Towards understanding the roll-back subduction of narrow oceanic domains: inferences from the modelling of Carpathians subduction zone

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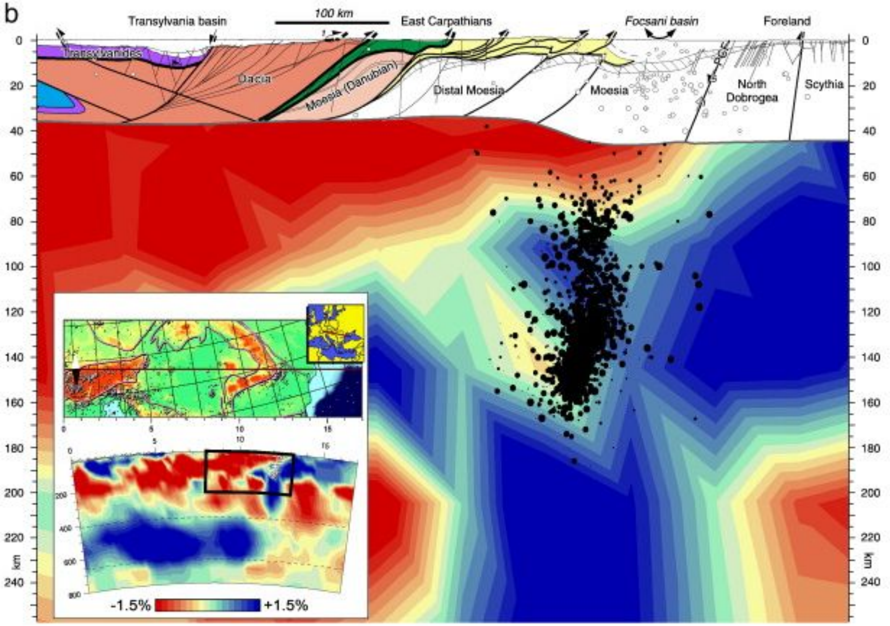
Subduction dynamics from surface to deep mantle

GD5.1

Geological Background: South-Eastern Carpathians

- there are several Mediterranean subduction zones that in the past gave rise to orogens such as the Alps, Dinarides and the Carpathian Mountains
- the evolution of these subduction zones is still not fully understood
- in most cases a subduction of a young, narrow oceanic slab is assumed



Geological and seismic tomography cross section of Eastern Carpathians, the Transylvanian Basin [1].

- Large slab lying between the 440 and 660 km mantle phase discontinuities ← indication that the most recent subduction of a narrow ocean had an inherited component from a previous subduction.
- Processes in the recent past and still ongoing:
  - detachment,
  - delamination.
- Ongoing detachment → occurrence of earthquakes (Vrancea-zone).
- Geodynamic numerical modeling can help to unravel the processes that shape such subductions.
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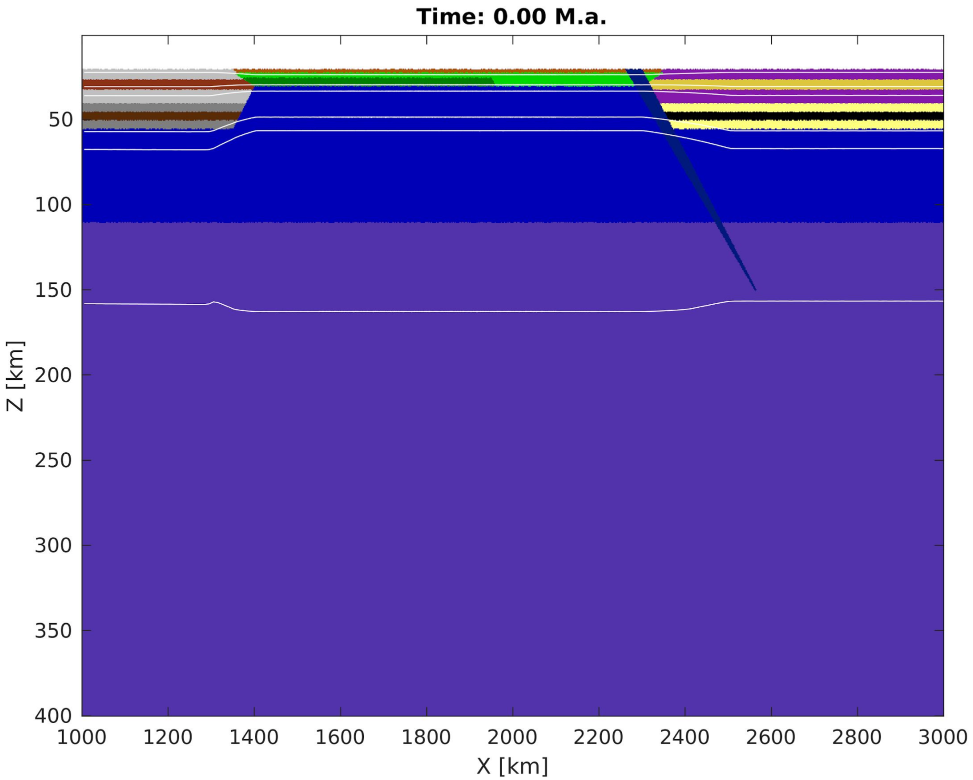
Numerical Geodynamic Modeling - Motivation and goals

- To model the Eastern Carpathians scenario we used a fully coupled two-dimensional thermo-mechanical [2] model that takes into account the visco-elasto-plastic behaviour of Earth's crust and mantle.
- Primary Goals to achieve:
  - sustained subduction of the oceanic plate
  - collision of the upper and lower plates and the formation of an orogen with characteristics of the Eastern Carpathians
  - approx. 200 km extension of the upper plate due to the roll-back of the subducting oceanic slab that should start after the onset of collision
  - approx. 50 km of delamination of the lower plate
  - detachment of the oceanic slab
- In our model:
  - upper plate represents the Tisza-Dacia microplate,
  - lower plate represents the non-moving Moesian platform,
  - oceanic slab to be subducted - Cehleau-Severin Ocean (200 km) with the rest ofthe slab (800 km) serves the part of the previous inherited oceanic subduction
- So far no similar model has been proposed to correctly reproduce the most important features of this subduction zone.

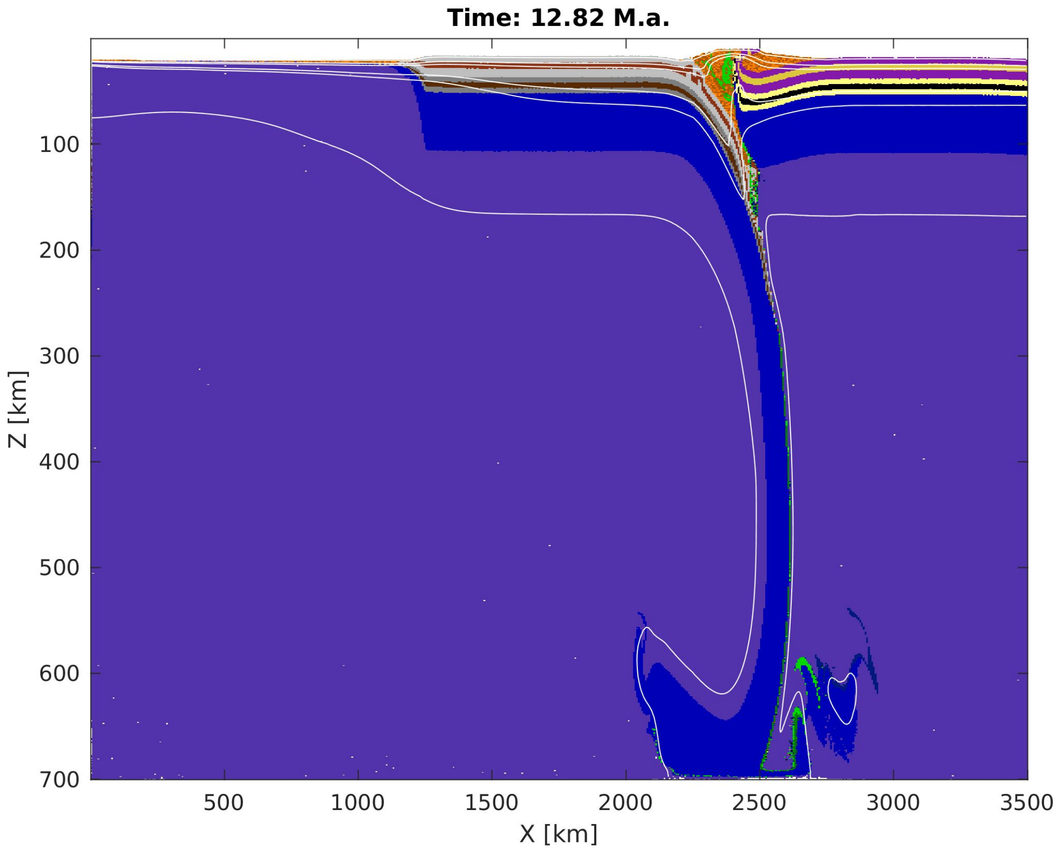
Model Setup

Large scale composition plot of the model setup. Light blue is the Earth's mantle, darker blue is the lithospheric mantle.



- a single 1000 km wide oceanic slab of 100 M.a. thermal age,
- two continental plates (varying colors) with identical rheological and mostly identical geometrical properties on either side of the oceanic slab (varying green),
- a weak zone (dark purple) between the interface of the oceanic and upper plate
- dimensions:
  - depth (Z): 700 km
  - width (X): 3500 km
- initial kinematic constraint: 10 cm / yr push until 7.5 M.a. (750 km of total convergence)

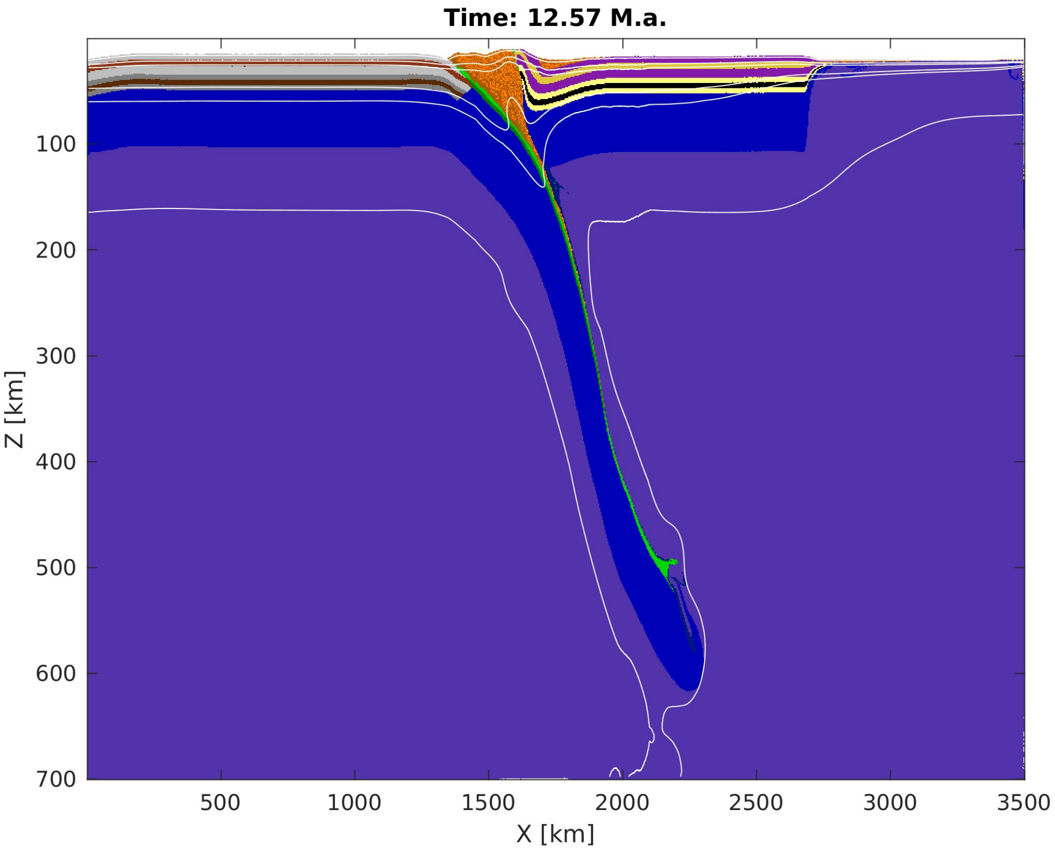
Model 1. - Push applied to the lower plate



Zoomed in composition plot of Model 1. Full video of model composition evolution can be viewed [here].

- kinematic push is applied to the lower plate
- Primary Goals to achieve:
  - sustained subduction of the oceanic plate ✅
  - approx. 50 km of delamination of the lower plate ✅
  - detachment of the oceanic slab ✅
  - formation of orogen with South-East Carpathians characteristics ❌ - double vergent orogen formed instead of single vergent
  - approx. 200 km extension of the upper plate ❌

Model 2. - Push applied to the upper plate



Zoomed in composition plot of Model 2. Full video of model composition evolution can be viewed [here](#).

- kinematic push is applied to the upper plate
- modified rheological parameters to better represent
- Primary Goals to achieve:
  - sustained subduction of the oceanic plate ✅
  - approx. 50 km of delamination of the lower plate ❌
  - detachment of the oceanic slab ❌
  - formation of orogen with South-East Carpathians characteristics ✅
  - approx. 200 km extension of the upper plate ❌

Conclusions

- Although Model 1. satisfied several of our criteria for an optimal model it has failed in other two important aspects:
  - it did not produce an orogen with the proper geometry (double vergent instead of single vergent),
  - major extension in the upper plate did not happen.
- To address these shortcomings Model 2. was developed:
  - push is applied to the upper plate instead of the lower plate is more in line with our geological understanding of the region,
  - this setup yielded a single vergent orogen
- Further criteria that Model 2. needs to satisfy:
  - approx. 50 km of delamination of the lower plate
  - detachment of the oceanic slab and approx. 200 km extension of the upper plate ← restricting the movement of the upper plate after kinematic constraints should achieve this
- Overall it was demonstrated that it is possible to recreate several characteristics of the subduction zone that formed the South-East Carpathians, with the assumption that the subduction of the Cehleau-Severin Ocean had an inherited component from a previous subduction.

Future plans

- **Finalize** a **model** that **satisfies** all **important criteria** for an optimal model.
- **Seismo-thermo-mechanical modelling** [3], based on the results of the large-scale thermo-mechanical modelling, to **explore** the **seismic cycle** of the **Vrancea zone**.

References

[1] Ismail-Zadeh, A., Matenco, L., Radulian, M., Cloetingh, S., & Panza, G. (2012). Geodynamics and intermediate-depth seismicity in Vrancea (the south-eastern Carpathians): current state-of-the art. *Tectonophysics*, *530*, 50-79.

[2] Gerya, T. V., & Yuen, D. A. (2007). Robust characteristics method for modelling multiphase visco-elasto-plastic thermo-mechanical problems. *Physics of the Earth and Planetary Interiors*, *163*(1-4), 83-105.

[3] Van Dinther, Y., Gerya, T. V., Dalguer, L. A., Corbi, F., Funiciello, F., & Mai, P. M. (2013). The seismic cycle at subduction thrusts: 2. Dynamic implications of geodynamic simulations validated with laboratory models. *Journal of Geophysical Research: Solid Earth*, *118*(4), 1502-1525.