A NEW ESTIMATE OF THE COMPOSITION OF THE FELDSPATHIC UPPER CRUST OF THE MOON. Randy L. Korotev, Department of Earth and Planetary Sciences, Campus Box 1169, Washington University, St. Louis, MO 63130 (rlk@levee.wustl.edu)

Introduction: Previous estimates for the composition of the feldspathic upper crust (FUpCr) of the Moon have been based on results of the Apollo X-ray and gamma-ray (AGRE) experiments and interelement correlations among Apollo samples [1–3]. Lunar meteorites provide an independent estimate [4–7]. Dar al Gani (DaG) 262 [8] is now the fifth lunar meteorite that represents regolith from the "Feldspathic Highlands Terrane" [9]. Like ALHA81005, Yamato 86032, MAC88105, and QUE93069, it appears to be virtually uncontaminated [8] with mare-derived material or KREEP-rich material from the "Procellarum KREEP Terrane," i.e., the unique, mafic, Th-rich province in the Imbrium-Procellarum area [10–13].

Method: Mean concentrations of all nongaseous chemical elements that have been reported for the five FLMs (feldspathic lunar meteorites) were calculated (Table 1). Y82192/3, which is probably paired with Y86032, was excluded because it appears to contain mare-derived material [7]. The treatment presumes that DaG 262 is not source-crater paired with QUE-93069, a possibility that cannot be excluded based on composition or exposure history [8] despite that the meteorites were collected ~13,500 km apart. Unlike some previous averages [6,14], means were calculated by laboratory, not on a mass-weighted basis. Prior to calculating averages, concentrations of any 'missing' REEs (rare earth elements) were estimated based on chondrite-normalized abundances of other REEs. Means and 95% confidence limits (when $3 \le N \le 5$) are presented in Table 1. For several elements (Mo, In, Sn, Te, I, Tl, Pb), the "mean" is based on only one or two analyses or meteorites.

The FLMs are regolith or fragmental breccias from near the surface of the Moon [15] and, consequently, all are contaminated with meteoritic material, largely from micrometeorites. To obtain an estimate of the composition of the upper few kilometers of lunar crust uncontaminated by extralunar material (FUpCr), concentrations of each element (C_{FUpCr}) were calculated from the equation $C_{FLM} = f\,C_{CI} + (1-f)C_{FUpCr}$, where C_{CI} is the concentration in CI chondrites [16] and f is the mass fraction of meteoritic material. The value f was assumed to be 1.94%, the value that yields $C_{FUpCr} = 0$ for Ir. For most volatile and siderophile elements, this process yielded values of essentially zero (~0 in Table 1b). Data for some elements believed to be affected by terrestrial weathering in DaG 262 [8] were not included in the averages. Antarctic eucrites and FLMs (particularly DaG 262) have anomalously high Ce concentrations as a result of terrestrial weathering [17,18]. Thus for Ce, the FUpCr value is an estimate based on La, Nd, and Sm. Values in parentheses appear high compared to unbrecciated lunar rocks [19] and may also result from terrestrial contamination of the FLMs or inappropriateness of the meteorite correction.

Results: The composition obtained here is more feldspathic than previous estimates (Table 1a) and corresponds to about 78 wt.% plagioclase. The FeO concentration (4.2%), however, agrees well with the "farside mode" (4.4%) obtained from Clementine spectral data [20]. Among major elements, the most uncertain is MgO, which is ~2× greater in ALHA-81005 (8.2%) than in the other four FLMs (4.0–5.3%). The TiO_2 concentration (0.23%) is considerably lower than values obtained for farside highlands from the AGRE (~1%) [3,21]. Concentrations of incompatible elements in the estimate based on FLMs are about half those of Taylor [2] because those of Taylor [2] are based on an area-weighted average of 0.9 ppm Th for the highlands from the AGRE [22] and, thus, include regions contaminated by Th-rich Imbrium ejecta [10]. In contrast, the FLM's range from 0.2–0.6 ppm Th, consistent with values for the farside highlands obtained by the AGRE [23] and Lunar Prospector [10, 24].

Table 1a. Mean concentrations of major element oxides in five feldspathic lunar meteorites and estimates of the composition of the feldspathic upper crust of the Moon.

	feldspathic lunar meteorites (FLM)		feldspathic upper crust (FUpCr)		
%	mean	± 95%	**this work**	T82 [2]	K80 [3]
SiO_2	44.9	0.3	**45.3**	45	45.1
TiO_2	0.23	0.04	**0.23**	0.56	0.5
Al_2O_3	27.8	1.4	**28.4**	24.6	26.5
Cr_2O_3	0.100	0.019	**0.094**	0.10	0.122
FeO	4.6	0.6	**4.2**	6.6	5.1
MnO	0.065	0.007	**0.062**	–	0.071
MgO	5.4	1.9	**5.2**	6.8	6.4
CaO	16.3	1.0	**16.6**	15.8	15.5
Na_2O	0.35	0.06	**0.34**	0.45	0.44
K_2O	0.026	0.008	**0.026**	0.075	0.052
P_2O_5	0.034	0.018	**0.029**	–	–
Σ	99.9	0.3	**100.5**	100.0	100.0
Mg´	68	5	**69**	65	69
Fe/Mn	71	5	**68**	–	72

Table 1b.

	feldspathic lunar meteorites (FLM)		feldspathic upper crust (FUpCr)		
µg/g or %	mean	± 95%	**this work**	T82 [2]	K80 [3]
Li	~3	–	**~3**		
F	~40	–	**~40**		
Na, %	0.26	0.05	**0.25**	0.33	0.33
Mg, %	3.3	1.1	**3.1**	4.1	3.9
Al, %	14.7	0.8	**15.0**	13.0	14.0
Si, %	20.97	0.15	**21.17**	21.03	21.1
P	150	80	**130**		
Cl	230	270	**(~220)**		
K	220	60	**210**	600	430
Ca, %	11.7	0.7	**11.9**	11.3	11.1
Sc	8.3	0.6	**8.3**	10	10.3
Ti, %	0.14	0.02	**0.14**	0.34	0.3
V	24	5	**23**	24	26
Cr	680	130	**645**	680	833
Mn	510	50	**477**		548
Fe, %	3.6	0.4	**3.3**	5.13	4.0
Co	19	5	**10**	15	15
Ni	220	100	**5**	100	62
Zn	17	14	**(11)**		
Ga	3.7	0.7	**3.5**		
Ge	0.5	0.5	**~0**		
As	0.07	0.07	**~0**		
Se	0.26	0.13	**~0**		
Br	0.11	0.02	**0.04**		
Rb	0.8	0.6	**0.8**	1.7	1.0
Sr	154	18	**156**	120	164
Y	9	3	**9**		16
Zr	37	17	**37**		34
Nb	2	2	**~2**		
Mo	~0.9	–	**~0.9**		
Ag	0.002	–	**~0**		
Cd	0.016	0.007	**~0**		
In	~0.0015	–	**~0**		
Sn	~0.3	–	**~0.2**		
Sb	~0.002	–	**~0**		
Te	~0.01	–	**~0**		
I	~2	–	**(~2)**		
Cs	0.038	0.016	**0.035**	0.07	
Ba	34	11	**34**	66	39
La	2.4	1.0	**2.4**	5.3	3.2
Ce	6.3	2.5	**5.8**	12	9.1
Pr	0.8	0.3	**0.8**	1.6	
Nd	3.6	1.4	**3.7**	7.4	
Sm	1.1	0.4	**1.1**	2	1.66
Eu	0.79	0.10	**0.81**	1.0	1.08
Gd	1.3	0.5	**1.3**	2.3	
Tb	0.23	0.09	**0.24**	0.41	0.33
Dy	1.5	0.6	**1.5**	2.6	
Ho	0.34	0.11	**0.34**	0.53	
Er	1.0	0.3	**1.0**	1.51	
Tm	0.14	0.04	**0.14**	0.22	
Yb	0.9	0.3	**0.9**	1.4	1.24
Lu	0.13	0.04	**0.14**	0.21	0.20
Hf	0.8	0.3	**0.8**		1.2
Ta	0.11	0.04	**0.11**		0.22
W	0.2	0.2	**~0.2**		
Ir	0.009	0.006	**=0**		
Au	0.0033	0.0013	**0.0006**		
Tl	~0.002	–	**~0**		
Pb	0.8	0.4	**0.7**		
Bi	~0.0007	–	**~0**		
Th	0.39	0.18	**0.40**	0.9	0.54
U	0.12	0.07	**0.13**	0.24	0.18

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