

10021
Regolith Breccia
255 grams



Figure 1: Photo of 10021,36. Middle piece is 2 cm across. NASA S75-31372.

Introduction

10021 is a rather friable soil breccia. It breaks into rounded pieces (figures 1 and 6). It was collected as part of the contingency sample from the area immediately in front of the Lunar Module (LM). The sample container (bag?) used for the contingency sample also contained other rather friable samples 10023, 10025, 10026, 10027, 10028 – some or all of which may be pieces of the same. The E1 surface of 10021 had numerous zap pits.

10021 is very mature regolith and was found to have more He than any other lunar breccia.

Fruland (1983) chose 10021 as one of the regolith breccias to be studied by the Regolith Breccia Initiative of LAPST.

Petrography

Fruland (1983) and Kramer et al. (1977) give the only petrographic descriptions. The matrix is made up of brown-black glass (figure 2) and does not appear to be very porous. Several large accretionary structures and relict agglutinates were observed in the matrix (Fruland 1985). Glass spheres and fragments are common, with a wide range of color and composition.

Chemistry

The composition of 10021 was determined by Goles et al. (1970) and others. It is not greatly different from that of soil sample 10084 (figures 3 and 4).

Schonfeld and Meyer (1972) calculated that 10021 was a mix of mare basalt with ~18 % gabbroic anorthosite and ~2 % KREEP, while Rhodes and Blanchard (1981) found it was a mix of soil and high-K basalt. However, Simon et al. (1984) could not identify such a high percentage of highland component.

Cosmogenic isotopes and exposure ages

The cosmic ray induced activity was reported by LSPET (1969) as $^{26}\text{Al} = 81$ dpm/kg., $^{22}\text{Na} = 41$ dpm/kg., $^{46}\text{Sc} = 10$ dpm/kg., $^{54}\text{Mn} = 15$ dpm/kg. and $^{56}\text{Co} = 38$ dpm/kg.

Other Studies

The total organic carbon content of 10021 was determined by hydrogen flame ionization pyrolysis (Ponnamperuma et al. 1970).

Funkhouser et al. (1970) and Hintenberger et al. (1971, 1975) determined the rare gas abundance and isotopic ratios (figure 5).

Robie and Hemingway (1971) determined calorimetric data (specific heat) for 10021.

Processing

Apollo 11 samples were originally described and cataloged in 1969 and “re-cataloged” by Kramer et al. (1977). It was returned in the contingency sample bag (see also 10023). There are 29 thin sections of 10021.

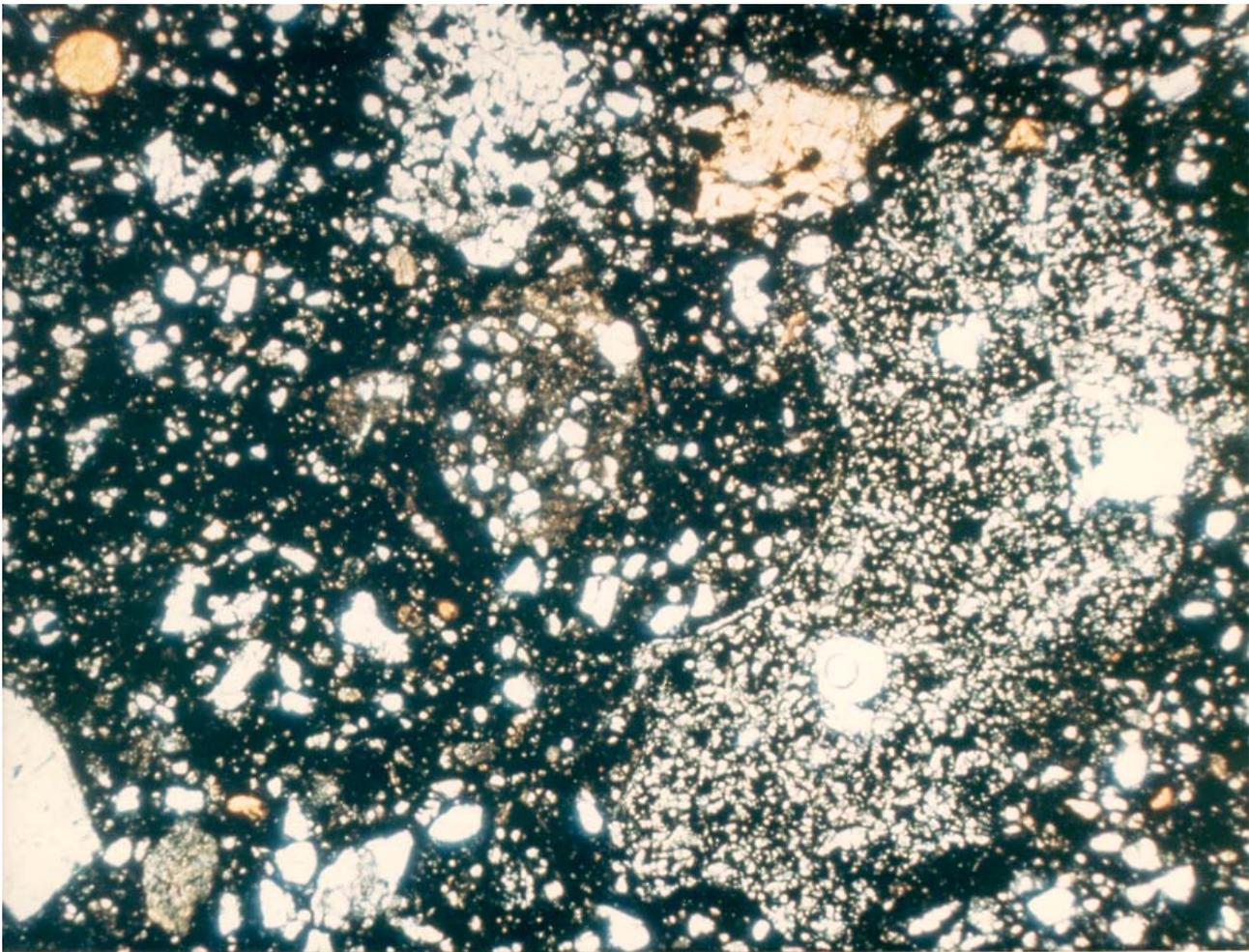


Figure 2: Thin section photomicrograph of 10021,28 showing orange fine-grained matrix with glass bead and rock clasts. Scale is 2.5 mm. NASA S70-49481.

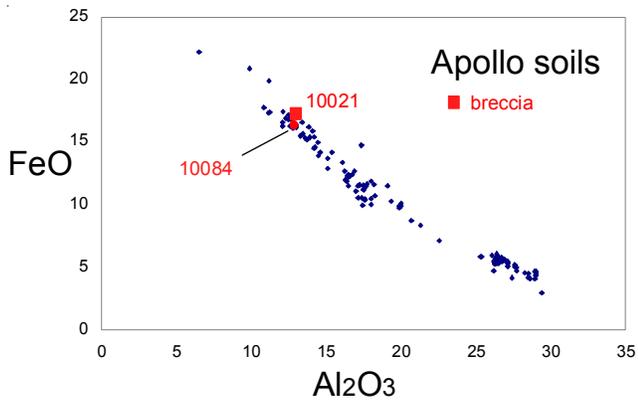


Figure 3: Composition of 10021 compared with that of Apollo soil samples.

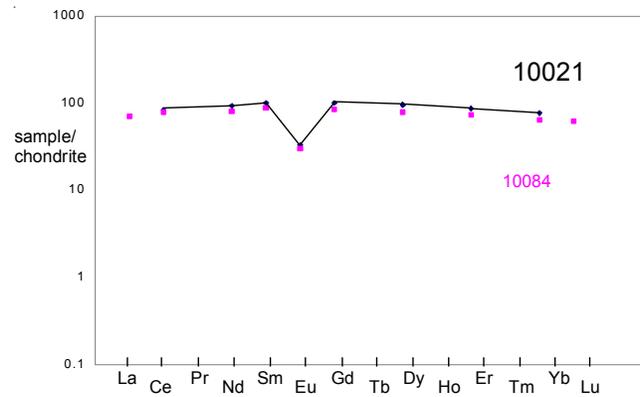


Figure 4: Normalized rare earth element diagram for breccia 10021 compared with soil 10084 (data from Rhodes et al. 1981).

Table 1. Chemical composition of 10021.

<i>reference weight</i>	<i>LSPET69</i>	<i>Wiesmann75</i> 51 mg	<i>Philpotts70</i> 137 mg	<i>Goles70</i>	<i>Annell70</i>	<i>Kharkar71</i>	<i>Wasson70</i>	<i>O'Kelley70</i> 157 g
SiO ₂ %	43			41.8				
TiO ₂	8.6	8.17	(a)	8.2		8.84		
Al ₂ O ₃	11			13				
FeO	19			16.8		15.7		
MnO	0.22			0.2	(b) 0.23	(c)		
MgO	7.4			8.3				
CaO	11			10.8		13.4		
Na ₂ O	0.2	0.5		0.46	(b)	0.47		
K ₂ O	0.15	0.19	(a) 0.19	(a)				0.193 (d)
P ₂ O ₅								
S %								
<i>sum</i>								
Sc ppm	68			61.8	(b) 72	(c) 72		
V	22			73	(b) 60	(c)		
Cr	2500			1950	(b) 2480	(c) 2100		
Co	13			30.7	(b) 33	(c) 27		
Ni	215				184	(c)		
Cu					12	(c)		
Zn					24	(c)		
Ga					4.6	(c)		
Ge ppb							410	(e)
As								
Se								
Rb		3.96	(a) 4.03	(a)	4	(c)		
Sr	150		165	(a)	130	(c)		
Y	300				113	(c)		
Zr	1500			250	(b) 424	(c)		
Nb					28	(c)		
Mo								
Ru								
Rh								
Pd ppb								
Ag ppb								
Cd ppb								
In ppb							22	(e)
Sn ppb								
Sb ppb								
Te ppb								
Cs ppm								
Ba	105	202	(a) 211	(a) 350	(b) 270	(c)		
La				17.5	(b) 22	(c) 17.8		
Ce		50.7	(a) 57.2	(a) 61	(b)	48.3		
Pr								
Nd		42.5	(a) 48.9	(a)				
Sm		14.7	(a) 17.2	(a) 15	(b)	11.2		
Eu		1.84	(a) 1.91	(a) 1.8	(b)	1.9		
Gd		19.9	(a)					
Tb				4.2	(b)	3.1		
Dy		23.3	(a) 25.2	(a)		20.9		
Ho				6.9	(b)			
Er		13.7	(a) 13	(a)				
Tm								
Yb		12.5	(a) 12.7	(a) 14.5	(b)	9.9		
Lu			1.99	(a) 2.25	(b)	2.2		
Hf				12.2	(b)	13.4		
Ta				1.6	(b)	1.8		
W ppb								
Re ppb								
Os ppb								
Ir ppb							7.5	(e)
Pt ppb								
Au ppb							2.4	(e)
Th ppm	1.8	(d)						2.5 (d)
U ppm	0.39	(d) 0.72	(a)	0.56	(b)			0.54 (d)

technique: (a) IDMS, (b) INAA, (c) emission spec., (d) radiation counting, (e) RNAA

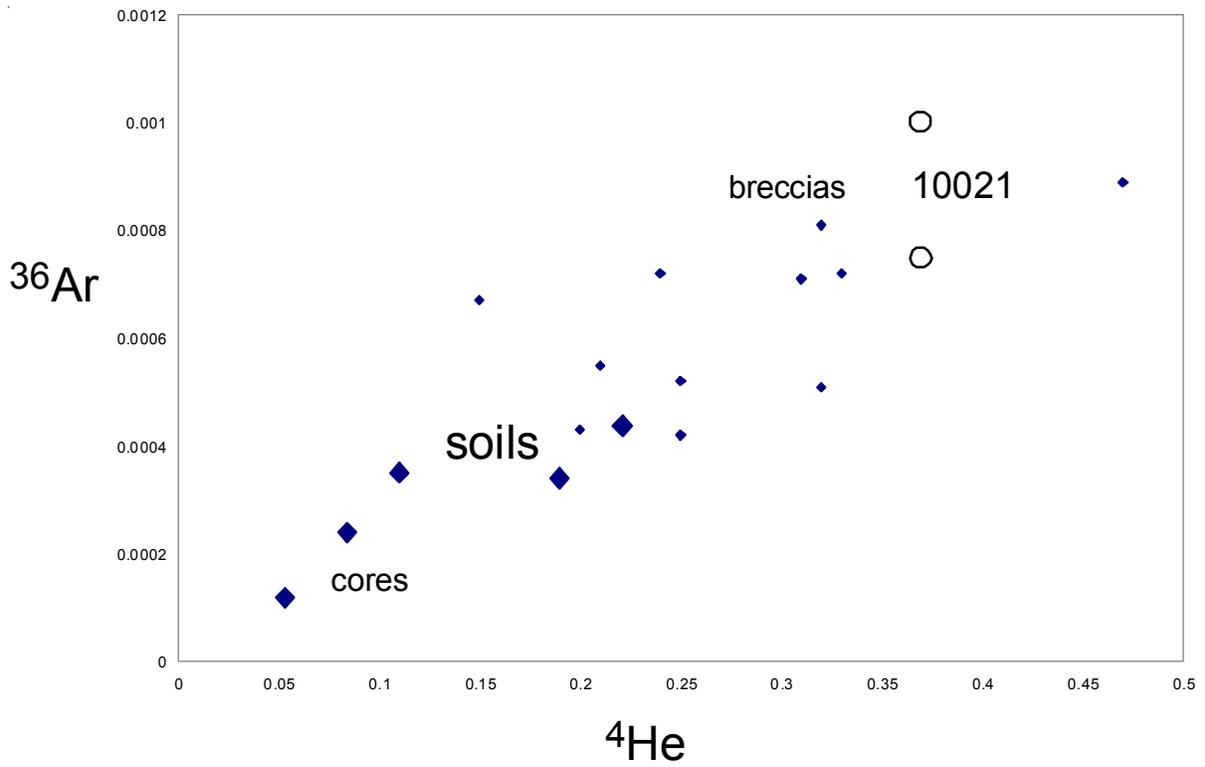


Figure 5: Implanted solar wind rare gas in 10021 compared with Apollo 11 soils and breccias (Funkhouser et al. 1970 and Hintenberger et al. 1976). Units STP cc/g.

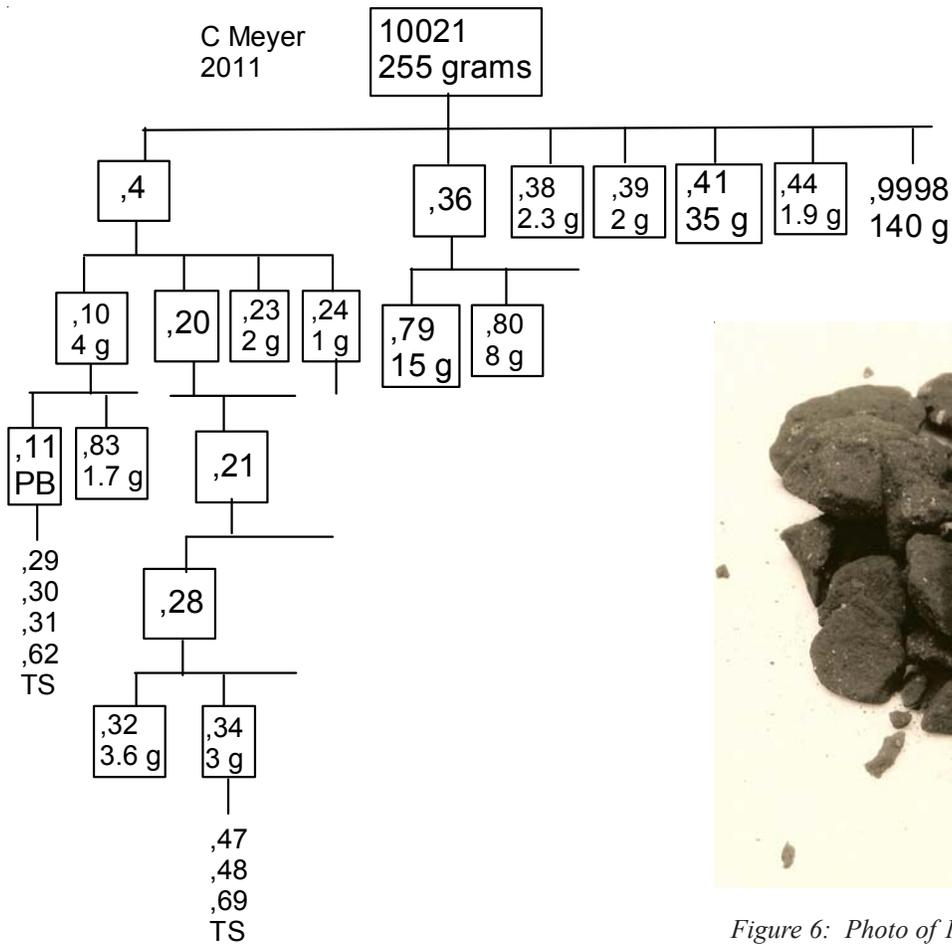


Figure 6: Photo of 10021,41. S72-33021

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Figure 7: Photo of 10021 taken during Apollo 11 PET. S69-45421.