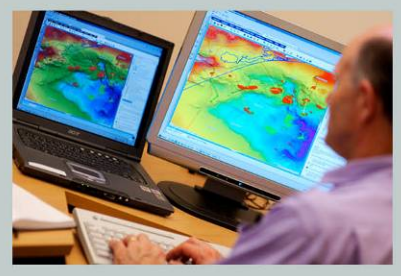
DEPARTMENT OF
PRIMARY INDUSTRIES

Geoffrey O'Brien, GeoScience Victoria

Assessment of the Gippsland Basin



Thanks to:
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Keyu Liu, Natt Arian & Joe Hamilton
CSIRO Petroleum & Schlumberger

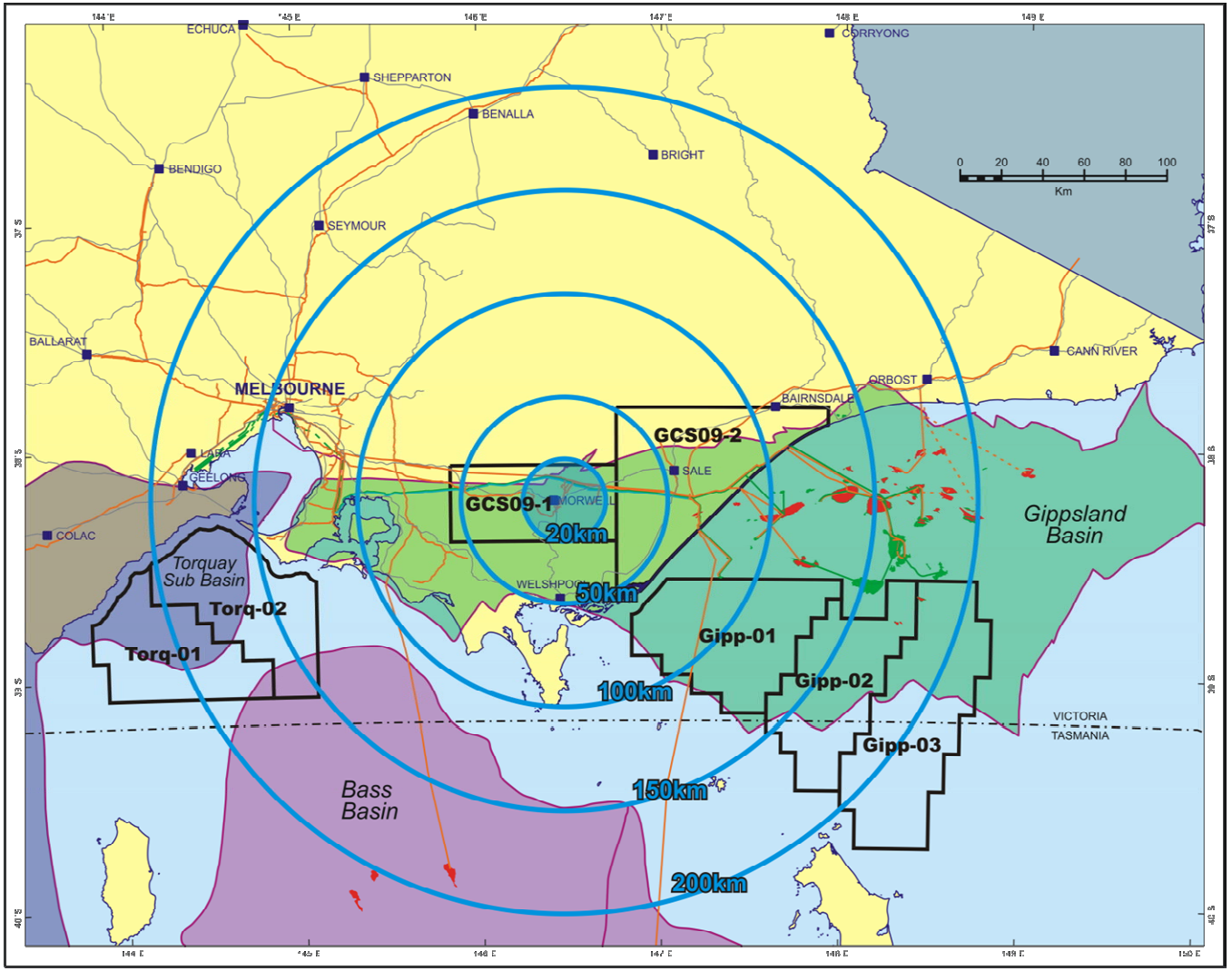
Victoria
The Place To Be

CAGS: Geoscience Australia January 2010

Outline

- **VicGCS Project objectives and background**
- **Regional setting**
  - Distribution of oil and gas
  - Reservoirs and seals
  - Water and hydrocarbon alteration
- **Top seal potential**
  - Top seal model based upon facies, thickness, capacity etc
  - Leakage and seepage indicators (sniffer, gas chimney mapping)
- **Injectivity-Capacity-Storage Potential**
- **First-order 3D generation-migration processes and architecture**
- **Integration and the way forward**

Importance of GCS

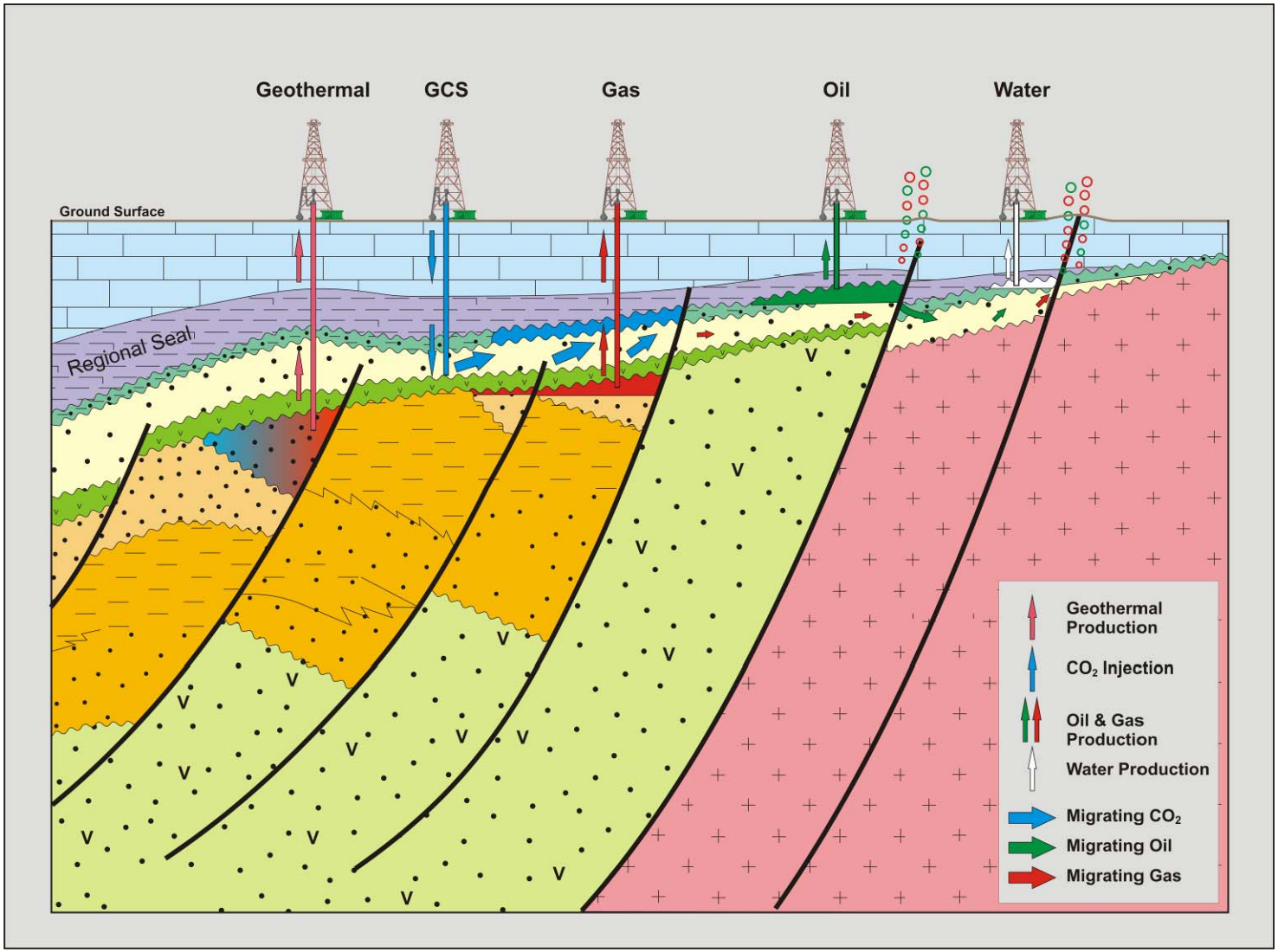


Victoria's total CO_2 emissions (~122 MT per year) are dominated (>50%) by those from brown coal-fired electricity generation in the Latrobe Valley

In a carbon-constrained world, this is unlikely to continue

Geological Carbon Storage is a one means of securing a low-emissions future for brown coal

The Challenge: Basins As Multiple-Use Zones



Geoscience information systems need to be adequate to allow the management of the basin as a multiple use zone

This will enable the GCS, geothermal, petroleum and water sectors, inter alia, to co-exist without conflict

Must be at a basin-scale in order to allow assessments of impact and relative value to be made

VicGCS: Assessing and managing Victoria's geological carbon storage (GCS) potential and resources for the benefit of the State

- **Understanding containment, injectivity-capacity, and CO_2 & hydrocarbon migration**
- **Developing a Basin Resource Management Framework**
  - Geoscience information and knowledge systems to allow informed management of basins as multiple use zones, enabling the GCS, geothermal, petroleum and water sectors to co-exist and prosper
  - Basin-scale to allow assessments to be made of potential impacts and relative values of all relevant earth resources

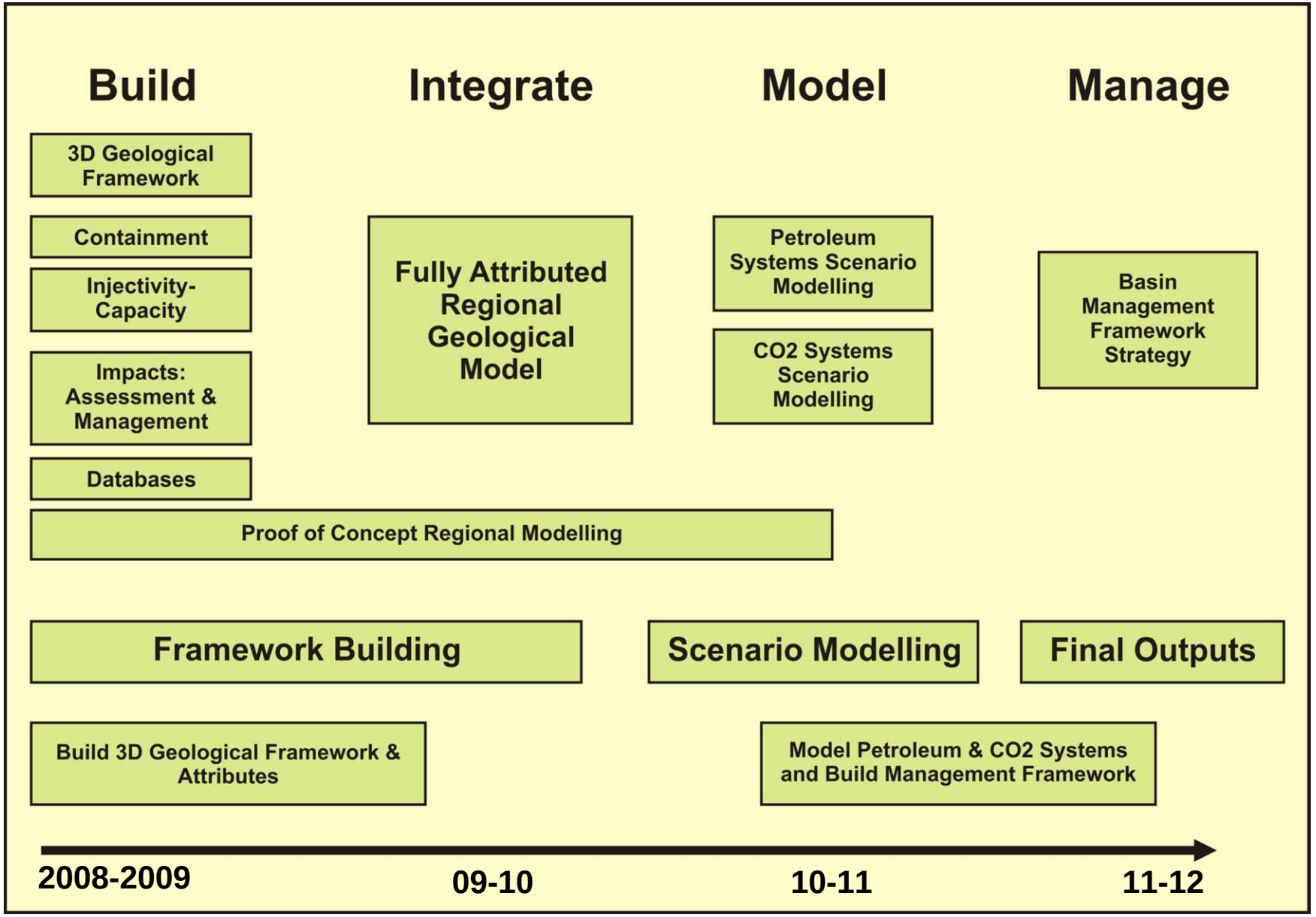
VicGCS:
Victorian Geological Carbon Storage

- **The Victorian Government's VicGCS initiative is characterising the regional CO_2 geological storage potential of the onshore and offshore Gippsland Basin**
- **4 year, $5.2 million (2008-2012)**
- **Delivered by GeoScience Victoria, in partnerships with key external organisations such as CSIRO**
- **Build and extend previous work done by CO2CRC**

Key technical elements

- **Containment**
  - Understand where CO_2 will be contained in the deep sub-surface
  - Understand the distribution and capacity of the fine-grained sealing rocks
  - Sealed area defines the limits of GCS play fairways
- **Injectivity & Storage Potential**
  - How much CO_2 can be safely put into the deep sub-surface?
  - Understand the porous sands or reservoirs underground
- **Impacts**
  - If it is injected, where will it go, in what timeframe and what effects might it have on existing hydrocarbon resources and infrastructure, on undiscovered hydrocarbon and other resources and on the physical and man-made environment?
  - Understand CO_2 migration and entrapment

Project Overview



Project Milestones @ 18 months

- Cohesive, qualified team recruited, assembled and developed
- Sound, predictive understanding of regional top seal
- Inventory of leakage and seepage indicators across basin
- Strategic science partnership with CSIRO Petroleum
- Full charge history assessment (with CSIRO)
- Evaluation of onshore GCS potential and acreage release (closes March 5, 2010), with onshore play fairways defined
- Updated poro-perm and pressure databases (with CSIRO)
- Preliminary 3D migration models
- Full 3D geological interpretation of onshore and offshore basin available June 2010 (tender 3D-Geo)
  - Attribution of model through 2010-11
- >8,000 line km of 2D seismic acquisition across southern flank of basin (GSV-GA-DRET) begins mid-February 2010; interpretation available Q3-4 2010

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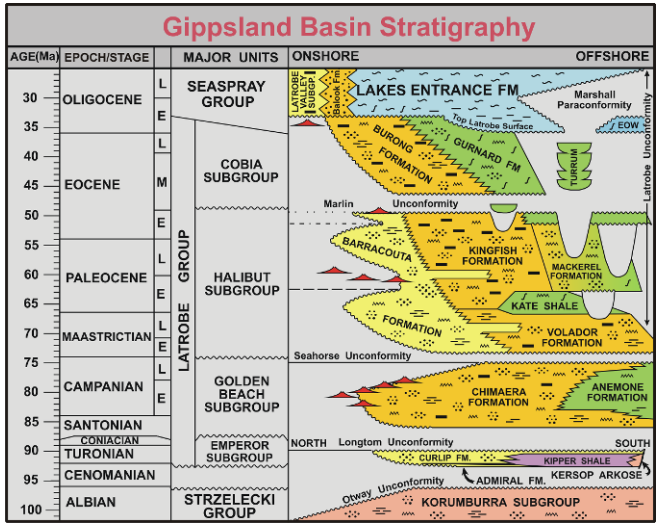
Gippsland Basin

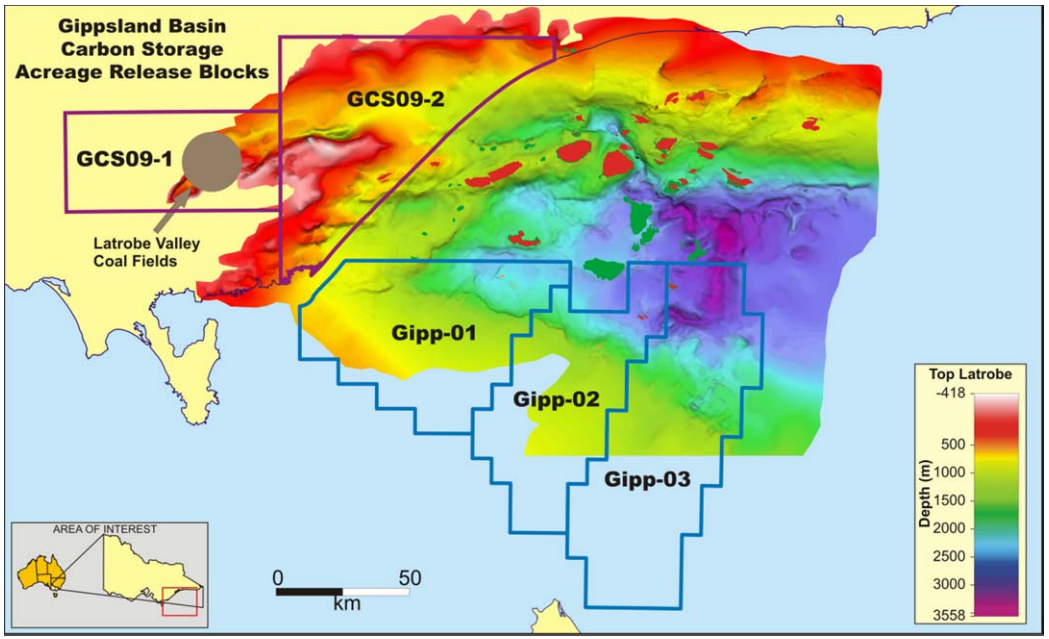


- Cretaceous-Tertiary rift basin
- Giant oil and gas fields
- Hydrocarbons reservoired within silici-clastics - principally (>85%) at the base of the regional seal
- Strongly compartmentalised distribution of oil and gas

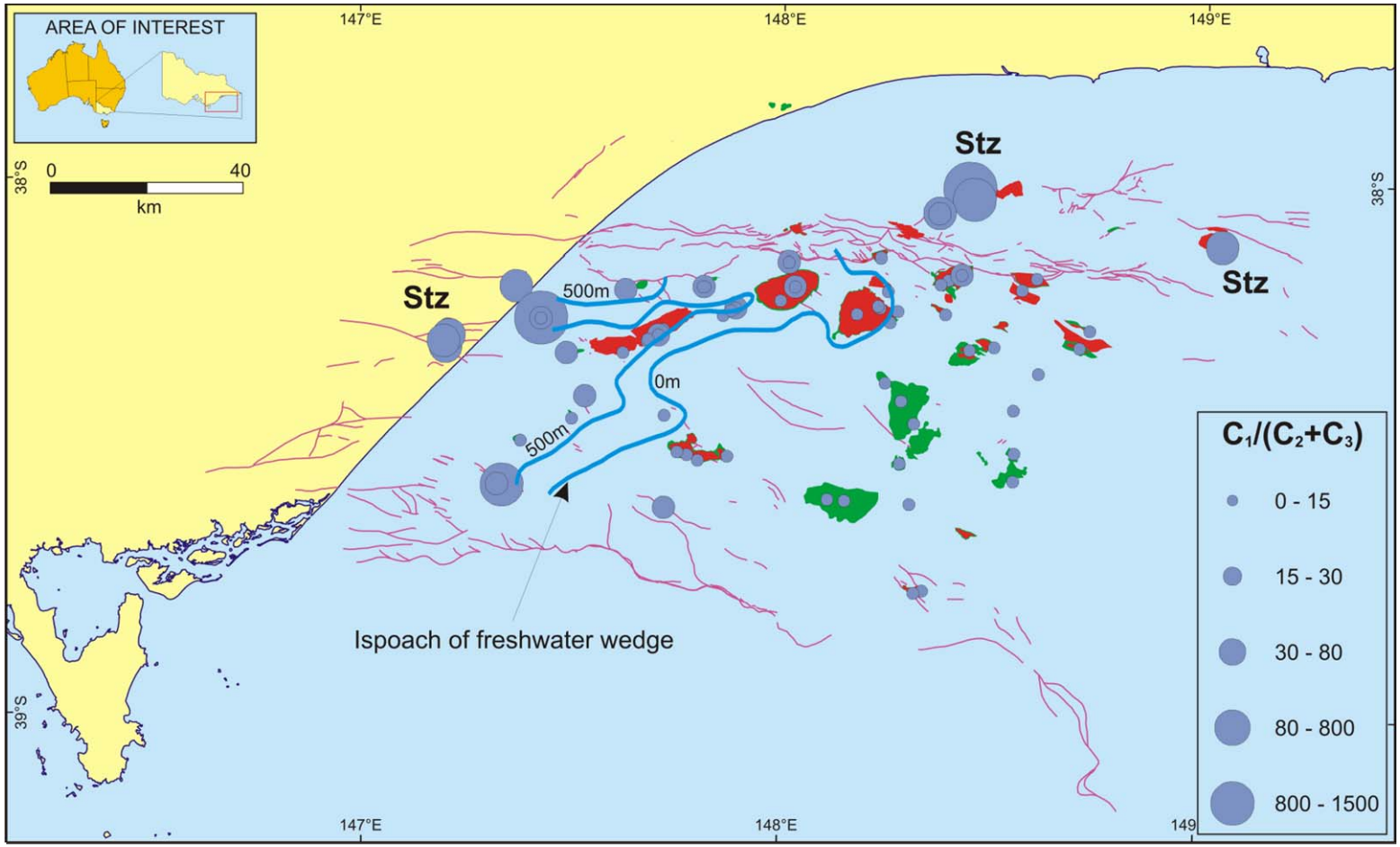
Late Cretaceous to Tertiary syn-rift silici-clastic reserviors

Regional Top Seal

- Lakes Entrance Formation
- Consists of calcareous claystones, mudstones and marls
- Deposited ~30 Ma across the post-rift Latrobe unconformity topography

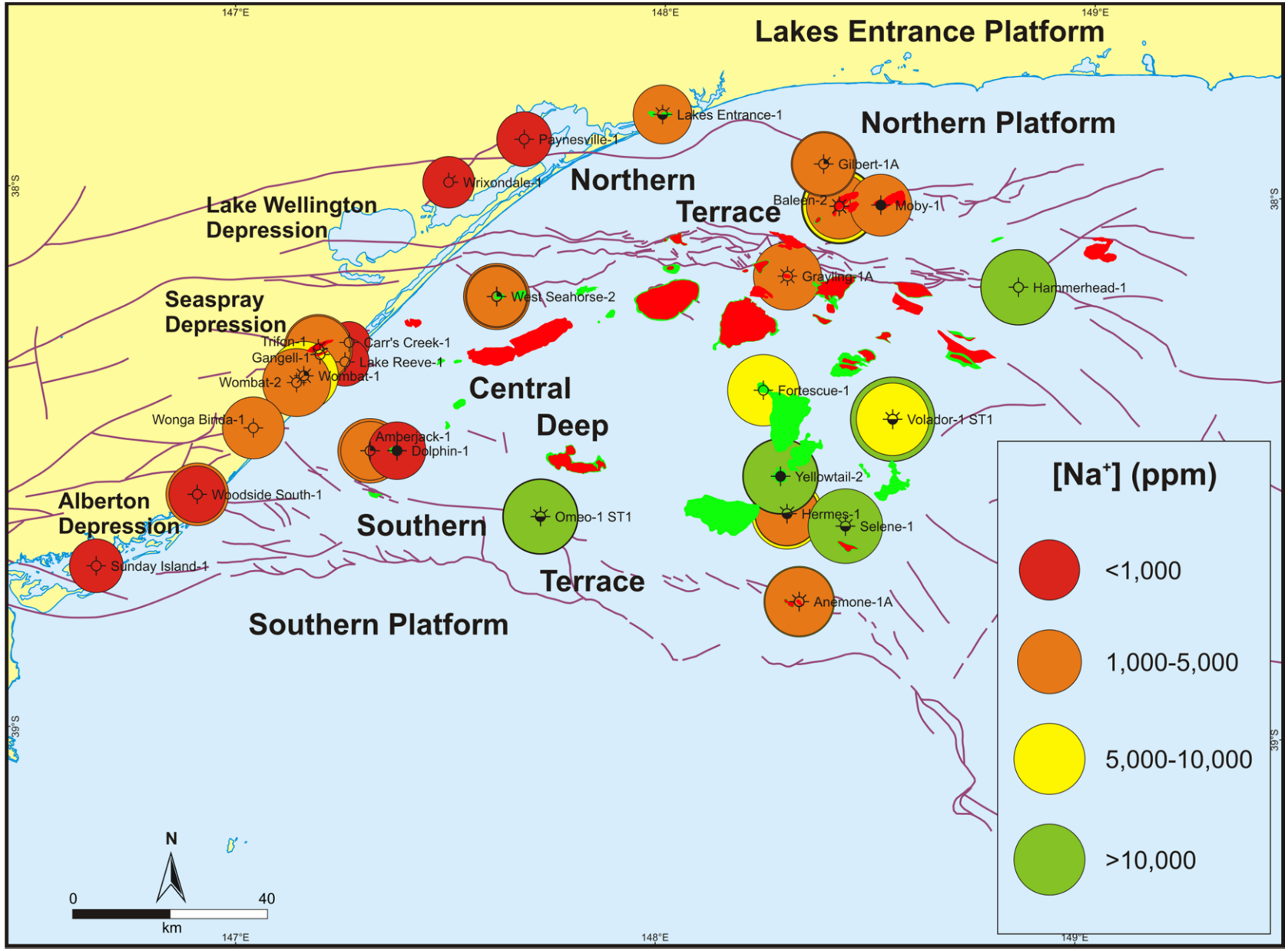


Fresh Water Wedge & Biodegradation



- Fresh water wedge extends from onshore to offshore
- Most biodegraded gas occurs at shallow depths associated with fresh water
- Perhaps wedge is more extensive than first thought?

Ground Water (>800 m) Chemistry



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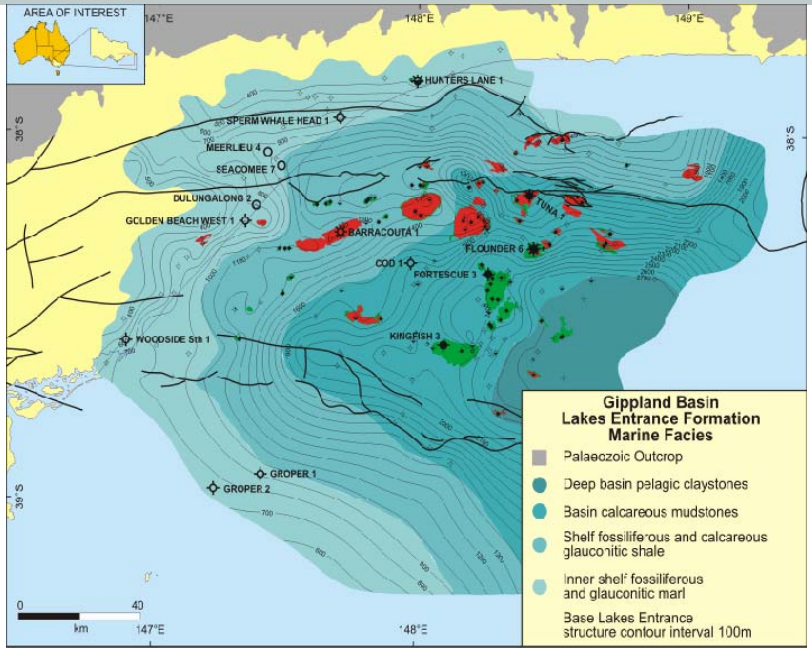
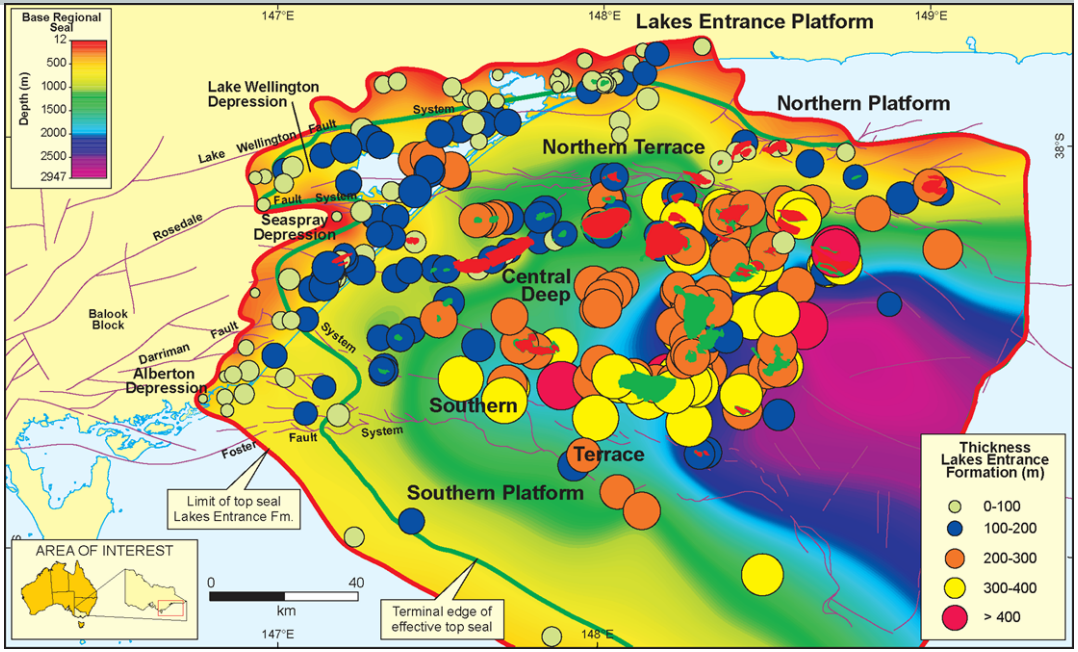
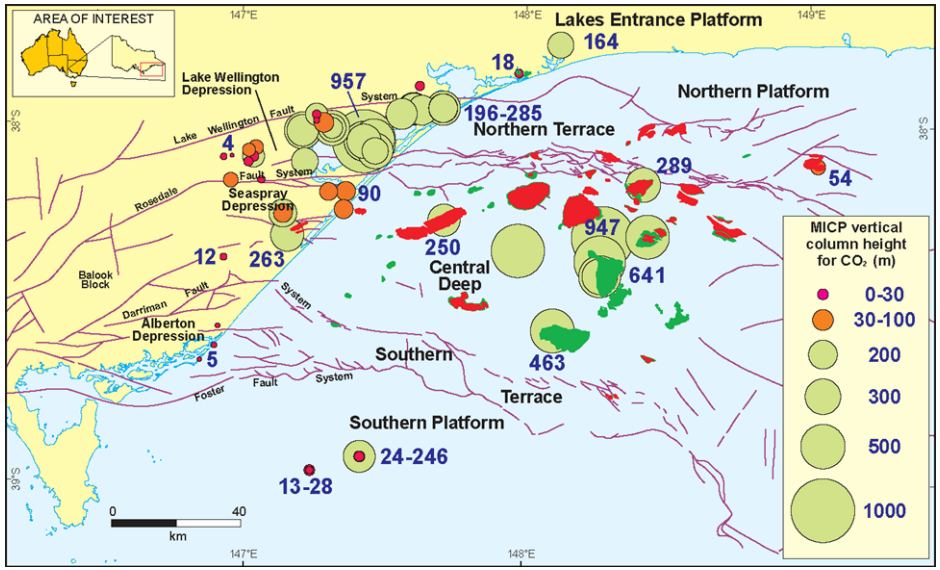
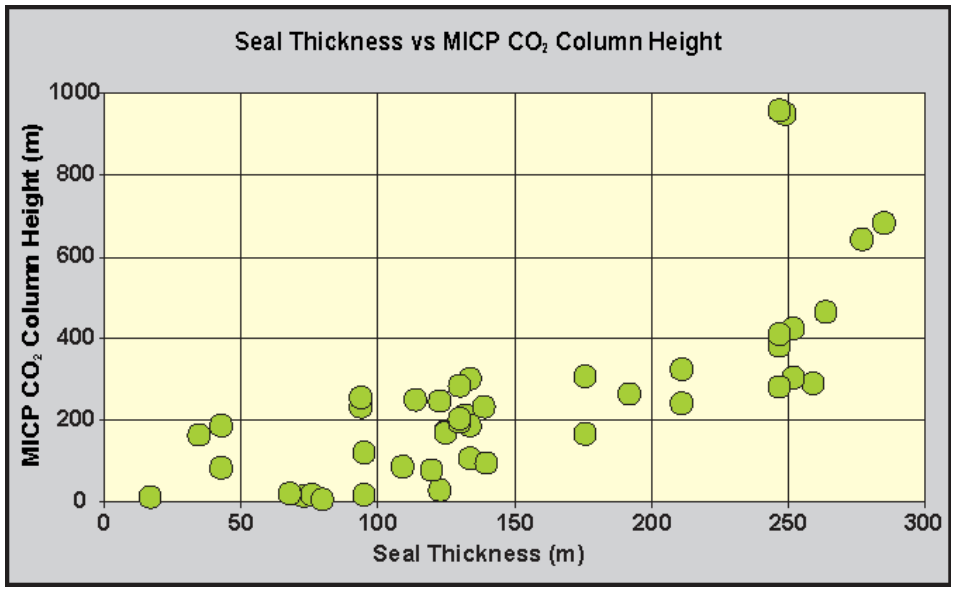
Seal Evaluation

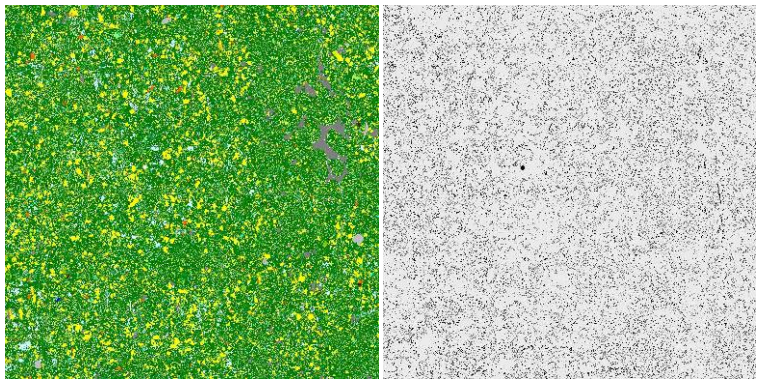




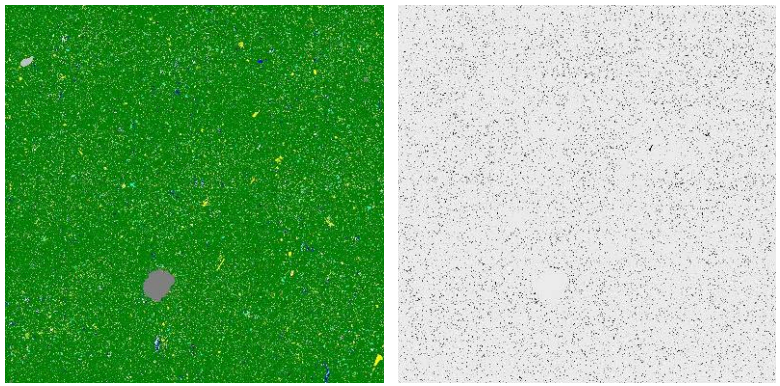




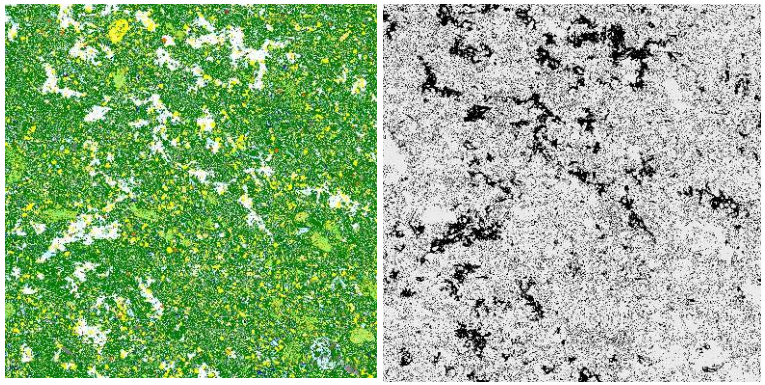
Automated Mineral Analysis



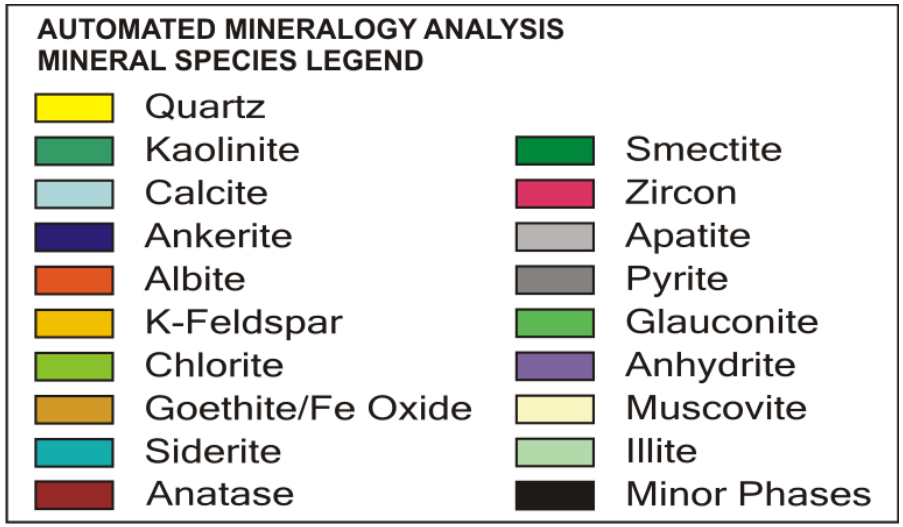
Wrasse-1 - offshore (2589m)



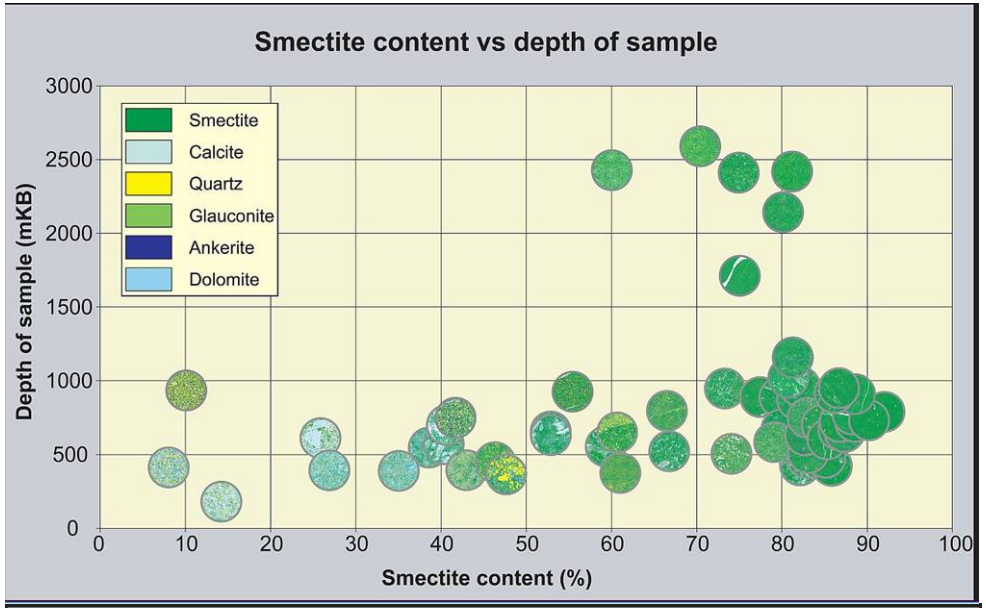
Meerlieu-4 - onshore (769m)

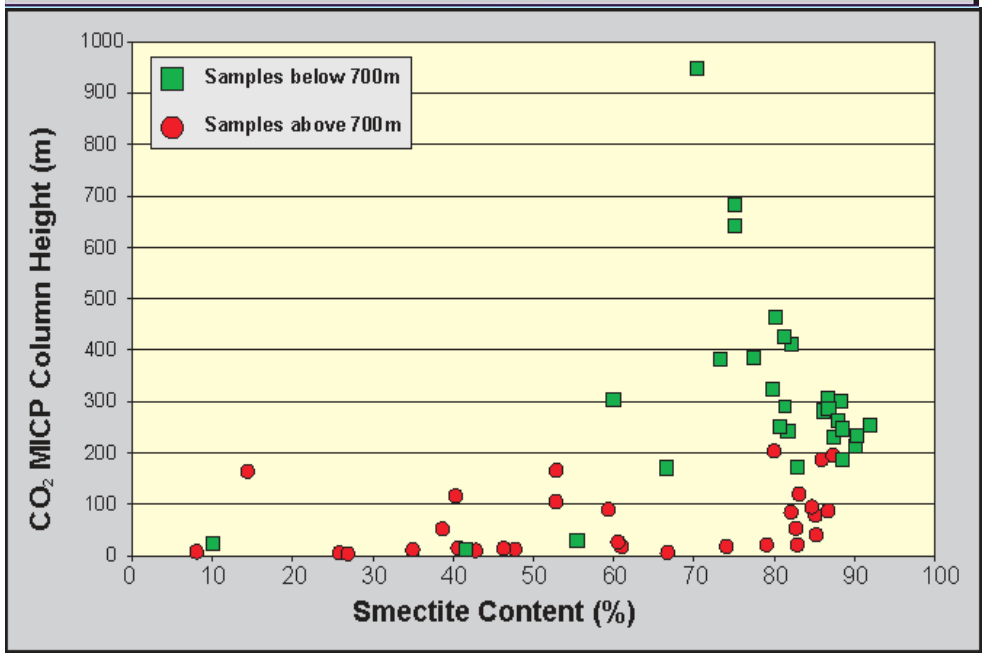


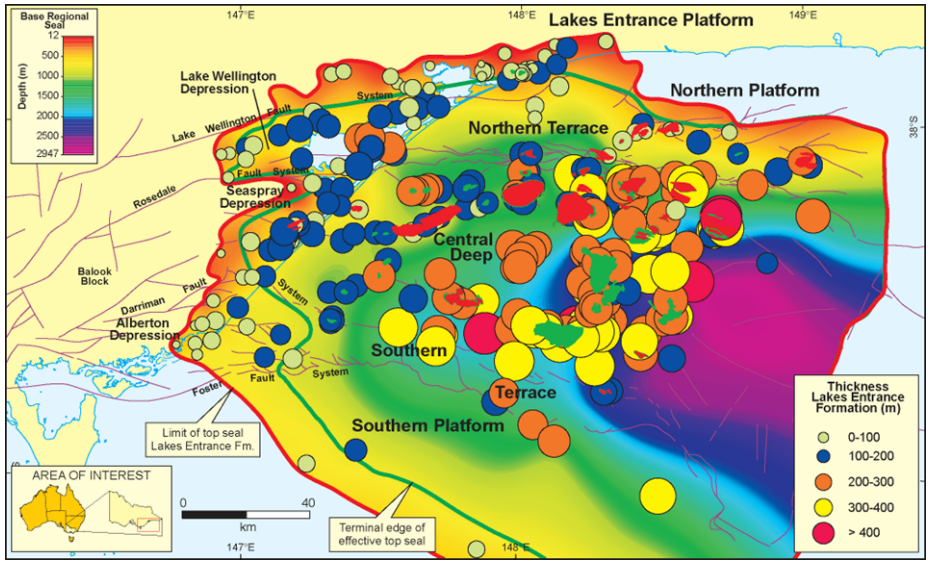
Gippsland Frome Lakes-4 onshore (503m)



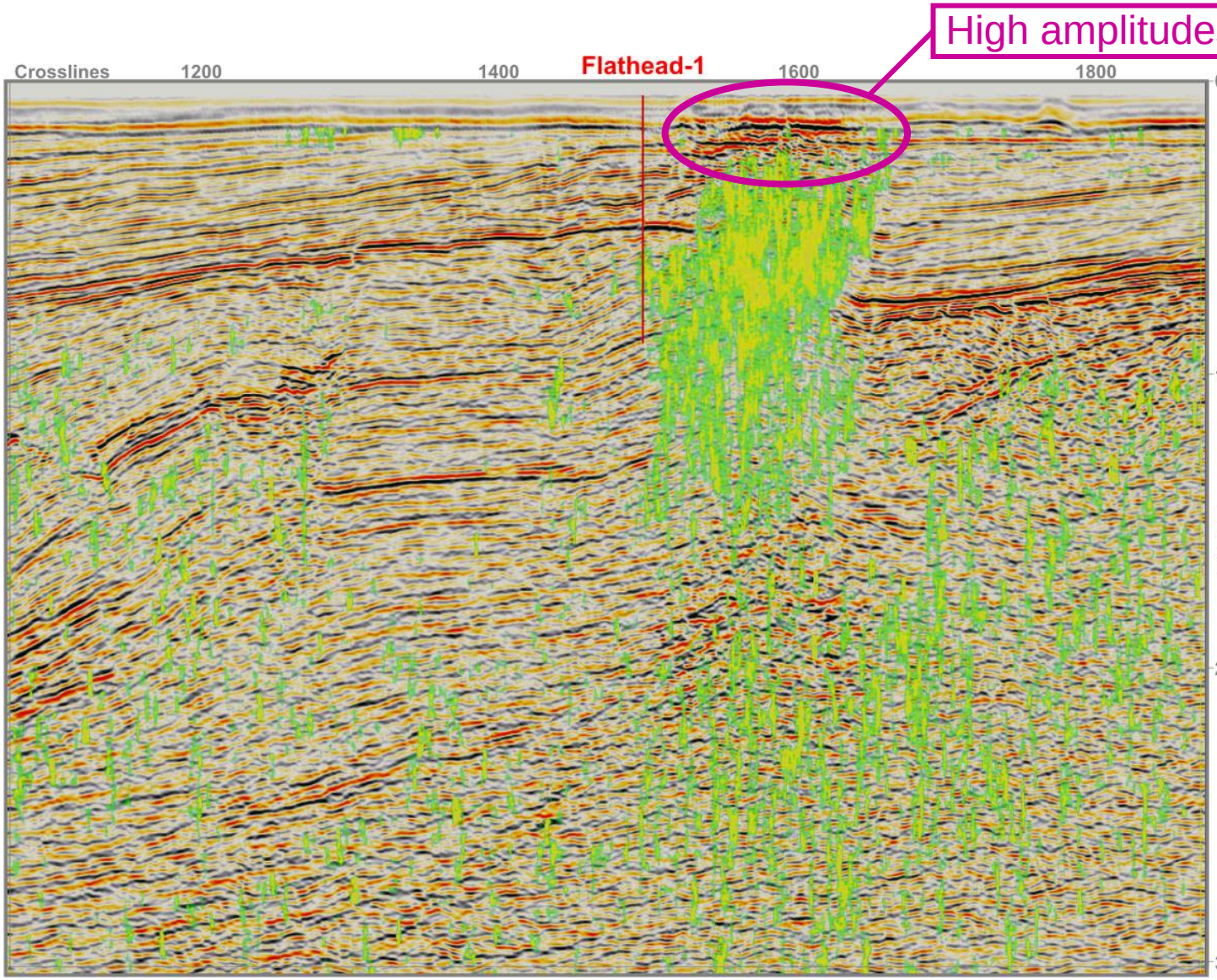
Mineralogy & Seal Quality







Flathead Gas Chimney



Trained neural network using OpendTect software matches well with the visible gas chimney

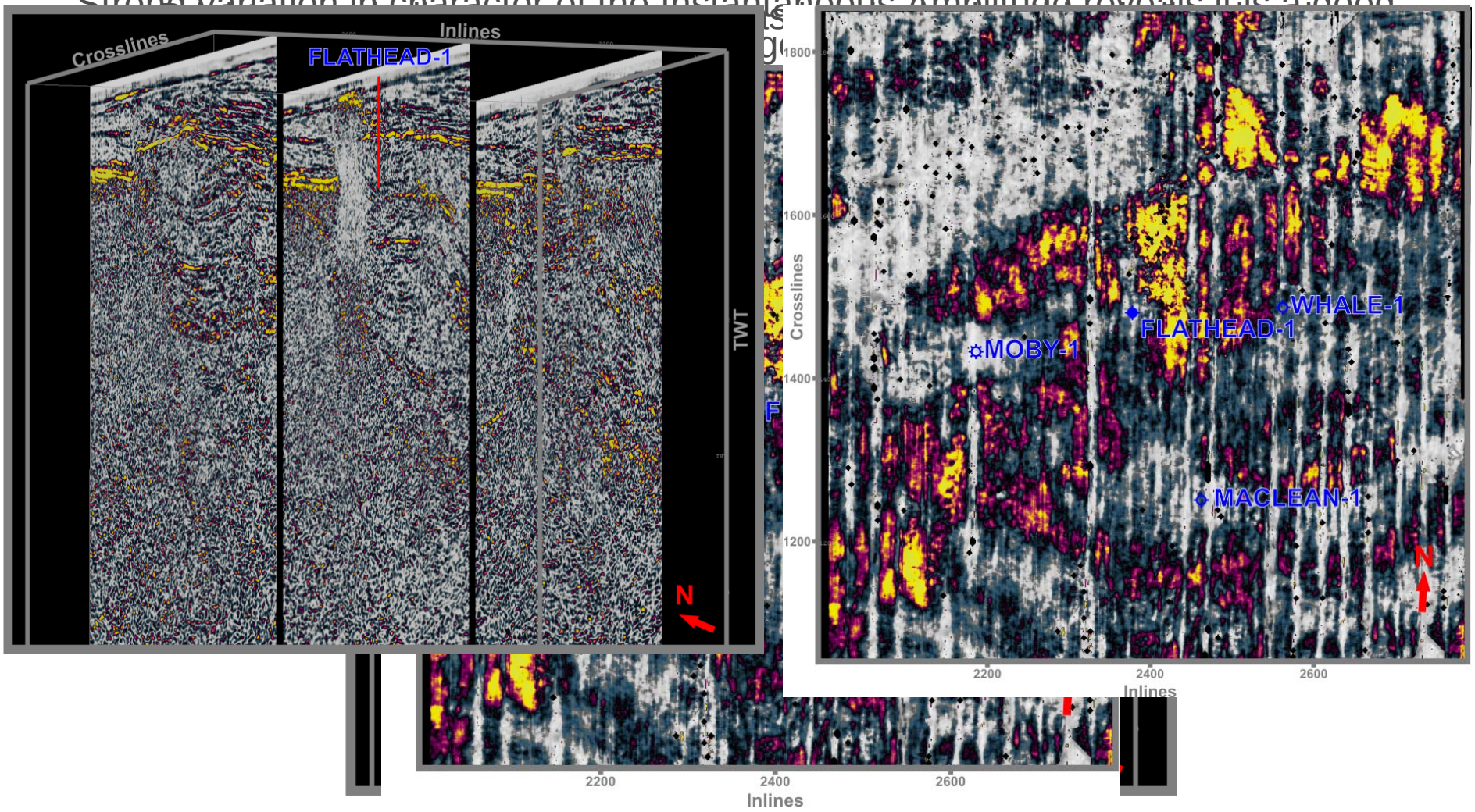
Evidence of vertical gas migration (i.e. gas chimney)

Flathead Gas Chimney

3D View of Instantaneous Amplitude attribute on inlines 2100, 2400 & 2700

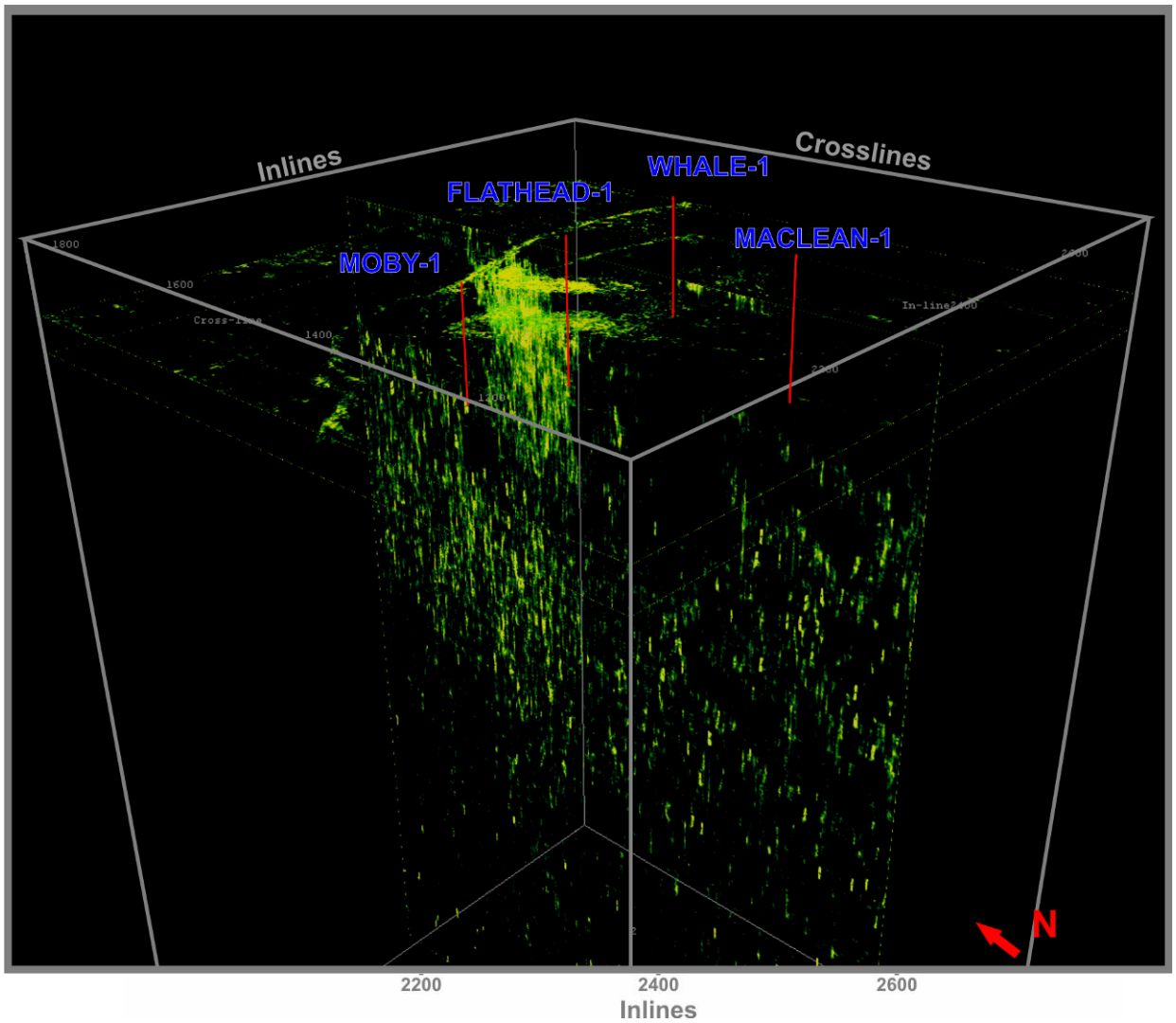
Instantaneous Amplitude map of the near sea-floor horizon

Strong variation in character of the Instantaneous Amplitude reveals it is a good

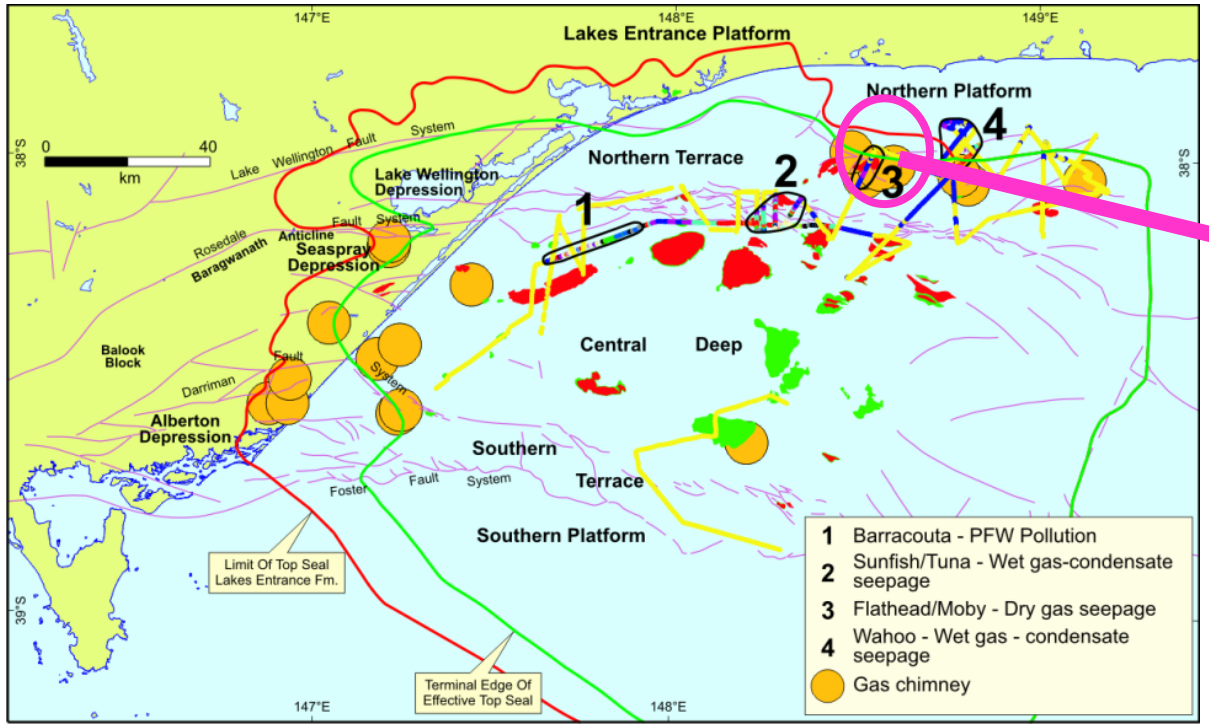


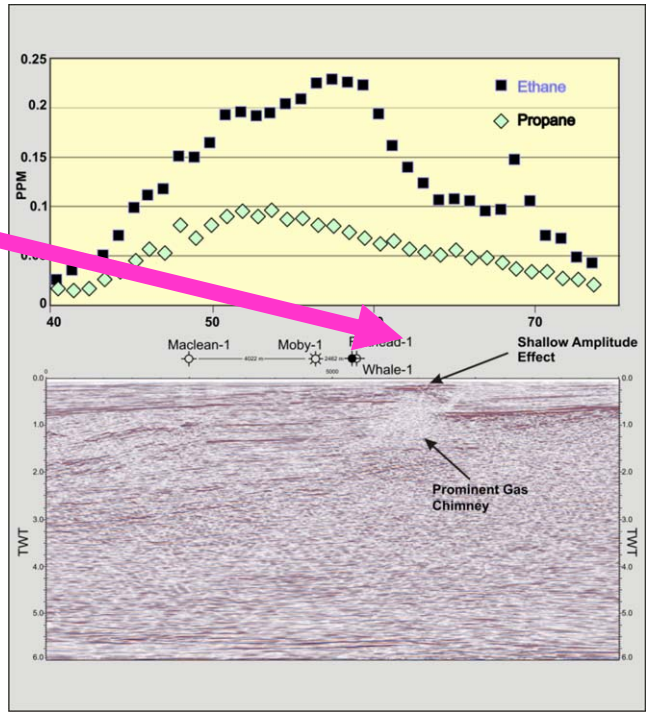
Flathead Gas Chimney

Neural network 3-D plan view on the 400ms timeslice



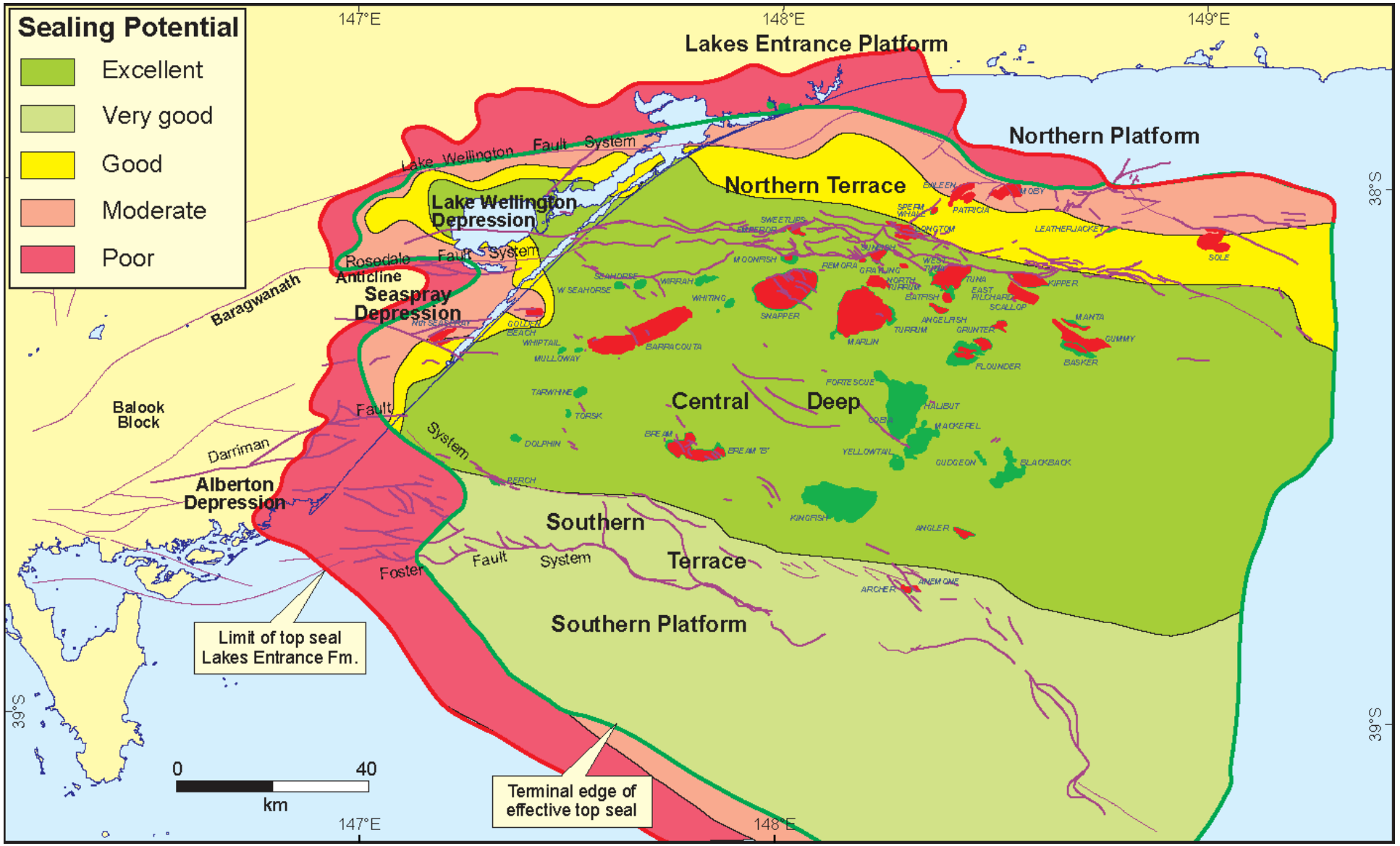
Flathead Chimney & Seepage Cluster





- Leakage and seepage indicators are most common along the edge of the top seal
- Through these areas of thin and marginal top seal, minor Neogene structural reactivation (inversion) is present, facilitating seal failure

Seal potential



Seal Observations

- Regional top seal is high quality over much of the offshore but of very limited extent across onshore
- The seal fails along the northern and southern margins and these areas are well-defined by gas chimneys and seeps
- Onshore and near-shore, the fresh water wedge has degraded seal quality substantially, especially in more carbonate-rich sealing intervals – gas chimneys are common through these areas

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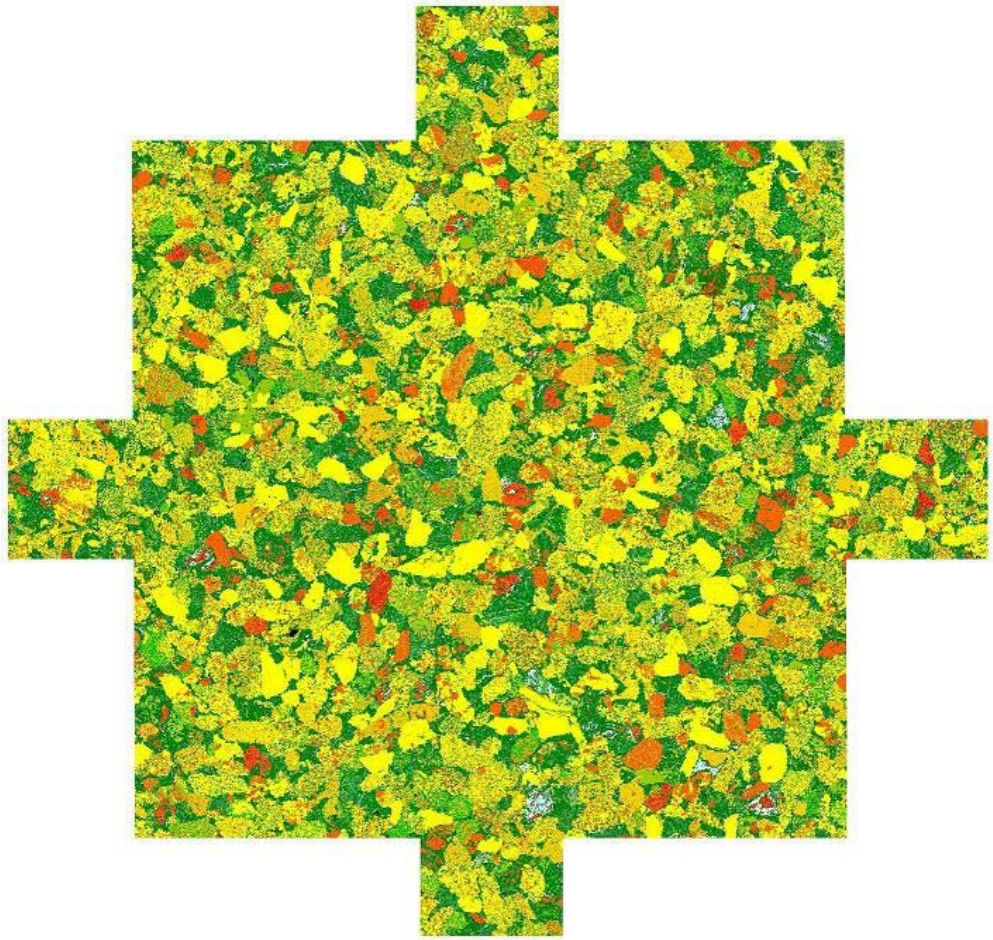
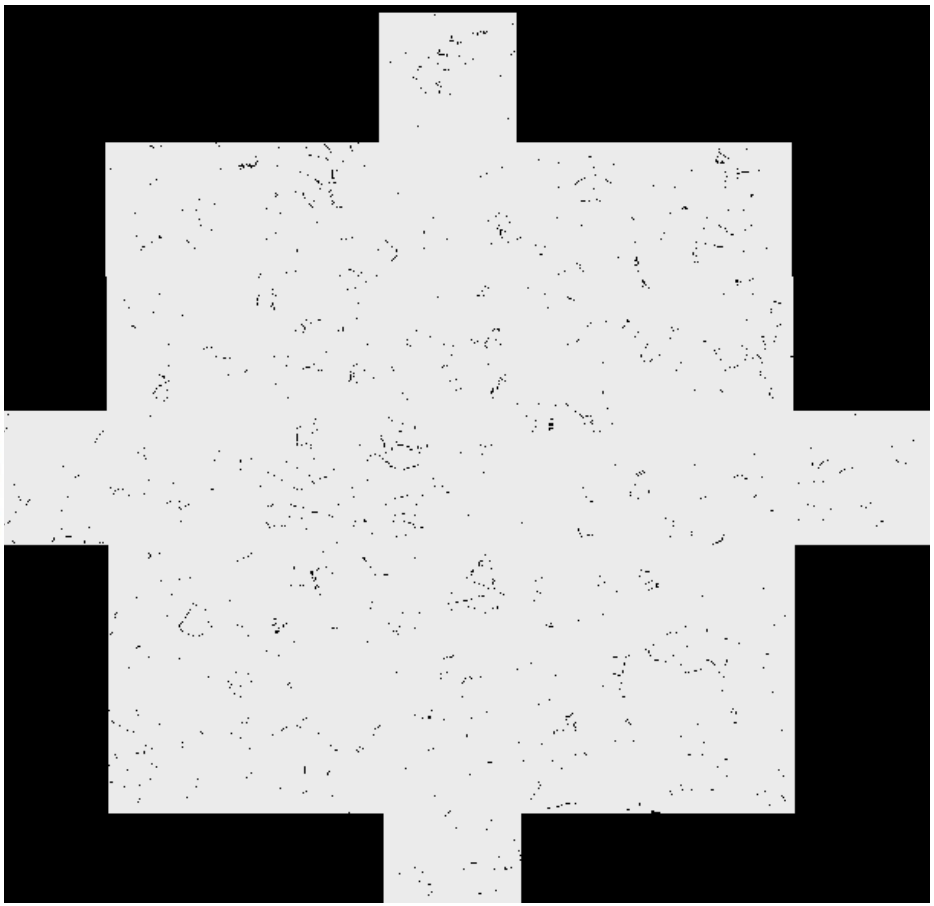
Injectivity-Capacity -Storage Potential

- Early days!
- Compiled comprehensive database of poro-perm data and acquired new data, especially across the onshore, where reservoirs are more problematics
- Substantial new work on AMA characterisation of reservoir facies (reactivity, provenance, pore characterisation)
- Integrating existing studies with new work on reservoir distribution and quality
- Working with Senergy and CSIRO on estimations of storage potential

Carr's Creek-1:
1633.8m; ;~0.6% porosity; Strzelecki Group





Quartz
Albite
K-Feldspar
Plagioclase
Smectite

Kaolinite
Illite/muscovite
Chamosite
Glauconite
Calcite

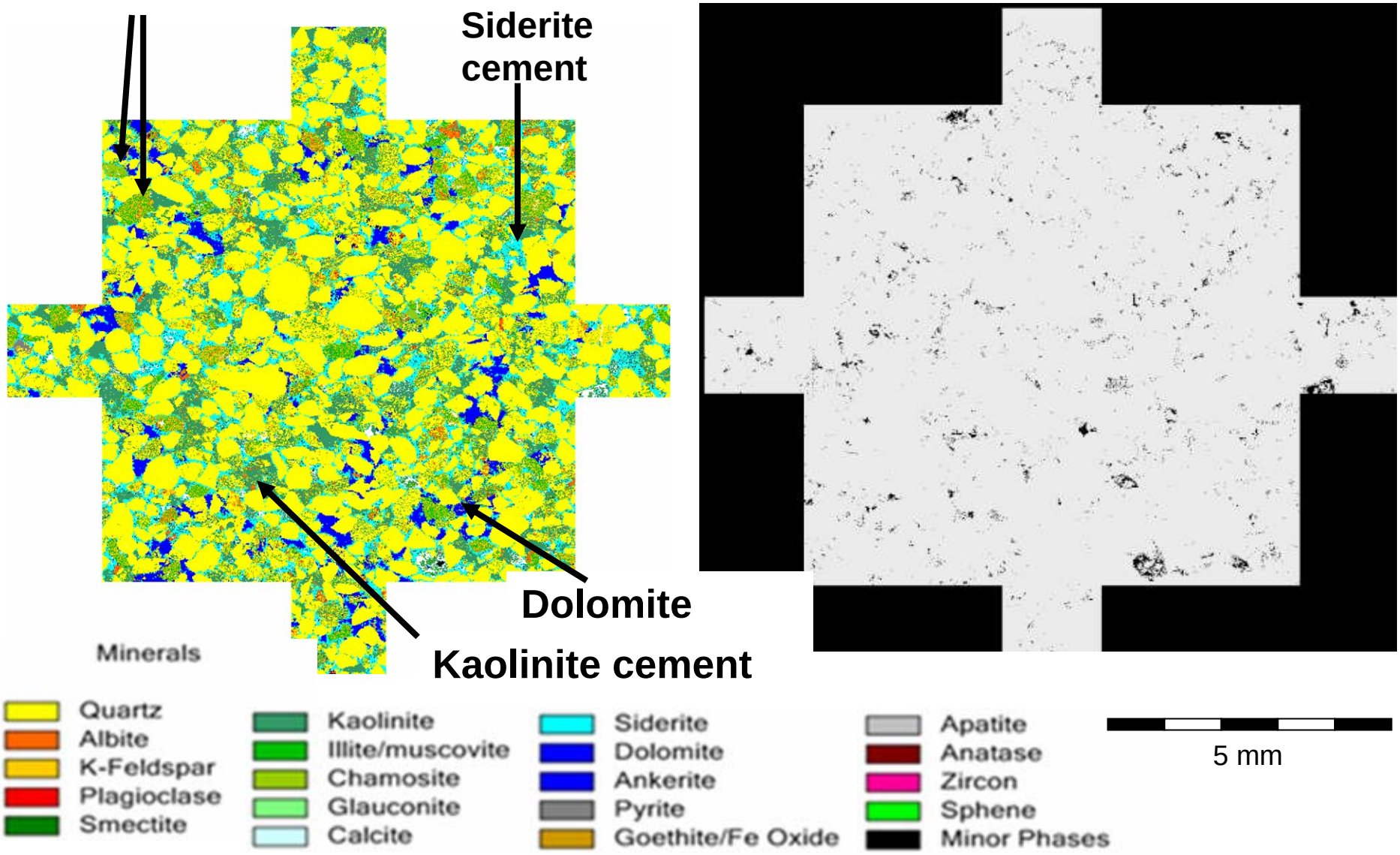
Siderite
Dolomite
Ankerite
Pyrite
Goethite/Fe Oxide

Apatite
Anatase
Zircon
Sphene
Minor Phases

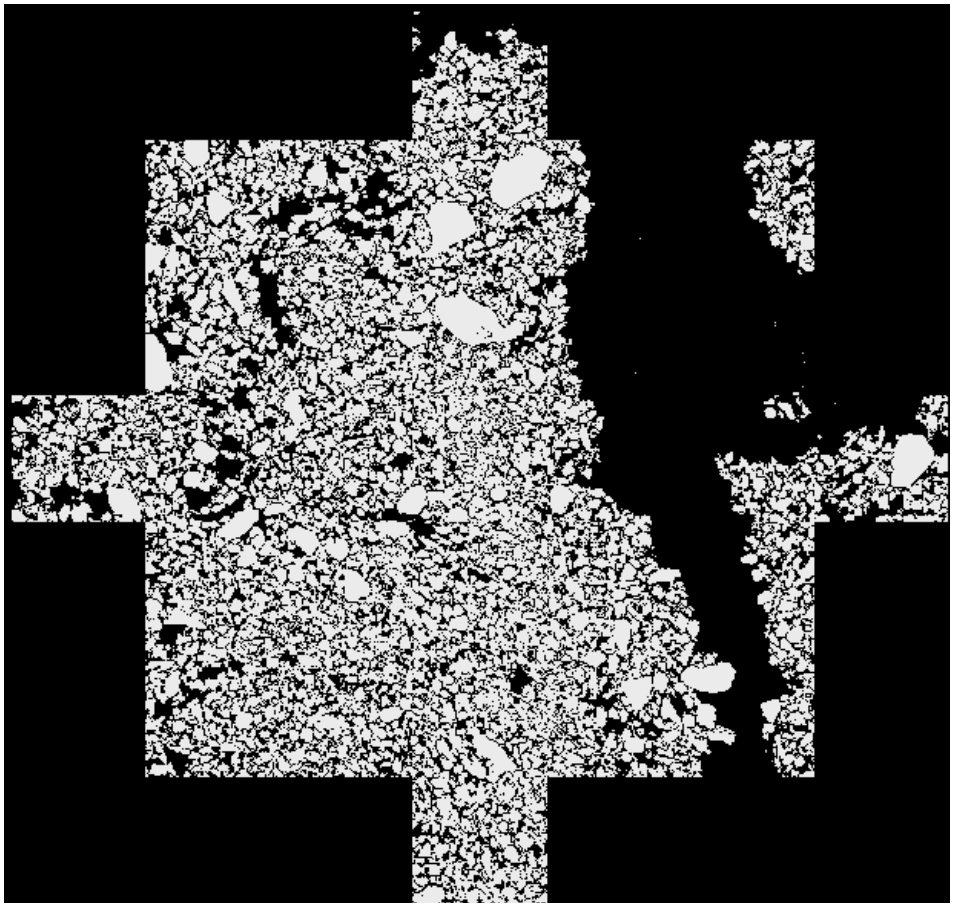
5 mm

Golden Beach West-1:
2165m; low porosity (~1.5%); Emperor Subgroup

Altered feldspar grains



Carr's Creek-1:
703.5m; 30% porosity; Latrobe Group



Quartz
Albite
K-Feldspar
Plagioclase
Smectite

Kaolinite
Illite/muscovite
Chamosite
Glauconite
Calcite

Siderite
Dolomite
Ankerite
Pyrite
Goethite/Fe Oxide

Apatite
Anatase
Zircon
Sphene
Minor Phases

5 mm

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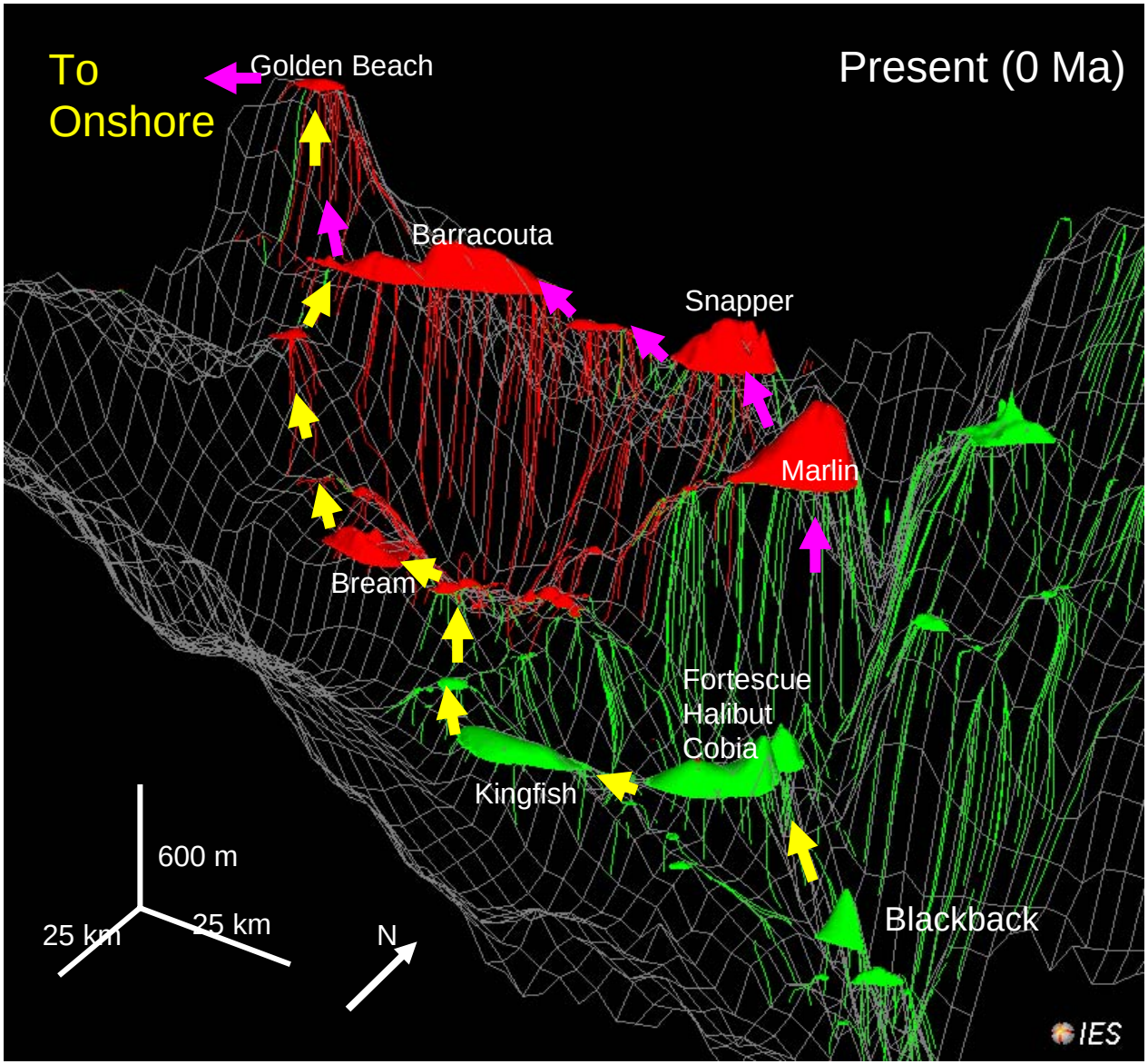
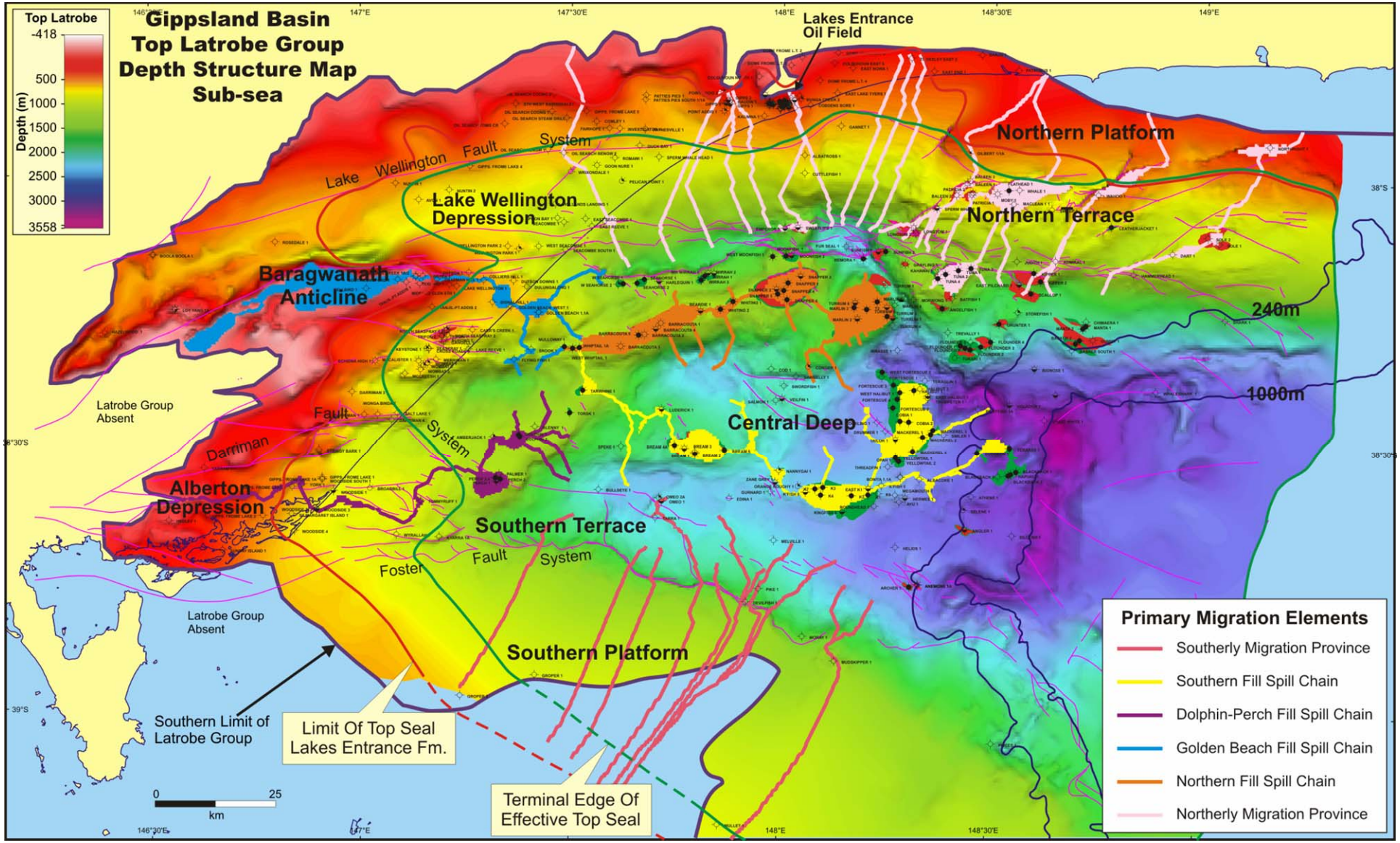
Migration Modelling

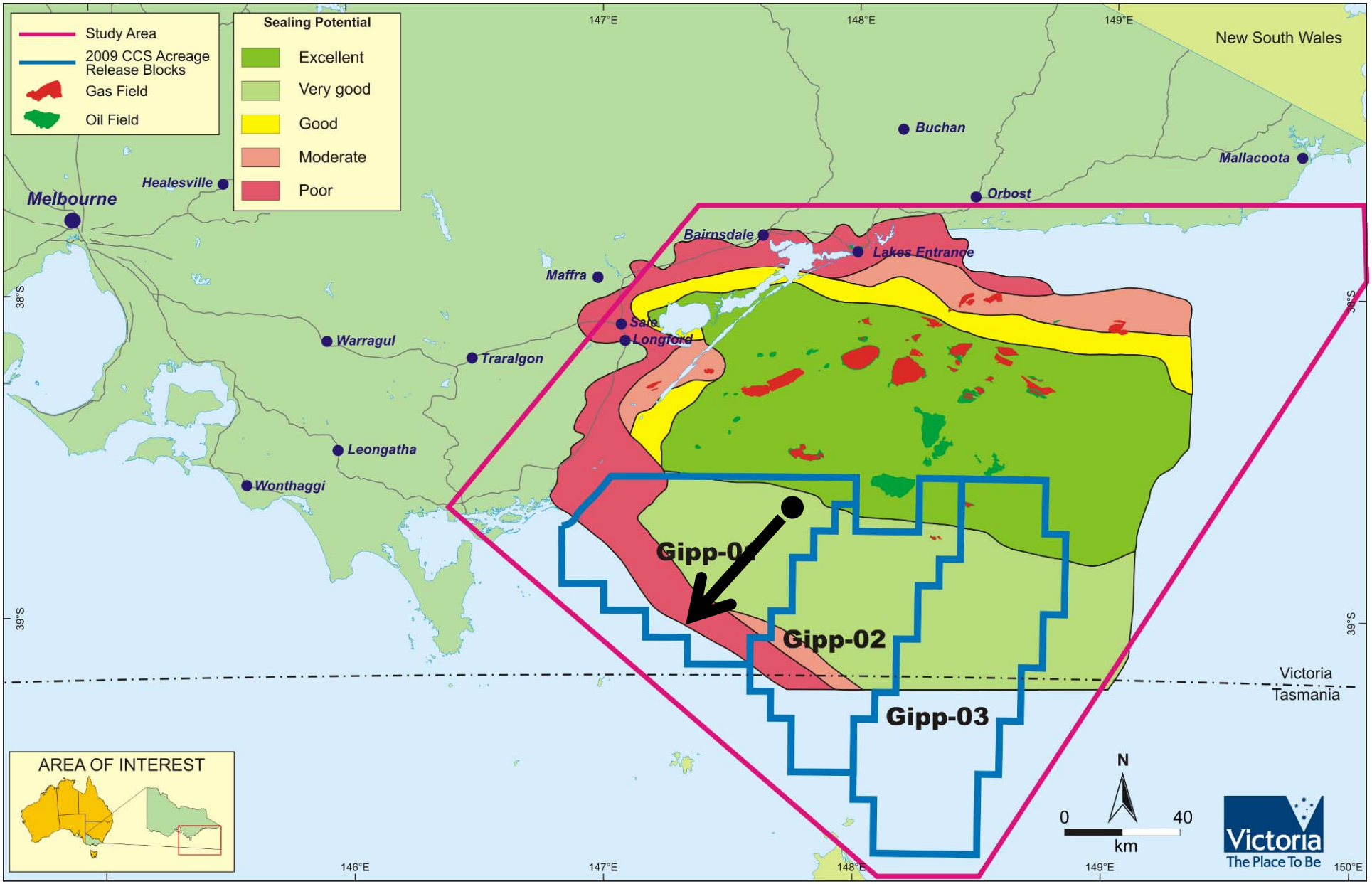


- Very prominent, completely filled fill-spill chains evident in the Gippsland Basin (extremely focussed migration)
- Charge history data show evidence for early oil charge with oil migrating through major fields via fill-spill chains?

Migration Pathways

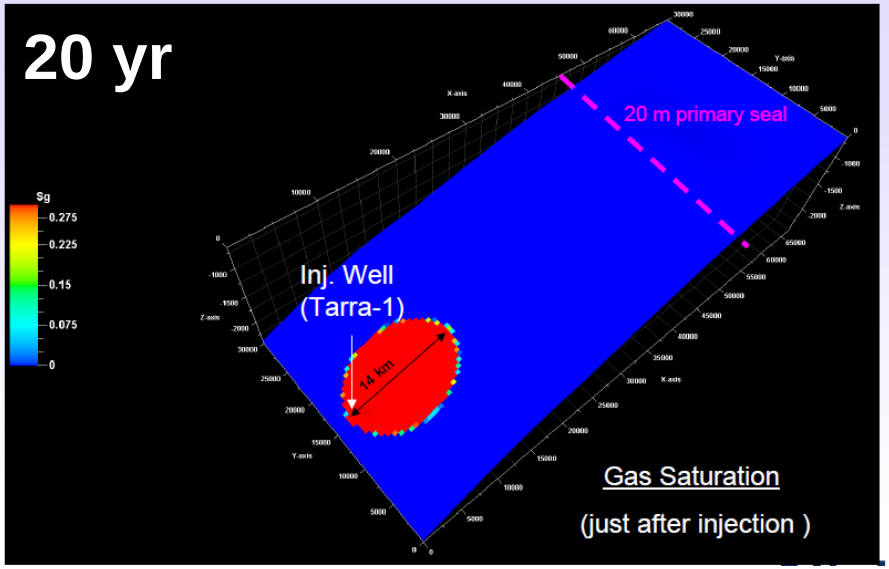


Containment & GCS Acreage

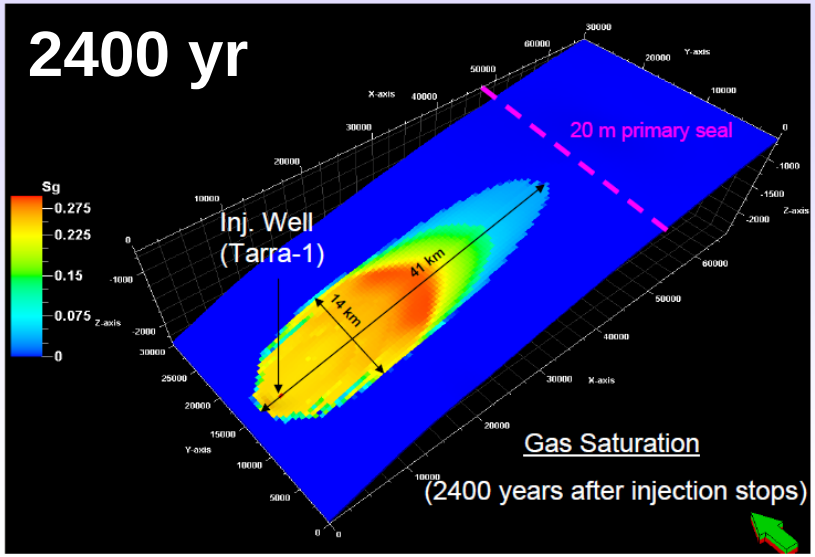


100 MT of Injected CO_2

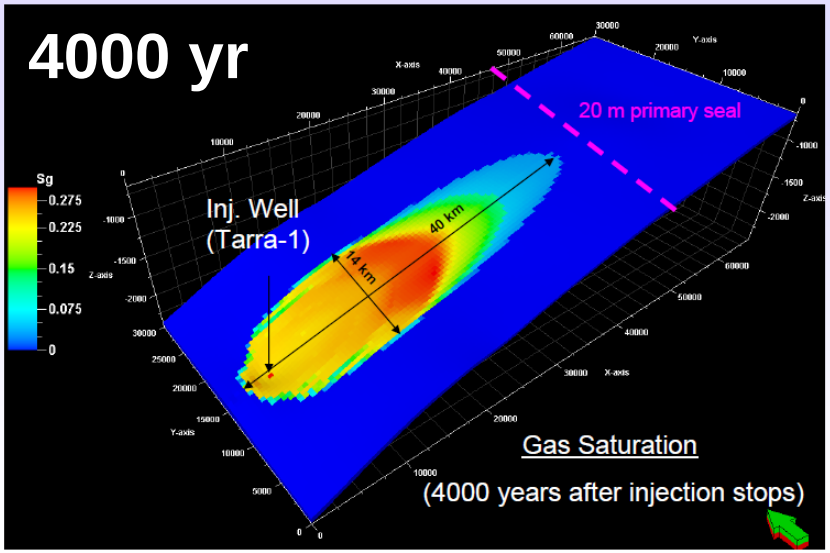
Just after injection



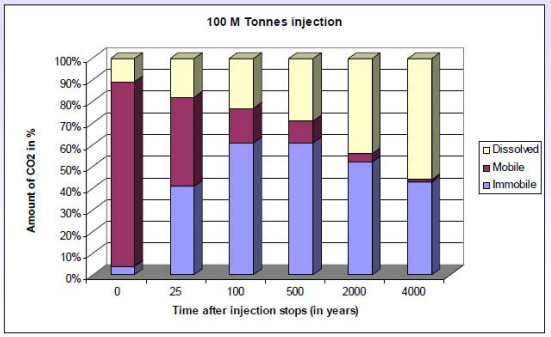
Maximum extension



At 4000 years after injection stops



- BHP up to 250 bars (28 bars difference)
  (limit=490 bars)
- Max extension = 41 km (2400 years)



16 % mobile* at 100 years

** Mobile stands for free phase CO_2 not "gas trapped" and not dissolved, it could be potentially hydrodynamic trapped (not taken into account by simulators)*

Schlumberger Modelling

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Integration & Way Forward

A sound predictive model for seal potential, fluid flow and leakage and seepage in the Gippsland Basin has been developed

Gippsland Basin is subdivided into several major fill-spill chains which control first-order fluid flow processes

These fill-spill chains link fluid flow between the offshore and onshore parts of the basin

The high connectivity between the onshore and offshore and the linkages within the basin mean the potential for resource conflict and adverse impact is significant

Leakage and seepage over the flanking terraces and platforms offshore and onshore correlate with the confluence of the fill-spill chains and decreasing top seal integrity

The ground water resources onshore and near-shore are fresh

Robust 3D fluid flow and basin models – and high qulaity staff - will be required by Government if basins are to develop as true multiple-use zones within which their maximum resource potential is to be realised

Basin-scale, geoscience information and knowledge systems will be required to allow informed management of basins as multiple use zones and provide knowledge-based assessments of potential impacts and relative values of all relevant earth resources