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 anhedra (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 that 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, fluroapatite, whitlockite and baddelyite (Keil et al. 1971).

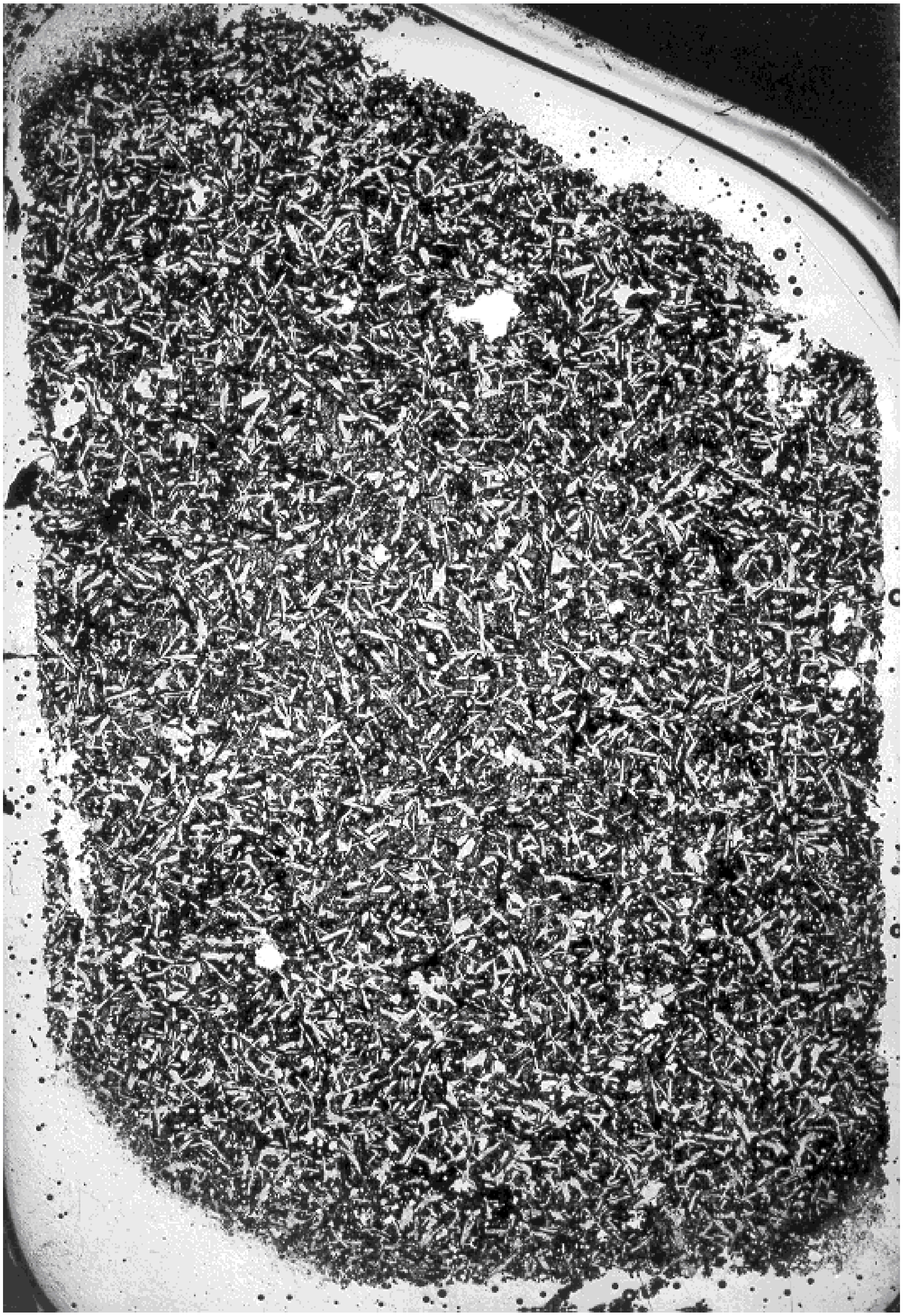

Figure 2: Photomicrograph of thin section 12051,53, showing basaltic texture. Field of view is 3 cm. NASA # S70-40820.

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 form this rock.

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

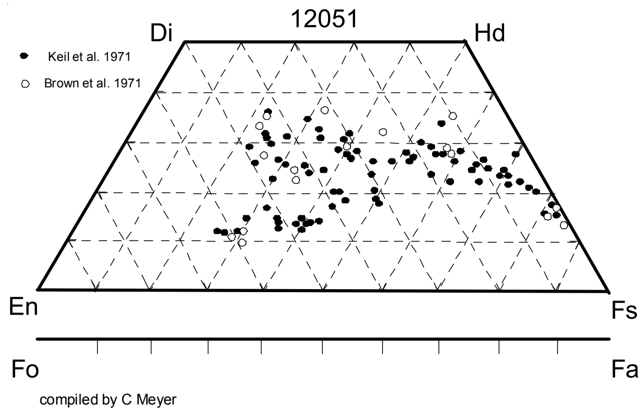

Figure 4: Pyroxene composition of 12051 (from Keil et al. 1971, Brown et al. 1971).

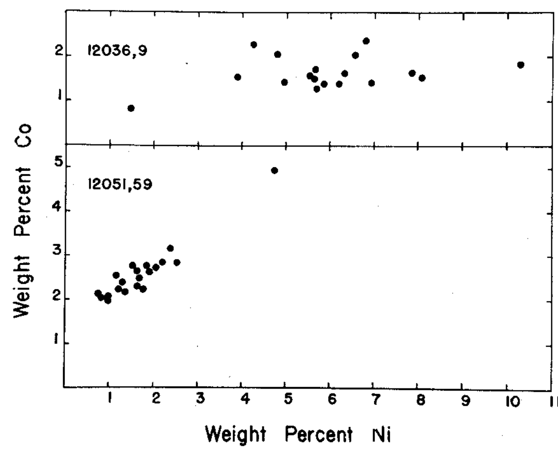

Figure 5: Ni and Co content of metallic iron grains in 12051 (from Keil et al. 1971).

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.

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 ± 0.1 b.y., figure 11). Turner (1971) determined 3.27 ± 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 ± 0.06 b.y. (figure 8). Compston et al. (1971) determined 3.58 ± 0.3 b.y. by internal Rb/Sr isochron (figure 9), Alexander et al. (1972) determined 3.32 ± 0.06 b.y. and Stettler et al. (1973) determined 3.16 ± 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}Na = 40 dpm/kg, ^{26}Al = 93 dpm/kg, ^{46}Sc = 7 dpm/kg and ^{54}Mn = 29 dpm/kg. Stettler et al. (1973) determined an ^{38}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.

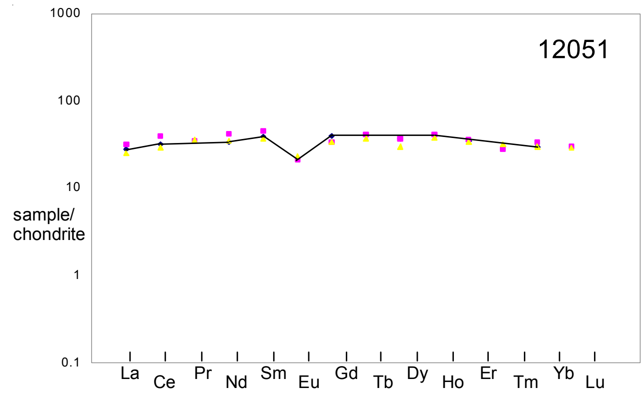

Figure 6: Comparison of neutron activation analysis of basalt 12051 (Morrison et al. 1971, Wakita et al. 1971) with isotopic dilution mass spectroscopy (line, Hubbard and Gast 1971, Wiesmann et al. 1975).

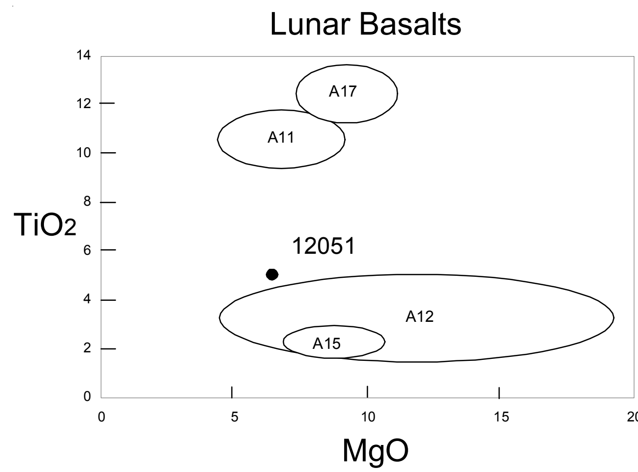

Figure 7: Composition of 12051 compared with other Apollo basalts.

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	

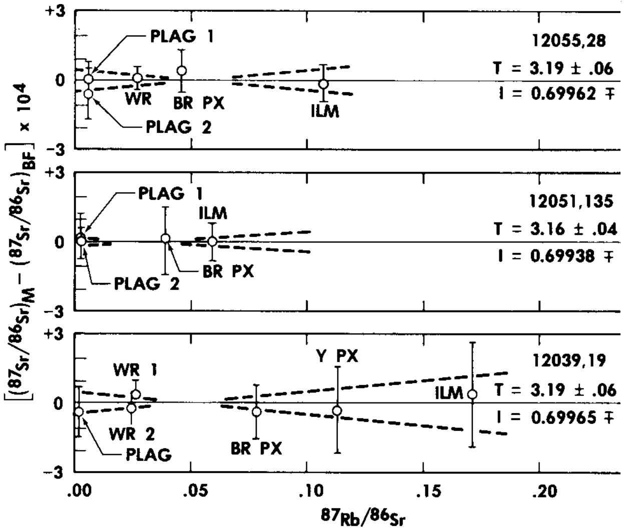

Figure 8: Rb-Sr isochron for 12051 (Nyquist et al. 1977).

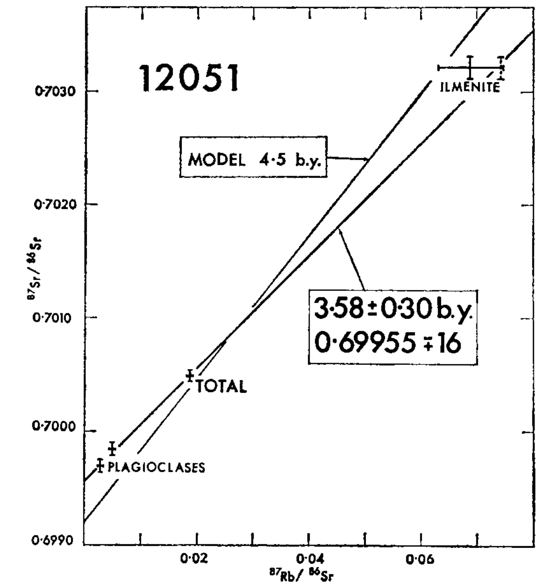

Figure 9: Rb-Sr isochron determined for 12051 (Compston et al. 1971).

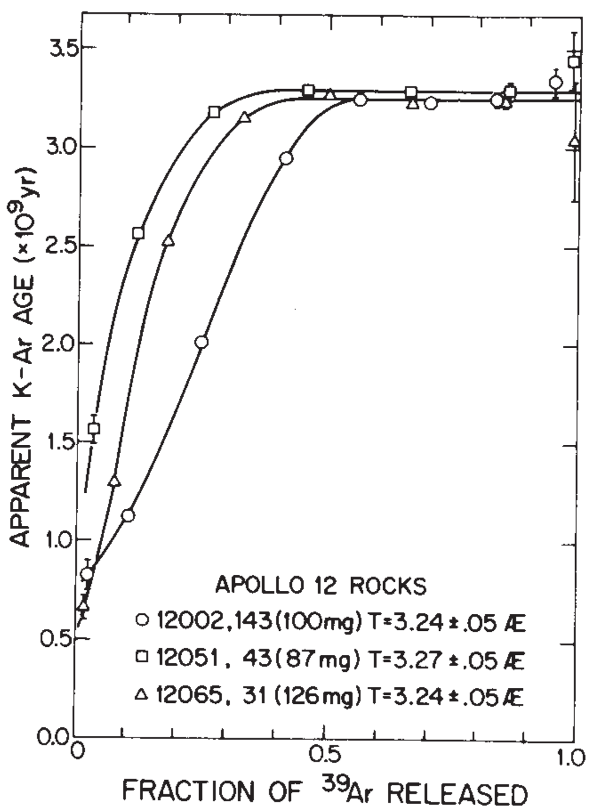

Figure 10: Ar-Ar release patten for 12051 (from Turner 1971).

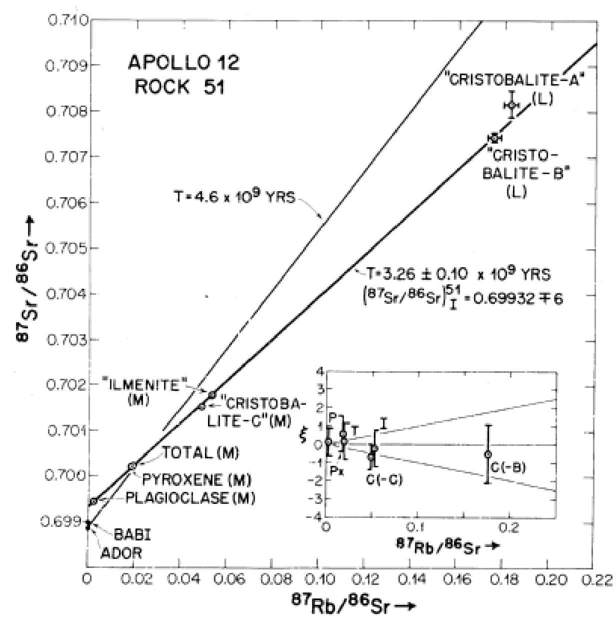

Figure 11: Rb-Sr isochron for 12051 as determined by Papanastassiou and Wasserburg 1970.

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	

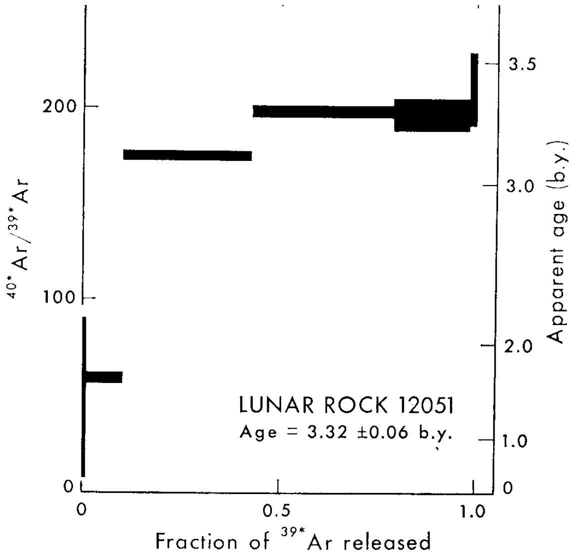

Figure 12: Ar-Ar release pattern for 12051 (from Alexander et al. 1972).

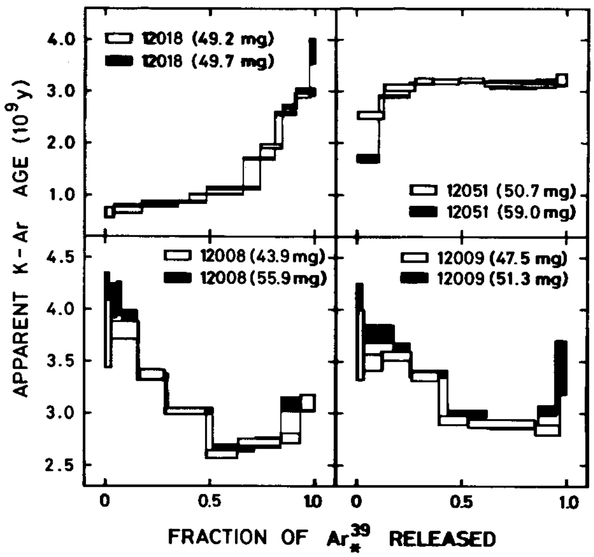

Figure 13: Argon release curves for Apollo12 basalts (from Stettler et al. 1973).

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Table 1a. Chemical composition of 12051.

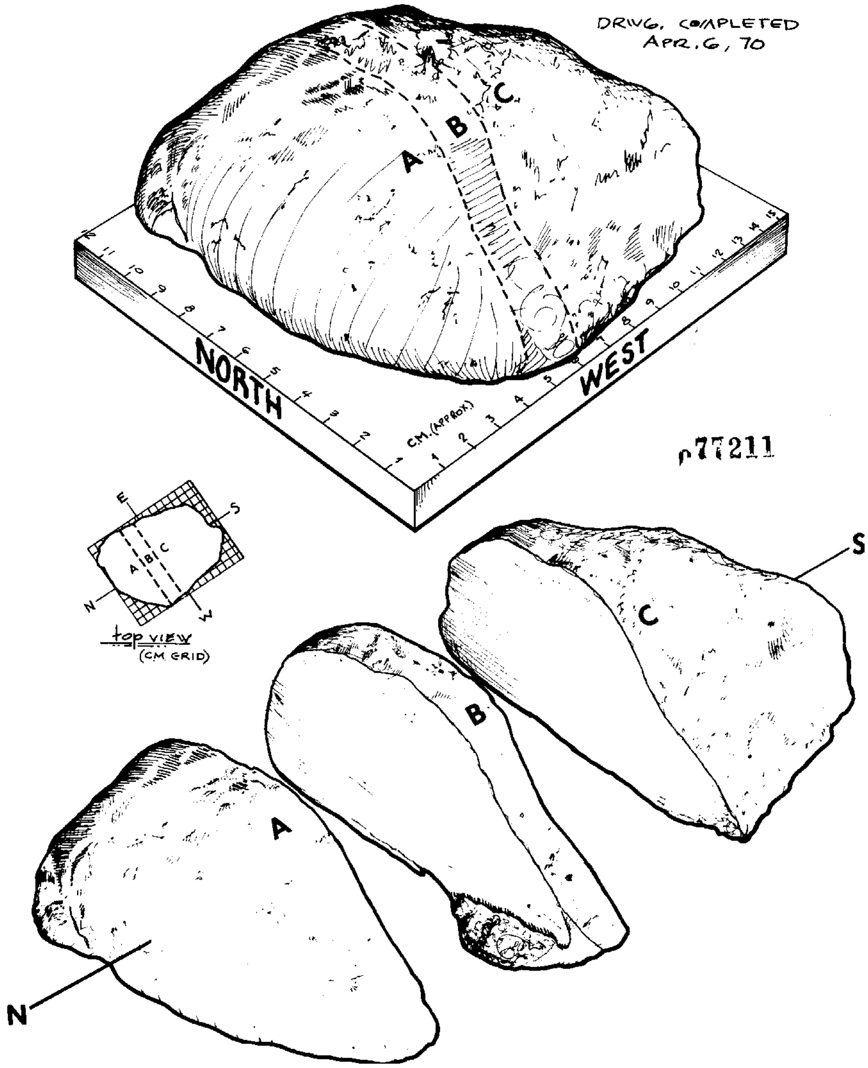
reference	Gast 70		Maxwell71		Hubbard71		Weismann75		O'Kelly71		Morrison71				Wakita71a, b		
weight					203 mg		203 mg		1660 g						0.449	0.535	
SiO2 %			45.54												47.1		(d)
TiO2	5.1	(a)	4.74								3.67	(d)			4.8	5	(d)
Al2O3			9.95								11.15	(d)			10.6	10	(d)
FeO			20.19								20.07	(d)			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)
Na2O	0.28	(a)	0.31								0.32	(d)			0.318	0.317	(d)
K2O	0.064	(a)	0.04		0.064	(a)	0.064	(a)	0.064	(c)	0.061	(d)				0.065	(f)
P2O5			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	Compston71				Anders71			Rancitelli71			Neal2001	
weight								545 g	765 g			
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											120	(h)
Te ppb					10	16	(f)					
Cs ppm					0.04	0.042	(f)				0.1	(h)
Ba											75	(h)
La	5	(g)									7.22	(h)
Ce											20.1	(h)
Pr											3.2	(h)
Nd											15.4	(h)
Sm											5.7	(h)
Eu											1.38	(h)
Gd											8.06	(h)
Tb											1.49	(h)
Dy											9.52	(h)
Ho											2.05	(h)
Er											5.68	(h)
Tm											0.89	(h)
Yb											5.16	(h)
Lu											0.73	(h)
Hf											4.22	(h)
Ta											0.58	(h)
W ppb											140	(h)
Re ppb												
Os ppb												
Ir ppb					0.09	0.54	(f)					
Pt ppb												
Au ppb					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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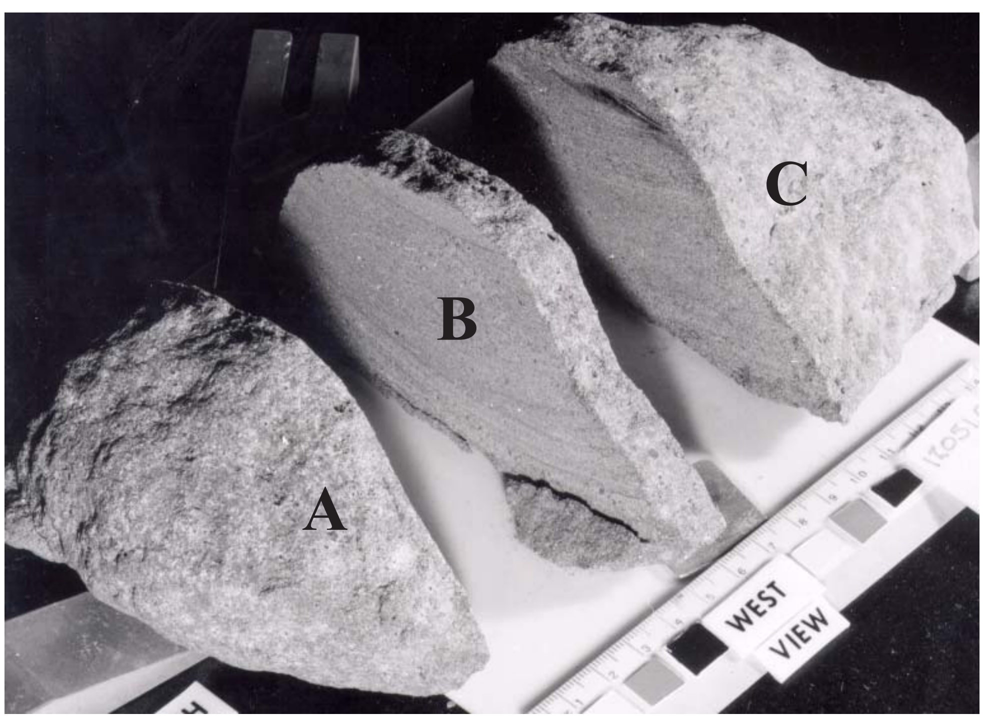
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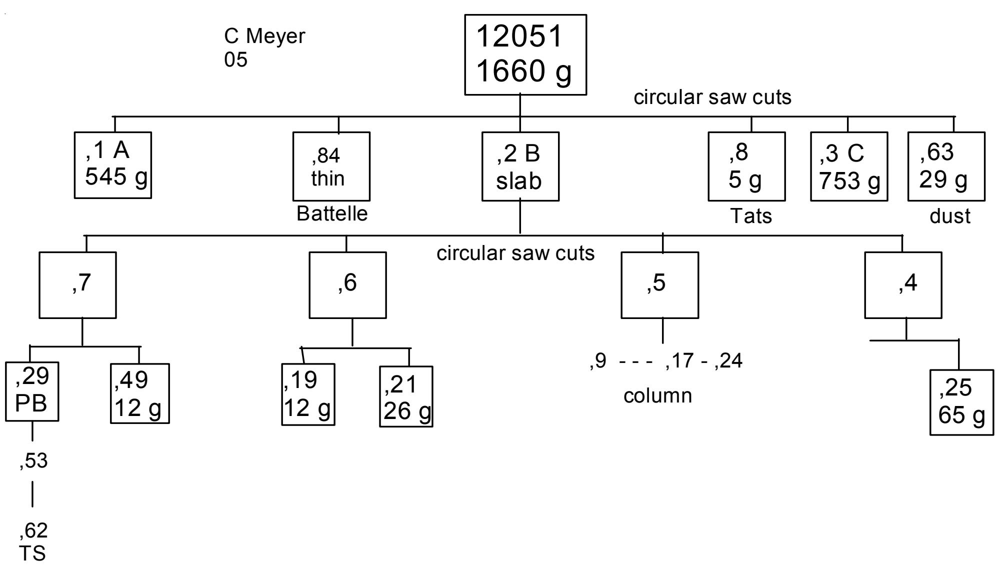
Figure 14: Top of the largest remaining piece of 12051 (,3 C). Scale in cm. NASA S94-35803.



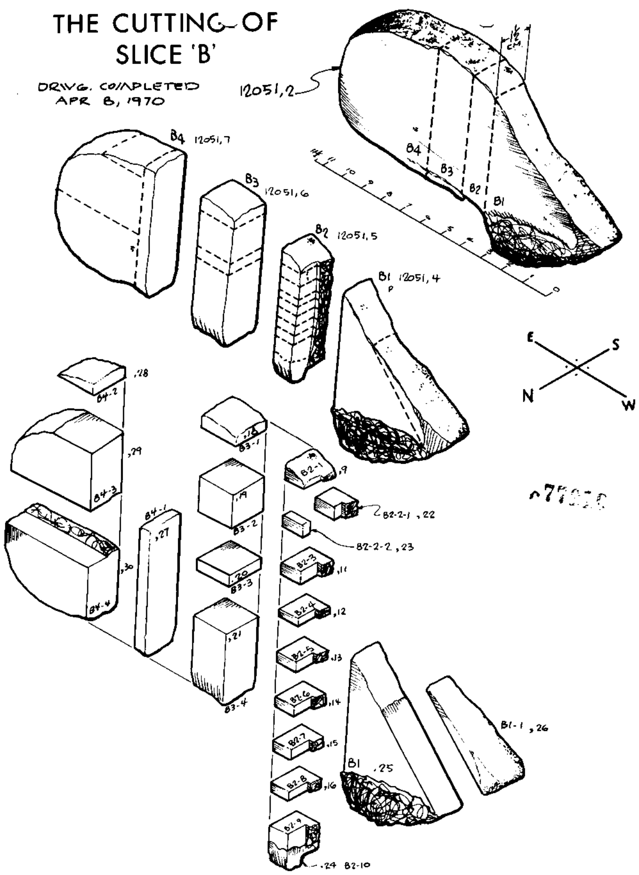


Figure 16: Group photo of pieces derived from end piece 12051,7. Scale in cm.

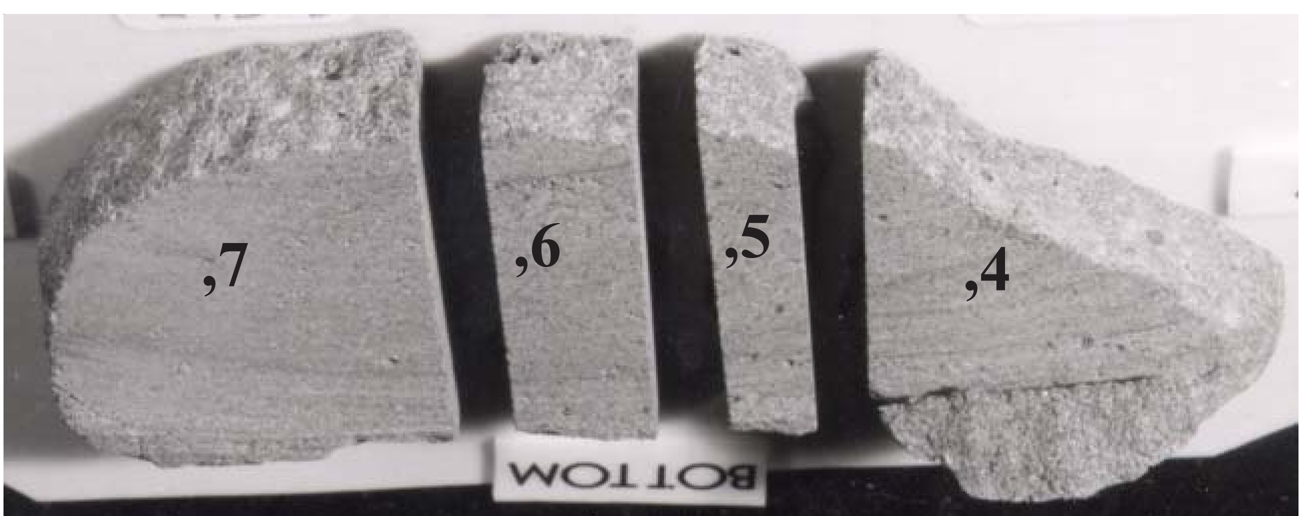
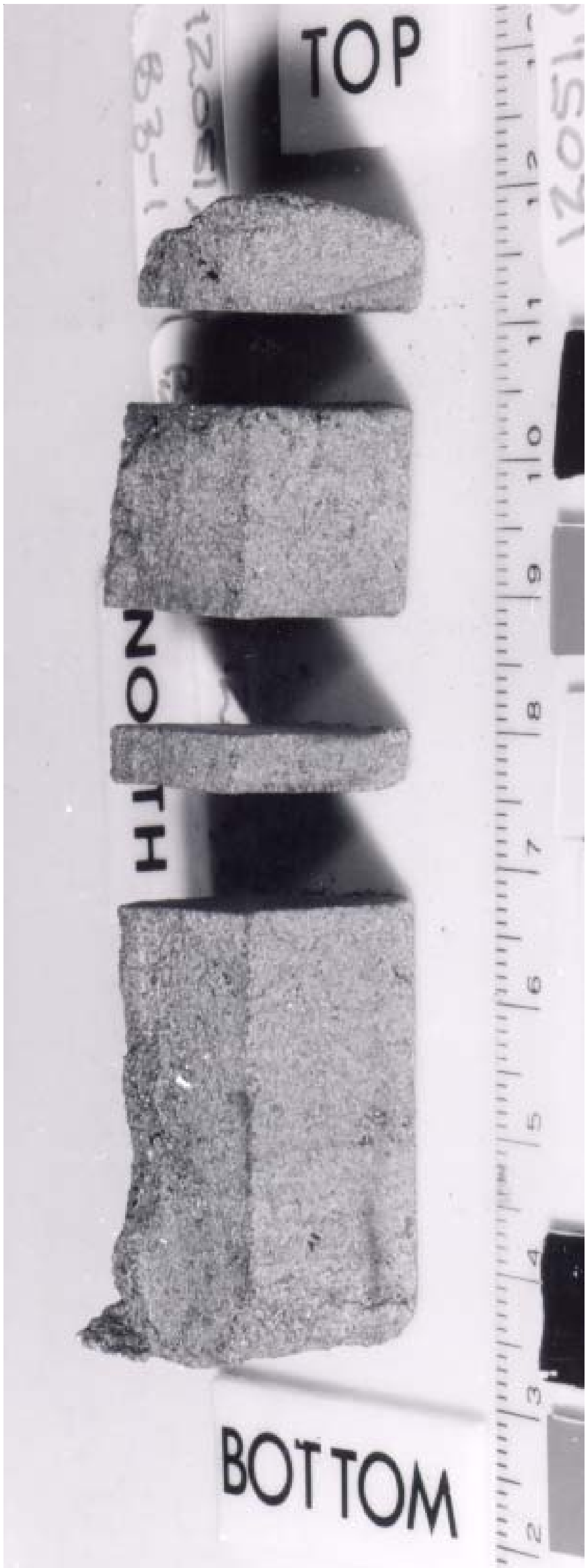
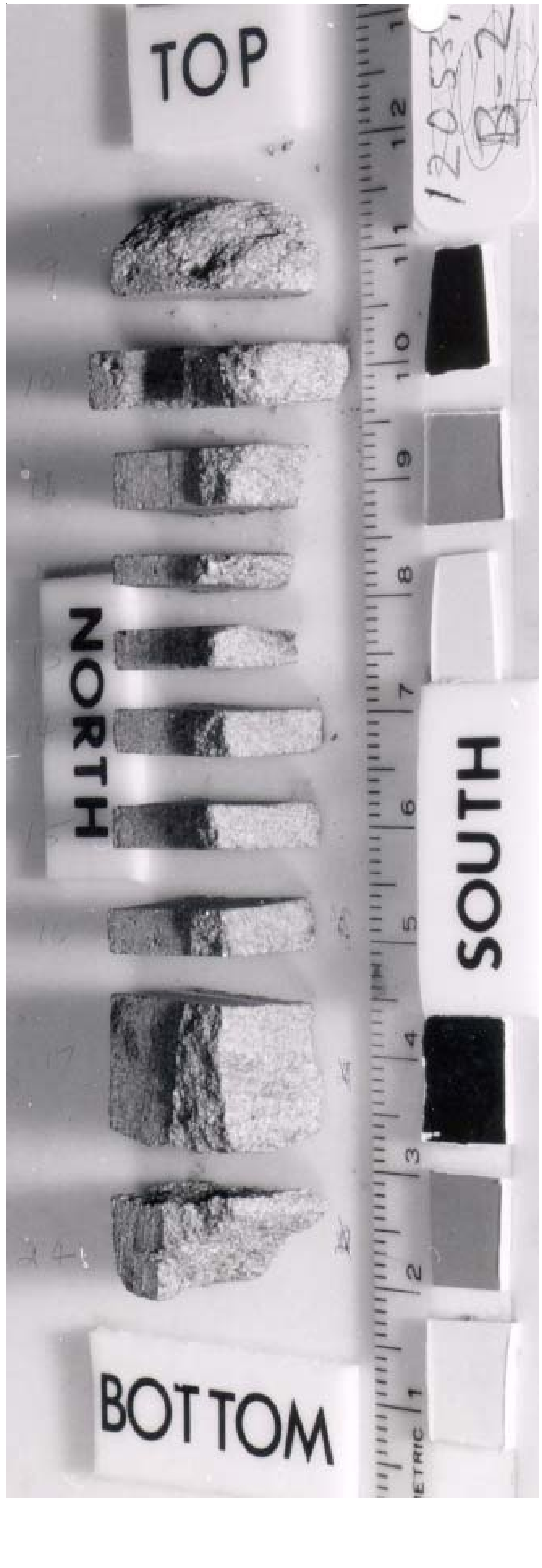


Figure 15: Group photo of pieces derived from 12051,2 (slab B). Slab is about 1.5 cm thick. NASA S70-36946.





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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