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Three-dimensional characterization of a crustal-scale fault zone: the Pusteria and Sprechenstein fault system (Eastern Alps). Part 1: geomodelling as applied to fault-zone architecture studies

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In this contribution we present theoretical considerations and the practical implementation which allowed a 3D realistic model of the architecture of the Pusteria and Sprechenstein-Mules fault system (Eastern Italian Alps) to be reconstructed. In a companion contribution (Part 2: implications for the mechanical evolution of crustal-scale strike-slip faults) we present some results of this model, regarding the mechanical evolution of the fault system.

A 3D geological model of the fault network, where each major fault segment is represented as a discrete surface, has been reconstructed from borehole data and a detailed 1:5000 geological map by means of the geomodeling package gOcad. In this model, continuous fault surfaces are discretised as triangulated surfaces interpolated with the DSI algorithm (Mallet, 2002, Oxford Un. Press). This algorithm is particularly well suited to model natural objects, such as fault networks, because, while retaining the imposed topology, it allows for different concurrent constraints to be set: hard and soft constraints on position, constraints on attitude, constraints on intersection with other fault surfaces, etc. The 3D fault network model has been interactively validated by means of retrodeformation of the Sprechenstein-Mules fault. The accuracy of the model has been evaluated with techniques described in Bistacchi et al. (2007, Computers and Geosciences, doi:10.1016/j.cageo.2007.04.002).

Having reconstructed the geometry and topology of the fault network, the next step is to populate the model with fault rocks and structural/geomechanical properties. Continuous or categorical properties (the latter being the result of some sort of classification) can be represented in a 3D geomodel as discrete functions defined either on volumetric or surface objects, and both these data structures has been used in our model for damage and core zones respectively. In any case, available classification and representation schemas have been modified and adapted in order to account for the scale and spatial resolution of the 3D model.

Core zones are assumed to have their mean surfaces coincident with surfaces of the fault network. The finite thickness of cores is not represented explicitly, with volumetric objects, because of the very low thickness of these objects with respect to areal extension. Therefore, we prefer to represent fault core thickness as a continuous property of fault surfaces. Also fault-rock classification and other continuous or categorical properties have been represented as discrete functions of surfaces of the fault network. Hence, each fault core in the model is represented with a triangulated surface, which carries properties such as core thickness and fault rock type (these properties can be visualized with isopachs or with a categorical colour-coded legend). Several problems and limitations have arisen in the interpolation and/or simulation of these properties, but in general the very flexible DSI algorithm can be applied successfully. The relationships between thickness of the fault core, type of fault rock, lithology of the host rock, and topological position in the fault network can be very effectively highlighted by means of this representation.

On the other hand, damage zones can be represented as fully-3D volumetric objects. Different properties, which concur in representing the “degree of damage”, are modelled as continuous or categorical functions defined on different 3D portions of the damage zones: number and attitude of joint sets, fracture spacing, etc. A multi-criteria classification, which attempts to summarise the “degree of damage”, is proposed.

As is shown in the companion contribution (Part 2: implications for the mechanical evolution of crustal-scale strike-slip faults), this 3D model provides new insights in the architecture of a crustal-scale fault zone and provides quantitative data in 3D, which can be directly compared with results from mechanical models. In the future, this kind of model might also be used as an input dataset for more detailed and realistic mechanical or hydraulic models.