THE TYPES AND ROLE OF STEPOVERS IN STRIKE-SLIP TECTONICS

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ABSTRACT: Stepovers are fundamental features along strike-slip faults of various lengths. Two types of stepover between strike-slip faults are considered in this paper: (1) along-strike stepovers that are due to en echelon arrangement of faults in map view, and (2) down-dip stepovers that are due to en echelon arrangement of faults in cross section. Along-strike stepovers produce pull-apart basins and push-up ranges depending on the sense of stepover. Down-dip stepovers of both senses may produce strike-slip faults in orientations different from the initial major strike-slip faults that are arranged en echelon. Some possible mechanisms that produce stepovers and control the sense of stepover are (1) bending of initially straight faults, (2) faulting within a weak zone oriented slightly off a local failure plane, (3) segmentation of faults to accommodate curved fault traces, (4) horizontal slip across pre-existing extensional fractures or dip-slip faults that have steps, (5) a change of physical parameters such as elastic moduli and pore pressure, and (6) stress field resulting from fault interaction.

INTRODUCTION

There has been an increasing interest in stepovers associated with strike-slip faults in recent years. It is now believed that stepovers on, or en echelon segmentation of, strike-slip faults is the rule rather than the exception. Numerous examples of stepovers of a wide range of sizes along strike-slip faults from all over the world are described in the literature. A few recent publications (e.g., Aydin and Nur, 1982; Mann et al., 1983; Bahat, 1984) provide surveys of previously recognized stepovers as well as a number of new ones.

The objectives of this paper are (1) to identify basic types of stepover, (2) to describe the geometry of the secondary structures associated with pull-apart basins, (3) to emphasize the role of stepovers in strike-slip tectonics, and (4) to explore possible origins and mechanisms of stepovers on strike-slip faults. A rather different classification of en echelon strike-slip faults, based on the map traces of the faults, has been given by Sharp (1979). In spite of numerous field and theoretical studies of pull-apart basins and push-up ranges (for references see the papers cited above) the nature and the orientation of the secondary structures and the origins of stepovers remain obscure.

TYPES OF STEPOVERS

Stepovers associated with strike-slip faults may be classified into two major groups: (1) stepovers along the strike of faults, and (2) stepovers along the dip of faults. Along-strike stepovers are observed in map view. The traces of strike-slip faults jump right or left but the faults are continuous in the dip direction (Fig. 1A). Down-dip stepovers occur when steps are along the dip direction of otherwise continuous strike-slip faults (Fig. 1B). These two markedly different varieties are likely to be the idealized end members of a continuous range of stepover configurations. For simplicity, in this paper we will be concerned with the two end members.

Both types of stepover may occur on the same fault or fault zone. Figure 1C elucidates the kinematics of a strike-slip fault system that includes along-strike (top view) and down-dip (side view) stepovers. As suggested in the figure, the nature of the deformation at the two stepovers is such that the left-lateral motion between the two blocks is accommodated in the most efficient way. Before discussing the nature of the deformation at these two types of stepover, it is necessary to deal with the mechanism(s) by which strike-slip faults initiate and propagate. As will be shown in this paper, the nature and geometry of such deformations are dependent largely upon the geometry of strike-slip faults at both the initial and successive stages of the faulting.

Micromechanisms for the initiation and propagation of faults are complicated and the matter is far from being resolved. We are evaluating here only the implications of two basic mechanisms of initiation and growth of strike-slip faults for the formation of, and deformation at, stepovers without analyzing the details of the processes involved in faulting. These two mechanisms are (1) shear faulting and (2) horizontal slip on pre-existing fracture planes such as joints and high-angle dip-slip faults.

Consider the lateral propagation of two non-colinear strike-slip faults (Fig. 2A). Two possibilities are likely to occur in this situation. If the separation between the faults is large enough, the neighboring fault tips will pass each other and propagate farther, resulting in parallel faults. On the other hand, if the two faults are close enough so that they interact, the two faults hinder each other's growth and form en echelon geometry (Fig. 2B, C). The critical value of separation for interaction or non-interaction is controlled primarily by the lengths of the faults and the prevailing stress system. An upper bound value of the critical separation can be estimated by examining the spacing of parallel faults of comparable lengths with about one hundred percent overlap in the same deformation domain. Exceptions to this rule may occur as a result of strain hardening or softening behavior within shear zones and perhaps different frictional behaviors of the faults involved.