Dynamical unfolding for quality control of geological cross-sections

Marcel Frehner[1], Daniel Reif[2], and Bernhard Grasemann[3]

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

Dynamical unfolding is a recently developed method to reconstruct folded geological cross-sections (Schmalholz, 2008; Lechmann et al., 2010; Frehner et al., 2012). Thereby, the present-day fold geometry is discretized in a finite-element model (Figure 2a) and subsequently extended by applying horizontal extensional boundary condition in the numerical simulation. This corresponds to a time-reverse simulation and various stages in the fold development can be investigated. Compared to classical palinspastic reconstruction techniques, dynamical unfolding allows incorporating rheological parameters and therefore studying the influence of rheology on the fold development. For example, Frehner et al. (2012) could identify interfacial slip between lithological units as a key deformation process during the development of the Zagros Simply Folded Belt in the Kurdistan region of Iraq (Figure 1).

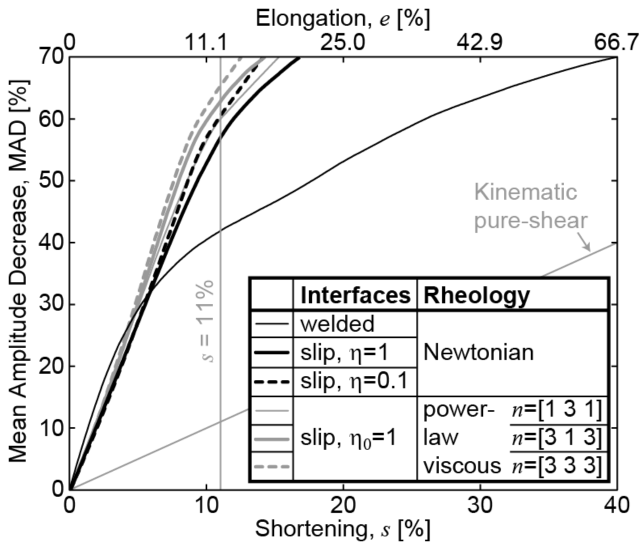

Figure 1: Comparison between dynamical unfolding simulations using various rheological parameters. Horizontal axis represents ongoing simulation time (i.e., increasing horizontal extension). Vertical axis represents the amplitude decrease during the dynamical unfolding simulations. The biggest difference is between the simulation with welded interfaces between lithological units and simulations with interfacial slip between these units. Other factors, such as various power-law exponents have a much smaller influence on the results. Modified from Frehner et al. (2012).

Besides estimating bulk shortening values, dynamical unfolding is also able to identify problematic areas in the geological cross-section (Figure 2b). These areas, where the dynamical unfolding is less efficient, may be characterized by either

1. higher geological complexity or
2. inaccurate cross-section construction.

The first point includes various deformation processes, such as intense brittle fracturing and faulting, non-volume conserving processes (e.g., solution-precipitation, compaction), or three-dimensional out-of-plane deformation. These processes are (currently) not included in the numerical algorithm. However, dynamic unfolding can identify these areas in the geological cross-section and therefore helps define targets of future field investigations.

The second point can be due to sparse or inaccurate data, from which the cross-section is constructed, or due to the cross-section construction method itself. Dynamical unfolding can identify areas in the cross-section, which are not well constrained or badly constructed. Therefore, dynamical unfolding is a valuable tool for quality control of geological cross-sections.

The presented work demonstrates how dynamical unfolding can be applied for both quality control and planning field investigations. As a case study the Zagros Simply Folded Belt in the Kurdistan region of Iraq is used.

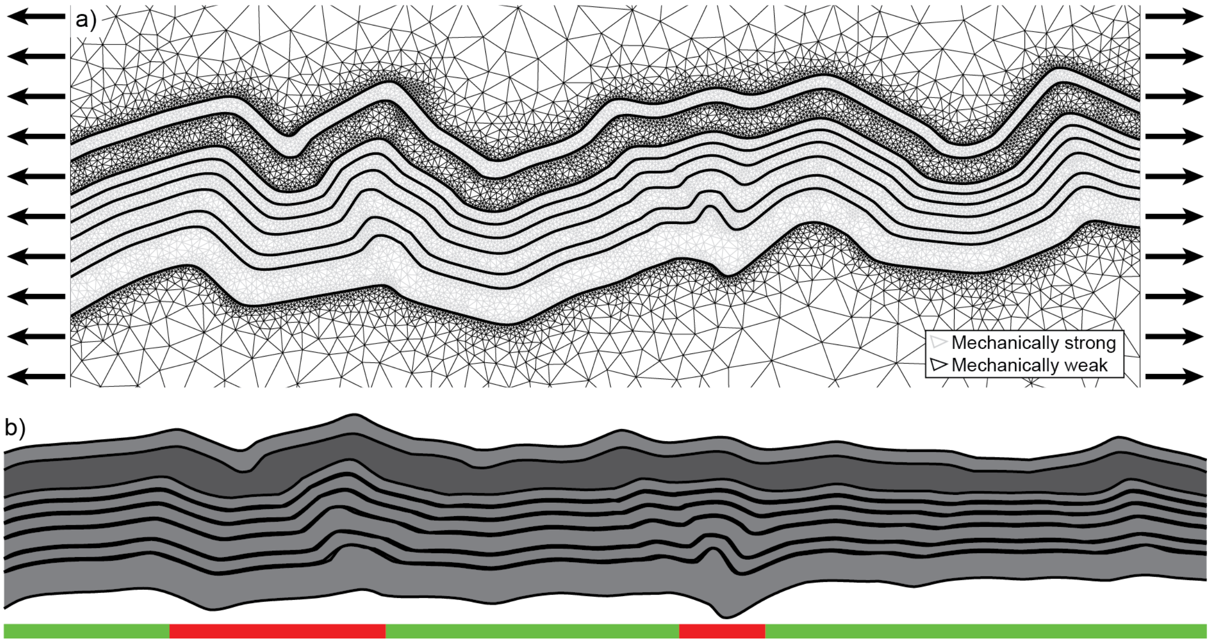

Figure 2: a) Present-day geological cross-section of a part of the Zagros Simply Folded Belt discretized with a finite-element mesh. b) The same cross-section after dynamical unfolding applying 12.4% extension in a finite-element simulation (corresponds to 11% shortening in a forward-time experiment). The mean fold amplitude decrease from a) to b) is 65.3%. The colorbar schematically indicates areas along the cross-section with efficient amplitude decrease (green) and less efficient amplitude decrease (red). This simulation corresponds to the gray dashed line in Figure 1. Modified from Frehner et al. (2012).

References

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