A SORTIE FOR PRISTINE ROCKS AT MARE TRANQUILLITATIS: A FERROAN ANORTHOSITE, A NEW GROUP D BASALT, AND THE ISOTOPIC COMPOSITION OF GROUP D HIGH-Ti BASALTS

Gregory A. Snyder, Eric A. Jerde, Lawrence A. Taylor, Der-Chuen Lee*, and Alex N. Halliday*, Planetary Geosciences Institute, Dept. of Geological Sciences, University of Tennessee, Knoxville, TN 37996-1410; *Dept. of Geological Sciences, University of Michigan, Ann Arbor, MI 48109.

Mare basalts comprise only a small fraction of the rocks found at the Moon's surface. However, the study of these basalts is of paramount importance to an understanding of the evolution of the mantle of the Moon. The high-Ti basalts at the Mare Tranquillitatis have provided important constraints on the mineralogy, chemistry, and depth of upper mantle cumulate sources. Previous studies have delineated five separate basalt groups at Mare Tranquillitatis, including the rare Group Ds [1,2]. This group is represented by only a few small 2-4 mm samples, but is crucial in advancing our knowledge of those basalts which contain significant whitlockite (0.2-0.8 wt.%) and, yet, may represent the inititiation of extrusive activity at Mare Tranquillitatis. Therefore, we have undertaken a sortie of 2-4 mm fragments from several other soils at the Apollo 11 landing site in the hope of uncovering other pristine basaltic rocks (possibly even some more group Ds). The first of three sets of analyses (of 12 rock fragments each) are presented in this abstract and do, indeed, include one "new" Group D high-Ti basalt. This proposed Group D basalt was then analyzed for its Nd and Sr isotopic composition, along with one other known group D basalt. Both Group D rocks indicate time-averaged LREE-enrichment (Sm/Nd decrease) when compared to other low-K high-Ti basalts. This enrichment is interpreted as being due to the earliest melting of a source, which contains a small proportion of KREEPy trapped liquid, and, due to its lower temperature of melting compared to the enclosing cumlate, makes up a larger proportion of the first small percentage partial melt. In order to fit these rocks into the lunar chronology, Ar-Ar ages currently are being determined for these rocks.

Table 1: Elements Analyzed by INAA for 2-4 mm Fragments from Soil 10002

Sub-samp	,1006	,1008	,1009	,1010	,1011	.1012	,1013	,1014	,1015	,1016	,1017	,1018
Na (ppt)	2.81	3.13	3.83	2.04	2.89	2.62	3.10	1.95	3.42	2.00	2.32	2.10
Ca	76.8	-----	100	-----	-----	-----	-----	94.9	97.3	-----	-----	54.1
Fe	146	172	113	149	171	43.4	175	40.8	139	146	143	84.1
K (ppm)	779	488	644	270	675	538	523	127	877	268	148	455
Mn	2130	2280	1870	2030	2260	630	2240	575	2100	2120	1920	1080
Sc	81.6	80.3	91.6	75.9	96.3	9.10	76.7	6.84	99.3	87.7	74.4	53.3
Cr	1610	1460	918	3150	1370	935	1260	893	1700	3250	2790	578
Co	14.3	13.9	11.2	20.5	12.0	18.1	13.9	19.1	12.2	20.3	19.6	7.88
Ni	-----	187	-----	50	50	110	60	200	-----	-----	-----	-----
Zn	60	-----	-----	-----	-----	14	43	18	74	-----	-----	99
Ga	5.1	5.5	6.3	3.1	4.3	3.7	4.3	4.6	6.0	3.9	3.6	2.9
Rb	4.8	-----	6.8	-----	5.4	-----	-----	7.1	10.8	-----	-----	5.9
Sr	162	89	-----	63	64	150	39	92	242	-----	-----	-----
Zr	388	282	337	188	214	75	396	-----	300	113	41	455
Cs	-----	-----	0.4	-----	0.06	0.1	0.26	-----	0.18	-----	-----	0.1
Ba	333	-----	96	117	104	101	124	11	119	45	-----	31
La	30.8	19.6	8.83	5.3	8.14	4.83	18.3	0.72	10.1	3.08	3.79	4.73
Ce	91.4	54.5	30.5	18.5	26.9	11.3	50.4	2.76	38.9	11.8	13.3	17
Nd	60.4	41.4	20.7	14.6	24.5	12.1	37.5	-----	29.8	9.6	9.9	14.3
Sm	21.7	18	13.6	7.83	12.2	2.15	16.2	0.32	16.2	5.39	6	6.48
Eu	1.99	2.22	2.71	1.66	2.21	0.89	2.15	0.69	2.82	1.32	1.64	1.35
Tb	4.73	3.98	3.47	1.91	2.95	0.36	3.69	0.07	4.25	1.38	1.66	1.54
Dy	31.2	23.2	21.9	12.5	20.9	1.4	24.7	-----	27.6	9.7	11.6	10.1
Ho	8.4	7.1	5.6	3.3	5.3	0.9	5.9	-----	6.1	2.4	2.5	2.1
Tm	2.4	2.2	1.6	1.2	1.6	0.3	1.9	0.03	2.0	1.0	1.1	-----
Yb	16.3	13.0	11.4	7.13	10.3	1.6	13.1	0.32	13.2	5.39	5.83	6.1
Lu	2.30	1.90	1.46	1.18	1.55	0.233	1.72	0.046	1.81	0.795	0.854	0.794
Hf	12.0	10.8	7.8	7.11	9.29	1.21	10.7	0.22	10.4	5.00	6.34	4.93
Ta	1.45	1.43	0.94	1.45	1.64	0.18	1.45	0.08	1.56	1.03	1.16	1.10
Th	2.81	1.44	0.68	0.21	0.52	0.66	0.83	0.09	0.76	0.17	0.26	0.31
U	0.45	-----	0.26	-----	-----	-----	-----	-----	0.17	-----	-----	0.15
Ir (ppb)	nd	8.0	nd	nd	4.0	7.6	17.6	5.3	nd	8.8	11.2	nd

nd = not detected (below detection limit [3 ppb]).

CHEMISTRY OF 2-4 MM FRAGMENTS FROM SOIL 10002 - - Twelve 2-4 mm fragments were carefully chosen from soil 10002 and analyzed by INAA methods for their trace-element contents (Table 1). Of these twelve, five contain no detectable Ir and are, therefore, considered tobe pristine. Two others contain relatively low abundances of Ir (,1011 and ,1014) and could possibly be pristine. These seven rocks are plotted in Figure 1and on a K vs. La diagram. The REE for these rocks are plotted relative to C1 chondrites on figure 2.

Of particular interest is clast **,1014**, which is comprised of mostly plagioclase and could be a **ferroan anorthosite** (FAN). It contains the lowest REE, Sc, Na, K, Ba, and Mn abundances of any of the clasts analyzed (e.g., see Figure 1) and high abundances of Ca. The most diagnostic characteristic of this clast is the large positive Eu anomaly (Figure 2), which again lends credence to its designation as a FAN.

Clasts **,1009**; **,1010; ,1011; ,1015; and ,1018** also plot within the field for **Group B3 basalts (,1015 could be a B1**; Figure 1), although they are coarser-grained than basalt ,1006. Thin-sections are being prepared by the Curatorial Staff at the Johnson Space Center and mineral chemistry will be determined on the electron microprobe to confirm or deny these designations. Rock **10002,1006 plots within the field for Group D basalts from Apollo 11** in Figure 1. The remaining 50 mg portion of this sample was then analyzed for its Nd and Sr isotopic composition (Table 2), along with one other Group D basalt.

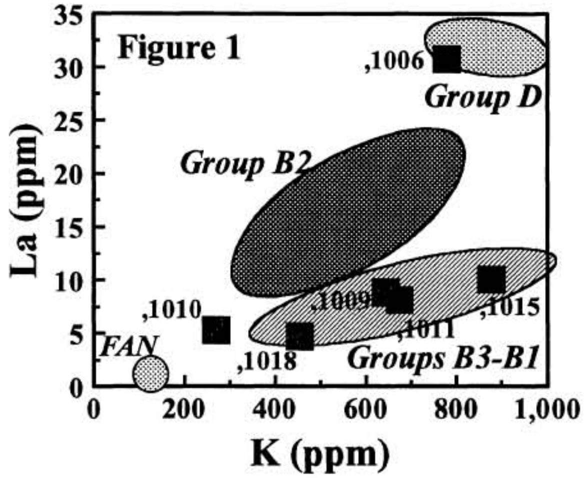
Nd AND Sr ISOTOPIC COMPOSITION OF GROUP D HIGH-Ti BASALTS – For the first time, two proposed Group D basalt rocklets were analyzed for their Nd and Sr isotopic compositions (Table 2).

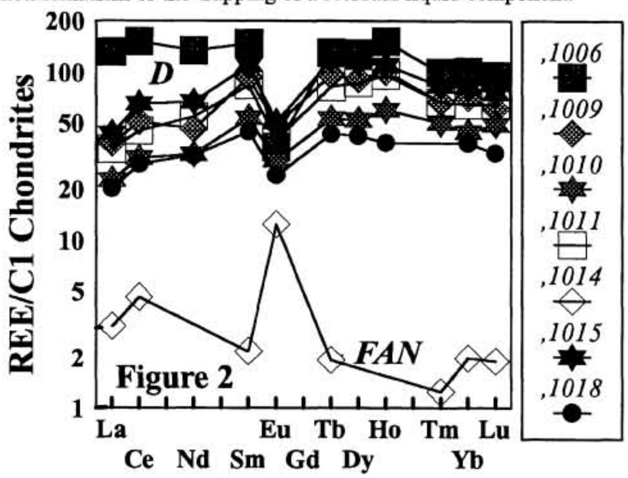
Nd & Sr ISOTOPE CHEMISTRY OF APOLLO 11 GROUP D BASALTS: Snyder, Jerde, Taylor, & Halliday

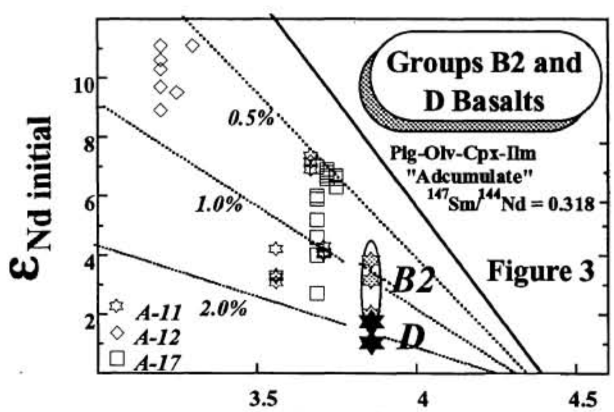
Table 2: Nd and Sr Isotopic Composition of Apollo 11 Group D Basalts

Rock	Grp.	wt.(mg)	Rb (ppm)	Sr (ppm)	$^{87}Rb/^{86}Sr$ [1]	$^{87}Sr/^{86}Sr$ [2]	$^{87}Sr/^{86}Sr_{(i)}$	T_{LUNI} (Ga)	Sm (ppm)	Nd (ppm)	$^{147}Sm/^{144}Nd$*	$^{143}Nd/^{144}Nd$	$\varepsilon_{Nd}(T)$	T_{CHUR}
10002,98	D?	31	4.67	168	0.0799	0.703751±13	0.69932±2	4.09	18.8	54.3	0.2089	0.513053±12	2.0±0.4	5.07
10002,1006	D	21	1.35	139	0.0279	0.700709±20	0.69916±3	4.17	19.6	60.2	0.1972	0.512715±12	1.2±0.6	18.5

The two samples do exhibit some variability in their initial Nd and Sr isotopic ratios (although the initial ε_{Nd} values are within analytical uncertainty). However, the Nd and Sr isotopic compositions of these Group D basalts are within the ranges for the Group B2 basalts from Apollo 11 ($^{87}Sr/^{86}Sr$ = 0.69920 to 0.69921 and ε_{Nd} = +2.0 to +3.9 at 3.85 Ga; [3,4,5] Figure 3). Rock 10002,98 does exhibit a slightly higher $^{87}Sr/^{86}Sr$ initial ratio than other B2 or D samples. However, because of the relatively large Rb/Sr ratio of this sample, a slight increase in either the Rb/Sr ratio (by no more than 2%) of the rock, or age (by less than 0.08 Ga) yields an initial ratio which is in line with other D and the B2 basalts. The similarity in Nd and Sr initial ratios is consistent with the model of Jerde et al. [6], whereby the **Group D basalts were derived from the Group B2 basalts by the simple addition of the mineral whitlockite**, either through metasomatism or the trapping of a residual liquid component.







EARLIEST MELTING BENEATH MARE TRANQUILLITATIS: HIGH-Ti BASALTS OF GROUPS B2 AND D – Nd and Sr isotopic heterogeneities in the sources of low-K high-Ti mare basalts (such as Groups B2 and D) could be the consequence of events unique to the Moon. In the late stages of LMO crystallization, when ilmenite was a liquidus phase, upper mantle cumulates trapped variable yet small amounts of residual LMO liquid [5,7]. A lack of recycling in the lunar environment would allow these slightly different portions of essentially the same source to diverge along separate isotopic evolutionary paths. Adcumulates with more trapped liquid would have higher contents of the heat-producing elements U, Th, and K and would likely melt first. Therefore, the earliest phase of volcanism at the Mare Tranquillitatiis (3.85 Ga ago, Group B2 and possibly D) involved the melting of a source which was relatively enriched in this KREEPy trapped liquid and the resultant magmas were slightly more aluminous, less titaniferous, and possessed a lower Mg# than the later B3 basalts [5]. These observations are consistent with these basalts being melted from a source which was relatively enriched in trapped KREEPy liquid. The volume of this KREEPy trapped liquid would be small, but, because of its high LILE content, could greatly affect the isotopic ratios of basaltic magmas that would have intruded through the upper crust en route to the surface of the Moon.

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