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Interpreting continuous-discontinuous deformation structures considering a continuum of fault slip styles: The example of flexural-slip folds.

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Flexural slip folds are distinctive of mixed continuous-discontinuous deformation in the upper crust, as folding is accommodated by continuous bending of layers and localized, discontinuous slip along layer interfaces. The mechanism of localized, layer-parallel slip and the stress and fluid pressure conditions at which flexural slip occurs are therefore distinctive of shear localization during distributed deformation. Similarly, the mechanisms accommodating finite strain by folding are responsible for continuous deformation under the same pressure-temperature conditions at which layer-parallel slip occurs. We therefore investigate flexural-slip folds, deformed at subgreenschist conditions, as an analogue to mixed continuous-discontinuous deformation styles recorded seismologically and geodetically at actively deforming margins.

In the Prince Albert Formation mudstone sequence of the Karoo Basin, the foreland basin to the Cape Fold Belt, South Africa, chevron folds are well developed and associated with incrementally developed bedding-parallel quartz veins with slickenfibres oriented perpendicular to fold hinge lines, locally cross-cutting axial planar cleavage, and showing hanging wall motion toward the fold hinge. Bedding-parallel slickenfibre-coated veins dip at angles from 18˚ to 83˚, implying that late increments of bedding-parallel shear occurred along unfavourably oriented planes. The local presence of tensile veins, in mutually cross-cutting relationship with bedding-parallel, slickenfibre-coated veins, indicate local fluid pressures in excess of the least compressive stress.

Slickenfibre vein microstructures include a range of quartz morphologies, dominantly blocky to elongate-blocky, but in places euhedral to subhedral; the veins are commonly laminated, with layers of quartz separated by bedding-parallel slip surfaces characterized by a quartz-phyllosilicate cataclasite. Crack-seal bands imply incremental slickenfibre growth, in increments from tens of micrometres to a few millimetres, in some places, whereas other vein layers lack evidence for incremental growth and likely formed in single slip events. Single slip events, however, also involved quartz growth into open space, and are inferred to have formed by stick-slip faulting. Overall, therefore, flexural slip in this location involved bedding-parallel faulting, along progressively misoriented weak planes, with a range of slip increments.

Folded sedimentary layers show evidence of fracture, cataclasis, and pressure solution as mechanisms accommodating buckling. These mechanisms must have been active while flexural slip occurred on layer interfaces, yet at least pressure solution is commonly interpreted as slow and steady, whilst incremental frictional sliding implied by crack-seal slickenfibres would typically be ascribed to episodic slip at elevated rate of displacement. Analogous to temporal slip rate variations that have, over the last decade, been reported in most well instrumented convergent margins, these observations of mixed continuous-discontinuous deformation can be viewed in light of spatial and temporal variations in strain rate. Although we have used the example of flexural slip folds to illustrate this point, a possible further inference is that deformation of heterogeneous lithological assemblages promotes spatial strain rate variations, leading to temporal variations in observed active deformation rates as different materials deform on different temporal and spatial scales.