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Research paper

Fault patterns associated with extensional fault-propagation folding

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ABSTRACT

Extensional fault-propagation (drape) folds are a common type of structure in rift basins, and a number of oil and gas fields produce from these structures. The detailed geometry and trap volumes are dependent on the relationship between the basement faults and the overlying folds and associated secondary faults in the sedimentary cover. Experimental models were used to study the 3-D geometry and secondary fault patterns of drape folds associated with single faults and two or more intersecting faults. Two-layer clay models, consisting of stiff and soft clay were used to model the deformation zones in the basement and sedimentary cover, respectively. Extension on single basement faults normal to the direction of extension results in the development of a deformation zone with expanding width, in which the fault density initially increases and then remains approximately constant. Extension on terminating faults results in conical drape folds with faults oblique to the fold axis along the propagating tip. Basement faults oblique to the direction of extension are characterized by oblique secondary faults along the boundaries of the deformation zone, which curve into a direction normal to the extension direction in the center.

Trapdoor fault geometries associated with two or more intersecting faults result in a triangular uplift with maximum relief at the apex. The difference in relief between the flanks and the apex is greatest in the case of propagating basement faults. En echelon secondary faults initiate on the flanks and extend into the apex area, curving into orientations that are closer to normal to the regional direction of extension. The width of the fault zone and the total fault length increase with increasing extension. The fault density initially increases and then remains approximately constant with increasing extension.

1. Introduction

Extensional fault-propagation folds, also known as drape folds or forced folds (Stearns, 1978), are recognized as a common type of structure in rift basins. The structures involve folding and secondary faulting within the sedimentary cover above basement-involved normal faults (Fig. 1). The fault slip on the basement fault is dissipated within a triangular deformation zone, also referred to as a trishear zone (Erslev, 1991). Variations of the basic model have been developed and applied to the interpretation of both surface and subsurface structures. Numerous examples of drape folds have been documented from the Moray Firth in the North Sea, the Norwegian Sea, the Gulf of Suez, and the Sirte basin, as well as from other basins (Linsley et al., 1980; Withjack et al., 1989; Pascoe et al., 1999; Sharp et al., 2000; Jackson et al., 2006). The geometry of map view structures have also been studied (Withjack and Callaway, 2000; Dooley et al., 2003). Deformation associated with drape folding has been modeled in cross-sectional view (Withjack et al., 1990; Jin and Groshong, 2006; Miller and Mitra, 2011; Mitra and Miller, 2013; Cardozo et al., 2011).

Mapping of drape folds requires a better understanding of their three-dimensional geometry and the patterns of secondary faults. Single faults are associated with plunging out of drape folds as the faults lose displacement along trend, whereas intersections of two sets of faults results in trapdoor structures. Both of these patterns are commonly observed in rift basins. Therefore, map patterns need to be studied for through going, laterally propagating, and terminating faults, as well as for sets of intersecting faults.

In this paper, we study the three-dimensional geometry and associated fault patterns for single faults and trapdoor structures using two-layer experimental models. The results of the study provide insights on the geometry and fault patterns for surface and subsurface basement structures and can be used to analyze similar structures with limited data.

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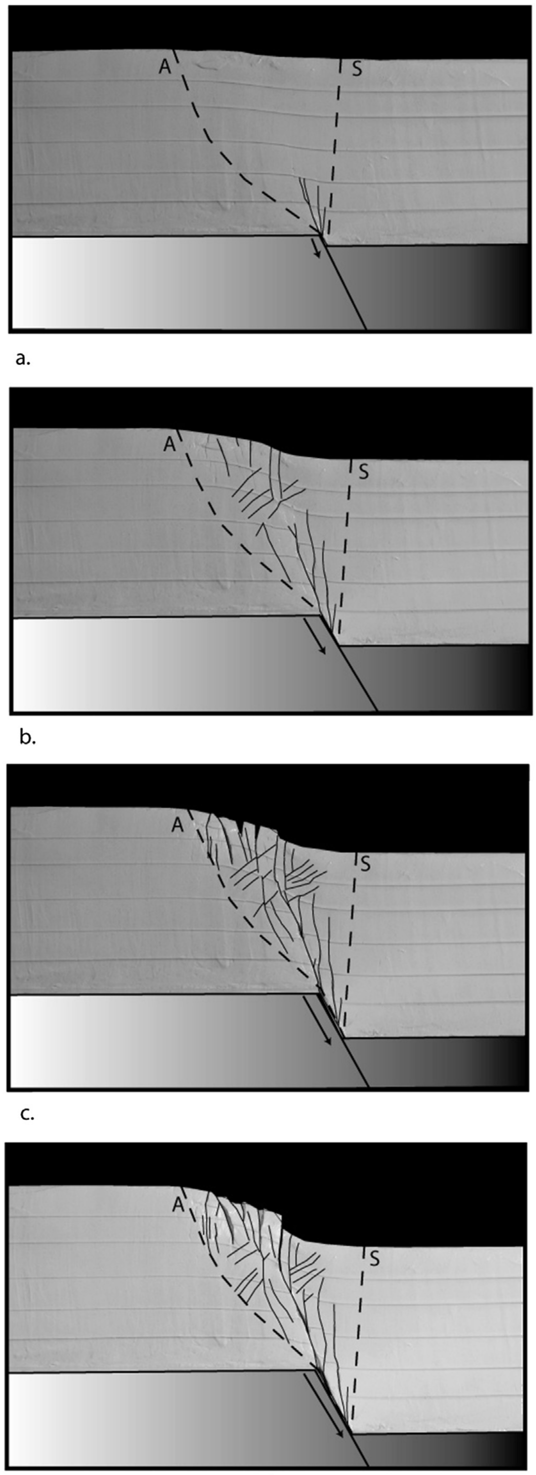

Figure 1. Experimental model of the progressive evolution of an extensional fault-propagation fold (drape fold) related to a basement fault dipping 60° in profile view. The basement slip is dissipated within the trishear zone bounded by the anticlinal (A) and synclinal (S) axial surfaces. The positions of A and S shown are the final positions at the end of the experiment. Modified from Miller and Mitra (2011).

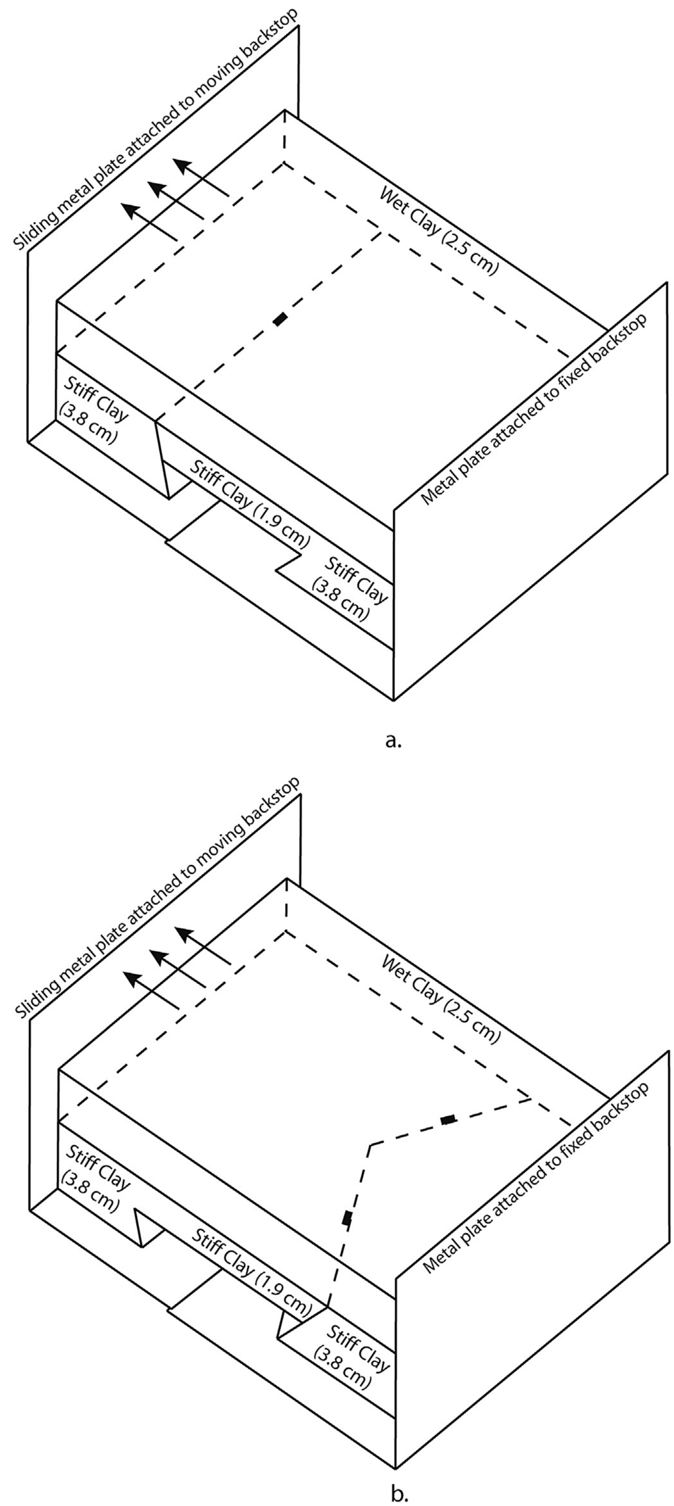

Figure 2. Experimental setup showing the configuration of base plates, the moving and fixed backstops, and the stiff and soft clay, which represent the basement and overlying sedimentary cover. Pre-existing cuts in the stiff clay represent preexisting basement faults which propagate both laterally and upwards through the soft clay with extension. a. Single faults. b. Trapdoors consisting of two intersecting faults. Detailed variations for each of these configurations is provided in Figure 3.