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Electromagnetic radiation in tunnels and its relation to local and regional stresses

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Electromagnetic radiation (EMR) was measured in a frequency range from 5 to 50 kHz with a Cerescope. EMR can be related to microfractures. Results from a number of tunnels in different geological settings of central and northern Europe are presented and interpreted in terms of a) origin and significance of EMR, and b) stress distribution around tunnels and at a regional scale. Because microfractures are oriented on the regional stress field of the lithosphere, it is possible to derive paramters of the stress field, in particular the orientation of the horizontal principal stress axes, from EMR measurements.

Around underground cavities such as deep mines and tunnels, the open space induces a secondary stress field, which is dependent on orientation and cross section of the tunnel, topographic load and the orientation of the regional stress field with respect to the long axis of the tunnel. Tunnel orientation and cross section, as well as topographic load are easily observed parameters. The secondary stress field consists of tangential stress, radial stress and shear stress between tangential and radial stress. While tangential stress and radial stress have maxima oriented either subvertical or subhorizontal (depending on regional stress field and topographic load), shear stresses have their maxima at approximate 45° angles to the vertical. Due to the high compressive strength of most rocks and the compressive nature of the regional stresses in the discussed tunnels, shear stresses are seen as the source of microcracks and therefore EMR emission in the tunnels. By measuring the EMR induced by the maximum shear stresses of the secondary stress field, it is possible to derive magnitude and orientation of the regional stress field. The method of measuring EMR along cross sections of a tunnel is handy in order to investigate the regional stress field, as well as in order to locate areas of high stresses in a tunnel.

The tunnels at Wald-Michelbach and Mörtelstein (Germany), as well as the Lövkullen supply tunnel (Sweden) are examples for tunnels in which the theoretically expected distribution of EMR is found. The parameters of the regional stress field from EMR measurements in these tunnels are consistent with the results of standard methods such as fault plane solutions, overcoring experiments and borehole breakout interpretations. Measurements at the Feuerberg tunnel (Germany) shows extraordinarily high EMR intensities (measured in impulses per time) in a specific area, which is interpreted as related to a fault. In the Steinfjellet tunnel (Norway) also an area with high EMR intensities is located, which may be related to a major fault, the suture of the old continents of Laurentia and Baltica. This fault may also be re-activated during the opening of the N-Atlantic ocean. The railway tunnel at Tüllingen (Germany) shows high EMR intensities from the tunnel floor, this radiation may be related to the swelling of anhydrite and/or clay minerals. The measurements from this tunnel are compared to measurements at a former mine at Neckarzimmern (Germany), where the swelling of anhydrite to gypsum results in deformation of the tunnel floor.

It is suggested that EMR measurements in tunnels should be subject to future studies and that measuring and data evaluation methods should be improved. It can be concluded that EMR methods represent an efficent way to investigate regional and local stress fields without influencing the rocks measured.