The neutral lines in buckle folds

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The neutral line in a fold is a fundamental concept in structural geology. It divides areas of outer-arc extension from areas of inner-arc compression. Indeed, in natural folds so-called outer-arc-extension structures (e.g., layer-perpendicular extensional fractures) and inner-arc-compression structures (e.g., stylolites, enhanced foliation) can be observed.

In the past, folds have often been constructed kinematically from a given neutral line geometry using the tangential longitudinal strain pattern, for which a continuous neutral line along the fold has to be assumed.

In this study, a mechanical finite element model is used to numerically buckle single-layer folds with Newtonian and power-law viscous rheology. Two neutral lines can be distinguished, the incremental neutral line (zero-contour line of the layer-parallel strain rate) and the finite neutral line (zero-contour line of the finite layer-parallel strain), whereas the former develops first and migrates through the layer from the outer arc towards the inner arc ahead of the latter. Both neutral lines are discontinuous along the folded layer and terminate either at the top interface of the layer (for small shortening values) or at the bottom interface (later during the folding history). For a decreasing viscosity ratio between the folding layer and the surrounding matrix and for decreasing initial amplitude, the neutral lines develop later during the folding history and, for some cases, no neutral line develops. These results are similar for Newtonian and power-law viscous rheology.

The results of the mechanical single-layer simulations are discussed in light of interpreting fold-related structures, such as outer-arc-extension structures and inner-arc-compression structures. Particularly the initiation of brittle structures (e.g., outer-arc extensional fractures or inner-arc thrusts) depends on the momentary stress state within the folding layer. Therefore, such structures may be attributed to the incremental neutral line. On the other hand, enhanced foliation or stylolithes in the inner-arc compressional field may be related to the finite strain and therefore to the dynamics of the finite neutral line.