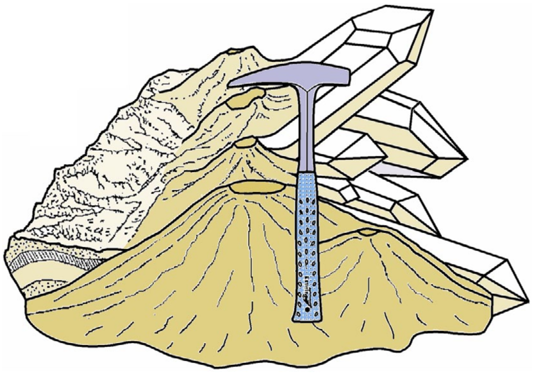

Geocene

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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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MULTI-PHASE EMPLACEMENT AND SIDE-ON CROSSBEDDING IN PYROCLASTIC DIKES IN IGNIMBRITE, NEAR WHITIANGA, COROMANDEL

Bruce W. Hayward

Pyroclastic dikes are periodically present cutting through ignimbrites. One of the best and most accessible locations to see them in New Zealand is in the low ignimbrite sea cliffs on either side of Flaxmill Bay, 1.5 km east of Whitianga (Fig. 1) (access by ferry and foot, or drive 37 km around Whitianga Harbour). A pyroclastic dike is a sheet-like body composed of fragments (clasts) of volcanic rock that has been intruded into a host rock during an explosive eruption.

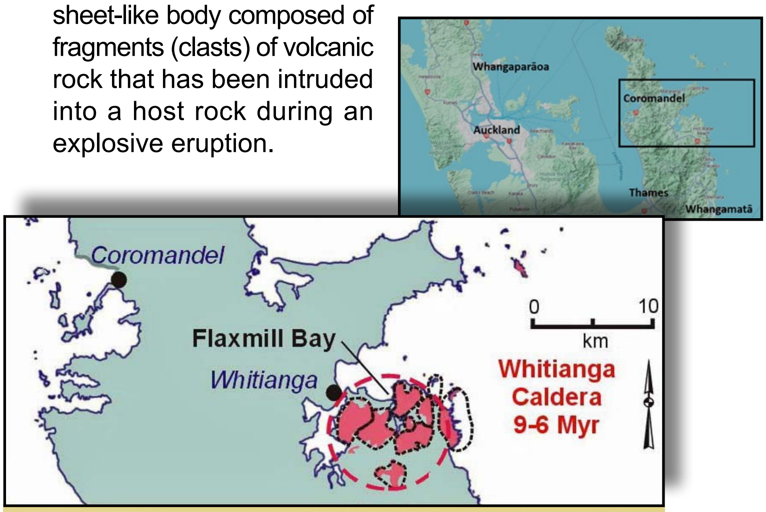

Fig. 1. Flaxmill Bay is located inside the northwest portion of the 9–6 myr-old Whitianga Caldera, near Whitianga on the Coromandel Peninsula.

All dikes intrude the Pumpkin Rock Ignimbrite that erupted ~ 6 myrs ago (Skinner 1995). It has been inferred to have erupted from a vent 12 km away in the southwest corner of the Whitianga Caldera (Skinner 1995, Malengreau *et al.* 2000). Around Flaxmill Bay the unwelded, massive ignimbrite is inferred to have filled the moat between the northeast wall of the caldera and a cluster of rhyolite domes that erupted nearer the caldera centre and were also mantled by the ignimbrite, which was apparently the youngest eruptive product from Whitianga Caldera (Skinner 1995).

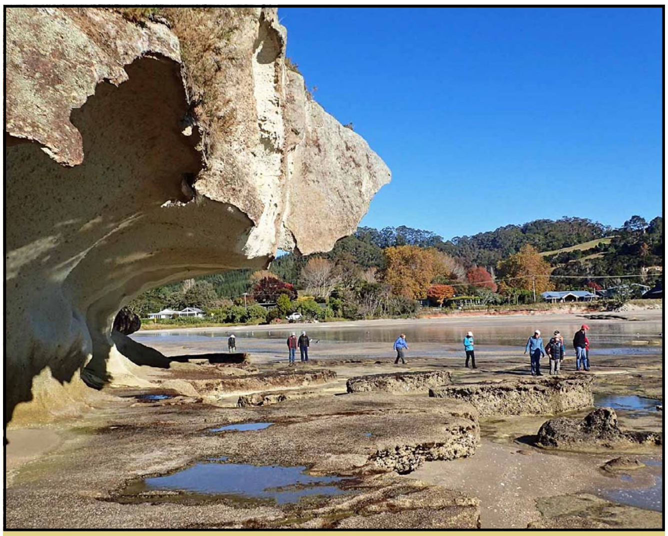

Fig. 2. Dragon's Mouth pyroclastic dike is exposed in the ignimbrite cliff and foreshore rocks beneath this spectacular high-tide notch.

Fig. 3. Dragon's Mouth pyroclastic dike is exposed in both vertical and horizontal cross-section in the cliff and shore platform. Note the two phases of fill material.

"Dragon's Mouth dike"

Description

The most prominent dike occurs in the cliff and shore platform at the east side of Flaxmill Bay where it occurs within the "Dragon's Mouth" high tidal notch, which by itself is also worth visiting (Fig. 2). This dike can be seen in both vertical (in cliff) and horizontal cross-section (shore platform) (Fig. 3). The level of the beach sand varies, sometimes burying the majority of the shore platform exposure of the dike, but on one visit in May 2024 the dike and its contents were beautifully exposed with no barnacles or algal cover because it had recently emerged from under the sand. The vertical dike (sheet) ranges in thickness between 0.6 and 1 m. The walls are mostly straight sided, but sometimes some minor erosion of the host ignimbrite is visible (Fig. 4). The fill of this dike consists of two distinct parts, consistent with multi-phase emplacement. The older parts of the fill are vertically laminated, fine rhyolitic ash that occurs in a layer up to 15 cm thick lining both walls inside the dike (Figs 4 & 5). The second, and younger part of the fill, consists of pumice and rhyolite fine lapilli tuff and lapilli stone with wide-spaced, diffuse horizontal bedding, sometimes slightly oblique and concave upwards, within the dike (Fig. 6).

The most unusual feature of the fill is the occurrence in several places of side-on (vertical) crossbedding within the laminated ash beds, often best developed where there are sudden jogs in the dike wall, sometimes produced

Fig. 4. Close-up view of one side of Dragon's Mouth pyroclastic dike with the host ignimbrite on left separated from the horizontally-stratified lapilli tuff fill (right) by the fine ash laminated parallel to the dike wall. Note slight irregularities (erosion) in the dike wall and also between the two phases of fill. Photo width 40 cm.

Fig. 5. The subvertical pyroclastic dike cutting through the ignimbrite in the cliff beneath the Dragon's Mouth overhang. Note the laminated ash lining the inside of the dike on either side.

Fig. 6. Close up of Dragon's Mouth pyroclastic dike in vertical section showing the laminated ash on the sides with diffuse, subhorizontally-bedded lapilli tuff on the inside. Width of photo: 1.3 m.

by a small fault displacement (Fig. 7). We are all familiar with crossbedding on moderately flat-lying surfaces produced by strong wind or current transport of sediment, but crossbedding produced in a vertical orientation is a first for me and must be quite unusual as I have yet to find other examples on the web. Other features are rapid thinnings in the laminated tuff (Figs 8 & 9), which may have several different origins.

Interpretation

The two kinds of fill were clearly deposited in separate phases. The crossbedding in the laminated ash indicates its deposition was in an open fissure and the horizontal bedding in the more massive coarse second phase also

Fig. 7. Shore platform exposure (horizontal cross-section) through side-on crossbedding of laminated ash that here lines the northern wall of the Dragon's Mouth pyroclastic dike. The upper portion of the photo is host ignimbrite and the lower portion is the last phase fill of the dike. Crossbedding indicates sideways emplacement of the ash into the fissure from left to right (west to east). Width of photo: 40 cm.

Fig. 8. Shore platform exposure of the southern edge of Dragon's Mouth dike with host ignimbrite at the bottom of the photo. Here the laminated tuff appears to have thinned as it passed over the crest of the small fault jog (scarp) in the host ignimbrite wall. Photo width: 50 cm.

Fig. 9. Shore platform exposure of the northern edge of Dragon's Mouth dike with host ignimbrite forming the upper part of the image. A possible explanation for the architecture here of the laminated tuff is that the dike wall was initially straight when 10 cm of laminated tuff was plastered onto it. Then the wall was displaced by a small fault and most of the tuff on the protruding side (right) was eroded off before an additional thin layer of tuff was plastered on top followed later by the lapilli tuff fill (lower). Photo width: ~50 cm

indicates deposition in an open fissure. The laminated ash of the first phase appears to have been sticky and progressively adhered to the two inside walls of the fracture more or less as a mirror image of each other, but not always exactly the same thickness. Where crossbedding occurs at a displacement of the wall, this feature is only seen in one side of the dike in the lee of the displacement. The crossbedding suggests a largely sideways flow of ash through the fissure in a west to east direction during the first phase of emplacement of the fill. The horizontal bedding of the coarse central fill of the dike seems to imply deposition under the influence of gravity with some size sorting that produced the coarser diffuse beds within it.

The questions remaining to be answered are:
1. What was the source of the ash and lapilli fill, and
2. What medium transported it within the open fissure and deposited them?
The ash was clearly injected sideways into and along the fissure under some considerable pressure, whereas the lapilli deposits were transported into the fissure and deposited more gently under the pull of gravity. If the Pumpkin Rock Ignimbrite was indeed from the last eruption from the Whitianga Caldera or anywhere nearby, and there is no evidence today to suggest otherwise, then this pyroclastic dike could not have been emplaced into the fissure by explosive eruptive phases of a later, nearby eruption.

There is another possibility and that is that maybe both the ash and lapilli fill came from Pumpkin Rock Ignimbrite itself. Gas elutriation processes have been suggested to be able to separate out the fines and coarser parts of an ignimbrite (Ross & White 2005, Pacheco-Hoyos *et al*. 2020) after its emplacement as it is cooling. This requires gas from within the ignimbrite being pressurised as the ignimbrite compacts and escaping under pressure towards the surface, or for steam being generated from water bodies or swamps beneath the emplaced ignimbrite and escaping upwards (e.g. Bailey & Carr 1994). As the fill was emplaced in an open fissure that in places was displaced by small faults, it implies that this (?upper) part of the ignimbrite had already cooled somewhat and was solid enough to act in a brittle way, while presumably deeper parts were still super-hot and unconsolidated. Clearly, there was insufficient ash to fill the entire fissure, or perhaps the fissure opened further, subsequent to the ash emplacement.

If gas elutriation winnowed out the fine ash fraction from the ignimbrite, there would eventually still be a coarser fraction left behind. Perhaps some of this was subsequently transported up a different conduit and erupted at the surface and had fallen back into the Dragon's Mouth fissure. Another, more likely, possibility is that after emplacement of most of the winnowed ash from below, the coarser lapilli fraction was transported up the same fissure, but the clasts were insufficiently sticky to adhere to the ash lining the inner dike walls. At some point during this transport of the lapilli, there could have been a sudden drop in gas pressure (a new escape vent opened up?) and the lapilli that were in suspension in the fissure then subsided/compacted back within the fissure with diffuse horizontal bedding/stratification.

West Flaxmill Bay dikes

Description
There are at least ten, often complex, pyroclastic dikes exposed in the low ignimbrite cliffs and foreshore west of Flaxmill Bay (only accessible around low tide, Fig. 10). Most are filled with laminated ash and some also with fine lapilli tuff. There are examples of vertical dikes, inclined dikes, dikes that wedge out, crosscutting dikes showing

Fig. 10. Dragon's Mouth dike is located at the foot of the ignimbrite cliffs just right of the centre of the photo across the bay. Flaxmill Bay is above the person's head and the cliffs west of Flaxmill Bay, with pyroclastic dikes, are just out of view on the right.

an order of multiphase emplacement (Fig. 11), branching dikes, highly dissected and irregular margins especially within layers in the dikes (Fig. 12), multiple parallel and small irregular branches (Fig. 13) or even circular pipes enclosing vertical cylinders of host rock (Fig. 14).

Interpretation

Dragon's Mouth dike is simple compared with the complexity of these dikes. Clearly there have been more than two phases of emplacement of vertically laminated, massive and subhorizontally stratified tuff and fine pumice lapilli tuff. The sharp contacts between different phases suggest the various lithologies were already cohesive and not loose when the next phase intruded, but the highly irregular erosional boundaries (Fig. 12) suggest the sheets were often quite soft and easy to erode, possibly by liquefaction. The precise three-dimensional architecture of the circular intrusions (in cross-section, Fig. 14) into the host ignimbrite is difficult to envisage.

I infer that these dikes were also a result of gas/steam elutriation within the hot deeper parts of the compacting ignimbrite, possibly having flowed into a waterbody or swamp in the caldera moat. The multiphase upwards and sideways intrusion of tuff and lapilli tuff by pressurised wet gas along fractures through the already somewhat solidified upper parts of the ignimbrite sheet may have been triggered by a number of earthquake-shaking events or merely by phreatic eruptions from beneath impermeable sealing layers in the ignimbrite (e.g. Bailey & Carr 1994).

Fig. 11. A low-angle pyroclastic dike of massive lapilli tuff that wedges out in the upper left, cutting across an earlier subvertical dike of laminated ash and subhorizontally stratified lapilli tuff in the western cliffs of Flaxmill Bay. Width of photo ~2.5 m

Fig. 12. Shore platform view (horizontal cross-section) of the fill in one of the west Flaxmill Bay pyroclastic dikes showing multiphase emplacement of sheets of massive and laminated lapilli tuff and laminated fine tuff. Note the highly irregular erosional contact across the middle of the photo, which resembles liquefaction features, although this view is in a horizontal cross-section. The host ignimbrite wall is at the top of the photo (north). Width of photo: 40 cm.

Fig. 13. Shore platform exposure of multiple parallel and cross-cutting irregular pyroclastic dikes through ignimbrite (darker coloured sections), west Flaxmill Bay. Width of photo: 50 cm.

Fig. 14. Shore platform exposure (horizontal cross-section) through a west Flaxmill Bay pyroclastic dike showing several phases of emplacement and both sheet and strange pipe-like geometries. The host ignimbrite is the darker lithology across the top and through the middle. Light grey is modern beach sand.
Width of photo: ~40 cm.

Acknowledgments

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AUCKLAND WAR MEMORIAL MUSEUM COTHAM MARBLE SPECIMENS

Hugh Grenfell

Naturally the Auckland War Memorial Museum (AWWM) Geology Collection has some very interesting specimens - some of which I have talked about to Auckland Geology Club (GeoClub) over the years - and often they are not restricted to just a geological story. The Museum has four rather nice and unique specimens of Cotham Marble (often referred to for obvious reasons as “Landscape Marble” - see Figs 1 & 2). They are accession numbers GE1969 (2 pieces), GE4027 and GE16079, and are not in fact marble (as is often the case) but are a limestone.

Cotham is an area in Bristol, southwest England, and the Rhaetian (latest Triassic) Cotham Marble forms part of the Cotham Member of the Lilstock Formation of the Penarth Group (Hamilton 1961, Gallois 2009, Wikipedia 2025a). The limestone is widely, but patchily, developed as lenses within outcrop of the Cotham Member stretching from Glamorgan in South Wales, through the Bristol area, to the coast of southeast Devon. The formation of the unusual cauliform structures in the limestone have been variously interpreted, but the current consensus is that they formed as microalgal stromatolites (Wikipedia 2025b). The structures are somewhat analogous to those to be seen at Shark Bay or at Lake Thetis, Western Australia, where much larger stromatolites can be seen growing today as living fossils (Wikipedia 2025b). The limestone was first published on by Edward Owen in 1754 (Owen 1754).

Before discussing the specimens, I need to briefly mention something about two 19thC (and early 20thC) British mineral dealers - Francis Henry Butler (1849–1935), the source of GE4027, and James Reynolds Gregory (1832–1899), the source of GE16079. In the mid to late 19thC, the burgeoning Victorian middle class had a great deal of

Fig. 1. Both sides of GE4027 with a pen and ink drawing on one side and F.H. Butler label on the other.

interest in collecting stuff, including fossils and minerals. James R. Gregory (and later iterations of his company) is the earlier of the two businesses (from 1858) and was based in London from various addresses. Usefully, if his original labels (which will have a particular address) survive with the specimens, they can be used to date the specimen (e.g. see below for GE16079). Gregory soon gained a reputation as one of the best dealers in the city and supplied many of the major collectors and museums of his day, as well as scientists needing samples for research purposes, e.g. James Hector - Museum of New Zealand / Te Papa (MONZ) collection.

Francis Butler had the impetus to begin his business in 1885 when he inherited a very large mineral collection from his friend and mineral dealer Richard Talling (1820–1883), who was born and lived in Lostwithiel, a beautiful part of Cornwall (see link to Lostwithiel below in Fig.4). Butler operated his London business from 1885–1927. In addition to his mineralogical business, Butler had a medical degree and was a "registered medical practitioner" (Microscopist.net 2025). When Butler closed his business in 1927, it was taken over by the "James R. Gregory Company", which was run by Albert Gregory after his father's death in 1899. Although I have spoken to GeoClub about the Victorian James Tennant and James R. Gregory Collections held by the AWWM, the MONZ and the Thames School of Mines (TSM), I should really write a more detailed account about them for the record - but not for this article.

The specimens

GE1969 is the "oldest" numbered specimen (i.e. first catalogued) in the three-volume paper Geology Collection catalogues. There are two pieces, but unfortunately I don't have any other information (or images).

GE4027 is the most interesting specimen and was donated in 1930 by Anglican Bishop Ernest Augustus Anderson (1859–1945) with other geological specimens (Auckland Museum Institute Annual Report 1930–31, p.28). Anderson was born in Milton Damerel, Devonshire, and spent most of his life in Australia as a clergyman before coming to New Zealand in 1925. The cut piece of limestone has had the "landscape" enhanced by a charming pen and ink drawing of a rural scene (Fig.1). A team of ?horses is ploughing the field and a man is hand sowing seed in the foreground. Also drawn is fence line on the left, birds (rooks or crows?) and bushes on the right. Given the method of ploughing and sowing illustrated, the drawing is presumably late 19thC. The reverse has an original label from "Butler, Brompton Road, London". Labels (and specimens) with this address (but no street number) are thought to be post-1890.

Fig. 2. GE16079 with original James R. Gregory label #450 c.1873.

A somewhat complicated digression is necessary for GE16079 (Fig.2). This specimen is part of what is now called the James R. Gregory Collection within the Geology Collections (#450). It was not catalogued and had no GE number or data when I came across it (hence the late five-digit GE catalogue number). The original 501 Gregory specimens were purchased by the first Auckland Museum curator/director Thomas Cheeseman from Gregory about 1873. The labels give Gregory's address at the time as 15 Russell Street, Covent Garden, London, and he was running his business from there between 1866 and 1874 (The Mineralogical Record 2025).

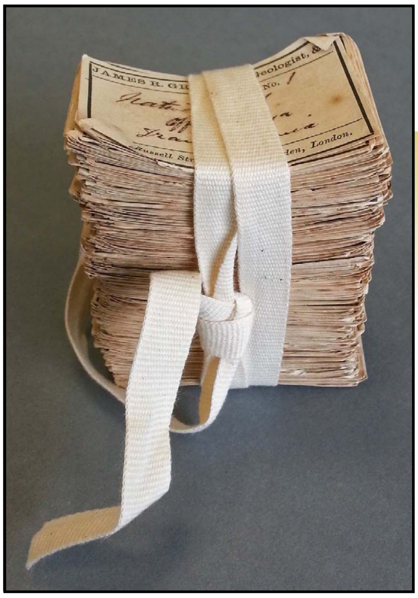

Fig. 3. Bundle of 495 orphaned James R. Gregory specimen labels from his then Russell Street, London address (1866-1874).

The "short story" is that while cataloguing the AWWM Geology Collection, I came across a bundle of 495 old James R. Gregory paper labels - six were missing from the sequence (Fig.3).

James R. Gregory was not mentioned anywhere in the databases or catalogues, and the labels had clearly been orphaned from any specimens for decades. It is amazing they survived. This all remained a mystery for some time until I came across old Henry Ward display labels used by Cheeseman (see Gill *et al*. 2019:32–33) from the first purpose built Auckland Museum site in Princes Street (1876–1929). Some of these small, yellow, cardboard labels were with specimens, some not. Some had on the reverse a penciled number that often matched a small paper label glued to the specimen itself (see Fig.4, GE172, for example). If it survives, the small glued paper number is found on all Gregory specimens I have catalogued (i.e. AWMM, MONZ & TSM).

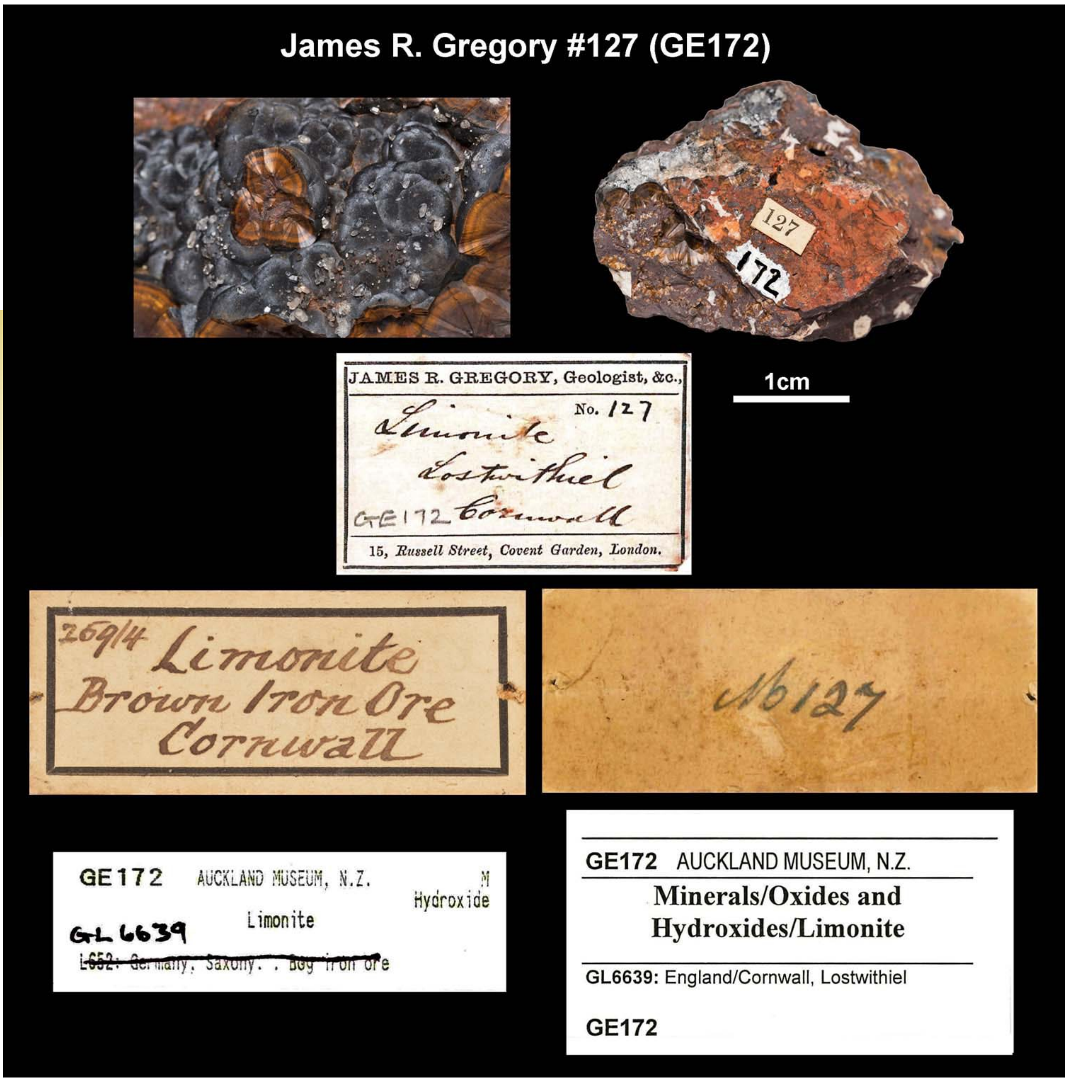

Fig. 4. From the top - close up of GE172 showing the radiating, acicular and mammiliform nature of the limonite, reverse of GE172 with original Gregory paper number (#127); original Gregory label #127; Princes Street Museum Ward display label and the reverse with the Gregory number; 1990's Tyvek label with incorrect data; final label with corrected data.

When all, or some, of the original numbers were present, and they matched the mineralogy and distinctive size (usually small) of Gregory specimens, an original Gregory label and number could be assigned to the specimen's data. The mineralogy where possible was also compared online with images of other mineral specimens (often of the same vintage) from the same locality for a match. Many Gregory specimens come from the "type" locality (where it was first described from) for a given mineral. For example, GE820 (Gregory #471) Aragonite, originally named after the type locality Gallo River, Molina de Aragón, Guadalajara, Spain (Mindat 2025). Since many of these localites (often mines) no longer exist, it makes these specimens unique and more important.

GE172 is a very good example of a Gregory specimen and many other early (i.e. pre-1929) specimens that I discovered had muddled labels and data (see below). In Volume I of the Geology paper catalogues, which were started after the 1929 move from Princes Street to the "new" Domain site (Stage 1 of the current AWMM), GE172 was said to be "Bog iron ore" and to come from Saxony, Germany. But the small, glued paper Gregory number on the radiating acicular and mammiliform specimen of limonite, and the same numbers written on the reverse of the later Ward display label, clearly relate it to the original Gregory label #127 for "Mineral: Limonite and Location: Lostwithiel, Cornwall". Note that if the later Ward label had been all we had from the 19thC, we would not know the original location – Lostwithiel. This reinforces why primary labels are so important.

Ironically, although we have the original Gregory label for the bog iron ore specimen from Saxony (i.e. James R. Gregory #131), the specimen itself is missing. I believe that when the Collections were moved from the Princes Street site about 1928–29, they were very poorly packaged, and dozens of specimens (and not just James R. Gregory material) got jumbled in their trays in transit, causing specimens and their data (labels) to be muddled. This remained the case for 85 years until I started working on the Geology Collections in 2013. About 304 of the original 501 James R. Gregory specimens have now been recovered / accounted for, reunited with their original labels (in reality a copy thereof since I decided the the original bundle should be retained for posterity with its own catalogue number), and catalogued by the process outlined above.

So, there is a little of the mysterious background of just two specimens in the AWMM Geology Collection. Imagine how many more tales there are to tell in the thousands of other specimens; and that's not even including the Palaeontolgy Collection! I also hope the article may introduce you to some interesting and extremely useful mineralogical websites.

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SILICIFIED WOOD IN THE NORTHLAND ALLOCHTHON

Phil Moore, Shirley Gates

Petrified (silicified) wood has been found in various parts of Northland, particularly in the Whangaroa area associated with the Early Miocene (22–19 Ma) Wairakau Volcanics, and on Hukatere Peninsula in the northern Kaipara Harbour in similar-aged (22–16 Ma) volcanic rocks. In these places the fossil wood was probably silicified by silica-rich groundwater, either in a subaerial or marginal marine environment, as at Tinopai. But what is not widely appreciated is that some silicified wood also occurs in areas of tectonically-displaced Late Cretaceous to Oligocene marine sedimentary rocks of the Northland Allochthon, not associated with any sub-aerial volcanics. So where did this wood come from, and how and when did it become incorporated into the Allochthon?

Fig. 1. Locations of silicified wood in the Northland Allochthon, and direction of Allochthon emplacement. See Table 1 for key to locations.

Occurrences of wood

So far we have identified 11 localities where silicified wood is, or appears to be, associated with sedimentary rocks of the Northland Allochthon (Fig. 1, Table 1). Any samples of silicified wood that we considered more likely to be derived from the Miocene Wairakau Volcanics or Hukatere volcanics were excluded, as these formations post-date the Allochthon.

There are a few localities where some information has been obtained on the context of the wood. The single piece from South Hokianga, for example, was collected from a stream bank within an area mapped as Punakitere Sandstone (Isaac 1996), suggesting it may have come from that unit (Fig. 2). At Curnow Rd, and also Tangiteriora, the wood is associated with a variety of semi-precious siliceous rocks (jasper-agate, chalcedony, carnelian) in an area mapped as undifferentiated Mangakahia Complex (Edbrooke & Brook 2009). It seems unlikely such siliceous rocks would form within ordinary sandstone and mudstone beds, and

Table 1. Location and inferred host rock of silicified wood occurrences in Northland (based on 1:250,000 geological maps). See Fig.1 for localities. All wood specimens are held in private collections.

No.	Locality	Host rock
1	Karuhiruhi, Sth Hokianga	Punakitere Sandstone
2	Tangiteroria	Mangakahia Complex
3	Curnow Rd	Mangakahia Complex (mélange)
4	Matakohe	Mahurangi Lst or mélange
5	Whakapirau	Mahurangi Lst or mélange
6	Batley	Mahurangi Lst or mélange
7	Port Albert	Mangakahia or Motatau Complex
8	Onerahi	Mélange
9	Pataua North	Mélange?
10	Kauri Mountain	Mélange?
11	Coopers Beach	Mangakahia Complex?

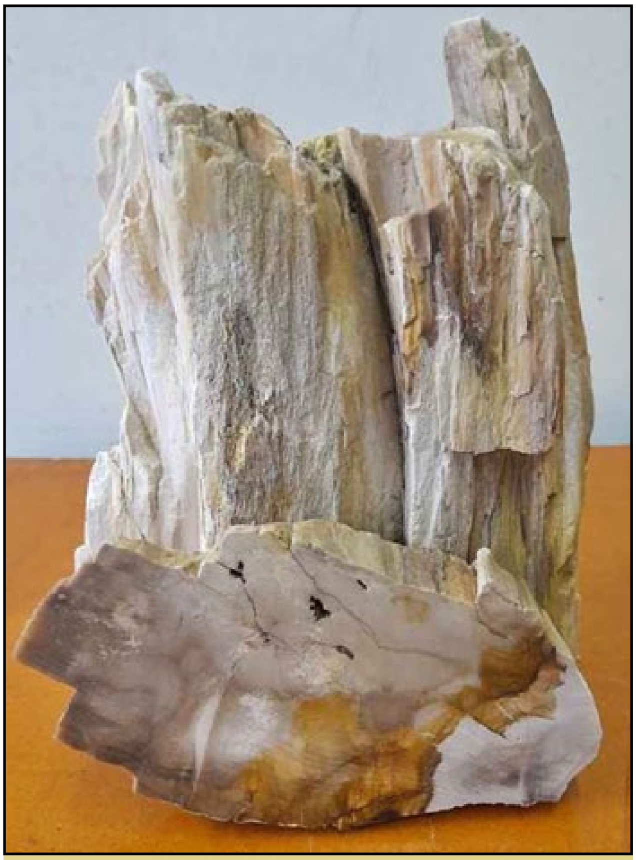

Fig. 2. Cut piece of silicified wood from Karuhiruhi, South Hokianga. The upstanding part is 18 cm high. Photo: Shirley Gates.

instead they may be derived from narrow, unmapped mélange zones separating sheets of allochthonous strata. Notably, some of the pieces of silicified wood at Curnow Rd are rounded and highly polished, which could have been caused by being rolled around within a slow-moving mélange (Fig. 3).

Elsewhere, there is less certainty about the context of the wood. For example, at those localities around the northeastern part of Kaipara Harbour, between Matakohe and Port Albert, the wood could be derived from the Mahurangi Limestone (of Motatau Complex), the Mangakahia Complex, or from mélanges. The two samples from the open coast north of Whangarei Heads (Pataua North and Kauri Mountain Beach) came from an area of Waipapa Terrane greywacke, which is not known to contain any wood. However, there is a sizeable area of mélange mapped further inland (Edbrooke & Brook 2009), and it is inferred that the samples originated from there.

Origin of the wood

The obvious explanation, that the silicified wood was simply eroded out of one or more of the Late Cretaceous to Oligocene sedimentary formations that make up the greater part of the Allochthon (i.e. the Mangakahia and Motatau complexes), might not necessarily be the case. The main issue is that none of the wood recorded here has actually been found in situ, and although some of the formations do contain minor carbonaceous material (Isaac *et al*. 1994), we have found no mention, at least in the general geological literature (Edbrooke & Brook 2009, Hayward 2017, Isaac 1996, Isaac *et al*. 1994), of the presence of degraded logs or silicified wood in any of the sedimentary rocks. Most notably, wood does not seem to have been recorded anywhere within the two main chert-bearing units - the Hukerenui Mudstone and Whangai Formation.

An alternative is that water-saturated logs (Wikipedia 2025: "deep-sea wood") residing on the sea floor were somehow incorporated into the Allochthon during its emplacement between 25 and 20 Ma (Hayward 2017).

Fig. 3. Pieces of naturally polished wood from Curnow Rd. Photo: Tim Goodwin.

This would mean the logs were no older than Late Oligocene. Here it is important to note that during the early stages of emplacement of the Allochthon from the northeast, about 23 Ma, much of the Northland peninsula had sunk to bathyal depths of >1000 m and land had retreated to the Auckland area (Hayward 2017 fig. 4.64, Isaac *et al*. 1994 fig. 7.8). It is conceivable that any logs sinking to the sea floor might have been picked up and quickly buried by advancing thrust sheets of sedimentary strata, then incorporated into mélanges, but whether they could survive intact in such a dynamic environment prior to silicification of the wood is another question. There is one factor, though, that might support such a possibility. This is that some of the wood has been found in association with considerable quantities of jasper-agate (brecciated chert) at certain localities, for example at Curnow Rd. This highly siliceous rock appears to occur within mélanges in some places, which would provide a possible explanation for the brecciated appearance of the jasper/chert if it was fractured during movement of the Allochthon. Pieces of this rock type were clearly re-cemented by chalcedony (in the form of agate) quite rapidly, which would suggest there was a readily available source of silica beneath the sea floor at the time the fracturing occurred.

Additionally, it is worth noting that some of the better-preserved silicified wood has retained good growth rings and not been unduly distorted (Fig. 4), which would seem to indicate that it had been at least partly silicified prior to being deeply buried or caught up in the sliding of sedimentary strata and formation of mélanges. Also, there

Fig. 4. Silicified wood from Tangiteriora showing well-preserved growth rings. Note the lack of distortion of the wood. Photo: Jackie Fowke.

does not appear to have been any significant deterioration of the wood (by bacteria, wood-boring bivalves, etc.), implying it may not have remained exposed on the sea floor for long. However, the presence of "worm holes" in one of the pieces from Onerahi perhaps suggests that some wood had drifted in the ocean for a period of time before being silicified.

None of this explains where the wood originated from. But paleogeographic reconstructions suggest that, prior to emplacement of the Northland Allochthon, from Late Cretaceous to Late Eocene time (100–35 Ma) there was a persistent landmass in the Northland-Auckland area (Hayward 2017, Isaac *et al*. 1994 figs 7.1–7.6), and that the sediments eroded from this landmass were probably deposited off its northeastern coast and transported into the deep ocean basin to the north to form the sedimentary rocks that were subsequently displaced. Coal seams (Kamo Coal Measures) were formed on eastern parts of this landmass in the Late Eocene (Edbrooke & Brook 2009), so there were obviously areas of forest, which would have been a source of driftwood.

Unfortunately, we are left with a lot more questions, none of which are likely to be satisfactorily answered without more detailed information on the geological context and nature of the silicified wood. For example, is the wood associated with only one of the sedimentary formations in the Allochthon, or several different ones? Or is it only found in mélanges, which consist of a sheared matrix with blocks of all the rock types present in the Allochthon? Food for thought.

Acknowledgements

Our thanks to those members of the Whangarei Rock and Gemstone Club who generously provided information on occurrences of silicified wood, and particularly Jackie Fowke and Tim Goodwin for supplying photos of their specimens. Thanks also to Bruce Hayward for comments on the paper, and Louise Cotterall for improving the map.

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ANTARCTIC ADVENTURES: EXPLORING ANCIENT HOT ROCKS IN COLD CLIMES

Katharine Gilchrist

The McMurdo Dry Valleys, South Victoria Land, are located along the Transantarctic Mountains, which split west and east Antarctica. Located approximately 150 km from Scott Base, this region is an extreme deglaciated desert, being, as its name suggests, one of the driest places on Earth. Temperatures are regularly found in the -15°C to -30°C range with wind speeds of 300 km/hr not uncommon.

This region also hosts fantastic exposures of the Ferrar large igneous province, emplaced 183 million years ago. Large igneous provinces (LIP) are massive areas of predominantly mafic magmatism, often with huge extrusive and intrusive magma components with volumes greater than 10^5 km^3 (Ernst 2014). Much of the intrusive magma volume within the Ferrar LIP is found in the form of sills, horizontal magma bodies up to 200 m thick that can be tracked laterally for many kilometres (Elliot & Fleming 2004). These sills intrude the Beacon Supergroup sedimentary sequence, which was deposited from the Devonian to the Triassic (400 to 250 ma) (Cox *et al*. 2012). The McMurdo Dry Valleys provide an ideal location for a field investigation into magma transport and heat flux within LIP sill complexes; an area of study rarely explored despite the potential for improving our understanding of LIP emplacement processes.

One of the key objectives for this field excursion was to collect a complete sample set at 30 m intervals through 3000 m of stratigraphy within the Ferrar LIP sill complex, with the aim to assess the magnitude of crustal heating that occurred during emplacement. To achieve this, we were to conduct fieldwork at five sites: Upper Wright Valley, Mt Fleming, Lake Vanda, Terra Cotta Mountain, and Beacon Heights (Fig. 1).

Researchers from the University of the Auckland, James Muirhead, Katharine Gilchrist and Zoe Armstrong, alongside Sandra Rodrigues, University of Queensland, set out to investigate the area, accompanied by our fabulous mountain guide, Bia Boucinhas (Fig. 2).

Our flight was due to take off on the 1st December 2024. The Antarctic had other ideas, sending day after day of uncertain weather that delayed all travel. After twelve days of waiting, one boomerang flight and one false call, the team finally received the much-anticipated text at

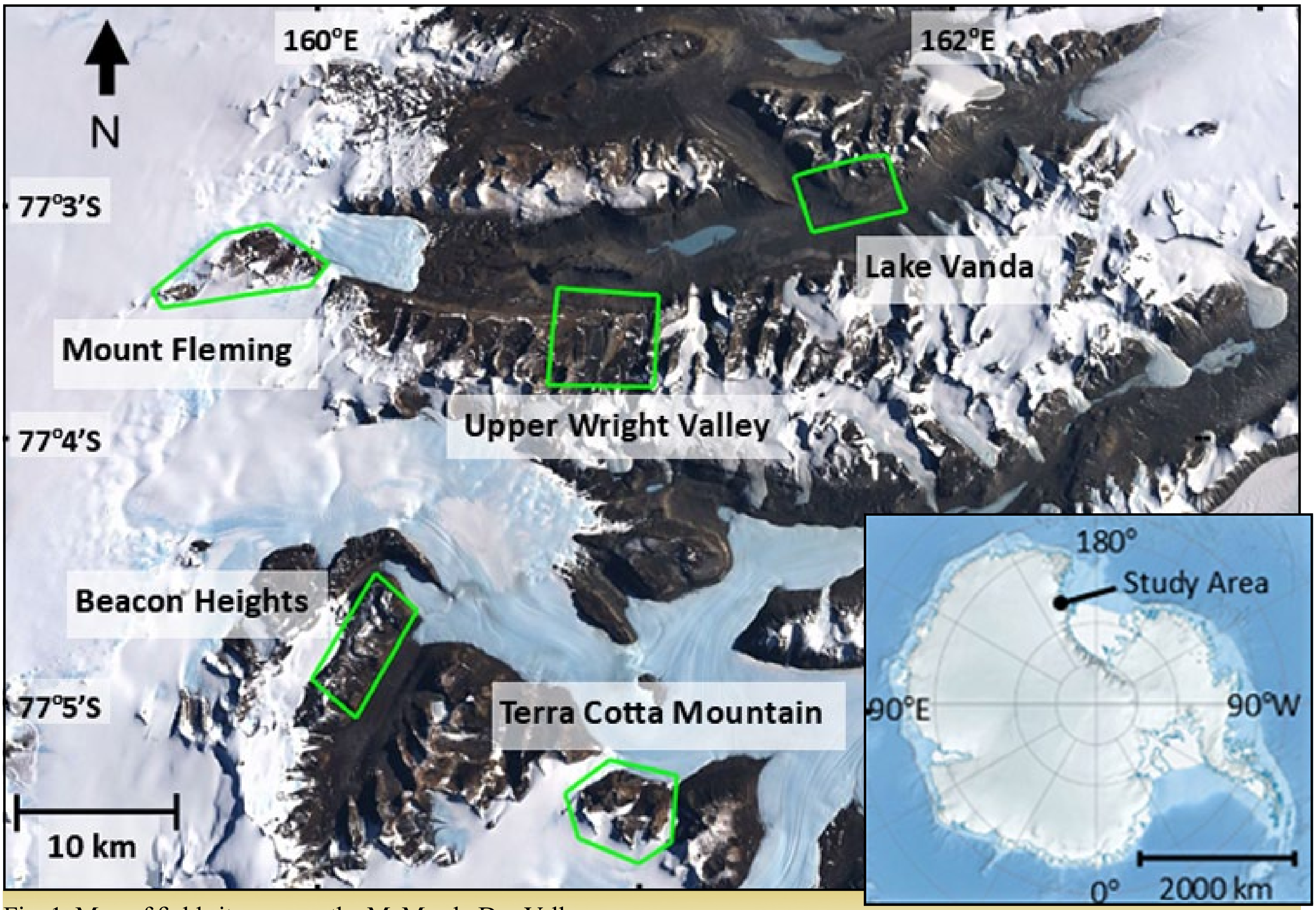

Fig. 1. Map of field sites across the McMurdo Dry Valleys.

Fig. 2. The Antarctic K012 Team outside Scott Base, Ross Island. From left: Bia Boucinhas, Katharine Gilchrist, Sandra Rodrigues, James Muirhead and Zoe Armstrong.

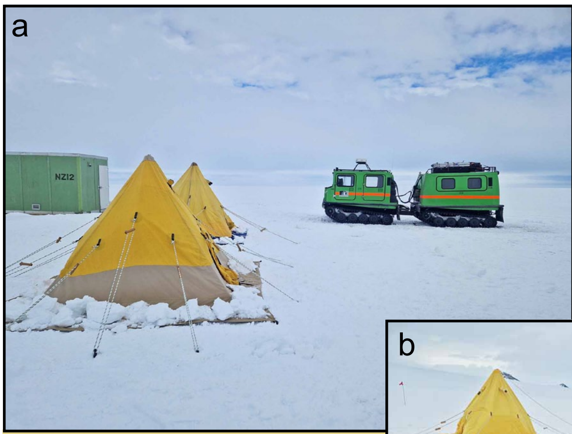

Fig. 4. Antarctic Field Training (AFT). (a) Haglund used for transport across the ice sheet to the campsite.
(b) Trainees enjoying a cup of tea and dinner in the freshly cut snow pit.

5.30am on the 12th December 2024: '*It's a GO today see you at 0800*'. Cue a quick breakfast and dash to Christchurch Airport!

Once again boarding the C-130J-30 Hercules aircraft, not knowing whether this was the day we would make the landing, we set off for Antarctica, with passengers bound for Scott Base and McMurdo (Fig. 3).

On approach to the continent, the broken ice sheet spread across the ocean was a remarkable sight. After landing and a short drive from the airfield in a well-used Haglund, we arrived at Scott Base and were greeted by staff wearing t-shirts and shorts. Quite the contrast to us in all our extreme weather gear.

Due to the delay, we had only three days to complete the relevant training and prep gear before shipping off to our first site. Antarctic Field Training (AFT) was our first taste of camping in Antarctica (Fig. 4). Our set up was surprisingly comfortable, with multiple sleeping mats and three 4-season sleeping bags each. By the two-week mark, we would be fully acclimatised, using just one sleeping bag and feeling uncomfortably toasty despite the -15°C temperatures outside the tent.

Fig. 3. Lining up to board the C-130J-30 Hercules at Christchurch Airport.

On 17th December, we embarked on our first helicopter flight across the continent. At an average temperature of -10°C, the Upper Wright Valley was a summer vacation. Our camp was quite luxurious, with individual sleeping tents, a toilet tent and a Polar Haven communal tent, fitted with a stove to stay warm during the evenings (Fig. 5). A good kitchen was set up with a cooking stove, prep area and makeshift spice rack laid out for easy access. We were primarily a vegan camp, with dinners consisting of a range of curries, chillis and pasta dishes on rotation. An array of hot sauces, provided by James, were a welcome addition.

Fig. 5. Returning to the Upper Wright Valley camp after our first reconnaissance of potential sample sites.

Fig. 6. (a) Mt Utgard Peak sampling location, with a fantastic exposure of the Asgard sill at the summit. Some of the team would find themselves summiting that very peak only a few days later.
(b) Katie and Zoe showing off their microspike skills on snowy slopes. (Photo: Bia Boucinhas).

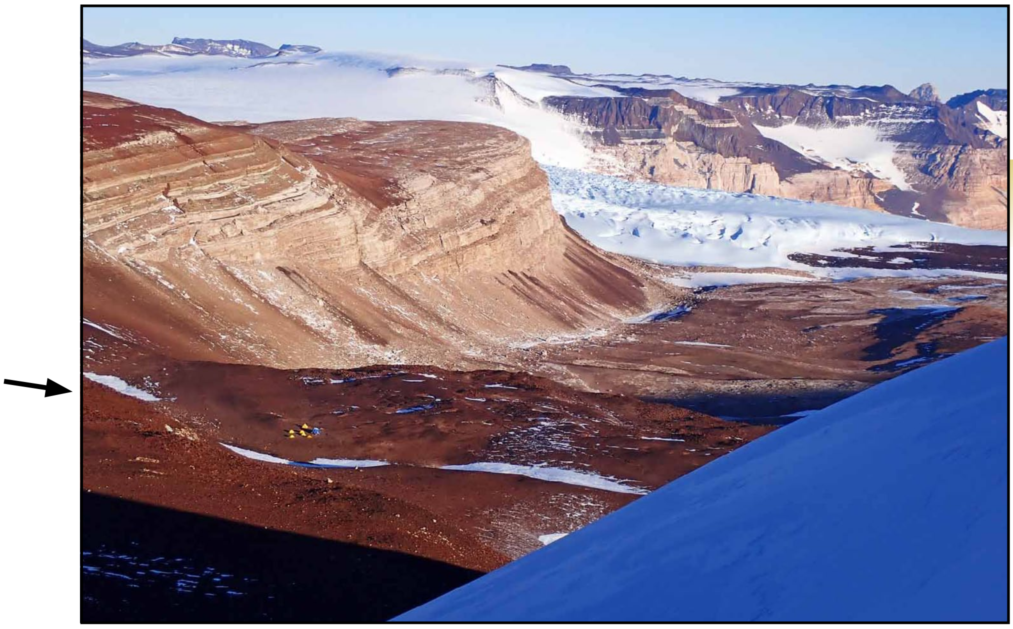

Fig. 7. Mt Fleming camp (arrow) as seen from the top of Mt Fleming sill. Across the valley the Asgard sill (dark brown colour) intrudes the Beacon Supergroup sedimentary sequence and appears to 'step' through the stratigraphy.

To collect samples efficiently through the vertical profile, we aimed for areas of steep but accessible terrain. Reaching sill outcrops was often challenging and involved being tied into one end of a rope while scrambling up/down some steep, rocky slopes (Fig. 6a). There were many occasions throughout the season where we returned to camp with 20 kg of rocks in our packs, not including all the additional survival gear carried out each morning. Upper Wright Valley also functioned as a practice ground for snow skills, including working with microspikes, crampons and ice axes (Fig. 6b).

Fig. 8. Returning to camp as the snow begins to set in, a precursor to the incoming blizzard that will keep us at camp for the next few days. (Photo: Bia Boucinhas).

Mt Fleming was our first real taste of what the Dry Valleys could offer (Fig. 7). Here, at an altitude of 1800 m, the average daily temperatures sat at -21°C with wind chill. The phrases, '*be bold, start cold*' and, '*there's no such thing as bad weather, only inadequate clothing*' became group mantras. During a blizzard, where we were forced to remain at camp, the coldest temperature reading was -37°C, with winds of around 100 km/hr (Fig. 8).

From here, we also set out on one of the longest days of the season, hiking three hours from camp to Horseshoe Mountain, which represented the highest part of the stratigraphy. After a helicopter flyby trip to check accessible routes, we left camp at around midday, traversing glaciers and mountains, arriving back at camp at 2:30 am. We slept in late that day.

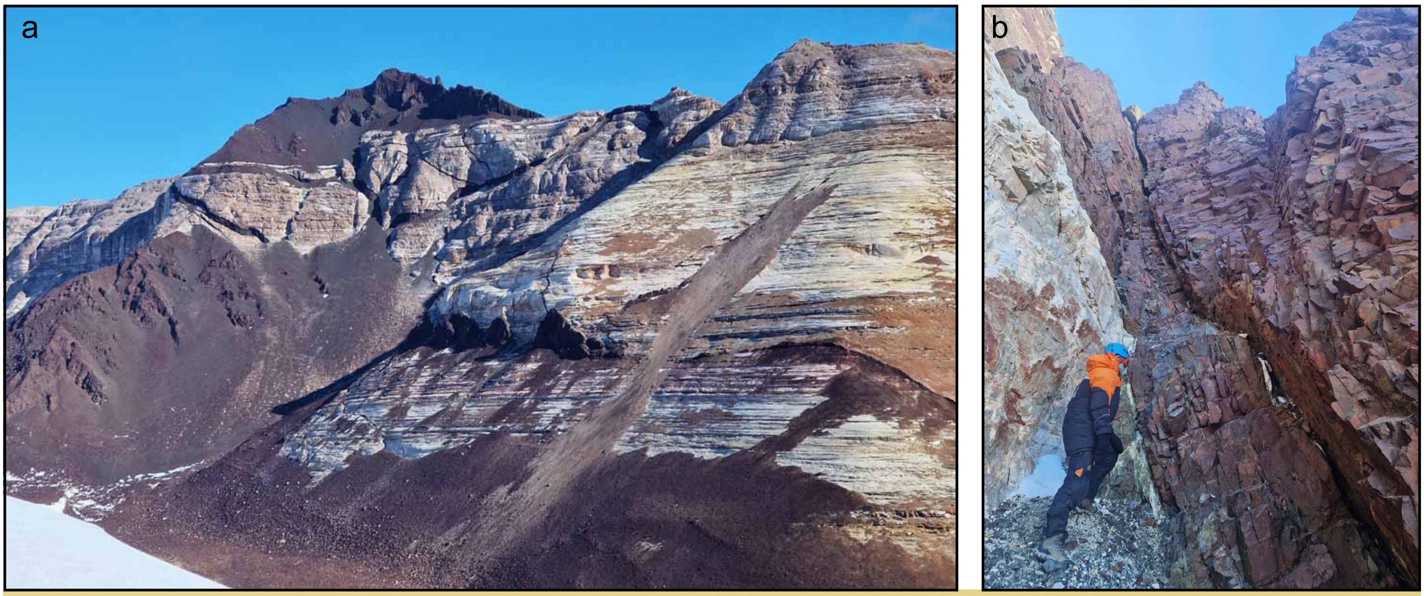

Fig. 9. (a) Eastern slopes of Terra Cotta Mountain, exhibiting exposures of both the Terra Cotta Sill at the summit, as well as multiple cross cutting, dark-coloured dyke intrusions, including a large 'dragon back' dyke cutting across the lower slopes. Lighter grey debris mars some of the slopes, not to be confused with intrusions.
(b) Standing at the contact between the 'dragon back' dyke and Beacon Supergroup host.

The final camp was located at Terra Cotta Mountain, which hosts a concentrated array of Ferrar dolerite intrusions. This provided the opportunity to investigate more closely the interconnectivity between dyke and sill intrusions within the province (Fig. 9). Despite remaining at the camp for two weeks, only five days were spent out in the field, due to a combination of poor weather and day trips to the other two sites. It was here that the 'heaviest pack on record' was awarded, weighing in at 32 kg.

Three daytrips were taken from Terra Cotta Mountain to the remaining two sites. Lake Vanda sat at the lowest elevation of all the sites and was therefore the warmest at around 0°C. Samples were collected through a kilometre of stratigraphy in just two days. Beacon Heights was a unique site, providing exposures of stratigraphy sandwiched between two minor sills, somewhat isolated from the larger sills found across most of the region.

Once back at Scott Base, after 42 days in the field, we were thankful for the chance to shower. The next week was spent packing up gear and prepping samples to be shipped back. Due to regulations surrounding sample collection in Antarctica, a full sample manifesto was required, detailing each sample ID and the location it was collected.

Overall, the field season proved to be a great success, with the team completing all objectives. With 650 kg of samples safely packed and transported to New Zealand and Australia, there is plenty of work still ahead, but we are excited to see the results from analysis over the next few months.

Acknowledgements
Thanks to the summer team at Scott Base, without whom we would not have been able to even set foot on the continent. I would also like to thank Claire Bower for her comments and storytelling abilities, adding a bit of flare to an article written by my academically-wired brain.

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WHY DO SO MANY PEOPLE THINK THE KAIMANAWA WALL IS MAN-MADE? BECAUSE IT IS. BUT NOT BY AN ANCIENT CIVILISATION

Bruce W. Hayward

This note is a supplement to the article I wrote on the Kaimanawa Wall in Geocene 39 (Hayward 2025) after visiting it in November 2024 with Geoclub. Since then, I have revisited the "wall" in June 2025 with Julian Thomson to make a video assessing the evidence for its origins for his YouTube channel – Out There Learning (2025). While there, we made additional observations that led us to a slightly different and new explanation for why so many people (both seemingly sensible and those with an overactive imagination) still think the wall looks man-made in spite of the fact that the vast majority (?all) of the geologists who have visited it agree it is a natural hillside of ignimbrite.

In the first two weeks since Julian's video was released on-line, there had been 235,000 hits (note - a small percentage of hits actually watch more than 50% of any video), 5000 likes and 1600 comments. About 80% of comments have been positive but the remainder have still doubted that the wall is natural rock. Some of these unbelieving comments reveal more about why they are still unconvinced, while the others will never accept the obvious, proving the proverb that *"there are none so blind as those who refuse to see"*.

Originally, I suggested that possibly some large ignimbrite blocks may have been removed to help make the access road (only 5 m away) to Clements Mill (just 200 m down the road). On our second visit, we searched the Clements Mill clearing but could find no remains of any ignimbrite blocks there. From the additional observations below, I am now certain that ignimbrite was removed from this locality to help build the road when the mill was established in the 1930s. The ignimbrite here is naturally cut into huge blocks and this appears to have made it easier for the workers to lift the blocks out for use, either as huge blocks or cut/broken up smaller ones. I am confident they would have been used in building up one or more of the several causeways where the road crosses small streams.

In the 1930s, Mr Clement would have had to have a lease agreement with the crown management agency at the time, presumably the State Forest Service. This would likely have spelt out terms of a permit to cut down trees, establish his mill and build an access road to it. Whether a copy of this agreement still exists is unknowable, but it would be unlikely to mention giving permission to extract a few blocks of hard rock beside the roadway to assist in its construction, as that would be a normal part of any such bush road construction at that time.

Here are the four aspects of the wall that still have some unconvinced it is natural rock:

1. Fresh appearance of the rock wall

This was the first argument for a man-made origin that I addressed previously (Hayward 2025). I wrote *"We could all agree that at first glance the 'wall' does indeed have a resemblance to a man-made one".* What I did not address was why it looks man-made. Firstly, it is because the rock face looks so pristine and fresh – it does not look like a natural exposure produced by erosion over thousands of years, and if it was formed by blocks of ignimbrite falling away along the natural joints, where are the blocks or their remains that came off? Indeed, the lack of any scree or blocks along the bottom of the wall is also unnatural, although not mentioned by doubters (Fig. 1).

Fig. 1. People undertaking ground penetrator radar investigations in front of the original Kaimanawa Wall (producing the reflection profile in Fig. 6). Note the unnatural flat-floored depression in front of the wall and the lack of scree along its base.

2. Orthogonal joints through the wall

I, and others, have already addressed reasons why these joints are clearly natural, but doubters still argue that excavation is the only way to determine what is behind the wall. During the second visit, we explored a further 20–30 m west of the original wall, where we found a tree had recently fallen over and a new vertical-sided fracture had opened-up a 1 m-deep and 50–80 cm-wide chasm in the ignimbrite rock (Fig. 2). The chasm is parallel to, and seemingly an extension of, the wall with its smooth vertical side. The smooth horizontal floor of the chasm is clearly one of the same horizontal planar joints of the original wall.

Uphill from this newly fallen tree and chasm, there has been some unsanctioned excavation of an area of approximately 10–15 m^2 of the hillside, above the "wall". The excavation has removed 20–30 cm of leaf litter, soil and pumice debris and exposed the hard rock surface of the ignimbrite that forms the hill. In this area the natural joints through the rock are not orthogonal as in the wall, although many are vertical or subvertical at a variety of diverging angles and distances apart (Fig. 3). For those who are still genuine doubters sitting on the fence, a brief examination of this excavation would surely convince them of the

Fig. 2. 50 cm-wide chasm that has recently appeared, 20–30 m west of the original Kaimanawa Wall, by the sideways movement (to right) of a block sliding along a horizontal joint plane, as seen in the bottom of the chasm. The vertical wall on left appears to be a lateral continuation of the vertical face in the original wall. The chasm has opened as a tree has fallen over to the right as a result of excavations loosening its roots. (From Out There Learning, 2025).

naturalness of the ignimbrite underlying the hill and forming the wall.

Conspiracy theorists who claim iwi and Department of Conservation are refusing to allow a thorough excavation investigation for political reasons, need only look at the result of this unofficial earth works, which not only have removed the regeneration of the forest floor over a significant area but have resulted in the recent tree falling over and opening up new rock fractures. An additional factor in the tree collapse, I suggest, was the fact that the small quarry face extended at least as far as this and had created a 2 m-high, unstable, man-made bluff that has now had the tree and excavated soil collapse over it. This part of the quarry face had been ignored up till now because it had been somewhat hidden from the adjacent road by nearly a century of regeneration of the forest.

Fig. 3. Part of the unsanctioned "excavation" of the hillside above the Kaimanawa Wall. Note the vertical joints cutting the ignimbrite at varying angles. (From Out There Learning, 2025).

3. Fresh top of the rock wall

Another major, although unstated, reason, in my opinion, as to why the public perceive the original wall to be unnatural, is that it is fresh hard rock on top, lacking any gradational weathered zone of clay beneath the pumice and soil cover. A fresh hard top would be consistent with the welded ignimbrite wall having been made in the last few hundred or thousand years or so. I suggest, however, that the real explanation is that this location, at moderately high altitude in the centre of the North Island, would have been above the bush line during thousands of years of the Last Ice Age, possibly up to about 15,000 years ago. In these seasonally icy conditions, most of the softer weathered portions of the 320,000 year-old ignimbrite sheet could have been removed by the strong glacial winds, leaving a hard rock surface separated by subalpine herb lands (e.g. Fig. 4).

Fig. 4. The Kaimanawa Wall locality could have resembled modern alpine landscapes with hard fresh rock at the surface separated by alpine meadows in depressions. Photo: Bruce Hayward

Also worth noting is that the smaller of Lake Taupō's two major ignimbrite eruptions occurred after the peak of the Last Ice Age and only 1800 years ago. This area would have been buried by unwelded pumice ignimbrite and ash many metres thick, as seen alongside the access road, and the forest would have been completely killed. On the somewhat steeper slopes of the spur where the wall is present, much of this loose pumice and ash was probably washed off in rain in the decades after the eruption, before the forest recolonised and stabilised the area. Thus, a fresh solid top to the natural ignimbrite forming this spur and the wall is not unexpected, with just a thin covering of loose pumice (? from later smaller eruptions) and forest litter and young soil that has accumulated following regrowth of the trees.

4. Bevelled top to the rock wall

I addressed this in my original assessment (Hayward 2025, point 13), yet some commentators still see it as unexplained. The sloping angle of the so-called bevel (Fig. 5) is not unexpectedly parallel to the slope of the hillside and is much shallower where the unsanctioned excavations have taken place (Fig. 3), and is not a constant angle as

Fig. 5. Person showing a bevelled slope on the top edge of blocks in the Kaimanawa Wall as apparent evidence of a buried pyramid (from Turehu NZ 2019).

claimed. I suspect that once again it is the fresh, hard nature of this sloping bevel that is misleading observers to think it is man-made and the slope of a buried pyramid.

The other aspect is that this "bevelled" slope is just part of the continuous natural hillside slope that continued on down to the level of the flat ground nearer the road, before the ignimbrite blocks were removed. It is the removal of the blocks that give the impression that the top of the upper row of blocks in the wall has been bevelled back.

Buried horizontal floor in front of the wall

In Hayward (2025, point 10), I wrote that another argument presented by some in favour of the presence of a pyramid or such was that *"There are buried 'blocks' beneath the ground surface in front of the 'wall' that were detected in 2019 by ground penetrating radar, some of which have been exposed in the past few years by unauthorised excavation (Tureaud 2019, McIvor 2023)"*. My possible explanation was that *"The exposed flat face of the 'wall' suggests that some blocks may have been removed from in front of it (roadside) for use by Clements Sawmill"*. I have now located the GPR image made of hard reflectors on a transect running along in front of the original wall (Fig. 6). The upper reflector, at 2–3 m depth, shows a horizontal surface with alternating up and down sections consistent with the size of the blocks and joints in the

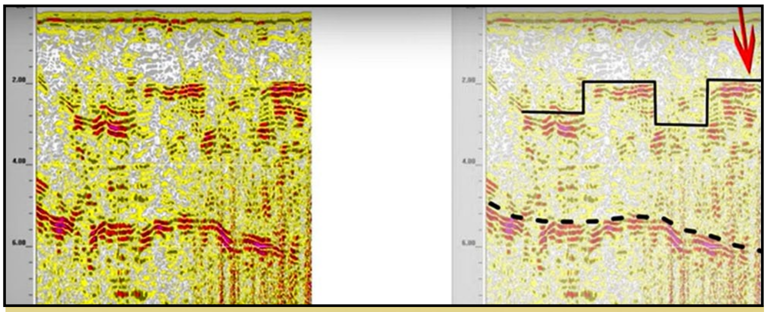

Fig. 6. Ground penetrating radar reflection profile along a transect in front of the Kaimanawa Wall (from Turehu NZ 2019). The cause of the lower reflector at 5–6 m down is not known, but the top of the groundwater table can produce similar results. Left image is raw and right has interpretation of reflector shapes.

original wall. These certainly appear likely to be man-made and while believers will see them as something to do with their pyramid, a more logical explanation is that they are the blocky floor of the small 1930's quarry pit. If that is the case, then the floor shape suggests that the quarrying was extracting large blocks making use of the natural orthogonal joints as cuts.

In the 1930s, quarries were able to remove blocks of this size by drilling holes in the sides of the blocks to attach their clamps to. Two unnatural looking round holes in the face of the original wall could be of this nature, but those blocks were not removed. They also had primitive derricks or cranes that were used to lift the blocks. The remains of such a device is abandoned in the forest at the end of Clements Rd (Fig. 7) and while it was probably used for lifting logs onto lorries for transport to the mill, it could also maybe have been used in this quarry when the road was being constructed.

Fig. 7. Abandoned primitive crane at end of Clements Rd (from SwampChook Overland 2022). A machine similar to this could have been used in the 1930s to lift blocks from the Kaimanawa wall quarry.

Turehu NZ (2019) used their ground penetrating radar and also state *"We scanned up the hill behind the wall and we scanned it in a criss cross pattern and can confirm there is NO pyramid there"*.

Several doubters claim they have visited the site and *"Even the ground under your feet feels different, it's like it's hollow"* (in Silva 2025). I can imagine that could have been the case in the early days of discovery when loosely compacted fill, branches and forest litter had filled the quarry hole in front of the wall. Nowadays after many thousands have walked around in front of the face, there is more of a slight depression (Fig. 1) and not the feel of hollow or soft ground beneath your feet. So, the presence of the small 1930s quarry pit can even explain some wild theories of buried hollow chambers (Silva 2025).

Conclusion

One of the major revelations of this exercise is the boundless limits of human imagination. If an archaeologist in the 1990s had not suggested that this 1930's quarry face was likely a part of a buried pyramid made by a pre-Polynesian civilisation in New Zealand several thousand years ago, I doubt the idea would have ever taken off. The fact that the archaeologist later admitted he was wrong (Brailsford 2019) has seemingly had no impact on those who use it to reinforce their blind beliefs. Yes, there are amazing megalithic stonework and pyramids built thousands of years ago, not only in Egypt but in South America, the Pacific islands and Asia, and I have made special trips to see some of them, but the Kaimanawa Wall in the back blocks of New Zealand is not one of them.

Acknowledgements

I thank Julian Thomson for making his Out There Learning video on the Kaimanawa Wall and for allowing me to include screen captures from it.

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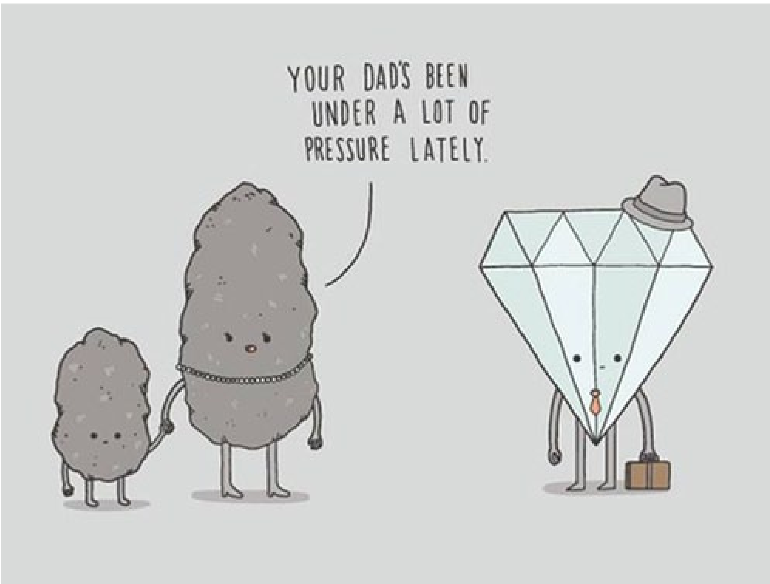

LAST INTERGLACIAL FLOOD-TIDAL DELTA, BEACH AND DUNE DEPOSITS, MOHAKATINO RIVER MOUTH, NORTH TARANAKI

Bruce W. Hayward, Julian Thomson

In May 2021, a Geoclub field trip called in at Mohakatino River mouth, North Taranaki (Fig. 1), to visit the Miocene sedimentary strata and sea caves in the coastal cliffs outside the river mouth to the south. On the way around the southern side of the lower estuary, ~300 m inside the mouth (Fig. 2), we passed cliffs (locality 1) made of soft, much younger, sedimentary deposits than the deep-marine Miocene strata. In June 2025, the authors revisited the coastal cliffs and further viewed and took photographs of these younger deposits and noted that the upper portion seemed to pass westward into the Last Interglacial (~125,000 yrs old, MIS 5e) sediments that sit unconformably above the Miocene in the upper parts of the sea cliffs (Fig. 2, locality 2). In this note we provide images and a brief account and interpretation of the soft sediment sequence.

Locality 1. Inside south side of Mohakatino Estuary
A small low point located 300 m inside the mouth of the estuary is composed of 4 m+ of massive, light chocolate-grey, carbonaceous siltstone containing scattered branches and stumps (Fig. 3). This is the lowest and oldest layer in the sequence, and we infer it to be a non-marine alluvial deposit possibly deposited by one or more floods and partly filling this part of the Mohakatino valley floor at a time when sea level was lower than present.

In the adjacent cliff to the south, this siltstone is overlain by 5 m+ of iron-stained bedded sandstone with beds picked out by varying concentrations of black titanomagnetite sand. Many horizons are 20–30 cm thick cross beds, in places separated by horizontal layers (Fig. 4). Looking closer, it is clear that some cross beds have been deposited by current transport moving inshore and others by currents moving seaward (sloping in opposite directions). These are an excellent example of herringbone cross bedding (Fig. 5) inferred to have been deposited by reversing

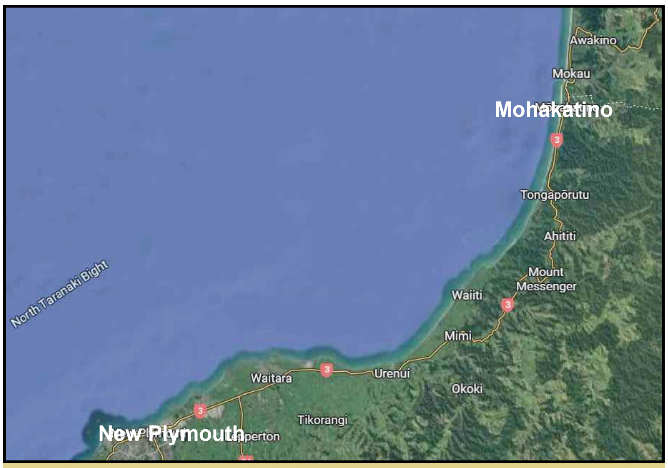

Fig. 1. Map of coastal North Taranaki showing the location of Mohakatino.

Fig. 2. Location of the two study sites in the cliffs, one 200 m inside the mouth of the Mohakatino Estuary and the other just outside and on the south side of the mouth.

Fig. 3. Massive siltstone containing branches exposed at base of sequence, 300 m inside mouth of Mohakatino Estuary. Photo 2.5 m wide.

Fig. 4. Unit of rusty, cross-bedded, black and cream sandstone that overlies the lower carbonaceous siltstone unit at locality 1. Height of photo ~5 m.

Fig. 5. Enlarged portion of figure 3 showing herring-bone cross bedding of black and cream sandstone at locality 1. Height of photo ~1.3 m.

Fig. 7. Conglomerate overlying unconformity eroded in the underlying Miocene sandstone at locality 2. From Out There Learning (2025). Photo 1 m wide.

tidal currents moving sand up the estuary and then back again. These beds are a shallow marine deposit, as it records the arrival of black sand transported by longshore drift from the south (Mt Taranaki source). They were likely deposited near low tide level or subtidally, maybe at depths as much as 5 m. As the unit is well inside the river mouth, we infer it is part of a flood-tidal delta that filled up the mouth of the valley as sea level was rising towards its peak in the Last Interglacial.

The top of the cross-bedded unit is hidden by vegetation, but it seems to be lower stratigraphically than the horizontally bedded beach sandstone that we could follow in the top of the cliffs to locality 2.

Locality 2. Just outside south side of mouth of Mohakatino Estuary

About 8 m up in the cliff at this locality, the Miocene sandstone has been eroded down to a subhorizontal plain (Fig. 6). Overlying this slight unconformity are lenses of sandy conglomerate with rounded pebbles of andesite, occasional spherical concretions and isolated shells (Fig. 7). The pebbles have been transported north from eroding lahar deposits forming the northern ring plain of Mt Taranaki. The concretions have eroded out of the underlying Miocene sandstone. These thin conglomerate lenses are overlain by 1.5–2 m of rusty orange-coloured, thinly-bedded sandstone. The colour reflects the high concentration of black sand grains that preferentially accumulate in the upper part of a beach because of their higher density than the lighter coloured grains.

The orange-coloured beach sand layer is overlain by 2–4 m of grey sandstone, reflecting the lower percentage of black sand. The grey sandstone is partly subhorizontally- and partly cross-bedded, indicating deposition by coastal sand dunes. This unit is overlain by up to 2–3 m of red-brown and brown-grey layers of weathered andesitic volcanic ash and soil, which have accumulated on top of the dunes (Fig. 8).

Fig. 6. Mohakatino locality 2 on the coast just south of the estuary mouth. The lower 8 m of the cliffs is composed of Late Miocene sandstone. The upper part of the cliff is composed of Last Interglacial and younger sedimentary deposits.

Fig. 8. Last Interglacial sequence of beach (rusty coloured) and sand dune (grey) sandstone overlying the unconformity and overlain by subsequent deposits of weathered volcanic ash and soil. From Out There Learning (2025). Photo 6 m wide.

Our interpretation of the sequence at locality 2 is that the conglomerate and rusty sandstone were deposited on a beach during the Last Interglacial high sea level stand of about 5–6 m higher than today. As sand accumulated, the beach sand was overlain by wind-blown sand dunes with low concentrations of heavy black sand grains. The sand dunes produced the typical rolling topography, which now can be seen on the Last Interglacial coastal terrace (Fig. 9). Subsequently the dunes would have been clothed in forest for at least 100,000 years during which time volcanic ash from Taranaki volcano and maybe thin rhyolitic ash has accumulated and form the upper part of the sequence along with thick soil deposits.

Fig. 9. Aerial view south over the Mohakatino Estuary mouth and down the coast. Locality 1 is 100 m east (left) of the edge of the photo, but locality 2 is in the cliffs above the bay just south of the mouth. Note the Last Interglacial coastal terrace that is mantled with the beach and sand dune deposits, and extends landward to the foot of the hills behind, which would have been sea cliffs 125,000 years ago.

The top of the beach sand unit is inferred to mark the Last Interglacial high tide mark. It is located about 9 m above present-day high tide level. Accounting for a Last Interglacial high stand of 5–6 m above present, this indicates that there has been about 3–4 m of tectonic uplift in the last 120,000 years. The Last Interglacial coastal terrace is present for most of the length of this part of the North Taranaki coast and is 500–1000 m wide. At the back of the uplifted terrace is the foot of steep hillsides (Fig. 9) which would have been coastal cliffs at the back of the beach during the Last Interglacial period.

Thus, we infer the two units at locality 1 accumulated as sea level was rising at the start of the Last Interglacial period about 130,000 years ago and were deposited inside the lower Mohakatino Valley, which had been eroded well down below present sea level during the preceding glacial period. We infer that the beach and sand dune deposits of locality 2 were deposited during the Last Interglacial high stand about 125,000 years ago, burying an eroded shore platform of Miocene sandstone on the open coast. At this time the beach and dunes also advanced over the top of locality 1.

Reference

Out There Learning, 2025. 10 million years in 10 minutes: The wild geology of Mohakatino Beach. https://www.youtube.com/watch?v=dLmIooyGvpA

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KEN'S TECTONIC MUSINGS

Ken Smith

I live in an Edwardian-age villa in Devonport, Auckland (Fig. 1). One day, whilst having a well-earned lie down, I was staring up at the bedroom ceiling (Fig. 2). It is a typical, nicely crafted, board and batten ceiling, constructed in the method of the time before sheet materials were freely available. The builder skilfully covered the whole ceiling area with individual pieces of timber of a size that you can practically get from a tree (even a big old Kauri tree).

The boards are an imperial 1 foot wide (305 mm). This ceiling (and the bedroom) is 12 boards wide (about 4 m). The house was built around 1910, so it is 115 years old - call it 100 years.

If, for no particular reason, you divide the width of the room by the age of the house you get:

4 m = 4000 mm
4000 mm / 100 yrs = 40 mm/yr

This measurement reminded me of something. A lightbulb moment went off in my head! A plate tectonic lightbulb to

Fig. 1. Our Edwardian home in Devonport.

Fig. 2. The board and batten ceiling.

do with the subduction process going on in this part of the world. The two maps (below and next page) show the situation as it is currently understood.

Figure 3 shows the obliquely converging relative motion of the Pacific Plate near Auckland is 49 mm/yr (Hirschberg & Sutherland 2023). Their map is rather complicated.

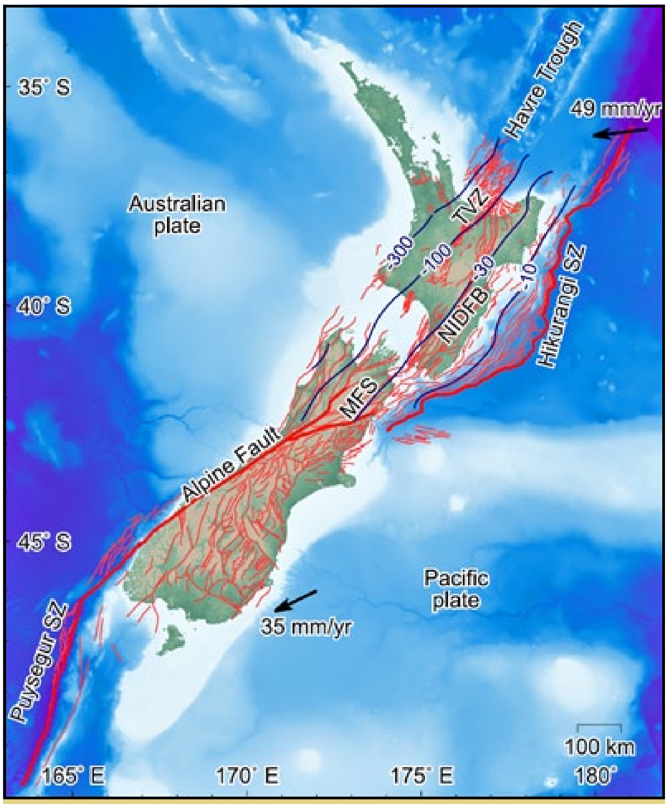

Fig. 3. Tectonic setting of New Zealand, figure 1 from Hirschberg & Sutherland (2023). Their caption is simplified here. Arrows indicate velocity of Pacific plate relative to Australian plate. Thin red lines are active faults. Thick red lines indicate the major plate boundary faults running from the Puysegur subduction zone (SZ), through the Alpine Fault and Marlborough Fault System (MFS), to the Hikurangi subduction zone. Dark blue contours indicate Hikurangi subduction interface depths in kilometres. Also shown are the North Island Dextral Fault Belt (NIDFB) and Taupō Volcanic Zone (TVZ).

A paper this year (Mortimer 2025), brought to my attention by Jill Kenny, contains a clearer, simpler map (Fig. 4). Covering a much larger region of the southwest Pacific than Fig. 3, it shows both the relative movement of the Pacific plate as viewed from the Australian plate (black arrows) and also the 'Absolute' movement of each plate relative to the deep mantle (blue arrows). As Mortimer (2025) describes – "The Pacific and Australian plates are both moving relative to Earth's deep mantle reference frame". So the familiar pattern of the black arrows with

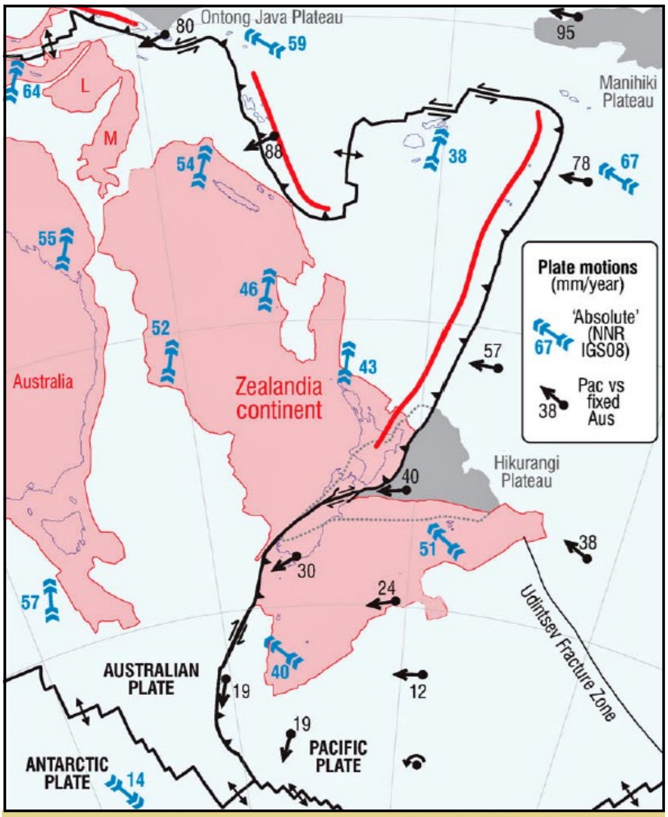

Fig. 4. Figure 2B: "Main tectonic elements" from Mortimer (2025). Rotation of the Pacific Plate relative to the fixed Australian Plate is shown with the black arrows. The absolute movement of both plates over the Earth's mantle is shown with blue arrows.

the curious rotation and oblique convergence is the result of each of the plates doing their own thing - the Australian Plate moving north and the Pacific Plate moving northwest. Mathematically, the black arrows are the vector subtraction of the two sets of blue arrows.

So, to a first approximation we can see that ...

… **in the time that our house has existed, the Pacific Plate has subducted towards it by a distance roughly equal to the width of one of its bedrooms, while being carried north on the Australian Plate roughly the same room width towards the equator!**

Acknowledgements

My thanks to Bruce Hayward and Jill Kenny for finding appropriate maps for me, and to Nick Mortimer for suggesting improvements.

References

Hirschberg H, Sutherland R 2023. Estimating plate tectonic forces at the New Zealand plate boundary using strain rates derived from a kinematic model of fault slip. *Journal of Geophysical Research: Solid Earth* 128 (8). https://doi.org/10.1029/2023JB026567

Mortimer N 2025. Tectonics, geology and origins of Te Riu-a-Māui / Zealandia. *New Zealand Journal of Geology and Geophysics*. https://doi.org/10.1080/00288306.2025.2500394

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HYPERLINK INSTRUCTIONS

Hyperlinks have been added to the contents page numbers column (coloured blue) to simplify finding each article. To activate a hyperlink, click on the coloured page number and you will be sent to the article beginning on that page.

At the end of each article there is another coloured hyperlink, which will take you back to the contents page.

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Correction to Geocene 39 crossword

If the 7 down clue prevented you from completing the Crossword on page 9 of Geocene 39, then here is what it should have been. Thank you to one observant reader.

17th letter of the Greek alphabet (3)

So now return to Geocene 39 and have another go. Take Google with you, and if that doesn't help you sufficiently, the answers are listed on the last page of that Geocene. A pdf of it can be found at: https://natlib-primo.hosted.exlibrisgroup.com/primo-explore/fulldisplay?docid=NLNZ_ALMA21350370940002836&vid=NLNZ&search_scope=NLNZ&tab=catalogue&lang=en_US&context=L