Growth of basement fault-cored anticlines

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Buckle folds and forced folds (Fig. 1) have been opposed through the deformation or not of the basement rocks underlying the sedimentary cover. The deformation of the basement in the forced fold model is simplified and assumed a localized thrusting surrounded by rigid blocks. Thus, the shape of the fold is mainly controlled by the geometry of the thrust fault and the stresses in the overlying fold are exclusively those arising from below.

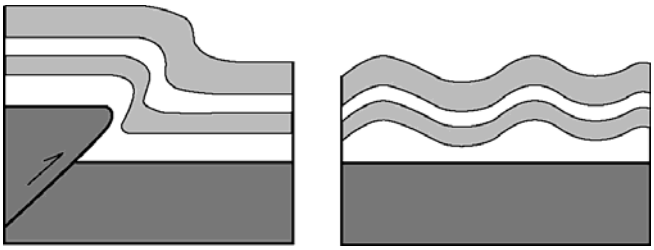

Fig. 1: Left: Trishear model of a forced fold. The basement (dark gray) deforms only along the thrust fault. In the cover (light gray), deformation occurs exclusively in a triangular zone attached to the fault tip where some shear folds the layers. Right: sketch of buckle folds. The cover is folded above an un-deformed basement that is not shortened.

Since the 50's, however, geologist have shown distributed deformation in basement blocks at significant distance from the thrust fault. On seismic lines through various uplifts in the Rocky Mountains (Fig. 2), one can see clear curved basement-cover interface that witnesses a distributed deformation in the basement. Field study in basement rocks have also shown distributed deformation throughout the basement around thrust faults.

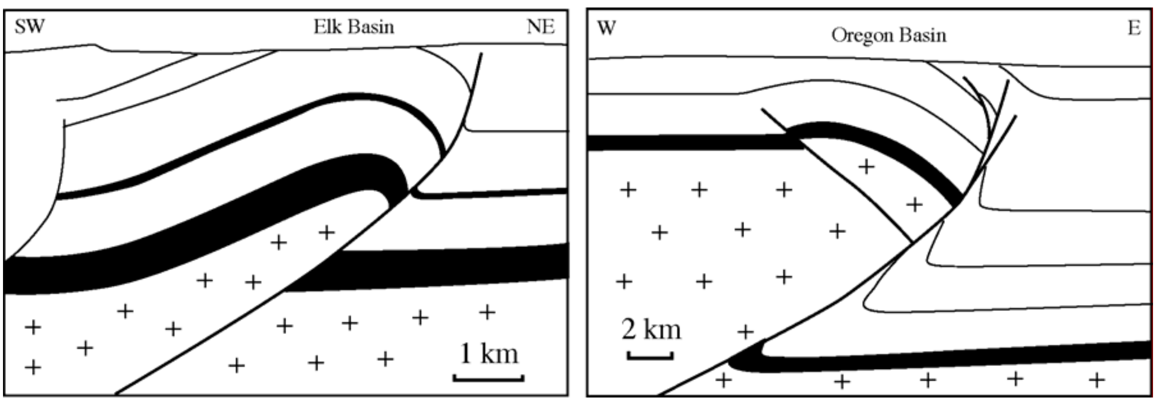

Fig. 2: Line drawing from interpreted seismic lines in From Stone (1993). Note that the basement-cover interface is curved, suggesting distributed deformation in the basement hangingwall block.

Another way to discuss the basement rocks behavior is to study fracture patterns in the sedimentary layers of a fold and determine if the patterns are compatible with a rigid basement or not. In this study we show that, at Sheep Mountain, a Laramide fold in Wyoming, USA, a vertical, compression-parallel joint set apparently formed during the early Laramide orogeny, at the very beginning of the folding event. Field data indicate that this joint set has a heterogeneous distribution over the fold: joints are much less numerous in the forelimb than in the hinge and backlimb (Fig. 3a).

Using 3D elastic dislocation models (Fig. 3b), we show that early slip along an underlying thrust fault would have locally perturbed the surrounding stress field, inhibiting joint formation above the model fault tip line. Relating the absence of joints in the forelimb of the Sheep Mountain Anticline to this stress perturbation, we are able to constrain the forelimb kinematics finding that the forelimb was originally located in the hangingwall, above the upper tip of the thrust fault. Thus, the mode of folding at Sheep Mountain is constrained: the anticline developed with a fixed hinge and rotating limbs, while the underlying basement rocks deformed (Fig. 3c).

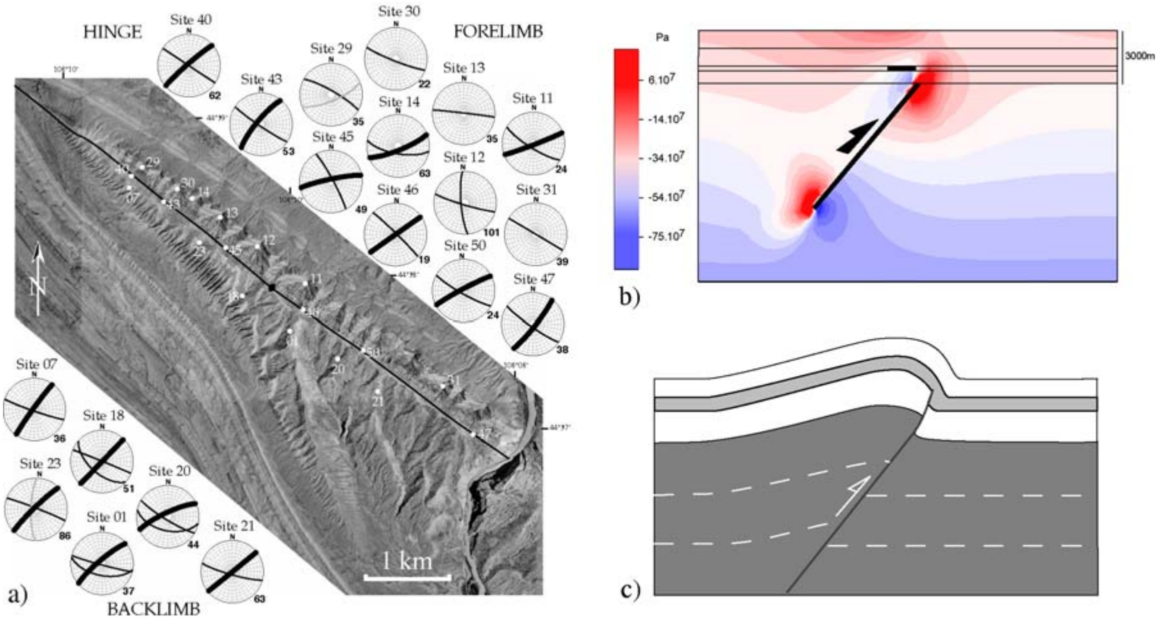

Fig. 3: a) Fracture data at Sheep Mountain Anticline, Wyoming, USA. The NE-SW early fractures (thick great circle) are present in both the backlimb and the hinge, but are significantly less abundant in the forelimb. b) Elastic model of stress perturbation around a thrust fault. In blue, compressive stresses, in red, tensile stresses. c) Conceptual model of a basement fault-cored anticline. The fold grows above the fold due to the basement distributed deformation. The hinge is fixed and the limbs are rotating.

This study illustrates the fact that the basement blocks (around thrust faults) may deform during the folding. This has been shown and suggested many times in the past but rarely taken into account in conceptual, kinematical, analogue, and mechanical models. Considering that, the differences between buckle and forced folds may not be that extreme (yet important). Especially, the way stresses are transmitted to the cover, in the basement fault-cored fold, is not exclusively vertically but also horizontally due to the far field compression. This has drastic consequences on fracture initiation and reactivation in the cover and the activation of other deformation mechanisms (pressure solution, for example).