

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.*

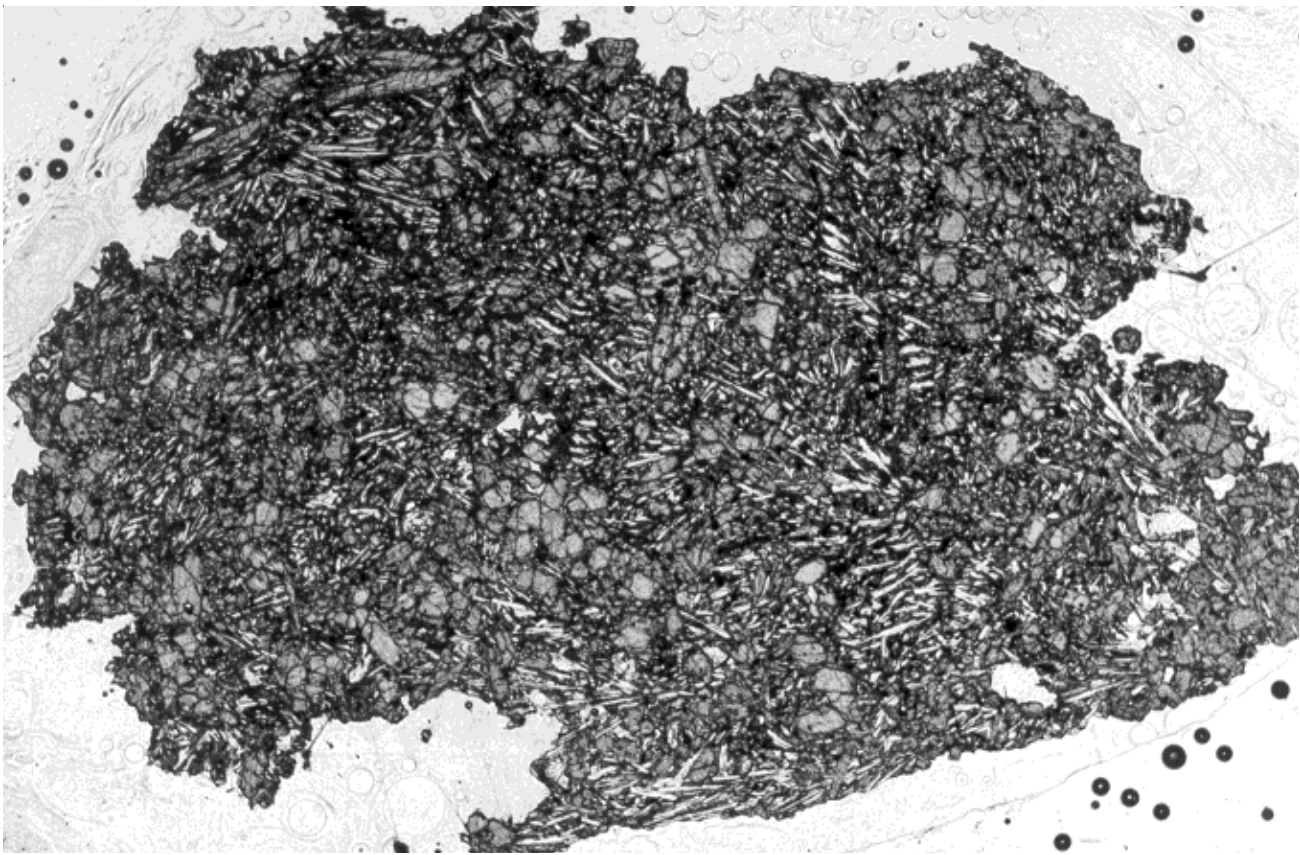


Figure 2: Thin section of 12004,8 showing glomerophyric and variolitic textures in different regions. NASA #S70-28678. Section is about 2 cm. across.

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).

Opagues: 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.

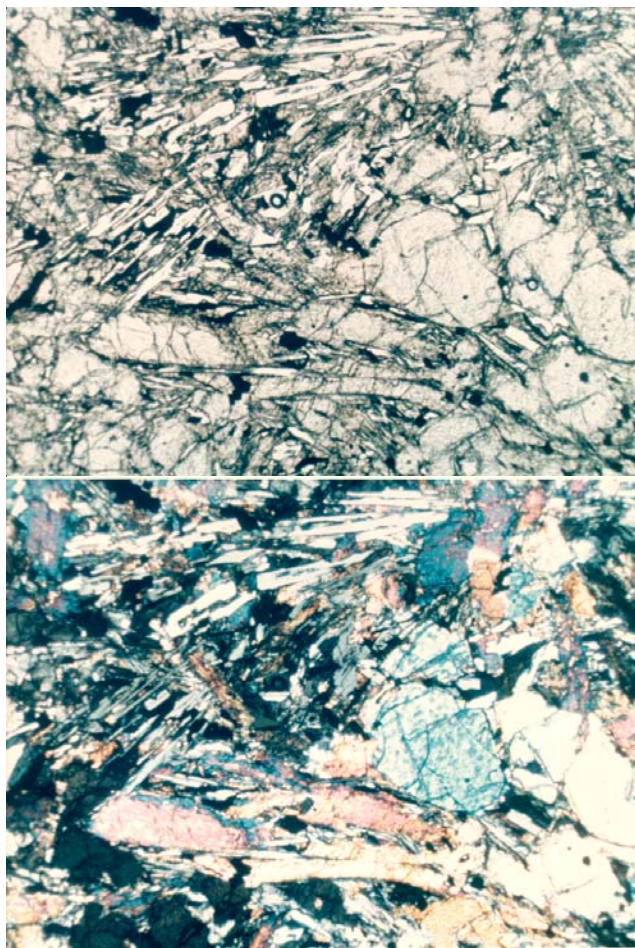


Figure 3: Photomicrographs of thin section 12004,10 showing equant olivine, elongate pyroxene and lath-like plagioclase. Top part is plane polarized light and bottom is cross-nicols. NASA #s S70-49548 and 49549. About 3 mm across.

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

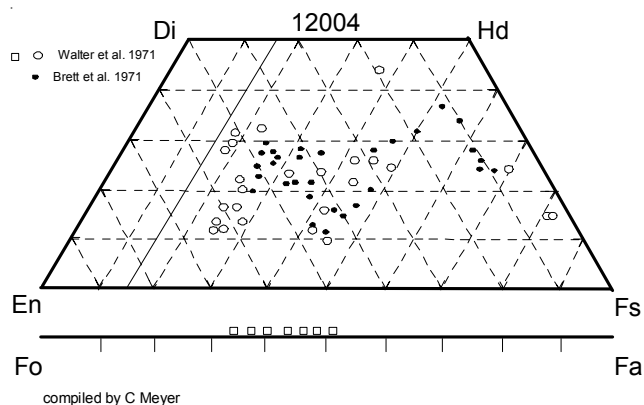


Figure 4: Composition of pyroxene in 12004 (from Brett et al. 1971 and Walter et al. 1971).

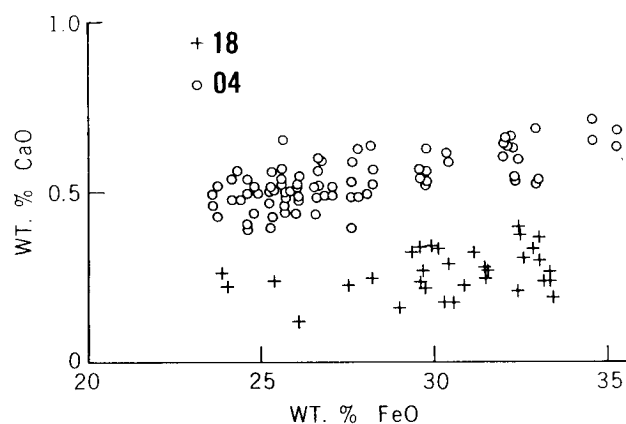


Figure 5: CaO composition of olivine in 12004 contrasted with that of 12018 (from Walter et al. 1971).

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	

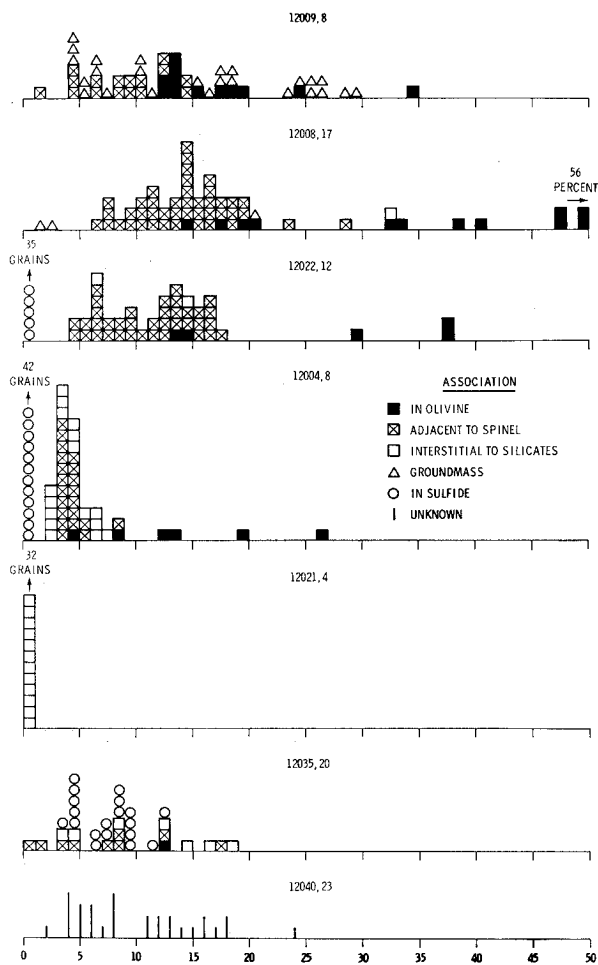


Figure 6: Histogram of Ni concentrations of metal grains in 7 lunar samples (lifted from Brett et al. 1971).

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 ^3He (60 m.y.), ^{21}Ne (53 m.y.) and ^{38}Ar (45 m.y.).

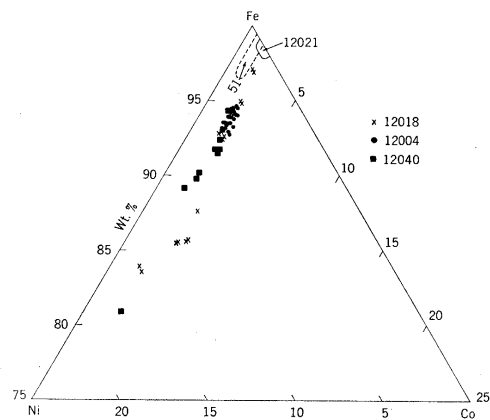


Figure 7: Composition of metal grains in 12004 compared with other Apollo 12 basalts (from Walter et al. 1971).

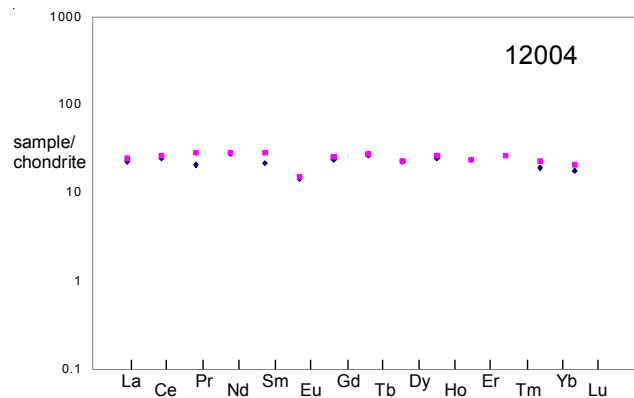


Figure 8: Normalized rare-earth-element composition diagram (data from Wanke et al. 1971 and Wakita and Schmitt 1971).

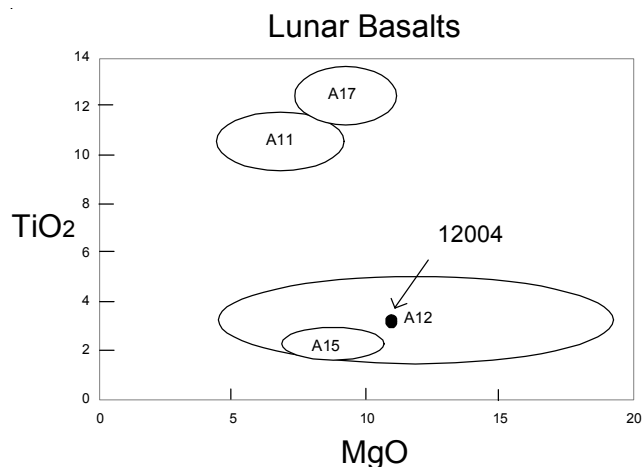


Figure 9: Composition of 12004 compared with that of other lunar basalts.

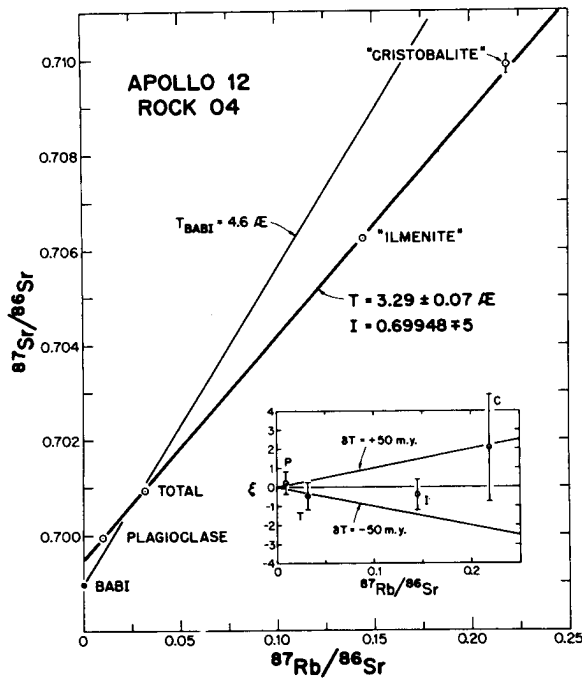


Figure 10: Rb/Sr internal isochron for basalt 12004 (from Papanastassiou and Wasserburg 1971b).

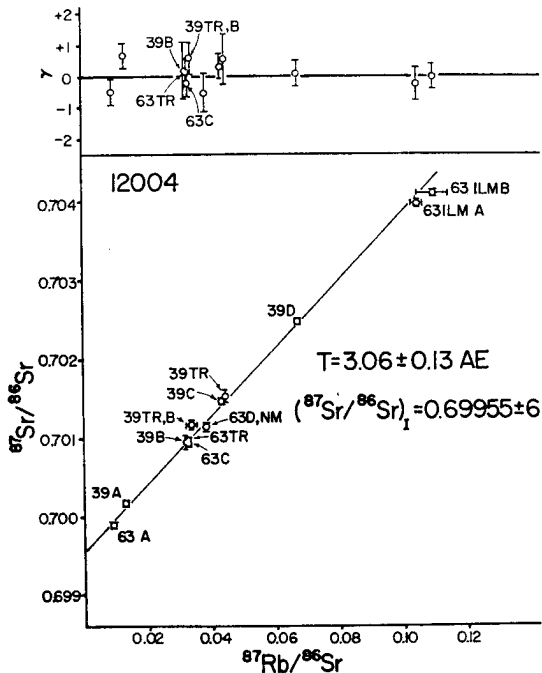


Figure 11: Rb-Sr isochron for 12004 (from Murthy et al. 1971).

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	
Compston et al. 1971		2.94 ± 0.11	(2.89 ± 0.11)

Beware: Not corrected for new decay constants.

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
 - S70-49548-549
 - S70-40692
- TS
TS
group

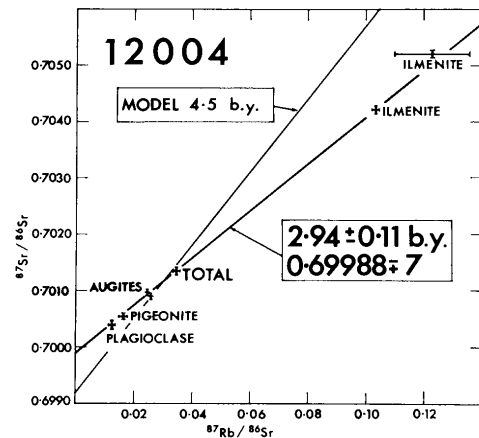


Figure 12: Rb/Sr isochron diagram for 12004 (from Compston et al. 1971).

Table 1a. Chemical composition of 12004.

reference weight	Maxwell71	LSPET70	LSPET70 502 g	Murthy71	O'Kelly71 502 g	Morrison71	Wanke71	Wakita71 .439 g	0.582	<i>a bit off</i> Bouchet71	
SiO ₂ %	45.24	37					46	(c) 44.3		(c) 40.43	(d)
TiO ₂	2.8	3.4				2.67	(c) 2.55	(c) 3.3	3.2	(c) 4.5	(d)
Al ₂ O ₃	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)
Na ₂ O	0.23	0.48				0.21	(c) 0.2	(c) 0.226	0.23	(c) 0.3	(d)
K ₂ O	0.07	0.058	0.058	(a) 0.044	(b) 0.0565	(a) 0.057	(c) 0.05	(c)	0.055	0.045	(d)
P ₂ O ₅	0.05										
S %	0.07										
<i>sum</i>											
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 weight	Compston71		Neal2001		
SiO ₂ %	44.59	(f)			
TiO ₂	2.88	(f)			
Al ₂ O ₃	8.02	(f)			
FeO	22.03	(f)			
MnO	0.29	(f)			
MgO	12.66	(f)			
CaO	9.05	(f)			
Na ₂ O	0.2	(f)			
K ₂ O	0.068	(f)			
P ₂ O ₅	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					
Te ppb					
Cs ppm					10 (h)
Ba	55				0.13 (h)
La	5				56.5 (h)
Ce					6 (h)
Pr					16.7 (h)
Nd					2.3 (h)
Sm					11.8 (h)
Eu					4.37 (h)
Gd					0.83 (h)
Tb					5.7 (h)
Dy					1.03 (h)
Ho					6.55 (h)
Er					1.35 (h)
Tm					3.79 (h)
Yb					0.53 (h)
Lu					3.66 (h)
Hf					0.48 (h)
Ta					2.97 (h)
W ppb					0.51 (h)
Re ppb					140 (h)
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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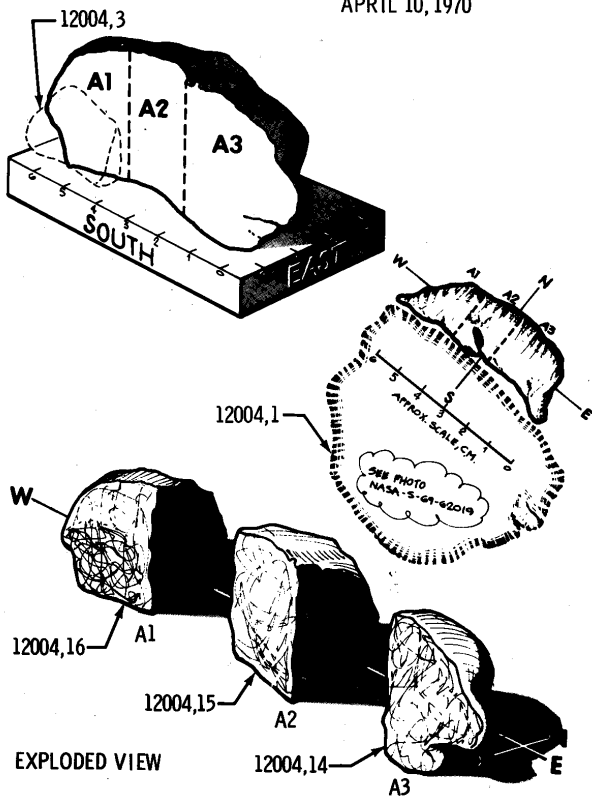
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**THE CUTTING OF
LUNAR ROCK NO. 12004,2**

DRWG COMPLETED
APRIL 10, 1970



THE CUTTING OF SLICE 'A2' NO. 12004,15

DRWG COMPLETED
APRIL 14, 1970

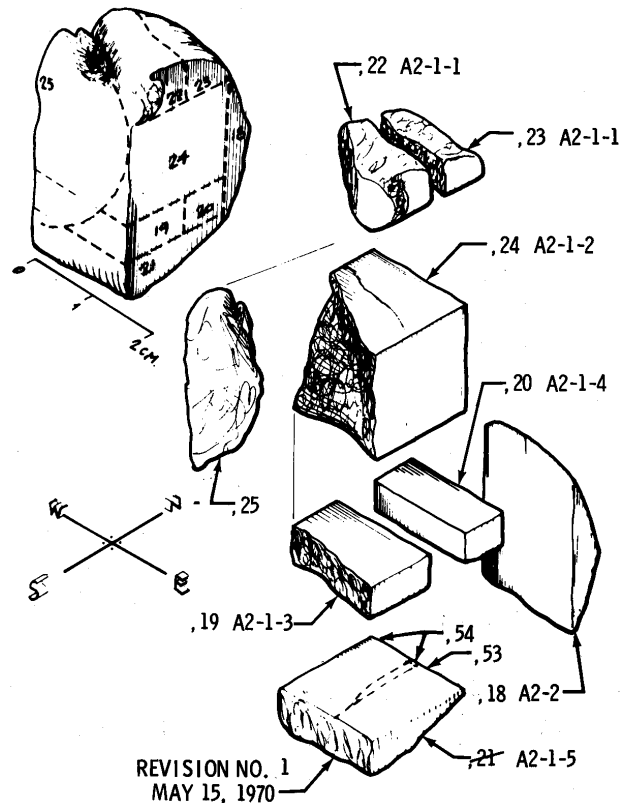


Figure 13: Exploded parts diagram for 12004.

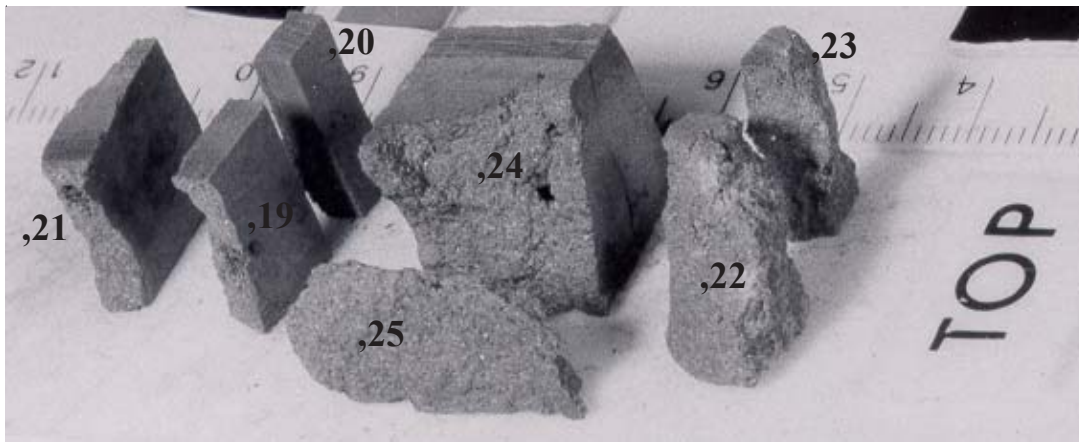


Figure 14: Group photo of thick slab (15) cut through 12004,2. NASA # S70-40692. Scale in cm.

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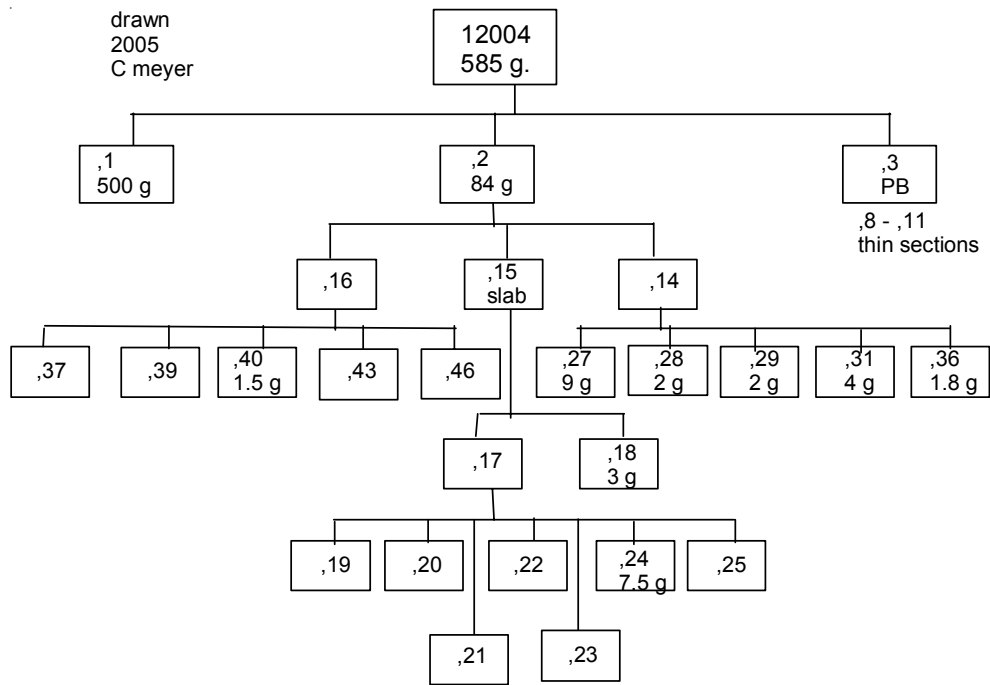


Figure 15: Overhead view of 12004 before it was dusted. Note the strange encrustation.
NASA #S69-62019.

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