

# VICTORIAN GAS PROGRAM

**GEOLOGICAL  
SURVEY OF VICTORIA**

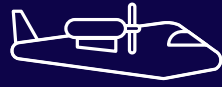
## **PROGRESS REPORT** REPORT Nº 3

October 2019



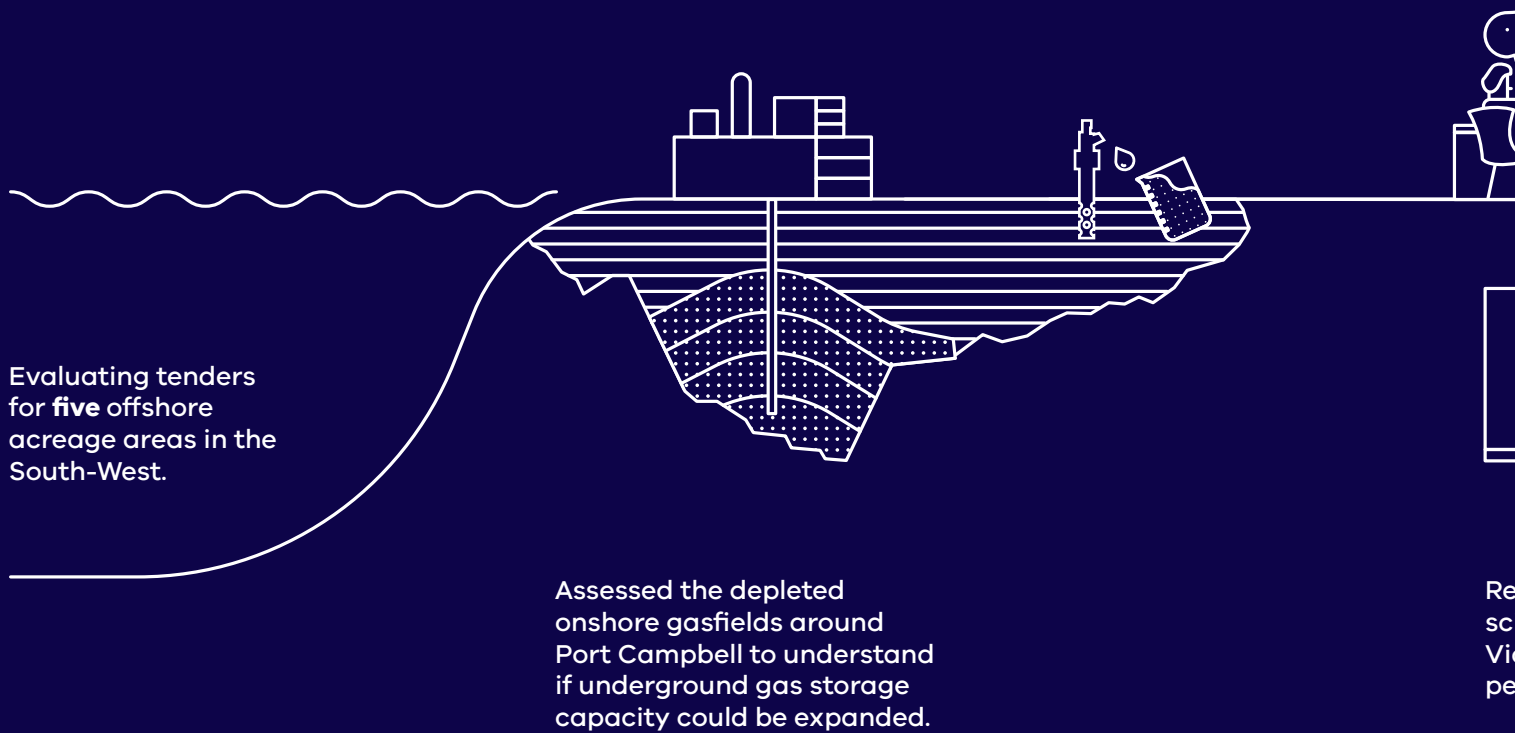
# The Victorian Gas Program story so far

Completed an airborne gravity survey of over **16,000 km<sup>2</sup>** of South-West Victoria to understand the shape and distribution of rock structures deep underground.



Sampled **100 groundwater bores** to develop an environmental snapshot of the Gippsland and Otway basins.

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Evaluating tenders for **five** offshore acreage areas in the South-West.

Assessed the depleted onshore gasfields around Port Campbell to understand if underground gas storage capacity could be expanded.

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## The Victorian Gas Program timeline

July 2017



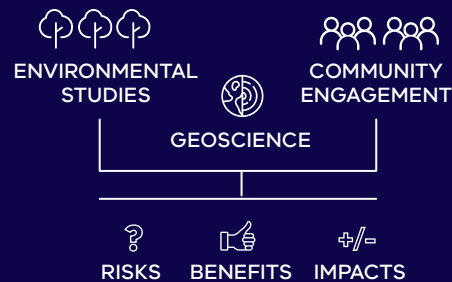
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undertaken **>710** engagements with communities and industry to help people understand the program and how they can be involved.

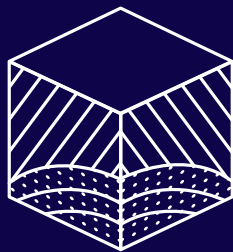
Opened a Geological Survey of Victoria office at Deakin University, Warrnambool.

Surveyed **~20,000 km** of roads measuring air quality (methane and carbon dioxide) to develop an environmental snapshot of the Gippsland and Otway basins.

Started the evaluation of the risks, benefits and impacts of onshore conventional gas.



Reviewed all of the scientific literature about Victoria's geology and petroleum systems.



Building 3D geological models to support gas resource estimates and groundwater impact assessments across the Gippsland and Otway basins.



Taken **>300,000** physical rock measurements to understand what rocks may generate gas and allow it to accumulate to create potential resources.



Published **nine** technical reports to date.

We are here ↓

June 2020



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### **About the Victorian Gas Program**

The Victorian Gas Program (the program) is a comprehensive science-led program, incorporating geoscientific and environmental research to assess the risks, benefits and impacts of potential onshore conventional gas exploration and production.

The program is also investigating the potential for further discoveries of onshore conventional and offshore gas in the Otway and Gippsland geological basins and assessing the feasibility of additional onshore underground gas storage in depleted reservoirs around the Port Campbell area.

The program includes an extensive, proactive and phased community and stakeholder engagement program, through which the results of the scientific studies are being communicated.

### **About the Geological Survey of Victoria**

The Geological Survey of Victoria (GSV) is the Victorian Government's geoscience agency and sits within the Department of Jobs, Precincts and Regions.

The Geological Survey of Victoria provides evidence-based knowledge and information to Government, industry, academia and the community, on Victoria's earth resources, using the latest geoscience technologies and methods.

For more details visit [earthresources.vic.gov.au/gsv](http://earthresources.vic.gov.au/gsv).

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# Executive summary

This report builds on the first two Victorian Gas Program Progress Reports published in January 2018 and February 2019. The Progress Reports provide updates on the three-year scientific studies being undertaken by the Geological Survey of Victoria to:

- investigate evidence of Victoria's potential for future gas supply
- inform the Victorian Government's decisions on the risks, benefits and impacts associated with onshore conventional gas.

This report presents a summary of the studies undertaken so far, including the data from environmental studies, and scientific information about onshore conventional gas, offshore gas and underground gas storage potential.

As the Victorian Gas Program progresses, more scientific data will be analysed and released to continue to share evidence-based results.

## Highlights – evidence to date

- Sampling of 100 groundwater bores has been completed with analysis of the bores' water chemistry now under way to establish baseline data and improve understanding of groundwater processes through the Otway and Gippsland regions.
- An atmospheric survey for carbon dioxide and methane levels, of approximately 20,000 kilometres of roadsides in the Otway and Gippsland basins, has been completed.
- Groundwater models for Otway and Gippsland basins have been built. Potential groundwater impact scenarios are now being undertaken.
- Baseline air quality (methane and carbon dioxide) measurements and analyses are complete. The data found that instances of elevated methane above background were rare and well below Environment Protection Authority limits.
- Analysis of the onshore petroleum regulatory framework indicate that it is robust for managing environmental and safety risks.
- The Victorian Gas Program continues to share the science by delivering an open and transparent engagement program with over 710 engagements to date.
- The Victorian Gas Program's methodology and results are independently tested via the guidance and advice of two groups led by Victoria's Lead Scientist – the Stakeholder Advisory Panel for Onshore Conventional Gas and the Victorian Gas Program Scientific Reference Group.

## Onshore conventional gas studies – new insights for the Otway Basin

The Victorian Gas Program's geoscientific, technical and environmental studies are providing an evidence-based estimate of prospective gas resources at a regional level. The studies are also looking closely at the risks, benefits and impacts associated with onshore conventional gas exploration and development. This work is informing government decisions during the onshore conventional gas moratorium, which is currently in place until 30 June 2020. The studies focus on Victoria's two most prospective regions for gas: the Otway Basin and the Gippsland Basin.

### Study methods

To date, the Victorian Gas Program's geoscientists have sampled more than 7170 Otway Basin rock specimens for rock characterisation studies, yielding over 300,000 measurements and observations. The new measurements have been interpreted to assess key components of the petroleum system: reservoir, seal and source rocks.

Three-dimensional (3D) geological framework models of the Otway Basin have been constructed, and a model for the Gippsland Basin is well advanced. These provide the framework for scientists to understand where rock formations that host gas are present as well as the location and movement of groundwater.

### **New insights for the Otway Basin**

The Victorian Gas Program has now identified all rock formations that may potentially host gas, and the geographic distribution of those locations. Parts of the Otway Basin have rock formations with the right characteristics and in the right sequence to potentially host conventional gas.

### **New environmental baselines**

The Victorian Gas Program has sampled groundwater from 100 Victorian Government observation bores across the Otway and Gippsland basins. The groundwater sampling provides a consistent measure of groundwater conditions, mainly in deep aquifers, across the regions. This is the first time many of these bores have been sampled in such detail, including measuring dissolved methane.

The Victorian Gas Program has also completed an atmospheric survey of carbon dioxide and methane levels along approximately 20,000 kilometres of roadsides in the Otway and Gippsland basins. This atmospheric survey found that instances of elevated methane above background were infrequent and well below the Environmental Protection Authority atmospheric emission concentration limit of 10,000 parts per million. Baseline concentrations of both methane and carbon dioxide in South-West Victoria and Gippsland are consistent with baseline concentrations for the southern hemisphere (CSIRO, 2018).

### **Further work**

The Victorian Gas Program is currently undertaking resource and land use planning activities in the onshore Otway Basin. The activities are:

- assessing key natural resources
- assessing cultural, environmental and existing and future land uses
- getting a better understanding of community views to ensure the best possible range of land use options are considered.

Further scientific studies are under way to calculate prospective gas resource estimates for areas in the Otway Basin. Estimate ranges will be published in 2020.

The Victorian Gas Program has also commenced an assessment of the risks, benefits and impacts of onshore conventional gas production and processing beginning with a pilot study on Beach Energy's Port Campbell gas processing facility. The pilot study looked at available data including socio-economic and environmental indicators. The results of the pilot study tested the assessment methodology and will support and inform the Victorian Gas Program's broader assessment of the risks, benefits and impacts of onshore conventional gas development.

## **Offshore gas studies – new pre-competitive geoscience data**

Natural gas has been extracted in waters off Victoria's coast for decades and is a vital part of the state's energy supply network. Future supply depends on new gas discoveries.

To encourage commercial exploration for potential new natural gas resources in the Otway Basin, the Victorian Gas Program has delivered:

- over 32,000 line kilometres of innovative airborne gravity/gradiometry data, providing new evidence about rock structures below the seafloor
- 3D geological models, providing key insights into where rocks that may host gas are present
- five new acreage areas in state-controlled waters (areas up to three nautical miles off the coast) between Port Campbell and the South Australian border.



## Underground gas storage – positive economic case for the development of new sites

The Victorian Gas Program has assessed the potential for further underground gas storage sites. The assessment helps make a positive economic case for the development of new sites. Increased underground gas storage may help to secure more reliable gas supplies and mitigate short-term price peaks, particularly during interruptions in the gas supply system. The assessment focused on 13 depleted gas fields around Port Campbell.

Out of the 13 fields that had suitable geology that could be converted for use as gas storage reservoirs, six fields were shortlisted to progress to a more detailed technical evaluation. All six shortlisted sites were found to be commercially feasible, both individually and when some individual fields were combined.

The Department of Environment, Land, Water and Planning in conjunction with the Geological Survey of Victoria have assessed the economic potential of additional gas storage in the onshore Otway Basin and the commercial drivers for development of that capacity. The study results are currently undergoing peer review and will be published in 2020.

## Program governance – independently testing our methodology and results

The methodology and results from the program's studies continue to be independently tested via the guidance and advice of two Victorian Gas Program governance groups:

- **The Stakeholder Advisory Panel for Onshore Conventional Gas**  
This panel has met eight times since its inception in August 2017. Chaired by Victoria's Lead Scientist the panel includes representatives from farming, environment, industry groups, local government and the community. The panel independently advises the Minister for Resources on the risks, benefits and impacts of potential onshore conventional gas exploration and production.
- **The Victorian Gas Program Scientific Reference Group**  
This group is also chaired by Victoria's Lead Scientist and meets when required. This group provides independent peer review advice to the Lead Scientist and the Geological Survey of Victoria on the study scope, methodology and outputs of the program.

## Community engagement – open and transparent

Underpinning the scientific studies is an open and transparent community engagement program. The Victorian Gas Program has a team of geoscientists and community engagement staff based at the Warrnambool Deakin University campus. The team frequently briefs local government, industry, farmers, local school students, and environmental and community groups on the program and geoscience studies. Over 710 engagements have taken place and more will occur as research activities continue. The Victorian Gas Program's geoscience team has also shared its knowledge and passion for geology by presenting to over 1200 South-West Victorian primary and high school students, many of whom viewed the state's 3D geological model.

Social baseline research is under way into community wellbeing and regional attitudes to conventional gas development in the Gippsland and Otway basins. The results will provide a structured response from potentially impacted regional communities on their attitudes and perceptions about any future onshore conventional gas exploration and development. The Victorian Gas Program will share its results with communities, local government and State Government and will be comparable with data collected from other Australian jurisdictions.

## Potential regulatory reform – importance of communities and stakeholders

The Victorian Gas Program has reviewed onshore conventional gas-related inquiries and reports to identify regulatory areas of importance to communities and stakeholders. The adequacy of the onshore petroleum regulatory framework which is contained in the Victorian Petroleum Act 1998 and Petroleum Regulations 2011 was also assessed.

The analysis showed the onshore petroleum regulatory framework is robust for managing environmental and safety risks. Potential areas for improvement include community and landholder engagement as well as transparency of industry activities.

Potential regulatory reforms will be informed further by the assessment of risks, benefits and impacts and the findings from the Victorian Gas Program's community engagement program.

### Next report

The next progress report will build on the work completed to date and analyse the evidence gathered from the Victorian Gas Program's scientific, regulatory and social research, to help inform future government decisions.

# 1. Overview

This progress report outlines the scope of the Victorian Gas Program, an overview of the techniques being used by the Geological Survey of Victoria to conduct the scientific studies, and the status of activities. Subsequent reports will provide further data analysis and results.

The Victorian Gas Program, which runs from 2017 to 2020, has four major components:

1. Onshore conventional gas – This component comprises geoscience and environmental studies on the risks, benefits and impacts of onshore conventional gas exploration and production, while the moratorium is in place until 30 June 2020. The geoscience investigations will provide an evidence-based prospective gas resource estimate. The studies are overseen by Victoria’s Lead Scientist and a Stakeholder Advisory Panel, made up of farmers, industry, local government and the community. The findings are peer reviewed by an expert Scientific Reference Group.
2. Offshore gas – Work is well under way to support commercial exploration for further discoveries of gas off Victoria’s coast to help increase gas supply.
3. Underground gas storage – Investigations into opportunities for further underground gas storage in the onshore Otway Basin have been assessed. The aim is to help secure more reliable gas supplies and to mitigate short-term price peaks, particularly during interruptions in the gas supply system.
4. Community engagement, resource planning and potential regulatory reform – To support the scientific investigations, an engagement program for farmers, industry, local government and regional communities is a core part of the Victorian Gas Program. Also, resource and land use planning and potential regulatory improvements projects are under way and will be informed by the findings of the Victorian Gas Program.

## 1.1 Technical reports published to date

- Technical Report 1 – New porosity and permeability measurements from legacy core, Onshore Otway Basin, Victoria
- Technical Report 2 – New seal capacity measurements from legacy core and cuttings, Onshore Otway Basin, Victoria
- Technical Report 3 – Mineralogical and textural characterisation of sedimentary rock samples, Onshore Otway Basin, Victoria
- Technical Report 4 – New vitrinite reflectance measurements from legacy core and cuttings, Onshore Otway Basin, Victoria
- Technical Report 5 – New source rock geochemistry measurements from legacy core and cuttings, Onshore Otway Basin, Victoria
- Technical Report 6 – Full Spectrum FALCON® airborne gravity and aeromagnetic survey, Otway Basin, Victoria
- Technical Report 7 – New palynology results from legacy core and cuttings, Otway Basin, Victoria
- Technical Report 8 – New micropalaeontological results from legacy core, Otway Basin, Victoria
- Technical Report 9 – A preliminary ranking of potential Underground Gas Storage sites, Otway Basin, Victoria

All study results and reports will be made available at [earthresources.vic.gov.au/gasprogram](http://earthresources.vic.gov.au/gasprogram).

## 2. Onshore conventional gas studies

### 2.1 Geoscience studies – Otway Basin

The geoscience studies in the Otway Basin are progressing well. Preliminary results have been delivered on Otway Basin rock characterisation and 3D framework modelling, and work on both is continuing.

Otway Basin legacy rock samples from the Geological Survey of Victoria's Werribee Drill Core Library have been selected and analysed for reservoir, seal and source rocks. In addition, the Geological Survey of Victoria has commissioned new analysis on the age of rock samples from fossils throughout the rock sequence. This is known as biostratigraphy, and it will help geoscientists to interpret, with greater certainty, the time (in millions of years) when rock units were deposited in the Otway Basin. The mineral content in rock samples has also been analysed to understand the characteristics of different sedimentary rock types and the minerals that comprise them. This is especially important in seals where the grain size is too small to see without a microscope. Chemostratigraphy, the last of the rock characterisation projects, is nearing completion. This specialist technique uses the chemical and mineral composition of rock samples to distinguish between rocks and to correlate across rock units between geographic locations.

Legacy data and new information acquired during the Victorian Gas Program have been used to compile preliminary maps of source, seal and reservoir units. These datasets are being synthesised and refined to create a map of prospective areas in the Otway Basin. The map, together with the petroleum systems modelling, will be used to help estimate Victoria's undiscovered conventional gas potential.

Most of the Otway Basin work discussed in the following sections focuses on the Otway and Sherbrook groups (see Figure 2.1). However, other studies such as 3D modelling and biostratigraphy are focused on mapping and/or studying all the rock units in the basin (see Figure 2.1). A summary geological history of the Otway Basin, including descriptions of the geological units that are the focus of the studies to date, is included as Appendix 2 of Progress Report 2 (DJPR, 2019).

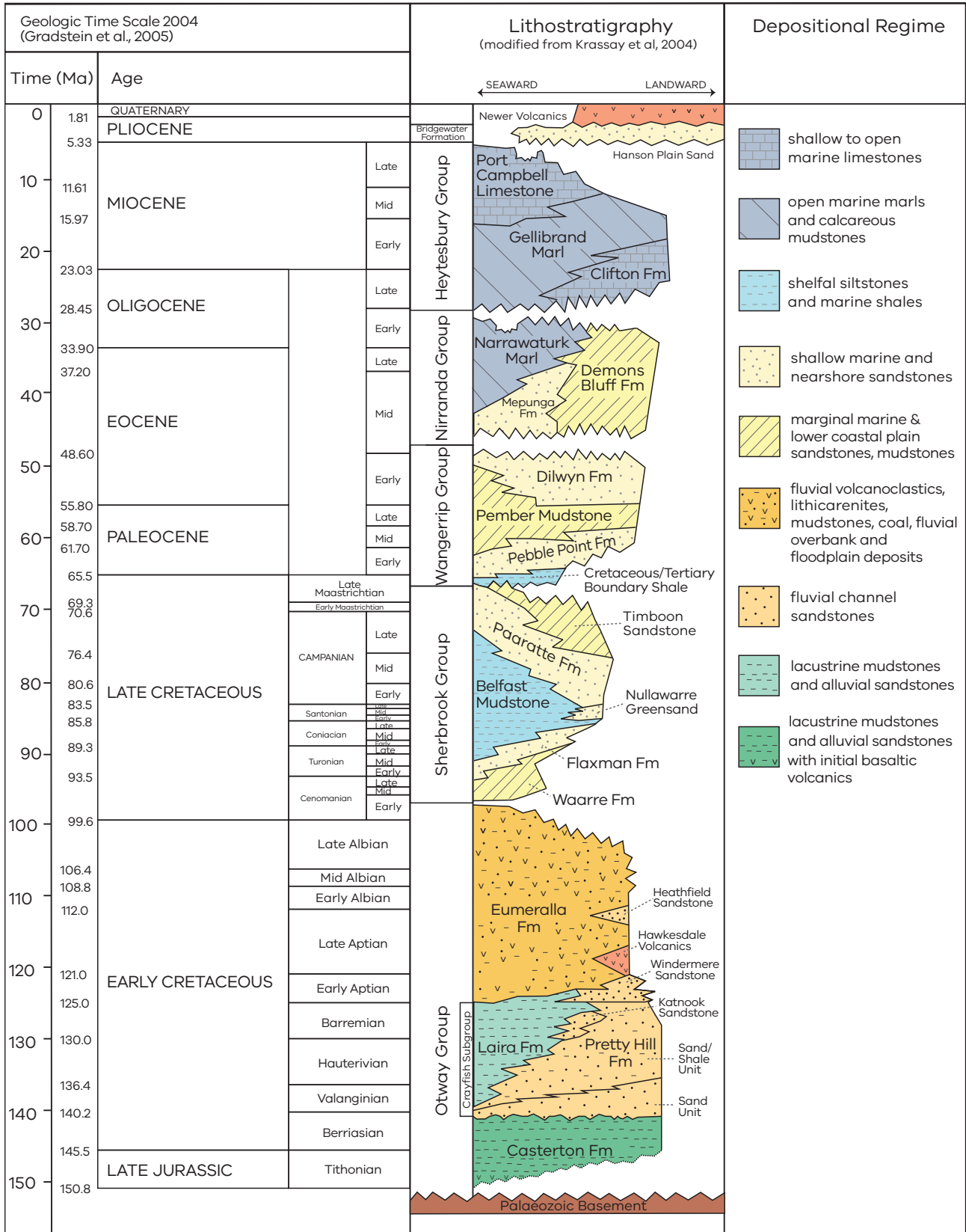


Figure 2.1 Otway Basin stratigraphy

## 2.1.1 Rock characterisation progress

The rock characterisation studies are nearing completion with 7172 rock samples analysed in total, including new measurements of:

- porosity and permeability (363)
- seal capacity (79)
- mineral analysis (180)
- source rock geochemistry (979)
- vitrinite reflectance (192)
- palynology and micropaleontology (1060)
- chemostratigraphy (4319).

The Victorian Gas Program technical reports that have been published so far have focused on the new data acquired from analysis of core and cuttings samples from Geological Survey of Victoria's Werribee Drill Core Library. Analyses of new porosity and permeability (Whittam et al., 2019), and seal capacity measurements (Goldie Divko & Karolia, 2019), along with analyses of rock mineralogies (Power & Goldie Divko, 2019) and source rock geochemistry (Revie, 2019 and Revie et al., 2019) have already been released. The Geological Survey of Victoria continues to integrate the data from these analyses to inform its interpretations.

Biostratigraphy analysis of 1060 samples has been completed (Charles et al., 2019 and Gallagher & Stanislaus, 2019) and a chemostratigraphy analysis is nearing completion. The new data from all these studies continues to provide new insights that will be presented in Victorian Gas Program technical reports.

Preliminary results for porosity and permeability, seal capacity and source rock measurements were summarised in Victorian Gas Program Progress Report 2 (DJPR, 2019). A summary of the work undertaken to date on mineral analysis, biostratigraphy and chemostratigraphy is presented in the following sections.

### 2.1.1.1 Mineral analysis

New mineral analysis was undertaken on selected legacy core and cuttings samples, and three surface samples from 21 sedimentary geological formations in the Victorian onshore Otway Basin. The aim was to improve the understanding of the contribution of different mineral suites and textures to variations in reservoir and sealing lithologies.

The analysis was carried out using two specialist analytical techniques: QEMSCAN (Quantitative Evaluation of Materials by Scanning Electron Microscopy) and XRD (X-Ray Diffraction) analysis. QEMSCAN is an automated mineral analysis system that provides rapid, statistically reliable, repeatable mineralogical and compositional data from any chemically distinct inorganic sample, such as a rock sample.

The analysis involved 180 rock core and cuttings samples, which were from 58 legacy petroleum wells and boreholes from the Geological Survey of Victoria's Werribee Drill Core Library, and three samples from surface locations. Samples were taken from most sedimentary units in the Victorian Otway Basin including the Casterton Formation, Pretty Hill Formation, Laira Formation, Eumeralla Formation, Heathfield Sandstone, Waarre Formation, Flaxman Formation, Belfast Mudstone, Nullawarre Greensand, Skull Creek Mudstone, Paaratte Formation, Timboon Sandstone, Pebble Point Formation, Pember Mudstone, Dilwyn Formation, Mepunga Formation, Narraturk Marl, Clifton Formation, Gellibrand Marl, Port Campbell Limestone and Bridgewater Formation.

As a result of the analysis, the samples were grouped into three broad lithologies (rock categories): sandstones, siltstones/mudstones and carbonates. These were further categorised into 30 lithotypes. The results were checked against the rock unit to which the specimen was attributed when it was sampled, and a provisional identification of each sample was determined. The bulk mineralogical compositions by mass percent are summarised for each of the three lithological categories in Figures 2.2, 2.3 and 2.4. Refer to Power & Goldie Divko (2019) for full analytical results.

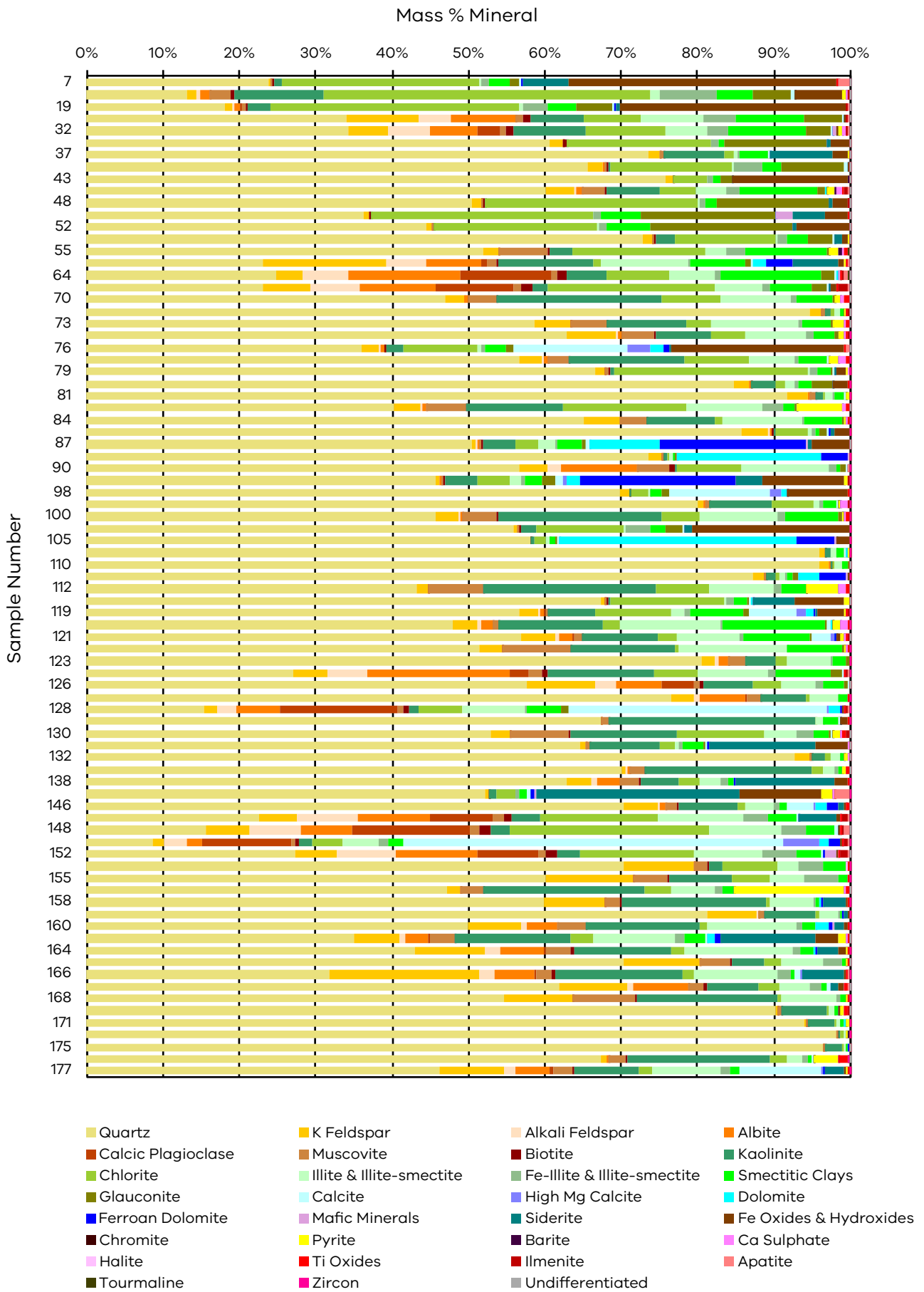


Figure 2.2 QEMSCAN bulk mineralogy versus sample number for sandstones.

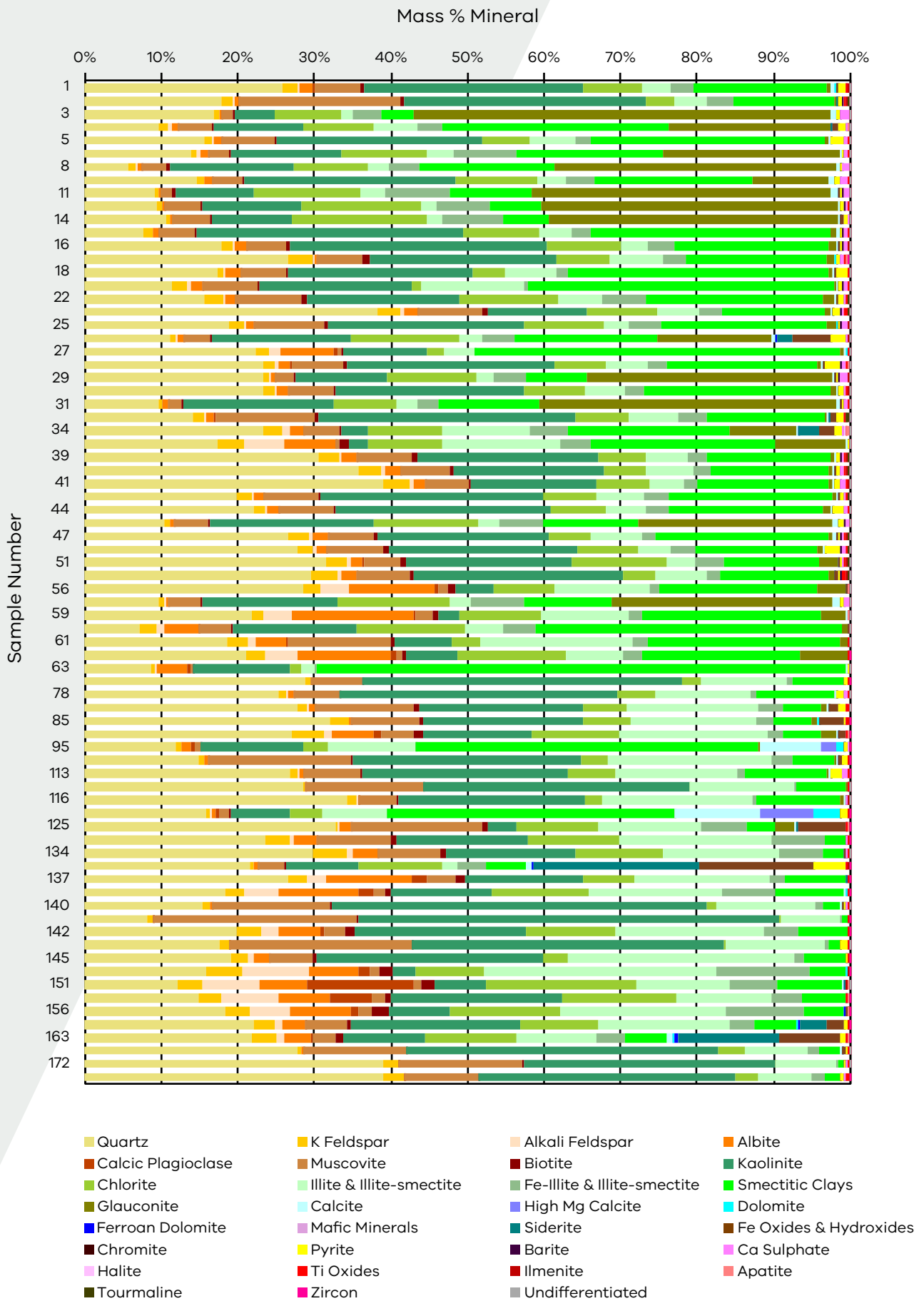


Figure 2.3 QEMSCAN bulk mineralogy versus sample number for siltstones and mudstones.



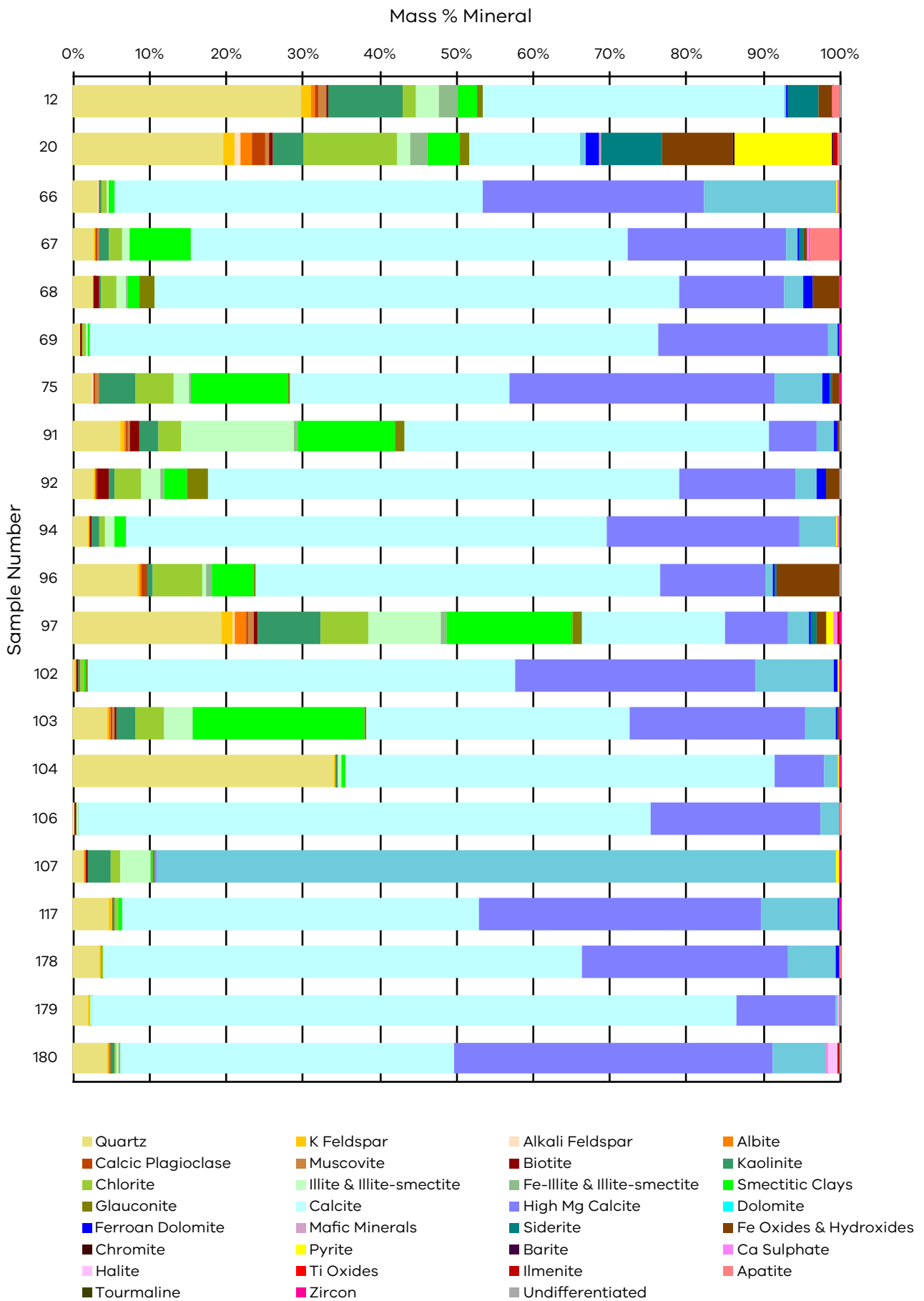
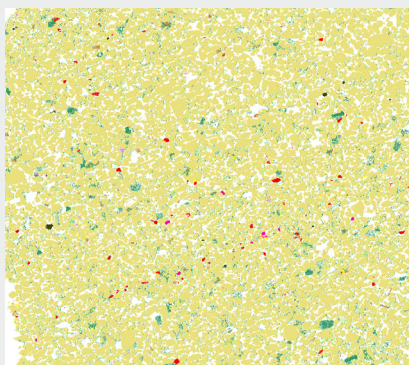
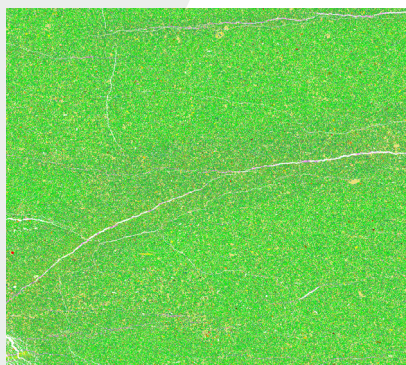


Figure 2.4 QEMSCAN bulk mineralogy versus sample number for carbonates.

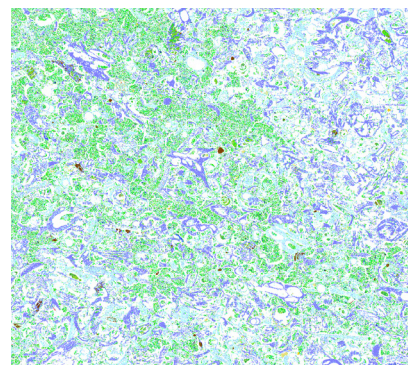
The mineral composition was identified for each of the 180 samples, and a mineral map was produced by scanning each rock sample. Three examples of mineral maps are provided in Figure 2.5. Two noticeable features are the difference in colours in each mineral map depicting the presence of different minerals, and the white gaps that are present between the coloured patches (this is porosity – a gap in the rock where fluids can reside).



Iona Obs-1 Waarre Formation



Flaxmans-1 Belfast Mudstone



Ardonachie-1 Port Campbell Limestone

**Figure 2.5 QEMSCAN mineral map examples from the Waarre Formation, Belfast Mudstone and Port Campbell Limestone.**

In Figure 2.5, the mineral map on the left is a sample from the Waarre Formation, the primary reservoir unit in the Port Campbell Embayment where gas has been discovered and produced in the past. The yellow grains that comprise most of the map represent quartz. The rock is a sandstone and it has a relatively high number of white gaps (porosity), which is an important characteristic of a good reservoir rock. The same is true for an aquifer, an example of which is provided in the mineral map on the right of Figure 2.5 (Port Campbell Limestone). The blue grains represent limestone and, again, white gaps are the pores available to store fluids, and in this case, groundwater. The image in the middle is different from the other two as it has very little porosity and the minerals are clays. The fine grain size, mineral composition and lack of porosity in this sample of Belfast Mudstone indicates that it is likely to be a good seal rock.

These new mineral analyses are being integrated with existing data and other new program datasets to provide a better understanding about the genesis and diagenesis (how the rocks were made and how they have changed over time) of the Otway Basin stratigraphic sequence. Some mineral groupings may inform provenance (where the grains that make up the rocks came from), while the identification of mineralogy, textures and cements will help determine sedimentary facies.

### 2.1.1.2 Biostratigraphy

Over geological time, living organisms such as plants and animals have evolved, diversified and adapted, and some have become extinct. When these organisms die, some of their remains are fossilised. Scientists who study spores and pollens (known as palynologists) and others who study microscopic creatures such as foraminifera (micropalaeontologists), can extract these remains from rocks and analyse them. They can determine the age of a rock and the environment the organisms lived in from their study of the fossils. This is useful to geologists as a robust biostratigraphic framework helps to correlate between underground rock layers and understand ancient depositional environments. These contribute to regional geological knowledge, allowing more confident assessments of the hydrocarbon prospectivity of the Otway Basin.

A major review of the biostratigraphy of the onshore Otway Basin included reviewing legacy data from 246 onshore Otway Basin wells and boreholes and 1060 new biostratigraphic analyses from 121 onshore Otway Basin boreholes. The study utilised both palynological (fossilised spores, pollen and organic-walled microplankton) and micropalaeontological (fossilised foraminifera) data, as these complementary approaches provide higher resolution correlations when combined. They often also work better in differing rock types (mud/siltstones versus carbonates), thus allowing a more complete understanding of the stratigraphy. The final study included new analyses on 748 palynology samples (115 wells) and 312 micropalaeontological samples (24 wells).

This study was only possible due to the large number of legacy core samples available at the Geological Survey of Victoria's drill core library and represents one of the most comprehensive, basin-scale biostratigraphic projects in Australia. The final datasets include all the available palynological and micropalaeontological data (both the new and fully reviewed legacy data) for the onshore Otway Basin.

Initially, all the available palynological and micropalaeontological data from the onshore Otway Basin wells (246 wells) was compiled into a single, coherent dataset. The data was captured in a uniform tabulated format that allowed simple upload to databases and geological correlation packages. The biozonal (intervals characterised by different fossil taxa) information was also standardised to the latest agreed schema, thus aiding consistent correlation and geological interpretations.

Following this phase of data gathering and review, major stratigraphic data gaps were infilled, and existing correlation issues were addressed. Another aim of the sampling was to provide strong geographic and stratigraphic coverage across the entire onshore Otway Basin. The final sampling list was confirmed by the Geological Survey of Victoria prior to instigating this second phase of the project.

Refer to Charles et al. (2019) and Gallagher & Stanislaus (2019) for full analytical results.

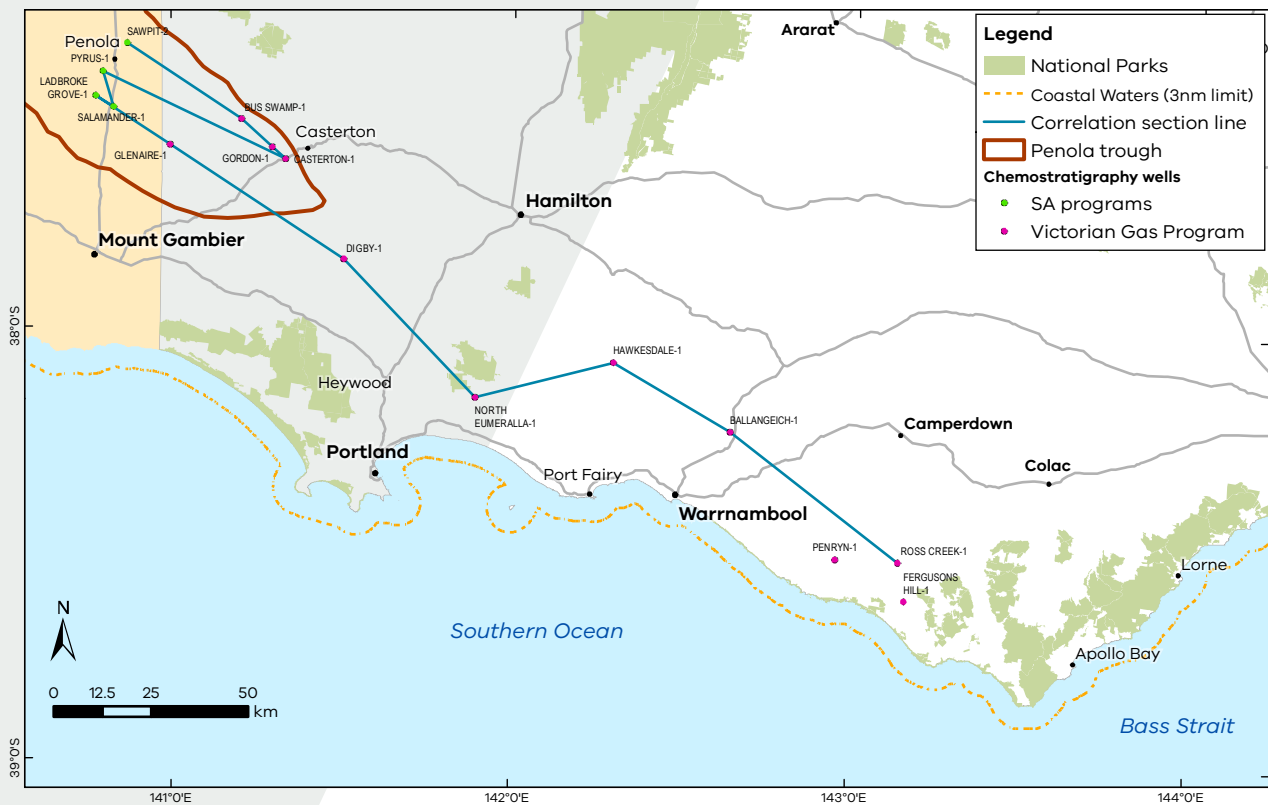
### **2.1.1.3 Chemostratigraphy**

Chemostratigraphy is the study of rock units whereby chemical and mineral composition is used to distinguish rocks and to correlate across rock units between geographic locations. Chemostratigraphy is a highly specialised technique that is not used routinely; however, it can uncover geochemical differences within apparently uniform rock units. This is useful when other geological datasets do not provide enough differentiation to inform a more advanced interpretation. This technique was used with success to correlate between petroleum wells in the South Australian section of the Otway Basin to define previously ambiguous lithostratigraphy in a geological area known as the Penola Trough.

The largest and most comprehensive basin-scale chemostratigraphic correlation study in Australian history is taking place in the Otway Basin as part of the Victorian Gas Program. The main objective is to geochemically characterise rock samples from 11 legacy petroleum wells and one side-tracked well from the Victorian Otway Basin.

The results are enabling the Geological Survey of Victoria to build a chemostratigraphic zonation and correlation between the 11 wells based on the new data, and compare the results to the established lithostratigraphy, correlating the Victorian Otway Basin stratigraphy across the border to the South Australian wells where producing petroleum fields are located. The study also aims to discover new information on reservoir quality, seal and source rocks intersected by these wells, along with new insights into mineralogy, lithology, weathering and provenance.

Chemostratigraphy data has previously been acquired from South Australian wells Sawpit-2, Pyrus-1, Salamander-1 and Ladbroke Grove-1. These wells have chemostratigraphic definitions through the Otway Group in the Penola Trough, providing a framework for the correlation of the Victorian section of the Penola Trough (Figure 2.6).



**Figure 2.6 Otway Basin well locations used in the chemostratigraphy study. The Crayfish Subgroup correlation line shown in blue.**

A total of 4319 rock cuttings samples were taken from the Geological Survey of Victoria’s Werribee drill core library from the 11 wells and one side-track well:

- Bus Swamp-1 (302 samples)
- Gordon-1 (383 samples)
- Casterton-1 (495 samples)
- Glenaire-1 (442 samples)
- Glenaire1-ST1 (131 samples)
- Digby-1 (333 samples)
- North Eumeralla-1 (383 samples)
- Hawkesdale-1 (360 samples)
- Ballangeich-1 (157 samples)
- Penryn-1 (242 samples)
- Fergusons Hill-1 (491 samples)
- Ross Creek-1 (600 samples).

These wells were chosen based on intersections of key stratigraphy related to petroleum geology.

Chemostratigraphy uses a group of specialist techniques known as Inductively Coupled Plasma-Optical Emission Spectrometry-Mass Spectrometry (ICP-OES-MS). For each of the 4319 rock samples submitted to the laboratory, the abundance of 50 separate chemical elements was determined. This new data was then analysed and interpreted to identify chemically distinct packages that can be correlated between the wells. The chemostratigraphic correlation between the South Australian wells and the Victorian wells in the Penola Trough was established with a high level of confidence. This substantially improves the understanding of the stratigraphy in the Crayfish Subgroup in the Victorian Otway Basin.

The geological units in the study wells were divided into seven sedimentary sequences and one basement sequence. The sedimentary sequences were further separated into 37 chemically distinct packages. The zonation of these packages is based upon changes in elemental ratios in the rocks.

Results to date include the:

- identification of distinctive elemental concentrations within the Casterton Formation
- division of the Crayfish Subgroup in the Victorian Penola Trough to correlate with established stratigraphy in the South Australian Penola Trough and recognition of erosional surfaces within the Pretty Hill Formation
- mineral trends within the Eumeralla Formation, with an increasing abundance of quartz upwards through the section in both wells and notable quartz-rich units occurring throughout the formation.

Distinctive trends in element concentrations are now being established within sequence and package level zonations throughout the stratigraphy.

The study is in the interpretation phase, with all laboratory analysis complete and the preliminary findings now being refined. A technical report is being prepared, detailing results and correlations across all 11 Victorian wells and incorporating the legacy work on four wells in the South Australian Otway Basin in the Penola Trough. The findings and analytical data will be released at the conclusion of the study.

## 2.1.2 Modelling progress

Victorian Gas Program geoscientists and independent reviewers are now reviewing the preliminary interpretation of the surfaces of the rock layers that make up the 3D geological framework model for the Otway Basin. In addition, a report on the process of building the framework models is under review and being refined.

The Otway Basin petroleum systems model continues to be built with all available new and existing data and interpretations being combined to help estimate undiscovered gas resources. The modelling work completed to date underwent independent peer review in June 2019.

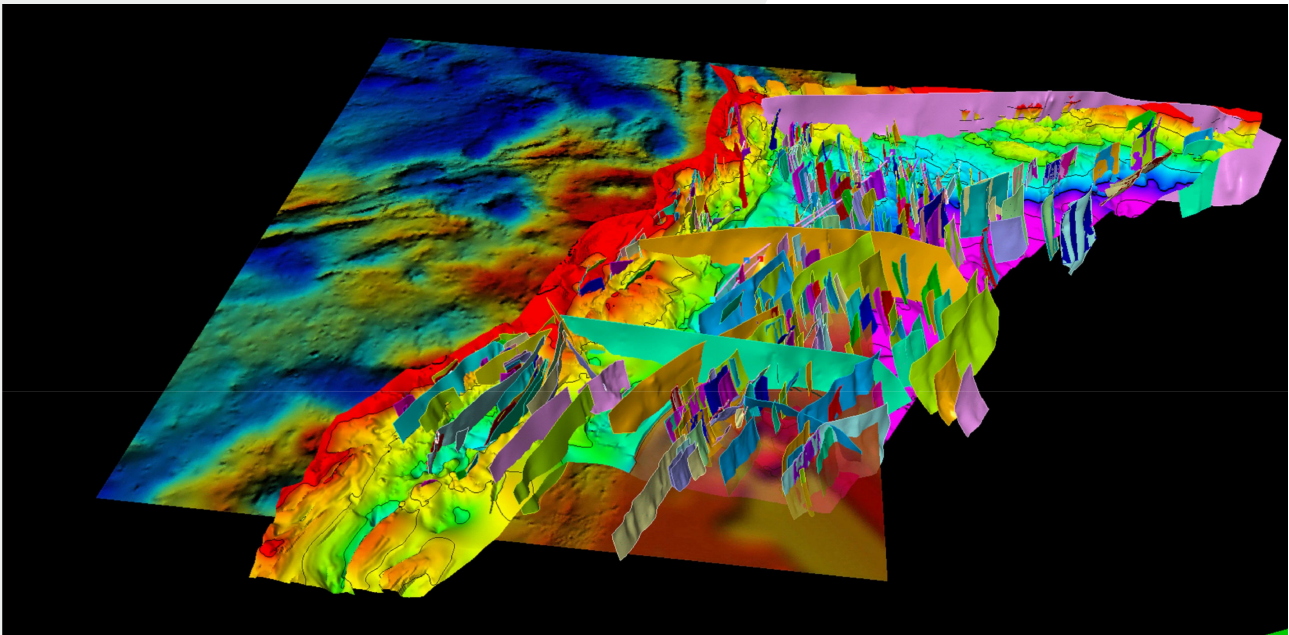
### 2.1.2.1 Regional 3D geological framework models

The Geological Survey of Victoria commissioned the construction of 3D geological framework models of the Otway Basin. These included a regional 3D model of the Victorian Otway Basin, and a more detailed 3D model of the Port Campbell Embayment and Shipwreck Trough. Both elements are inputs for petroleum systems and hydrogeological modelling.

Preliminary interpretation of seismic and well data was completed in June 2018, and review and refinement of the velocity model and interpretations are nearing completion. This will ensure that fit-for-purpose products inform subsequent modelling and the Geological Survey of Victoria's prospectivity assessment and resource estimate.

Seismic interpretation was undertaken using two-dimensional (2D) and 3D seismic data that has been acquired by industry over the past 50 years and is publicly available in the Geological Survey of Victoria's archives ([earthresources.efirst.com.au](http://earthresources.efirst.com.au)). Nine regional horizons were mapped across approximately 15,000 kilometres of 2D seismic lines and 4000 square kilometres of 3D seismic data. More than 150 wells and boreholes across the Otway Basin were included for interpretation.

The regional model extends the existing regional-scale onshore model and incorporates nearshore/offshore and onshore geological interpretation of the entire Victorian Otway Basin sedimentary sequence (such as Figure 2.7). The sequence includes the top of the Palaeozoic basement to the bathymetric surface/present-day land surface and all mappable sedimentary units in the basin.



**Figure 2.7** A screen capture of the 3D model showing initial integration and modelling of faults and the basement surface with a shaded gravity grid beneath.

### 2.1.2.2 Petroleum systems modelling

Petroleum systems modelling can be used to understand whether petroleum (for example, gas) is present and how much might exist in prospective rocks. Geological, geophysical and engineering data is used to create 3D models of the subsurface that incorporate the history of a sedimentary basin, including the processes and components necessary to form petroleum. Components include a source rock, reservoir, trapping mechanism, seal, and the appropriate relative timing of formation of these (Schlumberger, 2019).

The petroleum systems modelling for the Otway Basin combines new and existing data and interpretations, including seismic and structural interpretations from the 3D framework modelling and rock characterisation studies, including geochemistry, seal capacity and biostratigraphy. Existing data includes well, temperature and pressure data publicly available from company well completion reports, along with historical geological assessments to characterise present-day conditions of the basin. This data helps determine the depositional history of the basin and hydrocarbon generation, and movement and preservation throughout geological time.

To date, data from 274 wells has been collated and reviewed, with lithologies and petrophysical properties interpreted from wireline log data for each well and calibrated using data from new and existing core analysis. New palynology and micropalaeontology data from the biostratigraphy study has been incorporated, along with new formation tops (tops of rock layers) informed by new Geological Survey of Victoria interpretations from the chemostratigraphy study.

## 2.1.3 Prospectivity assessment

A prospectivity assessment of a resource such as gas is a qualitative or quantitative evaluation. For gas, a prospective resource is defined as one that is potentially recoverable from undiscovered accumulations. So, for a given a geographic area with some information available about its geology and previously encountered hydrocarbons, a prospectivity assessment seeks to answer two questions: (1) what is the likelihood of finding more hydrocarbons? and (2) in which locations is there a higher probability of finding hydrocarbons?

The aim of the prospectivity assessment is to integrate all available evidence, including legacy data, new data acquired, and interpretations arising from the technical studies. This will help identify which geographic areas in the Otway and Gippsland basins (within Victoria's jurisdiction – onshore and nearshore) are more likely or less likely to host gas that has not yet been discovered.

For the Otway Basin, this process has involved compilation of data to produce a series of maps that categorise conventional gas prospectivity across the basin. The main objective of the prospectivity assessment is to produce a map that shows how resource prospectivity changes across the region to the margin of that area (that is, to the point at where there is no prospectivity). To begin the prospectivity assessment, Geological Survey of Victoria geoscientists have compiled source, seal, reservoir and trap data in a specialist Geographic Information System (GIS) package. This task will be completed for a minimum of four potential plays across the Otway Basin, with additional plays included if the data provides evidence to indicate that is appropriate.

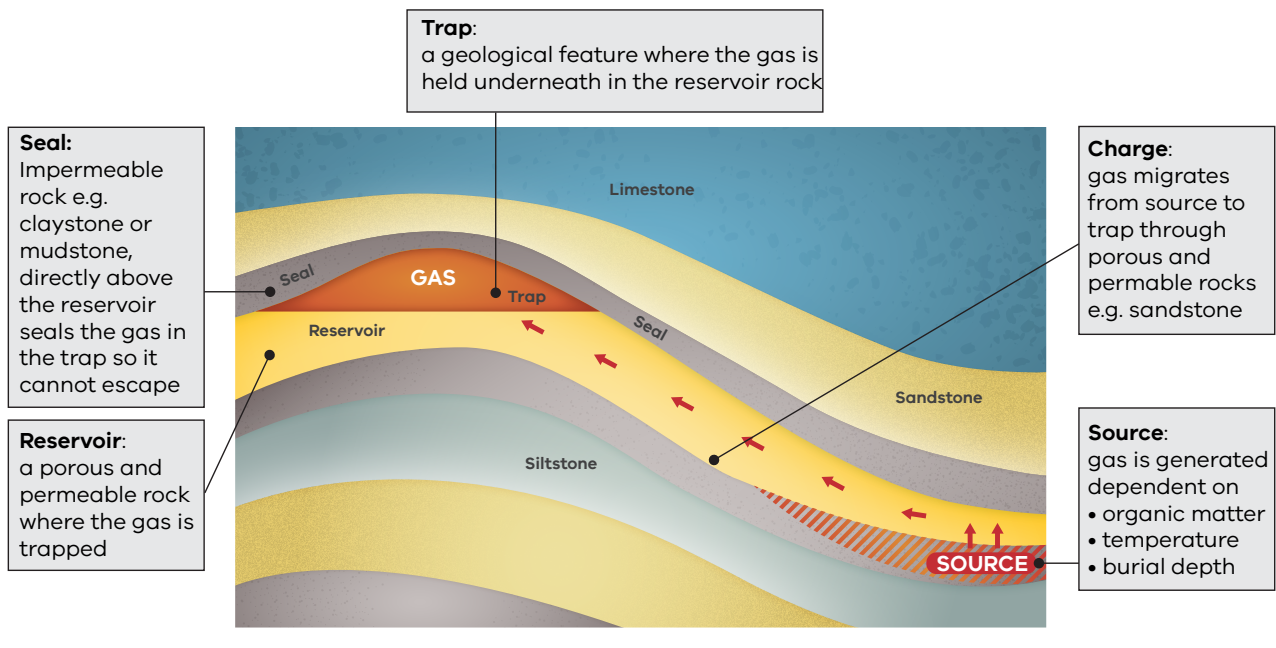
### 2.1.3.1 Play elements

When geoscientists are exploring for hydrocarbons, they use the term ‘play’ to refer collectively to the specific components that together make up a petroleum system: source, reservoir and seal rocks that have been identified previously through exploration and studies and are unique to the geographic location. While there are several interpretations as to what constitutes a play, for the purposes of this investigation a play is defined as a family of undrilled prospects and discovered pools of petroleum that are considered to share a common gross reservoir, top-seal and petroleum charge system (Allen & Allen, 2013).

To recap from previous Victorian Gas Program Progress Reports, petroleum system or play elements are illustrated in Figure 2.8 and defined as:

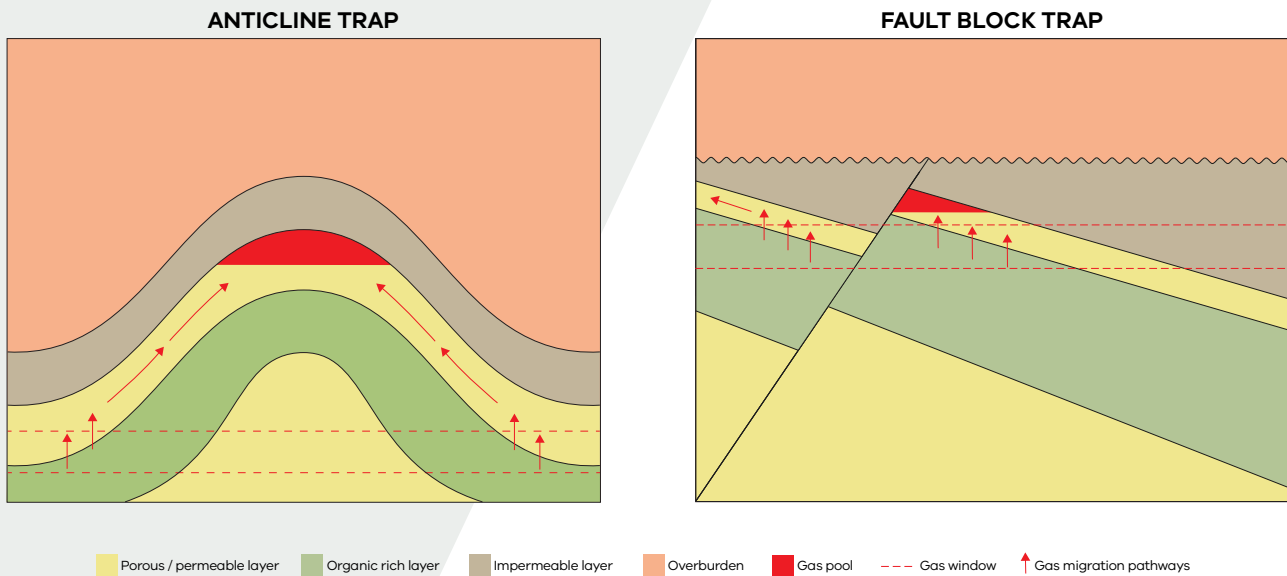
- A mature source rock is rich in organic matter, and if heated sufficiently and placed under sufficient pressure, will generate oil and/or gas.
- Reservoirs are rocks that are porous and permeable and may hold or allow migration of hydrocarbons within the pore spaces in the rock.
- Seals are impermeable rock that form a barrier or cap above reservoir rocks so that fluids cannot migrate beyond the reservoir.
- A trap is any barrier to the upward movement of oil or gas, allowing either or both to accumulate.
- Charge refers to the migration and timing of hydrocarbons into a trap.

Conventional gas reservoirs are commonly found in porous and permeable rocks such as sandstones. Impermeable rocks such as claystones or shales found directly above gas reservoirs are known as a seal or cap-rock. In conventional accumulations, gas is trapped in the reservoir under the seal, in discrete geological structures. Geological structures can be like an inverted dish, with the gas trapped beneath.



**Figure 2.8 A schematic showing play (source, reservoir and seal) and prospect (trap and charge) elements.**

Gas is generated from a source rock that has a relatively high content of organic matter. Generation depends on a number of variables, such as temperature and burial depth. The gas then migrates from the source via porous and permeable rocks or other conduits such as faults. The gas accumulates or is trapped in a reservoir. Overlying sealing rocks prevent the gas from migrating further. The gas is commonly trapped under geological structures such as those illustrated in Figure 2.9.



**Figure 2.9 Schematic diagram of two types of common hydrocarbon traps.**

The basic unit of prospectivity mapping is the play fairway. A play fairway is the geographic area over which a particular play is considered to extend, and although primarily constrained by the depositional or erosional limits of the reservoir unit, the fairway may be limited by the known absence of other factors (for example, seal or source).

Previous evaluations of the petroleum potential of the Otway Basin (for example, O'Brien et al, 2009) addressed source rock distribution and maturity in some detail but were less exhaustive in their evaluation of other critical play elements, so the extent of the associated play fairways is poorly understood. Play mapping (Table 2.1), with its focus on the distribution and effectiveness of potential reservoir rocks and their associated sealing units, complements petroleum systems analysis which primarily evaluates hydrocarbon charge.

A summary map is constructed for each play element based on lithofacies mapping in the case of reservoir and seal, or petroleum systems analysis for hydrocarbon charge.

**Table 2.1 Mapping play elements.**

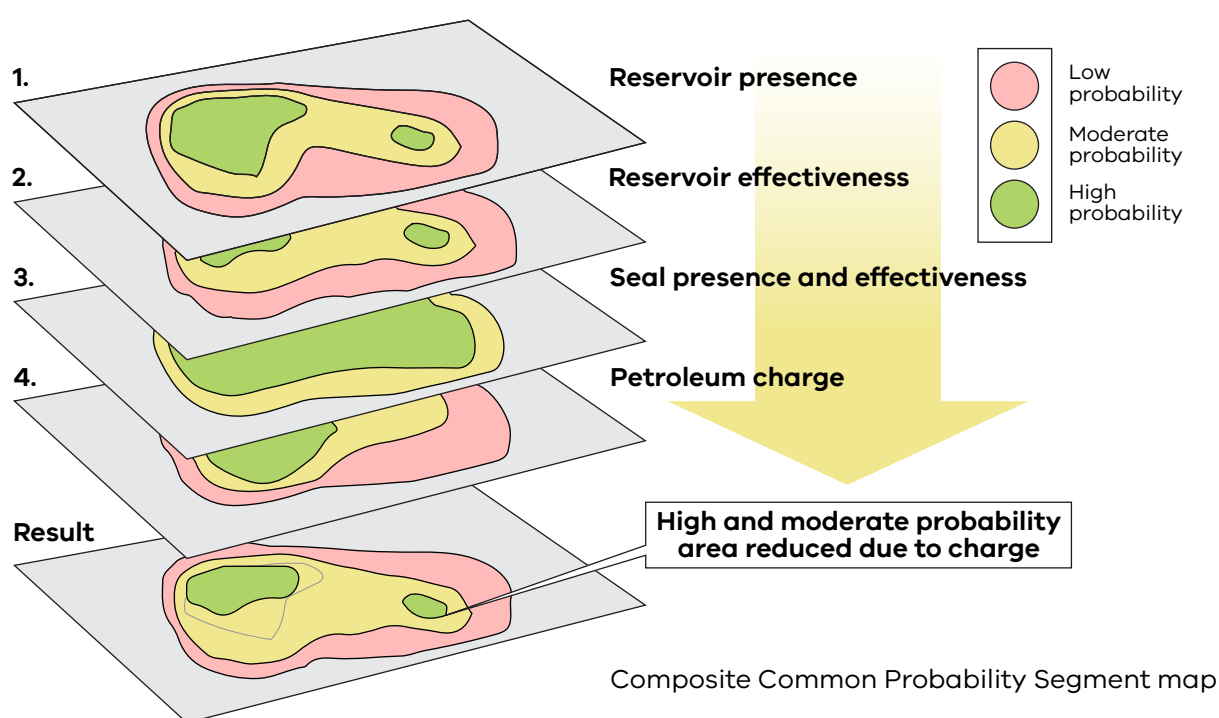
Summary map	Play element
Thickness and depositional/erosional limits of the reservoir unit	Reservoir presence
Distribution of reservoir facies (or porosity/permeability) within the gross reservoir unit	Reservoir effectiveness
Area where mature source rock is present (active source pod or kitchen)	Source presence
Area of migration linked to the active source pod	Source effectiveness
Thickness and depositional/erosional limits of the seal unit(s) – top, base, lateral/cross-fault	Seal presence
Lithofacies distribution within the identified seal(s)	Trap/seal effectiveness
Gross structural trends – major faults and anticlines	Trap presence and seal effectiveness and hydrocarbon migration

A commonly used approach to play element mapping is known as ‘traffic light mapping’ because, in its simplest form, the uncertainty in the geographic extent of the play element being mapped is colour-coded as follows: green (play element is known to be present), red (play element is likely to be absent) or yellow/amber (play element may be present).



A more sophisticated approach assigns a probability that the play element is present in each area (or segment), often with a range of probabilities being apportioned to the geographic areas with the greatest uncertainty (the yellow/amber traffic light). The resulting maps are referred to as common probability segment maps. When combined with an estimate of the resource potential of each play, the prospectivity of both individual plays and sub-areas within a specific play fairway can be ranked on a quantitative basis.

The limits of the play fairway are determined by overlaying the play element maps – the ‘map stack’ (Figure 2.10), to identify areas where all play elements are present (very high probability that hydrocarbons will be present), areas where one or more play elements are absent (high probability that hydrocarbons have not been trapped which increases as more play elements are interpreted to be missing), and areas where there is lower confidence that all play elements are present. A distinct advantage of play element mapping is that areas with a higher probability of gas charge can be identified and the definition of the play fairway tailored to gas potential (as opposed to oil).



**Figure 2.10** Schematic showing a map stack where the play elements are overlaying (modified from Longley & Brown, 2016).

### 2.1.3.2 Port Campbell Embayment

The Geological Survey of Victoria reviewed the scientific literature and carried out new work to identify prospective plays within the stratigraphic succession of the Victorian Otway Basin. The play elements – reservoir, source and seal – are now being mapped, along with trap data. The element of charge will be defined and refined as mapping progresses. Some elements are regional in scale, and others are sub-regional or more local. For each play element, the geographic and stratigraphic extent is defined by using GIS software to delineate where play elements are present or absent.

One play being investigated is the Waarre Formation (reservoir), Belfast Mudstone (seal) and Eumeralla Formation (source). The relative stratigraphic position of each play element is illustrated in Figure 2.11.

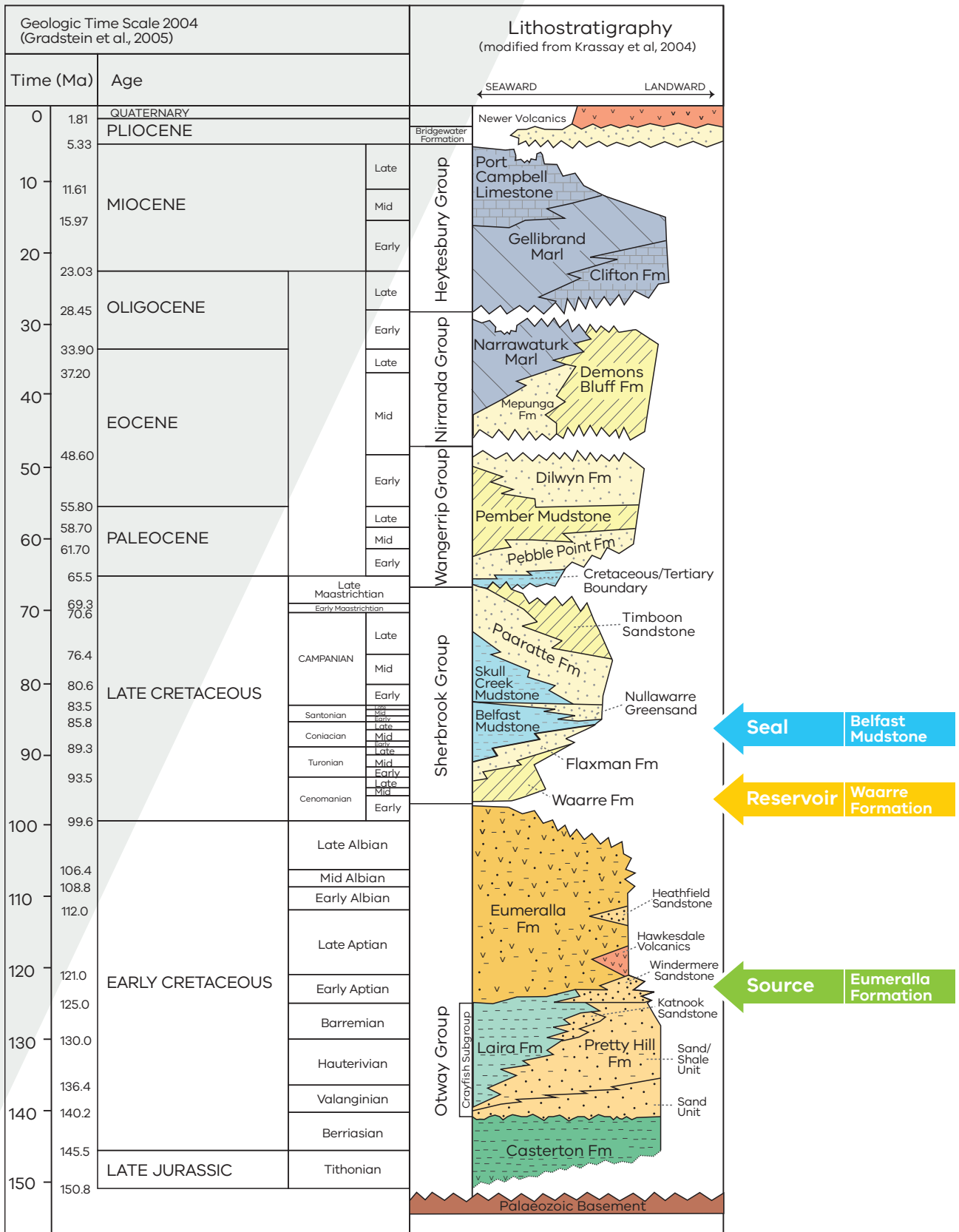


Figure 2.11 Stratigraphic relationship between play elements.

### Reservoir play element – the Waarre Formation

The **Waarre Formation** is a proven gas-bearing sandstone reservoir in the Victorian portion of the Otway Basin and was the primary objective of many of the exploration wells drilled in the vicinity of Port Campbell and adjacent offshore areas. It is the principal reservoir of the Austral-2 Petroleum System (O'Brien et al., 2009). The reservoirs of the Waarre Formation host the gas that is being produced offshore from the Casino, Halladale and Speculant gas fields. These reservoirs are also used for gas storage at the Iona underground gas storage facility.

### Seal play element – the Belfast Mudstone

The **Belfast Mudstone** in the Port Campbell Embayment is a known sealing unit overlying the Waarre Formation reservoir sandstones (for example, O'Brien et al., 2006). It has been intersected in more than 130 petroleum exploration wells and deep boreholes. Preliminary Victorian Gas Program results (Goldie Divko & Karolia, 2019) indicate that the Belfast Mudstone has good seal capacity, increasing with depth, and is capable of holding column heights of gas greater than are trapped.

### Source play element – the Eumeralla Formation

The **Eumeralla Formation** is found across the Otway Basin and outcrops at the surface as the Otway Ranges, Barrabool High and Merino High. It is a proven source rock that is currently generating hydrocarbons and contributing to proven gas fields in the Port Campbell Embayment and Shipwreck Trough (Mehin & Link, 1994; Foster & Hodgson, 1995; Luxton et al., 1995; Boreham et al., 2004).

When data and maps of the play elements (Waarre Formation, Belfast Mudstone and Eumeralla Formation) are entered into the specialist GIS package, a summary 'traffic light' map for each element (reservoir, seal and source) is produced (see Figures 2.12, 2.13 and 2.14). For the play, areas (polygons) of presence/absence/uncertainty have been assigned as previously described.

When the separate play element maps are combined, areas of overlap (or absence) of the critical play elements are derived and the boundaries/geographic extent of the prospective area – the play fairway is determined (Figure 2.15). Refinement of these maps will continue, as anomalies resulting from the process need to be validated (that is, anomalies may not be geological and may be an artefact from the map layering process).

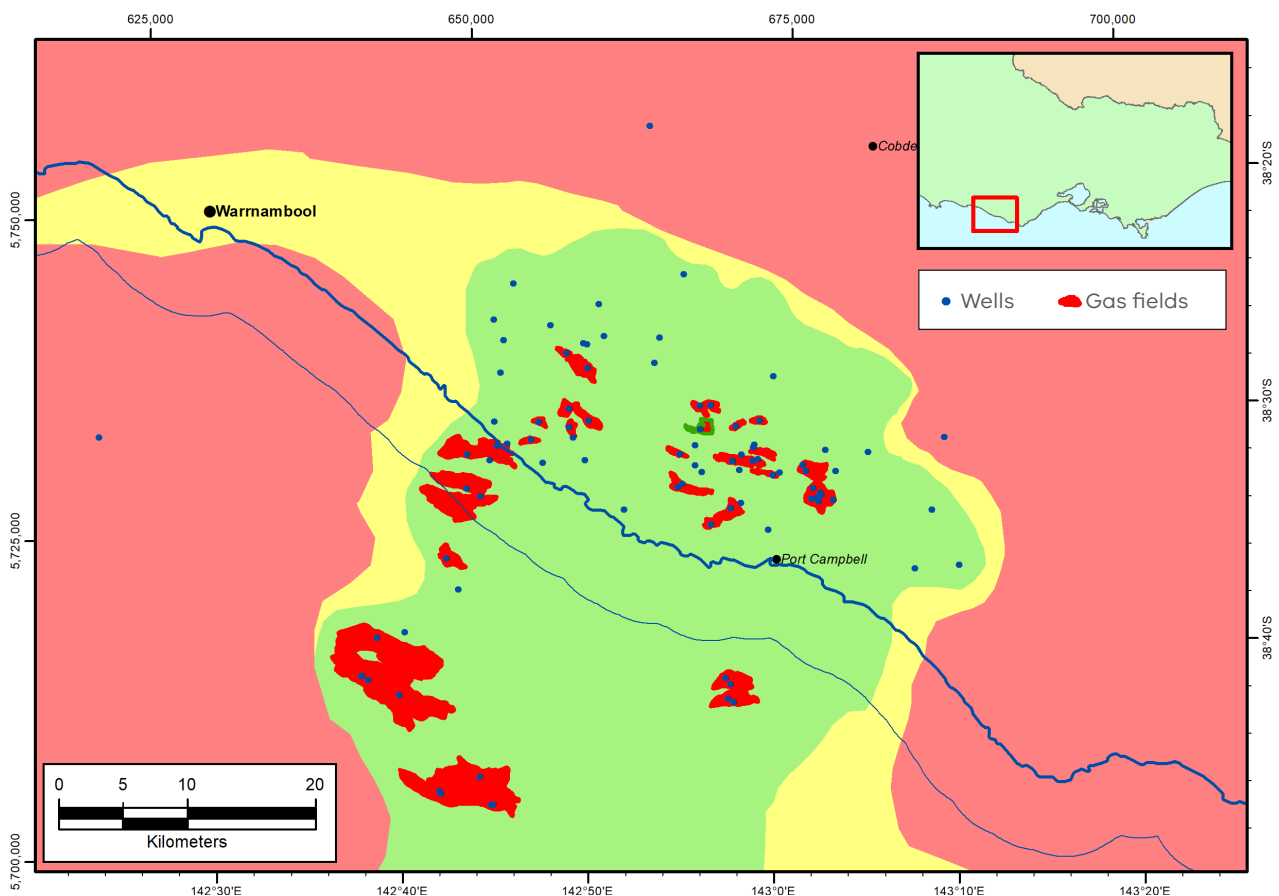


Figure 2.12 Preliminary play element summary for the Waarre Formation reservoir. Areas in green are high probability of reservoir presence, yellow indicates areas of moderate probability of reservoir presence.

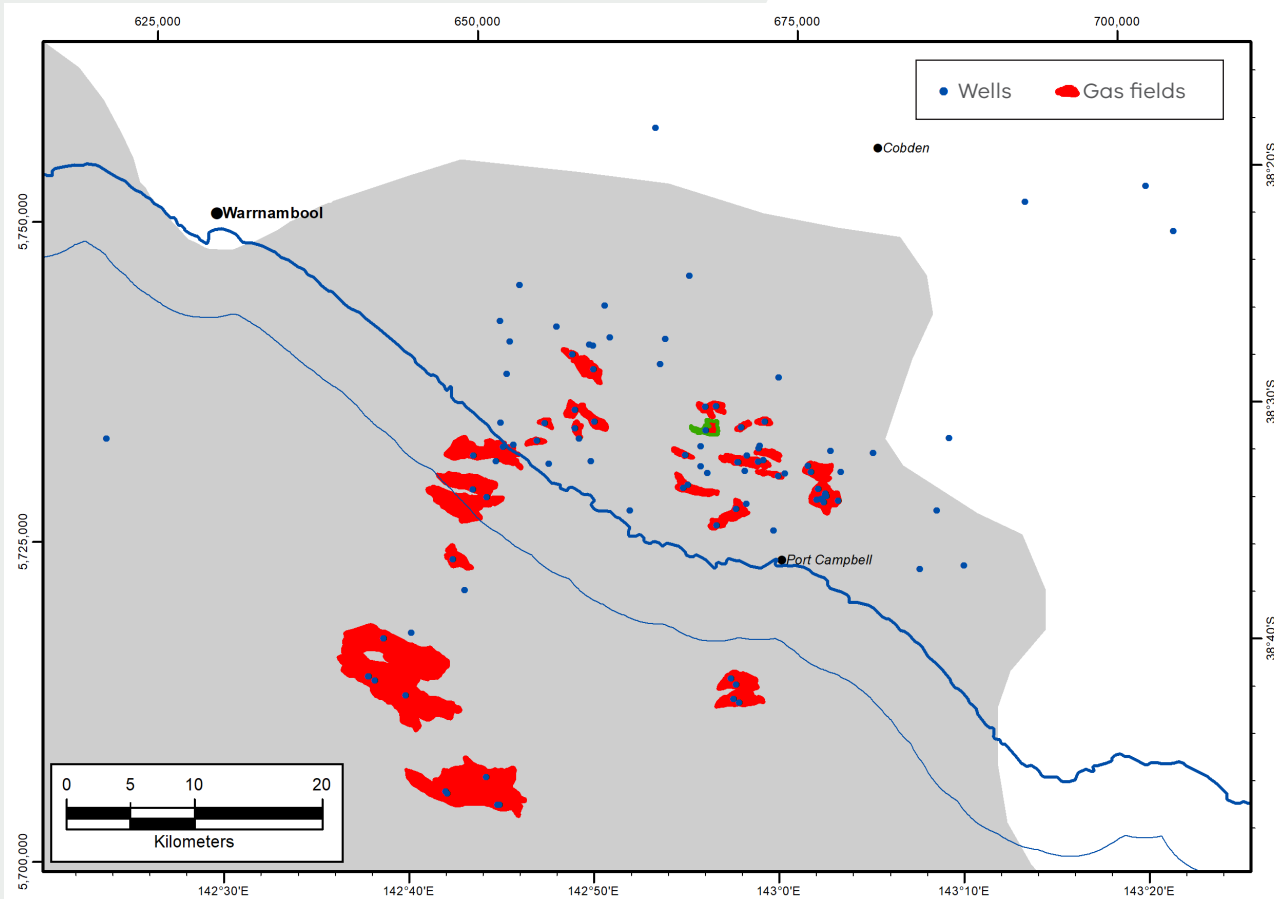


Figure 2.13 Preliminary extent of the Belfast Mudstone seal (in grey).

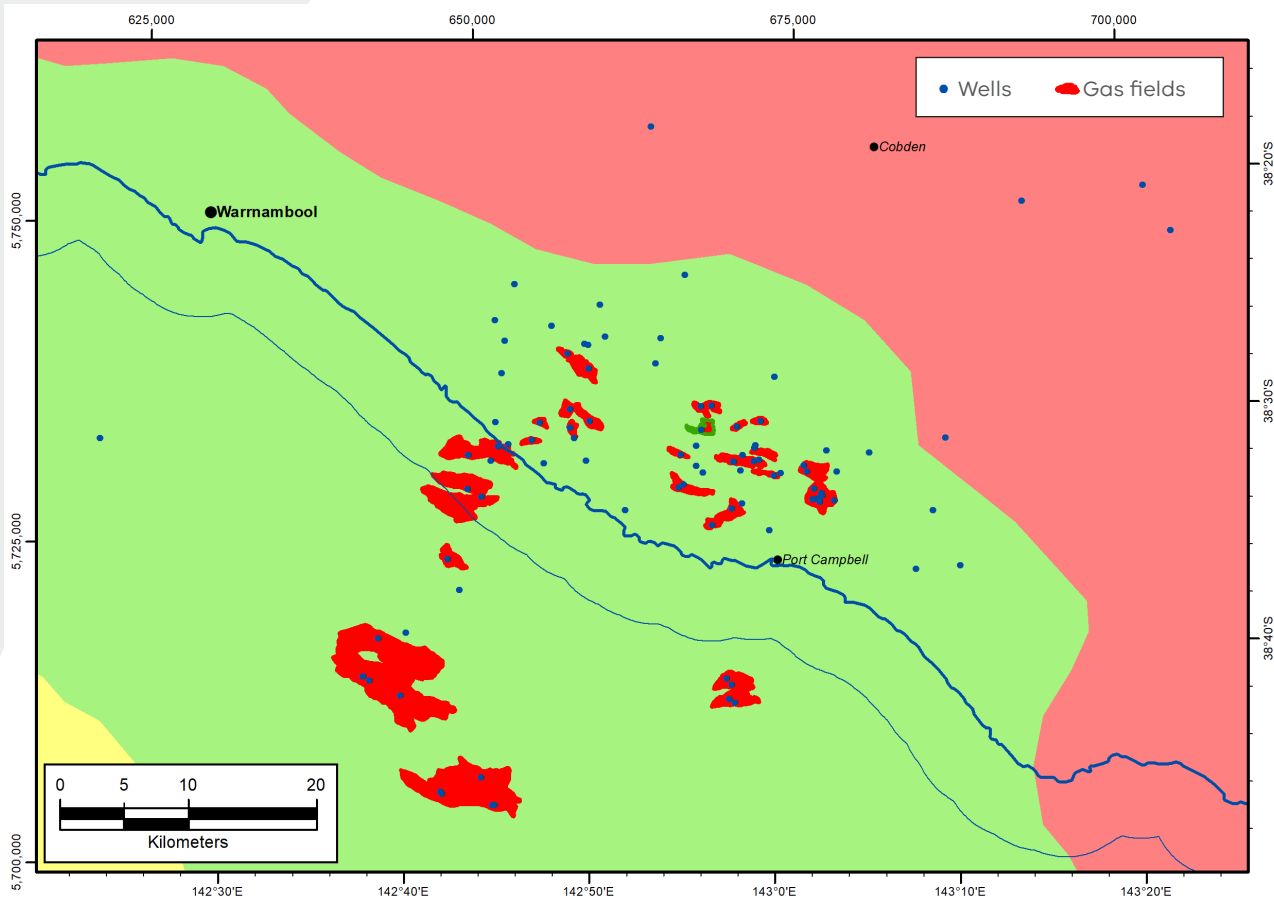
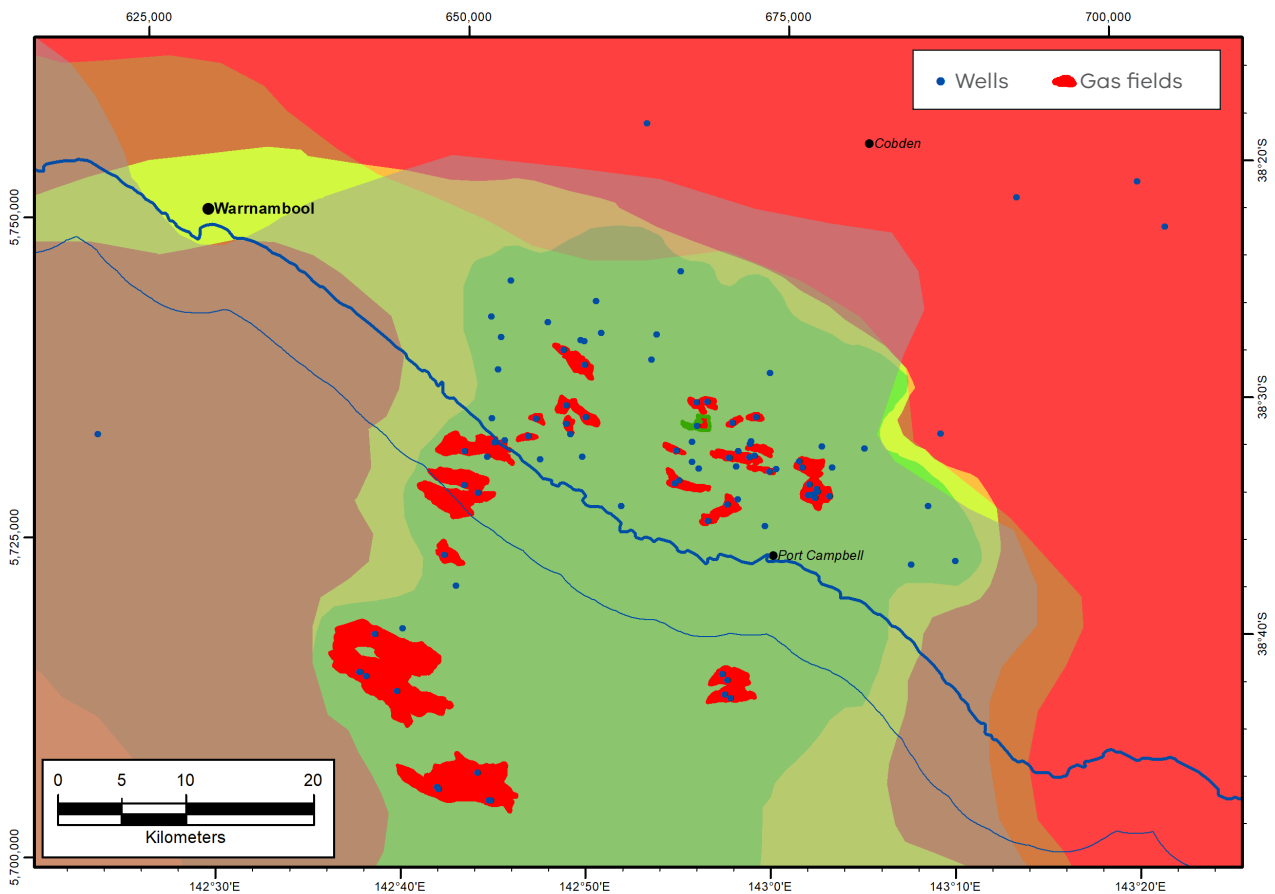


Figure 2.14 Preliminary play element summary for the Eumeralla Formation source. Areas in green are high probability of mature Eumeralla source, yellow indicates areas of moderate probability of mature Eumeralla source.



**Figure 2.15 Preliminary composite play element summary for the Waarre Formation, Belfast Mudstone and Eumeralla Formation combined. Areas in green and yellow indicate where there is a high and moderate probability, respectively, of the Waarre play being present.**

### 2.1.3.3 Preliminary prospectivity assessment

Play mapping has focused on prospective reservoir-seal pairs in the Late Jurassic to Cretaceous aged Otway and Sherbrook groups (see Figure 2.11), with work being prioritised on those plays which have already been proved by the successful discovery of gas during previous drilling campaigns. In addition to the Waarre Formation reservoir play, the extent of the Pretty Hill Formation and Sawpit Sandstone plays in the Crayfish Sub-group and the Windermere Sandstone play within the Eumeralla Formation have been mapped. The results from prior drilling were analysed as part of the workflow and used to create common probability maps for each play, which were then rendered as ‘traffic light’ maps (for example, see Figure 2.10). New GIS shape files were then created to show areas where prospectivity is proven (green), uncertain (yellow) or unlikely (red).

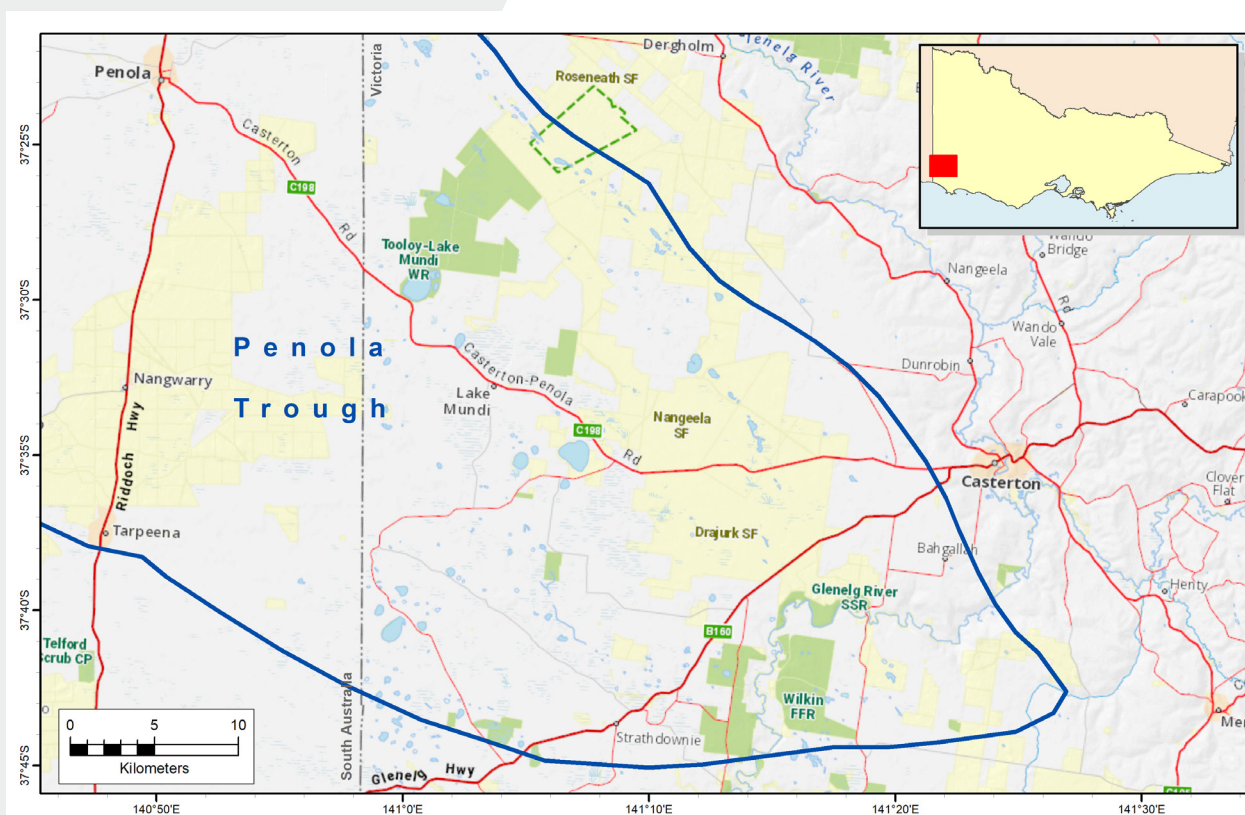
To date, summary play fairway maps have been composited for several play units to illustrate the full extent of prospective areas in the Otway Basin. This work is preliminary and will continue to be refined until all play fairways are mapped, including the element of charge. The work will be published once the mapping has been finalised.

## 2.1.4 Stratigraphic drilling

The stratigraphic drilling project aimed to fill key knowledge gaps and generate new information about local geology and Victoria's potential for gas resources in an underexplored area of the Otway Basin to inform an assessment of Victoria's undiscovered conventional gas potential.

The Geological Survey of Victoria has reviewed existing Otway Basin geology and petroleum data to investigate the optimal location for placement of a stratigraphic well that maximised the ability to decrease uncertainty relating to gas prospectivity and resource estimates.

An approach was developed to narrow potential locations from the entire onshore Otway Basin (hundreds of square kilometres scale) to areas of interest (square kilometre scale). This involved creating a GIS data model to compile all available geological and petroleum data to inform selection of an area of interest – a geological area known as the Penola Trough in South-West Victoria (Figure 2.16).



**Figure 2.16 Location of the Penola Trough in South-West Victoria.**

Following the selection of the optimal location for a stratigraphic well, it was determined that new data from the geoscience rock characterisation component, such as the chemostratigraphy (see Section 2.1.1.3), when combined with the data and knowledge collected over the past two years of the Victorian Gas Program, have provided more understanding of the Otway Basin and its prospectivity than was initially anticipated. As the purpose of the drilling project was to fill key geological knowledge gaps about Victoria's gas resources in an underexplored area of the Otway Basin, the value-add potentially offered by the drilling project was diminished. Data which would have been collected if the program were to drill is now unlikely to bring any additional significant insight than what the data collected to date indicates, other than confirming the stratigraphy in the study area. As a result, the program decided not to proceed any further with the stratigraphic drilling.

## 2.2 Geoscience studies – Gippsland Basin

The Victorian Gas Program is investigating the petroleum prospectivity of the onshore and offshore Gippsland Basin within Victoria's jurisdiction. An assessment of the potential for further conventional gas discoveries is being prepared.

The construction of a 3D geological framework model commenced in September 2018. The model is well advanced with completed seismic and wells interpretations and a refined velocity model, with the objective to seamlessly join the new onshore map with the existing offshore Gippsland Basin 3D geological model. The project has integrated existing well and 2D seismic data, including the South Gippsland regional seismic lines acquired by the Geological Survey of Victoria in 2015. A suite of maps illustrating the regional structure of the onshore Gippsland Basin and the thickness and geometry of key geological units will be released as part of the project. The interpretation and mapping of the onshore seismic data in the Gippsland Basin is being complemented by a detailed study of the relevant drill cores in the Geological Survey of Victoria collection at Werribee, which will be integrated into the final study report. It will include the construction of a 3D geological model that defines the structure and stratigraphy of the subsurface geology of the onshore Gippsland Basin.

The new model will complement and extend interpretations of the offshore Gippsland Basin, notably the work completed under the Geological Survey of Victoria's Victorian Geological Carbon Storage initiative in 2010-11 ([earthresources.efirst.com.au](http://earthresources.efirst.com.au)). The new interpretation addresses the full stratigraphic section from the top of the Palaeozoic basement to the present-day land surface, with emphasis on delineating intra-Latrobe Group units in the Seaspray Depression.

The Geological Survey of Victoria has commissioned an independent reviewer to provide feedback on the methodology and interpretations to the Geological Survey of Victoria, the Scientific Reference Group and other stakeholders.

While having similar goals and workflows as the Otway 3D geological framework models (see Section 2.2.1), the onshore Gippsland Basin study has a smaller scope in terms of geographical size and the amount of data available for evaluation.

A petroleum systems analysis of Victoria's Gippsland Basin has been commissioned and began in June 2019. The extent of the study area is shown in Figure 2.17. Input datasets are being compiled with the aim of building the model by November 2019 and delivering final results in April 2020.

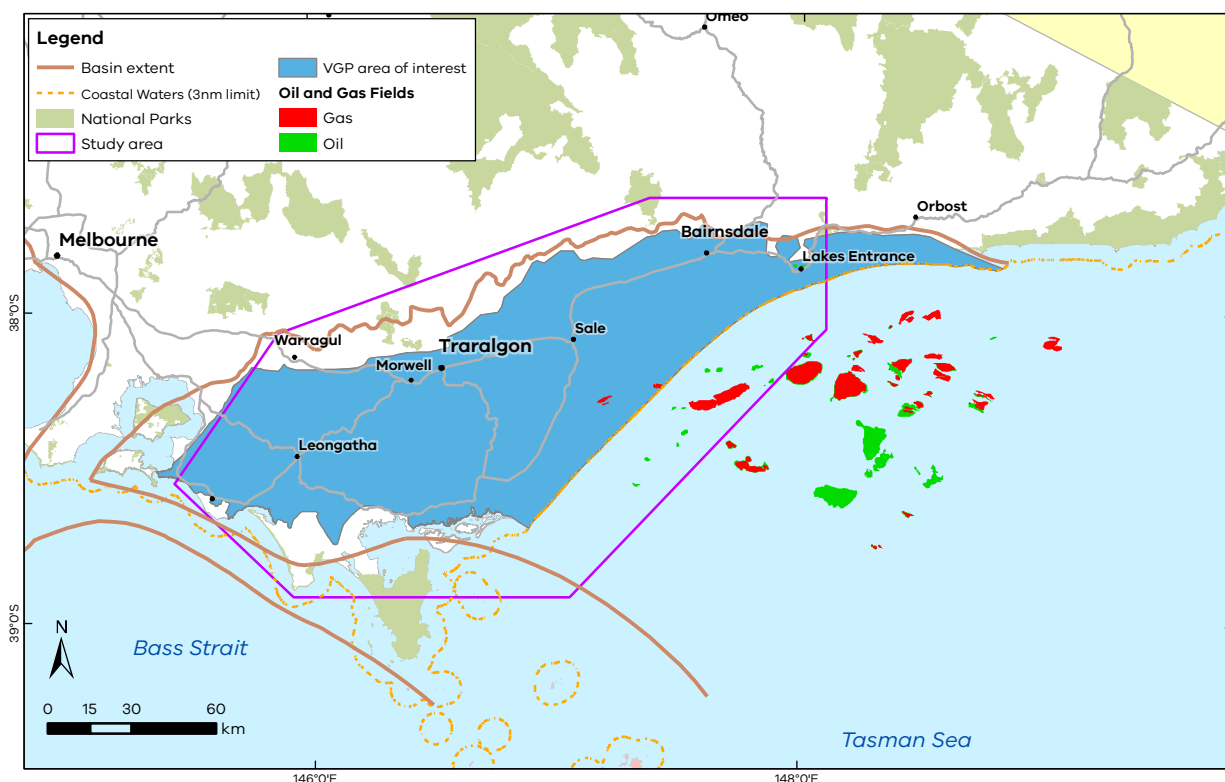


Figure 2.17 Gippsland Basin petroleum systems modelling extent.

## 2.3 Environmental studies

The environmental studies project is improving our understanding of the current environmental conditions and potential impacts should onshore conventional gas development occur. The Geological Survey of Victoria has undertaken baseline environmental studies (groundwater and air quality) to establish a baseline reference of environmental conditions and to improve understanding of groundwater processes through the Otway and Gippsland regions. This new data collected is a valuable environmental reference point for Victoria.

Environmental baseline indicators are being measured to ensure potential impacts can be quantified. Previously, the Victorian Water Science Studies (State Government Victoria, 2015) carried out a regional scale assessment of conventional development in the Otway Basin and found the potential impacts to ecosystems and water users were low. This study further refines the potential impacts in the Otway Basin and determines the potential impacts for the Gippsland Basin. All environmental data collected as part of this study will be publicly available upon completion of the program.

### 2.3.1 Regional baseline studies

#### 2.3.1.1 Groundwater sampling

Groundwater sampling of state groundwater observation bores is now complete in South-West Victoria and Gippsland (Figures 2.18 and 2.19). All 100 of the proposed groundwater samples plus repeat samples have been collected. This sampling provides one of the most comprehensive assessments of groundwater conditions (focusing on deep aquifers) undertaken in Victoria and will improve understanding of groundwater processes through these regions.

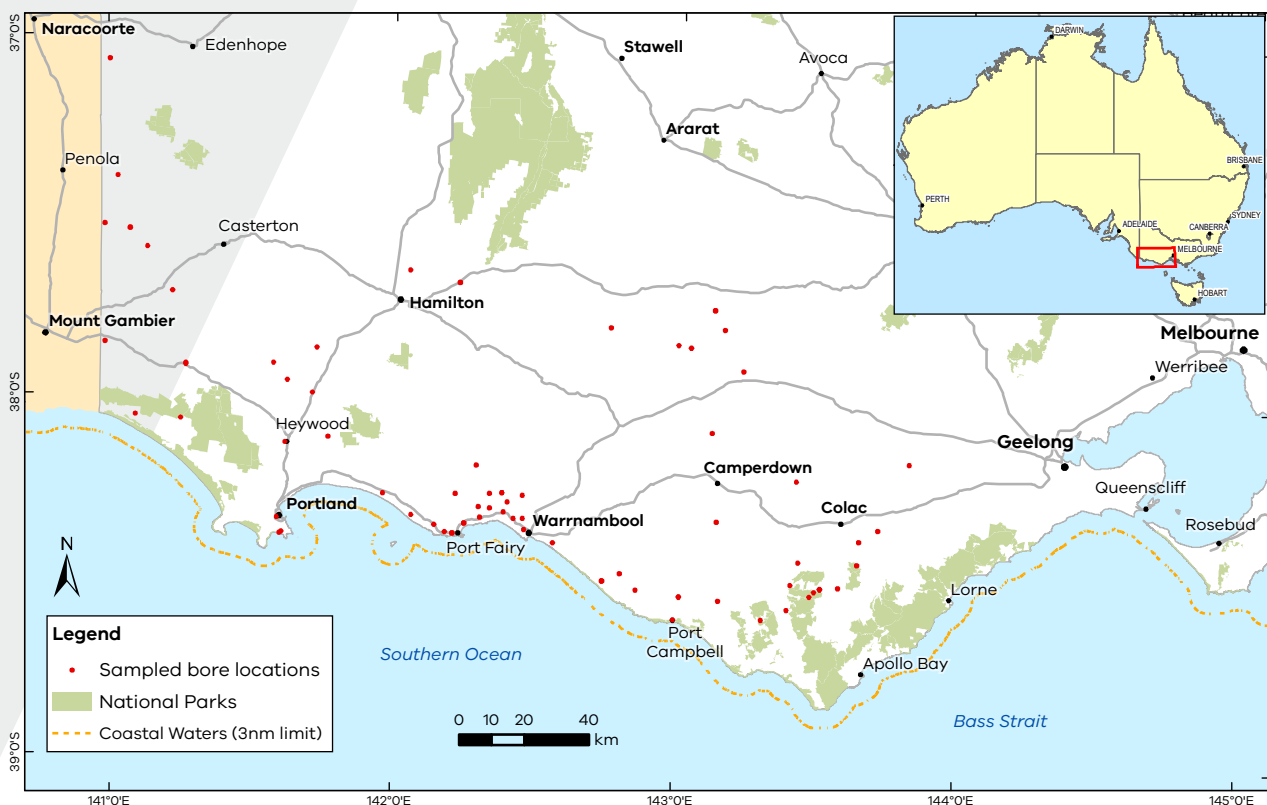


Figure 2.18 Groundwater bores sampled in the Otway Basin.





**Figure 2.19 Groundwater Bores sampled in the Gippsland Basin.**

Several groundwater samples have been collected from bores more than 800 metres deep, and some more than one kilometre deep, where the conventional gas source rock is nearby. In many instances, this is the first-time detailed water chemistry analysis has been collected from these bores. Overall, no unexpected results have been found, but local insight into groundwater and gas conditions has been gained.

A variety of chemical parameters have been analysed including stable isotopic tracers and dissolved methane. The dissolved methane concentrations in the groundwater collected from the differing aquifers has varied. Results show that the dissolved methane concentrations in South-West Victoria are generally lower than in Gippsland. In Gippsland, dissolved groundwater methane has been found to be as high as 73 mg/L.

Figure 2.20 presents groundwater methane, ethane, and propane analysis results according to different aquifers in the Otway and Gippsland basins. The ratio of these dissolved gases and the source signature of methane gives information about the type of methane in the groundwater (that is, microbial production or natural gas). Results show for both the Otway and Gippsland regions that the methane is predominantly produced by microbial activity in the groundwater. The microbial production of methane is classified as biogenic methane. Biogenic production can occur naturally in groundwater and gas-bearing geology.

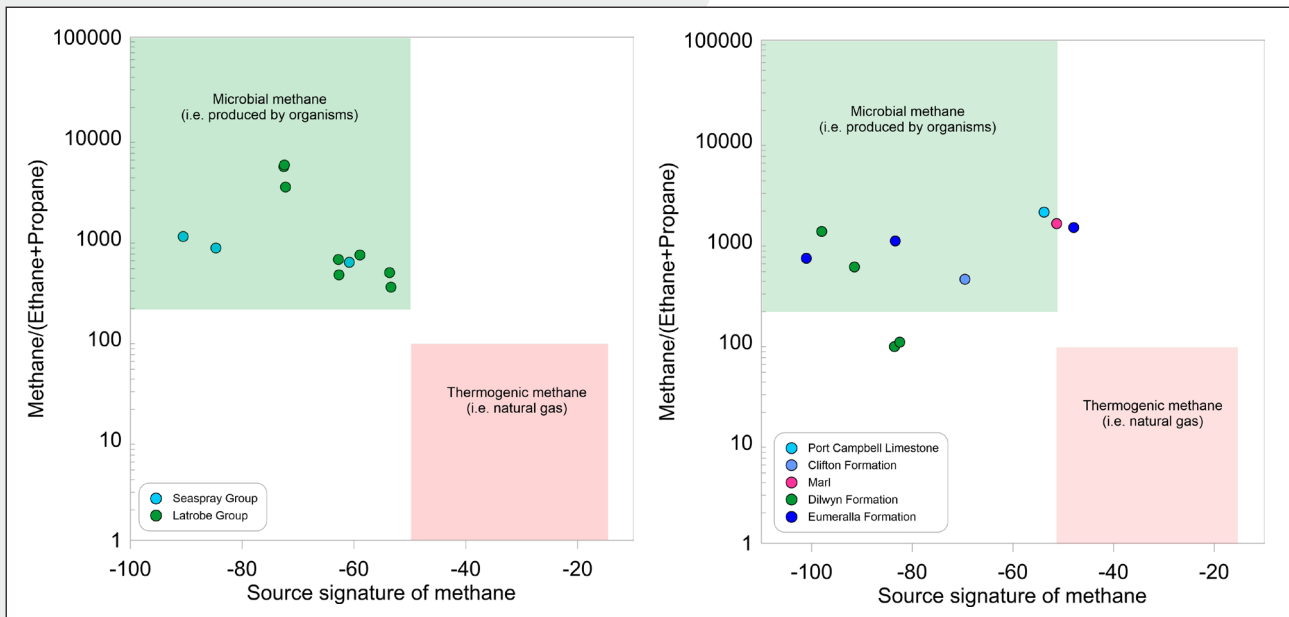


Figure 2.20 Groundwater methane isotopic ratios for Gippsland (left) and South-West Victoria (right).

### 2.3.1.2 Air quality measurements

Two regional air quality surveys were completed in April 2018 and November 2018. The surveys were conducted using atmospheric monitoring equipment commonly used for regional baseline studies and the assessment of fugitive gas source emissions. The technical report for each region is now in review.

Overall, the atmospheric survey found that instances of elevated methane above background were infrequent and well below the Environmental Protection Authority (EPA) atmospheric emission concentration limit of 10,000 parts per million (EPA, 2002; EPA, 2018). Baseline concentrations of both methane and carbon dioxide in South-West Victoria and Gippsland resemble baseline concentrations for the southern hemisphere monitored at Cape Grim (CSIRO, 2018).

## 2.3.2 Point scale well integrity impact assessment

Site scale modelling is in progress to consider the potential impact a poorly sealed well may have on groundwater. The modelling will quantify the possible impact a compromised well may have on groundwater. This assessment will enable better understanding of the magnitude of potential risks associated with conventional gas drilling and extraction, which will then be used to inform the regional groundwater impact scenario assessment and potential future regulations.

## 2.3.3 Regional groundwater impact assessment

The regional groundwater impact assessment will simulate the regional groundwater flow processes of South-West Victoria (and offshore) and the Gippsland Basin (and offshore) to consider the potential impact a conventional gas industry may have on the nearshore and onshore areas of Victoria. Understanding the groundwater processes in the regions, combined with point scale assessments, is important for assessing any future potential impacts a conventional gas industry may, or may not, have.

The simulation of groundwater processes will use some of the geological data sets that have been developed as part of the detailed stratigraphic assessments for the geoscience studies. Components of the groundwater flow modelling are:

- groundwater pumping
- groundwater-surface water interaction
- groundwater recharge
- groundwater evaporation
- existing conventional gas formation depressurisation.

The groundwater impact assessment model for South-West Victoria has been built using a stratigraphic framework which incorporates the 3D stratigraphic model developed as part of the geoscience studies (see Section 2.1.2.1) and the existing onshore hydrostratigraphic surfaces from the Victorian Aquifer Framework (GHD, 2012). Calibration of this model is now complete. The groundwater impact assessment model for Gippsland has been built and is calibrated. Groundwater impact assessment scenarios are currently being developed for both regions where prospective conventional gas areas will be simulated to determine if there is any groundwater impact.

## 2.4 Onshore conventional gas governance

### 2.4.1 Stakeholder Advisory Panel for Onshore Conventional Gas

Victoria's Lead Scientist, Dr Amanda Caples, chairs the Stakeholder Advisory Panel for Onshore Conventional Gas, which meets quarterly. The panel includes representatives from key sectors and groups, including farmers, industry, local government, environment and the community. The panel provides the Minister for Resources with advice on the risks, benefits and impacts related to onshore conventional gas during the moratorium, with particular attention paid to social, economic and environmental factors.

To date, the panel has formally met on eight occasions: 17 August 2017, 10 November 2017, 8 March 2018, 7 June 2018, 6 September 2018, 14 February 2019, 9 May 2019 and 8 August 2019.

Communiqués for these meetings are included as Appendix 1. The communiqués are also available on the Lead Scientist's web page: [djpr.vic.gov.au/victorias-lead-scientist](http://djpr.vic.gov.au/victorias-lead-scientist).

### 2.4.2 Victorian Gas Program Scientific Reference Group

Victoria's Lead Scientist also chairs the Victorian Gas Program Scientific Reference Group. This group provides independent peer review advice to the Lead Scientist on the study scope and outputs of the program.

Members with specific expertise review Victorian Gas Program activities related to their field of study on an ad hoc basis to ensure that scientific and technical outputs are robust.

The Scientific Reference Group meets formally when required.

## 2.5 Risks, benefits and impacts assessment for onshore conventional gas

### 2.5.1 Overview

The Victorian Gas Program's geoscientific and environmental studies and the findings from the community engagement program and the resource and land use planning will be consolidated through an assessment of the risks, benefits and impacts of future potential onshore conventional gas exploration and production in Victoria. The assessment will provide a key input to government decisions on future onshore conventional gas activity in Victoria. The assessment has been undertaken in two phases:

- an initial case study on Beach Energy's Otway gas plant
- a broader risks, benefits and impacts assessment for onshore conventional gas.

## 2.5.2 Beach Energy Otway gas plant case study

To inform the broader risks, benefits and impacts assessment, the Victorian Gas Program has completed an assessment of the project specific risks, benefits and impacts of Beach Energy's Port Campbell investments. Using a triple bottom line approach, the assessment examines the economic, social and environmental effects (benefits and impacts) of the operation both at a local and state-wide level. Beach's economic contributions have been estimated using an integrated regional input-output model developed for the region by Federation University.

The assessment found that the Beach Energy project has:

- created \$31 million of economic value (direct and indirect) in the Great South Coast region in 2018-19
- has engaged with local councils and communities
- managed environmental and safety risks as determined by regulatory frameworks.

The Otway Gas Plant is one of six gas plants in Victoria that process gas from offshore conventional gas fields. Beach Energy is the majority owner of the Licenced Operator of the plant, located approximately seven kilometres North East of Port Campbell in Victoria's South-West. The plant processes gas from four offshore conventional gas fields and distributes to the East Australian gas market, making up approximately 11 per cent of the annual processing capacity of Victorian gas plants. In the 2019, financial year, the plant produced approximately 25% of Victoria's daily gas demand..

### **Economic**

Beach Energy:

- currently employs 146 people (full time) in Victoria including 93 in the Great South Coast region
- created \$31 million of economic value (direct and indirect) in the Great South Coast region in 2018-19
- created \$17 million worth of economic value (direct and indirect) in the rest of Victoria in 2018-19.

The report confirmed that Beach's operations contribute to a number of economic measures at both a local and state level including employment and economic value, royalty payments to government, and the use of local firms and contractors.

### **Social**

Beach Energy:

- conducts active engagement with councils and communities to inform them of Beach Energy's plans and activities
- provides funding of community projects.

Beach Energy's operations have demonstrated compliance with legislation relating to sensitive areas such as the preparation of Cultural Heritage Management Plans which aim to protect areas of cultural significance. The local councils of Corangamite Shire and Moyne Shire have also confirmed Beach's compliance with permit conditions and local regulations.

### **Environment**

There is one record of the previous operator self-reporting breaches of their licence conditions for benzene emissions in 2016, for which they were fined by the Victorian Environment Protection Authority.

The environmental risk management frameworks relating to the Port Campbell site are extensive and complex. Beach has demonstrated compliance with these frameworks and there is no record of harm caused to the environment as a result of their operational activities in the Port Campbell area.

Beach Energy:

- adheres to industry and gas sector environmental frameworks including groundwater, fugitive gas emissions and geological impacts
- has a strong risk and environmental management platform.

Beach Energy recently reported in their 2019 financial year Annual Report that they had achieved the best safety and environmental performance on record across the company.

## 2.5.3 Risks, benefits and impacts assessment for potential future onshore conventional gas activity

The Victorian Gas Program is supporting the Lead Scientist and the Stakeholder Advisory Panel for Onshore Conventional Gas in their analysis of the broader risks, benefits and impacts of potential onshore conventional gas activity. The assessment will be based on hypothetical gas development scenarios across the Gippsland and South-West regions and will be informed by the Victorian Gas Program studies.

The proposed approach is used widely in fields including environmental science and engineering project management. Each gas development scenario will be assessed in relation to its benefits and impacts on the regional and state economy, communities and the environment. It is envisaged that benefits and impacts will be assessed by identifying economic, social and environmental 'receptors' and using a range of available information, with an emphasis on data collected from the various Victorian Gas Program studies. The proposed approach is summarised in Figure 2.21.

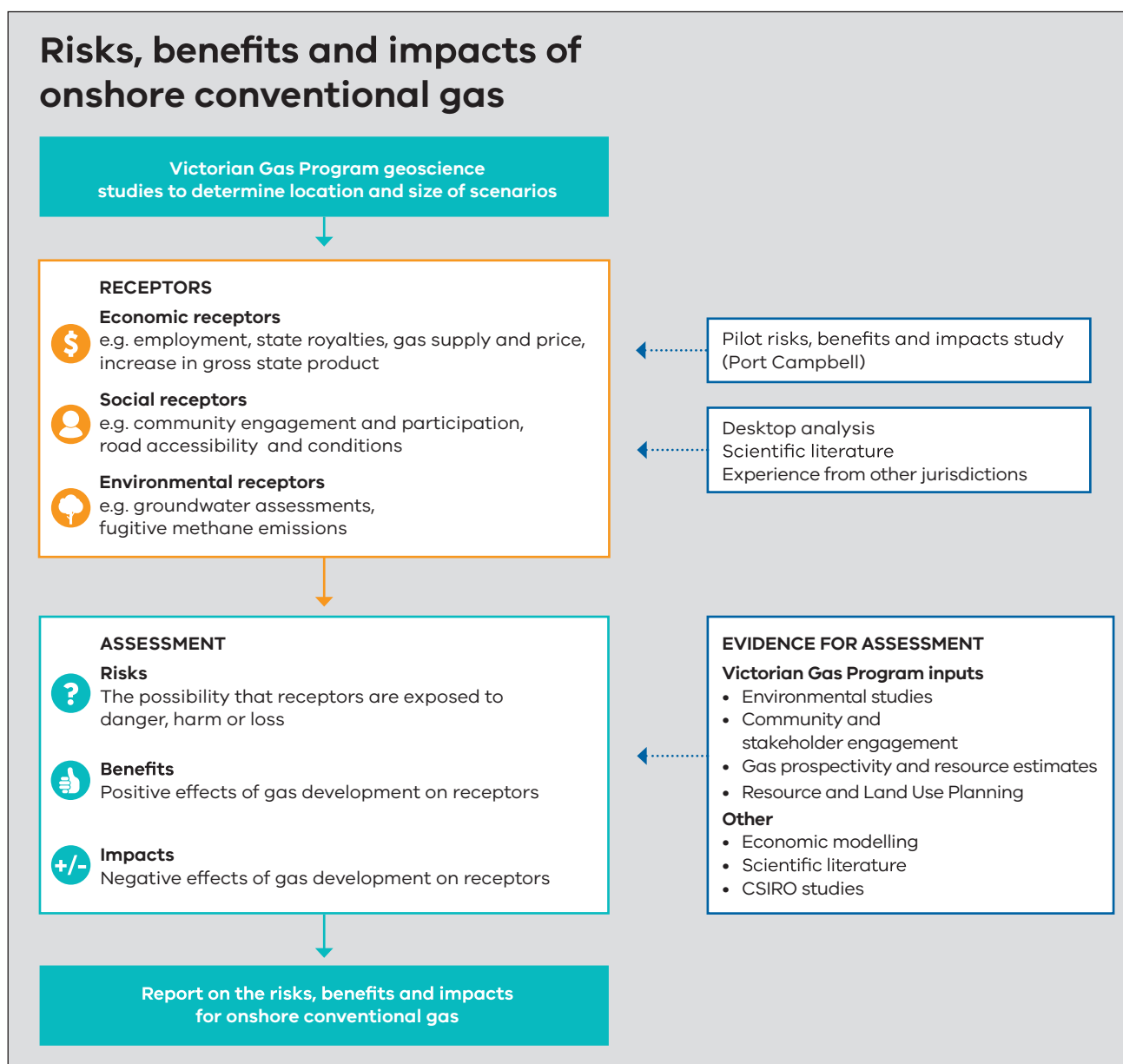


Figure 2.21 Overview of the risks, benefits and impacts assessment.

The assessment will identify any opportunities to enhance benefits and to mitigate risks and impacts through policy and legislative reform, as well as regulatory or industry practice reforms. The risks, benefits and impacts assessment represents the culmination of the Victorian Gas Program's extensive reviews and studies and will be a key input to Victorian Government decisions on onshore conventional gas activity currently under moratorium.

### 3. Offshore gas geoscience studies

The offshore gas geoscience studies are improving the understanding of gas prospectivity at a sub-basin scale by acquiring, processing and interpreting a new airborne gravity gradiometry dataset and via onshore gas geoscience studies, such as the 3D geological framework modelling (see Section 2.1.2.1).

Between August 2018 and January 2019, an airborne gravity gradiometry survey was conducted over 16,000 square kilometres of the Otway Basin, including state onshore and offshore areas and Commonwealth waters.

The seismic horizon and well data interpretation completed in June 2018 (see Section 2.2) identified areas off the Victorian coast in the Otway Basin that are likely to be prospective for offshore gas. This work underpinned the 2018 offshore acreage release and will continue to support commercial exploration for gas discoveries off the Victorian coast once acreage is awarded. The Victorian Gas Program continues to identify other prospective offshore areas that may be released in the future.

#### 3.1 Acreage release

In May 2018, the Victorian Government invited the petroleum industry to apply to explore five areas in Otway Basin state waters, which extend three nautical miles from the coast. The release areas are between Port Campbell and the South Australian border (Figure 3.1) and have a combined surface area of 1318 square kilometres.

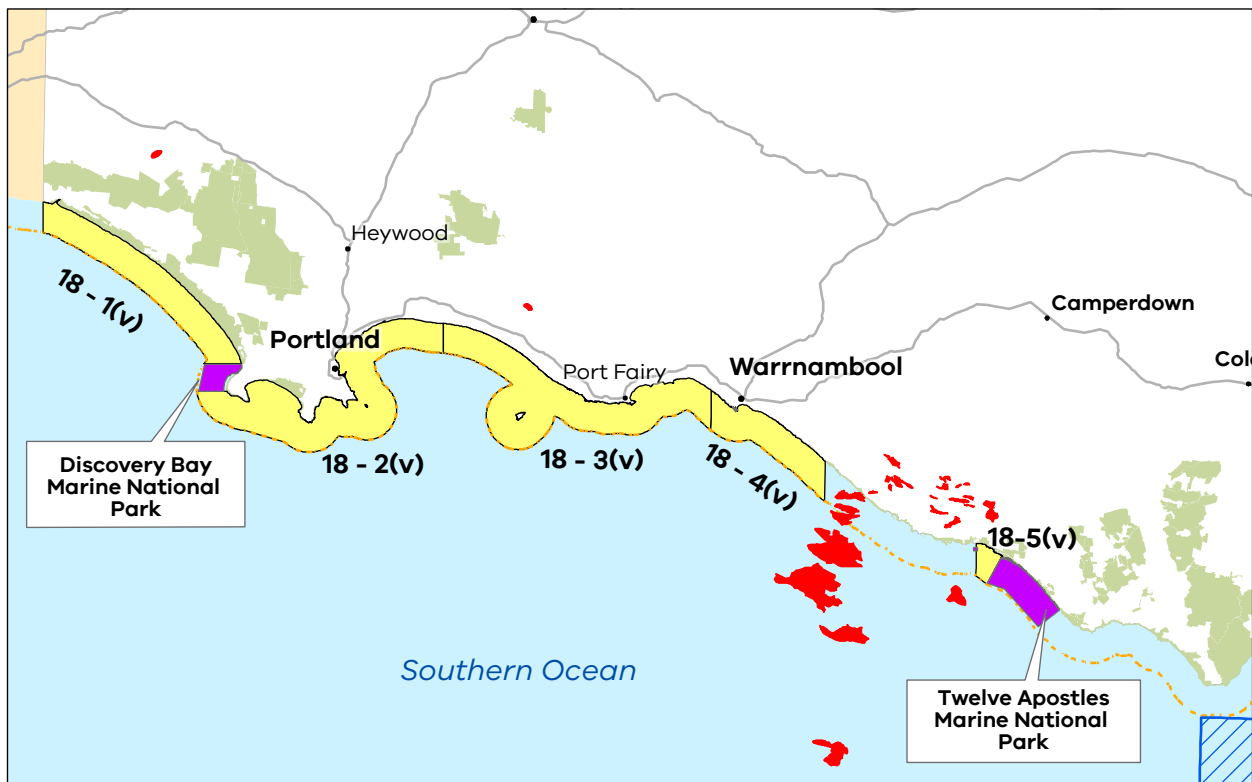


Figure 3.1 Location of offshore petroleum exploration acreage release areas in Victorian State Waters.

The release areas are under-explored, with no previous drilling. Several of the areas adjoin existing producing oil and gas fields.

An acreage release marks the start of the process to develop potential new gas fields. There are many more regulation and consultation steps that must take place should gas be discovered. As the first step, applicants must submit a work program proposal for assessment, a summary of financial and technical capability and records of past performance in Australia and overseas exploration and development operations.

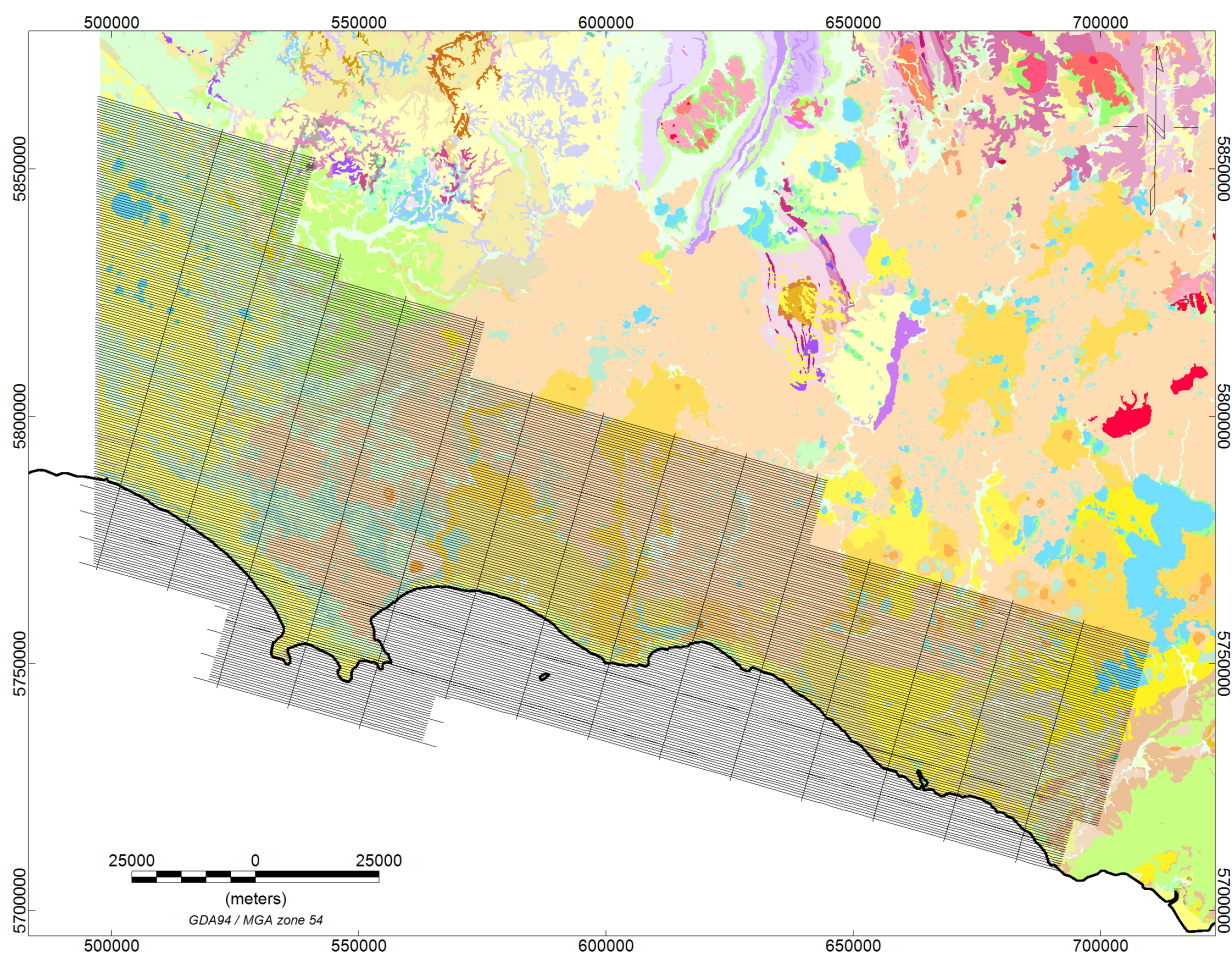
Marine National Parks are excluded from the release areas and from any future petroleum exploration or development proposals.

The acreage tender closed in February 2019 and the applications for Exploration Permits are being assessed in accordance with regulatory requirements.

Government outlined an expectation in the acreage release invitation that 'Australian domestic consumers will be given the first genuine and reasonable offer to buy any new gas that is discovered under any future production licence over the acreage release areas'. If any petroleum production licences are awarded as follow-on licences to the exploration permits of this tender, they will be conditioned accordingly.

## 3.2 Airborne gravity survey

The Geological Survey of Victoria commissioned an airborne gravity gradiometry survey in South-West Victoria (Figure 3.2). The survey began in August 2018 and was completed in January 2019. The survey has produced the largest airborne gravity dataset ever collected in Victoria. The new data set has been released (Carter et al., 2019) and provides superior quality gravity imagery in South-West Victoria, compared with pre-existing data.



**Figure 3.2 Airborne gravity gradiometry survey area over the Otway Basin; flight lines shown on surface geology map.**

The survey used a FALCON® airborne system, which can acquire airborne gravity and gradiometry data at the same time. Both will be useful, as conventional gravity is good for imaging deeper geological structures while gradiometry is more effective at imaging shallow structures. In addition, magnetic data was acquired concurrently, as well as laser scanner data, to effectively terrain correct the dataset.



Qualitative interpretations of the data will infill and complement seismic datasets in the Otway Basin, particularly over the three-nautical mile zone around the Otway coast where very little geological data has previously been acquired.

The objectives of the survey are to resolve the shape of:

- deeper structures, which have an impact on petroleum generation (that is, 500 metres to eight kilometres below ground)
- shallow structures, which have the potential to trap hydrocarbons (that is, 1.5 to 2.5 kilometres below ground).

Data from the survey has been processed (Figure 3.3) and an interpretation of the data by the Geological Survey of Victoria's geophysicists and modellers will be used to complement the onshore geoscience studies. Figure 3.3 shows a map of the acquired gravity data over the Otway Basin. Red and orange colours represent areas where high gravity values were recorded, and blue colours represent areas where low gravity values were recorded. These variations can be used to make interpretations about the sub-surface geological structure.

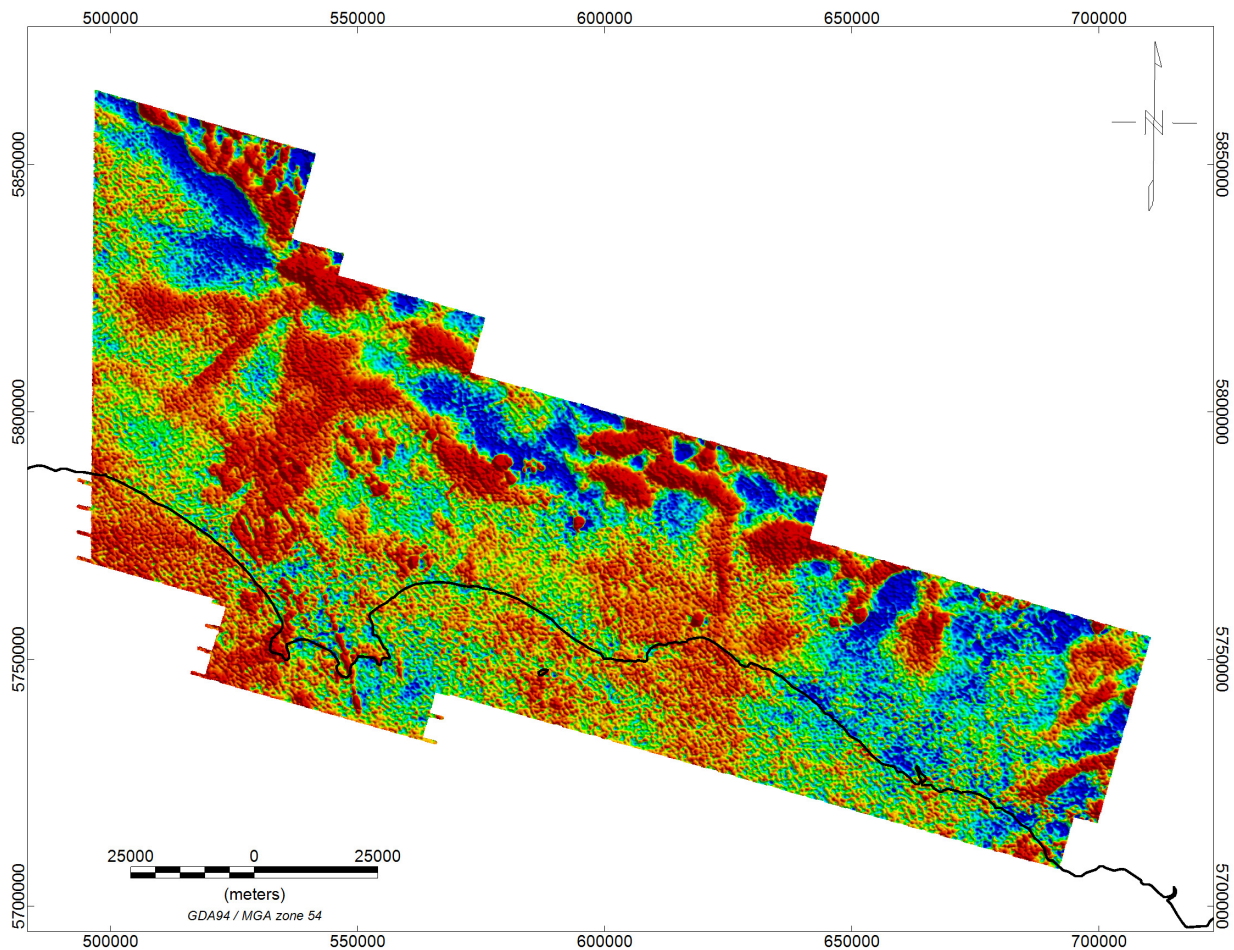
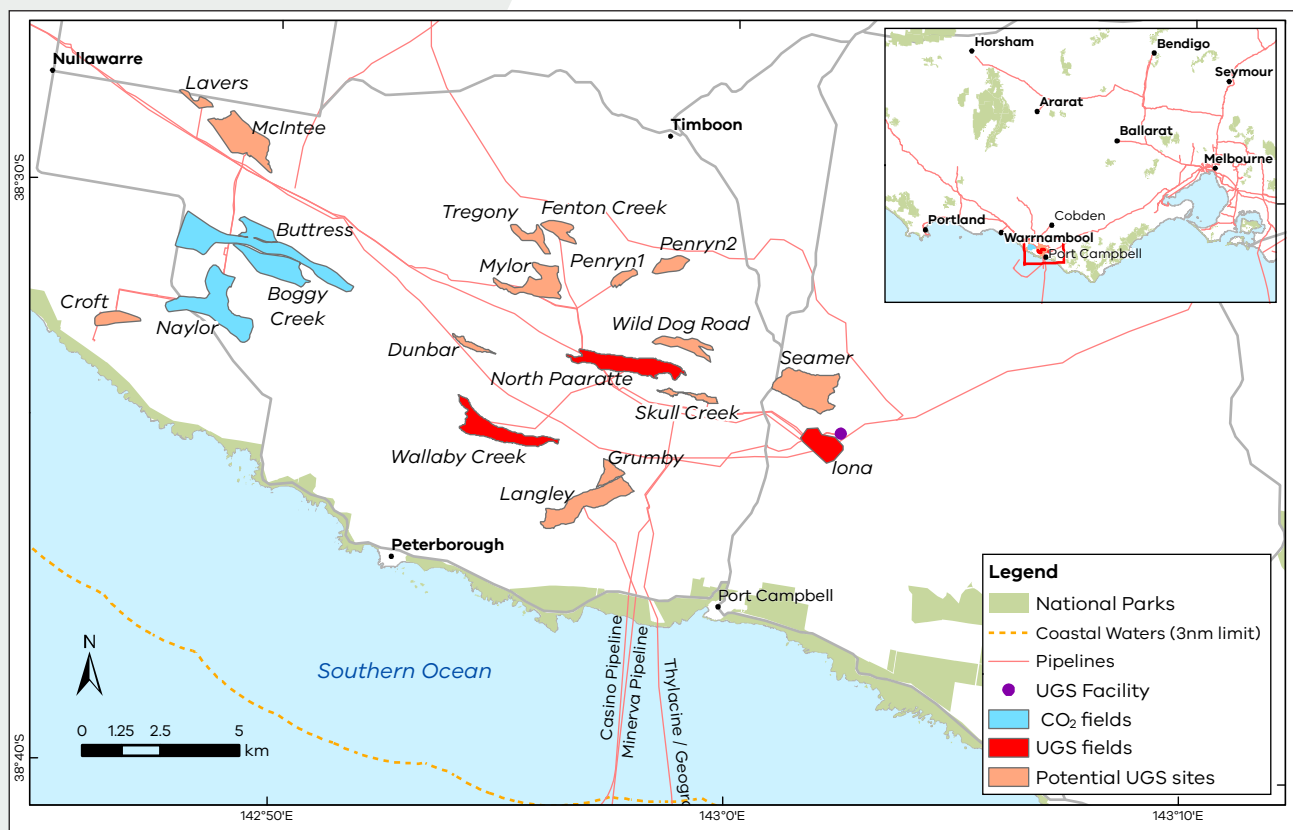


Figure 3.3 Otway Basin airborne gravity dataset.

## 4. Underground gas storage investigations

The Geological Survey of Victoria has investigated the opportunity for further underground gas storage. The focus of these studies was on the onshore Otway Basin and the potential was examined to develop further underground natural gas storage sites to help secure more reliable gas supplies and mitigate short term price increases, particularly during interruptions in the gas supply system.

In addition to the three gas fields that collectively form the Iona underground gas storage operation, another 13 depleted or unproduced gas fields were identified in the Port Campbell area of the Otway Basin (Figure 4.1). All of these fields have suitable geology which could be potentially converted into gas storage reservoirs. They all have a geological structure able to effectively and reliably contain gas over time as they either currently contain or have contained gas in the past. The fields have Waarre Formation sandstone reservoir (as at Iona) and are sealed by the overlying Belfast Mudstone.



**Figure 4.1 Gas fields in the onshore Otway Basin Port Campbell Embayment.**

The investigations comprised four components:

1. representative technical studies – findings previously reported in Progress Report 2 (DJPR, 2019)
2. detailed technical studies
3. assessment of commercial feasibility of additional gas storage
4. assessment of economic potential of additional gas storage.

## 4.1 Detailed technical studies

Late in 2018, the Geological Survey of Victoria commissioned detailed technical studies for underground gas storage, which have now been completed.

These studies evaluated opportunities for underground natural gas storage in the Otway Basin by completing a detailed geoscience assessment of the sites identified as potentially suitable for gas storage. The sites were then ranked and short-listed using the ranking methodology developed in the representative technical studies (see page 40 of Progress Report 2 – DJPR, 2019), and improved the estimation of storage capacity and additional petrophysical analysis. Out of the 13 sites evaluated, six were short-listed to progress to a more detailed technical evaluation based on their ranking, structural interpretation, co-location and any original gas remaining.

For the technical evaluation, a fine-scale geocellular static model was built that numerically represented the structure and properties of the selected reservoir, associated saline aquifer and overlying cap rock. Reservoir performance was modelled by simulating the fluid flow of multiple cycles of gas injection and withdrawal. Modelling of geomechanics of the seal, reservoir and overburden was also carried out. The results of the modelled sites, including potential storage capacities, are shown in Table 4.1.

**Table 4.1 Gas storage capacity of six potential gas storage fields**

Field	Original Gas in Place, petajoules	Potential gas storage capacity (petajoules)		
		Base	Mid	High
Croft	8.1	1.9	2.4	2.8
McIntee	22.3	2.9	3.8	4.8
Mylor	18.9	1.9	2.9	3.8
Tregony	9.0	1.9	2.6	3.0
Fenton Creek	5.2	2.6	2.8	3.4
Penryn	6.9	1.4	1.9	2.4
<b>Total</b>	<b>70.4</b>	<b>12.6</b>	<b>16.4</b>	<b>20.2</b>

Note: Petajoules calculated from estimated volumes using a heating value of 38 Megajoules per cubic metre.

Fault seal integrity was investigated with geomechanical modelling of multiple injection and withdrawal cycles and estimating ground heave or subsidence. The modelling confirmed the representative technical studies outcomes, which were that neither fault reactivation nor substantial ground movement were likely in normal operating conditions.

Reports on the results of the detailed technical studies are currently undergoing peer review and will be made publicly available later in 2019.

## 4.2 Assessment of commercial feasibility of additional underground gas storage

The results of the detailed technical studies were used to produce the assessment of commercial feasibility of further underground gas storage. This assessment estimated development and operational costs, and considered the potential financial return for three scenarios:

- field operations with third party processing
- field operations using the capacity of an existing plant for processing
- field operations using a new processing plant.

The results for the high capacity case, considering an internal rate of return of greater than 10 per cent, are summarised in Table 4.2.

**Table 4.2 Summary of commercial feasibility of individual fields.**

Field	Commercial feasibility of processing options for high case, internal rate of return, 10 per cent		
	Field operations only, third party processing	Field operations using an existing plant	Field operations using a new processing plant
Croft	✓	✓	✗
McIntee	✓	✓	✗
Mylor	✓	✓	✗
Tregony	✓	✓	✗
Fenton Creek	✓	✓	✗
Penryn	✓	✓	✗

Four combination cases were also considered using the high capacity cases. The findings demonstrated that all combination cases result in a positively economic outcome, as summarised in Table 4.3.

**Table 4.3 Summary of commercial feasibility of combined fields.**

Combinations	Commercial feasibility of processing options for high case, internal rate of return, 10 per cent		
	Field operations only, third party processing	Field operations using an existing plant	Field operations using a new processing plant
Mylor, Tregony, Fenton Creek	✓	✓	✓
Mylor, Tregony, Fenton Creek, Penryn	✓	✓	✓
Mylor, Tregony, Fenton Creek, Penryn, McIntee	✓	✓	✓
Mylor, Tregony, Fenton Creek, Penryn, McIntee, Croft	✓	✓	✓

Reports on the detailed findings of the assessment of commercial feasibility for underground gas storage are currently undergoing peer review and will be made publicly available in 2020.

## 4.3 Assessment of economic potential of additional gas storage

The results of the representative technical studies, the detailed technical studies and the assessment of commercial feasibility were used as inputs into an economic case to determine the potential for development of new underground gas storage facilities in Victoria. This assessment has been completed in conjunction with the Department of Environment, Land, Water and Planning and is currently undergoing peer review.

Reports on the results of the economic assessment for underground gas storage will be made publicly available in 2020.

# 5. Supporting program components

## 5.1 Community engagement

The stakeholder and community engagement program supports all the scientific components of the Victorian Gas Program. The program has reached out to community and industry leaders and the public about its objectives and scientific field activities. Community engagement is focused on the Otway and Gippsland basins, which are the focus of the Victorian Gas Program and have a history of gas production.

The broad objectives of the stakeholder and community engagement program are to:

- inform and educate stakeholders, local communities and the public about the Victorian Gas Program and its scientific findings
- build the capacity of stakeholders and communities to offer informed input
- build trust and nurture relationships
- enable the community to have a voice and inform decisions throughout the Victorian Gas Program.

### 5.1.1 Engagements to date

Engagement to date has focused on explaining the work of the program and sharing the science that underpins the investigative activities. The program has involved community and industry leaders and the general public.

The program has now engaged with over 710 individual stakeholders across South-West Victoria, Melbourne and Gippsland via more than 625 events (including briefings, meetings, forums, emails and telephone calls). Engagements are catalogued in the Victorian Gas Program stakeholder engagement database and issues raised by stakeholders are recorded. This database is updated regularly and stakeholders on the database are communicated to frequently as the program progresses.

Key engagement phases to date have included:

- introducing the program and explaining how onshore conventional gas accumulations are identified and estimated
- explaining the geology of the Otway and Gippsland basins
- promoting the environmental field studies regarding deep groundwater bore sampling and testing and atmospheric testing in the Otway and Gippsland basins
- advising on the regional airborne gravity survey over South-West Victoria
- informing about the potential for stratigraphic drilling in the Penola Trough in the northern part of the onshore Otway Basin
- developing social research to map out regional attitudes to community wellbeing and to conventional gas development in the Gippsland and Otway basins
- running geological education programs at schools in South-West Victoria
- sharing the results of the atmospheric baseline testing of the Gippsland and Otway basins.

Stakeholders are also regularly informed of the Stakeholder Advisory Panel's deliberations on onshore conventional gas via the communiques from each panel meeting (see Appendix 1). The communiques are placed on the Lead Scientist webpages and the link of each edition is emailed directly to all stakeholders on the Victorian Gas Program database.

The Geological Survey of Victoria has met several times with councillors, chief executive officers and senior staff in six local government authorities in the Otway Basin (Corangamite, Warrnambool, Southern Grampians, Glenelg, Moyne and Surf Coast) to keep them updated on the program. Mayors and chief executive officers of five Gippsland local government authorities (Lalor, Wellington, South Gippsland, Eastern Gippsland and Baw Baw) have also been updated on the Victorian Gas Program.

Snapshots of the main issues raised during engagements with local councillors, farming organisations, environmental groups, economic development associations, community groups and water authorities in Gippsland, South-West Victoria and the Melbourne metropolitan region are shown in Figure 5.1, 5.2 and 5.3 respectively.

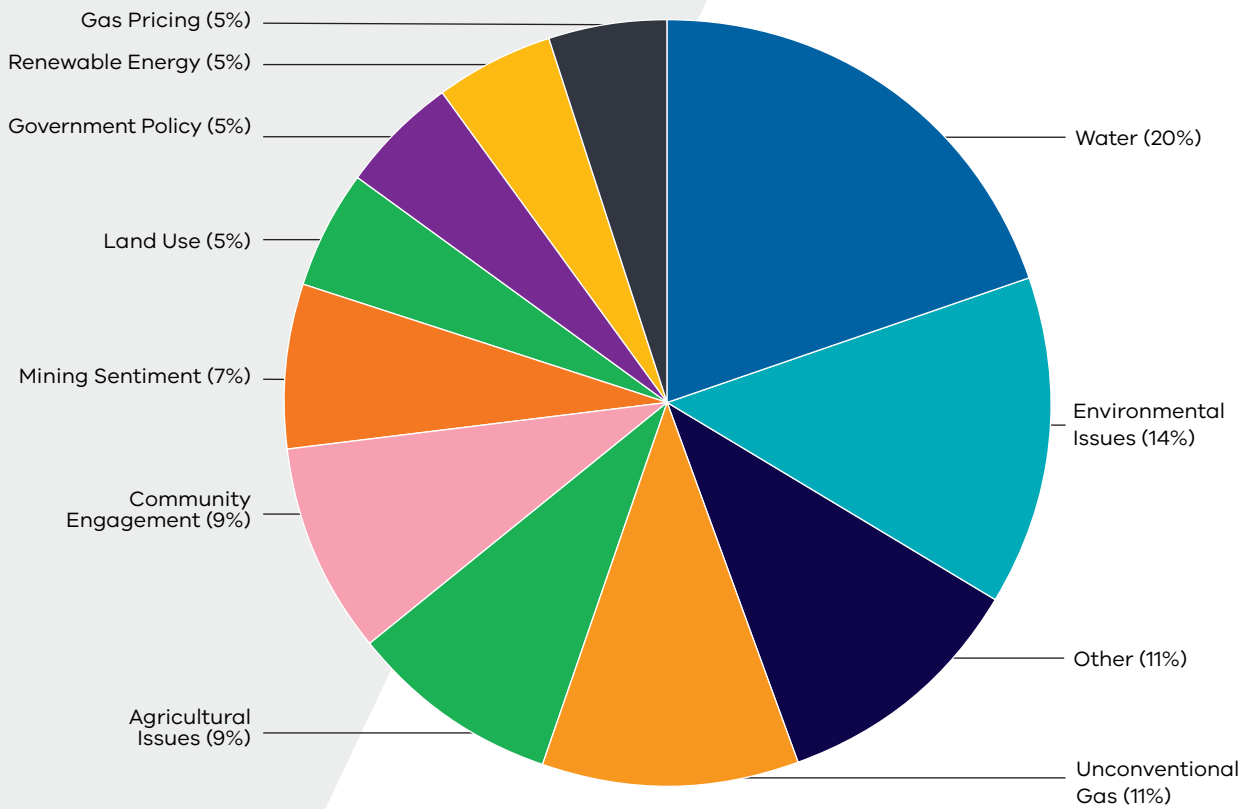


Figure 5.1 Key issues raised during Gippsland engagements about the Victorian Gas Program.

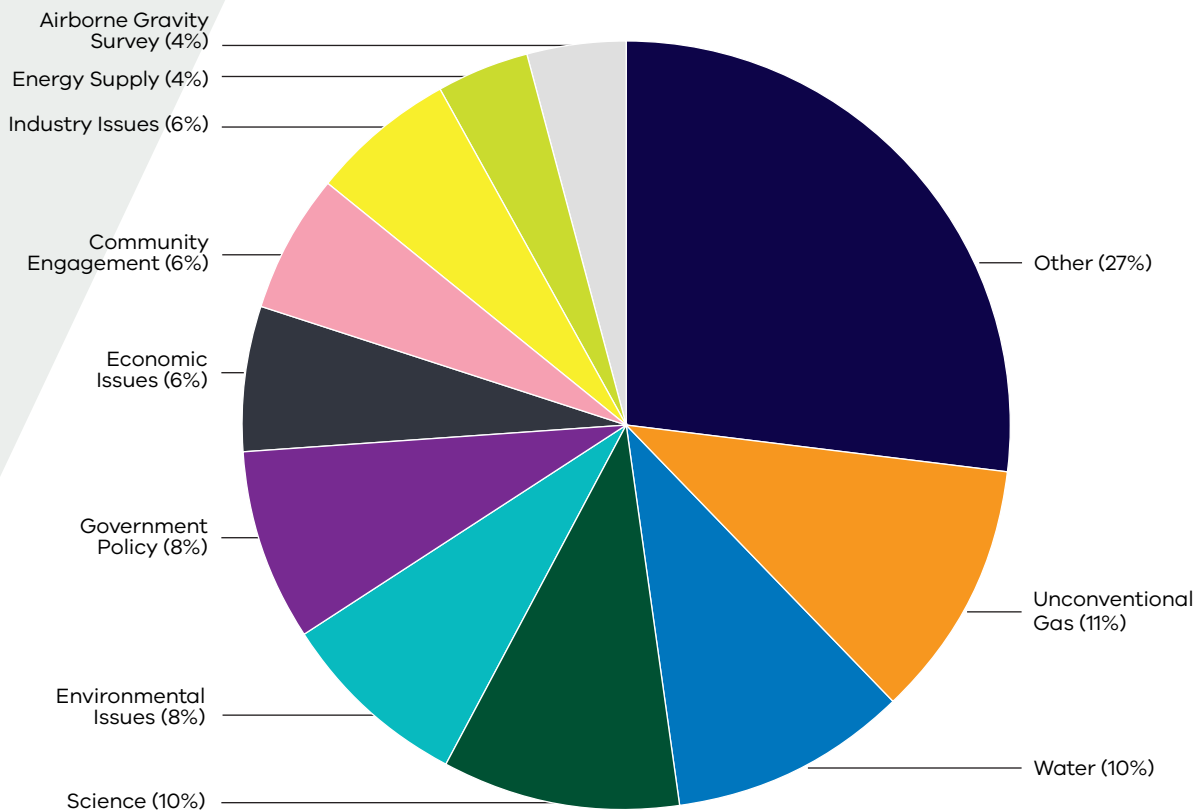
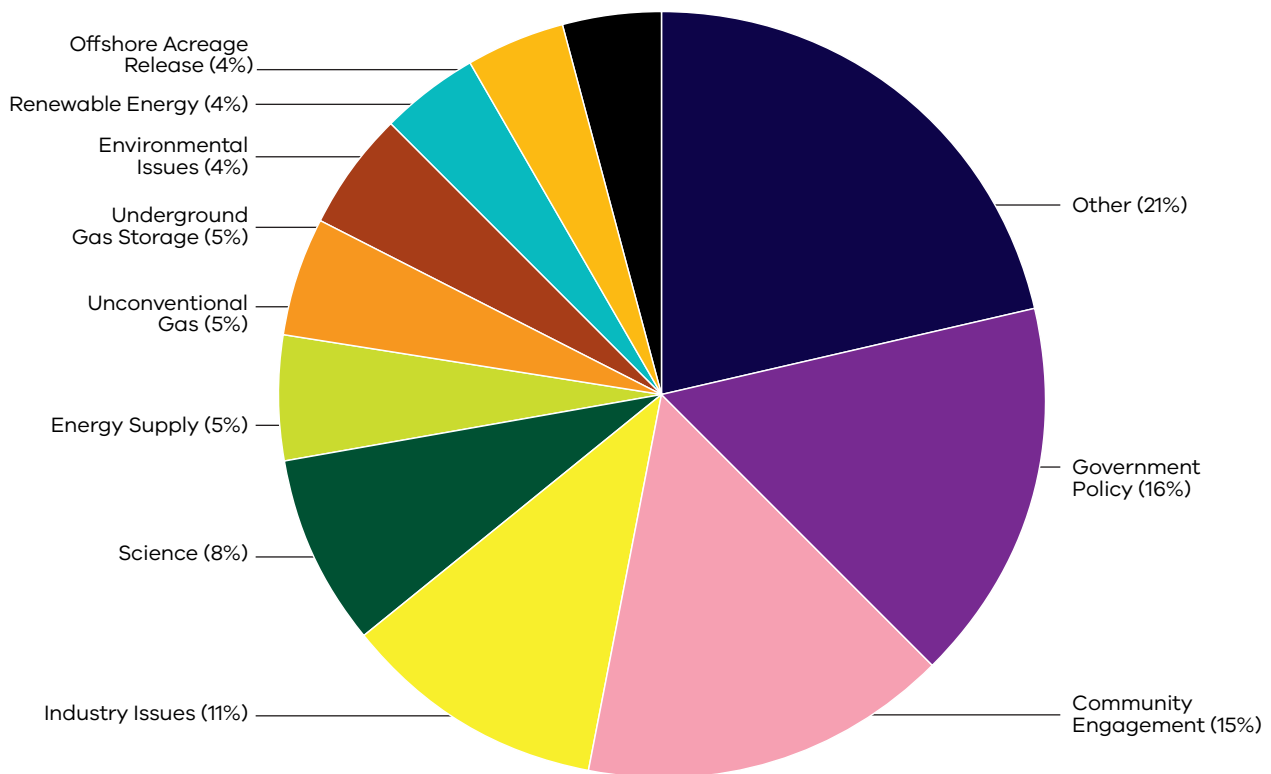


Figure 5.2 Key issues raised through South-West Victoria engagements about the Victorian Gas Program.



**Figure 5.3 Key issues raised through metropolitan Melbourne engagements about the Victorian Gas Program.**

While not definitive, the data highlights a broad range of issues and concerns that are common to regional communities in Gippsland and South-West Victoria. Findings from the Melbourne region’s engagements reflect stronger concern about government policy and industry issues. This is most likely due to the higher numbers of gas-using businesses and industries and environmental advocacy groups in the metropolitan area.

Victorian Gas Program staff also attended large agricultural events, including the Sungold Farm Field Days in Warrnambool in 2018 and 2019 and Sheepvention in Hamilton in 2018 and 2019. The events were attended by thousands of people which was an ideal opportunity to show the Geological Survey of Victoria’s 3D geological models and explain the purpose of the Victorian Gas Program to farmers and local community members.

The Geological Survey of Victoria has also conducted an extensive educational program to primary and secondary students in South-West Victoria. Over 1200 students from 21 schools have so far experienced 3D presentations of Victoria’s geology and how their region was made. Presentations included the techniques used to understand the earth, volcanism, minerals and resources of the state, dinosaurs in Victoria and where a career in the resources sector can lead.

The stakeholder engagement program has also kept the petroleum industry informed about the Victorian Gas Program with presentations and exhibitions at the Australian Petroleum Production and Exploration Association conferences in 2018 and 2019.

## 5.1.2 Social baseline assessment

The Victorian Gas Program has commissioned a regional social baseline research project to survey Victorian residents to gain their perceptions on gas. The survey will cover both community perceptions of their resilience to handle conventional gas exploration and development, and a range of collective wellbeing markers that can form baselines for future research. The South-West and Gippsland regions were surveyed between July and early September 2019, using a randomly selected representative sample of 800 residents.

The survey's results will be collated and analysed to provide an insight from potentially impacted regional communities, creating a framework for consultation and community concern if onshore conventional gas development is allowed to occur at some point in the future. The results will be shared with communities, local government and State Government and be comparable with data collected from other Australian jurisdictions.

### 5.1.3 Future engagements

Future engagement will focus on:

- informing local communities and groups about preliminary geological assessments in the Otway Basin (2019) and Gippsland Basin (2020) prospective for conventional gas
- informing communities in the Otway and Gippsland basins about groundwater modelling
- sharing the results of the social research on understanding regional attitudes towards the potential development of onshore conventional gas in the Otway and Gippsland basins.

## 5.2 Resource and land use planning

Resource and land use planning activities are taking place to build on the Victorian Gas Program's geoscientific and environmental studies. These activities will help ensure that any future onshore conventional gas exploration only takes place where it is appropriate to the local context.

Existing and future land uses, landscapes and features across the Otway and Gippsland basins are being considered. This includes assessing key natural resources, and cultural, environmental, existing and future land uses, with a clear understanding of community views to ensure that the best land use options are adopted.

The project is being delivered in four key stages:

- Stage 1: develop a resource and land use inventory (completed)
- Stage 2: develop a resource and land use framework and model (completed)
- Stage 3: undertake a stakeholder and community workshops
- Stage 4: deliver final resource and land use planning recommendations for the Otway and Gippsland basins.

The project will:

- produce a land resource model that provides a visualisation of the areas of significance and sensitivity
- ensure existing and future land uses and landscape value sensitivities in areas most prospective for onshore conventional gas in the Otway and Gippsland basins are identified
- provide opportunity for community and stakeholders to review and provide input into the areas that are sensitive or hold significance, and how these might be assessed in relation to any potential onshore conventional gas industry
- recommend appropriate consideration of underlying land uses and values to be incorporated into future regulations and approvals for onshore conventional gas (if the moratorium was lifted)
- inform the policy and regulatory review aspect of the Victorian Gas Program by making recommendations for any regulatory reform to mitigate land use conflicts and promote multi and sequential use.

### 5.2.1 Methodology

A methodology for multi-criteria spatial analysis has been used to align with the best practice recommended by the Commission for Better Regulation in the Victorian Guide to Regulation (2014). This adopts principles from the Council of Australian Governments Energy Council's 'Multiple Land Use Framework', developed to address challenges arising from competing land use, land access and land use change. The aim is to enable government, community and industry to meet land access and use challenges, expectations and opportunities.



A detailed spatial land inventory has been prepared that identifies key natural resource, cultural, environmental and economic features. A framework has been developed, which consists of guiding principles/criteria and the weightings used to determine how the inventory data is to be assessed and applied.

The multi-criteria analysis process applies a set of guiding principles and weighted criteria (a framework) to the land inventory to produce a heat map that identifies sensitivity or significance hotspots (a model), which enables a suitability surface to be generated for any onshore conventional gas exploration.

## 5.2.2 Next steps

A community and stakeholder workshops will be delivered across the Otway and Gippsland basins. The focus is to present the model and gain community feedback on how land use values have been incorporated into the model, to ensure it reflects local values. This will provide an objective basis for stakeholders to test whether a feature or value warrants consideration as an area of significance or sensitivity. There will be an opportunity to amend and alter the model, and to consider feedback or further information received during this process.

## 5.3 Regulatory reform

Research undertaken by CSIRO (Moffat et al, 2017) has shown that key drivers of community attitudes to mining and petroleum production include procedural fairness and governance capacity. 'Procedural fairness' refers to communities and landholders having a genuine voice in approvals for projects and during industry operations. 'Governance capacity' is the extent to which communities believe regulatory frameworks and government regulators hold the industry to account. CSIRO's model demonstrates that in resources development, perceived procedural fairness and governance capacity are strong indicators of community trust in the industry, leading to greater acceptance of industry development and enduring social licence to operate (Moffat et al, 2017).

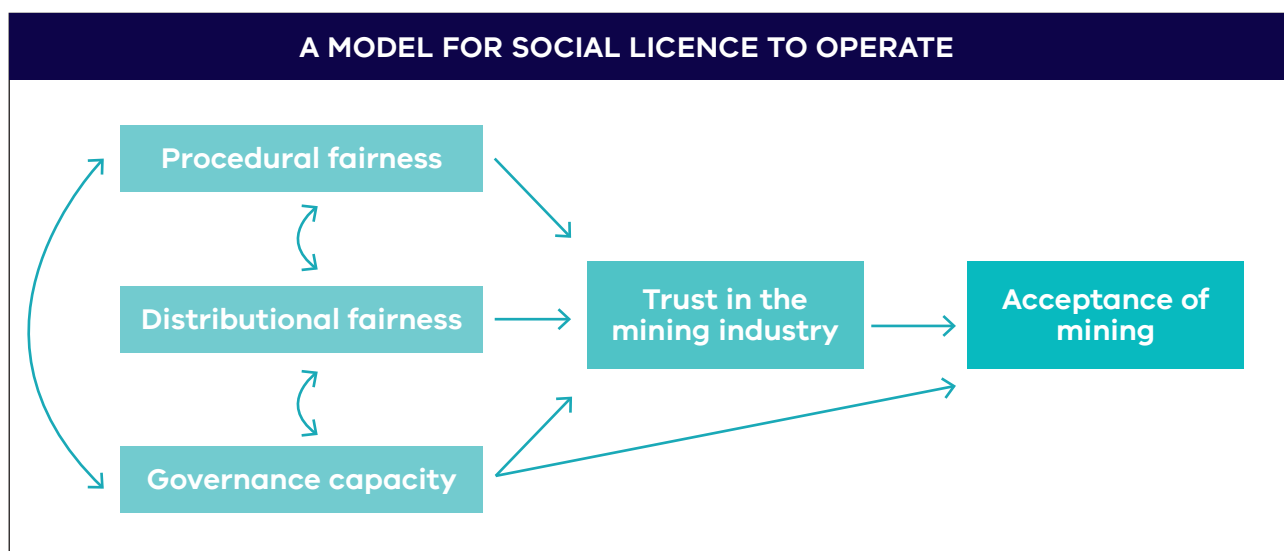


Figure 5.4 CSIRO attitudes to mining – a model for social licence to operate (adapted from Moffat et al, 2017).

The Victorian Gas Program has undertaken a desktop assessment of earth resources and onshore gas-related inquiries and reports to identify key regulatory areas of importance to communities and other stakeholders. The assessment extended to the identification of key regulatory gaps and inadequacies in these areas of the Petroleum Act 1998 and the associated Petroleum Regulations 2011 (the onshore petroleum regulatory framework), including jurisdictional review to identify current regulatory trends and leading practice. The gap analysis showed that while the onshore petroleum regulatory framework is relatively robust for managing environmental and safety risks, it could be improved in areas relating to:

- consideration and management of broader industry impacts on the economy, environment and communities in regulatory decision making
- community engagement obligations
- transparency of regulatory decisions and industry activities
- information asymmetries between industry and land holders.

The Victorian Gas Program is also considering regulatory reforms to address issues identified and to advise the government on future reform options. The potential regulatory reforms will complement the Victorian Gas Program geoscientific and environmental studies (see Sections 2.1 to 2.3), the risks, benefits and impacts assessment (see Section 2.5) and the community engagement program (see Section 5.1).

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## 7. Glossary

Term	Explanation
Basin	A geological depression filled with sediments.
Exploration	The phase of operations in which a company searches for oil or gas by carrying out detailed geological and geophysical surveys, followed up where appropriate by exploratory drilling in the most prospective locations.
Fault	A break or planar surface in a brittle rock across which there is an observable displacement.
Hydrocarbons	Organic compounds consisting entirely of hydrogen and carbon. Hydrocarbons are the principal components of oil and natural gas.
Permeability	The degree to which gas or fluids can move through a rock.
Petroleum	Liquid, gaseous and solid hydrocarbons; includes oil, natural gas, gas condensate, ethane, propane, butane and pentane.
Play	An area in which hydrocarbon accumulations or prospects of a given type occur.
Porosity	The amount of pore space in between the grains in a rock that are available for air, water, other fluids or gas to be stored.
Production	The phase of bringing well fluids to the surface and separating them, and storing, gauging and otherwise preparing the product for transportation.
Prospective resources	Petroleum that is potentially recoverable from undiscovered accumulations.
Prospectivity	An assessment, whether qualitative or quantitative, of the potential for prospective resources.
Reservoir	A rock or geological formation that may hold petroleum within the pore spaces in the rock.
Seal	An impermeable rock that forms a barrier or cap above reservoir rocks such that fluids cannot migrate beyond the reservoir.
Source rock	A rock rich in organic matter, which, if heated sufficiently and placed under sufficient pressure, will generate oil or gas.
Trap	Any barrier to the upward movement of oil or gas, allowing either or both to accumulate.

Source: APPEA (2019); Geoscience Australia (2019); Schlumberger (2019); SPE international (2019).

# Appendix 1: Stakeholder Advisory Panel for Onshore Conventional Gas communiques

## Communique 1 – August 2017

On 17 August 2017, I chaired the inaugural meeting of the Stakeholder Advisory Panel for onshore conventional gas studies, which is part of the State Government's Victorian Gas Program (<http://earthresources.vic.gov.au/earth-resources/victorian-gas-program>).

The Panel has been established by the [former] Minister for Resources, the Hon. Wade Noonan, to oversee the onshore conventional gas geoscientific and environmental studies over the next three years.

The role of the Panel is to provide the Minister for Resources with advice on the risks, benefits and impacts related to onshore conventional gas, with particular attention paid to social, economic and environmental factors.

The Panel will meet regularly over the next three years and includes a broad range of views, including farmers, industry, local government and the community. Panel members are able to provide feedback from the community and other stakeholders as the studies are undertaken.

The Panel members appointed are:

- Mr Stephen Bell, Chief Executive Officer, Genos
- Mr Ben Davis, Secretary Australian Workers' Union Victorian Branch
- Mr Gerald Leach, Chair of the Victorian Farmers' Federation Land Management Committee
- Ms Alison Marchant, Secretary of Frack Free Moriac
- Ms Linda French, Community Development Manager, Lattice Energy (formerly Origin Energy)
- Mr Tennant Reed, Principal National Adviser, Public Policy, Australian Industry Group
- Cr Joanne Beard, Mayor of Corangamite Shire and representative of the Great South Coast Group
- Mr Mark Wakeham, Chief Executive Officer, Environment Victoria

Minister Noonan welcomed the panel at its inaugural meeting. For the benefit of the panel, the Minister reiterated the course the Victorian Government had taken to legislate to permanently ban hydraulic fracturing (fracking) and coal seam gas, while extending the moratorium on onshore conventional gas to 30 June 2020. He said the moratorium would allow time for a scientific program to assess the potential onshore conventional gas resources of the State. The program will include environmental baseline studies and the community will be actively engaged over the life of the studies. The results of the study and the panel's work would help guide future decisions about the prospects for onshore conventional gas exploration and development beyond the middle of 2020.

During the meeting, representatives from Geological Survey of Victoria (GSV), the Government's geoscience unit, gave a briefing on the schedule of onshore conventional gas geoscientific and environmental studies that will be conducted.

The focus of the studies will be on the Otway Basin in South-West Victoria, particularly between Warrnambool and Port Campbell. The GSV has identified this area as having the greatest potential for onshore conventional gas. Some studies will be done in the Gippsland Basin, although based on existing data, the GSV considers this basin to be less likely to hold onshore conventional gas resources than the Otway Basin.

The geoscience studies will involve rock characterisation studies and analysis of current geoscience data. The results will assist in the development of 3D models for the Otway and Gippsland geological basins. The environmental studies in the field will provide baseline data on groundwater chemistry and atmospheric conditions across the Otway and Gippsland basins.

GSV representatives emphasised the importance of community engagement to support the geoscientific and environmental studies. This included insights of engagement activity undertaken to date with local regional councils, community groups, peak industry bodies, water catchment management authorities, gas exploration companies and academics.

An important part of the community engagement program is to progressively provide the results of the studies to the public. Factual information from the studies will be provided to farmers, industry, local government and regional communities. A local team of geology specialists and a dedicated community engagement officer based in Warrnambool will ensure the community remains involved and informed about the studies. In practical terms, this means that there are people on the ground who can answer questions for local residents and landholders.

As Victoria's Lead Scientist and panel chair, I am looking forward to working with the Panel over the next three years. I am sure the advice we will provide the Minister will assist the Government to make the best decisions possible about onshore conventional gas for all Victorians.

For more information visit the Victorian Gas Program on the Earth Resources website at <http://earthresources.vic.gov.au/earth-resources/victorian-gas-program>.

## Communique 2 – November 2017

The second meeting of the Stakeholder Advisory Panel for onshore conventional gas studies was held in south-west Victoria on 9 and 10 November 2017 at Port Campbell and Camperdown and surrounding areas. This region of Victoria in the Otway geological basin is a focus of the Victorian Gas Program.

The meeting commenced on 9 November 2017 with a visit to the Otway Gas Plant and the Halladale and Speculant Well site, near Port Campbell.

The tour of Origin Energy's facility provided the Panel with a first-hand view of a gas processing plant. Origin Energy representatives explained how the facility's design and operational procedures ensure stringent health, safety and environment regulations are met.

The Panel then moved to Nirranda to see the Victorian Gas Program groundwater science team in action, sampling and recording trace chemistry at a groundwater monitoring bore as part of the environmental baseline studies of the Program.

On 10 November 2017, the second day of the Stakeholder Advisory Panel's meeting was held in Camperdown.

The discussions covered progress reports on the geoscientific studies, environmental studies and community and stakeholder engagement to date.

The Panel received a briefing on the \$1.62 million 3D geological models of the Otway Basin (onshore and offshore) that will be built and how they form the foundation for providing a gas resource estimate. The Panel heard that rock characterisation studies (including chemostratigraphy, porosity and permeability analysis) – key inputs into the 3D geological models – have also commenced.

The onshore environmental science project intends to sample over 100 deep groundwater bores and undertake an atmospheric methane survey to establish regional baseline conditions during 2017 and 2018. To date, 14 water bores have been sampled.

Later in 2018, the environmental program will also investigate existing exploration wells to determine more local baseline conditions.



The Stakeholder Advisory Panel at the Otway Gas Processing Plant.





**The Stakeholder Advisory Panel learning about the groundwater monitoring program.**

The overview of the engagement program highlighted that over 80 individual engagements have occurred to date, covering local governments, gas explorers, gas users, regulators and environmental and community groups. Most engagements have been one-on-one discussions and small group meetings. As the Geological Survey of Victoria Warrnambool team reaches full complement more sophisticated engagements and presentations will commence.

Five media articles about the Victorian Gas Program had been featured in newspapers in south-west and regional Victoria since the program was announced. Additionally, while the Stakeholder Advisory Panel was in Camperdown, I gave an interview to ABC South-West regional radio about the Panel's work.

The Panel's review of the projects to date is providing valuable insights and suggestions to ensure that the scientific studies are meeting the concerns and interests of the various stakeholders connected to the onshore conventional gas studies.

**The next Stakeholder Advisory Panel meeting is scheduled for March 2018.**

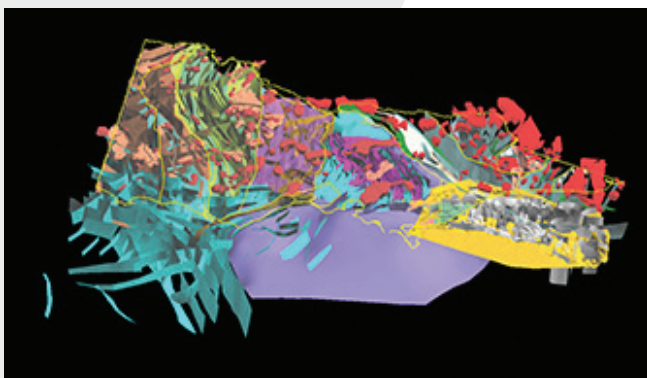
## Communique 3 – March 2018

**The third meeting of the Stakeholder Advisory Panel for the Victorian Gas Program's Onshore Conventional Gas Studies was held in Melbourne on Thursday, 8 March 2018.**

The meeting commenced with a presentation from the Geological Survey of Victoria on the current 3D geological models of the Otway and Gippsland basins. These models capture the sub-surface structure of each basin and will ultimately provide a picture of the presence of onshore conventional gas resources.

A significant objective of the Victorian Gas Program is to refine the current models through seismic data analysis together with rock characterisation studies to produce a much more detailed understanding of each basin's geological structure. The Geological Survey of Victoria is currently presenting these 3D geological models to councils in South-West Victoria to explain the scientific approach being taken by the Victorian Gas Program.

At the meeting, Panel members discussed the national gas market, the contribution of Victoria's offshore gas resources, and the possible impact of any onshore conventional gas resources identified through the Victorian Gas Program on gas supply and pricing. I acknowledged that the scientific work being undertaken is at a very early stage and highlighted that it will provide the State with the best picture of Victoria's potential for onshore conventional gas resources. This information will assist government to make future evidence-based decisions about any development of onshore conventional gas resources.



**Geological model of rock outcrops across Victoria**



**Public attending one of the Geological Survey of Victoria's 3D model presentations at Sungold Field Days**

The use of gas as an energy source in the context of the state's carbon emission targets and commitments on climate change was also discussed. A consolidated picture of how government is improving energy efficiency in businesses and households to reduce demand, including initiatives to increase supply of renewable energy, is being prepared to inform the Panel.

A major task of the Panel is to eventually provide government with advice on the risks, benefits and impacts of onshore conventional gas. At the meeting, the Panel began to consider the scope of work needed to be undertaken for this study. An initial environmental risk assessment framework was tabled for Panel members to consider. The study's scope will receive independent expert advice from the Scientific Reference Group throughout the Program.

The Director of Geological Survey of Victoria updated the Panel on the progress of the Victorian Gas Program. Key highlights included:

- Following months of data review and planning, the geoscience team is in the process of selecting rock samples for analysis of source, seal and reservoir rocks (necessary components of a petroleum resource system). Approximately 1400 samples have been selected for analysis, and a further 1700 samples will be analysed to establish mineral and fossil content.
- The environmental studies team has now sampled 25 groundwater bores for chemistry content and 42 bores for stygofauna (a miniature creature that may indicate the health of groundwater) in South-West Victoria. Groundwater bore testing will begin in Gippsland in late April, and air quality surveying in the Otway Basin is expected to begin in April. This data will help to establish the existing environmental baseline conditions, which would provide a benchmark for considering the potential risks and impacts of conventional gas activities.

- To support commercial exploration for further discoveries of gas off Victoria's coast an airborne gravity survey of the Otway Basin will be undertaken. The survey will measure minute differences in gravitational force from different rock strata both onshore and offshore. The data collected will provide a data set of varying rock densities across the basin.
- The community engagement program continues to connect with strategic stakeholders in South-West Victoria and Gippsland. A major community engagement initiative was held at Sungold Field Days, one of the largest agricultural shows in South-West Victoria, in February 2018. A marquee cinema showing 3D projections of Victoria's geology was set up to show the geology of the Otway Basin and introduce the VGP to farmers, students and community groups.

**The next Stakeholder Advisory Panel meeting will be held in June 2018.**

## Communique 4 – June 2018

The fourth meeting of the Stakeholder Advisory Panel for the Victorian Gas Program's (VGP) Onshore Conventional Gas Studies was held in Melbourne on Thursday, 7 June 2018.



**I was delighted to talk about the Victorian Gas Program in April to over 70 members from the Business and Professional Women South West Association at Deakin University Warrnambool campus.**

The Minister for Resources, Tim Pallas, opened the meeting and reinforced the Panel's key role in understanding and discussing the VGP's scientific findings and the risks, benefits and impacts of any onshore conventional gas development. He highlighted the importance of informed debate and the need for government to understand both the needs of industry and the diversity of views across the community.

The Minister responded to a range of questions from the Panel on regulatory issues such as landowner rights and community benefits, including how best to secure domestic supply from local resources. He also addressed contextual issues such as government's commitment to CO<sub>2</sub> emission reduction targets, how we manage the transition from coal to renewable energy technologies and the need for greater transparency in energy distribution and retail markets.

The Minister was followed by Ms Kylie White, Deputy Secretary, Energy, Environment and Climate Change in the Department of Environment, Land, Water and Planning (DELWP). Ms White reiterated the Victorian Government's commitment to an affordable, reliable and renewable energy future – with legislated targets and support for transition to zero (net) emissions by 2050. Ms White confirmed that Victoria is on track to achieving the Victorian Renewable Energy Target of 25% by 2020 with renewables producing over 16 per cent of Victoria's electricity in 2017, up from around 11 per cent in 2014. She provided an overview of current initiatives such as the *Energy Efficiency and*

*Productivity Strategy*, the *Renewable Energy Action Plan*, the *Victorian Renewable Energy Target Program Reverse Auction* and the *Victorian Energy Upgrades* program.

Ms White responded to questions from Panel Members who sought to understand how government is working with industry to reduce gas demand; clarification of the definition of zero emissions; and government plans to respond to the capacity of different sectors to transition from fossil fuels faster than others.

The Director of the Geological Survey of Victoria (GSV) advised the Panel that the VGP's scientific work is on schedule. The new 3D geological framework model for the Otway Basin is only a few months away. The geoscience team will next focus its efforts on filling critical knowledge gaps through a 'stratigraphic' drilling program to provide new rock samples for analysis.

He also advised that the baseline air quality surveying (measuring methane and carbon dioxide concentrations) of the Otway Basin, has commenced and will continue until July 2018.

The panel was also updated on several upcoming VGP announcements, including:

- a collaborative project between GSV and the Iona Gas Plant, near Port Campbell, to share analytical drill core data that could assist in understanding the potential for storing gas in depleted onshore gas fields in the area, and
- details of the supplier, timing and flight area of an airborne gravity survey of south west Victoria to better understand the regional, large-scale geology of the Otway Basin, both onshore and offshore.

The geoscience overview was followed by a community engagement update. The reach of the program to date now includes 290 stakeholders across south west Victoria, Melbourne and Gippsland.

GSV has presented its 3D geological models to Councillors across the Otway Basin and briefed Mayor and Chief Executive Officers across Gippsland on the VGP. Other regional networks such as farmer organisations, catchment management authorities, environmental groups, economic development associations and community groups have also been engaged.

**The next Stakeholder Advisory Panel meeting will be held in September 2018.**

## Communique 5 – September 2018

### **The fifth meeting of the Stakeholder Advisory Panel (SAP) for the Victorian Gas Program's (VGP) Onshore Conventional Gas was held in Camperdown on Thursday, 6 September 2018.**

The Panel received their first briefing on the VGP's regulatory reform project, which will develop policy, administrative and legislative reform proposals for Government once the broader scientific findings regarding the potential for onshore conventional gas are known.

The presentation covered the Government's current policy on gas, including the moratorium on onshore conventional gas in place until mid-2020. It detailed the legislative and regulatory controls currently in place through the Victorian Petroleum Act 1998 and Petroleum Regulations 2011 and where there might be opportunities to harmonise regulatory frameworks.

The onshore conventional gas regulatory reform program will include assessing best practice arrangements around gas exploration and production from other jurisdictions (including other Australian states and territories, New Zealand, North America, Canada and Europe) and recommendations from relevant reviews and inquiries. There is also potential for a social baseline assessment to be undertaken as part of building an evidence base of community attitudes to future gas exploration.

Panel members identified that landholders often had little knowledge about their rights and regulatory processes when dealing with gas explorers and developers, suggesting the need for better information products to support landholders. Members also discussed the lengthy time scale of resources projects and how communities would often be concerned about environmental impact and land rehabilitation. It was also suggested the regulatory reform program should look at the Victorian Pipelines Act 2005 to evaluate if the Act's provisions for dealing with landholders were superior to the Petroleum Act 1998.

Panel members recommended that as the Gippsland and Otway Basins were the focus of the VGP, workshops on how gas exploration and production were regulated should be prioritised for communities in those regions.

The Panel was updated on VGP activities including:

- the airborne gravity survey currently underway in South-West Victoria, including the engagement and community awareness campaign
- the completion of the rock sampling data collection phase, and the commencement of the analysis of source, seal and reservoir rock measurements
- progress on building the petroleum systems model, combining all available new and existing data and interpretations to estimate hydrocarbon resources (gas) in the Otway Basin
- 50% completion of groundwater bore sampling for chemistry in South-West Victoria, providing data that will assist to build a gas field groundwater impact assessment scenario model
- progress on the regional air quality survey program of the Gippsland and Otway Basins
- engagement of over 500 individual stakeholders across South-West Victoria, Melbourne and Gippsland through more than 420 events (i.e. briefings, meetings, forums, emails and telephone calls)
- progress on the geoscientific assessment of underground gas storage potential of depleted reservoirs around Port Campbell.

Following the meeting, a number of SAP members attended the official opening of the Geological Survey of Victoria's South West Regional Office at Deakin University Warrnambool. The office is undertaking a range of VGP scientific studies and engaging with the community.

**The next Stakeholder Advisory Panel meeting will be held in November 2018.**

*(Please note: The November 2018 Stakeholder Advisory Panel meeting was postponed due to the Government being in caretaker mode prior to the State Election.)*

## Communique 6 – February 2019

**The sixth meeting of the Stakeholder Advisory Panel for the Victorian Gas Program (VGP) Onshore Conventional Gas Studies was held in Melbourne on Thursday, 14 February 2019.**

Minister for Resources, Jaclyn Symes, spoke at the beginning of the meeting via teleconference. The Minister's remarks included her appreciation for the work of panel members in bringing diverse perspectives and advice on the issue of onshore conventional gas.

As scientists at the Geological Survey of Victoria gather and model the available data on the Otway Basin, critical gaps in information have emerged. The VGP provides scope for stratigraphic drilling to fill such data gaps and better understand rock layer changes across the basin. The Panel received their first briefing on how the VGP would prepare to undertake this work. Panel members asked questions about the need for undertaking the drilling activity and the benefit it would provide in terms of data and information. Questions were also raised about risks and how they would be mitigated, including engagement with the local community. A decision on whether to proceed with stratigraphic drilling will be taken later this year.

Late in 2019, the onshore areas of the Otway Basin with potential for conventional gas resources will be known. These areas will then be the focus of Resource Land Use Planning studies to understand the unique environmental, social and economic land use features of each area. The Panel was briefed on the methodology and process planned to undertake these assessments.

Amanda Caples and Corangamite mayors Victorian Gas Program hydrogeologists spent time at Sungold Field Days agriculture event in February, talking to farmers and others about groundwater in South-West Victoria.



- Completion of the airborne gravity survey across 16,000 km<sup>2</sup> of South-West Victoria, identifying extremely small variations in the earth's gravitational field. The interpreted data will be publicly available later in the year.
- Continuing geoscientific analysis and interpretation of new and existing rock measurements. The results will be incorporated into the petroleum systems modelling, along with existing data and interpretations, to help provide an estimate of hydrocarbon (gas) resources in the Otway Basin.

- Progress of sampling groundwater bores in south-west Victoria. A groundwater sampling campaign will commence in Gippsland in March 2019. The collected data will provide a comprehensive baseline of current groundwater conditions and will improve the understanding of groundwater processes.
- Completion of the second atmospheric baseline survey for Gippsland and South-West Victoria. The results were similar to the first survey round with slight increases of methane concentrations in urban areas, cattle yards and proximity to native vegetation burn off. Raised methane concentration readings were also repeated around the Port Campbell gas storage facility. All concentrations were well below EPA guidelines.
- Commencement of a desktop review of socio-economic and environmental receptors. These receptors will provide the baseline data to underpin a risk, benefit and impact assessment of a hypothetical onshore conventional gas development, once the detailed findings of the geoscientific and environmental studies are known.
- Engagement with over 580 individual stakeholders across south-west Victoria, Melbourne and Gippsland through more than 480 events (i.e. briefings, meetings, forums, emails and telephone calls).
- Commencement of detailed geoscientific assessment of the depleted gas reservoirs in the Port Campbell area. This work will continue to rank and differentiate the depleted reservoirs regarding their potential storage capabilities.

**The next Stakeholder Advisory Panel meeting will be held in May 2019.**

## Communique 7 – May 2019

The seventh meeting of the Stakeholder Advisory Panel for the Victorian Gas Program's (VGP) Onshore Conventional Gas Studies was held in Camperdown on Thursday, 9 May 2019.

Victoria's Lead Scientist and Chair of the Stakeholder Advisory Panel, Dr Amanda Caples, opened the meeting and welcomed newly appointed panel member Jonathan La Nauze, Chief Executive Officer Environment Victoria. Dr Caples also provided details of her activities since the last Panel meeting including attendance at the Australian Domestic Gas Outlook conference and a meeting with Friends of the Earth and Environment Victoria representatives to be briefed on key Victorian Gas Program activities.



**Groundwater sampling.**

Key presentations to the Panel included:

1. An update on the progress of the Resource Land Use Planning studies, which will assist in understanding the unique environmental, social and economic features of each prospective resource area (a zone with the geology to potentially host conventional gas) identified by the VGP's studies. The Panel will be involved in a workshop to determine the criteria and value weightings for the land use framework at its next meeting.
2. A briefing on the commencement of a case study regarding the risks, benefits and impacts of the Otway Basin gas production and processing facility in Port Campbell. This work will inform the next phase of work, which is a risk, benefit and impact assessment of hypothetical onshore conventional gas developments, based on the outcomes of the VGP's studies.
3. An update on potential policy and regulatory reform development, including the preliminary identification of practices to improve a social licence to operate, along with an assessment of the adequacy of the current regulations to manage these areas. Initial findings indicate that the regulations are quite robust but with potential areas for improvement, including; community and landholder engagement as well as transparency of industry activities.
4. An update on the stratigraphic drilling project to fill in key geological data gaps in the northern part of the onshore Otway Basin. If the project proceeds, an extensive community engagement program would be undertaken. Members discussed the proposed communications and engagement activities and raised queries about how climate change factors would be acknowledged.

Panel members were also updated on other VGP activities including:

- The start of the release of technical reports on new data acquired from the geoscientific studies of the Otway Basin.
- The completion of the data acquisition phase of the airborne gravity survey of the Otway Basin. The data will improve interpretation and visualisation of the deep rocks and structures of the Otway Basin.
- Deep groundwater bore sampling in the Otway Basin is now finished, and sampling in the Gippsland Basin is nearing completion.
- Scientific studies investigating the potential to expand Victoria's underground gas storage capacity are progressing well. Several depleted gas fields around Port Campbell are being assessed in terms of their geophysics, geology and commerciality for repurposing to provide underground gas storage.
- The potential timing for the announcement of preliminary resource areas for the Otway geological basin. Panel members discussed and made recommendations about a communications and engagement approach to support the announcement.
- To date, over 620 individual stakeholders have been engaged across south-west Victoria, Melbourne and Gippsland through more than 550 events (i.e. briefings, meetings, forums, emails and telephone calls).









