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Imaging near-subsurface subrosion structures and faults using SH-wave reflection seismics

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Subrosion is a term for underground leaching of soluble rocks and is a global phenomenon. It involves dissolution of evaporites due to the presence of unsaturated water, fractures and faults. Fractures and faults are pathways for water to circulate and to generate subsurface cavities. Depending on the leached material and the parameters of the generation process, especially the dissolution rate, different kinds of subrosion structures evolve in the subsurface. The two end members are collapse and depression structures. Subrosion is a natural process, but it can be enhanced by anthropogenic factors like manipulation of the aquifer system and groundwater flow and by e.g. extraction of saline water. The formation of sinkholes and depressions are a dangerous geohazard, especially if they occur in urban areas, which often leads to building and infrastructural damage and life-threatening situations. For this reason investigations of the processes that induce subrosion and a detailed analysis of the resulting structures are of importance. To develop a comprehensive model of near-subsurface subrosion structures, reflection seismics is one of the methods used by the Leibniz Institute for Applied Geophysics.

The study area is located in the city of Bad Frankenhausen in northern Thuringia, Germany. Most of the geological underground of Thuringia is characterized by Permian deposits. Bad Frankenhausen is situated directly south of the Kyffhäuser mountain range at the Kyffhäuser Southern Margin Fault. This major fault is one of the main pathways for the circulating ground- and meteoric waters that leach the Permian deposits, especially the Leine-, Staßfurt- and Werra Formations.

2014 and 2015 eight shear wave reflection seismic profiles were carried out in the urban area of Bad Frankenhausen and three profiles in the countrified surroundings. Altogether ca. 3.6 km were surveyed using a landstreamer as receiver and an electro-dynamic vibrator as source. The surveys were adjusted in able to measure in the medieval center of Bad Frankenhausen. This required special equipment and configuration due to the densely built-up area, the differing ground conditions and the varying topography.

The analysis of the seismic sections revealed structures associated with the continuing subrosion of the Permian deposits. The reflection patterns indicate heterogeneous near-surface geology of lateral and vertical variations in forms of discontinuous reflectors, small-scale fractures and faults. The fractures and faults also serve as additional pathways for the circulating water and the deposits are subsiding along these features, resulting in the formation of depression structures in the near-subsurface. Diffractions in the unmigrated sections indicate voids in the subsurface that develop due to the longtime subrosion processes. Besides these structures, variations of the traveltime, absorption and scattering of the seismic waves induced by the subrosion processes are visible.