LITHOLOGIC DIVERSITY IN LUNAR REGOLITH: LESSONS FOR FUTURE LUNAR EXPLORATION STRATEGIES WITH APPLICATION TO SOUTH POLE–AITKEN BASIN. B. L. Jolliff, L. A. Haskin, J. J. Gillis, R. L. Korotev, and R. A. Zeigler. Department of Earth and Planetary Sciences and the McDonnell Center for the Space Sciences, Washington University, St. Louis, MO 63130. <blj@levee.wustl.edu>

As a result of vertical and lateral mixing caused by impact processes, the lithologic components of lunar soils are extremely diverse despite locally well averaged bulk-soil compositions. We have now studied the lithologic components of individual soils from nearly all of the landing sites [e.g., 1-5]. Bulk soil compositions from a given landing site tend to have well averaged compositions and although variations relate clearly to local geology, they are small compared to the variation among individual rock fragments found in a given soil. Regolith samples collected on slopes where local and recent mass wasting has occurred may have a predominance of components derived locally from upslope, such as at station 2, Apollo 17, located at the base of South Massif. Rock fragments from this station consist mainly of impact-melt breccia derived from the Massif [3]. Even these soils, and more so others that lie on flatter terrain, contain a diversity of rock types, in some cases equaling or exceeding the diversity seen among the large-rock samples from an entire site. Such is the case for soils from Apollo 11, 12, 14, 16, and some Apollo 17 stations. In this abstract we highlight several examples of the significant lithologic diversity as a basis to support our contention that individual samples of regolith obtained by future missions such as to the interior of the South Pole-Aitken (SPA) basin are likely to contain a wide diversity of rock types, including fragments of impact melt produced by the SPA basin-forming event. Furthermore, consideration of regolith stratigraphy that results from large to basin-sized impacts in the SPA region indicates the likelihood of finding original substrate of the SPA basin floor is high.

Samples from the Apollo 17 landing site provide a fine example of lithologic diversity captured in a single soil. Sample 76503 was collected at Station 6 on the lower slopes of North Massif several hundred meters from the basaltic regolith of the Taurus-Littrow valley floor. In one sense, this is a favorable location for lithologic diversity because (1) mass wasting on the massif mixed materials downslope, (2) a cluster of secondary impacts into the valley floor from Tycho spread secondary ejecta from the valley floor up onto the lower massif slopes, and (3) the site is located within a regional pyroclastic deposit and so the regolith includes volcanic glass. Compositions of lithic fragments are shown in Fig. 1 for Th and FeO, and the lithologic diversity is evident from the labels. Samples include basalts, volcanic glass, igneous rock fragments such as troctolite and norite, granulitic breccias, impact-melt breccias of several varieties and possible origins, and a diverse group of regolith breccias. Most of the individual rock fragments are themselves breccias, including a diverse assortment of mineral and lithic clasts.

In another sense, the Apollo 17 site is not an ideal site for regional lithologic diversity because of its location so near the rim of the very large Serenitatis basin. Materials excavated from the basin are thus expected to dominate nonmare rocks at the landing site, with the strong possibility of addition of some material from the later and even larger Imbrium event [7].

Samples from the Apollo 14 site provide an example involving a very different geologic setting. This site lies within the Fra Mauro Formation, an ejecta deposit from the Imbrium basin. Again, material excavated from the basin is expected to dominate the lithologic diversity, and indeed it does; the majority of rock frag-

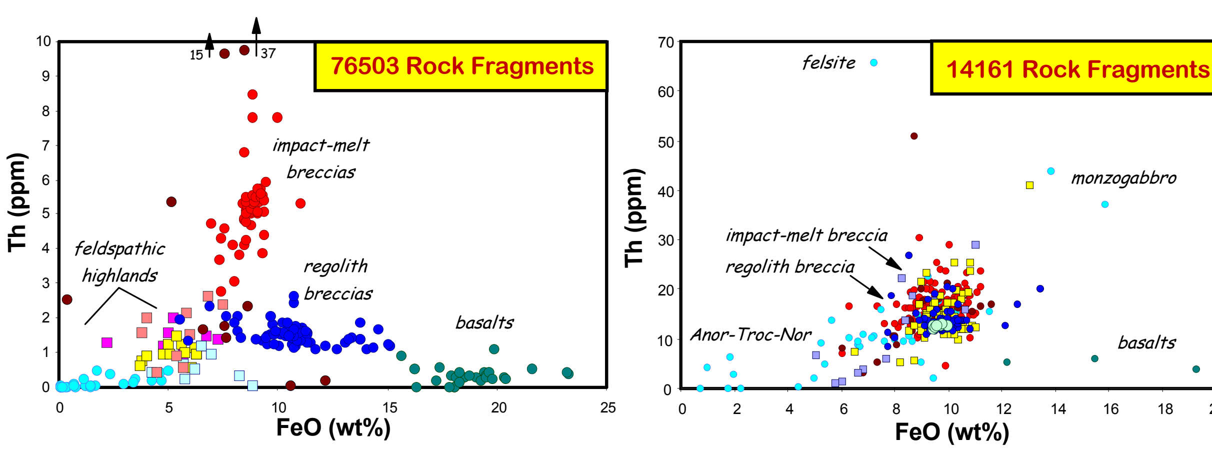

Figure 1. Compositions of lithic fragments in Apollo 17 and Apollo 14 individual regolith samples. Note different FeO and Th scales. For 76503, n=233 and for 14161, n=381. For 14161, the light green points mark the composition of the <1 mm soil.

ments are impact-melt breccias or regolith breccias of similar composition. Even so, fragments of rocks as diverse as basalt and ferroan anorthosite are found in the regolith [1].

Samples from the Apollo 12 regolith illustrate another key aspect of lunar regolith variations. Because of local geologic relationships such as where sample stations are located relative to local craters, the soils even in a small area can exhibit considerable variation. In Figure 2, the composition of soils from different Apollo 12 stations are shown along with lithic fragments from two of the stations. The soil variations can be understood in terms of mixing of basaltic components (high FeO) and KREEP-rich nonmare components (Th-rich). Lithic fragments from individual stations, however, show broad overlap and contain a diversity of rock types, including the main basalt groups and nonmare rocks delivered as ejecta from Copernicus and possibly other nearby large craters such as Reinhold, and from vertical mixing of material from below and between basalt flows [8].

What can we expect from sampling in the South Pole–Aitken Basin? A concern with single-point sampling within the basin is that a particular landing site might occur in an area dominated by ejecta from one or more younger basin impacts, e.g., Apollo, Ingenii, Planck, Poincaré. For two reasons, this should not be a concern. First, much of the floor of SPA basin has uniformly elevated Th concentrations (see Plate 1 in [9]), indicating that large impacts have for the most part simply redistributed floor material. Second, the emplacement of ejecta at the site will have been largely ballistic, which creates a mixture of added material and substrate [10], so as long as the site is not within the continuous ejecta of a large crater or basin, deposits should contain local substrate as well as ejecta. One might argue that the surface layer of regolith (or megaregolith) would be dominated by the last big basin impacts, i.e., Serenitatis, Imbrium, and Orientale. Indeed, it is likely that elevated Th concentrations in the northwestern part of the basin reflect deposits of ejecta antipodal to Imbrium [11] and/or Serenitatis [9].

The likelihood of ejecta from Imbrium even in SPA deposits brings up another point; the near-side Apollo landing sites are all located close enough to Imbrium that the surface deposits were likely to have significant Imbrium material [7]. Except for the antipodal deposits, dominance of surface deposits by Imbrium ejecta will not be a problem in the SPA region, especially south of 50°S latitude. Preliminary modeling of ejecta distribution indicates that near the center of the basin (55°S, 185-190°E), distances from the Apollo basin and other basins to the west and Orientale to the east are great enough that the top megaregolith deposits are expected to contain some 50% or more of original (basin floor) substrate (SPA impact melt or breccia).

Of course, a mobile (roving) sample collection system would be desired to maximize diversity at any site,

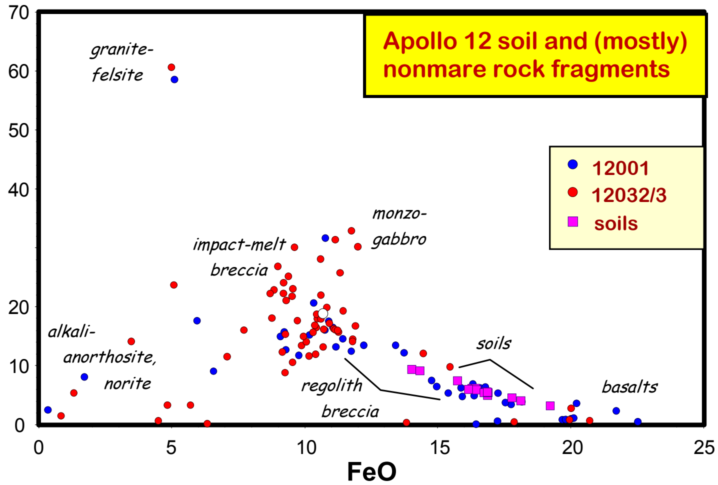

Figure 2. Apollo 12 soil and lithic fragments. Samples purposely biased against mare basalt fragments; there are many more basalt fragments in these samples.

but not absolutely necessary. On the basis of Apollo samples, regolith samples returned to Earth, coming from a mature soil, would be expected to contain on the order of 5 to 10 % lithic fragments (1-10 mm), or ~5000 lithic fragments per kilogram. Such a sample should offer the possibility of dating and characterizing material excavated from the SPA basin by younger basins and large impacts as well as the original SPA basin impact melt. It should not even matter whether sampling is on a mare or nonmare regolith because experience from the Apollo landing sites tells us that both mare and nonmare rock fragments will be present as a result of both vertical and horizontal mixing.

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