CONSTRAINTS ON THE IMPACT-ACCRETED CARAPACE HYPOTHESIS FOR THE LUNAR FARSIDE HIGHLANDS. Paul H. Warren, Institute of Geophysics and Planetary Physics, UCLA, Los Angeles, CA 90095, USA (pwarren@ucla.edu).

Jutzi and Asphaug [1] recently proposed an innovative model for the formation of the thick accumulation of highland crust that is found on the Moon's farside hemisphere. Briefly, their suggestion is that the farside highlands crust is thicker than its nearside counterpart because its mass was augmented by a carapace that was deposited over the farside when the last large renmant (apart from the Moon itself) of the orbiting disk created by the Moon-forming Giant Impact hit the Moon at moderate velocity of 2-3 km/s. The model assumes the "companion" body had survived for several times 10^7 years at a trojan point [2], and that its size (diameter) was roughly 1200-1270 km; i.e., 5.0 vol% of the final Moon's volume. As a well-deserved reflection of the achievements and prestige of Professor Asphaug (and *Nature*), this model has met with an enthusiastic reception, at least in the scientific news media. However, as I point out below, the impact-accreted carapace model appears ill-suited to meet some key constraints.

The most fundamental characteristic of the lunar highland crust is a density that is low by roughly 400-500 kg/m^3 in comparison to the underlying mantle. Low density is assumed in all geophyical models aimed at constraining the thickness of the highland crust [e.g. 3]; without the assumption of low density there would be little reason to assume that the farside crust is thicker than than its nearside counterpart. Thus, the impact-accreted carapace model implicitly assumes that the companion body (at least, in its final state as a component added to the Moon) is 400-500 kg/m^3 less dense than the bulk Moon.

Porosity might be higher in the smaller companion body, especially in the immediate aftermath of its transformation into a carapace on top of the lunar crust. However, porosity is ubiquitous in the shallower portions of the lunar crust, and is limited (especially in the first few times 10^8 years when the crust was still hot; plus, the proposed companion-body impact debris would have been warmed by impact heating) by the pressure- and depth-sensitive process of sintering [3]. Thus, porosity cannot have been, ultimately, a major influence on the density of the proposed carapace.

The impact-accretion carapace model [1] makes no precise claim for the bulk density of the "companion" body, but acknowledges there is little reason to suppose a bulk density much different from that of the final Moon. Chemically, and thus mineralogically, the two bodies must be similar, as both formed from the same orbiting melt+vapor disk; and in neither case are pressures high enough to have great effect on mineralogy. However, the model assumes a vastly larger proportion of crust for the smaller companion body: 12.6% of the radius (80/635 km), as opposed to roughly 3.5% (60/1738 km) in the Moon. In other words, the model assumes that 33 vol% of the companion body was "lunar-like" crust, in contrast with the known Moon's crust size of 10 vol%. In the absence of some mechanism to either fractioante the companion's bulk composition by a factor of 3 (for the crust-limiting element, aluminum), or else to somehow enhance its crust yield by a similar factor, it seems more plausible to assume that the companion body, like the Moon, contained ~10 vol% of crust.

Even if the body had a 33 vol% crust, its bulk pore-free density should have been close to the Moon's bulk density, 3340 kg/m^3. A carapace of this compositional density, even if it is to some plausible extent porous, would not have the density characteristcs of lunar crust.

Nor would the carapace have the compositional-mineralogical characteristics of the Moon's highland crust. For the farside crust, documented samples are not available. However, nearly half of the lunar meteoirtes are products of launches off the farside, and the total numbers are high enough, and enough of these meteorites are regolith breccias [4], that we can be sure that the farside highlands is fairly well represented. The composition indicated by the meteorites, consistent with orbital data [5], is if anything more anorthositic than the crust sampled by the archetypical highland site, Apollo 16; i.e., Al_2O_3 content close to 27 wt%. Even a body consisting of 33 vol% crust should have only about 9 wt% Al_2O_3. This composition mis-match is another significant weakness of the impact-accreted carapace model for origin of the farside highland crust.

As acknowledged by [1], a variety of other models have been proposed to account for the thick farside crust. Those other models may be comparatively mundane, but most do not carry quite such difficult-to-explain implications as the impact-accreted carapace model.

References: 1. Jutzi M. and Asphaug E. (2011) *Nature* 476, 69-72. 2. Cuk M. and Gladman B. J. (2010) *Icarus* 199, 237-244. 3. Warren P. H. (2011) *MAPS* 46, 53-78. 4. Korotev R. L. (2005) *Chemie Erde* 65, 297-346. 5. Prettyman T. H. et al. (2006) *JGR* 111, E12007.