A new TOC, Rock-Eval and carbon isotope record of Lower Jurassic age from the Slyne Basin, offshore Ireland

Ricardo L. Silva*; Charles A. M. Carlisle#; Grant Wach

Basin and Reservoir Lab, Department of Earth Sciences, Dalhousie University, PO Box 15000, Halifax, Nova Scotia, B3H 4J1 Canada
(*correspondence: ricardo.silva@dal.ca; # - presenting author)

Basin & Reservoir Lab
Roinn Cumarsáide, Fuinnimh & Acmhainní Nádúrtha
Department of Communications, Energy & Natural Resources
PIP Petroleum Infrastructure Programme

1. Introduction

The Lower Jurassic in the evolving Central and Northern Atlantic basins coincides with a series of major environmental perturbations and dramatic changes in marine biota. This interval is also a period of exceptional preservation of organic matter. Geochemical investigation of several wells from Ireland's offshore proved high total organic carbon (TOC) content in the Toarcian (≤7 %) and its viability as a hydrocarbon source rock (e.g. Scotchman, 2001).

The Slyne Basin (Fig. 1), one of many of Ireland's fully offshore basins, has been lightly explored (6 exploration wells and 8 appraisal and development wells since 1981), with two proven hydrocarbon discoveries: the Corrib gas discovery, a Carboniferous (source rock)-Triassic (reservoir) play; and the Bandon discovery (well 27/4-1z) within Pliensbachian to Late Sinemurian sandstones (12 MMBO, estimated oil-in-place), interpreted to be sourced from Lower Jurassic age shales (e.g. Dancer et al., 2005). Supported by the wealth of scientific evidence of planetary-scale events and changes in the Earth System during the Lower Jurassic, we hypothesize that: 1) the organic-rich intervals of Toarcian age in Ireland's offshore are coeval with the T-OAE and associated CIE; 2) the $\delta^{13}C$ record from this basin also records newly observed CIEs in the Sinemurian and Pliensbachian. To test and validate our hypothesis, we present here a novel and integrated Total Organic Carbon (TOC), Rock-Eval pyrolysis, and carbonate and organic matter $\delta^{13}C$ dataset of Upper Sinemurian–Aalenian age rocks from the Slyne Basin (well 18/25-1, Corrib Gas Field), Ireland. Our goals are to i) characterize the source-rock potential of the Broadford Beds and Portree Shale Equivalent units and ii) contribute to the understanding of the paleoenvironmental dynamics during the Lower Jurassic and the extent and causes of the secular events that ultimately led to the T-OAE.

2. Geological setting

The Slyne Basin is a narrow rift basin oriented NE-SW offshore the West of Ireland (Fig.1a and 1c). The basement is difficult to define using geophysical techniques due to the presence of Tertiary volcanics and chalks. Rifting was initiated in the Permo-Triassic and this basin includes sediments from the Carboniferous to recent (Fig. 1b) (e.g. Croker & Shannon, 1987). The Lower Jurassic interval in the Slyne Basin is currently divided into four lithostratigraphic units according to Figure 1b (see Trueblood & Morton, 1991; Dancer, 2005 and references therein).

Appraisal well 18/25-1 (Enterprise Oil plc) was spudded on the 1st May 1999 (surface UTM coordinates E 366859.3 m; N 6021201.6 m). It reached the Lower Triassic Sherwood Sandstone Group equivalent, total depth = 3770 m measured depth below rotary table (MDBRT), and drilled approximately 700 m of Lower Jurassic sediments (Enterprise Oil, 2000) (Fig. 2). A detailed geological description can be found in Well IRE 18/25-1 Geological Completion Report (Enterprise Oil, 2000) and a detailed biostratigraphic revision for the Slyne Basin was conducted by Millennia Limited (Millennia, 2004).

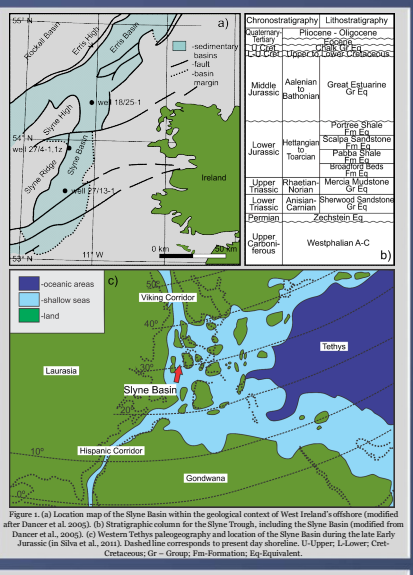

Figure 1. (a) Location map of the Slyne Basin within the geological context of West Ireland's offshore (modified after Dancer et al. 2005). (b) Stratigraphic column for the Slyne Trough, including the Slyne Basin (modified from Dancer et al., 2005). (c) Western Tethys paleogeography and location of the Slyne Basin during the late Early Jurassic (in Silva et al., 2011). Dashed line corresponds to present day shoreline. U-Upper; L-Lower; Cret-Cretaceous; Gr – Group; Fm-Formation; Eq-Equivalent.

3. Results

Analyses of well 18/25-1 (Slyne Basin, offshore west of Ireland) indicate that TOC varies from 0.8–5.2 wt. % (Fig. 2). The highest TOC values are observed in the middle portion of the Portree Shale Formation Equivalent, dated from the Lower Toarcian (around 2700 m MDBRT).

S_1, S_2, and S_3 varies between 1.36–8.28 mg HC/g rock, 1.44–20.36 mg HC/g rock, and 0.57–1.05 mg CO_2/g rock, respectively (Fig. 2). T_{max} ranges from 434–446 °C. HI and OI varies between 179–418 mg HC/g TOC and 12–95 mg CO2/g TOC (Fig. 2). Most of the samples present a negligible low temperature S_2 shoulder. Even considering this effect, there is a clear distinction between the Broadford Beds Formation Equivalent and Lower Jurassic Undifferentiated type II-III kerogens (even if S2 is artificially elevated) and the uppermost Lower Jurassic Undifferentiated, Portree Shale Formation Equivalent and overlying Middle Jurassic (Great Estuarine Group Equivalent) type II kerogens (Fig 2). T_{max} indicates that this portion of the well is mature, within the oil generation window.

$\delta^{13}C$ in carbonates and kerogen varies from -5.16 to 2.22 ‰ and -28.23 to 25.52 ‰, respectively (Fig. 2). Closer to 2725 m, it exhibits a sharp negative CIE, around 5 ‰ in carbonates and 3 ‰ in kerogens. This negative trend spans over 250m, corresponding to the Lower Toarcian. Above this interval, both isotopic records tend to more positive values, during the later stages of the Toarcian and Aalenian.

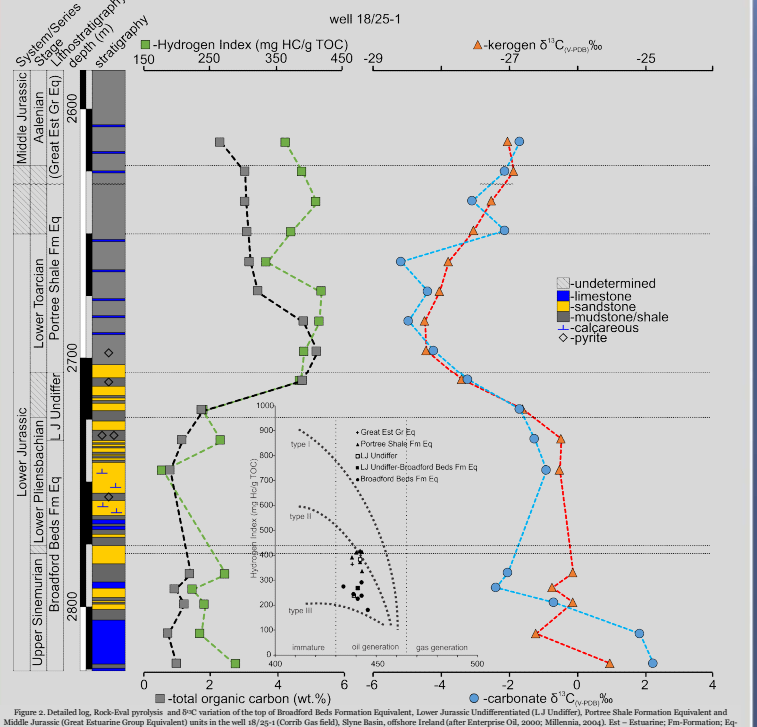

Figure 2. Detailed log, Rock-Eval pyrolysis and $\delta^{13}C$ variation of the top of Broadford Beds Formation Equivalent, Lower Jurassic Undifferentiated (L J Undiffer), Portree Shale Formation Equivalent and Middle Jurassic (Great Estuarine Group Equivalent) units in the well 18/25-1 (Corrib Gas field), Slyne Basin, offshore Ireland (after Enterprise Oil, 2000; Millennia, 2004). Est – Estuarine; Fm-Formation; Eq-Equivalent.

4. Discussion

The measured TOC and Rock-Eval Pyrolysis results from the well 18/25-1 indicates the Portree Shale Formation Equivalent (Lower Toarcian) as a mature source rock in this sector of the Slyne Basin (TOC up to 5.2 wt.%; type II kerogens; T_{max} ~440 °C) (Fig. 2). The Late Pliensbachian interval is not identified in our well. Despite the differences in TOC and occurrence, the kerogen types associated with each source-rock interval seem to be very similar across the entire Slyne Basin; type II-III (gas-oil prone) for the Pliensbachian and type II (oil-prone) for the Toarcian and Aalenian. The same trends are observed elsewhere around this entire region (e.g. Fleet *et al.*, 1987; Scotchman, 2001).

The Lower Jurassic interval is characterized by the occurrence of several CIEs and associated organic matter preservation intervals (OMPIs, Silva *et al.*, 2011) (Fig. 3). In a previously not explored paleogeographical domain in terms of stable carbon isotope chemostratigraphy, the obtained $\delta^{13}C$ record of the Slyne Basin from the well 18/25-1 shows a similar pattern observed elsewhere on the Central and Northern Atlantic margin: a positive CIE during the Upper Sinemurian; a negative CIE followed by a positive CIE during the uppermost Sinemurian–Lower Pliensbachian; and the negative CIE linked with the Toarcian Oceanic Anoxic Event (Fig. 3). In the case of the Upper Sinemurian and Lower Pliensbachian CIEs, the dataset presented here is of utmost importance due to the scarcity of contemporaneous data.

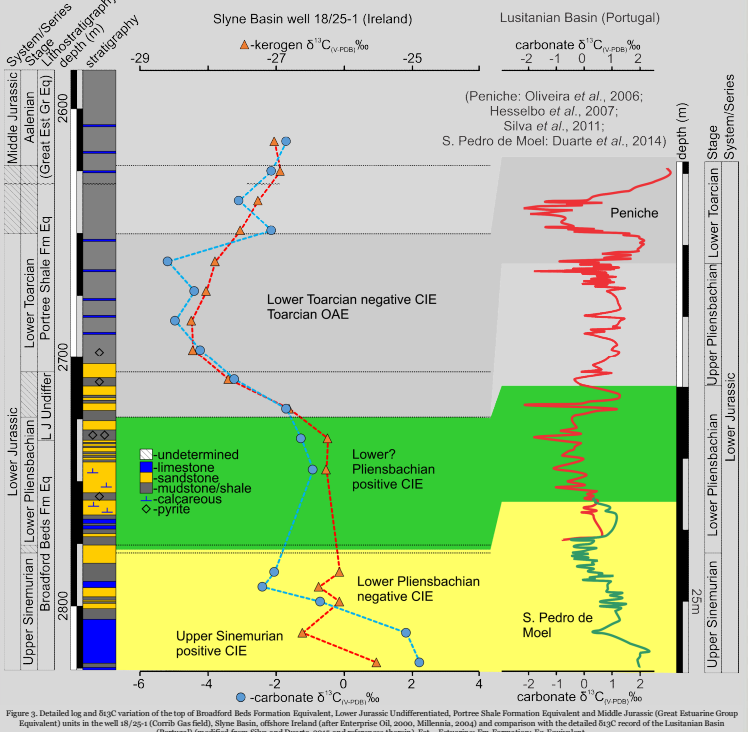

Figure 3. Detailed log and $\delta^{13}C$ variation of the top of Broadford Beds Formation Equivalent, Lower Jurassic Undifferentiated, Portree Shale Formation Equivalent and Middle Jurassic (Great Estuarine Group Equivalent) units in the well 18/25-1 (Corrib Gas field), Slyne Basin, offshore Ireland (after Enterprise Oil, 2000; Millennia, 2004) and comparison with the detailed $\delta^{13}C$ record of the Lusitanian Basin (Portugal) (modified from Silva and Duarte, 2015 and references therein). Est – Estuarine; Fm-Formation; Eq-Equivalent.

5. Concluding remarks

The Slyne Basin has the potential to become a reference area in the context of the North Atlantic Conjugate Margins. This study is a new and valuable addition to the understanding of the extent and causes of the secular events that led to the T-OAE. This study and comparison with the available data from offshore reveal important clues to the identification and/or understanding of a possible Lower Jurassic source rock interval of regional relevance Ireland's offshore, allowing the integration with known time-equivalent source rock outcrops on Atlantic conjugate margins, for example Canada, UK, Morocco, Portugal, and Spain.

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