

## NEW ZEALAND'S OFFSHORE SEDIMENTARY BASINS

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### SUMMARY

This document contains additional descriptions of the geological fill within sedimentary basins described in the paper '*New Zealand's offshore sedimentary basins*', published in the New Zealand Journal of Geology and Geophysics. The data presented herein are primarily derived from regional-scale assessments of New Zealand's major offshore sedimentary basins, undertaken as part of the Atlas of Petroleum Prospectivity research programme, which is described below.

### INTRODUCTION

The "Atlas of Petroleum Prospectivity" (APP) programme was a four-year (October 2014–September 2018) New Zealand Government-funded research programme (MBIE Energy and Minerals targeted research fund) led by GNS Science. The broad-scale objective was to synthesise the wealth of existing and new data, information, and knowledge within GNS Science, supplemented by other open-file sources, into a nationally significant baseline reference GIS-based atlas that for the first time summarised in one place the current understanding of New Zealand's geologically complex offshore petroleum basins. Essentially, the "atlas" comprises a series of new and updated digital maps (and associated metadata) of the key geological components relevant to petroleum exploration, providing a consistent template for evaluating stratigraphic architecture and petroleum prospectivity within and between offshore basins across that part of Zealandia within New Zealand's jurisdiction. The atlas also provides a basis for identifying where new geoscience data and interpretations

are required to better understand geological evolution of a region.

The entire suite of outputs from the APP programme, and documentation regarding methodologies used, are available for free download from <https://data.gns.cri.nz/pbe/>. The APP programme delivered a series of digital data sets of key petroleum system elements in NZ's offshore sedimentary basins. Where data coverage allowed, the completed data sets are map-based and include total sediment thickness, paleogeography, source and reservoir rock distribution, source rock maturity, structure, and other salient information. To achieve a phased delivery of programme outputs, New Zealand's offshore territory was subdivided into a series of geographically based "provinces" (Figure 1). Each province incorporates at least two sedimentary basins, which are connected in terms of their broad-scale geological history. The provinces are:

- Northwest Province (Reinga-Northland, inner Aotea [previously 'Deepwater Taranaki'], and Taranaki basins) – Arnot et al. (2016)
- Southeast Province (Canterbury-Great South basins) – Sahoo et al. (2017)
- Northeast Province (Raukumara, East Coast, and Pegasus basins) – Strogon et al. (2018)
- Southwest Province (West Coast, Fiordland, and western Southland basins) – Arnot et al. (2018)
- Tasman frontier (Aotea, Monowai [and Moore], Bellona, West Challenger basins) – Bland and Strogon (2018)
- Campbell frontier (Pukaki, Outer Pukaki, Campbell, and Outer Campbell basins) – Bland et al. (2018a)

- Chatham-Bounty frontier (Bounty Trough Basin and Chatham Rise) – Bland et al. 2018b).

An important outcome from the APP programme's datasets has been the opportunity to update our knowledge of the extent of New Zealand's offshore sedimentary basins (Figure 2) and the thickness of rocks within them (Figure 3), using a consistent framework with the same set of regional seismic horizons mapped where possible in all basins (Table 1), regardless of lithostratigraphy or facies. We provide herein a high-level regional-scale overview of the basins and the stratigraphy within them.

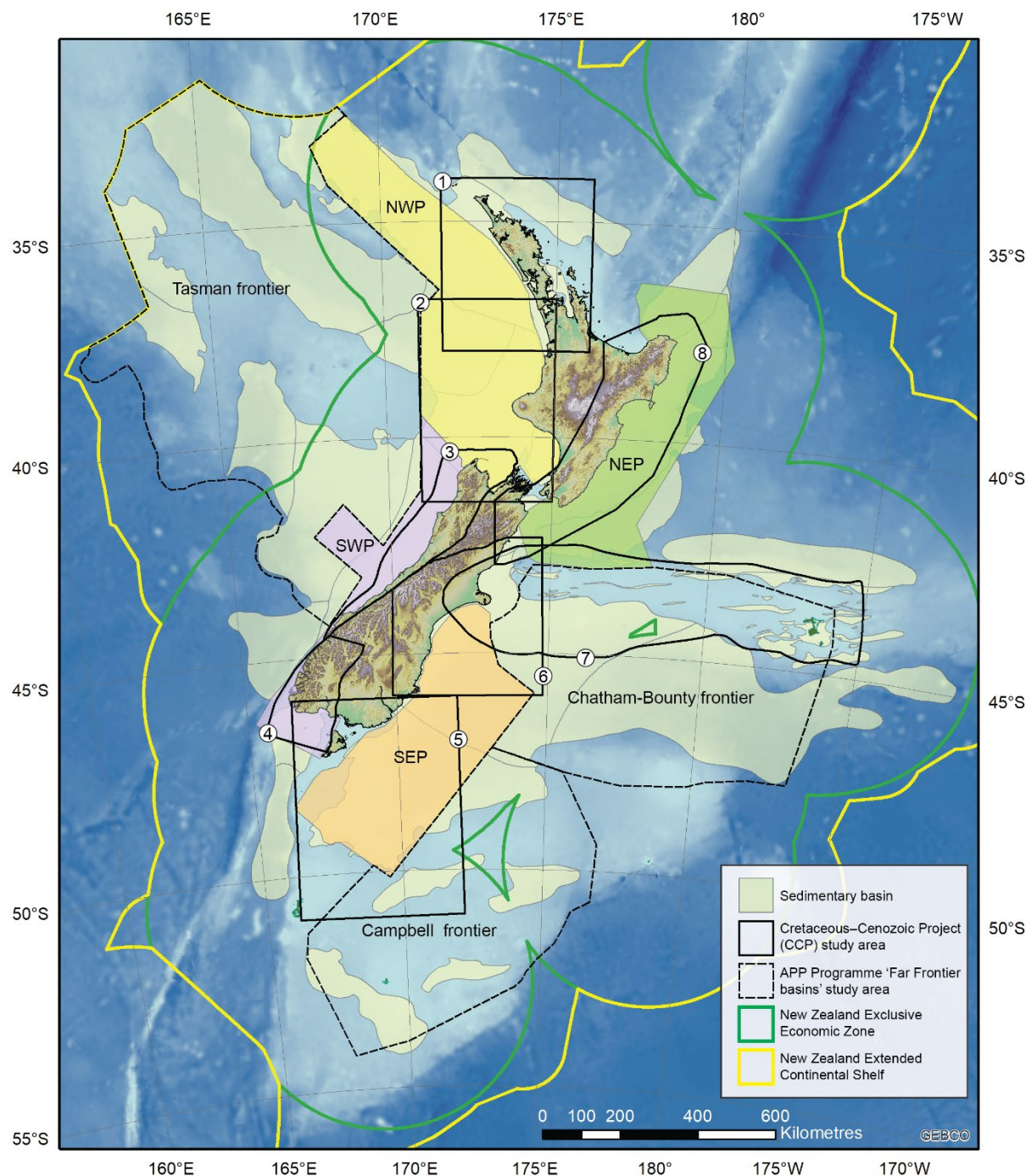


Figure 1 Overview map showing locations of sedimentary basins within New Zealand's Extended Continental Shelf, the APP programme's mapping areas (coloured polygons, and dashed-outline polygons), and the locations of Cretaceous–Cenozoic Project study areas with offshore components (numbered). NWP, Northwest Province (Arnot et al. 2016); NEP, Northeast Province (Strogen et al. 2018); SWP, Southwest Province; SEP, Southeast Province (Sahoo et al. 2017); Tasman frontier – Bland and Strogen (2018); Campbell frontier – Bland et al. ((2018a); Chatham-Bounty frontier – Bland et al. (2018b). 1 – Northland (Isaac et al. 1994); 2 – Taranaki Basin (King and Thrasher 1996); 3 – West Coast Region (Nathan et al. 1986); 4 – Western Southland (Turnbull et al. 1993); 5 – Great South Basin (Cook et al. 1999); 6 – Canterbury Basin (Field et al. 1989); 7 – Chatham Rise Region (Wood et al. 1989); 8 – East Coast Region (Field et al. 1997). Table 1 Summary listing of the 10 regional seismic horizons mapped, where possible, across New Zealand's EEZ/ECS as part of the Atlas of Petroleum Prospectivity programme and their relationship to the Zealandia-wide seismic naming scheme of Strogen & King (2014). Four additional/different horizons were mapped in the NEP (parts of the Pegasus–East Coast–Raukumara basins), highlighted in grey. The approximate ages assigned to the regional seismic horizons are referenced to the recalibrated New Zealand Geological Timescale of Raine et al. (2015a; also refer to Raine et al. (2015b) for more detail).

<b>Zealandia 4DT naming scheme</b>	<b>Age (NZ Stage)</b>	<b>Age (Ma, approx.)</b>	<b>Comments</b>
SEABED	Recent	0	Seabed
N90	Castlecliffian	1.5	Mid-Pleistocene; mapped in the Pegasus, Cook Strait, Wairarapa, and Hawke Bay areas (Strogen et al. 2018).
N80	Mangapanian	2.5	Base Pleistocene; mapped in the Pegasus and Wairarapa areas (Strogen et al. 2018)
N60	Late Opoitian	c. 4	Approximates base Pliocene
N40	Tongaporutuan	c. 11 Ma	Late Miocene. Mapped in the Pegasus and Wairarapa areas as an intra-Miocene unconformity (Strogen et al. 2018).
N10	Otaian	c. 21	Approximates base Miocene
N05	Waitakian	c. 23	Base Miocene in the Raukumara area (Strogen et al. 2018). Relates to base of the East Coast Allochthon where present, or correlative conformity
P50	Early Whaingaroan	c. 35	Base Oligocene
P10	Teurian-Waipawan boundary	c. 56	Base Eocene
P00	Haumurian-Teurian boundary	c. 66	Base Paleocene
K90	Late Haumurian	c. 75	Base Late Haumurian sub-stage
K80	Piripauan	c. 85	Base Early Haumurian Stage
K50	Ngaterian	c. 98	Mid-Cretaceous
BASEMENT	Variable across basins		Top Seismic Basement



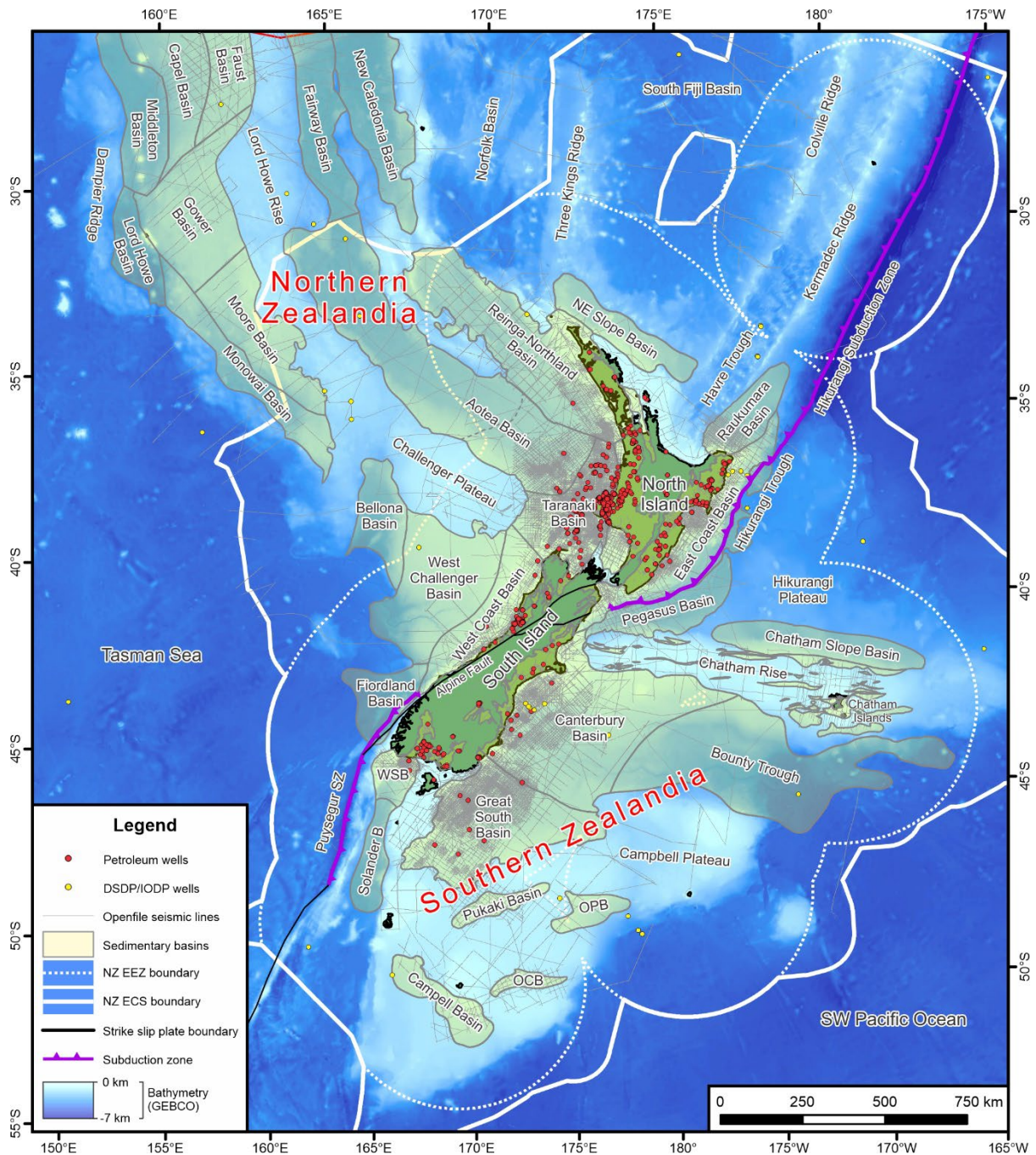


Figure 2 Distribution of open-file seismic reflection data, petroleum exploration drillholes, and DSDP/IODP wells used within the APP programme. Also shown are the revised sedimentary basin boundaries presented within Bland et al. (NZJGG).



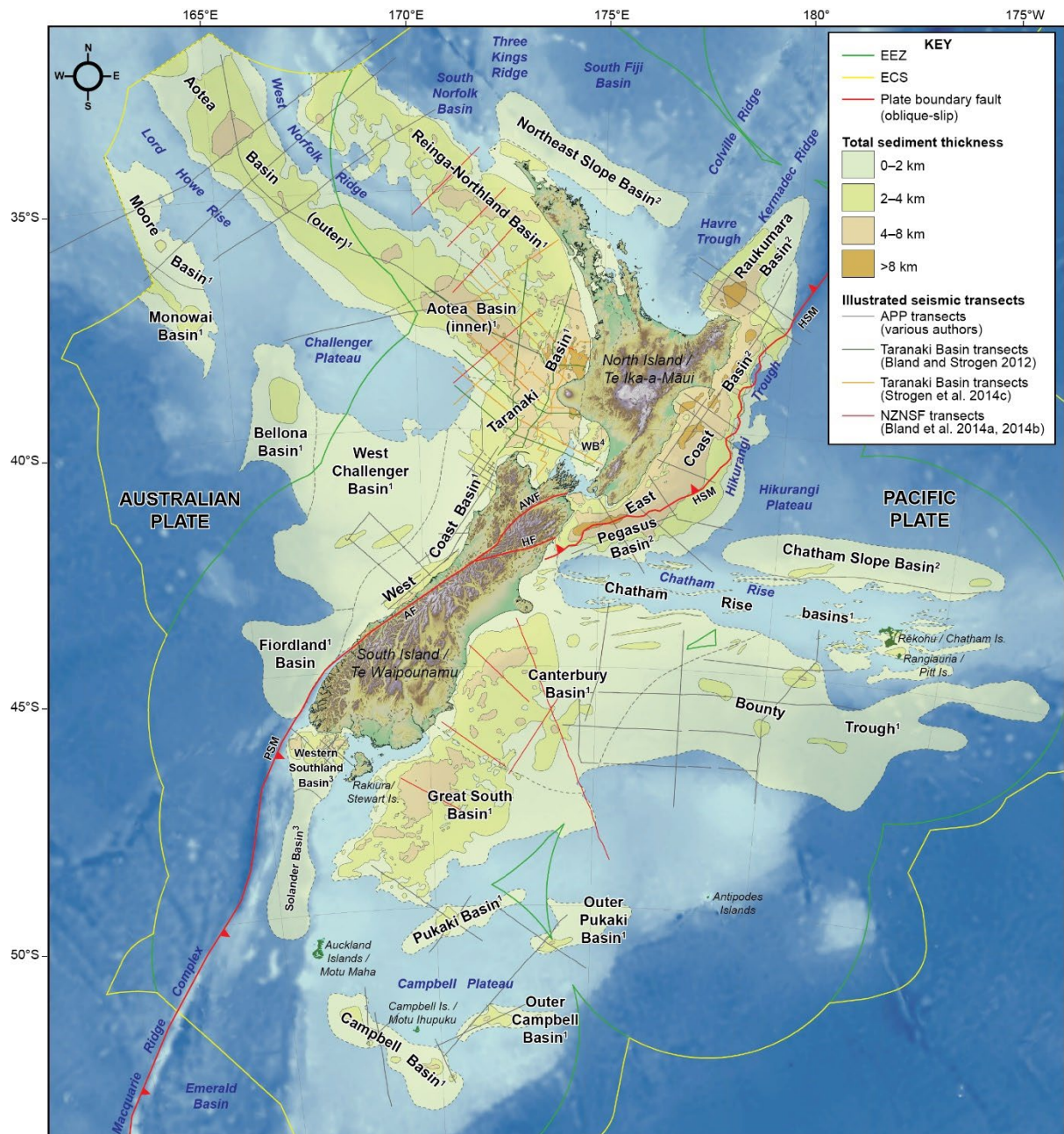


Figure 3 The major offshore sedimentary basins of Zealandia, and their sediment thicknesses. Shapefiles of the basin boundaries and sediment thickness are available for download. Superscript numbers relate to the primary type of basin origin: 1 – Cretaceous rifting associated with Gondwana breakup; 2 – deposition atop of the Gondwana accretionary wedge; 3 – Eocene–Oligocene rifting associated with Gondwana Basin opening; 4 – long-wavelength southwards-migrating pulldown associated with the Hikurangi subduction system. Locations of digital illustrated seismic transects are shown. These transects, from several different GNS-led studies and compilations, show the broad-scale architecture of basins and their sediment fill across much of New Zealand's EEZ/ECS.

## **BASINS OF NORTHERN NEW ZEALAND**

This region encompasses the Reinga-Northland, Aotea, Taranaki, and Whanganui basins. They contain a mid-Cretaceous to Holocene fill up to ~11 100 m thick (mean thickness ~3200 m; Figure 6) (Arnot et al. 2016). The thickest successions occur in proximal Taranaki Basin along the western side of the Taranaki Fault, north of Taranaki Peninsula. Depocentres >5 km thick are also present in the proximal Aotea, central Reinga, and south-eastern Northland basins (Figure 6).

### ***Basement***

Geological basement within the mapped area lies ~120–11500 m below sea level (mean depth ~4460 m). Basement rocks are represented by western parts of the Eastern Province metasedimentary terranes (Brook Street, Murihiku, Dun Mountain-Maitai, Waipapa/Caples terranes), Median Batholith, and Western Province metasedimentary terranes and Paleozoic and Mesozoic Tuhua intrusives (Kroeger et al. 2012; Mortimer 2021; Mortimer et al. 2014, 2017).

### ***Cretaceous***

The Cretaceous succession comprises non- to shallow-marine rocks, deposited within narrow fault-bound rift basins (e.g., Figure 7) or as part of a large progradational package (Baillie & Uruski 2004; Higgs et al. 2022) that built into the head of inner Aotea Basin (King and Thrasher 1996; Arnot et al. 2016; Strogen et al. 2017, 2022). Non-marine strata, including extensive coal measures, are over-topped by sandy shallow-marine rocks in the southeast of Taranaki Basin. Large intra-plate volcanoes, such as Romney volcano (Uruski 2020), occur within this Late Cretaceous succession. Cretaceous sedimentary rocks are thickest in inner Aotea Basin (~6400 m), up to 4000 m thick in Taranaki Basin, and up to ~3200 m thick in Reinga-Northland Basin. Cretaceous rocks are entirely absent from Whanganui basin.

The oldest Cretaceous rocks (pre-K50 horizon, >c. 98 Ma) are restricted to fault-controlled syn-rift basins in proximal Aotea Basin and northern Taranaki Basin, overlie basement, and are up to 3500 m thick, (mean 800 m thick) (Figure 7). The K50 horizon (c. 98 Ma) lies 2900–10 900 m deep (mean 6400 m), and is overlain by strata up to 3000 m thick (mean 600 m; Figure 8). The K80 horizon (c. 85 a) is 730–9100 m deep (mean 4900 m) and overlain by up to 2800 m of strata (mean 580 m; Figure 9). The K90 horizon (c. 75 Ma) lies 680–9000 m deep (mean 4100 m) and is overlain by up to 4000 m of strata (average 520 m; Figure 10).

### ***Paleocene***

The Paleocene succession is up to 2450 m thick (mean ~440 m) (Arnot et al. 2016). It is thickest adjacent to the Taranaki Fault, and it is also moderately thick in depocentres in the Reinga-Northland Basin (Figure 11). Paleocene rocks are completely absent in much of southern Taranaki and all of Whanganui basins. Paleocene rocks comprise non- to shallow-marine coal-bearing strata in eastern and central Taranaki Basin, with mudstone-dominated rocks elsewhere, which were often deposited in bathyal settings. A Late Paleocene interval with elevated terrestrial TOC ('Waipawa organofacies') occurs in parts of northern Taranaki and Northland basins (Killops et al. 2000; Hollis et al. 2014).





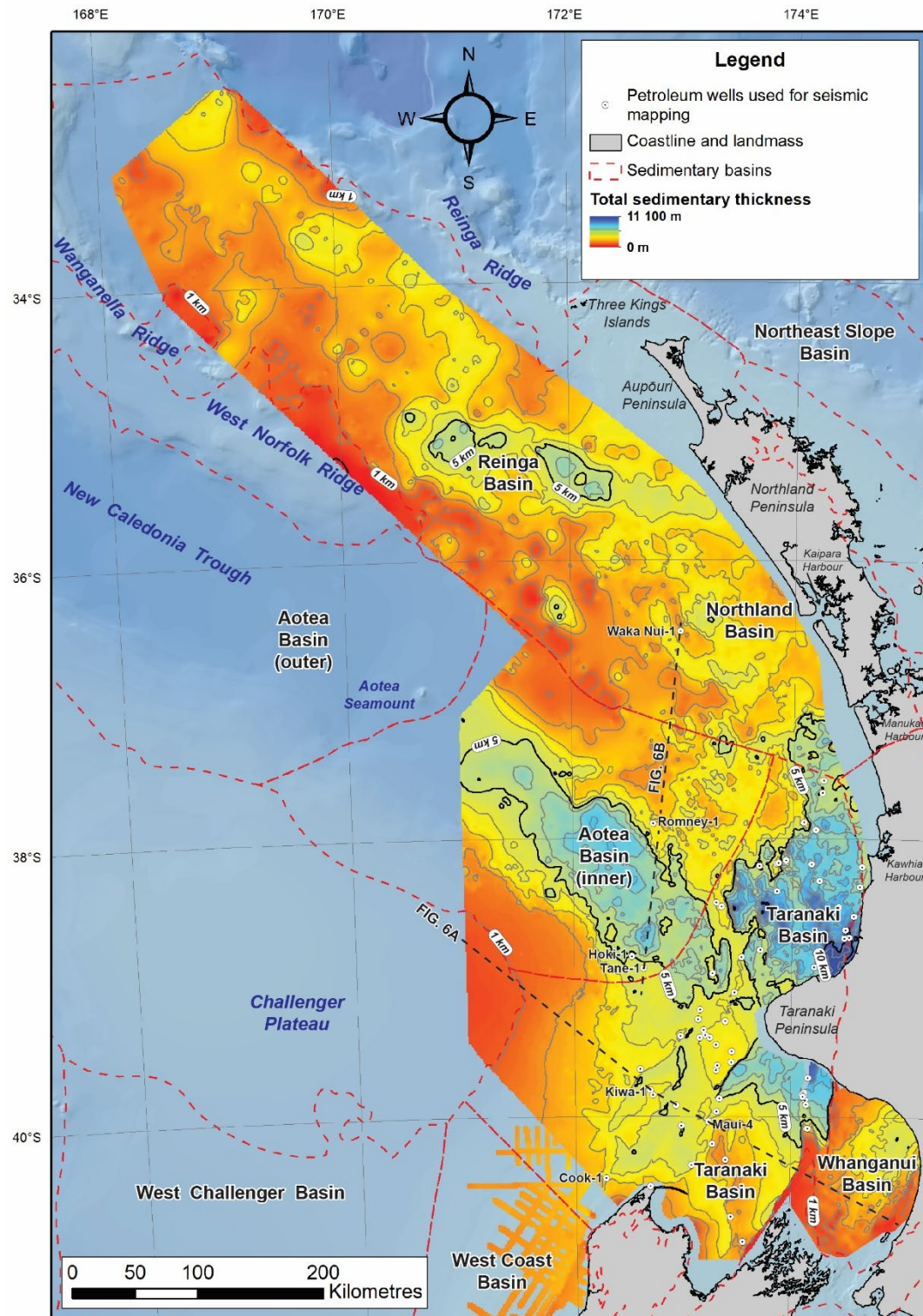


Figure 6 Mapped total sediment thickness within the Reinga-Northland, Taranaki, inner Aotea, and Whanganui basins (Arnot et al. 2016).



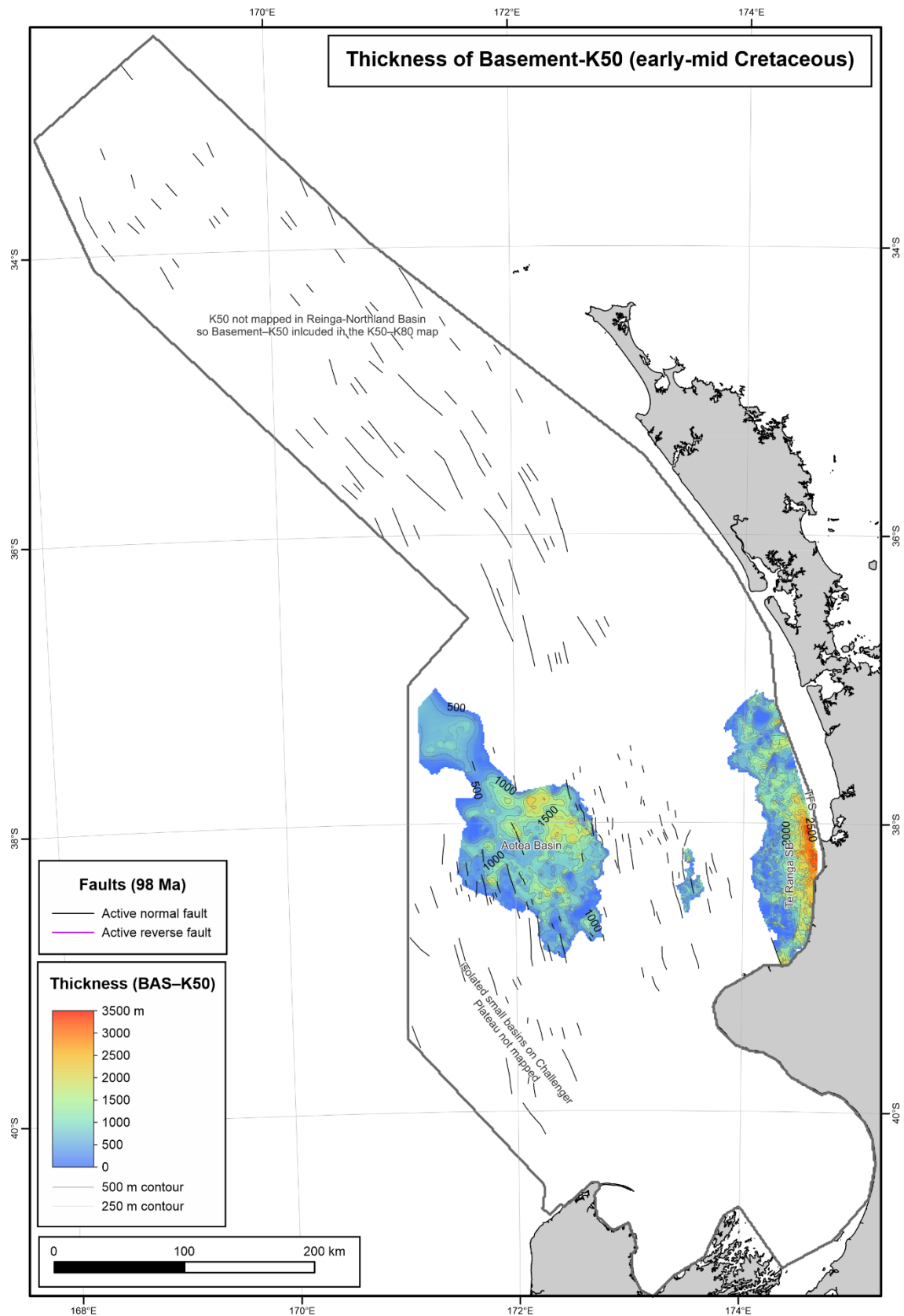


Figure 7 Thickness of mid-Cretaceous early syn-rift ('Zealandia rift phase', of Strogen et al. 2017) sedimentary rocks (>98 Ma) in the Taranaki and inner Aotea basins (after Arnot et al. 2016). These strata were deposited within active rift basins associated within Gondwana rifting and Tasman Sea opening. Note that strata of this age are included in the following map (Figure 8) in Reinga-Northland Basin.

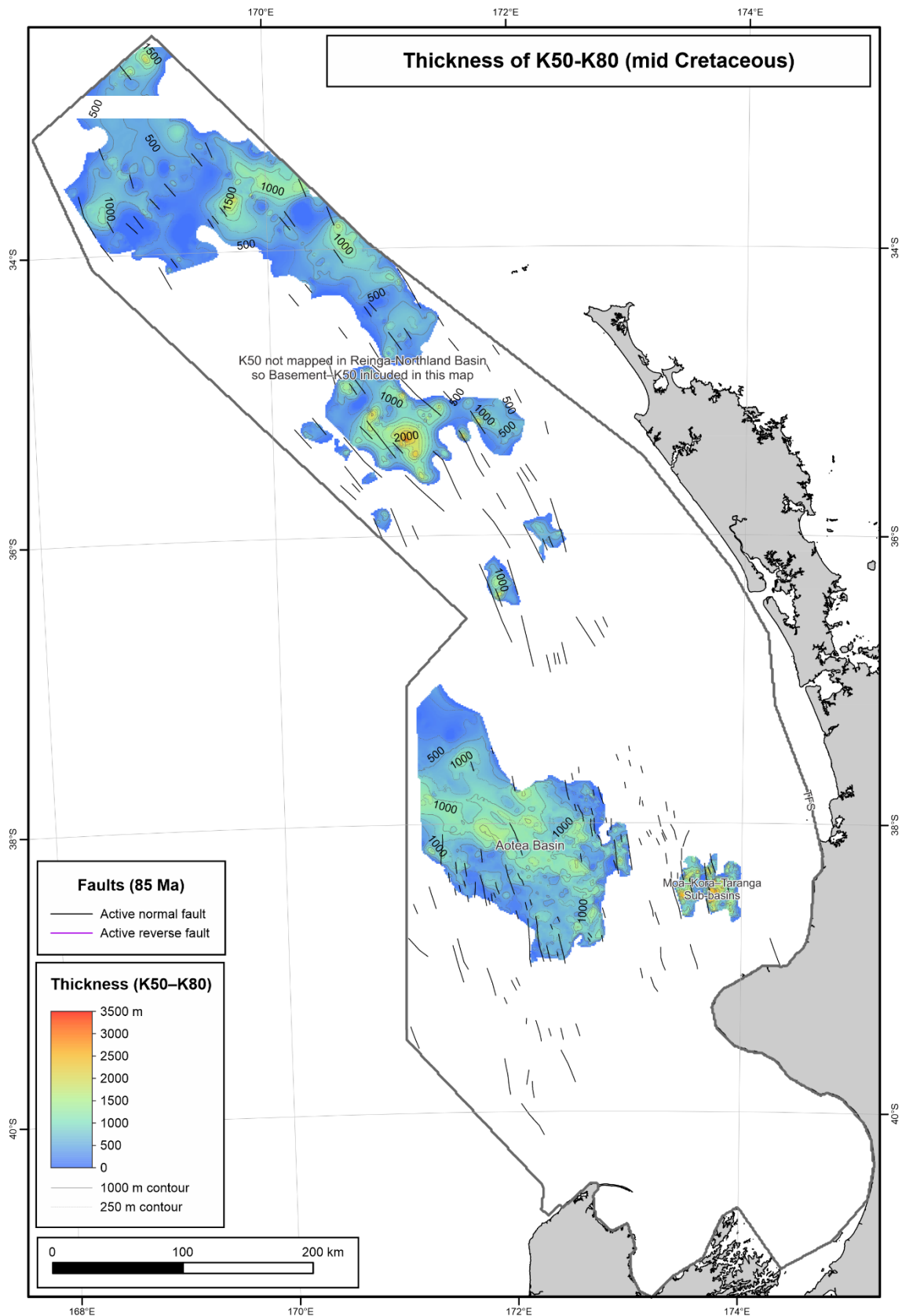


Figure 8 Thickness of mid-Cretaceous syn-rift to earliest post 'Zealandia-rift phase' sedimentary rocks (98–85 Ma) in the Taranaki and inner Aotea basins (after Arnot et al. 2016). These strata were deposited within active rift basins associated within Gondwana rifting and Tasman Sea opening.

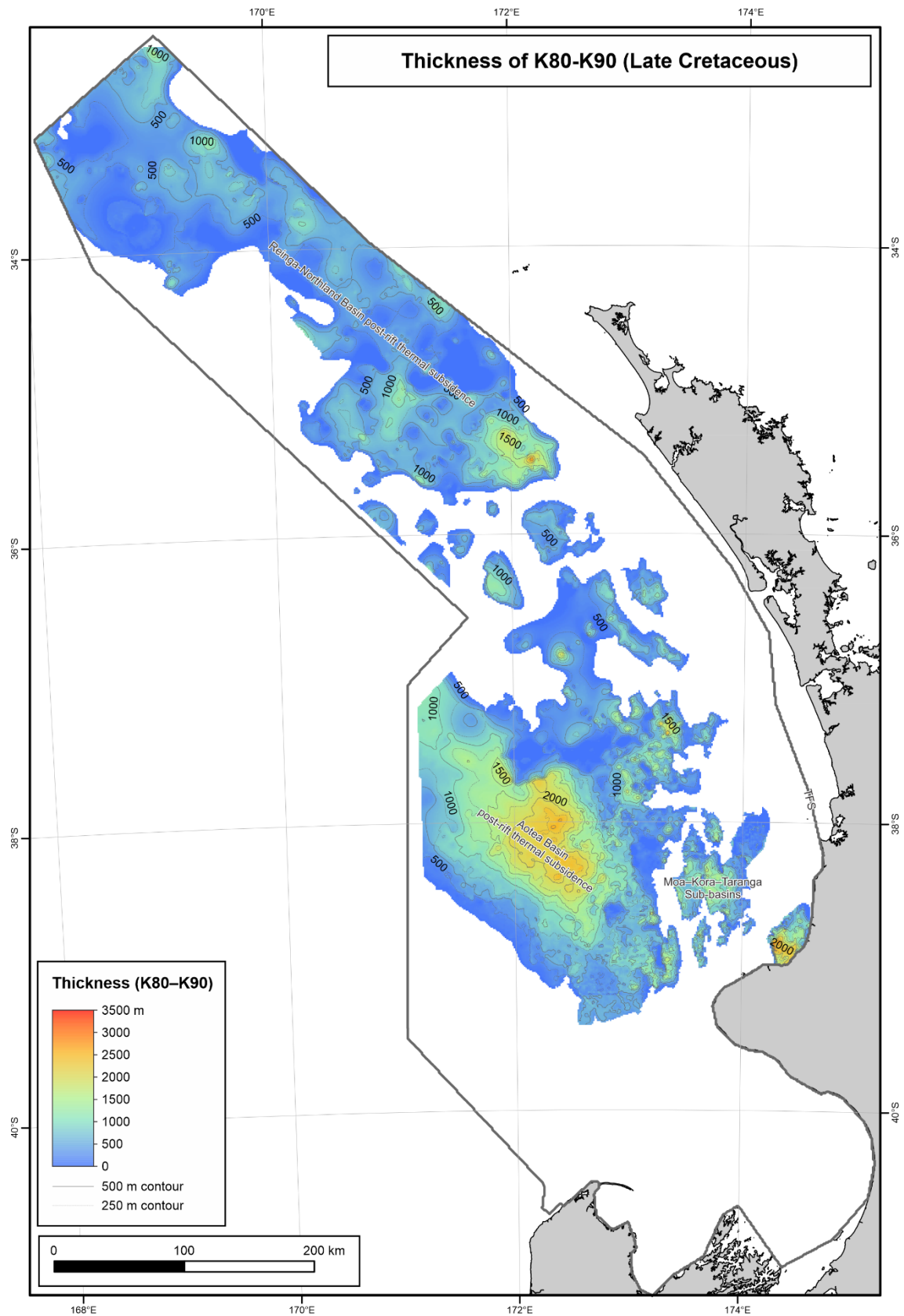


Figure 9 Thickness of Late Cretaceous early post-rift sedimentary rocks (>85–75 Ma) in the Taranaki and inner Aotea basins (after Arnot et al. 2016).

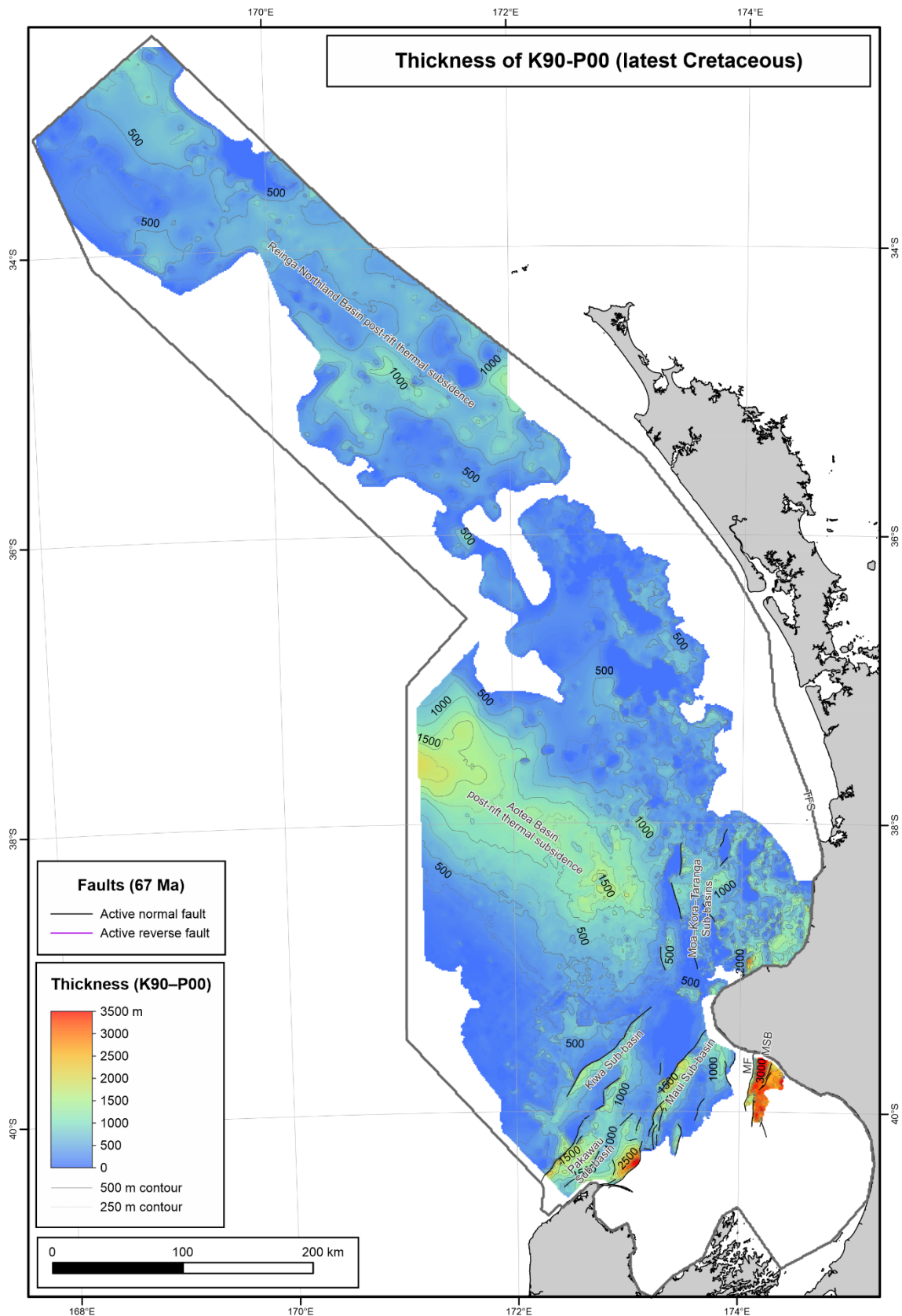


Figure 10 Thickness of latest Cretaceous sedimentary rocks (75–66 Ma) in the Taranaki and inner Aotea basins (after Arnot et al. 2016). Rocks across most of the region represent post-rift thermal subsidence deposition. Strata in the southeast of the region represent deposition associated with the ‘West Coast-Taranaki rift phase’ of Strogen et al. (2017).

### ***Eocene***

The Eocene succession is up to 3500 m thick (mean 410 m), and is thickest in Taranaki Basin, north of Taranaki Peninsula (Figure 12). Eocene rocks are significantly thinner in western parts of this area, and are absent in Whanganui Basin.

Eocene rocks consist of non- to shallow-marine strata in eastern and central Taranaki Basin and include thick coal measures. Marine mudstone rocks dominate elsewhere, often bathyal in origin.

### ***Oligocene***

The Oligocene succession is characterised by very condensed calcareous-rich lithofacies across most of the area, although thick packages containing terrigenous sandstone beds occur in the east, adjacent to the Taranaki Fault system (Strogen et al. 2014, 2019). The interval shows dramatic variations in thickness across the mapped area; it is up to 2620 m thick, adjacent to the Taranaki Fault Zone, although the average thickness is only 190 m (Figure 13).

This succession was typically deposited in deep-marine environments, with low rates of sedimentation.

### ***Miocene***

The Miocene succession is up to 5470 m (mean 750 m) and is significantly thickest in Taranaki Basin, especially south of Taranaki Peninsula

(Figure 14). Thick Miocene packages also occur within the Northern Graben of Taranaki Basin. Miocene rocks encompass a very wide range of depositional settings. Miocene deposition reflects the onset and development of rapid uplift and erosion on adjacent landmasses, especially Southern Alps and associated mountains (Bull et al. 2019). Marginal-marine to deep-bathyal depositional settings, represented by mudstone, sandstone, channel fill, turbidites, basin-floor fans, limestone lithofacies.

### ***Pliocene–Quaternary***

The Pliocene–Quaternary succession is up to 3380 m thick (mean ~770 m) (Figure 15). It is thickest in the Northern Graben and Cape Egmont Fault zone within Taranaki Basin, and in Whanganui Basin, to the east of the Taranaki–Manaia–Waimea–Flaxmore Fault system.

Rapid progradation of a wedge of foresets, now underlying the Taranaki shelf. Several kilometres thick, comprised of terrigenous sedimentary strata, derived from rapidly uplifting and eroding landmasses. Similar lithofacies to the Miocene succession; non-marine to deep-marine mudstone, sandstone, channel fill, turbidites, basin-floor fans, limestones. Deposited with strong influence from sea-level variations.



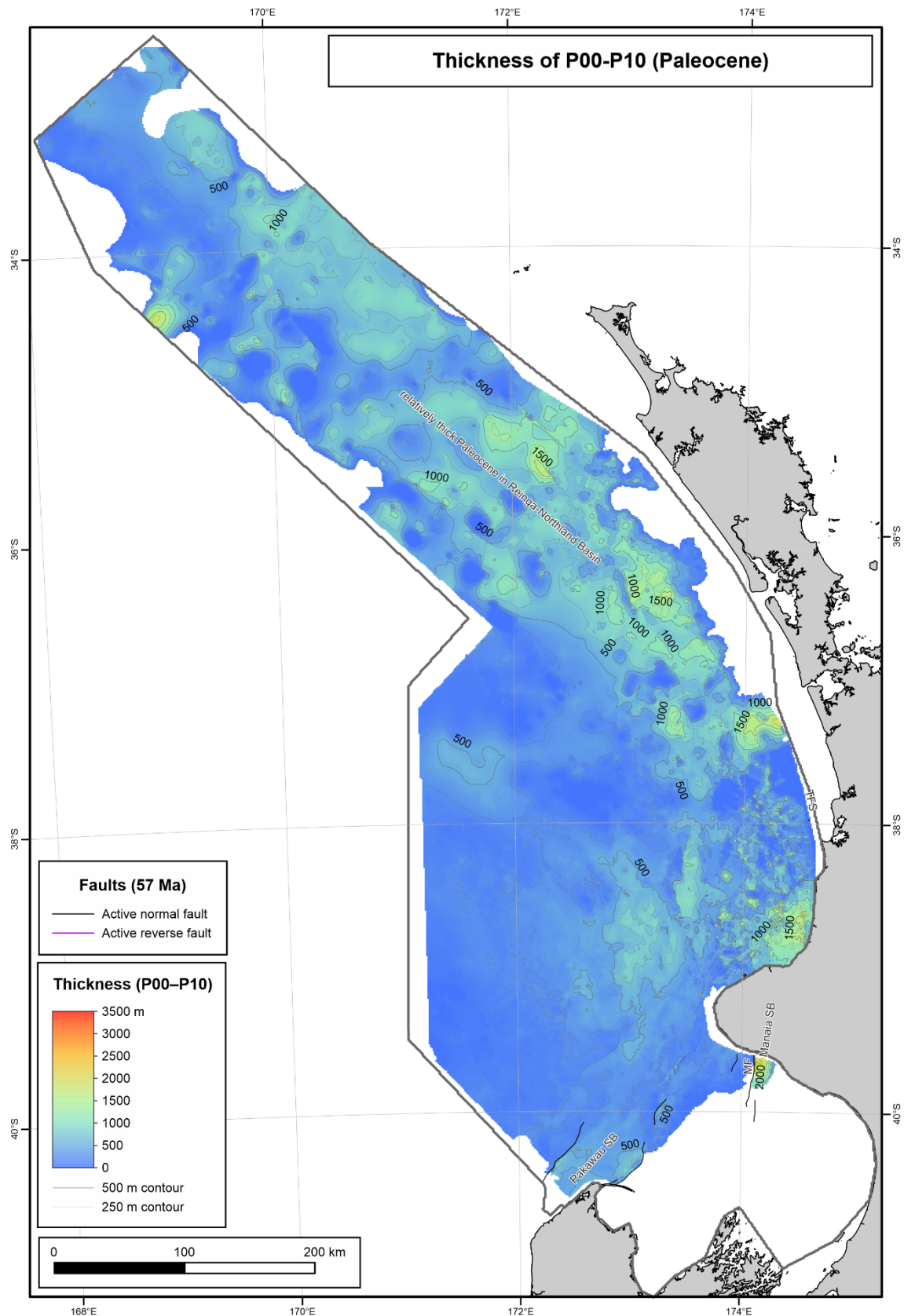


Figure 11 Thickness of the Paleocene succession in the Reinga-Northland, Taranaki, and inner Aotea basins (after Arnot et al. 2016). Thick Paleocene deposits in the Manaia Sub-basin (southern Taranaki Basin) relates to final parts of the West Coast-Taranaki rift phase (after Strogon et al. 2017).

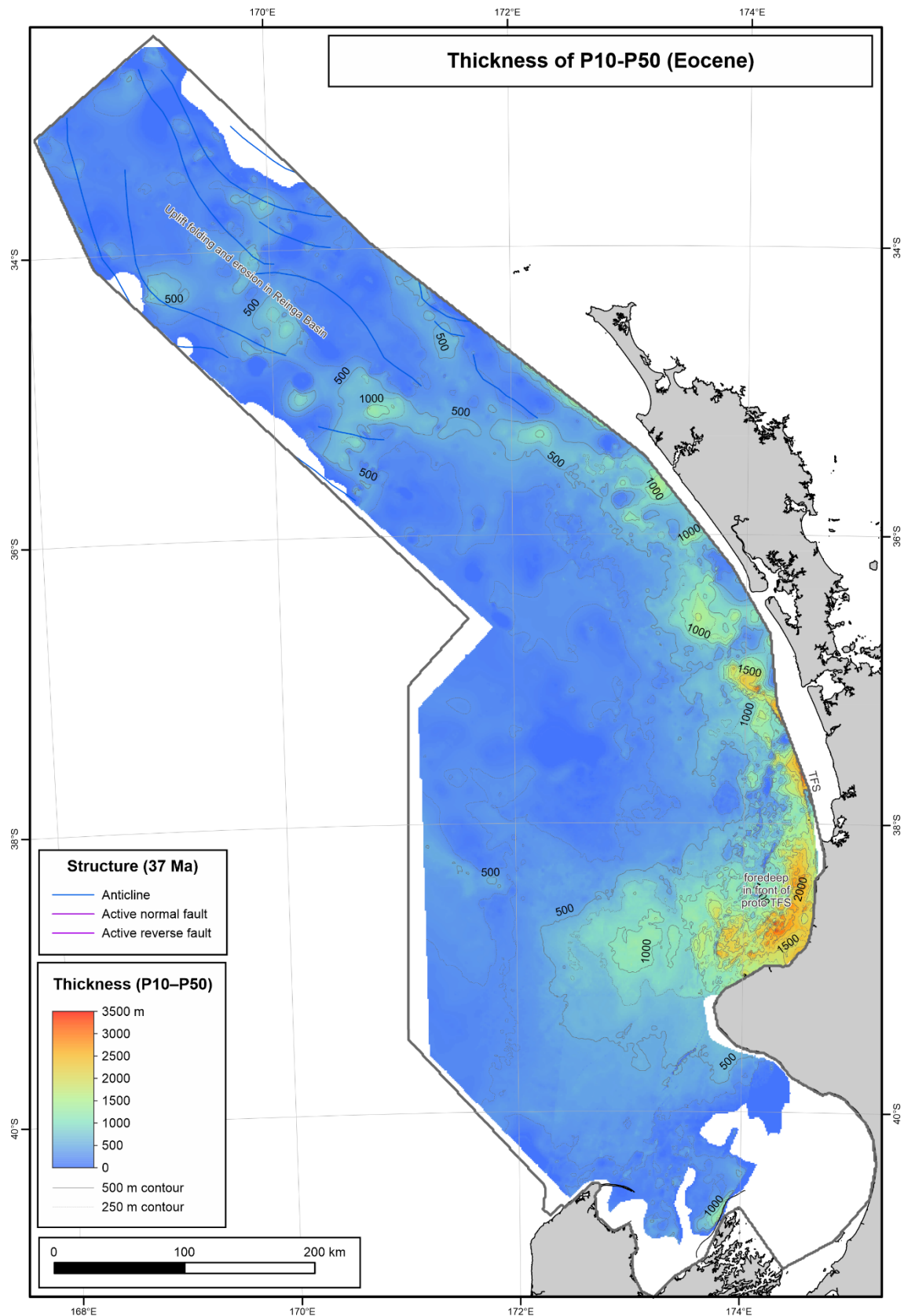


Figure 12 Thickness of the Eocene succession in the Reinga-Northland, Taranaki, and inner Aotea basins (after Arnot et al. 2016). Note the increased thickness of Eocene rocks in the east of the area, adjacent to the proto-Taranaki Fault System.

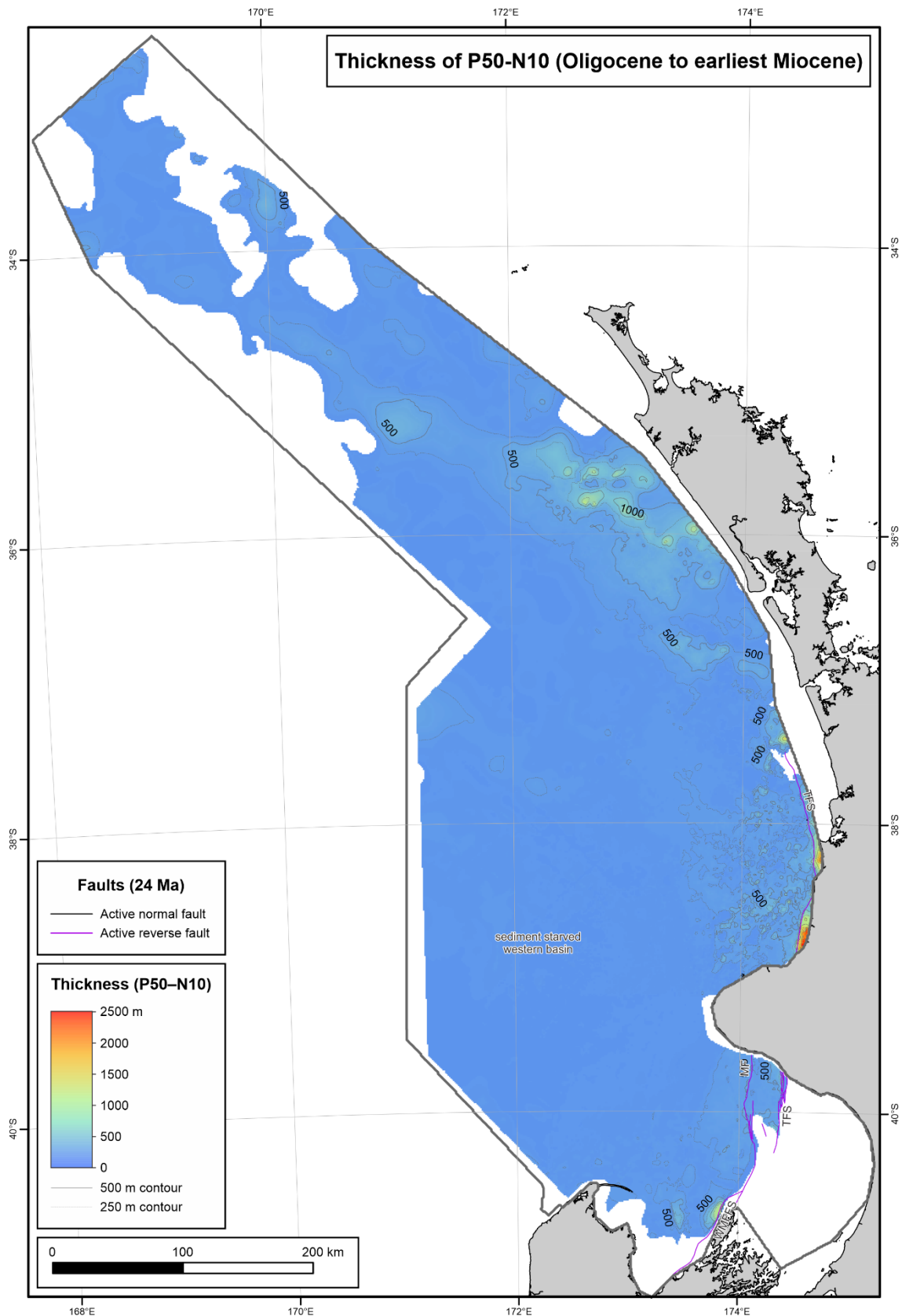


Figure 13 Thickness of the Oligocene to earliest Miocene succession in the Reinga-Northland, Taranaki, and inner Aotea basins (after Arnot et al. 2016). Other than areas close to the present-day coastline and the Taranaki Fault system, the Oligocene succession is very thin and condensed across much of this region.

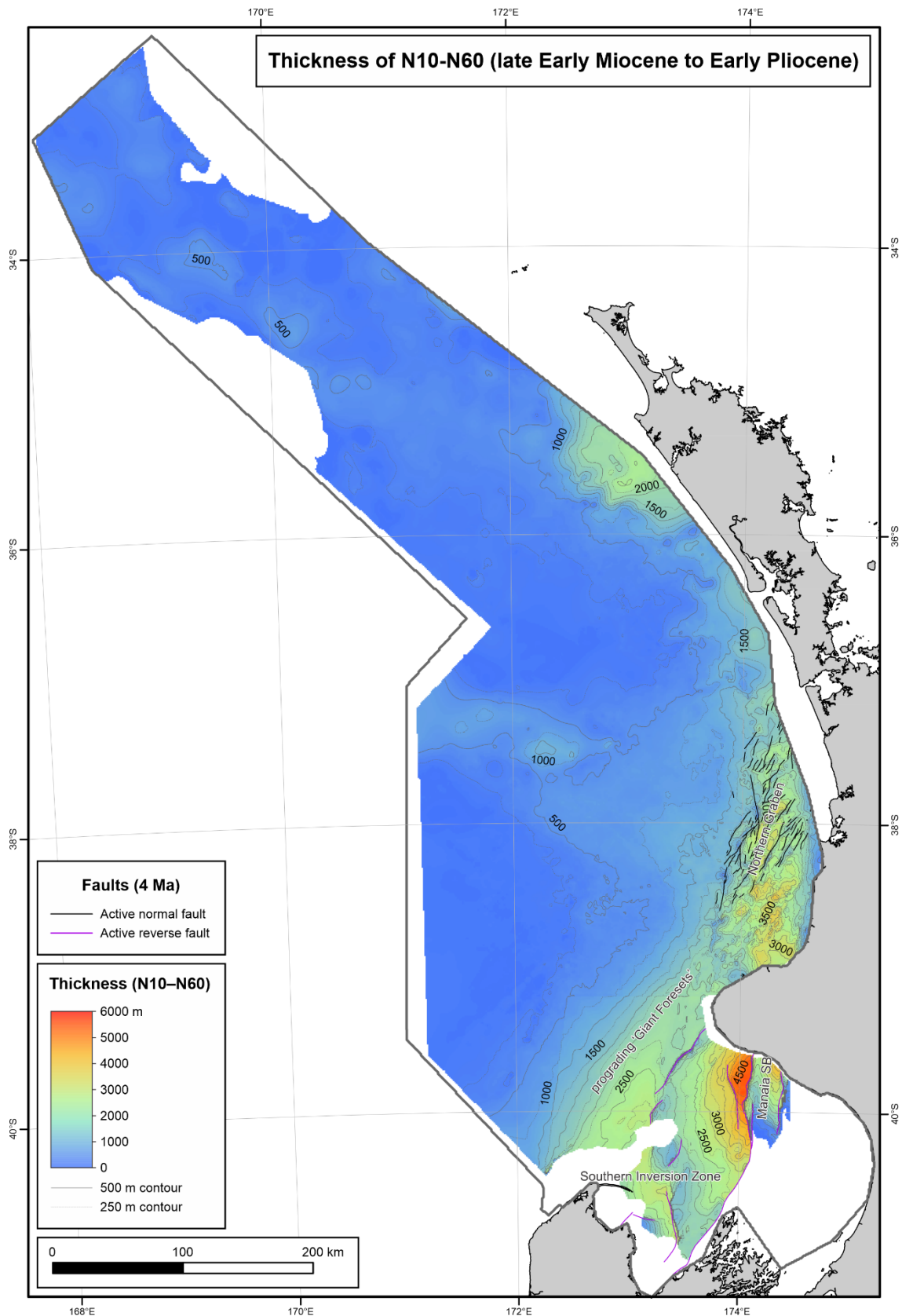


Figure 14 Thickness of the late Early Miocene–Early Pliocene succession in the Reinga-Northland, Taranaki, and inner Aotea basins (after Arnot et al. 2016). Note the largest thickness of sediment within the major fault systems in the east of the region, and proximity of those deposits to the present-day coastline.



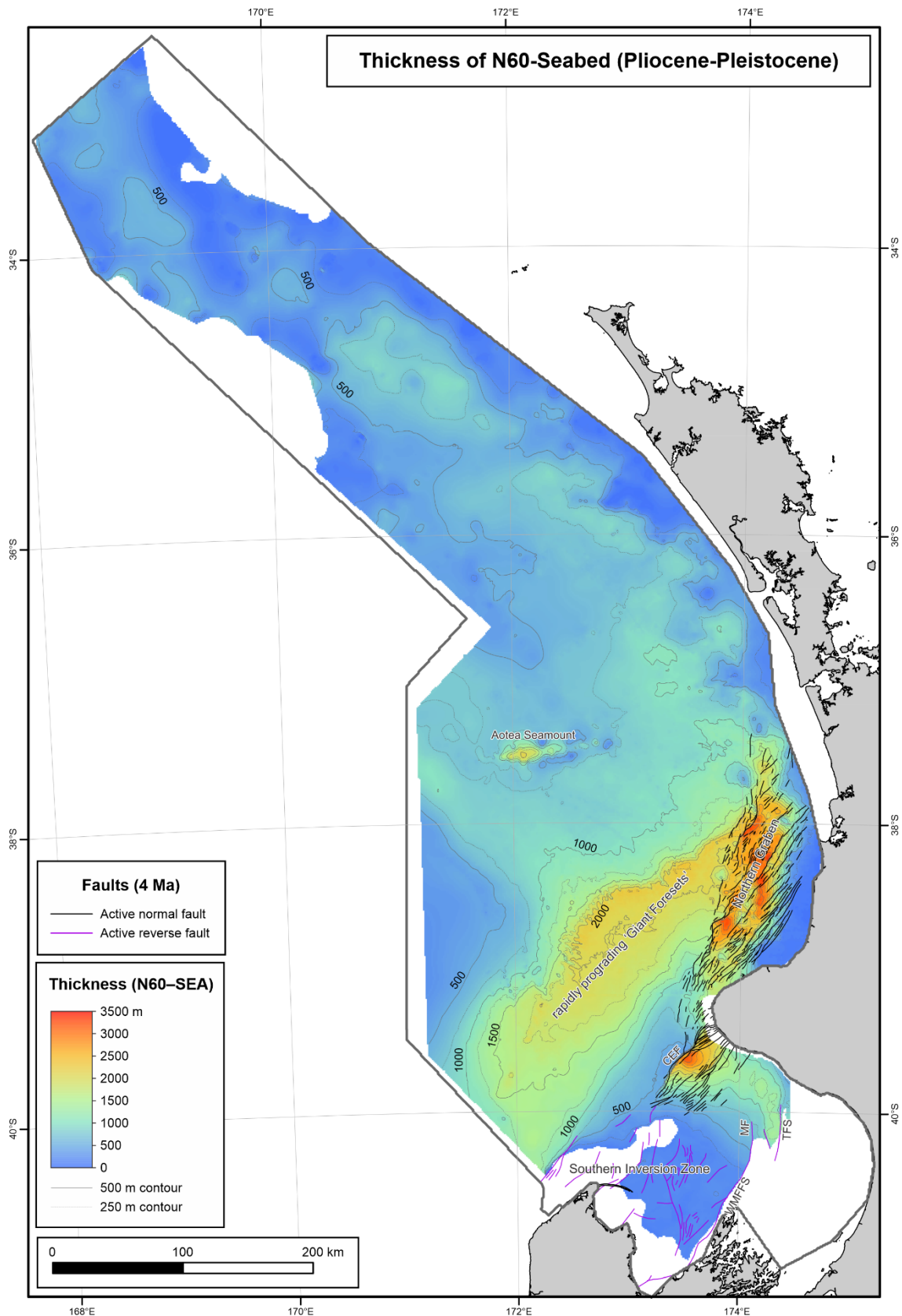


Figure 15 Thickness of the Pliocene–Quaternary succession in the Reinga–Northland, Taranaki, and inner Aotea basins (after Arnot et al. 2016). Note the large sediment thicknesses within the Taranaki Northern Graben, Cape Egmont Fault Zone and within the prograding Giant Foresets Formation.



## TASMAN SEA BASINS

This region encompasses an extensive part of New Zealand's western offshore territory, beneath which lie several large and essentially unexplored sedimentary depocentres including the Monowai, Moore, Bellona, West Challenger, and Fiordland basins, and the offshore portion of the better understood West Coast Basin. These basins all face out onto the oceanic crust of the Tasman Sea, where sea-floor spreading started in the Late Cretaceous (c. 83 Ma; Gaina et al. 1998), and are separated from those in the remainder of northern Zealandia by the structural highs of the Challenger Plateau and Lord Howe Rise.

Our understanding of the geological fill within the Tasman Sea basins is poorly constrained and largely inferred from poor-quality seismic data and strata preserved within surrounding regions. Sedimentary rocks of Eocene and younger age have been drilled on top of bathymetric highs close to the margins of the more offshore basins, giving some lithostratigraphic control. A few drillholes within the West Coast Basin provide limited lithologic control in eastern parts of the region. The age and lithologies of older pre-Eocene units remain virtually unknown.

### **Basement**

No drillholes in this region have reached basement beyond the shallow continental shelf within the West Coast Basin, although regional geological trends indicate likely basement composition. Basement rocks beneath the West Coast Basin lie ~1135–4840 m deep (mean depth ~2390 m) (Arnot et al. 2018), and comprise Western Province Paleozoic metasedimentary terranes, Paleozoic–Mesozoic igneous and meta-igneous rocks, and oceanic crust (Mortimer et al. 2020). Granitic rocks were interpreted in Toropuihi-1,

Kongahu-1, and Mikonui-1 drillholes (Kidd et al. 1981; Wiltshire 1984; Amoco 1987), and Haku-1 is interpreted to have drilled Paleozoic metasedimentary Greenland Group (Buller Terrane) (Hematite Petroleum (NZ) Ltd 1970; Geosphere 2009). Basement beneath Fiordland Basin probably comprises Western Province metasedimentary rocks (Buller Terrane) in the far east and oceanic crust of the Australian Plate elsewhere (after (Edbrooke, 2017; Mortimer *et al.*, 2017). Basement beneath the more distal Tasman Sea basins likely comprises Paleozoic Western Province metasedimentary terranes, with igneous rocks of the Median Batholith occurring beneath parts of the Challenger Plateau–Lord Howe Rise bathymetric highs.

### **Cretaceous**

The oldest parts of the mid- to Late Cretaceous succession consist of syn-rift deposits that accumulated during Gondwana break-up and separation ('Zealandia rift phase of Strogen et al. 2017). Such rocks were mostly likely deposited initially in non-marine settings, tending towards marine environments in later syn-rift times, especially outboard towards Tasman Sea, and potentially already deep marine by breakup (c. 83 Ma). Rift-related fluvial and lacustrine rocks of mid-Cretaceous age may occur in Fiordland Basin. Mid-Cretaceous rocks are probably absent from most offshore parts of the West Coast Basin; those Cretaceous rocks inferred to be present are of probable Late Cretaceous age and are restricted to the southwest part. These rocks, like those in other rift-related sedimentary basins in Zealandia (e.g., Strogen et al. 2017), probably comprise non- to marginal-marine lithofacies (Arnot et al. 2018).

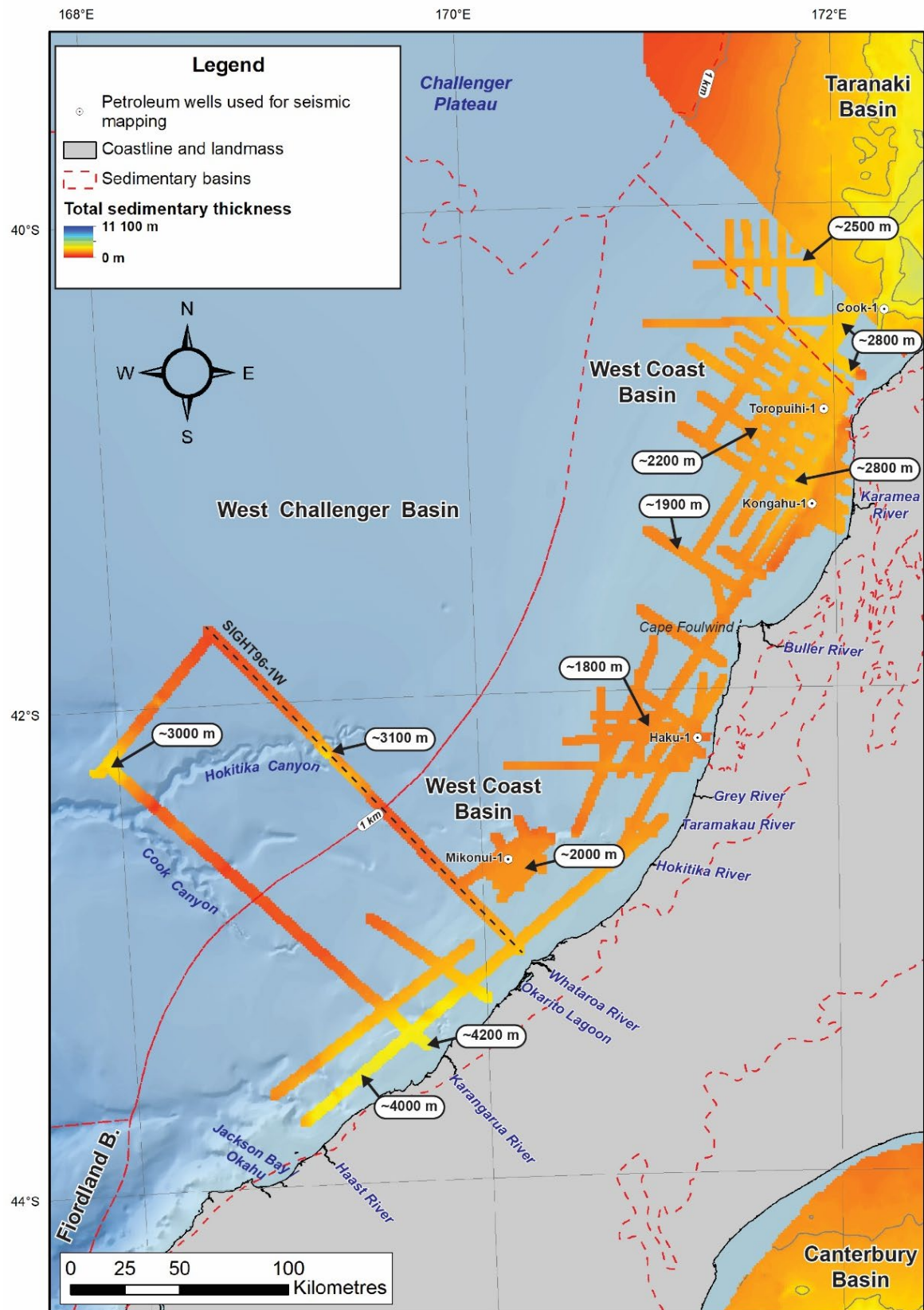


Figure 16 Mapped total sediment thickness within the West Coast Basin, shown as an example of the 'seismic ribbon grids' produced across this area, using available open-file seismic reflection data (after Arnot et al. 2018).

**Paleocene–Recent**

Paleocene rocks are not widespread in the offshore West Coast Basin, and their presence in other Tasman Sea basins is poorly constrained, although if present they are likely to be thin. The base of a mapped Paleocene succession in West Coast Basin erosionally truncates dipping beds of presumed latest Cretaceous age and onlaps basement in some areas. As mapped by Arnot *et al.* (2018), the base of the Paleocene succession lies ~2220–3490 m deep (mean depth ~2970 m). Probable non-marine strata of Paleocene and older age were intersected in Mikonui-1 (Kidd *et al.* 1981; Geosphere 2009). No Early Eocene rocks are present in Kongahu-1, Haku-1 and Mikonui-1 (Hematite Petroleum (NZ) Ltd 1970; Kidd *et al.* 1981; Wiltshire 1984; Geosphere 2009).

The base of the Eocene succession in West Coast Basin lies ~1350–3050 m deep (mean depth ~2210 m). Eocene strata in Kongahu-1 and Haku-1 are marked by non-marine deposition atop basement. In the more basinward Mikonui-1 well, Eocene strata comprise marginal-marine deposits that pass up-section into shelfal and outer shelf to bathyal deposits. The overlying Oligocene sedimentary succession is <100 m thick over most of West Coast Basin and onlaps basement to the southeast and south of Haku-1; Arnot *et al.* 2018). The base of the succession lies ~1010–3260 m deep (mean depth ~2020 m). Lithofacies include calcareous rocks deposited in inner shelf to upper bathyal settings, such as those intersected by Kongahu-1 and Mikonui-1.

Rocks of Eocene to Miocene age elsewhere in the Tasman Sea basins are thin and generally fine grained, often consisting of carbonate lithofacies, and can be correlated to DSDP drillholes (593 in West Challenger Basin, 207/592 in the Moore Basin). The Miocene to Recent succession across most of the Tasman Sea basins comprises thin condensed deepwater oozes typical of distal tectonically quiescent environments. In eastern areas the succession progressively includes thicker

packages of clastic sediments shed from the developing plate boundary. Such rocks include likely thick turbidite sequences (e.g. Fiordland Basin) (Wood *et al.*, 2000), and distal turbidites to toe-of-slope deposits in eastern West Challenger Basin. In the southeast of West Coast Basin, the base of the Miocene succession lies ~920–3850 m deep (mean ~1990 m), and onlaps basement from west to east (Arnot *et al.* 2018). Early Miocene strata are absent at Toropuihi-1, Kongahu-1, and Mikonui-1, although bathyal to shelfal strata of possible Early Miocene age are inferred to be present in Haku-1 (Hematite Petroleum (NZ) Ltd 1970; Geosphere 2009). Where intersected in wells the succession typically comprises fine-grained variably calcareous mid- to outer-shelf to bathyal facies, with occasional sandstone intervals (Geosphere 2009). In the northern offshore West Coast Basin, channels cut packages of continuous reflectors (Arnot *et al.* 2018). The base of the Pliocene–Quaternary succession lies ~100–2960 m deep (mean ~1570 m), with strata generally consisting of fine-grained lithofacies cut by channels that may contain coarse sandstone or conglomeratic facies (Kidd *et al.* 1981; Arnot *et al.* 2018). Seismic reflector patterns provide evidence for shelf to deep-marine deposits in some areas.

## **BASINS OF SOUTHWEST NEW ZEALAND**

This relatively small region includes a series of disconnected fault-controlled depocentres with mid-Cretaceous to Oligocene rift origins that are grouped into the Western Southland and Solander basins. We group these basins due to their primarily Eocene–Oligocene rift origin related to Emerald Basin opening, which generally did not affect other Zealandia basins other than (mostly onshore) parts of the West Coast Basin. These southwestern basins have been strongly to moderately overprinted by Neogene tectonism related to the development of the Australia-Pacific plate boundary along the Alpine Fault and Puysegur subduction

margin (Lamarche & Lebrun 2000; Barnes et al. 2002b).

The thickest sedimentary deposits in this area occur within the Waitutu and Hautere sub-basins, where a succession >5 km thick (and probably as thick as 7 km) occurs (Figure 17) (Arnot et al. 2018).

### **Basement**

Basement penetrations by Parara-1 and Solander-1 drillholes suggest that meta-igneous Median Batholith rocks underlie most of offshore Western Southland Basin (Watters in Hunt International Petroleum Co 1976; Watters in Engmann & Fenton 1986; Mortimer et al. 2020).

### **Cretaceous**

Rift-related fluvial and lacustrine rocks of mid-Cretaceous age occur in onshore parts of Western Southland Basin (Puysegur Sub-basin; Pocknall and Lindqvist 1988; Turnbull and Uruski et al. 1993; Turnbull et al. 2010; Bland et al. 2019). Strata of Late Cretaceous age are interpreted to overlie basement in the Waitutu and Hautere sub-basins (Figure 19) (Turnbull et al. 1993; Arnot et al. 2018), although their presence is highly speculative and not confirmed by drillhole data.

### **Paleocene**

Within Western Southland Basin, the interpreted and mapped base of the Paleocene succession is ~1270–7000 m deep (mean 4000 m; Figure 19) (Arnot et al. 2018). Rocks of Paleocene age were not intercepted in Solander-1 drillhole. Although rocks of possible Paleocene age were reported in Parara-1 (Hunt 1976), these are more likely to be Mid–Late Eocene in age (Mildenhall in Hunt 1976). Characteristics across the basin are inferred from seismic facies and regional onshore analogues.

### **Eocene**

The Eocene succession in Western Southland Basin includes coarse-grained alluvial fan deposits, fluvial sandstones, coals, and marine mudstones. These were deposited during active rifting from the Bortonian (late Middle Eocene) onwards (Turnbull et al. 1993).

The base of the Eocene succession is ~740–6075 m deep (mean depth ~3250 m; Figure 20). Eocene strata are faulted against the Solander Ridge to the northeast, and to the southeast onlap or are faulted against basement. Eocene strata were intersected in Parara-1. No Eocene rocks were present in Solander-1, where Oligocene strata sits on basement.

### **Oligocene**

The base of the Oligocene succession is up to ~250–5340 m deep (mean depth ~2650 m) in Western Southland Basin, and is mapped as a continuous high-amplitude reflector tied to the Parara-1 well (Arnot et al. 2018). In places this horizon erosionally truncates underlying strata. Oligocene strata are intersected at Parara-1 (~100 m thick) and Solander-1 (~130 m thick), and these provide the only well ties for this interval. Oligocene strata at Parara-1 consist of calcareous fine-grained strata with minor/trace coaly material noted towards the base, deposited in outer shelf to upper slope environments (HIPCO, 1976). The fine-grained outer shelf to upper slope deposits marks the onset of marine sedimentation in this sub-basin (HIPCO, 1976; Turnbull et al. 1993). At Solander-1, Oligocene strata overlie basement and consist of ~15 m of conglomerate at the base, overlain by interbedded carbonaceous mudstone and siltstone with occasional coal. This passes upwards into interbedded calcareous fine-grained sandstone and siltstone which is overlain by a variably calcareous coarse sandstone and conglomerate interval. The coarse interval is overlain by fine-grained calcareous siltstone and mudstone with interbeds of limestone (Engmann et al. 1986). The carbonaceous

mudstone and coaly interval encountered at the bottom of the Oligocene interval in Solander-1 suggests either that the change to a marine environment occurred slightly later than at Parara-1.

### **Miocene**

The Miocene succession is tied to the Parara-1 and Solander-1 wells. The base horizon lies ~90–4220 m below sea level (mean depth ~2100 m; Figure 22) and is erosionally truncated at the sea floor in the northwest part of the mapping area. In Solander-1, ~500 m of Early to Late Miocene strata are intersected, and at Parara-1 ~995 m is intersected (HIPCO, 1976; Engmann et al. 1986). To the southeast of Parara-1 the Miocene succession is faulted against or onlaps basement rocks below the Stewart Shelf. Based on the geological descriptions given in the well reports, the succession typically comprises overall fine-grained, variably calcareous strata of outer shelf to upper bathyal facies. The lower part is characterised by variably calcareous mudstones and siltstones, with minor sandstone, limestone, and coaly fragments (at the base). In the upper part of the succession there is a slight increase in the amount of sandstone, with interbeds of poorly sorted sandstone encountered in both wells. In addition, at Solander-1, 53 m of conglomerate was encountered. This may represent the coarse fill of a shelf channel, although a channel is not clearly imaged in seismic reflection data over this interval (Arnot et al. 2018).

Miocene strata in seismic transect HUNT D-201 are characterised by moderate to locally bright amplitude, variably continuous seismic reflector packages, like those observed along transect HUNT A-49&s86-051-3361\_composite (Arnot et al. 2018). Based on the similarity in seismic character it is inferred that the strata along this transect are likely to be similar to those intersected in Solander-1 and Parara-1. These comprise overall fine-grained, variably calcareous strata of outer shelf to upper bathyal

depositional settings. The lower part of the interval is characterised by variably calcareous mudstones and siltstones, with minor sandstone, limestone, and coaly fragments (at the base). In the upper part of the succession, there is a slight increase in the amount of sandstone, with interbeds of poorly sorted sandstone encountered in both wells. Along this transect there is some evidence for channels, in the SE part of Hautere Sub-basin and in the Parara sub-basin. These channels may contain coarser grained material, such as that intersected in Solander-1.

### **Pliocene–Quaternary**

Pliocene–Quaternary strata are also erosionally truncated at the sea floor in the northwest part of the basin. The base-Pliocene horizon lies ~50–2640 m deep (mean depth ~1400 m; Figure 23), and the base-Pleistocene horizon lies ~110–1810 m deep (mean depth ~840 m; Figure 24). In seismic lines intersecting Solander-1, only a thin interval of Pliocene strata was mapped by Arnot (et al. 2018). The presence of Pliocene strata at Solander-1 is questionable as available biostratigraphic evidence is equivocal (HIPCO, 1976). The base Pleistocene intersects seabed to the SSW of Solander-1 and is not intersected in the well. At Parara-1, ~1060 m of Plio–Quaternary strata is intersected, comprising fossiliferous soft clays and siltstones, with minor calcareous fine sandstone lenses (Engmann et al. 1986). In the Pliocene interval, these were deposited in mid-to outer-shelf settings and in the Pleistocene in slightly deeper outer shelf to upper bathyal settings (Engmann et al. 1986).

Pliocene–Quaternary strata along transect HUNT D-201 are characterised by bright to moderate amplitude, dipping to clinoform, variably continuous seismic reflector packages (Arnot et al. 2018). In the Parara Sub-basin there is some seismic evidence for channels. The succession is inferred to be similar to that observed in Parara-1, comprising fossiliferous, soft clays and siltstones, with minor calcareous



fine-sandstone lenses. In the Pliocene interval, these were deposited in mid- to outer-shelf settings and in the Pleistocene in slightly

deeper outer shelf to upper bathyal settings (Engmann et al. 1986).

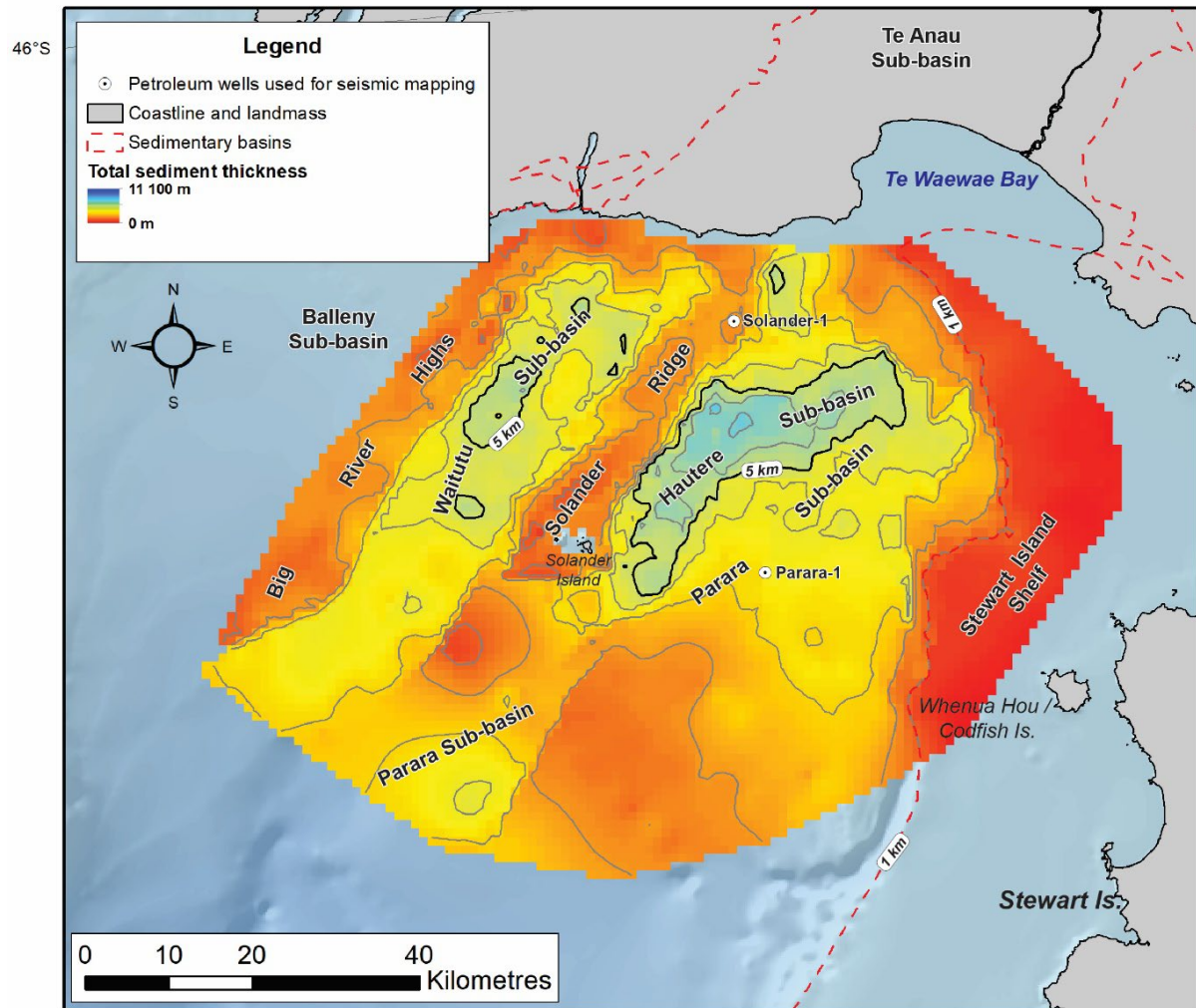


Figure 17 Total sediment thickness of Western Southland basin (after Arnot et al. 2018). The thickest successions lie within the Waitutu and Hautere sub-basins, where sediment thickness may be up to ~7 km.

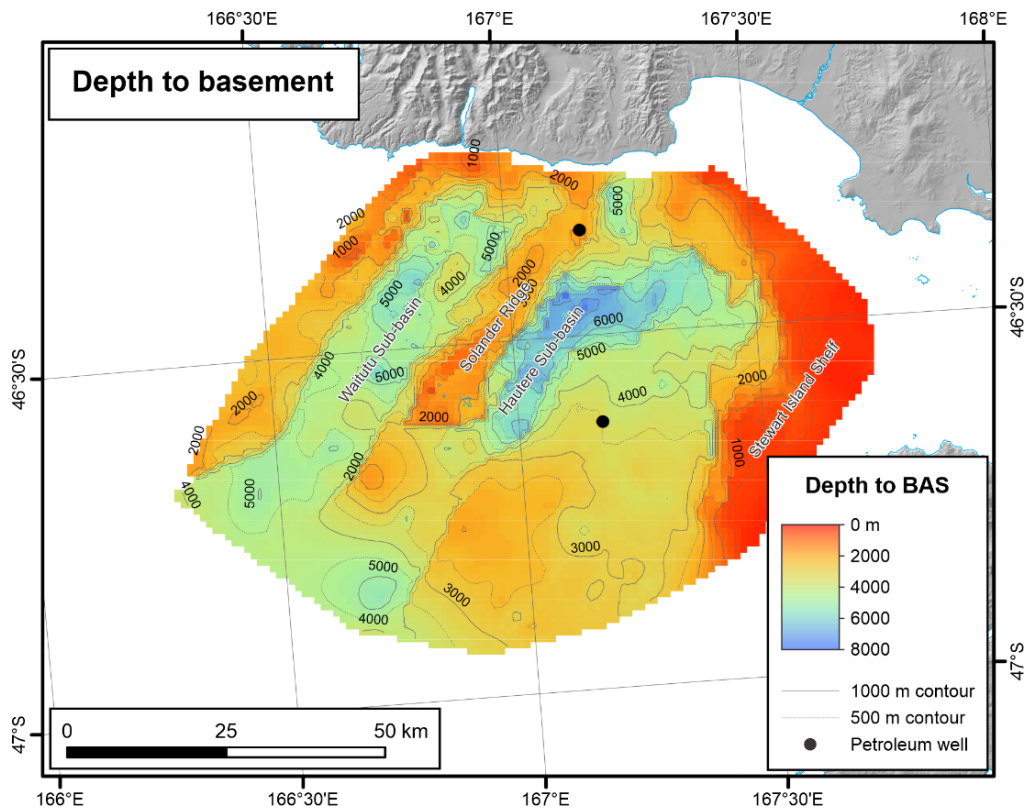


Figure 18 Depth to geological basement in Western Southland basin (after Arnot et al. 2018).

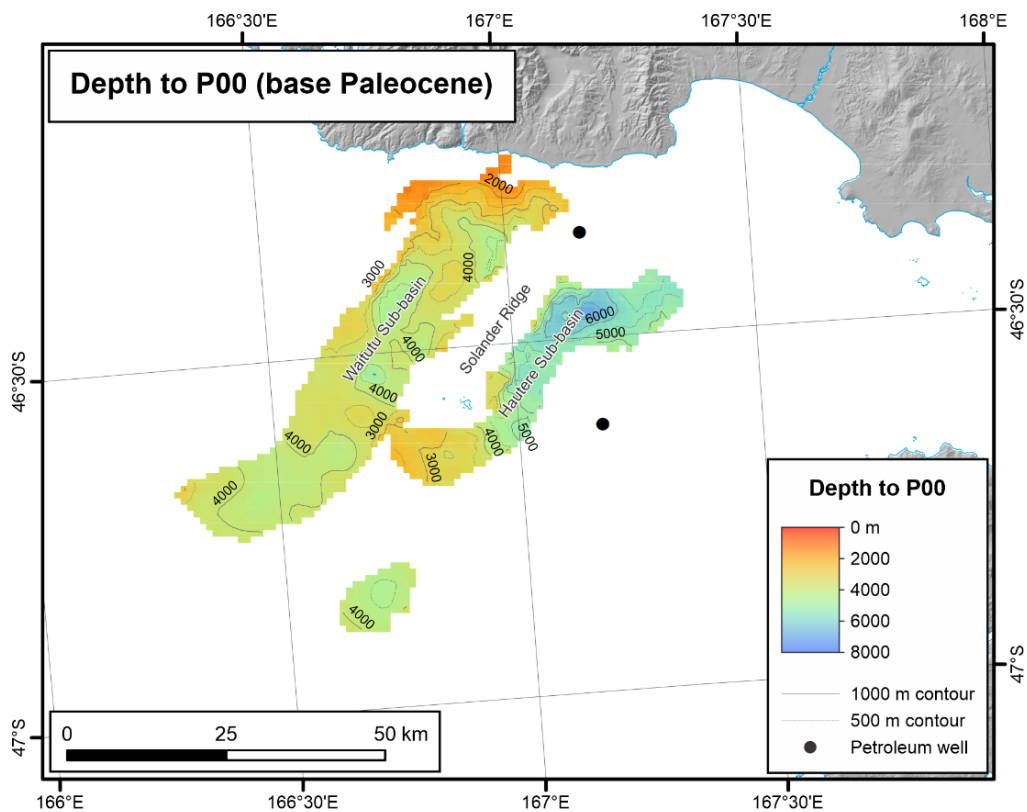


Figure 19 Depth to the base of the Paleocene succession ('top Cretaceous') in Western Southland basin (after Arnot et al. 2018). Note the restricted deposition of these rocks within the Waitutu and Hautere sub-basins.

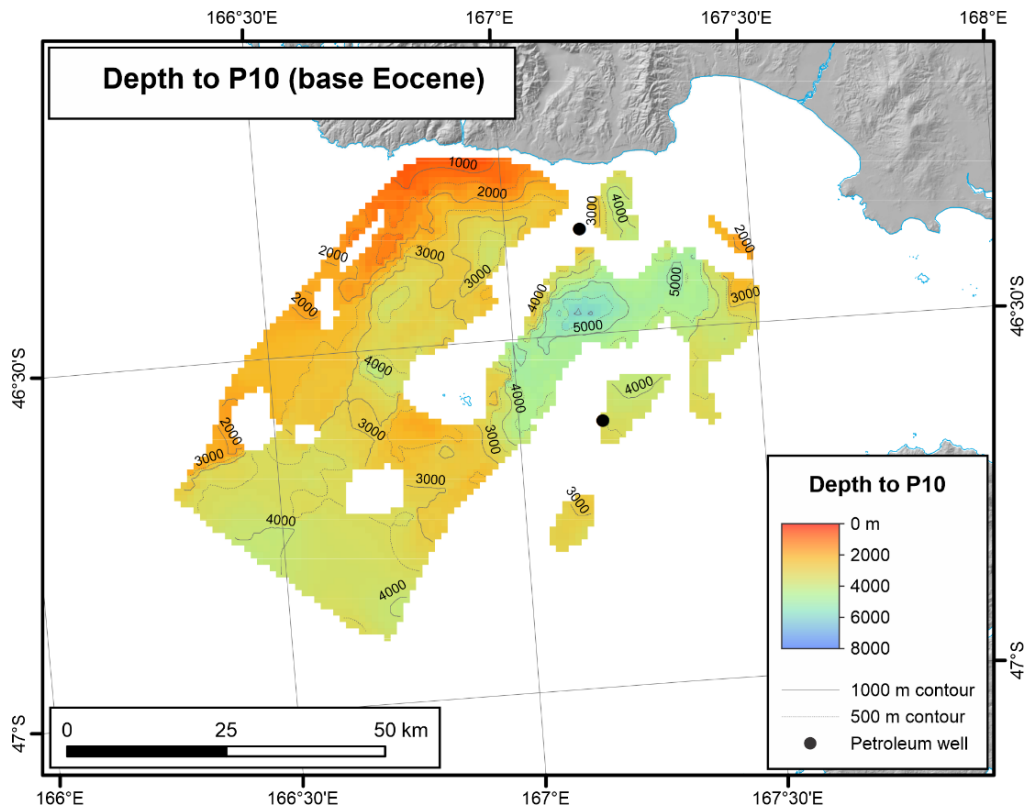


Figure 20 Depth to the base of the Eocene succession ('top Paleocene') in Western Southland basin (after Arnot et al. 2018).

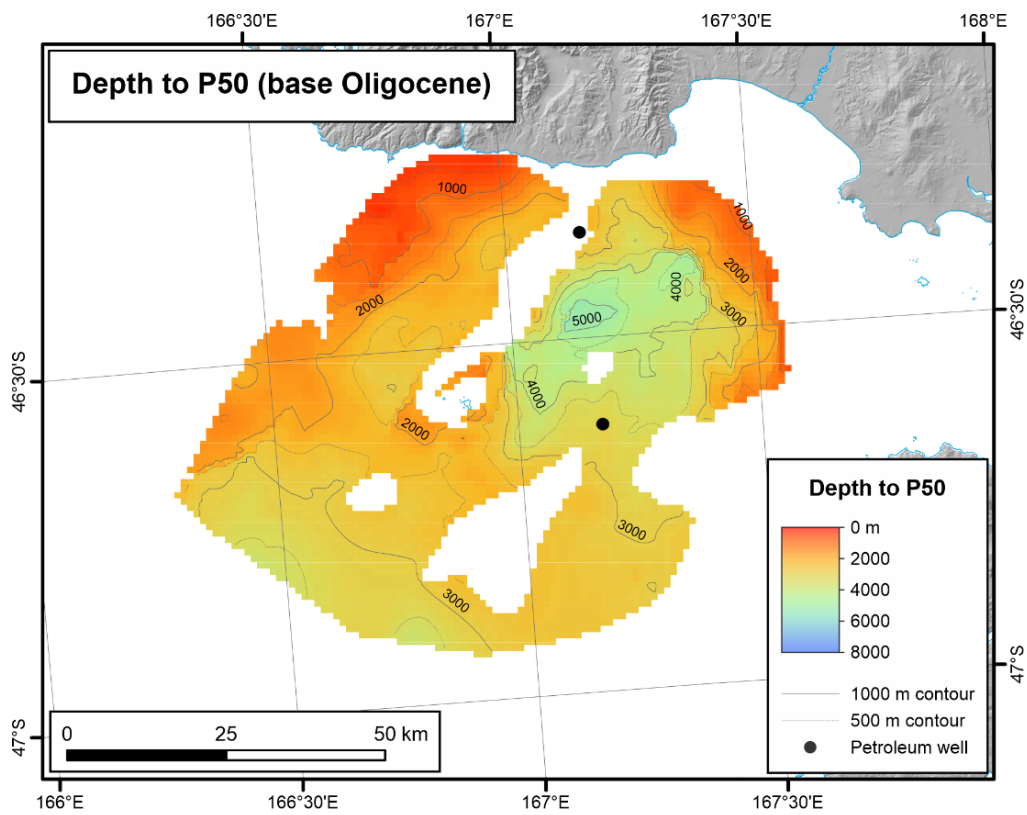


Figure 21 Depth to the base of the Oligocene succession ('top Eocene') in Western Southland basin (after Arnot et al. 2018).

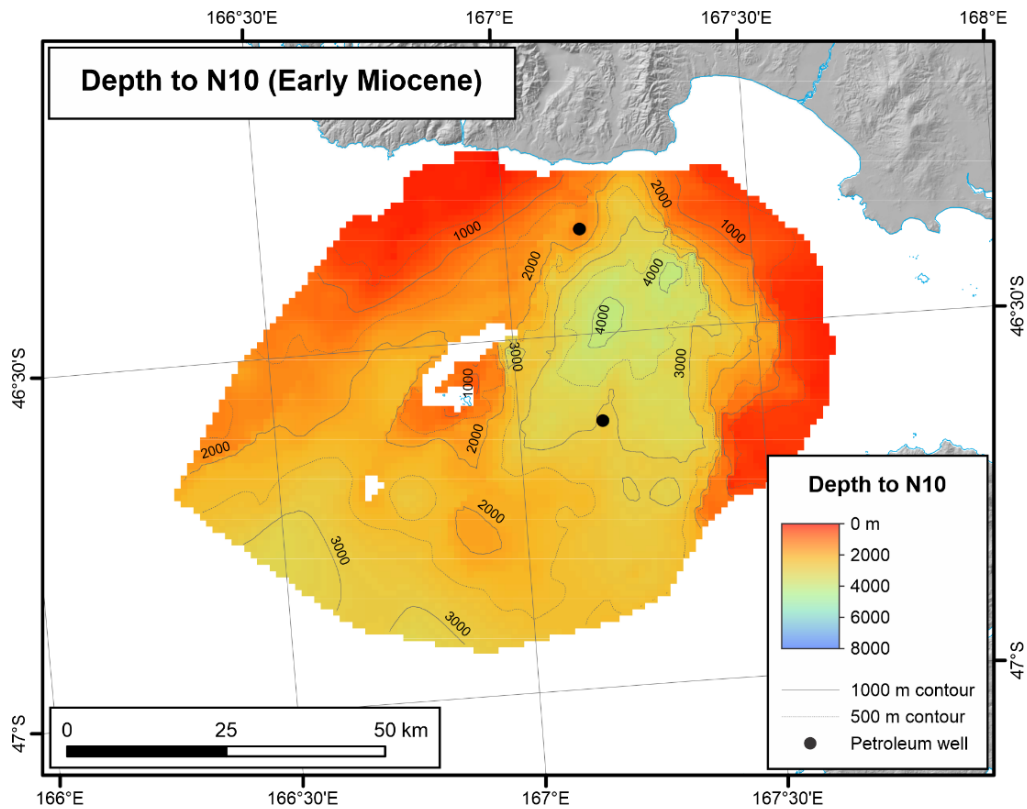


Figure 22 Depth to the base of the Early Miocene succession ('top Paleogene/Oligocene') in Western Southland basin (after Arnot et al. 2018).

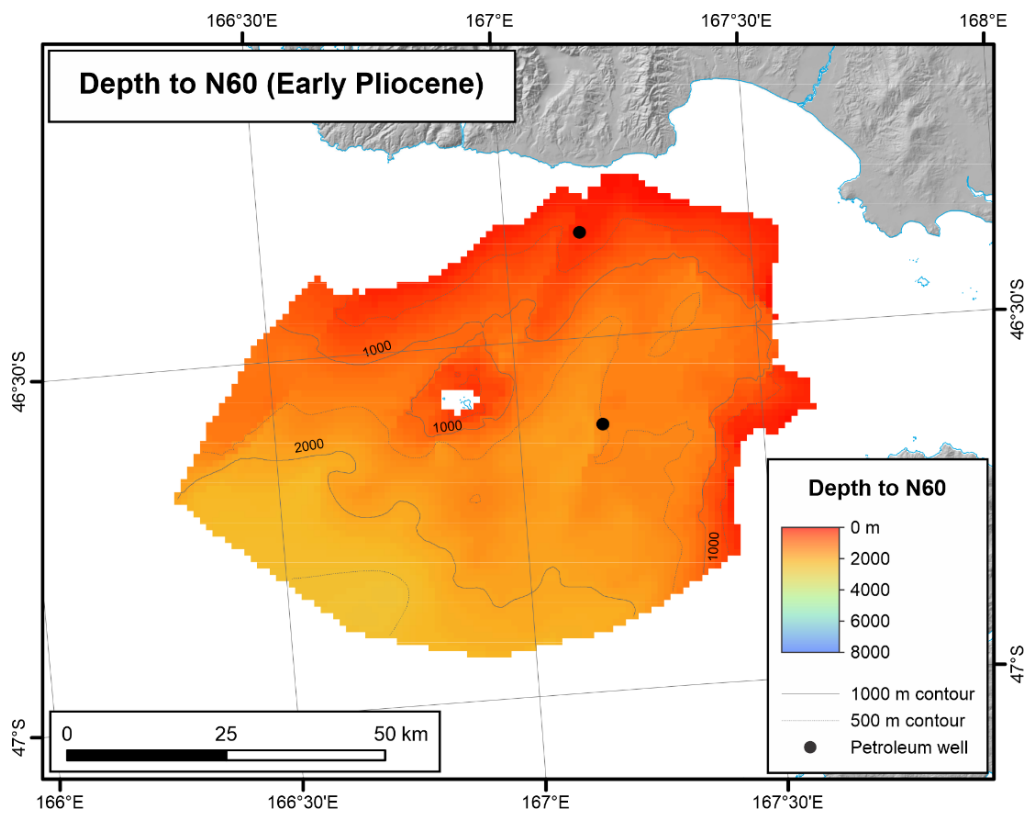


Figure 23 Depth to the base of the Pliocene succession ('top Miocene') in Western Southland basin (after Arnot et al. 2018).



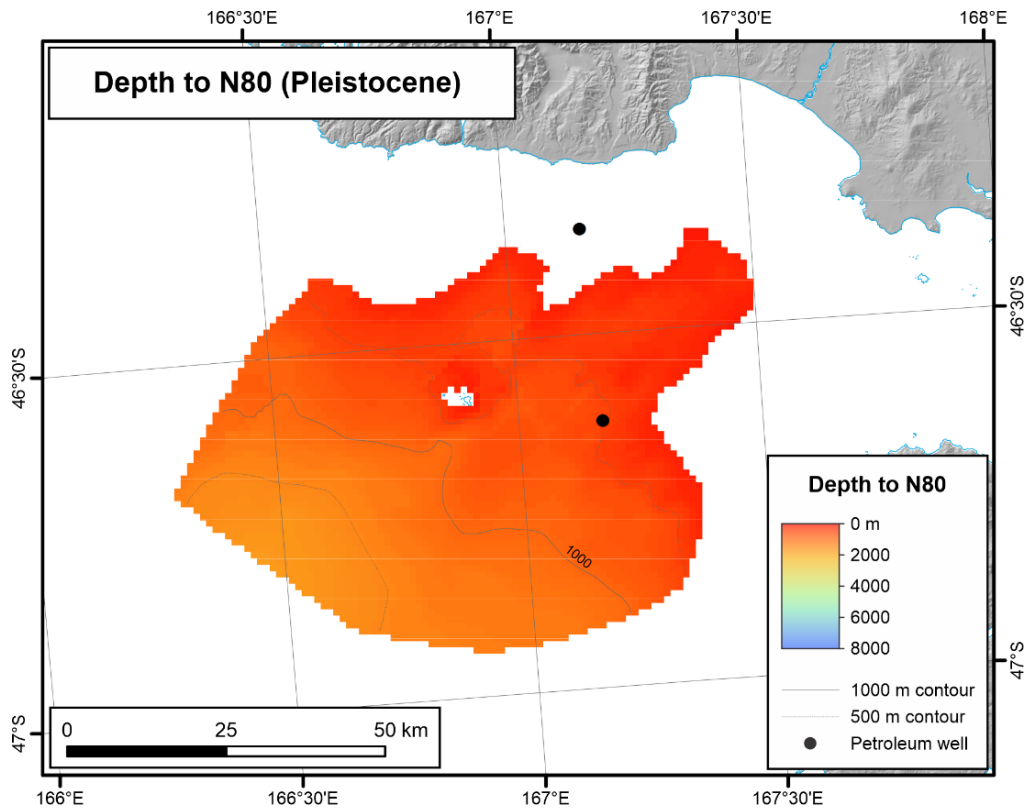


Figure 24 Depth to the base of the Pleistocene/Quaternary succession ('top Pliocene/Neogene') in Western Southland basin (after Arnot et al. 2018). The absence of Pleistocene strata in northern parts of this region reflects syn-depositional uplift and erosion of this part of Western Southland Basin.

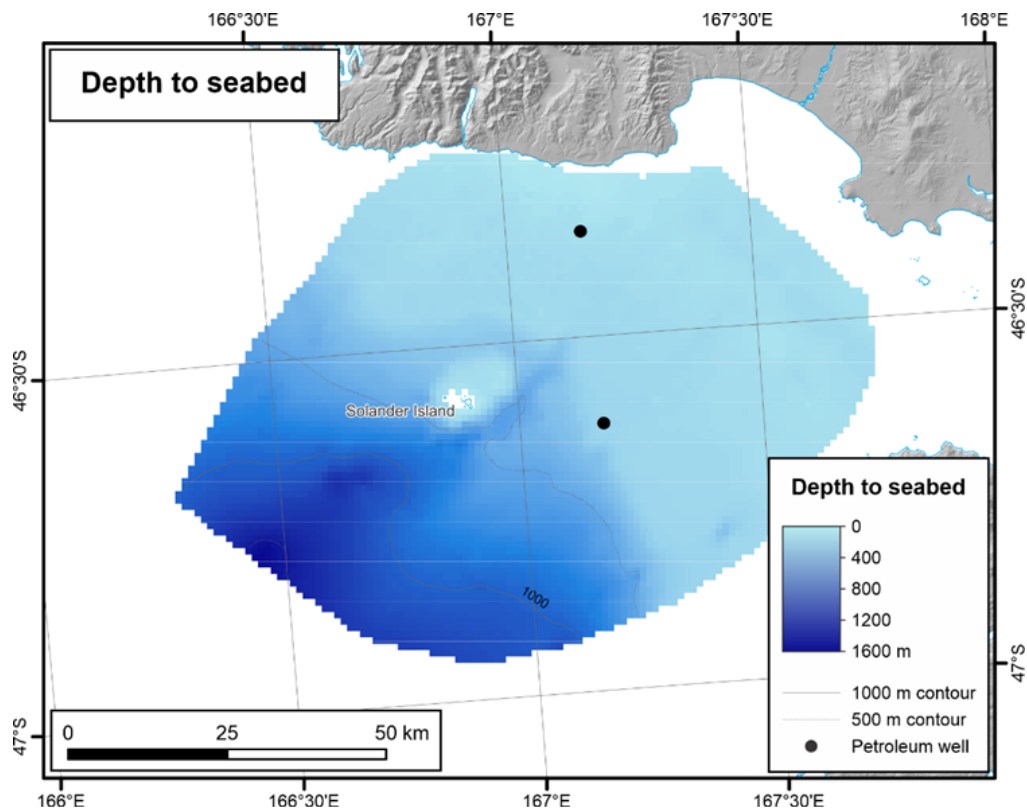


Figure 25 Depth to seabed in Western Southland basin (after Arnot et al. 2018).

## **BASINS OF SOUTHERN NEW ZEALAND**

This region encompasses the Canterbury, Great South, Pukaki, Outer Pukaki, Campbell, Outer Campbell, Bounty Trough, and Chatham Rise basins, all of which originated as mid- to Late Cretaceous intracontinental rifts and have been largely little modified by Neogene–Quaternary tectonics. The western and southern extremities of this area coincide with the probable extent of Zealandia continental crust (Figure 8) (see Mortimer et al. 2017; 2020).

### ***Basement***

Basement beneath this region consists of Eastern and Western Province, Median Batholith, and other Tuhua Intrusives metasedimentary, metamorphic, and igneous rocks of Paleozoic to late Mesozoic age, encompassed by several basement terranes (Tulloch et al. 2019; Mortimer et al. 2020).

### ***Cretaceous–Paleocene***

The oldest strata overlying basement in southern Zealandia are of mid-Cretaceous age, occurring in extensional half-grabens and comprising conglomerate, sandstone, mudstone, and in places coal measures (Cook et al. 1999; Sahoo et al. 2014; 2017; Bland et

al. 2018a; Higgs et al. 2019). The mid-Cretaceous succession in the Canterbury–Great South basins is up to ~3500 m thick, and the overlying Late Cretaceous is up to ~3000 m thick (Sahoo et al. 2017). These rocks were deposited under a general trend of marine transgression and the retrogradation of shoreline and non-marine environments towards the south and west.

The Paleocene succession in the Canterbury–Great South basins is up to ~1100 m thick (mean 390 m) (Sahoo et al. 2017) (Figure 35), and consists of mudstone, sandstone, and minor coal in western areas, becoming increasingly fine-grained and calcareous up-section. Within the Campbell Plateau area, the base of the Paleocene succession marks an unconformity in some areas where it erosionally truncates dipping beds of presumed latest Cretaceous age (Bland et al. 2018a). The base of the Paleocene succession within the Bounty Trough Basin drapes across the top of rotated and eroded basement blocks, consistent with ongoing syn-sedimentary subsidence in those basins and sedimentation focused between the basement highs. The horizon pinches out against some of the larger basement highs (Bland et al. 2018b).

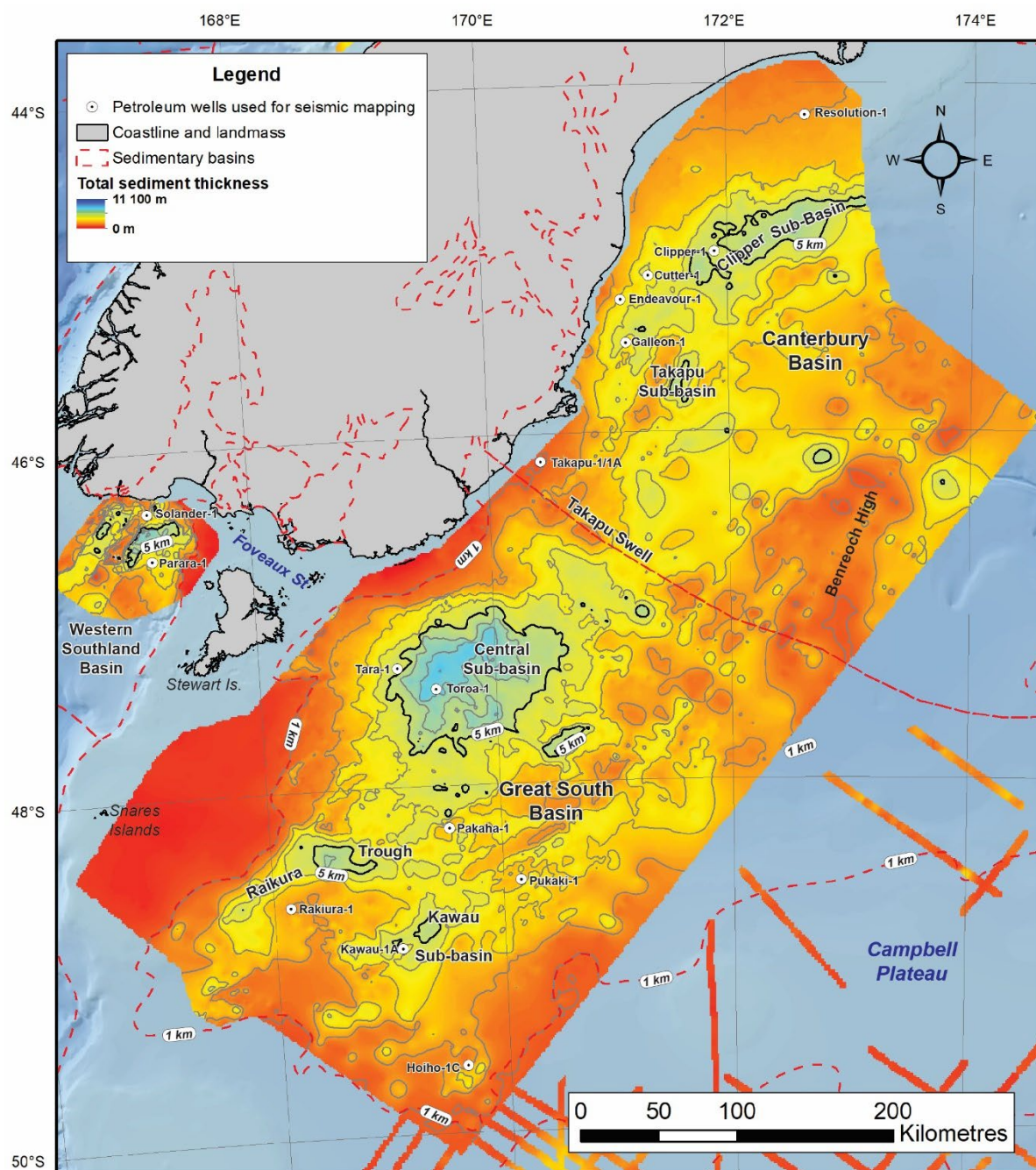


Figure 26 Total sediment thickness in the Canterbury-Great South basins (after Sahoo et al. 2017). The areas of greatest sediment thickness reflect mid-Cretaceous syn-rift depocentres.



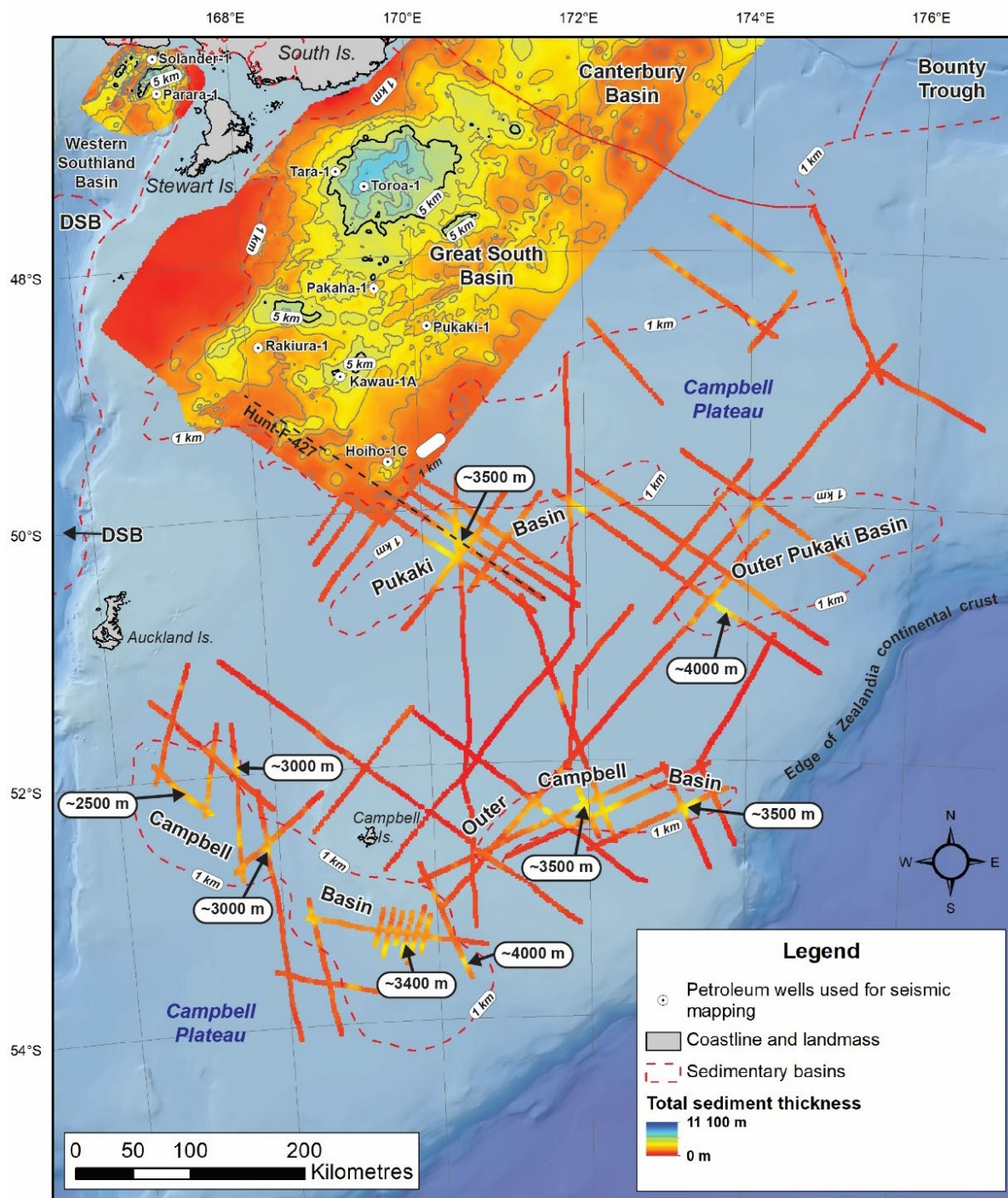


Figure 27 Campbell Plateau basins total sediment thickness 'ribbon-grids' (after Bland et al. 2018a).



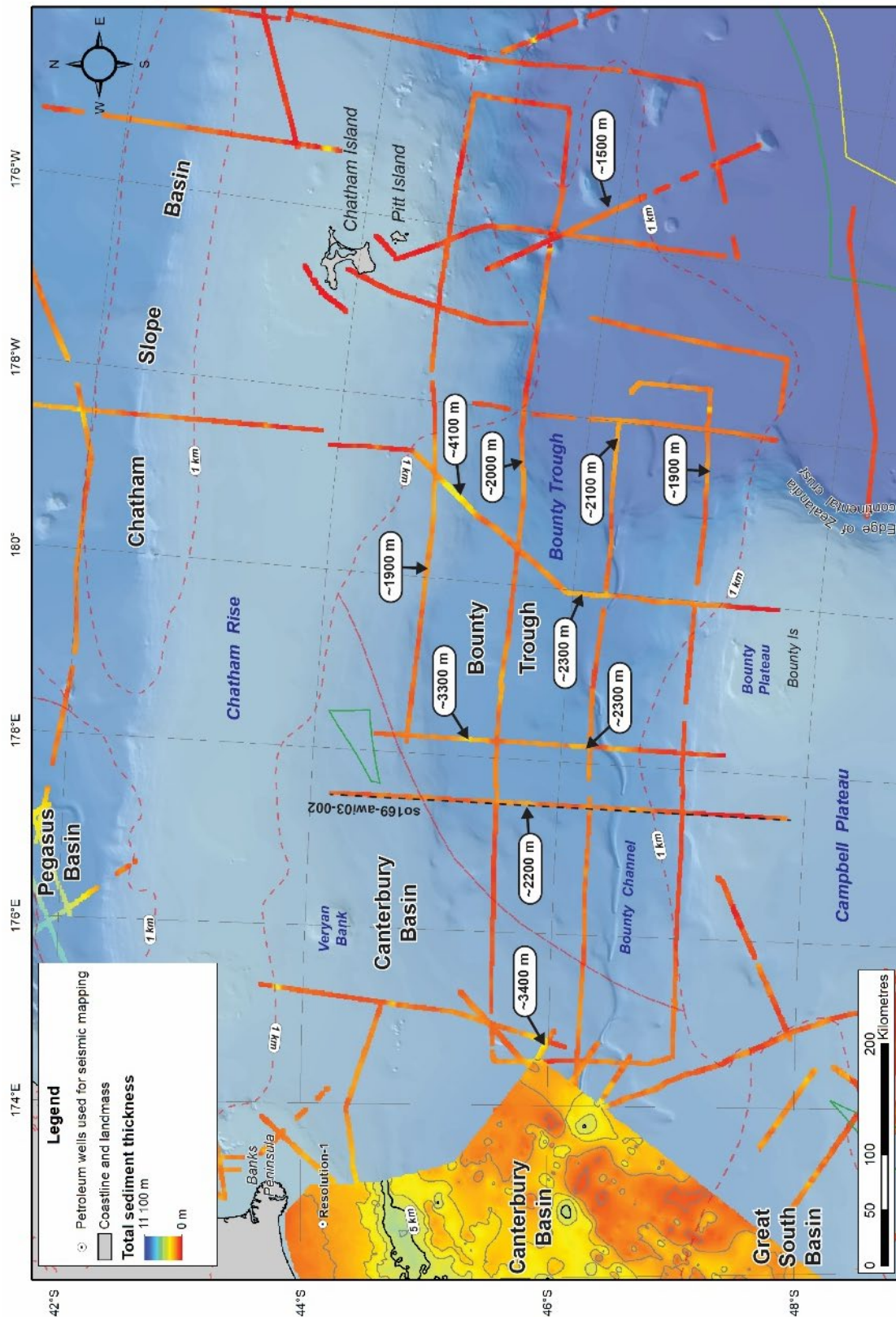


Figure 28 Total sediment thickness “ribbon-grids” across the Bounty Trough Basin (after Bland et al. 2018b).

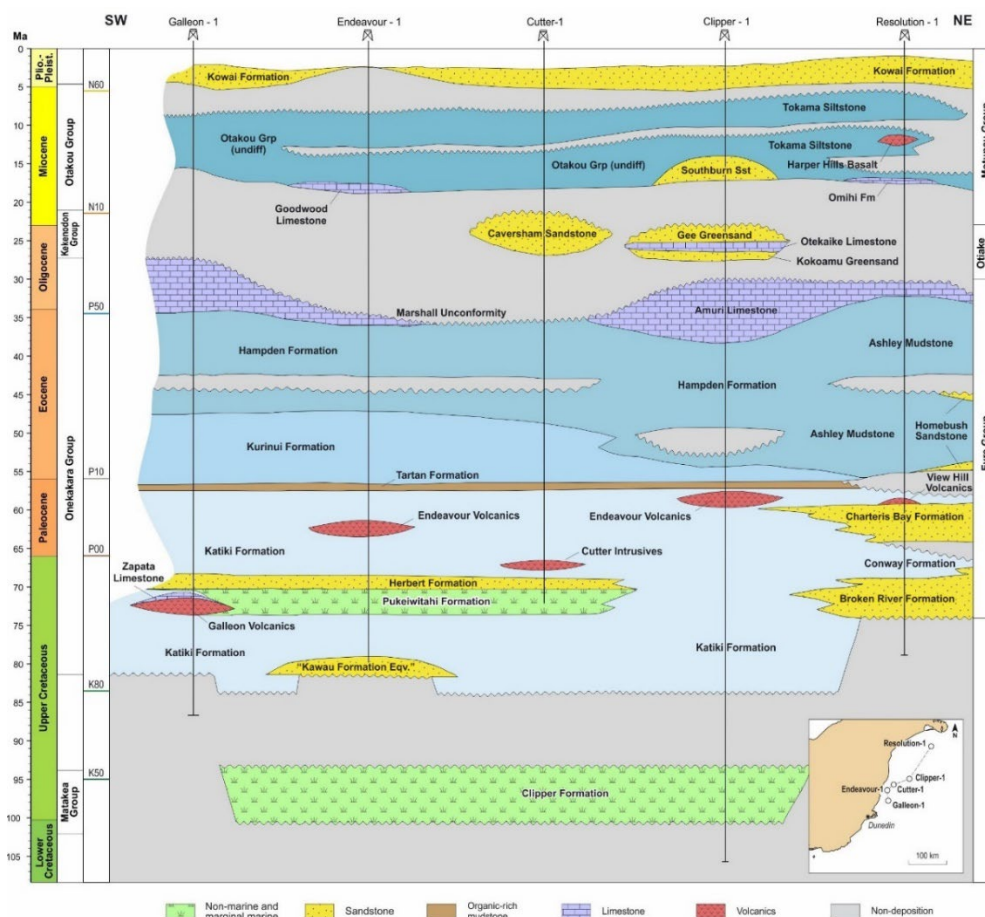


Figure 29 Generalized stratigraphy of the Canterbury Basin, illustrating the major lithostratigraphic units and ages of mapped regional seismic horizons (after Strogen & King 2014). Modified after Schiøler et al. (2011).

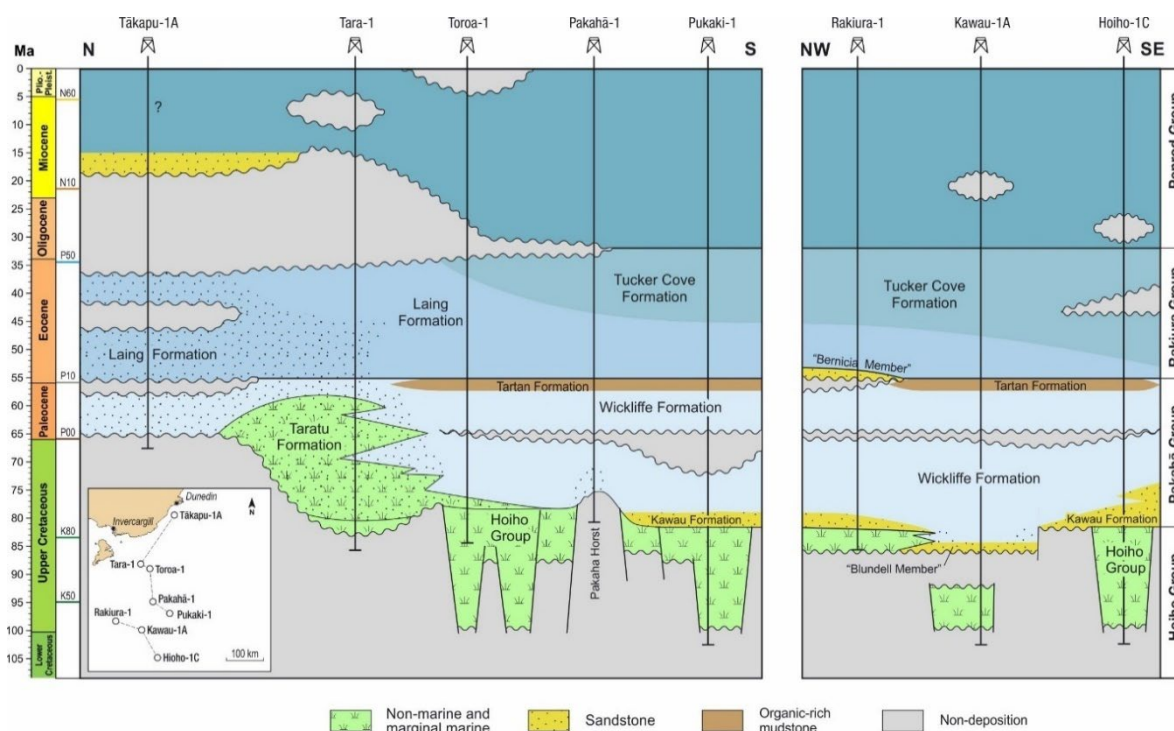


Figure 30 Generalized stratigraphy of the Great South Basin, illustrating the major lithostratigraphic units and ages of mapped regional seismic horizons (after Strogen & King 2014). Modified after Constable & Crookbain (2011), Cook et al. (1999), and Schiøler & Raine (2009).

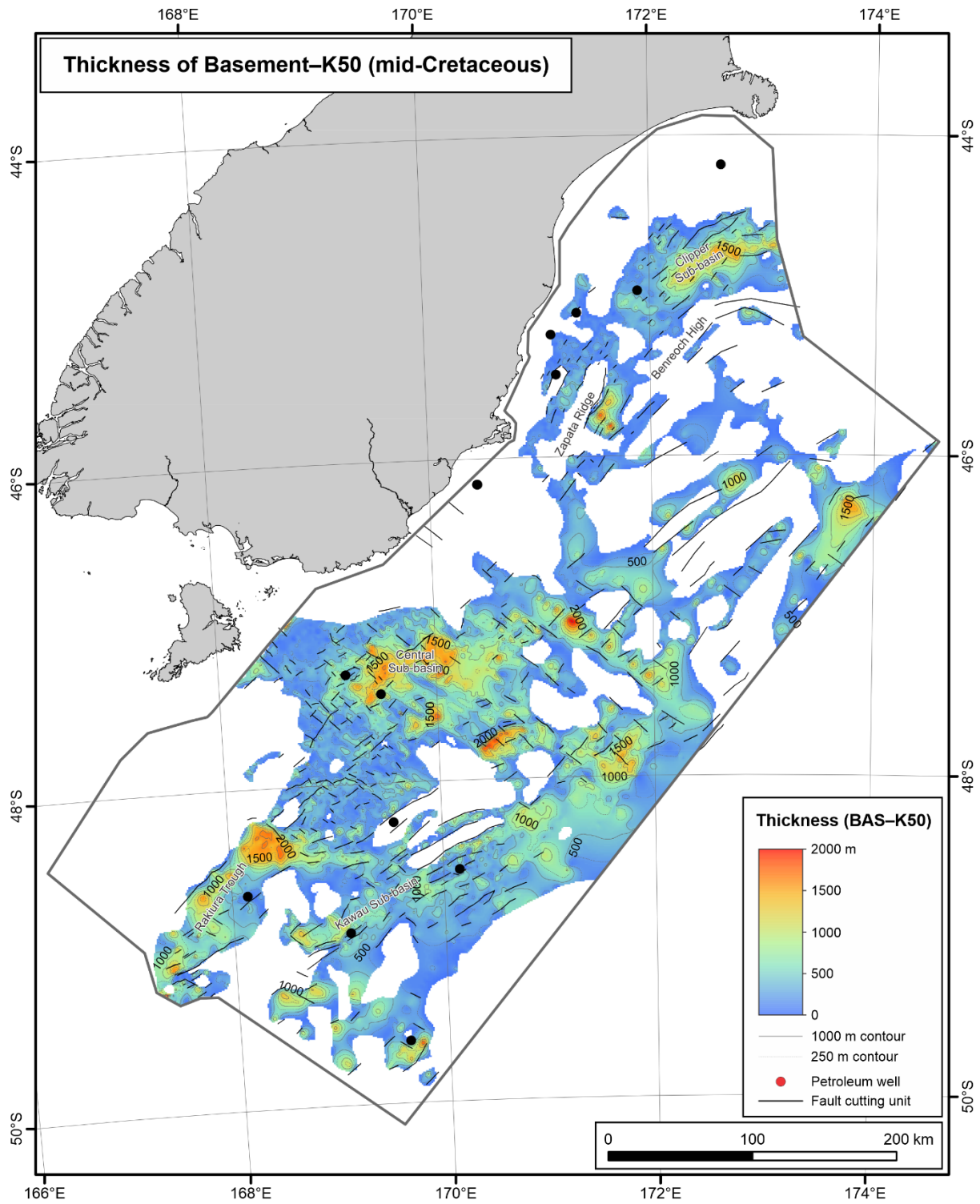


Figure 31 Thickness of mid-Cretaceous early syn-rift rocks (c. >98 Ma) in Canterbury-Great South basins (after Sahoo et al. 2017). The thickness of these strata shows the main depocentres within these basins, formed during the 'Zealandia rift phase' of Strogen et al. (2017).



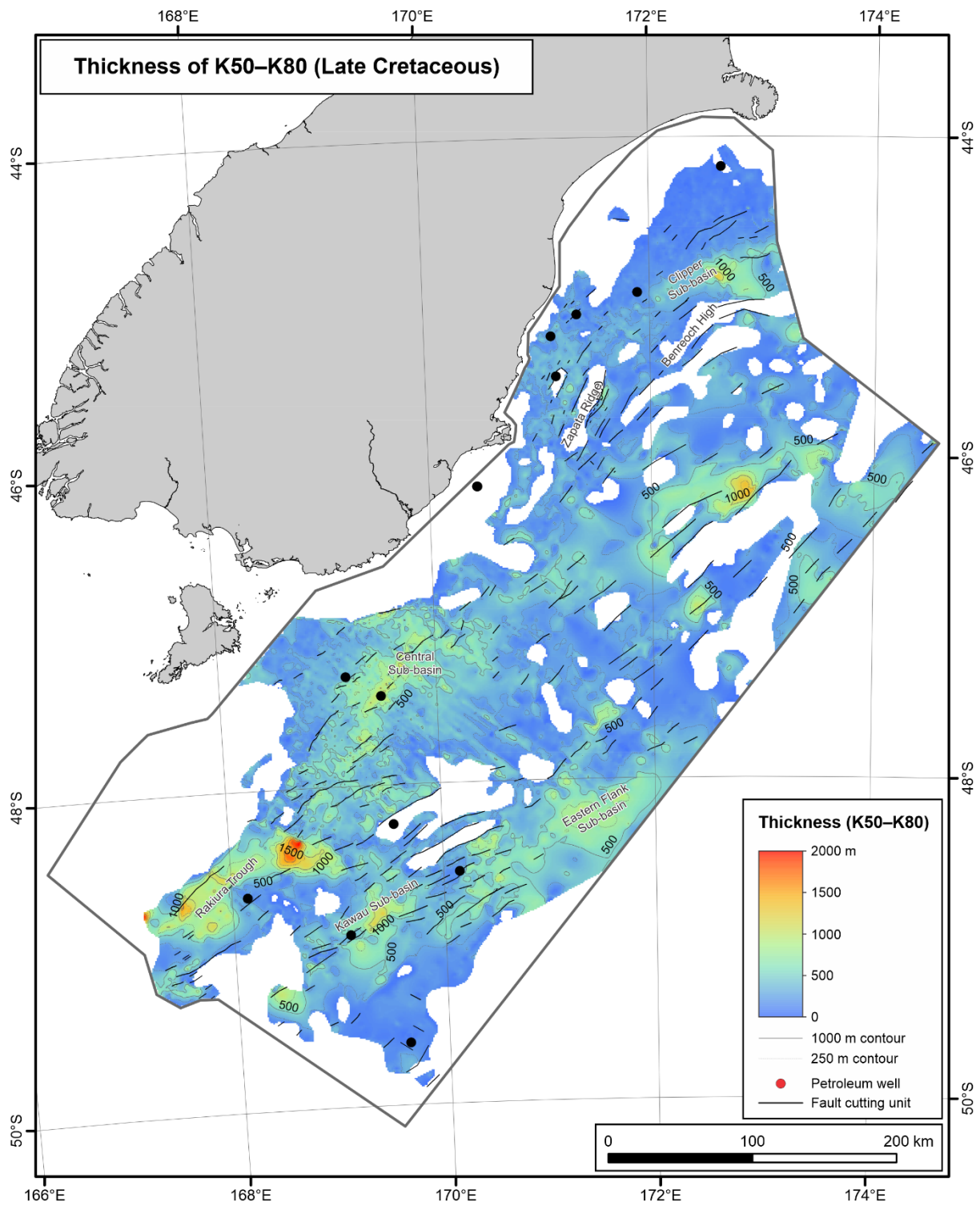


Figure 32 Thickness of Late Cretaceous syn-rift and earliest post-rift rocks (c. 98–85 Ma; 'Zealandia rift phase' of Strogen et al. 2017) in Canterbury-Great South basins (after Sahoo et al. 2017).



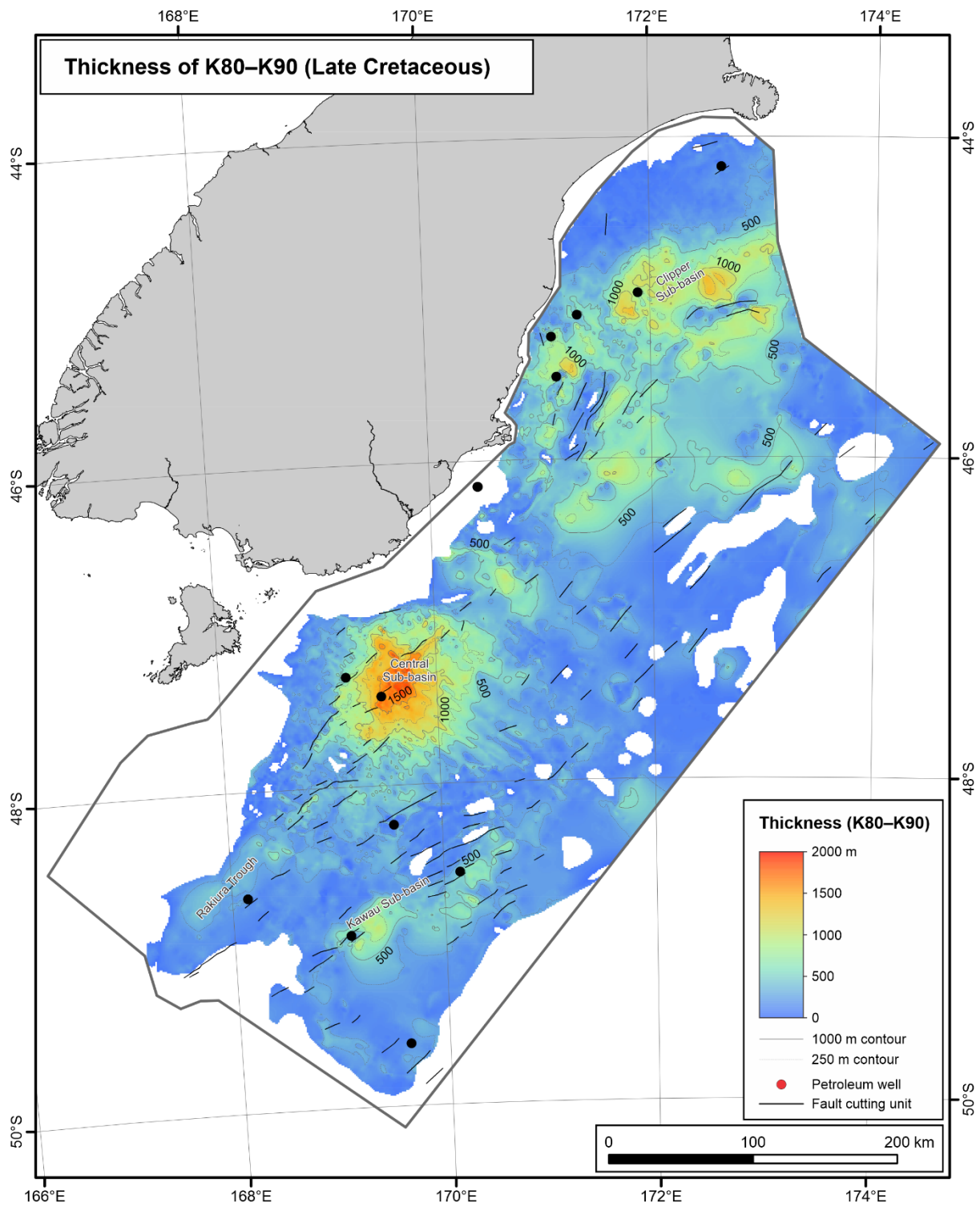


Figure 33 Thickness of Late Cretaceous post-rift rocks (c. 85–75 Ma) in Canterbury-Great South basins (after Sahoo et al. 2017). The primary depocentres in these basins (Rakiura Trough, Kawait, Central, and Clipper sub-basins) are clearly shown by the thickness of sediments.

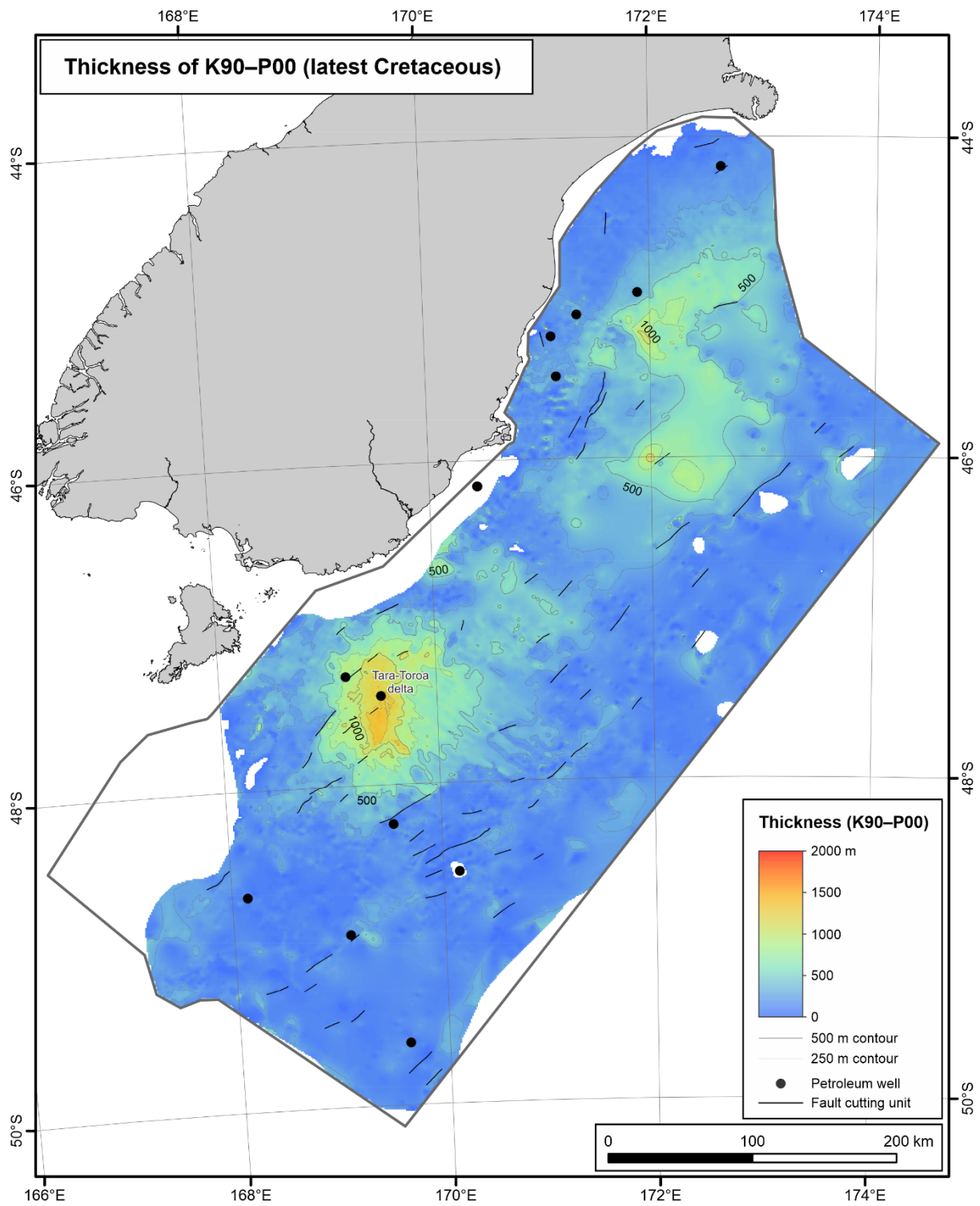


Figure 34 Thickness of latest Cretaceous rocks (c. 75–66 Ma) in Canterbury-Great South basins (after Sahoo et al. 2017). The thickest successions occur in the Central Sub-basin (Great South Basin) and Clipper Sub-basin (Canterbury Basin).

## ***Eocene***

The Eocene succession is thickest in the Canterbury-Great South basins (up to ~1740 m thick; mean ~580 m), although is typically much thinner and more condensed across the region (Sahoo et al. 2017) (Figure 36). Basement within the Campbell Plateau basins may be onlapped by rocks as young as latest Eocene (Bland et al. 2018a). The Eocene succession contains channel- and basin-floor fan-like features, though is dominated by fine-grained calcareous mudstone. Within the Bounty Trough Basin, the base of the Eocene succession is often marked by an unconformable surface that overlies a set of strongly reflective horizons, which become increasingly parallel on the northern slope of the Bounty Trough (Bland et al. 2014b, 2018b). The upper surface is characterised by roughness in places associated with discrete surface erosion features.

Eocene rocks throughout the basins of southern Zealandia contain significant areas of polygonal faulting, but especially so in the northern half of the area. The presence of polygonal fault systems indicates the presence of very fine-grained strata. In the southern part of the area the Eocene succession appears more disrupted and mounded, perhaps reflecting the influence of deep-marine marine currents upon deposition.

## ***Oligocene–Miocene***

The Oligocene succession across most of Canterbury-Great South Basin is <280 m thick, and generally mudstone or carbonate dominated (Sahoo et al. 2017) (Figure 37). Deposition of these fine-grained rocks reflects waning terrigenous sediment input from the subsiding adjacent hinterland. Deep-marine environments existed across most of southern Zealandia at this time. Sea-floor scour and erosion means that Oligocene rocks are either absent, or very condensed, along the western margin of the Great South Basin. Across much

of the Campbell Plateau and Bounty Trough Basin the Oligocene and Miocene successions cannot be easily differentiated on seismic reflection data due to the thin and stratigraphically condensed Oligocene interval (Bland et al. 2018b). Here, the succession consists dominantly of Miocene strata, with Oligocene rocks representing only the equivalent of one-or-two seismic reflection loops. Where mappable, the Oligocene succession is characterised by moderate- to high-amplitude parallel and often mounded reflectors that onlap the top of the Eocene succession.

The Miocene succession in southern Zealandia basins was deposited during renewed active convergent tectonics associated with the establishment of the Pacific-Australia plate boundary through Zealandia. The resulting compression is evident in slight compressional folding in inboard parts of the Canterbury-Great South basins, such as in the Tara–Toroa area. The active tectonics has also resulted in the progradation, from the Late Miocene onward, of a shelfal sedimentary succession out into Canterbury Basin. The sediment forming this growing shelfal package is derived from uplift and erosion of the Southern Alps and associated mountains. The Miocene succession is thickest near the modern Canterbury coastline (~1380 m) and has a mean thickness of ~370 m elsewhere in these basins (Sahoo et al. 2017) (Figure 38). An obvious mappable base to the Miocene succession occurs in central-western parts of the Campbell Plateau basins, and lies ~420–1185 m below sea level (mean 915 m) (Bland et al. 2018a). Much of the Miocene succession within the Bounty Trough Basin is interpreted to comprise turbidites associated with over-bank deposits from channels in the Bounty Trough. These sediments were sourced from the erosion of the rising compressional margin in onshore South Island. The succession is

affected by underlying polygonal faulting in the northern half of the basin.

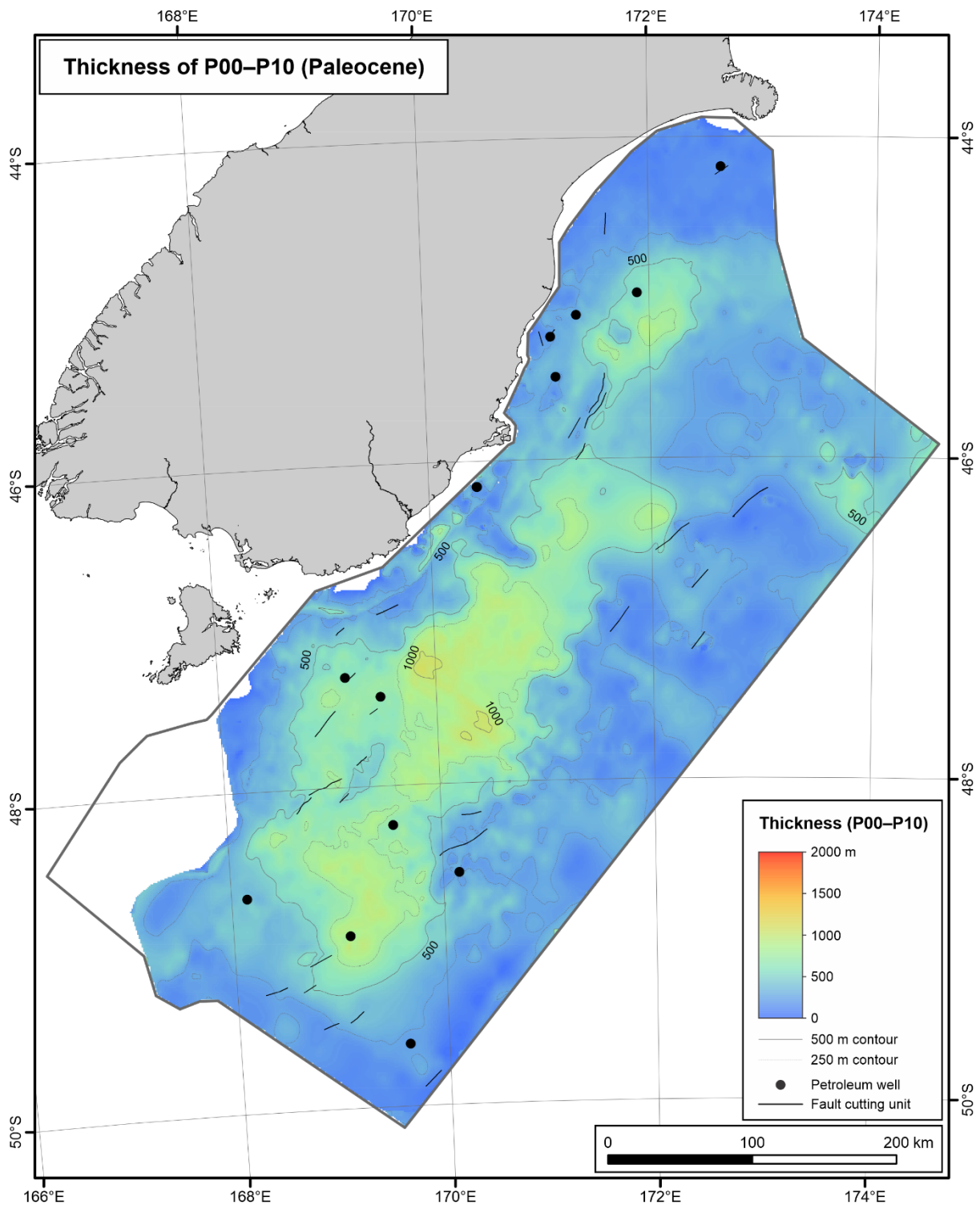


Figure 35 Thickness of Paleocene rocks (c. 66–56 Ma) in Canterbury-Great South basins (after Sahoo et al. 2017).



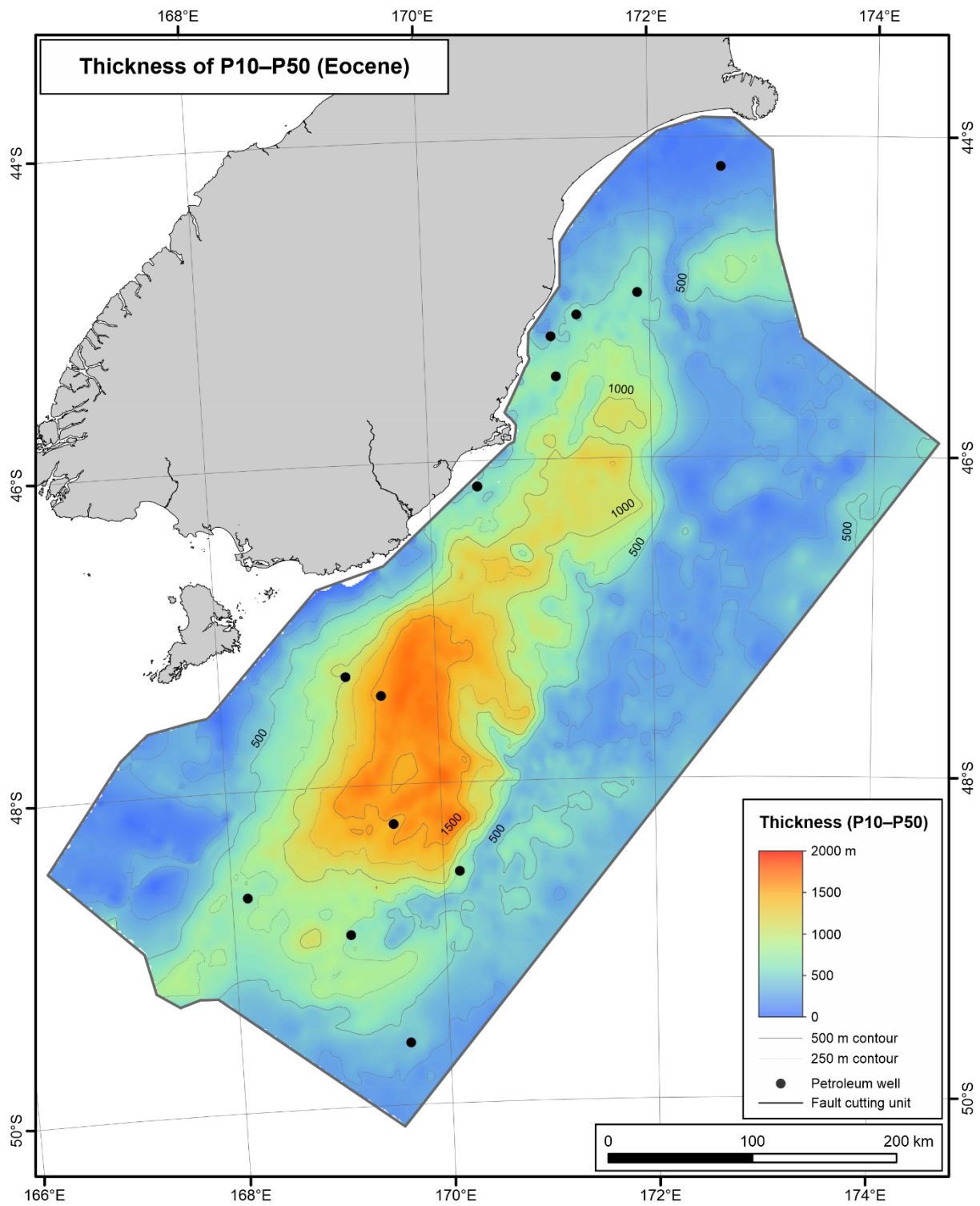


Figure 36 Thickness of Eocene rocks (c. 66–35 Ma) in Canterbury-Great South basins (after Sahoo et al. 2017). Note the increase in thickness in central parts of Great South Basin.

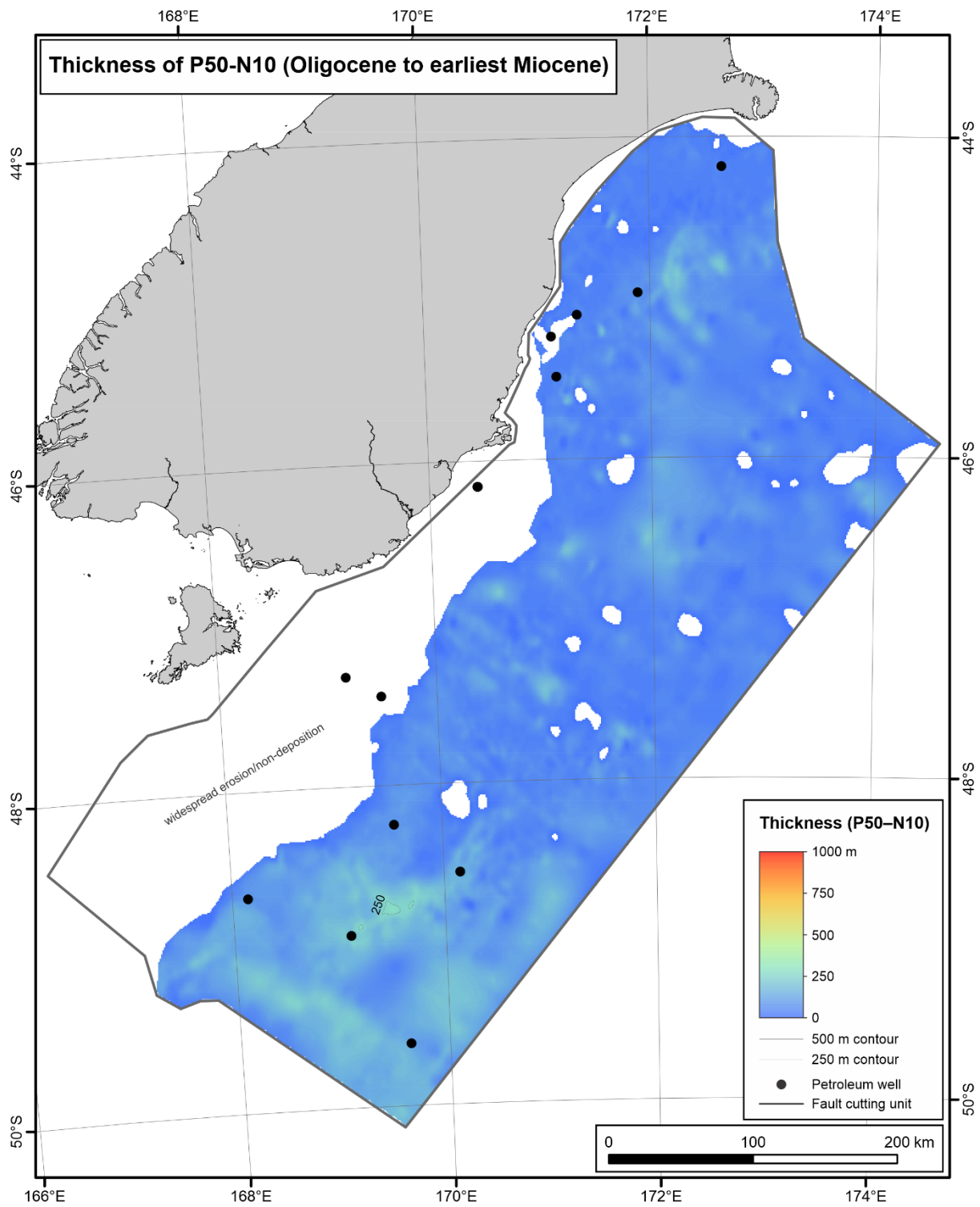


Figure 37 Thickness of Oligocene to earliest Miocene rocks (c. 35–21 Ma) in Canterbury-Great South basins (after Sahoo et al. 2017). Much of this succession is very thin and condensed across the basins. Deep-marine erosion and/or non-deposition was occurring in western parts of the region, as shown by the absence of rocks in that area.

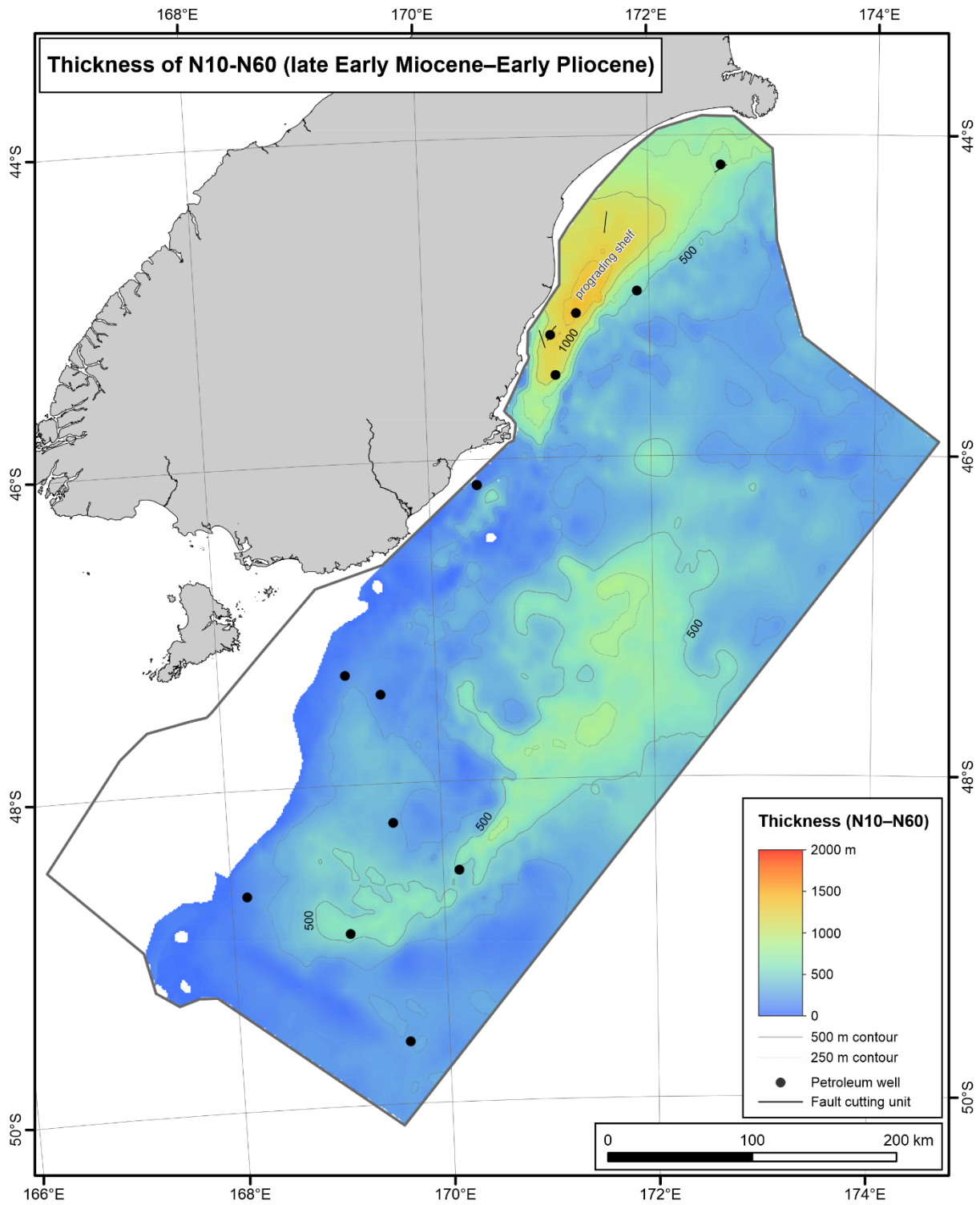


Figure 38 Thickness of Miocene to Early Pliocene rocks (c. 21–04 Ma) in Canterbury–Great South basins (after Sahoo et al. 2017). The succession is relatively thin across much of the area. Increased thicknesses in the Canterbury Basin area reflect sediment progradation caused by uplift and erosion associated with mountain building in central South Island.

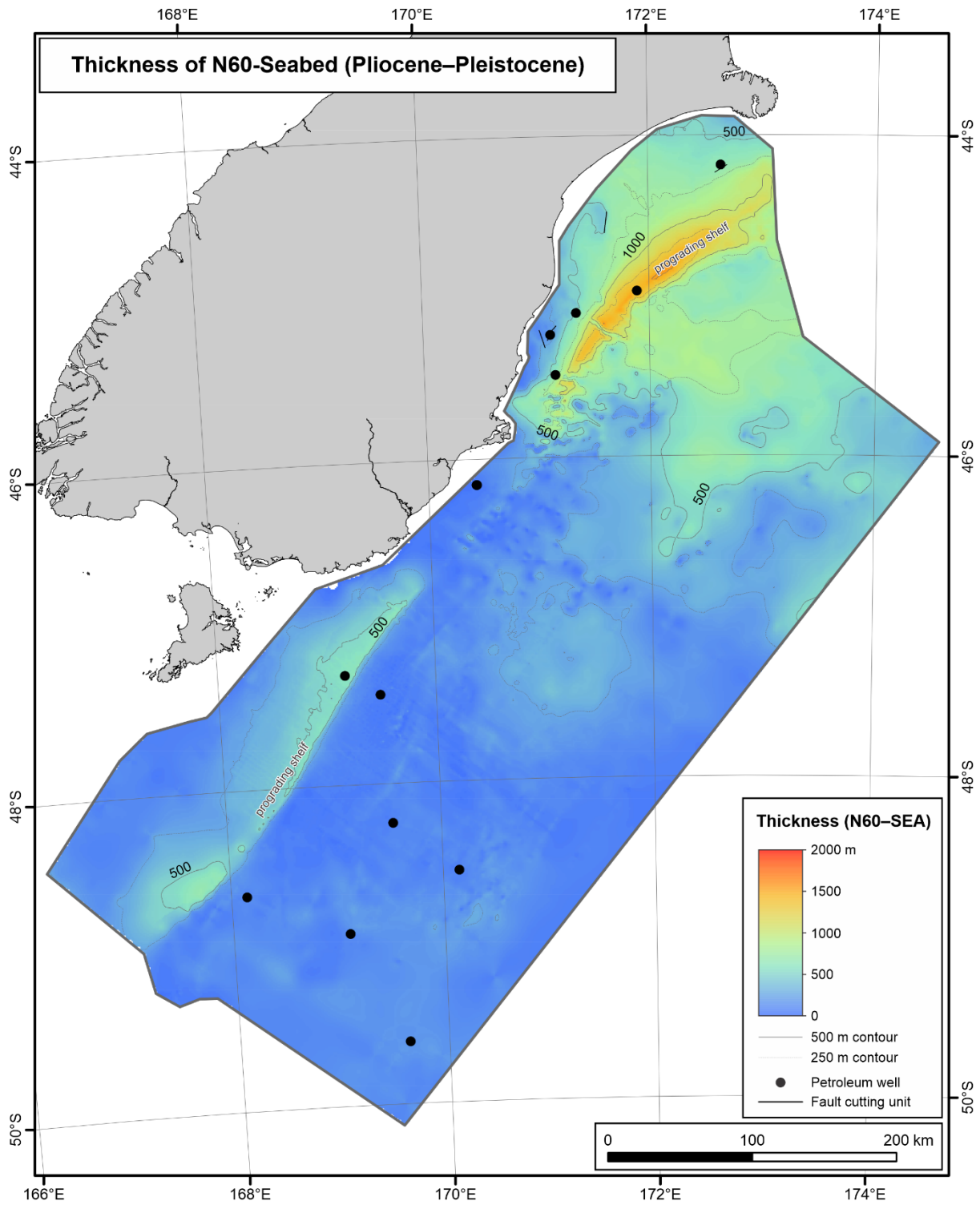


Figure 39 Thickness of Pliocene-Quaternary rocks (c. 0.4–0 Ma) in Canterbury-Great South basins (after Sahoo et al. 2017). The progradation of the continental shelves in this area is a consequence of uplift and erosion associated with contemporaneous mountain building in central South Island.



### ***Pliocene–Quaternary***

The thickest Pliocene–Quaternary succession in southern Zealandia occurs adjacent to the present-day coastline in Canterbury Basin, where it is up to ~1575 m thick, and averages ~300 m thick elsewhere (Sahoo *et al.* 2017) (Figure 39). It was primarily deposited as part of a progradational shelf margin strongly associated with uplift and erosion of metasedimentary basement rocks in the Southern Alps. A similar, though smaller amount of progradation, has also occurred since c. 4 Ma along the western margin of Great South Basin. The Pliocene–Quaternary succession in the Campbell Plateau basins generally consists of fine-grained lithofacies (Bland *et al.* 2018a). Seismic reflector patterns provide evidence for deep-marine sediment drift deposits in some areas. Similar facies also occur in the Bounty Trough Basin where, in northern parts of the basin, they are affected by polygonal faulting (Bland *et al.* 2018b). Also present are many ~100 m+-diameter pockmarks, including many on the modern sea floor (Davy *et al.* 2010; Hillman *et al.* 2015; Stott 2019).

### **BASINS OF NORTHEAST NEW ZEALAND**

The Raukumara, East Coast, and Pegasus basins represent thick sedimentary accumulations along and atop a large part of the New Zealand sector of the former Gondwana subduction margin (Stagpoole *et al.*, 2008; Uruski, 2010; Bland *et al.*, 2015; Crampton *et al.*, 2019). The top of geological basement in these basins marks the top of the deformed paleo-Pacific Gondwana accretionary wedge and the Early Cretaceous Hikurangi Plateau (Davey *et al.* 2008; Stagpoole *et al.* 2008; Bland *et al.* 2015). Northeast Zealandia did not experience the mid- to Late Cretaceous rifting that formed much of the remainder of New Zealand's offshore basins (Strogen *et al.*, 2022), and once Gondwana subduction ceased in the early Late Cretaceous (Davy, 2014; Bland *et al.*, 2015;

Reyners *et al.*, 2017; Crampton *et al.*, 2019; Riefstahl *et al.*, 2020) these basins experienced an extended period of relative tectonic quiescence. This passive margin sequence has, along much of the margin, been extensively overprinted by late Paleogene to predominantly Neogene–Quaternary tectonism associated with the development of the Hikurangi subduction margin (Field *et al.*, 1997; Barnes *et al.*, 2002; Nicol *et al.*, 2007; Bland *et al.*, 2015; Hines *et al.* 2022).

### **Geological fill**

Zealandia basement under much of the NEP consists of Torlesse Composite Terrane metasediments, although these taper eastwards to zero thickness, marking the edge of the paleo-Gondwana accretionary wedge. The exact position of this pinch out is often unclear in areas of thick sediment. Outboard of this point, basement consists of Hikurangi Plateau oceanic crust and its covering sediment veneer.

### ***Cretaceous–Paleogene***

Mid-Cretaceous–Paleogene rocks in northeast Zealandia were deposited atop remnant topographic and bathymetric features associated with the Gondwana subduction accretionary wedge, and the Hikurangi Plateau, thereby influencing the distribution and lithologies of strata (Bland *et al.* 2015; Hines 2018; Crampton *et al.* 2019). The base of the Cretaceous succession in Raukumara Basin lies ~3890–12 980 m deep, and overlying rocks are up to ~5250 m thick (mean thickness ~1430 m) (Strogen *et al.* 2018). Based on onshore analogues, the Cretaceous succession likely comprises flysch and other mass-emplaced sandstones within an otherwise siliceous mudstone-dominated package.

The base of the Paleogene succession within Raukumara Basin lies 3070–9000 m deep (mean ~1400 m), and overlying rocks are up to ~3640 m thick (mean thickness ~1700 m) (Strogen *et al.* 2018). The base of the

Paleogene succession lies 820–4150 m deep (mean ~2800 m) beneath offshore Wairarapa and ~1060–6270 m deep beneath Hawke Bay (mean ~930 m) (Strogen et al. 2018). Beneath Hawke Bay, the Paleogene succession, as mapped, is up to ~2600 m (mean thickness ~735 m), although this will likely include faulted repetition of strata. Based on onshore analogues, it is assumed that much of the Paleogene succession consists of fine-grained siliceous, smectitic, and calcareous lithologies, with occasional mass-emplaced sandstone beds. A high-amplitude seismic facies within the inferred Paleocene succession in Raukumara Basin has been tentatively correlated with the Late Paleocene Waipawa Formation (Stagpoole et al. 2008).

The Paleogene succession within parts of Pegasus Basin and the northern flanks of the Chatham Rise comprises a thin condensed interval with several strong reflectors and is equivalent to 'Sequence Y' of Wood and Davy (1994). These probably represent mudstones deposited in a deep-water setting. Beneath Pegasus basin the Paleogene succession is up to ~2150 m thick (mean thickness ~450 m) (Strogen et al. 2018).

Oligocene strata through the northeast Zealandia basins comprise marls to calcareous mudstones, with some thin- to medium-bedded flysch. These fine-grained carbonate-rich rocks reflect significant drowning of the Zealandia continent and very low terrigenous sediment input. The top of the Oligocene succession in the East Coast and Pegasus basins is marked by a series of bright reflectors, likely to represent carbonate-dominated units.

### **Miocene**

The Miocene–Quaternary succession in the northeast basins is marked by an abrupt change from carbonate-rich and comparatively condensed sedimentation to a phase characterised by high rates of siliciclastic-dominated sedimentation. Although mudstone

dominated, prominent and thick packages of sandstone mass-flow and debrite deposits occur within accretionary slope basins and channel systems. Bioclastic carbonate-rich intervals are also widespread, although are volumetrically limited.

The base of the Miocene succession in Raukumara Basin lies 1750–6160 m below (mean ~4760 m), and is placed at the base of a highly deformed package that occupies much of the western side of the basin ('sequence Y' of Stagpoole et al. 2008 and Ayling 2016) (Strogen et al. 2018). This package is correlated with the earliest Miocene East Coast Allochthon seen onshore (Stoneley 1968; Mazengarb and Speden 2000), and as such, potentially represents the only well-constrained reflector in the basin (Stagpoole et al. 2008; Sutherland et al. 2009; Strogen et al. 2018). The age of emplacement of the allochthon is close to the base Miocene (Mazengarb and Speden, 2000). Away from areas where the allochthon is present, the base of the Miocene succession is marked by a correlative conformity between the relatively condensed late Paleogene and much thicker Neogene successions ('sequence Z' of Stagpoole et al. 2008 and Ayling 2016).

Upper parts of the Oligocene interval (and therefore base of the Miocene succession) are often marked by a series of bright reflectors, likely to be carbonate-dominated units. This reflector package can be traced across most of the Pegasus Basin and offshore Wairarapa (Strogen et al. 2018). Using academic seismic reflection lines that run along the Hikurangi Trough, the horizon can be mapped to eastern Hawke Bay and Poverty Bay. There are significant challenges mapping it across thrust ridges into the sub-basins of Hawke Bay and offshore Gisborne. The base of the Miocene succession lies 150–4375 m beneath Hawke Bay (mean ~1860 m) (Strogen et al. 2018), and the interval is up to ~2320 m thick (mean thickness ~800 m).

Within the East Coast and Pegasus basins the Miocene interval has a characteristic pattern of three to four intervals of bright continuous reflectors separated by bands of low reflectivity. These individual packages can be mapped over large distances and show strong correlations across the first set of thrust sheets and slope basins. There are several complex angular

unconformities and para-conformities that complicate the interpretation on the northern slope of the Chatham Rise. Turbidites will be present. In both Pegasus Basin and the Wairarapa area, an intra-Miocene unconformity (N40) can be mapped. This is likely to be approximately base-Late Miocene in age (Strogen et al. 2018).

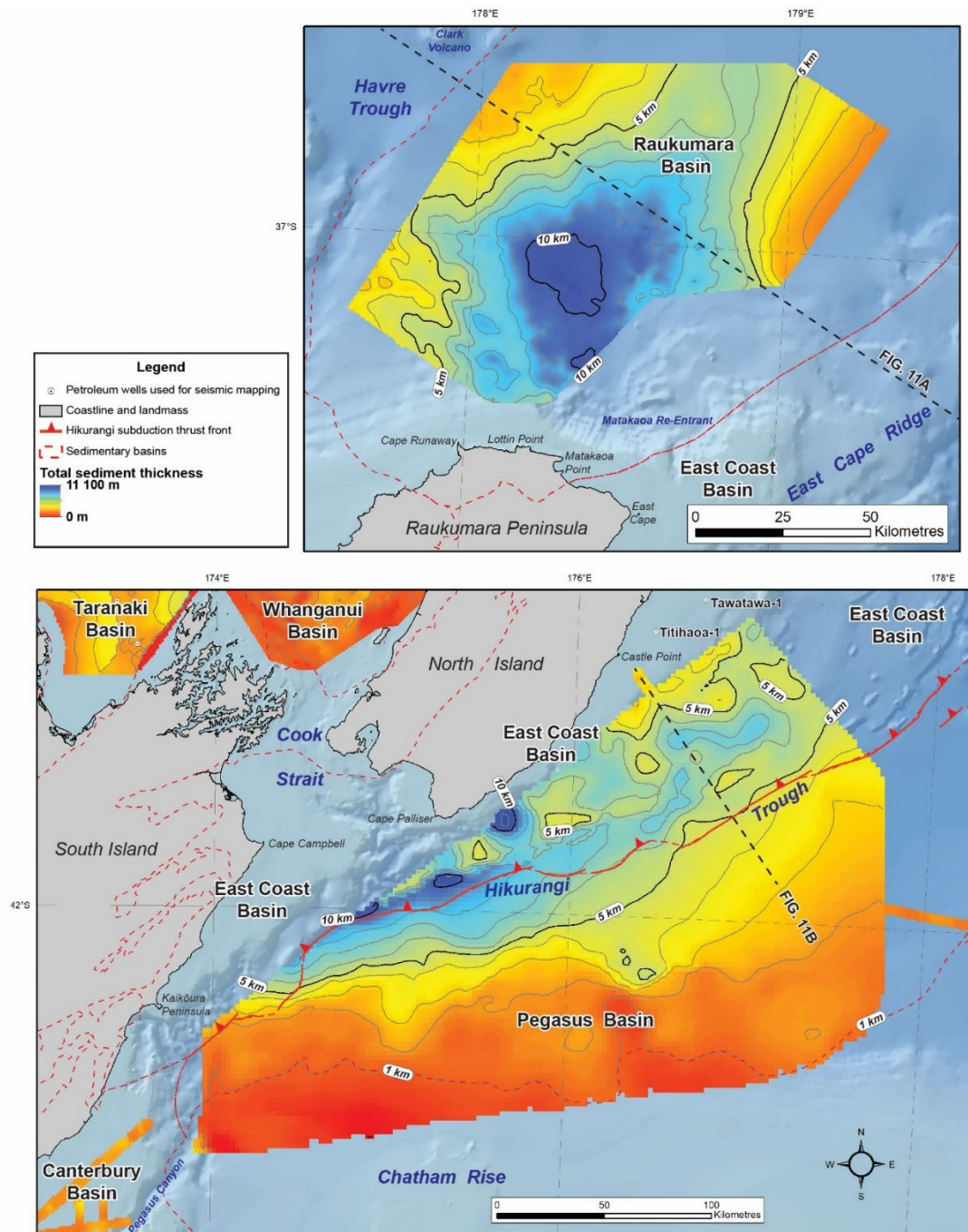


Figure 40 Total sediment thicknesses, Raukumara and Pegasus-southern East Coast basins (after Strogen et al. 2018).

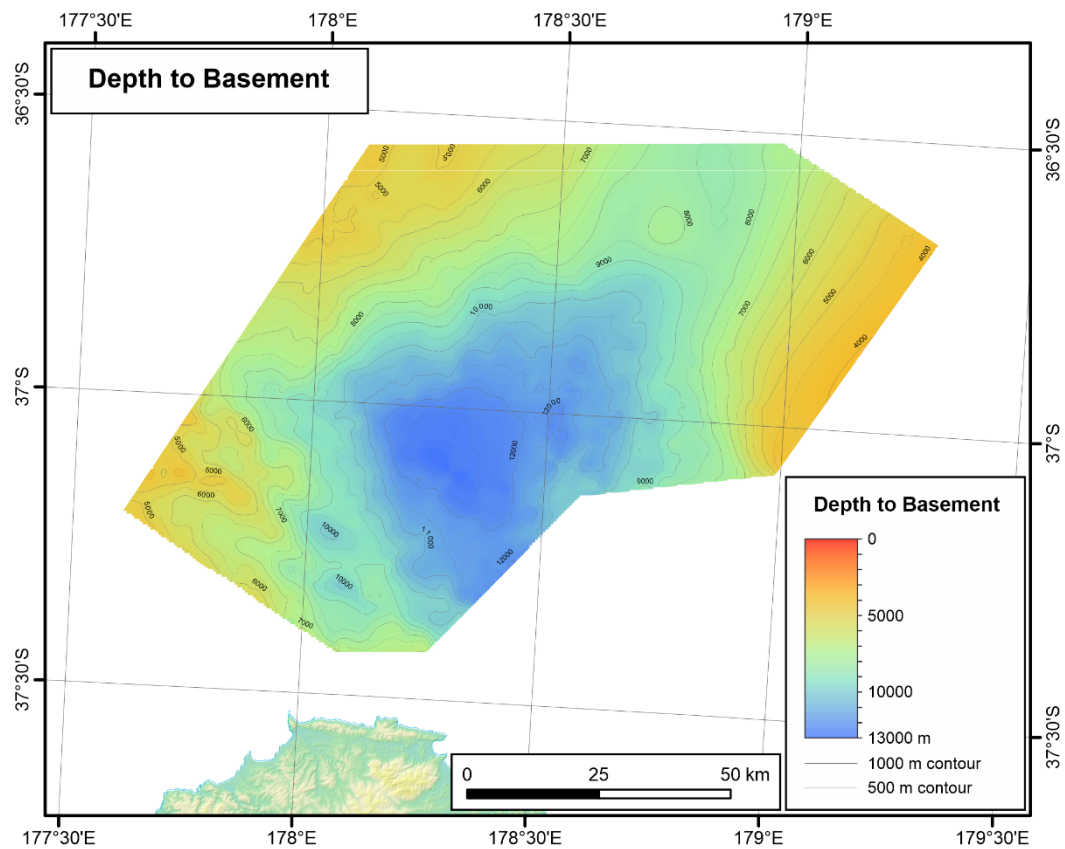


Figure 41 Depth to basement in Raukumara Basin mapping area (after Strogon et al. 2018).

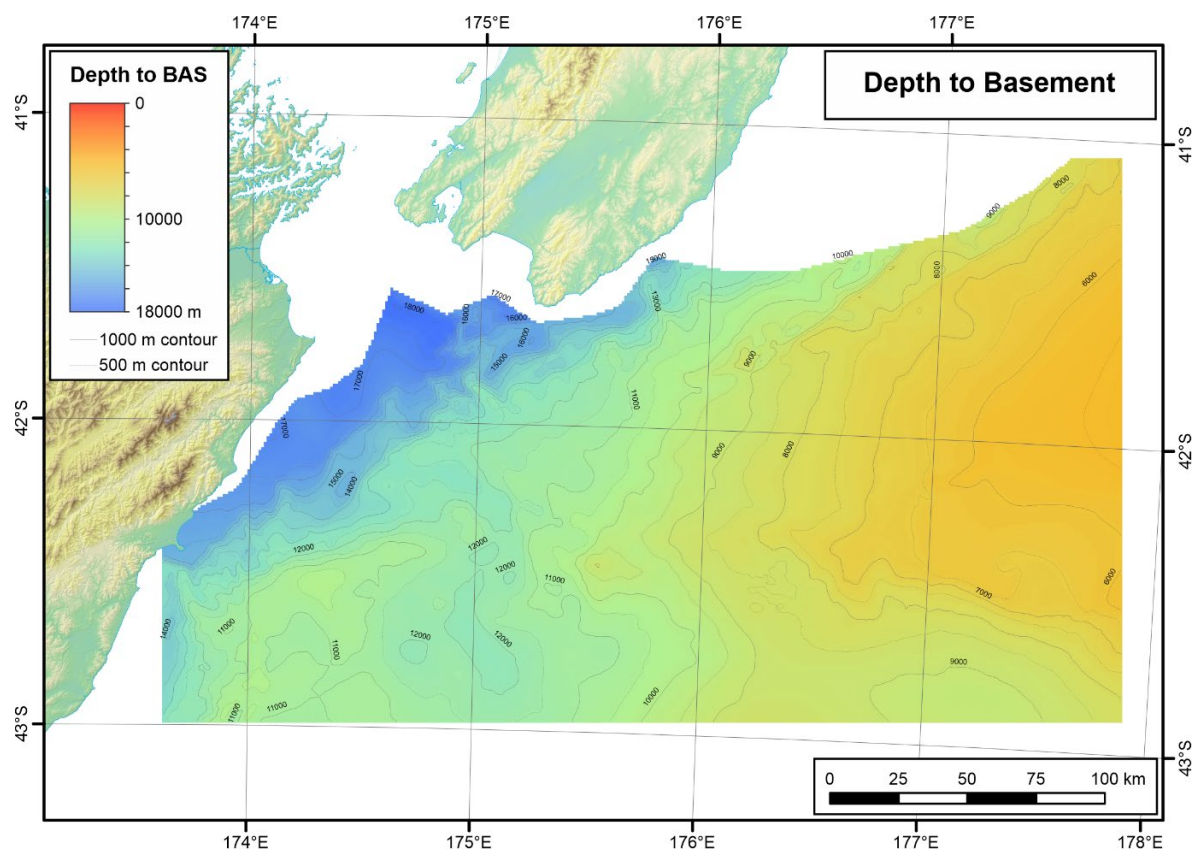


Figure 42 Depth to basement in Pegasus Basin mapping area (after Strogon et al. 2018).



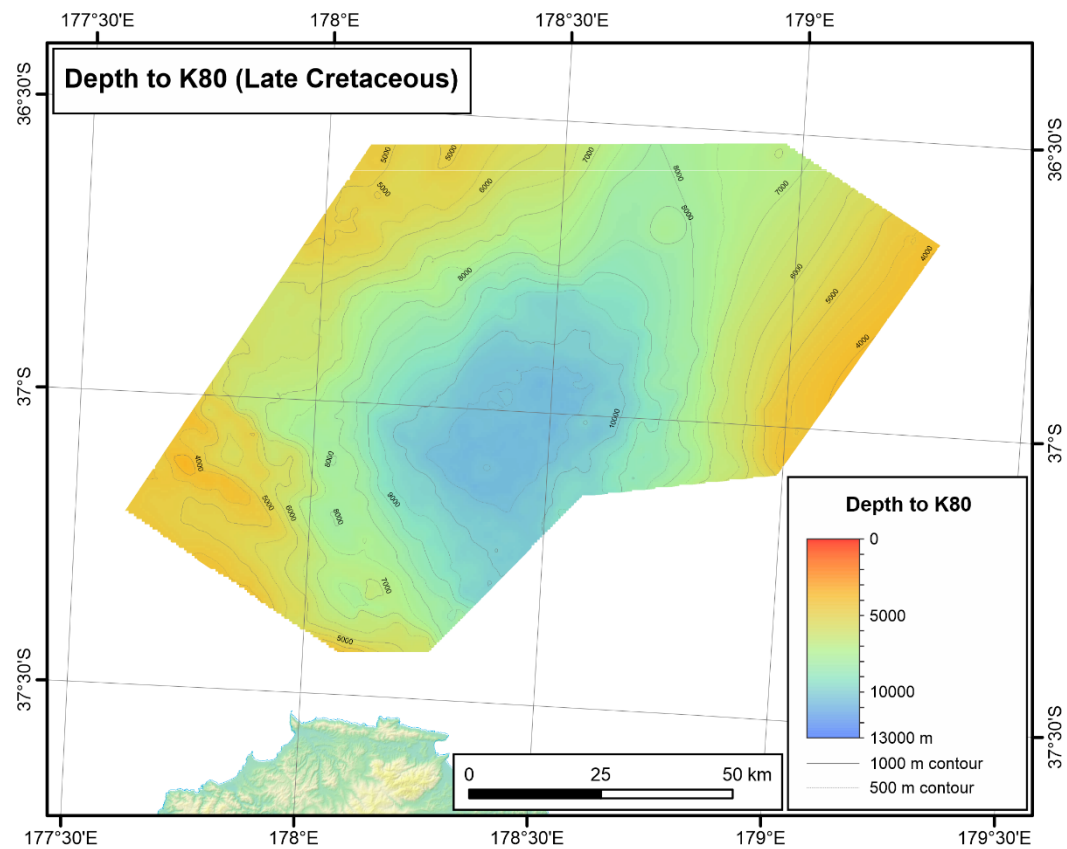


Figure 43 Depth to K80 (intra Late Cretaceous) in Raukumara Basin mapping areas (after Strogon et al. 2018).

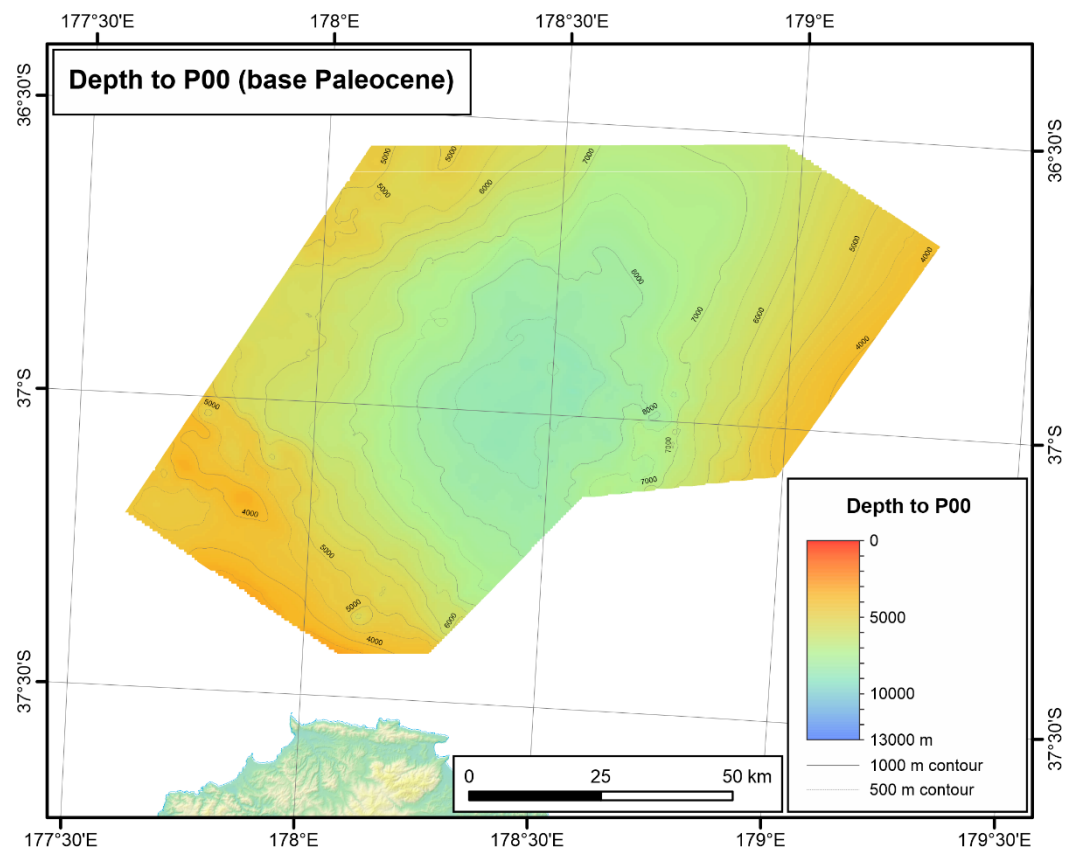


Figure 44 Depth to P00 (base Paleocene) in Raukumara Basin mapping area (after Strogon et al. 2018).

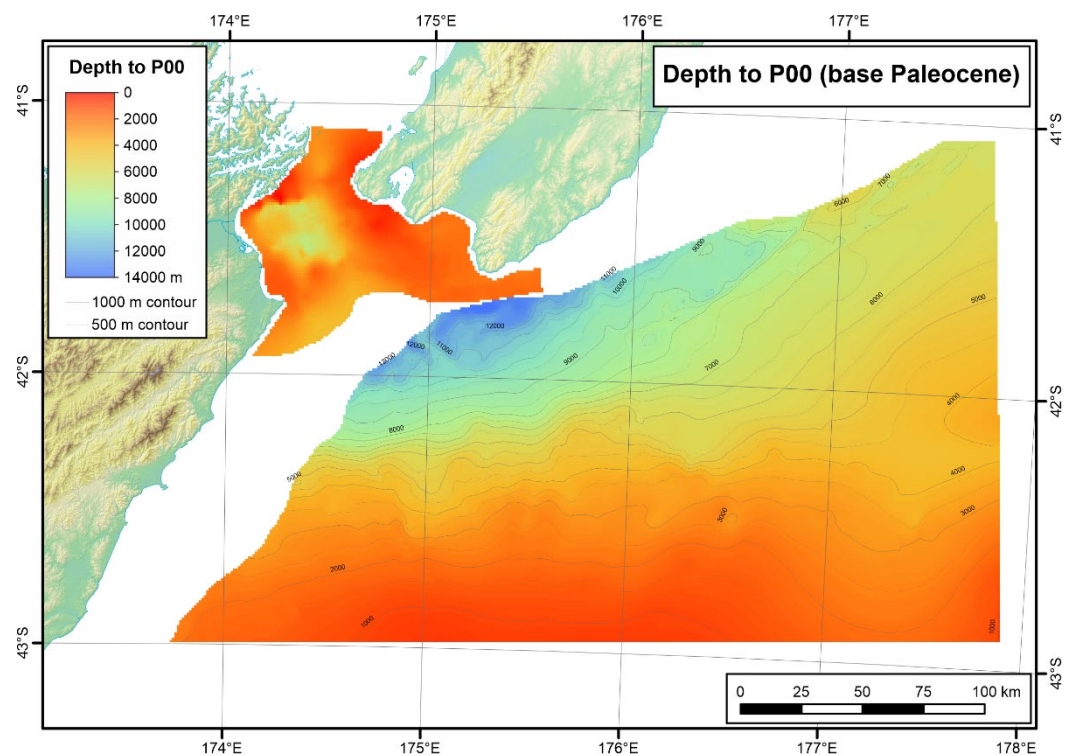


Figure 45 Depth to P00 (base Paleocene) in Pegasus Basin and Cook Strait mapping areas (after Strogon et al. 2018).

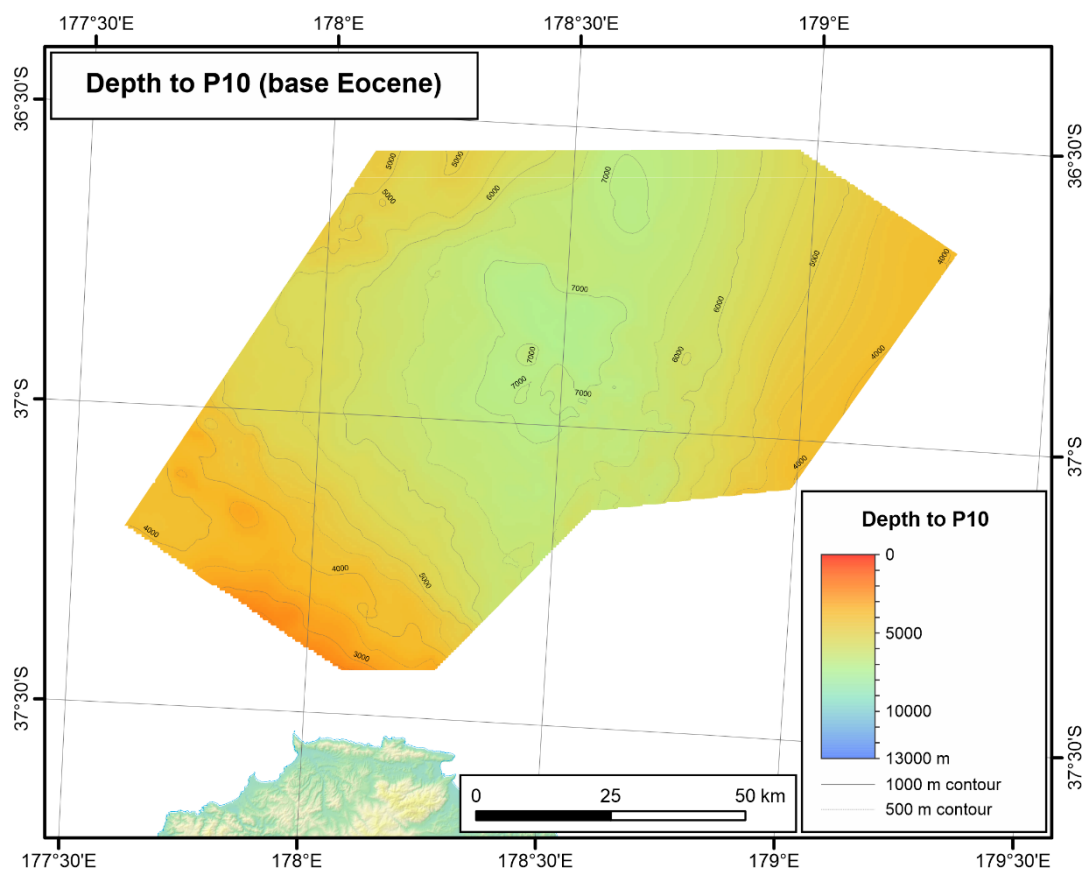


Figure 46 Depth to P10 (base Eocene) in Pegasus Basin mapping area (after Strogon et al. 2018).

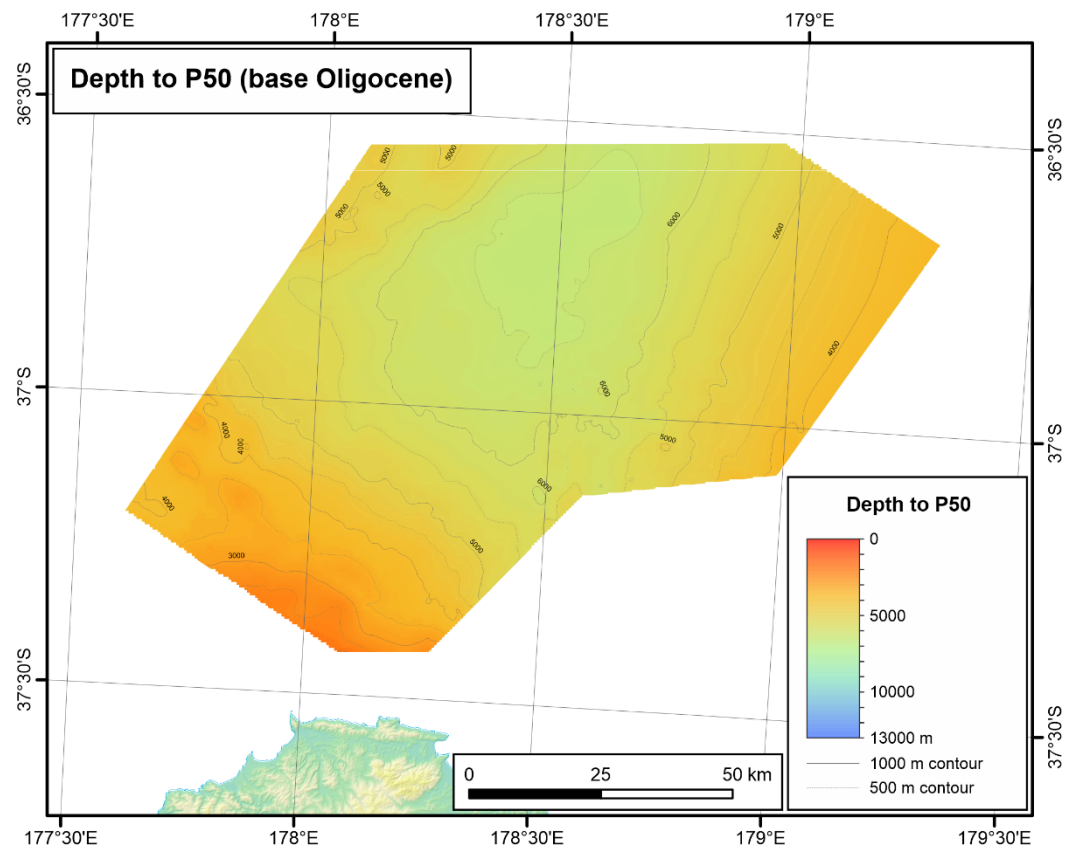


Figure 47 Depth to P50 (base Oligocene) in Pegasus Basin mapping area (after Strogon et al. 2018).

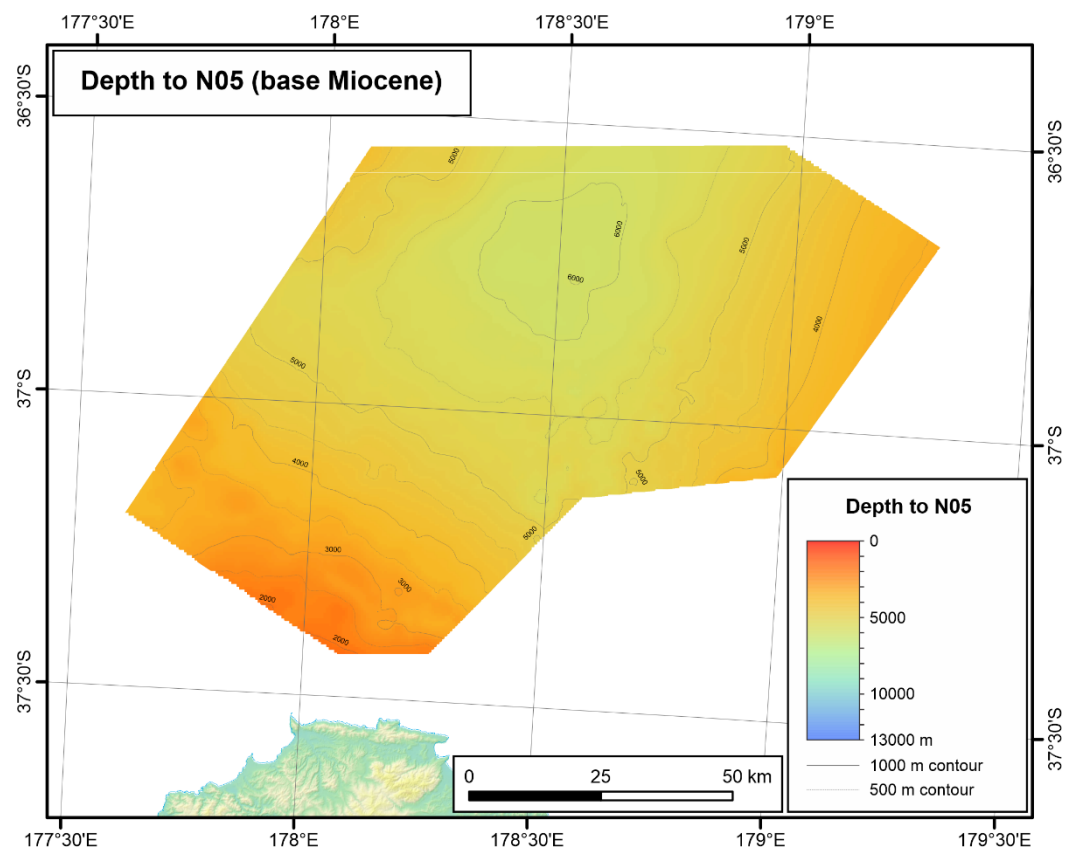


Figure 48 Depth to N05 (base Miocene) in Raukumara Basin mapping area (after Strogon et al. 2018).

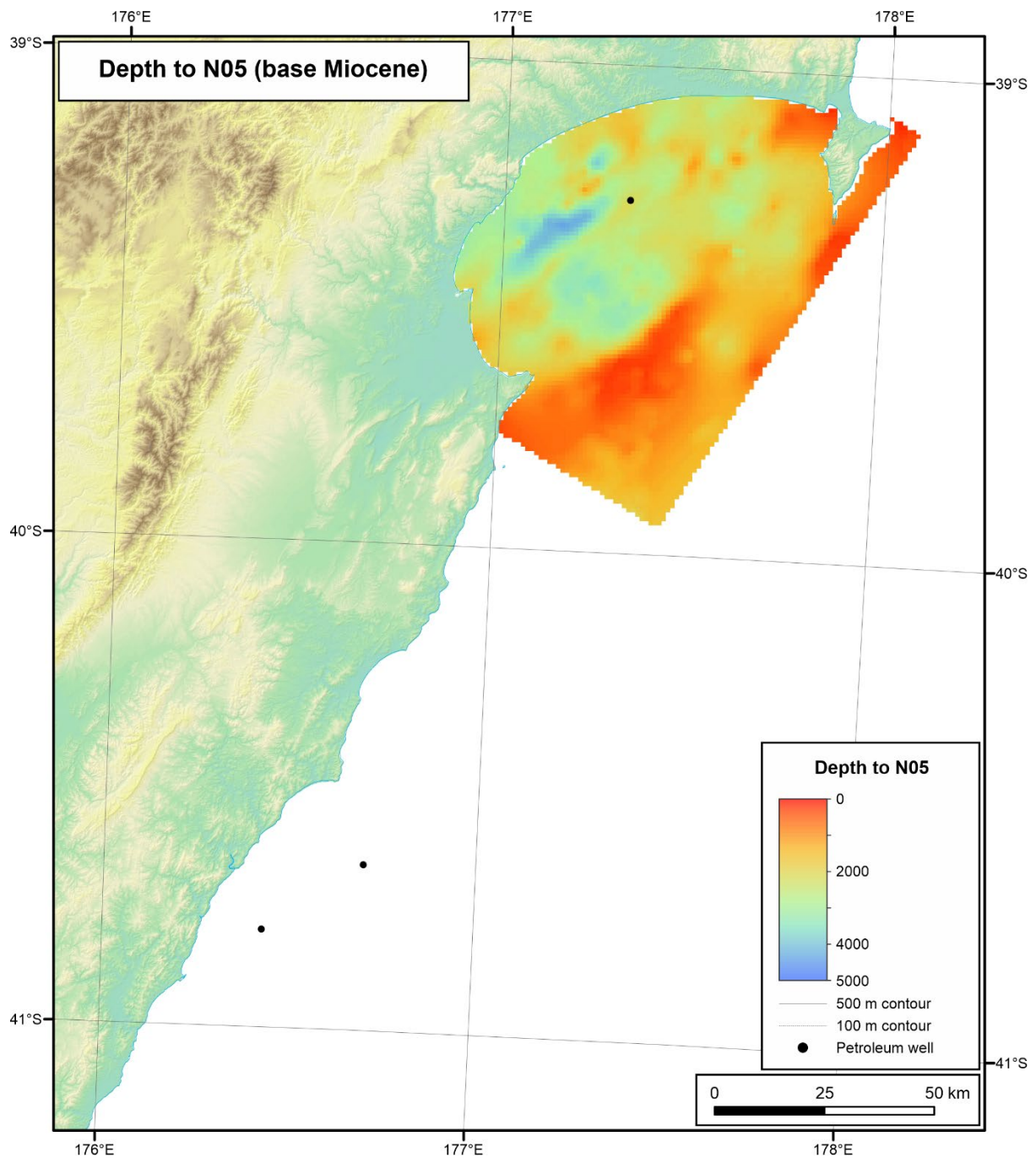


Figure 49 Depth to N05 horizon (base Miocene), Hawke Bay and northern Wairarapa mapping areas (after Strogon et al. 2018).



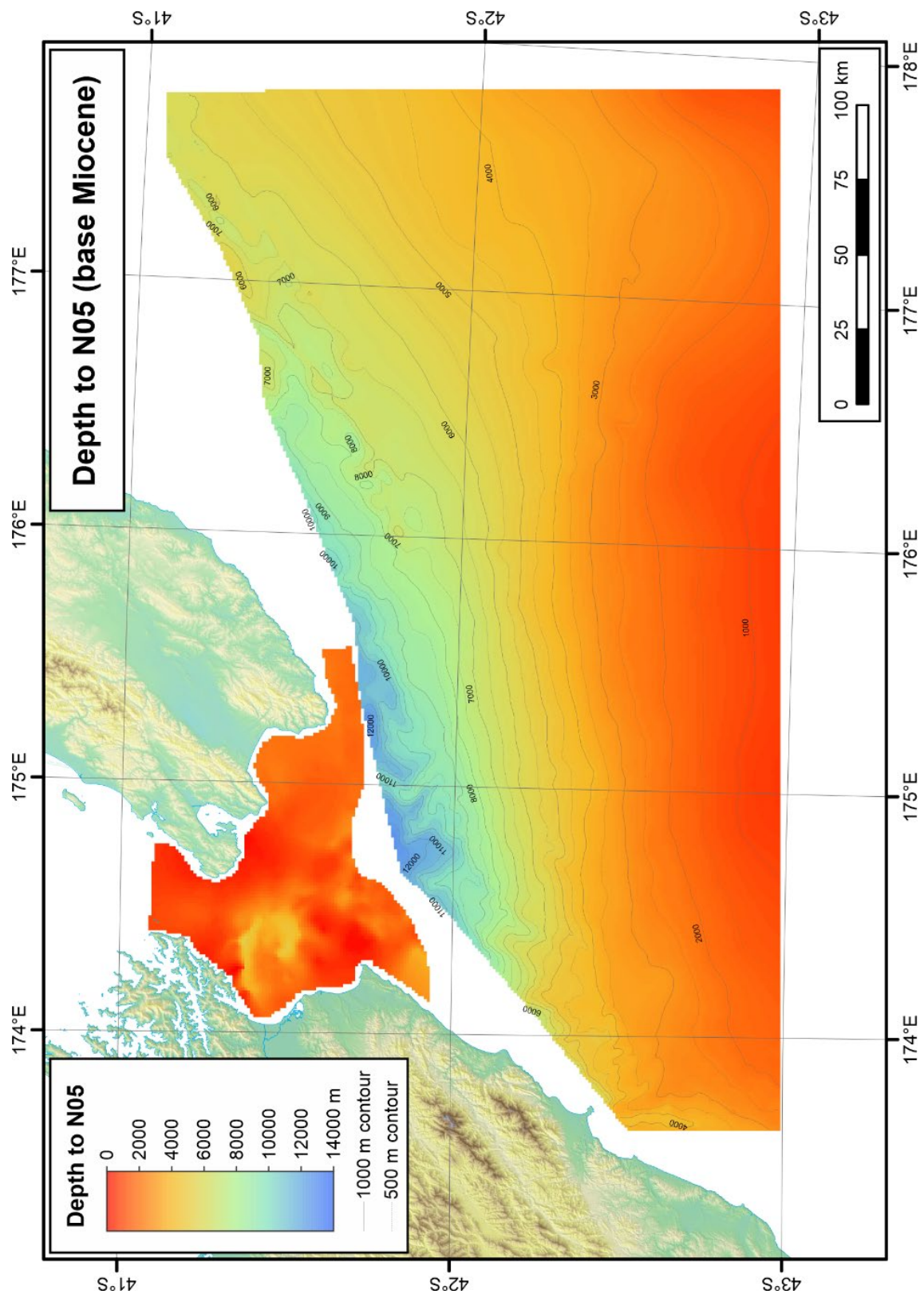


Figure 50 Depth to N05 horizon (base Miocene), Pegasus Basin and Cook Strait mapping areas (after Strogon et al. 2018).

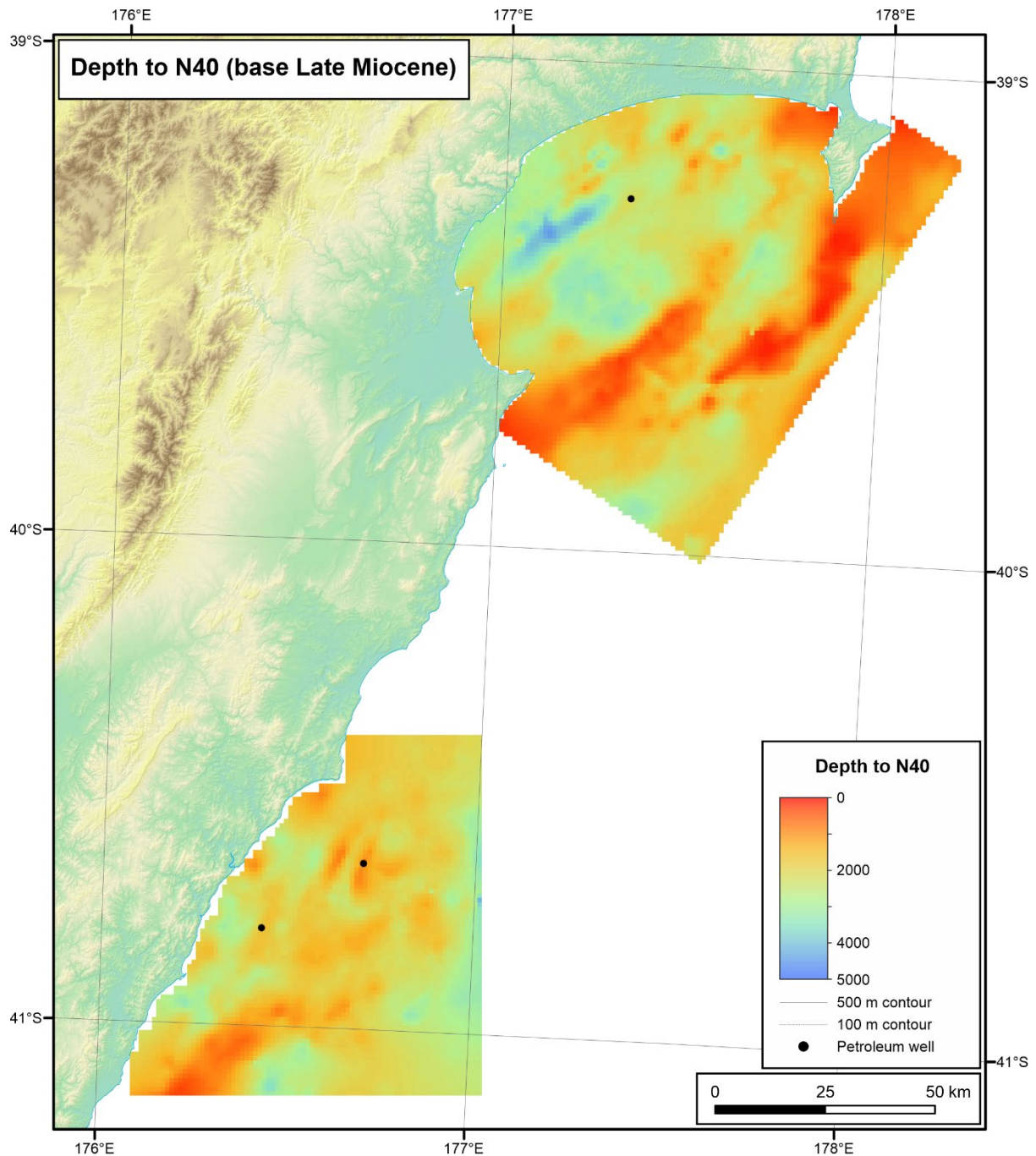


Figure 51 Depth to N40 horizon, Hawke Bay and northern Wairarapa mapping areas (after Strogon et al. 2018).

### ***Pliocene–Quaternary***

The base of the Pliocene–Quaternary succession in Raukumara Basin is 1310–4650 m deep (mean depth 3230 m) (Strogon et al. 2018). Rotated fault blocks, growth strata, and coalescing unconformities makes tracing the base of the Pliocene succession difficult in East Coast Basin (Strogon et al. 2018).

The Early Pleistocene interval in the Pegasus and East Coast Basin areas is often marked by a band of 3–5 bright reflectors within an otherwise low reflectivity package. The Pleistocene succession is likely to be dominated by fine-grained sedimentary rocks. Channels can be identified cutting through these flat-lying reflectors within the Pegasus Basin, indicating that pulses of coarse sediment are being injected into the basin. The shelf and

slope basins of Cook Strait, Wairarapa, and Hawke Bay are dominated by tight synclines and anticlines mapped out by the base-Pleistocene horizon.

In water depths greater than 650 m, the formation of gas hydrates produces a characteristic pattern of reflectivity that overprints the sedimentary successions. This bottom simulating reflector (BSR) is a negative-amplitude reflection that cuts at a low angle across the sedimentary strata. Care has been taken to pick this event as an indicator of the presence of gas hydrates. Changes in amplitude of the reflectors above and below the BSR can make correlating the Pleistocene events a challenge.

The base of the Pliocene–Quaternary succession lies 50–4150 m deep (mean ~1330 m) beneath offshore Wairarapa and ~50–2440 m deep beneath Hawke Bay (mean ~1030 m) (Strogen et al. 2018). Beneath Hawke Bay it is up to ~2390 m thick (mean thickness ~900 m). Seismic mapping by Strogen et al. (2018) suggests that the succession is up to ~3360 m thick within Pegasus Basin (mean thickness ~980 m), c.f., up to ~2700 m (Bland et al. 2015), though the APP grids probably include strata across the Hikurangi thrust and within the ECB, meaning that there's structural repetition.

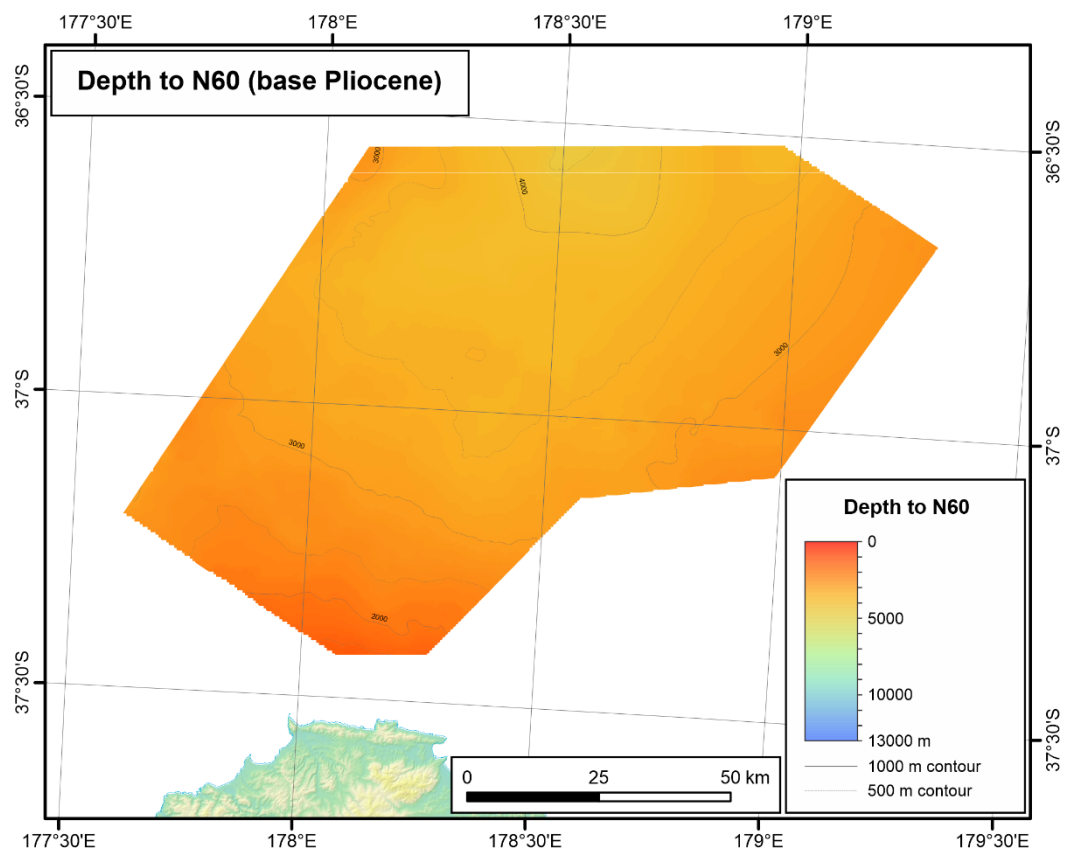


Figure 52 Depth to N60 (base Pliocene) in Raukumara Basin mapping area (after Strogen et al. 2018).



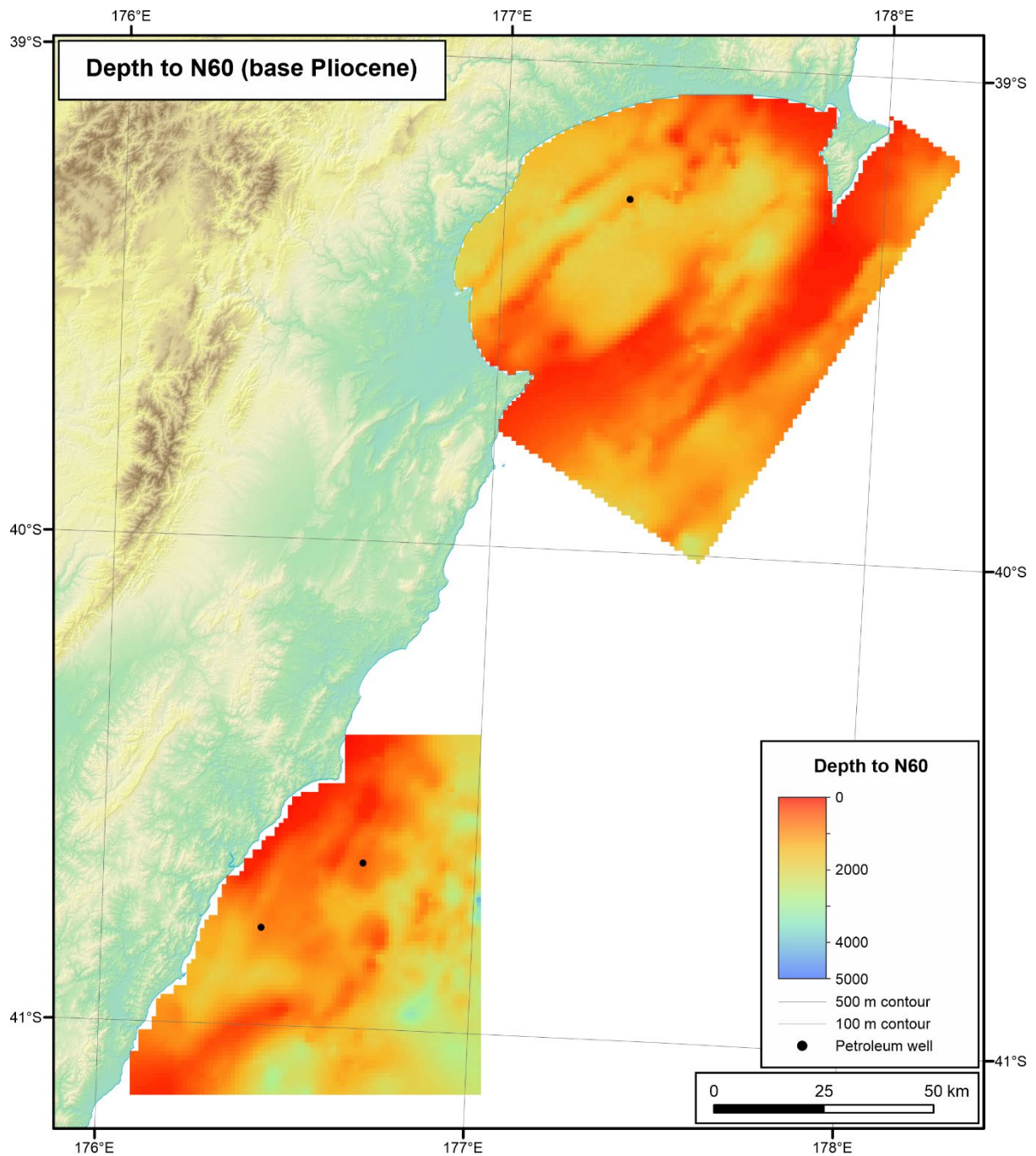


Figure 53 Depth to N60 horizon (Early Pliocene, c. 4 Ma), Hawke Bay and northern Wairarapa mapping areas (after Strogen et al. 2018).



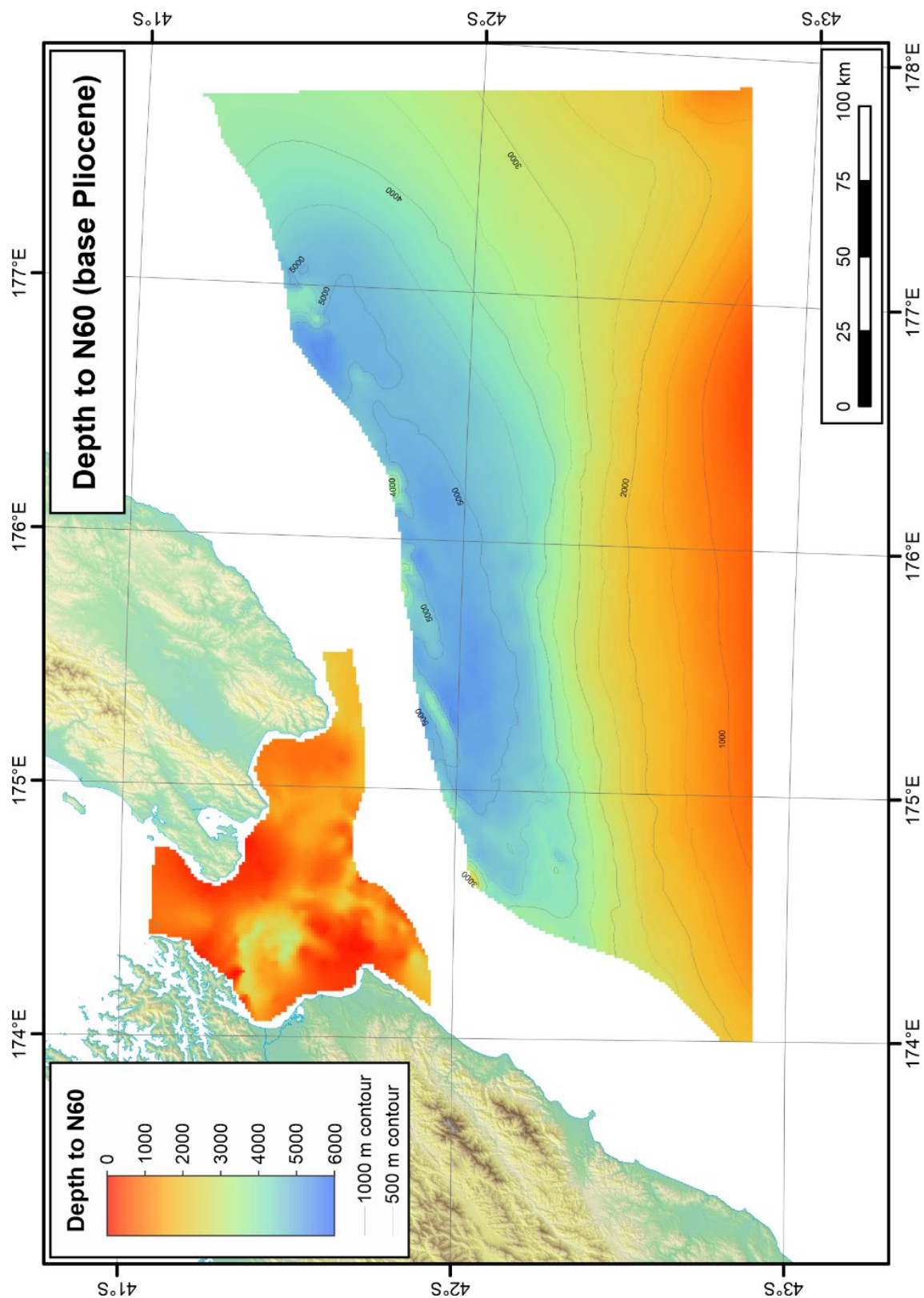


Figure 54 Depth to N60 horizon (base Pliocene), Pegasus Basin and Cook Strait mapping areas (after Strogon et al. 2018).

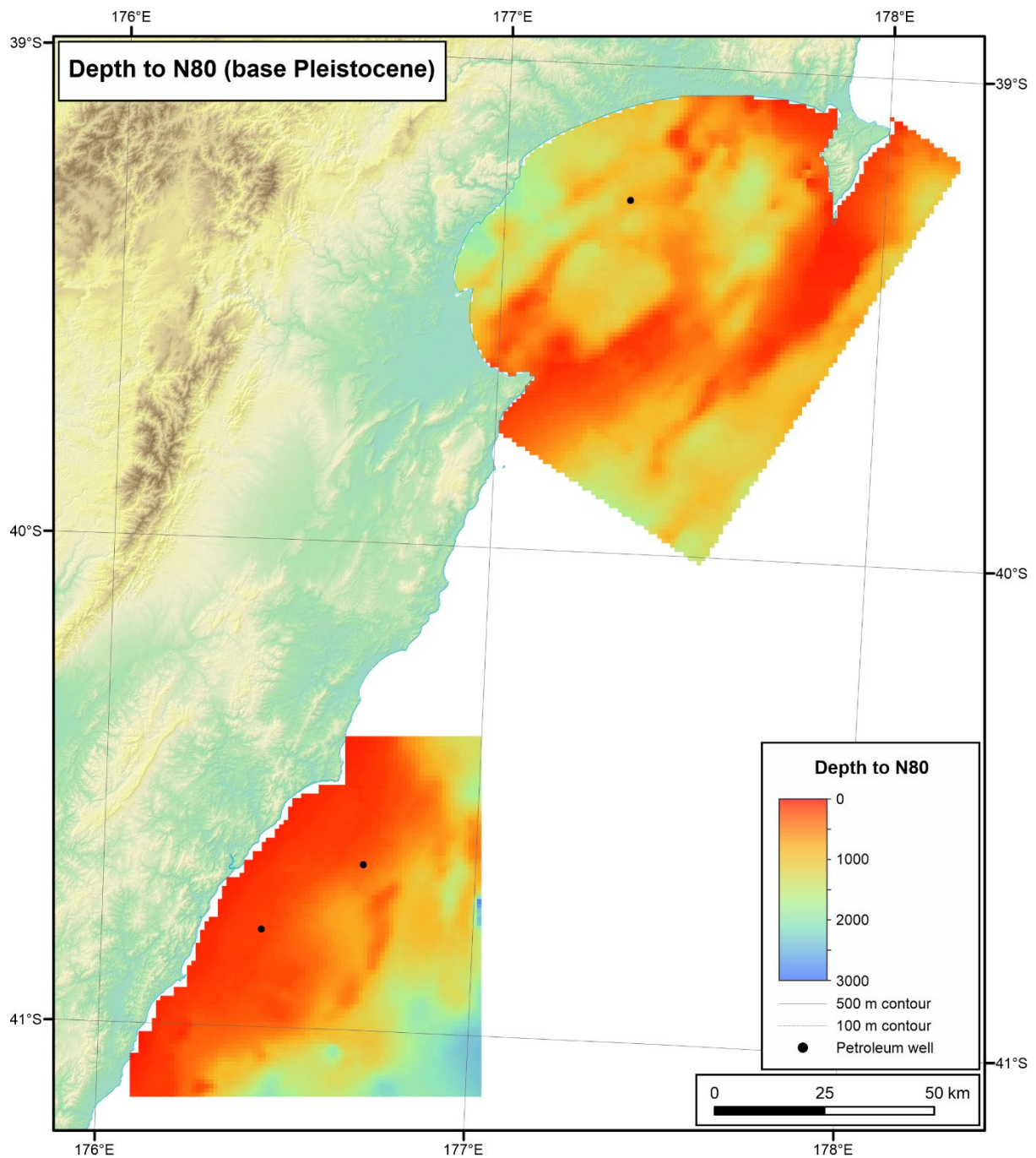


Figure 55 Depth to N80 horizon, Hawke Bay and northern Wairarapa mapping areas (after Strogon et al. 2018).

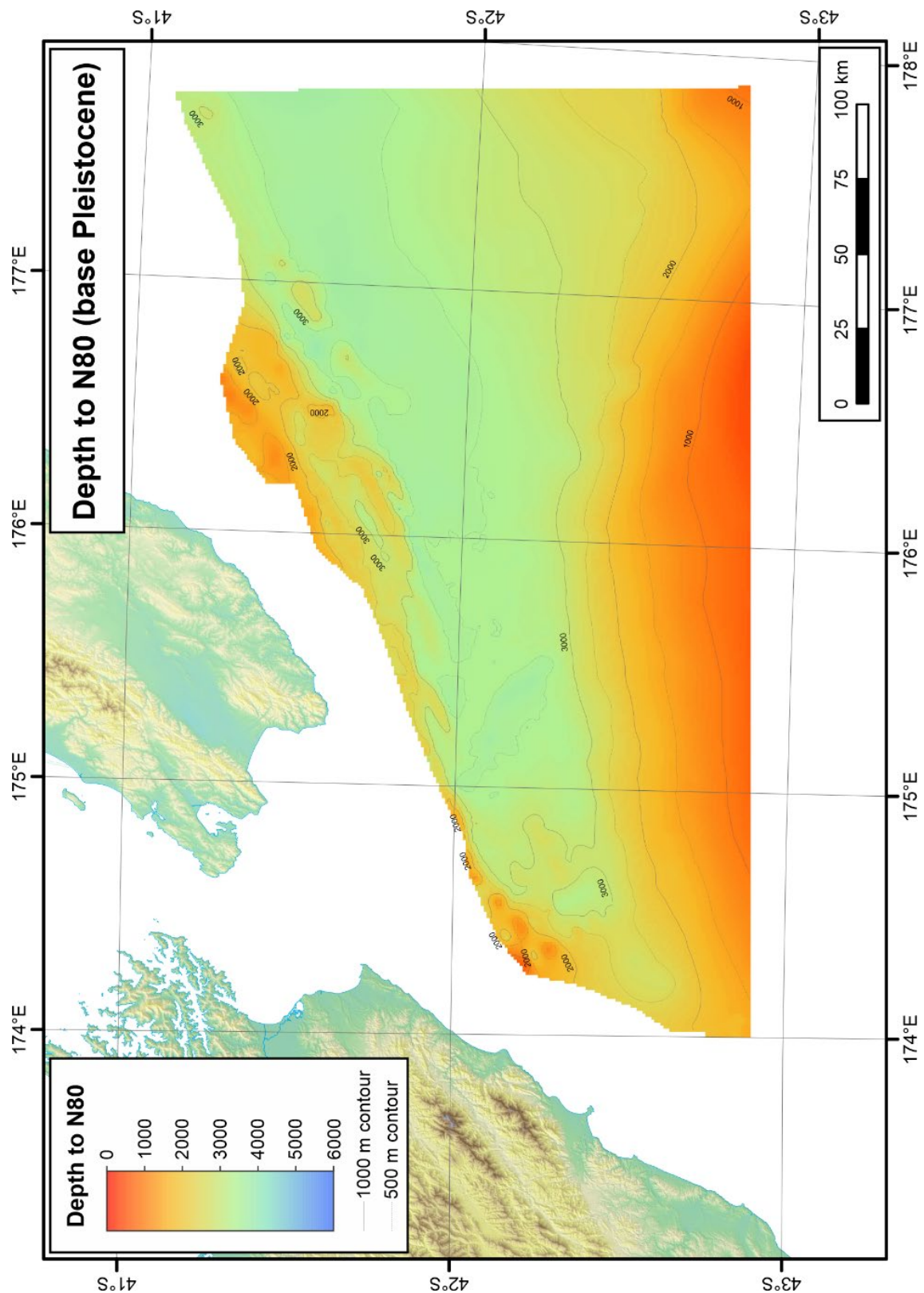


Figure 56 Depth to N80 horizon (base Pleistocene), Pegasus Basin mapping area (after Strogon et al. 2018).



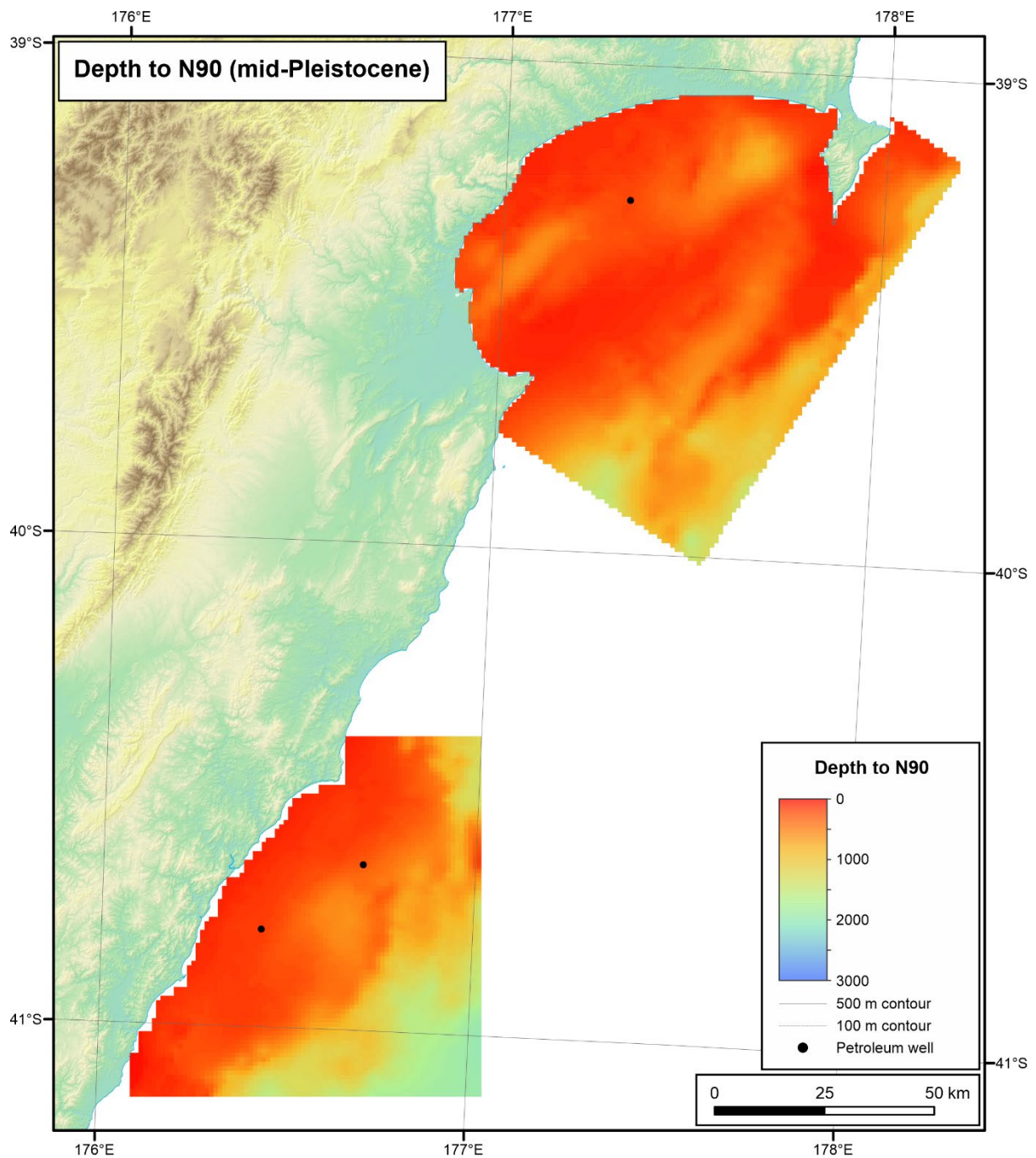


Figure 57 Depth to N90 horizon, Hawke Bay and northern Wairarapa mapping areas (after Strogon et al. 2018).



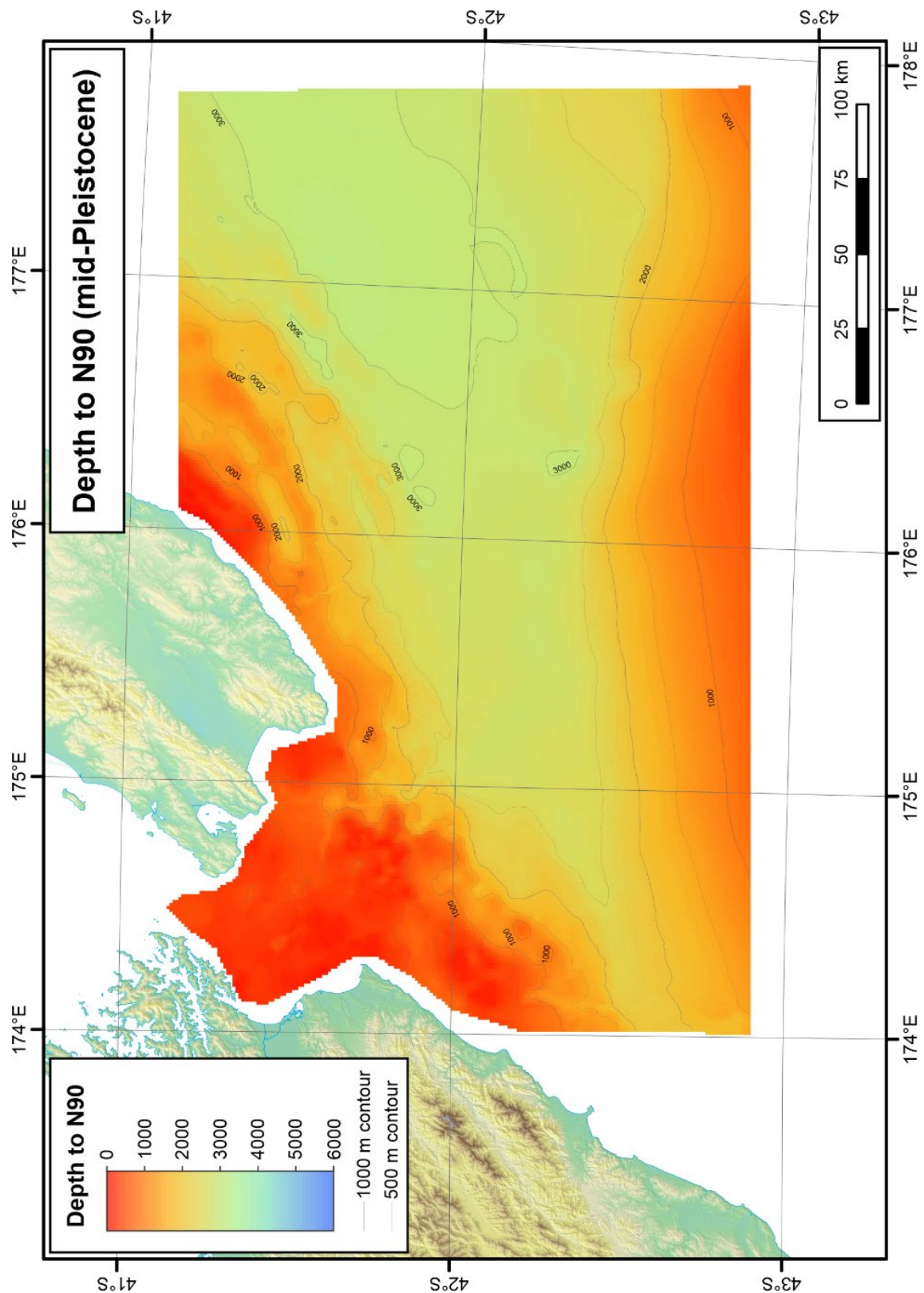


Figure 58 Depth to N90 horizon (mid-Pleistocene), Pegasus Basin and Cook Strait mapping areas (after Strogon et al. 2018).

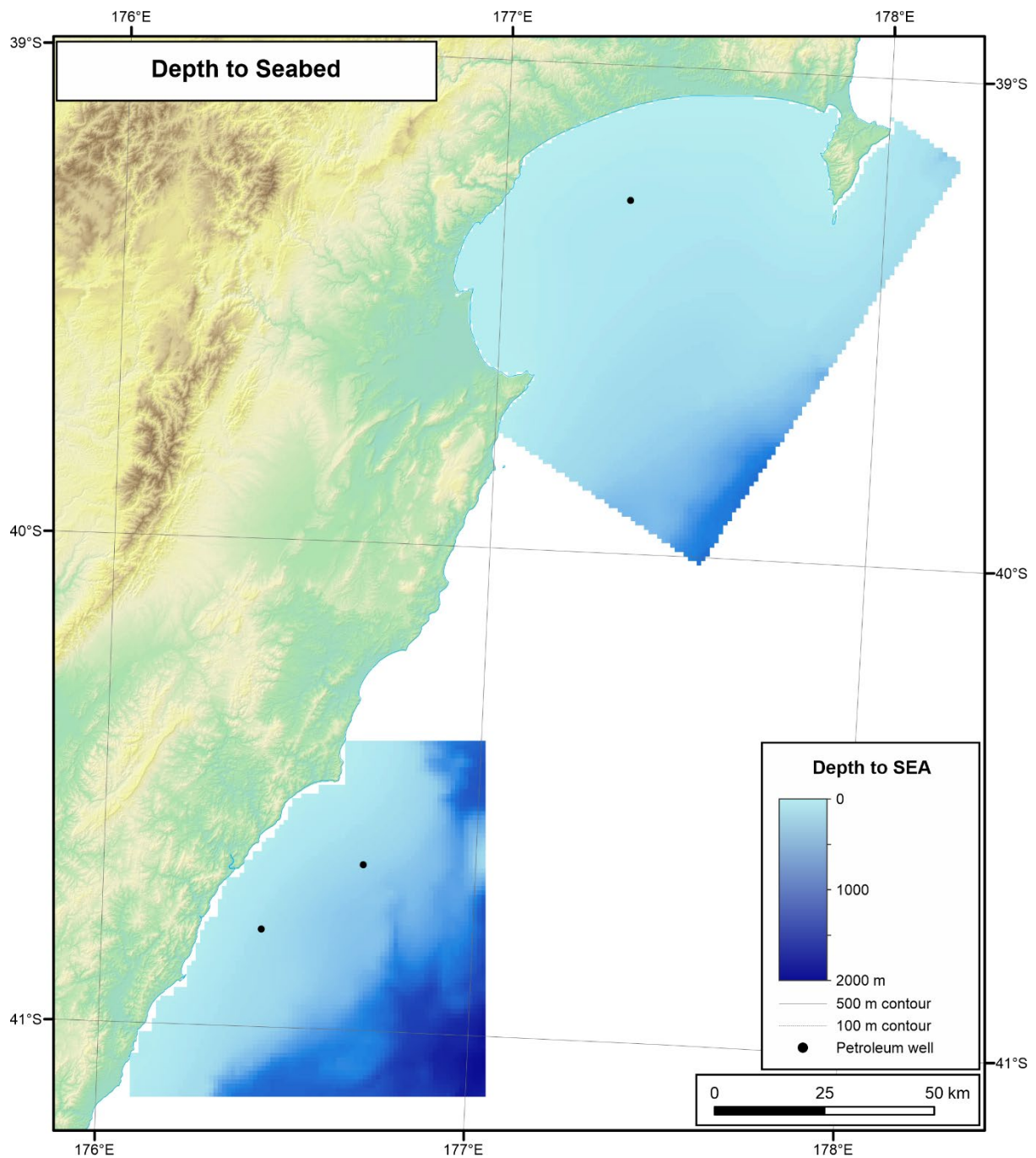


Figure 59 Depth to seabed, Hawke Bay and northern Wairarapa mapping areas (after Strogen et al. 2018).

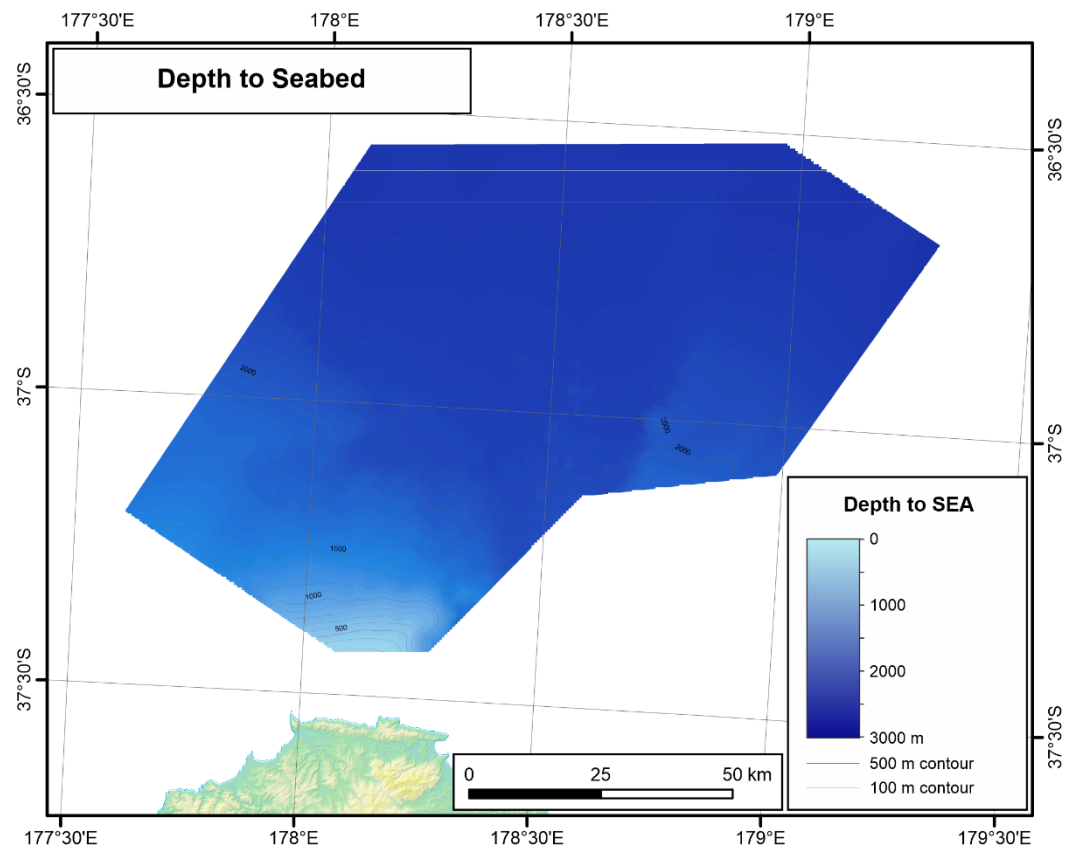


Figure 60 Depth to Seabed Raukumara Basin mapping area (after Strogon et al. 2018).

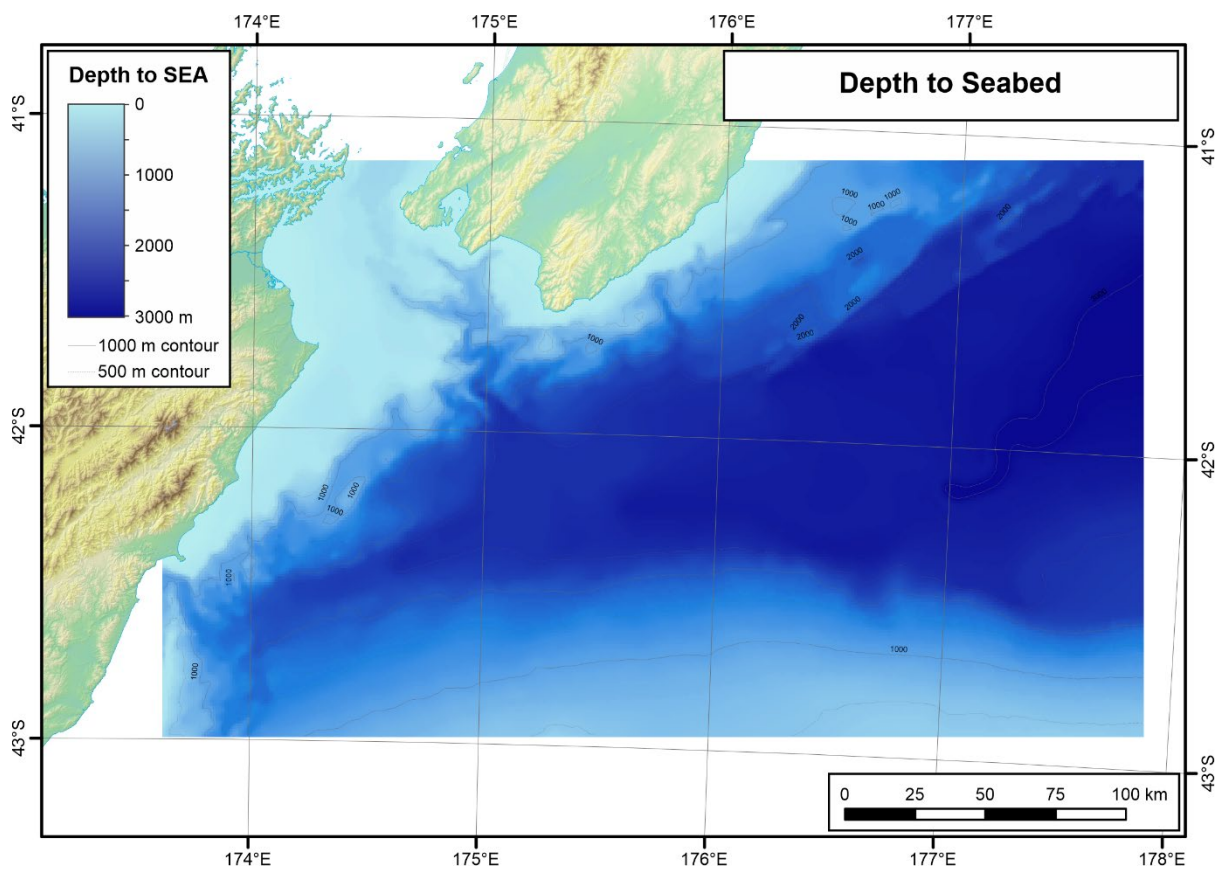


Figure 61 Depth to seabed, Pegasus Basin–Cook Strait area (after Strogon et al. 2018).

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