Detachment Folding

John Suppe

Department of Geosciences, Princeton University, Princeton, New Jersey, USA

Detachment folds seem conceptually to be the simplest of all fault-related folds, yet they continue to offer substantial and rich challenges that are symptomatic of fault-related folding in general. The standard picture of detachment folds goes back to August Buxtorf's widely reproduced 1916 regional cross sections of the Swiss Jura in which he interpreted the Jura box folds to be regionally detached from the basement along a weak layer of Triassic evaporites. However the box folds drawn by Buxtorf were in fact not at all constrained by subsurface data, except along the Grenchenberg railroad tunnel where a surprising and much more complex structure was encountered, involving a strongly folded thrust fault that was encountered three times in the 8.5 km long tunnel. Laubscher (1977) argued that such complexly folded thrust faults are in fact typical of many Jura box folds. Analogous structures have been observed in Canada, Mexico and Spain. Below I argue that that detachment folds with folded thrusts are one of several theoretically expected modes of detachment folding.

Most theoretical progress to date has made use of “toy models” that attempt to capture the essence of detachment folding in its most elemental form. Most of these models have been Buxtorf-like box-fold models or sinusoidal models with a Jura-like mechanical stratigraphy composed of a basal weak deformable detachment layer of finite thickness, overlain by a competent flexural roof sequence (e.g. Wiltschko & Chapple 1977, Jamison 1987, Homza & Wallace 1995, Poblet & McClay 1996). These toy models demonstrate that it is impossible to simultaneously conserve bed length in the flexural roof sequence and area in the basal layer for an isolated closed-system detachment fold with homogeneous shortening, with one geologically unlikely exception.

A number of structurally interesting solutions to this problem exist, which correspond to five primary modes by which detachment folds have been conceived to form: [1] Diapiric solutions exist involving local or regional diapiric flow of the basal layer (Wiltschko & Chapple 1977), for which many examples exist. [2] Duplex solutions exist involving a roof detachment at the top of the basal layer. [3] Roof-ramp solutions exist involving thrusts that ramp upward from the roof of the basal layer. Toy models involving such roof ramps predict structural geometries that are similar to Buxtorf's Grenchenberg anticline and other detachment folds containing folded thrusts that terminate within their cores. Thus the folded thrusts in the roof sequence of many detachment folds many not be fortuitous preexisting complexities, but rather are an essential part of the process of detachment folding. [4] Isoclinal box-fold solutions exist for a non-Jura-like stratigraphy composed of a competent flexural sequence, but with no deformable basal layer of substantial thickness (e.g. Mitra & Namson, 1989). [5] Pure-shear detachment- fold solutions exist involving a non Jura-like stratigraphy that deforms by heterogeneous layer-parallel pure shear, such that area is conserved but bed length and layer thickness are not (Groshong & Ephard 1994, Ephard & Groshong 1995). A number of examples of such pure-shear detachment folds are known. In such folds the operationally- defined curvimetric “bed-length shortening” is predicted to be 1-2 orders of magnitude less that the actual shortening at low-to-moderate limb dips, which is observed in such folds (Gonzalez-Mieres & Suppe 2004). Some of these five conceptual solutions to the detachment- folding problem are known to exist in combination, for example Yakeng