On the viability and style of subduction in a hotter Earth

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The tectonic regime of the early Earth remains an unresolved issue. The uncertainty in the actual mantle temperature through time, and the associated increased buoyancy of the differentiated oceanic lithosphere contributes to the ongoing debate about the viability, effectiveness and presence of the modern plate tectonic mechanism in a younger Earth: today, plate tectonics are the main characteristics of geodynamics, but a hotter Precambrian mantle resulted at first sight in conditions unfavorable for plate tectonics. More compositional buoyancy and less lithospheric strength in the early period of the Earth limit the applicability of the present-day subduction process. Our numerical modeling experiments provide the first quantitative results on this subject. The overall conclusions from those calculations are that modern-style subduction remains essentially the same in a mantle which is up to 100 K hotter than today. In an even hotter mantle, crustal delamination and detachment alter the appearance of subduction, and in some cases completely blocks it.

Model parameter analysis shows that: i) a large lithospheric yield strength reduces plate velocities for mantle temperatures up to 100 K hotter than today, but can improve the effectiveness of plate tectonics in a hotter Earth, because it suppresses slab detachment. Significant mantle dehydration during more extensive melting in the hotter Earth is expected to have a similar effect. ii) deep decoupling of converging plates is either achieved by a weak mantle wedge or weak oceanic crust. In the latter case, delamination of the thick crust in a hotter Precambrian mantle will hamper subduction significantly. iii) Heat flow analysis puts a constraint on the style of tectonics in a hotter Earth: tectonic plates had to be on average about 3 to 7 times younger than today in order to allow enough cooling. iv) A modest amount of fault friction (around 50 MPa) stabilizes the subduction process under hot mantle conditions and makes plate tectonics more viable. More friction, however, slows down the plate so much that it cannot effectively cool the Earth anymore. v) Slow eclogitization kinetics will hamper the subduction process for a thick crust in a hotter mantle. Whereas complete transformation within 1 Ma is still fast enough, 5 Ma makes plate tectonics too slow to efficiently cool the early Earth.