10023

Regolith Breccia

66 grams

Figure 1: Photos of 10023, top and bottom. Sample is about 6 cm across. NASA S69-45394 and S69-45390.

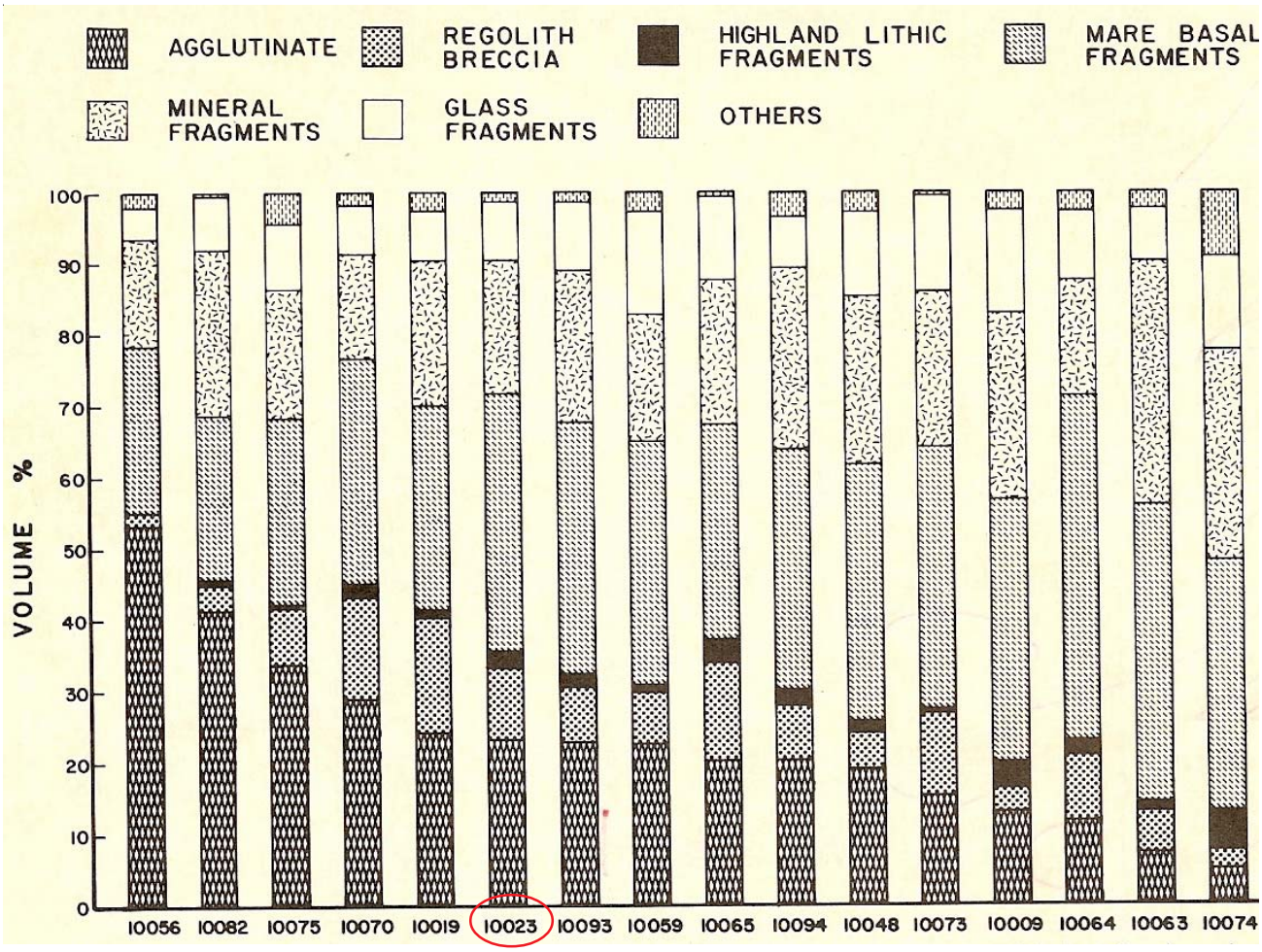

Figure 2: Comparison of lithic components in Apollo 11 breccias (from Simon et al. 1984).

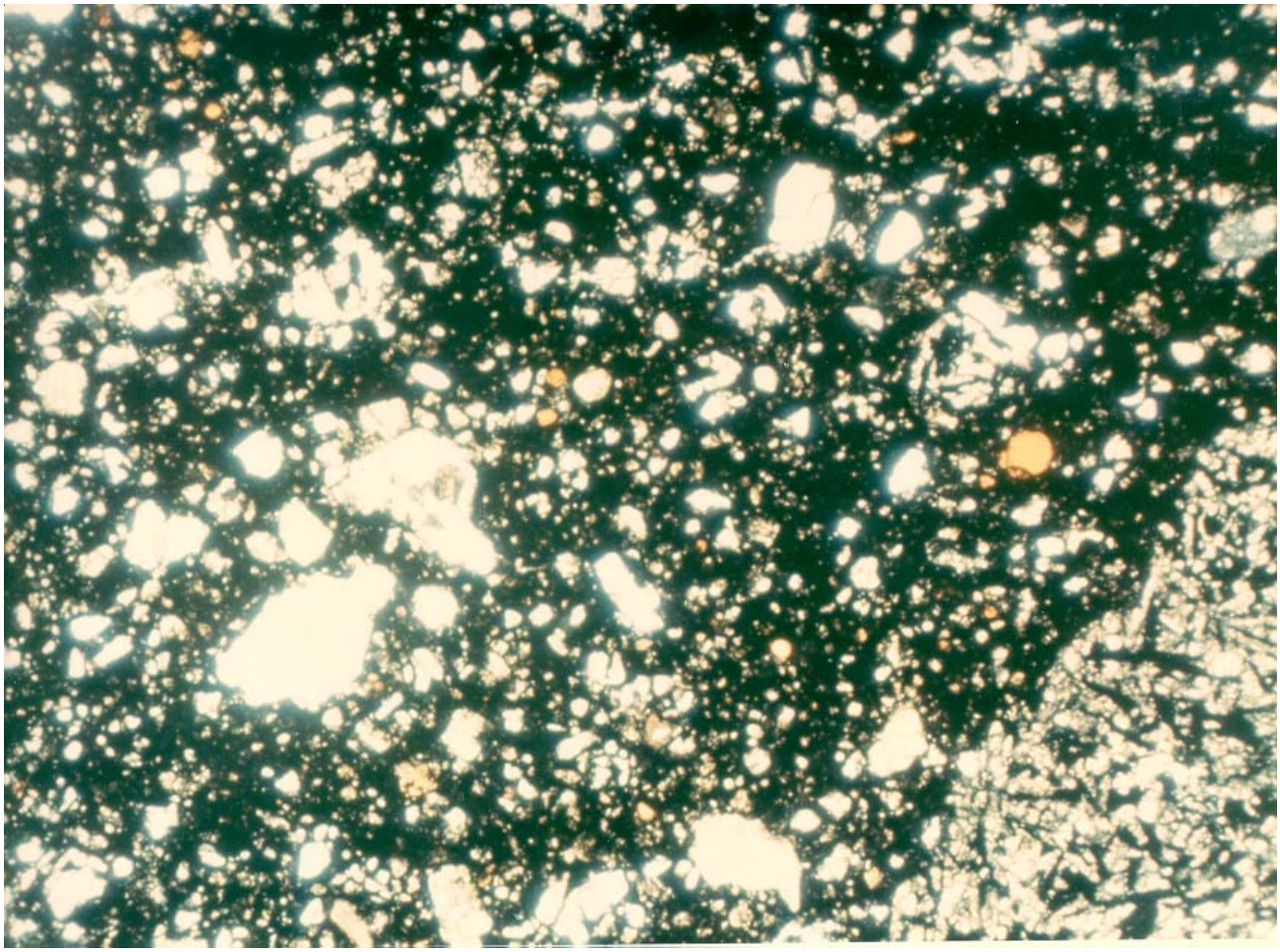

Figure 3: Photomicrograph of 10023,11 showing fine-grained matrix with orange glass bead and rock fragment. Thin section is 2.5 mm across and 30 microns thick. NASA S70-19245.

Introduction

10023 is a coherent regolith breccias with numerous micrometeorite pits on the top, rounded surface (figure 1). It was collected as part of the contingency sample and returned in air with the crew to the lunar receiving laboratory JSC. It was photographed before collection on the lunar surface and the lunar orientation is known (see Schmitt et al. 1970).

This is the rock where Strangway et al. (1969) originally reported finding a strong magnetization: *"If this rock was not magnetized by local fields in the spacecraft or in the lunar receiving laboratory, it must have been magnetized on the moon."*

Mineralogical Mode

	Chao et al. 1971
Basaltic rock	23.4
Anorthositic rock	0.4
Mineral fragments	6.3
Glass-welded aggregate	9.2
Devitrified glass	4.9
Heterogeneous glass	3
Homogeneous glass	2.3
Basaltic microbreccia	0.5
Anorthositec breccia	0.1
Shocked	0.1
Less than 25 microns	22.5
Pore space	27.3

Simon's Mode for 10023

	S	L
Mare Basalt	6.5	14.2
Highland Component	1	0.3
Regolith breccia	5.2	0.6
Agglutinate	11.9	1.3
Pyroxene	5.5	1.1
Olivine	0.1	
Plagioclase	2.6	
Ilmenite	1.5	
Orange glass	1.9	0.8
Other glass	2	0.6
Matrix	42.9 %	

Petrography

10023 is a rather typical regolith brecia from Apollo 11 (figure 2). Chao et al. (1971) reported that it had a glass matrix with 27 % pore space (figure 3). The mode has about 25 % mare basalt.

Simon et al. (1984) included breccia 10023 in their comprehensive study of Apollo 11 regolith breccias – their mode is given in the table. They calculated that it had about 19% highland component, but couldn't directly identify that many clasts of highland rock. Quaide and Bunch (1970) determined the size distribution of grains in 10023 (figure 7).

Chao et al. (1971) illustrate a cross section thru a micrometeorite crater in 10023.

Chemistry

Rhodes and Blanchard (1981) found that the composition of 10023 was different from the other regolith breccias and 10084 (figure 5). The rare earth element concentration of this breccia sample is slightly higher than for the soil 10084 (figure 6).

Other Studies

Funkhouser et al. (1970) determined rare gases (figure 8).

Processing

Apollo 11 samples were originally described and cataloged in 1969 and "recataloged" by Kramer et al. (1977). There are 6 thin sections.

References for 10023

Chao E.C.T., James O.B., Minkin J.A., Boreman J.A., Jackson E.D. and Raleigh C.B. (1970) Petrology of unshocked crystalline rocks and evidence of impact metamorphism in Apollo 11 returned lunar samples. *Proc. Apollo 11 Lunar Sci. Conf.* 287-314.

Chao E.C.T., Boreman J.A., Minkin J.A. and James O.B. (1970) Lunar glasses of impact origin: Physical and chemical characteristics and geologic implications. *J. Geophy. Res.* 75, 7445-7479.

Chao E.C.T., Boreman J.A. and Desborough G.A. (1971) The petrology of unshocked and shocked Apollo 11 and Apollo 12 microbreccias. *Proc. Second Lunar Sci. Conf.* 791-816.

Funkhauser J.G., Schaeffer O.A., Bogard D.D. and Zahringer J. (1970) Gas analysis of the lunar surface. *Proc. Apollo 11 Lunar Sci. Conf.* 1111-1116.

King E.A. *and a cast of thousands* (1969) Lunar Sample Information Catalog, Apollo 11. Lunar Receiving Laboratory, MSC 412 pp

Kramer F.E., Twedell D.B. and Walton W.J.A. (1977) Apollo 11 Lunar Sample Information Catalogue (revised). Curator's Office, JSC 12522

LSPET (1969) Preliminary examination of lunar samples from Apollo 11. *Science* 165, 1211-1227.

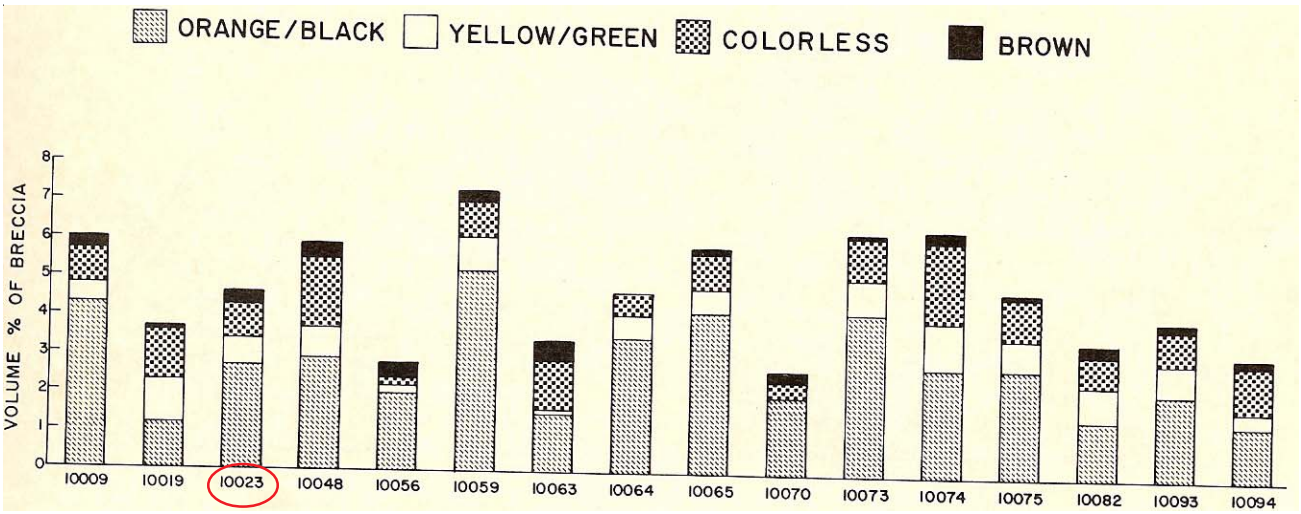

Figure 4: Percentage of glass particles in Apollo 11 soil breccias (Simon et al. 1984).

Table 1. Chemical composition of 10023.

reference	Wiesmann75		Rhodes81	
weight	54 mg			
SiO2 %			41.4	(b)
TiO2			8.4	(b)
Al2O3			11.67	(b)
FeO			16.65	(b)
MnO			0.22	(b)
MgO			7.76	(b)
CaO			11.62	(b)
Na2O			0.47	(b)
K2O	0.19	(a)	0.2	(b)
P2O5			0.13	
S %				
sum				
Sc ppm				
V				
Cr			2121	(b)
Co				
Ni				
Cu				
Zn				
Ga				
Ge ppb				
As				
Se				
Rb	4	(a)		
Sr	169	(a)		
Y				
Zr	380	(a)		
Nb				
Mo				
Ru				
Rh				
Pd ppb				
Ag ppb				
Cd ppb				
In ppb				
Sn ppb				
Sb ppb				
Te ppb				
Cs ppm				
Ba	206	(a)		
La	18.5	(a)		
Ce	55.3	(a)		
Pr				
Nd	45.5	(a)		
Sm	15.1	(a)		
Eu	1.85	(a)		
Gd	23.5	(a)		
Tb				
Dy	24.3	(a)		
Ho				
Er	14	(a)		
Tm				
Yb	13.1	(a)		
Lu				
Hf				
Ta				
W ppb				
Re ppb				
Os ppb				
Ir ppb				
Pt ppb				
Au ppb				
Th ppm	2.7	(a)		
U ppm	0.74	(a)		

technique: (a) IDMS, (b) XRF

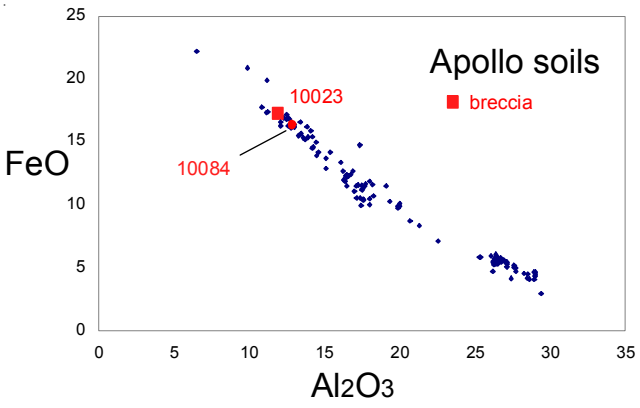

Figure 5: Composition of 10023 compared with that of Apollo soil samples.

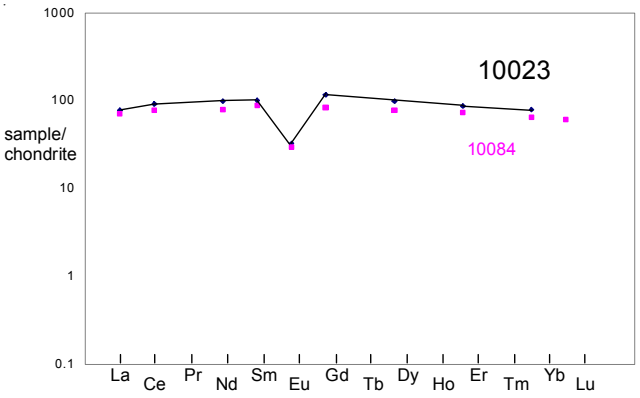

Figure6 : Normalized rare earth element diagram for breccia 10023 compared with soil 10084 (data from Wiesmann et al. 1975).

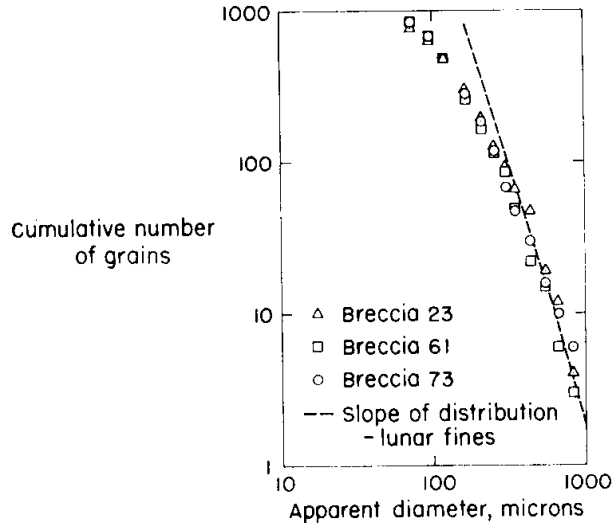

Figure 7: Size distribution for 10023 (Quaide and Bunch 1970).

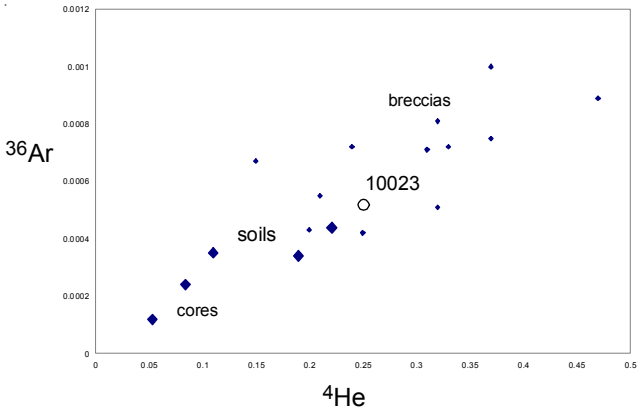

Figure 8: Implanted solar wind in 10023 compared with Apollo 11 soils and breccias (Funkhouser et al. 1070 and Hintenberger et al. 1976). Units STP cc/g.

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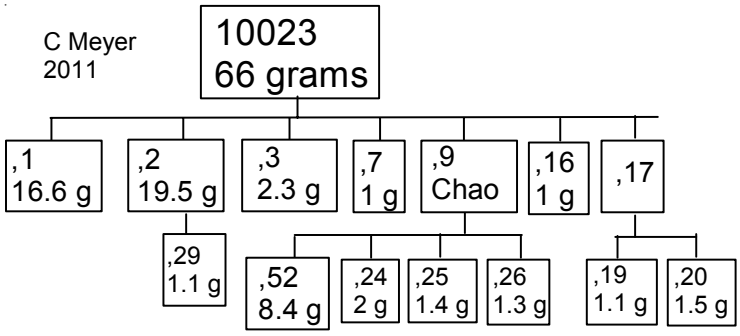
Simon S.B., Papike J.J. and Shearer C.K. (1984) Petrology of Apollo 11 regolith breccias. *Proc. 15th Lunar Planet. Sci. Conf.* in *J. Geophys. Res.* 89, C109-132.

Strangway D.W., Pearce G.W., Gose W.A. and Timme R.W. (1971) Remanent magnetization of lunar samples. *Earth Planet. Sci. Lett.* **13**, 43-52.