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Subduction orogeny along a seaward-concave plate boundary in the Central Andes: insights from 2D numerical and 3D thermo-mechanical laboratory experiments

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The influence of plate boundary curvature on the large-scale stress and strain patterns in an overriding plate is explored using 2D numerical and 3D thermo-mechanical analogue experiments. Numerical experiments reveal that trench-parallel compression is produced near the symmetry axis of a seaward-concave plate boundary if interplate friction is high and/or the subducting lithosphere has a low flexural rigidity. In contrast, trench-parallel compression is reduced along the oblique parts of the plate boundary. However, both the stress conditions on the interplate zone and the 3-D geometry of this zone control whether the trench-parallel stress in the centre of the curvature is a tension or compression. Low dip angle and high convergence obliquity angle favour trench-parallel compression. In the central Andes, N-S minor shortening in the centre of the Arica bend and strike slip systems north and south of the symmetry axis suggest that the effect of shear traction dominated during Cenozoic time when the curvature of the plate boundary was forming. We therefore argue that the processes responsible for the formation of the plate boundary curvature were assisted by enhanced interplate friction and/or reduced compressive non-hydrostatic normal stress. 3D thermo-mechanical laboratory experiments of oceanic subduction along a seaward-concave plate boundary are performed in order to investigate the large-scale deformation pattern in the upper plate. However, model deformation was restricted to the fore-arc domain because high friction was only imposed in the upper, shallow (0-50 km) part of the interplate zone. Nevertheless, the large-scale deformation pattern shows characteristics which fit observations in the Andes. Along the oblique section of the plate boundary, oblique subduction produces trench-parallel shearing of the fore-arc towards the centre of the curvature, significant trench-normal coaxial shortening but little to no trench-parallel coaxial shortening. This explains the excess-rotation obtained from paleomagnetic data and kinematic models. In contrasts, fore-arc deformation near the centre of the curvature includes the largest trench-normal coaxial shortening, significant trench-parallel coaxial shortening but no trench-parallel shearing. This strain pattern also corresponds to that obtained from kinematic models. Importantly, the model deformation reveal that trench-normal coaxial shortening is locally shifted inland because of the trench-parallel coaxial shortening occurring in the frontal part of the fore-arc. We therefore argue that this pattern is an intrinsic characteristic of the 3D deformation along seaward-concave plate boundary due to high interplate friction. This characteristic may extend to the arc/back-arc deformation if the high interplate friction is extended further down the interplate zone and the entire fore-arc block is dragged laterally instead of only its frontal part.