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Investigation of sinkhole areas in Germany using 2D shear wave reflection seismics and zero-offset VSP

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Sinkholes pose a serious geohazard for humans and infrastructure in populated areas. The Junior Research Group Subrosion within the Leibniz Institute for Applied Geophysics and the joint project SIMULTAN work on the multi-scale investigation of subrosion processes in the subsurface, which cause natural sinkholes.
In two case studies in sinkhole areas of Thuringia in Germany, we applied 2D shear wave reflection seismics using SH-waves with the aim to detect suitable parameters for the characterisation of critical zones. This method has the potential to image near-surface collapse and faulting structures in improved resolution compared to P-wave surveys resulting from the shorter wavelength of shear waves. Additionally, the shear wave velocity field derived by NMO velocity analysis is a basis to calculate further physical parameters, as e.g. the dynamic shear modulus.
In both investigation areas, vertical seismic profiles (VSP) were acquired by generating P- and SH-waves (6 component VSP) directly next to a borehole equipped with a 3C downhole sensor. They provide shear and compressional wave velocity profiles, which are used to improve the 2D shear wave velocity field from surface seismics, to perform a depth calibration of the seismic image and to calculate the Vp/Vs ratio. The signals in the VSP data are analysed with respect to changes in polarisation and attenuation with depth and/or azimuth.
The VSP data reveal low shear wave velocities of 200-300 m/s in rock layers known to be heavily affected by subrosion and confirm the low velocities calculated from the surface seismic data. A discrepancy of the shear wave velocities is observed in other intervals probably due to unsymmetrical travel paths in the surface seismics. In some VSP data dominant conversion of the direct SH-wave to P-wave is observed that is assumed to be caused by an increased presence of cavities. A potential fault distorting the vertical travel paths was detected by abnormal P-wave first arrivals in the VSP dataset of a borehole located near the city of Bad Frankenhausen. In addition, a strong attenuation of the source signals may indicate areas influenced by subrosion.