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Newfoundland – Ireland Conjugate Margin Oil Families: Siblings and Cousins Plus the Occasional Outsider*

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Abstract

The North Atlantic Mesozoic basins are tectonically linked and share a common evolution related to the opening of the North Atlantic Ocean. The offshore basins of Ireland and Newfoundland/Labrador have numerous oil and gas discoveries and to further enhance present understanding and help define future exploration strategy, an integrated geochemical study has recently been completed. This study addresses each basin of Ireland and Newfoundland/Labrador where drilling has taken place and as such, was able to access datasets from 600 offshore wells and additionally, from numerous scientific publications. One of the key aspects of this study has been the collation and integration of both existing and newly acquired analytical data pertaining to oil samples. In the South Atlantic, the oils of the seaboard basins of both continents can often be closely correlated. This study provided the opportunity to make the same assessment of the conjugate basins of Ireland and Newfoundland/Labrador. The database resulting from the study comprises over 100 individual analyzed oil samples from Newfoundland and Labrador plus more than 40 similar samples from Ireland. These are supplemented by numerous extracted samples from reservoir and source rock intervals. Integration of these data has confirmed similarities, for example between a number of oils in the Jeanne d'Arc/Flemish Pass and Porcupine basins, through the occurrence of key biomarkers such as Gammacerane. However, within these basins there are differing oil groupings indicating potential variation in source facies. Gammacerane appears to be absent from oils within the Rockall and Slyne basins. Furthermore, the occurrence of Bisnorhopane in Rockall Basin samples points to a closer association with Kimmeridge Clay Formation (KCF) sourced oils found to the north, in both the west and east Shetland basins. In addition to gas chromatography and GC-MS biomarkers, Carbon Isotope signatures from oils point to a range of environments of source deposition and to genetic associations. Locally, the situation can be more complex through potential mixing or alteration of oils. Nevertheless, this new database constructed from both existing and newly acquired datasets allows a greater understanding of origins, distribution, and relationships of oils in the study area.

Overview

This review of oils from basins of the North Atlantic realm is part of a comprehensive study that has been made to further understand the development and distribution of source facies and their resultant hydrocarbon products in this tectonically complex setting. The resultant database from the study comprises over 100 individual analyzed oil samples from Newfoundland and Labrador plus more than 40 similar samples from Ireland. These are supplemented by numerous extracted samples from reservoir facies. Integration of these data has confirmed some similarities but also the presence of some quite individual oils in addition.

Introduction

The North Atlantic Mesozoic basins are tectonically linked and share a common evolution related to the opening of the North Atlantic Ocean. The offshore basins of Ireland and Newfoundland/Labrador have numerous oil and gas discoveries and to further enhance present understanding and help define future exploration strategy, an integrated geochemical study has recently been completed. This study addresses each basin of Ireland and Newfoundland/Labrador where drilling has taken place and as such, was able to access datasets from 600 offshore wells and additionally, from numerous scientific publications. The principal basins covered by this study are depicted in Figure 1.

Source Rocks - Overview

In order to try to understand the complexities and relationships of the oils discovered within the study area an inventory of the occurrence and distribution of source rocks was made. These are intrinsically linked with the tectonic history of the area. This latter aspect in itself is complex as shown in Figure 2 and is one of the primary influences over the source rock developments that are stratigraphically noted in Figure 3. Up to 15 differing source rock horizons are noted across the study area (Figure 3). Of these, regionally the most significant are the sources of the Upper Jurassic. The Upper Jurassic rifting phase on the Newfoundland-Ireland conjugate margin resulted in the formation of a series of narrow and elongated basins. These in turn led to the development of a series of often restricted environments ranging from non-marine through shallow marginal marine to open marine. These sources are responsible for the majority but certainly not all of the hydrocarbon discoveries within the study area to date. The complexity in the variation in source facies within the Upper Jurassic is illustrated in Figure 4. Also, of considerable importance to the study area are sources of the Lower Jurassic and, in the case of the Porcupine Basin, the Middle Jurassic. These are responsible for a number of discoveries particularly in Irish basins. More localized source rock developments add to a rather complex set of oil family relationships. In addition to the distribution of these sources, variation in thermal maturity across basins also plays a significant role in the effectiveness of these sediments as producers of hydrocarbons.

Oils – Variation and Key Features

The resultant oils within the basins of offshore Ireland and Newfoundland are varied as a result of three phenomena. These are:

- Differing hydrocarbon products resulting from the divergence in source facies both in the aerial and stratigraphic sense.

- Mixing of hydrocarbons emanating from differing source facies resulting in hybrid types.
- Modification of some of these hydrocarbons within the reservoir through biodegradation.

Figure 5 serves to illustrate some of the variation that is observed in these oils through measurement of API gravity and subsequent gas chromatography analyses.

The initial point noted above is in part highlighted by the oil types from the western Irish basins (Rockall, Slyne, Erris, and Porcupine) (Figure 6). 28,30 bisnorhopane observed in Dooish (12/02-1) fluid, in the Rockall Basin, thus this oil stands apart from other oils in Slyne, Erris, Porcupine or indeed from the Celtic Sea or Newfoundland. 28,30 bisnorhopane is a biomarker commonly observed in North Sea oils sourced by the Kimmeridgian. It also occurs in East Shetland oils. In addition to the Dooish well, it is also observed in shallow core samples taken further south, but, only in the Rockall Basin. This observation suggests that Dooish fluid could share some characteristics with East Shetland or North Sea oils and therefore could also be sourced by a Late Jurassic source rock with a Kimmeridge Clay affinity. Conversely, in basins other than the Rockall, there is a common, widespread occurrence of Gammecerane both in source rock extracts and in oils. The occurrence of Gammacerane does not allow for oil-oil or oil-source correlations to be made based solely on its presence, but its absence, as in the case of Dooish, is notable. It is also worthy to note that whilst a number of differing organic facies were recognized across the study area, the common occurrence of Gammacerane in both oils and source rocks, a biomarker closely associated with stratified water columns and restricted environment, indicates that such conditions were not only wide ranging but paramount influence in source development.

The mixing of hydrocarbon types is thought to be widespread cross the basins within the study area. It is this aspect of hydrocarbon accumulation that perhaps gives the biggest challenge in determining cross-basin relationships between oil accumulations. For example, the Connemara oil (26/28-2, DST #2) does not have a good correlation with any one specific organo-facies noted in the Porcupine Basin. It shows intermediate values suggesting a mixture between a marine (restricted) and a marginal marine to non-marine source. Maturity computed from gasoline fraction compounds (Heptane and Isoheptane ratios) based on the correlation proposed by Thompson (1992) are indicative of an equivalent maturity of at least 0.9%Vro. Conversely, maturity calculated from number biomarker ratios is significantly lower. For example, sterane isomerization C29 αααS/(S+R) = 0.37 (equilibrium 0.55@0.8%), C29 ββS/(ββS+ααR) = 0.33 (equilibrium 0.7@0.9%), and Methylphenantrene Index MPI-1 = 0.6 (eq. To 0.7%Vro). All these parameters suggest a maturity lower than 0.8%Vro, probably 0.7-0.75%Vro. This discrepancy between the maturity computed from the gasoline fraction and biomarkers tend to suggest a fluid mixture from two sources at different maturity. In addition, fluid inclusion data from 26/28-2 show clearly two populations with a different homogenization temperature for the entrapment of oil from the cement (110°C) and the microfractures (160°C).

As many of the potential reservoirs in the southern Jeanne d'Arc Basin are at a rather shallow depths (<2,500m TVDSS) biodegradation is always a possibility. Comparative analysis of oils from various reservoirs within several wells reveals a complex charge history involving various pulses of oil of different maturity and biodegradation. Such occurrences have been studied by various researchers (von der Dick, 1989; Williamson et al., 1996; Fowler and McAlpine, 1995; Shimeld and Moir, 2001) looking into hydrocarbon accumulations in this part of the Jeanne d'Arc Basin. An example of the complexities of variation in hydrocarbon accumulation resulting biodegradation comes from observations initially made by Shimeld and Moir, 2001 in relation to the Hebron I-13. In this well there is mixing of biodegraded and unbiodegraded oil in the shallower reservoirs (DST#10 and #9, Figure 7A and Figure 7B). This could be indicative of two separate hydrocarbon charges, the initial one being degraded prior to the second charge reaching these reservoirs. The oil from DST#7 (Figure 7C) has the same geochemical characteristics as those from DST#10 and #9 leading to the conclusion that these oils may all have a common source. The oil sample from DST#1 (Figure 7D) shows evidence of being the product of a more terrestrially influenced (deeper and more mature?) source. This example alone goes some way to highlighting the complexities in unravelling the oil to oil and oil to source relationships within the offshore basins of Ireland and Newfoundland Labrador.

This study is underpinned by possibly the most comprehensive geochemical dataset accumulated for the North Atlantic basins. From this it is now possible to directly compare the oils and also the parent source facies not only within each basin but with other basins to aid in developing the prospectivity in all of these offshore basins. This is especially important in the under-explored portions of some basins (e.g. the southern Porcupine Basin) where the lack of well data might be seen as a constraining element to exploration. In having a unified geochemical dataset across these basins aids in helping to fill such gaps.

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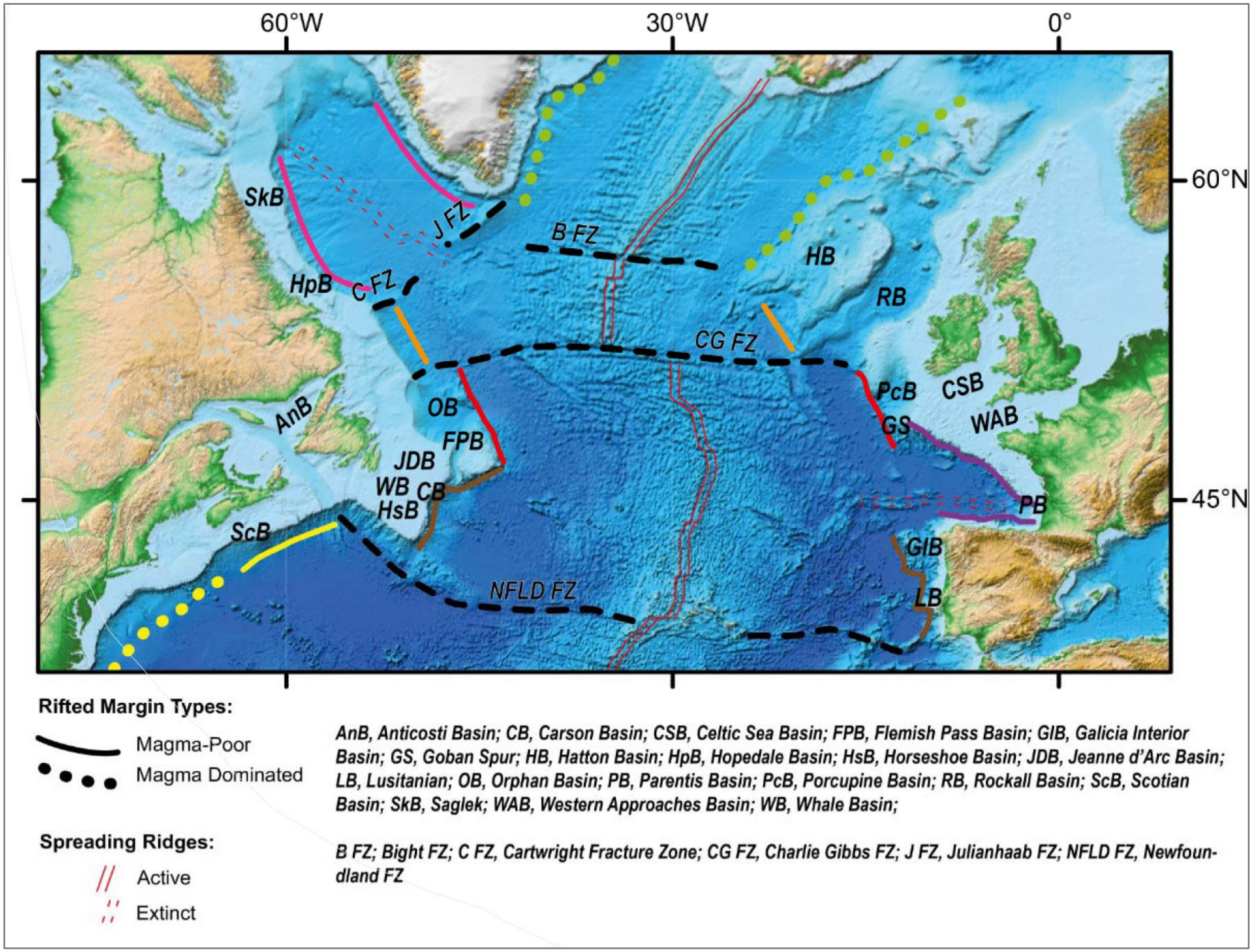

Figure 1. Study area and distribution of North Atlantic Basins.

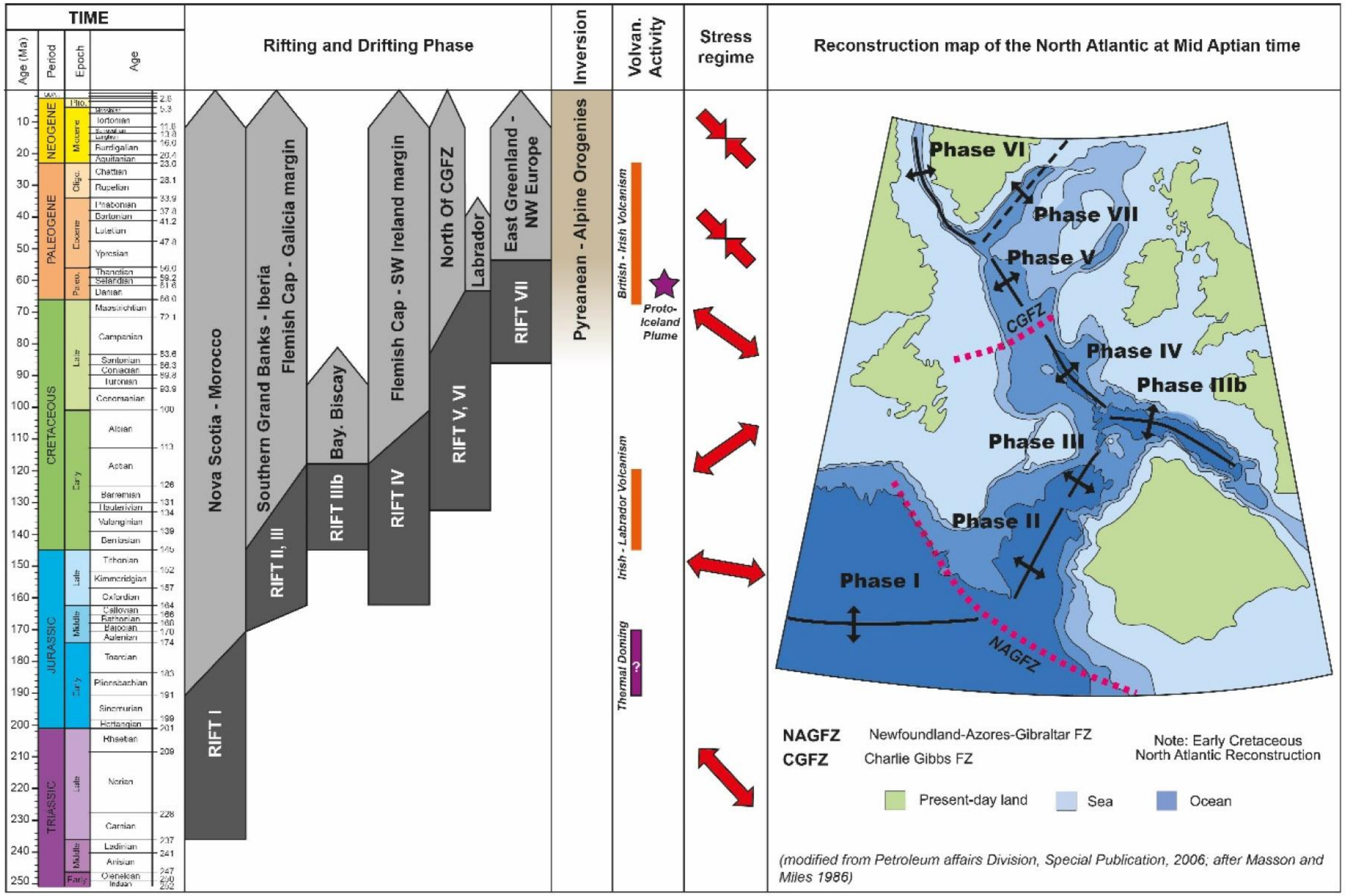

Figure 2. Main tectonic events along the North Atlantic margins.

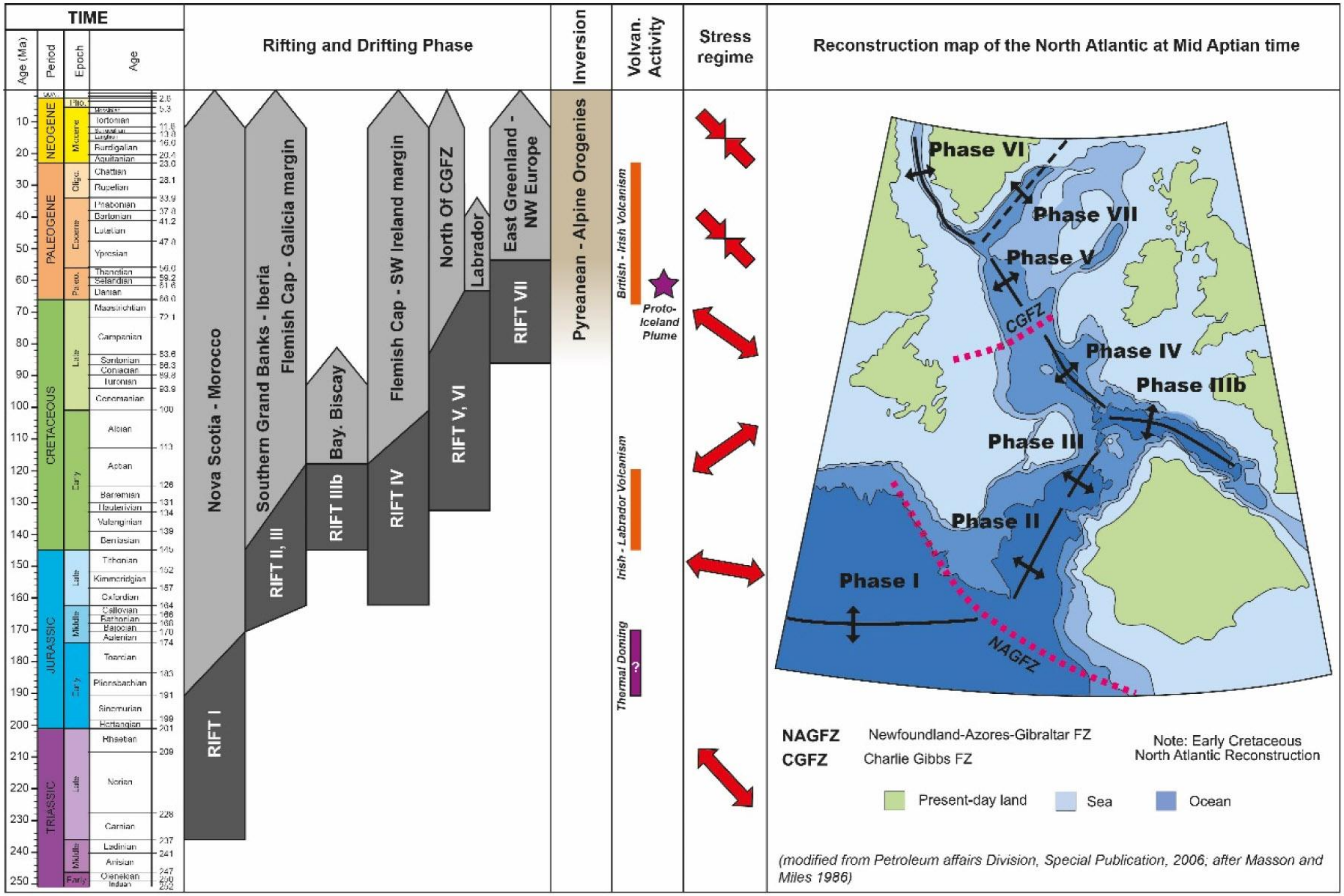

Figure 3. Stratigraphic position and nomenclature of potential source rocks in North Atlantic realm in Jurassic-Eocene interval.

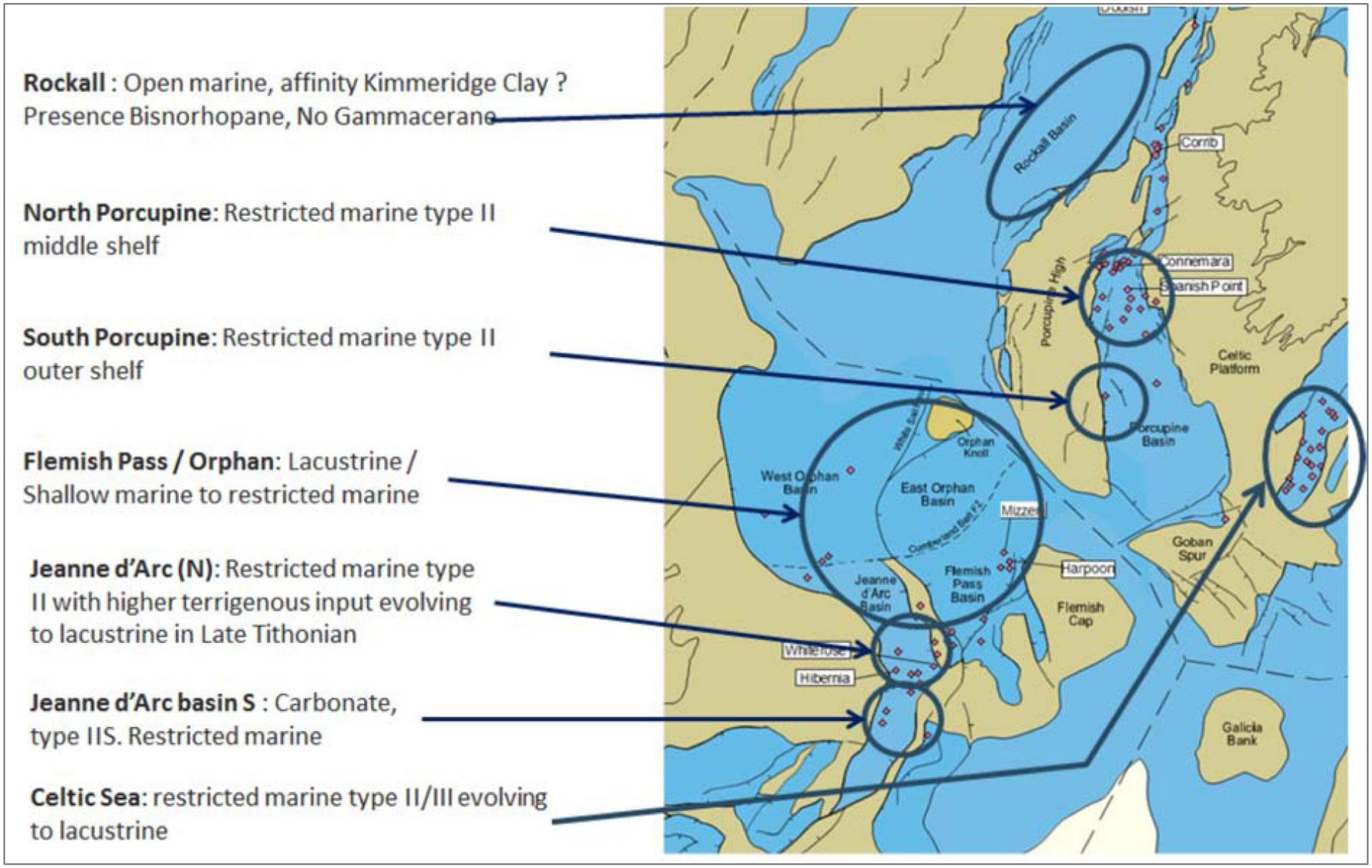

Figure 4. Summary of variation in organic facies in Kimmeridgian to Tithonian source rocks.

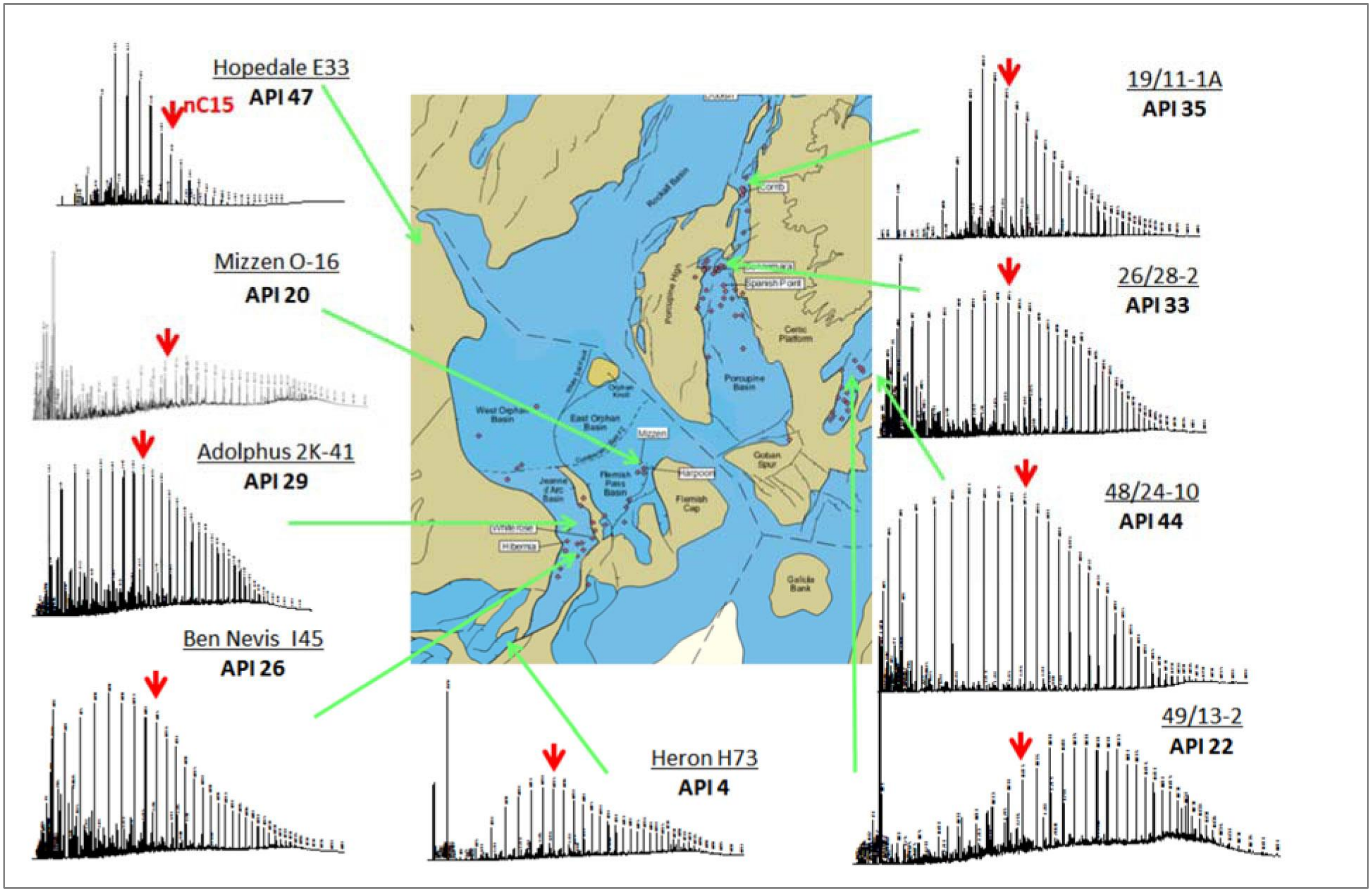

Figure 5. Examples of differing oils from offshore Ireland and Newfoundland/Labrador.

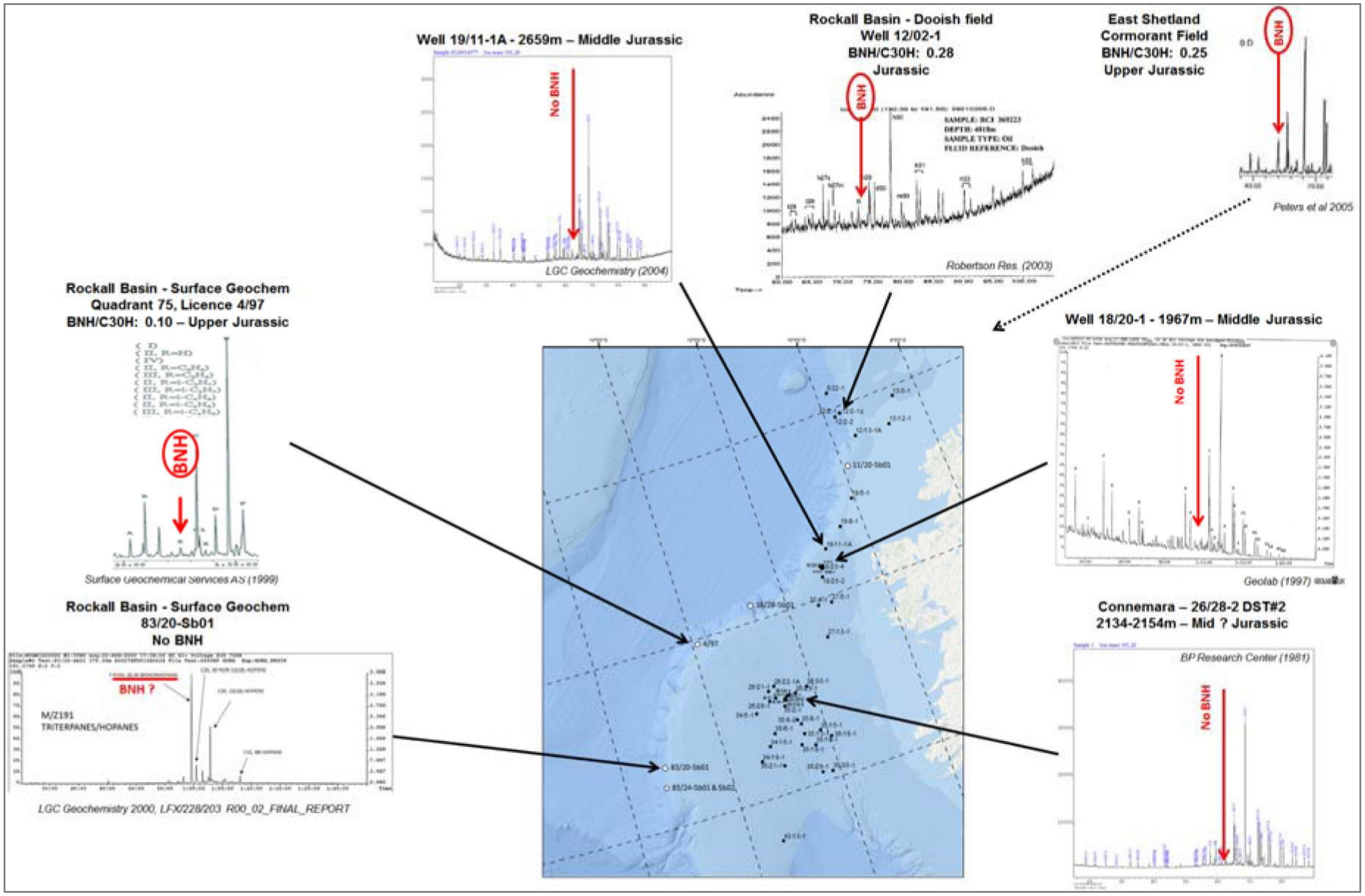

Figure 6. Presence/absence of Bisnorhopane in differing oils and extracts from offshore western Ireland.

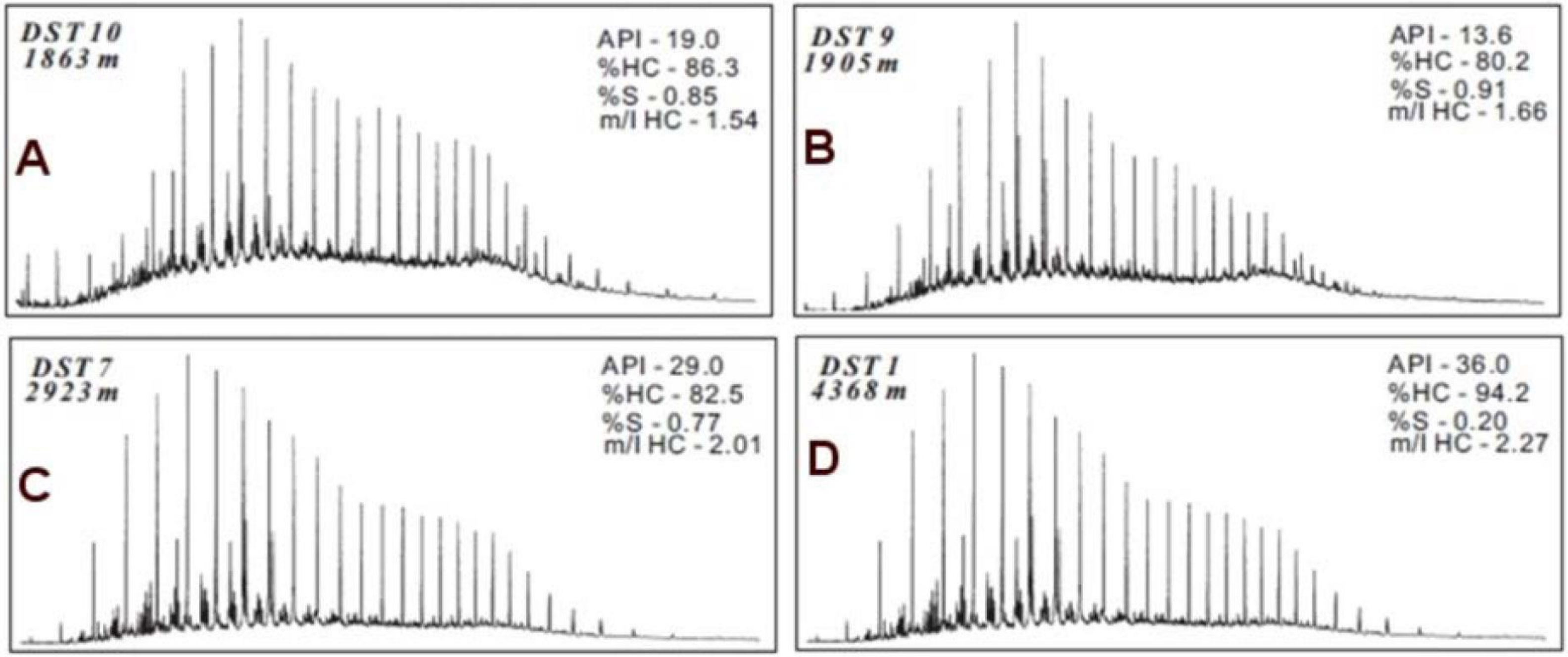

Figure 7. A-D: Saturate fraction gas chromatograms, Hebron I-13.