2 CRETACEOUS–CENOZOIC SEDIMENTARY BASINS OF THE SMANIAN CONTINENTAL MARGIN

Hill, N.F. Exon, P.W. Baillie, P.G. Quilty, J.L. Everard

.1 Introduction

yond the continental shelves of Tasmania, the deep seabed of margins and that of its marginal plateaus to the south and ıtheast is commonly steep and rugged (Fig. 9.11; Hill et al. 01a). The underlying basement geology and basin architecture structurally complex (Fig. 9.12), having evolved by processes the late Phanerozoic that include continental rifting, breakup, ıfloor spreading and intraplate volcanism. Offshore sedimentary sins (Hill & Exon 2004) cover an extensive area, several times the e of onshore Tasmania, and contain sediments of Cretaceous–nozoic age (Fig. 9.13) that are commonly several kilometres ck (Fig. 9.14). Areas of significant basin development include continental margins directly offshore, as well as adjacent ɔmerged continental plateaus, the South Tasman Rise (STR) d East Tasman Plateau (ETP). The tectonic evolution and basin velopment of the region is discussed by Hill & Exon (2004) and on et al. (2004).

Offshore basins with at least several kilometres of fill (Figs 9.11, 9.14) include the Sorell Basin (Baillie & Hudspeth 1989; Willcox et al. 1989; Hill et al. 1997) off western Tasmania, the southern Otway Basin off King Island, the Ninene Basin (Exon et al. 1997b; Hill & Moore 2001) on the STR, and the southern Gippsland Basin (Maung & Nicholas 1990) off Flinders Island. The intracratonic Bass and Durroon Basins (Fig. 9.14; Williamson et al. 1987; Morrison & Davidson 1989; Baillie & Pickering 1991) lie to the north of Tasmania in the central Bass Strait.

In contrast, the onshore area of Tasmania has little Cretaceous -Cenozoic basin development (Fig. 9.14). Scattered and relatively small onshore depocentres do occur, but these generally contain less than 1000 m of sediment and are limited mainly to Paleocene/Eocene and Miocene deposits. The only Cretaceous sediments known on land are in the coastal northeast and comprise relatively minor late Cretaceous alluvial fan deposits (Moore et al. 1984), which are onshore extensions of the Bass and Durroon Basins. Elsewhere any evidence of possible Cretaceous (and Jurassic) basins onshore has been removed by erosion (Seymour & Calver 1995).

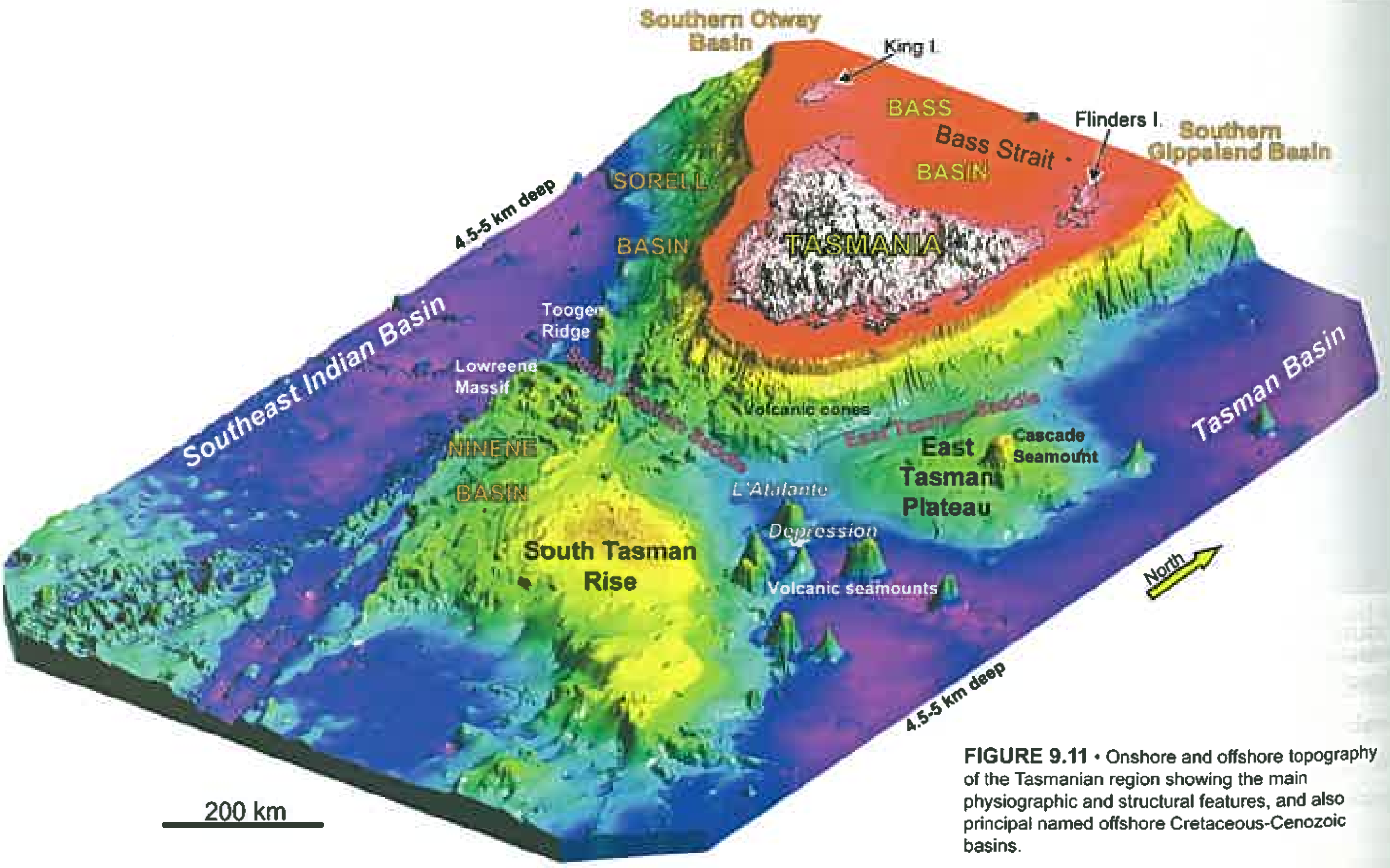

FIGURE 9.11 • Onshore and offshore topography of the Tasmanian region showing the main physiographic and structural features, and also principal named offshore Cretaceous-Cenozoic basins.

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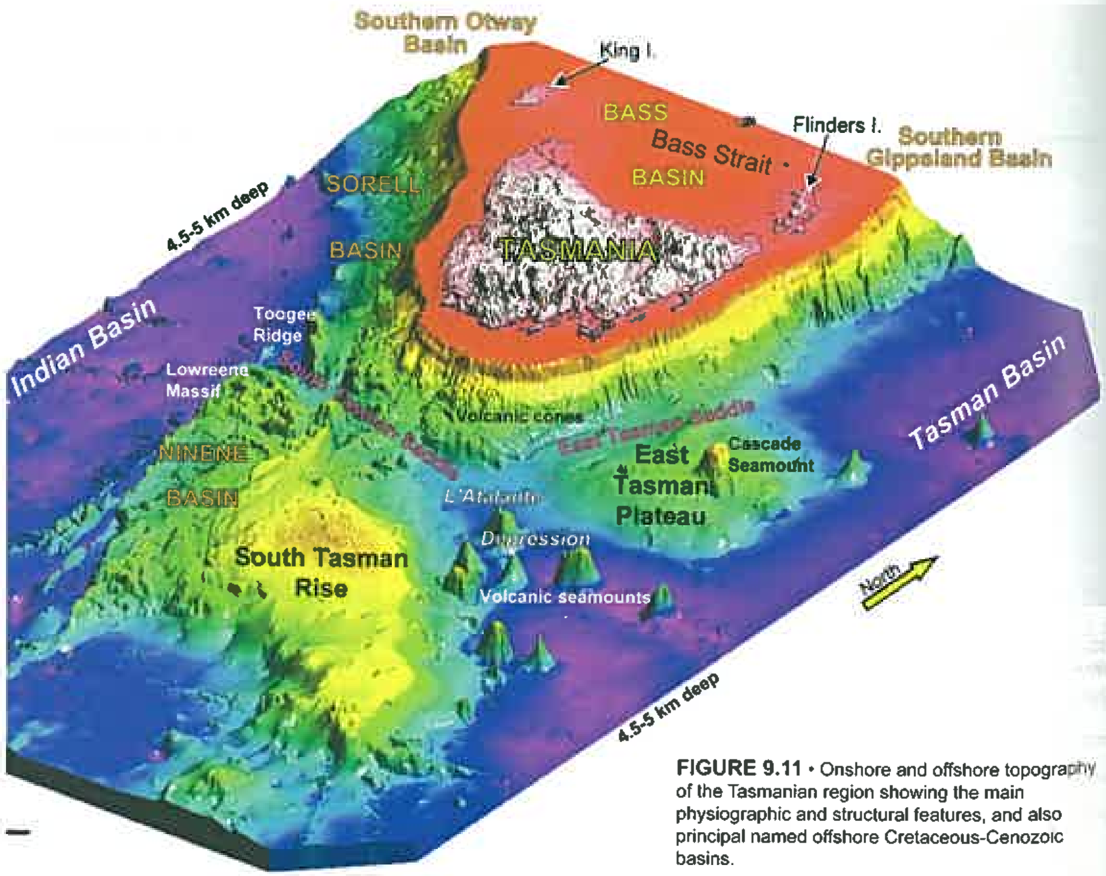


FIGURE 9.11 • Onshore and offshore topography of the Tasmanian region showing the main physiographic and structural features, and also principal named offshore Cretaceous-Cenozoic basins.

9.2.2 Regional tectonics and basin development

In the late Jurassic, Tasmania was part of eastern Gondwana with Victoria Land of East Antarctica abutting southwest Tasmania, and the southern Lord Howe Rise/Challenger Plateau adjacent to east Tasmania (Norvick & Smith 2001; Quilty in Section 9.1). Eastern Gondwana began to fracture during the latest Jurassic-earliest Cretaceous, with initiation of the Southern Rift System (Willcox & Stagg 1990) along the present southern margin of Australia. The extension direction was roughly NW–SE, with the eastern end of the fault system branching to form two arms, one roughly along the present Victorian coastline and the other off western Tasmania. Linked NE-trending pull-apart basins and oblique rifts developed in the Otway, Bass and Gippsland Basins and a sinistral wrench zone formed in the Sorell Basin. At least in the Otway and Gippsland Basins, this early rifting episode took place in two stages (Norvick & Smith 2001): the first during the Tithonian (with deposition of the Casterton Beds/'Jurassic Beds') and the second in the Neocomian (Crayfish Group/Lower Strzelecki Group deposited). These rift deposits included lacustrine sediments and coal measures. Renewed extension in the Aptian-Albian in a NE–SW direction (Etheridge et al. 1987), led to further filling of the southeast Australian basins with a flood of nonmarine volcanogenic sediments from the east sourced from dacitic volcanism, probably a volcanic arc/backarc system located along the Lord Howe Rise (Symonds et al. 1996; Bryan et al. 1997). These deposits formed the Otway Group in the Otway and Bass Basins and the Upper Strzelecki Group in the Gippsland Basin.

Much of the region was uplifted in the Cenomanian, with erosional denudation and development of a regional unconformity (Hill et al. 1995; O'Sullivan & Kohn 1997). This non-depositional episode was followed immediately by renewed continental rifting on the Australian southern and southeast (Tasman) margins. In the Gippsland Basin, the renewed extension that preceded Tasman breakup was short-lived (Turonian) and largely involved reactivation of pre-existing basin-forming structures. The synrift deposits (Emperor Subgroup of the Latrobe Group) comprised arkose, fluvial sandstone and then lacustrine shale (Bernecker & Partridge 2001). This rifting episode also had a dramatic effect on the nearby Durroon Basin, resulting in the

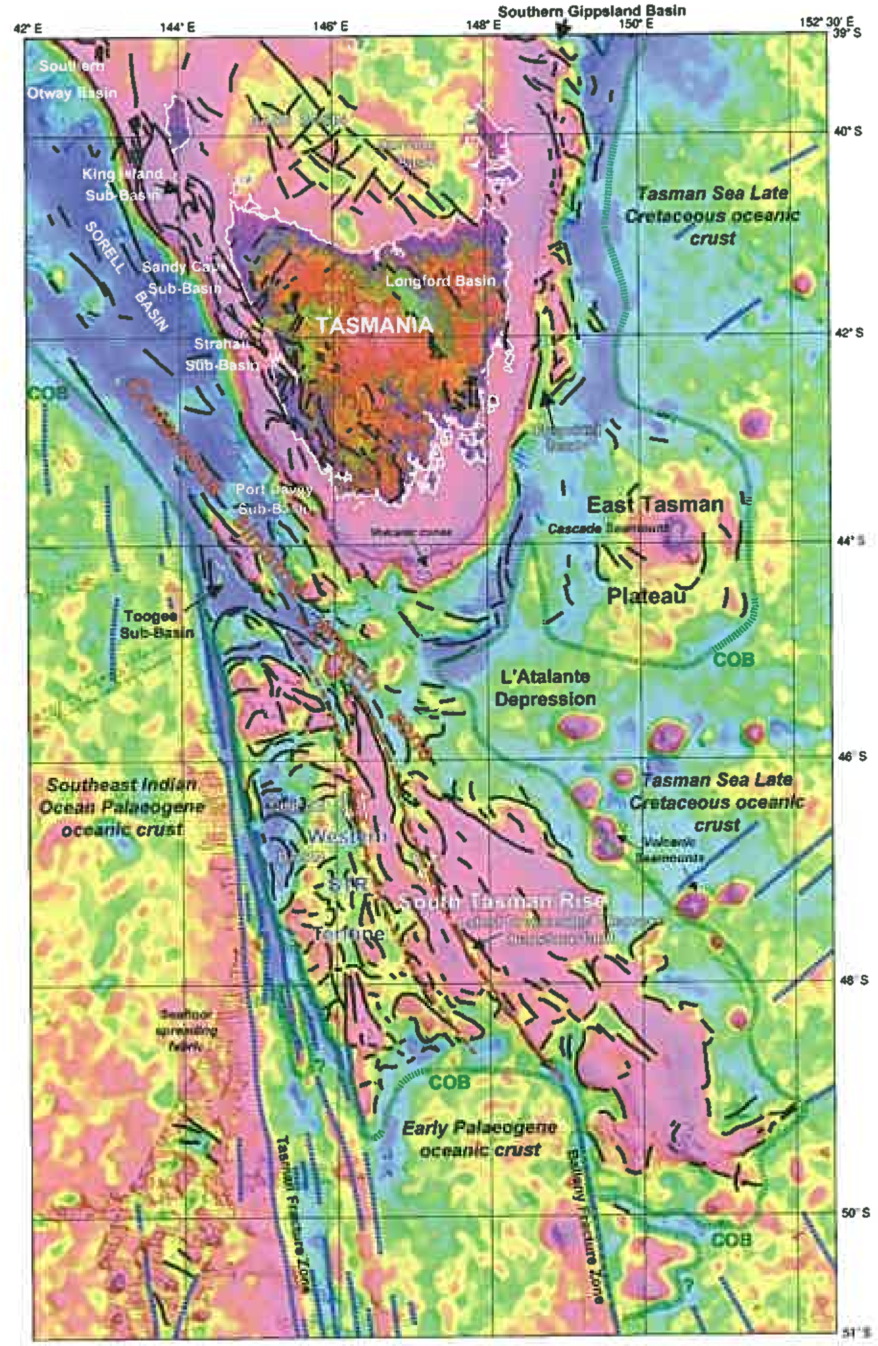


FIGURE 9.12 • Tectonic and structural elements map of the Tasmanian region with colour gravity anomaly and transparent topographic relief imagery as underlay. The colour-coded gravity imagery (magenta/red highs, blue lows) comprises free-air anomaly offshore and Bouguer anomaly onshore. The offshore gravity data are based on levelled shipboard surveys (Petkovic 2002) and satellite altimeter measurements (grid V9.2, Sandwell & Smith 1997). The topographic relief is based on integrated data sets (Petkovic 2002), including a number of Geoscience Australia swath surveys. Offshore the topographic relief imagery is grey-scale hill shading only, while onshore colour-coded elevation has been merged with the Bouguer gravity. Structures shown include: - the COB (continent-ocean boundary) as a thick broken green line, oceanic transform faults (fracture zones) as thick broken blue lines, and basement faults as black lines.

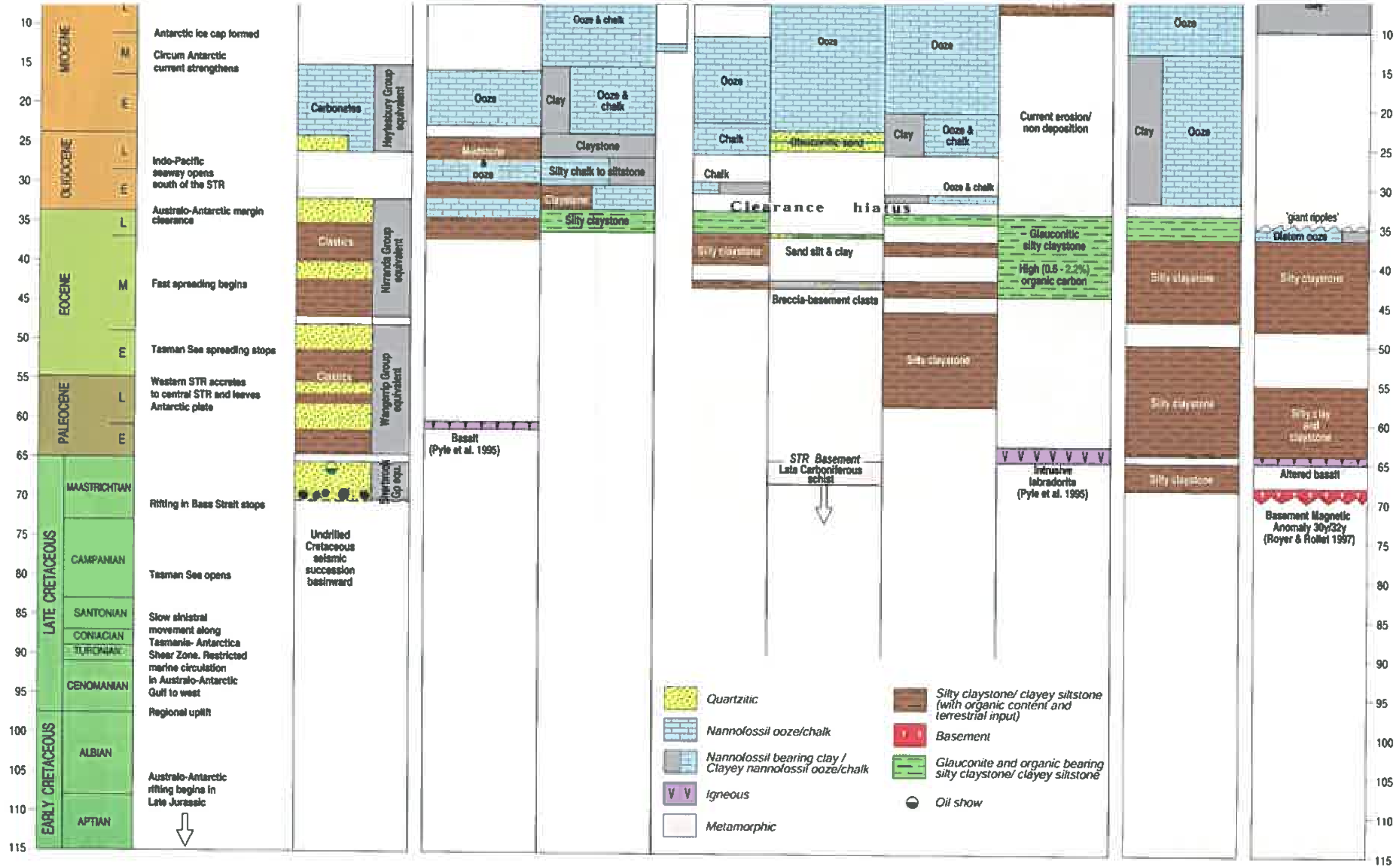
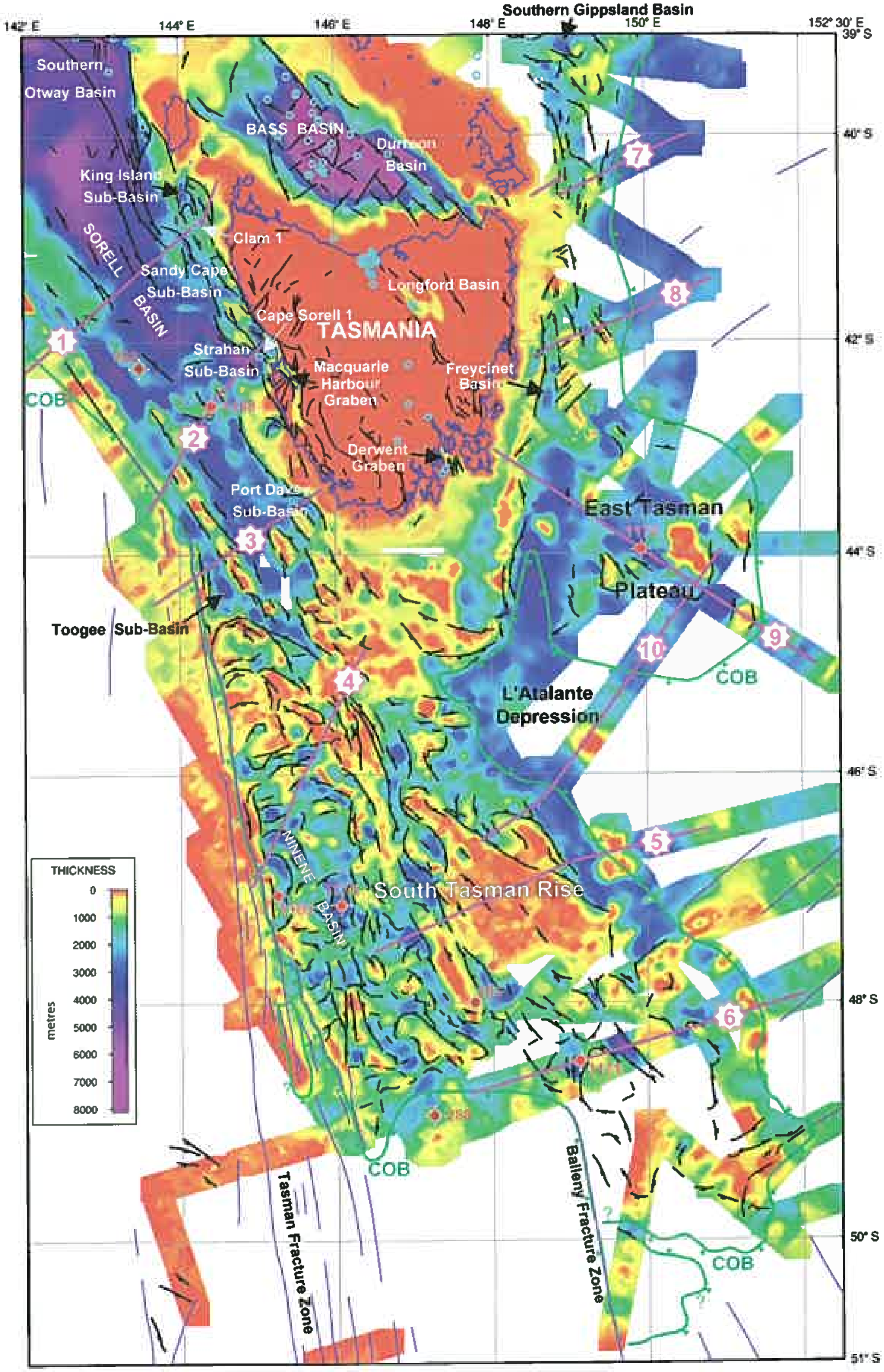


FIGURE 9.13 • Regional stratigraphic diagram based on deep sea drilling (DSDP and ODP) and offshore exploration well Cape Sorell 1 (Hill & Moore 2001). The locations of all sites (except DSDP 283) are shown in Fig. 9.14. DSDP 283 (Kennett, Houtz et al 1975a) was drilled on the Tasman Sea abyssal plain about 200 km east of the ETP.



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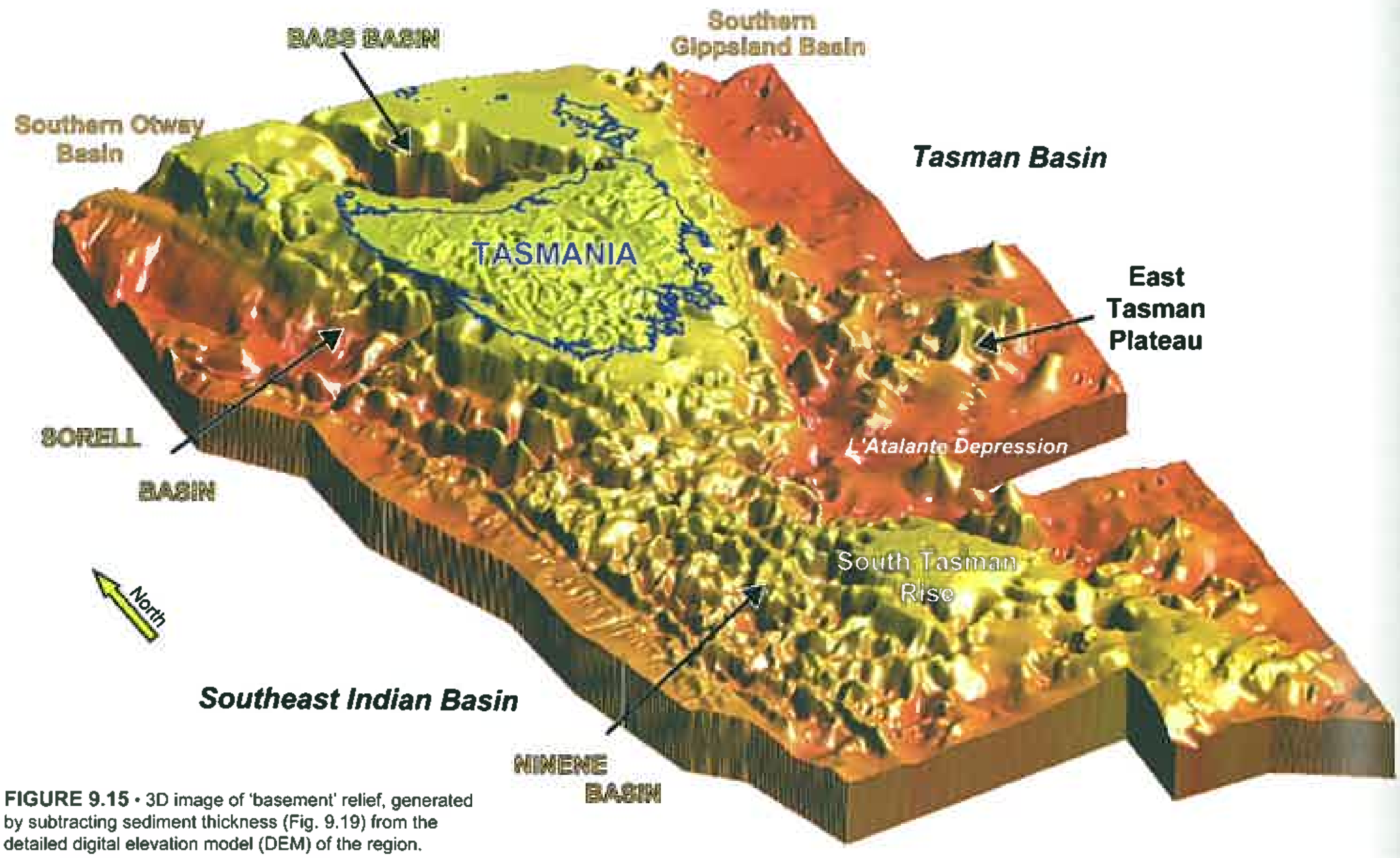


FIGURE 9.15 • 3D image of 'basement' relief, generated by subtracting sediment thickness (Fig. 9.19) from the detailed digital elevation model (DEM) of the region. Accordingly, basement shown here generally represents seismic basement (including the top of thick volcanic buildups) or the top of pre-Cretaceous formations.

rapid growth of large half-graben filled by terrestrial Turonian-late Santonian strata (Baillie & Pickering 1991; Blevin 2001, 2003). In marked contrast, the structural style in the Bass Basin to the west was much more subdued, characterised by regional sag and syndepositional faulting. By about 83 Ma (Early Campanian) rifting led to synchronous breakup in the Bight Basin (Sayers et al. 2001) and southern Tasman Basin (Royer & Rollet 1997; Gaina et al. 1998). Seafloor spreading adjacent to the ETP and eastern STR was in a SW–NE direction, with opening between these features forming the L'Atalante Depression (Fig. 9.12). Meanwhile, opening in the Great Australian Bight was linked to a major transform shear zone, the Tasmanian-Antarctic Shear (Exon et al. 2001b, 2004), trending northwest off western Tasmania and intersecting the proto STR.

By the Paleocene, a shift in relative motion between the Antarctic and Australia plates to a more N–S direction (Tikku & Cande 1999) led to onset of seafloor spreading off western Tasmania (Hill et al. 1997) and breakoff of part of the Antarctic plate (the western STR terrane; Fig. 9.12), which became welded to the eastern STR block, resulting in the present composite STR (Royer & Rollet 1997; Hill & Exon 2004). At about this time, seafloor spreading began at the southern margin of the STR (Pyle et al. 1995; Cande et al. 2000; Norvick & Smith 2001; Cande & Stock 2004), and ceased soon after in the Tasman Basin (55–50 Ma, Royer & Rollet 1997). The changes in plate tectonics that affected the region during the Paleocene to early Eocene resulted in varying degrees of uplift, structural inversion and mild folding throughout Tasmania and its margins (Exon et al. 2002a). Apatite fission track analysis (O'Sullivan & Kohn 1997) indicates cooling along the east and west Tasmanian coasts at this time, possibly due to uplift and denudation.

Commencing c. 43 Ma, fast N–S seafloor spreading in the Southern Ocean (Cande & Stock 2004) led to separation of the STR from Antarctica along the Tasman Fracture Zone and the creation of a major 500 km long escarpment along the western STR (Figs 9.11, 9.12). The STR and Antarctica cleared each other at the southwestern tip of the STR c. 33 Ma (Hill & Exon 2004), resulting in the opening of the Tasmanian Gateway and initiation of the Antarctic Circumpolar Current (Kennett, Houtz et al. 1975b; Exon et al. 2001a, 2001b), which had profound effects on regional climate and sedimentation (Kennett & Exon 2004). There was an accelerated subsidence of the margins (Hill & Moore 2001), which together with a cooler and drier climate, led to reduced siliciclastic sediment input and a change from deltaic deposition to that of pelagic carbonates in a more open marine environment (Exon et al. 2001b, 2001c). Studies of deep ocean cores (Stickley et al. 2004) indicate first connection of surface waters across the Tasmanian Gateway c. 34.5 Ma based on dinocyst assemblages, and that subsequent deepening of the Gateway led to onset of glauconitic deposition, and episodes of erosion and winnowing of sediments by energetic bottom currents to about 30 Ma. The Southeast Indian Ridge (SEIR) cleared the STR's southwest tip c. 23 Ma (Early Miocene). Since then Tasmania and its offshore areas ceased to be affected by local plate boundary tectonics; however, minor compression in the Miocene-Pliocene is recorded to the north (Otway and Gippsland Basins) due to farfield intraplate stress (Hill et al. 1995; Dickinson et al. 2002).

Imaging basement topography in 3D (Fig. 9.15) reveals the complex structural fabric of the region and the diversity of basin geometries.

9.2.3 Sorell and southern Otway Basins

The west Tasmanian continental margin is about 500 km long, and extends from King Island in the north to the South Tasman Saddle in the south (Fig. 9.11). It is about 200 km wide, and includes a shallow continental shelf (<300 m deep) about 30 km wide in the south and more than 55 km wide in the north. The continental slope, which has variable relief due to canyon downcutting and uplifted fault blocks, levels out onto a 4500–5000 m deep abyssal plain underlain by early Cenozoic oceanic basement.

Much of the margin has a thick cover of late Mesozoic-Cenozoic sediments, forming the Sorell Basin (Willcox et al. 1989; Hill et al. 1997) and the contiguous southernmost part of the Otway Basin (Fig. 9.14). The boundary between the Otway and Sorell Basins is not clearly defined, but has conventionally been taken as a line running roughly southwest of King Island. Nearshore, this boundary coincides with a basement high. Though the two basins are considered to be largely structurally and stratigraphically continuous (Moore et al. 2000), some differences exist, in particular the greater influence of strikeslip tectonics in shaping the Sorell Basin which has four main depocentres beneath the shelf and upper slope: the King Island, Sandy Cape, Strahan and Port Davey Sub-basins (Fig. 9.14; Moore et al. 1992).

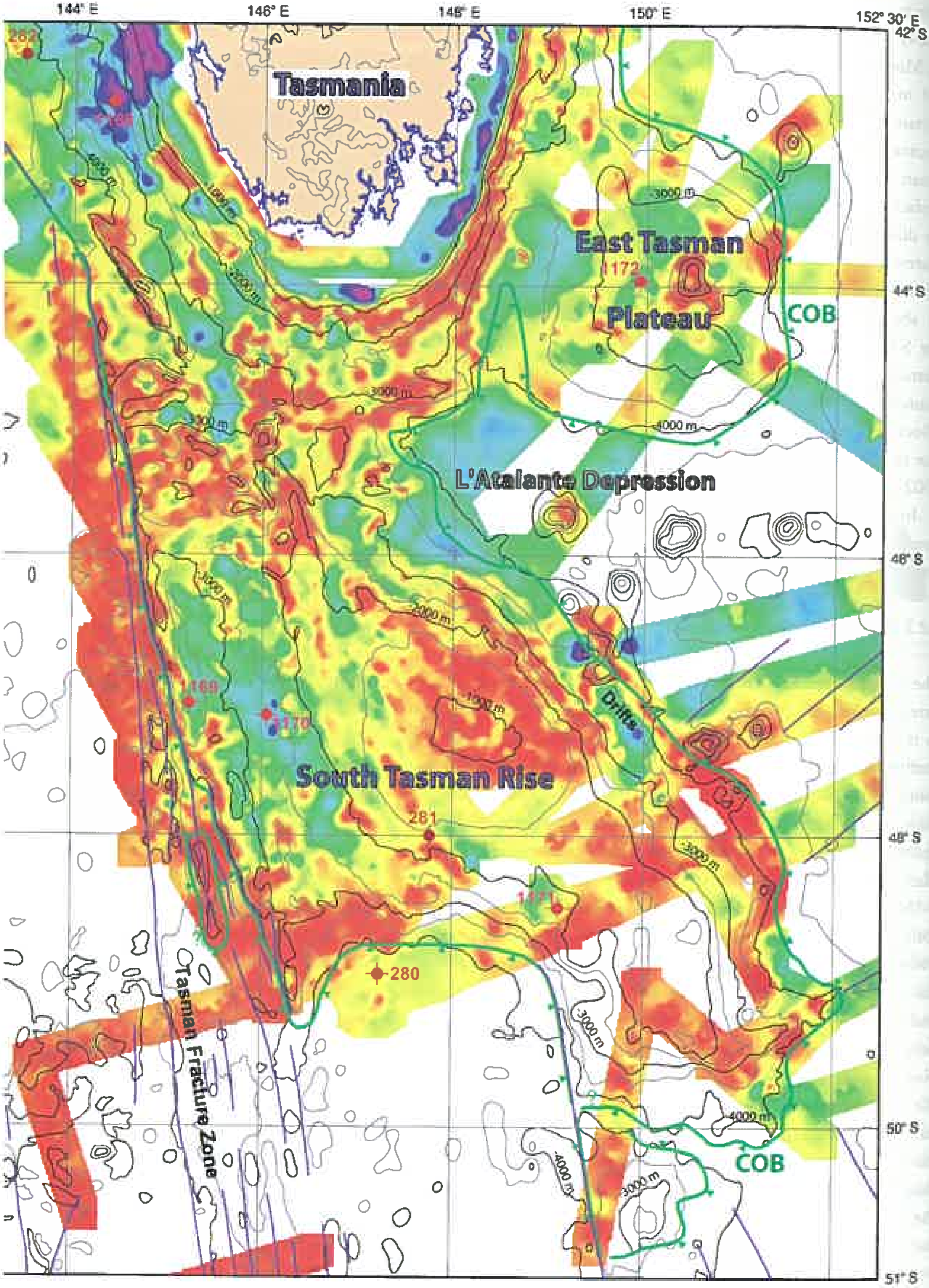
A representative set of interpreted seismic profiles (Fig. 9.17; Hill et al. 1997) illustrates the structure and stratigraphy of the west Tasmanian margin. These SW–NE-oriented dip lines extend from oceanic crust of the Southeast Indian Ocean abyssal plain, across the continent-ocean boundary (COB) and continental slope onto the continental shelf. The seismic stratigraphy is controlled mainly by the four exploration wells on the shelf (Prawn-1, Whelk-1, Clam-1 and Cape Sorell-1; Lodwick et al. 1999), DSDP Site 282 (Kennett, Houtz et al. 1975a), ODP Site 1168 (Exon et al. 2001b) and marine geological sampling data (e.g. Hinz et al. 1985; Exon et al. 1989, 1992, 1995).

The sediment distribution and principal structures in the Sorell Basin are shown in Figure 9.14. The main depositional area in the basin lies beneath the mid continental slope in the northern part of the west Tasmanian margin and contains 6 km or more of sediment. From the Oligocene to present, the outer Strahan Sub-basin has had one of the highest sedimentation rates in the region, accumulating up to 1000 m of sediment (largely carbonates) (Fig. 9.16).

As illustrated in Figure 9.17, the Paleocene section is relatively thick in the north and the Eocene section in the south. Palynological studies on dredge material confirm that these sequences are relatively shallow marine deltaic (Truswell 1997). Hill et al. (1997) inferred from the geometry that the depocentre moved relatively south during the Paleocene and Eocene, probably controlled by uplift and subsidence associated with the oceanic spreading centre's relative movement southward. Another feature of the seismic and dredging results is that the shallow marine Eocene sediments eventually rotated down to the ocean by as much as 4500 m, after Australia cleared Antarctica in the earliest Oligocene, and deep marine carbonates were deposited unconformably on the Eocene strata in what had become the continental slope.

The Late Cretaceous and older section has undergone significant deformation, comprising mainly seaward-dipping normal faulting ranging from near-vertical to low-angle listric, but also reverse faulting and gentle to moderate folding. Though most faults extend only to the top of the Cretaceous/Paleocene section, minor faulting extends into the upper Palaeogene sequence in some areas, particularly the nearshore part of the margin (including the Sorell Fault Zone parallel to and near the coast off King Island) and adjacent to the northern Tasman Fracture Zone.

Though complex in detail, the structural trend off west Tasmania is mainly NW–NNW, reflecting the underlying pattern of basin-forming faults (Fig. 9.15) that developed through both strike-slip and extensional mechanisms. As is the case with most wrench basins, the southern Otway/Sorell Basin comprises many relatively small, often deep, and irregularly distributed depocentres. The Cretaceous Sorell Sub-basins on the shelf and upper slope are typically half-graben or V-shaped, deep and narrow, reflecting their trans-tensional origin. These depocentres are located within



gocene-Holocene sediment thickness for offshore southern Tasmania, the STR and ETP (after Hill & Moore 2001).

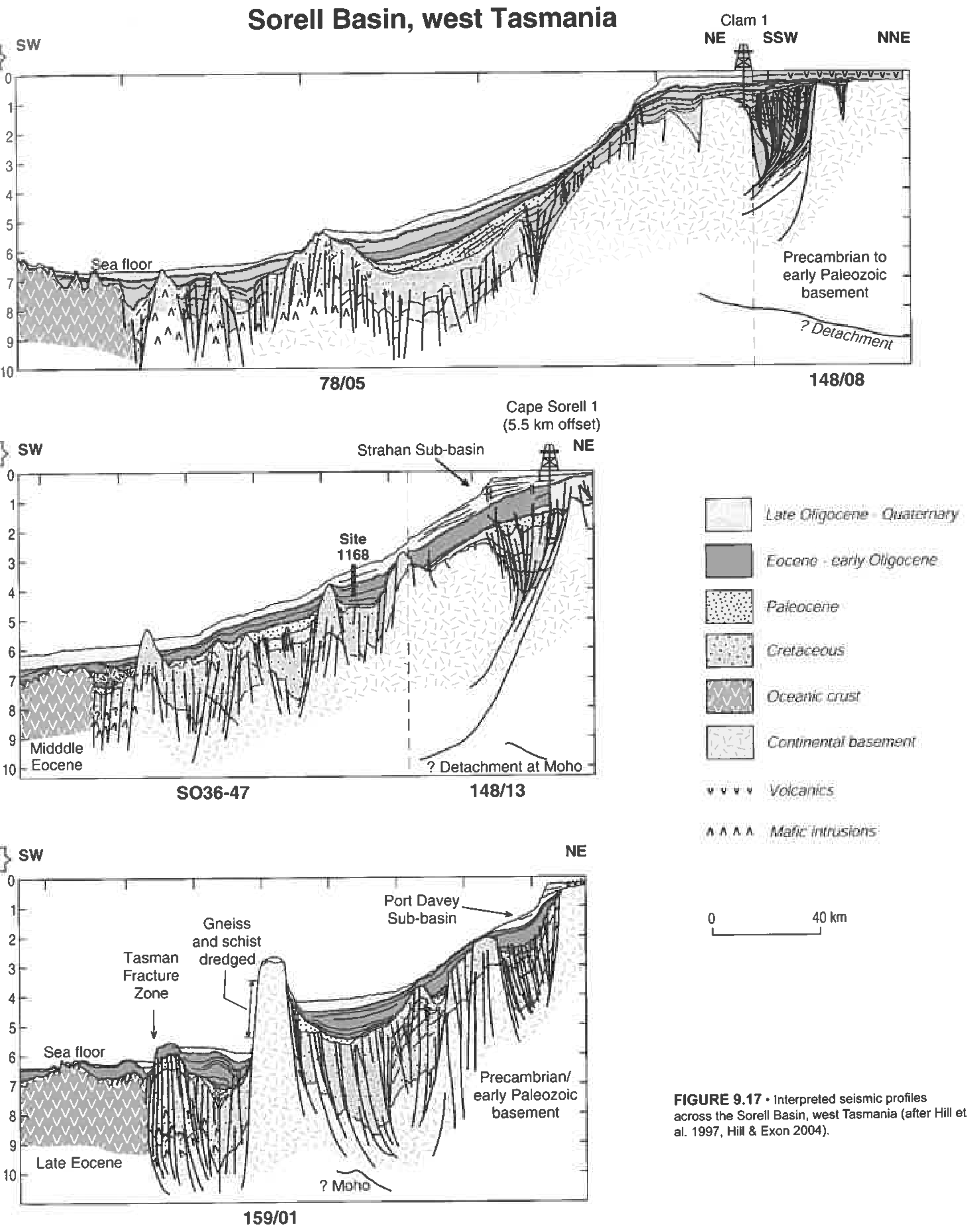


FIGURE 9.17 • Interpreted seismic profiles across the Sorell Basin, west Tasmania (after Hill et al. 1997, Hill & Exon 2004).

low Precambrian to early Palaeozoic basement and econds two-way time (s twt), or approximately 2.0 :ction. As in the Otway Basin, a strong, angular mid ?Cenomanian) unconformity occurs in the northern

thickness beneath the continental slope is generally he lower continental slope is characterised by a zone of uplifted basement blocks. This zone, about commonly contains two main ridges 30–40 km profiles across this structural high generally show of diffractions, particularly at depth, suggesting eous intrusive activity in this zone at or close to the up. Oceanic basement outboard of the high has a thin sediment cover generally less than 1 km thick, s exposed on the seafloor.

t, there is insufficient information available to mprehensive stratigraphic scheme for the Sorell :heless, by linking to Otway Basin stratigraphy hic nomenclature and using the limited existing 'rom Clam-1 and Cape Sorell-1 wells (Fig. 9.17; . 2002), a provisional summary of lithostratigraphic (at least for the nearshore part of the basin) is vick et al. 1999).

Group (mid-Oligocene–Miocene) equivalent: outer ate, including fossiliferous reefal limestone

roup (Middle Eocene–mid-Oligocene) equivalent: ne and calcareous mudstone deposited in a shelfal onment

Group (latest Maastrichtian-Middle Eocene) shallow marine quartz sandstone, siltstone and

Group (Late Cretaceous) equivalent: mainly d shale with some coaly beds deposited in a paralic in environment.

the Sorell and southern Otway Basins

nanian margin has been only sparsely explored, loration wells drilled to date. One field has been Thylacine gas-condensate field, situated in the 100 km northwest of King Island and just south y offshore boundary with Victoria. The Thylacine vered in 2001 and production commenced in 2007, onveyed from the production platform to Victoria line. The field had an initial in-place resource of 1000 billion cubic feet of gas.

carbon reservoirs of the Thylacine field are sandstone of the Turonian Waarre Formation, late Turonian marine Flaxman Formation, and the Santonian fluvio-deltaic Thylacine Member of the Belfast Formation. The overlying thick marine mudstone of the remainder of the Belfast Formation comprises the regional seal. The source rocks are believed to be carbonaceous siltstone and coal of the Albian non-marine Eumeralla Formation and possibly more deeply buried Waarre and Flaxman Formations to the south (Anon. 2003).

Minor oil shows were recorded in the Cape Sorell-1 well in the southern Sorell Basin, within a thick upper Cretaceous and Palaeogene, proximal sandy succession. Untested prospective areas with thick section, mature source rocks and potential traps occur under the west Tasmanian continental margin (Conolly & Galloway 1995; O'Brien et al. 2004).

9.2.4 South Tasman Rise

The South Tasman Rise (STR) (Exon et al. 1997b; Hill et al. 2001b) includes two main structural provinces:

- A complexly deformed western block with mainly N–S trends and less developed E–W trends
- A structurally simpler eastern block cored by shallow basement beneath the crest of the STR and flanked by narrow NW–SE-trending rift basins (Fig. 9.12). Interpreted profiles (Fig. 9.18) illustrate the structure of the STR in more detail.

The prominent NW–SE structural trend (Fig. 9.12) along the spine of the STR, and extending along the west Tasmanian margin, is a relic of the Tasmanian-Antarctic Shear, active in the Late Cretaceous to Palaeogene. The change in structural style occurs across the STR trend between about 146°E and 148°E (Fig. 9.12; Exon et al. 1996; Royer & Rollet 1997). The more complex nature of the western terrane is related to deformation within the area affected by the Tasmanian-Antarctic Shear during its transfer from the Antarctic to the Australian plate in the Paleocene, and then by N–S wrenching associated with transform movement along the Tasman Fracture Zone.

The eastern region of the STR, including the L'Atalante Depression, exhibits mainly NW–SE and NE–SW structural trends, consistent with the Tasman rift and spreading directions, respectively. The L'Atalante Depression is floored by sedimented oceanic crust. Arms of oceanic crust extend partly beneath the East and South Tasman Saddles (Figs 9.11, 9.12). The seismic data indicate that the saddles are probably mostly underlain by highly extended continental crust but it is difficult to be certain because of the extensive volcanism in these troughs (Fig. 9.18, profile 4; Fig. 9.19, profile 9).

Basins with relatively thick sediments >2 km have developed over much of the STR region (Fig. 9.14), including the western STR (Ninene Basin and Toogee Sub-basin), the flanks of the

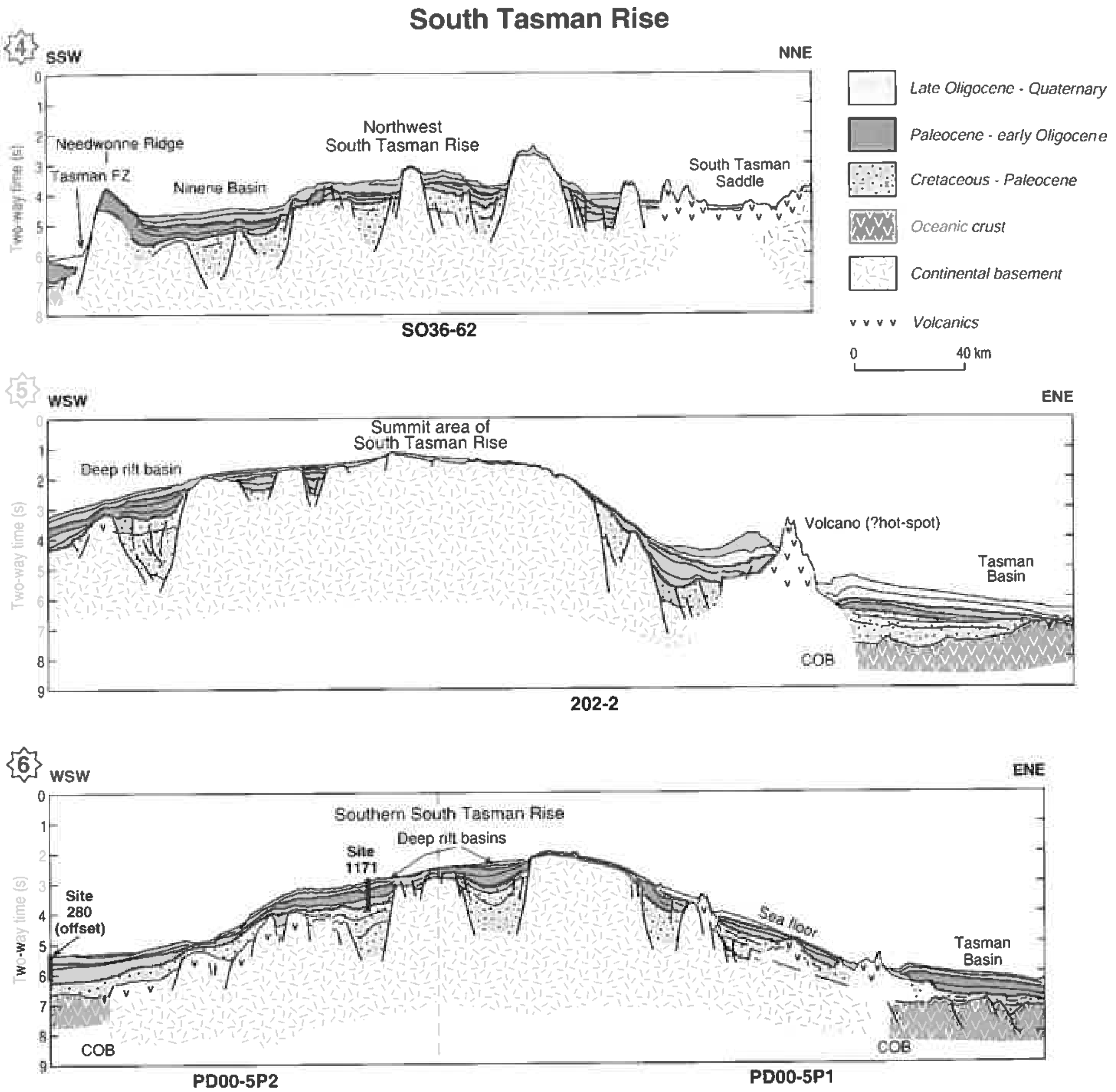
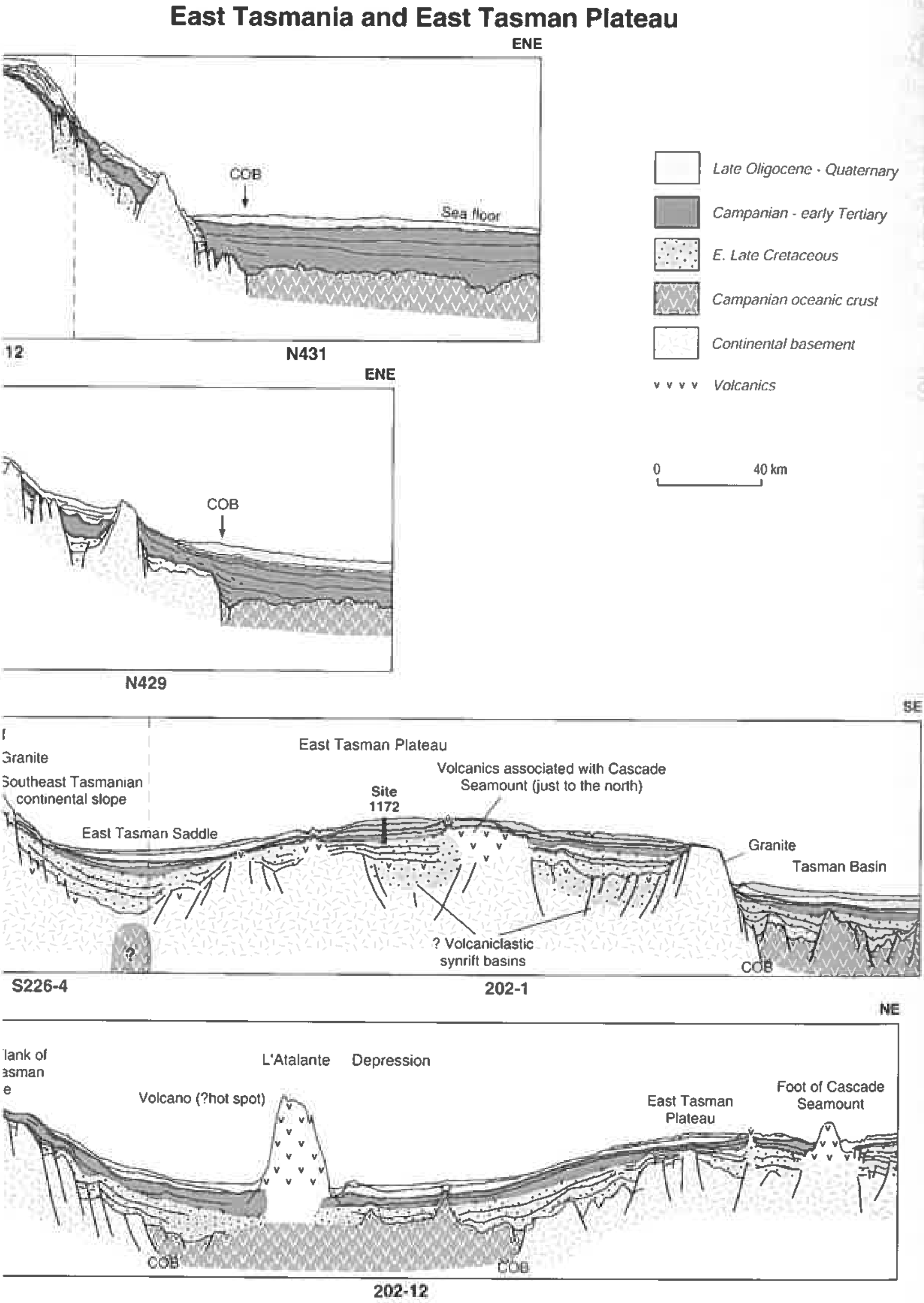


FIGURE 9.18 • Interpreted seismic profiles across the South Tasman Rise (after Hill & Moore 2001, Hill & Exon 2004).

central STR and the margins of the L'Atalante Depression. Beneath the western STR individual depocentres are relatively small (mainly less than 25 km across) and often rhomboid in shape, while on the flanks of the central STR the basins are deep and narrow (20–25 km wide) and trend NW–SE. The Ninene wrench basins and central STR transtensional rifts contain 3–4 km of sediment. The margin adjoining the L'Atalante Depression is underlain by more than 2 km of postbreakup sediments, and several large ?Eocene hotspot volcanoes straddle the COB (Fig. 9.18). In some areas, such as the South Tasman Saddle and the southeastern margin of the STR, potentially deep sedimentary section is masked in the seismic profiles by volcanics. Areas of shallow basement (mainly with <300 m of cover) are associated with the summit area of the STR, Palaeogene oceanic



preted seismic profiles across the east Tasmanian margin and East Tasman Plateau (after Hill et al. 1998, Hill & Moore 2001, Hill & Exon 2004).

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est of the STR, and the blocky terrain (Lowreenne Massif) iately south of the Toogee Sub-basin.

Palaeogene and younger sequences on the STR are ly well known from seabed sampling (Exon et al. 1995) ep sea drilling (Fig. 9.13; Kennett, Houtz et al. 1975a; Exon 001b; Exon et al. 2004). These comprise Paleocene-Eocene stics, overlain unconformably by Oligocene and younger carbonate (chalk and nannoforam ooze). The carbonate ce is generally less than a few hundred metres thick, but lower eastern margin of the STR it has accumulated as -controlled drifts to a thickness of about 800 m (Fig. 9.16, rofile 5). The siliciclastics, where drilled, are deltaic and marine silty claystone, often rich in organic carbon. No eous sediments have been recovered from the STR so far, smic evidence suggests that the deep basins on the STR thick accumulations of Late Cretaceous shallow marine ltaic deposits.

ffshore east Tasmania, southern Gippsland Basin and East n Plateau

stern Tasmania the continental shelf is 20–40 km wide. ntinental slope is about 80 km wide in the south, narrows ut 40 km off southern Flinders Island, and then broadens owards the Gippsland Basin.

smic profiles (Fig. 9.19; Hill et al. 1998; Hill & Moore 2001; et al. 2002a, 2002b) show the east Tasmanian continental to be complex, both structurally and stratigraphically. les of volcanism, related to Campanian breakup and Eocene ate ?hotspot activity, plus post-Eocene development of oceanic circulation (opening of the Tasmanian Gateway and pment of the East Australian Current), have complicated ion of the margin. Exploration drilling in the Gippsland provides useful stratigraphic control on the northern part margin, and recent ODP drilling on the ETP (Site 1172, et al. 2001b; Figs 9.18, 9.19) provides control down to the richtian in the south.

sement beneath the margin off eastern Tasmania steps lope in a series of large, normally faulted and tilted fault . Dredging of basement outcrop (Exon et al. 2002a) tes that it is largely granite, similar to the Devonian granites re, and the seismic data show extensive intrusion of younger ics. Small synrift graben and draping post-breakup sag ts fill the rugged basement relief. Sediment thickness is ely variable, from nil at basement outcrop to at least 1500 hin some of the larger graben, including a N–S-oriented rift ntral east Tasmania named the Freycinet Basin (Figs 9.12, .19, profile 8).

Many parts of the margin, particularly the lower slope, are underlain by a significant thickness (0.5–1.5 km) of early sag phase deposits (mainly Campanian-Paleocene). Part of this sequence is exposed, or covered by no more than a veneer of Holocene carbonate ooze, on the continental slope off southeast Tasmania. Coring recovered shallow marine, muddy sands containing late Campanian dinoflagellates and radiolarians (Harris et al. 1999; Pujana & Quilty 2002). In seismic profiles this early sag phase sequence appears relatively reflection-free. It has been folded and faulted in places beneath the Tasmanian continental slope and on the ETP, with the observed inversion apparently of Late Paleocene-Early Eocene age. This tectonism appears to have been regional in extent and was probably associated with major changes in plate kinematics at this time (e.g. termination of spreading in the Tasman Basin and change in relative Australia-Antarctic plate motion). The episode is marked by a strong unconformity at ODP Site 1172 on the ETP, as the end of folding at ODP Site 1171 on the STR (Exon et al. 2001b), and as Early Eocene inversion and canyon-cutting in the Gippsland Basin (Johnstone et al. 2001).

The Eocene and younger deposits on the continental slope are patchy, typically <500 m thick, and show evidence in places of erosion, current deposition and slumping. Sampling indicates that Neogene carbonate, often bryozoal calcarenite, is a major constituent of the upper slope (Quilty 1985; Quilty & Telfer 1994; Exon et al. 2002a). These carbonates were originally deposited in shallow water in a shelfal environment, but have since subsided by as much as a kilometre through margin sag.

The continental shelf is largely non-depositional at present with most of the surface sediments consisting of reworked Pleistocene deposits, mainly quartz sands nearshore, and bryozoal sands and gravels beneath the outer shelf (Jones & Davies 1983). Underlying the shelf is a prograding and seaward-thickening wedge of Neogene carbonate that attains maximum thickness beneath the shelf break of 500–800 m (Fig. 9.16; Exon et al. 2002a). Seabed samples recovered at the foot of the wedge indicate a basal layer of granitic arkose and siliceous sandstone.

The Tasman abyssal plain adjacent to the margin is mainly 4000–4500 m deep and is underlain by 1.5–2.0 km of post-breakup sedimentary section. The basal section is thick (~1.0 km) and relatively reflection-free and probably consists largely of Campanian-Paleocene clay. This is overlain by ~300 m of well-stratified, flat-lying Eocene section (clay/pelagic ooze), followed by an upper, post-Eocene layer of deepsea ooze and clay. The latter is of varying thickness (0–400 m) and shows mounding and evidence of erosion in places, particularly at the foot of the continental slope, indicating an active boundary current. Oceanic basement at the margin is presumed to be of Campanian age and lies at 7.0–7.5 s twt.

ater southern Gippsland Basin, multichannel 1972–73 Shell (Petrel); Colwell, Coffin et much as 2.5 s twt of sedimentary section of ection (Bernecker & Partridge 2001) on the wt of well-stratified postbreakup (Campanian nan Basin section beneath the adjacent rise The synrift section, comprising the Emperor Golden Beach (Santonian-Campanian) ssibly Strzelecki Group (Early Cretaceous), is and up to 2 s twt thick. The overlying post-rift :s (Halibut Subgroup, Maastrichtian-Eocene) ıd do not appear to be more than ~500 m thick. ıpper megasequence, the Seaspray Group, is a ıence mainly of marine carbonate prograding per continental slope but rapidly wedging out

hauls on the steep and canyoned continental f the Bass Canyon complex (Exon et al. mic profiles indicated rugged basement relief m of sedimentary section, yielded a variety of gies, including labile sandstone of the Golden Given the relatively thin sedimentary section e vicinity of the sites, it is likely that Strzelecki ı this area are very thin or absent.

rt of the east Tasmanian margin is dominated et al. 1997a; Hill & Moore 2001), a block of 50 km wide, that rifted off southern Tasmania ous. The shallowest point on the ETP is about of a large steepsided volcanic guyot, Cascade 1). The volcano erupted subaerially in the Late 97, 2001) but has since subsided. Apart from the upper surface of the plateau generally lies 2500–3000 m.

lerlain by about 2 km of post-breakup section ounger), and the adjacent East Tasman Saddle but slightly thicker succession. Basement of the saddle is probably 'transitional' partly extremely thinned continental crust intruded cs. The sedimentary section on oceanic crust also about 2 km thick. On the ETP the post-ears to be underlain by ?volcaniclastic synrift ickness (Fig. 9.19). Dredging of granite from ıt at the COB and also from the nearby steep continental slope indicates that basement in largely granitic. Volcanics associated with the occur within the Eocene and older sediments. ar to lie at the breakup unconformity on the

About 2 km of Campanian-Cenozoic sediments have been deposited within and on the margins of the oceanic L'Atalante Depression. Eocene sequences on the flanks of the adjacent ETP and STR prograde strongly downslope into the Depression. A 2 km high ?Eocene basaltic hotspot volcano, one of several large volcanic seamounts in the area (Fig. 9.11), has erupted through Campanian-Maastrichtian oceanic crust close to the middle of the L'Atalante Depression (Fig. 9.19, profile 10).

9.2.6 East Tasman Plateau and South Tasman Rise

Cenozoic volcanic structures are widespread on submerged thin continental crust south and southeast of Tasmania. Information comes largely from swath bathymetry, geophysical surveys, dredging and coring by the Australian Geological Survey Organisation (now Geoscience Australia) in 1994 and 1999–2000, using the RV *Rig Seismic* and the French oceanographic vessel *L'Atalante*, together with a few samples recovered during fishing operations.

The East Tasman Plateau, a continental extension of Tasmania lying about 100–250 km ESE of Cape Pillar, is surmounted by numerous volcanic seamounts. The largest, the Cascade Seamount (also known as the Soela Seamount) is a cone 10 km across and 1500 m high, rising to a flat top 635 m below modern sea level. $^{40}Ar/^{39}Ar$ dating and foraminifera in the matrix of associated volcaniclastic conglomerate indicate that it formed, probably within a few million years, in the Middle-Late Eocene (c. 36–40 Ma) and its morphology and sedimentology suggest a complex, partly subaerial history (Exon et al. 1997; Quilty 1997, 2001). Geochemistry and mineralogy of dredged samples, some of which are little altered, indicate intraplate alkali basalt with HIMU isotopic and trace element affinities (Lanyon 1994; Crawford et al. 1997).

A large cluster of about 80 volcanic cones, typically 200–500 m high, lie on the continental slope about 50–100 km south of Tasmania. Thin continental crust extends SSE across the South Tasman Saddle (3500 m depth) to the South Tasman Rise, the crest of which, at water depths of about 750–1000 m, is occupied by another large conefield. Another cluster of seamounts occurs on the southern end of the South Tasman Rise (about 650 km from mainland Tasmania). Just east of the faulted eastern margin of South Tasman Rise, a chain of large seamounts rests on thin continental crust and Cretaceous ocean crust in the southern part of the L'Atalante Depression, which lies at ~4000 m between the East Tasman Plateau and South Tasman Rise (Exon et al. 1997; Hill et al. 2001b).

Dredged basalt samples from these areas are more altered than those from the Cascade Seamount, but immobile element

...mistry suggests that they are also dominantly intraplate basalt with HIMU affinities, ranging to subordinate ...onal tholeiite (Crawford et al. 1997). Similar HIMU basalts ...cur on the Balleny Islands hotspot chain, but this signature ...s to Macquarie Island and mainland Tasmania (Lanyon et ...3; Kamenetsky et al. 2000) and appears too widespread in ...ace and time to record a single plume trace. Instead, they ...efine a regional lithospheric signature inherited from an (90–100 Ma) mantle plume (Crawford et al. 1997).

...ontrast, fragments of pillow basalts dredged from two small ...d seamounts resting on Eocene oceanic crust ~200 km west ...mania have N-MORB affinities similar to nearby DSDP ...82. They appear unrelated to intraplate hotspot trails and ...ly formed at 40–60 Ma in a ridge or near-ridge setting ...ford et al. 1997).

...ortheast Tasmania margin

...l volcanic seamounts rising on the continental slope ...ast of Tasmania were mapped from the RV *Melville* in 1997 ...swath bathymetry (Exon et al. 1999). The largest, St Helens ... a conical seamount located about 30 km ENE of St Helens ... It is 3.5 km across at the base at 1000 m depth, rising to ... b.s.l.. Although previously thought to rest on surrounding ...le Miocene limestones, $^{40}Ar/^{39}Ar$ dating indicates a Mid-...e (45–50 Ma) age (D. Phillips, in Hill & Moore 2001). ...its base there are possible parasitic vents and flows, which ...ave ponded to form a lava lake. Another smaller (<200 m ...cone lies 6 km further east. Further northeast, North Hill ...00 m to a summit 900 m below sea-level. These and similar ...are important fishing grounds.

...e small (<200 m), probably volcanic cones have been ...fied along the northeast Tasmanian margin between 40°15' ...1°S (Exon et al. 1999) and the steep, rugged continental ...east of Banks Strait may also be partly volcanic terrain (Hill ...2001).

...n interval of more than 185 m of altered glassy amygdaloidal ...nics was intersected at the bottom of Sailfish-1 (1234–...m, TD), an oil exploration well located 100 km ENE of ...ers Island near the southern margin of the Gippsland Basin. ...olcanics, which had been interpreted on seismic sections as ...hermal reefal complex, were thought to be Miocene or older, ...ossibly of trachytic basalt or trachytic andesite composition ...lner 1972). Similar isolated seismic features indicating the ...nce of volcanics are present on numerous other seismic lines ... region (Baillie 1987b).

9.2.8 Bass Basin

P. W. Baillie, P. G. Quilty

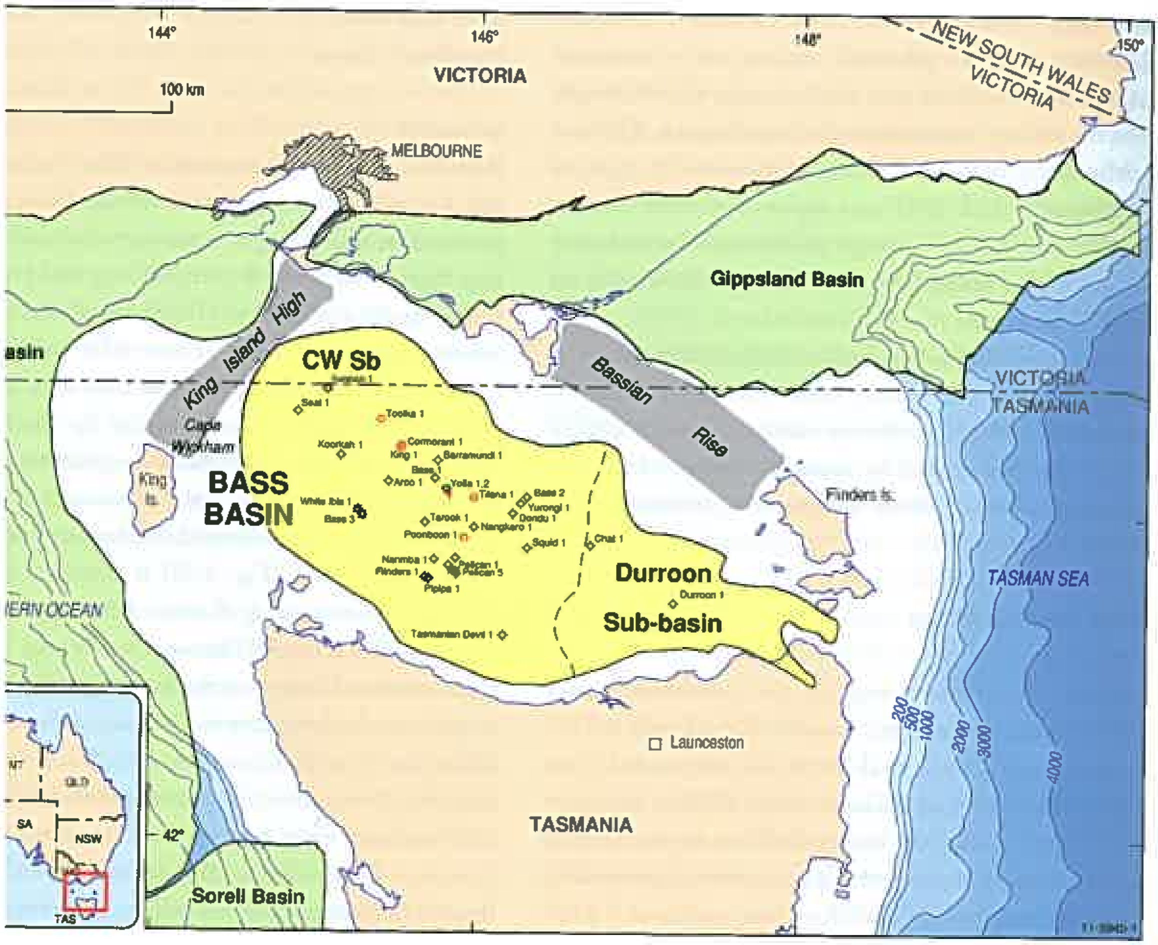
Introduction

Bass Basin, the main element of Bass Strait between Tasmania and Victoria, is a major intracratonic basin. Hydrocarbons are produced at the Yolla gas-condensate field, and evidence suggests that there is scope for further drilling and production. Since the review by Morrison et al. (1989), in addition to any commercial seismic data gathering, a further 4000 km of seismic data were collected in 1990–1992. The new data have led to the review of geology and hydrocarbon potential by Blevin (2003) and that nomenclature, even if informal, is used here. The Basin trends northwesterly beneath central Bass Strait, with a restricted version of the Basin covering some 42,000 km^2 or 320 × 150 km.

The Bass Basin (Fig. 9.20) is bounded to the northeast by the northwest-trending Bassian Rise, a shallow ridge between Flinders Island and Wilsons Promontory in Victoria, which separates Bass Basin from the Gippsland Basin to the east. To the northwest, the boundary is the King Island High linking King Island and Port Phillip approximately, and separating Bass Basin from the Otway Basin to the west. The north coast of Tasmania, and basement highs between Tasmania and King Island and the Furneaux Group, form the southern boundaries. The Basin is divided internally into southeastern Durroon and the areally larger northwestern Cape Wickham sub-basins, separated by the Chat Accommodation Zone (Blevin 2003), a NNE-trending basement structural feature. The Durroon Sub-basin extends southeasterly to join the small onshore Boobyalla Sub-basin (Moore et al. 1984; Baillie & Pickering 1991).

Basement seems to be different between the two sub-basins, with Lachlan Fold Belt rocks (but including the Jurassic Tasmanian dolerite) likely to exist beneath the Durroon Sub-basin, and older folded Proterozoic metasediments under the Cape Wickham Sub-basin. Durroon Sub-basin is the more intensely faulted unit of narrow half-graben. Fig. 9.21 is a diagrammatic cross section of the central Bass Basin and Fig. 9.22 is a summary of the stratigraphic units, nomenclature and their relationships to palaeo-environment.

Both sub-basins are characterised by half-graben but the pattern is different; in the Durroon Sub-basin, small depocentres are generated on the northeastern side of down-to-the-northeast half-graben. In contrast, most half-graben in the Cape Wickham Sub-basin are down-to-the-west or -southwest. The principal troughs in the Cape Wickham Sub-basin are the Cormorant, Yolla, White Ibis and Pelican Troughs (Fig. 9.23).



0 • Regional map showing location of Bass Basin, Bassian Rise, King Island High and neighbouring basins. Also shown are the locations exploration wells. CW Sb = Cape Wickham Sub-basin. (From Blevin 2003 with approval).

sedimentation

through three major tectonic rifting episodes r in which Australia and Antarctica separated of Gondwana. The first and third tensional nts along the southern margin of Australia id the second relates to events to the east in ollowing the third rifting phase, Bass Basin le of sagging and minor compression. It was Late Jurassic or Early Cretaceous as a failed ak-up of east Gondwana. By the end of the had already filled with up to 8 km of non- Morrison & Davidson 1989). The Durroon in Jurassic dolerite as on mainland Tasmania, vidence for tension within Gondwana. After Accommodation Zone separated the two ich had different histories controlled by the .

Sedimentation throughout basin evolution has been accompanied by extensive intrusion and extrusion of lavas, dominantly basaltic. None are visible on the Basin floor but have been encountered widely during drilling and are clear on seismic profiles.

The earliest rift phase (Otway Rift Phase) that defined the Basin may have begun in the latest Jurassic (Tithonian) but is well recognisable in the early Cretaceous (?Barremian-early Cenomanian). This phase affected the entire eastern area of the developing rift between Australia and Antarctica as the Southern Rift System of Stagg et al. (1990). NNE tension caused rifting with a WNW extension expressed as the bounding normal faults with throws of up to some 5 km. Orientation of the faults was affected partly by basement geology allowing formation of the two sub-basins.

Sedimentation during this tectonic phase led to deposition of the Aptian/Albian Otway Megasequence that is time-equivalent

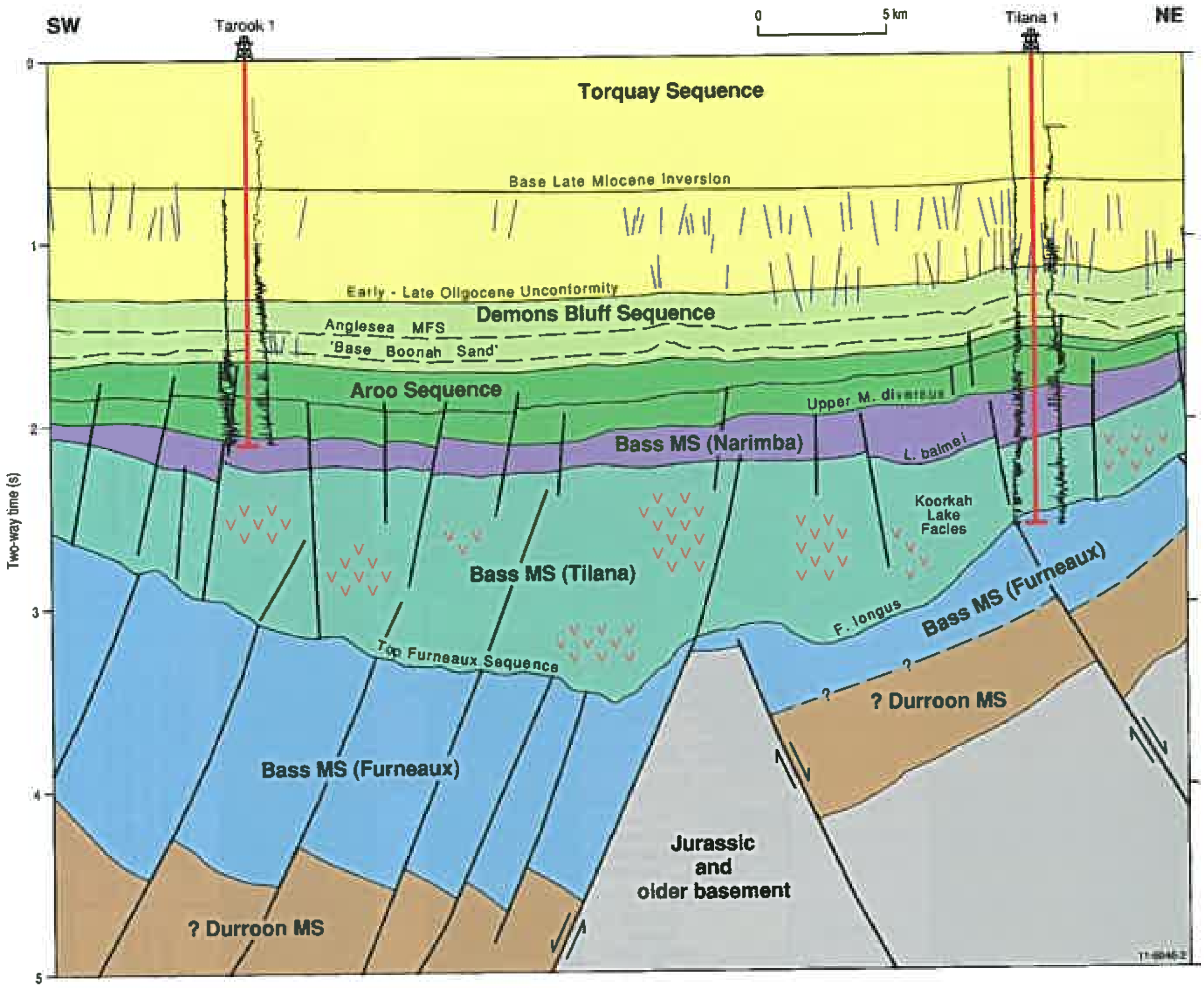


FIGURE 9.21 • Diagrammatic cross section of central Bass Basin showing the syntectonic nature of the Durroon and Bass sequences (Furneaux, Tilana and Narimba sequences), and the overlying post-rift successions of Aroo, Demons Bluff and Torquay sequences. (From Blevin 2003 with approval).

ıd lithologically similar to, the Eumeralla Formation of the ıy Basin and consists of fluvio-deltaic sandstone, minor coal volcaniclastics deposited in a fluvial channels and overbank–plain environments. It was deposited directly onto much older ment. It is best developed in the Durroon Sub-basin where it only sequence of this age to be penetrated by drilling, and m were intersected in Durroon-1. Interpretation of seismic les indicates that it also exists in the Cape Wickham Sub-. The upper boundary is an unconformity.

he second tectonic phase (Durroon Rift Phase) occurred in the Late Cretaceous (Turonian-mid-Campanian). It is d to the commencement of rifting to the east, the initiation e Tasman Sea, and affected the Durroon Sub-basin more the Cape Wickham Sub-basin. The Durroon Sub-basin underwent episodic faulting and short intervals of erosion to generate small, local unconformities. This was the last major event of the Durroon Sub-basin which then suffered only post-rift sedimentation.

Sedimentation of the Durroon Megasequence led to deposition of fluvio-deltaic to lacustrine equivalents of the Lower Eastern View Coal Measures, consisting of basal volcanics overlain by sandstone fining upwards into siltstone and shale. The drilled section in Durroon-1 consists of 374 m of sediment overlying 36 m of basalt. The megasequence has been intersected by drilling only in the Durroon Sub-basin but is likely to lie at depth in the Cape Wickham Sub-basin. The upper boundary is an unconformity.

The third and final rift phase (Bass Rift Phase) in the formation of Bass Basin took place during the latest Cretaceous-

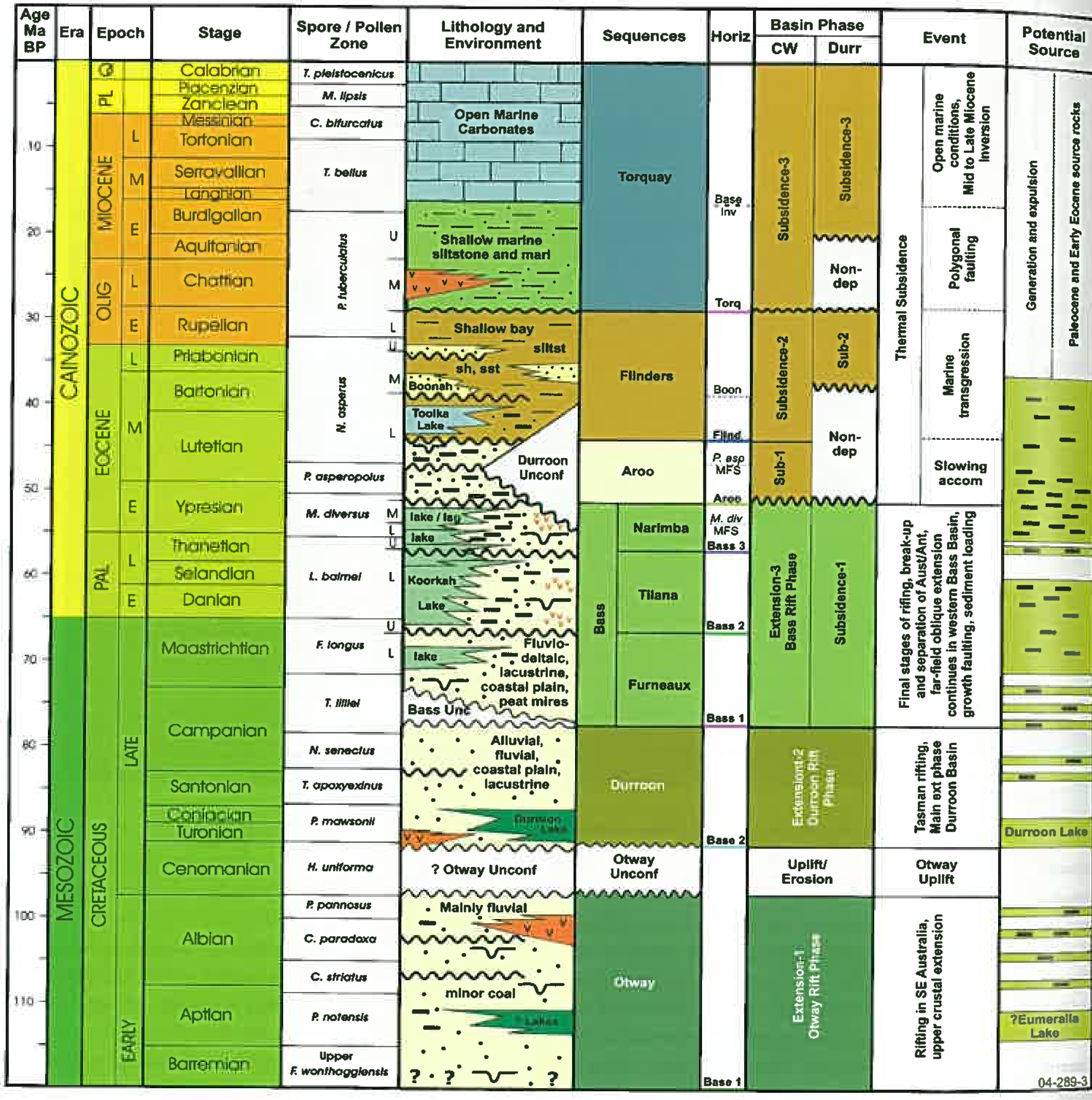


FIGURE 9.22 • Stratigraphic correlation chart for the Bass Basin showing the stratigraphic nomenclature scheme developed by Blevin (2003). (From Blevin 2003 with approval).

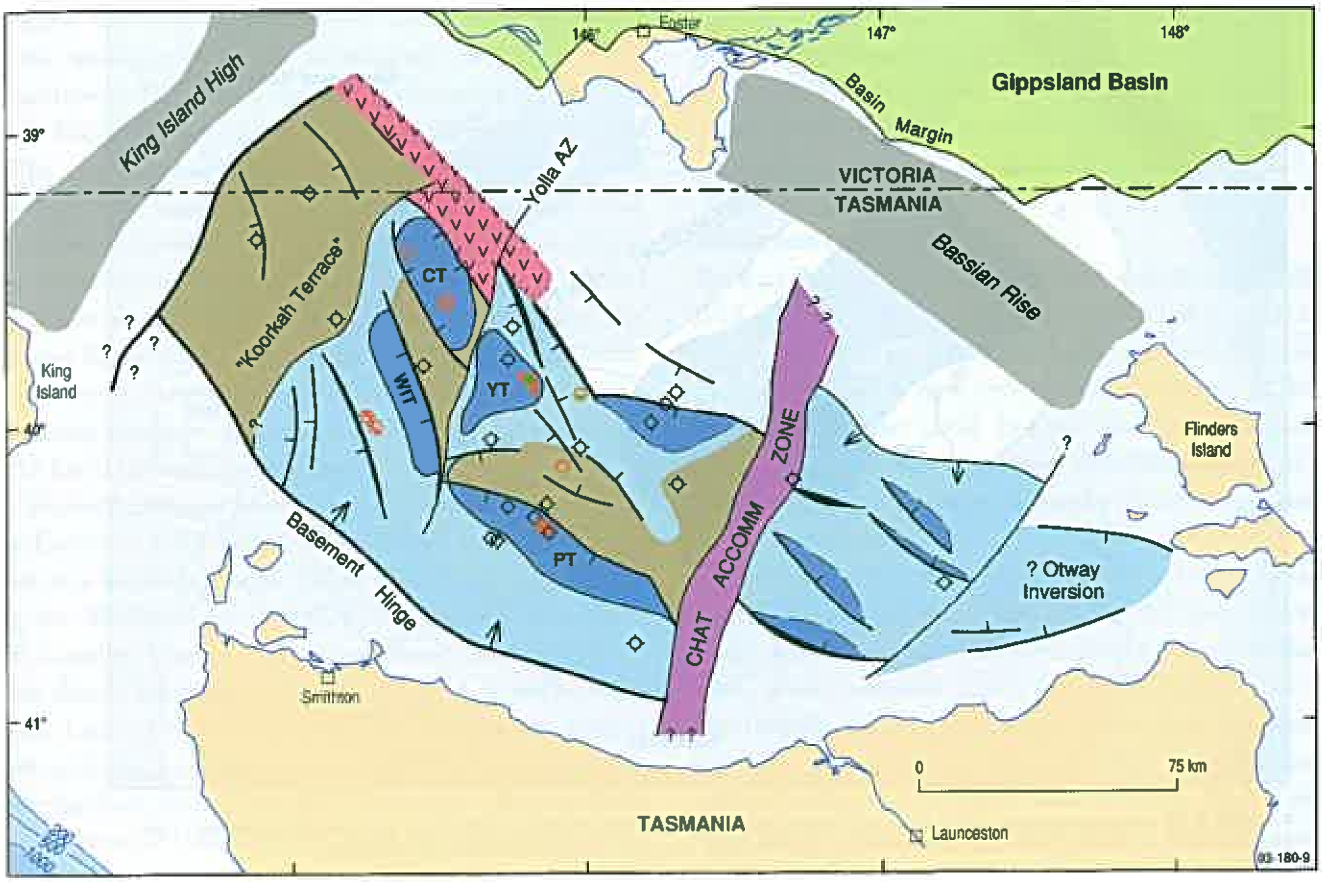


FIGURE 9.23 • Map of tectonic elements of Bass Basin and generalised fault trends. The main troughs in the Cape Wickham sub-basins are: Ct=Cormorant, YT=Yolla, WIT=White Ibis and PT=Pelican. Informal terms (Blevin 2003) include Koorkah Terrace and Yolla Accommodation Zone (YAZ).

early Palaeogene (Maastrichtian-late Early Eocene) and affected only the Cape Wickham Sub-basin. It was not a continuous simple event but consisted of a series of pulses, decreasing in intensity with time, commonly local on individual faults, and is represented by different sequences which may be local in extent. It is thus marked by local unconformities. It is associated with developments along the western margin of Tasmania while the Australo-Antarctic Gulf (McGowran 2009) evolved.

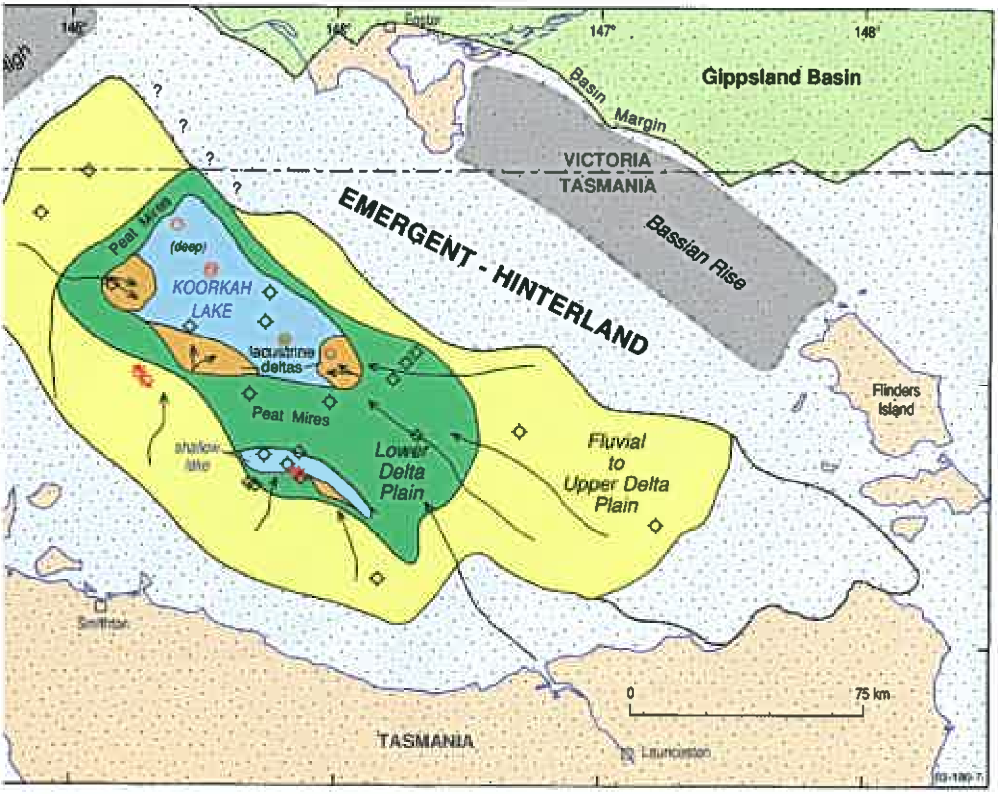
Sedimentation during the Bass Rift Phase generated the Bass Megasequence which, in turn is divided into three unconformity-bounded sequences:

- Narimba Sequence (latest Paleocene to late Early Eocene)
- Tilana Sequence (latest Maastrichtian to late Late Paleocene)
- Furneaux Sequence (mid-Campanian to latest Maastrichtian).

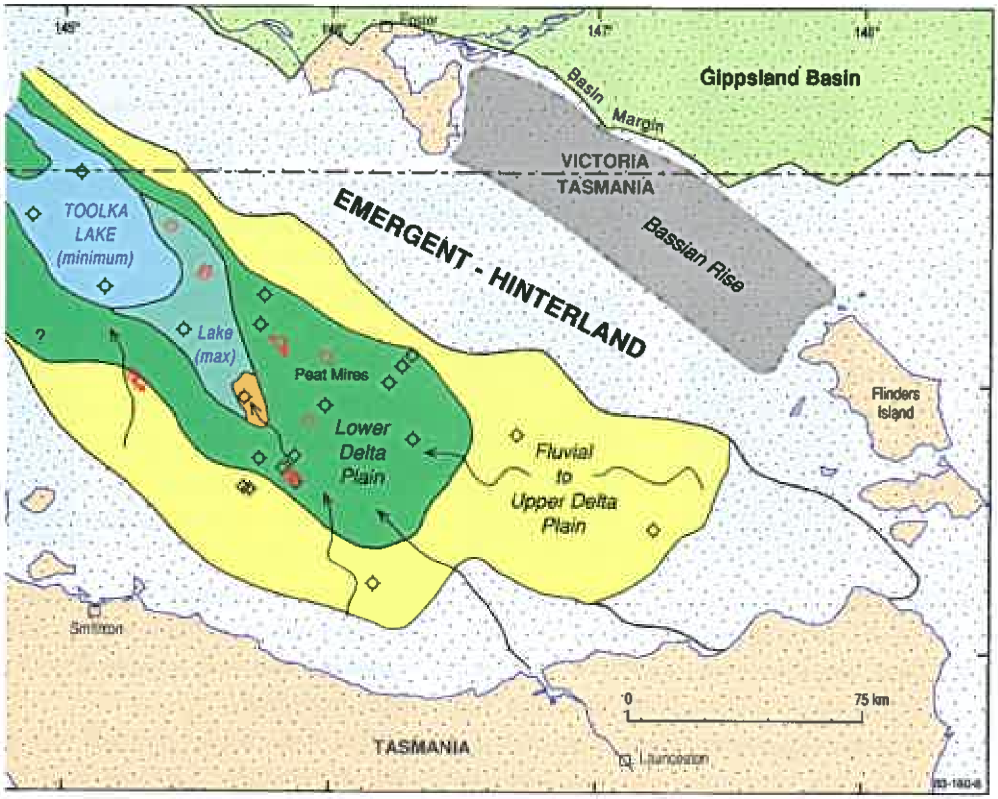
Furneaux and Tilana Sequences are time and lithology equivalents of the Middle Eastern View Coal Measures and the Narimba Sequence is equivalent to the Upper Eastern View Coal Measures. All sediments are non-marine and generally get finer with time. The Furneaux Group is of interbedded sandstone, siltstone and shale with minor coal, deposited in a fluvio-deltaic and lacustrine environment. It extends across the entire Basin and is deeply buried in the basin centre. The Tilana Sequence consists of sandstone, shale and coal laid down in a fluvio-deltaic, floodplain and lacustrine environment around Lake Koorkah (Fig. 9.24). It extends across the entire Basin but is thinner over the Durroon Sub-basin. The Narimba Sequence varies markedly in thickness (<100 to 900+ m) and consists of sandstone, shale and coal deposited in fluvio-deltaic to brackish lacustrine and lagoonal environments. Progradation geometry is developed in places. It occurs over most of the Basin. Figure 9.24 is a reconstruction of the palaeogeography during this time.

Major tectonic evolution now ceased and sedimentation changed character. Three further thin basinwide sequences were deposited, and were associated with post-tectonic subsidence or relaxation phases.

The Aroo Sequence marks the transition from rift to post-rift with subsidence an important factor. The age of the base of the unit varies a little across the basin and while some may have been deposited during the latest Paleocene, most is restricted



›geographic map showing maximum extent of Lake Koorkah (Partridge 2002; Tilana and Narimba sequences – Late ene) which was restricted to the Cape Wickham Sub-basin. (From Blevin 2003 with approval).



geographic map of Bass Strait showing maximum and minimum extents of Lake Toolka (Partridge 2002a, Aroo sequence *us* Zone – Middle-Late Eocene). Lake Toolka essentially is restricted to the Cape Wickham Sub-basin

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and early Middle Eocene. Some marine influence ening of the Basin to marginal marine conditions west. Minor fault movement continued and affected cene section, but timing and scale varied across the quence reaches a maximum thickness of some 450 varies widely but generally is of sandstone, and shale coal content than earlier, deposited in fluvio-deltaic, strine or lagoonal conditions, with some limited ence. Peat mires were well-developed around the fluvial conditions were more prominent to the south. e Eocene, the environment gradually became marine. n thickness of Cretaceous to Recent sediments is at at the main depocentre.

lers (Demons Bluff) Sequence resulted from further ne to Early Oligocene subsidence and occurs across a thickness of some 350 m of sand and marine shale. Middle Eocene, shallow Toolka Lake (Fig. 9.25) rine influence from the northwest. Its extent varied, erse lacustrine and fluvial marginal facies are well- ate in the Middle Eocene, the environment changed Toolka Lake gave way to shallow bay conditions. The s been divided into three formations—Boonah Sand, rmation and Demons Bluff Formation—separated mities. Other local unconformities and rapid facies est to low gradients across the Basin. In the west and eposition may have been continuous from the Aroo t is marked by an initial change in character to thick ls. Earlier topography was now buried and the Basin lat and relatively featureless.

phase in sedimentation in the Bass Basin is still identified as the Torquay Sequence. During the ne, sea level fell following the final separation of nd Australia and growth of the Antarctic icesheet. formation of a basinwide unconformity before a ene major sea-level rise caused incursion of marine Initially sediments were marine shale, siltstone and thickness of up to 650 m. This depositional phase een the mid-Oligocene and Middle Miocene when hanged to open marine with deposition of up to lcarenite. While basin-wide in occurrence, this unit the Cape Wickham Sub-basin than in the Durroon The early part of the Torquay Sequence extended Bass Basin proper to northern Tasmania and Bass s where it is expressed in coastal marine outcrop such Cape/Fossil Bluff, King Island, Preservation Island and uivalents elsewhere (Quilty 1972; Quilty & Seymour Miocene and perhaps Pliocene was an interval of some evelopment of anticlines caused by events as Australia collided with Asia to the north. These anticlines have been the subjects of hydrocarbon exploration.

Marine Pliocene sediments on the eastern side of Flinders Island (Sutherland & Kershaw 1971; Quilty 1985) can be considered marginal to Gippsland Basin.

Hydrocarbons in the Bass Basin

The Bass Basin is moderately explored, with 38 wells drilled since 1965. Exploration has been less successful than in the nearby Gippsland Basin, with only one field—the Yolla gas-condensate field—developed to date; production commenced in 2006. The Yolla field had an initial in-place resource of approximately 600 billion cubic feet of gas and 70 million barrels of oil and condensate. Smaller, nearby discoveries (White Ibis, Trefoil) may be developed in the future.

Coal and lacustrine shale of the Otway Group and Eastern View Coal Measures provide the main source rocks of the known hydrocarbon occurrences in the Bass Basin. The hydrocarbon reservoirs are in sands of Paleocene to Eocene age (middle and upper Eastern View Coal Measures), and sealed by intraformational lacustrine shale or by the overlying, regional sealing unit of marine shale (Demons Bluff Formation). Hydrocarbon generation has taken place in the Cormorant, Yolla and Pelican Troughs, with migration into structures (fault blocks, anticlines) within these depocentres and on the adjacent flanks (Blevin 2003; Cummings et al. 2002, 2004). A drilled Miocene/Pliocene anticline contained evidence of oil but it may be that the structure was breached during one of the local unconformities that affected high structures during the later Cenozoic. Blevin (2003) contains a detailed analysis of the hydrocarbon potential.

9.2.9 Igneous influences in the Bass Basin

P.W. Baillie and J.L. Everard

Basin development was affected at various stages by multiple episodes of igneous activity.

Most of the 38 offshore oil exploration wells drilled in Bass Basin between 1969 and 2011 intersected igneous (volcanic or intrusive) intervals. Seismic profiles indicate that many of the volcanics are fault-controlled, and that some reach the floor of Bass Strait. In several cases, associated high-amplitude seismic anomalies were misinterpreted prior to drilling as hydrocarbon indicators or carbonate reefal buildups (Trigg et al. 2003). Thermal effects associated with basalt intrusion and extrusion have locally increased hydrocarbon maturity levels. Some volcanic intervals described in well completion reports are in fact sedimentary rocks that have been strongly altered by hot magmatic fluids (Dance et al. 2004).

/ are often strongly altered and only limited
mation is available, igneous rocks are largely
ıssociated picritic cumulates, with a few strongly
mobile element ratios (e.g. Zr/Nb = 4.6–9.2; P.
.. data) lie mostly outside the HIMU range. On
ıey can be divided into three groups.

:anics

Otway Group correlatives in Bass Basin are
l were encountered by only one, possibly two,

of Durroon-1 well in the southeastern part of
-basin (Baillie & Pickering 1991) intersected
›us (Aptian) succession including volcanolithic
al to Otway Group sedimentary rocks in the
the Upper Strzelecki Group in the Gippsland
& Blevin 2003). The uniform abundance, lack
ssy volcanic fragments and wide distribution of
citic volcanic detritus through the Gippsland,
basins suggest strongly that local rift-related
: source for the rocks (Duddy 2003); however,
ed with subduction and an eastern Australian
›lex, as advocated by Bryan et al. (1997), cannot

›f the Early Cretaceous section in Durroon-1,
than 100 m thick of altered amygdaloidal
interbedded clastic sediments lies close to an
the Late Cretaceous base of the 'Eastern View
esh titaniferous augite suggests alkalic affinities
ıings & Blevin 2003). Log studies indicate that
›ccur as either two relatively thin intrusions, or
ssions (Baillie & Pickering 1991). The volcanics
smic data throughout much of the Durroon
›ear largely fault controlled (Edgerley & Taylor

:tor of the Boobyalla Sub-basin contains similar
volcaniclastic sediments, together with mid-
: and shoshonitic volcanics (Moore et al. 1984).
ntrusives and lamprophyre dykes of similar
rop out onshore in northeast Tasmania in the
ı and elsewhere (Jennings & Sutherland 1969;
rbett 1974; Moore et al. 1984; Baillie 1984;
›lume).
red near total depth (1527 m) in the Konkon-1
rn Bass Basin, include rocks described as very
olcanics (McKay 1973) but were considered
›logical analysis (T. Dance, pers. comm.).

Paleocene/Late Cretaceous volcanics

Paleocene to Late Cretaceous volcanics occur mainly in the central northeastern sector of the basin, but their full extent is unknown as many wells were not deep enough to reach this level.

Thick sequences of altered amygdaloidal basalt occur in the lower parts of the Aroo-1 (>544 m), Tilana-1 (>782 m) and Yolla-1 (>320 m) wells. In each well, overlying sediments contain a Paleocene (lower *L. balmei* Zone) microflora. Altered basalt from the Yolla-1 yielded a 54.1 Ma K/Ar minimum age (Wheeler & Kjellgren 1986), and intercalated sediments in Aroo-1 and Tilana-1 contain a Maastrichtian (*F. longus* Zone) microflora (Hodgson 1974; Cornell et al. 1986). The volcanics are usually extensively altered to calcite, chlorite, zeolites and silica minerals, but better-preserved samples from Aroo-1 are petrographically alkali olivine basalt and related picritic cumulates (Hodgson 1974).

Thinner intervals of very altered, probably Paleocene olivine basalt and associated tuff are present toward the bottom of the Bass-2 (78 m) and Yolla-2 (>81 m) (Esso 1966; Evans 1998).

The lowermost 80 m of the Chat-1 well contain olivine basalt, usually weathered, intercalated with siltstone containing a Campanian microflora (Furr 1986a). However, near total depth (3014 m), pigeonite-augite-bearing basalt has recently been radiometrically dated as middle Jurassic and is probably related to Tasmanian dolerite (Dance et al. 2004).

Late Eocene-Miocene volcanics

Late Palaeogene to Early Neogene volcanics are interpreted from seismic sections in central and western Bass Basin and have been intersected in three wells. The main centres were probably scoria cones developed on major faults. The volcanism has been dated at 18–32 Ma and was partly explosive and phreatomagmatic, as by this time marine conditions prevailed (Dance et al. 2004; Cummings & Blevin 2003).

Extrusives in Tasmanian Devil-1, underlying the latest Eocene to earliest Oligocene Demons Bluff Formation, consist of olivine, clinopyroxene, plagioclase and ilmenite, each displaying a small compositional range over several samples (Baillie & Brown 1984). The rocks are alkali olivine basalt, transitional to olivine-bearing tholeiites, and are similar to latest Eocene to earliest Oligocene (30–40 Ma) basalt occurring onshore in the Burnie-Waratah region (Baillie et al. 1987).

Tilana-1 intersected a 154 m (1242–1396 m) interval described as rhyolitic volcanics of probable Oligocene age, in the middle part of the Angahook Formation, towards the base of the Torquay Group (Cornell et al. 1986). A 68 m interval of altered Miocene pyroclastics has been described from Yolla-1, also within the Angahook Formation (Wheeler & Kjellgren 1986).

Bass-1 penetrated 169 m of tuff and agglomerate within wer Miocene marine beds and 73 m of tuff in Upper Oligocene rine beds, together with nearly 10 m of lowermost Oligocene taceous sandstone (Esso 1966). The lower Miocene horizon is own by seismic data to form a cone flanked by lava flows and fs. The structure and altered glassy volcanic material of these rizons are strongly suggestive of submarine aquagene volcanism. e rocks are composed largely of olivine basalt with vesicles and condary zeolites and carbonate, perhaps indicating palagonitised ali basalt.

gocene-Miocene intrusives

rusive bodies of Miocene age are common in the Eocene stern View Coal Measures, and some were previously erpreted as Eocene volcanics (e.g. Robinson 1974). The rusions vary in thickness from a few metres to several hundred tres and are prominent high amplitude reflectors on seismic tions.

Cormorant-1 passed through a body about 130 m thick hich has intruded into Early Eocene beds and segregated to picritic and coarse alkali gabbro phases. The picrite nsists of olivine and pyroxene, largely altered into hydrous icate phases, with late-stage biotite and amphibole, probably presenting deuteric reactions in a magnesium-rich cumulate. he gabbro contains sodic plagioclase, analcime and some otite. The intrusion is monchiquitic and probably intruded, actionated and altered within wet sediments (Esso 1973, therland et al. 1989). K-Ar dating of biotite gave an age of 2.4 Ma, relating the intrusion to Early Miocene volcanism utherland & Wellman 1986).

In Tilana-1, the Eocene succession is intruded by 212 m of kali gabbro, consisting of plagioclase and titaniferous pyroxene ith minor biotite, ilmenite and apatite. Similar but finer-grained trusions occur within Cretaceous/Paleocene volcanics in a 245 interval near the bottom of the well. Pyroxene concentrates ielded Miocene and Oligocene ages of 20.5 ± 1.0 Ma and 28.3 ± 5 Ma (Cornell et al. 1986).

A 67-m-thick body of similar dolerite or gabbro in Yolla-1 ielded a K-Ar biotite age of 23.8 ± 0.2 Ma (Wheeler & Kjellgren 986). Similar dolerite sills occur in Koorkah-1 (30 and 69 m hick; Amoco 1986) and Seal-1 (112 m and >30 m thick; Furr 986b). A dolerite sill about 70 m thick in Flinders-1 may be elated to Miocene volcanics to the southwest, which are inferred om seismic data (Migliucci & Reeve 1993).

Two thin (5 and 52 m) sill-like bodies within the Eastern View Coal Measures in Squid-1 were described as petrographically imilar to alkali olivine basalt (Baillie & Brown 1984a). Two hin igneous intrusions in Tarook-1 also are alkali olivine basalt or teschenite (R. Davy, in McKay 1972). Sidewall cuttings in the bottom 275 m of Toolka-1 were described as dominantly 'amphibolite' (probably mafic intrusives) (Isom 1974).

These intrusions were emplaced into thick piles of relatively unconsolidated sediment. Similar bodies are unknown from the Cenozoic of onshore Tasmania, where such conditions were generally absent.

9.3 CENOZOIC ONSHORE BASINS AND LANDSCAPE EVOLUTION

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9.3.1 Introduction

A number of elongate graben-type basins, typically with NW–SE trends, were developed on mainland Tasmania in the Cretaceous to early Neogene (Fig. 9.26). The basins were generally 5–10 km across, and relatively shallow (mostly <800 m sediment thickness). Basin fill consists largely of Palaeogene freshwater deposits, with a variable amount of basaltic volcanic rocks. The major basins are the Devonport-Port Sorell Sub-basin and the Tamar Graben-Longford Basin complex on the north coast, the Scottsdale and Boobyalla Sub-basins on the northeast coast, the Derwent and Coal River Graben in the south, the Macquarie Harbour Graben in the west, and the Oyster Bay Graben in the east. Thinner, more widespread Palaeogene-early Neogene terrestrial sediments extend outside the main basins, as valley fills (leads) and more extensive veneers, in many places underlying or interbedded with basalt. The sediments have been dated primarily with reference to the palynological zonal framework erected in the Bass and Gippsland Basins (Stover & Partridge 1973; Fig. 9.27). The basaltic volcanic rocks are treated in detail in Section 9.4.

There is little evidence that onshore Tasmania was affected by the late Jurassic-early Cretaceous rift phase (Stacey & Berry 2004), but apatite fission track data indicate a widespread phase of uplift and erosion in the Late Cretaceous-Paleocene (c. 100–50 Ma: O'Sullivan & Kohn 1997; Kohn et al. 2002). Faults associated with onshore basin development display a strong NNW trend, with individual faults ranging from northwest to north, both bounding the Cenozoic basins and in the surrounding terrain. Structures that terminate the basins along strike are generally less well known or understood. Although basin development in the north may be related to the development of the Bass Basin, and structures in the west to relaxation on the continental margin, the basins are of similar age in both areas and may relate to a single late Cretaceous-Palaeogene ENE–WSW tensional stress regime.

Erosional remnants of Neogene marine sediments, predominantly limestone, are found at localities up to 160 m above