



## **Paleostress analysis and in-situ stress measurements – an evaluation of results and methods from the investigation campaign for the Koralm Tunnel (Austria)**

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Knowledge about brittle tectonic faults and the related stress field is of major importance to assess the geotechnical and hydrogeological conditions to be expected in a tunnel project. Nevertheless kinematic discontinuity analysis and determination of paleostresses are in most cases still not state of the art in engineering geological site characterisation, especially when regarding the logging of drill cores (Brosch et al., 2001). This is also true for in situ stress measurements, although the estimation of in situ stress conditions is crucial for the evaluation of the rock mass behaviour in deep seated tunnels and consequently for the required support measures (Fairhurst, 2003). In this paper we want to outline the investigations related to stress assessment which were performed for the 32 km long Koralm tunnel in southern Austria. We want to point out the potential but also the difficulties associated with the determination of fault kinematics, paleostress orientations and in situ stress determinations.

The Koralm tunnel crosses the Koralm Complex, which forms a polycrystalline mountain range, in which brittle deformation conditions were prevailing from 60 Ma to 40 Ma onwards (Frisch et al., 2000; Frisch et al., 1998; Hejl, 1998). At the western margin of the Koralm the major bordering fault zone, the Pöls-Lavanttal fault zone, is regarded as still active with a dextral sense of shear derived from focal plane solutions (Reinecker, 2000; Reinecker and Lenhardt, 1999). During the subsurface investigation campaign for the Koralm tunnel kinematic discontinuity analysis was performed on more than 1200 m of drill core in 17 drill holes up to a depth of 1048 m be-

low surface. The method of kinematic discontinuity analysis on drill cores comprises the identification and structural geological analysis of discontinuities, which are re-orientated with the help of acoustic or optical borehole televiewer (Brosch et al., 2001). Kinematic discontinuity analysis was additionally performed on selected outcrops along the alignment corridor. Paleostress orientations were determined with the help of the PT method (Turner, 1953) and the Right Dihedra method (Angelier and Mechler, 1977).

The measurements of the in-situ stress conditions were performed in six boreholes by hydraulic fracturing and by the RACOS<sup>®</sup> method. With hydraulic fracturing the rock mass within a section of a borehole is pressurized and from the orientation of a newly generated or a reopened existing crack the stress tensor is calculated. RACOS is a procedure based on analysis of the propagation of elastic waves that determines the structural changes in the rock resulting from the removal of the in-situ stresses during sampling. Additionally borehole breakouts were analysed with the help of borehole televiewer images. In the central part of the Koralm stress measurements were carried out in boreholes with a depth of up to 1165 m (Goricki and Harer, 2004).

One aim of these investigations was to evaluate whether the stress field responsible for the regional fault pattern is still preserved in the in situ stresses. This was expected to be true as the major bordering fault system is still considered to be active. The results of the paleostress analyses along the tunnel alignment show that the neotectonic regime of the Pöls-Lavanttal fault system has left only subordinate traces in the analysed data set. The majority of the results reveal a pronounced extensional kinematic regime. These latest extensional deformation events can be linked to the subsidence of the Styrian and the Lavanttal basin, Miocene lateral extrusion of the Eastern Alps (Frisch et al., 2000) and Pliocene E-W compression (Sachsenhofer, 1996), and seem not to be affected by the regional neotectonic regime. The in situ stress measurements show that the maximum horizontal stress components are orientated between NW-SE and N-S, and generally represent the largest stress component. These results are compatible with the general stress field in this part of the Eastern Alps.

There are several difficulties associated with the determination of in situ stress magnitudes and directions as well as with the determination of paleostress directions. However, following our experience we consider the determination of paleostress orientations as an important supplement to interpret the measured in situ stress orientations. Vice versa in situ stress measurements may help to assess whether a determined paleostress field is probable to be still active.

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