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The sinkhole of Schmalkalden, Germany – Imaging of near-surface subrosion structures and faults

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In November 2010 a sinkhole of 30 m diameter and 20 m depth opened in a residential area in the village Schmalkalden, Germany, which fortunately led to damage of buildings and property only. The collapse was caused by leaching of soluble rocks in the subsurface, called subrosion. For an improved understanding of the processes leading to subrosion and sinkhole development a detailed characterization of the subsurface structures and elastic parameters is required. We used shear wave reflection seismic, which has proven to be a suitable method for high-resolution imaging of the near-surface.

The village Schmalkalden is located in southern Thuringia in Germany. Since the Upper Cretaceous the area is dominated by fault tectonics, fractures and joints, which increase the rock permeability. The circulating groundwater leaches the Permian saline deposits in the subsurface and forms upward migrating cavities, which can develop into sinkholes, if the overburden collapses.

In the direct vicinity of the backfilled sinkhole, five 2-D shear wave reflection seismic profiles with total length of ca. 900 m and a zero-offset VSP down to 150 m depth were acquired. For the surface profiles a 120-channel landstreamer attached with horizontal geophones and an electrodynamic micro-vibrator, exciting horizontally polarized shear waves, were used. For the VSP survey an oriented borehole probe equipped with a 3C-geophone and electrodynamic and hydraulic vibrators, exciting compression- and shear waves, were utilized.

The seismic sections show high-resolution images from the surface to ca. 100 m depth. They display heterogeneous structures as indicated by strong vertical and lateral variations of the reflectors. In the near-surface, depressions are visible and zones of low seismic velocities < 180 m/s show increased attenuation of the seismic wave field. These are probably the result of the fractured underground, due to fault tectonics and the ongoing subrosion. The unstable zones are additionally characterized by a low shear modulus < 120 MPa, which is derived from density and shear wave interval velocities. The results from the 2-D reflection seismics are supplemented with results of a VSP survey in a borehole near the former sinkhole. The VSP data shows anomalies of the Vp-Vs ratio with values above 2,5. This indicates unstable zones correlated with the anomalies revealed by the 2-D sections.

Possible factors for the development of the Schmalkalden sinkhole in 2010 are the presence of soluble Permian deposits, the strongly fractured underground and the identified faults.