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Searching deeper

The link between upper plate deformation and variations in plate geometry and or rheology

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Introduction

In classical analogue and numerical models, shortening during continental collision is accommodated by a series of thrust faults on the pro-wedge side and a single shear zone/ backthrust on the retro-wedge side. However natural examples of collision type orogens often contain retro-vergent fold and thrust belts. Most compressional analogue studies on crustal scale either investigate pro-wedge deformation via single vergent wedges or make use of a rigid indentor . Studies that do invesitgate double vergent orogens are mostly on lithospheric scale. The aim of this study is to infer favorable rheological conditions leading to the formation of retro-foreland fold and thrust belts on the upper plate. In this study key variables are the rheological stratification of the colliding plates and the geometry of the subducting plate.

Modelling results

Reference models

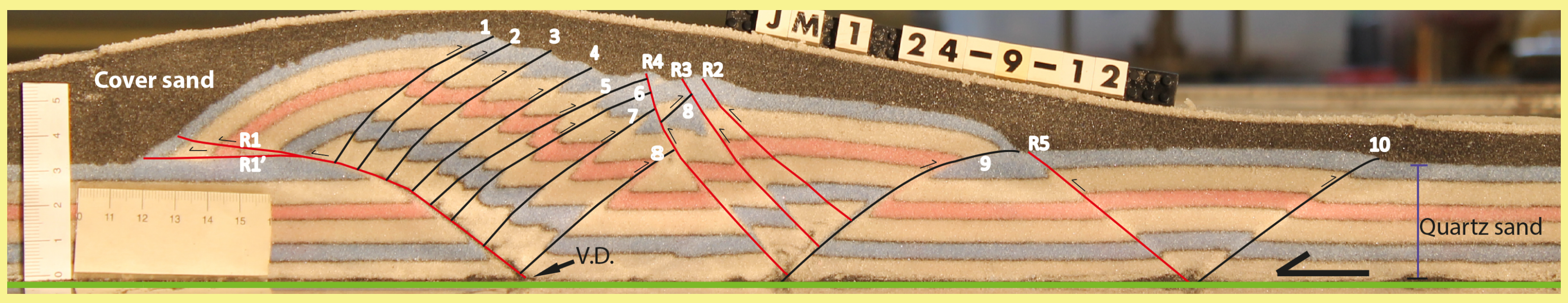


Figure 1: Reference model 1 - Brittle plates.

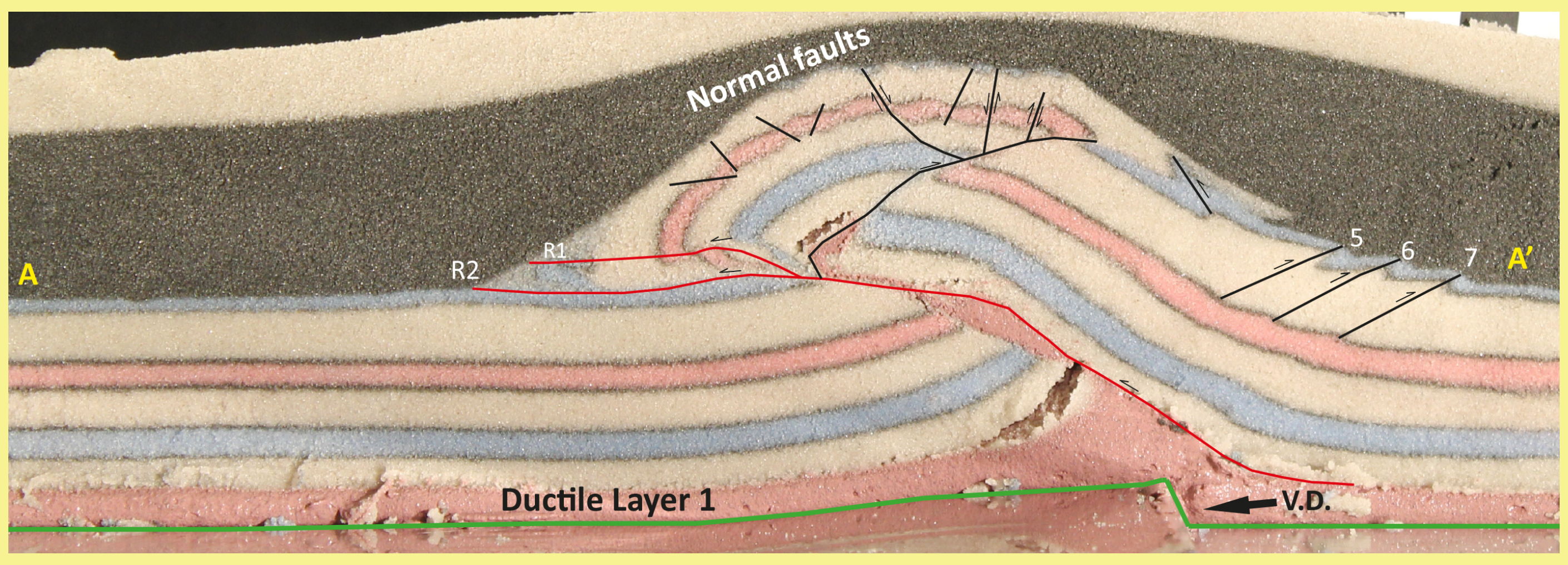


Figure 2: Reference model 2 - Brittle - Ductile plates.

Models containg variations in geometry and or rheology

These models contain heterogeneities in the upper plate.
See table 1 for initial model stratigraphy details

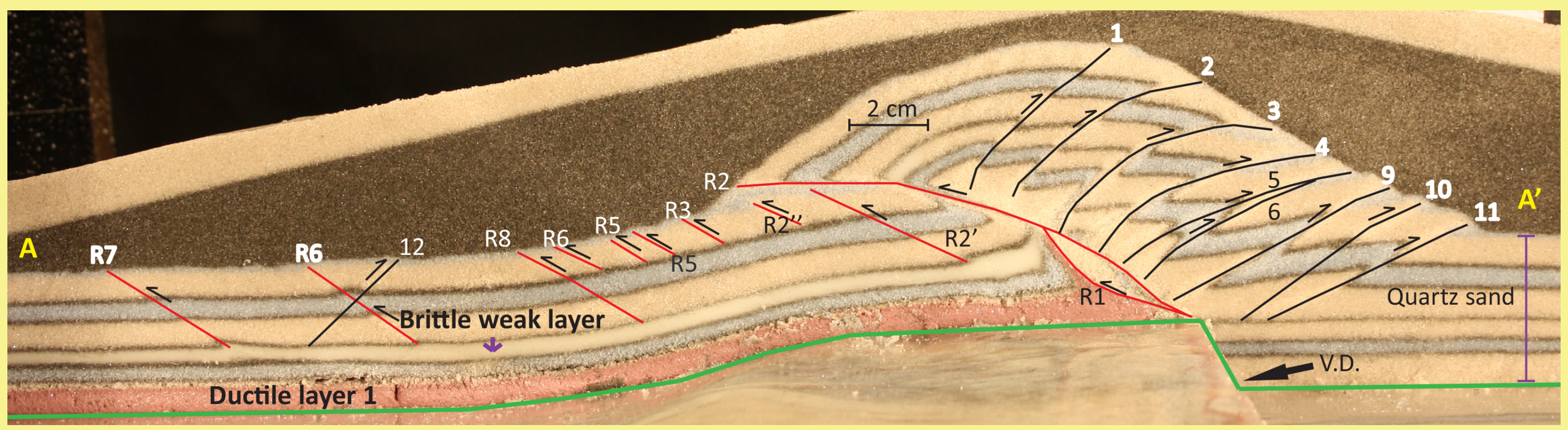


Figure 3: Model 3 - Brittle lower plate, Brittle - Ductile upper plate containing Brittle weak layer.

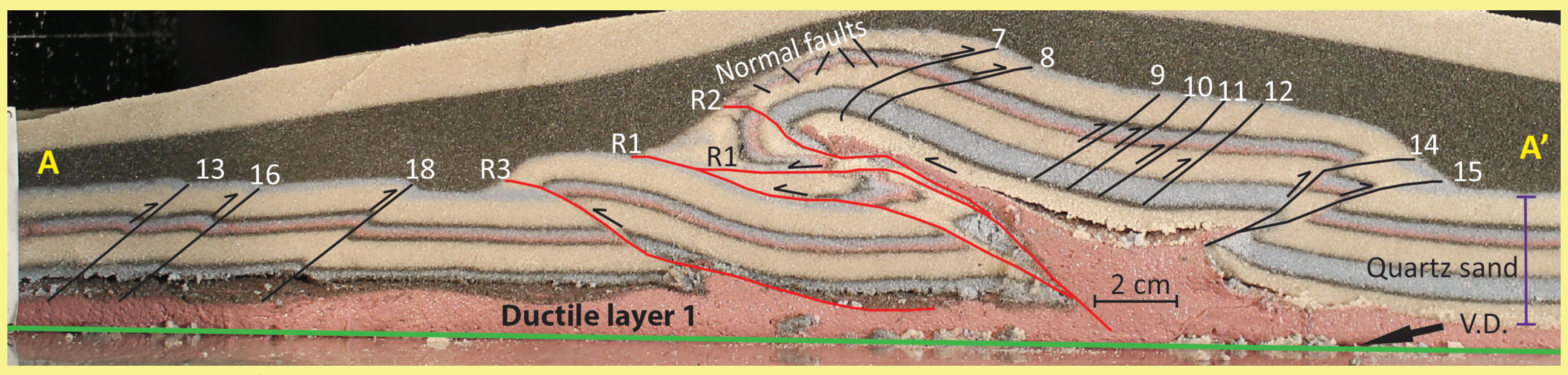


Figure 4: Model 4 - Brittle - Ductile lower plate, Brittle - Ductile upper plate. Weak layer in upper plate twice as thick.

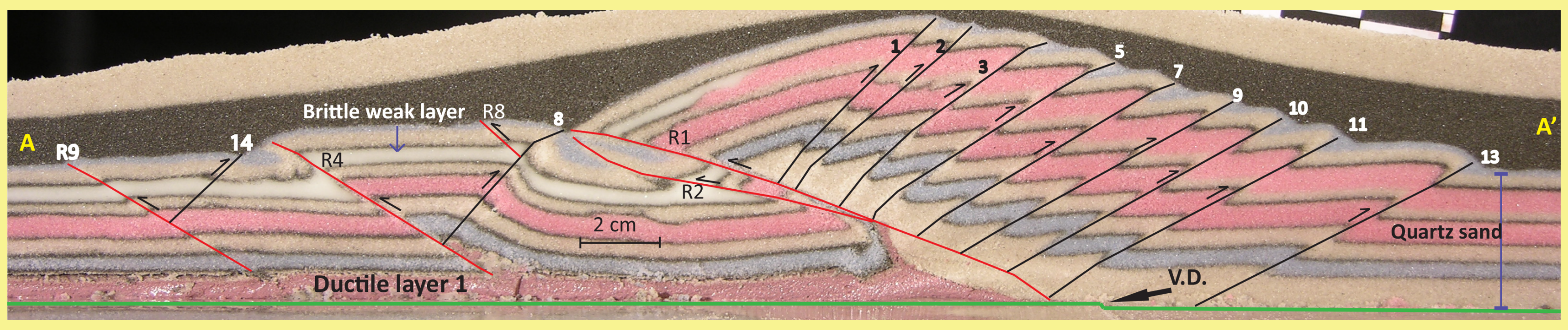


Figure 5: Model 4 - Brittle lower plate, Brittle - Ductile upper plate containing Brittle weak layer.

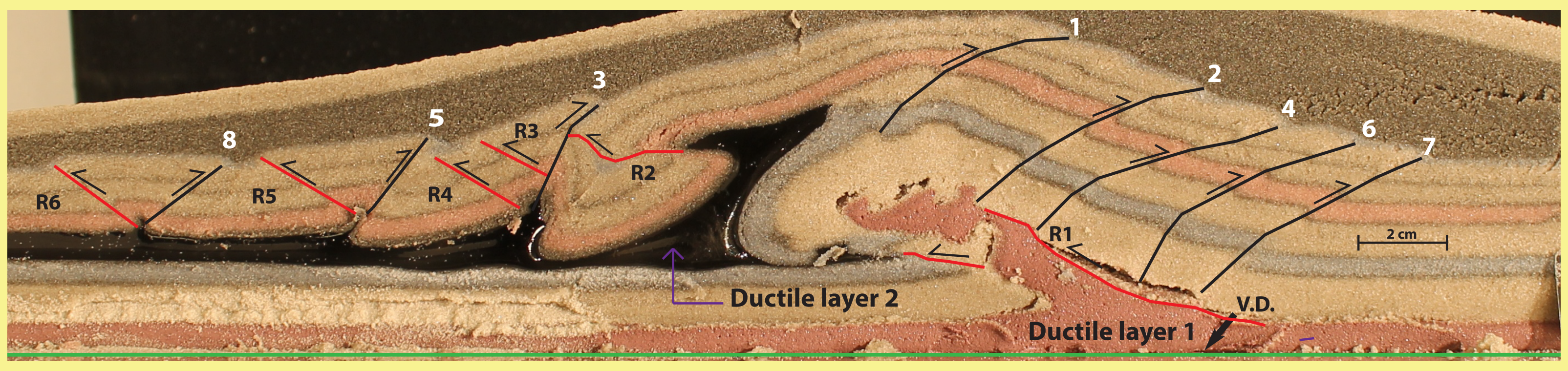


Figure 6: Model 6 - Brittle - Ductile lower plate, Brittle - Ductile upper plate containing second Ductile weak layer.

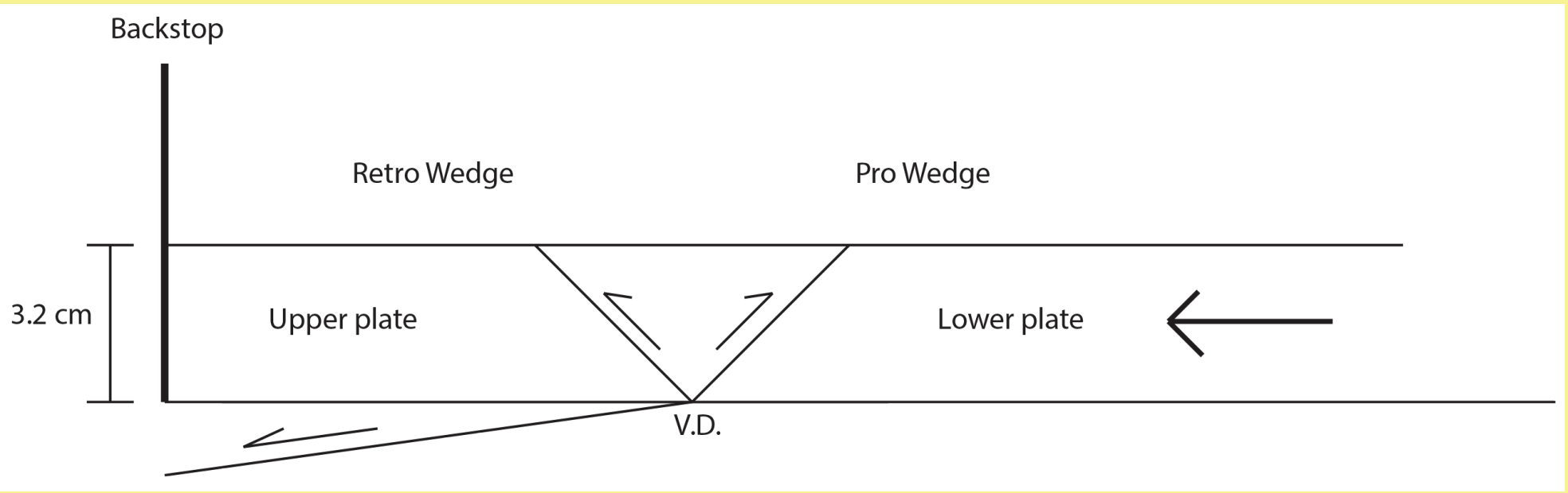
Model setup

Experimental velocity: 10 cm/h

Scaling ratio h*: 10^{-5} 1 cm = 1 km

Model	Upper plate rheology	Lower plate rheology
1	Qtz sand	Qtz sand
2	Duct. base layer 1+ Qtz sand	Duct. base layer 1+ Qtz sand
3	Duct. base layer 1 + frictional weak layer + Qtz sand	Qtz sand
4	Duct. base layer 1(*2x thickness*) + Qtz sand	Duct. base layer 1 + Qtz sand
5	Duct. base layer 1 + frictional weak layer + Qtz sand	Qtz sand
6	Duct. base layer 1 + duct. layer 2 + Qtz sand	Duct. base layer 1 + Qtz sand

Table 1: Overview of initial model stratigraphy.



Schematic overview of initial modelling setup.

Material	Density (g/cm^3)	Viscosity (Pas)
Qtz sand	1,5	-
Glass beads	1,4	-
Ductile layer 1	1,558	$1{,}01*10^4$
Ductile layer 2	1,0	10^4

Table 2: Overview of mechanical properties of used materials.

Comparison to natural examples

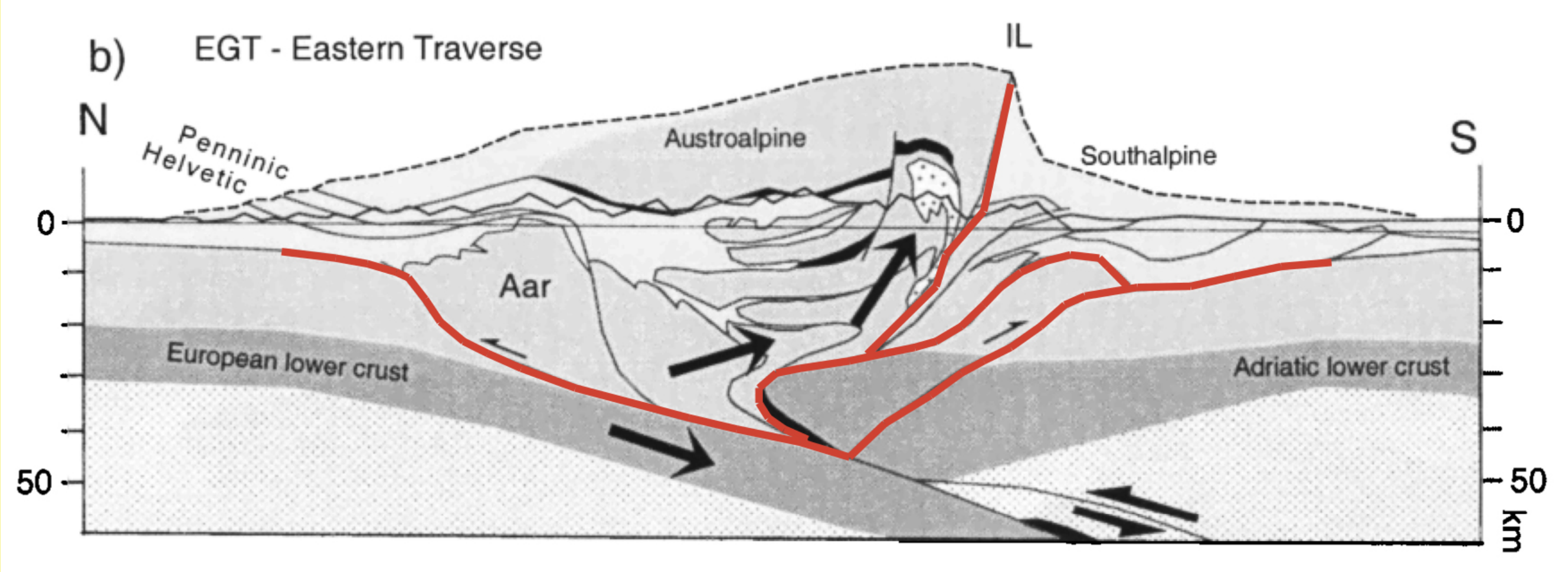


Figure 7: Cross-section through the Central Alps (modified from: Pfiffner *et al.*, 2000).

The Southern Alps are characterised by post collisional retro-vergent thrusting (Castellarin et al., 2006). It also contains a decollement at the interface between basement and the sediment cover. Comparing the structural style of the Central Alps with model 2 (figure 4) gives a good first order fit.

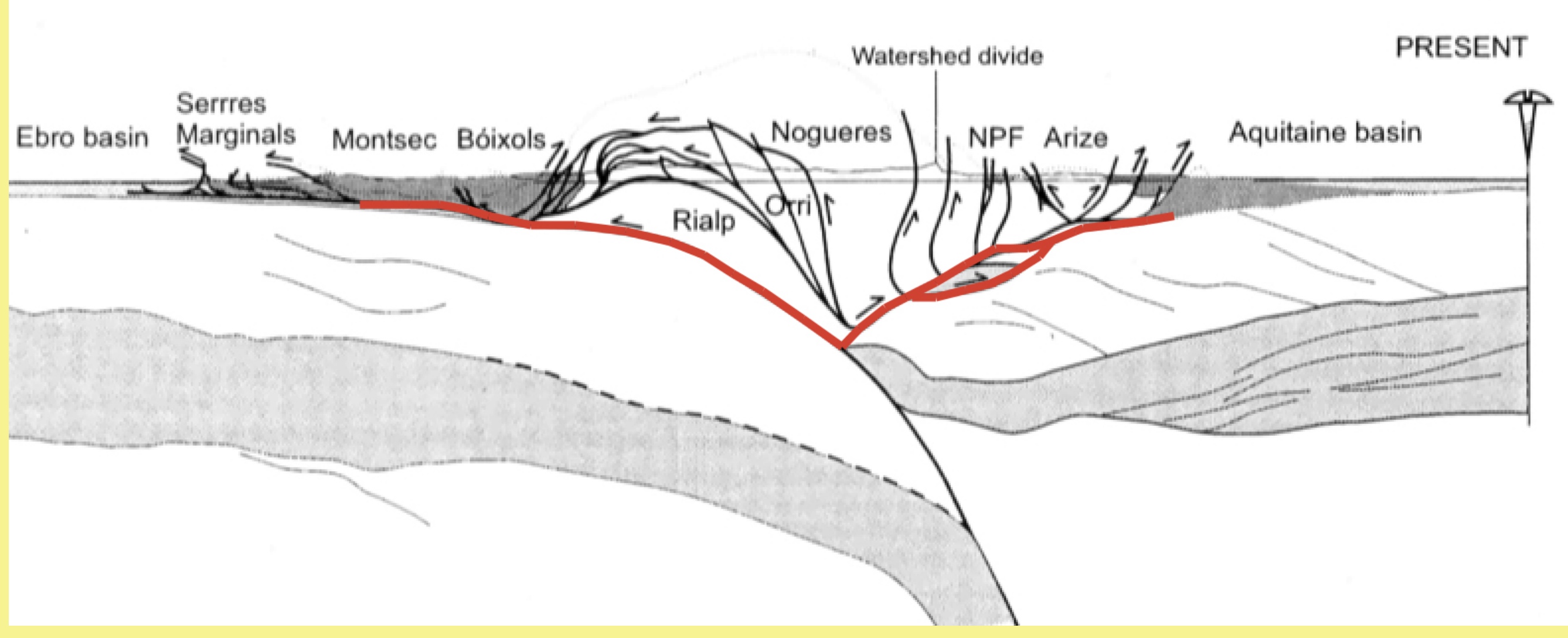


Figure 8: Cross-section through the central Pyrenees (modified from: Beaumont *et al.* 2000).

Beaumont et al. (2000) showed that the tectonic style of the central Pyrenees can be attributed to weak crustal inhomogeneities inherited from earlier phases of deformation and that structural inversion is complicated by the interaction between the midcrustal decollment and the weak Triassic layers. This suggests that, like in the Alps, a weak detachment layer in the crust of the upper plate is controlling the formation of retroward fold an thrust belts. This is in accordance with our models. results.

Timing of deformation

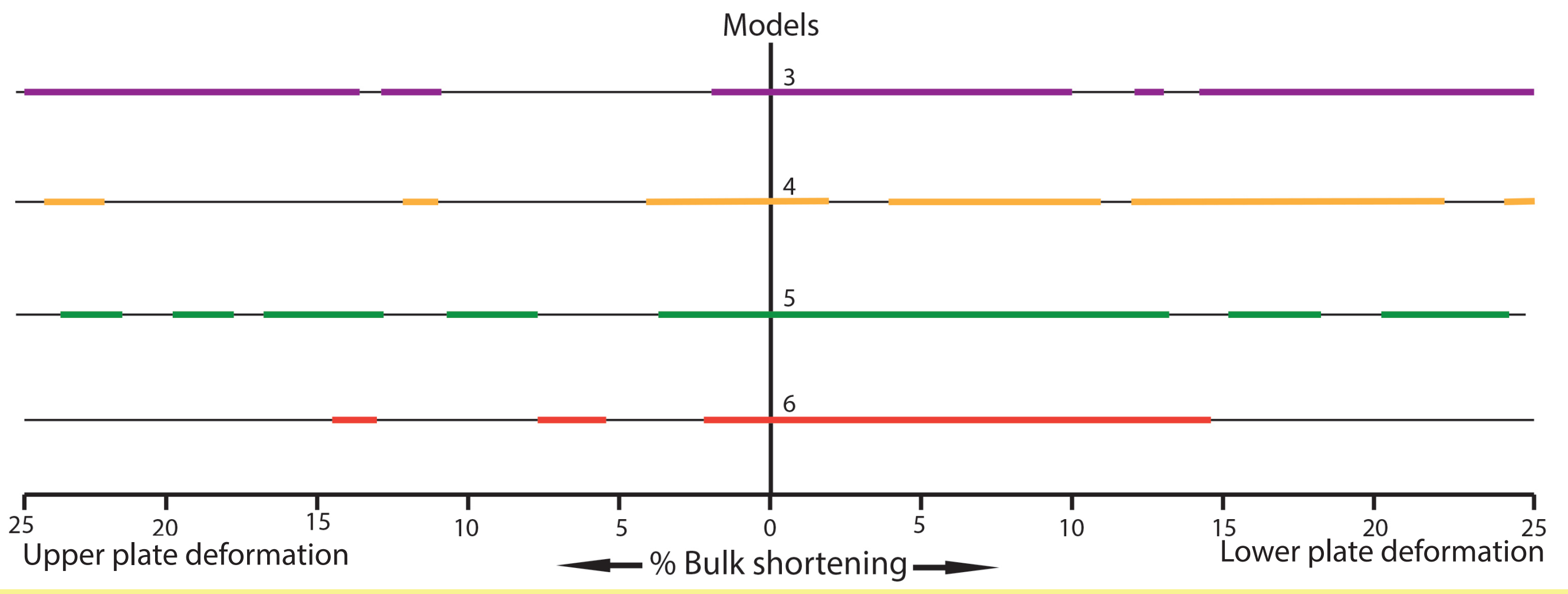


Figure 9: Spatial migration of the active deformation front of the models.

Conclusions

Analogue models have been used to investigate the role of rheological and geometrical variations in the upper and lower plate on retro-wedge deformation. The results lead to the conclusion that in order to produce upper plate deformation and retro-wedge formation, a ductile/ weak decollement has to be present in the upper plate. Observations of the spatial migration of the deformation front of the models (figure 9) indicate that upper plate deformation and retro-wedge formation takes place after 5-10% of bulk shortening. Comparing the structural style of the analogue models with that of natural examples, such as the Alps and the Pyrenees, a good first order fit is observed, particularly with model 4 (figure 4).

References

Beaumont, C., Muoz, J.A., H., and J., Fullsack, P. (2000). Factors controlling the alpine evolution of the central yrenees inferred from a comparison of observationsand geodynamical models. *Journal of Geophysical Research*, 105:8121–8145.
Castellarin, A., Nicolich, R., Fantoni, R., Cantelli, L., Sella, M., and Selli, L. (2006). Structure of the lithosphere beneath the eastern alps (southern sector of the transalp transect). *Tectonophysics,* 414(1-4):259–282.
Pfiffner, O., Ellis, S., and Beaumont, C. (2000). Collision tectonics in the swiss alps: insight from geodynamic modeling. *Tectonics*, 19(6):1065–1094.