Origin of multiple generations of extension fractures in detachment folds: an example from the northeastern Brooks Range, Alaska

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Most published literature on the origin of regional extension fractures focuses on extension fractures in either flat-lying rocks or folded rocks. However, it is likely that fracturing occurs in a continuum with other structures as flat-lying rocks are incorporated into a fold-and-thrust belt. Correctly interpreting the multiple generations of fractures and coexisting penetrative structures can yield important clues to the sequence and conditions of deformation.

The complex history of deformation and related fracturing in detachment-folded Lisburne Group carbonate rocks of the northeastern Brooks Range illustrates this point. Regional NNW-oriented extension fractures are well-developed in the Lisburne Group of the Sadlerochit Mountains and in the subsurface at Prudhoe Bay. These fractures probably formed parallel to maximum horizontal in situ stress ahead of and orthogonal to the northeastern Brooks Range fold-and-thrust belt. These early strike-normal fractures are a brittle response to layer-parallel shortening under relatively low temperature, low differential stress, and high pore fluid pressure conditions.

Detachment-folded Lisburne Group rocks south of the Sadlerochit Mountains reflect incorporation of previously flat-lying Lisburne into the fold-and-thrust belt. These rocks were north of the deformation front prior to being buried by the advancing thrust front and eventually incorporated into it. In the process, these carbonate rocks experienced increased differential stress, temperature and strain rate. Evidence of early mesoscopic strain (e.g., sheared stylolites, strained crinoid stems, etc.) suggests that layer-parallel shortening under these conditions probably was accommodated by semi-ductile processes prior to significant folding. Subsequent detachment folding of these layered rocks was initially dominated by flexural slip, with associated strike-parallel and/or strike-perpendicular shear and extension fractures. As the detachment folds tightened, ductile processes became increasingly important in the cores of the folds, resulting in the development of dissolution cleavage and local transposition of layering. However, with waning folding and/or uplift, temperature, strain rate and differential stress decreased and the rocks once more deformed brittlely, with formation of late, strike-normal NNW-oriented extension fractures.

This general deformational sequence suggests that extension fractures with similar orientations but due to different stress regimes may form at different times during the evolution of a fold-and-thrust belt. This may explain apparently conflicting relative ages of extension fractures in these structural settings. Recognizing these different generations of fractures and their timing of formation with respect to folding has important implications for predicting fracture distribution in folded reservoirs and consequent reservoir quality..