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3D fold growth rates in transpressional tectonic settings

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Geological folds are inherently three-dimensional (3D) structures; hence, they also grow in 3D. In this study, fold growth in all three dimensions is quantified numerically using a finite-element algorithm for simulating deformation of Newtonian media in 3D. The presented study is an extension and generalization of the work presented in Frehner (2014), which only considered unidirectional layer-parallel compression. In contrast, the full range from strike slip settings (i.e., simple shear) to unidirectional layer-parallel compression is considered here by varying the convergence angle of the boundary conditions; hence the results are applicable to general transpressional tectonic settings.

Only upright symmetrical single-layer fold structures are considered. The horizontal higher-viscous layer exhibits an initial point-like perturbation. Due to the mixed pure- and simple shear boundary conditions a mechanical buckling instability grows from this perturbation in all three dimensions, described by:

- Fold amplification (vertical growth): Fold amplification describes the growth from a fold shape with low limb-dip angle to a shape with higher limb-dip angle.
- Fold elongation (growth parallel to fold axis): Fold elongation describes the growth from a dome-shaped (3D) structure to a more cylindrical fold (2D).
- Sequential fold growth (growth perpendicular to fold axial plane): Sequential fold growth describes the growth of secondary (and further) folds adjacent to the initial isolated fold.

The term "lateral fold growth" is used as an umbrella term for both fold elongation and sequential fold growth. In addition, the orientation of the fold axis is tracked as a function of the convergence angle.

Even though the absolute values of all three growth rates are markedly reduced with increasing simple-shear component at the boundaries, the general pattern of the quantified fold growth under the studied general-shear boundary conditions is surprisingly similar to the end-member case of unidirectional layer-parallel compression (Frehner, 2014). Fold growth rates in the two lateral directions are almost identical resulting in bulk fold structures with aspect ratios in map view close to 1. Fold elongation is continuous with increasing bulk deformation, while sequential fold growth exhibits jumps whenever a new sequential fold appears. Compared with the two lateral growth directions, fold amplification exhibits a slightly higher growth rate.

The orientation of the fold axis has an angle equal to $\frac{1}{2}$ of 90° minus the convergence angle; and this orientation is stable with increasing bulk deformation, i.e. the fold axis does not rotate with increasing general-shear deformation. For example, for simple-shear boundary conditions (convergence angle 0°) the fold axis is stable at an angle of 45° to the boundaries; for a convergence angle of 45° the fold axis is stable at an angle of 22.5° to the boundaries.

REFERENCE:

Frehner M., 2014: 3D fold growth rates, Terra Nova 26, 417–424, doi:10.1111/ter.12116.