IMPACT-INDUCED MELTING BY GIANT IMPACT EVENTS. L. Manske[1], K. Wünnemann[1,2], N. Güldemeister[1], M. Nakajima[3,4] , C. Burger[5]. [1]Museum für Naturkunde, Berlin, Germany; [2]Institute of Geological Sciences, Planetary Sciences and Remote Sensing, Freie Universität Berlin, Germany; [3]Department of Terrestrial Magnetism, Carnegie Institution for Science, USA; [4]Department of Earth and Environmental Sciences, University of Rochester, USA; [5]Department of Astrophysics, University of Vienna, Austria.

Introduction: We revisited the long-standing problem of the generation of melt as a consequence of giant impact events, which may not be accurately addressed by classical scaling-laws [1,2,3]. The melt production in giant collisions such as the Moon-forming event on the young Earth or basin-forming impacts is influenced by several parameters. Classical scaling laws account for the impact velocity, the size of the impactor, the impact angle and to some extent also the compositions of the target and the impactor. However, if the impactor is larger than a certain threshold, the initial temperature of the target planet as a function of depth significantly affects the melt production and classical scaling laws are not applicable anymore. In particular for younger planets, where the initial temperature may be close to the solidus, melting may occur to a much larger extent than expected and therefore magma oceans can form more easily and may exist longer. To better understand and quantify the mechanism of heat production and melting as a consequence of large-scale impact events we carried out a series of numerical simulations and determined the volume of melt production as a function of impact parameters and target temperatures for different planetary objects (Mars, Earth and Moon).

Methods: For a systematic parameter study we use the iSALE Eulerian shock physics code [4,5] (Version Dellen) and two different SPH codes [6,7] for very large collision events. We use ANEOS [8] to calculate thermodynamic quantities for basalt, dunite, and iron representing the planetary crust, mantle and core, respectively. In our models melting occurs if the pressure/entropy is in excess of a critical peak shock pressure P_m or entropy S_m. It should be noted that the critical values P_m and S_m are a function of the initial temperature-depth profile inside the planet and the material's final lithostatic pressure. The initial temperature also affects the strength of matter inside the planet, which in turn has an influence on the attenuation of the shock wave (faster decay in materials with strength than in the hydrodynamic case). In addition we also take into account decompression melting as a consequence of structural uplift of matter in all iSALE models.

Results and Discussions:

For small impacts, where the temperature increase with depth in the target is negligible, our models agree well with the existing scaling laws [e.g. 1,2]. Sufficiently large impacts where the zone of peak shock pressures in excess of P_m reaches as deep as the bottom of the lithosphere and the temperature profile approaches the solidius, show a significant increase in melt production relative to the reference case. For example, assuming a 100 km deep lithosphere for an early Mars, the melt production is 2 - 3 times larger than scaling laws predict for impactors ~ 30 - 100 km in diameter (for vertical impact velocities from 10 - 20 km s^{-1} respectively). A similar behavior can be observed for Earth and Moon.

References: [1] Abramov O. et al. (2012) Icarus 218, 906-916. [2] Pierazzo et al. (1997) Icarus 127, 408-423, 1997. [3] Bjorkman, M. D. and Holsapple K. A. (1987) Int. J. Impact Eng. 5, 155–163. [4] Collins. G. S. et al. (2004) Meteoritics & Planet. Sci. 39, 217-231. [5] Wünnemann K. et al. (2006) Icarus 180, 514–527. [6] Schäfer C. et al., (2016) Astronomy & Astrophysics 590, A19. [7] Nakajima & Stevenson, (2015) EPSL 427, 286-295. [8] Thompson and Lauson (1972) Report SC-RR-71 0714, Sandia Natailonal Lab.