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3-D numerical modeling of plume-induced subduction initiation

Marzieh Baes (1), taras Gerya (2), Stephan Sobolev (1,3)

(1) Helmholtz-Zentrum Potsdam, Deutsches GeoForschungsZentrum GFZ, section 2.5, Potsdam, Germany (baes@gfz-potsdam.de), (2) Department of Earth Sciences, ETH-Zurich, Sonneggstrasse 5, 8092 Zurich, Switzerland, (3) Institute of Earth and Environmental Science, University of Potsdam, Karl-Liebknecht-Straße 24-25, 14476 Potsdam-Golm, Germany

Investigation of mechanisms involved in formation of a new subduction zone can help us to better understand plate tectonics. Despite numerous previous studies, it is still unclear how and where an old oceanic plate starts to subduct beneath the other plate. One of the proposed scenarios for nucleation of subduction is plume-induced subduction initiation, which was investigated in detail, using 2-D models, by Ueda et al. (2008). Recently. Gerya et al. (2015), using 3D numerical models, proposed that plume-lithosphere interaction in the Archean led to the subduction initiation and onset of plate tectonic. In this study, we aim to pursue work of Ueda et al. (2008) by incorporation of 3-D thermo-mechanical models to investigate conditions leading to oceanic subduction initiation as a result of thermal-chemical mantle plume-lithosphere interaction in the modern earth. Results of our experiments show four different deformation regimes in response to plume-lithosphere interaction, that are a) self-sustaining subduction initiation where subduction becomes self-sustained, b) freezing subduction initiation where subduction stops at shallow depths, c) slab break-off where subducting circular slab breaks off soon after formation and d) plume underplating where plume does not pass through the lithosphere but spreads beneath it (failed subduction initiation). These different regimes depend on several parameters such as plume's size, composition and temperature, lithospheric brittle/plastic strength, age of the oceanic lithosphere and presence/absence of lithospheric heterogeneities. Results show that subduction initiates and becomes self-sustained when lithosphere is older than 10 Myr and non-dimensional ratio of the plume buoyancy force and lithospheric strength above the plume is higher than 2.