Mechanical evolution of transpression zones affected by fault interactions: insights from 3D elasto-plastic finite element models

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Transpression zones, as a common tectonic setting in strike-slip fault systems, orogenic belts, and plate boundaries, result from oblique convergence between deforming crustal plates (Frehner 2016; Nabavi et al. 2017b). Transpression is characterized by simultaneous simple shearing parallel to the shear zone boundaries and coaxial flow producing shortening orthogonal to the shear zone boundaries. Transpression can have either a monoclinic or a triclinic kinematic symmetry, depending on the orientation of the pure shear axes with respect to the simple shear axes (Fernández & Díaz-Azpiroz 2009).

The mechanical evolution of transpression zones affected by fault interactions is investigated by a static 3D elasto-plastic mechanical model solved with the finite-element (FE) method using the commercial FE-package ABAQUS™. Ductile transpression between non-rigid walls implies an upward and lateral extrusion. The model demonstrates that the transpression zone evolves in a 3D strain field and along non-coaxial strain paths. Distributed plastic strain, slip transfer, and maximum plastic strain occurs within the transpression zone. Outside the transpression zone, fault slip is significantly reduced because shear offset is accommodated by distributed plastic shear. The results show that the mean and maximum principal stress increase inside the step between the fault segments compared to the region outside the step (Fig. 1a) (e.g., Nabavi et al. 2017a). With progressive deformation, the σ_3 axis rotates within the transpression zone forming an oblique angle to the regional transport direction (~9°-10°).

Rotation of the displacement vectors with the evolution of the oblique convergence suggests that the transpression zone evolves under an overall non-plane strain deformation. Slip decreases along fault segments and with increasing depth so that we can see a distinct slip decrease at depths from 0-5 km to 5-15 km (Fig. 1b). This can be attributed to the accommodation of bulk shortening over adjacent fault segments. Also, fault slip distributions in the elasto-plastic model shows quite some asymmetry (Fig. 1b). The model shows an almost symmetrical domal uplift, which is due to off-fault deformation, generating a doubly plunging fold (Fig. 2a) and a positive flower structure (Fig. 2c). Outside the overlap zone, expanding asymmetric subsidence basins showing negative flower structures develop on both sides of the transpression zone, and are called ‘transpressional basins’ (Fig. 2a).

Generally, the transpression zone undergoes lateral and vertical extrusion (Fig. 2b). Deflection at fault segments causes the fault dip to change to less than 90° (~86-89°) near the surface (~1.5 km). This results in a pure-shear-dominated, triclinic, and discontinuous heterogeneous flow of transpression zone (Fig. 2d).

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