MARE BASALT EVOLUTION: THE INFLUENCE OF KREEP-LIKE COMPONENTS. Clive R. NEAL and Lawrence A. TAYLOR: Dept. of Geological Sciences, University of Tennessee, Knoxville, TN 37996; Marilyn M. LINDESTROM: Johnson Space Center, Houston TX.

At the Apollo 14 site, mare basalts form a minor, yet highly significant component of the lunar crust. For example, the oldest mare basalt have been described from this area [1], as well as the important new VHK rock-type [2]. Three models have been proposed for the origins of these basalts: 1) cumulate melting [3,4]; 2) melting of a primitive source [e.g., 5]; and 3) assimilation [e.g., 6]. However, none of the models can account for all the data base increases from the continued "pull-apart" efforts on lunar breccias. Recently, the petrogenesis of mare basalts has been attributed to assimilation of a KREEP component by a basalt of primitive composition [2,7]. This model uses an Apollo 14 KREEP and an IKFM composition [8] to produce various groupings based on the HFS elements and REE's. The present paper refines such models on the basis of data from new basalt clasts from breccia 14321. Our data base includes the petrography, mineral chemistry, and whole-rock chemistry from 25 new 14321 mare basalt clasts.

PETROGRAPHY Probe mounts of 23 mare basalt have been studied from consortium breccia 14321 (Table 1). These are generally ophitic to sub-ophitic basalts dominated by plagioclase and pyroxene, with subordinate olivine. Importantly, olivine is always rimed by pigeonitic pyroxene and in ,1485 appears to have been totally replaced. Ophitic basalt 1118 has undergone post-crystallization granulation. Three vitrophores have also been studied (1471, 1473, 1486) and contain euhedral plagioclase and olivine phenocrysts in an opaque glass. Glass compositions are generally high Al/low Mg (11-31 wt% Al2O3; 0.5-7.6 wt% MgO) and low Al/low Mg types (2-5 wt% Al2O3; 17-23 wt% MgO). Other phases such as olivine, chromite-ulvöspinel and FeNi metal are present in minor amounts. FeNi metal is present in all samples, either enclosed in pyroxene or in the interstices, sometimes too small for analysis. Most show low Ni and Co abundances similar to Apollo 15 mare basalts and to previously studied Apollo 14 basalts [9]. Basalts which contain FeNi metal grains with >1 wt% Ni fall within the field of Apollo 14 mare basalt compositions [9] and above the range for "meteorite contamination". However, two samples plot above the field of Apollo 14 & 16 polymict rocks [10] and are similar to those described from Apollo 15 (increased Co).

WHOLE-ROCK GEOCHEMISTRY: Trace element abundances are similar to other Apollo 14 basalts, but extend the ranges of previously reported compositions [6]. The compatible trace elements (Cr = 2734-4190 ppm; Ni = 40-180 ppm; Sc = 55.0-64.1 ppm; Co = 28.0-43.4 ppm) fall within the ranges of low-Ti, high-Al basalts, which may be used as a general classification (not all of the major elements have been determined). The major variation in trace element geochemistry, especially in the REE's and LIL elements, is in particular Ba (28-216 ppm). The LREE range from approximately 20X chondrite to almost 100X. A change in the shape of the REE profile is also noted from almost chondritic La/Lu in basalts with the least...
REE's, to enriched ratios in those with the greatest REE abundances (similar to a KREEP pattern). Figure 1 shows the variation in the REE profiles as REE abundances increase during magma evolution. However, if mixing occurred at the base of the lunar crust, as suggested by [7], an AFC process would seem more appropriate. A problem inherent in this hypothesis is the range in KREEP compositions [11]. In Figure 2, an AFC trend has been modelled between KREEP reported by [12] and primitive basalt 14321,1422 (basalt data are from [2,7] and this study). Fractional crystallization is dominated by plagioclase (35%), with 25% olivine, and 20% each pyroxene and opx. This would produce the required continuum of basaltic compositions represented at the Apollo 14 site.

Further evidence for mare basalt evolution by AFC of a primitive basalt + KREEP is seen in Figure 3. The mare basalts are from this study, and [5,7]. They form a trend of decreasing Sc/Sm with slight increase in Ba, until Sc/Sm = 4-6, where a marked Ba increase is noted. The same proportions of crystallizing phases are used as in Figure 2. The dominance of plagioclase crystallization enhances the negative Eu anomaly in the REE profiles as REE abundances increase during magma evolution. However, even the most primitive types (i.e., 14321,1422) have a negative Eu anomaly, and experimental studies [13] indicate plagioclase was removed before the cumulate source formed. The mare basalt source region is considered to be a complimentary mafic cumulate of the same magma(s) that produced the ancient anorthositic crust (e.g., 14,15). It is concluded that after melting of this cumulate source, the mare basalt magma resided in a magma chamber at the base of the lunar crust, where it came into contact with a KREEP component (possibly interstitial in the anorthositic crust). As a consequence of AFC of the primitive magma + KREEP and periodic emissions, we now see a continuum of compositions between the primitive precursor and KREEP.