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Evolution of large amplitude 3D fold patterns: a FEM study

M. Dabrowski, D.W. Schmid, and M. Krotkiewski
PGP Oslo

The study of three dimensional fold patterns requires numerical models with large numbers of degrees of freedom (>100’000’000). We have developed BILAMIN, an unstructured (geometry fitted) mesh implementation of the finite element method for incompressible Stokes flow that is capable of solving such systems. All repetitive and computationally intensive steps are fully parallel-ized. One of the main components is the iterative solver. We chose the minimum residual method (MINRES) because it allows operating directly on the indefinite systems resulting from the incompressibility condition. We use BILAMIN in a case study of fold pattern evolution. Folds are ubiquitous in nature, and contain both mechanical and kinematic information that can be deciphered with appropriate 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 dome and basin (egg carton) structures resulting from folding instabilities in constriction is incorrect. The fold patterns resulting in this setting are curved, elongated folds with random orientation.