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Geology and hydrocarbon prospectivity of the deepwater Otway and Sorell basins, offshore southeastern Australia

Andrew Stacey, Cameron Mitchell, Heike Struckmeyer and Jennifer Totterdell

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by

Andrew Stacey, Cameron Mitchell, Heike Struckmeyer and Jennifer Totterdell



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Executive Summary

As part of the Offshore Energy Security Program (2007–2011), Geoscience Australia (GA) undertook an integrated regional study of the deepwater Otway and Sorell basins to improve the understanding of the geology and petroleum prospectivity of the region. Major outputs of this study include:

- New interpretations of basement architecture and structural fabric resulting in the recognition of the Avoca–Sorell Fault System as a major control on sedimentary basin development,
- Extension of the tectonostratigraphic framework of Krassay et al. (2004) into the deepwater Otway and Sorell basins, leading to new insights into the structural and accommodation histories of both basins, and
- Petroleum systems modelling indicating that these basins are mature for oil and gas generation.

The under-explored, frontier deepwater Otway and Sorell basins lie in water depths of <50–4,500 m, offshore of southwestern Victoria and western Tasmania. The basins contain up to 10 km of Cretaceous–Cenozoic sediments and lie adjacent to producing areas of the Otway Basin, including the Shipwreck Trough. Significant changes in basin architecture and depositional history from west to east reflect the transition from an orthogonal–obliquely rifted continental margin (western–central Otway Basin) to a transform continental margin (southern Sorell Basin).

Building on previous GA basin studies, new aeromagnetic data, open-file potential field, seismic and exploration well data have been integrated to develop new interpretations of basement structure and sedimentary basin architecture.

These investigations indicate a reactivated north–south Paleozoic shear zone (Avoca–Sorell Fault System) controlled the transition from extension through transtension to a dominantly strike-slip tectonic regime in this part of the southern margin. Depocentres to the west of this structure are large and deep in contrast to the narrow elongate depocentres to its east.

New seismic interpretations have shown the depositional sequences hosting active petroleum systems in the producing areas of the Otway Basin are also likely to be present in the southern Otway and Sorell basins. 2D petroleum systems modelling along two seismic lines across the southern Otway/northern Sorell basin and the Strahan Sub-basin suggests that if the equivalent petroleum systems elements are present, then they are mature for oil and gas. Generation and expulsion occurred mainly in the Late Cretaceous in the southern Otway/northern Sorell basins and during the Paleocene in the Strahan Sub-basin. The results of this study highlight the complex history of these basins, addressing many of the questions regarding the geological controls on their development and petroleum prospectivity.

1. Introduction

SCOPE AND STUDY AIMS

During the early 2000s the Otway and Sorell basins were the focus of renewed exploration interest by companies such as Origin, Santos, Woodside and Perenco. However, by 2009 it was clear that as a result of current and future relinquishments large areas of these basins were likely to be available for acreage release from 2011 onwards. Geoscience Australia (GA) undertook a comprehensive study of the onshore and offshore Otway Basin in 2002–2004 (Krassay et al., 2004); however, the last major work done by GA and its predecessors on the Sorell Basin was in the early 1990s. Since the time of those studies, extensive new geophysical data sets have become available and/or have been acquired over the deepwater Otway and the Sorell basins. By building on previous GA basin studies and on recently published petroleum systems models, the addition of this new data provided an opportunity to advance the regional understanding of the stratigraphic and structural architecture of these basins and their petroleum systems.

Recent work on petroleum systems in the Otway Basin (O'Brien et al., 2009) suggests there is potential for good quality marine source rocks to be present in the Late Cretaceous Shipwreck and Sherbrook supersequences in the deepwater, distal parts of the basin outboard of the Tartwaup–Mussel Fault Zone. The basin study undertaken by Krassay et al. (2004) showed that these sequences thicken into the deepwater basin. In addition, recent work by GA in identifying a new Cenomanian–Turonian marine source rock in the adjacent Bight Basin has significant implications for the petroleum prospectivity of the adjoining deepwater Otway Basin.

The Otway Basin developed in a predominately extensional tectonic regime leading up to and following Australian–Antarctic break-up, whereas development of the Sorell Basin was strongly influenced by a transcurrent tectonic regime on the transform portion of the southern margin. Transform margins are typically characterised by deep, narrow strike-slip basins, often with enhanced petroleum potential. Extending the existing seismic interpretation to the south, and using the new potential field data to constrain the geological model, enabled us to improve our understanding of the structural and stratigraphic framework, and potential petroleum systems of these basins.

This study covers an area from the Nelson Sub-basin of the central Otway Basin to the Strahan Sub-basin of the Sorell Basin (Figure 1.1). The study is based on the interpretation of an extensive seismic data set across this area. The key seismic data sets used were the regionally extensive Fugro DS01 and DS02 surveys, which cover the eastern Otway and northern Sorell basins (Figure 1.1). These were tied to seismic surveys in the Strahan Sub-basin via the Santos SS04 survey. Eleven exploration wells were used to tie biostratigraphically constrained well picks to the seismic data. (Figure 1.1) The stratigraphic interpretation utilised the Otway Basin sequence stratigraphic framework of Krassay et al. (2004). Potential field data, including new aeromagnetic and gravity was modelled to determine the structural elements and depth to basement (Morse et al., 2009; Nayak et al., 2010). GoCAD software was utilised to visualise the basin in 3D, to test the structural model and to incorporate the regional basement interpretation developed from the potential field data.

PREVIOUS WORK

The study area is well covered by a variety of geological and geophysical datasets. The earliest work conducted in the deepwater Otway and Sorell basins was in the mid–late 1960s by Hematite and Esso who acquired 625 miles of seismic data followed by the drilling of three exploration wells (Prawn 1, Clam 1 and Whelk 1). Two additional well were drilled in the area, DSDP Leg 29 (Site 282, Kennett et al., 1975) and ODP Leg 189 (Site 1168, Exon et al., 2001a & 2001b). Regional seismic data was acquired over both basins by Shell in 1972 using the M/V *Petrel* (Shell, 1972; Boeuf and Doust, 1975). GA's predecessors (AGSO and BMR) conducted several seismic, geological and geophysical surveys across the region in the 1970s–80s (Exon and Lee, 1987); these included a sparker survey (Survey 16, Tilbury, 1974) and two airgun surveys (Survey 48, Exon and Lee, 1987; Survey 78, Exon et al., 1989). The Bundesanstalt fuer Geowissenschaften und Rohstoffe (BGR) acquired approximately 1,000 km of data over the Sorell Basin in

1985 using the German R/V *Sonne* (Hinz et al., 1986), while in 1994 AGSO conducted Survey 137 acquiring approximately 3,500 km of regional deep seismic and other geophysical data across the offshore Otway Basin (O'Brien et al., 1994; Blevin et al., 1995). These geophysical and other datasets have underpinned a large body of research into the prospectivity, tectonic setting, sedimentology and architecture of the Otway and Sorell basins. Key literature includes: Hinz et al., 1986; Moore et al., 1992; Conolly and Galloway, 1995; Hill et al., 1997; Moore et al., 2000 and Exon et al., 2001 a & b.

In the last decade, four key studies have provided insights into the geology and hydrocarbon prospectivity of the region. Two of these studies focussed on the Strahan Sub-basin of the Sorell Basin; Boreham et al. (2002) assessed the petroleum prospectivity of the sub-basin based on new palynology, geochemistry and thermal history data, and O'Brien et al. (2004) looked at evidence of active petroleum systems in the area. In the Otway Basin, the sequence stratigraphic framework presented by Krassay et al. (2004), provided an integrated and predictive model for the tectonostratigraphic evolution of both onshore and offshore areas of the basin. Most recently, O'Brien et al. (2009), in an analysis of critical success factors for petroleum exploration in the Otway Basin, discussed the nature and distribution of known and potential petroleum systems in the Otway Basin, and suggested that Austral 3 source rocks are likely to be present in the deepwater basin.

DATA COVERAGE

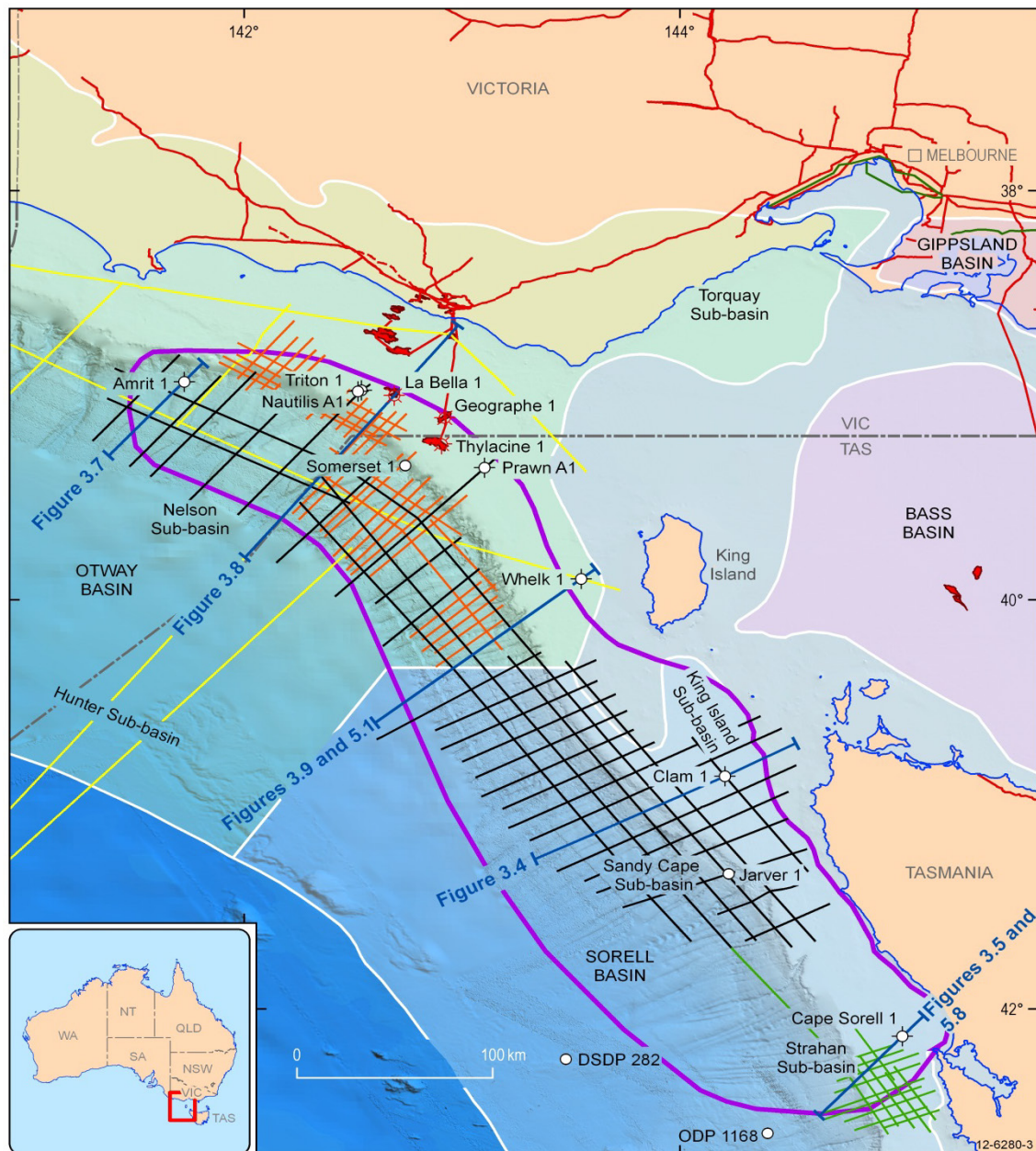
Several exploration wells have been drilled along the shelf-edge of the Otway Basin however, the slope and deepwater areas are relatively unexplored (Figure 1.1). The only two wells to have tested the potential of the deep water are Amrit 1 (2005) drilled by Santos in 1,396 m of water, and Somerset 1 (2009), which was drilled by Woodside Energy Limited in 503 m of water to test the Voluta Trough underlying the slope.

Exploration in the Sorell Basin has been focused on the northern sub-basins, where three petroleum exploration wells have been drilled: Clam 1 (1969) in the King Island Sub-basin, Cape Sorell 1 (1982) in the Strahan Sub-basin, and Jarver 1 drilled in May 2008 by Santos in the Sandy Cape Sub-basin. In addition to the petroleum exploration wells, a Deep Sea Drilling Project site (DSDP 282) and an Ocean Drilling Project site (ODP 1168) were located on the continental slope west of the Strahan Sub-basin.

Seismic coverage of both areas is a mixture of government and industry exploration grids. In 2001 Seismic Australia and Fugro-Geoteam AS acquired 3,612 and 2,034 line-km of non-exclusive seismic data over the deepwater Otway and northern Sorell basins (DS01 and DS02 surveys respectively), driving new exploration activity in the region. This new phase of exploration resulted in the acquisition of new 2D and 3D seismic data in addition to the reprocessing of a number of the older 2D surveys. Seismic coverage south of the Strahan Sub-basin is extremely sparse.

Numerous potential field datasets are available for the area. Gravity data has mostly been acquired in conjunction with seismic surveys, which become very sparse south of the Strahan Sub-basin. Over 70,000 line kilometres of aeromagnetic data was acquired by Geoscience Australia and Mineral Resources Tasmania over the West Tasmanian Margin in 2008. These data were merged with onshore aeromagnetic datasets to create a near continuous coverage of southeastern Australia (Morse et al., 2009).

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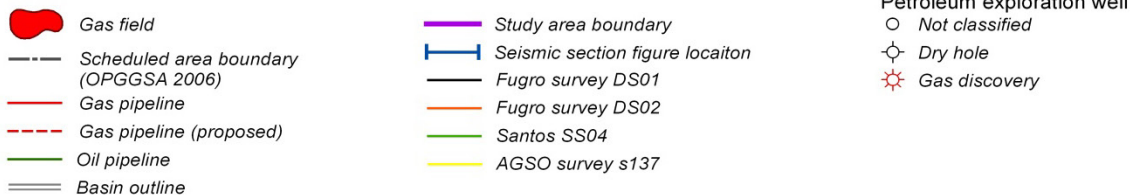


Figure 1.1: Location of study area, showing basin boundaries, wells and key seismic data sets.

2. Regional Geology

REGIONAL SETTING

Australia's southern rifted continental margin extends for over 4,000 km, from a structurally complex region south of the Naturaliste Plateau in the west, to the transform plate boundary adjacent to the South Tasman Rise in the east (Totterdell, 2012; [Figure 2.1](#)). The margin contains a series of Middle Jurassic to Cenozoic basins that developed during the break-up of eastern Gondwana—the Bight, Otway, Sorell, Gippsland and Bass basins, and smaller depocentres on the South Tasman Rise (STR; [Figure 2.1a](#))—and which together comprise the Southern Rift System (Stagg et al., 1990; Willcox and Stagg, 1990). The margin evolved through repeated episodes of extension and thermal subsidence leading up to, and following, the commencement of seafloor spreading between Australia and Antarctica (Totterdell and Bradshaw, 2004).

Initial NW–SE ultra-slow to slow seafloor spreading (latest Santonian–Middle Eocene), followed by N–S directed fast spreading, resulted in an oblique to normal rifted margin that extends from the westernmost Bight Basin to the central Otway Basin, a transform continental margin in the east (western Tasmania–STR), and a transitional zone between those end-members (southern Otway–Sorell basins) (Totterdell et al., 2011; [Figure 2.1b](#)). This margin segmentation appears to have been strongly controlled by the pre-existing basement architecture. The oblique–normal rifted margin is characterised by a broad zone of lithospheric thinning and thick extensional basin development (Totterdell et al., 2011). In the Bight and Otway basins, a well-developed distal ocean–continent transition zone includes basement highs interpreted as exhumed sub-continental lithospheric mantle (Totterdell et al., 2012). In the eastern part of the margin, where transcurrent stresses controlled deformation, lithospheric thinning is not as marked and the continent–ocean boundary combines rift and transform elements (Totterdell et al., 2011). In this part of the margin, NW–SE to NE–SW oriented extension resulted in the development of strongly transtensional basins. In the southern Sorell Basin and STR, the Tasman Fracture Zone forms the continent–ocean boundary.

BASEMENT ARCHITECTURE

The southern margin is underlain by a diverse suite of basement terranes that played an important role in both focusing initial extensional strain and determining the ultimate rifted margin architecture. In the western and central parts of the margin, Archean to Neoproterozoic basement architecture, structure and rheology influenced the segmentation of the rift, and the location and orientation of rift segments (Gibson et al., 2012). In the eastern part of the margin, the change from a roughly E–W oriented rifted margin to a N–S oriented transform margin was largely controlled by the strong N–S structural fabric of the underlying Neoproterozoic–Early Paleozoic fold belts (Gibson et al., 2011).

Northwest-trending half graben underlie much of the western Otway Basin, pointing to a common structural control and possible continuation of Archean and/or Proterozoic basement rocks eastwards beneath the Lower Paleozoic Delamerian Fold Belt and overlying Mesozoic rift basins (Gibson et al., 2012). These basins extend as far east as the Shipwreck Trough off western Tasmania where there is an abrupt change in basin geometry from NW- to dominantly north–south or NE-trending structures (Sorell and eastern Otway basins; [Figure 2.2](#)). This switch in basin geometry is also evident onshore and coincides with a west-dipping, crustal-scale, Paleozoic structure (Avoca Fault System) that forms the western boundary of a poorly exposed Proterozoic basement terrane in central Victoria (Selwyn block) and continues southward into the Tasman Fracture Zone (Gibson et al., 2012). Gibson et al. (2011) proposed that this basement terrane is a northward continuation of the Proterozoic Tyennan block in western Tasmania and, like the latter, may have originated elsewhere and been accreted to the Australian continent during the closing stages of the lower Palaeozoic Delamerian orogeny. Delamerian orogenesis broadly followed the contours of the earlier-formed Neoproterozoic (Rodinia) continental rifted margin and can be traced westward and northward along NE- and NW-trending segments of this former margin that match the trend of half-graben and basin-bounding normal faults in the Bight and Otway basins (Gibson et al., 2011). Crustal weaknesses inherited from the underlying basement rocks and present at the time of Rodinia break-

up evidently persisted into Mesozoic times when they were reactivated under extension for a second time during the separation of Australia from Antarctica.

STRUCTURAL ELEMENTS

The Otway and Sorell basins developed during rifting and continental separation between Australia and Antarctica from the Cretaceous to Cenozoic. The complex structural and depositional history of the basins reflects their location in the transition from an orthogonal–obliquely rifted continental margin (western–central Otway Basin) to a transform continental margin (southern Sorell Basin).

The Otway Basin is a northwest-trending passive margin rift basin that extends from southeastern South Australia to its boundary with the Sorell Basin west of King Island (Figure 2.2). The basin covers an area of 150,000 km², 80% of which lies offshore in water depths range from <50 to 3,000 m. The basin contains five major depocentres: the mainly onshore Inner Otway Basin, the eastern Torquay Sub-basin, and farther offshore, basinward of the Tartwaup–Mussel Fault Zone, the Morum, Nelson and Hunter Sub-basins that constitute the deepwater Otway Basin (Figure 2.2). The Otway Basin contains an Early Cretaceous to Cenozoic siliciclastic and carbonate sedimentary succession (Figure 2.3). The Latest Jurassic–Early Cretaceous Otway Supergroup (Crayfish and Eumeralla supersequences of Krassay et al. (2004)) comprises up to 8 km of continental and fluvio-lacustrine sediments that accumulated in graben and half graben formed during the first rifting event. Coastal plain, deltaic and marine sediments of the Late Cretaceous Sherbrook Group are up to 5 km thick. The Paleocene–Middle Eocene Wangerrip Group sediments were deposited in coastal plain, deltaic and inner shelf settings and are separated from the open marine, mixed carbonate/siliciclastic rocks of the Eocene–Miocene Nirranda and Heytesbury groups, by a major unconformity.

The Sorell Basin is a Cretaceous to Cenozoic transtensional basin that lies off the west coast of Tasmania (Figure 2.2) in water depths of 50 to 4,500 m. It is bounded by the Otway Basin to the north, the Tasmanian coast to the east, oceanic seafloor to the west; the South Tasman Rise lies to the south. The basin contains five sub-basin depocentres: the King Island, Sandy Cape and Strahan sub-basins in the north (Figure 2.2), and the Port Davey and Toogee sub-basins in the south. In addition, two as yet un-named depocentres have also been identified beneath the outer slope of the southern Sorell Basin, although poor seismic coverage precludes further definition. Sediment thickness varies from 6,500 m in the Strahan Sub-basin, to 3,000 m in the Port Davey Sub-basin.

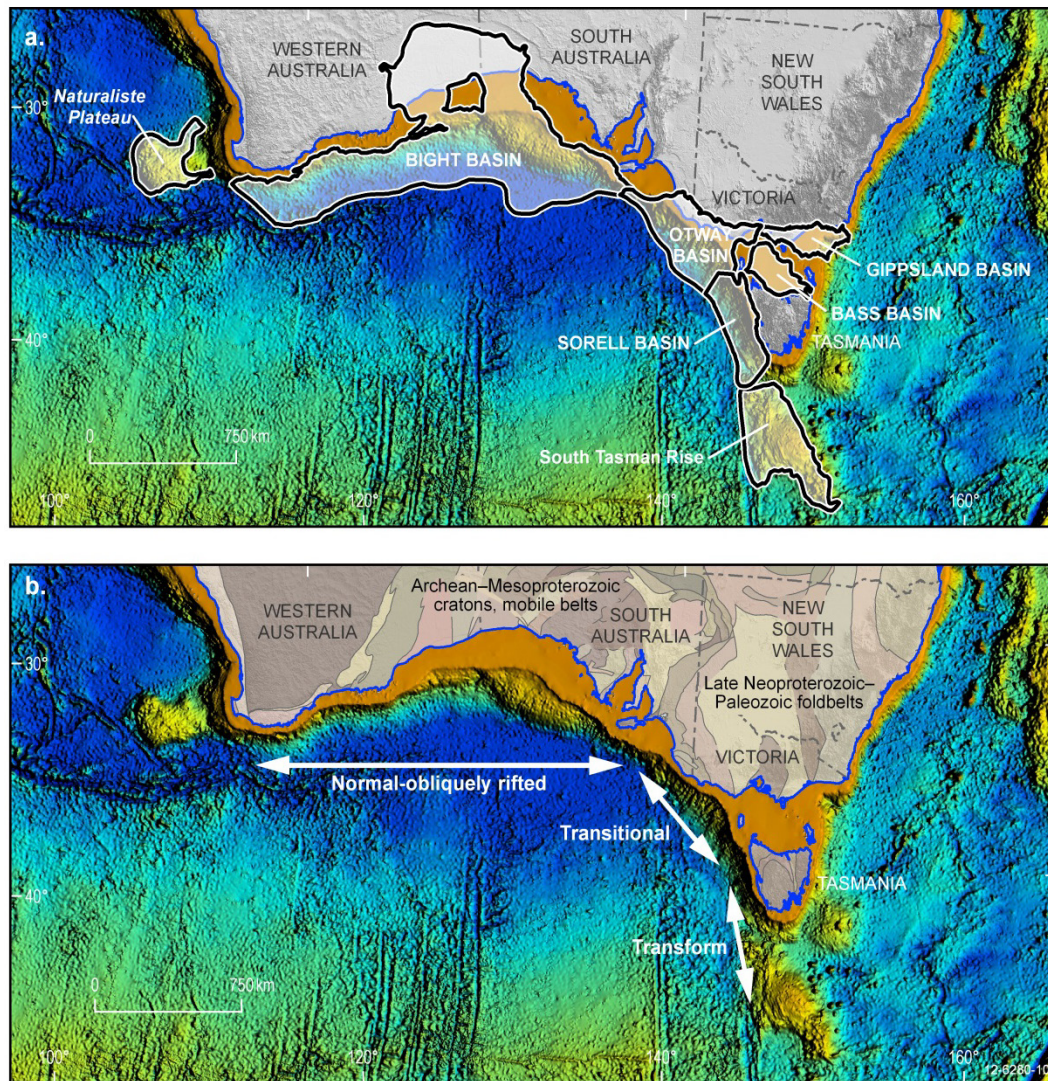


Figure 2.1: Southern rifted margin of Australia: a) basins; b) structural segmentation (after Totterdell et al., 2012)

BASIN DEVELOPMENT

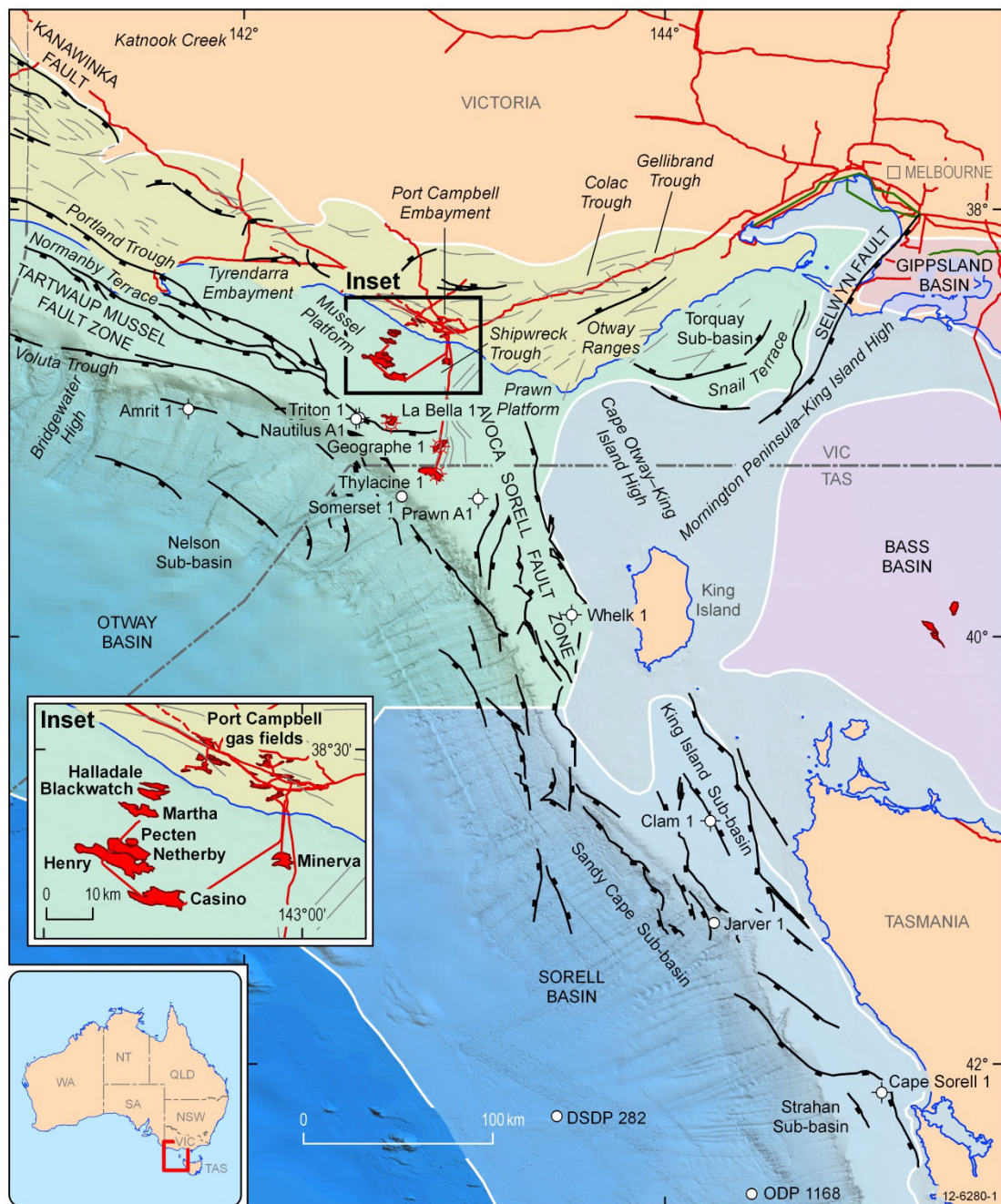
Middle–Late Jurassic intracontinental extension across the western and central parts of the southern margin resulted in the formation of a series of extensional and transtensional half graben from the Bremer Sub-basin in the west, across the eastern Bight Basin, to at least the western Otway Basin in the east (Totterdell and Bradshaw, 2004; Norvick and Smith, 2001; Figure 2.1). In the Early Cretaceous, upper crustal extension was focused in the eastern part of the southern margin. This period saw the development of extensional depocentres across the Otway and Sorell basins (Blevin and Cathro, 2008). The interaction between a generally north–south oriented extensional direction, and complexly deformed basement led to the development of extensional and transtensional depocentres of varying orientation: northwest–southeast in the onshore Otway Basins, east–west in the western and central Otway Basin, southwest–northeast in the eastern Otway Basin, and approximately north–south in the Shipwreck Trough and Sorell Basin (Figure 2.2). While most extension took place early in this phase, continued but diminished extension can be observed throughout the Early Cretaceous in this eastern part of the southern margin; this was termed the “rift-transition phase” by Blevin and Cathro (2008). During the Early Cretaceous, thick, volcanoclastic sequences accumulated in the Otway Basin derived from the active continental margin to the east and northeast.

During the early Late Cretaceous, coincident with lithospheric thinning and initial seafloor spreading in the Bight Basin to the west, and the opening of the Tasman Sea to the east, the eastern basins underwent a phase of inversion and uplift, followed by renewed extension. In the Otway Basin, the locus of extension migrated to the south, in the present-day offshore Otway Basin (Krassay et al., 2004). Thick non-marine, deltaic and marine successions accumulated during this time. In the eastern parts of the basin, deposition was focused in the transtensional Shipwreck Trough and smaller depocentres further south along the incipient transform margin (Sorell Basin).

Following the commencement of slow seafloor spreading in the Bight Basin in the Late Cretaceous, break-up propagated to the east, with seafloor spreading off the Otway Basin starting at ~65 Ma (Krassay et al., 2004). Development of the ocean–continent transform boundary off western Tasmania and the South Tasman Rise commenced around 55 Ma (Exon et al., 2004; Hill and Exon, 2004; Gibson et al, 2012). Progressive subsidence of the margin occurred as seafloor spreading propagated southwards, resulting in the deposition of thick prograding shelf margin sequences in the Otway and Sorell basins.

North–south oriented plate movement between Australia and Antarctica during the Middle to Late Eocene resulted in the formation of a transform plate margin and the development of the Australo-Antarctic Gulf, a narrow restricted seaway, along the western Tasmanian margin (Exon et al., 2004). Clearance between the Australian and Antarctic plates occurred around 34 Ma (Eocene/Oligocene boundary) resulting in the development of circum-Antarctic ocean currents (Exon et al., 2004). From the Late Oligocene to Pleistocene, open marine conditions prevailed along the entire southern margin.

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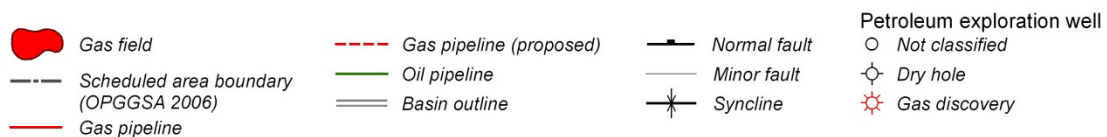


Figure 2.2: Structural elements of the eastern Otway and northern Sorell basins. Location of gas fields shown.

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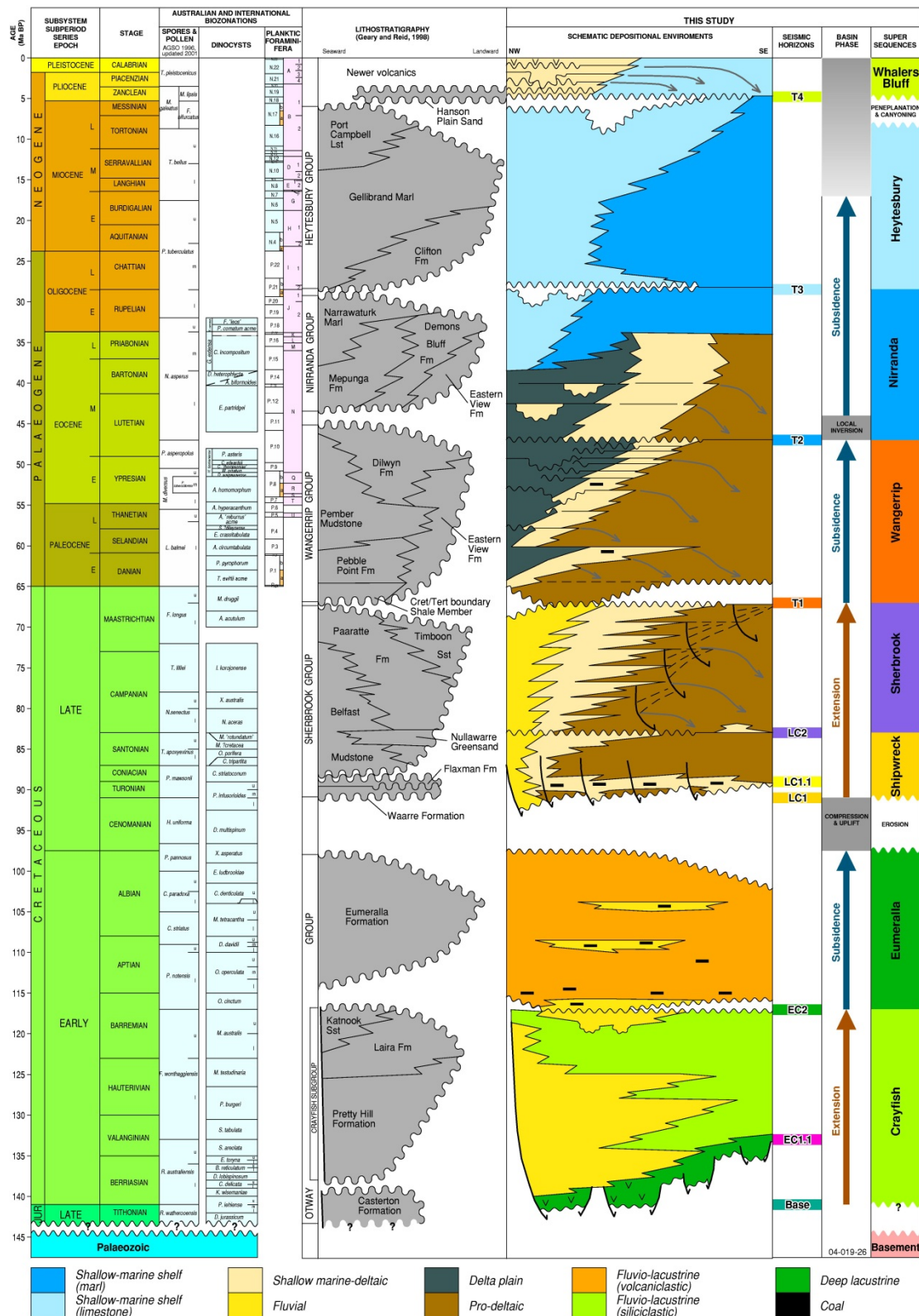


Figure 2.3: Krassay et al. (2004) Otway Basin stratigraphic and basin event chart showing relationship between their supersequences and the lithostratigraphy of Geary and Reid (1998). Based on the now superseded timescale of Young and Laurie (1996) and Partridge (2001).

3. Tectonostratigraphic Evolution

BASIN PHASES AND ACCOMODATION HISTORY

The under-explored, frontier deepwater Otway and Sorell basins lie in water depths of 100–4,500 m, offshore of southwestern Victoria and western Tasmania, and contain a Cretaceous–Cenozoic succession up to 10 km thick (Figure 3.1). This chapter documents the tectonostratigraphic evolution of the deepwater Otway and Sorell basins, and extends the Krassay et al. (2004) seismic and supersequence interpretation (Figure 2.3) from the producing regions of the Otway Basin to the frontier regions of the deeper water Otway Basin (i.e. the Nelson Sub-basin outboard of the Mussel Platform), and from the Prawn Platform further south to the King Island, Sandy Cape and Strahan sub-basins of the Sorell Basin (Figure 3.2). Eleven exploration wells have been used to tie biostratigraphically constrained well picks to the seismic data. Fugro DS01 and DS02 surveys (Figure 1.1) were the main seismic dataset used for this study because of their good regional coverage, quality and consistency in their seismic imaging. The Santos SS04 and SOSN06A surveys were also utilised to aid regional interpretation ties and to assist in obtaining more complete coverage and consistency in areas of geological complexity or data scarcity. Many other available open file seismic datasets have also been used to constrain the interpretation for regional time structure and isopach grids.

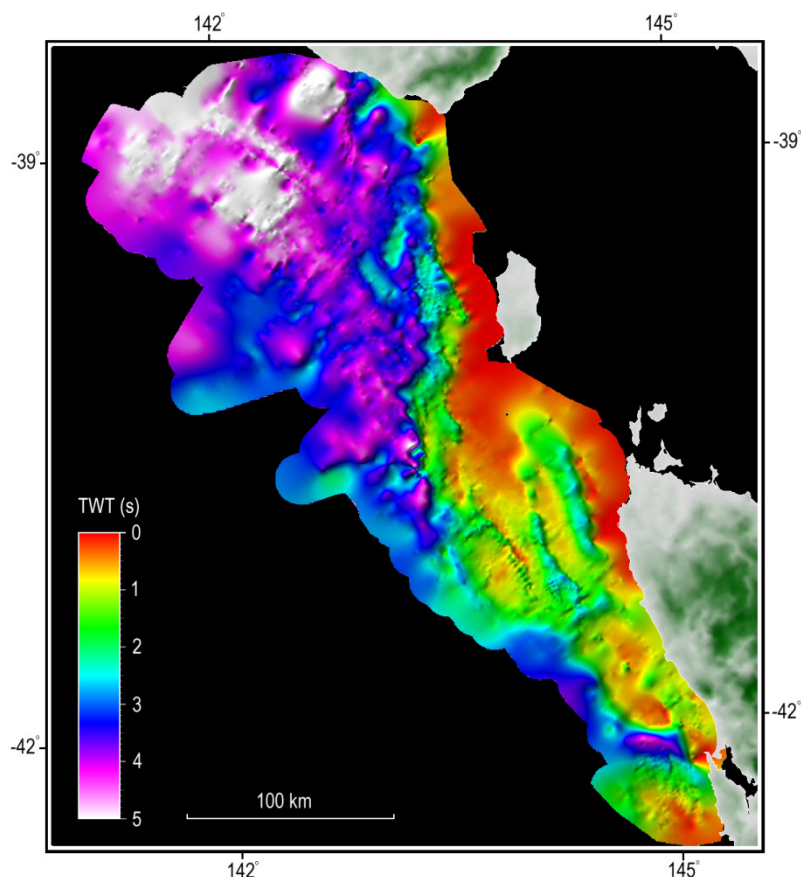


Figure 3.1: The deepwater offshore Otway and Sorell basins showing regional seismic interpreted thickness distribution of Early Cretaceous to present day sediments, in two-way time (s).

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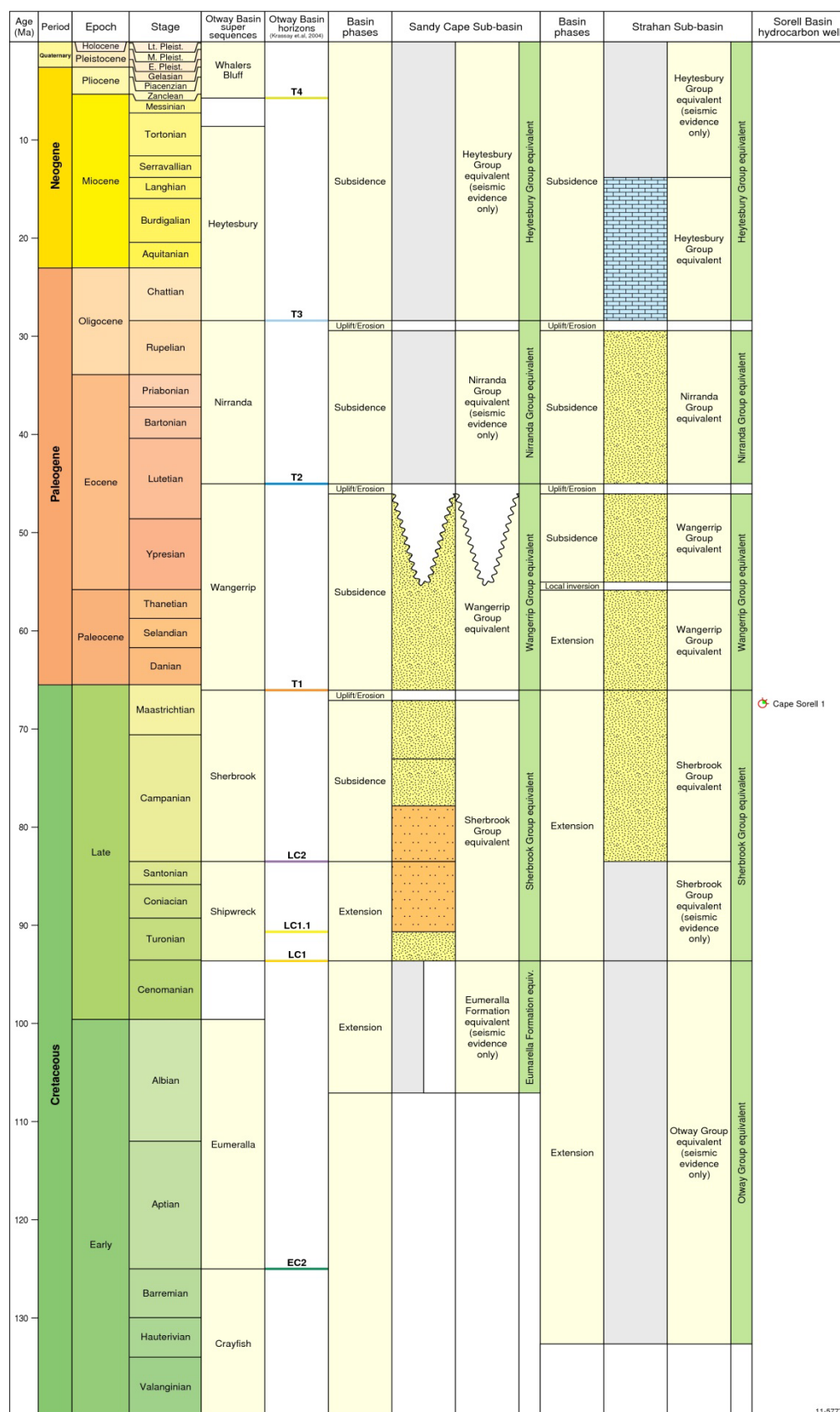


Figure 3.2: Sorell Basin stratigraphic correlation chart, including Otway Basin supersequences and horizons from Krassay et al. (2004). Geological timescale after Gradstein et al. (2004) and Ogg et al. (2008).

Five regionally mappable basin phases have been interpreted across the deepwater Otway and Sorell basins:

- Early Cretaceous Extension and Subsidence – Crayfish and Eumeralla Supersequences (Krassay et al., 2004)
- Late Cretaceous Extension 1 – Shipwreck Supersequence (Krassay et al., 2004)
- Late Cretaceous Extension 2 – Sherbrook Supersequence (Krassay et al., 2004)
- Cenozoic Subsidence 1 – Wangerrip Supersequence (Krassay et al., 2004)
- Cenozoic Subsidence 2 and Inversion – Nirranda, Heytesbury and Whalers Bluff Supersequences (Krassay et al., 2004).

Seismic mapping of these basin phases and their component supersequences has captured the diverse structural architecture (Figure 2.2 and Figure 3.1) along the Otway–Sorell margin, from the rifted margin of the Nelson Sub-basin in the northwest, to the transtensional depocentres of the southern areas of the Strahan Sub-basin.

EARLY CRETACEOUS EXTENSION AND SUBSIDENCE

The oldest seismically mappable unit is interpreted to be equivalent to the Early Cretaceous portion of the Otway Group (Figure 3.3). In shelfal parts of the Otway Basin, this unit comprises the Crayfish and Eumeralla supersequences (Krassay et al. 2004; Figure 2.3), and ranges in age from latest Jurassic to Albian (*R. watherooensis* to *P. pannosus* spore/pollen (s/p) zones; Table 3.1). The upper section, the Eumeralla Supersequence/Formation, is penetrated in La Bella 1, Prawn 1, and Whelk 1 (Figure 1.1) and is interpreted to have been deposited in fluvial to lacustrine environments.

Basement-involved Early Cretaceous faults across the deepwater Otway and Sorell basins exhibit a progressive clockwise rotation of strike from E–W, in the Nelson Sub-basin, to NW–SE and NNW–SSE orientations in the Sorell Basin (Figure 2.1). In general, the Early Cretaceous succession has a half-graben wedge geometry with an overlying post-rift fill. The exception is the Strahan Sub-basin where extension is observed to continue through to the Cenozoic.

Seismically, the Early Cretaceous section in the study area is characterised by a unit of high amplitude and moderately continuous reflections above a consistently low amplitude section. The high amplitude reflections are interpreted to represent coaly facies of the Eumeralla Formation, a key source rock in the Otway Basin. The internal stratal geometry of the unit can be difficult to distinguish due to the structural complexity, but in general, reflections diverge into the half graben-bounding faults. The unit lies unconformably on basement and the upper bounding surface appears to be conformable; internally, the unit exhibits aggradational highstand geometry. The time isopach map of this succession (Figure 3.3) shows a strong structural influence on deposition, with the unit largely concentrated west of the Avoca–Sorell fault system. However, the influence of the Tartwaup–Mussel Fault is also evident, with deposition thicker to the north of this structure. The thick section in the northern part of the map represents the Shipwreck Trough.

Early Cretaceous sediments are contiguous from the Otway Basin to the Sorell Basin west of the Avoca–Sorell fault into the deepwater portion of the Sandy Cape Sub-basin (Figure 3.3). They are also interpreted from seismic at the base of the King Island Sub-basin (Figure 3.4), and in the Strahan Sub-basin, below the Cape Sorell 1 well (Figure 3.5). In these areas, the interpreted Early Cretaceous section occurs as growth wedges in isolated half graben. In the Strahan Sub-basin, the growth section is thicker in the main E–W step-over fault suggesting an early N–S extension direction. The characteristic pull-apart structural style of the sub-basin, is consistent with sinistral strike-slip rifting of Australia and Antarctica along this part of the margin (Gibson et al., 2012).

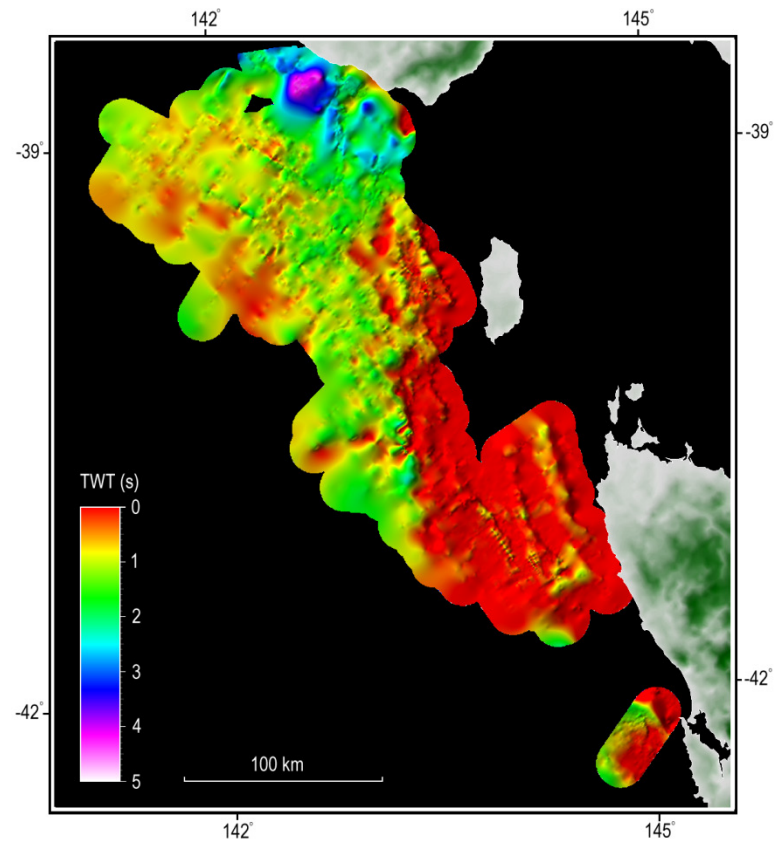


Figure 3.3: Regional seismic interpreted thickness distribution of Early Cretaceous sediments of the Crayfish and Eumeralla supersequences, in two-way time (s).

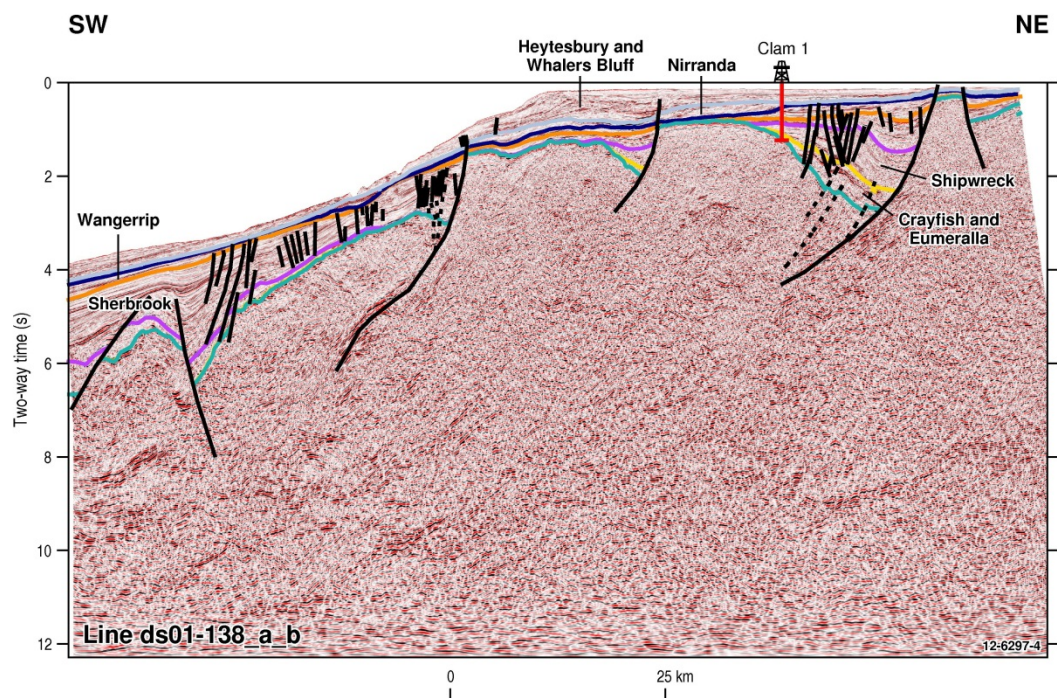


Figure 3.4: Seismic line DS01-138 through Clam 1, Sandy Cape and King Island sub-basins. Location shown on Figure 1.1.

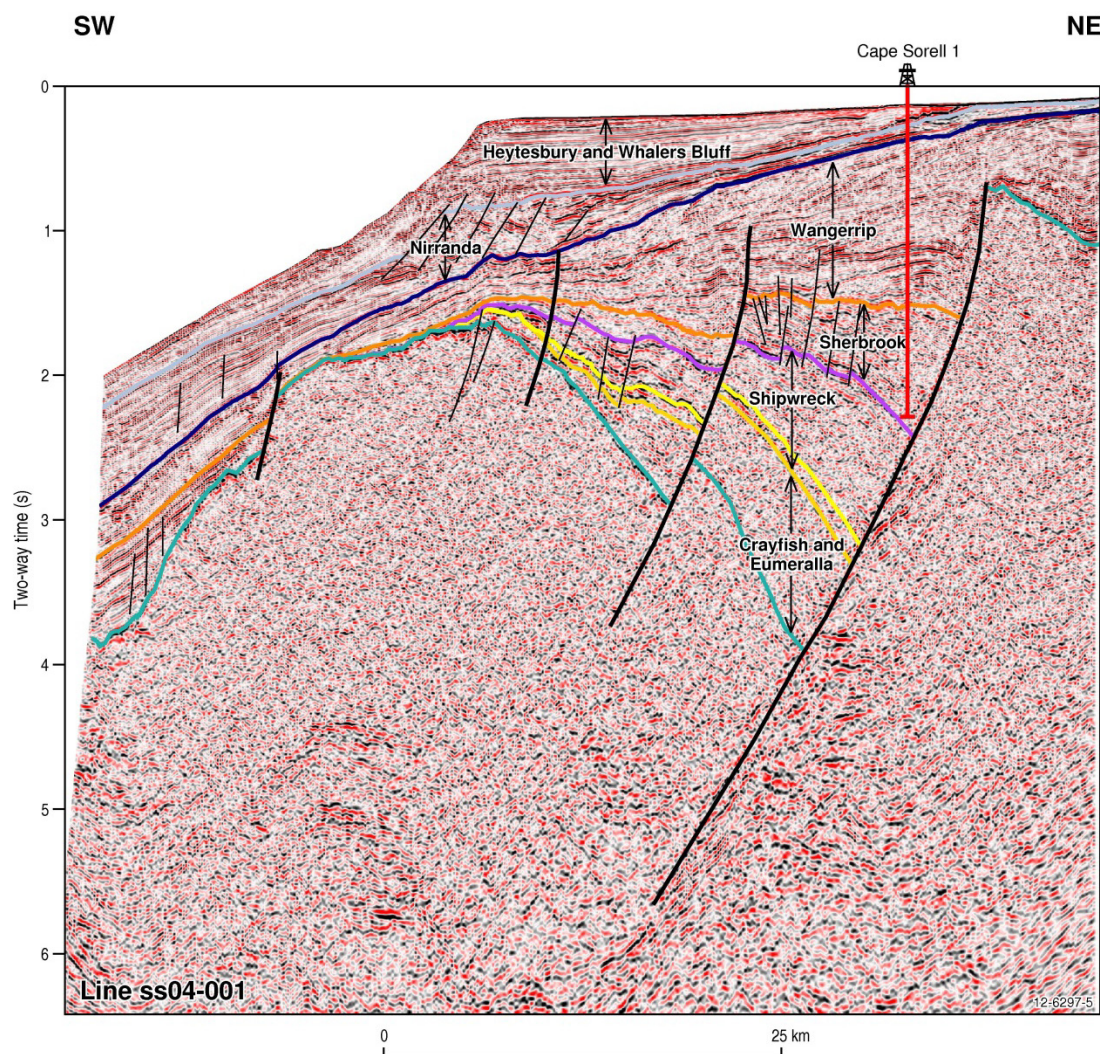


Figure 3.5: Seismic line SS04-001 through Cape Sorell 1, Strahan Sub-basin. Location shown on [Figure 1.1](#).

The end of the Early Cretaceous is marked by an unconformity which is attributed to deformation associated with a regional plate reorganisation (Norvick and Smith, 2001). The effects of compression and uplift can be seen on seismic data across much of the region. Regional Cenomanian inversion affected most of the Otway Basin (Norvick and Smith, 2001; Krassay et al, 2004). In the Sandy Cape Sub-basin, this event gave rise to small rollover anticlines caused by reverse movement on half-graben bounding faults west of the Avoca–Sorell Fault. However, in the Strahan Sub-basin, no evidence of this inversion event can be seen in the seismic record and rifting was continuous.

LATE CRETACEOUS EXTENSION 1

The Late Cretaceous Extension 1 phase of the Otway Basin, which comprises the Shipwreck Supersequence of Krassay et al. (2004) ([Figures 2.3](#) and [3.2](#)), is interpreted across the deepwater Otway and Sorell basins ([Figure 3.6](#)). The Shipwreck Supersequence is of Turonian to Santonian age (*P. mawsonii* to upper *T. apoxyexinus* (s/p) zones; [Table 3.2](#)) and records a second phase of rifting in the Otway Basin (Krassay et al., 2004). In hydrocarbon producing areas of the Otway Basin, the Shipwreck Supersequence includes the economically important reservoirs of the Waarre and Flaxman Formations, and the Thylacine Sandstone Member of the Belfast Mudstone. The Shipwreck Supersequence unconformably overlies the Eumeralla Supersequence across the whole of the study area. The section intersected in wells comprises fluvial to deltaic and marginal marine facies and reaches thicknesses in excess of 1300 m in Prawn 1.

In the northern deepwater Otway Basin (Figure 3.7 and Figure 3.8) and west of King Island (Figure 3.9), the seismic character of this section comprises low amplitude, moderate continuity, parallel–divergent reflections, consistent with deltaic to shallow marine facies. Further south, although the sequence thins, it maintains a low amplitude, moderate reflection continuity seismic character. In the Strahan Sub-basin, the Shipwreck Supersequence equivalent is interpreted to be present in the lower part of the half graben beneath Cape Sorell 1. In this isolated half graben it is characterised by divergent reflections with low–high amplitude and continuity. Although this section was not penetrated by the well, it is considered likely to consist of non-marine facies.

The interpreted regional thickness map (Figure 3.6) shows that deposition was concentrated basinward of the Tartwaup–Mussel and Avoca–Sorell fault systems, reflecting a regional basinward shift in facies. Along the eastern side of the study area, deposition was concentrated in small fault-bounded depocentres. The impact of the preceding phase of deformation and uplift can be seen in thinning of the Shipwreck Supersequence section across the eastern flank of the Shipwreck Trough.

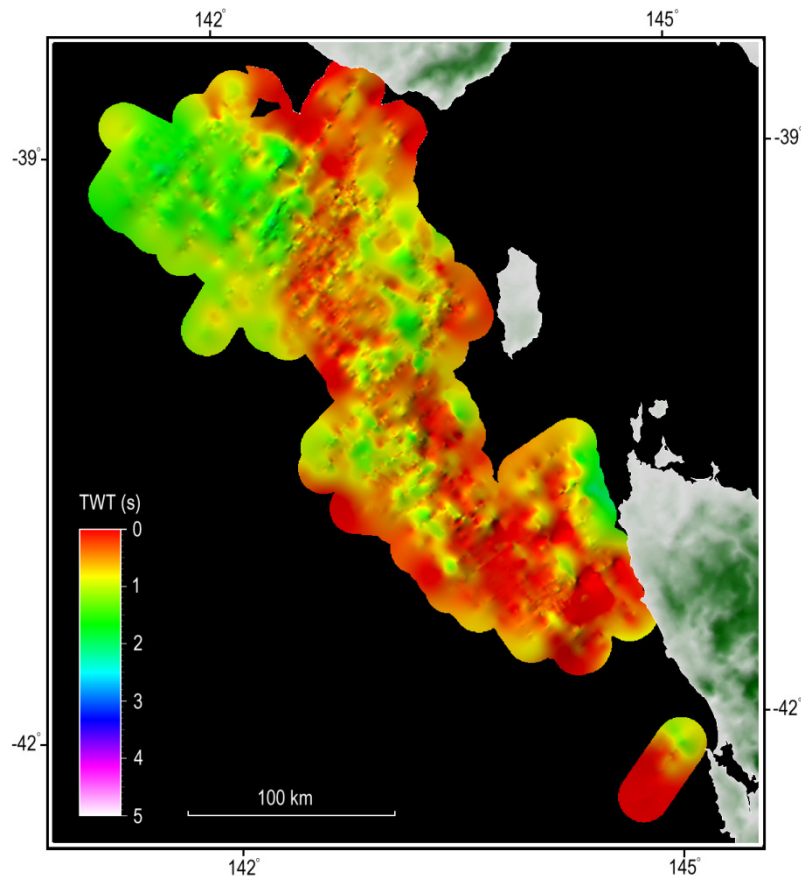


Figure 3.6: *Interpreted regional thickness distribution of Late Cretaceous 1 sediments of the Shipwreck Supersequence, in two-way time (s).*

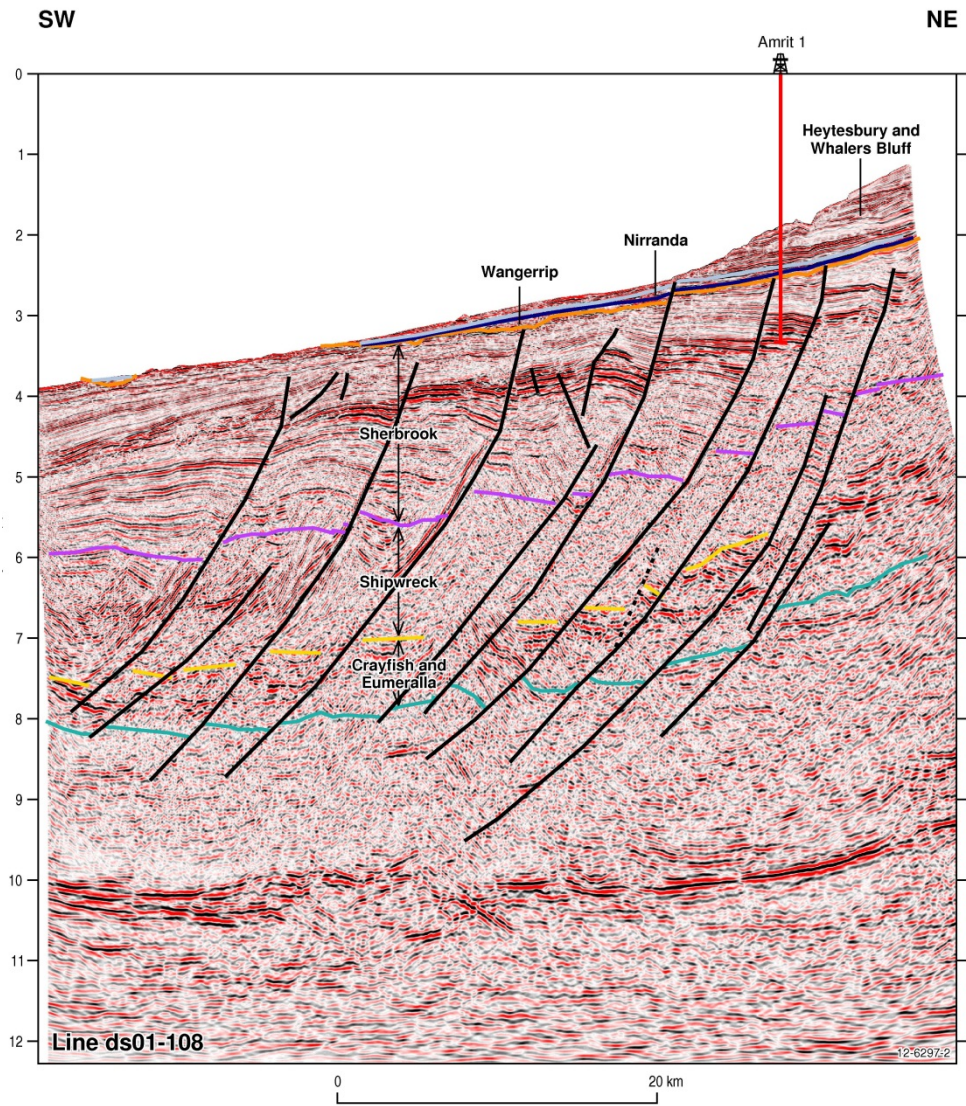


Figure 3.7: Seismic line DS01-108 through Amrit 1, Nelson Sub-basin. Location shown on [Figure 1.1](#).

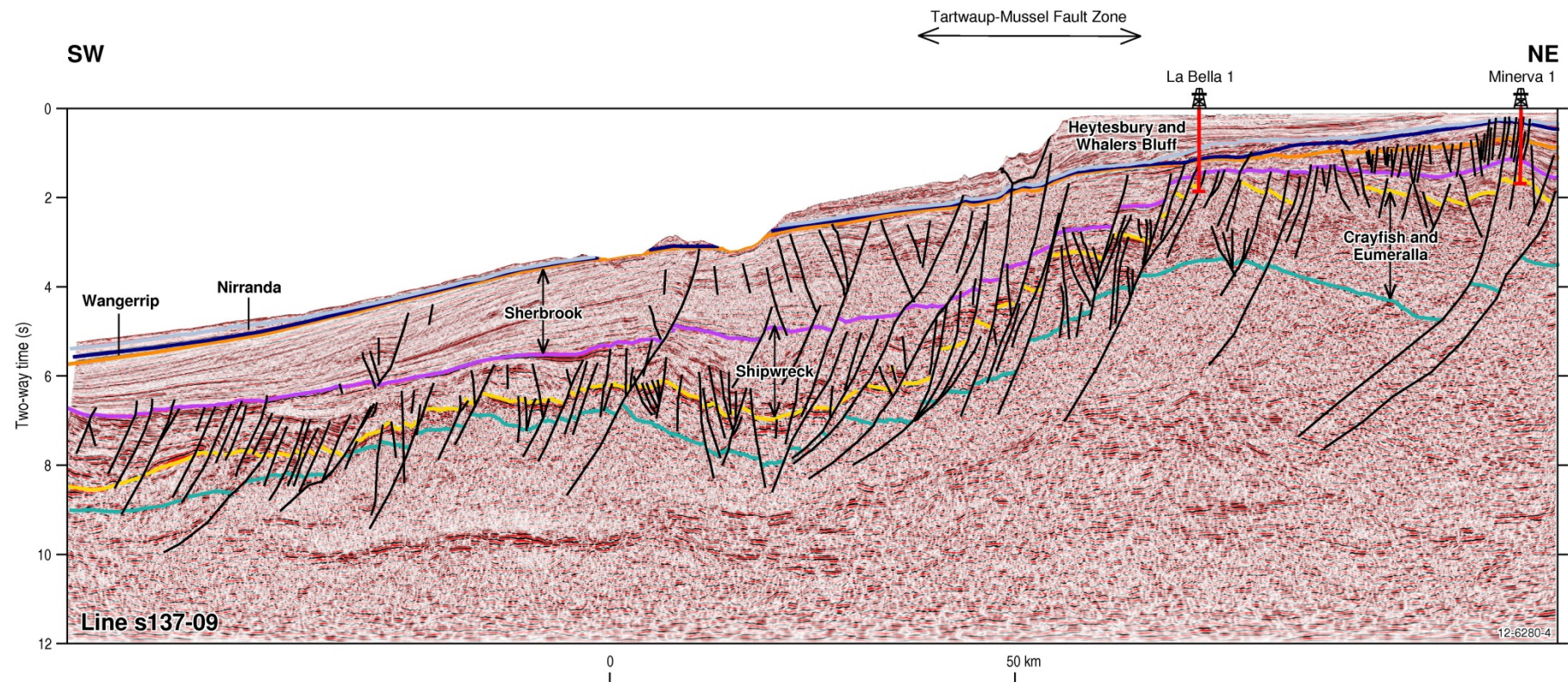


Figure 3.8: Seismic line s137-09 through La Bella 1 and Minerva 1, Otway Basin. Location shown on [Figure 1.1](#).

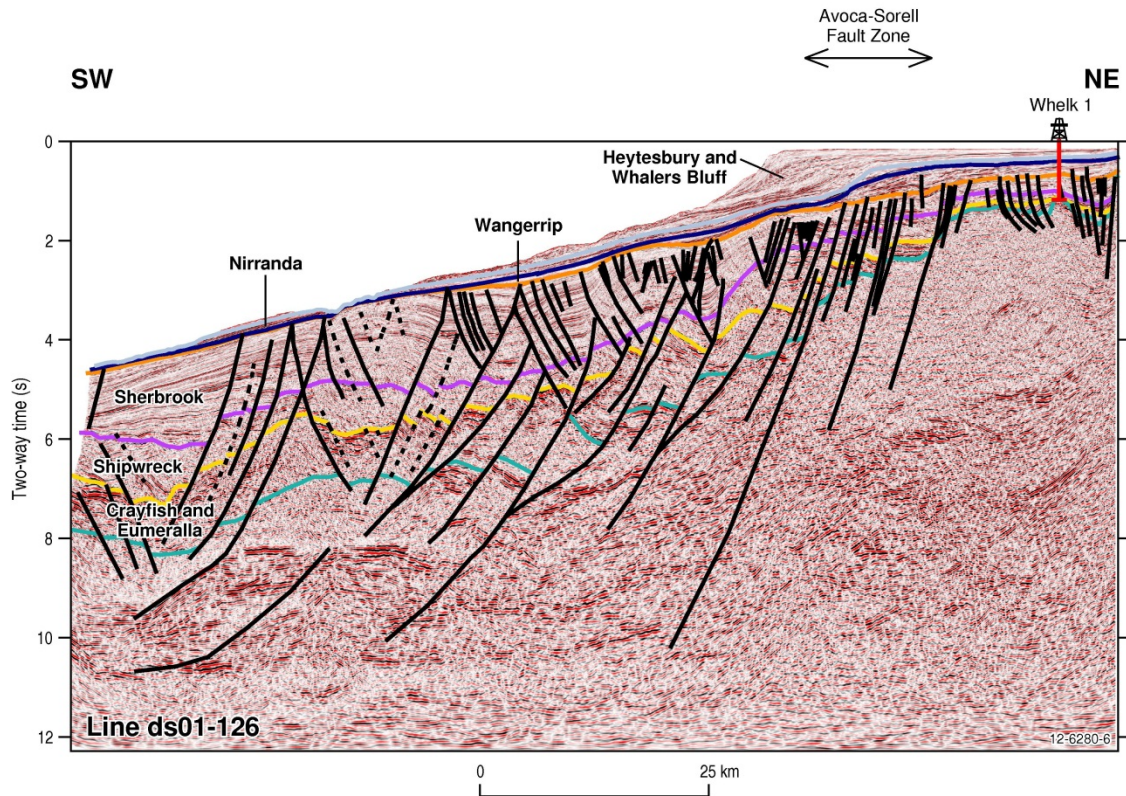


Figure 3.9: Seismic line DS01-126 through Whelk 1, Otway Basin. Location shown on Figure 1.1.

LATE CRETACEOUS EXTENSION 2

The Late Cretaceous sediments of the Sherbrook Supersequence represent rift-fill of Campanian to Maastrichtian age (*N. senectus* to *F. longus* (s/p) zones; Table 3.3). The unit comprises marginal marine to fluvial deltaic sediments deposited during a regional regression. The lower bounding surface is structurally conformable with the Shipwreck Supersequence across the whole study area. The upper bounding surface is an erosional unconformity with the overlying Cenozoic sediments except in the south of the area, in the Strahan Sub-basin, where deposition was continuous.

The gross distribution of this succession shown in the two-way time isochron map for this supersequence reflects a focus of deposition outboard of the Tartwaup–Mussel and Avoca–Sorell fault zones (Figure 3.10). In the northern part of the study area, the Sherbrook Supersequence equivalent consists of a thick, basinward thickening progradational prism (Figure 3.8). Amrit 1, in the northern part of the basin, terminates mid-way through the Sherbrook Supersequence, recording over 930 m of section (Figure 3.7). The unit thins to the south, before thickening into the Sandy Cape Sub-basin. There, the Sherbrook Supersequence section in Jarver is approximately 900 m thick. The thick section outboard of the Avoca–Sorell fault is consistent with a model of sediment supply from the east (Cliff et al., 2004).

Seismically, the section is characterised by high to low amplitude, high continuity, and parallel–divergent reflections across most of the study area. Where interpreted in the Strahan Sub-basin, the seismic character of this basin phase is one of low amplitude and moderate continuity reflections.

In the Nelson Sub-basin, the structural style of the Sherbrook Supersequence equivalent is that of widely spaced tilted fault blocks exhibiting minor inversion (Figure 3.7). Further to the southeast, antithetic faults and strong localised inversion are present outboard of Whelk 1 (Figure 3.9). A group of inversion anticlines occurs about 80 km west of King Island. These formed near the end of the Cretaceous, probably in response to the stresses associated with breakup on this part of the margin, which resulted in the

development of the basal Cenozoic regional unconformity. Anticlinal hinges are generally oriented NNW and occur in an area roughly 100 km north–south and 50 km wide. This area corresponds regionally to the eastern extension of the Tartwaup–Mussel Fault Zone, where it rotates to the southeast and merges with the dominant Avoca–Sorell Fault Zone (Figure 2.2). In the southern part of the area, closely spaced tilted fault blocks are common in the King Island, Sandy Cape and Strahan sub-basins (Figure 3.4 and Figure 3.5); farther outboard, extensional faults become more widely spaced.

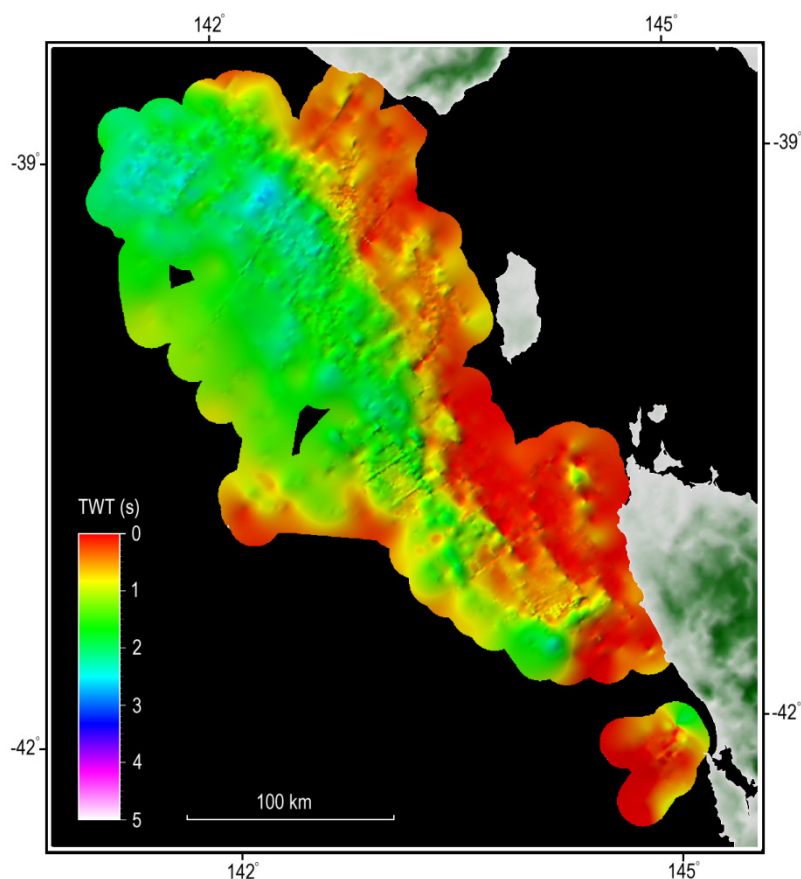


Figure 3.10: Interpreted regional thickness distribution of Late Cretaceous (2) sediments of the Sherbrook Supersequence, in two-way time (s).

CENOZOIC SUBSIDENCE 1

The T1 basin phase correlates with the Wangerrip Supersequence of Maastrichtian to Early Eocene age (intra upper *F. longus* to base *N. asperus* (s/p) zones; Table 3.4). The unconformity at the base of this supersequence is interpreted to represent the commencement of breakup between Australia and Antarctica along the Otway–northern Sorell part of the southern margin; the Wangerrip Supersequence forms the base of the post-breakup succession.

Sedimentary environments interpreted from well completion reports across the study area are shallow marine, marginal marine and deltaic. Regionally the supersequence is generally less than 500 ms (TWT) thick (Figure 3.11) with the exception of in the Strahan Sub-basin, where 1,534 m was intersected at Cape Sorell 1. The stacking patterns and stratal geometries of the section suggest that it comprises a basal transgressive systems tract overlain by well developed progradational highstand system tract, deposited in a slowly subsiding basin. In the Strahan Sub-basin, the section exhibits an aggradational to progradational highstand character.

The lower bounding surface unconformably overlies the Sherbrook Supersequence across most of the study area. Deeply incised canyons with accompanying canyon fill occur in the Nelson Sub-basin and to the southwest of Clam 1. The upper bounding surface is structurally conformable across the area and is characterised by conformable topsets in the Nelson Sub-basin and west of King Island (Figure 3.9). The seismic character of the unit is one of low to high amplitudes, moderate continuity, and generally parallel reflections, consistent with shallow shelfal deposition. In the Strahan Sub-basin, divergent–parallel reflections (Figure 3.5) indicate continued extension during deposition of the Wangerrip Supersequence in this area. In Cape Sorell 1, sediments from the Wangerrip rift-fill section are Paleocene–Early Eocene (*M. diversus* spore–pollen zone) in age. Following the cessation of extension (at about 51 Ma), there appears to have been limited accommodation in the Strahan Sub-basin; post-rift Wangerrip strata are strongly progradational and thin across the hinge side of the half graben, which appears to have remained relatively high.

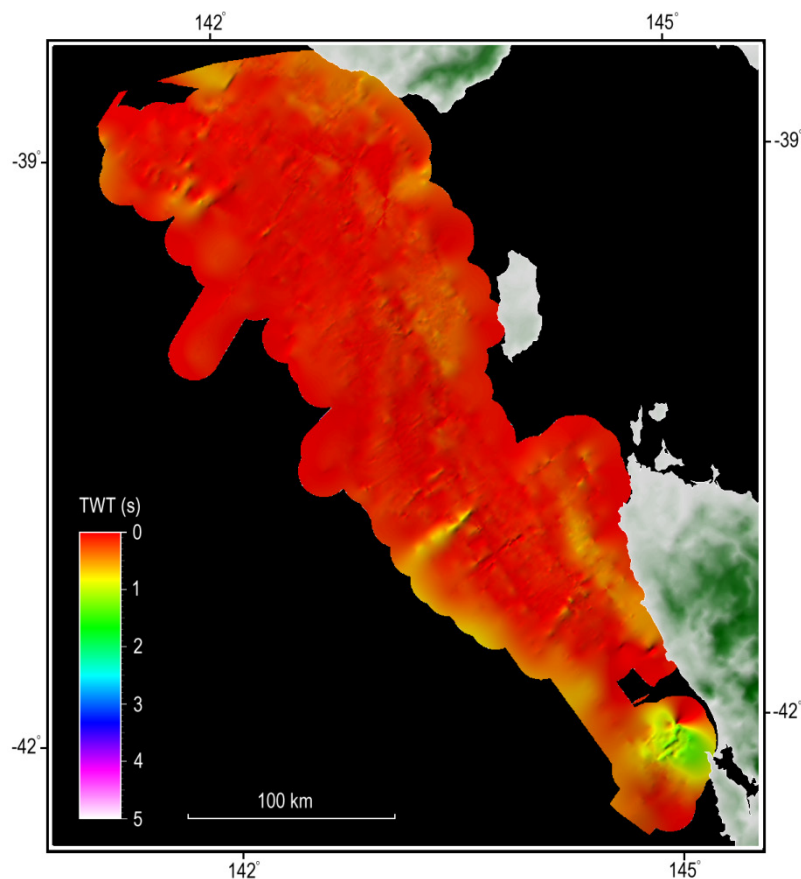


Figure 3.11: Interpreted regional thickness distribution of early Cenozoic (1) sediments of the Wangerrip Supersequence, in two-way time (s).

The base of the Wangerrip Supersequence is a regional erosional unconformity and the majority of faults terminate at its base. Structural style varies across the study area from northwest to southeast. In the Nelson Sub-basin, and west of King Island, the base of the Wangerrip Supersequence marks the cessation of extensional faulting (Figure 3.7 and Figure 3.9). However, reverse reactivation of faults and further inversion affects the section in the area west of King Island. In the King Island Sub-basin, block faulting continuing throughout deposition of the sequence (Figure 3.4), and in the Strahan Sub-basin to the south (Figure 3.5), this supersequence represents the final extensional phase in the basin; here, faulting terminated in the Early Eocene with only minor reactivation.

CENOZOIC SUBSIDENCE 2 AND INVERSION

The final basin phase comprises the Nirranda, Heytesbury and Whalers Bluff supersequences (Krassay et al., 2004) of middle Lutetian to Pleistocene age (Lower *N. asperus* to *T. pleistocenicus* (s/p) zones; Table 3.5). These supersequences accumulated during a prolonged period of Cenozoic thermal subsidence coinciding with plate clearance between Australia and Antarctica. A feature of this basin phase was several periods of compression and inversion (Holford et al., 2011). Sedimentation is dominated by a basal siliciclastic unit overlain by a thicker carbonate succession.

Well data from across the study area indicate that depositional environments were open marine. The unit is dominated by aggradational to progradational highstand systems tract geometries. The succession has a relatively uniform thickness across the region (Figure 3.12), ranging from 1300 ms (TWT) in the north and 1,100 ms (TWT) in the south. The thickest section occurs at the current shelf break.

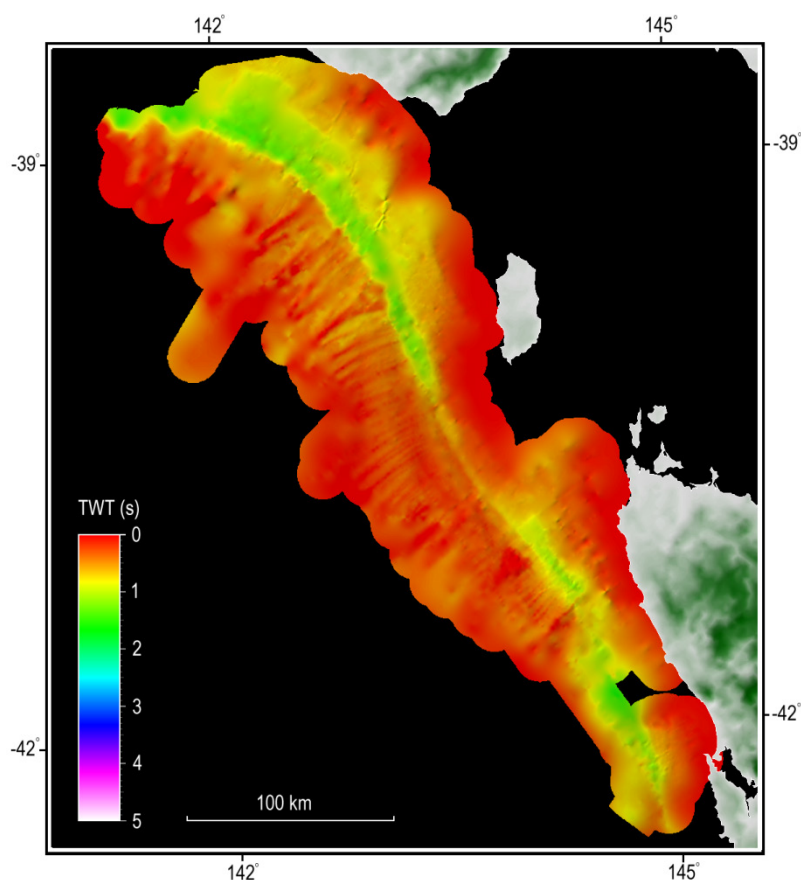


Figure 3.12: Interpreted regional thickness distribution of Cenozoic (2) sediments of the Nirranda, Heytesbury and Whalers Bluff supersequences, in two-way time (s).

Outboard of the shelf break, the lower bounding surface is structurally conformable with the Wangerrip Supersequence, and inboard the Nirranda–Whalers Bluff succession onlaps the basal sequence boundary. Seismic character is one of moderate–high amplitude, high continuity reflections across the study area with the exception of the Nelson Sub-basin, where more variable reflection amplitudes are common.

This succession represents regional basin subsidence; it is relatively undeformed and comprises at least three distinct progradational wedges. The Nirranda Supersequence marks a major marine transgression (Krassay et al., 2004) and is a relatively thin and undeformed progradational wedge that is located tens of kilometres inboard of the present-day shelf break, and conformably overlies the Wangerrip Supersequence.

This sequence exhibits initial strong progradation, followed by a more aggradational architecture, but there is a consistent basinward trajectory of the palaeo-shelf breaks (Figure 3.4, Figure 3.8. and Figure 3.9). The Nirranda Supersequence is thicker here than in the areas of the basin in the north, and the palaeo-shelf break is characterised by growth faults related to sediment loading. Beyond the shelf break, there is a basinward thickening wedge of sediments, in contrast to the predominantly low-accommodation, progradational nature of the inboard parts of the basin.

From the Late Oligocene, sequence geometry along the margin changed from dominantly progradational to progradational–aggradational, reflecting continued post-breakup subsidence. This change in architecture is more pronounced in the southernmost parts of the basin, where the Heytesbury exhibits a dominantly aggradational character; on some seismic lines the sequence has a retrogradational character with the shelf-break stepping landward (Figure 3.5). This apparent increase in accommodation may reflect subsidence related to the later breakup on this part of the margin. Elsewhere, the Heytesbury and Whalers Bluff supersequences exhibit progradational geometries stepping basinward to the present-day shelf break. Canyon incision is common at the shelf break, with a higher concentration in the Nelson Sub-basin. Slumps at the shelf break are also common. The thinnest section occurs where the granites of the King Island High subcrop on the shelf.

SUMMARY

The Otway Basin is a latest Jurassic to Cenozoic basin that formed in response to the break-up of Eastern Gondwana (Norvick and Smith, 2001). The availability of regional, open-file, seismic datasets has enabled a basin-scale interpretation of the stratigraphic section and has resulted in an improved understanding of the geology of the margin.

Structurally and stratigraphically, the Sorell Basin is contiguous with the Otway Basin. The structure of the eastern Otway and Sorell basins has been strongly influenced by the architecture and structural fabric of the underlying basement, particularly the Avoca–Sorell Fault System, which controlled the NW–SE transition from extension, through transtension, to a predominantly strike-slip regime (Gibson et al., 2011). This basement control and the variations in structural regime are reflected in: the architecture of the basins, particularly the long, narrow depocentres of the King Island and Strahan Sub-basins; the NW–SE changes in extensional fault strike from E–W in the Nelson Sub-basin to predominantly north–south in the vicinity of the Avoca–Sorell fault; and the north to south diachroneity of extension.

The tectonostratigraphic units mapped in this study document the approximately 130 million year evolution of the basin system and the easternmost part of the southern Australian rifted margin, from non-marine deposition in Early Cretaceous extensional depocentres to the development of an open seaway between Australia and Antarctica. Five distinct and regionally mappable chronostratigraphic basin phases have been identified:

- Early Cretaceous Extension and Subsidence – Crayfish and Eumeralla Supersequences
- Late Cretaceous Extension 1 – Shipwreck Supersequence
- Late Cretaceous Extension 2 – Sherbrook Supersequence
- Cenozoic Subsidence 1 – Wangerrip Supersequences
- Cenozoic Subsidence 2 and Inversion – Nirranda, Heytesbury and Whalers Bluff Supersequences

The first basin phase records the initiation of sedimentation during a period of Early Cretaceous upper crustal extension. During this time, and the subsequent period of thermal subsidence and structural quiescence, fluvial and lacustrine rocks were deposited across the study area, although depocentres in the southeastern part of the area were small and isolated. Deposition in the eastern part of the study area was strongly influenced by the north–south oriented Avoca–Sorell fault system. During this period, deposition in the Otway Basin was mostly focused north of the Tartwaup–Mussel Fault. At the end of the Early Cretaceous, the region was affected by a period of compression that resulted in uplift and inversion of many earlier rift structures.

The Cenomanian contractional event was followed by the renewal of regional extension. The Late Cretaceous Extension 1 basin phase was characterised by the deposition of fluvial and deltaic sandstone,

and an increasing marine influence. A basinward shift of facies is observed in the northern part of the study areas, but is less pronounced in the south, where deposition was focused in relatively isolated depocentres. The major Avoca–Sorell and Tartwaup–Mussel fault systems continued to have a strong control on deposition.

Continued extension during the Campanian–Maastrichtian (Late Cretaceous Extension 2) resulted in the accumulation of a thick marginal marine to fluvio-deltaic succession throughout the deepwater Otway and northern Sorell basins, basinward of the Avoca–Sorell and Tartwaup–Mussel fault systems. Sedimentation was thickest in the north; although the section is relatively thin in the Sorell Basin to the south, a major depocentre began to develop in the Sandy Cape Sub-basin during this time. This phase of extension culminated in the commencement of breakup on the Otway margin. Deformation related to breakup (extensional faulting, localised inversion) terminates at the angular unconformity between the Late Cretaceous and Cenozoic sections.

The progression of N–S oriented breakup along the developing transform margin resulted in regional differences in the development of the Cenozoic section in the study area. While a post-rift progradational passive margin succession accumulated across much of the Otway and northern Sorell basins in the Paleocene and Early Eocene (Cenozoic Subsidence 1), extension continued in the Strahan Sub-basin to the south. The geometry of the sedimentary units in the Strahan Sub-basin indicate that extension continued until about 51 Ma.

For the remainder of the Cenozoic (Cenozoic Subsidence 2), deposition was restricted to the accumulation of successive progradational–aggradational marine units. The widespread contraction and inversion that affected much of the Otway Basin, and broader region, in the late Cenozoic (Holford et al., 2011) appears to be largely absent in the southern Otway and Sorell basins, where the succession is relatively undeformed.

The new seismic interpretation shows that depositional sequences recognised in the Otway Basin, including those that host active petroleum systems in the producing areas of the basin, are also likely to be present in the deepwater Otway and Sorell basins. The integration of sequence stratigraphic interpretation of seismic data, and a regional structural analysis that utilised new potential field data, has resulted in a clearer understanding of the tectonostratigraphic evolution of this region.

Geology and Hydrocarbon Prospectivity of the Deepwater Otway and Sorell basins, offshore southeastern Australia

Table 3.1: Early Cretaceous extension and subsidence summary.

	<i>Deepwater Otway (Nelson Sub-basin)</i>	<i>West of King Is</i>	<i>Northern Sorell Basin</i>	<i>Strahan Sub-basin</i>
Unit name:	Crayfish and Eumeralla supersequences			
Formation equivalent:	Otway Group			
Basin phase:	Early Cretaceous extension and subsidence			
Age:	Latest Jurassic to Albian			
Top (Biozone):	<i>P. pannosus</i>			
Base (Biozone):	<i>R. watherooensis</i>			
Well examples)	La Bella 1: 2592–2735m (TD)	Prawn 1: 2950–3198m(TD)	Clam 1: possibly represented by basal rift fill interpreted as Devonian in WCR	Interpreted to be present at base of half graben beneath Cape Sorell 1
Lithology:	Argillaceous sandstone with interbedded claystone	Lithic sandstone with thin interbeds carbonaceous shale (Eumeralla Fm)	N/A	N/A
Depositional environment:	?Fluvial, lacustrine	Fluvial	?Fluvial to lacustrine	?Fluvial
Sequence Character:	Aggradational HST	Aggradational HST	Aggradational HST	Aggradational HST
Max thickness (TWT ms)	1100ms DS01-112	1500ms DS01-126 deepwater	600ms DS01-138_a_b King Is Sub-basin	600ms SS04-001 Strahan Sub-basin
Upper bounding surface:	Structurally conformable	Structurally conformable	Structurally conformable	Structurally conformable
Lower bounding surface:	Unconformable on basement	Unconformable on basement	Unconformable on basement	Unconformable on basement
Geometry:	Half-graben wedge and overlying unconformable post-rift fill	Half-graben wedge and overlying post-rift fill	Half-graben wedge and overlying post-rift fill; generally thin section at base of rift fill	Half-graben wedge
Seismic Character:	High amplitude and moderate–high continuity reflection at top coals above consistently low amplitude section	High amplitude and moderate–high continuity reflection at top coals above consistently low amplitude section	Generally-low amplitude and moderate–low continuity	Low–moderate–high amplitude, variable continuity
Structural style:	Closely spaced extensional tilted fault blocks	Closely spaced extensional tilted fault blocks	Outboard widely spaced and isolated extensional fault blocks; inboard, rotated half graben fault blocks (King Is. Sub-basin)	Outboard widely spaced extensional fault blocks; inboard, half graben fault blocks (Strahan Sub-basin)
Best Example:	DS01-112, DS01-114	DS01-120, DS01-126	DS01-136a	SS04-001
Play Elements:	Possible reservoirs in tilted fault blocks and stratigraphic traps but fault preservation risk. Potential source coaly facies	Possible reservoirs in tilted fault blocks and stratigraphic traps but fault preservation risk	Tilted fault blocks and stratigraphic plays	Tilted fault blocks and stratigraphic plays
Uncertainties with interpretation	No wells penetrate deepwater section. Base poorly imaged.	No wells penetrate deepwater section. Base poorly imaged.	No well test to section.	No well test of deepwater section. Base poorly imaged.

Table 3.2: Late Cretaceous extension 1 summary.

	<i>Deepwater Otway (Nelson Sub-basin)</i>	<i>West of King Is</i>	<i>Northern Sorell Basin</i>	<i>Strahan Sub-basin</i>
Unit name:	Shipwreck Supersequence			
Formation equivalent:	Lower Sherbrook Group			
Basin phase:	Late Cretaceous extension 1			
Age:	Turonian to Santonian			
Top (Biozone):	Upper <i>T. apoxyxenus</i>			
Base (Biozone):	<i>P. mawsonii</i>			
Well example(s)	La Bella 1: 2007–2580m	Prawn 1: 1571–2950m	Jarver 1: 2431–3028m (TD)	Interpreted to be present at base of half graben beneath Cape Sorell 1
Lithology:	Interbedded sandstone, siltstone and claystone	Basal conglomerate, interbedded sandstone and claystones	Coarse grained siliciclastics	N/A
Depositional environment:	Fluvial/marginal marine	Marginal marine	Fluvial - deltaic	N/A
Sequence Character:	LST	LST	LST	LST
Max thickness (TWT ms)	2000ms s137-09	1200ms DS01-126	600ms DS01-138_a_b King Is Sub-basin	600ms SS04-001 Strahan Sub-basin
Upper bounding surface:	Structurally conformable	Generally structurally conformable; erosional on some uplifted footwall blocks, particularly farther basinward	Structurally conformable	Apparently conformable
Lower bounding surface:	Unconformable on Eumeralla Supersequence	Unconformable on Eumeralla Supersequence	Unconformable on Eumeralla Supersequence	Unconformable on Eumeralla Super Sequence
Geometry:	Half-graben wedge and overlying post-rift fill; in places, successive half-graben wedges	Half-graben wedge and overlying post-rift fill	Half-graben wedge and overlying post-rift fill	Half-graben wedge
Seismic Character:	Low amplitude, mod continuity, parallel–divergent reflections. Higher amplitude reflections near top of section further inboard	Low amplitude, mod continuity, parallel divergent reflections. Higher amplitude reflections near top of section further inboard	Low amplitude and mod continuity.	Low–high amplitude and continuity, moderately divergent reflection
Structural style:	Closely spaced extensional tilted fault blocks	Closely spaced extensional tilted fault blocks; highly rotated further basinward	Outboard widely spaced extensional fault blocks; inboard, rotated half graben (King Is. Sub-basin)	Outboard sparsely spaced extensional fault blocks; inboard, half graben fault blocks (Strahan Sub-basin)
Best Example:	s137-09	DS01-126	DS01-136a	SS04-001
Play Elements:	Tilted fault blocks and stratigraphic plays	Tilted fault blocks, anticlines and stratigraphic plays	Tilted fault blocks and stratigraphic plays	Tilted fault blocks and stratigraphic plays
Uncertainties with interpretation	Well tie for inboard Tartwaup–Mussel section only, poorly imaged adjacent to main basin bounding fault below shelf break and structurally complex	Well tie for inboard Tartwaup–Mussel section only, poorly imaged adjacent to main basin bounding fault below shelf break and structurally complex	No well test of section.	No well test in the deepwater section. Section poorly imaged below Cape Sorell 1.

Table 3.3: Late Cretaceous extension 2 summary.

	Deepwater Otway (Nelson Sub-basin)	West of King Is	Northern Sorell Basin	Strahan Sub-basin
Unit name:	Sherbrook Supersequence			
Formation equivalent:	Upper Sherbrook Group			
Basin phase:	Late Cretaceous extension 2			
Age:	Campanian to Maastrichtian			
Top (Biozone):	Lower <i>F. longus</i>			
Base (Biozone):	<i>N. senectus</i>			
Well example(s)	Amrit 1: 2046–2976 (TD)	Whelk 1: 715–1223m	Clam 1: 745–1045m, Jarver 1: 1522–2431m	Cape Sorell 1: 1924 – beneath TD
Lithology:	Siltstone overly claystone (upper section only)	Upper clayey sandstone and lower sandy claystone	Coarse grained sandstone	Upper sandy shale and lower breccia-conglomerate sandy shale
Depositional environment:	Deltaic to marine (only upper section present)	?marginal marine	Fluvial-deltaic	Shallow marine to marginal marine
Sequence Character:	Regional regression; LST	Regional regression; LST	Regional regression; LST	Regional regression; LST
Max thickness (TWT ms)	2500ms s137_09	2000ms DS01-126	700ms in Kings Is Sub-basin, 1200ms deepwater	~700ms at SS04-001
Upper bounding surface:	Erosional unconformity	Erosional unconformity	Erosional unconformity	Generally appears to be conformable; erosional unconformable in places
Lower bounding surface:	Structurally conformable with Shipwreck	Structurally conformable with Shipwreck	Structurally conformable with Shipwreck	Structurally conformable with Shipwreck
Geometry:	Aggradational to progradational; large-scale clinoforms; Basal growth wedges with broad half graben	Half graben growth wedge in tilted fault blocks	Half graben growth wedge in King Is Sub-basin. Outboard, broadly progradational wedge; basal half graben.	Half graben growth wedge at Cape Sorell 1. Outboard, onlaps onto basement high
Seismic Character:	High to low amplitude, high continuity reflections	Dominated by widely spaced extensional faults and numerous antithetic and synthetic faults. Outboard of shelf break; strong localised inversion. Possible growth faulting in places	High–low amplitude, high–moderate continuity, moderately divergent parallel reflections. Some very high amplitude reflections probably represent igneous sills	Low–moderate amplitude high–moderate continuity
Structural style:	Widely spaced extensional tilted fault blocks; mild inversion on some faults	Outboard of shelf break antithetic fault and strong localised inversion.	Tilted fault blocks within King Island Sub-basin. Outboard widely spaced extensional faults. Localised inversion	Tilted fault blocks within half graben wedge of the Strahan Sub-basin. Outboard, widely spaced extensional faults.
Best Example:	S137-09	DS01-126	DS01-142x	SS04-001
Play Elements:	Gas shows in Paaratte sandstone in tilted fault blocks	Tilted fault blocks and horizon pinchouts	Horizon pinchout and subtle intraformational stratigraphic traps	Fault/stratigraphic traps and horizon pinchouts
Uncertainties with interpretation	Amrit 1 only penetrated upper section. Base poorly imaged in seismic	Base poorly imaged outboard of shelf break	N/A	Seismic quality deteriorates at this horizon

Geology and Hydrocarbon Prospectivity of the Deepwater Otway and Sorell basins, offshore southeastern Australia

Table 3.4: Cenozoic subsidence summary.

	<i>Deepwater Otway (Nelson Sub-basin)</i>	<i>West of King Is</i>	<i>Northern Sorell Basin</i>	<i>Strahan Sub-basin</i>
Unit name:	Wangerrip Supersequence			
Formation equivalent:	Wangerrip Group			
Basin phase:	Cenozoic subsidence			
Age:	Maastrichtian to Eocene			
Top (Biozone):	base <i>N. asperus</i>			
Base (Biozone):	intra-upper <i>F. longus</i>			
Well example(s)	Amrit 1: 1990–2046m	Whelk 1: 420–715m	Clam 1: 545–845m; Jarver 1: 1404–1522m	Cape Sorell 1: 390–1924m
Lithology:	N/A	Sandstone	Massive sandstone and siltstone	Sandstone and siltstone
Depositional environment:	Shallow marine	Deltaic to marginal marine	marginal marine to deltaic	Shallow marine to marginal marine
Sequence Character:	TST to HST	TST to HST	TST to HST	Aggradational to progradational HST
Max thickness (TWT ms)	<500ms outboard of Tartwaup–Mussel fault	<500ms outboard of shelf break	400ms in King Is Sub-basin and <300ms outboard of shelf break	1200ms at Cape Sorell 1
Upper bounding surface:	Structurally conformable; conformable topsets	Structurally conformable; conformable topsets	Structurally conformable – moderate incision	Structurally conformable
Lower bounding surface:	Unconformable on Sherbrook. Strongly incised in places with accompanying canyon fill.	Unconformable on Sherbrook	Unconformable on Sherbrook; deeply incised (canyons) in places; onlaps on basement SW of Clam 1.	Generally conformable on Sherbrook; erosional unconformity in places
Geometry:	Inboard: progradational wedge (HST). Basinward: flat-lying to low-angle downlaps (LST–TST). Most distal portion: reflections onlap basal sequence boundary.	Inboard: progradational wedge (HST). Basinward: flat-lying to low-angle downlaps (LST–TST). Onlaps inversion anticlines locally.	Aggradational at Clam 1 and overlain by HST prograding delta; progradational wedge outboard	Half graben growth wedge at Cape Sorell 1, overlain by aggradational TST and prograding HST
Seismic Character:	Inboard: low–high amplitude, moderate–high continuity clinoforms. Outboard: low–high amplitude, high continuity with generally parallel reflections.	Thin moderate–high amplitude and high continuity	Moderate amplitude and moderate–high continuity, character becomes more disrupted south of Clam 1 (affected by igneous/volcanic processes and overlying section)	moderate–high amplitude, moderate–high continuity, moderately divergent–parallel reflections
Structural style:	Regional erosional unconformity with majority of extensional faults terminating at basal sequence boundary.	Regional erosional unconformity at base and majority of extensional faults terminating below surface. Regional sag with localised reactivation on inversion structures and faults.	Regional erosional unconformity at base, majority of extensional faults terminating below surface. Tilted fault blocks continue through sequence in the King Is Sub-basin. Regional sag with localised reactivation on structures and faults.	Half graben growth section; final extensional phase in basin.
Best Example:	137-09	DS01-126	DS01-138_a_b	SS04-001
Play Elements:	Fault/stratigraphic traps. Potential seal; possible stratigraphic traps prograding facies	Reservoirs in stratigraphic plays	Fault/stratigraphic traps	Reservoirs in rollover anticlines and fault/stratigraphic traps
Uncertainties with interpretation	Amrit 1 check shot survey unavailable to tie to seismic			No well tie outboard of basement pinchout

Table 3.5: Cenozoic subsidence and recent compression and inversion summary.

	<i>Deepwater Otway (Nelson Sub-basin)</i>	<i>West of King Is</i>	<i>Northern Sorell Basin</i>	<i>Strahan Sub-basin</i>
Unit name:	Nirranda, Heytesbury and Whalers Bluff supersequences			
Formation equivalent:	Nirranda and Heytesbury groups			
Basin phase:	Cenozoic subsidence and inversion			
Age:	Middle Lutetian to Pleistocene			
Top (Biozone):	<i>T. pleistocenicus</i>			
Base (Biozone):	<i>Lower N. asperus</i>			
Well example(s)	Amrit 1: wb–1990m	Whelk 1: wb–420m	Jarver 1: wb–1404m (TD), Clam 1: wb–1546m	Cape Sorell 1: wb–~390m
Lithology:	Calcareous claystone overlain by marls, calcarenite and calcilutite	Shaly limestone overlain by calcarenite and calcilutite	Quartz sandstone overlain by silty mudstone, and limestone	
Depositional environment:	Marine	Marine	Marine	Marine
Sequence Character:	Aggradational to progradational HST	Aggradational to progradational HST	Aggradational to progradational HST	Aggradational to progradational HST
Max thickness (TWT ms)	1300ms 137-09 at shelf break	1200ms DS01-126 at shelf break	1200ms DS01-142x at shelf break	1100ms at SS04-001
Upper bounding surface:	Structurally conformable	Structurally conformable	Structurally conformable	Structurally conformable
Lower bounding surface:	Structurally conformable; onlaps Wangerrip	Structurally conformable; onlaps Wangerrip	Structurally conformable; onlaps Wangerrip	Structurally conformable; onlaps Wangerrip
Geometry:	LST, TST and progradational HST. Proximal: Aggradational–progradational shelf margin wedge. Distal: flat-lying packages	LST/TST thin sheet like geometry	Aggradational to progradational shelf margin wedge	LST, TST and progradational HST
Seismic Character:	Low–high amplitude, high continuity reflections	Moderate to high amplitude and high continuity	Moderate to high amplitude and high continuity	Moderate to high amplitude and high continuity
Structural style:	Relatively undeformed, low angle progradational wedge; some canyoning and slumps at shelf break	Relatively undeformed, low angle progradational wedge; some canyoning and slumps at shelf break	Relatively undeformed, low angle progradational wedge; some canyoning and slumps at shelf break	Relatively undeformed, low angle progradational wedge; some canyoning and slumps at shelf break
Best Example:	s137h9	DS01-126	DS01-13	
Play Elements:	Possible seals at thicker shelf break section at the base of Nirranda	Possible seals at thicker shelf break section at the base of Nirranda	Possible seals at thicker shelf break section at the base of Nirranda	Possible seals at thicker shelf break section at the base of Nirranda
Uncertainties with interpretation	N/A	N/A	N/A	N/A

4. Petroleum Geology

EXPLORATION HISTORY

Otway Basin

The deepwater Otway and Sorell basins are the least explored of the major southeast Australian offshore sedimentary basins. While several exploration wells have been drilled along the shelf-edge, in the Otway Basin the slope and deepwater areas are relatively unexplored.

Exploration in the region dates back as far as 1892, when coastal bitumen strandings led to the drilling of an exploration well in the South Australian Otway at Kingston. The first wells in the Victorian part of the Otway Basin were drilled in the 1920s to 1940s in the Anglesea and Torquay areas (Sprigg, 1986). In 1959, Port Campbell 1 was drilled into Upper Cretaceous sediments and intersected the first hydrocarbon column in the basin. Drilled by the Frome-Broken Hill consortium, it flowed at a rate of 4.2 MMcf/d from Waarre Formation sandstones. This was followed by further exploration success in the Port Campbell area, as well as gas discoveries in the Penola Trough in the South Australian portion of the onshore Otway Basin.

In the offshore Otway Basin, the discovery of gas by BHP at Minerva 1 (1993) and La Bella 1 (1994) on the flanks of the Shipwreck Trough was followed by a marked increase in activity in the offshore basin. A major exploration program by the Woodside Energy Ltd joint venture, which included the acquisition of 3D seismic, resulted in the large (approx. combined 1.3 Tcf GIP) Geographe and Thylacine gas discoveries. In 2002, another commercial offshore gas discovery was made by Strike Oil with the Casino 1 well, drilled some 20 km southwest of the Minerva field on the western flank of the Shipwreck Trough. This was followed in 2005 by the nearby Henry 1 gas discovery by Santos.

In the deepwater Otway Basin, the Voluta Trough was tested by the Amrit 1 (2004) and Somerset 1 (2009) wells, however both were dry holes.

Sorell Basin

The Sorell Basin is one of the least explored of Australia's southern margin basins. The focus of exploration has been on the northern sub-basins, where three petroleum exploration wells have been drilled.

Petroleum exploration began in the late 1960s, when Esso Exploration and Production Australia (Esso) and Magellan Petroleum Australia (Magellan) obtained reconnaissance seismic data on the west Tasmanian margin (O'Brien et al., 2004). Esso drilled three wells: Clam 1 (1969) in the King Island Sub-basin while Prawn A1 (1967) and Whelk 1 (1970) were drilled in the adjacent Otway Basin to the northwest. All wells were dry and were plugged and abandoned.

There was a relative hiatus in exploration activity during the 1970s. During this time, reconnaissance seismic surveys by Geoscience Australia (then the Bureau of Mineral Resources, Geology and Geophysics (BMR)) and Shell International along the western margin of Tasmania were the only major work undertaken.

A new phase of exploration began in 1981 when Amoco Australia Petroleum Company (Amoco) carried out a seismic survey in the Strahan Sub-basin, followed by the drilling of Cape Sorell 1 in 1982. This well tested a rollover structure and recorded minor amounts of free oil and residual oil traces, despite being drilled off structure (Amoco Australia Petroleum Company, 1982).

In 1990, Maxus Energy Corporation (Maxus) acquired a dense seismic grid in the Strahan Sub-basin. Although Maxus (1993) identified a number of drilling prospects, it failed to attract farm-in partners and the permit was relinquished (O'Brien et al., 2004).

In 2001 Seismic Australia and Fugro-Geoteam AS acquired 3,612 and 2,034 line-km of non-exclusive seismic data over the deepwater Otway and northern Sorell basins (DS01 and DS02 surveys respectively), rekindling interest in the basin. Santos had a major presence in the basin from 2002 operating permits

T/32P, T/33P, T/36P and T/48P, drilling the dry hole, Jarver 1 in T/33P during 2008. All of the Santos permits have been relinquished with the exception of T/32P, where the Santos share was taken over by Perenco (SE Australia) Pty Ltd in 2010. During this phase of exploration, Santos reprocessed the Maxus seismic and acquired a 2D infill and a 3D survey over the Strahan Sub-basin as well as acquiring several 2D infill surveys over the Sandy Cape Sub-basin. The only permit currently operating in the Release Area is T/32P, where Perenco acquired 1,000 km² of 3D seismic over the Wolseley prospect in early 2011.

PETROLEUM SYSTEMS ELEMENTS

Source Rocks

Hydrocarbon discoveries on Australia's southern margin are assigned to the Austral Petroleum Supersystem of Bradshaw (1993) and Summons et al. (1998), in which three subsystems are recognised:

- Austral 1: Upper Jurassic to lowest Cretaceous fluvio-lacustrine shales (Crayfish Supersequence);
- Austral 2: Lower Cretaceous fluvial and coaly facies (Crayfish and Eumeralla supersequences); and
- Austral 3: Upper Cretaceous to lowest Cenozoic fluvio-deltaic facies (Shipwreck and Sherbrook supersequences).

Interpretation of seismic data indicates the depositional sequences hosting active Austral 1, 2 and 3 petroleum systems in the producing areas of the Otway Basin are also likely to be present in parts of the deepwater Otway and Sorell basins.

The nature of potential source rocks basinward of the Tartwaup–Mussel Fault Zone in the Otway Basin is not well understood, and the only wells drilled beyond the fault zone, Amrit 1 (2004) and Somerset 1 (2009) were dry. Seismic interpretations indicate the sequences containing the Austral 1 and 2 petroleum systems thin basinward into the deepwater Otway Basin; conversely, the Shipwreck and Sherbrook supersequences containing the Austral 3 petroleum system thicken considerably basinward of the Tartwaup–Mussel Fault Zone (Figure 3.8). The Turonian Waarre and Flaxmans formations at the base of the Sherbrook and the overlying Coniacian–Campanian Belfast Mudstone contain marine, marginal marine and coastal plain sediments. The Cenomanian–Turonian boundary and the Coniacian–Santonian were times of global anoxia and source rock accumulation (Oceanic Anoxic Events (OAE) II and III; Arthur et al., 1990; Jenkyns, 2010). These rocks therefore have the potential to contain high quality source rocks, especially in distal marine parts of the basin (Gallagher et al., 2005; O'Brien et al., 2009). Potential source rocks of Cenomanian–Turonian boundary age with excellent liquids potential were recovered further west from the margin of the Ceduna Sub-basin of the Bight Basin (Totterdell et al., 2008).

While, hydrocarbons have not been definitively linked to Austral 3 source rocks, this does not necessarily mean that mature, generative and oil-prone Austral 3 source rocks are not developed in the Otway Basin. Most of the wells drilled in the Otway Basin have been located on inner shelf areas or onshore where the Sherbrook Group has not reached sufficient maturity for significant hydrocarbon generation. Gas discoveries in wells drilled on the outer shelf adjacent to the Tartwaup–Mussel Fault Zone (La Bella, Geographe and Thylacine) are significantly wetter and have higher CO₂ contents than discoveries on the inner shelf, where the Austral 2 system comprises the sole hydrocarbon charge (O'Brien et al., 2009). Migration of wet gas and magmatic CO₂ up the Tartwaup–Mussel Fault Zone as suggested by O'Brien et al. (2009) is a possible mechanism to explain this anomaly and evidence of an active Austral 3 petroleum system in the deepwater basin. However, it should be noted that significant sediment loading took place in the deepwater Otway Basin during the Late Cretaceous (Sherbrook Supersequence) and its likely both the Austral 2 and Austral 3 source rock intervals were thermally over-mature by approximately 82 Ma; therefore, the wet gas may only be generated in a narrow zone within the fault zone (O'Brien et al., 2009).

In the Strahan Sub-basin of the Sorell Basin, lower Maastrichtian (Austral 3) potential source rocks were intersected in Cape Sorell 1 in intercalated sandstones and shales of the lower Sherbrook Supersequence over a depth interval of 3,120–3,250 m (Figure 3.5). Measured Total Organic Carbon (TOC) ranging from less than 1% to 18.6% and Hydrogen Index (HI) values indicative of Type II/III and Type III kerogen, suggest good potential for both oil and gas (Lodwick et al., 1999; Boreham et al., 2002). The maturity of these lower Maastrichtian potential source rocks has been assessed as marginally mature to the beginning

of the oil window by Boreham et al. (2002), and immature to marginally mature by petroleum systems modelling conducted as part of this study. Cape Sorell 1 was not deep enough to intersect potential source rocks of the Austral 1 and 2 petroleum systems, however modelling for the Strahan Sub-basin indicates that if these source rocks are present they are gas to oil mature in the main half graben. Minor amounts of free oil were recorded in the sandstone and claystone intervals of the Sherbrook Group in Cape Sorell 1. Whether the oil was generated locally or from deeper Sherbrook or Otway Groups is uncertain, but its presence is encouraging evidence of an active Cretaceous petroleum system in the Strahan Sub-basin (Boreham et al., 2002).

Petroleum systems modelling of seismic line SS04-001 in the Strahan Sub-basin revealed that, if source rocks are present at the predicted levels, generation and expulsion would have occurred from the Late Cretaceous onwards for Austral 1 and 2 system sources, and from the Paleocene for Austral 3 sources. All generation and expulsion had probably ceased by the Eocene. A proportion of accumulated hydrocarbons are likely to have been lost as a result of the Paleocene/Eocene uplift and erosion. However, migration, remigration and accumulation may have continued throughout the Cenozoic.

Little is known about potential source rocks in the Sandy Cape Sub-basin. The only well drilled in the sub-basin (Jarver 1) terminated in basement overlain by the Waarre Formation equivalent. Recent seismic interpretation by Geoscience Australia show the sequences that would likely host any Austral 1, 2 and 3 potential source rocks, onlap or drape the basement high extending south from King Island (King Island High). As a result, the Upper Cretaceous sequences in the east of the sub-basin thin across the high, while the Lower Cretaceous sequences are either poorly developed or absent. Source rocks are likely to be better developed to the west of the King Island High in the deep water where the succession thickens.

Reservoirs

In the offshore Otway Basin, the primary reservoir facies occur in the Sherbrook Group (Shipwreck and Sherbrook supersequences). The Campanian–Maastrichtian Paaratte Formation, intersected by many wells in South Australia, is known to contain good quality reservoir intervals. In the Victorian part of the Otway Basin the Turonian Waarre Formation is the major regional reservoir interval. The Flaxman Formation and a sandy facies (Thylacine Member; Cliff et al., 2004) at the base of the Belfast Mudstone are also significant exploration targets. However, the extent to which these reservoir facies are developed in the deepwater Otway Basin is not known. Amrit 1 targeted the Paaratte Formation, where well developed sands were known northwest of the Hill 1 well site (Subramanian, 2005). Petrophysical analysis indicated 42.5m of net sand with an average porosity of 16.2% was intersected and while no hydrocarbon shows were recorded, the well confirms the presence of reservoir quality sands.

The only well in the Strahan Sub-basin, Cape Sorell 1, intersected a generally sandy section with few potential seals. However, due to the well's proximity to the basin boundary fault, the stratigraphy is unlikely to be representative of the rest of the sub-basin. Porosity values in the Wangerrip Group from 370–1,230 m are very high (30%+), but the lack of seal limits their reservoir potential (Conolly and Galloway, 1995). Interbedded sandstones lower in the Wangerrip Group (~1,250–1,480 m) have excellent reservoir potential with porosity ranging from 20–30%. Porosity decreases with depth, falling to <15% below 3,050 m in the Sherbrook Group near the base of the well. Towards the west, away from the boundary faults Lodwick et al. (1999) postulated that the Sherbrook Group sands become more deltaic to marine and could be winnowed and better sorted, improving their reservoir potential.

In the Sandy Cape Sub-basin, the Paleogene succession (Wangerrip and Nirranda groups) in Jarver 1 was also sandy. The Upper Cretaceous succession (Sherbrook Group) below about 1,500 m comprises interbedded sandstone, siltstone and claystone with siltstone and claystone dominating below 1,760 m (Pitman, 2008). Potential reservoirs are the Waarre Formation equivalent, the Thylacine Member at the base of the Sherbrook Group and sandstones in the Nirranda and Wangerrip groups. Petroleum systems modelling of seismic line DS01-126, which straddles the Otway–Sorell basin boundary (Figure 1.1), predicts porosity values for the Waarre Formation reservoir ranging from 20 and 25% on the platform, 10–18% on the terrace, and only 6–11% in the main part of the basin, while porosity values in the Wangerrip Group are likely to be higher than 15% throughout.

In summary, the best reservoir targets in the Sorell Basin are likely to be Eocene and Paleocene sandstones of the Wangerrip Group (Wangerrip Supersequence) and, away from boundary fault, Upper Cretaceous sandstones and possible conglomeratic sandstones of the Sherbrook Group (Shipwreck and Sherbrook supersequences). In wells drilled on the flanks of the sub-basins, the dominantly sandy Sorell Basin succession lacks the mudstones that seal and separate sandstone reservoirs of the Otway Basin (Lodwick et al., 1999). However, such sequences may be better developed to the west, away from the flanks of the sub-basins.

Seals

In the Otway Basin the most widely distributed sealing facies is the Belfast Mudstone, which provides a reliable regional top seal for reservoirs in the Waarre and Flaxman formations (Figure 2.3), while shales within the Flaxman Formation may act as intraformational seals. In the deepwater Otway Basin, likely seals occur within Paaratte Formation and Timboon Sandstone. These lithologies are characterised by intraformational mudstones which have good sealing capacity. Drilling at Amrit 1 proved the presence of reservoir quality sands and an overlying seal facies in mudstones age-equivalent to the more proximal Timboon Sandstone (Subramanian, 2005).

In the Sorell Basin, the sedimentary succession in wells drilled proximal to the inner margin of the basin is predominantly sandy, prompting suggestions that the basin lacks the thick, regional top seal provided by the Belfast Mudstone in the adjacent Otway Basin. However, the argument that the basin becomes more shale-prone seaward is demonstrated by Jarver 1, which was drilled in 2008. This well, located further offshore in the Sandy Cape Sub-basin, encountered over 1,300 m of Upper Cretaceous claystones and siltstones. These rocks belong to the Shipwreck and Sherbrook supersequences (Figure 3.2), which can be mapped seismically for a considerable distance seaward of the well. This thick, laterally continuous interval would provide an excellent regional seal for any hydrocarbon accumulation within Waarre Formation, Flaxman Formation or Thylacine Member reservoirs. The marls and fine-grained limestone in the Heytesbury Group could also provide seals to Nirranda and Wangerrip group reservoirs.

In the Strahan Sub-basin, shaly interbeds up to 20 m thick in the Wangerrip Group in Cape Sorell 1 indicate potential intraformational seal development near the sub-basin flanks. Basinward of the well, a potential sealing facies in the Wangerrip Group may be formed by an Eocene flooding surface overlain by downlapping progrades (O'Brien et al., 2004; Figure 3B). This surface can be seen in seismic data from the flanks of the sub-basins to the modern shelf break.

As in the Sandy Cape Sub-basin, facies in the Strahan Sub-basin are expected to become more shale-prone basinward. The relatively thin marls and fine-grained limestones in the Neogene Heytesbury Group could also be potential seals. Permeability barriers may also exist in carbonates and sandstones and at unconformities which could provide stratigraphic traps if laterally continuous (Lodwick et al., 1999).

Play types

Deepwater Otway Basin

Sandstones within the Shipwreck Supersequence (Sherbrook Group; Waarre and Flaxman formations) sealed by the Belfast Mudstone and charged by Austral 2 source rocks are the most successful exploration targets inboard of the Tartwaup–Mussel Fault Zone. While the Shipwreck Supersequence thickens outboard of the fault zone (Figure 3.8), rapid sediment loading in the Late Cretaceous resulted in Austral 2 source rocks undergoing complete organic matter transformation by 82 Ma (O'Brien et al., 2009). Therefore plays in the deepwater Otway Basin are likely to be reliant on charge from unproven Austral 3 source rocks. If present, Geary and Reid (1998) considered the Austral 3 source rocks in the lower Sherbrook Group to have the potential to generate oil in the Voluta and Portland troughs. Petroleum geochemical studies by O'Brien et al. (2009) support the proposal that mature Turonian source rocks (Sherbrook Group) in the deepwater Otway Basin may be capable of generating liquid hydrocarbons. However, O'Brien et al. (2009) report due to Late Cretaceous and Late Cenozoic loading the Austral 2 and basal Austral 3 source rocks become thermally over-mature in the deepwater basin by approximately 82 Ma and conclude that only a narrow band along the Tartwaup–Mussel Fault Zone is currently in the peak generation window. Further

basinward, source rocks younger and shallower than the basal Waarre and Flaxmans formations need to be present to charge any potential accumulations (O'Brien et al., 2009).

The Paaratte Formation in the Sherbrook Supersequence is another potential reservoir target basinward of the Tartwaup–Mussel Fault Zone. The deepwater well Amrit 1 targeted oil charge from the Belfast Mudstone reservoir in the upper, faulted deltaic section of the Paaratte Formation with top and cross-fault seal provided by the distal marine mudstones of the lower Timboon Sandstone (Subramanian, 2005). While, Amrit 1 confirmed the presence of reservoir quality sands and an overlying seal facies in mudstones age-equivalent to the more proximal Timboon Sandstone (Subramanian, 2005), the play remains unproven. In the more distal parts of the deepwater Otway Basin where the Sherbrook Supersequence is very thick but relatively unstructured, stratigraphic traps become the more likely exploration targets.

Only ongoing exploration, especially in the deeper parts of the basin, will shed light on the viability of these plays. As the depths become prohibitive over much of the deepwater Otway Basin, the most promising exploration targets lie in faulted anticlines and tilted fault-blocks immediately outboard of the Tartwaup–Mussel Fault Zone.

Sorell Basin

In the Strahan Sub-basin, petroleum systems modelling suggests that migration pathways are updip towards the western edge of the basin, where the most likely trap scenarios are high-side fault blocks, stratigraphic pinch-outs and, to a lesser extent, small rollover anticlines with updip closure. Fault block traps are predicted in the basal Shipwreck Supersequence (Waarre Formation equivalent) and at the base of the Wanggerip Group, charged by both Austral 2 and 3 source rocks. A pinch-out play lies along the western edge of the sub-basin where the sediments thin across the hinge of the half graben; such stratigraphic traps are likely to be charged by Austral 2 and 3 sources. Other potential traps in the sub-basin include rollover closures associated with major bounding faults and drape anticlines over canyons and fault blocks in the Wanggerip Group, while channel-fill in Paleocene–Lower Eocene canyons may form substantial stratigraphic traps.

The Sandy Cape Sub-basin partly underlies the continental shelf and attains a maximum sedimentary thickness of over 5,000 m. Similar sediment thicknesses underlie large areas of the continental slope in the southward deep water continuation of the adjacent Otway Basin (Nelson Sub-basin). These continental slope depocentres represent a vast, down-dip, kitchen area where, if present, oil-prone Austral 3 source rocks are likely to be in the peak generation window (O'Brien et al., 2004). Petroleum systems modelling of Austral 1, 2 and 3 source rocks north of the sub-basin indicates accumulations are most likely developed in structural traps (high-side fault traps and faulted anticlines) in the Waarre Formation and other Sherbrook Group reservoirs. The Paleocene–Lower Eocene canyons mapped in the Strahan Sub-basin also occur in the Sandy Cape Sub-basin, where they have the potential to form substantial stratigraphic traps if suitable seals are present. The canyons may also act as conduits for migrating hydrocarbons generated in the thick depocentres under the continental slope.

EXPLORATION ISSUES AND CRITICAL RISKS

The critical exploration issues and risks for region relate to the presence of source and seal, maturity, fault seal integrity, biodegradation of shallow reservoirs and potential loss of hydrocarbons as a result of uplift and erosion. The strata containing the active petroleum systems in the Otway Basin can be confidently mapped over the shelf break and downslope into the deep water and southwards into the Sorell Basin. Both areas contain no proven petroleum systems and interpretation of their presence is through analogy to the successful Otway Basin plays on the platform.

The major exploration risk in the deepwater areas of the Otway Basin is the presence and maturity of Austral 3 source rocks. Maturation modelling undertaken by O'Brien et al (2009) shows the basal, Turonian Austral 3 petroleum system is likely to be over-mature across the deep water basin except in a narrow band adjacent to the Tartwaup–Mussel Fault Zone, with the play reliant on younger and shallower source rocks. Poor fault-seal is also a risk for fault-related traps in the basin at large. In the present-day

stress field, traps bound by steeply dipping, northwest trending faults are considered the least likely to retain hydrocarbons (O'Brien et al., 2009).

In the Sorell Basin potential source rocks were intersected by Cape Sorell 1 and the presence of trace amounts of free oil in the well is encouraging evidence of an active Cretaceous petroleum system in the Strahan Sub-basin (Boreham et al., 2002). Wells drilled on the inboard part of the shelf are dominated by sandstone with no source and poor seal development. However, as Jarver 1 demonstrated, the more basinward areas are likely to be marine and more shale-prone. Petroleum systems models indicate biodegradation is a significant risk in shallow reservoirs of the Wangerrip Group where the temperature can be below 80°C.

5. Petroleum Systems Modelling and Play Analysis

SOUTHERN OTWAY–NORTHERN SORELL PROFILE: DS01-126

2D Petroleum systems modelling was carried out for line DS01-126 in the southeastern Otway–northern Sorell Basin using Petromod 11 SP3 software. The geological interpretation of this line utilised the tectonostratigraphic framework of Krassay et al. (2004). The geological model was prepared by depth converting the interpreted seismic horizons using stacking velocities (Fig. 5.1). Depth conversion indicates that the sedimentary section along this profile is up to 8 km thick.

Based on previous publications (Edwards et al., 1999; Krassay et al., 2004; Ryan et al., 2005; O'Brien et al., 2009), it is likely that two major petroleum systems are present along the modelled section – Austral 2 and Austral 3 (Fig. 5.2). Austral 2 refers to potential source rocks of the Early Cretaceous Crayfish and Eumeralla supersequences. They were deposited in fluvial to lacustrine environments and typically comprise Type III kerogen. Organic matter content was modelled as bulk total organic carbon (TOC). Austral 3 refers to potential source rocks of the Late Cretaceous Shipwreck and Sherbrook supersequences deposited in deltaic to marine environments. Kerogen kinetics used are those of Pepper & Corvi (1995), provided in the Petromod software.

The only exploration well along the line is Whelk 1, located in shallow water on the basin margin above the King Island basement high. The only data available for calibration are vitrinite reflectance data provided in the well completion report, indicating that sediments of the Shipwreck and Sherbrook supersequences are thermally immature for oil generation at this location (Fig. 5.3). The data calibrate with a model of high palaeo-heat flows and considerable erosion of the upper Sherbrook Supersequence during the Paleocene. Erosion during the Paleocene rather than Eocene (as modelled by Ryan et al. (2005)) is based on the assumption that continental break-up in this area occurred at approximately 65 Ma (Krassay et al., 2004). Underplating associated with breakup is suggested by a high velocity layer in the crust (Nayak et al., 2010). It should also be noted that the section also calibrates with the Whelk data without having to invoke the Paleocene heat flow spike; a declining or constant heat flow since 95 Ma results in a good correlation between measured and modelled maturity. It should also be noted that the section at Whelk 1 is not representative of the section farther basinward, therefore there is a degree of uncertainty regarding the present-day maturity model.

The thermal maturity level indicated by the vitrinite reflectance data suggests that an additional 600 to 900 m of Sherbrook Supersequence sediments were deposited during the Maastrichtian and subsequently eroded in the Paleocene. This is consistent with Duddy and Erout (2001) who invoked kilometre-scale uplift and erosion during the Maastrichtian to Paleocene for the eastern Otway Basin.

The model generated for present-day maturity along the section shows that the modelled Austral 2 potential source rocks S1 (Crayfish), S2 and S3 (Eumeralla) are mostly dry gas mature to overmature (Fig. 5.4). The Austral 3 potential source rocks S4 and S5 (basal Shipwreck) are modelled as mostly wet to dry gas mature, and S6 (Sherbrook) as mostly late oil to wet gas mature. On the eastern terrace, potential source rocks are oil mature, whereas potential source rocks on the Whelk platform are immature. The 1D depth extraction from the modelled line (Fig. 5.5) shows that the current levels of maturity were reached early during the depositional history, with no significant changes since the Paleocene.

Modelled present-day transformation ratios (Fig. 5.6) show that, apart from the inboard part of the basin (platform), 100% of kerogen from potential Early to Middle Cretaceous source rocks has been transformed and that kerogen of the Late Cretaceous Sherbrook Supersequence has been partially transformed. This level of transformation was reached by the Paleocene and has remained basically unchanged since then. Expulsion from the modelled source rocks occurred from the Aptian onwards (between 125 and 62 m.y.), with no expulsion occurring since the Paleocene (Fig. 5.7; Table 5.1).

Using the source rock parameters and depositional constraints shown in [Figures 5.2](#) and [5.3](#), the model predicts a number of potential accumulations along this 2D line. Although both liquid and vapour accumulations are represented on the diagram, flashing the reservoirs to surface conditions suggests that the accumulations probably comprise mainly gas with some condensate. The accumulations are likely to be located in structural traps (high side fault traps and faulted anticlines) in the two modelled reservoirs, the Waarre Formation and the nominal Sherbrook Supersequence reservoir.

However, the model predicts low porosities for the Waarre Formation reservoir along most of the line. They range between 20 and 25% on the platform, 10–18% on the terrace, and only 6–11% in the main part of the basin. Prospectivity in the deepwater part of the basin is therefore dependent on the presence and quality of potential reservoirs within the Sherbrook Supersequence. These have predicted porosities of about 15–25%. However, biodegradation is a potential risk for Sherbrook Supersequence reservoirs in outboard and inboard parts of the basin, where present-day temperatures are below 80°C.

While expulsion from potential source rocks probably ceased by the Paleocene, migration and accumulation continued throughout the Cenozoic. Initial accumulations formed in the early Campanian. A proportion of hydrocarbons were lost during the Paleocene uplift and erosion event, but traps were subsequently recharged during further subsidence.

In summary, the petroleum systems modelling of line DS01-126 has revealed that, if source rocks are present at the predicted levels, generation and expulsion would have occurred from the Albian onwards and ceased in the Paleocene. A proportion of accumulated hydrocarbons are likely to have been lost as a result of the Paleocene structural event, however, migration and accumulation continued throughout the Cenozoic and the model predicts present-day accumulations in mostly fault-related traps. Porosity at the Waarre Formation level is a major risk in the main basin, but good porosities at this level are expected on the platform and terrace. Prospectivity of the deepwater basin is reliant on reservoir and seal pairs being present within the Sherbrook Supersequence, however, if these are at shallow depths, biodegradation may be a risk. Very little is known about seal rocks.

Table 5.1: Timing of expulsion from potential source rocks, line DS01-126.

POTENTIAL SOURCE ROCK	TIMING OF EXPULSION
Austral 2 – S1 (Crayfish)	Aptian–Paleocene
Austral 2 – S2 (lower Eumeralla)	Aptian–Paleocene
Austral 2 – S3 (upper Eumeralla)	Turonian–Paleocene
Austral 3 – S4 (basal Shipwreck: marine)	Turonian–Paleocene
Austral 3 – S5 (basal Shipwreck: deltaic)	Campanian–Paleocene
Austral 3 – S6 (Sherbrook: marine)	Campanian–Paleocene

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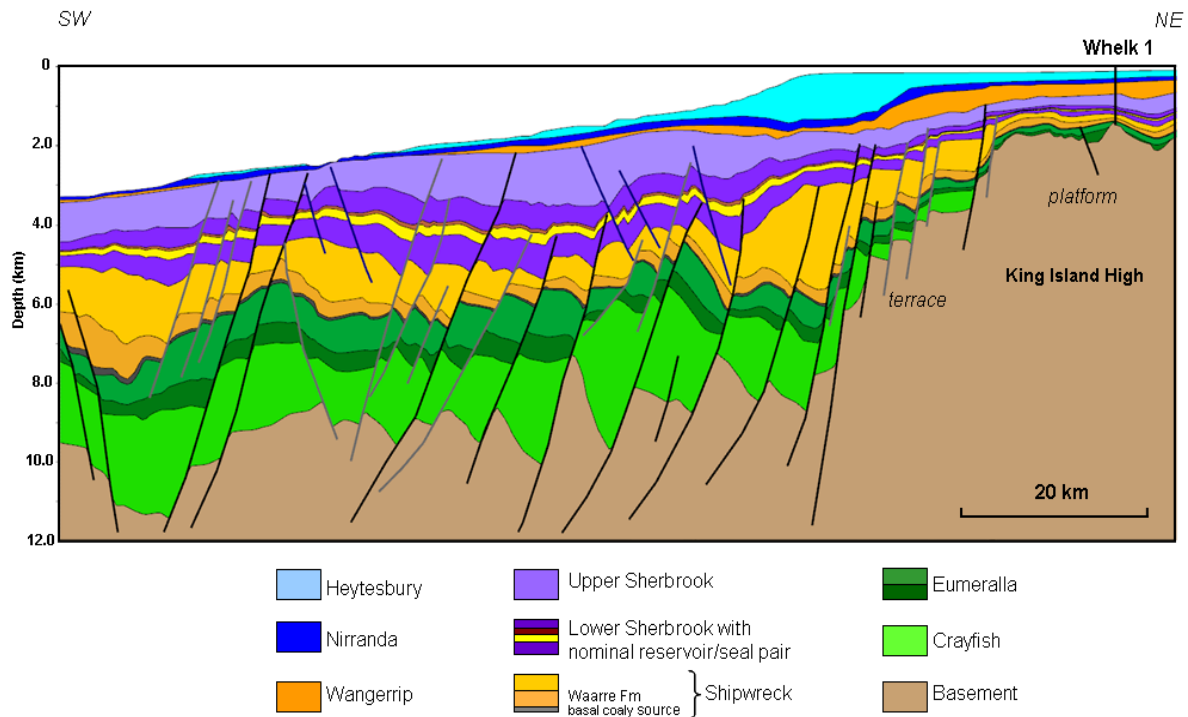


Figure 5.1: Geological model, line DS01-126. Location shown on [Figure 1.1](#).

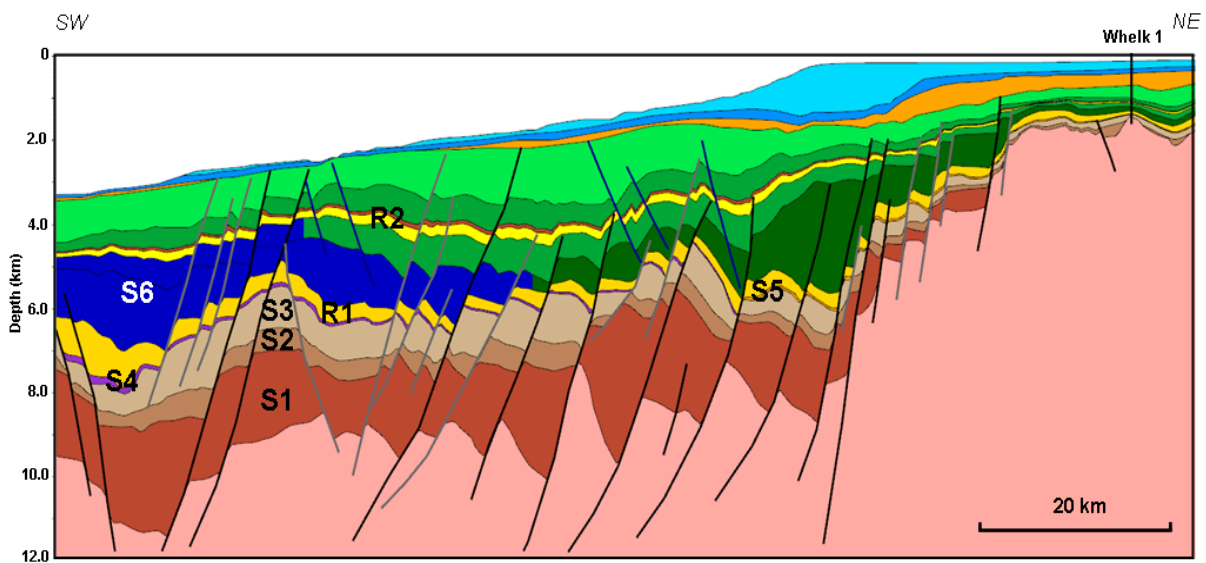


Figure 5.2: Modelled source rocks, line DS01-126. Early Cretaceous fluvio-lacustrine facies Austral 2 source rocks: S1 = Crayfish Supersequence, TOC 3%, Type III kerogen; S2 = Eumeralla Supersequence, TOC 5%, Type III kerogen; S3 = Eumeralla Supersequence, TOC 2%, Type III kerogen. Late Cretaceous deltaic facies Austral 3 source rocks: S4 = Shipwreck Supersequence (basal marine), TOC 5%, Type II kerogen; S5 = Shipwreck Supersequence (basal coaly), TOC 20%, Type III kerogen; S6 = Sherbrook Supersequence (Belfast Mudstone), TOC 2%, Type III/IV kerogen. R1 = Waarre Formation reservoir, R2 = nominal Sherbrook Supersequence reservoir.

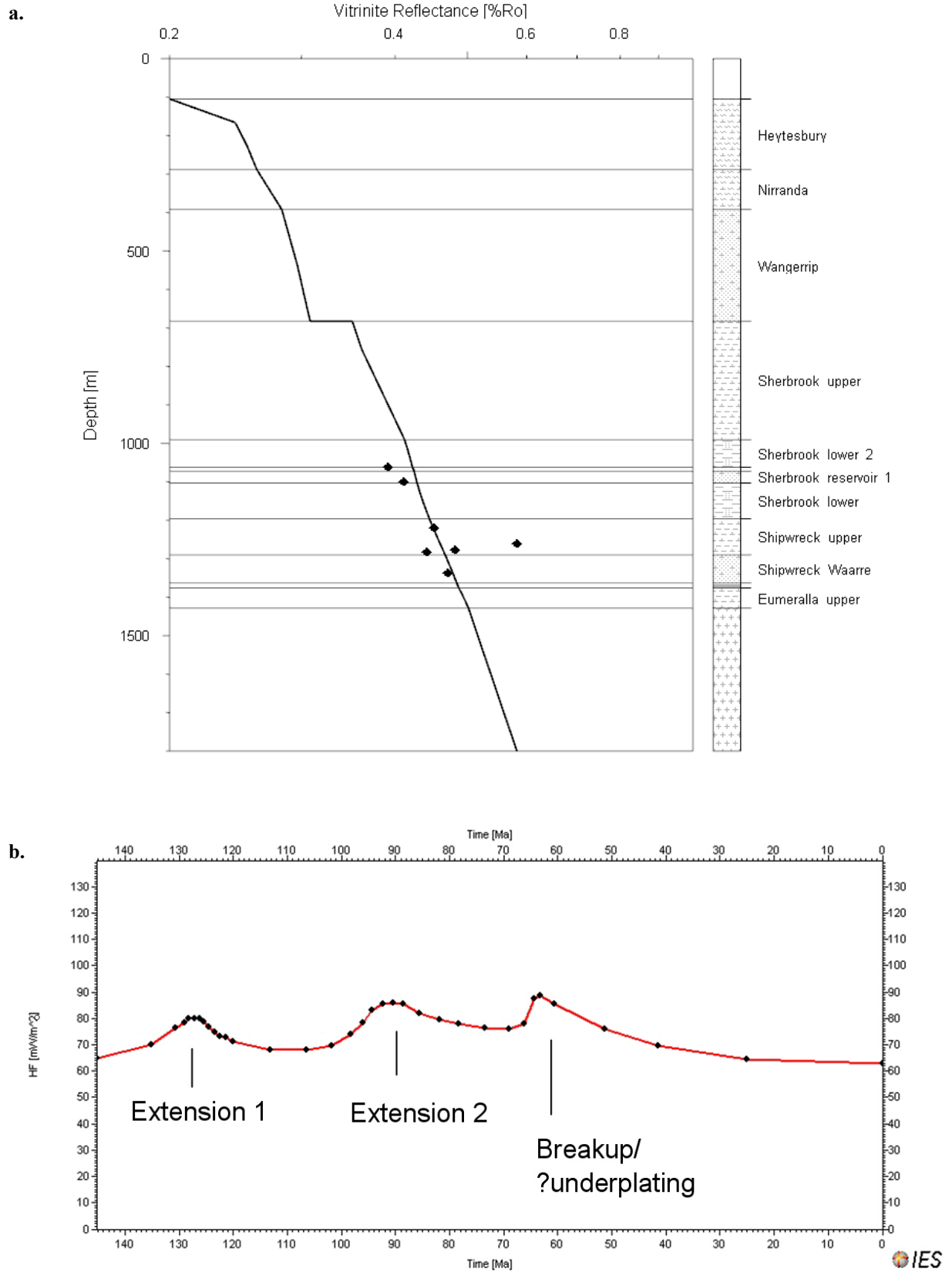


Figure 5.3: Model calibration at Whelk 1: a) vitrinite reflectance data; b) palaeo-heatflow model.

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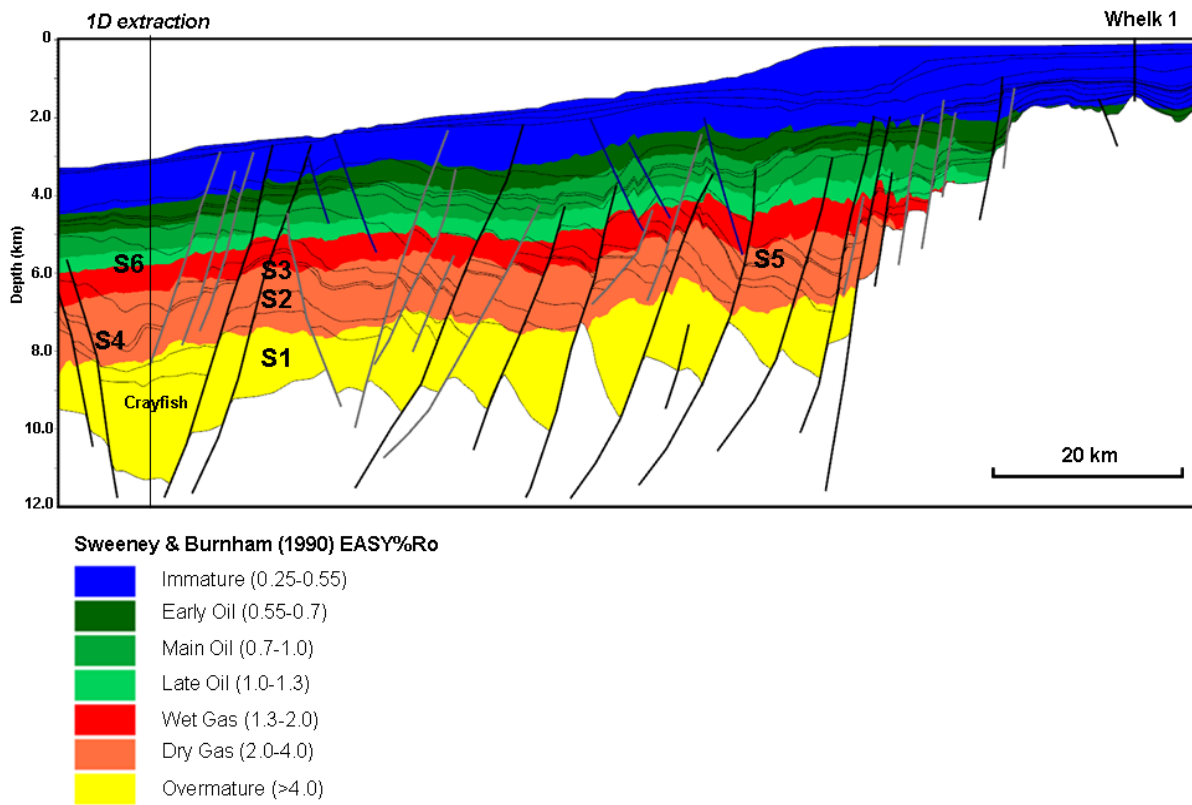


Figure 5.4: Present-day maturity model, line DS01-126.

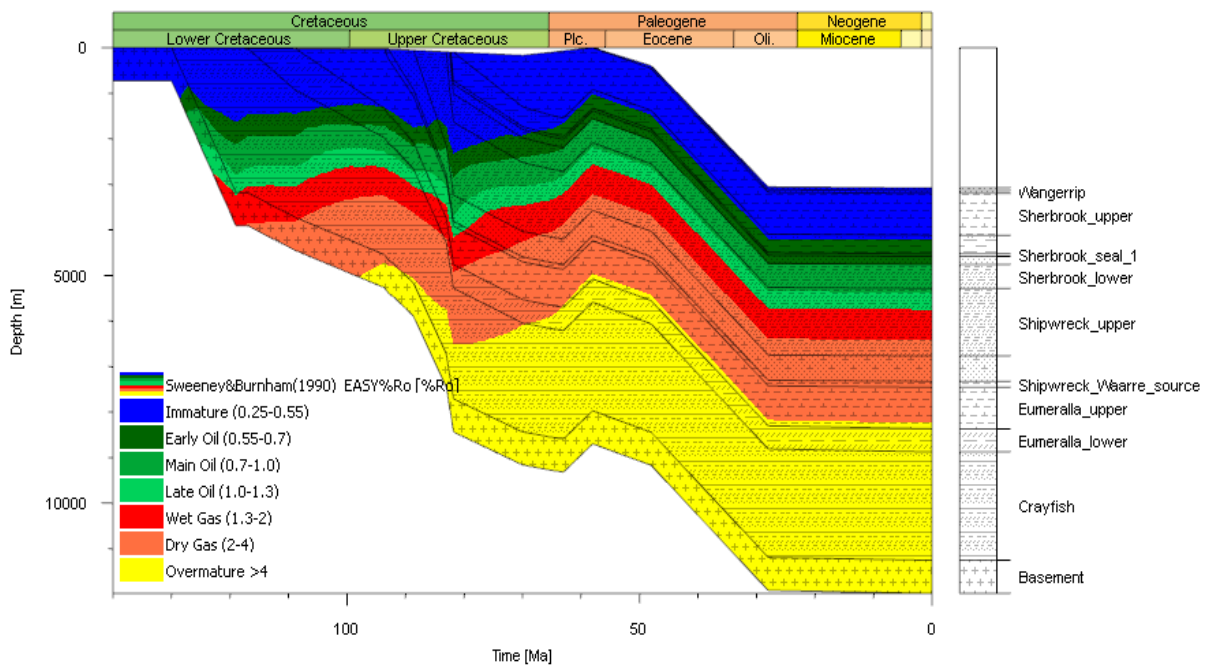


Figure 5.5: 1D depth extraction from the modelled line, DS01-126. Location of depth extraction shown in Figure 5.4.

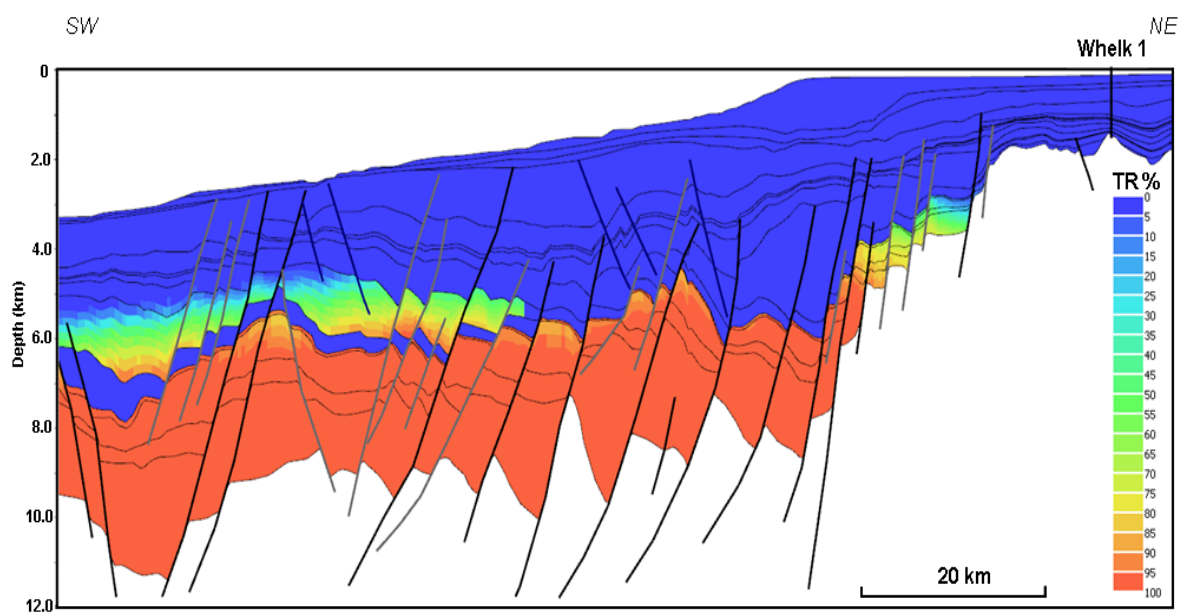


Figure 5.6: Modelled present-day transformation ratio, line DS01-126.

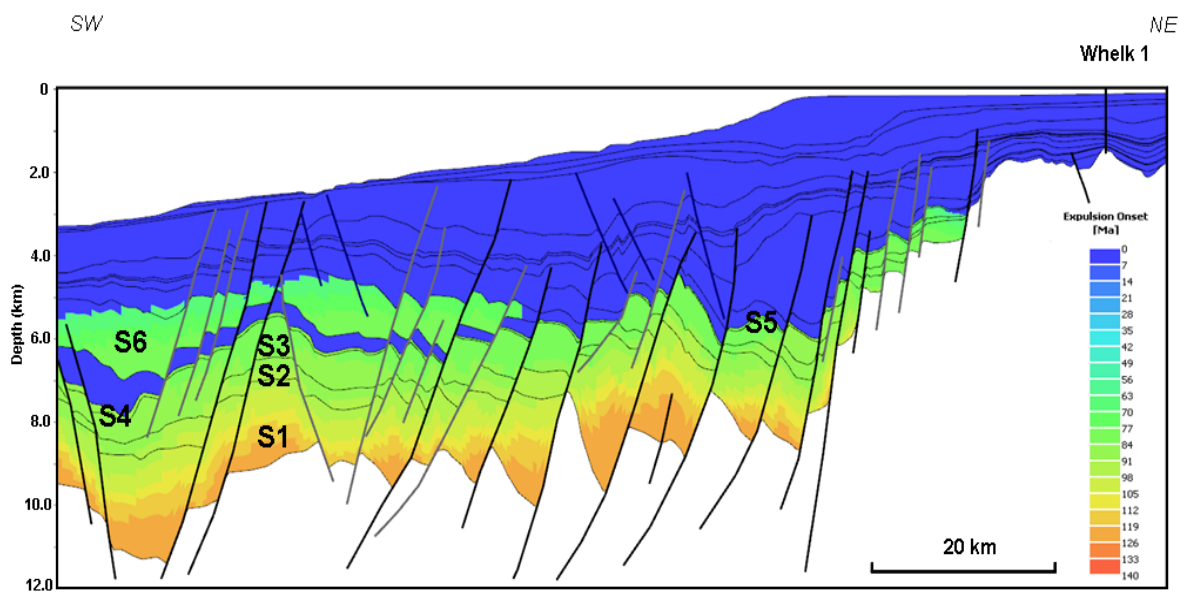


Figure 5.7: Timing of expulsion from modelled source rocks, line DS01-126.

STRAHAN SUB-BASIN PROFILE: SS04-01

2D Petroleum systems modelling was carried out for line SS04-001 in the Strahan Sub-basin of the Sorell Basin (Figure 1.1) using Petromod 11 SP3 software. Depth conversion of interpreted horizons (using stacking velocities) suggests that up to 8 km of sediment was deposited in the deepest half graben (Fig 5.8). The geological model is based on recent GA seismic interpretation building on the tectonostratigraphy proposed by Krassay et al (2004) for the Otway Basin.

Based on previous publications (Boreham et al., 2002; O'Brien et al., 2004), it is likely that two major petroleum systems (Austral 2 and Austral 3) are present along the modelled section (Fig. 5.9). Austral 2 refers to potential source rocks of the Early Cretaceous Crayfish and Eumeralla supersequences. They were deposited in fluvial to lacustrine environments and typically comprise Type III kerogen. Organic matter content was modelled as bulk TOC. Austral 3 refers to potential source rocks of the Late Cretaceous Shipwreck and Sherbrook supersequences deposited in fluvio-deltaic to marine environments. Only the S4 potential source rock of Early Maastrichtian age was actually intersected by Cape Sorell 1, where it occurs over a depth interval of 3,120 to 3,250 m with measured TOC values ranging from less than 1% to 18.6%. This interval was modelled with a bulk average TOC of 7%. As in the northern profile, Pepper & Corvi (1995) kerogen kinetics provided through Petromod software were used in the modelling.

The only exploration well along the line is Cape Sorell 1, located in shallow water and intersecting the main half graben down to Late Campanian/Early Maastrichtian-aged sediments. Data available for calibration include vitrinite reflectance data, indicating that sediments at the base of the well are marginally mature for oil generation (Fig. 5.10). The data calibrate with a model of a raised palaeo-heat flow during initial extension in the Early Cretaceous and a second increase during the Late Paleocene to Eocene reflecting breakup in this region and proximity to the mid-oceanic ridge during this time. Seismic data indicate an erosional event at the Sherbrook/Wangerrip unconformity level; therefore, about 300 m of erosion of upper Sherbrook Supersequence was modelled for the Paleocene. Boreham et al (2002) used a constant basal heat flow of 48 mWm^{-2} for their 1D model of Cape Sorell 1 and O'Brien et al (2004) used a constant basal heat flow of 54 mWm^{-2} . The latter produces similar maturation and generation history to the varying basal heat flow model used in this study.

Although there is a reasonably good correspondence between measured and modelled vitrinite reflectance levels, predicted temperatures below 2,500 m are lower than measured downhole temperatures (Figure 5.11) Boreham et al. (2002) discussed a similar issue, suggesting that either temperatures have increased to their measured values only recently or that the measured VR data are too low. They preferred the latter interpretation. For this study, the modelled temperature/VR values are taken as a reasonable approximation, considering the consistency of the VRF values (Boreham et al., 2002).

The modelled present-day maturity levels show that both Austral 2 and Austral 3 potential source rocks are gas to oil mature in the main central half graben of the sub-basin (Fig. 5.12). Rich coaly potential source rocks intersected in Cape Sorell are only marginally mature for oil generation. A 1D depth extraction from the modelled line shows that the current levels of maturity were reached early during the depositional history, with no significant changes since the Late Eocene (Fig. 5.13).

Modelled present-day transformation ratios show that only the deeper part of the main half graben has ratios above 30% (Fig. 5.14). 100% of kerogen from potential Early Cretaceous source rocks has been transformed in the deepest part of the main half graben, whereas transformation ratios reach up to 58% in the most deeply buried sediments of the more westerly half graben. Thus, only the Crayfish, Eumeralla and basal Waarre units are likely to have contributed to any potential accumulations. Transformation ratios for the Maastrichtian source (S5) range between 0 and 4%.

Expulsion from the mostly Early Cretaceous modelled source rocks would have occurred from about 100 Ma onwards, with only minor expulsion since the Late Eocene (Fig. 5.15; Table 5.2).

Using the source rock parameters and depositional constraints shown in Figures 5.10 and 5.11 and a migration algorithm based on a combined flow-path and Darcy flow model, the model predicts several small potential accumulations. The accumulations are likely to be located in both structural and

stratigraphic traps (high side fault traps and stratigraphic pinch-outs) in the Waarre Formation and the Wangerrip Supersequence.

Initial accumulations formed in the early Campanian. Migration paths tend to travel updip towards the western edge of the basin, with little migration occurring along the major bounding fault based on this model. Using a different migration algorithm, i.e. capillary invasion or “invasion percolation”, results in more accumulations and larger predicted totals.

The model predicts porosities of mostly 10–20% for the Waarre Formation reservoir at depths shallower than 4 km. Sherbrook Supersequence porosities are predicted to lie between 15 and 25% and porosities in the Wangerrip Supersequence are likely to be higher than 15% throughout. However, biodegradation is a potential risk for reservoirs where present-day temperatures are below 80°C.

In summary, the petroleum systems modelling of line SS04-001 has revealed that, if source rocks are present at the predicted levels, generation and expulsion would have occurred from the Late Cretaceous onwards and more or less ceased in the Eocene. A proportion of accumulated hydrocarbons are likely to have been lost as a result of the Paleocene/Eocene uplift and erosion, however, migration, remigration and accumulation continued throughout the Cenozoic and the model predicts present-day accumulations in mostly fault-related and pinchout traps. Porosity does not appear to be a major risk, but biodegradation may be a risk factor.

Table 5.2: Timing of expulsion from potential source rocks, line SS04-001

POTENTIAL SOURCE ROCK	TIMING OF EXPULSION
Austral 2 – S1 (Crayfish)	Late Cretaceous–Eocene
Austral 2 – S2 (lower Eumeralla)	Late Cretaceous–Eocene
Austral 2 – S3 (upper Eumeralla)	Campanian–Eocene
Austral 3 – S4 (basal Shipwreck: coaly)	Paleocene–Eocene
Austral 3 – S5 (Sherbrook: coaly)	immature

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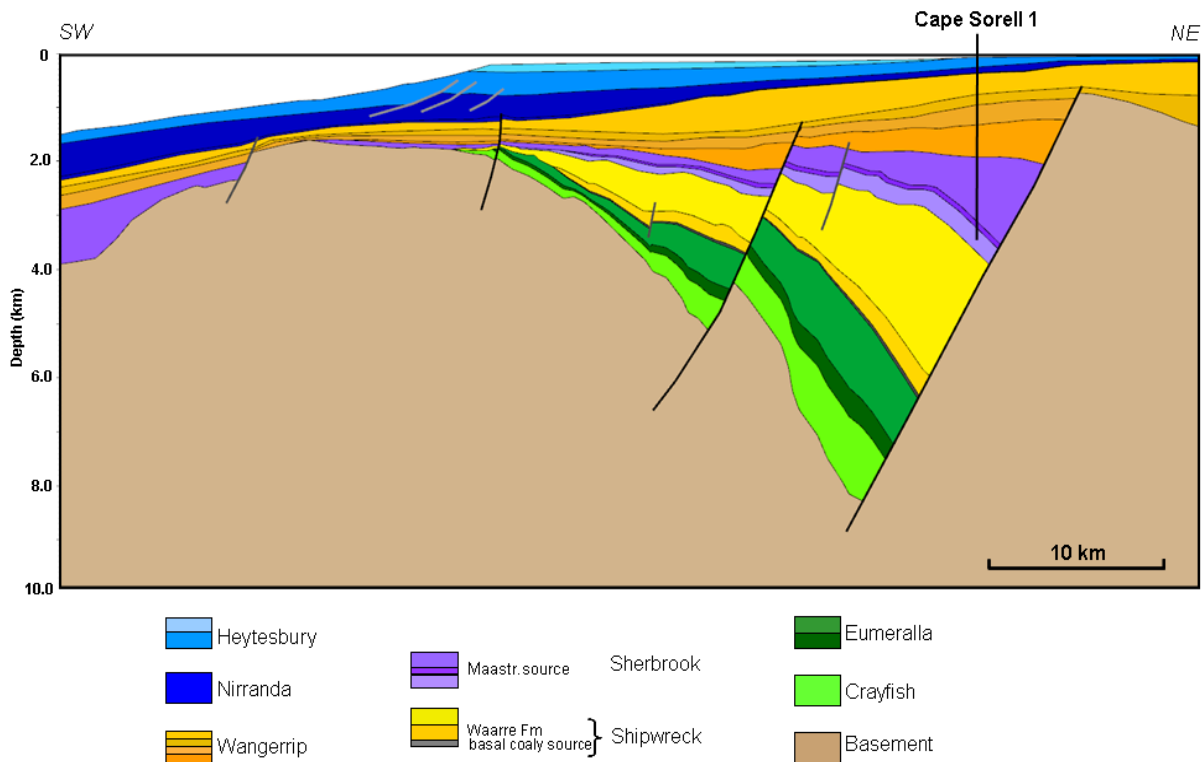


Figure 5.8: Geological model, line SS04-001. Location shown on [Figure 1.1](#).

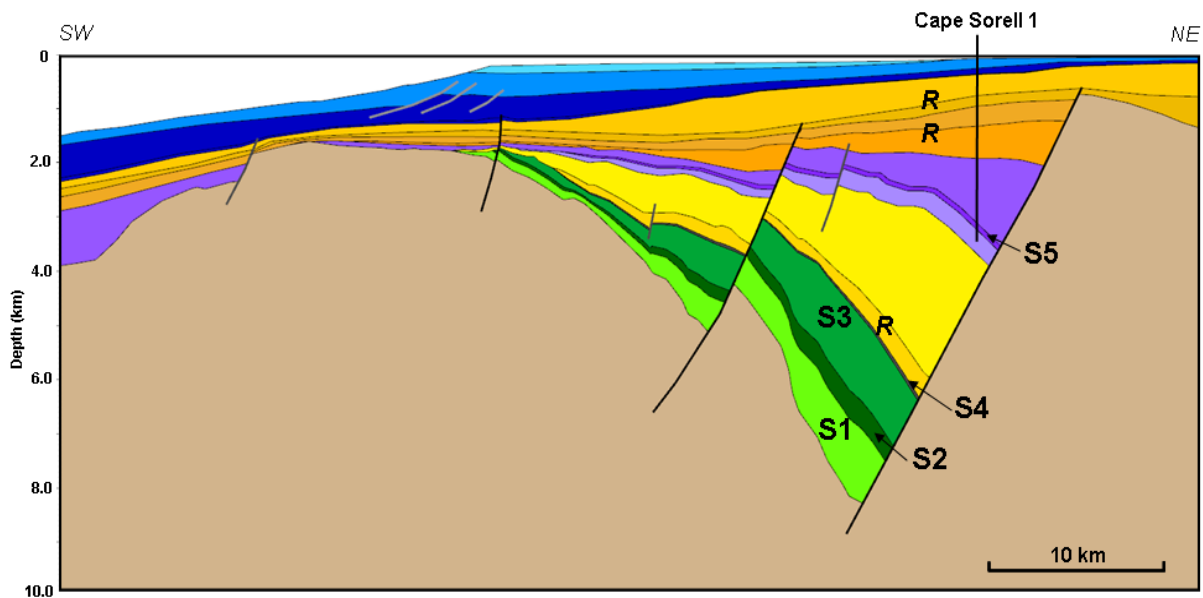
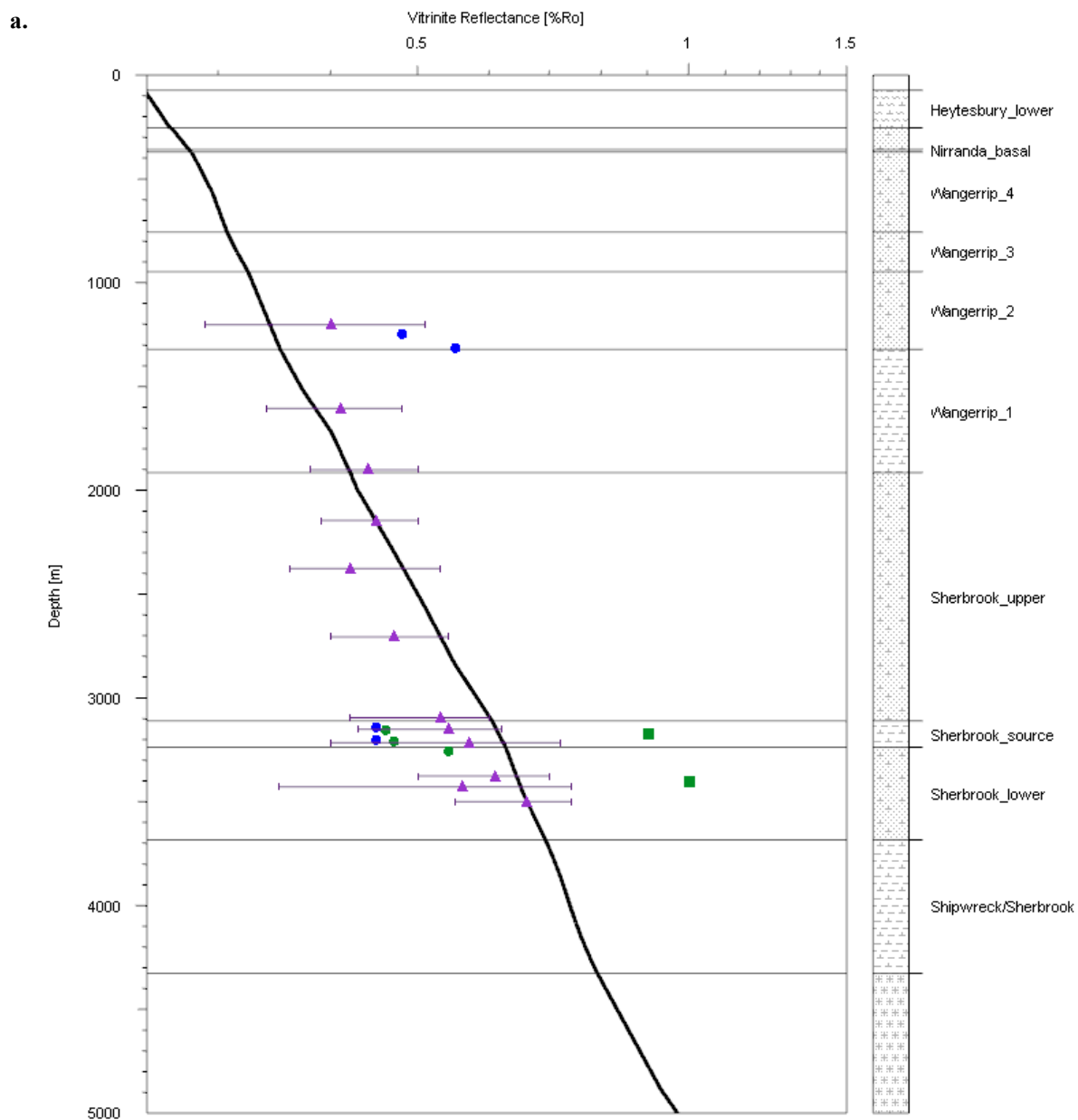


Figure 5.9: Modelled source rocks, line SS04-001. Early Cretaceous fluvio-lacustrine facies Austral 2 source rocks: S1 = Crayfish Supersequence, TOC 3%, Type III kerogen; S2 = Eumeralla Supersequence, TOC 5%, Type III kerogen; S3 = Eumeralla Supersequence, TOC 2%, Type III kerogen. Late Cretaceous deltaic facies Austral 3 source rocks: S4 = Shipwreck Supersequence (basal coaly), TOC 15%, Type III kerogen; S5 = Sherbrook Supersequence (early Maastrichtian), TOC 7%, Type III kerogen. R = nominal reservoirs.

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● SWC Robertson Research, 1983

■ SWC Robertson Research, 1982

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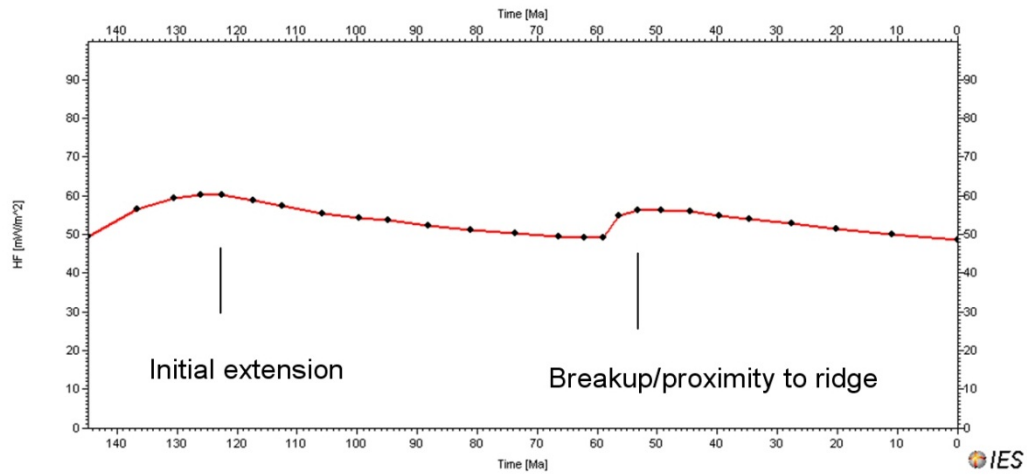


Figure 5.10: Model calibration at Cape Sorell 1: a) vitrinite reflectance data; b) palaeo-heatflow model.

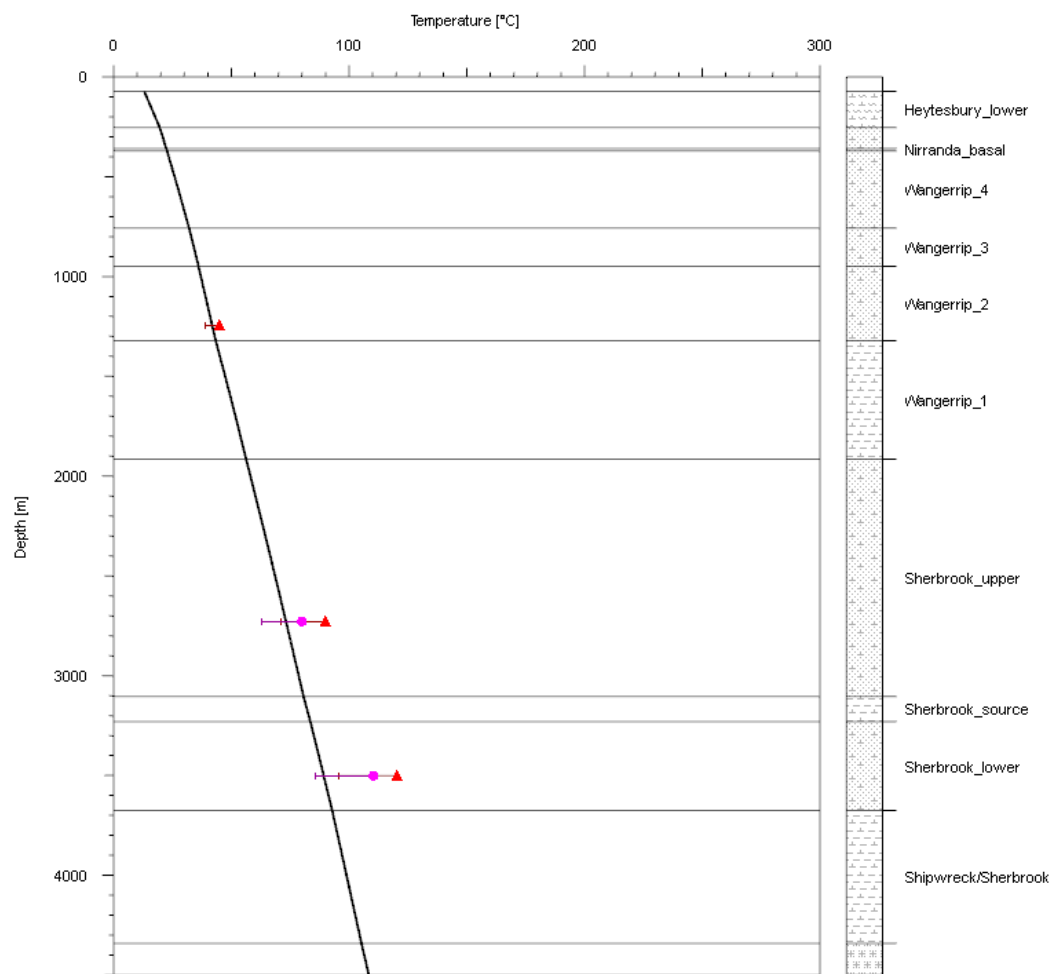


Figure 5.11: Downhole temperatures, Cape Sorell 1. Pink dots are uncorrected temperatures; red triangles are corrected temperatures [+10% °F].

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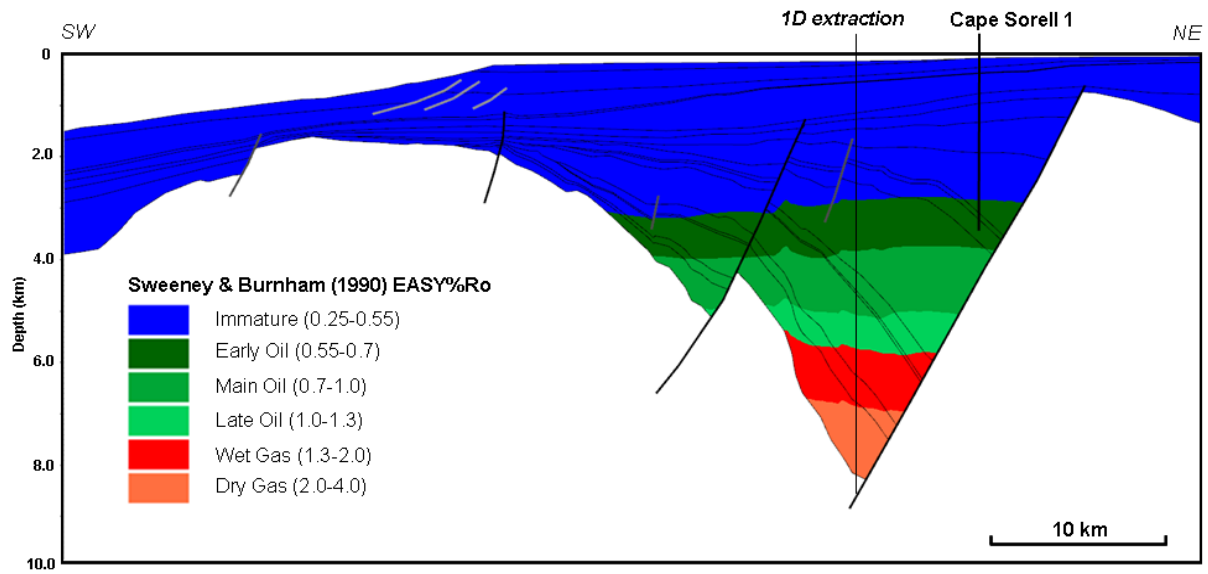


Figure 5.12: Present-day maturity model, line SS04-001.

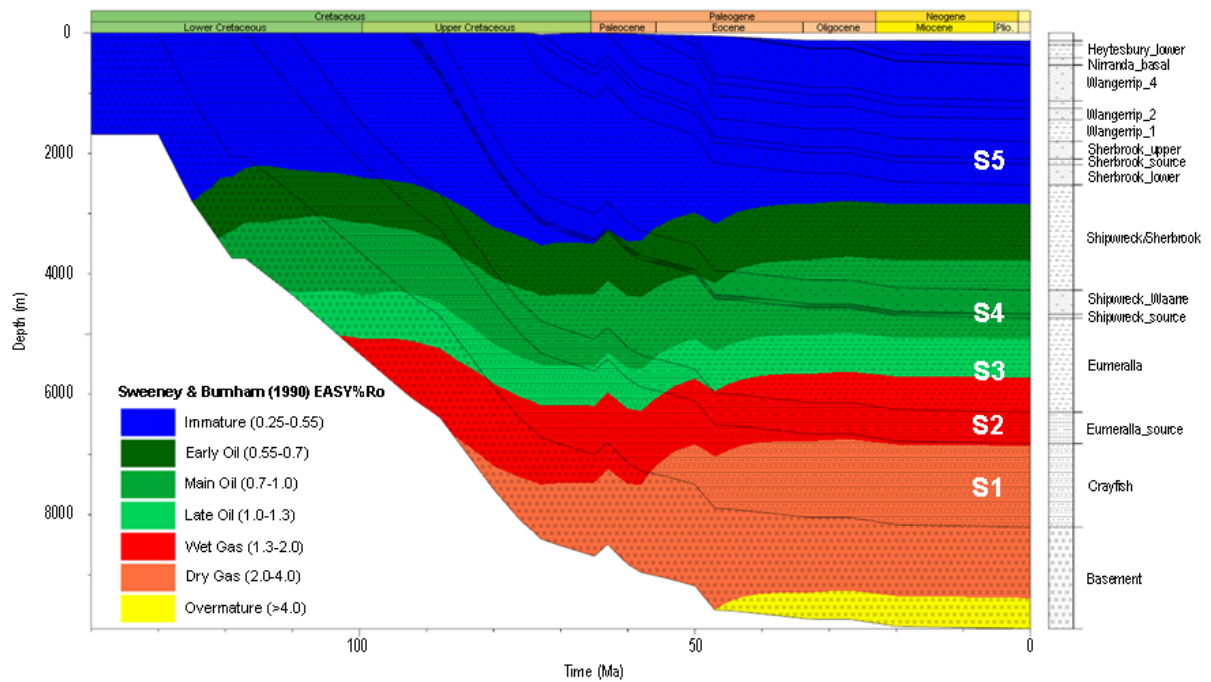


Figure 5.13: 1D depth extraction from the modelled line, SS04-001. Location of depth extraction shown in Figure 5.12.

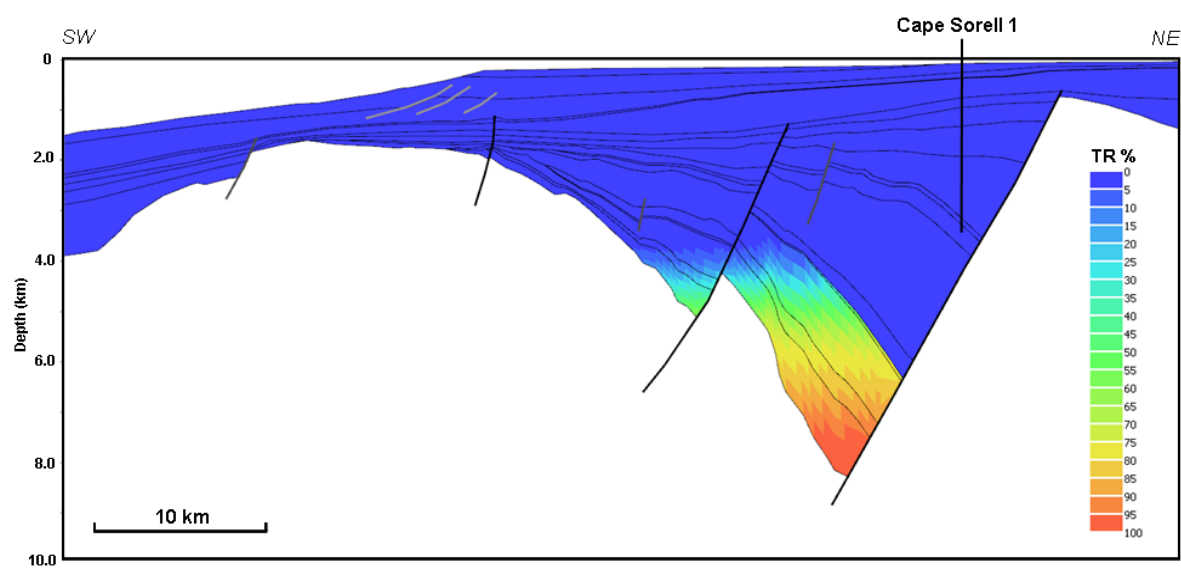


Figure 5.14: Modelled present-day transformation ratio, line SS04-001.

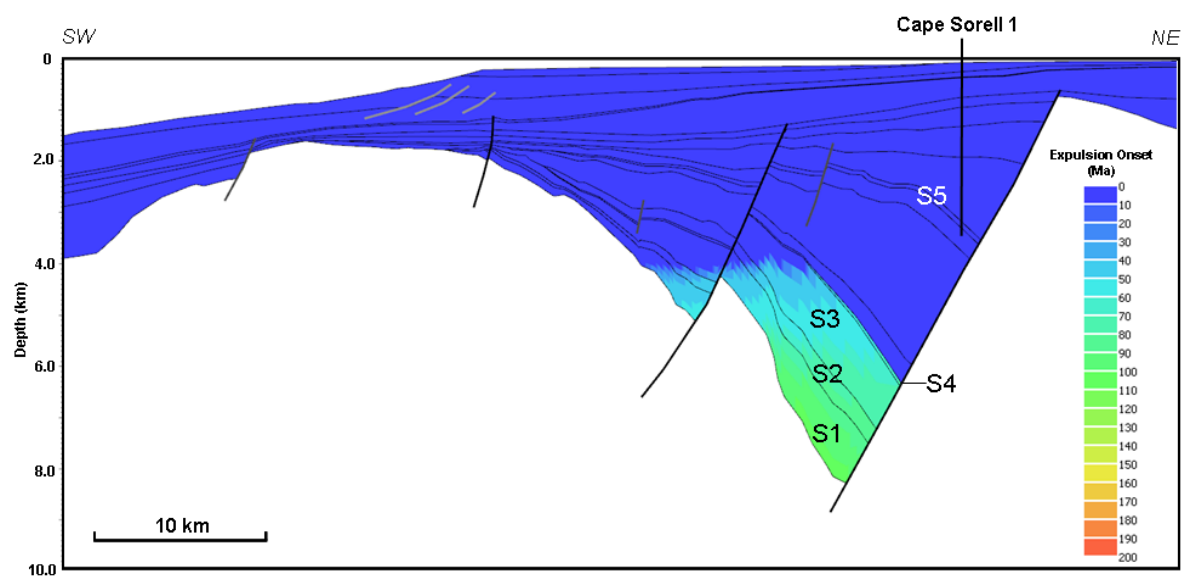


Figure 5.15: Timing of expulsion from modelled source rocks, line SS04-001.

6. Conclusions

The deepwater Otway and Sorell basins developed in the eastern part of the Southern Rift System (Stagg et al., 1990; Willcox and Stagg, 1990). These under-explored, frontier basins lie in water depths of <50–4,500 m, offshore of southwestern Victoria and western Tasmania adjacent to producing areas of the Otway Basin. Significant changes in basin architecture and depositional history from west–east reflect the transition from an orthogonal–obliquely rifted continental margin (western–central Otway Basin) to a transform continental margin (southern Sorell Basin). While the basins are contiguous both structurally and stratigraphically, the structure of the eastern Otway and Sorell basins has been strongly influenced by the architecture and structural fabric of the underlying basement, particularly the Avoca–Sorell Fault System. These structures controlled the NW–SE transition from extension, through transtension, to a predominantly strike-slip regime (Gibson et al., 2011). This basement control and the variations in structural regime are reflected in: the architecture of the basins, particularly the long, narrow depocentres of the King Island and Strahan Sub-basins; the NW–SE changes in extensional fault strike from E–W in the Nelson Sub-basin to predominantly north–south in the vicinity of the Avoca–Sorell Fault System; and the north to south diachroneity of extension.

TECTONOSTRATIGRAPHY

New seismic and tectonostratigraphic interpretations carried out as part of this study show the depositional sequences identified in the Otway Basin (Krassay et al., 2004) can be recognised and mapped in the deepwater Otway and Sorell basins. This tectonostratigraphic interpretation documents the evolution of the basin system from non-marine deposition in Early Cretaceous intracratonic rifts to the development of an open seaway between Australia and Antarctica. Five distinct and regionally mappable chronostratigraphic basin phases have been identified (Figures, 2.3 and 3.2):

- Early Cretaceous Extension and Subsidence – Crayfish and Eumeralla Supersequences
- Late Cretaceous Extension 1 – Shipwreck Supersequence
- Late Cretaceous Extension 2 – Sherbrook Supersequence
- Cenozoic Subsidence 1 – Wangerrip Supersequences
- Cenozoic Subsidence 2 and Inversion – Nirranda, Heytesbury and Whalers Bluff Supersequences

Early Cretaceous deposition (Crayfish and Eumeralla supersequences) was strongly focussed on north–south striking structures outboard of the Avoca–Sorell Fault System. In the southern Otway and northern Sorell basins, deposition occurred in small half graben developed on mainly west-dipping faults; structural control is less evident in the central Otway Basin. In the Strahan Sub-basin a Lower Cretaceous syn-rift section is interpreted at the base of the main half graben. Seismic facies in the Early Cretaceous succession are generally nondescript, indicative of lithologically uniform fluvio-lacustrine facies. A widely developed set of high-amplitude reflections near the top of the succession are interpreted as coals within the upper Eumeralla Formation. A major unconformity separates the Lower and Upper Cretaceous sections and reflects uplift along the eastern margin of the basins. At the end of the Early Cretaceous, the region was affected by a period of compression that resulted in uplift and inversion of many earlier rift structures.

The Late Cretaceous Shipwreck Supersequence is thickest in the central Otway Basin, basinward of the Tartwaup–Mussel Fault Zone, and west of the Avoca–Sorell Fault System. Deposition in fluvial, deltaic and shallow marine environments was controlled by extensional faults and is characterised by half-graben growth strata. In the Shipwreck Trough and southern Otway Basin, accommodation was controlled by small, mainly west-dipping faults. In the northern Sorell Basin, deposition on the platform was confined to small half graben. The sequence thickens basinward of the hinge zone and deposition was controlled by east- and west-dipping fault systems. In the Strahan Sub-basin, deposition was concentrated in a series of isolated half graben.

A major sequence boundary separates the Shipwreck and Sherbrook supersequences, marking renewed rifting and a major basinward shift in facies (Krassay et al, 2004). In the deepwater Otway and northern Sorell basins, the largely deltaic succession has a progradational geometry. Lying outboard of the present-day shelf-

break, the depocentre occupies a broad arcuate trough that narrows towards the southeast. The sequence thins markedly across the Shipwreck Trough and Prawn Platform indicating a southward shift in the locus of deposition. The supersequence is thickest outboard of the Tartwaup–Mussel Fault Zone in the Voluta Trough, progressively thinning towards the southwest and pinching out at the basins' deepwater margin. While structural control was minimal in the deepwater Otway Basin, in the northern Sorell Basin active faulting continued until the Cenozoic. In the Strahan Sub-basin, deposition of the Sherbrook supersequence was strongly structurally controlled, with thick growth wedges forming in the main half graben.

A major sequence boundary in the latest Cretaceous marks the initiation of seafloor spreading and the onset of post-rift passive-margin conditions in the deepwater Otway Basin and northern Sorell Basin. The Wangerrip, Nirranda, Heytesbury and Whalers Bluff supersequences are thickest at the present-day shelf break, thinning rapidly towards the deepwater area. Fault controlled growth wedges in early Wangerrip equivalent strata indicate that structurally controlled deposition in the Strahan Sub-basin continued into the Late Paleocene–Early Eocene. This change in the distribution of structuring is abrupt rather than gradual, reflecting the episodic nature of southern margin breakup.

PETROLEUM PROSPECTIVITY

Hydrocarbon discoveries on Australia's southern margin are assigned to the Austral Petroleum Supersystem, in which three subsystems are recognised:

- Austral 1 Upper Jurassic to lowest Cretaceous fluvio–lacustrine shales (Casterton Formation and Crayfish Supersequence);
- Austral 2 Lower Cretaceous fluvial and coaly facies (Crayfish and Eumeralla supersequences); and
- Austral 3 Upper Cretaceous to lowest Cenozoic fluvio–deltaic facies (Shipwreck and Sherbrook supersequences).

The depositional sequences that host Austral 2 and 3 petroleum systems elsewhere in the Otway Basin (O'Brien et al, 2009), are well developed throughout the study area. Similar fluvial and coaly Austral 2 and fluvio–deltaic Austral 3 source rocks are interpreted to be present. In addition, there is the potential for marine source rocks of Turonian or younger age in the deepwater, southern Otway and Sorell basins, which could be mature for hydrocarbon generation in a narrow zone outboard of the Tartwaup–Mussel Fault Zone.

2D petroleum systems modelling of two profiles from the southern Otway Basin (west of King Island) and Sorell Basin (Strahan Sub-basin) was undertaken to constrain the timing of generation and expulsion from the potential source rocks. The results suggest that Austral 2 and 3 source rocks are mature for oil and gas generation in large parts of the basin, with generation and expulsion occurring mainly in the Late Cretaceous in the north, and Paleocene in the south.

In the southern Otway–northern Sorell basins, modelled accumulations are likely to be located in structural traps (high-side fault traps and faulted anticlines) in the two modelled reservoirs, the Waarre Formation and the nominal Sherbrook Supersequence reservoir. Initial accumulations formed in the early Campanian and while expulsion had probably ceased by the Paleocene, migration and accumulation continued throughout the Cenozoic. A proportion of hydrocarbons were probably lost during a Paleocene uplift and erosion event, but traps may have been subsequently recharged during further subsidence. Critical exploration risks include the presence of source rocks and the possible loss of charge during Paleocene uplift and erosion. Modelled porosity at Waarre Formation level is poor and a major risk in the main part of the basin, but good porosities are expected on the platform and terrace. Prospectivity in the deepwater basin would rely on reservoir and seal pairs being present within the Sherbrook Supersequence.

In the Strahan Sub-basin, generation and expulsion from predicted source rocks would have occurred from the Late Cretaceous onwards, more or less ceasing in the Eocene. A proportion of accumulated hydrocarbons are likely to have been lost as a result of the Paleocene/Eocene uplift and erosion, however, migration, renewed migration and accumulation probably continued throughout the Cenozoic. The model predicts several small potential accumulations, mostly in fault-related and pinchout traps. Critical exploration risks include the presence of source rocks and loss of charge during Paleocene uplift and erosion.

Acknowledgements

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