THE SEARCH FOR IGNEOUS PRECURSORS OF APOLLO 14 IMPACT MELT BRECCIAS: CLUES IN SOIL PARTICLES. B. L. Jolliff, Dept. of Earth & Planetary Sciences and the McDonnell Center for the Space Sciences, Washington University, St. Louis, MO, 63130

Introduction. Samples returned from the Apollo 14 site are dominated by regolith and impact melt breccias; endogenous igneous rocks are scarce and found almost exclusively as clasts in breccias and as small fragments in soil samples. Thus it is difficult to ascertain what igneous rocks actually made up the pre-impact lunar crust from which the Apollo 14 samples were derived. If we assume that the breccia compositions were derived in a straight-forward manner from mixing of igneous lithologies, then we can model these compositions as mixtures of compositions of known igneous rocks. It is possible that not all of the appropriate igneous lithologies have been sampled or are represented among the returned lunar samples. Even lithic and mineral clasts within the breccias may not be representative of the bulk target lithologies. It is possible that breccia formation involves processes that mix rocks in such a way that original igneous compositions are either magmatically fractionated (i.e., impact melt segregation and fractionation) or are mixed non-modally (i.e., differential melting during impact such as documented for samples from Mistastin Lake [1]). McCormick et al. [1] speculate that there is an unsampled lithologic component of lunar materials with LKFM compositions that has Mg/(Mg+Fe) > 0.7, high transition metals (e.g., Ti, Sc) and variable ITE concentrations. We approach the problem of the missing igneous component(s) by detailed analysis of "mixed" compositions and modeling of the compositions as mixtures of known igneous lithologies with special attention given to the model residuals.

Modeling polymict compositions. As a first approximation, we use the igneous rock types most closely associated with Apollo 14 breccias as potential components. We have attempted to model the soil composition, using 14163, as a mixture of apparently monomict lithologies found among the soil particles (14161). (Low siderophile element concentrations and petrographic features [textures, mineral compositions] indicate that these particles are monomict.) In modeling Apollo 14 polymict materials, we are faced with a dilemma. The commonly used component with high incompatible trace element (ITE) concentrations is "KREEP." However, the only endogenous KREEP materials are KREEP basalts, and these have ITE concentrations that are exceeded by Apollo 14 breccias, indeed, some breccia compositions exceed ITE concentrations of "average high-K KREEP" [2]. As part of our compositional survey of 2-4 mm soil particles from Apollo 14 [3,4,5,6], we have found several particles whose compositions extend the range of ITE enrichment beyond that previously documented for lunar lithologies. Several of these are related to quartz monzodiorite (QMD) and may be fractionates of crustal magmas [7]. However, we have found a melt rock (360 ppm Ni, 42 ppm Co) with KREEPy ITE ratios for *all* ITE, but with ITE concentrations about 3 times those of average high-K KREEP. This fragment is also very magnesian (Mg/(Mg+Fe) of pyroxenes: 0.65-0.73) in relation to the anorthite content of its plagioclase (An_{63-69}). When we use the bulk composition of this particle as the component with high ITE concentrations, the principal effect is to require only about 1/3 the amount of "KREEP" component, i.e., ~16% rather than 50%, as has commonly been found in past studies of Apollo 14 materials, e.g., [8,9]. As a result, the major element composition of KREEP is not such a dominant factor in the mixture.

Another component that we use in modeling and which has KREEPy ITE ratios is KREEP basalt, distinct from Apollo 14 LKFM. We have found a number of fragments that are texturally and compositionally similar to some Apollo 15 KREEP basalts, especially 15382 [10] and have relatively low siderophile element concentrations (~30-70 ppm Ni), considering that these are soil particles and have been exposed in the regolith. Even if these prove not to be endogenous, their similarity to endogenous Apollo 15 KREEP basalts suggests that they derive from a similar lithology.

We have also used compositions of rocks and clasts of other Apollo 14 samples, taken from the literature, as chemical components. In either case, we can not satisfactorily match the bulk soil composition (<1 mm fines or 2-4 mm weighted mean). No matter what combination of components we select, the best fits yield mixtures with low transition metal concentrations (Sc, Cr, Fe) (cf. McCormick et al., 1989) and low Eu concentration. We note that the <1 mm fines are slightly enriched in Sc, Cr and Fe relative to the bulk 2-4 mm particle weighted mean composition, consistent with the addition of a mare component after the main breccia-forming event(s). (We also find separate mare basalt/basaltic glass fragments among the 2-4's, but few obvious polymict fragments of mare basalt and non-mare lithologies.) But a mare component alone does not account for the mass balance of the transition metals. We achieve a much more satisfactory fit of the model mixture to the bulk soil composition when we include an average crystalline (impact) melt breccia (CMB) as a component. This result is not new (cf. [9]), but this suggests that the "cryptic component" resides in the CMB's.

Modeling of an average composition of impact melt breccias yields constraints on the allowable proportions of known igneous lithologies in the source region of these breccias, and the model residuals indicate the compositional nature of the cryptic component. We use an average composition based on analyses of ~70 2-4 mm particles of CMB from 14161. As components, we consider ferroan anorthosite, "Mg-suite" anorthosite, alkali anorthosite, troctolitic anorthosite, norite, felsite, aluminous mare basalt, KREEP basalt, felsite, quartz monzodiorite, Fe-metal, C1 chondrite, and as the high-ITE component, KREEPy impact melt rock, 14161,7233. With this many components, there are no unique, "best-fit" solutions. However, many different combinations of components yield the following general constraints, based mainly on the elements in (): alkali anorthosite < 10% (Na, Eu); felsite <5% (Ba, Cs, Ta, Th, U, etc.); aluminous mare basalt < 8% (Sc, Cr). Anorthosites of all varieties are difficult to reconcile with other components due to CaO and FeO mass balances. The only potential component that can balance high CaO and low FeO is mare basalt, which is constrained as mentioned above. A greater proportion of troctolitic or noritic anorthosite can be tolerated (e.g., 10%) than of anorthosite. Fe-metal and chondrite compositions do fit the siderophile elements very well. Those components with compositions most similar to the CMB composition are most difficult to constrain. If we use the impact melt rock composition as the ITE-rich component, then norite or gabbroic norite (or a compositionally similar lithology) must be the major component, e.g., >50%, but of the monomict materials at Apollo 14, none have a composition that satisfactorily combines with the other components.

Based on our modeling, we predict that the cryptic component is mafic and has relatively high Sc, Cr and Fe concentrations and is less magnesian than the noritic igneous rocks that have been found among the samples. In our modeling, we have balanced Eu with alkali anorthosite, but this contributes to the CaO and FeO mismatch, thus we also predict that the ferroan, mafic component is relatively rich in Eu.

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