The role of lateral rheological lithospheric heterogeneities during intra-plate convergence

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Introduction

Lithospheric-scale analogue models were used to investigate the deformation pattern and topography development characterizing mountain building in intra-plate settings as a function of the presence of lateral rheological heterogeneities.
The presented series of models is the first part of a broader project that aims at the understanding of the interference pattern of short and long wavelength deformation as a function of the location and reactivation of pre-existing heterogeneities within the lithosphere (crust versus mantle) upon shortening and its bearing on dynamically supported topography.

Three layer (brittle crust/ductile crust/weak ductile mantle) models characterized by the presence of a “disturbance zone” (DZ) located either in the ductile mantle or in both ductile crust and mantle and striking perpendicular to the compression direction were deformed under normal gravity conditions.

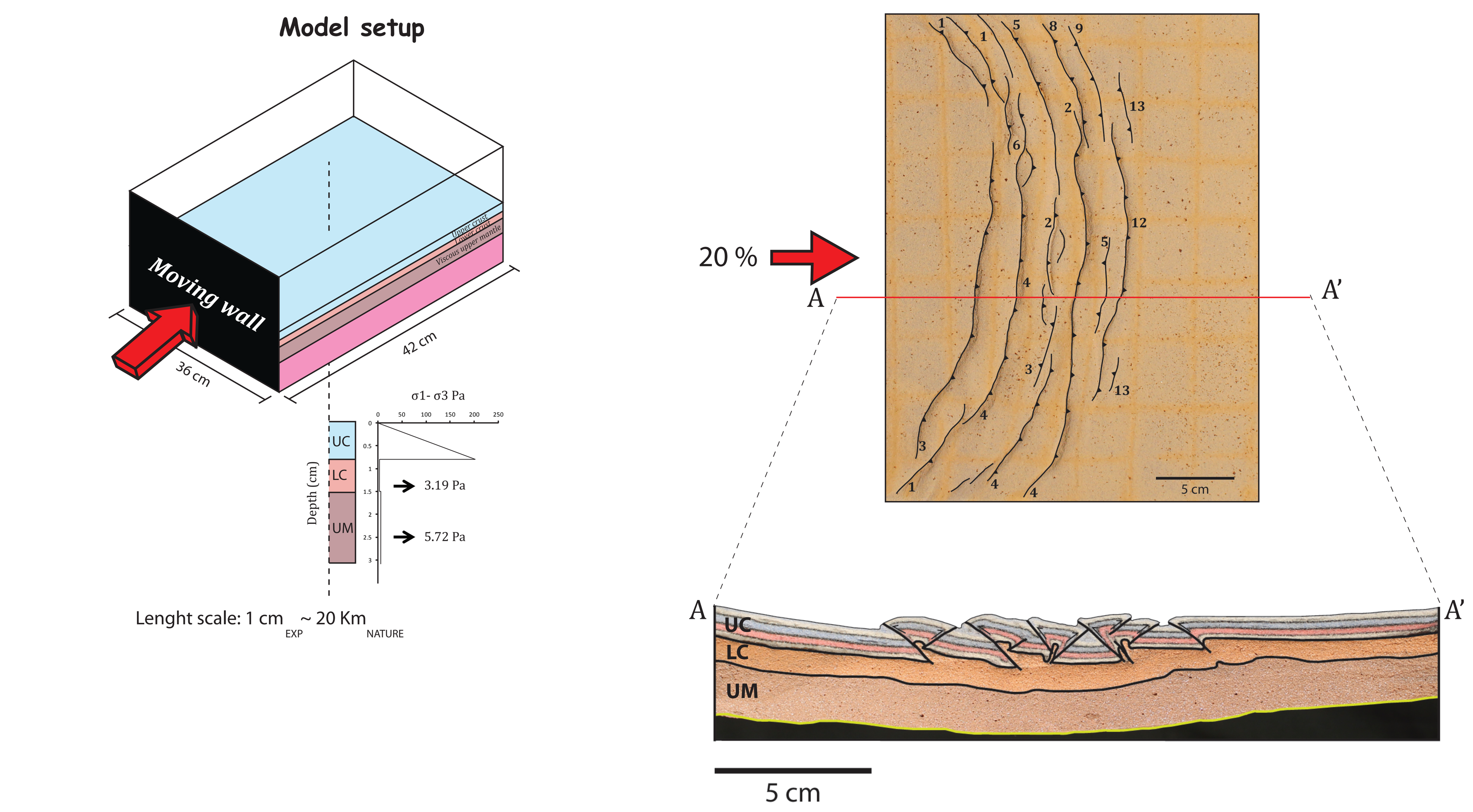
The modeled lithosphere is characterized by a relatively weak ductile crust and mantle and strong decoupling between the brittle and ductile domains.

Presence and location of the DZ and relative lateral strength contrasts within the lithosphere have been the main investigated parameters.

Results

Compression of a laterally uniform 3-layers weak lithosphere

Model 1

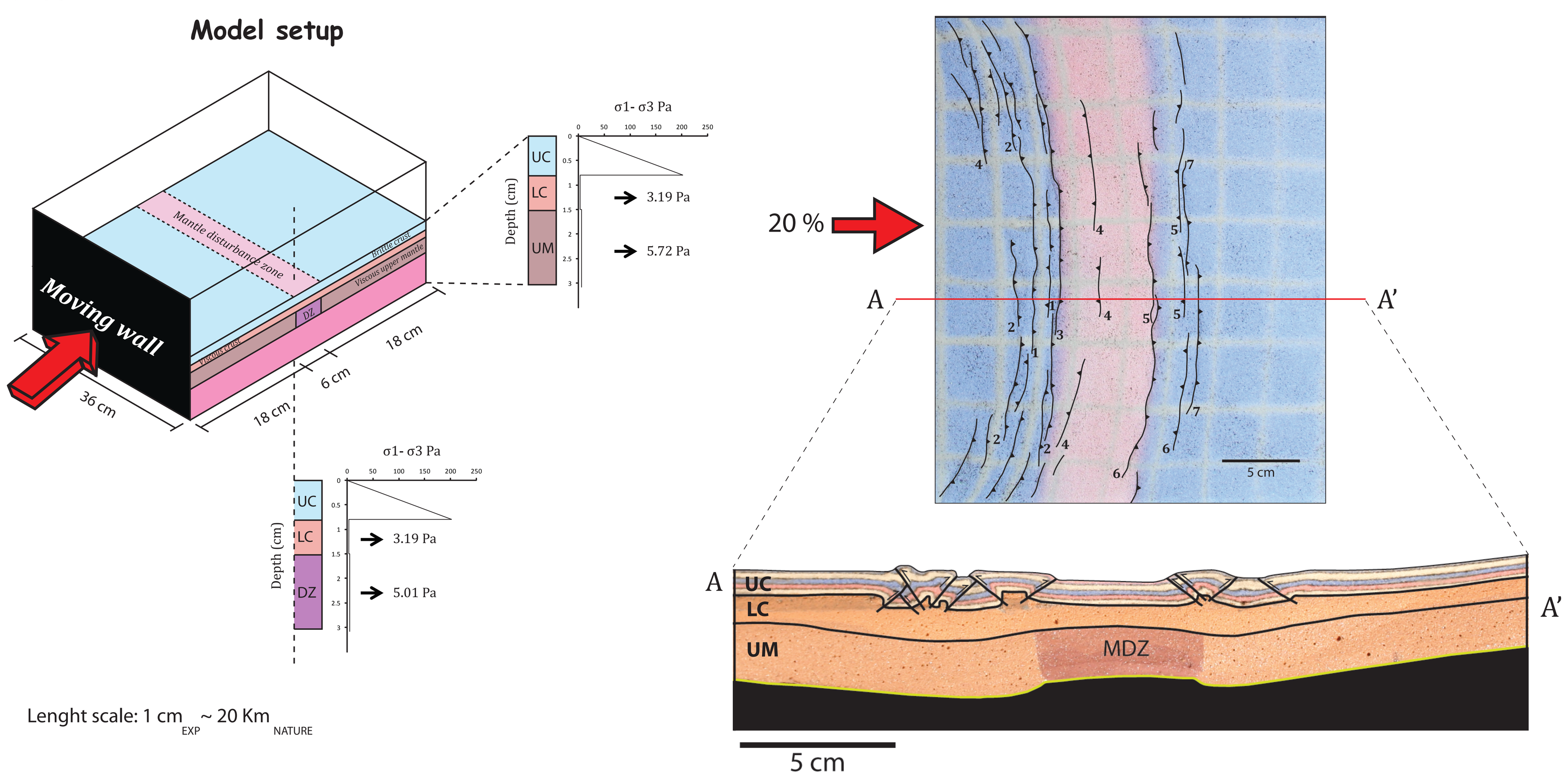


In the absence of a DZ the deformation history of a relatively weak lithosphere is characterized by early occurrence of pop-up and pop-down structures in the central part of the model. There deformation remains localized, in correspondence of a broad synform developed in the ductile part of the lithosphere. Deformation propagates from the moving wall towards the backwall.

Compression of a laterally heterogeneous 3-layers weak lithosphere

Disturbance zone in the upper mantle

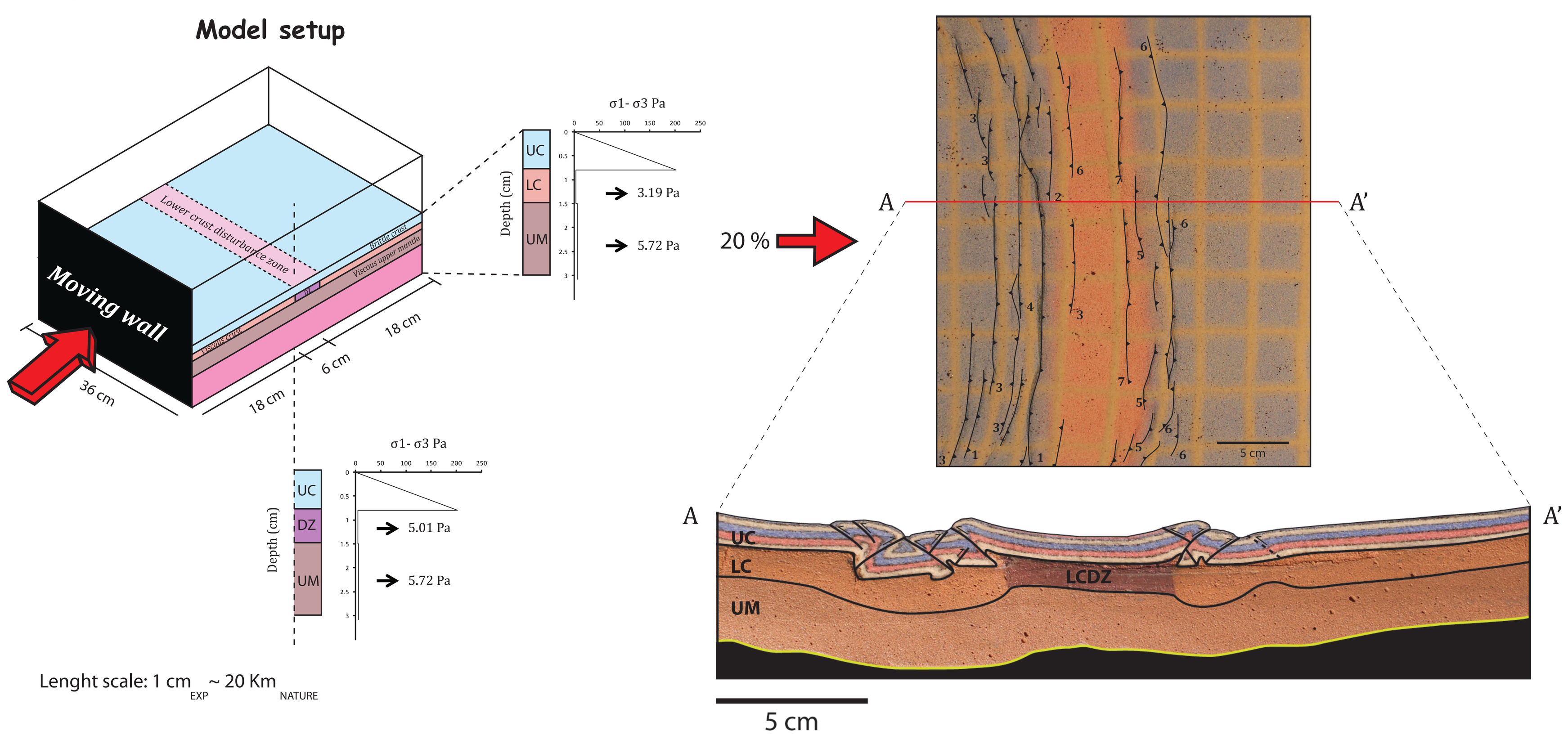
Model 2



The presence of a DZ located in the ductile mantle and characterized by a small strength contrast with respect to the surrounding lithospheric blocks localizes the deformation at its boundaries. Deformation starts close to the DZ inner boundary and propagates forward (away from the moving wall), leaving an undeformed region underlined by a relatively flat Moho above the DZ. Distribution of pop-up and pop-down structures in the brittle crust appears to correlate with the position of synforms in the ductile lithosphere.

Disturbance zone in the lower crust

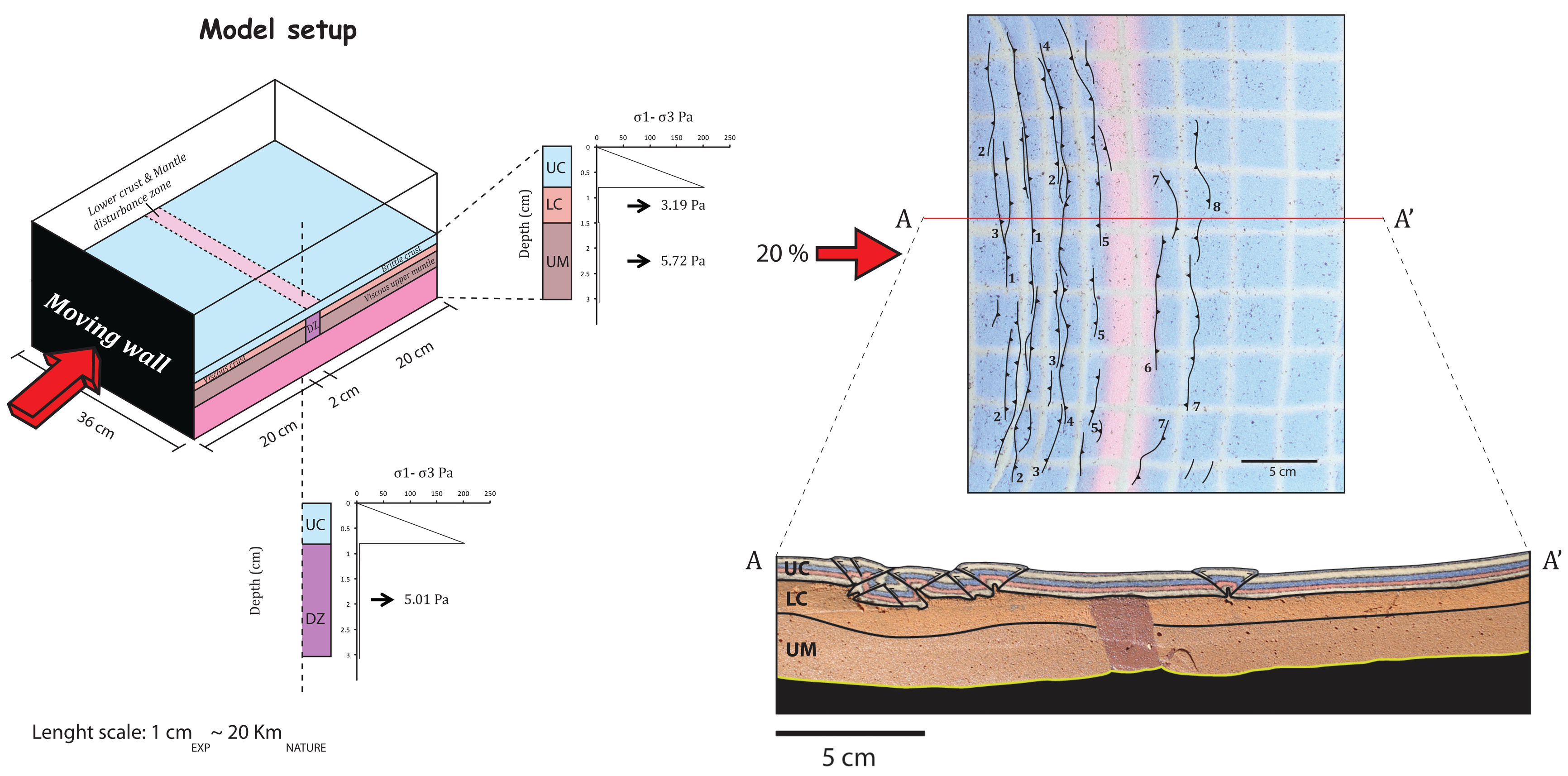
Model 3



Deformation pattern similar to Model2 and characterized by localisation at DZ boundaries is present when the DZ is located in the lower crust. Propagation of deformation still proceeds from the inner boundary (moving wall side) towards the outer boundary. Two main thrusts nucleating from the DZ boundaries enclose a gentle downwarped undeformed region. Pop-ups and -down are localized in correspondence of synforms developed in the ductile part of the lithosphere, which amplitude is greater with respect to a ductile mantle located DZ.

Disturbance zone in the lower crust & upper mantle

Model 4

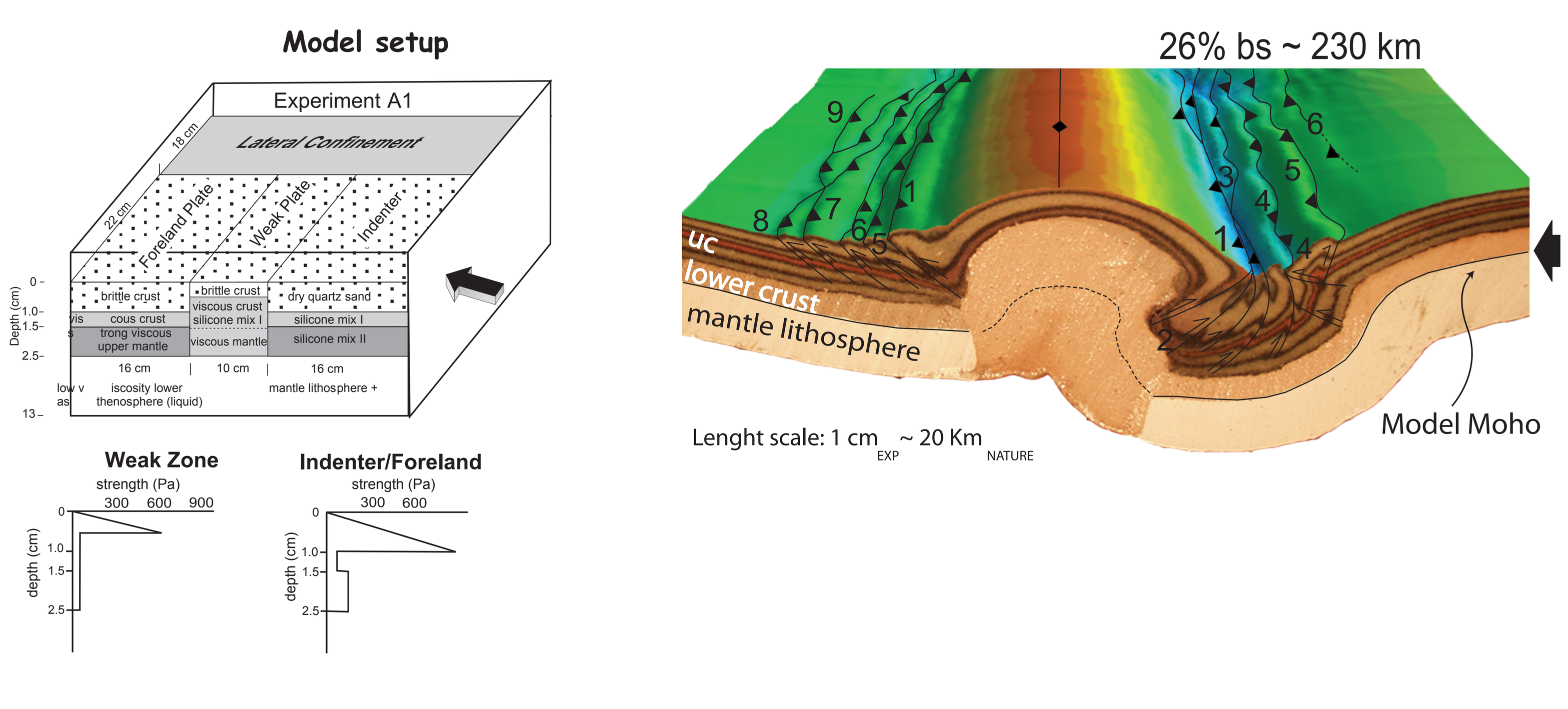


When the upper boundary of the DZ is located at the brittle-ductile transition a broad undeformed region is still present in the central part of the model. As a main difference with Model 2 and Model 3 upper crustal structures that enclose this flat region are not directly aligned with the DZ boundaries. Deformation propagates from the moving wall toward the back wall, and a complex pattern of pushed-down basins, localized in correspondence of a broad synform developed in the ductile part of the lithosphere, is present in the inner block.

Comparison with previous models

Strong lateral strength contrasts

Experiment A1



Previously conducted models analyzed the deformation pattern resulting from a stronger strength contrast between converging plates and an intervening weak zone. The setup was designed to simulate a weakened orogenic wedge bordered by undeformed continental lithospheric blocks. In this case the weak zone was deformed into a broad slightly asymmetric antiformal structure with prominent Moho uplift, flanked by a doubly vergent fold and thrust belt. The indentor block (close to the moving wall) shows high amplitude folding.

Conclusion

- The presence of lateral strength heterogeneities in the lithosphere affects the deformation pattern in compressional settings
- A small strength contrast between a DZ and the surrounding blocks results in a) localization of the deformation at the DZ boundaries and b) an undeformed region with flat Moho in correspondence to the DZ, despite the vertical location of the DZ
- A strong strength contrast between a weak DZ and strong lithospheric blocks results in a) localisation of the deformation at the DZ boundaries and b) strong Moho uplift in correspondence to the weak zone

References

Willingshofer E., Sokoutis D. & Burg J.P., 2005 - Lithospheric scale analogue modelling of collision zones invoking a pre-existing weak zone. In “ Deformation Mechanisms, Rheology and Tectonics: from Minerals to the Lithosphere ” (Eds. Gapais D., Brun J.P. & Cobbold P.R.). *Geological Society, London, Special Publication* 243, 277-294 ---- **Sokoutis D. & Willingshofer E., 2011** - Decoupling during continental collision and intra-plate deformation. *Earth and Planetary Science Letters* 305, 435-444