Conversion of passive margins

Subduction initiation in passive margins: insights from numerical models

***M. Baes(1,2) , A. Hampel(1)**, (1) Ilnstitut für Geologie, Leibniz Universität Hannover, (2) GFZ Potsdam*

In Short

- The aim of this study is to investigate conversion of passive margins into active ones.
- Finite element models are used to study the effect of suction flow in subduction initiation.
- The role of STEP faults in destabilisation of passive margins is evaluated.

Passive margins are the transition between oceanic and continental lithosphere. As their name indicates there are not much tectonic activities along these margins. These localities have been proposed as candidate locations for subduction initiation. Some of previous studies (e.g., [1,2]) noted the difficulty of conversion of passive margins into active ones due to the large force, which is needed to break and bend the old lithosphere. They suggested that the favourable locations for subduction initiation are pre-existing weakness zones in the lithosphere such as mid-oceanic transform faults/fracture zones. However, modelling studies have proposed some weakening mechanisms such as water weakening [3], weakening due to grain damage [4] and mantle suction flow [5] facilitating subduction initiation in passive margins. Mantle suction induced subduction initiation was investigated previously using 2d numerical models ([5]). In this study, we aim to expand our previous work by using 3d numerical models. We investigate the possibility of destabilising of a passive margin by mantle suction force. We also evaluate the possible role of STEP ((Subduction-Transform Edge Propagator) faults on conversion of passive margins into subduction zones.

The study of [5] was based on 2d numerical models. In 2d models it is not possible to investigate whether tearing of lithosphere inherited from adjacent subduction zones can propagate towards the passive margins and facilitate subduction initiation process. Moreover, we expect that considering three-dimensionality of the earth makes the rupturing of the lithosphere more difficult. Therefore, 3d numerical models may lead to different conclusions. [6] using numerical models showed that in the horizontal edges of slab continual tearing of the lithosphere results in the formation of a transform-like fault, which they called it STEP fault. They argued that there are STEP faults along the north and south ends of the both existing mature subduction zones of Atlantic Ocean (the Lesser-Antilles and South Sandwich subduction zones). One of the objectives of this project is to investigate whether these STEP faults in Atlantic Ocean can propagate northward along the passive margins to trigger subduction initiation. In this scenario, propagation of tearing is facilitated by negative buoyancy of old oceanic lithosphere. Numerical modelling of effect of STEP faults on subduction propagation using 2d models are impossible. Therefore, we establish 3d numerical models in which STEP faults are located next to an old passive margin. We use available geological, geophysical and seismological data to set-up our models as close to the tectonic setting of Atlantic subduction zones and passive margins as possible. Here, our goal is to explore the possibility of conversion of Atlantic type of passive margins into active converging plate boundaries using more sophisticated 3d numerical models. We aim to answer to the following questions:

- Can mantle flow coming from past and present subduction zones trigger conversion of an Atlantic type of passive margin into active one?

- Can STEP faults -which are strike-slip like faults located at the horizontal edges of subduction zones-facilitate conversion of passive margins into subduction zones?

To this aim, we first set up models in which a passive margin is under mantle suction force. We will investigate how big these mantle suction forces should be to trigger subduction initiation. In the next step, we will study effect of STEP faults on subduction propagation. We will setup models in which a passive margin is separated from subduction zone by STEP faults. To better verify the effect of STEP faults we setup similar models with and without STEP faults. The combination of STEP faults and suction flow forces will be studied in the next step.

We use ASPECT code to model subduction initiation in passive margins. This code was originally developed to solve the equations for Earth mantle convection ([7,8]). Since then, due to further developments of the code, it has been used in various geodynamic problems such as modeling of subduction (e.g., [9,10]) and rifting (e.g.,[11,12]). In this project we setup two series of 3d models. In the first set of experiments, we examine whether suction force alone is able to break the lithosphere and initiate a new subduction zone.Our 3d model setups are shown in Figure 1. The model consists of an old

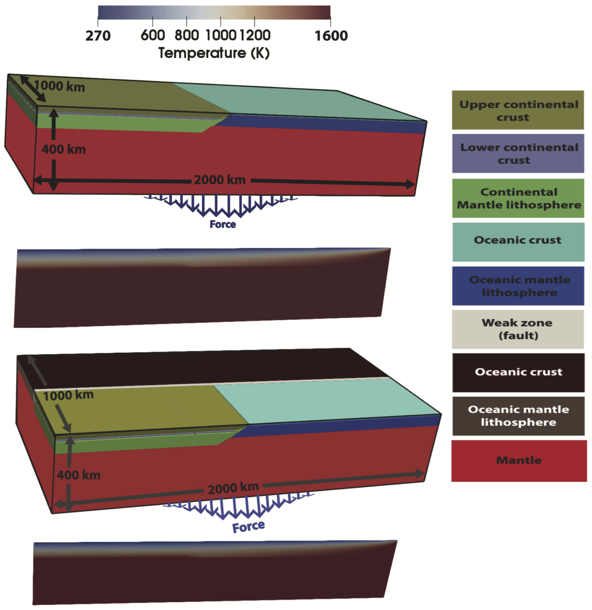

Figure 1: *Model setup. (a) Initial model setup of the first set of experiments. (b) Initial model setup of the second set of experiments. In (a) and (b) the upper panels show the compositional field (the color codes are shown in the right side of figure) and lower panels illustrate temperature field of a cross-section cutting through the middel of model.*

oceanic lithosphere, a continental plate and asthenosphere till depth of 400 km (Fig. 1a). The model domain is a cuboid of 2000*1000*400 km3. The temperature in the oceanic and continental lithosphere is calculated based on cooling half space model and steady state thermal field, respectively. All the side boundaries of the model are free-slip boundaries. The top boundary is a free surface boundary and we apply some velocities/tractions at the bottom of model to simulate suction force. In the second set of models we include a STEP fault to the midel of model to investigate its effect on subduction initiation (Fig. 1b). The STEP fault is defined by a weak low-viscosity zone in the middle of model.

More Information

[1] S Mueller, S.J. Phillips, *Journal of Geophysical Research.* **96**, 651-665 (1991).

[2] R.J. Stern, *Earth planet. Sci.* **226**, 275-292 (2004).

[3] K. Regenauer-Lieb, D.A. Yuen, J. Branlund, *Science* **294**, 578-580 (2001).

[4] E.Mulyukova, D. Bercovici, *Earth and Planetary Science Letters* **484**, 341-352 (2018).

[5] M. Baes, S. Sobolev, *Geochem. Geophys. Geosyst.,* **18**, https://doi.org/10.1002/2017GC006962.(2017).

[6] R. Govers, M.J.R. Wortel, *Earth planet. Sci. Lett.* **236**, 505-523 (2005).

[7] M. Kronbichler, T. Heister, W. Bangerth, *Geophys. J. Int.* **191**, 12-29 (2012).

[8] W. Bangerth, T. Heister, and others, *ASPECT user manual* **-**, (2015).

[9] A. Glerum, C. Thieulot, M. Fraters, C. Blom, W. Spakman, *Solid Earth* **9**, 267 (2018).

[10] M. Assanelli, P. Luoni, G. Rebay, M. Roda, M.I. Spalla, *Minerals* **10**, 985 (2020).

[11] E.L. Heckenbach, S. Brune, A.C. Glerum, J. Bott, *Geochem. Geophys. Geosys.* **22**, e2020GC009577 (e2020GC009577 2020GC009577) (2021).

[12] D. Neuharth, S. Brune, A. Glerum, C. Heine, J.K. Welford, *Geochem. Geophys. Goesys.* **22**, https://doi.org/10.1029/2020GC009615. (2021).

Funding

Project funding (DFG project number: BA 6613/2-1)