Charge Is Not an Issue – Or Is It?*

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Abstract

The advent of user-friendly map-based modelling software must be credited with significantly raising the profile of petroleum systems analysis. It made basin modelling accessible to a wider community of geoscientists, allowing them to test multiple source rock maturation and hydrocarbon migration scenarios very quickly. However, concurrent with the above appears a renaissance of common pitfalls, four of which will be discussed; these are 1) incorrect temperature correction, with 2) the subsequent conversion to geothermal gradients, 3) the use of vitrinite reflectance values to describe source rock 'maturity', and 4) leaping from a very regional map-based approach to very narrow, prospect-specific predictions without rigorously testing each charge model. Temperatures represent one of the most important calibration parameter for basin modelling. Even though most temperature information does require correction, it should only be done if the necessary additional information is available. On-line correction tools need to be treated with care, as incorrect information can make it into basin models and databases. Using geothermal gradients to describe subsurface temperature regimes within sedimentary basins presents another potential pitfall. Unless each gradient is referenced to a depth below mudline, such an approach can result in the incorrect assessment of heat flow changes across a basin, with detrimental consequences for source rock (SR) maturity predictions. Since SRs have a tendency to be located deeper than any available temperature information, assessing their maturity inherently comes with uncertainty. Converting modelled maximum temperatures or thermal stresses to VR values seems to be an unnecessary step, introducing yet more uncertainty. Given that different SR facies expel petroleum at very different thermal stresses, an 'early oil window' coloured in green on a VR map might be anything but. Additionally, a VR value of 0.6%, for example, will represent different thermal stresses altogether, depending on which kinetic scheme has been applied. While map-based assessments -

when performed correctly - are extremely powerful, it is highly advisable to add an additional analytical step before assigning charge risk to individual prospects. Running calibrated 2D/3D basin models, i.e. honouring all available off-set data, is a great way to rigorously test prospect-specific charge models and potentially avoid a costly dry hole in the middle of a ‘green’ VR map.

Charge is not an issue – or is it?

AAPG/SEG ICE, London 2017

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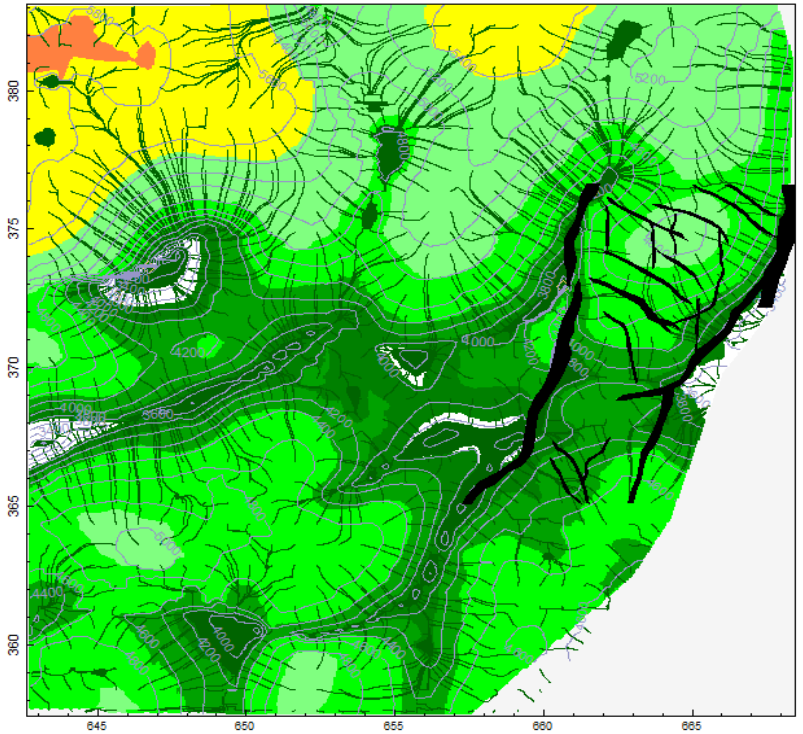
Table of Contents

My source rock is mature and my migration map shows filled structures everywhere.

What could possibly go wrong?

- Temperature & geothermal gradients
- Vitrinite reflectance & thermal maturity
- 2D/3D basin modelling
- Conclusions



Temperature Data

"Well Report-1"

Horner corrected temperatures, depths and gradients:

	deg C	*MD_RTE*	*degC/km*
Set 1	120	x400	40
Set 2	185	x750	55
Set 3	136	x800	39
Set 4	164	x900	46

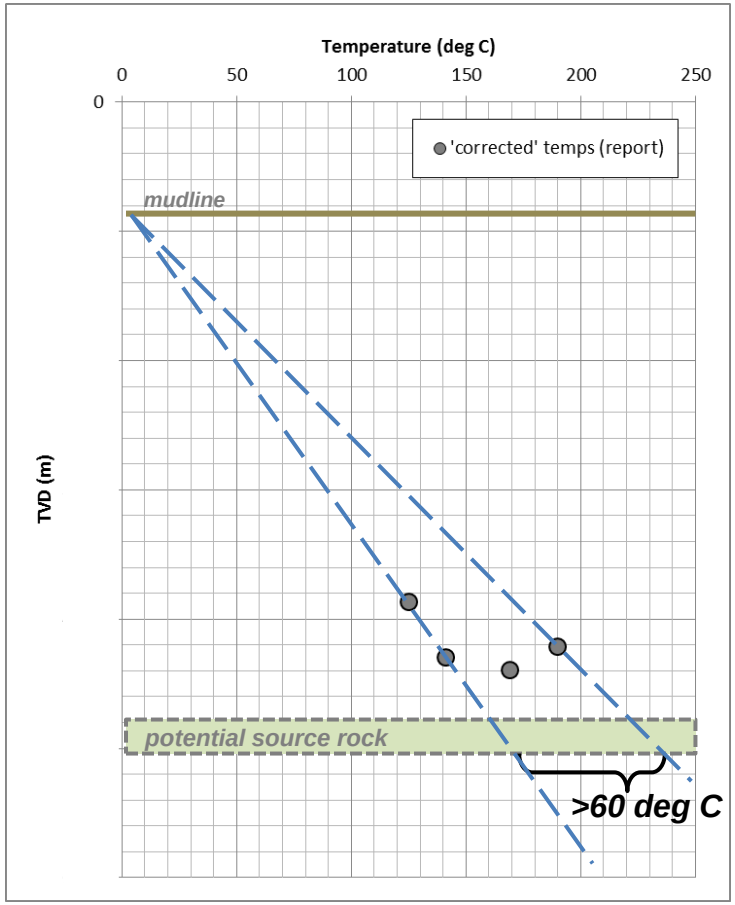
500 m

Average geothermal gradient = 45 degC/km.

Note: Data set has been altered to maintain confidentiality.

Which information within this dataset could be misleading?

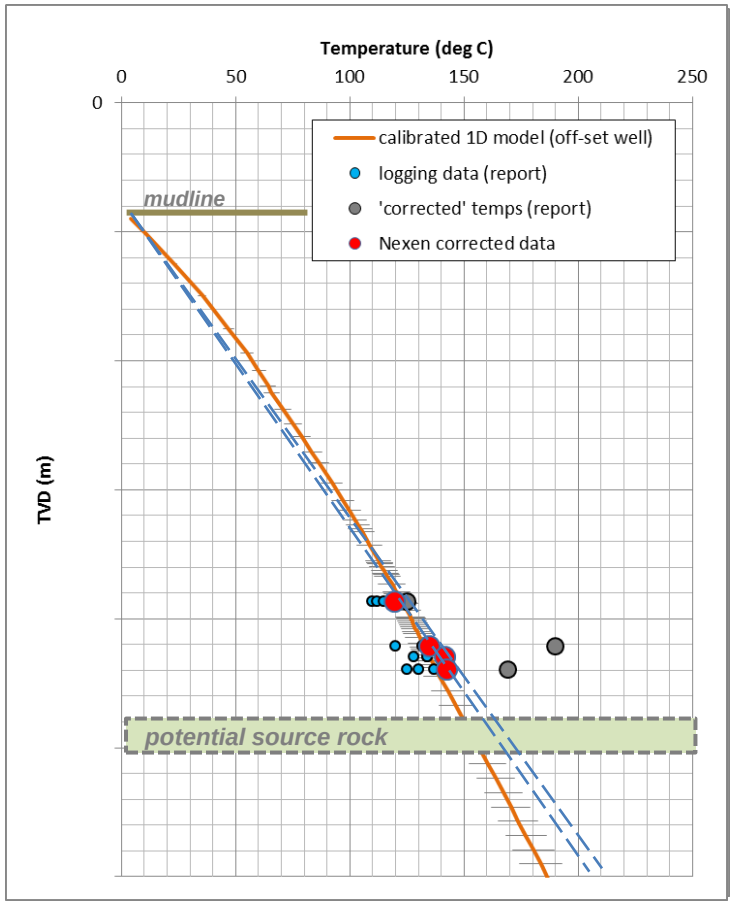
Temperature Correction (I)

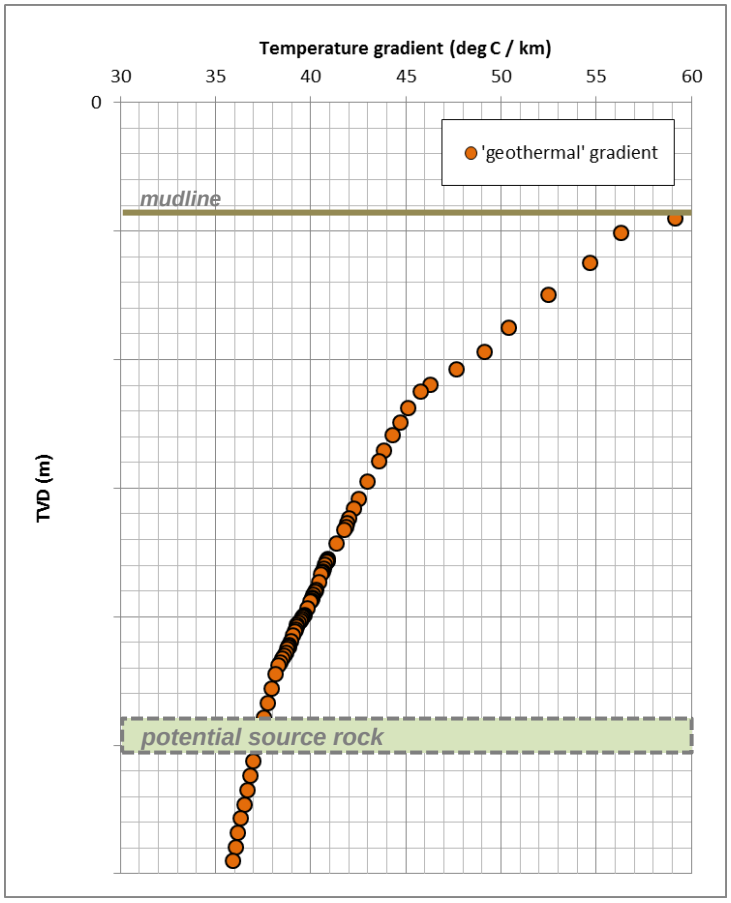


‘Corrected’ temperature measurements (from report)

- Calculated geothermal gradients range from **39 to 55 C/km**.
- Assuming a source rock below the logged intervals, the given geothermal gradients would theoretically equate to a temperature uncertainty of **> 60 C.**

Temperature vs Geothermal Gradient





Temperature & Gradients - Recommendations

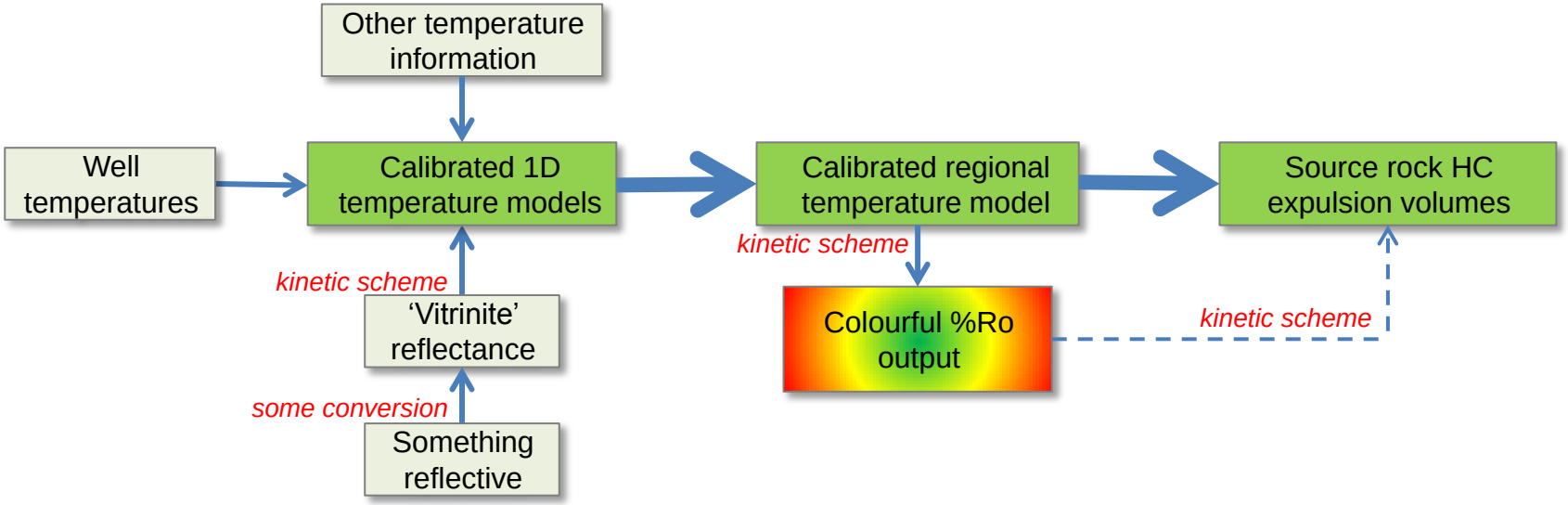
Temperature is a key calibration parameter for any basin model

- temperature data must be treated with utmost care (see also Peters & Nelson, 2009)
- ‘corrected’ values in public or legacy well reports can be wrong
- a single value with no other information cannot be accurately corrected
- explore other temperature information sources, such as LWD data

Temperature increase with depth (bml) is never linear

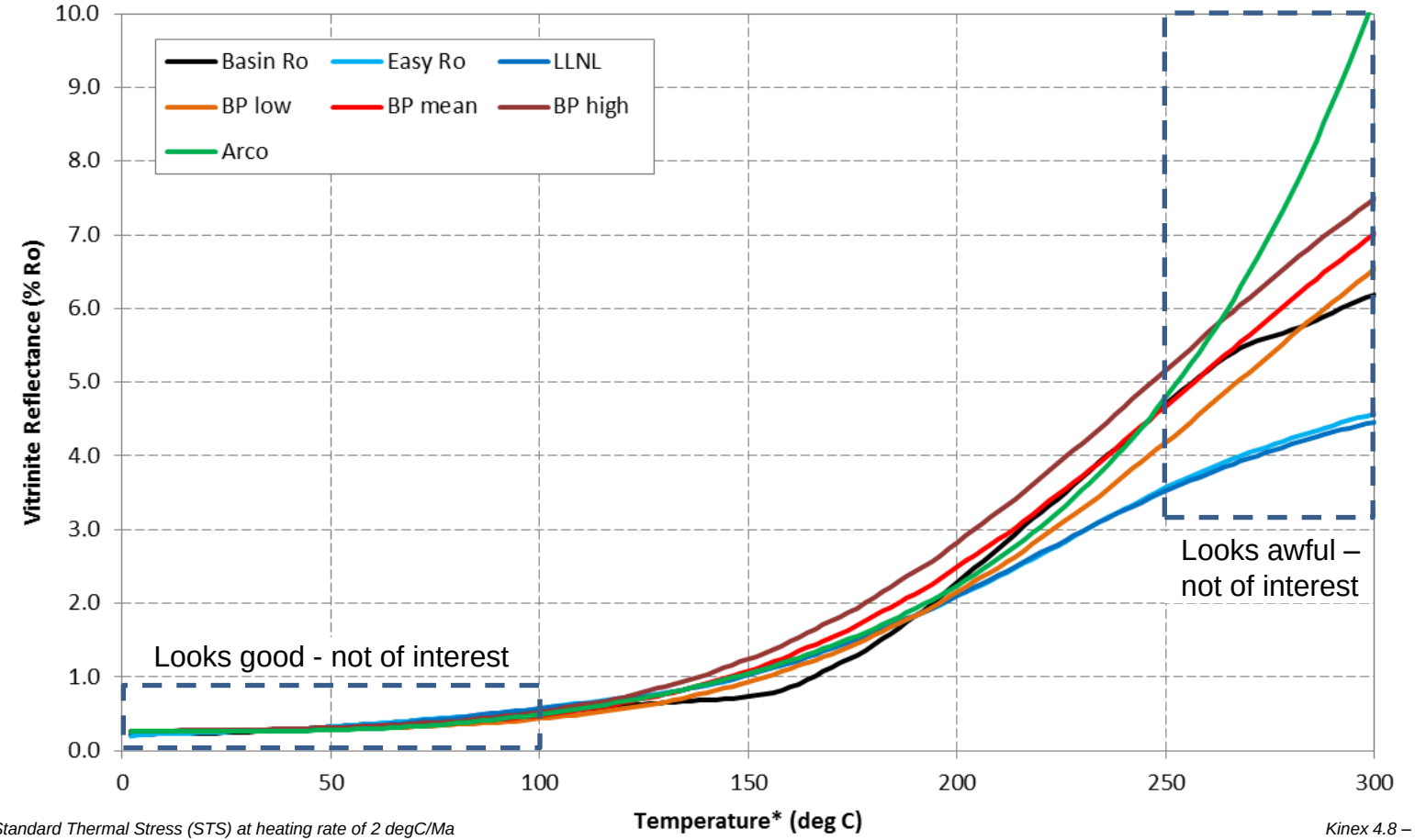
- geothermal gradients must be referenced to a vertical depth below mudline to be of any use

Vitrinite Reflectance & Thermal Maturity



Why use a highly uncertain vitrinite reflectance overlay to show results of a temperature model?

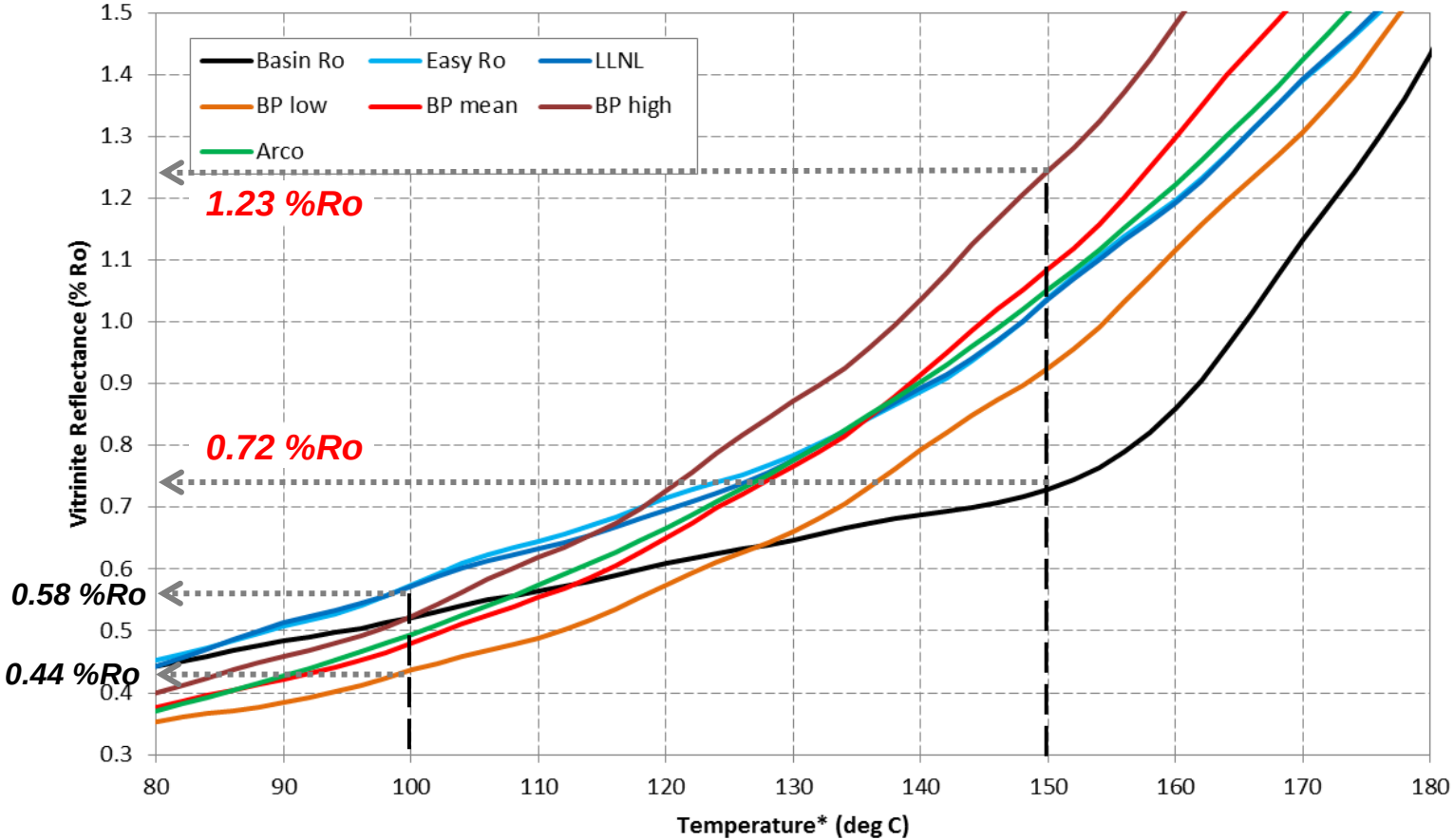
Vitrinite Reflectance & Thermal Maturity



** actually Standard Thermal Stress (STS) at heating rate of 2 degC/Ma*

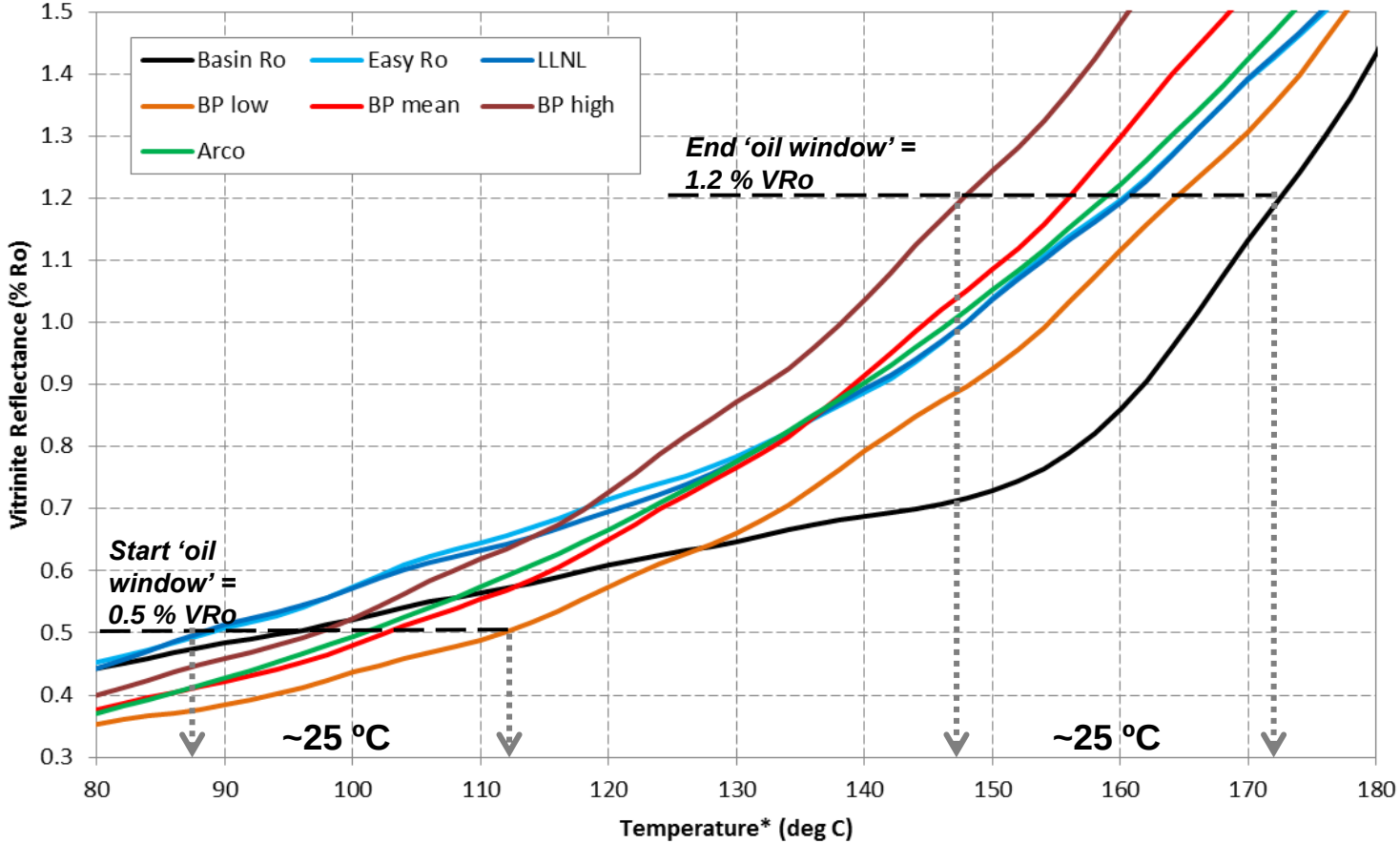
Kinex 4.8 – Zetaware Inc.

Temperature to %Ro



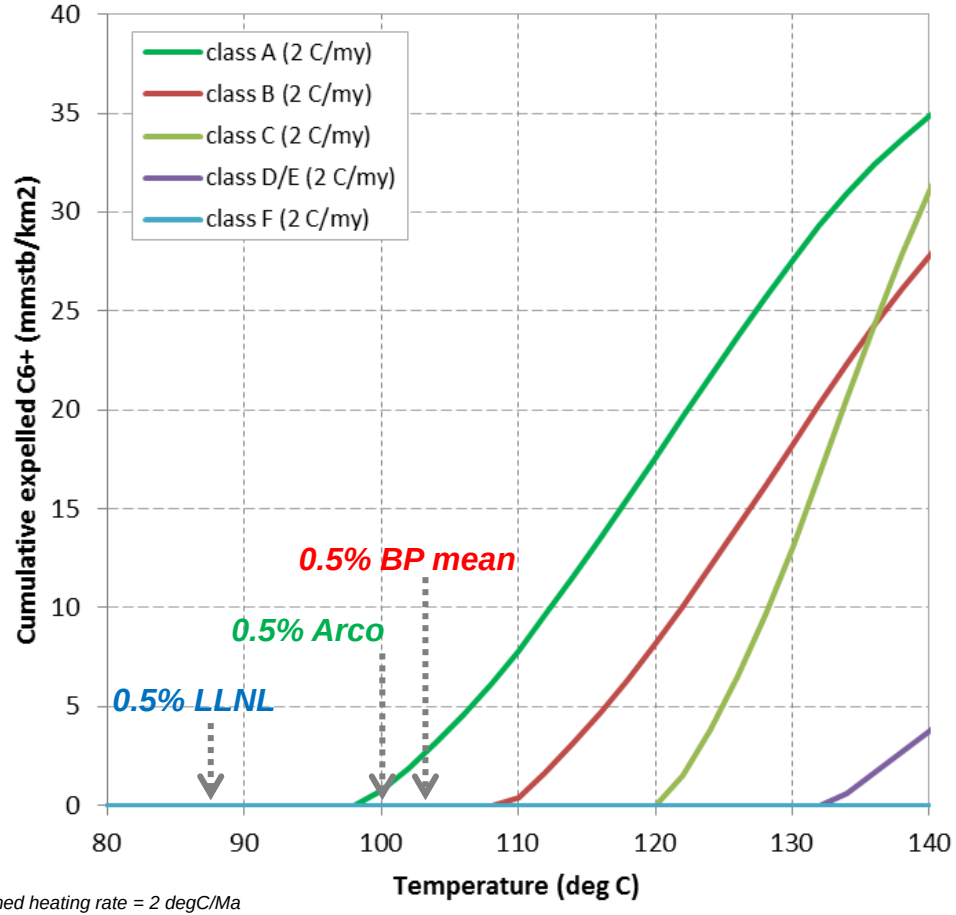
* = STS (2 degC/Ma)

%Ro to Temperature



* = STS (2 degC/Ma)

0.5 %Ro versus Oil Window



Assumed heating rate = 2 degC/Ma

Expelled ‘oil’ – same heating rates, different source rocks

LLNL

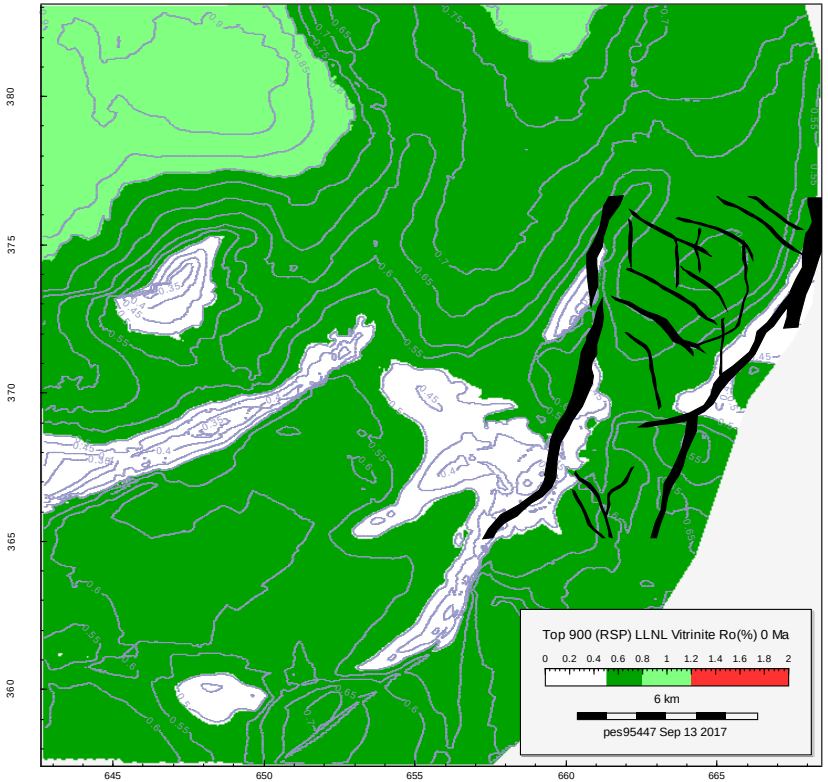
- 0.5 %Ro does not indicate the onset of oil expulsion for any type of source rock.

Arco & BP mean

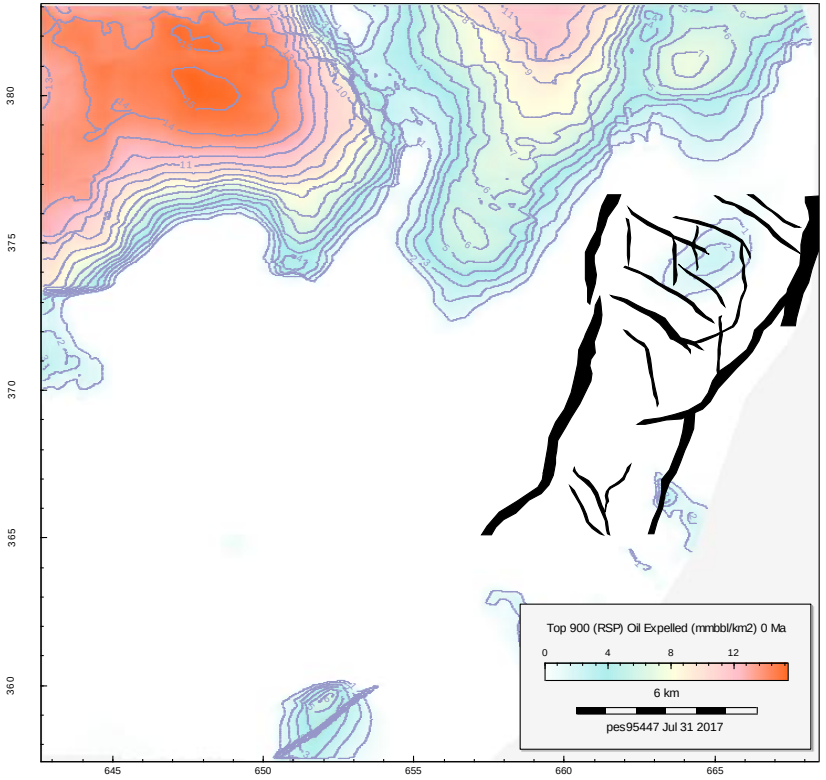
- 0.5 %Ro can be used as indicator for onset of oil expulsion for class A source rocks only!

‘Oil window’ in %Ro versus expelled ‘oil’

LLNL: ‘oil window’ 0.5 to 0.8 to 1.2 % VR



Class B source: expelled ‘oil’



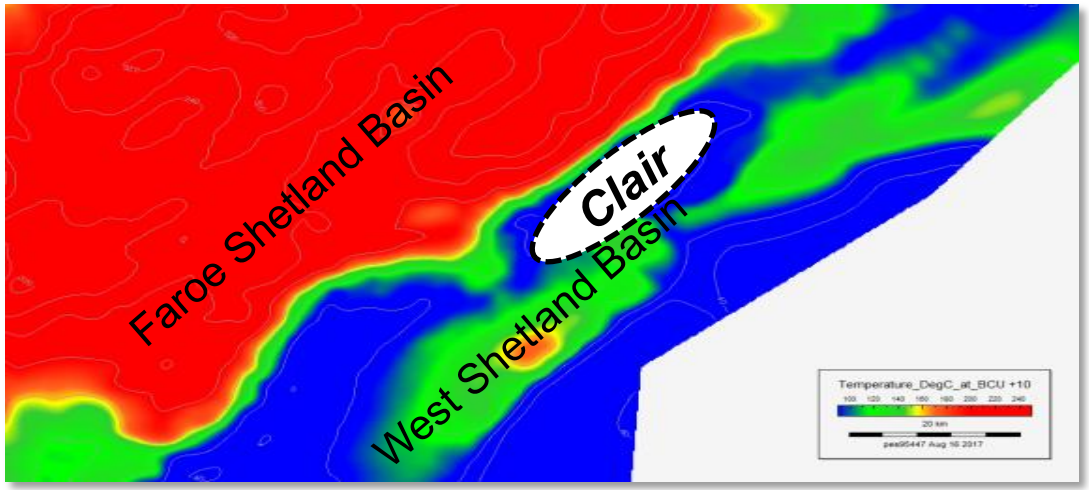
Incorrectly selected colour scheme can be very misleading.

VR & Thermal Maturity - Recommendations

- **Why generate VR outputs as maturity indicators at all?** It is just layering on additional uncertainties.
- **Every VR kinetic scheme requires a unique range of values for each source rock type** to be meaningful.
- Why not **simply use temperature or standard thermal stress** to determine maturity windows?

2D/3D Basin Modelling – Clair field (I)

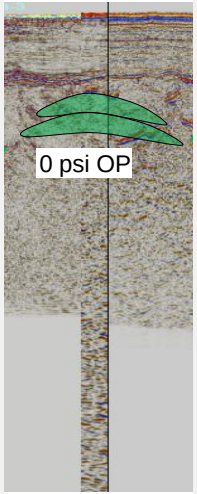
- Clair field is located up-dip of a deep, very mature basin.
- Taking a Kimmeridge clay thermal stress map and looking at present day fetch areas, the Clair field should contain more gas than it does.

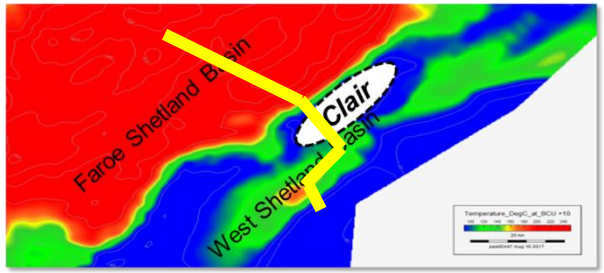


Regional, present-day STS map for KCF.

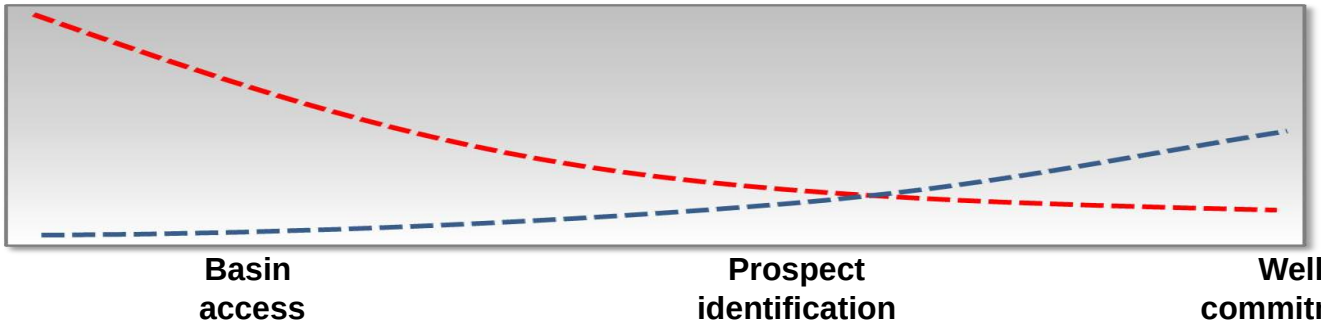
2D/3D Basin Modelling – Clair field (II)

Clair





2D/3D Basin Modelling - Suggestions



- **Map-based analysis is extremely useful** and should be performed (early) in any exploration process.
- **Prospect risk assessments should include pressure models and calibration** to support the proposed charge story.
- In other words, if a conceptual charge model cannot be replicated in a pressure-calibrated 2D/3D model, **charge risk might be higher than originally believed**.

Conclusions

Temperature & geothermal gradients

- acquiring reliable temperature information requires attention to detail
- single data points cannot and should not be corrected
- consider alternative data sources, such as temperatures from LWD tools
- geothermal gradients are meaningless if not referenced to a depth below mudline

Vitrinite reflectance & thermal maturity

- using VR to express source rock maturity may be unnecessary and can be misleading
- maximum temperature/STS with a source-dependent colour scale carries less uncertainty
- support any assessment with expelled volume calculations

2D/3D basin modelling

- map-based approach is a time- and cost-efficient method to guide subsequent analyses
- 2D/3D basin models include physical rigour and should guide (or illustrate) migration concepts

Overly simplistic assessments might result in costly surprises in areas where charge was not believed to be an issue.

Thank you!

Questions?