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The "Waipapa Terrane", North Island, New Zealand: Subdivision and correlation

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Abstract Waipapa terrane is the exposed basement of much of the central and northern North Island; it has in the past not been readily correlated with any of the terranes recognised in the South Island and southern North Island. Available information about the lithologies and age relations of rocks in the Waipapa terrane are summarised and three – possibly four – different geographically discrete tectonostratigraphic units, correlated with South Island terranes, are recognised:

Omahuta-Puketi area (= Caples terrane) containing volcanogenic greywackes and laminated argillites, cherts, basaltic tuffs and volcanics of Late Paleozoic age, metamorphosed to prehnite-pumpellite and pumpellite-actinolite facies and uplifted before Mid Jurassic.

Bay of Islands - northern Waipapa area (= Older Torlesse/Rakaia subterrane) of feldspathic sandstones exposed in western Bay of Islands and interleaved with argillites and lithic sandstones in the eastern Bay of Islands. Permian microfossils occur in some terrigenous argillites and in tectonically interleaved oceanic limestones and cherts. Compared with the extent of the South Island Rakaia subterrane the northern Torlesse is a very thin sequence; it is believed that the Torlesse has been tectonically thinned out by a series of imbrication zones parallel to Northland Peninsula and does not extend further to the north of New Zealand.

Helena Bay-Hunuas and Moehau-Morrinsville areas which both contain sediments of Upper Jurassic to ? Cretaceous in age, although precise ages and hence stratigraphic relationships are unknown; they are correlated with the Younger Torlesse or Pahau subterrane. However, there are significant differences between the areas: Helena Bay-Hunua rocks are a turbidite sequence containing volcaniclastic sandstones and interleaved basaltic and associated oceanic sedimentary material of Triassic-Jurassic age.

Moehau-Morrinsville rocks are dominated by coarser sandstones and argillite conglomerates and lack oceanic material; they are tentatively interpreted as a terrane collision facies blanketing zones of imbrication and younger than the Helena Bay-Hunuas facies.

Use of the term Waipapa terrane should be discontinued and Caples, Older Torlesse (Rakaia subterrane) and Younger Torlesse (Pahau subterrane) used instead.

Key words: Permian-Mesozoic, tectonostratigraphic terranes, imbrication zones, terrane collision facies, Waipapa terrane, New Zealand

INTRODUCTION

The basement rocks of much of New Zealand are arc and trench-related rocks of Permian to Cretaceous age which have been grouped into a number of tectonostratigraphic terranes (Coombs *et al.* 1976; Coombs 1985; Bradshaw 1993 etc.). While the South Island terranes are well described, and their relationships and extension into the southern North Island generally accepted, the basement rocks of the central and northern North Island (the Waipapa terrane of Spörli 1978) are enigmatic and have no universally accepted correlation with South Island terranes. Evidence is also

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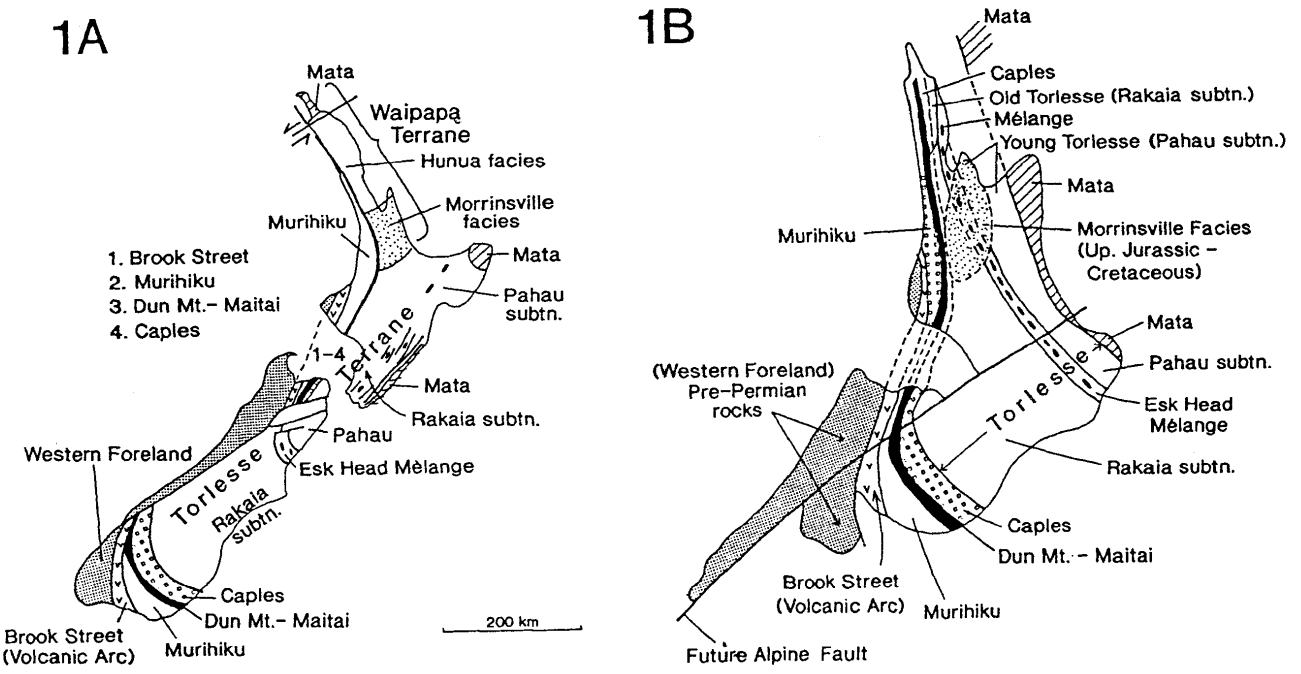

Fig. 1 1A - Pattern of basement terranes in New Zealand. 1B - Restoration of New Zealand to its configuration at the end of the Cretaceous showing the relationship between the terranes.

emerging that the Waipapa is a composite terrane (e.g., Jennings 1991ms). This paper summarises existing information about the Waipapa terrane and presents new data about their age, nature and geographic distribution. The objective is to investigate the feasibility of subdivision of the Waipapa and correlating the terranes recognised with those in the South Island.

Fig. 1A shows the present-day pattern of basement terranes in New Zealand. Descriptions of individual terranes are given in Coombs *et al.* (1976), Bishop *et al.* (1985), Korsch & Wellman (1988), Frost & Coombs (1989) and Bradshaw (1993). Two distinct associations of terranes – Western and Eastern Provinces – separated by a tectonic boundary known as the Median Tectonic Line or Zone are recognised (e.g., Bradshaw 1993).

In the South Island the Western (Foreland) Province is a Paleozoic Gondwana fragment while the Eastern Province was developed by convergent margin processes in the Carboniferous-Cretaceous (Bradshaw 1993) and includes a number of disparate terranes which are in sequence east of the median tectonic line: Brook Street, Murihiku, Dun Mt-Maitai, Caples, Torlesse and Mata terranes. The Torlesse terrane is divided into the Rakaia subterrane (Older Torlesse), which is Permian to Late Triassic in age and was sutured to the Caples terrane by Jurassic times, and the Pahau subterrane (Younger Torlesse) of Late Jurassic to Early Cretaceous age (Bishop *et al.* 1985). Bradshaw (1973) believed the Torlesse subterranes to be separated by a Melange Zone (Esk Head Melange). Work by Adams & Gabites (1985), Adams *et al.* (1985) and Adams & Robinson (1993) indicates that burial and recrystallisation of the Older Torlesse occurred by the Mid Jurassic but that uplift and cooling occurred in the Late Jurassic while the Younger Torlesse was being deposited. The Older Torlesse is believed to have been reworked into the Younger Torlesse based on the evidence of the latter's higher lithic content and detrital pumpellyite (MacKinnon 1983).

In the North Island, the Western Foreland, Median Tectonic Line and Brook Street terrane lie beneath the young sediments and volcanics of the Taranaki Basin (Korsch & Wellman 1988); the Murihiku terrane is well exposed along the west coast of the North Island but covered by younger sediments in the Northland Peninsula. Basement in the southern and eastern part of the North Island is usually considered to be Torlesse, with Cretaceous Mata terrane outcropping along the East Coast and similar rocks, here correlated with Mata terrane, in the northernmost part of Northland. In the west of the North Island the Waipapa and the Murihiku terranes are never seen in contact and are separated by a magnetic anomaly known as the Stokes or Junction Magnetic Anomaly (Hunt 1978). Where the rocks causing the anomaly are exposed they are seen to be serpentinites enclosing minor ultramafic rocks and these have been correlated with the Dun Mt

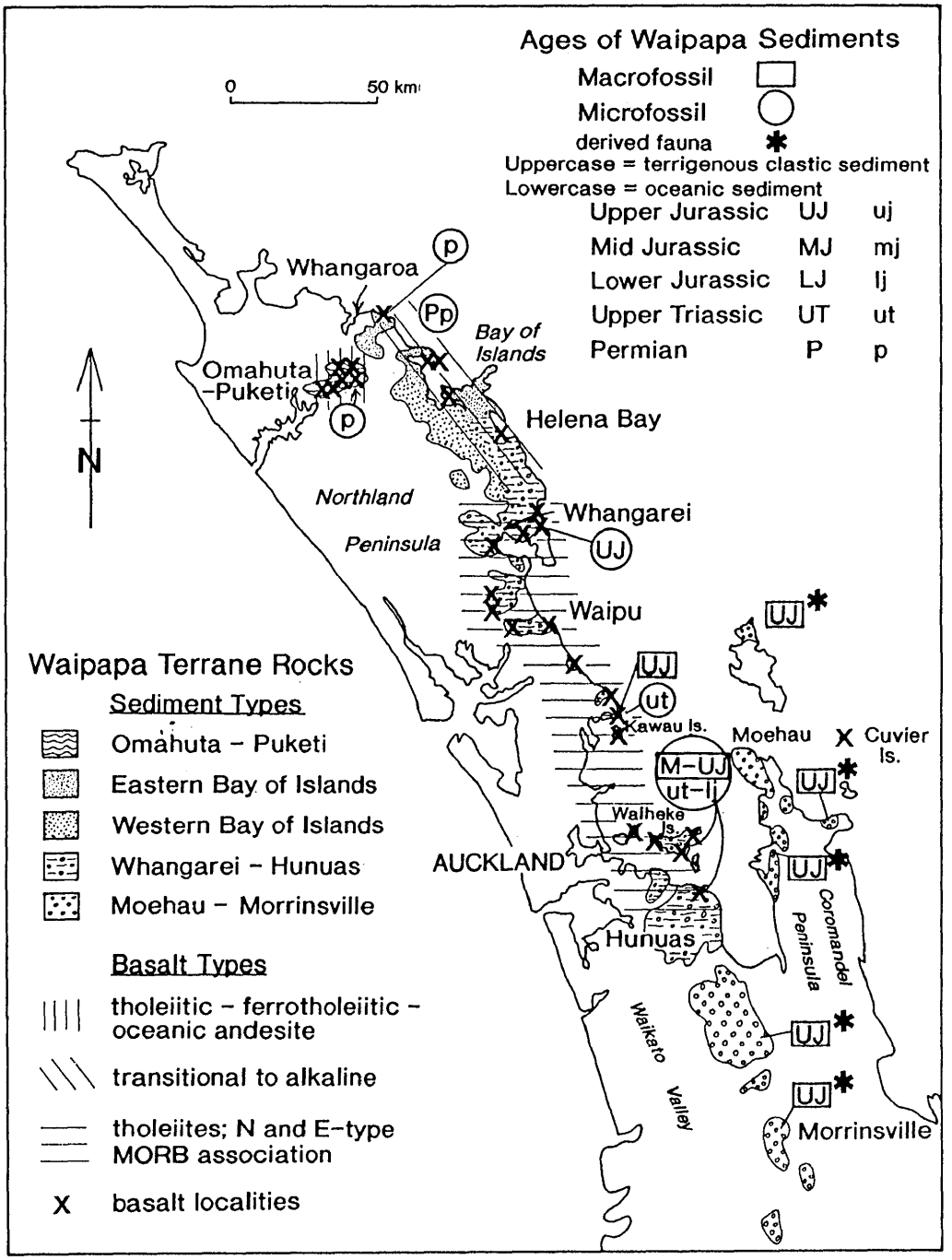

Fig. 2 Map of the northern North Island showing the distribution of the different types of terrigenous sediments and oceanic basalts in the Waipapa terrane. Data for basalts are from Jennings (1991ms) and for the ages of sediments from Aita & Spörli (1992).

Ophiolite Belt (Dun Mt-Maitai terrane). In the east and south the relations between the Waipapa and the Torlesse and Mata terranes are obscured by the voluminous volcanics of the Taupo Volcanic Zone.

The Waipapa terrane occupies an analogous tectonic position to the Caples terrane (Spörli 1978) but the Waipapa contains debris from a much wider range of source areas and, with the exception of the Omahuta-Puketi area of Northland (discussed later), lacks the in situ tuffs and volcanics commonly described in the Caples terrane (e.g., Bishop *et al.* 1976). Although the Torlesse and the Waipapa rocks are closely associated with each other in the central North Island (Beetham & Waters 1985) and in some reconstructions (e.g., Fig. 2B derived from Regenauer-Lieb 1992) appear to become along-strike equivalents, there are fundamental sedimentological differences between them (Mackinnon 1983; Beetham & Waters 1985). While the Torlesse terranes do contain some volcaniclastic material (Mackinnon

1983) they are dominantly quartzofeldspathic sandstones and argillites derived from a typical continental source (Frost & Coombs 1989); in contrast, the sandstones of the Waipapa terrane are believed dominantly volcaniclastic (Kear 1971; Beetham & Waters 1985).

The Waipapa terrane has long been known to be complex. Kear (1971) subdivided the Waipapa Group rocks into a Hunua facies and a Morrinsville facies, both being nontuffaceous, and largely composed of terrigenous sandstones and argillites. Kear believed that the Morrinsville and Hunua facies graded into each other with the difference between the facies being that the Hunua facies contained spilites, cherts, limestones and manganiferous sediments and appeared to have a wider time range than the Morrinsville facies, which lacked the spilites, cherts, limestones and manganiferous sediments and was characterised by chipwackes or argillite conglomerates and was believed upper Jurassic in age. However, more recent work by Spörli *et al.* (1989) and Spörli & Ballance (1989) has shown that the oceanic material (spilites, cherts and manganiferous sediments) is tectonically emplaced within the terrigenous sediments in extensive melange zones. Although this interpretation has removed most of the major lithologic distinctions between the two Waipapa facies there remain some important sedimentological differences – most notably the dominance of thick – bedded and coarse-grained lithologies including conglomeratic horizons in the Morrinsville facies - and the difference in known age ranges.

Unfortunately, in the northern North Island, inland exposures are very poor and the rocks are deeply weathered, so studies are confined to quarries which provide only occasional windows into the sequence. The coastal exposures of Waipapa terrane, from the Hunuas to northern Northland (Fig. 2), show a turbidite sequence which has been extensively melanged and contains tectonically interleaved slices of oceanic material oriented generally parallel to the Northland Peninsula (e.g., Wood 1976ms; Natawidjaja 1992ms; Swain 1993ms). In contrast, in the Waikato Valley and southern Coromandel Peninsula, where coarse sandstones dominate, the sequence is composed of coherent packages of rock separated by local zones of intense deformation which are usually localised in argillaceous horizons.

The Waipapa rocks have been extensively block faulted by Late Cenozoic Kaikoura Orogeny and flexure of the North Island caused by opening of the Rotorua-Taupo rift system (Regenauer-Lieb 1992ms; Bradshaw 1993). Some major faults with very large displacement dislocate lithologic and metamorphic sequences in adjacent blocks (Black 1989). North of Whangaroa there are no on-land exposures of pre-Cretaceous basement rocks. The Cretaceous autochthonous marine sediments and lavas which are exposed along the tip of the Northland Peninsula north of Whangaroa are interpreted by this writer as Mata terrane which has been offset to the west by the major sinistral fault recognised by Korsch & Wellman (1988, Fig. 1).

SEDIMENTARY ASSOCIATIONS IN THE WAIPAPA TERRANE

Reviews of thesis studies and examination of thin sections from all northern North Island greywacke quarries and many coastal exposures have shown that there are five geographically distinct groups of lithologic associations in the terrigenous sediments of the Waipapa terrane and these are summarised in Fig. 2. Oceanic sediments are tectonically enclosed within three of these associations and the oceanic sediment associations are also characteristic to each geographic grouping

1. Omahuta-Puketi. In the Omahuta and Puketi Forests, Jennings (1989) has described two units which are in distinct contrast to all other Waipapa associations although ironically the area does contain the type locality of the Waipapa Group from which the Waipapa terrane gets its name. The Omahuta Unit is dominated by massive volcanogenic and feldspathic metagreywackes and intervals of alternating volcanogenic metagreywackes and laminated argillites. The Puketi Forest unit consists of a series of massive basaltic lava flows and pillow lavas interbedded with red and green metatuffs, siliceous argillites and cherts, massive mudstone and minor interbedded sandstone and argillites. These rocks have been metamorphosed to prehnite-pumpellyite facies in the east and pumpellyite-actinolite facies in the west of the area. Samples of chert from the Puketi unit contain poorly preserved radiolarian of late Paleozoic to ?early Mesozoic age (R. Hori pers. comm.). Micas separated from recrystallised argillites from the Omahuta-Puketi terrane gave K-Ar dates of 168 million years (T. Itaya pers. comm. 1993) indicating Mid Jurassic uplift for this association of metamorphosed sediments and volcanics.

2. Western Bay of Islands. In the western Bay of Islands quartzofeldspathic sandstones (the western belt of arkoses described by Marshall 1974ms and Amos 1979ms) are exposed in quarries and occur in a strip along the western margin of the greywacke block. The age of these rocks is unknown but they appear to be in well bedded and coherent sandstone/argillite sequences with interleaved packages of lithic sandstone. No oceanic material (sedimentary or igneous) has been recorded in these sediments.

3. Eastern Bay of Islands. In the eastern Bay

of Islands sediments are dominantly clastics-poor siliceous argillites, sometimes containing phosphate nodules and horizons of feldspathic and lithic greywackes. Tectonically enclosed oceanic material includes fusulinid limestones and cherts. Cribrogenerina – a Permian restricted form – is found in a number of the sedimentary units (e.g., Meshesha & Black 1989) while Permian macro and microfaunas have been recorded in oceanic sediments (summarised in Aita & Spörli 1992).

4. Helena Bay-Hunuas. From Helena Bay south through Whangarei to the Hunuas the turbidite sandstones are dominantly lithic volcaniclastic sandstones (Amos 1979ms; Elliot 1967ms; Hawke 1978ms). Local horizons of massive sandstone occur. A feature of many of the sandstones is the abundance of lithic debris indicating a source area which was metamorphosed to prehnite-pumpellyite and actinolite-pumpellyite facies and actinolite and epidote are common detrital minerals. The tectonically enclosed oceanic sediments are cherts and red and green argillites. The age of the terrigenous sediments is Upper Jurassic on the evidence of rare macrofossils; while the tectonically enclosed oceanic sediments have been dated by radiolarian microfaunas as Upper Triassic to Lower Jurassic (Aita & Spörli, 1992).

5. Moehau-Morrinsville. This grouping includes the Morrinsville facies of Kear (1971) with its characteristic massive coarse sandstone and "chipwacke" horizons which are abundant in the Waikato Valley but also occur throughout the Coromandel Peninsula although becoming less frequent in the north where a typical turbidite sequence dominates. The sandstones in the turbidite sequence are feldspathic lithic sandstones (McFarlane 1993ms; Skinner 1993) with clastic debris from a wide variety of sources. Some detrital grains indicate derivation from a mature area metamorphosed at least to green schist facies since biotite schist fragments and garnet are relatively common while volcanic debris is both rhyolitic and andesitic. The chipwacke and conglomerate horizons are dominated by argillite pebbles but also contain other material including granite, and rare limestone and chert, and are interpreted as thick debris flow and fan deposits. No slices of either sedimentary or igneous oceanic material are known in the succession. Samples of argillite from localities in the Coromandel Peninsula all contain the genus Tricolocapsa (R. Hori pers comm.) which has a range from Mid Jurassic to Cretaceous but since derived macrofossils of Late Jurassic age have been recorded in several localities (Fig. 2) the age of the sediments seems to be late Jurassic to Cretaceous.

BASALTIC ROCKS IN THE WAIPAPA TERRANE

Jennings (1991ms) with a geochemical study of the basalt types in the Waipapa terrane showed quite clearly that there were three petrographically and geochemically different types of basalts, which also occurred in geographically distinct areas (Fig. 2):

1. A tholeiitic-ferro tholeiitic-oceanic andesite association occurs in the Omahuta-Puketi forest areas. The geochemical characteristics of the basalts indicate an oceanic rifting environment with a tectonic setting similar to that of the present-day Galapagos Rift.

2. Transitional to alkaline basalts are found in the Whangaroa-Bay of Islands area (northern Waipapa terrane). The geochemical features of these basalts indicate a within-plate source and origin either in an off-axis sea mount or oceanic island environment. The age of associated limestones and cherts indicate they are Permian ocean floor material.

3. Basalts in tectonic slices in the central Waipapa terrane (from Helena Bay to the Hunuas), are tholeiites with N and E-type MORB geochemical affinities similar to the basalts found in mid-ocean spreading centres. Radiolaria from associated cherts and argillites indicate Triassic to Jurassic age.

Aside from those volcanics in the Omahuta-Puketi unit, all the basalt localities lie in a zone of major imbrication which extends along the east coast of Northland down through the islands in the Hauraki Gulf into the Hunuas. South of the Hunua Ranges and in the Coromandel Peninsula no igneous rocks are known except in the furthermost east exposure of Waipapa terrane, on Cuvier Island, where pillow lavas, cherts and limestones similar to those of the northern Waipapa terrane exist in a melange zone in the greywacke sequence.

DISCUSSION

It is clear from Fig. 2 and the previous descriptions that there is a spatial and temporal coincidence of associations of terrestrial and oceanic lithologies. These time-lithologic-tectonic associations are sufficiently distinct that they should be regarded as individual tectonostratigraphic terrains. At the present we know little about either the age of the metamorphism or uplift or the timing of juxtaposition of these terranes although studies are in progress.

The basement rocks exposed in the Omahuta-Puketi area have little similarity to other Waipapa terrane areas but compare well in all repects (including proximity to the Dun Mt-Maitai terrane) to available descriptions of the Caples terrane

(Bishop *et al.* 1976) and it is concluded that the Omahuta-Puketi rocks represent the North Island exposure of the Caples terrane.

The quartzofeldspathic sandstones and argillites which occur in coherent packets in the western Bay of Islands area and slivers within the eastern Bay of Islands (Northern Waipapa terranes) show strong similarities in terms of lithologic association and age with the Older Torlesse or Rakaia subterrane although the sequence is considerably thinned in comparison with the South Island.

The Helena Bay-Hunua and the Moehau-Morrinsville associations are similar in age to the Younger Torlesse or Pahau subterrane and are broadly comparable as far as the nature of the sediments is concerned. However, there does seem to be a difference in the source of the clastic debris found in the sandstones of the two associations. The Moehau-Morrinsville association is also metamorphosed to a lower grade than the Helena Bay-Hunua association (Black 1989; Black *et al.* 1993). The major zone of imbrication which includes oceanic material extends along the Northland Peninsula but disappears south of the Hunuas where coarse sands and debris fan deposits dominate the sedimentary sequence. There is evidence from derived macrofossils found in the conglomerate horizons that by the Late Jurassic material was being shed from the Murihiku terrane into the Morrinsville facies so the Morrinsville facies rocks may be younger than Late Jurassic. The Morrinsville facies is tentatively interpreted as a terrane collision facies blanketing the older zone of imbrication.

Understanding the relations between the basement terranes requires that we restore the North Island to the configuration it had before the Rotorua Taupo rift opened up. Using the terrane reconstruction of Spörli & Ballance (1989) based on Bradshaw *et al.* (1981), and a reconstruction of the northern North Island by Regenauer-Lieb (1992ms) which removes the viscoelastic bending of the North Island crust and restores the Junction magnetic anomaly (Dun Mt belt) to a straight line, achieves the correlation and reconstruction of the North Island basement terranes shown in Fig. 1B.

The Brook Street, Murihiku, and Dun Mt-Maitai terranes are known to be present although the Brook Street terrane is not exposed in the North Island. Remnants of the Caples and Older Torlesse (Rakaia) are found in the Northern North Island; most of the Waipapa terrane is correlated with the Younger Torlesse or Pahau terrane. The Cretaceous Mata terrane, exposed along the East Coast is faulted westward and juxtaposed against the Pre-Cretaceous basement in the north. Fig. 1B shows that the zone of imbrication and interleaving of oceanic and terrigenous material that extends down the Northland Peninsula aligns with the Esk Head Melange of Bradshaw (1973) and the melanges in an equivalent position in the southern North Island. Bradshaw (1973) considered that the Esk Head Melange separated the Rakaia and Pahau subterranes. In the Bay of Islands area however, the mixed imbrication zone is within the Older Torlesse and in the south in the Younger Torlesse.

A conclusion drawn from the subdivision of the Waipapa terrane as outlined in this paper and correlation of the "subterranes" with the well described tectonostratigraphic terranes recognised elsewhere in New Zealand is that the term Waipapa terrane should no longer be used.

One interesting feature of the reconstruction of Fig. 1B is the narrowing of the Torlesse (particularly the Older Torlesse) towards the northern North Island. Since the Northland basement rocks are very imbricated, with melange and shear zones extending parallel to the trend of the peninsula it seems most likely that the narrowing is the result of tectonic thinning. However, an alternate interpretation of the interleaving of packets of arkosic and volcaniclastic material in northern New Zealand is that it could represent a mingling of material from two different sources. Whatever the cause of the thinning of the Torlesse we do know that neither the Caples nor Torlesse terranes are exposed further to the north in New Caledonia where only rocks correlated with Brook Street Volcanics, Murihiku and an equivalent of the Morrinsville Facies (Central Chain greywackes) are known (Black, in press).

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