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Mechanical analysis of the geometry of forced-folds

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Abstract

A mechanical model of forced-folding, comprised of an anisotropic cover overlying displaced, rigid basement blocks, is used to investigate the influence of various parameters on theoretical fold form: shape and dip of basement fault, strength of basement-cover contact, and degree of anisotropy of the cover. We show that the degree of anisotropy in the cover largely influences the geometry of the forelimb of the forced-fold. Folds produced in isotropic cover display forelimbs that taper from large dip angles near the basement-cover contact to low dip angles at the ground surface. In contrast, dips in the forelimbs of folds in anisotropic cover are nearly uniform with depth. We show that the basement-cover contact and the shape of the basement fault largely influence the geometry of the backlimb. Backlimb rotation occurs in cover welded to the basement and in cover underlying curved basement faults. In addition, the kinematic features of the theoretical folds are compared with the fold geometry generated by parallel kink and trishear models. Folds in isotropic cover overlying straight basement faults closely resemble the fold forms produced by the trishear kinematic model while fold forms in anisotropic cover more closely resemble folds produced by parallel kink geometric constructions. © 2002 Elsevier Science Ltd. All rights reserved.

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1. Introduction

Typical structures in the Rocky Mountain Foreland of the western United States are fault-related folds that form over basement faults. Outcrops and seismic profiles show that the folds are typically asymmetric monoclines with long, gently-dipping backlimbs and short, steeply-dipping forelimbs, overlying straight or curved fault surfaces in basement rock (e.g. Prucha et al., 1965; Stearns, 1971; Reches, 1978; Stone, 1983a,b, 1985; Schmidt et al., 1993). Forced-folding has been proposed as the mechanism for some of these structures. The essential features of the forced-folding mechanism are a sedimentary cover that deforms more or less passively and rigid basement blocks that are displaced along planar or listic faults (Reches and Johnson, 1978; Stearns, 1978). Evidence for undeformed, perhaps rigid, basement blocks that moved during folding of the sedimentary cover has been cited in several folds in the Rocky Mountain Foreland (Prucha et al., 1965; Stearns, 1971; Mathews, 1986; Erslev et al., 1988; Erslev and Rogers, 1993).

Efforts to explain forced-folds have followed three, largely divergent paths: theoretical analysis, experimentation, and kinematic analysis. The earliest study was a combined experimental/theoretical analysis by Sanford (1959), who experimented with clay models and performed theoretical analyses with elasticity theory. Several researchers have theoretically analyzed the deformation of a single layer or multi-layer overlying a buried fault in an underlying, dissimilar material. Reches and Johnson (1978) and Haneberg (1992, 1993) examined the deformation of elastic layers overlying effectively rigid, displaced forcing blocks. Rodgers et al. (1981) analyzed the folding of an elastic layer overlying an elastic half-space containing an inclined edge dislocation. Patton and Fletcher (1995, 1998) developed a mechanical model using viscous folding theory, in which a linear or power-law layer overlies displaced, rigid blocks.

Numerous experimental studies of forced-folding have been carried out using clay and rock. For example, Withjack et al. (1990) performed clay experiments of forced-folds over normal faults and Friedman et al. (1980) formed small forced-folds experimentally in rock specimens subjected to high pressures.

Kinematic models and geometric constructions are methods commonly used in the structural geology literature to describe forced folds. The parallel kink construction of basement-involved folding by Narr and Suppe (1994) assumes that bed length and cross-sectional area are preserved and bed thickness and limb dips are uniform

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