

79221 - 291 grams
 79241 - 330 grams
 79261 - 348 grams
 Trench Soils

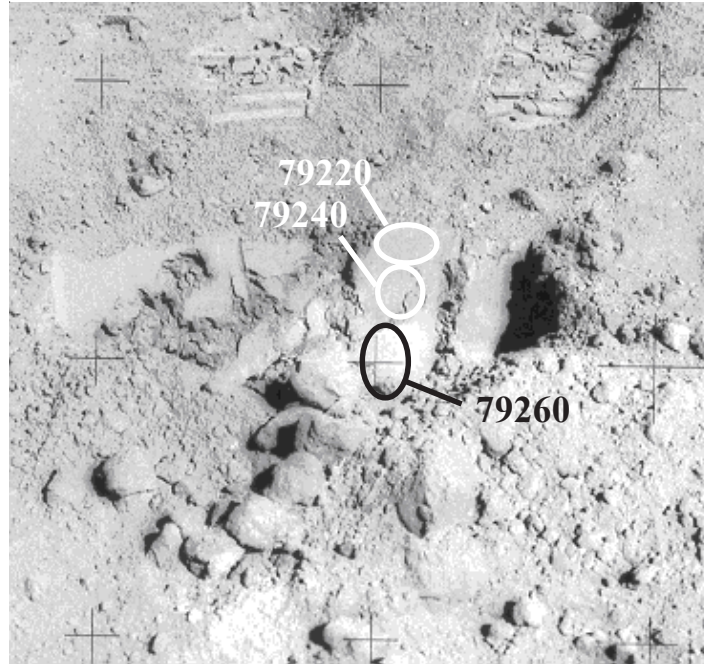


Figure 1: Trench at Van Serg Crater. AS17-142-21828.

Introduction

The trench dug near Van Serg Crater (figures 1 and 3) was 17 cm deep, with upper 2 cm (79220), next 5 cm (79240) and bottom 10 cm (79260). The material below the surface was light colored (see transcript). Numerous rocks can be seen in the surface photos, and several were collected with the soil samples.

The soil samples of this trench have been used to understand the color differences due “space weathering” (Noble et al. 2001, Taylor et al. 2001a, b). Darker soils are more mature.

Petrography

The maturity of 79261 is $I_s/FeO = 43$ and the average grain size is 90 microns (Morris 1978, Graf 1993). The surface sample, 79221, has an index of 81 and average grain size of 60 microns (very mature) and 79241 has an index of 51. (In any trench activity there is the chance that some of the surface material has slumped into the trench). The percentage agglutinates

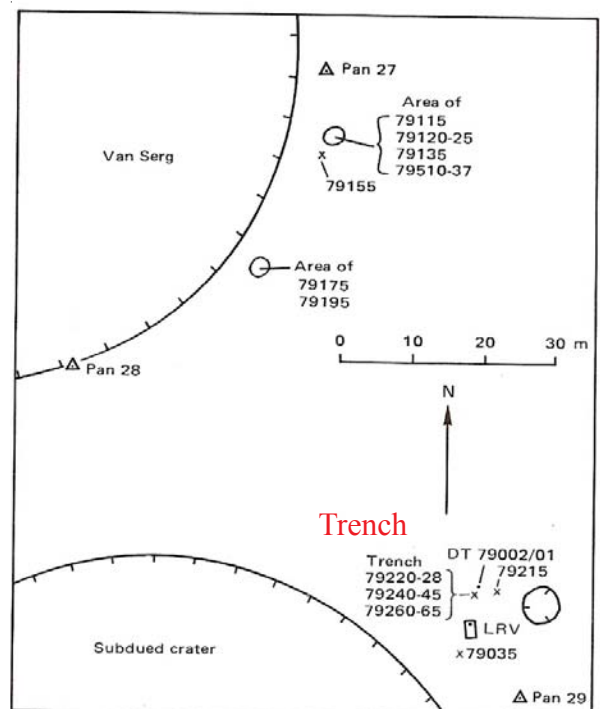


Figure 2: Map for station 9, Apollo 17.



Figure 3: Photo of regolith where trench was dug. ASI7-142-21829

Transcript 6 – 21 – 47+

CDR Jack, you ought to get a scoop of that dirt, though.

LMP Well, there's one scoop -- . Look what's underneath it. It's white.

CDR Well, I wanted to be sure we got some of those small glass balls.

LMP Yes, we'll get a scoop of it. Upon the top.

- - - -

LMP Come here, Gene, quickly. We can't leave this. This may be the youngest mantle ever – whatever was --

CDR Take pictures of it. I don't have any film.

LMP - was thrown out of the craters.

CDR What Jack has done is he dug a trench in the southwest – northeast direction, and he discovered about 3 inches below – 4 inches below the surface – a very light-gray material. Take that crust.

LMP I'm trying to get the upper portion there. There we go. The first 2 cm, bag 483 (79220). The next 5 (cm) in 484 (79240).

CDR Get some?

LMP I got quite a bit. And the next 10 cm of the light-gray material, probably in 485 (79260). A possibility here is that this upper 6 inches of gray material in here is the latest mantling in the area and the light-colored debris may be what's left over from the impact.

- - -

Modal content of soil 79221 (90-150 micron).
From Heiken and McKay 1974.

	79221	79261
Agglutinates	44.4	22.3 %
Basalt	14.4	13.3
Breccia	10.5	9.9
Anorthosite	0.3	1.2
Norite		0.3
Gabbro		
Plagioclase	6.9	12.7
Pyroxene	6.5	18.2
Olivine		
Ilmenite	1.3	7
Orange glass	4.2	4
Glass other	11.5	9.1

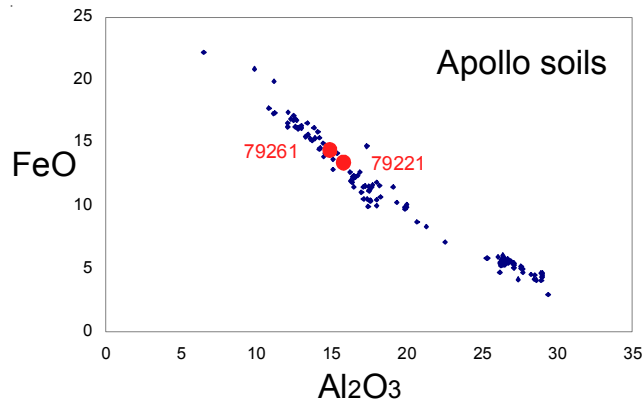


Figure 4: Composition of 79221 compared with other lunar soil samples.

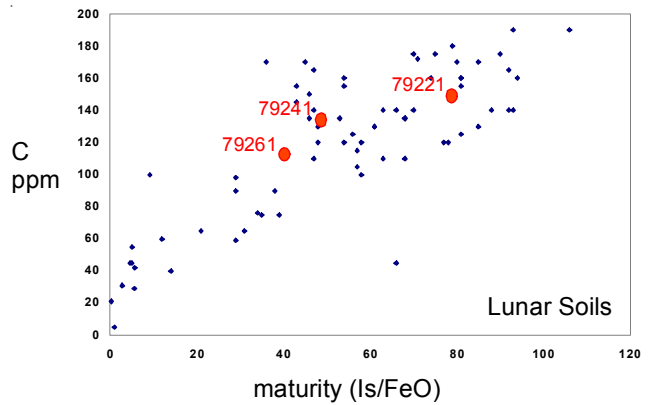


Figure 5: Carbon content and maturity index for trench samples at station 9.

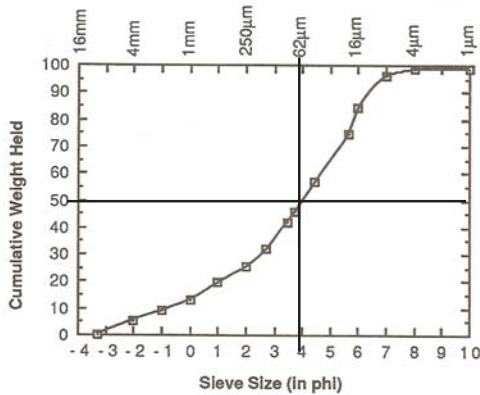
CC We've had a change of heart here again as usual, and we are going to drop station 10 now that we've hurried you so much, and we'd like to get a double core here. And we'd like you to get some football-sized rocks while you are doing that --

LMP You don't want a double core here. I don't think we can do it, now. It's too rocky.

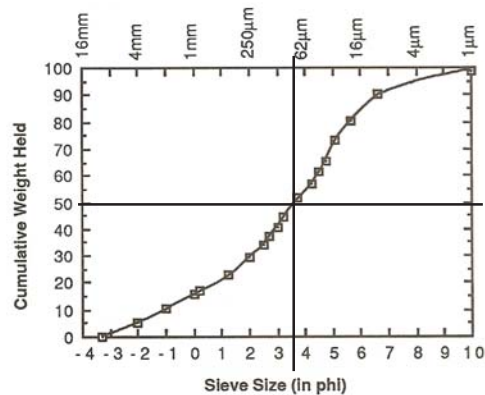
CDR You don't think we'll get through that stuff you just trenched?

LMP Well, I'm afraid there are rocks all through it.

CDR Let's try it. I've got it started (79002).



average grain size = 62 microns



average grain size = 80 microns

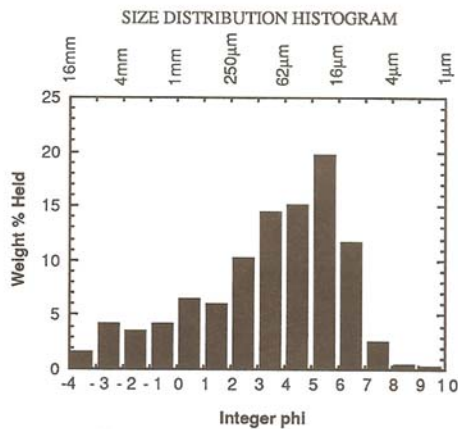


Figure 6a: Grain size distribution for 76220 (Graf 1993, data from McKay).

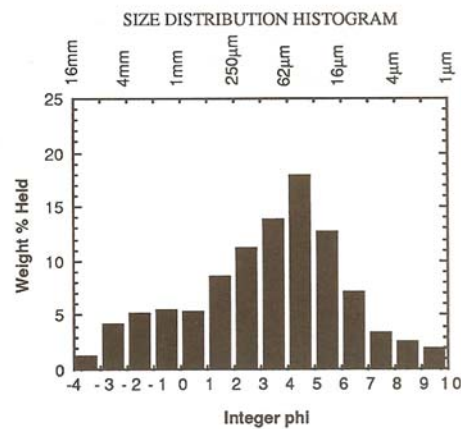


Figure 6b: Grain size distribution for 76240 (Graf 1993, data from King).

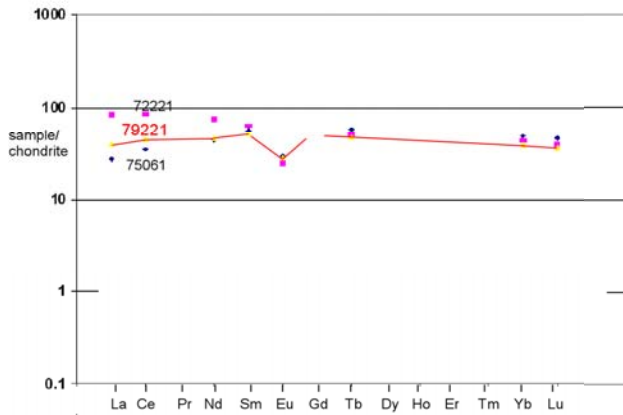


Figure 7: Normalized rare-earth-element diagram for 79221 compared with that of mare and highland soils from Apollo 17.

is high in the surface material and low in the light colored material below the surface (Heiken and McKay 1974).

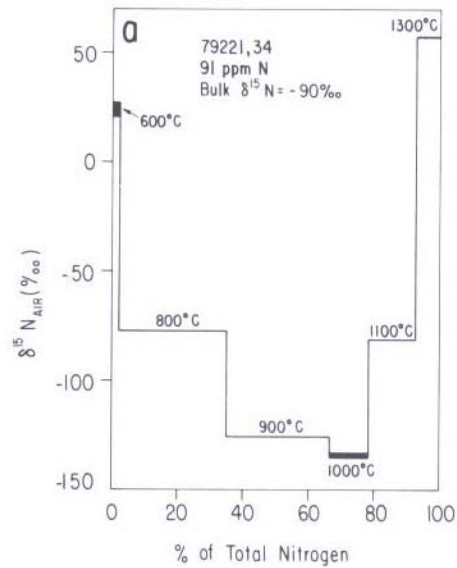
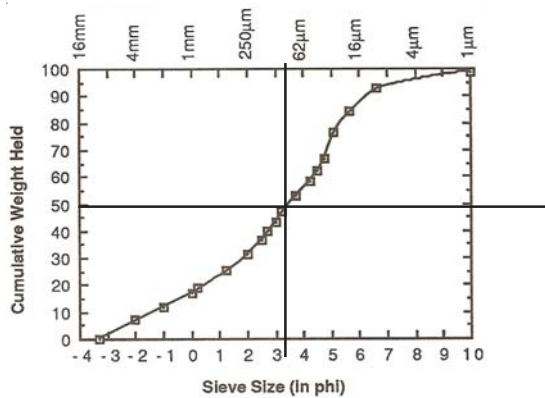


Figure 8: Isotopic composition of nitrogen from 79221 (Clayton and Thiemens 1980).



average grain size = 90 microns

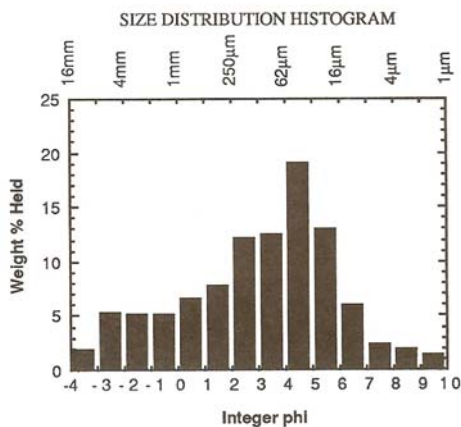


Figure :6c Grain size distribution for 79260 (Graf 1993, data from King).

Chemistry

The chemical composition of the three soils from this trench are slightly different (tables 1 – 3), but not such that it would explain the color difference.

The high maturity of the soil samples from this trench is confirmed by the carbon and nitrogen contents (figure 5). Moore et al. (1974) determined 150 ppm carbon for 79221, 140 ppm C for 79241 and 110 ppm C for 79261. Goel et al. (1975) found 111 ppm nitrogen for 79221, 118 ppm N for 79241 and 78 ppm N for 79261. Clayton and Thiemens (1980) reported 91 ppm nitrogen for 79221 (figure 8).

Cosmogenic isotopes and exposure ages

O'Kelley et al. (1974) determined the cosmic-ray-induced activity of $^{22}\text{Na} = 165$ dpm/kg, $^{26}\text{Al} = 130$ dpm/kg, $^{46}\text{Sc} = 65$ dpm/kg, $^{48}\text{V} = 30$ dpm/kg, $^{54}\text{Mn} = 215$ dpm/kg, and $^{56}\text{Co} = 470$ dpm/kg for surface soil 79221 and $^{22}\text{Na} = 43$ dpm/kg, $^{26}\text{Al} = 45$ dpm/kg, $^{46}\text{Sc} = 15$ dpm/kg, $^{54}\text{Mn} = 44$ dpm/kg, and $^{56}\text{Co} = 26$ dpm/kg for trench bottom 79261.

Other Studies

Jordan and Heymann (1975) studied the rare gas content and isotopic ratio of different grain size separates from different depths in the trench at Van Serg Crater. Clayton and Thiemens (1980) found that there were more than one sources of nitrogen (figure 8).

Table 1. Chemical composition of 79221.

reference weight	LSPET73 Rhodes74	Korotev92	Rose74	Eldridge74	Korotev76 90-150 <20 micron		
SiO2 %	41.67 (a)		41.63 (c)				
TiO2	6.52 (a)		6.48 (c)				
Al2O3	13.57 (a)		13.48 (c)				
FeO	15.37 (a)	15.5 (b)	15.43 (c)		16.3	14.7	(b)
MnO	0.21 (a)		0.2 (c)				
MgO	10.22 (a)		10.3 (c)				
CaO	11.18 (a)		11.19 (c)				
Na2O	0.34 (a)	0.394 (b)	0.35 (c)		0.402	0.477	(b)
K2O	0.09 (a)		0.11 (c)	0.084 (d)			
P2O5	0.06 (a)						
S %	0.12 (a)						
sum							
Sc ppm		49.9 (b)	59 (c)		55.6	39.6	(b)
V			74 (c)				
Cr	2874 (a)	2780 (b)	3010 (c)		3106	2928	(b)
Co		36.7 (b)	48 (c)		33.2	37.7	(b)
Ni	236 (a)	240 (b)	430 (c)		160	260	(b)
Cu			20 (c)				
Zn	51 (a)		21 (c)				
Ga			4.6 (c)				
Ge ppb							
As							
Se							
Rb	1.7 (a)		1.6 (c)				
Sr	156 (a)	200 (b)	135 (c)				
Y	61 (a)		62 (c)				
Zr	193 (a)	2140 (b)	205 (c)				
Nb	16 (a)		20 (c)				
Mo							
Ru							
Rh							
Pd ppb							
Ag ppb							
Cd ppb							
In ppb							
Sn ppb							
Sb ppb							
Te ppb							
Cs ppm							
Ba		94 (b)	115 (c)				
La		8.21 (b)			8.29	11.6	(b)
Ce		23.5 (b)			25.6	28.5	(b)
Pr							
Nd		20 (b)					
Sm		7.02 (b)			6.9	7.35	(b)
Eu		1.49 (b)			1.44	1.57	(b)
Gd							
Tb		1.79 (b)			1.78	1.75	(b)
Dy							
Ho							
Er							
Tm							
Yb		9.32 (b)	5.9 (c)		6.7	6.09	(b)
Lu		1.46 (b)			0.94	0.86	(b)
Hf		45.7 (b)			6.1	6.2	(b)
Ta		0.99 (b)			1.2	1.5	(b)
W ppb							
Re ppb							
Os ppb							
Ir ppb		7.5 (b)					
Pt ppb							
Au ppb		5 (b)					
Th ppm		1.23 (b)		1.12 (d)	0.9	1.3	(b)
U ppm		0.65 (b)		0.36 (d)			

technique: (a) XRF, (b) INAA, (c) "microchemical", (d) radiation count.

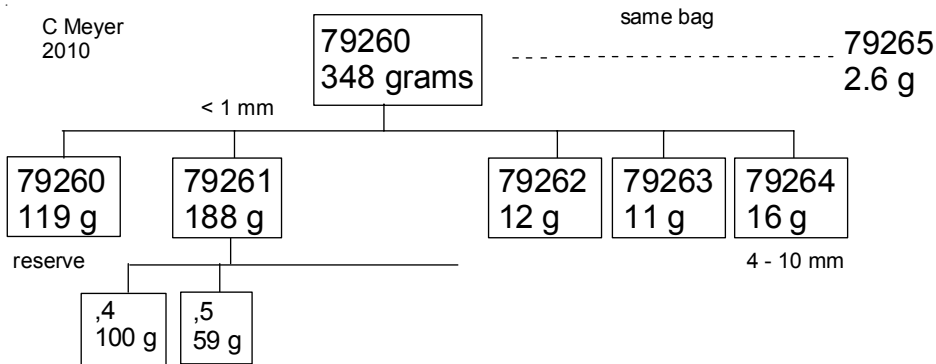
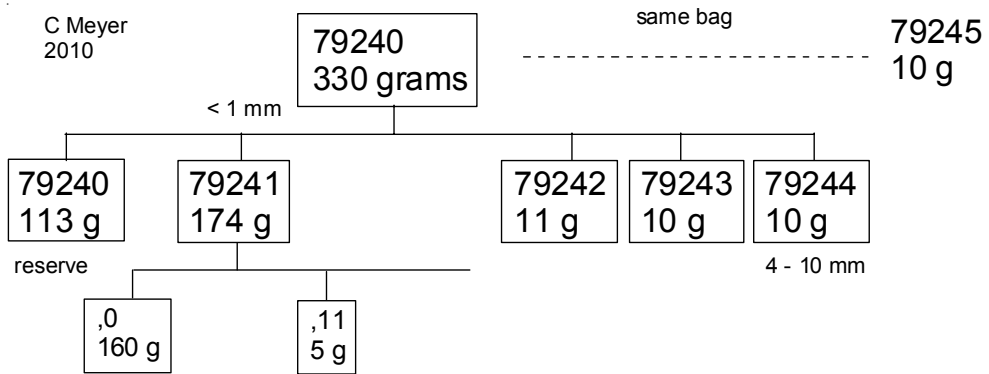
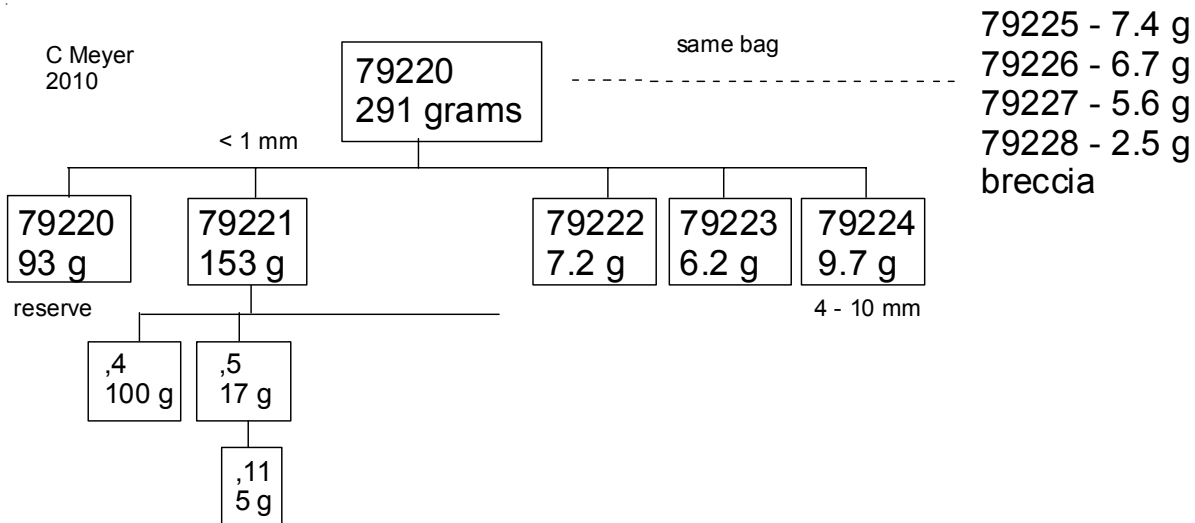
Table 2. Chemical composition of 79241

<i>reference</i>	Korotev92	Rose74	
<i>weight</i>			
SiO ₂ %		41.73	(b)
TiO ₂		6.79	(b)
Al ₂ O ₃		13.9	(b)
FeO	15.6	(a) 15.64	(b)
MnO		0.2	(b)
MgO		9.9	(b)
CaO		11.08	(b)
Na ₂ O	0.422	(a) 0.39	(b)
K ₂ O		0.09	(b)
P ₂ O ₅			
S %			
<i>sum</i>			
Sc ppm	50	(a) 56	(b)
V		81	(b)
Cr	2870	(a) 3147	(b)
Co	34.8	(a) 43	(b)
Ni	220	(a) 275	(b)
Cu		24	(b)
Zn		22	(b)
Ga		5.1	(b)
Ge ppb			
As			
Se			
Rb		1.9	(b)
Sr	160	(a) 147	(b)
Y		66	(b)
Zr	240	(a) 200	(b)
Nb		19	(b)
Mo			
Ru			
Rh			
Pd ppb			
Ag ppb			
Cd ppb			
In ppb			
Sn ppb			
Sb ppb			
Te ppb			
Cs ppm			
Ba	93	(a) 117	(b)
La	9.45	(a)	
Ce	27.2	(a)	
Pr			
Nd	21	(a)	
Sm	7.55	(a)	
Eu	1.58	(a)	
Gd			
Tb	1.72	(a)	
Dy			
Ho			
Er			
Tm			
Yb	6.3	(a) 6.4	(b)
Lu	0.877	(a)	
Hf	6.19	(a)	
Ta	0.98	(a)	
W ppb			
Re ppb			
Os ppb			
Ir ppb	10	(a)	
Pt ppb			
Au ppb	5	(a)	
Th ppm	1.36	(a)	
U ppm	0.4	(a)	
<i>technique: (a) INAA, (b) "microchemical"</i>			

Table 3. Chemical composition of 79261

reference weight	LSPET73 Rhodes74	Rhodes74 Wiesmann76	Korotev92	Rose74	Eldridge74
SiO ₂ %	42.26 (a)			42.58 (d)	
TiO ₂	6.09 (a)	5.84 (b)		6.28 (d)	
Al ₂ O ₃	14.43 (a)			14.51 (d)	
FeO	14.6 (a)		15.8 (c)	14.69 (d)	
MnO	0.2 (a)			0.19 (d)	
MgO	9.82 (a)			9.67 (d)	
CaO	11.48 (a)			11.35 (d)	
Na ₂ O	0.35 (a)	0.4	0.395 (c)	0.39 (d)	
K ₂ O	0.11 (a)	0.096 (b)		0.1 (d)	0.084 (e)
P ₂ O ₅	0.07 (a)				
S %	0.12 (a)				
sum	0.4 (a)				
Sc ppm			52.4 (c)	50 (d)	
V				63 (d)	
Cr	2737 (a)	2530 (b)	2900 (c)	2805 (d)	
Co			35 (c)	48 (d)	
Ni	177 (a)		180 (c)	300 (d)	
Cu				19 (d)	
Zn	48 (a)			15 (d)	
Ga				4.4 (d)	
Ge ppb					
As					
Se					
Rb	1.9 (a)	1.8 (b)		1.3 (d)	
Sr	153 (a)	154 (b)	160 (c)	131 (d)	
Y	59 (a)			56 (d)	
Zr	183 (a)	204 (b)	160 (c)	208 (d)	
Nb	16 (a)			19 (d)	
Mo					
Ru					
Rh					
Pd ppb					
Ag ppb					
Cd ppb					
In ppb					
Sn ppb					
Sb ppb					
Te ppb					
Cs ppm					
Ba		94 (b)	99 (c)	100 (d)	
La		8.31 (b)	8.44 (c)		
Ce		22.2 (b)	23.3 (c)		
Pr					
Nd		17.8 (b)	16 (c)		
Sm		6.18 (b)	6.82 (c)		
Eu		1.39 (b)	1.46 (c)		
Gd		8.49 (b)			
Tb			1.7 (c)		
Dy		10 (b)			
Ho					
Er		5.99 (b)			
Tm					
Yb		5.53 (b)	6.09 (c)	5.7 (d)	
Lu		0.713 (b)	0.846 (c)		
Hf			5.98 (c)		
Ta			1.11 (c)		
W ppb					
Re ppb					
Os ppb					
Ir ppb			6.5 (c)		
Pt ppb					
Au ppb			2.5 (c)		
Th ppm			1.01 (c)		1.08 (e)
U ppm		0.32 (b)	0.29 (c)		0.31 (e)

technique: (a) XRF (b) IDMS, (c) INAA, (d) "microchemical", (e) radiation count.



References for 79221, 79241 and 79261.

- Butler P. (1973) Lunar Sample Information Catalog Apollo 17. Lunar Receiving Laboratory. MSC 03211 Curator's Catalog. pp. 447.
- Butler J.C. and King E.A. (1974) Analysis of the grain size-frequency distributions of lunar fines. *Proc. 5th Lunar Sci. Conf.* 829-841.
- Clayton R.N. and Thiemens M.H. (1980) Lunar nitrogen: Evidence for secular change in the solar wind. In **The Ancient Sun**. 463-473. (eds Pepin, Eddy, Merrill)
- Eldridge J.S., O'Kelley G.D. and Northcutt K.J. (1974a) Primordial radioelement concentrations in rocks and soils from Taurus-Littrow. *Proc. 5th Lunar Sci. Conf.* 1025-1033.
- von Engelhardt W., Hurrle H. and Luft E. (1976) Microimpact-induced changes of textural parameters and modal composition of the lunar regolith. *Proc. 7th Lunar Sci. Conf.* 373-392.
- Evensen N.M., Murthy V.R. and Coscio M.R. (1974) Provenance of KREEP and the exotic component: Elemental and isotopic studies of grain size fractions in lunar soils. *Proc. 5th Lunar Sci. Conf.* 1401-1418.
- Fireman E.L., D'Amico J. and DeFelice J. (1973) Radioactivities vs. depth in Apollo 16 and 17 soil. *Proc. 4th Lunar Sci. Conf.* 2131-2144.
- Goel P.S., Shukla P.N., Kothari B.K. and Garg A.N. (1975) Total nitrogen in lunar soils, breccias, and rocks. *Geochim. Cosmochim. Acta* **39**, 1347-1352.
- Graf J.C. (1993) Lunar Soils Grain Size Catalog. NASA Reference Pub. 1265, March 1993
- Green G.M., King D.T., Banholzer G.S. and King E.A. (1975) Size and model analyses of fines and ultrafines from some Apollo 17 samples. *Proc. 6th Lunar Sci. Conf.* 517-528.
- Heiken G.H. (1974) A catalog of lunar soils. JSC Curator
- Heiken G.H. (1975) Petrology of lunar soils. *Rev. Geophys. Space Phys.* **13**, 567-587.
- Heiken G.H. and McKay D.S. (1974) Petrology of Apollo 17 soils. *Proc. 5th Lunar Sci. Conf.* 843-860.
- Herzog G.F., Moynier F., Albarede F. and Brezhnoy A.A. (2009) Isotopic and elemental abundances of copper and zinc in lunar samples - - . *Geochim. Cosmochim. Acta* **73**, 5884-5904.
- Hughes S.S., Delano J.W., and Schmitt R.A. (1990) Chemistries of individual mare volcanic glasses: Evidence for distinct regions of hybridized mantle and a KREEP component in Apollo 14 magmatic sources. *Proc. 20th Lunar Planet. Sci. Conf.* 127-138.
- Jordon J.L. and Heymann D. (1975) Inert gases in fines at three levels of the trench at Van Serg Crater. *Proc. 6th Lunar Sci. Conf.* 2201-2218.
- Jovanovic S. and Reed G.W. (1974a) Labile and nonlabile element relationships among Apollo 17 samples. *Proc. 5th Lunar Sci. Conf.* 1685-1701.
- Korotev R.L. (1976) Geochemistry of grain-size fractions of soils from the Taurus-Littrow valley floor. *Proc. 7th Lunar Sci. Conf.* 695-726.
- Korotev R.L. and Kremser D. (1992) Compositional variations in Apollo 17 soils and their relationships to the geology of the Taurus-Littrow site. *Proc. 22nd Lunar Planet. Sci. Conf.* 275-301.
- LSPET (1973a) Apollo 17 lunar samples : Chemical and petrographic description. *Science* **182**, 659-690.
- LSPET (1973c) Preliminary examination of lunar samples. Apollo 17 Preliminary Science Report. NASA SP-330, 7-1—7-46.
- McKay D.S., Fruland R.M. and Heiken G.H. (1974) Grain size and the evolution of lunar soils. *Proc. 5th Lunar Sci. Conf.* 887-906.
- Meyer C. (1973) Apollo 17 Coarse Fines (4-10 mm) Sample Location, Classification and Photo Index. Curator Report. pp. 182.
- Mitchell J.K., Carrier W.D., Costes N.C., Houston W.N., Scott R.F. and Hovland H.J. (1973) 8. Soil-Mechanics. In Apollo 17 Preliminary Science Rpt. NASA SP-330. pages 8-1-22.
- Moore C.B., Lewis C.F. and Cripe J.D. (1974a) Total carbon and sulfur contents of Apollo 17 lunar samples. *Proc. 5th Lunar Sci. Conf.* 1897-1906.
- Moore C.B., Lewis C.F., Cripe J.D. and Volk M. (1974b) Total carbon and sulfur contents of Apollo 17 lunar samples (abs). *Lunar Sci.* **V**, 520-522. Lunar Planetary Institute, Houston.
- Morris R.V. (1976) Surface exposure indices of lunar soils: A comparative FMR study. *Proc. 7th Lunar Sci. Conf.* 315-335.

- Morris R.V., Score R., Dardano C. and Heiken G. (1983) Handbook of Lunar Soils. Two Parts. JSC 19069. Curator's Office, Houston
- Morris R.V. (1978) The surface exposure (maturity) of lunar soils: Some concepts and Is/FeO compilation. *Proc. 9th Lunar Sci. Conf.* 2287-2297.
- Morris R.V. (1980) Origins and size distribution of metallic iron particles in the lunar regolith. *Proc. 11th Lunar Planet. Sci. Conf.* 1697-1712.
- Noble S.K., Pieters C.M., Taylor L.A., Morris R.V., Allen C.C., McKay D.S. and Keller L.P. (2001) The optical properties of the finest fraction of lunar soil: Implications for space weathering. *Meteor. & Planet. Sci.* **36**, 31-42.
- Nyquist L.E., Bansal B.M., Wiesmann H. and Jahn B.M. (1974) Taurus-Littrow chronology: Some constraints on the Early Lunar crustal development. *Proc. 5th Lunar Sci. Conf.* 1515-1540.
- Nunes P.D., Tatsumoto M. and Unruh D.M. (1974b) U-Th-Pb systematics of some Apollo 17 lunar samples and implications for a lunar basin excavation chronology. *Proc. 5th Lunar Sci. Conf.* 1487-1514.
- O'Kelley G.D., Eldridge J.S. and Northcutt K.J. (1974a) Cosmogenic radionuclides in samples from Taurus-Littrow: Effects of the solar flare of August 1972. *Proc. 5th Lunar Sci. Conf.* 2139-2147.
- Papike J.J., Simon S.B. and Laul J.C. (1982) The lunar regolith: Chemistry, Mineralogy and Petrology. *Rev. Geophys. Space Phys.* **20**, 761-826.
- Rhodes J.M., Rodgers K.V., Shih C., Bansal B.M., Nyquist L.E., Wiesmann H. and Hubbard N.J. (1974) The relationships between geology and soil chemistry at the Apollo 17 landing site. *Proc. 5th Lunar Sci. Conf.* 1097-1117.
- Rose H.J., Cuttitta F., Berman S., Brown F.W., Carron M.K., Christian R.P., Dwornik E.J. and Greenland L.P. (1974a) Chemical composition of rocks and soils at Taurus-Littrow. *Proc. 5th Lunar Sci. Conf.* 1119-1133.
- Schonfeld E. (1974) The contamination of lunar highland rocks by KREEP: Interpretations by mixing models. *Proc. 5th Lunar Sci. Conf.* 1269-1286.
- Taylor L.A., Patchen A., Taylor D.H.S., Chambers J.G. and McKay D.S. (1996) X-ray digital imaging of lunar mare soil: Modal analysis of minerals and glasses. *Icarus* **124**, 500-512.
- Taylor L.A., Pieters C., Keller L.P., Morris R.V., McKay D.S., Patchen A. and Wentworth S. (2001a) The effects of space weathering on Apollo 17 mare soils: Petrographic and chemical characterization. *Meteor. & Planet. Sci.* **36**, 285-299.
- Taylor L.A., Pieters C., Keller L.P., Morris R.V. and McKay D.S. (2001b) Lunar mare soils: Space weathering and the major effects of surface-correlated nanophase Fe. *J. Geophys. Res. Planets* **106**, 27985-28000.
- Wiesmann H. and Hubbard N.J. (1975) A compilation of the Lunar Sample Data Generated by the Gast, Nyquist and Hubbard Lunar Sample PI-Ships. Unpublished. JSC
- Wolfe E.W., Bailey N.G., Lucchitta B.K., Muehlberger W.R., Scott D.H., Sutton R.L and Wilshire H.G. (1981) The geologic investigation of the Taurus-Littrow Valley: Apollo 17 Landing Site. US Geol. Survey Prof. Paper, 1080, pp. 280.