SINGLE SOURCE ORIGIN FOR APOLLO 15 OLIVINE- AND QUARTZ-NORMATIVE BASALTS; D.W. Schnare[1], L.A. Taylor[1], M.D. Norman[2], and J.M.D. Day[1]
[1]Planetary Geosciences Institute, University of Tennessee, Knoxville, TN, 37996 (dschnare@utk.edu) [2]Australian National University, Canberra ACT 0200, Australia.

Introduction: A large suite of low-Ti mare basalts was collected during the Apollo 15 Mission to the Moon. These rocks were divided into two groups, the Olivine-Normative Basalts (ONBs), and the Quartz-Normative Basalts (QNBs), on the basis of their whole-rock chemical compositions. Previous studies have examined the relationships between these groups on the basis of whole-rock chemistry, but a clear explanation of their petrogenesis has not been forthcoming. Using newly determined mineral trace-element data from ONBs (15016, 15555) and QNBs (15475, 15499) and two sets of distribution coefficients, the parental- and evolved- melt compositions of these rocks have been modeled. Thereby, the relationships between the two basalt suites are addressed.

Results: The main silicate phases (pyroxene, plagioclase, olivine) were analyzed for their trace-element compositions. The pyroxene data (Fig. 1), used here in petrogenetic modeling, are the most relevant because pyroxenes contain significant amounts of trace-elements acquired over long temperature spans of crystallization. Pyroxene rare-earth-element (REE) profiles, normalized to CI chondrite, have convex-upward, sub-parallel patterns, small negative Eu anomalies, and increasing REE abundances with Fe-enrichment [1,2].

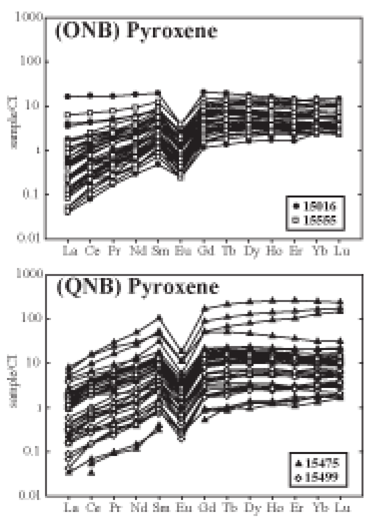

Figure 1. Rare-earth-element compositions for pyroxenes analyzed in this study.

Modeling Methodology: We have calculated the parental-melt REE compositions of these pyroxenes by inverting LA-ICP-MS data of the most primitive pyroxenes, using experimentally derived partition coefficients (D = min/melt). Choosing a good set of partition coefficients is complicated [3], as D values vary based on a number of factors, including, but not limited to, temperature, pressure, mineral, and melt compositions. The D values used are taken from McKay et al. [4]. These D values were selected because they were determined for low-oxygen fugacity (~ IW) and **Wo_{12}** pyroxenes (pigeonites), similar to those found as the primary pyroxene core compositions in Apollo 15 basalts. The average Wo content of the ONB-QNB pyroxene compositions used in the modeling is ~11 %. The primitive pyroxene compositions used for the inversion, along with their respective calculated parental-melt REE compositions, are presented in Figure 2.

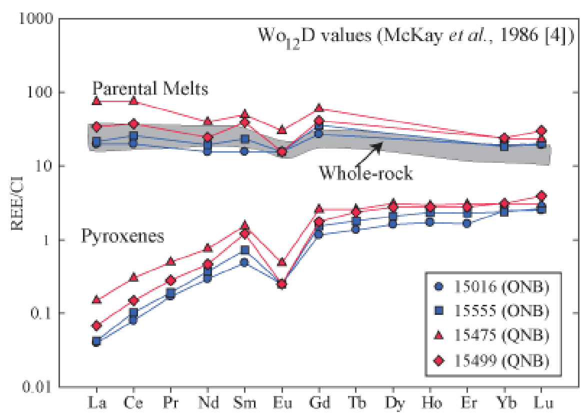

Figure 2. Primitive parental-melt REE- compositions using Apollo 15 pyroxenes with Wo_{11} contents from both ONBs and QNBs.

Parental-melts calculated by this method have REE contents similar to, but slightly elevated compared with, whole-rock compositions for their respective samples. These offsets might be due to the D values are being slightly wrong, as they were determined experimentally in a slighty different magmatic setting. Following the same inversion method as discussed above, evolved melts also have been calculated using D values from McKay et al.[4] for **Wo_{32}** pyroxenes (augites, Fig 3).

Discussion: The QNB calculated parental-melts possess higher REE contents than do the ONB melts (Fig. 2). This is strong evidence that the QNBs represent higher degrees of fractionation from parental-melts that are almost identical to those of the

ONBs. In general, the evolved parental-melt REE compositions (Fig. 2) have higher abundances of HREEs, lower LREEs, and more pronounced -Eu anomalies, compared to the calculated parental-melts. This is consistent with typical melt evolution.

These modelings of our large trace-element dataset have elaborated on the particular relationship between the two Apollo 15 basalt suites. **This modeling has shown these rocks have calculated parental-melt REE compositions similar to their whole-rock compositions; to the point that, within error, both rock types are likely derived from the same parental magma.** In our scenario, olivine (and chromite) fractionally crystallizes from a common parental melt and settles out. The residual melt is tapped subsequently to form the more-evolved quartz-normative basalts.

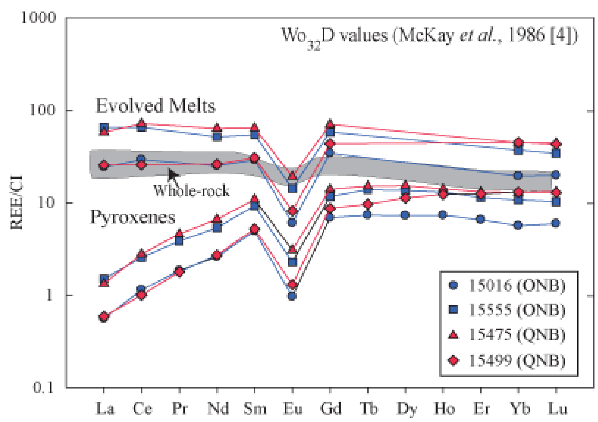

Figure 3. Calculated evolved-melt REE compositions.

The locations of the bulk-rock major-element compositions of these rocks from out modeling, when plotted on a Walker Diagram (Fig. 4), serve to illustrate the fundamental difference between the ONBs and QNBs. The small portion of olivine that crystallizes from QNB starting compositions is either fully reacted to form pyroxene at the reaction curve, or removed during fractional crystallization. The starting compositions of the ONBs result in their crystallization terminating at the peritectic. However, the QNBs, lacking olivine, 'skip' over the reaction curve and finish crystallization at the eutectic, crystallizing pyroxene, plagioclase, and tridymite. Simple modeling used a simplistic approach by subtracting out olivine (Mg# predicted by $K_D^{Fe/Mg}$ = 0.325; from [6]), from the ONB magma. Subtraction of 5-20% of crystallizing olivine will account for all QNB compositions (Fig. 5).

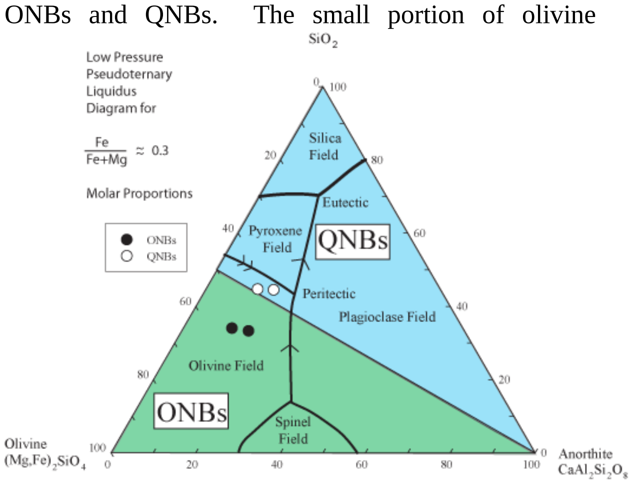

Figure 4. Psuedoternary liquidus diagram; after McKay et al. [4].

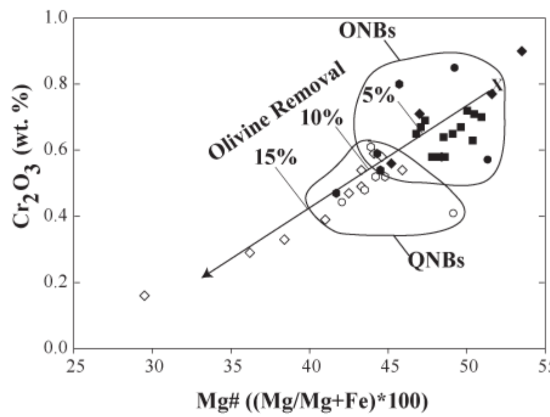

Figure 5. Whole-rock plot showing the progression of ONBs to QNBs with removal of olivine by fractional crystallization, as their common parental melt (represented by X) evolves.

Summary: Distribution coefficients were used to determine the parental- and evolved-melt compositions for these Apollo 15 basalts. The calculated parental melts for both the ONBs and QNBs are similar to measured whole-rock compositions and are consistent with fractional crystallization of olivine. **This petrogenetic modeling of melts has determined that the ONB and QNB suites can be related by simple fractional crystallization processes from a common parental melt.** The Apollo 15 basalts appear to have originated from a single parental melt, and are related by fractional crystallization of 5-20% olivine.

References: [1] Schnare D.W, Norman M.D., Day J.M.D., and Taylor L.A. (2005) *LPSC XXXVII* [CD-ROM] Abstract #2212; [2] Schnare D.W., Taylor L.A., Day J.M.D, and Norman M.D. (2007) *Geochimica et Cosmochimica Acta. In Preparation;* [3] Jones J. (1995) *A Handbook of Physical Constants, American Geophysical Union*, 74-104; [4] McKay G., Wagstaff J., and Yang S.R. (1986) *Geochimica et Cosmochimica Acta.*. 50, 927–937; [5] Walker D.W., Longhi J., and Hays J.F (1972) *PLSC.* III, 797-817; [6] Delano J.W. (1980) *PLSC XI*, 251-288