## Indentation modelling and exhumation of high grade rock in the Eastern Bohemian Massif: Insight from analogue and numerical modelling

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Recent petrological, structural and geochronological studies of the eastern margin of the Bohemian Massif (Czech Republic) suggest a conceptual geodynamical model to explain exhumation of lower-crustal (20 kbar, 800 degrees) felsic rocks.
The model involves indentation of a weak orogenic lower crust by adjacent rigid mantle lithosphere, resulting in crustal scale buckling of the weak orogenic lower/middle crust interface followed by extrusion of a ductile nappe over the rigid promontory.
The hypothesis has been checked using both analogue and numerical models. Analogue experiments using a three layer sand-silicone setup were carried out in Rennes laboratory (France).
Results show that the most important features of the conceptual model can be reproduced: extrusion of lowermost silicone over the indenter and flow of horizontal viscous channel underneath a rigid lid above the actively progressing promontory.

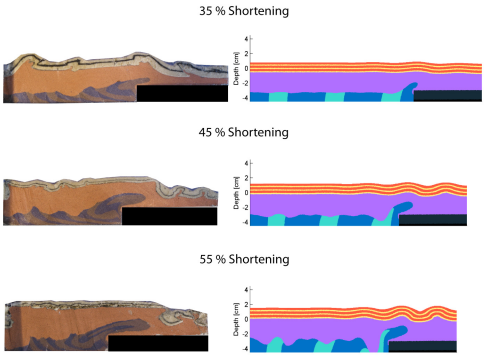


figure 1: Comparison between analogue and numerical models after similar amount of convergence. Progressive development of the nappe related to the expulsion of lower crustal material.

Two sets of sandbox scale numerical simulations were performed. The first set of numerical experiments is designed to study the influence of viscosity stratification within the crust on the extrusion process.
Allowing for a viscosity layering, we show that the larger the viscosity jump, the smaller is the volume of extruded material for the same amount of shortening.
Viscosity contrast larger than 1000 almost inhibits the development of the lower crustal nappe.

A second set of experiments were performed in order to quantify the influence of the viscosity and the geometry of the indentor.
A particularity of the indentation model is the vertical velocity anomaly that can be observed in front of the indenter.
This positive velocity anomaly is responsible for the expulsion of the lower material and is  a function of the geometry and the strength of the indenter.
We ran a systematic parametric study and derived non-dimensional scaling laws that predicts the maximum extrusion rates associated with the indentation mechanism.
Such laws enable to compute vertical extrusion rates that are in good agreement with natural exhumation rates inferred from petrological data of Eastern Bohemian Massif.

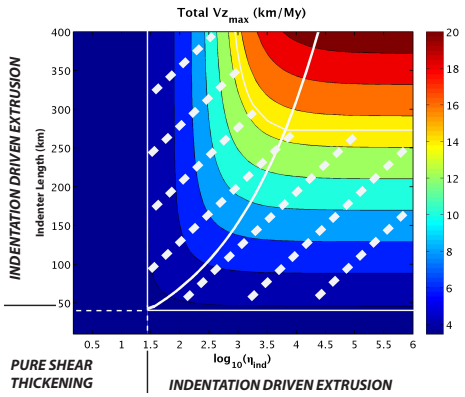


figure 2: Dimensional map of extrusion rates related to the indentation of a variable viscosity indenter into a weak crust.  Extrusion rates are function of the indenter geometry (thickness) and viscosity.