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Effects of strain rate on buckling of a thin elastic layer embedded in a viscous matrix

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Deformation of rocks produces structures that are in many cases periodic (folding or boudinage), with variable amplitude and wavelength. We have concentrated on the buckling of elastic layers embedded in a viscous matrix and post-deformation processes. Buckling is the process of layer parallel shortening that transforms an originally planar layer into a curviplanar surface. Buckling can occur at all scales, from microscopic to lithospheric scale. Elasticity theory does not account for the effects of strain rate, hence variations in amplitude and wavelength have been attributed to other factors like variations in thickness of the folded layer. We have chosen physical modelling as a first approach to investigate how a thin elastic layer reacts to shortening at different strain rates. The experiments were conducted on models comprising a thin elastic film embedded in a viscous matrix of silicone putty (PDMS). The thin layer lied with its length parallel to the shortening axis and was shorter than the box length (it did not touch any walls), which means that the thin layer was not pushed from its ends. The model was then subjected to pure shear at different strain rates.

The results show that: (1) fold amplitude and wavelength decrease with increasing strain rate, i.e. their frequency increase exponentially with strain rate; (2) unfolding of the elastic layer after cessation of model deformation is not a reversible process, ie. the particle paths of the elastic layer are not the same in the deformation and post-deformation stages.

Our interpretation is that: (1) the differential velocity between flowing viscous matrix and elastic layer results in traction of the viscous layer on the surface of the elastic layer, and that these stresses increase with increasing strain rate; (2) for low strain rates, the elastic energy building up in the buckling thin layer has enough time to be

dissipated during deformation. Hence, only few buckles form with large amplitude and wavelength. The end case (very low strain rate) would be the formation of only one buckle, or no buckles at all, because of very low shear stresses. In contrast, at high strain rate, the elastic energy rapidly builds up in the buckling thin layer because there is not enough time to dissipate it. Therefore, many buckles form with small amplitude and wavelength.

The buckling dependence on strain rate can be very important for lithopsheric buckling.