LUNAR HIGHLANDS BRECCIA 81005 (ALHA): SO APOLLO 18 FLEW, BUT WHERE DID IT SAMPLE? Randy L. Korotev, Larry A. Haskin, and Marilyn M. Lindstrom, Dept. of Earth and Planetary Sciences and the McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130.

Seven subsamples of meteorite ALHA81005 totaling 78 mg were analyzed by INAA for 33 elements (Table 1). Two are primarily (>80%) white lithology (samples 1A,3A), four primarily (>90%) dark (samples 2M1,2M2,3M1,3M2), and one is residue (3R). Compositions of all seven are similar, with subtle differences between dark and light lithologies. ALHA81005 has a characteristic lunar highlands composition including high concentrations of Al and Ca and, relatively, Cr; low concentrations of Na and K; and interelement ratios and relative REE abundances unlike those of other meteorites and typical terrestrial rocks.

In bulk composition ALHA81005 resembles many lunar breccias and soils of anorthositic norite composition, but is slightly less rich in Na, much less in Ti, and very much less in K and the large ion lithophile elements (LILE) associated with KREEP. The closest matches for the major elements (ME) are certain Apollo 16 VHA impact melts (e.g., 60018, 60335, and 61016 [see 14]) and some "anorthositic gabbro" clasts from Apollo 17 breccias (e.g., 72235,36 [1], 77017,57 [9], and 76315,62 [13]). However, ALHA81005 has lower concentrations of Na (0.7±0.3x), Ti (~0.35x), and LILE (Sm, 0.07-0.6x). In ME composition, ALHA81005 also resembles soils from Apollo 16 station 5 and 6 [5], but has less Na, Ti, K, and LILE, slightly less Al, and 1.4x more Mg. Polymict highlands rocks with comparable LILE concentrations are more anorthositic (e.g., 64435 and 67455 [12,10]). The pristine samples closest in ME composition to ALHA81005 are anorthositic norites 67215 [11,16] and 15565,113 [19] and troctolites 73235,127 [18] and 76255,58 [17]. All but 76255 also have low LILE concentrations.

Relative LILE concentrations in ALHA81005 resemble those of many lunar highlands samples that have little or no KREEP (Fig. 1). The magnitude of the Eu anomaly is in the narrow range characteristic of highlands samples with similar REE concentrations, a strong geochemical argument for a lunar origin. Among meteorites, only the Moore Co. eucrite has similar overall REE concentrations and Eu anomaly, but the chondrite normalized concentrations increase slightly with atomic number unlike most lunar patterns [15]; Moore Co. ME are unlike those of ALHA81005.

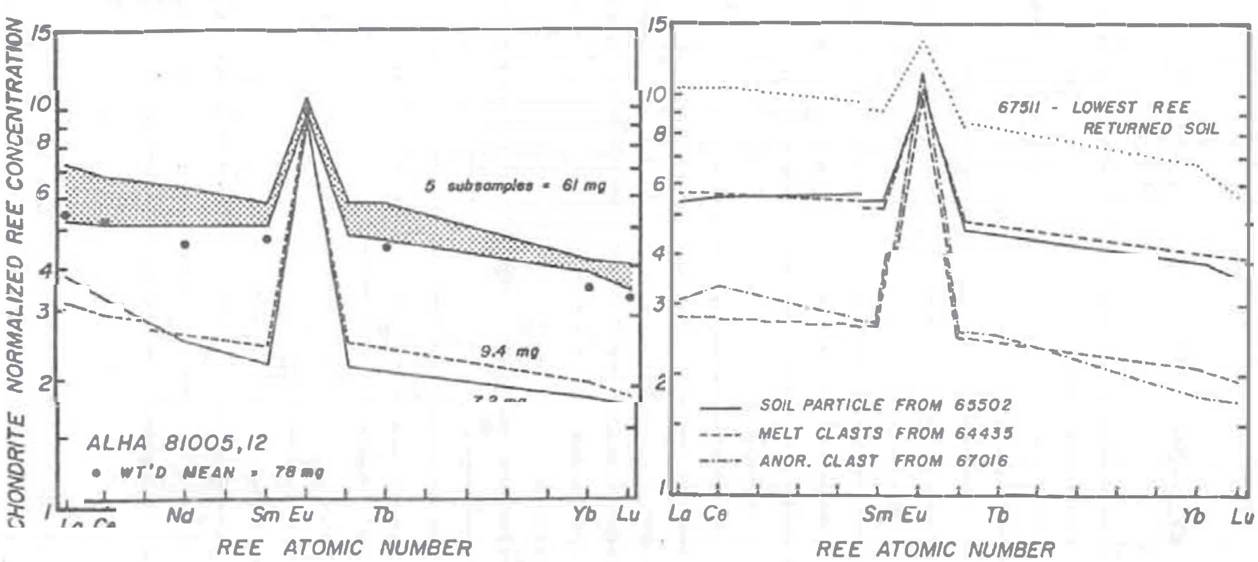
Nearly all lunar samples with LILE concentrations as low as ALHA81005 are more anorthositic. Polymict lunar samples with similar ME concentrations are much richer in LILE. KREEP-poor, polymict, anorthositic norites (gabbros) are rare in the lunar collection, but they could be a predominant rock type in areas uncontaminated by KREEP.

ALHA81005 represents a new highlands sampling site. Detailed study will give insight into types and compositions of endogenous highlands rocks and the importance of materials like KREEP and anorthosite. ME concentrations of light and dark lithologies are similar but differences in LILE are substantial, with the light material slightly poorer in Fe, Sc, and Co and much poorer in Ti, K and LILE, but slightly richer in Mg, Na, and Cr and much richer in Br. Ni and Ir concentrations are consistent with a 1-2% chondritic meteorite component, typical of polymict highlands materials. There is no difference in Al concentration between the light and dark samples, yet Fe and Sc differ by 24% and the REE by 200%. Hence the light material is not dark material plus anorthosite. Nor is the dark material simply white material plus KREEP. Only 1% KREEP would be needed to account for the LILE, yet Mg and Cr, which have similar concentrations in KREEP and ALHA 81005, are 24% and 12% more enriched in the light samples compared to the dark. The two lithologies represent different but similar mixtures with overall anorthositic norite compositions.

The variety of clasts [2,20, U. Marvin, pers. comm.] suggests that ALHA81005 was once a soil. ALHA81005 is more similar than sampled soils to typical lunar highlands as estimated from data from the Apollos 15 and 16 orbiting gamma-ray experiments [4]. Its Th concentration is lower (0.5x) and its TiO_2 concentration much lower (0.15x), raising further question about the accuracy of the gamma-ray data for Ti [4,8]. The gamma-ray experiment indicated that KREEP is principally a lunar nearside phenomenon. KREEP-free ALHA81005 may be our most representative sample of typical lunar highlands surface material and may even have come from Moon's farside!

References. [1]Blanchard D.P. et al. (1975) Moon, 359-372. [2]Drake M.J. (1983) this volume. [3]Govindaraju K. (1980) Geostandards Newslet., 49-138. [4]Haskin L.A. and Korotev R.L. (1981) PLPSC12, 791-808. [5]Korotev R.L. (1981) PLPSC12, 577-605. [6]Korotev R.L. (1982) PLPSC13, A269-A278. [7]Korotev R.L. (1983) 65502, this volume. [8]Korotev R.L., Haskin L.A., and Lindstrom M.M. (1980) PLPSC11, 395-429. [9]Laul J.C., Hill D.W., and Schmitt R.A. (1974) PLSC5, 1047-1066. [10]Lindstrom M.M. and Salpas P.A. (1981) PLPSC12, 305-322. [11]Lindstrom M.M. and Salpas P.A. (1983) PLPSC13, A671-A683. [12]Lindstrom M.M. and Salpas P.A. (1983) Dimict breccias, this volume. [13]Rhodes J.M. et al. (1974) PLSC5, 1097-1117. [14]Ryder G. and Norman M.D. (1980) Catalog of Apollo 16 Rocks, JSC 16904. [15]Schnetzler C.C. and Philpotts J.A. (1969) In Meteorite Research, P.M. Millman ed., p. 206-216, Reidel. [16]Taylor G.J. (1982) Abstract in LPSXIII, 798. [17]Warren P.H. and Wasson J.T. (1978) PLPSC9, 185-217. [18]Warren P.H. and Wasson J.T. (1979) PLPSC10, 583-610. [19]Warren P.H. et al. (1981) PLPSC12, 21-40. [20]Warren P.H., Taylor G.J., and Keil K. (1983) this volume.

Figure 1. Comparison of REE concentrations in ALHA81005 with those for some lunar samples [6,7,10,11].



COMPOSITION OF ALHA81005

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Table 1. Element concentrations in seven small samples of ALHA 81005,12 (along with the mass weighted means) and some standard rocks. Values in μg/g, except Ir in ng/g and oxides in % (total element as oxide).

Sample Designation	ALHA 81005 1A	3A	2M1	3M2	2M2	3M1	3R	±1	wt'd mean	Standard Materials BCR-1	DTS-1	AN-G	AN-G lit.	Flyash
TiO_2	<0.3	<0.3	0.27	0.24	0.37	0.30	0.23	0.10	0.23	2.5 .2	<0.3	0.26 .10	0.22	1.4 .2
Al_2O_3	25.1	24.7	24.8	25.7	26.6	24.6	24.8	0.3	25.1	13.6 .2	0.2 .1	---	29.8	27.0 .4
FeO_t	4.80	4.96	5.52	5.52	5.80	5.79	6.02	0.15	5.53	12.3 .3	8.06 .22	3.00 .08	3.02	12.23
MgO	9.7	11.0	7.3	8.6	8.5	8.9	9.2	1.5	8.8	4.7 1.2	56 3	3.0 1.2	1.8	<2.
CaO	14.6	14.5	15.4	14.9	15.3	15.0	14.6	0.3- 0.4	14.9	8.2 .3	---	15.9	15.9	2.25 .15
Na_2O	0.360	0.337	0.309	0.316	0.313	0.311	0.322	0.005	0.321	3.20 .06	0.015 .002	1.644	1.63	0.240 .010
K_2O	<0.03	<0.05	<0.12	<0.10	0.02	0.02	<0.08	0.01- 0.02	<0.04	1.5 .3	---	---	0.13	2.27
Sc	7.36	7.57	9.42	8.67	9.90	9.35	8.78	0.08	8.81	32.4 .3	3.44 .03	10.05 .10	10	38.6
V	25	22	21	22	24	25	21	6	23	380 50	10 2	---	70	260 30
Cr	945	995	870	865	870	870	915	10	900	10.8 .4	4250	46.3 .5	50	188 2
Mn	600	620	590	600	620	660	640	50	620	1400	820 30	380 40	300	230 30
Co	18.3	19.0	20.3	23.3	22.0	23.4	29.4	0.5	22.5	38.2 .8	143 3	25.1 .6	25	44.1
Ni	228	204	180	274	170	242	374	10- 15	243	<60	2410	40 11	35	132 30
Br	0.67	0.53	0.14	0.34	0.19	0.24	0.36	0.04- 0.08	0.33	---	---	3.59 .22	---	2.31
Rb	<4	<5	<5	<6	<6	<5	<8	(2)	<6	53 4	---	2.2 1.2	1	134
Sr	141	141	149	136	132	138	143	9-13	141	342 21	---	78 12	76	385
Zr	<35	<45	23	<50	38	22	23	8	19±12	122 18	---	---	15	240
Sb	0.020	0.041	0.026	0.027	0.063	0.012	0.031	0.008	0.030	0.60 .03	0.38 .02	0.091 .013	---	6.15
Cs	<0.08	<0.05	0.03	0.05	0.05	0.03	0.05	0.02	0.04± 0.02	1.00 .04	---	0.03 .02	---	10.42
Ba	11	13	26	34	30	25	24	4	24	665 20	---	31 5	34	1320
La	1.257	1.030	1.80	2.40	2.36	1.725	1.75	0.015- 0.02	1.80	24.0 .3	---	2.15 .03	2	76.7
Ce	2.95	2.55	4.5	5.95	5.5	4.55	5.0	0.3	4.55	52.2 .5	---	4.75 .09	4.7	168.8
Nd	1.56	1.56	2.7	3.8	3.4	2.85	2.9	0.2	2.75	29.4 .6	---	2.81 .17	2	81.4
Sm	0.414	0.456	0.952	1.047	0.978	0.920	0.945	0.006- 0.012	0.855	6.85 .08	---	0.747 .009	0.7	16.61
Eu	0.627	0.640	0.727	0.696	0.718	0.697	0.663	0.012	0.686	1.90 .03	---	0.361 .010	0.37	3.50
Tb	0.103	0.117	0.22	0.25	0.27	0.24	0.23	0.01- 0.02	0.21	1.12 .03	---	0.189 .009	0.2	2.69
Yb	0.375	0.41	0.785	0.77	0.83	0.78	0.805	0.015	0.705	3.41 .04	---	0.812 .018	0.85	7.68
Lu	0.0615	0.065	0.126	0.119	0.138	0.121	0.123	0.002- 0.003	0.113	0.527 .012	---	0.127 .003	0.12	1.146
Hf	0.27	0.31	0.70	0.64	0.90	0.70	0.73	0.02	0.63	5.08 .08	---	0.370 .023	0.38	7.29
Ta	0.030	0.023	0.094	0.084	0.089	0.114	0.084	0.010	0.079	0.78 .03	---	0.150 .013	0.2	1.93
Ir	5.9	3.8	5.9	9.2	6.9	7.5	12.7	1-2	7.6	---	---	---	---	---
Th	0.055	0.085	0.228	0.246	0.243	0.235	0.210	0.015	0.198	5.66 .07	---	0.016 .011	---	24.0
U	<0.05	<0.07	0.05	0.04	0.05	0.04	0.05	0.02	0.04	1.5 .2	---	---	---	10.3
mass (mg)	7.246	9.391	16.224	13.852	7.360	11.564	12.074		77.71	12.66	31.15	14.73		20.99

The standard for each element and the concentration used are indicated by the underlined values; all other values except "AN-G lit." were determined in this experiment against the standard values listed. Dashes indicate that no upper limit estimate was made or that no recommended value is available. Except for Ti,Al,Mg,V, and Mn standard concentrations are values recently determined in this laboratory on multiple large samples against primary chemical standards (Korotev, in prep.). "Flyash" is NBS SRM 1633a (coal flyash). BCR-1 and DTS-1 are USGS standard rocks and AN-G is a GIT-IWG rock reference sample (Greenland anorthosite). Column "AN-G lit." contains "proposed" values (Govindaraju, 1980) for comparison. For Ti and Mg a synthetic reference standard was used. Ir concentrations were determined parametrically without benefit of a standard.

Uncertainties are one standard deviation estimates of precision the principal component of which is "counting statistics." They do not include uncertainty associated with the standard values or any systematic error associated with heterogeneity of the small standards.