Interior of the Near Side Megabasin of the Moon.

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Introduction: The irregular shape of the Moon may be explained in detail by assuming that a single large impact struck the near side of the Moon and deposited its ejecta on the far side [4], [5], [8], [9]. The impactor would have been very large in order to deposit the 5 kilometer bulge on the far side, perhaps 300 to 600 kilometers in diameter, and the internal basin would have covered more than half the Moon [2]. Analysis of elevation data from the Clementine LIDAR instrument [10], together with a model of lunar impact basins and scaling laws, led to determining the parameters of the Near Side Megabasin (NSM) shown in Table 1.

Table 1: Parameters of the Near Side Megabasin [3]

Latitude	8.5° North	Longitude	22° East
Major Axis	3320 km	Minor Axis	3013 km
Depth	3500 m	Launch angle	50° from flat
Eccentricity	0.42	Orientation	53° W. of N.

These parameters were calculated to minimize the residual standard deviation of the Moon's elevation after subtracting models of the NSM, the South Pole-Aitken Basin (SPA), and over 50 other large impact features from the current elevation map of the Moon. The values of these parameters were mostly influenced by the shape of the bulge of ejecta on the far side, rather than details of the interior basin because the massive deposits of very level mare on the near side obscure the nature of the interior basin.

This abstract concentrates on the internal depression within the NSM.

Features of the NSM internal basin: In general, the interior of the NSM is similar to that of other large basins, despite its diameter being about three times that of the SPA, the largest basin previously identified. The NSM has a rim that rises about a kilometer over the pre-impact surface level. Below the rim, the basin slopes downward for a descent of about 1.7 km to a predominantly level floor (Figure 1). Of course, by "level" is meant having a uniform gravity potential, an even radius from the center of the Moon. The slope from the level floor to the rim rises 3.2 km over a distance of 1600 km, an angle of only 0.1°, while the Moon's curvature is 50° there. This is the reason that the slope has not been detected in photographs of the Moon [1].

The floor of the NSM is formed by crustal material, interrupted by mare at about the same level. Rims of the familiar impact basins separate some of this exposed crust from the mare that floods the basins. The crust, which is exposed in the central highlands and an area between the Crisium an Serentitatis Basins, has been shown by remote sensing and sample analysis to be anorthositic while the mare is basaltic.

There are two types of significant variations from the general levelness of the NSM floor. To the northwest, there is a horseshoe shaped depression beneath Oceanus Procellarum and Mare Frigoris. In part of the central highlands and in part of the area between the Crisium and Serentitatis Basins, there are crustal deposits that rise above the NSM level floor.

In the remaining sections of this abstract, hypotheses are proposed that may explain the major features of the NSM floor.

Level floor: Two hypotheses are proposed as alternate causes for the level floor of the NSM. At the time of the NSM impact, the magma ocean might have been either still partly molten or nearly molten. In either case, the NSM transient crater would have extended far below the 3.5 km depth of the center of the surface basin, perhaps hundreds of kilometers or even to the core of the Moon. The energy released in the transient crater might have turbulently re-mixed the crust with the mantle, if indeed it had separated. The resulting restored magma ocean may have reformed the crust. This regenerated crust, lighter than the newly regenerated mantle, may have risen within the floor of the basin. The process would be somewhat analogous to flooding a smaller basin with mare at a much later time, but different in nature because of the conditions at so early a time and because of the size and energy of the transient crater.

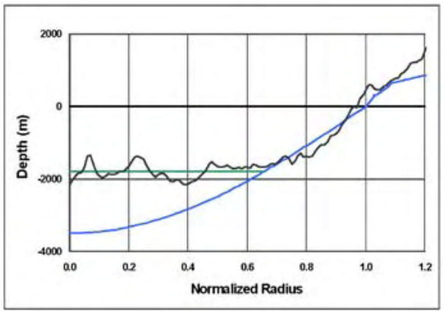

Figure 1: Radial profile of the floor of the NSM. The black line is depth relative to the estimated original target surface, averaged over the quadrants centered on the northwest major axis and the northeast minor axis (southern quadrants are distorted by the SPA). The blue line is the model of the NSM and the green line is the model of the level floor.

An alternate hypothesis is very different. In this scenario, the floor was level from the time of formation. An experiment with an explosive crater on Earth [7] formed a flat-floored crater because of the structure of the target material. That explosion was conducted in a region of unconsolidated sediment that was saturated with ground water below a certain level. Ejecta was removed in typical fashion down to just above that level, but no further. A similar condition might have applied to the NSM if the magma ocean was still about 2 km below the crust. The impact event might have encountered the transition between the crust and the magma ocean, with a sudden discontinuity in density and shear strength, causing the level floor to be formed. As in the first hypothesis, additional crust would have formed in and below the level floor as the magma ocean cooled.

Oceanus Procellarum depression: This horseshoe-shaped depression is shown in Figure 2. Oceanus Procellarum is near the northwest end of the major axis of the NSM. The Prospector mission [5] has revealed a large concentration of heavy elements, including iron and thorium, within the interior of the NSM, strongest in the northwest, roughly symmetric with the major axis of the NSM. Oceanus Procellarum underlies that region of thorium concentration and also the largest area of mare.

The proposed scenario for the formation of the Oceanus Procellarum depression is that the NSM impactor approached at a low angle, perhaps 20° from the horizontal, from the southwest. Penetration of the impactor along the major axis might have stirred up the heavy elements, enriching the crust in that area. A similar scenario has been suggested for the SPA [6].

The concentration of radioactive elements beneath Oceanus Procellarum might, in time (long after the NSM impact), have formed a large pool of molten basalt whose rise to the surface would have been abetted by the prior concentration of large impact basins such as Imbrium, Humorum, Nectaris, and possibly in the Oceanus Procellarum area, obscured by the mare there.

The depletion of the pool of subterranean molten basalt, its contraction as it cooled, plus the weight of the overlying crust and surface pools of mare, might have resulted in subsidence of the surface in this region. The total volume need not have been preserved because of the removal of ejecta from the concentration of impact craters here.

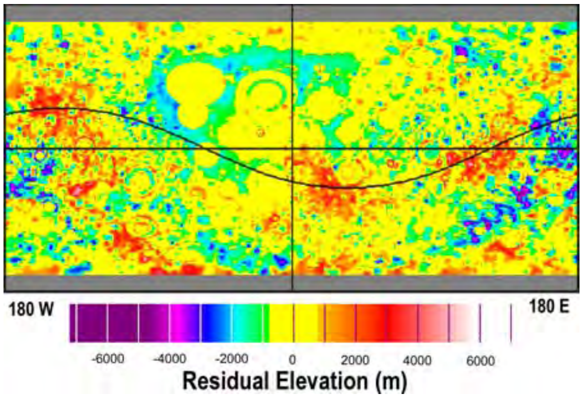

Figure 2: This geographic projection of the Moon shows the difference between the measured elevations and that of tthe models. The area within 12 degrees of the poles, where the LIDAR elevations are not accurate, are in gray. Two major anomalies are the Oceanus Procellarum depression (blue, northwest) and the three crustal deposits (orange, on a great circle with a pole at 65 N, 35 E).

Anomalous crustal deposits: These rises of crustal material (of anorthositic composition) are not easy to explain. Neither of the two anomalous rises within the NSM is in a position that could represent a central peak of the NSM. However, these rises are part of a global pattern of such features: similar rises appear on the far side of the Moon, after the models are subtracted from the current elevation map. Surprisingly, all of these features fall on a great circle (the black curve in Figure 2).

Could the Moon once have had a ring around it? Such a ring might have been formed by left-over material from the impact with earth of Theia, the planetary precursor of the Moon. Alternately, it could have been populated with ejecta that escaped from the Moon when the NSM was formed. Such a ring could not have lasted long in the presence of Earth's strong gravity, but part of it may have fallen onto the Moon, forming a somewhat irregular concentration of rises in a great circle band which may or may not have been equatorial to the Moon at the time.

Concentration of Mare: The large areas of mare material on the Moon are almost entirely within either the NSM or the SPA. The mechanism underlying the extrusion of these basaltic flows are well understood from orbital observation and sample analysis. The proposed NSM model does not change our current understanding of these features, but it does provide a causal explanation of why so many of the maria are concentrated within the NSM. The thinning of the crust there by the excavation of the basin would provide an easier path for the rise of molten basalt to the surface. Further, the NSM impact would have raised the heavy elements of the uranium series closer to the surface.

Summary: There is a clear pattern of a basin on the near side. The interior of its basin is in general agreement with the scaled model, but exhibits some unusual anomalies: a flat crustal floor, the Procellarum depression, and anomalous crustal deposits (also seen on the far side). This abstract proposes potential explanations of these anomalies, with the intent to stimulate discussion and perhaps to generate other explanations. Future spacecraft missions may contribute new evidence to support or refute these proposals.

Acknowledgements: The author is grateful to Ian Garrick-Bethell, Ray Hawke, Mark Robinson, and Paul Spudis for raising questions and discussing these features.

References: [1] Byrne, C.J., Lunar Orbiter photographic atlas of the near side of the Moon, Springer, 2005. [2] Byrne, C.J., The Near Sde Megabasin of the Moon, LPSC 37, talk, Abstract 1930. [3] Byrne, C.J., A large near side basin on the Moon, manuscript submitted to Earth, Moon, and Planets, October 4, 2006. [4] Cadogan, P.H., Oldest and largest lunar basin? Nature, v. 250 no. 5464, 1974. [5] Feldman, W.C., Gasnault, O., Maurice, S., Lawrence, D.J., Elphic, R.C., Lucey, P.G., and Binder, A.B., Global distribution of lunar composition: new results from Lunar Prospector, JGR Vol. 107, NO. E3, 2002. [6] Garrick-Bethell, I, Ellipses of the South Pole – Aitken Basin, LPSC 2004, Abstract 1515. [7] Housen, K.R., Effects of target properties on the cratering process, Workshop on Impact Cratering 2003, Abstract 8016. [8] Whittaker, E.A., The lunar Procellarum basin, Multi-ring basins: LPSCP 12, Part A, 1981. [9] Wood, J.A., Bombardment as a cause of the Lunar Asymmetry, The Moon 8, 1973. [10] Zuber, M.T., et al., Topogrd1 and Topogrd2, web site of the University of Washington at St. Louis, 1998.