Passive Margin Reservoir Distribution- Examples from the Scotian Margin

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Summary

All passive continental margins have an underpinning geologic platform that dictates their broad geomorphologic character and exerts control on sedimentation patterns. A significant issue in recent hydrocarbon exploration activities in deep water on the Scotian margin is the detection of reservoir rock, distributed by these sedimentation patterns. The objectives of this study were 1) to understand the complexities of shelf-to-slope and slope sedimentation patterns using Neogene to Recent analogues offshore Nova Scotia, the Grand Banks of Newfoundland and Suriname, South America, and 2) to understand the controls, inherent in mixed siliciclastic and carbonate shelf-edge depositional systems, particularly the inter play between the Abenaki carbonate platform and the Sable delta. In the first objective, younger analogues are studied where spatial and temporal resolution is not at issue and geologic events are better age-constrained.

New play concepts were developed that identified significant reworking of the margin that has not been recognised in the past. Our preliminary estimates suggest that over 50% of the Cenozoic margin has been reworked and in many instances the sediment has been remobilised and transported some distance from the shelf margin through canyon delivery systems, mass transport deposits, contourites, salt control on sediment redistribution, carbonate platform and mixed siliciclastic carbonate depositional systems. A thorough understanding of the interplay and complexity of these processes is necessary to develop and apply exploration models. The consequence of these sedimentary processes is movement of potential reservoir rock to greater depths than previously anticipated. Deciphering forcing functions, sediment pathways and depositional processes provide insights into exploration models for passive clastic margins. Validation of these hypotheses indicates that exploration must move to deeper water where shelf-equivalent rocks are transported and deposited.

Deep Panuke is possibly unique, situated in a thick platform of continuous carbonate, adjacent to a large delta. Over time the Sable delta buries some of the Abenaki platform, capping prodelta beds to give lignitic-humic source rock and seal. The reservoir and trap are the reef margin. Due to early cementation from rapid

and deep burial in deltaic sediments; the updip platform limestone is non-porous and acts as a lateral seal forming a partial stratigraphic trap. The shelf margin position develops fracturing and faulting but the occurrence is highly variable. These provided migration conduits for dolomitizing fluids and later hydrocarbons that result in a deeply buried reservoir with gas accumulation.

Introduction

It has been found that existing models of deep water sedimentation, particularly on passive continental margins, have greatly underestimated the linkages between shelf to slope sedimentation, the role of sediment mass failure and along slope sediment transport in redistributing sediment, and the role of canyon development leading to base of slope sediment distribution. These processes indicate that reservoir-grade sediments can be reworked, relocated and transported to great water depths and offer significant challenges to reservoir detection along the Scotian margin.

Methods

Five 3D seismic volumes distributed across the Scotian margin and an extensive grid of 2D seismic data were interpreted for this study. Data were interpreted on seismic workstations, including application of modern practices of seismic stratigraphy, sequence stratigraphy, seismic geomorphology and attribute analysis. The Abenaki carbonate platform and Sable Delta study incorporated seismic, well logs and cuttings and core data in over 25 Abenaki Formation wells.

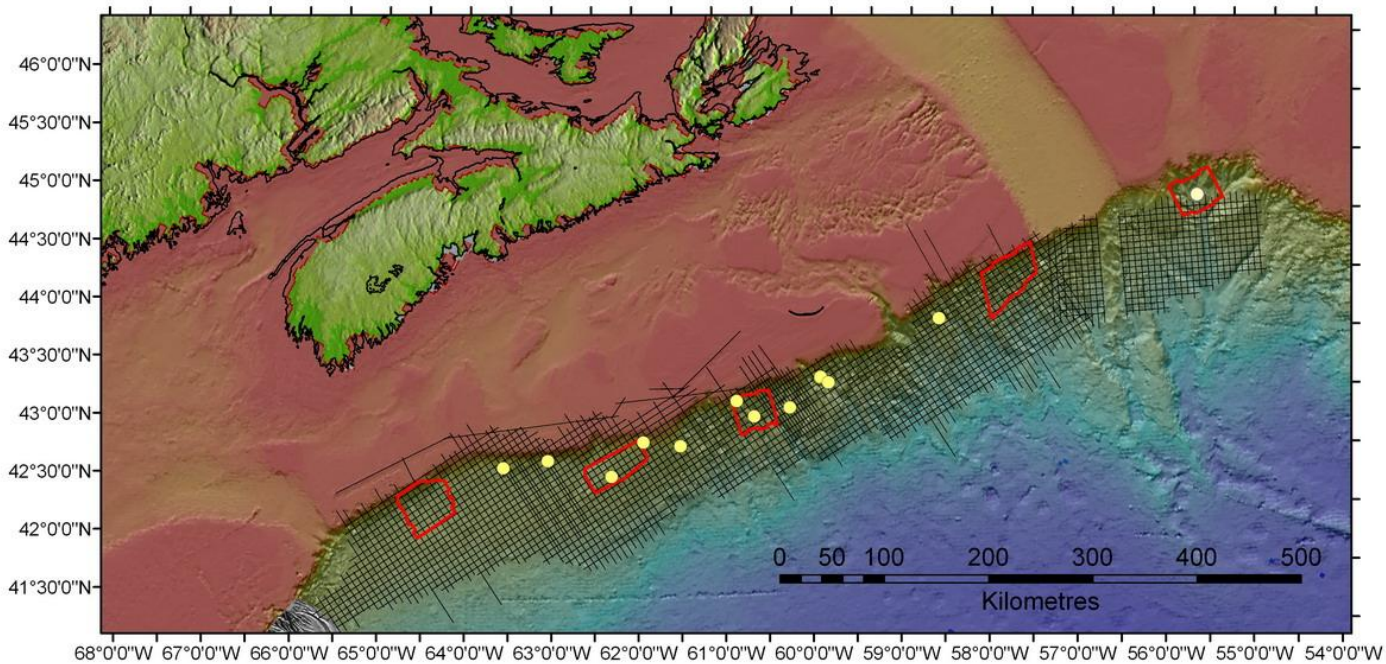

Figure 1: The modern seafloor bathymetry of the Scotian margin shows numerous canyons. Red polygons are 3D seismic volumes used in this study. Black lines are 2D seismic track lines (TGS-NOPEC). Yellow dots are exploration wells on the slope.

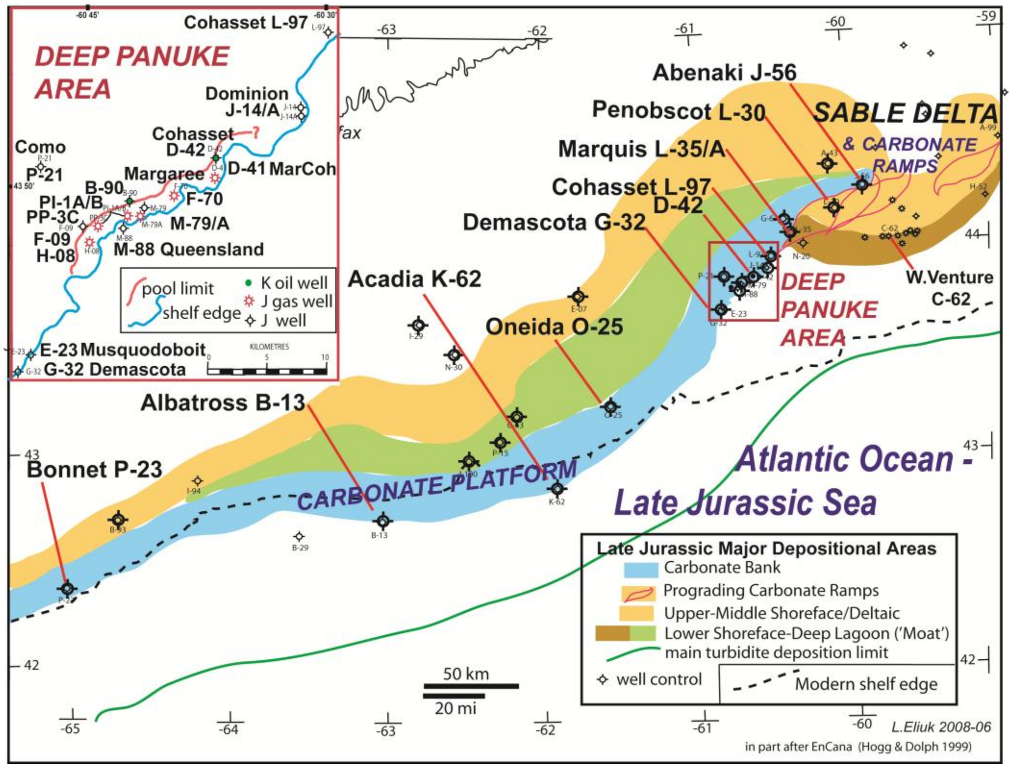

Figure 2: Distribution of the Mesozoic Abenaki carbonate platform and the Sable Delta illustrating the major depositional areas. The Abenaki Formation wells are in bold. Newer wells (1998+) are in the Deep Panuke area (inset map). The only post-1998 Abenaki wells outside the inset map are Marquis L-35 and its basinward whipped follow-up L-35A.

Conclusions

Mixed Carbonate Platform and Deltaic Successions: All passive continental margins have an underpinning geologic platform that dictates their broad geomorphologic character and to some extent controls subsequent sedimentation patterns. These building blocks can control the margin's hydrocarbon potential. The Abenaki Carbonate platform underpinning the Scotian margin controls subsequent sedimentation patterns. Sea level is recorded within the platform with subsequent unconformities and deltaic bypass sands. Sediment loading of the platform has and continues to play a significant role in controlling underlying salt migration that impacts sediment pathways along and across the slope. The relationship of reefs and deltas is generally thought to be one of complete incompatibility, but the Scotian margin is an exception. Detailed examination of all well and seismic data, coupled with outcrop and subsurface analog studies provided scales of the architectural elements and identified stratigraphic anomalies.

Reservoir distribution and quality: The principal source of sediment for continental slopes is the adjacent shelf with sediment delivered during sea level lowstands. The Sable shelf margin delta provides reservoir sands to deeper water. Progradation of the Sable delta to the shelf edge was controlled in part due to localized accommodation controls from differential mobilization of the underlying salt.

Margin erosion and reworking: Along the Scotian margin, sediment distribution is influenced predominantly by mass transport deposition, sediment by-pass through canyons, and sediment redistribution by strong deep-water contour currents. Canyons and mass-transport processes provided mechanisms for slope bypass and delivery to the rise and abyssal plane. Mass transport deposits are enigmatic depending on hydrocarbon type (gas or oil). They may in fact produce a good seal facies to reservoir facies, dependent upon sand, silt and clay content within stratigraphic intervals. Sediments deposited by contour-currents were only recently identified along the margin, leading to difficulty in predicting sediment distribution patterns, and ultimately prospectivity for hydrocarbons. Significant deep water margin erosion occurred at certain periods, apparently related to development of strong along-slope bottom currents. These currents were responsible for removal and redistribution of vast amounts of material. The prospectivity of the base-of-slope is unknown but it is clear that this too is dominated by mass transport deposition which strongly affects the stratigraphic distribution and sedimentary architecture. The broad correlation of sedimentary processes across the margin provides for some consistency in interpretation with reasonable predictability of sediment type on the large scale.

A thorough understanding of the interplay and complexity of these processes is necessary to develop and apply exploration models. These processes indicate that reservoir-grade sediments can be reworked, relocated and transported to great water depths and offer significant challenges to reservoir detection along the Scotian margin. The obvious consequence is that exploration must move to deeper water where shelf-equivalent rocks are transported and deposited. Concepts identified through this research project provide previously unrecognized opportunities on the Scotian margin that should be investigated further, and are applicable to other passive margins around the globe. New insights on the Cenozoic stratigraphic framework are applicable worldwide.

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