VERY HIGH POTASSIUM (VHK) BASALT PETROGENESIS: THE ROLE OF GRANITE AND KREEP COMPONENTS. Clive R. NEAL and Lawrence A. TAYLOR: Geological Sciences, Univ. of Tenn., Knoxville, TN 37996; Marilyn M. LINDSTROM: Johnson Space Center, Houston, TX.

The evaluation of the extent of igneous processes, such as batch melting, assimilation, and fractional crystallization, is vital in the understanding of lunar planetary evolution [1,2,3]. For example, assimilation of a KREEP component has been invoked to explain certain anorthosite compositions [4], as well as mare basalt evolution [5,6]. The discovery in Apollo 14 breccias of very high potassium (VHK) basaltic clasts [7,8,9] has heralded problems in achieving such compositions by partial melting of the lunar interior and/or fractional crystallization [10]. These VHK basalts are characterized by high abundances of K_2O >0.5 wt%, K_2O/Na_2O >1, and K/La ratios between 500 and 1500 (Fig. 1). VHK basalts do not form part of the mare basalt trend in Figure 1. These observations led to the hypothesis of VHK formation by mare basalt assimilation of lunar granite [10,11]. However, a problem inherent with this hypothesis is that granite is implied to be a major component of the lunar crust at the Apollo 14 site. As stated by Shervais et al. [11], "simple mixing of a granite whole-rock composition with basalt will not accurately reflect the assimilation process". The purpose of this present study is to evaluate and clarify the processes involved in VHK basalt petrogenesis in light of new data from five new VHK samples and a KREEP basalt from breccia 14303.

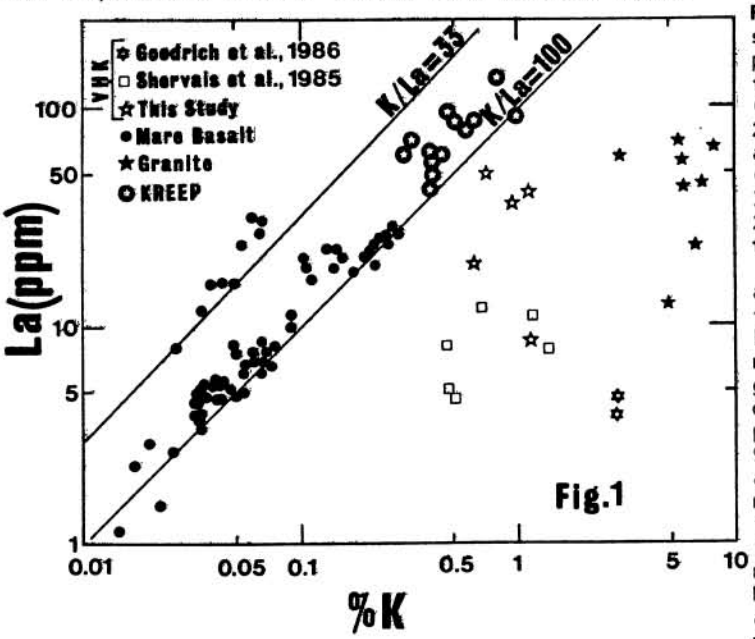


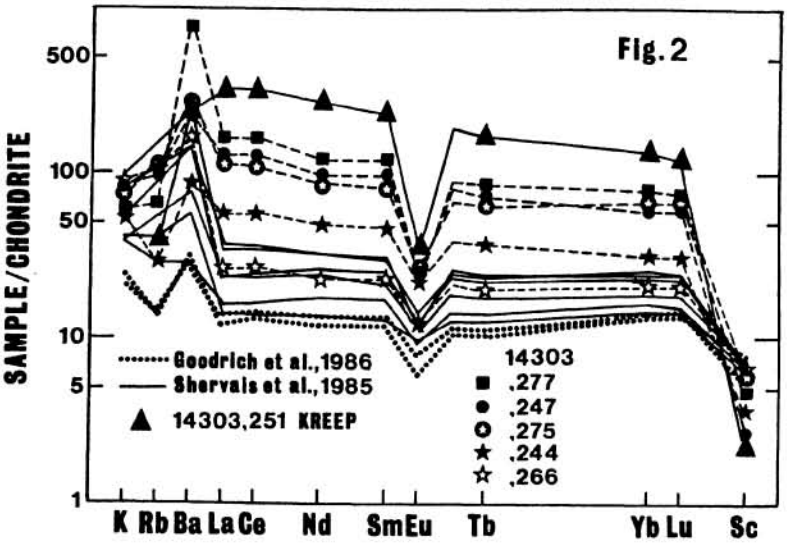
Fig.1

PETROGRAPHY: The VHK clasts are small (0.25-1cm diam.); thus, probe mounts (PM) have been made for only three: 14303,245 (,244); 14303,246 (,247); 14303, 249 (,249 was too small for INAA analysis) [INAA #'s given in ()]. INAA only was performed on 14303,266, 14303,275 and 14303, 277; PM's are being made from the "hot" samples.

The VHK basalts from 14303 are petrographically distinct from those described earlier [8,9,11]. They are fine- to medium-grained basalts with a general subophitic texture. All contain large (0.4mm diam.) plagioclase phenocrysts (An90-94) with a smaller, compositionally indistinguishable, groundmass generation. Fe-rich olivine is present only in ,245 (Fo51-52) as a corroded phase mantled by pigeonite. No Mg-rich olivine was observed in any of the 14303 samples, as in the 14305 examples [11]. Enstatite and augite are present in all three thin sections studied, with Mg pigeonite also in 14303,245 and ,249. Mg-rich pigeonite grades into subcalcic augite and intermediate pigeonite in 14303,245. There is some evidence of augite rimming pigeonite, but because of the small grain size of these samples, it is not possible to make out the exact nature of these relationships. Ilmenite forms an interstitial phase, with Mg# varying slightly within each specimen (,245: 18.7-19.8; ,246: 19.0-20.4; ,249: 17.1-18.8). In ,245, ilmenite (Mg#=11.3) occurs in association with chromite [Cr/(Cr+Al)=67.1-74.6; Mg/(Mg+Fe)=8.4-16.1] and Fe metal in one 0.2x0.2mm grain. Interstitial K-rich glass is present in these samples (≅14 wt% K_2O), accounting for the high K signature of these basalts.

Basaltic clast 14303,250 (,251) has the same texture as those described above with plagioclase phenocrysts (0.8mm diam.), but it also contains opaque clots (0.7mm diam.). These clots contain a core of ilmenite with glass inclusions, possessing a mantle of glass. Ilmenite shows little variation (Mg# = 24.1-25.6), but the glass has two distinct compositions: High Fe and Mg/low Al and Ca versus low Fe and Mg/high Al and Ca. Plagioclase phenocrysts show slight zonation from core (An87-92; Ab8-12; Or0.7-1.3) to rim (An76-88; Ab12-21; Or0.8-3.0). The groundmass plagioclases overlap the phenocryst compositions, trending toward more Ab and Or compositions (An77-90; Ab7-20; Or0.6-3.0). Plagioclase is the only silicate mineral present in the opaque clots and has higher Ab contents than both the groundmass and phenocryst types (An76-88; Ab11-21; Or1.0-3.0). Pyroxene compositions form two groups of augite and enstatite with little compositional variation. No olivine is present.

WHOLE ROCK GEOCHEMISTRY: The whole rock geochemistry of VHK basalts is remarkably similar to other Apollo 14 low-Ti, high-Al basalts [7-9,11]. Potassium is the only unusual major element (K_2O 0.75-1.3 wt%). The trace elements also show similarities to low-Ti, high-Al basalts, especially in the compatible element (Co 19-35ppm; Ni 50-210ppm). Sc and Cr (20-58ppm; 1014-3350ppm, resp.) are lower than for previously analyzed VHK's [8, 9,11]. Zr (245-700ppm) is enriched relative to mare basalts (200-450ppm; [6]). Hf values overlap those of mare basalt, but extend toward KREEP values. K and Rb are enriched relative to the REE's in 14304 and 14305 samples [8,9,11], but four samples describe the opposite relationship, having K/La <500 (137-344) indicating an enrichment in the REE's relative to K (Fig. 2). Ba is always enriched relative to the REE's. The VHK's have similar REE patterns and have similarities to KREEP (e.g., 14303,250) in the slightly enriched La/Lu ratios. The negative Eu anomaly increases with increasing overall REE abundances. KREEP basalt 14303,250 (,251) has extremely enriched REE abundances and contains no positive Ba anomaly as in the VHK's.



DISCUSSION: In an age determination for VHK basalt 14305,304, the initial $^{87}Sr/^{86}Sr$ ratio was indistinguishable from that of mare basalt. To generate the required Sr isotopic ratios, a 15 fold increase of Rb/Sr is required at the time of formation [12]. The only feasible way to achieve this is for a primitive mare basalt to assimilate a rock type rich in alkalis, such as the lunar granites [7,10,11]. VHK major and trace element chemistry, however, can only be modelled by varying amounts of granite assimilation depending on the element considered [11]. This could be explained by the effects of another component, such as KREEP. A KREEP signature may be inferred by the similarity of REE profiles between some of the VHK basalts and KREEP (Fig. 2). Many basaltic clasts from breccia 14321 appear to have assimilated a KREEPy component, possibly by anatexis of lower crustal plutonic material [3,6,9]. The conclusion of the present study is that while mare basalts appear to have assimilated varying proportions of a KREEPy component, some samples have also experienced contamination by granite. The implications of this are that **KREEP and granite are spatially related within the lunar crust**, also concluded by [11], and **granite assimilation occurs during contamination of these mare basalts by KREEP** (represented by 14303,250 [,251]). The restricted number of VHK basalt samples may therefore be a consequence of the rarity of granite on the moon, as witnessed by the lack of substantial granitic clasts.

REFERENCES: 1) Nyquist et al., 1979, PLPSC 10, 77-114; 2) Ringwood & Kesson, 1976, PLC7, 1697; 3) Shervais et al., 1985, JGR 90, C375-395; 4) Warren et al., 1983, JGR 88, B151-164; 5) Dickinson et al., 1985, JGR 90, C365-374; 6) Neal et al., this volume; 7) Shervais et al., 1984, LPS XV, 768-769; 8) Goodrich et al., 1986, JGR 91, D305-318; 9) Warren et al., 1986, JGR 91, D319-330; 10) Shih et al., 1985, JGR 91, D214-228; 11) Shervais et al., 1985, JGR 90, D3-18; 12) Shih et al., LPSXV 774-775; 13) Ryder, 1976, EPSL 29, 255-268.