

10060
Regolith Breccia
722 grams

DRAFT



Figure 1. Photo of 10060. NASA S86-38114. Sample is 11 cm high.

Introduction

Lunar sample 10060 is one of the largest and best studied Apollo 11 breccias. One side (the top?) of 10060 is smooth-rounded with a high percentage of

glass-lined micrometeorite pits (Schmitt et al. 1970). McGee et al. (1979) and Fruland (1983) describes 10060 as a “typical soil breccia”. Thiemens and

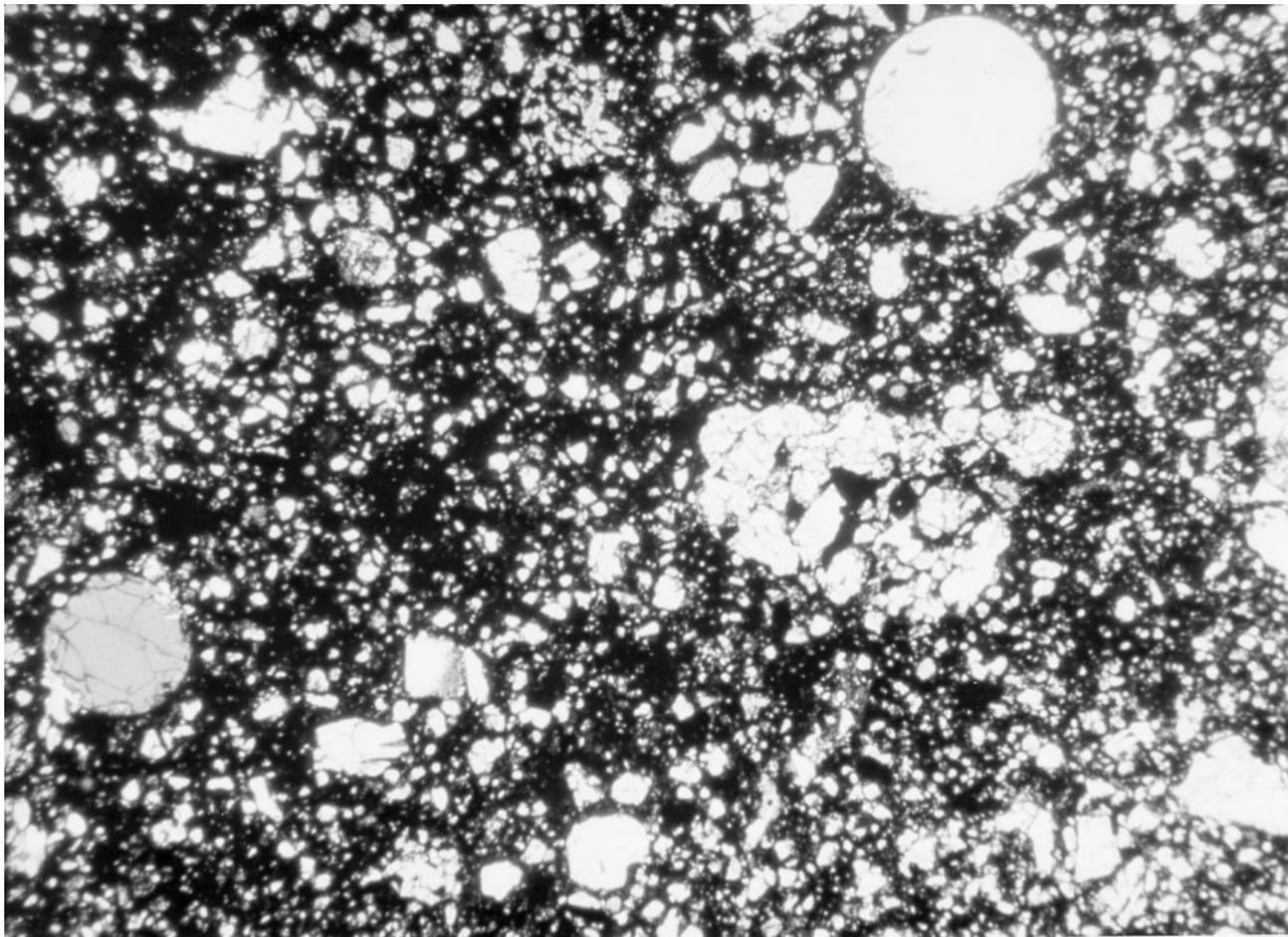


Figure 2: Photomicrograph of thin section of 10060. NASA S70-49013. Scale is 2.5 mm.

Clayton (1980) discuss the very long exposure age (~2.3 b.y.) of Apollo 11 soil breccias.

Petrography

10060 is a large, gas-rich, regolith breccia made up of ancient soil from the Apollo 11 site (Fruland 1983). The grain size distribution is seriate with a majority of grains less than 39 microns (McGee et al. 1979). It is porous with micron-sized intergranular voids that can best be seen in reflected light or by SEM (Phinney et al. 1976). It has an abundance of glass of various types and stages of devitrification (Lofgren 1971).

Basaltic fragments are the predominant lithic clast type in 10060. Beaty and Albee (1978) studied one of the largest basaltic clasts (17 delta) in 10060. Basaltic clast "delta" is a vitrophyre which contains subhedral to euhedral pyroxene phenocrysts (41%), subhedral olivine (3%), bladed armalcolite (1%) and bladed ilmenite (14%) set in a groundmass of basaltic glass with incipient feathery pyroxene. The large armalcolite grains have a reaction relation with the melt, forming ilmenite at the rims. Grove and Beaty (1980) were

Mineralogical Mode for basaltic clast "delta" in 10060

Olivine	3 %
Pyroxene	41
Plagioclase	
Armalcolite	1
Ilmenite	14
Glass	41

Mineralogical Mode for 10060

	McGee et al. 1979
Matrix < 39 microns	55
Plagioclase	1.2
Mafic	2.3
Opaque	0.4
Glass, hetero	2.6
Glass, homo	0.5
Glass, devitrified	4.4
Breccia, frags	3.7
Mare Basalt	29.8

able to reproduce this texture experimentally and discuss the cooling rate and crystallization history.

Phinney et al. (1976) used SEM petrography to determine the sintering of the glass in the matrix. They report a porosity of ~35% with filaments and thin glass films between very fine grains in the matrix. Uhlmann et al. (1981) calculate the cooling rate for 10060 from observation of the devitrification of glass in 10060 and their studies of nucleation barriers to crystallization of glass.

Chemistry

A large number of analyses were done on 10060 (table 1 and figure 3). Kaplan et al. (1970) determined the carbon (135 ppm C) and sulfur contents (1120 ppm S) and isotopic ratios. Thiemens and Clayton (1980) determined 93 ppm nitrogen (with a very negative delta ¹⁵N).

Schonfeld and Meyer (1972) calculated that 10060 was a mix of mare basalt with ~17 % gabboic anorthosite and ~1 % 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.

Radiogenic age dating

Silver (1970) determined the U, Th and Pb isotopes for 10060, finding them more like the soil (10084) than the rocks.

Cosmic ray exposure

Thiemens and Clayton (1980) discuss the very long exposure age (~2.3 b.y.) of gas-rich Apollo 11 soil breccias.

Other Studies

Hintenberger and Weber (1973) and Hintenberger et al. (1975) determined the rare gas abundance (figure 4) and reported the isotopic ratios. Friedman et al. (1970) determined the gas content evolved from heating 10060 in vacuum and in O₂. They found 83 ppm hydrogen with low D/H ratio and ~100 ppm C.

Processing

Apollo 11 samples were originally described and cataloged in 1969 and “re-cataloged” by Kramer et al. (1977).

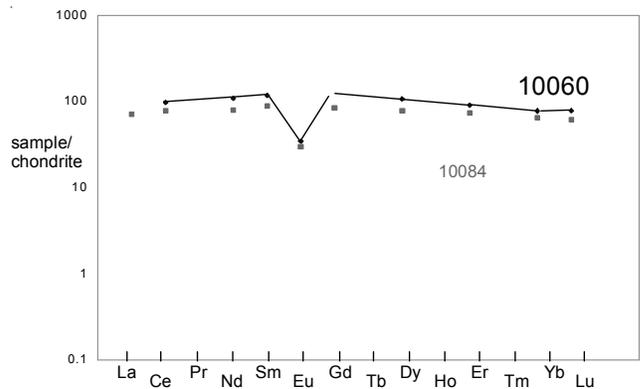


Figure 3: Normalized rare earth element diagram for breccia 10060 compared with soil 10084 (data from Wiesmann et al. 1975).

List of Photo #s for 10060

- S69-46491 – 46500
- S69-48450 – 48459
- S69-53976 TS
- S69-59239 – 59241 TS
- S76-25884 – 25891

Table 1. Chemical composition of 10060.

reference weight	Rhodes81	Wanke70	Philpotts70 218 mg	Haskin70	Goles70	Smales70	Morrison70	Agrell 70	Wasson70
SiO2 %	41.5	(a) 42.36	(b)		42.8	41.8	40	(d) 41.96	
TiO2	9.15	(a) 7.7	(b)		8.5	8.7	8.5	(d) 9.02	
Al2O3	11.8	(a) 11.7	(b)		11.5	11.5	11.3	(d) 11.85	
FeO	17	(a) 17.7	(b)		16.8	16.7	17.7	(d) 16.89	
MnO	0.23	(a) 0.17	(b)		0.21	(b)	0.2	(d) 0.23	
MgO	7.52	(a) 7.6	(b)		8.1	7.6	7.63	(d) 7.63	
CaO	11.6	(a) 11.6	(b)			11.2	14.5	(d) 11.38	
Na2O	0.78	(a) 0.48	(b)		0.49	(b) 0.51	0.55	(d) 0.49	
K2O	0.18	(a)		0.19 (c)		0.2	0.19	(d) 0.2	
P2O5		(a)					0.14	(d) 0.07	
S %								0.15	
sum									
Sc ppm		70	(b)		64	(b)	70	(d)	
V					58	(b)	62	(d)	
Cr	2258	(a) 1820	(b)		1880	(b)	2200	(d) 2121	
Co		30.1	(b)		31.6	(b)	32	(d)	
Ni									
Cu							11	(d)	
Zn							25	(d)	
Ga							5.1	(d)	
Ge ppb							1400	(d)	240 (e)
As							90	(d)	
Se							900	(d)	
Rb			4.13	(c)		4.2	4	(d)	
Sr			167	(c)			180	(d)	
Y							210	(d)	
Zr					770	(b)	580	(d)	
Nb							45	(d)	
Mo							0.7	(d)	
Ru									
Rh									
Pd ppb									
Ag ppb							10	(d)	
Cd ppb							300	(d)	
In ppb									1030 (e)
Sn ppb									
Sb ppb							5	(d)	
Te ppb									
Cs ppm						0.17	0.2	(d)	
Ba			224	(c)			250	(d)	
La		18	(b)	20.8	(b) 17.7	(b)	24	(d)	
Ce		60	(b) 59	(c) 58	(b) 61	(b)	62	(d)	
Pr							13	(d)	
Nd			50	(c) 46	(b)		82	(d)	
Sm		13.8	(b) 17.5	(c) 15.4	(b) 15.4	(b)	24	(d)	
Eu		1.61	(b) 1.98	(c) 2.06	(b) 1.84	(b)	2	(d)	
Gd				24	(b)		28	(d)	
Tb		4.2	(b)	3.6	(b) 3.7	(b)	5	(d)	
Dy			26.2	(c) 26.3	(b)		41	(d)	
Ho					5.3	(b)	10	(d)	
Er			14.5	(c) 16	(b)		30	(d)	
Tm							1.8	(d)	
Yb		10.9	(b) 12.7	(c) 13.2	(b) 13.2	(b)	22	(d)	
Lu		1.57	(b) 1.92	(c) 2	(b) 2.3	(b)	2	(d)	
Hf		14	(b)		12.1	(b)	13	(d)	
Ta		1.9	(b)		2.1	(b)	1.7	(d)	
W ppb							350	(d)	
Re ppb									
Os ppb									
Ir ppb									5.4 (e)
Pt ppb									
Au ppb									1.4 (e)
Th ppm							3	(d)	
U ppm					0.51	(b)	0.6	(d)	

technique: (a) XRF, (b) INAA, (c) IDMS, (d) various, (e) RNAA

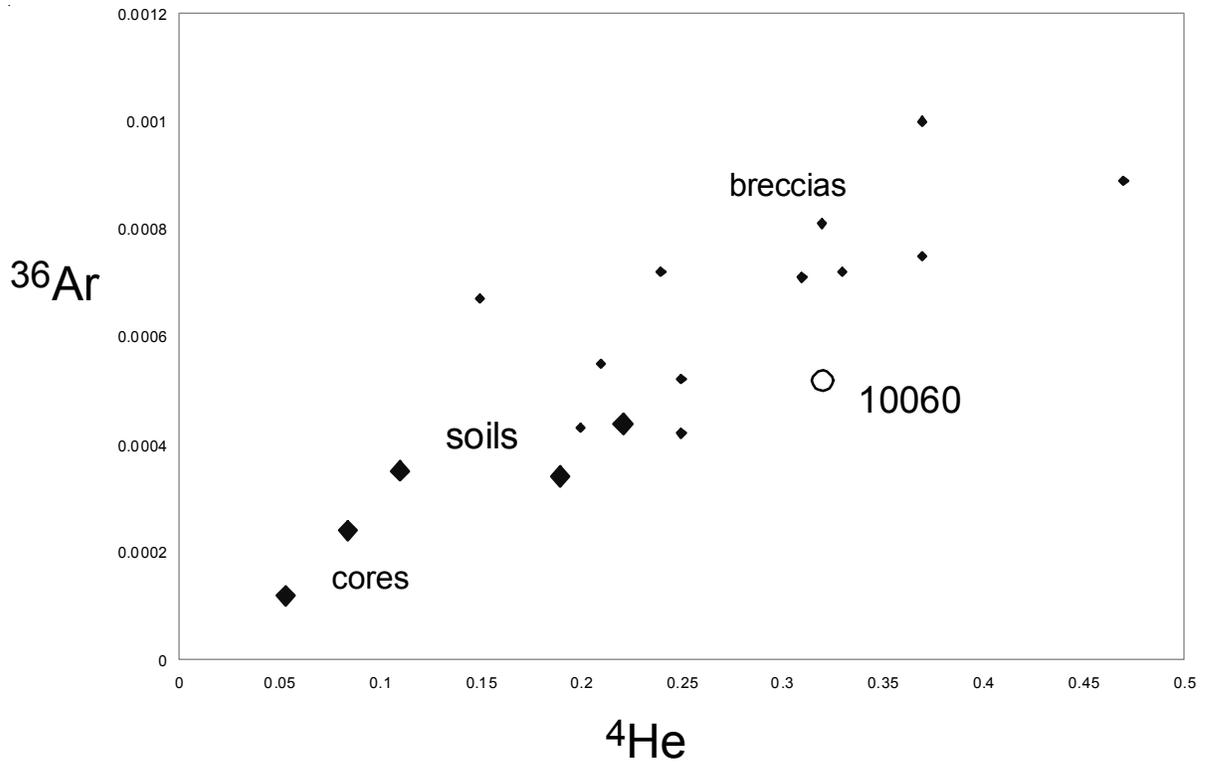
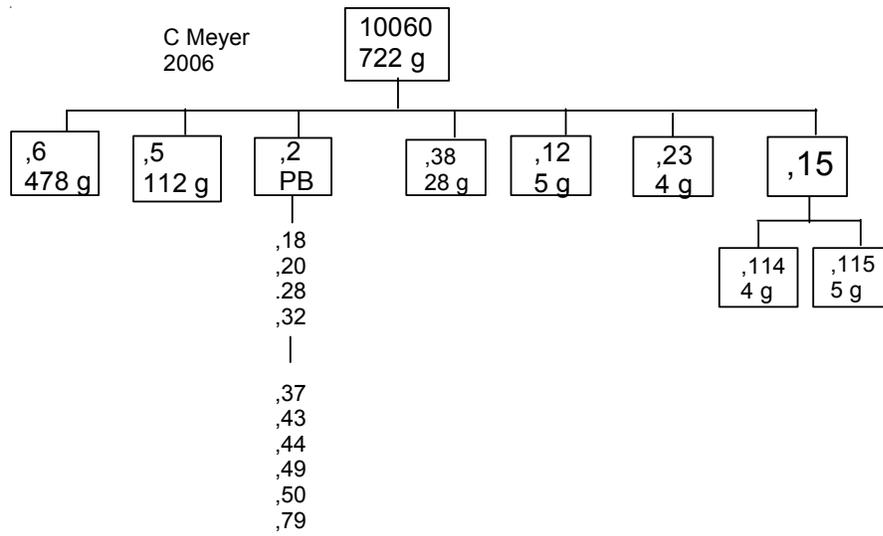


Figure 4: Implanted solar wind in 10060 compared with Apollo 11 soils and breccias (Funkhouser et al. 1070 and Hintenberger et al. 1976). Units STP cc/g.