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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 50-300 warmer Precambrian mantle resulted in the formation of a thick buoyant crust and weaker mantle material, and plate tectonics, but particularly subduction, has been questioned for these conditions. Subduction is one of the key features of plate tectonics, and provides the driving force for the moving plates. This 'slab pull' is a result of thermal and compositional buoyancy. The latter was more important in an early Earth, because the warmer conditions resulted in a relatively thick buoyant crust. We quantified the style and viability of subduction with numerical models.

Without the transformation to eclogite, the 20-40-km Precambrian crust would easily make oceanic lithosphere unsubductable, comparable to the situation for present-day continental lithosphere. But the formation of eclogite has a profound influence on the density of the subducting slab, making predictions about the subductability in the past less straightforward. Our numerical calculations indicate that the kinetics of eclogitisation are important: Subduction velocities in a 300-K hotter mantle range from several m/yr in case of equilibrium transition down to zero (i.e. collision) for modest kinetic hindrance. Another consequence of the hotter conditions is a decreased mantle and crustal strength as a result of strong temperature-dependent rheology. One consequence of this is an increased tendency towards slab detachment and/or crustal delamination in a hotter Earth. Furthermore flat subduction has been suggested to have been more abundant in the past, but our calculations show that a 75-K-hotter mantle is already too weak to support low dip angles. In conclusion, the presence and mode of subduction in the Precambrian is a complicated interaction between crustal thickness, eclogitisation rate, and rheology of both crust and mantle.