

# 12051

## Ilmenite Basalt

1660 grams



Figure 1: Photo of 12051,0. 6 cm wide. NASA # S69-62685

### **Introduction**

12051 is a medium-grained subophitic ilmenite basalt dated at about 3.2 b.y. It was collected from the blocky ejecta of a fresh, 4 meter crater on the south rim of Surveyor Crater. The lunar orientation of 12051 given by Hörz and Hartung (1971) (based on cratered – uncratered surfaces) differs from that found by Sutton and Schaber (1971) (based on surface photography). The large flat surface of 12051 was resting on the lunar surface and protected from zap pits. The top and rounded sides are covered with zap pits and the sample was clearly shaped by the micrometeorite bombardment.

12051 has been analyzed many times. Ages range from 3.15 to 3.5 b.y., with exposure to cosmic rays for 205 m.y.

### **Petrography**

McGee et al. (1977) describe 12051 as “a medium-grained porphyritic basalt characterized by subhedral to anhedral phenocrysts of pyroxene (up to 10 mm) set in a subophitic matrix consisting of plagioclase tablets (0.02 – 1 mm) and rare plagioclase anheda (0.2 to 0.3 mm) intergrown with equant pyroxene crystals (0.2 to 1 mm) and rounded laths of ilmenite (0.3 to 1 mm).” Ilmenite laths commonly cut across the silicates. Mesostasis includes glass, troilite, metallic iron, cristobalite and trace tranquillityite (Keil et al. 1971). French et al. (1972) describe 12051 as “a completely crystalline, fine-grained rock with average grain size less than 1 mm”.

Dungan and Brown (1977) briefly describe 12051 as medium-grained, equigranular, with lath-shaped plagioclase intergrown with equant to slightly elongate pyroxene - suggestive of coetectic crystallization of a homogeneous lava. No olivine phenocrysts have been reported. Elongate ilmenite and small segregations of “symplectoid mesostasis” are common features.

Residual glass with high silica and high potassium is found interstitially and is associated with K-feldspar, fluoroapatite, whitlockite and baddelyite (Keil et al. 1971).

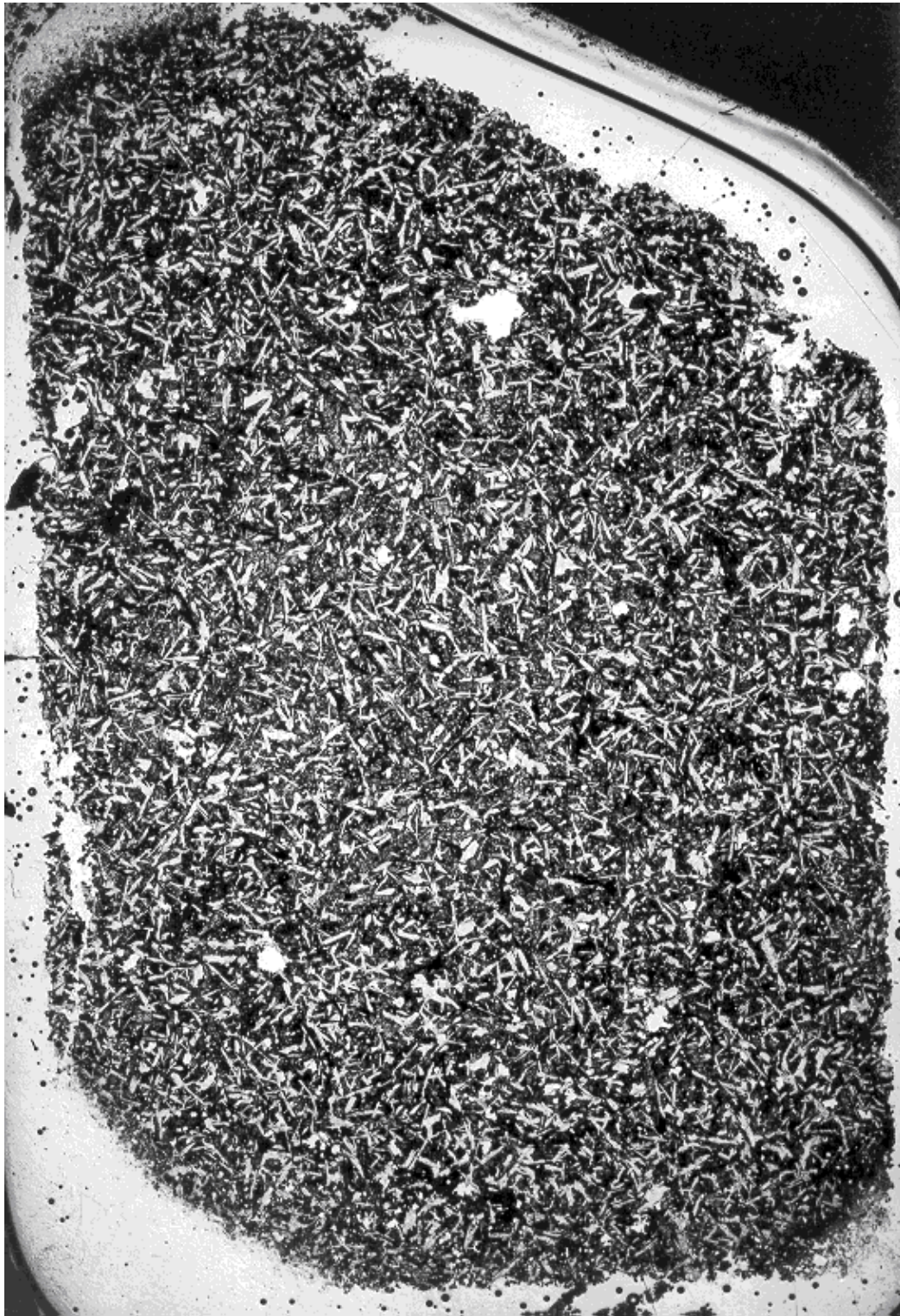


Figure 2: Photomicrograph of thin section 12051,53, showing basaltic texture. Field of view is 3 cm. NASA # S70-40820.

### **Mineralogy**

**Pyroxene:** Keil et al. (1971) and Walter et al. (1971) determined the pyroxene composition (figure 4). Core augite and core pigeonite zone to high iron endmembers, including pyroxferroite.

**Plagioclase:** The plagioclase in 12051 is  $An_{97-89}$  (Keil) or  $An_{94-92}$  (Walter). Wenk et al. (1971) studied the crystallographic and optical properties of plagioclase from this rock.



Figure 3: Photomicrographs of thin section 12051,62 (plane-polarized, crossed-nicols). Field of view 2.6 mm. NASA # S7049833-834.

**Tranquillityite:** Lovering et al. (1971) give the analysis of tranquillityite found in 12051.

**K-spar:** Keil et al. (1971) reported 2.8% BaO in K-spar in 12051.

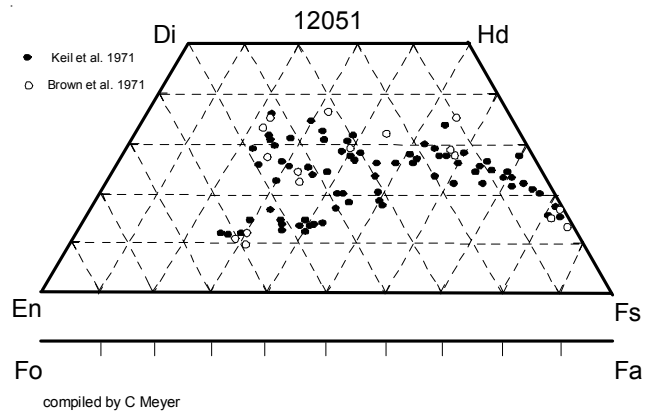


Figure 4: Pyroxene composition of 12051 (from Keil et al. 1971, Brown et al. 1971).

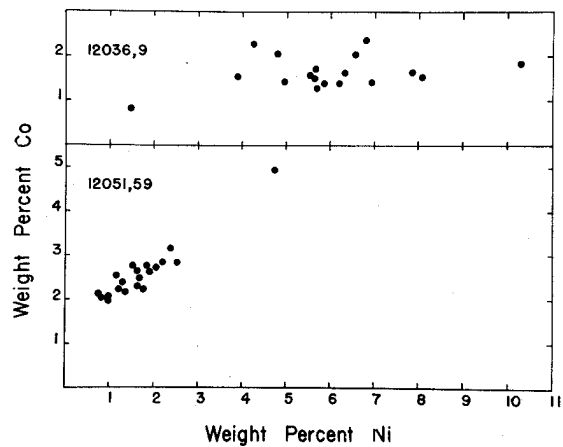


Figure 5: Ni and Co content of metallic iron grains in 12051 (from Keil et al. 1971).

**Metallic iron:** Figure 5 shows the Ni and Co contents determined in minute iron grains in 12051. Walter et al. (1971) found that Ni was low and restricted.

### Mineralogical Mode of 12051

	McGee et al. 1977	Neal et al. 1994	Brown et al. 1971	Papike et al. 1976	Dungan and Brown 1976
olivine	--				
pyroxene	57-61	60.4	60.8	56.7	58.8
plagioclase	22-31	30.7	21.7	31.2	26.5
opaques	8-11		10.7	7.9	9.3
ilmenite		5.3			
chrom + usp		1.4			
"silica"	2-3	0.3	2.2	3.4	2.8
mesostasis	1-3	1.2	2.7	0.8	2.6

## **Chemistry**

The chemical composition of 12051 was determined by numerous labs using a variety of techniques (table 1). 12051 has a high Fe/Mg ratio (figure 7) and a flat REE pattern (figure 6).

## **Radiogenic age dating**

Papanastassiou and Wasserburg (1970) determined the age of 12051 by Rb-Sr mineral isochron ( $3.26 \pm 0.1$  b.y., figure 11). Turner (1971) determined  $3.27 \pm 0.05$  b.y. by Ar/Ar (figure 10). The Rb/Sr age was also determined by Nyquist et al. (1977) to be  $3.19 \pm 0.06$  b.y. (figure 8). Compston et al. (1971) determined  $3.58 \pm 0.3$  b.y. by internal Rb/Sr isochron (figure 9), Alexander et al. (1972) determined  $3.32 \pm 0.06$  b.y. and Stettler et al. (1973) determined  $3.16 \pm 0.05$  b.y. by the Ar/Ar high temperature plateau technique (figures 12 and 13).

## **Cosmogenic isotopes and exposure ages**

Rancitelli et al. (1971) determined the cosmic-ray-induced activity of  $^{22}\text{Na} = 40$  dpm/kg,  $^{26}\text{Al} = 93$  dpm/kg,  $^{46}\text{Sc} = 7$  dpm/kg and  $^{54}\text{Mn} = 29$  dpm/kg. Stettler et al. (1973) determined an  $^{38}\text{Ar}$  exposure age of 205 m.y.

## **Other Studies**

Bogard et al. (1971) reported the content and isotopic composition of rare gases in 12051. Hartung et al. (1972) discuss the different spall zones of a large zap pit on 12051.

## **Processing**

A slab was cut from the middle of 12051 using a circular saw (figures 14-18). Two columns were also cut with the circular saw. There are 15 thin sections. 12051 has been widely distributed and studied.

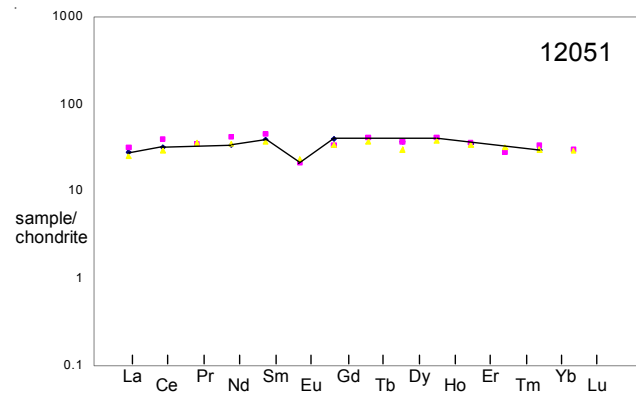


Figure 6: Comparison of neutron activation analysis of basalt 12051 (Morrison et al. 1971, Wakita et al. 1971) with isotopic dilution mass spectroscopy (line, Hubbard and Gast 1971, Wiesmann et al. 1975).

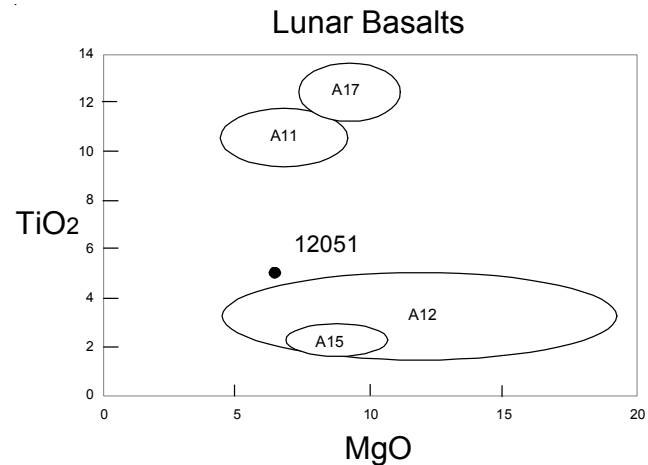


Figure 7: Composition of 12051 compared with other Apollo basalts.

## **List of Photos # for 12051**

S69-62675 – 62686	B & W
S69-63827 – 63830	color mug
S70-40820	
S70-22468 – 22475	color mug
S70-61514 – 61537	B & W mug
S70-36940 – 36946	processing
S70-63987 – 63992	
S70-49829 – 49834	TS color
S76-20806	TS
S76-20793	TS
S79-27084 – 27086	
S94-035800 – 03	

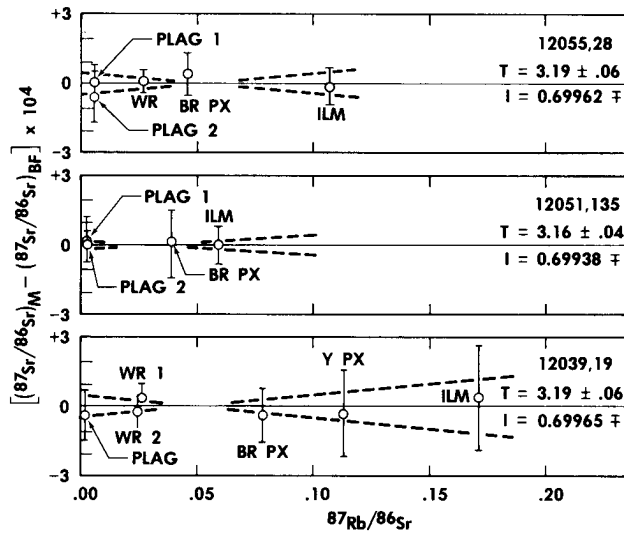


Figure 8: Rb-Sr isochron for 12051 (Nyquist et al. 1977).

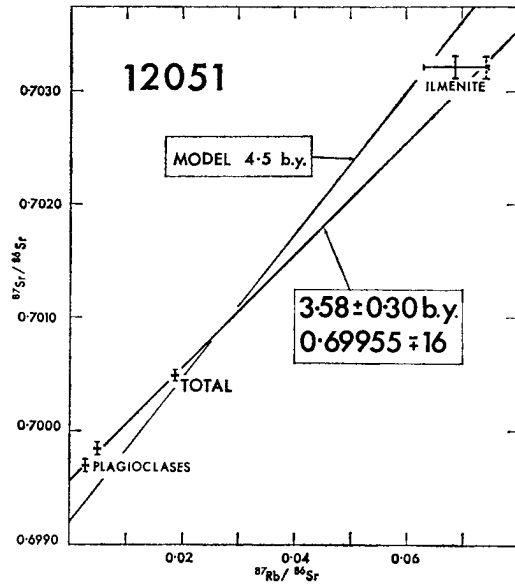


Figure 9: Rb-Sr isochron determined for 12051 (Compston et al. 1971).

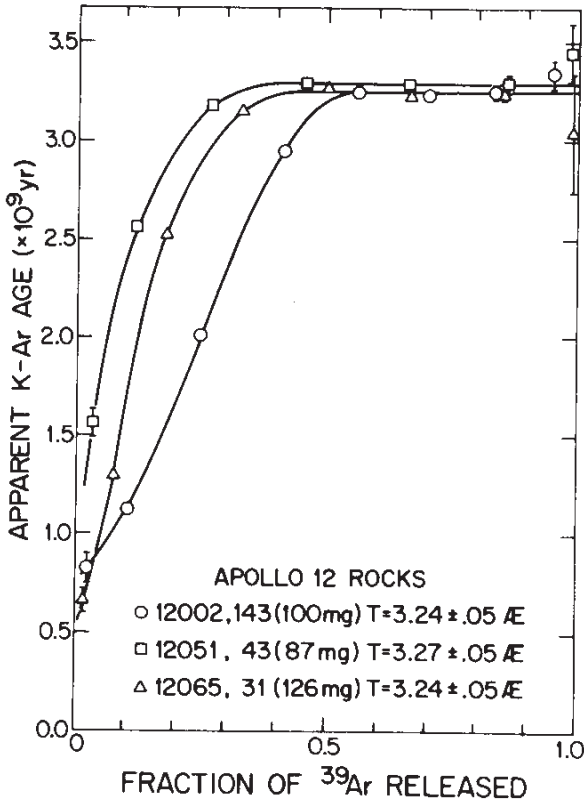


Figure 10: Ar-Ar release pattern for 12051 (from Turner 1971).

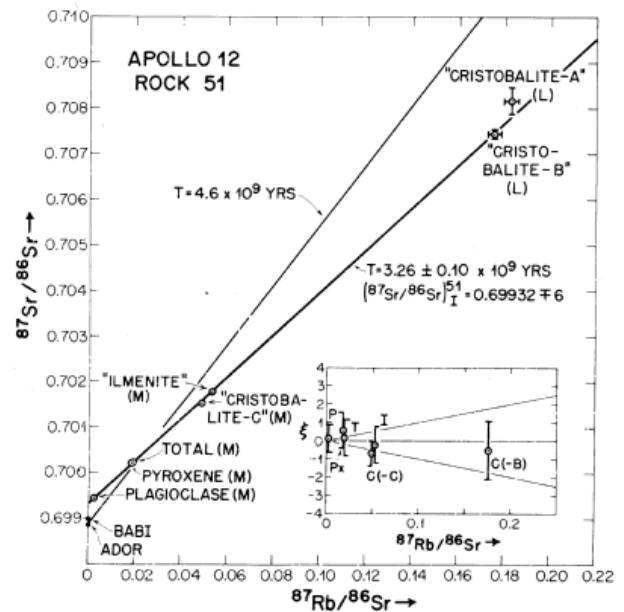


Figure 11: Rb-Sr isochron for 12051 as determined by Papanastassiou and Wasserburg 1970.

### Summary of Age Data for 12051

	Ar/Ar	Rb/Sr	Nyquist 1977 (recalculated)
Turner 1971	3.27 ± 0.05 b.y.		
Alexander et al. 1972	3.32 ± 0.06		
Stettler et al. 1973	3.16 ± 0.05		
	3.15 ± 0.07		
Nyquist et al. 1979		3.19 ± 0.06	
Compston et al. 1971		3.58 ± 0.3	(3.52 ± 0.3)
Papanastassiou and Wasserburg 1970		3.26 ± 0.1	

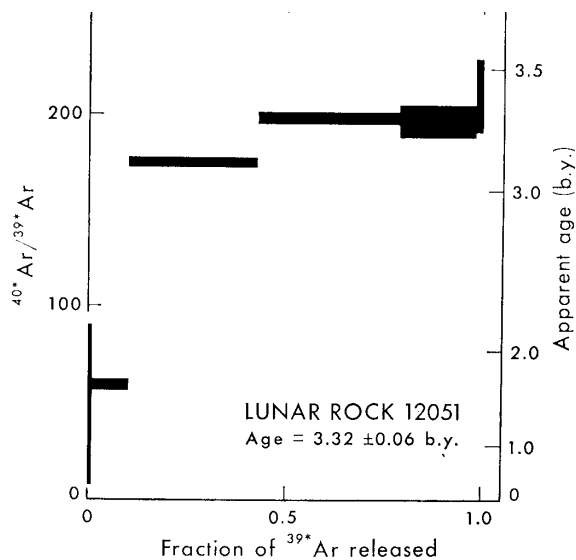


Figure 12: Ar-Ar release pattern for 12051 (from Alexander et al. 1972).

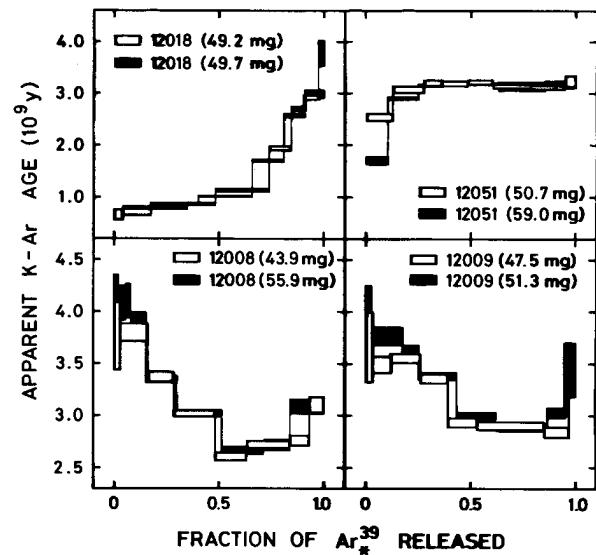


Figure 13: Argon release curves for Apollo 12 basalts (from Stettler et al. 1973).

## References for 12051

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**Table 1a. Chemical composition of 12051.**

reference weight	Gast 70	Maxwell71	Hubbard71 203 mg	Weismann75 203 mg	O'Kelly71 1660 g	Morrison71	Wakita71a, b 0.449 0.535	
SiO <sub>2</sub> %		45.54					47.1	(d)
TiO <sub>2</sub>	5.1 (a)	4.74				3.67 (d)	4.8 5	(d)
Al <sub>2</sub> O <sub>3</sub>		9.95				11.15 (d)	10.6 10	(d)
FeO		20.19				20.07 (d)	21	(d)
MnO		0.28				0.27 (d)	0.261 0.273	(d)
MgO		6.82				7.63 (d)	6.1	(d)
CaO	10.7 (a)	11.33				10.2 (d)	12.3 11.7	(d)
Na <sub>2</sub> O	0.28 (a)	0.31				0.32 (d)	0.318 0.317	(d)
K <sub>2</sub> O	0.064 (a)	0.04	0.064	(a) 0.064	(a) 0.064 (c)	0.061 (d)	0.065	(f)
P <sub>2</sub> O <sub>5</sub>		0.07						
S %		0.1						
sum								
Sc ppm						48 (d) 41 (e)	60	(d)
V		180 (b)				100 (d) 120 (e)	130	(d)
Cr		2460 (b)				1600 (d)	2100	(d)
Co		42 (b)				35 (d) 35 (e)	35	(d)
Ni						66 (d) 43 (e)		
Cu		16 (b)				9.1 (d)		
Zn						1.6 (d)		
Ga						3.9 (d)		
Ge ppb								
As						0.02 (d)		
Se								
Rb	0.909 (a)		0.909 (a)	0.909 (a)			1.2 (e)	1 (f)
Sr	148 (a)	140 (b)	148 (a)	148 (a)			150 (e)	
Y		64 (b)					65 (e)	42 (f)
Zr		170 (b)				130 (d)	130 (e)	
Nb							11 (e)	
Mo								
Ru								
Rh								
Pd ppb								
Ag ppb								
Cd ppb								
In ppb								2.3 (f)
Sn ppb								
Sb ppb						4 (d)		
Te ppb								
Cs ppm								
Ba	73.6 (a)	76 (b)	73.6 (a)	73.6 (a)		96 (d) 95 (e)	100	
La	6.53 (a)		6.53 (a)	6.53 (a)		7.4 (d) 7.6 (e)	5.9 5.9	(f)
Ce	19.2 (a)		19.2 (a)	19.2 (a)		28 (d) 24 (e)	17.8	(f)
Pr							3.1 (e)	3.2 (f)
Nd	15.4 (a)		15.4 (a)	15.4 (a)		19 (d) 19 (e)		15.8 (f)
Sm	5.68 (a)		5.68 (a)	5.68 (a)		6.9 (d) 6.7 (e)	5.5 5.49	(f)
Eu	1.23 (a)		1.23 (a)	1.23 (a)		1.3 (d) 1.2 (e)	1.27 1.3	(f)
Gd	7.89 (a)		7.89 (a)	7.89 (a)		6.8 (d) 6.7 (e)		6.7 (f)
Tb						1.8 (d) 1.5 (e)		1.35 (f)
Dy	9.05 (a)		9.05 (a)	9.05 (a)			8.9 (e)	7.2 (f)
Ho						2.4 (d) 2.3 (e)		2.1 (f)
Er	5.57 (a)		5.57 (a)	5.57 (a)			5.8 (e)	5.4 (f)
Tm						0.69 (d) 0.68 (e)		0.78 (f)
Yb	5.46 (a)	7.5 (b)	5.46 (a)	4.86 (a)		6.1 (d) 5.6 (e)	5 4.9	(f)
Lu						0.73 (d) 0.72 (e)	0.75 0.71	(f)
Hf				0.23 (a)		4.4 (d) 3.9 (e)	3.3	(d)
Ta						0.5 (d)		
W ppb						90 (d)		
Re ppb								
Os ppb								
Ir ppb								
Pt ppb								
Au ppb								
Th ppm					1 (c)	0.95 (d)	1.1	(d)
U ppm					0.26 (c)			

technique: (a) IDMS, (b) OES, (c) radiation counting, (d) INAA, (e) ms, (f) RNAA, (g) XRF

**Table 1b. Chemical composition of 12051.**

reference weight	Compston71		Anders71		Rancitelli71 545 g 765 g		Neal2001			
SiO2 %	45.07	(g)								
TiO2	4.62	(g)								
Al2O3	9.96	(g)								
FeO	20.25	(g)								
MnO	0.28	(g)								
MgO	7.21	(g)								
CaO	11.45	(g)								
Na2O	0.28	(g)								
K2O	0.08	(g)			0.07	0.07	(c)			
P2O5	0.09	(g)								
S %	0.09	(g)								
sum										
Sc ppm							64	(h)		
V	102	(g)					161	(h)		
Cr	1780	(g)					2547	(h)		
Co	33	(g)					40	(h)		
Ni	6	(g)					14	(h)		
Cu	6	(g)					24	(h)		
Zn			0.52	0.54	(f)		34	(h)		
Ga	2.9	(g)	4.6	4.3	(f)		4.3	(h)		
Ge ppb										
As										
Se			0.201	0.204	(f)					
Rb	1.02	(g)	0.96	(a)	1.03	1.06	(f)	1.24	(h)	
Sr	147.9	(g)	146.3	(a)				163	(h)	
Y	48	(g)						59	(h)	
Zr	128	(g)						133	(h)	
Nb	7	(g)						8.6	(h)	
Mo								0.11	(h)	
Ru										
Rh										
Pd ppb										
Ag ppb			0.82	0.8	(f)					
Cd ppb			1.2	1.1	(f)					
In ppb			2	1.2	(f)					
Sn ppb										
Sb ppb										
Te ppb								120	(h)	
Cs ppm			10	16	(f)					
Ba			0.04	0.042	(f)			0.1	(h)	
La	5	(g)						75	(h)	
Ce								7.22	(h)	
Pr								20.1	(h)	
Nd								3.2	(h)	
Sm								15.4	(h)	
Eu								5.7	(h)	
Gd								1.38	(h)	
Tb								8.06	(h)	
Tb								1.49	(h)	
Dy								1.49	(h)	
Dy								9.52	(h)	
Ho								2.05	(h)	
Er								5.68	(h)	
Tm								0.89	(h)	
Yb								0.89	(h)	
Yb								5.16	(h)	
Lu								5.16	(h)	
Lu								0.73	(h)	
Hf								0.73	(h)	
Hf								4.22	(h)	
Ta								4.22	(h)	
Ta								0.58	(h)	
W ppb								0.58	(h)	
W ppb								140	(h)	
Re ppb										
Os ppb										
Ir ppb			0.09	0.54	(f)					
Pt ppb										
Au ppb										
Th ppm			0.008	0.007	(f)					
Th ppm						0.94	0.864	(c)	0.97	(h)
U ppm						0.234	0.234	(c)	0.34	(h)

technique: (c) radiation counting, (f) RNAA, (g) XRF, (h) ICP-MS



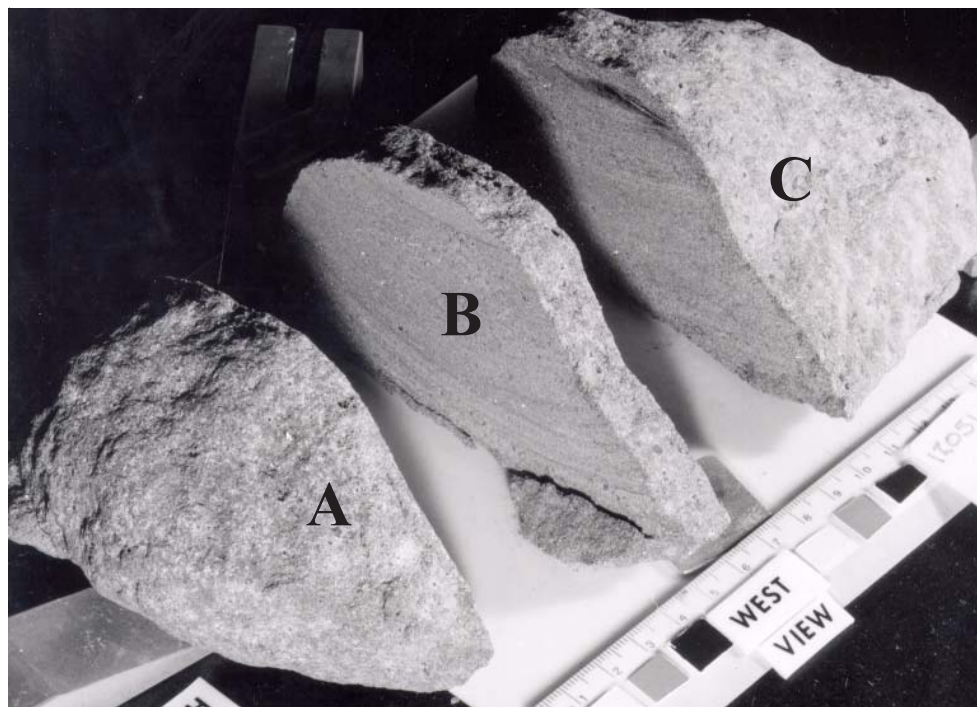
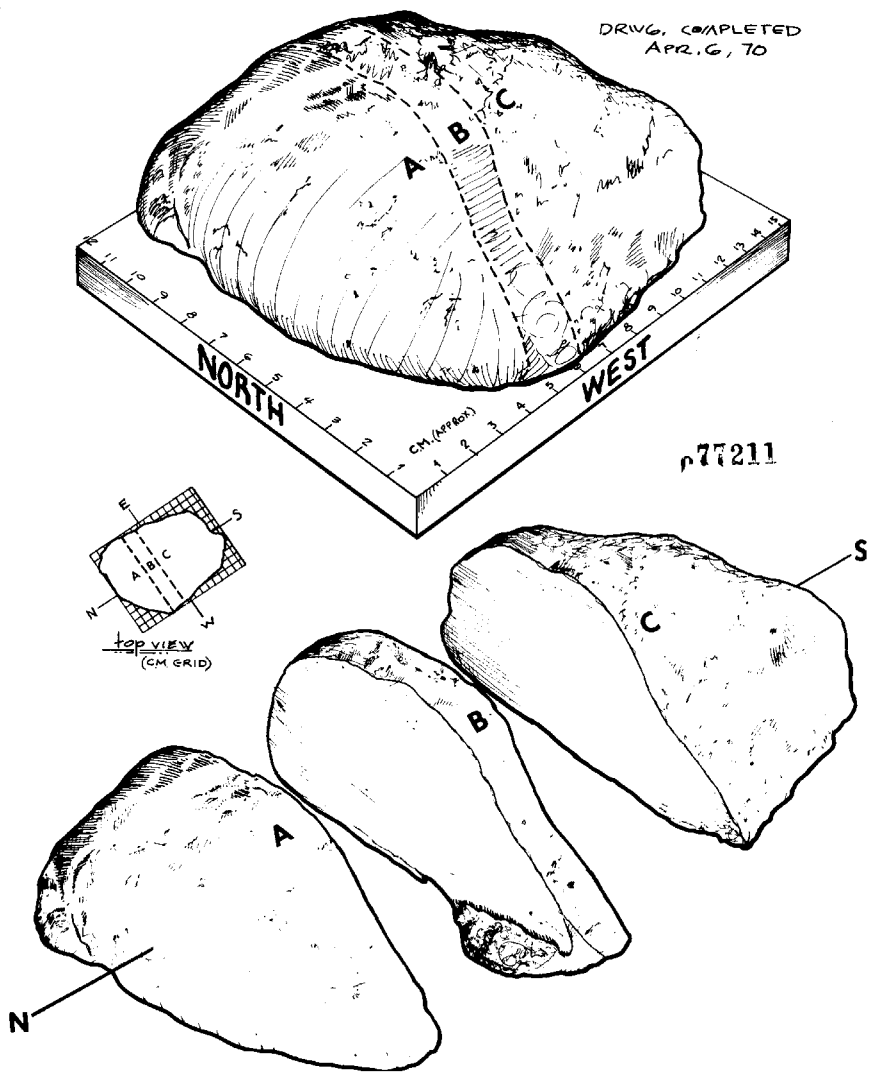
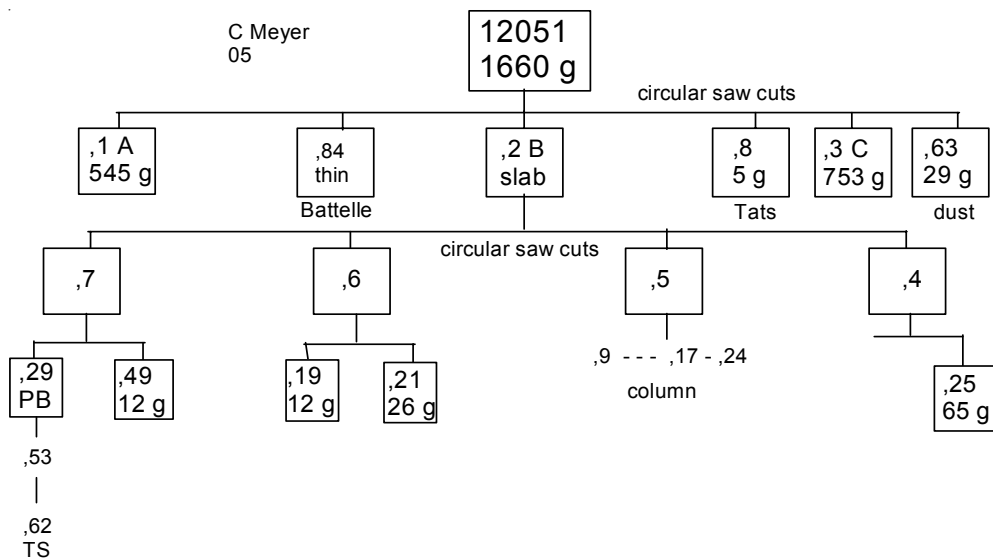




Figure 14: Top of the largest remaining piece of 12051 (,3 C). Scale in cm. NASA S94-35803.



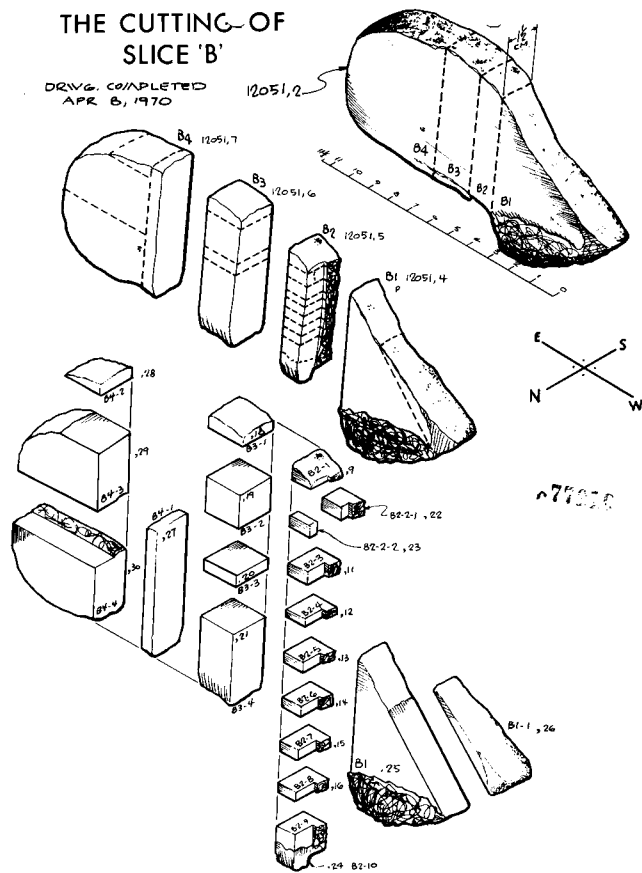


Figure 16: Group photo of pieces derived from end piece 12051,7. Scale in cm.

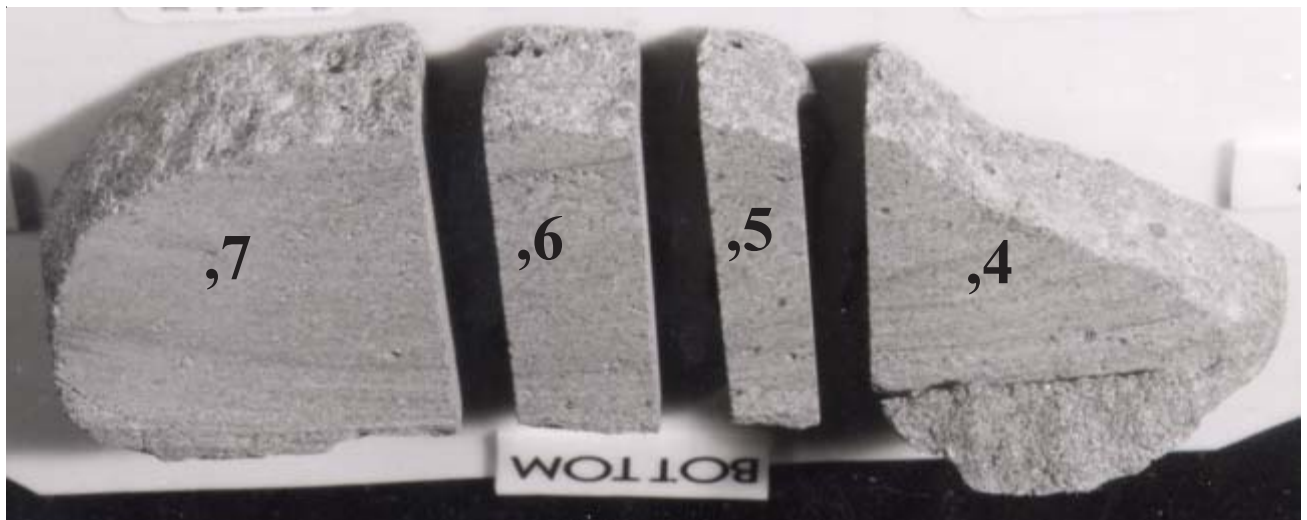
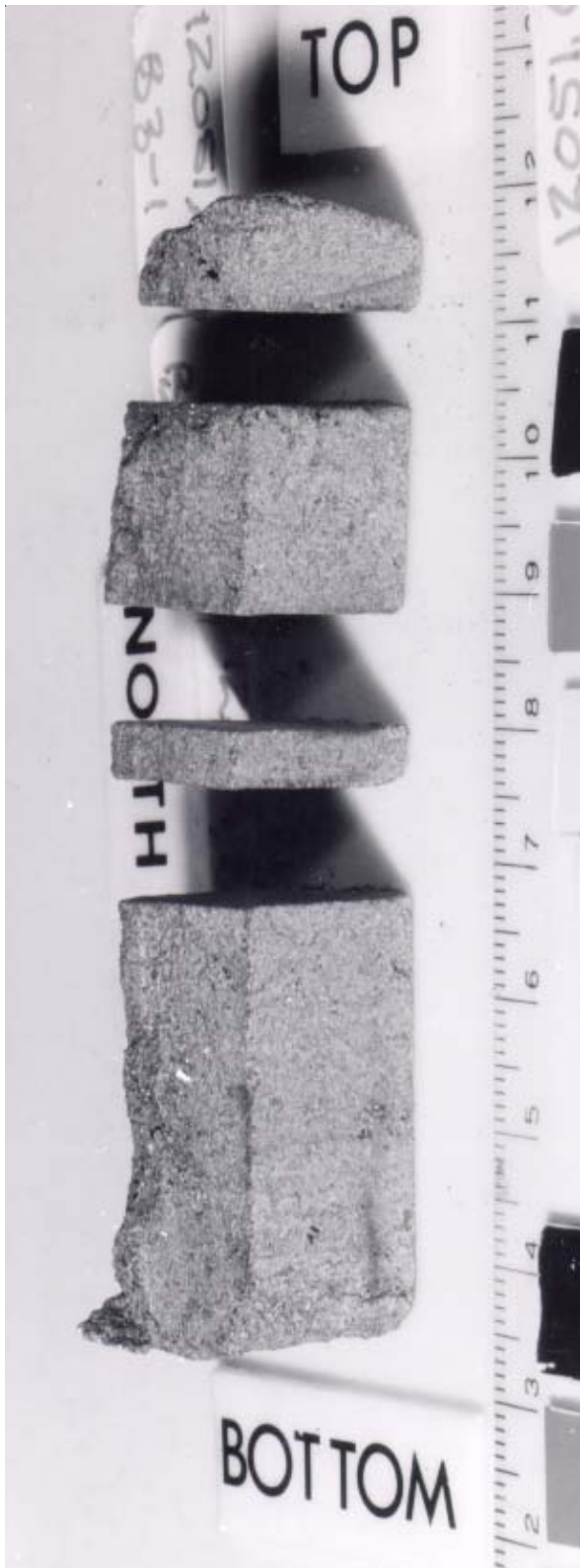


Figure 15: Group photo of pieces derived from 12051,2 (slab B). Slab is about 1.5 cm thick. NASA S70-36946.



Figures 17, 18: Group photos of columns ,6 a, ,5 cut from slab (12051,2). Scale is in cm. Total length of columns top-to-bottom only 6 cm.

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