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).

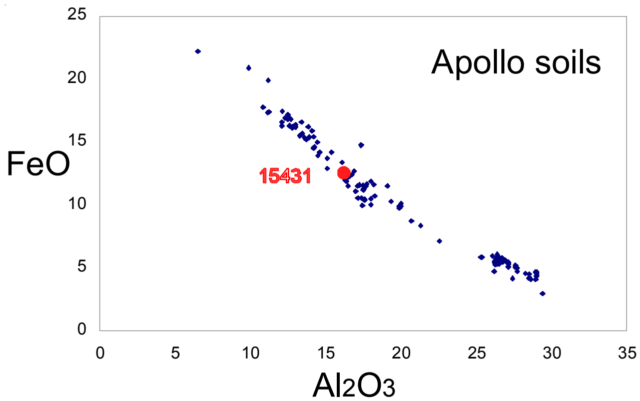


Figure 2: Chemical composition of 15431 compared with other Apollo soil samples.

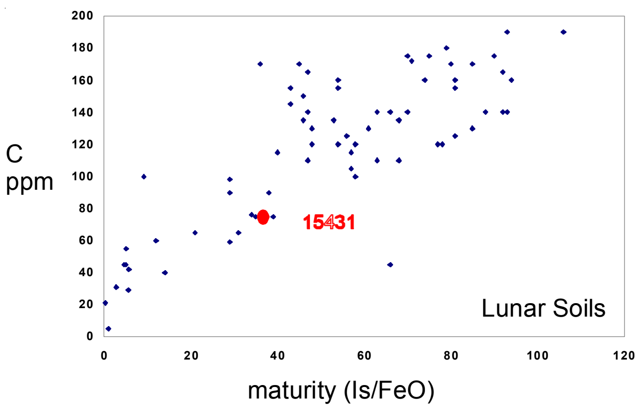


Figure 3: Carbon content and matruity index for 15431 (Moore et al. 1973, Morris 1978).

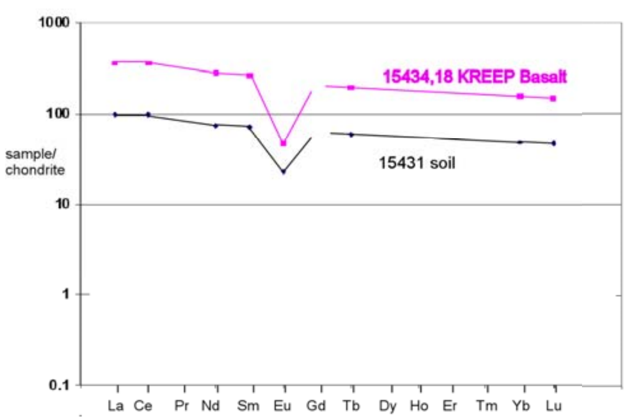
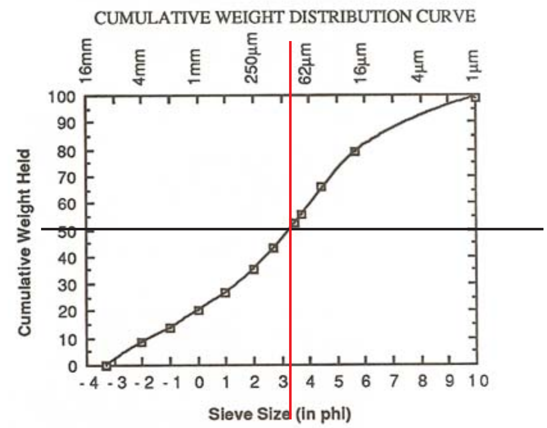


Figure 4: Normalized rare-earth-element diagram for 15431 (Korotev 1987) and KREEP basalt 15434,18 (Ryder and Sherman 1989).



Average grain size = 101 microns

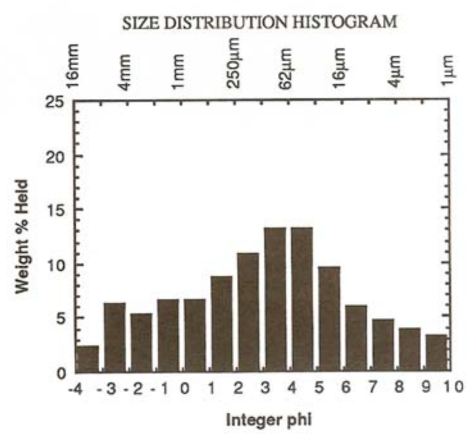


Figure 5: Grain size distribution of 15430 (Graf 1993).

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

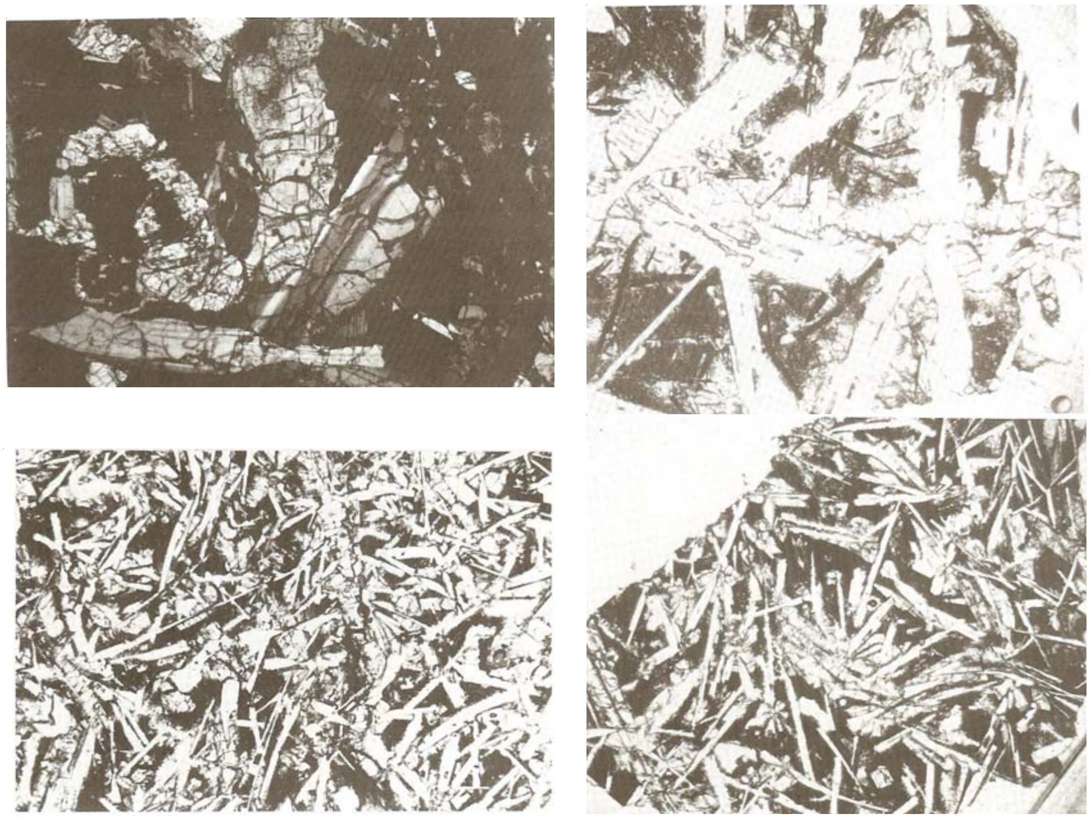


Figure 6: Photomicrographs of KREEP basalt from 15434 (Ryder and Sherman 1989). Each view is about 2 mm across.

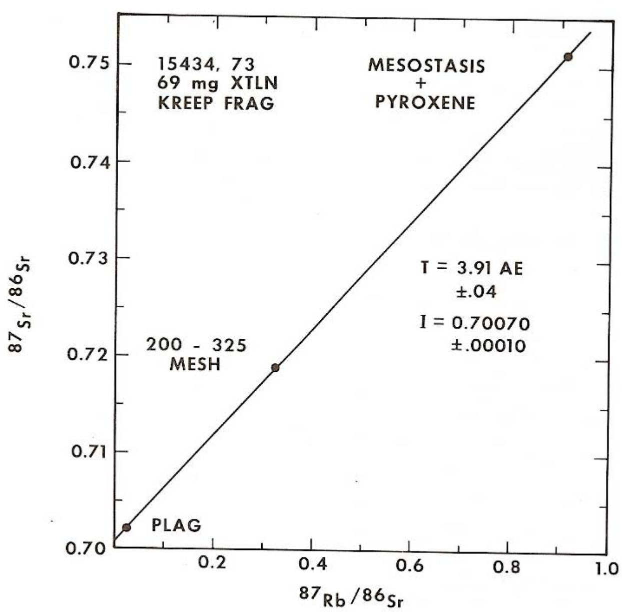


Figure 7: Rb/Sr isochron for KREEP Basalt fragment 15434,73 (Nyquist et al. 1974).

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.

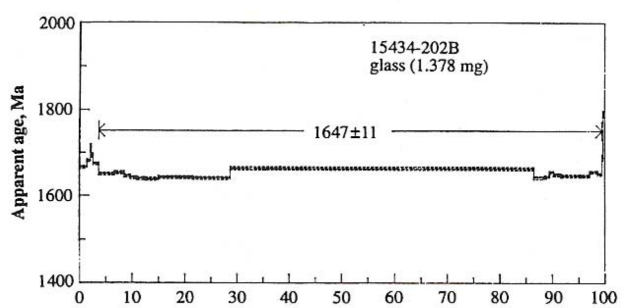


Figure 8: Ar/Ar plateau age for 15434,202 glass bead (Dalrymple and Ryder 1996).

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-inducted-activity of ^{22}Na = 36 dpm/kg, ^{26}Al = 66 dpm/kg and ^{54}Mn < 12 dpm/kg.

Table 1. Chemical composition of 15431.

reference	Rose75			Morgan72		Keith72		Korotev87	
weight				Ganapathy73					
SiO2 %	47.07	46.53	(a)						
TiO2	1.33	1.32	(a)					1.32	(d)
Al2O3	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)
Na2O	0.5	0.49	(a)					0.45	(d)
K2O	0.28	0.23	(a)			0.224	(c)		
P2O5	0.27	0.21	(a)						
S %									
sum									
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)			0.26	(d)
Ba	338	429	(a)					244	(d)
La	32	35	(a)					22.7	(d)
Ce								59	(d)
Pr									
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)			2	(d)
Pt ppb									
Au ppb				1.63	(b)			<2	(d)
Th ppm						4.86	(c)	3.9	(d)
U ppm						1.12	(c)	0.97	(d)

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

Table 2a. Chemical composition of KREEP basalt.

15434	,29		,25		,25		,16		,17		,17	,18			,189		
reference	Ryder89		Ryder89		Ebihara		Nyquist74		Ryder89		Powell74	Ryder89					
weight							Ryder89				in Irving						
SiO2 %	51.3	(a)	51.5	(a)			51.4	(a)	53.5	(a)	52.1	52.8	52.6	(a)	51.6		(a)
TiO2	1.96	(a)	2.32	(a)			2.16	(a)	2.2	(a)	2.3	2.14	2.1	(a)	1.92		(a)
Al2O3	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)
Na2O	0.75	(a)	0.79	(a)			0.79	(a)	0.89	(b)	0.58	0.85	0.85	(a)	0.8	0.79	(b)
K2O	0.5	(a)	0.8	(a)			0.8	(a)	0.83	(b)	0.73	0.77	0.76	(a)	0.55	0.49	(b)
P2O5	0.46	(a)	0.58	(a)			0.56	(a)			0.6	0.62	0.62	(a)	0.46		(a)
S %																	
sum																	
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	(b)							
Pt ppb																	
Au ppb					0.24	(c)			<3	(b)					<3	<4	
Th ppm	10.2	(b)	12.9	(b)			11	(b)				14.9	14	(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				
SiO2 %			52.14		51.9	52.8	(b)
TiO2	1.9	(a)	2.23		2.09	2.17	(b)
Al2O3	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)
Na2O	0.81	(a)	0.64		0.84	0.87	(b)
K2O	0.56	(a)	0.61		0.72	0.76	(b)
P2O5			0.71		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	(a)	78.2	81.4	(a)
Ce	190	(a)	228	(a)	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	
SiO2 %	48.5					
TiO2	1.24		1	1.1	0.91	(a)
Al2O3	15.7		16	12.9	16.8	(a)
FeO	7.6		9.6	11.2	9.3	(a)
MnO	0.13		0.13	0.15	0.125	(a)
MgO	15.2		11.8	15.7	11.5	(a)
CaO	10.1		10.4	8.2	10.9	(a)
Na2O	0.42		0.57	0.58	0.56	(a)
K2O	0.07		0.35	0.094	0.35	(a)
P2O5						
S %						
sum						
Sc ppm	21.9	(a)	20	19	18	(a)
V			50	50	50	(a)
Cr	2200	(a)				
Co	42.5	(a)	25.7	35	47	(a)
Ni			160	360	420	(a)
Cu						
Zn						
Ga						
Ge ppb						
As						
Se						
Rb						
Sr			160	120	160	(a)
Y						
Zr	560	(a)	350	420	410	(a)
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	(a)
La	45	(a)	49	43	42	(a)
Ce	125	(a)	125	110	105	(a)
Pr						
Nd	81	(a)	80	70	70	(a)
Sm	21.7	(a)	22	19.5	18.5	(a)
Eu	1.88	(a)	2.3	1.75	2.1	(a)
Gd			28	24	23	(a)
Tb	4.8	(a)	4.7	3.9	3.6	(a)
Dy			30	25	23	(a)
Ho			6.4	5.9	5.2	(a)
Er						
Tm			2.2	2	2	(a)
Yb	14.5	(a)	15	13.1	13.5	(a)
Lu	2.15	(a)	2.05	1.95	1.91	(a)
Hf	15.6	(a)	9.5	12.5	11	(a)
Ta	1.9	(a)	1.3	1.7	1.4	(a)
W ppb						
Re ppb						
Os ppb						
Ir ppb			5	4.7	1.2	(a)
Pt ppb						
Au ppb			2	6.9	5.7	(a)
Th ppm			6.05	7.2	7	(a)
U ppm	7.4	(a)	1.6	1.8	1.6	(a)

technique: (a) INAA

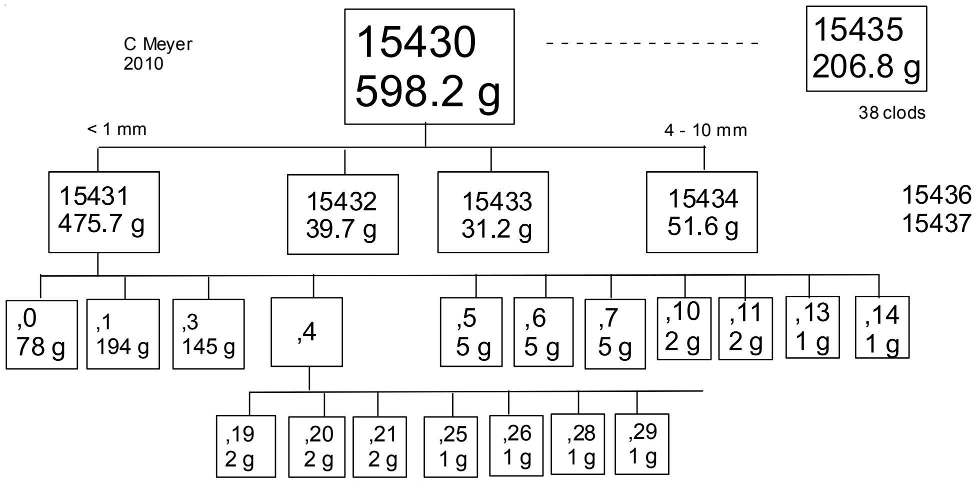


Table 4. Composition of Whitlockite.

15434	,181		
reference	Simon87		
weight			
SiO2 %	0.45	0.29	(a)
Al2O3	0.06	0.05	(a)
FeO	3.83	4.29	(a)
MnO	0.13	0.07	(a)
MgO	1.67	1.58	(a)
CaO	40.26	40.91	(a)
P2O5	42.21	41.14	(a)
Y2O3	2.6	2.5	(a)
La2O3	0.95	0.84	(a)

technique: (a) e probe

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 contains material abraded off of them (Butler 1972).

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