Dating the SPA Impact Event: What Samples are Needed and Where are They? C.R. Neal[1], R.L. Klima[2], and J. Plescia[2] [1]Dept. Of Civil & Env. Eng. & Earth Sciences, University of Notre Dame, Notre Dame, IN 46556, [2]The Johns Hopkins Unversity, Applied Physics Laboratory, Laurel MD. (neal.1@nd.edu, Rachel.Klima@jhuapl.edu, Jeffrey.Plescia@jhuapl.edu).

Introduction: The South Pole-Aitken (SPA) basin defines a huge elliptical basin spanning from the lunar South pole to the Aitken Basin on the lunar farside; it is the largest impact basin in the Solar System (**Fig. 1**) [1]. It is the result of a massive impact early in the history of the Moon. Defining exactly when this impact occurred is important for testing the Late Heavy Bombardment hypothesis (cf. [2]) and has resulted in "SPA Sample Return" of impact melt being cited as a candidate New Frontiers class mission in the last two Planetary Science Decadal Surveys [3,4]. However, there has been much discussion of what would constitute an impact-melt composition from the SPA-forming event and how easily it could be acquired and recognized (given the subsequent geologic history). There have been several studies that allude to various features that could represent exposed mantle rocks and/or impact lithologies, but results remain equivocal. Here, we review the current state of knowledge with regard to SPA lithologies and use remote sensing data to examine potential SPA impact-melt sample return sites.

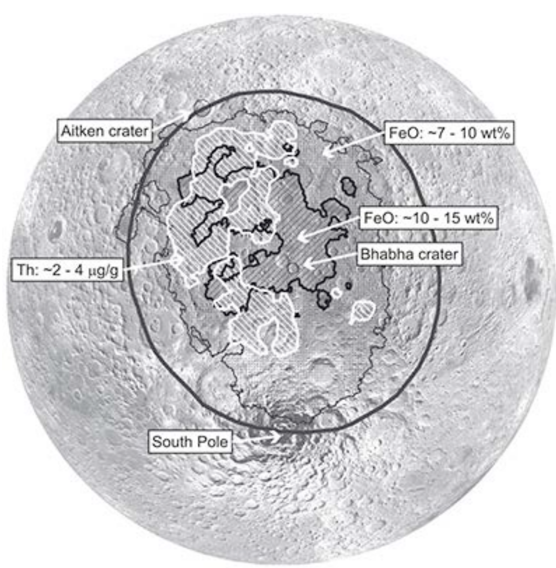

Fig. 1. SPA basin as presented in [6]. Various geochemical provinces are highlighted based upon data from [5,6].

SPA Basin: The size of the impact that formed the basin would have produced a melt sheet ~50 km thick [3,4] that subsequently underwent differentiation. This modeling suggests that noritic lithologies would dominate the surface composition [7,8]. Some authors have also suggested that the upper mantle would be dominated by orthopyroxene rather than olivine, which would enhance the noritic signature of the differentiated impact melt [9,10].

Modeling of the SPA impact melt differentiation involves calculation of the thickness of impact melt (~50 km – [7,8]) followed by crystallization. Hurwitz & Kring [8] produced a number of models for the differentiation of the impact melt assuming different LMO crystallization scenarios and whether or not the LMO cumulate pile underwent overturn. These authors also considered the crystallization of the impact melt if it was "contaminated" by crustal materials. In **Figure 2**, the impact melt differentiation models of [7,8] are plotted against the excavation depths calculated by [7]. This indicates that the dominant SPA impact lithology would be norite to gabbro with subordinate pyroxenite and dunite.

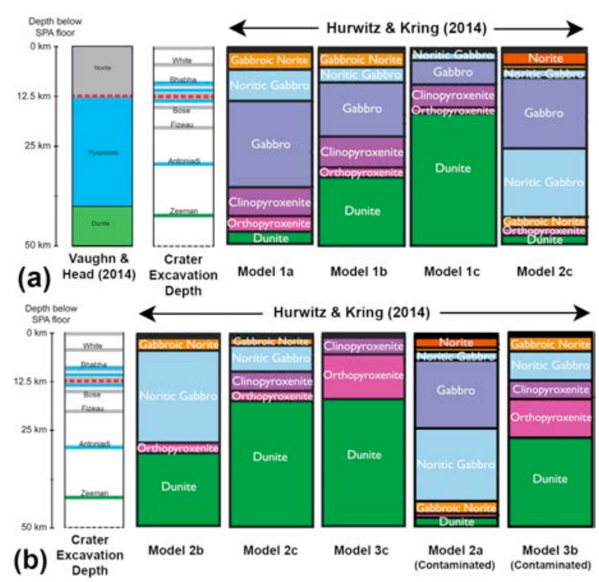

Fig. 2. SPA impact melt differentiation models [7,8].

Therefore, it seems that if a SPA Sample Return mission landed on a surface dominated by norite, the mission could be accomplished.

However, the situation is complicated by subsequent activity in the SPA basin. In particular, subsequent volcanic eruptions [11-13] can obscure impact lithologies and be confused with them or vice versa (cf. [14]). Subsequent impacts within and adjacent to SPA have also complicated the picture (**Fig. 2**).

Vaughan & Head [7] chose those craters with central peaks and calculated their depths of excavation. These models can produce the central peak lithologies observed in impact craters within the SPA basin [7,8,15]. Therefore, compositional variations coupled with morphological examination of the SPA basin area should be able to identify landing sites with a high probability of containing differentiated SPA impact melt materials. While these may have been reworked due to subsequent impacts, the Apollo experience has demonstrated that not all chronometers are reset if the material is only mechanically disrupted. For example, Apollo 14 breccia 14321 contains basaltic clasts that represent the oldest recorded lunar volcanism [16]. Modeling of post-SPA ejecta distribution suggests that the basin floor would be covered by <1.5 km of post-SPA ejecta deposits [17]. Despite this, the modeling results indicate that materials derived from the original SPA melt breccia comprise at least 15% of the present regolith, although the most realistic combinations of model parameters predict a SPA melt breccia component that is 50-80% of the current regolith [17].

To complement previous spectral studies of orthopyroxene (Opx)-rich deposits interior to SPA (e.g., [15]), we examined several locations along the perimeter of the basin, in or exterior to the region identified as having 7-10 wt% Fe in Fig. 1. For comparison, we also include the spectrum of Antoniadi crater, which occurs within the more Th-rich center (**Figs. 1 & 3**). All sites exhibit prominent 1 and 2 µm bands, characteristic of Opx. The 1 µm band occurs at nearly the same wavelength in all cases, suggesting similar Opx composition. The 2 µm band occurs at a slightly longer wavelength at locations 3 and 4 (both at low latitudes), potentially due to contamination from nearby mare material or due to a residual thermal signature. Modeling by [18] of two of these craters, Doerfel S (loc 2) and Dryden (loc 3) craters suggested that they were among the most Mg-rich of the orthopyroxenes in SPA [18]. Of the craters modeled by [15] the two nearest the rim of the basis also appeared to be the more Mg-rich than those towards the center.

Sampling Sites: While the floor of the basin has typically been considered as the site for an SPA sample return mission, sites on the rim present a different geologic envrionment than the floor and possibly a clearer sampling scenario. While the rim, like the floor, has been subjected to subsequent geologic events, it has not suffered from extensive post-impact volcanism. Rim areas would consist of a basement of uplift highlands crust originally capped by SPA ejecta. Subsequently, additional ejecta deposits from nearby basins would be superposed on the SPA ejecta. Over time, larger (km-10s km) craters on the rim would mix the original SPA material with other ejecta in a homogenous fashion. Thus, SPA melt material would be present on the rim and could be sampled. Using the modeling that has been conducted on the SPA impact melt differentiation, impact melt can be used to age date the SPA impact. Sampling on the SPA rim would alleviate the potential of landing on a post-basin unit on the floor that has not had SPA melt redeposited on it [19].

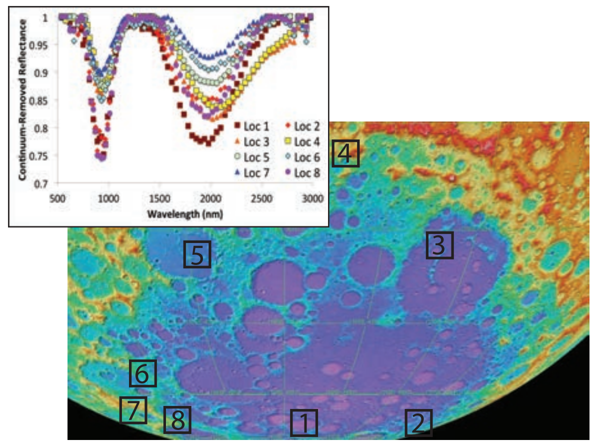

Fig. 3. M3 Spectra collected at Antoniadi crater (Loc 1) and several locations around the rim of SPA basin.

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