

# Oils of the North Atlantic: Long lost families or just a similitude of strangers?

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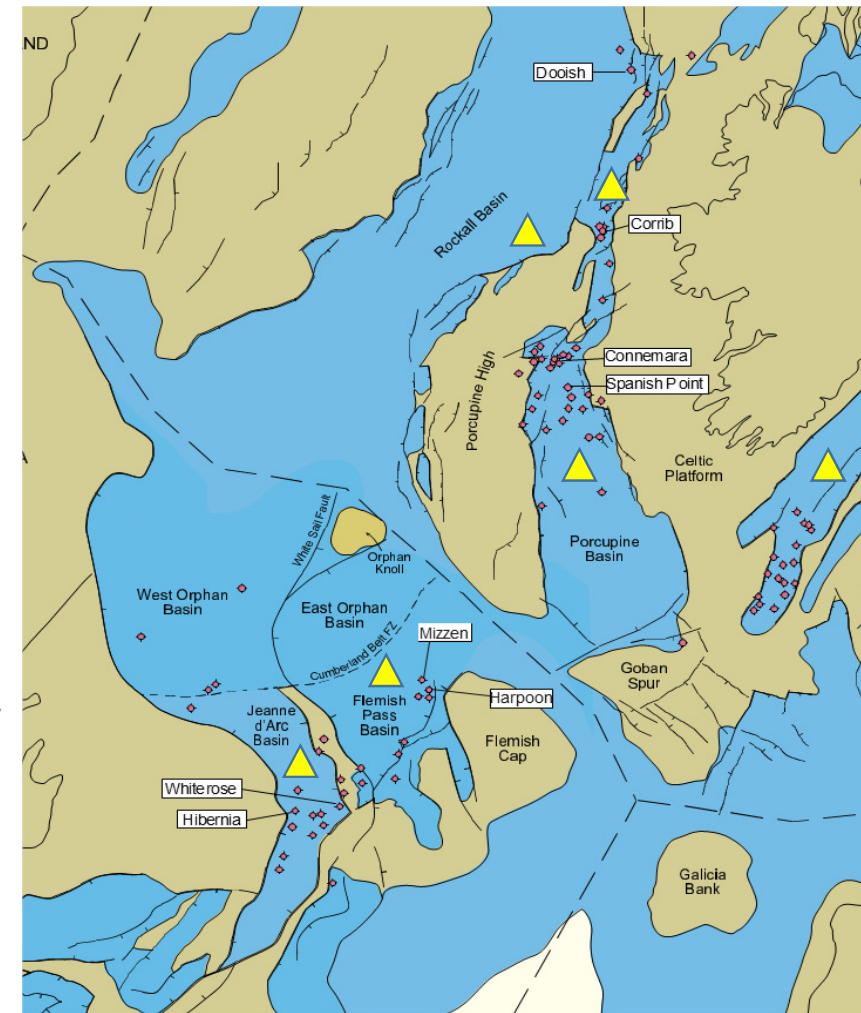
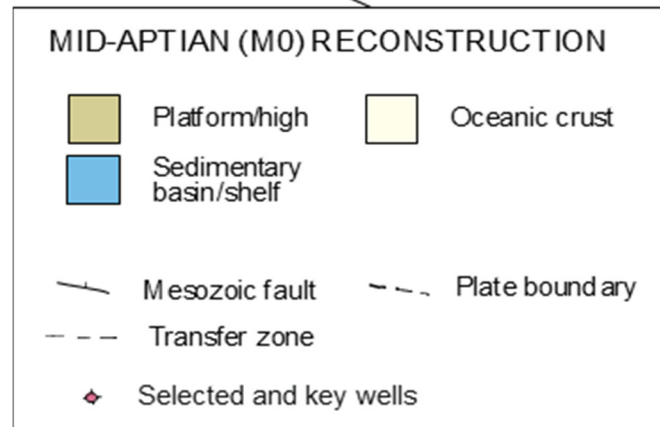
(1). Petroleum Systems Limited, Prestatyn, Wales, UK., (2). Beicip-Franlab, Rueil-Malmaison, France., (3). Nalcor Energy - Oil and Gas, St. John's, Newfoundland-Labrador , Canada.,  
(4). Petroleum Affairs Division, Department of Communications, Climate Action and Environment, Dublin, Ireland.

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▲ Studied basins

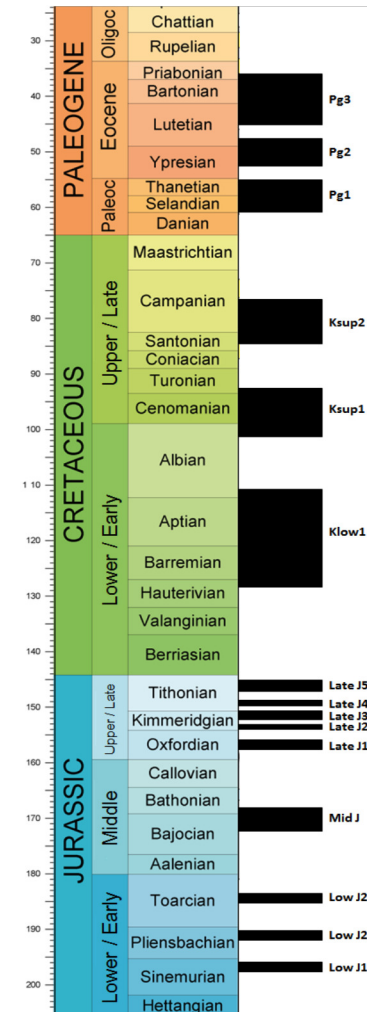
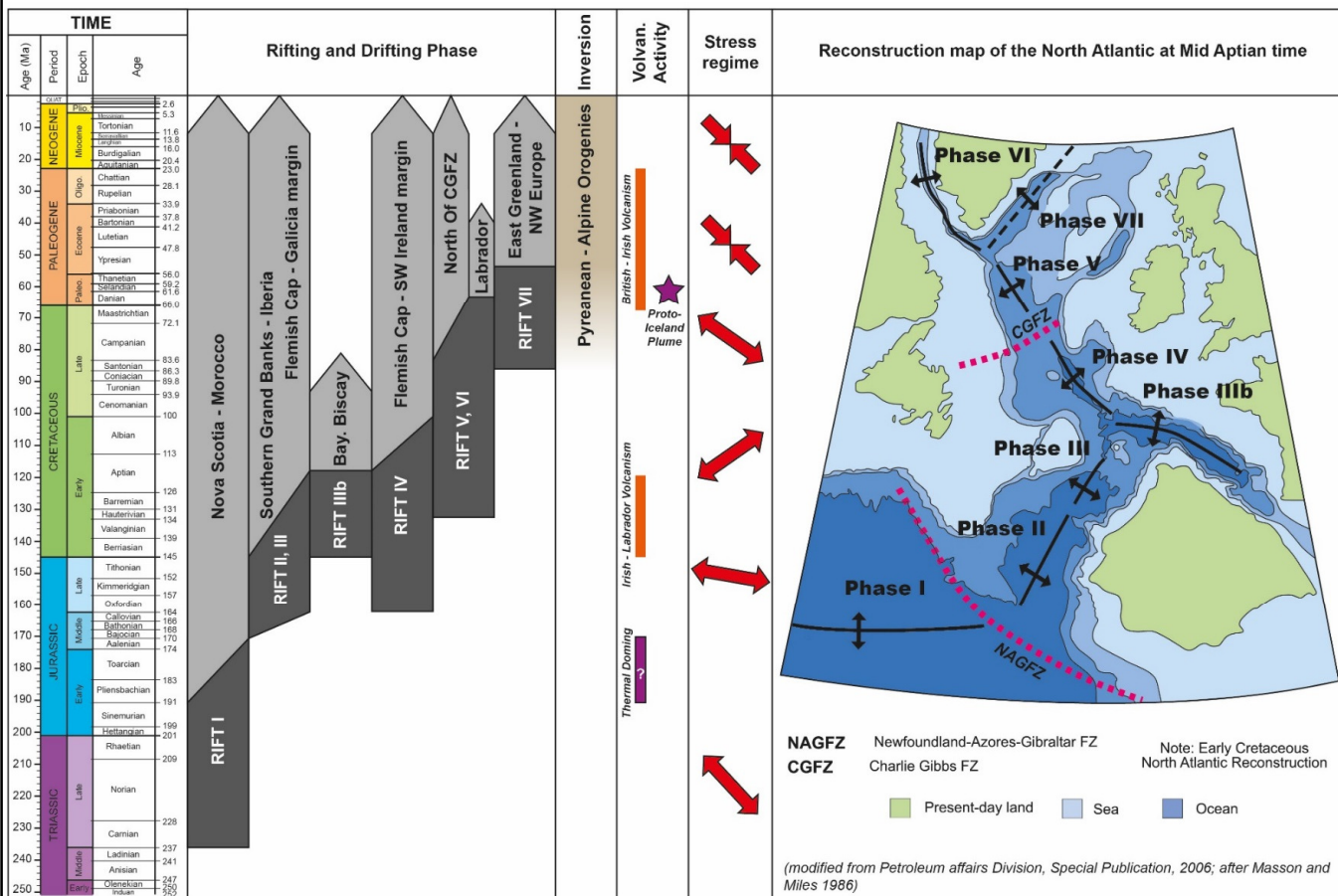


After Ternan 2007





# Source Rocks



Fifteen (15) potential source rock horizons are noted across the study area from within Mesozoic and Early Tertiary sediments.

This widespread distribution of sources related to the episodic rifting phases across the North Atlantic realm.

It is also recognised that older sources may locally be significant (e.g. Corrib Field, Ireland – Carboniferous source rock)

Also see Gehlen et al, Poster on display for more detail of sources

Episodic, extensional regime that, through successive rifting stages shaped basin development in the North Atlantic



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# Source Rocks

## Classic OM

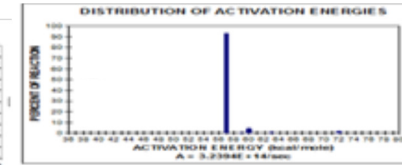
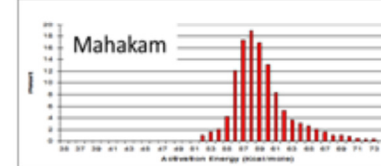
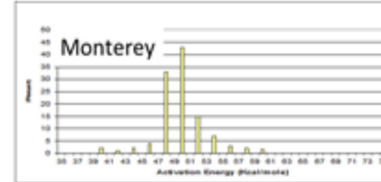
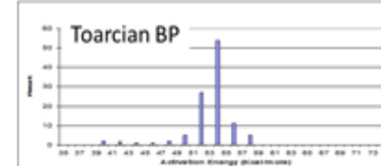
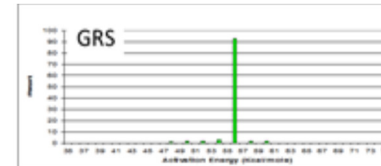
### Types

#### Type I

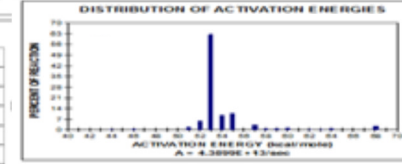
#### Type II

#### Type IIS

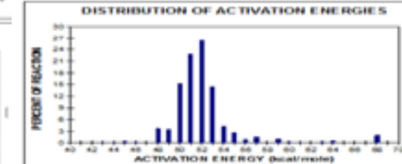
#### Type III



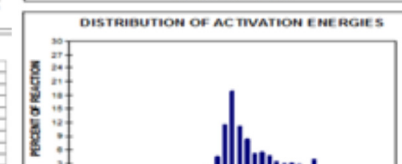
**Purbeck Formation**  
**50/11-3**



**Toarcian**  
**27/13-1**

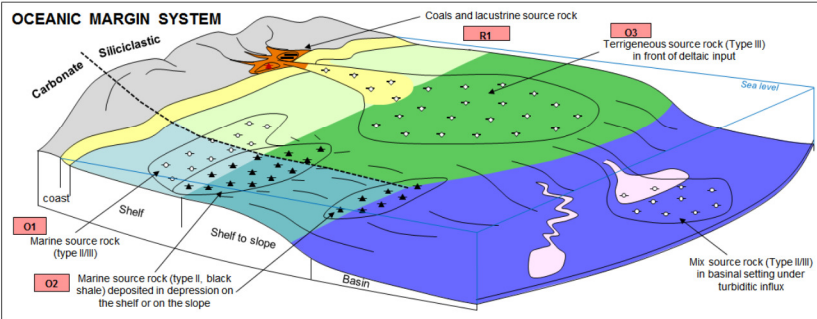
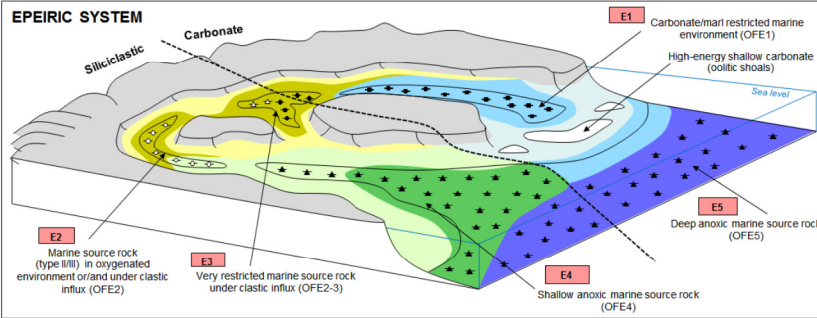
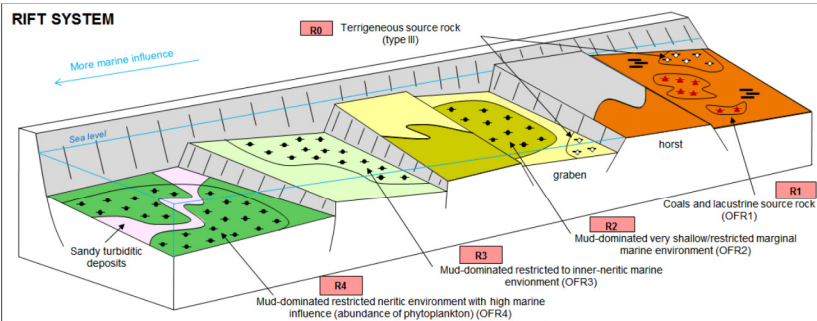


**Egret Member**  
**Egret K-36**



**Westphalian**  
**27/5-1**

Considerable variation in source facies has been recognised from the available geochemical datasets. Thirteen differing potential facies are proposed. Subsequent analyses to determine kerogen kinetics show that there are source facies present within the study area that can readily be related to classic organic matter types.



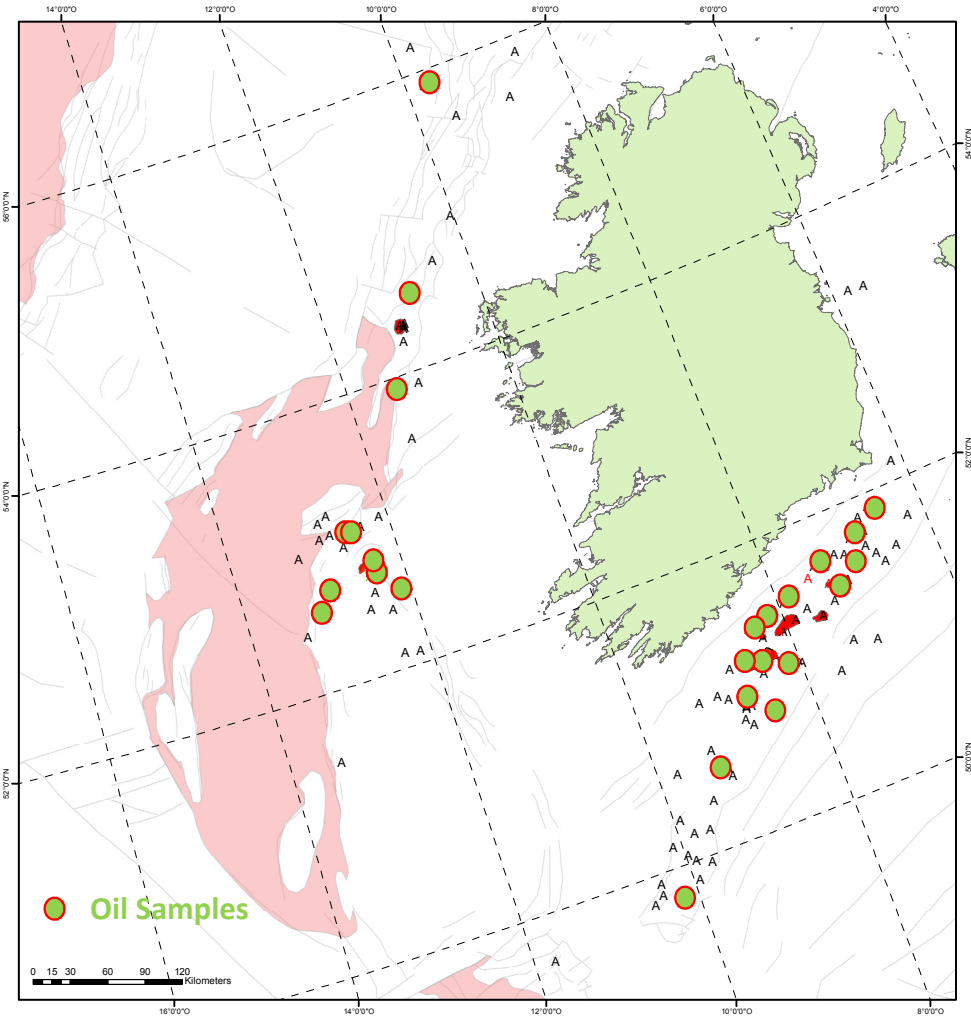


# Irish Oils

The Irish database includes **27 wells with oil samples** plus numerous extracted oil shows. The oil samples are as follows:

<b>Rockall Basin</b>	<b>Celtic Sea and Fastnet/Goban Spur</b>
12/2-1	48/18-1
<b>Slyne - Erris Basin</b>	48/19-2
19/11-1a	48/23-3
27/4-1(1z)	48/24-1
	48/24-2
<b>Porcupine Basin</b>	48/24-3
26/28-1 (a1/a1z/a2)	48/24-10
26/28-2	48/28-1
34/15-1	49/9-2
35/6-1	49/9-4
35/8-1	49/13-2
35/8-2	49/19-1
35/15-1	50/6-1
	50/11-3
	56/14-1
	57/9-1
	63/10-1

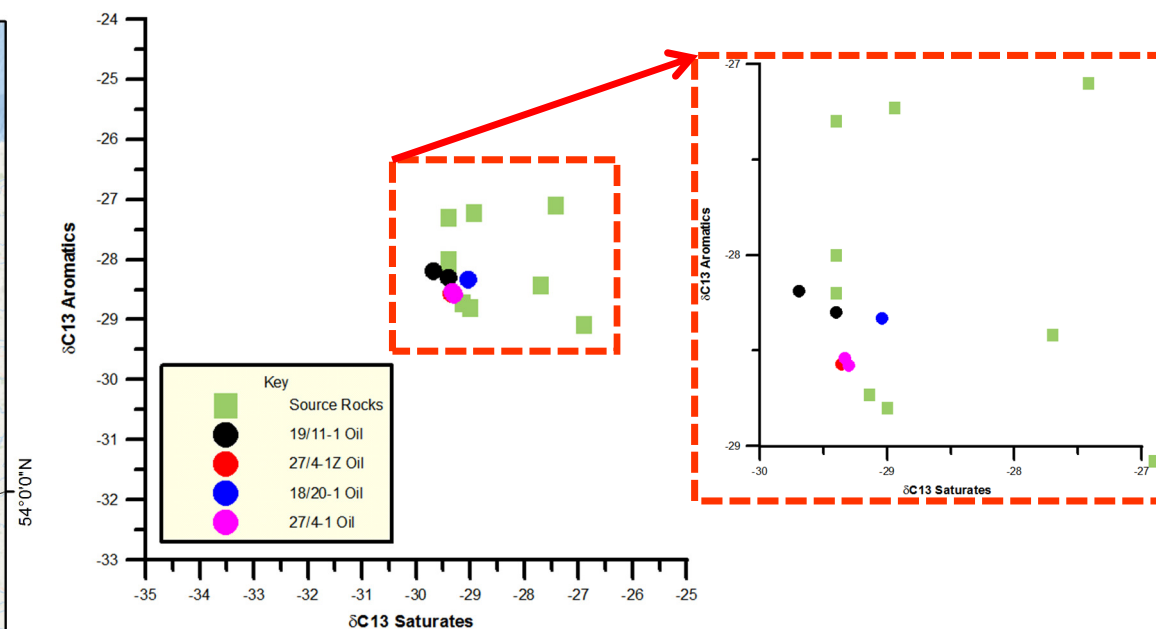
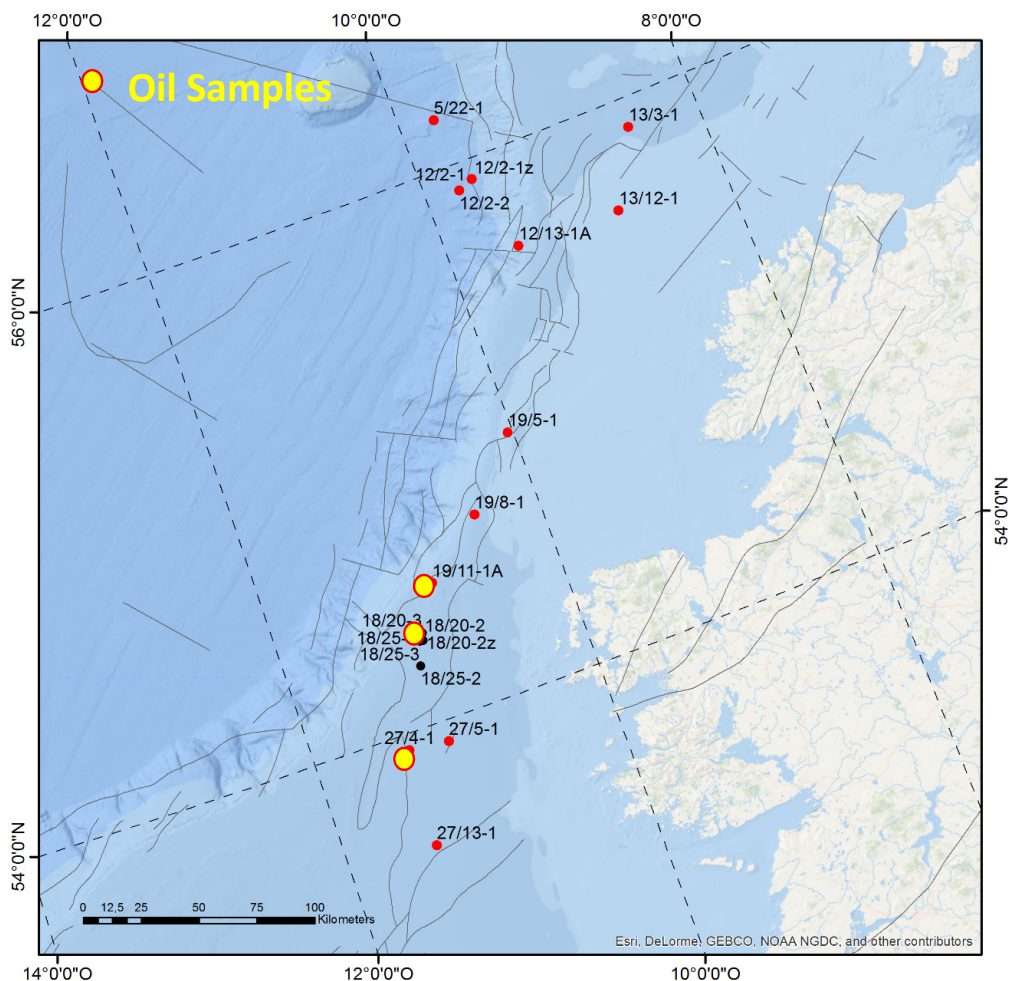
**In total there are 38 Irish oils in the database**



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## Oils of the west of Ireland basins – Slyne/Erris



Carbon isotope analyses indicates a close relationship between the oils that have been encountered within the Slyne Basin.

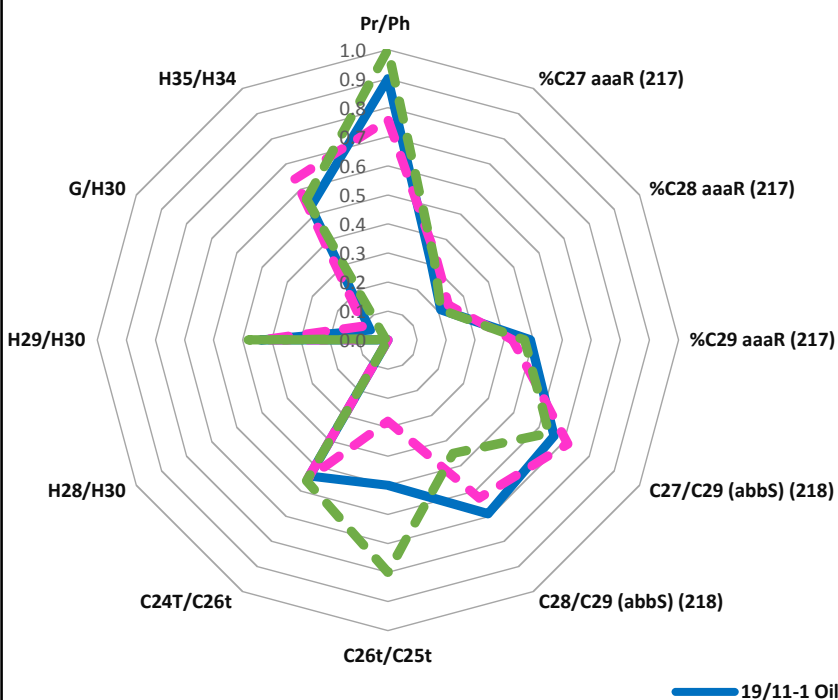
There is also a close isotopic relationship between these oils and Early Jurassic source rocks.



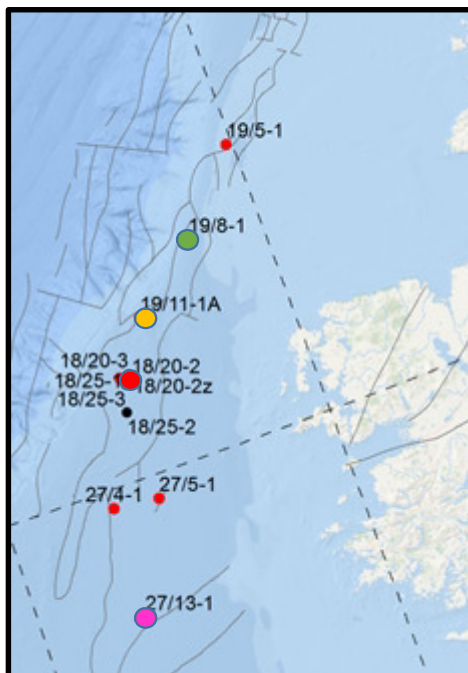


# Oils of the west of Ireland basins – Slyne/Erris

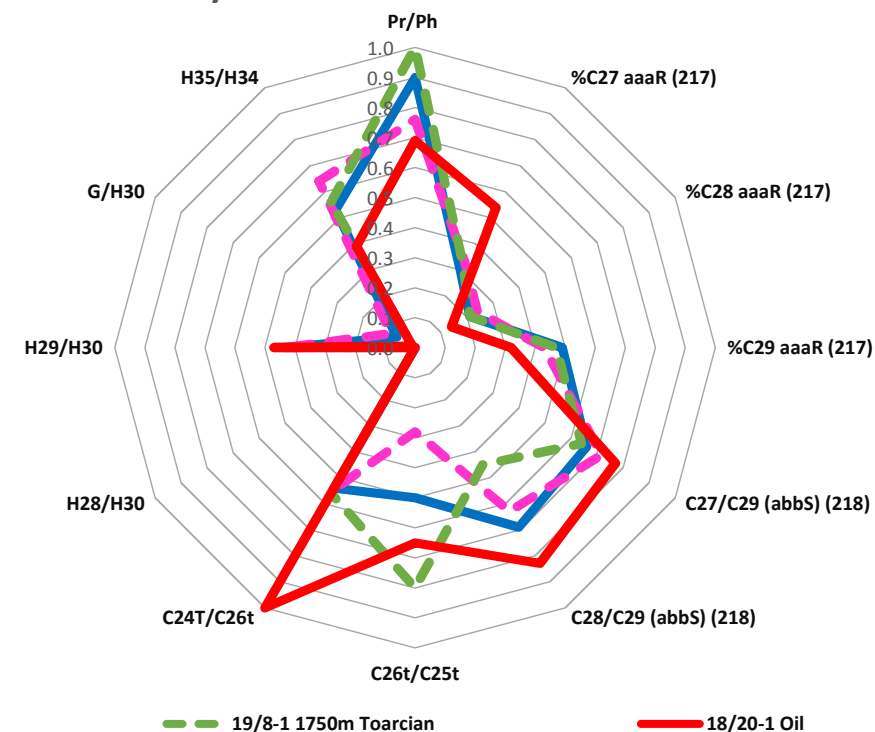
Slyne oil-source correlation



Biomarker ratios obtained from gas chromatography and GC-MS analyses also indicate a close relationship between the 19/11-1 oil and Early Jurassic source facies within the basin



Slyne oil-source correlation



The 18/20-1 oil has an offset trend to its biomarker ratios relative to the 19/11-1 oil and associated source rocks. This may indicate a modification in source facies with perhaps the parent source of the 18/20-1 oil having a more marine signature.

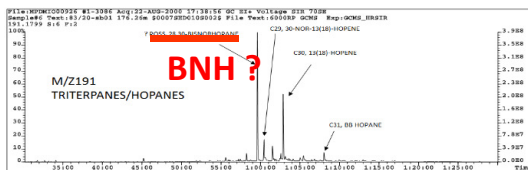
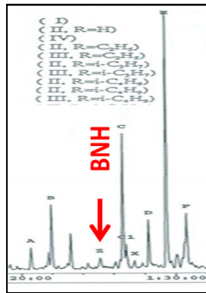


# Oils of the west of Ireland basins

Rockall oils and oil shows often (although not always) have Bisnorhopane present. This biomarker is also present in both West and East Shetland basins.

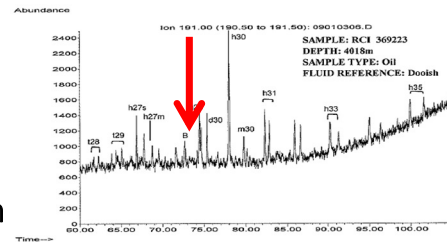
Rockall Basin - Surface Geochem  
Licence 4/97 Upper Jurassic

**Bisnorhopane  
Present**



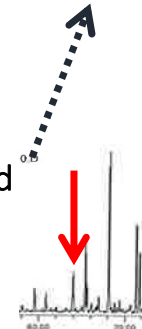
Rockall Basin - Surface Geochem  
83/20-Sb01 BNH?

Rockall Basin – Dooish  
Well 12/02-1 Jurassic

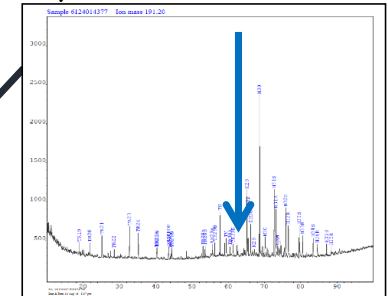


East Shetland  
Cormorant Field  
Upper Jurassic

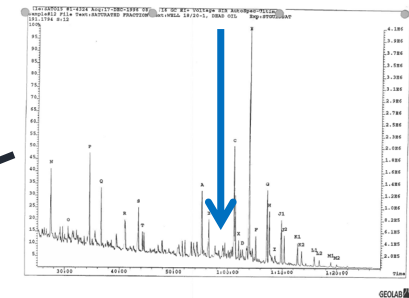
*Peters et al 2005*



Well 19/11-1A – Middle Jurassic



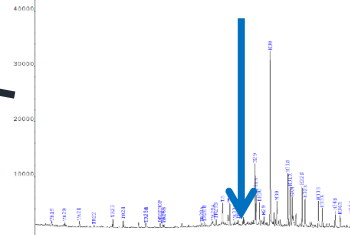
Well 18/20-1 - 1967m – Middle Jurassic



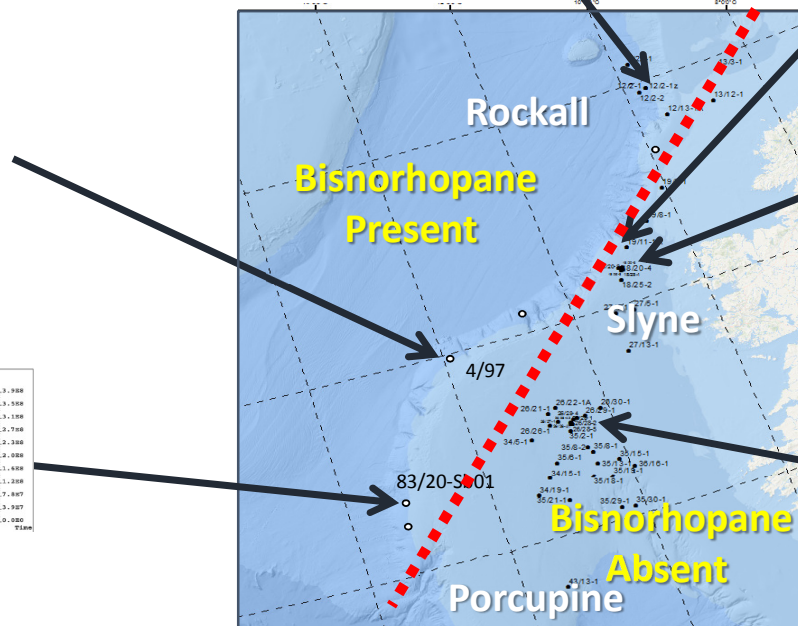
Slyne, Erris and  
Porcupine oils  
and oil shows  
are lacking in  
Bisnorhopane

Connemara – 26/28-2 DST#2

– Mid ? Jurassic



**Bisnorhopane  
Absent**

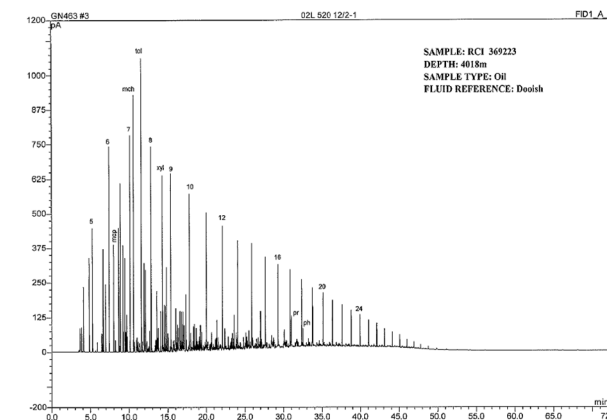
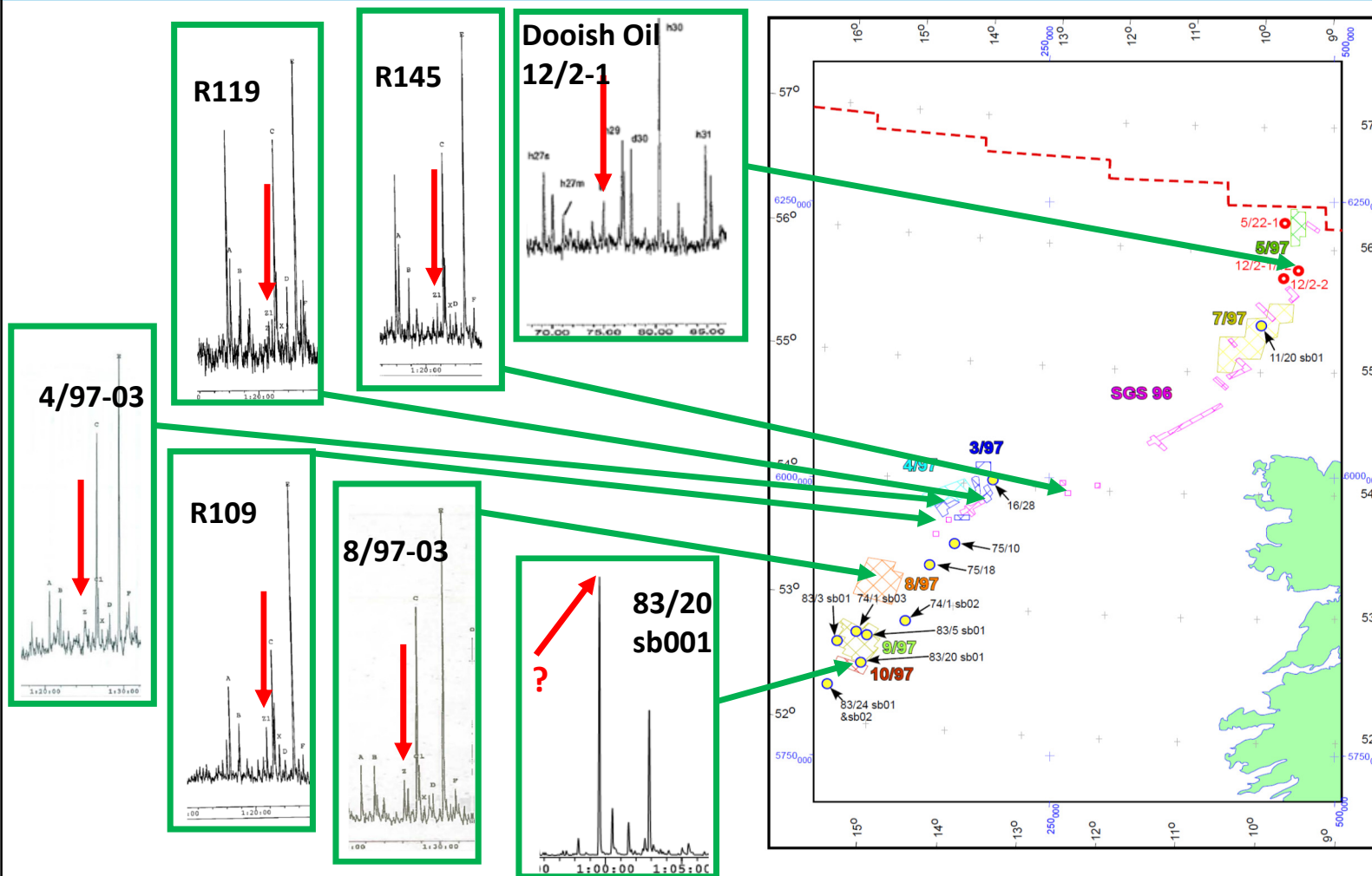


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# Oils of the west of Ireland basins – Rockall Basin



To further expand on the distribution of Bisnorhopane, having a cohesive dataset allows more detailed analysis of the distribution of this biomarker in the Rockall Basin to be made. Furthermore, other independent geoscientific data can be integrated to try to explain this occurrence and its potential significance



# Oils of the west of Ireland basins – Rockall Basin

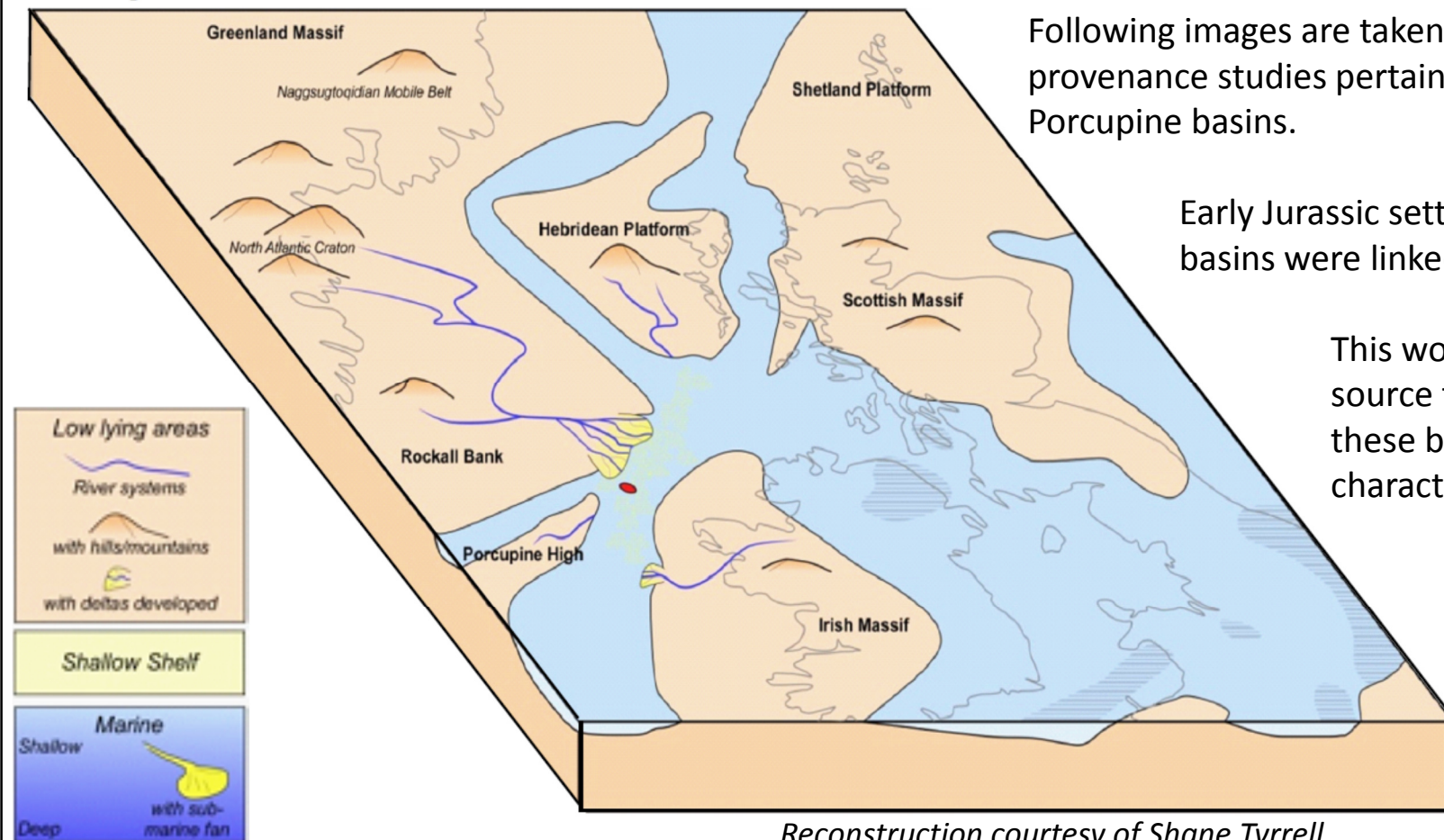
## Early Jurassic

Following images are taken from interpretation of sand provenance studies pertaining to the Rockall, Erris, Slyne and Porcupine basins.

Early Jurassic setting suggests that all the above basins were linked to marine areas to the north.

This would further suggest that any source facies developing at this time in these basins may display common characteristics.

Early Jurassic sources in the Erris, Slyne and Porcupine basins are associated with some of the oils and oil shows discovered in these basins.



Reconstruction courtesy of Shane Tyrrell



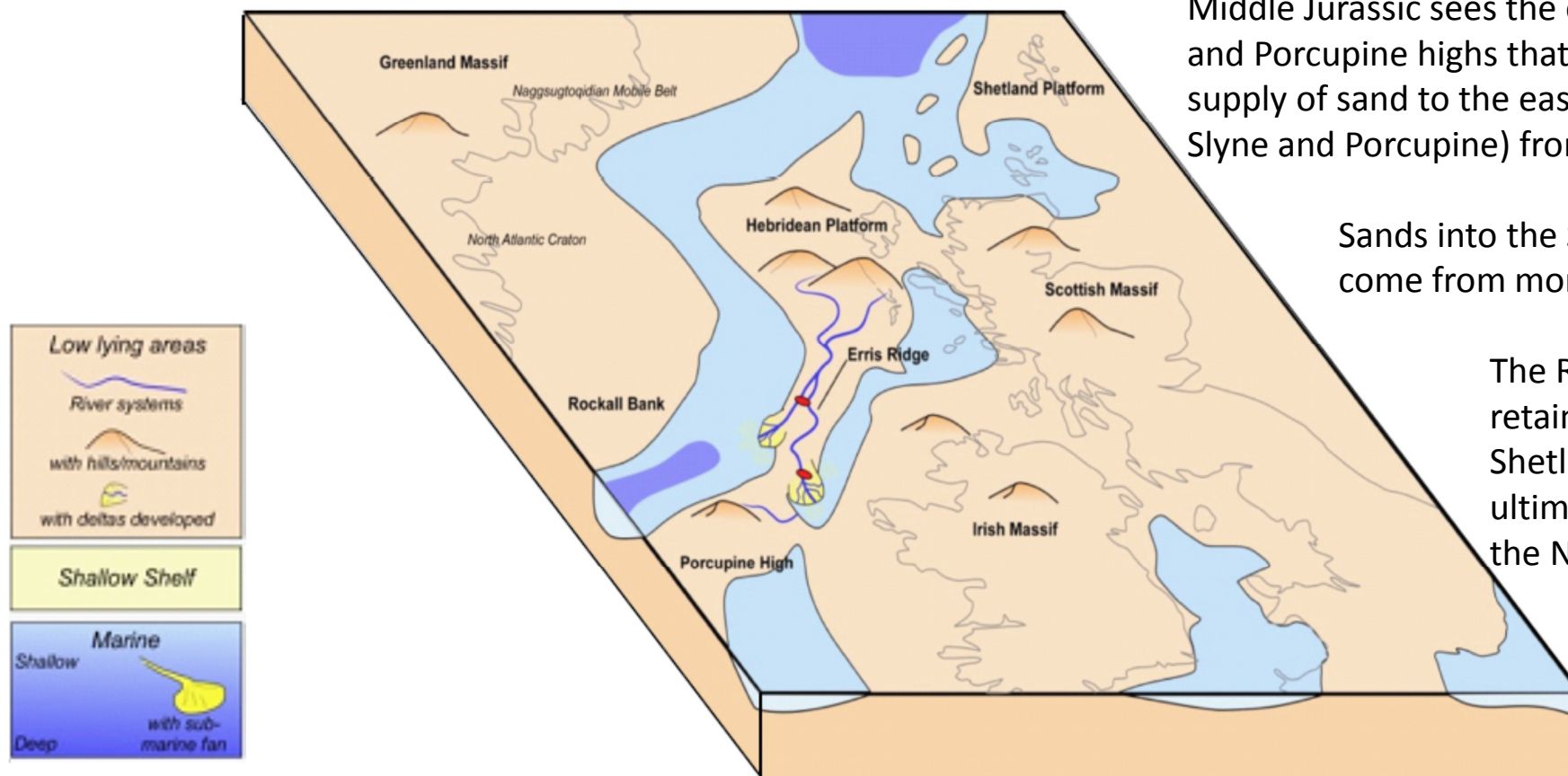
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# Oils of the west of Ireland basins – Rockall Basin

## Middle Jurassic



Middle Jurassic sees the emergence of the Erris and Porcupine highs that effectively cut off the supply of sand to the eastern basins (Erris, Slyne and Porcupine) from the west.

Sands into the Slyne and Porcupine come from more local sources.

The Rockall Basin still retains links to the West Shetland Basin and ultimately to the basins of the North Sea.

*Reconstruction courtesy of Shane Tyrrell*

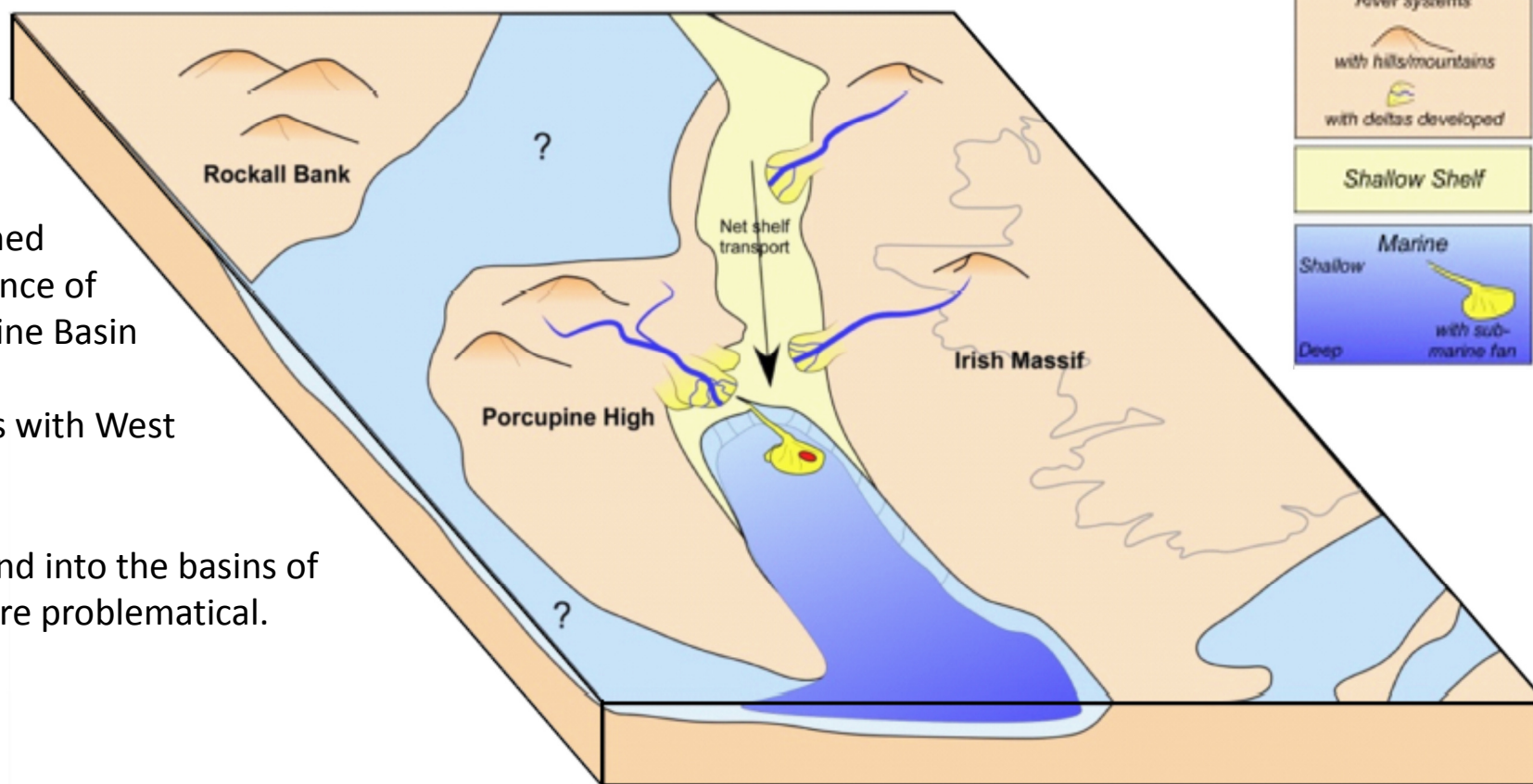


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## Oils of the west of Ireland basins – Rockall Basin

### Late Jurassic



Porcupine High well established and influential over provenience of sediments within the Porcupine Basin

Rockall Basin still retains links with West Shetland Basins to the north.

Extent of links to the south and into the basins of the conjugate margin are more problematical.

*Reconstruction courtesy of Shane Tyrrell*



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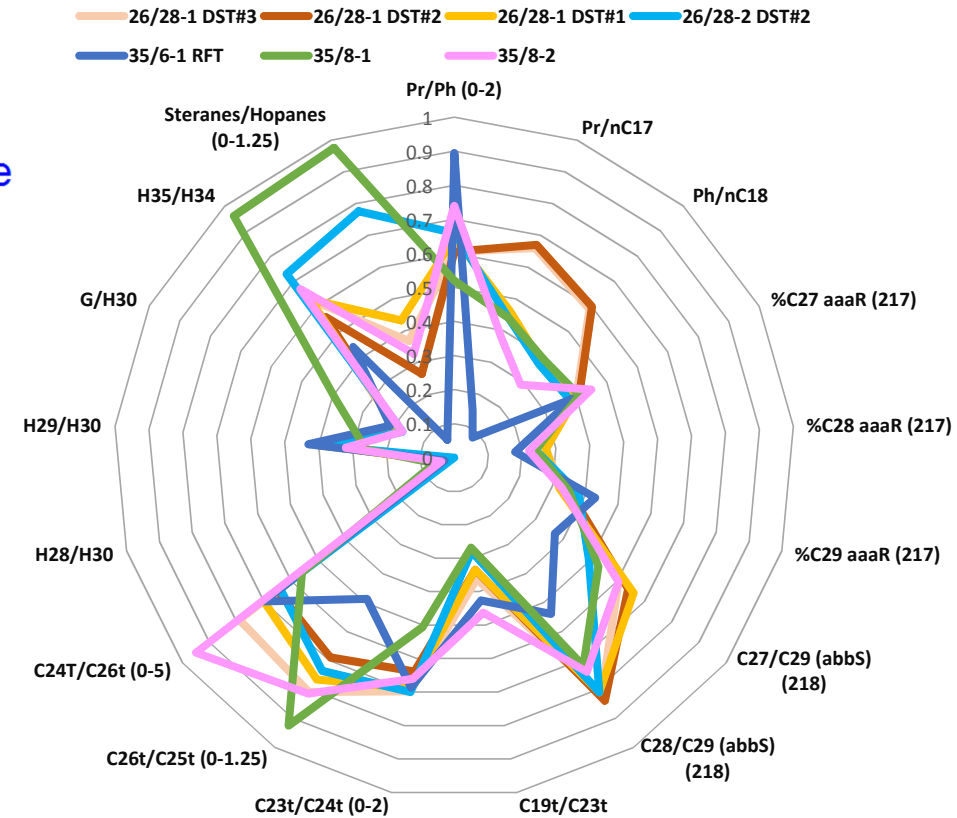
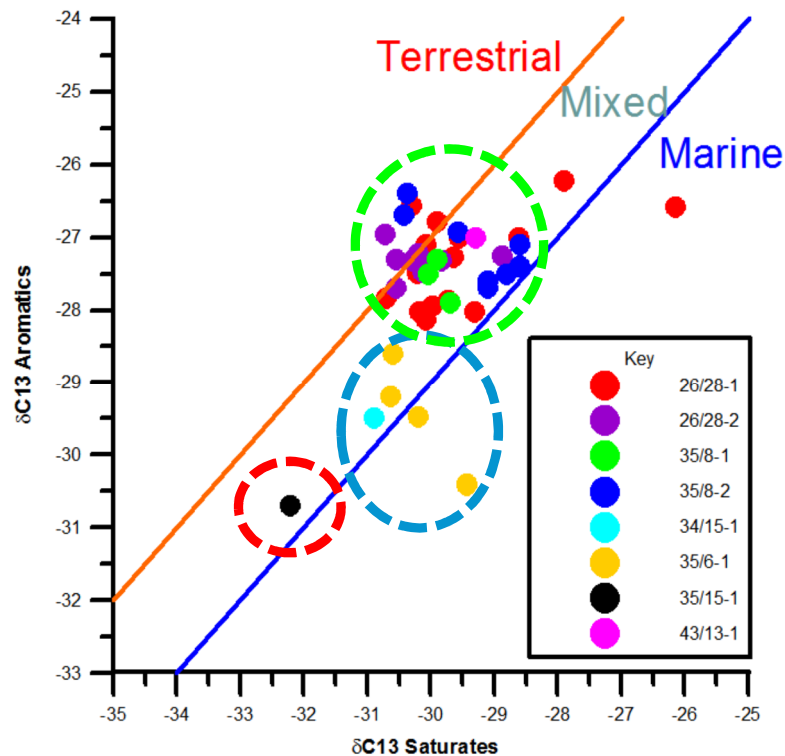
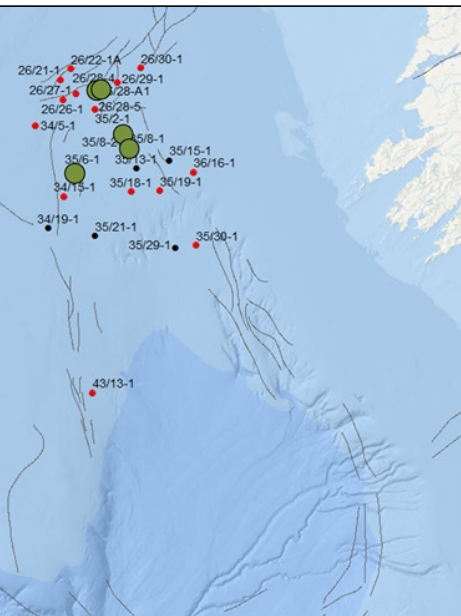


# Oils of the west of Ireland - Porcupine Basin

## Oils – North Porcupine Basin

## Isotope determinations – North Porcupine Basin

## North Porcupine oils and oil shows



Carbon isotope determinations, gas chromatography and GC-MS biomarker analyses of the oils are indicative of more than one source facies for these oils and oil shows. Three principal oil families are recognised.



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# Oils of the west of Ireland basins – Porcupine Basin

## Family Porcupine A

34/15-1 (3745m) Bath./Bajc. 35/6-1 RFT

%C27  
aaaR  
(217)

%C28  
aaaR  
(217)

%C29  
aaaR  
(217)

C27/C29  
(abbS)  
(218)

C28/C29  
(abbS)  
(218)

H28/H30

H29/H30

G/H30

H35/H34

Ster/Hop

**Family Porcupine A:** Correlation using GC-MS biomarker ratios between 35/6-1 oil and Bathonian / Bajocian source rock of 34/15-1

**Family Porcupine B:** Correlation using GC-MS biomarker ratios between 35/8-1 oil and Kimmeridgian source rocks of 35/8-2

## Family Porcupine B

35/8-1 Oil 35/8-2 14500-14560ft 35/8-2 14550-14600ft

%C27  
aaaR

%C28  
aaaR

%C29  
aaaR

C27/C29  
(abbS)

C28/C29  
(abbS)

C19t/C23t

C26t/C25t

C24t/C26t

H28/H30

H29/H30

G/H30

H35/H34

St/Hop

**Family Porcupine C:** Correlation using GC-MS biomarker ratios between 26/28-1 and 35/8-2 oils and Kimmeridgian source rock of 35/2-1

## Family Porcupine C

35/2-1 3265-3270m K/O 26/28-1 DST#3 35/8-2

%C27  
aaaR

%C28  
aaaR

%C29  
aaaR

C27/C29  
(abbS)

C28/C29  
(abbS)

C19t/C23t

C26t/C25t

C24t/C26t

H28/H30

H29/H30

G/H30

H35/H34

St/Hop

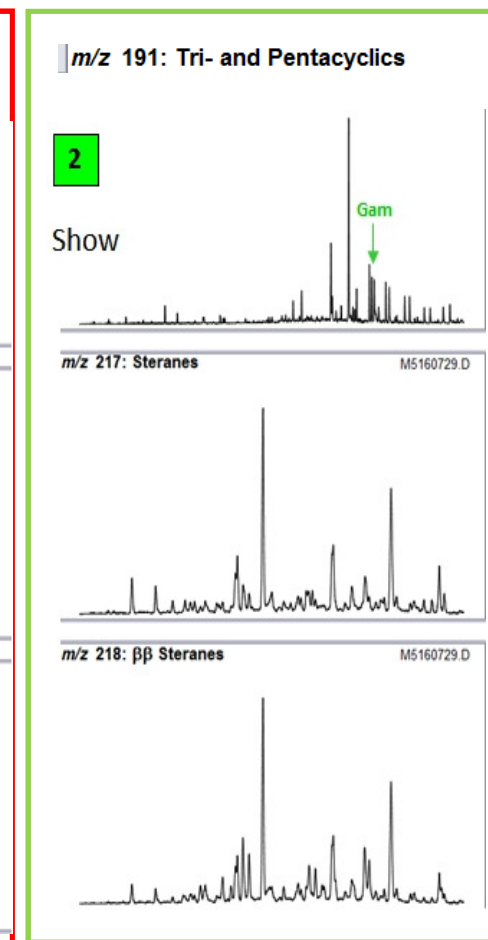
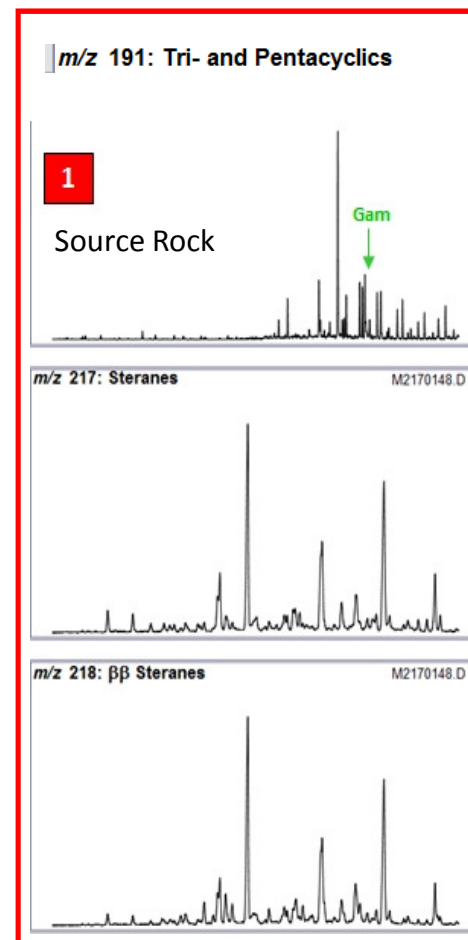
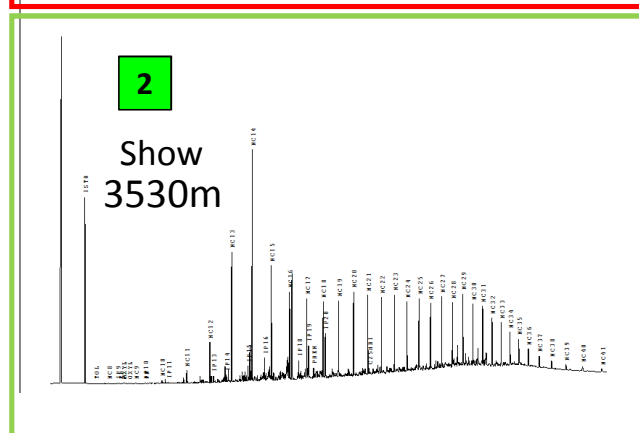
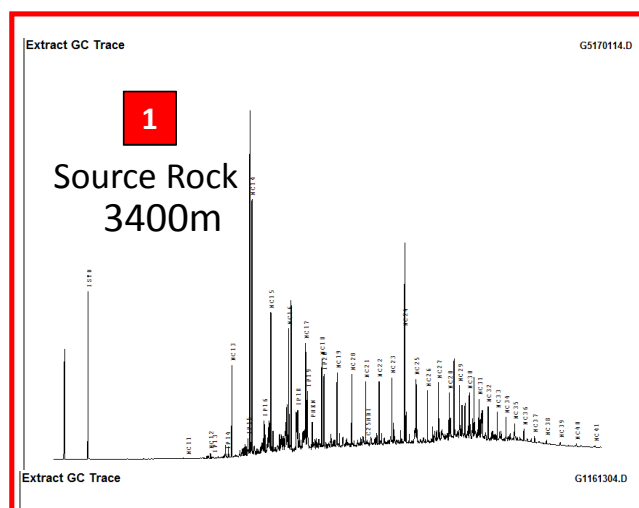
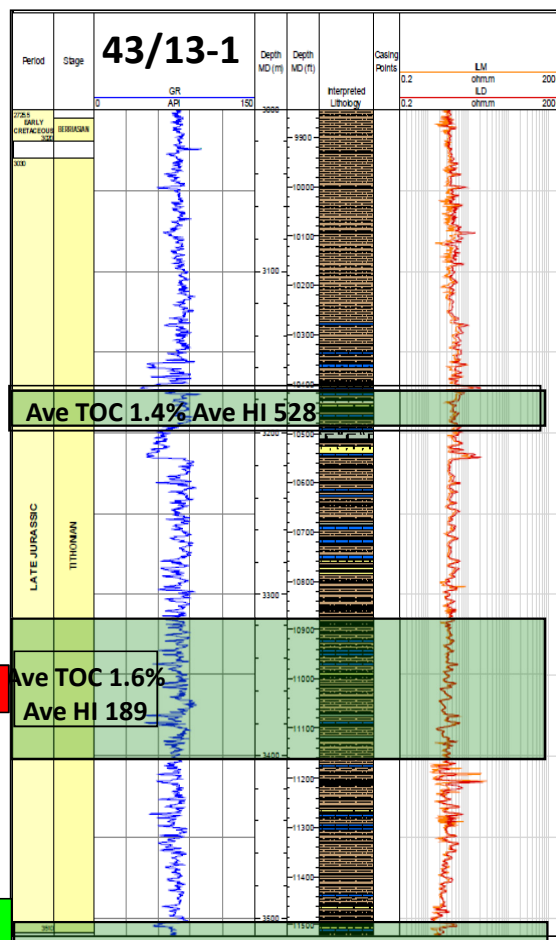


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# Oils of the west of Ireland - Porcupine Basin, 43/13-1



Geochemical characteristics of oil shows and source rock samples from the 43/13-1 well – Porcupine Basin



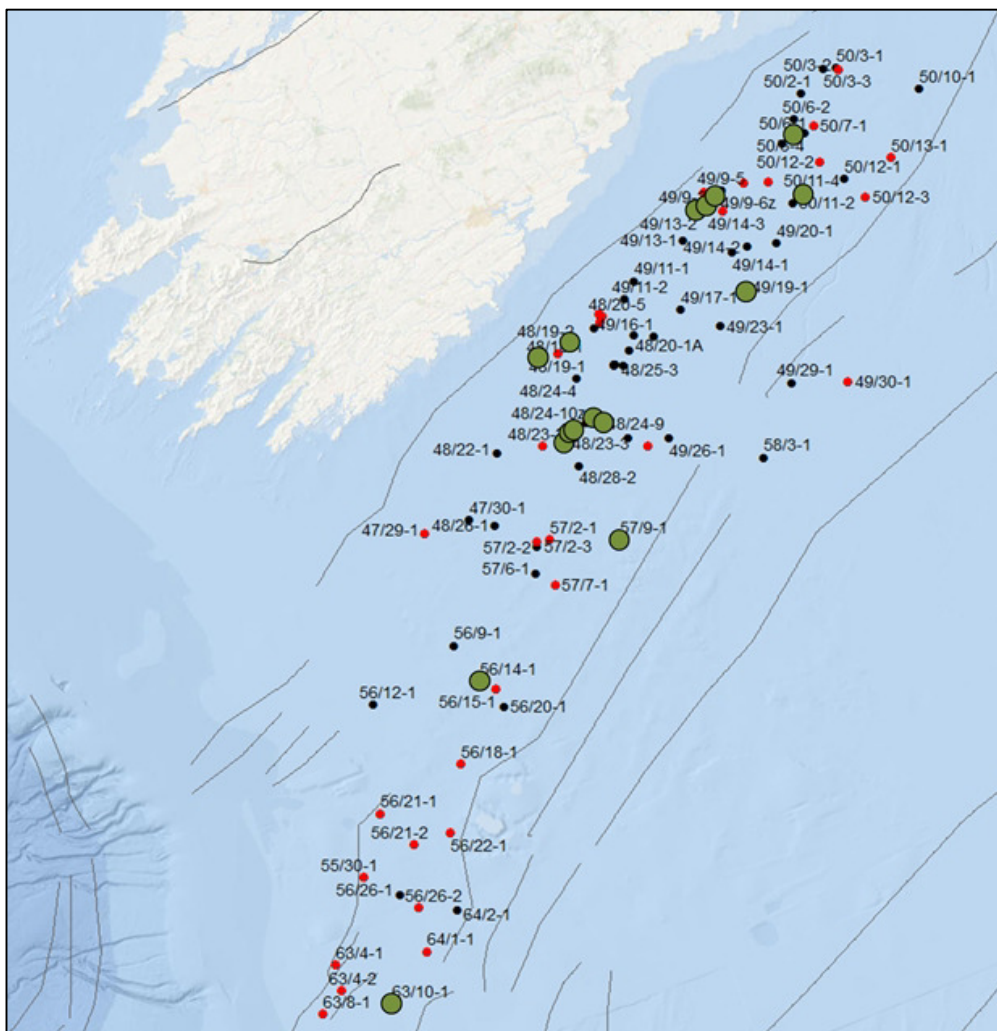
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## Oils of the south of Ireland basins

### Celtic Sea and Fastnet/Goban Spur

48/18-1  
48/19-2  
48/23-3  
48/24-1  
48/24-2  
48/24-3  
48/24-10  
48/28-1  
49/9-2  
49/9-4  
49/13-2  
49/19-1  
50/6-1  
50/11-3  
56/14-1  
57/9-1  
63/10-1



Seventeen oil samples within the database, most have geochemical analyses that include gas chromatography.

A more limited number also have carbon isotope determinations and GC-MS biomarker analyses

From the available datasets two broad families are recognised:

**Family Celtic A:** This family is divided into two sub-families, both having major contribution to oils from non-marine/lacustrine source rock .

**Family Celtic B:** Oils of this family lack the lacustrine source characteristics and display a marine influence

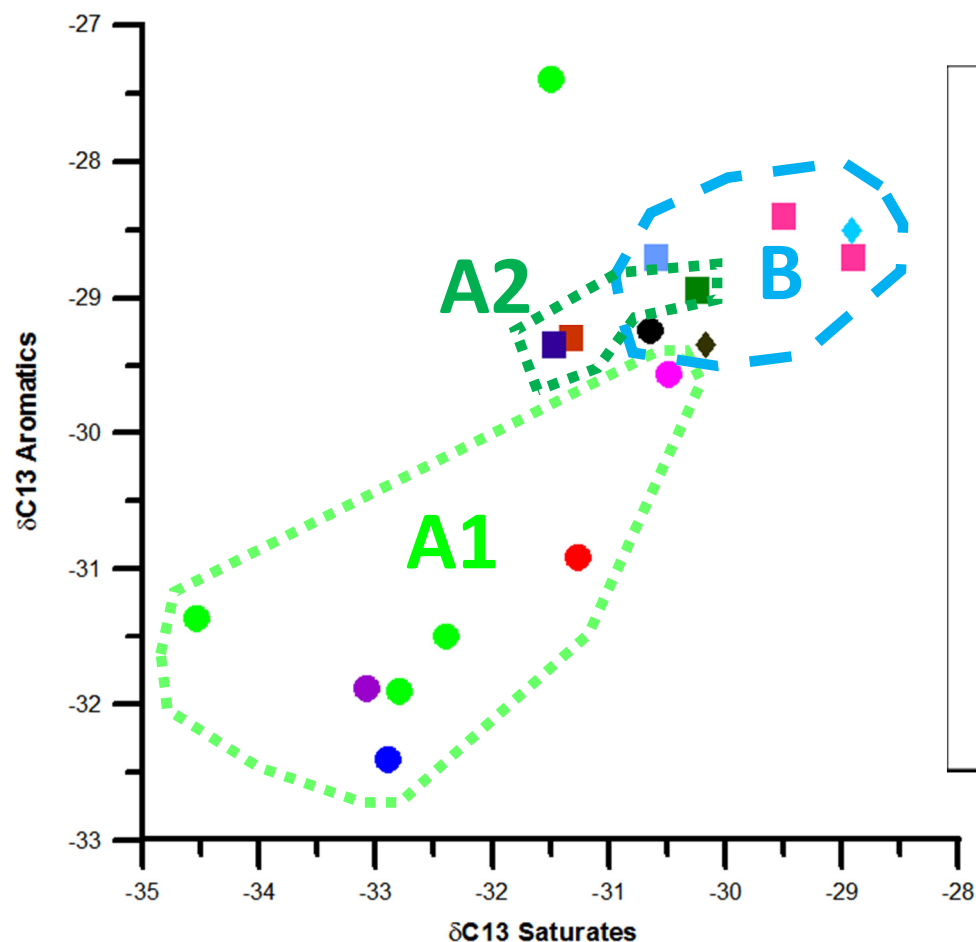
● Oil Samples



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## Oils of the south of Ireland basins



**Oil Family Celtic A1:** Oils include 48/24-10z, 48/28-1, 48/24-2 and 49/14-1 and exhibit strong lacustrine signature. Isotopically these oils often very light (i.e. more negative).

**Oil Family Celtic A2:** Oils include 49/13-2 and 50/11-3. Still exhibit a clear lacustrine affinity but this is attenuated compared to Family A1 suggesting a contribution of a marine influenced source.

**Oil Group Celtic B:** In this group are the 49/9-2, 49/9-4, 49/10-4, 50/6-1 and 57/9-1 oils. These oils display a marine influence and are relatively heavy (less negative) isotopically.

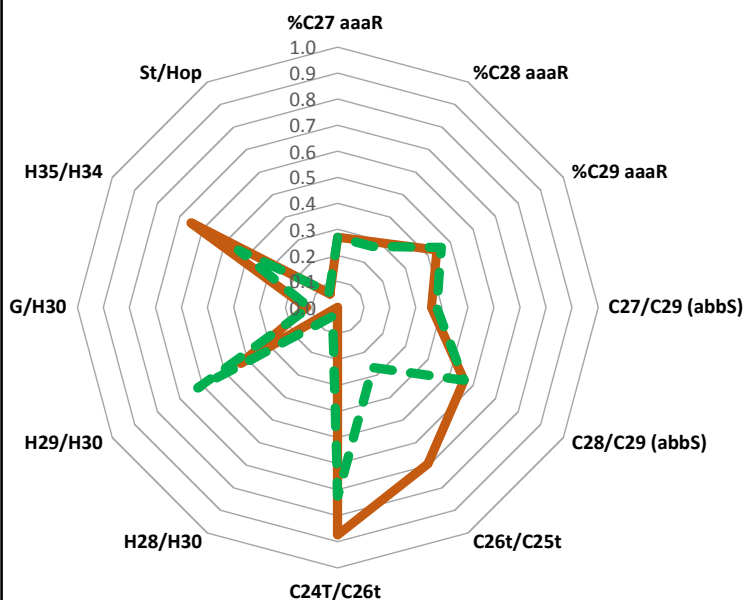




# Oils of the south of Ireland basins

## Family Celtic A1

48/24-10 oil 50/11-3 4380ft Purb.

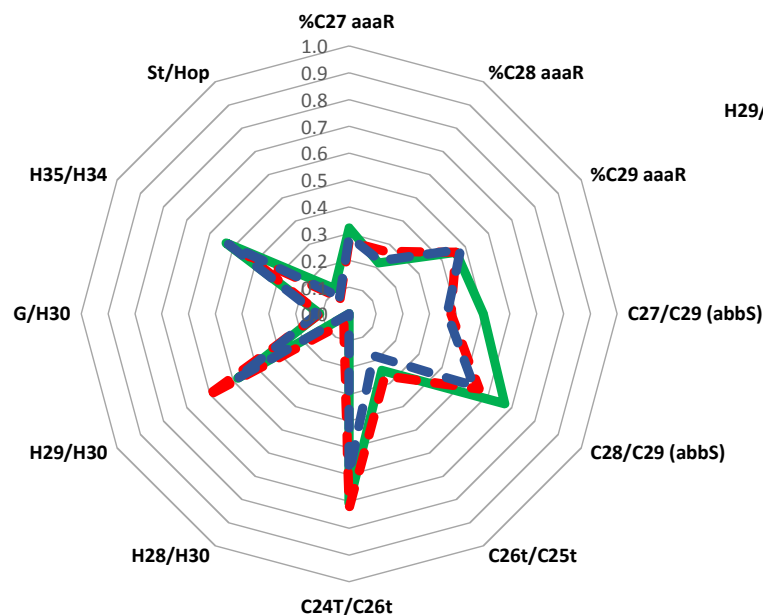


**Family Celtic A1:** Correlation using GC-MS biomarker ratios between 48/24-10 oil and Purbeck source rock of 50/11-3

**Family Celtic A2:** Correlation using GC-MS biomarker ratios between 49/13-2 oil, Purbeck source of 50/11-3 and Kimmeridgian source of 49/13-2

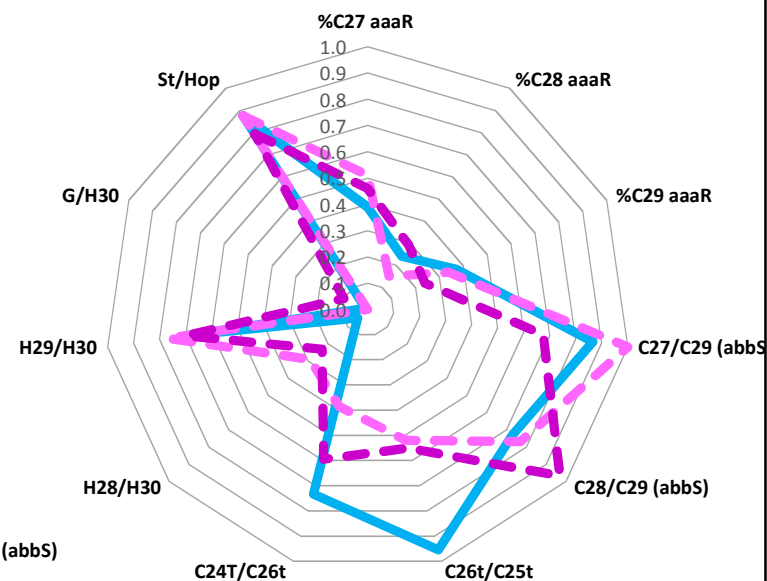
## Family Celtic A2

49 13-2 oil 50/11-3 4380ft Purb. 49 13-2 sr Kimm



## Family Celtic B

57/9-1 DST#1A 57/7-1 6780ft Pliens/Sin.  
57/7-1 6960ft Pliens/Sin.



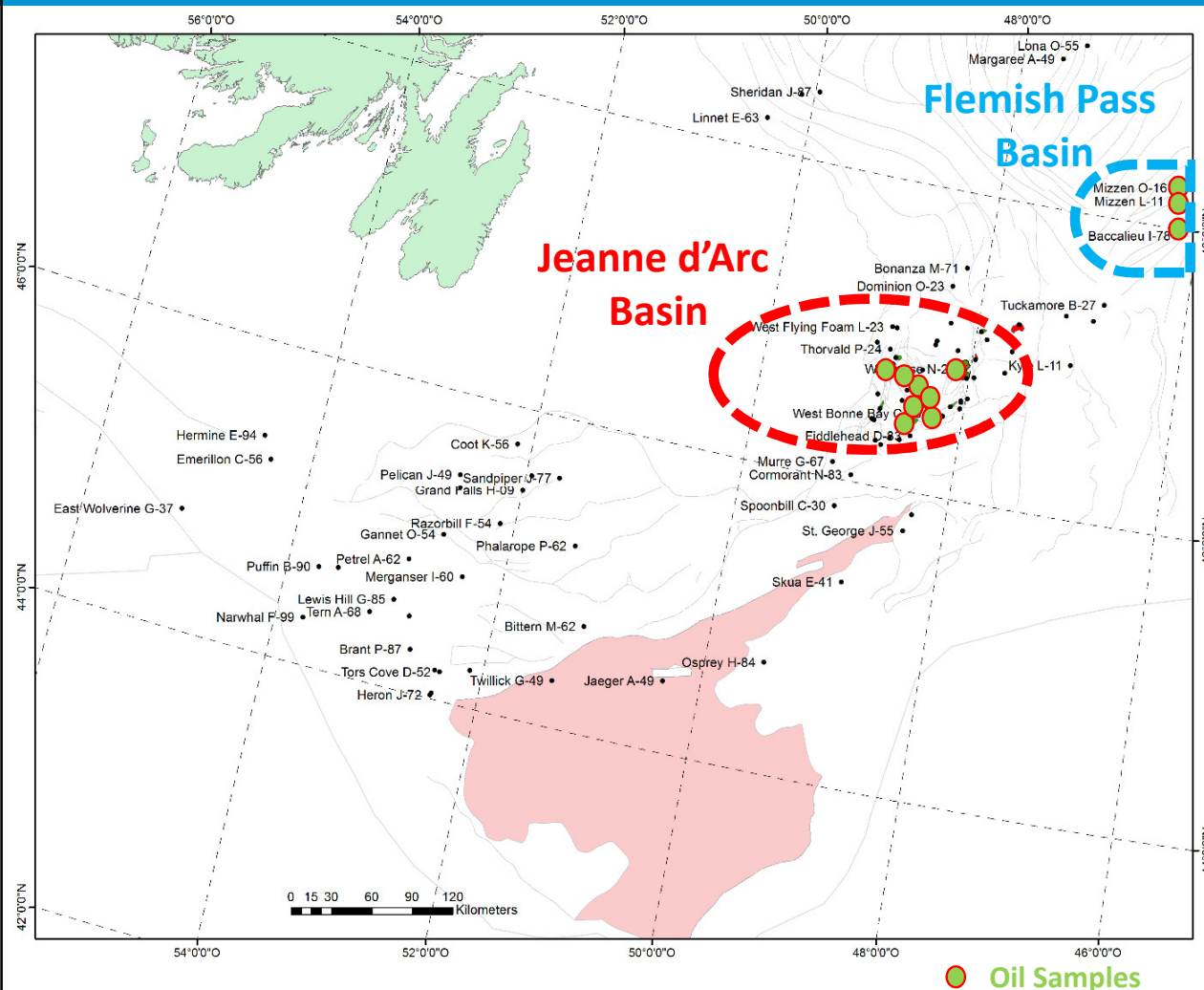
**Family Celtic B:** Tentative correlation between 57/9-1 oil and Early Jurassic source rocks of 57/7-1



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# Canadian Oils



The Canadian database includes **38 wells with 89 oil samples** plus numerous extracted oil shows. The oil samples are as follows:

Adolphus 2K-41 (1)  
 Beothuk M-05 (2)  
 Fortune G-57 (3)  
 Hebron I-13 (6)  
 Hibernia B-27 (1)  
 Hibernia C-96 (4)  
 Hibernia I-46 (2)  
 Hibernia K-14 (2)  
 Hibernia P-15 (4)  
 Mizzen L-11 (1)  
 Nautilus C-92 (3)  
 North Ben Nevis M-61 (1)  
 South Mara C-13 (2)  
 South Tempest G-88 (4)  
 Terra Nova C-90 (2)  
 Terra Nova K-07 (2)  
 Terra Nova K-18 (1)  
 Trave E-87 (1)  
 White Rose E-09 (2)  
 White Rose L-61 (1)

Bay du Nord C-78 (1)  
 East Rankin H-21 (1)  
 Harpoon O-85 (1)  
 Hibernia B-08 (9)  
 Hibernia C-96 (4)  
 Hibernia J-34 (1)  
 Hibernia O-35 (7)  
 Mara M-54 (2)  
 Mizzen O-16 (2)  
 North Dana I-43 (1)  
 North Ben Nevis P-93 (4)  
 South Merasheen K-55 (1)  
 Springdale M-29 (1)  
 Terra Nova E-79 (3)  
 Terra Nova K-08 (1)  
 Thorvald P-24 (1)  
 West Ben Nevis B-75 (2)  
 White Rose J-49 (4)  
 White Rose N-22 (2)



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## Canadian Oils - Jeanne d'Arc Basin

### Summary of Oils in Jeanne d'Arc Basin

**South Tempest:** oil in Kimmeridgian sandstone, API 38-44°

**White Rose Field:** oils API ranging 32 to 49° (also in Paleocene API 62-70°)

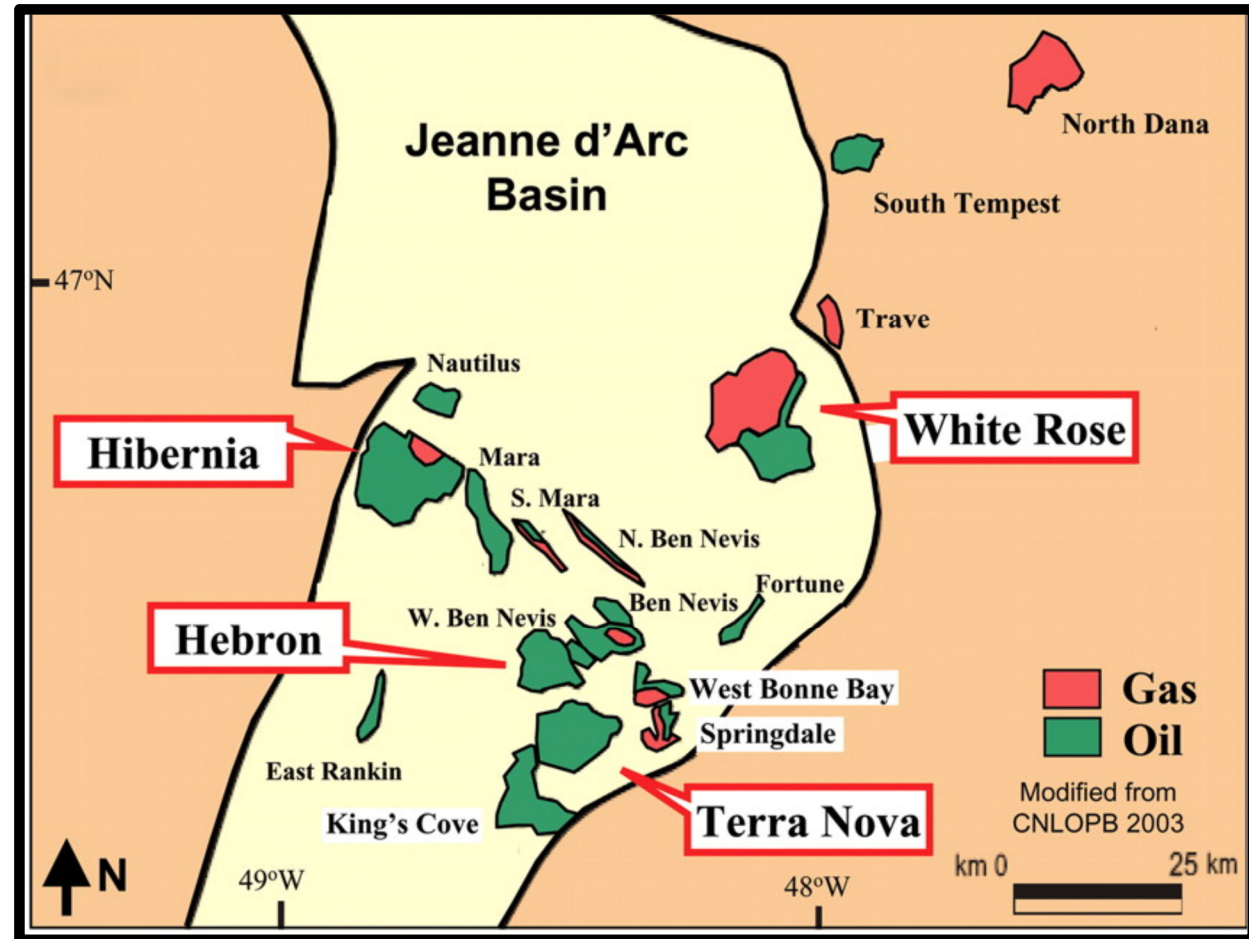
**Hibernia Field:** oils API 30-41°

**Ben Nevis Field:** oils in multiple horizons (API 27-37° through to 48-52°)

**Mara (well C-54):** oils in Cenomanian (API 24°) and Early Eocene (22°)

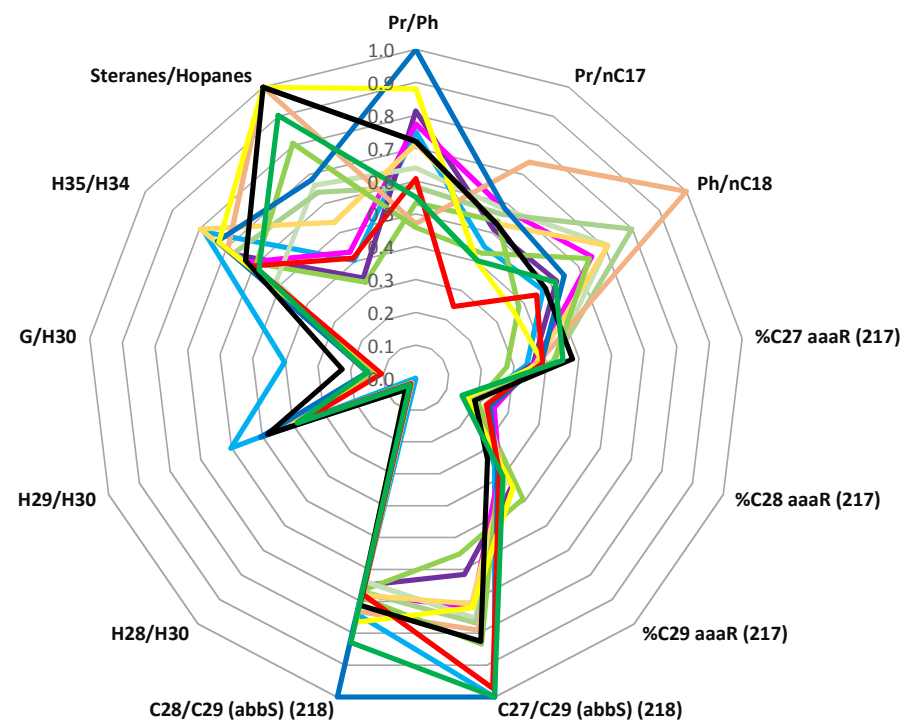
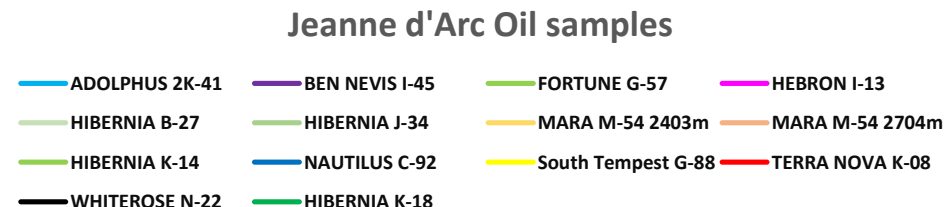
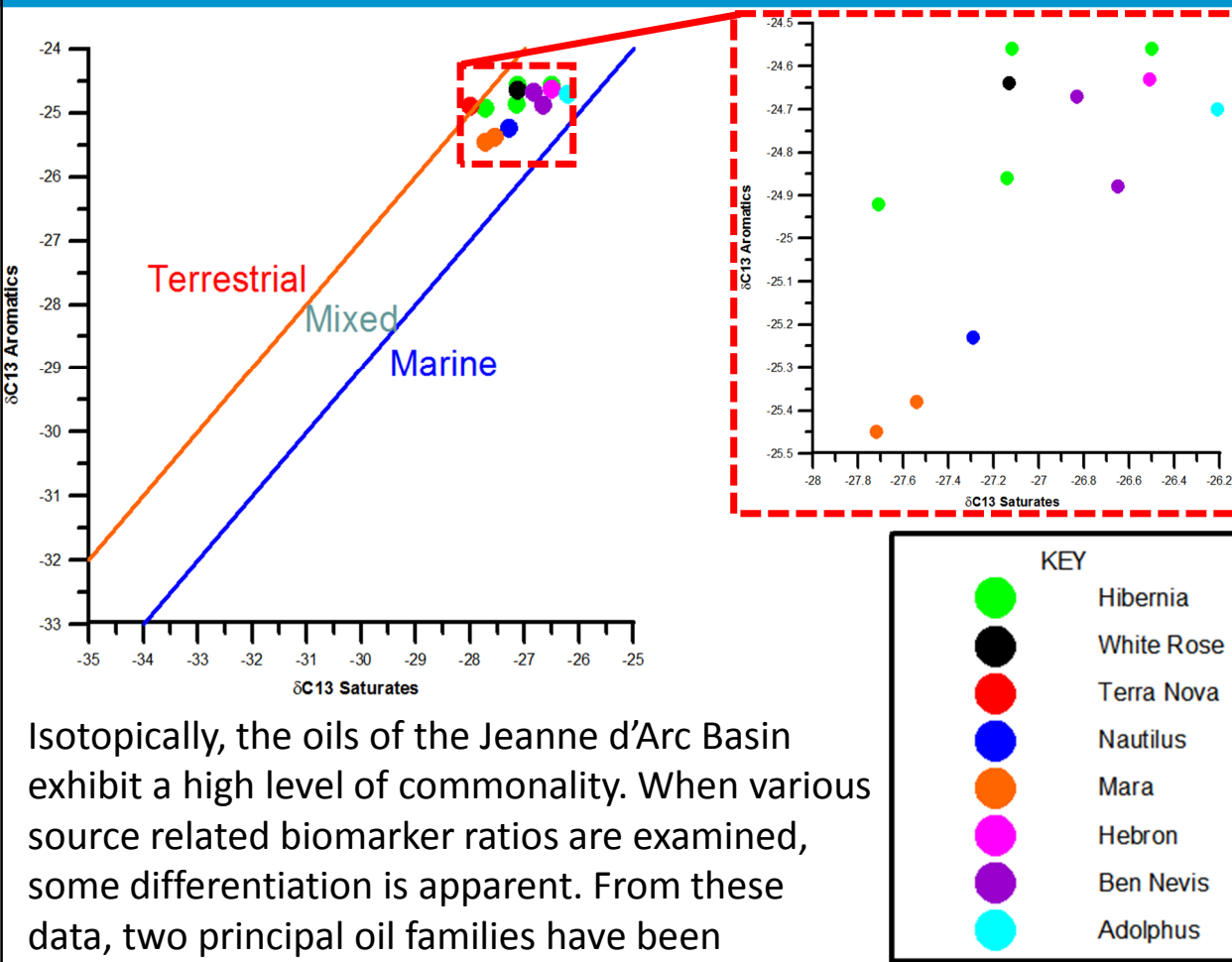
**Terra Nova Field:** oils in Middle and Late Jurassic (API range 33-41°)

**Hebron Field:** is estimated to capable of producing more than 700 million barrels of recoverable resources.





# Canadian Oils - Jeanne d'Arc Basin



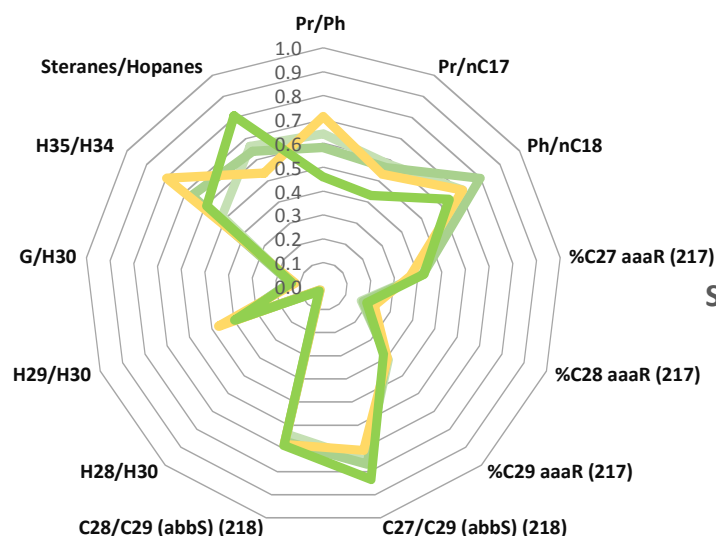
Isotopically, the oils of the Jeanne d'Arc Basin exhibit a high level of commonality. When various source related biomarker ratios are examined, some differentiation is apparent. From these data, two principal oil families have been recognised, one of which is further subdivided



# Canadian Oils - Jeanne d'Arc Basin

## Hibernia and Mara M-54 Oils

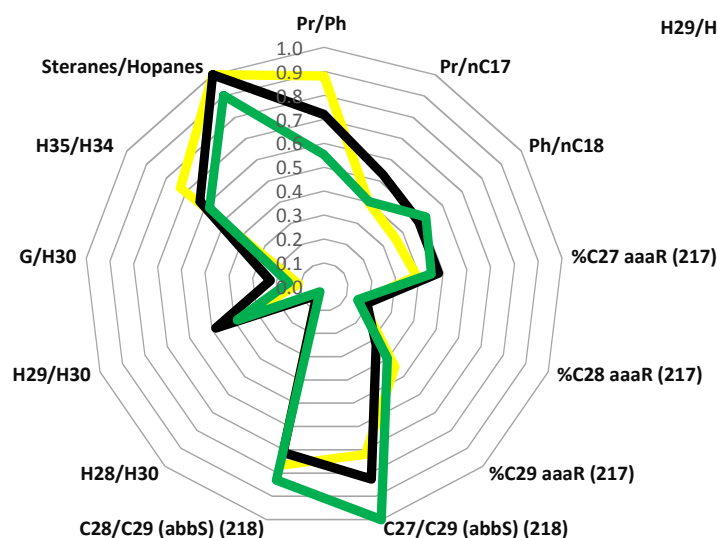
HIBERNIA B-27 HIBERNIA J-34 MARA M-54 2403m HIBERNIA K-14



**Family Jeanne d'Arc A2:** This grouping includes oils from localities to the east of Family A1 represented here by the South Tempest and White Rose oils. The Hibernia K-18 oil also appear similar.

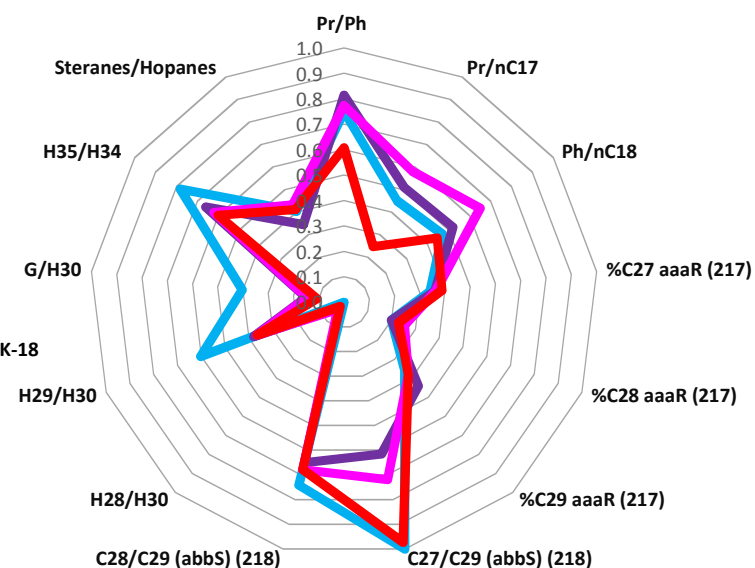
## South Tempest, White Rose and Hibernia K-18 Oils

SOUTH TEMPEST G-88 WHITE ROSE N-22 HIBERNIA K-18



## Adolphus, Ben Nevis, Hebron and Terra Nova Oils

ADOLPHUS 2K-41 BEN NEVIS I-45 HEBRON I-13 TERRA NOVA K-08



**Family Jeanne d'Arc A3:** This group of oils includes Terra Nova, Ben Nevis and Hebron oils. The Adolphus oil may be a further subdivision of this grouping or possibly a separate family.

**Family Jeanne d'Arc A1:** Correlation using GC-MS biomarker ratios between numerous oils represented here by examples of the Hibernia and Mara oils

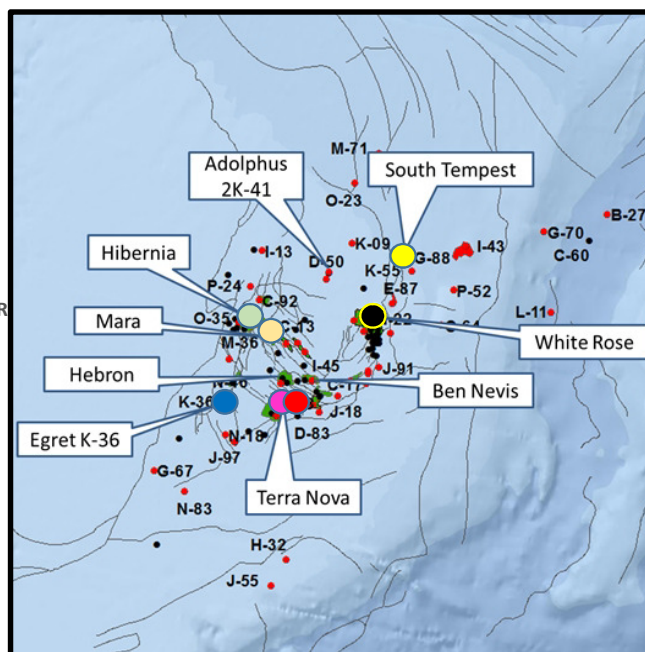
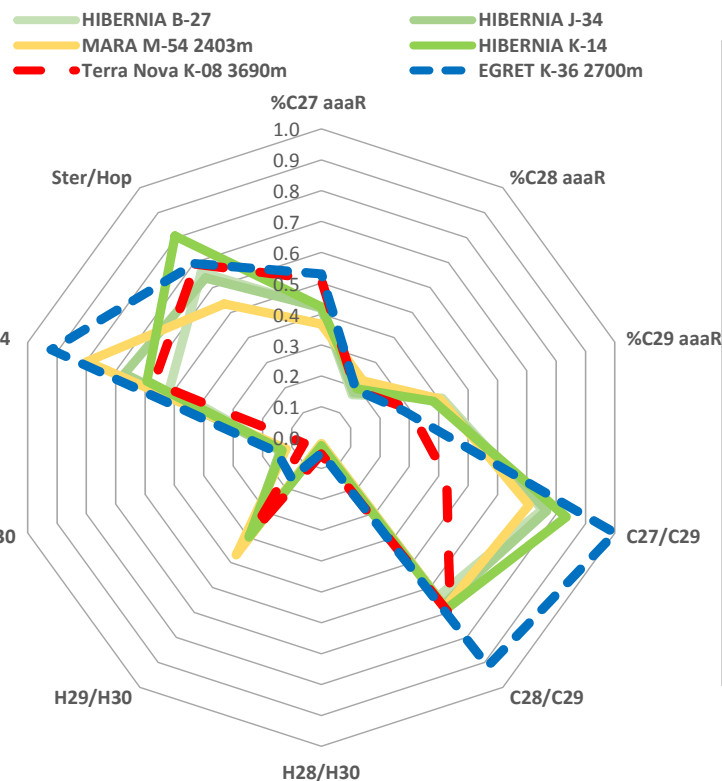


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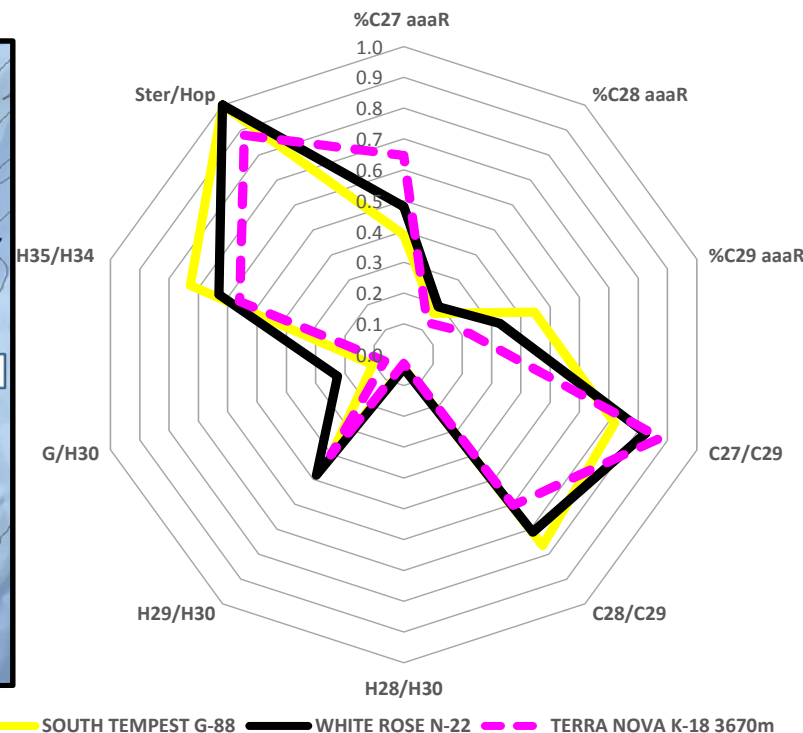


# Canadian Oils - Jeanne d'Arc Basin

## Oil - Source correlation Family A1



## Oil - Source correlation Family A2



In addition to carbon isotope determinations, correlation between oils and source facies can be established using GC-MS biomarker ratios. Shown above are potential oil-source correlations for the **Jeanne d'Arc A1 and A2** families. The source facies are all representative of rich Kimmeridgian aged source rocks.



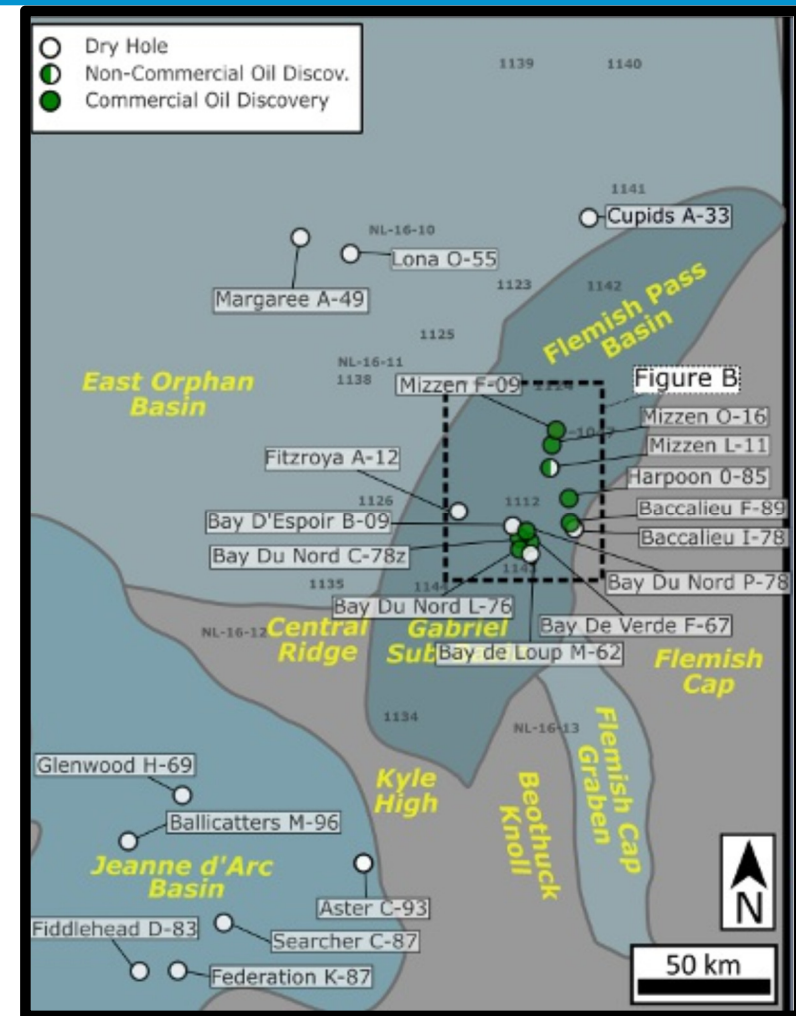


## Canadian Oils – Flemish Pass Basin

### Summary of Oil in the Flemish /Orphan basins

Oils discoveries in Late Jurassic and Early Cretaceous deltaic sandstones

- Mizzen O-16
- Mizzen L-11
- Mizzen F-09
- Baccalieu F-89
- Bay du Nord C-78
- Harpoon O-85



After Caulfield, 2016

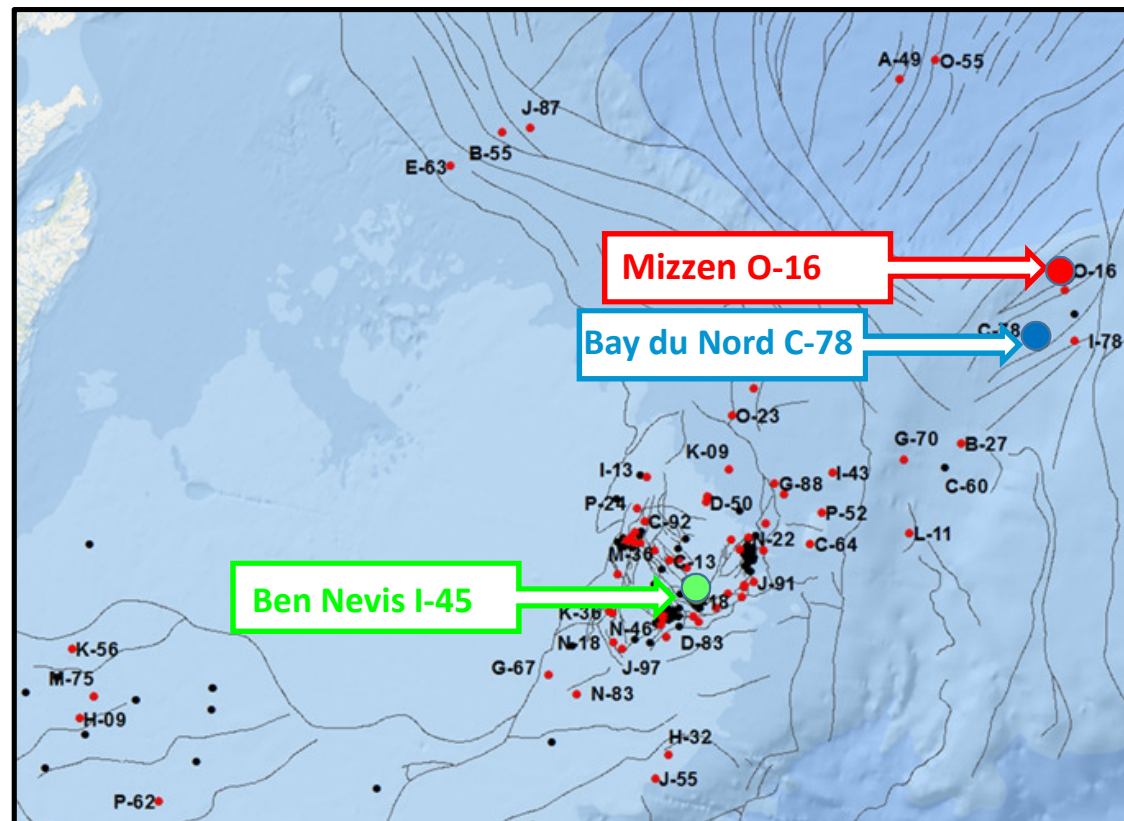
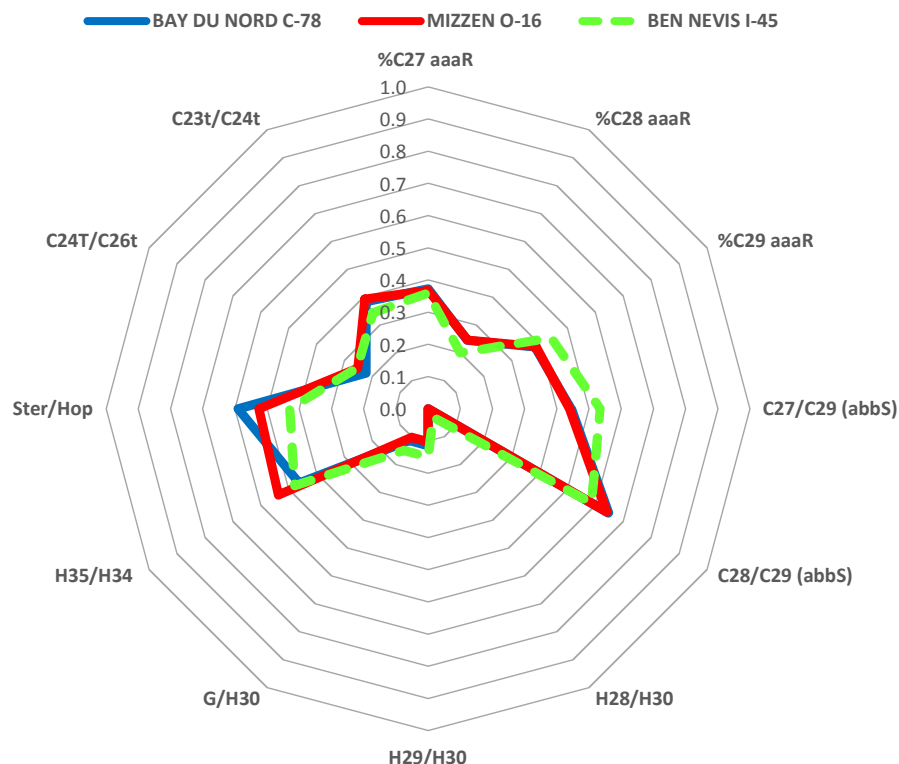


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# Canadian Oils – Flemish Pass Basin

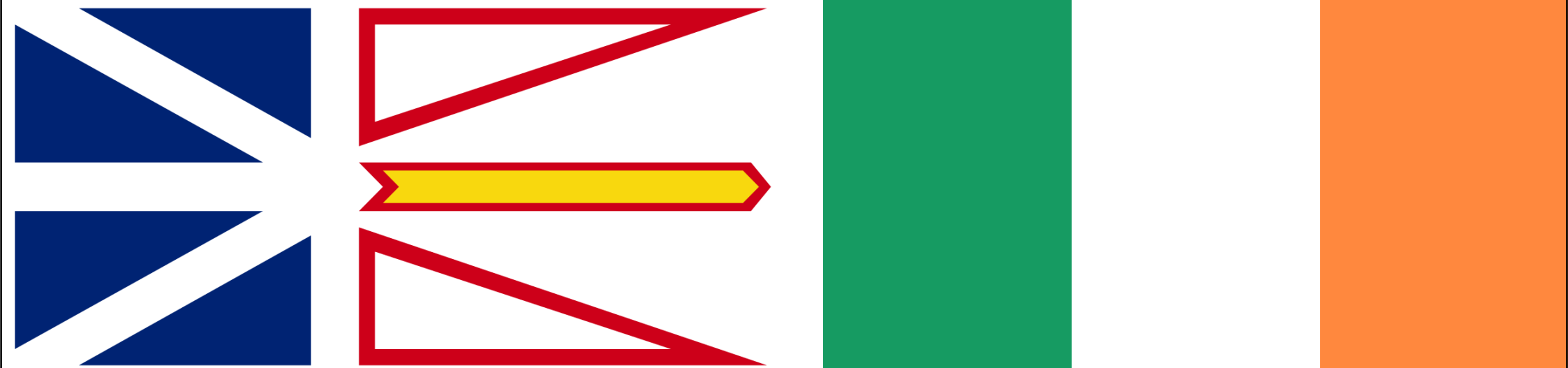
## Flemish Pass Oils vs Ben Nevis I-45



The Flemish Pass oils of the Bay du Nord C-78 and Mizzen O-16 wells have very similar distributions of a number of GC-MS ratios. Gas chromatography ratios have been omitted as the Mizzen O-16 oil is slightly biodegraded, this affecting Pristane and Phytane ratios. Also shown is the relationship between these two oil and the Ben Nevis I-45 oil.

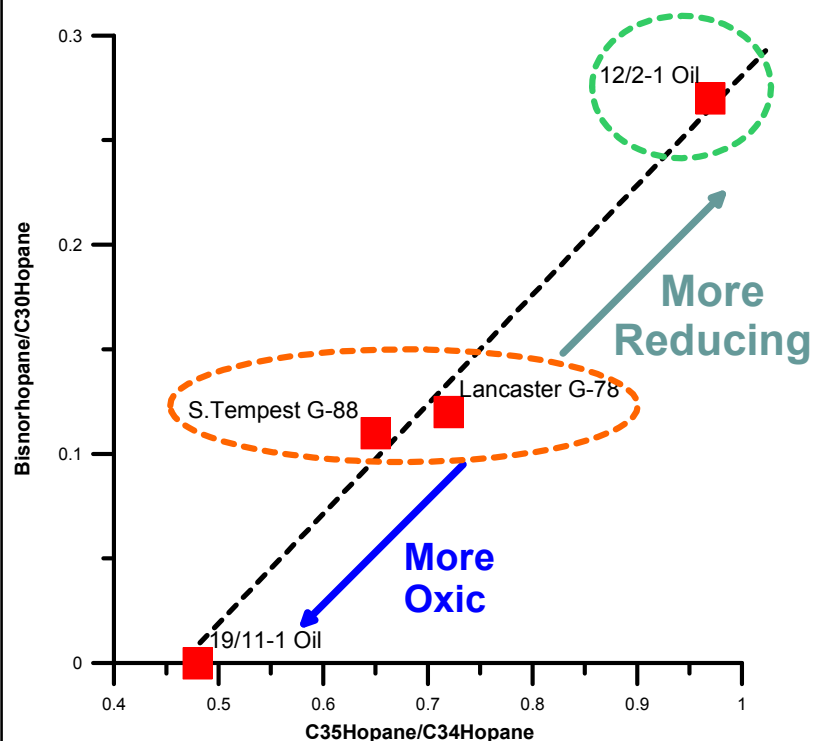


# Cross Atlantic Relationships

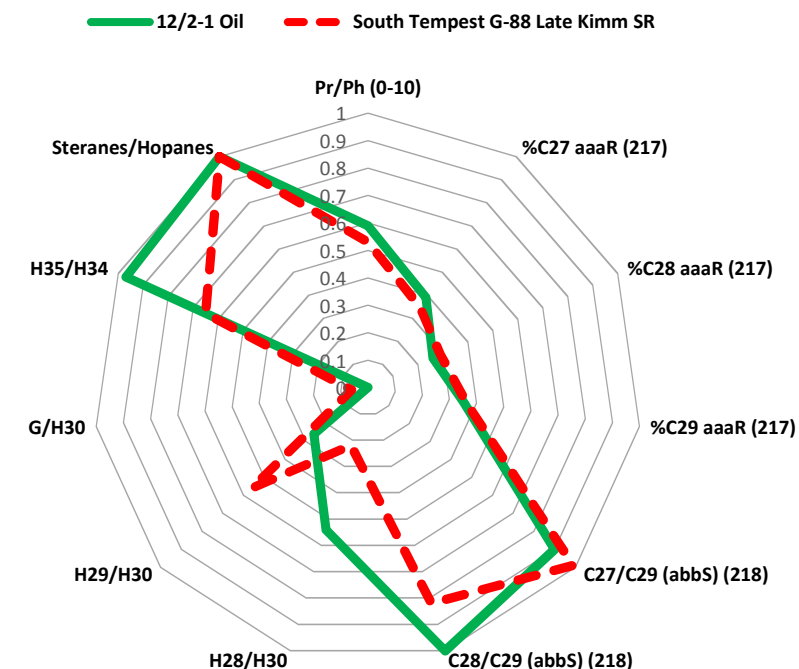




## Cross Atlantic relationships – Bisanorhopane extent



### 12/2-1 Oil vs S. Tempest Kimmeridgian Source Rock

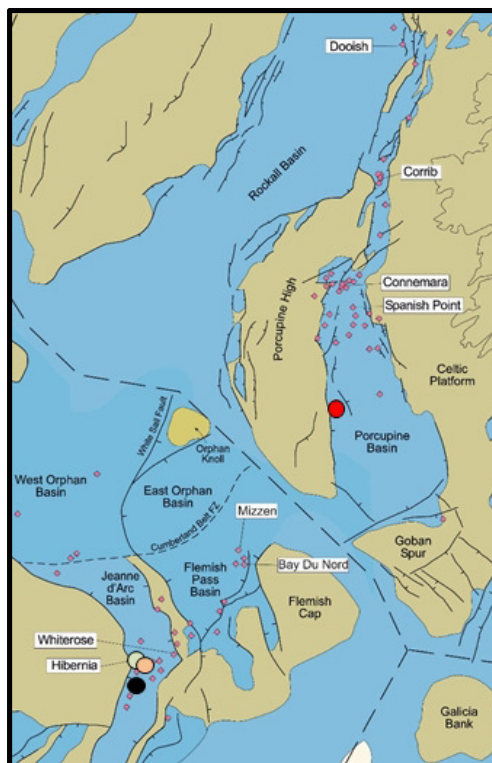
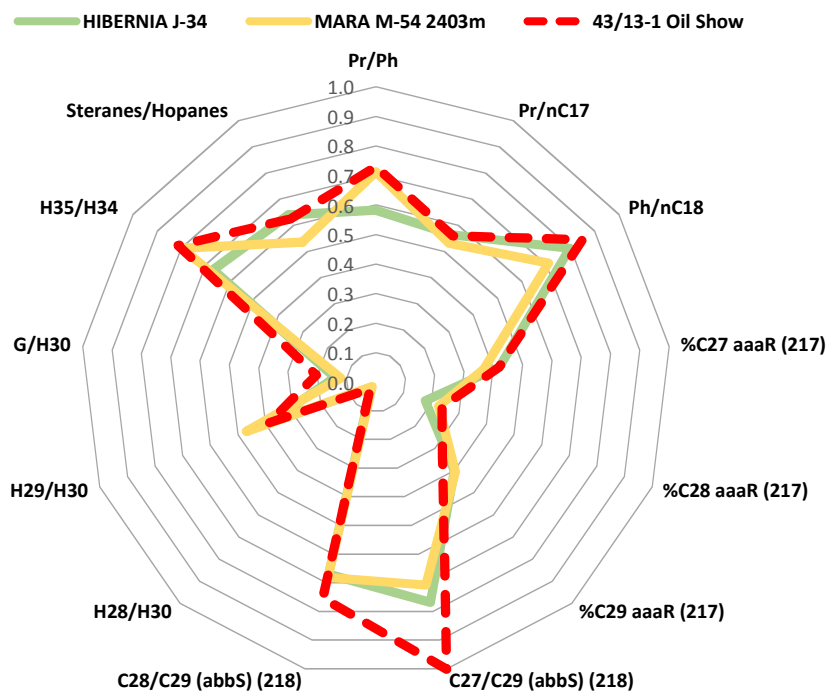


As well as in the Rockall Basin there are occasional indications of Bisanorhopane enrichment in the north-eastern portion of the Jeanne d'Arc basin within the South Tempest G-88 and Lancaster G-70 wells. Both have instances of Late Jurassic source facies that have relatively enhanced Bisanorhopane content and indeed, the GC-MS biomarker ratios of the South Tempest G-88 example are consistent with the Dooish oil.

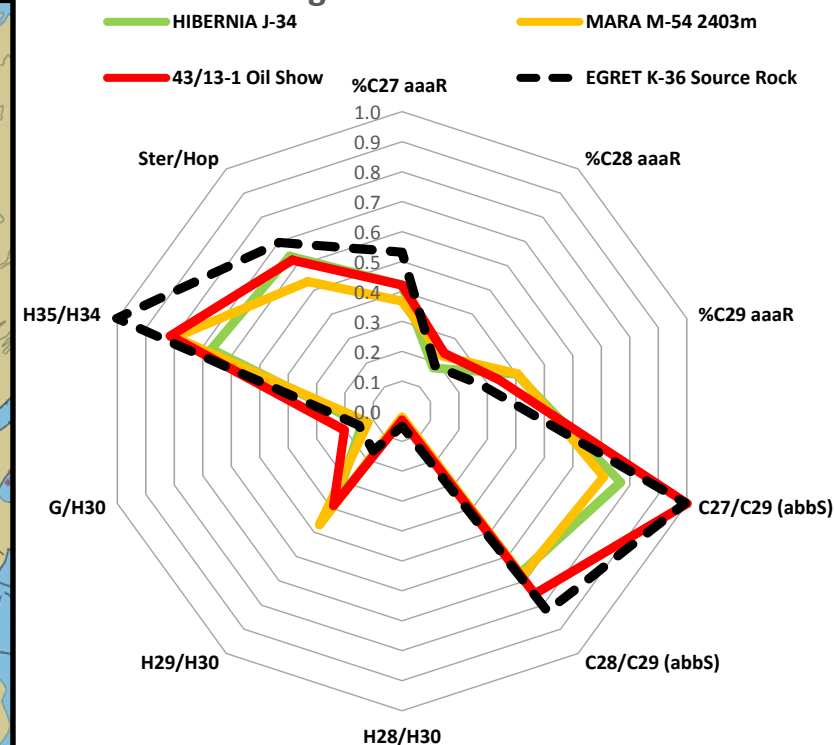


# Cross Atlantic relationships – Porcupine/Jeanne d’Arc oils

Jeanne d’Arc Family A1 Oil samples vs 43/13-1 Oil show



Jeanne d’Arc Family A1 Oil samples and 43/13-1 Oil show vs Egret K-56 Source Rock



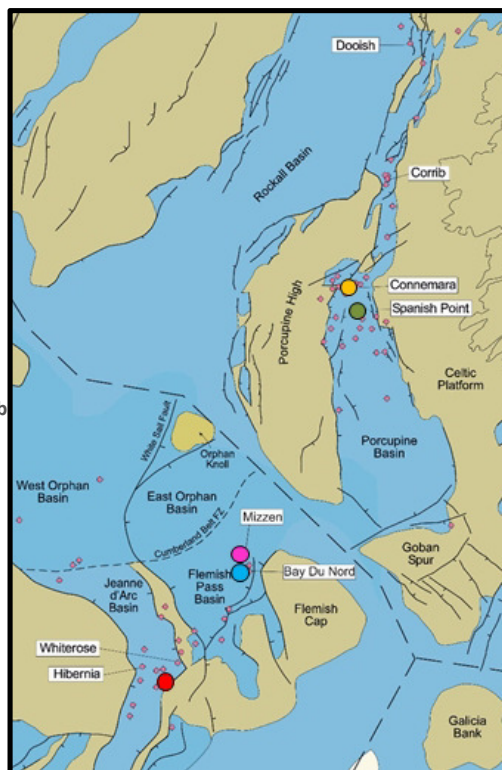
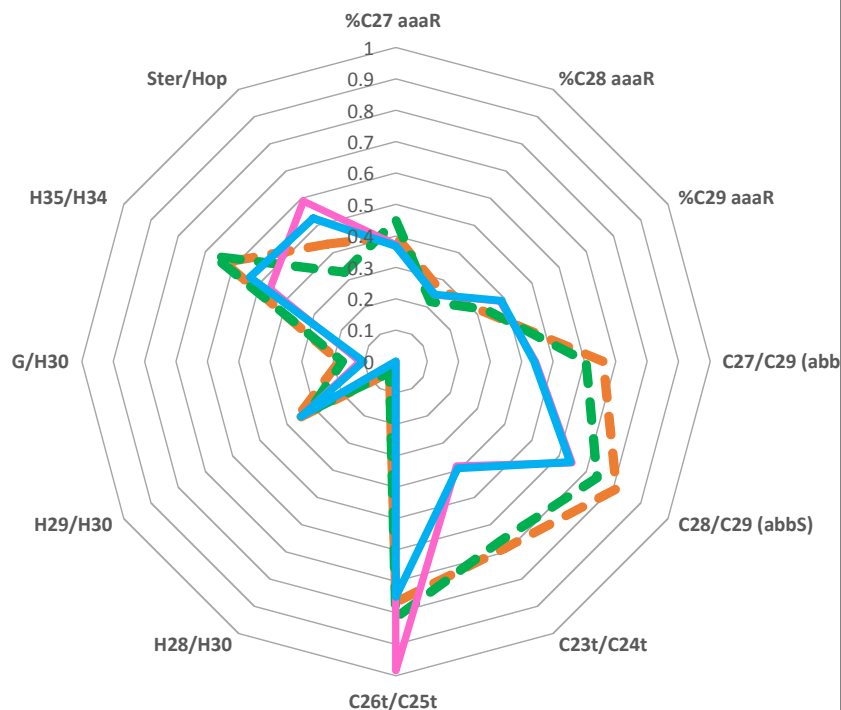
These two diagrams help illustrate some of the common relationships between the oils of the Jeanne d’Arc Basin (specifically oils from Family A1) and the oil show from the 43/13-1 well in the southern portion of the Porcupine Basin. Additionally, the relationship of these hydrocarbon samples to the Kimmeridgian source of the Egret K-36 well is also illustrated.



# Cross Atlantic relationships – Porcupine/Jeanne d'Arc oils

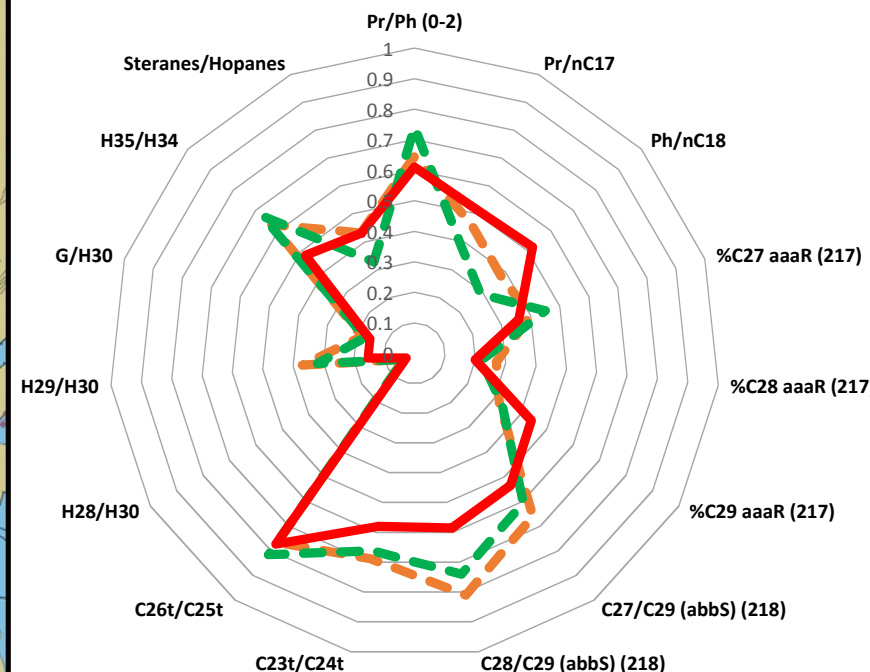
## Porcupine Family C Oils vs Flemish Pass Oil

26/28-1 DST#1 35/8-2 BAY DU NORD C-78 MIZZEN O-16



## Porcupine Family C vs Ben Nevis I-45 Oil (Jeanne d'Arc A3)

26/28-1 DST#1 35/8-2 BEN NEVIS I-45



The oils of the Connemara Field (specifically 26/28-1) and Spanish Point (35/8-2) make up of Porcupine Family C and show close relations as illustrated by CG-MS biomarker and gas chromatography ratios with both oil of the Flemish Pass (Bay du Nord C-78 and Mizzen O-16 and particularly with the Jeanne d'Arc Family A3 (represented by Ben Nevis I-45).



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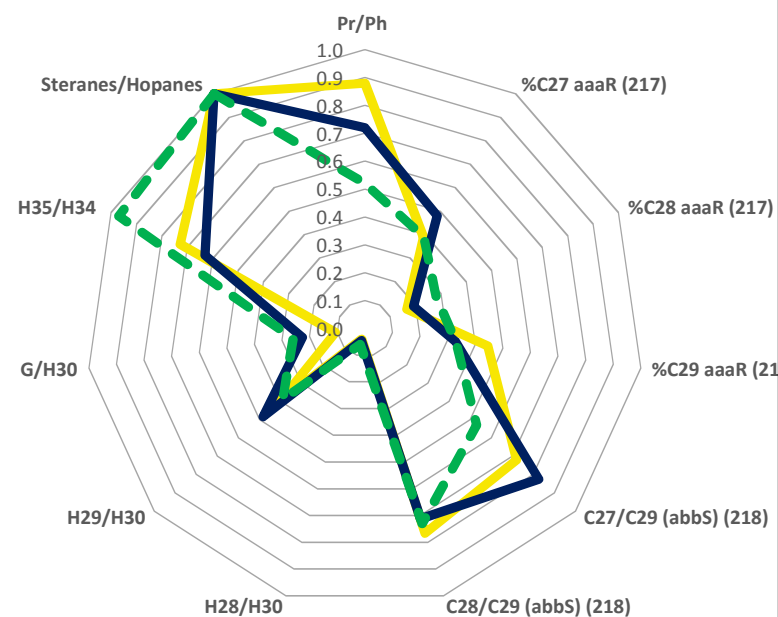




# Cross Atlantic relationships – Porcupine/Jeanne d'Arc oils

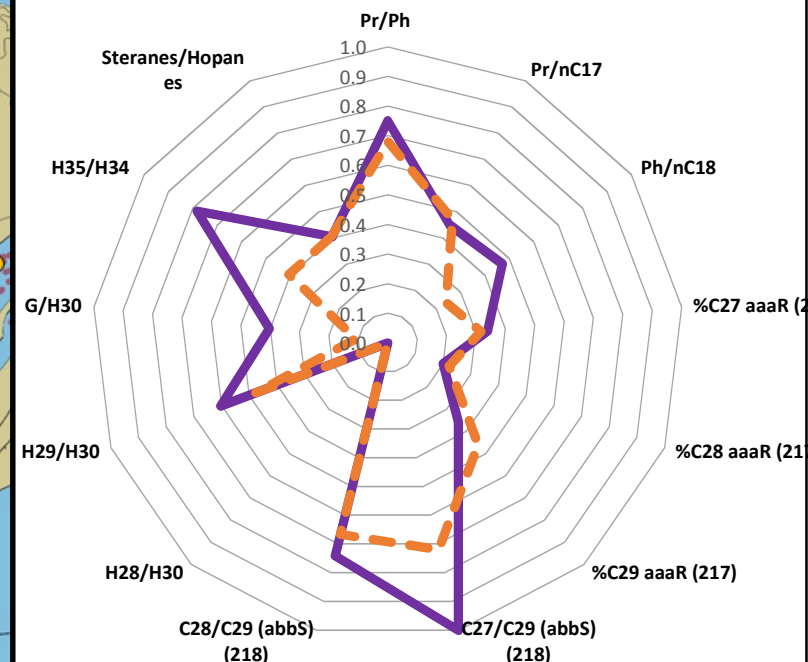
## Family Porcupine B vs Jeanne d'Arc Family A2

SOUTH TEMPEST G-88 WHITEROSE N-22 35/8-1 (BURREN)



## Adolphus 2K-41 vs 49/13-2 Oils

ADOLPHUS 2K-41 49/13-2 Oil



The oils of Porcupine Family B (35/8-1) are compared to those of Jeanne d'Arc Family A2. Also noted are the oils of 49/13-2 and Adolphus 2K-41. These two oils are considered to have input from both marine and lacustrine sources, containing both significant amounts of C30 steranes (marine markers) and Tetracyclic Polyprenoids (TPP – lacustrine marker).



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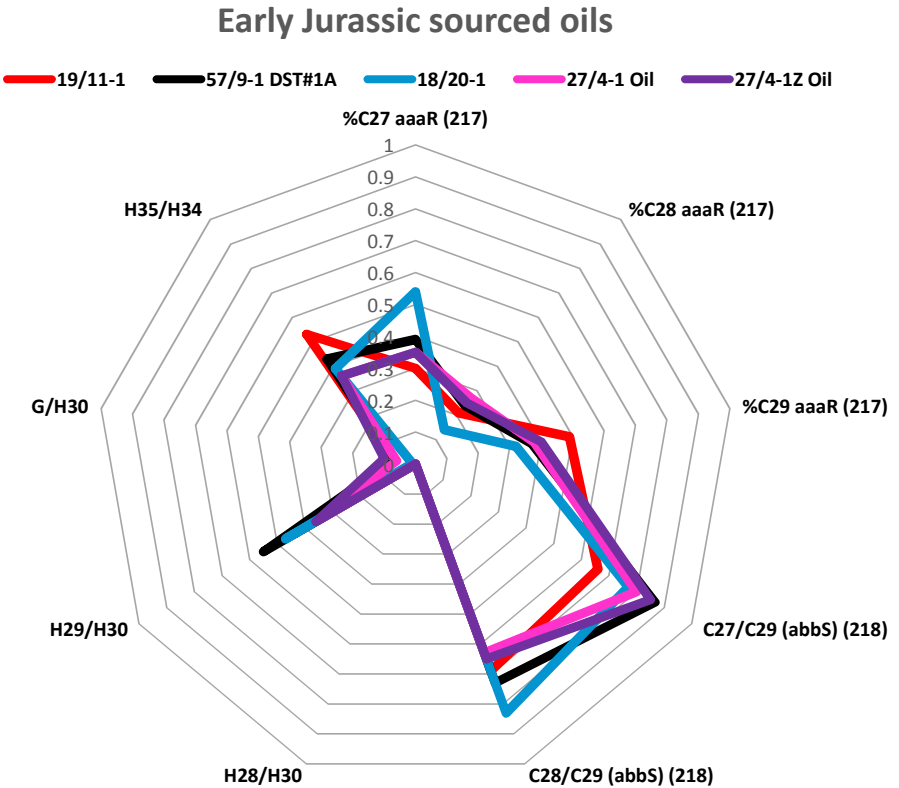
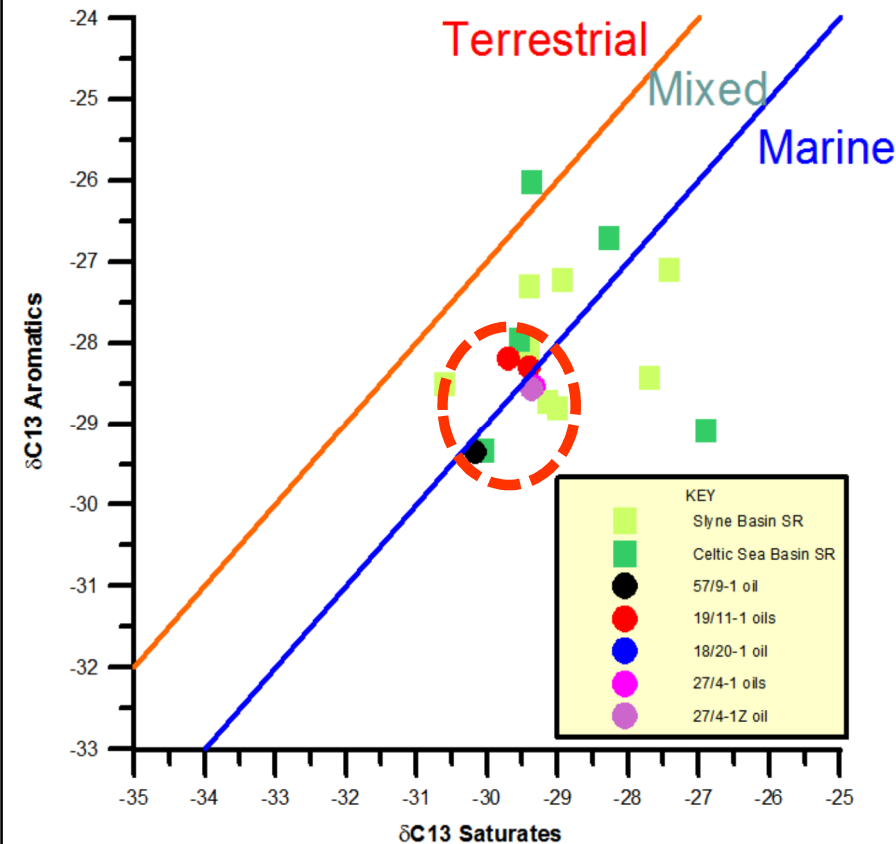
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## Cross basin relationships – Early Jurassic Oils



Although yet to be proved as a significant source in the basins of Newfoundland/Labrador, the Early Jurassic is considered to be the primary source for a number of oil discoveries in the Slyne and Celtic Sea basins. These oils are isotopically similar and also have some closely related source-associated biomarker ratios. Similar oils are anticipated in the English Channel and Paris Basin.



## Conclusions



**“Boreal, Bismorhopane”  
influenced facies**



**Possible extension**



**Jeanne d’Arc – Porcupine  
facies complex**



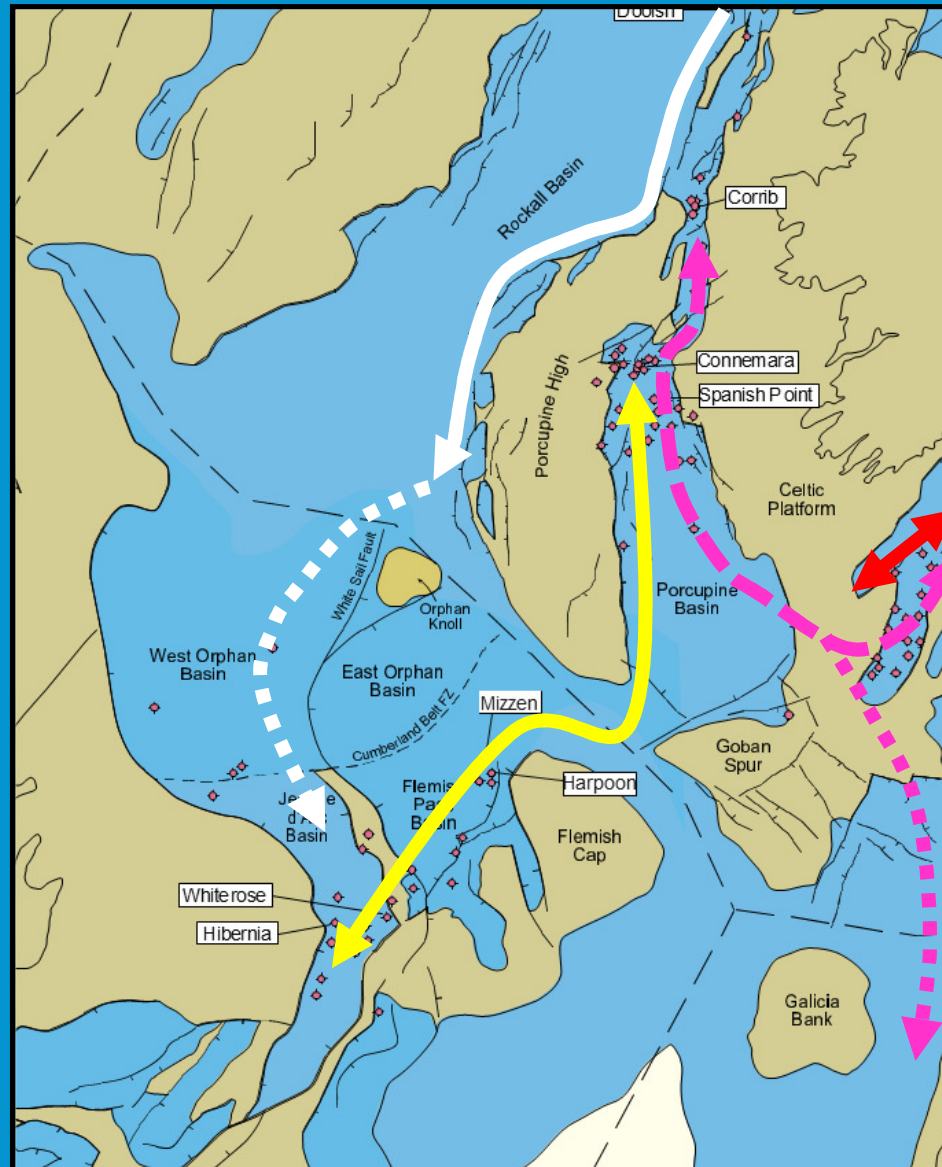
**Early Jurassic Marine  
facies**



**Possible extension**



**Late Jurassic Lacustrine  
facies**



**Summary of the possible facies influence pertaining to oils within the study area.**

Rockall Basin ( and sub-basins) considered to have a “boreal” influence that possibly extends into the northern Jeanne d’Arc.

Jeanne d’Arc – Porcupine have similar but complex characteristics resulting from variation in essentially marine facies.

Early Jurassic sources result in oils in both the Slyne and Celtic Sea basins.

Late Jurassic lacustrine oils most prolific in the Celtic Sea Basin.



## Conclusions

- All of the basins considered in this presentation contain wells with oil discoveries.
- These basins contain a variety, both in terms of age and facies, of source rocks.
- Whilst Late Jurassic sediments appear to hold the primary source rocks for the oils discovered in these basins to date, locally other source facies may be important and should not be ignored. Mixing of oils from differing sources adds further complexity.
- Cross-basin relationships are evident although these are often more subtle than those noted in other conjugate margin settings (e.g. South Atlantic – Brazil/Gabon)
- The establishment of a single database has allowed some of these cross-basin relationships to be recognised. These still need further refinement.
- In addition to further detailed work, on produced oils and oil show samples in particular, the adoption of a consistent method of recording and reporting such geochemical data would benefit further research in oil to oil relationships across these basins.
- Integrating such geochemical data with a broad understanding the petroleum geology of this transform margin is key to wider exploration success.
- Despite the lack of data in the under-explored parts of some basins the results of the study have positive implications for petroleum prospectivity in offshore basins on both side of the conjugate margin.



## Acknowledgements

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