The neutral lines in buckle folds

Marcel Frehner*

*Geological Institute, ETH Zurich, Sonneggstrasse 5, CH-8092 Zurich
(marcel.frehner@erdw.ethz.ch)

The neutral line in a buckle fold is a fundamental concept in structural geology. It divides areas of outer-arc extension from areas of inner-arc shortening. Indeed, in natural folds so-called outer-arc-extension structures (Figure 1) or inner-arc-shortening structures (Figure 2) can occur.

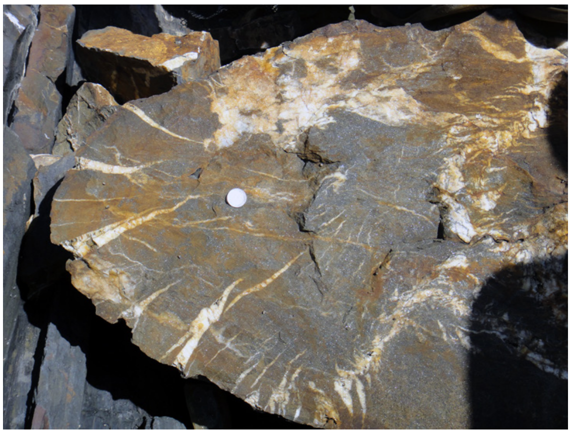

Figure 1: Folded Carboniferous quartzwacke-layer near Almograve, Portugal. Extension in the outer arc of the fold is evident from outer-arc-extension structures, i.e., quartz-filled extensional fractures perpendicular to the folded layer.

Figure 2. Folded Triassic limestone-marl multilayer sequence near Bad Eisenkappel, Austria. Shortening in the inner arc of the multilayer fold is evident from an inner-arc-shortening structure, i.e., a brittle thrust of approximately 20 cm offset.

In the past, folds have been constructed kinematically from a given neutral line geometry using the tangential longitudinal strain (TLS) pattern. In this study, a mechanical finite element (FE) model is used to numerically buckle single-layer folds with Newtonian and power-law viscous rheology. Two neutral lines can be distinguished:

1. The incremental neutral line (INL) (zero layer-parallel strain rate)
2. The finite neutral line (FNL) (zero finite layer-parallel strain)

The former develops first and migrates through the layer from the outer towards the inner arc ahead of the latter (Figure 3). Both neutral lines are discontinuous along the fold and terminate either at the bottom or top interface of the layer. For decreasing viscosity ratio between layer and matrix and for decreasing initial amplitude, the neutral lines develop later during folding and, for some cases, no neutral line develops (Figure 4). The dynamical behaviour of the neutral lines is similar for Newtonian and power-law viscous rheology if the viscosity ratio is large, but substantially different for small viscosity ratios (Figure 5).

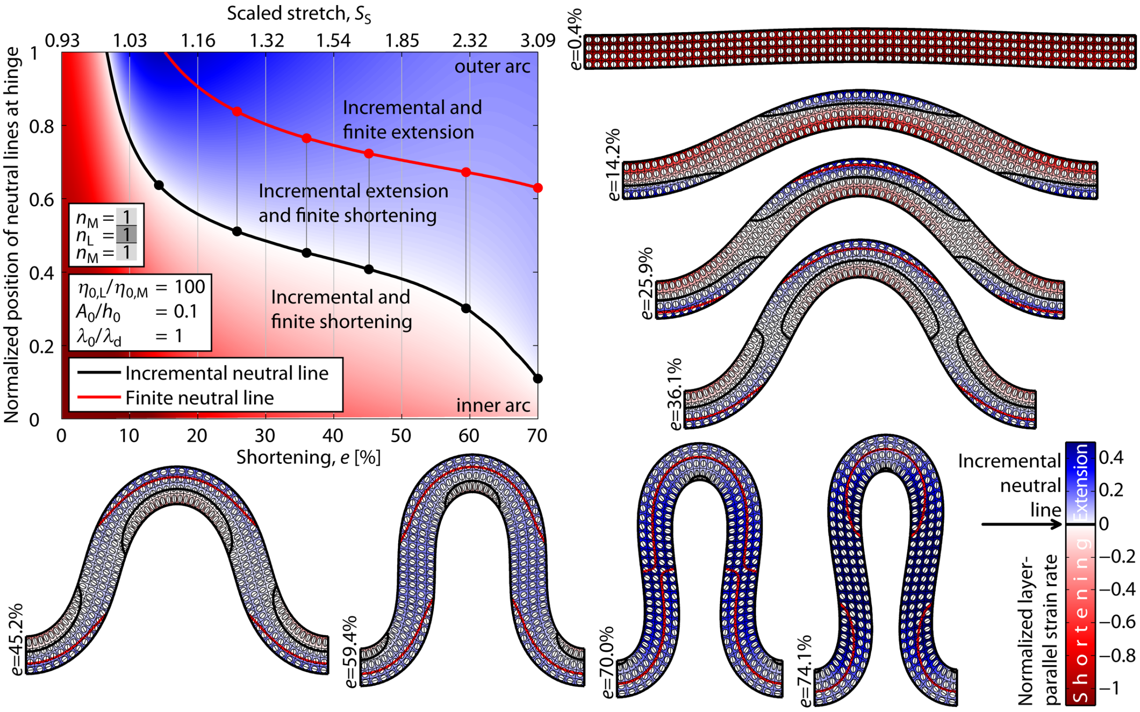

Figure 3. Simulation snapshots of a progressively shortened Newtonian single-layer fold with the indicated modelling parameters. Colours represent the layer-parallel strain rate normalized by the absolute value of the externally applied strain rate. The INL is drawn as a thick black line. The FNL is drawn as a thick red line. Finite strain ellipses with their major axis and a passive, initially orthogonal marker-grid are plotted. The upper-left diagram shows the layer parallel strain rate and the positions of the two neutral lines on the axial plane trace, normalized by the current thickness of the layer at the hinge, with increasing shortening (and scaled stretch). The dots indicate the shortening for which the different simulation snapshots are plotted.

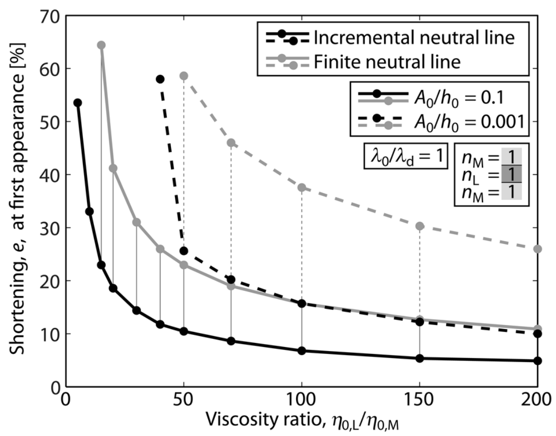

Figure 4. Shortening value at the first appearance of the neutral lines in the single-layer fold for all simulations using a Newtonian rheology.

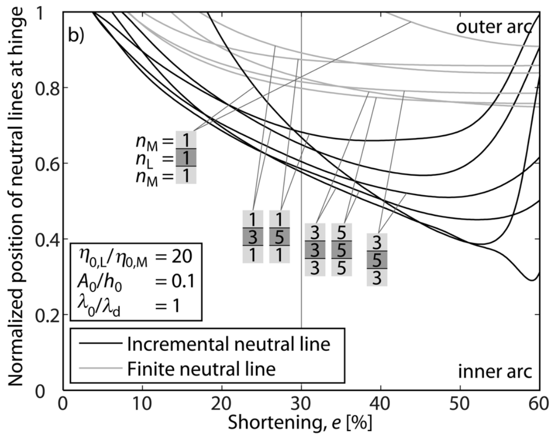

Figure 5. Positions of the two neutral lines on the axial plane trace of different power-law single layer folding simulations, normalized by the current thickness of the layer at the hinge.

REFERENCE

Frehner, M. 2011: The neutral lines in buckle folds, Journal of Structural Geology, doi:10.1016/j.jsg.2011.07.005.