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

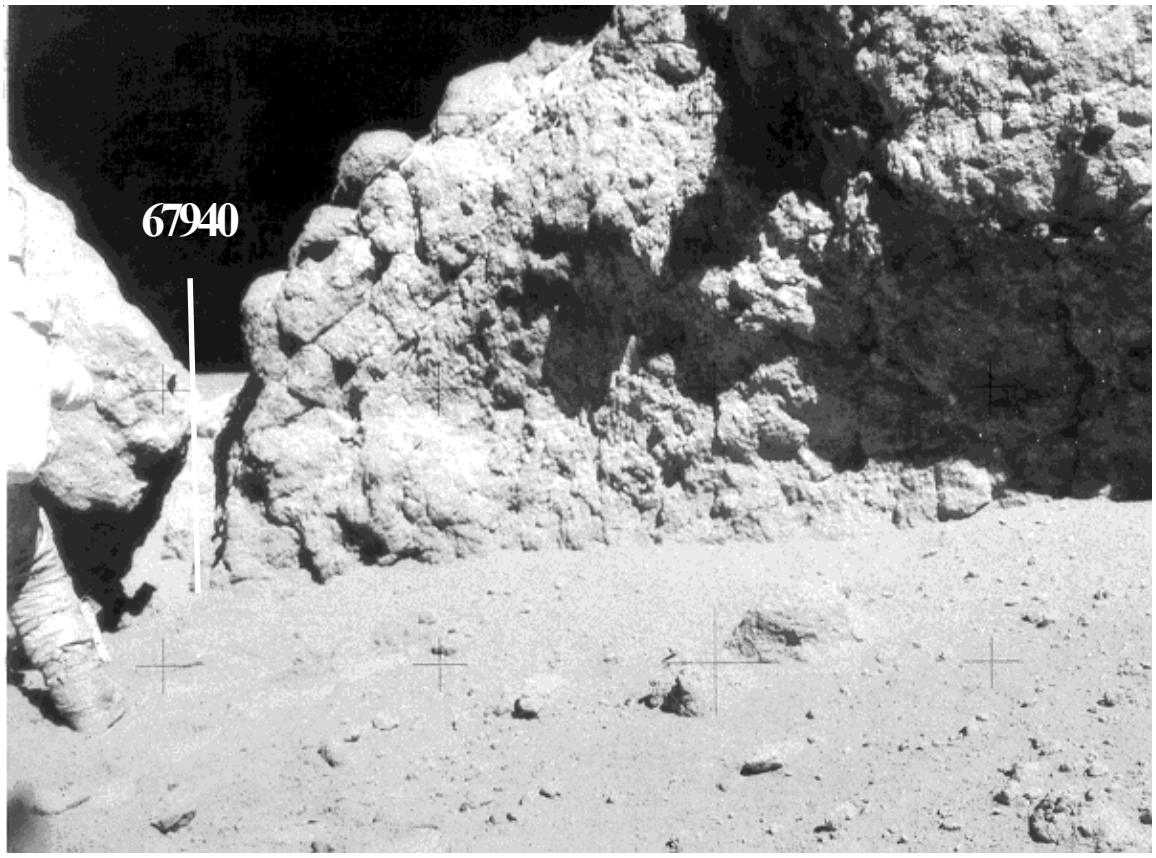


Figure 1: House Rock and location of 67940 in crack with Outhouse Rock.

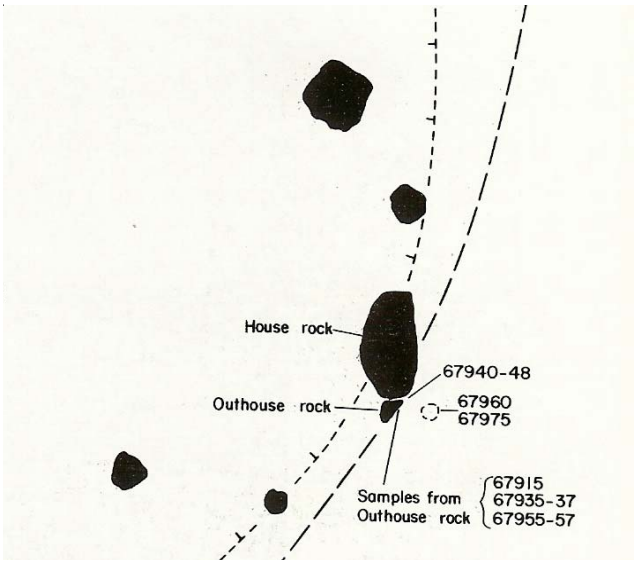


Figure 2: Map of House and Outhouse Rock on rim of North Ray Crater (Sutton 1981). 69940 was from a shielded region between rocks and 69960 was collected in the sun as reference soil.

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

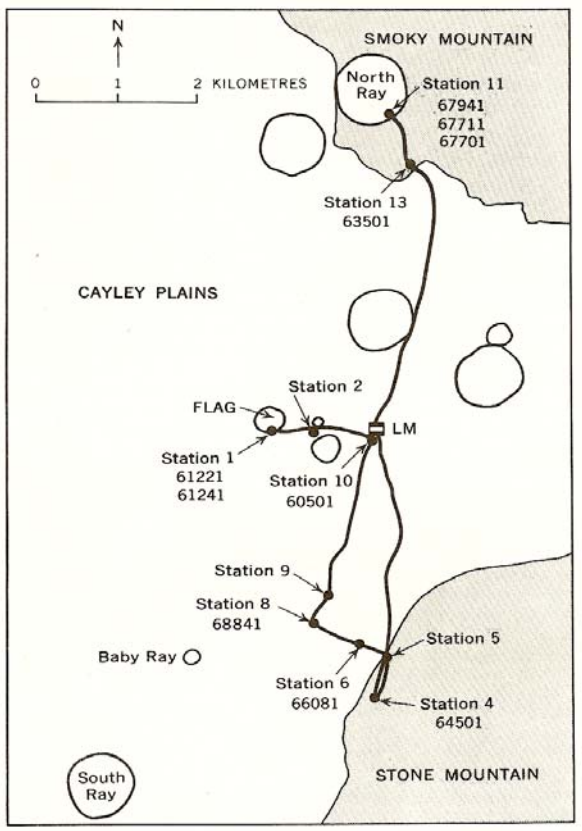


Figure 4: Map of Apollo 16 site with North Ray Crater.

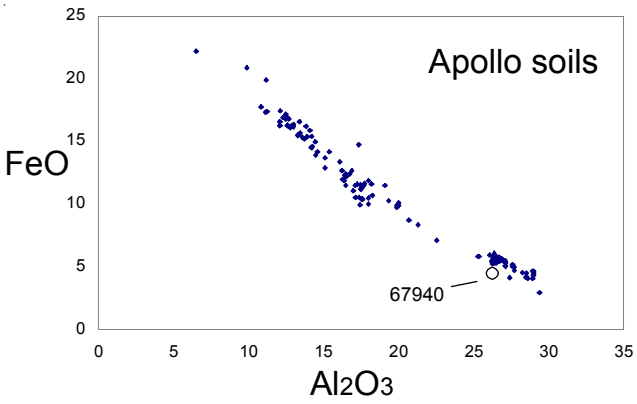


Figure 5: Composition of 67941 compared with that of other Apollo soil samples.

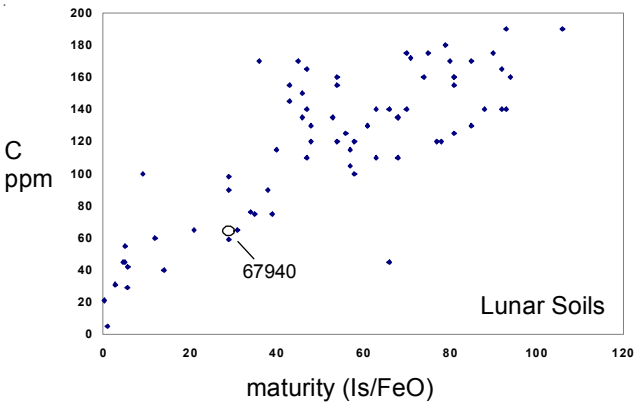


Figure 6: Carbon content and maturity index for 67941.

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.

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

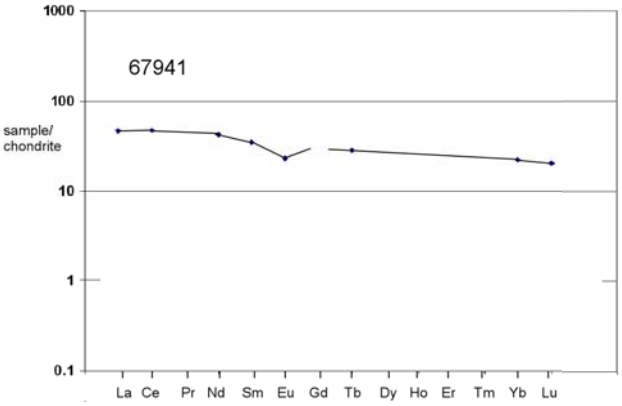


Figure 7: Normalized rare-earth-element diagram for 67941.

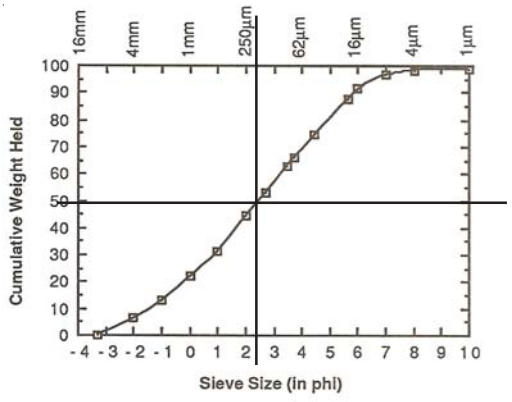
Chemistry

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}Al = 158 dpm/kg and ^{22}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

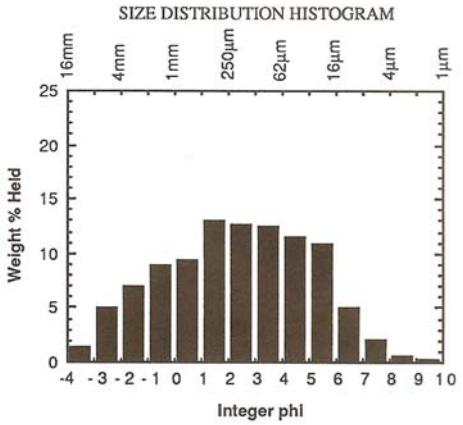


Figure 8: Grain size distribution for 67940 (Graf 1993; data from Heiken et al. 1973).

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 ^{4}He 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	Korotev91		Rose75		Finkelman75			Boynton75			Philpotts73		Finkelman75				ave. st. 11 Korotev81
weight													90-1000	30-90	<30 um		
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)	2.8
Eu	1.27	(a)						1.12	1.27	(a)	1.83	(e)	1.3	1.3	1.3	(a)	1.13
Gd											6.4	(e)					
Tb	1.02	(a)						0.9	1	(a)							0.56
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)	2.05
Lu	0.489	(a)						0.51	0.58	(a)	0.604	(e)	0.58	0.56	0.55	(a)	0.29
Hf	3.6	(a)						3.4	4.2	(a)			3.5	4	3	(a)	1.85
Ta	0.441	(a)											0.5	0.7		(a)	0.3
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)	1
U ppm	0.61	(a)															0.27

technique: (a) INAA, (e) IDMS, (c) OES

Table 2. Chemical composition of 67960.

reference	Korotev82		Philpotts73	
weight				
SiO2 %				
TiO2				
Al2O3				
FeO	4.56	(a)		
MnO				
MgO				
CaO	16.1	(a)		
Na2O	0.527	(a)		
K2O			0.113	(b)
P2O5				
S %				
sum				
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)		

technique: (a) INAA, (b) IDMS

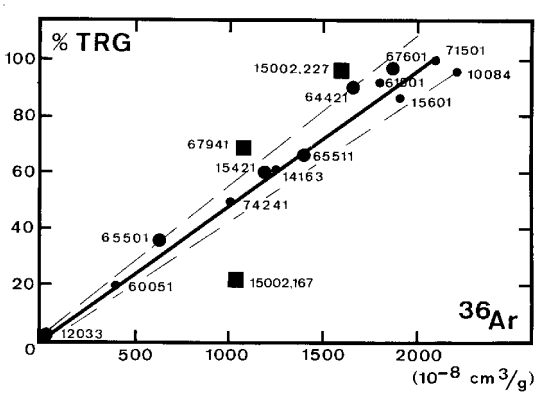


Figure 9: Percentage of track-rich grains plotted against 36Ar content (Wieler et al. 1980).

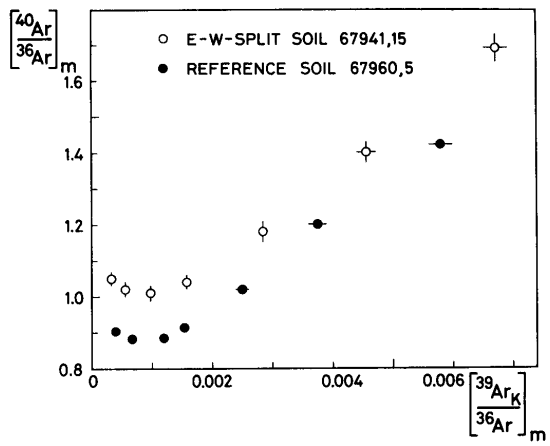


Figure 10: Argon data for shadowed soil 67941 (Eberhardt et al. 1976).

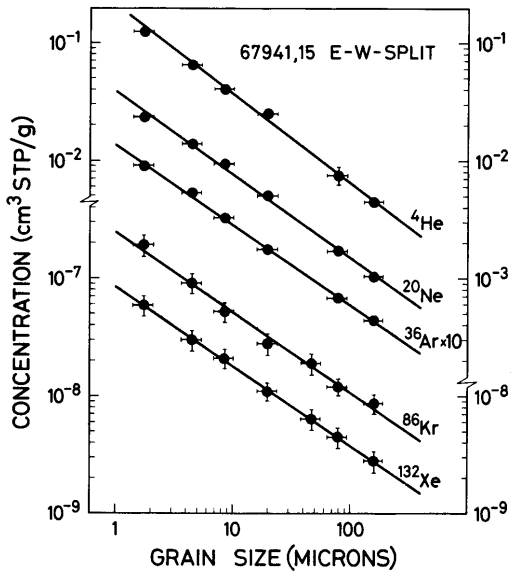
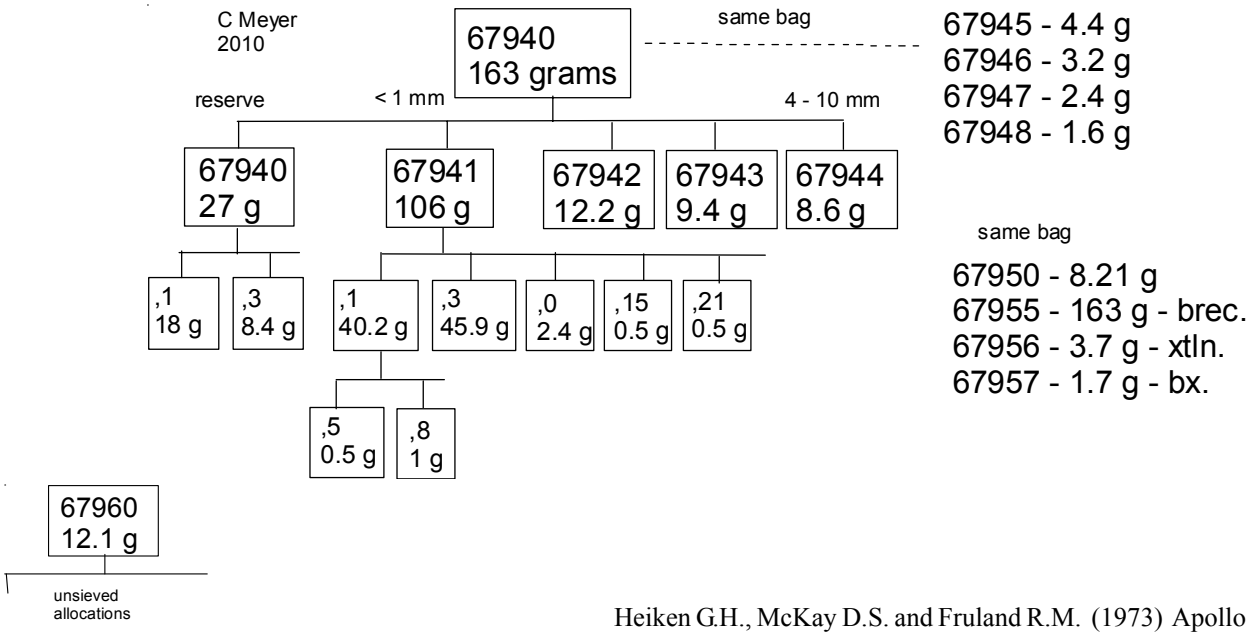


Figure 11: Rare gas as function of grain size for 67941 (Eberhardt et al. 1976)



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