Geochemical Evidence for a non-Tithonian source for oil staining in northern Scotian Shelf wells

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Summary

Extensive staining was reported in a number of older wells drilled on the north east Scotian Shelf but never previously followed up. Samples from these stained sections were geochemically analyzed to investigate if they had the same Tithonian deltaic source rock as the light oils in the Sable Island area. The geochemical data was not easy to interpret because of a large number of different factors, including the extent of biodegradation of some samples, a contribution of low maturity hydrocarbons from intervals close to where some samples were collected, evaporation of more volatile hydrocarbons, drilling contamination and possibly the effects of multiple hydrocarbon charges. Taking this all into account, the samples with better quality data clearly have hydrocarbons with very different characteristics to other Scotian Shelf oils and hence are thought to have different source rocks. Based on regional maturity and the geochemistry, these source rocks are suggested to be Lower Jurassic marine carbonates/marls.

Introduction

The major source rocks offshore Atlantic Canada are Upper Jurassic Kimmeridgian-Tithonian age. Consequently, petroleum systems based on these have been the focus for exploration in the region. Although generally overlook, Lower Jurassic source rocks, especially of Sinemurian-Pleinsbachian age, occur in many parts of the eastern North Atlantic such as offshore Ireland, Scotland, Portugal and Morocco (e.g. Scotchman, 2001; Duarte et al., 2010; Sachse et al., 2012). Evidence for a Lower Jurassic source rock has been elusive offshore Canada, although recently Fowler et al (2021) reported evidence for Lower Jurassic oil stains that show good evidence for a Pleinsbachian source rock in the Southern Grand Banks. The presence of a Lower Jurassic source rock would solve the problem of a lack of Upper Jurassic source in the southern Grand Banks and Scotian Slope areas that are thought to make these areas less prospective for petroleum exploration.

This presentation uses geochemical evidence from some stained intervals in wells from one area of the Scotian Shelf that is difficult to interpret because of sample type and age, reservoir processes and drilling additives, to propose a Lower Jurassic source for the staining hydrocarbons.

Methods

The Lower Jurassic has been very rarely penetrated offshore Nova Scotia and no source rocks encountered. Hence evidence for the presence of Lower Jurassic petroleum systems in this area must be implied from analysis of oils or stains. Extensive staining was reported in the Erie-Mic Mac-Wyandot wells, drilled about 100 km north east of Sable Island. These were some of the first wells drilled on the Scotian Shelf (mostly 1970-1971). The origin of the staining hydrocarbons has not been previously reported, possibly as there was little interest in this area after the large discoveries in the Sable Island area that were made in 1979 and later. Legacy geochemical data was provided by Shell for an oil obtained from a Lower Cretaceous wireline test at Mic Mac J-77. This showed very different characteristics to other Scotian Shelf oils. This old data was interpreted to suggest that the J-77 oil has a marine marly source rock deposited under more restricted conditions than the Tithonian deltaic source rock responsible for most of the hydrocarbons in the Sable Island area.

Subsequently, Lower Cretaceous-Upper Jurassic cuttings and one core from reported stained intervals were collected from the Erie D-26, Mic Mac D-89, Mic Mac J-77, Mississauga H-54 and Wyandot E-53 wells. Samples were extracted and analyzed by gas chromatography (GC) and gas chromatography-mass spectrometry (GC-MS), plus carbon isotopic analyses of the saturate and aromatic hydrocarbon fractions.

Results and Discussion

Before identifying the source of the staining hydrocarbons, it was first necessary to identify which of the analyzed samples actually contain migrated hydrocarbons. This was based on the amount of extractable organic matter and its composition (e.g. proportion of hydrocarbons), the appearance of the saturate fraction gas chromatogram and whether the sample had biomarkers of sufficient maturity to have migrated from a source rock. The in situ organic matter at the depth of the staining is immature in most samples so any mature biomarkers should be representative of migrated hydrocarbons. Biomarkers were then used to determine the characteristics of the source rock. However, interpretation of the data was greatly complicated by biodegradation, presence of low maturity hydrocarbons from organic matter within or close to the sampling intervals, evaporation of more volatile components from these ‘old’ samples (most wells drilled about 50 years ago), drilling contamination and probable multiple hydrocarbon charges (e.g. Fig 1). Taking this into account, samples showing the best evidence for staining can be split into two stain types that show relatively minor but consistent differences. Both stain types are very different to Scotian Shelf light oils/condensates derived from the Tithonian source rock. One stain type is suggested to have a marine source rock deposited under more restricted and carbonate conditions than the other.

Based on maturity of stains and that the Tithonian source rock is immature in the Erie-Mic Mac area (PFA, 2011) and generates hydrocarbons with different geochemical characteristics elsewhere on the Scotian Shelf, it is suggested that the stains maybe derived from two or more Lower Jurassic intervals deposited under slightly different conditions that are stratigraphically close to each other. An analogy would be Pleinsbachian – Sinemurian intervals in the Lusitanian Basin (e.g. Duarte et al., 2010).

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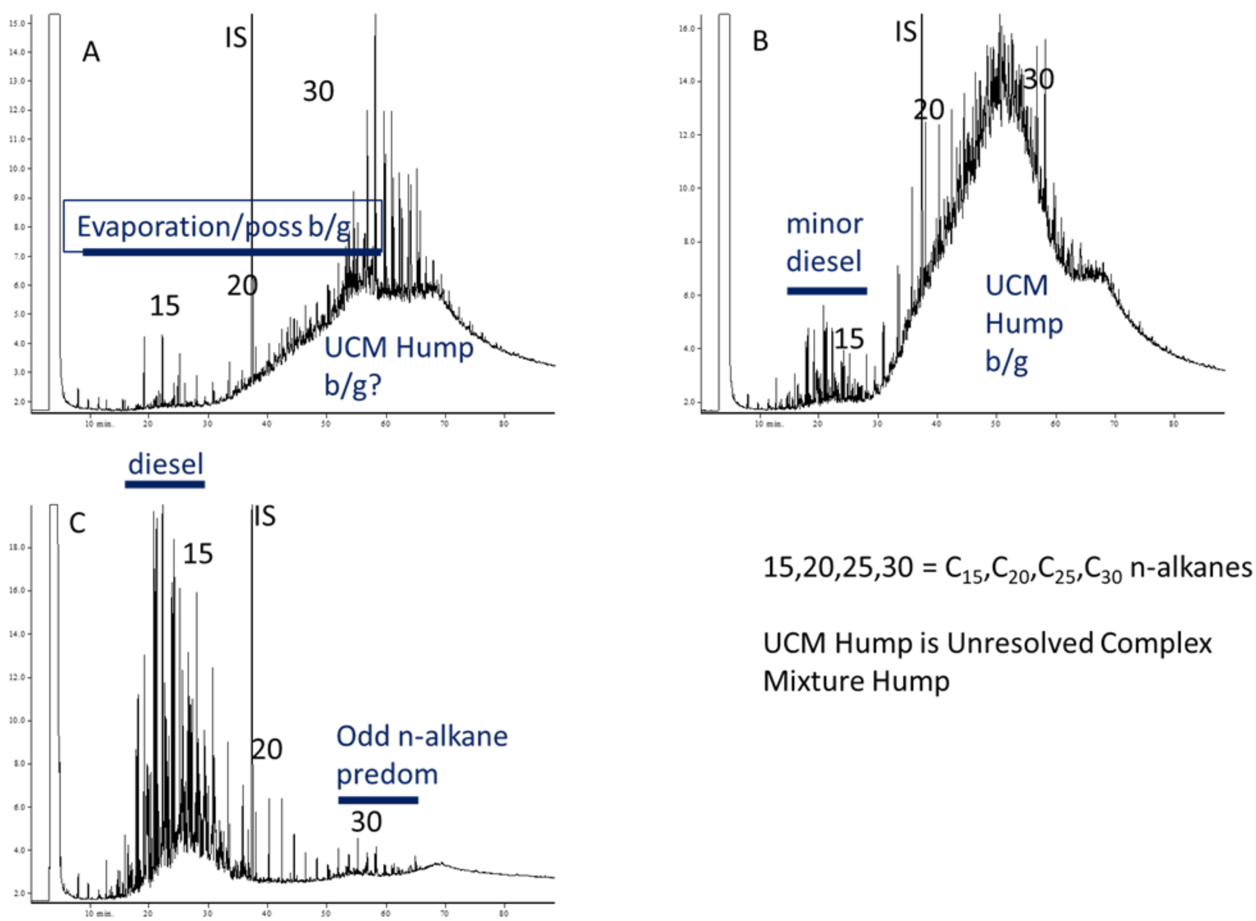

Figure 1. Saturate fraction gas chromatograms of extracts from stained sections: A) Erie D-26 7381 ft core showing loss of light ends due to evaporation and a UCM hump caused by biodegradation, B) Mic Mac J-77 3210 ft cuttings showing minor diesel contamination and large UCM hump caused by biodegradation, C) Mic Mac D-89 2950 cuttings showing strong diesel contamination and an odd n-alkane predominance over C_{25}-C_{33} range indicating a contribution from immature terrestrial derived organic matter.