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The petrogenesis of the Apollo 14 high-Al mare basalts

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Abstract

In this paper, we report analysis of various basaltic lunar samples including 14053 and 14072, KREEP basalt 15386, thirty basalt clasts from Apollo 14 breccia 14321, as well as impact-generated samples (matrix from breccia 14168, olivine vitrophyres 14321,1180 and 14321,1539, and impact melt 14310) using a combination of solution and laser ablation inductively coupled plasma mass spectrometry (ICP-MS). The basalt clast samples were previously analyzed by instrumental neutron activation. On plots of incompatible trace elements (ITEs) vs. compatible trace elements, the Apollo 14 high-Al basalts form three approximately subparallel trends that, on the basis of current data, are also separated by age. Plots of ITE ratios (i.e., Nb/Ce vs. Zr/Y) can be used to indicate source composition, and also divide the basalts into three groups: Group A (~4.3 Ga); Group B (~4.1 Ga); and Group C (~3.9 Ga). New data for 14072 suggest the sample does not fit with any of the three groups defined here, and may indicate the presence of a fourth group of high-Al basalts in the proximity of the Apollo 14 site. The Apollo 14 high-Al basalts are compositionally distinct from known Apollo 14 impact melts and impact-generated lithologies. The three groups cannot be related by varying degrees of partial melting of a single, KREEP-contaminated source and, therefore, require three separate source regions. The new data indicate that Group A basalts evolved through closed-system crystal fractionation. However, the new data from basalts forming Groups B and C require open-system evolution that involves combined assimilation and fractional crystallization (AFC). Unlike previous AFC modeling of the Apollo 14 high-Al basalts, an assimilant composed of KREEP is not sufficient to generate the compositional ranges of each basalt group. The modeling of both groups requires a mixture of KREEP and granite as the assimilant, which supports the notion of a genetic relationship between these two lunar components.

Keywords: Moon, assimilation, basalt petrogenesis, Apollo 14 high-Al basalts, mare basalts, fractional crystallization, KREEP, granite