between the frictional and viscous décollements, which is one of the main conclusions of Cotton and Koyi (2000).

Latin lyric poet and satirist Horace has said "In serious works and ones which promise great things; one or two purple patches are often stitched in, to glitter far and wide". Cotton and Koyi's (2000) observation that adjacent décollements with two entirely different mechanical characteristics result in formation of a complicated deflection zone was a 'purple patch' of that article which Costa and Vendeville (2002), unfortunately, seem to have missed.

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Experimental insights on the geometry and kinematics of fold-and-thrust belts above weak, viscous evaporitic décollement: reply to comments by Hemin Koyi and James Cotton☆

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In their comment on Costa and Vendeville (2002), Koyi and Cotton contest some of our statements dealing with their article (Cotton and Koyi, 2000).

Our sentence "The experiments we present in this article suggest that the pattern of forward fold-and-thrust propagation observed in Cotton and Koyi's experiments does not occur in plain-stress, plain-strain models, where the influence of lateral friction has been reduced by lubricating the model's lateral boundaries", regarded by Cotton and Koyi as an 'out-of-place critique', was not written as a demeaning criticism of their work, but was intended merely to explain why and illustrate how folds and thrusts in our models had a drastically different propagation sequence and kinematic history.

The taper and the propagation modes of thrusts in fold-and-thrust belts are controlled by stresses resisting forward advance of the brittle cover. These resisting shear stresses are of two types. The first type of shear stresses are the horizontal shear stresses acting at the base of the cover and associated with sliding above a frictional detachment or gliding above a viscous décollement. The effect of such stresses can be predicted using 2-D computer simulations in dip-oriented cross-sections. The brittle cover responds to shortening by forming a wedge whose width and surface slope angle depends on the magnitude of the basal shear stress. Provided that the length of the décollement/detachment is infinite or very large, folds and thrusts are expected to propagate forward, with younger structures forming in front of older ones. The second type of stresses resisting the advance of the deformation front is related to the third dimension. These are shear stresses acting along any boundaries (whether located within or along the lateral sides of the fold belt) oriented parallel to the direction of transport. Like basal shear stresses, lateral shear stresses resist forward advance of the brittle cover; therefore, their impact on fold-belt evolution is similar: high lateral friction leads to steeper wedge tapers and shorter fold belts.

In numerical models, the influence of lateral shear

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stresses can be readily prevented by designing (1) 2-D models or (2) 3-D models, whose lateral boundaries are free slip. By contrast, experimental (physical) models are inherently 3-D objects; hence, some amount of lateral friction is always present.

The impact of lateral shear stresses on the structural development of fold-and-thrust belts depends greatly on their magnitude relative to other stresses—namely, the basal shear stresses. For example, in the absence of significant lateral friction, shortening of a model detaching above a high-friction layer (glass microbeads, having an angle of internal friction $>20°$) always leads to closely spaced, asymmetric forethrusts, and to a taper typically ranging from 5 to 20°. If, as in Vendeville (1991), lateral shear stresses are applied and their sense and magnitude varied (e.g. if the sidewalls remain fixed or if they move along with the backstop), the overall belt taper can increase or decrease by as much as 5°, and the thrust spacing can change greatly.

The influence of lateral shear stresses is noticeably increased if the basal shear stress is proportionally low—for example, in experiments simulating shortening above a weak, viscous salt layer. With no lateral friction, the critical taper associated with the low basal shear stress should be exceedingly low. As illustrated by Costa and Vendeville (2002), the length of the wedge rapidly exceeds the length of the basin (i.e. the area underlain by salt), as early as after the formation of the first thrust. The second thrust forms against the distal salt pinch-out, and the wedge can no longer grow according to the critical-taper theory. Instead of deforming as a wedge, the cover behaves like a stiff beam resting on a weak matrix. Younger structures form within the belt, rather than in front of older structures. The fundamental reason for the absence of a wedge and the lack of forward thrust propagation in these models is the near complete absence of resisting shear stresses. Without such resisting stresses, the maximum compressive stress can be transmitted effectively across the entire cover's length. The advance of the cover is resisted only by the décollement pinch-out, which acts as a distal buttress.

In Costa and Vendeville's (2002) work, low lateral friction was achieved by coating the sidewalls using a low-viscosity polymer. Vendeville (1991) conducted similar experiments above a weak viscous décollement, but with no lateral lubrication in order to estimate the influence of the magnitude and sense of lateral shear stresses. In one set of models, the sidewalls remained fixed. There, lateral shear stresses were influential enough to trigger the formation of a forward-facing and -advancing steep wedge, with thrusts forming first near the backstop and propagating away from it (i.e. forward, in a piggy-back fashion). A similar kinematic history was described in an experiment by Mulugeta (1988), in which a narrow model was shortened above a layer of mercury. Considering the very low viscosity of mercury, the presence of a wedge and the piggy-back thrust propagation must be attributed to lateral, rather than basal, shear stresses. Note that in Mulugeta's model, the deformation eventually reached the end of the box, although later than Costa and Vendeville's models did. In the second set of models conducted by Vendeville (1991), the sense of lateral shear was reversed by having the sidewalls move forward at the same rate as the backstop. Results were drastically different. Thrusts first formed on the other side of the model, against the wall opposite the backstop, and younger thrusts propagated toward the backthrust. The wedge dipped toward the backstop and advanced toward it (i.e. backward). These results demonstrate that lateral shear stresses can exceed basal shear stresses and therefore control the deformation style.

In summary, results from these two sets of models clearly demonstrate that where the basal shear stress is low, lateral stresses can greatly control the structural outcome.

The above observations can be applied to Cotton and Koyi's (2000) models. Regardless of the physical properties along the sidewalls of their model, the most important boundary in Cotton and Koyi's model is the boundary between a region underlain by a high-friction layer (glass microbeads) and a region underlain by a low-viscosity décollement. A fold-and-thrust belt above a high-friction layer is typically narrow and forms a short and thick wedge that advances slowly. In contrast, in the absence of lateral friction, the neighbouring region (overlying the weak layer) would be wider and form a thin and long wedge advancing faster, in a manner similar to Costa and Vendeville's models. In Cotton and Koyi's (2000) models, however, the fold belt in the 'weak' region advances slowly and only a little, owing to the added friction along the internal boundary, described above, and that along the sidewall. Comparing results of models whose evolution is unimpeded by lateral effects (Costa and Vendeville, 2002) with those subjected to greater lateral shear stresses (Cotton and Koyi, 2000) suggests that such stresses have controlled the fold-belt kinematic history significantly.

In nature, of course, all salt basins have lateral boundaries, along which shear stresses may affect the structural evolution of the entire fold belt. This may be particularly applicable to fold-and-thrust belts in salt salients (e.g. the Monterrey salient, Mexico; Fox and Vendeville, 2000). In many other salt-bearing regions, where the alongstrike length of the belt is vastly greater than its alongdip width, because there the influence of lateral shear stresses should be much lower, using Cotton and Koyi's result to decipher the kinematic evolution of the belt could lead to erroneous conclusions. For example, folds in most salt-cored, deep-water belts have grown coevally, rather than propagated sequentially forward, as predicted by Cotton and Koyi's modelling results (Rowan et al., 2004).

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