

67941 – 163 grams
67960 – 12 grams
 Shielded Soil and reference

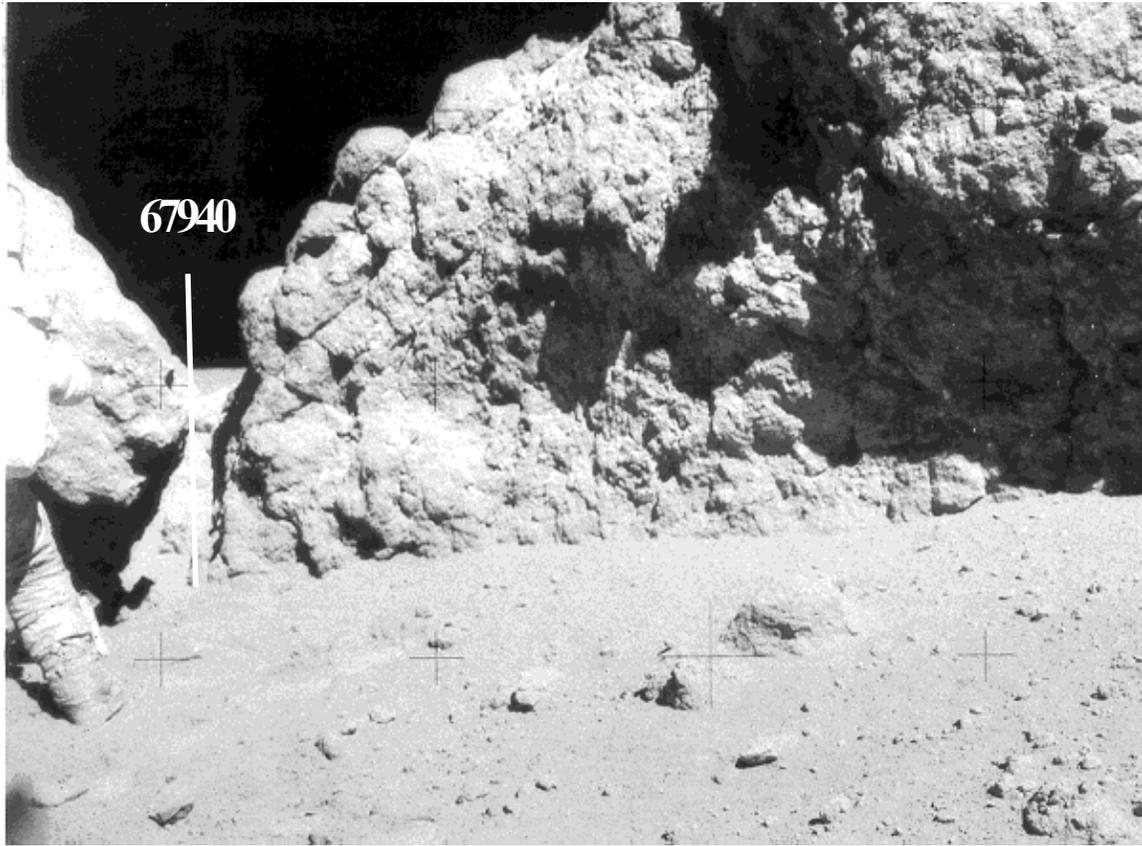


Figure 1: House Rock and location of 67940 in crack with Outhouse Rock.

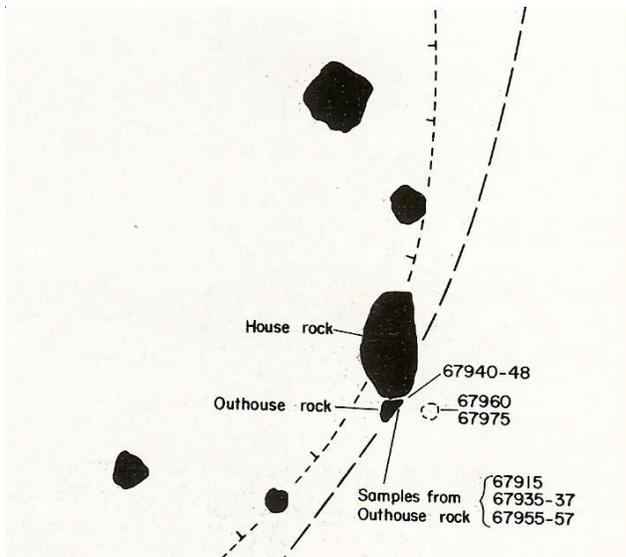


Figure 2: Map of House and Outhouse Rock on rim of North Ray Crater (Sutton 1981). 67940 was from a shielded region between rocks and 67960 was collected in the sun as reference soil.



Figure 3: Photo of area where 67960 was collected. AS16-106-17347.

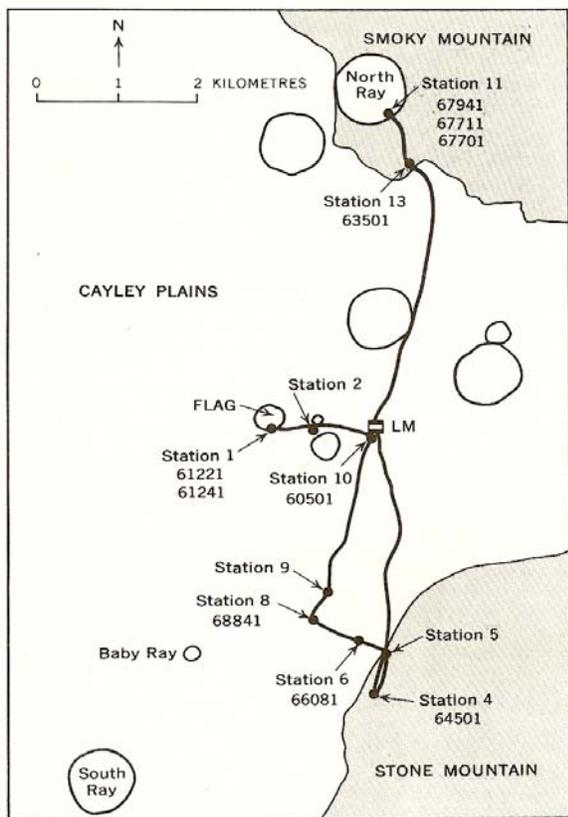


Figure 4: Map of Apollo 16 site with North Ray Crater.

Introduction

Soil sample 67940 was collected from the regolith in a narrow E-W split in House Rock, station 11 (Sutton 1981). This sample was specifically collected to check on the idea that ionized rare gases may be accelerated along and redistributed by solar wind electric field along trajectories that are north-south (Horz et al. 1972). 67960 is the reference soil collected about 5 meters to the east of House Rock. House Rock is 3-10 m high and the opposing "Outhouse Rock" 2.5 m high; the crack between them is about 2 m long with the sample location about midway. However, this soil is probably NOT permanently shadowed from the Sun (figure 1).

Petrography

67940 and 67960 are both immature soils from the near the rim of fresh North Ray Crater. Heiken et al. (1973) reported the mineralogical mode of 67940 – with only 12 % agglutinates. Morris (1978) found 67940 had a low maturity index ($I_s/FeO = 29$). The average grain size of 67941 is 193 microns (high for an Apollo 16 soil). The reference soil (67960) was also immature with $I_s/FeO = 20$.

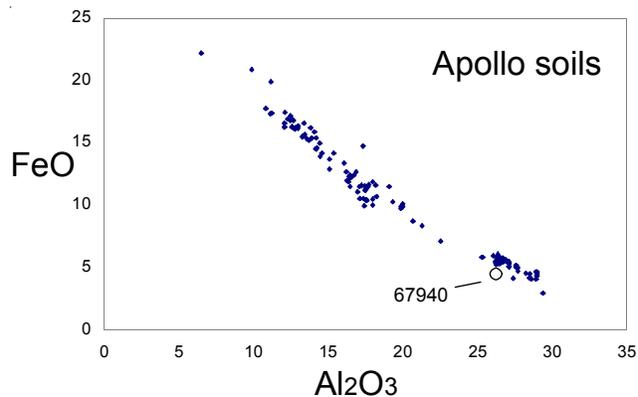


Figure 5: Composition of 67941 compared with that of other Apollo soil samples.

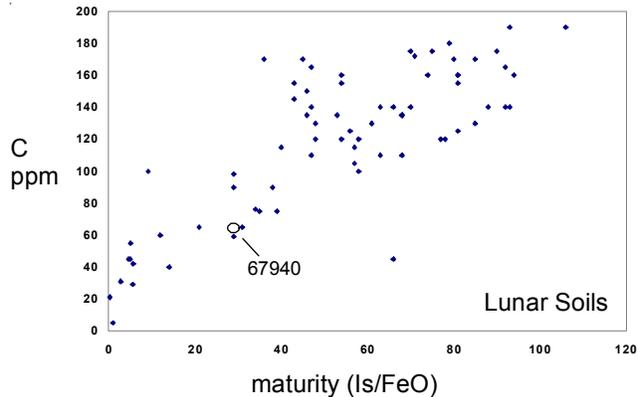


Figure 6: Carbon content and maturity index for 67941.

Powell et al. (1975) studied the mineralogy of the rock fragments in soil 67941. Ryder and Norman (1980) cataloged the fragments (67945-67948) picked from this soil. House Rock and other samples of North Ray Crater are breccias.

Modal content of soils 67941 (90-150 micron).

From Heiken et al. 1973.

Agglutinates	12 %
Basalt	8.3
Breccia	53.2
Anorthosite	2.6
Norite	1.6
Gabbro	0.3
Plagioclase	13.3
Pyroxene	4.6
Olivine	-
Ilmenite	-
Glass other	5.2

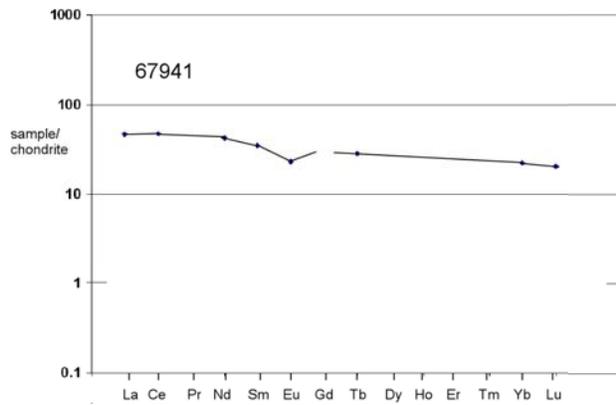


Figure 7: Normalized rare-earth-element diagram for 67941.

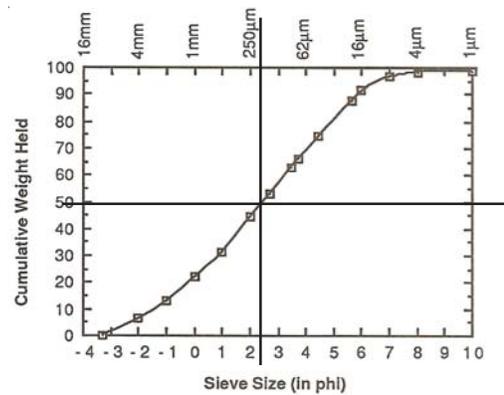
Chemistry

Rose et al. (1975), Finkelman et al. (1975), Boynton et al. (1975), Eldridge et al. (1973) and Korotev (1982) determined the composition of 67940 and found it identical to the reference soil 67960 (table 1 and figures 5 and 7) and is typical of the regolith at North Ray Crater. Jovanovic and Reed (1973) studied the halogens in 67941 finding that they were within the range of other Apollo 16 materials.

Moore et al. (1975) reported 59 ppm carbon, consistent with low maturity (figure 6). Kerridge et al. (1975) and Moore and Lewis (1975) reported 27 ppm and 91 ppm nitrogen for 67941, respectively.

Cosmogenic isotopes and exposure ages

Eberhardt et al. (1976) give the average exposure age of 104 m.y. for 67941 and 95 m.y. for 67960 based on various rare gas isotope determinations. This is to be compared with the 50 m.y. old exposure age of the various boulders thrown out of North Ray Crater (dating the crater). Obviously, these soils contain an ancient regolith component that predates North Ray Crater. Eldridge et al. (1973) found $^{26}\text{Al} = 158$ dpm/kg and $^{22}\text{Na} = 27$ dpm/kg for 67941 and Yokoyama et al. (1975) found that 67941 “shows an almost saturated activity in solar cosmic (SCR) produced ^{26}Al , in spite of complete shielding from SCR, which can be interpreted as the result of an intense lateral transport.”



average grain size = 193 microns

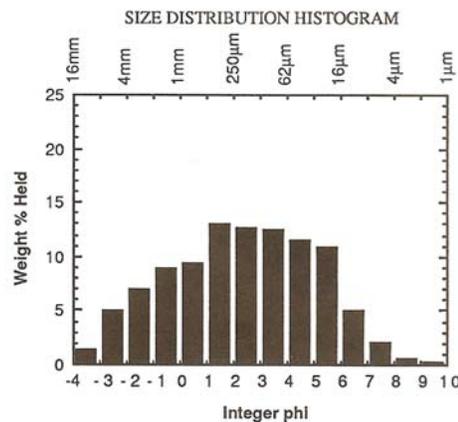


Figure 8: Grain size distribution for 67940 (Graf 1993; data from Heiken et al. 1973).

Other Studies

Eberhardt et al. (1976) carefully studied 67940 and multiple grain size separates of this sample for all the isotopes of the rare gases (figures 10 and 11). They found high excess ^4He and ^{40}Ar which is typical of soils from the rims of relatively recent craters. However, they did not find less excess ^{40}Ar in the shielded soil (67940) than the reference soil (67960), which had been predicted.

Wieler et al. (1980) included 67940 in their careful study of solar flare tracks compared with implanted solar wind rare gases. In general, they find a relatively constant ratio of tracks to implanted ions (ie. ^{36}Ar) but 67940 was significantly off the line (figure 9).

Processing

67460 has never been sieved.

Table 1. Chemical composition of 67941.

reference weight	Korotev91	Rose75	Finkelman75	Boynton75	Philpotts73	Finkelman75	ave. st. 11
						90-1000 30-90 <30 um	Korotev81
SiO2 %		45.75 (b)					45.1
TiO2		0.54					0.41
Al2O3		26.18					28.9
FeO	4.57 (a)	4.73		4.5 4.76 (a)			4.2
MnO		0.06		0.066 (a)			0.056
MgO		6.48					4.3
CaO	15.4 (a)	15.56		15.2 15.4 (a)			16.5
Na2O	0.538 (a)	0.53		0.52 0.51 (a)			0.48
K2O		0.14			0.13 (e)		0.065
P2O5		0.1					
S %							
sum							
Sc ppm	8 (a)	9	9	9 (c)	7.8 8.1 (a)	8.2 8.5 8.3	(a) 7.3
V		15	17	13 (c)			18
Cr	684 (a)	616			660 700 (a)	691 712 724	(a) 515
Co	18.2 (a)	16	18	9 (c)	22 18 (a)	16.3 23.6 14.1	(a) 14.5
Ni	241 (a)	319	46	270 (c)			140
Cu		11	4	8 (c)			
Zn		10	7	15 (c)			
Ga		3.7	3	3 (c)			
Ge ppb							
As							
Se							
Rb		2.2	11?	(c)		3.42 (e)	1.65
Sr	180 (a)	141	220	200 (c)		183 (e)	180
Y		38	41	36 (c)			20
Zr	144 (a)	150	165	109 (c)			83
Nb							
Mo							
Ru							
Rh							
Pd ppb							
Ag ppb							
Cd ppb							
In ppb							
Sn ppb							
Sb ppb							
Te ppb							
Cs ppm	0.13 (a)						
Ba	118 (a)	148	87	87 (c)	120 (a)	132 (e)	71
La	10.9 (a)				11.3 11.5 (a)	11 15 14	(a) 5.9
Ce	28.1 (a)				30 34 (a)	29.3 (e)	28 31 32 (a)
Pr							
Nd	19 (a)					19.1 (e)	
Sm	5.05 (a)				5.4 5.5 (a)	5.38 (e)	5.7 6.3 5.7 (a)
Eu	1.27 (a)				1.12 1.27 (a)	1.83 (e)	1.3 1.3 1.3 (a)
Gd						6.4 (e)	
Tb	1.02 (a)				0.9 1 (a)		
Dy						6.7 (e)	1.3 1.2 1.2 (a)
Ho							
Er						4.06 (e)	
Tm							
Yb	3.63 (a)	4	2.3	2.9 (c)	3.5 4 (a)	3.55 (e)	3.9 4.5 4.2 (a)
Lu	0.489 (a)				0.51 0.58 (a)	0.604 (e)	0.58 0.56 0.55 (a)
Hf	3.6 (a)				3.4 4.2 (a)		3.5 4 3 (a)
Ta	0.441 (a)						0.5 0.7 (a)
W ppb							
Re ppb							
Os ppb							
Ir ppb	7.3 (a)						
Pt ppb							
Au ppb	6 (a)						
Th ppm	1.75 (a)				2 2.1 (a)		1.7 2 1.8 (a)
U ppm	0.61 (a)						
technique:	(a) INAA, (e) IDMS, (c) OES						

Table 2. Chemical composition of 67960.

reference	Korotev82	Philpotts73
<i>weight</i>		
SiO ₂ %		
TiO ₂		
Al ₂ O ₃		
FeO	4.56	(a)
MnO		
MgO		
CaO	16.1	(a)
Na ₂ O	0.527	(a)
K ₂ O		0.113 (b)
P ₂ O ₅		
S %		
<i>sum</i>		
Sc ppm	7.76	(a)
V		
Cr	624	(a)
Co	16.2	(a)
Ni	215	(a)
Cu		
Zn		
Ga		
Ge ppb		
As		
Se		
Rb		2.79 (b)
Sr	175	(a) 178 (b)
Y		
Zr	175	(a)
Nb		
Mo		
Ru		
Rh		
Pd ppb		
Ag ppb		
Cd ppb		
In ppb		
Sn ppb		
Sb ppb		
Te ppb		
Cs ppm	0.13	(a)
Ba	127	(a)
La	10.14	(a)
Ce	27.6	(a)
Pr		
Nd		
Sm	4.77	(a)
Eu	1.248	(a)
Gd		
Tb	1.04	(a)
Dy		
Ho		
Er		
Tm		
Yb	3.53	(a)
Lu	0.519	(a)
Hf	3.77	(a)
Ta	0.532	(a)
W ppb		
Re ppb		
Os ppb		
Ir ppb	5.3	(a)
Pt ppb		
Au ppb		
Th ppm	1.88	(a)
U ppm	0.51	(a)
<i>technique: (a) INAA, (b) IDMS</i>		

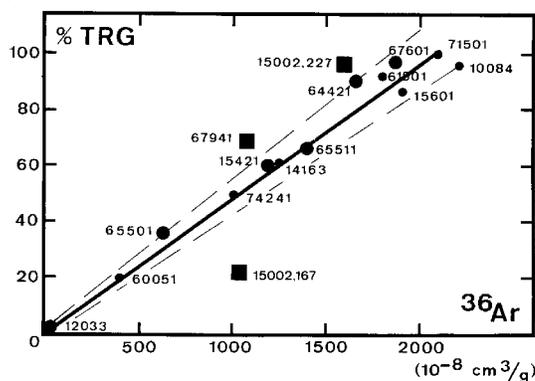


Figure 9: Percentage of track-rich grains plotted against ³⁶Ar content (Wieler et al. 1980).

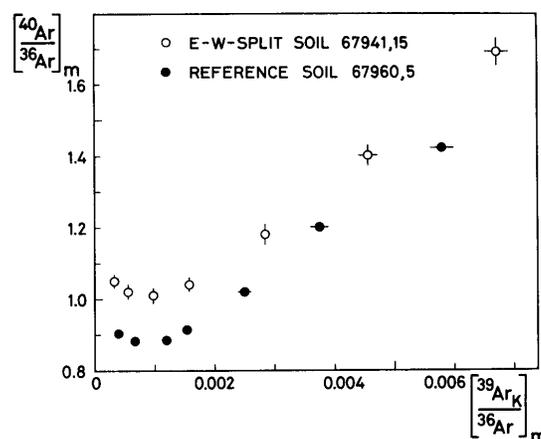


Figure 10: Argon data for shadowed soil 67941 (Eberhardt et al. 1976).

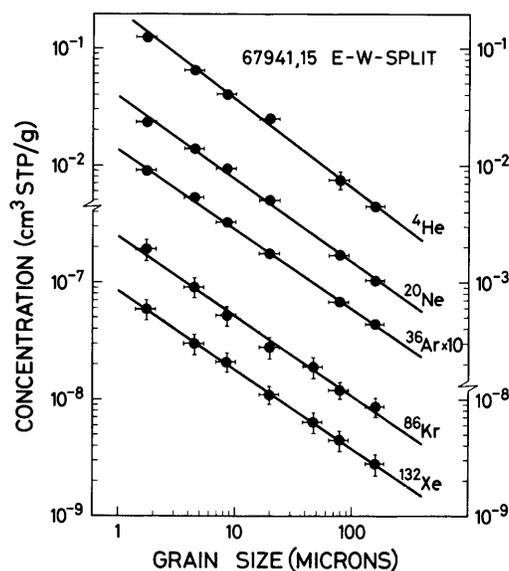
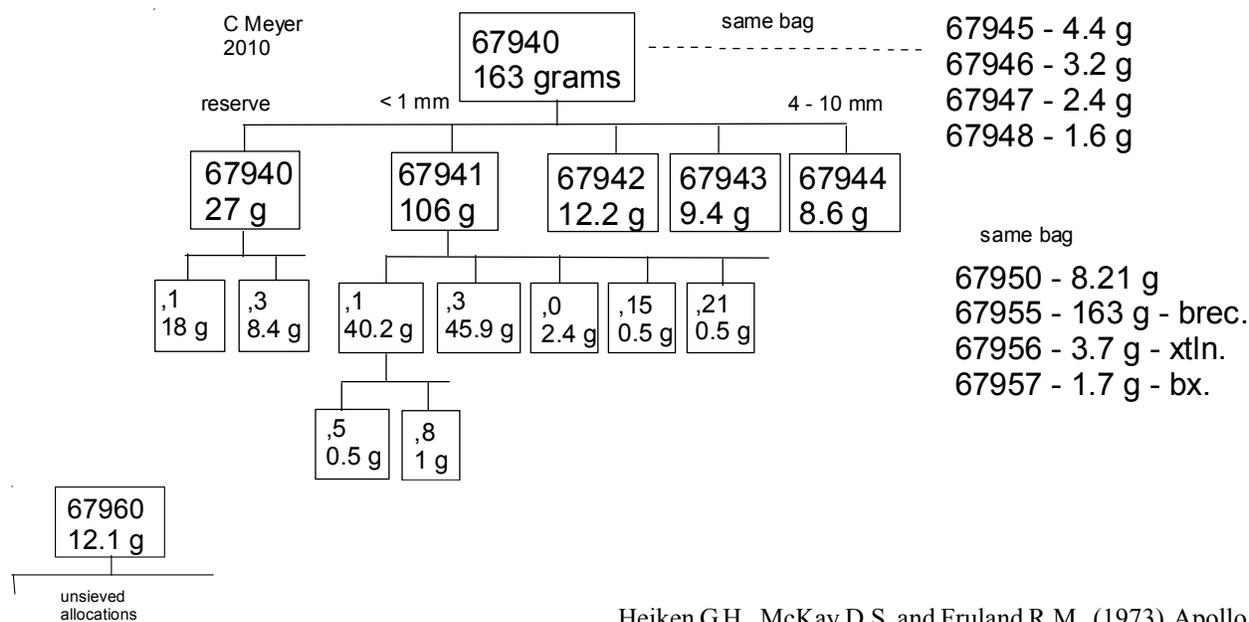


Figure 11: Rare gas as function of grain size for 67941 (Eberhardt et al. 1976)



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