14063 - 135.45 grams
14064 - 107.5 grams
Light matrix Breccia

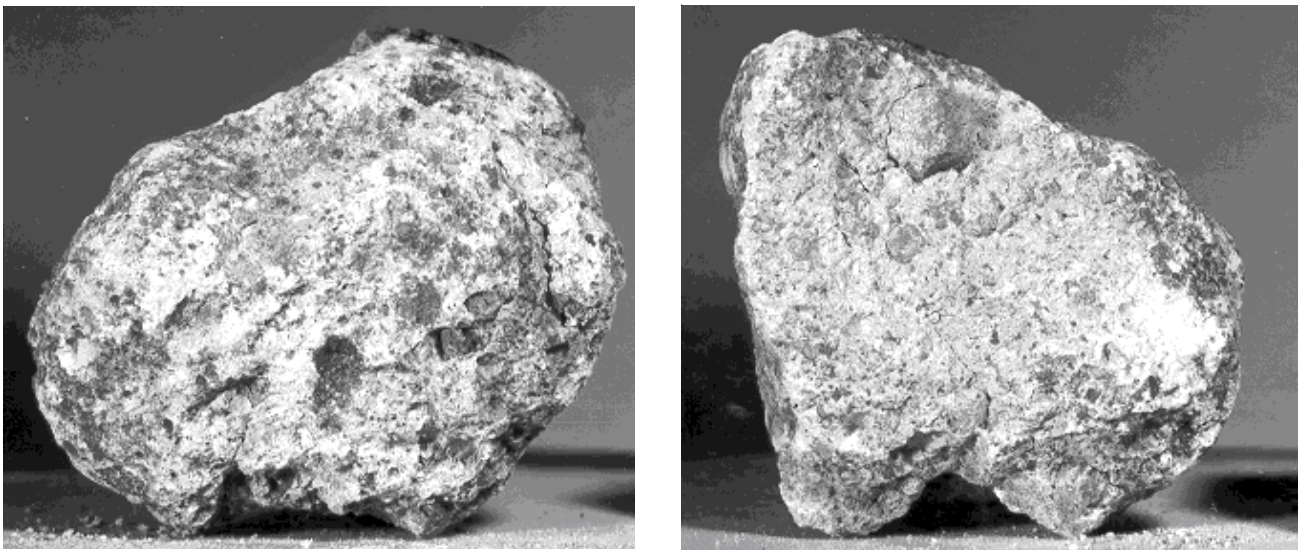


Figure 1: Two views of 14064. NASA S71-33303 and 33313. Sample is about 2 inches round. Note the large zap pit in the middle of the first photo and the small round clast (,2) at the top of the second photo.

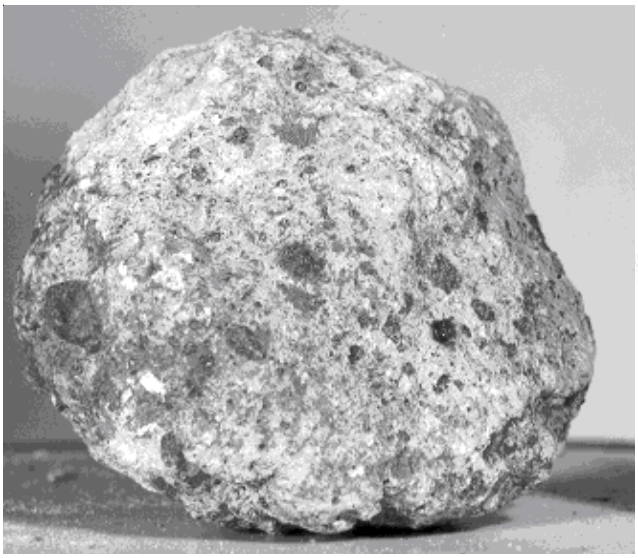


Figure 2: Photo of 14063. NASA S71-28516. Cube is 1 inch.

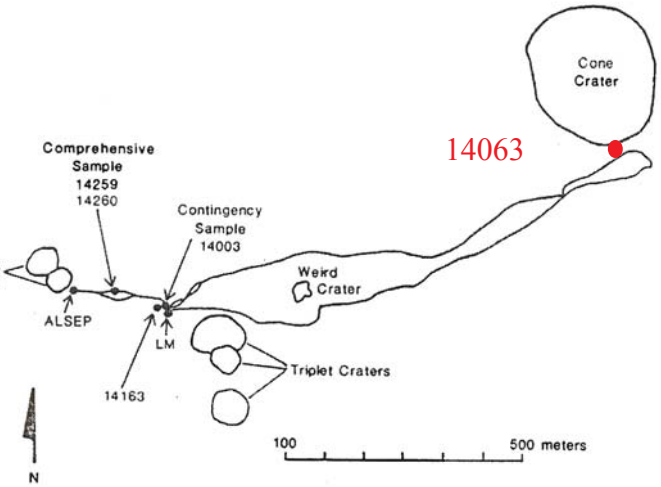


Figure 3: Map of Apollo 14 traverse to Cone Crater and location of white rocks.

Introduction

14063 and 14064 were grab samples picked up from the regolith at the rim of Cone Crater and brought to Earth is the same bag (16N). 14063 is from the light rock lithology in the boulder field where 14082 and 14083 were collected. They are blocky, subangular rocks with a light to moderate density of glass-lined zap pits (figure 1 and 2). Irregular fractures are poorly developed. A number of subrounded clast molds occur in both rocks. The rocks are friable breccias having about 40% of subangular to subrounded clasts in a very

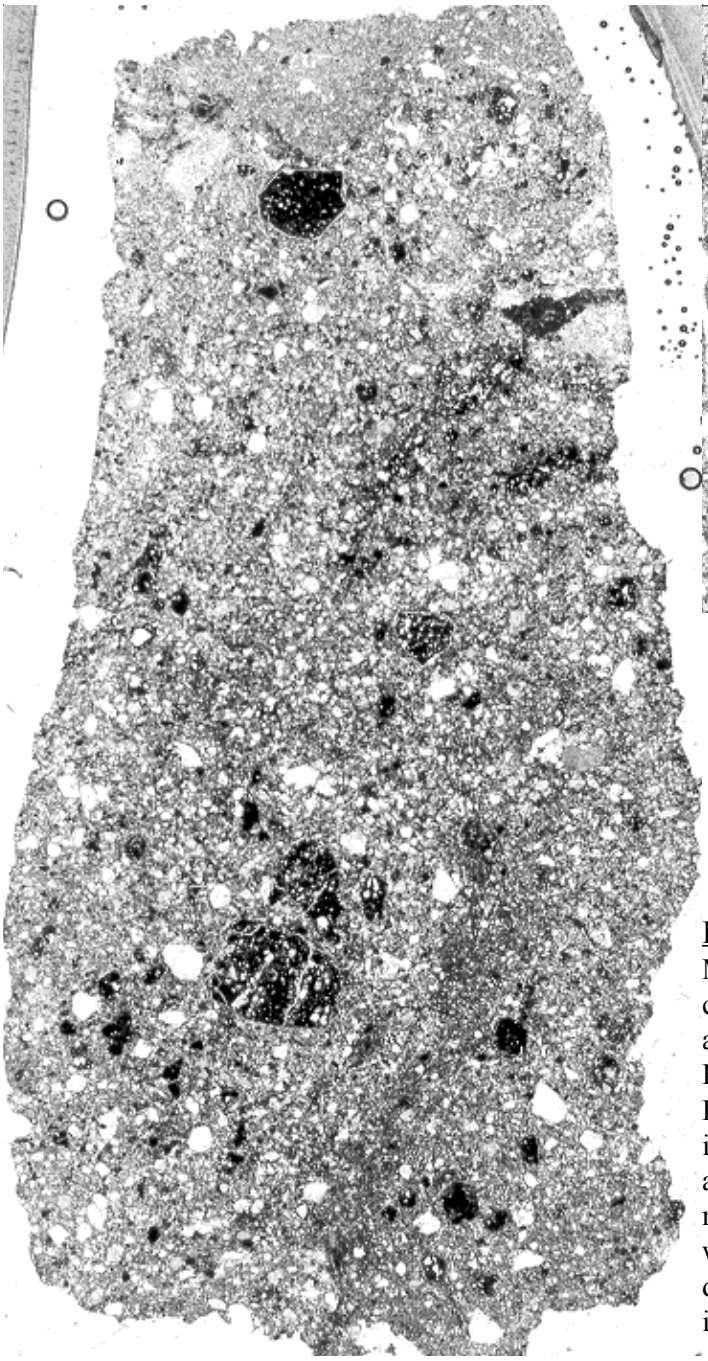


Figure 4: Thin section photomicrograph of 14063,51 showing seriate fragmental texture. NASA S71-40530. About 1 cm by 3 cm.

light-gray fine-grained matrix. Dark clasts are subordinate to light clasts, and there is some glass.

The light matrix breccias seem to have relatively low meteoritic siderophiles compared with the dark matrix breccias. The ages are 3.8 to 3.9 b.y., with an exposure to cosmic rays of about 24 – 36 m.y.

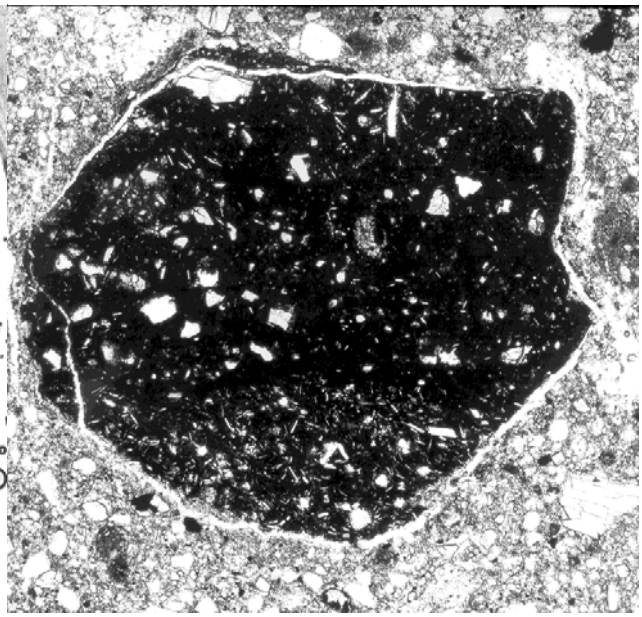


Figure 5: Close up of black clast in figure 3.

Petrography

McGee et al. (1977) and Simonds et al. (1977) classified these samples as light matrix breccias, which are more fragmental than the dark matrix breccias. However, they are undoubtedly another facies of the Fra Mauro Formation, because of their interlayering in the boulders (see figure 1 in section on 14082). In any case they are a polymict breccias composed of a mixture of lithic and mineral clasts in a fine matrix with seriate grain size distribution. Plagioclase is the dominant mineral, with subordinate pyroxene, olivine, ilmenite, spinel and metallic iron grains.

Quaide and Wrigley (1972), Ryder and Bower (1976) and Steele and Smith (1976) also studied the complexity of 14063-14064 breccias. They found several different areas in each, all breccias. They also reported glass in these breccias, but not of the kind found in regolith breccias. Chao et al. (1972) and Stadermann et al. (1991) also give modal analysis of various portions of 14063.

Ridley (1975) studied small clasts of aluminous mare basalt found in 14063 (figure 6). They have high TiO_2, Na_2O, Mg/Fe and lower FeO than other aluminous mare

scale = 2.8 mm across

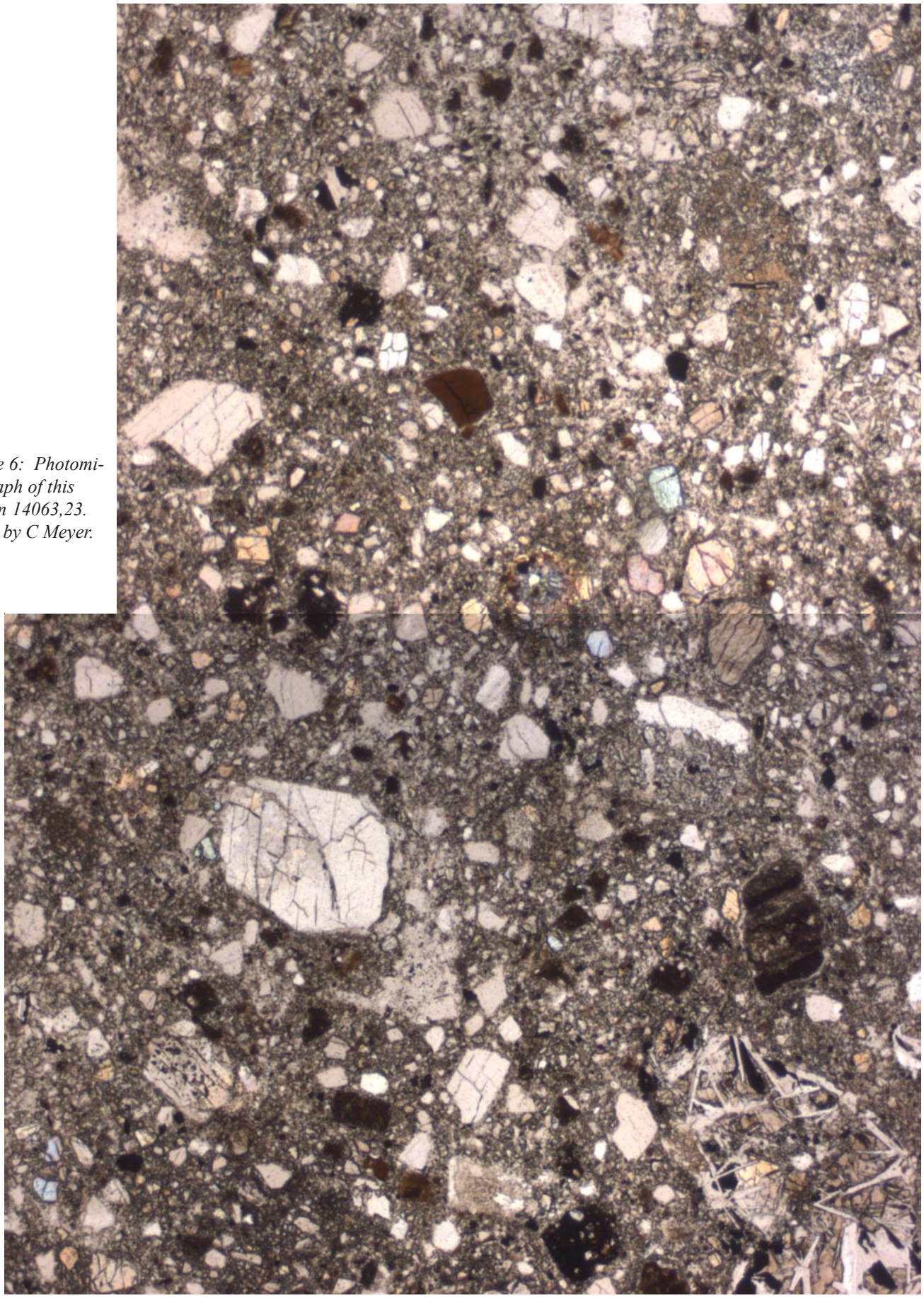


Figure 6: Photomicrograph of this section 14063,23. Photo by C Meyer.

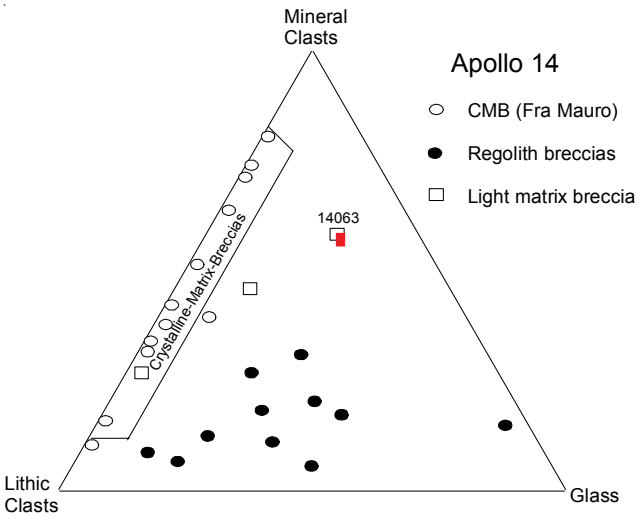


Figure 7: Simonds diagram for Apollo 14 breccias.

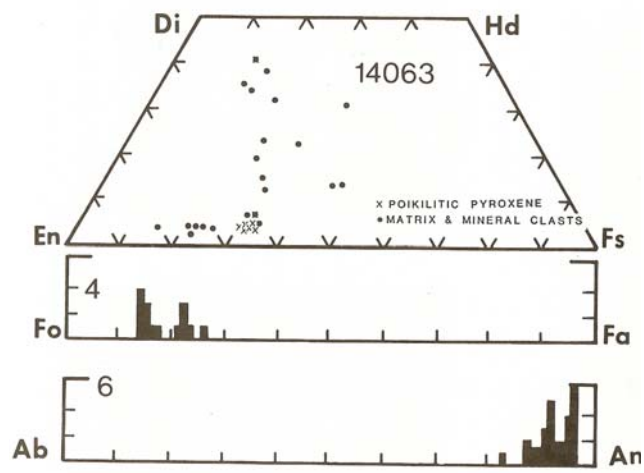


Figure 8: Composition of olivine, yroxene and plagioclase in 14083 (McGee et al. 1977).

basalts and texture defined by lathy to acicular plagioclase, lathy ilmenite, intergranular pyroxene and pale-brown mesostasis. Steele and Smith (1976) also reported the presence of mare basalt in 14063.

Pink spinel is said to be abundant in 14063 (see Christophe-Michel-Levy (1972) and Steele (1972). However, it is rare but easily spotted because of its vivid color.

Chemistry

Rose et al. (1972), Laul et al. (1972), Taylor et al. (1972), Helmke et al. (1972), Ebihara et al. (1992) and others have analyzed 14063, 14064 (tables 1 and 2, figures 9 and 10). These light matrix breccias are more aluminous and less Fe-rich than the typical Fra Mauro breccias.

Morgan et al. (1972), Hertogen et al. (1977), Gnos et al. (1976) and Ebihara et al. (1992) found that 14063 and 14064 were "nearly pristine" – i.e. low Ni, Ir, Au (table 1 and 2).

Moore et al. (1972) and Cadogen et al. (1972) reported the C content (figure 11).

Radiogenic age dating

Stadermann et al. (1991) dated quite a few bits of 14063, finding a range of ages from 3.81 b.y. to 3.94 ± 0.02 b.y. based on Ar/Ar plateau technique (figure 12). Bernatowicz et al. (1978) determined the age of 14064 as 3.81 ± 0.04 b.y. (figure 13).

Cosmogenic isotopes and exposure ages

Stadermann et al. (1991) determined exposure ages of various lithologies of 14063 ranging from 24 to 36 m.y. by the ^{38}Ar method. Cone Crater is ~ 26 m.y.

Mineralogical Mode for 14063

	Simonds et al 1977
Matrix	73 %
Clasts	
Plagioclase	9
Mafic	5.5
Breccia	8.5
Granulite	1
Mare basalt	
Felds basalt	0.5
Pore space	

Mineralogical Mode for 14064

	Simonds et al 1977
Matrix	74 %
Clasts	
Plagioclase	5.5
Mafic	2
Breccia	12
Granulite	
Mare basalt	
Felds basalt	5
Pore space	0.5

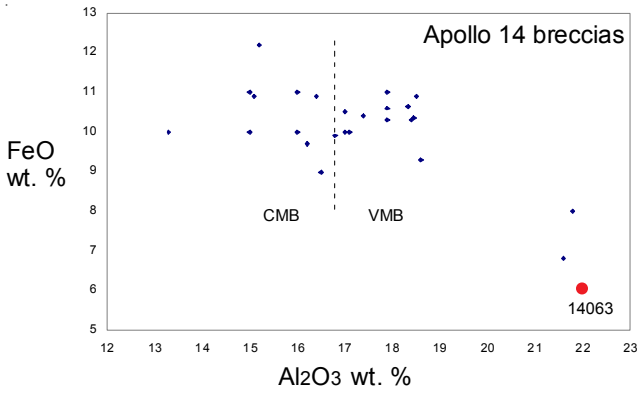


Figure 9a: Composition of Apollo 14 breccia samples with 14063 highlighted.

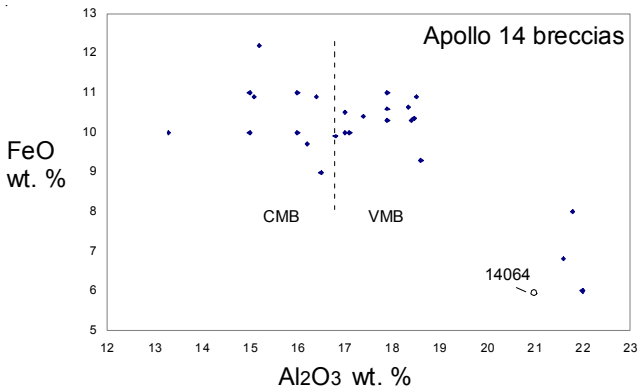


Figure 9b: Composition of Apollo 14 breccias.

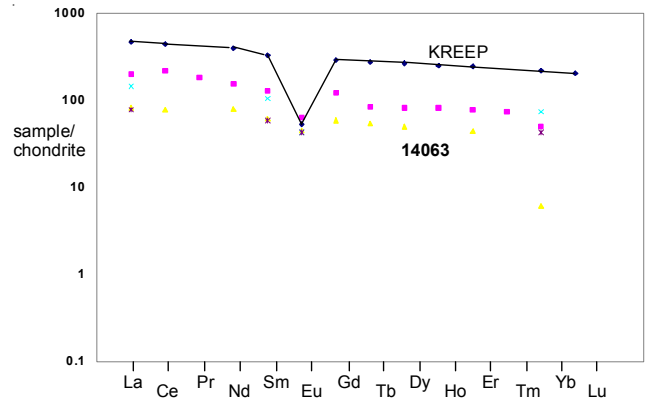


Figure 10a: Normalized rare-earth-element diagram for 14063 compared with that of KREEP.

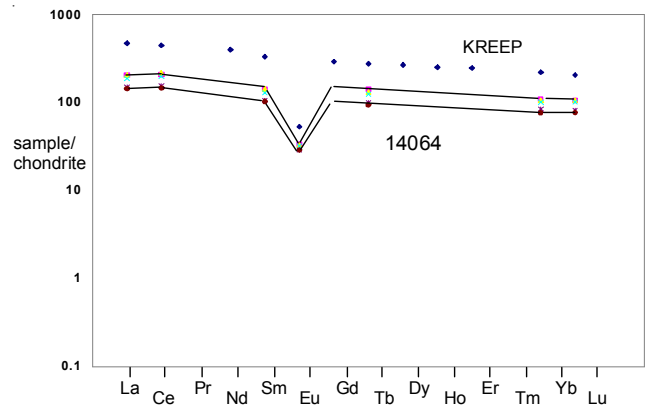


Figure 10b: Normalized rare-earth-element diagram for 14064 compared wtih that of KREEP.

Other Studies

Drozd et al. (1976) studied the Xe isotopes finding no evidence of excess fission Xe in this sample.

Magnetic studies by Nagata et al. (1972, 1975) and Gose et al. (1972) found nothing special.

Schwerer et al. (1972) and Huffman et al. (1974) determined the Mossbauer spectra (figure 14).

Dran et al. (1972) studied tracks, Tatsumoto et al. (1972) studied Pb isotopes, and Epstein and Taylor (1972) studied oxygen, carbon, silicon and hydrogen isotopes etc.

Processing

14063, 14064 and 14065 were returned in bag 16N in ALSRC 1006, which was sealed from air. There are 30 thin sections of 14063 and 19 for 14064.

14064 was studied by the Imbrium Consortium led by John Wood

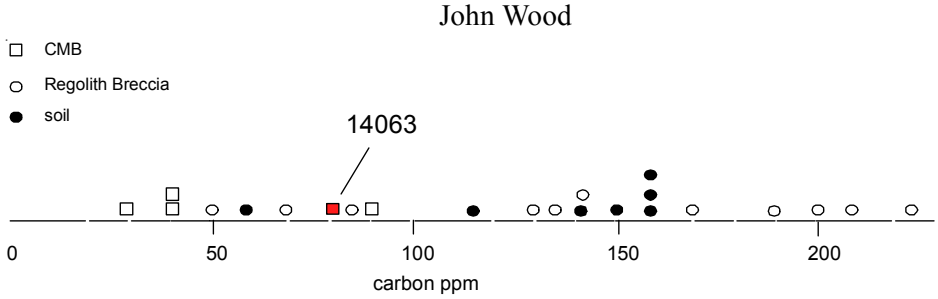
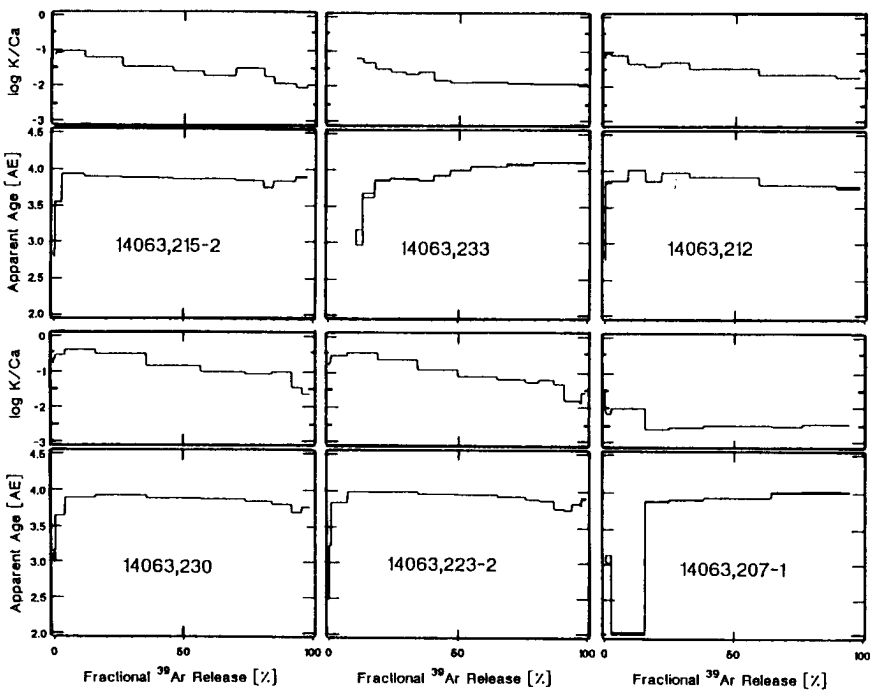


Figure 11: Carbon content of Apollo 14 samples.



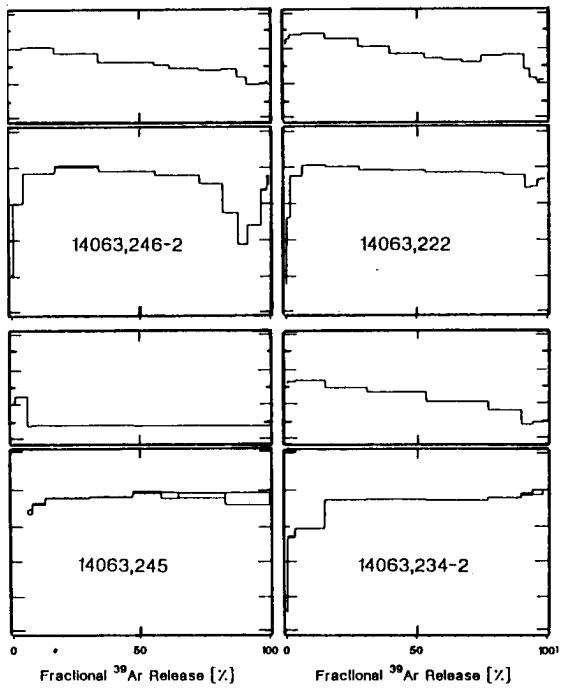


Figure 12: Ar plateau diagrams of various splits of 14063 (from Staderman et al. 1991).

Summary of Age Data for 14063

	Ar/Ar
Stadermann et al. 1991	3.88 ± 0.01 b.y.
	3.87 ± 0.01
	3.88 ± 0.03
	3.81 ± 0.08
	3.94 ± 0.02
	3.86 ± 0.02
	3.92 ± 0.02
	3.90 ± 0.02
	3.90 ± 0.03
	3.86 ± 0.01
Bernatowicz et al. 1978	3.81 ± 0.04 b.y.

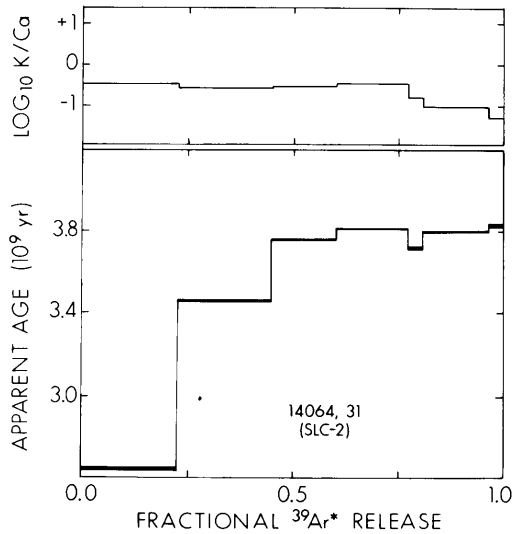


Figure 13: Argon 39/40 release pattern for 14064 (Bernatowicz et al. 1978).

Table 1a. Chemical composition of 14063.

reference	Chao 72b			Rose 72				Taylor72		Morgan72				Helmke72		
weight					Chao72			matrix		matrix	matrix	clast		fines	frag.	
SiO2 %	49.1	44.6	(d)	44.69	45.02	45.22	(d)	45.5								
TiO2	1.18	1.2		1.48	1.58	1.87	(d)	1.27								
Al2O3	22.1	24.8		22.31	21.53	21.02	(d)	23								
FeO	5.7	4.5		6.71	7	6.94	(d)	5.82								
MnO	0.09			0.08	0.09	0.09	(d)	0.1								
MgO	6.9	9		10.8	10.79	10.4	(d)	9.67								
CaO	12.4	14.2		12.7	12.4	12.76	(d)	13								
Na2O	0.85	0.95		0.76	0.93	0.93	(d)	0.7								
K2O	0.61	0.16		0.15	0.2	0.16	(d)	0.11								
P2O5				0.22	0.29	0.23	(d)									
S %																
sum																
Sc ppm				13	15	18	(d)	12	(a)					14.2	12.6	(b)
V				33	38	36	(d)	23	(a)							
Cr	410			1437	1300	1163	(d)	1095	(a)							
Co				16	17	16	(d)	17	(a)	19	18	26	(c)	21	15	(b)
Ni				110	110	110	(d)	99	(a)							
Cu				2.3	3.3	5	(d)	10	(a)							
Zn				4	4	4	(d)			5.9	5.3	7.2	(c)			
Ga				4.8	6	5.5	(d)	3	(a)							
Ge ppb										23	36	42	(c)			
As																
Se										8	8	31	(c)			
Rb				5	6	4	(d)	3.5	(a)							
Sr				205	220	200	(d)	235	(a)							
Y				94	130	110	(d)	90	(a)							
Zr				260	300	340	(d)									
Nb				16	20	16	(d)	20	(a)							
Mo																
Ru																
Rh																
Pd ppb																
Ag ppb										0.8	0.87	2.3	(c)			
Cd ppb										4.5	18	2.3	(c)			
In ppb										2.8	3.3	3.1	(c)			
Sn ppb																
Sb ppb										1.4	1.3	0.46	(c)			
Te ppb																
Cs ppm										0.238	0.309	0.178	(c)			
Ba				250	380	315	(d)	460	(a)							
La				27	30	26	(d)	47	(a)					19.4	15.9	(b)
Ce								133	(a)					47	49	(b)
Pr								16.5	(a)							
Nd								70	(a)					36	17	(b)
Sm								19	(a)					9.17	6.84	(b)
Eu								3.6	(a)					2.55	2.89	(b)
Gd								24	(a)					11.6	8.3	(b)
Tb								3.1	(a)					1.96	1.49	(b)
Dy								20	(a)					12	8.3	(b)
Ho								4.6	(a)							
Er								12.5	(a)					7		(b)
Tm								1.8	(a)					6.8	4.7	(b)
Yb				6.8	9.5	8.2	(d)	8.2	(a)					0.99	0.71	(b)
Lu																
Hf								6.8	(a)					11	12	(b)
Ta																
W ppb								400	(a)							
Re ppb										0.26	0.064	0.099	(c)			
Os ppb																
Ir ppb										0.71	1.37	1.82	(c)			
Pt ppb																
Au ppb										0.22	0.28	0.28	(c)			
Th ppm								3.2	(a)							
U ppm								0.82	(a)							

technique: (a) spark source mass spec., (b) INAA, (c) RNAA, (d) "microchemical"

Table 1b. Chemical composition of 14063.

reference	Laul72						Ryder76		
weight							matrix		
SiO2 %							51.4	50.8	(a)
TiO2	1.5	1.4	1.3	1.8	1.6	(b)	0.55	1.37	(a)
Al2O3	22	21.5	20.4	22.8	23.5	(b)	24.9	20.3	(a)
FeO	7	6.8	7.7	6.5	6.4	(b)	3.9	6.1	(a)
MnO	0.081	0.081	0.085	0.079	0.076	(b)	0.06	0.08	(a)
MgO	.						4.5	5.4	(a)
CaO	13.1	13.2	11.6	13.3	14.6	(b)	12.5	11.7	(a)
Na2O	0.835	0.782	0.755	0.782	0.795	(b)	0.95	0.87	(a)
K2O	0.17		0.11	0.12	0.13	(b)	1.74	1.55	(a)
P2O5							0.02	0.42	(a)
S %									
sum									
Sc ppm	13.6	12.4	13.5	14.7	14.1	(b)			
V	29	27	31	17	18	(b)			
Cr	1231	1440	1596	1095	1006	(b)			
Co	20	18	27	17	17	(b)			
Ni									
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	360	550	280	310	260	(b)			
La	26.5	34.3	18.6	22.6	21.8	(b)			
Ce									
Pr									
Nd									
Sm	10.6	15.6	8.7	10.6	10.1	(b)			
Eu	2.4	2.4	2.4	2.4	2.5	(b)			
Gd									
Tb									
Dy									
Ho									
Er									
Tm									
Yb	10	12	7	8.6	8	(b)			
Lu	1.4	1.7	1	1.2	1.11	(b)			
Hf									
Ta									
W ppb									
Re ppb									
Os ppb									
Ir ppb									
Pt ppb									
Au ppb									
Th ppm									
U ppm	1.1	1.8	0.5	0.9	0.8	(b)			

technique: (a) defocused beam analysis, (b) INAA

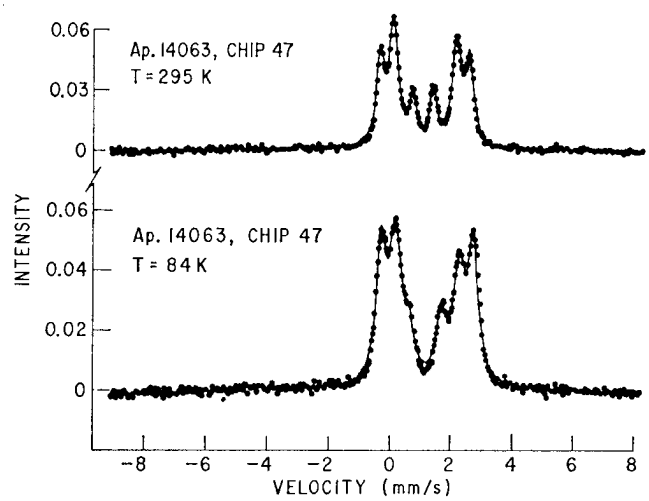


Figure 14: Mossbauer spectra of 14063 from (Schwerer et al. 1972).

Table 1c. Chemical composition of 14063.

reference	Stadermann et al. 1991							plag.
weight	,215	,233	,212	,246	,222	,230	,223	,245
SiO2 %	48.1	40.9	46.6	48.1	49.35	52.5	50.9	43.9
TiO2	0.97	0.84	2.18	2.07	1.26	0.39	0.87	0.1
Al2O3	16.5	19.9	17.7	16.8	22.8	21.7	19.7	34.85
FeO	8.9	7.25	9.8	9.7	5.1	5.2	7.7	0.03
MnO	0.1	0.08	0.15	0.14	0.12	0.09	0.08	
MgO	15.4	18.7	6.8	10.2	5.75	5.25	8.5	
CaO	8.55	9.4	11.8	8.55	12.3	10.1	10.25	18.45
Na2O	0.59	0.73	1.18	0.95	1.89	0.87	0.14	0.55
K2O	0.1	0.11	0.25	0.29	0.66	1.36	0.65	0.07
P2O5	0.2	0.8	0.5	1.1	0.68	0.26	0.52	
S %								
sum								
Cr								
Co	43.4	30.8	20.4	44.5	19.7	12.4	23.6	1
Ni	710	600	198	550	190	80	320	
La	41	18.5	29.3	82.3	42.3	55.7	61.5	4.88
Eu	1.74	2.24	1.34	2.91	1.84	1.87	1.89	2.63
Lu	2.06	0.83	1.45	3.74	2.2	2.88	3.25	0.025
Ir ppb	27	3	4	12	5.9	3	10	2
Au ppb	8.5	0.5	2.8	13	3.4	1	2.4	1

Table 2. Chemical composition of 14064.

reference	Ebihara 92				Gros 76			Blanchard in Imbrium Consortium					
weight								unpublished					
SiO2 %													
TiO2													
Al2O3													
FeO								6.4	6.5	6.2	6.5	6	(b)
MnO													
MgO													
CaO													
Na2O								0.87	0.79	0.9	0.78	0.95	(b)
K2O													
P2O5													
S %													
sum													
Sc ppm								12	12.6	11.5	12.2	13.2	(b)
V													
Cr								770	850	740	980	810	(b)
Co								12.6	12.9	13.1	15.5	13.7	(b)
Ni	70.7	92.8	101	(a)	76	71	(a)	60	70	60	80	90	(b)
Cu							(a)						
Zn					3.1	2.5	(a)						
Ga							(a)						
Ge ppb	32.1	37.4	25.8	(a)	32.9	31	(a)						
As													
Se					13	30	(a)						
Rb	*170*	*66.2*	*59.3*	(a)	21.8	21.7	(a)						
Sr													
Y													
Zr													
Nb													
Mo													
Ru													
Rh													
Pd ppb	0.81	1.15	6	(a)	0.89	0.6	(a)						
Ag ppb	0.399	0.614	1.21	(a)	0.32	0.45	(a)						
Cd ppb	29.2	13.1	20.3	(a)	16.7	31.9	(a)						
In ppb	2.18	5.38	1.9	(a)	4.8	9.2	(a)						
Sn ppb													
Sb ppb	0.044	14.9	7.7	(a)	0.18	0.19	(a)						
Te ppb	1.51	1	37.9	(a)	1	1.5	(a)						
Cs ppm	1.12	0.705	1.665	(a)	0.465	0.38	(a)						
Ba													
La								48.4	48	44.1	35	34	(b)
Ce								126	130	119	94	89	(b)
Pr													
Nd													
Sm								20.8	21	19.1	15.6	15.1	(b)
Eu								1.88	1.84	1.8	1.83	1.61	(b)
Gd													
Tb								5.1	4.8	4.5	3.6	3.4	(b)
Dy													
Ho													
Er													
Tm													
Yb								17.9	17.3	16.4	13.8	12.4	(b)
Lu								2.58	2.58	2.48	1.98	1.87	(b)
Hf								20.7	19.6	19.1	14.3	12.7	(b)
Ta								3.5	3	3.2	2.5	2.3	(b)
W ppb													
Re ppb	0.086	0.142	0.135	(a)	0.14	0.1	(a)						
Os ppb	1.39	2.45	2.34	(a)	1.87	1.4	(a)						
Ir ppb	1.39	2.13	2.98	(a)	1.63	1.39	(a)						
Pt ppb													
Au ppb	0.162	0.128	0.378	(a)	0.128	0.17	(a)						
Th ppm								13.4	12.3	12.7	8.9	9.6	(b)
U ppm	6.55	3.4	3.9	(a)	3.1	3.71	(a)						
technique:	*(a) RNAA, (b) INAA*												

Table 3a: Defocused beam analysis of thin sections 14064.

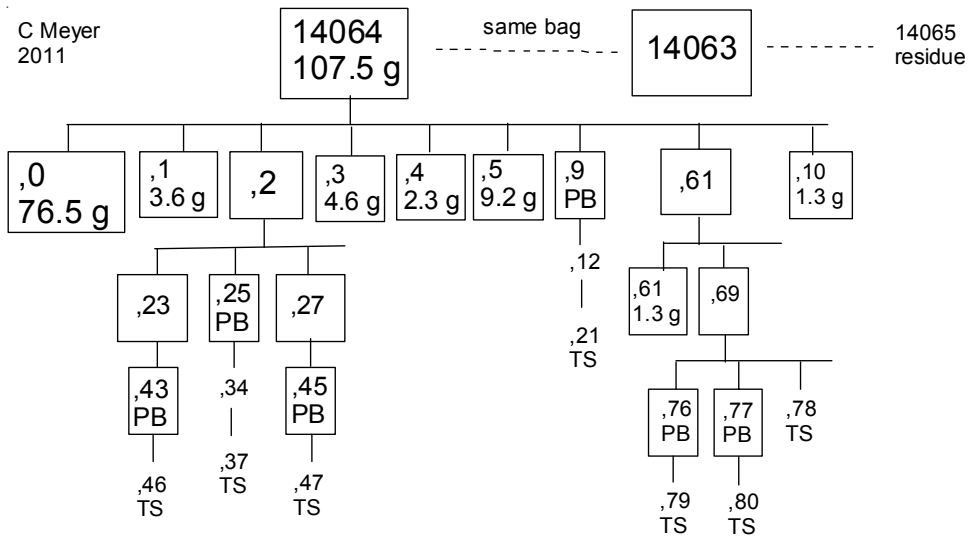
by Ryder and Bower 1972 (matrix with inclusions)

	1	2	3	4	5	6
SiO2	46.7	46.3	46.7	49.5	49.4	47.9
TiO2	0.19	0.49	0.65	0.72	0.96	0.52
Al2O3	20.4	20.8	21.8	21.3	24.3	24
FeO	6.4	4.2	5.1	5.2	4.6	3.6
MnO	0.07	0.04	0.05	0.06	0.06	0.06
MgO	15.1	13.2	8	7.7	6.2	5.8
CaO	10.5	12.7	12.4	12.8	13.2	13.6
Na2O	0.22	0.98	0.97	1.23	1.37	1.09
K2O	0.01	0.2	0.59	0.54	0.38	0.6
P2O5	0.08	0.23	0.16	0.18	0.19	0.22
Cr2O3	0.07	0.31	0.06	0.08	0.06	0.06

Table 3b: Defocused beam analysis of thin sections 14064.

by Ryder and Bower 1976 (matrix without clasts)

	3	4	5	6	7	8	9
SiO2	49.5	51.2	50.5	50.8	51.3	50.2	46.6
TiO2	0.85	0.94	0.78	0.53	0.56	0.6	0.53
Al2O3	23	21.8	22.1	21.2	20.5	21.9	22
FeO	5.4	5.5	5	5.1	6	5.3	5.2
MnO	0.01	0.04	0.06	0.03	0.04	0.07	0.08
MgO	5.8	7	5.9	7.4	7.3	7.9	7.9
CaO	12.4	11.9	12.1	11.5	11.4	11.8	12.3
Na2O	0.89	0.94	1.05	0.86	1.06	1.13	1.09
K2O	1	1.11	1.41	1.07	0.99	0.83	0.55
P2O5	0.23	0.22	0.23	0.2	0.14	0.14	0.16
Cr2O3	0.06	0.05	0.06	0.06	0.05	0.06	0.07
BaO		0.23	0.09	0.17	0.25	0.17	0.08
mg*	0.52	0.56	0.54	0.59	0.55	0.6	0.6



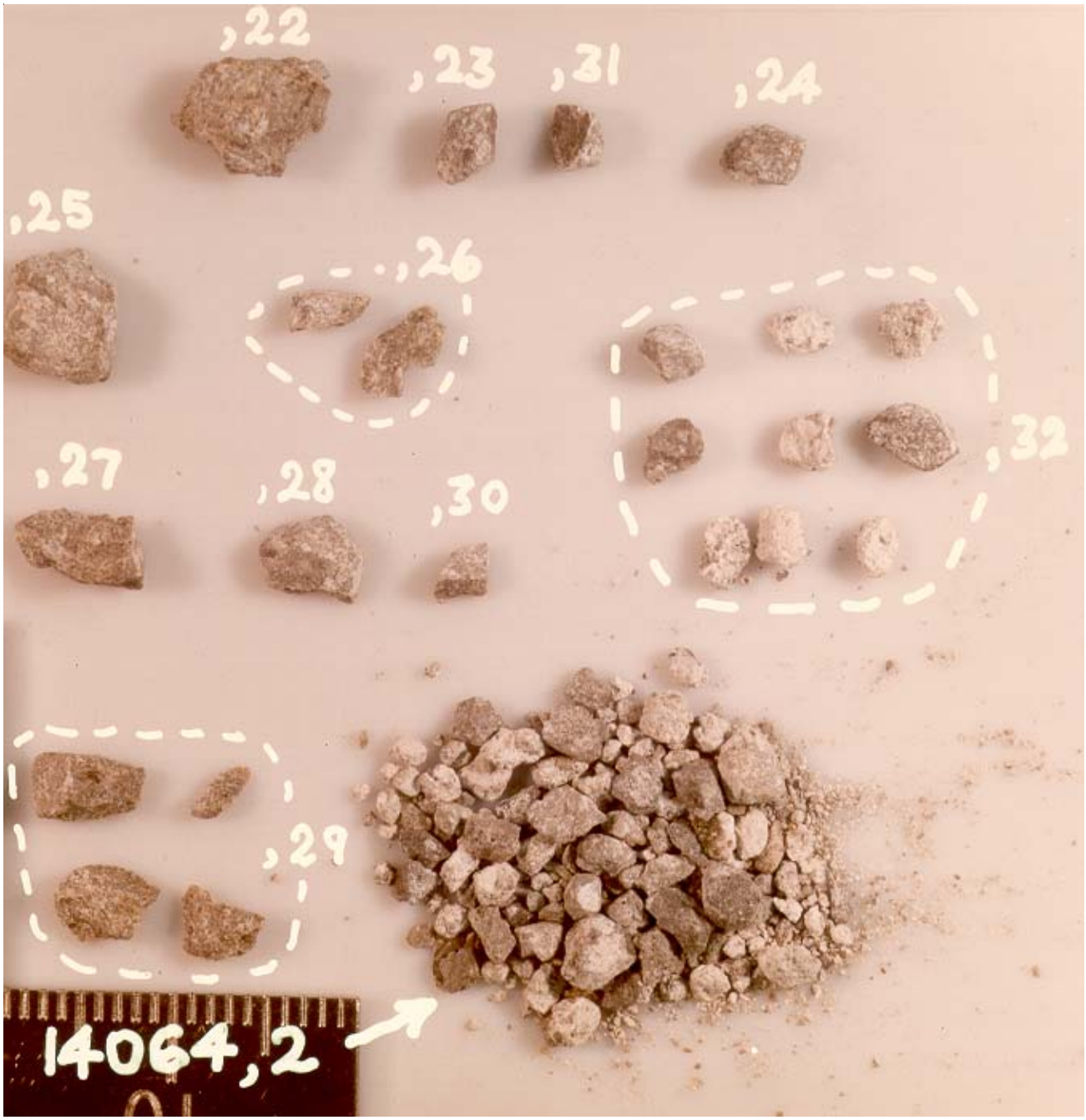
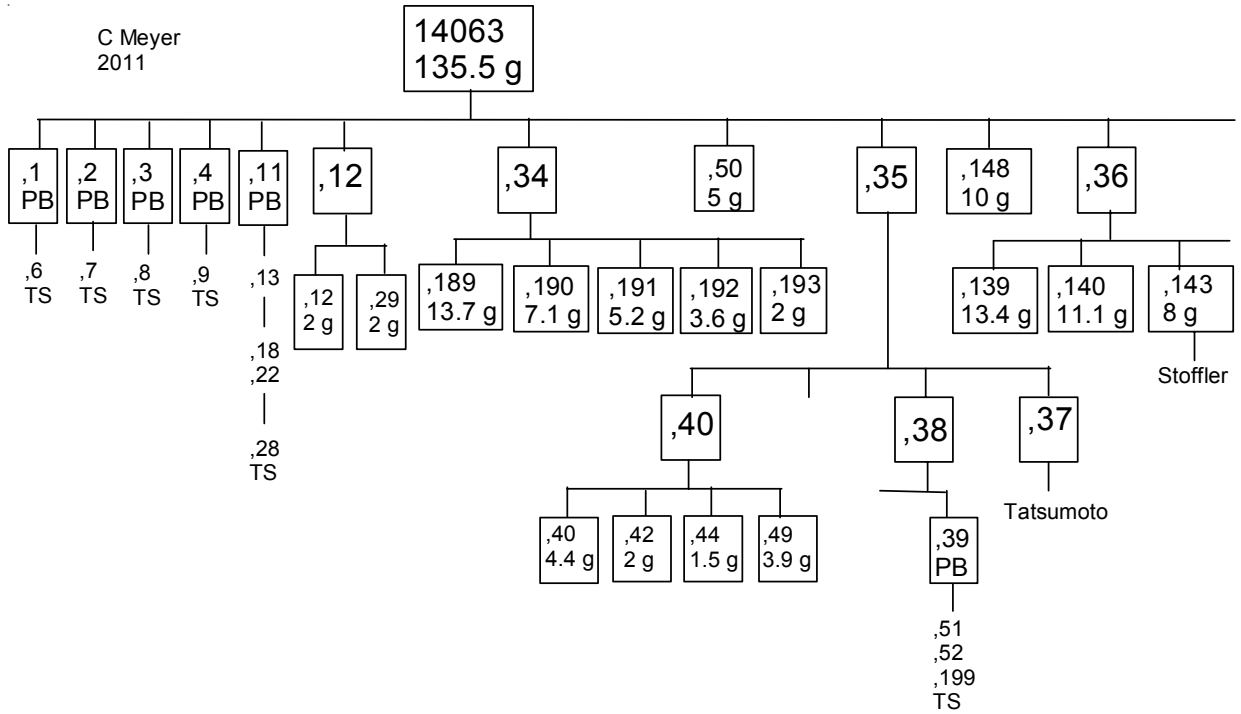


Figure 15: Splitting of 14064.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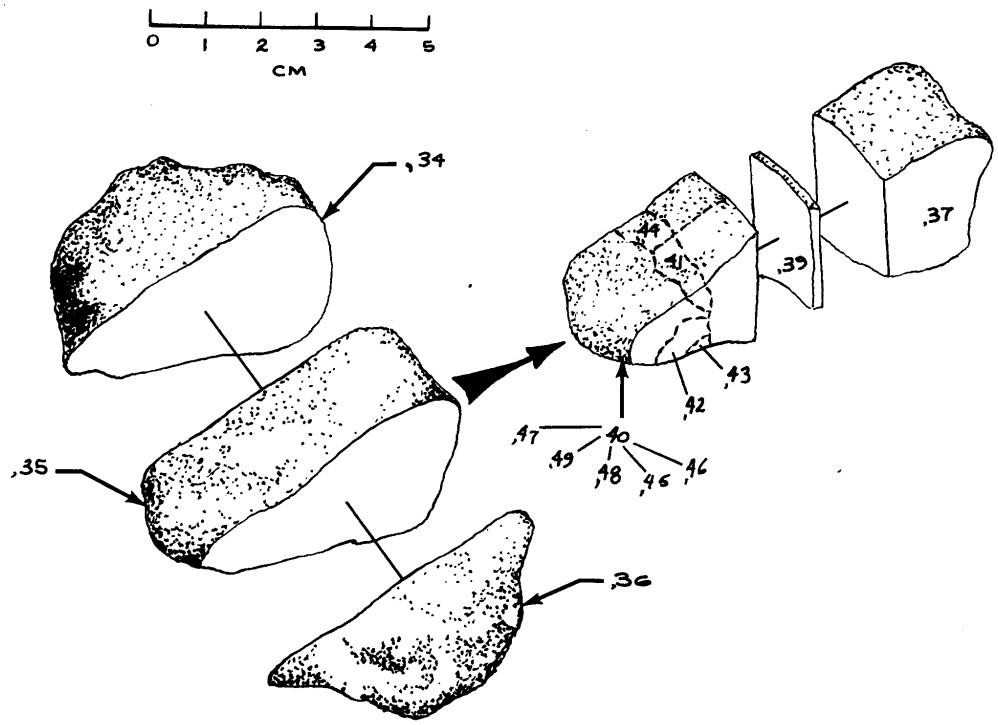
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