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High-Resolution Electromagnetic and Gravity Imaging of Wadi Sahba in Central Saudi Arabia

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ABSTRACT

Wadi Sahba in central Saudi Arabia is considered to be one of the most difficult areas for seismic exploration in the whole Kingdom. The extremely low quality of the seismic data in the wadi section prevents the reliable interpretation of the boundaries of important oil and gas fields. The geologic nature of the wadi has been debated with geomorphological, dissolution collapse and structural processes being proposed. The first model proposes the dissolution of evaporites followed by roof collapses of the formations above as the mechanism generating the wadi depression. The structural model postulates the existence of a major transcurrent fault system, possibly still active, which generated the wadi Sahba depression and other similar structures to the west. Transpressional and transtensional stress regimes along the faults would generate complex patterns of flower faults reaching the surface. The adequate imaging of the near surface with a combination of seismic and non-seismic methods enables better interpretation of the past and present geologic processes, other than providing means for improving seismic imaging by integrated velocity modeling. A high-resolution 3D multi-geophysics program was acquired over the full-fold area of recent 3D seismic surveys with the scope of enhancing the near-surface velocity modeling by multi-parameter joint inversion. The program comprised helicopter-borne transient electromagnetics (TEM), audio magnetotellurics (AMT) and precision gravity. Unprecedented high resolution images of the wadi were obtained, which surpassed in quality and details any seismic data acquired to date. TEM, in particular, provided images of the wadi structures at a resolution comparable to seismic reflectivity. A first pass standalone inversion of the data illuminated sharp structural discontinuities that clarified the tectonic processes and associated deformations at the origin of the structure. Evidence from the near-surface investigation support the model of a complex pattern of faults subsiding the outcropping limestone formation of Um Er Radhuma. The extremely high resolution in the horizontal and vertical dimensions, shown in particular by TEM data, provides sharp images of the near surface that we integrate with seismic for generating enhanced velocity models for seismic imaging.