3D FE-modelling of inclined, brittle-ductile transpression

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Transpression kinematic is a direct consequence of oblique convergence where velocity vectors are oblique to boundaries between deforming crustal blocks. Transpression zones form from the simultaneous operation of two components (Frehner 2016; Nabavi et al. 2017a): (i) simple shearing parallel with the shear zone boundaries; and (ii) coaxial flow producing shortening orthogonal to the shear zone and stretching parallel to it. Many natural transpression zones develop as the non-vertical zones, which may be termed “inclined transpression” (Nabavi et al. 2016, 2017b). The simple inclined transpression of Jones et al. (2004) involves simultaneous pure shearing (coaxial deformation) and strike-slip and dip-slip simple shearing resulting in triclinic flow.

The mechanical evolution of inclined transpression zones is investigated by a static 3D elasto-plastic mechanical model solved with the finite-element (FE) method using the commercial FE-package ABAQUS^{TM}. The model comprises three blocks – an upper ‘active’ block (made up of three layers with different rheologies), which slides frictionally on top of a rigid lower block with 5 km thickness. The lateral dimensions of the ‘active’ block are 75.5×50×9.5 km and two parallel primary dipping faults (=70°) have a length of 50 km length. A regional oblique shortening of 16% (3 km shortening) is imposed at a convergence angle of 25° (α=25°).

The imposed oblique convergence results in inclined transpression accommodated throughout the entire model (Fig. 1). Oblique convergence is accommodated along mixed dextral-thrust faults, where the higher values of incremental shear strain are recorded. The incremental boundary-normal shortening accommodated within the transpression zone is compensated by differential uplift, such that the total thickness increases from 9.5 km in the undeformed stage to ~15 km after the maximum shortening (16%) (Fig. 1a). The incremental shear strain pattern shows that maximum strain is concentrated within the transpression zone and with the largest strain values along the oblique reverse faults (Fig. 1b,d). In addition, results show high shear strain values located along the left boundary (fault 2) of the inclined transpression zone, suggesting that this fault is more active than the right boundary (fault 1). In addition, there are different shear strain in competent (high amount) and incompetent (low amounts) layers. The overall oblique displacement results in shortening and associated up-dip extrusion, mainly produced at the frontal part of the oblique-reverse faults. Displacement vectors within the inclined transpression zone are rotated counter-clockwise with respect to vectors in the fixed backstop. Rotation of the displacement vectors with time suggests that the transpression zone evolves under an overall non-plane strain deformation. Structures observed in this model are mainly mixed dextral-reverse faults sub-parallel with the backstop and obliquely oriented, related folds, accountable for contraction-dominated transpression. Results demonstrate that deformation can be accommodated by folding in all blocks. Deformation accommodated as folding in the mobile backstop produces an asymmetric anticline so that permanent strains develop principally in the forelimb. As the simulated oblique convergence increases, inclined transpression begins to accommodate a progressively greater fault slip and the overall anticline growth in the mobile backstop is characterized by an increase in fold amplitude rather that its width. The model results demonstrate that the transpression zone evolves in a 3D strain field and along non-coaxial strain paths. The results show the mean and maximum principal stress increases inside the transpression zone (Fig. 1c).

Also, the fault slip distributions in the elasto-plastic model is asymmetric. Generally, the transpression zone undergoes lateral and up-dip extrusion. Modelling results show that strain partitioning occurs between a narrow simple-shear-dominated domain and a broad contraction-dominated domain (Fig. 1). This type of strain partitioning is defined as discrete partitioning.

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