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Wavelength selection and evolution in high-resolution 3D numerical models of multilayer detachment folding

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Many fold-and-thrust belts are dominated by crustal scale folding that exhibits fairly regular fold spacing. For example, the Fars region in the Zagros Mountains shows a fold spacing with a normal distribution around a dominant wavelength of 14 Km $\pm$ 3 Km, yet having a wide variability of aspect ratios (length to wavelength ratios; Yamato et al., 2011). To which extend this is consistent with a crustal-scale folding instability or how the regional spacing of folding can be used to constrain regional rheological parameters are not fully resolved questions. To get insights into these problems we have investigated the dominant wavelength selection and evolution in a true multilayer system (Schmid and Podlachikov, 2006) with three different viscosities: lower salt layer (η_s), and overlying weak layers (η_w) and competent layers (η_c). This has been done by means of two tools: a semi-analytical solution and numerical models.

The 2D semi-analytical approach was applied to derive mechanical phase diagrams that can be used to distinguish different folding modes using two viscosity ratios (R_1= η_c/ η_s and R_2= η_c/ η_w). To test the validity of the phase diagrams beyond the initial stages of folding for which the analytical approach is valid, we performed several 3D high-resolution forward numerical runs using a finite element code (LaMEM).

Additionally, irregular bottom topography was implemented in the numerical runs in order to account for variable salt thickness distribution and consequently study its effect on the wavelength selection. A straight but gradual salt thickness variation, sudden thickness variations due to a basement step or an arc shaped salt basin among other cases could be investigated. It was observed that the bottom topography exerts an impact on the velocity field of the different folding modes and as a result, its influence can be observed on the resulting topography. However, not all the folding modes exhibit an initial wavelength that is dependent on the basal salt thickness.

The fold wavelength of the 3D simulations was extracted using 1D spectral analysis and its evolution and selection during deformation was tracked. Furthermore, the forward numerical simulations could be used to investigate the evolution of amplitude and aspect ratio of the folds, as well as the interaction between different individual folds.

The final wavelength that is selected during strain in the performed numerical simulations is in fact in agreement with the calculated phase diagrams. Therefore, the fold spacing and other regional observations in natural examples of folded belts could be used together with 3D numerical runs and a semi-analytical approach to successfully constrain the effective viscosity structure of the deformed layers.

References

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