14149 - 232 grams - bottom
14148 - 85 grams - top
14156 - 162 grams - middle
Trench Soils

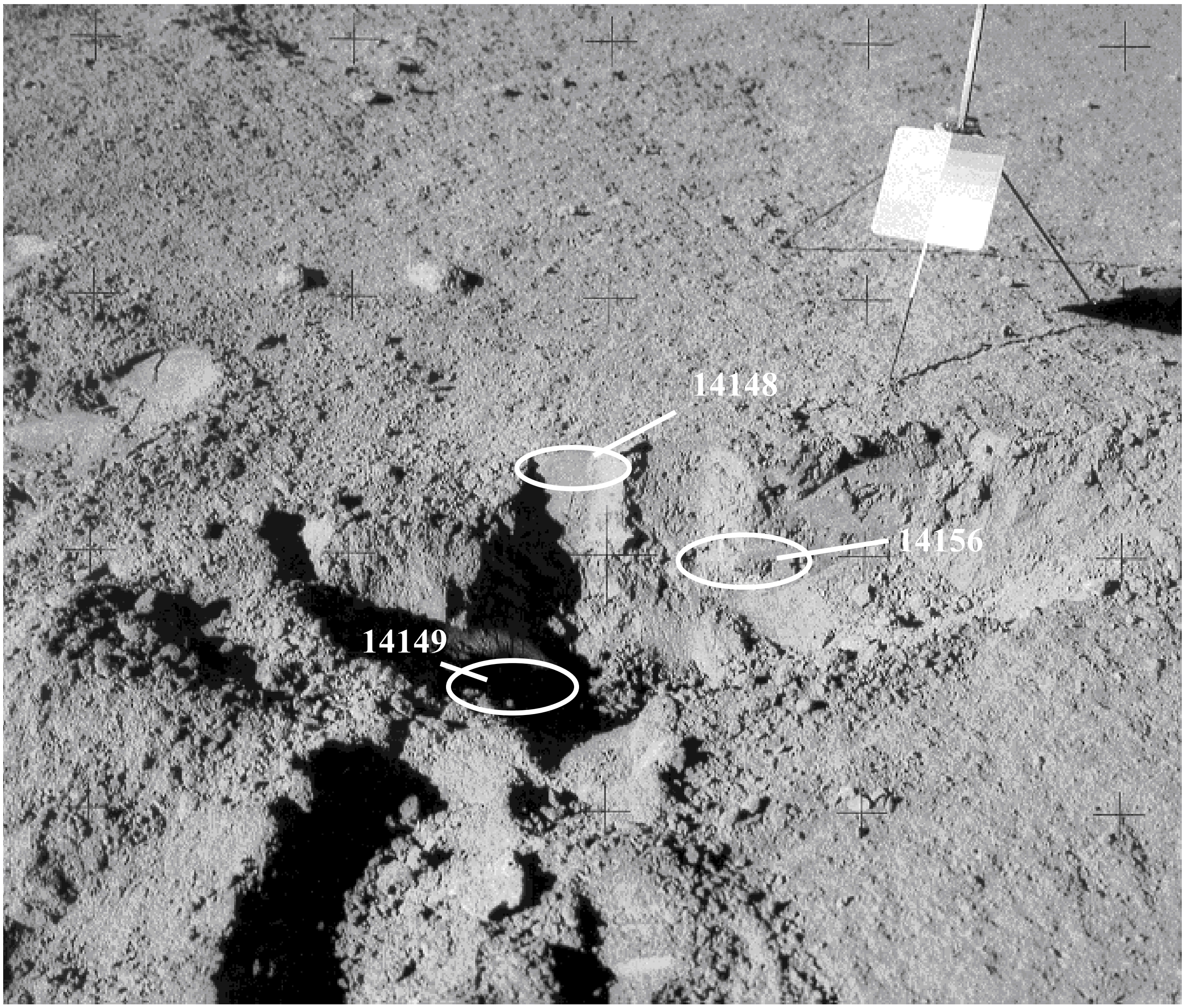


Figure 1: Soil Mechanics Trench at Apollo 14, Triplet Crater. Note walls are not stable. AS14-64-9161. Gnomen legs are 50 cm apart. Trench is about 30 cm deep. SESC sample 14240 also collected from this trench.

Introduction

The Soil Mechanics Trench for Apollo 14 was planned for 60 cm depth, but CDR Al Shepard found that the walls were caving in (see transcript), so he discontinued digging at about 18 inches or 30 cm. Numerous samples were collected from this trench including 14149 and 14240 (SESC) which were taken from the bottom of the trench. 14148 is the soil from the surface and 14156 from about the middle of the trench wall (figure 1). Samples 14145, 14080, 14073 to 14079 are rock samples taken from the same trench. Sample 14149, 14148 and 14156 are less than 1 mm fines. When these soil samples were sieved, additional sample numbers were assigned to the coarse-fines (see diagrams). 14220 and 14230 are drive tube samples taken nearby. 14310 (basalt) was also collected nearby.

Transcript for trench

CDR I've got a trench here. It's going easily, but I need the extension handle to get it deeper. I'm cutting into the rim of a crater which is approximately 6 meters in diameter, has a depth of about three-quarters of a meter. And we're back in about in about one diameter away from the north – Triplet. The trench is going through at least three layers that I can see. The fine-grain surface, dark brown; then, a layer of what appears to be quite a bit of black; and then, a third layer of some very light material. And, we should be able to sample all three of these.

CDR We did not mention this white layer down in this area before that was so obvious to us just below the surface up near the flank of Cone. But it appears as though it is relatively deep, as far as visual observation is concerned. And certainly not any would be picked up by footprints, or tracks or the like. But there appears to be some here in this trench.

CDR You know what's happening in this trench; surface fines are so loose that they're just falling down covering the layering that we want to get. I'll tell you we are not going to get a classical vertical wall here, Houston, on this trench.

CDR Okay, Fred. Bag 19 for the sample of the fine-that is, from the surface layer of the trench (14145-14148).

CDR I am unable to take from the wall of the trench the blocky type of material that I could see when I was digging; so, I'll just get a bag full of that, and we'll mix the surface layer with the second layer.

CC Roger, Al. How deep did you finally end up getting down?

CDR Well, the trench is about a foot and half deep. I gave up actually not because it was hard digging, but because the walls kept falling in on it; and it was covering all the evidence of stratigraphy. And bag 21(14080-81; 14153-156) is kind of a collection of the combination of the top two layers. Second layer is a thin layer of small-glassy pebbles. I was unable to separate them by the trench method, so I gave it to you mixed up in the bag; and the last bag will be pebbles from the bottom layer.

CC Okay, Al. What is the thickness of the intermediate layer there?

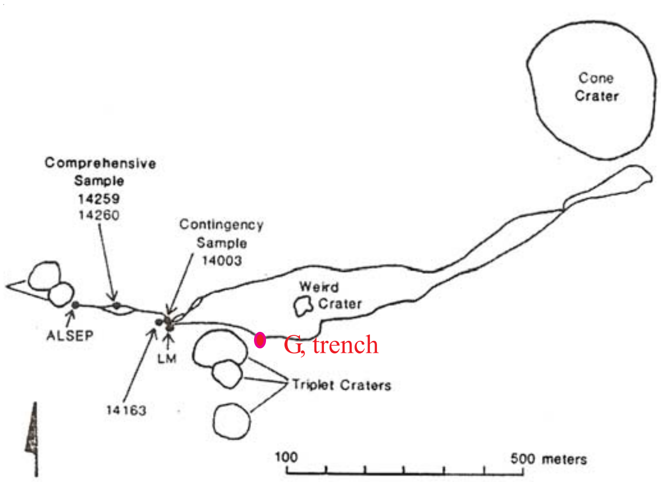
CDR Well, it's really ephemeral it's very thin. I would say no more than a quarter of an inch thick, and I just noticed it because of the difference of the gain structure as I was digging the trench. And in bag 20, we'll just fill a sample of the bottom material; also, mixed up with some of the surface material that has fallen down in on top of it. And that is about 18 inches below the surface (14073-79; 14149-152).

CC Okay. And, Al, one question, did you get the SESC sample (14240) out of the bottom of the trench?

CDR Well, I told you the trench was kind a miserable thing, because the walls kept falling down, but it wouldn't be the bottom, I'm afraid.

CC I guess we'd still like the SESC sample from the bottom of the trench, even though it probably isn't the bottom.

CDR Well, I'll tell you, I'll go back and whack at it a little bit. See what I can do. We're digging the bottom of the trench for you, Freddo. I'm re-digging the trench.



Station G was on the flank of North Triplet Crater (see map). The best description of the digging of the trench at station G is given in Mitchell et al. (1971). *"The site chosen for trenching was the western rim of a small crater approximately 6 m in diameter and 0.75 m deep." "The CDR reported digging was easy and estimated his first cut to be a depth of approximately 15 cm with sidewalls at an angle of 70 to 80 degrees, but at that point they started caving in". "The excavation passed through three distinct layers. The upper 3 to 5 cm were dark brown and fine grained. Next a very thin layer (0.5 cm thick or less) of black, glassy particles was encountered. Beneath this layer was a much lighter colored and coarser grained material."*

Petrography

McKay et al. (1972) and Simon et al. (1982) showed that there was not much difference in the samples taken between the bottom and top of the trench *(however, LSPET 1971 and Mitchell et al. 1971 discuss a difference in grain size top to bottom, apparently based on data collected in PET, figure 2)*. 14149 from the bottom had less agglutinates and was slightly less mature (maturity index I_s/FeO = 53) compared with 14148 from the top (I_s/FeO = 70) or 14156 from the middle (I_s/FeO = 68, Morris 1978). King et al. (1972)

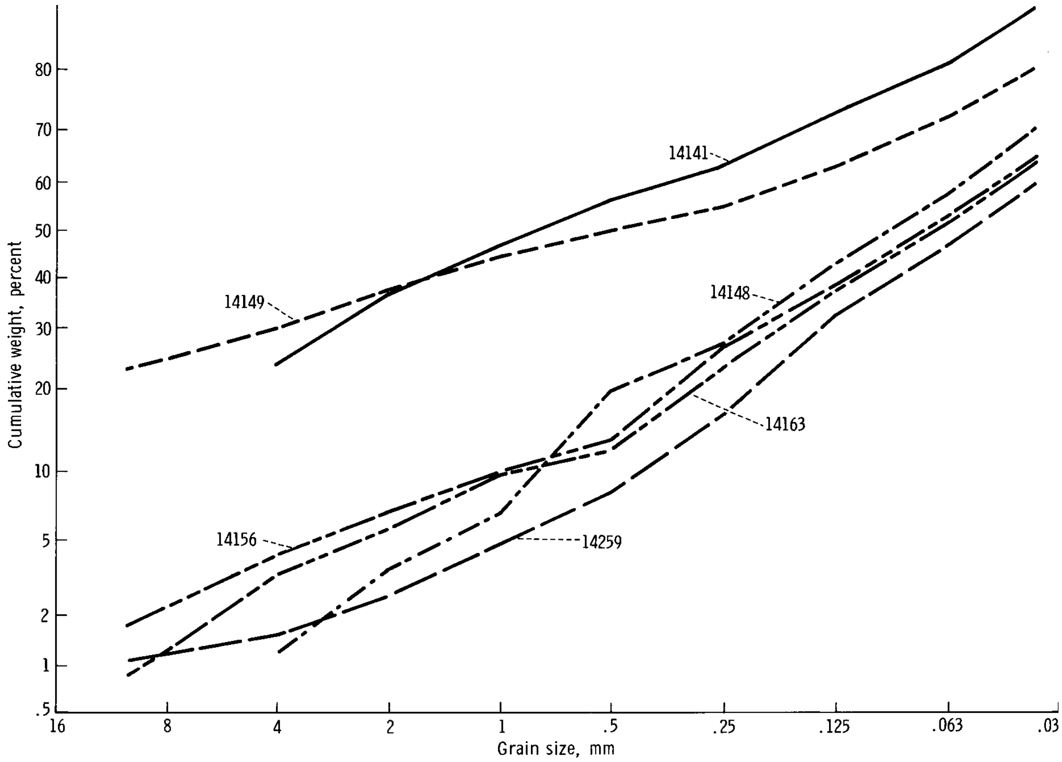


Figure 2: Grain size distribution for Apollo 14 soils showing the coarse grain size of the soil from the bottom of the trench (14149) and the rim of cone crater (14141) (from LSPET 1971).

and Graf (1993) reported the size distribution of the three soils (figures 3 a,b,c).

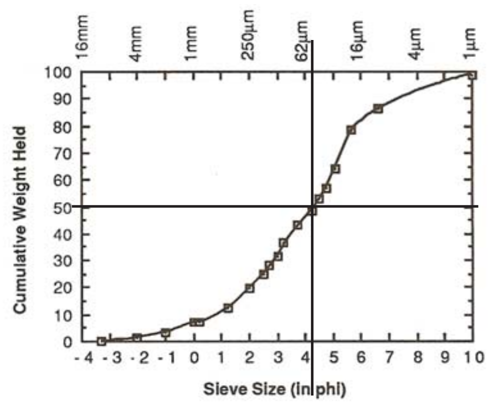
Chao et al. (1972), Nelen et al. (1972) and Glass et al. (1972) studied the glass beads in the three trench soils. 14156 was also one of the soils studied by the Apollo Soil Survey (see Reid et al. 1972a and b).

Some of the best KREEP basalts were found in this trench (14073 – 14079, 14080 – 14081). Kramer and Twedell (1977) also described some of the coarse-fines, finding numerous basalt fragments. *Note: 14310 was collected nearby.*

Chemistry

Lindstrom et al. (1972), Laul et al. (1982) and others determined the chemical composition of the soils from this trench (tables, figures 4 and 5).

Cadogen et al. (1972) give a nice discussion of carbon found in samples from this trench (and correlation with track density). Consider also the results of the study of 14240.



Average grain size = 73 microns

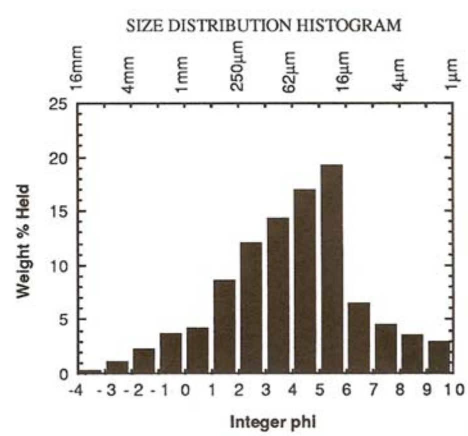
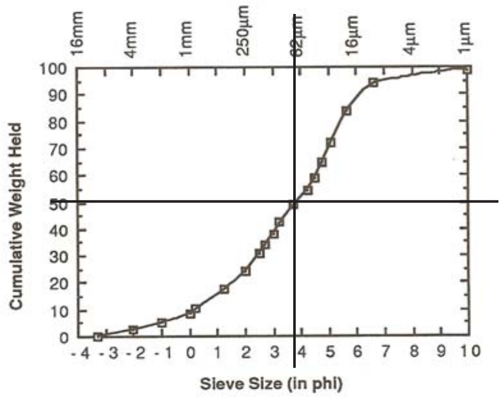


Figure 3a: Grain size distribution for 14148 (Graf 1993, from data by Butler). Top of trench.



Average grain size = 83 microns

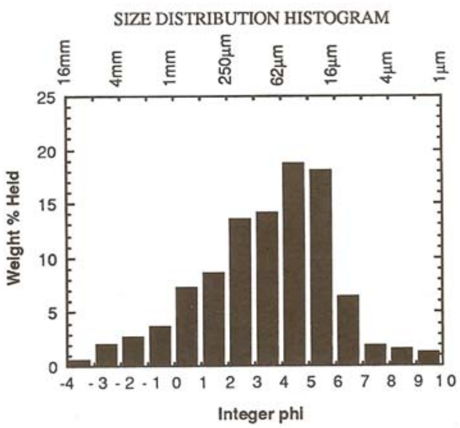
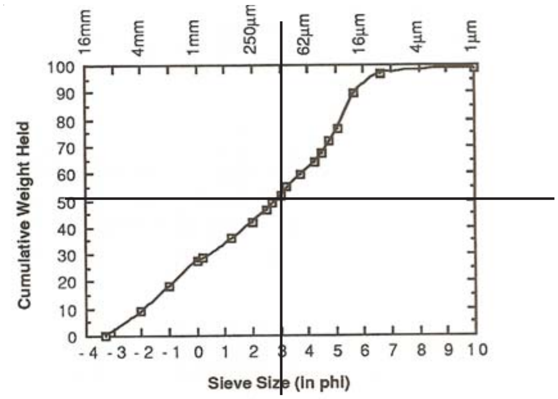


Figure 3b: Grain size distribution for 14156 (Graf 1993, from data by Butler). Middle of trench.



Average grain size = 200 microns

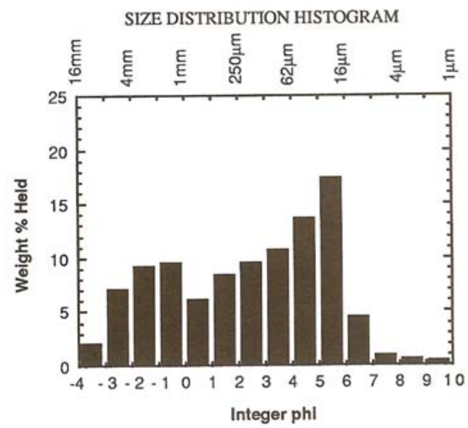


Figure 3c: Grain size distribution for 14149 (Graf 1993, from data by Butler). Bottom of trench.

Modal content of soils 14148, 14156 and 14149.
90-150 micron fraction
From McKay et al. 1972.

	14148	14156	14149
trench	top	middle	bottom
Agglutinates	50.2%	47.7	26.4
Basalt	2	6.4	
Breccia	28.8	23.4	35.2
Anorthosite			
Norite			
Gabbro			
Plagioclase	3	5.4	7.8
Pyroxene	3.2	5.6	11
Olivine	0.8	0.2	
Ilmenite	0.4	0.4	0.4
Glass other	11.4	17.2	12.8

Modal content of soils 14148 and 14149.
From Simon et al. 1982.
90 - 1000 micron

	14148 (top)	14149 (bottom)
Agglutinates	39.6 %	24.3
Basalt	0.6	3.1
Breccia		
Dark	10.5	18.1
Light	18.9	27.4
Anorthosite	0.9	0.4
Norite		
Gabbro		
Plagioclase	4.6	1.8
Pyroxene	6.5	6.6
Olivine		
Ilmenite	0.1	0.4
Glass other	12.7	8.4

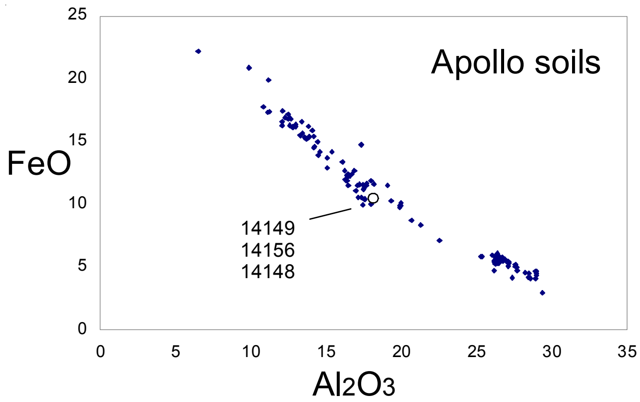


Figure 4: Chemical composition of Apollo 14 trench samples.

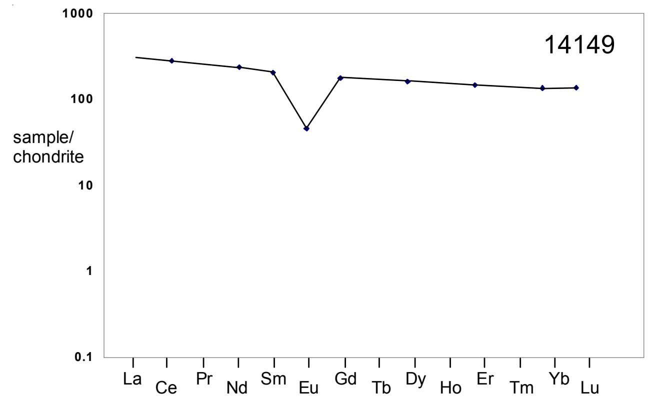


Figure 5: Normalized rare-earth-element content of trench sample 14149 (exactly the same as 14156 and 14148 same trench)(superior isotope dilution data from Philpotts et al.1972).

Cosmogenic isotopes and exposure ages

Eldridge et al. (1972) and Keith et al. (1972) found slightly less ^{26}Al and ^{22}Na in the bottom sample of the trench (14149). Keep in mind that the trench wall were constantly falling into the trench.

Other Studies

Basford et al. (1973) determined the isotopes of Xe and Kr. Nautiyal et al. (1981) and Venkatesan et al. (1980) studied the ^{22}Ne and Kr isotopes in 14148.

Bhandari et al. (1972), Hart et al. (1972), Berdot et al. (1972), Crozaz et al. (1972) and Bhai et al. (1978) studied the cosmic ray tracks in the grains of the trench, collectively finding that there was an order of magnitude less tracks in grains from the bottom of the trench (14149).

Processing

The samples from the bottom of this trench (14149 and 14240) may have been contaminated by surface material that fell into the trench during digging (see transcript).

During Apollo 14, there was a very strange numbering system (see diagrams). It appears that all of each soil was sieved, leaving no unsieved "reserve" sample, as was the case in later missions. In addition to these sample, SESC sample 14240 was also collected from the bottom of this trench (after re-digging).

About 72 grams from the bottom of this trench were apparently ground to <105 microns and sacrificed to the "biopool-quarantine" operation.

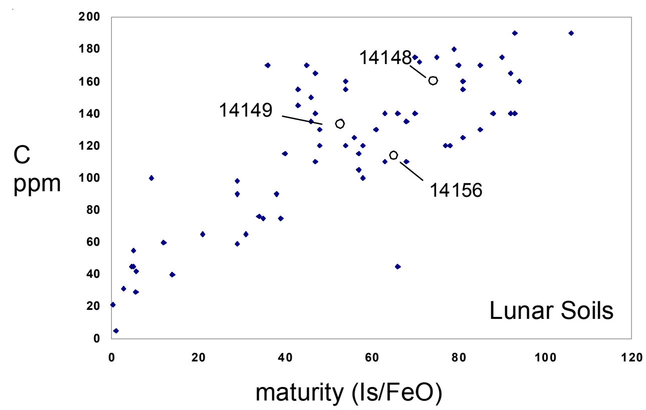
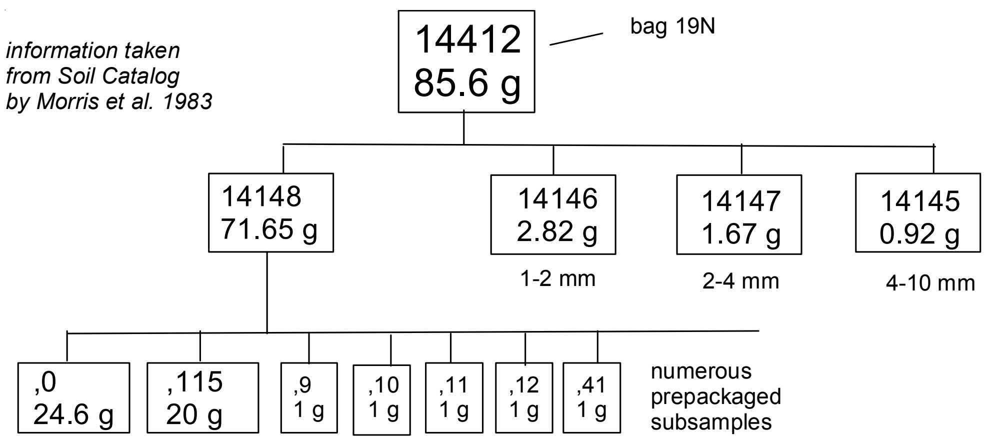
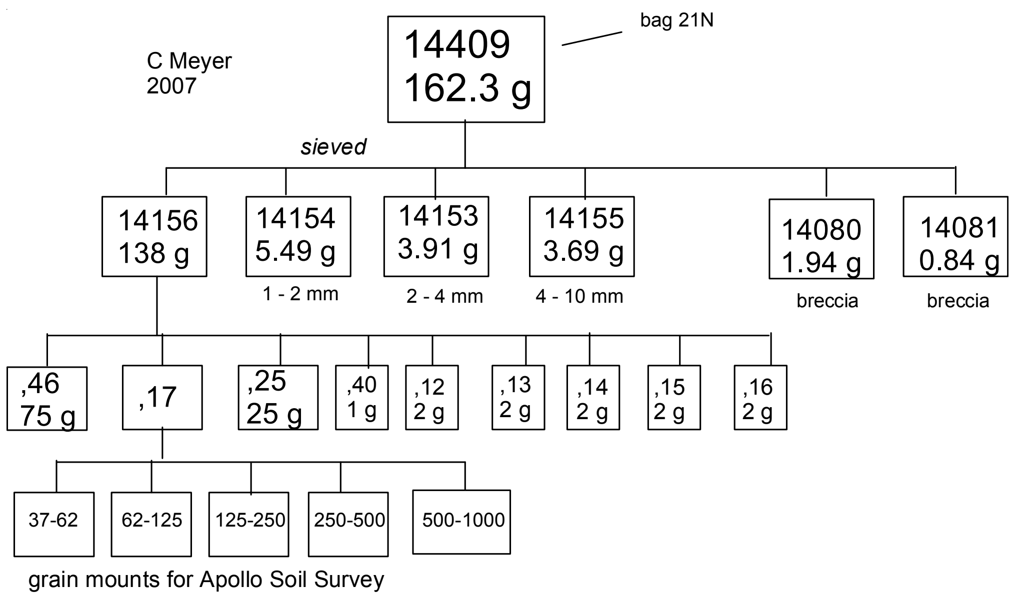
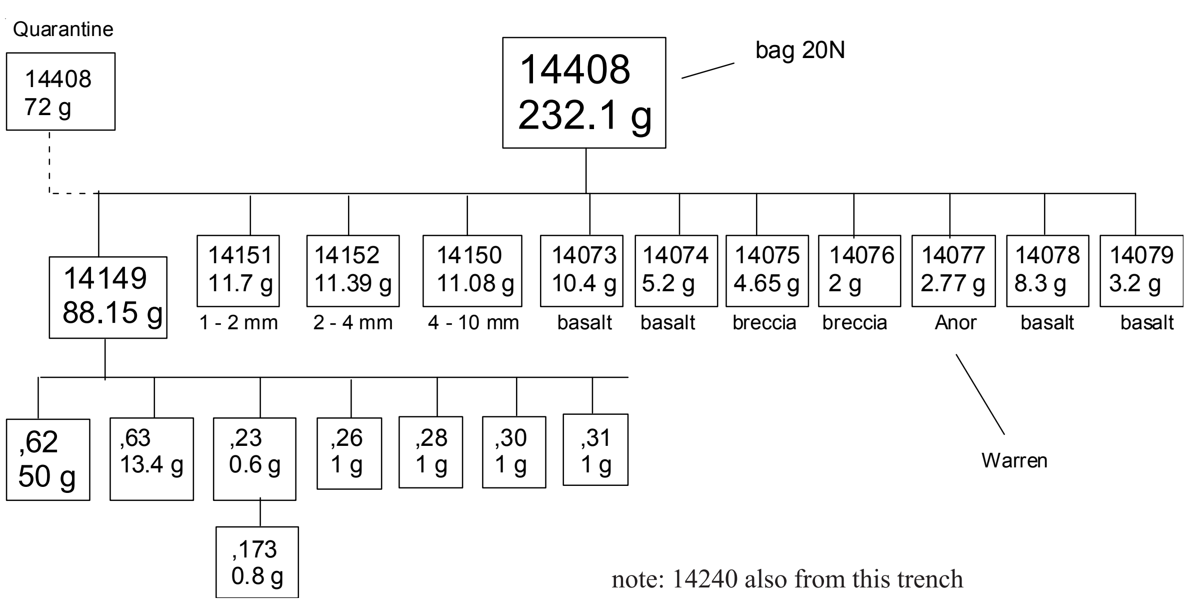


Figure 6: Carbon content and maturity from magnetic measurement







note: 14240 also from this trench

Table 1. Chemical composition of 14149.

reference	Lindstrom72		Philpotts72		Morgan72		Laul82		Murthy72		Eldridge72		Keith72	
weight														
SiO2 %														
TiO2	1.55	(a)					1.6	(a)						
Al2O3	17.3	(a)					17.9	(a)						
FeO	10.16	(a)					10	(a)						
MnO	0.117	(a)					0.13	(a)						
MgO							9.9	(a)						
CaO							11	(a)						
Na2O	0.71	(a)					0.78	(a)						
K2O	0.54	(a)	0.64	(b)			0.58	(a)	0.62	(b)	0.6	(d)	0.62	(d)
P2O5														
S %														
sum														
Sc ppm	20.5	(a)					21	(a)						
V							40	(a)						
Cr	1300	(a)					1232	(a)						
Co	40	(a)					27.5	(a)						
Ni							320	(a)						
Cu														
Zn					19	(c)								
Ga														
Ge ppb														
As														
Se					290	(c)								
Rb			14.5	(b)	13.9	(c)			17.9	(b)				
Sr			177.5	(b)			170	(a)	183.5	(b)				
Y														
Zr	660	(a)	907	(b)			680	(a)						
Nb														
Mo														
Ru														
Rh														
Pd ppb														
Ag ppb					11.8	(c)								
Cd ppb					199	(c)								
In ppb														
Sn ppb														
Sb ppb					2.8	(c)								
Te ppb					15	(c)								
Cs ppm	0.66	(a)			0.6	(c)								
Ba	740	(a)	827	(b)			870	(a)	817	(b)				
La	65.1	(a)					60.5	(a)						
Ce	177	(a)	169	(b)			170	(a)						
Pr														
Nd	100	(a)	108	(b)			110	(a)						
Sm	31.6	(a)	30.1	(b)			26.5	(a)						
Eu	2.76	(a)	2.56	(b)			2.2	(a)						
Gd			34.7	(b)										
Tb	6.7	(a)					5.4	(a)						
Dy			39.3	(b)			37	(a)						
Ho							8.2	(a)						
Er			23.4	(b)										
Tm							3.3	(a)						
Yb	21.7	(a)	22	(b)			20.2	(a)						
Lu	3.08	(a)	3.34	(b)			2.8	(a)						
Hf	23	(a)	20.8	(b)			21.9	(a)						
Ta	4.8	(a)					3	(a)						
W ppb														
Re ppb					1.05	(c)								
Os ppb														
Ir ppb					11.1	(c)								
Pt ppb														
Au ppb					7.5	(c)								
Th ppm	13.6	(a)					13.3	(a)			11.4	(d)	13.3	(d)
U ppm							3.6	(a)			3.2	(d)	3.5	(d)

technique: (a) INAA, (b) IDMS, (c) RNNA, (d) radiation counting

Table 2. Chemical composition of 14148.

reference	Lindstrom72		Philpotts72		Morgan72		Laul82		Eldridge72		Keith72	
weight												
SiO2 %												
TiO2	1.68	(a)					1.6	(a)				
Al2O3	17.25	(a)					16.6	(a)				
FeO	10.3	(a)					12.2	(a)				
MnO	0.127	(a)					0.14	(a)				
MgO							9.9	(a)				
CaO							10.3	(a)				
Na2O	0.68	(a)					0.74	(a)				
K2O	0.5	(a)	0.54	(b)			0.53	(a)	0.53	(d)	0.55	(d)
P2O5												
S %												
sum												
Sc ppm	21	(a)					25.5	(a)				
V	44	(a)					45	(a)				
Cr	1310	(a)					1437	(a)				
Co	34.4	(a)					39	(a)				
Ni							*700*	(a)				
Cu												
Zn					22	(c)						
Ga												
Ge ppb												
As												
Se												
Rb			14.8	(b)	16.8	(c)						
Sr			177.4	(b)			170	(a)				
Y												
Zr	690	(a)	992	(b)			830	(a)				
Nb												
Mo												
Ru												
Rh												
Pd ppb												
Ag ppb					12.6	(c)						
Cd ppb					111	(c)						
In ppb												
Sn ppb												
Sb ppb					2.8	(c)						
Te ppb					25	(c)						
Cs ppm	0.4	(a)			0.695	(c)						
Ba	750	(a)	824	(b)			850	(a)				
La	64.3	(a)					61	(a)				
Ce	176	(a)	171	(b)			170	(a)				
Pr												
Nd	98	(a)	107	(b)			100	(a)				
Sm	31.5	(a)	30.6	(b)			27	(a)				
Eu	2.68	(a)	2.55	(b)			2.5	(a)				
Gd			34.4	(b)								
Tb	6.6	(a)					6	(a)				
Dy			38.9	(b)			38	(a)				
Ho							9.2	(a)				
Er			23.2	(b)								
Tm							3.3	(a)				
Yb	21.7	(a)	21.6	(b)			20.2	(a)				
Lu	3.18	(a)	3.31	(b)			2.85	(a)				
Hf	25.7	(a)	20.6	(b)			26	(a)				
Ta	4.7	(a)					3.3	(a)				
W ppb												
Re ppb					1.34	(c)						
Os ppb												
Ir ppb					13.7	(c)						
Pt ppb												
Au ppb					6.9	(c)						
Th ppm	13.8	(a)					14	(a)	11.4	(d)	13.4	(d)
U ppm							3.5	(a)	3.3	(d)	3.7	(d)

technique: (a) INAA, (b) IDMS, (c) RNAA, (d) radiation counting

Table 3. Chemical composition of 14156.

reference	Lindstrom72		Philpotts72		Morgan72		Eldridge72		Keith72	
weight										
SiO2 %										
TiO2	1.65	(a)								
Al2O3	16.95	(a)								
FeO	10.42	(a)								
MnO	0.125	(a)								
MgO										
CaO										
Na2O	0.68	(a)								
K2O	0.52	(a)	0.54	(b)			0.57	(d)	0.52	(d)
P2O5										
S %										
sum										
Sc ppm	20.9	(a)								
V	36	(a)								
Cr	1350	(a)								
Co	36.2	(a)								
Ni										
Cu										
Zn					20	(c)				
Ga										
Ge ppb										
As										
Se					280	(c)				
Rb			14.7	(b)	13.5	(c)				
Sr			179.2	(b)						
Y										
Zr	700	(a)	913	(b)						
Nb										
Mo										
Ru										
Rh										
Pd ppb										
Ag ppb					11.7	(c)				
Cd ppb					77	(c)				
In ppb										
Sn ppb										
Sb ppb					3.6	(c)				
Te ppb					25	(c)				
Cs ppm	0.54	(a)								
Ba	780	(a)	813	(b)						
La	65.1	(a)								
Ce	175	(a)	169	(b)						
Pr										
Nd			107	(b)						
Sm	31.4	(a)	29.9	(b)						
Eu	2.66	(a)	2.57	(b)						
Gd			34.9	(b)						
Tb	6.6	(a)								
Dy			38.9	(b)						
Ho										
Er			23.1	(b)						
Tm										
Yb	21.5	(a)	21.8	(b)						
Lu	3.05	(a)	3.27	(b)						
Hf	23.2	(a)								
Ta	4.8	(a)								
W ppb										
Re ppb					1.11	(c)				
Os ppb										
Ir ppb					12.7	(c)				
Pt ppb										
Au ppb					5.3	(c)				
Th ppm	13.8	(a)					11.9	(d)	13.9	(d)
U ppm							3.3	(d)	3.8	(d)

technique: (a) INAA, (b) IDMS, (c) RNAA, (d) radiation counting

References for 14149, 14156, 14148

Basford J.R., Dragon J.C., Pepin R.O., Cosio M.R. and Murthy V.R. (1973) Krypton and Xenon in lunar fines. Proc. 4th Lunar Sci. Conf. 1915-1955.

Berdot J.L, Chetrit G.C., Lorin J.C., Pellas P. and Poupeau G. (1972) Track studies of Apollo 14 rocks, and Apollo 14, Apollo 15 and Lunar 16 soils. Proc. 3rd Lunar Sci. Conf. 2867-2881.

Bhai N.B., Gopalan K., Goswami J.N., Rao M.N. and Venkatesan T.R. (1978) Solar cosmic ray produced neon and xenon isotopes and particle tracks in feldspars from lunar fines 14148 and 24087. Proc. 9th Lunar Planet. Sci. Conf. 1629-1645.

Bhandari N., Goswami J.N., Gupta S.K., Lal D., Tamhane A.S. and Venkatavaradan V.S. (1972) Collision controlled radiation history of the lunar regolith. Proc. 3rd Lunar Sci. Conf. 2811-2829.

Bogard D.D. and Nyquist L.E. (1972a) Noble gas studies of regolith materials from Apollo 14 and 15. Proc. 3rd Lunar Sci. Conf. 1797-1821.

Cadogen P.H., Eglington G., Firth J.N.M., Maxwell J.R., May B.J. and Pillinger C.T. (1972) Survey of lunar carbon compounds: II. The carbon chemistry of Apollo 11, 12, 14 and 15 samples. Proc. 3rd Lunar Sci. Conf. 2069-2091.

Chao E.C.T., Best J.B. and Minkin J.A. (1972) Apollo 14 glasses of impact origin and their parent rock types. Proc. 3rd Lunar Sci. Conf. 907-925.

Crozaz G., Drozd R., Hohenberg C.M., Hoyt H.P., Ragan D., Walker R.M. and Yuhas D. (1972) Solar flare and galactic cosmic ray studies of Apollo 14 and 15 samples. Proc. 3rd Lunar Sci. Conf. 2917-2931.

Drozd R., Hohenberg C. and Morgan C. (1975) Krypton and xenon in Apollo 14 samples: Fission and neutron capture effects in gas-rich samples. Proc. 6th Lunar Sci. Conf. 1857-1877.

Eldridge J.S., O'Kelley G.D. and Northcutt K.J. (1972) Abundances of primordial and comogenic radionuclides in Apollo 14 rocks and fines. Proc. 3rd Lunar Sci. Conf. 1651-1658.

Epstein S. and Taylor H.P. (1972) O18/O16, Si30/Si28, C13/C12 and D/H studies of Apollo 14 and 15 samples. Proc. 3rd Lunar Sci. Conf. 1429-1455.

Farr T.G., Bates B.A., Ralph R.L. and Adams J.B. (1980) Effects of overlapping optical absorption bands of pyroxene and glass and the reflectance spectra of lunar soils. Proc. 11th LPSC 719-729.

Flory D.A., Wikstrom S., Gupta S., Gibert J.M. and Oro J. (1972) Analysis of organogenic compounds in Apollo 11, 12 and 14 lunar samples. Proc. 3rd Lunar Sci. Conf. 2091-2108.

Glass B.P., Storzer D. and Wagner G.A. (1972) Chemistry and particle track studies of Apollo 14 glasses. Proc. 3rd Lunar Sci. Conf. 927-937.

Glass B.P. (1972) Major element composition of Apollo 15 glasses. In The Apollo 15 Samples. 73-77. LPI

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

Hart H.R., Comstock G.M. and Fleischer R.L. (1972) The particle track record of Fra Mauro. Proc. 3rd Lunar Sci. Conf. 2831-2844.

Holland P.T., Simoneit B.R., Wszolek P.C. and Burlingame A.L. (1972) Compounds of carbon and other volatile elements in Apollo 14 and 15 samples. Proc. 3rd Lunar Sci. Conf. 2131-2149.

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.

Kramer F.E. and Twedell D.B. (1977) Apoloo 14 coarse fines (4-10 mm) sample location and clasification. JSC 12922

King E.A., Butler J.C. and Carman Max (1972) Chondrules in Apollo 14 samples and size analyses of Apollo 14 and 15 fines. Proc. 3rd Lunar Sci. Conf. 673-686.

Laul J.C., Papike J.J. and Simon S.B. (1982) The Apollo 14 regolith: Chemistry of cores 14210/14211 and 14220 and soils 14141, 14148 and 14149. Proc. 13th Lunar Sci. Conf. in J. Geophys. Res. 87, A247-259.

Lindstrom M.M., Duncan A.R., Fruchter J.S., McKay S.M., Stoeser J.W., Goles G.G. and Lindstrom D.J. (1972) Compositional characteristics of some Apollo 14 clastic materials. Proc. 3rd Lunar Sci. Conf. 1201-1214.

LSPET (1971a) Preliminary Examination of Lunar Samples from Apollo 14. Science 173, 681-693.

LSPET (1971b) Preliminary examination of lunar samples. In Apollo 14: Preliminary Science Report NASA SP -272, 109-131.

McKay D.S.. Heiken G.H., Taylor R.M., Clanton U.S., Morrison D.A. and Ladle G.H. (1972) Apollo 14 soils: Size distribution and particle types. Proc. 3rd Lunar Sci. Conf. 983-995.

Mitchell J.K., Bromwell L.G., Carrier W.D., Costes N.C. and Scott R.F. (1971) Soil Mechanics Experiment. In Apollo 14: Preliminary Science Report NASA SP-272.

Moore C.B., Lewis C.F., Cripe J.D., Delles F.M., Kelly W.R. and Gibson E.K. (1972) Total carbon, nitrogen and sulfur in Apollo 14 lunar samples. Proc. 3rd Lunar Sci. Conf. 2051-2058.
14149 14240

Morgan J.W., Laul J.C., Krahenbuhl U., Ganapathy R. and Anders E. (1972) Major impacts on the moon: Characterization from trace elements in Apollo 12 and 14 samples. Proc. 3rd Lunar Sci. Conf. 1377-1395.

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

Murthy V.R., Evensen N.M., Jahn B-M. and Coscio M.R. (1972) Apollo 14 and 15 samples: Rb-Sr ages, trace elements and lunar evolution. Proc. 3rd Lunar Sci. Conf. 1503-1514.

Nagle J.S. (1979) Preliminary description and interpretation of Apollo 14 cores 14211/14210. Proc. 10th Lunar Planet. Sci. Conf. 1299-1319.

Nautiyal C.M., Padia J.T., Rao M.N. and Venkatesan T.R. (1981) Solar flare neon: Clues from implanted noble gases in lunar soils and rocks. Proc. 12th Lunar Planet. Sci. Conf. 627-637.

Nelen J., Noonan A. and Fredricksson K. (1972) Lunar glasses, breccias and chondrules. Proc. 3rd Lunar Sci. Conf. 723-737.

Pepin R.O., Bradley J.G., Dragon J.C. and Nyquist L.E. (1972) K-Ar dating of lunar fines. Proc. 3rd Lunar Sci. Conf. 1569-1588.

Philpotts J.A., Schnetzler C.C., Nava D.F., Bottino M.L., Fullagar P.D., Thomas H.H., Schuhmann S. and Kouns C.W. (1972) Apollo 14: Some geochemical aspects. Proc. 3rd Lunar Sci. Conf. 1293-1305.

Reed G.W., Jovanovic S. and Fuchs L.H. (1972) Trace element relations between Apollo 14 and 15 and other lunar samples, and the implications of a moon-wide Cl-KREEP coherence and Pt-metal noncoherence. Proc. 3rd Lunar Sci. Conf. 1989-2003.

Reid A.M., Ridley W.I., Jakes P. and Warner J.L. (1971) Microprobe analyses of glasses from Apollo 14 sample 14156. NASA TMX 58081 JSC, Houston.

Reid A.M., Warner J., Ridley W.I., Johnston D.A., Harmon R.S., Jakes P., Cobleigh T. and Brown R.W. (1972a) The major element composition of lunar rocks as inferred from glass compositions in the lunar soils. Proc. 3rd Lunar Sci. Conf. 363-378.

Reid A.M., Ridley W.I., Harman R.S., Warner J., Brett R., Jakes P. and Brown R.W. (1972b) Highly aluminous glasses in lunar soils and the nature of the lunar highlands. Geochim. Cosmochim. Acta 36, 903-912.

Reid A.M., Ridley W.I., Harman R.S., and Jakes P. (1973) Major element chemistry of glasses in Apollo soil 14156. Geochim. Cosmochim. Acta 37, 695-699.

Simon S.B., Papike J.J. and Laul J.C. (1982) The Apollo 14 regolith: Petrology of cores 14210/14211 and 14220 and soils 14141, 14148 and 14149. Proc. 13th Lunar Sci. Conf. in J. Geophys. Res. 87, A232-246.

Swann G.A., Bailey N.G., Batson R.M., Eggleton R.E., Hait M.H., Holt H.E., Larson K.B., McEwen M.C., Mitchell E.D., Schaber G.G., Schafer J.P., Shepard A.B., Sutton R.L., Trask N.J., Ulrich G.E., Wilshire H.G. and Wolf E.W. (1971) Preliminary geologic investigations of the Apollo 14 landing site. In Apollo 14; Preliminary Science Report. NASA SP-272, 39-85.

Swann G.A., Bailey N.G., Batson R.M., Eggleton R.E., Hait M.H., Holt H.E., Larson K.B., Reed V.S., Schaber G.G., Sutton R.L., Trask N.J., Ulrich G.E. and Wilshire H.G. (1977) Geology of the Apollo 14 landing site in the Fra Mauro highlands. U.S. Geological Survey Professional Paper 880

Venkatatesan T.R., Nautiyal C.M., Padia J.T. and Rao M.N. (1980) Solar (flare) cosmic ray proton fluxes in the recent past. Proc. 12th Lunar Planet. Sci. Conf. 1271-1284.

Warner J. (1971) Apollo 14 Lunar Sample Information Catalog. Curators Office NASA MSC Houston

Weeks R.A. (1972) Magnetic phases in lunar material and their electron magnetic resonance spectra: Apollo 14. Proc. 3rd Lunar Sci. Conf. 2503-2517.