Fold axis rotation during transpressional folding: Insights from numerical modeling and application to the Zagros Simply Folded Belt

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Transpression is the combination of strike-slip deformation and shortening orthogonal to the deformation zone. Whereas in the upper crust transpression is dominantly accommodated by faulting, viscous parts of the lithosphere dominantly deform by folding. In some cases, transpressional strain is geographically partitioned (Tikoff and Teyssier, 1994) between a strike-slip domain lacking major shortening structures and a neighboring pure-shear domain (e.g., fold-and-thrust belt) lacking major strike-slip structures.

Here, the growth and rotation of folds during transpression as a function of the convergence angle is investigated using 3D numerical finite-element models (Figure 1; Frehner, in press). The model setup comprises upright single-layer buckle folds in Newtonian materials, which grow from an initial point-like perturbation due to a combination of in-plane shortening and shearing (i.e., transpression). The numerical results suggest that fold axes are always parallel to the major horizontal principal strain axis (λ_{max}), and that sequential folds appearing later form parallel to already existing folds and rotate with λ_{max} with increasing strain. This suggests that fold axes are not passive material lines and that fold hinge migration occurs during transpression.

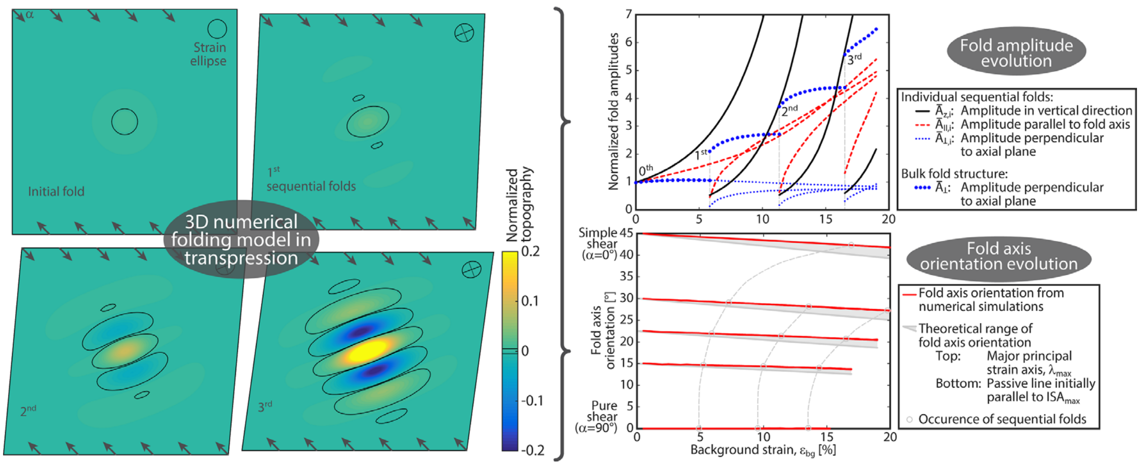

Figure 1: Graphical abstract of main results. Left: Top view snapshots of example simulation with a convergence angle, α=45°. With increasing background strain, the fold structure grows in all three dimensions. Top right: Fold amplitude evolution in three directions: vertical (fold growth), parallel to fold axis (fold elongation) and perpendicular to axial plane (sequential fold growth). Bottom right: Fold axis orientation with increasing background strain for different convergence angles (α=0°–90°). For all cases, the fold axis is always parallel to the major principal strain axis, λ_{max}; hence it is not a passive marker line.

Because the fold axis is always parallel to λ_{max}, there is an analytical triangular relationship between the convergence angle, the amount of strain, and the fold axis orientation. If two of these values are known, the third can be determined. Importantly, this relationship is independent of the viscosities and viscosity ratios involved in the folded layers.

For the Zagros Simply Folded Belt (ZSFB) in NE Iraq, the far-field convergence angle (from GPS; Vernant and Chéry, 2006) is α=35°. Strain is partitioned between the ZSFB and the bordering strike-slip fault-system. However, the degree of partitioning is disputed, ranging from full partitioning (α=90° in the ZSFB; Talebian and Jackson, 2004) to intermediate partitioning (α=60° in the ZSFB; Vernant and Chéry, 2006). Zero strain partitioning (α=35° in the ZSFB) is unrealistic because some strike-slip movement along bordering strike-slip fault-system is clearly documented (Talebian and Jackson, 2002). The above mentioned triangular relationship is applied to the Zagros fold-and-thrust-belt to estimate the degree of strain partitioning (Figure 2). Despite some data scatter, the orientation of the majority of fold axes indicates a convergence angle within the ZSFB of α=60°–90°, confirming the proposed range. However, the data covers this entire range and it is not clear which end-member model is more appropriate.

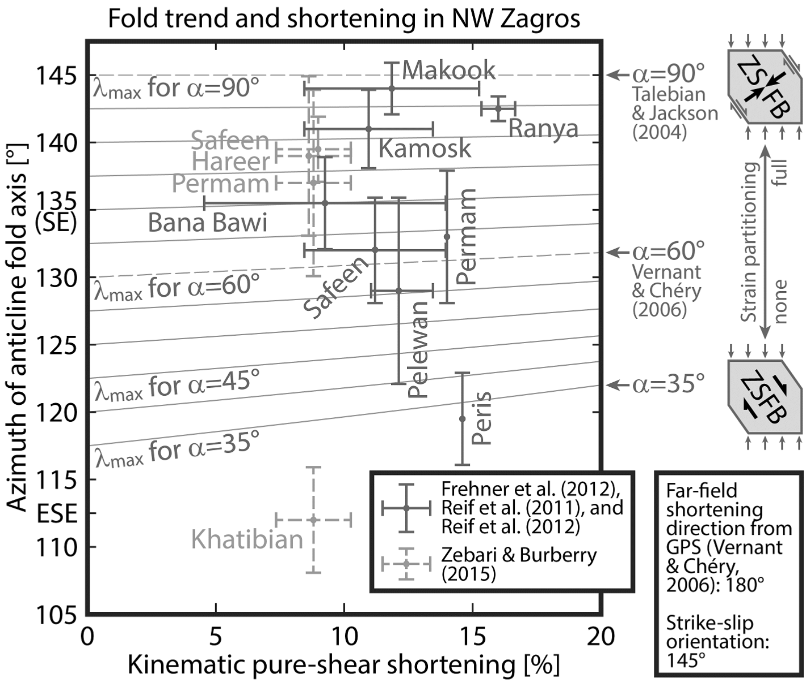

Figure 2: Fold axis orientations versus strain estimates in the ZSFB. In the back, theoretical fold axis orientations, λ_{max}, are plotted for different convergence angles. End-member convergence angles are sketched on the right based on the far-field shortening direction and strike-slip fault orientation: 90° (pure shear; full strain partitioning), 35° (zero strain partitioning).

REFERENCES

Frehner, M. in press: 3D fold growth in transpression, Tectonophysics, doi:10.1016/j.tecto.2016.01.002.
Talebian, M. & Jackson, J. 2004: A reappraisal of earthquake focal mechanisms and active shortening in the Zagros mountains of Iran, Geophysical Journal International, 156, 506–526.
Tikoff, B. & Teyssier, C. 1994: Strain modeling of displacement-field partitioning in transpressional orogens, Journal of Structural Geology 16, 1575–1588.
Vernant, P. & Chéry, J. 2006: Mechanical modelling of oblique convergence in the Zagros, Iran, Geophysical Journal International, 165, 991–1002.