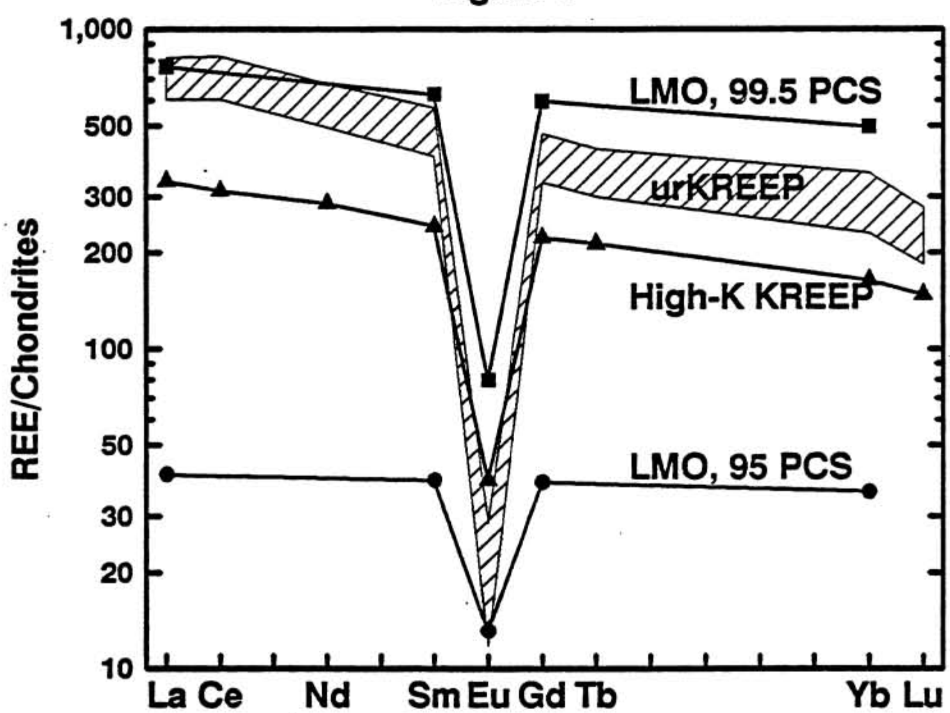
IN SEARCH OF THE urKREEP RESERVOIR: TRAPPED RESIDUAL LUNAR MAGMA OCEAN LIQUID IN THE INTERSTICES OF UPPER MANTLE CUMULATES Gregory A. SNYDER & Lawrence A. TAYLOR, Dept. of Geological Sciences, University of Tennessee, Knoxville, TN 37996-1410.

Many lunar basalts have been overprinted by a pervasive chemical signature termed KREEP [1]. That this signature exists, that it seems to be well-distributed over the whole Moon, and that it is surprisingly uniform, where it is found, has been well-documented [1]. However, the location of this "KREEPy reservoir", whether in the upper mantle or lower crust, as pods [2] or as a distinct layer [3] is still unknown. We propose that the reservoir for KREEP (termed pristine KREEP or urKREEP) resides in the interstices of cumulus minerals in the upper portion of the lunar mantle as trapped residual liquid from the crystallization of the Lunar Magma Ocean (LMO).

KREEP AS A CHEMICAL SIGNATURE: The chemical signature of KREEP that makes it unique includes relatively elevated abundances of K, REE, and P (thus the acronym), and other LILE, including U, Th, and K, and a LREE-enriched pattern. Warren & Wasson [1] defined this chemical signature by calculating an average composition for incompatible-element-enriched breccias from Apollo 14. However, samples from other landing sites which show incompatible-element enrichment exhibit similar relative fractionations in these elements. This observation must necessarily rule out partial melting models for the derivation of KREEPy rocks [1]. This led Warren & Wasson [1] to postulate "a single major source that could provide KREEP to widely separated locations on the nearside of the moon."

GENERATION OF THE KREEP RESERVOIR: Warren & Wasson [1] stated that the residual liquid left after 99% fractional crystallization of the Lunar Magma Ocean (LMO) would be enriched in incompatible elements. They hypothesized that this residual liquid was primeval KREEP, or urKREEP. Snyder et al. [4] and Hughes, et al. [5,6], have shown that the residual liquid left after over 90% crystallization of the LMO does indeed start to take on a KREEPy signature (Figure 1). This is due mostly to the fact that mafic cumulus minerals, which would have fractionated from the LMO to generate the lunar mantle, are incompatible with the LILE such as K, P, U, Th, and the REE. Consequently, the residual liquid would become progressively enriched in these elements.

Figure 1



We have proposed that the lunar mantle contains $\geq$ 1% **trapped instantaneous residual liquid** (TIRL) throughout [4]. The composition of this TIRL component would reflect the composition of the residual LMO at various stages in its evolution. At 98-99 per cent solid (PCS) the residual LMO liquid has the composition of urKREEP (as calculated by Neal & Taylor [2]; see Figure 1).

WHERE'S THE urKREEP?: If a Moon-wide melt layer is proposed for the incipient LMO, then this KREEPy TIRL would also be distributed throughout the Moon. Neal & Taylor [2] envisioned the urKREEP reservoir as pods of residual LMO liquid situated in the upper mantle and lower crust. Warren & Wasson [1] postulated that the urKREEP reservoir is a more or less continuous 1-2 km layer of crystallized residual LMO liquid. They also speculated that the distribution of urKREEP in the moon is asymmetrical. This possibility can also be accounted for in the "layered-intrusion" model for the evolution of urKREEP. Slight tilting (or in spherical coordinates, bulging and corresponding formation of depressions) of the cumulate pile would allow the last dregs of the LMO to be concentrated on one side (the west-central part of the near-side in this case, [1]) of the moon. As the last 1-2% of the mafic cumulate pile crystallized, the liquid trapped in the interstices would maintain this urKREEP composition. This model allows for the distribution of urKREEP over a much broader area and to much greater depths.

AVAILABILITY OF KREEP AS A "CONTAMINANT" FOR MARE BASALTS: The high concentration of radioactive, heat-producing species (U, Th, and K) in this **urKREEP TIRL**, and its lower melting point when compared with the enclosing cumulates, would allow it to be readily melted after initial solidification. Rising basaltic diapirs could selectively and readily melt-out this KREEPy liquid first. Most mare basalt magmas were generated by small percentages of partial melting of the lunar mantle. Therefore, the volume of magma produced would be relatively small. Combined with the fact that the *incompatible element concentrations of the urKREEP trapped liquid are 1-2 orders of magnitude greater than the ascending basalt magma*, this means that only small amounts of the urKREEP component trapped in the mafic cumulates would be required to impart a KREEPy signature to the basaltic magma. In turn, this could explain both the pervasive and seemingly ubiquitous nature of the KREEP signature in lunar samples. In fact, we may wonder why this signature is not more universal. The answer could be found in the imperfection of nature. The trapped liquid component of the cumulates in some locations may be non-existent (leading to perfect adcumulates), whereas in other locales the trapped liquid may be voluminous, producing orthocumulates. Basaltic magmas may then encounter fertile (containing an abundance of urKREEP trapped liquid) or non-fertile cumulates as they ascend to the surface.

CONCLUSIONS: The urKREEP reservoir can be found in the trapped liquid component of upper mantle cumulates. This model allows for a wide distribution of the urKREEP reservoir over virtually the whole moon. **The lower melting point of this crystallized late-stage (last 10% of crystallization of the LMO) liquid and its relatively higher proportion of heat-producing elements (K, U, Th), makes it a fertile component for melting during the ascent of basaltic magmas through upper mantle orthocumulates.** This model is consistent with the pervasive and consistent nature of the KREEPy signature in lunar samples from widely spaced locations on the near-side of the moon.

REFERENCES: [1] Warren & Wasson (1979), **Rev. Geophys. Space Phys. 17**, 73-88; [2] Neal & Taylor (1989), **GCA 53**, 529-541; [3] Warren (1985), **Ann Rev. Earth Planet. Sci. 13**, 201-240; [4] Snyder et al. (1990), **Mare Basalt Workshop**, in press; [5] Hughes et al. (1988), **GCA 52**, 2379-2391; [6] Hughes et al. (1989), **PLPSC 19**, 175-188.