12004

Olivine Basalt

585 grams

Figure 1: Photo of 12004. NASA #S70-32688-690. Note the apparent "encrustation" or patina that is being broken loose near the bottom of illustration.

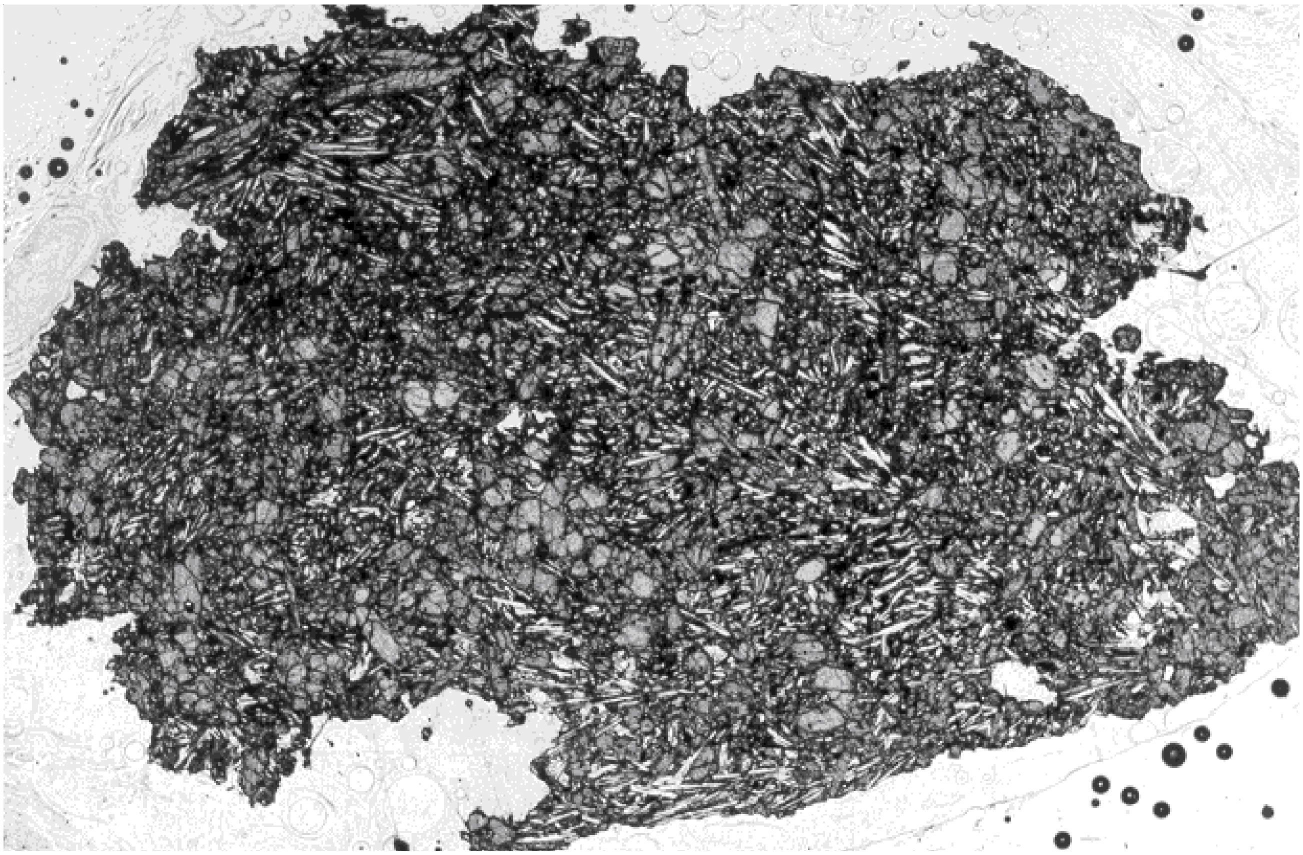


Figure 2: Thin section of 12004,8 showing glomerophyric and variolitic textures in different regions. NASA #S70-28678. Section is about 2 cm. across.

Introduction

12004 is a porphyritic olivine basalt with small olivine and pyroxene phenocrysts set in a fine-grained variolitic groundmass (figure 2). One side is rounded and covered with a thick encrustation or patina (figure 1).

Petrography

Walter et al. (1971) reported that "12004 contains approximately equal amounts of larger clinopyroxene and olivine crystals, from 0.5 mm to several mm in size, which together compose about 40% of the rock. The groundmass (60%) consists chiefly of finer-grained plagioclase and pyroxene with pronounced variolitic textures". Brett et al. (1971) describe the texture of 12004 as subvariolitic. According to French et al. (1972) the texture of the rock "suggests an earlier phase of crystallization of larger olivine and pyroxene crystals, followed by a later phase involving more rapid crystallization of a fine groundmass".

Olivine crystals in 12004 are often found in clumps (glomerophyric?)(figure 2). Metallic iron grains formed early and continued throughout the crystallization sequence (Simpson and Bowie 1971, Brett et al. 1971).

Mineralogy

Olivine: Butler (1973) determined the minor element content of olivine. Walter et al. (1971) reported the CaO content of olivine (~0.5 wt. %) (figure 5). Hewins and Goldstein (1974) determined the Ni and Co contents of olivine.

Pyroxene: Brett et al. (1971) and Walter et al. (1971) determined the composition of pyroxene in 12004 (figure 4).

Plagioclase: The plagioclase in 12004 is An_{92-95} (Walter et al. 1971).

Opaques: Ilmenite and chromite analyses are given in Simpson and Bowie (1971). Early formed aluminous chromite is overgrown with ulvöspinel. The chromite grains are often associated with metallic iron grains.

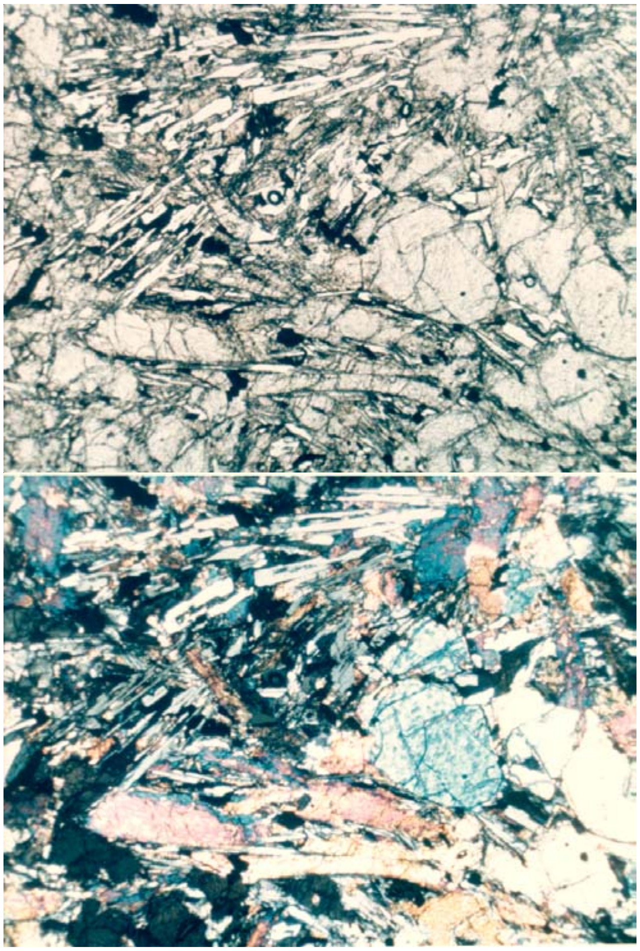


Figure 3: Photomicrographs of thin section 12004,10 showing equant olivine,elongate pyroxene and lath-like plagioclase. Top part is plane polarized light and bottom is cross-nicols. NASA #s S70-49548 and 49549. About 3 mm across.

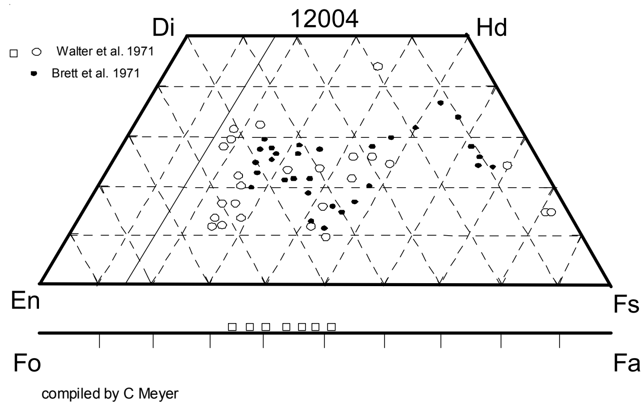


Figure 4: Composition of pyroxene in 12004 (from Brett et al. 1971 and Walter et al. 1971).

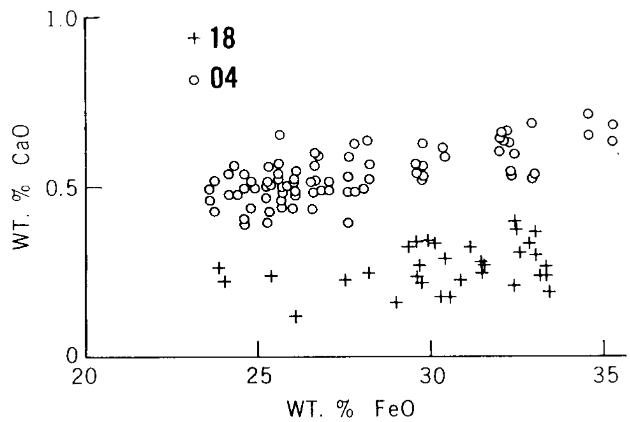


Figure 5: CaO composition of olivine in 12004 contrasted with that of 12018 (from Walter et al. 1971).

Metal: Reid et al. (1970), Brett et al. (1971), Walter et al. (1971), Simpson and Bowie (1971) and Taylor et al. (1971) determined the Ni and Co contents of minute metallic iron grains in 12004 (figures 6, 7). Hewins and Goldstein (1974) found that Ni content of metal grains correlated with position in olivine grains such that Ni decreased as olivine grew.

Chemistry

The chemical composition of 12004 was determined by Compston et al. (1971), Maxwell et al. (1971), Morrison et al. (1971), Wänke et al. (1971) and Wakita and Schmitt (1971) (table 1, figures 8, 9).

Mineralogical Mode for 12004

	Neal et al. 1994	Brett et al. 1971	Papike et al. 1976	French et al. 1972
Olivine	17.8	15	12.5	19
Pyroxene	43.4	57.2	63.6	57
Plagioclase	30.5	19.7	14.4	14
Opaque				9
Ilmenite	1.4	2.9	9.1	
Chromite +Usp	3.7	1		
Mesostasis	1.8	2.1	~3	
“silica”			0.4	

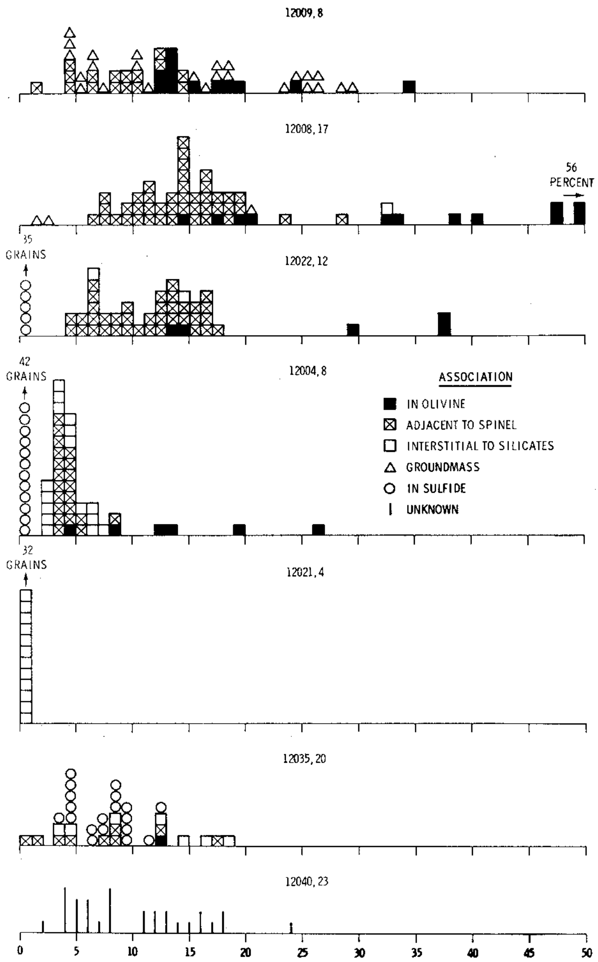


Figure 6: Histogram of Ni concentrations of metal grains in 7 lunar samples (lifted from Brett et al. 1971).

Radiogenic age dating

Ages for 12004 were not found to be concordant! Papanastassiou and Wasserburg (1971b) dated 12004 at 3.29 ± 0.07 b.y. by Rb-Sr internal mineral isochron (figure 10). Murthy et al. (1971) reported an age of 3.01 ± 0.11 b.y. (figure 11) and Compston et al. (1971) reported 2.94 ± 0.11 b.y. (figure 12). This discrepancy has not been fully explained (but see Nyquist's experiments on 15555).

Cosmogenic isotopes and exposure ages

Hintenberger et al. (1971) determined exposure ages for 12004 using ^{3}He (60 m.y.), ^{21}Ne (53 m.y.) and ^{38}Ar (45 m.y.).

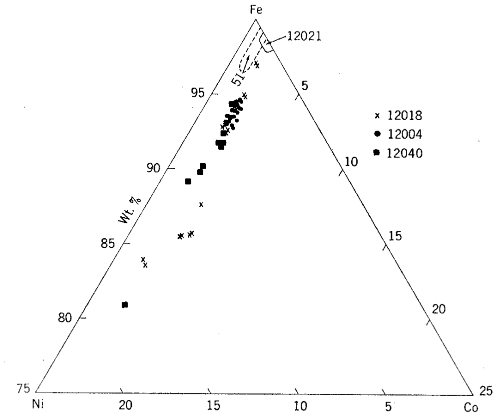


Figure 7: Composition of metal grains in 12004 compared with other Apollo 12 basalts (from Walter et al. 1971).

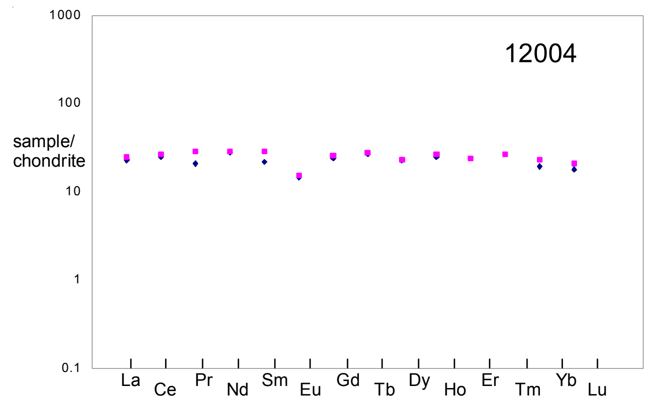


Figure 8: Normalized rare-earth-element composition diagram (data from Wanke et al. 1971 and Wakita and Schmitt 1971).

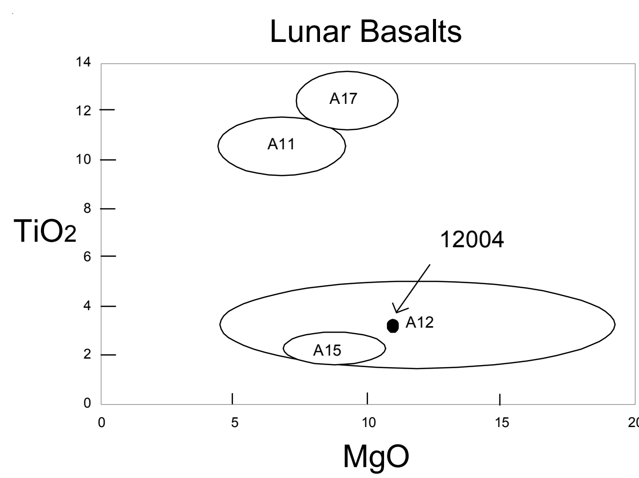


Figure 9: Composition of 12004 compared with that of other lunar basalts.

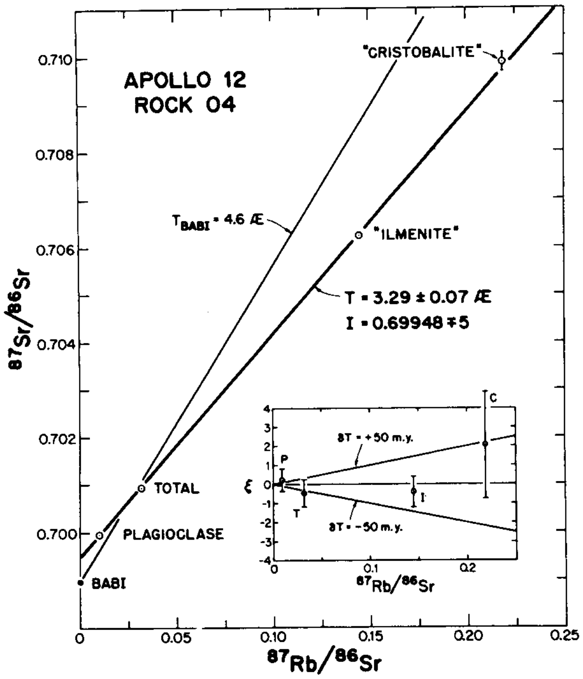
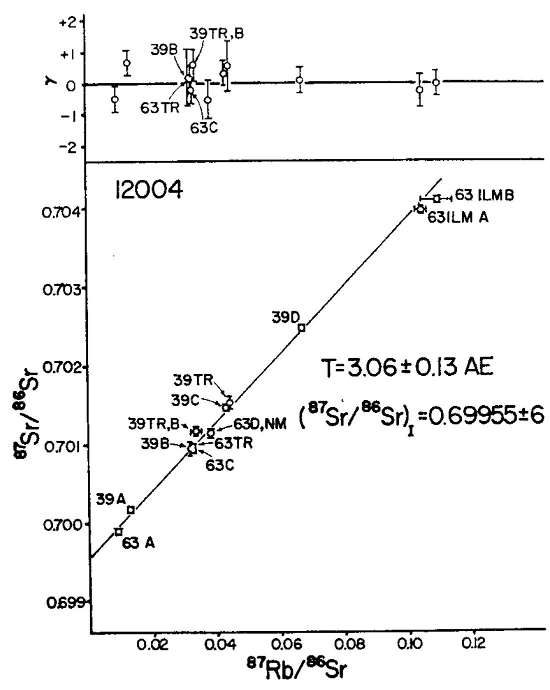


Figure 10: Rb/Sr internal isochron for basalt 12004 (from Papanastassiou and Wasserburg 1971b).



Firure 11: Rb-Sr isochron for 12004 (from Murthy et al. 1971).

Other Studies

Bogard et al. (1971) reported the content and isotopic composition of rare gases in 12004.

Processing

A small piece (80 g ?) broke off and was used for most allocations. This piece (,2) was sawn into three pieces (figure 13). The center piece (,15) was essentially a thick slab. Figure 14 shows how it was further subdivided. Figure 15 shows another view, again illustrating the strange encrustation (patina?, yet to be explained).

There are 13 thin sections.

List of Photo #s 12004

S69-62019	
S70-32688-690	
S70-28678	TS
S70-49548-549	TS
S70-40692	group

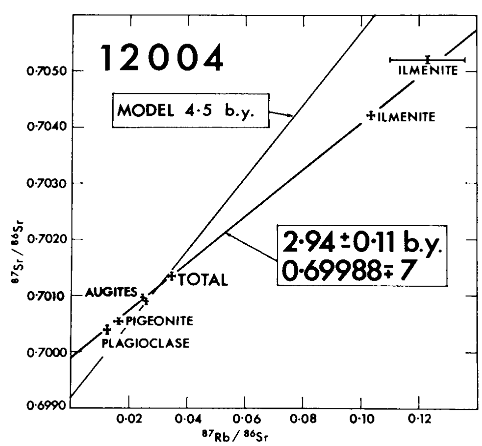


Figure 12: Rb/Sr isochron diagram for 12004 (from Compston et al. 1971).

Summary of Age Data for 12004

	Ar/Ar	Rb/Sr	Nyquist (recalculated)
Papanastassiou and Wasserburg 1971b		3.29 ± 0.07 b.y.	
Murthy et al. 1971		3.01 ± 0.11	
		3.03 ± 0.09	
Compston et al. 1971		2.94 ± 0.11	(2.89 ± 0.11)

Beware: Not corrected for new decay constants.

Table 1a. Chemical composition of 12004.

																a bit off	
reference	Maxwell71	LSPET70	LSPET70		Murthy71		O'Kelly71		Morrison71		Wanke71		Wakita71			*Bouchet71*	
weight			502 g				502 g						.439 g	0.582			
SiO2 %	45.24	37									46	(c)	44.3		(c)	*40.43*	*(d)*
TiO2	2.8	3.4							2.67	(c)	2.55	(c)	3.3	3.2	(c)	*4.5*	*(d)*
Al2O3	8.51	10.5							8.88	(c)	8.73	(c)	8.5	8.5	(c)	*10.96*	*(d)*
FeO	20.65	23							20.6	(c)	21.1	(c)	21.5		(c)	*24.4*	*(d)*
MnO	0.28	0.23							0.28	(c)	0.257	(c)	0.274	0.249	(c)	*0.245*	*(d)*
MgO	12.53	15							13.9	(c)	12.4	(c)	10.9		(c)	*10.8*	*(d)*
CaO	8.99	10							11.2	(c)	8.26	(c)	9.9	9.8	(c)	*10.8*	*(d)*
Na2O	0.23	0.48							0.21	(c)	0.2	(c)	0.226	0.23	(c)	*0.3*	*(d)*
K2O	0.07	0.058	0.058	(a)	0.044	(b)	0.0565	(a)	0.057	(c)	0.05	(c)		0.055		*0.045*	*(d)*
P2O5	0.05																
S %	0.07																
sum																	
Sc ppm		45							44	(c)	43.8	(c)	43			*73*	*(d)*
V	230	85							180	(c)			210	220	(e)	*100*	*(d)*
Cr	4650	5800							4800	(c)	4100	(c)	4851		(c)	*4900*	*(d)*
Co	63	50							60	(c)	47.9	(c)	58			*31*	*(d)*
Ni	73	90									80	(c)				*62*	*(d)*
Cu	22								6.2	(c)	6.9	(c)				*9*	*(d)*
Zn									4.2	(c)						*8*	*(d)*
Ga									2.5	(c)	3.8	(c)				*4.5*	*(d)*
Ge ppb											100	(c)				*500*	*(d)*
As									0.007	(c)	0.004	(c)				*0.1*	*(d)*
Se																*0.3*	*(d)*
Rb		0.47			1.34	(b)					0.9	(c)		0.7	(e)	*2*	*(d)*
Sr	95	145			87.4	(b)					72	(c)				*115*	*(d)*
Y	49	52												36	(e)	*87*	*(d)*
Zr	150	170							120	(c)						*204*	*(d)*
Nb																*12*	*(d)*
Mo																*0.6*	*(d)*
Ru																*0.7*	*(d)*
Rh																*0.3*	*(d)*
Pd ppb																	
Ag ppb																	
Cd ppb																*1*	*(d)*
In ppb											10.4	(c)		2	(e)	*0.7*	*(d)*
Sn ppb																	
Sb ppb									10	(c)							
Te ppb																	
Cs ppm											0.09	(c)		0.05	(e)	*0.3*	*(d)*
Ba	73	60			51.8	(b)			69	(c)	79	(c)	60			*165*	*(d)*
La									6.4	(c)	5.43	(c)	6	5.9	(e)	*18*	*(d)*
Ce									21	(c)	15	(c)		16.3	(e)	*26*	*(d)*
Pr											1.9	(c)		2.6	(e)	*5.5*	*(d)*
Nd									13	(c)	12.9	(c)		13.2	(e)	*16*	*(d)*
Sm									5.4	(c)	3.2	(c)	4.7	4.32	(e)	*5*	*(d)*
Eu									0.89	(c)	0.82	(c)	0.96	0.87	(e)	*1.4*	*(d)*
Gd									7.4	(c)	4.7	(c)		5.2	(e)	*5*	*(d)*
Tb									1.4	(c)	0.97	(c)		1.04	(e)	*2*	*(d)*
Dy											5.5	(c)		5.7	(e)	*9*	*(d)*
Ho									1.3	(c)	1.4	(c)		1.5	(e)	*0.2*	*(d)*
Er											3.84	(c)		3.9	(e)	*8.6*	*(d)*
Tm									0.51	(c)				0.66	(e)		
Yb	6.2								5.7	(c)	3.17	(c)	3.7	3.7	(e)	*7*	*(d)*
Lu									0.61	(c)	0.44	(c)	0.52	0.51	(e)	*1.3*	*(d)*
Hf									3.9	(c)	5.1	(c)	2.7			*5*	*(d)*
Ta									0.5	(c)	0.33	(c)					
W ppb									70	(c)	140	(c)					
Re ppb																	
Os ppb																	
Ir ppb											*33*	(c)					
Pt ppb											*4*	(c)					
Au ppb																	
Th ppm			0.88	(a)			0.92	(a)	0.79	(c)	0.82	(c)	0.4			*1.7*	*(d)*
U ppm			0.25	(a)			0.24	(a)	0.19	(c)	0.238	(c)				*0.29*	*(d)*

technique: (a) radiation counting, (b) IDMS, (c) INAA, (d) Spark, (e) RNAA

Table 1b. Chemical composition of 12004.

reference	Compston71					Neal2001	
weight							
SiO2 %	44.59	(f)					
TiO2	2.88	(f)					
Al2O3	8.02	(f)					
FeO	22.03	(f)					
MnO	0.29	(f)					
MgO	12.66	(f)					
CaO	9.05	(f)					
Na2O	0.2	(f)					
K2O	0.068	(f)					
P2O5	0.08	(f)					
S %	0.07	(f)					
sum							
Sc ppm						43	(h)
V	145	(f)				136	(h)
Cr	3750	(f)				3588	(h)
Co	52	(f)				53	(h)
Ni	52	(f)				63	(h)
Cu	9	(f)				11.6	(h)
Zn	3	(f)				14.7	(h)
Ga	1.2	(f)				2.8	(h)
Ge ppb							
As							
Se							
Rb	1.13	(f)	1.34	1.123	(g)	1.31	(h)
Sr	96	(f)	100	94.3	(g)	83	(h)
Y	36	(f)				33	(h)
Zr	110	(f)				98	(h)
Nb	7	(f)				7	(h)
Mo						0.08	(h)
Ru							
Rh							
Pd ppb							
Ag ppb							
Cd ppb							
In ppb							
Sn ppb							
Sb ppb						10	(h)
Te ppb							
Cs ppm						0.13	(h)
Ba	55					56.5	(h)
La	5					6	(h)
Ce						16.7	(h)
Pr						2.3	(h)
Nd						11.8	(h)
Sm						4.37	(h)
Eu						0.83	(h)
Gd						5.7	(h)
Tb						1.03	(h)
Dy						6.55	(h)
Ho						1.35	(h)
Er						3.79	(h)
Tm						0.53	(h)
Yb						3.66	(h)
Lu						0.48	(h)
Hf						2.97	(h)
Ta						0.51	(h)
W ppb						140	(h)
Re ppb							
Os ppb							
Ir ppb							
Pt ppb							
Au ppb							
Th ppm						0.69	(h)
U ppm						0.22	(h)

technique: (f) XRF, (g) IDMS, (h) ICP-MS

References for 12004

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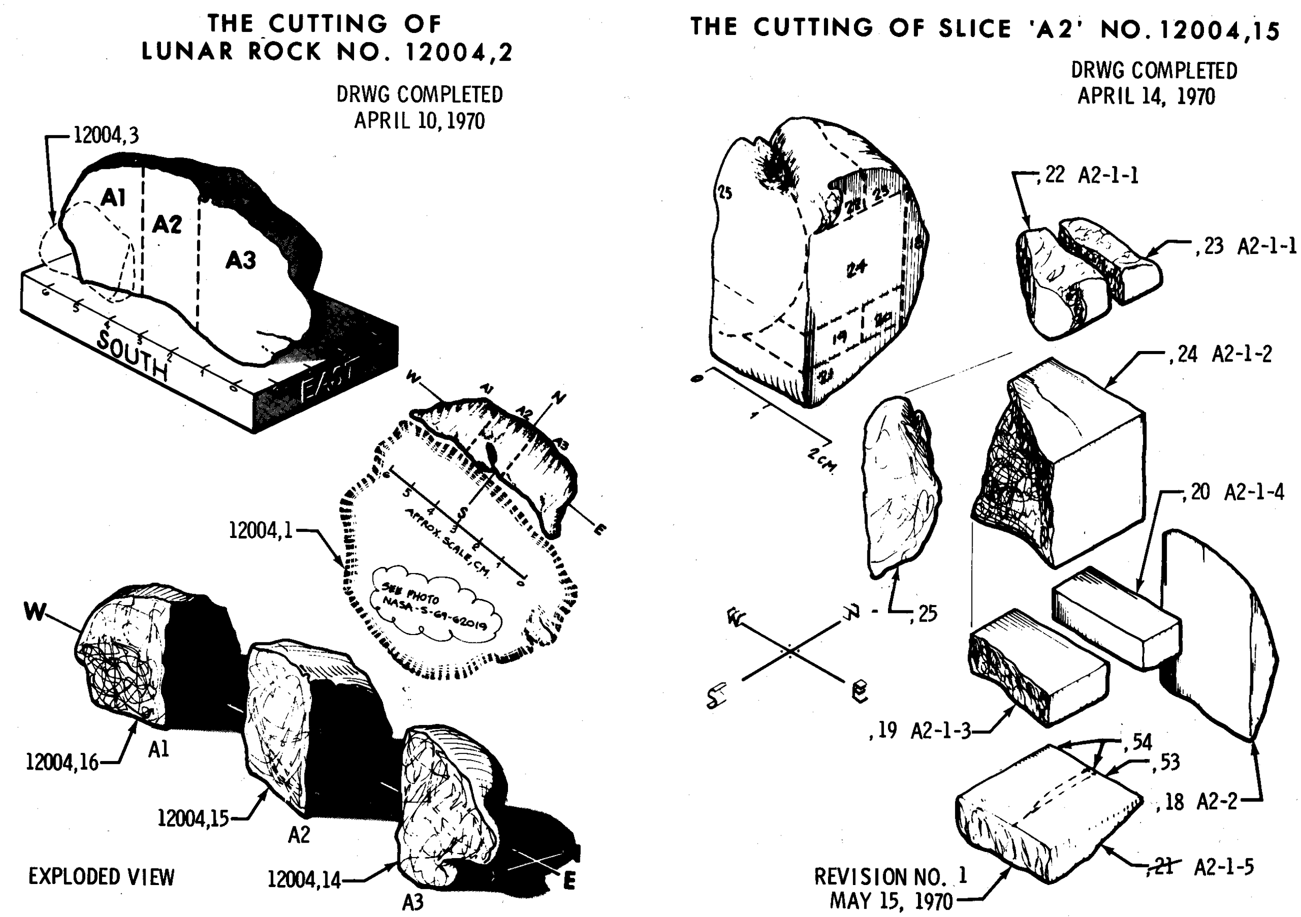

Figure 13: Exploded parts diagram for 12004.

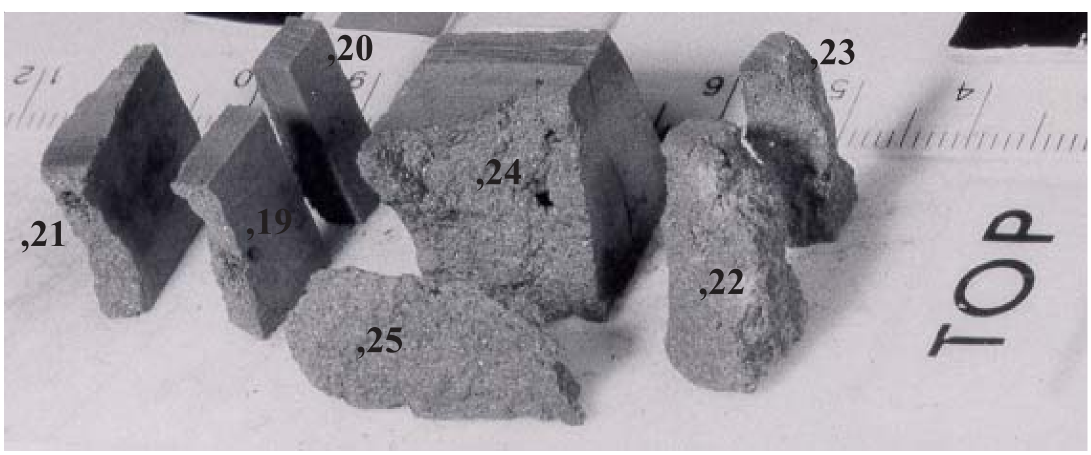

Figure 14: Group photo of thick slab (,15) cut through 12004,2. NASA # S70-40692. Scale in cm.

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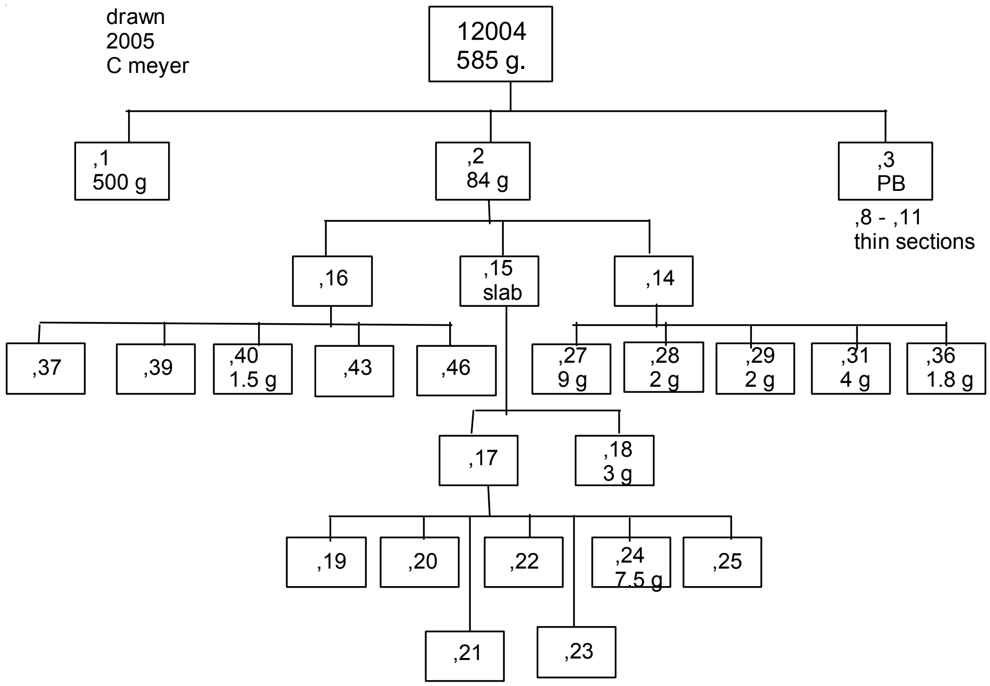

Figure 15: Overhead view of 12004 before it was dusted. Note the strange encrustation. NASA #S69-62019.

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