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## **Modeling a fluid injection in the pilot hole of the “Kontinentale Tiefbohrung der Bundesrepublik Deutschland“(KTB) using finite elements**

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During the last years several hydrogeological investigations were undertaken in the drill holes of the KTB. The recent experiments consist of one pumping test lasting from June 2002 till June 2003 followed by a relaxation phase of one year. Afterwards an injection test took place from June 2004 till April 2005. During this experiment a fluid volume of  $85000 \text{ m}^3$  was injected into the pilot hole at 4000 m depth. This increased the pore pressure about 12 MPa in the close vicinity of the injection point and caused a deformation of the surrounding rocks and the earth's surface. The deformation was observed by a tiltmeter array of 5 Askania tiltmeters which were installed in drill holes around the KTB site. The analysis of the collected data revealed changes in the tilt of about 100 - 150 ms. However, this tilt changes did not occur radial to the injection site but showed significant discrepancies in their direction. Therefore a numerical modeling of the KTB site and the fluid injection was accomplished to discover which processes are relevant to transfer pore pressure and how geological structures influence the resulting deformation.

The finite element model has a size of 20 km x 20 km x 10 km and consists of 25600 hexagonal elements. It features poroelastic rheology of the modeled rocks, gravity and an initial stress field. The rock parameters are based on the analysis data of the drilled cores. Additional to this rock definition four faultzones were included. These are two fault zones belonging to the Franconian Lineament which is the most prominent fault system in the surrounding area. The other two are

smaller local faults striking only a few hundred meters away from the KTB. The fault zones differ from the modeled rock in an increased permeability and void ratio. The other parameters are equal for the fault zones and the rocks. The modeled timeframe comprises the ten months injection phase and the following one year relaxation phase.

Results of the modeling show tilt changes in the same magnitude as the measured data. While models with inactive fault zones produce tilt changes which are directed radial to the injection center, models with permeability contrast between rocks and fault systems lead to variations in tilt directions. With increasing permeability within faults the deformation of the earth's surface is not dominated by a bulge above the injection point only but is superposed by increasing deformation above the fault zones. However, the tilt direction is mainly affected during the relaxation period following the injection. Since the fluidflow within the model is controlled mostly by faults, these faults influence the discharge of the injected fluid. This process leads to an irregular decrease of the bulge which can be recognized with tilt measurements.