Seismic interpretation of Cree Sand channels on the Scotian Shelf

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Summary

Potential reservoirs can be found within deltaic channels, these channels have the ability to form continuous transport systems for hydrocarbons. Distributary sand-filled channels in particular can serve as excellent reservoirs. The emphasis of this study is taking a detailed look into the sand channels within the Cree Sand of the Logan Canyon, as well as using coherence and coherent energy seismic attributes to delineate these features. Extensive studies have been performed in analysis of deltaic channel systems and their ability to act as reservoirs for hydrocarbons. The paper will follow an equivalent approach, employing 3D seismic survey data and seismic interpretation techniques to identify and map sand channels. The study area is focused on the Penobscot field, located off of the eastern shores of Nova Scotia.

Introduction

Deltaic channel systems are among the largest reservoirs for petroleum exploration in submarine environments. Distributary channels are formed through river bifurcation, or the splitting of a single river flow into multiple streams. As sediment flows into the delta, the coarsest sediment is quickly deposited in these channels, due to the flow being too slow to carry sand-sized grains. Thus, deltaic distributary channels are typically filled with reservoir-grade sands (Slatt, 2006). The Cree Sand of the Logan Canyon Formation contains many of these channels, giving it excellent reservoir potential.

Coherence and coherent energy seismic attributes aid in interpretation of discontinuous features, which are not readily identifiable using alternative attributes. As a result, these seismic attributes have gained great prominence. Since their inception during the 1990s, they have become the favored tool for the mapping of stratigraphic depositional environments (Peyton et al, 1998). These advances in seismic attributes allow us to delineate in detail the subtle levees and fans of a deltaic system.

Geology of the study area

The Scotian Basin is located in offshore Nova Scotia, continuing approximately 746 miles from the Yarmouth Arch / United States border in the southwest, to the Avalon Uplift on the Grand Banks of Newfoundland in the northeast (Figure 1). The stratigraphic framework is episodic and dominated by a long history of passive-margin deposition. The Cree Sand of the Logan Canyon Formation is located at an approximated depth of 5,100 to 6,600 ft, with an overall thickness of 1,500 ft (Figure 2).

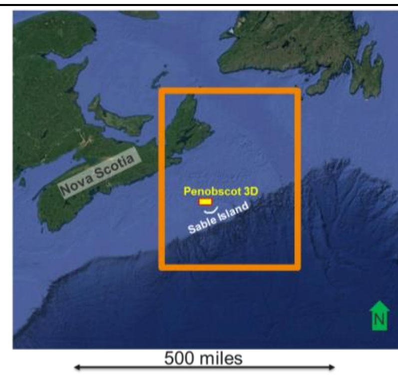

Figure 1(a). Location map of the study area (Google Earth Maps). The Penobscot 3D seismic survey is displayed in the yellow rectangle.

Building of the Scotian Basin began soon after the separation and rifting of the North American continent from the African continent, all during the break-up of Pangea. The Scotian Basin is made up of a series of depocenters and platforms, which includes the Sable Subbasin. Working in conjunction, the series of platforms and subbasins have significantly controlled sediment distribution for a period of over 190 million years.

Early deposition in the area is characterized by an initial transition (Anisian to Taorcian) from terrestrial rift sediments to shallow marine carbonates and clastics (NSDE, 2011). This is followed by an initial postrift carbonate-dominated sequence (Aalenian – Tithonian). The second postrift sequence (Berriasian – Turonian) consists of a thick, rapidly deposited deltaic wedge (Missisauga Formation) and a series of thinner, backstepping deltaic lobes (Logan Canyon Formation). These two deltaic formations are separated by the Naskapi Shale (Aptian MFS). The Cree is the oldest deltaic member of the Logan Canyon formation, and thus contains the thickest and most abundant channel sand deposits.

Seismic attribute study

The Penobscot 3D seismic survey was acquired offshore Nova Scotia in 1992 with a 4 ms sample rate. (Figure 1). Seismic data was of moderate quality. The survey area is approximately 33.4 mi^2. The data was prestack processed with a bin size of 39ft x 82 ft (12.5m x 25m).

Seismic amplitude interpretation

Figure 3a shows the top surface of the Petrel formation, a Late Cretaceous chalk, which is the most prominent seismic marker above the Cree Sand (Figure 3b).

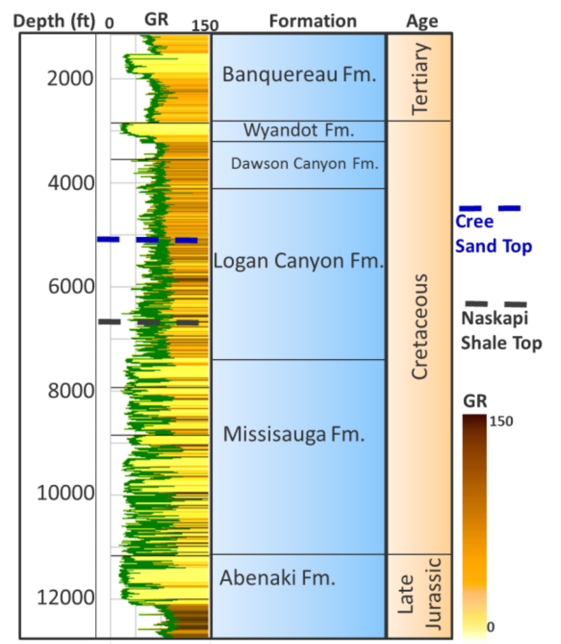

Figure 2. Stratigraphic column of the study area. The first track indicates measured depth. The second track shows the gamma ray log for well L-30, the darker color signifies high gamma ray values, which indicates shaly facies, whereas the light colors are for low gamma ray values, indicating sand rich facies. The third track shows the name of the formation and geological age (modified from Bhatnagar et al., 2017).

Coherence and Coherent Energy attribute

Coherent energy and coherence help interpreters to see discontinuous features which are hard to see with other attributes. The coherent energy was calculated by computing the energy of the coherent component of the seismic reflectors within an analysis window, whereas the coherence attribute was derived by measuring the change in seismic amplitude and waveform shape (DelMoro et al., 2013). High amplitude continuous features such high porosity sands lying on top of impermeable shales will display high coherent energy. Likewise low amplitude continuous/discontinuous features such as identical stack shales will display low coherent energy. Channels will often exhibit a sharp lateral change in amplitude and waveform shape, giving rise to a coherence anomaly (Figures 4).

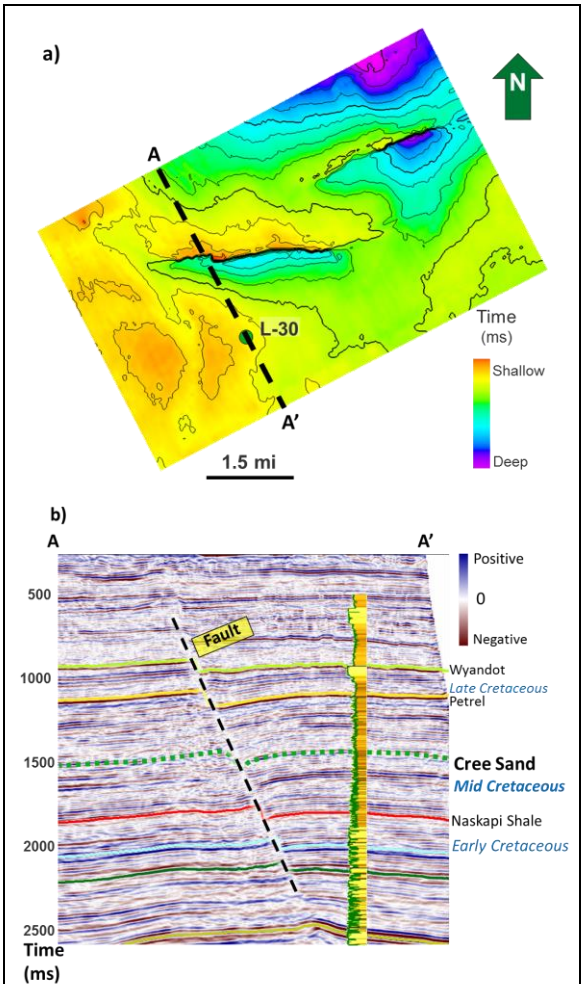

Figure 3. (a) Time structure map of Petrel top surface, Well L-30 shown as a green dot in Figure 3a. (b) Seismic amplitude section through AA'. Gamma ray log from the L-30 well is posted on seismic to indicate the sandy and shaly lithology (see Figure 2 for color scale). Annotations on the right hand side indicate the name of the formation tops (in black regular font) and their ages (in light blue italics font).

We start by looking at the deepest section of our formation. The coherence attribute is used to find these channels as they help delineate discontinuous features really well. The major channels are highlighted with a red boundary for better visualization (Figure 4b). Coherent energy was applied to the same stratal slice to distinguish the channels with a better contrast (Figure 4a). The location of well L-30 is shown on the stratal slice with a green dot.

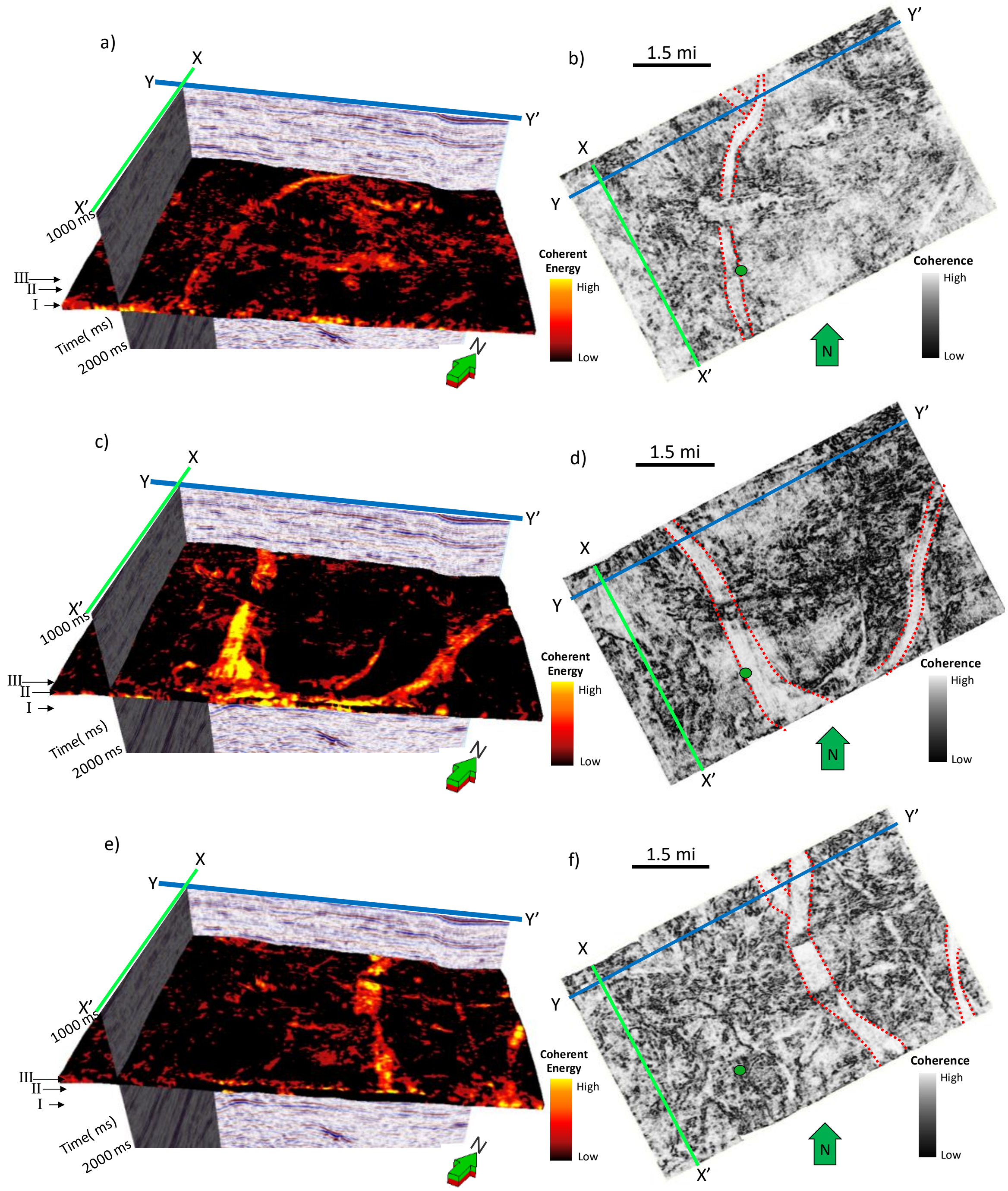

Figure 4. Channel delineation with the help of seismic attributes. In left (a, c and e) seismic amplitude on the vertical sections (same color bar as Figure 3b), and coherent energy on a stratal slice. In right (b, d, f) coherence stratal slices. This figure shows three levels of channels, from deepest (a and d) to shallowest (e and f). For clarity, we indicate these stratal slices as levels I, II and III. Notice that the deepest stratal slice, Level I (a and b, at stratal slice 614 ms below Petrel) shows relatively thin channels. Whereas at the shallower Level II (c and d, at stratal slice 490 ms below Petrel) contain broader channels, and the shallowest Level III (e and f, at stratal slice 430 ms below Petrel) shows even broader channels.

As we move up the formation, the channels start getting thicker and wider, which we are able to accurately image with the coherent energy attribute (Figure 4c). The high coherent energy indicates low impedance sands, which could possibly signal the presence of hydrocarbons in these channels. The coherence attribute (Figure 4d) also help us visualize these channels on either side of the faults.

As we approach shallower depths of the Cree Sands, one can see distributary channels with multiple crevase splays. Again, we are able to distinguish this with the help of coherence and coherent energy attribute (Figure 4e and Figure 4f).

Discussion and conclusions

The Cree deltaic lobe is characterized by a slow progradation, which displays a number of deltaic facies and changes in channel types, capped by sea level rise. During Aptian time (Figure 5b), sea level is relatively high, and the deepwater/prodelta Naskapi shale is deposited. By the Early Albian (Figure 5c), sea level has begun to drop and the delta front moves forward, with the study areas seeing mainly distal delta channels tributaries. These channels are thinner, such as those in Figure 4a and 4b. During the Mid-Albian (Figure 5d), as the sea level drops further, the study areas sees relatively proximal part of the delta, and the broad channels dominate; this is similar to Figure 4c and 4d. Finally, during the Late Albian (Figure 5e), sea level increases, and the shale rich pro delta facies of the Sable shale are deposited.

Coherence and coherent energy seismic attributes were used to delineate the features of interest. We were able to use our seismic interpretation to identify different channel assemblages. Based on how these assemblages changed through time, we were able to create the composite interpretation seen in Figure 5. Thus, we were able to use seismic imaging to identify and interpret deposition environment changes within the known deltaic system.

Acknowledgements

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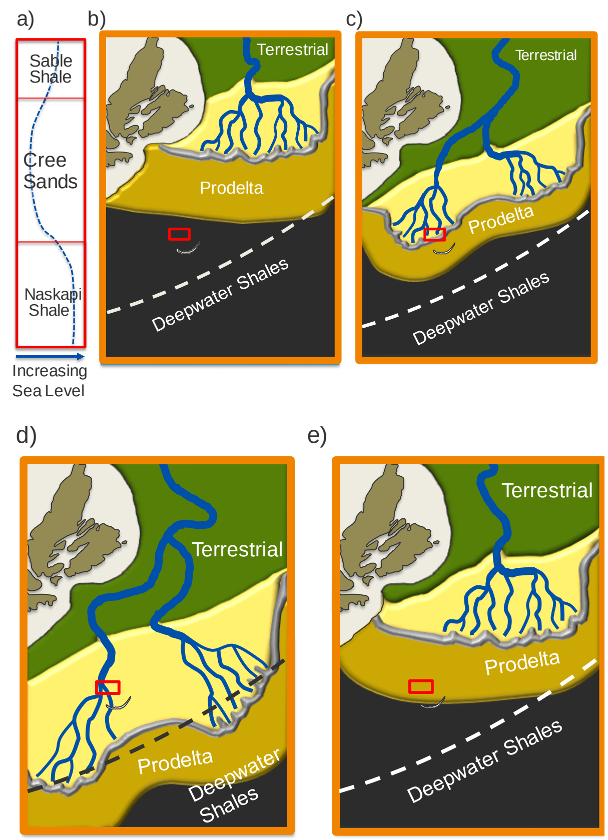

Figure 5. Interpretation of the deltaic channels based on the seismic attribute interpretation. (a) sea level curve, obtained from Haq et al, 1987. (b-d) the changing position of the delta due to sea level, from older to younger. Here, this model is bounded by the orange rectangle shown in the Figure 1. The dashed line represents the Aptian paleo shelf break.

EDITED REFERENCES

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