Slab tearing and Lateral variation in the exhumation of ultra-high pressure terranes with application to the Norwegian Calidonides

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Introduction

The High Pressure and Ultra High pressure rocks are of interest as they are a potential tracer for the dynamics of collision and consequently have experienced near mantle conditions.

The Western Gneiss is the largest known continuous HP UHP terrain on earth and in parts has experienced pressures high enough to form coesite and micro diamonds.

The Western gneiss has been proposed to have been exhumed by eduction, a reversal of the subduction motion.

Numerical experiments in 2D fail to produce realistic PT paths via eduction.

Here we test if the 3D nature of the collision between Larentia and Baltica could have assisted in exhuming the Western Gneiss

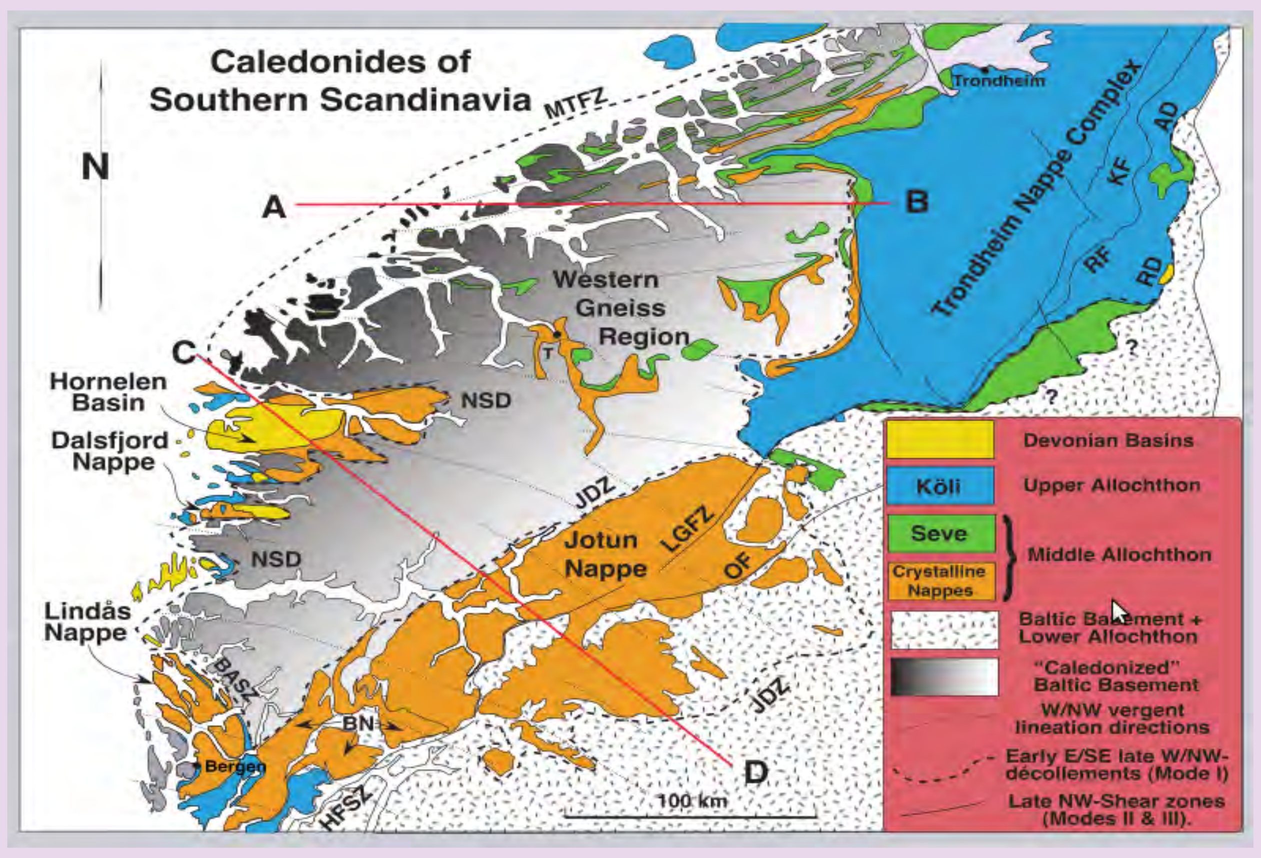


Figure1: Simplified tectonic map of the Western Gneiss Region, Trond-heim Basin, and the Jotun, Lindås, Dalsfjord, and Bergesdalen (BN) Nappes. The increase in grey scale shading for the Western Gneiss region represents higher temperatures and pressures achieved [1].

Method

Citcom a 2D/3D finite element model [2,3,4]

Modelling frame work is 1:4:4 Cartesian grid 660km 2640km 2640km

Temperature & stress dependant rheology.

Subduction facilitated by a weak zone.

Tracers allow tracking of continental material.

Specific tracers followed throughout calculation to obtain PT paths

Asynchronous collision designed to investigate along strike variations in eduction

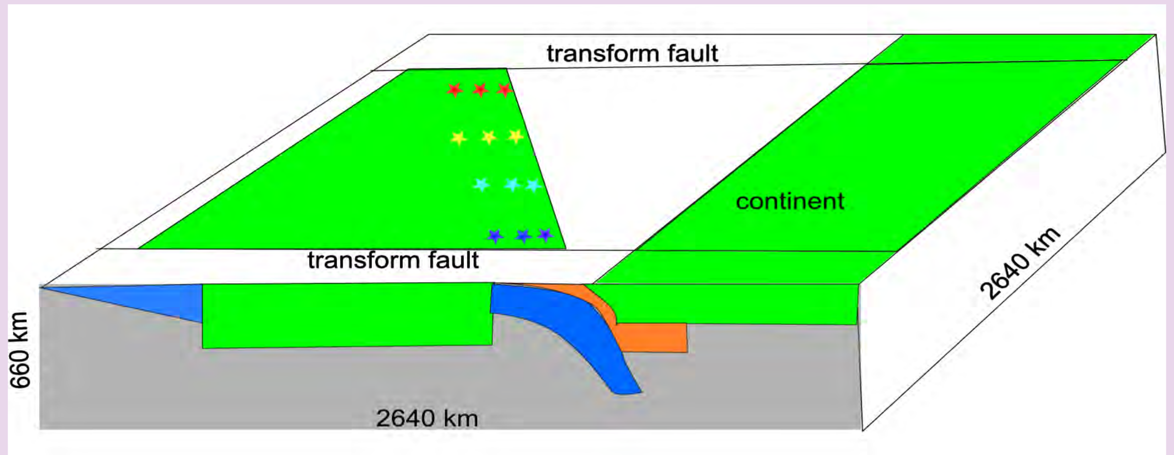
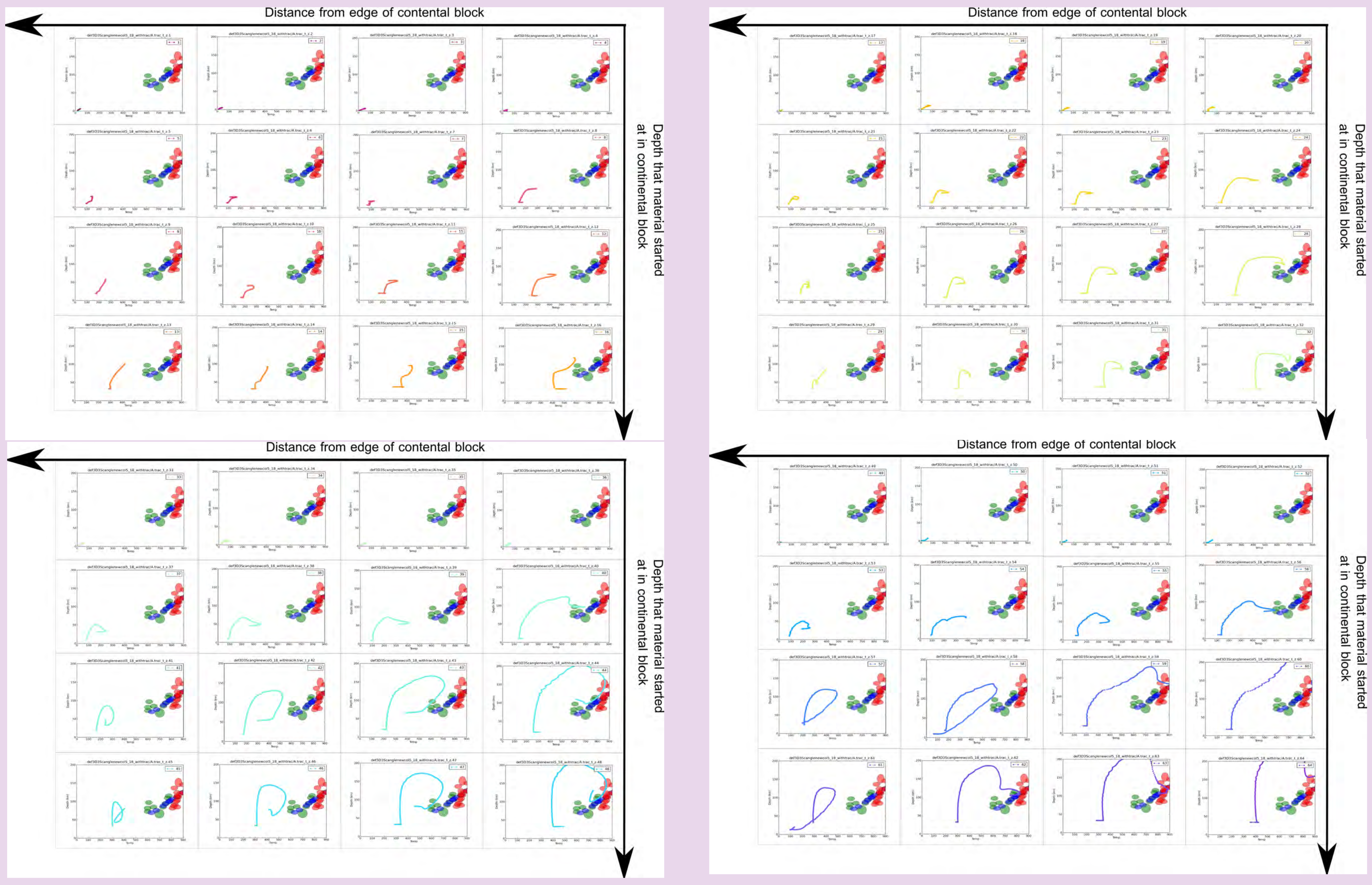
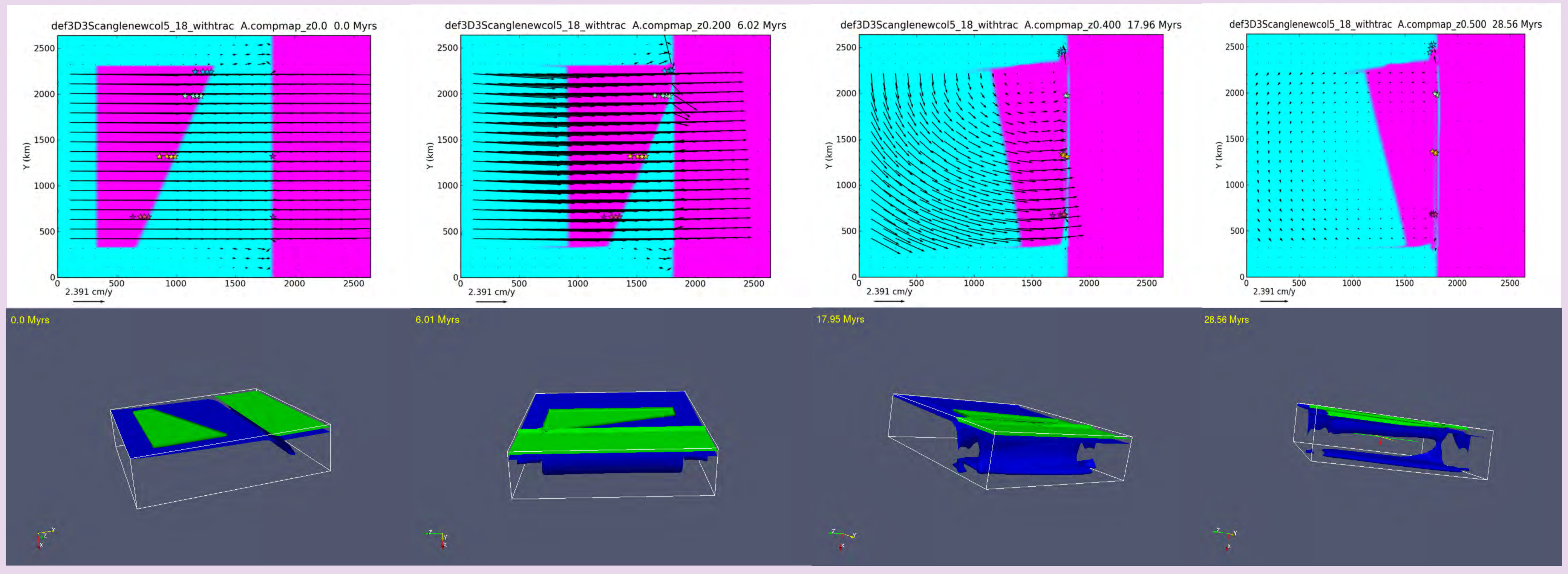


Figure2: A schematic diagram showing the model set up. The stars represent a family of 16 tracers. These families are placed at 660km, 1320km, 1980km and 2244km along the models y axis. Each family of tracers has a tracer at depths of 0km, 10km, 20km and 30km and 0km, 30km, 60km and 120km from the front edge of the continental plate.

Results



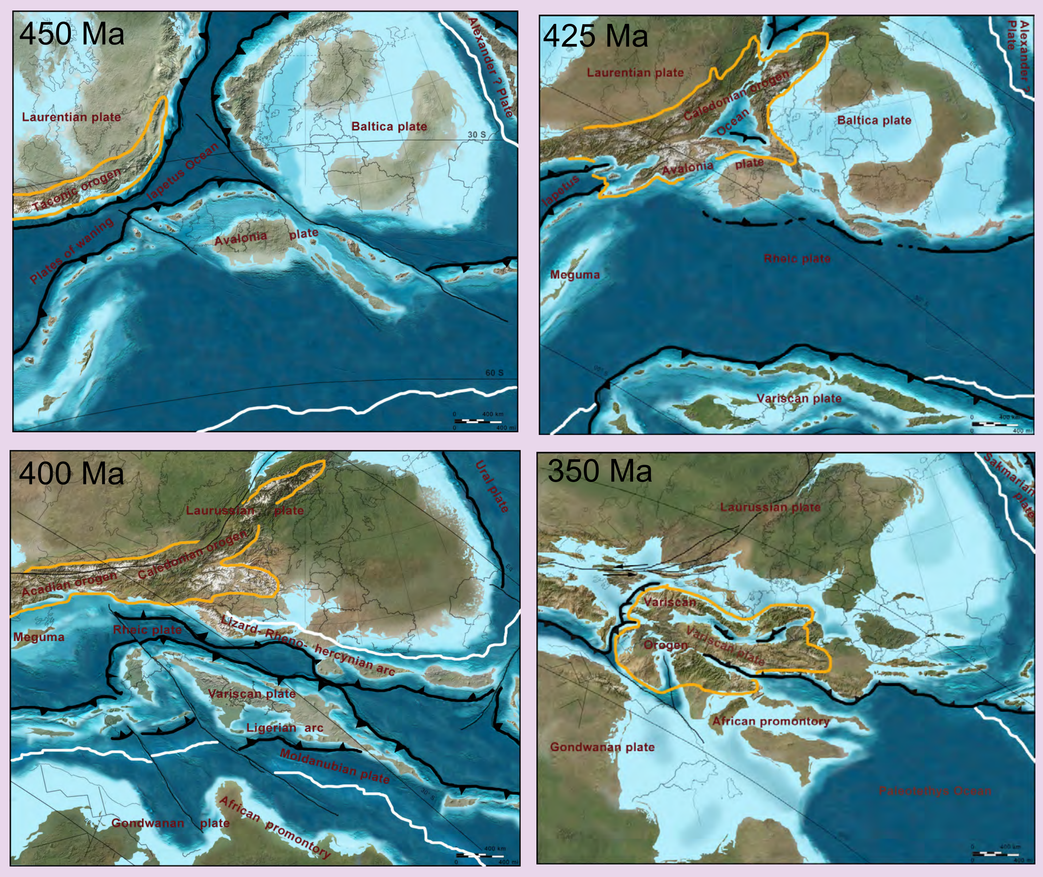
Here we show all the PT paths generated from the 4 families of tracers placed in the overriding plate. The red family of PT paths (top left) are from tracers placed on the last bit of continent to collide. The yellow family of PT paths (top right) are from tracers at the centre of the colliding continental block. Light blue set of PT paths (bottom left) are from tracers placed at 660km laterally from the prow of the continental block. Dark blue PT paths (bottom right) are from tracers placed at the prow of the continental block. The coloured patches Green [5] Red [6] Blue [7] represent different authors estimates for peak PT conditions experienced by the Western Gneiss.



Top plots show the surface velocity field evolution through time represented by vector arrows. The background colour pink representing continental material and blue oceanic. Below the model dynamics evolution are also shown as an iso-temperature surface with continental material highlighted in green. Here it can be seen that the slab tears along the subduction system. This combination of tearing and the asynchronous collision causes a rotation in the subducting plates velocity.

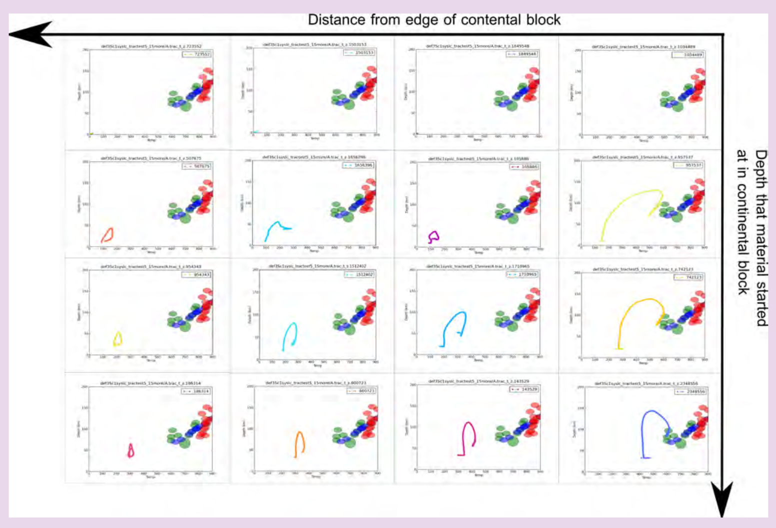
Discussion

The collision between Larentia and Baltica started approximately 425 Ma with the area that is presently south west Norway colliding with present day Greenland. The collision then continued northwards with collision occurring all along the origin by 350 Ma. Estimates for the timing of the exhumation of the Western Gneiss vary from 405 -390 Ma. The collision zone has since broken up due to Atlantic spreading.



Qualitatively our model attempts to simulate the Larentia Baltica collision by having a trapezium shaped colliding continental block. This creates a collision that propagates along the subduction zone.

By comparing the results from our 3D model with those obtained from a 2D model, with the same start-up parameters we see that the 3D model produces more realistic PT paths. However only the set of tracers that are located right at the prow of the continental block show much improved exhumation. The 3D model also seems to improve the peak temperature and pressures reached by returning tracers. This is likely due to continental material being held at depth while subduction is continuing further along the subduction zone.



Other interesting features produced by the model are the prograding towards higher metamorphic grade towards the subduction zone and nappe like structures riding on top of the educting plate. These feature are also seen in the South West of Norway and offer further evidence that the eduction mechanism is responsible for creating the Western Gneiss.

Open questions

Why do we not find large educted UHP / HP terranes at other collision zones?

There are other areas of HP UHP material associated with the Caledonian collision. the largest of these is in Greenland. How does this fit with our proposed assisted exhumation due to plate rotation?

Why do our models (and others) produce colder PT paths than are observed?

How much continental material was subducted during the Larentia Baltica collision and what happened to the material that wasn't returned to the surface?

What influence does the subduction plate interface have on the ability of a collision to produced UHP rocks via eduction?

Conclusions

An asynchronous collision that causes rotation of the subducting plate assists the exhumation of material from depth. This could offer a possible explanation for the existence of the Western Gneiss.

When modelling subduction / collision systems 3D motion may prove important to fully fit results to surface observables.

Acknowledgements

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