THE UNIQUE NATURE OF APOLLO 17 VLT MARE BASALTS. S. Wentworth, G. J. Taylor, R. D. Warner, K. Keil, Dept. of Geology and Inst. of Meteoritics, Univ. of New Mexico, Albuquerque, NM 87131 and M.-S. Ma and R. A. Schmitt, Dept. of Chemistry and Radiation Center, Corvallis OR 97331.

Introduction. Very low titanium (< 1% TiO_2) mare basalts were first discovered in thin sections from the Apollo 17 deep drill core (1,2) but they also occur at other sites (3) and are the prevalent basalt type returned by Luna 24. Petrogenetic modeling of the Luna 24 VLT basalts has been done on the basis of trace element and isotopic data (4). Until now, no trace element data has been available for the Apollo 17 VLT basalts, due to small sample size, except for rake sample 78526 (5-7). Sample 78526 consists primarily of vitrophyric pale-green glass with subordinate mineral and lithic fragments. Its bulk composition is similar to those of VLT basalt lithic fragments found in the Apollo 17 drill core. The lithic relics within 78526 are VLT basalt fragments with both porphyritic and granular textures. Sample 78526 has been interpreted (7) as an impact melt of at least two VLT basalt varieties (represented by the granular and porphyritic relics) and a somewhat more TiO_2-rich mare basalt component (represented only by mineral relics).

In a consortium study of lithic fragments hand-picked from the Apollo 17 deep drill core, three VLT basalt fragments were found (70006,371; 70007,289B; and 70007,296). Table 1 shows 21 major, minor and trace elements for these three fragments analyzed via INAA. The chondrite-normalized (c.n.) K, REE, Sc, Hf, and Ta abundances of these VLT basalts, two Luna 24 VLT basalts, 78526, and the Apollo 15 green glass 15426 are plotted in Fig. 1.

Petrography and Mineral Compositions. Both 70006,371 and 70007,296 have granular textures, with grain sizes ranging from .05-.2 mm. The fragments consist primarily of pyroxene and plagioclase with minor olivine and traces of chromite, troilite, Fe metal, and ilmenite. The appearance of these fragments is much like that of the granular relics in 78526, except 70006,371 and 70007,296 are somewhat finer-grained. Mineral compositions of 70006,371 and 70007,296 are typical of Apollo 17 VLT basalts (2,7), and are almost identical to each other. Pyroxenes show normal iron enrichment trends. Ti/Ti+Cr in the pyroxenes monotonically increases as Fe/(Fe+Mg) increases, which is typical of Apollo 17 VLT basalts. Plagioclase compositions have a narrow range, from An_{94} to An_{97}. Olivine in 70007,296 shows normal zoning, with compositions ranging from $Fo_{62.2}$ to $Fo_{75.2}$. Olivine in 70006,371 is unzoned and has an average composition of $Fo_{60.5}$. (Sample 70007,289B is not yet available for petrography and mineralogy).

Bulk Compositions. Major-and minor-element abundances of 70006,371, 70007,289B, and 70007,296 fall in the ranges of other Apollo 17 VLT basalts (1-3), although FeO in 70006,371 (15.5%) is among the lowest. Compared to Luna 24 VLT basalts, these Apollo 17 VLT basalts contain less TiO_2, FeO, CaO, and Na_2O, and more MgO, Cr_2O_3 and V. FeO, Fe/Fe+Mg and REE abundances increase in the sequence 70006,371 to 70007,296 to 70007,289B. These variations may be caused by varying degrees of partial melting of a common source, but not by fractional crystallization of olivine or low-Ca pyroxene: Changing REE abundances by a factor of $\sim$ 2.4 requires the fractional crystallization of over 50% of the melt as olivine or low-Ca pyroxene, which would yield a much greater range in Fe/(Fe+Mg) (and much lower MgO) than observed. Although absolute REE abundances differ, the REE patterns for the three fragments are similar to the pattern for 78526. This pattern, which has a monotonic increase from La to Lu with a negative Eu anomaly and $(La/Lu)_{c.n.}$ of $\sim$ 0.5 is unique among all lunar basalt patterns known to date, including the Luna 24 VLT basalt patterns. The similarities in major and minor element abundances and the REE patterns suggest a common origin for 78526 and the Apollo 17 VLT basalts. Most element abundances, including the REE, of 78526 fall between those of 70006,371 and 70007,289B, which indicates that 78526 may be a mixture of subequal amounts of those two components.

Discussion. On the basis of the REE patterns, neither primitive nor assimilated source material is likely for the Apollo 17 VLT basalts. Primitive source material (8,9) is unlikely because magmas produced by partial melting of primitive material (with chondritic REE abundances) would either have chondritic REE patterns (total melting) or patterns enriched in light REE (olivine + pyroxene in residue). Assimilated source material (10,11) is unlikely because magmas derived from the assimilation of primitive lunar material with the late-stage residuum (10) or with the "sinking" differentiated ilmenite pods (11) would also be enriched in the light REE.

The heavy-REE enriched pattern of the Apollo 17 VLT basalts can be explained by the cumulate-remelting model (12,13). The pattern could be produced by large (> 30%) degrees of partial melting of olivine + pyroxene cumulates that crystallized from a fractionated lunar magma with (La/Lu)c.n. $\sim$ 0.5, similar to the La/Lu ratios found in Apollo 17 VLT basalts. The Apollo 17 VLT basalt La/Lu ratio could also be produced by small degrees of partial melting of early, deep-seated olivine-pyroxene cumulates with La/Lu c.n. $\sim$ 0.1, which crystallized from the primitive lunar magma ocean. The high V abundances (> 200 ppm) in the Apollo 17 VLT basalts, however, favor large degrees of partial melting of the source, with significant depletion or exhaustion of orthopyroxene. Isotopic data of Rb/Sr and Sm/Nd ratios could permit a lower limit to be set for the degree of partial melting of the source material.

Distinct differences in major element compositions and in REE patterns rule out any simple genetic relationships between Apollo 17 and Luna 24 VLT basalts. Fractional crystallization or different degrees of partial melting cannot account for the differences. Nor does the Apollo 17 VLT basalt appear to have a genetic relationship with Apollo 15 green glass, such as 15426.

Conclusion. The REE pattern for Apollo 17 VLT basalts is distinct from that of Luna 24 VLT basalts, the Apollo 15 green glass, and every other lunar rock reported to date. Different source materials are required for the Apollo 17 and Luna 24 VLT basalts. The Apollo 17 VLT basalt REE pattern cannot be explained by either the primitive source model or the assimilation model, but may have resulted from partial melting of cumulate material with a heavy-REE enriched pattern.

References. (1) Vaniman D.T. and Papike J.J. (1977) P.L.S.C. 8th,, 1443. (2) Taylor G.J. et al (1977) Geophys. Res. Lett. 4, 207. (3) Taylor, G.J. et al (1978) Mare Crisium: The view from Luna 24, 357. (4) Ma M.-S. et al. (1978) Mare Crisium: The view from Luna 24, 569. (5) Laul J.C. and Schmitt R.A. (1975) Lunar Sci. VI, 489. (6) Murali A.V. et al. (1977) Lunar Sci. VIII, 700. (7) Warner R.D. et al. (1978) P.L.P.S.C., 9th, (in press) (8) Ringwood A.E. (1970) J.G.R. 75, 6453. (9) Ringwood A.E. and Essene E. (1970) P. Apll L.S.C., 769. (10) Hubbard N.J. and Minear J.W. (1975) Lunar Sci VI, 405. (11) Ringwood A.E. and Kesson S.E. (1976) P.L.S.C. 7th, 1967. (12) Smith J.V. et al (1970) P. Apll L.S.C., 897. (13) Shih C.-Y and Schonfeld E. (1976) P.L.S.C. 6th, 1757.

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Table 1. Chemical composition of VLT basalts from the Apollo 17 deep drill core.[a]

Element	70006,371 2.42 mg	70007,296 10.8 mg	70007,2898 2.15 mg	78526[b] 916 mg	24109,78[c] 0.342 mg
TiO_2(%)	0.7	0.4	1.1	0.9	1.3
Al_2O_3	11.6	10.3	10.4	11.0	11.6
FeO	15.5	17.0	20.2[e]	17.5	22.4
MgO	11	12	12	11.5	7
CaO	9.3	9.7	10.1	9.9	12.3
Na_2O	0.150	0.147	0.210	0.15	0.29
K_2O	0.014	0.013	0.011	0.018	0.022[d]
MnO	0.243	0.257	0.267	0.267	0.258
Cr_2O_3	0.930	0.645	0.999[e]	0.832	0.381
Sc (ppm)	47	54	61[e]	50	47
V	256	202	245	226	177
Co	30	36	46[e]	45	36
Ni	30±20	---	---	---	80
La	0.72	0.88	1.7	1.2	2.0
Sm	0.55	0.70	1.3	1.0	1.9
Eu	0.17	0.24	0.35[e]	0.28	0.58
Tb	0.14	0.20	0.35[e]	0.28	0.44
Dy	1.1	1.5	2.6	1.9	2.8
Yb	0.82	1.1	1.9	1.4	1.9
Lu	0.13	0.19	0.31	0.23	0.29
Hf	0.49	0.62	0.78[e]	0.6	1.1
Ta	---	---	---	0.006	---

[a]Estimated errors due to counting statistics are: Al_2O_3, FeO, Na_2O, MnO, Cr_2O_3, Sc, Co, La and Sm, ±1-5%; CaO, V, Eu and Yb, ±5-10%; MgO, K_2O, Lu and Hf, ±10-15%; TiO_2, Tb and Dy, ±15-20%.

[b]Weighted averages reported by Laul et al. (1975) and Murali et al. (1976).

[c]Ma et al. (1978).

[d]From Luna 24 ferrobasalt 24174,7 (Laul et al., 1978).

[e]Preliminary data.

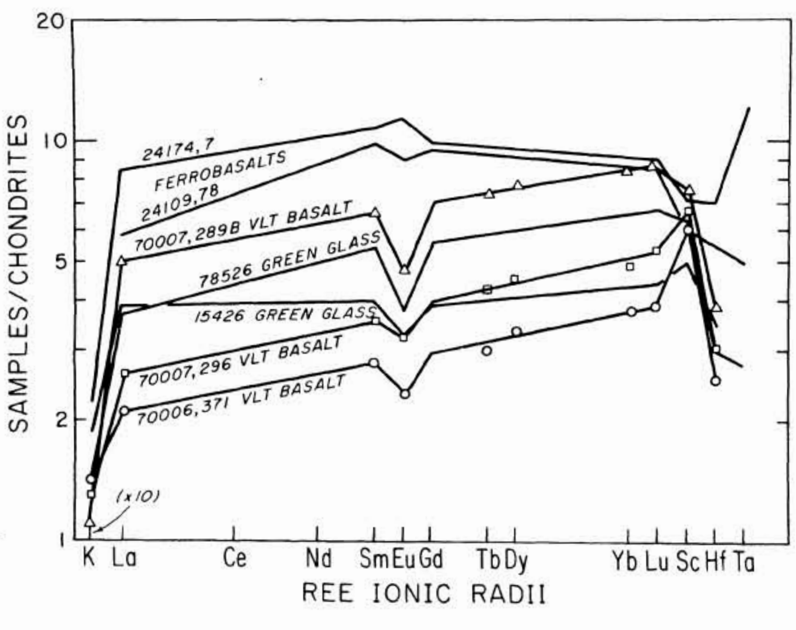

Figure 1. Chondrite-normalized K, REE, Sc, Hf, and Ta abundances. Note that Luna 24 VLT basalts have bow-shaped patterns typical of mare basalts, whereas Apollo 17 VLT basalts do not.