61140, 61160 and 61180

Soils

229, 153 and 271 grams

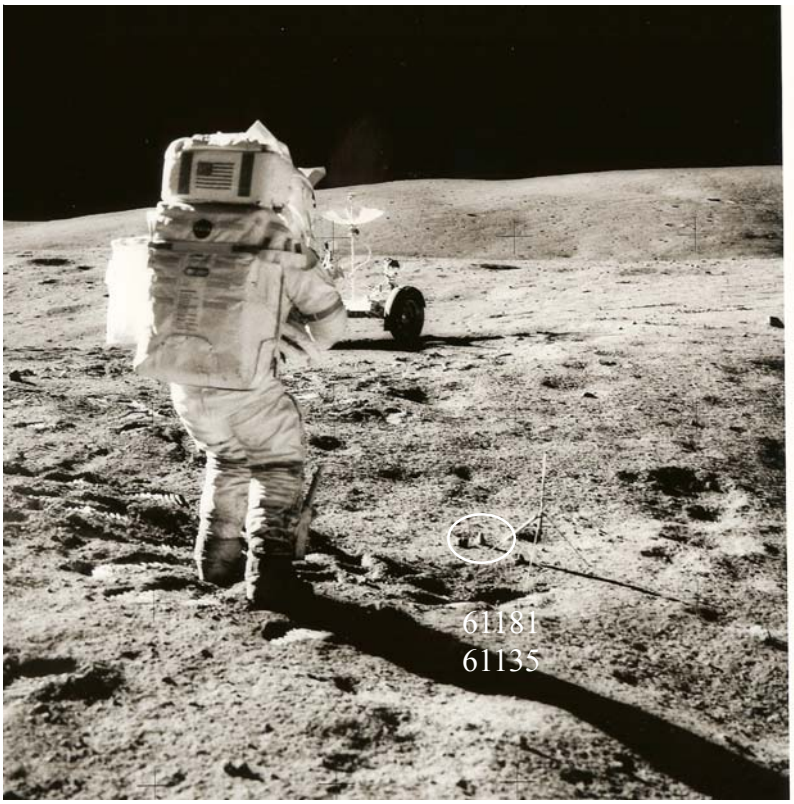


Figure 1: Apollo 16 commander taking picture of 61135 before collecting 61181. AS16-109-17800.

Introduction

61140, 61160 and 61180 were part of radial sample collected at Plum Crater, Apollo 16. 61180 was collected from beneath rock sample 61135 on the rim of Plum Crater (Sutton 1981). Plum Crater is on the rim of a large crater (Flag Crater, 200 m across, ~ 40 m deep) that, according to pre-mission planning, should have penetrated the regolith and sampled the underlying Cayley Formation (Head 1974). 61140 was collected about 30 m from the crater rim. However, these samples do not appear to have been studied together as a suite; different samples were allocated to different investigators. Perhaps this is because there are several

Modal content of soils 61161 (90-150 micron).

	Heiken et al. 1973	Houck 1982
Agglutinates	37 %	35.4
Basalt	0.3	0.3
Breccia	33.3	27.8
Anorthosite	4.7	1.4
Norite	-	
Gabbro	0.9	
Plagioclase	14.7	21.7
Pyroxene	2.6	2.5
Olivine	-	
Ilmenite	-	
Glass other	4.1	7.2

Modal content of soils 61181 (90-150 micron).

	Heiken et al. 1973	Houck 1982
Agglutinates	59.6 %	56
Basalt	0.6	2.9
Breccia	25.9	27.8
Anorthosite	4.3	0.7
Norite	-	
Gabbro	0.9	
Plagioclase	6.9	10.5
Pyroxene	0.9	0.3
Olivine	-	
Ilmenite	-	
Glass other	0.6	4

craters in the area and a radial sample didn't quite make sense here.

Petrography

61161 and 61181 are surface soils with high maturity (I_s/FeO = 82) and an abundance of agglutinates. For some reason, 61141 apparently has lower maturity (I_s/FeO = 56) (Morris 1978). The mineralogical mode was determined by Houck (1982) and Heiken et al. (1973). Butler et al. (1973) reported the grain size distribution for 61141; McKay et al. (1973) reported 61161 and 61181. The average grain size is 110, 88 and 91 micron, respectively (figure 3 a,b,c).

Keller and McKay (1992) studied vapor deposits on grains in 61181 as part of their investigation of "space weathering". They found that the ultra-fine (<20 micron) fraction contained numerous tiny glass spheres with either refractory composition (HASP) or volatile-rich (VRAP). HASP stands for high alumina silica poor; VRAP stands for volatile-rich alumina-poor. They are apparently complementary material derived by high-temperature volatilization and re-condensation during impact into feldspathic highland rocks (figure 6).

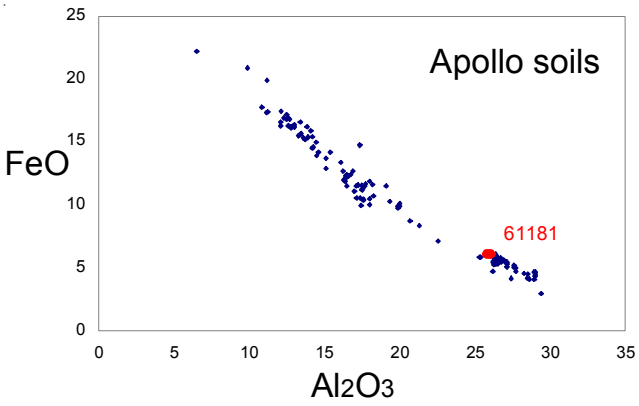
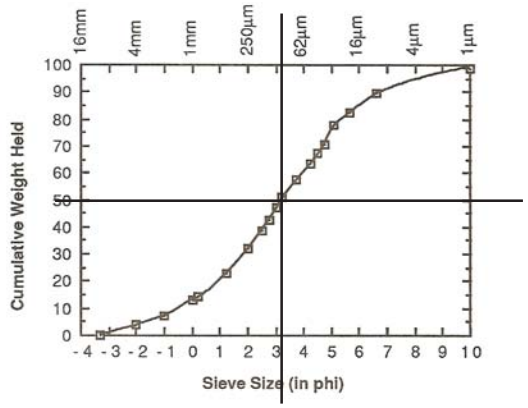


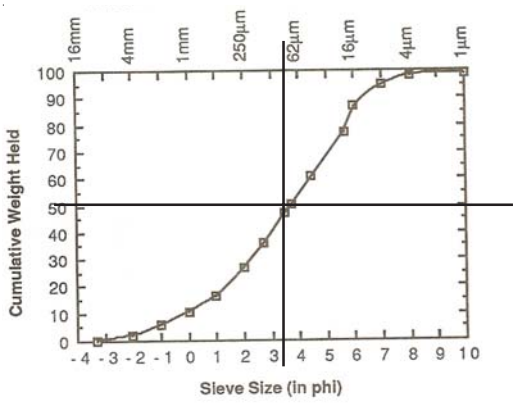
Figure 2: Chemical composition of lunar soils including 61181 (see table).

Chemistry

Eldridge et al. (1973) and Wrigley (1973) reported the U, Th and K content of bulk samples, in general agreement with trace element analysis of sample splits (Rose et al. 1973, Wanke et al. 1973,Taylor et al. 1973 and Korotev 1982).



average grain size = 110 microns



average grain size = 88 microns

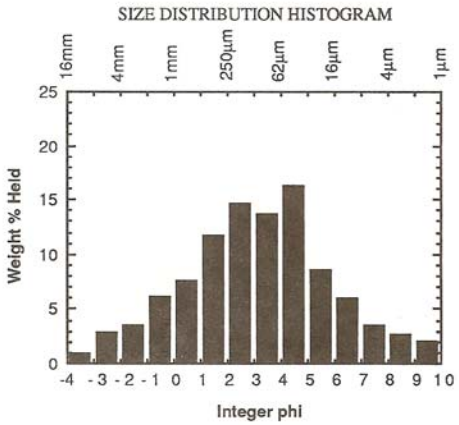


Figure 3a: Grain size distribution for 61141 (Graf, from data by Butler).

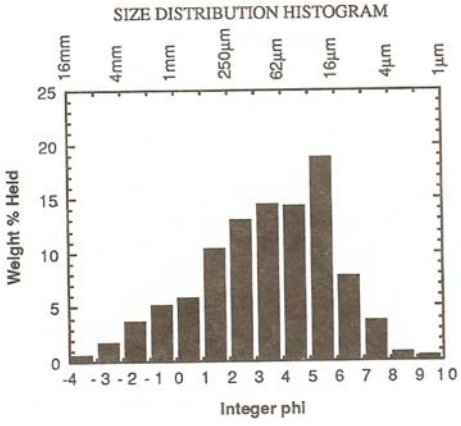


Figure 3b: Grain size distribution of 61161 (Graf 1991, from data by Mckay et al.).

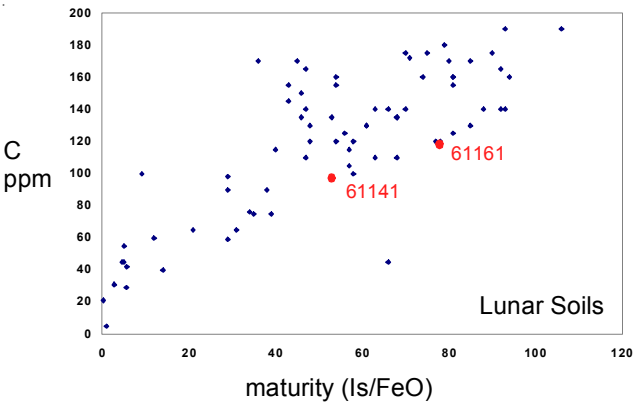
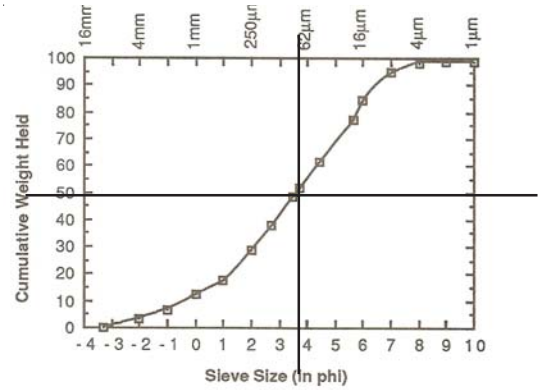


Figure 4: Carbon content and maturity index for 61141 and 61161 (Kerridge et al. 1978, Morris 1976).

Kerridge et al. (1978) and Becker (1980) reported 98, 111 and 116 ppm C and 59 - 73 ppm N for 61141 and 61161 (figure 4). C and N are closely correlated, indicating that they are both from solar wind implantation. Kerridge et al. (1975) reported 330 ppm S in 61141 and 470 ppm S in 61161. Cirlin and Housley (1981) reported excess, surface–correlated, Cd and Pb in 61161.



average grain size = 91 microns

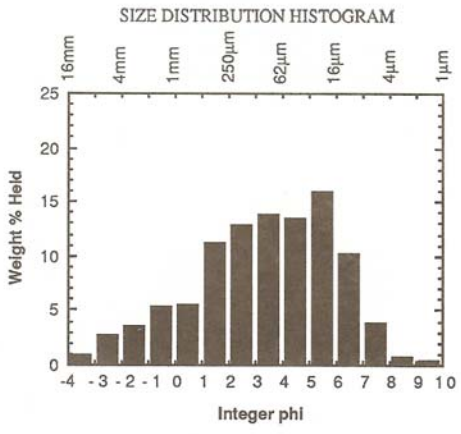


Figure 3c: Grain size distribution of 61181 (Graf 1991, data by McKay)

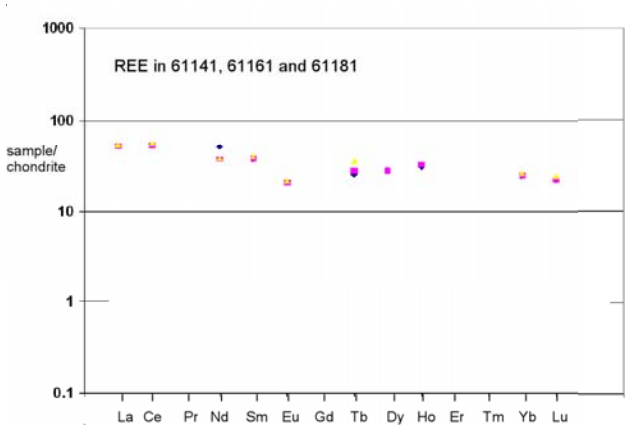


Figure 5: Normalized rare-earth-element diagram for 61141, 61161 and 61181 (data from tables).

Cosmogenic isotopes and exposure ages

The cosmic-ray-induced activity of 61181 is ^{22}Na = 40 dpm/kg and ^{26}Al = 204 dpm/kg (Eldridge et al. 1973). The activity of 61161 is ^{22}Na = 65 dpm/kg and ^{26}Al = 202 dpm/kg (Wrigley 1973).

Behrmann et al. (1973) and Bhattacharya et al. (1975) studied the cosmic-ray tracks in grains from 61181.

Other Studies

The rare gas content of 61181 was reported by Kirsten et al. (1973) and Walton et al. (1973). It has high Ne content.

Several investigators studied the magnetic properties (Tsay et al. 1973, Weeks 1973, Griscom et al. 1973).

Isotopic ratios for N and C were determined by Kerridge et al. (1978) and Becker (1980).

Processing

Marvin (1972) documented the coarse fine particles.

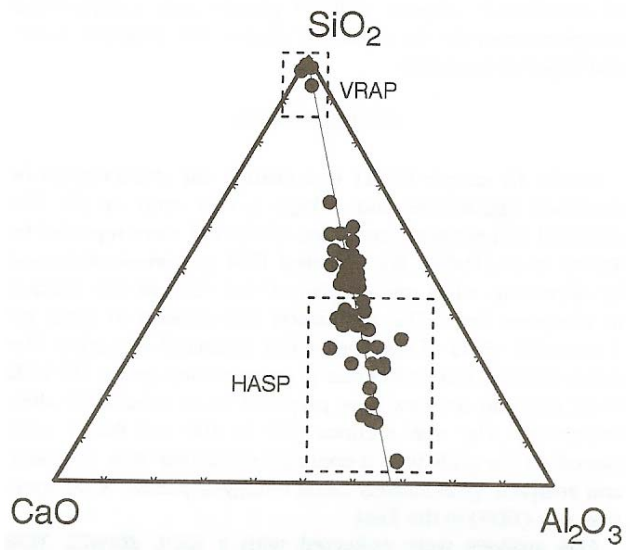
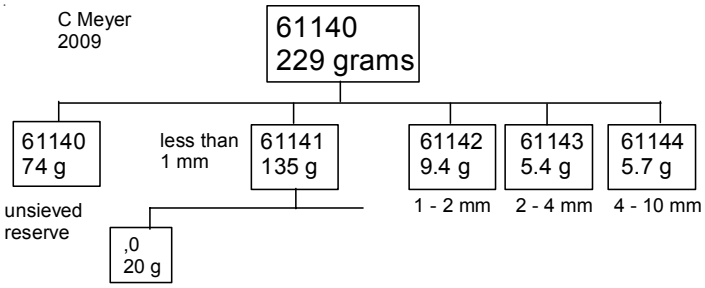
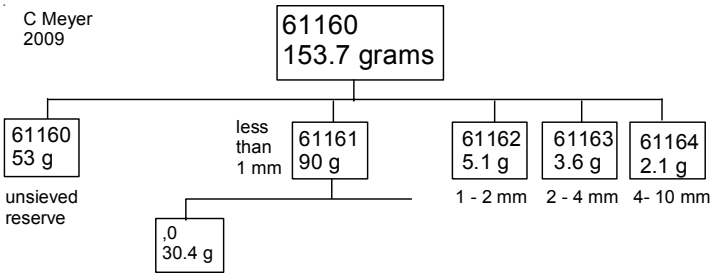


Figure 6: Chemical composition of glass condensates (VRAP) and refractory residual (HASP) in 61181 (Keller and McKay 1992).





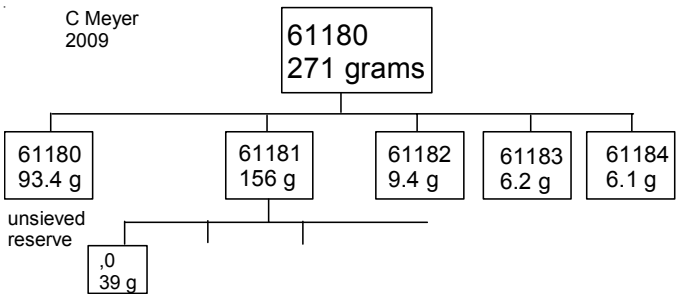


Table 1. Chemical composition of 61141.

reference	Rose73		Wanke73		Evenson73	
weight						
SiO2 %	45.2	(a)	44.9	(b)		
TiO2	0.58	(a)	0.53	(b)		
Al2O3	26.4	(a)	26.5	(b)		
FeO	5.29	(a)	5.33	(b)		
MnO	0.07	(a)	0.06	(b)		
MgO	6.1	(a)	6.2	(b)		
CaO	15.32	(a)	15.1	(b)		
Na2O	0.52	(a)	0.45	(b)		
K2O	0.14	(a)	0.11	(b)	0.11	(c)
P2O5	0.12	(a)				
S %						
sum						
Sc ppm	9.5	(a)	8.4	(b)		
V	20	(a)				
Cr	890	(a)	660	(b)		
Co	19	(a)	24.4	(b)		
Ni	310	(a)	400	(b)		
Cu	11	(a)				
Zn	28	(a)				
Ga	4.3	(a)				
Ge ppb						
As						
Se						
Rb	2.8	(a)			2.55	(c)
Sr	165	(a)	140	(b)	170	(c)
Y	39	(a)	38	(b)		
Zr	126	(a)	167	(b)		
Nb			11	(b)		
Mo						
Ru						
Rh						
Pd ppb						
Ag ppb						
Cd ppb						
In ppb						
Sn ppb						
Sb ppb						
Te ppb						
Cs ppm						
Ba			110	(b)	122	(c)
La			12.7	(b)		
Ce			33	(b)		
Pr						
Nd			23	(b)		
Sm			5.4	(b)		
Eu			1.17	(b)		
Gd						
Tb			0.92	(b)		
Dy			6.9	(b)		
Ho			1.7	(b)		
Er						
Tm						
Yb	2.6	(a)	3.9	(b)		
Lu			0.53	(b)		
Hf			4	(b)		
Ta			0.42	(b)		
W ppb						
Re ppb						
Os ppb						
Ir ppb			12	(b)		
Pt ppb						
Au ppb			10	(b)		
Th ppm			1.7	(b)		
U ppm						

technique: (a) "microchemical", (b) INAA, (c) IDMS

Table 2. Chemical composition of 61161.

reference	Eldridge73		Wanke73		Wrigley73		Korotev81		
weight							C	F	
SiO2 %			44.7	(a)					
TiO2			0.58	(a)					
Al2O3			26.3	(a)					
FeO			5.65	(a)			5.23	5.44	(a)
MnO			0.065	(a)					
MgO			6.35	(a)					
CaO			15.9	(a)					
Na2O			0.47	(a)			0.499	0.515	(a)
K2O	0.1	(b)	0.1	(a)	0.11	(b)			
P2O5			0.12	(a)					
S %									
sum									
Sc ppm			8.7	(a)			9.4	9.4	(a)
V									
Cr			670	(a)			785	905	(a)
Co			29	(a)			22.2	23	(a)
Ni			400	(a)			305	390	(a)
Cu									
Zn									
Ga									
Ge ppb									
As									
Se									
Rb									
Sr			150	(a)					
Y			37	(a)					
Zr			184	(a)					
Nb			11.5	(a)					
Mo									
Ru									
Rh									
Pd ppb									
Ag ppb									
Cd ppb									
In ppb									
Sn ppb									
Sb ppb									
Te ppb									
Cs ppm									
Ba			120	(a)					
La			12.2	(a)			11.9	12.7	(a)
Ce			32	(a)			32	34	(a)
Pr									
Nd			17	(a)					
Sm			5.6	(a)			5.6	5.85	(a)
Eu			1.15	(a)			1.2	1.19	(a)
Gd									
Tb			1	(a)			1.27	1.27	(a)
Dy			6.7	(a)					
Ho			1.8	(a)					
Er									
Tm									
Yb			4	(a)			3.9	4.05	(a)
Lu			0.54	(a)			0.56	0.56	(a)
Hf			3.8	(a)			4.2	4.3	(a)
Ta			0.52	(a)			0.6	0.7	(a)
W ppb									
Re ppb									
Os ppb									
Ir ppb			19	(a)					
Pt ppb									
Au ppb			13	(a)					
Th ppm	1.97	(b)	1.5	(a)	1.97	(b)	1.8	2	(a)
U ppm	0.55	(b)			0.54	(b)			

technique: (a) INAA, (b) radiation counting

Table 3. Chemical composition of 61181.

reference	Eldridge73		Taylor73		Korotev82	
weight						
SiO2 %			44.6	(b)		
TiO2			0.66	(b)		
Al2O3			27.1	(b)	25.2	(c)
FeO			5.47	(b)	5.54	(c)
MnO					0.069	(c)
MgO			5.78	(b)	5.9	(c)
CaO			15.56	(b)	14.4	(c)
Na2O			0.51	(b)	0.463	(c)
K2O	0.11	(a)	0.25	(b)		
P2O5			0.18	(b)		
S %						
sum						
Sc ppm			12	(b)	9.26	(c)
V			29	(b)	21	(c)
Cr			850	(b)	760	(c)
Co			27	(b)	31.5	(c)
Ni			340	(b)	435	(c)
Cu			8.5	(b)		
Zn						
Ga						
Ge ppb						
As						
Se						
Rb						
Sr					180	(c)
Y			44	(b)		
Zr			197	(b)	185	(c)
Nb			13.7	(b)		
Mo						
Ru						
Rh						
Pd ppb						
Ag ppb						
Cd ppb						
In ppb						
Sn ppb			0.11	(b)		
Sb ppb						
Te ppb						
Cs ppm					0.18	(c)
Ba					139	(c)
La			13.9	(b)	12.43	(c)
Ce			38.5	(b)	33.9	(c)
Pr			5.6	(b)		
Nd			22.1	(b)		
Sm			6.05	(b)	5.92	(c)
Eu			1.51	(b)	1.185	(c)
Gd			7.77	(b)		
Tb			1.15	(b)	1.28	(c)
Dy			7.63	(b)		
Ho			1.79	(b)		
Er			4	(b)		
Tm			0.79	(b)		
Yb			4.76	(b)	4.17	(c)
Lu			0.74	(b)	0.593	(c)
Hf			3.9	(b)	0.654	(c)
Ta						
W ppb						
Re ppb						
Os ppb						
Ir ppb					15.9	
Pt ppb						
Au ppb						
Th ppm	2.02	(a)	2.12	(b)	2.09	(c)
U ppm	0.56	(a)	0.55	(b)	0.54	(c)

technique: (a) radiation counting, (b) spark source mass spec., (c) INAA

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