ON THE COMPOSITIONAL DIFFERENCES BETWEEN THE "ANCIENT" AND "YOUNG" REGOLITH AT APOLLO 16; Randy L. Korotev, Dept. of Earth & Planetary Sciences and the McDonnell Center for the Space Sciences, Washington University, St. Louis, MO, 63130.

McKay et al. [1] showed that a subset of Apollo 16 regolith breccias is "ancient" in that the fine material from which they are constructed was irradiated at the surface on the order of 4 Gy ago. Ancient regolith breccias (ARBs) are characterized by excess fission Xe and high ratios of trapped $^{40}Ar/^{36}Ar$ ("~8-12," compared to ~1 for present soils). All identified ARBs also have low values of the surface exposure index I_s/FeO (<1; for present submature to mature surface soils, I_s/FeO is >30). McKay et al. [1] also noted several compositional differences between Apollo 16 ARBs and the present Apollo 16 regolith (below). Since the study of McKay et al. [1], additional data have been obtained both for Apollo 16 regolith breccias [2,3] and <1 mm fines [4]. For the present study, new INAA data were obtained for samples from ARBs. These new data are used here to review the compositional distinctions between the present regolith and the ARBs.

Samples. Six regolith breccia samples were selected for study (Fig. 1). The samples span a range of coherency, from very friable (60016) to very coherent (60019). All are probably "ancient" in the context of McKay et al. [1] in that observed ratios of $^{40}Ar/^{36}Ar$ exceed 12, except for 60019, for which $^{40}Ar/^{36}Ar$ equals 9.7. [$^{40}Ar/^{36}Ar$ ratios corrected for estimated component of ^{40}Ar from *in situ* decay range from 10.5 to 12.5, except for 60019 (8.8) and 65095 (~0, because of very low Ar concentrations)]. Approximately 71 >1 mm clasts were separated from these breccias for analysis by INAA. Several "matrix-rich" (i.e., relatively free of large clasts) bulk samples of the breccias were also analyzed.

Results. Data for Apollo 16 regolith breccias are plotted in Figs. 1 and 2 (see also Figs. 8-12 of [1]). For Fig. 2, all samples with observed (uncorrected) $^{40}Ar/^{36}Ar$ exceeding 12 are plotted as "ancient" (this excludes only 60019 of this study). For all ancient samples, I_s/FeO is <1 [1]. $^{40}Ar/^{36}Ar$ and I_s/FeO have not both been measured on a many "young" regolith breccias, but in the study of McKay et al. [1], all samples with $^{40}Ar/^{36}Ar$ ratios of <5 had I_s/FeO of >5. Thus, for Fig. 2 it is assumed that any regolith breccia with I_s/FeO exceeding 5 is not an ARB. The major effect of this assumption is that the nine recent analyses of Jerde et al. [3] are plotted as "young" regolith breccias; for these samples I_s/FeO was measured (range: 27-85) but $^{40}Ar/^{36}Ar$ was not. All remaining samples (usually those with $^{40}Ar/^{36}Ar$ ranging between 5 and 12, e.g., 60019) are plotted as "intermediate."

Also plotted in Fig. 2a is the trend of <1 mm fines from regolith core 60009/10 [4]. Nearly all surface, trench, and core soils from the central and southern part of the site (i.e., Cayley soils [4]) plot along this trend. (Exceptions are some core soils containing excess mare material. These plot off the trend on the high-Sc side; see below.) All mature soils from the surface of the site plot on the high-Sc end of the trend. The trend results from mixing of mature (Sc- and Sm-rich) soil with anorthosite consisting of nearly pure plagioclase (Sc and Sm poor) [4].

In Fig. 2a, most of the ARBs plot along the trend first observed by McKay et al. [1] (solid line) while the young regolith breccias plot along the trend of the present <1 mm fines (dashed line). Fig. 2b substantiates the observation first made by McKay et al. [1] with fewer data that the ARBs are more magnesian (lower Mg# = bulk molar Mg/[Mg+Fe]) as well as poorer in Sc. These observations suggest that the "young" breccias formed from the present soil but that the ARBs did not form from a regolith with the composition of the present surface regolith [1].

Most of the clasts from the ARBs are richer in Sm (and other incompatible trace elements) than the matrix samples (Fig. 1). Based on their compositions, the Sm-rich clasts are almost certainly all impact-melt breccias [5]. (Sampling bias may be important here because melt-breccia clasts are usually coherent and are more easily removed from the breccia matrix.) With few exceptions, both the high- and low-Sm clasts plot generally along extensions of the trend for the matrix-rich samples (Fig. 1). This suggests that the ARB matrix is composed primarily of lithologies such as those observed as large clasts in the ARBs. The high-Sm melt breccia clasts also have the largest Sc concentrations of the ARB components (except for a few intriguing high-Sc, low-Sm clasts). Thus, they are the principle carriers of mafic silicates and they will determine the Mg/Fe concentration ratio of the ARBs. The average Mg# of the ARBs (~70.5, Fig. 2b) is similar to that of Apollo 16 mafic melt breccias (uncorrected for Fe-Ni metal [6]). However, the present soils must contain an additional Sc-rich component (Fig. 2a), one with a lower Mg# and which is not well represented by the ARB clasts. McKay et al. [1] suggested that this component was either mare basalt or some mafic, ferroan (low Mg#) highlands material. Simon et al. [2] noted that young regolith breccias (as well as the present <1 mm fines) contained significant amounts of glass of mare derivation (and rare lithic fragments) whereas the ARBs are practically devoid of mare material. Both low- and high-Ti varieties of glass were observed. Thus, small mare-derived glass fragments, probably pyroclastics, are the likely cause of the compositional differences seen in Fig. 2. Simon et al. [2] did not state the fraction of mare glass in the young regolith, but concentration of all discrete glass fragments was usually <4 %. A chemical component of mare material on the order of 5 % is required to provide the excess Sc in typical surface fines (~10 μg/g, Fig. 2b) compared to average ARB matrix (~7 μg/g). This proportion of mare material is also sufficient to explain the lower Mg# of the present soil and young regolith breccias. Although Sc concentrations are significantly greater in the present regolith than in the ARBs, TiO_2 concentrations are equivalent, indicating that the mare component of the soils cannot be dominated by high-Ti varieties.

How did the mare glass get in the Apollo 16 soils? Mare volcanism of the type that produced the Apollos 15 and 17 pyroclastic glass beads may have delivered mare glass to areas distant from the vents, however, mixing trends in the <1 mm fines suggest that the mare component of the Apollo 16 regolith was not added to the site directly as ash fall. If it were, we would expect mixing trends that extrapolate in the high-Sc direction toward glass compositions, as we do in the Apollos 15 and 17 soils [7,8]. In contrast, surface soils collected over several kilometers of traverse all plot within a narrow range of Sc concentrations (Fig. 2a), indicating that the mare material and other mafic materials (mostly melt rocks) are well mixed and occur in relatively constant proportion to each other. This constancy exists at least to the 2-m depth of the deep drill core. Nearly all compositional variation in fines from the central and southern part of the site results from mixing between coarse-grained anorthosite and a previously-well-mixed mafic soil such as occurs presently at the surface; this results in the dashed mixing trend of Fig. 2a [4]. Some core soils are relatively *more* enriched in mare material, however, mafic soils *less* contaminated by mare glass do not occur [4]. These various observations are most simply explained by a model in which the present surface soils were formed elsewhere and mare glass was mixed with fines prior to or during emplacement of the fines at the Apollo 16 site over a regolith similar in composition to the ARBs. The emplacement event may have been the event that formed the Cayley Plains as the present, mature surface soils appear to be the Cayley component of the site [4].

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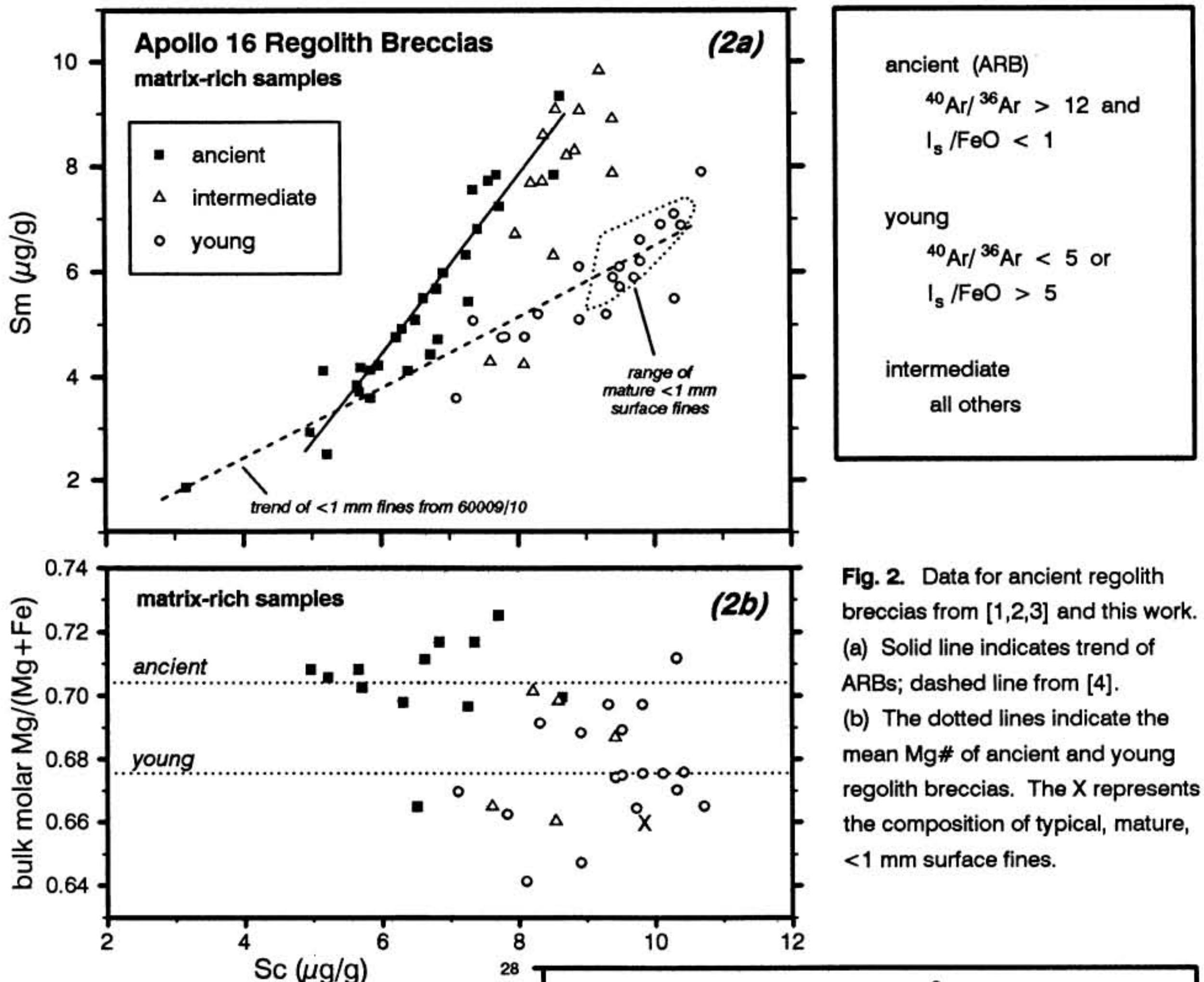

Fig. 2. Data for ancient regolith breccias from [1,2,3] and this work. (a) Solid line indicates trend of ARBs; dashed line from [4]. (b) The dotted lines indicate the mean Mg# of ancient and young regolith breccias. The X represents the composition of typical, mature, <1 mm surface fines.

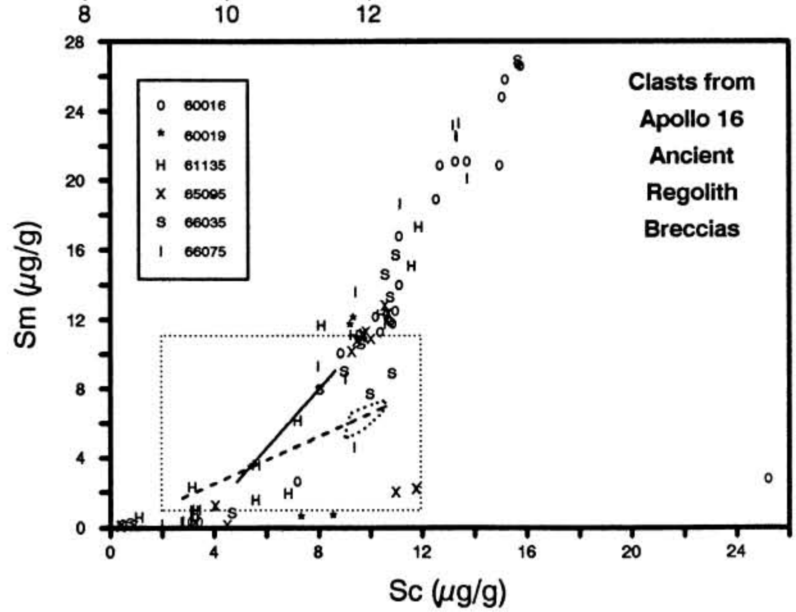

Fig. 1. Data for clasts separated from ARBs (from this work). The dotted rectangle indicates the range of Fig. 2a. The diagonal lines are the same as those in Fig. 2a.