

The Waipounamu Erosion Surface: questioning the antiquity of

eustatic fluctuations, the Waipounamu Erosion Surface must be regarded as being diachronous, a composite formed during successive sea-level encroachments and planation episodes. Comparable diachroneity has been demonstrated at very local scales during Late Cretaceous onset of transgression/planation by Crampton, Schiøler & Roncaglia (2006).

New Zealand's biota is regarded as having evolved largely from plants and animals sequestered on a drifting fragment of the Gondwanaland supercontinent. In isolation for more than 80 million years, a distinctive New Zealand biota is envisaged as evolving, to a greater or lesser extent, from archaic Gondwanan stock (Fleming, 1962, 1979; Mildenhall, 1980; Stevens, 1985; Cooper & Millener, 1993). This hypothesis has been popularly referred to as 'Moa's Ark' (Bellamy, Spingett & Hayden, 1990). In contrast, an important corollary to the wave-planation hypothesis is that the amount of landmass shrank dramatically from Late Cretaceous to Early Miocene time (85 to 22 million years) at which time most, if not all, of the New Zealand region was inundated (LeMasurier & Landis, 1996).

During this time, we suggest that the original Moa's Ark (Zealandia) probably sank beneath the sea and lost its precious cargo. Although previous workers, treating the surface as a peneplain, recognized that Palaeogene transgression reduced the area of land in the New Zealand region (e.g. Wellman, 1953; Fleming, 1962; Suggate, Stevens & Te Punga, 1978; Stevens, 1985; Cooper & Cooper, 1995; King *et al.* 1999), they nevertheless portray the region as one of substantial land even at the time of maximum transgression (Fig. 1). The main arguments supporting the existence of sizeable remaining land areas during Oligocene–Early Miocene time are not clear and have never been properly discussed. They appear to depend substantially, but tacitly, on three factors: (1) the nature and diversity of the *modern* New Zealand flora and fauna, (2) the fossil record and (3) the absence today of middle Cenozoic marine sedimentary rocks from inland portions of North and South islands as well as from central Fiordland and Stewart Island. Interpretations drawn from these starting points may not be soundly based and, most worryingly, probably suffer from circular reasoning (Waters & Craw, 2006).

We maintain that the modern landscape combined with the Cenozoic sedimentary record provide evidence which is incompatible with the existence of substantial land areas of Late Oligocene–earliest Miocene age. Furthermore, we argue that available data are compatible with complete inundation of the New Zealand region during

m01.7131Tm(f)T8.46040010.4608681.5601301.7131Tm(Cenozoic)TjETBT10.40080010.4608132.03.700217

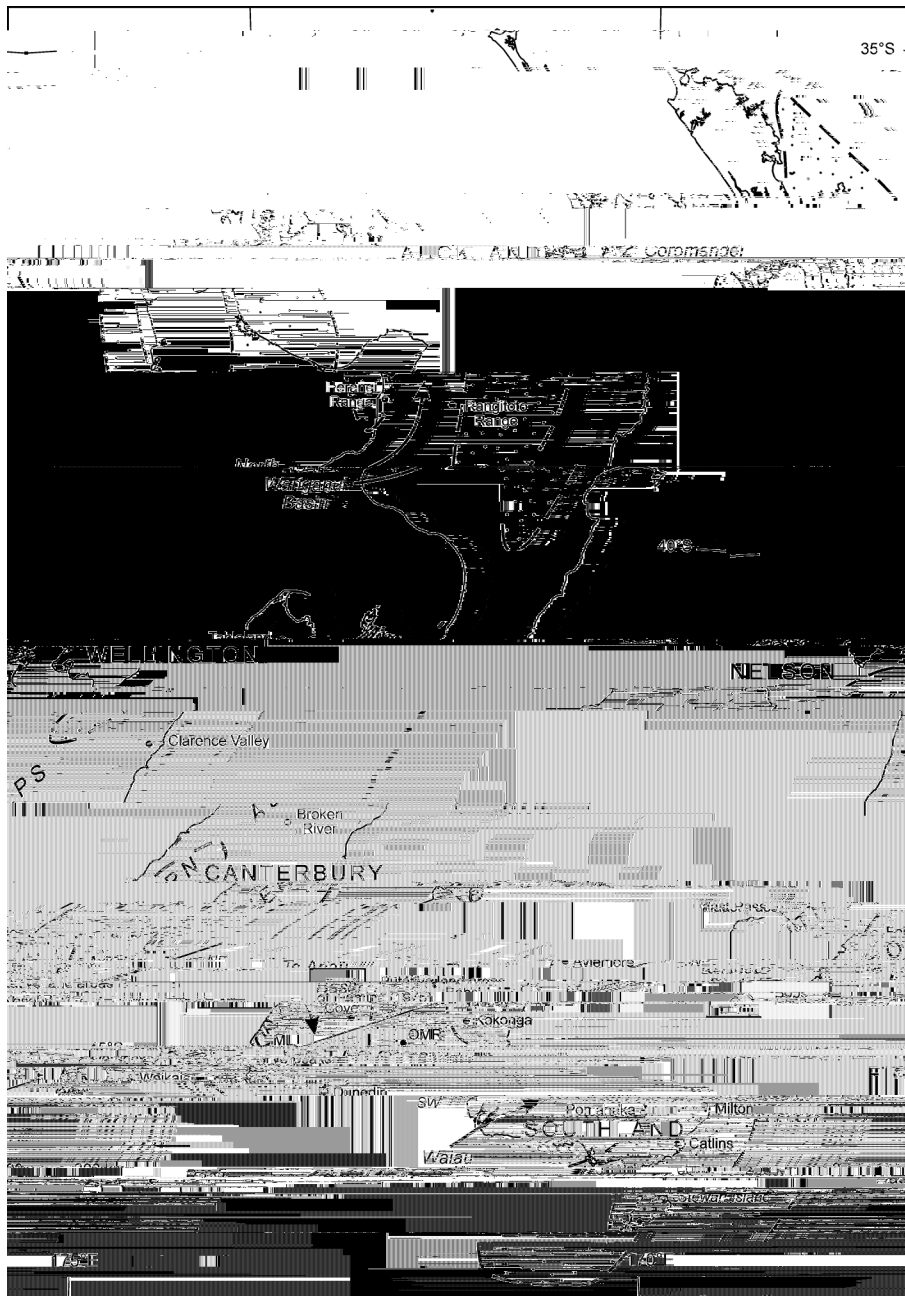


Figure 1. Map showing localities referred to in text and extent of land during maximum transgression as proposed by Fleming (1962). We propose that all the land areas shown by Fleming, as well as other authors such as Stevens (1974, 1985), Kamp (1986) and King (1998, 2000), may have been completely submerged during the Oligocene. HR – Hawkdun Range, PR – Pisa Range, ML – Mt Luxmore, OMR – Old Man Range. The NE–SW line refers to the cross-section shown in Figure 5.

It is important to distinguish between the Waipounamu Erosion Surface and the ‘Cretaceous Peneplain’. The ‘Cretaceous Peneplain’ (also referred to as Otago Peneplain) refers to a widespread unconformity of terrestrial origin. It is characterized by an unconformity with weakly indurated Late Cretaceous sand, gravel and coal measures resting upon indurated and deformed Palaeozoic–Mesozoic igneous, sedimentary and metamorphic basement. A non-marine origin is inferred from fluvial and paludal features of the overlying sedimentary cover. In contrast, the Waipounamu Erosion Surface is of marine origin. It too is

extensively developed directly onto the Palaeozoic–Mesozoic basement, while elsewhere it constitutes a disconformity developed upon the scoured top of the non-marine strata covering the ‘Cretaceous Peneplain’. In areas where the Waipounamu Erosion Surface is developed directly on older basement, the ‘Cretaceous Peneplain’ is absent. Formation by marine and littoral processes is inferred from marine fossils, glauconite and sedimentary features in the basal sedimentary cover. Thus the two unconformities are sub-parallel surfaces. In many

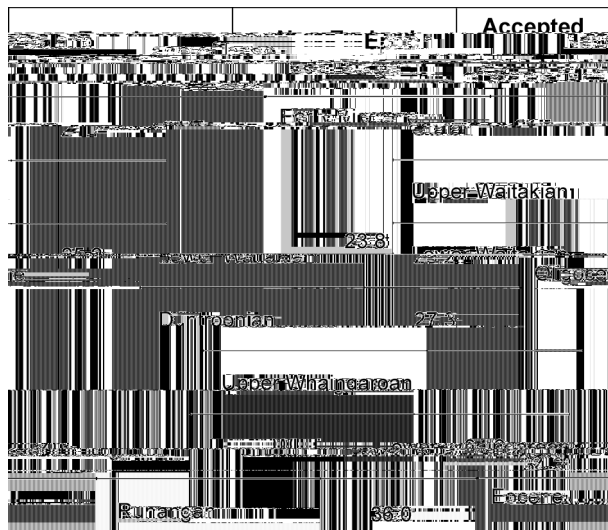


Figure 2. The local New Zealand biostratigraphic subdivision for latest Eocene, Oligocene and earliest Miocene time is based on marine faunas f



Figure 3. Spatial relationships between the 'Cretaceous Peneplain' and the Waipounamu Erosion Surface. Assuming an original high-relief mountainous landscape in Zealandia dating from middle Cretaceous



Figure 4. Hawkdun Range viewed from the south showing the distinctive planar summit at 1500 m (location in Fig. 1). This high-level plateau is a remnant of the Waipounamu Erosion Surface, eroded into Palaeozoic–Mesozoic greywacke during Cretaceous–Oligocene marine transgression. The range has been uplifted during the last five million years. Inferred Palaeogene marine cover has been removed by Neogene fluvial and periglacial erosion processes. However, a well-developed marine transgressive Palaeogene sequence culminating in limestone and greensand rests on greyw

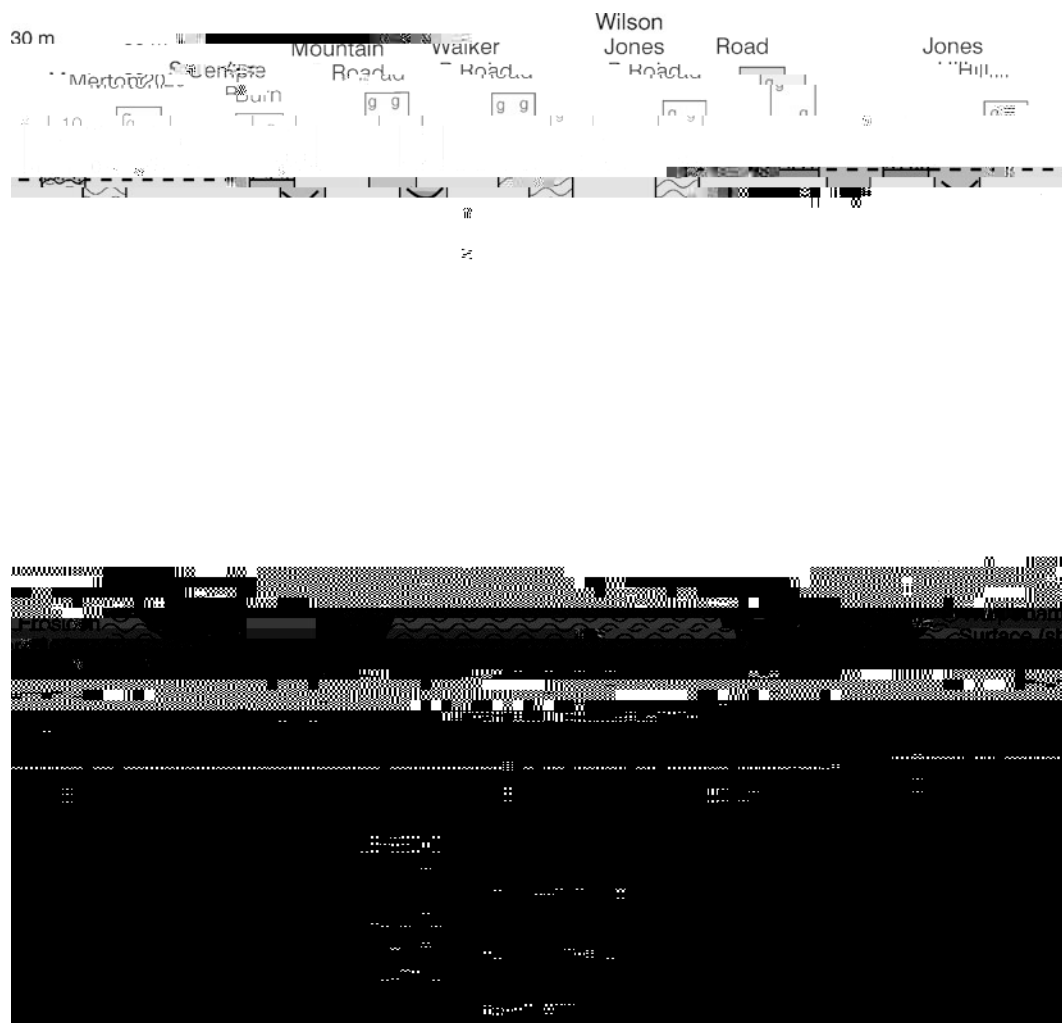


Figure 6. Stratigraphic relations between basement and cover

transgression is generally shown as being less than today but still substantial.

Although detailed evidence for placement of shorelines has not been discussed by previous workers (e.g. Fleming, 1979; Hornibrook, 1992; King *et al.* 1999), different combinations of eight factors appear to have influenced palaeogeographic map reconstructions:

- (a) The interpretation of Oligocene submarine unconformities as surfaces of subaerial erosion.
- (b) The interpretation of the most inland outcrops of Oligocene–Early Miocene marine sedimentary rock as near proxies f431609.5651ar

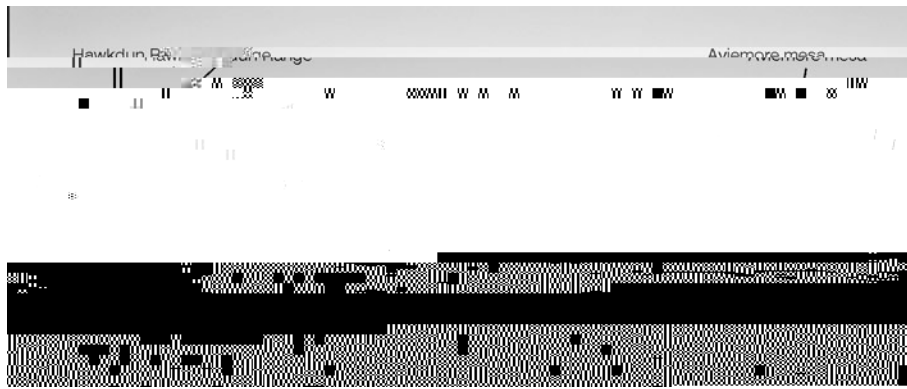


Figure 7. Aviemore, a mesa-like remnant of the stripped Waipounamu Erosion Surface; to immediate right of the Lake Aviemore Dam (see Fig. 1 for location). Aviemore is the most inland remnant of preserved Cenozoic marine sequence. Gravelly Eocene marine sediments rest directly on greywacke basement. These are overlain by a transgressive marine sequence including Oligocene limestone and greensand. The crest of the Hawkdun Range (Fig. 4; see HR on Fig. 1) is visible in the far distance about 40 kilometres away. Pleistocene alluvial terraces are conspicuous along the southern (left) side of the valley. View looking NW up the Waitaki River valley. Photo: Lloyd Homer, GNS Science.

Browne, 1989; I. McDermid, unpub. report, 1998).
 Age and thickness of this transgressive sequence imply
 that submarine accommodation space

surfaces is attributed to late Cenozoic uplift and associated terrestrial erosion. Not only that, but the absence of erosion surfaces further to the west can itself be attributed to ongoing Neogene uplift and erosion. Reduced erosion at lower elevations has permitted the outlying marine remnants to be preserved.

3.f. Evidence that is permissive but n

last 70 million years. Crampton *et al.* (2006) have established that the fossil record for post-Eocene molluscs is representative of 40–45 % of the original total molluscan fauna. In contrast, the terrestrial fossil record is sparse and incomplete. Terrestrial animal fossils older than Pleistocene are particularly scarce, and fossil plants, with noted exceptions from Miocene time, are known mainly from pollen studies. Only the last 22 million years of terrestrial life are known with any modicum of detail.

In spite of the incomplete record, there remains a widely held belief that a substantial proportion of the extant biota has evolved from plants and animals that were present when New Zealand separated from Gondwanaland about 85 million years ago. Modern workers have generally maintained the continuous existence of a diverse Gondwanan terrestrial biota (Stevens, McGlone & McCulloch, 1988; Cooper & Cooper, 1995; Lee, Lee & Mortimer, 2001) and reference to ‘Gondwanan biota’ is commonplace. A biotic ‘bottleneck’ within the Oligocene was proposed by Cooper & Cooper (1995), and Pole (2001) considered the case that the New Zealand flora represents a complete biotic turnover from the original Gondwanan biota. Both of these papers have assumed the continuous existence of a landmass, though with reduced area in the Oligocene.

Lee, Lee & Mortimer (2001) argued for a continuous Cenozoic terrestrial flora record in New Zealand. They recognize only one unit that spans the critical Oligocene to earliest Miocene period: the Gore Lignite Measures. These strata are portrayed by Lee, Lee & Mortimer (2001) to have accumulated during the interval between 16 and 31 million years ago; no breaks in this sequence are discussed. Although palynological evidence for sedimentation of the Gore Lignite Measures during this period is well documented (Pocknall, 1990), no case has been made for continuous terrestrial sedimentation (e.g. Isaac & Lindqvist, 1990) and middle Cenozoic marine beds are well known in the area (Cooper, 2004; see also Section 3.e above). Rather enigmatically, the palaeogeographic maps of Lee, Lee & Mortimer (2001) show the Gore area lying 100–200 km offshore at both 20 and 30 million years ago.

New Zealand palynologists have long been aware of a terrestrial floral turnover in the vicinity of the Oligocene/Miocene boundary. The spore/pollen range chart of Couper (1960) shows this clearly, even within the limits of accurate dating at the time. Immediately after the demise of many Palaeogene taxa there was a sudden and dramatic influx of new Neogene taxa, ancestral to the present New Zealand flora. There was also

Journal of Biogeography

flooding of Zealandia. The ages of these fossil biotas, mainly palynomorphs, are just too imprecise.

In the last few decades, two very exciting fossil biotas of Early to Middle Miocene age have been discovered in New Zealand (Lee, Lee & Mortimer

What then, is the evidence for a landmass in this region during the Oligocene? Although not discussed by pre

in areas south of the Tableland (e.g. Buller region), where the unconformity is overlain by non-marine strata, no planar Cenozoic erosion surface has been documented. In fact, Nathan (1996, p. 28) recorded a 'local relief of up to 50 m beneath the Buller Coalfield'. Alteration of basement rock underlying the erosion surface in the Northwest Nelson–Buller region has been interpreted as being due to chemical weathering and cited as evidence supporting peneplanation (Nathan *et al.* 1986). Elsewhere in the South Island, similar alteration effects have formed along the Waipounamu Erosion Surface unconformity by groundwater alteration following deposition of the Cenozoic cover strata. In contrast, in areas such as the Tableland where the unconformity surface is of conspicuously planar nature, the basal sediments are marine. We conclude that while a 'mature' regional landscape formed by Cretaceous–Eocene subaerial processes, the planar surface of the Tablelands was formed by marine erosion bevelling an earlier landscape.

6.d. The Southeast Nelson–North Canterbury island

An Oligocene–Early Miocene landmass approximately 150×150 km (Fig. 1) is portrayed in the Southeast Nelson–North Canterbury area on maps of Fleming (1962), Stevens (1985) and others. Lying along the southeastern side of the Alpine Fault and within the Marlborough fault zone, this is an area of rapid tectonic uplift and erosion (Wellman, 1979). We are not aware of any evidence to suggest Oligocene land existed in this region, nor are there any published discussions justifying its existence. The only rocks exposed within the area of the putative island are Mesozoic greywacke and schist; any Oligocene cover strata or any remnant erosion surfaces that may have once been present have been removed by erosion during the past 10 million years.

The closest areas of middle Cenozoic strata are found in fault angle depressions along the Clarence Valley (Fig. 1), 20 km southeast of the proposed landmass. Here marine limestone and marl of Late Eocene, Oligocene and Early Miocene age are well exposed. Detailed

Furthermore, at many localities the marine sequence, including limestone, rests directly on eroded Mesozoic basement. Apart from a small area at the southeastern end of this putative Oligocene island, the proposed landmass lies off the west coast of the present North Island (Fig. 1). Although the location and extent of the island have not been discussed, we note that it coincides approximately with a chain of seamounts lying parallel to the coastline. Recent work (e.g. King & Thrasher, 1996; Hayward *et al.* 2001) indicates that these are Miocene sea-floor volcanoes.

An

& Landis, 1972; Fulthorpe *et al.* 1996), and there are good examples of regions being submerged throughout the Oligocene and Early Miocene but leaving little or no surviving sedimentary record. Overlying the basal Waitemata Group, younger Waitemata sediments are bathyal–abyssal turbidites that imply rapid subsidence of the area between 22 and 19 Ma (Isaac *et al.* 1994). Thus any original Late Oligocene–Early Miocene (27–22 Ma) marine sequence may be represented by a non-depositional hiatus (paraconformity) or have been eroded away prior to deposition of the basal Waitemata Group beds (22–21 Ma).

Study of remnant outliers of Oligocene strata in the Coromandel Peninsula (directly east of Auckland; Fig. 1) shows a basal unconformity overlain by fan-delta sediments of Early to middle Oligocene age that are in turn overlain by younger Oligocene shallow marine limestone (Dix & Nelson, 2004). A prominent intraformational erosion surface separates the lower shelf clastic sediment and limestone from overlying deep-water Oligocene–Early Miocene limestone (Dix & Nelson, 2004). This surface, interpreted as a sequence boundary by Dix & Nelson (2004), separates a highly variable, carbonate-dominated, transgressive basal marine sequence from overlying more uniform, and slightly less steeply dipping, deep sea carbonate sequence. Limestone-forming conditions persisted from Late Oligocene (24 Ma) to Early Miocene time (21 Ma).

6.g. Putative landmasses north of New Zealand

Herzer (1998, 2003) and Lee, Lee & Mortimer (2001) have proposed that land bridges and stepping-stone islands existed north of New Zealand during the Oligocene and Early Miocene. Herzer (1998, p. 47) maintains that successive uplifts of the sea-floor favoured ‘one-way north-to-south’

Howe Island is less than 1 % as large as New Zealand, and its land surface at least 10 million years younger. The Lord Howe Island biota is remarkably diverse with 8.6 genera of endemic angiosperms per km², whereas New Zealand has 0.001 genera per km² (Lee, Lee & Mortimer, 2001). The Lord Howe fauna includes a bat, gecko, skink and an abundance of freshwater and land invertebrates. Native birds, now depleted by introduced predators, included a flightless rail. Extinct land animals included a giant horned turtle (Morris & Ballance, 2003).

There can be no doubt that the Lord Howe endemic fauna and flora have descended from ancestors that arrived by long-distance dispersal from neighbouring lands during the last 6.5 million years. Similar situations exist in many other Cenozoic volcanic islands, such as Norfolk Island (Green, 1994), Fiji (Ryan, 2000) and Hawaii (Craddock, 2000). Sanmartin & Ronquist (2004) have summarized the relative dispersal rates of species on islands in the Southern Hemisphere while De Queiroz (2005) has emphasized the 'resurrection' of oceanic dispersal as a mechanism in the biological literature. We regard New Zealand's biota as

that there has been land continuously in Zealandia, so there has not been any expectation of finding a unique biota. Second, if a 'Zealandian' biota did exist as suggested above, it would have been substantially or totally destroyed by marine inundation in latest Oligocene time.

This raises a difficulty or paradox for the 'Moa's Ark hypothesis' with respect to the ancestry of modern biota on small landmasses (especially oceanic islands) that are remote to large fragments of dispersed Gondwanaland. Just how easy is it to distinguish between 'Gondwanan' biota that existed on Gondwanaland in the Late Cretaceous as opposed to biota that existed on dispersed fragments of Gondwanaland in the middle Cenozoic? After all, if a new land area emerged in the SW Pacific in the middle Cenozoic, it would be colonized by biota from the nearest persistent landmasses which would have a large component of biota that is directly descended from Gondwanan stock. Herein lies the paradox: the 'new colonizers' would appear to be Gondwanan. This potential effect would lead to a conclusion that the biota under consideration is Gondwanan. It is only by consideration of the timing of divergence obtained from fossils and DNA that we can distinguish between these scenarios. An attendant constraint on recognition of a 'Zealandian' biota is the fossil record.

was submerged from Late Cretaceous to Late Pliocene or Pleistocene time with occasional small volcanoes possibly breaking the surface. With Pleistocene uplift and emergence, the modern Chatham Island terrestrial biota has become established by colonization through long-distance dispersal processes (Campbell *et al.* 2006; Paterson

CARTER, R. M. 2003. The Marshall

species; *L. katipo* and *L. atritus* (Araneae: Theridiidae).
Journal of Arachnology **33**, 776–84.

GRINDLEY, G. W. 1961. *Sheet 13 Golden Bay. Geological
Map of New Zealand 1:250,000*. Wellington, New Z

Abstracts, AESC2006. Australian Earth Sciences Congress

- STÖCKLER, K., DANIEL, I. L. & LOCKHART, P. J. 2002. New Zealand Kauri (*Agathis australis* (D. Don) Lindl, Araucariaceae) survives Oligocene drowning. *Systematic Biology* **51**, 827–32.
- STRATFORD, J. M. C. & RODDA, P. 2000. Late Miocene to Pliocene palaeogeography of Viti Levu, Fiji Islands. *Palaeogeography, Palaeoclimatology, Palaeoecology* **162**, 137–53.
- SUGGATE, R. P., STEVENS, G. R. & T