Goldschmidt 2025 Abstract
https://doi.org/10.7185/gold2025.27127

Giant impacts, mantle melting and the state of the early Earth

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Over the past decade or so, I and colleagues have tried to reignite an old idea that meteorite impacts played a fundamental role in the production, modification and destruction of lithosphere, and thereby tectonics, on the early Earth [1–4]. In these and other manuscripts, we have proposed that large impacts (collisions with bodies > or >> 1 km in diameter) will induce mantle melting and the production of new (juvenile) crust of mafic to ultramafic (basaltic to komatiitic) composition. Most reviewers, including experts in early Earth geology, planetary science and impact cratering, have stated that they consider the idea of impact-induced mantle melting to be ‘pure speculation’ or even an ‘untestable hypothesis’ that is thereby unscientific. The few that have agreed that impacts can induce mantle melting consider it only possible for massive (basin-forming) impact craters hundreds of kilometres in diameter, such as those that formed the dark lunar maria.

Here we'll examine the logical consequence of large meteorite impacts into the solid surface (lithosphere) of silicate bodies using the rudiments of physical science and undergraduate petrology. We compare these logical predictions with observations from the Earth, Moon and other silicate bodies in the inner solar system to show that mantle melting is not only possible, but an inevitable consequence of large impacts. Accepting this inevitability, and an impact flux proportional to that endured by the Moon, provides a framework for understanding several longstanding conundrums in geology. Impacts were fundamental to the tectonics of the early Earth, whether we like it or not.

[1] Johnson et al. (2018), *Nature Geoscience* 11, 795–799
[2] Johnson et al. (2022), *Nature* 608, 330–335
[3] Kirkland et al. (2022), *Geology* 50, 1312–1317
[4] O'Neill et al. (2017), *Nature Geoscience* 10, 793–797