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Depositional Sequence Characterization from Uniformitarianism-Based Experiments to Real-World Basins

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Abstract

Seismic stratigraphy can be a complex discipline for geoscientists who have no access to outcrop analogues or actual depositional system models to apply uniformitarianism. This paper shows how digitized analogue models from sandboxes can be compared to real-world basin seismic datasets toward building a catalogue of depositional sequences and geobody expressions, using the Relative Geological Time 'RGT' method (Pauget et al, 2009).

The signal driven RGT modeling approach consists of a two-step workflow. First, a discrete stratigraphic framework called 'Model-Grid' is computed to convert all the seismic reflections into horizons. Those horizons are stratigraphically sorted, enabling the geoscientist to individually edit and refine as needed. A 3D interpolation of the discrete Model-Grid finally converts each seismic sample into relative geological time and delivers a continuous RGT model. The RGT model is then used to generate a series of advanced stratigraphic attributes, from which sub-seismic sample stratal slicing can be performed.

The presented workflow is here applied to synthetic 3D seismic datasets generated from the 'XES02' analogue model ('eXperimental Earthscape Basin' facility, National Center for Earth-Surface Dynamics at the University of Minnesota). Experiments conducted in this large-scale sand-box express the effects of user-designed scenarios for sea-level changes, subsidence, and sediment supply on depositional systems architectures. High-resolution photographs of dip-direction cross-sections are upscaled to real-world dimensions, converted into elastic properties, combined into 3D elastic models, then used to generate the synthetic 3D seismic datasets at various resolution scales (datasets courtesy of SeisMomentum Limited). The author performs the global RGT modeling approach to investigate the impact of seismic resolution on sequence stratigraphic analysis by combining a high solution stratigraphic framework that delineates depositional geometries in 3D dimensions and provides Wheeler-transformed sections. Encompassed parasequences are stratal-sliced to conduct a multi-attribute analysis including RGT-based gradients (both stratigraphic and structural), and a Hilbert transform-based 'Amplitude Technique Volume' attribute ('tecVA', corresponding to the Root Mean Square amplitude with a phase shift of -90 degrees). Results are compared to real seismic datasets from Taranaki Basin (rift basin, offshore New-Zealand, datasets courtesy of New Zealand Petroleum and Minerals) and Neuquén Basin (back-arc basin, onshore Argentina, dataset courtesy of YPF), both featuring a 20-million-year time span progradational sequence with a deepwater depositional system, but with significantly different sedimentation rate and dimension. For those examples, magnitudes are generated from spectral decomposition to emphasize geobodies' expressions, and optional seismic inversion and waveform classification processes enable to address the vertical and lateral facies distribution of the related sand fairways.

Such a methodology offers new perspectives and insights in stratigraphic trap characterization and resource potential evaluation from early-stage geological reconnaissance to longer term and detailed seismic portfolio revision for large scale

surveys with sparse or scarce well data. The characterization of each parasequence and related geobody expressions using seismic and well data, is ultimately integrated with conceptual deposition models to constrain Forward Stratigraphic Modeling workflows.