SOUTH POLE-AITKEN BASIN: GEOLOGY, BASIN FLOOR, AND UNIT COMPOSITIONS P. D. Spudis and D.B.J. Bussey, MP3-E128, Applied Physics Laboratory, Laurel MD 20723-6099

At 2600 km diameter, the South Pole-Aitken (SPA) basin is the largest on the Moon and has profoundly influenced lunar crustal configuration and subsequent evolution [1-4]. SPA is significant for two principal reasons: 1) its immense size suggests that it has excavated most or all of the lunar crust at its target site, thus giving us a window into the very deep lunar interior; 2) because it is the oldest basin in relative terms (i.e., it has the highest density of superposed impact craters [2]), determination of its absolute age through the radiometric dating of melt samples could establish the existence and characteristics of the terminal lunar "cataclysm", a proposed sharp increase in the bombardment rate of the Moon early in its history [5]. For these reasons, the SPA basin has been identified as a high-priority target for future exploration, including a possible robotic sample return mission [6].

We have compiled a variety of remote sensing data in order to understand as completely as possible, the geological setting of basin units, with the aim of identifying targets where specific exploration goals can be addressed. We have used Apollo, Galileo, Clementine, and Lunar Prospector data to make compositional and geological maps of the basin and its environs. Our objectives are to address the following questions: 1) Does a basin "impact melt sheet" exist in such form that samples of it could be identified and returned to Earth for analysis?; 2) Do units of mantle provenance exist within the floor of SPA basin?; 3) How deep into the Moon did the SPA impact excavate and what is the crustal provenance of various basin units?; 4) Do post-SPA basin geologic units obscure the original basin configuration and if so, to what degree and where? This paper is a preliminary report on our attempts to address these questions.

Approach We have formatted remote-sensing data into co-registered image cubes, projected into orthographic map images (Figures 1 & 2). These data sets have been analyzed using techniques described previously to make petrological maps that show the compositional affinities of surface units for rock types found in the Apollo samples [7-9]. We use two different approaches to petrological mapping. The Fe-Ti-Th system [7] shows the surface relation to known groups of primary lunar igneous rocks, including anorthosites, mare basalts, and the KREEP/Mg-suite as a whole. The Fe-Ti-Al system [9] shows units in relation to surface compositions of sampled Apollo and Luna sites and allow us to determine how "different" the units of the SPA basin floor are from the allegedly "well understood" Apollo sites. We then compare these inferences with geological and geophysical data to reconstruct the lunar crustal configuration in the SPA basin region.

SPA Petrological and Geological Units The SPA basin has long been noted as a compositional anomaly on the far side [1,3,8,10], being more mafic than not only the rest of the far side, but most of the near side highlands as well [9]. It has been commonly assumed that this mafic nature reflects the removal of upper lunar crust by the SPA impact (e.g., [3,10-12]) although the effects of post-basin mare volcanism have not gone unnoticed [13]. Our petrological maps show two principal relations: 1) the SPA basin floor has compositional affinities with more mafic members of the highland rock suite; and 2) at least part of the basin floor has affinities with KREEP/Mg-suite highland compositions. The mafic nature of the SPA floor has long been known and ranges from 8-12 wt.% FeO, significantly higher than other far side highlands, which range from 1-4 wt.% FeO. On the petrologic maps of [9], the basin floor falls into classes along the Fe-Ti side of the ternary, indicating a pronounced mafic character. The floor shows significantly higher Ti than the feldspathic rocks of the highlands (on the order of 0.5 to 1.0 wt.%, the lower value predominating; [10]) and elevated amounts of the significant trace elements Th and Sm [14,15]. The major mafic mineral of the floor of SPA is orthopyroxene [11], which is commonly interpreted as "norite" but in fact, could be a component of a wide variety of lunar rock types, from impact melt breccias to pristine norites to granulitic impact breccias [16]. On the petrologic maps of [8], the basin floor is enriched in the KREEP/Mg-suite component at concentrations about an order of magnitude less than the Procellarum terrain on the near side [12].

Broadly, this composition is an aluminous variety of the ubiquitous near side composition known as "low K Fra Mauro basalt", which is an impact mixture found in melt breccias from all of the Apollo and Luna landing sites. Although it is often asserted that the composition of the SPA basin floor is "unique" [11], in fact, the material known as "VHA basalt" from the Apollo 16 landing site is a very close match to the basin floor in major and minor element composition [8,9] and bulk mineralogy [16]. However, this does not resolve the enigma of the origin of basin floor material because the origin of basaltic impact melts is unknown. They cannot represent melt sheets from large highland craters because the impact targets of such craters are typically both more feldspathic and less KREEP-rich than the composition of these rocks. Although some parts of the near side appear to have such composition [8,9], the basaltic impact melts are found widely across the Moon and are not restricted only to circum-Imbrium regions.

Another possibility is that the composition of the SPA basin floor confirms an alternative hypothesis for the origin of basaltic impact melts – that these rocks, formed in large, basin-forming impacts, represent the average composition of the *lower* lunar crust [17,18]. If the upper crust has been stripped off, the basin floor might represent the lower crust. This supposition is complicated by the likely former presence of an impact melt sheet [e.g.,10], which may have been extremely voluminous [19]. If so, such a melt sheet could have retained heat for an extended time, thus differentiating into a layered igneous sequence, as has been proposed for the Sudbury basin [20]. But even if this happened (and there is no evidence that it did), subsequent impact gardening would have re-mixed the unit into an "average" composition, as seen remotely.

Some Initial Conclusions On the basis of our study of SPA basin units, we make several inferences. There is no identified exposure of lunar mantle at the surface of SPA basin floor; all units can be explained as crustal rock types. There is no "intact" basin melt sheet. Subsequent impact and volcanic flooding has mixed the basin melt sheet into a complex breccia unit, with considerable heterogeneity. Finding *in situ* melt breccias that can be reliably associated with the SPA impact will be difficult, perhaps more difficult than sampling basin ejecta from the near side.

References [1] Stuart-Alexander D. E. (1975) USGS Map *I-1047* [2] Wilhelms D.E. (1987) *USGS Prof Paper* 1347, 300 pp. [3] Head J.W. *et al.* (1993) *JGR* 98, 17149. [4] Spudis P. D. *et al.* (1994) *Science* 266, 1848. [5] Ryder G. (1991) *EOS* 71, 313.[6] Decadal Study Committee (2002) *New Frontiers in the Solar System*, National Academy Sciences, in press. [7] Davis P.A. and Spudis P.D. (1987) *JGR* 92, E387. [8] Bussey D.B. *et al.* (1999) *New Views of the Moon* II, 5. [9] Spudis P.D. *et al.* (2002) *LPS* XXXIII, 1104. [10] Lucey P.G. *et al.* (1998) *JGR* 103, 3701. [11] Pieters C. *et al.* (2001) *JGR* 106, 28001. [12] Jollif B. *et al.* (2000) *JGR* 105, 4197. [13] Yingst R.A. and Head J.W. (1999) *JGR* 102, 18957. [14] Lawrence D.J. *et al.* (2000) *JGR* 105, 20307. [15] Elphic R. *et al.* (2000) *JGR* 105, 20333. [16] Heiken G. *et al.* (1991) *Lunar Sourcebook*, Cambridge Press, Ch. 6. [17] Ryder G. and Wood J. (1977) *PLSC* 8, 655. [18] Spudis P.D. and Davis P. A. (1986) *JGR* 91, E84. [19] Cintala M.J. and Grieve R.A.F. (1998) *MPS* 33, 889. [20] Grieve R.A.F. *et al.* (1991) *JGR* 96, 22753

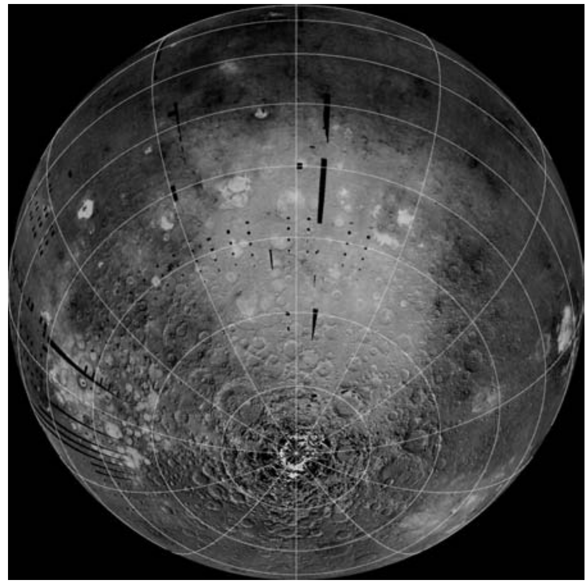

Figure 1. Iron map of SPA, centered on 56°S 180°W. Brighter regions are higher in iron.

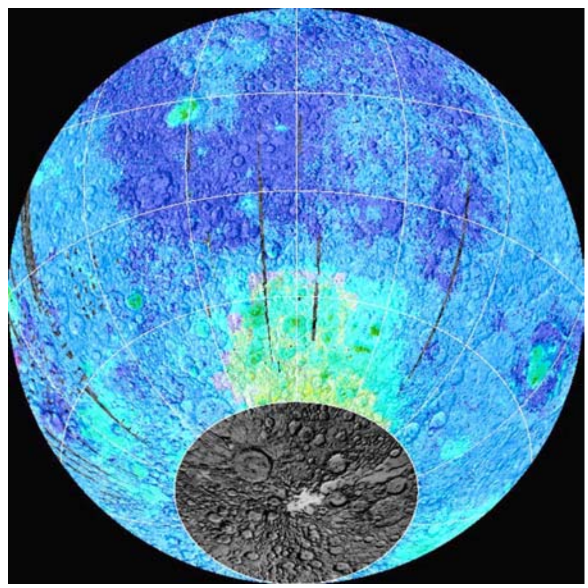

Figure 2. Petrologic map of SPA. The green colors indicate the enriched mafic content associated with the floor of the basin. For a full explanation of the colors, see [8].