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# Scaling Law of Impact Induced Shock Pressure in Planetary Mantle

Julien Monteux (1) and Jafar Arkani-Hamed (2)

(1) Laboratoire Magmas et Volcans, Université Blaise Pascal, Clermont-Ferrand, France (j.monteux@opgc.univ-bpclermont.fr), (2) Department of Physics, University of Toronto, Canada (jafar@physics.utoronto.ca)

While hydrocode simulation of impact induced shock pressure inside planetary mantle is more accurate, it is not suitable for studying several hundreds of impacts occurring during the accretion of a planet. Not only simulation of each impact takes over two orders of magnitude longer computer time than that of a scaling law simulation [1], but also it is cumbersome to apply for growing proto-planets where size of a proto-planet and impact velocities of the accreting bodies increase significantly. This is compounded by the formation of the iron core during the accretion with increasing size. Major impacting bodies during accretion of a Mars type planet have very low velocities. We use iSale hydrocode simulations and adopt physical properties of dunite for the mantle to calculate shock pressure and particle velocity in a Mars type body for 11 impact velocities ranging from 4 to 60 km/s. Large impactors of 100 to 1000 km in diameter, comparable to those impacted on Mars and created giant impact basins, are examined. The results are in good agreement with those of Pierazzo et al. [2] which were calculated for impact velocities higher than 10 km/s and impactor of 0.2 to 10 km in diameter. The internal consistency of our models indicates that our scaling laws are also accurate for lower impact velocities. We found no distinct isobaric region, rather the peak shock pressure changes relatively slowly versus distance from the impact site in the near field zone, within $\sim$ 3 times the impactor radius, compare to that in the far field zone as also suggested by Ahrens and O'Keefe [3]. Hence we propose two distinct scaling laws, the power law distribution of shock pressure P as a function of distance R from the impact site at the surface, one for the near field zone and the other for the far field zone:

$\text{Log } P = a + n \text{ Log } (R/R_{imp})$

With

$n = 1.72 – 2.44 \text{ Log}(V_{imp})$ for $R < \sim 3 R_{imp}$, and
$n = -0.84 - 0.51 \text{ Log}(V_{imp})$ for $R > \sim 3 R_{imp}$

where a is a constant, Rimp is the impactor radius, and Vimp (in km/s) is the impact velocity. The scaling law provides us a mean to determine impact heating of a growing proto-planet. We also show the effect of dynamic phase change in dunite at around 220 GPa during the passage of the shock wave occurring for impact velocities higher than 10 km/s.

[1] Arkani-Hamed, J., and Ivanov, B., (2014), Phys. Earth Planet. Inter., 230, 45–59. [2] Pierazzo, E., Vickery, A.M., and Melosh, H.J., (1997), Icarus 127, 408–423. [3] Ahrens, T.J., and O'Keefe, J.D., (1987). Int. J. Impact Eng. 5, 13–32.