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Handling and quantifying uncertainty in geological 3D models: A methodological approach based on remote-sensing and field work.

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Geological 3D models are always just an approximation of a complex natural situation. This is especially true in regions, where hard underground data (e.g. bore holes, tunnel mappings and seismic data) is lacking. One of the key problems while developing valid geological 3D models is the three-dimensional spatial distribution of geological structures, particularly with increasing distance from the surface.

In our study, we investigate the Alpine 3D Deformation of the crystalline rocks of the Aar massif (Haslital valley, Central Switzerland). Deformation in this area is dominated by different sets of large-scale shear zones, which acted under both ductile and brittle deformation conditions. The goal of our study is the prediction of the geometry and the evolution of the structures in 3D space and time. A key point in our project is the generation of a reliable 3D model of today's structures. In this sense, estimation of the reliability of the surface information for the extrapolation to depth is mandatory. Based on our data, a method will be presented that contributes to a possible solution of the questions addressed above. The basic idea consists of the fact that (i) mechanical anisotropies as shear zones and faults show prominent three-dimensional information in the landscape, (ii) these geometries can be used as input data for a geological 3D model and (iii) that the 3D information mentioned allows a projection to depth. As a great advantage of the study area, a large number of underground tunnels exist, which allow to evaluate the quality of the aforementioned extrapolations.

The method is based on a combined remote-sensing and field work approach: morphological incisions recognized on digital elevation models as well as on aerial photos on the computer screen were evaluated, described and attributed in detail in the field. Our approach is based on a six step workflow: (1) Elaboration of a large-scale structural map of geological structures by means of remote-sensing, (2) conduction of a shear zone map, its verification in the field and subsequent update, (3) combination of the results of the previous steps in order to obtain valid input data for 3D modelling, (4) construction of a 3D model of the geological structures by making use of the best-fit-plane approach by FERNANDEZ (2005), (5) verification of the modelled structures by correlating them with the underground data available and (6) calculation and visualisation of the uncertainty of the 3D model obtained.

In this study, uncertainty is defined as the discrepancy of the projected continuation of a given structure at the underground level and its deviation from the actually found structure at the different tunnel levels. It is assumed that the structures observed run top down as planar features. In these terms, uncertainty is a function of parameters measured at the surface compared to those obtained in the subsurface. These parameters are: (i) width of the structures, (ii) height difference vertically and parallel to the structures, (iii) dip direction and dip azimuth and (iv) the horizontal deviation between the expected appearance of structures at depth and their real occurrence at the tunnel level.

Results show that (1) remote-sensing and field-based data correlate very well, (2) the resulting information can be used to generate reliable 3D models of the study area and (3) the uncertainty related to 3D projection met at this stage of the work is rather small.
This method has not yet been tested in other areas and the correlation of individual structures between surface and subsurface data presents a major difficulty. The latter is scale dependent and therefore, the correct picking of the corresponding structures is very demanding.

The data obtained so far, builds an important base for a future quantitative characterisation of the above-mentioned deformation structures on the large-scale, in terms of their 3D orientation, 3D spatial distribution,

kinematics and evolution in 3D. In addition to this study, additional analysis on the small-scale will allow detailed insight into the deformation history and the associated changes in deformation mechanisms of the rocks in the study area (see Wehrens et al., this Volume).