Geophysical Research Abstracts
Vol. 18, EGU2016-1258-1, 2016
EGU General Assembly 2016

Modelling study of challenges in sinkhole detection with shear wave reflection seismics

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The detection of cavities with reflection seismics is a difficult task even if high impedance contrasts are assumed. Especially the shear wave reflection method with a higher resolution potential trough lower velocities and short wavelength has come into focus of investigation. But shear wave propagation fails if material exists that partially has no shear strength. The shear wave does not propagate into or through those voids. Here, we evaluate the influence of a possible fracture zone above a cavity. We simulate shear wave propagation with finite difference modelling for two reference models, with and without cavity, and various sets of input models with a fracture zone above the cavity.

Reflections and multiples of the reference models image the subsidence structure and the cavity. For the fracture input models, we implemented a fracture network, derived from numerical crack propagation modelling (Schneider-Löbens et al., 2015). The cracks possess the minimum possible aperture of one grid point (i.e. 0.1 m) and no shear stiffness. The seismic modelling exhibits that the shear wave does not pass through the fracture zone and shadows the subjacent cavity. Sequences of randomly discontinuous cracks, cf. displacement discontinuity model with zero crack stiffness, approximate partially seismic connected rock on both sides of the crack. The amount of these seismic pathways determines whether a reflection of the cavity can be detected at the surface or not. Cracks with higher aperture, e.g. two or three grid points, need a higher amount of intact rock/defective cracks, since more connected grid points are necessary to create seismic pathways.

Furthermore, it turns out that the crack filling is important for shear wave transmission. While a mineralized fracture zone, implemented with high velocity, facilitate shear wave propagation, water or air-filled cracks avoid shear wave transmission. Crack orientation affects the shear wave propagation through the geometry. A conjugated fracture system shadows the cavity with crossing cracks, but in a tensile fracture zone the shear wave travels parallel to the cracks and reflects at the cavity. For P-wave propagation the fracture zone has no fundamental influence on the cavity reflection.

We reveal that a fracture zone can hamper transmission of shear waves and shadow a cavity, and that seismic pathways are crucial for shear wave propagation through a fracture zone.

Schneider-Löbens, C., Wuttke, M.W., Backers, T. & Krawczyk, C.M. (2015). Numerical modeling approach of sinkhole propagation using the eXtended FEM code ‘roxol‘. Geophysical Research Abstracts, Vol. 17, EGU2015-12230-2.