Structural inheritance during multilayer buckle folding: How pre-existing asymmetries result in parasitic folds with wrong vergence

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Introduction

Parasitic folds are typical structures in geological multilayer folds; they are characterized by a small wavelength and are situated within folds with larger wavelength (Ramberg, 1963; Frehner and Schmalholz, 2006). Parasitic folds exhibit a characteristic asymmetry (or vergence; i.e. S-, Z-, or M-folds) reflecting their structural relationship to the larger-scale fold.

Here we (Frehner and Schmid, 2016) investigate if and how a pre-existing asymmetry (e.g., from sedimentary structures or folds from a previous tectonic event) can be inherited during buckle folding to form alleged parasitic folds with wrong vergence. We conduct 2D finite-element simulations of Newtonian multilayer folding. The applied model setup comprises a thin layer containing the pre-existing asymmetry sandwiched between two thicker layers, all embedded in a lower-viscosity matrix and subjected to layer-parallel shortening. During ongoing layer-parallel shortening and buckling, we track the asymmetry's amplitude with respect to the larger-scale fold median line.

Results

Typical results demonstrate that during the early folding stages the geometrical asymmetry both grows in amplitude and intensifies its asymmetry (increasing skew angle) (Figure 1). However, at later folding stages, when the larger-scale fold also macroscopically amplifies, the asymmetry de-amplifies and reduces its skew angle again.

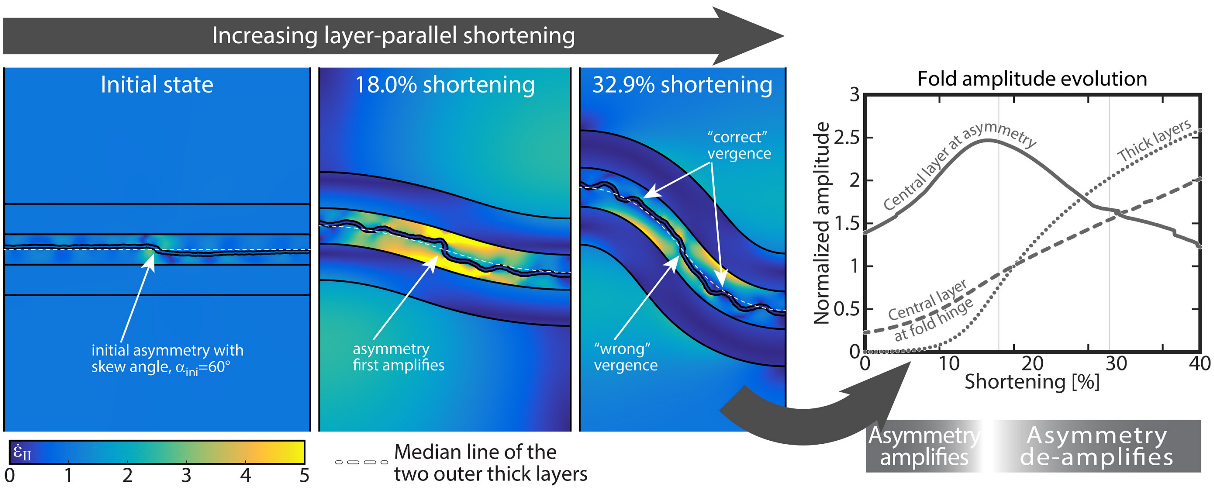

Figure 1: Graphical abstract of the main results. Left: Simulation snapshots visualizing the evolution of the multilayer system containing an initial geometrical asymmetry of the central thin layer. Colors: second invariant of the strain rate tensor, $\dot{\varepsilon}_{II}$. Dashed white line: larger-scale median line. The initial asymmetry survives the early stages of buckle folding, which results in an alleged parasitic fold with wrong vergence, alongside true parasitic folds with correct vergence. Right: From the numerical simulation, different (normalized) fold amplitude evolutions can be calculated. Shown are the amplitude of the larger-scale fold (thick layers; dotted line), as well as the amplitude of the central thin layer at the larger-scale fold hinge (dashed line) and at the larger-scale fold limb (i.e., amplitude of the initial asymmetry; solid line).

We systematically vary the intensity of the initial geometrical asymmetry (open to tight; Figure 2A) and its position on the larger-scale fold (from fold hinge to fold limb; Figure 2B). We investigate how the efficiency of de-amplification is controlled by the interplay between larger-scale and smaller-scale fold amplification.

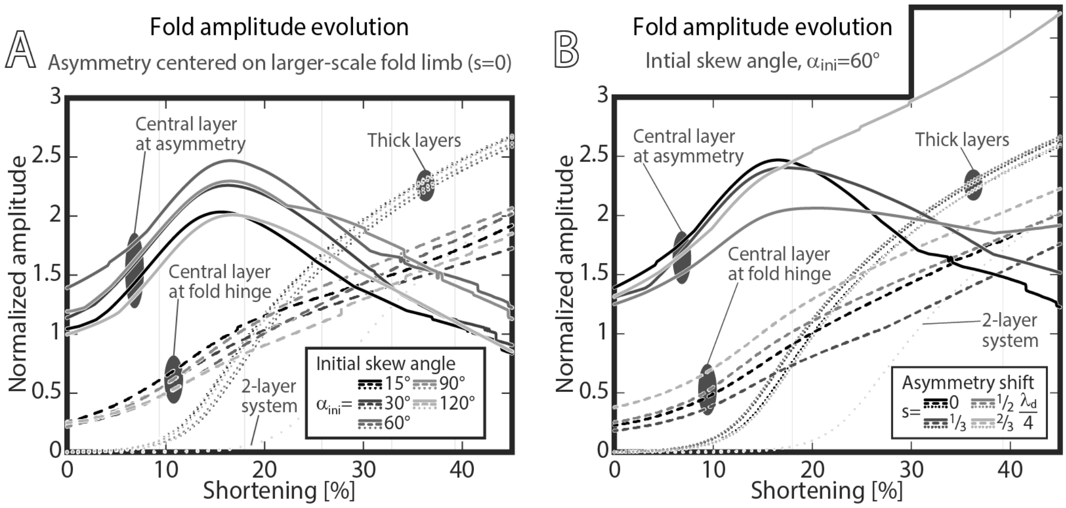

Figure 2: Same as Figure 1 right, but for different initial skew angles (A) and for different positions of the initial asymmetry on the larger-scale fold (B).

Discussion & Conclusions

When the two outer thick layers buckle and amplify to finite amplitudes, two processes work against the asymmetry: (i) layer-perpendicular flattening (i.e., pure shear between the two thick layers) and (ii) the rotational component of flexural flow folding (i.e., simple shear between the two thick layers). Both processes promote de-amplification and unfolding of the pre-existing asymmetry.

We conclude that pre-existing folds that are open, exhibit low amplitude, and/or are situated on the limb of the larger-scale fold are prone to de-amplification and may disappear during buckling of the multilayer system. Large-amplitude and/or tight to isoclinal folds and/or folds situated close to the hinge of the larger-scale fold may be inherited and develop into alleged parasitic folds with wrong vergence resembling type 3 fold interference patterns.

References

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Keywords

Parasitic folds, Buckle folds, Fold vergence, Asymmetric folds, Structural inheritance, Finite-element method