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Otto Ampferer Award Lecture

Computational Structural Geology – Examples from combined fold observations and modeling

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Abstract

Since many years the discipline of structural geology and tectonics is transforming from an observant and descriptive to an increasingly quantitative science. Modern structural geological studies quite commonly use computational modeling software to investigate, for example, deformation processes or the development of rock structures. Such computer simulations add a whole new level of physical understanding to field- and laboratory-based structural geological studies.

Unfortunately, the increasing technical demand for programing and maintaining computational modeling software scares many geologists away and a modeling community developed quite independently from field-based structural geologists. However, Computational Structural Geology can only be of any relevance in combination with field observations, because the ultimate goal of this scientific discipline is the physical understanding of structures that can be observed in nature.

In my award lecture I present two examples of combined field and computational structural geological studies. Both studies are applied to geological folds and emerged during my employment at the University of Vienna.

The first study focuses on structures in and around outcrop-scale folds. For example, outer-arc extension structures (e.g., extensional fractures) and inner-arc shortening structures (e.g., thrusts, pressure solution) may be observed in natural folds (Fig. 1). The conceptual model of the neutral line, an immaterial line on the fold with no deformation, is commonly used to explain the observed structures. Using numerical models of buckle folding (Fig. 1) I could quantify the neutral line in mechanically self-consistent folds (Frehner, 2011). The resulting neutral line geometries, dynamically changing with increasing fold amplification, will help field geologists better interpret fold-related structures. Using similar numerical models, we (Frehner and Exner, submitted) were able to reproduce foliation refraction fans around outcrop-scale folds in NW Spain. However, highly relevant for structural geologists is the fact that the geometry of the foliation fan is not suitable for finite strain estimates because different strain measures result in very similar foliation fan patterns.

The second study focuses on orogen-scale folds in the Zagros Simply Folded Belt in NE Iraq. We (Burscher et al., 2012) used differential geometrical methods to analyze the folds based on digital elevation models, which allows tracing some key structural features and helps identify targets for more

detailed field work. Extensive structural field data in combination with remote sensing data resulted in a 55 km long geological cross-section (Fig. 2a). In Frehner et al. (2012) we developed a new methodology (dynamic unfolding) to restore the folded cross-section using numerical time-reverse modeling (Fig. 2b). In contrast to kinematical fold restoration, dynamic unfolding allows taking into account rheological parameters. We identified interfacial slip between the individual units as an essential mechanism during folding, without which the observed fold geometry cannot be explained.

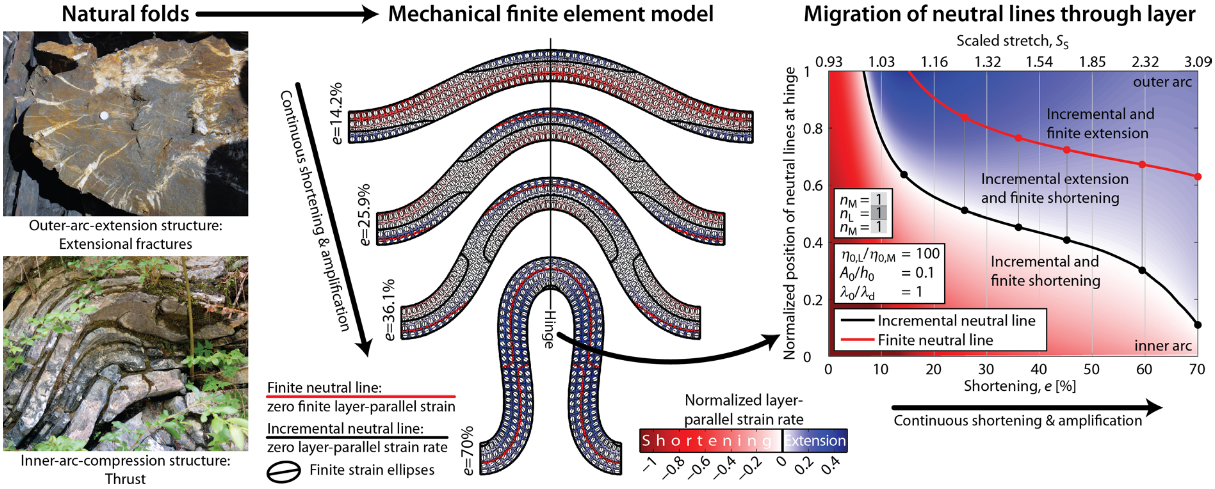

Fig. 1: Natural observations of outer-arc extension structure and inner-arc shortening structure and mechanical explanation using a finite-element simulation of the migration of the neutral lines.

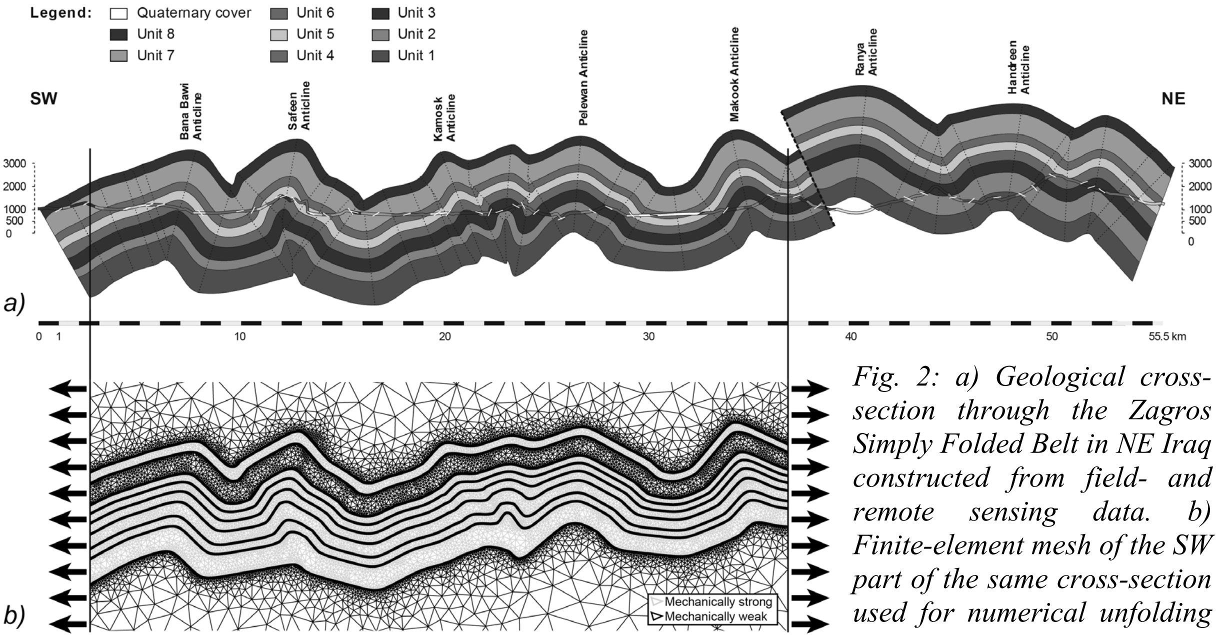

Fig. 2: a) Geological cross-section through the Zagros Simply Folded Belt in NE Iraq constructed from field- and remote sensing data. b) Finite-element mesh of the SW part of the same cross-section used for numerical unfolding simulations.

References

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