COMPOSITIONAL DIFFERENCES BETWEEN FELDSPATHIC FRAGMENTAL BRECCIAS AND ANCIENT REGOLITH BRECCIAS FROM APOLLO 16;

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FBs and RBs. Fragmental breccias and regolith breccias are two common types of polymict breccia from the lunar highlands. Most of the lunar meteorites are fragmental or regolith breccias [1]. Fragmental breccias contain "rock clasts in a porous clastic matrix of fine-grained rock debris (mineral clasts)" and regolith breccias contain "clastic regolith constituents including glass spherules with brown vesiculated matrix glass" [2]. For regolith breccias with only a small amount of glassy matrix and low abundances of glass spherules, the distinction from fragmental breccias is sometimes ambiguous. Some samples have been classified differently by different investigators depending upon the abundance of glass spherules in the particular thin section under study (e.g., Apollo 16 samples 63588 and 63595 [3,4], meteorite MAC88105 [5-8]). Thus, some regolith breccias are regarded as a type of fragmental breccia [e.g., 4].

FFBs. At the Apollo 16 site the most common fragmental breccia is the feldspathic fragmental breccia (FFB) in which both the clastic and matrix material is dominated by anorthite. Apollo 16 FFBs typically contain 29±2% Al_2O_3, i.e., 76-87% normative feldspar. FFBs are most prevalent at stations 11 and 13 near North Ray crater and appear to be "the typical lithology of the North Ray crater basement" [3]. The most common type of mafic clast in the FFBs is basaltic impact melt with elevated abundances of incompatible trace elements (ITEs) [9,10]. FFBs are variable in composition and modal distribution of clast types [3]; glass fragments are rare.

ARBs. Among regolith breccias from Apollo 16 is a subset composed of immature regolith known as "ancient regolith breccia" (ARB). They are regarded as "ancient" because they have high $^{40}Ar/^{36}Ar$ ratios and contain excess fission Xe, which indicate that the material of which they are composed existed as fine-grained regolith 4 Ga ago [4]. Although the ARBs are compositionally dissimilar to surface soils from the Cayley plains, most were collected from stations where the regolith composition is typical of the Cayley plains. None of the ARBs were collected at station 11 on the edge of North Ray crater, but two were collected at station 13 about 1 km away [4,11]. Thus the ARBs are clearly components of the Cayley regolith, but not of the subregolith (sub-Cayley) basement at North Ray crater. Like the FFBs, the ARBs also contain clasts of ITE-rich, basaltic impact melt. These melts are compositionally similar to large samples of "poikilitic" melt and "VHA" melt, such as the melt phase of the dimict breccias [12]. Both types of melt breccia are characteristic of the Cayley plains at the Apollo 16 site.

ARBs from FFBs? Petrographically, the ARBs are similar to the FFBs except that the ARBs contain a higher abundance of glasses with a larger variety of compositions [13,14]. This led Takeda et al. [14] to suggest that perhaps FFBs like sample 67016 were precursors to the ARBs, i.e., that the FFBs represent an even more ancient regolith with virtually no surface exposure (megaregolith) and that later surface exposure or addition of surface components (glasses) led to materials like the ARBs. Compositional data for clast and matrix material from ARBs and FFBs show that simple scenario to be unlikely, however.

Compositional differences. McKay et al. (1986) [4] noted that matrix samples of ARBs formed a linear trend on a plot of Sm vs. Sc (Fig. 1a, solid line). This is a mixing trend between a variety of well mixed, Sm-poor, feldspathic ("ANT suite") components and clasts of Sm-rich, mafic melt breccias (Fig. 1b) [4,12]. In contrast, FFBs from North Ray crater form a similar, but parallel, trend offset to a higher Sc concentration (Fig. 1a, dashed line). This requires that both the Sm-poor and Sm-rich components of the FFBs are richer in Sc than the corresponding components of the ARBs. This suggests a slightly greater abundance of clinopyroxene or other more ferroan, mafic minerals in the FFBs. Although the data are not conclusive, the average *Mg'* (bulk mole % Mg/[Mg+Fe]) for FFBs (67±5) is less than that for ARBs (70.4±1.5) (± = standard deviation). This suggests a fundamental difference in mafic components of the two types of breccia.

New data for melt rocks from North Ray crater indicate that the "VHA" (very high-alumina) melt breccia characteristic of FFBs (and regolith samples from stations 11 and 13 in general) is compositionally distinct from the otherwise very similar melt in ARBs and dimict breccias characteristic of the Cayley stations [15,16]. The NRC melt is richer in Sc (Fig. 1c) and has slightly greater relative concentrations of heavy REE and lower average concentrations of Ni (~650 μg/g vs. 1120 μg/g). Also, melt clasts with 16-32 μg/g Sc (i.e., "poikilitic" or "group 1" melts) are common in the ARBs, but uncommon in the FFBs. One FFB (67975) contains clasts of a very Sm-rich melt unlike anything seen in the ARBs or Cayley regolith [17]. Together, these observations indicate that the FFBs from North Ray crater are assembled from a different population of components than the ARBs.

Conclusions. The FFBs from North Ray crater (specifically, the more typical low-Sm varieties) are interpreted as samples of megabreccia consisting largely of feldspathic, KREEP-free Nectaris ejecta (Descartes formation) with variable (but small) amounts of basaltic, KREEP-bearing melt of pre-Imbrium age [3]. The ARBs are a component of the overlying Cayley formation and probably represent old regolith consisting of lithologically similar, but compositionally distinct components. The greater abundance of ITE-rich melt rocks (greater average Sm concentration; Fig. 1a) in the ARBs suggests that the ARBs derive from region of greater KREEP abundance than the FFBs, i.e., toward the Imbrium basin. This is consistent with the inferred direction of emplacement of the Cayley plains deposits. Although some type of fragmental breccia may be a precursor to the Apollo 16 ARBs, the ARBs cannot derive simply from addition of small amounts of surface regolith to the North Ray crater FFBs.

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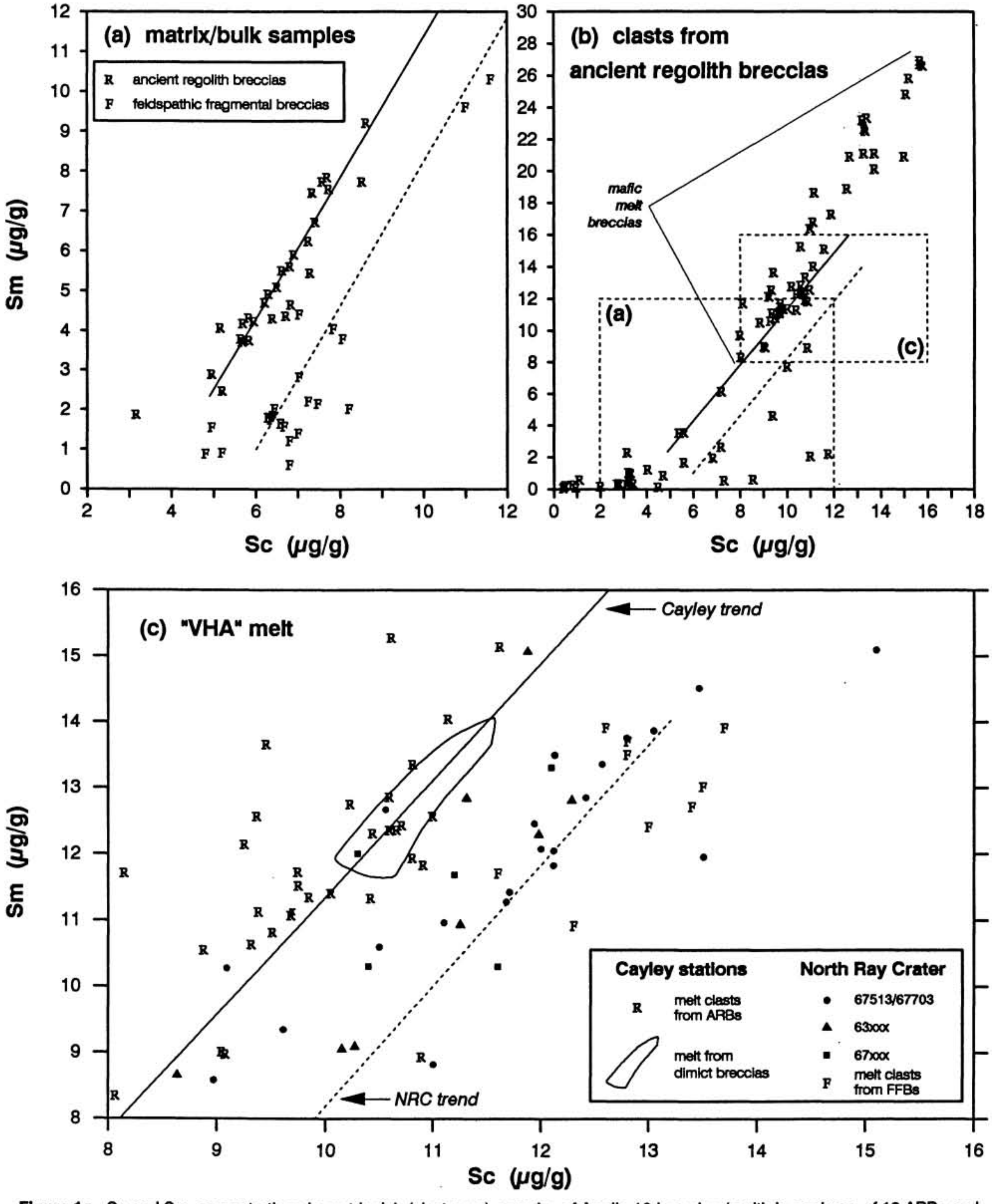

Figure 1a. Sc and Sm concentrations in matrix-rich (clast poor) samples of Apollo 16 breccias (multiple analyses of 10 ARBs and 9 FFBs). The solid line is fit to the ARB points and is reproduced in (b) and (c). The dashed line is for reference only and roughly connects the matrix samples with the mafic melt samples of (c). See [11] for sources of ARB data; FFB data from [9,10] and sources listed in [18].

Figure 1b. Sc and Sm concentrations in clasts from ARBs [11].

Figure 1c. Comparison of "VHA" melt from samples from the surface of the Cayley plains (dimict breccias [12] and ARB clasts [Fig. 1b]) with samples from North Ray crater (2-4 mm particles from 67513 and 67703 [16], clasts from FFBs [9,10,19], and rake and large melt rocks with 63xxx and 67xxx numbers [10,15, other lit.].