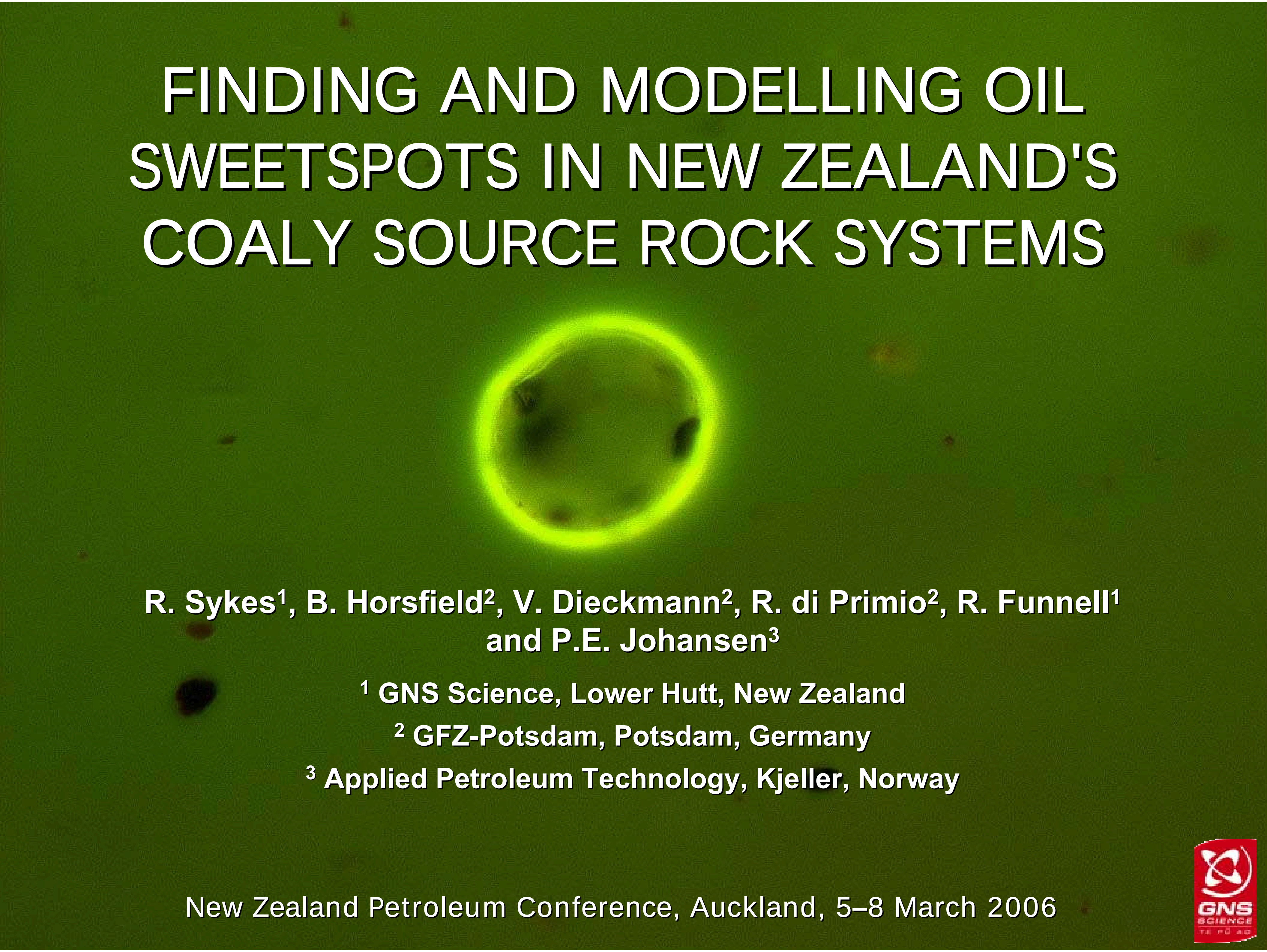

FINDING AND MODELLING OIL SWEETSPOTS IN NEW ZEALAND'S COALY SOURCE ROCK SYSTEMS

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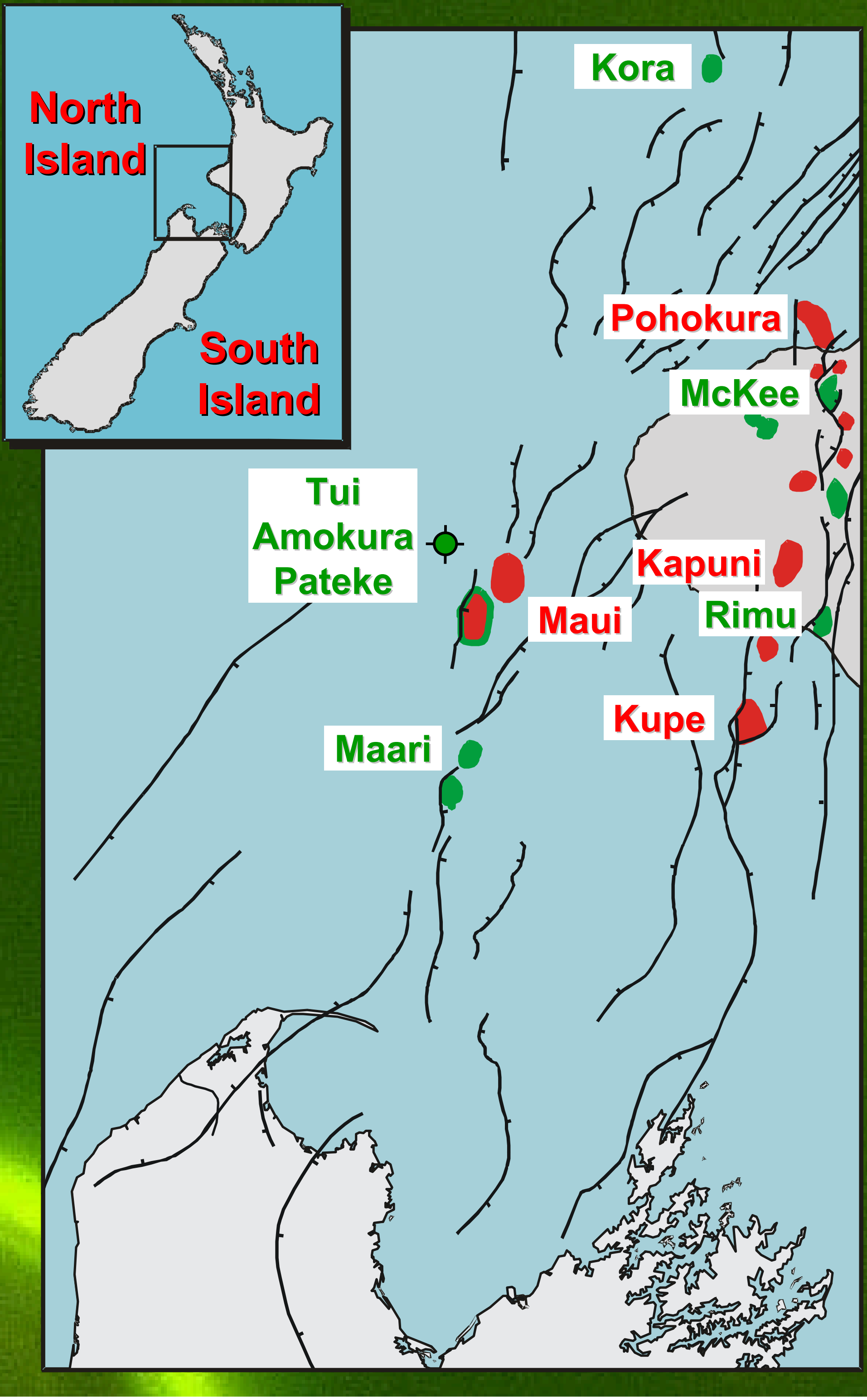
Coals source only
gas and condensate.

Yeah right.

Tui



Taranaki Basin: a primarily terrestrially sourced, gas-condensate-rich province …

Total recoverable reserves

Gas	6.5 tcf
Oil/Cond.	438 mmbbl
Gas:liquids	2.7

(Crown Minerals, 2004)

but with a steady growth of small- to medium-sized (<50 mmbbls) oil discoveries

Objective

To summarise some recent advances in knowledge and technology that have the potential to help increase the rate of oil discoveries in New Zealand basins, through:

- Improved understanding of the distribution of oil-prone coaly facies.
- Better modelling of expelled and reservoired petroleum phases and properties (e.g., GOR, API) through time.

Outline

1. Coaly source rocks (defining the range)
2. Leaf biomass (main control on waxy, paraffinic oil potential)
3. Marine influence (enhancer of total oil potential)
4. Scaling up for basin modelling
5. Phase Kinetics
6. Conclusions

Acknowledgement

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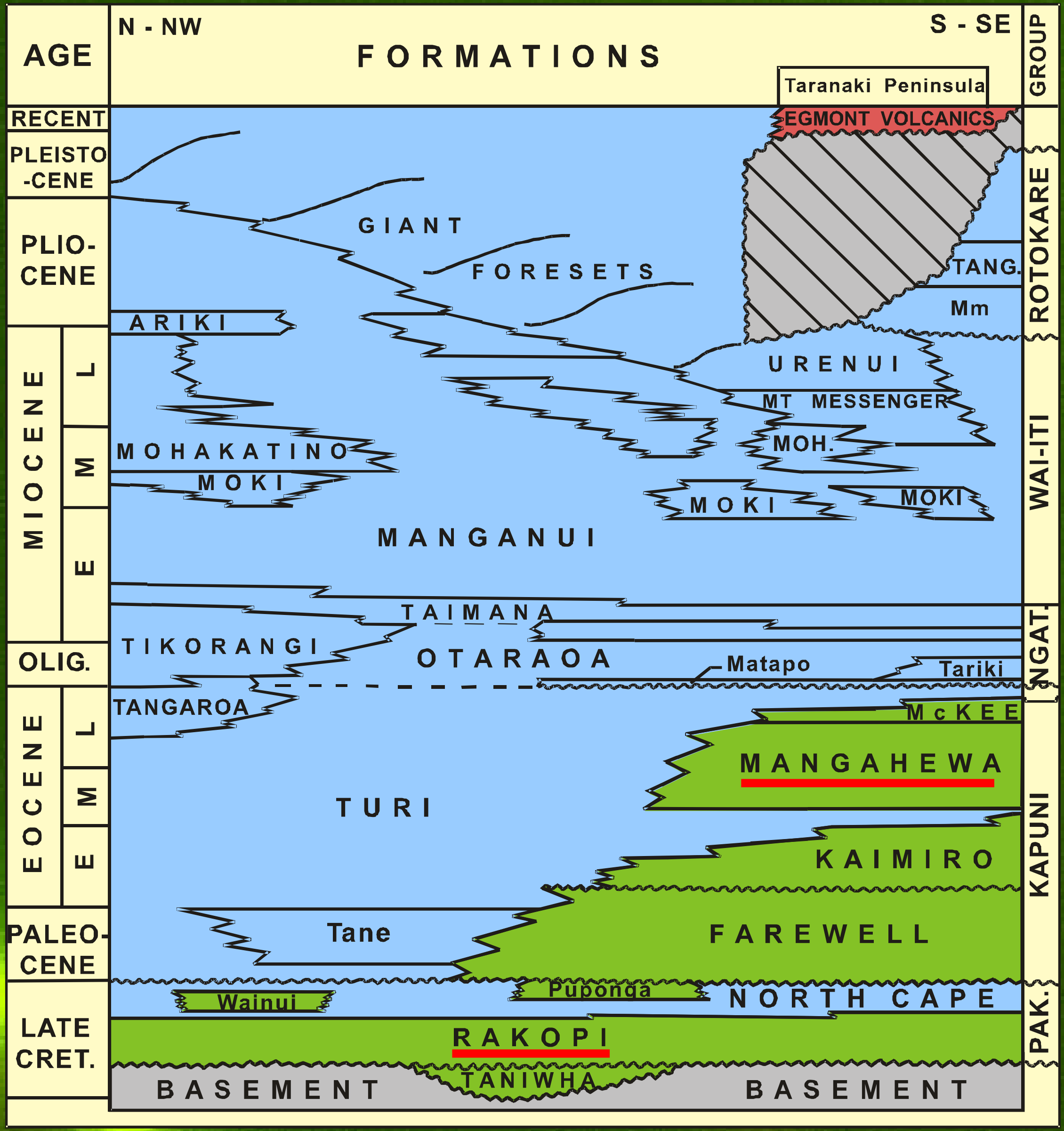
1. Coaly source rocks

Taranaki coaly source rock formations



Kapuni Group
Paleocene–Eocene

Pakawau Group
Late Cretaceous

Taniwha Formation
Mid Cretaceous

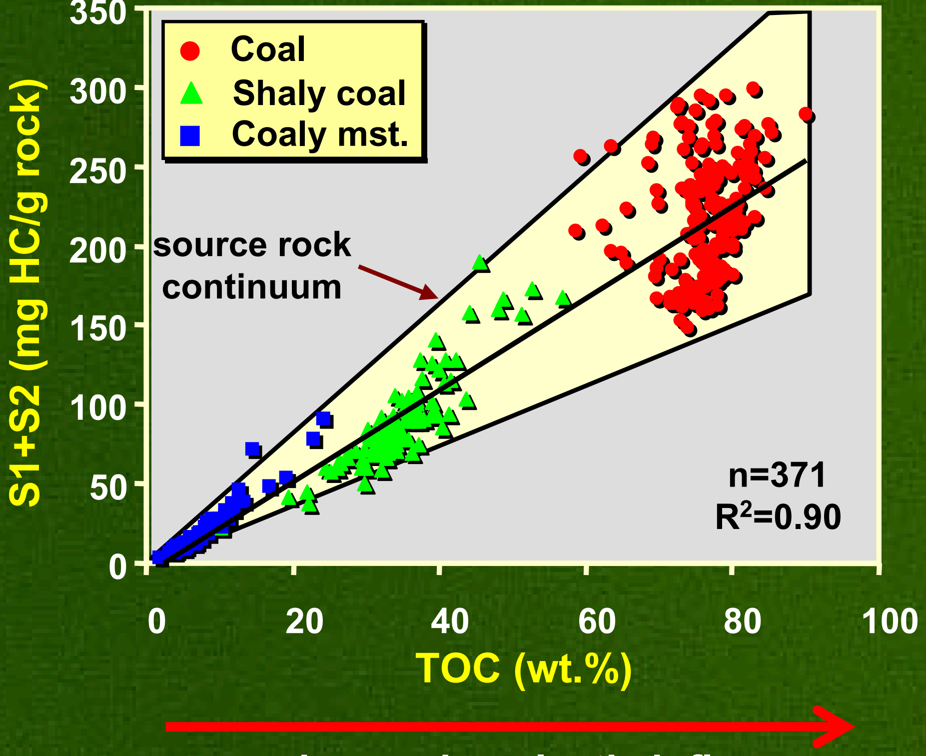
NB. All Taranaki coal measure formations and many of those in other NZ basins are marine-influenced

(after King & Thrasher 1996)

Coaly source rock continuum

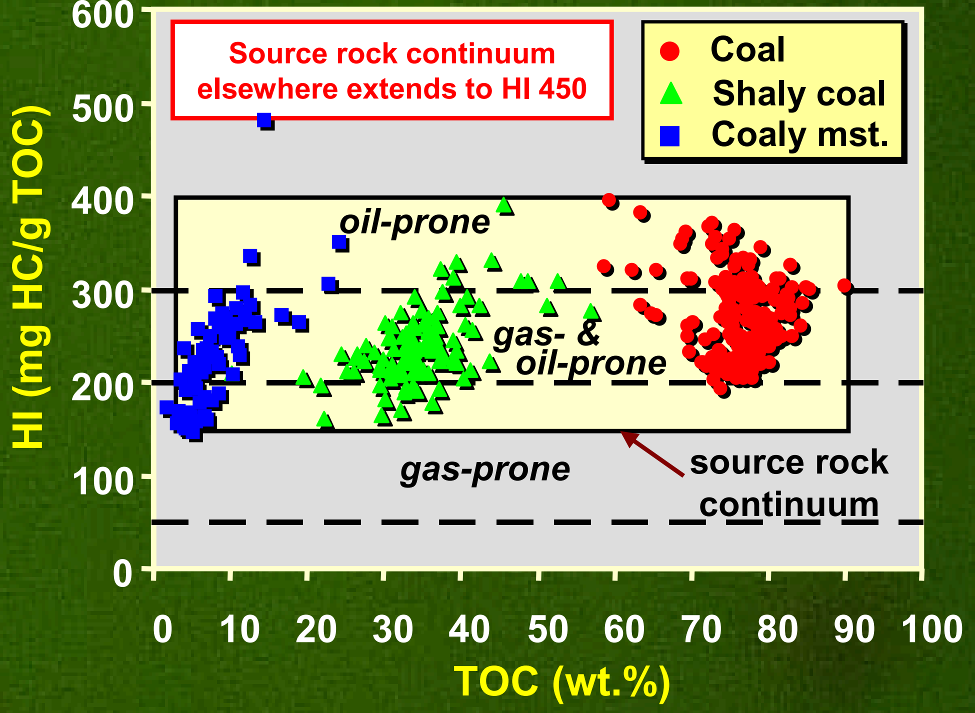
Mangahewa Formation, Taranaki

Total Genetic Potential



decreasing clastic influx

Kerogen Quality



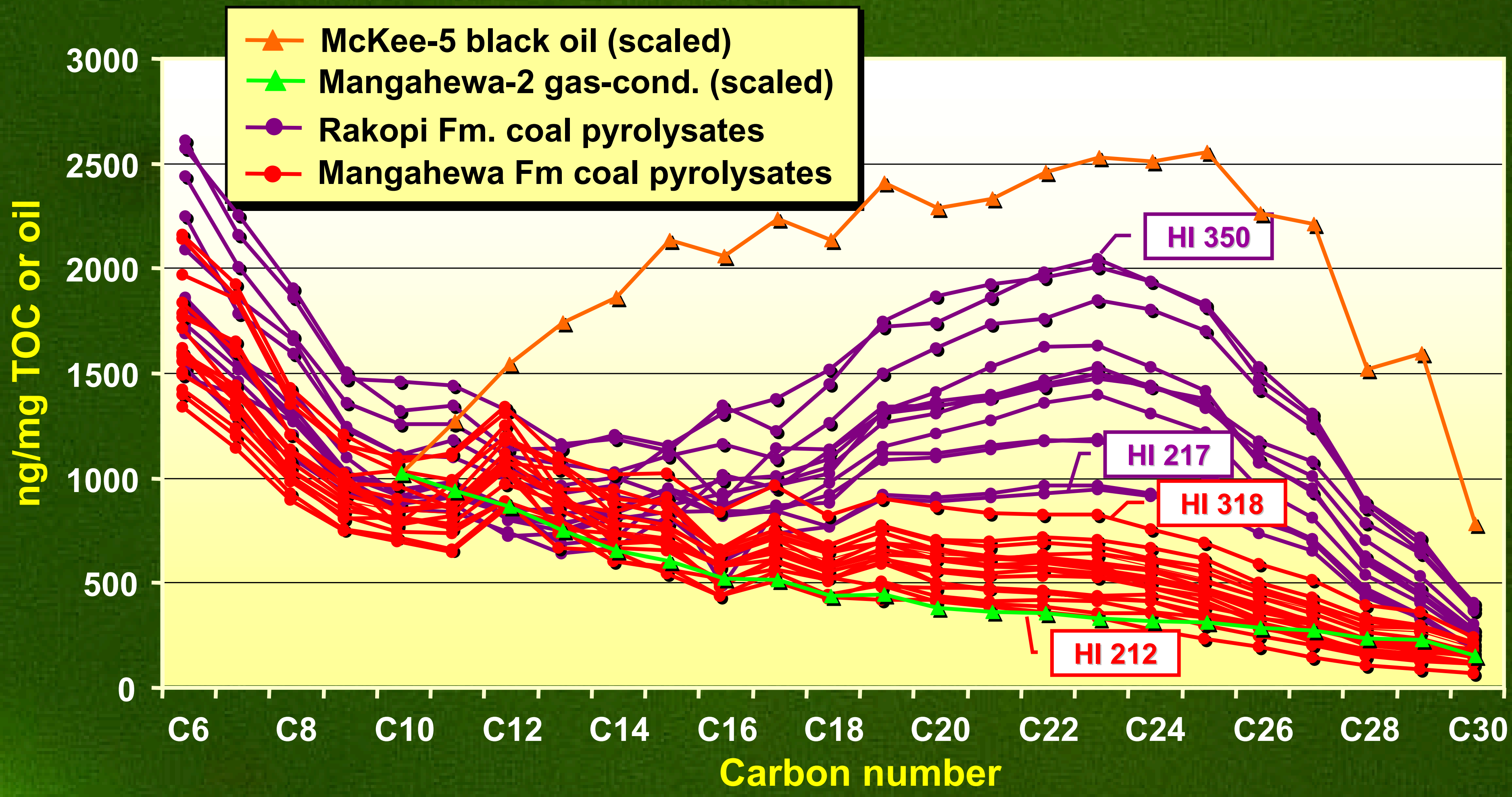
Source rock continuum elsewhere extends to HI 450

(Sykes 2001)

- The effective coaly source rock continuum begins at ~3% TOC (slightly coaly mudstone).
- Coaly mudstone is the dominant contributor to total genetic potential in some sequences.

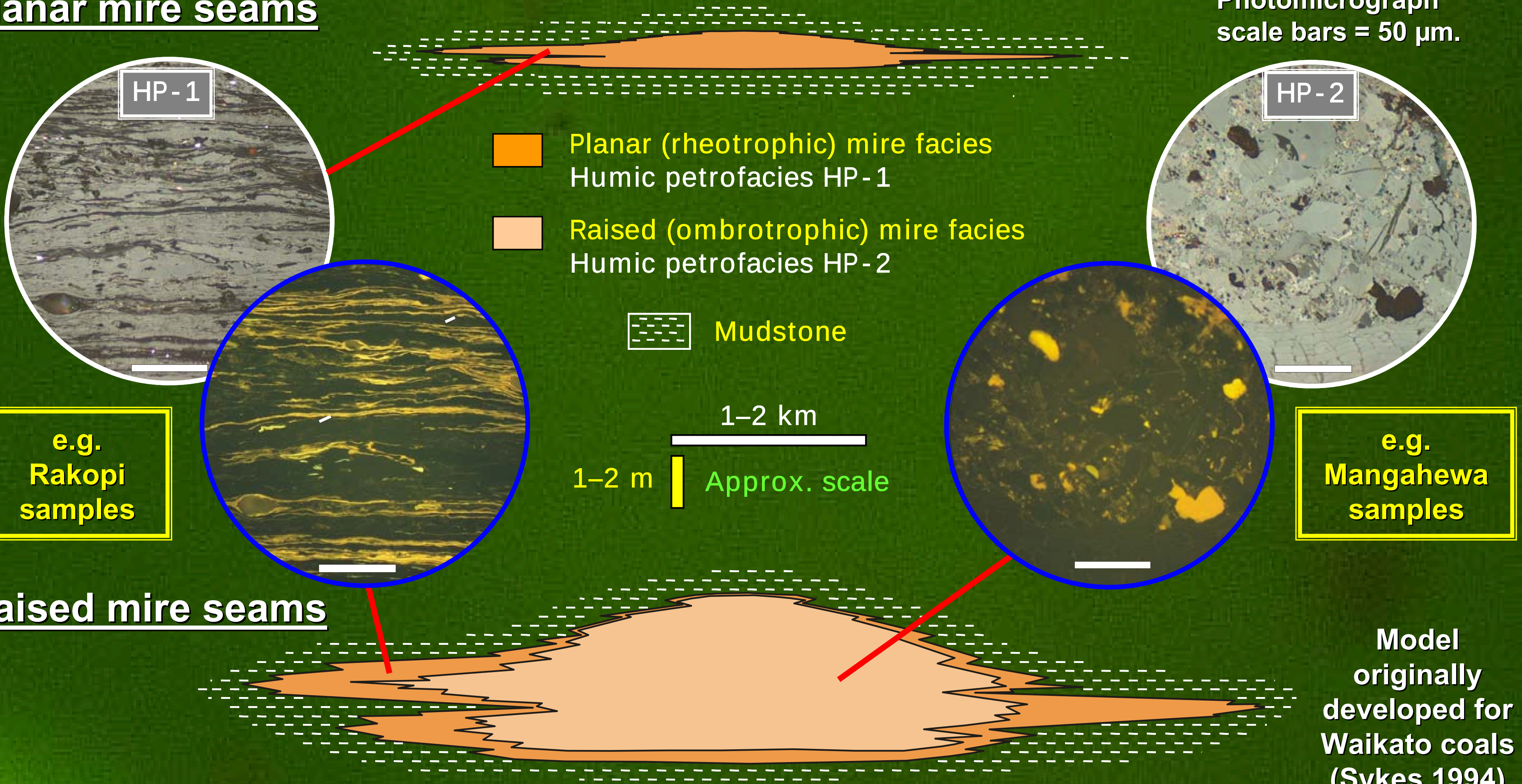
- Broadly similar kerogen type throughout the continuum, but with important variation.
- So where do we find the more oil-prone coaly source rocks and do all high-HI coaly facies expel black oil?

Clues from the fluids


Comparison of *n*-alkyl chain length distributions

- HI is not always a reliable indicator of black oil potential.
- Finding terrestrially sourced black oils must logically begin with understanding controls on the generation and expulsion of waxy, paraffinic ($n\mathrm{C}_{15+}$) oil from coaly source rocks.

NZ coal seam facies model



Planar mire seams

Raised mire seams

Photomicrograph scale bars = 50 µm.

🟧 Planar (rheotrophic) mire facies
Humic petrofacies HP-1

🟧 Raised (ombrotrophic) mire facies
Humic petrofacies HP-2

▨ Mudstone

1–2 km
1–2 m Approx. scale

e.g. Rakopi samples

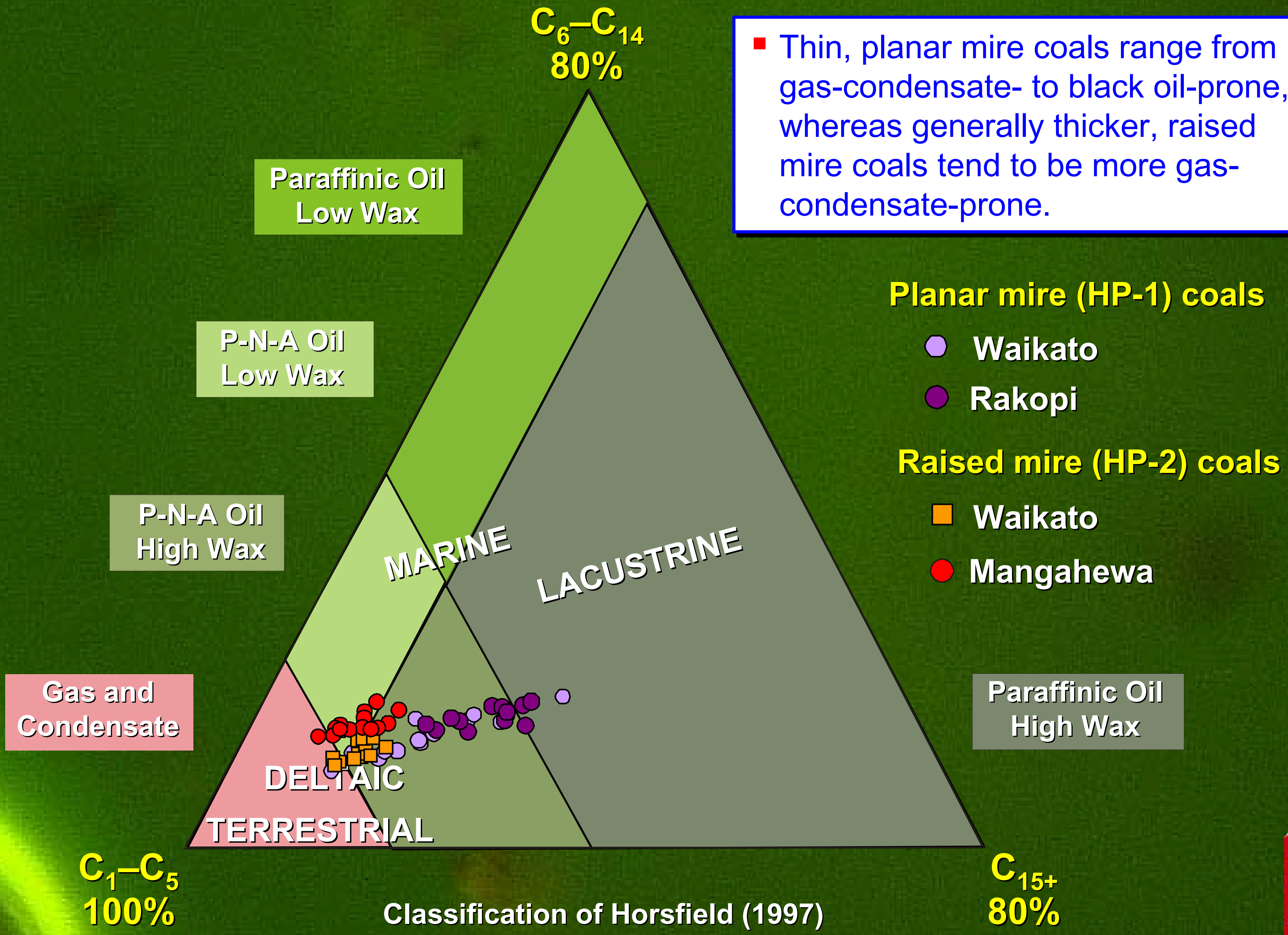
e.g. Mangahewa samples

Model originally developed for Waikato coals (Sykes 1994)

- The two end-member humic petrofacies (HP-1 and HP-2) dominate NZ Cretaceous-Eocene coals and their distributions are, to a degree, predictable.

Oil versus gas-condensate

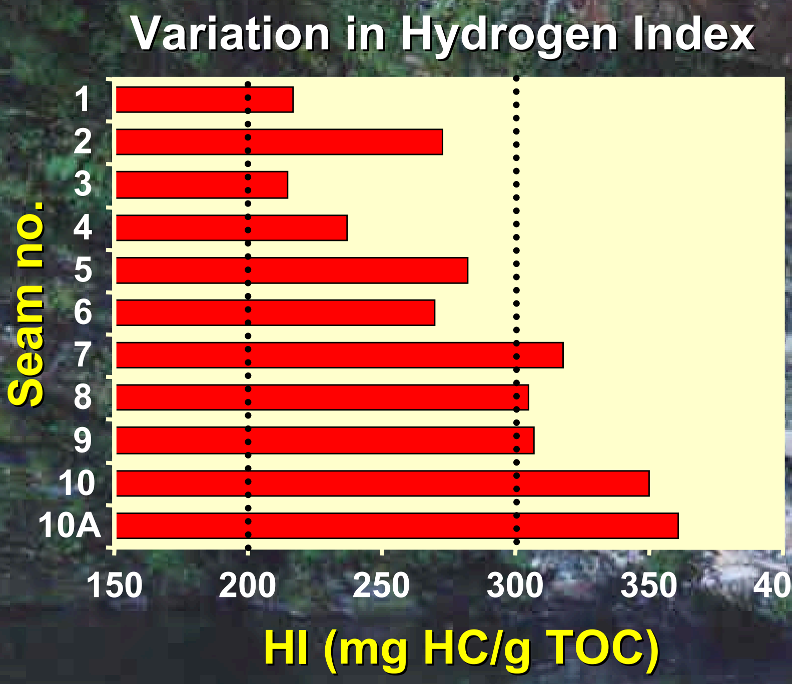
- Thin, planar mire coals range from gas-condensate- to black oil-prone, whereas generally thicker, raised mire coals tend to be more gas-condensate-prone.



Classification of Horsfield (1997)

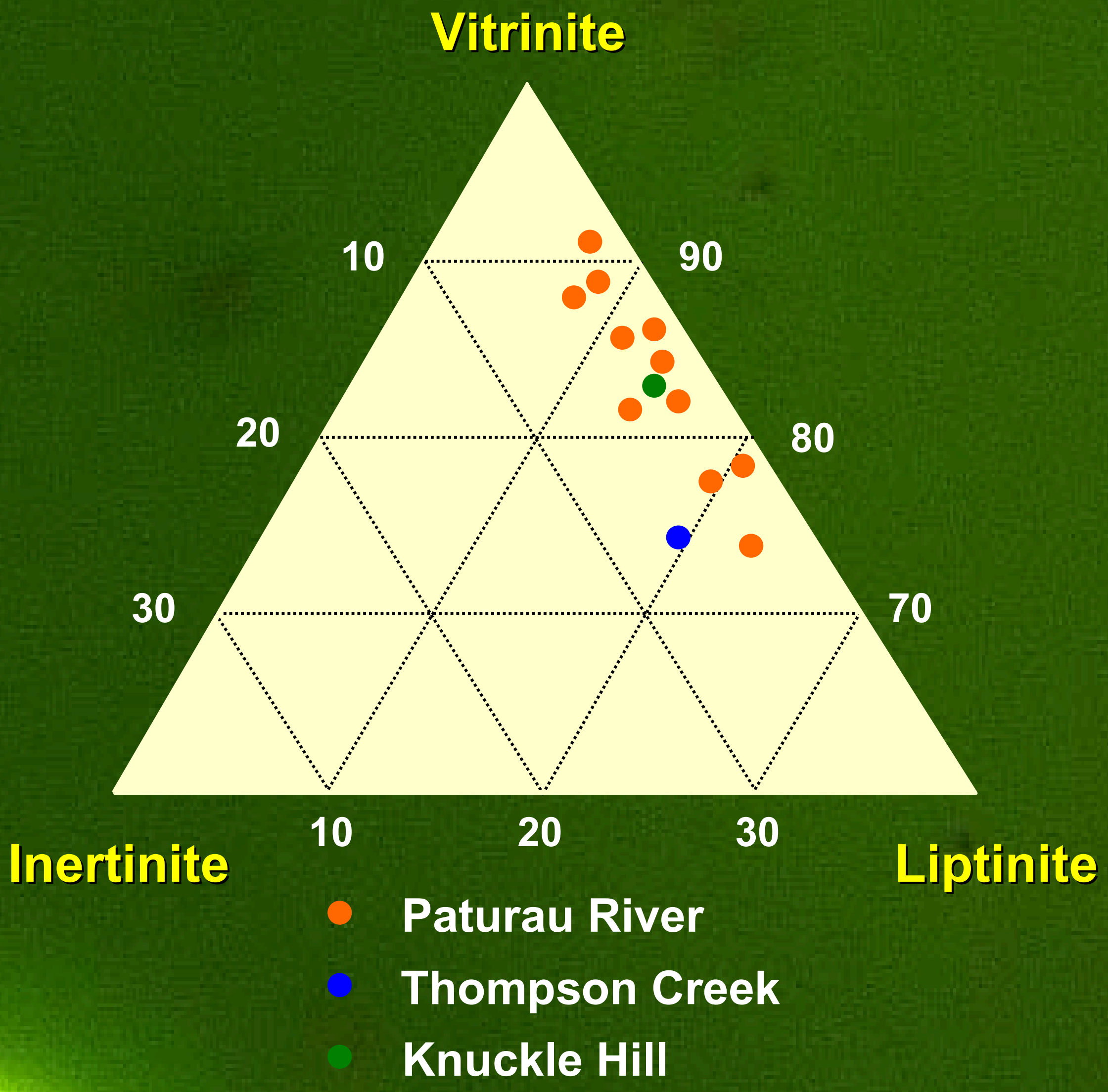
2. Leaf biomass

Study of Rakopi coal seams in NW Nelson (Sykes et al. 2004) – First empirical identification of leaf biomass as main source of waxy, paraffinic oil in Taranaki Basin



11 samples from Paturau River (this image) and 2 from Thompson Ck and Knuckle Hill

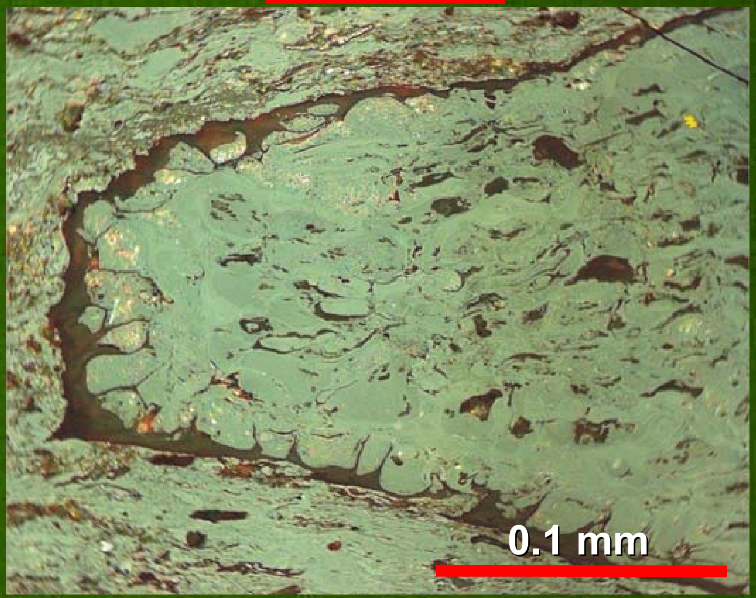
Variation in petrographic composition

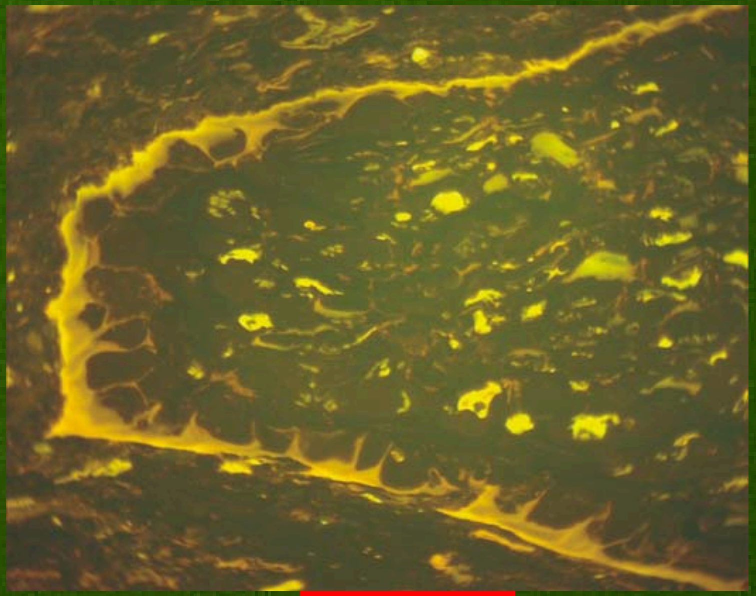


Vitrinite: 74.1–91.0 vol.% (mmf)

Liptinite: 7.3–22.7 vol.% (mmf)

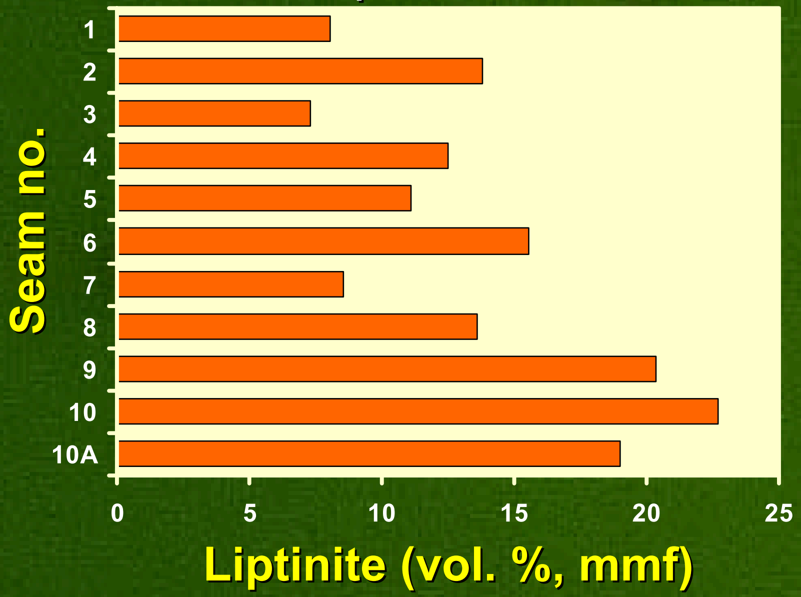
White light

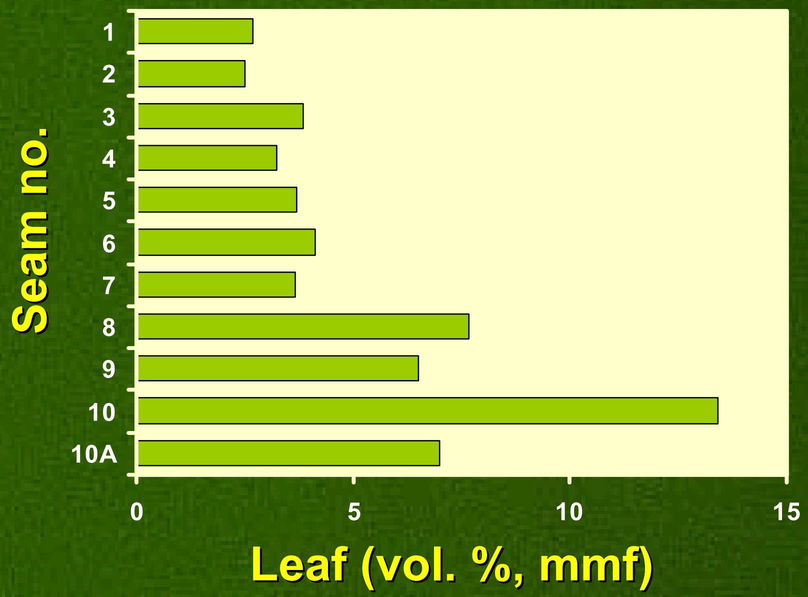


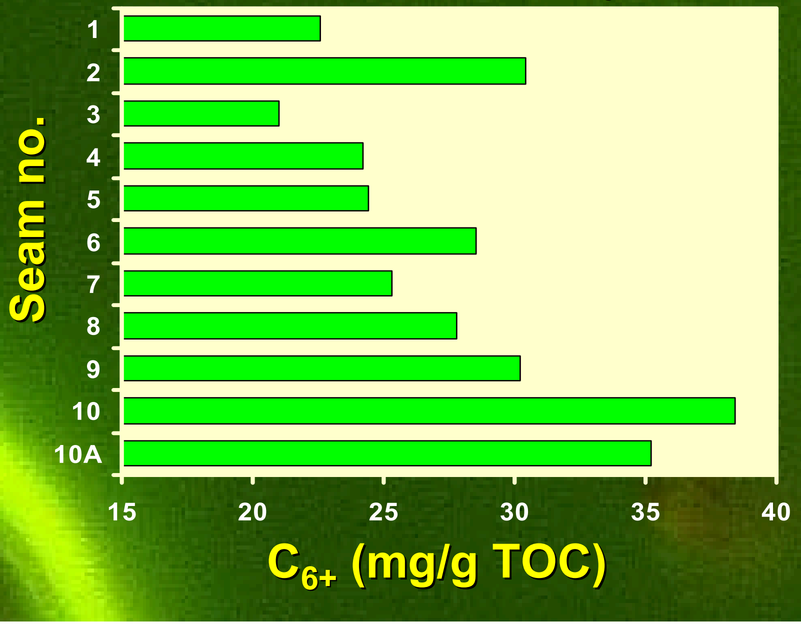


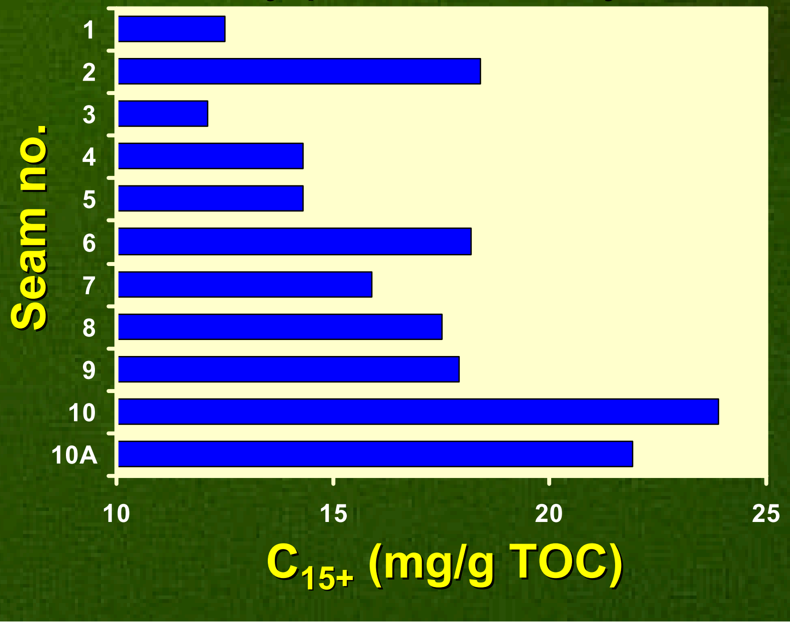
Blue light

Petrography and paraffinic oil yield

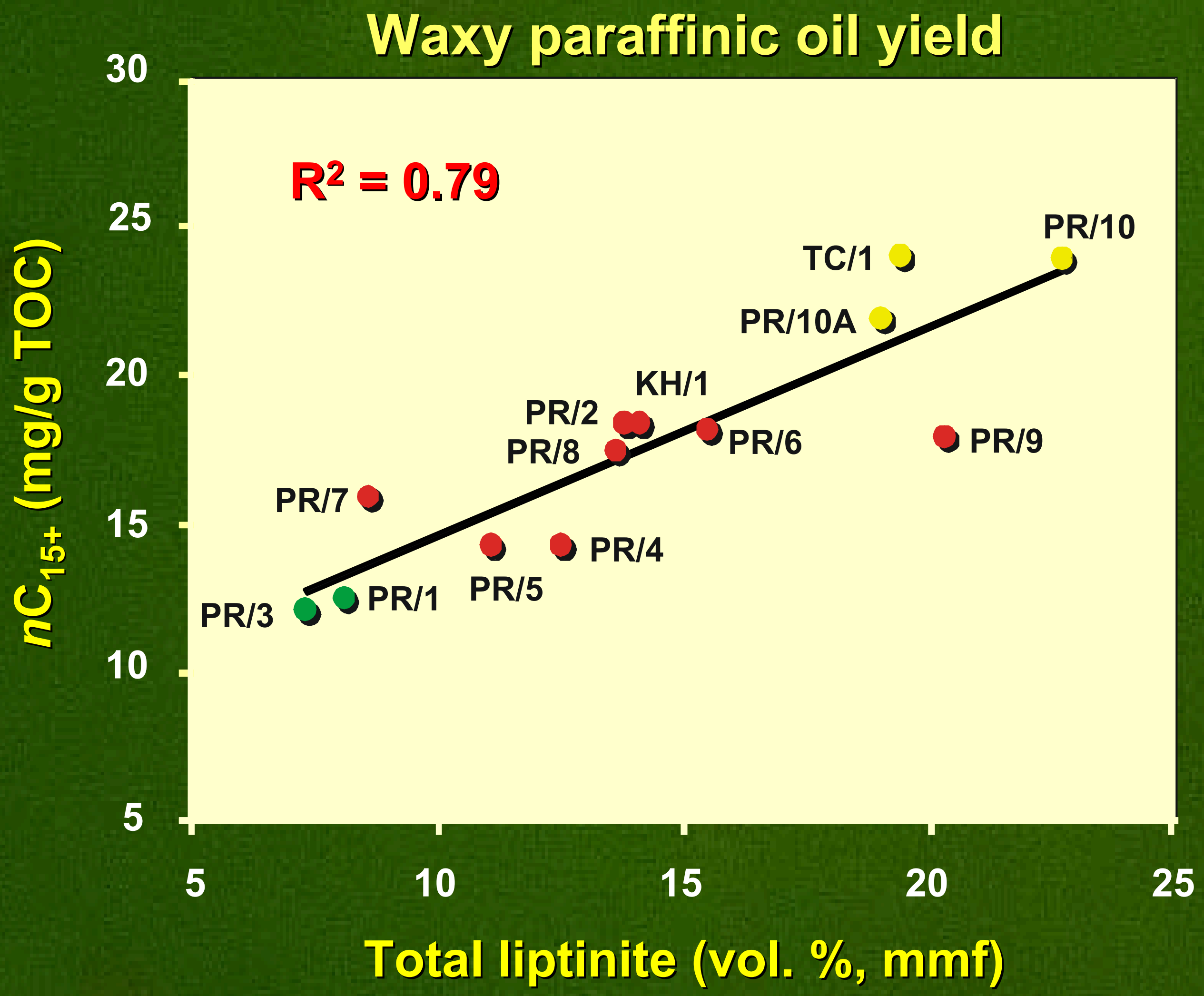

Total liptinite content


Leaf tissue content


Total paraffinic oil yield


Waxy paraffinic oil yield

Waxy paraffinic oil vs liptinite content



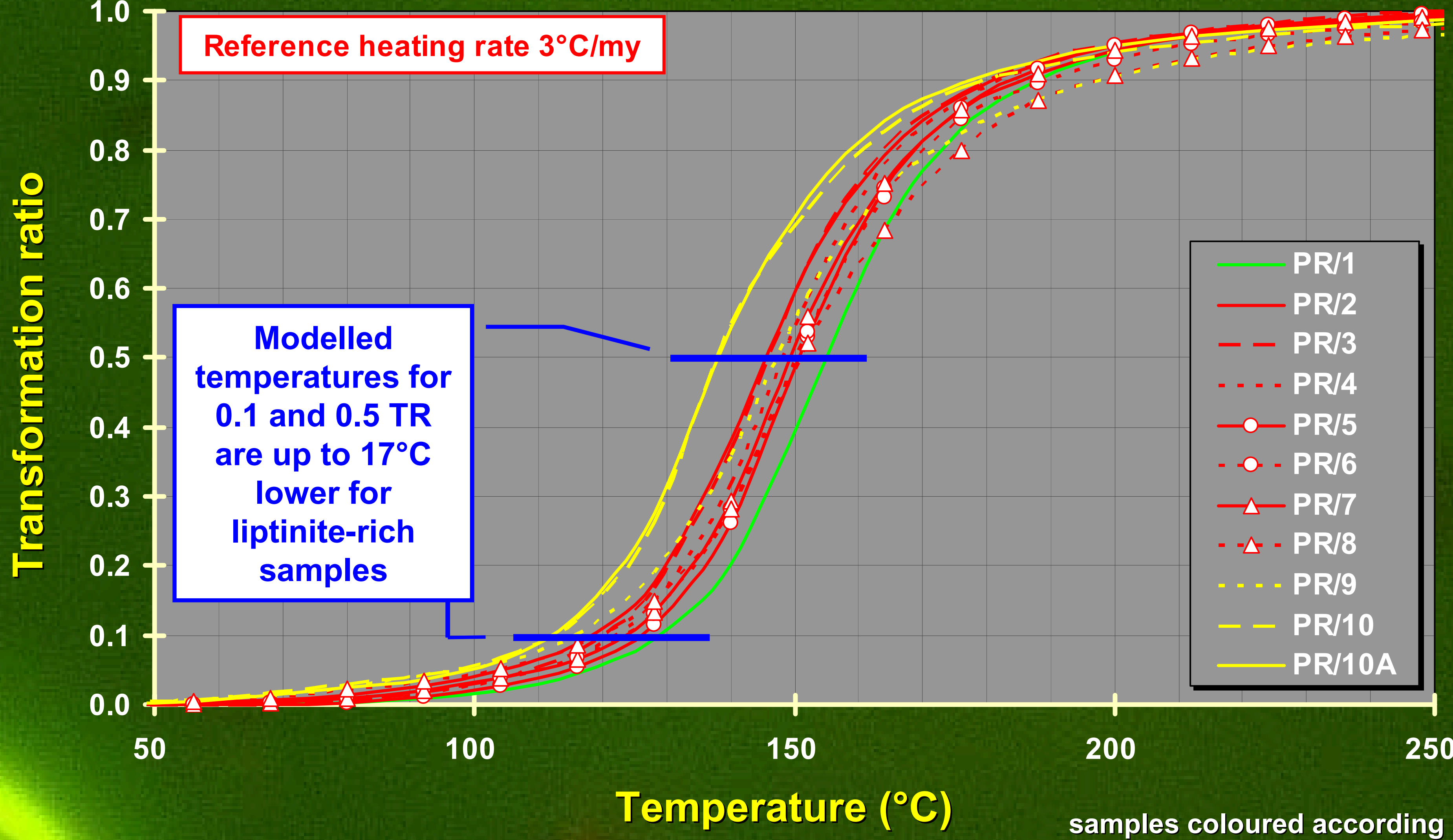
Liptinite in these samples is primarily leaf-derived cutinite and liptodetrinite

samples coloured according to HCA groupings

- Despite constituting <25% of the coaly kerogen, leaf-derived liptinite is the main control on waxy, paraffinic oil yield.
- Similar results obtained for Late Cretaceous coals in Canterbury Basin (Sykes 2004).

Leaf biomass also affects kinetics

Modelled temperatures for kerogen transformation

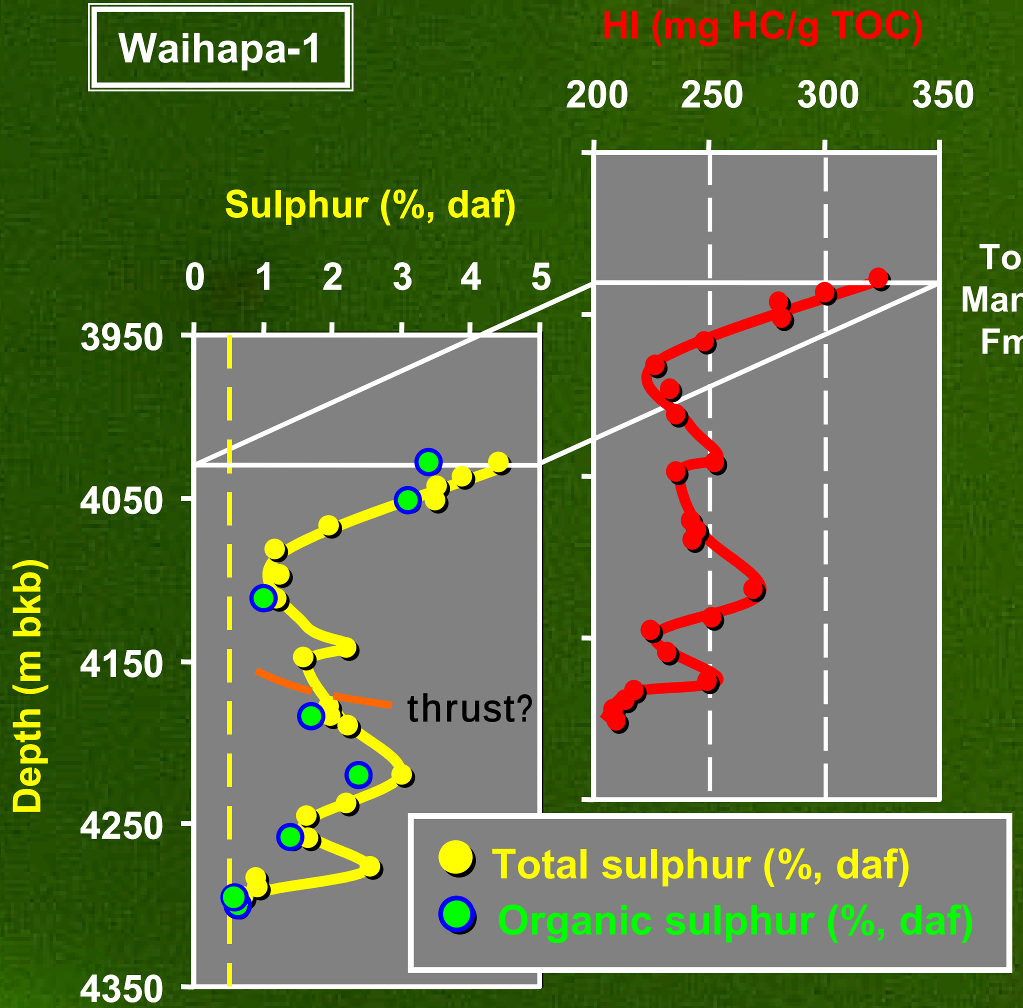


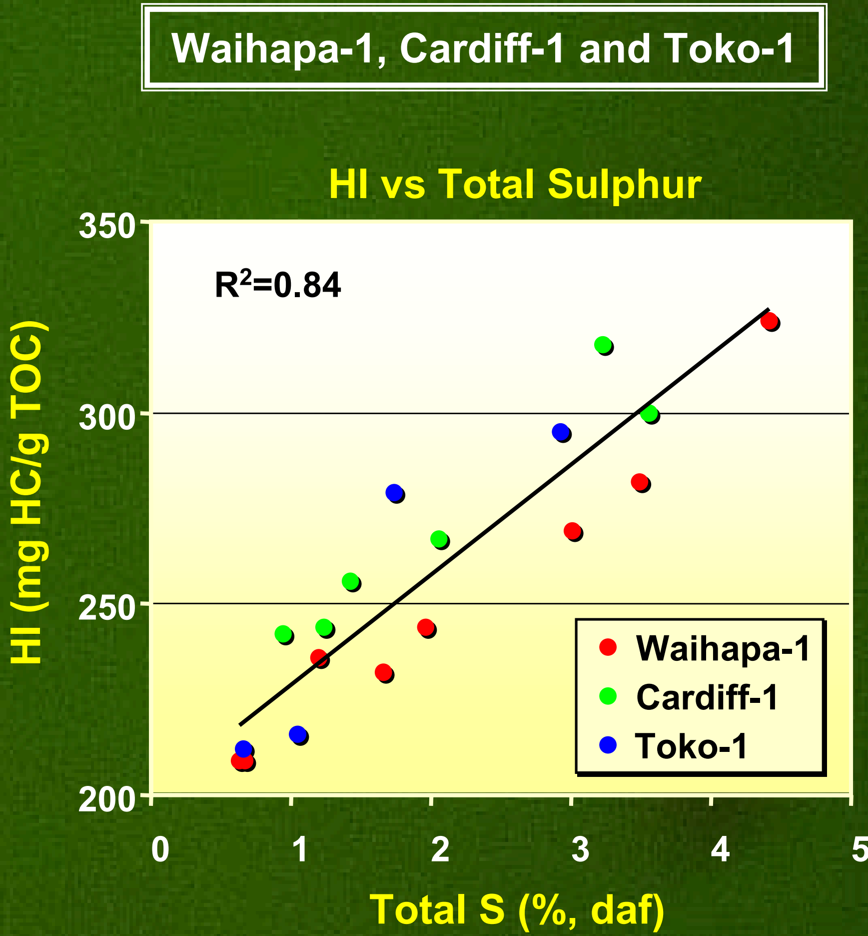
Reference heating rate 3°C/my

Modelled temperatures for 0.1 and 0.5 TR are up to 17°C lower for liptinite-rich samples

samples coloured according to HCA groupings

3. Marine influence


Waihapa-1


Waihapa-1, Cardiff-1 and Toko-1

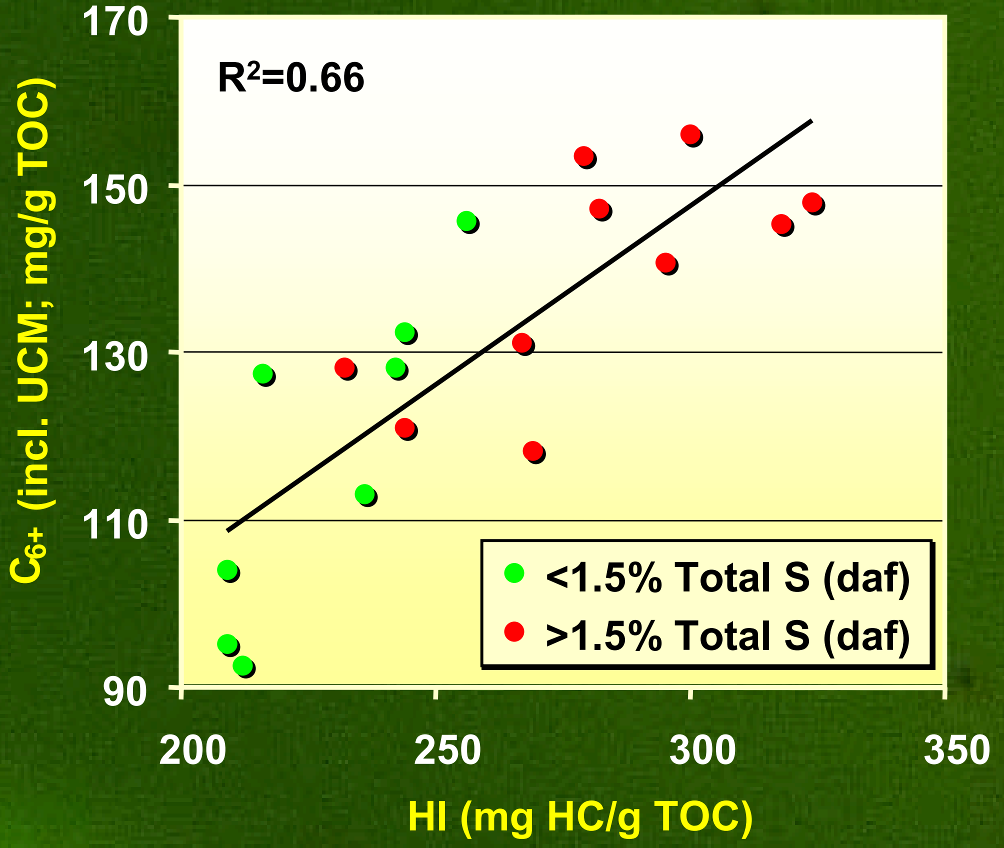
(Sykes et al. in prep.)

- Stratigraphic variations in coal sulphur content indicate synsedimentary marine influence in <u>all</u> coaly source rock formations in Taranaki, Canterbury and Great South basins.
- Marine influence enriches coaly kerogen in hydrogen.

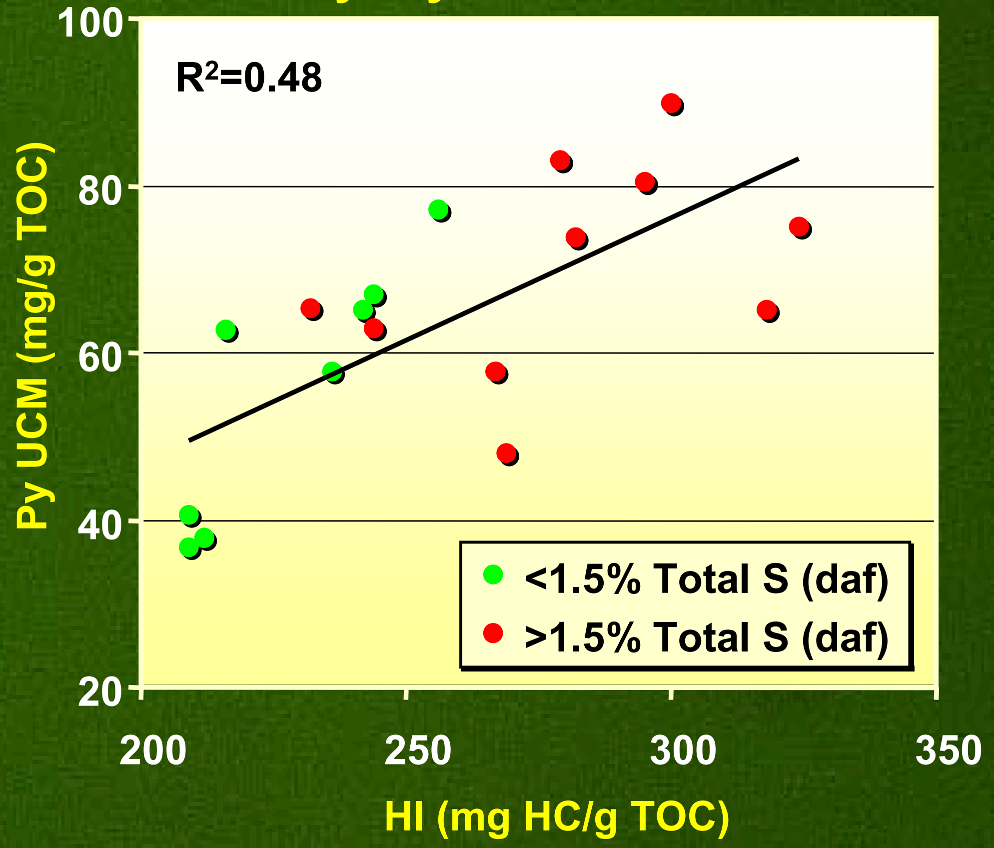
Effect of marine influence on total oil potential

Mangahewa Fm. coals from Waihapa-1, Cardiff-1 and Toko-1

Total oil vs HI

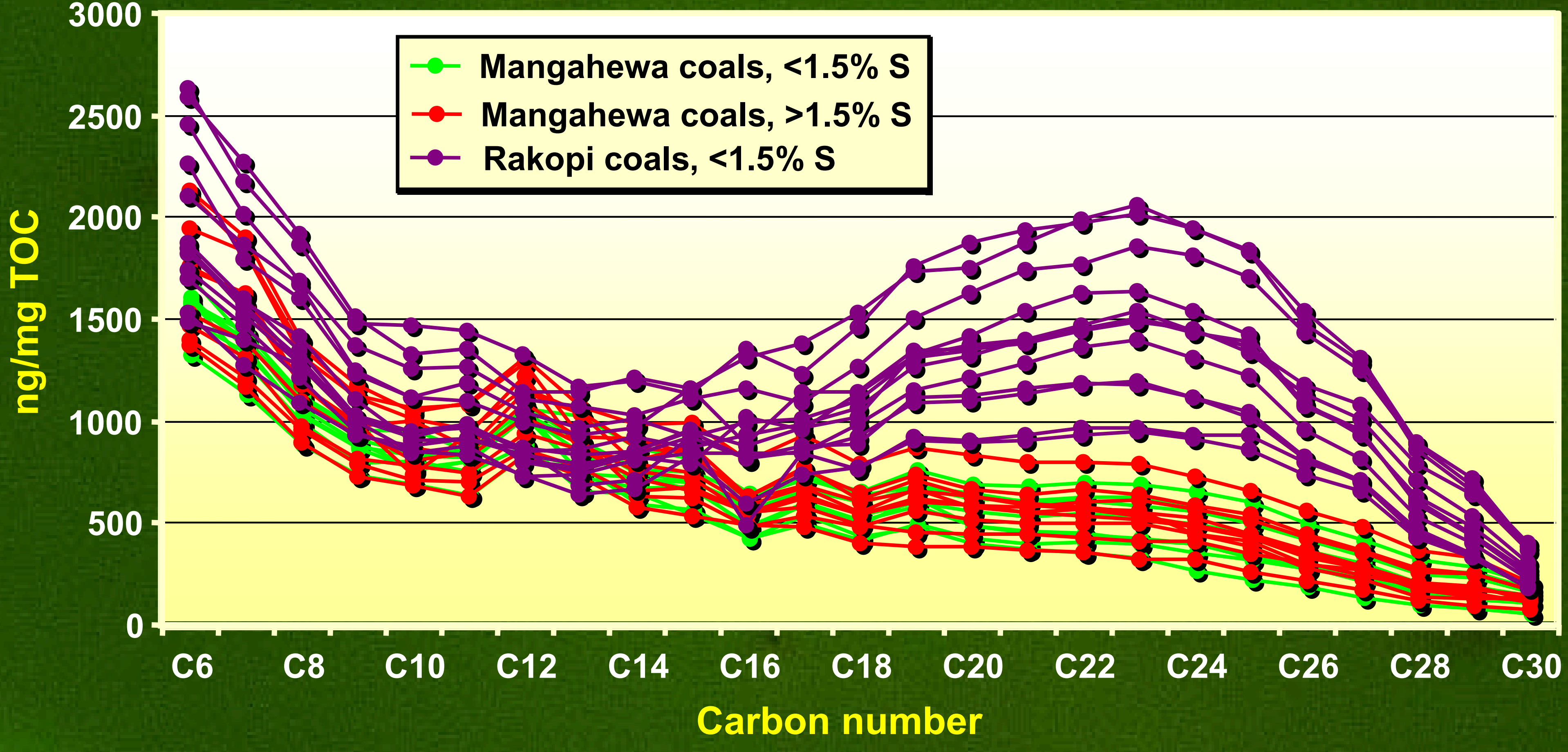


Pyrolysate UCM vs HI



- Marine influence enhances total oil potential by up to 170%, but much of the increase consists of unresolved complex mixture (UCM).

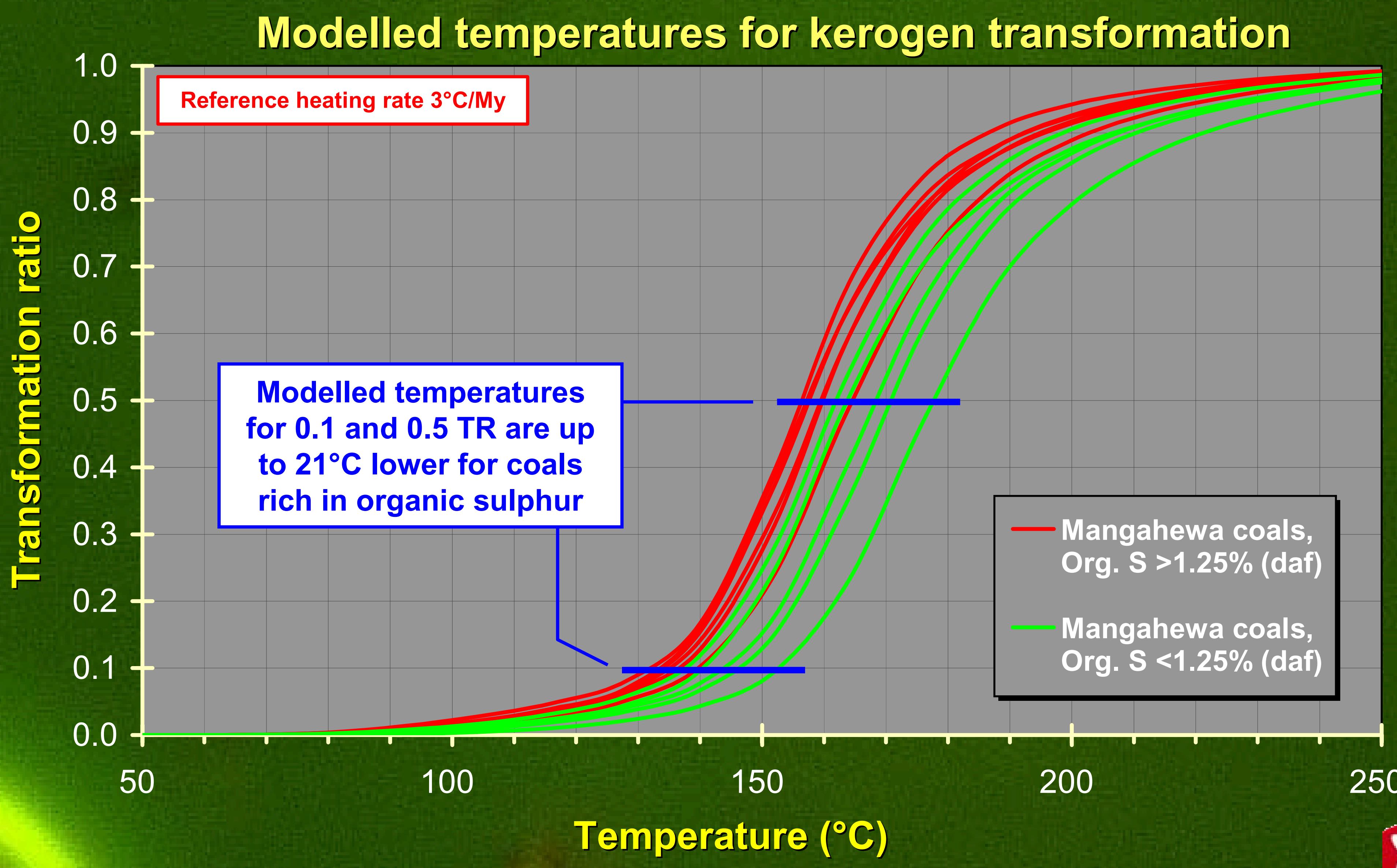
Effect of marine influence on paraffinic oil potential



C_{6+} *n*-alkyl chain length distributions

- The degree of marine influence does not have a major effect on paraffinic oil yield, particularly in the non-volatile (C_{15+}) range.
- The waxy, paraffinic oil (nC_{15+}) potentials of these particular Mangahewa coals are low compared to the Rakopi samples owing to lower leaf biomass input and/or preservation potential.

Effect of marine influence on kinetics



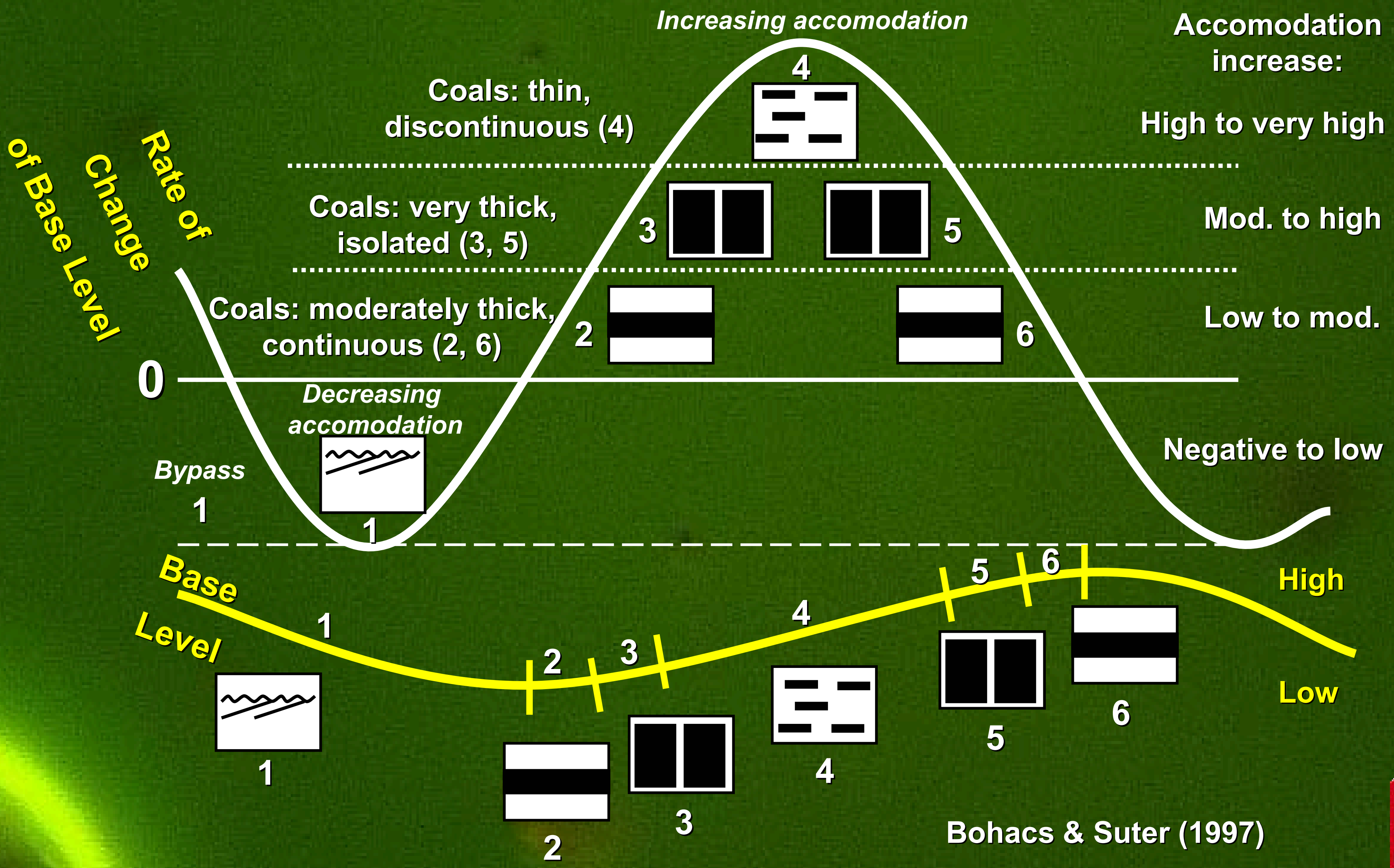
Modelled temperatures for kerogen transformation

Reference heating rate 3°C/My

Modelled temperatures for 0.1 and 0.5 TR are up to 21°C lower for coals rich in organic sulphur

4. Scaling up for basin modelling

Using sequence stratigraphy to map coaly source rock facies



Bohacs & Suter (1997)

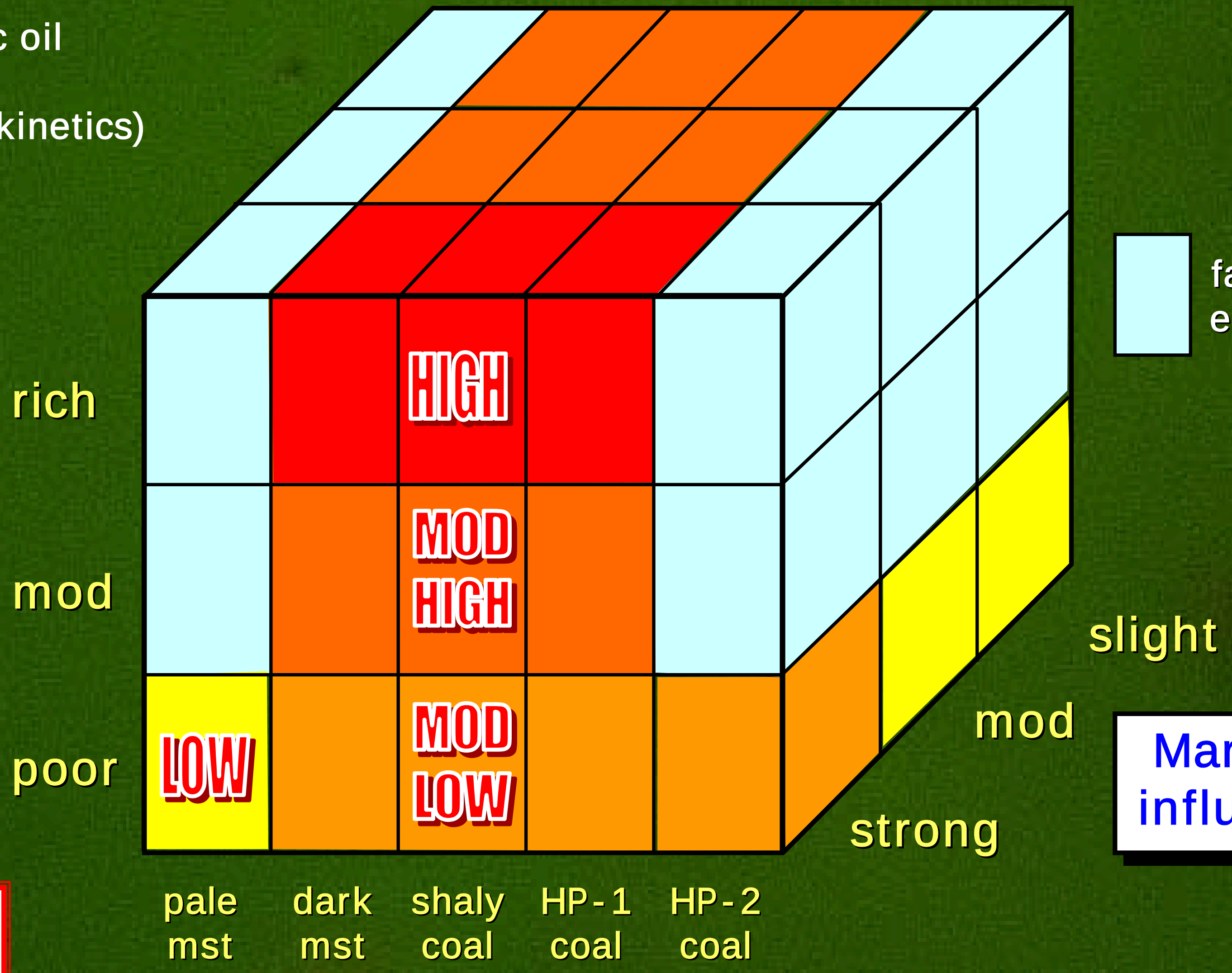
Coaly source rock facies array: oil potential

A facies-based framework for discretization of modelling inputs

HIGH High paraffinic oil potential (+ low-temp. kinetics)

↑

LOW Low paraffinic oil potential (+ high-temp. kinetics)



Leaf biomass

coaly lithofacies

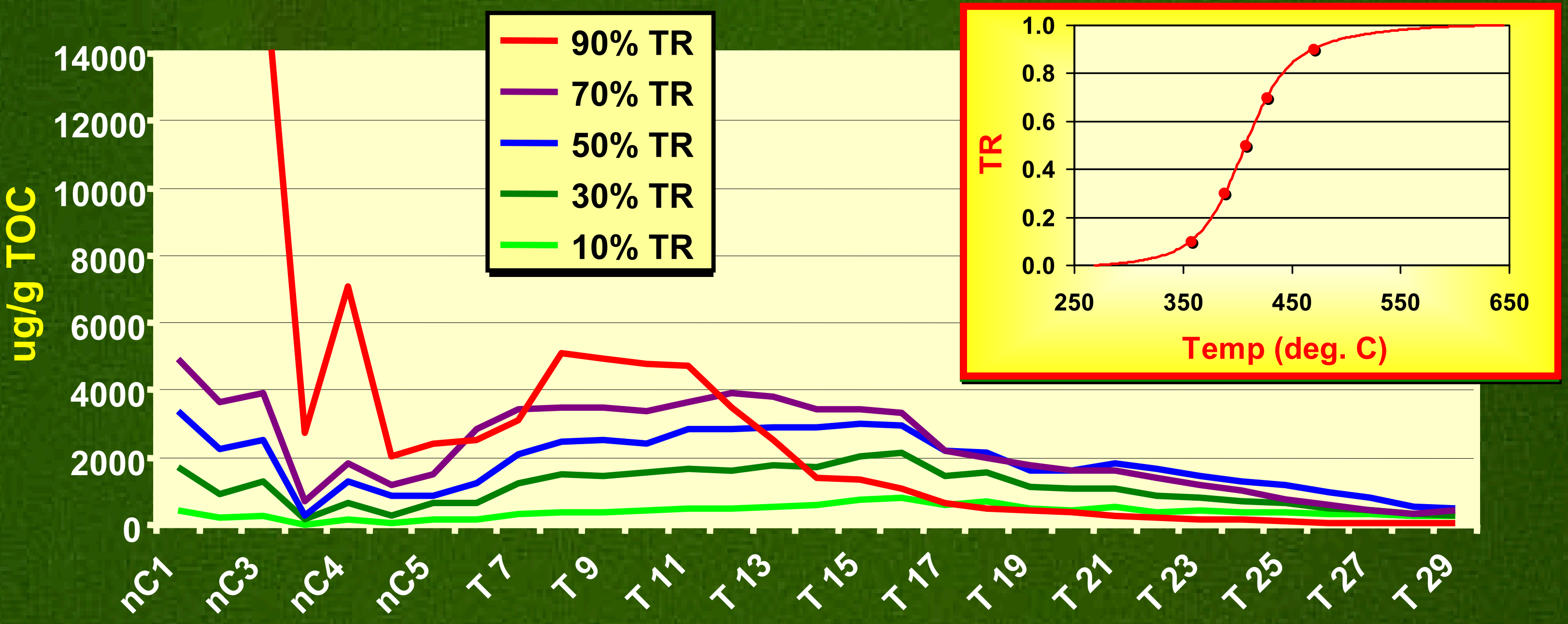
Marine influence

🟦 facies not expected

HP-1 = planar mire coal
HP-2 = raised mire coal

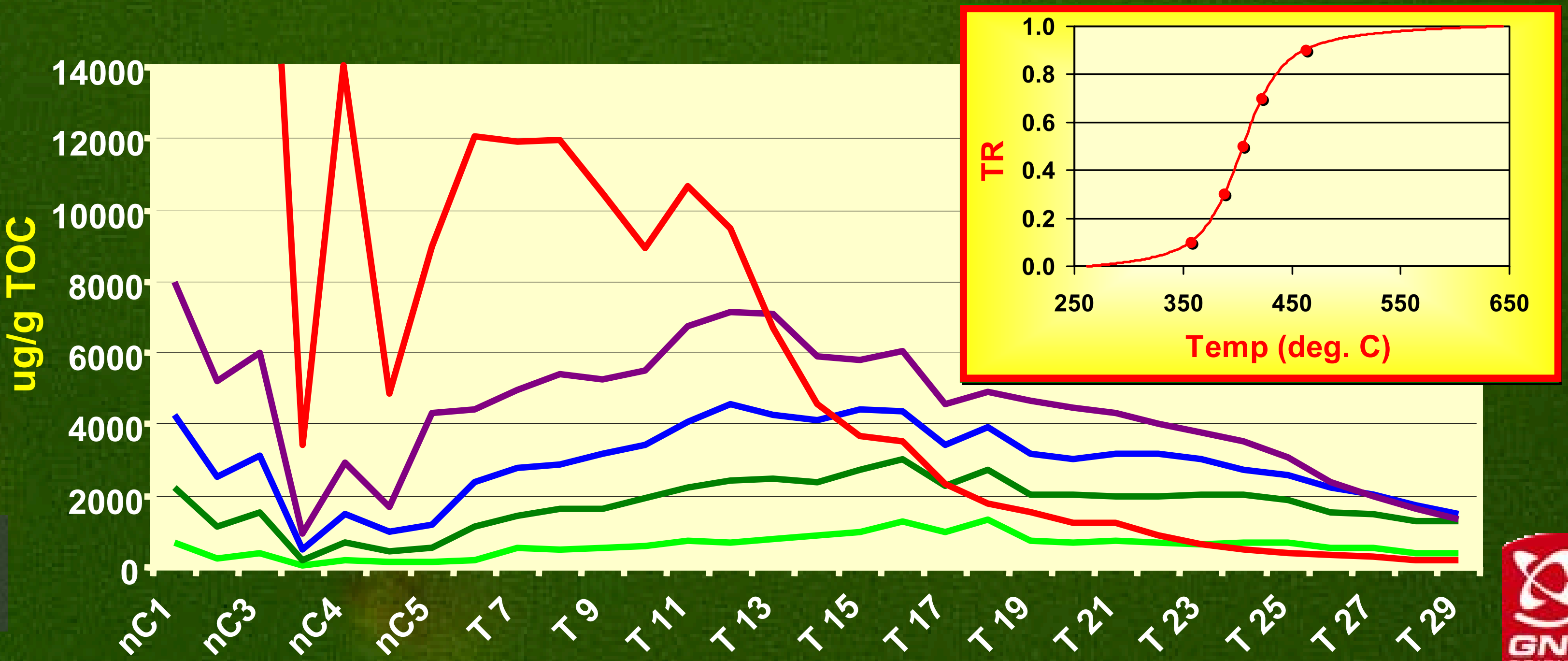
5. Phase Kinetics[1]

Leaf-poor Rakopi coal
(PR/1, HI 217)



MSSV pyrolysis component yields are measured at five transformation ratios

Leaf-rich Rakopi coal
(PR/10, HI 350)



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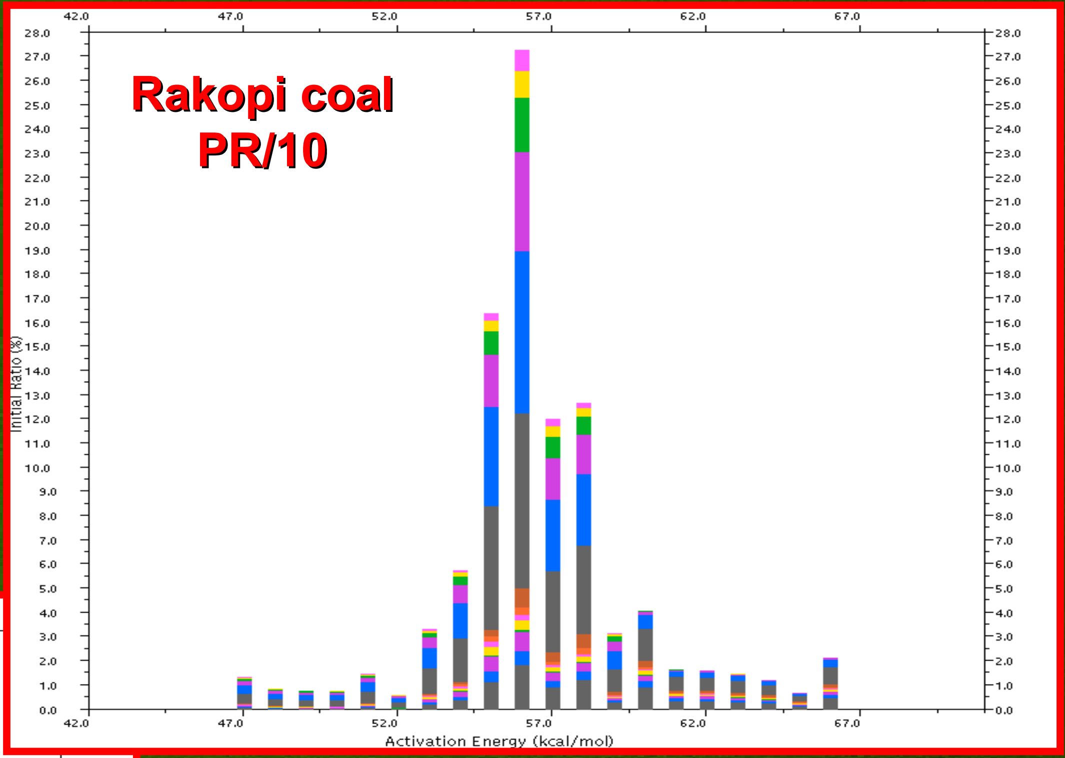
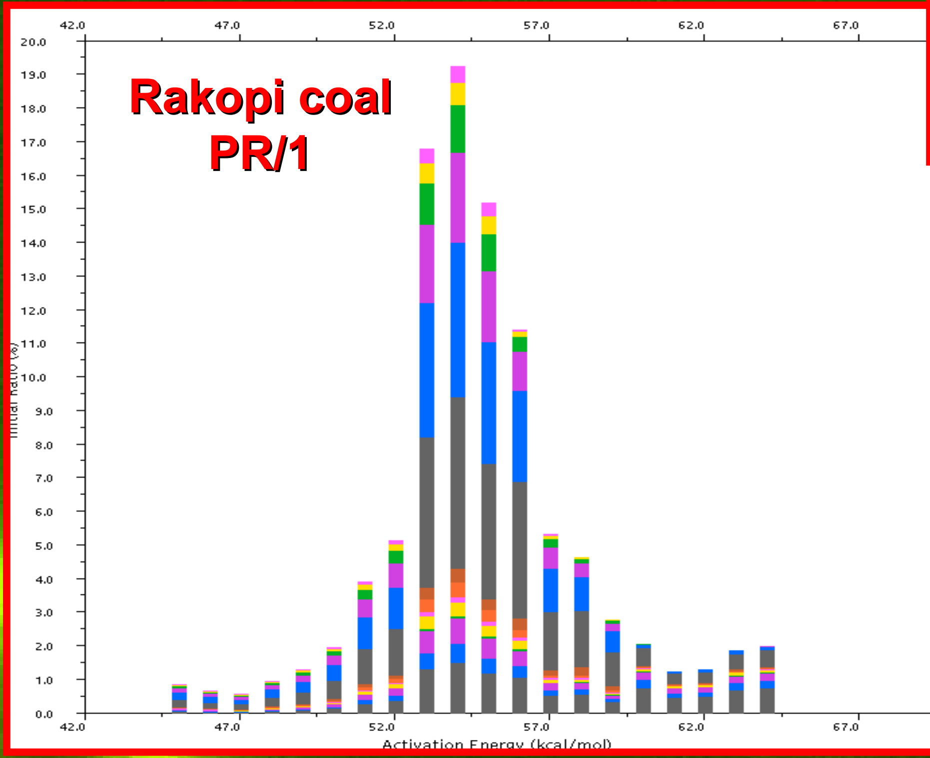
[1] Developed by IES and GFZ-Potsdam

Hybrid compositional kinetics

MSSV compositional yields at 5 TRs are assigned to the relevant activation energies determined from bulk kinetics

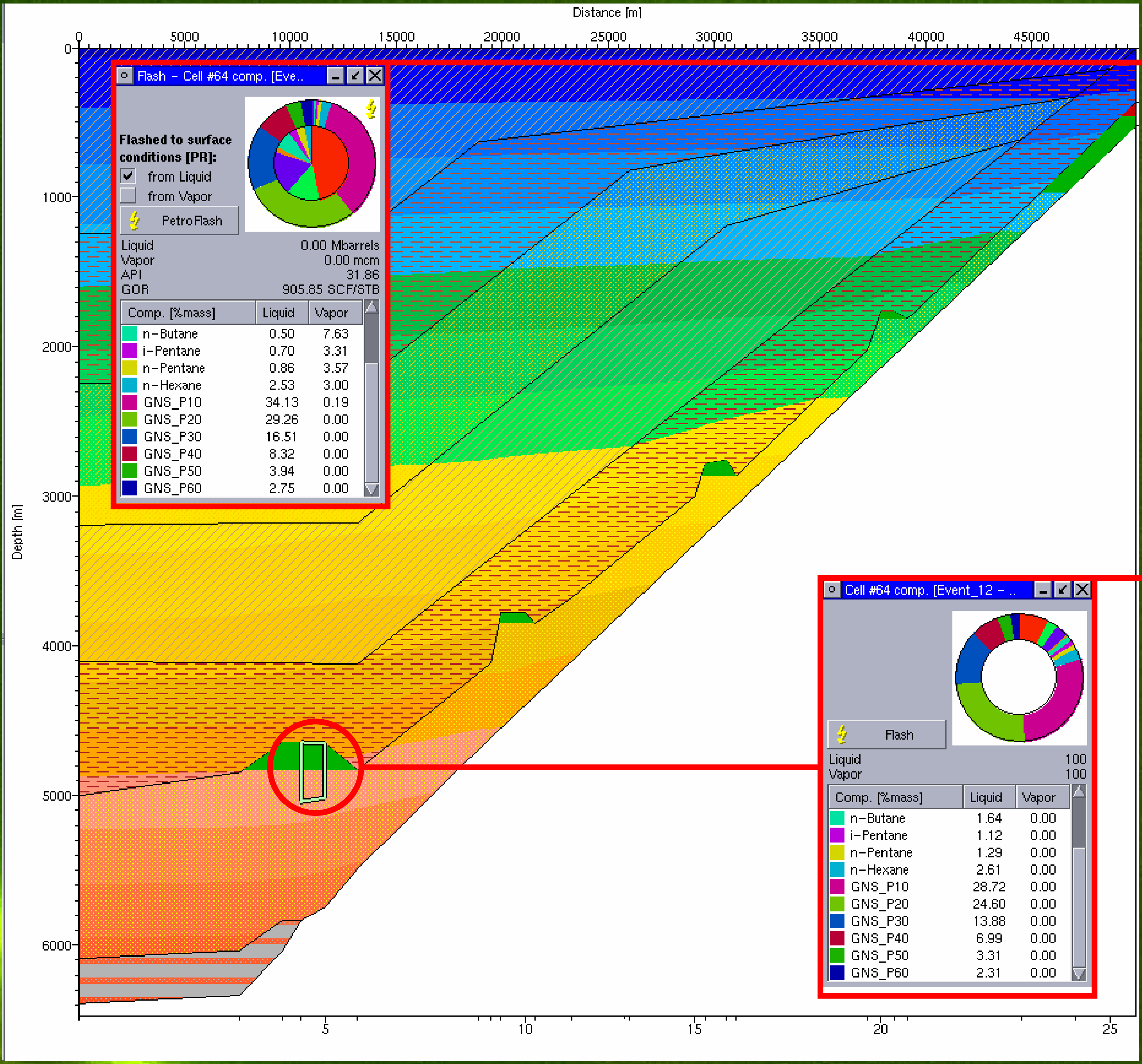




C56-80
C46-55
C36-45
C26-35
C16-25
C7-15
n-C6
n-C5
i-C5
n-C4
i-C4
n-C3
n-C2
n-C1

The 14-component, C_{7+} format enables PVT simulation of petroleum phase and properties

Example of Phase Kinetics output



Flashed to surface conditions [PR]:

☑ from Liquid

☐ from Vapor

Liquid	0.00 Mbarrels
Vapor	0.00 mcm
API	31.86
GOR	905.85 SCF/STB

Comp. [%mass]	Liquid	Vapor
n–Butane	0.50	7.63
i–Pentane	0.70	3.31
n–Pentane	0.86	3.57
n–Hexane	2.53	3.00
GNS_P10	34.13	0.19
GNS_P20	29.26	0.00
GNS_P30	16.51	0.00
GNS_P40	8.32	0.00
GNS_P50	3.94	0.00
GNS_P60	2.75	0.00

Liquid	100
Vapor	100

Comp. [%mass]	Liquid	Vapor
n–Butane	1.64	0.00
i–Pentane	1.12	0.00
n–Pentane	1.29	0.00
n–Hexane	2.61	0.00
GNS_P10	28.72	0.00
GNS_P20	24.60	0.00
GNS_P30	13.88	0.00
GNS_P40	6.99	0.00
GNS_P50	3.31	0.00
GNS_P60	2.31	0.00

Two-phase oil and gas compositions at surface conditions, with GOR and API

Undersaturated oil composition at reservoir PT conditions

Output from IES PetroMod 2D v9.0

6. Conclusions (1)

1. Taranaki and other NZ coaly source rocks comprise a continuum of coaly mudstones, shaly coals and coals, which range from gas-condensate- to waxy, paraffinic oil-prone and all of which contribute to the petroleum potential of kitchen areas.

2. The paraffinic oil potential of NZ coaly facies appears to be controlled primarily by the abundance of leaf-derived liptinites.

3. Thin, planar mire coals and associated coaly mudstones appear to be better sources of waxy crude oil than are thick, raised mire coals owing to greater leaf biomass input and/or preservation potential.

4. Synsedimentary marine influence significantly enhances the total oil potential of coals, but does not have a major effect on waxy, paraffinic oil potential.

6. Conclusions (2)

5. Abundant leaf biomass and strong marine influence may each reduce the temperature thresholds for the onset of oil generation by up to ca. 20°C, resulting in significantly earlier and shallower expulsion of oil and, ultimately, a broader oil window.

6. Oil sweetspots in NZ coaly source rock systems probably coincide with kitchen areas containing abundant thin, leaf-rich and marine-influenced coals and coaly mudstones.

7. Well- and seismic-based sequence stratigraphy should enable mapping of the distribution and source properties (e.g., HI, GOR, kinetics) of coaly facies – and hence the targeting of oil sweetspots – in NZ basins, but only after extensive calibration.

8. Phase Kinetics are a powerful new tool for improved phase prediction, but have yet to be tested in a properly constrained NZ basin model with natural fluid PVT data.