60600 and 60610

Soil

540 and 35 grams

It proved easy to get lots of rake samples at this site.

CC: *- - and make a triangle with the other double drive core and the deep core.*

CC: *Yes, we would like a double core. The rake soils is first priority and the double core.*

LMP: *Look at that regolith. We've got some glass-coated frags here, Tony - - in the rake. Okay, that was about half a bag full. One scoop.*

CDR: *Bag's full – lost two biggest rocks - -*

CDR: *Let's get the soil, Charlie.*

Introduction

Soil sample 60600 was collected adjacent to double drive tube 60014/60013 and rake sample 60610, about 65 meters southwest of LM in vicinity of ALSEP site. It is a typical Apollo 16 soil.

Petrography

60600 is a mature soil with a maturity index of I_s/FeO = 85 (Morris 1976). The grain size distribution has not been reported, but it should be noted that no walnuts (>1 cm) were found in the sieved soil. A mineralogical mode has not been reported.

Marvin (1972) and Taylor et al. (1973) described the coarse-fine particles. Taylor et al. found that there was a high proportion of "poikoblastic" (22%) and "spinel troctolite" (10%) fragments.

Wlotzka et al. (1973) studied metal particles in 60601.

See et al. (1986) and Morris et al. (1986) determined the composition of glass splashes on rake samples 60629, 60639, 60657, 60665 and 60666 (figure 3). It looks like the glass splash on these particles was derived from melted soil, and presumably some of the glass in the soil is also of this origin.

Rake Samples

The rake sample (60610) contained 33 fragments larger than 1 cm (table 2). Warner et al. (1976) produced a catalog of rake samples. Tables 2 and 3 tabulate what is known about these samples and some of the largest are illustrated in figures 5, 6 and 7.

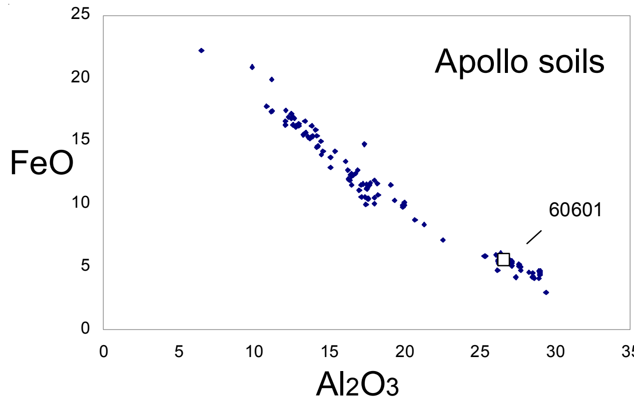

Figure 1: Composition of soil sample 60601 compared with other Apollo 16 soils.

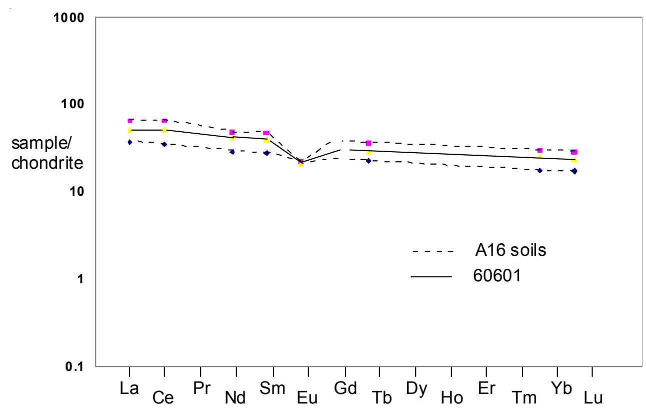

Figure 2: Normalized rare-earth-element diagram comparing 60601 with other Apollo 16 soils.

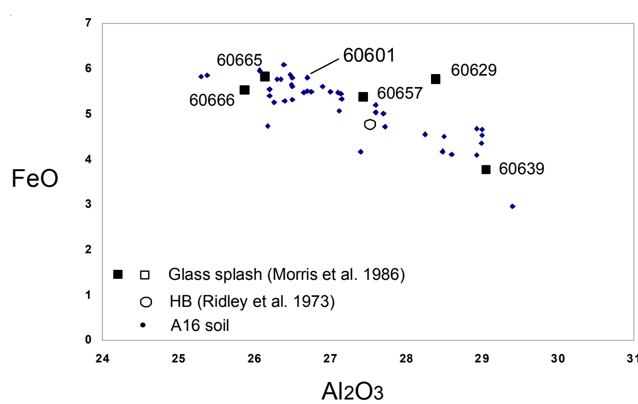

Figure 3: Composition of glass coatings on rake samples compared with that of Apollo 16 soils and 'highland basalt' (HB a la Ridley et al. 1973).

Chemistry

Clark and Keith (1973), Wanke et al. (1973), Haskin et al. (1973), Taylor et al. (1973), McKay et al. (1986) and others have determined the chemical composition of 60601 (table 1). It is similar to that of other Apollo 16 soils (figures 1 and 2), and has concentrations of meteoritic siderophile elements (Ni, Ir and Au).

C and N have not been determined.

Cosmogenic isotopes and exposure ages

Clark and Keith (1973) determined the cosmic-ray-induced activity of ^{26}Al = 109 dpm/kg., ^{22}Na = 36 dpm/kg., ^{54}Mn = 9 dpm/kg. and ^{46}Sc = 2 dpm/kg. for soil sample 60601.

Other Studies

Walton et al. (1973) and Hintenberger and Weber (1973) determined the rare gases and their isotopes in 60601.

Pearce et al. (1973) reported the magnetic properties of soils 60600 and 60501.

References 60600 and 60610.

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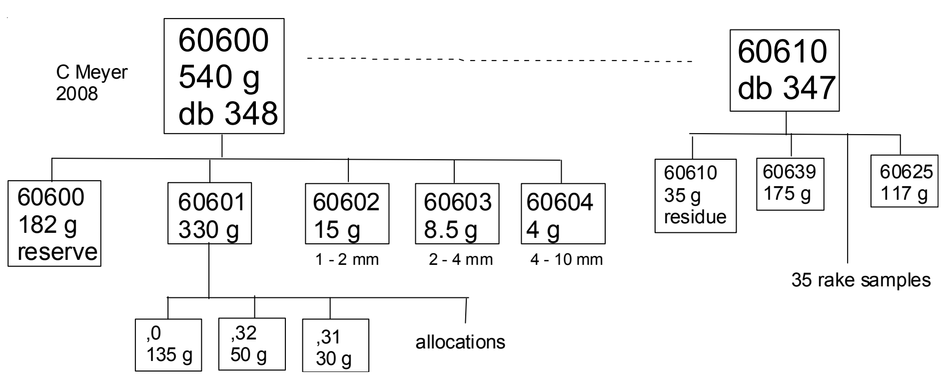
Table 1. Chemical composition of 60600.

reference	LSPET 72		Laul 73		Wanke 73		Haskin 73		Taylor73		McKay86		Korotev91		Evenson74 Nunes 74		Clark 73	
weight																		
SiO2 %	45.35	(b)			45.35	(c)	45.4		44.7	(e)								
TiO2	0.6	(b)	0.57	(a)	0.55	(c)	0.93		0.53	(e)								
Al2O3	26.75	(b)	26.6	(a)	26.26	(c)	26.4		27	(e)	26.8	(a)						
FeO	5.49	(b)	5.5	(a)	5.63	(c)	5.96		5.24	(e)	5.28	(a)	5.32	(a)				
MnO	0.07	(b)	0.07	(a)	0.07	(c)	0.067											
MgO	6.27	(b)	6.4	(a)	6.48	(c)	5.92		6.32	(e)	6.27	(a)						
CaO	15.46	(b)	15.5	(a)	16.9	(c)	15.8		15.4	(e)	15.9	(a)	15.5	(a)				
Na2O	0.38	(b)	0.46	(a)	0.47	(c)	0.47		0.43	(e)	0.46	(a)	0.453	(a)				
K2O	0.11	(b)	0.11	(a)	0.107	(c)	0.127		0.23	(e)							0.12	(e)
P2O5	0.13	(b)																
S %	0.07	(b)																
sum																		
Sc ppm			9.7	(a)	9.2	(c)	9.22	(a)	12	(e)	9.18	(a)	9.35	(a)				
V			26	(a)					27	(e)								
Cr	770	(b)	732	(a)	720	(c)	840	(a)	750	(e)	720	(a)	768	(a)				
Co			32	(a)	31.2	(c)	31.4	(a)	28	(e)	31.6	(a)	27.7	(a)				
Ni	293	(b)	580	(a)	400	(c)			340	(e)	453	(a)	395	(a)				
Cu					7	(c)			7.2	(e)								
Zn					24	(c)	22	(a)										
Ga					4.6	(c)	5.3	(a)										
Ge ppb					1100	(c)												
As					0.16	(c)												
Se																		
Rb	2.9	(b)			6	(c)	2.8	(a)	2.35	(e)					2.87	(d)		
Sr	173	(b)			170	(c)					183	(a)	176	(a)	171	(d)		
Y	43	(b)			42	(c)			40	(e)								
Zr	186	(b)	180	(a)	186	(c)			192	(e)	160	(a)	186	(a)				
Nb	12	(b)			11	(c)			14	(e)								
Mo																		
Ru																		
Rh																		
Pd ppb					24	(c)												
Ag ppb																		
Cd ppb																		
In ppb					18	(c)												
Sn ppb									0.15	(e)								
Sb ppb																		
Te ppb																		
Cs ppm					0.17	(c)	0.125	(a)	0.1	(e)	0.12	(a)						
Ba			140	(a)	120	(c)			190	(e)	110	(a)	144	(a)				
La			13.1	(a)	13.4	(c)	12.5	(a)	12.4	(e)	10	(a)	12.8	(a)				
Ce			32	(a)	34	(c)	32.6	(a)	33.8	(e)	26.4	(a)						
Pr					4.6	(c)			4.6	(e)								
Nd			21	(a)	23	(c)	21.1	(a)	19.6	(e)	10	(a)						
Sm			6.1	(a)	6	(c)	3.9	(a)	5.75	(e)	5.77	(a)	5.91	(a)				
Eu			1.21	(a)	1.29	(c)	1.13	(a)	1.17	(e)	1.19	(a)	1.192	(a)				
Gd					7.4	(c)	7.81	(a)	7.1	(e)								
Tb			1.2	(a)	1.1	(c)	1.22	(a)	1.1	(e)	1.04	(a)	1.17	(a)				
Dy			7.6	(a)	7.4	(c)	8.02	(a)	6.89	(e)								
Ho					1.8	(c)			1.66	(e)								
Er					5.4	(c)	4.6	(a)	4.8	(e)								
Tm									0.77	(e)								
Yb			4.5	(a)	4.3	(c)	3.99	(a)	4.64	(e)	3.91	(a)	4.18	(a)				
Lu			0.62	(a)	0.57	(c)	0.58	(a)	0.72	(e)	0.57	(a)	0.581	(a)				
Hf			4.2	(a)	4.2	(c)	4.6	(a)	3.75	(e)	4.28	(a)	4.48	(a)				
Ta			0.51	(a)	0.55	(c)					0.51	(a)	0.533	(a)				
W ppb					0.3	(c)												
Re ppb					2.6	(c)												
Os ppb																		
Ir ppb			15	(a)	15	(c)					16.1	(a)	14.6	(a)				
Pt ppb																		
Au ppb			10	(a)	10	(c)					7.5	(a)	8.4	(a)				
Th ppm	1.9	(b)	2.1	(a)	1.6	(c)			2.16	(e)	*22.1*		2.17	(a)	2.218	(d)	2.21	(e)
U ppm			0.55	(a)	0.57	(c)			0.54	(e)	0.62	(a)	0.56	(a)	0.595	(d)	0.57	(e)

technique: (a) INAA, (b) XRF, (c) INAA, RNAA, XRF, (d) IDMS, (e) SSMS, (f) rad. Count.

Table 2: Rake Samples in 60610 (DB347).

	weight	Ryder		ref
60615	32.97	basaltic impact melt	coherent	Dowty 74, Laul 73
60616	3.4	poikilitic impact melt	coherent	
60617	2.77	crystalline impact melt		
60618	21.67	basaltic impact melt/anorthosite		Dowty 74, Laul 73
60619	28	granobalstic anorthosite		Dowty 74
60625	117	poikilitic impact melt		
60626	15.87	poikilitic impact melt		Laul 73
60627	12.09	crystalline impact melt		
60628	6.86	cataclastic anorthosite		
60629	4.92	cataclastic anorthosite, glass covered		Morris 86, See 86
60635	15.05	basaltic impact melt		Dowty 74
60636	35.65	subophitic to poikilitic impact melt		Laul 73
60637	7.89	regolith breccia		
60638	0.72	fragmental polymict breccia		
60639	175.1	fragmental polymict breccia, glass coated		Dowty 74
60645	33.5	fine-grained heterogeneous impact melt		
60646	3.39	fine-grained or glassy vesicular impact melt		
60647	1.76	clast-laden, glass impact melt		
60648	2.84	clast-laden, glassy breccia		
60649	1.03	clast-laden, glassy breccia		
60655	8.63	glassy impact melt		
60656	11.23	glassy impact melt		
60657	6.05	fragmental polymict breccia, glass coated		Morris 86
60658	5.47	glassy impact melt, glass coated		
60659	22.2	fragmental polymict breccia		Warner 76
60665	90.1	vesicular glass, white clasts		Morris 86
60666	15.95	shocked basalt? w. glass		Wasson 77, Morris 86
60667	7.66	glassy impact melt		
60668	2.91	glassy impact melt		
60669	2.54	vesicular glass		
60675	1.3	vesicular impact melt		
60676	8.92	glassy impact melt		
60677	5.23	polymict glassy breccia		
60678	1.25	vesicular glassy impact melt		
60679	2.96	vesicular glassy impact melt		



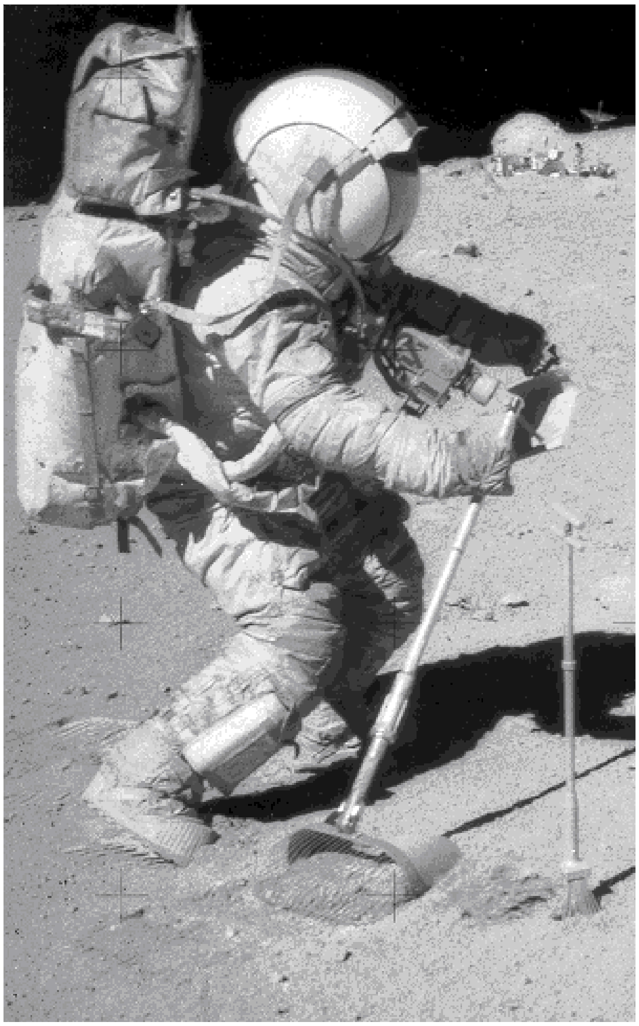


Figure 4: Astronaut collecting rake samples at North Ray Crater. AS16-106-17340.

Figure 6: Photo of 60639, glass-coated fragment wtih mare basalt clast found in rake sample 60610 (see section on 60639).

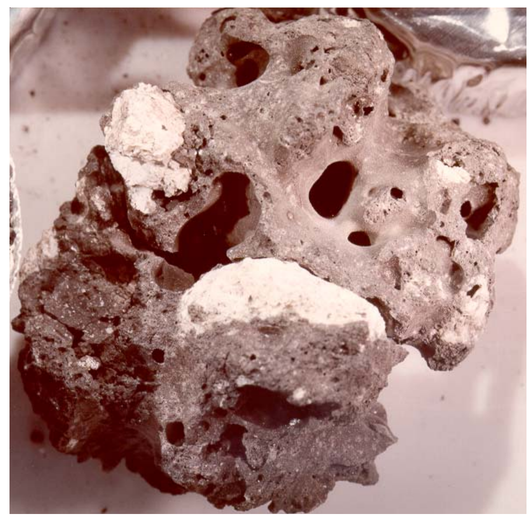


Figure 7: Photo of 60665, glass-cemented fragment wtih anorthosite clasts found in rake sample 60610 (see section on 60665).

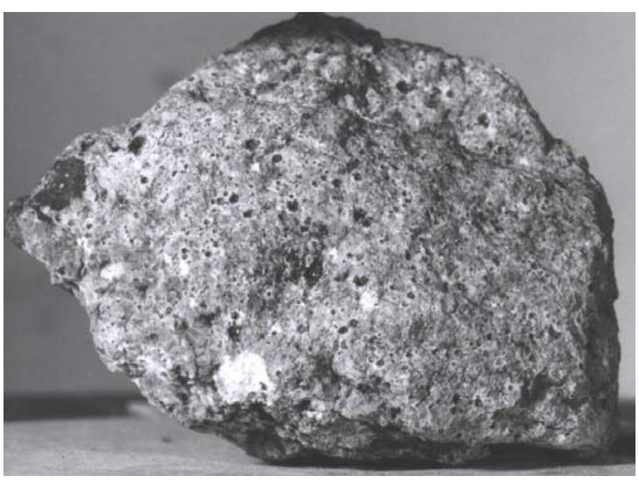


Figure 5: Photo of 60625, a potato-like fragment wtih zap pits on all sides found in rake sample 60610 (see section on 60625).

Table 3a. Chemical composition of rake samples.

	60615		60615		60616		60618a	60619	60625	60625		60626		60626		60629		60629
reference	Laul73		Dowty74		Warner76		Dowty74		Fruchter74			Laul73				Dowty74		Morris 86
weight			Warner76				Murali77			Warner76				Warner76		Warner76		See86
SiO2 %			44.9	(b)	45.5	(b)				44.7	(b)			45.3	(b)	44.6	(b)	45.54
TiO2	0.54	(a)	0.49	(b)	0.68	(b)	see	see		0.67	(b)	0.37	(a)	0.32	(b)	0.01	(b)	0.3
Al2O3	21.5	(a)	22.1	(b)	24.5	(b)	sample	sample	25.9	22.6	(b)	29.1	(a)	29.6	(b)	35.1	(b)	28.4
FeO	5.8	(a)	4.7	(b)	5.9	(b)			5.4	7.8	(b)	5	(a)	3.7	(b)	0.36	(b)	4.24
MnO	0.071	(a)	0.05	(b)	0.06	(b)				0.06	(b)	0.061	(a)	0.04	(b)			
MgO	14	(a)	14.2	(b)	8.3	(b)				9.8	(b)	3	(a)	3.3	(b)	0.26	(b)	5.18
CaO	12.1	(a)	12.8	(b)	14.3	(b)				13.2	(b)	16.2	(a)	17.1	(b)	19.2	(b)	16.28
Na2O	0.386	(a)	0.45	(b)	0.56	(b)			0.49	0.54	(b)	0.444	(a)	0.47	(b)	0.41	(b)	0.63
K2O	0.12	(a)	0.14	(b)	0.2	(b)				0.21	(b)	0.15	(a)	0.05	(b)	0.02	(b)	0.08
P2O5			0.09	(b)	0.22	(b)				0.25	(b)			0.04	(b)	0.03	(b)	
S %																		
sum										100				100		100		
Sc ppm	9	(a)							9.7			10	(a)					6.15
V	30	(a)										20	(a)					
Cr	985	(a)							840			657	(a)					776
Co	32	(a)							27			14	(a)					66
Ni	490	(a)										30	(a)					1321
Cu																		
Zn																		
Ga																		
Ge ppb																		
As																		
Se																		
Rb																		
Sr																		
Y																		
Zr	170	(a)										35	(a)					
Nb																		
Mo																		
Ru																		
Rh																		
Pd ppb																		
Ag ppb																		
Cd ppb																		
In ppb																		
Sn ppb																		
Sb ppb																		
Te ppb																		
Cs ppm																		
Ba	140	(a)							190			40	(a)					174
La	16.9	(a)							20.7			2.1	(a)					10.27
Ce	44	(a)							49			6	(a)					23.4
Pr																		
Nd	28	(a)							34			4	(a)					
Sm	7.6	(a)							10.5			1.1	(a)					4.43
Eu	1.13	(a)							1.4			0.96	(a)					1.15
Gd																		
Tb	1.4	(a)							1.4			0.2	(a)					0.94
Dy	9.2	(a)										1.5	(a)					
Ho																		
Er																		
Tm																		
Yb	5.3	(a)							6.7			1	(a)					3.02
Lu	0.77	(a)							1			0.14	(a)					0.43
Hf	5	(a)							6.3			0.85	(a)					3.21
Ta	0.65	(a)							0.7			0.12	(a)					0.35
W ppb																		
Re ppb																		
Os ppb																		
Ir ppb	9	(a)																
Pt ppb																		
Au ppb	8	(a)																
Th ppm	2.7	(a)							4.1			0.3	(a)					2.34
U ppm	0.8	(a)																0.52

technique: (a) INAA, (b) broad beam e. probe

Table 3b. Chemical composition of rake samples (cont.).

	60629		60635		60636		60636		60639a	60657	60659	
reference	Morris 86		Dowty74		Laul73		Murali 76			Morris 86	Warner76	
weight	See 86						Warner76		Dowty74	See 86		
SiO2 %	45.54	(b)	45.8	(b)			48	(b)		45.77	44.3	(b)
TiO2	0.3		0.34	(b)	1.1	(a)	0.93	(b)	*see*	0.54	0.02	(b)
Al2O3	28.4		27.6	(b)	20.3	(a)	24.2	(b)	*sample*	27.41	35.4	(b)
FeO	4.24		4.7	(b)	9.2	(a)	6.2	(b)		5.07	0.3	(b)
MnO			0.04	(b)	0.112	(a)	0.07	(b)				
MgO	5.18		4.1	(b)	10	(a)	6.1	(b)		6.53	0.21	(b)
CaO	16.28		15.8	(b)	11.3	(a)	13.9	(b)		15.06	19.3	(b)
Na2O	0.63		0.54	(b)	0.57	(a)	0.79	(b)		0.51	0.43	(b)
K2O	0.08		0.09	(b)	0.4	(a)	0.73	(b)		0.15		
P2O5			0.09	(b)			0.4	(b)			0.03	(b)
S %												
sum			99				101				100	
Sc ppm	6.15	(a)			15	(a)				6.74		
V					35	(a)						
Cr	776				1430	(a)				588		
Co	66				33	(a)				44		
Ni	1321				420	(a)				730		
Cu												
Zn												
Ga												
Ge ppb												
As												
Se												
Rb												
Sr												
Y												
Zr					470	(a)						
Nb												
Mo												
Ru												
Rh												
Pd ppb												
Ag ppb												
Cd ppb												
In ppb												
Sn ppb												
Sb ppb												
Te ppb												
Cs ppm												
Ba	174				320	(a)				148		
La	10.27				63	(a)				16.1		
Ce	23.4				165	(a)				45.4		
Pr												
Nd					100	(a)						
Sm	4.43				27	(a)				6.87		
Eu	1.15				3.71	(a)				1.22		
Gd												
Tb	0.94				5.5	(a)				1.35		
Dy					30	(a)						
Ho												
Er												
Tm												
Yb	3.02				16	(a)				4.46		
Lu	0.43				2.3	(a)				0.67		
Hf	3.21				13	(a)				4.83		
Ta	0.35				1.6	(a)				0.65		
W ppb												
Re ppb												
Os ppb												
Ir ppb												
Pt ppb												
Au ppb												
Th ppm	2.34				5.2	(a)				3.41		
U ppm	0.52				1.6	(a)				0.86		

technique: (a) INAA, (b) broad beam e. probe

Table 3c. Chemical composition rake samples (cont.)

	60665	60666	60666	60666	60666		60676	60677	
reference		Wasson77		melt	glass			Warner76	
weight	See 86		Dowty74		Morris 86		Warner76		
SiO2 %	Morris 86		42.7	45.1	45.05	(b)	46.4	44.3	(b)
TiO2	*see*	0.5	0.21	0.27	0.45	(b)	0.7	0.04	(b)
Al2O3	*sample*	29.66	20.8	18.9	25.7	(b)	23.5	34.2	(b)
FeO		5.56	4.2	5	5.82	(b)	6.7	1.04	(b)
MnO		0.07	0.05	0.05		(b)	0.07	0.01	(b)
MgO		6.47	18.6	19	8.12	(b)	9.7	1.4	(b)
CaO		15.54	11.7	11	14.2	(b)	13.8	18.3	(b)
Na2O		0.47	0.39	0.36	0.53	(b)	0.55	0.56	(b)
K2O		0.084	0.1	0.11	0.11	(b)	0.18	0.03	(b)
P2O5			0.04	0.06		(b)	0.24	0.03	(b)
S %									
sum							102	100	
Sc ppm		6.5			6.14	(a)			
V		27				(a)			
Cr		820			784	(a)			
Co		53			50	(a)			
Ni		800			938	(a)			
Cu									
Zn		5.7				(a)			
Ga		3.6				(a)			
Ge ppb		530				(a)			
As									
Se									
Rb									
Sr									
Y									
Zr		204				(a)			
Nb									
Mo									
Ru		46				(a)			
Rh									
Pd ppb									
Ag ppb									
Cd ppb		17				(a)			
In ppb		7.6				(a)			
Sn ppb									
Sb ppb									
Te ppb									
Cs ppm									
Ba		132			117	(a)			
La		11.4			10.58	(a)			
Ce		28			29.7	(a)			
Pr									
Nd		19				(a)			
Sm		4.9			5.01	(a)			
Eu		1.2			1.05	(a)			
Gd									
Tb		1.02			0.96	(a)			
Dy		7.4				(a)			
Ho									
Er									
Tm									
Yb		3.6			3.23	(a)			
Lu		0.49			0.47	(a)			
Hf		3.8			3.2	(a)			
Ta		0.39			0.4	(a)			
W ppb									
Re ppb									
Os ppb									
Ir ppb		28				(a)			
Pt ppb									
Au ppb		9				(a)			
Th ppm		1.69			1.38	(a)			
U ppm		0.48			0.55	(a)			

technique: (a) INAA, (b) broad beam e. probe

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