LUNAR HIGHLAND COMPOSITION; S. R. Taylor, M. Gorton, P. Muir, W. Nance, R. Rudowski and N. Ware, Research School of Earth Sciences, Australian National University, Canberra, Australia, and The Lunar Science Institute, Houston, Texas, 77058.

The good positive correlations between elements of diverse geochemical character for the Apollo 14-17 highlands samples are shown in Figure 1. These correlations allow extrapolation from the orbital gamma ray values for thorium to obtain abundances for most other trace elements at any given highland site. Extrapolation from the orbital XRF Al/Si and Si/Mg ratios, using interelement correlations allow a complete element abundance pattern to be built up.

An average highland composition, based on data from Table 1 and earlier results (1) is given in Table 1, Col. 1. (Al/Si = 0.60, and Th = 1.8 ppm). The element abundances in the highland breccias can be represented by a four component system, with end members of (1) Anorthosite (An) (2) Anorthositic gabbro or Highland basalt (HB) (3) High-Al basalt or low-K Fra Mauro basalt (LKFM) (4) Norite, KREEP Basalt or Medium K Fra Mauro basalt (MKFM). Gabbroic anorthosite, spinel troctolite, and High-K Fra Mauro basalt do not appear as abundant constituents.

The average highland composition proposed from the orbital data, when tested against these components in a mixing model is equivalent to 70% anorthositic gabbro (Highland basalt) and 30% High-Al basalt or low K Fra Mauro basalt. These two constituents appear to be the most important components of the highlands crust. Their normative mineralogy is dominated by plagioclase (70 and 53% respectively), orthopyroxene (20 and 30%) and olivine (9 and 10%). LKFM has 9% clinopyroxene (2).

The rare earth data is shown in Figure 2. Note that the average highland composition does not have a significant Eu anomaly. The trace element abundances do not allow a simple relationship between the various major compositions by fractional crystallization models involving addition or removal of major mineral phases. The highland compositions contain a number of seemingly incompatible geochemical features. These include high Cr and Mg, indicating an unfractionated component, high Ca and Al indicating plagioclase separation, and a third group of incompatible trace elements K, Rb, Be, Zr, REE, U, Th, Nb which are not readily accommodated in plagioclase, olivine or orthopyroxene lattice sites. The high concentrations (50-100X chondrites) indicate extensive fractionation or concentration by condensation processes.

The orbital XRF and gamma ray data show many variations across the highlands (3). These do not correlate with geological units such as the Cayley Formation (4). Evidently the intense early cratering did not homogenize the highland crust, and thus lateral transport of ejecta on a scale of a few hundred kilometers is not an efficient process. On this interpretation, Al/Si ratios represent initial crustal heterogeneity. A model to account for the geochemical characteristics of the highland crust, which contains such diverse geochemical features as high Mg, Cr, Al, Ca, Eu and KREEP components is presented in this volume (5).

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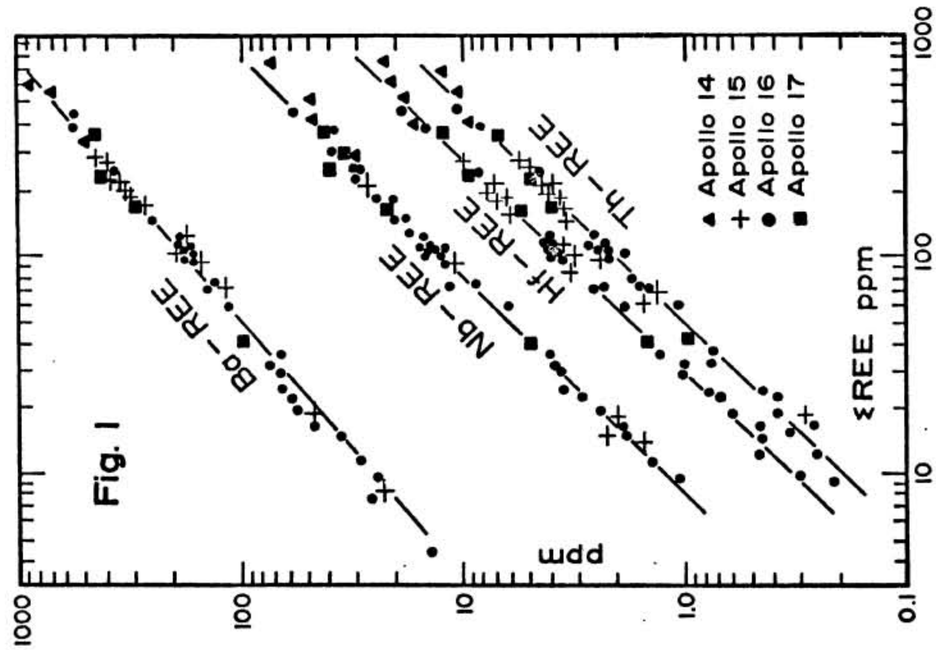

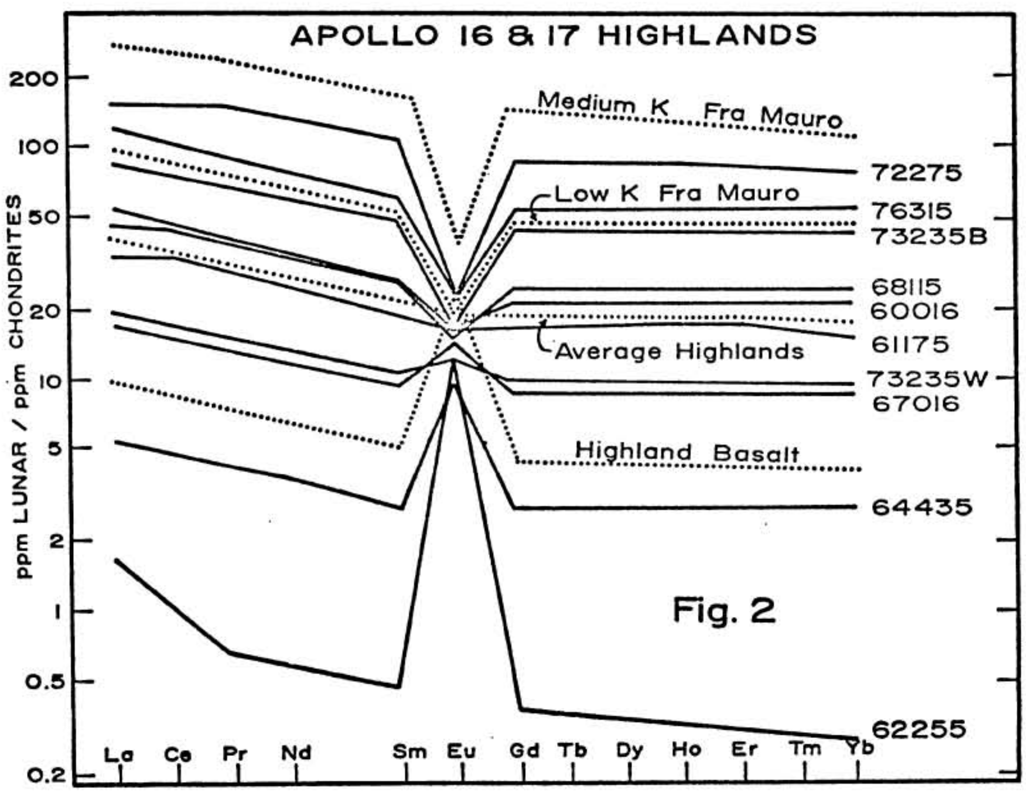

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3. Adler I. et al. (1973) Proc. 4th Conf. 2783, Metzger A. F. Science, 179, 800.
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	Average Highland	72275 108	76315 75	73235 black	73235 white	68115 80	60016 67	67016 63	64435 40	61175 80	62255 20
SiO_2	45.0	48.5	46.9	46.4	44.2	44.8	45.0	44.9	44.5	43.9	44.1
TiO_2	0.50	0.95	1.46	0.63	-	0.34	0.29	0.22	-	0.05	-
Al_2O_3	24.5	17.2	18.7	21.2	23.1	27.6	28.2	30.1	30.8	35.2	35.3
FeO	6.0	11.4	8.55	7.33	5.06	5.10	4.28	3.45	3.13	0.41	0.20
MgO	8.0	8.94	11.5	10.7	14.0	5.79	5.51	3.70	3.38	0.83	0.37
CaO	15.0	11.6	11.4	12.5	12.7	15.4	15.9	16.8	17.4	18.9	19.1
Na_2O	0.45	0.40	0.56	0.47	0.30	0.47	0.43	0.47	0.39	0.41	0.49
K_2O	0.11	0.25	0.34	0.18	0.06	0.06	0.10	0.06	0.02	0.06	0.09
Cs	0.1	0.31	0.23	0.15	-	0.13	0.10	0.04	0.02	0.07	-
Rb	2.3	6.1	6.4	3.1	-	2.6	1.91	0.71	0.39	1.28	-
Ba	150	440	460	315	100	173	173	69	28	125	14.6
Pb	1.7	4.0	4.3	3.0	1.2	3.5	2.4	0.8	2.1	2.3	0.6
La	11	42.9	32	24	5.31	14.3	13.3	4.52	1.54	9.26	0.46
Ce	31	114	88	61	13.3	38.8	38.4	12.1	3.99	25.2	0.72
Pr	4.0	17	10.9	7.92	1.76	4.95	4.95	1.54	0.47	3.51	0.07
Nd	15	73	42.4	33.5	7.33	20.0	19.2	6.25	1.95	13.8	0.32
Sm	4.5	21.3	11.5	8.95	2.17	5.48	5.21	1.82	0.53	3.90	0.11
Eu	1.5	1.57	1.64	1.20	0.79	0.99	1.17	1.00	0.68	1.12	0.80
Gd	5.4	24.4	15.3	12.1	2.73	6.96	6.34	2.42	0.72	5.01	0.10
Tb	0.85	3.86	2.49	1.88	0.48	1.09	0.99	0.37	0.13	0.78	-
Dy	5.4	24.4	15.9	11.9	2.97	7.13	6.20	2.51	0.80	5.30	-
Ho	1.3	5.85	3.85	2.85	0.67	1.71	1.52	0.59	0.19	1.24	0.02
Er	3.6	15.8	10.6	8.15	1.85	4.90	4.28	1.66	0.53	3.50	0.06
Tm	0.5	2.1	1.6	1.2	0.28	0.75	0.65	0.26	0.087	0.50	-
Yb	3.4	13.9	9.70	7.47	1.72	4.53	3.94	1.60	0.53	3.01	0.06
Lu	0.4	2.1	1.5	1.2	0.27	0.70	0.61	0.25	0.082	0.47	-
Σ REE	88	362	247	183	41.6	112	107	36.9	12.2	76.6	$\sim$2.9
Y	31	160	105	85	18	45	42	15	4.53	30	-
Th	1.8	6.70	5.7	4.3	1.0	2.66	2.10	0.73	0.23	1.56	-
U	0.5	1.70	1.51	1.1	0.27	0.74	0.51	0.17	0.12	0.35	-
Zr	150	485	450	350	85	191	158	48	17	109	0.45
Hf	3.0	13.3	10.5	6.5	1.53	4.12	3.59	1.36	0.52	2.38	-
Nb	11	31	33	21.5	5.2	11.8	12.0	4.12	1.38	8.1	0.15
Cr	680	2800	3200	1500	600	660	-	-	-	-	17
V	25	115	45	58	33	24	29	23	22	24	7
Sc	11	48	19	17	5	9	10	10	7	10	-
Ni	-	120	210	250	28	2000	330	110	56	200	-
Co	-	33	17	33	17	105	28	15	26	16	-
Cu	-	5	3	3	1	17	6	3	4	9	<1

DATA FOR FIRST EIGHT ELEMENTS IN WT.% (E.PROBE) OTHER DATA IN PPM (SPARK SOURCE MASS SPEC)