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Stress field modelling from digital geological map data

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To create a model for the lithospheric stress a functional geodatabase is required which contains spatial and geodynamic parameters. A digital structural-geological map is a geodatabase, which usually contains enough attributes to create a stress field model. Such a model is not accurate enough for engineering-geological purposes because simplifications are always present in a map, but in many cases maps are the only sources for a tectonic analysis. The here presented method is designed for field geologist, who are interested to see the possible realization of the stress field over the area, on which they are working.

This study presents an application which can produce a map of 3D stress vectors from a kml-file. The core application logic is implemented on top of a spatially aware relational database management system. This allows rapid and geographically accurate analysis of the imported geological features, taking advantage of standardized spatial algorithms and indexing. After pre-processing the map features in a GIS, according to the Type-Property-Orientation naming system, which was described in a previous study (Albert et al. 2014), the first stage of the algorithm generates an irregularly spaced point cloud by emitting a pattern of points within a user-defined buffer zone around each feature. For each point generated, a component-wise approximation of the tensor field at the point's position is computed, derived from the original feature's geodynamic properties. In a second stage a weighted moving average method calculates the stress vectors in a regular grid. Results can be exported as geospatial data for further analysis or cartographic visualization.

Computation of the tensor field's components is based on the implementation of the Mohr diagram of a compressional model, which uses a Coulomb fracture criterion. Using a general assumption that the main principal stress must be greater than the stress from the overburden, the differential stress is calculated from the fracture criterion. The calculation includes the gravitational acceleration, the average density of rocks and the experimental 60 degree of the fracture angle from the normal of the fault plane. This way, the stress tensors are calculated as absolute pressure values per square meters on both sides of the faults. If the stress from the overburden is greater than 1 bar (i.e. the faults are buried), a confined compression would be present. Modelling this state of stress may result a confusing pattern of vectors, because in a confined position the horizontal stress vectors may point towards structures primarily associated with extension. To step over this, and to highlight the variability in the stress-field, the model calculates the vectors directly from the differential stress (practically subtracting the minimum principal stress from the critical stress). The result of the modelling is a vector map, which theoretically represents the minimum tectonic pressure in the moment, when the rock body breaks from an initial state. This map – together with the original fault-map – is suitable for determining those areas where unrevealed tectonic, sedimentary and lithological structures are possibly present (e.g. faults, sub-basins and intrusions).

With modelling different deformational phases on the same area, change of the stress vectors can be detected which reveals not only the varying directions of the principal stresses, but the tectonic-driven sedimentation patterns too. The decrease of necessary critical stress in the case of a possible reactivation of a fault in subsequent deformation phase can be managed with the down-ranking of the concerning structural elements.

Reference:

Albert G., Ungvári ZS., Szentpéteri K. 2014: Modeling the present day stress field of the Pannonian Basin from neotectonic maps - In: Beqiraj A, Ionescu C, Christofides G, Uta A, Beqiraj Goga E, Marku S (eds.) Proceedings XX Congress of the Carpathian-Balkan Geological Association. Tirana: p. 2.