3D fold growth rates

Frehner Marcel

Geological Institute, ETH Zurich, Sonneggstrasse 5, CH-8092 Zurich
(marcel.frehner@erdw.ethz.ch)

Geological folds are inherently 3D structures. Therefore, a fold also grows in three dimensions (Bretis et al., 2011; Grasemann and Schmalholz, 2012). In this study, fold growth in all three dimensions is studied and quantified numerically using a finite-element algorithm for simulating 3D deformation of Newtonian materials. Upright symmetrical single-layer folds are considered. The higher-viscous layer exhibits a 2D Gaussian initial perturbation. Horizontal compression in x-direction leads to a folding instability, which grows from this perturbation in all three dimensions (Figure 1). Fold amplification in 3D setups has been described analytically by Fletcher (1991) for low limb dips, but fold growth in all three dimensions has not been quantified. It is described by:

<u>Fold amplification (growth in z-direction):</u> Fold amplification describes the growth from a low-limb-dip fold to a higher-limb-dip fold.

<u>Fold elongation (growth in y-direction):</u> Fold elongation is parallel to the fold axis. It describes the growth from a dome-shaped structure to a more cylindrical fold.

<u>Sequential fold growth (growth in x-direction):</u> Sequential fold growth is parallel to the shortening direction and describes the growth of secondary (and further) folds adjacent to the initial isolated fold.

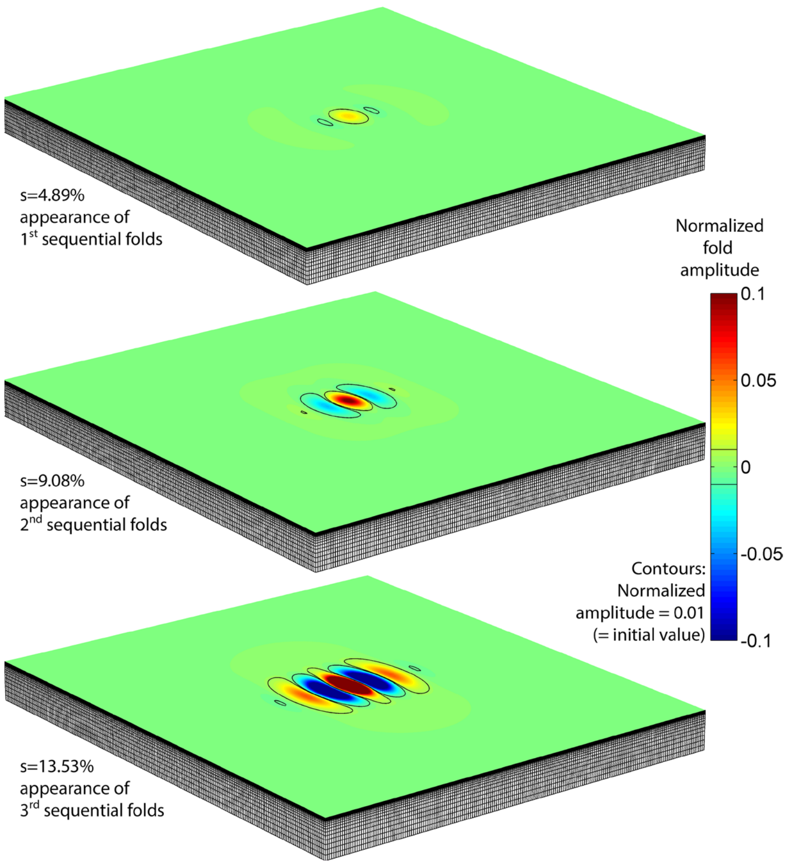

Figure 1: Growth of a 3D fold from a 2D Gaussian initial perturbation in all three dimensions.

Both fold elongation and sequential fold growth have previously been referred to as lateral fold growth, which is here used as an umbrella term for both.

The numerical results demonstrate that the two lateral directions generally show a very similar averaged growth (Figure 2). However, the fold elongation is smooth and continuous, while the sequential fold growth exhibits jumps in its evolution. These jumps occur whenever a secondary or further fold appears for the first time (Figure 1) and the entire fold structure therefore suddenly occupies more space in x-direction. For a given initial perturbation, the jumps occur earlier in the folding history for larger viscosity ratios.

Compared to the fold amplification, the two lateral directions grow slower (i.e., values <1 in Figure 2). Exceptions only occur for the sequential fold growth direction in early folding stages in the case of very narrow initial perturbations (Figure 2a). In these cases, the fold amplification is particularly slow and the sequential fold growth rate can therefore be larger. Generally, all three normalized fold amplitudes are of the same order (Figure 2), particularly at the early folding stages.

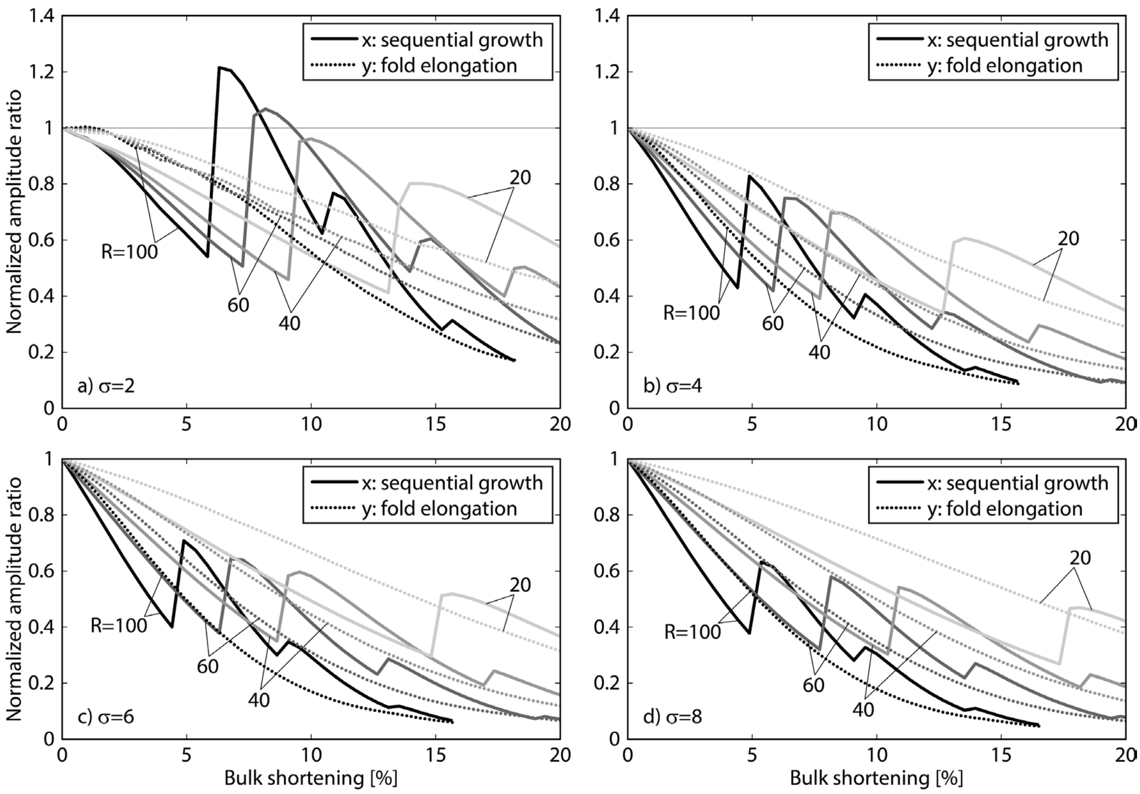

Figure 2. Ratios of normalized amplitudes A_x/A_z (sequential growth/amplification, bold line) and A_y/A_z (elongation/amplification, dotted line) for different initial perturbation widths (σ=2: narrow initial perturbation; σ=8: narrow initial perturbation) and different viscosity ratios $R=\eta_{\mathrm{layer}}/\eta_{\mathrm{matrix}}$. Values below 1 mean that the corresponding normalized lateral fold amplitude is smaller than the normalized vertical amplitude.

REFERENCES

Bretis, B., Bartl, N. and Grasemann, B. 2011. Lateral fold growth and linkage in the Zagros fold and thrust belt (Kurdistan, NE Iraq). Basin Research, 23, 615–630.

Grasemann, B. and Schmalholz, S. M. 2012. Lateral fold growth and fold linkage. Geology, 40, 1039–1042.