**UNRAVELLING THE VOLCANIC HISTORY OF SOUTH POLE-AITKEN BASIN.** I. Antonenko[1] and G.R. Osinski[1], [1]Centre for Planetary Science and Exploration & Canadian Lunar Research Network, University of Western Ontario, 1151 Richmond St., London, ON, Canada, iantonen@uwo.ca.

**Introduction:** The South Pole-Aitken (SPA) basin is the largest known impact basin on the Moon, located on the south-central farside and measuring approximately 2,500 km in diameter [1]. It has been identified as a high priority science target [2], and is the selected destination for the proposed MoonRise sample return mission [3]. Therefore, it is important to understand the geology of SPA, including its volcanic history.

Thus motivated, we have begun a large scale study of volcanism in SPA. Our goal is to identify and characterize ancient cryptomare (hidden mare) deposits. We present our results to date.

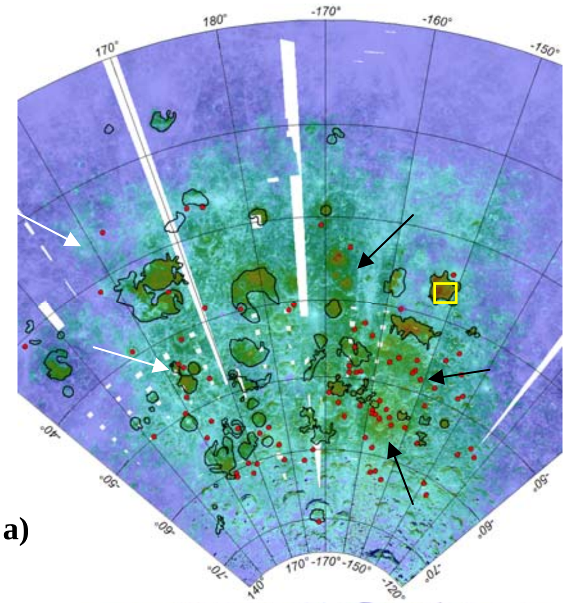
**Data:** We compiled a variety of different data sets for the central SPA region (Figure 1), including Clementine UVVIS, FeO [4], optical maturity [5], and LOLA topography data, all at a resolution of 1 km/pix. In addition, geologic maps [6,7,8] were coregisted and layered on the data. High resolution LROC images were also obtained and examined for selected targets.

**Method:** Cryptomare are generally identified and characterized using dark-haloed craters (DHC's) [9, 10]. Historically, DHC's have been identified by the presence of a mature, low albedo halo surrounding an impact crater [9]. However, with the proliferation of new data sets, excavation of basalts can also be identified using the presence of Fe anomalies and basalt spectra in and around craters [10]. This allows a wider range of craters to be used as basalt probes, including craters too small to eject sufficient basalt material beyond their rims (incipient DHC's), craters whose halos have not matured enough to appear dark (young DHC's), and large craters that have penetrated through the cryptomare and excavated large amounts of highland substrate (obscured DHC's) [10]. The expectation is that, for all these cases, continuously re-exposed basalts should be detectable in the crater walls.

In order to aid in the identification of these fresh basalts, we applied an automated basalt identification algorithm [11] to the study area. Figure 2 shows how the algorithm distinguishes an annulus of fresh basalt spectra just inside the rim of craters in a known mare area. It should be noted that this algorithm was developed for a different region of the Moon, so results may not be applicable here. Consequently, we use this algorithm as a guide only, to identify pixels of interest, whose spectra are then examined as required.

**Results and discussion:** The SPA region is proving to be unexpectedly difficult to study. First, Clementine data varies widely over the range of latitudes

a)




b)

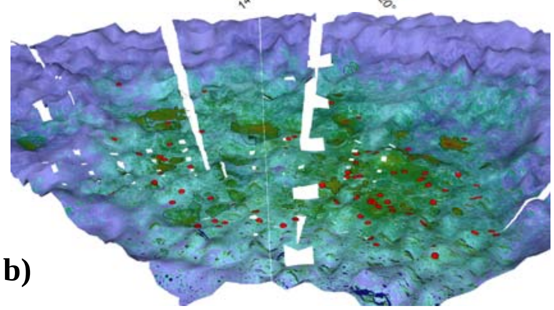


**Figure 1: a)** Clementine 750 nm basemap of the central SPA study area, with Wt % FeO [4] overlay (blue is low, green, yellow, red is progressively higher FeO). Mapped mare units [6,7,8] are outlined in black. Red circles indicate locations of preliminary basalt-excavating craters. Yellow box show location of Fig. 2. White arrows show the two previously identified DHC's [9]. Black arrows indicate areas where albedo and FeO values argue for the presence of unmapped surface mare. **b)** Map from a) overlain on a 3D relief DEM of the LOLA topography data.

involved, resulting in problems with consistency from one area to the next. The main issue is sun (or phase) angle, which varies with latitude. High sun angle data is needed to identify dark halos, but it is not available at high latitudes. Even at low latitudes, the sun angle is often insufficient to allow dark halos to be distinguished. Similarly, the FeO [4] and optical maturity [5] values depend on phase angle and become unreliable at high latitudes. Finally, the UVVIS spectra appear to also be affected by phase angle, producing more kinks and unexpected behaviour at high latitudes. All these

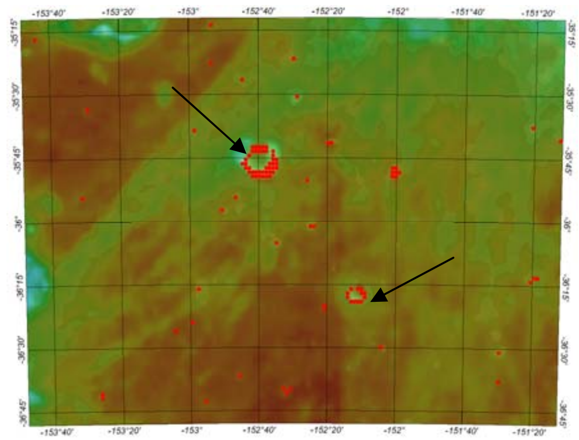


**Figure 2:** Section from yellow box in Fig. 1 showing a close up of the central mare in Apollo crater. Red squares show the results of the automated basalt algorithm.. Black arrows point out two craters where the algorithm identified an annulus of fresh basalt spectra inside the crater rim.

together make the definitive identification of basalt excavation very difficult in the SPA region.

As a test, we located the two previously identified DHC's in the SPA area [9] and evaluated them on the basis of our criteria. One had a patchy dark halo, FeO anomaly, (both inside and out), and basalt spectra presence. The other had a well developed, mature, dark albedo and Fe-rich halo, but almost no basalt spectra present within the crater. Clearly, no single set of criteria will apply to all basalt excavating craters. New techniques, possibly using more data, will need to be developed to address this issue.

Proceeding with the techniques and data currently available, we have preliminary identified 83 basalt-excavating craters (Figure 1). All of these are large craters, ranging in size from 5 to 65 km in diameter. Not surprisingly, many excavate well below the cryptomare base, making them unsuitable for estimating cryptomare thicknesses. To fully utilize these craters, new techniques for estimating the thickness of penetrated basalt layers will need to be developed. Where available, LROC images were used to identify and measure the layer boundaries, and several early images suggested that this might be possible (e.g. Figure 3). However, in the course of this study, it was found that clear demarcation of layer boundaries in crater walls is rare in LROC images, being dependant on having a favourable sun-angle, but minimal glare.

Two undisputed DHCs, which have symmetrical albedo and FeO halos and fresh basalt spectra, are particularly large (65 and 32 km). One of these is a previously identified DHC [9], the southernmost of the two white arrows in Figure 1. These two DHC's occur in roughly the same region, at the northeast corner of the high Fe area of central SPA, and argue for the presence of either a deep or thick (2.5-5km from the surface) cryptomare layer in this area. Conversely, they could be tapping iron-rich lower crust, though it is not clear if this would excavate sufficient crustal material to form the high FeO halos observed.

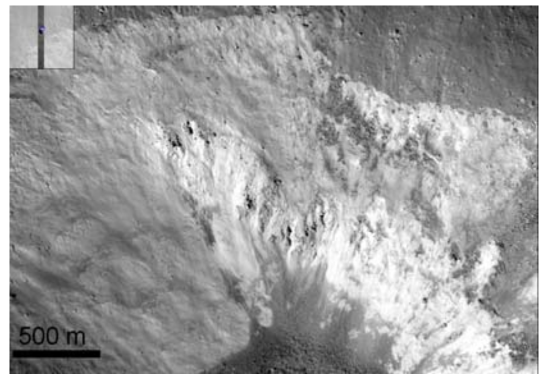



**Figure 3:** LROC image of the wall of a fresh crater in SPA. Hints of layering are visible in this section, showing a possible grey unconsolidated layer underlying a thin melt veneer (blocks from here can be seen downslope) and overlying a thick possibly stronger white layer.

During our DHC search, it was noted that a number of larger older craters, such as Davisson, Alder, Bose, BhaBha, and others, tend to have many small craters (<3 km diameter), which contain a few fresh basalt spectra pixels each. The interiors of these larger craters are mapped as "Ip units," (smooth light plains of Imbrian age or younger) [6,7,8]. We suspect that these craters may contain relatively young cryptomare units. Further work with higher resolution data (100 m/pixel or better) will be needed to clarify these.

We also identified several areas (indicated by black arrows in Figure 1) where albedo and very high FeO anomalies (~17 wt%) argue for the presence of surface mare deposits, where none are mapped [6,7,8]. These deposits occur in Oppenheimer and south of Apollo, where they are mapped as various basin materials of Nectarian to Imbrian age. However, we note from the LOLA topography data (Fig. 1 b) that these regions area as smooth as the mapped mare and in some cases smoother. Clearly, the old maps should be updated to take advantage of the newer data.

**References:** [1] Wilhelms D.E. (1987) *USGS Prof. Paper #1348*. [2] NRC (2007) *The National Acad.* Press, 107. [3] Jolliff B.L. et al. (2010) *Ann LEAG Meeting*, Abstract #3072. [4] Lucey P.G. et al (2000) *JGR*, 105, 20,297-20,305. [5] Lucey P.G. et al (2000) *JGR*, 105, 20,377-20,386. [6] Stuart-Alexander D.E. (1978), *USGS Map, I-1047*. [7] Scott D.H. et al (1977) *USGS Map I-10348*.[8] Wilhelms D.E. et al. (1979) *USGS Map I-1162*. [9] Schultz P.H. and Spudis P.D. (1979) *Proc LPSC* $10^{th}$, 2899-2918. [10] Antonenko I. (1999) *Thesis*, Brown Univ. p309. [11] Antonenko I. and Osinski G.R. (2010) *Submitted to PSS*.

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