

Using Biodegradation to Date Hydrocarbon Entry Into Reservoirs: Examples From the Cooper/Eromanga Basin, Australia*

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Search and Discovery Article #41749 (2015)**

Posted December 28, 2015

*Adapted from oral presentation given at AAPG/SEG International Conference & Exhibition, Melbourne, Australia, September 13-16, 2015

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Abstract

This study identifies common biodegradation of Cooper/Eromanga Basin (CEB) oils and condensates from changes to the n-alkane and isoprenoid whole oil gas chromatograph (WOGC) hydrocarbon profiles, which because of their generally mild degradation has not been previously identified or has been ignored. Three hydrocarbon families are recognized on the basis of their level of biodegradation (biodegraded, biodegraded with fresh charge, and essentially non biodegraded). A review of biodegradation processes suggests that these families can be related to different reservoir entry temperatures and a scale relating biodegradation to reservoir entry temperature is proposed. The WOGC biodegradation profiles from the CEB oil Families allow a better understanding of reservoir fill history and provide a guide to the approximate temperature range during liquid hydrocarbon reservoir fill in the CEB. Combining the hydrocarbon fill temperature data provided by biodegradation with maturity and temperature data from the basin can help constrain the hydrocarbon charge history of the CEB, and the principles presented can be applied to other basins. The development of a better understanding of reservoir fill timing can then be combined with conventional basin modelling to provide constraints on hydrocarbon expulsion timing.

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Using biodegradation to date hydrocarbon entry into reservoirs: Examples from the Cooper / Eromanga Basin, Australia

Lindsay Elliott

September 2015

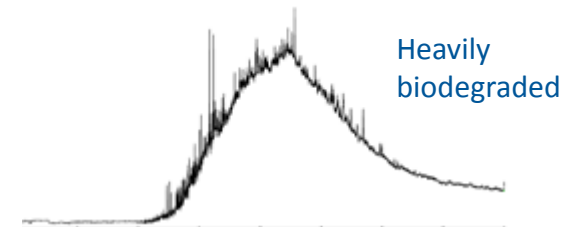
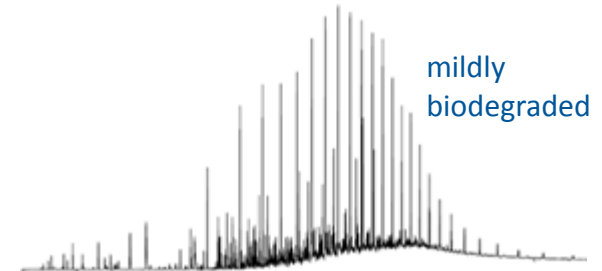
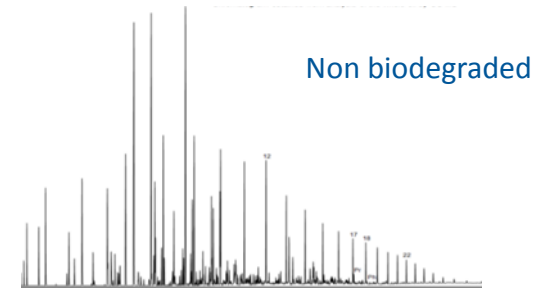
- What is biodegradation?
- How do we recognise it?
- Biodegradation, temperature/maturity and WOGC profiles – Their relationship
- Reservoir Entry timing – using biodegradation as a temperature control in modelling
- Will use examples primarily from the Cooper/Eromanga Basins

Biodegradation is the alteration of hydrocarbons by bacteria

- Affects both liquids and gases, with some gases both degraded by and produced by, bacteria
- Can occur at reservoir temperatures less than $\sim 70^{\circ}\text{C}$
- Usually anaerobic bacteria are responsible in the reservoir; while aerobic bacteria mostly responsible at surface
- Of interest in exploration because changes in biodegradation severity related to temperature can be used in petroleum system modelling

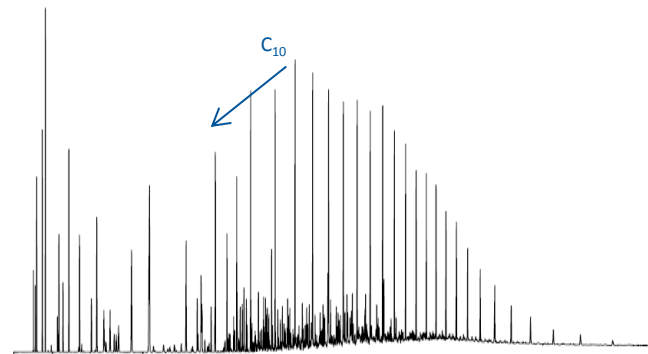
Biodegradation - How do we recognise it?

- Biodegradation can be identified using whole oil gas chromatograph (WOGC)
- In mild cases only the n-alkanes are lost starting at ~nC10
- At higher biodegradation levels isoprenoids followed by conventional biomarkers can be removed
- 25-norhopanes are produced via loss of a methyl group from hopanes at high degradation levels by anaerobic bacteria. 25-norhopanes rare in surface seeps
- Possibility that phytane can be converted to pristane by loss of a methyl group at low - moderate degradation levels

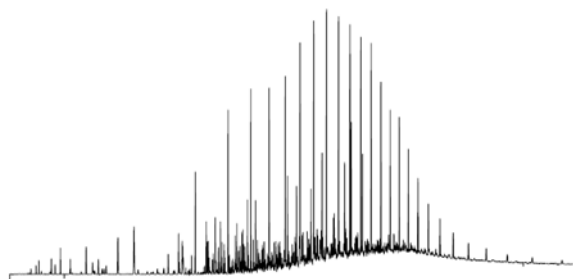


Biodegradation - How do we recognise it?

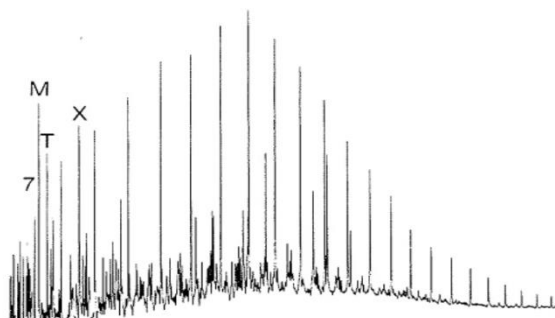
- Biodegradation be distinguished from water washing as water washing only effects n-alkanes up to ~nC10
- Biodegraded WOGC profiles have been misinterpreted as due to 'evaporative fractionation' a process introduced by Thompson (1987, 1988) or 'immature' hydrocarbons



Water washed

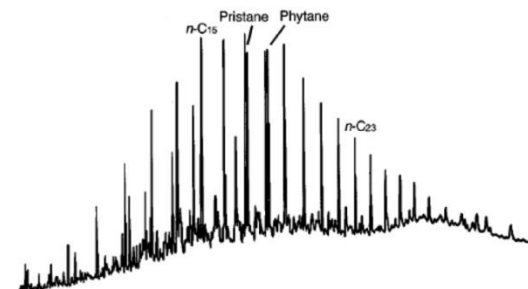


Mild biodegradation



"Evaporative fractionation"

From Thompson (1988)

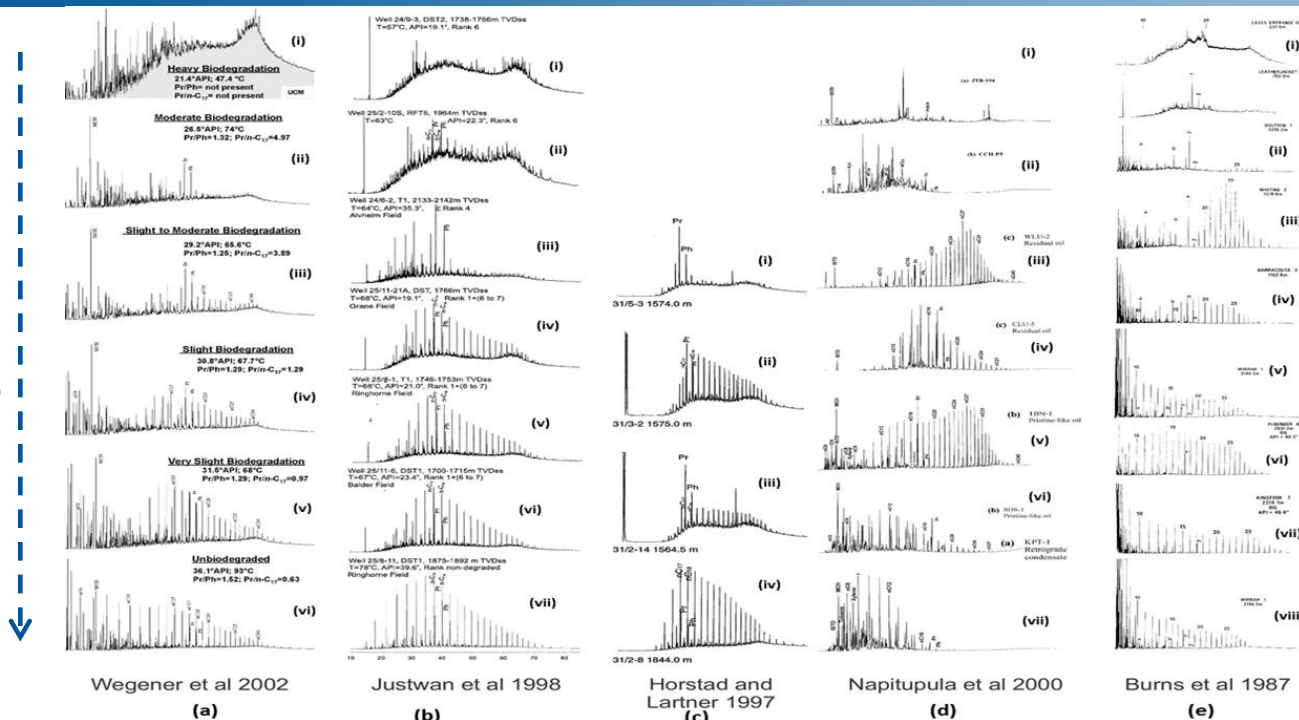


"Immature"

From Peters et al (1995)

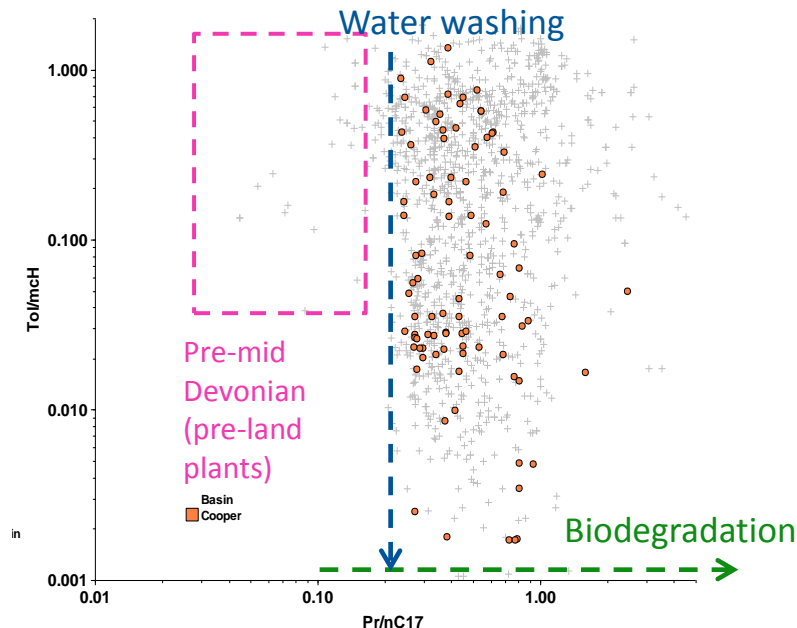
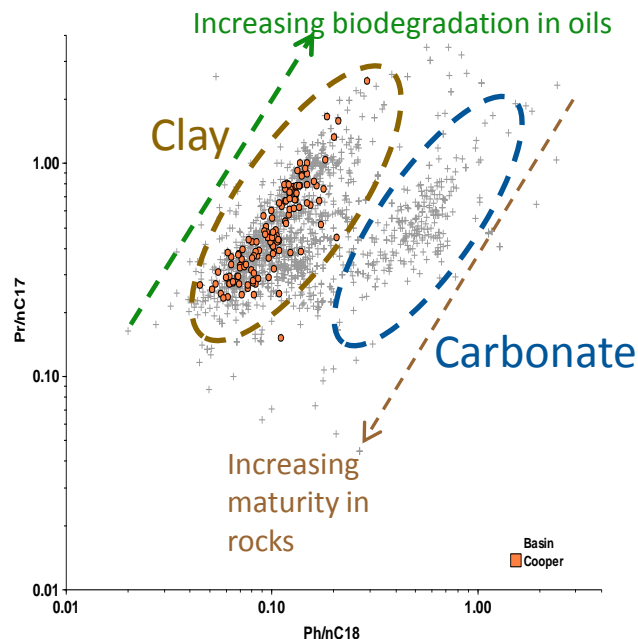
Biodegradation - How do we recognise it?

Increasing
Temperature



- Lots of different WOGC profiles
- Biodegradation is related to reservoir temperature; the lower the temperature, the more biodegradation and greater loss of hydrocarbons

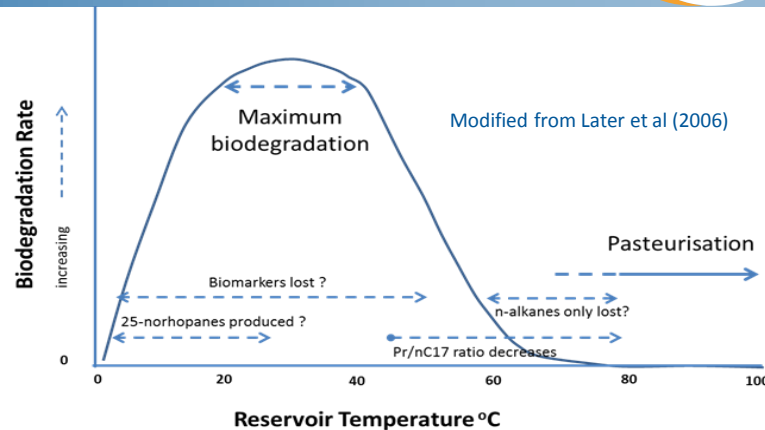
Biodegradation - How do we recognise it?



- $Pr/nC17$ v $Ph/nC18$ plot shows increasing biodegradation in oils and maturity in rock samples – two fields – appears to be clay v carbonate source in oils
- Can determine water washing v biodegradation from T/MCH v $Pr/nC17$
- Field of low $Pr/nC17$ values primarily oils in pre-mid Devonian reservoirs – some source implications for ratio

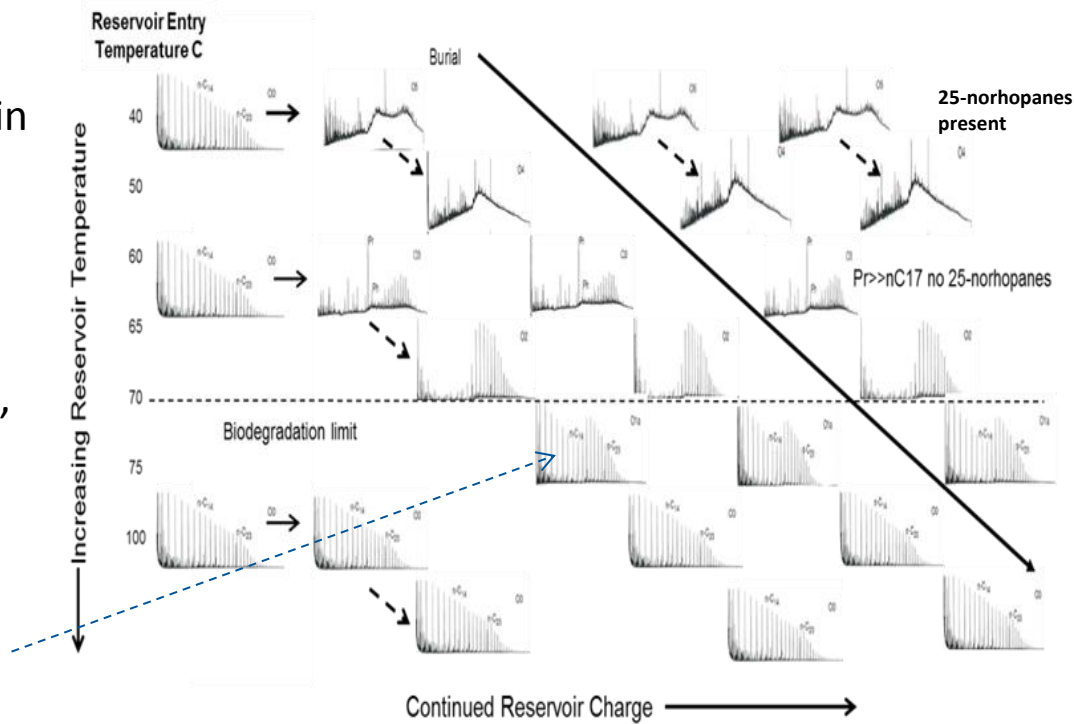
The presence of biodegradation is useful in helping to determine reservoir entry timing of the hydrocarbon as biodegradation only occurs at temperatures $\sim < 70^{\circ}\text{C}$.

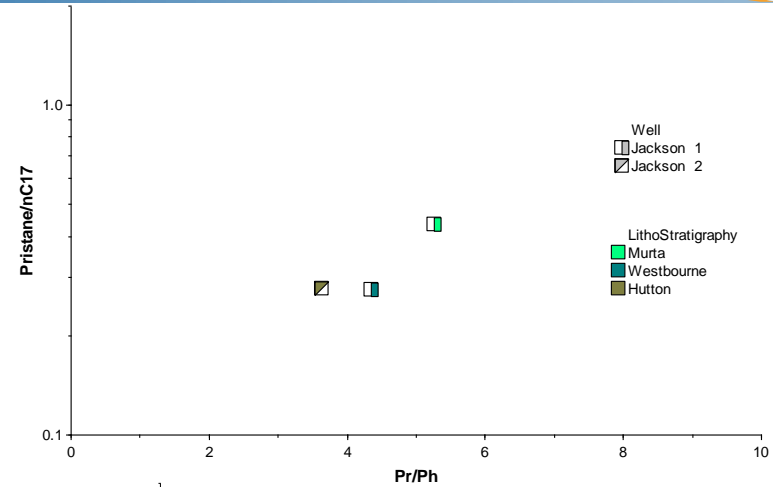
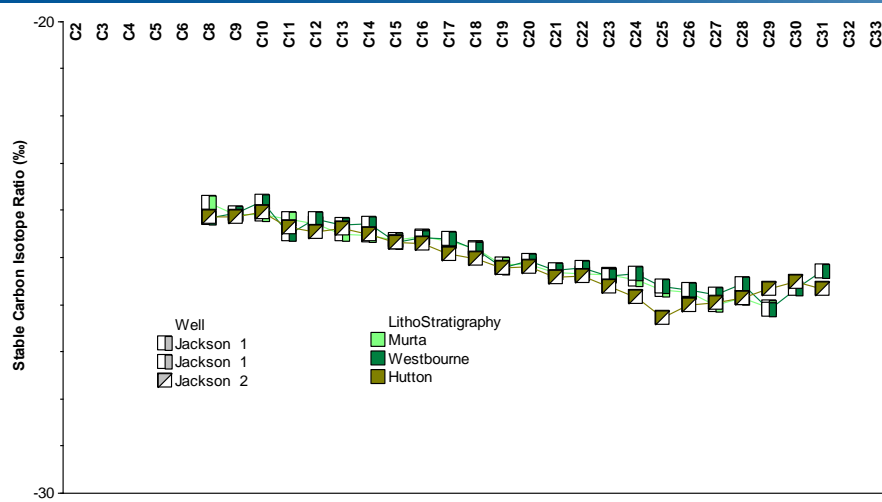
- The presence of 25-norhopanes indicate extreme biodegradation at some time and is interpreted to occur below $\sim 40^{\circ}\text{C}$
- High Pr/nC_{17} ratios are also indicative of biodegradation and may indicate biodegradation of the hydrocarbons followed by recharge with non biodegraded hydrocarbons
- WOGCs will change depending on the amount of fresh v biodegraded charge and the reservoir temperature
- Biodegradation of hydrocarbons is very common and is often ignored when a full n-alkane profile remains



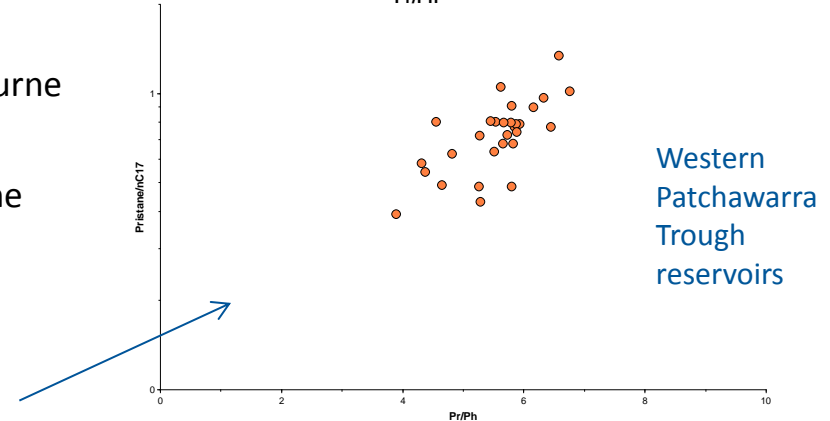
- Biodegradation scale when used for reservoir entry timing is almost inverse of regular scale
- It is a compound retention rather than loss scale

- Mature hydrocarbon enters reservoir
- Level of biodegradation dependant on reservoir temperature resulting in different WOGC profiles
- As reservoir buried WOGC profile changes with additional charge
- Once temperature $> \sim 70^{\circ}\text{C}$ reached, mature hydrocarbon profile can be re-obtained but Pr/nC_{17} ratio commonly still elevated due to underlying biodegraded residual. A period when residual $>$ than non biodegraded giving hump in profile

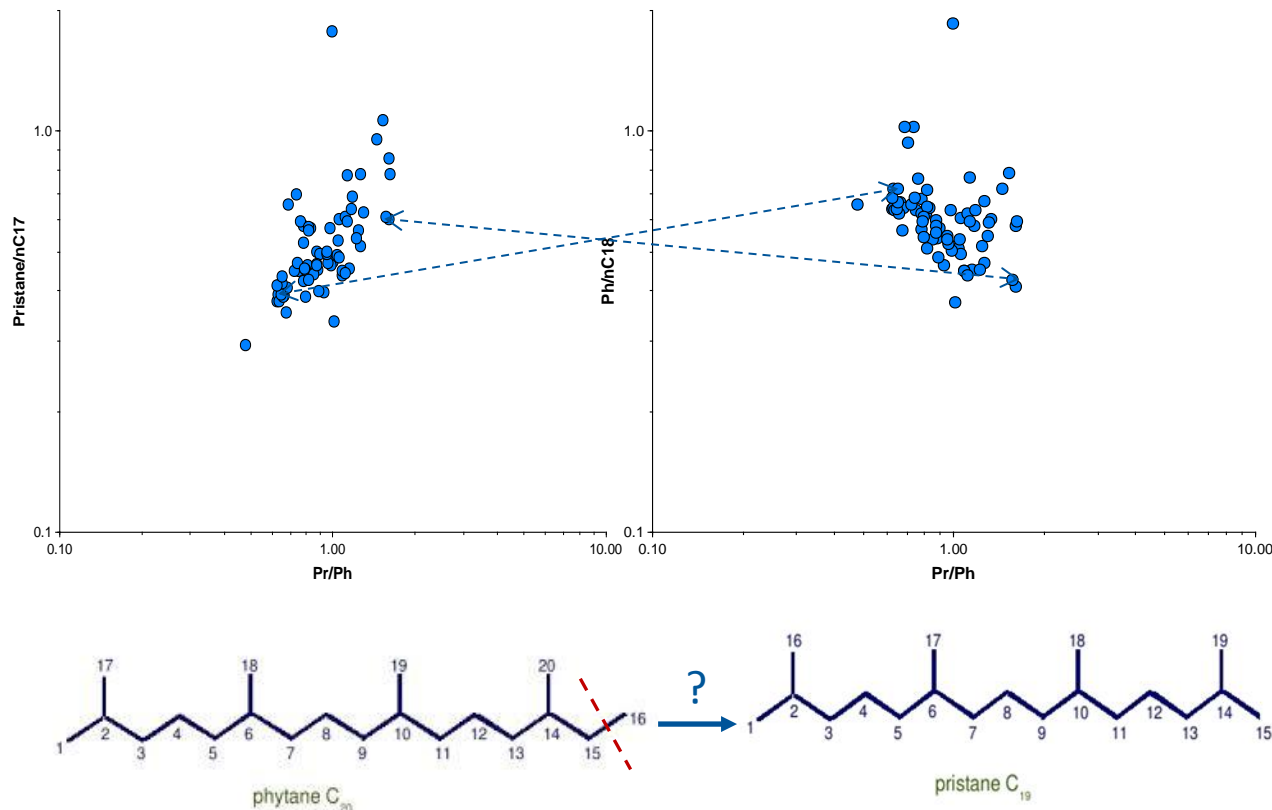




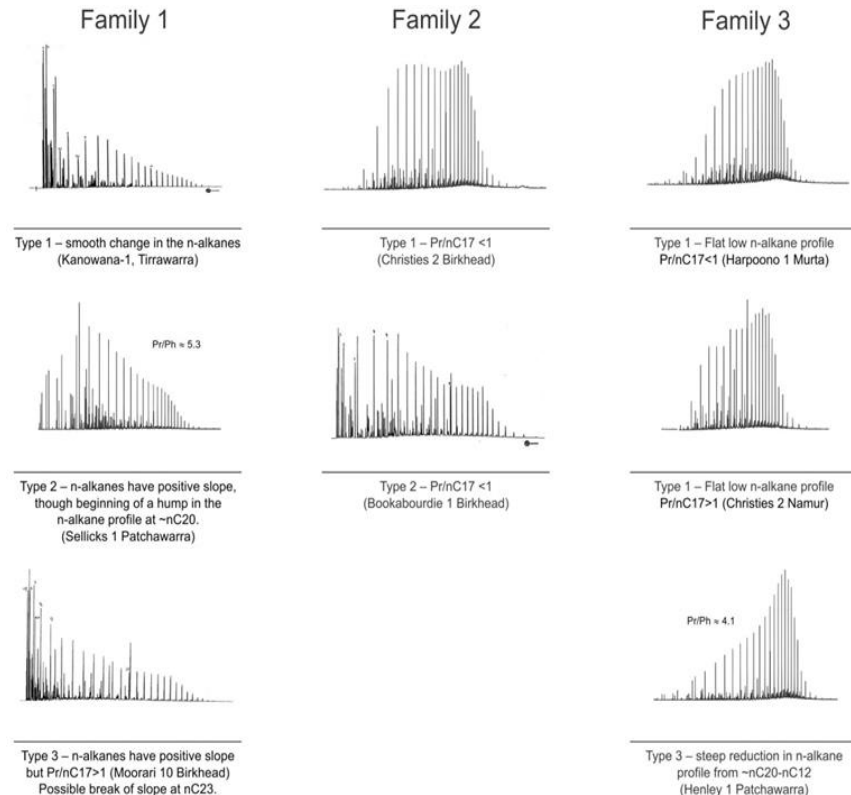
- Isotope data from Jackson Field indicates Hutton, Westbourne and Murta oils from same source
- Is there a link between the difference in Pr/Ph ratio and the increase in Pr/nC_{17} ?
- Is this to do with maturity or biodegradation?
- Similar relationship seen elsewhere in Cooper/Eromanga



- In the Gulf of Suez data an increase in Pr/nC_{17} shows a decrease in Ph/nC_{18} raising the possibility that biodegradation removes a methyl group from phytane \rightarrow pristane
- A reduction in Ph/nC_{18} is not obvious in most data sets, perhaps due to lower phytane values relative to pristane and much lower Ph relative to nC_{18} in many oils



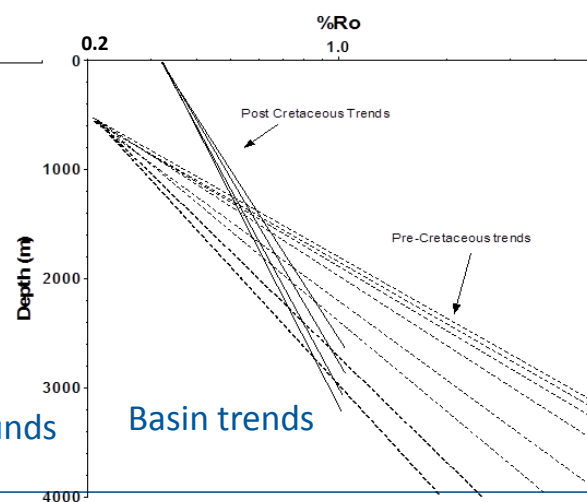
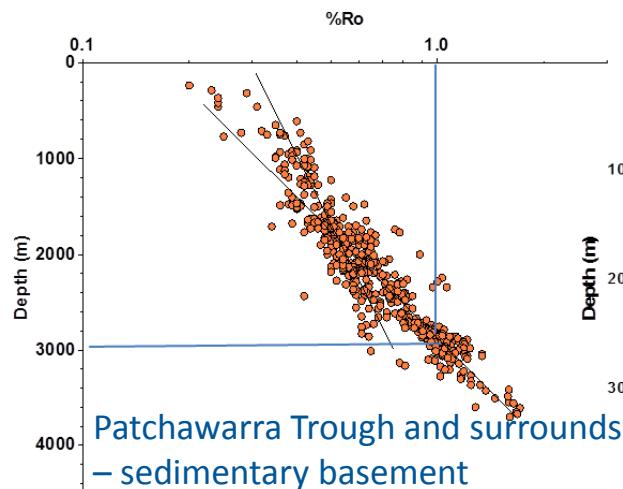
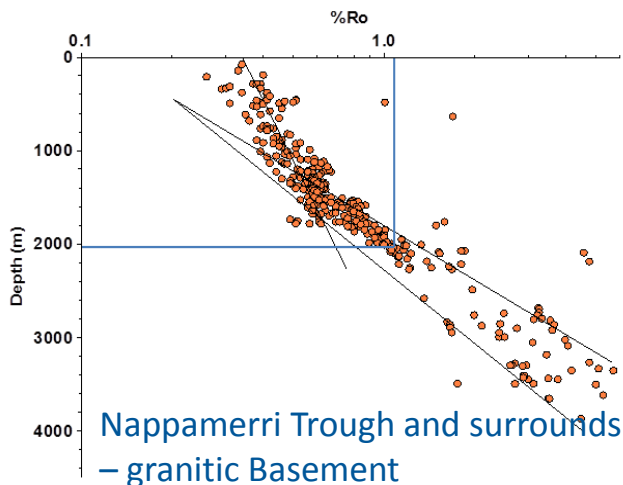
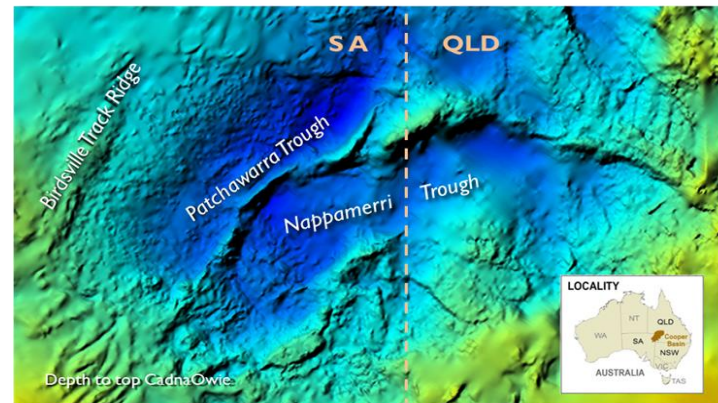
- Three WOGC ‘families’ have been recognised in the Cooper/Eromanga
- The division can be related to the extent of biodegradation which can provide information on reservoir entry timing via reservoir temperature
- Family 1 – basically non-biodegraded with charge predominantly post 70°C. Some show evidence of an early biodegraded component
- Family 2 – early biodegradation with continuing charge past 70°C. Later charge smaller than early charge, resulting in dip in central portion of WOGC. Usually high Pr/nC₁₇ ratio
- Family 3 – biodegraded with loss of lighter n-alkanes. Charge ceased prior to 70°C.



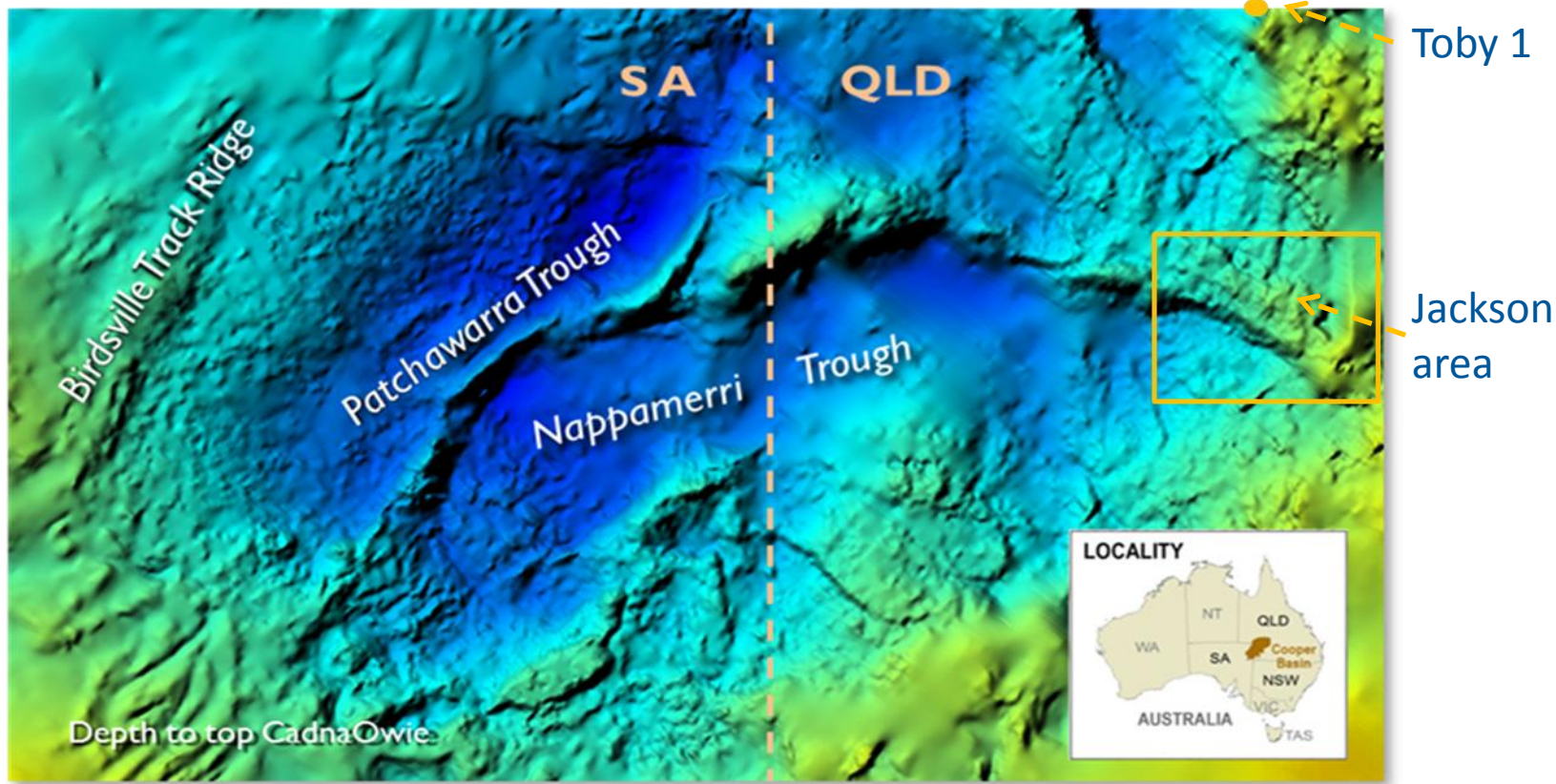
No WOGC ‘Family’ relationship to stratigraphy

Cooper / Eromanga temperature and maturity

- Basin not at maximum temperature due to uplift of eastern Australia in mid Cretaceous and introduction of active aquifer – need to use maturity (V_r)
- Significant differences in temperature and maturity gradients across basin.
- Different Pre and Post Cretaceous gradients
- Granitic 'Basement' has much higher gradients than sedimentary 'Basement'.



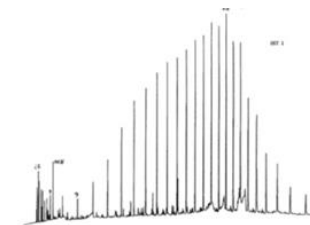
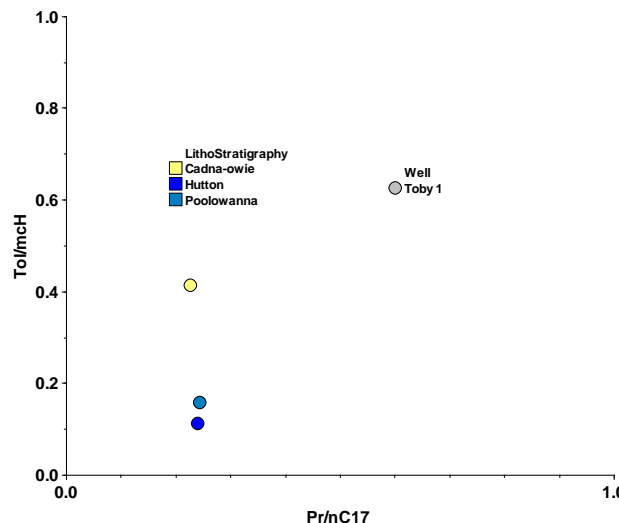
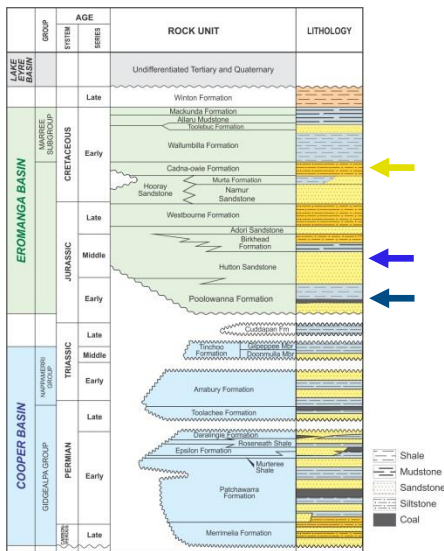
Determining reservoir entry timing



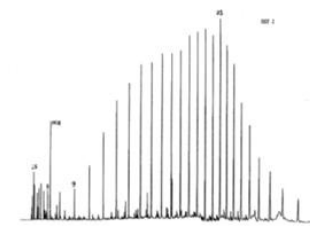
- Examples used in this presentation are Toby - 1 and Jackson area

Reservoir entry timing – Toby 1

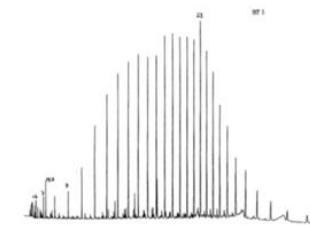
- Toby 1 has 3 oil reservoirs in the Eromanga section
- WOGC data indicates all three Toby 1 Eromanga Basin reservoirized oils, are very mildly biodegraded with almost identical Pr/nC_{17} ratios. The Poolowanna oil contains significant 25-norhopanes indicating early severe biodegradation. The main difference between the oils is the level of water washing with Poolowanna and Hutton Reservoirs more water washed



Toby 1 Cadna-owie Formation



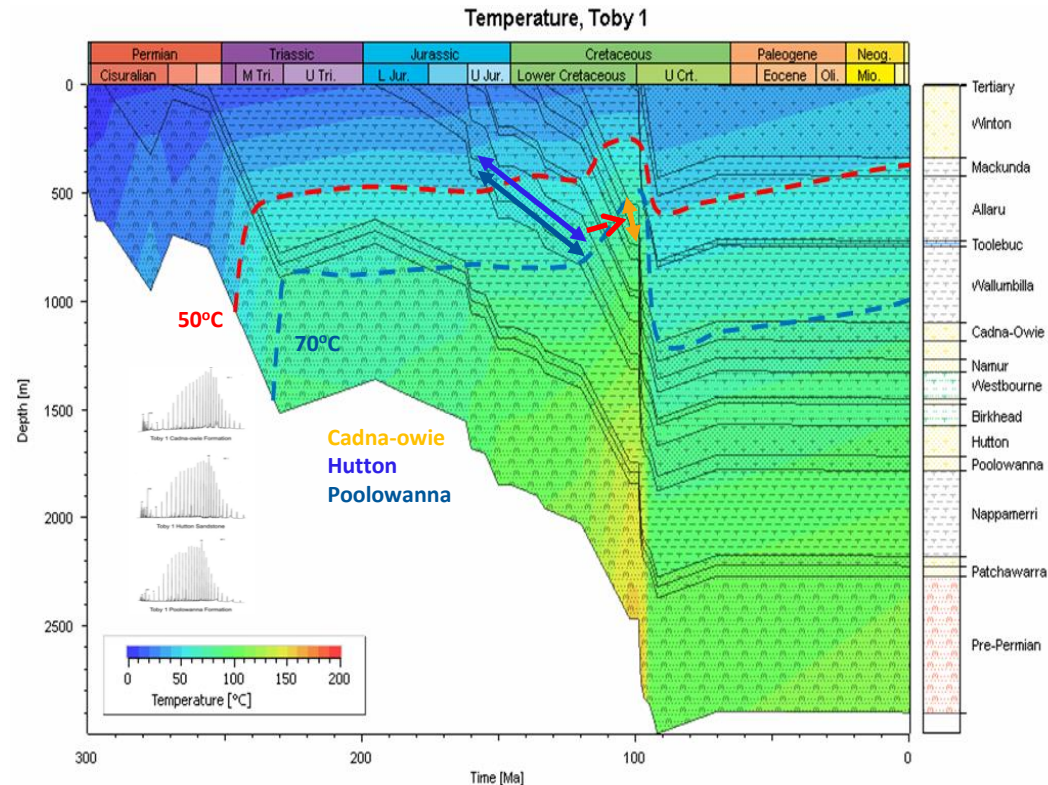
Toby 1 Hutton Sandstone



Toby 1 Poolowanna Formation

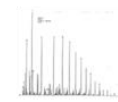
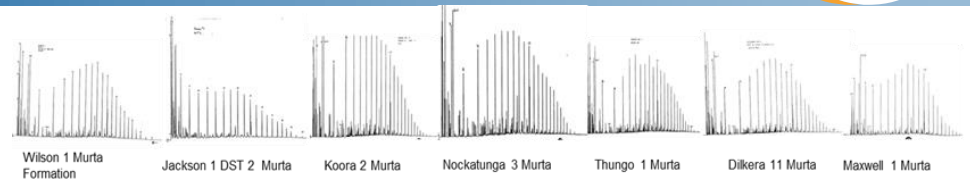
Reservoir entry timing – Toby 1

- The presence of significant 25-norhopanes in the Poolowanna oil indicates initial reservoir entry was probably $< 40^{\circ}\text{C}$. The WOGC profile is only mildly biodegraded with low Pr/nC_{17} indicating final reservoir entry was $\sim 70^{\circ}\text{C}$.
- Migration into the Toby 1 Poolowanna reservoir commenced in the middle-late Jurassic and continued during the early Cretaceous
- The oil in the Hutton reservoir may have been biodegraded at the same time as the oil in the Poolowanna
- The oil in the Cadna-owie reservoir appears to have spilled from the Poolowanna/Hutton during later structuring as a significantly different Cadna-owie reservoir WOGC profile would be expected if reservoir entry was at the same time as the Poolowanna as the reservoir was at $< 50^{\circ}\text{C}$ at that time. Entry at $> 70^{\circ}\text{C}$ and no further charge retains the WOGC profile

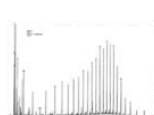


Reservoir entry timing – Jackson area

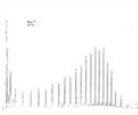
- The Jackson area contains an number of fields with some wells containing up to 4 separate oil reservoirs
- At Jackson 1 and Wilson 1 both the Hutton and Westbourne oils were biodegraded; however the younger Murta and Namur accumulations show fresh charge past 70°C reservoir temperature
- The differences in the WOGC profiles indicates that migration pathways changed at Jackson and Wilson with the Hutton and Westbourne reservoirs entering a migration shadow (no charge post 70°C) while new charge post 70°C reached the Namur and Murta reservoirs
- WOGCs show Koora and Nockatunga Birkhead and Murta oils both with charge mainly >70°C, however the Westbourne reservoir remained in a migration shadow with oil entry < 70°C



Wilson 1 Namur



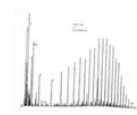
Wilson 1 Westbourne



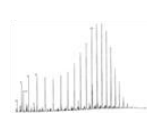
Jackson 1 Westbourne



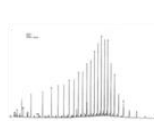
Nockatunga 1 Westbourne



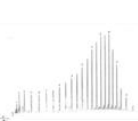
Thungo 1 Westbourne



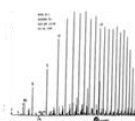
Maxwell 1 Westbourne



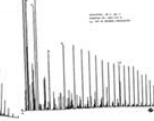
Wilson 1 Hutton



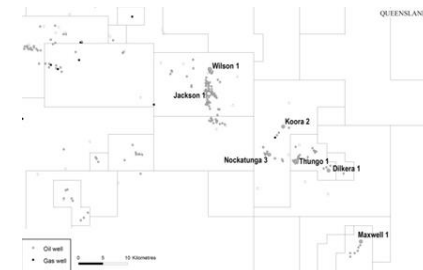
Jackson 1 Hutton



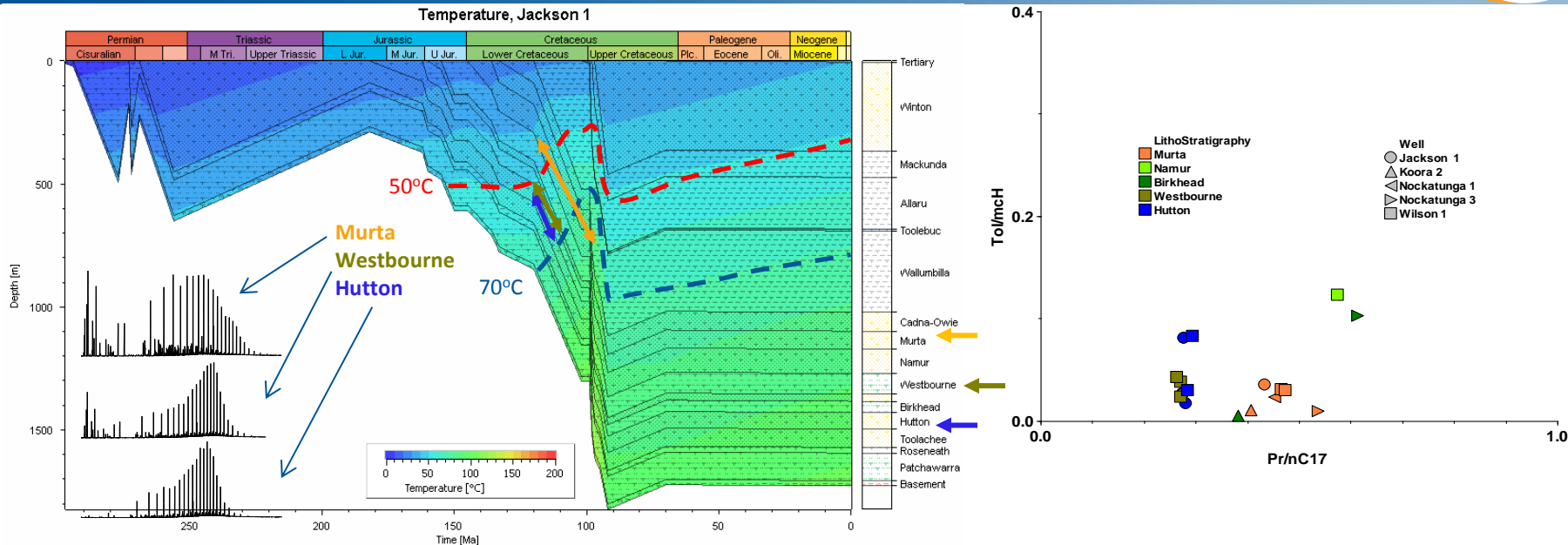
Koora 2 Birkhead



Nockatunga 3 Birkhead



Reservoir entry timing – Jackson area



- Hutton and Westbourne reservoirs in Jackson 1 show similar biodegradation levels to one another indicating similar reservoir entry temperature. Very low levels of 25-norhopanes are present
- Birkhead, Namur and Murta show similar biodegradation levels to one another - higher than Hutton suggesting hydrocarbon entry at lower temperature than Hutton – probably similar initial entry timing but access to hydrocarbons over a longer period
- Reservoir entry timing in early Cretaceous reservoirs was at about start of Wallumbilla Fmn deposition

- Biodegradation is common in the Cooper/Eromanga basin, much of it ignored or unrecognised
- Biodegradation is often not recognised when at low levels or where the volume of charge into reservoir at $> 70^{\circ}\text{C}$ is greater than charge $< 70^{\circ}\text{C}$
- WOGC profiles, Pr/nC_{17} ratios and presence/absence of 25- norhopanes can be used to recognise the presence of biodegradation and constrain the hydrocarbon reservoir entry temperature
- A good basin temperature/maturity model is needed to allow timing of hydrocarbon charge to be determined, which should then allow better identification of source supplying charge
- The presence of biodegradation can enable differentiation of the original migrated oil into the reservoir from the spill from a lower breached reservoir in certain circumstances – often associated with later structuring

Thank you