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Seismic Imaging of a Near-Surface Collapse Structure in Qatar

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The Middle-East has seen a recent boom in construction including the planning and development of complete new sub-sections of metropolitan areas including buildings and support infrastructure such as highways, public transportation and utility lines. Before planning and construction can commence, however, the development areas need to be investigated to determine their suitability for the planned project. Subsurface parameters such as the type of material (soil/rock), thickness of top soil or rock layers, depth and elastic parameters of basement, for example, comprise important information needed before a decision concerning the suitability of the site for construction can be made. A similar problem arises in environmental impact studies, which are typically required for each construction project, particularly on the scale of the aforementioned metropolitan areas in the Middle East.

The current study was conducted in Qatar at the location of a future highway interchange to evaluate a suite of 3D seismic techniques in their effectiveness to interrogate the subsurface for the presence of a karst-like collapse structure. The survey comprised an area of approximately 5,000 m2 and consisted of 550 source- and 192 receiver locations. The seismic source was an accelerated 40 kg weight drop while the geophones consisted of 3-component 10 Hz velocity sensors. The seismic survey generated over 300,000 seismic traces with excellent signal-to-noise ratio, indicated by low noise levels before the P-wave arrivals visible on the seismograms. The low attenuation of seismic energy is due to the compact limestone and dolomite rocks that are ubiquitous throughout the peninsula of Qatar. Data processing consisted of estimating over 150,000 P-wave phase arrivals from the recorded waveforms. Travel-time distance plots were derived from the P-wave phase arrival times, which were converted in initial 1D velocity models. The 1D velocity models were subsequently used as starting models for high-resolution 3-D tomographic imaging of the P-wave velocity structure in the shallow subsurface. High variance reduction between calculated and observed travel times during initial iteration steps indicated that the 1D velocity models were good representations of the true 3D subsurface structure. The S-wave velocity structure was estimated based on dispersion analysis of recorded surface waves. First, S-wave phase velocities were estimated using 2D inversions of phase dispersion measured in subarrays at discrete frequencies. These phase velocities were subsequently post-processed into 3D S-wave velocity estimates. The resulting 3D P- and S-wave velocity models indicate a layered-subsurface geology with low-velocity near surface deposits that are preliminarily interpreted as clastic beach sands and cemented beach rocks that have occupied voids left by the dissolved limestone, the latter is characterized by intermediate P- and S-wave velocities. The limestone is underlain by dolomite, which is represented by higher P- and S-wave wave velocities. The derived 3D inversion results are indicative of the presence of a typical collapse structure with subsurface voids that have been infiltrated by sand and cemented beach deposits.