

15431
Soil ?
598.2 grams



Figure 1: 15415 perched on pedestal 15430-15435. AS15-86-11670.
The feet on the gnomon are 50 cm apart.

Introduction

Lunar sample 15430 contains the “pedestal” under 15415 (figure 1) as well as some of the local soil. This sample was collected from the rim of Spur Crater, station 7, near soil samples 15410 and 15420, but the lithology of 15431 – 15434 is different from these soils (Phinney et al. 1972).

It contained some of the best examples of KREEP basalt. The sample bag included 15435 which is an assemblage of soil breccias that must have degraded during transport.

Petrography

The maturity index (I_s/FeO) of 15431 is 39 (submature) (Morris 1978) and the grain size

distribution is broad (average = 101 microns)(figure 5). The modal mineralogy has not been reported.

KREEP basalt

15431 – 15434 contains numerous small particles of what is known as KREEP basalt (Meyer 1977). These plagioclase-rich basalts contain orthopyroxene as an early phase and have very high a distinctive rare earth and large ion lithophile element concentrations (table 2). They also generally lack meteoritic siderophiles. Examples of KREEP basalt are illustrated in figure 6.

Simon et al. (1987) give the composition of whitlockite in KREEP basalt fragment 15434,181 (table 4).

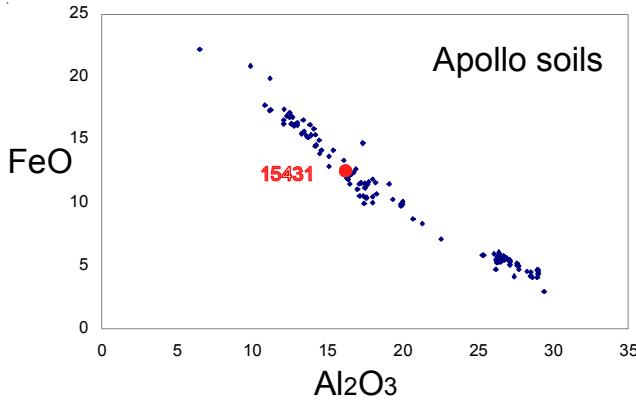


Figure 2: Chemical composition of 15431 compared with other Apollo soil samples.

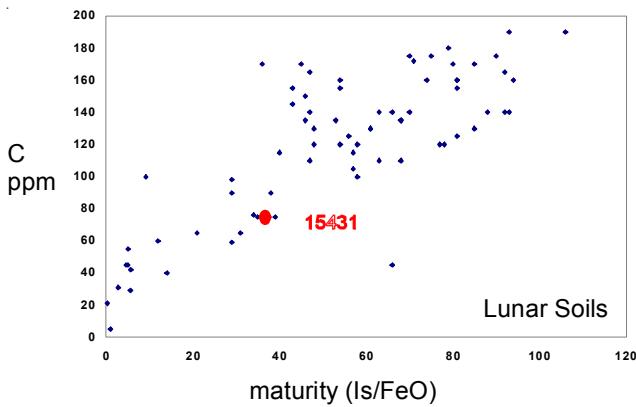


Figure 3: Carbon content and maturity index for 15431 (Moore et al. 1973, Morris 1978).

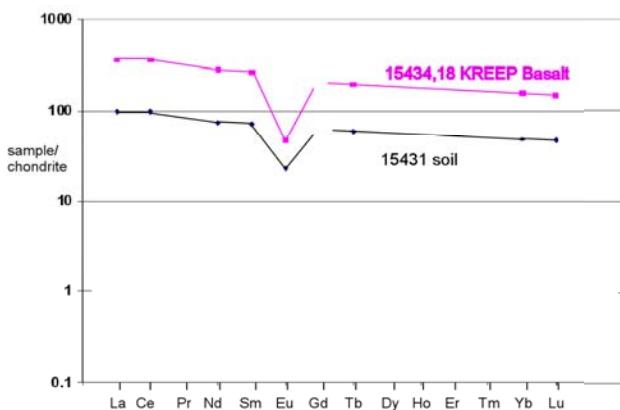
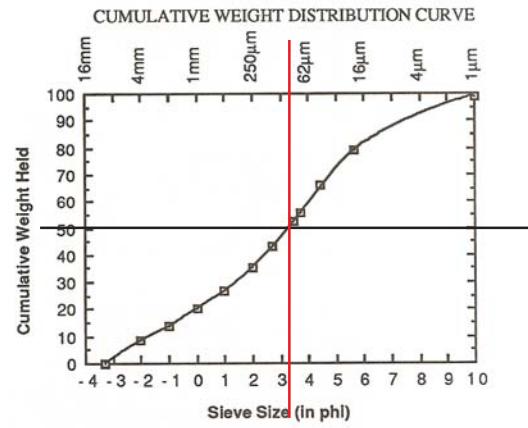


Figure 4: Normalized rare-earth-element diagram for 15431 (Korotev 1987) and KREEP basalt 15434,18 (Ryder and Sherman 1989).



Average grain size = 101 microns

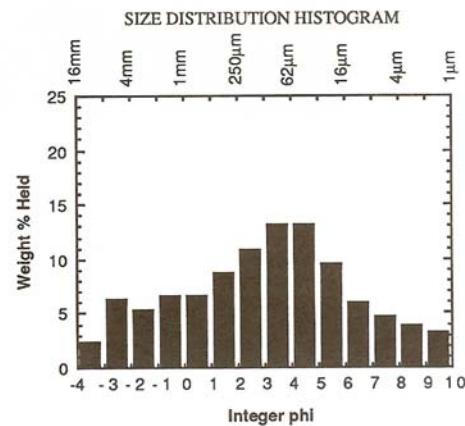


Figure 5: Grain size distribution of 15430 (Graf 1993).

Powell et al. (1972 and 1973), Phinney et al. (19720 and Ryder and Sherman (1989) reported the percentages of rock types found in the coarse-fines from 15431 – 15434.

Impact melt breccia

To date (2010), lunar scientists have not clearly identified specific samples impact melt rock from the Imbrium impact. Ryder and Spudis (1987) studied a few microbreccias from the Apennine Front and Laul et al. (1987) found three candidate samples with poikilitic textures and high trace element content (table 3). Dalrymple and Ryder (1991 and 1993) dated some of these impact melt rocks, but did not included any from 15430 – 15434.

Chemistry

Keith et al. (1972), Korotev (1987), Rose et al. (1975) and Morgan et al. (1972) determined the chemical composition of 15431 (table 1, figures 2 and 4). The REE pattern is dominated by KREEP (figure 4). Moore



Figure 6: Photomicrographs of KREEP basalt from 15434 (Ryder and Sherman 1989). Each view is about 2 mm across.

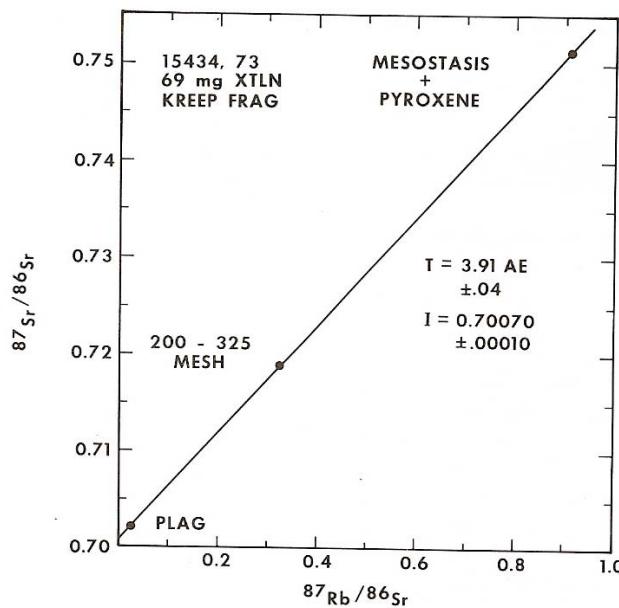


Figure 7: Rb/Sr isochron for KREEP Basalt fragment 15434, 73 (Nyquist et al. 1974).

et al. (1973) reported 73 ppm C consistent with maturity as determined by magnetic measurement figure 3).

Walker and Papike (1981) calculated that 15431 was 19 % mare basalt and 36 % KREEP.

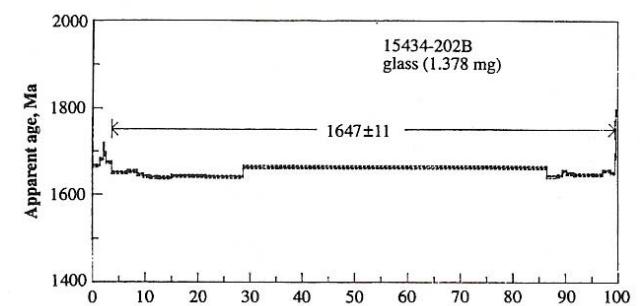


Figure 8: Ar/Ar plateau age for 15434, 202 glass bead (Dalrymple and Ryder 1996).

Radiogenic age dating

Nyquist et al. (1974) determined the age of one of the KREEP basalt particles (15434, 73)(figure 7). Ryder et al. (1996) determined the Ar/Ar age for a 6 mm glass bead (figure 8).

Cosmogenic isotopes and exposure ages

Keith et al. (1972) determined the cosmic-ray-induced-activity of $^{22}\text{Na} = 36 \text{ dpm/kg}$, $^{26}\text{Al} = 66 \text{ dpm/kg}$ and $^{54}\text{Mn} < 12 \text{ dpm/kg}$.

Table 1. Chemical composition of 15431.

reference weight	Rose75	Morgan72 Ganapathy73	Keith72	Korotev87
SiO ₂ %	47.07	46.53	(a)	
TiO ₂	1.33	1.32	(a)	1.32 (d)
Al ₂ O ₃	16.3	16.39	(a)	16.3 (d)
FeO	11.94	11.8	(a)	12.1 (d)
MnO	0.18	0.17	(a)	0.17 (d)
MgO	10.39	11.39	(a)	10.9 (d)
CaO	11.25	11.2	(a)	10 (d)
Na ₂ O	0.5	0.49	(a)	0.45 (d)
K ₂ O	0.28	0.23	(a)	0.224 (c)
P ₂ O ₅	0.27	0.21	(a)	
S %				
<i>sum</i>				
Sc ppm	25	24	(a)	23.8 (d)
V	58	57	(a)	80 (d)
Cr	2052	2052	(a)	2240 (d)
Co	42	42	(a)	35.4 (b) 37.8 (d)
Ni	220	199	(a)	150 (b) 167 (d)
Cu	11	14	(a)	
Zn	18	16	(a)	25 (b)
Ga	4.6	5.4	(a)	
Ge ppb			271	(b)
As				
Se				
Rb	4.5	5.7	(a)	5.2 (b)
Sr	125	121	(a)	140 (d)
Y	94	102	(a)	
Zr	365	388	(a)	330 (d)
Nb	28	34	(a)	
Mo				
Ru				
Rh				
Pd ppb				
Ag ppb			12	(b)
Cd ppb			49	(b)
In ppb			5.6	(b)
Sn ppb				
Sb ppb			1.1	(b)
Te ppb			11	(b)
Cs ppm			0.245	(b)
Ba	338	429	(a)	0.26 (d)
La	32	35	(a)	244 (d)
Ce				22.7 (d)
Pr				59 (d)
Nd				33 (d)
Sm				10.5 (d)
Eu				1.3 (d)
Gd				
Tb				2.15 (d)
Dy				
Ho				
Er				
Tm				
Yb	11	13	(a)	7.8 (d)
Lu				1.14 (d)
Hf				8.9 (d)
Ta				1.03 (d)
W ppb				
Re ppb			0.58	(b)
Os ppb				
Ir ppb			4.5	(b)
Pt ppb				2 (d)
Au ppb			1.63	(b)
Th ppm				<2 (d)
U ppm				4.86 (c) 3.9 (d)
				1.12 (c) 0.97 (d)

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

Table 2a. Chemical composition of KREEP basalt.

15434 reference	.29 Ryder89	.25 Ryder89	.25 Ebihara	.16 Nyquist74	.17 Ryder89	.17 Powell74 in Irving Ryder89	.18 Ryder89	.189
<i>weight</i>								
SiO ₂ %	51.3	(a) 51.5	(a)	51.4	(a) 53.5	(a) 52.1	52.8	52.6 (a) 51.6 (a)
TiO ₂	1.96	(a) 2.32	(a)	2.16	(a) 2.2	(a) 2.3	2.14	2.1 (a) 1.92 (a)
Al ₂ O ₃	15.5	(a) 14.7	(a)	15.7	(a) 16.2	(a) 17	15.2	15.4 (a) 16.4 (a)
FeO	9.7	(a) 10	(a)	10	(a) 9.5	(a) 11.1	10	10 (a) 10 9.6 (b)
MnO	0.16	(a) 0.14	(a)	0.155	(a) 0.16	(a) 0.23	0.15	0.15 (a) 0.14 (a)
MgO	8.8	(a) 8	(a)	8	(a) 7.6	(a) 6.3	7.4	7.6 (a) 9.2 (a)
CaO	9.6	(a) 9.6	(a)	9.8	(a) 9.8	(a) 10.3	9.4	9.4 (a) 9.8 (a)
Na ₂ O	0.75	(a) 0.79	(a)	0.79	(a) 0.89	(b) 0.58	0.85	0.85 (a) 0.8 0.79 (b)
K ₂ O	0.5	(a) 0.8	(a)	0.8	(a) 0.83	(b) 0.73	0.77	0.76 (a) 0.55 0.49 (b)
P ₂ O ₅	0.46	(a) 0.58	(a)	0.56	(a)	0.6	0.62	0.62 (a) 0.46 (a)
S % <i>sum</i>								
Sc ppm	20.5	(b) 21.3	(b)	21.3	(b) 22.6	(b)	23.2	22.1 (b) 19.4 19.7 (b)
V								
Cr								
Co	20.7	(b) 19.7	(b)	19.2	(b) 18.4	(b)	18.6	17.7 (b) 19.7 20.2 (b)
Ni	34	(b) 16	(b) 43	(c) 23	(b) 31	(b)	25	20 (b) <20 <30 (b)
Cu								
Zn				3.15	(c)			
Ga								
Ge ppb				74.2	(c)			
As								
Se				91	(c)			
Rb	12.8	(b) 20.4	(b) 22.2	(c) 16	(b) 22.5	(b)	23.5	22.6 (b) 14.7 15.4 (b)
Sr	202	(b) 183	(b)	190	(b) 201	(b)	170	200 (b) 187 203 (b)
Y								
Zr	749	(b) 905	(b)	794	(b) 1038	(b)	995	975 (b) 729 764 (b)
Nb								
Mo								
Ru								
Rh								
Pd ppb								
Ag ppb				1.67	(c)			
Cd ppb				32	(c)			
In ppb				4.14	(c)			
Sn ppb								
Sb ppb								
Te ppb				4	(c)			
Cs ppm	0.55	(b) 0.9	(b) 0.93	(c) 0.76	(b) 1	(b)	1.02	0.94 (b) 0.62 0.63 (b)
Ba	649	(b) 752	(b)	680	(b) 846	(b)	871	795 (b) 664 670 (b)
La	64.7	(b) 74.2	(b)	69	(b) 80.9	(b)	83.5	78.3 (b) 63 63.9 (b)
Ce	167	(b) 191	(b) 187	(c) 180	(b) 211	(b)	216	202 (b) 164 167 (b)
Pr								
Nd	99	(b) 109	(b) 116	(c) 101	(b) 121	(b)	125	114 (b) 92 97 (b)
Sm	29.8	(b) 33.2	(b)	31.7	(b) 36.8	(b)	38.2	35.5 (b) 28.8 30.1 (b)
Eu	2.48	(b) 2.42	(b) 2.25	(c) 2.54	(b) 2.65	(b)	2.63	2.55 (b) 2.39 2.49 (b)
Gd								
Tb	5.55	(b) 6.27	(b) 6.72	(c) 5.9	(b) 7.1	(b)	7.1	6.7 (b) 5.3 5.4 (b)
Dy								
Ho								
Er								
Tm								
Yb	20	(b) 23.2	(b) 21.3	(c) 21.2	(b) 25.7	(b)	25.1	24.5 (b) 19.6 18.9 (b)
Lu	2.68	(b) 3.17	(b) 3.18	(c) 2.9	(b) 3.5	(b)	3.6	3.36 (b) 2.65 2.74 (b)
Hf	24	(b) 28.5	(b)	25.9	(b) 31.6	(b)	31.5	30.2 (b) 23.6 23.1 (b)
Ta	2.7	(b) 3.15	(b)	2.9	(b) 3.5	(b)	3.42	3.4 (b) 2.63 2.57 (b)
W ppb								
Re ppb				0.05	(c)			
Os ppb				0.77	(c)			
Ir ppb				0.68	(c)	<3		
Pt ppb								
Au ppb				0.24	(c)	<3		
Th ppm	10.2	(b) 12.9	(b)	11	(b)		14.9	<3 (b) 10.5 10.6 (b)
U ppm	2.96	(b) 3.51	(b) 3.71	(c) 3.1	(b)		4.3	3.8 (b) 2.9 2.9 (b)

technique: (a) fused-bead e-probe, (b) INAA, (c) RNAA

Table 2b. Chemical composition of KREEP.

15434	,181	,21	,192	,194	
reference	Simon 87	Helmke73	Ryder89		
weight		Powell			
SiO ₂ %		52.14	51.9	52.8	(b)
TiO ₂	1.9	(a) 2.23	2.09	2.17	(b)
Al ₂ O ₃	14.6	(a) 16.16	15.14	15	(b)
FeO	10.4	(a) 10.82	10.5	10	(b)
MnO	0.15	(a) 0.17	0.17	0.15	(b)
MgO	8.8	(a) 7.84	8.6	7.6	(b)
CaO	9	(a) 9.67	9.5	9.5	(b)
Na ₂ O	0.81	(a) 0.64	0.84	0.87	(b)
K ₂ O	0.56	(a) 0.61	0.72	0.76	(b)
P ₂ O ₅			0.58	0.63	(b)
S %					
sum					
Sc ppm	21.2	(a) 38.7	22.5	22.3	(a)
V	60	(a)			
Cr					
Co	19	(a) 36	18.8	18	(a)
Ni			25	<25	(a)
Cu					
Zn					
Ga					
Ge ppb					
As					
Se					
Rb			20.9	22.5	(a)
Sr	180	(a)	173	187	(a)
Y					
Zr	980	(a)	963	957	(a)
Nb					
Mo					
Ru					
Rh					
Pd ppb					
Ag ppb					
Cd ppb					
In ppb					
Sn ppb					
Sb ppb					
Te ppb					
Cs ppm			0.94	0.92	(a)
Ba	780	(a)	816	849	(a)
La	74	(a) 90	78.2	81.4	(a)
Ce	190	(a) 228	203	215	(a)
Pr					
Nd	110	(a) 150	(a) 115	125	(a)
Sm	33	(a) 40.4	(a) 35.7	37.8	(a)
Eu	2.7	(a) 3	(a) 2.49	2.59	(a)
Gd	40	(a) 48	(a)		
Tb	6.5	(a) 7.9	(a) 6.7	7	(a)
Dy	42	(a) 51.7	(a)		
Ho	9.1	(a) 11	(a)		
Er		27	(a)		
Tm	3.4	(a)			
Yb	21.8	(a) 27.2	(a) 24.5	24.8	(a)
Lu	3.2	(a) 4.12	(a) 3.35	3.54	(a)
Hf	23.9	(a) 40	(a) 30.2	31.1	(a)
Ta	2.9	(a)	3.4	3.4	(a)
W ppb					
Re ppb					
Os ppb					
Ir ppb					
Pt ppb					
Au ppb					
Th ppm	12.8	(a)	13.6	14.9	(a)
U ppm	3.5	(a)	3.8	4.1	(a)
technique:	(a) INAA				

Table 3. Composition of impact melt.

15434	reference	Ryder 87	Laul87		
weight		,13	,145	,187	,183
SiO ₂ %		48.5			
TiO ₂		1.24	1	1.1	0.91
Al ₂ O ₃		15.7	16	12.9	16.8
FeO		7.6	9.6	11.2	9.3
MnO		0.13	0.13	0.15	0.125
MgO		15.2	11.8	15.7	11.5
CaO		10.1	10.4	8.2	10.9
Na ₂ O		0.42	0.57	0.58	0.56
K ₂ O		0.07	0.35	0.094	0.35
P ₂ O ₅					
S %					
sum					
Sc ppm		21.9	(a) 20	19	18
V			50	50	(a)
Cr		2200	(a)		
Co		42.5	(a) 25.7	35	47
Ni			160	360	(a)
Cu					
Zn					
Ga					
Ge ppb					
As					
Se					
Rb					
Sr			160	120	160
Y					(a)
Zr		560	(a) 350	420	410
Nb					
Mo					
Ru					
Rh					
Pd ppb					
Ag ppb					
Cd ppb					
In ppb					
Sn ppb					
Sb ppb					
Te ppb					
Cs ppm		0.1	(a)		
Ba		430	(a) 480	400	460
La		45	(a) 49	43	42
Ce		125	(a) 125	110	105
Pr					
Nd		81	(a) 80	70	70
Sm		21.7	(a) 22	19.5	18.5
Eu		1.88	(a) 2.3	1.75	2.1
Gd			28	24	23
Tb		4.8	(a) 4.7	3.9	3.6
Dy			30	25	23
Ho			6.4	5.9	5.2
Er					
Tm			2.2	2	2
Yb		14.5	(a) 15	13.1	13.5
Lu		2.15	(a) 2.05	1.95	1.91
Hf		15.6	(a) 9.5	12.5	11
Ta		1.9	(a) 1.3	1.7	1.4
W ppb					
Re ppb					
Os ppb					
Ir ppb			5	4.7	1.2
Pt ppb					
Au ppb			2	6.9	5.7
Th ppm			6.05	7.2	(a)
U ppm		7.4	(a) 1.6	1.8	1.6
technique:	(a) INAA				

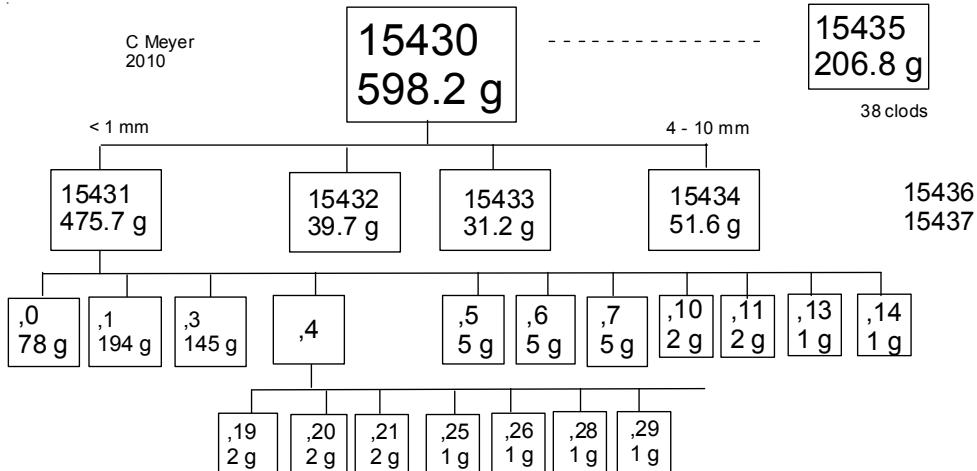


Table 4. Composition of Whitlockite.

15434	,181
reference	Simon87
weight	
SiO ₂ %	0.45
Al ₂ O ₃	0.06
FeO	3.83
MnO	0.13
MgO	1.67
CaO	40.26
P ₂ O ₅	42.21
Y ₂ O ₃	2.6
La ₂ O ₃	0.95
technique:	(a) e probe

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Other Studies

Frick et al. (1973) studied the rare gasses in 15431.

Processing

15430 was returned in a sample collection bag (#5) and placed in ALSRC#2, which did not seal. It was collected and returned with numerous grey "soil clods" (15435) and may contain material abraded off of them (Butler 1972).

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