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3D Numerical Simulations of Viscous Single-layer Folding

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Folds are common structures in rocks and occur on all scales. Folds are always three dimensional (3D) structures. The mechanics of folding has mainly been studied in 2D due to the analytical and numerical complexities of 3D folding processes. Results for 2D folding are applicable to natural folds if the natural folds have a dominantly cylindrical geometry. Here, numerical simulations of 3D, incompressible, viscous (Newtonian) single-layer folding are presented. The applied numerical algorithm is based on the finite element method using 3D quadrilateral isoparametric Q2-P1 (27/4) elements, a Galerkin approach and Uzawa iterations to achieve incompressibility. The impact of initial geometrical perturbations on the final fold shape is investigated. Complex 3D fold geometries, which could be interpreted as the result of several deformation phases, are generated by a simple, single deformation phase. For 3D folding, initial conditions appear to have a much stronger impact on the final fold shapes as for 2D folding. Also, in 3D folding studies a huge variety of boundary conditions exist which can have a strong impact on the final fold shape. In this study, the impact of the change in the shortening direction during fold amplification on the final fold shape is investigated. A particular focus is on the relative orientation of the final fold axes to the youngest shortening direction. This study raises several major questions on 3D folding which should be studied in future research. Furthermore, the results of this study have implications for interpreting and reconstructing tectonic deformations using field based fold geometry measurements.