The influence of the rotation of Adria and extension in the Pannonian Basin on lateral extrusion in the Alps:

insights from crustal-scale analogue models

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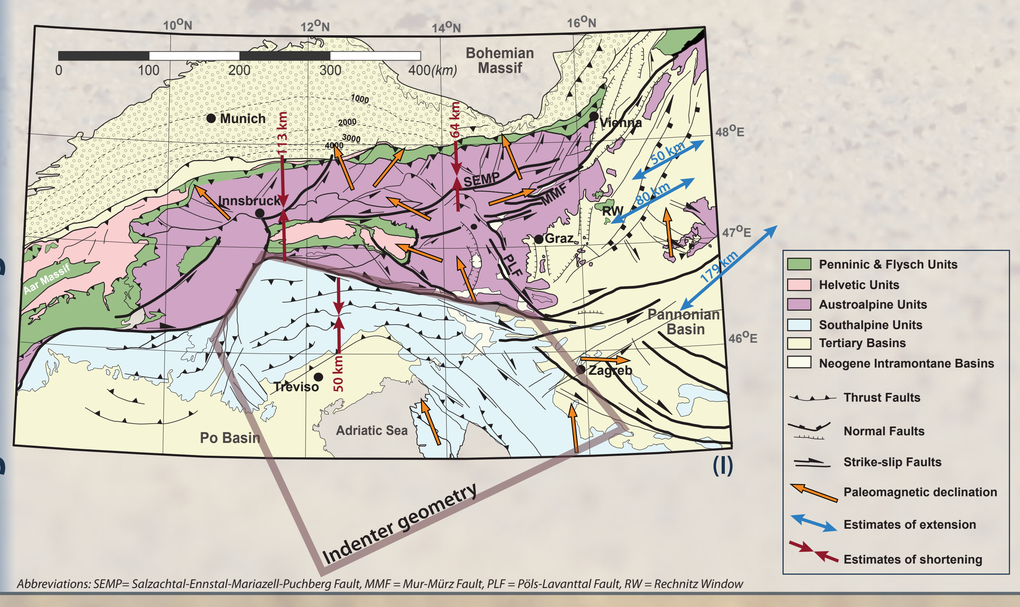
Introduction The implications of 20° counterclockwise rotation of Adria during Miocene times on the tectonic evolution of the Eastern Alps are unresolved, as is the effect of slab-pull driven extension on lateral extrusion in the Eastern Alps. We have used analogue crustal scale modelling to study these interactions. The models invoke a northward indentation, 20° ccw rotation and an extensional eastern boundary; simulating the Alps-Adria convergence and perpendicular slab-pull driven extension, respectively.

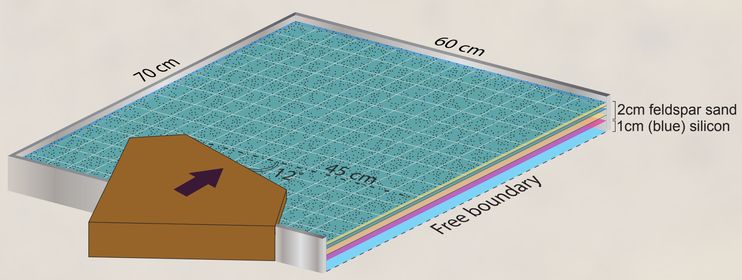
Methodology The analogue models had a brittle-ductile rheology (see model set-up) representing the brittle and ductile crust, respectively. The models are scaled to nature and modelling parameters such as amount of shortening, extension, rotation and indenter geometry are derived from literature and map (See figure I). Parameters that are varied are the amount, timing and direction of extension, the width of the deformable area aswell as a 20° counterclockwise rotation of the indenter. Top-view images of the models have been analysed with digital particle tracing techniques (DPIV) using the MatPIV software (Sveen, 2004) for Matlab®. DPIV analysis created surface vector fields and strain localizations images of the incremental deformation over a specific time interval (Δt=3 min). The DPIV data has also been used to deduce the stress regimes.

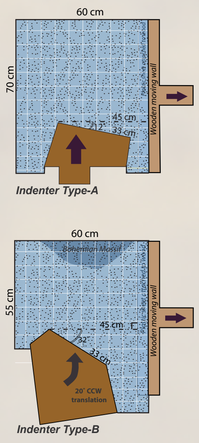
Geological setting



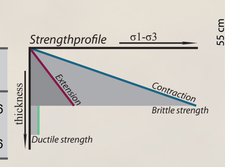
Abbreviations: SEMP= Salzachtal-Ennstal-Mariazell-Puchberg Fault, MMF = Mur-Mürz Fault, PLF = Pöls-Lavanttal Fault, RW = Rechnitz Window

Model set-up



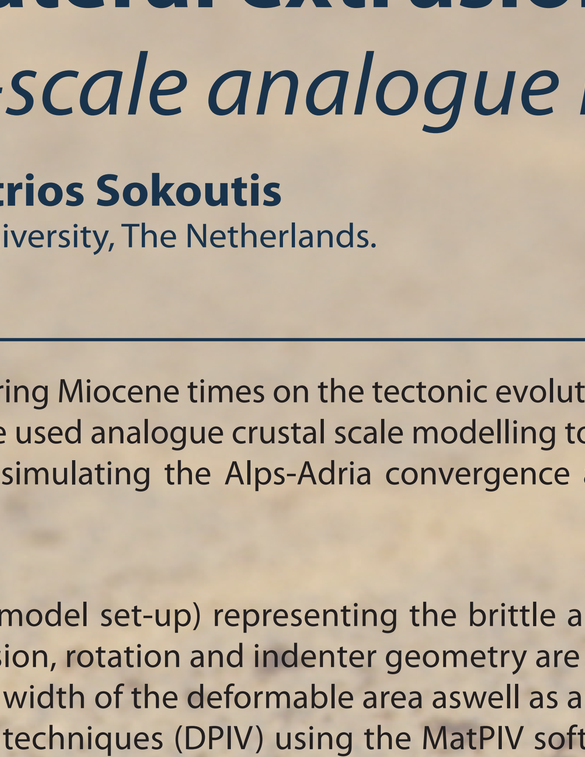


Layer	Analogue material	Density ρ (kg/m3)	Friction C μ	Viscosity η (Pa.s)	Power n	Thickness (m)	Velocity (m/s)
Upper crust	Feldspar sand	1300	0,7	-	-	0,02	5,56*10^-6
Lower crust	Silicon mix	1367	-	3,8*10^4	1,2034	0,01	5,56*10^-6

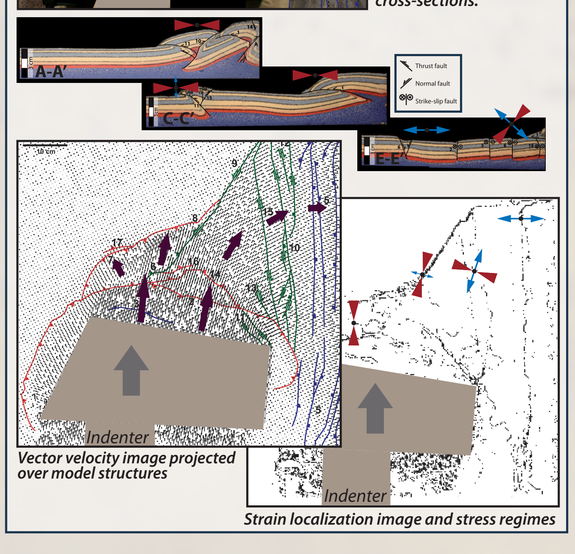


Modelling results

Model 1: Extension at 2 cm/hr



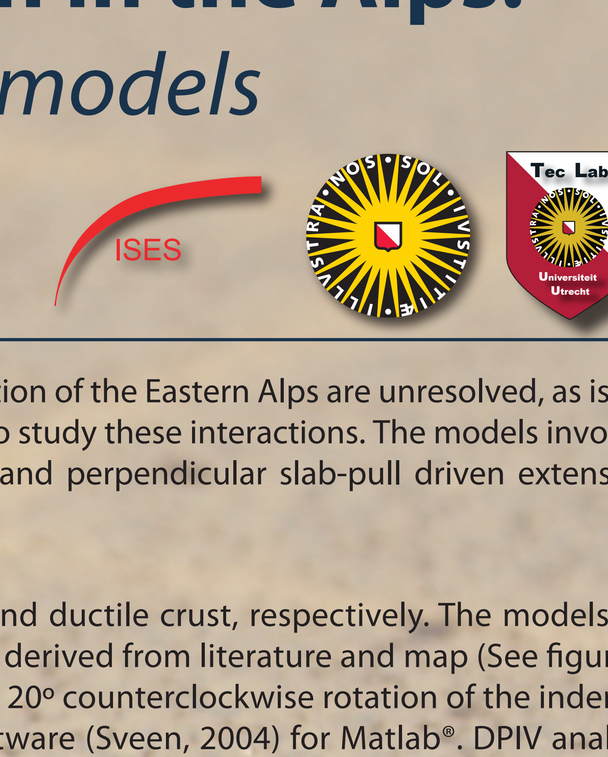
All models are interpreted using topview images and cross-sections.



Vector velocity image projected over model structures

Strain localization image and stress regimes

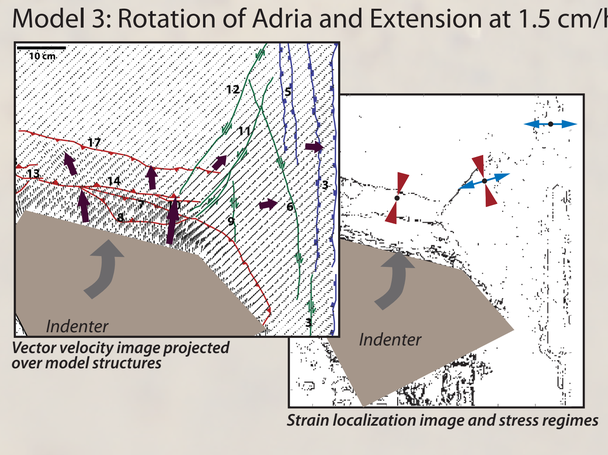
Model 2: Unconfined boundary



Vector velocity image projected over model structures

Strain localization image and stress regimes

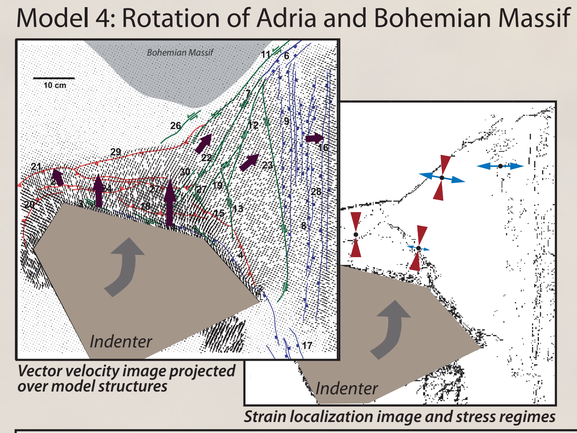
Model 3: Rotation of Adria and Extension at 1.5 cm/hr



Vector velocity image projected over model structures

Strain localization image and stress regimes

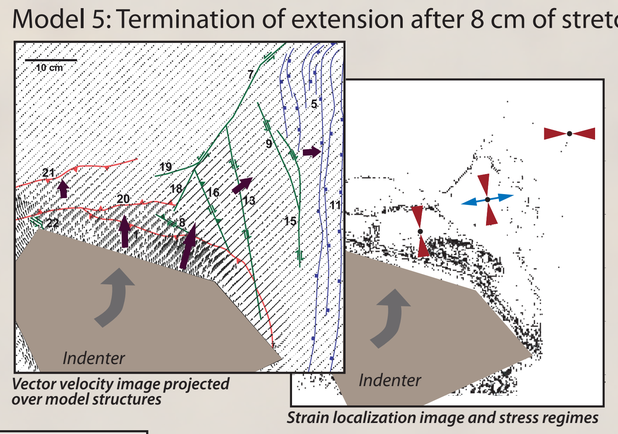
Model 4: Rotation of Adria and Bohemian Massif



Vector velocity image projected over model structures

Strain localization image and stress regimes

Model 5: Termination of extension after 8 cm of stretch

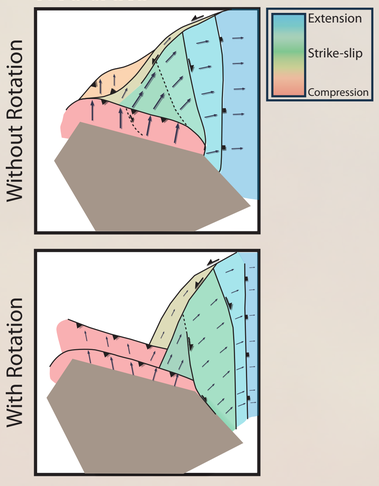


Vector velocity image projected over model structures

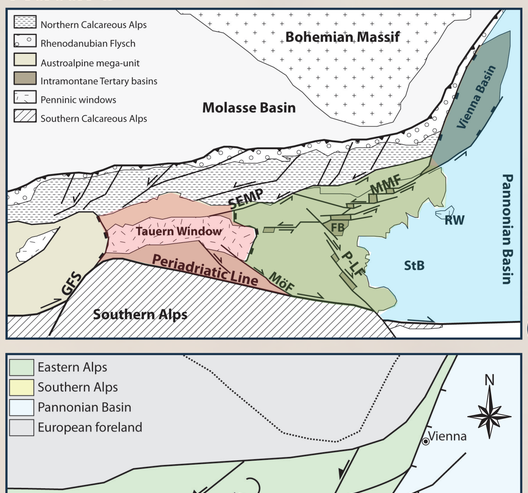
Strain localization image and stress regimes

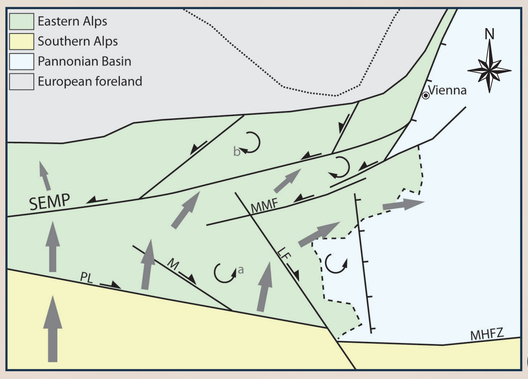
compressional regime | transpressive regime | strike-slip regime | transtensive regime | tensional regime | representative vectors

Models

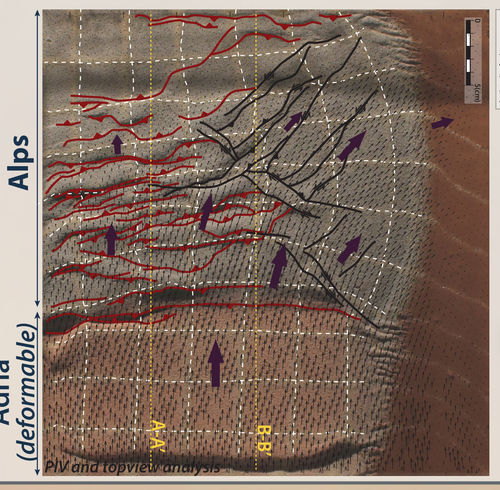


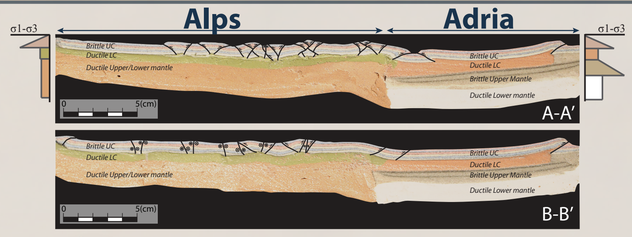
Nature

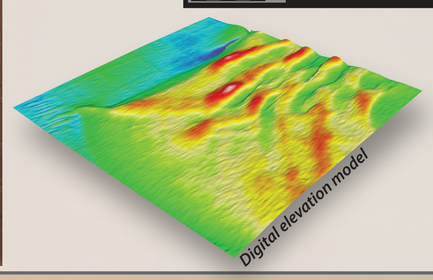




Outlook







Prospect:
Lithospheric-scale models, with a 4-layered system, subduction and deformable Adria.

Aim:
Deduce the effects of subduction and rotation of Adria along with eastward extension on the Alpine lithosphere

Summary

- Induced extension, oriented perpendiculair to indentation:
  - caused an increase of activated strike-slip faults (M1 versus M2).
  - leads to enhanced propagation of the extruding domain towards the west. Thus, the transition from a stike-slip dominated regime to a compressional regime shifts westwards (M1 versus M2).
- Including a CCW rotation of Adria decreased the area that accomodates extrusion and hampered the formation of strike-slip faults (M3 versus M2).
- A decrease in the width of the deformable area (M4) fosters conjugate strike-slip faulting, also when a ccw rotation of the indenter is applied.

Conclusions

Interaction between lateral extrusion and slab-pull driven extension leads to an increase of crustal 'en-bloc' rotations and the formation of a large extruding wedge due to a westward shift of the strike-slip and extensional domain.
CCW rotation of the indenter favors deformation by thrusting over strike-slip faulting in front of the indenter and leads to the development of relativly small extruding wedges.
In agreement with recent GPS data, we infer that lateral extrusion continues after the cessation of extension (M5), suggesting that this process is dominantly driven by the push of the indenter.

References Sveen (2004), An Introduction to MatPIV v. 1.6.1. Mechanics and Applies Mathematics, vol. 2, Department of Mathematics, University of Oslo; **(Geological setting) I -** Modifed after Willingshofer and Cloetingh (2003), Present day lithospheric strength of the Eastern Alps and its relationship to neotectonics. Tectonics, vol 22, no. 6. **() . (Summary) II -** Modified after Pischinger et al. (2008), Fault slip analysis in the Koralm Massif (Eastern Alps) and the consequences for the final uplift of 'cold spots' in Miocene times. Swiss Journal of Geoscience, vol. 101(1), pg. 235-254. **III -** Paleomagnetic rotations **a)** Marton et al. (2000), Miocene rotations in the Eastern Alps- paleomagnetic results from intramontane basin sediments. Tectonophysics, vol. 323, pg. 211-223 and **b)** Thöny et al. (2006), Paleomagnetic evidence for large en-bloc rotations in the Eastern Alps during Neogene orogeny. Tectonophysics, vol. 414, pg 169-189.

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