Prospectivity of the Cook Strait region

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Abstract

Cook Strait lies between the North and South Islands of New Zealand. In 2000 Tyers Petroleum obtained a grid of over 260 km of 12 fold seismic that provides new data on Cook Strait's westerly Wairau Basin. Three horizons were correlated around the new seismic grid. Due to an absence of direct well control within the region, the seismic stratigraphy is based on outcrops in the adjacent onshore and previous interpretations. A "Green Horizon" is interpreted to be most likely Top Pliocene in age. A "Brown Horizon" is either the top of the Miocene or Middle Miocene whereas the "Purple Horizon" is either Middle or Early Miocene. The Wairau Fault, identified on the adjacent South Island, continues in a sinuous east-northeast direction in the offshore and defines a significant tensional zone across which the northwest margin of the Wairau Basin is downfaulted. Likewise the Awatere Fault can be interpreted in the offshore, indicating the Wairau Basin is dissected by offshore extensions of the Wairau, Awatere and Clarence Faults. Overall the Wairau Basin structural style is one dominated by normal, tensional, structuring. Steep structural gradients on opposing North and South Island margins indicate a significant north-northwest to northwest component of structural control in the regions Neogene development, however, onshore continuation of these trends are not conspicuous, presumably because of their truncation by the Wairau Fault.

Based on the current interpretation four distinct petroleum plays are recognised:

- broad regional, compressional folds within the basin depocentre
- pinchout and unconformity traps at the Mid-Miocene level across the Marlborough Shelf
- tensional fault block plays along the lower Marlborough Shelf
- antithetic fault blocks associated with offshore extensions of the Awatere Fault
- antithetic fault block and associated rollovers into offshore extension of the Wairau Fault.

Gravity modelling in the onshore part of the adjacent Southern Wairarapa also suggests structural highs that could be charged by hydrocarbon migration from the deeper offshore part of the basin in the Palliser Bay area.

Introduction

Cook Strait was the subject of several petroleum company seismic surveys in the early 1970s (Figure 1). They include Magellan (1970) 6-fold stack (lines CSP-1, 2, 3, 4 & 5); and 12-fold stack (lines CSC-1, 3, 4, 5 & 6); Mobil (1972) 3-fold on-board stack (lines 72-001 and 72-118); and 3-fold stack (lines 72-117, 72-174); and Gulf (1973) on-board stack (fold unknown) (lines NZ-65, 66, 67, 68, 69, 70 and 113); and 24-fold stack (lines NZ-71, 72 and 73).

In 1994, GNS acquired a 15-fold migrated stack line OGC-102 across the southern side of Cook Strait out into the Pacific Basin subsequently reprocessed to better image the upper section for Tyers Petroleum in 2000. In 1998 a mainly 12-fold NIWA deeper-seismic acquisition was shot over the western part of Cook Strait (Figure 1). Some 258.6 km of this data was processed to mainly 24-fold for CVL/Tyers and provides new data on the Wairau Basin. However the deep subsurface geology still remains to be better imaged, and seismic interpretations lack meaningful ties with well and outcrop data.

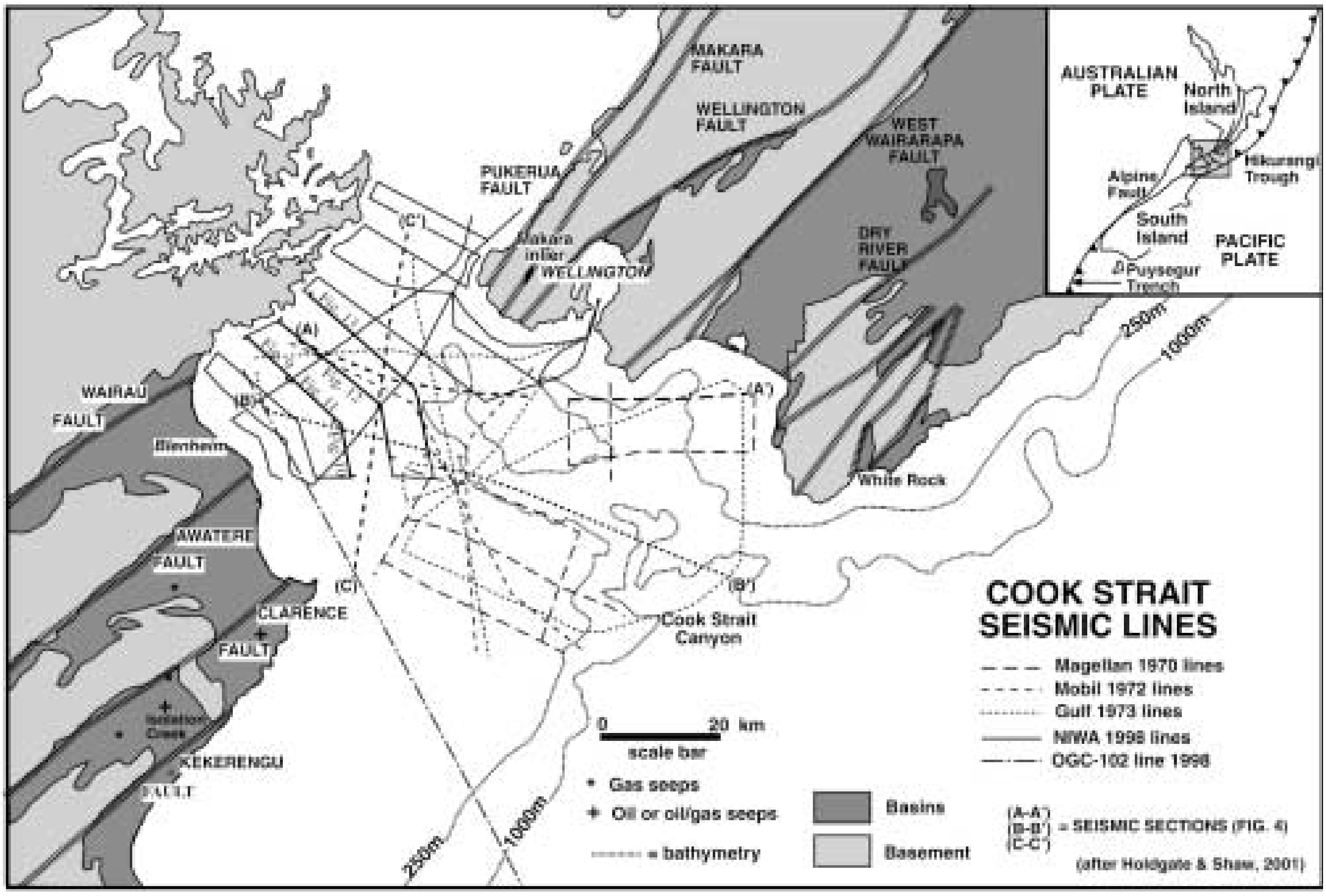


Figure 1: Location map for Cook Strait seismic lines, and structures and prospects defined by Field & Uruski (1997), main onshore faults, and basement blocks. Inset shows relationship of the Cook Strait area to the plate tectonic setting of New Zealand (modified from Holdgate & Shaw, 2001).

No petroleum wells have been drilled in the Cook Strait area. The nearest petroleum well is Titihaoa-1, located offshore Castlepoint in the East Coast Basin. Interpretations of offshore seismic has defined a number of folds and faults, indicating the Cook Strait basins were affected by open folding. The recent surveys indicate some prospective younger structures, and an extensive regional seal over much of the area.

Previous work on stratigraphy and structure of Cook Strait

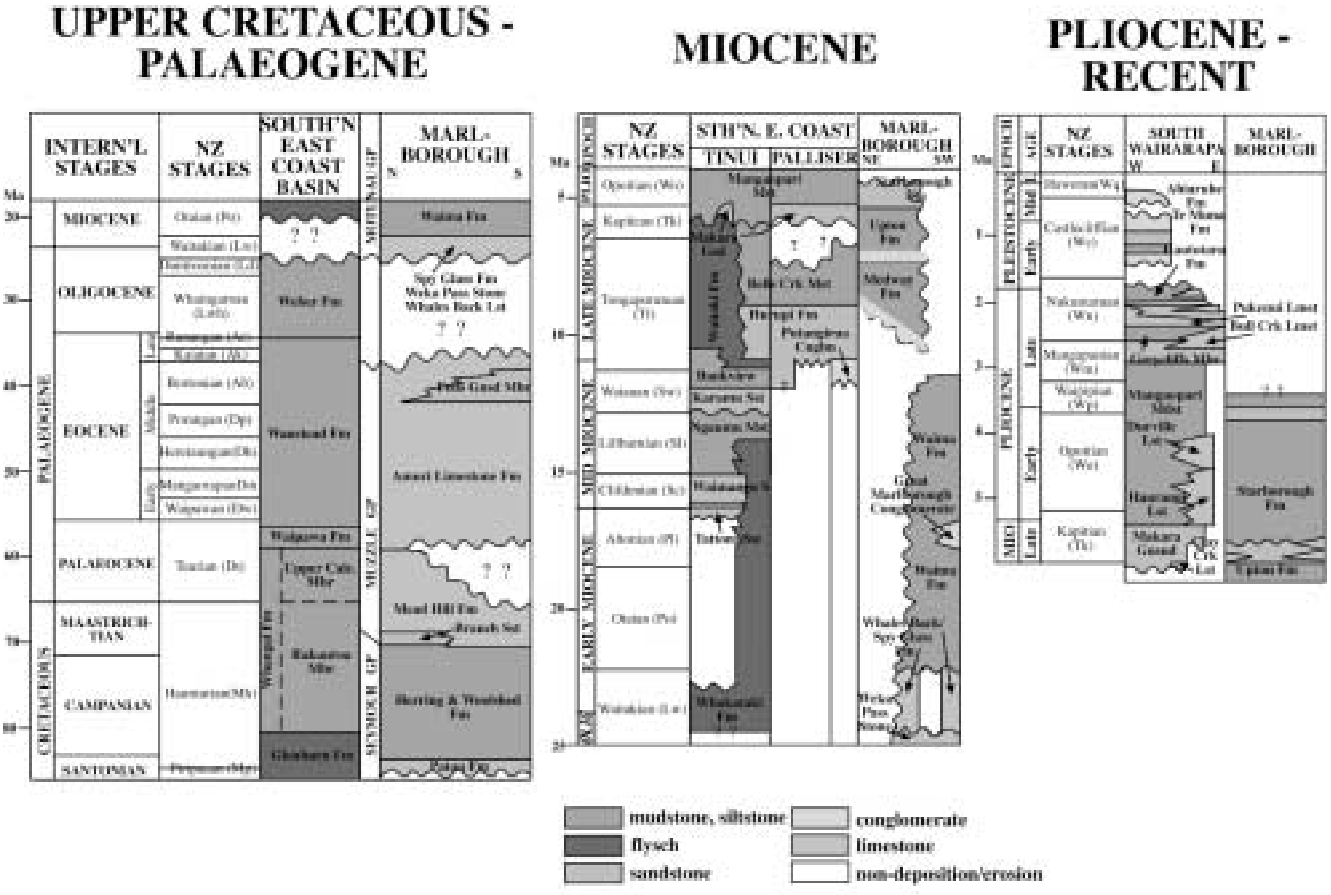
Basement exposed onshore near Cook Strait consists of greywackes of Lower Cretaceous Torlesse and Hurupi Groups separated from the Marlborough Sounds metamorphics of Palaeozoic age at the Wairau Fault (Figure 2). In both islands the Cretaceous basement rocks comprise a parallel east-northeast trending Rakaia-Wellington Subterrane belt, a central Esk Head-Rimutaka Subterrane belt and an easterly Pahau-Wairarapa Subterrane belt. Dextral offset of the three Cretaceous terranes across Cook Strait is in the order of 140 km (Mazengarb et al. 1993; Barnes & Audru, 1999).

Unconformably overlying the basement are basin-filling sediments beginning in the Late Cretaceous in response to opening of the Tasman Sea and separation of the New Zealand sub-continent from Antarctica. In common with many other New Zealand basins, they broadly subdivide into a Cretaceous-Paleogene rift sequence, and a Neogene drape (blanket) sequence.

Cretaceous-Paleogene rift sequence

The earliest basin-fill sediments are also the most likely source rocks in the area and comprise mainly dark shales of the Whangai Formation and Paleocene black shales of the Waipawa Formation. These units outcrop extensively around the East Coast and Marlborough. Eocene to Early Miocene sedimentation also includes some likely source and reservoir beds such as glauconitic facies of the Weber Formation and Marlborough limestones of the Motunau Group (Figure 2).

Structural contours in two-way-time at the Top Paleogene level shown for the Cook Strait basins on Figure 3 is based on the 1970s seismic, as interpreted by Uruski (1999). Seismic picks of five Cook Strait petroleum company seismic lines (Uruski 1992, 1999) are also shown as three seismic transects (A-A', B-B', C-C') across Cook Strait (Figure 4). The Wairau Basin is defined to the west by the offshore extensions to the Wairau Fault in Marlborough and appears to continue in a sinuous east-northeast direction across Cook Strait to the Wellington Peninsula (Figure 5). A significant tensional zone occurs across the fault, against which the Wairau Basin sequence is downfaulted southeast by greater than 4 seconds TWT. Within the depocentre, structuring occurs along extensions of the Wairau and Awatere faults and as folds and



(after Holdgate & Shaw, 2001)

Figure 2: Stratigraphic charts for the Upper Cretaceous to Pleistocene in the adjacent parts of the onshore basins to Cook Strait (modified from Field & Uruski, 1997).

minor inversion between these faults. These faults are interpreted to be high angle normal faults that were subject to late Miocene or Pliocene transpressional movements. Across shallowing basement, towards the boundary with the Wairarapa Basin, major shortening within the Neogene-Recent sedimentary section has resulted in the development of a major west-hading detachment surface or surfaces. Gravity induced faulting, involving block rotation, is evident in the direction of Nicholson Bank on Line 72-117 (Figure 4). The older data clearly indicate that the shallow and deeper structural regimes are quite distinct and as such the more recent NIWA data highlight only the potential associated within the Neogene-Recent sediment package (Figures 6 to 13).

On the eastern side of the Wairau Basin all reflectors rise through complex overthrusts and normal faults, derived from offshore extensions to the Awatere and Clarence Faults, onto a shallower basement area that divides the Wairau and Wairarapa basins (Figures 3 & 4). Regional line (NZ-72, Figure 4) illustrates a considerable degree of detachment between the Neogene – Recent section and deeper sections, not evident on Lines 72-117 and NZ-174. Reverse movements are interpreted on the Awatere Fault and a major detachment is interpreted along the Clarence Fault, which merges northwards with the Awatere Fault. Note that the Clarence Fault detachment involves a thick, relatively unstructured Neogene section over-riding a block-faulted deeper section across the boundary between the Wairau and Wairarapa basin margins. Subsequent erosion, at either the top of the Miocene or during the Pliocene, has produced major sub-unconformity plays along this boundary.

The Wairarapa basin is present to the east of the Clarence-West Wairarapa faults and may include parts of the Flaxbourne Basin (Barnes & Audru, 1999). Basement reflectors can occur at over 4 seconds TWT in depth (Figure 3). Faulting in this basin appears to be more complex internally than the Wairau Basin with some closures produced by fault rollover and overthrusting (eg. prospects “A”, “B”, “G”, “H” and “I”; Figure 3). In places, the seismic reflectors are distorted by hard-bottom seabed conditions along the modern Cook Strait canyon systems (Carter, 1992). In the east, poor reflector definition makes interpretation difficult, except in the Palliser Bay area where the Top Paleogene reflector is prominent. The large prospect “I” (Figure 3) mapped by Field & Uruski (1997) along the eastern side Palliser Bay is produced by mainly west dipping surfaces, and may not have closure beyond the eastern limits of the seismic lines.

Neogene drape sequence

Further significant basinal sedimentation occurred in the Cook Strait area during the Early Miocene, either as interbedded sandstones and rare algal limestones of the

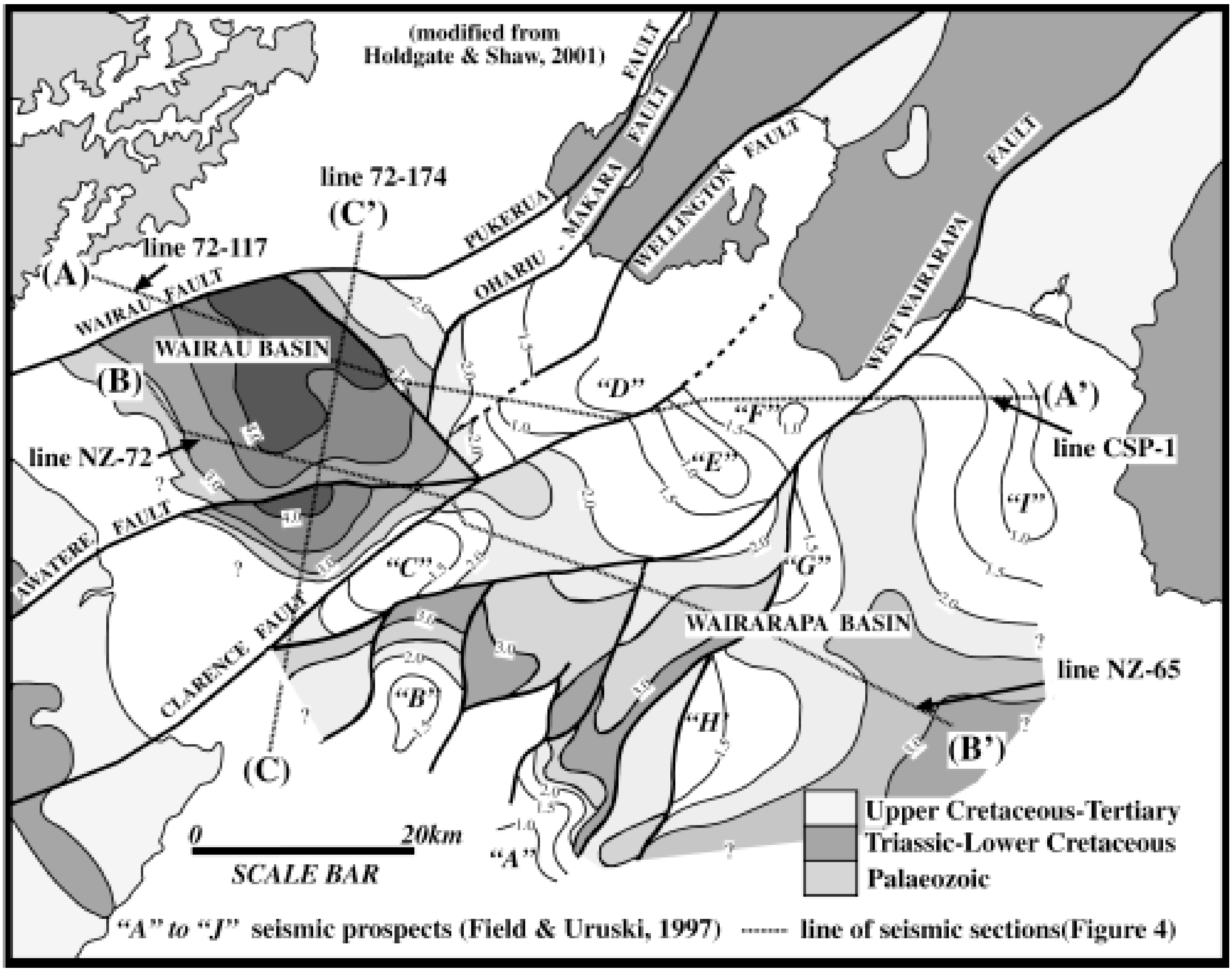
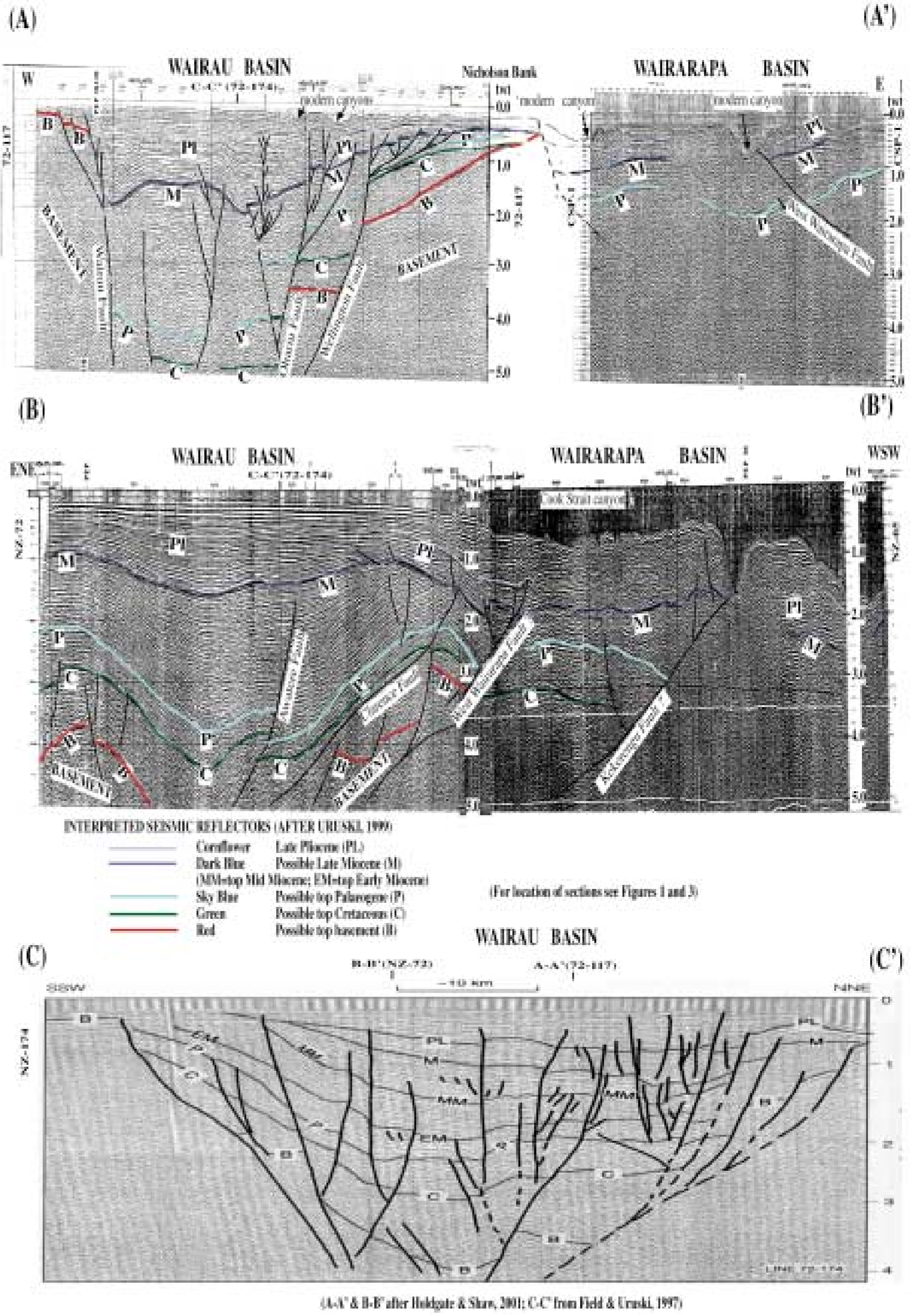


Figure 3: Time-structure TWT contours for the “Possible Top Paleogene (sky blue) Reflector” interpreted from the Cook Strait seismic lines (Figure 1). Location of seismic sections A-A’, B-B’, C-C’ (Figure 4) shown, and crestal positions for structures and prospects *“A”* to *“J”* defined by Field & Uruski (1997).

Takiritini Formation, or more usually as Kuamahanga/Palliser Group sandstones and mudstones of Clifdenian to Tongaporutuan Stage (Middle Miocene to Early Pliocene age - Figure 2). The earlier Middle to Late Miocene succession includes regionally significant reservoirs throughout the East Coast Basin (Francis 1998). Sandstones such as the Tattons, Waimangu and Karamu sandstones are contemporaneous with those in the northern part of the basin, and are of similar age to the recent gas sand discoveries in the Wairoa area.

The principal seal is a thick series of mudstones and turbidites of the Palliser and Onoke groups. These span the NZ stages Tongaporutuan to Mangapanian (Late Miocene to Late Pliocene). Several significantly thicker turbidite sandstones are present within the sequence and could also constitute shallower reservoirs. An unconformity exists within the sequence at around the early Kapitean Stage (Late Miocene). The main basin-filling episode was terminated in the Late Pliocene by major uplift in the adjacent ranges, although sedimentation probably continued across Cook Strait. Pliocene-aged marine beds at Makara could represent preserved sediments of a larger Wairau Basin prior to uplift of the Wellington Peninsula (Grant-Taylor & Hornibrook, 1964). Onshore, the succession rapidly shallows up through shelfal mudstones into shallow water Early Nukumaruan (early Pleistocene age) carbonates of the Pukenui Limestone. These limestones cap the major structures and can form reservoirs. Subsequent onshore deposition in the Pleistocene generally consists of minor sandstones and coquinas of Upper Nukumaruan age unconformably overlain by terrestrial conglomerates and sandstones. In Cook Strait, marine sedimentation probably continued to the present.

Dextral offsets of Tertiary strata are less obvious than for the Cretaceous, but some Pliocene palaeomagnetic data suggests the northeast Marlborough coast has rotated clockwise 20-40 degrees about a northwest striking kink-plane since about 5 Ma, but less than half this in Wairarapa (Little & Roberts, 1997). Dextral offsets are more apparent in Quaternary gravel terraces where cut by some of the major faults. In common with the rest of the East Coast Basin, major Cook Strait faults generally dip westward, appear to be relatively steep, and may therefore be obliquely compressional strike-slip faults rather than pure thrusts. In the Wairau Basin, movement is documented by an onlapping latest Miocene sequence. Faults break the seabed and an unconformity, perhaps the mid-Castlecliffian or a younger unconformity (as occurs in offshore southern Wairarapa) is widespread. Further east,



(For location of sections see Figures 1 and 3)

(A-A' & B-B' after Holdgate & Shaw, 2001; C-C' from Field & Uruski, 1997)

Figure 4: Three seismic lines (A-A', B-B', C-C') across Cook Strait showing main reflector identifications by Field & Uruski (1997), Uruski (1999). For locations of lines see Figure 3.

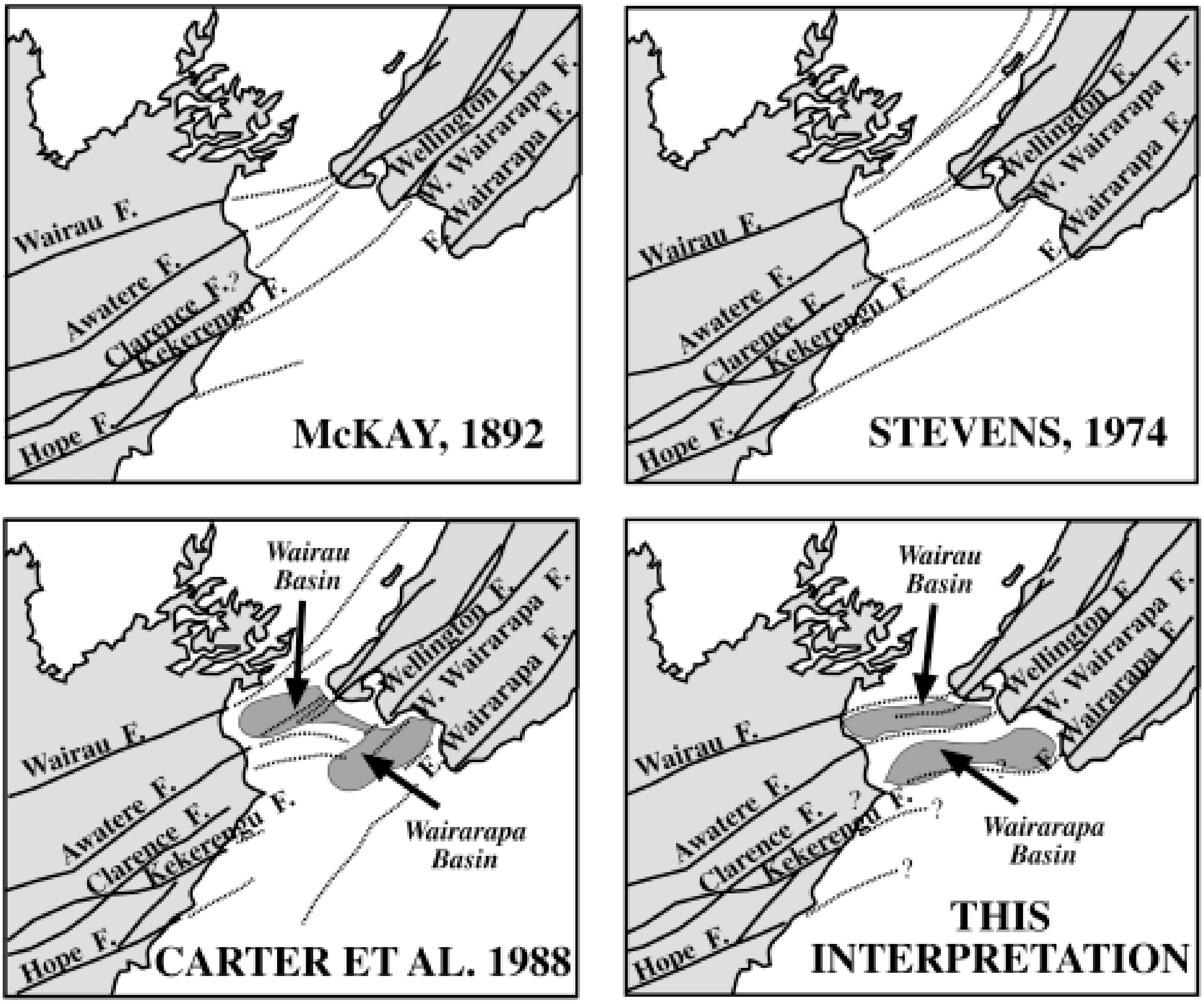


Figure 5: Four interpretations of fault connections across Cook Strait: McKay, 1892; Stevens, 1974; Carter & Lewis, 1988, and this paper.

thrusts and back-thrusts produce pop-up blocks with intervening basins that are filled in post-Miocene time.

The opening of Cook Strait is intimately linked with possible rotation and dextral slip in Marlborough and southern North Island. Lewis et al. (1994) showed the main branch of the Wairau Fault projects in an arch around the north side of the Wairau Basin and into the northwest trending Cook Strait Canyon. Earlier solutions are shown also on Figure 5. On the NIWA seismic the Wairau Fault appears to connect with offshore extensions to the Oteranga-Pukerua Fault west of Wellington (Figures 1 and 3) (a similar fault interpretation was suggested by McKay, 1892). The Wellington and Makara faults are poorly developed offshore, and die out within the basin centre. Near Wellington they define south-plunging basement structures (eg. prospect “D”, Figure 3) that in the basin centre are developed as small scale reverse and normal faulting with pronounced development of diapiric flows and gas chimneys down the fault zones. Similar faulting northwest of the Awatere Fault defines north-plunging structures that have discrete closures in the offshore Wairau Basin.

A major canyon system is incised into the Cook Strait seabed and in the last 5 Ma has delivered as much as 4 km thickness of sediment to the deep Pegasus Basin at the foot of the continental slope (Field & Uruski, 1997; Uruski and Baillie, 2001). Tidal and headwall erosion from the deep-water Cook Strait canyon has exposed Plio-Pleistocene beds in the canyon walls (Barnes and Audru, 1999). The hard canyon floor cause seismic multiple problems (Carter 1992).

Source rocks, maturity and reservoirs in the Cook Strait basins

The Waipawa black shale has been identified as the most likely source for the origins of the oil and gas seepages in the East Coast Basin (Johnson *et al*. 1992; Murray *et al*. 1994). It is probably also a likely source for seepages in the Cook Strait area (Figure 1). The two-way time contours shown on Figure 3 are shortly above this formation. Cretaceous coal measures of the Marlborough area may also extend northwards into Cook Strait and with burial depths of up to 4 seconds may be mature (Uruski 1992). Mudstones of the Palliser and Onoke groups contain a low content of organic matter (both terrestrial and marine) that could provide an additional biogenic gas source. Interpreted burial history plots at the top Palaeogene level in the centre of the Wairau

Basin (and applicable to the offshore Wairarapa Basin) suggests oil generation commenced in the Early Miocene and still continues today as a result of continuous subsidence (Field & Uruski, 1997). Gas generation would have commenced in the Late Miocene, and currently Top Paleogene vitrinite reflectance resides at about 0.85% Ro (max). Leakage history is unknown, but given the number of faults, some of which extend to the surface, is likely to be complex. Seabed hydrocarbon seepages have been recorded by sniffer surveys (Sigalov 1986) and are probably related to upfault migration from the Paleogene.

Potential East Coast Basin petroleum reservoirs described by Field (1995) and Francis (1998) include Middle Miocene sandstones, probably continuous into the Cook Strait Basins. They include the Tattons Sandstone, Waimangu Sandstone Member and upper Karamu Sandstone (Figure 2). The sandstones can be up to 400 m thick. Other reservoir units probably occur within earlier Tertiary units below Cook Strait. These could include equivalents to the Putangirua Conglomerate/Great Marlborough Conglomerate that outcrop near Palliser Bay and Marlborough, deep-water fan sandstones of the Whakataki Formation (Early Miocene), and glauconitic sandstones of the Eocene-Oligocene Weber Formation (Field 1995). The Eocene Amuri Limestone facies in the Marlborough region overlie, and are probably interbedded with Waipawa shales beneath southern Cook Strait. They could also include carbonate reservoirs similar to the Taranaki Basin although in outcrop at White Rock (southeastern Wairarapa coast) thin sections suggest they are well cemented and tight. In the East Coast Basin the Early Pleistocene Pukenui Limestone is charactised by good porosities. In the more deeply buried parts of the offshore basins, the Pukenui Limestone, if present, is likely to constitute a reservoir target.

Thick mudstones of the Bankview, Bells Creek, Morland and Mangaopari formations constitute an effective seal over the Karamu and older sandstones. The mudstones include localised sandstones that exhibit graded bedding and tuffaceous beds. The succession is probably over 1.5km thick in the offshore area. Older seal units include flysch facies of the Whakataki, Weber and Wanstead formations (Figure 2).

NIWA seismic surveys and interpretation in the Wairau Basin

A total of 258.6 km of seismic reflection data were acquired from the NIWA survey CR 3048 that was considered pertinent to the PEP 38338 lease (Figure 1). All lines except Line 57 are dip orientated, northwest to southeast trending. Line 57 being a northeast-southwest trending strike line providing control between adjacent dip lines. Acquisition was conducted using a 48 channel seismic streamer, a GI gun seismic source, air compression and acquisition recorder with real-time seismic controller. The streamer was 300m long with 6.25m group spacing. Lines 46 to 51 were run at 4 knots providing 12-fold CDP coverage. Line 53 has CDP coverage of 8-fold, and Lines 52 and 57 have a 6-fold coverage. Processing was undertaken by NIWA using Globe Claritas™ interactive processing software.

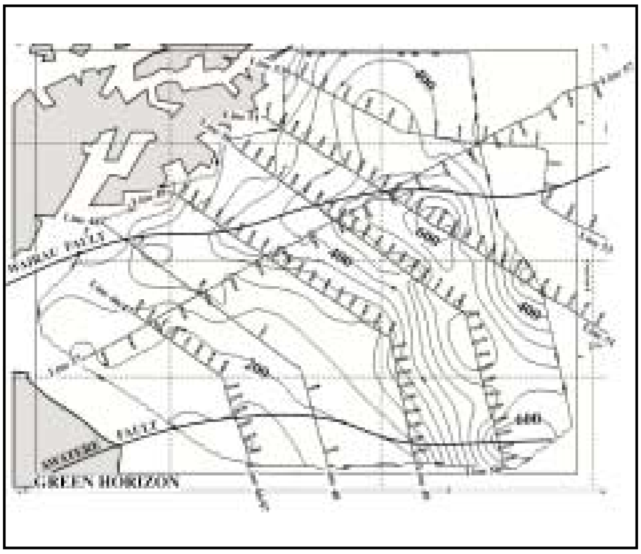


Figure 6: Green Horizon time-structure map (Top Pliocene “G”) - Wairau Basin, based on NIWA seismic grid (also shown). Contour interval equals 40 msec.

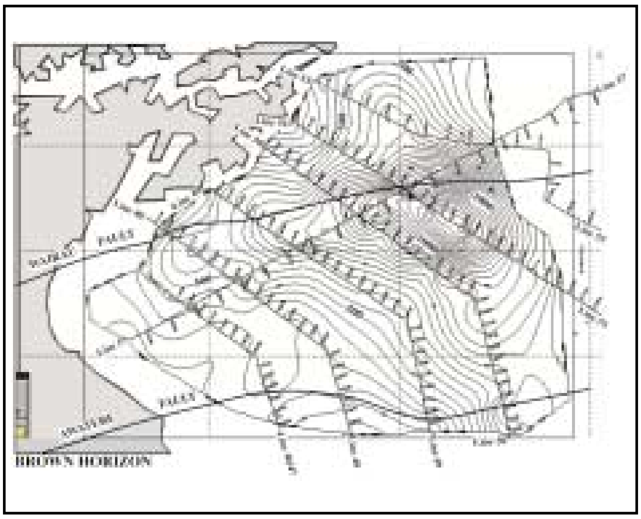


Figure 7: Brown Horizon time-structure map (Top Miocene “B”) - Wairau Basin, based on NIWA seismic grid (also shown). Contour interval equals 40 msec.

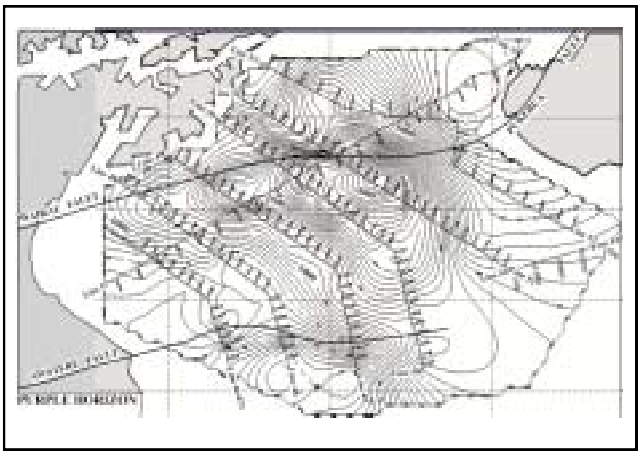


Figure 8: Purple Horizon time-structure map (Middle Miocene “P”) - Wairau Basin, based on NIWA seismic grid (also shown). Contour interval equals 40 msec.

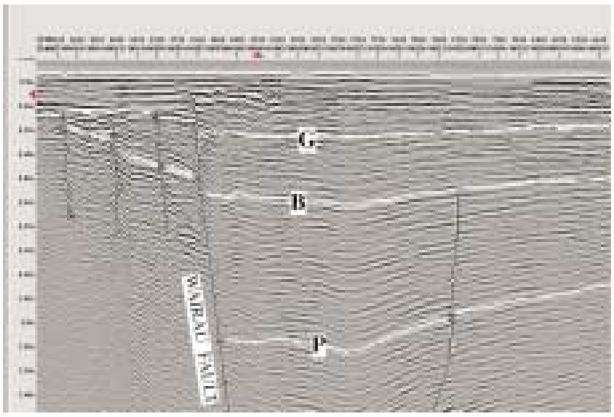


Figure 9: Western half of NIWA Line 48 showing the relationship between the Wairau Basin, Wairau Fault(s), and shallow basement areas to the west (left of figure). Note truncation at green horizon level "G" (here top Pliocene level) and the conspicuous nature of the unconformity surface associated with this event in the southwestern part of the basin. Identification of reflectors are: "G" = Top Pliocene; "B" = Top Miocene; "P" = Middle Miocene. For location see Figure 1.

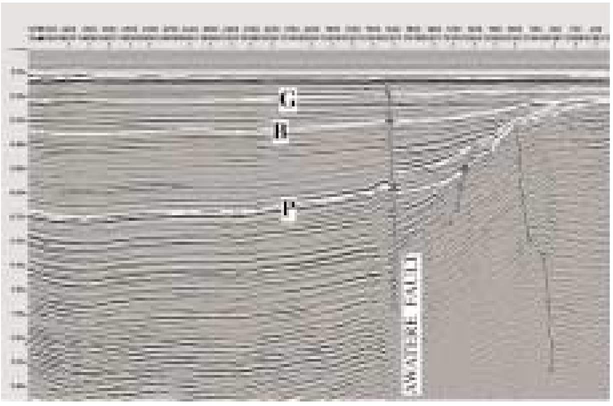


Figure 10: Eastern half of NIWA Line 48 showing the relationship between the Wairau Basin, Awatere Fault(s), and shallow basement areas to the east (right of figure). Note near vertical faults and associated disruption zones that may be associated with diapirism or gas. Faulting provides basinward limit of high amplitude sediments shed from adjacent high to the right. Reflector identification as in Figure 9. For location see Figure 1.

Three horizons could be reliably mapped within the NIWA survey and contoured in two-way-time on Figures 6 to 8.

The Green Horizon

The shallowest Green Horizon was the easiest interpreted horizon, although coinciding with a conspicuous erosional surface, it exhibited considerable lateral change in character, making positive identification sometimes difficult. It varies from 140 msec to more than 640 msec in the Wairau Basin centre with a maximum thickness of 400 msec (~ 320m assuming 1600 m/sec). The Wairau Fault appears to control the northwest side of the depocentre (Figure 6). The Green Horizon opens out southeast towards the Wairarapa Basin. Relatively steep gradients between Lines 49 and 50 suggest that the Marlborough Shelf margin is structurally controlled by a northwest trend which is not evident on the adjacent onshore, presumably being truncated by the Wairau Fault in that direction.

The interval above the Green Horizon contains prograding wedges within the upper beds that have long foresets suggestive of strong currents and establishment of through flow in Cook Strait. Progradation extends from south to north and provides some bathymetric expression. Non-deposition or scouring to this unit takes place closer to Wellington. Channelling and cut and fill are present particularly at the footwall of some faults, and high amplitude events in the south are suggestive of conglomeratic deposits.

The Green Horizon locally delineates a conspicuous unconformity separating relatively flat lying shallower reflections from the more structurally controlled underlying reflectors (Figure 9). Regionally it appears to coincide with the cessation of widespread tensional faulting although a number of minor fault displacements occur above this level (Figures 10 & 11). These faults are all imaged as high angle normal faults, some of which have broad zones of disturbance suggesting that they may also be associated with diapirism or gas chimneys. On the basis of the similarity in stratigraphic and structural attributes to the southwest part of Line 72-174 (Figure 4C) a Top Pliocene age is preferred.

The Brown Horizon

The Brown Horizon was readily identified along Lines 48 and 49 within the basin depocentre. Elsewhere its character was weaker, especially to the west of the Wairau Fault across the shallowing margin. The interval is more arcuate than Green Horizon with pronounced control by the Wairau Fault (Figure 7). The maximum interval thickness exceeds 1000 msec (900 m, assuming 1800 m/sec). In the southeast it thins rapidly by onlap and erosional truncation at the Green Horizon level (Figure 10). Localised thinning occurs on the Marlborough shelf associated with differential drape across basement noses. Several potential pinchouts are observed across the southern, western and northwestern margins. Correlation to Line 72-174 (Figure 4C) suggests the Brown Horizon is either a Late Miocene or Middle Miocene event with preference given to the former.

The Purple Horizon

The deepest Purple Horizon was hard to correlate along several of the lines, and is absent on the western extremities of Lines 51, 52 and 53 due to the up-tilted nature of the sequence in this area (Figure 8). It lies approximately 500 msec below the Brown Horizon within the depocentre (Figure 13) and may be a Middle Miocene event. This horizon is broadly folded and faulted (eg. Figure 11). Along part of Line 48 it represents a conspicuous high amplitude event which changes character across the shallowing margin (Figure 10). The Purple horizon can be mapped to more than 2000 msec (1800m, assuming 1800 m/sec) and is strongly controlled by the Wairau and Awatere faults. Within the brown to purple interval the reflectors are better defined to the east and southeast suggesting a deepening of the depositional environment in this direction.

Hydrocarbon prospects of the onshore Palliser Bay region

Approximately 20% of PEP38338 lease area extends onshore from Palliser Bay into the southern Wairarapa (East Coast Basin). The flood plain of the Ruamahanga River lies between the uplifted basement blocks of the Rimutaka Ranges to the west demarcated by the West Wairarapa Fault, and the Aorangi Range to the east.

Two significant positive gravity anomalies centrally located on the Wairarapa floodplain are shown in regional gravity maps (Reilly, 1972), and occur east of Lake Wairarapa and shortly west of Pirinoa village. Detailed gravity surveying and modelling over these anomalies was carried out as part of the Tyers 1999 work program and aimed to tie the subsurface geology beneath the Wairarapa Valley to the Late Cenozoic and basement outcrops on the eastern and western sides (Figure 14). Some 31 stations were measured along two traverse lines, and were tied to the NZGNS Primary Gravity Network (Figure 14). A gravity modelling process based on the Interpex MagixPlus™ version 3-2D interactive modelling software utilises relative density as density contrast to predict geological structure. The generated model calculates a synthetic response that is compared against field data. The degree of match of the synthetic and field data is expressed as percentage error fit, and the best fit is taken as the closest to geological reality. The assigned densities were derived from Hicks & Woodward (1978) Cape (1989) and Cape et al. (1989). Cretaceous greywacke with an adopted density of 2.61 gm/cm3 underlies the whole of the modelled area. The Tertiary units varied between 0 and 400 m in thickness and follow the stratigraphic nomenclature of Hicks & Woodward (1978). The age, thickness and relative density of Tertiary units to basement are given in Table 1.

The two traverse interpretation plots are shown on Figure 15. Each geological section is generated by the Interpex modelling from the field data (square data points) overlain by the synthetic curves. The fit between field and synthetic gravity trends generally ranged between 1.2 and 1.4% ie. an acceptable range of probability.

Using a 3-density Tertiary layer model the best-fit gravity profile indicates a vertical to overthrust section on the western side of the valley reaching about 1000 m in depth against the West Wairarapa Fault. A central-valley basement high near Pirinoa and Te Opai with positive gravity residuals corresponds to a rise in the basement surface between 300 m and 400 m of the surface. Thinning of the Quaternary and Miocene over these highs was justified by the modelling densities used, and in the light of known seismic results across the Wairarapa Valley to the north (Cape, 1989). Closure of the gravity trends on the Te Opai anomaly measures approximately 7x2.5 km in area with basement rising to -430 m depth. The Pirinoa gravity anomaly also measures approximately 7x2.5 km in area with basement rising to

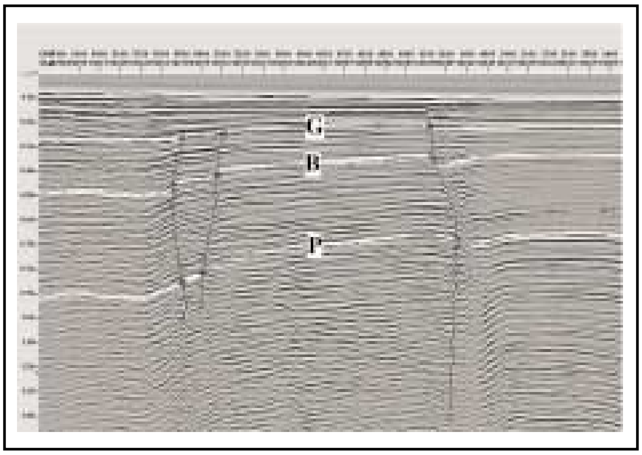


Figure 11: Portion of NIWA Line 48 showing typical rollovers identified within the Wairau Basin centre. The faults are identified as offshore continuations of associated faults of the Awatere Fault system. Note rollovers on the footwall side and broad flexure on the hanging wall of the fault. Rollover into the fault may be growth related and at depth enhanced by transpressional structuring. Reflector identification as in Figure 9. For location see Figure 1.

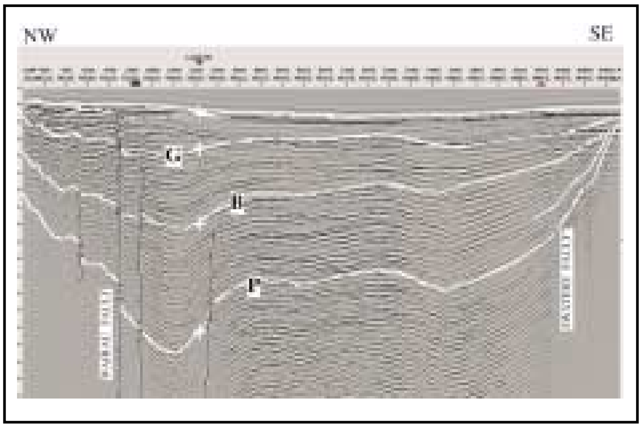


Figure 12: Line 49 showing truncation of the top/mid Miocene horizon (here shown as “P”) and disruption zones due to diapirism or gas. Note the potential for unconformity traps and the presence of strong water bottom multiple at 0.3 seconds. Reflector identification as in Figure 9. For location see Figure 1.

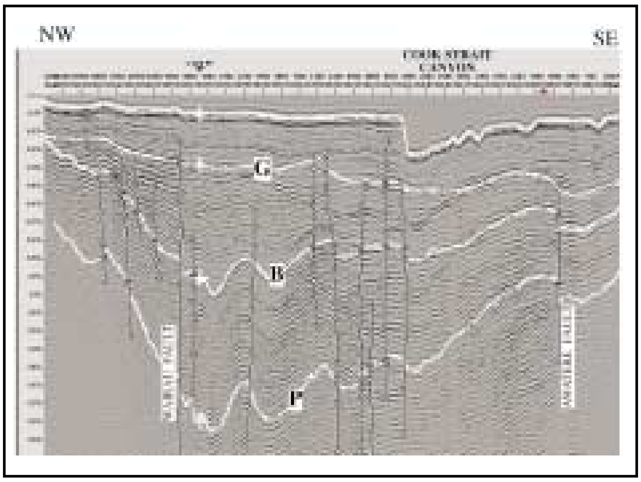


Figure 13: Line 50 showing truncation of the Top and Middle Miocene horizons (here shown as “P” & “B”) on the western side of the Wairau Basin. Note the potential for unconformity traps and the presence of strong water bottom multiple at 0.3 seconds beneath the Cook Strait Canyon. Reflector identification as in Figure 9. For location see Figure 1.

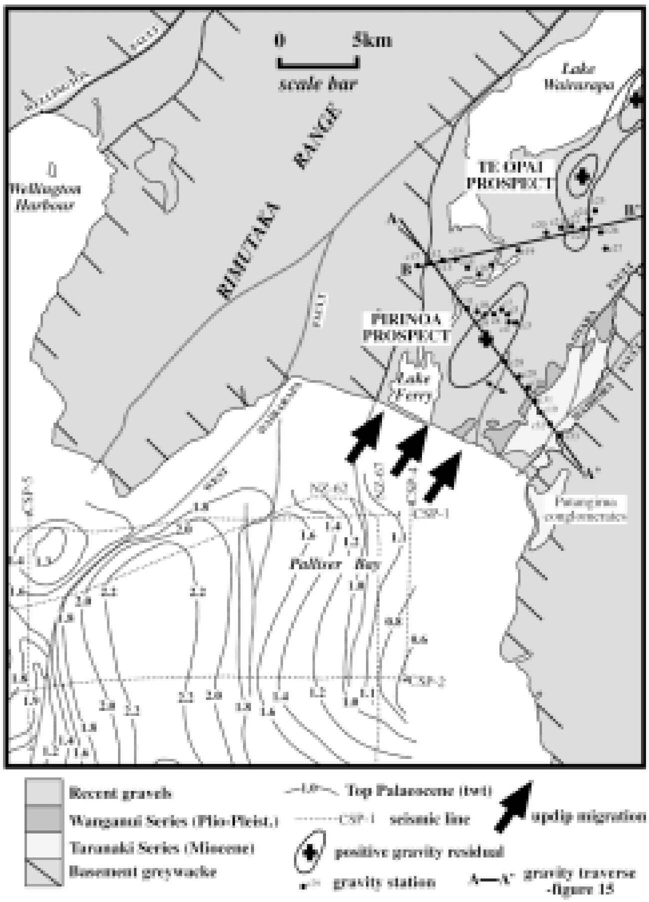


Figure 14: Locality map and gravity stations and traverses of the Pirinoa and Te Opai prospects, onshore southern Wairarapa, and the Top Palaeogene seismic contours in Palliser Bay as interpreted from the Magellan 1970 seismic lines. The potential up-dip migration pathways coming from the offshore basin is shown by arrows.

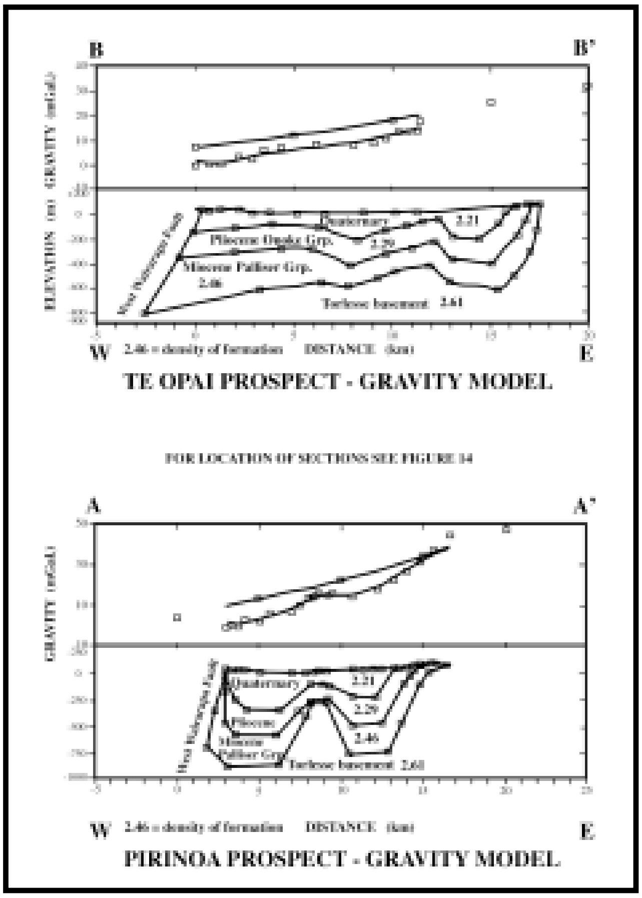


Figure 15: Gravity models of the Pirinoa and Te Opai prospects in southern Wairarapa. The geology model for each traverse is shown together with the field and synthetic gravity responses. Relative density contrasts are shown together with the major formations (see Table 1).

–260 m depth. The thicknesses in the surrounding lows are considered unlikely to be enough to generate hydrocarbons. However seismic coverage in the nearby offshore part of Palliser Bay indicates considerably greater Tertiary section up to 1.8 msec (1620 m, assuming 1800 m/sec) (Figure 14) from which updip migration could occur into the nearest onshore structures including the Pirinoa and Te Opai gravity structures.

Hydrocarbon prospects of the offshore Cook Strait region

Based on previously acquired industry seismic data a number of prospects and leads had been identified within the Cook Strait portion of PEP 38338 (Field & Uruski, 1997; Holdgate, 1999; Holdgate & Shaw, 2001). Most of these features lie outside of the NIWA survey area or at depths below the penetration capabilities of the energy source used, eg. a previously identified “C” feature is at Middle Miocene and shallower levels, and is a composite of several discrete structures (Figure 3). Interpretation of the NIWA data identifies a number of broad rollovers at levels below the Top Pliocene Green Horizon. These appear to be associated with minor, high angle normal faulting. At the mapped levels rollovers are interpreted to be mostly fault independent and are fold or drape related. At depths beyond the current level of penetration, folds may become asymmetric and associated with thrust or reverse faulting, compressional style, which predate Wairau Basin formation. Because of the wide line spacing only one four-way dip closure is mapped, centred on Line 48. This prospect is located towards the eastern end of Line 48, and appears to coincide with a broad compressional flexure on the edge of the southeastern margin of the Wairau Basin. The structural closure in the east and west direction is provided by compressional folding, whereas structural shallowing provides a component of the north-south closure. Northerly basinal dips accentuate the closure component in this direction. Based on current seismic coverage the culmination is mapped in the vicinity of shot-point 345 on Line 48. The areal extent of this closure is approximately 8 km^2 with a vertical relief of 50 m. At depth this feature may be related to structuring associated with the offshore extension of the Awatere Fault or associated fault.

The western, northern and southeastern margins of the Wairau Basin each display significant onlap by Neogene to Recent sediments with the potential for pinchout plays sealed both intraformationally and formationally by unconformities. The largest of these plays is centred on the eastern extremity of Line 48. As mapped closures against shallowing basement cover approximately 200 km^2 they give rise to potentially enormous reserves. Lack of penetration prevented underlying pre-Middle Miocene structure from being resolved. Based on the current interpretation five distinct petroleum play types can be recognised within the area associated with the principle trapping mechanisms.

1) Broad regional, compressional folds within the basin depocentre.
2) Pinchout and unconformity traps at the Mid-Miocene level across the Marlborough Shelf.
3) Tensional fault block plays along the lower Marlborough Shelf.
4) Antithetic fault blocks associated with offshore extensions of the Awatere Fault.
5) Antithetic fault block and associated rollovers into offshore extension of the Wairau Fault.

This interpretation has not enabled confirmation of a number of significant deep structures, mostly of compressional style which have previously been identified by earlier industry seismic surveys (Field & Uruski, 1997). The present survey has however provided much superior resolution of shallow structuring within the northwestern portion of the offshore PEP 38338 Cook Strait area.

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Table 1– Gravity modelling layers and densities

Strata Age	Thickness (max. m)	Approx. density (gm/cc)	Relative density (gm/cc)	Groups
Quaternary	250m	2.21	-0.40	Pleistocene Gravels
Pliocene	300m	2.29	-0.32	Onoke Group
Miocene	400m	2.46	-0.15	Palliser & Kumahanga Gp
Cretaceous Torlesse	?m	2.61	0	Mangapurupuru Group

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