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Salt Velocity Model Building by Seiemic-CSEM Joint Inversion in the Red Sea

Daniele Colombo[1], Diego Rovetta[1], Ersan Turkoglu[1], Gary W. McNeice[1], and Ernesto Sandoval-Curiel[1]

[1]Saudi Arabian National Oil Company, Dhahran, Saudi Arabia.

ABSTRACT

Salt exploration is generally complicated by high contrast velocity fields and complex salt geometries, which cause, among other things, intricate wavepaths and seismic scattering. While the subsalt imaging challenges can be in many cases addressed by advanced imaging algorithms, a fundamental problem remains in the determination of robust velocity fields in conditions of poor signal-to-noise ratio. Even the most advanced methods for depth-domain velocity analysis, such as full waveform inversion (FWI), require starting from a good initial estimate of the velocity model to enable local minimization to converge to a correct result. Non-seismic methods such as electromagnetics (EM) can help guide the generation of robust velocity models to be used for further processing. Using the multi-physics data acquired in the Red Sea in three deepwater blocks, we develop and apply seismic-controlled source electromagnetic (CSEM) joint inversion for velocity model building in a complex area dominated by nappe-style salt tectonics. The integration is achieved by a rigorous approach of multi-scaled inversions looping over model dimensions (1D first followed by 3D) and by defining a hierarchy in the integration guided by a parameter sensitivity analysis. The final step of the integration consists of joint inversion of seismic travel times and CSEM data where a common-structure coupling mechanism, represented by the model cross-gradient operator, is used. Minimization is performed over the seismic data residuals and cross-gradient operator without inverting for the resistivity model, which is used as a reference for the seismic inversion (hierarchical approach). Results are demonstrated through depth imaging where the velocity model derived through seismic-CSEM joint inversion outperforms the results of a seismic-only derived velocity model. More geology-consistent results and flatter image gathers are obtained through the joint inversion approach.