

Supporting Information

Table S1: 76001.XLS: Results of INAA for samples from the 76001 drive tube

Table S2: Luna.XLS: Results of INAA for samples from Luna 16, 20, and 24

Table S3: model_components.xls: Compositions of model components

Mass-Balance Modeling

The mathematics of the least-squares mass-balance modeling are the same as that described in Korotev and Kremser (1992) and Korotev et al. (1995) with the following exceptions.

- (1) MnO, K₂O, and P₂O₅ were included.
- (2) Imprecisely determined Ta was excluded.
- (3) Mean compositions of most components were recalculated based on newer data, mostly that of Jolliff et al. (1996).
- (4) Sums were constrained to 100.0%

Components

Compositions and data sources of components are presented in Table S3.

Procedures

The least-squares mass balance calculation was done for each of the 5 tested AnNo (anorthositic norite) components (columns 9–13 of Table S3): lunar meteorite ALHA 81005, the AnNo component of Korotev and Kremser (1992), Apollo 17 ferroan granulitic breccia, Apollo 17 magnesian granulitic breccia, and mean typical feldspathic lunar meteorites. Tables S4 and S5 show examples of the model input and output using ALHA 81005 as the tested AnNo component. In this first set of calculations, TiO₂ concentrations were not used to constrain mass balance (WF(rel) of Table S4 was set to 5000) and the model results overestimate TiO₂ by 5–15% (mean: 9%, e.g., Table S5) presumably because the basalt component of the station-6 regolith has a lower TiO₂ concentration than the basalt component of the model (column 3 of Table S3). As noted in the main text, however, there is no petrographic justification for invoking a mare basalt component with a lower TiO₂ concentration.

For elements carried mainly by major mineral phases (Si, Al, Cr, Fe, Mn, Mg, Ca, Na, Sc, Sr, and Eu), the contributions from the MB, OG, NorBrx, Troct and Cl components were subtracted from the observed concentrations in the soils in the proportions predicted by each model result and the remaining mass normalized to 100%. This procedure leads to 5 different estimates of major element concentrations in the ideal AnNo component of the station 6 soil (Table S6). The procedure leads to negative values for TiO₂, however, because of the overestimation of TiO₂ issue of Table S5. Thus, TiO₂ concentration for each of the 5 AnNo compositions were instead estimated from FeO and Sc concentrations.

As an alternate approach to deal with the titanium problem, another set of 5 mass-balance calculations were done that (1) included ilmenite (Table S3 column 4) as a model component and (2) the WF(rel) value for TiO₂ of Table S4 was changed from 5000 to 1, i.e., TiO₂ was forced to fit within 1% of the observed concentration value. This procedure leads to % ilmenite components ranging from -0.5% using ferroan granulitic breccia to -1.1% for magnesian granulitic breccia. It also leads to 5 new

estimates of the ideal AnNo component of the station 6 regolith (Table S6). For all subsequent modeling, the mean of the 10 estimates was used (column 14 of Table S3 and “mean” of Table S6).

Incompatible elements cannot be accurately estimated by the technique described above because only about 10% (7–16%; Tables S7 and S8) of the incompatible elements are contributed by the AnNo component. Thus, for the incompatible elements (K₂O, P₂O₅, Zr, Ba, trivalent REE, Hf, Th, and U) the mean of the 5 AnNo tested components is used, i.e., the values of column 14 of Table S3 are the means of columns 9–13.

The “total feldspathic component” (Table 2 and Table S3 column 15) is estimated by combining 72.73% AnNo (Table S3 column 14) and 27.27% 76535 troctolite (Table S3 column 8), that is, the proportions of the results of Table S7.

	MB 92-08	OG	NorBrx stn 6	vf CI	troct 76535	ALHA 81005		soil station 6	WF (rel)	WF (abs)
SiOx	39.6	38.6	46.5	33.2	42.9	44.9		43.5	2	0.87
TiOx	11.38	8.76	1.52	0.10	0.05	0.27		3.34	5000	167
AlOx	9.08	6.53	18.20	2.40	20.70	25.81		18.23	2	0.36
CrOx	0.497	0.680	0.190	0.572	0.110	0.129		0.278	7	0.019
FeOx	18.71	22.20	9.00	34.61	4.99	5.47		10.71	4	0.43
MnOx	0.26	0.29	0.12	0.36	0.07	0.07		0.15	5	0.007
MgOx	8.67	14.39	11.70	23.77	19.10	8.20		10.83	4	0.43
CaOx	10.8	7.7	11.2	1.9	11.4	14.9		12.2	2	0.24
NaOx	0.375	0.366	0.667	0.976	0.220	0.303		0.403	7	0.028
KOx	0.058	0.077	0.270	0.100	0.029	0.024		0.116	20	0.023
POx	0.059	0.059	0.281	0.345	0.030	0.021		0.095	20	0.019
Sc	80.0	48.3	17.0	8.6	2.2	9.1		28.8	5	1.4
Co	21.1	61.5	28.0	751	48.0	21.0		32.0	40	13
Ni	5	113	240	15814	25	200		214	20	43
Sr	163	205	172	12	114	135		159	10	16
Zr	186	184	480	6	24	31		194	20	38.80
Ba	64	78	350	3.4	33	20		129	12	15.48
La	5.24	5.94	34.70	0.35	1.51	2.18		10.08	12	1.21
Ce	18.1	18.1	90.0	0.9	3.8	5.7		27.5	11	3.0
Sm	8.00	6.71	15.60	0.22	0.61	0.99		6.19	8	0.50
Eu	1.653	1.790	1.920	0.083	0.730	0.690		1.325	4	0.053
Tb	1.97	1.48	3.21	0.05	0.13	0.21		1.40	6	0.08
Yb	7.72	4.31	11.30	0.23	0.56	0.85		5.01	6	0.30
Lu	1.105	0.590	1.520	0.036	0.079	0.130		0.701	5	0.035
Hf	7.24	5.77	12.60	0.18	0.32	0.76		5.1	7	0.36
Ir	0.0	0.7	6.8	680	0.1	6.7		8.2	20	1.6
Au	0.0	0.3	3.6	213	0.1	2.2		3.5	20	0.7
Th	0.39	0.42	5.62	0.04	0.13	0.31		1.64	13	0.21
U	0.15	0.13	1.61	0.01	0.06	0.10		0.45	14	0.06
x	1	1	1	1	1	1		1	0.0001	0.0000

Table S4. Example of model input using the composition of lunar meteorite ALHA 81005 as the nominal anorthositic norite component. In words, the WF(rel) (relative weighting factor, Table S3 column 20) column says “Try to fit SiO₂ and Al₂O₃ to 2% of the value... P₂O₅ to 20% of the value, etc., but do not use

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TiO₂ to constrain the mass balance.” The bottom row labeled x is a mathematical trick to constrain the sum of oxides to 100%.

	<i>Mg'</i>	64.3	63.9					<i>fit for:</i>			
		observed	estimated	diff.	% diff.	e-diff.	e-diff ²	soil station 6		±	
									%		
1	SiOx	43.50	43.33	-0.17	-0.38	-0.19	0.04	1	MB 92-08	20.00	1.71
2	TiOX	3.34	3.65	0.31	9.21	0.00	0.00	2	OG	10.41	1.77
3	AlOx	18.23	18.12	-0.11	-0.62	-0.31	0.10	3	NorBrx stn 6	23.48	0.59
4	CrOx	0.278	0.275	-0.003	-1.02	-0.15	0.02	4	vf Cl	0.58	0.08
5	FeOx	10.71	10.82	0.11	1.01	0.25	0.06	5	troct 76535	8.16	1.96
6	MnOx	0.147	0.144	-0.003	-2.09	-0.42	0.17	6	ALHA 81005	37.37	1.82
7	MgOx	10.83	10.74	-0.09	-0.83	-0.21	0.04	7		0.00	0.00
8	CaOx	12.15	12.12	-0.03	-0.28	-0.14	0.02	8		0.00	0.00
9	NaOx	0.403	0.407	0.004	0.89	0.13	0.02	9		0.00	0.00
10	KOx	0.116	0.095	-0.021	-18.15	-0.91	0.82	10		0.00	0.00
11	POx	0.095	0.096	0.001	1.34	0.07	0.00	11		0.00	0.00
12	Sc	28.8	28.6	-0.2	-0.56	-0.11	0.01	12		0.00	0.00
13	Co	32.0	33.4	1.4	4.22	0.11	0.01		S	100.00	3.68
14	Ni	214	238	24	11.40	0.57	0.33				
15	Sr	159	154	-5	-3.02	-0.30	0.09		<i>N</i>	30	
16	Zr	194	183	-11	-5.83	-0.29	0.09		χ^2	5.63	
17	Ba	129	113	-16	-12.21	-1.02	1.04		χ^2/v	0.235	
18	La	10.08	10.75	0.67	6.65	0.55	0.31				
19	Ce	27.5	29.1	1.6	5.71	0.52	0.27				
20	Sm	6.19	6.38	0.19	3.08	0.39	0.15				
21	Eu	1.325	1.286	-0.040	-3.00	-0.75	0.56				
22	Tb	1.40	1.39	-0.01	-0.60	-0.10	0.01				
23	Yb	5.01	5.01	0.00	-0.01	0.00	0.00				
24	Lu	0.701	0.695	-0.006	-0.92	-0.18	0.03				
25	Hf	5.10	5.32	0.22	4.27	0.61	0.37				
26	Ir	8.2	8.2	0.0	-0.48	-0.02	0.00				
27	Au	3.5	3.0	-0.5	-15.61	-0.78	0.61				
28	Th	1.64	1.57	-0.07	-4.46	-0.34	0.12				
29	U	0.45	0.46	0.01	2.87	0.20	0.04				
30	x	1.00	1.00	0.00	0.00	0.54	0.30				
31	0	0.00	0.00	0.00	0.00	0.00	0.00				
32	0	0.00	0.00	0.00	0.00	0.00	0.00				
							5.63				

Table S5. Example of model output for the data of Table S4. “Observed” is the data of Table S3 column 16 (mean composition of the station 6 surface and trench soils). The e-diff. column is the %diff. column divided by the corresponding WF (rel) value of Table S4. The sum of the e-diff.² values, χ^2 , is the quantity minimized (“least-squares”). Note the 9.2% overestimate for TiO₂.

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	Estimate TiO ₂ from Fe and Sc					With ilmenite component					mean	SD	RSD	95%	min	max
	ALHA 81005	AnNo K&K	Fe GrBrx	Mg GrBr	TypFLM 2021	ALHA 81005	AnNo K&K	Fe GrBrx	Mg GrBr	TypFLM 2021						
SiO _x	44.95	45.24	45.34	45.20	45.88	44.49	44.89	45.03	44.63	44.96	45.06	0.39	0.9%	0.28	44.49	45.88
TiO _x	0.256	0.308	0.338	0.236	0.190	0.264	0.334	0.340	0.235	0.176	0.268	0.060	22.6%	0.043	0.176	0.340
AlO _x	25.86	25.54	26.08	25.96	28.96	26.13	25.78	26.30	26.27	29.55	26.64	1.40	5.3%	1.00	25.54	29.55
CrO _x	0.135	0.161	0.153	0.123	0.100	0.123	0.151	0.145	0.109	0.077	0.128	0.027	20.9%	0.019	0.077	0.161
FeO _x	5.13	5.86	5.89	5.08	3.66	5.49	6.07	6.11	5.61	4.50	5.34	0.78	14.5%	0.56	3.66	6.11
MnO _x	0.079	0.090	0.091	0.078	0.065	0.080	0.090	0.091	0.080	0.069	0.081	0.009	11.4%	0.007	0.065	0.091
MgO _x	8.36	7.49	6.36	8.09	4.33	8.25	7.42	6.28	7.87	3.92	6.84	1.60	23.4%	1.14	3.92	8.36
CaO _x	14.88	14.93	15.35	14.82	16.44	14.83	14.87	15.31	14.78	16.40	15.26	0.64	4.2%	0.46	14.78	16.44
NaO _x	0.291	0.318	0.326	0.332	0.309	0.285	0.314	0.323	0.325	0.298	0.312	0.016	5.1%	0.011	0.285	0.332
Sc	9.4	11.9	14.1	8.1	7.3	9.3	11.2	13.7	8.5	7.9	10.1	2.5	24.2%	1.8	7.3	14.1
Co	17.2	11.4	16.0	24.7	-0.1	16.7	11.2	15.8	23.8	-1.9	13.5	8.8	65.4%	6.3	-1.9	24.7
Ni	133	48	265	357	77	131	47	264	355	69	175	124	71.1%	89	47	357
Sr	146	156	153	146	154	143	153	151	141	146	149	5	3.4%	4	141	156
Eu	0.79	0.90	0.86	0.83	0.75	0.75	0.87	0.83	0.78	0.66	0.80	0.07	8.9%	0.05	0.66	0.90
Ir	6.7	2.8	12.7	16.2	5.2	6.7	2.8	12.7	16.2	5.0	8.7	5.2	60.3%	3.8	2.8	16.2
Au	3.6	2.5	5.7	6.7	3.8	3.6	2.6	5.7	6.7	3.8	4.5	1.6	35.9%	1.1	2.5	6.7
Σ	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00					
Mg'	74.4	69.5	65.8	74.0	67.9	72.8	68.5	64.7	71.4	60.8	69.0	4.4	6.3%	3.1	60.8	74.4

Table S6. Ten estimates of the major- and siderophile-element composition of the anorthositic norite component of the station-6 regolith. Note that the high relative uncertainties for FeO, MgO, and Mg' are in part an artifact of having included the typical feldspathic lunar meteorite (FLM) component, which is substantially more feldspathic than the other 4 components tested.

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<i>Mg'</i>	64.3	64.0					<i>fit for:</i>			
	observed	estimated	diff.	% diff.	e-diff.	e-diff^2	soil station 6		±	
SiOx	43.50	43.25	-0.25	-0.58	-0.29	0.08	1	MB 92-08	19.94	1.07
TiOx	3.34	3.65	0.31	9.26	0.00	0.00	2	OG	10.81	1.1
AlOx	18.23	18.22	-0.01	-0.08	-0.04	0.00	3	NorBrx stn 6	22.11	0.37
CrOx	0.278	0.275	-0.003	-1.11	-0.16	0.03	4	vf CI	0.53	0.05
FeOx	10.71	10.75	0.04	0.37	0.09	0.01	5	76535 Tr	12.71	1.08
MnOx	0.147	0.147	0.000	-0.17	-0.03	0.00	6	NoAn stn 6	33.90	1.02
MgOx	10.83	10.74	-0.09	-0.80	-0.20	0.04	7		0.00	0.00
CaOx	12.15	12.10	-0.05	-0.44	-0.22	0.05	8		0.00	0.00
NaOx	0.403	0.401	-0.002	-0.55	-0.08	0.01	9		0.00	0.00
KOx	0.116	0.099	-0.017	-14.87	-0.74	0.55	10		0.00	0.00
POx	0.095	0.096	0.001	1.24	0.06	0.00	11		0.00	0.00
Sc	28.8	28.7	-0.1	-0.40	-0.08	0.01	12		0.00	0.00
Co	32.0	31.7	-0.3	-0.83	-0.02	0.00		S	100.00	2.17
Ni	214	213	-1	-0.37	-0.02	0.00				
Sr	159	158	-1	-0.78	-0.08	0.01		<i>N</i>	30	
Zr	194	179	-15	-7.69	-0.38	0.15		χ^2	2.22	
Ba	129	118	-11	-8.57	-0.71	0.51		χ^2/v	0.092	
La	10.08	10.53	0.45	4.51	0.38	0.14				
Ce	27.5	28.3	0.8	2.88	0.26	0.07				
Sm	6.19	6.26	0.07	1.16	0.14	0.02				
Eu	1.325	1.313	-0.012	-0.93	-0.23	0.05				
Tb	1.40	1.39	-0.01	-1.04	-0.17	0.03				
Yb	5.01	4.98	-0.03	-0.69	-0.12	0.01				
Lu	0.701	0.700	-0.001	-0.12	-0.02	0.00				
Hf	5.10	5.26	0.16	3.09	0.44	0.19				
Ir	8.2	8.2	0.0	-0.23	-0.01	0.00				
Au	3.5	3.5	0.0	-0.02	0.00	0.00				
Th	1.64	1.59	-0.05	-2.89	-0.22	0.05				
U	0.45	0.48	0.03	6.24	0.45	0.20				
x	1.00	1.00	0.00	0.00	-0.05	0.00				
0	0.00	0.00	0.00	0.00	0.00	0.00				
0	0.00	0.00	0.00	0.00	0.00	0.00				
						2.22				

Table S7. Like Tables S4 and S5 but using the estimated mean composition of the noritic anorthosite component of the station-6 soil (Table S6) as the noritic anorthosite component. Again, note the 9.3% overestimation of TiO₂.

	MB 92-08	OG	NorBrx stn 6	vf Cl	76535 Tr	NoAn stn 6	Σ
SiOx	18.1	9.6	23.6	0.4	12.5	35.1	99.4
TiOx	67.9	28.4	10.1	0.0	0.2	2.7	109.3
AlOx	9.9	3.9	22.1	0.1	14.4	49.5	99.9
CrOx	35.7	26.4	15.1	1.1	5.0	15.6	98.9
FeOx	34.8	22.4	18.6	1.7	5.9	16.9	100.4
MnOx	35.1	21.1	17.9	1.3	5.6	18.8	99.8
MgOx	16.0	14.4	23.9	1.2	22.4	21.4	99.2
CaOx	17.7	6.8	20.5	0.1	11.9	42.6	99.6
NaOx	18.6	9.8	36.6	1.3	6.9	26.2	99.4
KOx	10.0	7.2	51.5	0.5	3.2	12.9	85.1
POx	12.4	6.7	65.4	1.9	4.0	10.7	101.2
Sc	55.3	18.1	13.0	0.2	1.0	11.9	99.6
Co	13.1	20.8	19.3	12.5	19.1	14.3	99.2
Ni	0.5	5.7	24.8	39.5	1.5	27.7	99.6
Sr	20.5	13.9	23.9	0.0	9.1	31.7	99.2
Zr	19.2	10.3	54.7	0.0	1.6	6.6	92.3
Ba	9.9	6.5	60.0	0.0	3.3	11.8	91.4
La	10.4	6.4	76.1	0.0	1.9	9.7	104.5
Ce	13.1	7.1	72.3	0.0	1.8	8.5	102.9
Sm	25.8	11.7	55.7	0.0	1.3	6.7	101.2
Eu	24.9	14.6	32.0	0.0	7.0	20.5	99.1
Tb	28.1	11.4	50.7	0.0	1.2	7.5	99.0
Yb	30.7	9.3	49.9	0.0	1.4	8.0	99.3
Lu	31.4	9.1	47.9	0.0	1.4	9.9	99.9
Hf	28.3	12.2	54.6	0.0	0.8	7.1	103.1
Ir	0.0	0.9	18.3	44.3	0.2	36.0	99.8
Au	0.1	0.9	22.7	32.5	0.4	43.4	100.0
Th	4.7	2.8	75.8	0.0	1.0	12.9	97.1
U	6.5	3.1	79.1	0.0	1.6	15.9	106.2

Table S8. Fraction (%) of element contributed by each component from the results of Table S7. Note that for incompatible elements (orange), only ~10% is contributed by the AnNo (anorthositic norite) component. The NorBrx and AnNo components carry a substantial fraction of the siderophile elements.

References

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