Mechanical versus kinematical shortening reconstructions of the Zagros High Folded Zone (Kurdistan Region of Iraq)

Marcel Frehner[1], Daniel Reif[2] and Bernhard Grasemann[2]

[1] Geological Institute, ETH Zurich, Switzerland, marcel.frehner@erdw.ethz.ch
[2] Department of Geodynamics and Sedimentology, University of Vienna, Austria

Introduction

The retro-deformation of geological cross-sections is a key tool to unravel the geological deformation history in a certain area. When the deformation is dominated by folding, the shortening necessary to produce the observed fold geometries can be estimated from such unfolding calculations. Commonly, shortening estimates are done using kinematical reconstructions of balanced cross-sections. However, kinematical methods only have limited capabilities to account for the different mechanical behaviors of the individual folded units and purely kinematical shortening estimates may be inaccurate.

Schmalholz (2008) suggested a method to include the mechanical behavior of the folded layers, termed dynamical unfolding. Hereby, the present-day fold geometry is used as the initial condition of a numerical finite-element model of folding, but applying horizontal extensional boundary conditions to reverse the folding process and dynamically unfold the cross-section. This method has been proven to be accurate in the case of two-dimensional folds with Newtonian or power-law viscous rheology (Lechmann et al., 2010), as well as three-dimensional folds with Newtonian rheology (Schmalholz, 2008). This new methodology has only been applied once to a natural fold by Lechmann et al. (2010).

Geological setting and balanced cross-section

The studied area and the reconstructed NE-SW-trending, 55.5 km long cross-section (Figure 1) is located in the High Folded Zone of the Zagros fold-and-thrust belt in the Kurdistan Region of Iraq, NE of the city of Erbil. The lithologies comprise Jurassic to Cenozoic sediments consisting mainly of limestone, dolomite, sandstone, siltstone, claystone and conglomerate. The structures and the stratigraphy are summarized in eight units trying to identify the main geometric and mechanical characteristics. The shortening is kinematically estimated using the dip-domain method to 11%–15%.

The studied region is dominated by open to gentle harmonic folding with amplitudes of less than 2.5 km and a characteristic wavelength of 5–10 km. The cross-section lacks major faults, except one in the NE-part. Several meters thick detachment horizons within the cover rocks, for example Triassic evaporites, Cretaceous shales or Miocene evaporites, decouple the deformation between different units and play an important role in the regional deformation and in the formation of the folds.

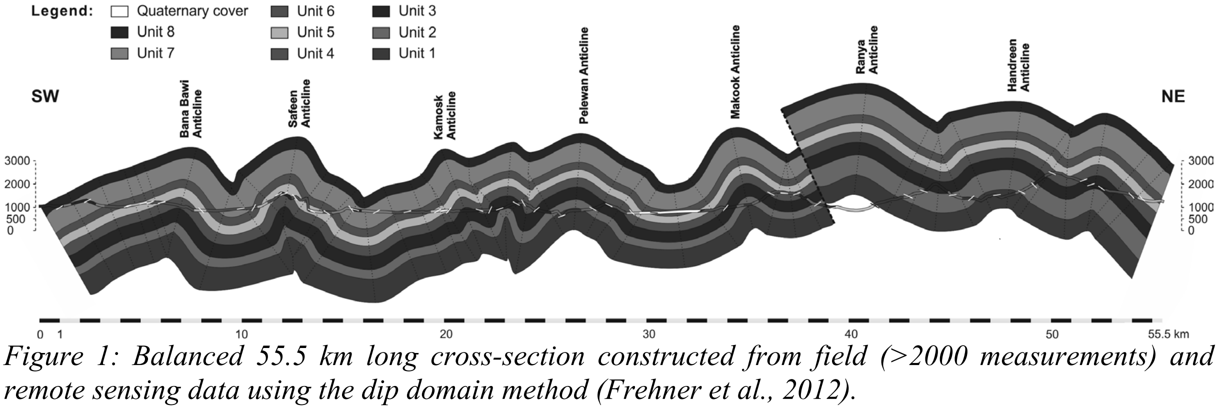

Figure 1: Balanced 55.5 km long cross-section constructed from field (>2000 measurements) and remote sensing data using the dip domain method (Frehner et al., 2012).

Modeling results

Only the SW-part of the cross-section, excluding the thrust, was used for dynamic unfolding simulations. Various combinations of rheological parameters were tested for the mechanically weaker and mechanically stronger layers. The tested parameters include (i) linear viscous (Newtonian) rheology, (ii) power-law viscous rheology using a power-law exponent of n=3, (iii) welded interfaces between the units, and (iv) interfacial slip condition between the units. Also, simulations were performed excluding a basement (i.e., lower boundary condition far enough away from the cross-section to avoid boundary effects) and including a basement at depth *d*.

Figure 2 shows the Mean Amplitude Decrease (MAD) with progressive extension (elongation, *e*, and equivalent shortening, *s*) for the different dynamic unfolding simulations. Welded interfaces between the units leads to an inefficient amplitude decrease with a rate similar to kinematic pure-shear for shortening values larger than s=11% (Figure 2a). On the other hand, all simulations accounting for interfacial slip result in a much more efficient dynamic unfolding (i.e., MAD=70% at s<17%). Including a basement below the layer stack reduces the efficiency of the dynamic unfolding simulations. However, the rate of MAD stays significantly larger than for kinematic pure-shear and the effect of the presence of a basement is much less significant than including interfacial slip.

Based on these results, it is concluded that interfacial slip and decoupling of the deformation along detachment horizons is an important mechanical parameter that controlled the folding processes in the Zagros High Folded Zone.

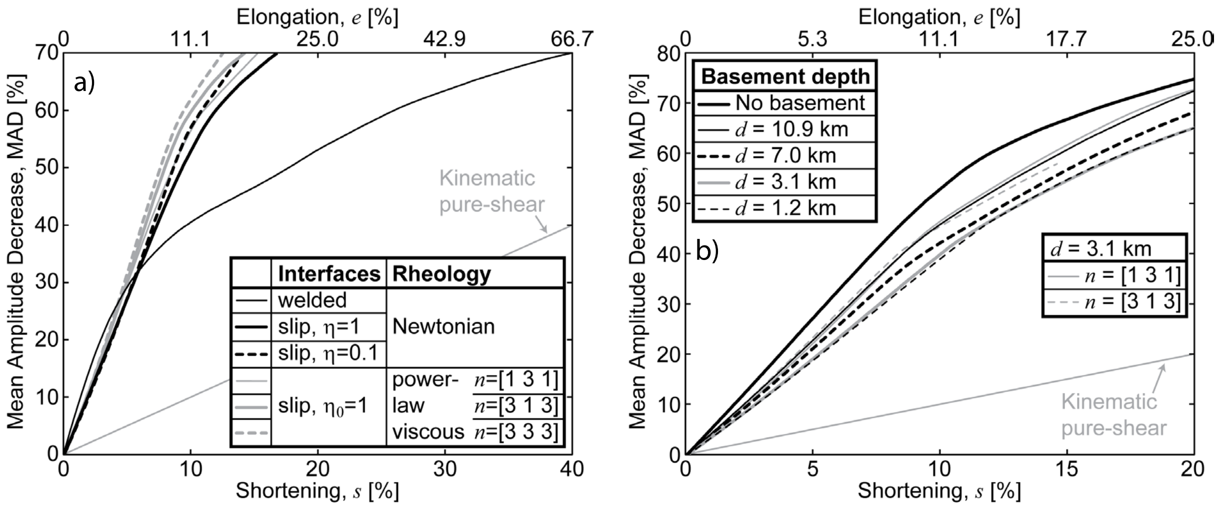

Figure 2: Mean Amplitude Decrease during different progressive dynamical unfolding simulations (a) without and (b) with a basement at depth d. The bold black line is the same in (a) and (b). The legend in the upper-left corner in (b) corresponds to simulations using a Newtonian rheology; the second legend corresponds to simulations using power-law viscous rheologies. Kinematical pure-shear is equivalent to dynamical unfolding with no mechanical difference between the layers (MAD=s).

References

Frehner, M., Reif, D. and Grasemann B., 2012: Mechanical versus kinematical shortening reconstructions of the Zagros High Folded Zone (Kurdistan Region of Iraq), Tectonics, accepted.

Lechmann, S.M., Schmalholz, S.M., Burg, J.-P. and Marques, F.O., 2010: Dynamic unfolding of multilayers: 2D numerical approach and application to turbidites in SW Portugal, Tectonophysics 494, 64–74.

Schmalholz, S.M., 2008: 3D numerical modeling of forward folding and reverse unfolding of a viscous single-layer: Implications for the formation of folds and fold patterns, Tectonophysics 446, 31–41.