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Feasibility of plate tectonics during the Archean: Insights from 3D numerical thermo-mechanical modelling

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Slab-pull forces are considered the major driving forces of the present-day plate tectonic. Their efficiency relies on the buoyancy contrast between asthenosphere and subducting plate and on the strength of the latter. Subduction is not only pivotal for understanding the dynamics of plates but also represents the only modern geodynamic setting that produces significant amount of juvenile continental crust and allows exchange between the mantle, lithosphere and atmosphere.

One of the most important unsolved questions is related to the onset of plate tectonics, which is inherently linked to feasibility of the subduction during the early in Earth history. During the Archean, the mantle potential temperature was higher than nowadays, which promoted extensive mantle melting and possibly a weaker lithosphere. The intense magmatism associated with the high mantle potential temperature generated highly residual lithospheric mantle that was more buoyant than the underlying asthenosphere. Altogether these factors may have inhibited the dynamic effect of slab pull and prevented modern style tectonic during the Archean. However, the Archean mantle potential temperature is still not well constrained, and many of these theoretical considerations have not been fully tested by integrating petrological forward modelling into 3D numerical geodynamic modelling.

In our contribution, we focus on the feasibility of modern style plate tectonic as a function of the mantle potential temperature and the composition and structure of the lithosphere. We compute representative phase diagrams that represents the composition of mantle lithospheric and its complementary crust as a function of the mantle potential temperature and integrate them into large-scale 3D numerical experiments. The numerical setup is constructed assuming the existence of a set plates interacting with each other. We prescribe the principal plate boundaries and allow the model to spontaneously evolve as function of the thermal ages of the prescribed plate, testing the effect of continental terrains and oceanic plateau on overall geodynamic evolution. The overall goal is to understand the feasibility of plate tectonics at high mantle potential temperature and to estimate the amount of fluid released by the subduction processes, which provide useful insights on the formation of continental crust.