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Investigation of subrosion processes using an integrated geophysical approach

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Subrosion, i.e. leaching of readily soluble rocks, is usually of natural origin but can be enhanced by anthropogenic interferences. In recent years, public awareness of subrosion processes in terms of the in parts catastrophic implications and incidences increased. Especially the sinkholes in Schmalkalden, Tiefenort and Nordhausen (Germany) are three dramatic examples. They show that the knowledge of those processes and therefore, the predictability of such events is insufficient.
The complexity of subrosion processes requires an integrated geophysical approach, which investigates the interlinking of structure, hydraulics, leaching, and mechanics. This contributes to a better understanding of the processes by reliable imaging and characterisation of subrosion structures.
At LIAG an inter-sectional group is engaged in geophysical investigation of subrosion processes. The focus is application, enhancement and combination of various geophysical methods both at surface and in boreholes. This includes the monitoring of surface deformation and the application of time-lapse gravity as well as seismic, geo-electric and electromagnetic methods. Petrophysical investigations (with focus on Spectral Induced Polarisation - SIP) are conducted to characterise the processes on pore scale. Numerical studies are applied to advance the understanding of void forming processes and the mechanical consequences in the dynamic interaction.
Since March 2014, quarterly campaigns are conducted to monitor changes in gravity acceleration at 15 stations in the urban area of Bad Frankenhausen. The standard deviations of the adjusted gravity differences are in the single-digit μGal range. The gravity acceleration changes in the range of 0 to 15 μGal over a timespan of three years and the accompanying levelling locally shows continuous subsidence in the mm/year-range. Sixteen SH-wave and four P-wave reflection seismic profiles together with three VSP′s were surveyed in the city of Bad Frankenhausen. Additionally, five SH-wave profiles and one VSP were carried out around the sinkhole of Schmalkalden. The underground in the local subrosion areas is heterogeneous with many fractures and faults. Subrosion structures were imaged in high-resolution and by defining the shear-modulus. Vp/Vs-ratio unstable areas have been identified. Electric and electromagnetic methods have been used to investigate the geological structure of a karst system based on the different bulk resistivities of the various geological units and reflections of electromagnetic waves at interfaces. The borehole georadar has been used to detect a cavity and areas of disruption. Different types of carbonates were analysed with laboratory SIP-measurements. First results show polarisation effects for all carbonate types. Four different phase behaviours were observed in the phase spectra. Further experiments will be conducted to get more insight into the phase behaviour of carbonates. Numerical modelling is applied to simulate the collapse mechanism and rock failure to specify the conditions in which sinkholes form. Important parameters for failure are thickness of overburden, lateral dimension and shape of the cavity, existing fracture network and layer boundaries, which partly can be provided by the other methods.
This diversity of methods allows a characterisation of karst systems and subrosion structures based on various complementary properties and on many scales from pore size to the big picture of the karst system.