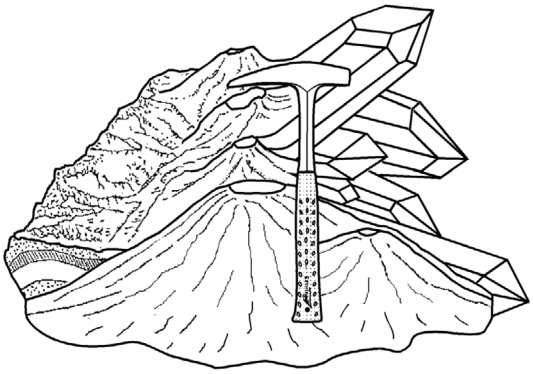

# Geocene

## Auckland GeoClub Magazine
## Number 30, August 2022

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Contributions about the geology of New Zealand (particularly northern New Zealand) from members are welcome. Articles are lightly edited but not refereed.

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# ORIGINS OF BAKED AND UNBAKED SEDIMENT PACKAGES WITHIN RANGITOTO LAVA FLOWS

Bruce W. Hayward

In 1985, well-known bare-footed marine biologist, Steve de Cook, discovered a slab of unbaked, fossil-bearing sediment within the basalt lava flow sequence at high tide level on a small islet (Queen Victoria Rock) near Rangitoto Beacon on the northwest corner of the island (Figs 1, 2). He showed some of the fossil shells to Auckland University paleontologist, Jack Grant-Mackie, who recognised the presence of the locally extinct Sydney mud cockle, *Anadara trapezia*. They jointly visited the site in 1985 and wrote up their findings and interpretation (Grant-Mackie & Cook 1990).

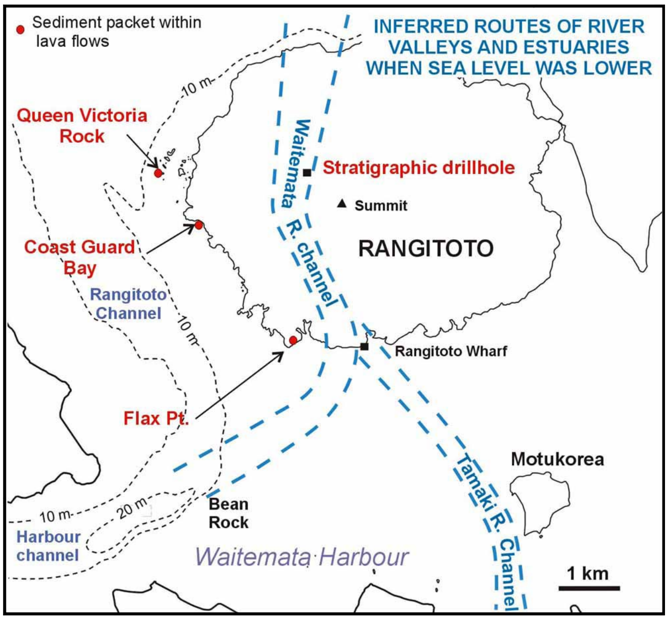


Fig. 1. Map of Rangitoto and Motukorea islands showing the inferred routes of the now sediment-filled Tamaki and Rangitoto channels and the localities where sediment packets have been seen within the Rangitoto lava sequence.

Fig. 2. Queen Victoria Rock is on a small islet on the northwest corner of Rangitoto, near the beacon (distance). The packet of sediment is where the geologist with white shirt is crouched.

In September 2002, an Auckland Geology Club trip led by Jack Grant-Mackie visited the northwest tip of Rangitoto on a spring low tide and several members waded waist-deep across to the small islet to see the fossils. On the way back to Rangitoto Wharf, we found more fine-grained sediment, some of it hardened or red-baked, near high tide in Coast Guard Bay, close to the coast road (Table 1) (Figs 3, 4). In March 2016, Hugh Grenfell, Simon Baker and myself ventured forth in a small runabout to look for and study the sediment packets in more detail. We landed on Queen Victoria Rock and examined all the other islets and reefs in the vicinity before walking south around the coast past Coast Guard Bay and for a further 1 km (Fig. 1). We easily refound the packets of sediment at Coast Guard Bay but had no luck elsewhere. On several other occasions between 1996 and 2021 I have

Table 1. Coastal localities on Rangitoto where packets of sediment have been seen within the basalt lava flow sequence.

| |
|---|
| **Locality 1. Queen Victoria Rock (36°47'01.8"S, 174°49'25.3"E), R11/f148, high tide level, an 8 x 3 m packet of unbaked, mud and fine sand containing fossils and a 5 cm thick bed of fine pebbly volcaniclastic sand. Originally collected by Cook and Grant-Mackie (1990).** |
| **Locality 2. Coast Guard Bay (36°47'26.4"S, 174°49'53.4"E), R11/f276, intertidal and high tidal occurrence of several packets of baked and partly baked mudstone with fragments of shell.** |
| **Locality 3. Flax Pt (36°48'23.9"S, 174°50'41.7"E), R11/f7581, intertidal exposures of numerous mostly red-baked mudstone sediment within basalt lava flows along 100-200 m of coastline.** |

Fig. 3. Red baked sediment (arrowed) beneath black lava just above high tide level, Coast Guard Bay, Rangitoto.

Fig. 4. Red baked mudstone with natural brick columns oriented perpendicular to the contact with the lava that cooked it. Coast Guard Bay. Photo: 0.5 m across.

Fig. 5. The central area of a packet of baked mudstone within a lava flow at Flax Pt., Rangitoto. Photo 1.5 m across.

visited the Flax Pt area, 1 km west of Rangitoto wharf and been amazed at the amount of red-baked fine-grained sediment present seemingly engulfed by the lava flow for 100–150 m of shoreline (Fig. 5). Here some of the red-baked sediment has beautifully developed natural brick with columns perpendicular to the contact surface with the basalt lava or seemingly radiating outwards from a central point as in a pillow lava lobe (Figs 6, 7).

I wondered why some of the sediment in the lava flows is highly baked, providing evidence for prolonged contact or engulfment by hot molten magma; and why is other sediment seemingly little baked with excellently preserved fossil shells.

**Origin of the baked sediment packets, Coast Guard Bay and Flax Pt**

The sediment packets are mostly within the size range of 1–5 m across and mostly occur intertidally at least as low as low tide. The less-baked sediment here appears to be mostly slightly sandy, slightly shelly mudstone and the red-baked sediment seems to be of similar fine-grained lithologies. To be engulfed and baked like this, I infer that these sediment packets have probably been plucked from the upper part of the vent wall in the centre of the island and been carried along in a lava flow and transported 3 km to their present location. The flow toes on the coast must be among the youngest in the volcano and would have flowed down over the top of earlier flows forming the lava shield, or the magma has partly flowed through lava tubes before breaking out as a surface flow part way down the slope.

Support for this vent-sourced hypothesis includes:

1. The lava containing the baked sediment flowed down from the centre of Rangitoto across lava flows and would have had no opportunity to pick up any seafloor sediment until it reached the coast and entered the sea.

Fig. 6. Part of a packet of red-baked mudstone at Flax Pt with natural brick mini-columns perpendicular to the contact with the black lava and radiating inwards to the centre of the packet. Photo: ½ m across.

Fig. 7. Red-baked sediment, Flax Pt, surrounded a tongue of black lava that seems to have intruded into and cooked the sediment from the inside of the packet. Photo: 40 cm across.

As the flow entered the sea water it would have chilled rapidly, especially on the outside, and there would have been very little opportunity for any incorporated seafloor sediment to have been extensively baked like it has (Figs 4–7).

2. Fine-grained, slightly shelly sediment like this occurs beneath the centre of the shield cone in the stratigraphic drillhole (R11/f262), located about 600 m from the main cone conduit. This sediment has been radiocarbon dated as 7.5–0.65 kyr old (Holocene) (Linnell *et al*. 2016).
3. Shell within a less-baked packet of mudstone at Flax Pt (R11/f7581) has been dated as late Holocene, 1.1±0.05 kyr (Grant-Mackie & Cook 1990).
4. The foraminiferal fauna in the least-baked sample (R11/f 276; AU17715) is strongly dominated by *Ammonia* (90%) with subsidiary *Haynesina* (6%) and *Elphidium advenum* (3%) and is remarkably similar to samples from the Rangitoto stratigraphic drillhole (R11/f262) (Linnell *et al*., 2016) at 132.2 m (dated at 3 kyr old) and 136.07 m (6 kyr old) (pers. obs.).
5. These foraminiferal faunas imply accumulation in a highly sheltered low tide to shallow subtidal (0–5 m depth) environment. A highly sheltered environment is also necessary for the mud accumulation. Such an environment, sheltered by an island, appears to have been of limited extent near the middle of the entrance to the Waitemata Harbour prior to the eruption of Rangitoto about 600 years ago. Such sheltered conditions do not exist around the shores of Rangitoto today with the closest analogue faunas being in the mud accumulating in the sheltered bays near Rangitoto Wharf.

**Origin of the unbaked sediment packet, Queen Victoria Rock**

Compared with the baked sediment packets, this slab is slightly larger and the sediment more indurated and weakly bedded. Bedding is near vertical and includes distorted lenses or beds of fossil shell and fine basalt lapilli to coarse volcanic ash (Figs 8, 9). Among the fossils are juvenile Sydney mud cockle *Anadara trapezia* that live intertidally today in brackish estuaries along the east coast of Australia. This species is now extinct in New Zealand. Four radiocarbon dates on *Anadara* and *Tawera* shells in this Rangitoto package (R11/f148) give an age range of 37–32 kyr (Grant-Mackie & Cook, 1990; Bryner & Grant-Mackie, 1993). These authors accepted these ages as real but struggled to explain how the shells could be found in sediment at Rangitoto (and in tuff on nearby Motukorea Island), as sea level was more than 40–60 m lower than present during this period (e.g. Pico *et al*., 2016).

The main Waitemata Channel is up to 29 m deep today near Bean Rock and drillholes near Motukorea indicate that the Tamaki Channel, now filled with sediment, was eroded 35–40 m deep into the underlying Waitemata Sandstone by the Tamaki River when sea level was lower (Bryner & Grant-Mackie 1993) (Fig. 10). Thus, the main channel beneath Rangitoto, eroded by the

Fig. 8. Part of the large packet of unbaked sediment beside Queen Victoria Rock. Note the vertical bed of hardened muddy sandstone (beneath scraper). We cleared some of the loose basalt cobbles away to better show the sediment. Photo: 1 m across.

Fig. 9. Vertically stratified unbaked sediment at Queen Victoria Rock containing broken fossil mollusc shells and basalt lapilli. Photo: 40 cm across.

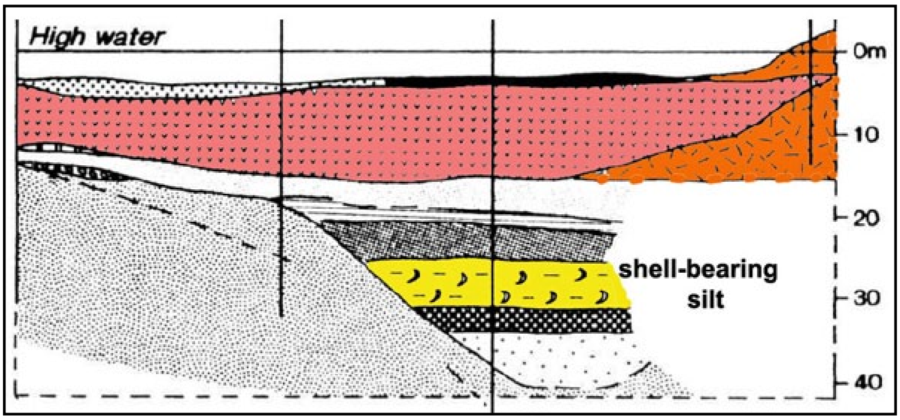


Fig. 10. A west-east cross-section beneath the seafloor off the west coast of Motukorea, constructed from drillhole logs (from Bryner & Grant-Mackie 1993). This shows the depth of the sediment-filled Tamaki Channel with a thick unit of silt containing shells (yellow), inferred to be the source of the *Anadara* that were thrown out by the phreatomagmatic early eruptions of Motukorea.

Waitemata River, could potentially be 40–50 m below present sea level. The Rangitoto stratigraphic drillhole hit Waitemata Sandstone at 27 m below present sea level (Linnell *et al.* 2016) but was probably not in the deepest part of the main channel. Numerous *Anadara* shells have been found in dredgings from 15–18 m below present sea level in Rangitoto Channel today (Bryner & Grant-Mackie 1993; Beu *et al.* 2004). Thus, sea level must have been no lower than ~18 m at the time the *Anadara* were living here.

Beu *et al*. (2004) documented the occurrences of fossil *Anadara* in New Zealand and determined an age range of 400–120 kyr (MIS11-5e). They ignored the young radiocarbon dates as clearly altered and inferred the Rangitoto and Motukorea occurrences are 130–120 kyr old (Last Interglacial peak, MIS 5e). No other conclusion can be reached as sea level has not been as shallow as 18 m below present between the Last Interglacial and present Holocene (120 and 9 kyr ago). I infer that the fossil *Anadara* of Motukorea and Rangitoto lived in an intertidal, brackish environment in and on the side of the Waitemata and Tamaki estuaries as sea level was rising or falling before or after the peak sea level of the Last Interglacial (around 130 kyr, or soon after 118 kyr). The *Anadara* in the sediment packet at Queen Victoria Rock were most likely sourced from sediment correlative with that dredged nearby in Rangitoto Channel at 15–18 m below modern sea level. I concur with Grant-Mackie and Cook (1990) that the sediment was probably plucked from the sea floor by the toe of a lava flow that may have ploughed or intruded into the soft sediment and was then shunted upwards by the force of lava behind. Since this would have occurred well below sea level, the lava flow toe would have been chilled and solid on the outside and had insufficient heat to bake the sediment at all.

**Conclusions**

An unbaked packet of stratified sediment within basalt lava flows at Queen Victoria Rock is likely of Last Interglacial age (~130 or ~118 kyr) and been pushed up from the sea bed at 15–18 m depth by the chilled toe of the flows. Packets of red-baked mudstone within lava flows at Coast Guard Bay and Flax Pt are likely of Holocene age (9–0.6 kyr old). I infer they were plucked from the upper part of the volcano's central vent by moving lava and baked while being transported by and within the lava flows for ~3 km to where they are seen today on the coast.

**Acknowledgment**

I thank Jill Kenny for comments on the routes of the Waitemata and Tamaki River channels based on her work on drillhole log data.

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# MAGNETIC FAULT ROCKS ASSOCIATED WITH A MÉLANGE IN WAIPAPA TERRANE GREYWACKE BASEMENT, RANGIHOUA, PURERUA PENINSULA, NORTHLAND

K. Bernhard Spörli, W. Ross H. Ramsay, Chris Booth, Amaru Booth *

**Introduction**

Whilst fossicking in Rangihoua Bay, one of the authors, Amaru Booth, identified the presence of strongly magnetic, sheared, black material within a sequence of rocks in this bay (Figs 1, 2).

The site was subsequently visited again for further observations on which this report is based. The outcrops lie on the coast west of the Rangihoua volcanic sequence and west of the Marsden Cross site. Access can be sea, by walking the Marsden Cross Walk, or by car through the 'Landing' property (permission required).

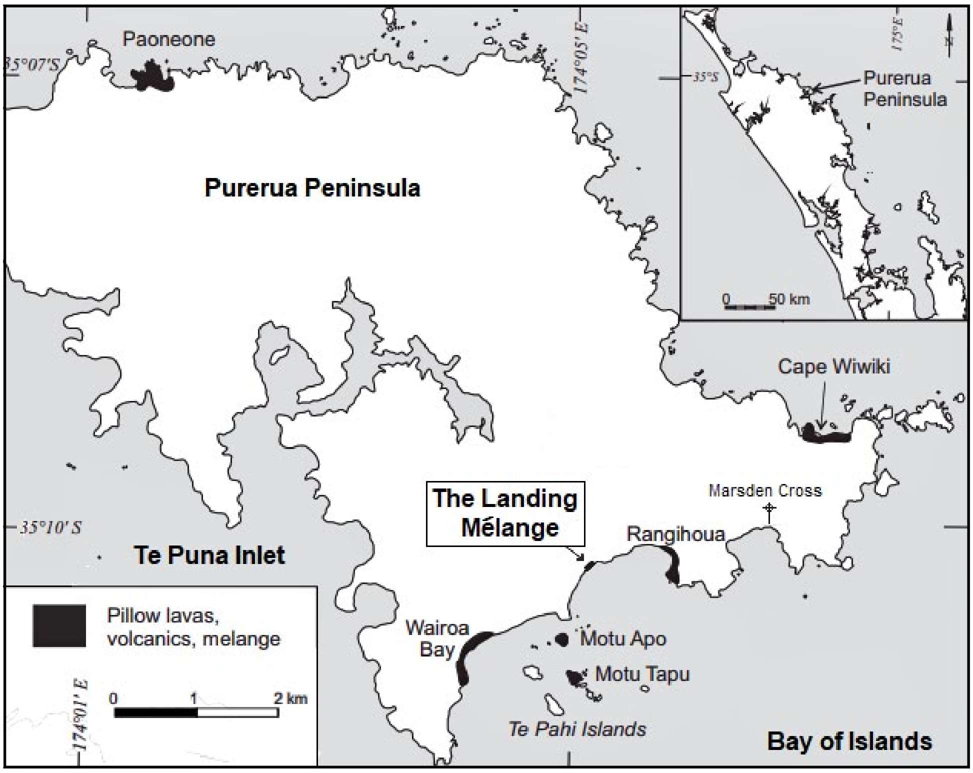



Fig. 1 Location of study area. Modified from Meshesha and Black (1989).

**Framework**

The rocks we describe originated when New Zealand was still part of the margin of the supercontinent Gondwana. This margin was a long-lived subduction zone active through the late Palaeozoic and Mesozoic (300–100 million years ago, see Hayward 2017), when plate convergence was moving the floor of the Paleo-Pacific Ocean (Panthalassa) under the Gondwana margin in the subduction zone (Figs 3A, B).

Huge fans of material eroded from the continent were deposited far out onto the sea floor, but the plate movement eventually pushed these beds back onto the margin, to form an accretionary prism (Fig. 3A). Because of their relatively low density, the layers of sand and mud and their immediate oceanic substrate of cherty sediment and volcanic rocks (including pillow lavas) did not go down with the subducting plate, but were sliced

Fig. 2. View looking east across Rangihoua Bay towards the Landing Mélange (yellow arrow). The Rangihoua Pa site marked with a red arrow and the Rangihoua volcanic sequence obscured by Norfolk Island Pine.

* KB Spörli (Auckland), WRH Ramsay (Kerikeri), C. Booth (Kerikeri), A. Booth (Kerikeri)

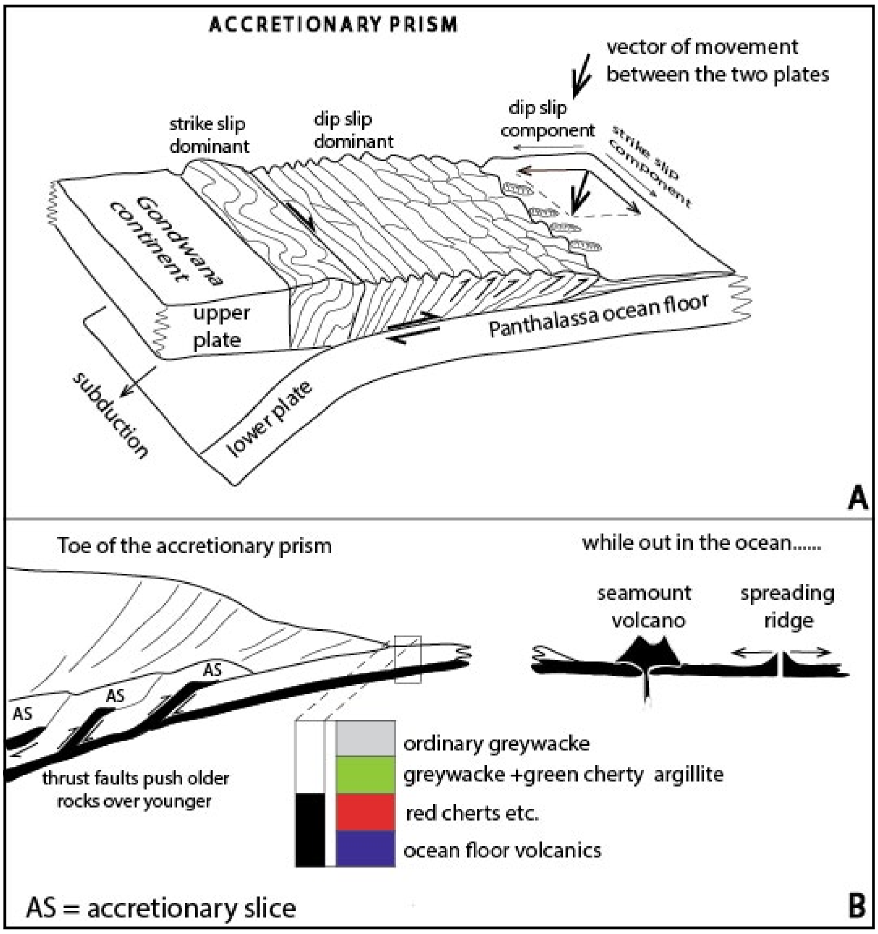



Fig. 3. Tectonics of the Gondwana margin:

A) Plate tectonic setting of the accretionary prism in which the rocks at the Landing were deformed. Note initial folds oblique to the margin. Modified after Spörli & McAlister 1995.

B) Formation of accretionary slices by multiple thrust faults, and section of incoming ocean floor. Modified after Kusky & Bradley 1999. The coloured key represents typical stratigraphy that might be expected to occur within an accretionary slice.

off and stacked up (accreted) against the continental margin in an accretionary prism. On their way to their final destination, they nevertheless did descend 10 km or so, and were heated up and consolidated (metamorphosed) before ascending back up to the surface.

The various accreted fans of continental debris are today recognised in the basement rocks of eastern New Zealand as separate 'terranes'. The one in our area is termed the Waipapa Terrane (Spörli 1978, Adams & Maas 2004, Hayward 2017). In this terrane, narrow zones of cherts and volcanic rocks - often associated with disrupted, mixed rocks of various origin, called 'mélanges' (Raymond 1984) - mark the fault zones (thrusts) on which the accretionary slices have been pushed over each other. This causes older rocks from the ocean floor at the base of an upper slice to overlie the younger greywackes at the top of a younger slice (Fig. 3B) - a situation that is especially well documented in the Auckland region (Spörli *et al.* 1989). The exposure we describe illustrates one of these thrust zones and its complex reworking.

Slivers of two chemically different types of volcanics of the oceanic plate can be recognised in the Waipapa terrane (Fig. 3B): 1) those formed at the Panthalassa spreading ridge, and 2) those formed at intra-oceanic seamounts, similar to the volcanoes of Hawaii (Wilson 1989, Jennings 1991).

The structures we see today are mostly inherited from a complex history of deformation due to the oblique convergence of the two plates, where different components of the movement were dominant at successive stages of the accretion (Fig. 3), but there are also deformation features due to the subsequent history of these rocks.

**Some important concepts**

1) **Strike and dip of planar features** (e.g., bedding, faults): The strike is the orientation of a horizontal line on an inclined plane. The dip is at right angle to the strike and is the angle of maximum inclination on the plane, measured down from horizontal (= $0^o$). On maps, strike and dip are conventionally shown with a 'T' symbol (see Fig.4). In verbal descriptions, the direction of dip is always quoted downwards e.g., "the beds dip $20^o$ towards the south".

2) **Fold axis and axial plane:** The fold axis is a line that marks the hinge (maximum curvature) in a fold. Each layer in the fold has such a hinge. Together these hinges can be visualised as forming a surface, or simplified as the axial plane (see Fig. 10). If a fold axis is inclined downwards, it is said to plunge in that direction.

3) **Facing (younging) of beds:** Parts of structurally complex rocks may be overturned. In sedimentary sequences, it is possible to recognise such packets by identifying the original bottoms and tops of beds with the

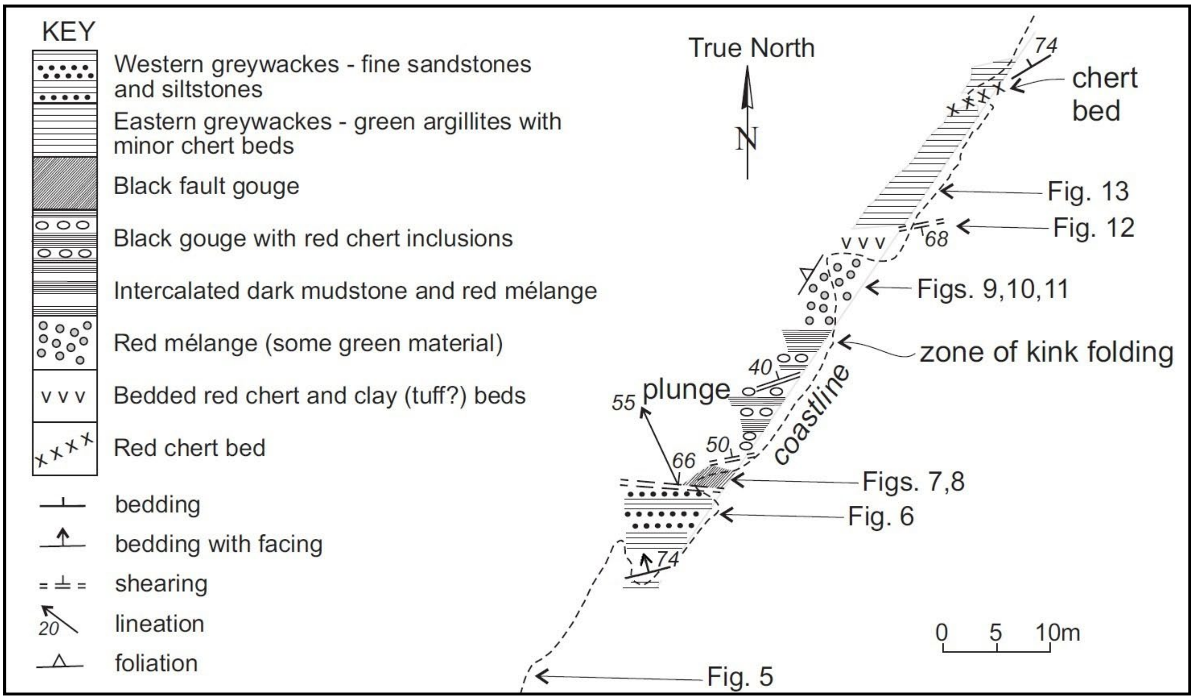
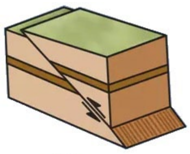


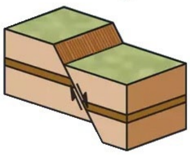

Fig. 4. Geological sketch map of the Landing Mélange.

help of sedimentary structures such as graded bedding, current marks, and sole marks. The direction in which the beds get younger is called 'facing' or 'younging'. An example can be seen in Fig. 4 where sediments of the western greywackes dip to the northwest and young in that direction too.

4) **Thrust fault:** A contraction fault that moves older rocks over younger rocks, causing repetition of ages. Here, the Landing thrust is an example.



**5) Normal fault:** An extensional fault that moves younger rocks over older rocks, causing excision of ages.



**6) Mélange:** A highly disrupted rock consisting of blocks [often having a significantly different (exotic) origin] in a finer-grained, sheared matrix - see Raymond, 1984.

**Rock types and structural geology**

We will now describe the structural geology and the rock types of the 'Landing Mélange' site, going from southwest to northeast (see Fig. 4). The sequence illustrates a multi-deformed contact between two thrust slices in the Waipapa accretionary prism (Waipapa Terrane).

At the northeastern end of the long beach in Rangihoua Bay (Figs 1, 2), we first pass through the **western greywacke sequence** - a typical, in part weathered, example of the most common basement rock in New Zealand (Fig. 5), consisting of grey metamorphic sandstone beds interbedded with dark grey or black mudstones - now argillites (Fig. 6). Bedding dips quite regularly to the northwest at around 70$^{o}$ and faces or youngs to the northwest, i.e., is not overturned.

Fig. 5. View looking southwest of weathered greywackes of the western greywacke sequence overlain unconformably by oxidised Quaternary sands. The basal unconformity is marked with a green line.


Fig. 6. Close view of bedded sediments of the western greywacke sequence.

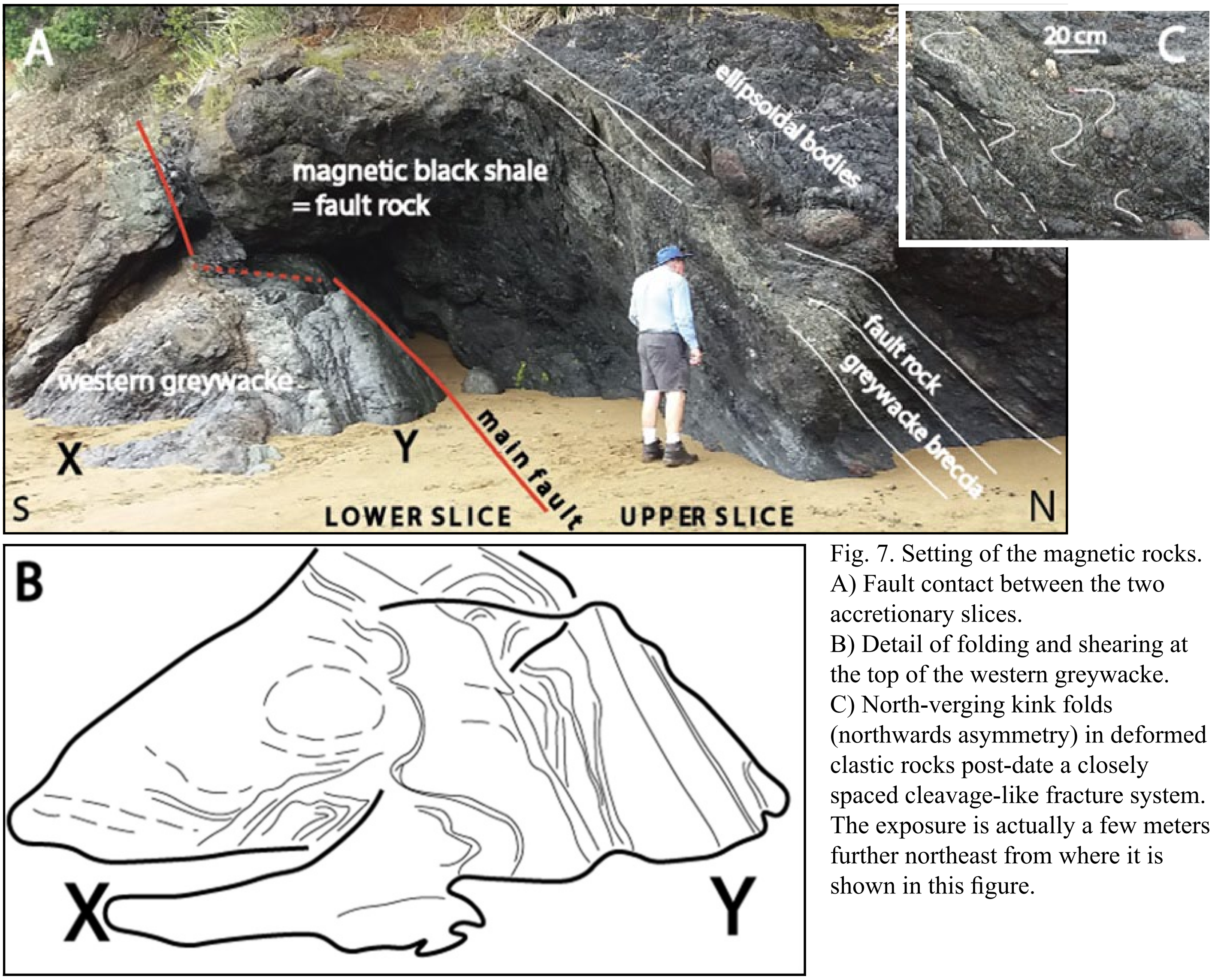


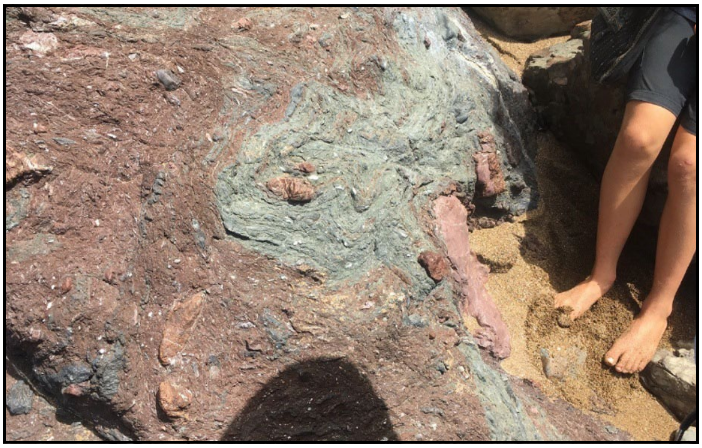

Fig. 7. Setting of the magnetic rocks.
A) Fault contact between the two accretionary slices.
B) Detail of folding and shearing at the top of the western greywacke.
C) North-verging kink folds (northwards asymmetry) in deformed clastic rocks post-date a closely spaced cleavage-like fracture system. The exposure is actually a few meters further northeast from where it is shown in this figure.

Proceeding north into a cliff embayment with two small caves (Fig. 7), we now enter an interval of complexity that marks the thrust zone at the base of the next imbrication slice in the accretionary prism. The **black magnetic mudstones** that occupy the western, larger cave, overlie the western greywackes at the top of the lower slice on a steep, sharply defined, often polished surface. Steep, parallel, corduroy-type stripes, interpreted to be coarse mullion structures on the polished thrust surface, plunge 55° to northwest (also see Fig. 4). A fine foliation in the mudstones is mostly parallel to the contact. Near the top of this zone, fragments of red chert appear to be included within the foliated black mudstone (Fig. 8), followed by a 20–40 cm thick zone of brecciated greywacke-type rocks with very angular fragments. These fault rocks are overlain by a more massive, ~2 m thick unit with large ellipsoidal bodies of as yet unknown origin. This is in turn overlain by a thick unit of highly **disrupted grey mudstones with isolated blocks of other rocks**. They have pervasive, closely spaced fractures (a fracture cleavage). This cleavage has been deformed into asymmetric, north-verging kink folds, which indicate top-to-the-north shear (Fig. 7C).

Fig. 8. Angular red chert inclusions in black foliated magnetic rock.

We next cross a sharp contact (Fig. 9) into a spectacular sequence of rocks: a mélange (Figs 10, 11). The contact (Fig. 9) is folded into at least two tight asymmetric folds that again indicate top-to-the-southeast shear. The unit consists of fragments of various lithologies (volcanics, chert, limestone and greywacke-type rocks) set in a mudstone (argillite) matrix that is predominantly red, but sometimes also green (Fig. 10). At least two phases of folding can be recognised. Phase 1 probably corresponds to the folds in Fig. 9. Phase 2 relates to the kinks in Fig. 7C, indicating top-to-the-north shear. While some of the rock inclusions are smooth and rounded, many are angular, with rhombic cross sections (lozenges). The example in Fig. 11 shows

Fig. 9. Tightly folded  sharp contact between kinked grey mudstone and overlying red mélange, causing at least 3 repeated seams of grey mudstone in the mélange. Note the rock fragments in the grey mudstone, such as the  red chert (yellow arrow).



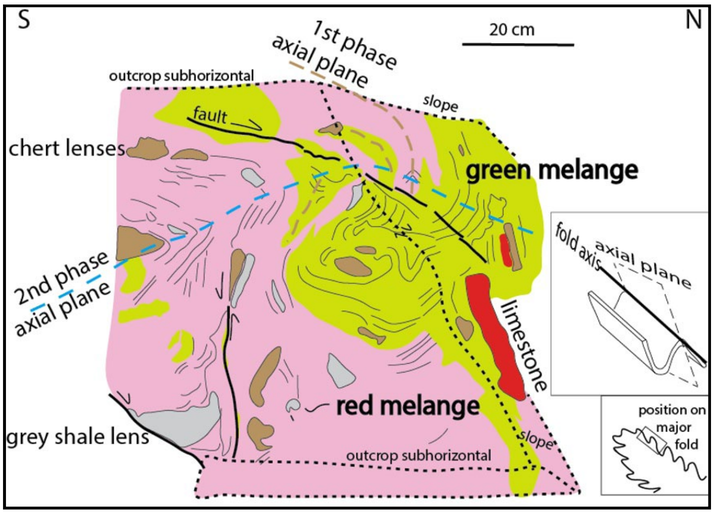



Fig. 10. Typical mélange, showing intermixing of red and green materials. Outcrop picture at the left, tracing on the right. At least 2 phases of folding, and late faults can be seen. Note that the kink in the 2nd phase axial plane trace is due to the intersection of a planar feature with changing topography. The large inset explains the axial plane geometry. The small inset shows the possible position of the second phase fold on its major fold, determined from its asymmetry (vergence).

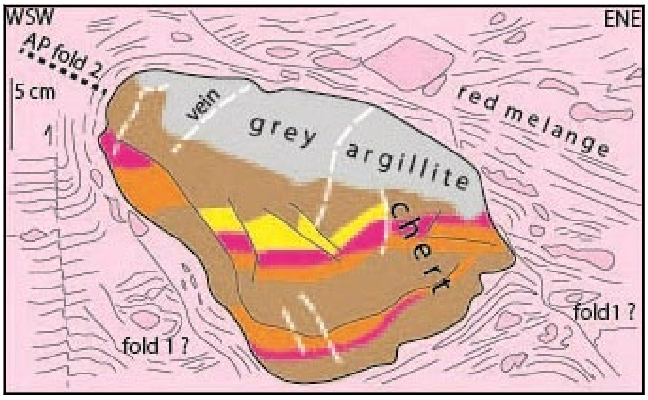



Fig. 11. Detail of a lens (lozenge) in the red mélange. It consists mostly of multi-coloured cherts, and some grey argillite. Shearing, faulting and assembly of different rock types took place before or during metamorphism (veins) and continued after inclusion of the lozenge in the mélange.  AP = trace of axial plane (see Fig. 10 inset for explanation) of a post-mélange fold. Other lenses in this outcrop are of diverse origin too but are shown in one colour for simplicity. Note the late subvertical fault to the left of the large lens.

that the fragmentation and inclusion in the mélange was a lengthy multiphase process, straddling the metamorphism of these rocks. The mélange merges to the east into a section of partially disrupted bedded red siliceous rocks and yellowish units, possibly tuffaceous (Fig. 12).

The contact to the next unit northward, the **eastern greywacke sequence**, is a steep fault which abruptly juxtaposes the mélange rocks and bedded siliceous rocks against the greywackes (Fig. 12). The eastern greywacke sequence is different from the western greywacke sequence in that beds are thinner and consist of very fine-grained siliceous (cherty) sandstone beds interbedded with green argillites (Fig. 13). The higher intensity of folding in the eastern unit compared to the western unit may only be apparent because the thinner beds in the former may allow a greater number of smaller folds to develop. Similar to the western unit, the structural fabric in the eastern greywacke dips to the northwest. Many of the fold axes are sub-horizontal and probably correspond to the folds in Fig. 9 and phase 1 in Fig. 10. Reconnaissance by Amaru Booth indicates that the eastern greywacke sequence extends a considerable distance further east towards the Rangihoua volcanic sequence (Fig. 1).

Fig. 12. Contact between the mélange sequence (left) with sediments of the eastern greywacke sequence (right). Discordant bedding in the eastern greywacke sequence (yellow line) to the mélange sequence indicates possible substantial movement along the contact.

**Discussion**

A panorama of The Landing Mélange looking westwards (Fig. 14) shows the various units that comprise this multi-deformed contact between two thrust slices in the Waipapa accretionary prism (Waipapa Terrane).

*Significance of the magnetic rocks*

These black magnetic rocks are unique to Northland. To our knowledge, no equivalents have yet been recorded in the Waipapa basement of the North Island. One of the authors (AB) first recognised these magnetic rocks while fossicking in the bay. A second author (WRHR), on being shown samples, assumed that such rocks might represent a new sheared metabasite unit within the Waipapa Terrane, as yet unrecorded. Several trips were organised to this locality, and in the most recent with KBS, no evidence of relict metabasite cores was recognised.

The most recent visit confirmed the position of this black magnetic material in the mélange sequence, its extremely fine-grained nature, and that it is a fault rock or gouge material ground up in the main fault between two accretionary slices (Fig. 7). The origin of the magnetisation

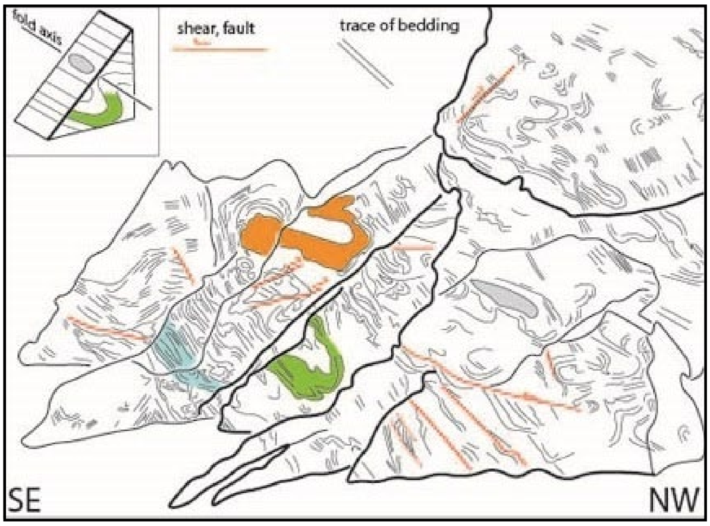



Fig. 13. Strongly folded eastern greywackes. Tracing of bedding etc. in the photo on the left is shown on the right. Prominent pieces of the sedimentary sequence are coloured. Note the general downward inclination (dip) of structures and beds to the northwest. The inset in the tracing shows two different erosional sections through a fold, with the colours matching the corresponding features in the outcrop. Some top-to-the-southeast shear is indicated. Red lines are faults and shears.

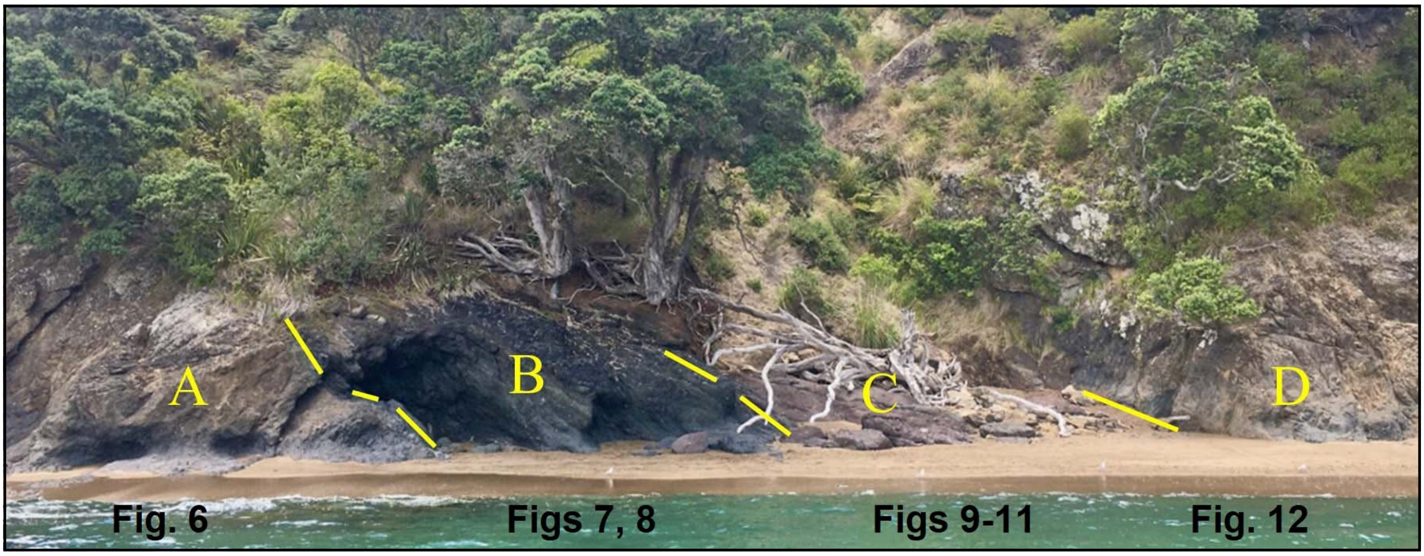



Fig. 14. View of The Landing Mélange looking west showing the main structural units described in this paper. A) Western greywacke sequence. B) Dark magnetic rock unit that grades to the right into kinked grey mudstone. This unit has been thrust over unit A. C) Mélange sequence largely red oxidised material, but some green-grey material. This unit has a sharp discordant contact to the right with; D) eastern greywacke sequence.

cannot be determined without detailed petrographic and geophysical investigations in the laboratory, to which we currently have no access. To speculate, the most likely source mechanism for the magnetism would be grinding up of ocean floor volcanics and concentration of their iron oxides (magnetite, ilmenite etc) by protracted fault movement. Any subsequent magnetic imprint would not single out the fault zone but would also affect neighbouring rocks unless those adjacent rocks were removed during further shearing. No primary deposits of magnetised rocks are known in the greywacke terranes of eastern New Zealand.

The scattered coastal exposures of basement volcanic rocks on the Purerua Peninsula (Fig. 1) mark thrust surfaces between accretionary slices. If more of them contain these magnetic rocks, it may eventually be possible to trace some of them inland and even connect them up by geophysical surveying to create a more coherent picture.

*Significance of the mélange*

Red mélanges such as seen at this locality are not common in the Waipapa terrane. Other examples, so far known only in Northland, are to be found at Arrow Rocks and Stephenson Island (Aita & Spörli, 2007). Mélanges with a green matrix (green mélanges) are much more common. The difference in colour may be primary in that the green mudstones are normal ocean floor material while the red mudstones may be volcanic tuffs. Alternatively, the two colours may be due to differences in the oxidation state of the iron in the two background lithologies. Their close juxtaposition again witnesses the significant amount of movement and translocation along these fault zones.

*Western versus eastern greywacke sequences*

The difference between these two sequences is a visual signal of plate motion: The eastern, more siliceous greywackes originated further offshore in Panthalassa than the western greywackes, which were deposited nearer to the Gondwana continental margin and consequently are more contaminated with coarser continental debris. In a complete section, the eastern sequence would underlie a western greywacke type stratigraphic section (Fig. 3B). These relationships have been well documented in the Auckland region (Spörli *et al*., 1989) and on Arrow Rocks in Northland (Aita & Spörli, 2007). The bottom and top of such a stratigraphic section could have been deposited hundreds of kilometres or more apart during plate movement. The western greywacke-type rocks at Rangihoua are considered to be of Late Triassic age (210–200 million years old) from grains of zircon deposited with the sandstones from Gondwana (Adams *et al*., 2013).

*Direction of thrust movements*

Fold axes, axial planes and asymmetrical structural features can be used to determine the direction of movement and sense of shear in deformed rocks. However, in our case there are so far too few observations to unravel the complex history. However, fold asymmetries indicate that there was a top-to-the-southeast movement, followed by a top-to-the-north movement in these rocks. In addition, we have detected deformation that began before metamorphism (Fig. 11) and outlasted it until the rocks had become brittle at shallow depths in the crust (Fig. 7 C).

**Acknowledgements**

We thank the owners of The Landing Estate for vehicle access permission, Louise Cotterall for draughting of Figs 1 & 4. Robin Booth helped with photography.

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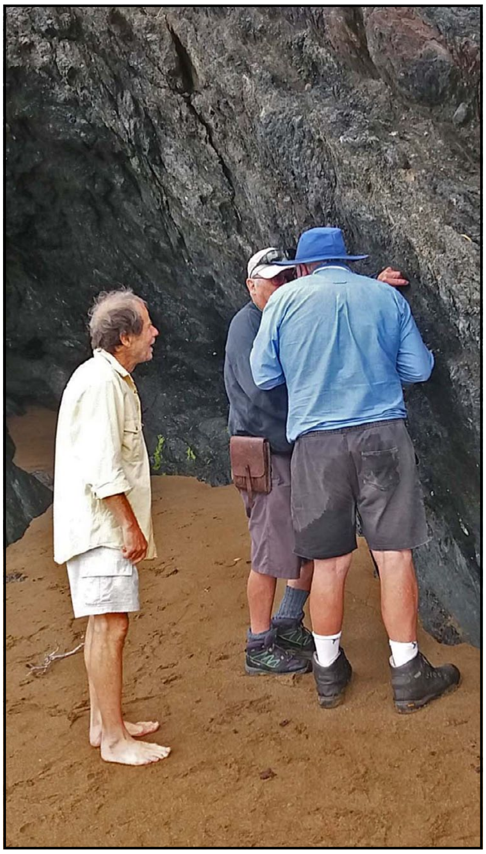
**The photo and words below appeared in Geocene 25 (2020) and now the article above answers the 2020 teaser.**



## WHO ARE THESE PEOPLE?

Who are these three people? Two GeoClubbers and a famous Northland sculptor, no less. They are promising an article on this outcrop for the next issue of Geocene. The caption below will then make sense.

Oops – a wet Landing!

**So now you know!**

# REPORT ON LATE CRETACEOUS MARINE REPTILE REMAINS (MOSASAURIDAE) FROM KOUTU BOULDERS, HOKIANGA, NORTHLAND, NEW ZEALAND

Seabourne Rust

**Summary**

Fossil marine reptile bones are reported from the Late Cretaceous Punakitere Sandstone (?Haumurian Stage) of the Northland Allochthon at Koutu Boulders, in the Hokianga District, Northland, New Zealand. These are very worn and fragmentary, making identification difficult – in this initial diagnosis they are thought to represent a variety of skeletal elements consistent with mosasaur remains.

**Introduction**

The fossil record of marine reptile material from the New Zealand Late Cretaceous consists mostly of specimens from Hawkes Bay, Marlborough-North Canterbury and Otago (see review in King *et al*. 2009). Here I provide an initial report on a number of bones recently recovered from Koutu Boulders in the Hokianga District of Northland. Although somewhat limited in taxonomic information due to poor preservation, these specimens represent the first record of a fossil marine reptile from the locality (shark vertebrae were described from Koutu by Rust in 2014), and add to the record of vertebrates from the Cretaceous-Cenozoic strata of northern New Zealand (e.g. Grant-Mackie *et al.* 2011, Sachs & Grant-Mackie 2003).

*Locality*

The fossils were discovered on a stretch of Hokianga Harbour shoreline known as the 'Koutu Boulders' for its large spherical concretions, some five kilometres northeast of Opononi, in the Hokianga region of Northland, New Zealand (Fig. 1).

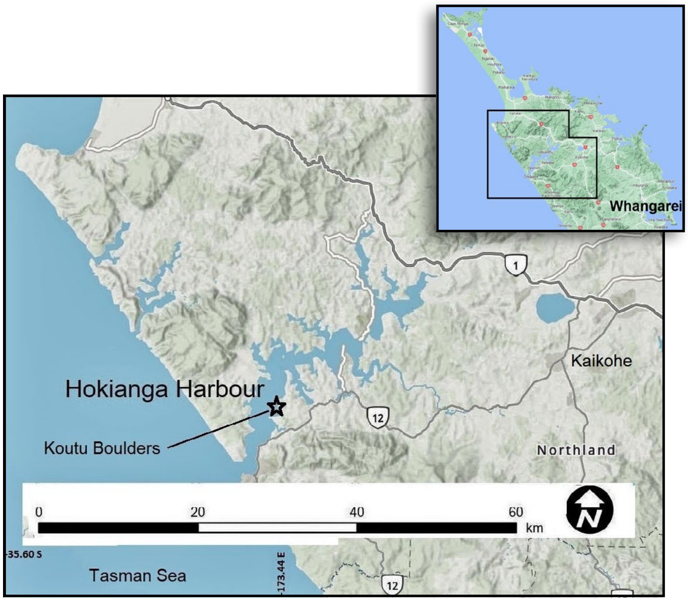



Fig. 1. Map of central western Northland showing the location of the Koutu Boulders, Hokianga.

The specimens were collected by S. Rust & D. Yanakopulos during September - October 2021 as isolated pieces from concretions eroded from an outcrop of Late Cretaceous (Maastrichtian = Piripauan–Haumurian Stage) Punakitere Sandstone (Hay 1960, Isaac 1996), exposed at low tide, in the vicinity of the southernmost group of large (>1 m diameter) concretions, on the shoreline between Koutu and Kauwhare Points on the southern side of Hokianga Harbour (Fig. 2). Details of the locality are recorded in New Zealand Fossil Record File database (www.fred.org.nz), with the registration number O06/f0125; the map reference is NZMS 260 O06/485 373.

Fig. 2. Photo of the locality on the shore of the Hokianga Harbour looking north. Note large spherical concretions among boulders on shore platform.

The locality and its concretions are a well-known tourist attraction and have been frequented by walkers and recreational users over many years (Rust 2012- online). There is also a long history of Maori occupation and seafood gathering in the area. As an important site, collection of geological specimens is not encouraged, yet active erosion and vehicle damage to the shore platform is occurring.

*Geological setting*

Much of Northland is covered by a significant succession of allochthonous Cretaceous and early Cenozoic strata that formed originally as a passive margin to the northeast. The Northland Allochthon was emplaced as active subduction proceeded in the area during the early Miocene. Across northern Northland, these structurally complex sequences have been mapped as large thrust sheets, later deformed by regional uplift, faulting and folding (Hayward 2017, Isaac 1996).

In the Hokianga area, an allochthonous sedimentary sequence of Late Cretaceous and Paleocene quartzose sandstone and siliceous mudstone (included in the Mangakahia Complex) overlies Cretaceous Tangihua Complex rocks of the Waima Range. Locally, the Late Cretaceous Punakitere Sandstone is dominated by bedded or concretionary quartzofeldspathic sandstone and mudstone with minor conglomerate. Concretions are often large, spherical, often with cone-in-cone structure rims and cemented with barite or siderite (Rust 2012 online, Hayward 2017). The regional distribution and lithology of the formation have been documented by Hay (1960), Isaac (1996) and Mason (1953).

**Systematic Paleontology**

Phylum CHORDATA
Class Reptilia
Order Squamata
Family Mosasauridae
Gen. et Sp indet.

MATERIAL: The remains found on the shore platform are unfortunately fragmentary and worn. As they were mostly recovered as eroded specimens from an area approximately 10 x 20 m, with the matrix surrounding the associated specimens consisting of a very hard, well cemented, fine grained, grey to reddish brown sandstone, they are assumed to have come from an individual animal, possibly once preserved in a single concretion, long since broken apart and eroded (Fig. 3).

One exception is a single isolated limb bone, probably a worn radius or tibia, found on the shore platform some 50 m further to the south. This bone is a much darker colour surrounded by a light grey sandstone matrix, suggesting different preservation history, and perhaps originates from a second animal.

The fossil specimens are to be housed in the paleontology collection at the University of Auckland, Auckland, New Zealand.

DESCRIPTION: The specimens consist of a number of dislocated bones, somewhat worn and abraded.

Fig. 3. Assemblage of all the pieces of concretion with marine reptile bone found at the site. Scale in cm.

From this initial study they appear to include:
**Skull/jaw elements:** The three largest pieces of concretion contain very dense bone, probably mandible fragments (maxilla/upper jaw) at least 350 mm in total length (Fig. 4). The very dense central portion of the element is worn but with several slightly raised circular areas representing broken tooth bases.

The presumed distal (snout) end is laterally convex on the outer (labial) surface, giving a curved D shape profile in section, approximately 80 x 80 mm across (Fig. 5). A dense central region can be seen beneath the tooth bases, with pores possibly representing part of the neurovascular system. Towards the proximal end of the element, it appears to become flatter and wider, reaching 140 mm across.

Another unusual element, comprising pale-coloured dense bone with an oval hollow central portion (70 x 45 mm), also possibly represents part of the jaw or skull (Fig. 6).

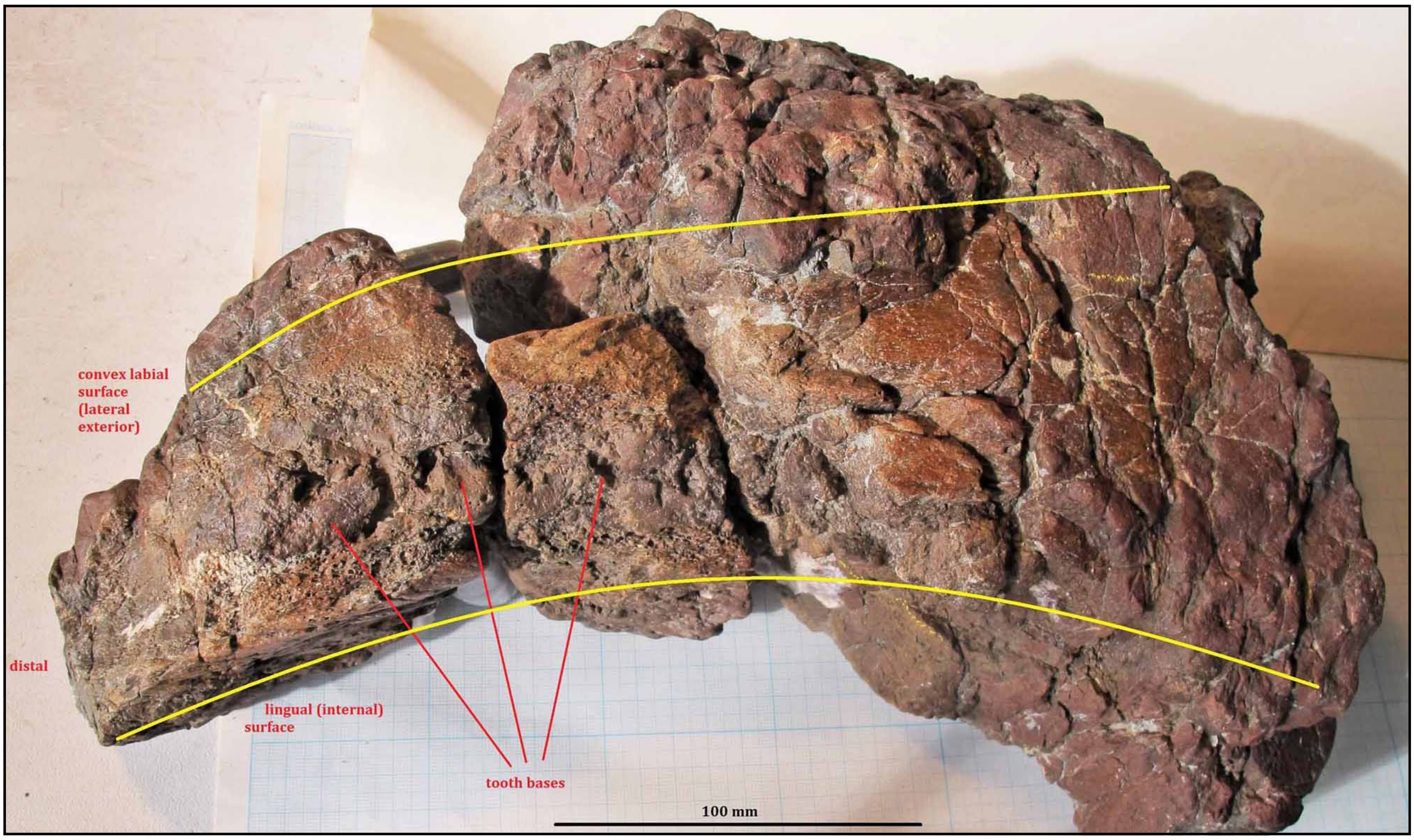



Fig. 4. Fragmentary and worn partial jaw (occlusal view). Yellow lines indicate approximate edges of bone.

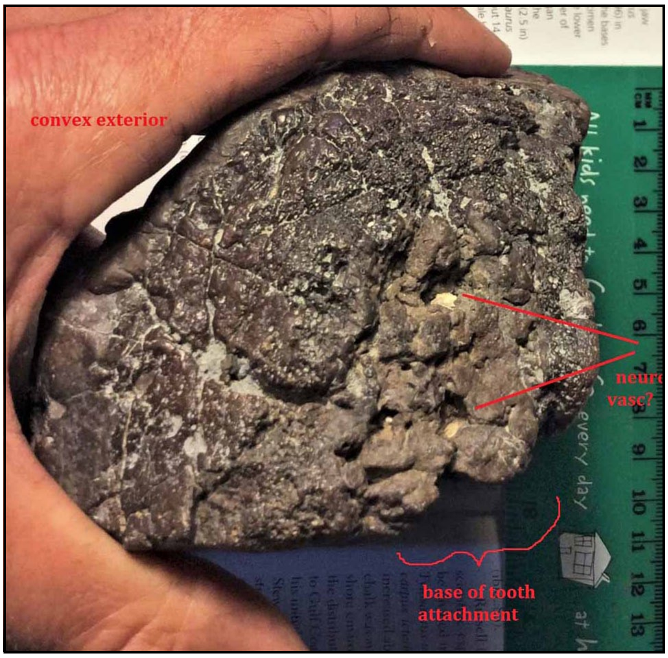



Fig. 5. Jaw fragment (showing element in section).

Fig. 6. An unidentified element of pale dense bone.

**Partial Rib:** A fairly straight element, measuring at least 200mm in length, is present as three connecting pieces of concretion (Fig. 7). It is square in cross section, approximately 30 mm across.

**Vertebral column:** A number of rather porous bone fragments, up to 80 mm across, might represent parts of vertebrae. It is likely that several worn centra are present in the Koutu material - one possible cervical or dorsal centrum measures approximately 60 x 60 mm (Fig. 8). Mosasaur centra are typically procoelus (Russell 1967), which means that the anterior face is concave, while the posterior end is convex, as seen in this partial specimen. In contrast, plesiosaur centra tend to be flat faced, while ichthyosaur and fish centra are amphicoelus - concave at both ends. Mason (1953) noted the occurrence of some amphicoelus centra from another Cretaceous Hokianga locality.

**Limb bones:** At least one isolated radius or tibia from a paddle-like limb is present. The dark bone, located from 50 m south, is typically short and solid (Fig. 9). The element is broken longitudinally with one side missing, however enough of the convex articular faces remain at each end of the bone to suggest an approximate length of 110 mm, width 80 mm and thickness some 50 mm.

**Discussion**

Several genera of mosasaur are known from the New Zealand Cretaceous, including *Moanasaurus*, *Taniwhasaurus* and *Prognathodon*; all were large aquatic predators (Wiffen 1990, Caldwell *et al*. 2005, Everhart & Lewis 2009, King *et al*. 1990). Propelled by side-to-side motion of their long tails, most mosasaurs captured their prey in strong jaws lined with large conical teeth (Fig. 10). Systematic interpretation of mosasaur (or any marine reptile) from isolated bones is severely limited; teeth tend to provide more useful taxonomic information. Unfortunately, teeth have yet to be found at the Hokianga site. But the bones from Koutu do compare well in texture and internal structure with other marine reptile material seen by the author in Late Cretaceous strata from Haumuri Bluff, Marlborough, and in photographic comparison with the only other possible mosasaur remains known from Northland, several worn vertebral centra found in 1980 from the Kaipara District (presumably those mentioned by Evans 1985), and now in the Auckland University collection (N. Hudson pers.comm., Hayward 2017).

The Mangakahia Complex of the Northland Allochthon includes a marine clastic flysch association thought to have been deposited in outer shelf to bathyal depths (Hayward *et al*. 1989, Evans 1985). Sedimentary structures within the sequence indicate some deposition from turbidites and gravity flow mechanisms (Isaac 1996), and there is some evidence of concretions being reworked (Evans 1985). The source of the Punakitere Sandstone exposed at Koutu, and in particular the concretions, was likely somewhat shallower on the shelf - the substrate was sandy and gravelly, with some shell debris as well as

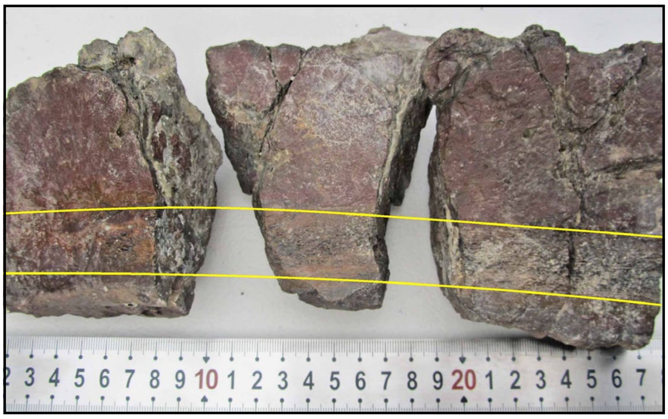


Fig. 7. Several pieces of concretion containing a partial rib.

Fig. 8. Worn vertebra (posterior view), insert shows a reconstruction sketch.

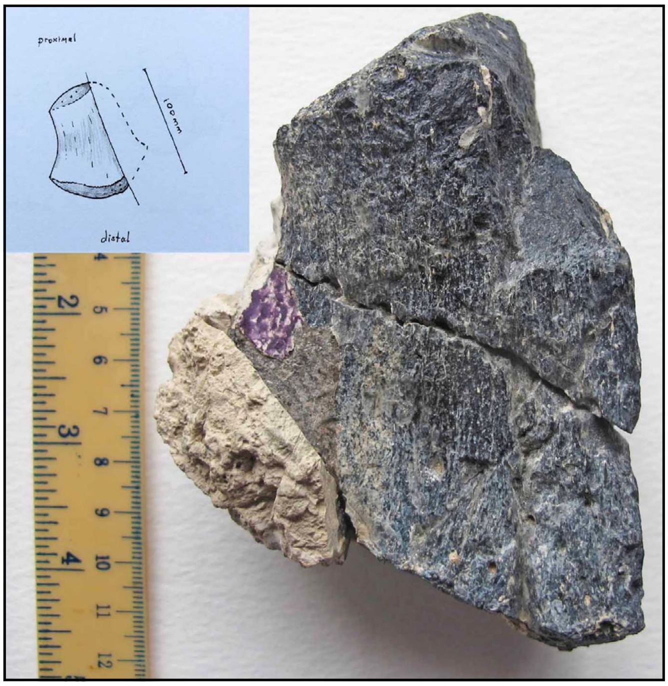



Fig. 9. Partial limb bone (radius?), insert shows a reconstruction sketch.

occasional woody material. Casts of burrows and other trace fossils are relatively common, as are fragments of the large bivalve *Inoceramus*. Other local fossils include some rare bony fish remains (isolated bones and scales), shark vertebrae (Rust 2014) and age-diagnostic coiled ammonites such as *Maorites tenuicostatus* (Fig. 11) and *Kossmaticeras (N.) sulcatum* Marshall (1926) (Fig. 12).

The concretion containing the mosasaur bones described here had long since broken apart. It is possible other parts of these rare fossils have previously been removed from the locality. If so, it is hoped they will be recognised, recorded and made available for study.

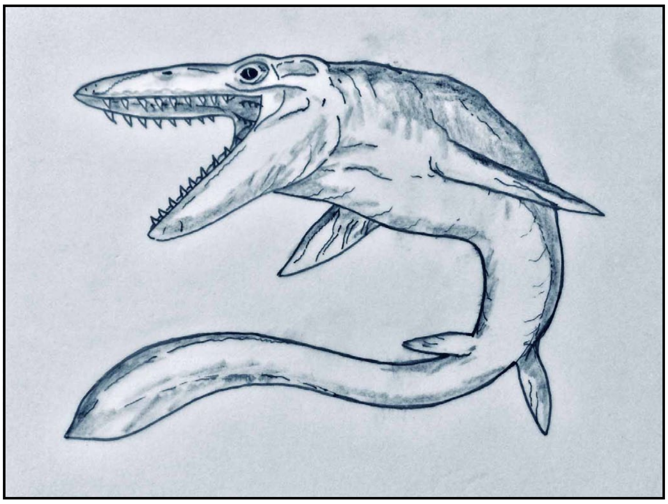


Fig. 10. Drawing of a tylosaurine mosasaur based on reconstructions in Everhart *et al*.(2009) and others. Some species of these aquatic predators may have reached up to 14 m or more in length. As an estimate, the Koutu specimen may have been only half that size.


Fig. 12. Late Cretaceous ammonite from the Koutu site, *Kossmaticeras sulcatum*.


Fig. 11. Late Cretaceous ammonite *Maorites tenuicostatus* from Koutu.

**Acknowledgements**
The author gratefully acknowledges field assistance from Diane Yanakopulos, plus advice and input from Neville Hudson, Marianna Terezow, Paul Schofield and Mike Everhart.

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# DEEP BOREHOLES AND EATING CROW: THOUGHTS AND OBSERVATIONS NORTH OF AUCKLAND

Roger Evans

**Deep boreholes**

Boreholes often provide new information that can improve subsurface knowledge and correct prior misconception. While reading a paper on four deep boreholes in or near urban Auckland that reached greywacke basement (Hayward & Waterhouse 2019), I was reminded of a fifth.

It was while I lived in Okaihau that I got to know Snow Brown of Kiwi Welldrillers, and through him his two sons Kevin and Shane. Snow and his son Kevin had a driller's interest in the deeper geology of Northland, and would often push a borehole deeper to prove what lay at depth (Evans 1990).

Both of Snow's sons inherited the same interest. In 2000 Shane Brown drilled a bore at Wainui for Sunny Heights Nurseries (NZGD* 81139, 512 Wainui Road - listed under References) and found Waitemata sandstone at 37m beneath "Onerahi Chaos" (contrary to Schofield's 1:50,000 map: Schofield 1989). Asked to drill a water bore for Geoff Barnes in the "Onerahi Chaos" at Cemetery Road, Wainui (west of Orewa), Kevin and Shane decided to put this observation to the test.

For 106m, the drill penetrated multicoloured mudstone, pushed through a zone of "heaving formation" then continued in argillaceous limestone, breaking out at 220m into broken Waitemata sandstone and finishing at 317m (NZGD 82589). Expectation of good water supply from the sandstone was thwarted when the bore collapsed.

Nevertheless, Kevin and Shane had proved their point, declaring at the end of the log: *"Shane drilled this probe hole to prove his theory that the interchange from lime to sandstone was at approx. 240.00m and not 600.00m as the geologists have stated on the local maps. Shane was right in his theory of the interchange. This bore opens up a large region of new drilling, in what was once a no drill region."* Which map predicted Waitemata sandstone beneath limestone at 600m is not stated.

Encouraged by Shane's success, and willing to go for greywacke to prove a point, Kevin sent driller Sam Korewha to drill a water bore for Tony Ruiterman at a nearby site at 637 Wainui Road (NZGD 82562) (Fig. 1). After drilling approximately 385m of "Onerahi Chaos" and argillaceous limestone, the bore penetrated sandstone, siltstone, and mudstone, presumably Waitemata Group; ending at 583–585m in "very hard greywacke". The bore was successfully completed, having obtained a good supply of water (presumably from the sandstone).

While no assessment of the cuttings was made by a geologist, the description of "sandstone and mudstone" prior to encountering greywacke indicates that Waitemata Group underlies Onerahi Chaos (= Northland Allochthon) and directly overlies basement, confirming the conclusions of Waterhouse (1966).

Logs of all three boreholes can be found on the NZGD database.

**Eating Crow**

In 2010, before I came across these logs, I wrote a speculative paper theorising about the relationships between Pakiri Formation, East Coast Bays Formation, Paremoremo Formation and Northland Allochthon at Orewa and Wainui.

As shown by Waterhouse (1966), and as I had observed in surface earthworks during the Millwater development, Northland Allochthon rests upon East Coast Bays Formation at a low angle contact. How though did Northland Allochthon relate to Schofield's (1989) Paremoremo Formation and to

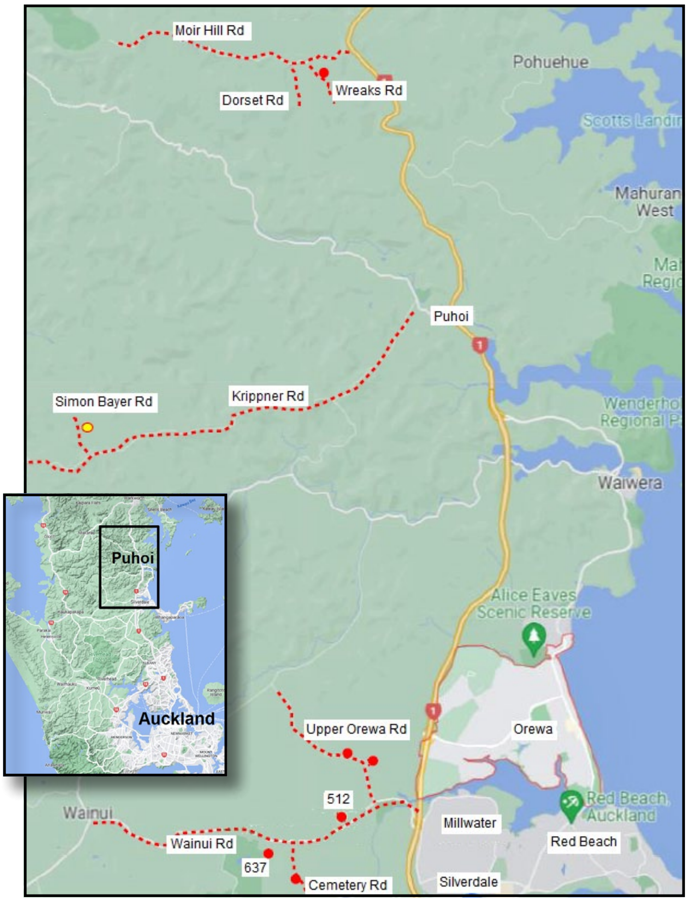


Fig. 1. Location Map, showing places mentioned in text. Red circles are boreholes, yellow circles are outcrop locations.

* *NZGD = New Zealand Geotechnical Database*

the nearby Pakiri Formation? After some quick fieldwork, I gathered my premature thoughts and wrote a brief paper speculating on Waitemata Group stratigraphy, arguing that Paremoremo and Pakiri Formation both overlay Northland Allochthon (Evans 2010). However, my conclusions were flawed, as subsequent discovery was to show.

Speculative efforts to distinguish Paremoremo from East Coast Bays Formation around Grand Drive on grounds of weathering difference, proved afterward in fresh exposure to be wrong. Logs from two boreholes on Upper Orewa Road (NZGD 81737, 82761) affirm that Northland Allochthon up to 30m thick overlies what I had mapped as Paremoremo Formation*, so that (in terms of Waterhouse 1966) the strata here must belong to the underlying East Coast Bays Formation.

As to the relationship between Northland Allochthon and Pakiri Formation, the Puhoi to Warkworth motorway extension completely overturned my speculations, when borehole 210 on Wreaks forestry road (off Moir Hill Road), at the edge of a high plateau, penetrated sheared brown mudstone of the Northland Allochthon *overlying* Pakiri Formation at 14.5m depth (NZTA 2013; NZGD 64633) (Fig. 2). To suppress all doubt, hand augers I undertook outside 70 Moir Hill Road, high on the same plateau, confirmed the same Northland Allochthon lithology at surface.

Evidence continues to appear, confuting my earlier speculation. Drilling and hand augers on Dorset forestry road, atop the next ridge west of Wreaks, encountered sheared brown mudstone of the Northland Allochthon surrounded by, and presumably in-faulted into, Pakiri Formation. A white quarry at the side of Simon Bayer Road, spotted from Krippner Road in a drive-by and clearly visible from aerial imagery (Fig. 3), suggests the presence of Mahurangi Limestone (Northland Allochthon) within or on top of the surrounding Pakiri. This elevated outcrop - which I have not yet visited - could make for an interesting Geoclub field trip.

**Conclusions**
The relationship of Waitemata Group to Northland Allochthon is currently understood to involve a complex dual mechanism of gravitational slumping and thrusting, with southward advance of the Allochthon across Pakiri Formation into East Coast Bays Formation, accompanied and followed by detachment and southward displacement of large sections of Pakiri Formation (Hayward 1982, 1987, Kenny 2013). At field level much remains to be done, assessing prior interpretation on grounds of new evidence, while carefully mapping out the intricacies of the geological puzzle.

Science is a process of ongoing discovery and of progressive enlightenment, if one is willing to eat crow pie. The boldest step in learning is being prepared to admit that you were wrong.

Roger Evans, Geotechnics Ltd

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**Paremoremo Formation, defined by Schofield (1989) as comprising Waitemata strata deposited on and deformed around his "Silverdale Dome" (now recognised as the southern toe of the Allochthon) was synonymised with East Coast Bays Formation by Isaac et al. (1994, p.100) and is mapped today as undifferentiated East Coast Bays Formation (Edbrooke 2001).*

*While Schofield regarded Paremoremo Formation as older than East Coast Bays and Pakiri Formation, current understanding of relationships between Waitemata Group and Northland Allochthon show that all three are approximately contemporaneous (Hayward 1982; Isaac et al. 1994, fig. 5.18). When Schofield proposed a separate Paremoremo Formation, most of his colleagues did not accept it and advised that separation based mainly on Paremoremo's greater structural complexity was insufficient grounds for a separate formation (Mansergh & Schofield 1990).*

Fig. 2: Excerpt from photo accompanying log (from NZGD 64633), showing the transition from sheared Allochthon to competent Pakiri at 14.5m.

Fig. 3. Aerial image from Google maps showing the presumed outcrop of Mahurangi Limestone at Simon Bayer Road.

**Acknowledgements**
Thanks to Bruce Hayward and Jill Kenny for their valuable comments in revision, and to Bruce regarding to the current status of Paremoremo Formation. All remaining errors are attributable entirely to myself.

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81737 Drillwell Exploration Ltd 1994. Client JC Barker, 114 Upper Orewa Road. NZTM 5949249 1747731
82671 Drillwell Exploration Ltd 1990. Client Rodney District Council. Corner of Upper Orewa Road/ Russell Road. NZTM 5949121 1747700
81139 Shane Brown 2000. Client Sunny Heights Nurseries, Wainui Road. NZTM 5948372 1746936
82589 Kiwi Welldrillers NZ Kevin Brown Ltd. 2000 Client Geoff Barnes, Cemetery Road. NZTM 5947181 1746226
82562 Kiwi Welldrillers NZ Kevin Brown Ltd. 2007. Client T. Ruiterman, 637 Wainui Road. NZTM 5947547 1745640
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# EVERY GOOD DIKE MUST COME TO AN END

Bruce W. Hayward

In geology a dike is usually a sheet of solidified lava that cuts across the strata or other kinds of rock. A dike forms when molten magma intrudes along a fracture, forcing the rock on either side apart and hence it usually has smooth, parallel sides. Once magma injection ceases, it cools and solidifies into rock. While cooling, the magma shrinks and columnar cracks usually form perpendicular to the cooling surfaces (sides of the dike). Most dikes are vertical or steeply-sloping and the columnar joints are typically horizontal or nearly so.

The magma would typically be forcefully intruded into the fracture from below or sideways, but how far is it before they finally come to an end and what does that end look like? In the Waitakere Ranges there are many vertical to steeply-dipping andesite and basaltic andesite dikes (of Early Miocene age, 15–18 million years old) intruding through the volcanic conglomerate of the Piha Formation (e.g., Hayward 1977, 1983). Most of these dikes are seen in the cliffs along the west Tasman Sea coastline and they disappear into the cliffs and up into the air with no signs of their nether reaches. A few can be seen in stream bed exposures, but again these are usually brief glimpses with no hint of their extent. Cowan Stream, a tributary of Pararaha Stream, runs along the strike of a 1–2-m-wide dike which can be followed for at least 1 km (Hayward 1983) with no visible end to the sheet in either direction.

In May 2022, a Geoclub trip visited North Piha enroute to Whites Beach. At the north end of Piha Beach, we examined a prominent, steeply-dipping (70° to East), 2 m-thick dike that can be seen intruding the Piha Formation for at least 15 m up into the cliffs (Figs 1–2). It had a well-developed, 1–2-cm-wide zone of black glass along its contact with the country rock (Fig. 3). The aspect that caught our attention most was the southward extension of the dike as seen in two large intertidal rocks that protruded out of the beach sand a few metres from the bottom of the cliff (Fig. 4).

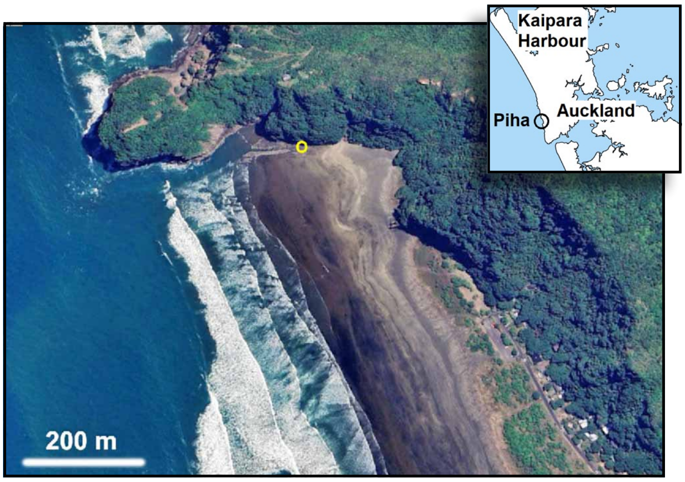


Fig. 1. Vertical photo of North Piha showing location of the studied dike (yellow circle). From Google Earth.

Fig. 2. The prominent steeply-dipping dike seen in the sea cliffs at North Piha with weakly developed, columnar cooling joints perpendicular to the smooth cooling surfaces on either side.

Fig. 3. Black glassy contact of the dike (right) with the Piha Formation conglomerate (left) that it intruded at North Piha. Photo width 1 m.

Fig. 4. The rocks, containing eroded sections of dike that protrude from the beach sand, 5–10 m seaward of the foot of the cliff exposure of the same steeply-sloping, lichen-covered dike (behind).

In the seaward of these two rocks, the dike has expanded to about 4 m wide and instead of having horizontal joints, the columnar jointing splays outwards with vertical columns in the centre and curved sloping columns fanning outwards to either side (Fig. 5). From the orientation of the columns, which are inferred to have formed perpendicular to the cooling edge of the dike, it is possible to envisage the shape of the rounded and inflated end of the dike within 1–2 m of the top of the rock (Fig. 6). If we visualize the shape of the dike prior to the recent sea-erosion, it would seem it had a steeply-sloping edge along its southern margin extending from just above this rock to well above the top of the dike that is visible in the cliff (Fig. 2).

The expanded or inflated width of the edge of this dike, which is evident in the rock stack, is reminiscent (though not exactly the same) of the two dikes that feed pillows (elongate rolls in 3 dimensions) along their upper edges (intruding sandstones), exposed in the cliffs south of Muriwai (Pillow Lava Bay and Bartrum Bay – Hayward 1979) (Fig. 7). Here at North Piha, we have the fortuitous opportunity to see the steeply-sloping, inflated and rounded edge (elongate roll) of one of the many dikes that intrude conglomerate in the Waitakere Ranges. This one example does not necessarily mean that all these dikes have the same endings.

Fig. 5. View looking seaward (south) at the outer of the two rocks that stick out of the beach at North Piha showing the radiating fan of columns in this part of the dike. Photo width 4 m.

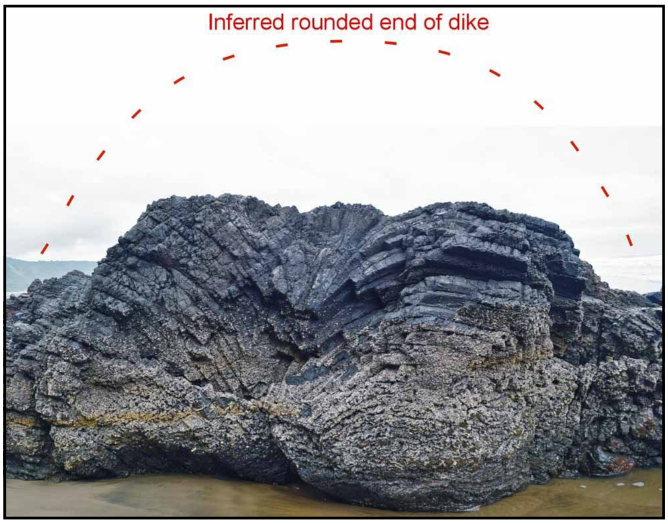


Fig. 6. Same view as figure 5 showing inferred location of the upper end (or edge) of the dike where it would have had an intrusional contact with the volcanic conglomerate.

Fig. 7. The dike feeding a pillow-lava roll at Pillow Lava Bay, south of Muriwai. The expanded rounded upper edge has similarities to the edge of the North Piha dike, except that the latter does not appear to pinch down to a narrow sheet that fed the "pillow", which has columnar joints radiating right around the almost complete roll. Photo width 10 m.


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## VISIT TO WAIARIKI SPRING, CENTRAL AUCKLAND

Michael Coote

At the end of the CBD Building Stones Geoclub field trip in July 2022, some members took the short, steep walk down from Waterloo Quadrant via the paved right-of-way alongside Newman Hall to the car park at the rear of the Auckland Law School. There, in a section of exposed historic yellow brick wall marked with a pair of commemorative bronze plaques, they found the relict aquifer mouth of the once coveted Waiariki Spring. These days, radically dwindled by long-term local water table depletion, the much-diminished spring manifests itself as a bare trickle of groundwater leaking from two plastic pipes originating from sloping land above owned by the Roman Catholic church. In its heyday the spring was so powerful that, due to scarcity of potable water around the Waitemata Harbour, it attracted the substantial prehistoric Maori settlement of Rerenga-ora-iti and subsequently persuaded Governor William Hobson to select the adjacent site of his second colonial capital at what he named Auckland in 1841. In the 1840s there was a severe drought and relief water from the spring was piped down to the now reclaimed Official Bay. In the 1850s the pipe was extended out to the end of the long-vanished Wynyard Pier to enable docking ships to fill their water barrels. Grey & Menzies, a 1902 amalgamation of two drinks companies, John Grey and Son from Auckland and Robert Menzies from Thames, owned a factory situated at 15 Eden Crescent that manufactured popular cordials from the still copious spring water. Today the ghostly residue of the Waiariki Spring glistens from a fragment of the old cordial factory wall and visitors can drink from it (if they dare).

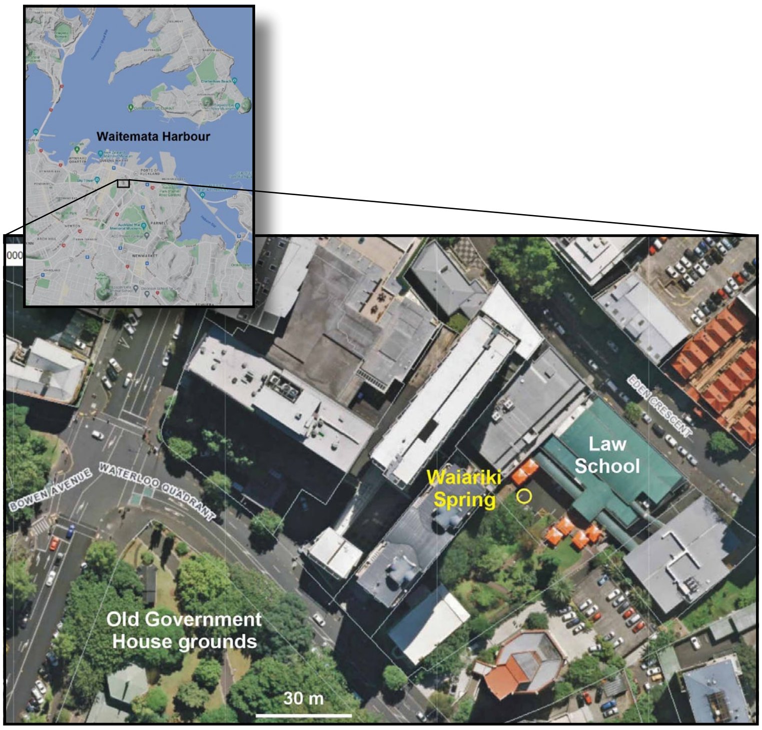


Fig. 1. Location of Waiariki Spring today.

Fig 2. Plaques above where the water issues forth from the remains of Waiariki Spring.

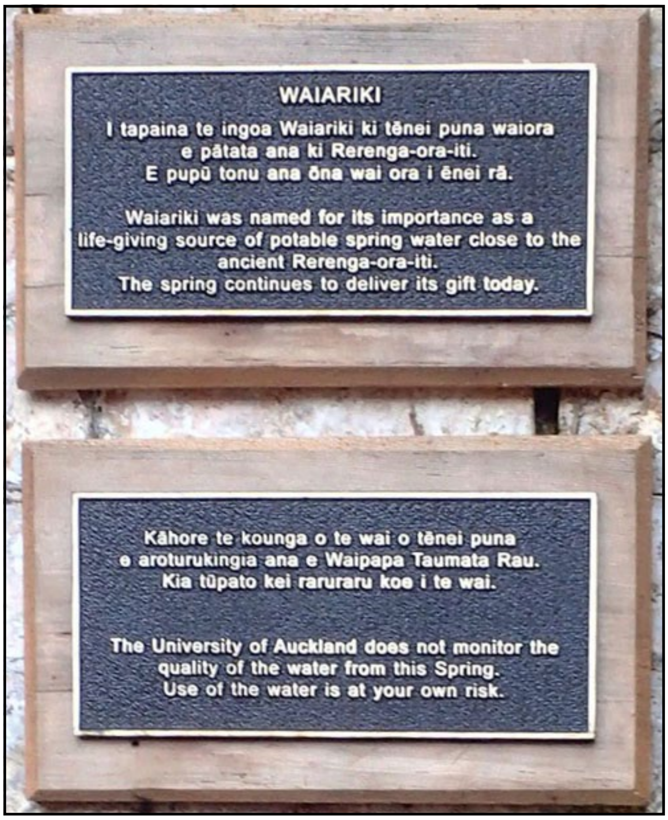


Fig. 3. Wording on the plaques.

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## REMEMBERING KEL ANGLESEY

Bruce W. Hayward, Ian E.M. Smith, Hugh Grenfell, Maureen Burke

For more than two decades Kelvin Malcolm Anglesey (Kel) was a staunch and prominent member of the Auckland Geology Club (formerly called the Auckland Museum Geology Club). He was the Club's first treasurer (1992–1994) and for 15 years he was the reliable purchaser and provider of suppers for our monthly meetings, initially when held at the Museum and later in the Geology Department at the University of Auckland. Kel was a foundation member of the Geology Club in 1992 and a member of the Committee for 24 years (1992–2015). During that period, Kel participated in the majority of our field trips and was leader of three - Volcanoes of Central Auckland (June 1993), Inland Port Waikato (March 1997), and Tarawera, Whakatane and Matata (April 2008 with Garry Carr).

Kel was always present at our monthly meetings, setting out the supper and washing up afterwards. He also gave us three talks - Auckland Volcanoes (May 1993, with Les Kermode), "A different perspective on Auckland Geology" (June 1995) and "How geysers work" (short talk, 2002), and was so enthused by the significance of our first Kidds Beach trip that he wrote an account of it in Geocene no. 2 (2007). He died in 2021 after a long illness that prevented him from participating in club activities after 2015.

Kel was a great friend to everyone in the club. He always had a smile on his face and a twinkle in his eye and would go out of his way to make sure everyone was happy and well-catered for. He was always good to talk to and happy to carpool or offer a seat in his car. He was a truly lovely man who was always genial and calm. He loved his geology and also loved concerts.

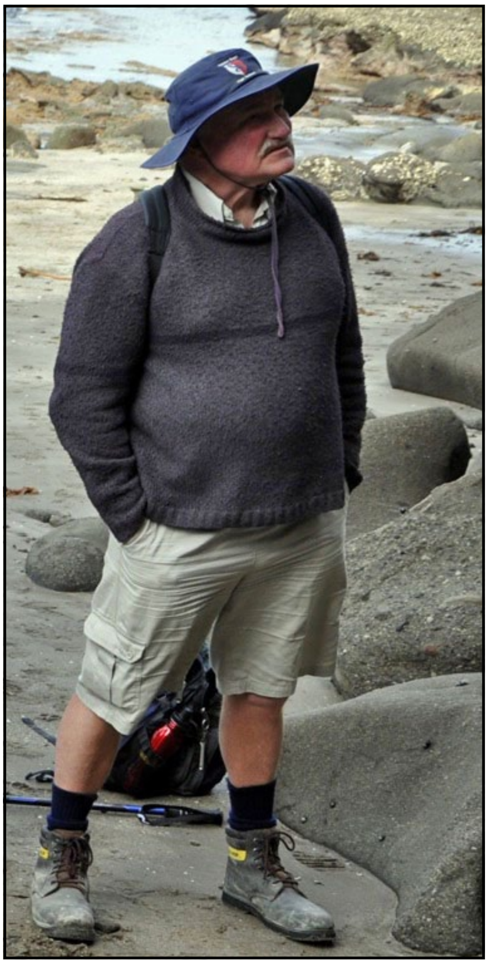
Fig. 1. Kel Anglesey at North Head, 2012.

Kel was educated at Opunaki High School in Taranaki and obtained a BSc in Chemistry from Victoria University. After a short stint teaching at Westlake Boys High School in the early 1970s, Kel shifted to Kelston Boys High School where he remained for 34 years, before retiring in 2010. At Kelston, he was described as "*the wingnut that held the staff together. His warmth and compassion and his sheer joy of life made him a true legend. Whether it was his tireless effort with the PPTA (Awarded NZ Service Award, 2009), his expertise and vast knowledge of Science teaching, or his unequalled talent in organising social events, Kel left a mark wherever he went.*" At Kelson, Kel rose through the ranks and was head of Science when he retired.

Kel "discovered" Auckland Geology Club as it was being formed during the year he spent as a Royal Society teaching fellow in the Geology Department at University of Auckland. His challenge as a teaching fellow was to interact with the ivory tower and produce something useful for the school environment. He rose to the challenge and for the year became a colleague attending lectures entering into discussions and participating in field trips. Kel's lasting legacy was the establishment of an annual 'teachers day' focusing on a geological experience. Kel devised a simple strategy. Bring into the university environment a group of interested teachers (generally ~40), give them a lecture on some recent research development, provide them with a challenge (field based, lab based) give them a slap-up, sit-down lunch, provide time for a discussion and finish the day with free beers in the Geology staff room. Each year the content was different. The formula was a winner and the annual teachers day became a sell out for 13 years. It was always fully subscribed because Kel made sure that the advertising got to the right people. Kel was the master at

Fig. 2. Kel, Cheviot, 2012.

Fig. 3. Kel (centre) at Young Nicks Head, Poverty Bay, 2015.



organising a happy mix of social and learning events that teachers returned for, year after year. For most of that time it was hosted by the Department of Geology, but when that was subsumed into the School of Environment, it survived the additional input of the geographers.

After Kel's fellowship year he maintained his association with the Geology Department, attending talks, field trips and the all-important weekly historical study group meeting on Thursdays at the University staff club. He was a willing participant at times when staffing limitations jeopardized important field courses.

Kel will also be remembered for annual Beethoven's birthday concerts and, for a more select audience, marathon movie sessions involving all (at the time only 6) of the Star Wars movies and all of the Lord of the Rings movies.

As one of the foundation members of Auckland Geology Club, we remember Kel for his enormous contribution to the smooth running of our group for so many years.

Fig. 4. Kel at Castor Bay, 2012.

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