PETROGENESIS OF KREEP-RICH AND KREEP-POOR NONMARE ROCKS,
G.J. Taylor, M.J. Drake, J.A. Wood and U.B. Marvin, Smithsonian
Astrophysical Observatory, Cambridge, Mass. 02138

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, illus-
trates this division. KREEP-rich rocks are notably enriched in
normative orthoclase plusapatite (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 γ-ray measurements (Metzger et al.,1972) which
indicate that high concentrations of U, Th, and K (characteris-
tic 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 con-
tent 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 be-
tween 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 SiO₂) was residual after the fractional crystalliza-
tion event that led to the formation of the KREEP-poor lunar
PETROGENESIS OF NONMARE ROCKS

Taylor, G.J. et al.

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 residuum.

References

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$_2$O$_3$ vs. atomic ratio Fe/(Fe+Mg) for pyroxenes in KREEP-poor noritic, troctolitic, and anorthositic lithic fragments.