MAGNESIAN ANORTHOSITES FROM THE WESTERN HIGHLANDS OF THE MOON: ISOTOPE GEOCHEMISTRY AND PETROGENESIS

Gregory A. Snyder and **Lawrence A. Taylor,** Dept. of Geological Sciences, University of Tennessee, Knoxville, TN 37996; **Alex N. Halliday,** Dept. of Geological Sciences, University of Michigan, Ann Arbor, MI 48109

Breccias from the Apollo 14 landing site have provided a wealth of information on the genesis of the lunar highlands. Various pristine rock-types have been discovered in relative abundance, including rare ferroan anorthosites, and alkali-suite and magnesian-suite rocks (e.g., [1-3]). Mineral-chemical and radiogenic isotopic data are reported here for a newly discovered Mg-suite anorthosite from Apollo 14, sample 14303,347. Meyer et al. [4] reported U-Pb zircon analyses of Mg-suite highlands rocks from the western limb of the Moon. We have compiled these ages and generated a weighted average age of **4211 + 5 Ma; some 200 Ma younger than ferroan anorthosites**. Utilizing this age for Mg-anorthosite 14303,347, our data results in an initial ε_{Nd} value of -1.0 and initial $^{87}Sr/^{86}Sr$ of 0.69915. Based on trace-element, isotopic, and mineral-chemical data, the western highlands Mg-suite is interpreted to be crustal precipitates of a picritic magma, which assimilated KREEPy trapped liquid from upper-mantle cumulates during its transport to the crust.

MINERALOGY AND PETROLOGY OF ANORTHOSITE 14303,347 -- Clast 14303,347 consists of approximately 95% coarse-grained plagioclase and 5% olivine in a brecciated matrix. Plagioclase composition varies from $An_{93.0}$ to $An_{95.5}$, and olivine composition varies from $Fo_{86.6}$ to $Fo_{88.0}$. The composition of olivine is a clear indication that this sample is not a ferroan anorthosite, but an anorthosite of the Mg-suite (Figure 1) as defined by Lindstrom et al. [3].

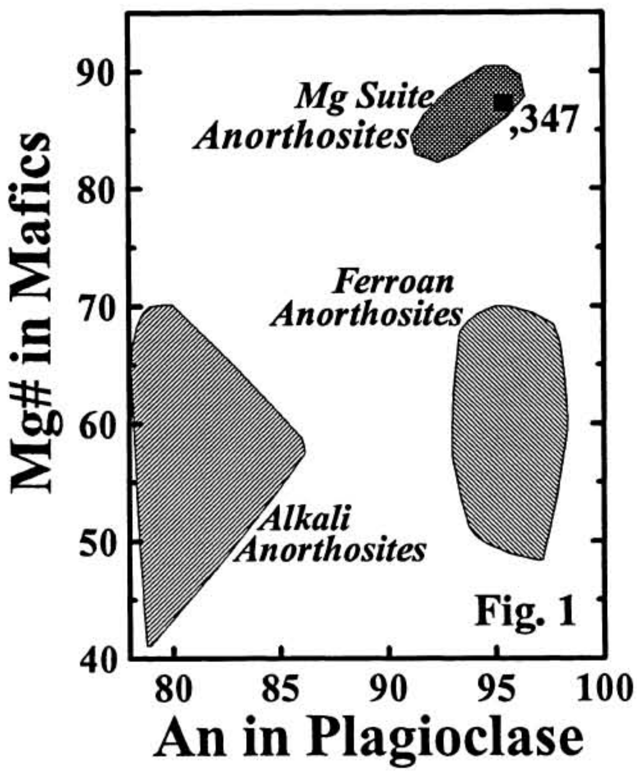

Fig. 1

Nd AND Sr ISOTOPIC RESULTS FOR Mg-SUITE ANORTHOSITE 14303,347

A total of six magnesian anorthosites have been analyzed from the western lunar highlands. Of these, only the one presented herein has been analyzed for Nd and Sr isotopic composition. The measured Sm-Nd ratio for anorthosite 14303,347 is similar to that measured for lunar KREEP. It must be pointed out that this observation, in and of itself, does not necessitate a relationship with KREEP. This is simply an artifact of the partitioning behavior of plagioclase, such that the slope of the LREE in plagioclase is identical to KREEP. Nd and Sr isotopic initial ratios for 14303,347 (Table 1) are consistent with this anorthosite being derived from an enriched portion of the Moon.

Table 1: Rb-Sr and Sm-Nd isotopes of Mg-Suite Anorthosite 14303,347

Rb	Sr	$^{87}Rb/^{86}Sr$	$^{87}Sr/^{86}Sr$	$^{87}Sr/^{86}Sr_{(i)}$	Sm	Nd	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	$\varepsilon_{Nd(i)}$
0.494	257	0.00556	0.699492+13	0.69915	12.3	44.0	0.16825	0.511792+6	-1.0

PETROGENESIS OF WESTERN HIGHLANDS ANORTHOSITES -- Based on mineral chemistry alone, three distinct types of anorthosites have been determined from the Moon: (1) Ferroan Anorthosites -- uncommon in the western highlands; (2) Magnesian Anorthosites -- of which there are only six recognized from the western highlands; and (3) Alkali Anorthosites -- the most common type in the western highlands (eighteen have been recognized). Fields for these anorthosite types are indicated in Fig. 1.

Based on primitive plagioclase compositions (An_{92}-An_{96}), more-evolved mafic-mineral compositions, and an age of 4.44 $\pm$ 0.02 Ga [5], ferroan anorthosites are thought to be flotation cumulates from the lunar magma ocean. Due to their mineral compositions and trace-element contents, alkali anorthosites are likely cumulates from an evolved quartz-monzodiorite (QMD) liquid [6,7]. An age of 4110 $\pm$ 41 Ma for alkali anorthosite 14304,267 [7] obviates a direct relationship to the lunar magma ocean and is consistent with the QMD parent being a re-melt of an evolved pluton or remobilized KREEP. However, magnesian anorthosites are more difficult to explain.

MAGNESIAN ANORTHOSITES -- Magnesian anorthosites exhibit mineral chemistry consistent with their derivation from a primitive source (picrite?), but have trace-element contents consistent with an evolved parentage. REE contents vary widely, but in all cases, the REE are at least an order of magnitude higher than those in ferroan anorthosites [3]. A compilation of U-Pb zircon ages for Apollo 14 Mg-suite rocks (14305,91:norite = 4211 $\pm$ 5 Ma; 14306,150:troctolite = 4245 $\pm$ 75 Ma; 14306,60:gabbronorite = 4200 $\pm$ 30 Ma; [4]) yield a weighted average age of 4211 $\pm$ 5 Ma (MSWD = 0.54). **Therefore, the Mg-suite is demonstrably younger than the ferroan anorthosites and also must have crystallized some 200 Ma after magma ocean solidification.** However, the enriched Nd isotopic signature for anorthosite 14303,347 (ε_{Nd} = -1.0) obviates its derivation from depleted mantle cumulates alone (which would have exhibited *positive* ε_{Nd} values at 4.2 Ga). Therefore, the Mg-suite could represent re-melted portions of the Moon's deep interior which have been contaminated (metasomatized?) by an enriched component.

As indicated by Lindstrom et al. [3], it is likely that these Mg-anorthosites, and indeed, the whole Apollo 14 Mg-suite, are mixtures of a primitive Mg-rich magma and urKREEP. A primitive picritic magma, possibly derived from the lower mantle, would have been relatively hot and could have assimilated a small amount of KREEPy trapped liquid from the interstices of upper mantle cumulates during transport to the lunar crust. A troctolitic cumulate from this picritic magma would then have an evolved incompatible element chemistry while still exhibiting primitive mineral compositions.

REFERENCES: [1] Shervais, J.W. et al. (1983), *PLPSC 14th*, B177-B192; [2] Shervais, J.W. et al. (1984) *PLPSC 15th*, C25-C40; [3] Lindstrom, M.M. et al. (1984), *PLPSC 15th*, C41-C49; [4] Meyer, C. et al. (1989), *LPSC XX*, 691-692; [5] Carlson, R.W. and Lugmair, G.W. (1988), *EPSL 90*, 119-130; [6] Snyder, G.A. et al. (1992), *PLPS 22*, 399-416; [7] Snyder, G.A. et al. (1993), *LPSC XXIV*, this volume.