LUNAR SOUTH POLE-AITKEN IMPACT BASIN: TOPOGRAPHY AND MINERALOGY

H. Hiesinger, J.W. Head III
Dept. of Geological Sciences, Brown University, Providence, RI, 02912; Harald_Hiesinger@brown.edu

Introduction: Lunar impact basins show a variety of internal and external structure [e.g., *Wilhelms,* 1987; *Head et al.,* 1993, *Spudis,* 1993] and states of degradation and preservation. Orientale, one of the youngest and best-preserved large basins, shows a configuration of internal topography, ring structure, and deposit morphology (Orientale-type) that is generally similar to other relatively undegraded lunar basins. This basin type formed by impact into a target that has sufficient target rigidity to form a small number of multiple rings and to preserve them over geologic time Other, more heavily degraded basins on the Moon (Tranquillitatis-type) have apparently undergone significant viscous relaxation subsequent to their formation, reducing basin topography [*Solomon et al.,* 1982]. They formed in a manner likely similar to the Orientale type but in a target thermal structure that subsequently allowed for long-term crustal flow and viscous relaxation of the major topographic elements to produce a very shallow basin. These older basins have also been subject to significant impact degradation. Both of these morphologies are in contrast to some impact basins on icy satellites characterized by many more rings and little topographic expression (Valhalla-type) (e.g., *Passey and Shoemaker,* 1982; *Greeley et al.,* 2000), a morphology thought to have been formed as part of the very early modification stage of the impact event, due primarily to sublithospheric flow into the cavity area and attendant formation of many multiple rings but little basin topography [*McKinnon and Melosh,* 1980].

Orientale Basin structure and cross-section interpretation: The Orientale basin, exhibits several clearly defined ring structures, the Cordillera ring, the Outer Rook ring, and the Inner Rook ring. *Head et al.* [1993] proposed that the transient crater penetrated to lower crustal depth and then collapsed along an outer rim fault (Cordillera ring) and rim material rotated inwards and upwards in order to form the Outer Rook ring and the Inner Rook peak ring (Figure 1). *Head* [1974, 1977] and *Bratt et al.* [1985] suggested that the Orientale Cordillera ring was equivalent to a scarp marking the outer part of a collapsed megaterrace, the Outer Rook ring was the closest approximation to the transient crater rim, and the Inner Rook Mountains were equivalent to a peak ring.

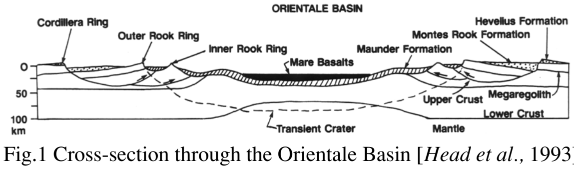

Fig.1 Cross-section through the Orientale Basin [*Head et al.,* 1993]

South Pole-Aitken basin topography and structure: Clementine altimetry data indicate a complex structure of the SPA basin and support earlier findings based on Zond [e.g., *Rodinov et al.,* 1971, *Shevchenko,* 1980, *Shpekin,* 1983; *Leikin and Sanovich,* 1985] and Apollo laser altimetry data [e.g., *Wollenhaupt and Sjogren,* 1972; *Kaula et al.,* 1973]. Clementine data show that the SPA basin is more than 8 km deep, hence having a morphology very different from the Valhalla-type multiringed impact basins. On the basis of Clementine topographic data, we identified three, possibly four rings for the SPA basin. The three outer rings are best defined in the eastern and northeastern sections of the SPA basin, but are indistinguishable from the highland terrain in the western parts of the basin, probably due to pre-SPA topography and post-SPA modifications by younger basins. Our outermost ring (#1 in Figure 3) is defined by a sharp drop in elevation of ~3-4 km and can be traced for several hundreds of kilometers. Ring 2 is characterized by another drop in elevation of ~2-3 km and can be traced for similar distances. Parts of this ring are modified by the younger Apollo basin (Figure 3). Ring 3 encloses the deepest parts of the basin, which are ~2-3 km below the terrain between ring 2 and 3. These three ring structures form a stairstep-like topography across the northeastern quadrangle of the SPA basin (Figure 2 and 3).

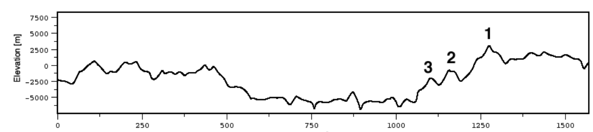

Fig. 2 Profile across the SPA basin (along the black line in Fig. 3) showing the approximate position of three possible ring structures and a stairstep-like topography

We propose that our ring 1 might be related to the initial collapse of the SPA transient crater, inward slumping of the rim along an outer rim fault, and the formation of a megaterrace. Ring 2 and 3 might have formed by inward and upward movement of crustal blocks in response to the transient crater collapse. In this scenario, ring 2 would be the closest approximation of the transient crater. If our interpretation is correct, this makes ring 1 similar to the Orientale Cordillera ring, ring 2 might be the analog to the Outer Rook ring, and ring 3 the analog of the Inner Rook ring of the Orientale basin. Thus we interpret the original dimension and structure of the basin as follows: ring 1 is approximately 2400 km in diameter, ring 2 is ~2100 km in diameter, and ring 3 is ~1500 km in diameter. On the basis of our ring structures, we find the basin center at roughly 174°W and 55°S. Previous attempts to define ring structures of the South Pole-Aitken basin suffered from the fact that the basin was located at high southern farside latitudes, limited image coverage, and the lack of topographic data. *Stuart-Alexander* [1978] proposed that the basin is 2000 km in diameter, centered at 180°W and 50°S. *Wilhelms et al.* [1979] mapped a basin 2500 km in diameter and centered at 180°W and 56°S and a possible inner ring 1800-2000 km in diameter. *Wood and Gifford* [1980] estimated a diameter of

~2600 km with a center at 180˚W and 60˚S, whereas *Leikin and Sanovich* [1985] find the diameter of the SPA basin to be ~ 2200 km and its center at 176.5˚W and 41.5˚S.

Gravity and Crustal Thickness: On the basis of Clementine data, Zuber et al. (1994) globally estimated the crustal thickness and gravity field of the Moon. The map of Zuber et al. (1994) does not show any large, sharply defined positive gravity anomalies for SPA as are observed for other lunar basins, e.g., Serenitatis. For SPA, there is no ring-like negative gravity anomaly around a prominent positive gravity anomaly, as seen for the Orientale basin. Clementine data only indicate a small, ill-defined negative anomaly mostly in the eastern regions within ring 2. Lowest gravity values were found north of crater Leibnitz and at Apollo. The crustal thickness of the SPA basin is well correlated with the infered rings. The thickness of the lunar crust is significantly thinner within ring 2, intermediate between ring 1 and 2, and thickest in isolated areas outside ring 1. Post-SPA craters within ring 2 and 3 exhibit the thinnest crust within the basin. Compared to similar-sized or larger craters outside the basin structure, the craters within the SPA basin have a much thinner crust.

Mineralogy: On the basis of Lunar Prospector gamma-ray and x-ray data (e.g., *Prettyman et al.,* 2002, *Lawrence et al.,* 2003), we make the following observations. Iron is mostly concentrated within the basin center, that is within ring 3 and immediately north and south of the basin center within ring 2. The concentrations are slightly enhanced between ring 1 and 2 compared to regions outside ring 1. Titanium concentrations are higher within ring 2 and 3 and low concentrations are associated with craters Apollo, Zeeman, Schrödinger, Planck and Gagarin. Thorium and potassium show similar distributions, respectively. For both elements we observe high concentrations south of Ingenii and north of Oppenheimer/Leibnitz as well as in the Antoniadi area within ring 3. Both elements are mostly concentrated within ring 2 and 3 with western parts being richer in Th and K. For magnesium abundances we observe a good correlation with our topographically defined rings. The highest magnesium concentrations occur within ring 3, with somewhat lower abundances between ring 2 and 3, less concentrations between ring 1 and 2, and likely even lower concentrations outside ring 1. Calcium concentrations are lowest within ring 3, intermediate between ring 2 and 3, and high outside ring 2. We did not observe changes in concentrations of calcium across ring 1. Aluminum exhibits a speckled distribution throughout the SPA basin, with low concentrations associated with Apollo and probably Leibnitz. For silica we observe slightly reduced concentrations compared to the surrounding highlands, especially within ring 3. Similarly, hydrogen shows a speckled distribution and we did not observe differences between the interior and the exterior of the basin as defind by our topographic rings.

Conclusions: We conclude that the South Pole-Aitken basin is not the Valhalla-type, and that it is also not the Tranquillitatis-type in that there has not been significant viscous relaxation. Thus, the implication is that the impact was originally into a target that was not sufficiently ductile at depth to produce initial Valhalla-type basin structure, and also not to produce longer-term viscous relaxation.

References: Bratt et al., (1985), JGR 90; Greeley et al., (2000), Planet. Space Sci. 48; Haskin, (2002), LPSC 33; Head, (1974), Moon 11; Head, (1977), Pergamon Press; Head et al., (1993), JGR 98; Kaula et al., (1973), PLPSC 4; Lawrence et al., (2003) JGR 108; Leikin and Sanovich, (1985), Astron. Vestnik 19; McKinnon and Melosh, (1980), Icarus 44; Passey and Shoemaker, (1982), Arizona Press; Pieters et al., (2001), JGR 106; Prettyman et al., (2002) LPSC 33; Rodinov et al., (1971), Kosm. Issled. 9; Shevchenko, (1980), Moscow Science; Shpekin, (1983), Kazan Univ. Thesis; Solomon et al. (1982) JGR 87; Spudis, (1993), Cambridge Univ. Press; Stuart-Alexander, (1978), I-1047; Wilhelms, (1987), USGS Prof. Paper 1348; Wilhelms et al. (1979) I-1162; Wollenhaupt and Sjogren, (1972), NASA SP-315; Wood and Gifford, (1980), LPI Rep. 414; Yingst and Head, (1997), JGR 102; Yingst and Head, (1999), JGR 104; Zuber et al., (1994), Science 266.

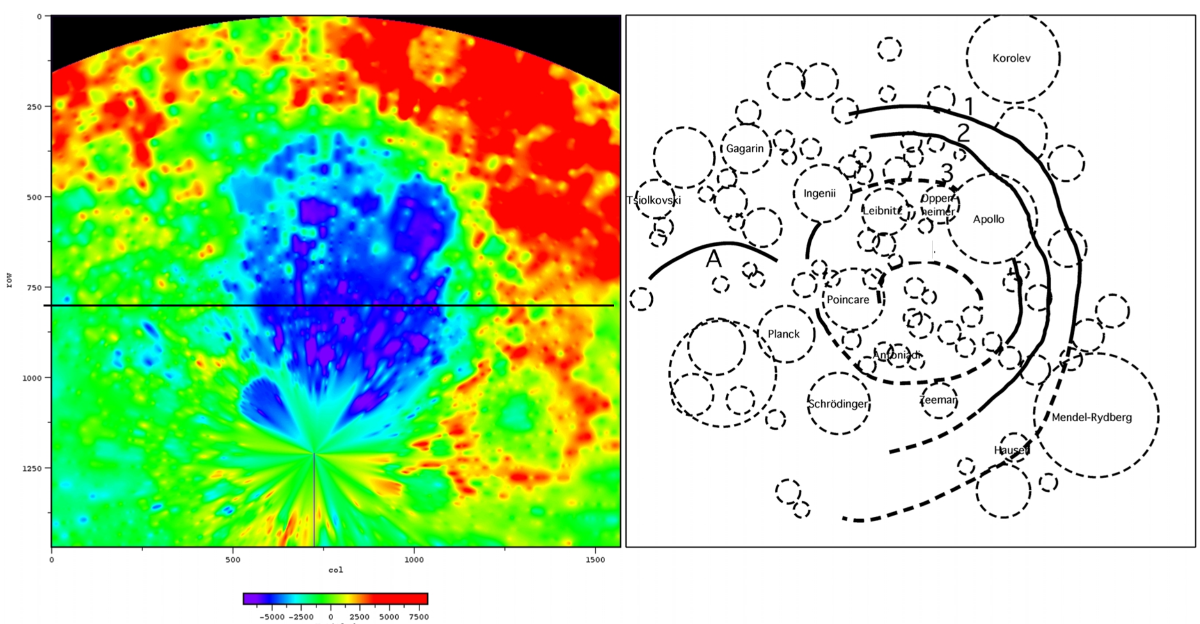

Fig. 3 Clementine Topography of the South Pole-Aitken Basin and interpretative sketch map of its ring structures