Comparison of large contourite drifts in the western North Atlantic

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Abstract: *Large contourite depositional systems (CDS) are a common morphological feature of the North American margin of the western North Atlantic Ocean. High quality seismic reflection data and drilling results allow correlation and comparison of these features over several thousands of kilometres. Greatest apparent drift growth was during the Late Miocene and Pliocene. The locations of CDS coincide with pre-existing structural features such as ancient faults and bedrock promontories. Most CDS show evidence of gas hydrate accumulation. Submarine slope failures are associated with CDS; on detached drifts, thick accumulations of mass transport deposits and stepped escarpment morphology indicate repeated instability over time. The synchronicity of maximum drift growth over such a vast region implies that ocean-wide changes in circulation, continental-scale changes in tectonics and climate, and eustacy dominate over local changes in sediment supply in controlling CDS development.*

Key words: *North Atlantic, Pliocene, contourite, mass transport deposit, gas hydrates*

INTRODUCTION

Some of the earliest recognized contourite depositional systems (CDS) are from the western North Atlantic (WNA), specifically the US Atlantic margin (e.g. Heezen et al., 1966). Subsequent work focused on the analysis of seismic reflection data, supplemented by ocean drilling data, to determine timing of significant drift development and major erosional periods (Mountain and Tucholke, 1985; Arthur et al., 1989 among others). Since the initial discovery and study of these features in the 1960s-1980s, vast amounts of high quality seismic reflection, scientific and exploration drilling, and seabed data have been collected. This study focuses on deposits along an approximately 6000 km long segment of the NE United States and Canadian margin, exposes broad similarities between WNA contourite drifts, and examines some of the questions raised by these observations.

DATA AND RESULTS

This study uses a range of geophysical and geological data including: 1) multi- and single-channel seismic reflection data collected by the petroleum industry, academia, and government; 2) lithological and biostratigraphic information from scientific boreholes and exploration wells; and 3) high resolution bathymetry data. In addition, this study incorporates and synthesizes previously published results from CDS in the study area.

The Cenozoic seismic stratigraphy for most of the WNA margin is remarkably consistent. The stratigraphy can be broadly divided into 4 units (Table I). Large contourite deposits are principally confined to Unit 3 (Upper Miocene to Pliocene). The quality of age control for Unit 3 varies across the margin, however there are several indications that apparent drift development was greatest during the latest Miocene and Pliocene, and that changes in the dominant current system occurred in the Early Pliocene; for example the Chesapeake Drift (Locker and Laine, 1992), the Nova Scotia margin (Campbell, 2011), the Newfoundland Basin (unpublished results), Sackville Spur (Kennard et al., 1990), Hamilton Spur (unpublished results) and Davis Strait (Nielsen et al., 2011) (Figure 1).

Seismic Unit	Age	Character
Unit 4	Quaternary	Gravity flow, hemipelagic and plume fall-out deposition predominance.
Unit 3	Upper Miocene-Pliocene	CDS predominance.
Unit 2	Oligocene-Middle Miocene	Primary depositional modes overprinted by polygonal faults, local CDS development.
Unit 1	Upper Cretaceous-Eocene	Variable reflection geometry, higher seismic amplitude, local CDS development.

TABLE I. General division of Cenozoic seismic stratigraphic units of the western North Atlantic margin.

Large CDS in the study area comprise separated, detached, and plastered drifts. Major pre-existing structural elements exert first order control on the distribution of these deposits (Figure 1). In general, drifts are located where significant changes in the trend of the margin occur. In some cases, these changes correlate to ancient fault and fracture zones, for example at Hamilton Spur, Funk Island Spur, and Sackville Spur. In other locations, large CDS are anchored to pre-existing submarine bedrock promontories, for example the CDS around Flemish Cap, Newfoundland Ridge, the Nova Scotia margin, and the Chesapeake Drift (Figure 1). Another feature shared amongst most CDS in the study area are bottom simulating reflections (BSRs) indicative of the presence of gas hydrates in the sub-surface (e.g. Mosher 2011). Coincident with gas hydrate indicators are gas and fluid chimneys and seabed mounds. Most CDS in the study area exhibit evidence of seabed instability during their development. For example, in the case of detached drifts, layered mass transport deposits, in places >200 m thick, are interbedded with contourite deposits on the gently-dipping down-current sides, while stepped failure terraces characterize the steeply-dipping up-current sides (Figure 1).

DISCUSSION

The results from this study show several broad similarities in CDS over a vast extent of the WNA margin which include the location of initiation, propensity for large slope failure during development, and the presence of gas hydrates. The observed timing of apparent increased drift growth during the latest Miocene and Pliocene in the WNA agrees with drifts in the northern and eastern North Atlantic, especially the Gardar and Eirik drifts (Wright and Miller 1996). The timing of drift growth implies that the tectonic events across the Greenland-Scotland Ridge that influenced CDS development patterns in the eastern North Atlantic had far-reaching effects "downstream" in the system. Additionally, the synchronous timing indicates that more global events such as Northern Hemisphere glaciations and the onset of glacioeustacy were important in driving local changes in sediment supply and circulation.

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REFERENCES

Arthur, M., Srivastava, S.P., Kaminski, M., Jarrad, R., Osler, J., 1989. Seismic stratigraphy and history of deep circulation and sediment drift development in the Baffin Bay and the Labrador Sea, in: Srivastava, S.P., Arthur, M., Clement, B. (Eds.), Proceedings of ODP Scientific Research. Ocean Drilling Program, 105, pp. 957-988.

Campbell, D.C. 2011. The Late Cretaceous and Cenozoic geological history of the outer continental margin off Nova Scotia, Canada: Insights into margin evolution from a mature passive margin. Ph.D. Dissertation, Department of Earth Sciences, Dalhousie University, Halifax, Nova Scotia. 307 p.

Heezen, B.C., Hollister, C.D., Ruddiman, W.F., 1966. Shaping of the continental rise by deep geostrophic contour currents. Science 152, 502-508.

Kennard, L., Schafer, C., Carter, L., 1990. Late Cenozoic evolution of Sackville Spur: a sediment drift on the Newfoundland continental slope. Canadian Journal of Earth Sciences 27, 863-878.

Locker, S.D., Laine, E.P., 1992. Paleogene-Neogene depositional history of the middle U.S. Atlantic continental rise: mixed turbidite and contourite depositional systems. Marine Geology 103, 137-164.

Mosher, D.C., 2011. A margin-wide BSR gas hydrate assessment: Canada's Atlantic margin. Marine and Petroleum Geology 28, 1540-1553.

Mountain, G.S., Tucholke, B.E., 1985. Mesozoic and Cenozoic Geology of the U.S. Atlantic Continental Slope and Rise, in: Poag, C.W. (Ed.), Geologic Evolution of the U.S. Atlantic Margin. Van Nostrand Reinhold. pp. 293-341.

Nielsen, T., Andersen, C., Knutz, P.C., Kuijpers, A., 2011. The Middle Miocene to Recent Davis Strait Drift Complex: implications for Arctic–Atlantic water exchange. Geo-Marine Letters 31, 419-426.

Wright, J.D., Miller, K.G., 1996. Control of North Atlantic Deep Water circulation by the Greenland-Scotland Ridge. Paleoceanography 11, 157-170.

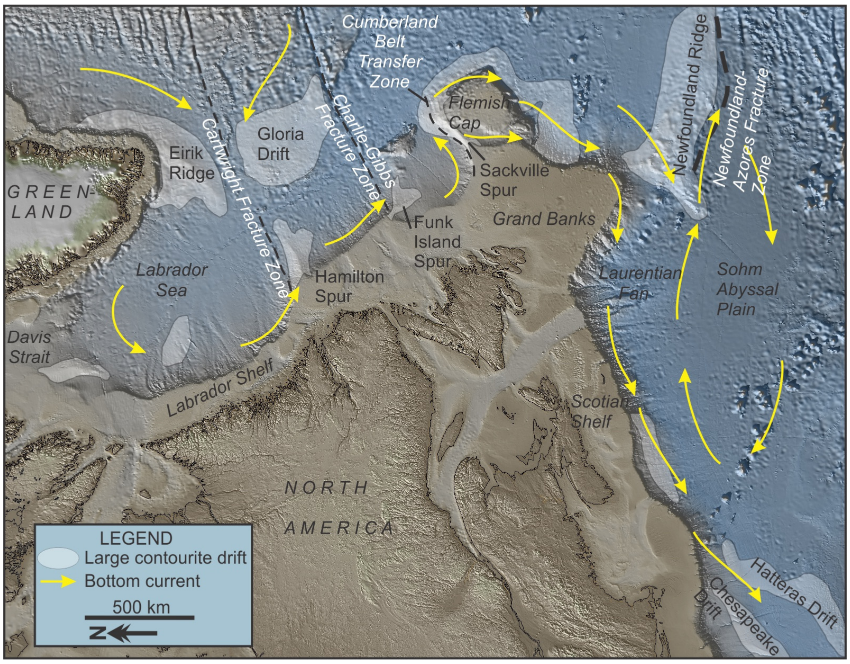

FIGURE 1. Map showing the distribution of CDS in the western North Atlantic and locations discussed in the text.