

# **Source Rock Mapping using Fluid Inclusion Geochemistry in the Offshore Perth Basin\***

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## **Abstract**

The fill history of petroleum reservoirs is often a prolonged process where oils represent multiple oil charge events. Oils trapped in fluid inclusions (FI) are contained in sealed time capsules and can be used to track petroleum systems through geological time. This case study from the offshore Perth Basin presents geochemical data from seven FI and crude oils, together with new data on source rocks and oil stain which were used for the mapping of effective source rocks in this region.

In the Abrolhos Sub-basin, Cliff Head FI and reservoir oil from Permian strata sealed by Kockatea Shale (KS) are very similar and sourced by the Hovea Member of the basal KS. Evidence for a KS source includes a high wax content, a low Pr/Ph ratio, high abundance of extended tricyclic terpanes, and the highly diagnostic C33 n-alkylcyclohexane (ACH 33) anomaly.

FI oils from Permian strata of three wells to the west and northwest of the Cliff Head oil field come from a region where the KS was previously thought to be an ineffective source rock. Hadda-1 FI oil is extremely waxy, shows the ACH 33 anomaly and other features consistent with a major KS input. FI oils from Flying Foam-1 and Leander Reef-1 are less waxy but also show typical KS markers. However, FI oils from Hadda-1 and Flying Foam-1 also differ from the Cliff Head oils, e.g. have higher abundances of C19 tricyclic and C24 tetracyclic terpanes. This may reflect facies variations of the KS or charge from an additional source unit. Direct evidence for the latter comes from Leander Reef-1 FI oil that has a heavy n-alkane <sup>13</sup>C isotope signature more consistent with a deeper terrestrial source.

In post-Triassic successions, FI oils from Houtman-1 in the Houtman Sub-basin and from Gage Roads-2 in the Vlaming Sub-basin have different source characteristics. Houtman-1 FI oil from the Middle Jurassic Cadda Formation may be derived from the Early Jurassic

Cattamarra Coal Measures, with a possible contribution from an unknown lacustrine source. Gage Roads-2 FI oil from the Early Cretaceous Carnac Formation is derived from source rocks of relatively low maturity containing a high proportion of Araucariacean-type land-plant organic matter typical for the Early Cretaceous Parmelia Group and Late Jurassic Yarragadee Formation. Collectively the geochemical evidence indicates that the KS is an effective source rock in the Abrolhos Sub-basin, greatly extending the proven distribution of this oil-prone source rock.

### References

- Jones, A.T., J.M. Kennard, C.J. Nicholson, G. Bernardell, D. Mantle, E. Grosjean, C.J. Boreham, D.C. Jorgensen, and D. Robertson, 2011, New exploration opportunities in the offshore Northern Perth Basin: APPEA Journal, v. 51, p. 45-78.
- Kempton, R.M., S. Gong, J. Kennard, H. Volk, D. Mills, P. Eadington, and K. Liu, 2011, Detection of palaeo-oil columns in the offshore northern Perth Basin; extension of the effective Permo-Triassic charge system: APPEA Journal, v. 51, p. 377-396.
- Peters, K.E., and M.R. Cassa, 1994, Applied source rock geochemistry, *in* LB. Magoon, and W.G. Dow, (eds.), The petroleum system; from source to trap: AAPG Memoir 60, p. 93-120.



# Source rock mapping using fluid inclusion geochemistry in the offshore Perth Basin

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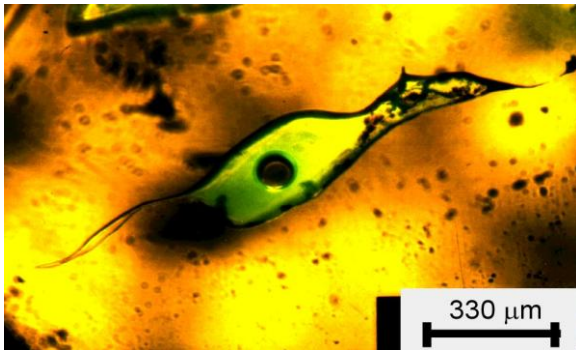
AAPG International Conference & Exhibition, 16-19 September 2012, Singapore

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# Objectives

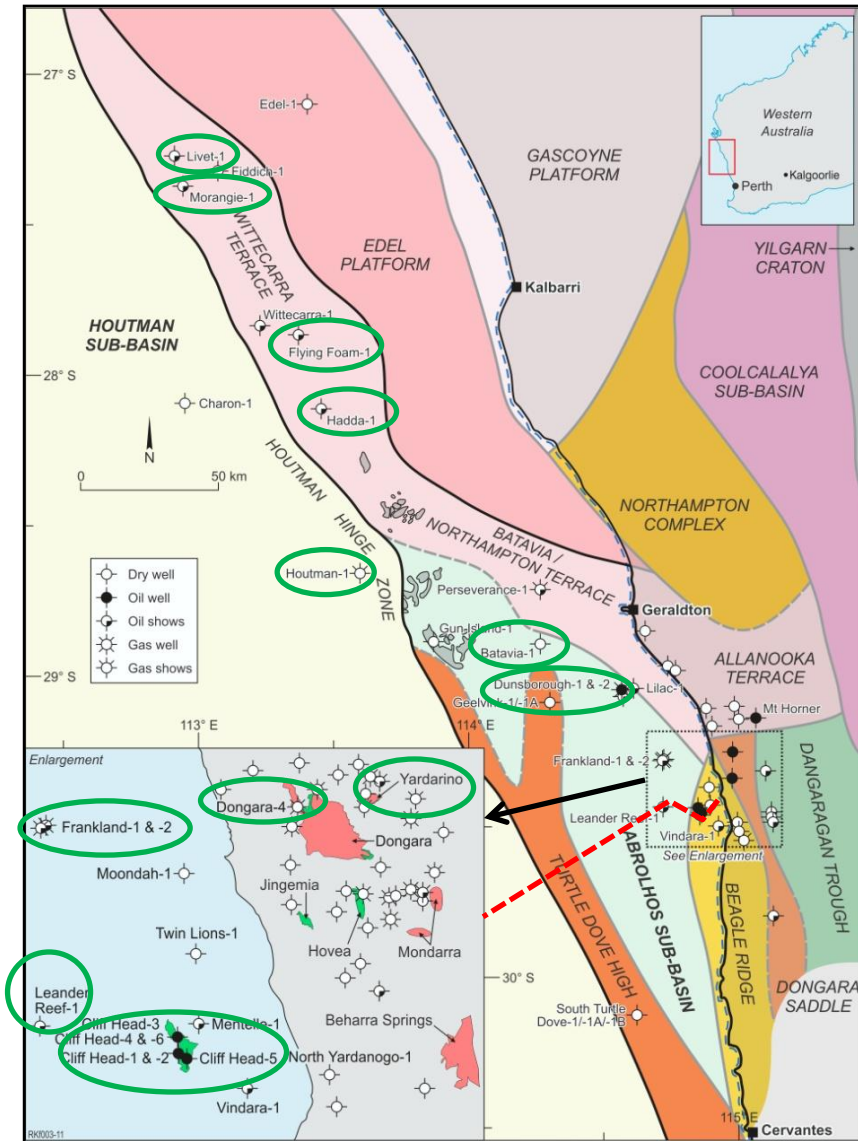
- Invert geochemical information
- Use free oils, oil stains and fluid inclusion (FI) oils
- Map effective source rocks



## Outline

- Study area
- FI petrography and geochemistry
- Molecular and isotope geochemistry
  - oil-source correlation
- Conclusions

# Northern Perth Basin



- Abrolhos Sub-basin

Free oils (1) : Cliff Head-6

FI oils (5) : Cliff Head-3

: Leander Reef-1

: Hadda-1

: Flying Foam-1 (2)

Oil stains (8) : Batavia-1

: Dunsborough-1

: Flying Foam-1

: Frankland-1

: Morangie-1

- Houtman Sub-basin

FI oils (1) : Houtman-1

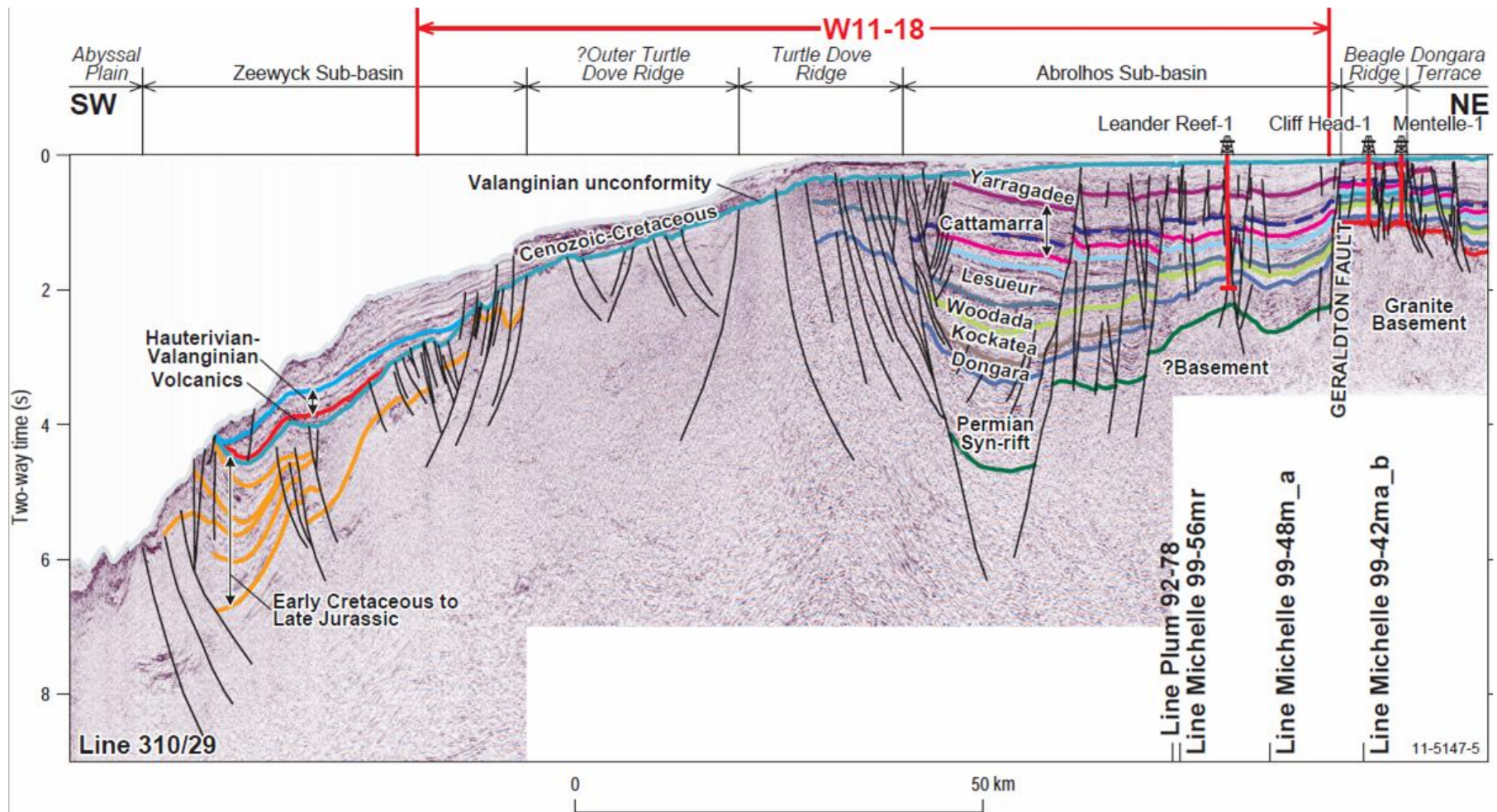
- Dongara Saddle (onshore)

Free oils (2) : Dongara-14

: Yardarino-1

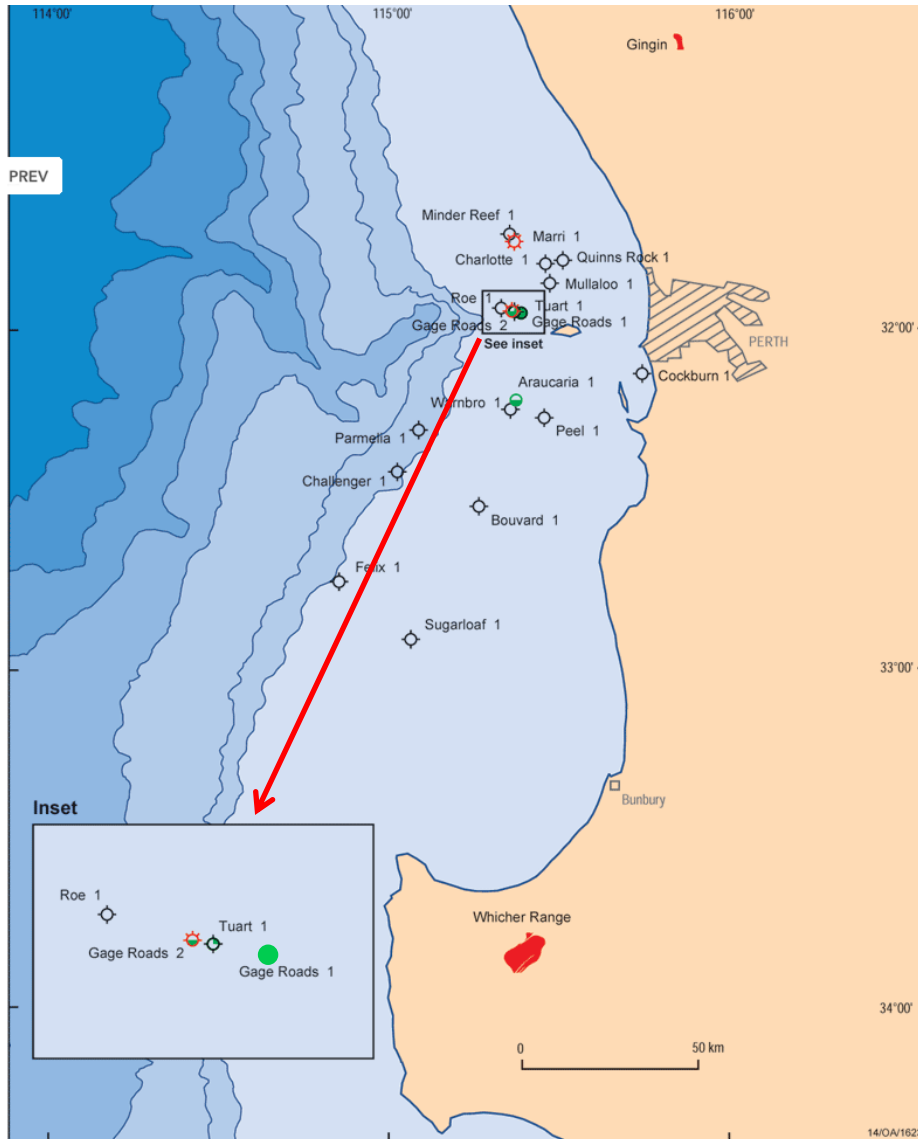


# Cross section Northern Perth Basin



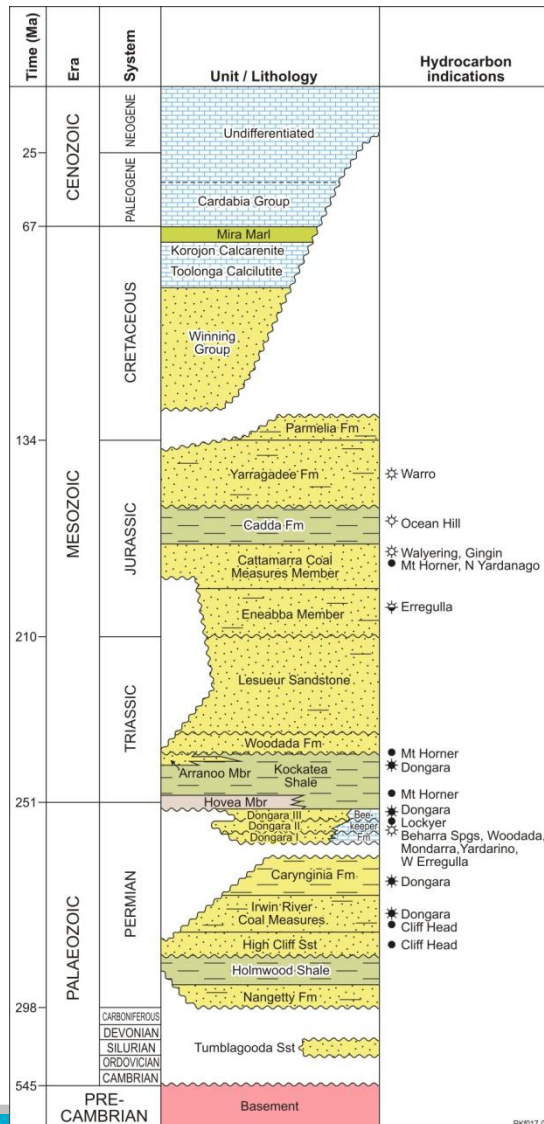
Jones et al., 2011

# Southern Perth Basin



- Vlaming Sub-basin  
FI oil (1): Gage Roads-2

# Source rock candidates



Post breakup  
subsidence

Breakup greater India and Australasia

- ← Lacustrine source pods in Parmelia Fm. ?
- ← Lacustrine source pods in Yarragadee Fm. ?
- ← Marine mudstones Cadda Fm.
- ← Cattamarra Coal Measures
- ← Lacustrine source pods in Eneabba Member ?

3 rifting episodes

- ← Hovea Member of Kockatea Shale (PT extinction )
- ← Marine mudstones Carynginia Fm.
- ← Irwin River Coal Measures



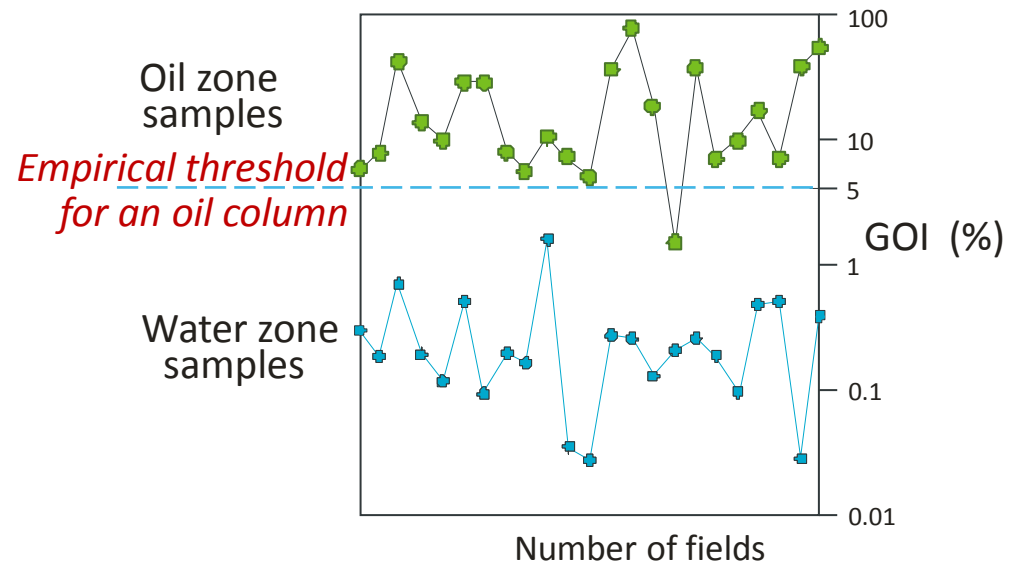
# Fluid inclusion petrography

Grains with Oil  
Inclusions  
(GOI™)

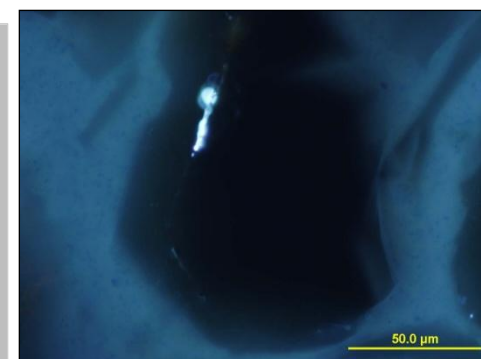
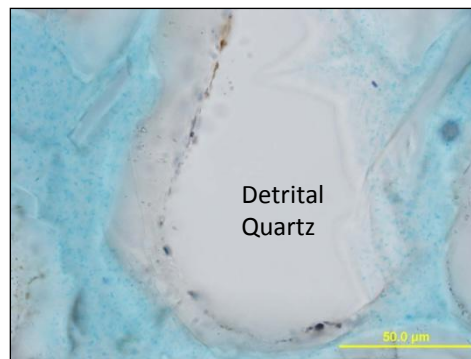
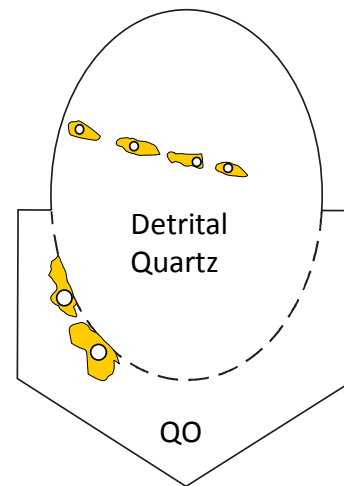
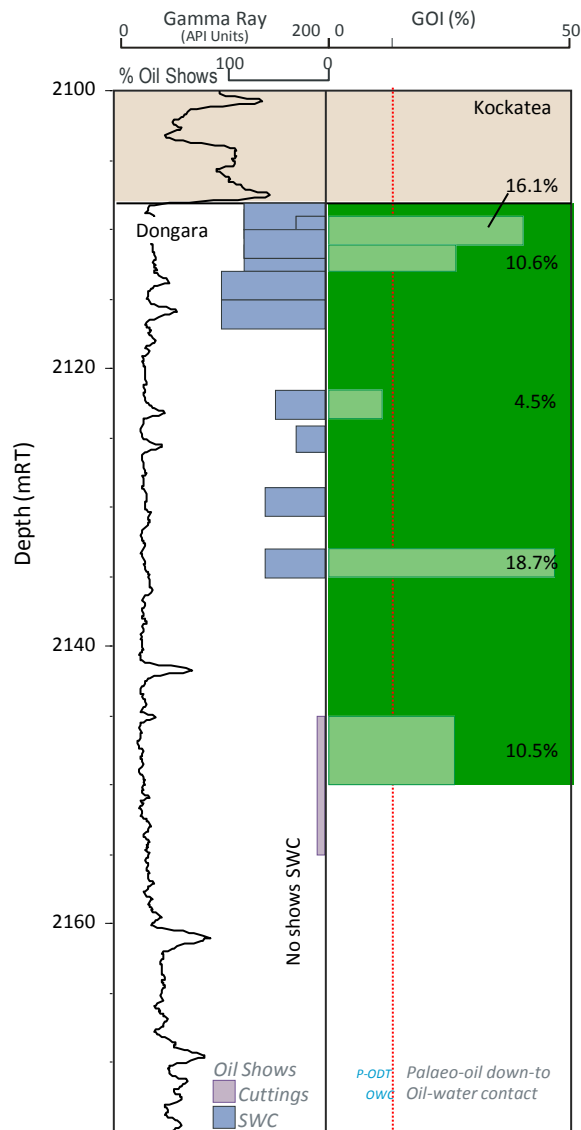


Evidence for Palaeo-oil

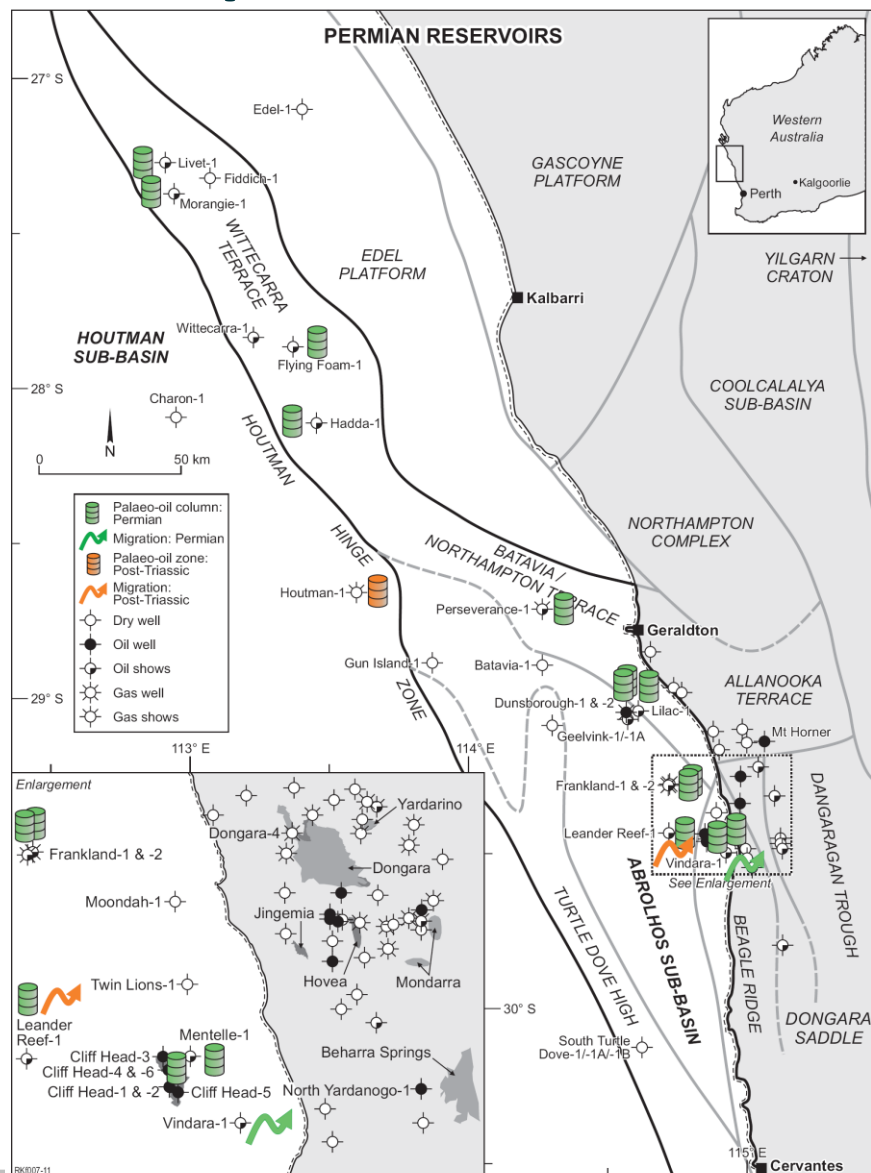
- Accumulation
- Migration



# Palaeo-oil column: example from Morangie-1



# Other palaeo-oil columns

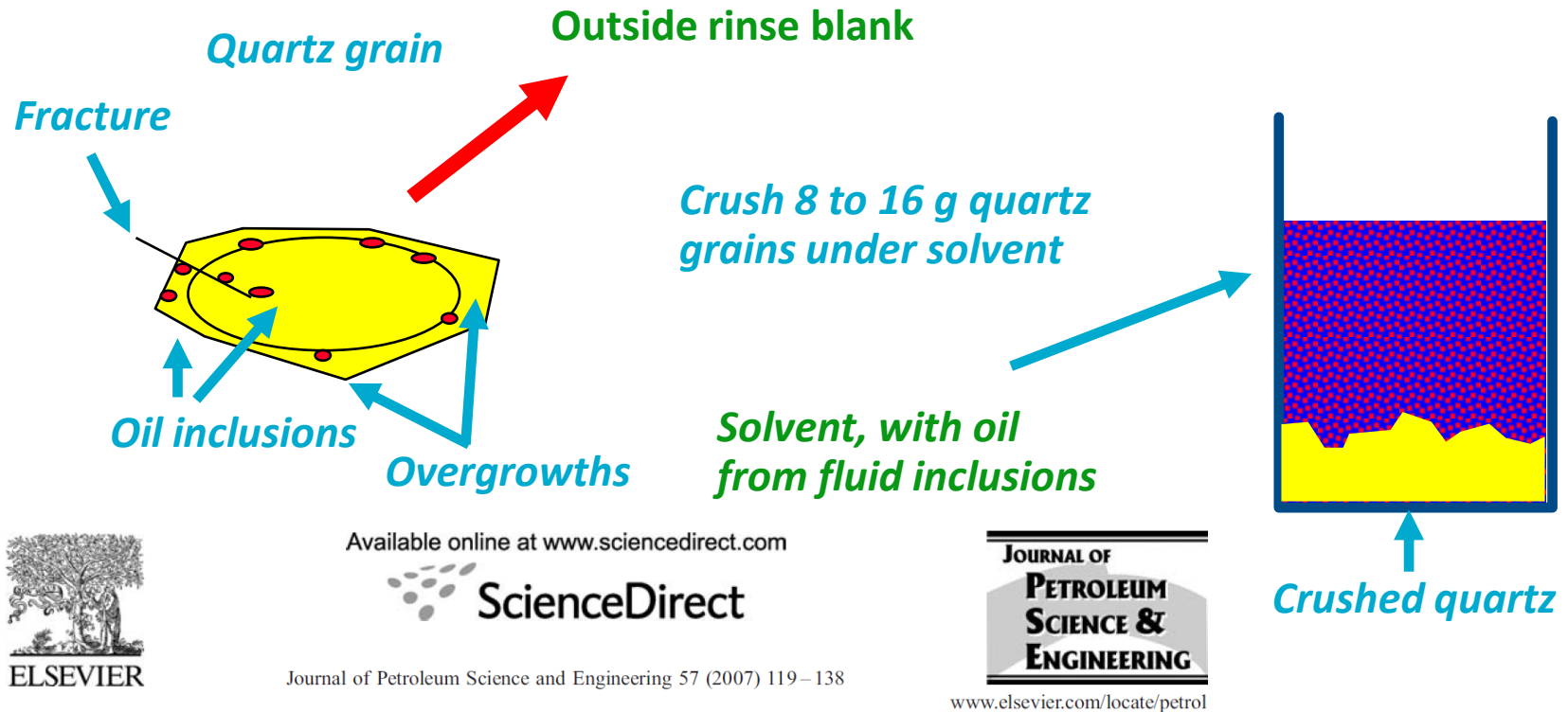


- Permian, Northern Perth Basin
  - 76% of wells have palaeo-oil columns
  - 6% have evidence for migration
  - 18% have no evidence for palaeo-oil
- Jurassic, Northern Perth Basin
  - Palaeo-oil column in Houtman-1
- E. Cretaceous, Southern Perth Basin (Vlaming Sub-Basin)
  - Palaeo-oil column in Gage Roads-2

Kempton et al., 2011

# Molecular Composition of oil Inclusions (MCI)

## Off-line crushing and leaching of inclusion oil



Geochemical analysis techniques and geological applications of oil-bearing fluid inclusions, with some Australian case studies

Simon C. George <sup>a,\*</sup>, Herbert Volk <sup>b</sup>, Manzur Ahmed <sup>b</sup>

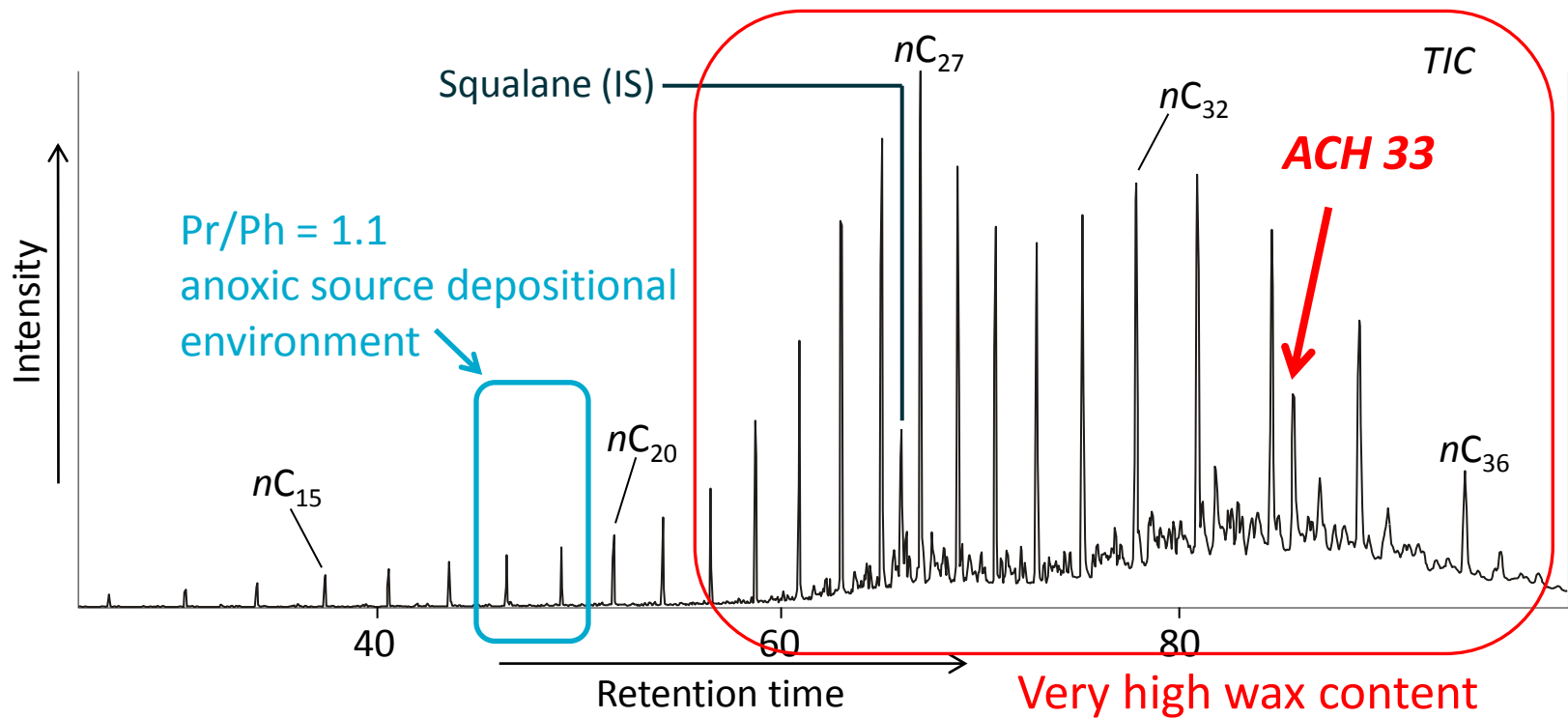
# Hovea member (Kockatea Shale) sourced oils

Can be very waxy

Hadda-1 [FI oil]

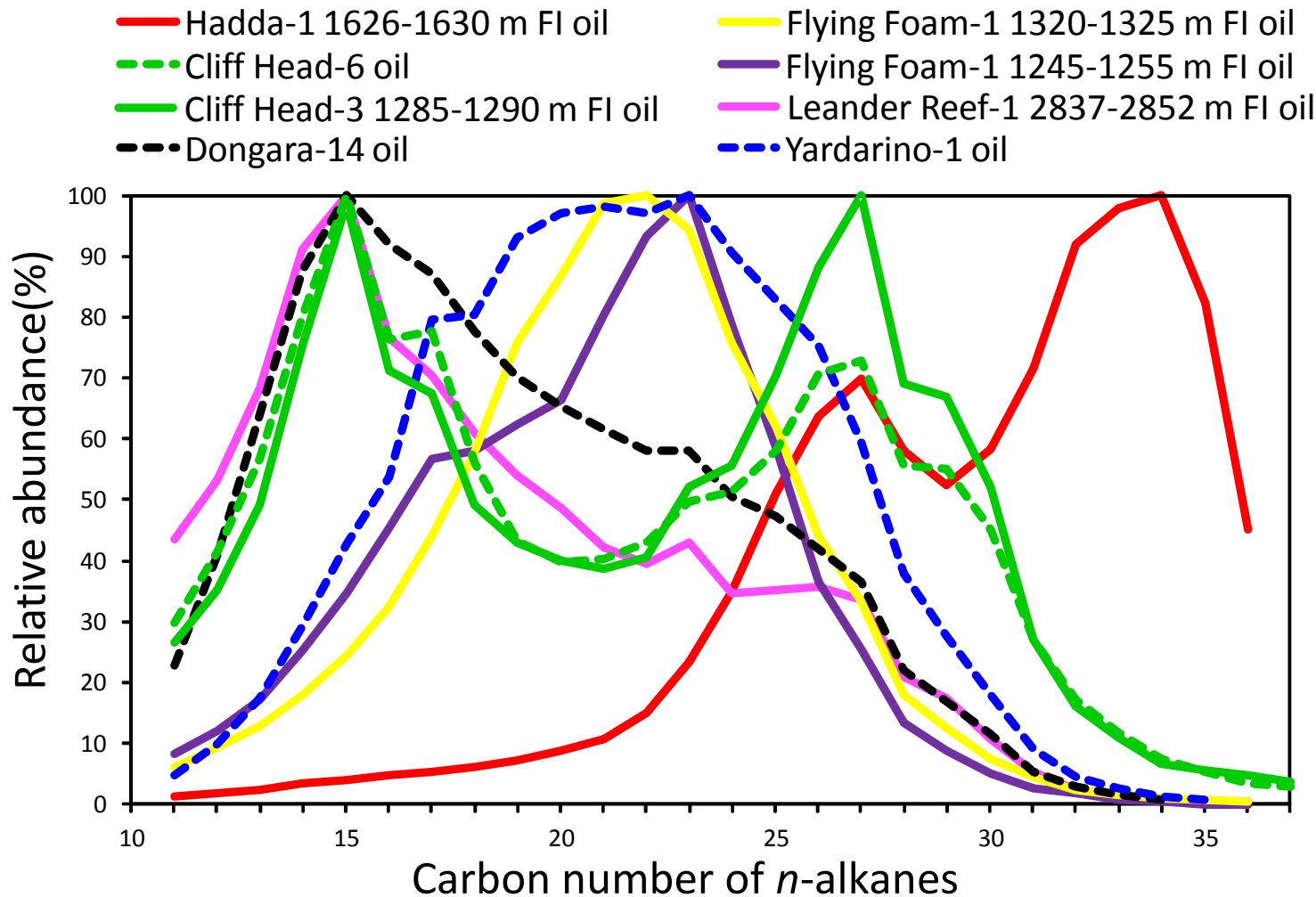
$$CPI_{22-32} = 1.0$$

no odd over even predominance



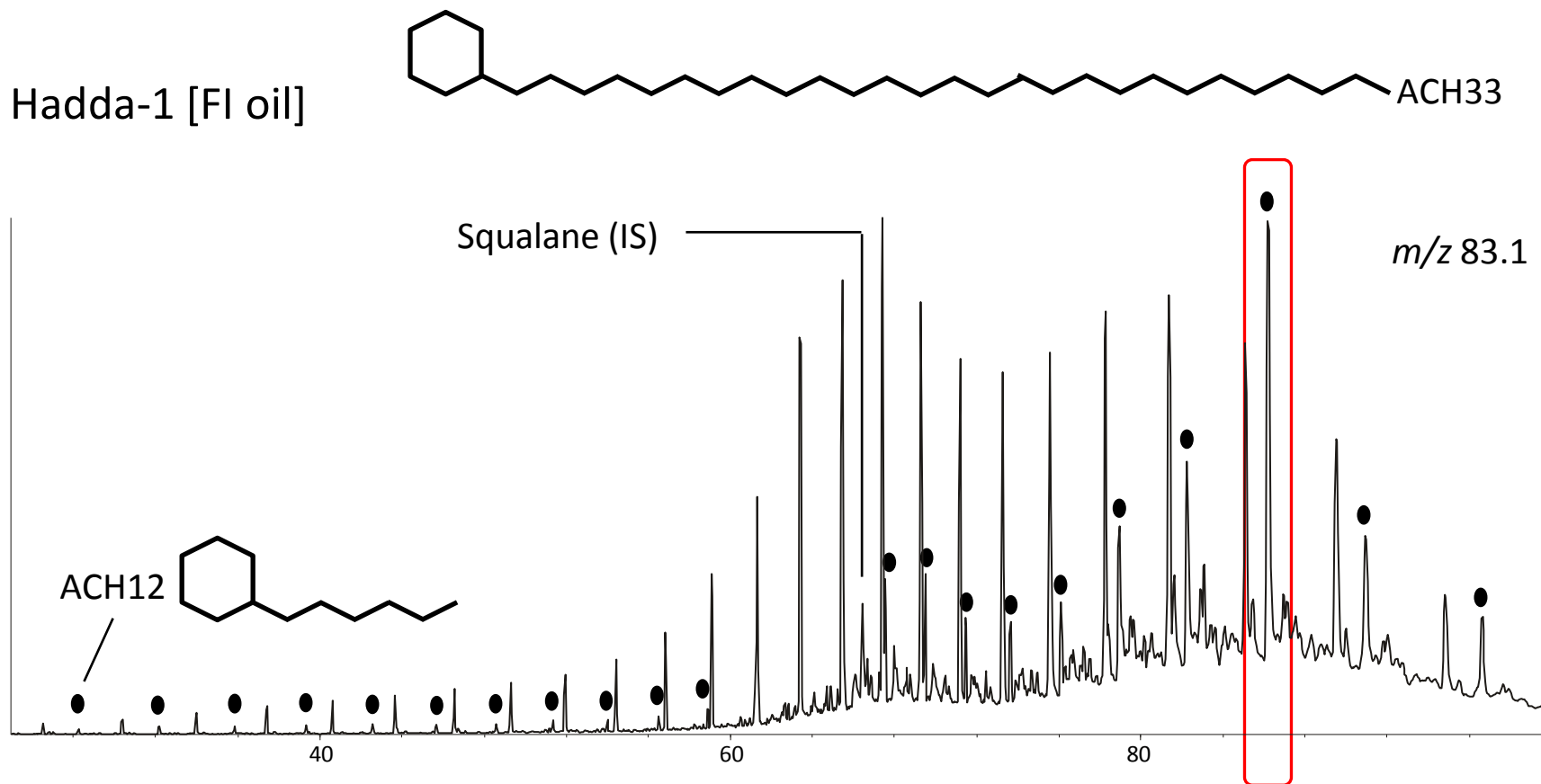


# Vastly different *n*-alkane profiles for oils linked to the Kockatea Shale



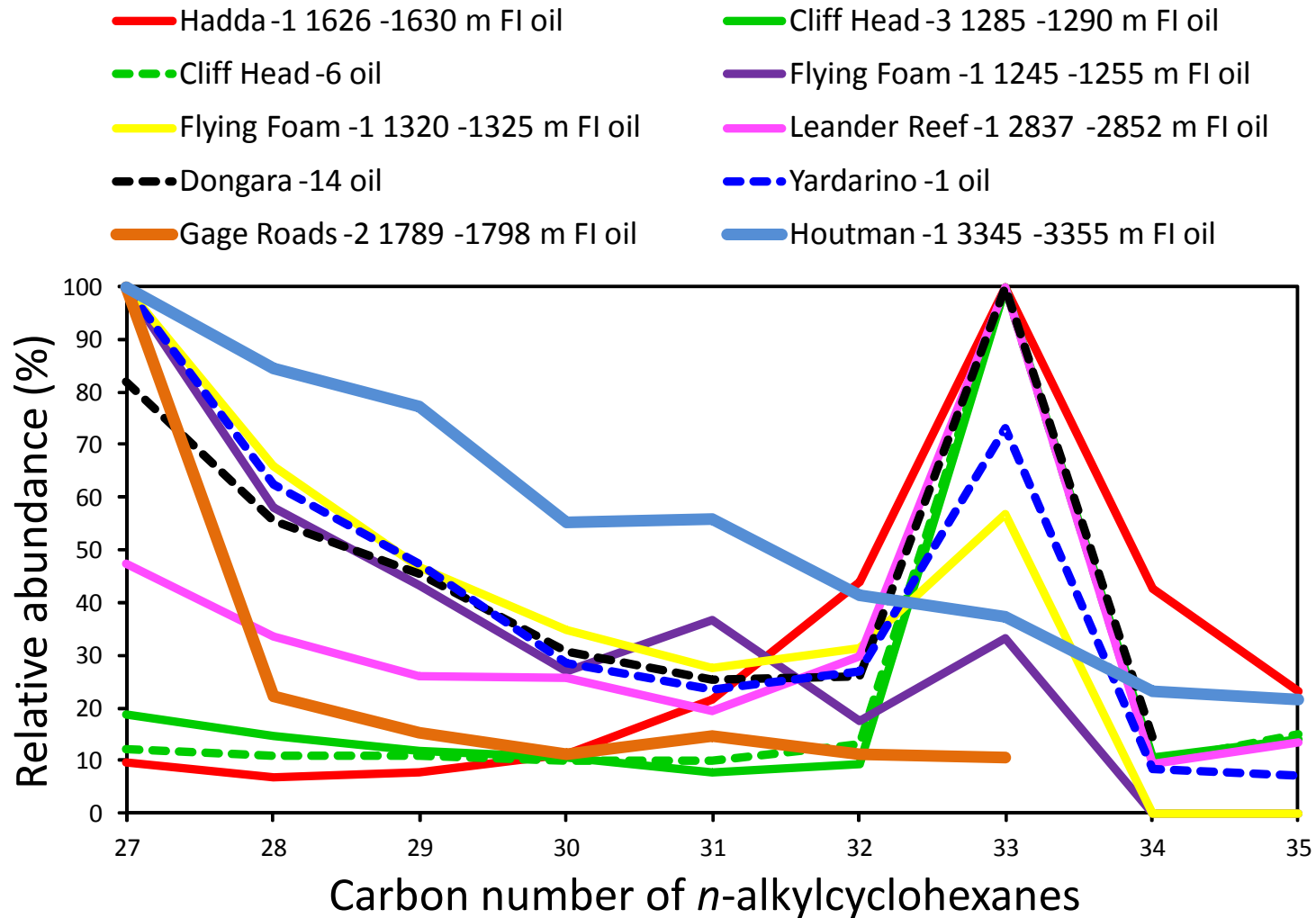
# Hovea Member (Kockatea Shale) sourced oils

## ACH33 anomaly



ACH33 → highly diagnostic biomarker and restricted to the Hovea Member

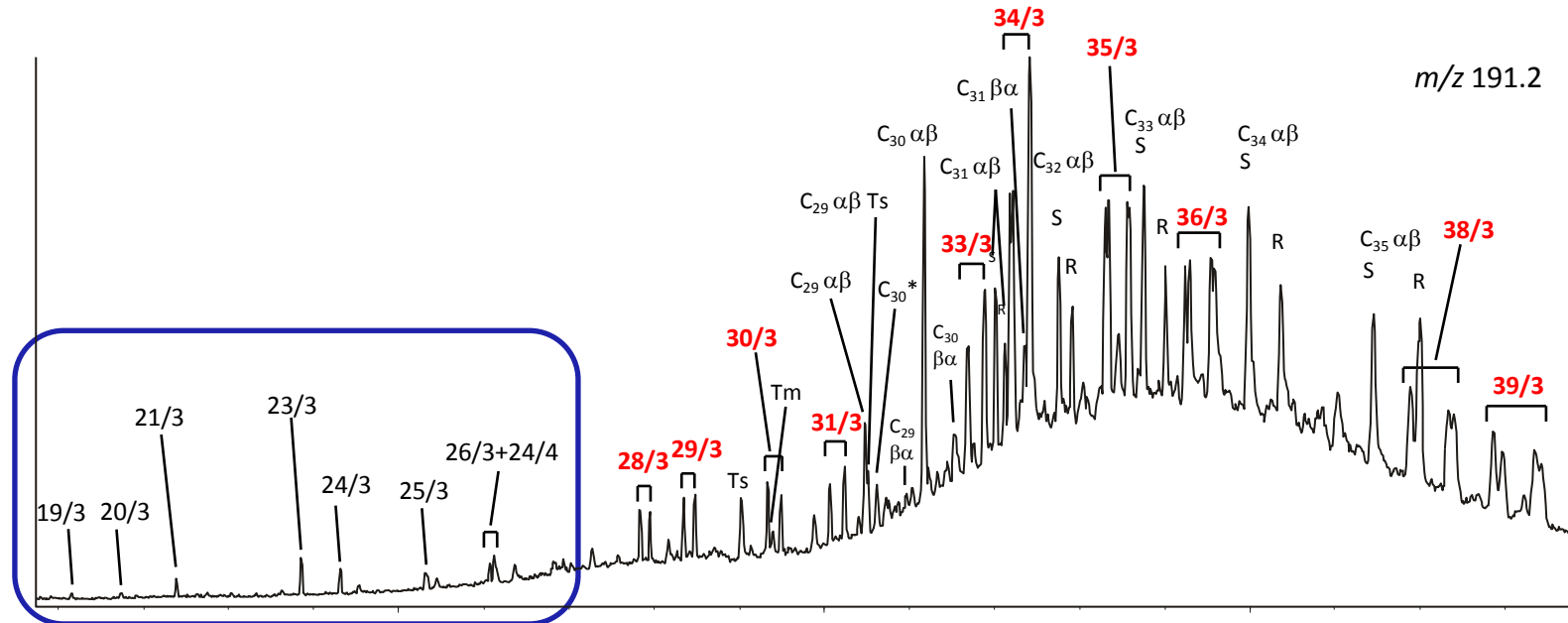
# *n*-Alkylcyclohexane profiles



# Tricyclic terpanes

Hadda-1 [FI oil]

Extended tricyclic terpanes  $C_{28-40}$

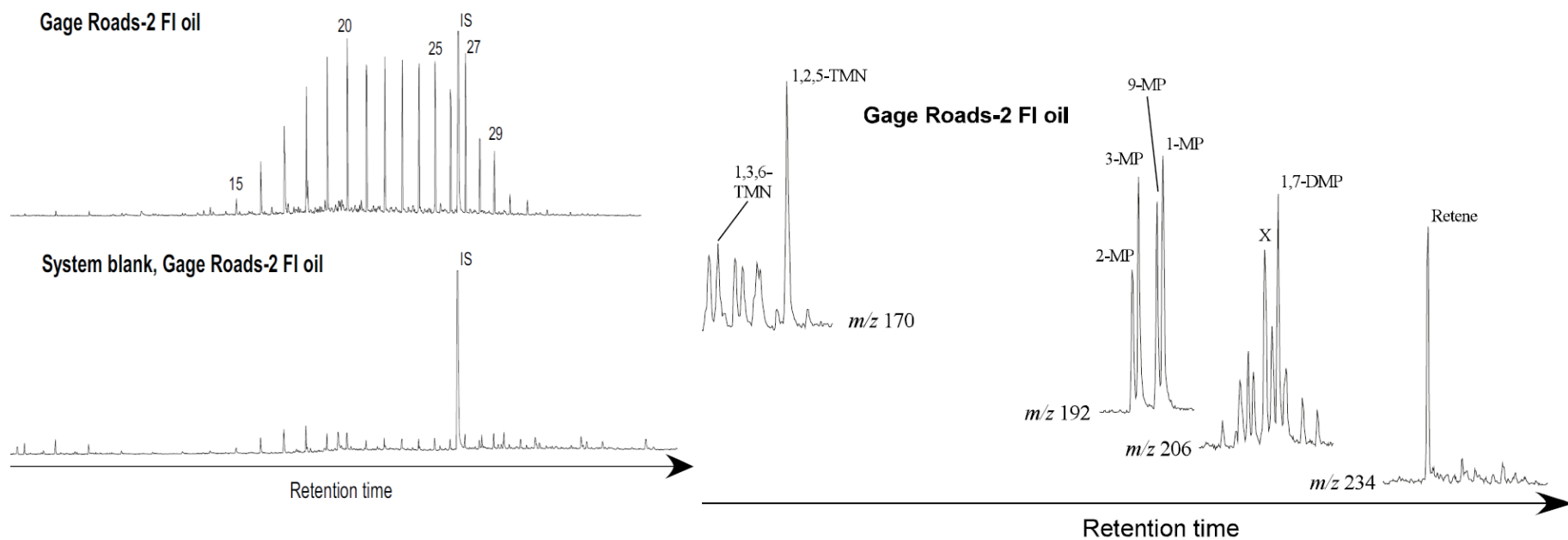


- $C_{21}T$  and  $C_{23}T$  dominant over  $C_{19}T$  and  $C_{24}Te$   
→ minor input from terrigenous OM
- Extended tricyclic terpanes  
→ strong algal contribution

# Oils from Jurassic or Cretaceous formations

## Southern Perth Basin (Vlaming sub-basin)

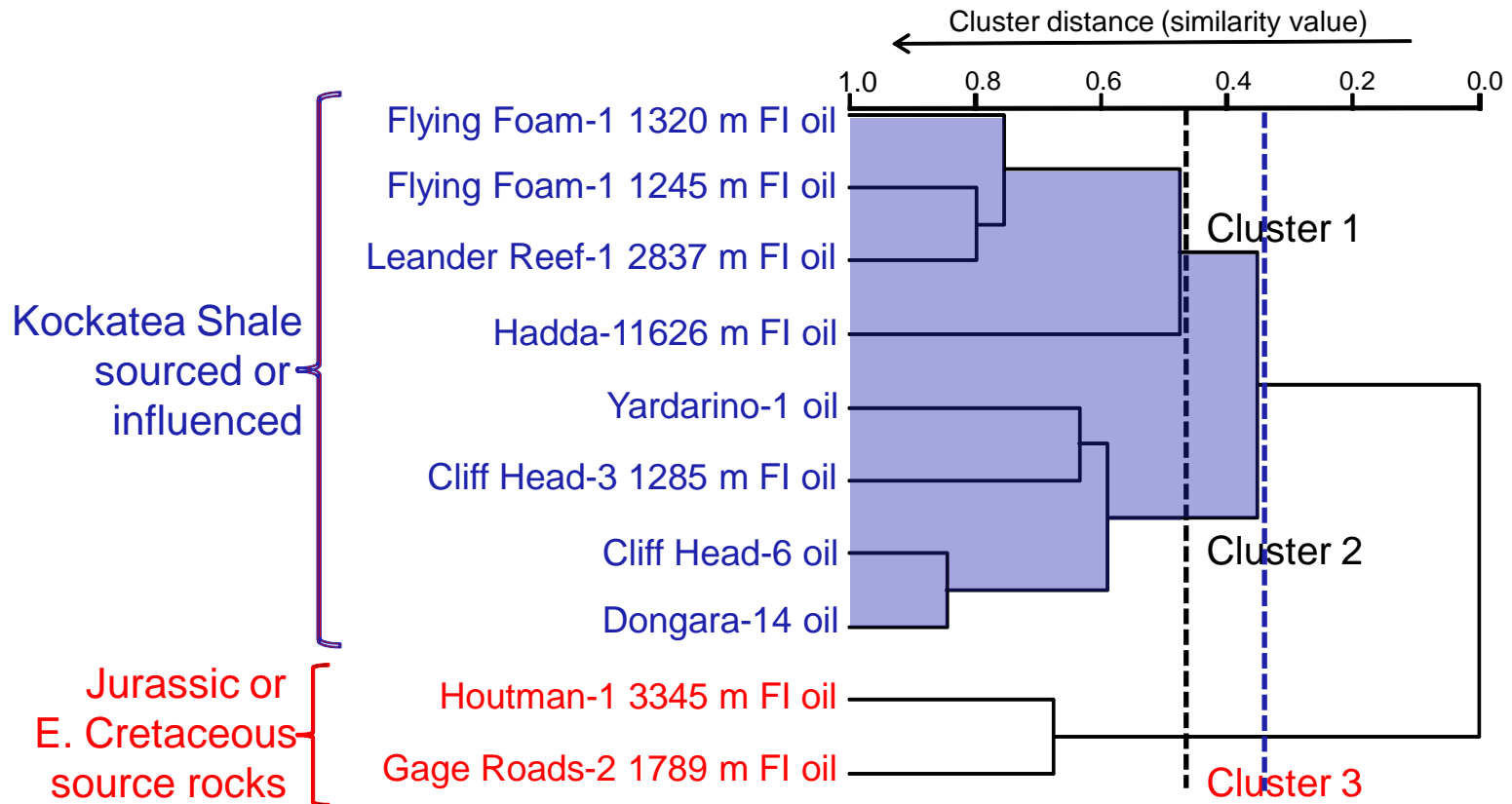
- Gage Roads-2 FI oil
  - Less mature than other fluids of this study
  - Sourced from terrestrial OM
  - High proportion of *Araucariacean*-type land-plant organic matter
  - Derived from L. Jurassic Yarragadee Fm. or E. Cretaceous Parmelia Group





# Multivariate statistics for correlation -

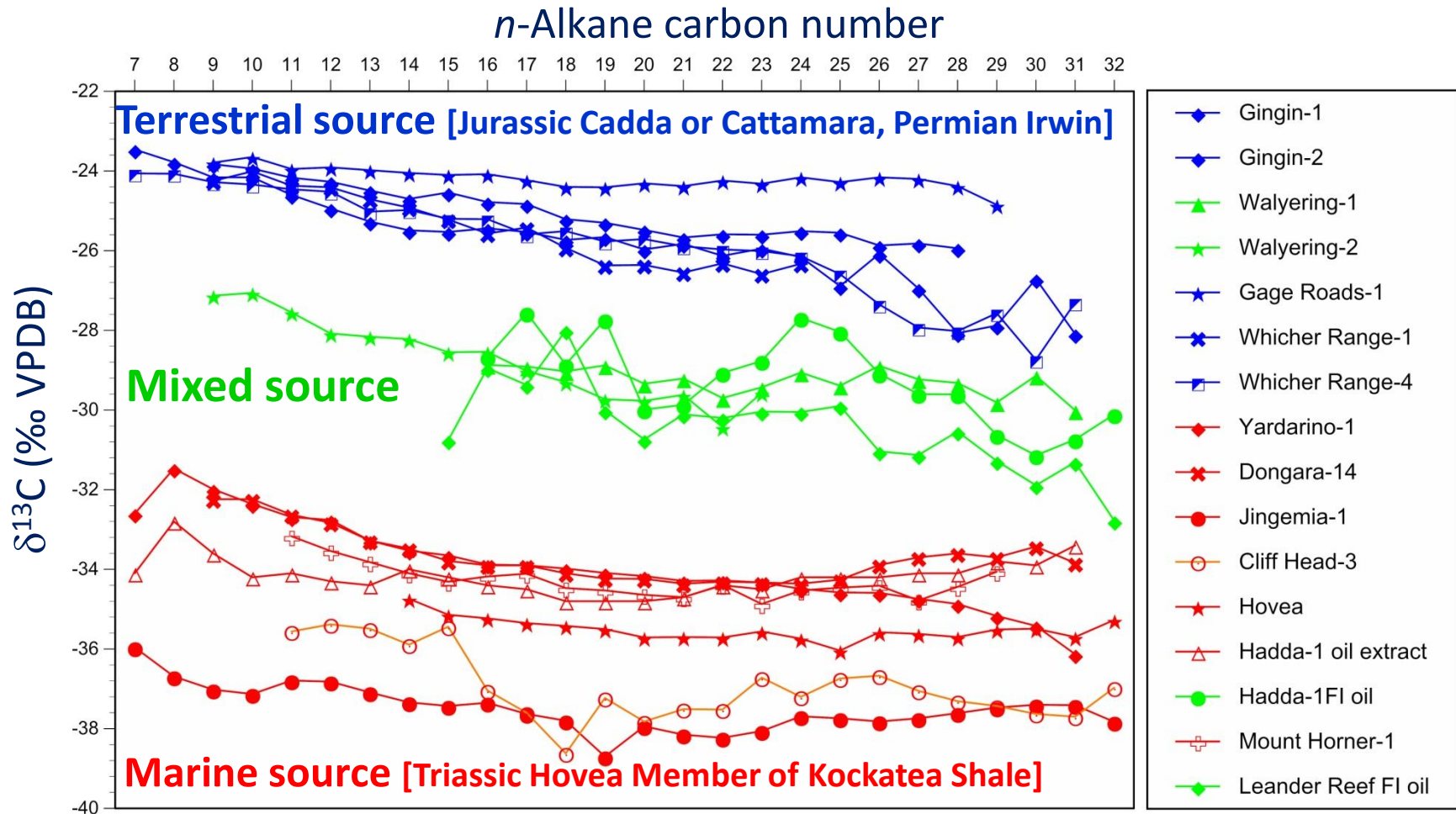
## e.g. Hierarchical Cluster Analysis



### Source specific molecular parameters

- Pr/Ph
- ACH33/ACH32
- $C_{29}$   $\alpha\beta$  hopane/ $C_{30}$   $\alpha\beta$  hopane
- $ETR = (C_{28}+C_{29})$  tricyclics terpanes/Ts
- $(C_{28}+C_{29})/C_{23}$  tricyclic terpane
- $C_{32}$  2 $\alpha$  Me/( $C_{32}$  2 $\alpha$  Me +  $C_{31}\alpha\beta$  hopanes)

# Isotopic approach for source correlation



# Conclusions

- Geochemistry of FI oils played important roles in identifying effective source rocks in the largely unexplored offshore Perth Basin
- The Abroholos Sub-basin oils and FI oils generated from or received significant inputs of Early Triassic Kockatea Shale
- The Houtman Sub-basin FI oil originated from E. Jurassic Cattamara CM
- The southern Perth Basin FI oil sourced from L. Jurassic Yarragadee Fm. or E. Cretaceous Parmelia Group

# Thank you

**Organic and Isotope Geochemistry Team**

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# Spare slides



# Conclusions - 1

E. Triassic Hovea Member  
sourced/influenced oils

Livet-1  
Morangie-1  
(stains)

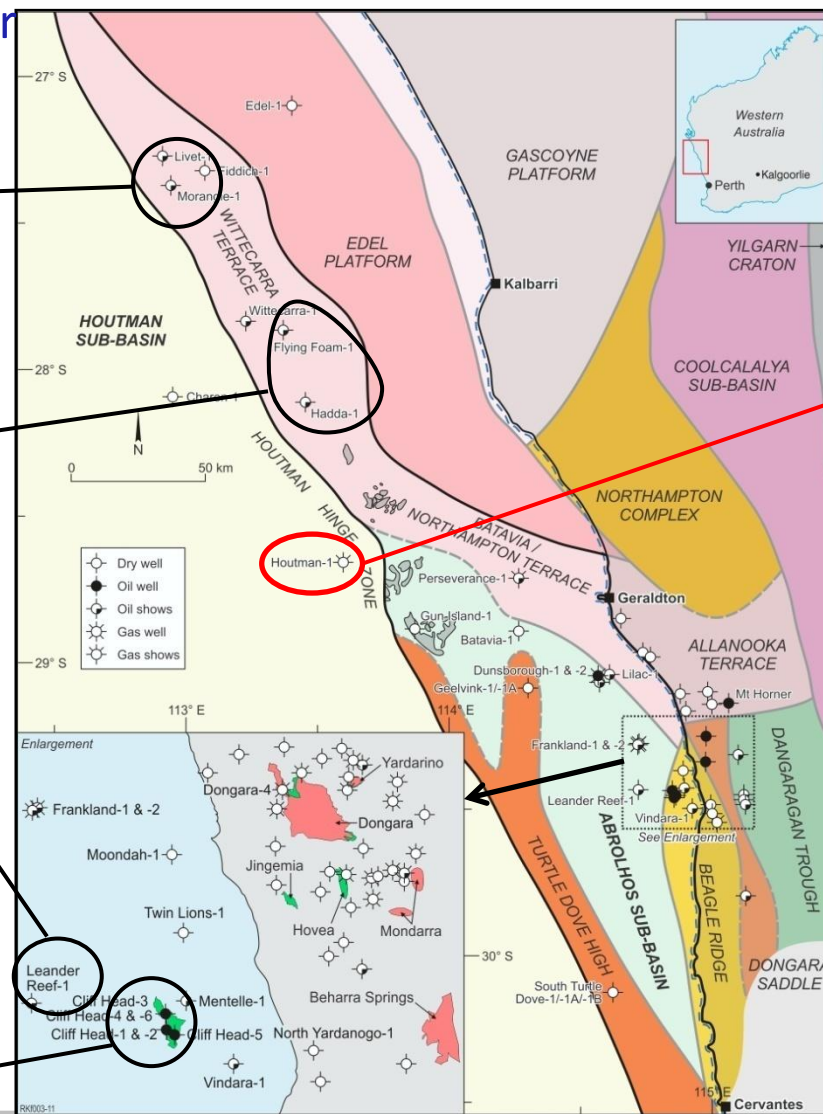
Hadda-1  
Flying Foam-1  
(stains and FI oils)

Leander Reef-1  
(FI oil)

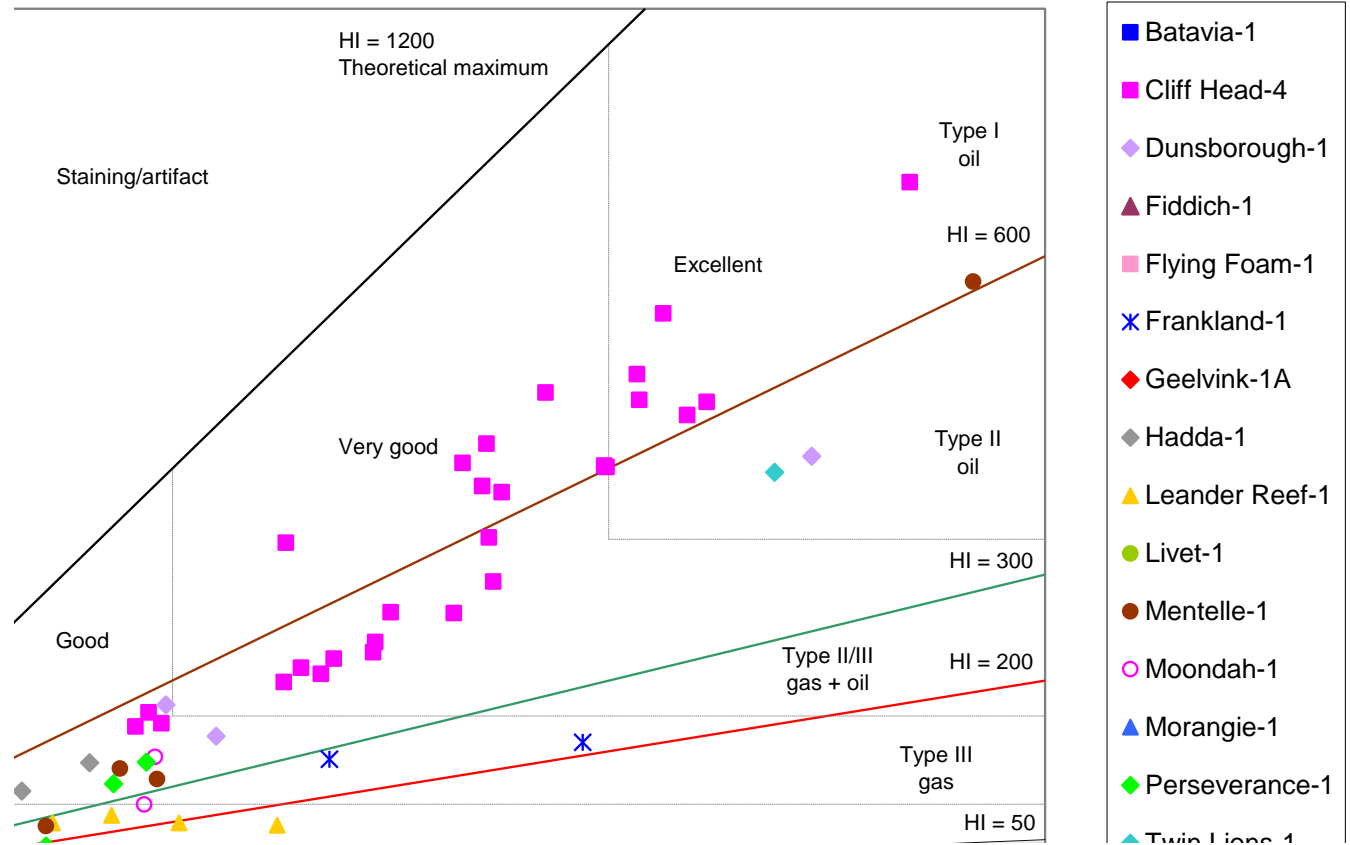
Cliff Head  
(oils and FI oil)

Jurassic  
Cattamra CM/  
Eneabba Fm./  
Yarragadee Fm.  
sourced oils

Houtman-1  
(FI oil)

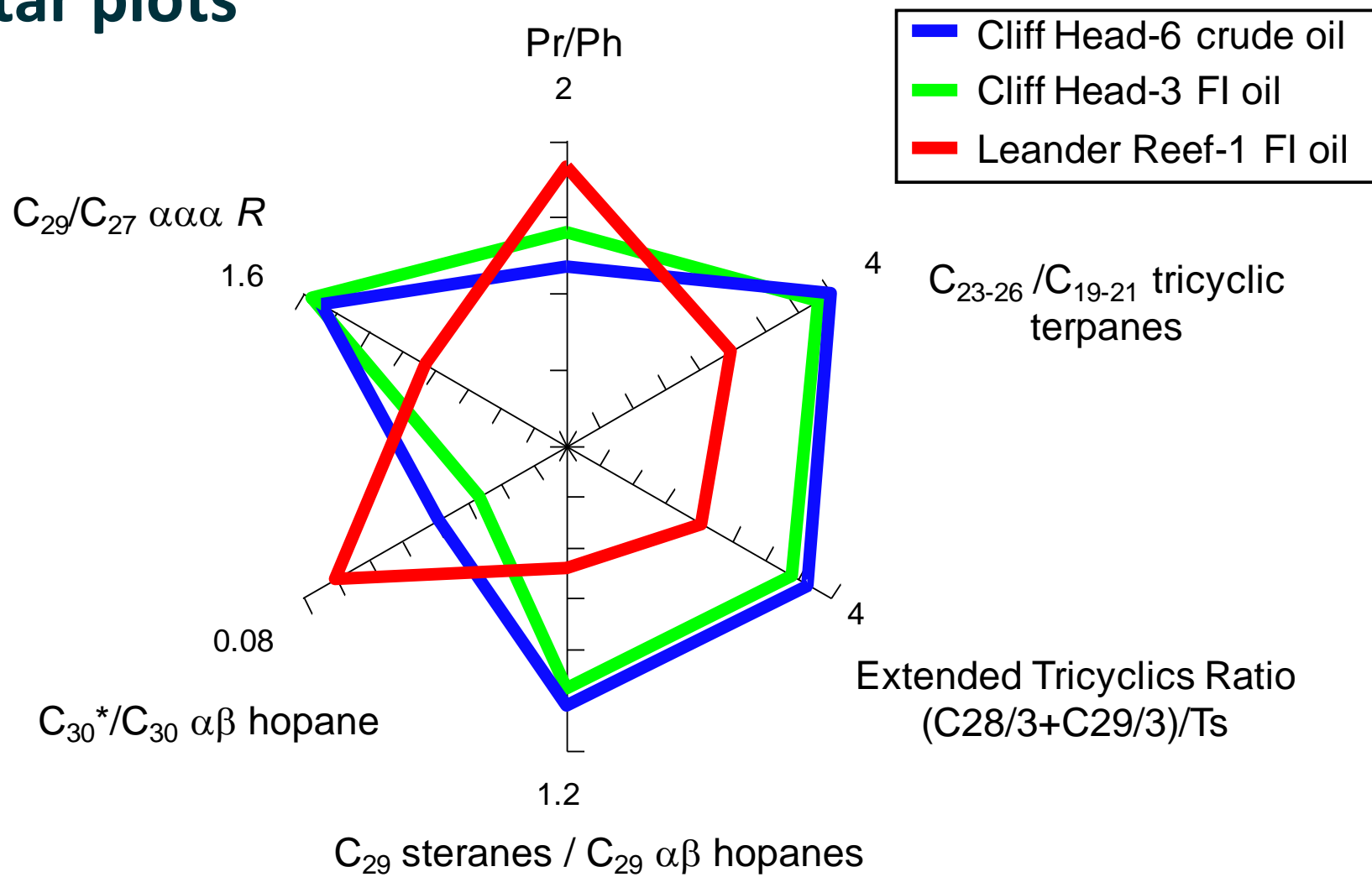


# Hovea Member - Quality and maturity



Fields from Peters and Cassa (1994)

# Molecular approach for oil-oil correlation - Star plots



# Correlating oil stains and source rock extracts using $\delta^{13}\text{C}$ of Saturated HCs and ACH anomaly

