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Seismic and Lithological Characterization and Source Rock Potential of the Aptian Naskapi Shale Member, Logan Canyon Formation, Offshore Nova Scotia

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Abstract

The Cretaceous fluvial-deltaic successions of the Logan Canyon and Missisauga Formations, offshore Nova Scotia, have produced hydrocarbons in the Sable sub-basin. Distal deposits of the Jurassic-Cretaceous Verrill Canyon Formation (Bajocian – Barremian) and the Logan Canyon Formation (Aptian – Albian) contain transgressive shale sequences, several of which correspond to worldwide oceanic anoxic events (OAEs). A significant one is the Aptian Naskapi Member of the Logan Canyon formation, which is the focus of this study.

Identifying organic-rich intervals and determining source rocks is helpful in understanding hydrocarbon systems, and of interest in petroleum exploration. The distal Cretaceous and Jurassic shale section offshore Nova Scotia has been viewed as a lean source rock; however, it is uncertain if there are sufficient concentrations of total organic carbon (TOC to form the continuous fluid phase necessary for effective primary hydrocarbon migration. In many parts of the world, Cretaceous Oceanic Anoxic Events (OAE's) are associated with significant amounts of organic rich matter, and with sufficient thermal maturity, these have generated prolific volumes of petroleum. When comparing existing levels of total organic carbon (TOC) from the Scotian Basin with those from OAE's found elsewhere in the world, the Cretaceous Naskapi Member exhibits lower levels of organic matter. This study addresses this inconsistency and proposes it is due to:

a) A high delta-derived sediment load focused in the Sable sub-basin during the Cretaceous, that resulted in high dilution rates of organic matter.
b) The direction and strength of the ocean current regime during that time was not conducive for sufficient preservation of organic matter.

Datasets from 95 wells on the Scotian Shelf were examined, incorporating temperature, total organic carbon, x-ray fluorescence, gamma ray, sonic, density and neutron wireline logs, lithological descriptions from cuttings and cores, biostratigraphy, sedimentation rates, paleo-ocean currents and seismic interpretations of the Naskapi Formation This analysis resulted in the creation of an extensive suite of isochore maps and 3-D models. The ensuing maps portray the stratigraphy, sedimentology, and diagenesis of the Naskapi depositional interval. Comparison of the Scotian margin with time equivalent Cretaceous deposits found elsewhere on the Atlantic margin indicates that low levels of effective Cretaceous source rocks are due to paleo-ocean current patterns and high amounts of sediments shed from the adjacent Appalachian Mountains, which diluted the concentration and impeded the preservation of organic rich intervals.

Theory / Method / Workflow

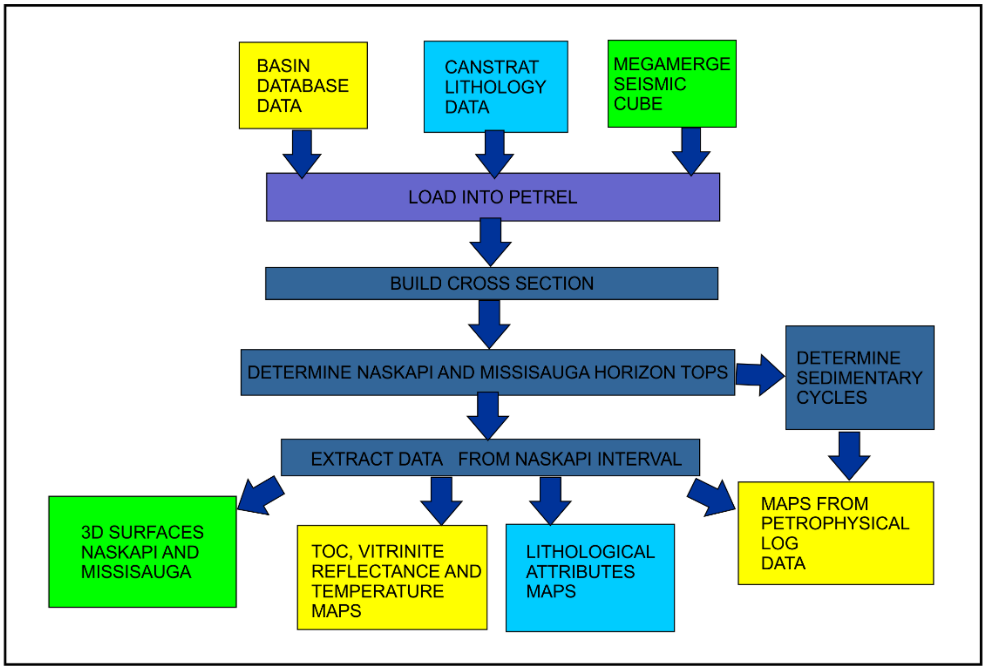

Fig 1.1. Flow chart outlining workflow with available data. TOC, vitrinite reflectance data, and temperature data from the BASIN Database were extracted, Canstrat LAS 2.0 file data, and the Megamerge seismic cube were loaded into Petrel. From this information, a cross section was built from all the wells which had acceptable wireline logs (gamma ray, resistivity and neutron), plus acceptable Canstrat well data. The wells in the cross section were within the boundaries of the Megamerge seismic cube. From the cross section, the Naskapi and Missisauga (bottom of the Naskapi) horizons were selected. TOC, vitrinite reflectance and temperature data was extracted where available in the depths defined as the Naskapi interval. Using Petrel, spreadsheets of these data were loaded and mapped. Canstrat data spreadsheets were also input and mapped. Geophysical logs (gamma ray, density and neutron logs) were mapped in Petrel. Using the Megamerge seismic data, well ties were made with all wells in the polygon, and Naskapi and Missisauga horizons were picked and mapped in 3-dimensions.

Results, Observations, Conclusions

The composition and maturity of organic matter within the Cretaceous "black shale" sequence have been studied in several Deep-Sea Drilling Project (DSDP) sites in the Atlantic Ocean, and worldwide, which were carried out between 1968 and 1983. Black, dark green or dark grey sediments with greater than 1% total organic carbon (TOC) were reported as widespread in Cretaceous sediments. These are also considered to be possible source rocks if they are buried sufficiently to become mature (Summerhayes 1987).

From geochemical studies, it has been shown that there is a distinct difference in the southern North Atlantic with abundant marine organics preserved (up to 45% TOC with average 10%), and the northern North Atlantic with mostly terrestrially sourced organic matter deposited by turbidites interbedded with dark pelagic mudstone (TOC's of 26% with an average of 5 – 6 %) exhibiting marine organic matter (Summerhayes 1981, Tissot et al 1980, Forster et al 2007, Kuypers et al 2004, Trabucho-Alexandre et al 2010).

The cores, cuttings and well data examined in the area show a medium to dark grey shale interbedded with sands and silts. In the study area, the Naskapi contains significant interbedded sands and silt, due to the fluvial deposits from the Sable Delta. Modeling of paleo ocean currents favorable to upwelling and high nutrient level, however the high amount of clastic deposition undoubtedly diluted the amount of organic matter preserved.

In this study, further work is being done on making a summation of organic matter as determined in well logs using the Delta Log R method of crossing the sonic and density logs to define source rocks vs sand components. The extent of the source rock will be plotted on 2D and 3D maps.

Novel/Additive Information

Comparison of the Scotian margin with time equivalent Cretaceous deposits found elsewhere on the Atlantic margin indicates that low levels of effective Cretaceous source rocks are due to paleo-ocean current patterns and high amounts of sediments shed from the adjacent Appalachian Mountains, which diluted the concentration and impeded the preservation of organic rich intervals.

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