CRETACEOUS AND CENOZOIC TECTONICS OF THE WEST COAST REGION OF THE SOUTH ISLAND

D J Bishop
Research School of Earth Sciences
Victoria University of Wellington
Wellington

Abstract

Open-file seismic reflection data and exploration well data from onshore and offshore areas of North Westland and North-West Nelson have been re-interpreted and integrated with recent field observations and a synthesis of the extensive literature of the region. Eight subsurface seismic units and seven horizons are picked and correlated with onshore stratigraphy, conformity and unconformity surfaces. Horizons are of regional extent and are dated as early Motuan (middle Albian), early Haumurian (middle Campanian), Early Eocene, Early Oligocene, Early Miocene, Middle Miocene and Early Pliocene.

Middle-Late Cretaceous basins include the Takutai Half-Graben; Late Cretaceous-Oligocene basins include the Paparoa Basin and the Pakawau Basin; Eocene-Oligocene basins include the Reefton Basin, Buller Basin, Westport-Karamea Basin and various un-named offshore basins; Neogene basins include the Westport-Karamea Basin, southern Paparoa Basin and Grey-Inangahua Basin.

Rocks of middle Cretaceous-Eocene age are the main hydrocarbon-bearing rocks of the region. Many of the onshore middle Cretaceous-Eocene basins have been subject to inversion associated with the transpressional Neogene Australia-Pacific plate boundary. Offshore middle Cretaceous-Eocene basins are mainly beyond the Neogene deformation front and have simpler structure. Maturation of hydrocarbons is most likely to have taken place during the Oligocene and the Pliocene-Recent. Kitchen areas for the latter are likely to be where source rocks have been particularly deeply buried by Neogene sediments. Structural traps have mainly formed during the Miocene-Recent.

Introduction

The West Coast of South Island can be divided into two primary structural domains: the Western Platform and the West Coast basin and range province (Nathan et al. 1986). The geology of both areas comprises: (i) "basement", which is mainly low-grade (plus minor high-grade) metasediments and igneous rocks of Precambrian - Early Cretaceous age, and (ii) a mainly unmetamorphosed "cover" sequence of igneous and sedimentary rocks of Early Cretaceous - Recent age. The predominant structural trend in the onshore and nearshore region (which is the "basin and range province") is N-S to NE-SW (Figure1), owing in part to Mesozoic terrane accretion (Bishop *et al.* 1985), Late Cretaceous - Oligocene extension and Neogene shortening (both the subject of this paper). The Western Platform, which lies entirely offshore west of the South Island, shows little sign of Neogene shortening, being further from the cause of Neogene deformation: the Pacific-Australia plate boundary. Bishop (in press, [a]) shows that pre-Neogene structures are well preserved in the Western Platform, such as the Takutai Half-Graben (Figure1). The Western Platform has been buried during the Neogene by a blanket of sediment up to 2 km thick, which, like the Giant Foresets Formation to the north (Shell, B.P. & Todd 1977) is probably derived from the erosion of rising mountain ranges.

Seismic reflection data

A considerable number of seismic reflection surveys have been carried out in the West Coast, offshore and onshore, the results of which are available on open-file (D.S.I.R. Geology & Geophysics, Lower Hutt, New Zealand). Industry-standard seismic reflection profiles of good to excellent quality have been selected and re-interpreted on a regional basis (Bishop 1989 and in prep.). The surveys used are listed (Table 1). The interpreted data covers the offshore area from Harihari to Cape Farewell and the onshore area from Harihari to just northeast of Greymouth (Figure 2). A total of 178 migrated and/or stacked time sections have been interpreted (Bishop in prep.).

Well data

The presence of oil seeps, such as the one at Kotuku (Morgan 1911) has encouraged drilling for petroleum. Several wells have given oil and gas shows, e.g. SFL-1 (Superior Oil Company 1943) and Niagara-1 (Matthews 1990). Most well completion reports are available on open-file (D.S.I.R. Geology & Geophysics, Lower Hutt, New Zealand) and those utilised in this study are listed (Table 2). Other sources of well data include Wellman (1971), Nathan *et al.* (1986), Robinson (1987) and the Ministry of Energy (1989).

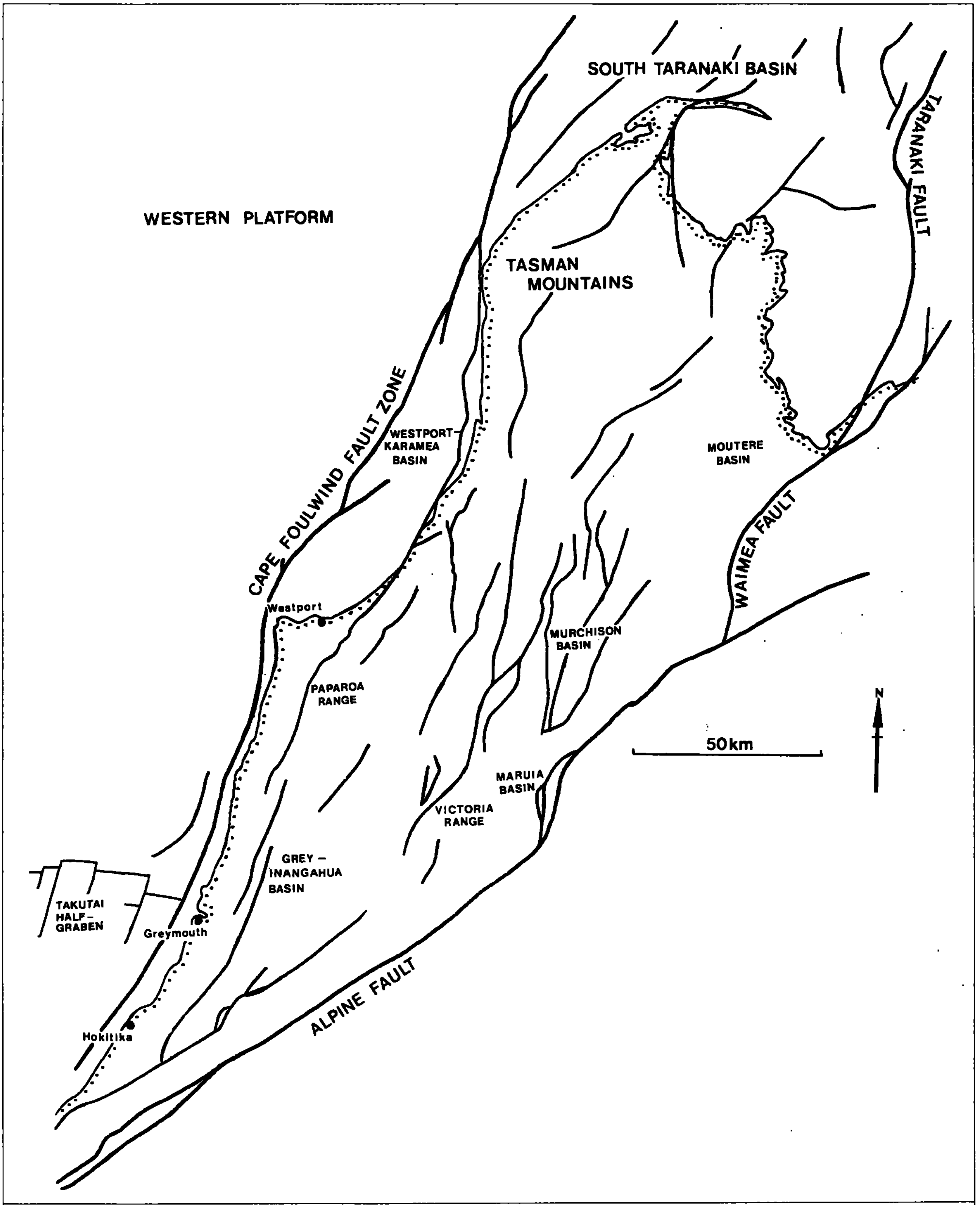

Figure 1: Map showing main structural elements of the West Coast of Cretaceous-Cenozoic age.

Seismic horizons and units

Seismic reflection lines were firstly examined to see which horizons and units were easily recognised over the whole grid of lines. These were correlated with lithological well logs, sonic logs and synthetic seismograms (Bishop in prep.). Seven horizons and eight units, which proved easy to correlate over most of the seismic grid, were selected and correlated with the West Coast stratigraphy (Table 3). The horizons picked were given colour and three-letter codes: red (RED), orange (ORA), dark blue (DBL), light green (LGR), dark green (DGR) and yellow (YEL). Since the stratigraphy has been reasonably well dated (Nathan *et al.* 1986), it is possible to infer ages for these horizons, based on the ages of units underlying and overlying each horizon:

YEAR	SERIES	OPERATOR	ACQUISITION / PROCESSING	REFERENCE
1969	EZC, EZF	ESSO	Western Geophysical	Esso (1969)
1971	LINE	N.Z. Petroleum Company Ltd	Teledyne Exploration Company	N.Z.Petroleum Co.Ltd (1974)
1972	LINE	N.Z. Petroleum Company Ltd	Geophysical Service Incorp.	N.Z.Petroleum Co.Ltd (1974)
1978	GV	Petrocorp	Seismograph Service Ltd	Rubens (1978)
1981	CK-81	Cultus Pacific	Western Geophysical	Cultus Pacific (1981)
1981	SH81	Seahawk Oil International	Geophysical Service Incorp.	Grearson (1982)
1982	DS1	Diamond Shamrock	Petty Ray Geophysical	Diamond Shamrock (1983)
1982	DS3	Diamond Shamrock	GECO	Diamond Shamrock (1982)
1984	WV	Petrocorp	Petty Ray Geophysical	Petty Ray (1984)
			Hosking Geophysical Corp.	
1984	P-059-84	Petrocorp	Western Geophysical / GECO	Petrocorp (1984)

Table 1: Seismic reflection surveys used in this study.

RED = early Motuan (middle Albian) unconformity, ORA = early Haumurian (middle Campanian) unconformity, DBL = Early Eocene unconformity, LGR = Early Oligocene conformity/unconformity, LBL = Early Miocene conformity/unconformity, DGR = Middle Miocene conformity/unconformity and YEL = Early Pliocene conformity/unconformity. These horizons have been interpreted over most of the seismic grid and allow subsurface structures and timing of deformation to be deduced (Bishop in prep.). Interpreted lines with these horizons picked are described below.

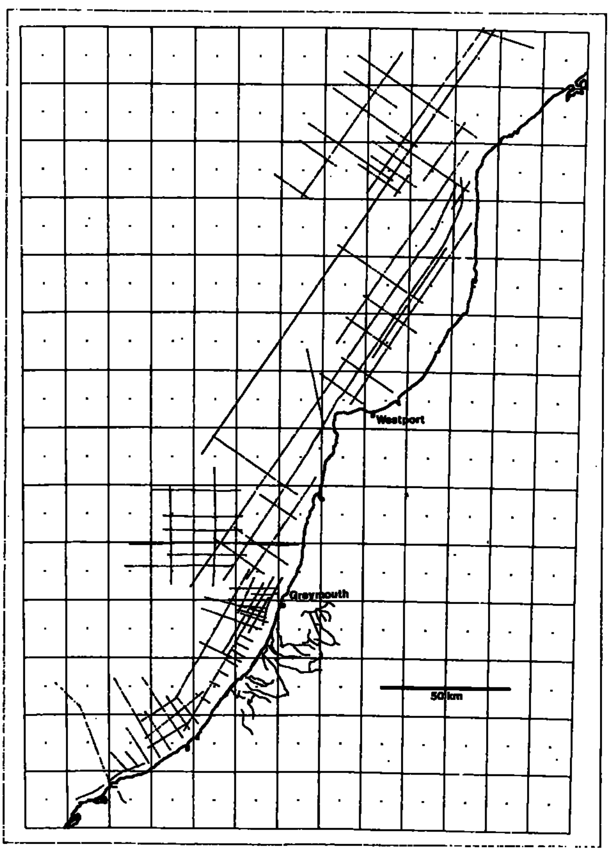

Figure 2:Map showing location of all seismic lines interpreted in this study. Grid lines have a 0.2° spacing.

Takutai Half-Graben

About 5 km offshore from Greymouth there is a WNW-ESE trending basin, more than 40 km long and up to 15 km wide (Bishop in press [a]): the Takutai Half-Graben. The structure has major bounding normal faults on the NNE side which downthrow to the SSW (Figure 3) and is divided into at least five segments by NNE-striking transfer faults. The western end is not defined by available data, but the eastern end is clearly truncated by Neogene uplift east of the Cape Foulwind Fault zone. The basin fill has not been drilled, but it has been inferred (Bishop in press [a]) to be middle - Late Cretaceous in age, perhaps lithologically similar to the breccias, sandstones and mudstones of the Pororari Group onshore, which fills basins with a similar trend and age. The Takutai

WELL NAME	TOTAL DEPTH (m)	GRID REFERENCE (METRIC)	GAS/OIL	BASEMENT REACHED ?	YEAR
Ahaura-2	1069	K31/914709	N	Y	1978
Arahura-1	1736	J33/537295	N	N	1964
Aratika-2	1149	K32/813503	N	Y	1977
Aratika-3	1729	K32/857497	N	Y	1978
Arnold River-1	710	K32/820491	N	N	1985
Bore No.252	459	K32/c704598	O&G show	N	1944
Cape Farewell-1	2817	M24/823803	N	N	1986
Card Creek-1	1342	J32/687502	N	N	1986
Chasm Creek Bore 4	160	L28/253586	N	Y	1905
Cook-1	2689	L24/48988476	N	N	1970
Corehole-10 (Aratika-1)	445	K32/817494	N	N	1942-3
Corehole-11	423	J32/677481	N	N	1943
Corehole-9 (Kotuku-1)	218	K32/840507	N	Y	1942
Glenn Creek-1	739	K32/807480	Oil show	N	1986
Haku-1	1677	J31/63218740	N	Y	1970
Harihari-1	2527	I34/044852	N	Y	1971
Kawhaka-1	852	J32/562311	N	N	1943
Kokiri-1	3233	K32/769574	N	Y	1980
Kongahu-1	2015	L26/15659504	N	Y	1984
Kotuku d23 *	290	K32/844519	N	Y	1911
Kotuku d25 *	245	K32/838512	Oil show	Y	1912
Kotuku d28 *	293	K32/832504	Gas show	Y	1921
Kotuku d30 *	375	K32/837529	Gas show	Y	1923
Kumara-2,2A	1771	J32/619464	Gas show	N	1985
Mawhera-1	697	K32/835549	N	N	1985
Mikonui-1	1846	I32/76163170	N	Y	1981
Niagara-1	1513	K32/794450	Oil show	Y	1986
Notown-1	2053	K31/819613	N	Y	1944
Paddy Gully-1	294	K32/826571	N	N	1929
S44/d253	670	J32/698591	N	N	1952
S44/d289	600	K31/725638	N	Y	1955
S44/d318	830	K31/702683	N	N	1955
SFL-1 (Kumara-1)	1661	J32/612446	Gas show	N	1942
SFL-2 (Marsden-1)	908	J32/686485	N	N	1943
Taipo Creek-1	679	K32/830485	N	N	1985
Taramakau-1	2129	J32/565450	N	Y	1964
Toropuihi-1	2193	L26/210388	N	Y	1987

Table 2: Exploration wells used in this study.

UNIT	GROUPS	FORMATIONS	MEMBERS
8	upper Blue Bottom	Eight Mile	
	Old Man	Winding Shelly Sandstone	
		Moonlight Beds	
		Giant Foresets	
7	middle Blue Bottom	O'Keefe	
		Rotokohu Coal Measures	
		upper Stillwater Mudstone	
6	lower Blue Bottom	lower Stillwater Mudstone	
		Inangahua	
		Welsh	
		Tarakohe Mudstone	
		Titira	
5	Nile	Cobden Limestone	Port Elizabeth
		Potikohua Limestone	
		Tiropahi Limestone	
		Waitakere Limestone	
		Fletcher Limestone	
		McMurray Limestone	
		New Creek	
		Steel Bridge Limestone	
		Takaka Limestone	
		Matiri	
		Garibaldi Sandstone	
		Abel Head	
		Awarua Limestone	
		Whitecliffs	
		Lyell Sand	
		Te Wharau Sand	
		Kongahu	
4	Rapahoe	Brunner Coal Measures	Omotumotu
		Motupipi Coal Measures	Torea Breccia
		Kaiata	
		Te Wharau Sand	
		Mawhera Sandstone	
		Island Sandstone	
3	Pakawau	Paparoa Coal Measures	Jay Coal Measure
		Farewell	Ford Mudstone
		North Cape	Morgan Coal Measure
		Puponga	Waiomo Mudstone
			Rewanui Coal Measure
			Goldlight Mudstone
			Dunollie Coal Measure
2	Pororari	Hawks Crag Breccia	Stitts Tuff
		Ohika	
		Bullock	
		Slaty Creek	
		Watson	
1*	Greenland		
	Waiuta		
	Haupiri		
	Aorere		
	Mt. Arthur		
	Baton		

*N.B. Unit 1 also includes igneous rocks such as the Karamea Batholith, Separation Point Batholith, Rahu Suite intrusives (Tulloch 1983), and metamorphosed rocks such as the Charleston Metamorphic Group (Nathan 1975).

Table 3. Correlation of seismic units with West Coast stratigraphy (Grindley 1961, Bowen 1964, Nathan 1974, Nathan *et al.* 1986).

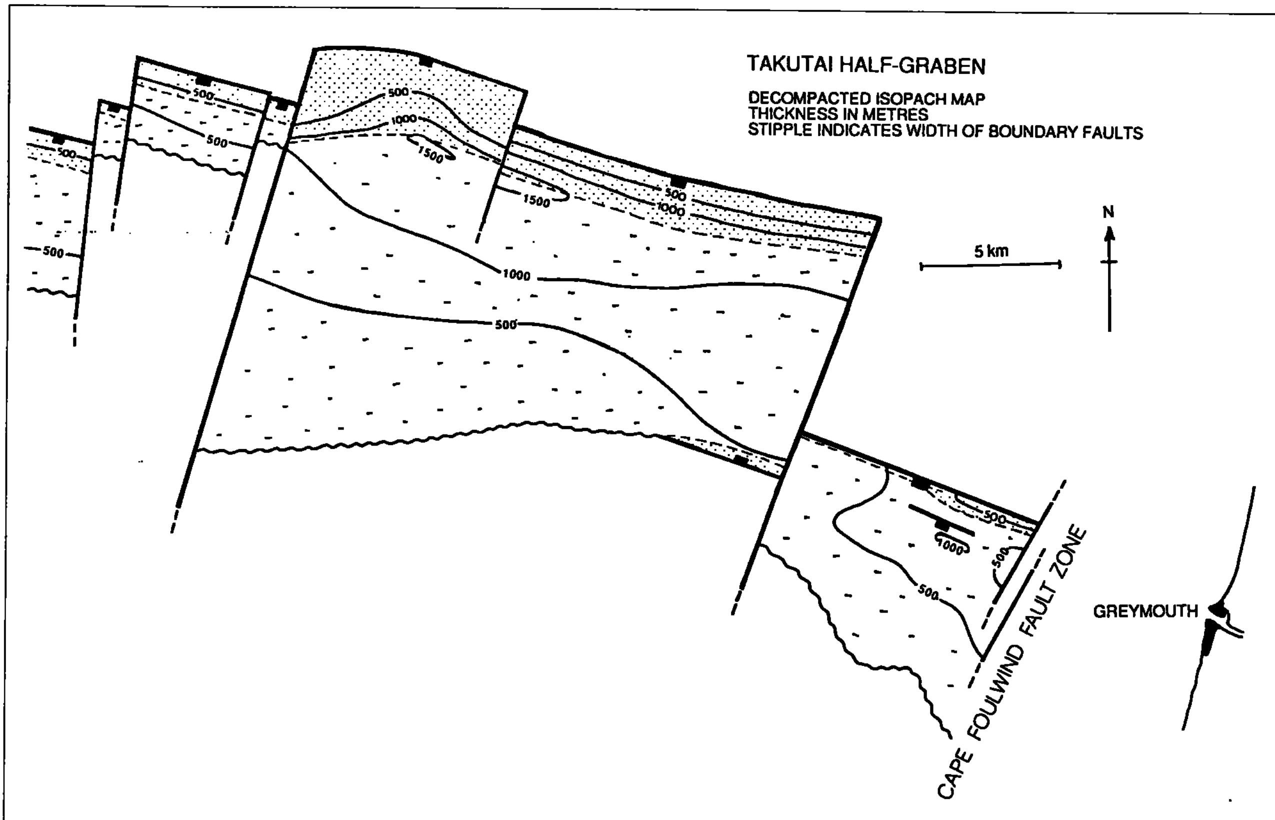

Figure 3: Decompacted isopach map of Takutai Half-Graben.

half-graben is one of many basins of this age and trend in the New Zealand continental region, which together form a widespread intra-Gondwana middle - Late Cretaceous extensional province (Bishop in press [a]).

Paparoa Basin

The Paparoa Basin formed during the Late Cretaceous, possibly due to transtension along a NNE-SSW trending West Coast-Taranaki rift corridor which linked a transform in the opening Tasman Sea, with the New Caledonia Basin (Bishop in press [a]). The basin shows active extension until the Eocene, as evidenced by fault-scarp derived breccias intercalated with Eocene marine mudstones (Laird & Hope 1968). Subsidence continued during the Oligocene, with limestones being deposited, the greatest thickness of which are along the basin axis (Bishop in prep.). Late Cretaceous-middle Eocene deposits of the Paparoa Basin are thick terrestrial coal measures and lacustrine mudstones (Nathan *et al.* 1986). Since the early Miocene, shortening across the region has reactivated some faults as reverse faults and much of the northern half of the basin has been inverted, mainly owing to reverse motion on boundary faults such as the Cape Foulwind, Grey Valley, Montgomerie, Kongahu (Lower Buller) and Maimai faults (Bishop in prep.). The inversion in the northern half of the basin has been great enough to produce mountains (the Paparoa Range) from which most of the Cretaceous - Cenozoic cover has been removed by erosion. In the central and southern end of the ranges there are exposed Late Cretaceous - Eocene coal measures: the Pike River Coalfield (Wellman 1948, Newman 1985) and the Greymouth Coalfield (Gage 1952, Newman 1985). South of Greymouth the Cretaceous-Paleogene deposits of the Paparoa Basin are buried by Neogene deposits (Figure 4), which comprise marine mudstones, siltstones and sandstones, overlain by terrestrial gravels and conglomerates (Nathan *et al.* 1986). The entire cover sequence has been deformed by NNE-SSW trending folds and thrusts during the Neogene (Figure 5).

Pakawau Basin

The Pakawau Basin is similar to the Paparoa Basin and is thought to have formed in the West Coast-Taranaki rift corridor during the Late Cretaceous (Thrasher 1990, Bishop in press [a]). The basin was active until the Oligocene during which time it accumulated a thick succession of terrestrial coal measures, marine mudstones (Thrasher, this volume), and lacustrine deposits; followed by transgressional shelly sandstones, marine siltstones and limestones (Nathan *et al.* 1986).

Since the early Miocene, several faults have been reactivated as reverse faults, such as the main eastern boundary fault: the Wakamarama Fault. The onshore part of the basin has been uplifted and tilted to the west. Much of the Cretaceous-Cenozoic cover sequence has been removed by erosion, especially in the Wakamarama Range, along the eastern margin of the basin. Offshore, the basin has been buried by Neogene marine mudstones and sandstones (Nathan *et al.* 1986, Thrasher & Cahill 1990).

Reefton Basin

During the Eocene-Oligocene the area around Reefton accumulated terrestrial coal measures, followed by marine

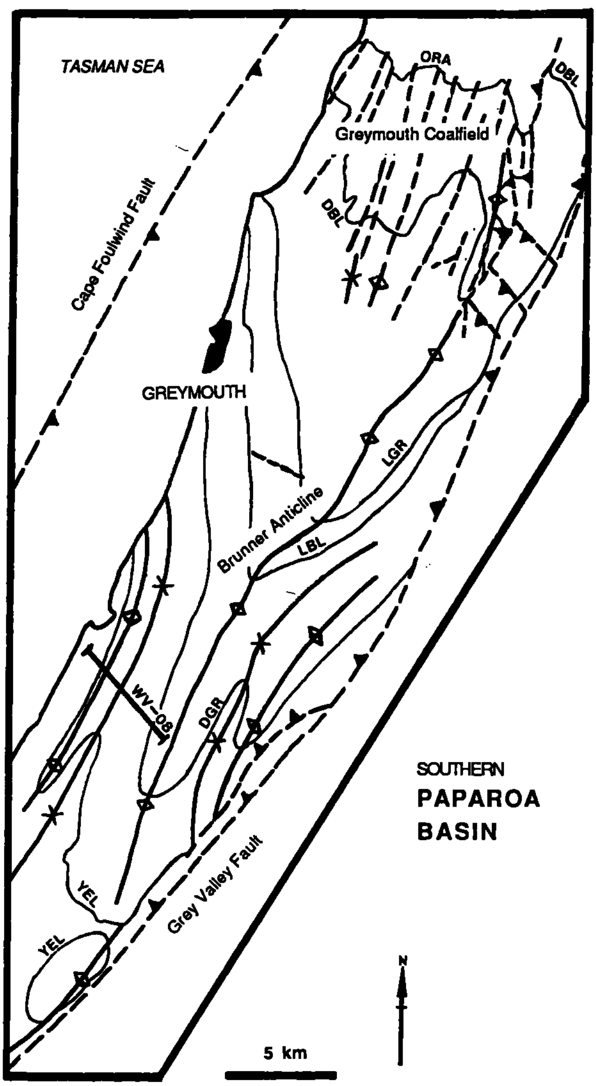

Figure 4: Map showing deformation of southern Paparoa Basin (adapted from Nathan 1978a, Carter & Bulte 1983). See text for definition of horizon codes.

siltstones, sandstones and limestones (Suggate 1957, Nathan *et al.* 1986). Regional subsidence is thought to be an important reason for deposition in the area, although extensional faulting is observed to affect these deposits, e.g. at the Garvey Creek Mine Island Block (Bishop in prep.). Since the early Miocene, the area has been uplifted and subject to erosion, which has removed much of the cover sequence. The main faults in the area have been reactivated as reverse faults (Suggate 1957), and thrusting and folding of the cover sequence is intense along the margins of the main structural blocks (Bishop in prep.). The area is now dominated by N-S to NE-SW striking reverse faults which bound uplifted and tilted blocks.

Buller Basin

The Buller Basin is defined as the region bounded by the Buller River (south), Mohikinui River (north), Glasgow Fault (east) and Kongahu Fault (west). During the Eocene - Oligocene the area accumulated a sequence of terrestrial coal measures, marine mudstones, siltstones, sandstones and intercalated breccias (Laird 1968, Nathan *et al.* 1986). Regional subsidence is thought to have controlled sedimentation, although abrupt lateral thickness changes may be owing to paleotopography and/or extensional faulting (Titheridge 1988). The western boundary of the basin was a normal fault scarp, as indicated by eastward thinning and fining breccias (Laird 1968). Since the early Miocene, the basin has been uplifted to about 800-900 m above mean sea level and erosion has removed part of the cover sequence, particularly the less resistant marine deposits, exhuming underlying coal measures. The basin is bounded by the southeast-dipping Kongahu and Glasgow reverse faults, and shortening across the region (directed WNW-ESE) has produced gentle folds, joints and strike-slip faults (Barry & MacFarlan 1988, Todd 1989, Bishop in press [b]).

Westport-Karamea Basin

This basin is now bounded by Neogene reverse faults, namely the Cape Foulwind Fault to the west and the Kongahu (Lower Buller) Fault to the east. Eocene-Oligocene deposits are found in the basin: Eocene coal measures are present in the onshore part of the basin, between Barrytown and Westport (Laird 1988, Nathan 1975, 1976), and north of Karamea township (Neef 1981). The distribution of coal measures in the offshore Karamea Bight remains uncertain, although they were drilled by Kongahu-1 (Wiltshire 1984) and are recognised on seismic lines (Bishop in prep.). The Eocene - Oligocene sequence is transgressive and the coal measures are overlain by marine sandstones, mudstones and calcflysch (German 1976, Nathan *et al.* 1986). The coal measures were probably deposited during a period of regional subsidence. Breccias intercalated with calcflysch indicates syndepositional extension during the Oligocene (German 1976, Bishop in prep.). The Paleogene deposits are overlain in most places by thick Neogene marine mudstones, siltstones, sandstones and ultimately terrestrial gravels and conglomerates (Nathan *et al.* 1986). The Cenozoic cover has been folded and cut by reverse faults and thrusts, which trend NNE-SSW (Neef 1981, Laird 1988), although the degree of shortening decreases westwards, as can be seen on seismic reflection profiles (Bishop in prep.).

Offshore Eocene basins

The offshore wells– Haku-1, Mikonui-1 and Kongahu-1– all drilled into Eocene deposits, 100-200 m thick (Hematite Petroleum 1970, Diamond Shamrock 1981, Wiltshire 1984). These deposits comprise coal measures and mudstones, similar to the onshore sequence of the same age. They can be recognised and mapped using seismic lines and occupy broad shallow depressions, with few faults (Bishop in prep.). These basins are probably formed by regional subsidence. The Eocene basins are now buried beneath Oligocene-Recent limestone, marine mudstone, siltstone and sandstone. The bulk of these deposits are a Pliocene-Recent sequence, about 1500-2000 m thick, which has prograded from the coast toward the continental margin (i.e. generally WNW to NW) and is recognised on seismic lines as giant clinoforms (Bishop in prep.). This Pliocene - Recent sequence is correlated here with the Giant Foresets Formation to the north, which has a very similar appearance on seismic lines and is of the same age (Shell, B.P. & Todd 1977).

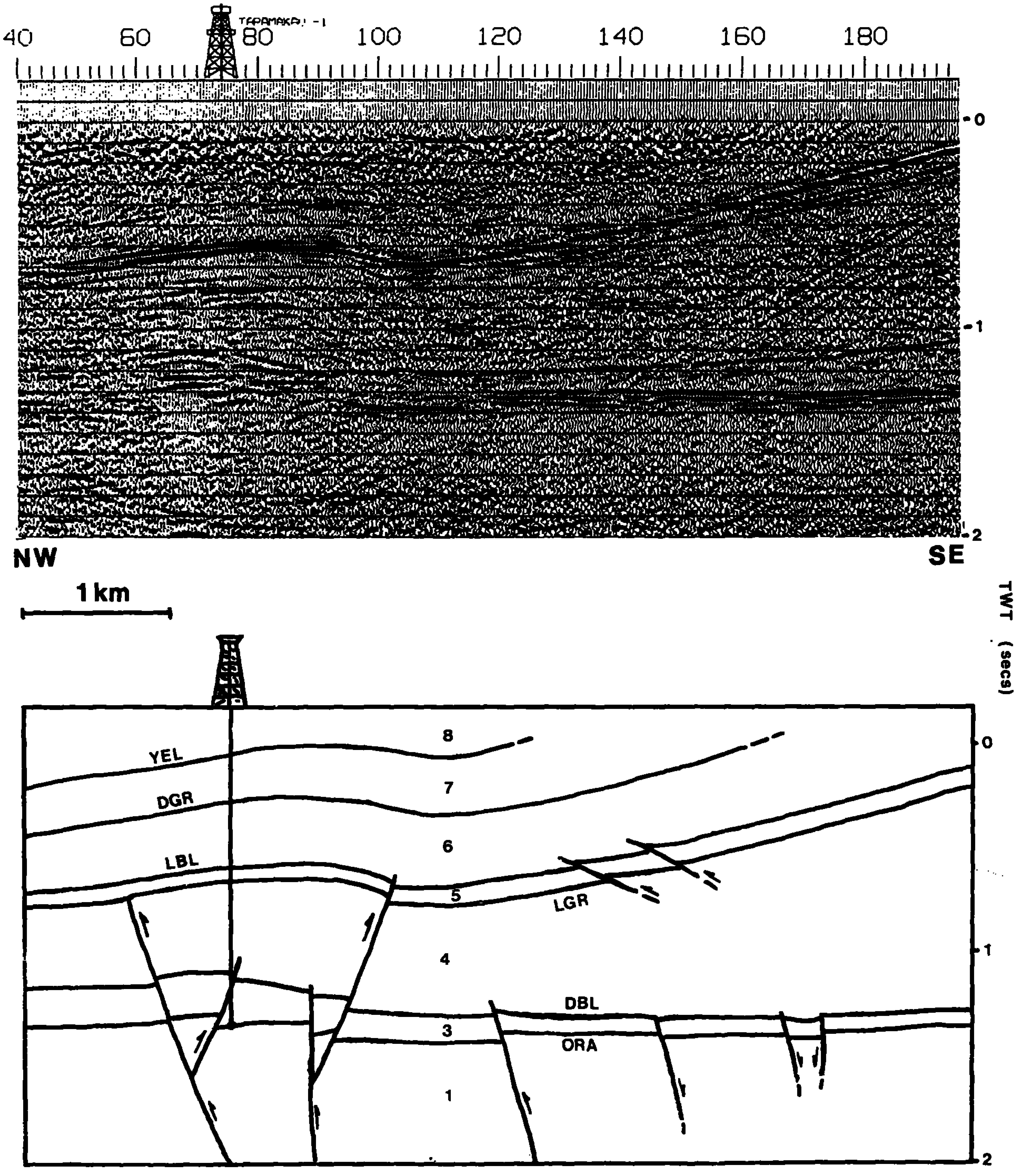

Figure 5: Interpretation of line WV-08 (Petty Ray 1984), a migrated stacked time section (location on Figure 4). See text for definition of horizon codes and Table 3 for unit numbers.

Grey-Inangahua Basin

This Neogene foredeep basin is now bounded by reverse faults and mountain ranges (Figure 6), with the Paparoa Range, Glasgow (Inangahua), Maimai, Montgomerie and Grey Valley faults to the west, and the Victoria Range, Hohonu Range, Lyell and Hohonu faults to the east. Cretaceous-Paleocene coal measures have been located by drillholes in the southern part of the basin, such as Mawhera-1 and Aratika-2 (Petroleum Resources 1985, Harrison 1977). Eocene sandstones have also been drilled in this area, e.g. by Mawhera-1 and Card Creek-1 (Petroleum Resources 1985, Dunn *et al.* 1986). Eocene coal measures outcrop at the northern end of the basin (Nathan 1978b, Suggate 1957). Oligocene limestone is widespread in the basin, recognised in outcrop (Nathan 1978b, Suggate 1957) and in the subsurface from wells and seismic lines (Matthews 1990). The bulk of the basin fill is Neogene marine mudstones, siltstones and sandstones, overlain and partly interdigitating with terrestrial coal measures, gravels and conglomerates (Nathan *et al.* 1986). The basin and its sedimentary fill have

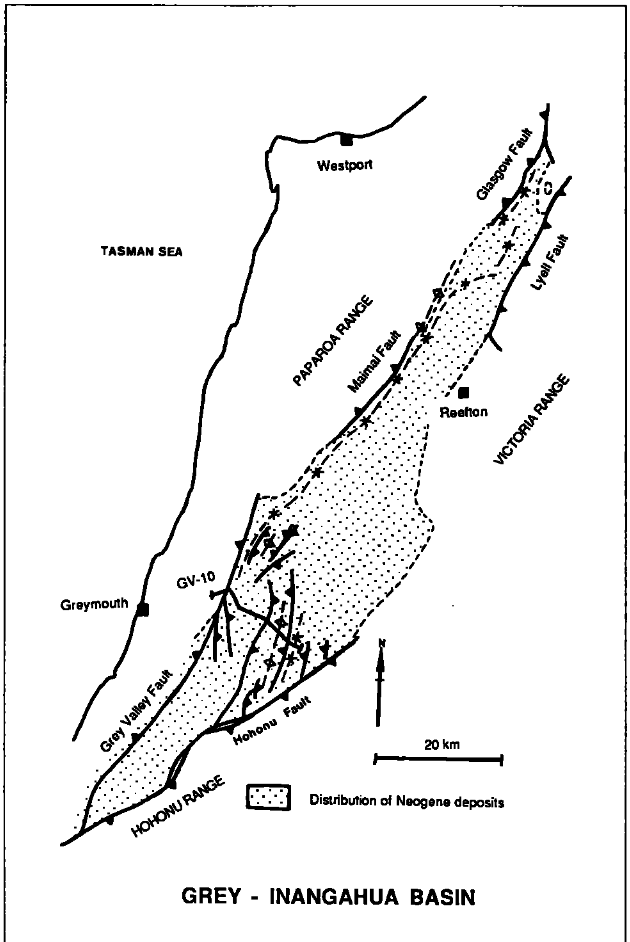

Figure 6: Map showing deformation of Grey-Inangahua Basin (adapted from Nathan 1978a,b, Nathan *et al.* 1986, Matthews 1990).

been deformed by generally NNE-SSSW trending folds and thrusts during the Neogene (Figure 6 and Figure 7).

Petroleum exploration potential

The potential source rocks for gas and oil are middle Cretaceous to Eocene in age, on the basis that these have the highest Total Organic Carbon (TOC) and genetic potential (Table 4). Potential reservoir rocks in the region include Pororari Group (although much of it is pervasively cemented), Paparoa Coal Measures, Brunner Coal Measures, Kaiata Formation sandstone members (e.g. Omotumotu Member)

	Total organic carbon (TOC) * %	Genetic potential kg/tonne*
Kaiata Formation	0.85	1.0-1.8
Brunner Coal Measures	0.96-4.79	0.7-13.5
Paparoa Coal Measures	2.3	2.2-7.3
Pororari Group	3.29	5.2

* Carbonaceous mudstones

Table 4: Potential source rock data (Nathan *et al.* 1986).

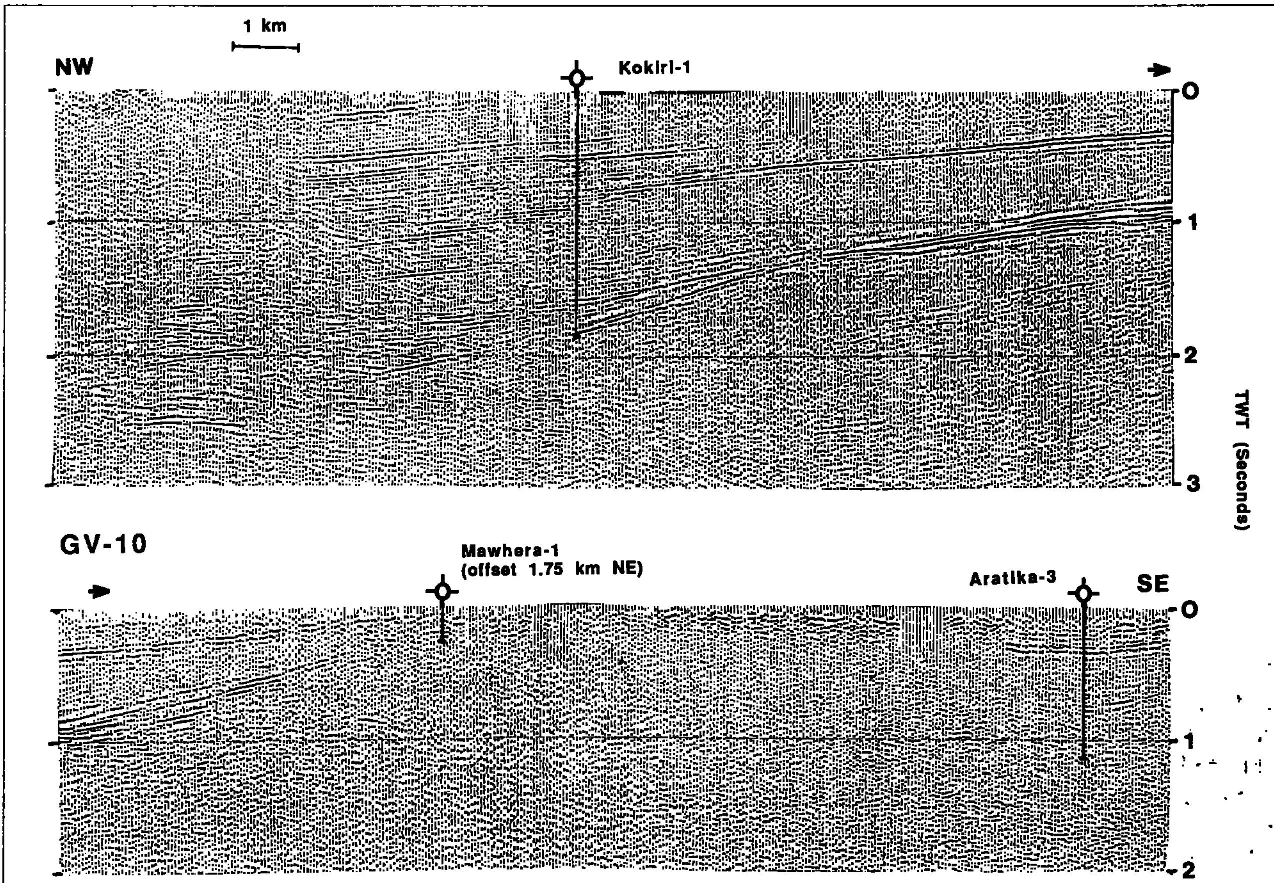

Figure 7a: Interpretation of line GV-10 (Rubens 1978), a stacked time section (location on Figure 6). See text for definition of horizon codes and Table 3 for unit numbers.

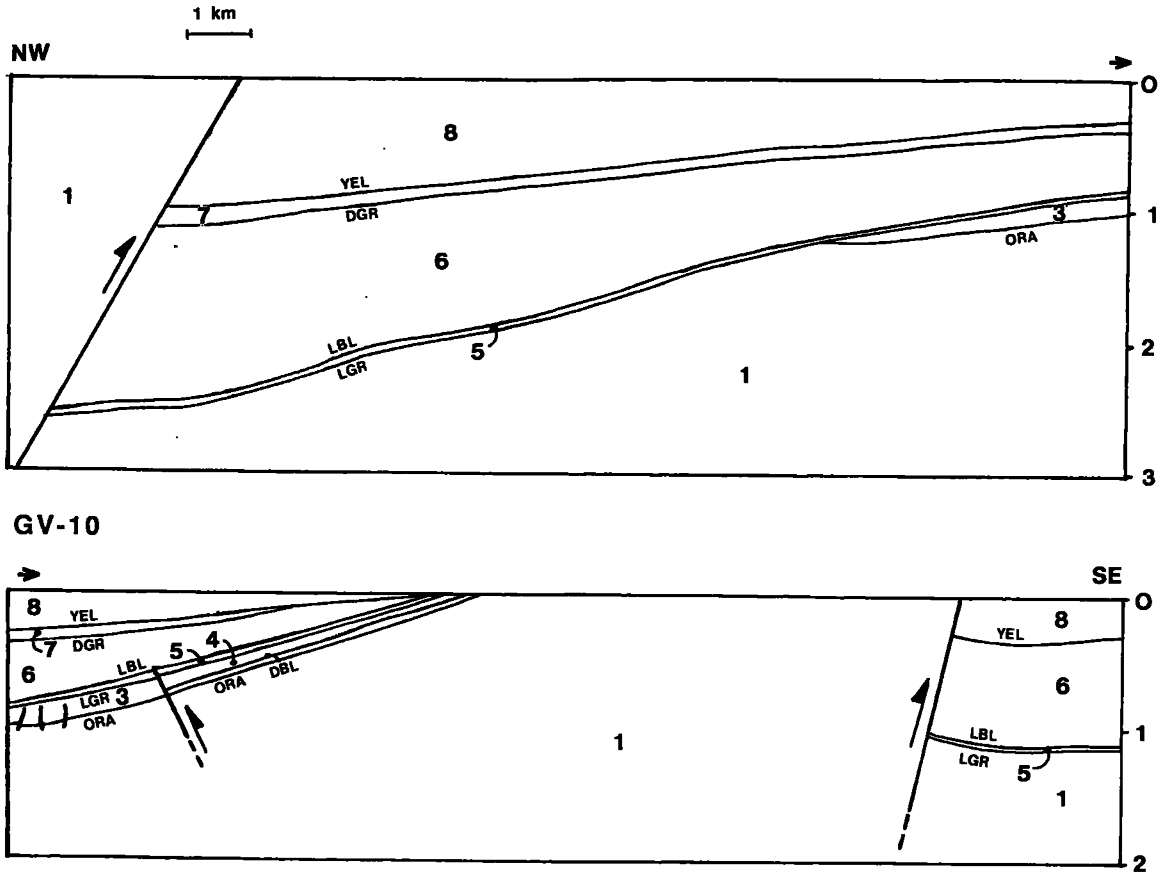

Figure 7b: Interpretation of line GV-10 (Rubens 1978), a stacked time section (location on Figure 6). See text for definition of horizon codes and Table 3 for unit numbers.

and Blue Bottom Group sandstone members (e.g. Niagara Sandstone), (Nathan *et al.* 1986, Matthews 1990). Potential cap rocks include Blue Bottom Group mudstones and Nile Group limestones (Nathan *et al.* 1986). Suggate (1959) showed from the metamorphism of Cretaceous-Eocene coals of the West Coast that maximum burial took place in the late Eocene to Oligocene, in the Paparoa, Pakawau, Reefton and Buller basins, all of which have since been substantially inverted. Therefore, conditions were best for maturation of hydrocarbons in these basins during the late Eocene-Oligocene. However, traps which existed at that time are most likely to have been removed by subsequent uplift/ erosion and/or breached by Neogene thrusts and reverse faults. One possible exception may be the Takutai Half-Graben, which has largely escaped Neogene deformation and which may have been charged by migration from the adjacent Paparoa Basin in the late Eocene-Oligocene. Potential source rocks in the Grey-Inangahua Basin, Westport-Karamea Basin, southern Paparoa Basin, Takutai Half-Graben and other offshore basins have all been buried since the early Miocene, mainly during the Pliocene-Recent (Figure 8). Depths of burial greater than 3 km have been achieved in the southern Grey-Inangahua basin (Nathan *et al.* 1986) and in the lower part of the Takutai Half-Graben (Bishop in press [a]), which may be sufficient to mature source rocks and generate oil or gas. Widespread folding and thrusting in the Neogene basins has created numerous potential traps. Traps may exist along the nearshore fold and thrust belts (e.g. Cape Foulwind Fault Zone and Kongahu Fault Zone, (Bishop in prep.)), which would be better resolved with further seismic reflection surveys. Structural traps exist up-dip of deep kitchen areas in onshore fold and thrust belts (e.g. southern Paparoa Basin (Wellman 1950), central-northern Grey-Inangahua Basin (Matthews 1990, Nathan 1978b)).

Conclusions

The tectonic history of the West Coast is one of polyphase deformation (Bishop in prep.), but four main phases can be distinguished:

- middle Cretaceous-Late Cretaceous rifting with a WNW-ESE trend, part of a regional Gondwana rifting province;
- Late Cretaceous-Paleocene transtensional rifting concentrated along a NNE-SSW trending corridor through the West Coast and Taranaki;
- Eocene-Oligocene regional subsidence followed by local rifting, progressing from south to north with time; and
- Miocene-Recent shortening directed WNW-ESE, re-activation of faults as reverse and/or strike-slip faults, folding and thrusting of the cover sequence, inversion of pre-Neogene basins and creation of Neogene foredeep basins.

The potential source rocks for oil and gas generation are middle Cretaceous-Eocene in age and are widespread. Suitable reservoir and cap rocks are present. Depending on location, maturation peaked in the late Eocene-Oligocene or

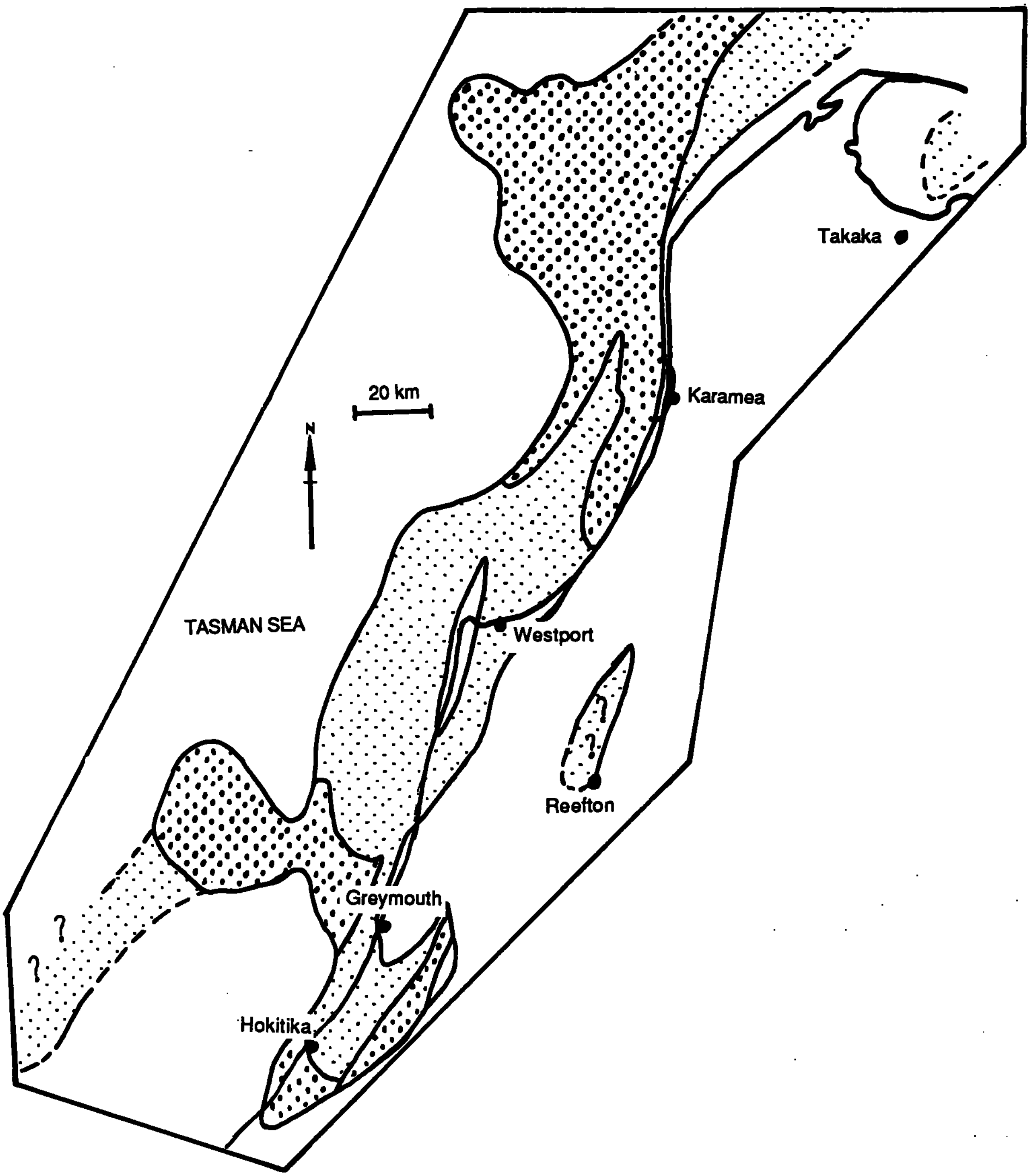

Figure 8: Map showing distribution of potential source rocks of middle Cretaceous - Eocene age, within the main regions of Neogene subsidence. Heavy stipple indicates where source rocks are buried to over 2000 m (from Nathan *et al.* 1986 and Bishop in prep.)

during the Pliocene-Recent. Any oil and gas generated during the earlier period is not likely to be present now, except perhaps in the Takutai Half-Graben. Any generated during the later period is much more likely to have been trapped, since structural traps have been formed during the Miocene-Present.

References

BARRY, J.; MACFARLAN, D. 1988: Geology and coal resources of the Upper Waimangaroa and Mt. William South sectors, Buller Coalfield. Coal geology report 13. Ministry of Energy.

BISHOP, D. G.; BRADSHAW, J. D.; LANDIS, C. A. 1985: Provisional terrane map of South Island, New Zealand. *In* Tectonostratigraphic terranes of the circum-Pacific region (ed. D.G. Howell). Circum-Pacific Council for Energy and Mineral Resources, *Earth science series, no. 1.*

BISHOP, D. J. 1989: The structural interpretation of seismic reflection data between Hokitika and Cape Foulwind, South Island. New Zealand geology & geophysics conference 1989, Auckland, abstracts volume: 23. *Geological Society of New Zealand miscellaneous publication 43.*

____________ in press [a]: Extensional tectonism and magmatism during the middle Cretaceous to Paleocene, North Westland, New Zealand. *New Zealand journal of geology and geophysics.*

____________ in press [b]: Neogene deformation of part of the Buller Coalfield: implications for the West Coast region, New Zealand. *New Zealand journal of geology and geophysics.*

BOWEN, F. E. 1964: Sheet 15 - Buller. Geological map of New Zealand 1:250,000. Department of Scientific and Industrial Research, Wellington.

CARTER, M.; BULTE, G. 1983: Interpretation report PPL 38070 (Petroleum Corporation of NZ (Exploration) Ltd). Report no. 0210. D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no.956.

CULTUS PACIFIC 1981: Operations report marine seismic survey Karamea NZ CK-81. (Cultus Pacific N.L.) Geophysical Service Incorporated. D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no. 884.

DIAMOND SHAMROCK 1981: Mikonui-1 well report. D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no. 836.

____________ 1982: Seismic reflection data, PPL 38059. Westland Basin. (Diamond Shamrock). Geco. D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no. 1124.

____________ 1983: Vibroseis survey conducted in PPL 38059 (offshore Westland). (Diamond Shamrock Oil Company (Aust.) Pty Ltd. D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no. 1193.

DUNN, P.; KELLY, C.; HILLYER, N.; TOOMATH, A.; GARLAND, B. 1986: Card Creek-1 well completion report, PPL 38070. D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no. 1186.

ESSO 1969: Final report of marine seismic surveys, PPL 711 (offshore Karamea) (Esso Exploration and Production N.Z. Inc.). D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no.401.

GAGE, M. 1952: The Greymouth Coalfield. *New Zealand Geological Survey bulletin 45.*

GERMAN, R. C. 1976: Stratigraphy and sedimentology of the Nile Group (Oligocene) Southwest Nelson. Unpublished M.Sc. thesis. University of Canterbury, New Zealand.

GREARSON, L. S. 1982: Seismic interpretation report PPL 38129 offshore New Zealand. (Seahawk Oil International Inc.). D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no. 867.

GRINDLEY, G. W. 1961: Sheet 13 - Golden Bay. Geological map of New Zealand 1:250,000. Department of Scientific and Industrial Research, Wellington.

HARRISON, J. 1977: Well completion report Aratika-2 (Offshore Mining Company Ltd). D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no. 719.

HEMATITE PETROLEUM 1970: Haku-1 well report. D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no. 553.

LAIRD, M. G. 1968: The Paparoa Tectonic Zone. *New Zealand journal of geology and geophysics 11(2)*: 435-454.

____________ 1988: Sheet S37 - Punakaiki. Geological map of New Zealand 1:63,360. Department of Scientific and Industrial Research, Wellington.

LAIRD, M. G.; Hope, J. M. 1968: The Torea Breccia and the Papahaua Overfold. *New Zealand journal of geology and geophysics 11(2)*: 418-434.

MATTHEWS, E. R. 1990: Exploration in the onshore Westland basin. 1989 New Zealand oil exploration conference proceedings volume 1:62-70. Petroleum and Geothermal Unit, Energy and Resources Division, Ministry of Commerce.

MINISTRY OF ENERGY 1989: Petroleum wells in New Zealand 1865-1989. Ministry of Energy.

MORGAN, P. G. 1911: The geology of the Greymouth subdivision, North Westland. *New Zealand Geological Survey bulletin 13.*

NATHAN, S. 1974: Stratigraphic nomenclature for the Cretaceous - Lower Quaternary rocks of Buller and North Westland, West Coast, South Island, New Zealand. *New Zealand journal of geology and geophysics 17(2)*:423-445.

____________ 1975: Sheets S23 & S30 - Foulwind and Charleston (1st Edn.). Geological map of New Zealand 1:63,360. Department of Scientific and Industrial Research, Wellington.

____________ 1976: Sheets S23/9 and S24/7 - Foulwind and Westport. Geological map of New Zealand 1:25,000. Department of Scientific and Industrial Research, Wellington

____________ 1978a: Sheet S44 - Greymouth. Geological map of New Zealand 1:63,360. Department of Scientific and Industrial Research, Wellington

____________ 1978b: Sheets S31 & part S32 - Buller-Lyell (1st edn.). Geological map of New Zealand 1:63,360. Department of Scientific and Industrial Research, Wellington.

NATHAN, S.; ANDERSON, H. J.; COOK, R. A.; HERZER, R. H.; HOSKINS, R. H.; RAINE, J. I.; SMALE, D. 1986: Cretaceous and Cenozoic sedimentary basins of the West Coast Region, South Island, New Zealand. *New Zealand Geological Survey basin studies 1* Department of Scientific and Industrial Research, Wellington.

NEEF, G. 1981: Cenozoic stratigraphy and structure of Karamea - Little Wanganui district, Buller, South Island, New Zealand. *New Zealand journal of geology and geophysics 24(2)*:177-208.
NEW ZEALAND PETROLEUM COMPANY LTD 1974: Seismic surveys of the West Coast, South Island. D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no. 523.
NEWMAN, J. 1985: Paleoenvironments, coal properties and their interrelationships in Paparoa and selected Brunner Coal Measures on the West Coast of the South Island. Unpublished Ph.D. thesis. University of Canterbury, New Zealand.
PETROCORP 1984: Seismic survey conducted in PPL 38059 (offshore Westland). (Petroleum Corporation of NZ (Exploration Ltd). Western Geophysical Company/GECO. D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no. 1194.
PETROLEUM RESOURCES 1985: Mawhera-1 well completion report. D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no.1085.
PETTY RAY 1984: Grey River Basin NZ, Westland Vibroseis Survey. PPL 38070. (Petroleum Corporation of NZ (Exploration) Ltd). D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no. 1082.
ROBINSON, P. H. 1987: Review of the geology and hydrocarbon prospectivity of PPL 38501, coastal Westland, New Zealand. D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no. 1362.
RUBENS, C.T.P. 1978: Grey Valley seismic survey. Field operations and processing report - file no. 0078 (Petroleum Corporation of N.Z. (Exploration) Ltd). D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no. 743.
SHELL, B.P., TODD 1977: Well resume Tane-1 (offshore) PPL 38007, sub-area of Taranaki, New Zealand. D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no. 698.
SUGGATE, R. P. 1957: The geology of the Reefton subdivision. *New Zealand Geological Survey bulletin 56.*
_____________ 1959: New Zealand coals. *Department of Scientific and Industrial Research Bulletin 134.*
SUPERIOR OIL COMPANY 1943: Well data and correspondence on wells drilled by the company - (Corehole 9, 10 and SFL-1, 2). D.S.I.R. Geology & Geophysics unpublished open-file report no. 173.
THRASHER, G. P. 1990: Tectonics of the Taranaki Rift. 1989 New Zealand oil exploration conference proceedings volume 1. Petroleum and Geothermal Unit, Energy and Resources Division, Ministry of Commerce.
THRASHER, G. P.; CAHILL, J. P. 1990: Subsurface maps of the Taranaki Basin region, New Zealand. *New Zealand Geological Survey report G142* .
TITHERIDGE, D. G. 1988: Sedimentology of the Brunner Coal Measures. Unpublished Ph.D. thesis, University of Wollongong, Australia.
TODD, A. 1989: Geology and coal resources of the Denniston sector, Buller Coalfield. Coal geology report 18. Ministry of Energy.
TULLOCH, A. J. 1983: Granitoid rocks of New Zealand - a brief review. *Geological Society of America memoir 159*: 5-20.
WELLMAN, H. W. 1948: Geology of the Pike River Coalfield, North Westland. *New Zealand Journal of Science and Technology B30(2)*: 84-95.
_____________ 1950: Tertiary geology of sheet S51 (Kumara), with notes on the Cretaceous and Tertiary outliers to the south (S57,S58,S64). Unpublished manuscript held at D.S.I.R. Geology & Geophysics library, Lower Hutt, New Zealand.
_____________ 1971: Geology of the Kotuku Oilfield, Westland. *New Zealand Geological Survey report 48.*
WILTSHIRE, M. J. 1984: Well completion report Kongahu-1. PPL 38058 offshore, West Coast, South Island, New Zealand. Home Energy Company Ltd. D.S.I.R. Geology & Geophysics unpublished open-file petroleum report no. 1035.

Acknowledgments

This paper summarises some of the results of a Ph.D. thesis currently in preparation by the author at the time of writing. The Ph.D. project has been financially supported by a Commonwealth Scholarship (New Zealand Vice Chancellors' Committee), Victoria University of Wellington Internal Research Grants and Victoria University of Wellington Department of Geology. I would like to thank my supervisors Dick Walcott and Angela Jayko; D.S.I.R. Geology & Geophysics, Lower Hutt for providing access to open-file seismic reflection and well data; and GECO NZ for duplicating seismic reflection lines.

Author

DAN BISHOP gained a B.A. (Hons.) in Geology at Oxford University in 1988. He completed a seismic interpretation and mapping study of the North Sea Central Graben for Mobil Exploration in London in the same year, before taking up a Commonwealth Scholarship to Victoria University of Wellington. He is currently completing a Ph.D. on Cretaceous-Tertiary tectonics and seismic interpretation of North Westland and Northwest Nelson.