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Numerical modelling of giant collisions – The Moon-forming impact event

Nicole Güldemeister (1), Lukas Manske (1) and Kai Wünnemann (1,2)
(1) Museum für Naturkunde, Leibniz Institute for Evolution and Biodiversity Science Berlin, Germany (nicole.gueldemeister@mfn-berlin.de), (2) Freie Universität Berlin, Institute for Geological Science, Germany

1. Introduction

Planetary collisions (e.g. the impact of a mars-size object impacting onto proto-earth) play an important role in the evolution of the planetary system. In particular the late phase of planet formation is characterized by collisions of large bodies (giant impact phase). The Moon-forming impact event is thought to be Earth's last giant collision event, marking the end of the accretion of the Earth. This large event (re)set the conditions for the subsequent thermochemical evolution of both bodies, Earth and Moon. Large parts of proto-earth and, presumably, the entire impactor are thought to melt as a consequence of the impact.

To quantify the volume of melt production and to constrain the initial conditions for the subsequent thermochemical evolution of Earth and Moon, we carried out numerical simulations in 2D and 3D of giant collisions including the Moon-forming impact event.

2. Methods

Previously, the Moon-forming giant impact has mostly been modelled with mesh-free so-called smoothed particle hydrodynamics (SPH [1]). In contrast to previous work, we have used an Eulerian shock physics code and fixed grid in space, the two-dimensional (2D) and three-dimensional (3D) iSALE code [2,3,4], to model the giant collision of a mars-sized object with proto-earth. iSALE accounts for multi-material and strength and is expected to provide more accurate results on shock wave propagation. In 2D, we account for a differentiated impactor and target. We assume a structure of the colliding bodies both having a core and mantle. For simplification we neglect the effect of the crust in those models. We take into account an initial thermal profile for the impacted body. The core of both bodies is represented by the Analytical Equation of State (ANEOS, [5]) for iron and the mantle by an ANEOS for dunite. Further, we account for the lithostatic pressure inside the planet as a consequence of the gravitational field using either central or self-gravity. Simulations in 2D allow for self-gravity, which is also planned for 3D in future simulations. In 2D head-on collisions are simulated. In 3D we also carry out a series of oblique impacts with different impact angles. In order to quantify the amount of melt that is produced by such a large impact, we use an approach introduced by [6] calculating the local final temperatures by using the peak shock pressure method. To record the peak pressures we use langrangian tracers.

3. Preliminary Results

Preliminary results carried out in 2D (head-on collisions) with differentiated impactor and target, taking into account self-gravity show that the volume that is fully or partially molten after the impact event is about 4 times the impactor volume.

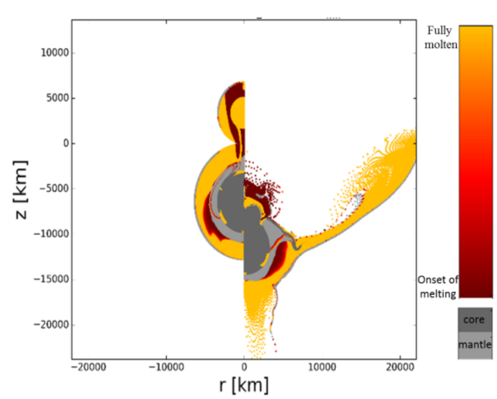

Figure 1: Melt distribution including the degree of melting one hour after the impact. On the left, the used tracers have been mapped back to the initial position. On the right, the final positions of the tracers are shown.

The degree of melt is shown in Figure 1 presenting partially and fully molten areas of the impactor and impacted body. It can be seen that the impactor is completely molten, the iron core of the impacted body is not molten where the entire mantle is almost fully molten. First 3D tests allow for simulations of an oblique impact. Figure 2 shows the temperature and pressure as it develops during a giant collision for an oblique impact of 45 degree angle considering central-gravity where a dunitic impactor strikes a differentiated proto-earth (mantle and core) with an initial temperature profile.

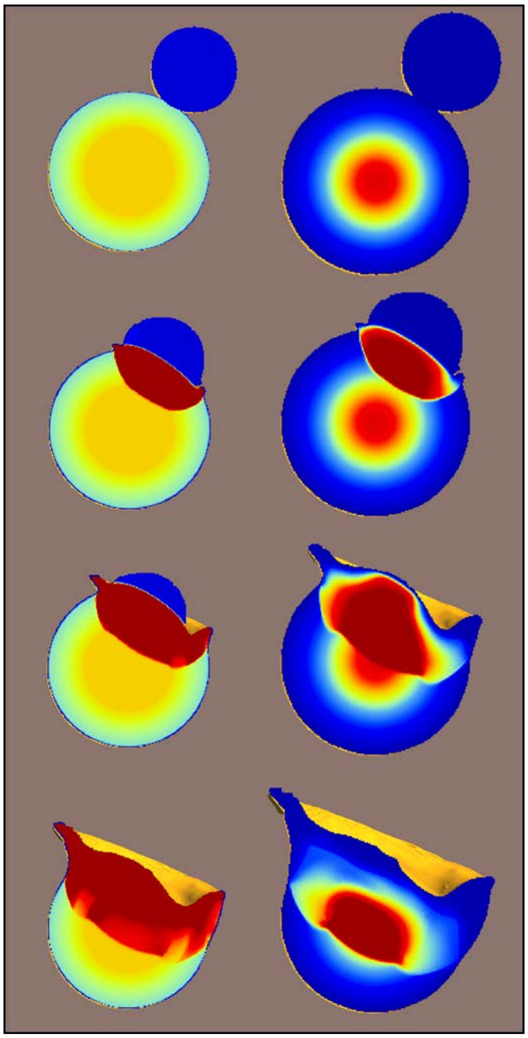

Figure 2: Sequence of the qualitative development of temperature (left) and pressure (right) with time (top to bottom) during a 45 degree impact of a mars-size impactor onto proto-earth with a differentiated target body (mantle and core) and initial temperature profile.

3. Conclusions and Future Work

First numerical simulations of the Moon-forming event in 2D provide estimates about the melt production during such an impact event. First simulations in 3D of oblique impacts show the qualitative distribution of pressure and temperature during the impact event. Future work will include the implementation of a self-gravity routine in iSALE3D incorporating a Barnes and Hut approach [8] similar as in SPH codes. The upcoming simulations will mainly be carried out in 3D to consider more realistic and relevant impact scenarios of the oblique impact of a mars-size object onto proto-earth. In addition we will include differentiated bodies for 3D simulations which will require further code developments. We intend to quantify melt production and to estimate the possible mixing of core material of the impactor with the mantle and core material of the proto-earth.

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References

[1] Monaghan, J.J.: Smoothed particle hydrodynamics, Annu. Rev. Astron. Astrophys. 30, 543–574, 1992.

[2] Collins, G. S., Melosh, H. J., and Ivanov, B. A.: Modeling damage and deformation in impact simulations. Meteoritics & Planetary Science, 39, 217–231, 2004.

[3] Wünnemann, K., Collins, G. S., and Melosh, H. J.: A strain-based porosity model for use in hydrocode simulations of impacts and implications for transient crater growth in porous targets. Icarus, 180, 514–527, 2006.

[4] Elbeshausen, D.: Dreidimensionale numerische Modellierung schräger Meteoriteneinschläge - Strategien und Anwendungen - Dissertation, Freie Universität Berlin, Fachbereich Geowissenschaften. 283 pages, 2012.

[5] Thompson, S. L.: ANEOS Analytical Equation of State for Shock Physics Codes Input Manual. Technical Report SAND89-2951 UC-404, Sandia National Laboratories.76 pages, 1990.

[6] ManskeL., Wünnemann K., Nakajima M., Plesa A.-C.: Impact-Induced Melting by Giant Impact Events. 49th LPSC, abstact# 2269, 2018.

[7] Barnes, J., Hut, P.: A hierarchical O (N log N) force-calculation algorithm, 1986.