



Regional Geology of the Bight Basin

The Bight Basin formed during the break-up of eastern Gondwana in the Late Jurassic–Early Cretaceous. It extends for ~2000 km along the Australian southern margin (**Figure 1**) and comprises a series of extensional depocentres. No significant hydrocarbons have been found in the basin, which remains Australia's largest exploration frontier. Renewed exploration activity is currently focused on the Ceduna Sub-basin in the eastern Bight Basin, which hosts a large deltaic system in which oil-prone source rocks have been identified.

Basin outline

The Bight Basin is situated on the western and central continental margin of southern Australia and extends from south of Cape Leeuwin in the west, to south of Kangaroo Island in the east, where it adjoins the Otway Basin (**Figure 1**). The basin developed during the break-up of eastern Gondwana in the Jurassic and Cretaceous. Today, water depths vary from less than 200 m on the shelf to over 4000 m in the distant offshore.

The Bight Basin contains five main depocentres—the Ceduna, Duntroon, Eyre, Bremer and Recherche sub-basins (**Figure 2**). The largest depocentre is the Ceduna Sub-basin, which covers approximately 126 300 km² and contains a Jurassic–Upper Cretaceous succession over 15 km thick. To the north and east of the main depocentres, a thin Bight Basin succession overlies Proterozoic basement (including the Gawler Craton and Albany–Fraser Orogen) and deformed Proterozoic–lower Paleozoic rocks of the Adelaide Fold and Thrust Belt (**Figure 3**). To the south, the uppermost sequences of the Bight Basin onlap highly extended continental crust and rocks of the continent–ocean transition on the abyssal plain between Australia and Antarctica (Sayers et al, 2001). Basement trends have had a profound influence on the structural development of the Bight Basin and controlled the location and orientation of early basin-forming structures (Stagg et al, 1990; Totterdell et al, 2000; Teasdale et al, 2003; Totterdell and Bradshaw, 2004). The Bight Basin is overlain unconformably by the dominantly cool water carbonates of the Cenozoic Eucla Basin.

Basin evolution and tectonic development

The Bight Basin is one of a series of Mesozoic to Cenozoic depocentres that developed along Australia's southern margin during the breakup of eastern Gondwana (Fraser and Tilbury, 1979; Bein and Taylor, 1981; Willcox and Stagg, 1990; Stagg et al, 1990; Hill, 1995; Totterdell et al, 2000; Norvick and Smith, 2001; Teasdale et al, 2003; Totterdell and Bradshaw, 2004). The basin evolved through repeated episodes of extension and thermal subsidence leading up to, and following, the commencement of sea-floor spreading between Australia and Antarctica (Totterdell and Bradshaw, 2004). The tectonostratigraphic development of the basin can be described in terms of four basin phases that reflect those different tectonic drivers (**Figure 4**; Totterdell et al, 2000).

Middle Jurassic–Lower Cretaceous extension and post-rift subsidence

The Bight Basin was initiated during a period of Middle–Late Jurassic to Early Cretaceous upper crustal extension. At that time, a convergent margin existed on the eastern side of the continent and incipient rifts were developing between Australia and Antarctica, India and Antarctica, and India and Western Australia, the three extensional systems forming a triple junction (Norvick and Smith, 2001). Rifting along this system eventually resulted in sea-floor spreading between India and Australia/Antarctica, but the rift along the southern margin failed at that time. In the Bight Basin, a northwest–southeast to north-northwest–south-southeast extension direction, superimposed on east–west and northwest–southeast-oriented basement structures, resulted in oblique to strongly oblique extension and the formation of en-echelon half graben in the

Bremer, Eyre, inner Recherche, Ceduna and Duntroon sub-basins (**Figure 5, Figure 6, Figure 7, Figure 8**). The full areal extent of the early extensional structures beneath the Ceduna Sub-basin has not been imaged on seismic data due to the thickness and nature of the overlying sedimentary section. The thickness of the sub-basin may indicate, however, that Jurassic–Early Cretaceous rifts are present at depth.

The Early Cretaceous was characterised by post-rift thermal subsidence in the Bight Basin. Deposition during the initial extensional phase and the subsequent period of thermal subsidence was largely dominated by non-marine sediments, with evidence for some late marine influence in this phase recorded in wells located on the inboard margins of the basin. Continental breakup along the southern part of the western margin commenced in the Early Cretaceous, so by the mid-Cretaceous, an open ocean lay to the west and a seaway was beginning to develop along the southern margin towards the eastern Bight Basin.

Mid-Cretaceous accelerated subsidence

An abrupt increase in subsidence rate in the mid-Albian (Totterdell et al, 2000; Totterdell and Bradshaw, 2004) signalled the onset of the third phase of basin development. This period of accelerated subsidence, which continued until the commencement of sea-floor spreading between Australia and Antarctica in the late Santonian, coincided with a period of rising global sea level. This combination of factors resulted in a rapid increase in accommodation, the first major marine flooding event in the basin and the widespread deposition of marine silts and shales of the Albian–Cenomanian Blue Whale Supersequence (**Figure 4**). Progradation of the deltaic sediments of the White Pointer Supersequence into a narrow seaway commenced in the Cenomanian. High rates of deposition resulted in a short-lived period of shale mobilisation and growth faulting throughout the northern half of the Ceduna Sub-basin (**Figure 5**; Totterdell and Krassay, 2003a). The Cenomanian deltaic facies include a broad band of coaly sediments in the inner part of the Ceduna Sub-basin. The White Pointer Supersequence is overlain by the marginal marine, deltaic and open marine sediments of the Turonian–Santonian Tiger Supersequence. The Tiger Supersequence thickens markedly to the south reflecting a shift in the locus of deltaic deposition during this time (MacDonald et al, 2013).

Australian–Antarctic sea-floor spreading and post-breakup subsidence

The commencement of ultra-slow to very slow sea-floor spreading in the latest Santonian was followed by a period of thermal subsidence and the establishment of the southern Australian passive margin. In the Eyre, Duntroon and Bremer sub-basins, a period of structural deformation coinciding with the commencement of break-up resulted in inversion, uplift and erosion of much of the Upper Cretaceous succession (Totterdell et al, 2014). In the Ceduna and Duntroon sub-basins, the passive margin phase of basin development is represented by the latest Santonian–Maastrichtian Hammerhead Supersequence, a sand-rich deltaic system characterised by strongly prograding stratal geometries (**Figure 5**; Krassay and Totterdell, 2003; King and Mee, 2004). Because of the slow rate of sea-floor spreading, the seaway into which the deltas prograded would have been relatively narrow. A dramatic reduction in sediment supply at the end of the Cretaceous saw the cessation of deltaic deposition. Regional uplift resulted in the erosion of the Hammerhead Supersequence and much of the underlying Tiger Supersequence from the Eyre Sub-basin and the progressive erosion of the Cretaceous section across the Madura Shelf.

From the late Paleocene to the present, the largely cool-water carbonates of the Eucla Basin accumulated on a sediment-starved passive margin. In the middle Eocene (around 45 Ma) there was a dramatic increase in the rate of seafloor spreading (Tikku and Cande, 1999), which resulted in widespread subsidence of the margin. A short phase of magmatism coincided with the onset of rapid spreading. This magmatic phase was characterised by both extrusive volcanism (volcanoes, flows, volcanic build-ups) and the intrusion of sills, dykes and deeper igneous bodies in the central Ceduna Sub-basin (Schofield & Totterdell, 2008; Holford et al, 2012; Reynolds et al, 2017).

Exploration history

Petroleum exploration in the eastern Bight Basin (Eyre, Ceduna and Duntroon sub-basins) has occurred in three major cycles – the late 1960s to early 1970s, the early 1990s, and 2000–present (see O’Neil, 2003). After nearly fifty years of exploration in the offshore Bight Basin, only ten petroleum exploration wells have been drilled (**Figure 2**). With the exception of Gnarlyknots 1/1A, all wells have been drilled in relatively shallow water near the basin margin. The deeper part of the basin remains largely untested. No significant hydrocarbons have been discovered and the Bight Basin remains an exploration frontier. Recently, exploration activity in the main depocentres in the eastern part of the basin has increased and exploration permits cover parts of the Ceduna Sub-basin (Statoil/Equinor, Murphy/Santos, Karoon) and the easternmost Ceduna–Duntroon sub-basins (Bight Petroleum; **Figure 9**). New seismic data have been acquired in the basin, including ION Geophysical’s BightSPAN deep regional seismic survey, and several large 3D surveys over the Ceduna Sub basin. These new surveys have augmented the 100 000 line km of legacy 2D seismic data with modern 2D and 3D seismic data.

During the 1960s and 1970s, exploration was undertaken by Shell Development (Australia) (Shell) and Outback Oil. Seismic, shipboard magnetic and aeromagnetic data were acquired. Several prospects were developed from these activities and three exploration wells were drilled – Echidna 1 (Duntroon Sub-basin, 1972), Platypus 1 (Ceduna Sub-basin, 1972) and Potoroo 1 (Ceduna Sub-basin, 1975). By 1977, Shell had surrendered its Bight Basin petroleum exploration permits. In the early 1980s, limited exploration took place in the central Ceduna Sub-basin, with exploration efforts concentrating on shallower, flanking depocentres. Esso Exploration and Production Australia (Esso), in a joint venture with Hematite Petroleum acquired seismic surveys and drilled Jerboa 1 (1980) in the Eyre Sub-basin, and Outback Oil and BP drilled Duntroon 1 (1986) in the Duntroon Sub-basin.

In early 1990, BP acquired an Airborne Laser Fluorosensor (ALF) survey over the inboard Bight Basin. The initial results were disappointing, but reprocessing and reinterpretation of the data resulted in the identification of 941 confident fluors (Cowley, 2001). In 1991, BHP Petroleum (Australia) (BHP) commenced an exploration program focussing on the eastern Ceduna and Duntroon sub-basins. In 1993, BHP drilled three wells – Borda 1 and Greenly 1 in the Ceduna Sub-basin, and Vivonne 1 in the Duntroon Sub-basin. Although all three were plugged and abandoned, their results vastly improved knowledge of the basin succession. Gas shows and oil indications in Greenly 1 provided some encouragement for further exploration.

The latest phase of petroleum exploration commenced in 2000 when exploration permits EPP 28, EPP 29 and EPP 30 were awarded to a joint venture comprising Woodside Energy (operator), Anadarko Australia and PanCanadian Petroleum (now EnCana) in the Ceduna Sub-basin. The joint venture acquired approximately 15 400 line km of 2D seismic data and in 2003, drilled Gnarlyknots 1/1A in EPP 29. The well failed to reach its objective and was suspended due to adverse weather conditions while drilling. No exploration well has been drilled in the Bight Basin since. The lack of success for this well, the first well to target the thicker, more prospective succession in the outboard Ceduna Sub-basin, had a large negative impact on perceptions of prospectivity in the basin and raised doubts about the presence of hydrocarbon source rocks in the basin. In early 2006, Woodside acquired the 1250 km² Trim 3D seismic survey in the outer Ceduna Sub-basin, but in 2007 they surrendered all three permits.

During this period, permits were also held in the Duntroon Sub-basin and on the eastern margin of the Ceduna Sub-basin by the Woodside-Anadarko-EnCana joint venture and Santos Offshore. Approximately 2300 line km of seismic data were acquired within the permits, prior to surrender in 2007.

Following the failure of the Gnarlyknots 1A well, Geoscience Australia undertook a precompetitive study in 2007–2009 to address some of the key uncertainties and negative perceptions. The study centred on an extensive marine sampling survey which aimed to sample potential source rocks and identify possible seepage areas. The resulting collection and identification of world-class marine, oil-prone potential source rocks in the Bight Basin (Totterdell et al, 2008; Totterdell and Mitchell, 2009), stimulated renewed exploration interest and the release of exploration areas across the basin.

Following acreage release in the northern and central Ceduna Sub-basin in 2009, four permits (EPPs 37–40) were awarded to BP Exploration (Alpha) Ltd in January 2011. The guaranteed work program included the acquisition of over 11 000 km² of 3D seismic data and the drilling of four wells. In 2013, Statoil took a 30% interest in these permits.

Two areas in the easternmost Ceduna and Duntroon sub-basins, released in 2010, were awarded to Bight Petroleum in 2011 with a guaranteed work program that included the drilling of one well.

Further acreage to the northwest and southeast of the BP permits was released in 2012. In October 2013, two permits (EPPs 44, 45) were awarded to Chevron Australia New Ventures Pty Ltd.; the guaranteed work program included the acquisition of 21 000 km² of 3D seismic data and the drilling of four wells. One permit (EPP 43) was awarded to Murphy Australia Oil Pty Ltd and Santos Offshore Pty Ltd, with a guaranteed work program that included the acquisition of 2D and 3D seismic data.

The remaining exploration areas in the eastern Bight Basin were released in 2014 and 2015. An Eyre Sub-basin permit (WA-517-P) was awarded to Santos-JX Nippon in August 2015, and in October 2016, EPP 46 in the Ceduna Sub-basin, to the east of Chevron's EPP 45, was awarded to Karoon Gas Australia.

The guaranteed work programs of geological and geophysical studies for the eleven permits in the eastern Bight Basin awarded from 2011–2017 totalled a minimum exploration investment in excess of \$1.2 billion. Since award of these permits, exploration activities by the permit holders have resulted in the acquisition of ~42 000 km² of 3D seismic data—the Ceduna (12 022 km²), Nerites (21 488 km²) and Springboard (8013 km²) 3D surveys. These new data sets have completely altered the knowledge base for the basin, from disparate 2D seismic data of varying vintages to an almost blanket coverage of modern high quality 3D seismic data across the northern and central Ceduna Sub-basin, and have delivered new insights into the evolution and petroleum geology of the basin (e.g. Klauser-Baumgärtner et al, 2019; Strømsøyen et al, 2019).

Exploration efforts in the basin suffered a setback in October 2016 when BP announced it would not progress its exploration drilling programme in the Great Australian Bight, citing that the project would not be able to compete for capital investment with other upstream opportunities in its global portfolio (BP, 2016). In an asset transfer agreement with joint venture partner Statoil, BP was assigned a 100% interest in EPP 37 and EPP 38 (which were ultimately cancelled), and Statoil a 100% interest in EPP 39 and EPP 40. Statoil announced that a well would be drilled in EPP 39 by late 2019 (Statoil, 2017).

BP's withdrawal was followed by Chevron's announcement in October 2017 that they would not be proceeding with their drilling campaign in EPP 44 and EPP 45. Chevron stated that; "while the Great Australian Bight is one of Australia's most prospective frontier hydrocarbon regions, in the current low oil price environment it was not able to compete for capital in Chevron's global portfolio" (Chevron, 2017).

In November 2019, Karoon Gas relinquished their interest in permit EPP 46 adhering to their broader stakeholders' concerns about exploration risk. The company was also waiting for BPs and Chevron's drilling results to re-assess their forward work program (Karoon Gas, 2019).

Statoil changed its name to Equinor in May 2018 and confirmed its plans to drill the BP-mapped Stromlo-1 prospect in EPP 39. After a lengthy process of obtaining regulatory approvals for the well, Equinor was given the final go-ahead to drill the prospect in November 2019. The Stromlo prospect is located in the Ceduna Sub-basin approximately 98 km southwest of Gnarlyknots 1/1A, in water depth of 2239 mMSL (Equinor, 2019). The well was designed to reach TD at 5186 mMSL, with the main objective located between 4941–5086 mMSL. The drilling period was planned for the summer window of 2020/2021. However, shortly after final approval was given Equinor announced that they were no longer pursuing their Ceduna-Sub-basin exploration program. Citing commercial considerations, the company followed BP and Chevron in abandoning plans to test the Bight Basin's hydrocarbon potential, the last untested Cretaceous deltaic system in the world (Equinor, 2020).

The Bremer Sub-basin, in the far western part of the basin, is a frontier exploration province in which no wells have been drilled. The western Bight Basin has seen two phases of exploration – in the early 1970s and 2005–2014. Between 1972 and 1974, initial exploration in the area was undertaken by Esso Australia Limited and Continental Oil Company. During this time, seismic and aeromagnetic data were acquired across the Bremer Sub-basin and shelfal areas to the east. Although Esso identified large structures in the Bremer Sub-basin, no further work was undertaken. Between 2003 and 2005, Geoscience Australia undertook a petroleum prospectivity study of the Bremer Sub-basin, acquiring seismic data and undertaking dredge sampling (Bradshaw, 2005). These data underpinned the release of exploration areas in 2005. Two permits (WA-279-P and WA-280-P) were initially awarded to Plectrum Petroleum. In 2008, the titles were transferred to a joint venture comprising Arcadia Petroleum and Enovation (now Cathay Petroleum). In 2009–10, the joint venture acquired over 4000 line km of 2D seismic data. Interpretation of that data suggests that all petroleum systems elements are developed in the Bremer Sub-basin (Cathay Petroleum and Arcadia Petroleum, 2012). This conclusion is supported by the analyses of dredge samples recovered by Geoscience Australia in 2004 which identified three oil prone potential source rock units (Ryan et al, 2005). In 2014, both exploration permits in the Bremer Sub-basin were cancelled due to the operator's failure to attract a farm-in partner; the acreage is currently vacant.

Regional petroleum systems

The thick sedimentary succession in the Bight Basin and its evolution from local half-graben depocentres during the Jurassic, to an extensive sag basin in the Early Cretaceous, marine embayment and large prograding deltaic systems in the mid-Cretaceous, and passive margin during the Late Cretaceous to Holocene, implies that there is significant potential for the presence of multiple petroleum systems.

Although the limited exploration drilling in the basin has not resulted in a discovery, evidence for the presence of petroleum systems is provided by oil and gas shows or indications, fluid inclusion evidence of migrated hydrocarbons and palaeo-oil accumulation in some wells, and seismic amplitude (including AVO) anomalies (Struckmeyer et al, 2001; Ruble et al, 2001; Tapley et al, 2005; Kempton et al, 2017; Rajeswaran and Przywara, 2017). Seepage of hydrocarbons from the basin is supported by the presence of bitumens/asphalts stranded on beaches around the Great Australian Bight, fault-related biogenic mounds interpreted on seismic data, and remotely sensed indications of seepage (Edwards et al, 1998; Struckmeyer et al, 2001; Edwards et al, 2016; Langhi et al, 2016; Ross and Kempton, 2017; Edwards et al, 2018).

Petroleum Systems Elements

Sources	<ul style="list-style-type: none">• Oxfordian–Berriasian Sea Lion and Minke Supersequence lacustrine shale and coal• Turonian–Santonian Tiger Supersequence marine shales• Cenomanian White Pointer Supersequence coals• Albian–lower Cenomanian Blue Whale Supersequence marine shales
Reservoirs	<ul style="list-style-type: none">• Upper Santonian to Maastrichtian Hammerhead Supersequence deltaic and shallow marine sandstones• Turonian to Santonian Tiger Supersequence shallow marine sandstones• Cenomanian White Pointer Supersequence• Valanginian to Albian Bronze Whaler Supersequence
Seals	<p><i>Regional seals</i></p> <ul style="list-style-type: none">• Middle Eocene to Holocene Dugong Supersequence marls and limestone• Turonian–Santonian Tiger Supersequence marine shales• Albian–lower Cenomanian Blue Whale Supersequence marine shales <p><i>Intraformational seals</i></p> <ul style="list-style-type: none">• Upper Santonian to Maastrichtian Hammerhead Supersequence marine shales
Traps	<ul style="list-style-type: none">• fault-related hanging wall and footwall traps with either rollovers or dip closures, lowside and highside fault-related traps, structural and stratigraphic traps associated with Middle Jurassic–Early Cretaceous half graben

Source Rocks

In depocentres within the eastern Bight Basin (Ceduna, Eyre and Duntroon sub-basins), regional sequence stratigraphic analysis suggests the presence of at least eight potential source rock units at different stratigraphic levels (Blevin et al, 2000; Totterdell et al, 2000; Struckmeyer et al, 2001; Boreham et al, 2001). These include Upper Jurassic syn-rift lacustrine shale, Lower Cretaceous fluvial and lacustrine deposits, Aptian–Albian marginal marine to coastal plain mudstone and coal, Albian–Cenomanian and Turonian–Santonian marine shale, Cenomanian deltaic and shallow marine shale and coal, and Santonian–Campanian prodelta shales (**Figure 10**). Recent regional studies of the paleodepositional environments, that included high-resolution 3D seismic-facies interpretations linked to analysis of the structural development of the basin and available well data, further supports the presence of multiple source rocks within the Cretaceous sequences (Klauser-Baumgärtner et al, 2019; Strømsøyen et al, 2019).

While the Jurassic–Lower Cretaceous non-marine source rocks are important in the shallower, more proximal parts of the basin, the key to the petroleum prospectivity of the region resides in Upper Cretaceous marine and deltaic facies. Dredge samples of upper Cenomanian–Turonian organic-rich marine rocks have confirmed

the presence of high quality source rocks in the basin significantly reducing exploration risk (Totterdell et al, 2008; Boreham, 2009).

No wells have been drilled in the Bremer Sub-basin, so assessment of its hydrocarbon potential is dependent on the tectonostratigraphic interpretation (**Figure 8, Figure 4**) of 2D seismic data and samples from 45 dredge sites, and comparisons with adjacent depocentres in the eastern Bight and Perth basins. Ryan et al (2005) concluded that these data support the presence of all essential petroleum systems elements, and that the sub-basin is prospective for hydrocarbons.

Reservoirs and seals

In the Ceduna Sub-basin, excellent quality reservoir rocks and potential intraformational seals are present within the Upper Cretaceous deltaic succession, and regional seals could be provided by Upper Cretaceous marine shales (**Figure 10**). Upper Cretaceous reservoir rocks could be well developed in the proximal parts of the basin, however, the absence of competent seals constitutes a significant exploration risk in this area. Interpretation of seismic data indicates that there are numerous trap styles in the basin and some structures are associated with seismic amplitude anomalies, providing potential exploration targets. In the shallower half-graben systems of the Bremer, Eyre and Duntroon sub-basins, prospective targets comprise Upper Jurassic–Lower Cretaceous sandstones overlain by thick, dominantly lacustrine mudstone successions.

Timing of generation

Petroleum systems modelling (**Figure 11**; Totterdell et al, 2008; Struckmeyer, 2009) suggests that generation and expulsion from the upper Cenomanian–lower Turonian potential source rocks in the Ceduna Sub-basin commenced in the Turonian. However, the bulk of expulsion occurred during the mid-Campanian to Holocene, after structuring related to breakup (**Figure 10**). As a result, accumulations of both liquid and gaseous hydrocarbons are modelled to be present within sandstones of the Turonian–Santonian Tiger and/or uppermost Santonian–Maastrichtian Hammerhead supersequences (Struckmeyer, 2009). Sediment loading by the Upper Cretaceous succession, particularly the Hammerhead Supersequence, was the critical event in the maturation of successively younger systems.

These results are supported by a recent reconnaissance-scale fluid inclusion and pressure-temperature study, which concluded that oil charge driven by loading of the Hammerhead Supersequence occurred in the basin depocentres in the Late Cretaceous, and was followed by oil, gas-condensate and gas charge to the depocentres and the basin margin in the Miocene (Kempton et al, 2017).

Generation and expulsion from potential Jurassic source rocks occurred during the Early Cretaceous in most of the Ceduna Sub-basin, however, on the inboard flanks of the sub-basin where the overburden is less than about 3000–4000 m, expulsion is likely to have occurred during the late Early to Late Cretaceous. Regional-scale petroleum systems modelling suggests that expulsion from the overlying Lower Cretaceous source rocks would have occurred from the Albion to Turonian. Some of the early generated and expelled hydrocarbons are likely to have been lost during major structuring related to breakup. An integrated 3D basin and petroleum systems modelling of the Great Australian Bight was also undertaken more recently (Frery et al, 2017).

In the Duntroon Sub-basin, expulsion from Upper Jurassic–Lower Cretaceous potential source rocks is likely to have occurred largely in the Late Cretaceous, following a major phase of structuring prior to breakup (Smith and Donaldson, 1995).

Burial history modelling indicates that in the Eyre Sub-basin, the early rift section in the deepest half-graben entered the oil window in the latest Cretaceous. The presence of an active petroleum system is supported by the identification of a breached accumulation at Jerboa 1 in the Eyre Sub-basin, based on the presence of Grains with Oil Inclusions (GOI™) anomalies in the basal reservoir units (Ruble et al, 2001).

In the Bremer Sub-basin, appropriate maturities for hydrocarbon generation are likely in the main basin depocentres where sediments have been buried to depths of more than three kilometres. Burial history modelling has shown that for the oldest predicted source rocks (Jurassic lacustrine facies), the major phase of oil and gas expulsion occurred during rapid burial in the Tithonian–Valanginian. Generation and expulsion from overlying Lower Cretaceous fluvio-lacustrine shale and coal is modelled to have occurred from the Berriasian to Turonian (Ryan et al, 2005).

Play types

The Bight Basin contains a broad range of structural and stratigraphic plays (Totterdell et al, 2000; Tapley et al, 2005). In the Ceduna Sub-basin, the main plays are associated with faults in the post-Albian White Pointer, Tiger and Hammerhead supersequences (**Figure 12**). The structural architecture of much of the sub-basin is controlled by a series of generally northwest-oriented, listric normal faults that formed as a result of shale tectonics during deposition of a major delta system in the Cenomanian. Albian–Cenomanian and Turonian–Santonian marine shales, and Cenomanian coaly source rocks are predicted to have charged a range of play types across the Ceduna Sub-basin. Potential plays include fault related hanging wall and footwall traps and associated rollovers and dip closures with Cenomanian to Santonian sandstone objectives. Inner basin plays are predominantly fault-dependent traps with Cenomanian to Santonian reservoirs, charged laterally and vertically by Turonian and older sources. Outer basin plays are mostly fault dependent closures with Turonian–Santonian or Campanian deltaic sandstone objectives, charged by either Cenomanian–Turonian and older marine shales, Cenomanian coal, or Santonian–Campanian prodelta shales. Stratigraphic plays, particularly within progradational Upper Cretaceous deltaic facies of the Hammerhead Supersequence, could also provide exploration targets. In addition, there may be some potential for Middle Jurassic–Early Cretaceous half-graben plays along the eastern margin of the Ceduna Sub basin.

In the Duntroon Sub-basin, key plays associated with the Hammerhead and Wobbecong supersequence reservoirs are sealed by thick transgressive marls at the base of the Dugong Supersequence. Intraformational plays within the dominantly fine-grained Lower Cretaceous section could also be present.

In the Bremer and Eyre sub-basins and along the northern and eastern flanks of the Ceduna Sub-basin, the key plays are structural closures related to half-graben bounding faults and associated stratigraphic plays. In contrast with plays across the most of the Ceduna depocentre, in these areas of the basin, prospectivity is focused on non-marine source rocks such as lacustrine shales and coaly sediments in the Jurassic–Lower Cretaceous rift and post-rift succession.

Critical risks

Prior to 2008, lack of an effective source rock and thus adequate hydrocarbon charge were perceived as the primary exploration risks in the sub-basin. While these risks have been significantly reduced following the identification of a high-quality Cenomanian to Turonian marine source rock, and fluid inclusion evidence of petroleum generation, expulsion and migration, the widespread presence of mature source rocks and significant volumes of hydrocarbons in the basin have not yet been demonstrated.

Perceptions of the petroleum prospectivity of the Bight Basin are largely derived from the interpretation of seismic data, particularly in the Ceduna Sub-basin where recent exploration effort have been focused. Much of the northern and central parts of the Ceduna Sub-basin is covered by extensive high-quality 3D seismic data, which existing and past operators (most recently Equinor, Klauser-Baumgärtner et al, 2019; Strømsøyen et al, 2019) have used to develop robust structural and stratigraphic interpretations. However, limited well control in the region means that there is a degree of uncertainty about the stratigraphic/lithological interpretation, particularly for the deeper, pre-Turonian section, and the cross fault seal capacity for structural plays in the sub-basin. A lack of certainty about facies evolution across the sub-basin, as well the impact of deep reservoir burial, make it difficult to assess the extent of effective reservoirs and source rock maturity in the area.

The presence of volcanic and intrusive rocks within and overlying the Upper Cretaceous succession in some parts of the Ceduna Sub-basin presents a potential risk for petroleum systems.

Geoscience Australia products and data

Regional geology and seismic

- Petroleum geology inventory of Australia's offshore frontier basins. [Geoscience Australia Record 2014/009 by Totterdell et al, 2014](#)
- Bight Basin geological sampling and seepage survey, R/V Southern Surveyor Survey SS01/2007: post-survey report. [Geoscience Australia Record 2009/24 by Totterdell and Mitchell, 2009](#)
- Ceduna Sub-basin: environmental summary. [Geoscience Australia Record 2009/09 by Hughes et al., 2009](#)
- AUSCAN seafloor mapping and geological sampling survey on the Australian southern margin by Marion Dufresne in 2003: Final Project Report. [Geoscience Australia Record 2004/04 by Hill and De Deckker, 2004](#)
- A revised structural framework for frontier basins on the southern and southwestern Australian continental margin. [Geoscience Australia Record 2003/03 by Bradshaw et al, 2003](#)
- Seafloor mapping of the South-east Marine Region and adjacent waters. AUSTREA final report: Lord Howe Island, south-east Australian margin (includes Tasmania and South Tasman Rise) and central Great Australian Bight. [Geoscience Australia Record 2001/08 by Hill et al, 2001](#)
- Marine geological data collected during Southern Surveyor voyage 01/00: eastern Bass Strait and Great Australian Bight. [Australian Geological Survey Organisation Record 2000/43 by Harris et al, 2000](#)
- Scientific post-cruise report – R/V Rig Seismic cruise 102: geological sampling in the Great Australian Bight. [Australian Geological Survey Organisation Record 1993/18 by Feary and Shipboard Party, 1993](#)

Stratigraphy

- [Geoscience Australia's Basin Biozonation and Stratigraphy Chart Series](#): Bight Basin Biozonation and Biostratigraphy Chart 35, 2013. [Chart by Totterdell et al, 2013](#)
- Distribution, timing and origin of magmatism in the Bight and Eucla basins. [Geoscience Australia Record 2008/24 by Schofield and Totterdell, 2008](#)
- Maastrichtian and younger sediments from the Great Australian Bight. [Bureau of Mineral Resources Geology and Geophysics Report 288 by Davies et al, 1989](#)
- Sequence stratigraphic correlation of onshore and offshore Bight Basin successions. [Geoscience Australia Record, 2003/02 by Totterdell and Krassay, 2003](#)

Petroleum systems and accumulations

- Ceduna Sub-basin, Bight Basin: results of 3D petroleum systems modelling. [Dataset by Struckmeyer, 2009](#)
- MkII airborne laser fluorosensor survey reprocessing and interpretation report: Great Australian Bight, southern Australia. [Australian Geological Survey Organisation Record 2001/18 by Cowley, 2001](#)

Data discovery tools

- The [National Offshore Petroleum Information Management System \(NOPIMS\)](#) provides access to wells and survey data acquired primarily in Commonwealth waters and submitted under legislation, currently the Offshore Petroleum and Greenhouse Gas Storage Act 2006. This data can be downloaded or packaged on request. NOPIMS has been upgraded to provide access to over 50 years of data submission of well and survey information. It represents more than 1 million records and includes an [interactive mapping tool](#) for data discovery.
- [Geoscience Australia's Data Discovery Portal](#) provides full access to Geoscience Australia data and other publically available data sources as well as a suite of analytical and multi-criteria assessment

tools. This includes an [Energy persona](#) that allows access to a wide range of geological and geospatial data. Themes include source rock geochemistry, petroleum wells, stratigraphic information, province and basin geology, geophysical survey data coverage and other fundamental geospatial and administrative datasets.

- The [National Petroleum Wells Database](#) application provides access to Geoscience Australia's Oracle petroleum wells databases. Data themes include header data, biostratigraphy, organic geochemistry, reservoir and facies, stratigraphy, velocity and directional surveys. Data is included for offshore and onshore regions, however scientific data entry is generally limited to offshore wells and is dependent on Geoscience Australia's project activities.

Marine and environmental information

The following section contains information about the existing marine parks, their special habitat zones and physiographic features within the Bight Basin (**Figure 13**). The information is provided in support of business decisions with respect to planned exploration and development activities.

Australian marine parks

Australian Marine Parks (Commonwealth marine reserves proclaimed under the EPBC Act in 2007 and 2013) are located in Commonwealth waters that start at the outer edge of state and territory waters, generally 3 nautical miles (nm) (5.6 km) from the shore, and extend to the outer boundary of Australia's Exclusive Economic Zone, 200 nm (370.4 km) from the shore. Marine parks have also been established by the state and territory governments in their respective waters. The marine parks operate under management plans that provide a balance between protection of the marine environment, and sustainable use of the area. Links to these management plans are provided for each marine park or marine park network in the Bight Basin region.

South-west Marine Parks Network

The [South-west Marine Parks Network](#) comprises five marine parks offshore South Australia and nine parks off the coast of southwest Western Australia. The marine environment of the region is characterised by a low gradient continental shelf, steep slope that is incised by numerous submarine canyons (including Perth Canyon), deepwater plateaus and abyssal plains. Hotspots for biodiversity include mixed temperate and tropical marine species that inhabit the waters surrounding of Houtman Abrolhos Islands, Recherche Archipelago and the world's richest known temperate soft sediment communities in the Great Australian Bight. Endangered southern right whales migrate through the region to coastal waters off South Australia and Western Australia.

The South-west Marine Parks Network includes the following parks that intersect the Bight Basin: the South-west Corner Marine Park, the Bremer Marine Park, the Eastern Recherche Marine Park; the Twilight Marine Park, the Great Australian Bight Marine Park, the Murat Marine Park and the Western Eyre Marine Park. Management plans and values of individual marine parks of the South-west Marine Parks Network can be viewed at: <https://parksaustralia.gov.au/marine/pub/plans/south-west-management-plan-2018.pdf>.

Below is a summary of the values of the parks of the South-west Network, extracted from the plan:

Statement of significance

The South-west Network was designed to protect representative examples of the region's ecosystems and biodiversity in accordance with the Goals and principles for the establishment of the National Representative System of Marine Protected Areas in Commonwealth waters (ANZECC, 1998).

Natural values

Bioregions—the South-west Marine Region is divided into areas of ocean with broadly similar characteristics based on the distribution of marine species and seafloor features. The South-west Network represents examples of the region's marine environments including ecosystems, species and habitats. There are nine bioregions represented in the Network.

Key ecological features—elements of the marine environment considered to be of importance for biodiversity or ecosystem function and integrity, represented in the Network are:

- Albany Canyons Group and adjacent shelf break;
- Ancient coastline at the 90–120 m depth contour;
- Cape Mentelle upwelling;
- Commonwealth marine environment surrounding the Houtman Abrolhos Islands;
- Commonwealth marine environment surrounding the Recherche Archipelago;
- Commonwealth marine environment within and adjacent to Geographe Bay;
- Commonwealth marine environment within and adjacent to the west-coast inshore lagoons;
- Diamantina Fracture Zone;

- Kangaroo Island Pool, canyons and adjacent shelf break, and Eyre Peninsula upwellings;
- Naturaliste Plateau;
- Perth Canyon and adjacent shelf break, and other west-coast canyons;
- Wallaby Saddle;
- Western demersal slope and associated fish communities; and
- Western rock lobster.

Species and habitats—all species and habitats are important components of the ecosystems represented in the South-west Network. Many species are protected under the EPBC Act and international agreements such as the Convention on the Conservation of Migratory Species (CMS or Bonn Convention), the Japan– Australia Migratory Bird Agreement (JAMBA), the China–Australia Migratory Bird Agreement (CAMBA), and the Republic of Korea–Australia Migratory Bird Agreement (ROKAMBA). Further information on these agreements is available in the plan.

Biologically important areas—the South-west Network supports important habitats, including biologically important areas, for a range of protected species. Biologically important areas are where aggregations of individuals of a protected species breed, forage or rest during migration. More information on protected species and biologically important areas can be found in the Marine bioregional plan for the South-west Marine Region (2012) and the conservation values atlas on the Department's website

The Murray Commonwealth Marine Reserve

The [Murray Commonwealth Marine Reserve](#), that forms part of the [South-east Marine Reserves Network](#), intersects the Bight Basin. The Murray Commonwealth Marine Reserve spans an extensive area across the Lacedpede Shelf, continental slope and deeper water ecosystems that extend from South Australia to Tasmania. The reserve contains the Murray Canyon, which is considered one of the most spectacular geological formations on the Australian continent margin. The canyon is deeper than America's Grand Canyon, descending to 4600 m below sea level and stretching for more than 150 km.

The reserve protects samples of the key features in the area, including continental shelf and slope, abyssal plain and Sprigg Canyon.

The reserve is important for many marine species, including those migrating through its inshore waters. The southern right whale uses the inshore area of the reserve to nurse its young. Offshore, many seabird species can be seen foraging. Upwelling of nutrient-rich water occurs in the reserve, although these upwellings are less strong than to the east where they are known as the Bonney Upwelling. Blue whales have been sighted on several occasions in the reserve. White shark also forage in the reserve

Management plans for the South-east Marine Reserves Network, including the Murray Commonwealth Marine Reserve, are in place, and can be viewed at:

<https://parksaustralia.gov.au/marine/pub/plans/se-network-management-plan2013-23.pdf>

South Australian Marine Parks

South Australia contains [19 marine parks](#), nature reserves, and management areas. These marine protected areas were created to protect natural features and aesthetic values of the marine environment whilst also allowing recreational and commercial uses that do not compromise conservation values. The Far West Coast Marine Park and Nuyts Archipelago Marine Park are proximal to the Bight Basin.

Far West Coast and Nuyts Archipelago Marine Parks

Located between the Western Australian border and the Tchalngaby Sandhills the [Far West Coast](#) Marine Park is a sanctuary for whales, including the Southern Right Whale, that return every year to breed, give birth and raise their young. Around Nuyts Archipelago the waters are unusually warm for South Australia, supporting tropical marine life such as the Basket Star and the tiny sea star 'Little Patty', which gives birth to live young and is found nowhere else in the world.

The rocky cliffs rising from the Far West Coast are an iconic coastline image. Whale watching and the colonies of fur seals and sea lions throughout Nuyts Archipelago provide major tourism interest.

Fishing is popular on the Far West Coast, with fishers still able to catch Abalone, Rock Lobster, scale fish and shark outside the sanctuary zones. Diving is allowed throughout the park.

Heritage

Maritime Heritage

Australia protects its underwater cultural heritage through the [Underwater Cultural Heritage Act 2018](#). There are about 8,000 historic shipwrecks, sunken aircraft and other underwater cultural heritage sites in Australian waters, representing some of the unique and irreplaceable physical evidence of our past. The [Australasian Underwater Cultural Heritage Database](#) (AUCHD) contains historical and environmental information about shipwrecks, sunken aircraft and other types of underwater heritage sites located in the Oceania and Southeast Asian regions. This database also includes the records of artefacts that originate from these sites and serves as the register of protected underwater cultural heritage for the *Underwater Cultural Heritage Act 2018*.

There are no underwater cultural heritage protected zones in the Bight Basin.

Cultural Heritage

The Aboriginal Lands Trust owns and manages Yalata lands, including the Head of Bight (HOB) Visitor Interpretive Centre. Yalata Indigenous Protected area management plan states that the area ‘contains spectacular coastal scenery with large dunes, fringing reefs and few obvious signs of human presence. The Head of the Bight public viewing area provides varied coastal scenery with views of the Nullarbor Cliffs, Twin Rocks, coastal dune fields and distant views of the eastern shore of the Bight. During the months of June to October this site also provides the best and most reliable cliff-top whale watching in Australia (Yalata Community Inc, 2000).

Fisheries

The following fisheries occur in the Bight Basin area:

- [Small Pelagic Commonwealth Fishery](#), western sub-area. The season runs 12 months starting 1 May.
- [Southern and Eastern Scalefish and Shark Fishery](#), Commonwealth GAB Trawl Sector, Commonwealth Scalefish Hook Sector and Commonwealth Gillnet and Shark Hook Sector. The season runs 12 months starting 1 May.
- [Southern Bluefin Tuna Commonwealth Fishery](#). The season runs 12 months beginning 1 December.
- [Southern Squid Jig Commonwealth Fishery](#). The season runs 12 months beginning 1 January.
- [Western Tuna and Bill Fishery](#). The season runs 12 months, beginning on 1 February.
- The following [South Australian fisheries](#) occur in coastal waters; Abalone, Charter boat and Northern zone of the Rock Lobster fishery.

Climate of the region

The region is characterised by a semi-arid temperate climate, with precipitation below potential evapotranspiration throughout the year and few temperature extremes. Mean minimum and maximum temperatures are 10.5°C and 23.5°C respectively, for the period 1939–2017. Mean annual rainfall recorded over 51 years at Ceduna is 295.1 mm.

Oceanic regime

Mean open coast sea surface temperatures in the Great Australian Bight (GAB) vary from 14°C to 18°C in winter, and these averages decrease to 11–12°C under the influence of upwelling (Edyvane, 1998). Coastal

tides are typically microtidal and semi-diurnal, with a mean tidal range of 0.8–1.2 m. The Bight is open to the vast Southern Ocean, and frequent gales and persistent large swells deform the shelf and coastal waters. South-west swells are less than 2 m for half of the year, 2–4 m for 30–45% of the year, and exceed 4 m for the remaining 10% of the year. Wind generated swells provide additional wave energy, and exceed 2 m for 10–15% of the year (Edyvane, 1998). Several large embayments and shelves in the lee of obstructing islands receive reduced wave energy.

The GAB is a region of complex oceanography which is largely driven by zonal winds and the behaviour of the 5500 km long NW Leeuwin Current (LC) (Ridgeway and Condie, 2004), which originates in waters off northwestern Australia. The LC feeds the easterly flowing Coastal and Flinders Currents (Middleton and Cirano, 2002), which bring warm and nutrient poor waters across the Bight (Middleton and Bye, 2007). Two water masses restrict large-scale upwelling in the GAB: 1) a warm, highly saline water mass called the ‘GAB Plume’, which forms in the western GAB from high evaporation and surface heating and travels eastwards across the GAB; and 2) the warm, nutrient-poor Leeuwin Current (Richardson et al, 2005). Intense downwelling typically occurs during winter (Middleton and Bye, 2007) and periodic upwelling occurs in both the eastern and western sections of the GAB, during summer when the LC is weakest (James et al, 2001). Strong ENSO events, which occur at intervals of 4 to 7 years, can depress these currents (Middleton et al, 2007; Middleton and Bye 2007). Recently, the central GAB has been shown to play a more important role in regional productivity than previously thought, as measured by base nitrogen and reworked nitrogen trophic transfer to zooplankton (Kloser and Van Ruth, 2017). Repeated phytoplankton blooms throughout the region challenge the widespread assumption that the GAB shelf waters are oligotrophic and may explain the high abundance of small pelagic fish and apex predators in the region (Kämpf and Kavi, 2017).

Seabed environments: regional overview

The Great Australian Bight is the most extensive physiographic feature on the southern margin of the Australian continent. Spanning 1500 km of coastline between Cape Pasley in the west and Cape Catastrophe in the east, the seabed within the Bight comprises a broad continental shelf and continental slope that descends to 4500 m water depth (**Figure 2**; Hughes et al, 2009). The continental shelf is widest within the central GAB, extending approximately 200 km and tapering to about 70 km at each end with the shelf edge at 150 m to 200 m water depth. Rocky reefs are concentrated in the shallower nearshore areas and around islands in the eastern Great Australian Bight. Across the shelf, the seabed is flat to gently sloping on a gradient of less than 0.01°. The boundary with the upper slope ranges from a convex slope of 200 m relief in the northwest to a steep escarpment in the southeast that reaches a maximum height of 1000 m.

Seaward of the shelf, the continental slope comprises an upper and lower slope, with the upper slope forming the Ceduna Terrace where prospective petroleum areas are located. Water depths across the Ceduna Terrace range from 500 m to 2000 m on a gradient of 0.6°, and beyond this the lower slope steepens to almost 4° to the foot of the slope. High resolution mapping across the western part of the Ceduna Terrace in 1999 (Hill et al, 2001) shows a dissected seabed characterised by troughs, gullies and erosion scarps that are tens to hundreds of metres in height. These features are evidence for mass wasting of the seabed over geological timescales (Hughes et al, 2009).

Seabed sediments on the shelf and upper slope comprise carbonate sands and gravels derived from extensive colonies of bryozoans and sponges that thrive under the influence of seasonal up-welling of nutrient-rich waters onto the shelf (James et al, 2001, 2004). This zone of sediment production has been termed a “sediment factory” and is recognised as integral to the progradation (seaward advance) of the upper slope during the Cenozoic (66 Ma to present; James et al, 2004). In deeper waters of the outer Ceduna Terrace and lower slope, seabed sediments are dominantly muds, comprising calcareous ooze.

Submarine canyons have incised deeply into the continental slope within the Great Australian Bight. Of the 74 canyons mapped between the western end of the Bight (123.5°E) and offshore from the Coorong (139°E), most are located in the southeast of the Bight and in deep water of the continental slope, including 45 canyons that form the Murray Canyon group (Huang et al, 2014). Only two canyons are shelf-incising canyons (Du Couedic Canyon and Sprigg Canyon), reaching to water depths less than 300 m. These shallower canyons are known to provide habitat for rich communities of biota. For example, Du Couedic Canyon supports approximately 140 species of seabed fauna and flora, mostly sponges (Currie and Sorokin, 2014). Canyons also influence local productivity of the Great Australian Bight by acting as pathways for localised upwelling of nutrient-rich waters, e.g. in the vicinity of the shelf-incising canyons south of Kangaroo Island (presumably Du Couedic and Sprigg canyons), where a subsurface pool of cold and nutrient-rich water occurs along the coast in summer (Kämpf, 2010).

Coast

The coast of the Great Australian Bight is part of the world's longest south-facing continental margin. It experiences small tidal heights but is exposed to the strong wind and wave regimes generated in the Southern Ocean, and is therefore referred to as a wave-dominated coast. Intense low-pressure systems that traverse the Southern Ocean occasionally hit the coast. The Great Australian Bight coast is dominated by the Cenozoic marine limestone cliffs of the Nullarbor Plain, in places forming sheer faces up to 120 m high. Beaches to the east and west of the cliff line are composed of carbonate or mixed carbonate/quartz sand. Along the low-lying sections of coast there are also vast sand flats and large dune fields (e.g. Kaniaal and Warren beaches, Western Australia), with a few small estuaries on the eastern margin. A defining feature of much of this southern coast is the negligible discharge of terrigenous sediment by rivers compared with the volume of bioclastic carbonate sediment produced on the Continental Shelf (<200 m water depth). The Reef Life Survey citizen science program classified the GAB and Tasman Sea with the highest threatened species index relating to rocky and coral reefs throughout Australia (Stuart-Smith et al, 2017)

Ecology

Cetaceans and other megafauna

At least 17 species of cetacean have been recorded in the Great Australian Bight, including migratory species such as Sperm, Blue, Minke and Humpback whales and residential species such as Orcas and dolphins (Edyvane, 1998). Short-beaked Common Dolphins (*Delphinus delphis*) are particularly abundant in coastal waters (Evans et al, 2017), while the most common whale in the Great Australian Bight is the Southern Right Whale (*Eubalanea australis*) which is listed as 'endangered' under the *Environment Protection and Biodiversity Conservation Act 1999*. Due to the migratory nature of this species, it is difficult to estimate population sizes. There is a transient Australian population of around 1500 individuals that migrate from their feeding grounds in the Southern Ocean to breeding grounds along the southern Australian coast, one of only two habitats in the world in which this species will reproduce (Edyvane, 1998). Once in coastal waters, most animals aggregate within a narrow zone 1 km from the coast at the Head of Bight. This globally important calving habitat has been recognised as a major conservation value in the Great Australian Bight Marine Park.

The GAB contains more than 90% of Australia's Long-nosed Fur Seal (*Arctocephalus forsteri*) and Australian Sea Lion (*Neophoca cinerea*) populations (Evans et al, 2017). In addition, the region is a stable and consistent habitat for juvenile Southern Bluefin Tuna (SBT, *Thunnus maccoyii*) from summer through autumn (Chambers et al, 2017), and broad observations of their movement suggest tagged individuals remain in the region during seismic surveys (Evans et al, 2017). The GAB shelf edge, slope and associated canyons provide important habitat for large megafauna such as juvenile Shortfin Mako (*Isurus oxyrinchus*) (Rogers et al, 2015), as well as habitat-forming sessile invertebrates (see section below).

Demersal Fish

For fish collected in deep waters in the GAB (200–3000 m), most collected species (90%) were previously recorded from Australian waters and were dominated by typical deep-sea families (Macrouridae, Synphobranchidae, Moridae, Oreosomatidae, Alepocephalidae, Ophidiidae, Halosauridae). Endemic species were more prevalent in shelf break and upper to mid-slope depths, with no longitudinal patterns associated with seasonal upwelling in the east (Williams and Tanner, 2017).

Benthic Invertebrates

The Great Australian Bight supports one of the world's most diverse soft-sediment ecosystems (Ward et al, 2006) and has a high level of endemism, meaning many species occur nowhere else in the world. An estimated 85% of fish, 95% of molluscs, and 90% of echinoderms are endemic to southern Australia. Similarly, the Great Australian Bight has one of the world's highest species richness of macroalgae, with over 1200 species (McLeay et al, 2003) and 75% of red algae species endemic to southern Australia (Womersley, 1990). In contrast, infauna (animals beneath the seafloor) do not appear to be particularly diverse in the Bight (Currie et al, 2009).

High levels of species richness and endemism in the Great Australian Bight may be explained several ways. The Leeuwin Current allows for incursions of tropical species to the region, and over time, some of these may

have established isolated populations and evolved independently of their tropical source populations (Hughes et al, 2009). In addition, the continental shelf is quite wide in the Great Australian Bight, providing a relatively large area in which many shallow water species can exist. Submarine canyons are also more likely to contain endemic fauna than nearby areas without canyons at similar depths (Vetter and Dayton, 1998; 1999), due to geographic barriers to recruitment and evolutionary isolation. Finally, the relative isolation of the Great Australian Bight due to geographic barriers allows species to evolve in a defined region, with minimal migration to and from other parts of Australia.

Until recently, most information about biodiversity in the Great Australian Bight was for the continental shelf. In a survey of sponges in the former Benthic Protection Zone, only 25% of taxa were able to be identified to species level, and of these, 48% were new records for the Great Australian Bight (Sorokin et al., 2007). Other patterns from the Great Australian Bight shelf waters include:

- Suspension feeders were the most common feeding group collected on the continental shelf of the Great Australian Bight Marine Park Benthic Protection Zone (GABMP BPZ), representing 86% of species found. This is unusually high and may reflect a lack of terrigenous sediment input, which limits the food available to deposit feeders (Ward et al, 2006). The outer shelf and upper slope are often dominated by abundant bryozoan and sponge communities, which occur more frequently on hard seabed substrates. Hardgrounds composed of Paleogene, Neogene (66–2.6 Ma) and Pleistocene (2.6 Ma–11.7 ka) limestone outcrops on the seabed contain the most abundant fauna, including bryozoans, sponges and other sessile invertebrates. Rippled sandy bottoms have almost no epibenthos (Richardson et al, 2005).
- On the continental shelf, species richness and biomass decline with increasing water depth and the proportion of mud in the seabed sediments, except for crabs and shrimp which increase with mud content (Ward et al, 2006). Smaller sessile species may be more prevalent in deeper waters with higher proportions of mud, as they may be able to better use fine sediments (Sorokin et al, 2007).

Recently, CSIRO and South Australian Research and Development Institute (SARDI) undertook benthic biodiversity assessments of epifauna, infauna, meiofauna and microbes in the deeper waters of the GAB (200–3000 m depth) (Williams and Tanner, 2017). For epifauna, ~25% of species were undescribed, with an additional 13% being new records for Australian waters, although faunal composition was typical for temperate deep-sea regions. Endemism among epifauna was low, although there was a clear eastwards biogeographic affinity. For infauna, assemblages were different at various depths, as shown for decapod diversity which decreased by 75% in the transition from the mid-lower continental slope (1000–3500 m) to abyssal depths (>3500 m) (Farrelly and Ah Yong, 2019)

Recent geological history

The majority of the GAB shelf remained submerged during most of the Late Quaternary (Richardson et al, 2005). Even during periods of very low sea level, such as the last glacial when sea level was at least 120 m below present (Chappell and Shackleton, 1986), the outer shelf was submerged (James and von der Borch, 1991). Relict foraminifera specimens indicate that the inner GAB was an area of shallow marine lagoons and bays, while the outer shelf remained a shallow shelf sea, especially in the period between the last interglacial and last glacial (~90 ka to 20 ka) when sea level ranged between 20 m and 120 m lower than today (Li et al, 1999).

The shelf has been a site of cool-water carbonate production throughout the last 2 Ma. Very high rates of sediment deposition on the outer shelf during the Pleistocene (2.6 Ma to 10 ka) have resulted in progradation of the shelf. Pleistocene sediments are more than 550 m thick and were deposited at rates equal to the fastest growing tropical carbonate systems known. Lobe-shaped, prograding sediment structures (clinoforms) can be seen in seismic profiles of the shelf (James, 1997, 2004). Also seen in seismic profiles are bryozoan reef mounds which have been interpreted as cool water reefs that grew on the outer shelf during the Pleistocene. Similar structures are common in the geologic record but not in the recent past. They are the first examples to be found in the Quaternary, and are also the first to be found in their original depositional setting (Hine et al, 1999; James et al, 2000). Bryozoan mound growth is attributed to a weakening of the LC during glacial periods, allowing for increased upwelling and higher productivity in the region. Nutrient levels would have been similar to those in Antarctic waters today, and prolific carbonate production was high enough to form these carbonate mounds (Bone and James, 2002). They are presently found in water depths of ~200–350 m, have up to 65 m vertical relief and extend laterally for hundreds of metres. None are growing today; they were

drowned when sea level rose rapidly after the last glacial maximum and are now buried under a thin layer of Holocene sediments (James et al, 2000, 2001).

Overall, oceanographic conditions throughout the Holocene have been similar to those of today, with year-round downwelling in a high-energy environment, and prolific carbonate production occurring on the outer shelf. It is thought these patterns also persisted throughout most of the Quaternary (James et al, 2001).

National seabed mapping data and information

Geoscience Australia provides acoustic datasets including bathymetry, backscatter, sidescan sonar and sub-bottom profiles to assist in understanding the shape and composition of the sea floor. Geoscience Australia also maintains the Marine Sediment database ([MARS](#)), comprising information (e.g. percentage mud/sand/gravel, mean grain size, and sediment texture) from seabed sediment samples collected during marine surveys between 1905 and 2017.

These data are discoverable and accessible through the AusSeabed [Marine Data Discovery Portal](#). [AusSeabed](#) is an innovative national seabed mapping initiative designed to coordinate data collection efforts in Australian waters and provide open access to quality-controlled seabed data.

Other online information resources

Please follow these links for more detailed information pertaining to the marine and environmental summaries provided in this section.

- [Bureau of Meteorology: climate statistics](#)
- [National Conservation Values Atlas](#)
- Australian Marine Parks: [South-west Marine Parks Network](#)
- [South Australian marine parks](#)
- [AusSeabed](#)
- [Commonwealth Fisheries](#)
- [AFMA Commonwealth Fisheries](#)
- [South Australian Commercial Fisheries](#)
- [Underwater cultural heritage](#)
- [Protected Matters Search Tool](#)
- [Atlas of Living Australia](#)

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Figure captions

- Figure 1** Map of the Bight Basin showing bathymetry and well distribution.
- Figure 2** Tectonic elements map of the Bight Basin showing bathymetry, major faults, well distribution and location of cross-sections.
- Figure 3** Tectonic elements map of the Bight Basin showing depocentre age.
- Figure 4** Stratigraphic chart for the Bremer, Ceduna Duntroon and Eyre sub-basins. Based on the Bight Basin Biozonation and Stratigraphy Chart 35 (Totterdell et al, 2013). Geologic time scale after Ogg et al. (2016); sea-level curve of Haq et al (1988) calibrated to the time scale.
- Figure 5** Seismic cross-section across northern Ceduna Sub-basin, showing structural and stratigraphic relationships. Location of the cross-section shown in Figure 2, refer to Figure 4 for Supersequence ages.
- Figure 6** Cross-section through the Eyre Sub-basin, Madura Shelf and Ceduna Sub-basin, showing structural and stratigraphic relationships. Location of the cross-section shown in Figure 2, refer to Figure 4 for Supersequence ages.
- Figure 7** Cross-section through the Duntroon and Ceduna sub-basins, showing structural and stratigraphic relationships. Location of the cross-section shown in Figure 2, refer to Figure 4 for Supersequence ages.
- Figure 8** Cross-section through the central Bremer Sub-basin, showing structural and stratigraphic relationships; based on the extensional basin model of Nicholson & Ryan (2005). Location of the cross-section shown in Figure 2, refer to Figure 4 for Supersequence ages.
- Figure 9** Map of the Bight Basin showing current petroleum licences and operators.
- Figure 10** Stratigraphy and potential petroleum systems, Ceduna Sub-basin. Geologic time scale after Ogg et al. (2016); sea-level curve of Haq et al (1988) calibrated to the time scale.
- Figure 11** Profiles showing petroleum systems modelling results for the Ceduna Sub-basin.
- Upper:** 2D transect across central Ceduna Sub-basin showing the modelled stratigraphic units and potential source rock layers.
- Middle:** 2D transect across central Ceduna Sub-basin showing modelled present-day maturity zones (% Ro). Supersequences are labelled.
- Lower:** 2D transect across central Ceduna Sub-basin showing modelled present-day transformation ratios (%) of three potential source rock units within the Blue Whale, upper White Pointer and Tiger supersequences.
- Location of the profile is shown in Figure 2. After Totterdell et al, 2008.
- Figure 12** Schematic cross-section and indicative play types in the Ceduna Sub-basin. After Klauser-Baumgärtner et al, 2019.
- Figure 13** Map showing marine reserves, marine parks, multiple use zones and ecological features in the Bight Basin.