A layered model of the Moon's far side bulge. C. J. Byrne, Image Again, 39 Brandywine Way, Middletown, NJ, 07748, charles.byrne@verizon.net.

Introduction: There are now two explanations of the bulge on the far side of the Moon being derived from impact. One is that a hypervelocity impact on the near side formed the Near Side Megabasin (NSM) [1, 2]. The ejecta from the NSM created the far side bulge. A more recent proposal is that a subsonic impact of a Companion Moon (CM) [3] on the far side formed the bulge directly.

The center of the detailed shape of the far side bulge would be the same for the two hypotheses (9 º south and 156 º west) in the southern part of the Korolev Basin), but the actual shape would be different, as discussed in Abstract 1025 of this meeting [4]. An additional difference would be the deep layered structure of the bulge, the subject of this abstract.

Layered structure of the CM bulge: The CM would produce a layer of crustal material over the primitive crust and there would be additional crustal material over that due to subsequent impacts, primarily from the South Pole-Aitken Basin (SPA).

Layered structure of the NSM ejecta: The NSM would produce two distinct layers of crustal ejecta between the primitive crust and the ejecta from subsequent impacts. The cavity of the proposed NSM covers more than half of the Moon (its diameter is about 220 º). Consequently, each cone of ejecta has relatively little landing area. Initially, the scaling laws of the Maxwell-Z model [5] for an impact this large determine that the ejecta would escape the Moon. As the ejection proceeded and the velocity dropped, an ejecta layer passed over the antipode (which would become the center of the far side bulge), fell short of what would become the far rim, and then retreated toward the antipode. There would be a scarp at the edge of this layer. As the ejection progressed, a second layer of ejecta fell short of the antipode, retreating back toward the rim, when the ejection process ceased.

Fig. 1 shows a simulation of what the two layers would have looked like if the NSM and its ejecta were formed at their current depth and had not been subjected to isometric compensation and if the South Pole-Aitken Basin (SPA) had not impacted the far side bulge.

The NSM subsurface profile: Actually, since there is a negligible long-wavelength free air gravity anomaly over the bulge [6], essentially complete isostatic compensation has occurred, indicating that the bulge was much higher when it was formed. .

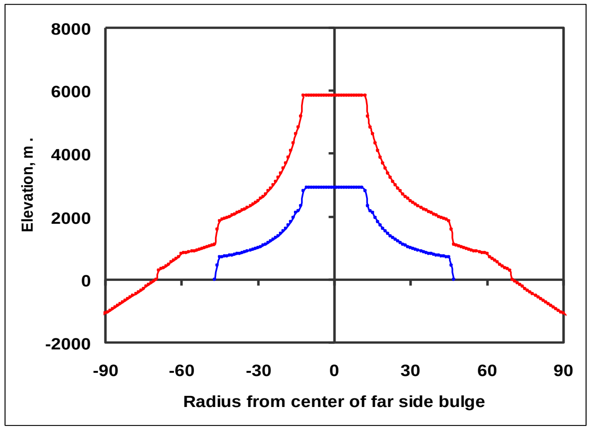

Fig. 1: This shows a cross section of the far side bulge produced by NSM ejecta, centered on 9 º south and 156 º west, as if it had not been subjected to isostatic compensation. The blue line represents the contact between a lower layer, limited in extent by ejecta driven to escape the Moon, and an upper layer that covered the area from the antipode to the NSM rim. The truncation at the center of the bulge represents the chaotic process of ejecta meeting from all sides, limiting the height of the bulge.

For reasonable assumptions about the density of the crust (2800 kg/m^3) and the density of the mantle (3360 kg/m^3) [7], complete isostatic compensation (Airy model) would imply that a large height of crust added to the surface would be compensated by depression of the mantle by a factor of 5/6, leaving only 1/6 of it above the initial surface.

Allowing for this ratio, the realistic contact between the two layers of the far sided bulge, if caused by ejecta from the NSM, would be as shown in Fig. 2.

The depth of each of the two layers is not subject to isostatc compensation: they simply settle. The initial depth of the contact between the crust and mantle is shown as 47 km [2]. This is the value that corresponds to the maximum crustal depth of 85 km [7].

Note that the thin incompatible layer between crust and mantle, the source of heat for eruption of molten mantle material, is also depressed. This probably accounts for the relative sparseness of maria on the far side bulge.

The CM subsurface profile: The subsurface profile of the CM would look similar to Fig. 2 except that there would be no separate layers, and the shape of the bulge would be more rounded than that of the spiked shape resulting from the NSM [4].

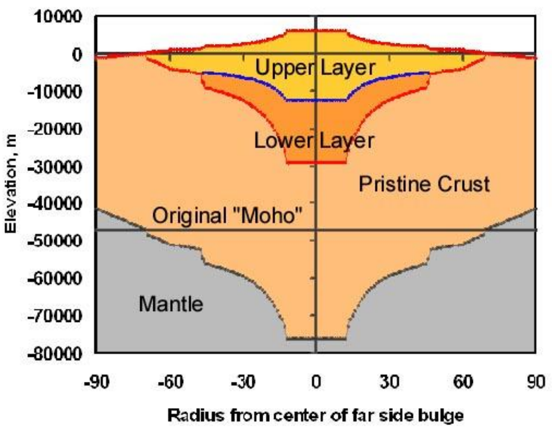

Fig. 2: The surface and subsurface of the far side bulge as it is now, after full isostatic compensation (assuming the Airy model: there is no horizontal strain in the crust or mantle).

Detection of the layers: The GRAIL mission will detect variations in the subsurface of the Moon through precise measurement of the near-surface gravity field, to be compared with the topography measured by Lunar Reconnaissance Orbiter.

How could the contact between the two layers be detected? The upper surface of the lower layers would have been relatively porous because of the chaotic nature of its deposition, like any other ejecta blanket. If this consequent porosity (and implied lower density) survived the deposition of the upper layer, the contact between the layers might be detectable as a density variation. Because of this possible porosity effect, future seismometers on the far side might also detect a velocity variation at the contact between layers.

A distinction between the layers themselves is that according to the Maxwell-Z model [5], the lower layer, being ejected closer to the center of the NSM, would carry material from a shallower depth of the pristine crust than would the upper layer. This is a typical example of ejecta overturn. If the pristine crust had a density that increased with depth, perhaps due to more mafic content, then the upper layer would be denser than the lower layer. There would be no difference near the center of the bulge and the greatest difference would be at the edge of the lower layer. This effect might also be observable at the surface of the bulge (below the overburden of SPA and later ejecta), as an increase of density from the center of the bulge toward its periphery.

Summary: The more accessible way to distinguish between the NSM and CM origin proposals for the far side bulge is examination of the detailed topography of the bulge [4].

There are more subtle but distinct differences between the subsurface structures of the two proposals. Perhaps distinguishing evidence will be produced by GRAIL.

References: [1] Byrne, C.J., The Near Side Megabasin of the Moon, LPSC 2006, Abstract 1930. [2] Byrne, C. J., A large basin on the near side of the Moon, Earth, Moon, and Planets, v. 101, p. 153 – 188, 2007, doi:10.1007/s11038-007-9225-8, 2007 (on line), 2008 (print). [3] Jutzi, M, and Asphaug, E**.,** Forming the lunar far side highlands by accretion of a companion moon, Nature Letter, Vol. 476, p. 69-72, August 4, 2011. [4] Byrne, C.J., The shape of the Moon, LPSC 2012, Abstract 1025. [5] Housen, K. R., Schmidt, R. M., and Holsapple, K. A., Crater ejecta scaling laws: fundamental forms based on dimensional analysis, JGR, 88 (B3), 1983: p. 2485-2499. [6] Neumann, G. A., Zuber, M. T., Smith, D. E., and Lemoine, F. G., The lunar crust: global structure and signature of major basins, JGR 101(E7): 16,841-16,843, 1996, [7] Hikida, H. and Wieczorek, M.A., Crustal thickness of the Moon: new constraints from gravity inversion using polyhedral shape models, LPSC 2007, Abstract 1547.