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Geophysical investigation of subrosion processes – an integrated approach

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Subrosion, i.e. leaching of readily soluble rocks mostly due to groundwater, 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 and Tiefenort (Germany) are – based on unforeseen collapse events and associated damage in 2010 – two dramatic examples. They illustrate that to date the knowledge of those processes and therefore the predictability of such events is insufficient.

The complexity of the processes requires an integrated geophysical approach which investigates the interlinking of structure, hydraulics, solution processes, and mechanics. This finally 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 monitoring of (surface) deformation and variation of gravity as well as seismic, geoelectric 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 time-lapse gravity changes at 12 stations in the urban area of Bad Frankenhausen. The standard deviations of the gravity differences between the survey points are low and the accompanying levelling locally shows continuous subsidence in the mm/year-range. Eight shear-wave reflection seismic profiles were surveyed in Bad Frankenhausen using a landstreamer and an electro-dynamic vibrator. This method is suitable for high-resolution imaging of near-surface subrosion structures. The analysis revealed a heterogeneous underground with fractures, faults and depression-structures and variations of traveltime, absorption and scattering of seismic waves. Electric and electromagnetic methods have been used to investigate the geological structure of a karst system (e.g. banking and dipping of limestone) based on the different bulk resistivities of the various geological units and reflections of electromagnetic waves at interfaces. The borehole georadar has successfully been used to detect a cavity and areas of disruption. First results of laboratory SIP measurements on different carbonates show clearly polarization effects and a strong relationship between real and imaginary part of electrical conductivity. All samples of Edwards Brown carbonates show a significant phase peak and the same chemism. Therefore, they are ideal for a more systematic study to derive robust empirical relations between IP and petrophysical parameters. 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.