University of Anbar

College of Science

Department of Applied Geology

Structural Geology

Title of the lecture

Relations between folds and thrusts

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Relations between folds and thrust

Research in thrust belts has shown that most folds are ultimately generated by fault movement at depth. There is a systematic and predictable geometric relation between a fold and the thrust that generated it. Thus, we can use the geometry of an exposed fold to infer the position and geometry of a fault at depth. The kink-like character of folds in thrust belts can be generalized in cross-section construction by use of the ‘‘kink-fold’’ method, which is described below. This method, developed in the early 1980s by John Suppe, assumes that the folds are produced by a flexure-slip mechanism so that bed thickness does not change. This assumption of constant bed thickness will be taken, but it must be established for each individual geologic situation. Another assumption of the kink-fold method is that the footwall remains undeformed during the formation of folds in the hanging wall.

Many folds in thrust belts are associated with underlying thrust ramps. Two types of ramp-related folds are the most common. These are fault-bend folds and fault-propagation folds, each of which is described below.

Fault-bend folds

Fault-bend folds occur where a thrust fault steps up from a structurally lower flat to a higher flat. Figure (1) shows the evolution of a fault-bend fold. Initially, two kink bands form in the hanging wall, one above the base of the ramp, and the other above the top of the ramp (Fig. 1a). With continued slip on the fault, these two kink bands grow in width (Fig. 1b). As the truncated hanging wall moves up the ramp, and the two kink bands widen, an anticline forms at the top of the ramp. This anticline terminates downward into the upper flat (Fig. 1c). The ramp anticline grows in amplitude as the kink bands grow in width. Meanwhile, one syncline develops at the base of the ramp, and another develops on the foreland-side of the anticline (Fig. 1c). Note that the ramp height determines the amplitude of the fold, which, in turn, determines the structural relief. Notice that throughout the development of a fault-bend fold, axial traces A and B coincide with the top and bottom of the ramp, respectively, and the hanging wall ‘‘rolls’’ through these hinges as it traverses the ramp. The other two axial traces (A' and B') migrate along the fault, but they are fixed with respect to the rocks in the hanging wall. When the cutoff point of the lowest stratigraphic unit in the upper plate reaches the upper flat (Fig. 1c), the fold ceases to grow in amplitude, but the distance between the axial traces of the ramp anticline (A and B' in Fig. 1c) increases with increasing displacement. In a fully developed fault-bend fold, axial traces A and A' are fixed with respect to the hanging-wall rocks, and they move along the flat with movement on the fault.

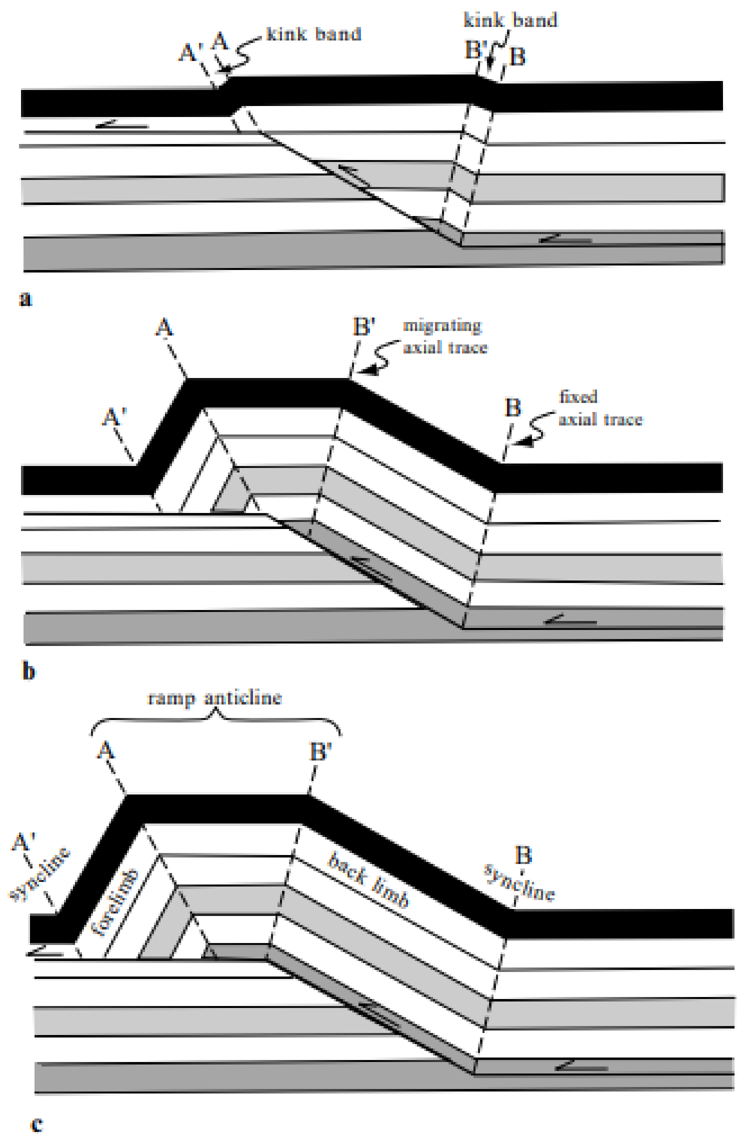

Figure 1: Progressive development of a fault-bend fold as the thrust sheet moves over a ramp in a decollement (after Suppe, 1983). Letters A, A', B, and B' denote the axial traces.

Note that all fold axial traces bisect the interlimb angle of the fold, i.e., the angle between adjacent panels. Look at (Fig. 1c) again and note the following important relations between an exposed fault bend fold and the associated thrust. These relations allow us to infer subsurface fault geometry from known fold shape.

1. In originally horizontal or gently dipping strata, the backlimb of the hanging-wall anticline always dips more gently than the forelimb.
2. The dip of the backlimb is equal to the dip of the ramp in all stages of fold growth.
3. The axial trace of the hanging-wall syncline (axial trace B) terminates at the base of the ramp.
4. In a fully developed fault-bend fold, the axial trace that separates the backlimb from the upper flat (axial trace B') terminates at the top of the ramp.
5. For every hanging-wall cutoff there must be a corresponding footwall cutoff of equal stratigraphic thickness.
6. For every hanging-wall flat there must be a corresponding footwall flat of equal length.

Fault-propagation folds

In a fault-propagation fold, rather than stepping from one flat to another, the fault simply dies out upward, into the axial surface of a syncline (Fig. 2). A fault-propagation fold is the surface expression of a blind thrust. Shortening above the fault terminus, or fault tip, is accommodated by folding. As is the case with fault-bend folds, there are several important relations between the exposed fault-propagation folds and the associated thrusts that allow us to infer fault geometry at depth. Note that in both types of folds the axial trace bisects the interlimb angle of the fold. This is the geometry required to preserve constant bed thickness.

1. In cases where the fault cuts originally horizontal (or gently dipping) strata (as in Fig. 2), the backlimb dips more gently than the forelimb. In general, fault-propagation folds are more strongly asymmetric than are fault-bend folds, and the forelimb of a fault-propagation fold is typically very steep to overturned (Fig. 2c). This characteristic alone

is an important clue about the type of fold you are dealing with, especially in the absence of other information.

2. The dip of the backlimb is equal to the ramp angle.
3. The axial trace of the syncline that forms on the hinterland-side of the fold (axial trace B in Fig. 2) terminates at the base of the ramp.
4. The thrust terminates in an asymmetric syncline that forms on the foreland side of the structure. The fault tip lies at the intersection of the synclinal axial surface and the thrust ramp (Fig. 2c).
5. The fault-propagation model of fold formation explains why box folds commonly reduce to simple chevron folds in their cores. The two axial traces of a box-like fold (A and B' of Fig. 2c) bound a flat panel that separates the backlimb from the forelimb of the anticline. The stratigraphic horizon at which the fault terminates is the same stratigraphic horizon at which the two axial traces merge to form a single axial trace (Fig. 2c). This single axial trace bisects the angle between the fold forelimb and fold backlimb (Fig. 2c).

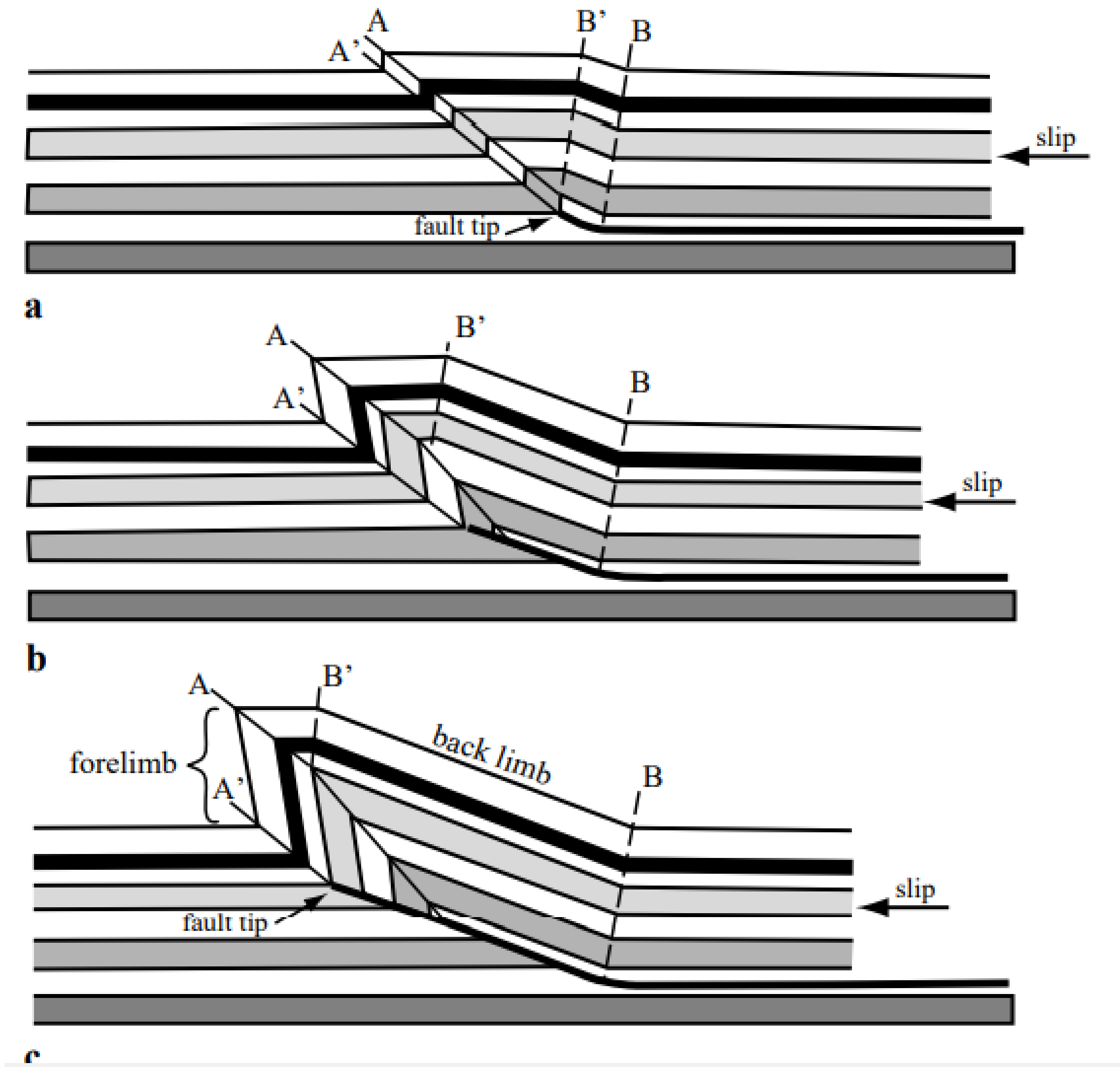

Fig. 2 Progressive development of a fault-propagation fold at the tip of a thrust, as the thrust sheet moves over a ramp in a decollement (from Suppe, 1983). Letters A, A', B, and B' denote the axial surfaces. Note that the fault tip coincides with the hinge of an asymmetric syncline.

References

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