Salt-Sediment Interaction in Sable Sub-Basin, Nova Scotia (Canada)*

Francky Saint-Ange¹, Dimitri Savva², Bernard Colletta¹, Emerson Marisi¹, Laurent Cuilhe², Adam MacDonald², and Matt Luheshi³

Abstract

The Sable Sub-basin is a complex geological sub-basin located in the Central slope of the Scotian margin. It is characterised by an intricate interplay between structural inheritance, salt tectonics and synkinematic sedimentation. One challenge faced during deep-water exploration in the area was to understand reservoirs distribution along the slopes. Part of the challenge is the difficulty in identifying preserved canyons or long-lasting sediment conduits that connect the shelf to the slope. We present here an update on the current view on the evolution of the Central Slope sedimentary system through time in response to salt tectonics. For this purpose, we use newly reviewed and reinterpreted seismic data and related thickness maps on the Central Scotian slope. Results show that the Central Scotian slope can be subdivided into three tectonostratigraphic compartments. The first phase of deformation occurred in the northeast of the study area during Callovian-Tithonian interval, with rapid salt migration over the Alma ridge leading to the creation of the Banquereau Synkinematic Wedge (BSW). Post BSW mechanical adjustment allows the accumulation of a thick Valanginian interval against the main listric faults. The BSW acts as a topographic high and forces the sediment to flow toward the central part of the study area. In the central and southwestern part of the Sub-basin, salt deformation starts at the end of the Jurassic and intensifies shortly after the base Cretaceous unconformity in response to the deposition of the Mississauga Fm. The initiation of a salt canopy by the Hauterivian time disrupts the sediment supply to the deeper part of the basin, and sediment starts to pile up ahead of the salt wall. During the Aptian–early Cenomanian salt canopies are well developed. The significant sediment load over the salt canopy leads to the formation of numerous short-lived intra salt mini-basins. Additionally, due to the amount of growth fault at the shelf edge, several mini–basins appear to form on the upper slopes, which would tend to trap sandstones early on. Because of the intense salt tectonics, canyons do not last very long and sediment conduits are perpetually evolving. The southwestern part of the study area is characterised by the development of a large roho system. Salt movements and withdrawal creates a large turtle back structure bordered by two large permanent sediment conduits. These conduits allow a direct connection between the shelf to the basin.
References Cited


Salt – Sediment Interaction in Sable Sub-basin, Nova Scotia (Canada) - PART 1

Franky Saint-Ange1, Dimitri Savva1, Bernard Colletta1, Emerson Marfisi1, Laurent Cuilliez2, Adam MacDonald1, Matt Luhepsi

1. Nova Scotia Department of Energy, Joseph Howe Building, 1999 Hollis Street, Halifax, B3J 1V7
2. Leptis E & P Ltd, Backinghamshire, UK

ABSTRACT:

The Sable Sub-basin is a complex geological sub-basin located in the Central slope of the Scotian margin. It is characterized by an intricate interplay between structural inheritance, salt tectonics and synkinematic sedimentation. One challenge faced during deep water exploration in the area was to understand reservoir distribution along the slopes. Part of the challenge is in identifying preserved canyons or long-lasting sediment conduits that connect the shelf to the slope. The present work updates the current view on the evolution of the Central Slope sedimentary in the northeast of the study area during Callovian - Tithonian interval, with rapid salt migration over the Alme ridge leading to the creation of the listric faults. The BSW acts as a topographic high and forces the sediment to flow toward the central part of the study area. In the central and southwestern part of the Sub-basin, salt deformation starts at the end of the Jurassic and intensifies shortly after the base Cretaceous unconformity in response to the deposition of the Mississippian. The initiation of salt tectonics by the Alme time disrupts the sediment supply to the deep (part of the locus and sediment) at the shelf edge toward the upper slope. In the central area, sediment starts to pile up ahead of the salt wall. This is due to the amount of growth fault at the shelf edge, several mini-basins appear to form on the upper slope which would tend to trap sediments early on. Because of the interest of salt tectonics, canyons do not last very long and sediment conduits are perpetually evolving. The southwestern part of the study area is characterized by the development of a large mini-system. Salt movements and withdrawal reduces a large tectonic structure bordered by two large sediment conduits. These conduits allow a direct connection between the shelf to the basin.

Introduction:
The Sable Sub-basin lies across the central slope of the Scotian Margin and has been the main focus of offshore oil and gas exploration in Nova Scotia, with several major fields discovered. Exploration activity is ongoing due to the development of the Sable Offshore Energy Project in the late 1980s (Figures 1 and 2). One of the main issues faced across the margin during exploration phases is the geologic complexity of the area and the significant impact of salt tectonics leading to synkinematic sedimentation.

Figure 1: Areal view of the Scotian Margin showing distribution of key structural elements (From Kendell et al., 2016). The main conclusions from the established work on salt tectonics were that:

- Lower and Upper Cretaceous deposits are strongly controlled by salt tectonics (synkinematic wedge and salt structures) (O'Connor et al., 2018).
- Two major salt layers (autochthonous and allochthonous) including a pinchout are active during Cretaceous reservoir deposition (Rastall, 2012).

Figure 2: Regional cross section from shelf (from OERA, 2017).

Structural analysis and Postmortem

Figure 2: PFA2011 (Figure 3) 10,000 VP gathered area controlled by salt tectonics/ synkinematic sedimentation study superimposed on herocline.

Principal results from the PFA (2011) (Figures 3 and 4):
- Lower and Upper Cretaceous deposits are strongly controlled by salt tectonics (synkinematic wedge and salt structures).
- Two major salt layers (autochthonous and allochthonous) including a pinchout are active during Cretaceous reservoir deposition (Rastall, 2012).
- The BSW acts as a topographic high and forces the sediment to flow toward the central part of the study area. In the central and southwestern part of the Sub-basin, salt deformation starts at the end of the Jurassic and intensifies shortly after the base Cretaceous unconformity in response to the deposition of the Mississippian. The initiation of salt tectonics by the Alme time disrupts the sediment supply to the deep (part of the locus and sediment) at the shelf edge toward the upper slope. In the central area, sediment starts to pile up ahead of the salt wall. This is due to the amount of growth fault at the shelf edge, several mini-basins appear to form on the upper slope which would tend to trap sediments early on. Because of the interest of salt tectonics, canyons do not last very long and sediment conduits are perpetually evolving. The southwestern part of the study area is characterized by the development of a large mini-system. Salt movements and withdrawal reduces a large tectonic structure bordered by two large sediment conduits. These conduits allow a direct connection between the shelf to the basin.

Figure 3: Areal view of the Scotian Margin showing distribution of key structural elements (From Kendell et al., 2016). The main conclusions from the established work on salt tectonics were that:

- Lower and Upper Cretaceous deposits are strongly controlled by salt tectonics (synkinematic wedge and salt structures) (O'Connor et al., 2018).
- Two major salt layers (autochthonous and allochthonous) including a pinchout are active during Cretaceous reservoir deposition (Rastall, 2012).

Focusing on the slope in Sable Sub-basin, postmorten analysis completed on Balvenie B-79, Crimson F-B1 and Annapolis 2001 Marathon 1740m water depth. Major objectives included mapping and characterizing key sedimentary features on the BSW. Results suggest overall sand proportions between 10 and 25% in deep water (Figure 4). From the Postmortem the following conclusions were drawn (Figure 5):

- Lower and Upper Cretaceous deposits are strongly controlled by salt tectonics (synkinematic wedge and salt structures) (O'Connor et al., 2018).
- Two major salt layers (autochthonous and allochthonous) including a pinchout are active during Cretaceous reservoir deposition (Rastall, 2012).

From the Postmorten the following conclusions were drawn (Figure 5):

- Rms analysis of Balvenie B-79 shows a clear sand channel with a high amplitude reflection in the upper part of the reservoir.
- The main exploration risk in the slope area is mainly a reservoir issue;
Salt – Sediment Interaction in Sable Sub-basin, Nova Scotia (Canada) - PART 2

Francky Saint-Ange¹, Dimitri Savva¹, Bernard Colletta¹, Emerson Marfisi¹, Laurent Cuilhe¹, Adam MacDonald¹, Matt Luheši²

¹: Nova Scotia Department of Energy, 2: Leptis E&P Ltd

Reconstruction of salt movement in response to sediment load

Figure 10: Thickness maps in m for the Jurassic, Early and mid Cretaceous showing the shift in depocentres

Conclusion:

These three dip sections across the Sable Sub-basin illustrate the variability and complexity in structural and sedimentary architecture of the Central Scotian Margin since the Break-up Unconformity (J200). Salt tectonics is the key feature as it controls the majority of the faulting systems, as well as sediment distribution and the resulting architecture. Decreases in the size of the salt basin coincides with changes in salt tectonic styles, with changes occurring rapidly, along the J200- K137 transition. Growth belts system related to the top of salt. Synkinematic wedges (Transect 1 and 2) characterized by extension in the upper part and compression in the downdip part, depocentres, A-cho system with autochthonous salt feeders (Transect 1). Salt canopy in Transects 1 and 2 as well as dolines in Transect 3.

In summary, the study area is divided into three distinct structural zones. It appears that where the autochthonous salt is more extensive the deformation is more significant than where salt was at its maximum extent. The first and rapid salt-related deformation occurred where the salt was at its maximum extent, whereas complex rocks distribution and displacements occurred where salt was at its minimum extent.

During the Jurassic, prominent carbonate banks alternated with siliceous sediments over the sequence. The main sediment source is from the northeast Canadian Shield. The section shows that the syn-rift sedimentation of the Atlantic Ocean to the recent post-glacial period. The salt basin was fed by clastic sediments from a large drainage system over the northeastern Canadian Shield. The study area is divided into three distinct structural zones. It appears that where the autochthonous salt is more extensive the deformation is more significant than where salt was at its maximum extent. The first and rapid salt-related deformation occurred where the salt was at its maximum extent, whereas complex rocks distribution and displacements occurred where salt was at its minimum extent.

Maps on the left show successively the distribution of autochthonous salt, allochthonous salt and salt canopy. We can observe that the largest synkinematic wedge occurred where salt had the largest allochthonous salt. The later synkinematic wedge and salt canopy occurred where the salt had the largest allochthonous salt. Largest concentration of allochthonous salt occurs between the two areas.

During the Early Cretaceous, the main sediment source is from the northeast Canadian Shield. The section shows that the syn-rift sedimentation of the Atlantic Ocean to the recent post-glacial period. The salt basin was fed by clastic sediments from a large drainage system. The main river systems are blocked by salt bodies, and salt can be observed in the Bay of Fundy. During the Mid-Cretaceous, the main river systems are blocked by salt bodies, and salt can be observed in the Bay of Fundy. During the Late Cretaceous, the main river systems are blocked by salt bodies, and salt can be observed in the Bay of Fundy. During the Cenozoic, the main river systems are blocked by salt bodies, and salt can be observed in the Bay of Fundy.

Wells Correlation: Wells on the left show the upper Jurassic, but most of the section is from the Cretaceous succession. Most of preserved accumulation is in the Foreland sediments. The salt basin was restricted to the back of the foreland basin, whereas Cretaceous series are related to deltaic systems. During the Early Cretaceous, the main dranoa system is from the northeast Canadian Shield. The section shows that the syn-rift sedimentation of the Atlantic Ocean to the recent post-glacial period. The salt basin was fed by clastic sediments from a large drainage system. The main river systems are blocked by salt bodies, and salt can be observed in the Bay of Fundy. During the Mid-Cretaceous, the main river systems are blocked by salt bodies, and salt can be observed in the Bay of Fundy. During the Late Cretaceous, the main river systems are blocked by salt bodies, and salt can be observed in the Bay of Fundy. During the Cenozoic, the main river systems are blocked by salt bodies, and salt can be observed in the Bay of Fundy.

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