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Effective Porosity and Gamma Ray Estimates from Seismic Data

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Why

Gamma ray and effective porosity are powerful tools for the understanding of subsurface geology and reservoir character. The gamma ray enables an interpreter to determine sand and shale distributions in the subsurface. Effective porosity logs are used to estimate hydrocarbon storage volumes and to also provide insight on reservoir permeability.

Case Study Workflow

In this study, three industry standard approaches are used to estimate effective porosity and gamma ray volumes from seismic data volumes and thereby evaluate and quantify hydrocarbon reservoir properties to enhance our understanding of a subsurface sedimentary section. The techniques used are; 1) cross-plot interpretation of the pre-stack simultaneous inversion for elastic rock properties, 2) extended elastic impedance (EEI) with Chi angle rotation and 3) deep Learning neural networks combined with pre-stack simultaneous inversion for elastic rock properties. Our case study is from deep water, Atlantic margin Cretaceous turbidite deposits from offshore Ghana, West Africa, which provide the sedimentary basin and reservoir objectives that are used to illustrate the three methods used and their resulting estimates.

Cross-plot interpretation (Ødegaard and Avseth, 2003) and extended elastic impedance, or EEI, (Whitcombe et al., 2002), have been widely discussed and the results of these methods to our offshore West African case study are illustrated. Pre-stack simultaneous inversion (SI) for elastic rock property estimates was described by Hampson et al. (2005) and has more recently been combined with Deep Learning Neural Networks (DLNN) by Colwell and Kjøsnes (2018). This method is used to estimate gamma ray and effective porosity log volumes for our offshore West Africa example. The validity of the technique is evaluated and verified using the cross-validation technique, which holds some of the real well data back and predicts the well data at the known locations. The well logs and rock property estimates used to estimate the porosity and gamma ray properties are the bulk density, P-wave velocity, and shear wave velocity.

The quality of seismic rock property estimates is highly variable with many potential problems that have been widely discussed in the industry. It is demonstrated in this example that modern, full offset range, marine seismic data and careful pre-stack simultaneous inversion works well in providing the elastic property estimates to subsequently estimate the porosity and gamma ray volumes.

Validity of the neural network rock property prediction model is tested with logs from a single well and the variable stratigraphy available in that wellbore. Stability of the geological model with respect to other areas of the data is evaluated by testing the model against a hidden well from the dataset. In our example the neural network prediction model appears to be stable across the complete data area. If rock property parameters were to vary with depth in the geological section such that a definable relation does not exist between the elastic logs and the target logs, the method will have problems. However, our experience to date suggests that a valid relation is determinable for large intervals of most sedimentary basins. A single model and log relation may not apply for an entire sedimentary section as the model may be controlled by major diagenetic and lithological changes. In this case the log prediction model may be varied and controlled synchronously with those changes so that valid log estimates result.

Conclusion

Results with each of the techniques are illustrated. Each method presents different and complementing value for the understanding of the subsurface rock properties so all can be very cost effectively applied in a seismic based, expenditure optimization process.

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