ABSTRACT

The influence of Neogene tectonics in the SE Australian basins has generally been underestimated in the petroleum exploration literature. However, onshore stratigraphic and offshore seismic data indicates that significant deformation and exhumation (up to one km or more) has occurred during the late Tertiary-Quaternary. This tectonism coincides with a change in the dynamics of the Australian plate, beginning at around 12 Ma, resulting in a WNW–ESE compressional regime which has continued to the present day.

Significant late Miocene tectonism is indicated by a regional angular unconformity at around the Mio-Pliocene boundary in the onshore and nearshore successions of the SE Australian basins. Evidence of on going Pliocene-Quaternary tectonism is widespread in all of the SE Australian basins.

Late Tertiary tectonism has produced structures in the offshore SE Australian basins which have been favourable targets for petroleum accumulation (e.g. Nerita structure, Torquay Sub-basin; Cormorant structure, Bass Basin). In the offshore Gippsland Basin, most of the oil- and gas-bearing structures have grown during Oligocene-Recent time. Some Gippsland Basin structures were largely produced prior to the mid-Miocene, while others have a younger structural history. In areas of intense late Tertiary exhumation and uplift (e.g. proximal to the Otway and Strzelecki Ranges), burial/maturation models of petroleum generation may be significantly affected by Neogene uplift.

Many structures produced by late Miocene-Pliocene deformation are dry. These relatively young structures may post-date the major maturation episodes, with the post-structure history of the basins dominated by exhumation and cooling.

KEYWORDS

SE Australia, Neogene, uplift, tectonics, Miocene-Pliocene unconformity, Plio-Pleistocene barriers, Gippsland Basin, Bass Basin, Otway Basin.
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**OFFSHORE GIPPSLAND STRUCTURES**

In the offshore Gippsland Basin (Fig. 2), the late Oligocene to Recent-aged Seaspray Group overlies the hydrocarbon-bearing Latrobe Group of Cretaceous to Eocene age. Holdgate et al (2000) have divided the Seaspray Group into three major subgroups (Angler, Albacore and Hapuku subgroups) based on lithologies and wireline log characteristics, which are here used to define the timing of structural events from seismic data. The Angler Subgroup represents strata from the top of the Latrobe Group to the base of the major submarine canyoning episode that began in the mid Miocene (Zonules D2/D1 of Taylor, 1966). Mid to late Miocene canyon-dominated sediments are referred to as the Albacore Subgroup and the Hapuku Subgroup encompasses all Pliocene to Recent deposits.
Two main structural styles are expressed in the Seaspray Group: 1) reactivation and inversion of basin-margin normal faults with associated high amplitude hanging wall anticlines; and 2) broad low-relief anticlines in the Central Deep reflecting reactivation of deep fault blocks.

The principal basin margin faults that affect Seaspray Group sediments are the offshore extensions of the Rosedale Fault System/Monocline (including the Wellington Fault) and the Foster Fault System. The Rosedale and Foster Fault Systems trend roughly East-West dividing the Northern Platform and Southern Platform from the Central Deep respectively (Fig. 1). Both systems are expressed as a series of en-echelon normal faults that are in parts reactivated and reversed. Around Wahoo–1, the Rosedale Fault System is reversed offsetting sediments of the Seaspray Group. The stratigraphic similarity in the thickness of the Top of Latrobe to mid-Miocene succession across the fault indicates compression and faulting occurred post-mid Miocene (Fig. 3). The Top of Latrobe surface is offset by up to 600 ms of TWT. Similar relationships can be seen on the Foster Fault system to the south.

The second and economically most important group of structures are the broad anticlines of the Central Deep which host the majority of the producing oil and gas fields. Most Top-of-Latrobe structures are also expressed as large-scale anticlines in the Seaspray Group. The timing of structural development can, therefore, be examined using stratigraphic relationships within this. The Barracouta, Seahorse, Turrum-Morwong, Flying Fish and Tarwhine fields are used here to illustrate the general structural history of the Central Deep.

In the Barracouta-field (Fig. 4), a broad northeast trending anticline has folded Pliocene sediments. Onlap of early Miocene reflectors onto the anticline shows the presence of this structure in the Oligocene-early Miocene. Sediments of Miocene age show erosion and truncation due to submarine canyoning. However, the continued growth of this structure into the Pliocene is clearly evident from the onlap, stratigraphic thinning and folding higher in the section.

A similar history of structural growth can be seen around Seahorse–1 (Fig. 4). At Seahorse, reactivation and inversion has resulted in offset of the Oligocene-early Miocene sediments. The thicker sequence of strata to the north of the fault indicates an Oligocene-early Miocene age for this fault. An anticline persists upwards into the mid-Miocene of the Seaspray Group, indicating a small amount of younger movement on this structure. A comparable structural history is apparent at Flying-Fish–1 (Fig. 5). Within the Flying-Fish structure, onlap of reflectors onto the anticline indicates deformation was initiated prior to the early Miocene. Continued growth of
this structure well into the Pliocene is evident from the presence of onlapping reflectors, stratigraphic thinning and folding higher in the section.

Figure 6 illustrates extensive pre-Seaspray Group erosion of the Latrobe Group. The onlap of Seaspray Group reflectors onto the Latrobe surface is evidence of pre-existing relief on this Top of Latrobe surface. To the northwest of Turrum–1, reflectors can be seen onlapping an anticlinal structure within the early Miocene. This indicates deformation occurred during Oligocene-early Miocene time. There is little or no folding present in the late Miocene to Pliocene section, indicating that the growth of the anticline had ended by this time.

A shallow seismic line across the Tarwhine-field (Fig. 2) displays folded Pliocene-Quaternary sediments with erosion of the structure at the sea floor (Fig. 7). This indicates deformation on the Tarwhine structure into the Pliocene. Elsewhere on shallow seismic profiles, anticlinal structures can be seen persisting to the present sea floor, indicating continued deformation into the Quaternary.

Brown (1986) documented a similar extended history for other structures in the Gippsland Basin, and suggested deformation episodes occurred within the Eocene and Oligocene-early Miocene and continued into the Pliocene. Furthermore, Brown (1986) suggested that one of the most intensive and regionally extreme deformation events occurred at about 13 Ma (mid-Miocene, within the D1 and D2 Taylor zonules) and cited Kingfish as a good example of mid-Miocene deformation.

It is possible that Brown (1986) over-emphasised the significance of mid-Miocene deformation in the Gippsland Basin. The mid-Miocene (D1 and D2 zonules) is a period of major canyon development (Holdgate et al, 2000). This canyoning event itself may have led Brown (1986) to the conclusion that a tectonic event occurred in the mid-Miocene, i.e. tectonic uplift caused subaerial or submarine erosion. However, evolution of the canyon system is complex and dependent on other variables such as climate, eustasy, ocean circulation and sedimentological processes (e.g. slope stability). Significantly, no major correlative unconformities of mid-Miocene age exist in the onshore...
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Figure 5. Seismic line G92A-3070 in the vicinity of Flying-Fish–1, offshore Gippsland Basin. Early Miocene sediments onlap (blue arrows) the Flying-Fish structure, indicating deformation within the Oligocene-early Miocene. Continued deformation into the Plio-Pleistocene is also evident higher in the section.

Figure 6. Seismic line G92A-3053 from Turrum–1 to Grunter–1, offshore Gippsland Basin. To the northwest of Turrum–1, early Miocene reflectors can be seen onlapping an anticlinal structure within the basal Seaspray Group, indicating deformation occurred during Oligocene-early Miocene time.

Another complicating factor in determining the structural history of the mid-Miocene is the very complex stratigraphic geometry of the canyon facies. Mounded and lobe-shaped geometry, like those above the Kingfish field, can be the result of canyon migration and are unrelated to deformation (Holdgate et al., 2000). Velocity pull-ups below the canyon facies can also complicate structural interpretations.

In some clay-rich sections of the Seaspray Group, numerous closely spaced (0.5–1 km) faults with small normal offsets are common. These faults are stratigraphically controlled and do not penetrate underlying and overlying units of the Seaspray Group. Similar faults have been described from elsewhere (e.g. North Sea) and have been interpreted as compactional faults caused by the dewatering of mud-rich lithologies (Lonergan and Cartwright, 1999). We, therefore, suggest that these stratigraphically controlled fault sets in the Seaspray Group are unrelated to tectonic deformation.

LATE MIOCENE STRUCTURES AND DEFORMATION

The boundary between Miocene and Pliocene aged sediments in SE Australia is almost invariably marked by a major unconformity, often of an angular nature with phosphatic clasts, in onshore and nearshore sections (Fig. 8). This Mio-Pliocene unconformity is present in the Murray, Otway, Torquay, Port Phillip, Gippsland (Fig. 9) and Bass portions of the basin (Holdgate and Gallagher, 1997).

In some clay-rich sections of the Seaspray Group, numerous closely spaced (0.5–1 km) faults with small normal offsets are common. These faults are stratigraphically controlled and do not penetrate underlying and overlying units of the Seaspray Group. Similar faults have been described from elsewhere (e.g. North Sea) and have been interpreted as compactional faults caused by the dewatering of mud-rich lithologies (Lonergan and Cartwright, 1999). We, therefore, suggest that these stratigraphically controlled fault sets in the Seaspray Group are unrelated to tectonic deformation.
Basins. The boundary marks not only a significant break in the stratigraphic record, but also represents a change in the style of Neogene sedimentation from Miocene pure cool water carbonates to Pliocene mixed clastic-carbonate sediments. This same relationship can also be seen in the St Vincent Basin of South Australia, which occurs adjacent to the Mt Lofty Ranges (Tokarev et al, 1998).

Constraints on the timing and origin of this unconformity can be determined from a number of stratigraphic sections across the onshore portions of the Otway, Port Phillip and Gippsland Basins. Because of the extensive erosion at the unconformity, most of the pre-unconformity sediments are mid-Miocene or older (e.g. Batesford, Beaumaris, Dartmoor, Shelford). The onset of regional regression is best constrained where the youngest Miocene sediments outcrop at Portland and Hamilton in the Otway Basin. Foraminiferal biostratigraphy indicates a late Miocene (N16) age at both locations. This is supported by $\text{Sr}^{87}/\text{Sr}^{86}$ marine carbonate dating at Hamilton where pre-unconformity sediments have an age of 10 Ma (Dickinson et al, in press) (Fig. 9).

Sediments overlying the unconformity have relatively poorly constrained ages because of a lack of diagnostic planktonic foraminifera, but have generally been assigned a Pliocene age (Singleton, 1941). Strontium isotope dates indicate an early Pliocene (5 Ma) age for sections at Hamilton and Beaumaris (Dickinson et al, in press) (Fig. 9). Shallow marine sediments of early Pliocene age appear to overlie the unconformity at most localities across the SE Australian Basins (e.g. Moorabool Viaduct Formation and Hanson Plain Sand, Otway Basin; Loxton-Parilla Sands, Murray Basin and Jemmys Point Formation, Gippsland Basin).

Similar age relationships are present across the SE Australian basins (Fig. 9), indicating that regression and erosion commenced during the late Miocene (8–9 Ma), with completion of the episode by the Pliocene (~5 Ma).

**Torquay Sub-basin**

The Torquay sub-basin extends offshore from the Port Phillip Basin to the east of the Otway Ranges (Fig. 10). Shallow seismic profiles taken offshore from the Otway Ranges (Fig. 11) show the presence of a very prominent near-surface angular unconformity. Correlation from the nearby wells Nerita–1 and Nepean–29 indicates the unconformity is of late Miocene to early Pliocene age. The underlying strata are equivalent to the carbonate-rich Torquay Group, with an age range from Late Oligocene to late Miocene (Trupp et al, 1994).

From the shallow seismic sections (Fig. 11) it is evident that the late Miocene Torquay Group and underlying succession were folded and faulted prior to Pliocene deposition. On industry seismic profiles, similar relationships can be observed (Fig. 12). Reverse faults present in the underlying Cretaceous Otway Group and Paleozoic basement generally grade into monoclinal structures in the Torquay Group sediments. Folding and faulting affects the entire Torquay Group section up to the late Miocene.

On the Nerita–1 structure (Fig. 12), up to 400 m of Miocene section is interpreted to have been eroded and outcropping sediments at the sea floor are of early Miocene age (Shell, 1967). It also appears that the Nerita–1 structure is almost entirely due to late Miocene deformation, with no evidence of stratigraphic thinning or onlap through the section. There is also no thinning of the
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Torquay Group towards the Otway Ranges or the Mornington Peninsula visible on seismic, suggesting that a large thickness of Torquay Group has been stripped from these structural highs. Near the Otway Ranges coastline, the entire Torquay Group and the underlying Angahook and Boonah formations have been eroded, indicating approximately (greater than) 600 m of erosion (Fig. 13).

The nature and timing of the structural deformation as it appears in the Torquay Sub-basin seismic data indicates that most of the deformation and erosion occurred during the late Miocene. However, some folding of the Miocene-Pliocene unconformity is evident from these structural highs. Near the Otway Ranges coastline, the entire Torquay Group and the underlying Angahook and Boonah formations have been eroded, indicating approximately (greater than) 600 m of erosion (Fig. 13).

A burial history model for Anglesea–1 (Fig.14) indicates that Late Neogene uplift and erosion is the most significant inversion event since the Cretaceous uplift. Failure to incorporate Miocene burial and subsequent exhumation into the maturation model would have little effect on the Cretaceous section, but would significantly alter the predicted maturity values for the Eocene section.

Bass Basin

Evidence of young deformation is also present in the Bass Basin. Here, late Miocene deformation has occurred in the northern region as a result of uplift along the offshore extension of the Mornington Peninsula High in conjunction with compression from the Strzelecki Ranges (Smith, 1986).

An angular unconformity between the Miocene and Pliocene succession in the Bass Basin has been identified from seismic sections (e.g. east side of King Island, seismic line 33, Jones and Holdgate, 1980). A number of Bass Basin structures display evidence of late Miocene – Pliocene deformation (e.g. Cormorant–1, Konkon–1, Pipipa–1 and Bass–2). In fact the doming of the Cormorant Trough, and formation of the gas-bearing Cormorant structure appears to be largely due to late Miocene deformation (Smith, 1986).

Onshore Gippsland Basin

Much of the onshore Gippsland Basin is characterised by a thick succession of Eocene-Miocene brown coals. These non-marine deposits are lateral equivalents of the offshore Oligo-Miocene cool-water carbonate (Seaspray Group) sequence. Non-marine gravels of the Pliocene Haunted Hill Formation and marine sandy marls of the Jemmys Point Formation (Fig. 9) unconformably overlie both. The angular nature of the
Mio-Pliocene unconformity in the onshore Gippsland Basin can be seen in cross sections from coal bores (Figs 15 and 16). Folding within the Eocene-Miocene coal measures indicates post coal-measure deformation. Since the Pliocene sediments that overlie the unconformity are undeformed, deformation and erosion must be of Mio-Pliocene age.

Palynological data suggests the youngest age for the coal measures to be within the *Cingulolatisporites bifurcatus* Zone (Fig. 9) (Dawson, 1983). This indicates that deformation and erosion can be no older than late Miocene. Deformation of the Tertiary coal measures appears to be related to uplift of the surrounding ranges. Increased erosion of coal seams occurs towards the
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Figure 12. Seismic line OS88A-12 across the Torquay Sub-basin and corresponding interpreted and depth converted line. Folded Miocene Torquay Group sediments are overlain by a veneer of Pliocene. Bedding has been projected above the sea floor to indicate the amount of eroded section (400 m or more at Nerita-1). V.E. = x14.4. (Modified from Dickinson et al, in press)

Strzelecki Ranges (Fig. 15) and Eastern Highlands. Areas of maximum uplift have been largely stripped of their Tertiary cover, and this stripping may exceed 200 m in places (e.g. Loy Yang Dome, Fig. 16), with dips within the coal measures exceeding 45 degrees.

The majority of structures expressing compressional deformation in the onshore Gippsland Basin tend to strike NE. These structures, some bounded by reverse faults, others defined by Tertiary drape over monocline warping, all formed after late Miocene coal measure deposition.

Uplift and exhumation of lower cretaceous highlands

The present limit of Tertiary sediments across the Otway, Port Phillip and Gippsland Basins is partly defined by blocks of Lower Cretaceous sediment (Mornington Peninsula, Otway and Strzelecki ranges) which form structural highs bounded by reverse faults (Fig. 1). The timing of uplift for these highlands has been debated for over a century (Krause, 1874).

The highlands themselves are composed of feldspathic sandstones, mudstones and shale, and yet the Oligo-Miocene successions that flank them show no siliciclastic influence to their makeup. Clean carbonate-rich marine strata and non-marine brown coal deposits dominate the sediments surrounding the highlands. If the Cretaceous highlands had been present during the Oligo-Miocene, feldspathic material would have constituted a significant portion of the basin fill. Clastic sediments do not reappear regionally in the basin until the Pliocene, where mixed clastic-carbonate deposition dominates. From this observation, it would appear that the Cretaceous blocks had not been uplifted and exposed to significant erosion until the end of the Miocene.

Offshore seismic sections and onshore well constructions provide insights into the relationship between the Cretaceous Blocks and the surrounding Tertiary sediments. Seismic profiles in the Torquay sub-Basin suggest little or no stratigraphic thinning or onlap of the Oligo-Miocene Torquay Group towards the Otway Ranges (Figs 12 and 13). This suggests the Otway Ranges had a relatively low relief during the Oligo-Miocene and consequently, that uplift of the ranges was post Mid-late Miocene. In the onshore Gippsland Basin, a similar relationship exists between the Latrobe Valley coal measures and the neighbouring Strzelecki Ranges and Eastern Highlands. Once again, there is little or no stratigraphic thinning of Oligo-Miocene coal measures towards the Strzelecki Ranges (Fig. 15).

Deformation and erosion of Oligo-Miocene successions appears to be most intense in regions adjacent to the uplifted Cretaceous blocks (e.g. Latrobe Valley and Torquay sub-Basin). On seismic profile OS88A-1 (Fig. 13) from the Torquay Sub-basin, the entire Tertiary section appears to
have been stripped from the Otway Ranges, amounting to around 600 m or more of late Neogene uplift and erosion. Cooper and Hill (1997) similarly suggest around 1 km of Miocene-Pliocene erosion around the Otway Ranges.

### PLIO-PLEISTOCENE TECTONICS

The presence of a widespread angular unconformity at the Miocene-Pliocene boundary indicates that a major tectonic episode occurred during the late Miocene in the SE Australian basins. There is also abundant evidence that tectonism continued into the Pliocene-Quaternary. The most definitive evidence comes from deformation and uplift of Plio-Pleistocene near-shore sands in the onshore Murray and Otway basins.

In the Murray Basin, the Loxton-Parilla Sands cover more than half the basin and consist of regressive shoreface, beach, dune and back-barrier-lagoonal sediments (Roy et al, 2000). The topographic expression of this unit is a series of crescent-shaped ridges which are interpreted to represent the position of successive shorelines (Brown and Stephenson, 1991). The Loxton-Parilla Sands are considered to range in age from 6–2 Ma becoming younger to the southwest as the shoreline prograded across the Murray Basin (Brown and Stephenson, 1991). These Pliocene sands are also host to economic deposits of heavy minerals such as rutile, zircon and ilmenite.

The surface expression of Plio-Pleistocene faulting of the Loxton-Parilla Sands is very obvious on digital elevation models. The Danyo fault (Fig. 17) is a NE oriented structure that displaces the Pliocene shoreline ridges by up to 80 m, indicating that it formed after 6–5 Ma. The fault appears to have had an influence on the shoreline of Lake Bungunnia, suggesting that it was in existence by around 2.5 Ma. The formation of Lake Bungunnia itself appears to have been caused by uplift of the Pinnaroo Block and Padthaway Ridge, which resulted in tectonic damming of the Murray River (Gill, 1973). Other structures like the Cadell fault near Echuca and the Morgan fault in South Australia have similarly young origins. On the Dundas Tablelands in western Victoria, the Loxton-Parilla Sands are at an elevation of 300 m, again indicating significant and extensive Plio-Pleistocene uplift.

In the eastern Otway Basin, to the west of the Otway Ranges, a dissected plain known as the Timboon Surface is underlain by the Pliocene Hanson Plain Sands (Tickell et al, 1992). The Hanson Plain Sands overlie the early Miocene Gellibrand Marl, the contact being an angular unconformity (Fig. 8). Erosional dissection of the Timboon Surface has produced a series of alternating ridges and swales that run from Simpson north to Colac orientated in a northwesterly direction (Fig. 18). Although thought to
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reflect incipient slump faulting (Sprigg, 1986) or underlying structural features (Tickell et al., 1992), they are clearly strandline features. Their crescent-shaped geometry, together with the near-shore marine facies (at the type section of the Hanson Plain Sands near Simpson, Fig. 8) indicates this Pliocene unit is a regressive barrier system, similar to the Loxton-Parilla Sands of the Murray Basin.

The ridges are absent from the Otway Ranges, but do extend to the Ferguson Hill region. The geometry of the ridges as they approach the Otway Ranges indicates the presence of a topographic high or coastal headland (Fig. 18). The Otway Ranges were, therefore, in existence by the Pliocene. The Timboon Surface itself has a series of folds and fault scarps that have a northeasterly orientation (Fig. 18). The Simpson and Ferguson Hill Anticlinales are examples of such northeasterly structures. Since these structural features affect the Hanson Plain Sand and Timboon Surface, the deformation must be of Plio-Pleistocene age. The Ferguson Hill Anticline has an elevation of 220 m indicating extensive young uplift in this region.

**ORIGIN OF NEOGENE DEFORMATION**

The Australian continent is currently under a compressional stress regime. The origin of the stress field is apparently related to pressure at the boundary between the Australian and Pacific plates along the New Zealand, Papua New Guinea and Himalayan collisional boundaries and attributed to the associated changes in relative plate motion and forces (Coblentz et al., 1995). This has resulted in an E–W to WNW–ESE orientated stress field in SE Australia, whilst northern Australia has a N–S orientation (Tokarev et al., 1998). Neogene deformation in the SE Australian basins, initiated in the late Miocene, is consistent with this present day stress regime.

The initiation of the stress in SE Australia during the Neogene appears to correlate with compressional tectonism on the Australia-Pacific plate boundary through New Zealand (Fig. 19). Strike-slip movement during the late Oligocene at about 25 Ma dominated the initial movement along the boundary. A compressive force did not become active until 12 Ma, which initiated the uplift of the Southern Alps. Rapid uplift of the Southern Alps

![Figure 14](image-url) Burial history diagram for Anglesea–1 (modified from Cooper and Hill, 1997). Mio-Pliocene uplift and erosion have a significant effect on the maturation history for the Tertiary sequence.

![Figure 15](image-url) Cross section across the Alberton coal field (modified from Holdgate, 1982). Oligo-Miocene brown coal measures have been deformed and eroded prior to deposition of the early Pliocene Jemmys Point Formation. V.E. = x14.2.
began ~ 6–5 Ma as a dramatic increase in convergence occurred across the plate boundary, continuing through to the Quaternary (Walcott, 1998). A similar timing to the initiation of convergence across the Australia-Pacific plate boundary can be seen to the north, with the uplift of northern Papua New Guinea at 12–10 Ma (Hill and Raza, 1999).

**TECTONICS VERSUS EUSTACY**

The unconformity between Miocene and Pliocene sediments in the SE Australian basins has often been interpreted as being due to a global regression in the late Miocene (e.g. Carter, 1978; Roy et al., 2000). The sea level curve of Haq et al. (1988) shows a long period of relatively low sea levels in the late Miocene. However, there is unequivocal evidence for deformation of Miocene strata prior to the deposition of early Pliocene sediments at many localities in the SE Australian basins (e.g. Figs 8, 11, 12, 15 and 16). Furthermore, there is equally unequivocal evidence for widespread tectonism continuing into the Plio-Pleistocene (e.g. Figs 17 and 18). Therefore, in the SE Australian basins, a significant deformation episode unarguably occurred during the late Miocene and continued into the Quaternary (Fig. 19).

However, eustatic events probably did play a large role in the development of the Mio-Pliocene unconformity in the SE Australian basins. The transgression that is responsible for the deposition of earliest Pliocene sediments across the SE Australian basins is almost certainly of eustatic origin. It appears unlikely that such a rapid and synchronous flooding of the region could be the result of tectonic subsidence following a compressional event. The deepsea stable isotope record also indicates warm (and possibly ice-free) early Pliocene conditions (Shackleton et al., 1995).

The early Pliocene transgression was probably responsible for much of the erosion which occurred at the Mio-Pliocene unconformity. Marine erosion and phosphatisation are widespread at this unconformity. It also seems likely that the Plio-Pleistocene regression which followed the early Pliocene transgression was of eustatic origin, as it occurs in all of the SE Australian basins and coincides with a period of global cooling (Shackleton et al., 1995). In this sense, the Mio-Pliocene unconformity may be a result of a major eustatic transgressive-regressive cycle being superimposed on a longer-lived period of tectonism in SE Australia. Without the early Pliocene transgression (of probable eustatic origin), there would be no angular unconformity and no stratigraphic record of late Miocene tectonism.
CONCLUSIONS

In the offshore Gippsland Basin, Neogene tectonism has had a profound influence on the distribution of oil and gas bearing structures. Many of the major traps are a direct result of Neogene compressional deformation. In the Central Deep, post-Latrobe Group deformation commonly began in the late Oligocene-early Miocene and continued to the present day. However, there are significant differences in the timing of structural development between fields. In the Turrum field for example, early (Oligocene-early Miocene) deformation appears to dominate, with very little evidence for post-mid-Miocene deformation. However, in other fields (e.g. Barracouta

Figure 17. Digital elevation model (DNRE, 1999) of the Mildura-Ouyen region in the Murray Basin (see Fig. 1 for location). Interpreted image illustrates the arcuate strandline features of the Pliocene Loxton-Parilla Sands, offset by the Danyo Fault. The low-lying (dark blue) areas on the digital elevation model correspond to the position of the former Lake Bungunnia. These relationships constrain the age of faulting to be between ~6 and 2.5 Ma.

Figure 18. Digital elevation model (DNRE, 1999) of the Simpson-Colac region, west of the Otway Ranges in the Otway Basin (see Fig. 10 for location). Interpreted image illustrates strandline features of the Pliocene Hanson Plain Sand. Around Simpson, the strandline features have been exaggerated by erosional dissection. The Ferguson Hill and Simpson Anticlines are superimposed on the Hanson Plain strandline features, indicating considerable Plio-Pleistocene deformation and uplift.
and Flying Fish), deformation has continued from the Oligocene to the present day. The faults which border the Northern and Southern Platforms display evidence of post-mid-Miocene reverse movement. Likewise, in the Bass Basin late Miocene inversion has produced gas-bearing structures (e.g. Cormorant).

In the onshore portions of the Otway, Port Phillip, Torquay and Gippsland Basins, there is unequivocal evidence for a strong late Miocene pulse of tectonism which continued into the Plio-Pleistocene. The areas of most intense structural development appear to be around the Otway Ranges, Mornington Peninsula and Strzelecki Ranges. In these areas, uplift and erosion may have been on the order of 1 km. Large structures like Nerita (in the Torquay Sub-basin) are a result of late Miocene-Pliocene deformation, with some 400 m or more of section being removed from the crest of the structure. Many of the structures produced by late Miocene-Pliocene deformation have been dry. This may be because the structures postdate the major maturation/burial episodes, with uplift and exhumation dominating the post-structure history of the basins.

The timing of Neogene tectonism in SE Australia correlates with the initiation of compressional stress across the Australia-Pacific plate boundary, at 12–5 Ma. This change in plate dynamics is arguably the cause of deformation evident across SE Australia during the late Miocene to Quaternary. However, preservation of the tectonic episode is probably the result of a major eustatic transgressive-regressive cycle causing erosion of the Miocene strata and subsequent deposition through the Plio-Pleistocene.

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Authors’ biographies over page.
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