Marine and Petroleum Geology 65 (2015) 22–42

Contents lists available at ScienceDirect

Marine and Petroleum Geology

journal homepage: www.elsevier.com/locate/marpetgeo

Research paper

Seismic stratigraphic framework and depositional history of a large Upper Cretaceous and Cenozoic depocenter off southwest Nova Scotia, Canada

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ARTICLE INFO

Article history:
Received 22 December 2014
Received in revised form
18 March 2015
Accepted 21 March 2015
Available online 31 March 2015

Keywords:
Seismic stratigraphy
Cenozoic
North Atlantic Ocean
Margin evolution

ABSTRACT

Interpretations of the Late Cretaceous to Quaternary geological history of the North American Basin rely on a seismic and lithostratigraphic framework developed predominantly from data along the northeastern United States margin. Prior to this study, attempts to extend this framework northward to the Nova Scotia margin were hindered by correlation issues across seamounts, limitations in data coverage, and significant complications caused by widespread canyon erosion and shallow salt structures. These challenges are overcome using modern seismic reflection data along the southwestern Nova Scotia margin, in the Shelburne sub-basin, where Upper Cretaceous through Quaternary sequences manifest four distinct phases in the interplay between down-slope and along-slope depositional and erosional processes. The first phase, spanning the Late Cretaceous to Late Eocene, is characterized by widespread periods of gully erosion interspersed with periods of pelagic and hemipelagic, carbonate-rich sedimentation. Extensive failure of upper slope regions related to the Montagnais meteorite impact also occurred during this time. The second phase, spanning the Oligocene to Late Miocene, is dominated by widespread erosion, deposition by gravity flow processes, and sediment re-working by bottom currents. Marked erosion and/or non-deposition along the mid-to lower slope is attributed both to down-slope and along-slope processes. The third phase, spanning the Late Miocene to Late Pliocene, is dominated by bottom current deposition including stacked sequences of giant sediment waves and large contourite drifts along the slope. The final phase, from the Late Pliocene to present, exhibits a return to predominance of down-slope gravity flows with deposition focused below the upper slope. This four phase history of depositional and erosional processes is similar to that documented south of the study area along the U.S. margin.

1. Introduction

The North American Basin (NAB) is a large bathymetric depression in the western North Atlantic bound to the north, south and west by the eastern North American margin and to the east by the Mid-Atlantic Ridge (Fig. 1A). The Upper Cretaceous to present geology and seismic stratigraphy of the continental slope and abyssal plain in the NAB is known largely from data acquired along the United States Atlantic margin, south of the New England Seamounts (Emery et al., 1970; Jansa et al., 1979; Tucholke and Mountain, 1979; Mountain and Tucholke, 1985; Poag and Ward, 1993). The continental margin offshore Nova Scotia (herein referred to as the Scotian margin) forms the northern edge of the NAB. The Upper Cretaceous and Cenozoic stratigraphy and geological history of the outer Scotian margin are not well known. This knowledge gap is due to a number of factors that include: 1) difficulty extending the seismic stratigraphy of the NAB north of the New England Seamounts, 2) historically sparse seismic data coverage, 3) the absence of scientific boreholes along the Scotian margin, 4) widely spaced hydrocarbon exploration wells, and 5) uncertainties of seismic correlation across areas highly deformed by salt diapirism (Swift, 1987; Ebinger and Tucholke, 1988; Wade et al., 1995; Piper, 2005; Schlee et al., 1985). Additionally, most

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http://dx.doi.org/10.1016/j.marpetgeo.2015.03.016
0264-8172/

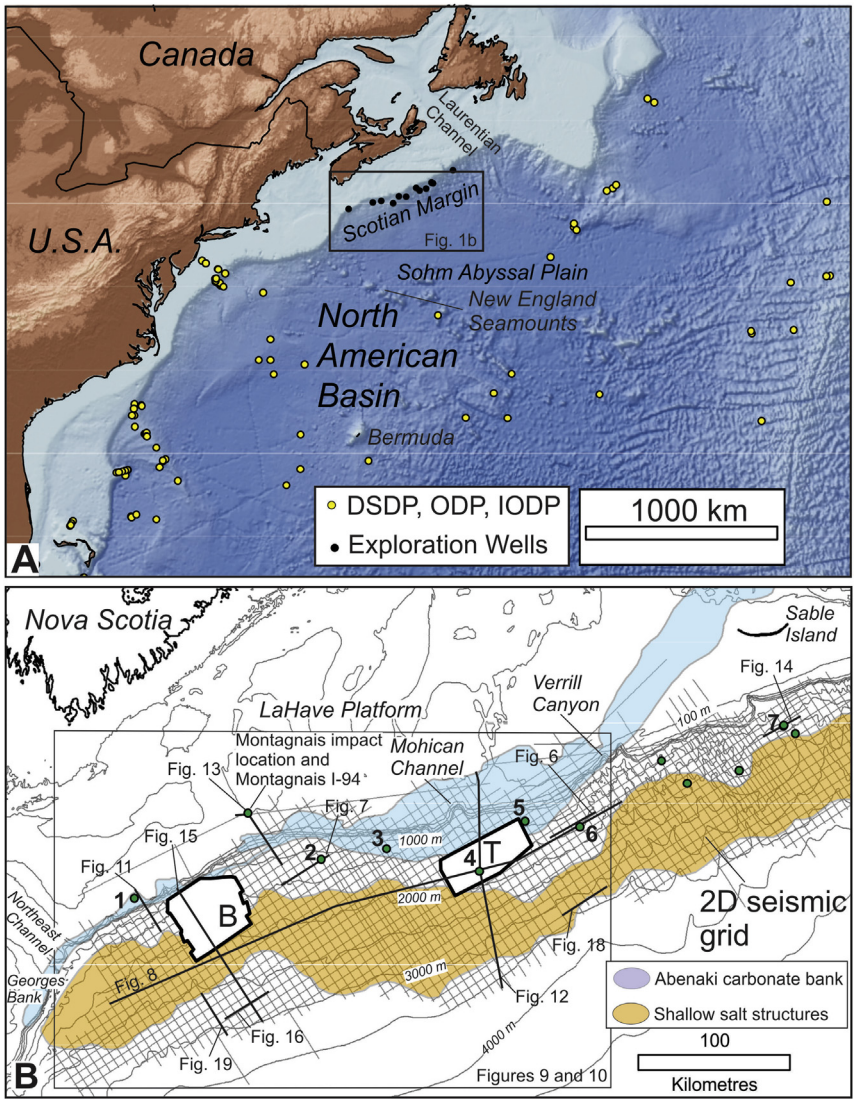

Figure 1. A) Map of the western North Atlantic showing locations discussed in the text, the distribution of ocean drilling sites and, for the Nova Scotia margin, deepwater hydrocarbon exploration wells. B) Map of the data used for this study and major structural elements. Regional 2D seismic reflection data are shown as a grid. 3D seismic datasets are shown as white polygons and consist of the Barrington (B) and Torbrook (T) survey areas. Exploration wells used for the study are Bonnet P-23 (1), Shelburne G-29 (2), Albatross B-13 (3), Torbrook C-15 (4), Acadia K-62 (5), Shubenacadie H-100 (6), Newburn H-23 (7), Weymouth A-45 (8), Balvenie B-79 (9), and Annapolis G-24 (10).

deepwater hydrocarbon exploration wells from the Scotian margin show substantial biostratigraphic unconformities in the Cenozoic section (Wade et al., 1995; Fensome et al., 2008; Weston et al., 2012). Together, these factors made it difficult to extend the margin stratigraphy south of the New England Seamounts northward and to link the stratigraphy of the deep basin onto the continental slope and shelf.

The purpose of this study is to improve the understanding of the stratigraphy and geological history of the NAB by examining the Late Cretaceous and Cenozoic sedimentary succession of a large (~50 000 km^2) deep-water depocenter along the southwestern Scotian margin. The expanded stratigraphy within the depocenter preserves a detailed record of margin processes that are interpreted within the framework of ten regional seismic stratigraphic horizons beneath the southwest Scotian slope and rise. This seismic stratigraphy is compared to the well-studied NAB margin to the south. High quality 2-D and 3-D seismic reflection datasets collected sine 1998 along the outer Scotian margin are integrated with data from ten exploration wells to address the issues related to seismic correlation experienced by earlier researchers.

2. Study area and geological setting

The Scotian margin consists of the continental shelf, slope and rise south of Nova Scotia and forms most of the northern margin of the NAB (Jansa et al., 1979). The margin initiated during Late Triassic and Early Jurassic rifting of Pangea and the opening of the central North Atlantic Ocean which created a series of inter-connected sub-basins seaward of more stable structural elements and a major basement hinge zone (Fig. 2) (Grant et al., 1986; Wade and MacLean, 1990; Deptuck and Campbell, 2012). This study focuses on the Upper Cretaceous and Cenozoic deposits along the outer Scotian margin west of Verrill Canyon in the Shelburne sub-basin where Jansa and Wade (1975) and Swift (1987) identified the existence of a >2 km thick depocenter (Figs. 1 and 2).

Late Cretaceous and Cenozoic depositional patterns in the study area are influenced by several important regional structural features. The Jurassic Abenaki Fm carbonate bank flanks the outer LaHave Platform and approximately coincides with the margin hinge zone (Figs. 1B and 2) (Wade and MacLean, 1990; Deptuck and Campbell, 2012). The hinge zone defines the northern margin of the