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Looking beyond kinematics: 3D thermo-mechanical modelling reveals the dynamics of transform margins

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Transform margins represent ~30% of nonconvergent margins worldwide. Their formation and evolution have traditionally been addressed through kinematic models that do not account for the mechanical behaviour of the lithosphere. In this study, we use high-resolution 3D numerical thermo-mechanical modelling to simulate and investigate the evolution of intra-continental strain localization under oblique extension. The obliquity is set through velocity boundary conditions that range from 15 (high obliquity) to 75 (low obliquity) every 15 for rheologies of strong and weak lower continental crust. Numerical models show that the formation of localized strike-slip shear zones leading to transform continental margins always follows a thinning phase during which the lithosphere is thermally and mechanically weakened. For low- (75) to intermediate-obliquity (45) cases, the strike-slip faults are not parallel to the extension direction but form an angle of 20 to 40 with the plate motion vector, while for higher obliquities (30 to 15) the strike-slip faults develop parallel to the extension direction. Numerical models also show that during the thinning of the lithosphere, the stress and strain re-orient while boundary conditions are kept constant. This evolution, due to the weakening of the lithosphere, leads to a strain localization process in three major phases: (1) initiation of strain in a rigid plate where structures are sub-perpendicular to the extension direction; (2) distributed deformation with local stress field variations and formation of transtensional and strikeslip structures; (3) formation of highly localized plate boundaries stopping the intra-continental deformation. Our results call for a thorough re-evaluation of the kinematic approach to studying transform margins.