# East Shetland Platform Petroleum Geochemistry and Prospectivity*

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## Abstract

An investigative study into the East Shetland Platform, part of the mature UK Continental Shelf petroleum province with a focus on geochemistry. The platform bounds the Viking Graben to the west. It was a high throughout most of the Mesozoic, having been affected by Variscan deformation. A thin veneer of recent Tertiary sediment cover is found. The platform is significant for clastic sediment routed through incised valleys and channels on it, into the adjoining basin. Unlike the basin, there remains considerable scope for further exploration on marginal areas such as the platform. The dataset consisted primarily of geochemical reports of highly biodegraded oils, dating back to 1977 of wells drilled in the area. The aim of the study was to determine a link between oils found on the platform and basin based Kimmeridge Clay Formation source rocks. This was done through evaluation of the biomarker data embedded in gas chromatogram and mass spectroscopy data where available in the dataset. Isoprenoids such as pristane and phytane, and terpanes such as gammacerane provided the best indicators of both source maturity and environment. Existing stratigraphic templates were adapted and applied to the raw data to further constrain outputs. The results confirmed the decrease in oil maturity further inbound of the platform, while demonstrating the ability of distal Kimmeridge shales to charge over long distances onto reservoir units on the platform. High well coverage in the area is conducive to 3D petroleum systems modelling in future investigations. Application of statistical tests on biomarker variability posited a possible link between contamination and the observed standard deviation in the measurements. This raises a possible avenue of further research into the effects of drilling on the natural biomarker signature in mature petroleum provinces.

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# East Shetland Platform Petroleum Geochemistry and Prospectivity


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# Overview

- The report is an overview of the petroleum prospectivity of the East Shetland Platform of the UKCS.
- There is a particular emphasis on an examination of the geochemistry.
- Target area is part of mature petroleum province.

# Location

## UKCS license blocks and fields

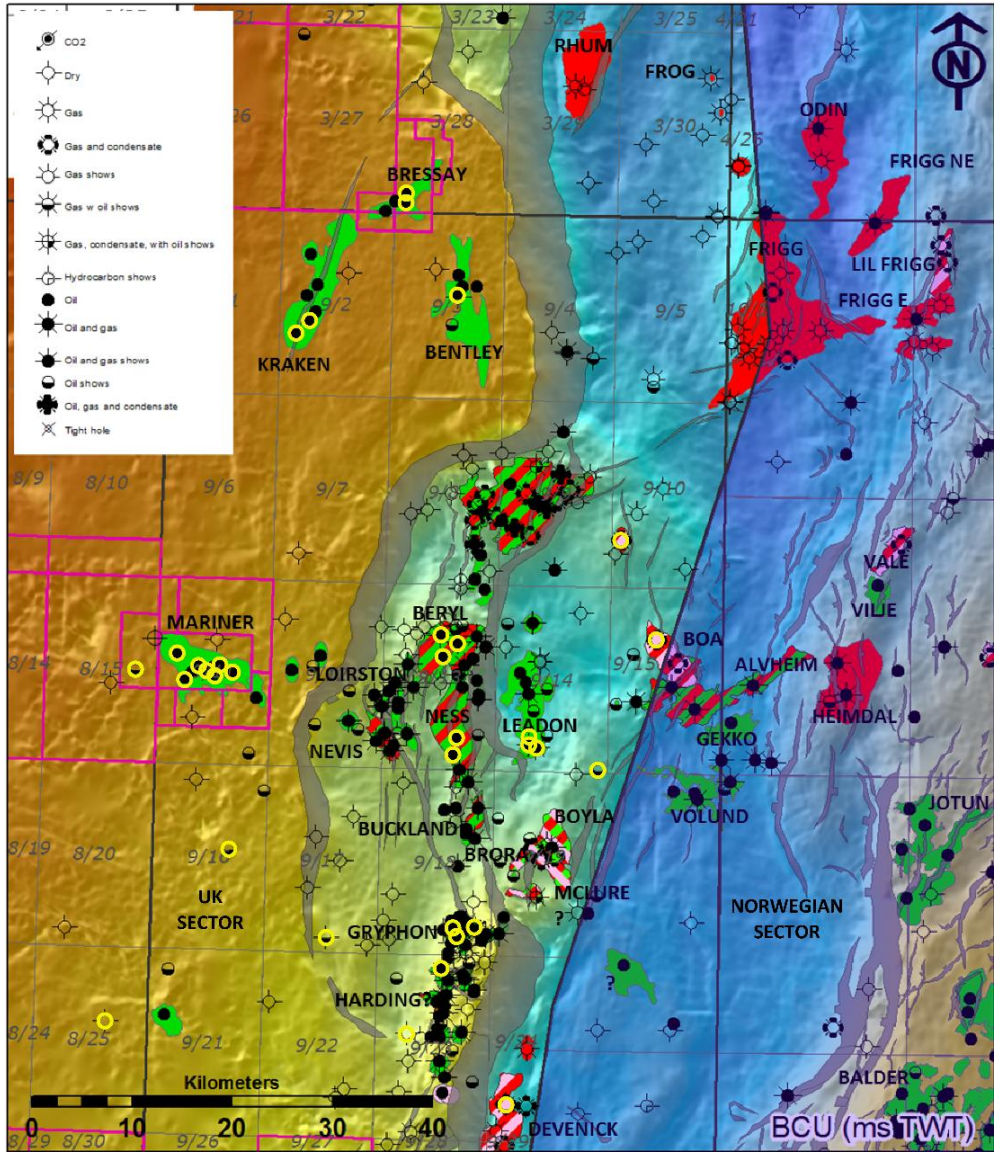



Fig 1: Study area with dataset wells marked with yellow circles.

## Regional structural elements

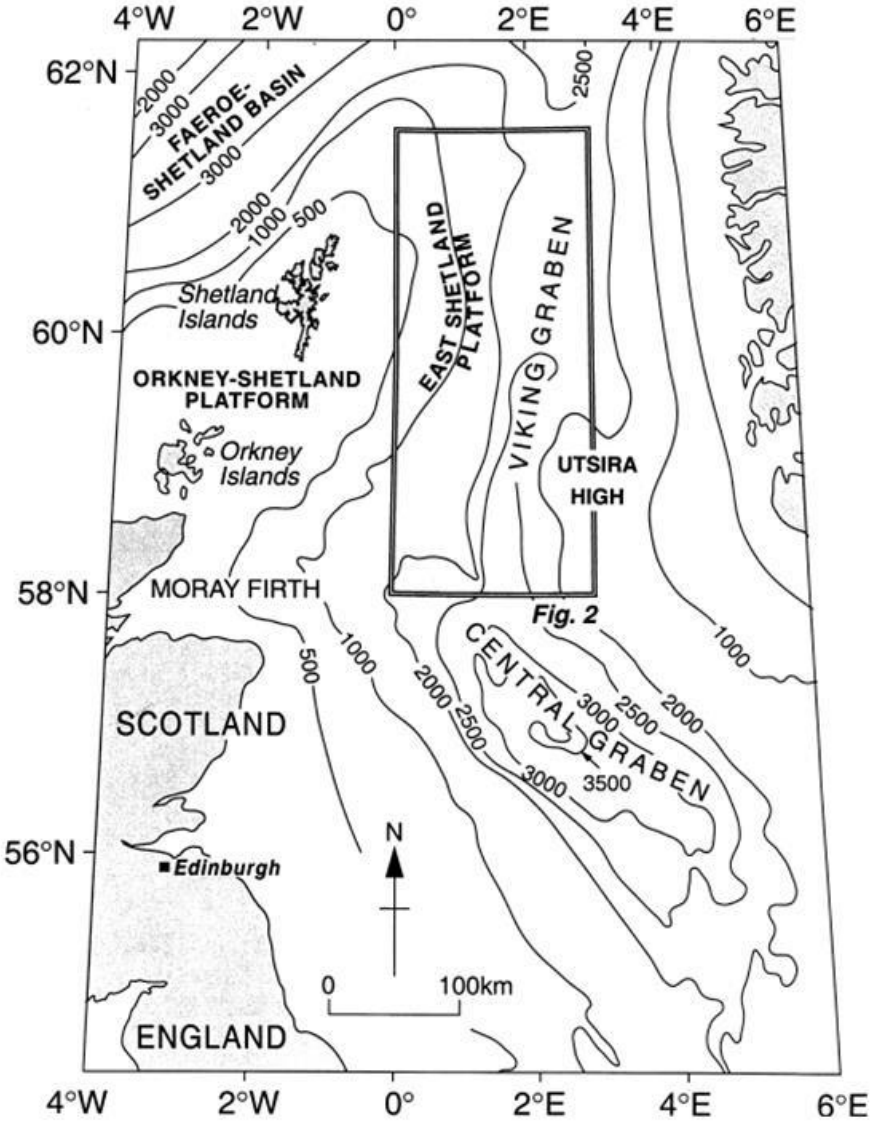
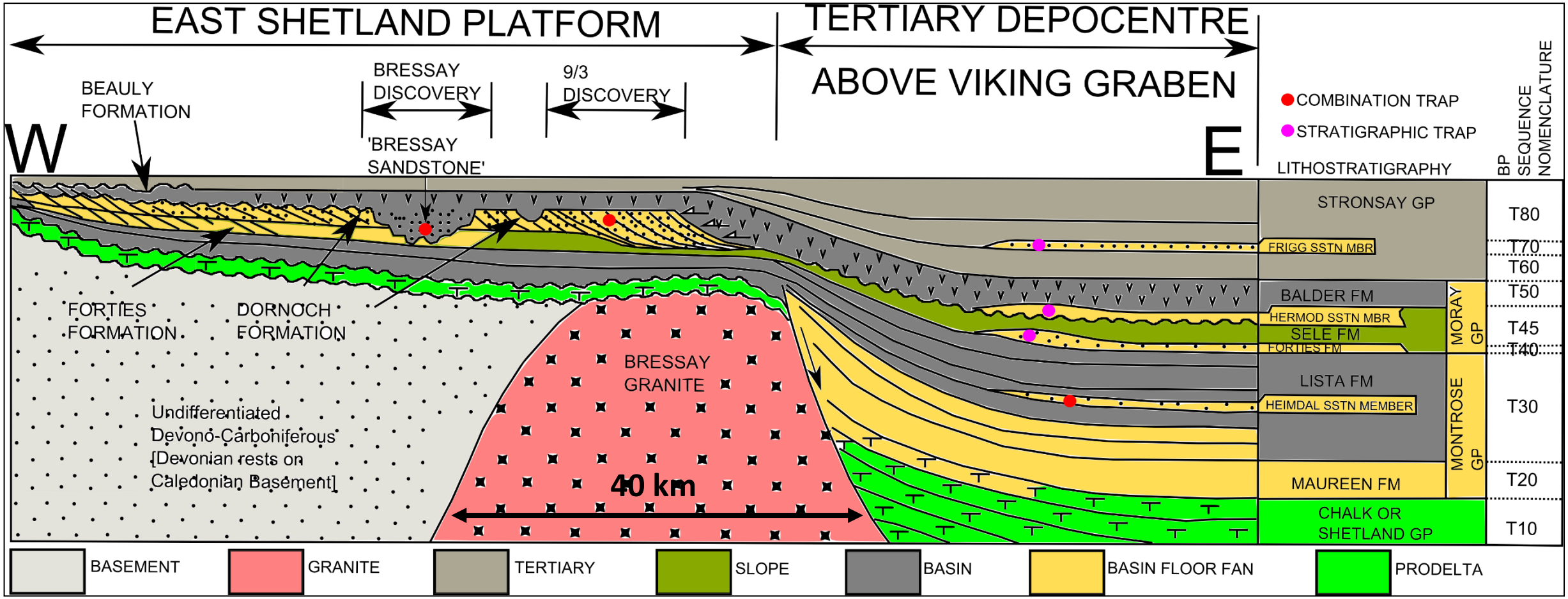



Fig 2: A bathymetric profile of the Northern North Sea illustrating the main structural elements. (Adapted from Underhill, 2001)

# Regional history




- Platform was a high during Mesozoic.
- Underwent Variscan age deformation.
- Cored by Caledonian granitic batholith.

Fig 3: Schematic platform cartoon focused around Bressay discovery with major lithostratigraphic and sequence stratigraphic units shown. (Adapted from Underhill, 2001)

# Stratigraphy

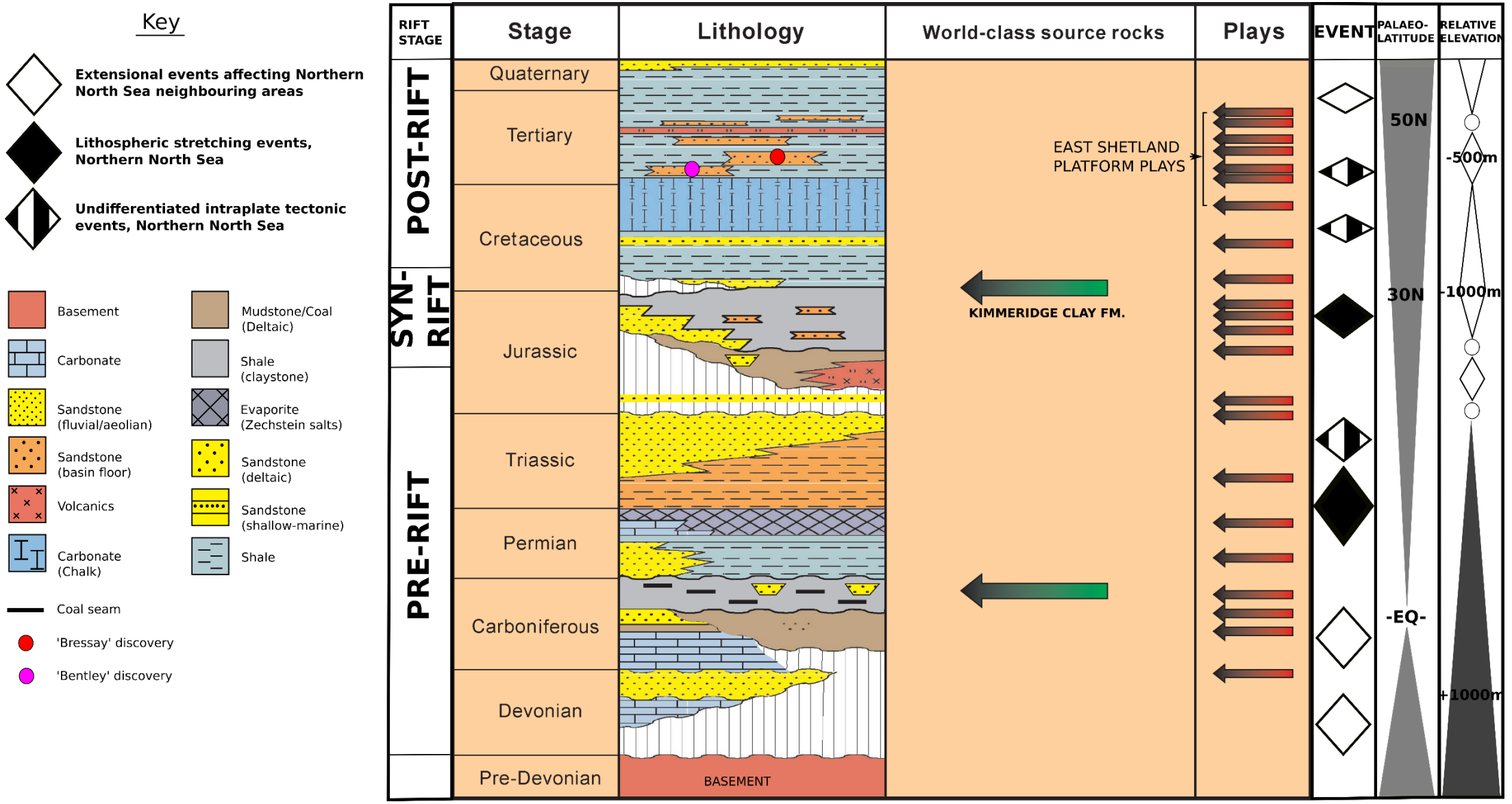



Fig 4: Known plays of the North Sea with corresponding lithostratigraphy, palaeolatitude, tectonostratigraphy, and bathymetry. (Adapted from Vining et al., 2005, Nottvedt et al., 1995 & Gray, 2010)

# Exploration history

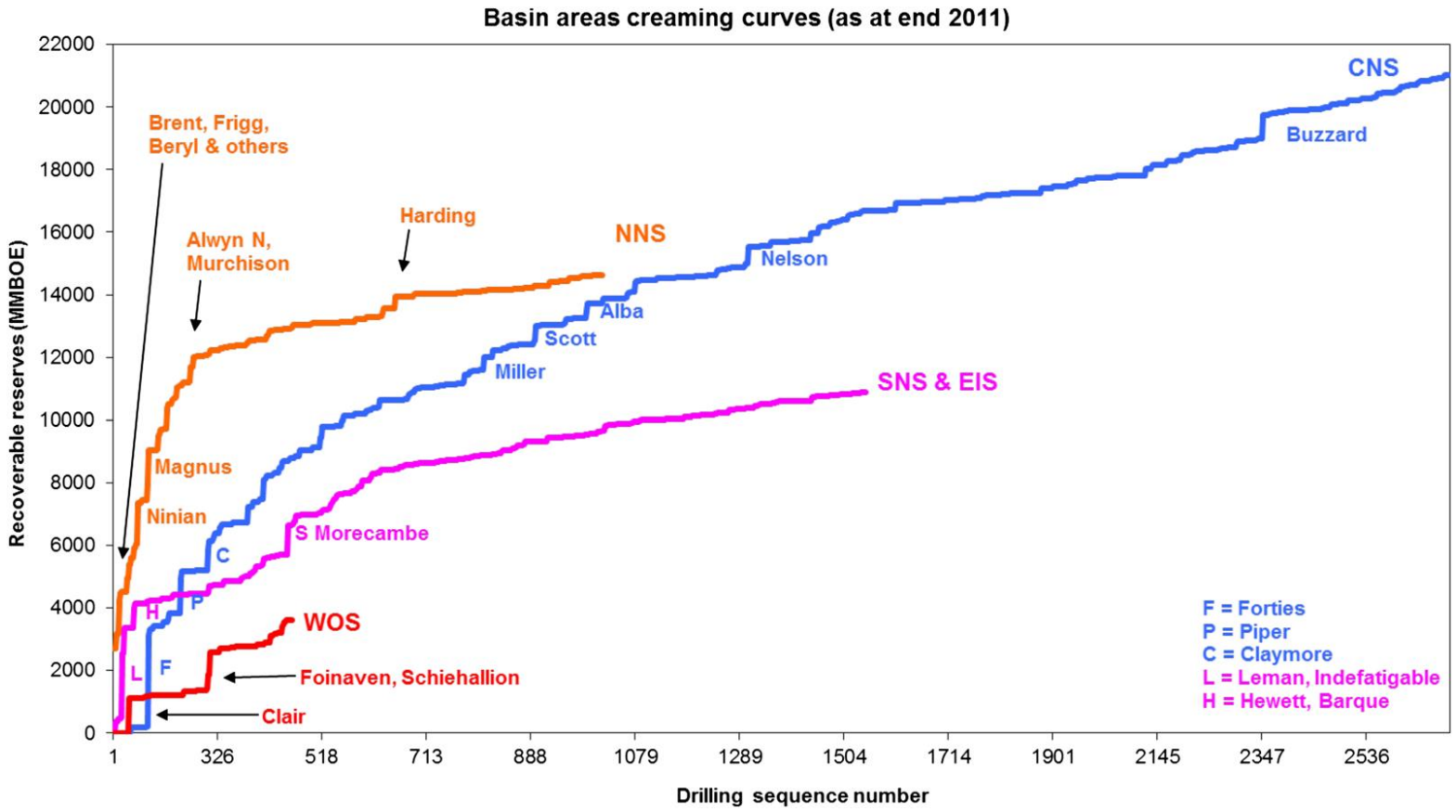



Fig 5: UKCS production history creaming curves against number of wells drilled. NNS in orange. (From Austin et al., 2014)

- 4350 wells estimated to have been drilled over 44 years.
- 344 producing fields.
- 160 significant discoveries, of which 13 under development currently.
- Largest recent find – Buzzard in 2000 (in place reserves 800-1100 MMbl).

# Database

| SUMMARY OF DATA | |
|---|---|
| **Blocks** | 16 (example – 3/28-1, 9/14B-1, etc.) |
| **Fields** | 9 (example – Bressay, Mariner, etc.) |
| **Wells** | 39 |
| **Geochemistry reports** | 42 (compiled by Fugro, Robertsons, et al. ) |
| **Composite logs** | 39 |
| **Specialised reports** | 52 (includes brine analyses for example) |
| **Oil analyses** | 17 |

# Investigation workflow

- Study aims to provide evidence in support of further exploration of previously peripheral areas of a mature petroleum province.
- Conduct a literature review to gain an understanding of the regional geological context.
- Index the dataset for Gas Chromatogram (GC) and Gas Chromatogram-Mass Spectrometry (GC-MS) data.
- Reconstruct GC and generate biomarker plots using data.
- Analyse for environmental and maturity information pertaining to oils.

# Key aspects

- Hopane found distributed in nearly all organic matter.
- Observe varying amounts of bisnorhopane in North Sea crudes.
- Bisnorhopane levels decrease with increasing maturity.
- Isoprenoids pristane and phytane are key biomarkers.
- m/z 191 is the key fragmentogram used for the report.

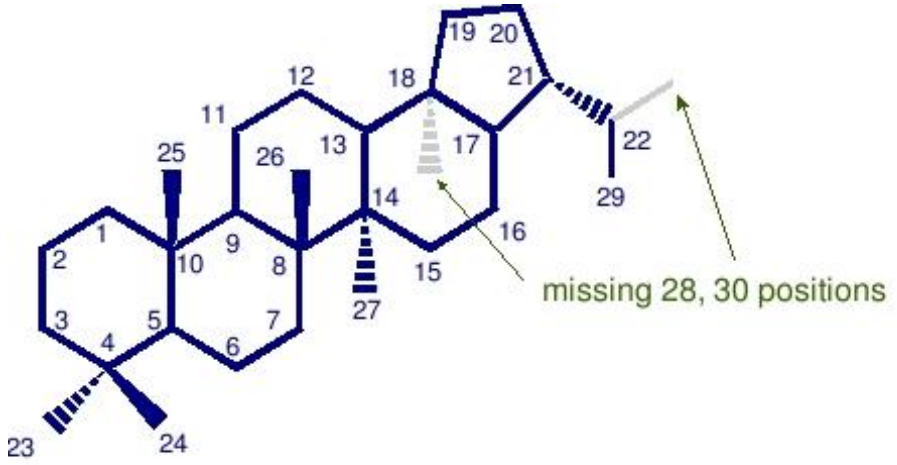



Fig 6: Bisnorhopane molecular structure. (From summons.mit.edu)

# Gas Chromatograms (GC)

## Standard GC output with baseline drift

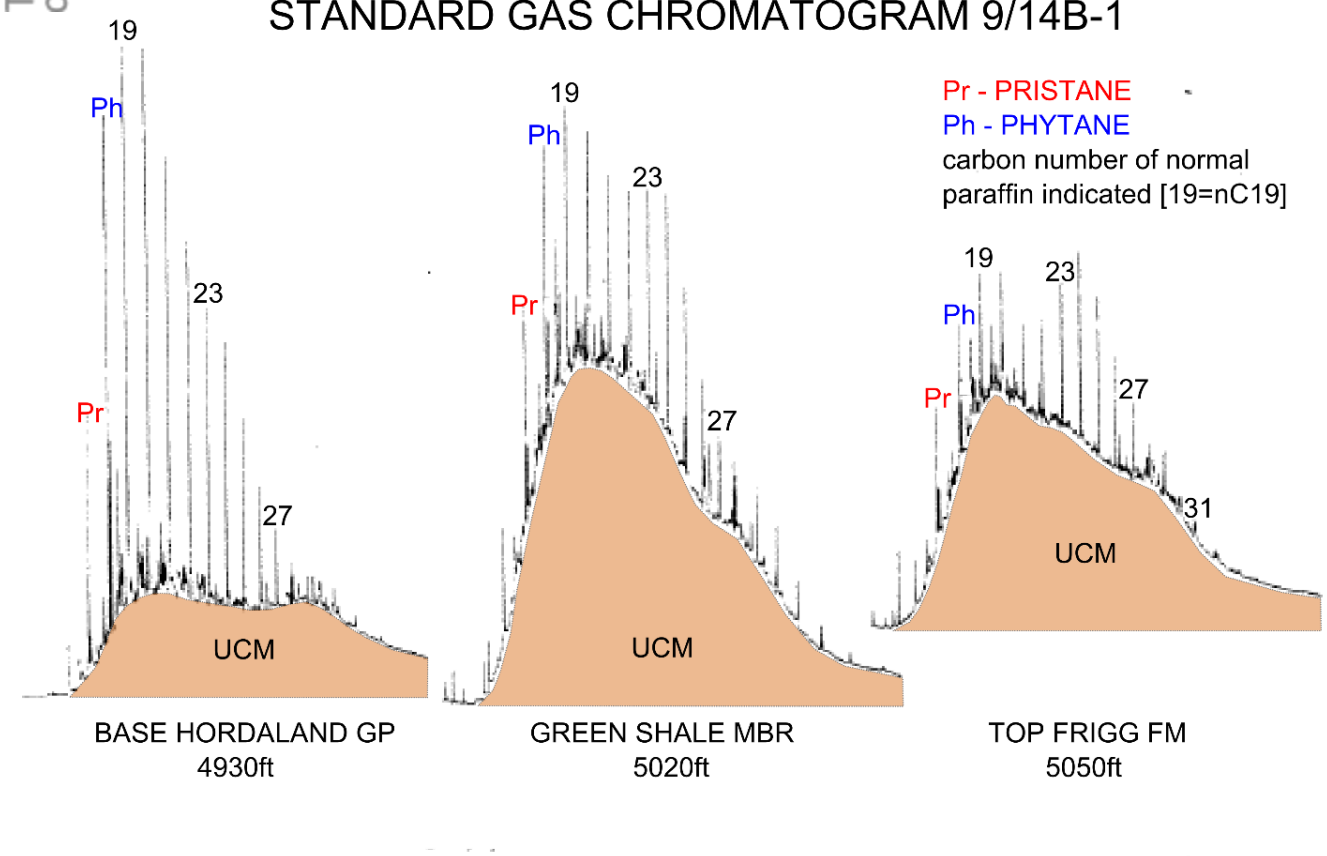



Fig 7: Sample GC from dataset well report demonstrating large baseline drift prevalent.

## Typical reconstructed normalised GC

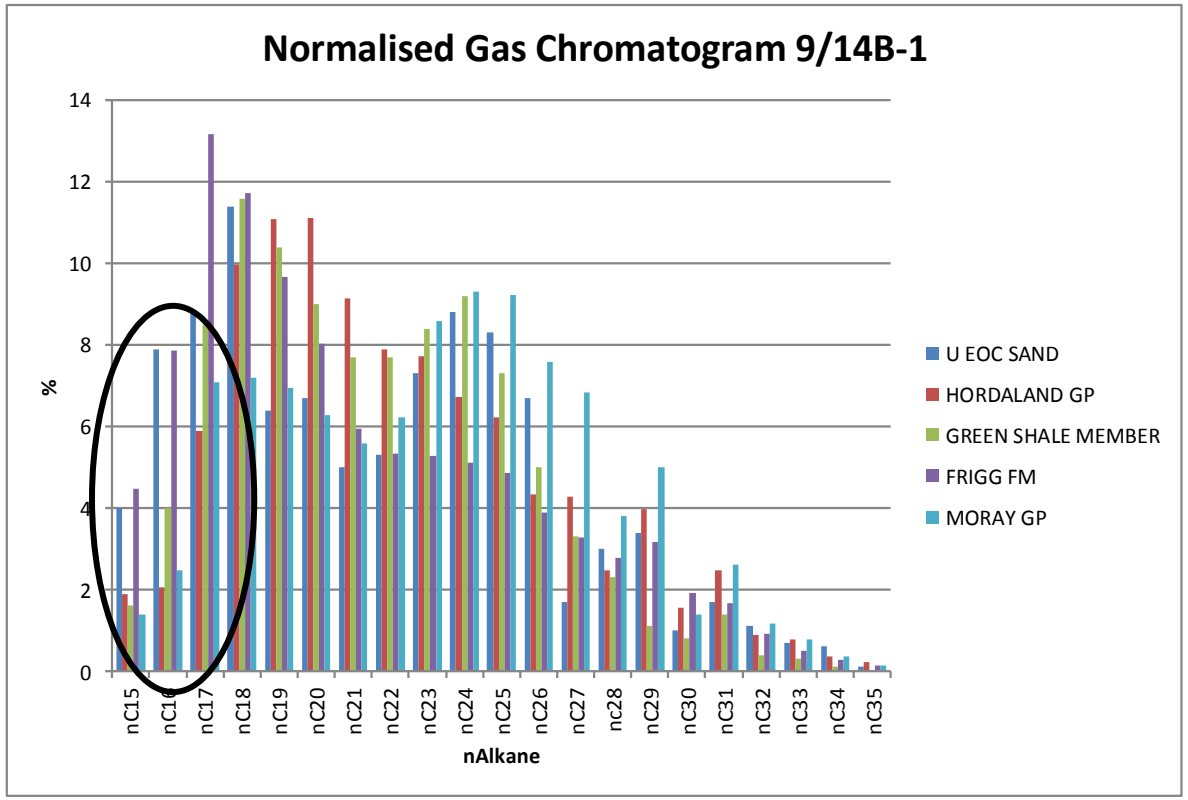
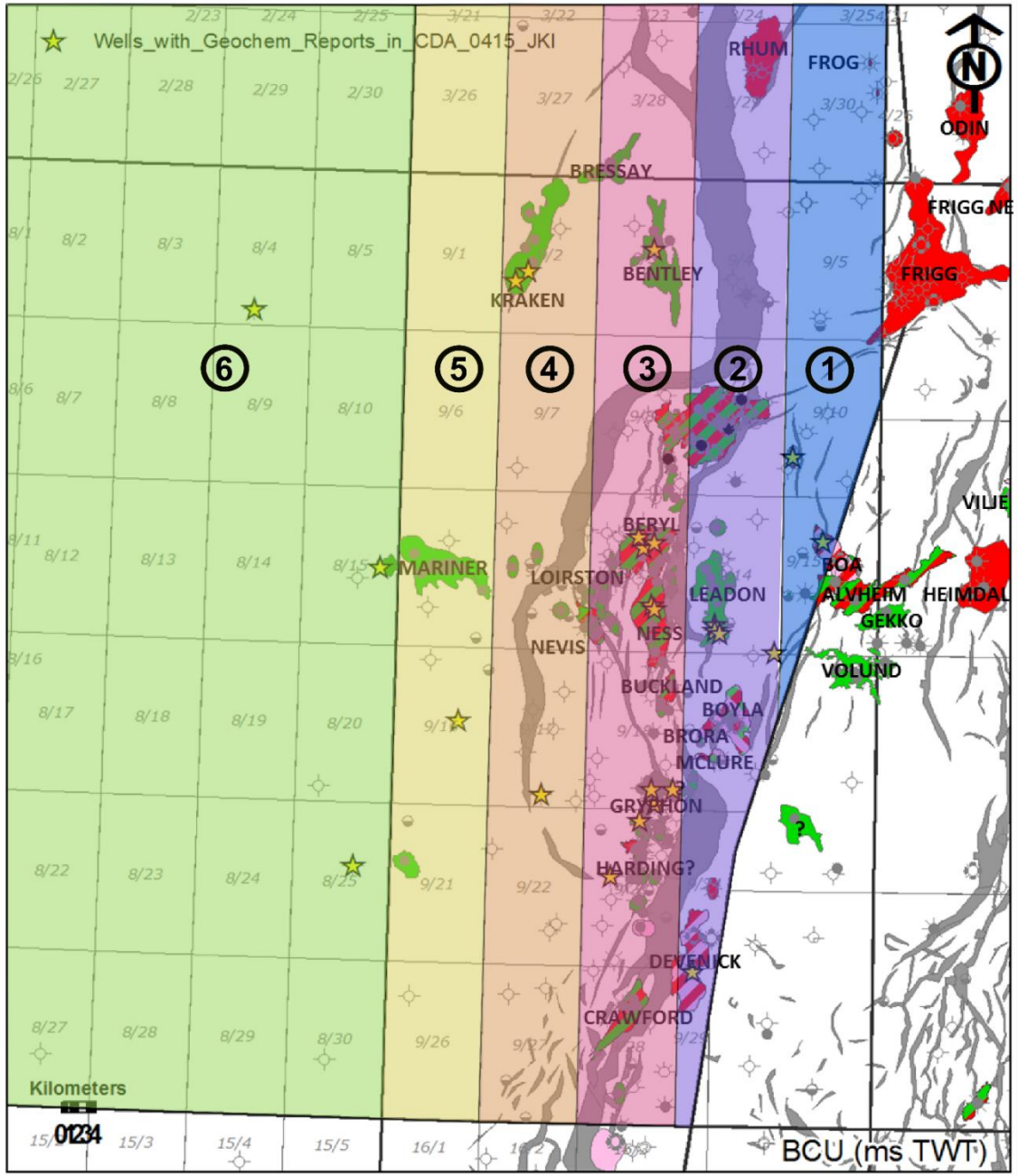



Fig 8: Normalised chromatogram allows noteworthy features of alkane envelope to be distinguished. Circled area potentially indicates water washing.

# An areal comparison




- Zones of relative distance from basin.
- Expect to see trends in oil maturity and environment moving away.

Fig 9: UKCS license block map with coloured overlay of study zones.

# Biomarker analysis

## Difference in output through application of stratigraphic templates

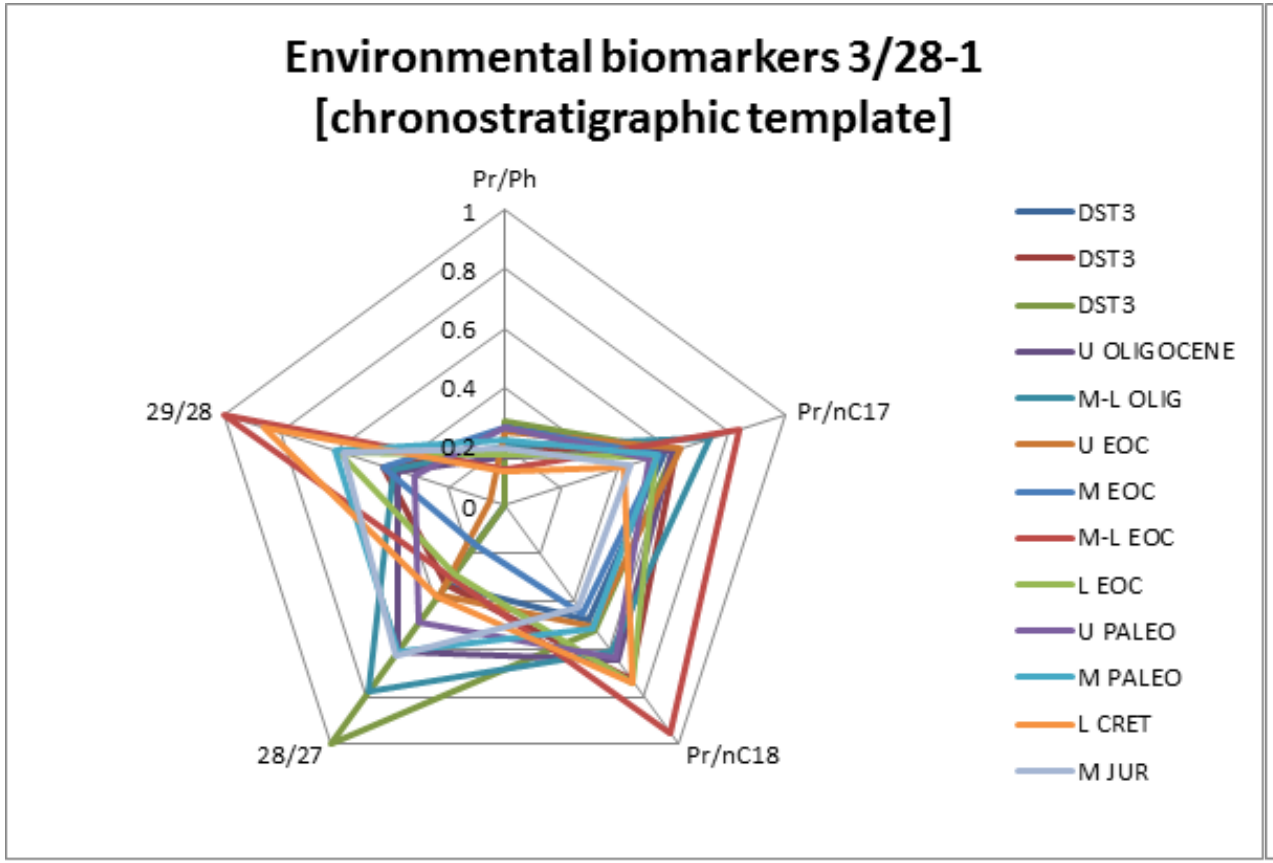



Fig 10: Biomarker radar plot demonstrating range of oils sampled.

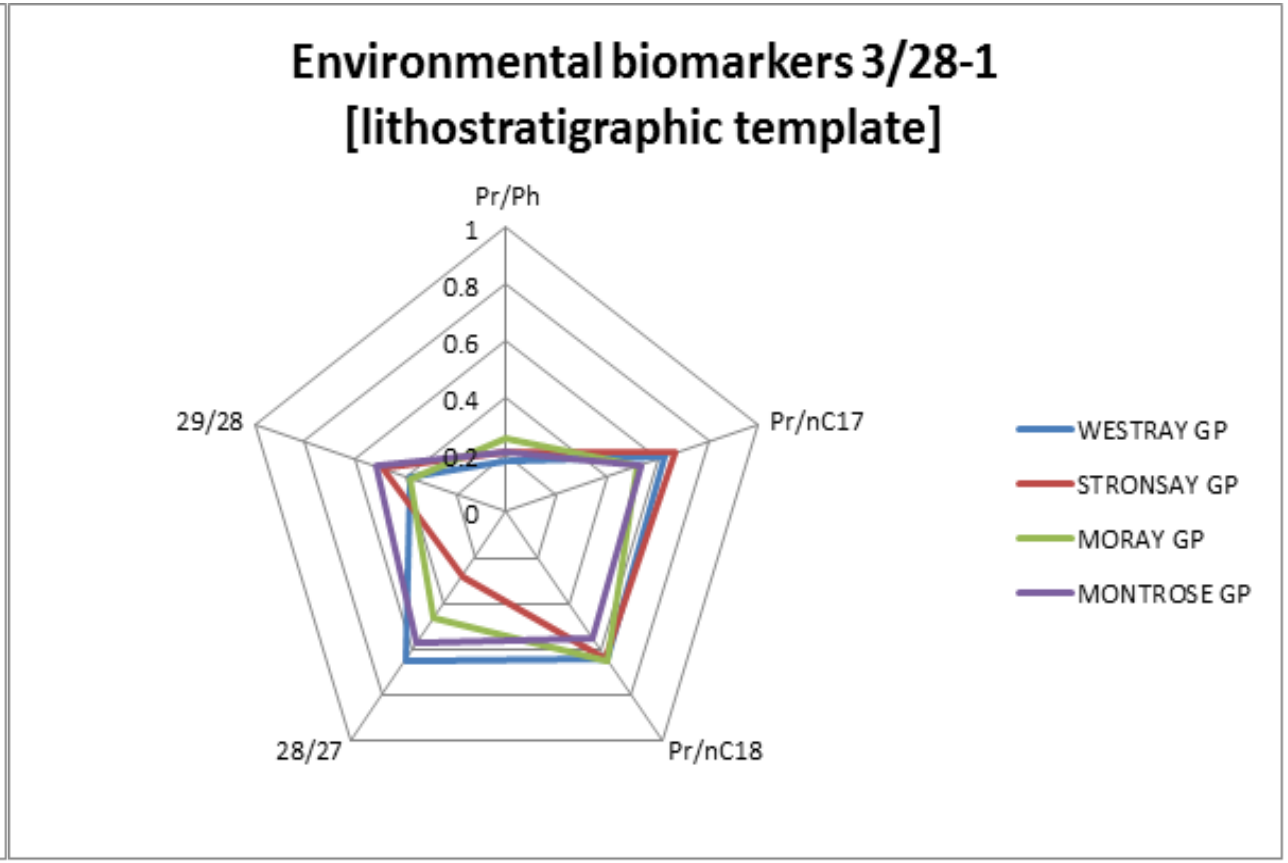



Fig 11: Application of a different template causes some trends to become more apparent, though outliers are lost.

# A statistical examination

- Standard deviation insufficient for hypothesis testing.
- Raises possibility of variation due to:
  - Length of time after drilling
  - Introduction of contaminants
- Combination of two is also a possibility.

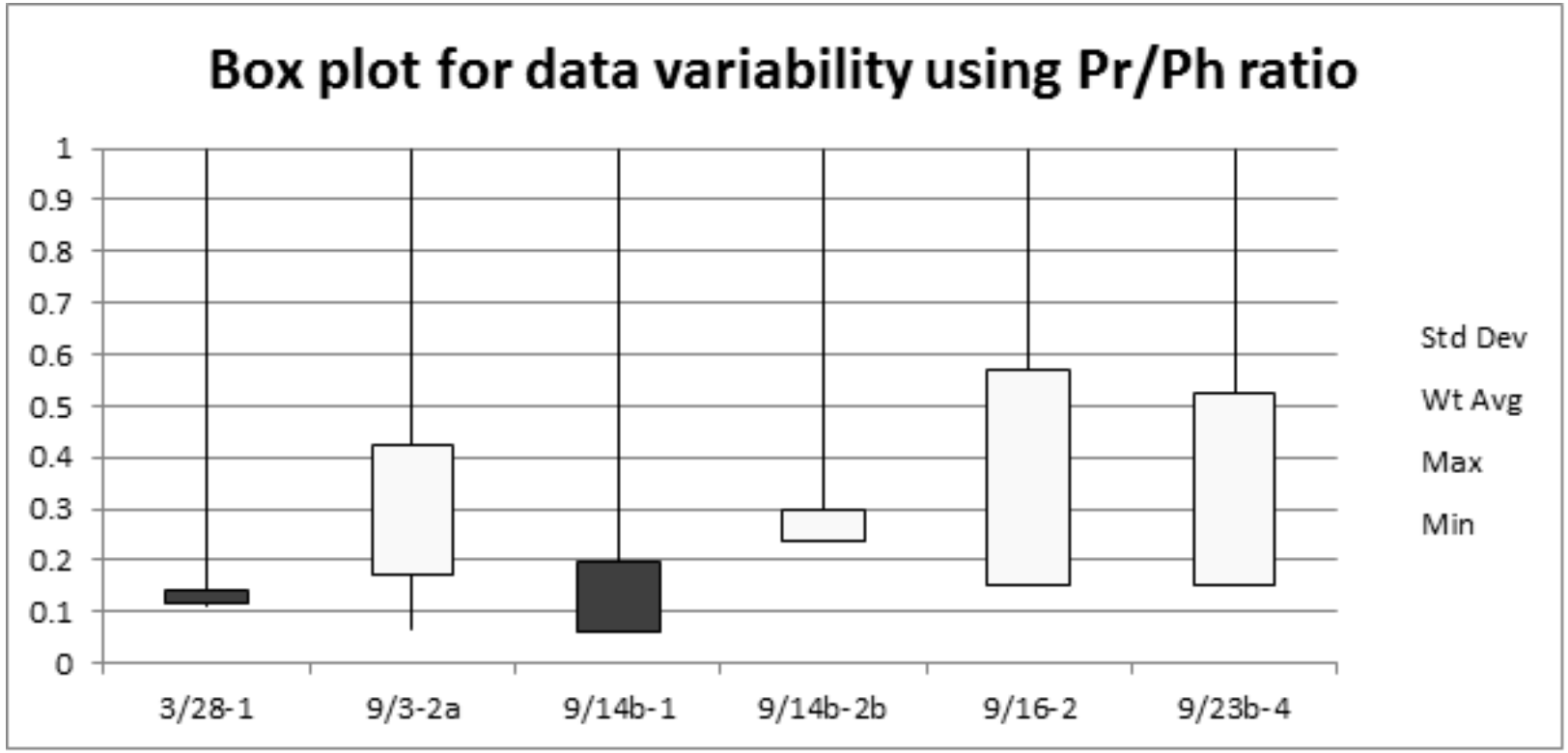



Fig 12: Box plot attempting to depict degrees of error inherent in dataset.

# Implications & Uncertainties

- Manipulation of dataset to condense data and to extrapolate gaps increases inherent uncertainty in analysis.
- Various source authors of well reports can lead to incompatibility due to proprietary standards.
- Many techniques have greatly improved with time or are recent developments.

# Conclusions & Recommendations

- Biodegradation observed in majority of dataset wells.
- Alkane evidence for bacterial influence as well as synthetic contaminants such as oil based muds (XP-07).
- Matching biomarker fingerprints indicates platform reservoirs able to be charged from basinward mature Kimmeridge Clay Fm.
- Maturity trend seen to decrease away from graben source, however sporadic evidence of localised source inconclusive for Devonian play.
- Potential for future studies of transport pathways into platform and further statistical examination to ascertain what effect drilling has on natural geochemical signatures.

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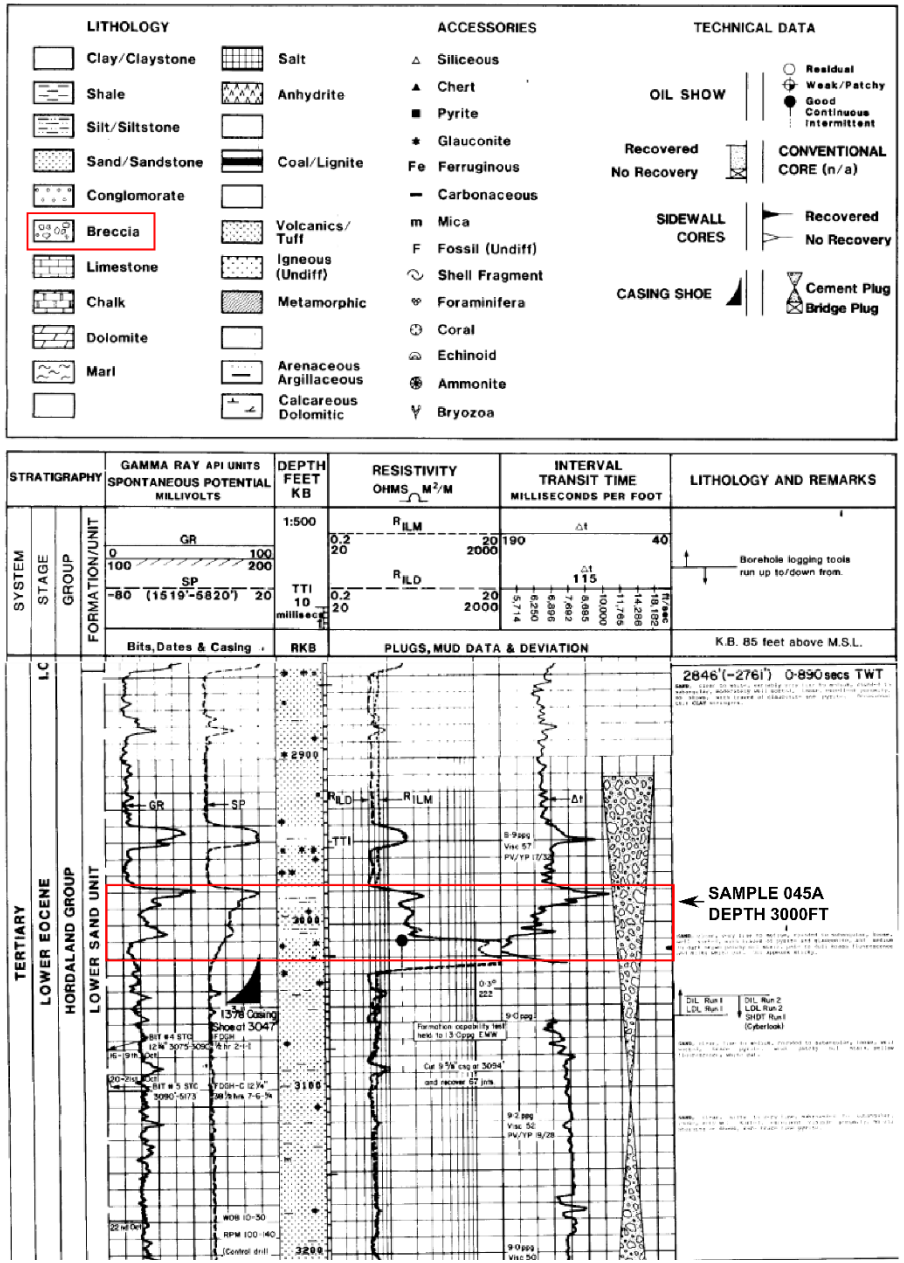
# Appendix



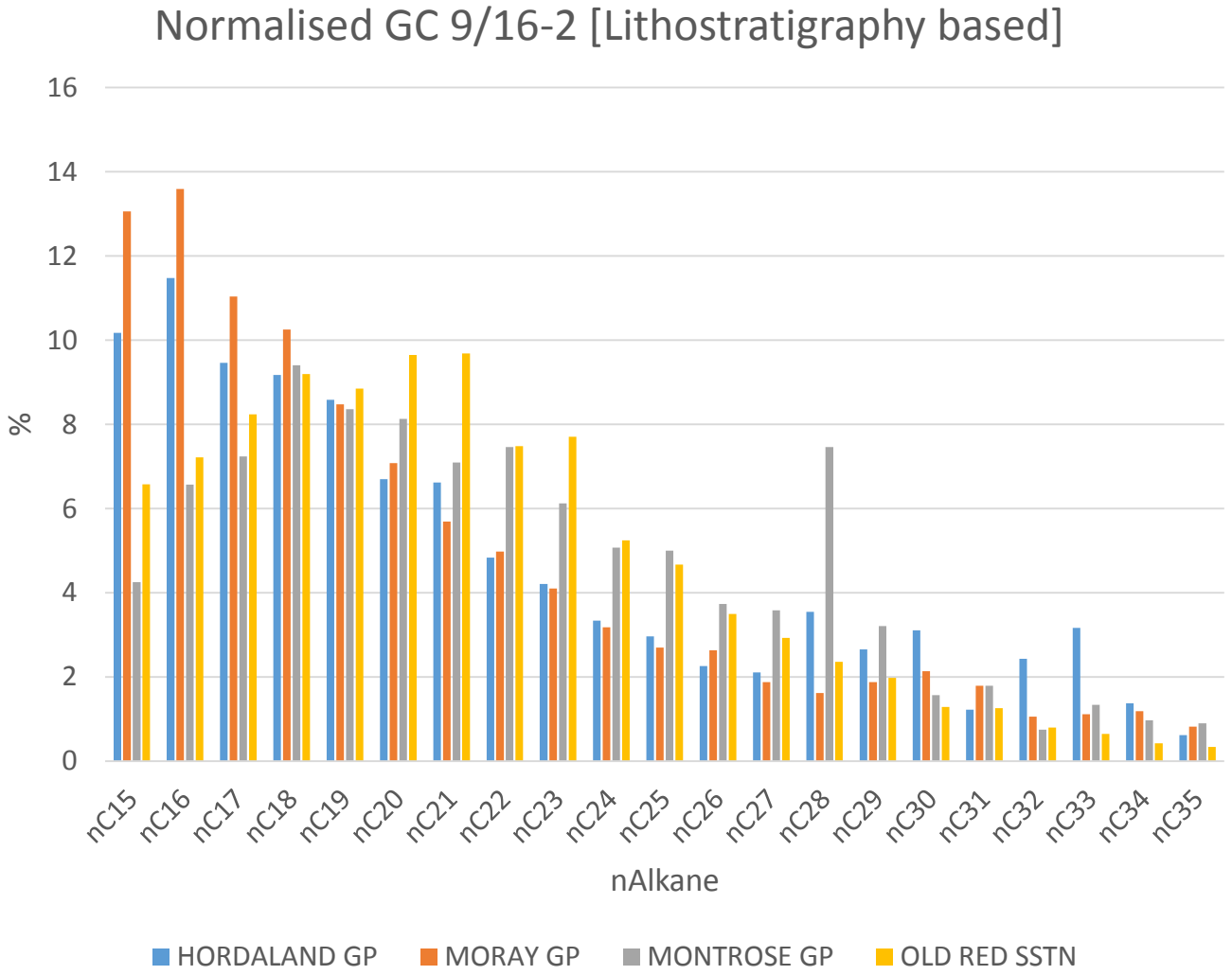




Fig 13 (A&B): Elevated continental biomarker signature in raw data linked to distinct lithology change as shown in composite log.

# Appendix

| LITHOSTRATIGRAPHIC GC | | | | |
|---|---|---|---|---|
| | HORDALAND GP | MORAY GP | MONTROSE GP | OLD RED SSTN |
| nC15 | 10.17 | 13.05667 | 4.25 | 6.575 |
| nC16 | 11.475 | 13.58667 | 6.57 | 7.215 |
| nC17 | 9.46 | 11.03667 | 7.24 | 8.24 |
| nC18 | 9.175 | 10.25 | 9.4 | 9.19 |
| nC19 | 8.585 | 8.473333 | 8.36 | 8.85 |
| nC20 | 6.7 | 7.08 | 8.13 | 9.645 |
| nC21 | 6.62 | 5.69 | 7.09 | 9.685 |
| nC22 | 4.83 | 4.98 | 7.46 | 7.48 |
| nC23 | 4.205 | 4.096667 | 6.12 | 7.705 |
| nC24 | 3.335 | 3.176667 | 5.07 | 5.24 |
| nC25 | 2.96 | 2.7 | 5 | 4.67 |
| nC26 | 2.26 | 2.633333 | 3.73 | 3.495 |
| nC27 | 2.11 | 1.873333 | 3.58 | 2.925 |
| nC28 | 3.545 | 1.62 | 7.46 | 2.355 |
| nC29 | 2.655 | 1.876667 | 3.21 | 1.975 |
| nC30 | 3.105 | 2.136667 | 1.57 | 1.29 |
| nC31 | 1.225 | 1.79 | 1.79 | 1.255 |
| nC32 | 2.43 | 1.056667 | 0.75 | 0.8 |
| nC33 | 3.165 | 1.113333 | 1.34 | 0.645 |
| nC34 | 1.375 | 1.186667 | 0.97 | 0.42 |
| nC35 | 0.62 | 0.816667 | 0.9 | 0.34 |

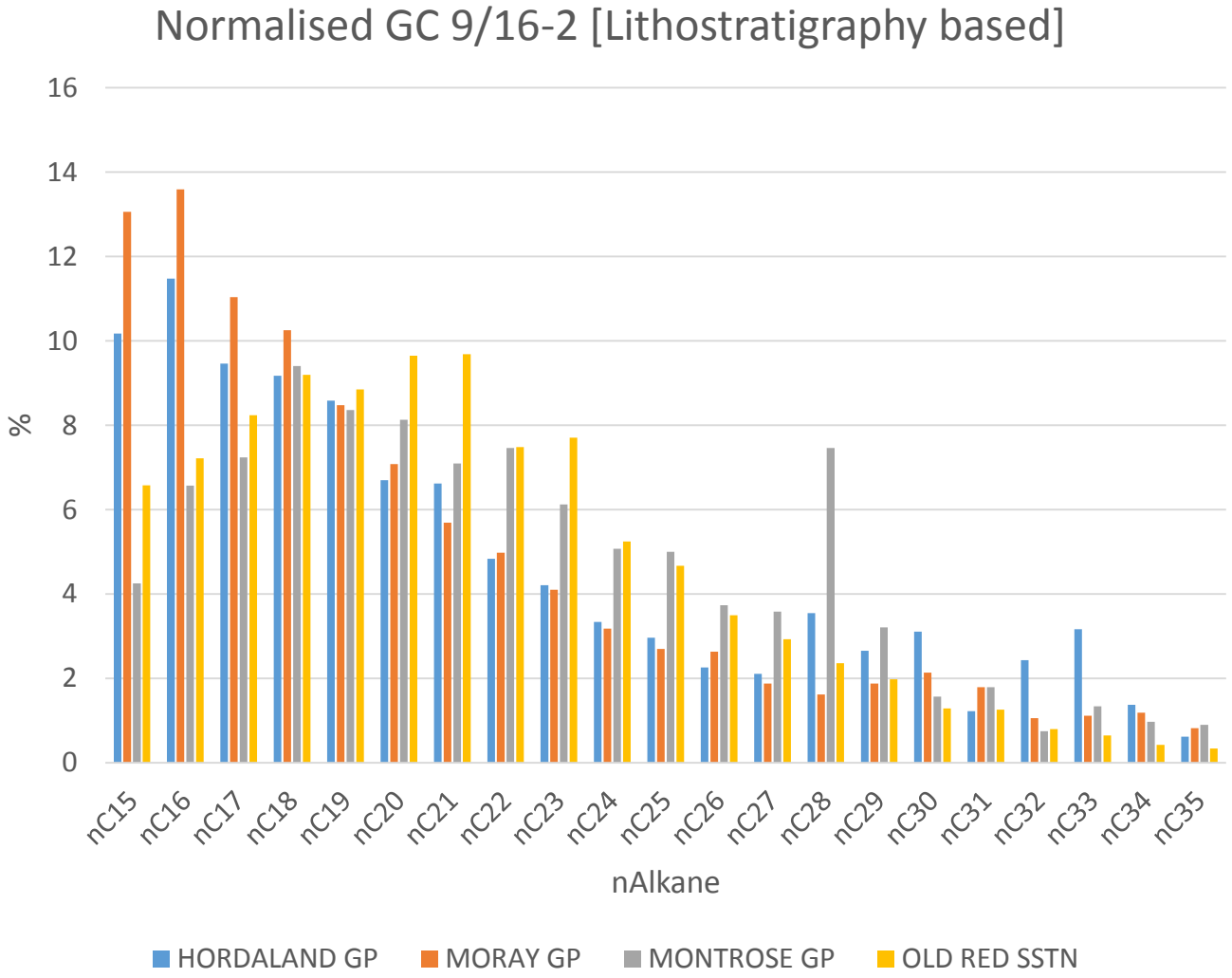



Fig 14: Elevated value for Montrose Gp as highlighted in raw data table.

# Appendix

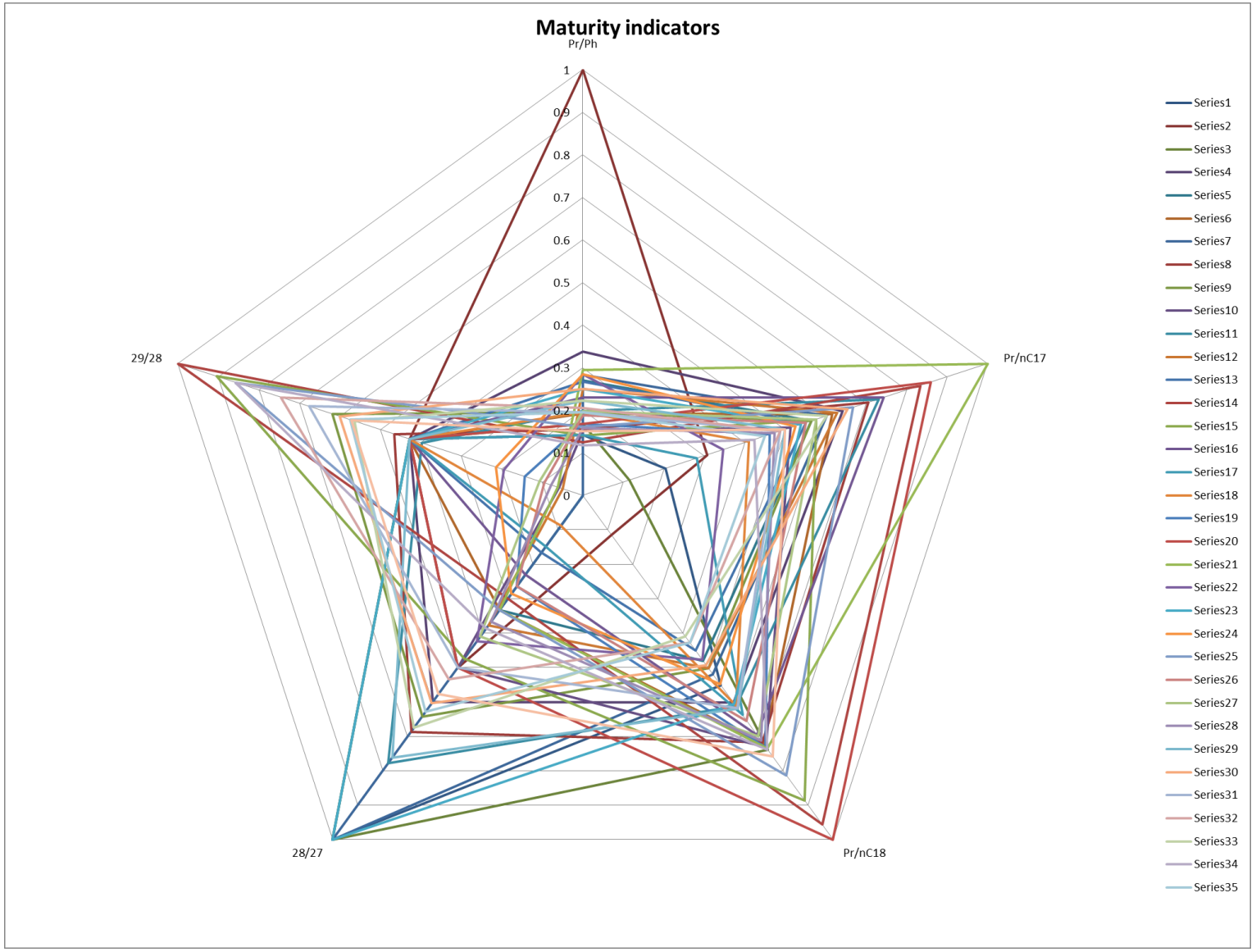



Fig 15: Example of raw data biomarker radar plot. Extremely difficult to identify trends without application of stratigraphic templates.

# Appendix

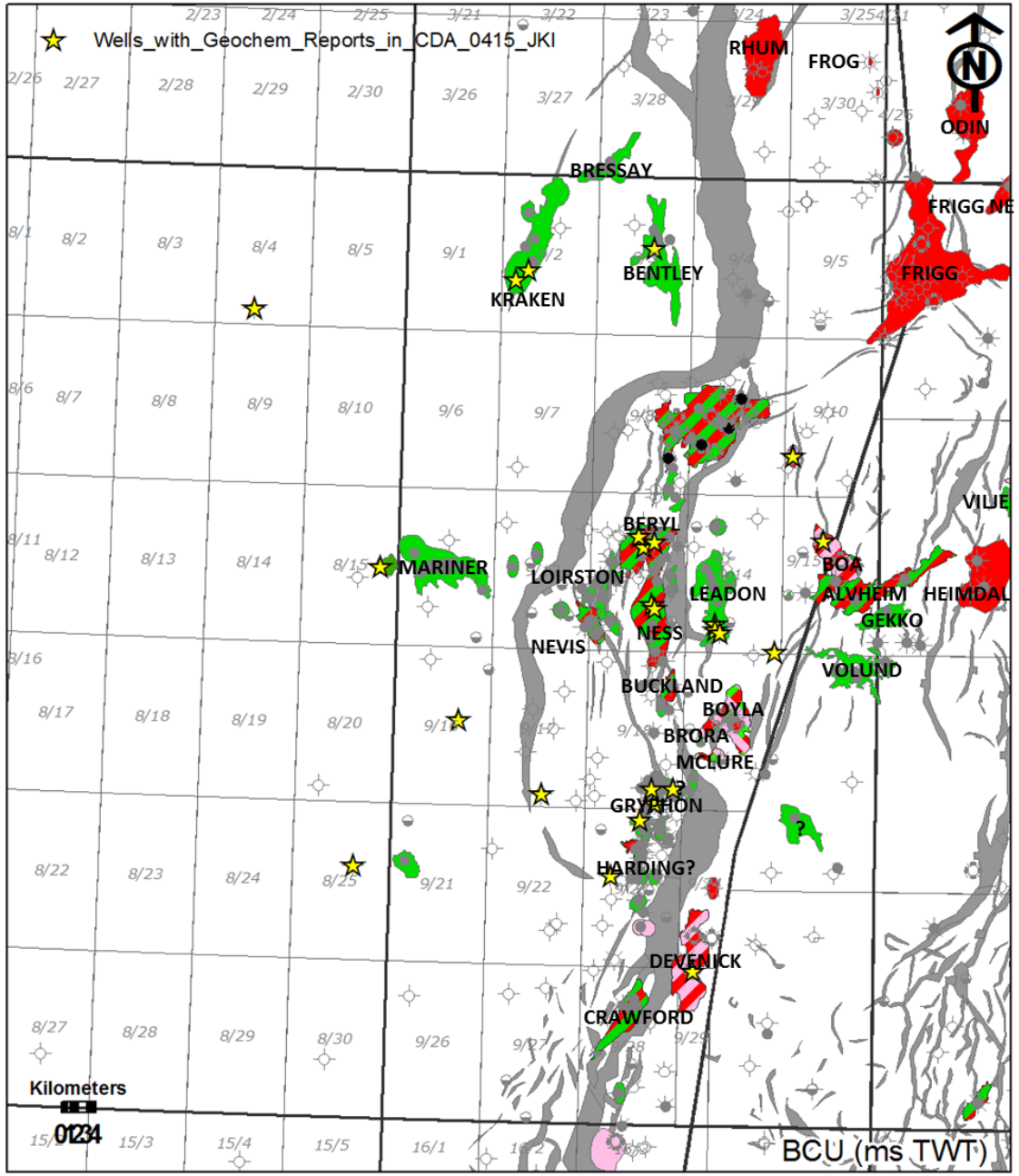



Fig 16: Study area (Standard oil field key).