COMPOSITION, PETROGRAPHY, AND GENESIS OF APOLLO 17 HIGH-TI MARE BASALTS, M.-S. Ma and R.A. Schmitt, Dept. of Chemistry and the Radiation Center, Oregon State University, Corvallis, OR 97331 and R.D. Warner, G. J. Taylor, and K. Keil, Department of Geology and Inst. of Meteoritics, University of New Mexico, Albuquerque, NM 87131.

Studies of Apollo 17 high-Ti mare basalts have pointed to the conclusion that they mainly consist of two types (A and B) which are nearly isochemical in major element composition but are distinguishable by important differences in trace element abundances and key trace element ratios, and that observed chemical variations in each type are due largely to olivine and opaque oxide fractionation (1-3). A few mare basalts (all from Station 4) belong to a separate magma type (C) characterized by higher MgO and Cr_2O_3 concentrations. In order to further validate (or negate) the above conclusions, we have measured by INAA abundances of 23 major, minor and trace elements in an additional 28 Apollo 17 high-Ti mare basalts.

Composition In Table 1 we have listed the basalt analyses in order of increasing La abundances. The major and trace element abundances and REE patterns of most of the samples fall within the spread for 56 Apollo 17 high-Ti basalts previously analyzed in this laboratory (2-4). We find no evidence among the samples analyzed for additional olivine partial cumulates such as 71597 (5).

Among the various trace elements which have proved useful as a discriminant between types A and B Apollo 17 basalts is Sm. Type A basalts typically contain > 9.5 ppm Sm whereas most type B basalts contain < 8 ppm Sm. On the basis of this criterion 20 of the samples (those with > 8.1 ppm Sm) can be assigned to type B and 6 samples (Sm > 9.8 ppm) to type A. One coarse-grained basalt, 78577, is of uncertain affinity, and sample 74247, which contains > 0.6 wt.% Cr_2O_3 and has olivine microphenocrysts as magnesian as Fo83, is a type C basalt.

Petrography Preliminary petrographic examination of 22 of the basalts reveals a variety of textures similar to those that have been previously described (2,6,7). According to the textural classification reported by (7), we group these basalts as follows: olivine-microporphyritic ilmenite basalt-71037, 71046, 71065, 71066, 71067, 71069, 71086, 71156, 71505, 71506, 74247 (?) and 79516; and plagioclase-poikilitic ilmenite basalt - 70136, 70137, 70315, 71045, 71085, 75085, 78507, 78509, 78577, and 79515. None of the new basalts are of the subophitic-granular "Apollo 11-type" variety. As noted previously, for example by (7), the coarser-grained plagioclase-poikilitic ilmenite basalts tend to contain less olivine, armalcolite, and Cr-ulvospinel, and more pyroxene than do the finer-grained olivine-microporphyritic basalts. Ilmenite typically occurs as large, amoeboid crystals in the plagioclase-poikilitic basalts vs laths or acicular crystals in the olivine-microporphyritic varieties.

Genesis In order to study compositional variations and possible genetic relationships among the Apollo 17 high-Ti mare basalts, we have plotted Sm vs TiO_2 and MgO, respectively (Figs. 1 and 2). To minimize sampling problems and interlaboratory bias, we have used only fine-grained basalts and data obtained in our laboratory in constructing these plots. Also shown in Figs. 1 and 2 are fields of the three types, A, B, and C, from (1), and expected fractionation trends resulting from separation of olivine plus ilmenite and/or armalcolite. Ranges of Sm, TiO_2, and MgO exceed those observed by (1). However, the majority of the samples fall within or close to the previously defined basaltic fields. Data points are somewhat more scattered in the Sm vs MgO plot, and this could be attributed to the greater analytical uncertainty in MgO relative to that for TiO2. Basalts that plot close to the type A field (such as 70255, 71546, etc.) can be fairly confidently assigned to that group on the basis of SiO2, FeO, TiO2, and Cr2O3 vs MgO correlation diagrams (1). Basalts 71539 and 78598 are interpreted as fractionated members of type A basaltic liquid (8). High Sm sample 74245 is classed as type C on the basis of major element correlations as well as on petrographic grounds, specifically the presence of Fo80 olivine microphenocrysts. In the low Sm cluster, 71066 and 71069 (tentatively) are both grouped with the type B basalts.

Separation of ∿ 12% olivine, ∿ 12% ilmenite + armalcolite, and ∿ 1% Cr-ulvospinel would yield the fractionation trend from 75089 to 71539 and 78598 in the type A basalts (3). Less extensive crystal separation is required to yield the amount of fractionation observed in type B basalts. It has been suggested that short-range unmixing could play a more important role than fractional crystallization in producing the compositional variations observed among type A and B basalts (9). However, from Fig. 4 in (9), we suggest that the systematic changes in phase proportions from MgO-rich to MgO-poor samples is indicative of olivine and opaque oxide fractionation, which resulted in higher pyroxene and plagioclase contents in the residual magma, rather than short-range unmixing, from which one would expect random correlations of MgO with phase proportions. From these observations we conclude that the fine-grained Apollo 17 high-Ti mare basalts can be satisfactorily classified by the scheme proposed by (1), and that systematic compositional variations within types A and B basaltic groups are best explained by fractionation involving early crystallizing phases.

The different trace element characteristics of the types A and B basaltic groups preclude the one being derived from the other via near-surface differentiation (1-3). These differences must largely be inherited from the source regions, that is, the source regions may be very similar with respect to major elements but markedly heterogeneous as regards minor and trace elements (1). One possibility is that the two types could be derived by similar degrees of partial melting of late-stage cumulates which contained variable quantities of trapped intercumulus liquid but were otherwise homogeneous (2,3).

References: (1) Rhodes, J.M. et al. (1976) Proc. Lunar Sci. Conf. 7th, p. 1467-1489. (2) Warner, R.D. et al. (1975) Proc. Lunar Sci. Conf. 6th, p. 193-220. (3) Warner, R.D. et al. (1975) in "Origins of Mare Basalts and their Implications for Lunar Evolution", p. 179-183. (4) Murali, A.V. et al. (1977) in "Lunar Science VIII", p. 703-705. (5) Warner, R.D. et al. (1977) Proc. Lunar Sci. Conf. 8th, p. 1429-1442. (6) Papike, J.J. et al. (1974) Proc. Lunar Sci. Conf. 4th, p. 471-504. (7) Warner, R.D. et al. (1978) Spec. Publ. No. 18, UNM Inst. of Met., 88 pp. (8) Warner, R.D. et al. (1978) Amer. Mineral. 63, in press. (9) Lindstrom, M.M. and Haskin, L.A. (1978) Proc. Lunar Planet. Sci. Conf. 9th, in press.

APOLLO 17 HIGH-TI MARE BASALTS

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Element Abundances in 28 Apollo 17 Mare Basaltic Rocks*

Sample #	Wt. (mg)	TiO_2 ( )	Al_2O_3 ( )	FeO ( )	MgO ( )	CaO ( )	Na_2O ( )	K_2O ( )	MnO ( )	Cr_2O_3 ( )	Sc (ppm)	V (ppm)	Co (ppm)	La (ppm)	Ce (ppm)	Nd (ppm)	Sm (ppm)	Eu (ppm)	Tb (ppm)	Dy (ppm)	Yb (ppm)	Lu (ppm)	Hf (ppm)	Ta (ppm)
71085,3	293	14.2	7.7	18.1	10	10.8	0.333	0.032	0.246	0.576	96	163	20	2.8	11	13	5.1	1 21	1.3	9	5.6	0.83	5.5	1.3
70315,10	970	13.1	9.3	17.9	10	10.2	0.387	0.039	0.240	0.547	81	148	20	3.2	13	14	5.8	1.40	1.4	10	5.6	0.81	5.7	1.3
78507,1	458	11.9	8.8	18.0	10	9.7	0.407	0.037	0.222	0.536	79	130	21	3.4	13	16	6.0	1.59	1.4	10	5.8	0.86	5.5	1.3
71045,1	484	12.7	8.6	18.6	10	11.6	0.390	0.044	0.232	0 515	82	137	21	3.7	15	18	6.7	1.50	1.5	11	6.3	0.91	6.5	1.5
78509,1	530	12.3	9.2	19.0	8	10.9	0.414	0.040	0.252	0.388	89	101	22	3.9	14	16	5.8	1.22	1.3	9	5.5	0.80	5.1	1.3
70136,1	509	11.3	11.1	17.2	9	10.1	0.486	0.045	0.218	0 492	72	128	18	4.0	15	18	6.7	1.85	1.6	11	6.2	0.85	6.7	1.4
70137,1	510	12.0	9.2	18.0	10	10.3	0.421	0.048	0.226	0.534	77	132	21	4.0	17	19	7.0	1.63	1.6	11	6.6	0.93	6.7	1.5
71046,1	323	11.6	8.9	19.1	8	10.2	0.320	0.040	0.256	0.407	83	109	19	4.3	18	19	7.0	1.56	1 9	13	7.5	1.10	6.7	1.5
71069,2	223	12.2	8.6	19.1	10	9.8	0.312	0.032	0.246	0.474	85	140	21	4.3	17	20	7.4	1.55	1.9	12	7.4	1.07	6.6	1.5
71068,2	296	13.6	8.3	18.9	9	9.8	0.368	0.038	0.244	0.530	79	135	25	4.4	17	19	7.1	1.62	1.8	12	7.2	1.06	7.3	1.7
78577,1	540	12.1	8.8	18.9	9	10.6	0.416	0.051	0.244	0.424	82	89	20	4.7	18	21	8.3	1.73	1.9	13	7.6	1.04	7.2	1.5
71065,2	258	12.5	8.9	19.8	8	10.0	0.389	0.041	0.256	0.377	89	102	22	5.1	18	19	6.9	1.34	1.7	11	6.9	1.01	6.8	1.7
71066,2	201	14.2	8.9	20.5	9	9.4	0.406	0.041	0.259	0.486	89	133	24	5.1	18	18	6.5	1.33	1.6	11	6.7	1.02	6.4	1.8
79516,1	535	12.3	8.4	19.9	8	10.0	0.384	0.045	0.245	0.399	87	109	22	5.2	20	21	6.9	1.33	1.7	12	6.6	0.94	6.3	1.6
79515,1	951	10.2	9.1	18.7	9	11.0	0.385	0.048	0.275	0.439	82	120	23	5.3	20	21	7.7	1.42	1.7	12	6.7	0.96	6.2	1.4
71155,31	566	10.1	9.2	19.1	8	10.8	0.353	0.048	0.246	0.488	81	118	23	5.6	21	23	8.1	1.49	1.8	12	6.9	0.97	6.3	1.3
78585,7	524	12.2	9.1	19.6	7	11.0	0.396	0.041	0.245	0.361	86	79	21	5.6	20	21	7.5	1 42	1.8	12	6.9	0.97	6.4	1.6
71505,2	343	10.5	9.6	19.2	7	10.3	0.367	0.048	0.252	0.306	86	87	18	5.9	21	22	7.8	1.57	1.9	13	7.6	1.09	6.9	1.6
71086,2	246	11.6	10.0	19.3	8	10.8	0.381	0.050	0.268	0.312	84	102	18	6.0	22	23	8.1	1.68	2.1	14	7.7	1.15	7.4	1.7
71037,1	540	11.2	8.9	19.4	7	11.2	0.425	0.046	0.246	0.310	85	73	20	6.1	21	23	8.1	1.54	1.9	13	7.4	1.02	7.0	1.7
71506,1	246	10.7	10.0	19.5	7	11.6	0.376	0.052	0.266	0.353	85	106	19	6.1	23	22	8.1	1.64	2.1	14	7.4	1.10	7.2	1.9
74248,1	228	12.3	8.9	18.9	8	10.7	0.420	0.067	0.261	0.417	83	104	19	6.3	26	27	9.8	2.01	2.6	18	9.6	1.38	9.4	2.1
71156,1	210	12.3	8.7	18.5	8	10.4	0.395	0.068	0.242	0.435	79	103	18	6.6	25	27	10.4	2.01	2.7	18	9.9	1.39	8.8	2.0
71067,2	298	12.7	8.9	19.5	9	10.7	0.421	0.069	0.254	0.408	82	101	20	6.8	26	28	10.9	2.09	2.6	18	10.3	1.48	9.2	2.2
70075,1	231	12.1	9.3	19.4	8	10.3	0.417	0.067	0.253	0.409	86	86	19	6.9	27	28	10.9	2.21	2.8	18	10.4	1.53	9.0	2.1
74247,1	220	12.3	8.6	19.4	9	9.5	0.381	0.083	0.238	0.643	77	140	22	7.1	27	28	10.5	2.01	2.4	16	9.1	1.31	9.0	2.0
74249,1	223	12.7	9.1	19.9	9	10.4	0.439	0.074	0.262	0.395	87	100	19	7.2	29	30	11.3	2.25	3.0	19	10.6	1.52	10.0	2.3
75085,1	310	13.1	8.7	18.8	9	9.9	0.416	0.064	0.249	0.471	81	133	19	7.5	31	32	11.6	2.32	3.0	19	10.6	1.54	9.7	2.2

*These specimens were chipped from rocks that ranged in mass from 3.0 - 148.6 g.

Analytical errors are similar to those reported previously by our group.

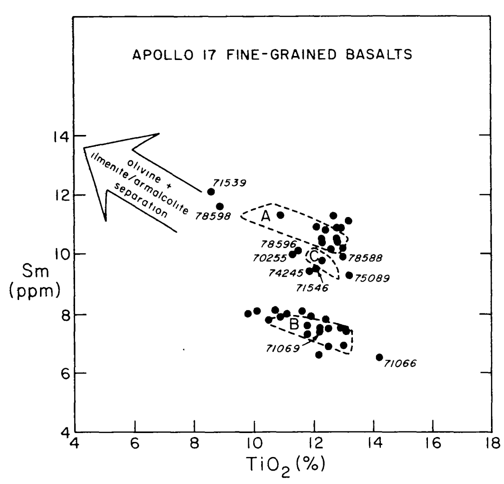

Figure 1

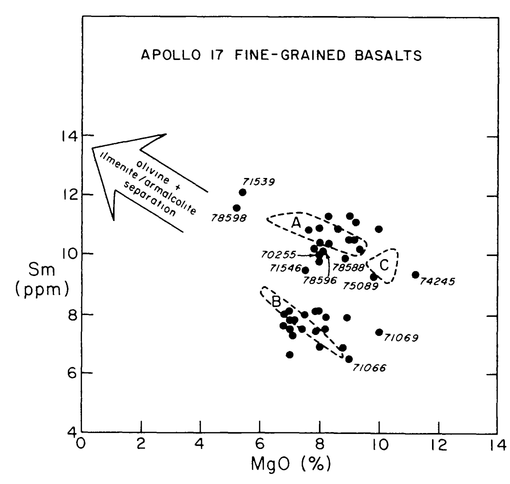

Figure 2