12033

Trench Soil

450 grams

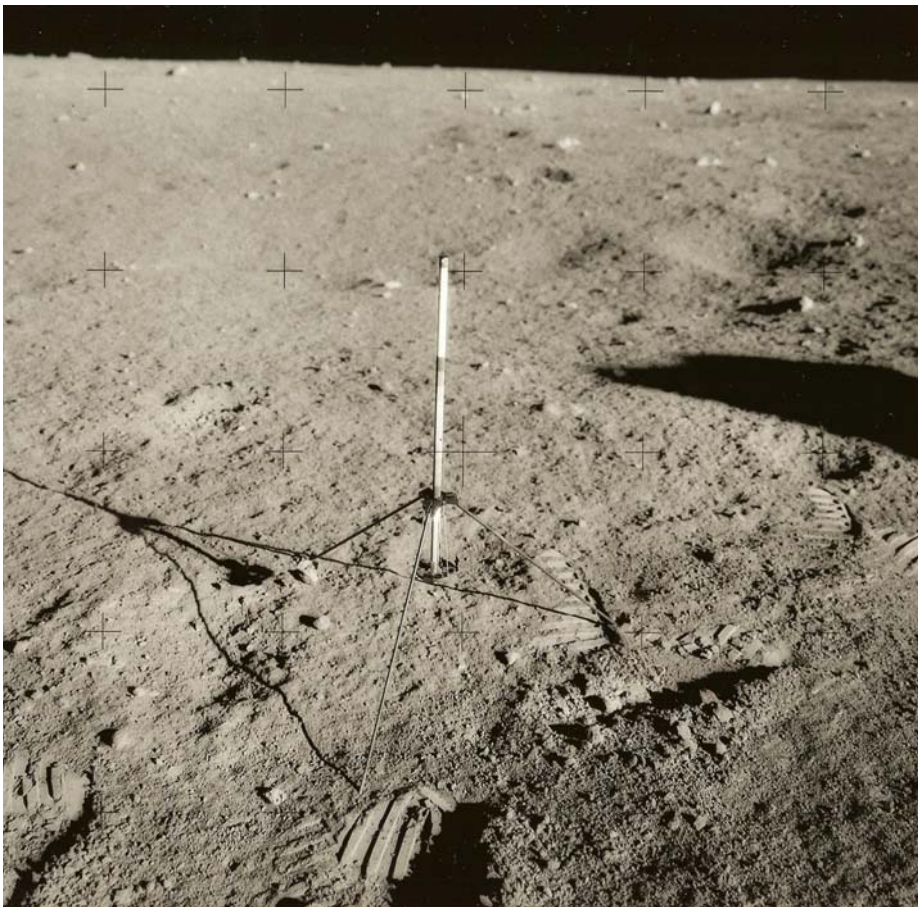


Figure 1: Location of 12033 before trenching. AS12-49-7191.

Introduction

Sample 12033 was collected from 15 cm below the surface and are the fines collected in documented bag 5. The location is near Head Crater. The subsurface was lighter in color than the top (figure 1).

12033 is the ropy glass sample made famous by Meyer et al. (1971), who suggest that it came from Copernicus and may represent material from the Fra Mauro formation. 12033 was used as a "reference soil" for the Lunar Highland Initiative (Papike et al. 1982).

Breccia sample 12034 was also from this trench.

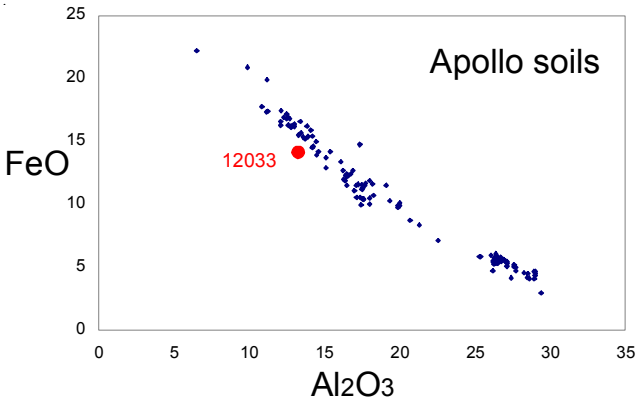


Figure 2: Composition of 12033 compared with other lunar soils (data from Compston et al. 1971).

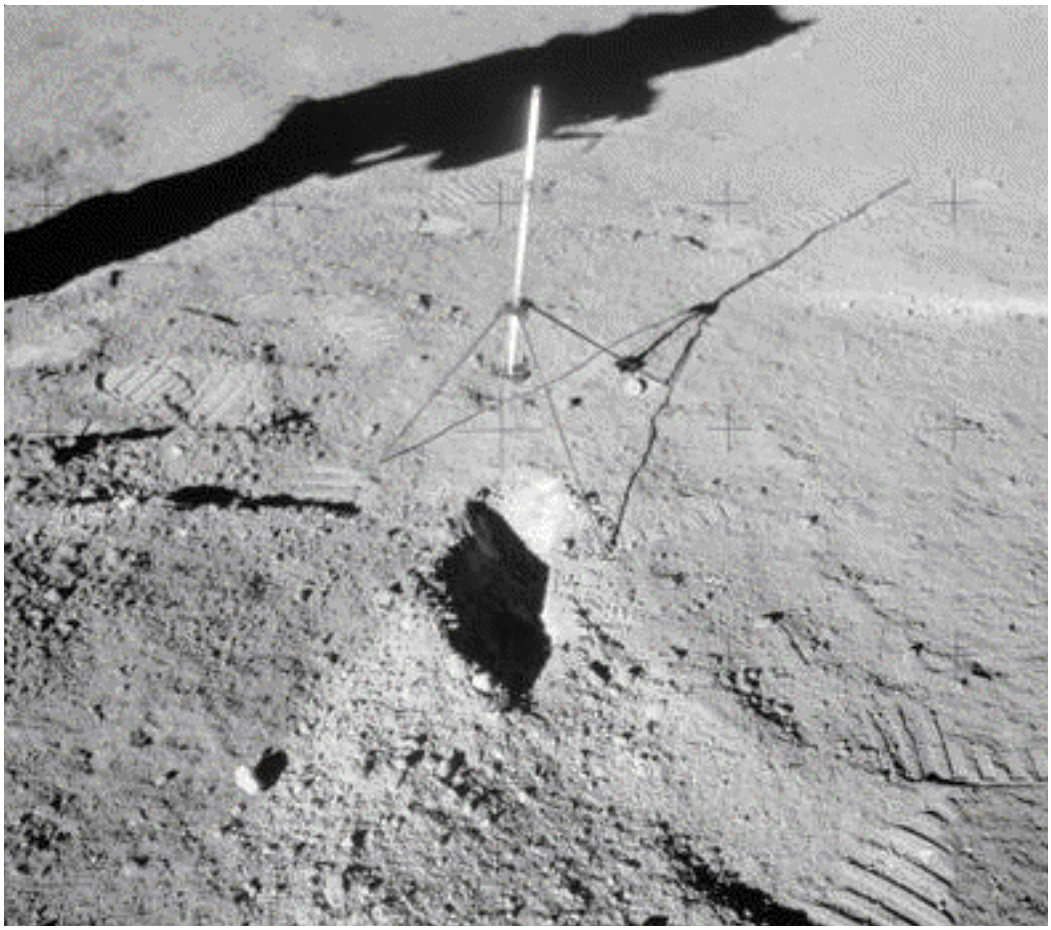


Figure 3: Trench for 12033 at Head Crater. Note the light color material from the trench.

Modal Mineralogy of 12033

Simon et al. 1981 (1000-90 micron)

LITHIC FRAGMENTS	
Mare basalt	7.5
Highland Component	
ANT	1.3
LMB	0.3
Feld. basalt	-
RNB/POIK	3.7
FUSED SOIL COMPONENT	
DMB	11.9
Agglutinate	17
MINERAL FRAG	
Mafic	26.3
Plag	9.9
Opaque	1.3
GLASS FRAG	
Orange/black	1.5
Yellow/Green	0.2
Brown	7.8
Clear	-
MISC	
Devitrified glass	10.8
Others	0.5

Mineralogical Mode

Frondel et al. 1971

Olivine + Pyroxene	54.4 %
Plagioclase	24.1
Opaques	8.6
Glass, angular	9.8
Glass, rounded	1.5
Silica	1.7

Mineralogical Mode

McKay et al. 1971

Grain size	37-62.5	62.5-125
Olivine	6 %	2
Pyroxene	19	24
Plagioclase	22	18
Glass	39	21
Aggregates	**14**	**25**

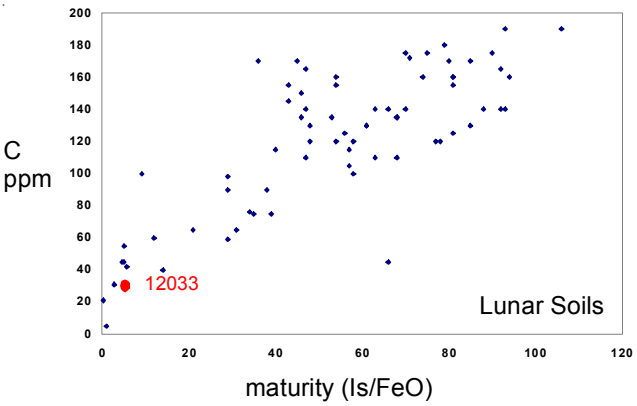


Figure 4: Carbon content and maturity index for 12033, compared with that of other Apollo soil samples.

Mineralogical Mode (250-1000 microns)

McKay et al. (1971)

Glazed	
Aggregates	2 %
Single xtl.	10
Glasses	75
Rocks	3
Breccias	1.5
Spherules	0.2

Mineralogical Mode for 12033

Labotka et al. 1980

	90-20 micron	20-10 micron
Lithic clasts	0.2	0.2
Agglutinates	22.1	7.2
Pyroxene	30.8	24.4
Plagioclase	17.9	26.6
Olivine	3	3.2
Silica	0.8	1.2
Ilmenite	3	5.2
Mare glass	4.4	11.5
Highland glass	17.1	18.5

Petrography

The maturity index (I_s/FeO) is very low (4.6) for 12033, indicating that it is a very unusual soil (figure 4). The average grain size of 12033 is 54 microns.

Frondel et al. (1971) determined the mineral mode but did not specify agglutinates. McKay et al. (1971) also determined the mode, and reported 75% glass and only 2 % "glazed aggregates" (agglutinates).

Labotka et al. (1980) reported the mode for the fine-grained portion and Marvin et al. (1971) did the statistics on coarse particles (figure 7).

Meyer et al. (1971) and Engelhardt et al. (1971) give the chemical composition of a large number of maroon glass particles in 12033.

Meyer et al. (1971) described the ropy glass and fragments of K-rich impact melt. The materials were found to be basaltic in composition. They are found to have microlites of feldspar, and inclusions of orthopyroxene (figure 5).

Simon and Papike (1985) describe 2 large particles from 12033 (figure 10). Warren et al. (1987) studied a" large" felsite (12033,507). Marvin and Walker (1985) reported on a "troctolite" fragments.

Chemistry

Laul and Papike (1980) give the most definitive analysis (table 1 and figure 9).

The trace element analysis by Hubbard and Gast (1971) is from a "ground up, coarse fine fraction" and is especially rich in trace element content (probably due to ropy KREEP glass).

The carbon content of 12033 was reported by Epstein and Taylor (1971) as 30 ppm (figure 4). Moore et al. (1971) reported two values for carbon content (23 and 50 ppm). They also reported 46 ppm nitrogen. However, Kerridge et al. (1978) found only 24 ppm C and 7 ppm N in this immature soil.

Radiogenic age dating

There is considerable evidence for a glass-forming impact event at ~800 m.y. ago (Eberhardt 1973, Bogard et al. 1994, Bara et al. 2006, Zellner). Alexander et al. (1977) determined an age of 1.23 b.y.

Hubbard et al. (1971) and Nyquist et al. (1972) provide Sr isotope data for "anorthosite", apparently derived from KREEP magma.

Other Studies

Heymann et al. (1972) reported rare gas content and isotopic ratios. Wieler et al. (1980) showed that there was very low ^{36}Ar, which correlated with the lack of track-rich grains (figure 12).

Arrhenius et al. (1971) studied the frequency of grains with high fossil nuclear tracks in 12033 (and all other Apollo 12 soil and core samples). 12033 had very few grains with high track density.

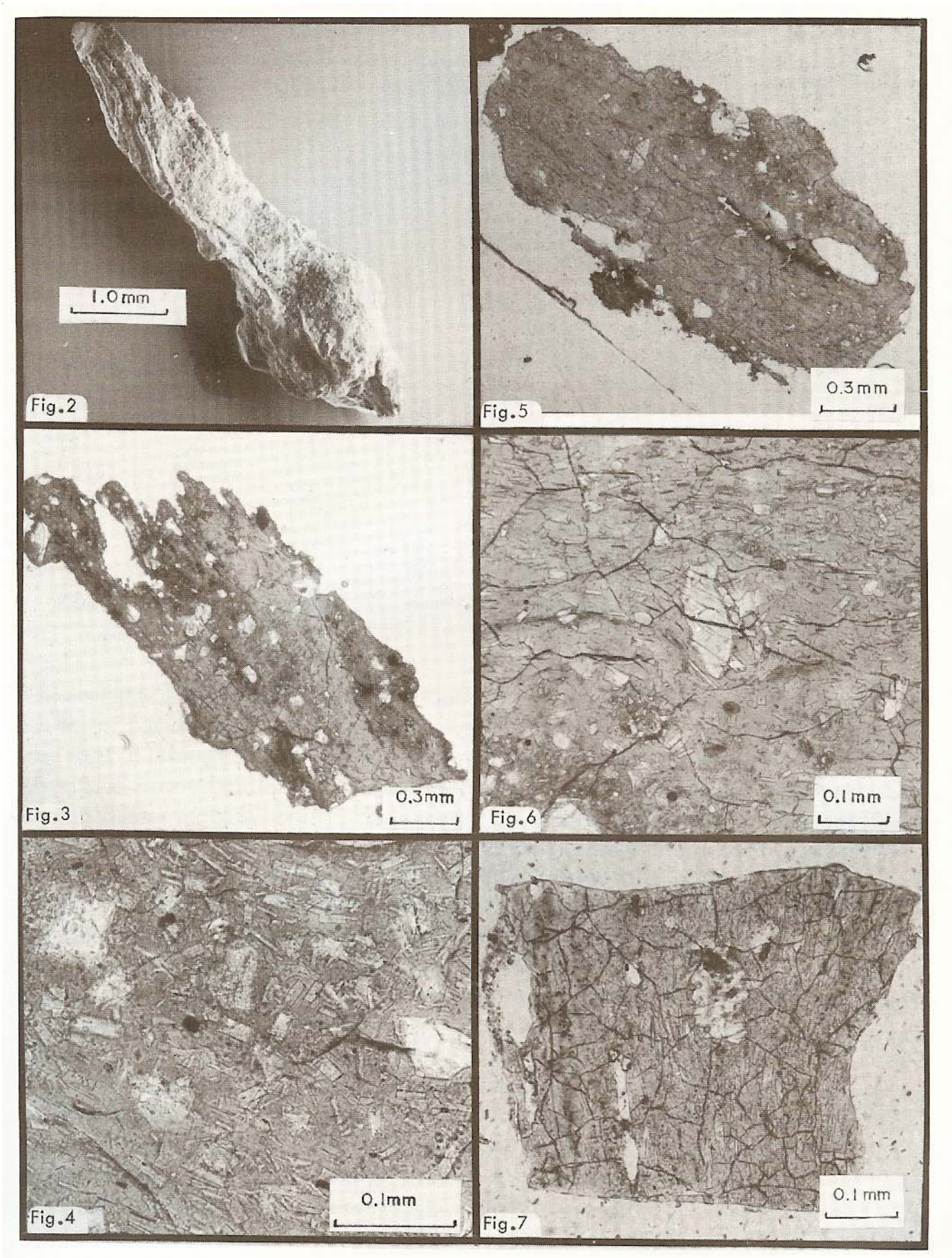


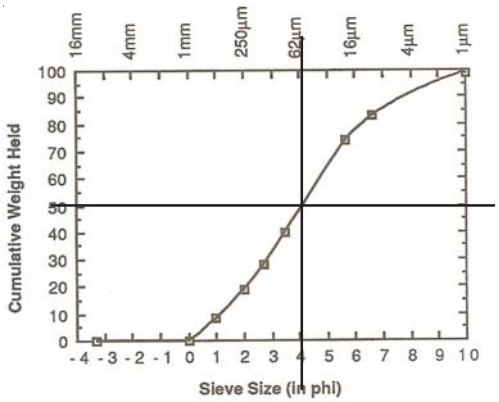
Figure 5: SEM and thin section photos of ropy glass found in 12033 (Meyer et al. 1971).

Caddenhead et al. (1977) showed that 12033 was a most unusual lunar soil, with very little surface area.

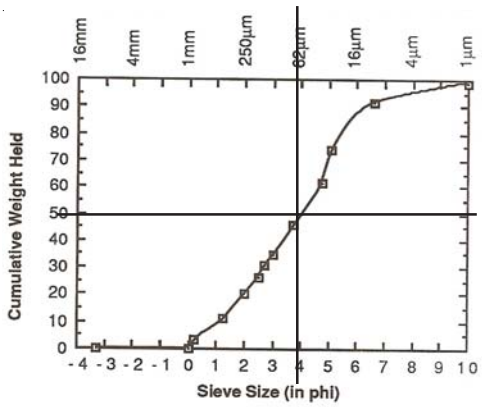
Grosman et al. (1974) used 12033 to obtain the oxygen isotopic composition of the Moon (really).

Processing

12033 was returned in ALSRC D, which was found to have leaked air.



average grain size = 54 microns



average grain size = 73 microns

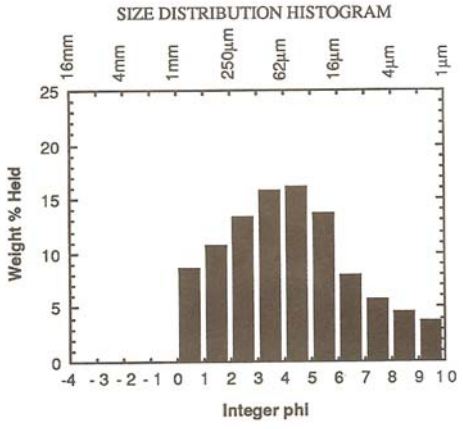


Figure 6a: Grain size distribution for 12033 (Graf 1993, from data by McKay et al. 1971).

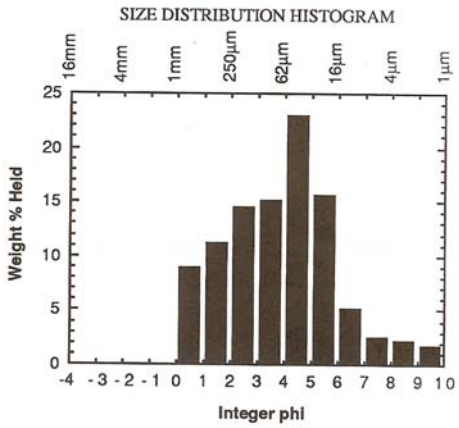


Figure 6b: Grain size distribution for 12033 (Graf 1993, from data by King et al. 1971).

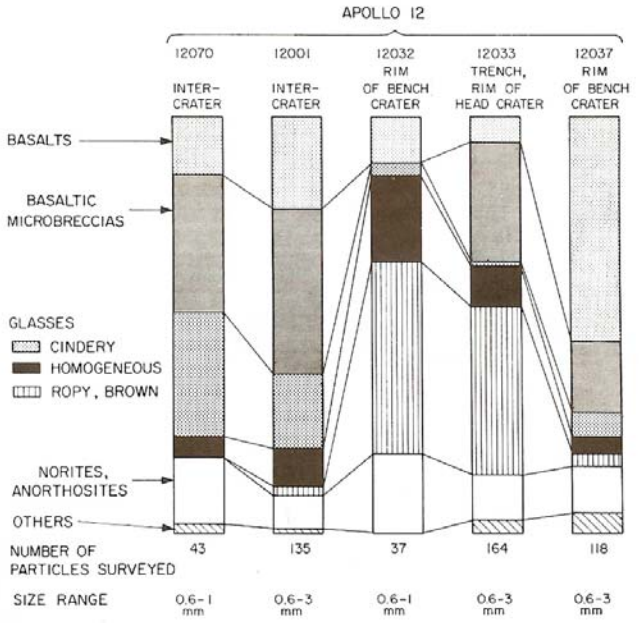
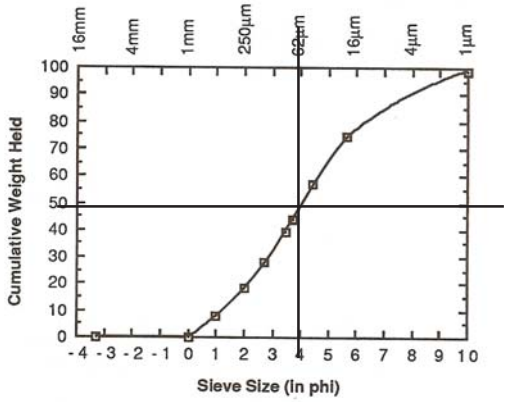


Figure 7: Modal analysis of coarse particles in Apollo 12 soils (Marvin et al. 1971).



average grain size = 51 microns

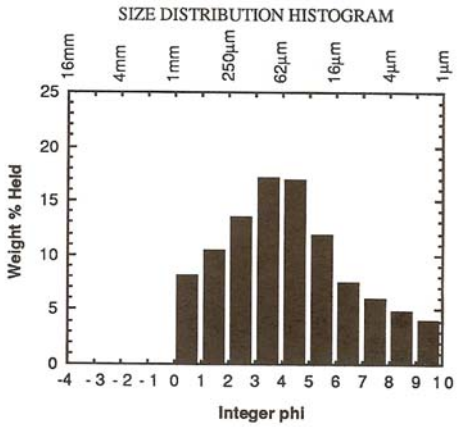


Figure 6c: Grain size distribution for 12033 (Graf 1993, from data by McKay et al. 1971).

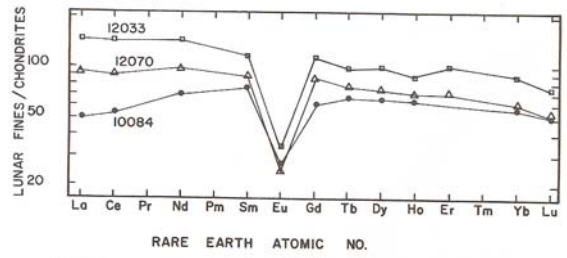


Figure 8: REE patterns compared (Haskin et al. 1971).

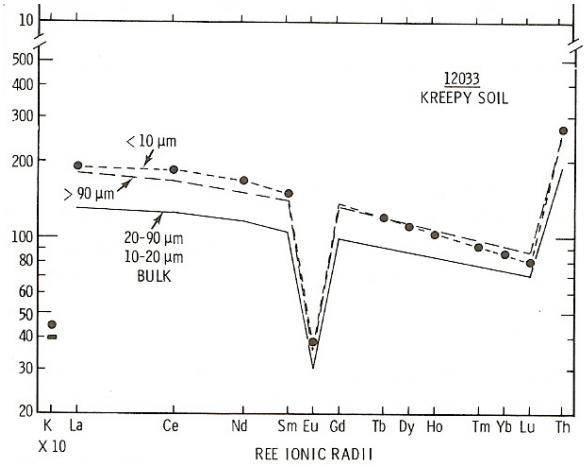


Figure 9: Normalized rare-earth-element diagram for 12033 (Laul and Papike 1980).

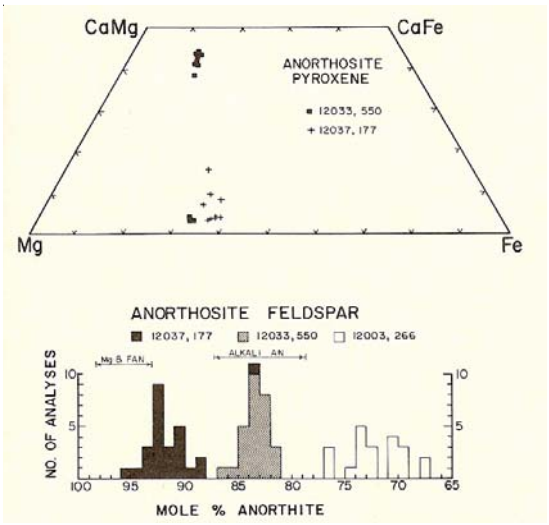


Figure 10: Pryoxene and plagioclase composition of an apparent anorthosite found in 12033 (Simon and Papike 1985).

Table 1a. Chemical composition of 12033.

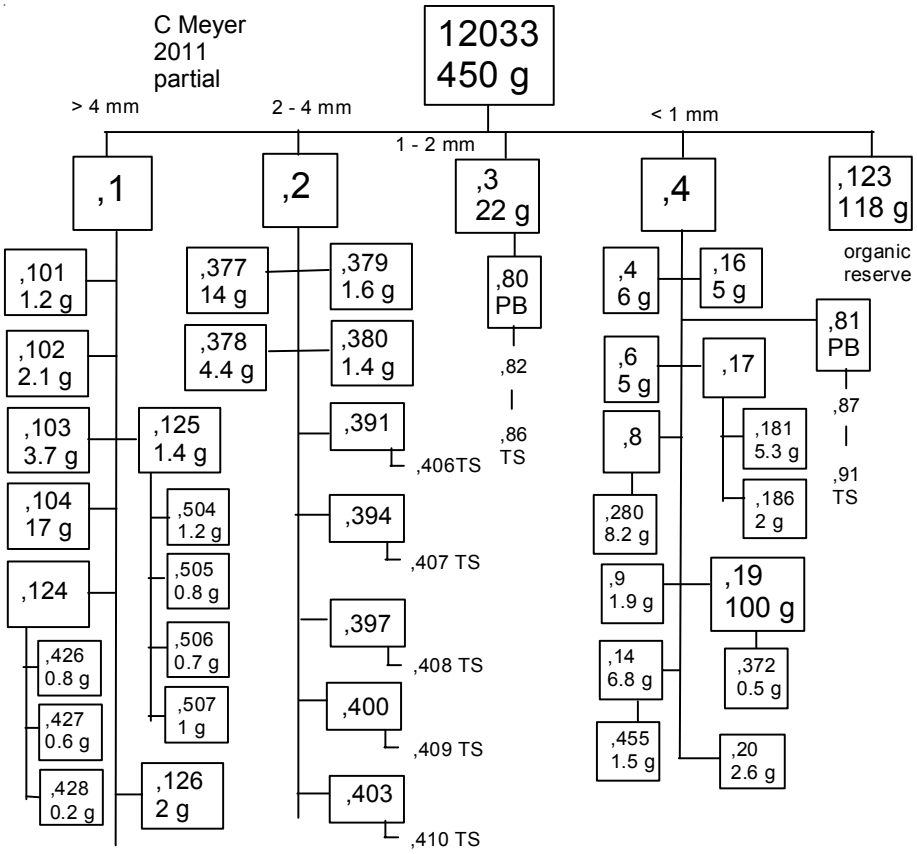
reference	LSPET70		Hubbard72 Wiesmann75	Laul71		Wakita71			Laul81		Compston71		Frondel71		Baedecker71	
weight			132 mg													
SiO2 %	41	(b)				46.9		(a)	46.9	(a)	46.96	(c)	46.2	(e)		
TiO2	2.6	(b)				2.3	2.8	(a)	2.3	(a)	2.5	(c)	2.7	(e)		
Al2O3	16	(b)				17.3	16.8	(a)	14.2	(a)	13.99	(c)	16.2	(e)		
FeO	16	(b)				11.7		(a)	15.4	(a)	14.65	(c)	14	(e)		
MnO	0.23	(b)				0.154	0.168	(a)	0.195	(a)	0.19	(c)	0.19	(e)		
MgO	11	(b)				10.6			9.2	(a)	8.96	(c)	8.5	(e)		
CaO	11.5	(b)				12.3	11.9	(a)	11.1	(a)	10.68	(c)	11	(e)		
Na2O	0.54	(b)	0.82			0.834	0.805	(a)	0.67	(a)	0.66	(c)	0.62	(e)		
K2O	0.39	(b)	0.56				0.469	(a)	0.41	(a)	0.41	(c)	0.38	(e)		
P2O5											0.43	(c)				
S %											0.07	(c)				
sum																
Sc ppm	33	(b)				27		(a,d)	36.4	(a)						
V	37	(b)				80	90	(a,d)	100	(a)	75	(c)				
Cr	2100	(b)				1608		(a)	2648	(a)	1990	(c)	1847	(e)		
Co	34	(b)		34	(d)	30		(a,d)	34.3	(a)	32	(c)				
Ni	140	(b)							130	(a)	108	(c)				
Cu											19	(c)				
Zn				5	(d)						14	(c)			7.1	(d)
Ga				4.7	(d)						3.1	(c)			5.4	(d)
Ge ppb															223	(d)
As																
Se				0.18	(d)											
Rb	7.5	(b)	14.4	8.3	(d)						10.1	(c)				
Sr	260	(b)	185						160	(a)	171.5	(c)				
Y	260	(b)					211	(a,d)			162	(c)				
Zr	950	(b)				510		(a,d)			762	(c)				
Nb											44	(c)				
Mo																
Ru																
Rh																
Pd ppb																
Ag ppb				12	(d)											
Cd ppb				26	(d)										64	(d)
In ppb							8	(a,d)							47	(d)
Sn ppb							2	(a,d)								
Sb ppb																
Te ppb				40	(d)			(a,d)								
Cs ppm				0.4	(d)	0.42		(a,d)								
Ba	720	(b)	858			600		(a,d)	600	(a)	585	(c)				
La			69.7			75	62	(a,d)	50	(a)	48	(c)				
Ce			180				180	(a,d)	133	(a)	131	(c)				
Pr							21	(a,d)								
Nd			108				91	(a,d)	85	(a)						
Sm			31			32	29	(a,d)	22.8	(a)						
Eu			2.79			3.08	2.89	(a,d)	2.45	(a)						
Gd			35.7				33	(a,d)								
Tb							5.4	(a,d)	4.9	(a)						
Dy			39.2				32	(a,d)	30	(a)						
Ho							8.8	(a,d)	7.2	(a)						
Er			25.1				20.1	(a,d)								
Tm							2.9	(a,d)	2.6	(a)						
Yb			21.4			26.3	21	(a,d)	17.3	(a)						
Lu						3.2	2.61	(a,d)	2.45	(a)						
Hf							20		16.6	(a)						
Ta									2.2	(a)						
W ppb																
Re ppb																
Os ppb																
Ir ppb				3.9	(d)										3.9	(d)
Pt ppb																
Au ppb				1.5	(d)											
Th ppm						13.5		(a,d)	8.5	(a)	10.3	(c)				
U ppm									2.4	(a)	2.7	(c)				

technique: (a) INAA, (b) es, (c) XRF, (d) RNAA, (e) wet

Table 1b. Chemical composition of 12033.

reference	Cuttitta71			Haskin71		Maxwell71	Murthy71	
weight								
SiO2 %	47.2	48.2	(a)					
TiO2	2.48	2.33	(a)					
Al2O3	14.3	15.1	(a)					
FeO	14.2	12.9	(a)					
MnO	0.19	0.18	(a)					
MgO	9.28	8.45	(a)					
CaO	10.6	10.6	(a)					
Na2O	0.66	0.87	(a)					
K2O	0.41	0.54	(a)				0.35	(d)
P2O5	0.52	0.55	(a)					
S %								
sum								
Sc ppm	38	38	(b)					
V	106	80	(b)					
Cr	2960	2680	(b)					
Co	36	106	(b)					
Ni	137	210	(b)					
Cu	8.7	8	(b)					
Zn	4	4.6	(b)					
Ga	5.2	4.8	(b)					
Ge ppb								
As								
Se								
Rb	10.3	16	(b)				10.25	(d)
Sr	137	178	(b)				162	(d)
Y	190	245	(b)					
Zr	645	790	(b)					
Nb	38	74	(b)					
Mo								
Ru								
Rh								
Pd ppb								
Ag ppb								
Cd ppb								
In ppb								
Sn ppb								
Sb ppb								
Te ppb								
Cs ppm								
Ba	667	990	(b)				575	(d)
La	61	88	(b)	48.5	(c)			
Ce				127	(c)			
Pr								
Nd				90	(c)			
Sm				21.5	(c)			
Eu				2.31	(c)			
Gd				28	(c)			
Tb				4.6	(c)			
Dy				31.8	(c)			
Ho				6.1	(c)			
Er				20	(c)			
Tm								
Yb	20	23	(b)	17.4	(c)			
Lu				2.43	(c)			
Hf								
Ta								
W ppb								
Re ppb								
Os ppb								
Ir ppb								
Pt ppb								
Au ppb								
Th ppm								
U ppm								

technique: (a) "microchemical", (b) OES, (c) INAA, (d) IDMS



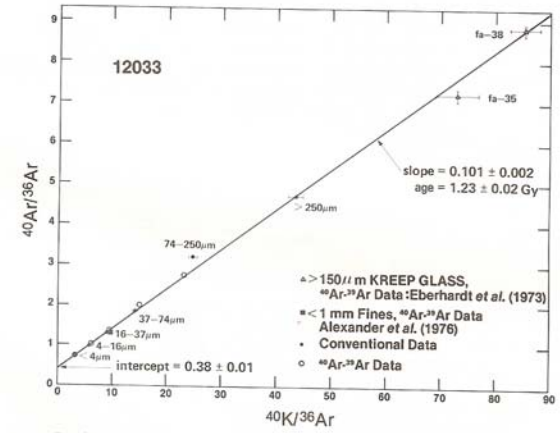


Figure 11: Ar data for 12033 (Alexander et al. 1977).

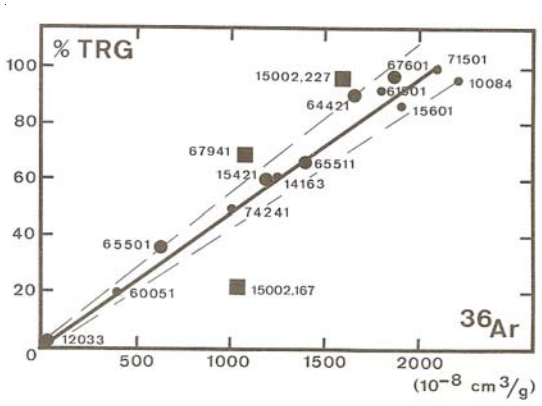


Figure 12: 12033 has very low 36Ar and very few track-rich grains consistent with its recovery from the bottom of a trench (Wieler et al. 1980).

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