10068

Regolith Breccia

218 grams

Figure 1: Part of 10068,5. NASA S76-22545. Sample is 5 cm across.

Introduction

Fruland (1983) describes 10068 as a "coherent, medium grey regolith breccia." The original rock was blocky in shape and had rounded surfaces that were covered with micrometeorite craters, although one side was relatively flat with no observable microcraters (figure 1).

This sample was the subject of a detailed consortium study led by Abhijit Basu. It was de-lithified using a freeze-thaw technique (Basu et al. 2000), the grain size distribution determined (figure 5) and the composition of each size measured (figure 4).

Petrography

Keil et al. (1970) originally determined the mode of the breccia matrix and of included basalt fragments.

Mineralogical Mode (Basu et al.)

	>500	250-500	150-250	90-150	45-90	20-45 microns
Mare rock	72.3	52	47.7	38	21	12.6
Highland rock	4.3	2.3	1.7	0.3	0.3	0.7
Reg. Breccia	12.8	25.8	30	38.7	50.7	43.2
Agglutinate	10.6	10.9	12	12.7	12.7	14.3
Plagioclase	0	1.3	1	1	4.3	5.3
Pyroxene	0	1.3	3.7	6	6.3	13
Ilmenite	0	0	0.3	0.3	1.3	8
Glass	0	6.3	3.7	3	3.3	2.7

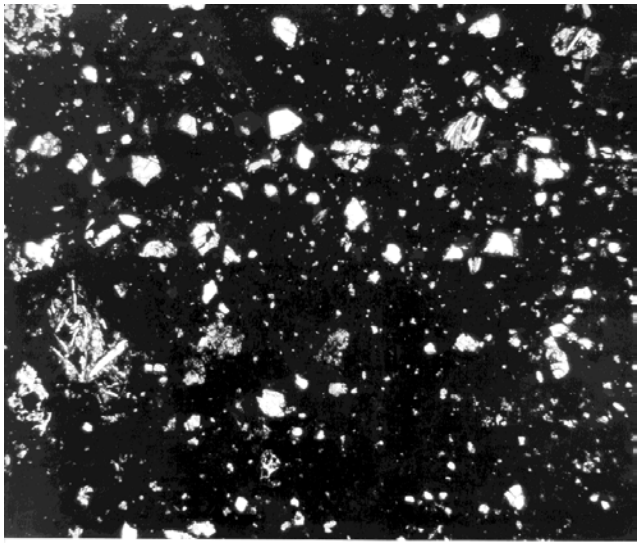


Figure 2: Photomicrograph of thin section 10068,35. NASA S76-26328.

McKay et al. (1970) remarked on the apparent sintering at sharp boundaries of broken glass particles.

Basu et al. (2000) found that the maturity index I_s/FeO = 84 (compared with 78 for soil 10084). They observed that 10068 was "*extremely rich in recycled agglutinates*"(about 12 %). However, a mature soil has about 30 % agglutinates. Funkhouser et al. (1970) determined that 10068 had rare gas content similar to soil, although, in general, Apollo 11 breccias had higher rare gas contents than the soils due to solar wind implantation and subsequent degassing (figure 8).

Mineralogy

Pyroxene: Keil et al. (1970) studied the compositions of pyroxene grains in 10068.

Plagioclase: Keil et al. (1970) studied the compositions of "shock vitrified" plagioclase in 10068.

Chemistry

Goles et al. (1970) and Annell and Heltz (1970) determined the composition of 10068. The rare earth element pattern for 10068 is similar to the soil (figure 3). Lindstrom (1999) reported trace element analyses of different grain sizes (figure 4). Note the high Ni content. The carbon content of 10068 is relatively high (figure 9).

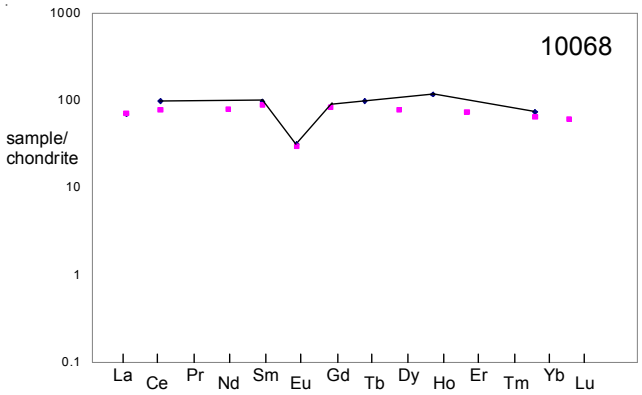


Figure 3: Normalized rare earth element diagram for breccia 10068 compared with soil 10084 (data from Goles et al. 1970).

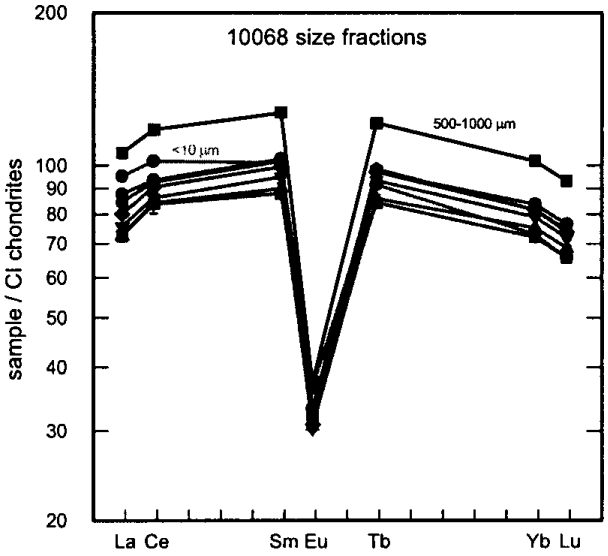


Figure 4: Normalized rare earth contents of different grain size fractions of 10068 (Lindstrom 1999).

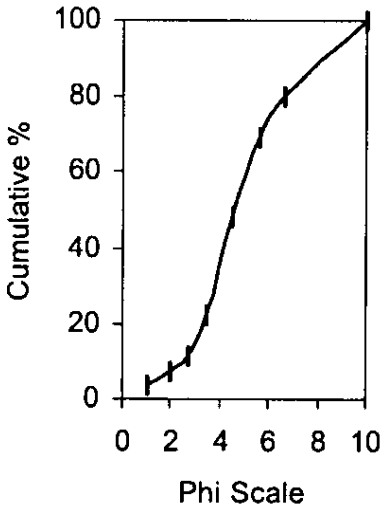
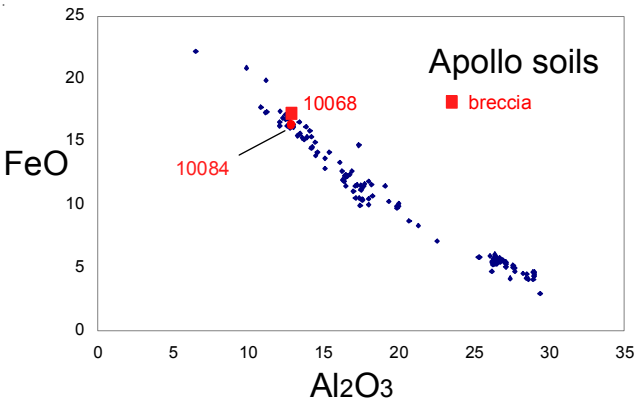


Figure 5: Grain size distribution of 10068 after freeze-thaw cycling (Basu et al. 1999).

Table 1. Chemical composition of 10068.

reference	Goles70		Annell70		Lindstrom99	
weight						
SiO2 %	41.3					
TiO2	7.8					
Al2O3	12.3					
FeO	16.5				16.7	(a)
MnO	0.19	(a)	0.26	(b)		
MgO	6.5					
CaO	12.2				11.6	(a)
Na2O	0.44	(a)			0.47	(a)
K2O					0.22	(a)
P2O5						
S %						
sum						
Sc ppm	60.9	(a)	71	(b)	67.6	(a)
V	46	(a)	58	(b)		
Cr	1890	(a)	2600	(b)	2190	(a)
Co	31.7	(a)	33	(b)	29.7	(a)
Ni			205	(b)	250	(a)
Cu	15	(a)	12	(b)		
Zn			22	(b)		
Ga			4.7	(b)		
Ge ppb						
As						
Se						
Rb			3.3	(b)		
Sr			130	(b)	177	(a)
Y			108	(b)		
Zr	700	(a)	482	(b)	441	(a)
Nb			31	(b)		
Mo						
Ru						
Rh						
Pd ppb						
Ag ppb						
Cd ppb						
In ppb						
Sn ppb						
Sb ppb						
Te ppb						
Cs ppm						
Ba	150	(a)	250	(b)	219	(a)
La	16.4	(a)	21	(b)	20	(a)
Ce	60	(a)			58.1	(a)
Pr						
Nd						
Sm	14.4	(a)			15	(a)
Eu	1.8	(a)			1.86	(a)
Gd						
Tb	3.6	(a)			3.42	(a)
Dy						
Ho	6.6	(a)				
Er						
Tm						
Yb	12.2	(a)			12.9	(a)
Lu	2.6	(a)			1.81	(a)
Hf	11	(a)			12.4	(a)
Ta	1.8	(a)			2.33	(a)
W ppb						
Re ppb						
Os ppb						
Ir ppb						
Pt ppb						
Au ppb						
Th ppm					2.6	(a)
U ppm	0.61	(a)			0.7	(a)

technique: (a) INAA, (b) emission spec.



Other Studies

Funkhouser et al. (1970) determined the isotopic ratio of rare gases in 10068. Epstein and Taylor (1971) determined the isotopic variation of oxygen and silicon for fine grain sizes in 10068 by partial fluorination techniques (figure 6). They also reported hydrogen and carbon contents and isotopic ratios (figure 7).

The total organic carbon content of 10068 was determined by hydrogen flame ionization pyrolysis (Ponnamperuma et al. 1970).

Noble et al. (2002 and 2003) have studied space weathering of grains in 10068 and have been able to distinguish between vapor deposits and glass rims (which contain nanophase iron).

Processing

Apollo 11 samples were originally described and cataloged in 1969 and "re-cataloged" by Kramer et al. (1977). There are 12 thin sections of 10068 and a number of grain mounts.

List of Photo #s for 10068

S69-46656
S76-22545

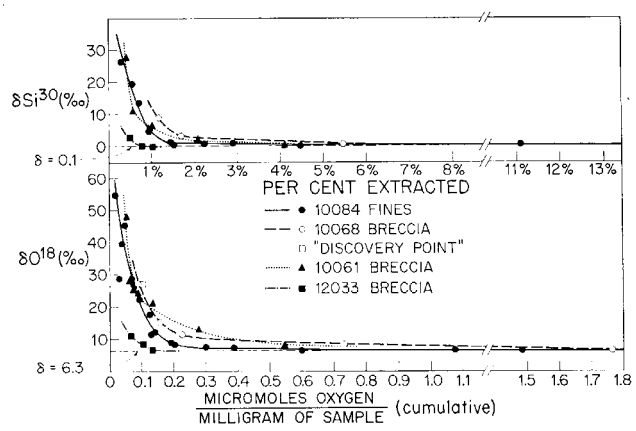


Figure 6: Partial fluorination experiment showing enriched 30Si and 18O on surfaces of finest fraction (Epstein and Taylor 1971).

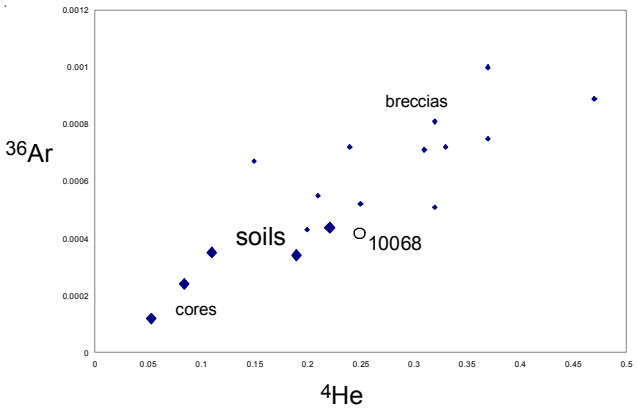


Figure 8: Implanted solar wind in 10068 compared with Apollo 11 soils and breccias (Funkhouser et al. 1070, Hintenberger et al. 1976). Units STP cc/g.

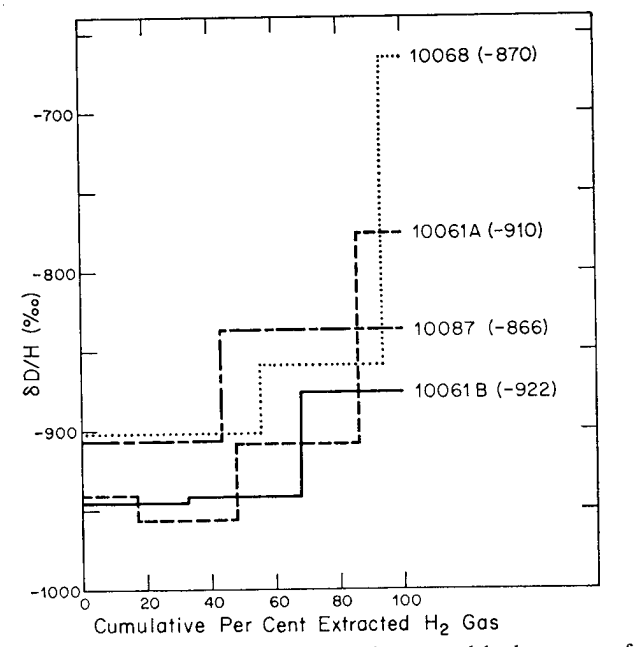


Figure 7: Hydrogen isotopes as function of outgasing temperature (Epstein and Taylor 1971).

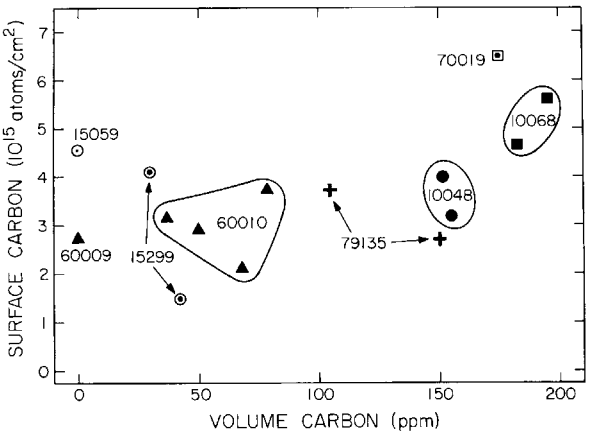


Figure 9: Unknown

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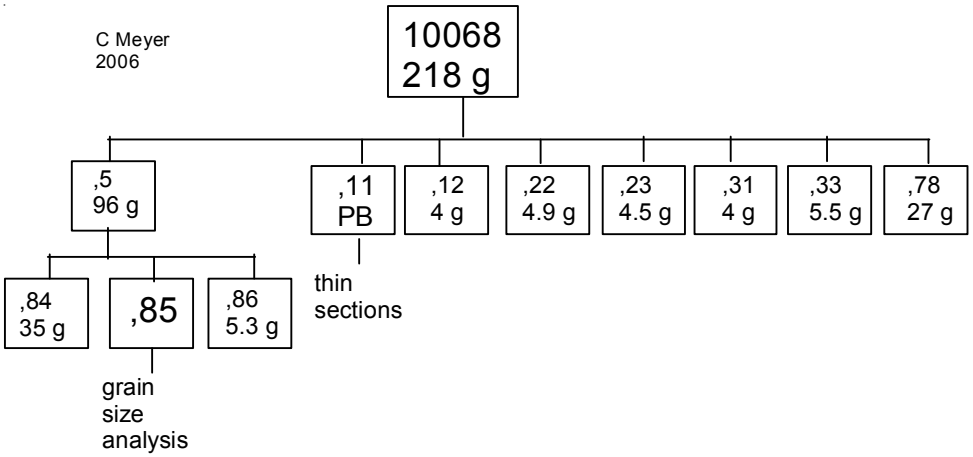

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