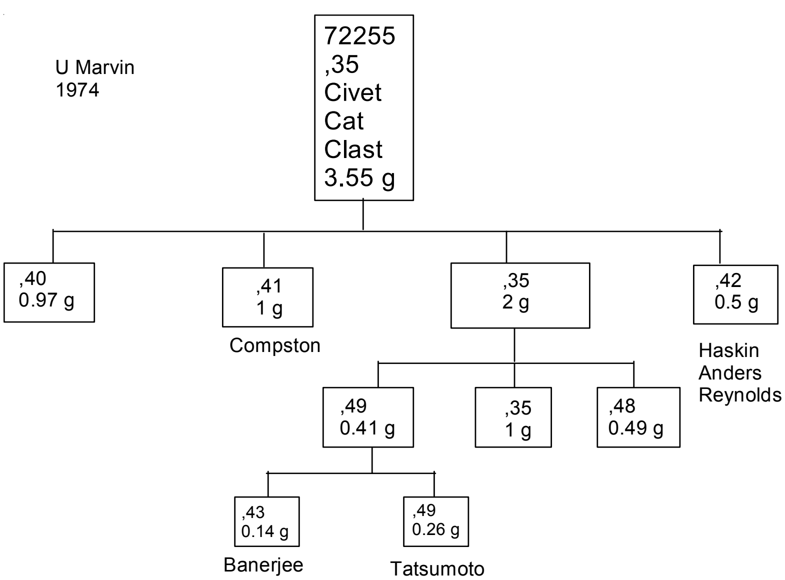


Figure 18: Cutting plan for "Civet Cat" norite clast in slab of 72255 - compare with previous figure (from Marvin 1974, Appendix A).



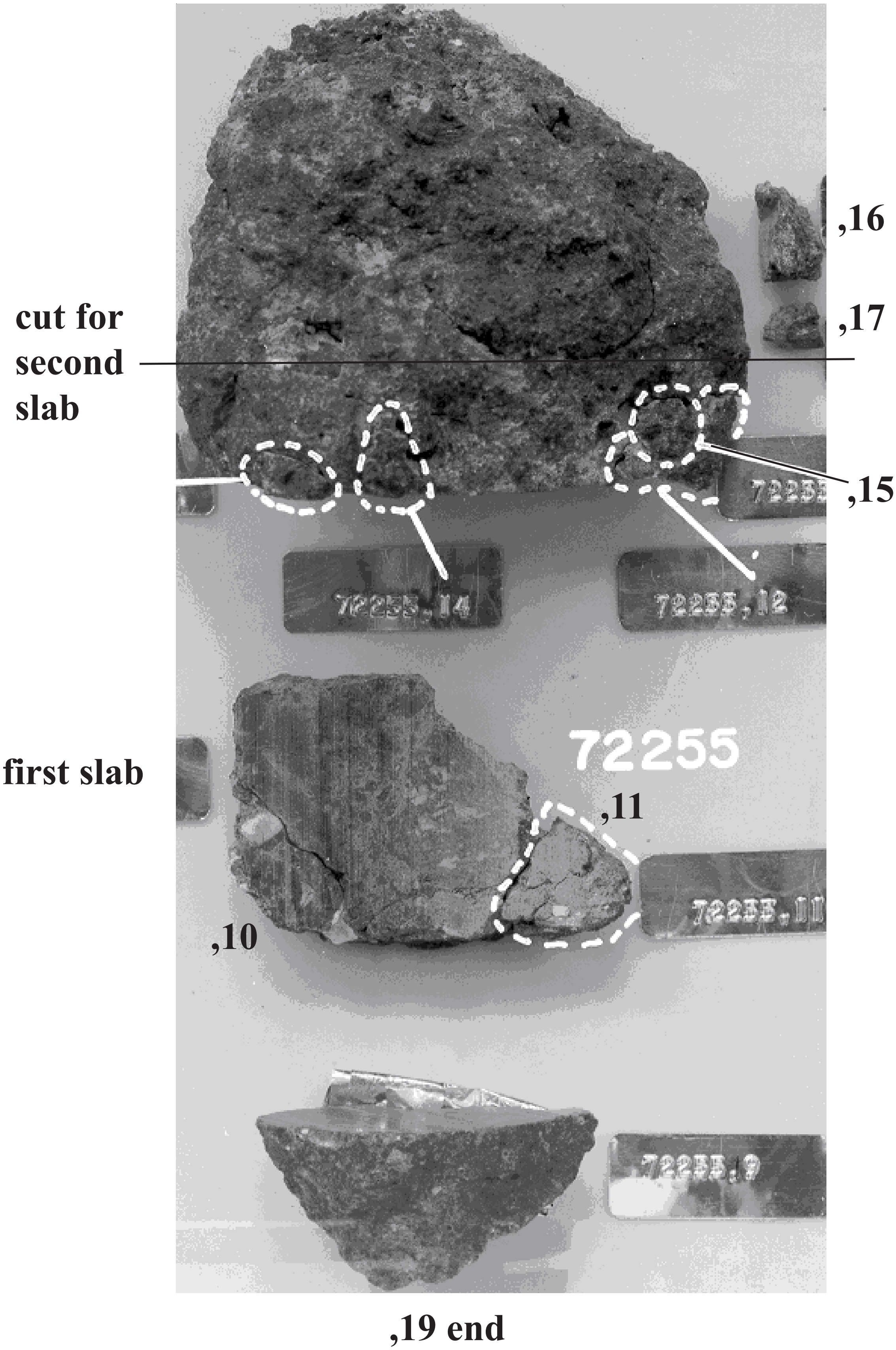


Figure 19: Processing photo for 72255 showing first slab and approximate position of second slab. NASA S73-32620.

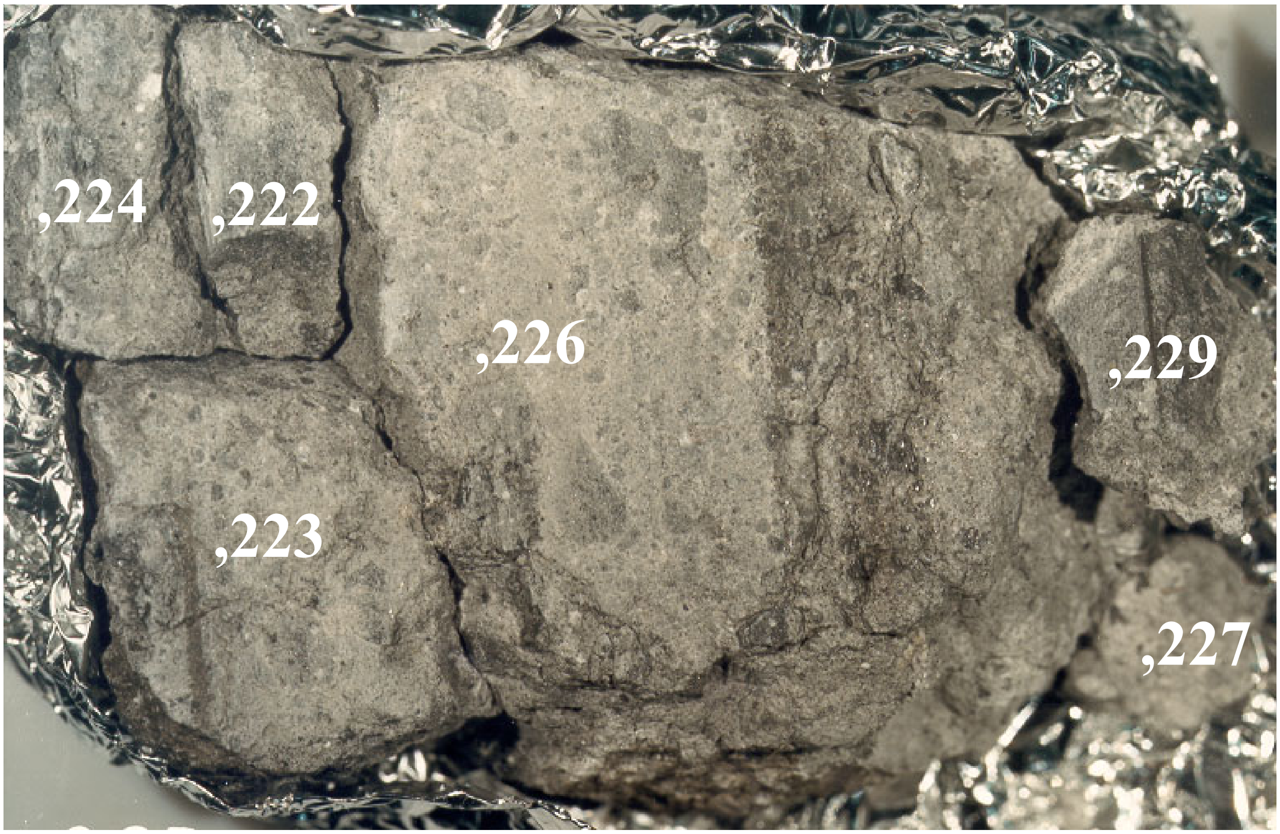
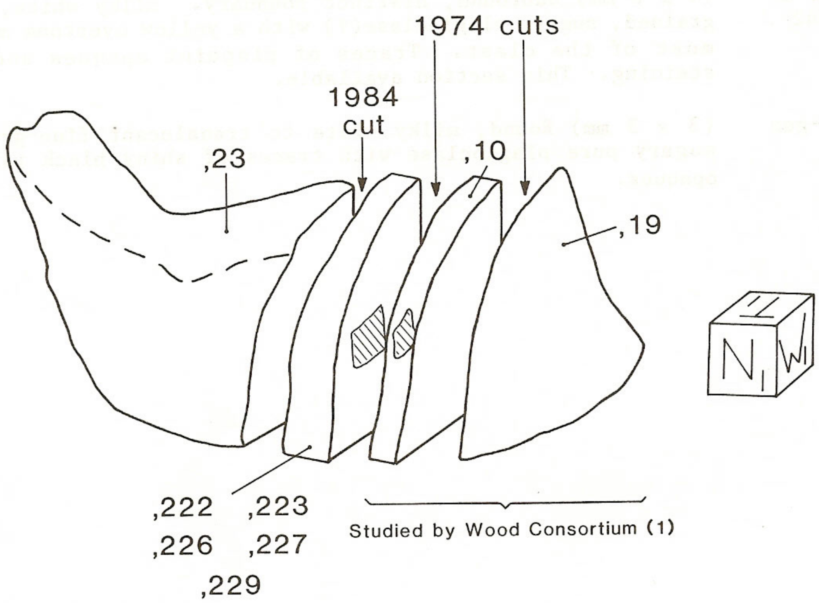


Figure 20: Photo of second slab cut thru 72255. Sample is 6 cm across. East face. NASA S90-48699. Note that Civet Cat Norite clast does not extend through slab.

Table 4: 72255	U ppm	Th ppm	K ppm	Rb ppm	Sr ppm
Nunes et al. 1974	1.145	4.222			
	1.536	5.724			
	1.663	6.362			
Compston et al. 1975				2.56	101.4
				3.02	100.9
				14.95	145.6
				1.11	140.6



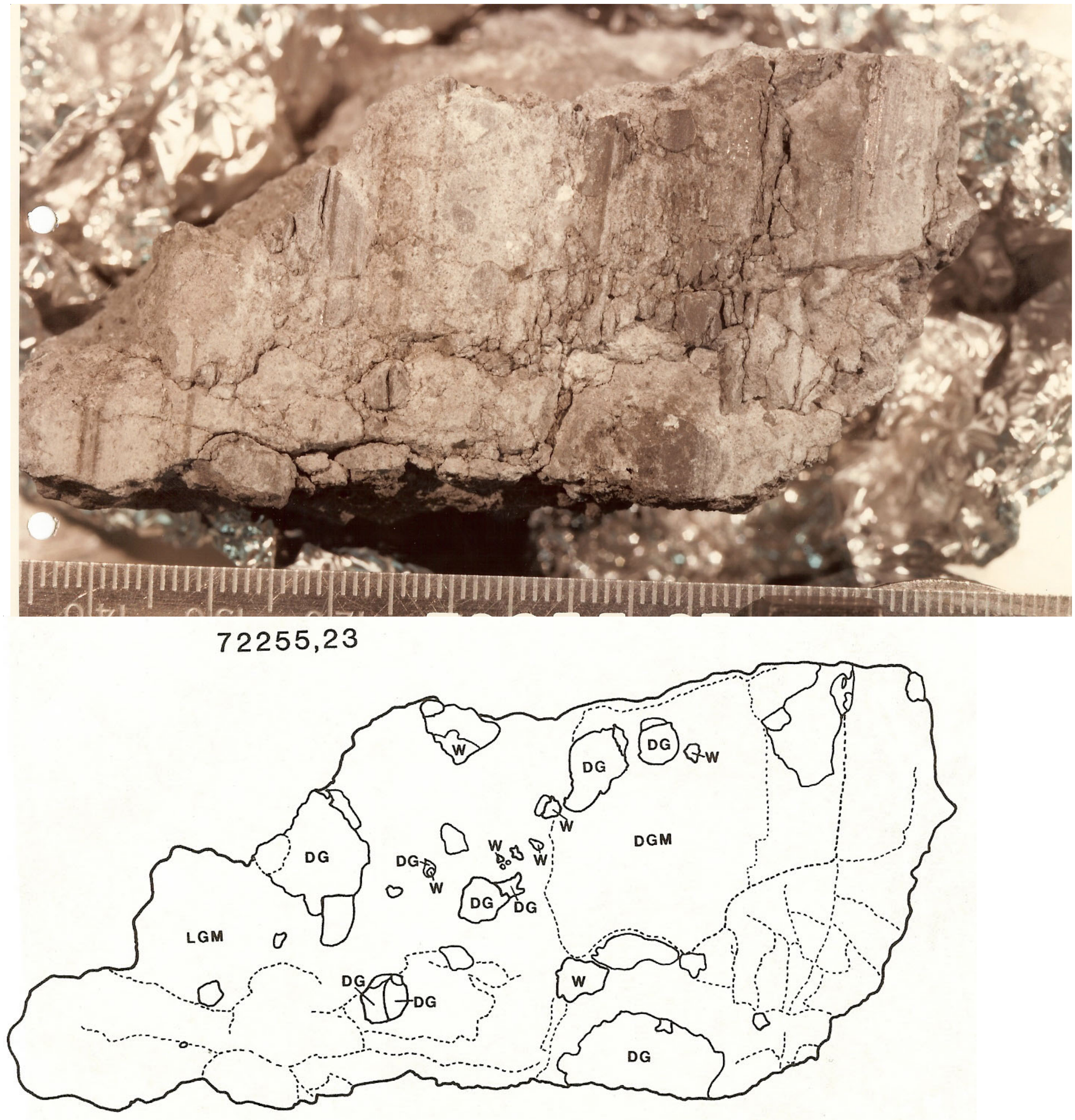


Figure 21: Photo and map of butt end of 72255 (Mosie 1985). S84-41704. Scale is metric.

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