Terrestrial core formation aided by flow channelling instabilities induced by iron diapirs

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The terrestrial core formation process remains poorly known. Isotopic constraints by Hf/W systematics indicate a fast process which was largely completed within 33 Ma for the Earth. An unstable gravitational configuration of dense molten metallic ponds overlying a chondritic protocore is predicted by most studies at latest for the time a planetary embryo reaches Mars size [1,2]. This leads to the formation of Rayleigh-Taylor instabilities. We propose the application of Stevenson's [3] stress-induced melt channelling mechanism in the regions surrounding incipient iron diapirs. We therefore perform numerical experiments solving the two-phase, two compositions flow equations within a 2D rectangular box. We apply the Compaction Boussinesq Approximation (CBA) [4] and include a depth-dependent gravity. We use a temperature and stress-dependent viscosity for the solid phase and melt fraction dependent rheology for the partially molten region around the diapir. We investigate the development of the channelling instability in cases with and without interaction with surrounding diapirs. In interactive cases we vary the distance between the diapir centres between 1 and 5 diapir radii and apply pseudoplasticity with power law exponents ranging from 1 to 6. As a result for single diapirs we observe for sufficiently small retention numbers [5] the development of iron-rich melt channels within a region of approximately twice the diapir's radius. This could lead to effective draining of the surrounding region and might initiate cascading daughter diapirs or iron dykes. For small distances between interactive diapirs the channelling mechanism is delayed for several million years compared with models without close-by neighbours. Channels seem also to develop preferentially in directions pointing away from the closest neighbouring diapir. The iron channels propose an effective mechanism to extract iron melt also from deeper parts of the initially chondritic protocore. This mechanism could effectively enhance melt accumulation in the Earth's protocore, accelerate the process of core formation and affect the metal-silicate equilibration in the deep planetary interior prior the Moon-forming giant impact. Therefore the channelling mechanism could also be interesting for planets like Mars, which probably never experienced complete melting.

References

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