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Regional Deep Water Salt Geology, Offshore Nova Scotia, Canada

Abstract

A pre-stack depth migration project has been undertaken to better image the deep water salt and associated geology of offshore Nova Scotia, Canada. A 28,000 kilometer regional grid (6x6 km) of 2D seismic data is being used for this study. Experience gained from years of depth imaging and interpreting salt in the US Gulf of Mexico is being applied to offshore Nova Scotia where salt was also a significant factor in creating structures.

The pre-stack, depth-migrated data clearly reveal both autochthonous and allochthonous salt within the area. The Mesozoic and lower Tertiary sequences are also well recognized. Deflated salt autochthons loaded predominantly by Cretaceous sediments commonly exhibit rollover structures. Diapiric salt structures and salt canopies, some locally rooted, are common in the area. Many salt canopies commonly show Roho structures with the leading edges prograding down slope. Salt movement was primarily influenced by the deposition of a pre-Tertiary sediment wedge that is significantly expanded in the Nova Scotia basin, compared to the US Gulf of Mexico where the majority of the salt movement is related to the thick Tertiary sediment influx.

Introduction

Nova Scotia offshore remains to be an under-explored basin. Oil companies started exploration in the Nova Scotia offshore beginning in 1967 with a total of 134 wells drilled through 2004. That includes only 11 wells drilled on the slope with water depths varying from 200 meters to 4000 meters. The passive margin stratigraphy of offshore Nova Scotia is similar to the US Gulf of Mexico, with its sediments ranging from carbonate reef margins to clastics mixed with salt autochthons and allochthons and their related rollover structures. However, the Scotia Basin differs in the age of the proven reservoir rocks being Jurassic and Cretaceous in contrast to the Tertiary of the US Gulf of Mexico. Proper seismic imaging of the salt related structures and associated reservoir rocks has been a challenge but images obtained with the pre-stack depth migration processing of this large 2-D seismic grid offers an opportunity to recognize the salt basin geology that will be discussed in this paper.

Data

Seismic data used in this study consisted of 28,000 line kilometers of 2D data shot on a NW-SE, NE-SW 6 kilometer grid (Fig. 1). A full 14 seconds of data were acquired with 6-8 kilometers cable offsets, 80-106 fold and a 2 millisecond sampling interval. The original 1998 vintage data was pre-stack time migrated and has been only recently pre-stack depth migrated employing cutting edge processing techniques.

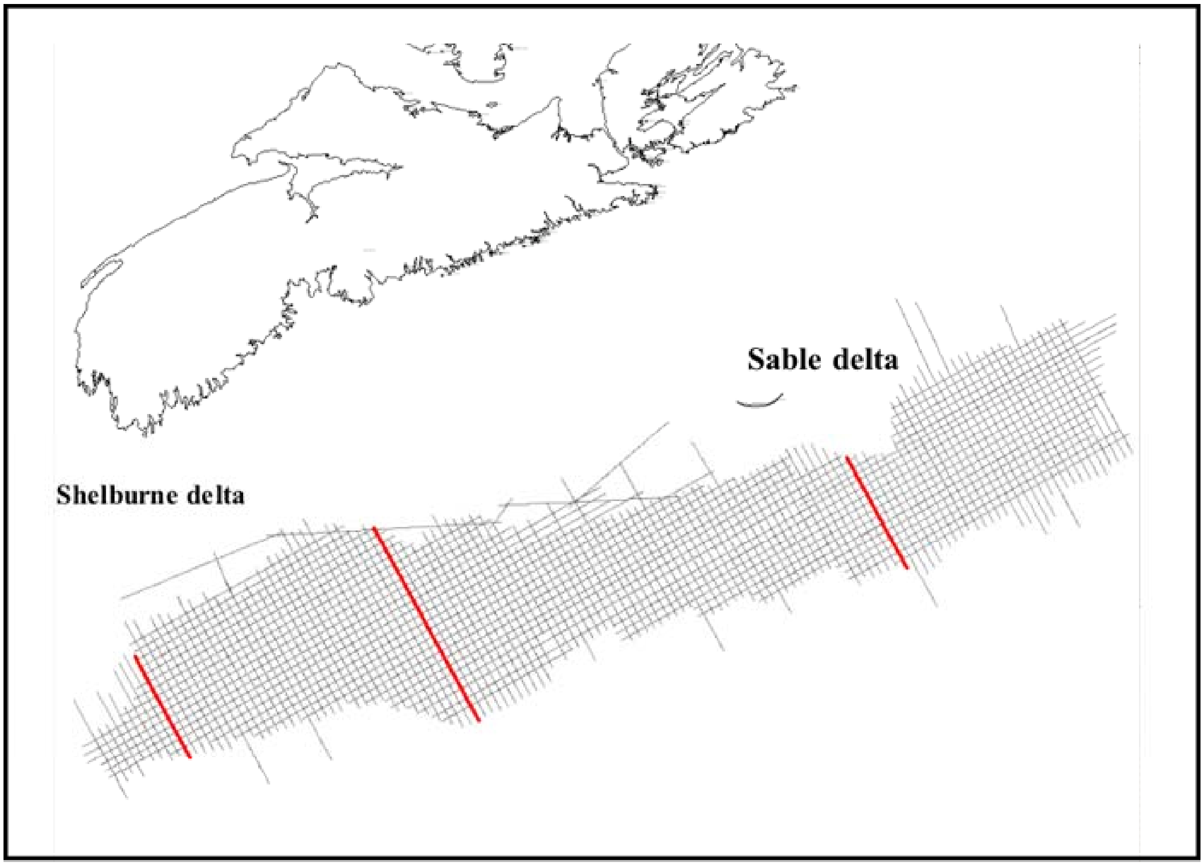

Figure 1
Study area showing the seismic grid with 3 key lines highlighted

Methodology

The pre-stack depth migration processing utilized detailed velocity modeling of the subsurface geology. The migration velocity from the pre-stack time migrated seismic data was used as an initial input. A sedimentary velocity model was created and the data was migrated with this velocity. The top salt model was interpreted based on its seismic signature of high amplitude, low frequency reflections, and diagnostic reflection geometries. The subjacent top salt areas were migrated with salt velocity and the base salt was interpreted. Detailed analyses of the flatness of common depth gathers were incorporated in building this iterative salt velocity model. The primary salt reflections were carefully discriminated from the multiple reflections of water bottom and top salt, and were cross-tied for accuracy.

Deep Water Salt Geology

The deep water salt geology of Nova Scotia offshore changed significantly from west near the George's Bank to the east off Sable delta. Selected pre-stack depth migrated northwest-southeast dip oriented seismic sections depict the geology.

In the west (Fig. 2) the autochthonous mother salt of Late Triassic age (Argo salt) can be recognized. The salt is constrained mostly within the Mesozoic sections. The salt moved down slope due to active sediment loading during the relative lowstands of sea level when Shelburne delta progradation formed Roho structures. Inflation of this salt due to sediment loading of Mesozoic strata is well documented. Some rejuvenation of sediment loading after a hiatus was initiated during the Cenozoic time as depicted from the deflation of the salt particularly updip in the northwest towards the shelf. A combination of diapiric structures to the northwest and salt tongues at the leading edge of the slope is common in the area. The effect of Cenozoic loading of the strata is more prevalent to the east in the west-central part of the basin (Fig.3), where the Tertiary sediments appear to be inflated due to movement of allochthonous salt bodies. Salt detachments during this period are evident in the data.

In the east (Fig. 4), the progradation of Sable delta during the Tertiary caused the formation of the allochthonous salt canopies that dominate this part of the basin. For this age section, the salt tectonics, salt canopies and associated geology can be correlated with those in the deep water frontal areas of the Gulf of Mexico along the Mississippi Fold Belt and the Sigsbee Escarpment. In the US Gulf of Mexico, the Mississippi delta prograded basinward during the late Tertiary lowstands that mobilized salt and created folded structures as the salt deflated. The Peridido Fold Belt, however, in the western Gulf of Mexico associates salt tectonics involving relatively older rocks of lower Tertiary ages. Both the US Gulf of Mexico and Nova Scotia passive margin basins have approximately 25 kilometers of total sediment thicknesses (Wade, J. A., and B.C. MacLean, B.C., 1990.). However, the Tertiary sediments of the Gulf of Mexico that predominantly influenced halokinesis are about 18 kilometers thick. In contrast, the Tertiary rocks in the Scotia Basin are only about 3 km thick showing very limited influence on salt mobilization. The Mesozoic sections in the Scotia Basin are significantly expanded where salt related structures and reservoir rocks are more common.

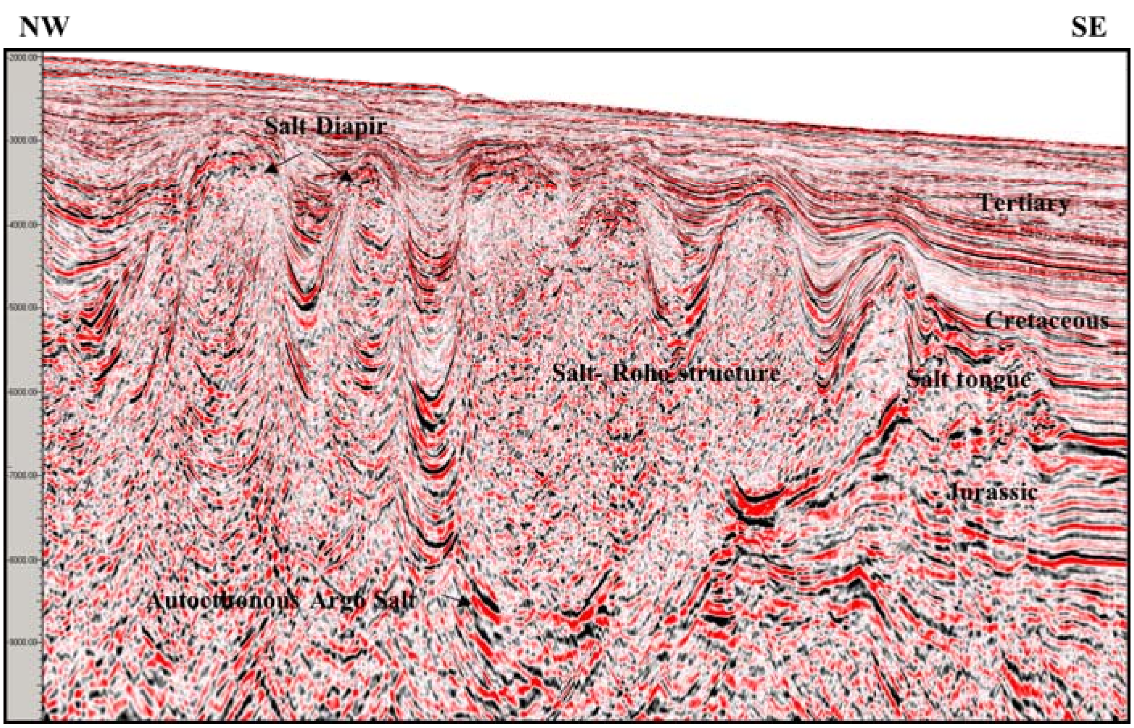

Figure 2
Seismic section in the west showing Mesozoic salt and associated geology

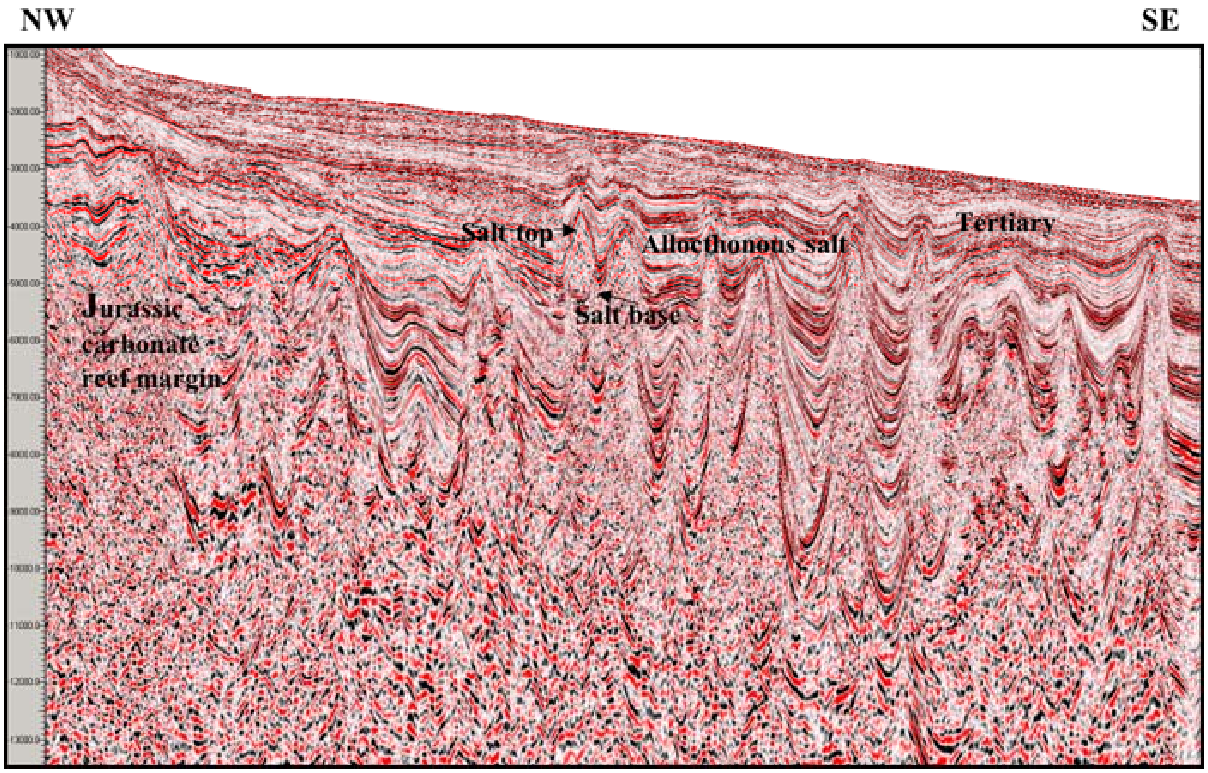

Figure 3
Seismic section in west central part showing some inflation of salt in the Tertiary section

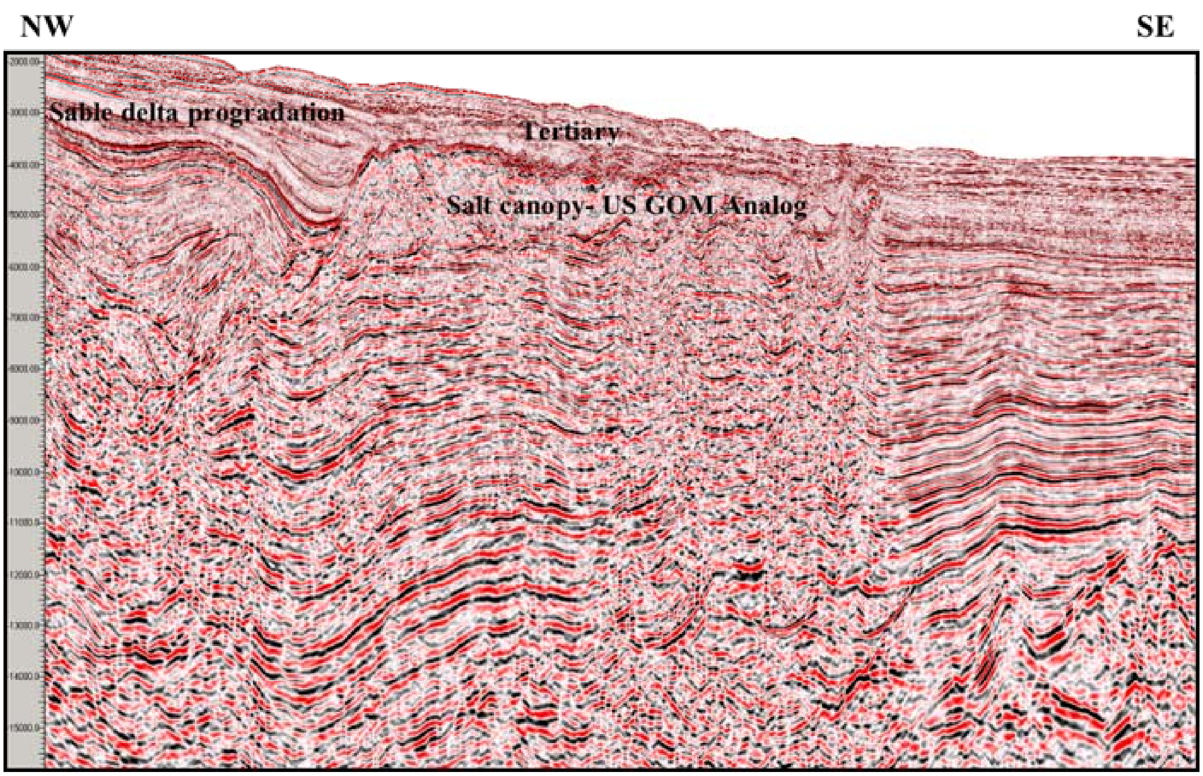

Figure 4
Seismic section to the east showing Sable delta progradation and salt canopy – US Gulf of Mexico analog

Conclusions

The deep water salt geology of the Nova Scotia basin is better imaged with the recently processed pre-stack depth migrated data. Oil companies have experienced some disappointments in some of their recently drilled wells. This data should provide the tools required to decipher the regional geologic elements and focusing on prospects in supra or sub -salt provinces at optimal locations.

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