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Forming the Martian dichotomy with realistic impact scenarios

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The Martian dichotomy features a ~25 km difference in crustal thickness and ~5 km contrast in topography between the southern highlands and northern lowlands [1]. Among various origin hypothesis, a southern impact [2,3] creates a magma pond which, upon cooling, induces crustal thickening and thereby forms the crustal dichotomy within 10s of million years.

Our previous study [4], which utilizes a head-on parametrized impact in 2D geometry, shows that an impact-induced magma pond in the southern hemisphere is able to not only create a thickened crust in the south, but also a satisfying volcanic history with localized melt production in the equatorial region at geologically recent time. Depleted material, formed from crystallization of the magma pond, spreads and underplates the thicker and colder Northern lithosphere undisturbed by the impact, reinforcing the lesser extent of volcanism in the northern hemisphere. Our resultant mantle structure is consistent with existing simulation efforts that focus on the post-dichotomy formation evolution history [5], and in addition gives the context of how such thermochemical structure is developed.

In order to include a more realistic impact scenario, we use smoothed particle hydrodynamics (SPH) simulations [6] to model the first 24-36 hours of a giant impact between proto-Mars and its impactor. The SPH result is then transferred to the mantle convection code StagYY [7], as an initial thermal condition, to simulate the long-term evolution of the crust and mantle for the subsequent 4.5 billion years. We systematically vary the impactor size, impact velocity and pre-impact Martian mantle temperature. Our preliminary results show that a 45-degree impact does not form a Martian dichotomy-like crustal structure, while a 15-degree impact is a better match. With a realistic impact, the mechanisms reported in our parametrized impact study still hold.

References:

[1] Watters, T., McGovern, P., & Irwin III, R. (2007). Hemispheres Apart: The Crustal Dichotomy on Mars. *Annual Review Of Earth And Planetary Sciences*, *35*(1), 621-652.

[2] Reese, C., Orth, C., & Solomatov, V. (2011). Impact megadomes and the origin of the martian crustal dichotomy. *Icarus*, *213*(2), 433-442.

[3] Golabek, G., Keller, T., Gerya, T., Zhu, G., Tackley, P., & Connolly, J. (2011). Origin of the martian dichotomy and Tharsis from a giant impact causing massive magmatism. *Icarus*, *215*(1), 346-357.

[4] Cheng, K.W., Tackley, P.J., Rozel, A.B., Golabek, G.J. (2021). Martian Dichotomy: Impact-induced Crustal Production in Mantle Convection Models, Abstract [DI35B-0023] presented at 2021 Fall Meeting, AGU, New Orleans, LA, 13-17 Dec.

[5] Plesa, A., Padovan, S., Tosi, N., Breuer, D., Grott, M., & Wieczorek, M. et al. (2018). The Thermal State and Interior Structure of Mars. *Geophysical Research Letters*, *45*(22), 12,198-12,209.

[6] Emsenhuber, A., Jutzi, M., Benz, W. (2018). SPH calculations of Mars-scale collisions: The role of the equation of state, material rheologies, and numerical effects. *Icarus*, 301, 247-257

[7] Tackley, P. (2008). Modelling compressible mantle convection with large viscosity contrasts in a three-dimensional spherical shell using the yin-yang grid. *Physics Of The Earth And Planetary Interiors*, *171*(1-4), 7-18.