Geophysical Research Abstracts
Vol. 18, EGU2016-2131, 2016
EGU General Assembly 2016

Seismic Techniques for Subsurface Voids Detection

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A major hazards in Qatar is the presence of karst, which is ubiquitous throughout the country including depressions, sinkholes, and caves. Causes for the development of karst include faulting and fracturing where fluids find pathways through limestone and dissolve the host rock to form caverns. Of particular concern in rapidly growing metropolitan areas that expand in heretofore unexplored regions are the collapse of such caverns. Because Qatar has seen a recent boom in construction, including the planning and development of complete new sub-sections of metropolitan areas, the development areas need to be investigated for the presence of karst to determine their suitability for the planned project. In this paper, we present the results of a study to demonstrate a variety of seismic techniques to detect the presence of a karst analog in form of a vertical water-collection shaft located on the campus of Qatar University, Doha, Qatar.

Seismic waves are well suited for karst detection and characterization. Voids represent high-contrast seismic objects that exhibit strong responses due to incident seismic waves. However, the complex geometry of karst, including shape and size, makes their imaging nontrivial. While karst detection can be reduced to the simple problem of detecting an anomaly, karst characterization can be complicated by the 3D nature of the problem of unknown scale, where irregular surfaces can generate diffracted waves of different kind. In our presentation we employ a variety of seismic techniques to demonstrate the detection and characterization of a vertical water collection shaft analyzing the phase, amplitude and spectral information of seismic waves that have been scattered by the object. We used the reduction in seismic wave amplitudes and the delay in phase arrival times in the geometrical shadow of the vertical shaft to independently detect and locate the object in space. Additionally, we use narrow band-pass filtered data combining two orthogonal transmission surveys to detect and locate the object. Furthermore, we showed that ambient noise recordings may generate data with sufficient signal-to-noise ratio to successfully detect and locate subsurface voids. Being able to use ambient noise recordings would eliminate the need to employ active seismic sources that are time consuming and more expensive to operate.