PETROGENESIS OF APOLLO 17 HIGH-TITANIUM BASALTS USING CRYSTAL STRATIGRAPHY.

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Introduction: Apollo 17 high-titanium basalts (HTBs; $TiO_2 > 6$ wt%) have a range of compositions and are classified by major and trace element composition. Previous studies have shown the HTB suite originated from multiple source regions [1-4]. Work by [1] modeled type A, B1 and B2 crystallization on the basis of whole rock compositions, concluding that each type experienced moderate closed-system fractional crystallization (FC). Textural studies of thin sections have revealed centimeter-scale variations in these samples that are lost when analyzing whole rock powders [5]. By analyzing individual phases, a much more detailed petrogenetic history can be discerned.

This study investigates magma evolution through compositional changes across and between ilmenite, armalcolite and pyroxene crystals. A17 basalts contain high abundances of ilmenite, which is an early-forming phase and remains on the liquidus for the majority of crystallization [2,3,6]. Therefore, changes in magma composition will be reflected in progressive crystallization of ilmenite. This can be witnessed in core-to-rim and crystal-to-crystal variations.

Samples and Methods: This study investigated 16 Apollo 17 HTBs:
Type A (70135,64; 71048,6; 75015,52);
Type B1 (70315,27; 71557,7; 75075,86; 78575,10);
Type B2 (70275,35; 71035,32; 77516,30; 79516,9);
Type C (71509,5; 74255,55; 74275,312; 75115,4); and
Type D (79001,2187).
These samples are also the subject of a quantitative

petrography study using crystal size distributions [5].

Major and minor element abundances and x-ray maps were obtained on a JEOL JXA-8200 electron microprobe (EMP) at Washington University, St. Louis. Analyses were acquired using the Probe for Windows software, and x-ray correction was performed using the CITZAF correction software [7]. A 5-10 μm beam size was used with a 20 kV accelerating potential and 25 nA probe current.

Trace element abundances in ilmenite (Sc, V, Cr, Co, Zr, Nb, Hf, Ta) were obtained on an Element2 high-resolution inductively coupled plasma mass spectrometer (ICP-MS) coupled to a UP213 Nd:YAG New Wave laser ablation system. A spot sizes ranged between 65-80 μm. Raw counts were calibrated to the NIST SRM 610 glass as the external standard and TiO_2 contents obtained by EMP as the internal standard. Abundance data was reduced using *Glitter* [8].

Crystallization modeling was performed by back calculating melt compositions from that of ilmenite and plagioclase. Ilmenite-melt and pyroxene-melt partition coefficients (Kds) of investigated trace elements are from the literature. Crystal trace element abundances were divided by the appropriate Kds to calculate melt composition. The starting crystallization sequence used for the parent magmas determined by [1] consisted of olivine + spinel + armalcolite. Spinel and armalcolite dropped off as ilmenite and pyroxene began to crystallize, and plagioclase was introduced after 60% crystallization. The relative amounts of each
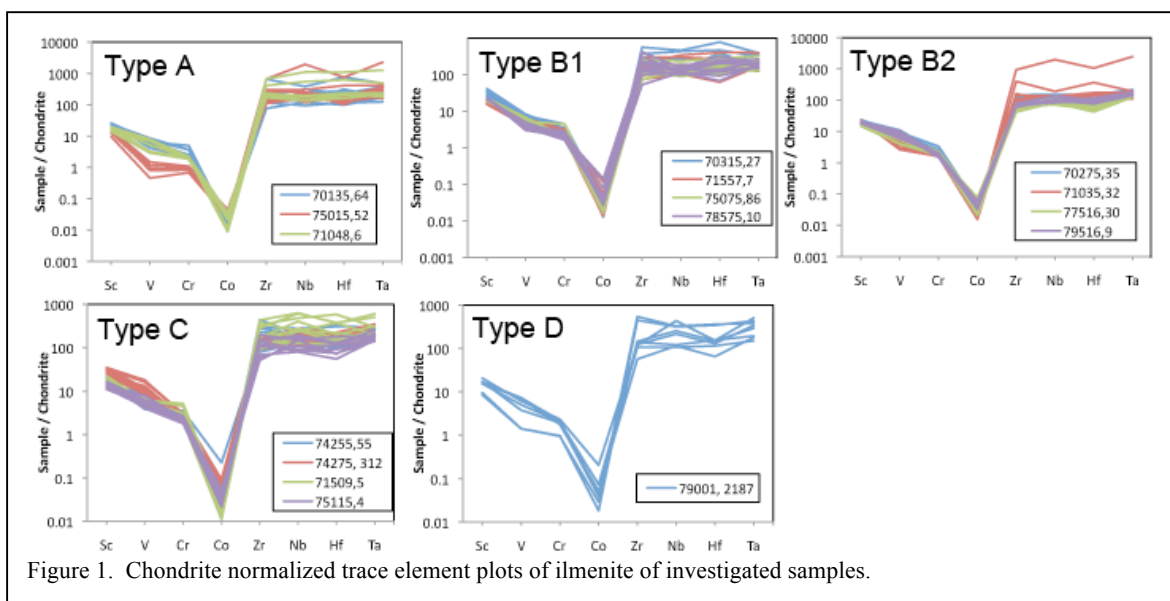

Figure 1. Chondrite normalized trace element plots of ilmenite of investigated samples.

phase varied between basalt types.

Results: Chondrite-normalized trace element abundances follow the same general pattern among the different basalt types (Fig. 1). There is a decreasing trend from Sc to Co, and all ilmenite analyses from a sample define a flat profile from Zr to Ta. Within an individual crystal, however, the trend is jagged with Zr abundance similar to Hf, and Nb similar to Ta.

Fractional crystallization modeling results are presented in Fig. 2. The kink in the FC path marks the end of olivine crystallization and an increase in ilmenite and pyroxene crystallization. The kink is not present in 79001,2187 (Type D) as textural studies have indicated ilmenite began crystallizing with or slightly before olivine [4].

Discussion: For the majority of samples, a single FC path adequately models the calculated melt composition. Thus a single flow or source region may be responsible for each type of HTB. There are several analyses that do not fall close to the FC path, most notably 75015,52 (discussed below). Further modeling to explain errant points are underway. This study agrees with the findings of [1] that the Type A, B1 and B2 samples have a relatively simple petrogenesis, and that fractional crystallization is the most important post-magma crystallization process. We find that this process can also explain the petrogenesis of Type C and D basalts.

All ilmenite analyses from sample 75015,52 plot separately from the other Type A basalts. To generate melt compositions of 75015,52 from the same Type A starting composition requires the removal of 5-7% armalcolite (± minor spinel) prior to the start of ilmenite crystallization. Armalcolite is rare in Type A basalts and within these samples, it has only been noted in trace amounts in 70135. Whole rock analyses of 75015 have found it to contain lower TiO_2 (8.7 wt% and 9.56 wt%) compared to the other two Type A samples investigated here (12.9-13.84 wt%) [1,9,10]. Thus it is possible that 75015,52 originated from a possibly more evolved magma or from a separate source region.

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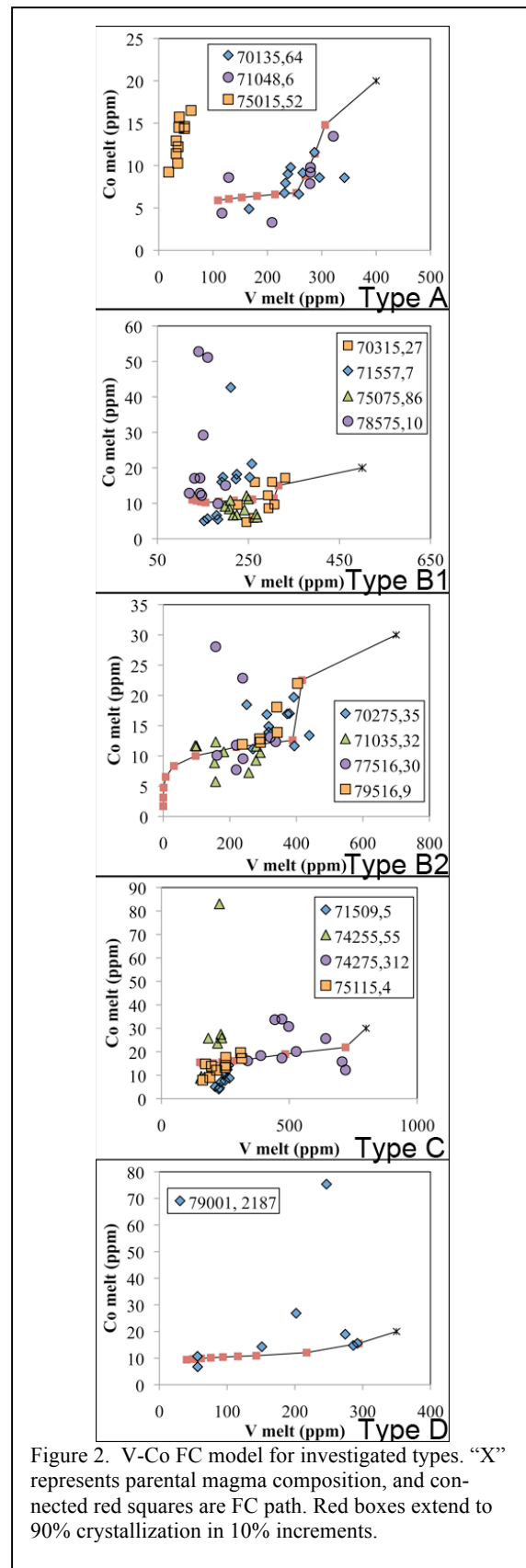

Figure 2. V-Co FC model for investigated types. "X" represents parental magma composition, and connected red squares are FC path. Red boxes extend to 90% crystallization in 10% increments.