Integrating analogue experiments and seismic interpretation for improved understanding of sedimentation and salt dynamics in Mesozoic sub-basins and their deepwater extensions, offshore Nova Scotia

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Salt-deformation features beneath the shelf and slope of the Scotian Margin manifest complex tectono-stratigraphic relationships with high rates of sedimentation and progradation during the Jurassic and Early Cretaceous. Exploration and seismic interpretation concepts developed in other salt basins (e.g., Gulf of Mexico and South Atlantic basins) are not directly transferable to the Scotian Margin due to differences in palaeographic setting, sediment supply, and primary salt-basin geometry.

We have begun an integrated geoscience study with innovative 4D physical simulations using scaled analogue models and 2D/3D seismic interpretation. Our objective is to investigate the complex interplay between sedimentation and salt deformation in different sub-basins and their deepwater extensions that are characterized by contrasting salt deformation styles ranging from major extension and roho-style detachment to minor extension and vertical salt movement.

Public domain seismic data provide the boundary conditions for the experiments including tectonic setting, geometry of salt basins, and sedimentation pattern and rates. The evolution of the sedimentary basins and the dynamic salt system is simulated in physical experiments that consist of scaled granular-viscous models with syntectonic sedimentation. Model deformation is analysed by time-series of images and 3D displacement data obtained with high-resolution optical image correlation techniques (2D/3D PIV – Particle Imaging Velocimetry).

Structural 3D models are built from model sections with commercial seismic interpretation software to provide insights in the architecture of the linked salt-controled basins and fault structures. The integration of structural interpretation with time-series of fault strain data allows the reliable 3D fault correlation and the mechanical analysis of complex fault systems. For the first time, this new modelling approach allows us to quantitatively assess: 1) the timing and mechanisms of faulting, folding and salt migration, 2) the role of variable sedimentation patterns and rates, and 3) the coupling between extensional, translational and compressional regimes.

In this experiment series we have investigated the role of basin floor dip, sedimentation pattern and rates on the basin evolution at regional scale. The experiment results show that gravitational collapse and salt mobilization generate complex 3D structures similar to those observed along the Scotian Margin, including crestal grabens, landward-and seaward-dipping roller structures, triangular-shaped reactive and active diapirs, turtle structures, canopies, and allochthonous salt detachments. The tectonic evolution is strongly controled by sedimentation. Individual sub-basins and their deep-water compressional belts are coupled spatially and temporally and are characterized by lateral and temporal migration and highly variable and localized subsidence patterns. Our results show that a strong relation exists between sedimentation, rate of extension and dominant structural styles.

Integration of 4D physical simulations with 2D/3D structural modelling and seismic interpretation will lead to a new generation of improved interpretation templates for salt-related structures and basins of offshore Atlantic Canada. The project will significantly improve our understanding of the interaction of dynamic salt systems with sedimentation and erosion processes and will aid interpretation of complex structures beneath the Scotian Margin.