Field Cases of the Combined Deterministic Petrophysical Inversion of Gamma-Ray, Density, and Resistivity Logs Acquired in Thinly Bedded Clastic Rock Formations

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Limited vertical resolution of logging tools causes shoulder-bed effects on borehole measurements, therefore biases in the assessment of porosity and hydrocarbon saturation across thinly-bedded rock formations. Previously, a combined inversion procedure was developed for induction resistivity and density logs to improve the petrophysical assessment of multi-layer reservoirs. In this paper, we include the inversion of gamma-ray (GR) logs in the interpretation method and evaluate three field cases that comprise hydrocarbon-saturated Tertiary turbidite sequences. Formations under consideration are unconsolidated to poorly consolidated. All wells were drilled with oil-base mud (OBM), logged with triple-combo tools, and sampled with whole and sidewall cores.

We transform layer-by-layer inversion results into petrophysical properties via a shaly-sand model. On average, inversion results yield 19% better agreement to core measurements and lead to 28% increase in hydrocarbon reserves when compared to standard well-log interpretation procedures.

The wide variety of sand-shale distributions and layer thicknesses included in the example data sets enables us to generalize recommendations for best practices of combined inversion, including criteria for bed-boundary detection, sensor selection, and modification of our “UT Longhorn Tool” flux sensitivity functions (FSFs) to replicate those of commercial tools. The most critical step for reliable and accurate inversion results is the detection/selection of bed boundaries. Inversion of field data also indicates that the minimum bed thickness resolvable with combined inversion is about 0.7ft, and that inflection points of density logs are the best option for bed-boundary detection.

We show that combined inversion allows the detection of noisy, inconsistent, and inadequate measurements, including cases of abnormal measurement-correction biases otherwise difficult to diagnose on processed logs.