Partitioning and Transfer of Displacement Through a Shortened and Thickened Zone: Implications for the Development of Structures in the Central Alberta Foothills

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Summary

A deformation zone that shortens and thickens, through duplexing or folding, provides a mechanism for transferring displacement from a lower stratigraphic level to a higher stratigraphic level. The shortening and thickening reduces displacement along the lower detachment by an amount that is commensurate with the amount of shortening and thickening. Within a short horizontal distance, displacement is transferred from a lower slip surface to an upper slip surface. In our study area it provides a relatively steep kinematic linkage between the basal detachment surface and thrust faults at the ground surface.

Introduction

Within portions of the Central Alberta Foothills, Palaeozoic strata are carried several kilometres toward the foreland along very low-angle thrust faults. The angle between the dip-directed ramp and stratigraphy at the Palaeozoic level can be less than fifteen degrees. Just to the foreland of the Palaeozoic hanging wall cut-off is the surface expression of a thrust fault that appears to be linked to the thrust fault at the Palaeozoic level. Tying the fault at surface directly to the fault at the Palaeozoic level requires a very steep kinematic linkage. Seismic data that image the upper and lower thrust faults do not show a simple linkage between the faults. It appears that a deformation zone with shortening and thickening is the mechanism that ties the two thrust faults together.

Identifying a zone with large amounts of deformation can be challenging. Seismic images of the deformation zone rarely show the intensity of the deformation; they typically show relatively smooth and continuous events. Three lines of evidence point towards the presence of a deformation zone linking the two faults together. 1) The interpretation of fault geometries based on good quality 3-D seismic data often produce inconsistencies in the displacement along the thrust faults. The inconsistencies may be due to linked folding and duplexing that accommodate changes in displacement along the fault surface. 2) Units within the deformation zone are thickened considerably compared to their counterparts in the undeformed Plains to the east. 3) Well data with dip meter or image logs confirm that small scale folding and faulting has significantly thickened stratigraphic units.

Discussion

Conservation of volume requires horizontal shortening to produce vertical thickening, assuming movement during deformation does not take place in the strike direction (Dahlstrom, 1969, p. 745). Figure 1 illustrates a deformation zone developing between a lower and an upper slip surface. The lower unit remains stationary whereas the middle unit shortens and thickens and the upper unit passively slides over the middle unit. Note how displacement along the upper and lower slip surfaces changes along their lengths. Relative displacement increases to the right along the upper slip surface whereas relative displacement decreases to the right along the lower slip surface. The change in displacement along the upper and lower slip surfaces is directly linked to the local shortening and thickening of the middle unit. Displacement is transferred from the lower slip surface to the upper slip surface in a manner that is commensurate with the amount of shortening and thickening of the middle unit. The deformation model presented in Figure 1 is a simplified model based on the concentric fold model of Dahlstrom, (1970, p. 363) and the duplex model of Boyer and Elliott (1982, p. 1208).

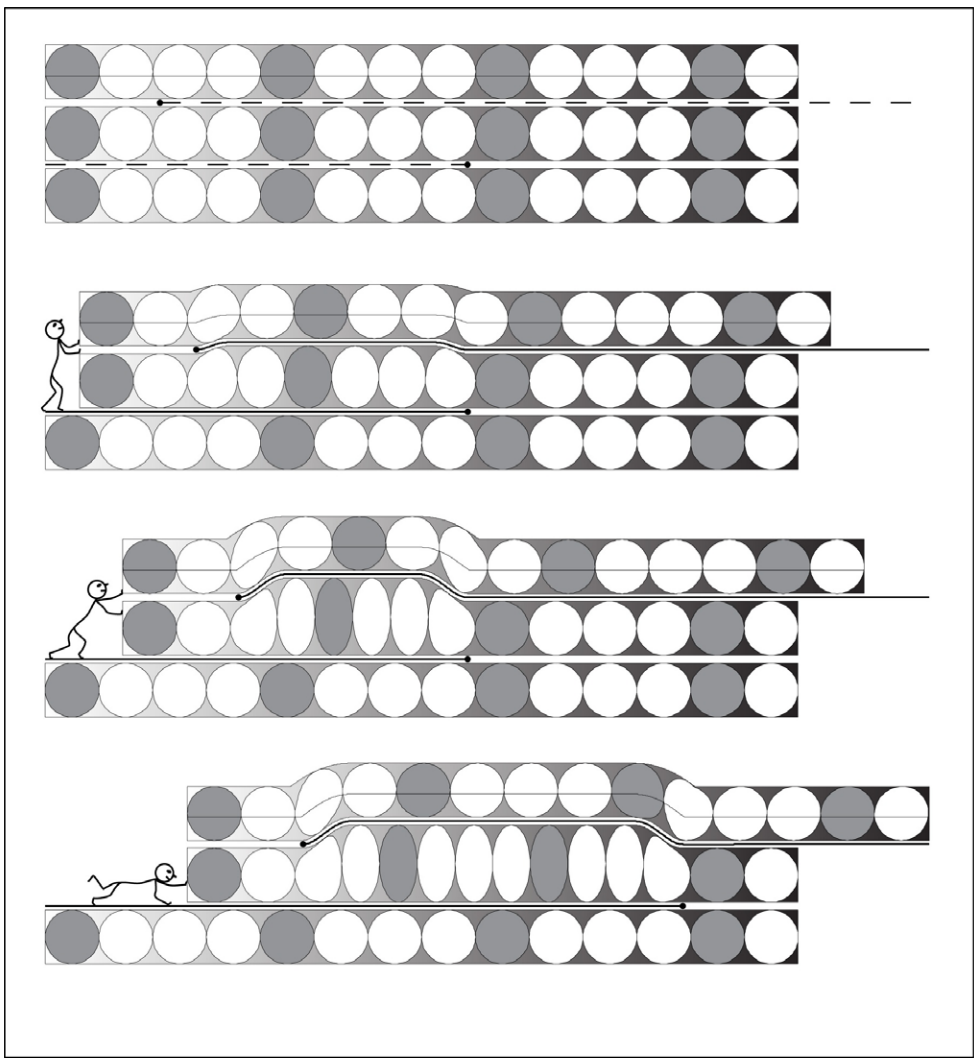

Figure 1: Deformation zone model. The four panels show a kinematic model as it develops increasing deformation. The upper panel shows the initial state with no deformation. The stick person shows displacement along the lower slip surface. Strain ellipses show the shortening and thickening within the middle unit. The upper unit slides on the upper slip surface and passively folds over the deformed middle unit.

In our study area the lower slip surface does not terminate at the tip point but instead continues to the foreland where it is linked with shortening and thickening in the deformed Plains and the upper slip surface does not continue horizontally to the right but rises up to the surface along a dip-directed ramp. Our model suggests that the surface expression of the Ancona thrust fault is directly linked to shortening and thickening of the middle unit and a decrease in displacement along the basal detachment.

Displacement along the basal detachment surface that enters the deformation zone from the hinterland is partitioned into displacement that continues toward the foreland and displacement that is transferred to shortening and thickening of overlying units. The decrease in displacement along the lower detachment expresses itself through shortening and thickening of overlying units and an increase in displacement on the Ancona thrust fault. Measuring the amount of shortening and thickening of the middle unit can provide an estimate of the amount of displacement that is transferred from the lower slip surface to the upper slip surface.

The cross-section in Figure 2 shows a thrust fault at surface located to the southwest of the Ancona thrust fault. To the north of the cross-section the surface expression of the fault separates into four distinct faults: the Beaverdam, Brazeau, Chungo and Canyon Creek thrust faults. All of the foreland-verging thrust faults shown on the cross-section in Figure 2 are linked to a zone of shortening and thickening just off the southwestern edge of the section. As the surface expression of these faults separates to the north, how is this reflected in the deformation zone at depth? Does the zone of shortening and thickening at depth separate in a similar manner to the north or is the linkage weakly coupled? Future work will include examining the nature of the variation along strike of the linkage between the deformation zone and the upper and lower slip surfaces.

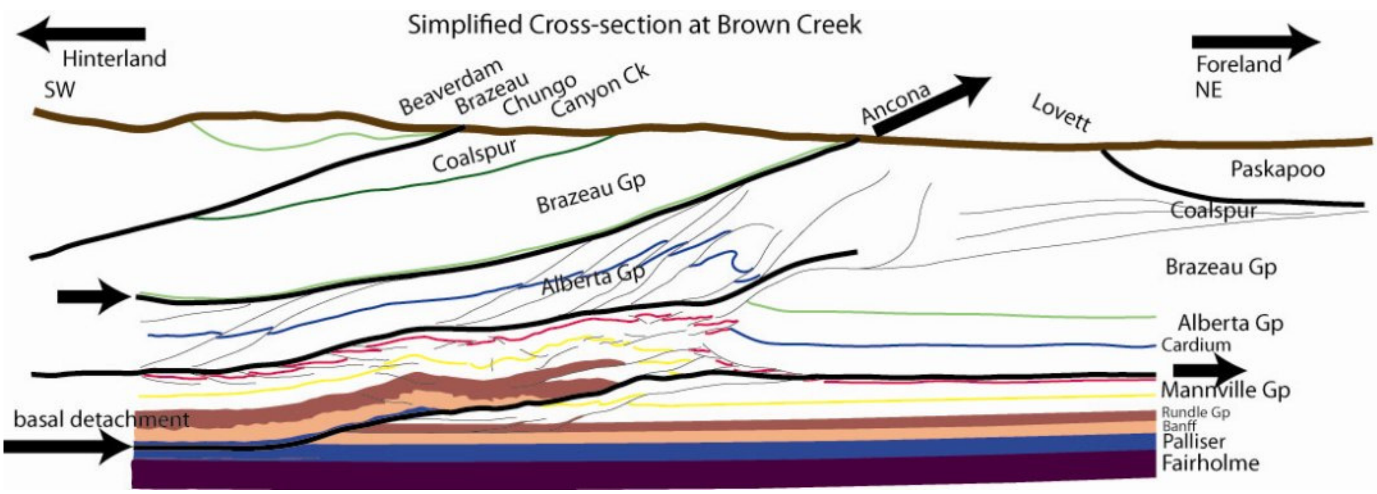

Figure 2: Simplified cross-section at Brown Creek based on seismic and well data. Lengths of arrows are not to true scale but do represent amounts (in a relative sense) of displacement along detachment surfaces. Palaeozoic strata are in solid colours whereas younger strata are shown in outline. The progressive loss of displacement left to right along the lower detachment is progressively gained by the upper detachment.

Conclusions

A deformation zone that shortens and thickens stratigraphic units transfers displacement from a lower slip surface to a shallow slip surface. The amount of displacement transferred between slip surfaces is directly related to the amount of shortening and thickening. The deformation zone provides a mechanism for developing a relatively steep kinematic linkage between the basal detachment at depth and a fault at the ground surface.

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