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Plume-induced subduction initiation: dynamics and significance for modern and early Earth

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Subduction initiation scenarios can be markedly different in case of globally active vs. globally absent plate tectonics. Most present-day subduction initiation mechanisms require acting plate forces and/or preexisting zones of lithospheric weakness, which are themselves the consequence of plate tectonics (Stern 2004). In contrast, spontaneous plume-induced subduction initiation - suggested on the basis of numerical thermo-mechanical experiments (Ueda et al., 2008) and supported by data re-interpretation of how subduction started in Late Cretaceous time around the Caribbean LIP (Whattam and Stern, 2015) - does not require pre-existing lithospheric fabric, such as are created by active plate tectonics and is viable for both stagnant lid and mobile/deformable lid conditions. Here, we present results of high-resolution 3D numerical thermo-mechanical modeling of plume-induced subduction resulting from tectono-magmatic interaction of an ascending thermal mantle plume with old, cold, dense oceanic lithosphere. We demonstrate that weakening of the strong lithosphere by plume-induced magmatism is the key factor enabling subduction initiation around the plume head. A large plume head is required to overcome ring confinement by slab tearing, and subduction initiation is further favored when plume activity and lithospheric weakening continues for several tens of Ma. We further discuss possible implications of this scenario for modern plate tectonics as well as for plate tectonics initiation in the early Earth.

References

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