15271
Reference Soil
798.3 grams

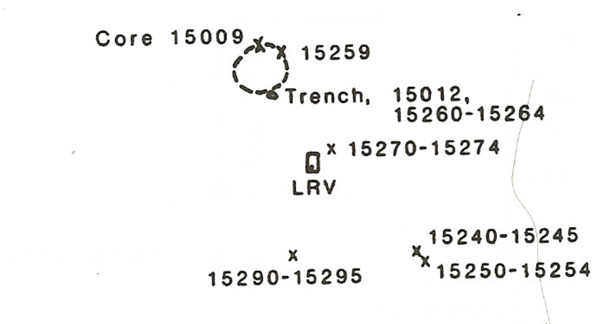


Figure 1: Location of soil samples, trench and drive tube at station 6, Apollo 15.

Figure 2: Picture of hole dug in rover track to obtain soil sample 15270. AS15-85-11657. Gnomen for scale.

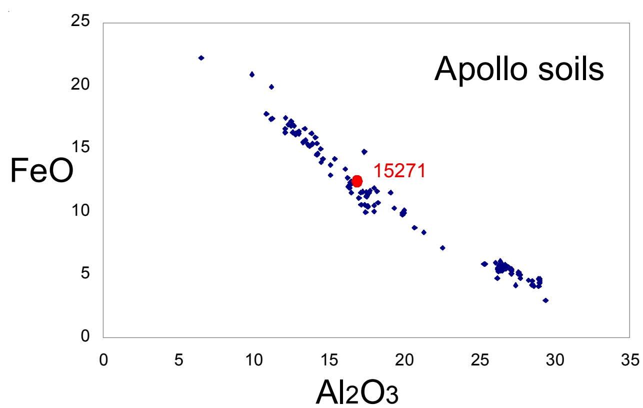


Figure 3: Chemical composition of 15271 compared with other Apollo soils.

Introduction

15271 was one of the soils that Papike et al. (1982) chose for their reference suite. It was collected at station 6, on the lower slope of the Apennine Front and contains a mixture of mare material, highland material and green glass.

Surface soil 15271 was collected from the rover track as part of the soil mechanics experiment and contains numerous friable "soil breccias" which may be compressed material from the rover track (figure 2). Otherwise it is a typical surface soil to be compared with 15291, 15261 (from the bottom of a trench), 15241 and 15251 (rim a center of small crater) and top of drive tube 15009 (30 cm).

Modal content of soil 15271.
From Basu 1981

Agglutinates	42.2
Mare basalt	3.6
KREEP basalt	2.7
Breccia	12.7
Anorthosite	1
Norite	
Gabbro	0.3
Plagioclase	7
Pyroxene	11.4
Olivine	1.8
Ilmenite	0.2
Glass other	14.1

Petrography

15271 is a mature soil with I_s/FeO = 63 (Morris 1978) with agglutinate content 42 % (Basu et al. 1981). The average grain size is 58 microns (figure 5). Basu et al. (1981) and Simon et al. (1981) determined the mineral mode

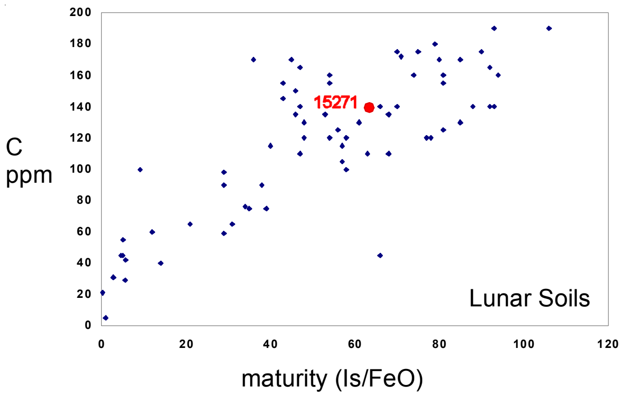
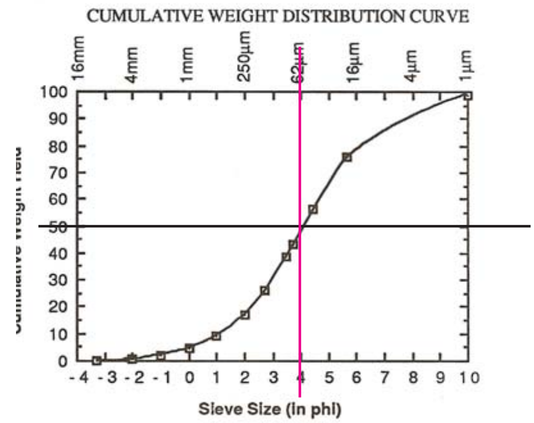


Figure 4 : Maturity index (Morris 1978) and carbon content (Moore et al. 1974).



Average grain size = 58 microns

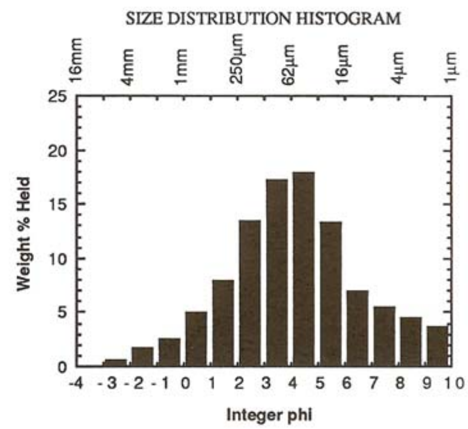


Figure 5: Grain size distribution of 15270 (Graf 1993).

15271 is one of the reference soils (Labatka et al. 1980) and they determined the composition of many mineral grains. Most notable was that many of the pyroxene grains were Mg-rich orhtopyroxene, as is found in KREEP basalt (figure 6).

KREEP basalt

Hubbard et al. (1973) determined the composition of KREEP basalt particles (figure 8).

Green Glass

Best and Minkin (1972) analyzed green glass from 15271.

Modal Mineralogy of 15271

Simon et al. 1981

LITHIC FRAGMENTS	
Mare basalt	3.2
Highland Component	
ANT	2.2
LMB	0.4
Feld. basalt	1.9
RNB/POIK	2.8
FUSED SOIL COMPONENT	
DMB	12.9
Agglutinate	37
MINERAL FRAG	
Mafic	13.5
Plag	7.4
Opaque	0.3
GLASS FRAG	
Orange/black	1.6
Yellow/Green	7
Brown	0.3
Clear	3.8
MISC	
Devitrified glass	5.6
Others	0.2

Chemistry

Taylor et al. (1972), Maxwell et al. (1972), Duncan et al. (1975), Korotev (1987), Laul and Papike (1981), Ryder et al. (1987) and others reported the chemical composition (table 1, figure 3). The REE content is dominated by the presence of KREEP basalt (figure 7) and it has a high meteorite component (Baedecker et al. 1973). The fine fraction is enriched in KREEP (Laul and Papike 1981).

Moore et al. (1973) reported 140 ppm C, consistent with high maturity (figure 4).. Kothari and Goel (1973) and Muller (1973) reported 95 – 111 ppm N. Kaplan et al. (1976) determined 127 ppm C, 91 ppm N and 700 ppm S (and included the isotopic ratios). Thode and Reese (1976) also determined S and the isotopic ration of S as function of grain size (figure9).

Walker and Papike (1981) calculated that 15271 was 28 – 34 % mare basalt, 25 % KREEP, 25 % LKFM and 4 – 15 % green glass. Wanke et al. (1973) calculated as much as 49 % KREEP.

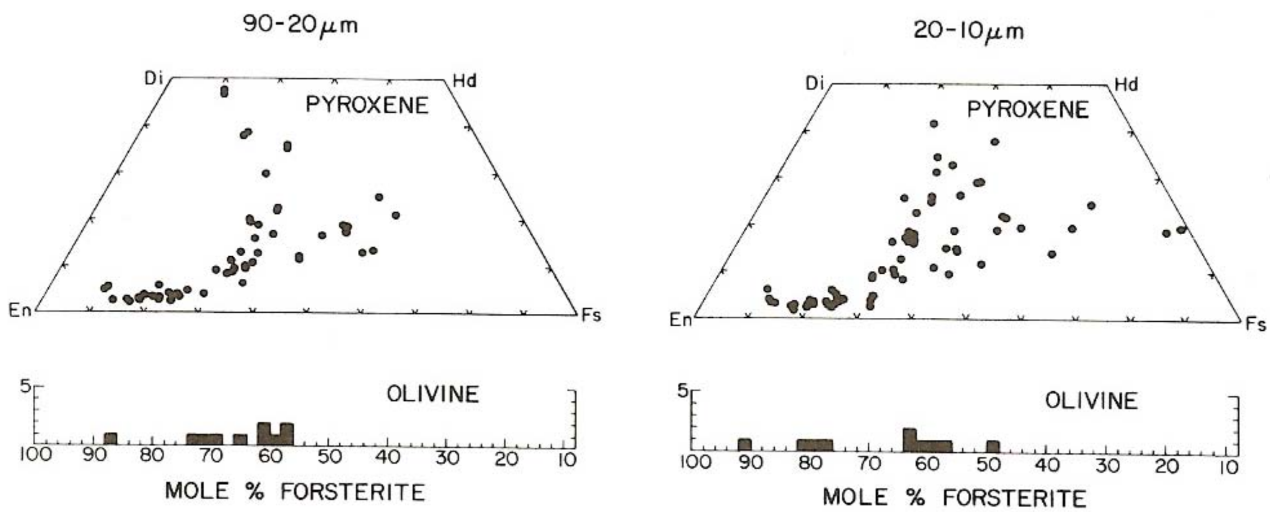


Figure 6: Composition of olivine and pyroxene in 15271 (Labotka et al. 1980).

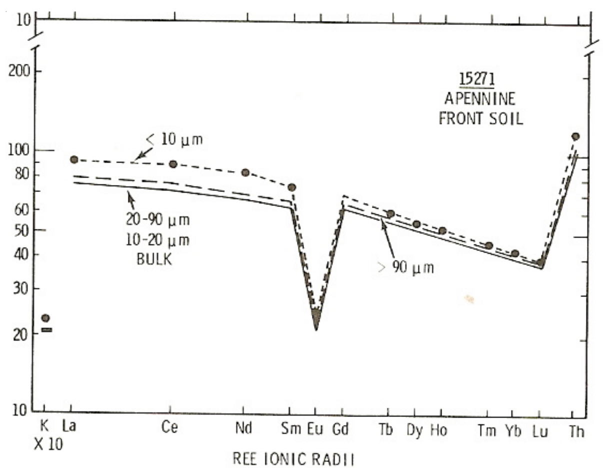


Figure 7: Normalized rare-earth-element content for 15271 (Laul and Papike 1980).

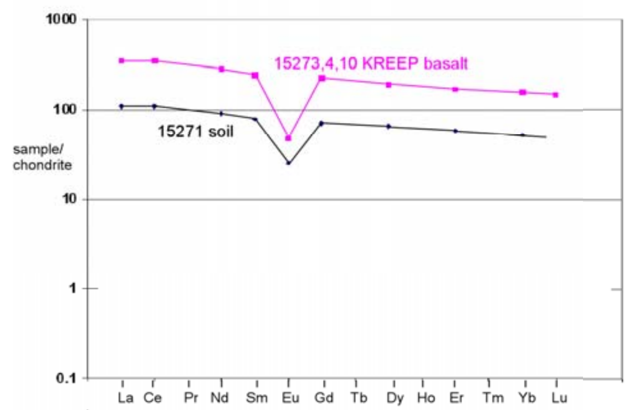


Figure 8: Normalized rare-earth-element diagram for 15271 soil and a fragment of KREEP basalt (Wiesmann and Hubbard 1976).

Radiogenic age dating

Nyquist et al. (1973) and Mark et al. (1973) determined Sr isotopes.

Cosmogenic isotopes and exposure ages

Rancitelli et al. (1972) determined the cosmic-ray-induced activity of ^{22}Na = 50 dpm/kg and ^{26}Al = 136 dpm/kg. Fireman et al. (1972) determined the activity of ^{3}H and ^{37}Ar.

Other Studies

Phakey et al. (1972) studied solar flare tracks.

Jordan et al. (1974), Bogard and Nyquist (1973) and Bogard et al. (1974) reported rare gas content and isotopes for 15271 and its various components.

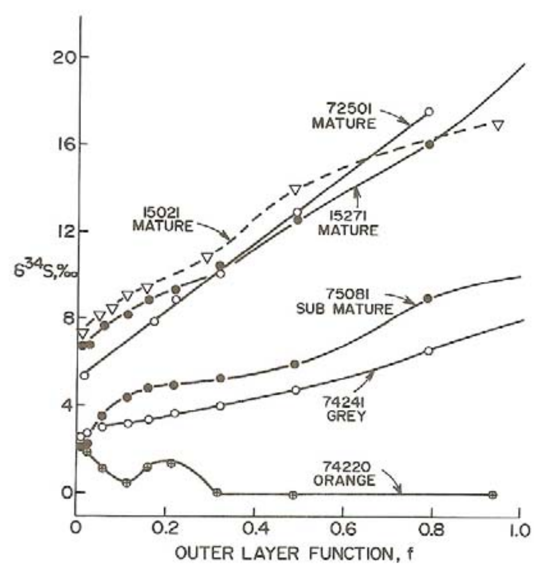


Figure 9: Isotopic composition of sulfur as function of grain size (surface) (Thode and Reese 1979).

Table 1a. Chemical composition of 15271.

reference	LSPET71		Korotev 87			Duncan75		Laul81		Taylor72a		Maxwell72		Rancitelli72		Baedecker73		
weight										Taylor72b				104 g				
SiO2 %	46.7	(b)				46.62	(b)	46	(a)			46.73	(d)					
TiO2	1.47	(b)	1.47	1.5	(a)	1.5	(b)	1.5	(a)			1.42	(d)					
Al2O3	16.51	(b)	16.5	16.6	(a)	16.57	(b)	16.4	(a)			16.19	(d)					
FeO	12.15	(b)	12.2	11.9	(a)	12.14	(b)	12.8	(a)			12.19	(d)					
MnO	0.16	(b)	0.155	0.157	(a)	0.157	(b)	0.162	(a)			0.17	(d)					
MgO	10.55	(b)	10.6	10.7	(a)	10.66	(b)	10.8	(a)			10.48	(d)					
CaO	11.29	(b)	10.5	10.7	(a)	11.24	(b)	11.7	(a)			11.23	(d)					
Na2O	0.43	(b)	0.44	0.48	(a)	0.41	(b)	0.49	(a)			0.53	(d)					
K2O	0.21	(b)				0.196	(b)	0.22	(a)			0.19	(d)	0.21	(e)			
P2O5	0.21	(b)				0.222	(b)					0.21	(d)					
S %	0.08	(b)				0.084	(b)					0.07	(d)					
sum																		
Sc ppm			23.8	23.5	(a)			24.3	(a)	19	(c)	31	(d)					
V						80	(b)	80	(a)	76	(c)	110	(d)					
Cr	2600	(b)	2260	2230	(a)	2354	(b)	2395	(a)	2400	(c)							
Co			41	39.3	(a)	40	(b)	40.5	(a)	40	(c)	39	(d)					
Ni			281	246	(a)	231	(b)	230	(a)	220	(c)	240	(d)			268	274	(f)
Cu						4	(b)			9	(c)	10	(d)					
Zn						20	(b)									24	21	(f)
Ga																5	4.9	(f)
Ge ppb																470	410	(f)
As																		
Se																		
Rb	5.6	(b)				5.9	(b)			5.7	(c)							
Sr	144	(b)	135	145	(a)	137	(b)	130	(a)	141	(c)	130	(d)					
Y	84	(b)				81.5	(b)			86	(c)	88	(d)					
Zr	382	(b)	380	370	(a)	390	(b)			390	(c)	470	(d)					
Nb	23	(b)				24.6	(b)			24.5	(c)							
Mo																		
Ru																		
Rh																		
Pd ppb																		
Ag ppb																		
Cd ppb																60	59	(f)
In ppb																5.1		(f)
Sn ppb																		
Sb ppb																		
Te ppb																		
Cs ppm			0.27	0.28	(a)					0.22	(c)							
Ba			250	297	(a)	265	(b)	300	(a)	360	(c)	260	(d)					
La			24.5	27.6	(a)			25.8	(a)	27	(c)							
Ce			64	72	(a)			70	(a)	76	(c)							
Pr										10	(c)							
Nd			36	37	(a)			45	(a)	41.5	(c)							
Sm			11.5	12.9	(a)			12	(a)	10.6	(c)							
Eu			1.39	1.47	(a)			1.5	(a)	1.48	(c)							
Gd										12.2	(c)							
Tb			2.22	2.52	(a)			2.6	(a)	1.99	(c)							
Dy								15	(a)	13.3	(c)							
Ho								3.9	(a)	2.91	(c)							
Er										9.2	(c)							
Tm								1.4	(a)									
Yb			7.8	9.1	(a)			8.54	(a)	8.65	(c)	10	(d)					
Lu			1.17	1.29	(a)			1.2	(a)									
Hf			9.4	10.4	(a)			8.6	(a)	7.1	(c)							
Ta			1.11	1.26	(a)			1.2	(a)									
W ppb																		
Re ppb																		
Os ppb																		
Ir ppb			7.1	8.3	(a)											8.6	8.7	(f)
Pt ppb																		
Au ppb			2.3	3.9	(a)											3.4	4.2	(f)
Th ppm	4.4	(b)	4.3	4.6	(a)			4.6	(a)	4.37	(c)			4.87	(e)			
U ppm			1.18	1.4	(a)			1.2	(a)	1.16	(c)			1.22	(e)			

technique: (a) INAA, (b) XRF, (c) SSMS, (d) wet+AA, (e) radiation counting, (f) RNAA

Table 1b. Composition of 15271 (cont.).

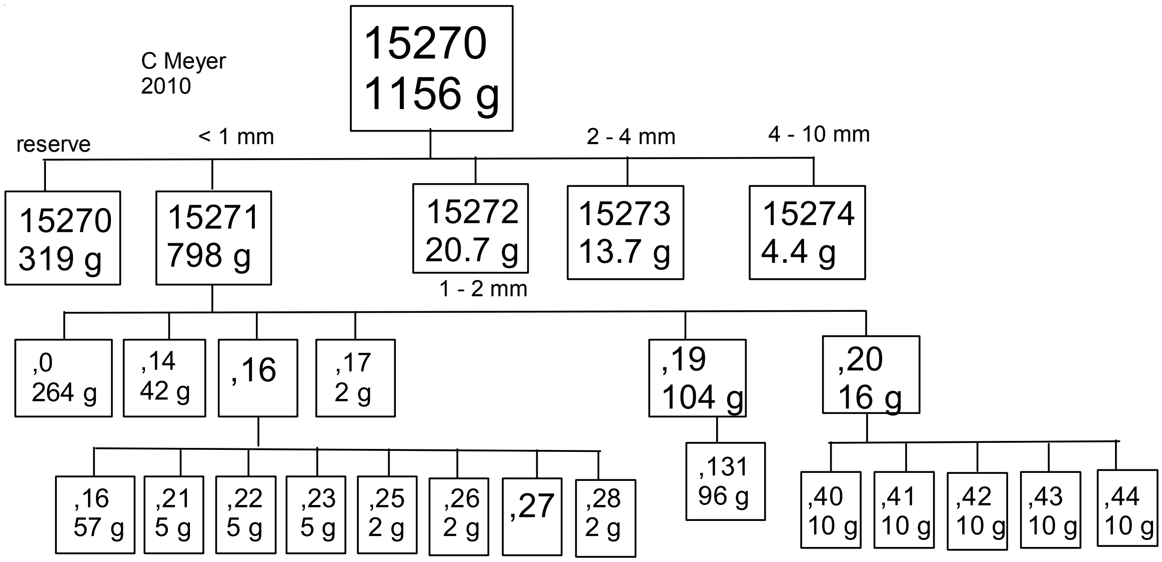
reference	Wiesman76		Keith72		Ryder1987	
weight			527 g			
SiO2 %						
TiO2						
Al2O3						
FeO					12.1	(a)
MnO						
MgO						
CaO					10.4	(a)
Na2O	0.46				0.449	(a)
K2O	0.21	(a)	0.195	(b)		
P2O5						
S %						
sum						
Sc ppm					23.3	(a)
V						
Cr					2230	(a)
Co					39.5	(a)
Ni					230	(a)
Cu						
Zn						
Ga						
Ge ppb						
As						
Se						
Rb	5.7	(a)				
Sr	140	(a)			184	(a)
Y						
Zr					320	(a)
Nb						
Mo						
Ru						
Rh						
Pd ppb						
Ag ppb						
Cd ppb						
In ppb						
Sn ppb						
Sb ppb						
Te ppb						
Cs ppm					0.29	(a)
Ba	264	(a)			290	(a)
La	25.3	(a)			26.9	(a)
Ce	65	(a)			74.4	(a)
Pr						
Nd	40.6	(a)			46	(a)
Sm	11.5	(a)			12.3	(a)
Eu	1.41	(a)			1.5	(a)
Gd	13.8	(a)				
Tb					2.36	(a)
Dy	15.7	(a)				
Ho						
Er	9.24	(a)				
Tm						
Yb	8.38	(a)			9.95	(a)
Lu					1.21	(a)
Hf					9.63	(a)
Ta					1.16	(a)
W ppb						
Re ppb						
Os ppb						
Ir ppb					5.8	(a)
Pt ppb						
Au ppb					4.9	(a)
Th ppm			4.1	(b)	4.43	(a)
U ppm	1.22	(a)	1.21	(b)	1.2	(a)

technique: (a) IDMS, (b) radiation couting

Table 2. Composition of KREEP basalt.

reference	Hubbard73		
weight	Wiesmann76		
SiO2 %	273,4,9	273,4,10	
TiO2	2.05	2.12	(a)
Al2O3			
FeO	10	9.7	(a)
MnO			
MgO	7.8	7.6	(a)
CaO	9.6	6.5	(a)
Na2O	0.93	0.76	(a)
K2O	0.57	0.64	(a)
P2O5			
S %			
sum			
Sc ppm			
V			
Cr			
Co			
Ni			
Cu			
Zn			
Ga			
Ge ppb			
As			
Se			
Rb	14.6	17.1	(a)
Sr	191	189	(a)
Y			
Zr	1173	1293	(a)
Nb			
Mo			
Ru			
Rh			
Pd ppb			
Ag ppb			
Cd ppb			
In ppb			
Sn ppb			
Sb ppb			
Te ppb			
Cs ppm			
Ba	740	788	(a)
La	73.1	80.2	(a)
Ce	195	207	(a)
Pr			
Nd	118	126	(a)
Sm	32.4	35.3	(a)
Eu	2.69	2.71	(a)
Gd		43.6	(a)
Tb			
Dy		45.4	(a)
Ho			
Er	24	26.8	(a)
Tm			
Yb	21.9	25.1	(a)
Lu	3.21	3.56	(a)
Hf	31	35.5	(a)
Ta			
W ppb			
Re ppb			
Os ppb			
Ir ppb			
Pt ppb			
Au ppb			
Th ppm			
U ppm	3.39	3.92	(a)

technique: (a) IDMS



Processing

15270 was returned in sample collection bag 3 which was placed in ALSRC#2 (which did not seal).

References for 15271

Basu A. and McKay D.S. (1979) Petrography and provenance of Apollo 15 soils. *Proc. 10th Lunar Sci. Conf.* 1413-1424.

Basu A., McKay D.S., Griffiths S.A. and Nace G. (1981) Regolith maturation on the Earth and the Moon with an example from Apollo 15. *Proc. 12th Lunar Planet. Sci. Conf.* 433-449.

Basu A. and McKay D.S. (1985) Chemical variability and origin of agglutinate glass. *Proc. 16th Lunar Planet. Sci. Conf.* D87-94. J. Geophys. Res. **90**

Best J.B. and Minkin J.A. (1972) Apollo 15 glasses of impact origin. *In* **The Apollo 15 Lunar Samples**, 34-39. Lunar Planetary Institute, Houston.

Bogard D.D. and Nyquist L.E. (1973) $^{40}Ar/^{36}Ar$ variations in Apollo 15 and 16 regolith. *Proc. 4th Lunar Sci. Conf.* 1975-1986.

Bogard D.D., Hirsch W.C. and Nyquist L.E. (1974) Noble gases in Apollo 17 fine: Mass fractionation effects in trapped Xe and Kr. *Proc. 5th Lunar Sci. Conf.* 1975-2003.

Butler P. (1971) Lunar Sample Catalog, Apollo 15. Curators' Office, MSC 03209

Compston W., de Laeter J.R. and Vernon M.J. (1972) Strontium isotope geochemistry of Apollo 15 basalts. *In* **The Apollo 15 Lunar Samples** 347-351. LPI

Church S.E., Bansal B.M and Wiesmann H. (1972) The distribution of K, Ti., Zr and Hf in Apollo 14 and 15 materials (abs). *In* **The Apollo 15 Lunar Samples**, 210-213. LPI

Devine J.M., McKay D.S. and Papike J.J. (1982) Lunar regloith: Petrology of the <10 micron fraction. *Proc. 13th Lunar Planet. Sci. Conf.* in J. Geophys. Res. **87**, A260-A268.

Duncan A.R., Sher M.K., Abraham Y.C., Erlank A.J., Willis J.P. and Ahrens L. (1975) Interpretation of compositional variability of Apollo 15 soils. *Proc. 6th Lunar Sci. Conf.* 2309-2320.

Engelhardt W.v., Arndt J. and Schneider H. (1973) Apollo 15 – evolution of the regolith and origin of glasses. *Proc. 4th Lunar Sci. Conf.* 239-250.

Fireman E.L., D'Amico J., DeFelice J. and Spannagel G. (1972) Radioactivities in returned lunar materials. *Proc. 3rd Lunar Sci. Conf.* 1747-1762.

Gibson E.K. and Moore G.W. (1973) Carbon and sulfur distributions and abundances in lunar fines. *Proc. 4th Lunar Sci. Conf.* 1577-1586.

Graf J.C. (1993) Lunar Soils Grain Size Catalog. NASA Reference Pub. 1265, March 1993

Kaplan I.R., Kerridge J.F. and Petrowski C. (1976) Light element geochemistry of the Apollo 15 site. *Proc. 7th Lunar Sci. Conf.* 481-492.

Keith J.E., Clark R.S. and Richardson K.A. (1972) Gamma-ray measurements of Apollo 12, 14 and 15 lunar samples. *Proc. 3rd Lunar Sci. Conf.* 1671-1680.

Kothari B.K. and Goel P.S. (1972) Total nitrogen abundances in five Apollo-15 samples (Hadley-Apennine region) by neutron activation analysis. *In* **The Apollo 15 Lunar Samples**, 282-283. LPI

Kothari B.K. and Goel P.S. (1973) Nitrogen in lunar samples. *Proc. 4th Lunar Sci. Conf.* 1587-1596.

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.

Hubbard N.J., Rhodes J.M., Gast P.W., Bansal B.M., Shih C.-Y., Wiesmann H. and Nyquist L.E. (1973b) Lunar rock types: The role of plagioclase in non-mare and highland rock types. *Proc. 4th Lunar Sci. Conf.* 1297-1312.

Jordan J.I., Heyman D. and Lakatos S. (1974) Inert-gas patterns in regolith at Apollo 15 landing site. *Geochim. Cosmochim. Acta* **38**, 65-78.

Labotka T.C., Kempa M.J., White C., Papike J.J. and Laul J.C. (1980) The lunar regolith: Comparative petrology of the Apollo sites. *Proc. 11th Lunar Planet. Sci. Conf.* 1285-1305.

Laul J.C. and Papike J.J. (1980a) The lunar regolith: Comparative chemistry of the Apollo sites. *Proc. 11th Lunar Planet. Sci. Conf.* 1307-1340.

LSPET (1972a) The Apollo 15 lunar samples: A preliminary description. *Science* **175**, 363-375.

LSPET (1972b) Preliminary examination of lunar samples. Apollo 15 Preliminary Science Report. NASA SP-289, 6-1—6-28.

Mark R.K., Cliff R.A., Lee-Hu C. and Wetherill G.W. (1973) Rb-Sr studies of lunar breccias and soils. *Proc. 4th Lunar Sci. Conf.* 1785-1795.

Maxwell J.A., Bouvier J.-L. and Wiik H.B. (1972) Chemical composition of some Apollo 15 lunar samples. *In* **The Apollo 15 Lunar Samples**, 233-238. LPI

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.

Moore C.B., Lewis C.F. and Gibson E.K. (1973) Total carbon contents of Apollo 15 and 16 lunar samples. *Proc. 4th Lunar Sci. Conf.* 1613-1923.

Morris R.V. (1976) Surface exposure indicies of lunar soils: A comparative FMR study. *Proc. 7th Lunar Sci. Conf.* 315-335.

Morris R.V. (1978) The surface exposure (maturity) of lunar soils: Some concepts and Is/FeO compilation. *Proc. 9th Lunar Planet . Sci. Conf.* 2287-2298.

Morris R.V. (1980) Origins and size distribution of metallic iron particles in the lunar regolith. *Proc. 11th Lunar Planet. Sci. Conf.* 1697-1712.

Morris R.V., Score R., Dardano C. and Heiken G. (1983) Handbook of Lunar Soils. JSC 19069

Müller O. (1972) Alkali and alkaline earth elements, La, and U in Apollo 14 and Apollo 15 samples. *In* **The Apollo 15 Lunar Samples***,* 240-243. LPI

Müller O. (1973) Chemically bond nitrogen contents of Apollo 16 and Apollo 15 Lunar fines. *Proc. 4th Lunar Sci. Conf.* 1625-1634.

Nyquist L.E., Hubbard N.J., Gast P.W., Bansal B.M., Wiesmann H. and Jahn B-M. (1973) Rb-Sr systematics for chemically defined Apollo 15 and 16 materials. *Proc. 4th Lunar Sci. Conf.* 1823-1846.

Papike J.J., Simon S.B., White C. and Laul J.C. (1981) The relationship of the lunar regolith <10 micron fraction and agglutinates. Part I: A model for agglutinate formation and some indirect supportive evidence. *Proc. 12th Lunar Planet. Sci. Conf.* 409-420.

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.

Phakey P.P., Hutcheon I.D., Rajan R.S. and Price B. (1972) Radiation effects in soils from five lunar missions. *Proc. 3rd Lunar Sci. Conf.* 2905-2915.

Powell B.N. (1972) Apollo 15 Coarse Fines (4-10mm): Sample classification, description and inventory. MSC 03228 Curator's Office JSC

Powell B.N., Aitken F.K. and Weiblen P.W. (1973) Classification, distribution and origin of lithic fragments from the Hadley-Apennine region. *Proc. 4th Lunar Sci. Conf.* 445-460.

Rancitelli L.A., Perkins R.W., Felix W.D. and Wogman N.A. (1972) Lunar surface processes and cosmic ray characterization from Apollo 12-15 lunar samples analyses. *Proc. 3rd Lunar Sci. Conf.* 1681-1691.

Ryder G., Lindstrom M.M. and Willis K. (1988) The reliability of macroscopic identification of lunar coarse fines particles and the petrogenesis of 2-4 mm particles in Apenine Front sample 15243. *Proc. 18th Lunar Planet. Sci. Conf.* 219-232. Lunar Planetary Institute, Houston.

Ryder G. and Sherman S.B. (1989) The Apollo 15 Coarse Fines. Curators Office #81, JSC#24035

Simon S.B., Papike J.J. and Laul J.C. (1981) The lunar regolith: Comparative studies of the Apollo and Luna sites. *Proc. 12th Lunar Planet. Sci. Conf.* 371-388.

Swann G.A., Hait M.H., Schaber G.C., Freeman V.L., Ulrich G.E., Wolfe E.W., Reed V.S. and Sutton R.L. (1971b) Preliminary description of Apollo 15 sample environments. U.S.G.S. Interagency report: 36. pp219 with maps

Swann G.A., Bailey N.G., Batson R.M., Freeman V.L., Hait M.H., Head J.W., Holt H.E., Howard K.A., Irwin J.B., Larson K.B., Muehlberger W.R., Reed V.S., Rennilson J.J., Schaber G.G., Scott D.R., Silver L.T., Sutton R.L., Ulrich G.E., Wilshire H.G. and Wolfe E.W. (1972) 5. Preliminary Geologic Investigation of the Apollo 15 landing site. *In* Apollo 15 Preliminary Science Rpt. NASA SP-289. pages 5-1-112.

Taylor S.R., Gorton M., Muir P., Nance W., Rudowski R. and Ware N. (1972b) Composition of the lunar highlands II The Apennine Front. *In* **The Apollo 15 Lunar Samples**, 262-264. LPI

Taylor S.R., Gorton M.P., Muir P., Nance W., Rudowski R. and Ware N. (1973b) Lunar highlands composition: Apennine Front. *Proc. 4th Lunar Sci. Conf.* 1445-1459.

Thode H. G. and Reese C.E. (1976) Sulfur isotopes in grain size fractions of lunar soils. *Proc. 6th Lunar Sci. Conf.* 459-468.

Thode H.G. and Rees C.E. (1979) Sulfur isotopes in lunar and meteorite samples. *Proc. 10th Lunar Planet. Sci.* 1629-1636.

Wanke H., Baddenhausen H., Balacescu A., Teschke F., Spettle B., Dreibus G., Palme H., Quijano-Rico M., Kruse H., Wlotzka F. and Begemann F. (1972) Multielement analyses of Lunar Samples and some implications of the results. *Proc. 3rd Lunar Sci. Conf.* 1251-1268.

Walker R.J. and Papike J.J. (1981b) The Apollo 15 regolith. *Proc. 12th Lunar Planet. Sci. Conf.* 485-508.

Walker R.J. and Papike J.J. (1981c) The Apollo 15 regolith: Chemical modeling and mare/highland mixing. *Proc. 12th Lunar Planet. Sci. Conf.* 509-517.

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)