ALUMINOUS MARE BASALTS AND BASALTIC-TEXTURED KREEPy ROCKS FROM APOLLO 14 COARSE FINES, M.-S. Ma and Roman A. Schmitt, Department of Chemistry and Radiation Center, Oregon State University, Corvallis OR 97331 and Richard D. Warner, G. Jeffrey Taylor, Steven Barker and Klaus Keil, Department of Geology and Institute of Meteoritics, University of New Mexico, Albuquerque NM 87131 USA.

Basalts of apparent mare affinity but with Al_2O_3 contents higher than customarily found have been reported from Apollo 12 (12031; 12038), Apollo 14 (14053; 14072), Apollo 16 (60639 clast) and Luna 16 (predominant basaltic lithology at that site) (1-5). Because of their rare occurrence (except for Luna 16) and rather scattered distribution, aluminous mare basalts have not received the attention that other mare basalts have, and their petrogenesis is consequently not as well understood. In order to shed more light on the origin of these rocks, we have undertaken a study of basaltic-textured fragments from the Apollo 14 coarse fines. Based on preliminary examination at the curatorial facility, ten samples were selected for this study. Compositions of the samples were determined via INAA, and their mineralogy and petrology are currently being studied by optical microscopy and electron microprobe. The results show that 4 samples are aluminous mare basalts and 6 are basaltic-textured KREEPy rocks.

Aluminous mare basalts: The four aluminous mare basalts show considerable variability in composition (Table 1) and texture. 14004,34 is much higher in TiO_2 (5.4 wt%) than the other three basalts and also contains the most FeO (18.4 wt.%). It is fine-grained and has an intergranular texture. Plagioclase (An_{85-93}) occurs as thin laths $\leq$ 0.1 mm wide. Pyroxene mostly ranges in composition from ferroaugite ($\sim En_{34}Fs_{34}Wo_{32}$) to pyroxferroite; a few more Mg-rich grains of intermediate Wo content also occur. Laths of ilmenite [Fe/(Fe+Mg), 0.98-0.99] are abundant. Cristobalite also is relatively abundant. 14160,103 and 14256,10 are similar in major element composition. 14160,103 has a granular texture. Plagioclase (An_{81-92}) occurs as stubby laths or subequant crystals 0.1-0.3 mm across. Pyroxene includes both pigeonite ($En_{58}Fs_{33}Wo_9$ --> $En_{22}Fs_{58}Wo_{20}$) and augite ($En_{38}Fs_{27}Wo_{35}$ --> $En_{26}Fs_{44}Wo_{30}$). Anhedral ilmenites [Fe/(Fe+Mg), 0.94-0.98] are dispersed through the basalt. 14256,10 is a fine-grained metabasalt. Plagioclase ranges An_{87-95} in composition. Pyroxene compositions cluster in two distinct populations at $\sim En_{35}Fs_{33}Wo_{32}$ and $\sim En_{41}Fs_{45}Wo_{13}$. Accessory opaque oxides include ilmenite and chromian ulvospinel [Fe/(Fe+Mg), 0.91-0.92 and 0.94-0.97, respectively]. 14168,38 has lowest TiO_2 and highest MgO and Cr_2O_3 of the four basalts. It is unusually K_2O-rich (0.57 wt%). It is the coarsest-grained (average grain size $\sim$ 0.3-0.5 mm) of the basalts, and has a granular texture. Plagioclase is mostly An_{89-94}, but a few more sodic grains ($\sim An_{80}$) are present. 14168,38 is the only one of the 4 basalts to contain olivine (Fo_{66-37} plus minor fayalitic olivine). Pyroxene is mostly pigeonite ($En_{68}Fs_{26}Wo_6$ --> $En_{45}Fs_{41}Wo_{14}$) but augite is also present. Accessory opaque oxides include both ilmenite and chromian ulvospinel [Fe/(Fe+Mg), 0.88-0.94 and 0.86-0.96, respectively]. The basalt also contains abundant K-rich mesostasis.

Different REE patterns (Fig. 1) are observed for the 4 basalts. None are similar to either 14053 (6) or 14072 (7). 14004,34 has a bow-shaped pattern similar to 12031 (1), 12038 (8-11), and Luna 16 (5). However, 14004,34 cannot be genetically related to any of these rocks. Because TiO_2 behaves like an incompatible trace element in low-Ti basaltic liquids, a positive La-TiO_2 correlation should be observed if fractional crystallization from a common magma occurred. 14004,34 and the Luna 16 basalts contain similar TiO_2, but differ in La by a factor of $\sim$2, while 14004,34 and 12038 show an inverse

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La-TiO_2 relationship. Thus, 14004,34 cannot have crystallized from the same magma as Luna 16 or 12038. 14004,34 and 12031 show a positive La-TiO_2 correlation, but the factor of ∿2 difference in REE abundances, which requires extensive crystallization of minerals (e.g., olivine) having very low REE partition coefficients, is inconsistent with their similar Fe/(Fe+Mg) ratios (0.60 vs 0.57). To relate 14004,34 and 12031, 12038 or Luna 16 via partial melting of similar source material is equally implausible. To produce similar REE patterns but a factor of ∿3 range in absolute REE abundances requires a factor of ∿3 range in the degree of partial melting. If plagioclase was a liquidus phase, to account for the similar Al_2O_3 and CaO abundances of the basalts, then large differences in Sm/Eu ratios would be expected, with Luna 16 basalt having the highest Sm/Eu. Instead, a small range in Sm/Eu (3.6-4.5) is observed, with Luna 16 intermediate (4.0). If, on the other hand, plagioclase was exhausted during partial melting, to account for the small Sm-Eu fractionation, then it would be difficult to produce similar Al_2O_3 and CaO abundances over a factor of ∿3 range in degree of partial melting.

14160,103 has a negative light-REE slope (La-Sm) like 14053 and 14072, but has an unfractionated heavy-REE pattern (Sm-Lu) and a KREEP-like Hf-Ta-Th pattern (12). Absolute REE abundances are fairly high, but the rock's low K_2O (0.079 wt.%) and flat heavy-REE pattern make admixture of significant ($\geq$ 5%) KREEP component unlikely. We conclude that the rock represents an aluminous mare basalt type with a unique REE pattern.

The nearly unfractionated (except for Eu) patterns of 14168,38 and 14256,10 are also distinct among known lunar mare basalts, and could be derived by high degrees of partial melting of unfractionated, primitive source material, analagous to the derivation of the eucrite Stannern by partial melting of primitive chondritic material (13). The high K_2O of 14168,38, coupled with its high MgO and Cr_2O_3, preclude derivation of 14256,10 from the same magma via fractional crystallization. The combination of high K_2O and low REE observed for 14168,38 is unique: the sample deviates significantly from the La-K_2O correlation trend established for lunar basalts (14).

It thus appears that all 4 aluminous mare basalts have had different origins. Further, they appear to be distinct from all other aluminous mare basalts analyzed. Despite the wide variety in REE patterns and absolute abundances (factor of ∿4) observed for aluminous mare basalts, Sc abundances in these rocks vary by only ∿ ±30%, indicating that clinopyroxene, which has a high Sc partition coefficient, is definitely present in the residue of the various aluminous mare basalt source regions.

Basaltic-textured KREEPy rocks: All but 14004,33 have very similar major and minor element compositions and REE abundances (Table 1). 14004,33 contains lower Al_2O_3 and CaO and higher FeO, MgO (almost 2x) and K_2O (∿2x) than the other samples. It has a similar REE pattern, but ∿50% higher REE abundances, and is enriched in Ni by a factor of ∿5. The REE patterns of all 6 samples resemble those of Apollo 14 KREEP and soils (12). All have fine-grained basaltic textures, and none contain xenoliths. Nevertheless, the high Ir and Ni abundances of the rocks, especially of 14004,33, lead us to interpret the rocks as impact melts into which a KREEP component, which dominates the incompatible trace element pattern, was admixed.

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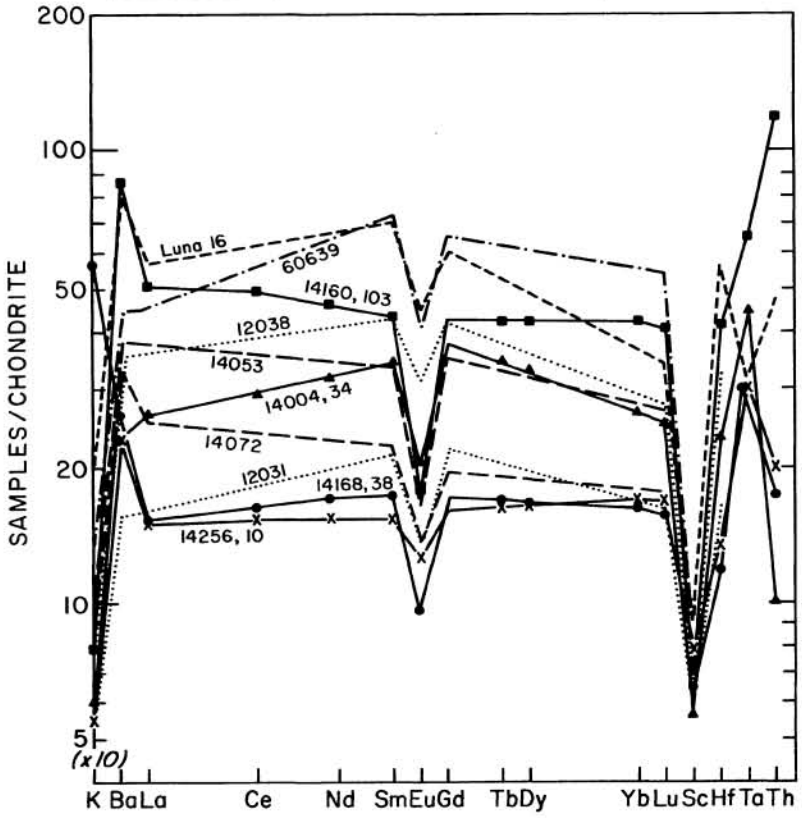

Fig. 1. Chondrite-normalized K, Ba, REE, Sc, Hf, Ta, and Th abundances in 4 aluminous mare basalts from Apollo 14 coarse fines. Patterns of other aluminous mare basalts shown for comparison.

Table 1. Chemical Analyses of Basaltic-Textured Rocks from Apollo 14 Coarse Fines[a]

	Aluminous Mare Basalts				KREEPy Rocks					
Wt. (mg)	14004,34 41	14160,103 29	14168,38 176	14256,10 134	14004,33 179	14004,35 67	14145,3 172	14150,12 233	14150,13 92	14160,102 71
TiO_2(%)	5.4	2.5	1.7	2.6	1.4	1.1	1.3	1.3	1.2	1.1
Al_2O_3	12.0	13.3	12.4	13.1	13.6	18.3	21.2	19.2	20.6	20.9
FeO	18.4	14.8	15.5	16.5	10.0	7.5	7.7	8.3	7.6	7.2
MgO	6.9	8.4	11.0	7.8	13.7	7.1	8.4	7.6	6.4	7.0
CaO	10.4	11.1	9.9	11.9	8.[illegible]	10.3	13.0	12.1	11.0	11.6
Na_2O	0.412	0.544	0.366	0.376	0.869	0.669	0.703	0.737	0.742	0.726
K_2O	0.061	0.079	0.57	0.055	0.[illegible]5	0.46	0.44	0.50	0.47	0.48
MnO	0.237	0.213	0.215	0.238	0.112	0.089	0.096	0.102	0.094	0.091
Cr_2O_3	0.232	0.235	0.544	0.332	0.174	0.125	0.140	0.154	0.142	0.130
Sc(ppm)	56	46	52	63	19	16	17	19	18	17
V	109	63	139	113	39	24	40	39	32	26
Co	25	19	31	19	55	17	18	18	14	13
Ni	---	---	(40)	(20)	820	150	130	160	110	100
Zr	170	350	80	100	800	610	550	660	630	630
Ba	90	330	100	90	900	590	620	660	650	650
La	9.0	17.1	5.2	5.1	75.3	50.4	51.7	56.7	54.4	54.4
Ce	25	42	14	13	166	115	115	125	119	119
Nd	20	30	11	10	115	78	79	85	82	82
Sm	6.7	8.5	3.4	3.1	32.3	22.7	22.7	24.3	23.2	23.8
Eu	1.49	1.31	0.71	0.93	2.41	1.92	2.05	2.13	2.12	2.19
Tb	1.6	2.0	0.80	0.78	6.2	4.4	4.4	4.9	4.6	4.5
Dy	11	14	5.4	5.4	41	29	29	32	31	31
Yb	5.9	9.4	3.6	3.8	24.1	16.6	16.8	18.5	17.6	17.6
Lu	0.86	1.40	0.53	0.58	3.[illegible]1	2.37	2.44	2.63	2.53	2.48
Hf	4.7	8.3	2.4	2.7	24.2	17.0	16.2	19.3	17.7	17.9
Ta	0.9	1.3	0.6	0.6	3.[illegible]	2.5	2.5	2.8	2.6	2.6
Th	0.4	4.9	0.7	0.8	13.7	9.4	9.3	10.8	9.9	10.2
U	---	1.3	---	---	3.6	2.7	2.7	3.1	2.5	2.7
Ir(ppm)	---	---	---	---	9	2	---	2	2	2

[a]The estimated errors due to counting statistics are Al_2O_3, FeO, Na_2O, MnO, Cr_2O_3, Sc, Co, La and Sm, ±1-5%; TiO_2, CaO, K_2O, (>0.1%), V. Ce (>20ppm), Eu, Tb, Yb, Lu and Hf, ±5-10%, MgO, K_2O (<0.1%), Ce (<20ppm) Dy, Ta, Th and U, ±10-15%, Ni, Zr, Ba, Nd, and Ir, ±15-30%.

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