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Fold pattern formation in 3D

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The vast majority of studies concerned with folding focus on 2D and assume that the resulting fold structures are cylindrically extended in the out of place direction. This simplification is often justified as fold aspect ratios, length/width, are quite large. However, folds always exhibit finite aspect ratios and it is unclear what controls this (cf. Fletcher 1995). Surprisingly little is known about the fold pattern formation in 3D for different in-plane loading conditions. Even more complicated is the pattern formation when several folding events are superposed. Let us take the example of a plane strain pure shear superposed by the same kind of deformation but rotated by 90 degrees. The text book prediction for this event is the formation of an egg carton structure; relevant analogue models either agree and produce type 1 interference patterns or contradict and produce type 2. In order to map out 3D fold pattern formation we have performed a systematic parameter space investigation using BILAMIN, our efficient unstructured mesh finite element Stokes solver. BILAMIN is capable of solving problems with more than half a billion unknowns. This allows us to study fold patterns that emerge in randomly (red noise) perturbed layers. We classify the resulting structures with differential geometry tools. Our results show that there is a relationship between fold aspect ratio and in-plane loading conditions. We propose that this finding can be used to determine the complete parameter set potentially contained in the geometry of three dimensional folds: mechanical properties of natural rocks, maximum strain, and relative strength of the in-plane far-field load components. Furthermore, we show how folds in 3D amplify and that there is a second deformation mode, besides continuous amplification, where compression leads to a lateral rearrangement of blocks of folds. Finally, we demonstrate that the textbook prediction of egg carton shaped dome and basin structures resulting from folding instabilities in constriction is largely oversimplified. The fold patterns resulting in this setting are curved, elongated folds with random orientation.

Reference

Fletcher, R. C. 1995. 3-Dimensional Folding and Necking of a Power-Law Layer - Are Folds Cylindrical, and, If So, Do We Understand Why. *Tectonophysics* **147**(1-4), 65-83.