PETROGENESIS OF KREEP-RICH AND KREEP-POOR NONMARE ROCKS,

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This report focuses on the compositions and origins of the nonmare lithic fragments present in lunar soil samples. On the basis of chemical (Fig. 1) and modal (Fig. 2) compositions we identify two main classes of nonmare rock: KREEP-rich and KREEP-poor. Fig. 1, a ternary plot of normative components, illustrates this division. KREEP-rich rocks are notably enriched in normative orthoclase plus apatite (i.e., in K+P) and are noritic or troctolitic. KREEP-poor rocks embrace a range of compositions, from anorthositic to noritic or troctolitic. Fig. 2 (Taylor et al.,1973) illustrates the relative proportions of KREEP-rich and KREEP-poor nonmare fragments in Apollo 11, 14, 15, and 16 and Luna 20 soils, as well as the range of compositions represented within each group. (The KREEP-content can be inferred from the abundance of phosphate phases present in the fragments.) KREEP-rich rocks are most abundant in Apollo 14, moderately abundant in Apollo 15 and 16, and rare in Apollo 11 and Luna 20. Note that the abundance of KREEP-rich fragments in the samples shown in Fig. 2 decreases with increasing distance from the Imbrium-Procellarum region of the Moon. These results are consistent with the orbital $\gamma$-ray measurements (Metzger et al.,1972) which indicate that high concentrations of U, Th, and K (characteristic of KREEP) are confined to this unique region.

Fig. 2 also demonstrates that the KREEP-poor rocks in the lunar terrae have a wide range of compositions, from norite or troctolite to anorthosite. Pyroxene compositional trends (Fig.3) in the KREEP-poor noritic/troctolitic/anorthositic suite suggest that these rocks formed by fractional crystallization in an early, moonwide magma system (Taylor et al.,1973). (Pyroxenes in an individual lithic fragment are quite homogeneous; the trend in Fig.3 results from interparticle variations.) During this monumental event, plagioclase floated and the mafic silicates sank, thus forming two cumulate layers, the upper one enriched in plagioclase relative to the lower one. There appears to be two distinct groups of pyroxene compositions in Fig. 3, one richer in Fe than the other; this is particularly evident for the Luna 20 data. Significantly, pyroxenes with the same Cr content in each group have much different Fe/(Fe+Mg) ratios. This suggests that the two compositional groups crystallized under different conditions so that Cr was partitioned differently between pyroxenes, liquid and other phases. They most probably formed in two different magmas.

We propose that a KREEP component (rich in K, REE, P, U, Th, Ba, Fe, and $SiO_2$) was residual after the fractional crystallization event that led to the formation of the KREEP-poor lunar

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crust. KREEP-rich rocks may have formed by the mechanical mixing of small amounts (< 10%) of this residual material with KREEP-poor noritic rocks during impact events. The trace element geochemistry of this mechanical mixture would be dominated by the residual component while the major element geochemistry would be dominated by the KREEP-poor noritic rocks. The localization of KREEP-rich rocks in Oceanus Procellarum is consistent with the hypothesis of Wood (1973) that the lunar crust in this region is thinner than elsewhere, because of preferential meteoroid bombardment. The upper, more anorthositic crust may have been stripped away leaving the underlying noritic rock to be mixed with the KREEP residium.

References

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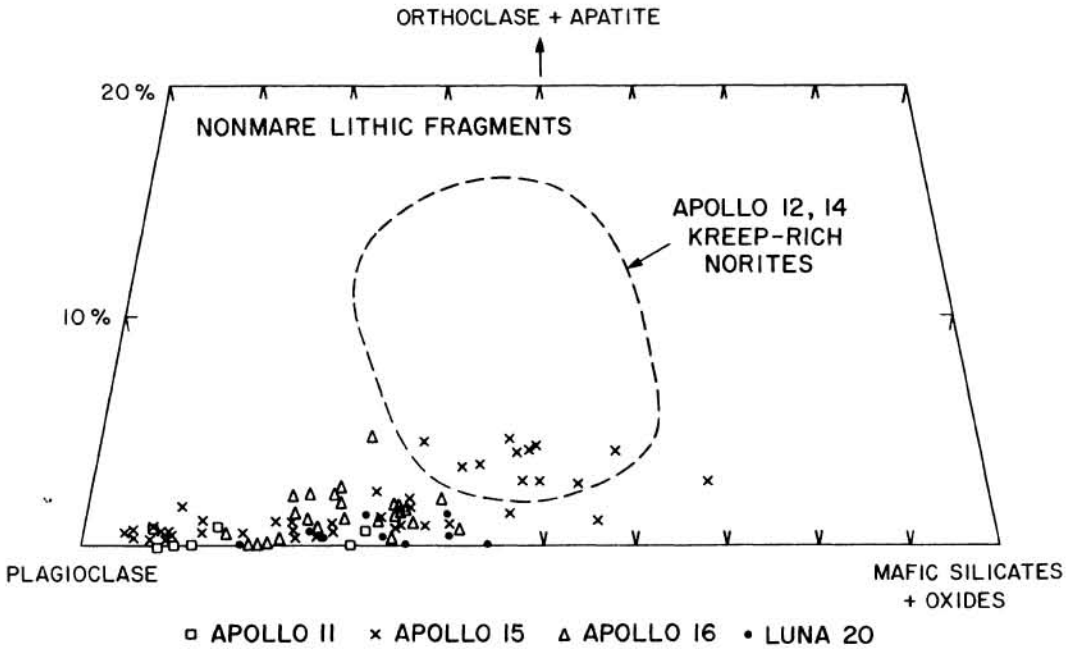


Fig. 1. Ternary plot of normative components (wt.%), calculated from whole-rock, defocused-beam microprobe analyses, for nonmare lithic fragments.

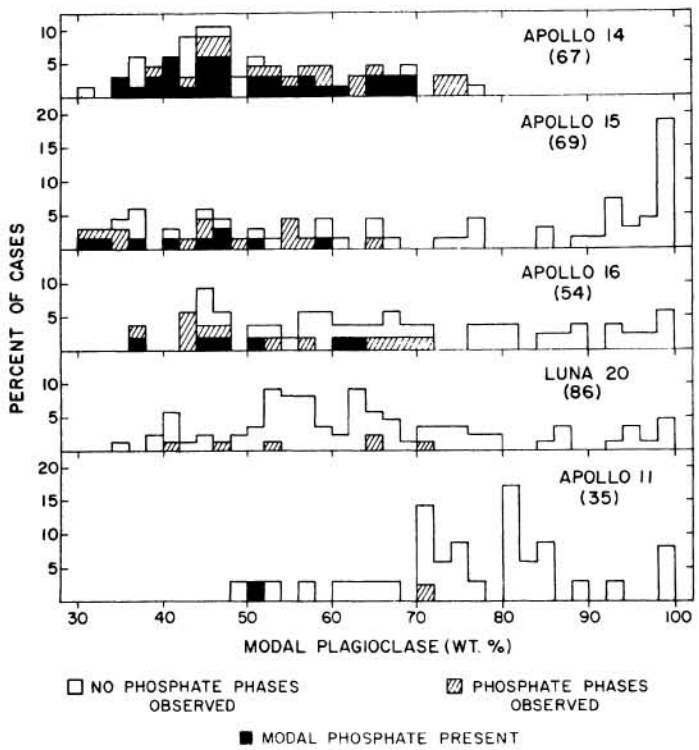


Fig.2. Histograms of modal plagioclase contents (wt.%) in samples of non-mare lithic fragments; numbers in parentheses refer to the number of fragments analyzed in each sample.

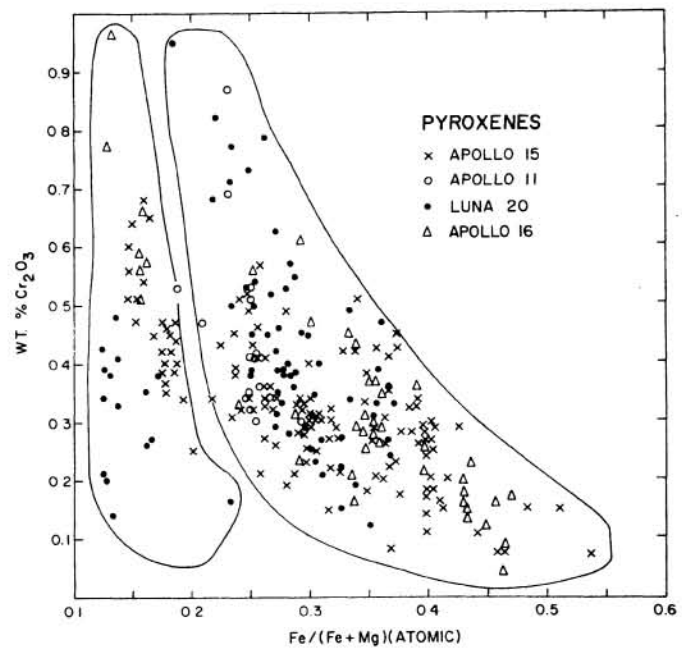


Fig.3. Plot of wt.% $Cr_2O_3$ vs. atomic ratio Fe/(Fe+Mg) for pyroxenes in KREEP-poor noritic, troctolitic, and anorthositic lithic fragments.