Early Basin Insights and AVO Supported Leads From New Long Offset 2D Seismic Data, Labrador Sea, Canada

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Summary

The first regionally extensive long offset 2D seismic program has been acquired in the slope and deepwater regions of the Labrador Sea, offshore Canada. The survey was planned integrating well ties from the shelf, regional gravity data, and newly acquired satellite slick data that suggested the potential for oil prone hydrocarbon systems in the previously unexplored deepwater areas. The early data results from this initial 2011-2012 program (22,000 line km) are encouraging and have resulted in the identification and delineation of new basins, play types, and AVO supported leads.

Introduction

The Labrador shelf region of offshore Eastern Canada saw significant exploration activity in the 1970's and 1980's. During that period, over 20 wells were drilled on the Labrador shelf resulting in five gas discoveries in the Hopedale Basin totaling over four TCF of gas resources. While there was significant exploration activity on the shelf during this time, the exploration of the slope and deepwater areas was very limited and no wells were drilled beyond the shelf edge. As a result of the gas discoveries on the shelf, the broader area was largely thought to be gas prone and exploration became dormant after the 1980's. To better understand the potential for oil prone source rock presence throughout the offshore area, Nalcor and Astrium Services undertook a regional satellite oil slick mapping survey covering all of Newfoundland and Labrador's offshore area (approximately 1.5 million square kilometers). This satellite mapping survey located slick anomalies in areas of known discoveries (Jeanne d'Arc Basin, Grand Banks) and also imaged slicks in frontier areas of the offshore, including numerous anomalies in the Labrador Sea slope and deepwater areas out beyond legacy seismic coverage. The presence and location of the satellite slicks in the Labrador Sea raised new questions. If the slick anomalies were resulting from in situ migration, this suggested the potential for the presence of a liquids prone source rock in the slope and deepwater. Additionally, the location of some of the seaward slicks further suggested the potential for basins extending significantly further offshore than previously understood.

To address these fundamental questions and delineate the potential of the largely unexplored slope and deepwater areas of the Labrador Sea, Nalcor Energy invested and partnered with TGS and PGS in a new 2D long offset GeoStreamer® seismic survey spanning the Canadian Labrador Sea from the shelf edge to the Canada-Greenland border as shown in ***Figure 1***. Due to large areal coverage and the coarse spacing of the lines (average 60 x 60 km grid), line placement was a primary consideration and was optimized utilizing well ties, regional gravity data, and satellite slick data.

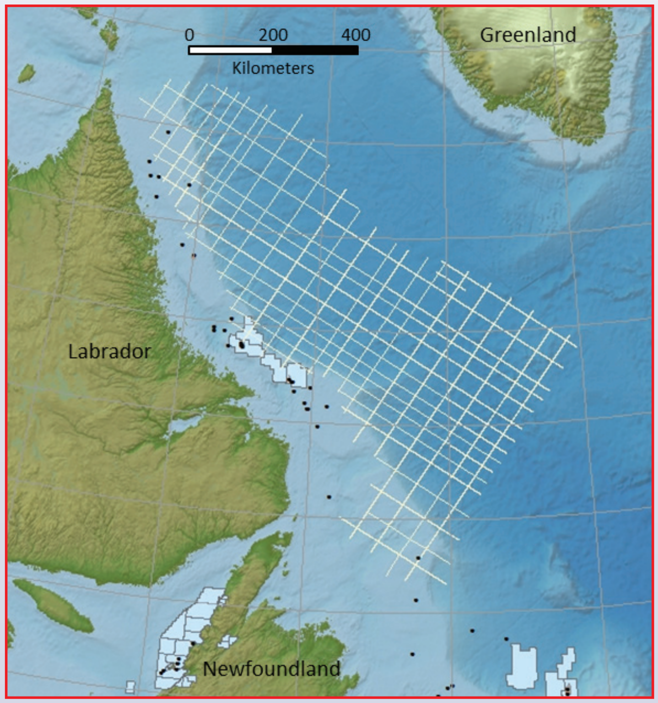

Figure 1: Map showing 2011-2012 Labrador Sea seismic program lines. The line placement was optimized by well ties, gravity data, and satellite slick anomalies.

Discussion

The significant size of Canada's Labrador Sea area required that careful consideration of survey design be employed to ensure optimal planning of a 22,000 line km survey to regionally delineate an area over 300,000

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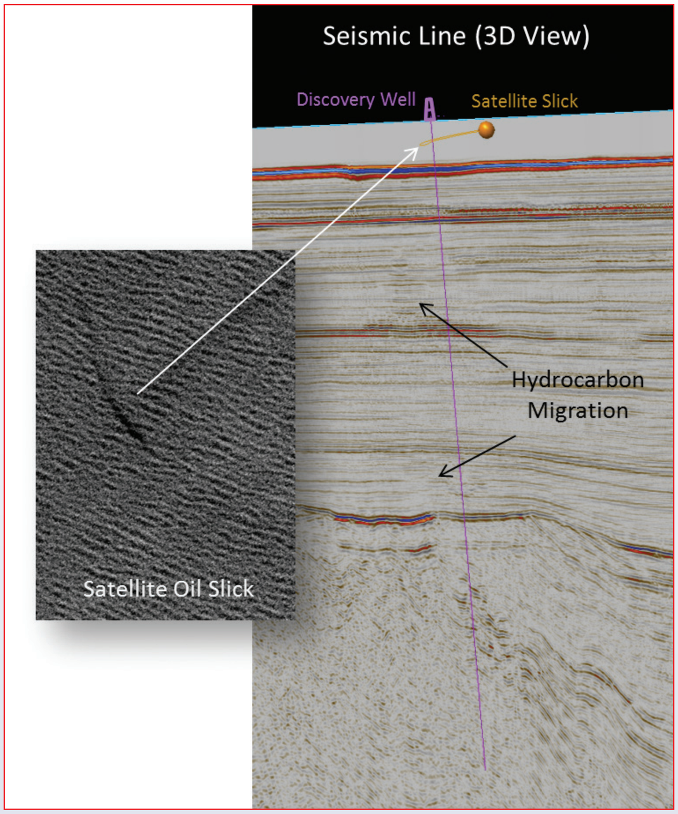

Figure 2: Satellite oil slick imaged over known oil discovery offshore Newfoundland and Labrador.

km^2 in size. Optimal planning would help achieve the objective of economically delineating prospective areas in a largely unexplored slope/deepwater region. The key considerations for survey design were: (1) tying wells on the shelf to extend the stratigraphic interpretation from the known shelf to the unknown deepwater; (2) gravity anomalies that could indicate the presence of sedimentary basins; and (3) tying satellite-identified oil slicks in the slope/deepwater. The satellite slick data were screened and processed for wind, wave, vessel traffic, natural film, and ice conditions that existed during scene acquisition to ensure that identified anomalies were consistent with conditions that could yield in situ related oil expressions on the sea surface. In offshore eastern Canada, the vast majority of satellite data are disqualified for slick detection through this process - largely based on unsuitable wind and wave conditions. While this results in the removal of the majority of anomalies from consideration, the remaining slick anomalies that can not be disqualified for these and other factors could be related to in situ oil migration to the ocean surface. While this process enhances confidence in the results, we additionally calibrated the slick data to areas of known oil discoveries in the Jeanne d'Arc basin to the south of the Labrador Sea area. ***Figure 2*** shows a screened satellite slick expression and a seismic section with the slick identified above the location of an oil discovery with a vertical fluid migration expression in the seismic.

This rigorous screening and calibration process increased our confidence to utilize the slick data in conjunction with potential fields data to plan a large portion of the seismic program in deepwater areas previously considered to be non-prospective thin sedimentary layers over oceanic crust.

With layout and line positioning optimized, the 22,000 line km seismic survey was acquired over two acquisition seasons, from June to November in 2011 and over the same period in 2012. Early results from the seismic survey have been encouraging. Prior to this survey being undertaken, the seaward extents of the Hopedale and Saglek basins (Enachescu, 2006) of the Labrador Shelf were limited by the lack of data in the slope and deepwater. ***Figure 3*** shows the new basin configuration of the Labrador Sea resulting from this seismic program (Carter et al, 2013).

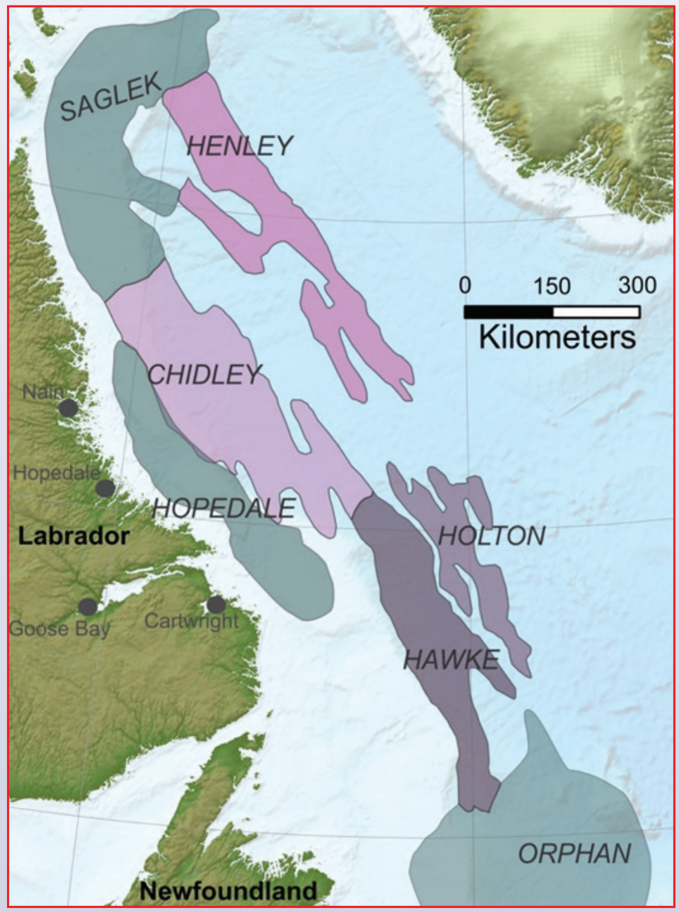

Figure 3: New basin configuration of the Canadian Labrador Sea. (after Carter et al, 2013)

Three new basins have been delineated in the deepwater: the Chidley Basin, the Henley Basin, and the Holton Basin. The Hawke Basin, which previously was thought to exist further south with limited extent has been expanded. The value of using the satellite slick data in planning the survey was borne out by the fact that many of the slicks in

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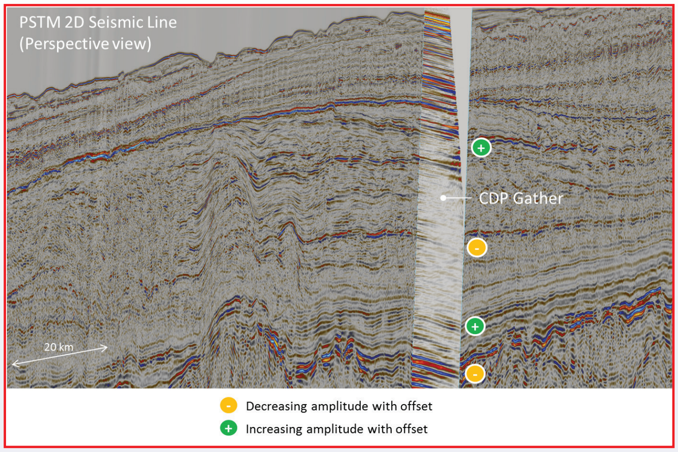

Figure 4: Perspective view of a 2012 deepwater Labrador Sea seismic line showing a broad Eocene aged structure and a CDP gather showing Class III AVO behavior in the upper portion of the structure.

the deepwater were delineating updip subcrop edges and structures in these previously unknown basins. These newly delineated basins have both Tertiary and Mesozoic fill and while early, the new data contain evidence of a number of potential play types including listric fault anticline trends, turbidite flows, amalgamated channel complexes, and deepwater basin floor fan systems.

In addition to the structural and stratigraphic definition, the long offset data are indicating the potential to use AVO to discriminate litho/fluid types. With seismic velocities in the early Tertiary/late Cretaceous section of 2000-3000 m/s, the rock compressibility should be generally favorable to AVO type analysis. ***Figure 4*** shows a full stack seismic line from the Labrador Sea deepwater basin delineating a 2D expression of a broad Eocene aged structure. A CDP gather (0-8 km) is shown intersecting perpendicular to the section at the CDP location on the full stack. The gather shows a variety of seismic events with differing AVO character – some increasing amplitude with offset, some decreasing, and others having flat AVO. The quality of the gathers and the AVO character suggests that the amplitude variation with offset being imaged is reflective of lithology/fluid content and not processing or acquisition effects. The Class III AVO responses both in the upper part of the structure and the deeper floor fan deposition are encouraging, and more work is planned to quantitatively delineate the expected response due to reservoir presence and/or hydrocarbon saturation.

Figure 5 shows a deepwater Labrador seismic line delineating a Tertiary listric rollover anticline feature (position 1) with a toe thrust (3) shown to the right side of the image. The upper panel shows the near angle stack (5-12 degrees) with the lower panel displaying the far angle stack (40-47 degrees). Overall, there is a decrease in background amplitude from near to far (2), which is consistent with wet sand/shale trends seen in analogue basins. At position (1), there is a marked increase near to far in trough over peak amplitude representing a soft unit. This type of amplitude response is consistent with models of hydrocarbons accumulating near the crest of the roll over structure. At position (3) the amplitude response of the crest of the toe thrust increases in the far angle stack, potentially suggesting the updip accumulation and migration of hydrocarbons from the downdip low at position (2). To estimate potential lithogy/fluid combinations that could exist in these structures, a detailed Labrador Sea rock physics project has been initiated. This project is drawing on shelf wells and global analogues to create representative rock physics models for the slope and deepwater. The goal of this ongoing project is to delineate depth dependent rock property trends to ascertain the potential to discriminate sand and shale, and if possible, the potential to discriminate wet sand from gas sand and oil sand. The integration of the rock physics with the AVO character being imaged in the new data should provide significant insight into potential lithology/pore fluid types in the new basins, providing an important tool to reduce exploration risk in these frontier areas.

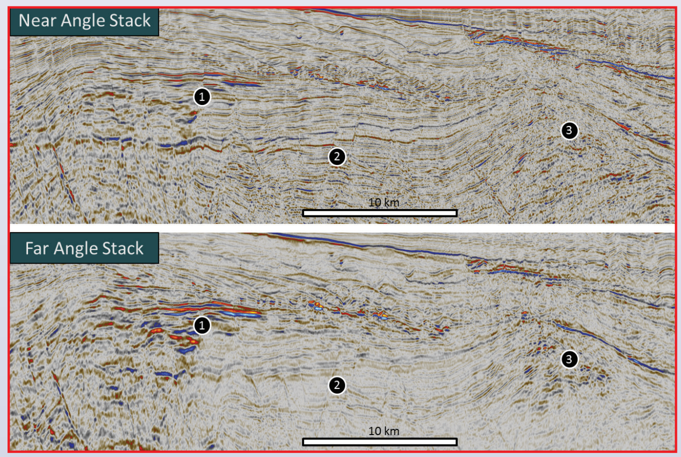

Figure 5: Near and Far Angle Stacks for a 2011 Labrador Sea deepwater seismic line. Amplitude increases with offset at (1) and (3), and decreases at (2) and the general background trend decreases. Signatures at (1) and (3) provide evidence of potential hydrocarbon charge in these structures.

Conclusions

The early data results from the first regionally extensive slope and deepwater seismic survey for the Canadian Labrador Sea have been encouraging. The concept of using screened and calibrated satellite oil slick data to aid in the location of frontier survey lines has proven to be a success as numerous slick anomalies corresponded to previously un-imaged basin rims and structures. Three new basins have been delineated and while early in the exploration cycle for the area, structures and play types

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within the new basins show promise for prospectivity. In addition, early reconnaissance AVO analysis has delineated geologically reasonable anomalies and amplitude signatures that could be consistent with hydrocarbon charge. Planned rock physics work will calibrate these anomalies and help further de-risk these frontier areas as exploration advances in the region.

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