

Water Washing: A Major Hydrocarbon Alteration Process. Part 2 – Processes, Controls and Hydrocarbon Type Prediction*

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Abstract

Water washing is a significant hydrocarbon alteration process that has not been widely recognized in the literature. An earlier review investigated the geochemistry and water washing relationship associated with Australian North West Shelf oils and gases. This review investigates and incorporates the Cooper/Eromanga Basin hydrocarbons in central Australia to gain additional insights into the water washing processes, controls, and whether they can be used to predict hydrocarbon type. Water washing is controlled primarily by water movement in the aquifer and the solubility of individual hydrocarbon compounds. Porosity determines the water volume available to dissolve soluble components, while permeability controls the rate of flow. The sedimentary facies and associated architecture control the reservoir connectivity and thus the regional aquifer flow. This review examines the relationship between reservoir porosity and permeability with temperature/maturity providing a predictive relationship. This was compared with the changes in hydrocarbon composition particularly in the nC1-C10 range. These indicate that reservoir architecture including overpressure development and temperature/maturity plays a role in determining hydrocarbon composition. Permeability in particular is important in determining nC1-C10 hydrocarbon composition in the reservoir. The processes and controls on water washing allow prediction of hydrocarbon type, with a number of key predictive parameters outlined.

Selected Reference

McAuliffe, C.D., 1979, Oil and Gas Migration - Chemical and Physical Constraints: AAPG Bulletin, v. 63/5, p. 761-781.

Water washing: A major hydrocarbon alteration process.

Part 2 – Processes, controls and hydrocarbon type prediction

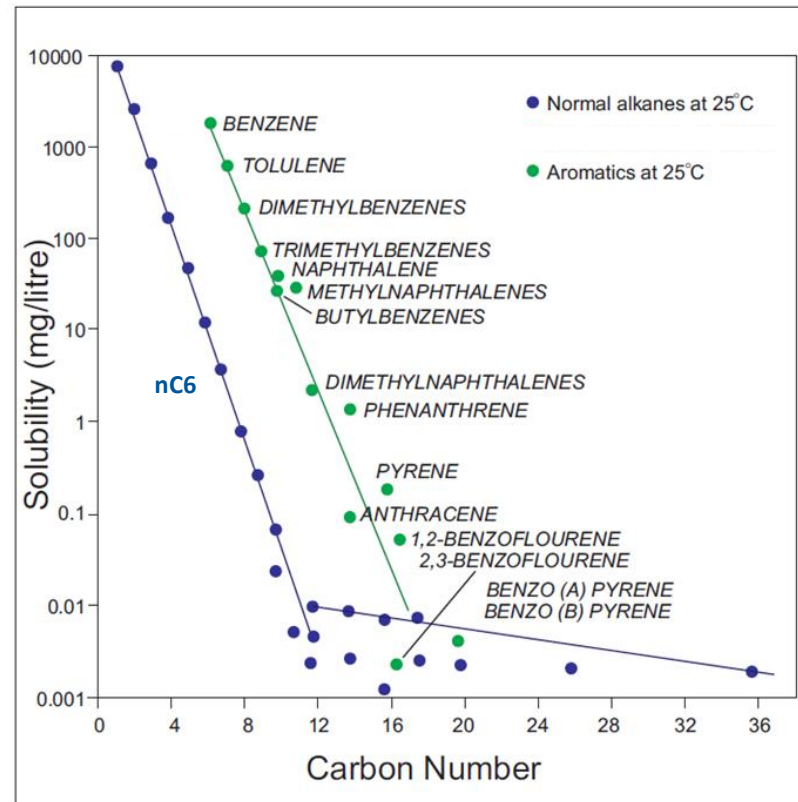
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- What is water washing?
 - How do we recognise it?
 - What are the processes and controls on water washing?
 - Use in exploration
 - Hydrocarbon type prediction
 - Conclusions
-
- Will use examples from the Australian NW Shelf , Cooper/Eromanga and North Sea basins

What is water washing?

- Water washing is the process of stripping the more soluble hydrocarbons from a gas or oil accumulation via dissolution in the associated aquifer
- Affects the light hydrocarbons $< \sim C_{10}$
- Solubility order
 - Aromatics > cyclic > straight chain hydrocarbons for same C number
 - Lower molecular weight > higher molecular weight in same group eg methane >> hexane

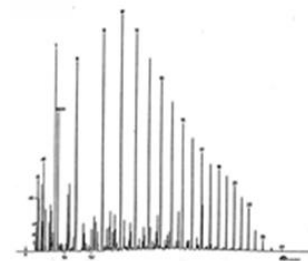


From McAuliffe, 1979

How do we recognise it?

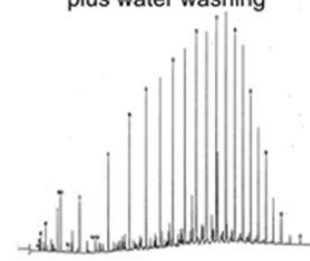
- Loss of n-alkanes on WOGC up to about C10 – can distinguish from mild biodegradation as biodegradation effects > C10
- Various gasoline range ratios - slope appears related to relative solubility but source can impact relationship for some compounds particularly aromatics
- Oils show higher water washing (loss of solubles) than gases (and their associated condensates)

Heavily water-washed

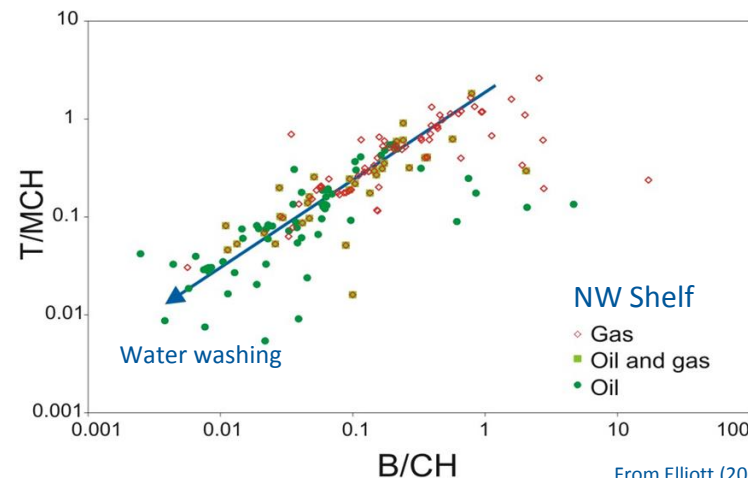
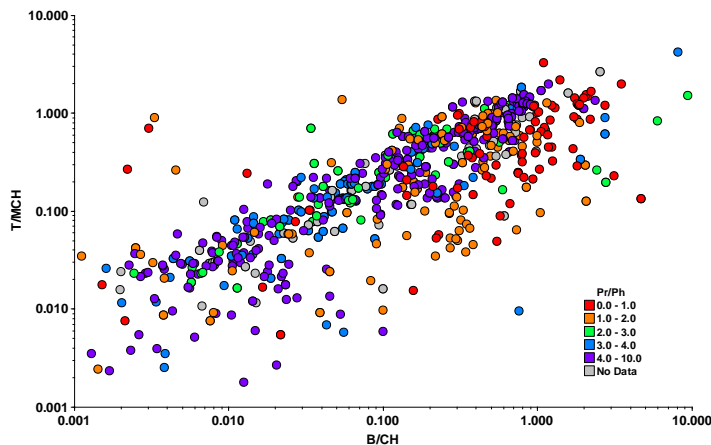


Yanda 1 Hutton

Mild biodegradation plus water washing



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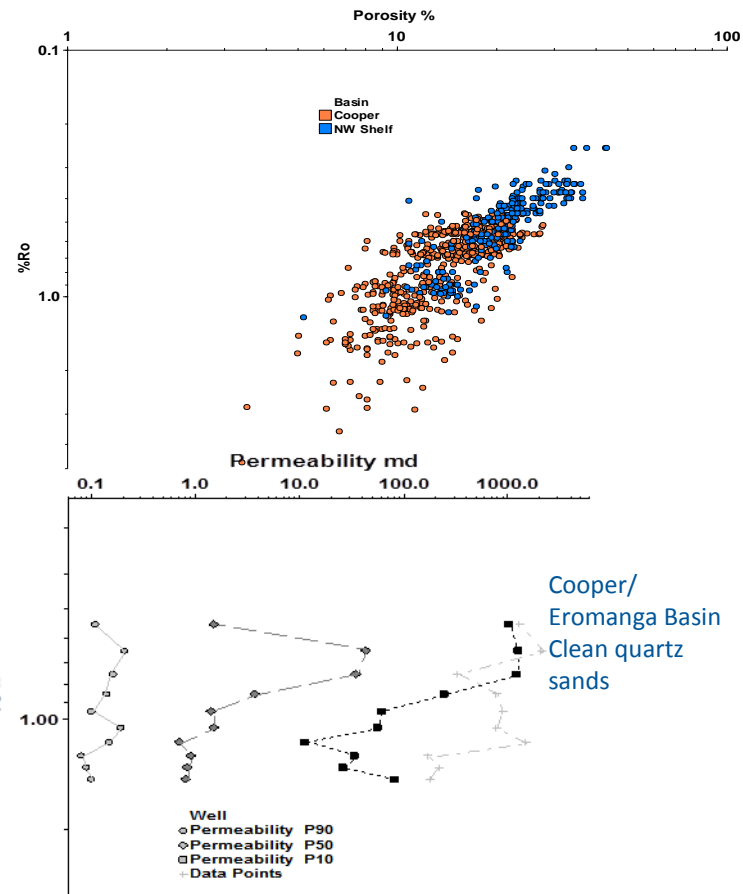
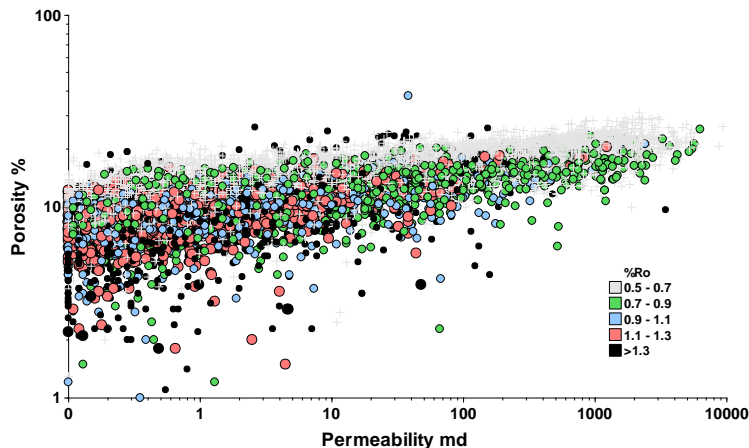


From Elliott (2008)

Significant water washing requires an active aquifer capable of removing dissolved hydrocarbons from the reservoir location

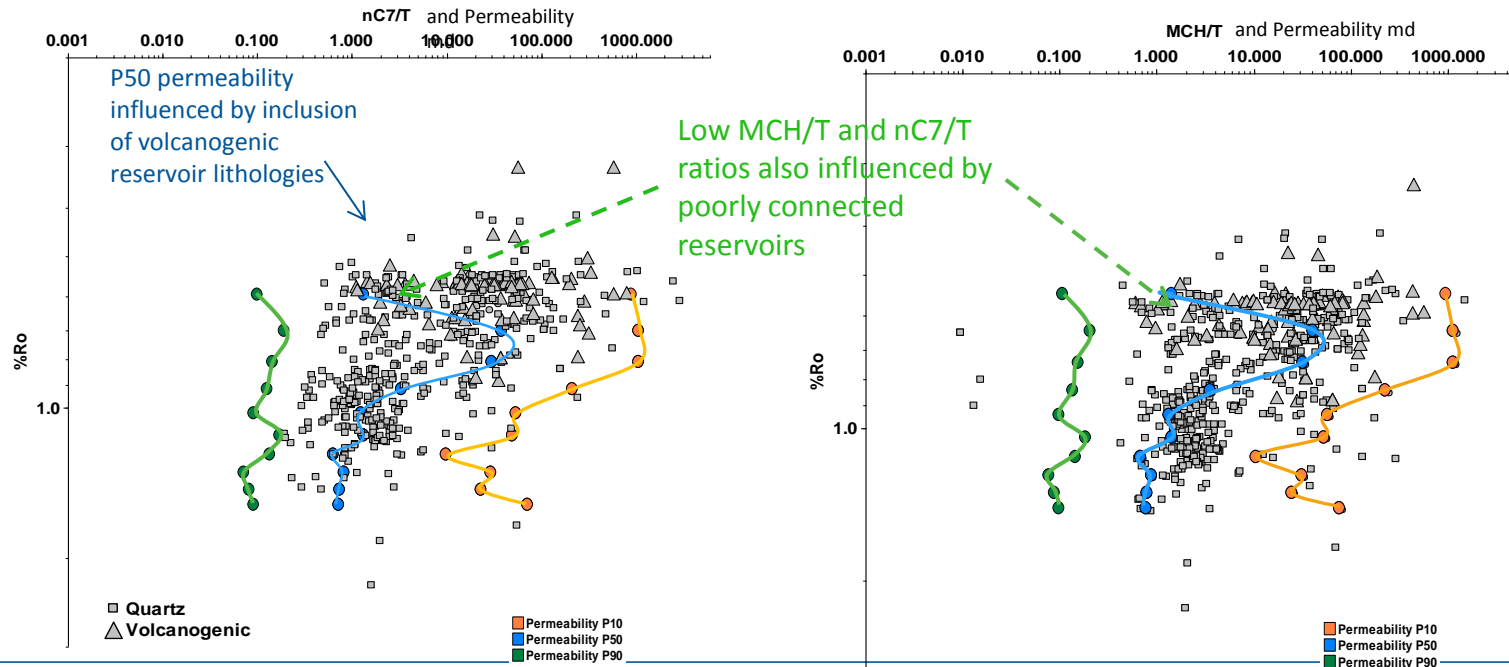
- The main controls on water flow are
 - reservoir volume (porosity) and permeability and how both are connected in a regional sense. Large high volume - high permeability aquifers can remove larger volumes of hydrocarbons than restricted low permeability aquifers
 - Sedimentary facies largely controls the distribution and connectivity of individual reservoirs
 - Overpressure should inhibit any significant flow
- Other controls are
 - Hydraulic head available – higher head can potentially result in higher flow rates
 - Time – primarily an in-reservoir process. Reservoir residence time usually >> migration pathways
 - Source Type – gas generation Type III >> Type II > Type I. Less need in Type I but gasoline ratios still affected
 - Aquifer salinity – can be an issue at high salinities – but in general no aquifer connection at high salinity. Fresh water more effective in dissolving and removing solubles

- Porosity related to temperature/maturity. General loss with increasing temperature
- Permeability also related to temperature/maturity
- Permeability loss much faster than porosity
- Significant loss of permeability at 0.7-0.8%Ro (120-130°C) and major reduction in water washing ability



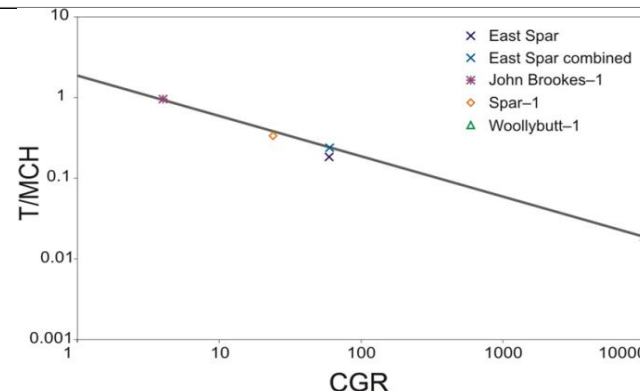
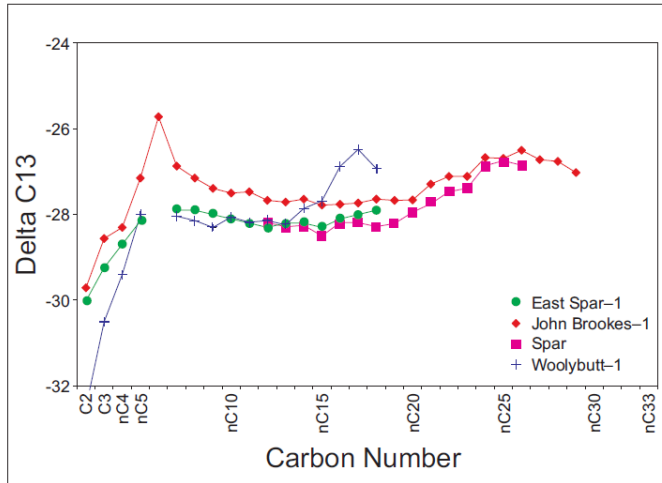
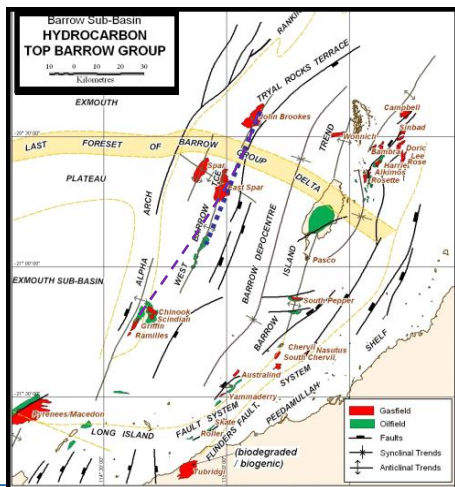
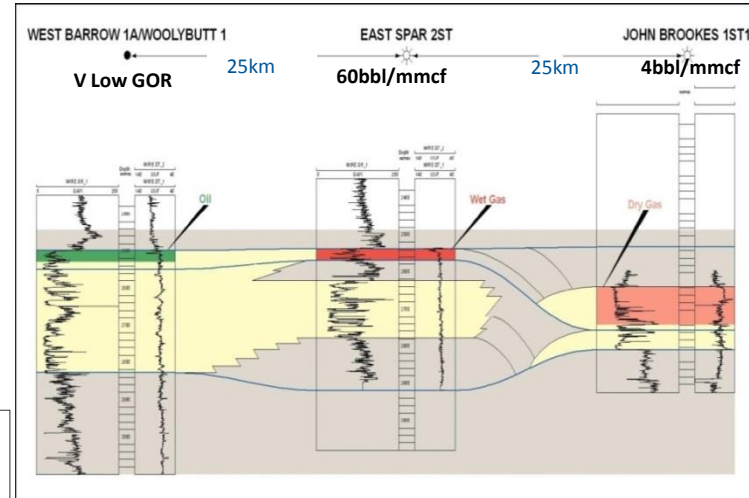
Permeability and reservoir geochemistry ratios

- Strong correlation of permeability with geochemistry ratios (nC7/T, MCH/T)
- Lower maturity data shows more variability due to variation in aquifer connectivity
- At %Ro>0.7 tight bunching of data points for both ratios due to difficulty in water washing at low permeability

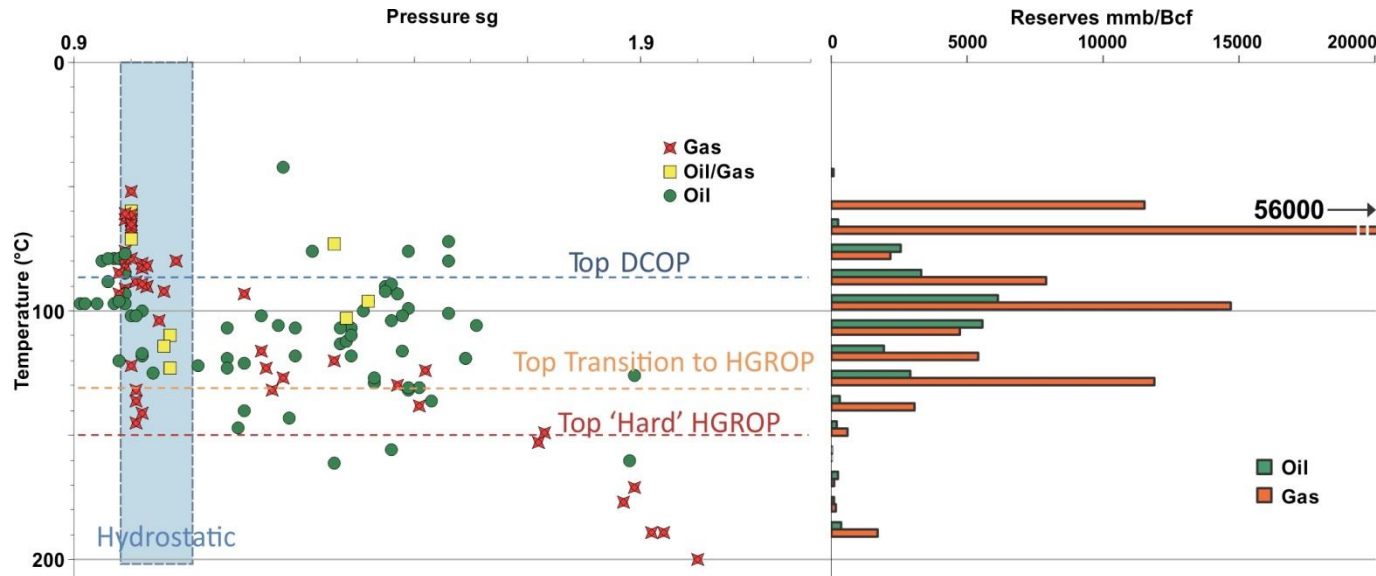


Reservoir connectivity - Barrow sub-basin (NW Shelf) example

- N-S cross-section through the Cretaceous Barrow delta showing the change of hydrocarbons GOR and CGR changing associated with decrease in reservoir thickness from Woollybutt to East Spar within the delta facies and then to turbidite facies at John Brookes
- Relationship of T/MCH v CGR seen in many other basins
- Isotope and biomarker data suggest same source and similar maturity



- Most oil in temperature range $< 130^{\circ}\text{C}$. Volumetrically insignificant at temperature $> 130^{\circ}\text{C}$ and mainly condensate
- Little oil in hydrocarbon generation related overpressure (HGROP). HGROP occurs from ~ 120 - 130°C where sufficient TOC available. Why so little oil in the oil generation zone? – low permeability and low aquifer connectivity
- Disequilibrium compaction overpressure (DCOP) does not appear to significantly influence hydrocarbon type - ? Reservoired before DCOP commenced. DCOP generally occurs from $\sim 90^{\circ}\text{C}$ but can occur at lower temperature

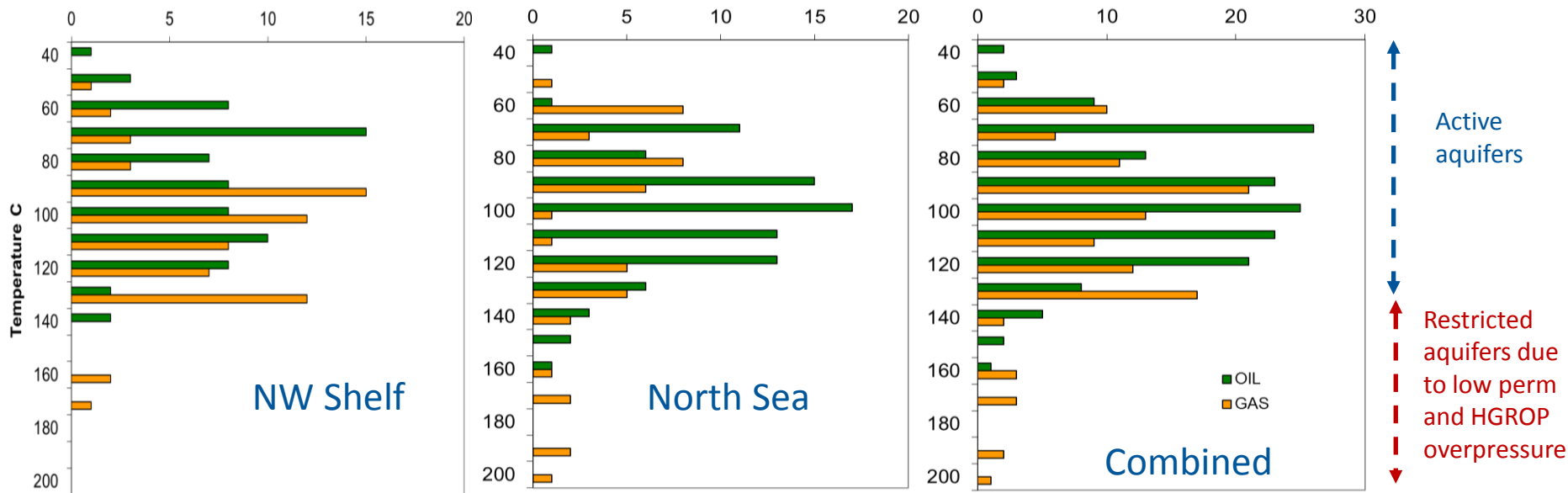


- Helps determine if two reservoirs are in communication via gasoline range ratios
- Helps determine the likely connection to the regional aquifer – pressure maintenance implications
- Can indicate the presence of a gas cap or oil leg in oil or gas reservoirs respectively where there is good GOR or CGR versus T/MCH correlation
- Can assist in determining reservoir entry timing with biodegradation, e.g. if an oil or condensate is significantly water washed and currently at greater than 130°C/0.8%Ro then emplacement in reservoir likely at lower temperature
- Hydrocarbon type (phase) prediction

Hydrocarbon type prediction

- Most oil fields reservoirized at $<130^{\circ}\text{C}$. Mirrors reserves on earlier slide
- Black oil at $>130^{\circ}\text{C}$ (0.8%Ro) reservoir temperature potentially initially reservoirized at $<130^{\circ}\text{C}$

Number of Fields



Data up to 1995-2000

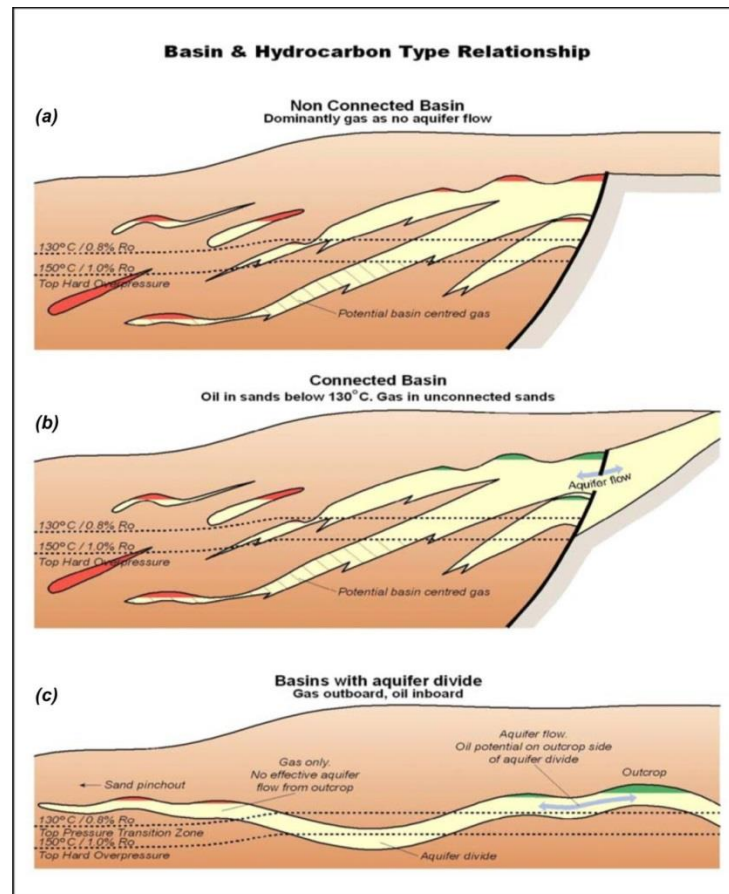
Gas dominant phase where

- Reservoir not connected to main regional aquifer (unless Type I source)
- Reservoir maturity $> 130^{\circ}\text{C}/0.8\%\text{Ro}$
- Reservoir is in hydrocarbon generation overpressure

Oil dominant phase where

- Type I source supplying hydrocarbon
- active aquifer where movement sufficient to remove gas when Type II or III source
- and when reservoir maturity $< 130^{\circ}\text{C}/0.8\%\text{Ro}$

- Basin architecture plays a role in facies connectivity and determination of whether active aquifer present
 - a) Aquifer system not connected to outcrop or sea floor – difficult to water wash and gas dominant hydrocarbon type. Eg Otway and Browse basins
 - b) Aquifer system connected to outcrop or sea floor. Gas can be removed. Oil present in well connected reservoirs $<0.8\%Ro$. Eg Carnarvon, Gippsland and Cooper/Eromanga basins
 - c) Aquifer buried below $0.8\%Ro$ in outer part of basin creating aquifer divide. Oil in proximal part of basin accessing outcrop or sea floor, gas present in outer portion of basin. Eg Carnarvon – Exmouth Plateau basins



- Water washing is an important hydrocarbon alteration process – removing more soluble liquids and gases, particularly methane
- Given sufficient aquifer flow, hydrocarbon phase can be transformed from gas to oil.
- Interpreted to be primarily an in-reservoir process
- Strong relationship between reservoir permeability and gasoline range ratios of reservoired hydrocarbons
- Strong relationship between reservoir temperature/maturity and hydrocarbon type
- Has value in being able to help predict hydrocarbon type when little is known of source kerogen type, using basin architecture knowledge from seismic data
- Useful in conjunction with biodegradation in timing hydrocarbon entry into reservoirs

Thank you