AAPG Search and Discovery Article #90172 © CSPG/CSEG/CWLS GeoConvention 2010, Calgary, Alberta, Canada, May 10-14, 2010

Reservoir distribution and characterization: continental slope depositional systems along the Scotian margin

David C. Mosher*
Dalhousie University, Department of Earth Sciences, Halifax, NS, B3H 4J1
dmosher@nrcan.gc.ca

and

G.D. Wach, D.C. Campbell*, M.K. Giles, V.I. Brake†

Dalhousie University, Department of Earth Sciences, Halifax, NS, B3H 4J4

*present address: Geological Survey of Canada - Atlantic, 1 Challenger Dr., Dartmouth, NS, B2Y 4A2

† present address: Geological Survey of Canada – Québec, 490, rue de la Couronne, Québec, QC, G1K 9A9

Summary

Numerous unsuccessful deep water exploration wells indicate a global need to recognize and understand continental shelf-to-slope and slope sedimentary systems. This study addresses this issue through study of analogues on the Scotian margin using 3D seismic volumes and an extensive network of 2D seismic data. Results indicate the need for regional comprehension of the margin that includes ties to global paleoceanographic events in order to establish the stratigraphic framework and predict lithologic facies.

Introduction

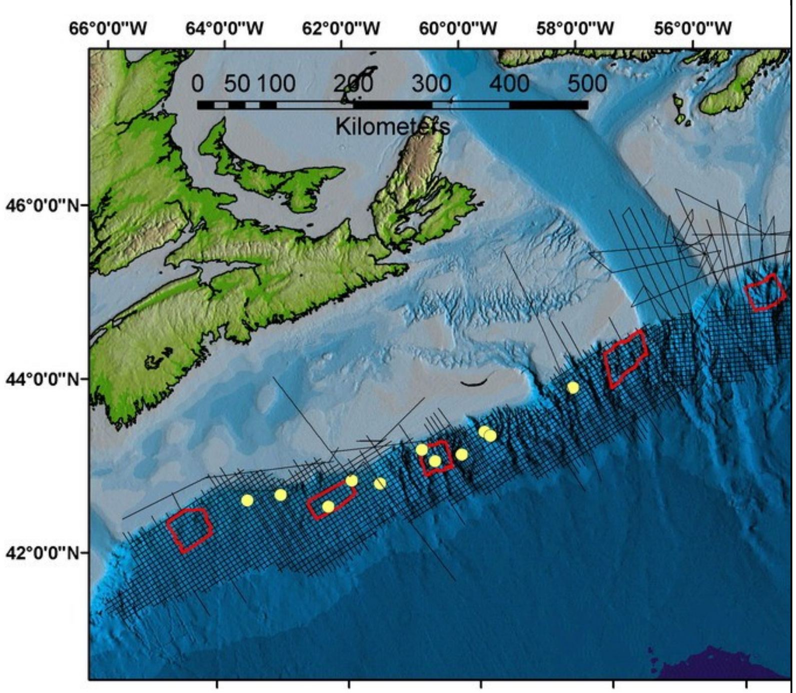

Figure 1. The modern seafloor of the Scotian margin shows numerous canyons. Red polygons are 3D seismic volumes used in this study. Black lines are 2D seismic track lines. Yellow dots are exploration wells on the slope.

The Scotian margin endured a number of unsuccessful hydrocarbon exploration attempts because of insufficient understanding of continental shelf-to-slope and slope geologic processes. The Shubenacadie H-100 and Shelburne G-29 wells were drilled on mounded seismic morphologies, interpreted as depositional fans. In post-drill analysis with modern seismic coverage, it is apparent that these structures are erosional remnants resulting from canyon cutting across the slope (Kidston et al., 2007). More recently, the Torbrook C-15 well was drilled into a presumed Tertiary fan; an interpretation based on modern 3D seismic data. In this case, a mass transport deposit was encountered.

The Annapolis B-24 well targeted a turbidite fan; again an interpretation based on modern 3D seismic data. It was the only discovery well in deep water, but was non-commercial. Kidston et al (2007) admit that they are uncertain as to the origin of the reservoir facies within the conceptual submarine fan body. They suggest that the Annapolis area may represent an overall bypass zone on the slope. Our studies suggest it may be a contourite interval.

The above examples highlight a global need to recognize and understand continental shelf-to-slope and slope sedimentary processes and depositional systems. This study addresses this issue through study of analogues on the Scotian margin wherein there is sufficient data resolution and fewer complicating factors such as sediment compaction, structural faulting and salt mobilization deformation.

Methods

Five 3D seismic volumes distributed across the Scotian margin and an extensive grid of 2D seismic data were interpreted for this study (Figure 1). Data were interpreted on seismic workstations, including application of modern practices of seismic stratigraphy, sequence stratigraphy, seismic geomorphology and attribute analysis.

Results and Discussion

For the Scotian margin, application of conventional seismic sequence stratigraphic methods has proven difficult to apply because of the dominance of erosive processes. Such processes include numerous episodes of canyon cut and fill coupled with slope bypass, mass transport reworking and re-deposition, and along-slope sediment erosion and transport by deepwater contour currents (contourites). These poorly understood processes dominate over sediment input and sea level controls and greatly impact the preserved stratigraphic record with significant spatial and temporal variation.

The modern seafloor of the eastern Scotian Slope is heavily incised by canyons and valleys, providing recognizable conduits for off-shelf sediment transport, slope by-pass and deposition on the continental rise and abyssal plain (Fig.1; Mosher et al., 2004; Jenner et al., 2006). Canyon incision appears to have been episodic throughout the Cenozoic, involving multiple phases of cut-and-fill with new systems often re-occupying old, perhaps in response to underlying basement control (Brake, 2009) (Fig. 2). This episodic canyon incision indicates a limited residence period of sediments on the shelf and slope, having implications for potential

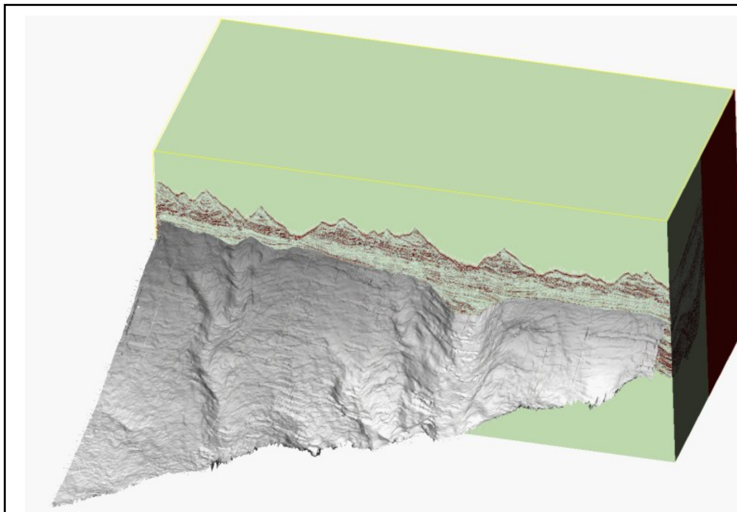

Figure 2. A 3D surface render of a preseumed Oligocene canyon system on the Scotian Slope (from Brake, 2009)

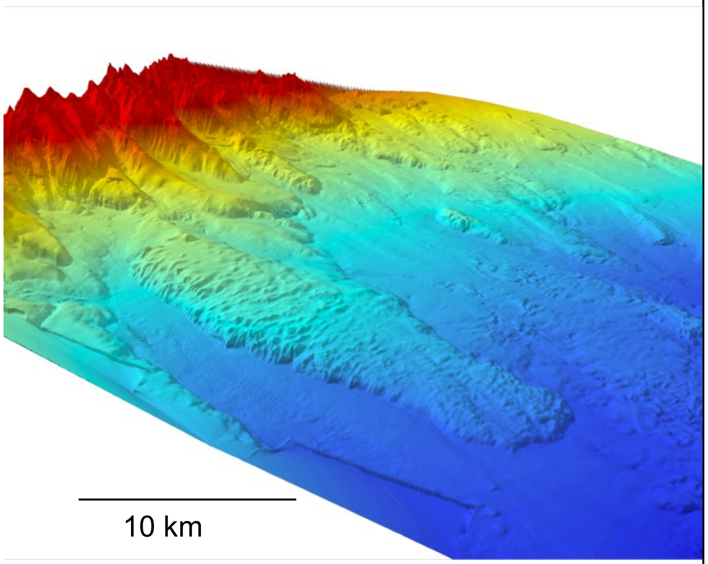

Figure 3. 3D surface rendering of a mass transport deposit on the Scotian Slope.

reservoir distribution. Mass transport processes are a fundamental aspect of continental slope construction (Fig. 3; Mosher et al., 2010; Giles et al. 2010). Their deposits are enigmatic depending on hydrocarbon type (gas or oil). They may produce a good seal to reservoir facies, dependent upon sand, silt and clay content and may lead to down-dip high density turbidite facies which may form reservoirs. The magnitude of sediment redistribution by contour-currents was only recently recognized along this margin (Fig. 4; Campbell et al., 2009, 2010). This process leads to difficulty in predicting sediment distribution patterns and ultimate prospectivity for hydrocarbons. The prospectivity of the base-of-slope is unknown but it is a region dominated by mass transport and turbidite deposition (e.g. Fig. 5).

Despite these complexities in sedimentary processes, there are consistencies in depositional patterns across the margin and Atlantic-wide paleoceanographic events permit establishment of a broad stratigraphic framework. For example, a major Eocene canyon cutting period and a mid-Miocene bottom current intensification period provide stratigraphic markers despite having varying depositional signatures across the margin. These results indicate the need for regional comprehension of the margin that includes ties to global paleoceanographic events.

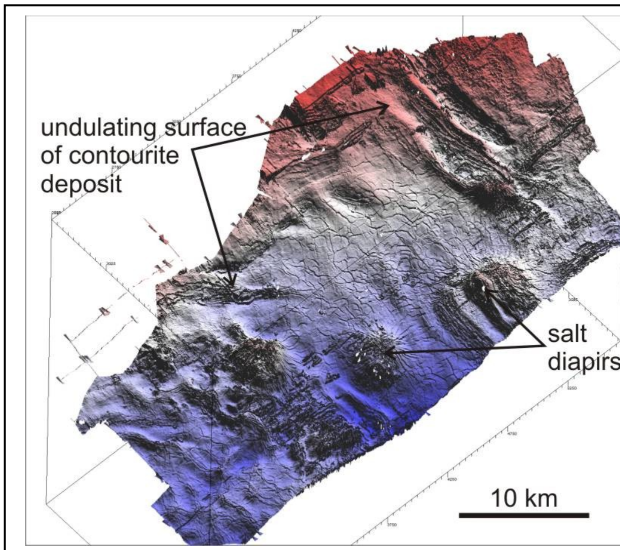

Figure 4. A 3D surface rendering of a seismic horizon with bedforms resulting from along-slope bottom currents

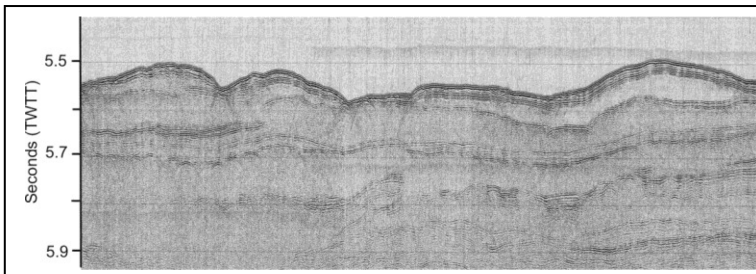

Figure 5. Seismic profile of stacked MTDs on the Scotian continental rise

Conclusions

- Along the Scotian margin, canyons and mass-transport processes provided mechanisms for slope bypass and delivery to the rise and abyssal plane.

- Mass transport processes resulted in removal of stratigraphic section and transport of significant amounts of sediment downslope.

- 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 processes indicated above 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. A thorough understanding of the interplay and complexity of these processes is necessary to develop and apply exploration models.

Acknowledgements

We would like thank TGS-Nopec, EnCana and ConocoPhillips for their generous contribution of datasets for these projects. Without the generous contributions of data by these companies student research projects and training for careers for petroleum industry would not be possible. Financial and/or in-kind support of OETR (Offshore Energy Technology Research) association, NRCAN, NSERC, the Nova Scotia Department of Energy and Pengrowth through funding to the principal investigators and scholarships to our students is gratefully acknowledged.

References

Brake, V.I., 2009, Evolution of an Oligocene Canyon System on the Eastern Scotian Margin. Unpublished M.Sc. Thesis, Dalhousie University, Halifax, NS., 113 pp.

Campbell, D.C., and Mosher D.C., 2010. Middle to late Miocene slope failure and the generation of a regional unconformity beneath the western Scotian Slope, eastern Canada. In: Mosher, D.C., Shipp, C., Moscardelli, L., Chaytor, J., Baxter, C., Lee, H. and Urgeles, R. (eds). Submarine Mass Movements and Their Consequences IV; Advances in Natural and Technological Hazards Research, Vol 28, DOI 10.1007/978-90-481-3071-9, Springer, The Netherlands, p. 645-656.

Campbell, D.C., D.C. Mosher, M.E. Deptuck and G.D. Wach, 2009. The formation of a Miocene Deepwater Erosional Unconformity and Subsequent Deposition Patterns on the Western Scotian Slope, Canada Canadian Society of Petroleum Geologists Conference, Calgary, Alberta, May 4-7, 2009

Giles, M.K., Mosher, D.C., Piper, D.J.W., and Wach, G.D., 2010. Mass transport deposits on the southwestern Newfoundland Slope. In: Mosher, D.C., Shipp, C., Moscardelli, L., Chaytor, J., Baxter, C., Lee, H. and Urgeles, R. (eds). Submarine Mass Movements and Their Consequences IV; Advances in Natural and Technological Hazards Research, Vol 28, DOI 10.1007/978-90-481-3071-9, Springer, The Netherlands, p. 657-666.

Jenner, K.A., Piper, D.J.W.P., Campbell, D.C. and Mosher, D.C., 2006. Lithofacies and origin of late Quaternary mass transport deposits in submarine canyons, central Scotian Slope, Canada. Sedimentology, 53., 20 pp.

Kidston, A.G., Smith, B.M., Brown, D.E., Makrides, C., Altheim, B., 2007, Nova Scotia Deepwater post-drill analysis, 1982-2004. Unpublished Report to the Canada-Nova Scotia Offshore Petroleum Board, 181 pp. http://www.cnsopb.ns.ca/geoscience_publications.php.

Mosher, D.C., Shipp, C., Moscardelli, L., Chaytor, J., Baxter, C., Lee, H. and Urgeles, R. (eds), 2010. Submarine Mass Movements and Their Consequences IV; Advances in Natural and Technological Hazards Research, 28, DOI 10.1007/978-90-481-3071-9, Springer, The Netherlands, 792 pp.

Mosher, D.C., Piper, D.J.W.P., Campbell, D.C., and Jenner, K.A., 2004. Near surface geology and sediment failure geohazards of the central Scotian Slope. American Association of Petroleum Geologists Bulletin, 88, p. 703-723.