



IMOG 2019

29TH INTERNATIONAL MEETING
ON ORGANIC GEOCHEMISTRY

.....
GOTHENBURG · SWEDEN
.....

1 - 6 SEPTEMBER 2019

WELCOME

Recognizing the causes of complex (mixed) molecular maturity signals in oils

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Integrated Geochemical Interpretation (IGI) Ltd.

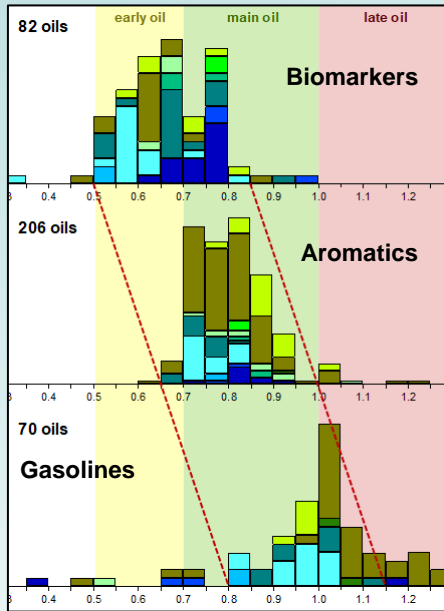
IMOG 2019 (Gothenburg): 3rd September 2019

Introduction

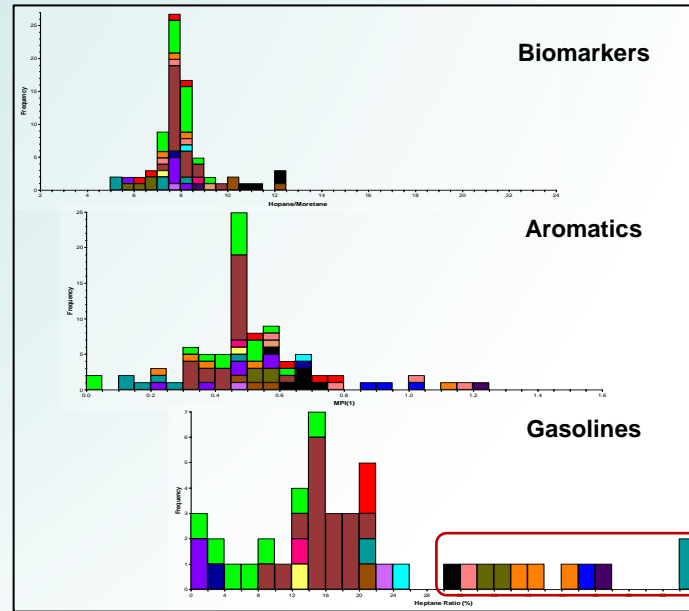
Aim & scope of this presentation

Show examples of mixed **maturity signals** in oils from several petroleum systems and examine **the causes** of these:

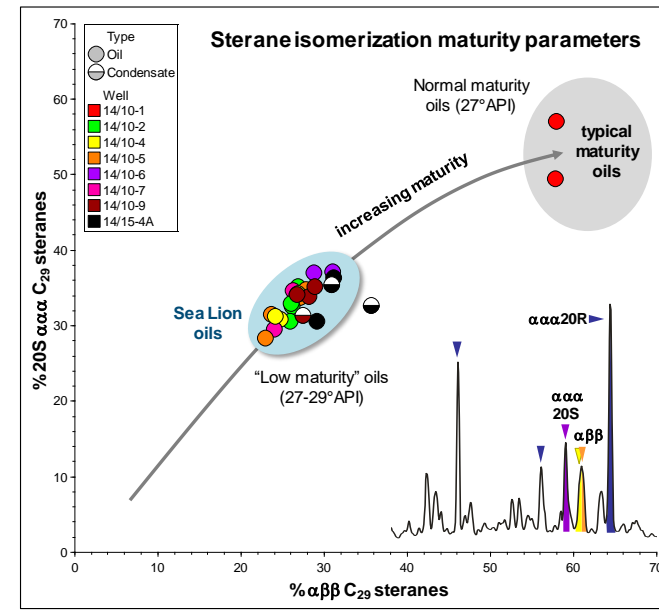
1. Inherent maturity differences between compound classes



2. Discrete high maturity charge



3. Leaching of immature biomarkers in reservoir or during migration



Encourage careful interpretation of maturity data using all compound classes

Draw particular attention to the risks of mis-interpretation where leaching is not recognized
Often overlooked and poorly represented in the literature

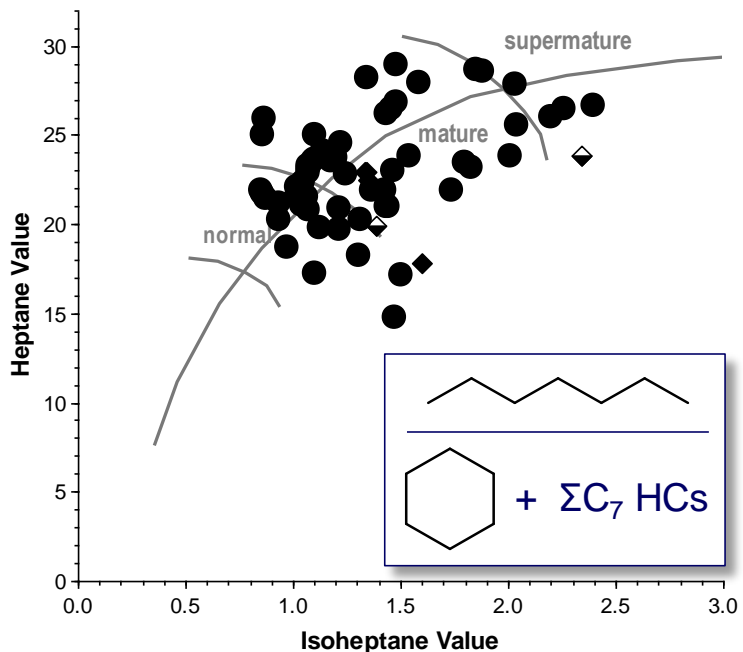
Introduction

Molecular maturity indicators

A multitude of molecular parameters are available to measure maturity
Using a wide range of compound classes:

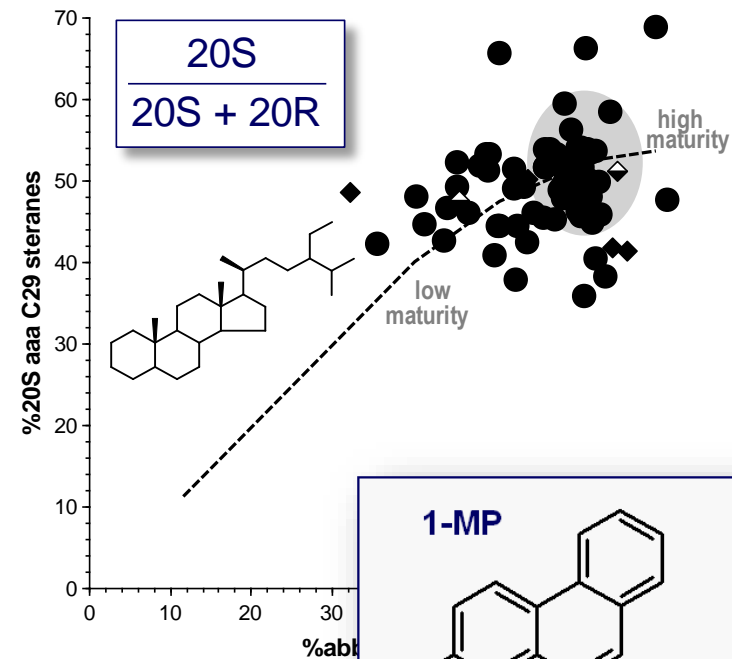
Gasolines

Gasoline maturity

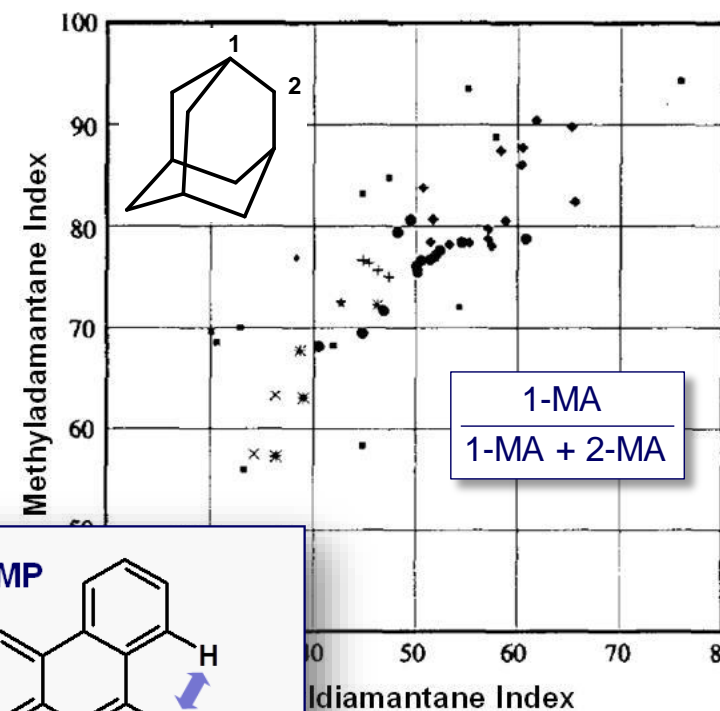


Biomarkers

C29 Sterane Isomerisation



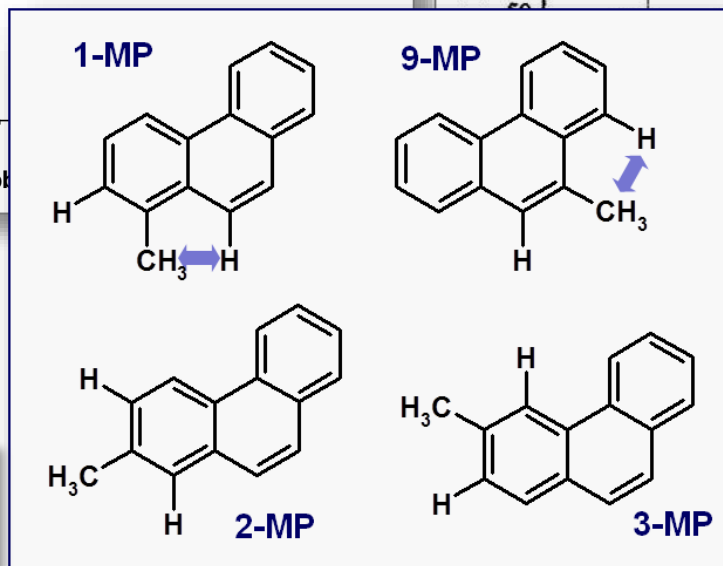
Diamantoids



Chen et al. (1996)

Aromatics

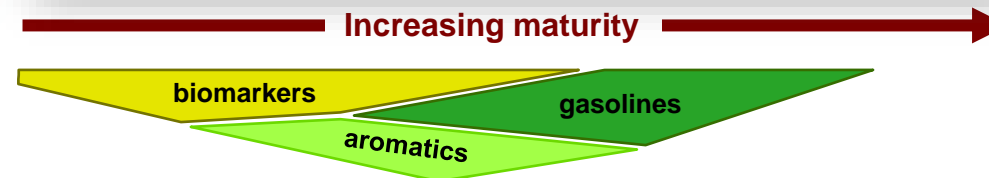
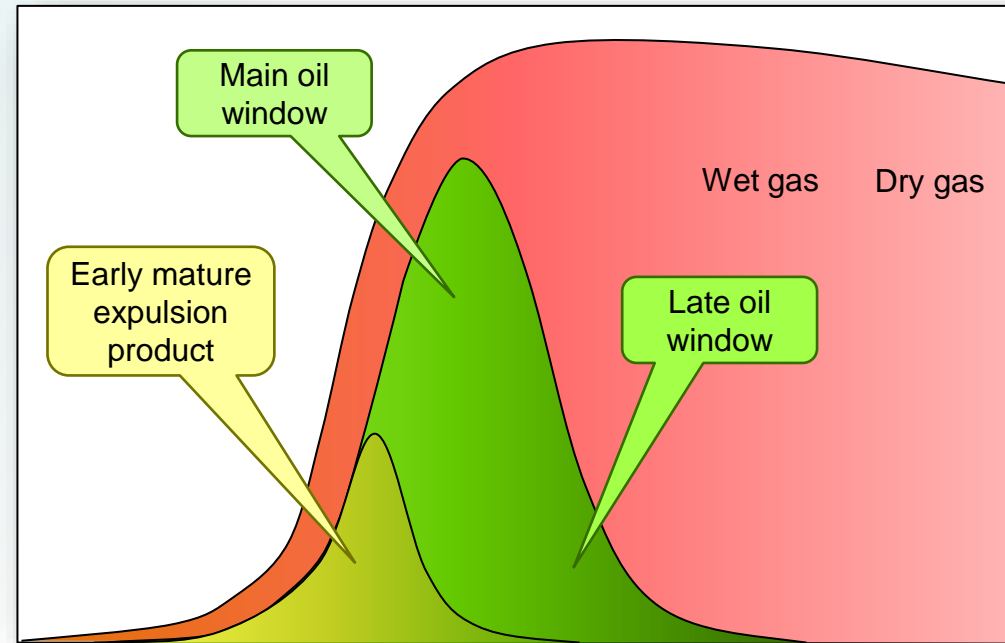
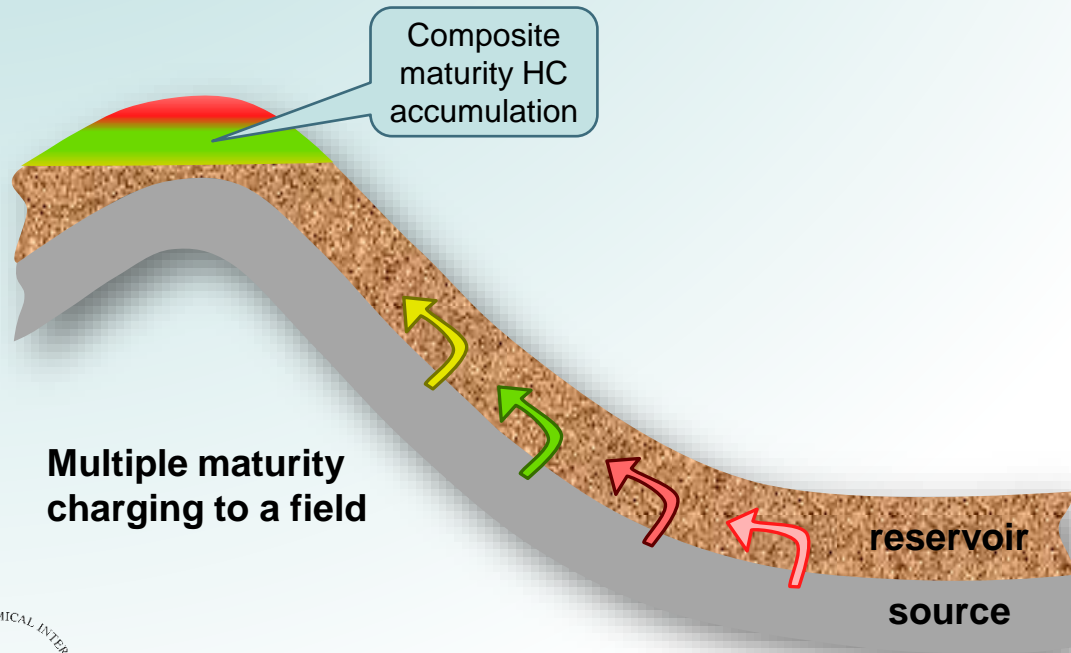
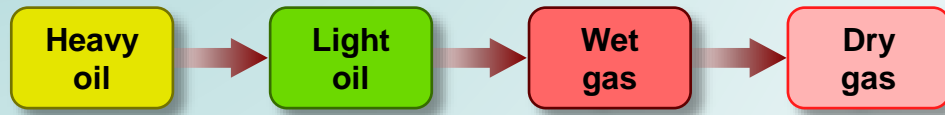
$$\frac{1.5 ([2\text{-MP}] + [3\text{-MP}])}{([P] + [1\text{-MP}] + [9\text{-MP}])}$$



Oil generation & composition

Compound classes through generation windows

The composition of generated petroleum changes during the maturation process:



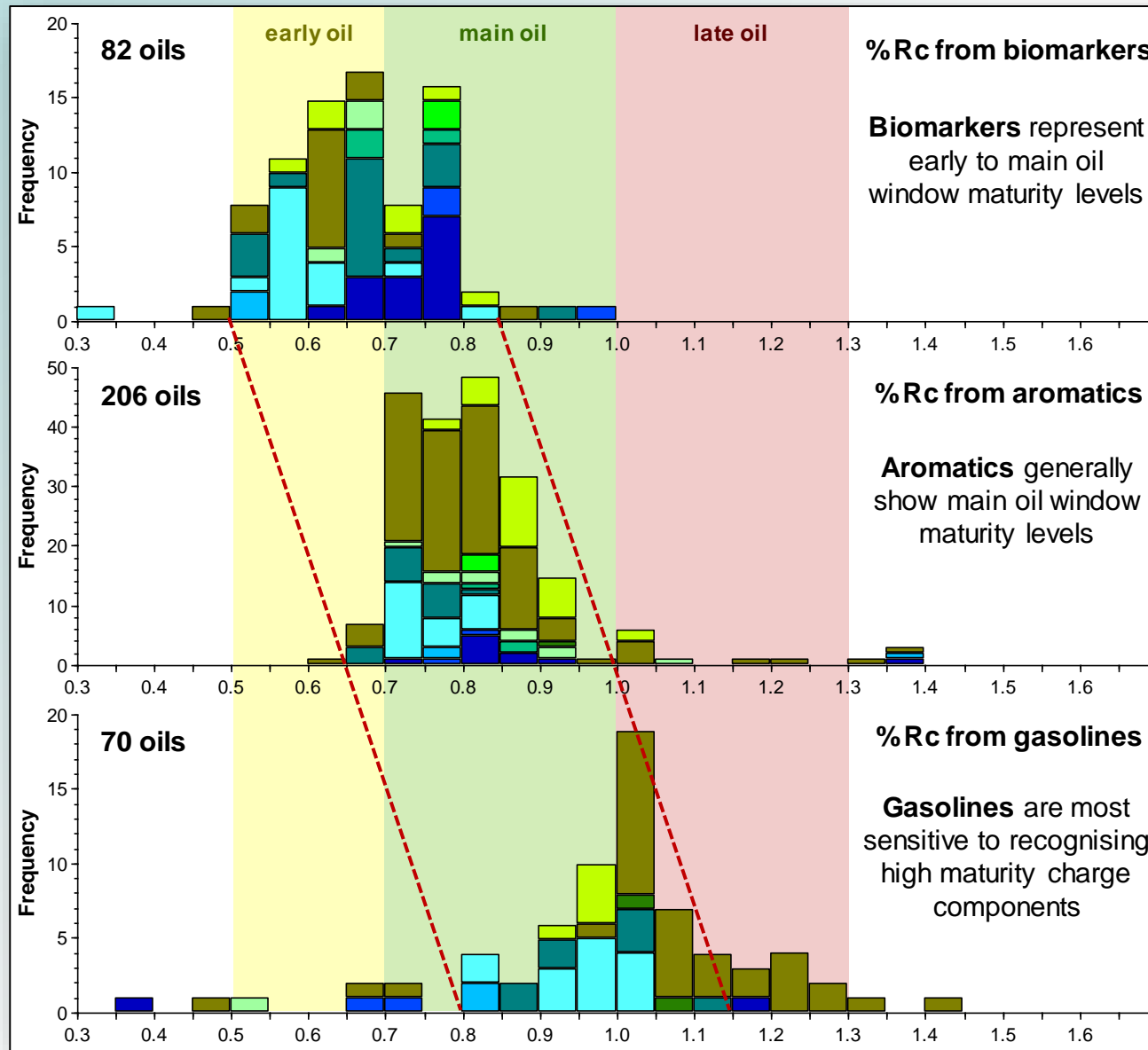
Different compound classes preferentially generated at different maturity levels

Maturity signals from different compound classes

Example: North Sea, Norway



Released data
(Norwegian
Petroleum
Directorate)



Biomarkers preserve a lower maturity signal than do the aromatics and the gasolines

This mismatch between maturity signals from different compound classes was well demonstrated by Wilhelms & Larter (2004)

“All oils are mixtures”

Even when dealing with a single source rock in a single kitchen

Wilhelms & Larter (2004). In: “Understanding Petroleum Reservoirs: towards an Integrated Reservoir Engineering & Geochemical Approach” *Geol. Soc. Spec. Pub.* 237, 27-35.

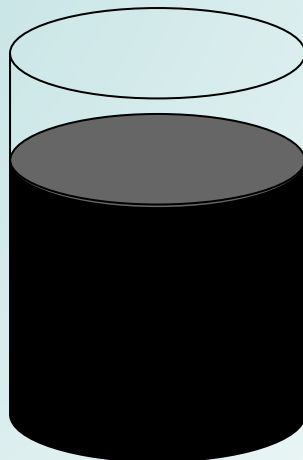
Mixing discrete charges of different maturity

Bias in the different compound classes

Concentrations are key:

Black oil

Abundant biomarkers
Moderate aromatics
Low gasolines
Low diamondoids

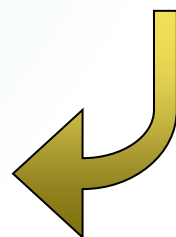
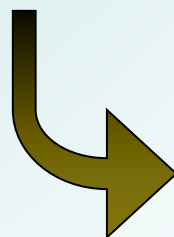
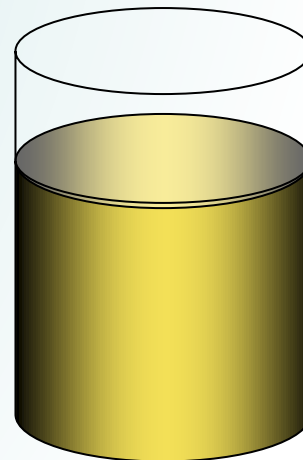


For example:

- 2 sources in the same kitchen
- 2 different kitchens
- Same source & kitchen, later charge

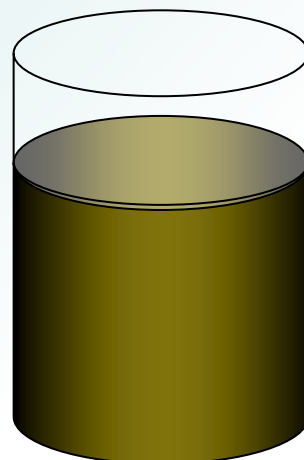
Gas condensate

Low biomarkers
Higher aromatics
High gasolines
High diamondoids



Mixture

Biomarkers mainly from oil
Aromatics from both
Gasolines mainly from condensate
Diamondoids mainly from condensate

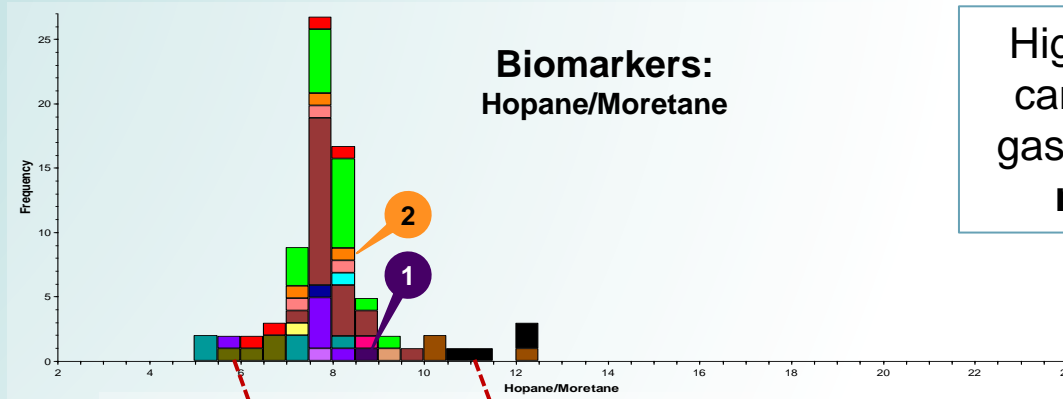


Mixing discreet charges of different maturity

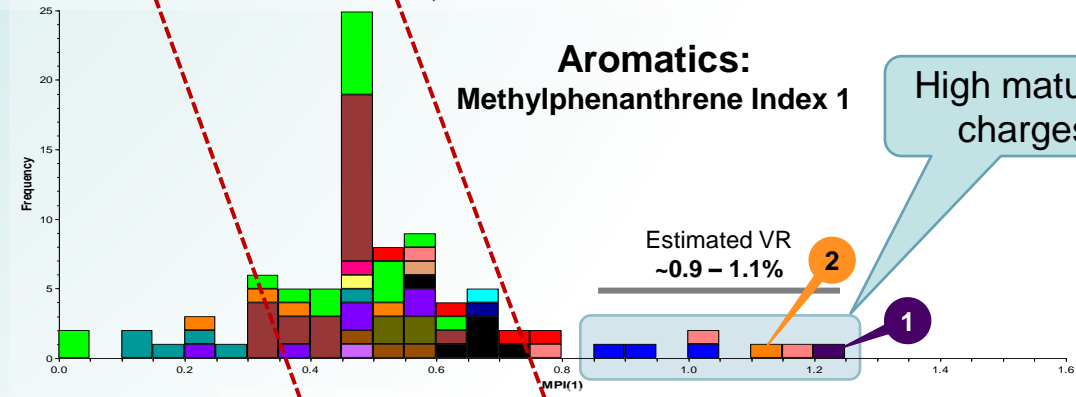
Example: Barmer Basin, India

Farrimond *et al.* (2015a)

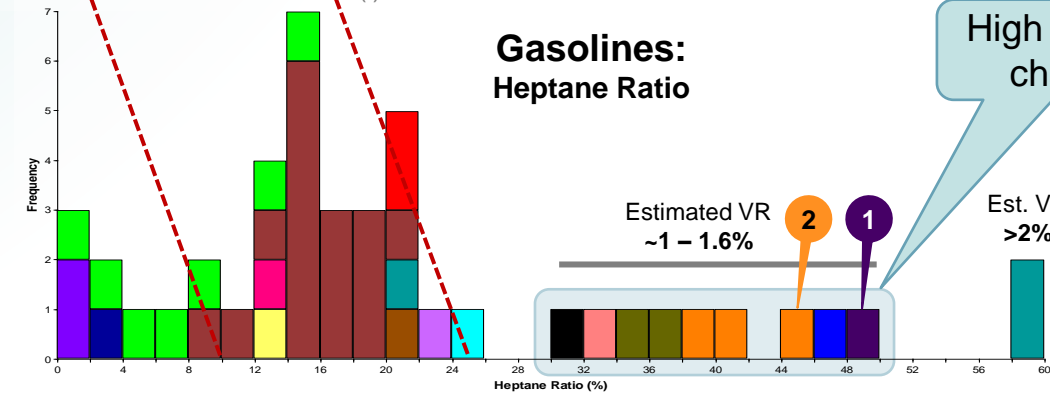
- Field
- Aishwariya
- Bhagyam
- Guda
- Guda South
- Kaameshwari
- Kaameshwari West
- Mangala
- N-C West
- N-E
- N-I
- N-P
- N-R
- Raageshwari
- Saraswati
- Shakti
- Tukaram
- Vandana
- Vijaya



High maturity component can be recognized in the gasolines & aromatics, but **not the biomarkers**



High maturity charges



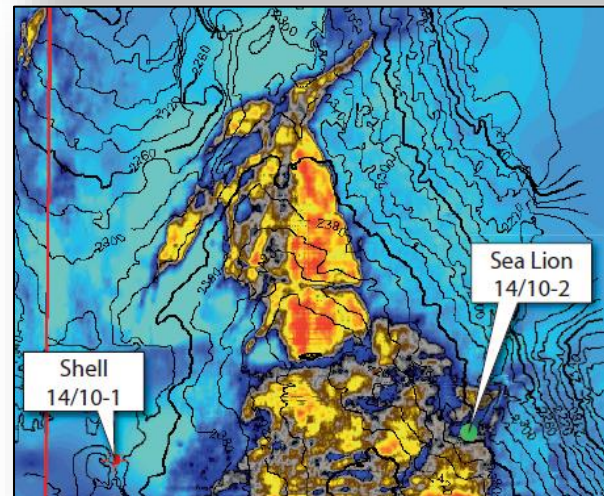
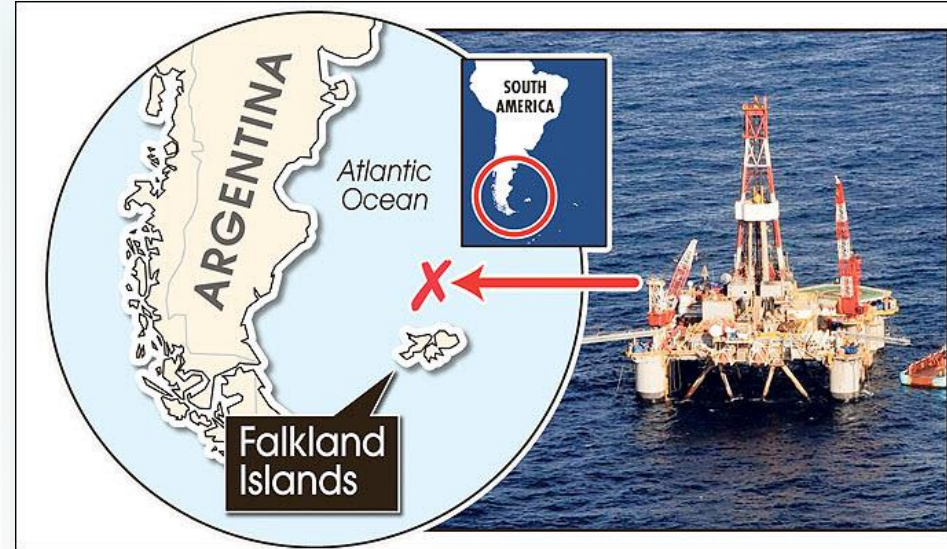
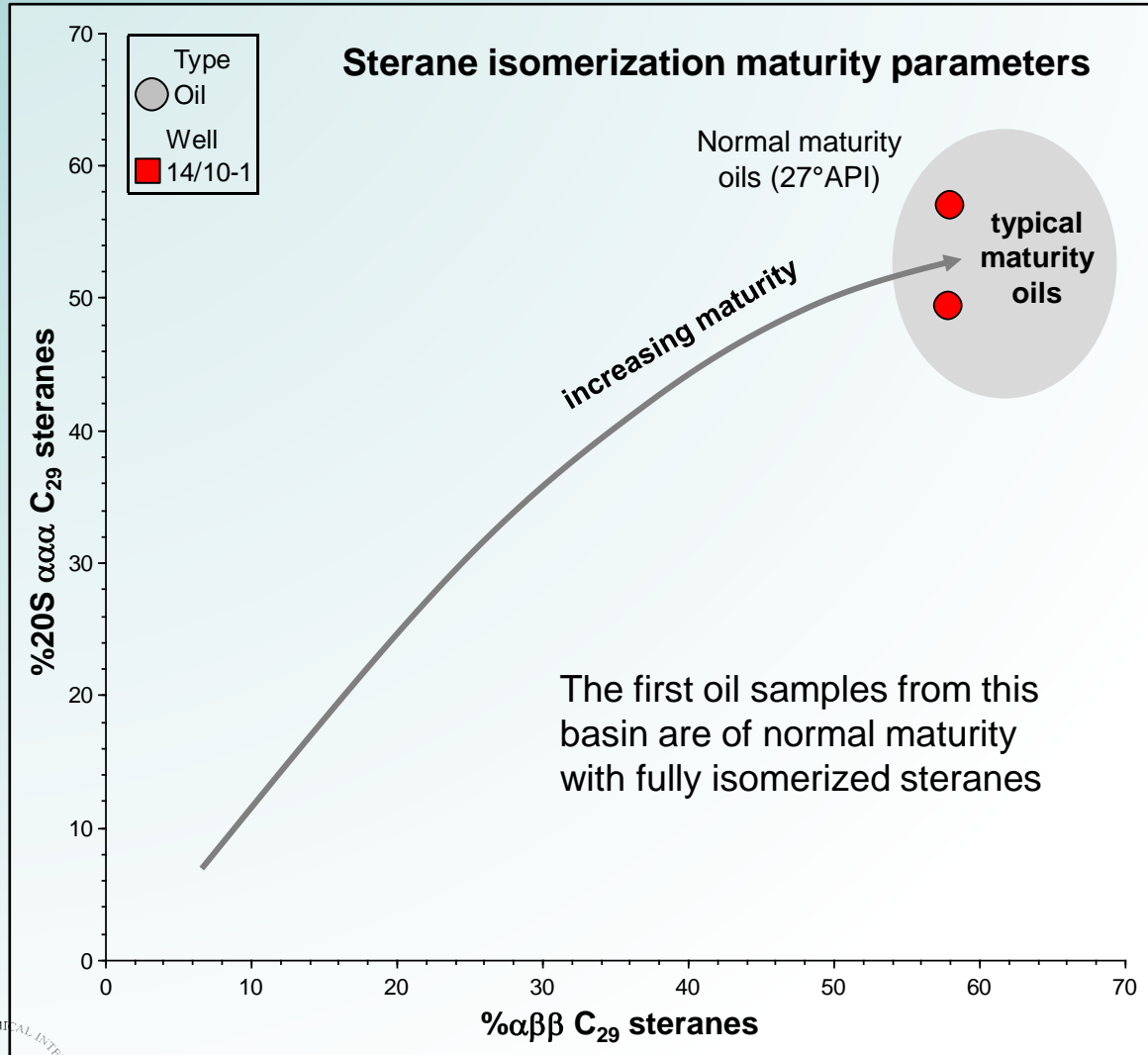
High maturity charges

Farrimond *et al.* (2015a). *Petroleum Geoscience* 21, 301-321

Anomalously immature oils

Example: Falkland Islands (Sea Lion discovery)

Lower Cretaceous lacustrine sourced oil



Farrimond *et al.* (2015b)

Petroleum Geoscience 21, 125-135

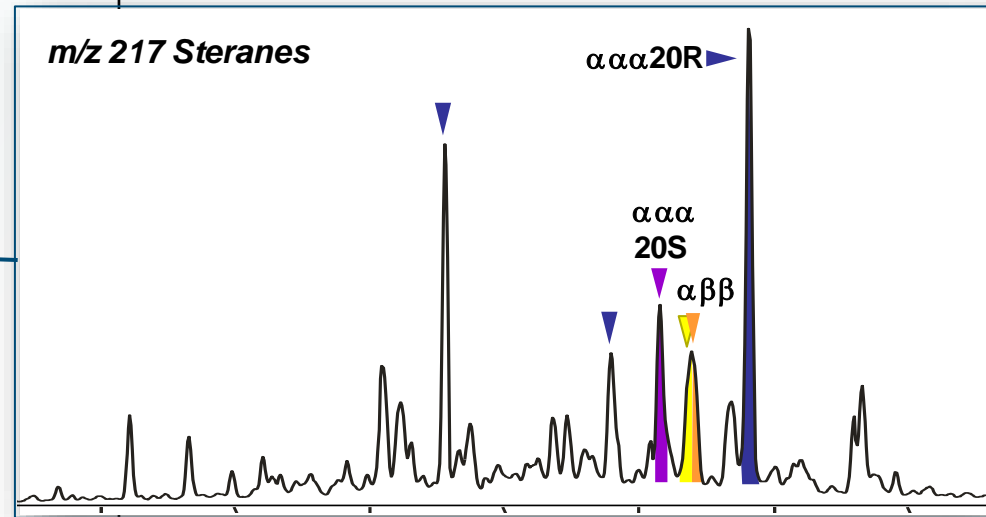
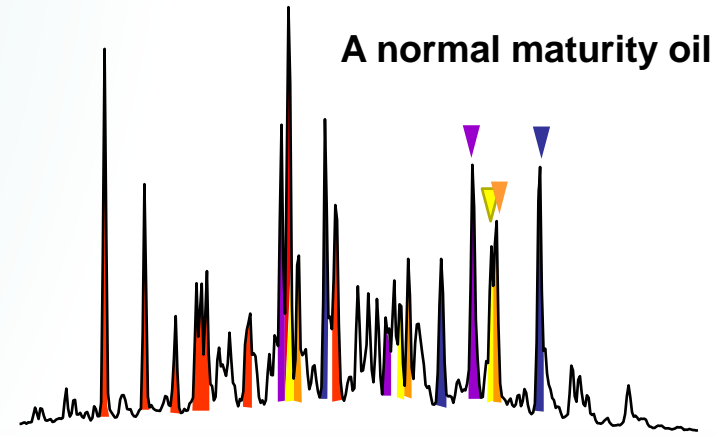
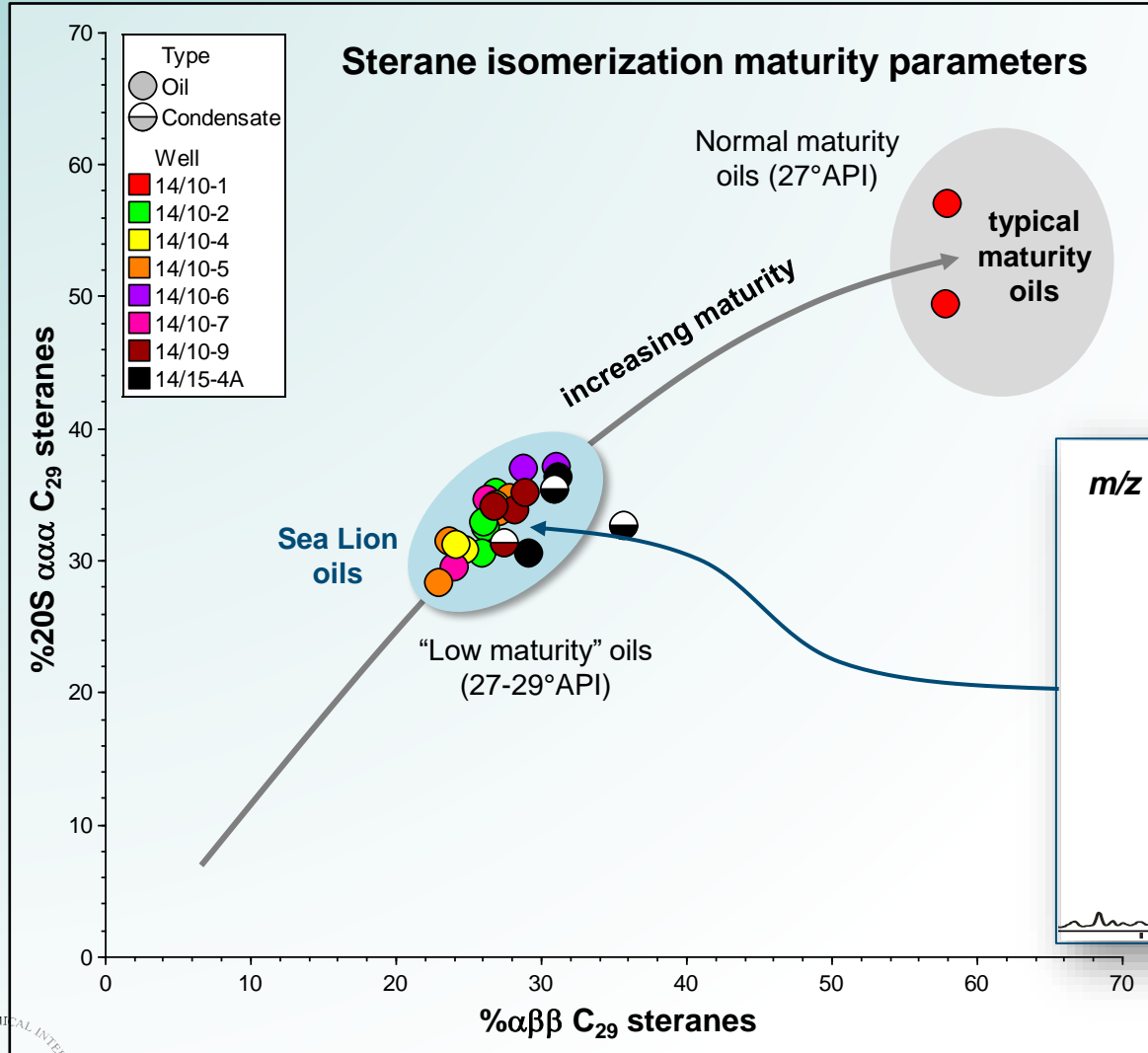
MacAulay (2015)

Petroleum Geoscience 21, 111-124

Anomalously immature oils

Example: Falkland Islands (Sea Lion discovery)

Lower Cretaceous lacustrine sourced oil



Anomalously low maturity steranes

Farrimond *et al.* (2015b)

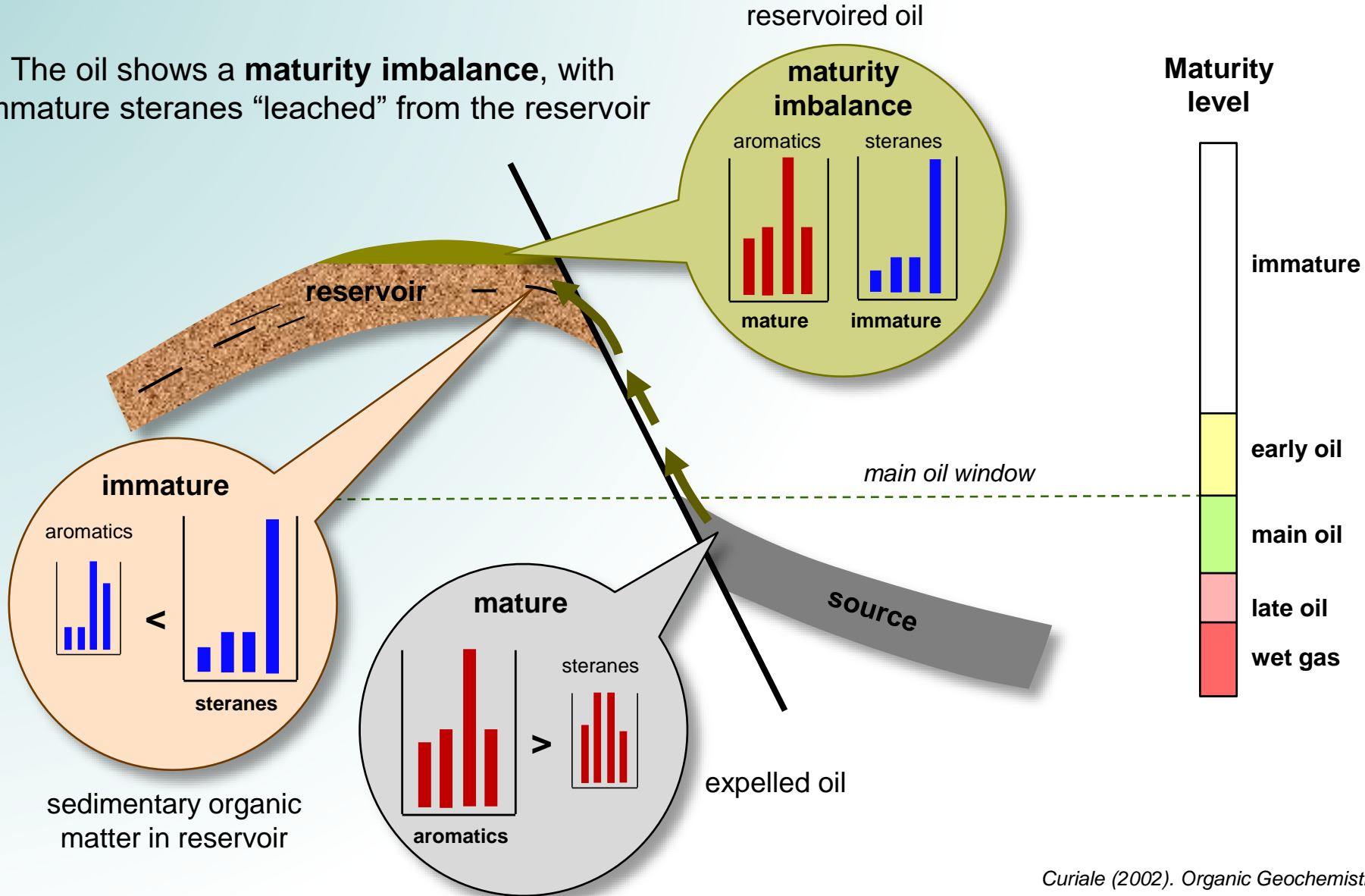
Petroleum Geoscience 21, 125-135

Recognizing "leaching" in oils

Maturity imbalances

After Curiale (2002)

The oil shows a **maturity imbalance**, with immature steranes "leached" from the reservoir

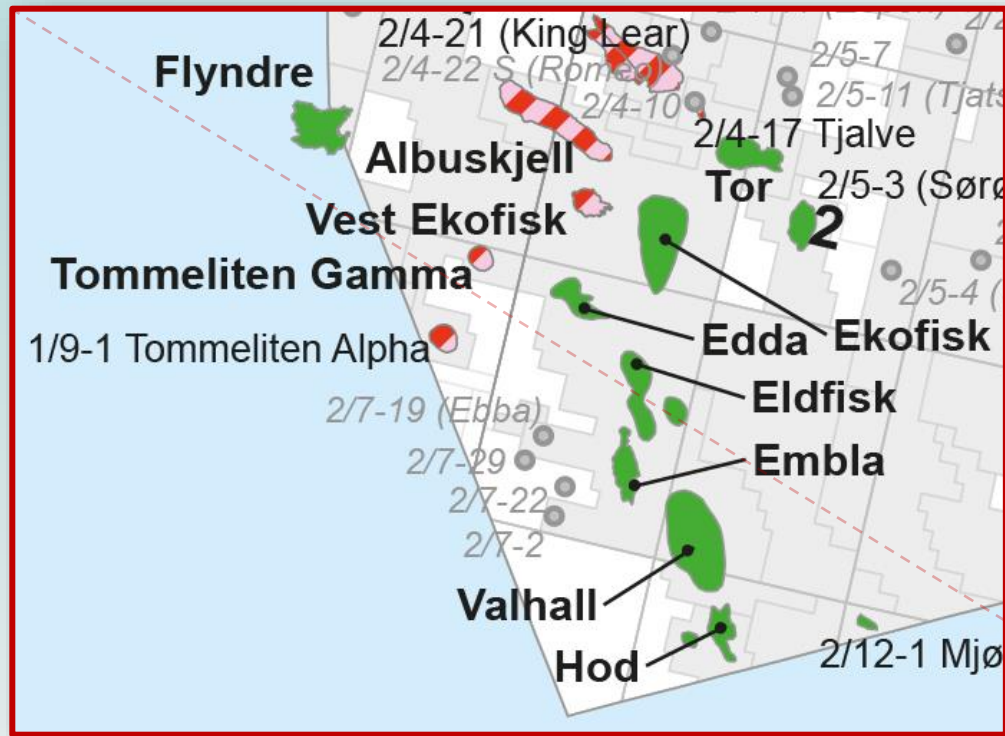


Curiale (2002). *Organic Geochemistry* 33, 1389-1400.

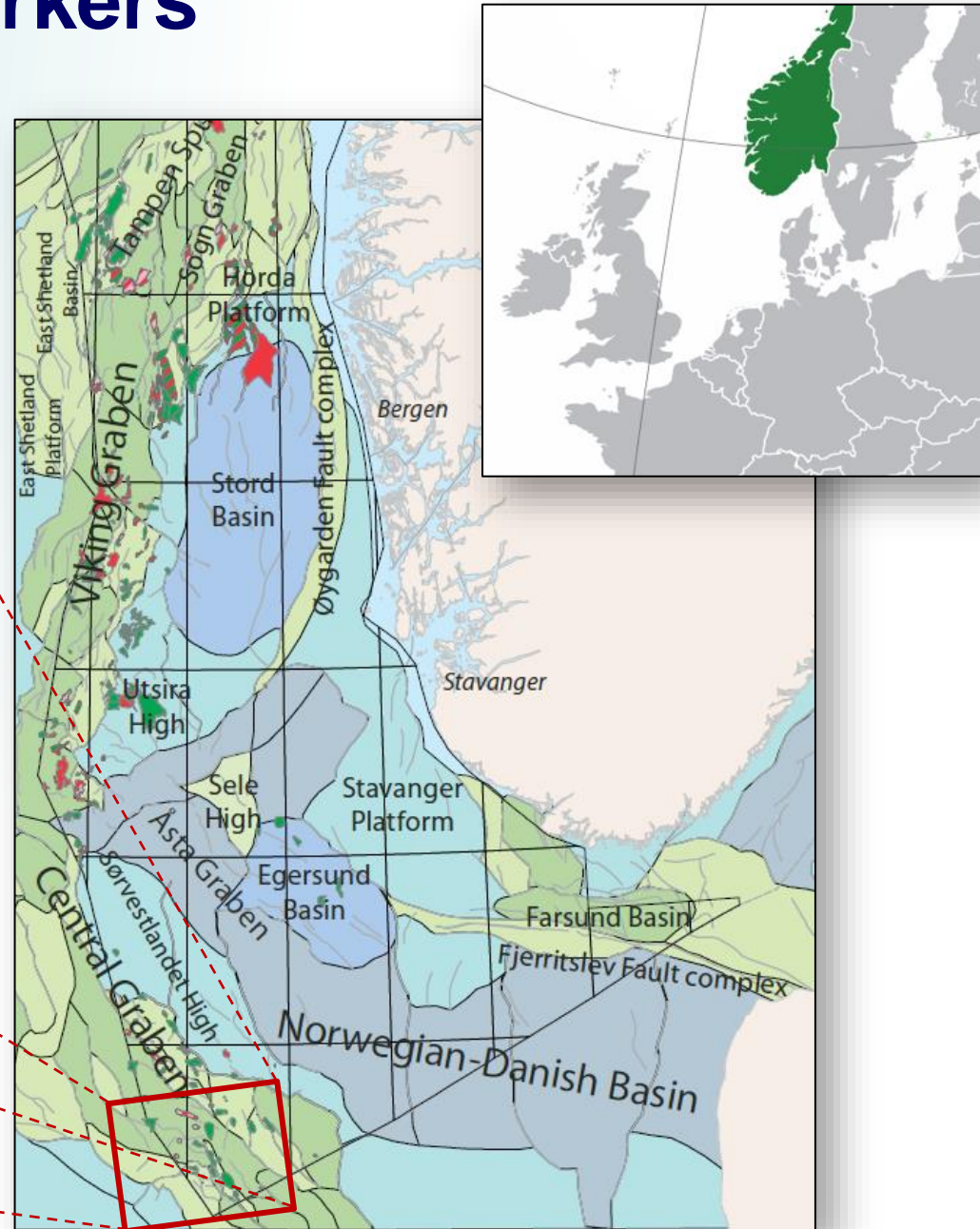
Leaching of immature biomarkers

Example: Hod & Valhall Fields (North Sea)

Chalk fields of the Norwegian North Sea



Norwegian Petroleum Directorate

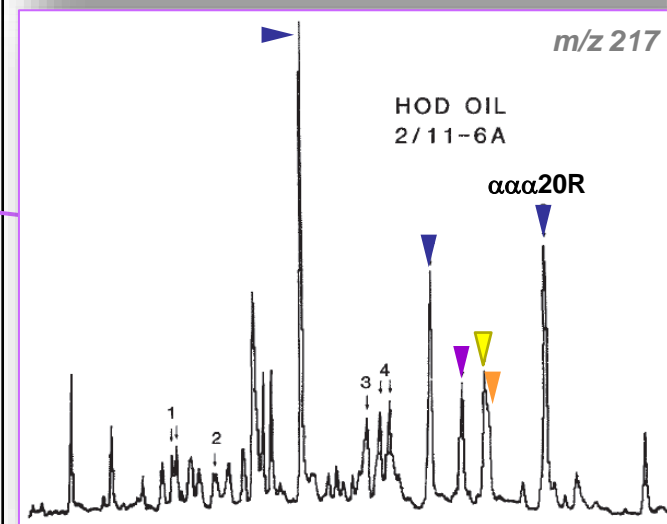
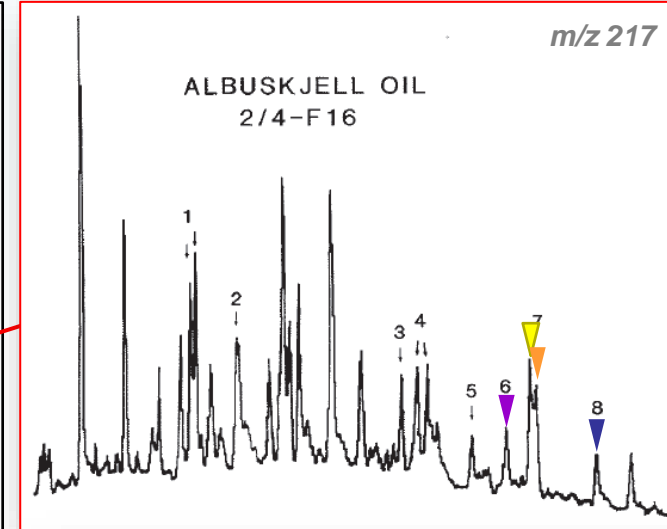
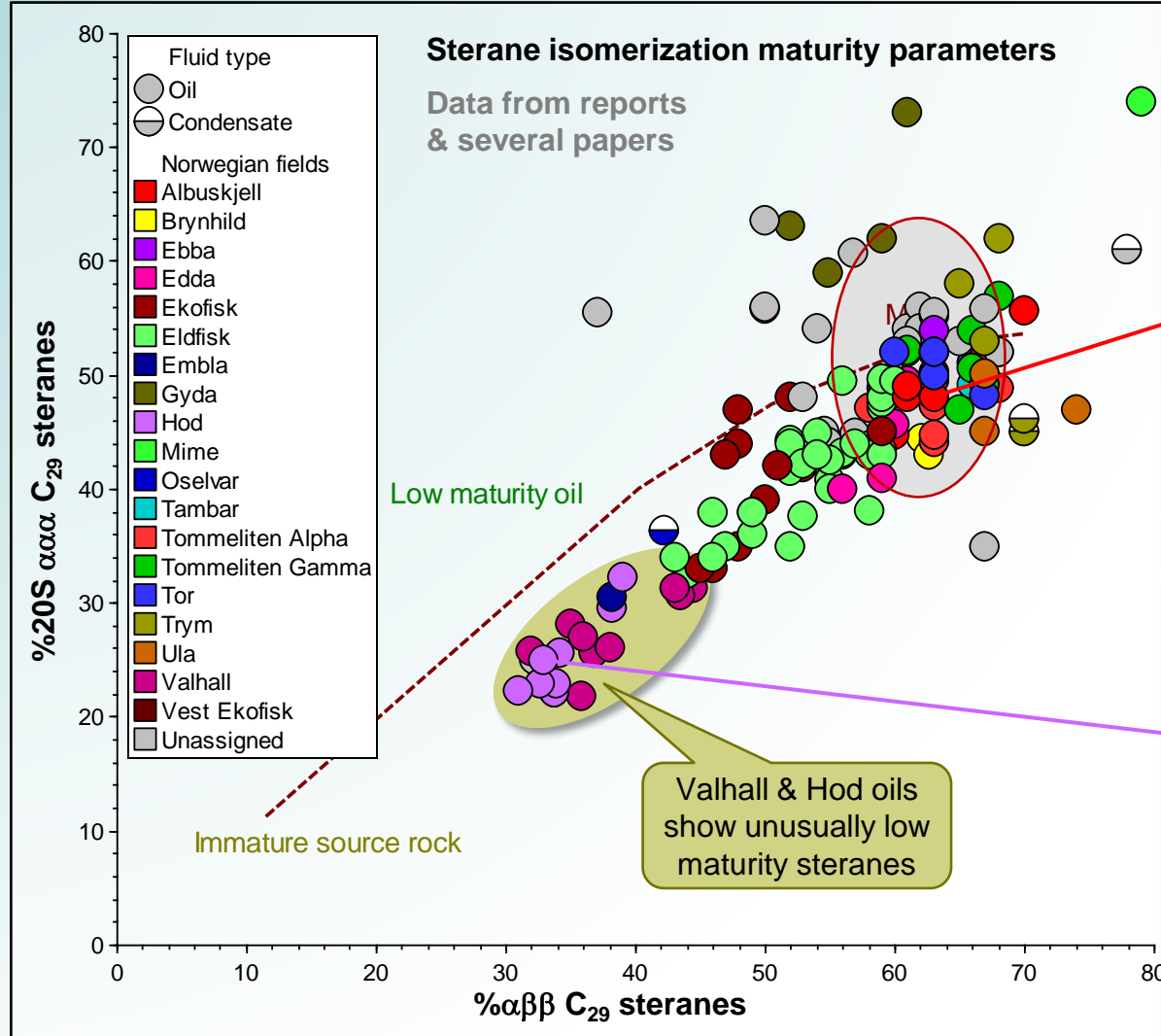


Leaching of immature biomarkers

Example: Hod & Valhall Fields (North Sea)

Released data

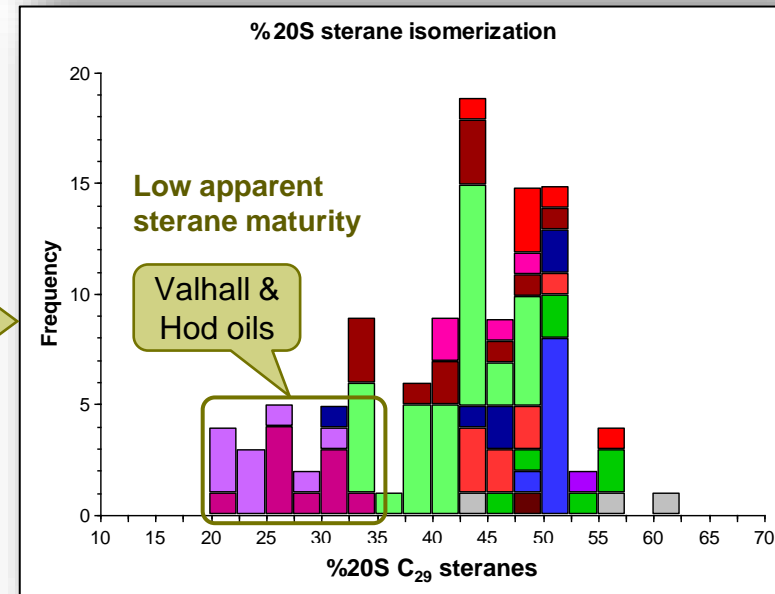
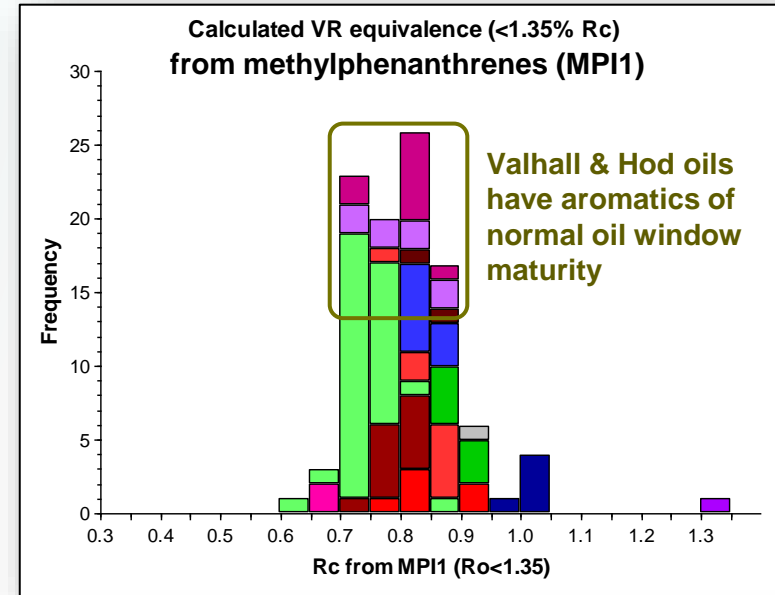
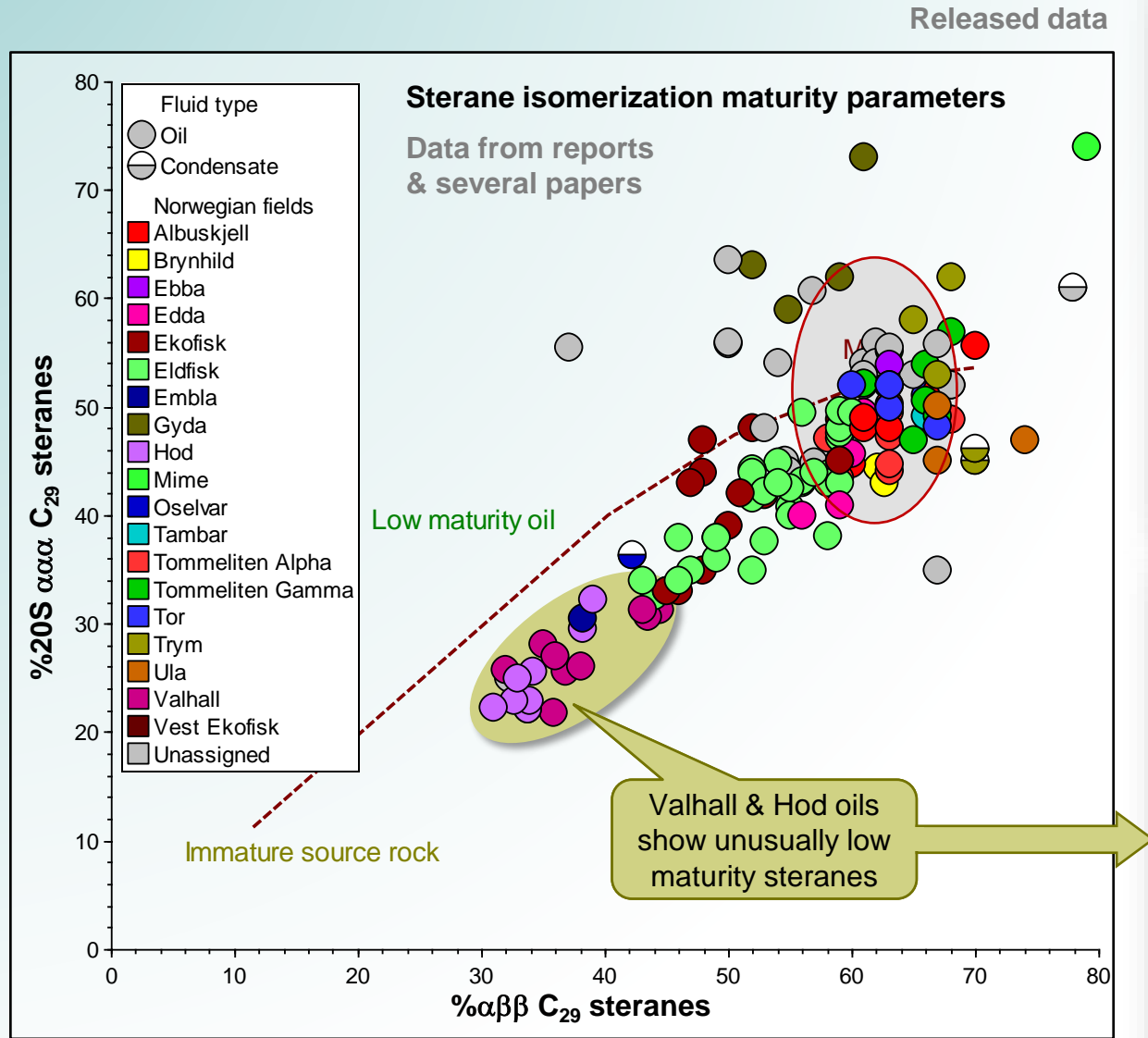
Hughes et al. (1985)



Hughes et al. (1985). In: "Petroleum Exploration of the Norwegian Shelf", 75-92.

Leaching of immature biomarkers

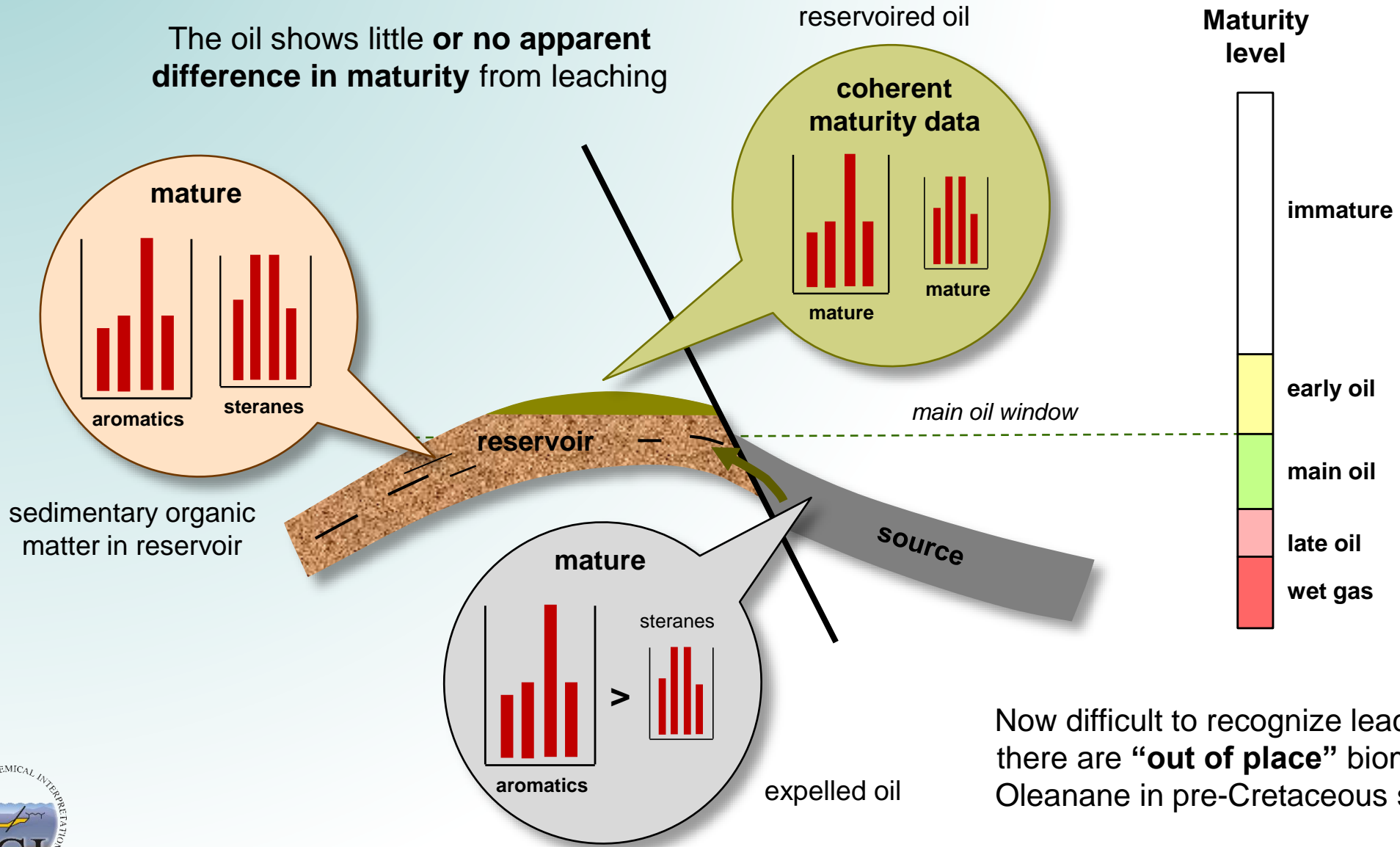
Example: Hod & Valhall Fields (North Sea)



Leaching of mature organic matter

Little influence on maturity parameters

The oil shows little or no apparent difference in maturity from leaching

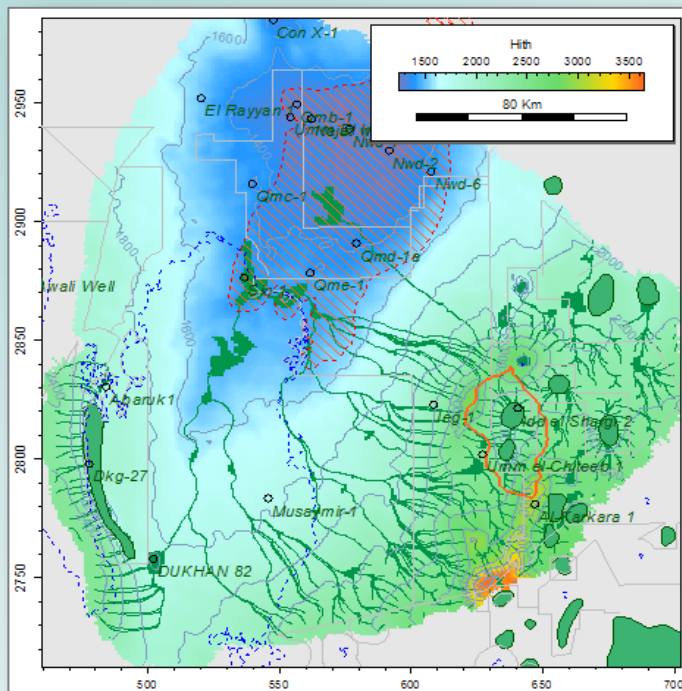


Now difficult to recognize leaching, unless there are “out of place” biomarkers (e.g. Oleanane in pre-Cretaceous sourced oils)

Significance of leaching

Potential impacts & precautions

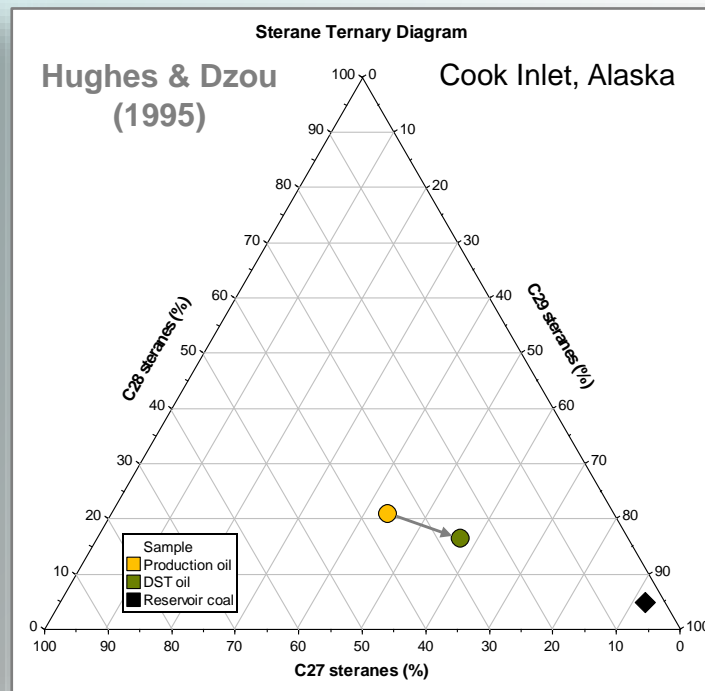
Error in maturity interpretation



Incorrect calibration of models

- Over-estimation of generation

Error in source assignment



Incorrect correlation & sourcing

- Oleanane: incorrect age
- C₃₀ steranes (marine markers)
- Coaly biomarkers

Precautions to be taken:

- Check for **unsaturated biomarkers** (diasterenes)
- Identify any evidence of unusually **low maturity biomarkers** (any imbalance with aromatics & gasolines)
- Consider possibility of “**out of place**” biomarkers
- Is the oil likely to show leaching ? (condensate or very light oil with **low biomarker concentrations**)

Summary

Take home messages

All oils normally show mixed maturity signals

- Different compound classes are biased to different stages of generation

High maturity charges are not seen in the biomarkers

- But can be seen in gasolines, diamondoids & bulk properties

Unusually immature oils often the result of leaching

- Biomarkers typically immature, aromatics are usually normal

Leaching creates problems for interpretation

- Use compounds other than biomarkers

Leaching is especially problematic for:

- Gas condensates & light high maturity oils
- Interbedded (stacked) reservoirs (often Tertiary)

Leaching is more common than generally thought

- The process happens all the time
- Often not significant enough to be seen

Acknowledgements



Falkland Islands example
(Farrimond *et al.*, 2015b)



Barmer Basin example
(Farrimond *et al.*, 2015a)



NORWEGIAN
PETROLEUM
DIRECTORATE

Released data for the
Norwegian North Sea



Key take home messages:

All oils are mixtures

High maturity charges are
not seen in the biomarkers

Leaching creates problems
for interpretation...

...and is more common
than generally thought