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Accommodation of Penetrative Strain during Deformation above a Ductile Decollement

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Penetrative strain constitutes the proportion of the total shortening across an orogen that is not accommodated by the development of macroscale structures, such as folds and thrusts. The accommodation of shortening by penetrative strain is widely agreed to be an important process during compression, but the effects of penetrative strain in a compressional system with a ductile décollement is not well understood. In order to create a framework for understanding penetrative strain above a ductile décollement, seven analog models, each with the same initial set-up configuration were shortened to different amounts in a deformation apparatus. Models were set up in a sandbox apparatus with a 5mm layer of silicon polymer base layer, acting as an analog to rock salt. Three fine-grained sand layers were placed on top of the silicon to represent a brittle system with a salt base. A grid to track penetrative strain throughout shortening overlay the model's upper surface. As the model was compressed, a series of pop-up and pop-down structures developed. A zone of penetrative strain was also indentified, based on measurements of the grid. Penetrative strain amounts within this foreland zone increased exponentially until just before the initiation of a new thrust. After a new thrust forms, penetrative strain in the foreland zone dropped to <1% shortening, and then again increased exponentially until the next thrust developed. Restoration of the model layers indicates that penetrative strain accounts for between 1-16% of total shortening in a compressive system with a ductile décollement. This is less than in a brittle system as measured in Burberry (2015) due to strong partitioning of the strain into the décollement layer. However penetrative strain can account for a considerable amount of missing shortening in an orogenic zone. Analog model geometries were consistent with the mechanics and deformation styles observed in salt-floored systems, such as the Salt Ranges of Pakistan. Penetrative strain has not been accounted for in previous studies of the Salt Ranges of Pakistan or other similar areas, and estimates of this type could help better calculate true total shortening and resolve concerns related to so-called "missing shortening" highlighted by GPS data.