Reassessment of Exploration Risks in Taranaki Basin Related to Gondwana Margin Evolution and Establishment of an Active Plate Boundary in New Zealand Using Integrative 3-D Basin Modelling*

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Abstract

The discovery of the giant Maui gas-condensate field in 1969 initiated a long history of petroleum exploration in offshore Taranaki Basin. The large discovery was followed by many smaller finds but also by a very large number of dry wells through to present-day. Factors controlling prospectivity are still insufficiently understood despite 400 wells being drilled. Recent remapping of the southern Taranaki Basin as part of the GNS Science 4D Taranaki project has identified rapid changes in basin evolution and illustrated the structural complexity of the basin. Heterogeneities in the crust inherited from the Mesozoic Gondwana margin subduction system directly impact on heat flow and heat generation potential. The architecture of the crust was also affected by Late Cretaceous rifting related to the opening of the Tasman Sea as well as the initiation of the present-day convergent plate margin. These processes influenced the evolution of heat flow through time whilst increasing the thermal heterogeneity in the basin. In addition to heat flow, variability in source rock properties and a complicated petroleum plumbing system add further complexity. Although the capacity of the Late Cretaceous Rakopi Formation to charge the Maui Field as well as other accumulations has been demonstrated, the spatial variability of the source rock potential of the Rakopi Formation is not well known. The change from rifted to convergent margin has resulted in fragmentation and inversion of parts of the southern Taranaki Basin. Change in basin configuration has affected migration pathways and has likely compromised the integrity of several structures. Many factors such as crustal composition and heat generation potential are currently mapped only very broadly. We therefore choose a scenario-based basin modelling approach to illustrate risks to petroleum expulsion and charge of traps using PetroMod software. Instead of merely reproducing charge, which very often leads to overly optimistic predictions for untested prospects, we identify basin conditions that could prevent charge and assess their geological likelihood in the context of recent research on plate boundary evolution. We integrate thermal evolution and petroleum migration scenarios to better reflect the number of dry wells in the basin and to better understand exploration risks.

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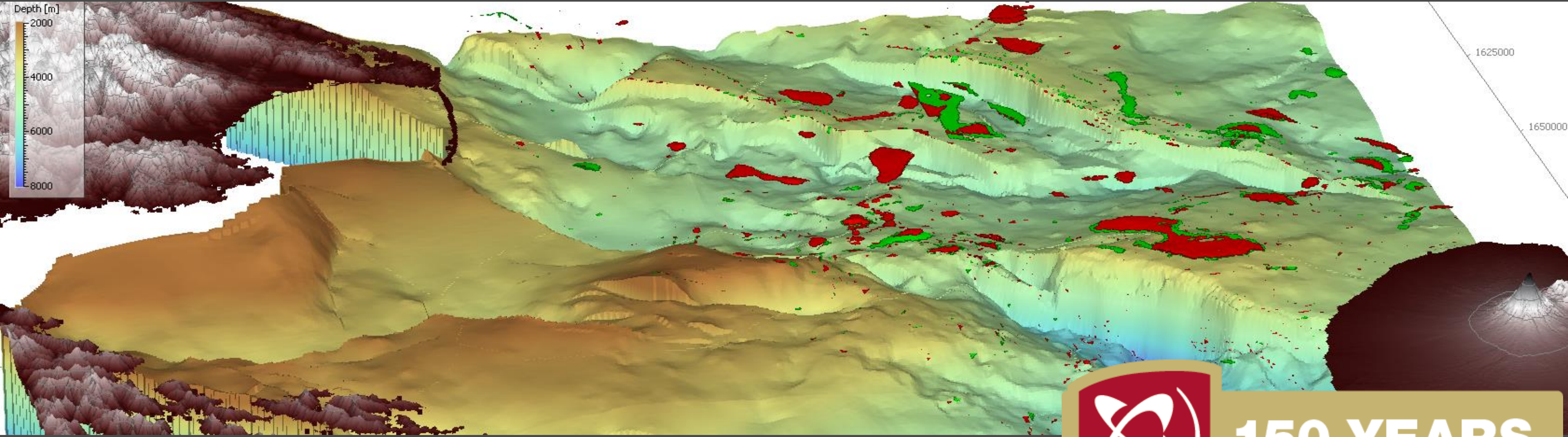

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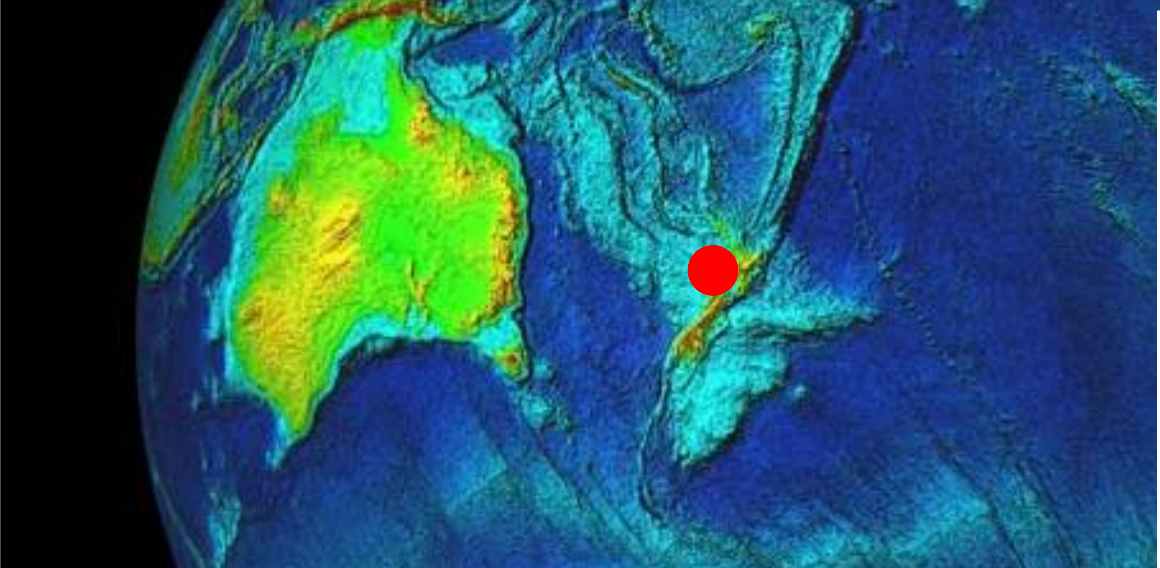
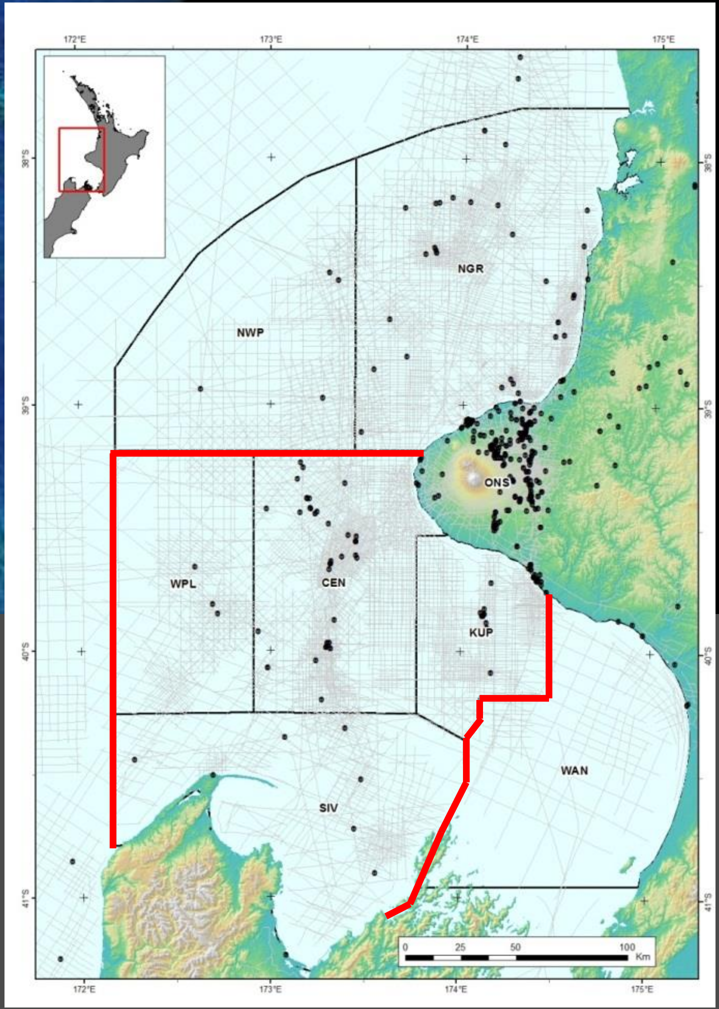
For a better New Zealand



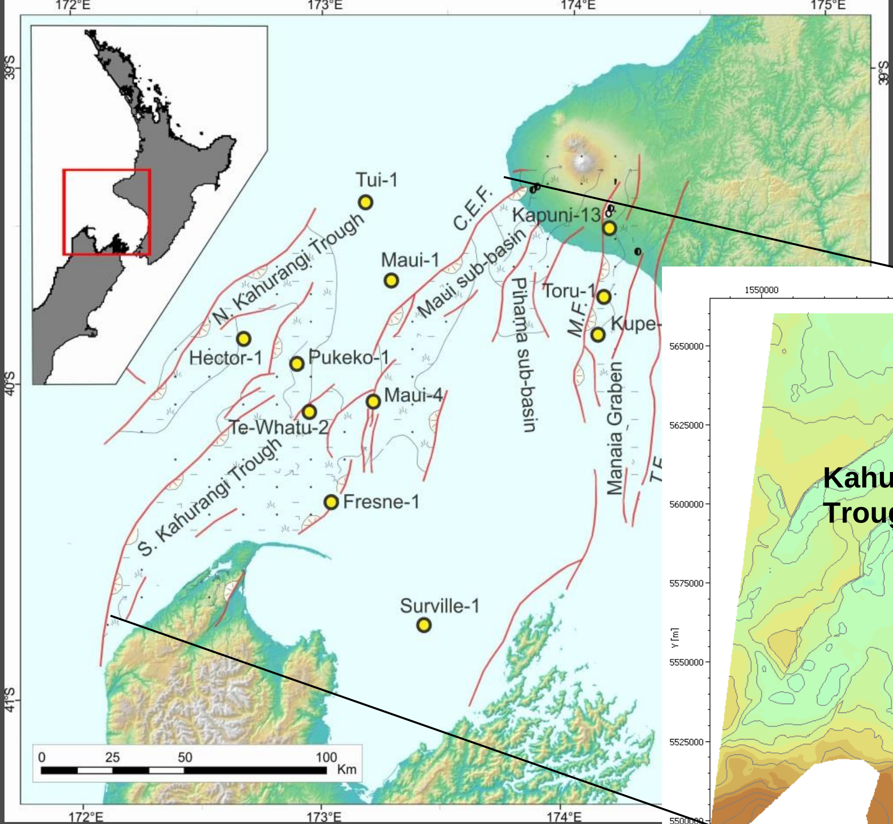
The 4D Taranaki Project:

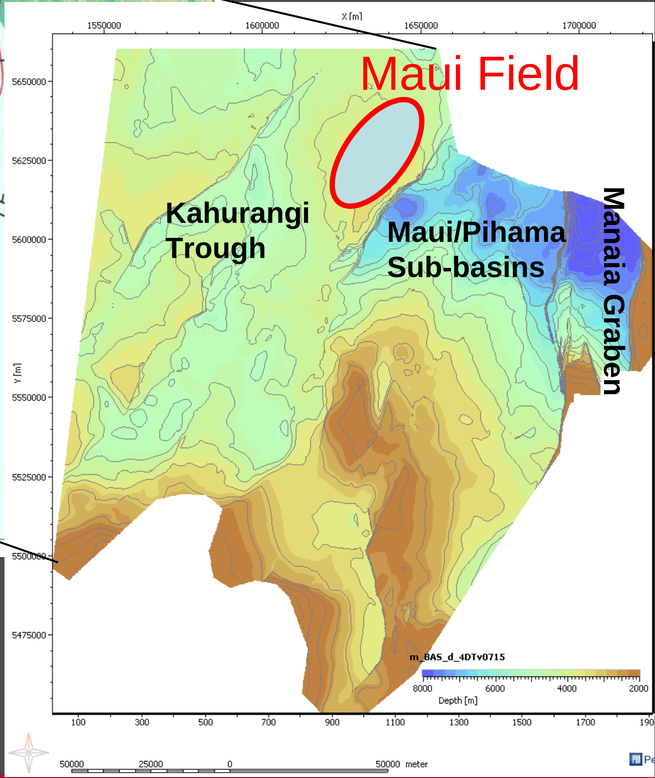
- Re-mapping Taranaki Basin at high resolution to create a 3D digital data space
- Better understand tectono-sedimentary evolution and petroleum potential
- Mapping of southern Taranaki Basin completed



Objectives

- 9 out of 10 wells dry – do we not understand the basin?
- Are all kitchen areas mature, especially the Kahurangi Trough?
- Charge of the biggest accumulation in the basin, the giant Maui gas-condensate field still debated





What can we learn regarding the remaining potential?

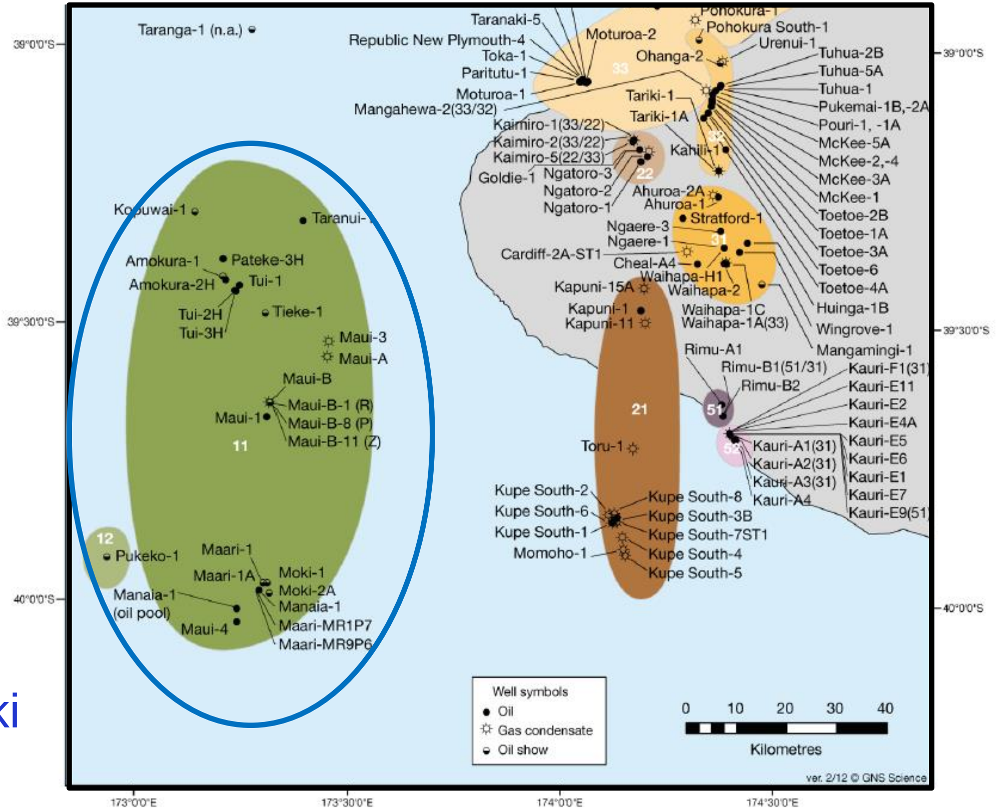
Southern Taranaki Oil Families

Late Cretaceous (U. Mh), terrestrial
- 11 More marine-influenced, more anoxic
- 12 Less marine-influenced, more oxic

Paleocene–Eocene, terrestrial
- 21 Greater gymnosperm input
- 22 Greater angiosperm input

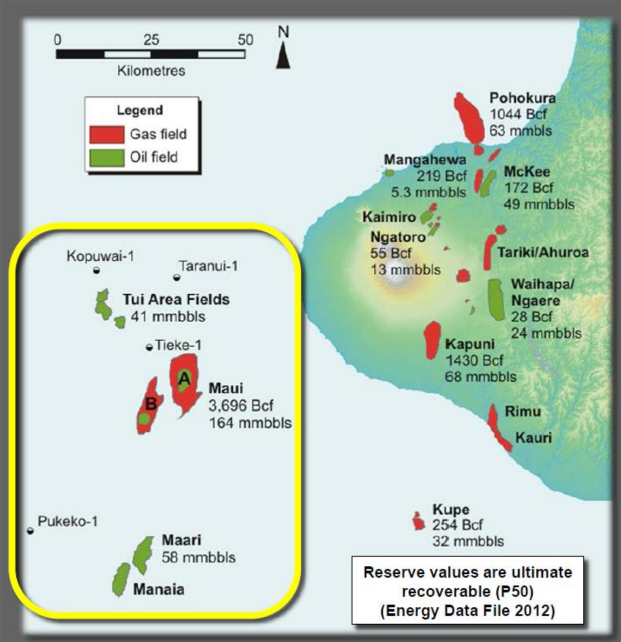
Eocene, terrestrial to coastal facies
- 31 Less marine-influenced, lower angiosperm input
- 32 Less marine-influenced, greater angiosperm input
- 33 More marine-influenced, terrestrial–coastal facies

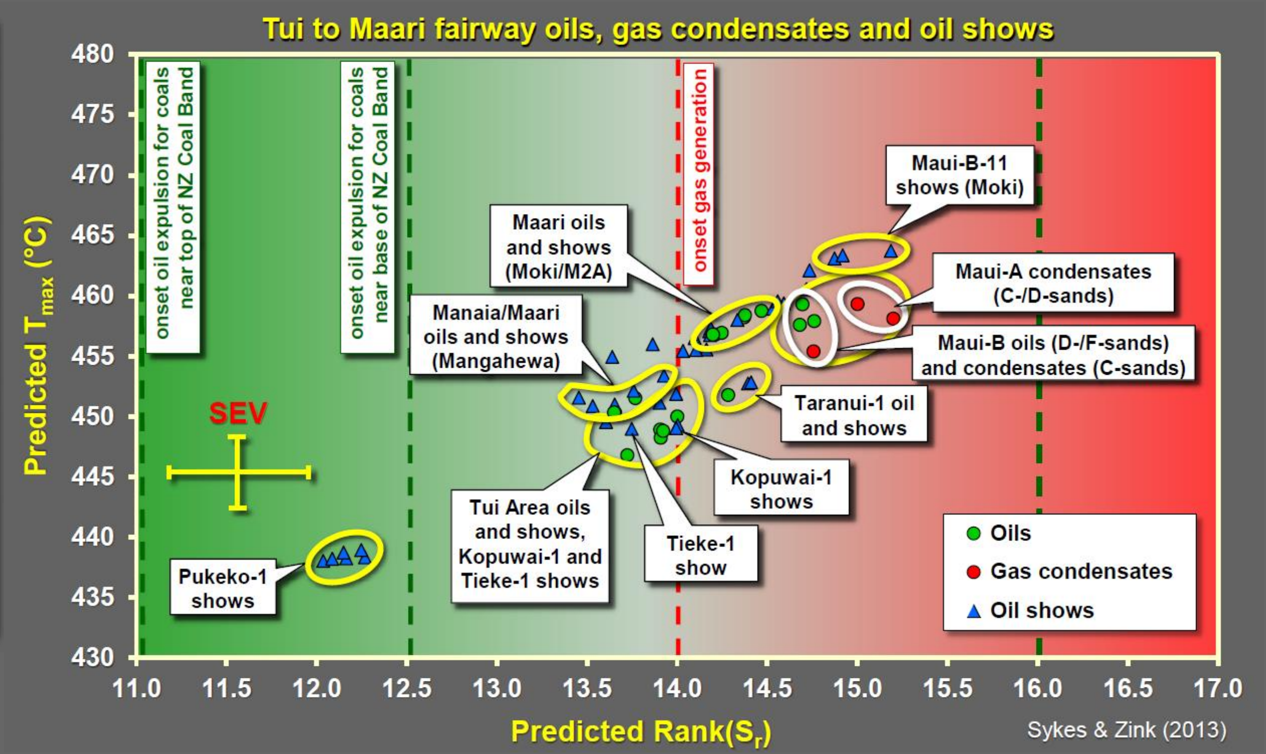
Rakopi Formation is the likely source in the south-western offshore Taranaki Basin based on geochemistry



Sykes et al. 2012

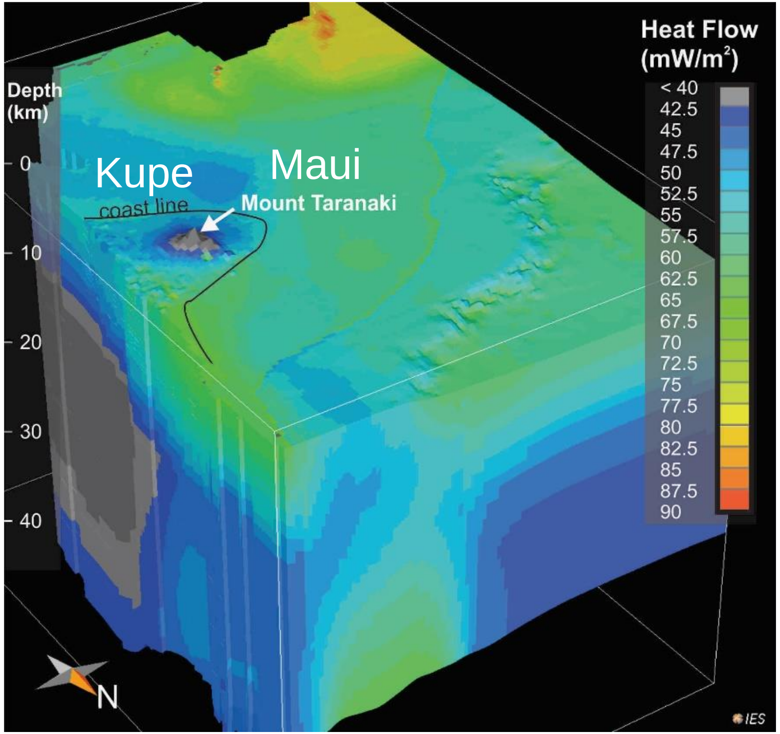
Calibrated maturities of fairway fluids





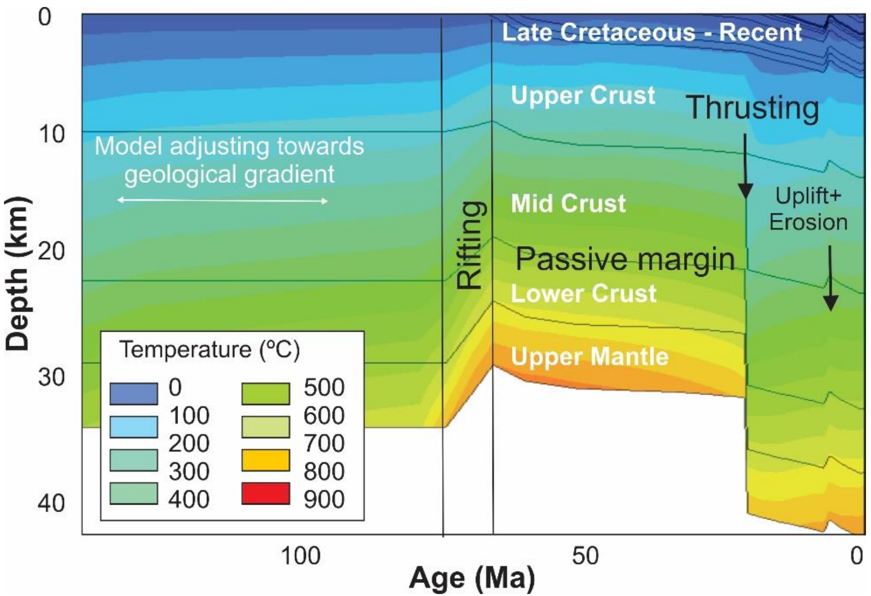
Maturity data appear to indicate charge of Maui Field from a more mature kitchen than other SW Taranaki accumulations

Basin maturity: Previous regional modelling



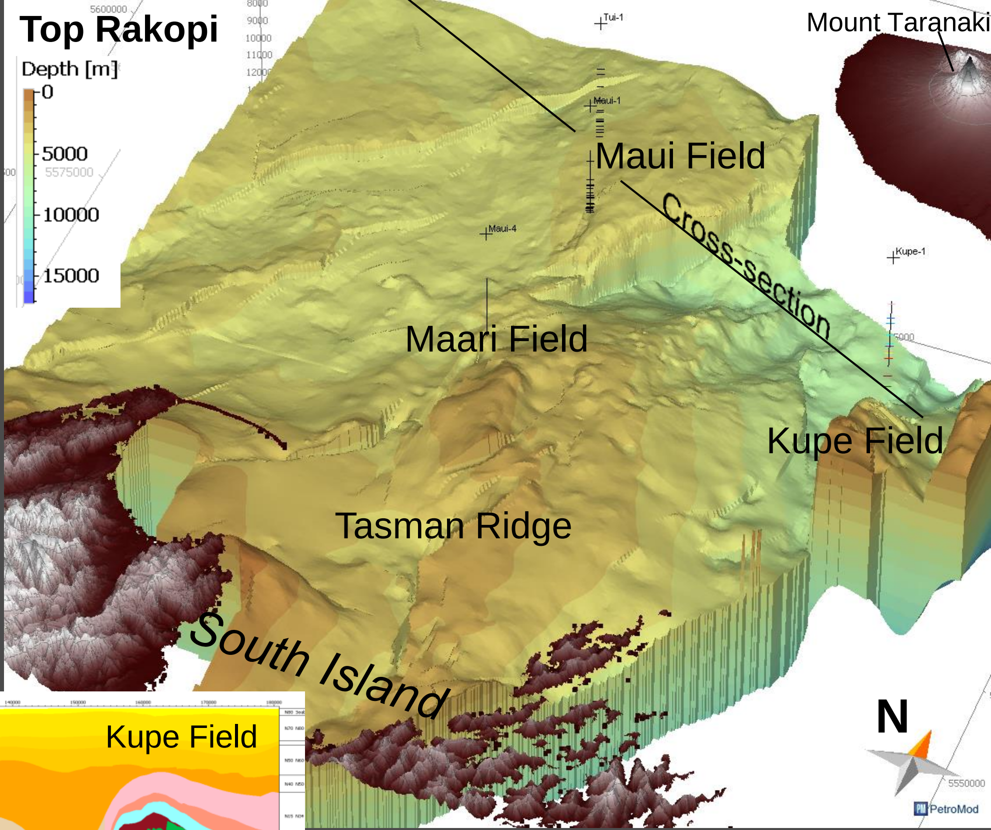
Kroeger et al. 2013

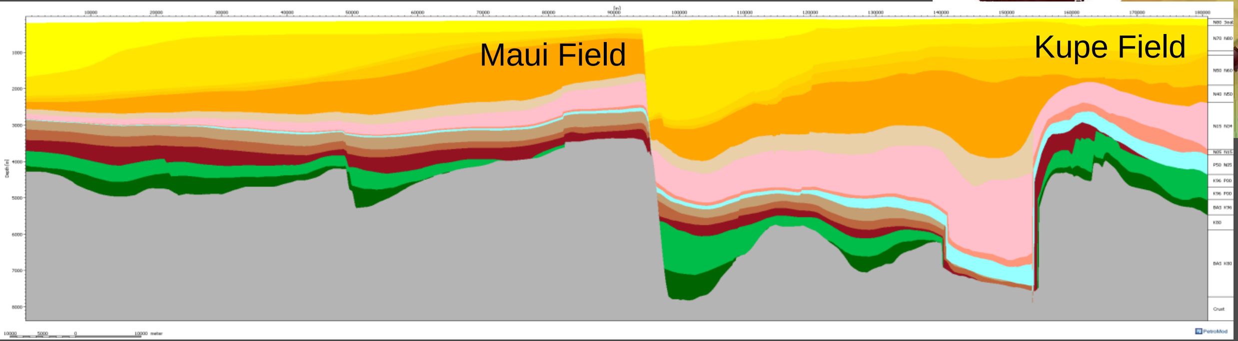
Basement composition emerges as the most important factor controlling variation in surface heat flow followed by structural change



South Taranaki 3D model
using PetroMod

- Take a fresh look at heat flow fundamentals and maturity
- Impact of maturity on charge
- Charge scenarios for the giant gas-condensate Maui Field and impact on basin prospectivity

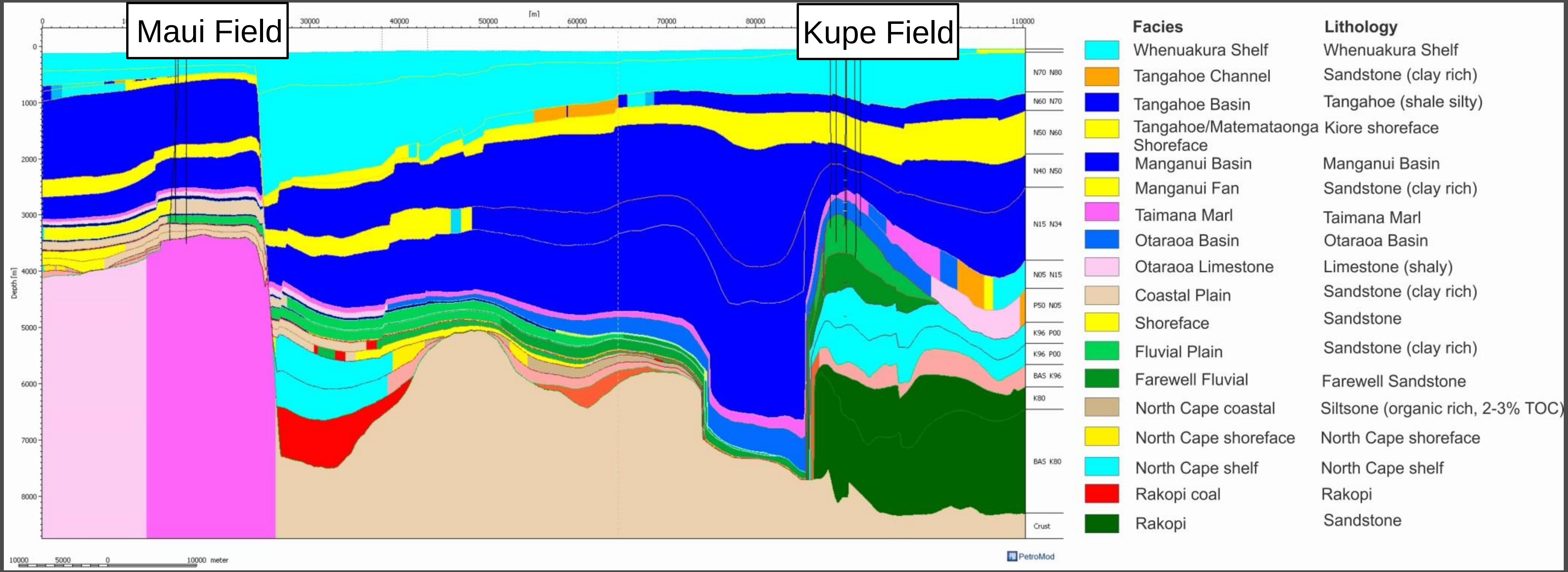




Data from Bull et al. (2015 a,b,c)

Property implementation

NW SE

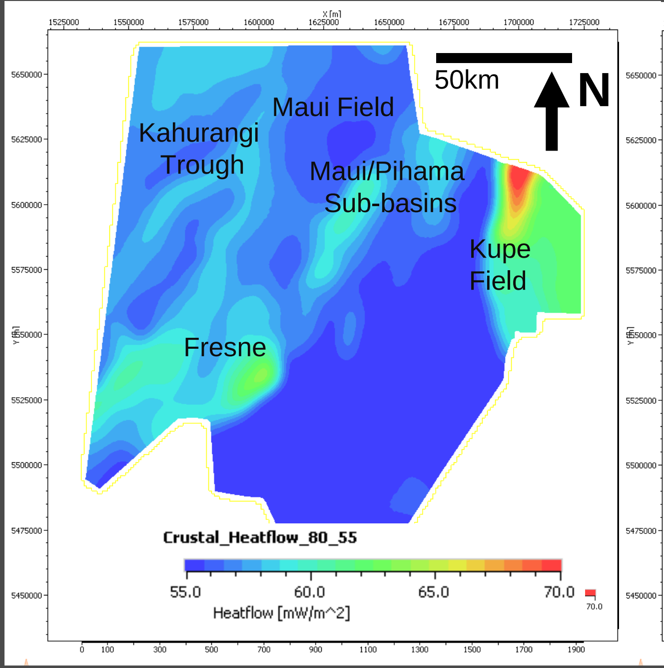


Maturity modelling workflow

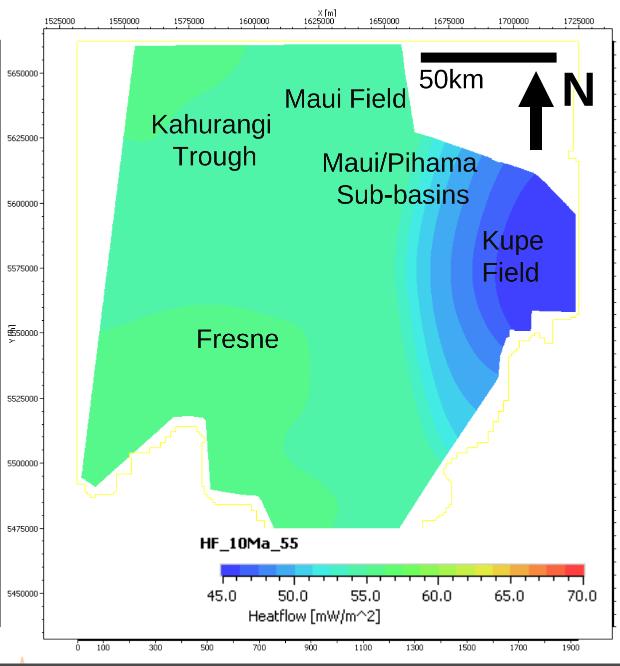
1. Create a model that best fits the well data

2. Assess impact of uncertainties, specifically related to basement composition

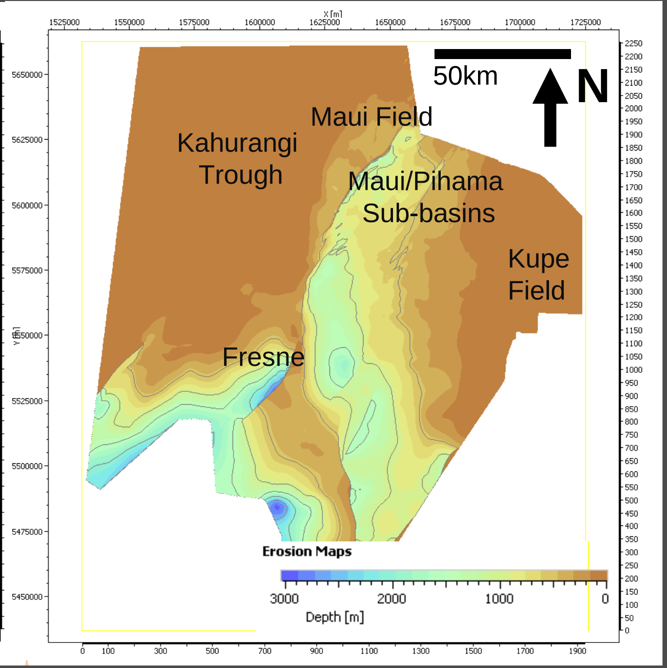
Cretaceous heat flow: impact of extension



Neogene heat flow: impact of thrusting



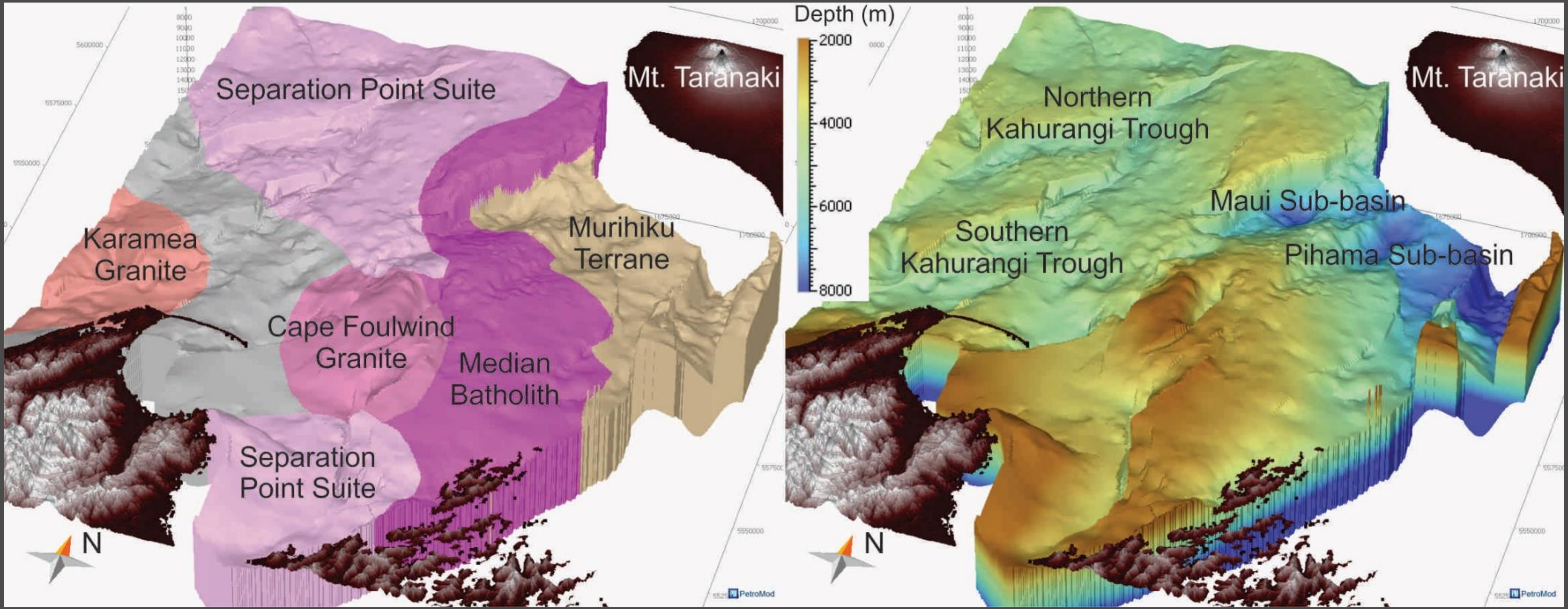
Late Miocene Erosion



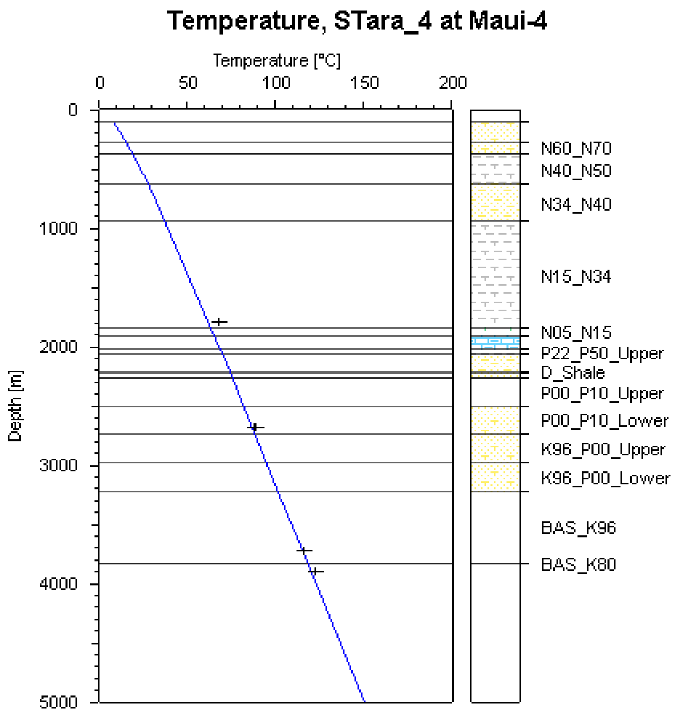
Source rock kitchens and basement composition

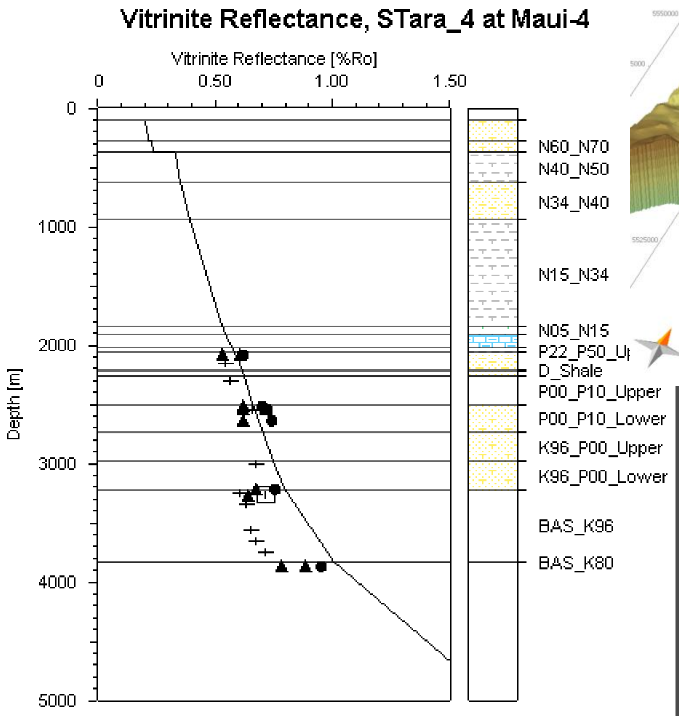
Basement composition modified from Kroeger et al. (2013), model uses 5 km of upper crust

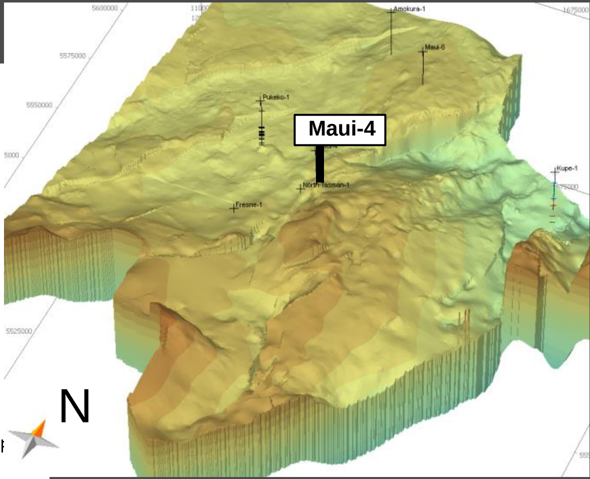
Depth to basement and main kitchen areas with Late Cretaceous source rocks



Modelled 55mW/m^2 back-ground heat flow best fits calibration data

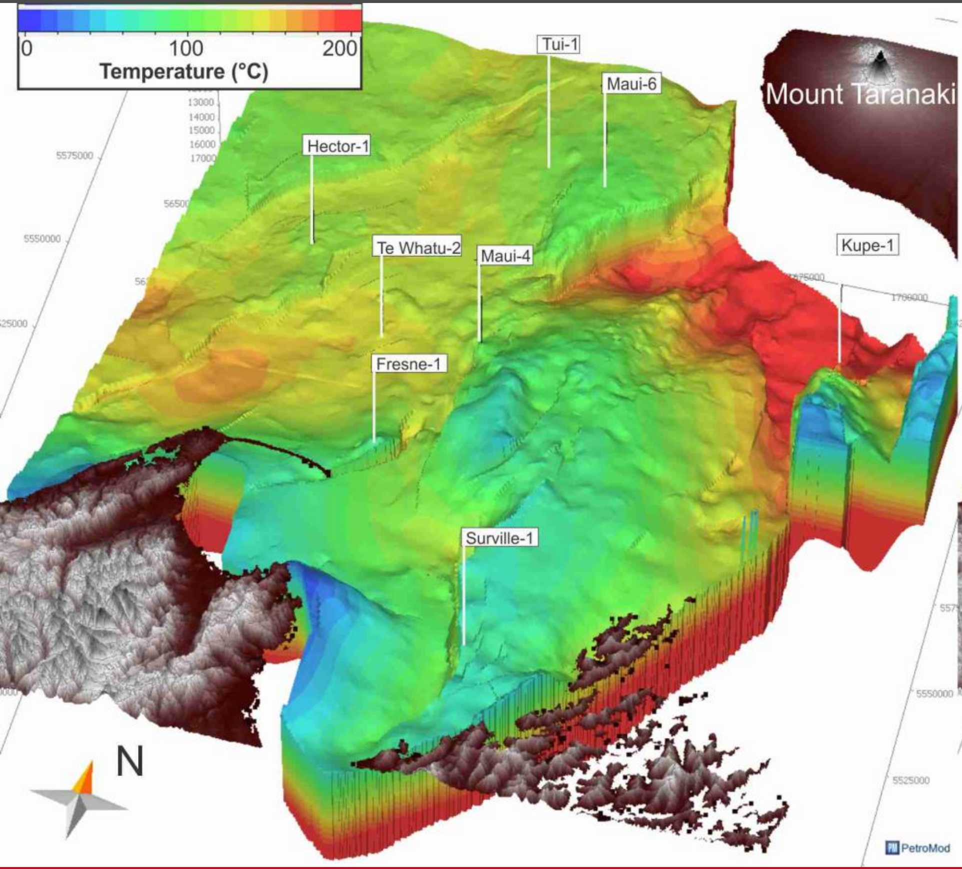


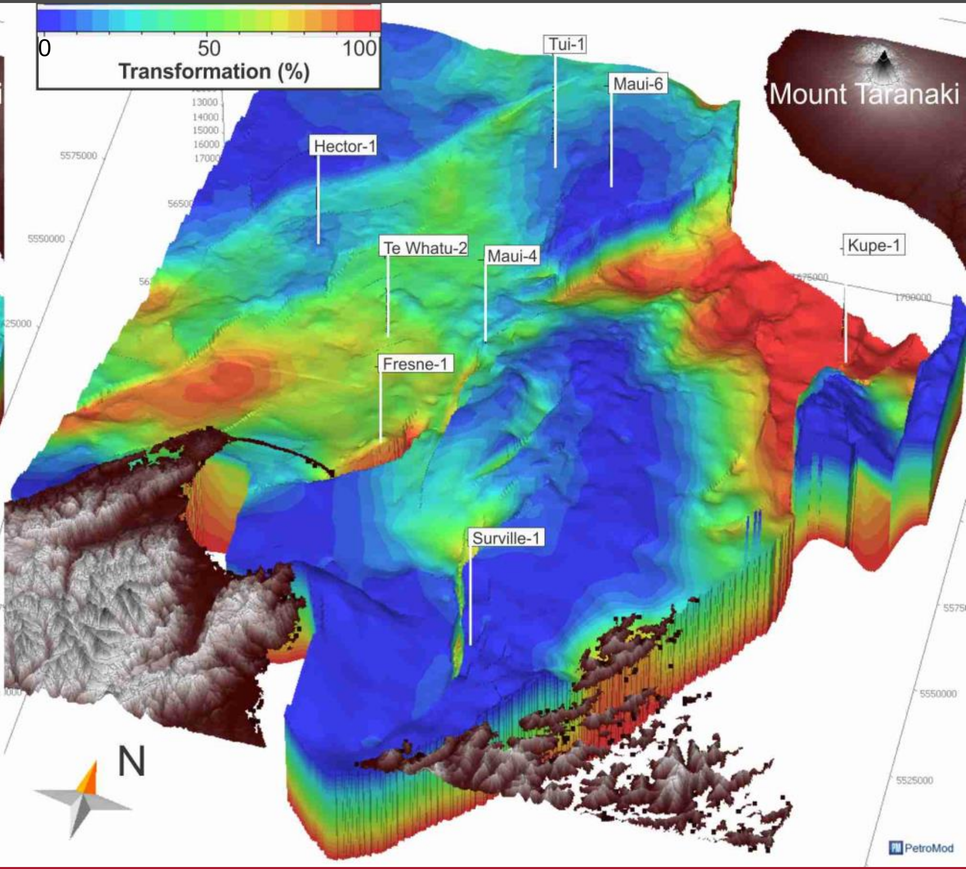




Best-fit model predictions

At Top Rakopi Formation, maturity independent of source rock presence





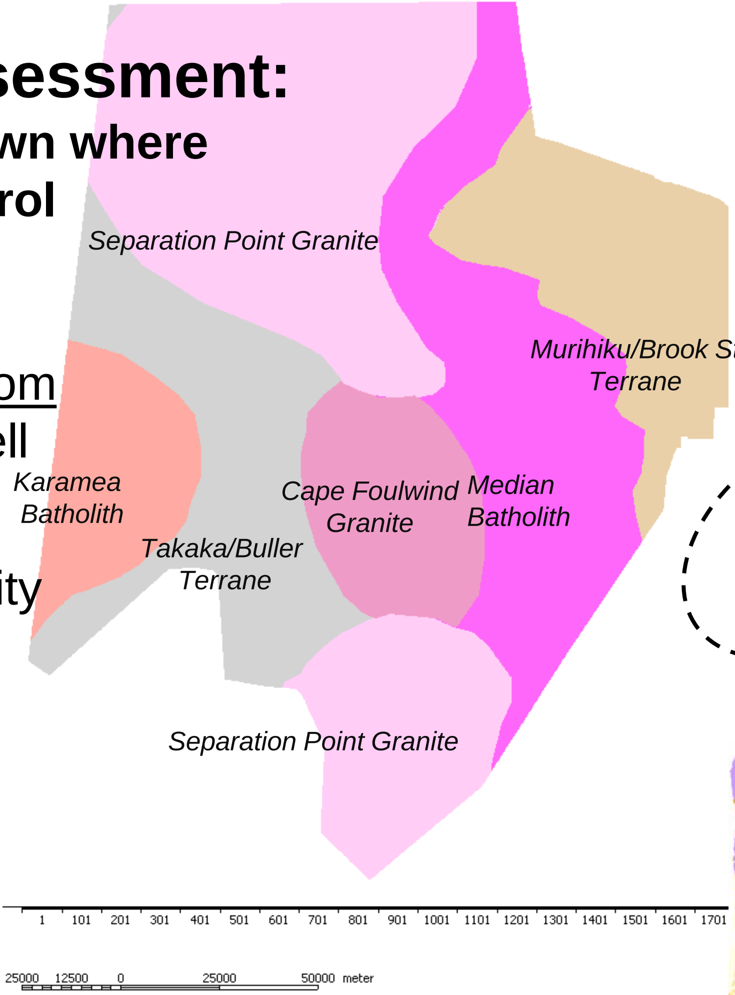
Uncertainty assessment:

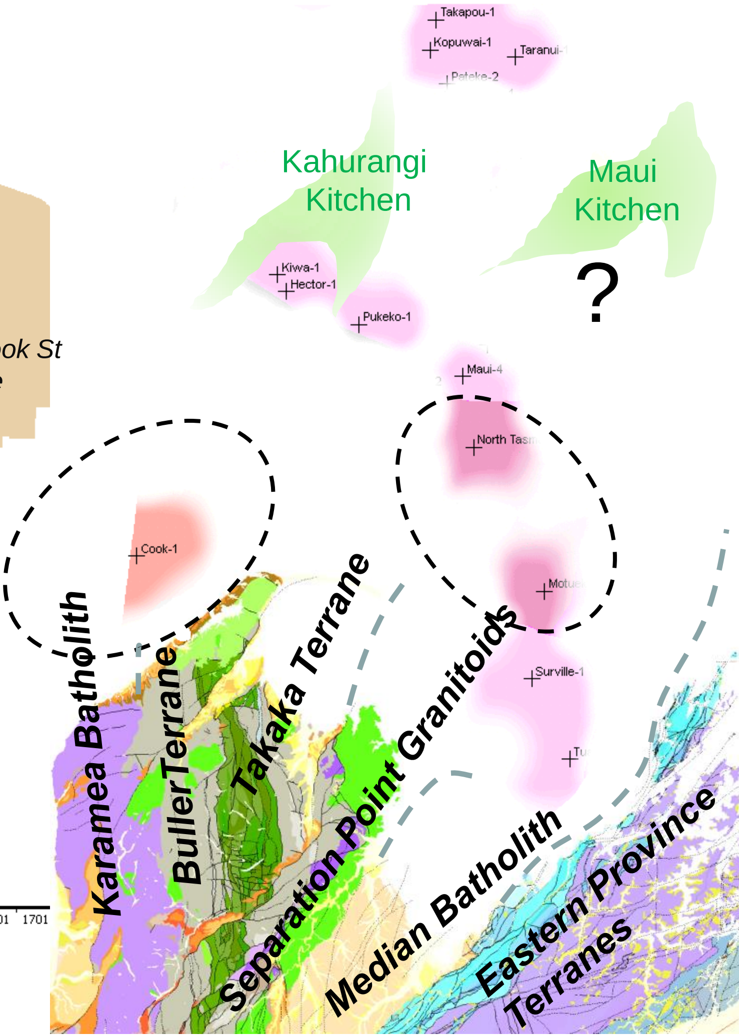
impact of the unknown where there is no well control

1. Basement

Model map derived from

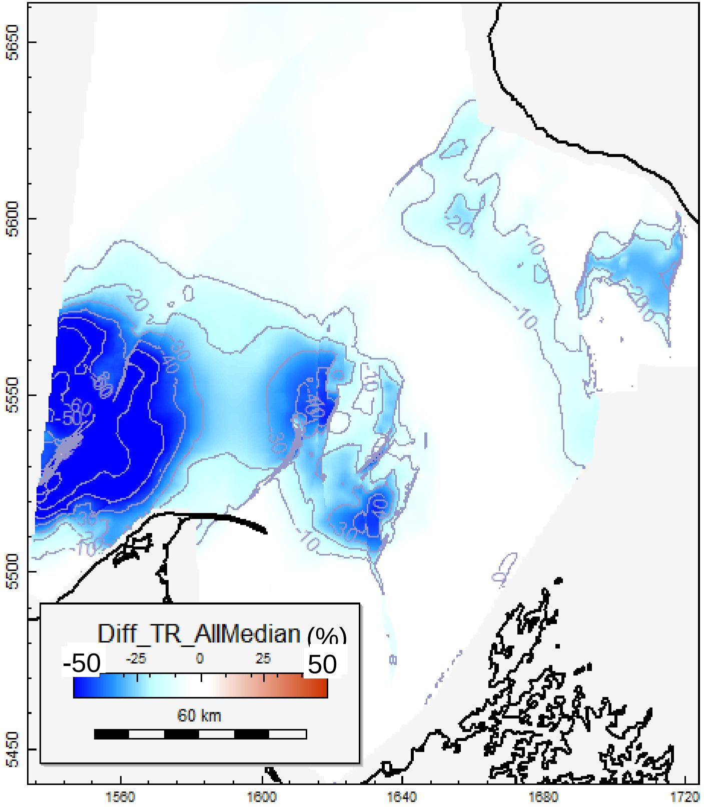
- Extrapolation of well and outcrop data
- Magnetic and gravity data
- Structural considerations
- Seismic character



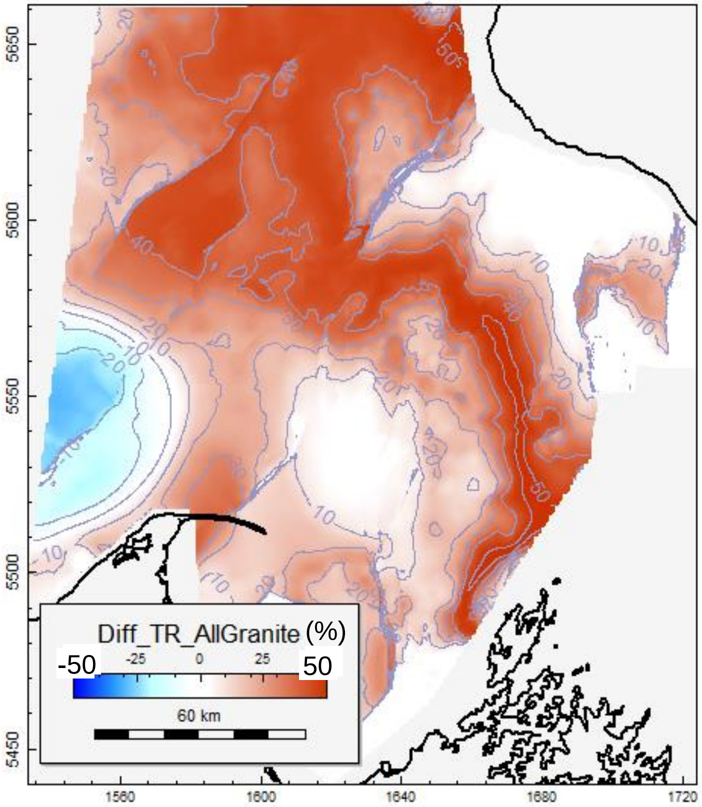


Impact of uncertainty in basement composition on organic matter transformation

andesitic basement everywhere

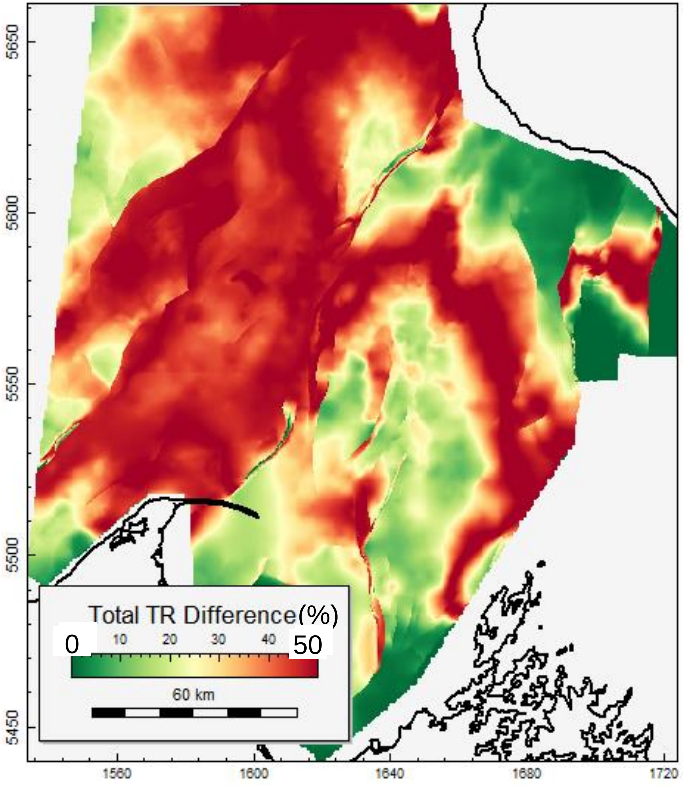


granitic basement everywhere

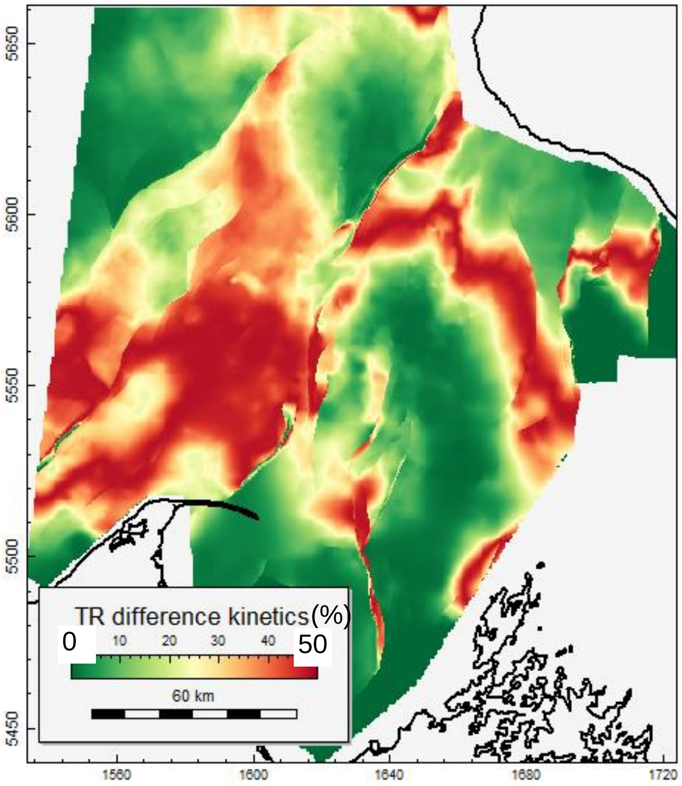


Comparison of impact of basement heat flow and kinetics

Variability of TR between end-member basement scenarios

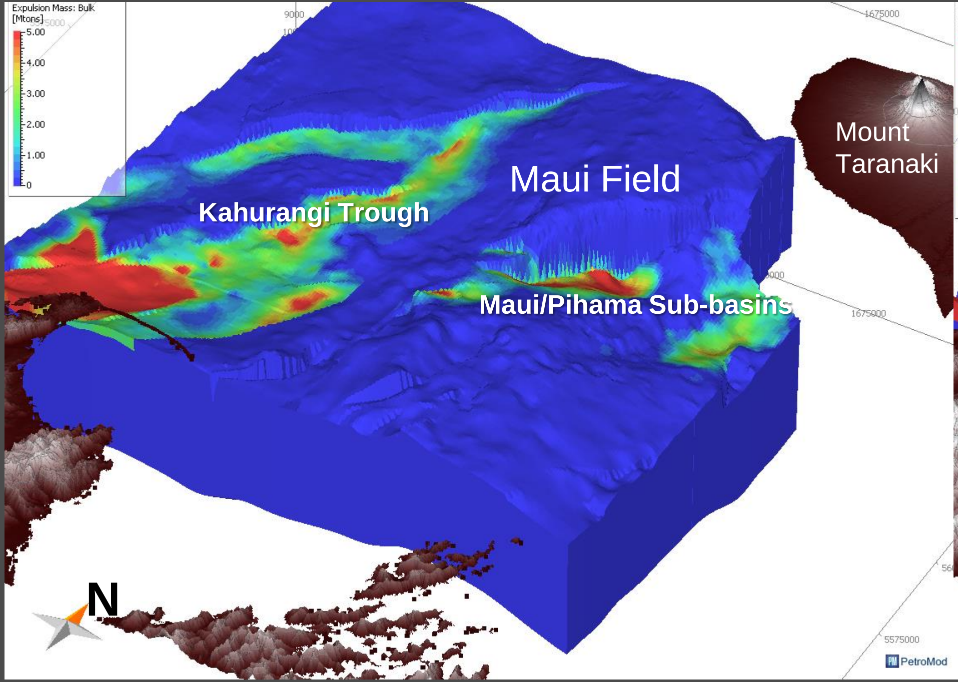


Difference in TR using Pepper and Corvi (1995) and locally derived kinetics

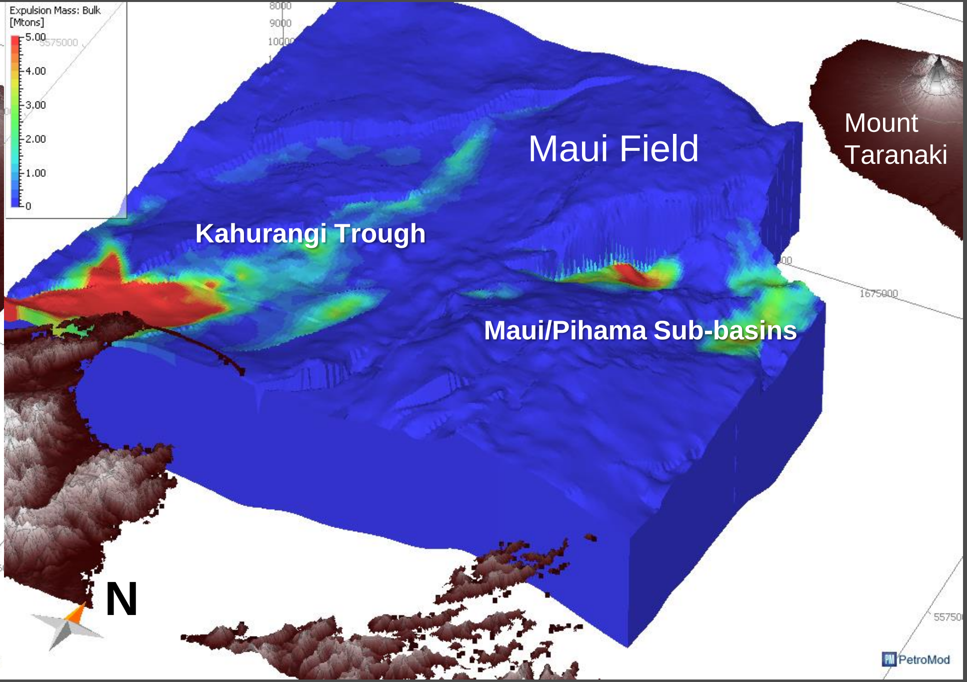


Expulsion prediction

Using Pepper and Corvi (1995) kinetics



Using Maui-4 kinetics



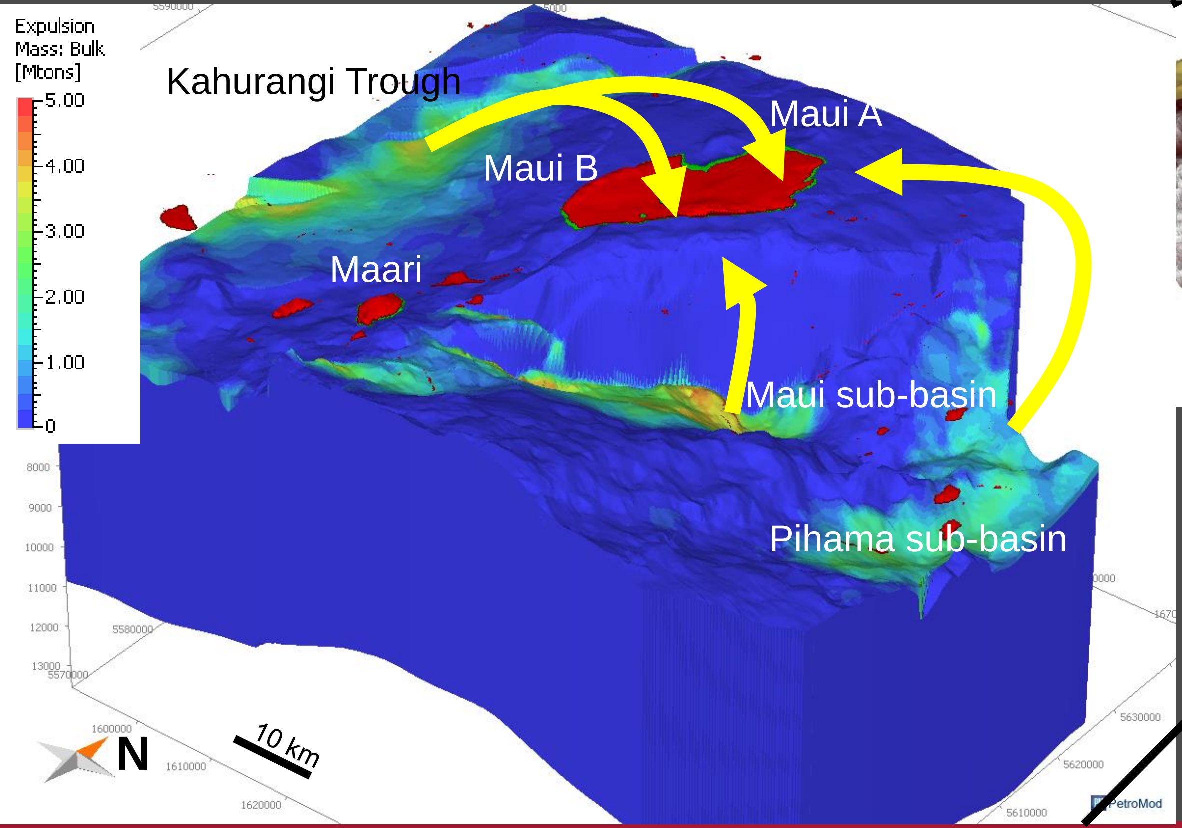
Migration Modelling - objectives

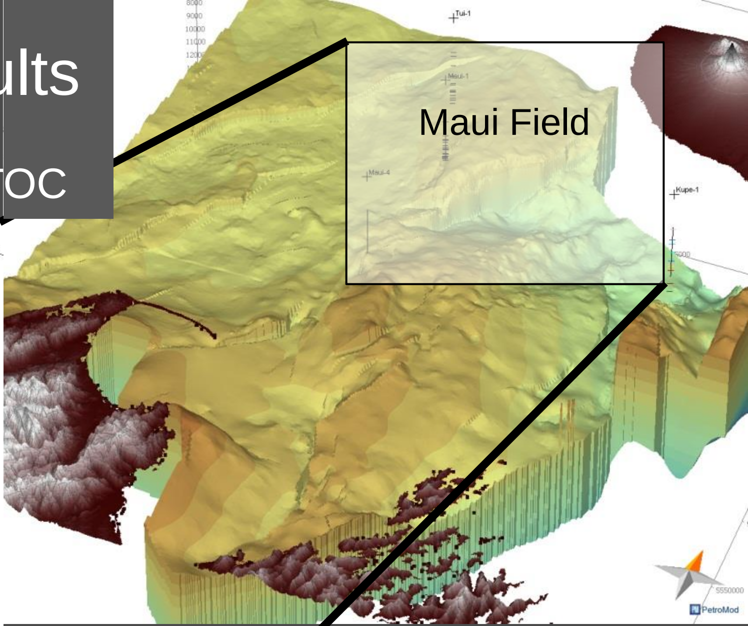
- Impact of maturity modelling on charge prediction
- Impact of structure and fault properties on charge
- Charge of the giant Maui Field and surrounding structures model – comparison of model predictions and well results
- How do model results fit with indicated maturities from geochemical data and GOR?

Migration modelling: scenario without faults

Best fit scenario 55 mW/m^2

constant source rock properties, 3% TOC and 300 mgHC/gTOC

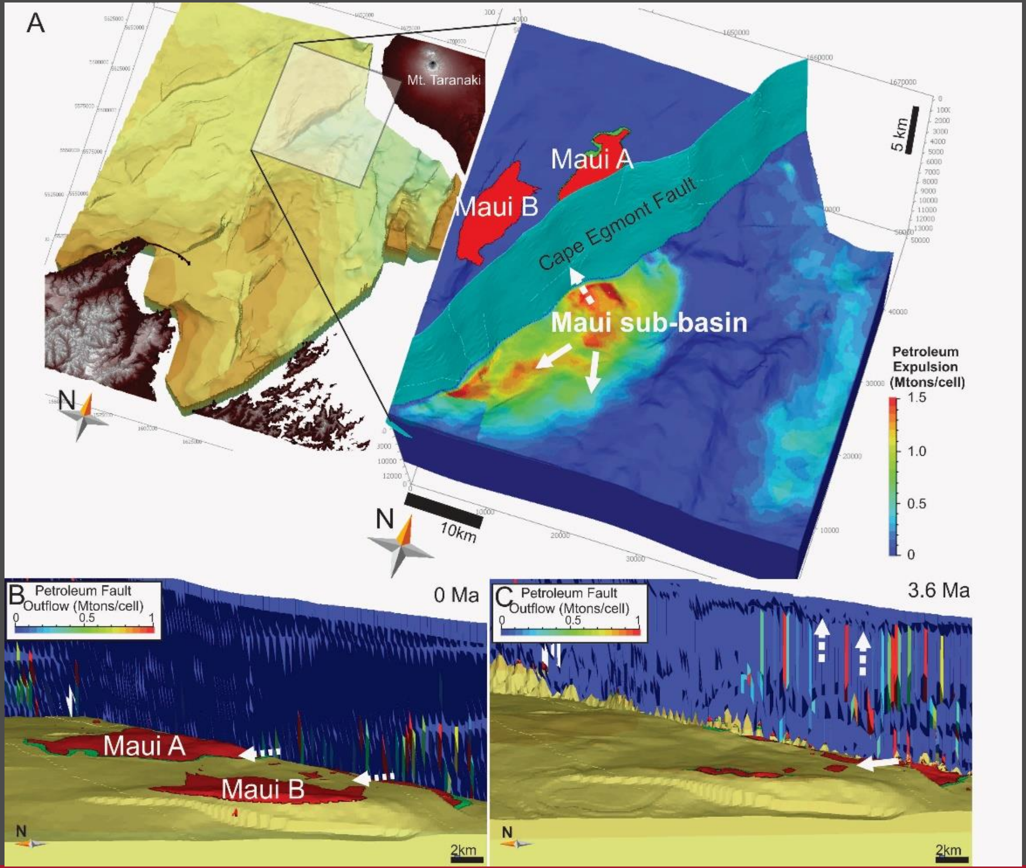




Charge possible from east and west side

Impact of Cape Egmont Fault on migration

Modelling faults as volumetric elements



A model with increasing shale gouge ratios and charge from Maui and Pihama sub-basins only with 6% TOC in the Maui sub-basin and 3% TOC in the Pihama sub-basin best fits the estimates of recoverable oil and gas

Model prediction Maui A+B
4194 BCF gas
485 MMbls oil

Estimate (source: Energy News March 2015)
4069 BCF gas
171 MMbls oil

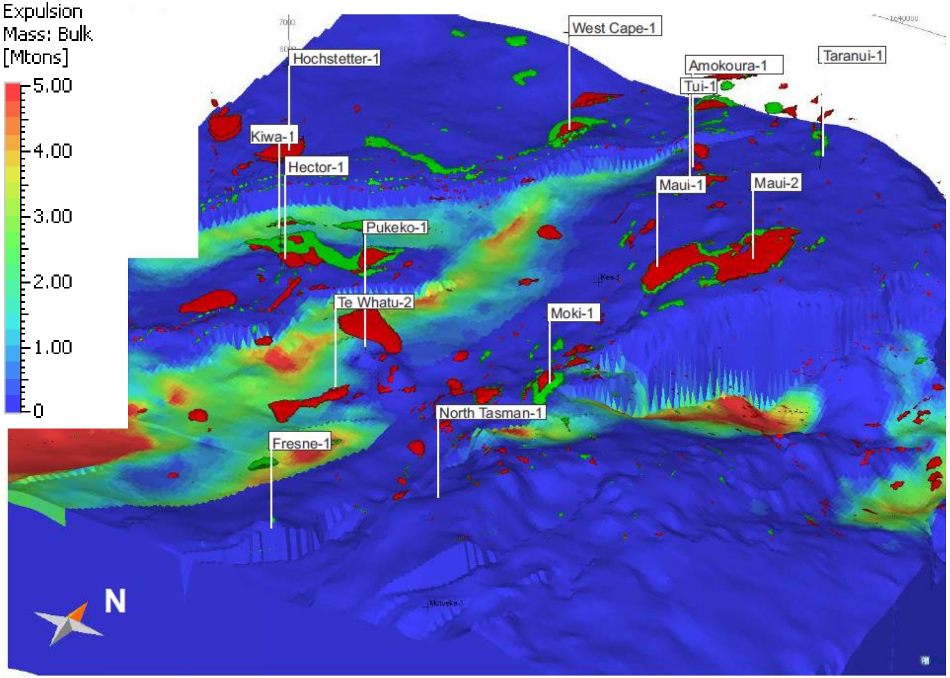
Reilly et al. (2016)

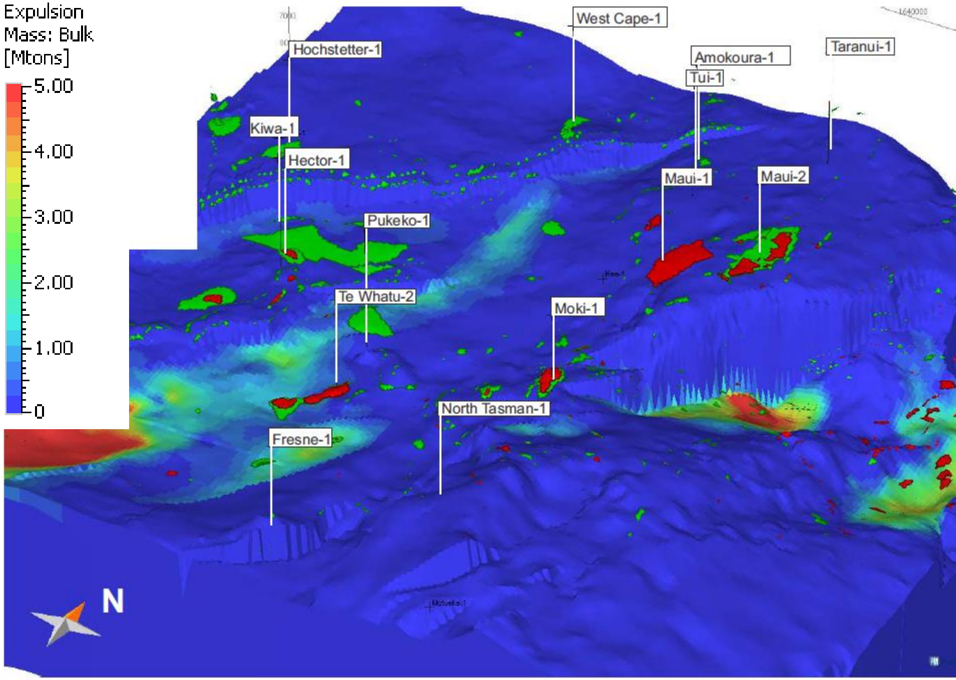
Impact of kinetics, source rock distribution and maturity on other accumulations

Model using Pepper and Corvi (1995) kinetics

Model using Maui-4 kinetics

Kroeger et al. *in press*





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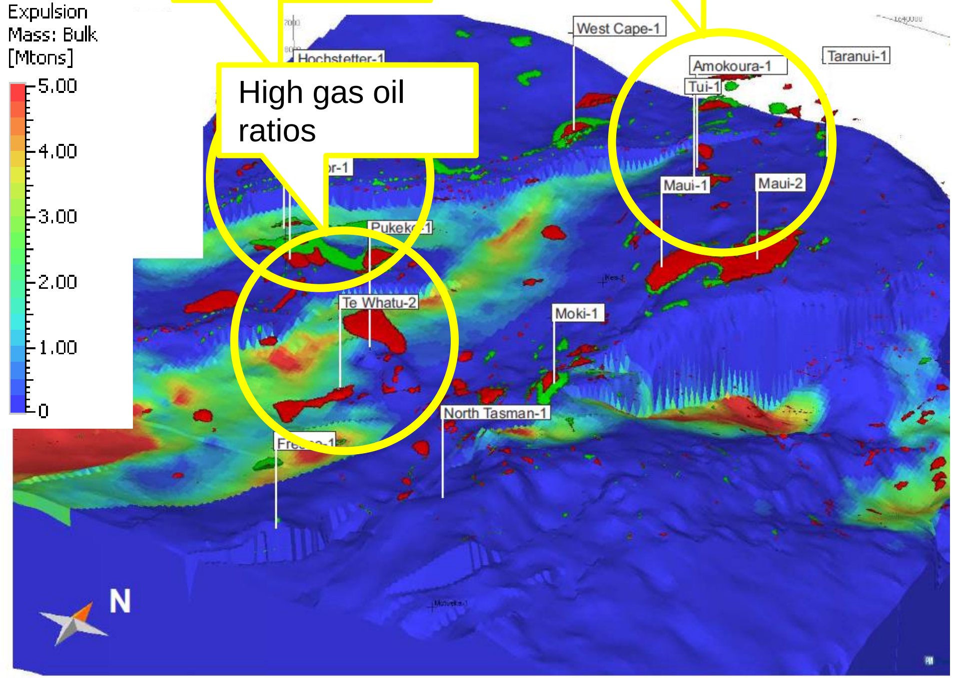

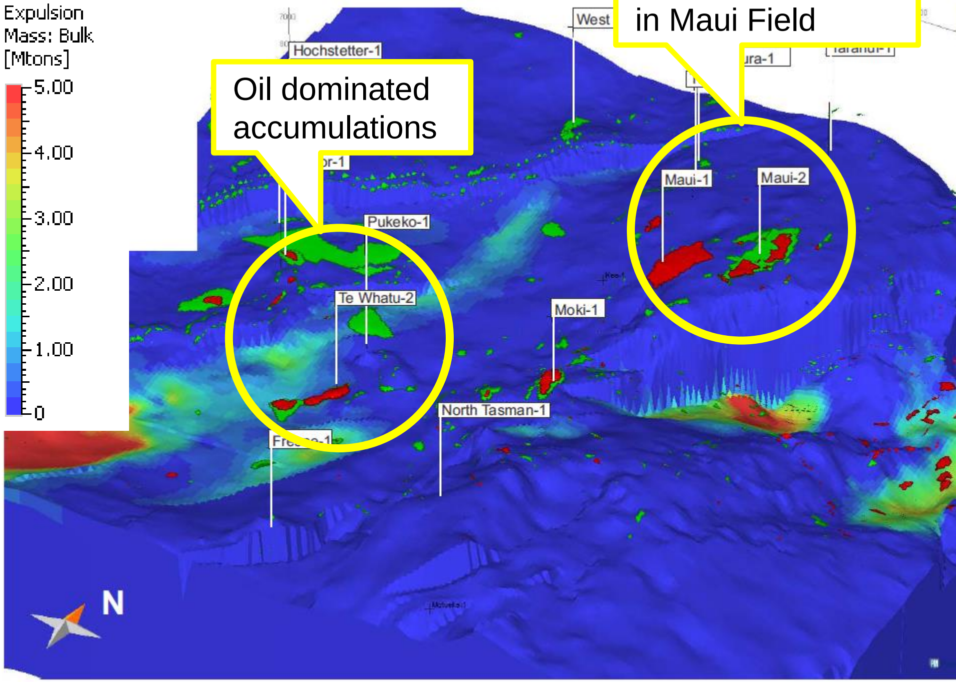

Conclusions

- Basement composition is the main uncertainty in maturation modelling due to the lack of data and calibration points in the main kitchen areas
- Kinetic models equally important for expulsion prediction
- Charge of the Maui Field is possible from both east and west, but the deeper Maui sub-basin is more likely to provide sufficient gas charge
- A model using charge from the east only and increasing shale gouge ratios (Reilly model) in the Plio-Pleistocene provides the best volumetrical match
- There is currently no single model that explains both, charge of Maui gas-condensate field and oil dominated charge in the west
  - We do not yet fully understand the complexity of source rock facies and expulsion behaviour
  - Processes during migration, phase separation and potential loss of oil or gas phase need to be better understood

Acknowledgements

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ZetaWare, Inc.
Interactive Petroleum System Tools

PetroMod

Schlumberger