Geostatistics and Gradient-Based Structure Coupling for Integration of Uphole Data with Tomography

Ersan Turkoglu, Daniele Colombo, Ernesto Curiel, Hala Alqatari

Saudi Aramco

Abstract

Reliable seismic depth imaging of low relief structures depends on accurate and detailed near-surface velocity models. Tomographic or full waveform inversions provide detailed velocity models but accuracy of these models at very shallow depths especially in complex arid regions still pose a significant challenge due to limited availability of short offsets, low first arrival quality and low velocity layers. On the other hand, uphole data is a direct way of interpreting shallow subsurface velocities accurately but sparsely. Empirical relations such as sand dune correction curves are used to interpolate the uphole velocity for the interwell space assuming the base of sand is a well-defined surface from topography, tomography and other observations. Therefore, indirect interpolation of the uphole velocity for the interwell space is highly dependent on the uphole density, spatial regularity and the knowledge on the base of weathered layer. We integrated tomographic inversion with uphole interpretations in a simultaneous joint inversion scheme via geostatistics and gradient-based structure coupling. Firstly, surface-consistent, refraction-based automated 1D velocity models were generated from offset binned travel time data. This velocity model then used to interpolate the uphole data into a continuous volume by use of the co-kriging method. This process allows combining sparse but accurate uphole data with abundant but less accurate velocity field which are calibrated by the uphole velocities. The tomographic inversion of the first arrival data is structurally coupled to the hybrid velocity model obtained from upholes and 1D velocity models. Inversion objectives are to reduce travel time residuals and to increase the similarity of the inversion model and reference model structures. Fitness of the uphole velocities to the inverse model at the uphole locations are checked at each iteration and anomalous upholes are removed from the process. This automated uphole model QC further improves the joint inversion quality and reduces the travel time residuals. Using multivariate kriging of the uphole data with the surface-consistent refraction-based 1D velocity models provides superior initial model and final inverse models for the tomographic inversion compared to univariant kriging approach.