Available online at www.sciencedirect.com
SCIENCE DIRECT
Tectonophysics 415 (2006) 225–238
TECTONOPHYSICS
www.elsevier.com/locate/tecto

Discrete element modelling of the influence of cover strength on basement-involved fault-propagation folding

Stuart Hardy [a,b,*], Emma Finch [c,1]

[a] ICREA (Institució Catalana de Recerca i Estudis Avançats), Spain
[b] GGAC, Facultat de Geologia, Universitat de Barcelona, C/ Martí i Franquès s/n, 08028 Barcelona, Catalonia, Spain
[c] Basin and Stratigraphic Studies Group, Department of Earth Sciences, University of Manchester, Manchester M13 9PL, U.K.

Received 26 August 2004; received in revised form 12 January 2006; accepted 18 January 2006

Abstract

A discrete element model is used to investigate the influence of sedimentary cover strength on the development of basement-involved fault-propagation folds. We find that uniformly weak cover best promotes the development of classical, trishear-like fault-related folds showing marked anticlinal thinning and synclinal thickening, with cover dips increasing downwards towards the fault tip. Uniformly strong cover results in more rounded fold forms with only minor hinge thickening/thinning and significant basement fault-propagation into the sedimentary cover. Heterogeneous, layered, cover sequences with marked differences in strength promote the development of more complex and variable fold forms, with a close juxtaposition of brittle and macroscopically ductile features, which diverge from the predictions of simple kinematic models. In these structures the upper layers are often poor indicators of deeper structure. In addition, we find that in layered cover sequences fault-propagation into the cover is a complex process and is strongly buffered by the weaker cover units.

Keywords: Folding; Faulting; Trishear; Modelling; Basement

1. Introduction

Fault-propagation folds, and their associated blind faults, have recently been recognized as extremely important for their seismic hazard potential (e.g. Shaw and Shearer, 1999; Allmendinger and Shaw, 2000) and for their importance in controlling stratigraphic architectures in sedimentary basins (e.g. Ford et al., 1997; Gawthorpe et al., 1997). They are also the location of many oil and gas traps (e.g. Mitra and Mount, 1998). Where a faulted, rigid basement is involved in the deformation, the folds are sometimes called "drape" or "forced" folds (Stearns, 1978; Fig. 1a,b) where the overall shape and trend are dominated by the forcing (basement) member below, in contrast to other fault-related folds which are the result of fault movement *within* the cover rocks. Here we refer to such structures simply as basement-involved fault-propagation folds. Evidence from well-exposed folds in the Laramide orogen (e.g. Erslev and Mayborn, 1997), the Bighorn

* Corresponding author. ICREA (Institució Catalana de Recerca i Estudis Avançats), Universitat de Barcelona, C/ Martí i Franquès s/n, 08028 Barcelona, Catalonia, Spain. Fax: +34 934021340.
E-mail addresses: stuart.hardy@icrea.es (S. Hardy), Emma.Finch@man.ac.uk (E. Finch).
[1] Fax: +44 1612753947.

0040-1951/$ - see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.tecto.2006.01.002

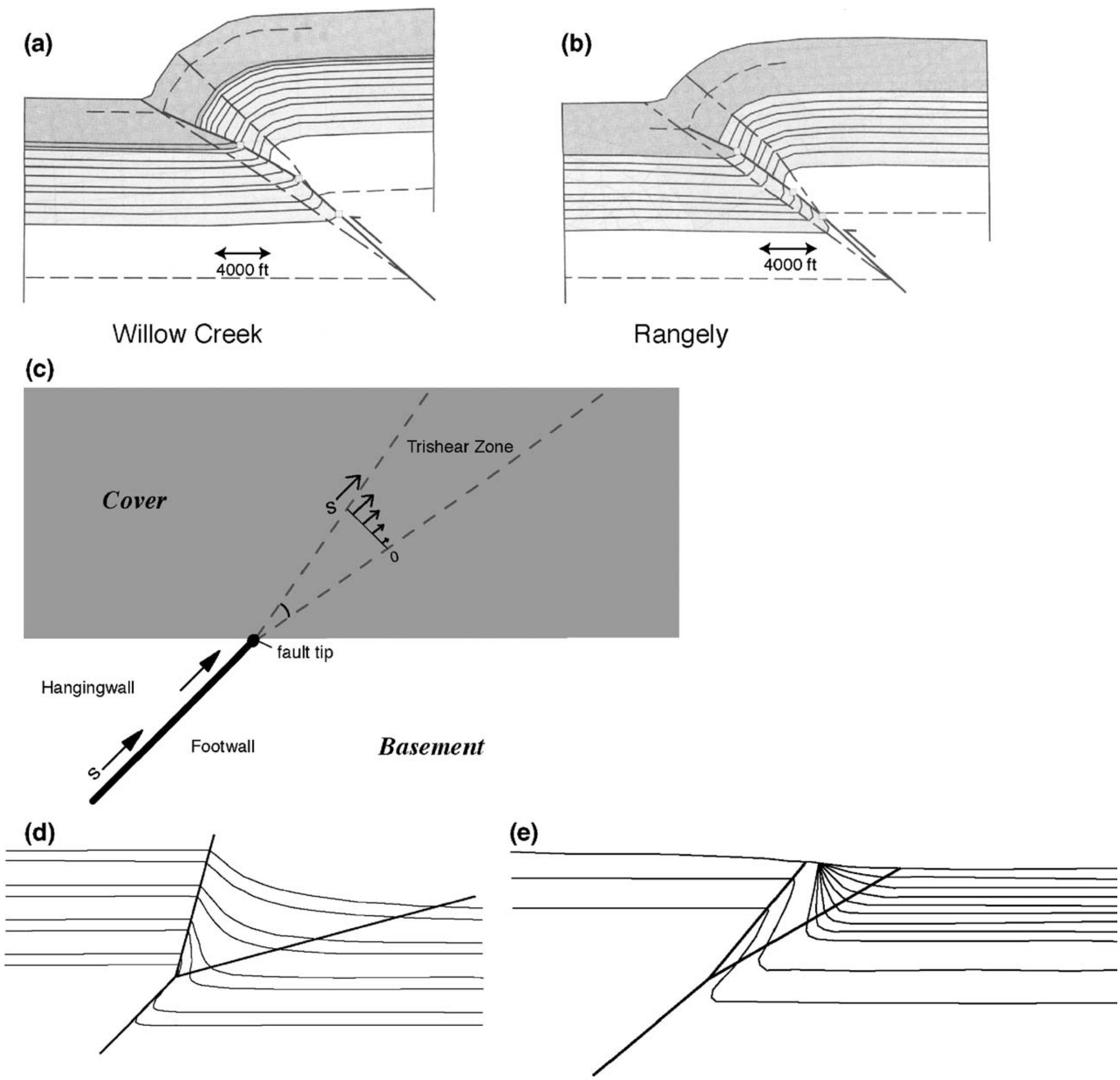

Fig. 1. Natural examples of basement-involved structures: (a) the Willow creek and (b) Rangely anticlines (after Mitra and Mount, 1998), in both cases a fault rooted in deeper basement has propagated into the sedimentary cover causing folding. (c) Schematic diagram illustrating the trishear kinematic model. In the trishear model a triangular zone of distributed shear opens outwards and upwards from the fault tip. The hangingwall moves rigidly parallel to the fault at the slip rate (S) while the footwall is static, with the shear zone acting as a transition between them. The arrows indicate the velocity vectors within the trishear zone. (d) The geometry of a trishear fault-propagation fold, redrawn from Zehnder and Allmendinger (2000), thin lines are bedding tops and thicker lines the fault and trishear zone boundaries. (e) The geometry of a basement-involved trishear fault-propagation fold with growth strata, redrawn from Hardy and Ford (1997).

and Uinta basins (Mitra and Mount, 1998), the Californian peninsular ranges (e.g. Allmendinger and Shaw, 2000), and from analogue (e.g. Withjack et al., 1990; Mitra and Islam, 1994) and numerical modelling (Patton and Fletcher, 1995; Johnson and Johnson, 2002a,b; Cardozo et al., 2003) has indicated that such basement-involved folds form as upward widening zones of distributed deformation (monoclines) above discrete faults at depth. Field studies indicate that a variety of mechanisms are responsible for the distributed deformation including “ductile” flow, bedding slip, rigid rotation and small extensional and thrust faults (e.g. Gawthorpe et al., 1997; Sharp et al., 2000). Analogue modelling studies have shown that with increasing